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# ICHNOLOGY

TRACE FOSSILS IN SEDIMENTOLOGY AND STRATIGRAPHY

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• -. , r F  The Mid-America Paleontology Society [MAPS] was formed to promote popular interest in the subject of paleontology, to encourage the proper collecting, study, preparation and display of fossil material; and to assist other individuals, groups and institutions interested in the various aspects of paleontology. It is a non-profit society incorporated under the laws of the State of Iowa.

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BY SAMUEL J. CIURCA, Jr.

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## FOREWORD

Trace fossils? Why would anyone want to collect or study a trace of something? That is a question that has been on the lips of many of my friends this year. Those squiggly lines and marks on the rocks that we break up in search of trilobites and other fossils have a story of their own to tell. And not all the information written on the stony pages of the earth is easily deciphered.

Other than the tracks, trails and burrows left by nameless invertebrates in limy muds and sandy shores of ancient seas, there are many different forms of trace fossils. There are dinosaur tracks, bird tracks, gastroliths, coprolites, bite marks, insect damage on leaf fossils, burrows, nests etc. And the knowledge gained from these traces can not be found in the remains of the creatures that produced them.

## ACKNOWLEDGEMENTS

As a new editor for the MAPS EXPO Digest, I wish to extend my hearty thanks to all the fine authors who contributed articles for this edition. This year's theme proved to be both exciting and challenging. The more I investigated the scope of trails and burrows, [not to mention all the rest of the various groups of trace fossils], the larger the field study became. Our authors have met the challenge and have provided for our reading enjoyment articles on invertebrate trails, dinosaur trackways and last but not least - the scoop on poop!

## THE COVER

This is a portion of an illustration submitted by Bruce Stinchcomb, one of our authors. These are block diagrams of various marine and terrestrial creatures going about their daily lives and creating tracks, trails and burrows. By observing the undersides of some of the block diagrams we may observe impressions, furrows and ridges commonly encountered in sedimentary rocks. I personally like the rabbit - nice touch!

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### QUESTIONS AND ANSWERS ABOUT TRACE FOSSILS

- Q. Is there a branch of paleontology which deals with trace fossils and what is it called?
- A. Yes, there is! It's called Ichnology.

Q. What is a trace fossil?

- A. It's evidence in the form of some type of track or trail of some organisms (usually an animal) which is capable of yielding specific information as to the fossils taxonomic position, behavior or both.
- Q. What is the geologic age of the oldest known trace fossils?
- A. If one considers stromatolites to be trace fossils, 3.5 billion year old Stromatolites from Australia and South Africa.
- Q. What are stromatolites?
- A. They are structures produced by the life (physiological) activities of a community of Micro-organisms, usually monerans.
- Q. What are monerans?
- A. Very primitive and simple life forms such as bacteria, blue-green algae and archeobacteria.
- Q. What is the difference between a fossil burrow, a track and a fossil trackway?
- A. A burrow is made by an organism moving through (or burrowing) soft sediment. Its Formed within the sediment. A Track is made by an organism moving on the sediment surface. A trackway is a series of tracks, viz. One footprint is a track, a whole series of them is a trackway.
- Q. What is the geologically oldest known fossil burrow or track?
- A. Worm-like "tracks" have been found in rocks as old as 2.5 billion years, however the origin of these is unclear and they probably are not from animals as we know them.
- Q. What is the oldest **undoubted** fossil track or burrow?
- A. Very late Precambrian, that is some 600+ million years ago.
- Q. Are fossil trackways allways made by vertebrates such as amphibians and reptiles?
- A. No! Arthropods such as trilobites, aglaspids, horseshoe-like animals, insects and arachnids can make fossil trackways.
- Q. What is the age of the oldest known vertebrate trackways and what made them?
- A. Earliest are early Devonian, they were made by early amphibians.
- Q. What is the geologic age of the oldest trolobite tracks or trackways?

A. Very late Precambrian, just below the Precambrian/Cambrian boundary.

- Q. If trilobite tracks are found, how come there are no actual trilobites known from this strata?
- A. Trilobites (and most other shelled animals), lacked shells or other hard parts before the Cambrian.
- Q. How can you be sure that these tracks or trackways were really made by trolibites if no actual exoskeleton material occurs?
- A. Many trilobites (or trilobite-like animals) were soft bodied and lacked an exoskeleton even in the Paleozoic. These animals made trackways indistinguishable from those of shelled trilobites. These soft bodied trilobite-like animals are known as trilobitmorphs.
- Q. Are trace fossils given scientific (Linnean) names?
- A. Yes! Trace fossils are given what are known to paleontologists as form genera and form species. These differ from the names of the trackmaker because in most cases the track maker remains unknown.
- Q. What are grazing tracks?
- A. Animals that feed on organic material on the ocean floor sometimes feed (graze) in a regular, systematic pattern. This is particularly characteristic of deep sea animals to conserve energy and achieve maximum efficiency in obtaining food.
- Q. Are fossils of deep sea organisms known from the rock record?
- A. Yes! Sediments deposited in deep sea trenches are known from the rock record and often yield grazing tracks characteristic of deep sea organisms.
- Q. Where are some of these deep sea grazing trace fossils found?
- A. In regions where deep sea sedimentary rocks exist such as the coastal ranges of California, the Ouachita Mountains of Arkansas and Oklahoma and the Alps of Europe.
- Q. You mean to say that the Alps were once part of a deep sea trench?
- A. Yes! The sedimentary rocks which make up the Alps, were once deposited in a deep sea trench.
- Q. I thought that the Alps were composed of metamorphic rock?
- A. Some of it is metamorphic rock (low grade) for the process of mountain building can change sediments to Metamorphic rock.
- Q. I thought that metamorphic rock didn't have any fossils in it?
- A. Low grade metamorphic rocks such as slate, phyllite and quartzite will preserve trace fossils. Many of the deep sea trace fossils showing grazing patterns are found in low grade metamorphic rocks.

## TRACE FOSSILS AND THE APPEARANCE OF MULTICELLED ANIMAL LIFE

## Bruce L. Stinchcomb

Throughout most of the early sedimentary rock record, fossils are either rare, or they are represented by primitive monerans such as blue-green algae (cyanobacteria), usually as the pecular and distinctive structures called stromatolites. Strata of the age range of 4.0 billion Years (early Archean) to 650 million years (late Proterozoic or Neoproterozoic) essentually show no (or little) evidence of the existance of multicelled life, especially animal life. As most knowledgable fossil affectionatos know, fossils become abundant all of a sudden about 545 million years ago with the beginning of the Cambrian Period. This "explosion" of life had something to do with the appearance of animals with shells, tests and other hard parts. However animal life can also leave a good record of its existance in the form of tracks and trails that is tracefossils or lebenspüren. These have the benefit of not requiring the presence of hard parts and the earliest appearance of animals should be, and is marked by their first appearance.

What that in mind, what are the earliest trace fossils like? The earliest late Proterozoic trace fossils are simple sinuous surface tracks, the product of some sort of "slithery creature. Worms probably? After these appear, some complex forms such as those shown below can appear. Some seem to be made by Trilobitemorphs, soft bodied trilobite-like organisms with no hard parts (*Mariella* of the Burgess shale is A good comparison). Some of these trace fossils are unlike those found in later Paleozoic rocks. Like animals of the Cambrian with hard parts, these seem to represent life forms which were "experimental" and have no later or recent counterparts. Others are well represented in younger rocks and are even found in modern ocean floor sediments.

What organisms were responsible for these tracks is often difficult to determine, even with modern Tracks in ocean floor sediments. Modern tracks and trackways also often are very vague, the process of lithification of sediment seems to enhance the enclosed lebenspuren.

Some of the puzzleing tracefossils found at the Precambrian (late Proterozoic)/Cambrian boundary are as follows;



*Oldhamia*, a fan-like tracefossil first described in the mid 19<sup>th</sup> century from Lower Cambrian strata of Ireland. *Oldhamia* seems to be most frequent in the Lower Cambrian but has been found slaty rocks of younger Paleozoic age. Some believe that it represents a feeding strategy of a group of organisms feeding on monerans along bedding planes just below the surface. This is suggested to be a prelude to more extensive burrowing in sediments, burrowing which produced the majority of trace fossils.

## Scolithus sp.

A vertical burrow found in sandstone and quartzite. *Scolithus* is particularly characteristic of the lower and mid Cambrian. In a few areas such as the Chilthowee Series of the southern Applachians, *Scolithus* is considered to occur earlier than fossil of hard parts, hence some have placed it in the very late Precambrian as well as in the Paleozoic where it can be common.



# Scolithus canadensis, Billings.



Woodcut of Scolithus in Cambrian quartzite.



Dactyloidites asteroides Fitch Found in slate of Vermont and eastern New York, Dactyloidites was considered by Charles D. Walcott As being a fossil jellyfish. (Medusa). It is now considered as being a trace fossil.

ATTER





A deep sea (abyssal) grazing track Spirorhaphe (left) and Spirophycus (right)





Grazing tracks produced by deep sea Animals. Bottom; two "form species" of The "form genus" *Spirodesmos*.

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Monocraterion lesleyi.



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Astropolithon Dawson Originally described by J. W.Dawson as a plant from Lower Cambrian slates. The form is probably a radial trace fossil related to Dactyloidites which also comes from the Lower Cambrian.



