Triassic Pre-Dinosaurian Communities, National Park's Land, Utah: The Oldest Megatracksite in North America

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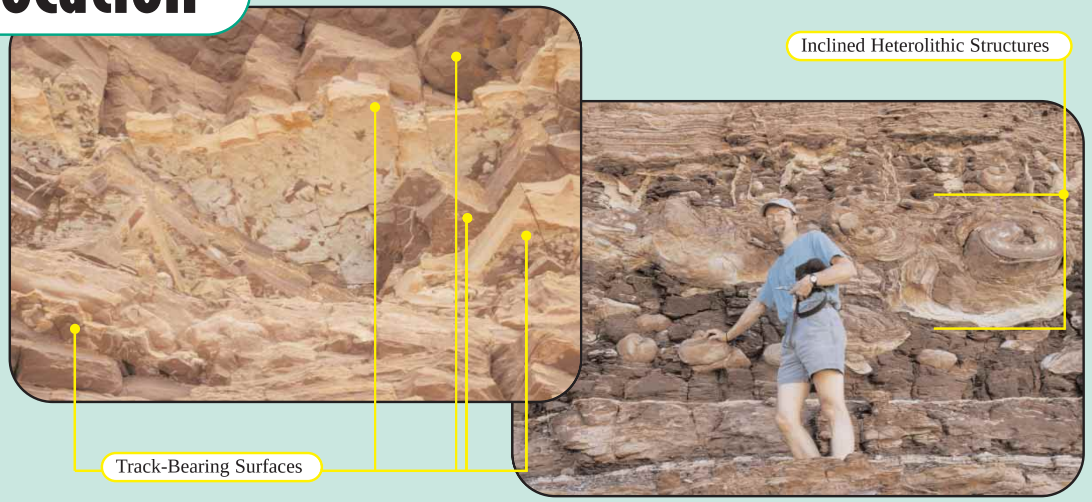
Abstract

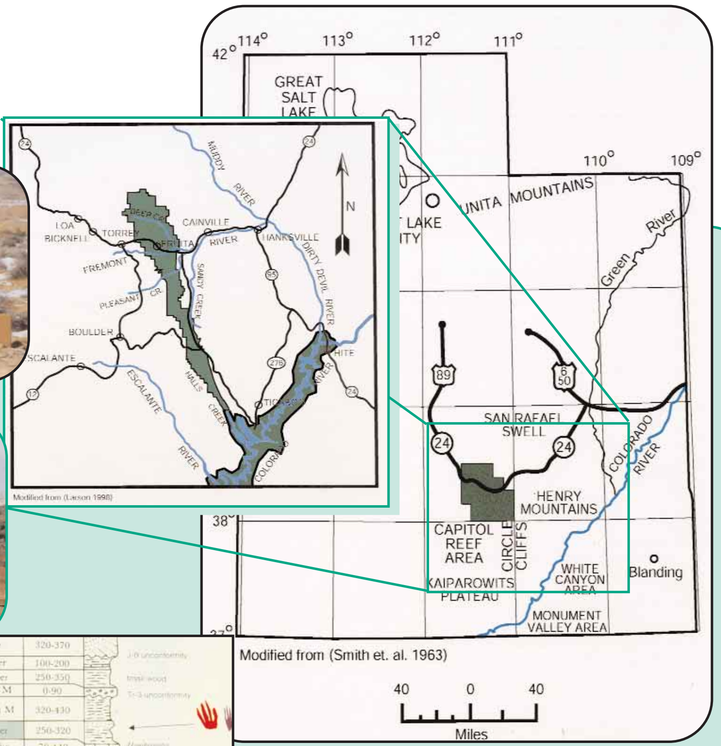
Recent exploration in the Capitol Reef National Park (CRNP) and Glen Canyon National Recreation Area (GCNRA) has revealed new sites of terrestrial and subaqueous vertebrate traces and is the oldest and most laterally extensive megatracksite surface documented in North America. Two different vertebrate track types (*Chirotherium)* and (*Rhynchosauroides)* and rare fish fin drag marks (*Undichna*) have been identified in the Torrey Member of the Moenkopi Formation (Early Triassic). Multiple vertebrate ichnostratigraphic units are distinguished in the Torrey Member based on the stratigraphic occurrence of track sites within CRNP and GCNRA Park's boundaries. Tracks are preserved as convex hyporelief sandstone casts filling impressions in the underlying mudstones. Exposed traces occur on the undersides of resistant sandstone ledges where the mudstone has eroded away. The Torrey Member represents deposition on a broad, flat-lying coastal delta plain. Both nonmarine (fluvial) and marine (principally tidal) processes influenced deposition. Even-bedded mudstones, siltstones, claystones, and fine grained sandstones containing abundant ripple marks and parallel laminations dominate lithologic types. Ichnites indicating swimming/floating behavior are associated with the walking trackways in CRNP and GCNRA. The water depth was sufficiently shallow to permit the vertebrates to touch the substrate with manus and pedes when moving through the water.

