THE USE OF TRACE FOSSILS IN REFINING DEPOSITIONAL ENVIRONMENTS AND THEIR APPLICATION TO THE CREATIONIST MODEL

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Abstract

Trace fossils are evidence left by animals in the rock record (such as tracks, trails, burrows and borings) that can be used by the creationist modeler to: (1) more accurately interpret depositional environments and (2) more confidently defend the creationist model. Trace fossils are useful in these regards, because they reflect animal responses to a wide variety of environmental conditions, such as abundance of nutrients, photic levels, salinity, temperature, pressure, oxygen levels, and predators, to which lithologic materials cannot easily respond. Trace fossils are important because: (1) they are found in numerous rocks devoid of body fossils, (2) they have a narrow facies range, (3) they are almost never transported, and (4) they span most, if not all, of the sedimentary record. By being able to interpret these "contemporaneous witnesses," the creationist modeler has another "arrow in the quiver" in the argument against the concepts of uniformitarianism and geological evolution.

Key Words: trace fossils, ichnology, depositional environments, ichnogenera, ichnospecies, ichnofacies.

Introduction

Accurate interpretation of aqueous depositional environments represented by the stratigraphic record requires the use of multiple geologic disciplines. Traditionally, these disciplines have been stratigraphy, sedimentology, paleontology and paleoecology. A recently employed discipline that has proven to be powerful in the interpretation of marine and non-marine depositional environments is Ichnology, or the study of trace fossils. (Ichnos is the Greek word for "trace.")

Specifically, Ichnology is the study of animal substrate relationships and how animals reacted to environmental conditions, such as erosion, deposition, changes in energy regimes, abundance of nutrients, photic levels, salinity, temperature, pressure, oxygen levels, amounts of interstitial water, substrate cohesion and predators. How animals related to the substrate and environmental stimuli are expressed in the rock record in the form of their tracks, trails, burrows, borings and other traces. Unlike body fossils (which are the remains of actual animals, such as trilobites and dinosaurs), trace fossils are evidence of the organisms' behavior as they responded to environmental conditions that are (and sometimes are not) recorded in the rock record. Because organisms respond to more environmental conditions than do geologic materials, the record left by these "contemporaneous witnesses" can provide the creationist modeler with a new tool in understanding sedimentological paleoenvironments.

The purpose of this paper is to provide creationist modelers with a basic understanding of ichnology for use in reconstructing past geologic events in application of creationists' models. Additional information on the specifics of Ichnology and its use as an environmental indicator is found in the *References* and *Additional Resources* sections at the end of this work.

Basic Concepts of Ichnology

Trace fossils have four important characteristics: (1) they are found in numerous rocks devoid of body fossils, (2) they have a narrow facies range, (3) they are almost never transported, and (4) they span most, if not all, of the sedimentary record. According to Crimes (1975, pp. 121-122), many trace fossils serve as geopetal structures in that they are useful in determining the vertical orientation during time of deposition. Additionally, trace fossils can indicate relative amounts of compaction and deformation.

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Behavioral Trace Indicators

Three fundamental concepts of ichnology are: (1) behavioral implications, (2) the type of trace fossil preservation, and (3) the environment in which traces were made.

Behavior is the single most important aspect of ichnology. Animal behavior, as expressed in the traces left by organisms in sedimentary rock (Figure l), is classified as follows (Seilacher, 1964a, pp. 298-299; 1964b, pp. 253-256, unless otherwise cited):

A. **Cubichnia** (resting trace). Shallow traces formed where vagile animals settled temporarily in the sediment. The behavior represented by the trace may include hiding as well as resting (Figure 1, number 2).

B. **Domichnia** (dwelling burrow). Three-dimensional, permanent or semi-permanent domiciles constructed by vagile or hemisessile animals. Such burrows may represent multiple discrete behaviors, e.g., protection, breeding, brooding and feeding (Figure 1, number 5).

C. **Fodinichnia** (feeding burrows). Vertical and horizontal shafts and tunnels made by vagile or hemisessile deposit feeders within the substrate. These traces generally reflect the search for food; some also fit the requirements for shelter (Figure 1, number 4).

D. **Pascichnia** (feeding trails). Trails or burrows of vagile deposit feeders made upon the substrate. Such structures are often systematically constructed and tightly wind or meander, reflecting a "grazing" search for food. An important characteristic of these traces is that they usually do not rework previously "mined" sediment (Figure 1, number 3).