Fig. 364. - Burrows of Proterozoic worms. A, cast of large burrow (Planolites corrugatus). B, imprint of the actual annelid tube (Helminthoidichnites meeki). After Walcott.

Tracks resembling those made by annelids or some other form of worm-like animal occur sparsely in Precambrian rocks. Some of these like Rhysonetron probably represent a structure formed from drying algal matts. Others may be some sort of aberrant stromatolite. There is however, as with UFO investigations, a small residue of fossils deep in the Precambrian which seem best explained as worm tracks and hence suggestive of multicelled animals. A problem because multicelled animals are generally not considered to have appeared until the very end of the Precambrian.

Tigillites bohmei Branaugh Mid Proterozoic Mescal Limestone This is another "Precambrian worm" fossil. The occurrence is near Miami, Arizona in somewhat metamorphosed Limestones associated with stromatolites.

Top view of slice cut parallel to bedding and transverse to verticle "burrows". Scan of slab done on a flat bed scanner, x 1.

> Side view of slab cut transverse to bedding. Scan of slab, x 1.

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"Worm burrows" showing "segments" produced as a consequence of paristaltic movement the producing animal through soft sediment. Early Paleozoic.



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Trackways which can be made by a trilobite or trilobitmorph.

Diplichnites-walking

Rusophycus-resting

J.W.D.

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Palæophycus beverlyensis.

Allocolichnus-striding

Cruziana-furrowing

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(fucoid,) but probably a " mould of the track of

some animal.-Cambri-

an rocks. C.

Rusophycus bilobatus (Fucoides

Y,

R.

Hall,



*Phycodes* sp. A trace fossil indicative of Moderate depths of ancient and modern Marine sediments.



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Zoophycos sp. Another deep sea trace fossil Originally thought to be a fossil plant. Note the Ending "**phycos**".

Diplocraterion sp. A trace fossil indicative of

*Spirophyton* sp. Cork screw-like burrows found in both Paleozoic, Mesozoic and Cenozoic deep sea sediments.

## **TRACE FOSSILS**

BY

## CHARLES EDWARD OLDHAM, PG

## **TRACKS, TRAILS, AND BURROWS**

Early literature placed most trails and burrows under such broad categories as "worm trails", "sea-weed" and certain feeding traces were even assigned to the "jellyfish". The authors classified trace fossils in whichever category the trace fossil's appearance prescribed. Up until about 1940 little attention was paid to trace fossils by paleontologists, many believing that later workers describing the stratigraphy would attend to these "structures". And stratigraphers believed paleontologist would describe these "fossil oddities".

Many different approaches have been taken to name and or classify trace fossils. Ichnotaxonomy is a system based on shape and biological behavior. Other systems attempt to assign traces to large biotaxonomical groups, reducing them to smaller groups, as more information becomes available. Other systems are military in nature, ignoring any biological affinity and classifying tubes as straight curved u-shaped etc.

The accepted system is Ichnotaxonomy. This system is based on morphology and is recognized by the International Commission of Zoological Nomenclature [ICZN].

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Ichnotaxonomy uses binomial names similar to the genus and species designations used in botany and zoology. In order to make a clear distinction between the two systems the prefix [incho] needs to precede the genus and species of trace fossils. The ICZN now recognizes inchnofamily, ichnogenus, ichnospecies and some intermediate levels such as ichnosubgenera and ichnosubspecies. The binomial name is always italicized, the ichnogenus is always capitalized and the ichnospecies is always in lower case [*Cruziana rugosa*].

Trace fossils are classified for what they represent - a trace of a creature walking, crawling, feeding etc. A record persevered in stone of some type of behavior of an organism. Unlike zoology which uses common descent as a unifying link, trace fossils have no single simple framework upon which trace hierarchy.

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Therefore, some interpretation is required. First one must establish that the structures being studied are of biogenic origin. Then one must devise some sort of a series of biological behavior traits to develop a hierarchy. Examples may include a burrow that is first used for feeding and then provides a structure for a dwelling. The creature that created the burrow for feeding may not necessarily be the organism who lives in the burrow.

Because we are inclined to think in terms of which creature produced the trace instead of determining the particular behavior which produced the trace, there exists a tendency to attach significance to minute variations.

Example in point: *Rusophycus* and *Cruziana* are considered to be pits or furrows made by arthropods. These pits and furrows have a wide variety of imprints, scratch patterns and marks. These have been attributed to the shape, size, and arrangement of spines, claws, and appendages of the arthropods that produced them. *Cruziana rugosa* generally has twelve parallel sets of scratches, *Cruziana furcifera* has multiple, parallel, and oblique sets of scratches and *Cruziana barbata* have sets of four transverse scratches.

Any arthropod may have produced the traces named *Rusophycus* and *Cruziana*, provided they have the necessary set of appendages to produce the track. I have witnessed a number of these sets of tracks with a trilobite in close proximity to the track way. However it is very doubtful that the individual trilobites found in association with these tracks produced the tracks. Very seldom is the organism that produced the trace found preserved with the trace.

Attempts to assign biotaxa identities to ichnotaxa traces have created a need to define the relationship between the two systems [ichnotaxonomy and biotaxonomy]. Thus warding off the possibility for problems in synonymy [two names for the same organism]. An example is "the burrow of a *Callianassa major*" [biotaxonomy] or *Ophiomorpha nodosa* [ichnotaxonomy] are both correct.

In rare cases certain distinctive imprints are found associated with traces. A *Cruziana* from the Lexington Limestone of Frankfort, Kentucky contained a series of imprints of the underside of an *Isotelus sp.* [a large "burrowing" trilobite], including an imprint of the hypostome. [The owner of the specimen believed that he had a complete trilobite that was turned upside down. He consequently had it prepared as such and the specimen was ruined].

Is this an indication that the trilobite *Isotelus sp.* produced all the *Cruziana* from the Lexington Limestone? Not likely, but it is an indication that *Isotelus sp.* have produced some the *Cruziana* traces.

Attempting to use trace fossils for stratigraphic markers or index fossils is flawed. Trace fossils are records of behavior, not a fossil record of a single biological entity. *Cruziana rugosa* and other similar traces were used as index fossils for the Lower Ordovician in Western Europe [Crimes, 1968] and [Seilacher, 1970]. [Alpert, 1976] described *Cruziana rugosa* from the Lower Cambrian in White-Inyo Mountains of California. And [Bradshaw, 1981] described *Cruziana rugosa* from the Devonian -Taylor Group, in Antarctica.

Putting aside the attempts to assign specific creatures to certain traces, the problems associated with assigning a hierarchy to a group of trace fossils have just begun. The worker must get inside the creature's "head". The behavior of an echinoderm may be quite different than that of an arthropod. And the trace left in a muddy bottom will likely be quite different from the same creature on a sandy substrate.

Morphological features in certain traces may be clearly defined, or not. Some traces contain recurrent patterns, others fluctuate. Are these changes in behavior or do they represent differences in preservation? Do fluctuations in feeding traces indicate that the proper nutrients were not present in certain areas?

The one saving grace in this system is that for most invertebrate traces, there are only two levels of hierarchy - inchogenus and ichnospecies. Inchnofamilies are generally reserved for tracks and traces of vertebrates.

While invertebrate trace fossils are many times problematic at best; vertebrate track ways provide a wealth of information. The presence of track ways in various strata, in the absence of skeletal remains provides an indication of the vertebrates that once roamed the area.

The trackway of the oldest [Mississippian age- 320 million years old], known North American reptile was found imprinted on a sandstone slab [float] in McCreary County, Kentucky. The trackway has been identified as *Notalacerta missouriensis*. The trackway consists of forefoot and hindfoot prints with a straight tail drag mark. No other traces or skeletal remains have been found.

Vertebrate track ways leave clues to the posture, speed, herding behavior and distribution of weight. Posture may be inferred by wide to narrow pace angulation in comparison to the midline of the track way. Salamanders and reptiles would have a wide pace angulation while birds and dinosaurs would have a narrow pace angulation.

The evidence for determining the speed of an animal from a track way is open to much discussion. However there are documented cases for track ways in which the track maker appears to be running. Herding may be inferred when track ways of the same type of animal are all going in the same direction and are in close proximity to each other. Also the occurrence of two different species of leaving footprints in the same strata provide an indication of co-existence.

Besides track ways, vertebrates have also left behind coprolites, burrows, nests, gastroliths and even bite marks. Coprolites provide clues as to the diet of the creature that made them. Burrows or dens sometimes contain remains of other animals were the prey of the den maker. Dinosaur nests are well documented; other nest makers include birds [flightless], lizards, snakes, turtles and crocodiles. Eggs are considered by some workers to be trace fossils. A cephalopod from the lower middle Pennsylvanian of Kentucky [Mapes and Hansen, 1984] shows bite marks that may have been from a cladodont shark.

Gastroliths have been found in association with skeletal remains, but often times they are found in isolated clutches. In 1984 while exploring the Worland Basin in Wyoming I observed a great number of highly polished clutches of gastrolith stones associated with Cretaceous sediments. I did not observe any associated skeletal remains. I have been told that these clutches may represent dung piles and the gastrolith stones had become small enough to excrete?

One area of trace fossils that is generally ignored by most collectors is the feeding traces on leaf and plant material by arthropods, mainly insects. In the attempt to collect the most perfect leaf fossils obtainable, bite marks and holes are not desirable features. Therefore many interesting and scientifically important trace fossils are discarded. In addition to feeding traces there are also egg cases, and damage caused by disease.