Tracks form locally dense concentrations of toe scrape marks which sometimes occur with complete plantigrade manus and pes impressions. Fish fin drag marks are preserved with tetrapod swim tracks. In addition to vertebrate ichnites, fossil invertebrate traces of *Palaeophycus* and *Fuersichnus*, are abundant within the track bearing units.

Lateral correlations of the ichnostratigraphic units identified in CRNP and GCNRA will aid interpretations about the paleoecology of in the Western Interior during the Early/Middle(?) Triassic.

Location





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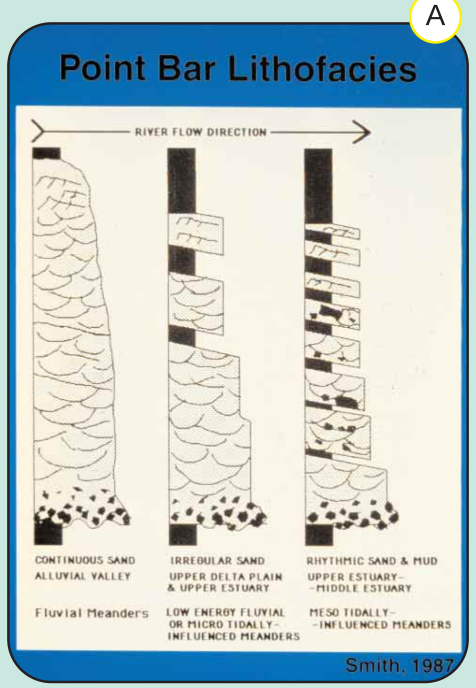

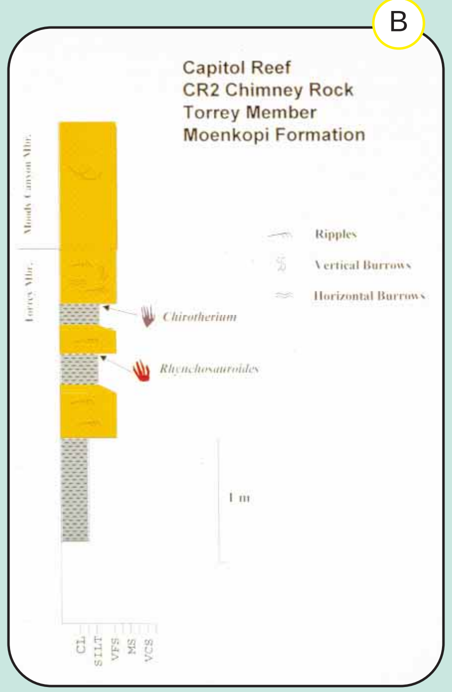

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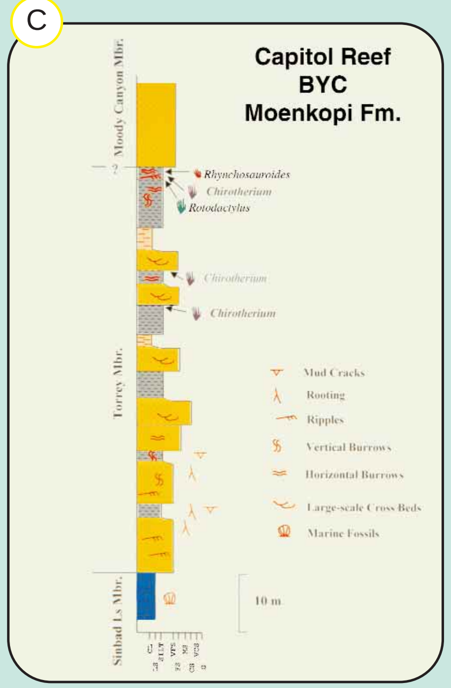
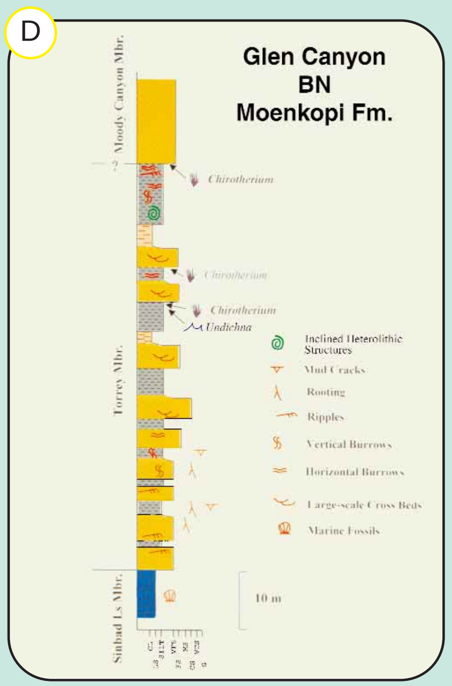




The Torrey Member of the Moenkopi Formation has been the subject of investigation for almost 50 years (Mckee, 1954; Smith et al, 1963; Blakey, 1973 and 1977; Stokes 1980). However, these studies were more broad based regional studies, and only recently has the Torrey Member been studied in stratigraphic detail with emphasis on the extensive tetrapod track-bearing surfaces of pre-dinosaurian communities present within it (Mickelson *et al*., 2000,and 2001). At present, the track-bearing horizons are known to extend from west of Capitol Reef National Park to east of Arches National Park and as far south as northern Arizona. Currently, the Torrey Member vertebrate tracks are the oldest and most laterally extensive megatracksite horizons ever recorded.

Following the deposition of the Sinbad Member in a clear shallow sea, a change in tectonic and/or climatic conditions caused the progradation of a major delta succession into southeastern Utah. This delta complex is preserved as the Torrey Member, which preserves the delta-plain, delta-front, and delta-slope facies. The track-bearing horizons are preserved within the delta-plain deposits.

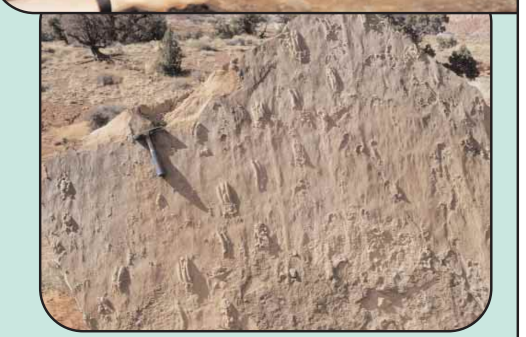
Basal deposits of the Torrey Member include interbedded siltstones, dolomites, and very fine-grained sandstones that were laid down in advance of the prograding delta (delta-front and delta-slope deposits). This sequence grades upwards into ledge-forming coarser grained sandstones and interbedded siltstones of the upper delta-plain facies. Several track-bearing horizons are present within this facies. The delta-plain facies includes channel deposits of large-scale trough cross bedded fine to medium grained sandstone that was deposited within the fluvial-dominated reaches of the upperdelta-plain. Tetrapod tracks have been identified within these deposits.

Also present are channel bodies dominated by ripple to large-scale trough cross bedded sandstones and interbedded mudstones that are organized into inclined heterolithic packages. Also present within these sandstone and mudstone-dominated channels are large-scale soft sediment deformational features and clay-draped ripple- and dune-scale bedforms. Tetrapod tracks and fish-fin drag marks are typically associated with these deposits. These inclined barforms are likely pointbar deposits that experienced tidal influence and may represent the more seaward lower delta-plain expression of the sandstone-dominated fluvial channels.

A threefold lithofacies classification model (A) produced by Smith (1997) was adapted to describe depositional environments of the Torrey Member delta-plain channels. Outcrop measured sections (B), (C), and (D) from west to east are similar to Smith's, (1987) lithofacies classification for meandering river estuarine systems.

Moenkopi Trace Fossil Assemblages

Swim Traces for *Chirotherium*



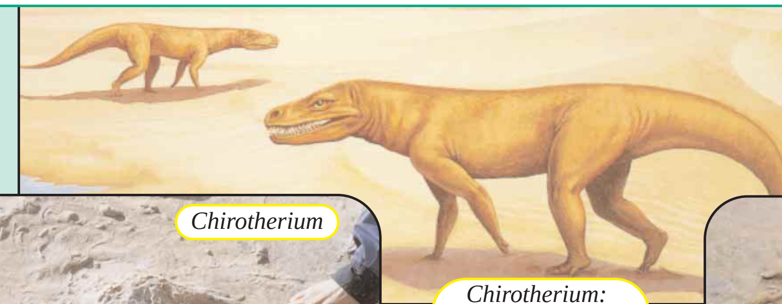
Peabody (1948) first described swim tracks from the Moenkopi Formation from several locations in Arizona. More recently, McAllister (1989) and McAllister and Kirby (1998) introduced a criteria for identifying and describing tetrapod swim traces which indicate trackmaker buoyancy. Such swim traces in the Moenkopi Formation are characterized primarily by posterior overhangs and reflectures of the individual digit impression; and secondarily by striations and claw marks along their length, and the often incomplete nature of the trails. These swim tracks grade into subaqueous traces formed by more typical terrestrial propulsion and demonstrate less buoyancy as the water became more shallow, and disappear as the trackmaker became fully buoyant. In addition, the sedimentary criteria that form the environmental interpretation should agree with the expected environment of the swim trace fossils.