One way to become familiar with the different types of leaf damage that may be observed in the fossil record is to refer to gardening books or literature from your local county agent. Better yet look at the leaves on trees and plants in your yard. Late summer is the best time.

I have observed a great number of leaves with insect damage in the Eocene flora from the Holly Springs formation of Western Kentucky and Tennessee. And I have a number of fern leaf fossils from Illinois, Kansas, Oklahoma, Indiana, Ohio, Pennsylvania, and Kentucky that appear to have feeding traces - bite marks and holes, including window or skeleton feeding.

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Now that you have been introduced to the many types of trace fossils preserved in the fossil record, go look over your collection. You may also been a collector of trace fossils and not even known it.

Enjoy you collection, each and every little detail!

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## COMMON TERMS USED IN DESCRIBING TRACE FOSSILS

**Borings** = produced by the cutting through grains or crystals in either the substrate or the tests of other organisms.

**Coprolites** = petrified dung.

**Ethological Trace Fossils** = based on the interpretation of the purpose of the behavior that produced the trace:

[a] argichnia = gardening or entrapment

[b] cubichnia = resting places

[c] domichnia = dwelling places

[d] fodinichnia = feeding traces

[e] fugichnia = escape traces

[f] pascichnia = grazing traces

[g] praedichnia = perdition traces

[h] repichnia = locomotion traces

**Formational Trace Fossils** = The trace originally occurred at the surface of the substrate.

- [a] exogenic formed at sediment surface
- [b] endogenic- formed within the substrate
- [c] intergenic formed at the subsurface strata boundary

Gait = the style of locomotion- walking, running, crawling etc.

Gastroliths = [Stomach Stones] stones ingested to aid in the grinding of food.

**Gleno-acetabular distance** = body length.

**Inchnotayonomy = Inchnofossils**, the fossil trace [s] of behavior. This system utilizes zoological nomenclature and taxonomic hierarchy similar to that used for the classification organisms.

**Ichnotaxobases** = morphological features on which ichnotaxonomic classification is based. These features should demonstrate a behavior which has a recurrent pattern and is easy to distinguish from other similar features.

Trace = borings, burrows, surface furrows, imprints, footprints

Simple linear burrows & furrows; Straight Meandering Spiraling Sinuous & irregular Branching complex; Right angle Dichotomous Radiating Tree-like Simple branching Two-dimensional mazes Three-dimensional mazes [box works]

Spreiten = overlapping of burrows as in the mining of a large volume of sediment - deposit feeding.

**Ornamentation** = indentations, scratch marks, distal terminations.

Linings = a coating of an different material, or a smoothing or altering of the parent material, that separates the interior of the trace from substrate surrounding the trace.

No Linings - substrate forms the burrow wall

## Linings -

**Thin linings** - most burrows originally had such a lining, however it is generally not preserved. Sometimes a discoloration along the substrate wall is an indication that a thin mucus lining was originally present.

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**Constructed Linings** - can be organic secretions or granules, clasts, pellets or a combination.

**Laminated Linings** - generally an indication of long occupation and or modification.

Internal Structures = open or backfilled, partitioned chambers, changes in backfill rates.

**Substrate Choice** = predominately found in a particular substrate.

Manus = [hand] the front foot.

 $\underline{Midline}$  = an imaginary line drawn at midpoint between the tracks defining the longitudinal [sagittal] plane of the creature who made the track.

**Pace** = distance between two footprints made by opposite feet.

**Pace angulation** = the angle created by two sequential paces.

 $\mathbf{Pes} = [foot], the rear foot.$ 

**Preservational Trace Fossils** = traces preserved in full or partial relief

<u>Secreted Tubes</u> = are generally excluded and in general biogenic structures used as body parts including some borings. Some authors do not make this exclusion particularly if their zoological affinity is unknown.

**Stride** = the distance between two footprints made by the same foot.

<u>Substrate</u> = what comprises the ocean, lake or stream floor i.e. silt, mud, sand, gravel, combinations, etc. Contains, burrows, tubes and tunnels that are produced by the manipulation of substrate materials for the purposes of feeding, living, escaping [hiding], egg laying, resting etc.

 $\underline{Surface}$  = the top of the substrate. Contains drag marks, trails, furrows, scratches, footprints etc., produced by appendages and other body parts. Comprising indications of locomotion, feeding, resting etc.

# An Aglaspid Takes a Stroll in the Cambrian

Gerald Gunderson 6413 Elmwood Avenue Middleton, WI 53562

Was it a mat of Ordovician algae? As a person new to fossil collecting in the mid-1950s, I thought the flat specimen I had collected in northeastern Wisconsin looked like it might be algae. It wasn't until much later that I realized that the almost flat crisscrossing assemblage was in fact a cluster of burrows left by an unknown animal or animals. It was what is known as a *trace fossil*—what I think of as the fossilized remains of the activity of animals left in sediment.

Ordovician and Silurian trace fossils were not very common or very diverse in the northeastern part of the state. They did not appear to be as complex as trilobites or brachiopods, so it was hard to believe that they were worth collecting. At the time, these traces did not conjure up much of a compelling image of what life in the past might have been like.

My perception of trace fossils started to change in the 1970s, however. During this time, while looking for Upper Cambrian fossils on the west side of the state, a large number of well preserved trace fossils were found. In the Cambrian, fine-grained sandstone, interspersed with very fine shaley partings, preserved even slight disturbances on the surface of the ocean floor.

On some Cambrian bedding surfaces, one could find evidence of where detritus had been swept across the sea floor. One type of trace fossil was formed by the impressions left by this moving material. These impressions included numerous faint, narrow, shallow groves that covered some sandstone surfaces with scratch-like marks. Most of these marks were parallel to each other (Fig. 1a), which was an indication there had been an ocean current at the time of their preservation. Trilobite parts, brachiopods, and other animals probably left these traces. Other fine sediments, such as clay, presented some of the best media for trace fossils like these to form. In this fine medium, a trace could easily be left by a trilobite's free cheek lightly grazing the soft sedimentary surface as it was whisked along.

Another relatively common type of trace fossil in Wisconsin Cambrian rocks is the burrow. Many burrows are found parallel to the bedding plain and often close to the bedding plain's surface. Animals that made these burrows were likely tunneling through the sediment in search of something to eat. As a result, other fossils are rarely found in the same sediments, because the burrowers would have eaten them. It's likely that worms or arthropods excavated most of these burrows.

Vertical burrows were also found in the course of searching for Potsdam trilobites with Dan Fredrickson, and Ron Meyer. These burrows were small in diameter and found in dark brown, coarse sandstone blocks in a cemetery wall east of Berlin, Wisconsin. Worms could have lived in these vertical tubes. Secretions from their bodies might have cemented the sand grains together, so the wall did not collapse. *Scolithus* is the genus name given to many of these vertical burrows and are common in many horizons.

A much rarer trace fossil is one that looks like a pattern left by an animal at rest. These fossils consist of two elongate depressions, lying side by side, that appear to have been dug out by many pairs of legs. Most of these excavations are attributed to the activity of trilobites. Some sandstone slabs in the Eau Claire Formation of west central Wisconsin have a large concentration of these resting patterns. It is a puzzle as to why animals made such depressions. Could they have been feeding on bits of food that were in the sediment? Were they trying to hide by lying flush to the ocean bottom? Were these depressions for egg laying? Or, was it simply a spot just to rest?

There are also resting patterns that are not typical. One atypical fossil group was found on the green clay bedding plains in the St. Lawrence Formation south of Muscoda, Wisconsin.

There were so few brachiopods and complete trilobites found at this site that it was the more abundant and diverse trace fossils that helped paint a better picture of life in this part of the Cambrian. Among the trace fossils at this site, a few were of the atypical resting variety. These trace fossils were donated to the University of Wisconsin Geology Museum. Eventually, graduate student Steve Hesselbo, who was working on the taxonomy of aglaspids for a Ph.D. dissertation, took an interest in them.

Steve 's adviser, Dr. Derek Briggs, had seen the donated trace fossils, and urged Steve to study them to determine if there was a connection between these resting patterns and the aglaspids that Steve was studying. Aglaspids were probably closely related to the trilobite. They look something like a horseshoe crab, and have long tails, referred to as a "tail spines," that resemble the tails of horseshoe crabs. Steve found that indeed there was a relationship between aglaspids and the resting patterns. He discovered that the number of appendages found on one aglaspid and its general shape matched up with the trace fossils found in the St. Lawrence Formation. He eventually wrote the article "Trace fossils of Cambrian aglaspidid arthropods" in the journal *Lethaia* (1988, Vol. 21).

Steve Hesselbo found that not only did the aglaspid's torso match up with these resting patterns, but some of these forms had a faint, very narrow pair of groves directly behind the main portion of the fossil trace (Fig. 1b). It so happened that one of the aglaspids in my own collection had a tail spine sporting a short double-forked tip (Fig. 1c). The ends of other tail spines probably were broken off. It is very likely that the two small tips were weakly attached to the tail and broke off after the animal died. From this extra bit of evidence it can be assumed that, as the aglaspids swam up off the sea floor, narrow furrows were made by the ends of their doubled-forked tails as they dragged over the sediment. Rarely can a trace fossil be attributed to an animal with such certainty, but these three morphological characteristics tie an ancient animal—the aglaspid—to a specific trace fossil.