Important differences between locomotion on land and in water can be attributed to buoyancy. In a floating animal the digits can extend farther posteriorly in the propulsive phase without unbalancing (losing the necessary support to maintain posture) the organism. This allows the propulsive force to be on a more horizontal plane and scrape instead of compressing downward into the sediment.

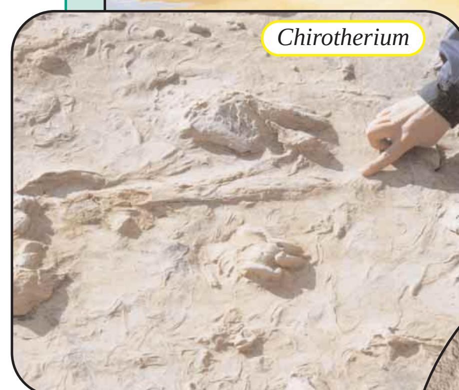
The Moenkopi tracks were originally impressed into a muddy matrix and later filled in with a fine sand. The swim tracks are elongated, striated scratch marks (produced by scales and nails) preserved in the substrate (A) and (B). Z-shaped traces demonstrated in (C) are unique. Two trackway sequences are recognized. The original orientation of the trace block is unknown but each trackway is oriented at 40 degrees to the apparent direction of the current. Both trackways have evidence of locomotion by all four appendages. One trackway composed of 13 traces, has three Z-shaped traces. Z-traces are interpreted as little double kicks of the trackmaker as the tips of the toes graze the substrate. The initial protraction, quick retraction, and continued final protraction, is interpreted as the trackmaker being at the limits of limb extension (barley touching the substrate) while in an offsetting current.

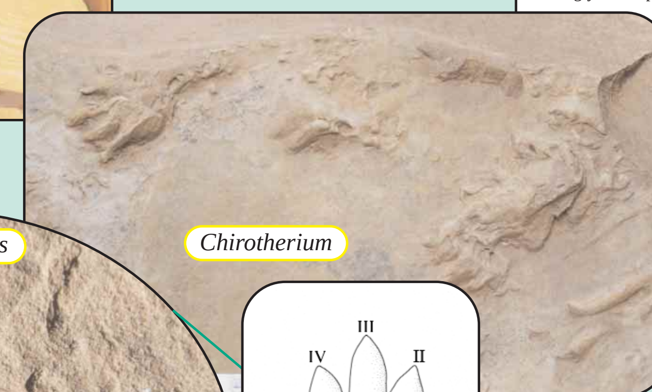
Kick-off scours (C) occur immediately posterior to the traces. The sandstone cast unfilled the scour and is seen as the irregular positive relief behind the digit scrapes. They represent the action of the water eddies created behind the digits as they pass close over the sediment. At the end of the propulsive phase (kick-off phase of Thulborn and Wade, 1989).

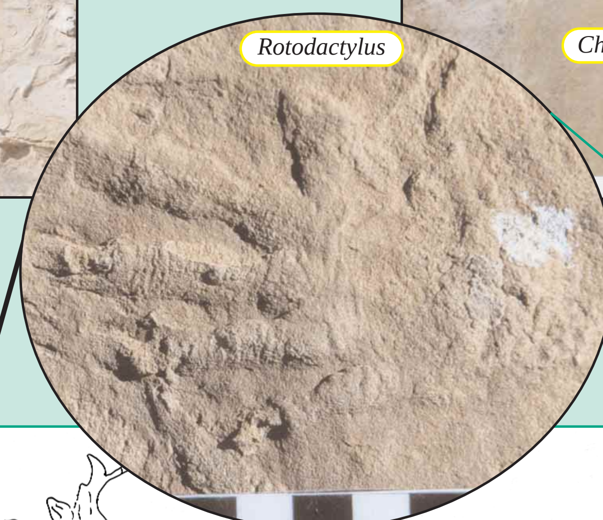
Terrestrial Tracks, Dragmarks, and Skin Impressions for *Chirotherium* & *Rotodactylus*

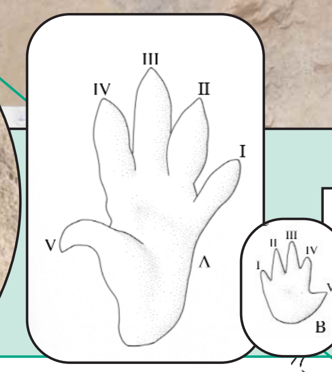


Chirotherium:
Treise and Sarjent









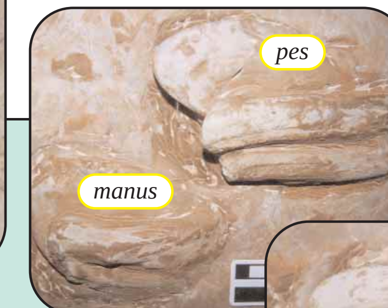
A. Chirotherium (pes)
B. Chirotherium (manus)