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Now you would think this is where the tale ends. Sorry for the pun, but there is more.

In the year after working with Steve, I started to find fossil trails from animals that seemed to be just walking over the floor of the Cambrian sea. Typically, these trackways consisted of two long rows of many small depressions (Fig. 2a). The two rows were about a centimeter apart, and one could imagine some kind of smallish arthropod had made the trails. One day, when searching for just a few more specimens, I found a handsized scrap of rock in which there were trace fossils of a larger than normal walking trail. To my surprise it had two narrow groves down the middle (Fig. 2b), and it was about the width of the aglaspid resting pattern. Was this a place where an aglaspid had taken a stroll in the Cambrian? It would surely seem so.



Figure 1. Sketches of Wisconsin Upper Cambrian fossils: a. traces caused by moving water, 1x; b. the aglaspid resting pattern <u>Raaschichnus</u> gundersoni Hesselbo, 1.5x; c. a line drawing of the aglaspid <u>Glypharthrus simplex</u>, collected near Muscoda, Wisconsin, 2.8x.



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Figure 2. Traces found in the Cambrian St. Lawrence Formation south of Muscoda, Wisconsin: a. this trackway is relatively common and is much like the genus <u>Diplichnites</u> sp., 2x; b. an unnamed trackway as it might have been when an aglaspid was walking on the sea floor, 1.1x.



Figure 3. Sometimes aglaspid resting patterns are found in long series: this figure shows part of one of these series as one might imagine it being created, 1.5x. Most animals that died during Wisconsin's Cambrian times were transported some distance before being fossilized, while aglaspids found in the strata containing their resting traces and any trackways very likely lived in the immediate area.

In 1995 I had joined a group of Canadian geologists and paleontologists in Texas for a trip checking dinosaur locations. Dr. Phil Currie, Royal Tyrrell Museum, Drumheller was the science leader. Our group covered numerous areas for Lubbock to Big Bend, visiting many universities, laboratories and track sites resulting in many related photographs.

The following is the description of the enclosed photographs:

- 1. Tracks from the F-6, 1879 Ranch with Dr. Phil Currie in the upper right hand corner and to his left is Mike Skepnick, an excellent dinosaur artist. These tracks were considered those of the Acrocanthrosaurus but can't be confirmed in this location as no other bone evidence has been found. Other localities in this region have been identified with this association. It is early Cretaceous 140-100 million years old.
- 2. and 3 are separate foot prints of the same reptile in the same general area.
- 4. Is a foot print from Glen Rose, Texas of possibly a similar reptile, although Glen Rose has been noted as having also prints of Pleurocelus and Apatosaurus.

Hope you find a use for the pictures.

Yours truly, The Lewis

MAPS Member.









### FOOTPRINTS IN THE MUDS OF PERMIAN TIME by Tom Walsh 501 East 19th Avenue, Coal Valley Illinois 61240

Would you like to be a member of a dig at a site destined to become famous. fossil comparable to Dinosaur National mavhe Monument? Well, I did it! At 6:00 A.M. on June 15th, 1990, I was driving up to a leveled-off parking area in the Robledo Mts. near Las Cruces, New Mexico. I met Jerry MacDonald, Doug Wood, and Mark waiting in the cool quiet dawn. Schult, had discovered and developed the and Doug Wood was Jerry's local Jerrv site. helper. I had only met Mark the evening before at his campsite in a state park, but we had corresponded, and I agreed to help on the dig for a week. Mark is working on his doctorate at Indiana University and had been working on the trackway dig since mid-He plans to develop the paleoecology Mav. of the reptile and amphibian footprint fauna. He had mentioned in one of our phone converstaions that he would be camping in Leasburg State Park, North of Las Cruces.

wife and I had pulled our camping My trailer from our home in Illinois, and we were camped in a nice KOA campground with a swimming pool. Once we were comfortably settled in the campground we decided to try to find Mark at Leasburg State Park. He was not hard to find once we got there. He was the only camper in the whole campground. It was easy to understand why; there were no trees and little vegetation, and the wind blew constantly the temperature was around 105. The only shade was under shelters built at each campsite. Peg and I spotted a solitary camper sitting at a picnic table beside a tent, other camping equipment and a pile of rocks all under a shelter. It had to be Mark, and it was. We talked with him quite a while, and he seemed pleased to have visitors to his desolate little abode. He gave me directions to the place where we would meet the next day near the dig. Mark said to meet there at 6:00 A.M. They work early because it gets hot in the afternoon.

The next morning I was relieved to see them waiting by the entrance since I wasn't sure I had remembered the directions exactly. Jerry lowered the chain so the two 4-wheel drive vehicles could drive through; then he put the chain up again. There was a sign saving the BLM gave a permit for this scientific work and everyone should keep Jerry MacDonald, who has been working out. on this site for three years, went through the necessary steps to get this permit. I was pretty excited as we slowly drove down the rough rock-strewn trail winding around the big boulders and creeping over slabs of sloping rock layers. After about half a mile we had to park and walk up a dry canyon about a quarter of a mile or more to the site. We each carried canteens of drinking water.

surprised by the size of the was excavation in the side of the canyon. I'd estimate it to be about 150 feet wide and about ten to fifteen feet back into the canvon wall. The (redbed) Permian lavers slope up the canyon at about twelve degrees, and the tracks are found in this When I got close, I could see a formation. would not person have to use his imagination to see the trackways. The first one I saw was still in place and looked like the animal had just walked across the slab the night before. Each footprint was about five inches in diameter and the trackway went about fifteen feet before it disappeared back into the mountain. Jerry pointed out one trackway of large tracks which had a trackway of a smaller animal intersect it and stop there. Did the larger animal capture the smaller one? There was no sign of struggle.

There are many exposed trackways of vertebrates and invertebrates and many more just waiting to be exposed to tell their part in the events that took place 280 million years ago. These tracks are being found in the Abo Formation in what was an early Permian shore line. Over fifty of vertebrate separate species and invertebrate animals and eight species of plants have been found there by Jerry. The discovery, it has been said, will provide the only record of the existence of many new species. He has taken samples of the material and photographs of the trackways to the Smithsonian Institution and the

Carnegie Museum of Natural History. The site has been visited by a scientist from each of these organizations.

We tried to do most of the heavy work in the early morning before it got too hot. The layers of rock were two to eight inches thick, and if they had no tracks, we removed them; or if the layer was all was removed. This waste crumbled, it accumulated pretty quickly and had to be shoveled down the side of the canyon. The solid layers of rock were swept off and checked for tracks. The rock was more like siltstone, and we all got pretty dirty each day from the dust.

The sun came over the mountain and hit the site at about 9:00 A.M. Then it started heating up, so we changed from the heavier work to less physical things like taking measurements and photographs. Mark took many measurements of one trackway after he chalked a grid on one-half meter had squares over the length of it. I recorded his measurements under the headings he had listed. He said he would later use all of his measurements to duplicate the footprints on grid paper. Also, he drew a stratigraphic column of one section of the dig by starting at the bottom layer of rock and measuring each layer, which had previously been numbered from the top down. I read the ruler, and he recorded how many centimeters thick each layer was. At the same time he drew the column showing the harder, more resistant layers standing out farther than the softer, more crumbly layers. He also indicated what each was, such as shale, siltstone, sandstone, etc.

I really enjoyed my week of going to the Last year I read Don trackway dig. Johanson's book Lucy and thought what an adventure it would be to go on an expedition like that, looking for hominid fossils in Ethiopia. Well, my adventure was not quite so glamorous, but it was educational, exciting, and rather prestigeous since Jerry MacDonald assures me it is the largest, most prolific and varied Permian trackways dig in the world. He hopes to see a building built over it some day, like at Dinosaur National and to have a complete panorama Monument, of the reptiles, amphibians, plants, and invertebrates displayed for everyone.



The "discovery" slab, found on June 6th, 1987 at the AF 2 excavation. On the right is the imprint surface, and the left slab is the natural cast made when a fresh layer of mud washed over the trackway. The lines through much of the slabs surface are desication cracks which formed when the mud begas to dry in the sun.

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It has been a special thrill for me, a guy who loves nature and science and adventure, to stand in a canyon out beyond the sight and sound and smell of civilization and be surrounded by beautiful rock formations and unusual plants and animals. Then to split layers of rock and be able to look back 280 million years and see a Dimetrodon waddling across a mud flat in the morning sun and haze. Oh what a thrill! Also I have the satisfaction of having contributed a few shovelfuls of effort toward the advancement of scientific knowledge..

If you would like to do something like this, I suggest you contact the head of the geology department of your local (or any) university or college. Tell them what you are interested in and ask if they need any volunteer help.

\*From: MacDonald, Jerry Paul. Finding Footprints. Paleozoic Trackway Project, Las Cruces, NM. 1990. p. 21.

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# COLLECTING DINOSAUR TRACKS IN THE CONNECTICUT RIVER VALLEY

By

Professor Dr. Allan P. Russell RUSSELL'S FOSSIL MUSEUM 40 Mechanic Street Barre, MA 01005

The thrill of finding and recognizing a dinosaur track is hard to describe. When Pliny Moody, in 1802, located a slab of rock in his pasture with strange markings on it, he had no idea as to what he actually found. In fact he had to solicit the aid of the local religious leaders to determine what made the strange markings in the rocks. These knowledgeable men mistakenly identified the tracks, in the slab, as belonging to the long lost Noah's raven of biblical fame. It is no wonder why this bird did not return to the ark, for it was stomping around in the mud of the Connecticut River Valley. Moody, for his part, was happy to sell off portions of the slab to passersby to make a little extra profit. One of his relatives, through marriage, still performs this task today at "Nash's Dinoland."