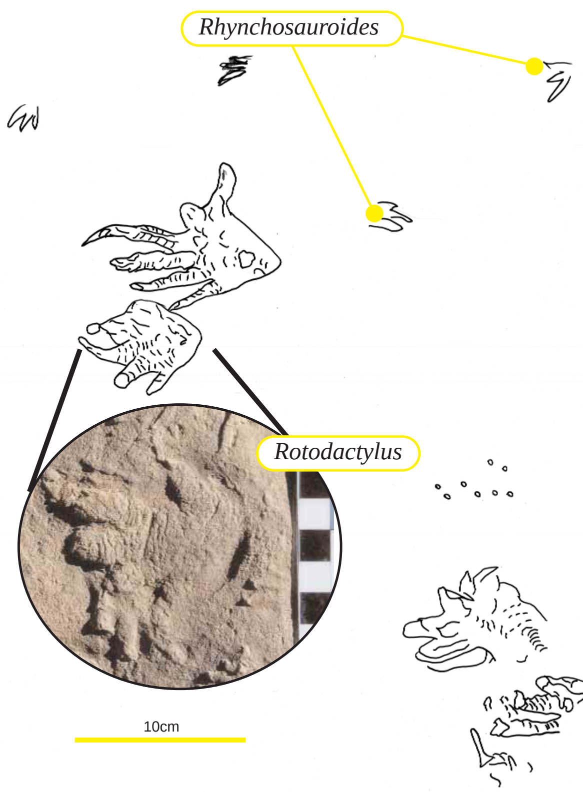
Chirotherium Tracks (A): Relatively narrow, quadrupedal trackways indicating the normal tetrapod walking gait; in the walking gait a small pentadactyl manus impression regularly occur immediately in front of, but never overlapped by a much larger, pentadactyl pes which generally resembles a reversed human hand. Manus and pes are digitigrade, and in large forms the pes tends to be plantigrade; digits I-IV point more or less forward, manus digits IV is always shorter than III being largest; the footprints may or may not show specialized metatarsal pads. Clear impressions often show a granular or beaded skin surface (skin impressions).
Rare tail drag marks (?) or ventral belly (?) traces centered down the midline between right and left footprint sequences may be the first reported.

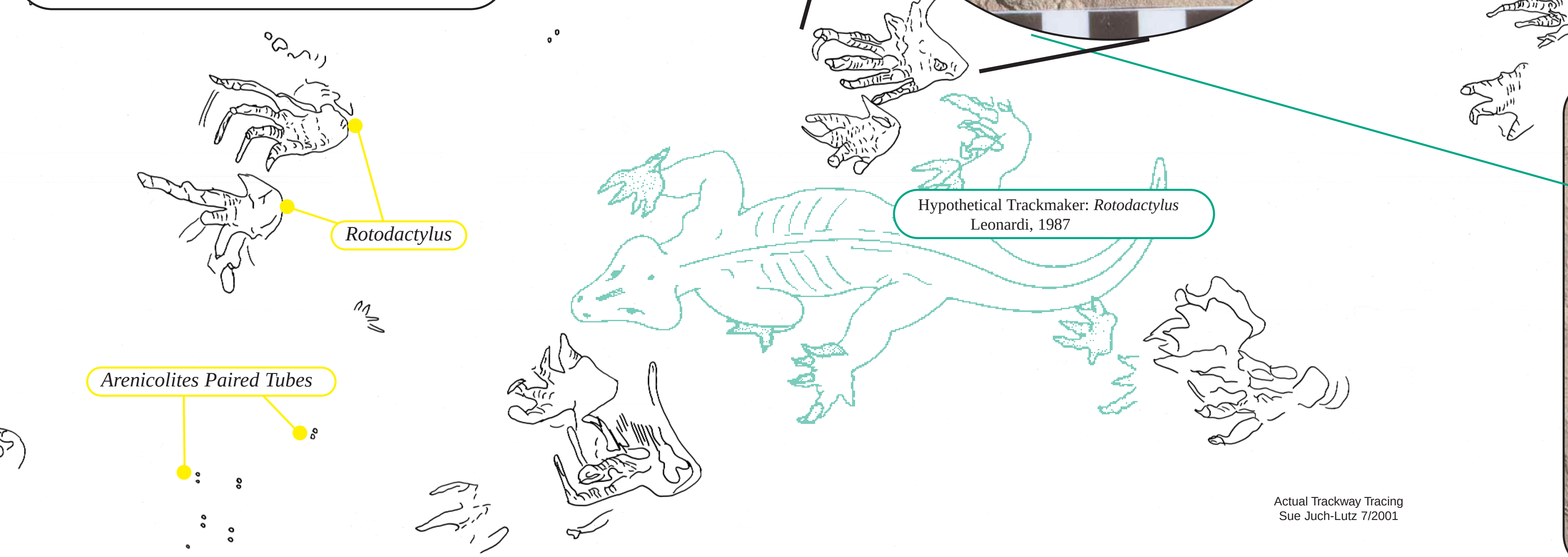
Distribution is well represented in North America and Europe from the Triassic redbeds of the Moenkopi or equivalent strata. Competition with increasing numbers of dinosaurs during the Upper Triassic was a possible contributing factor to final extinction of the family. Proposed trackmaker based on *Ticinosuchus* Skeletal material and track morphology.