I have been lucky enough to have very supportive parents, who were willing to take their budding paleontologist son out to look for dinosaur tracks in the famous Connecticut River Valley. As luck would have it, my dad and I were able to secure a large footprint from a locality called "the horse race at Gill" in the literature. Since that time the collection of these wonderful static pictures of dinosaur behavior has increased to more than 400 slabs. I will admit that some of the dinosaur tracks are not as clear as they should be and that a little chalk helps the uninitiated (skeptic) to see what I see. Can you still go out and find dinosaur tracks today? Are they not all collected and stored in museum basements? That is what this article is about.

To begin with, you need the correct equipment. Two or hree flat splitting chisels will begin to give you the necessary tools to split wide layers of rock along a common seam. To drive these two and a half to three inch wide chisels into the cracks in the sedimentary rock layers you need at least a four-pound sledgehammer. Don't forget to wear safety goggles and protective leather gloves. Rock chips can easily fly backward and damage an eye or cut into your skin. You might also want to have a "mason's" hammer (sometimes called a soft rock hammer), which is a hammer with a square head and long a chisel-like back part that can be used to split smaller rocks along cracks. There are belt "holsters" to slide this type of hammer into so you don't misplace it. It might be wise if you were to paint the grip of the hammer orange so that it is easy to spot if you lie it down for a minute to look over some interesting slab. Next you will need to have a crowbar to pry up the slabs to a position that allows viewing between the layers. My dad had a blacksmith make one for me that is about four feet long. It has a hand loop at one end and at the other end a six-inch flattened portion that is angled at about 15 degrees. This gives you leverage to easily move slabs that are four feet wide, eight feet long and about four inches thick.

Where to look is the key to a successful trip. Geologists and paleontologists of the past have been very helpful in publishing articles as to their findings. In fact, the President of Amherst College, Edward Hitchcock, in 1858 published, at the request of the Commonwealth of Massachusetts, <u>Ichnology of New England</u>. This rare book listed all the sites where President Hitchcock was able to find tracks along the Connecticut River Valley. Hitchcock, unfortunately, did not refer to the tracks as dinosaurs, even though dinosaurs had been recognized in Europe. He called them fat-toed and thin-toed birds and felt that there were large flocks of these "birds" in the valley. He also noted the presence of insects, small reptiles and even some clam trails.

In 1915 Richard Swann Lull of Yale University reevaluated Hitchcock's work in <u>Triassic Life of the Connecticut River Valley</u>. He concluded that the majority of footprints were of theropod dinosaurs. He also noted the possibility of a plant-eating dinosaur in the valley. Lull's book was revised in 1953 and again published by the Connecticut State Library. This new edition even had some artwork of what some of the track makers looked like. This revised edition uses Cartesian diagrams, which chooses one particular track as the norm and then all other tracks of this type are compared to this norm. Curved grid lines accentuate any change from the norm. The greater the curve lines the greater the difference. These changes could actually demonstrate a sexual dimorphism or a sign of age.

As we grow older our feet become longer and wider and this probably also took place in these dinosaurs.

Many of the sites that are listed in the references listed above are not accessible at the present time. New sites have been found since Hitchcock and Lull were out collecting. Fossil tracks have been found from Northfield, Massachusetts to New Haven, Connecticut. Areas in New Jersey and Virginia round out the

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Newark Supergroup. The sediments can be found approximately 15 miles on either side of the Connecticut River. You should also note that some localities within the possible collecting area do not contain any tracks.

One of the best ways to find a new locality is to find out where new construction is taking place. Seek out the construction manager and describe what you are looking for. See if you can look around in the area, after the construction workday. Usually the construction manager can tell you if any tracks have been found in the area. Don't be discouraged. The construction site might be in a "dry" area. I have been lucky enough to have gotten some spectacular slabs, with even the metatarsals shown in the slabs, by this method (see photo 1).

One of the best times to go out to collect dinosaur tracks is early in the morning or late in the afternoon, and after a rainstorm. The angle of the sun's rays on the rock slabs can place enough shadow on the slab to show you the position of any tracks present. Rain is also helpful in locating tracks. After a storm the depressed areas will pool the rainwater and therefore look darker, or the rainwater will drain, or evaporate, away from raised areas and therefore look light in color compared to the background matrix.

What you are looking for is a three-toed structure, with or without a halux claw. These tracks can range from one inch long to over two feet long. The lateral toes can be close to the central toe or they can be wide apart. The toes can look very thick or pencil thin. They can be quite deep within the sediment or just disturbing the surface and can only be seen using shadows. I have often left slabs leaning against the house for weeks before I can remember where the track was that I saw in the field.

I often walk out early in the morning and look over these slabs from various angles. In the old days I used diluted white shellac to outline and paint in the tracks. I do not recommend this today as most people feel you "just painted it in." It is recommended that the tracks be outlined in chalk. In fact, you might want to photograph your slab and keep the photo handy in case the chalk rubs off. It should be noted that some tracks are so very well preserved that there is no need for chalk to be used.

Another recommendation would be to see if several slabs fit together and form what Hitchcock called a "book" (see photos 1-3). These books show some underprints, which can demonstrate why many tracks look different. These underprints could also be one reason for the many different species of these interesting animals.

Try to split as large a layer as you can because this is the way you find trackways (see photo 4). A trackway helps demonstrate the rate of speed the animals was traveling at. To do this you should consult Spencer Lucas's book, <u>Dinosaurs: The Textbook</u>, which gives the various formulas, needed to accomplish the calculations. You can find out how high up off the ground the animal's pelvis was by simply multiplying the length of the track by five.

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Once in a lifetime you come across a spectacular track (see photo 5). This happened to a friend of mine, Mr. George Champoux. George had the ability to be in the right spot at the right time and find some of the most interesting slabs, including tracks in coprolite. He and I have given many slabs of dinosaur tracks to high schools and colleges and museums.

When you arrive at a location for collecting, walk the length of the site looking for telltale signs of tracks. Don't overlook raindrop markings and mud cracks. Look for small, elongated triangles (about ½ inch long), which might be claw markings. Walk along the side of the collecting site, if possible, to determine if there are any cracks in the layers where you can place a chisel. Finding one, place the chisel in place and start it by hitting it with the hammer a couple of times. Now move about two feet further along the layer and see if you can see the crack opening up. Place another chisel in line and tap it in a few inches. Repeat this with a third chisel if you have one. Go back to the first chisel and hit it again with the hammer. Do this repeatedly and listen to the sound of the hammer and chisel. The sound will rise higher and higher until the layer cracks open.

Place the crowbar into the crack and using a fulcrum lift the slab. Hold the bar down with one hand and place a boulder within the crack or have another person place the boulder in place while you push down on the bar. Continue to raise the slab higher and higher by using larger and larger boulders, until you can look under and see what is there. If nothing can be seen on the bottom of this layer it can be broken. If you see bumps hanging downward there may be natural casts found here. When you turn this slab over the tracks seen on this layer will be raised higher than the matrix and they are called natural casts (see photo 4). The depressed tracks will be seen on the lower slab when the upper slab is removed. If you have a good set of tracks, be sure to make the lower cut deeper than the upper layer as the footprint puts stress on the slab and it could easily break if you're not careful.

To move a large slab to your vehicle for removal from the quarry, you should either make a sled or roll the slab. Use an old military knapsack (you can

obtain them at Army-Navy stores) with the straps extended to form a makeshift sled. If you are going over rugged territory to remove the slab, try rolling it along.

A word on preservation. If you find a slab with a great track in it and you don't have the correct equipment to collect it, please leave it and return with the correct equipment. Damaging the track should not be done. Also please don't forget to obtain permission to collect specimens from the appropriate landowner.

Museums could not possibly collect all of the tracks that are available. You can do your part and collect these wonderful trace fossils. Share your finds with those studying them as professional paleontologists (if you have something special). You can also share them with the children at your local elementary schools. I wish you good luck in your attempts to find fossil tracks.



4. Trackway showing both manus (in foreground) and two pes natural casts.





5. Grallator cuneatus, Hitchcock Correlated with Coelophysis bauri



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# DINOSAUR TRACKWAYS OF MOUNTAIN PASS, CALIFORNIA: A CHAPTER SCRATCHED INTO THE SANDS OF TIME

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ABSTRACT—A little-known dinosaur track site in the Mescal Range near Mountain Pass, California, is the only site of its kind in the state. Designated an Area of Critical Environmental Concern due to its unique status, it is protected by Federal law. Tracks here provide evidence of several sorts of animals: coelurosaurs similar to those assigned to <u>Grallator</u> and <u>Anchisauripus</u>; an unidentified ostrich-sized, web-footed dinosaur; smaller, quadrapedal dinosaurs similar to <u>Batrachopus</u>; lizards; and insects and scorpions. Ripple marks, rain pockmarks, and impressions from salt crystals hint of the physical environment and climate. Cross-bedded frosted quartz sandstone hints of fluvial-derived dunes along an ancient bay. This Aztec Sandstone formation is of early Jurassic age (180 million years old). In all, the assemblage is remarkably similar to much more widely studied and publicized track sites from the Triassic/Jurassic boundary in New England and the Mid-Atlantic states and helps fill in a story of early Jurassic life stretching from coast to coast.

## **INTRODUCTION**

 ${f F}$  or dinosaur lovers in California, the truth hurts: you'll find them few and far between. That's not to say dinosaurs never graced the state. It's just that, unfortunately, conditions during the Mesozoic Era weren't very conducive for a Jurassic Park to be well preserved on America's "Left Coast." For starters, most of the state was under water at the time, at the edge of a subduction zone. Ancient marine reptiles such as plesiosaurs, ichthyosaurs, and mosasaurs have long been known from Mesozoic sediments here, but remains of true dinosaurs have proven frustratingly rare because California's sedimentary rocks simply formed in the wrong environment to capture the remains of land animals. All that have been found to date have tended to be fragmentary remains of just a handful of dinos that were washed out to sea. As a result, the true dinosaur aficionado might well turn thumbs down on California, in general.

However, dinosaurs left other traces in the Golden State well worth our admiration and attention. On a mountain ledge in the desert near Mountain Pass (Figs. 1 & 2) sits an abandoned quarry with a spectacular view of Kokoweef Mountain and the Piute Valley. Here, operators of the Delfont Quarry once split hard layers of red and pink sandstone beautifully interwoven with buff-, yellow-, and cream-colored fingers. The layers they split were destined for use as building stones and flagstones. Sometime along the way, someone began to notice



FIGURE 1 – Location of the Mountain Pass Jurassic dinosaur trackways in easternmost San Bernardino County, California.

unusual impressions along some of the bedding planes. I haven't been able to find out just when this was, but the first scientific mention appears a 1958 master's thesis by J. R. Evans. These impressions



FIGURE 2 – The steep dirt road to the left of this photo leads through a Joshua tree forest in the Mojave Desert and ends at a ridge of red sandstone on the south side of the Mescal Range near Mountain Pass, California. The light-colored ridge running at an oblique angle along the middle of this photo holds the fossil footprints of dinosaurs from the Jurassic Period.

proved to be no less than footprints in the sands of time, and they record the passing of small, graceful dinosaurs.

On the East Coast, dinosaur footprints have been known since the early 1800s. The very first were uncovered in South Hadley, Massachusetts, by farm boy Pliny Moody exactly 200 years ago, in 1802. Such East Coast prints made big news in 1966 when bulldozer operator Ed McCarthy uncovered an enormous dinosaur track site in Rocky Hill, Connecticut. So enthralled were the citizens of Connecticut with the dinosaurs in their backyard that Dinosaur State Park was born, a park that remains a popular family destination to this day.

But California's one and only dinosaur track site remain. virtually unknown among the general public. Even in California itself. And even though it represents the earliest evidence of dinosaurs within the state! My hope, perhaps unrealistic in an age of budget deficits, would be to see it one day preserved and developed in a manner similar to Connecticut's Dinosaur State Park.

Because this is the only dinosaur track site yet found in California, the Bureau of Land Management designated it an Area of Critical Environmental Concern in 1986 at the urging of San Bernardino County paleontologist Robert Reynolds and others. While untold tons of rock have been hauled out and slabbed to grace patios in the past, today absolutely no collecting is allowed, per federal law. Even designated officials of museums and universities (such as Reynolds, himself) create and remove only molds and casts of the prints here, not the prints themselves. For instance, the San Bernardino County Museum conducts expeditions under permit to make latex and fiberglass molds for study and exhibit. So if you ever visit this spot, please remember: take away only pictures, and leave behind only footprints, so to speak.

## DIRECTIONS

This site is located near Mountain Pass in the Bureau of Land Management's Needles Resource Area in easternmost San Bernardino County. (Readers of Charles Schulz's *Peanuts* comic strip will recognize Needles as the hometown of Snoopy's brother, Joe.) The trackways lie on the south side of the Mescal Range in the East Mojave, just south of Interstate Highway 15 midway between Cima Road

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to the west and Nipton Road to the east. This is some 35 miles northeast of Baker and some 50 miles southsouthwest of Las Vegas. The site is marked on the BLM's New York Mountains Desert Access Guide Map Number 9 for the California Desert District.

To reach it, take the Bailey Road exit from I-15 at Mountain Pass and proceed south. (Look across to the north of I-15, and you'll see the big Molycorp mining operation.) Following signs to Kokoweef, take the first left and proceed 0.7 mile to where the pavement ends. Continue another 0.5 mile on the well-maintained dirt road, and you'll come to a fork next to a corral. Take the left fork and proceed 1.8 miles to another fork. Take the left fork once again and proceed 1.4 miles to the entrance of the Kokoweef Mining Camp and Caverns. (You should build in time for a tour here. Legend has it that a lost river of gold is hidden within the bowels of Kokoweek Mountain, and a group of treasure hunters keeps up the search in the little mining camp you'll enter.) Proceed 0.2 mile through the mining camp, and then follow the right fork for 0.7 mile.

Exit the main road at this point and then make a decision. Do you have four-wheel drive, or do you want to park and walk? Even with four-wheel drive, you may want to park, especially since you don't need to worry about carrying any heavy rocks back with you. Directly ahead is a half-mile stretch of a very steep, deeply rutted road leading to the quarry.

The entire drive from I-15 to the quarry takes you through a Joshua tree forest (if these odd shaggy plants can honestly be called trees, much less a forest) beautifully carpeted by desert flowers in the spring. When my family visited the site, every cactus we passed seemed to have a brilliant yellow, red, or purple blossom.

However, if this doesn't entice you and you'd prefer to avoid dirt roads, you can view a cast of the trackways on a wall of the BLM desert information center in Barstow. During my first trip to Mountain Pass, I stopped at this center to ask what they knew about the famous dinosaur footprint locality in the desert. They said they'd never heard of it. After chatting a bit further, I turned around to see this cast in plain view on their wall! I'm hoping that on my next visit, the attendants here will have proven a bit more attentive of their own surroundings. More casts are on display at the San Bernardino County Museum in Redlands, California.

#### THE FOSSILS

The Mountain Pass trackways record the passing of several different types of dinosaurs. The scientific study of ancient tracks is known as "ichnology" (from the Greek *ichnos*, meaning "trace"), and such

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tracks are called "ichnofossils." They are grouped into "ichnotaxa" and "ichnogenera" rather than being assigned the genus and species classification that bones and teeth receive. Lacking a dead dinosaur at the end of a trackway, scientists can't say for certain what dinosaur species may have created a particular track. However, that doesn't preclude guestimates based upon the foot structure of dinosaur skeletons found in sediments of equivalent age, and a whole science has sprung up trying to match ichnogenera of footprints with the genus of dinosaurs that may have left them. However, it's because we are talking about guesswork that the footprints are given their own classification, usually ending in -ipus, -opus, -podus, or -ichnium. Thus, a track that is speculated to have been left by a Tyrannosaurus is called a Tyrannosuripus.

Paleontologists believe they've identified up to five different species of dinosaurs at this locality. Based upon the size of some tridactyl (or three-toed) tracks at Mountain Pass, scientists have postulated bipedal ostrich-sized dinosaurs. Bipedal dinosaurs ran upright on two hind legs, like today's ostriches and turkeys. These tracks are 10-12 cm in diameter and seem to represent three different species of coelurosaurs. Two are similar to tracks of *Grallator* sp. and *Anchisauripus* sp. from late Triassic and early Jurassic localities in New Jersey and the Connecticut River valley on the East Coast (Fig. 3). The third, which seems to be partially webbed like a duck, has



FIGURE 3 – A Mountain Pass trackway designated *Anchisauripus* sp. A cast of this trackway is on display at the San Bernardino County Museum in Redlands, California.



FIGURE 4 – Small prints similar to those designated *Batrachopus* sp. were the most common that we encountered during our trip to the Mountain Pass locality. These included scattered individual prints or pairs of prints (above) and entire trackways (below).



yet to be formally identified

Coelurosaurs were lightly built theropods. This group includes several well-known dinosaur genera and species, such as *Compsognathus*, *Deinonychus*, *Dilophosaurus*, *Ornithomimidae*, *Utahraptor*, and, ultimately, good old *Tyrannosaurus rex*. In the current dinosaur/bird debate, some paleontologists have designated coelurosaurs as the ancestors of today's birds—or at the very least, kissin' cousins due to strong anatomical similarities.

Coelurosaurs were active and agile, and it's thought that they may have fed on small quadrupedal (or four-legged) dinosaurs and lizards. Tracks of just such animals have also been found within the Mountain Pass quarry. In fact, these were the most common tracks that my family and I saw during our visit (Fig. 4). They measure 2-4 cm in diameter and are more-or-less round with broad, stubby digits ending in sharp little claw points. The tracks resemble those that have been designated *Batrachopus* at other localities. In addition, scientists have found gracile, or more slender, footprints of unidentified quadrupeds.

Dinosaurs weren't the only animals to leave their signatures in the sand here. Insects and scorpions left small but distinctive trails, as did smaller reptiles that walked on all fours and ranged in size from that of a gecko to that of an iguana. In addition, some beds in the area have produced plant fossils similar to horsetails.