Rotodactylus Tracks : Long-striding, trackways of a medium pentadactyl reptile are well preserved with rare skin and claw impressions. These tracks commonly occur with smaller *Rhynchosauroides* footprints. The manus is always closer to the midline and in some cases overstepped even in the walking gait by the much larger pes in a moderately narrow trackway pattern; pace angulation (pes) as high as 146 degrees in a running trackway and as low as 93 degrees in a walking trackway. The pes impression indicates a foot with an advanced digitigrade posture (Peabody, 1948), and with a strongly developed but slender digit V rotated to the rear where it functioned as a prop. Manus digit V may or may not be rotated backward but it has a propping function. Digit IV on both manus and pes is longer than III; digit I may fail to impress; claws are evident and distinct on digits I-IV. Scaly plantar surface (well defined skin impressions) most often preserved in exquisite detail, is characterized by transversely elongate scales on the digit axis bordered by granular scales.

Distribution of *Rotodactylus* is confined to the Triassic Moenkopi Formation of the Western U.S. Tracks of *Rotodactylus* were first found this summer (2001) by Steve and Sue Lutz and therefore are not included in the abstract as an additional track type found in the Moenkopi.



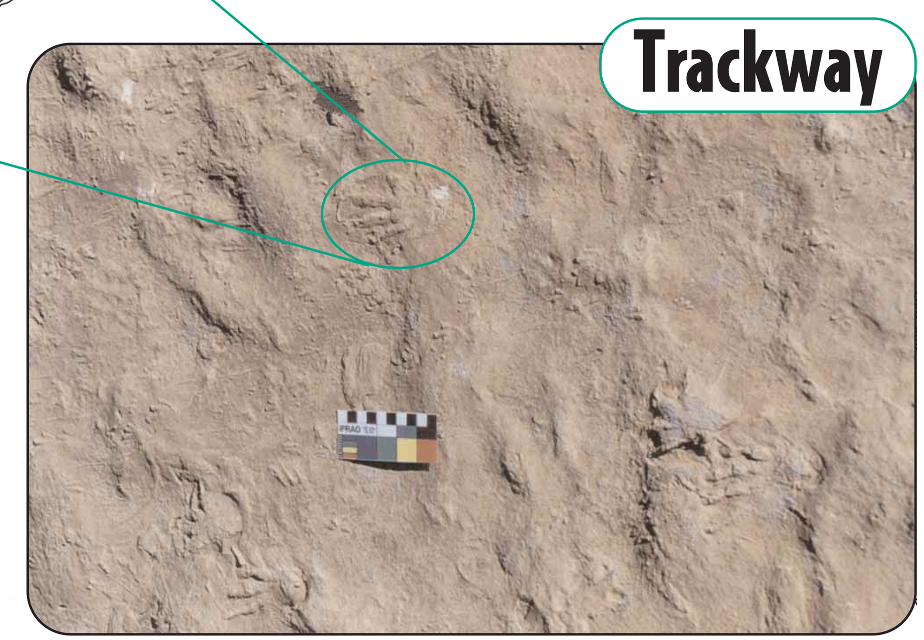




Hypothetical Trackmaker: *Rotodactylus*
Leonardi, 1987

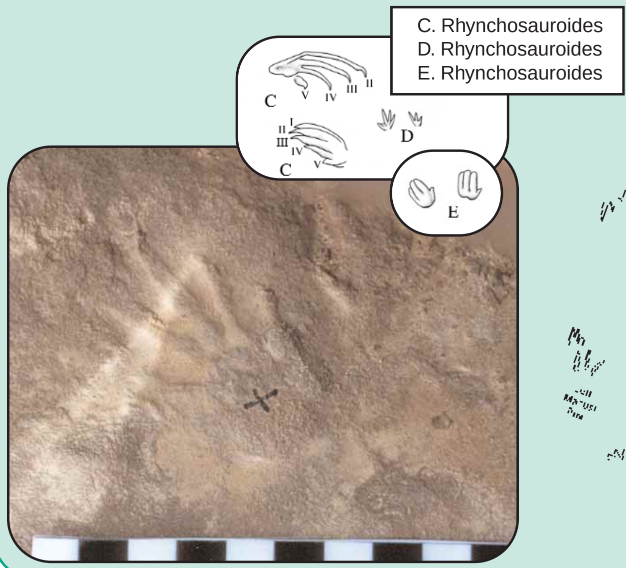
Actual Trackway Tracing
Sue Juch-Lutz 7/2001