Taken together, all provide evidence of a thriving community, the only hint of which today are tracks and traces from which we're left to fill in the gaps and guess at the ghostly shapes of these wonderful creatures scampering across a bygone landscape.

## THE GEOLOGIC HISTORY

The Mesozoic Era is known as "The Age of Dinosaurs," and the Jurassic Period fell in the middle of this Age. The trackways here have been placed within the Aztec Sandstone unit of the Early Jurassic, at approximately 180 million years old. This age estimate is based upon dating of younger volcanic rocks overlying the Aztec Sandstone that were at least 155 million years old. The age estimate was also made by correlation with other sedimentary units at other localities, such as the Navajo Sandstone, which hold similar dinosaur footprints.

Scientists speculate that southern California was an island arc during this early Jurassic period with offshore volcanoes and a marine embayment lapping at a sandy shore. The sandstones, composed of frosted quartz grains, are believed to be fluviatile (or derived from rivers) and eolian (wind-blown). Thus it's speculated that dunes, composed of sands derived



FIGURE 5 – Similarity between a contemporary Pacific Coast sand dune still shifting with winds and waves (left) and the fossil dunes of Mountain Pass frozen in time (right).

from rivers, cloaked the shore of the ancient embayment. Comparing dunes on a contemporary Pacific Coast beach with the sedimentary sequence at Mountain Pass, you find a resemblance that is immediately apparent (Fig. 5).

Across the dunes waddled quadrupeds, pursued by a variety of bipedal dinosaurs whose tracks became frozen in time like the still frames of a motion picture. As Greg Paul, author of *Predatory Dinosaurs of the World*, puts it, "fossil footprints are the closest thing to dinosaur motion pictures that we have." By mapping trackways, scientists draw conclusions about the numbers of track makers, their size, mode of locomotion, posture and gait, speed of travel, and the directions in which they were traveling. They can suggest whether the dinosaurs moved alone or were social animals traveling in herds, and how dinosaurs associated with one another.

Volunteers working for the San Bernardino County Museum have painstakingly chiseled off hard sandstone overburden to allow scientists to follow and map several of the trackways. They've dubbed one site the "dinosaur freeway," where 31 tracks representing perhaps a dozen dinosaurs crisscross over an undulating dune. One of the trackways, dubbed "mother and child reunion," shows a medium-sized dinosaur walking parallel with a smaller one. These excavated trackways have been re-buried to prevent unlawful looting and to protect the tracks from weathering, so don't expect to see them during your own visit here.

The geology of the Mescal Range is relatively complex. Anticlinal folding, faulting, and mountainbuilding activity have overturned segments of sediments, making it difficult to tell up from down in some areas. Fortunately, the fossil footprints help in sorting out the geologic history of the region by assisting stratigraphers in spotting sediments that have been overturned.

In addition to the tracks, the stones here record evidence of the physical environment inhabited by the dinosaurs. Cross-bedding of the sand indicates that this was an area of dunes built by the winds. Ripple marks record the ancient shoreline of the nearby sea. Passing rainstorms left small, round pockmarks on some layers, and other layers record the growth of salt crystals during dry seasons.

All-in-all, the assemblage of footprints and ripple marks in the sands and muds of the Mountain Pass area is remarkably similar to an assemblage that was being laid down at the very same time on the other side of the continent in the present-day Mid-Atlantic states of New Jersey and Pennsylvania and in the Connecticut River valley of New England. As I noted at the beginning of this article, dinosaur footprints were first discovered in New England in the early 1800s, and the science of ichnology began

with the publications of the Reverend Edward Hitchcock of Amherst College, Massachusetts, starting in 1849.

Ichnology has made remarkable strides in recent decades, if you'll pardon the pun, and the tracks at Mountain Pass have added to this fascinating science. It's a science that fleshes out mere bones and teeth and allows us to press our own hands into cavities shaped by the hands and feet of creatures alien yet strangely familiar. Beneath the desert sun of the Mojave, you can feel the warmth these dinosaurs themselves surely felt in sands baked by the very same sun. This chapter literally scratched into the pages of time by dinosaurs themselves fills in a piece of a story that now stretches across the ages and from sea to shining sea.

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## COLLECTING AND STUDYING COPROLITE THE SCOOP ON POOP

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I am intrigued by all trace fossils, but coprolites are definitely my favorites. There is, depending on your point of view, something decidedly disgusting and/or hugely humorous about the things. As with all ichnofossils, they are evidence of animal activity, and you <u>know</u> what the animals were doing! My coprolite exhibit at a DVPS Fossil Fair in Philadelphia attracted groups of giggling school children, and one woman was so fascinated she stood gaping and asking questions for half an hour. The title of the exhibit came from a t-shirt I had seen in Moab, Utah: "Coprolite Happened!"

My introduction to coprolites came at an Aurora Fossil Festival in North Carolina. I was smitten by a huge black Pleistocene croc dropping for sale by the avid diver and shark tooth collector, Vito Bertucci. This imposing specimen impressed me far more than Bertucci's huge reconstruction of a C. megalodon jaw full of six-inch teeth, and I bought it. I accepted on faith Vito's identification of it as coming from the hind end of a crocodilian. The next purchase I couldn't live without was a six-incher from the upper Cretaceous Pierre Shale of South Dakota, possibly from a plesiosaur or mosasaur. It had lovely tapered ends and longitudinal striations left by the anal sphincter. Who could resist?

I soon began finding coprolites myself, and I continued buying almost every one I saw. Collecting paleo-poop became a matter of seeing how many different specimens I could acquire. The most obvious differences to look for are size, color and shape. My smallest specimens are insect droppings in a piece of Miocene amber from the Dominican Republic. The largest is a six by eight-inch dino dung patty from the American Southwest. In between they are every size and all shades of cream, orange, brown, grey and black. They are rough, smooth, sausage-shaped, crescent-shaped, straight, round, rolled, twisted, twirled and contorted. They come from Paleozoic, Mesozoic and Cenozoic layers of the U.S.A., England, Madagascar, Morocco and Australia. Many of my fellow fossilers regularly bring me what they have found, along with the inevitable scatological asides. I was handed one large croc dropping with the comment, "This is better than anything I ever did!"

Only recently did I become seriously interested in coprolites as objects of scientific study. This has led to a closer look at my collection and a search for more solid information on the specimens in it and on coprolite in general. What can you know for sure about a coprolite, and what can it tell you about the past? There is a real scarcity of information on coprolite in most general fossil books. At best you are given a definition of the word and maybe a drawing or photo of one representative specimen. I have actually gotten some clues to the nature of some of my specimens from these isolated pictures, but for any deeper knowledge, you have to go to more scientific papers.

The superstar, the only star, of coprolite research is self-styled paleoscatologist Karen Chin. I had the pleasure of meeting Dr.Chin at Dino Fest 98 and hearing her speak. She specializes in dinosaur droppings, but has branched out into the study of all types of coprolite. I learned from her that aquatic environments favor the preservation of feces. "For every creature, you have only one skeleton, but thousands of defecations!" says Chin. "A highly mineralized diet produces feces which are easy to fossilize, so 90% of coprolites were produced by carnivores. Herbivore coprolites are much rarer." Dr. Chin hopes to provide a context for evaluating coprolites by devising a system for their identification and classification beyond just herbivore/carnivore. If a coprolite can be linked with its original producer, then you can learn something more about the creature's behavior, diet and possibly its digestive tract.

A look at my own collection in light of Karen Chin's observations and research leads to many more questions than answers. The first question would be, "How do I know when I have a coprolite?" While many specimens do look uncomfortably like what they are, some pieces with seeming coprolitic qualities may turn out to be nodules or concretions and some nondescript looking rocks may be pieces of coprolite. I can only say that after looking at a lot of dung, I do feel I have an eye for it. I look for fold marks and surface striations on questionable specimens; I swear there is just a "look," I feel pretty secure about most of my collection, but my "dino patty" was bought through the Internet, where it is offered by the pound. It claims to be from herbivorous sauropods, but Chin has pointed out that fossilized dung of herbivores is quite rare. So, do I have dino dung or interesting big rocks? Without access to an electron microscope or chemical analysis, I can't be sure at the moment.

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Another big question is, "How do I know what animal produced a particular plopper?" Only rarely could you possible know for sure. I brought back one prize fish from the Green River Formation of Wyoming which appears to be "caught in the act." It reminds me of every goldfish I've ever seen swimming around the aquarium, dangling doo. This example aside, identification of a dropping with its source animal is always highly speculative. Size, shape, location and its association with other fossil material may help to make an educated guess, but gross morphology is one of the least important factors in making the determination. Even so, some recurring shapes just <u>must</u> be diagnostic of certain animals, if we could only figure out which ones. The "turtle" turds from Washington state have a consistent twisting design, and I've noticed a particular pucker at the ends of at least two of my specimens which might indicate they came from the same kind of creature.

One notable exception to the usual anonymity of fossil feces is shark coprolite, which can often be identified to order by markings left by the shark's intestinal valve, which molds the fecal mass as it is extruded. Lamniform sharks, such as makos and the giant white *C. megalodon* have a spiral shaped valve, leaving a spiral groove on the specimen. (My oldest coprolites are tiny, black, spirally grooved ones from the Pennsylvanian of West Virginia!) Carcharhiniform sharks, such as the snaggletooth and tiger sharks, have a scrollshaped valve, which leaves the specimen looking like a deli wrap or roll-up.