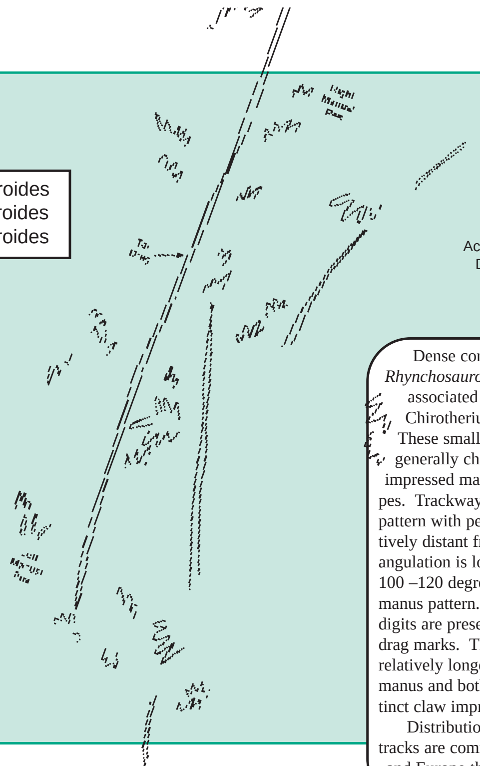
Trackway



Moenkopi Trace Fossil Assemblages

Rhynchosauroides





Actual Trackway Tracing
Dan Chaney 7/2001

Dense concentrations of *Rhynchosauroides* tracks are commonly associated with the trackways of Chirotherium and *Rotodactylus*. These small lacertoid footprints are generally characterized by deeply impressed manus and a faintly impressed pes. Trackways exhibit a relatively wide pattern with pentadactyl footprint relatively distant from the midline. The pace angulation is low , below 90 degrees – 100 –120 degrees if figured from the manus pattern. Most often only 3 to 4 digits are preserved with occasional tail drag marks. The digits are slender and relatively longer in the pes than in the manus and both sometimes exhibit distinct claw impressions.

Distribution of Rhynchosauroides tracks are common in the Western U.S. and Europe throughout the Triassic.

Undichna Fin Traces

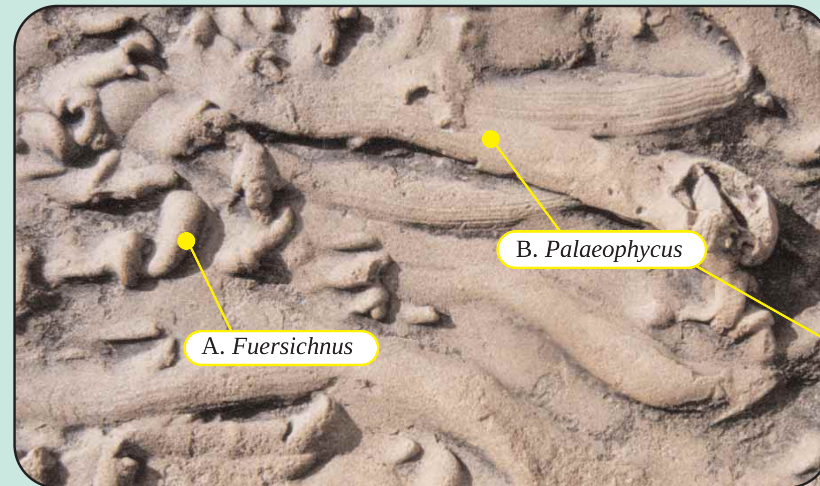
The Moenkopi Formation is known for its exceptional vertebrate fossil record. Fish are rare and have been little studied in detail, and fish trails (fish fin drag marks) have never been recorded. The purpose of this study is to describe the first known occurrence of fish trails (fish fin drag marks), *Undichna* from the Early/Middle (?) Triassic Torrey Member of the Moenkopi Formation. This ichnogenus has been reported in abundance from the Late Paleozoic, Permian,Cretaceous and more recently from the Eocene (Loewen, 1999). *Undichna* from the Torrey Member of the Moenkopi Formation represents the first and only known occurrence of fish trace fossils in the Triassic in the Western U.S.