I have collected hundreds of coprolites from two ancient marine localities. Miocene examples come from Lee Creek site in North Carolina. Shark roll-ups are abundant, and pockets of tiny, squiggly fish coprolite often accompany pockets of shark teeth. I have enough specimens from this site to feel that I see several other distinct types. Another rich source of marine coprolite is the Eocene Fisher/Sullivan site in Virginia, popularly known as Muddy Creek. Here, shark and other fish coprolites are the most prevalent fossils found. What makes these specimens so special is the frequency with which they show evidence of their contents. Fish scales, teeth and bones, including vertebrae and jaws, are visible and numerous on the surfaces of many of the specimens. By comparison, I've only noticed bone fragments on the surface of <u>one</u> of my Lee Creek specimens.

A third question is, "What can coprolite tell us about the setting in which it was produced?" The sheer abundance of shark coprolite available from Lee Creek and Muddy Creek suggests an organized study might yield useful information as to specific diet of certain animals, adding to our knowledge of food webs for these sites. (If you are what you eat, you were what you excrete!) Karen Chin's ultimate goal is to be able to reconstruct ancient ecosystems. Dr. Chin has actually discovered probable Maiasaur coprolite containing conifer material and backfilled dung beetle burrows, linking these three organism in a Cretaceous food web and telling us things about all three that might not be evident from body fossils. This is great paleo detective work! After reading the details on dung beetle burrow diameter in one of Chin's papers, I'm feeling more confident in believing that the groove in one of my Cretaceous specimens is evidence of dung beetle transit!

People have told Karen Chin that studying fossil fecal matter is "such a waste." She doesn't think so, and I don't either! I am still left with more questions than answers, but I am looking forward to finding out more about the specimens I already have and collecting more.

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#### Acknowledgements:

I would like to especially thank Mike McCloskey for his photography of the coprolites from my collection.

I would also like to thank everyone who has contributed to that collection in any way, especially Mike McCloskey, Mark Bennett, Jim Savia and Eric Woody.

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"Fish Caught in the Act" Knightia sp. 83 mm. Eocene Green River Formation Kemmerer, Wyoming



Coprolite 10 mm. Eocene Najemoy Formation Muddy Creek, Virginia

Note the abundance of small fish vertebrae showing on the surface.



Partial tail fin 70 mm. Unidentified fish Eocene Green River Formation Wyoming



Coprolite 41 mm. Cretaceous Niobrara Chalk Lane County near Shields, Kansas

The bones showing in this specimen are clearly from the tail fin of a fish.

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Coprolite 73 mm. Carcharhiniform shark Miocene Yorktown Formation Lee Creek, North Carolina |Coprolite 64 mm. Possible shark Early Upper Cretaceous Kem Kem Beds Taouz, Morocco





Coprolite 94 mm. Possible turtle Eccene or Miccene State of Washington

These are commonly seen for sale. They are orange to reddishbrown, always elegant and allegedly turtle. I have two smaller (50 mm.) specimens of the same shape.



Coprolites Early Devonian Catskill Formation near Hyner, Pennsylvania

These are the oldest coprolites I've seen to date. They come from the famous Red Hill freshwater site and are, I believe, the first to be found there. I photographed them at the site's small museum.



Coprolite 156 mm. Possible mosasaur or plesiosaur Upper Cretaceous Pierre Shale Formation South Dakota

This specimen is brownish-orange. The dark interior suggests a high organic content. Longitudinal striations are visible on the surface.



Coprolite 44 mm. Upper Cretaceous Lance Creek Fm. Niobrara County Wyoming

I believe the groove on the left side was made by dung beetle transit.

# A NEW TRACE FOSSIL HORIZON WITHIN THE LATE SILURIAN, EURYPTERID-BEARING, BERTIE GROUP IN ONTARIO, CANADA

Samuel J. Ciurca, Jr., Rochester, New York

While studying a eurypterid bed in a quarry in Ontario, Canada, I observed a unique bedding plane within the sequence. The bedding plane discovered was unusually smooth and unfossiliferous, but contained peculiar, curved structures (trace fossils), that I hadn't observed in 30 years of eurypterid collecting. What follows is a brief description of the new find, its precise stratigraphic position, and its relationship to the sequence of rocks displayed within the type area of the Bertie Group.

# **Nature of the Trace Fossils**

The structures observed are curved depressions upon a single bedding plane within the Williamsville A Waterlime (Figure 1). This waterlime, deposited in the Late Silurian Period, was formed from a fine lime mud. As such, any impressions imprinted upon such a surface are not likely to be preserved. Perhaps only the most deeply incised impressions are encountered.

Upon first examination, I was hopeful that I had found trackways of some arthropod—especially that of a eurypterid. Eurypterid remains constitute the most common fossil specimens found within the Williamsville Formation. It is easy to rationalize the curved impressions as those made by the (relatively) large swimming legs of the most common form, viz. *Eurypterus lacustris*. However, while some of the curved impressions appear to be properly aligned, little else is evident. It is difficult to see how the other eurypterid appendages affected the substrate, unless they simply weren't preserved. Impressions made by the other appendages may have been subsequently diffused because of the very fine-grained nature of the sediment. In the aqueous environment, such fine muds often simply refill any disturbed areas of the sediment interface. Several examples of eurypterid trackways are known (in the literature), but I have not yet seen one similar to those noted here.

Eurypterids have 5 pairs of jointed appendages (including their swimming legs) that reach out from the body. In addition, most have a small pair of anteriormost pincers (chelicerae). See Figure 3.

Trackways attributed to eurypterids (eg. icnogenus *Palmicnium*) are known mostly from terrigenous deposits (sandstones, shales, etc.) in Europe. Trackways made by horseshoe crabs are especially well-known from the Jurassic interreef limestones of Solnhofen. While horseshoe crabs have telsons similar to those of many eurypterids, they do not have swimming legs (paddles) like most eurypterids possess. Notable in horseshoe trackways is the median depression made by dragging of the telson. I've looked carefully for such marks in the track horizon, but none have been found to date. Ironically, a very small horseshoe crab (*Pseudoniscus*) occurs relatively commonly in the same bed (Williamsville A) bearing the prolific *Eurypterus lacustris. Pseudoniscus*, however, is generally less than 2 inches in length and I have observed no trace fossils that I could attribute to this form.

## Trace Fossil Horizon

Thus far, the trace fossil horizon seems to be unique to a bedding plane about 4 to 6 inches below the top of Williamsville A Waterlime. Williamsville A Waterlime is the principle eurypterid-bearing unit of the Williamsville Formation (Bertie Group) and is only 18-24 inches thick. The bedding plane bearing the trace fossils is an event horizon within this thin unit and has not been observed at any other level within the unit. However, when traced into other areas of the quarry, I found that the same bedding plane exhibited criss-crossed patterns which I interpret as reticulate salt crystal structures. A dilemna suggests itself.

I maintain that all of the eurypterid remains occurring in the various eurypteridbearing waterlines were transported to the areas we observe them. The trace fossil horizon seems to indicate a level in which some creature left impressions on a surface of fine lime mud. If my interpretation is correct, this bedding plane seems to have formed during a period of hypersalinity—what was crawling around in an environment in which salt (halite) was crystallizing out of solution?

It is my contention that the Bertie eurypterid fauna did not live in the areas where we find specimens—most, if not all of the remains we find, were transported into the region of deposition of the waterlime units. If the curved structures are indeed trace fossils, then something was crawling around in the mud at this time. Most waterlime units contain abundant evidence of hypersalinity and it is likely that few organisms would relish such an environment.

While the trace fossil horizon has thus far been observed at only one interval within the Williamsville Waterlime (see Figure 2), prolific trace fossils characterize the overlying Williamsville B and the entire Akron Formation. These trace fossils, however, are tubular and were formed by burrowers which bioturbated the sediment, particularly within the Akron Formation. The possible origin of the Akron Formation is being treated elsewhere (Ciurca; in NYSGA, September of 2002 at Lake George, New York).

## COMMENTS

Over the past 3 years, only 3 small areas within the site revealed the reticulate surface horizon. Fortunately, one transition into the trace fossil horizon documented the lateral equivalency of the horizons. I found a small area where both the reticulate patterns and the curved structures occurred together. The enigma presented is that something made the trace fossils described herein, yet, if my interpretation is correct and the reticulate patterns observed are the result of the crystallization of halite, whatever generated the curved structures (the trace fossils) did so under extreme conditions of hypersalinity. Finding trackways made by eurypterids as they walked on the bottom sediment has been one of my goals for many years. Afterall, in New York and Ontario, Canada, there are numerous, distinct, eurypterid horizons. Eurypterids were swimming, eating, walking and (presumably) resting within the waters of eastern North America. The search goes on!

# ON THE WORLD WIDE WEB

Arthropod Trackways: References and Links http://palaeo.gly.bris.ac.uk/personnel/lane/traces/references/ref.html

Introduction To Ichnology – Emory University http://www.emory.edu/COLLEGE/ENVS/research/ichnology/

Simon J. Braddy Home Page http://www.man.ac.uk/Geology/research/palaeo/SJB.html



# Late Silurian Bertie Group (Type Area), Niagara Peninsula, Ontario, Canada

Ridgemount Quarry South, Bertie (Fort Erie) Township – Samuel J. Ciurca, Jr., Rochester, NY



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