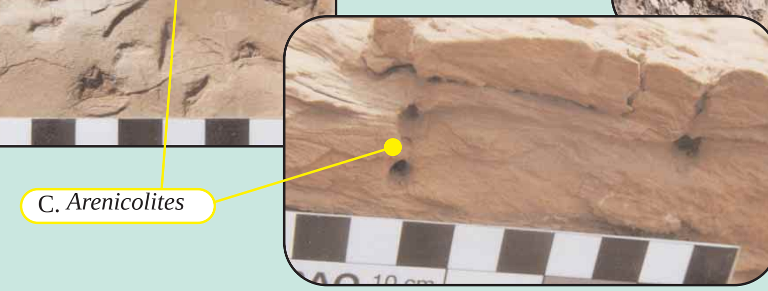
The fish fin trace fossils are preserved as convex hyporelief sandstone casts with filled imprints preserved in underlying mudstone. Exposed traces occur on the undersides of resistant sandstone ledges where the mudstone eroded away. *Undichna* commonly occur with locally dense concentrations of swim traces of *Chirotherium.*

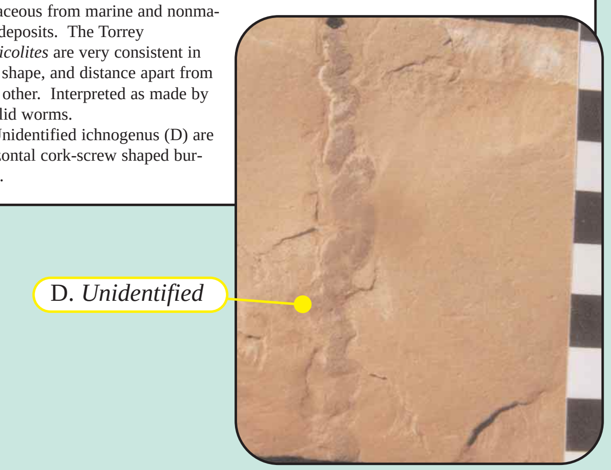
Occurring in clusters, one isolated fish fin trace consists of a single, slightly-asymmetrical, sinusoidal trail. The trace is 56 cm. Long and includes 6.5 cycles with wavelengths varying from 9 to 10 cm and amplitudes of 3.5 to 4.5 cm.

The trails were most likely produced by a fish with a large caudal or anal fin able to reach the sediment without any other fin doing so. The low wavelength to amplitude ratio is most consistent with a caudal fin. This occurrence of Undichna is similar to other previous descriptions and it confirms that the preservation of these trails are favored in fine-grained sediments, deposited under low oxygen conditions in the absence of infaunal bioturbation (Loewen, 1999).

Invertebrate Traces







The Torrey Member of the Moenkopi Formation assemblage studied is considered herein as an example of the *Glossifungites* ichnofacies and commonly occur with vertebrate swim tracks. This ichnofacies has been restricted to firm but unlithified nonmarine and marine surfaces. The *Glossifungites* ichnofacies is characterized by low diversity and high density assemblages which include *Fuerichnus, Palaeophycus, Arenicolites,* and *Skolithos.*

The ichnogenus *Fuersichnus* (A) is a relatively rare trace fossil that has been documented from Triassic and Jurassic nonmarine deposits and only recently documented in marine deposits from the Upper Cretaceous (Buatois, 1995). The ichnogenus consits of horizontal to subhorizontal, isolated of loosely clustered, U-shaped, curved to banana-like burrows, characterized by distinctive striations parallel to the trace axis. It is interpreted as a dwelling structure probably produced by crustaceans or polychaetes.

The ichnogenus *Palaeophycus* (B) a common trace fossil that has been documented from Pre-Cambrian to Holocene nonmarine and marine deposits (Pemberton and Frey, 1982). Branched, and irregularly winding, cylindric or subcylindric tubes, that sometimes cross-cut one another. These horizontal galleries most often have vertically striated lined burrows or rarely nearly smooth surface textures. *Palaeophycus* represents passive sedimentation within an open dwelling burrow constructed by a predaceous or suspension-feeding animal.

The ichnogenus *Arenicolites* (C) are simple U-tubes (paired tubes) without spereite, perpendicular to bedding plane; usually varying in size, tube diameter, distance of limbs, and depth of burrows; limbs rarely somewhat branched, some with funnel-shaped opening; walls commonly smooth. A common trace fossil documented from Triassic to Cretaceous from marine and nonmarine deposits. The Torrey *Arenicolites* are very consistent in size, shape, and distance apart from each other. Interpreted as made by annelid worms.

Unidentified ichnogenus (D) are horizontal cork-screw shaped burrows.

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Comments

All track localities within Capitol Reef National Park and Glen Canyon National Recreation Area were identified with GPS location coordinates and a detailed map was provided to each park's science research coordinator. The new information affects both fossil resource management and park interpretive programs about pre-dinosaur ecosystems. It is important to understand that these vertebrate track sites are non-renewable resources. This study will aide in the protection and management of these resources.