E. **Repichnia** (crawling trails). Tracks, trails or burrows made by vagile animals upon the substrate

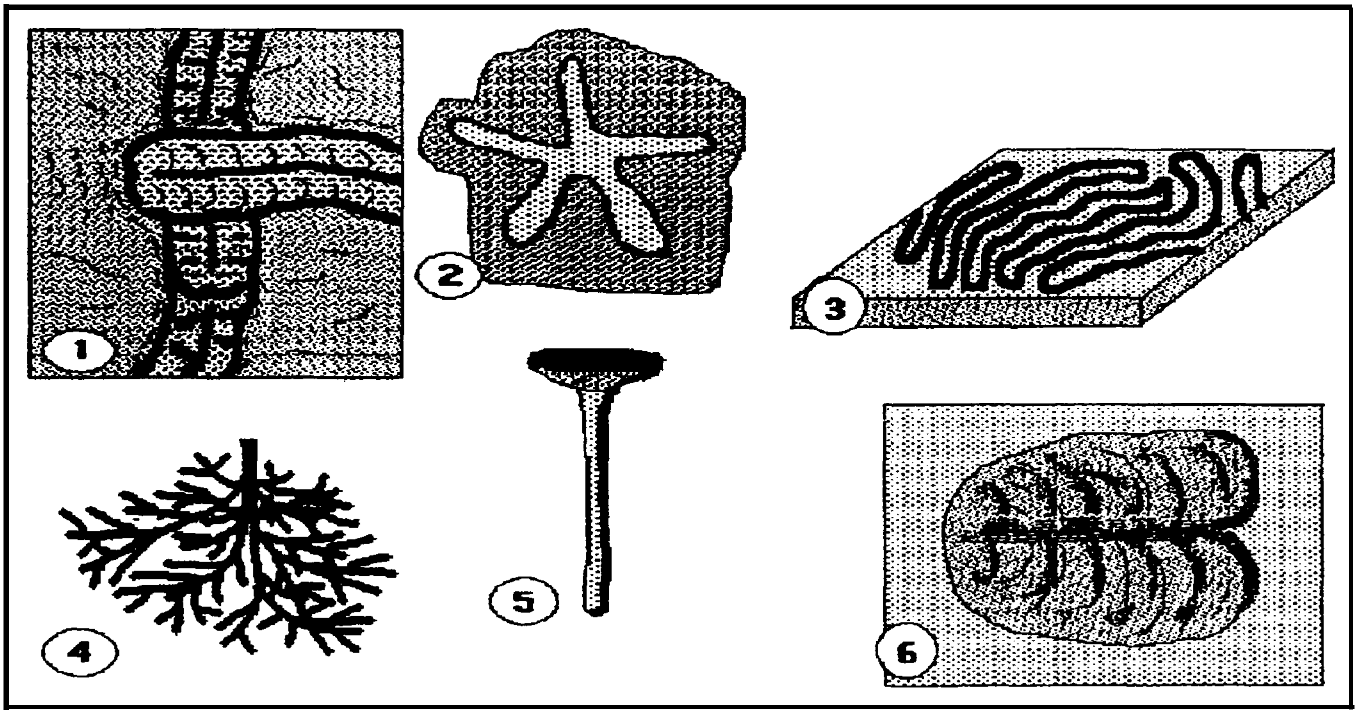

Figure 1. Examples of behavior represented by trace fossils. (1) planar view of crawling trace *Cruziana,* (2) planar view of resting trace *Asteriacites,* (3) planar view of grazing trace *Helminthoida,* (4) two dimensional representation of three dimensional feeding structure *Chondrities,* (5) two dimensional representation of three dimensional dwelling structure *Monocraterion,* (6) planar view of resting trace *Rusophycus.* Modified and combined from Frey (1978, p. 53) and Osgood (1975, p. 94).

surface or along sedimentary layers during directed locomotion [Figure 1, number 1).

F. **Fugichnia** (escape structures). Burrows made by an organism in an attempt to uncover itself after having been buried by an influx of sediment, or by borrowing deeper into the sediment to offset erosion at the substrate surface (Simpson, 1975, pp. 50-51.

C. **Agrichnia** (farming and/or trapping structures). Borrows which serve as both a permanent dwelling and provide a source of food, perhaps by means of farming or trapping within the borrow (Ekdale, A. A., R. G. Bromley, and S. G. Pemberton, 1984, p. 23). Also known as graphoglyptids (Seilacher, 1977, pp. 269-296). These structures are of uncertain behavioral significance.

Ichnofacies Classification

(Note to the reader: The ichnofacies classification is underlined and specific ichnogenera/species are italicized. Additionally, a glossary is included for selected terms.)

Within the behavioral classifications listed above are a wide variety of discrete trace fossil morphologies. These differing morphologies have been classified into ichnogenera and, where possible, to ichnospecies. Traces have been codified (see Häntzschel, 1975) just as body fossils have been.

Seilacher (1964a, pp. 307-314; 1967, pp. 414-416) introduced the concept of "ichnofacies," in which characteristic ichnogenera/species associations represent a diagnostic assemblage of traces. Eight ichnofacies are recognized in the literature and are summarized below. The four most prominent are marine ichnofacies from soft substrate depositional environments. These are (in order of relative increasing depth): the Skolithos, Cruziana, Zoophycos and Nereites ichnofacies (Ekdale et al., 1984, p. 26). Firm substrates (i.e., stiff but uncemented such as mud) contain the Glossifungites ichnofacies, while hard substrates (i.e., fully indurated or rocky) are host to the Trypanites ichnofacies. Figure 2 presents an oceanic bathymetric profile upon which is superimposed the various ichnofacies associated with those bathymetric zones. Fresh water (lacustrine and fluvial) environments are typified by the Scoyenia ichnofacies, and wood substrates host the Teredolites ichnofacies. All of these ichnofacies have been summarized and described by Ekdale et al., (1984, pp. 26-28) as follows:

The Skolithos ichnofacies represents the high energy littoral (intertidal) zone in which are preserved primary sedimentary structures as well as abundant domichnia (e.g., agglutinated worm tubes, branching pellet-walled crustacean borrow systems and various Y- and U-shaped burrows). Also found are occasional repichnia (i.e., epichnial worm, gastropod and arthropod trails) and fugichnia. Due to the high energy associated with this zone most of the burrows are in the vertical plane as exemplified by such vertical domichnia as *Skolithos* and *Diplocraterion.*

The Cruziana ichnofacies occurs in the lower energy inner-sublittoral zone, just below low tide but within the wave base. Trace fossil diversity is generally high with virtually all the behavioral groups of trace fossils often being represented in this zone. The lower energy associated with this environment permits traces that are predominantly horizontal in nature, however verti-

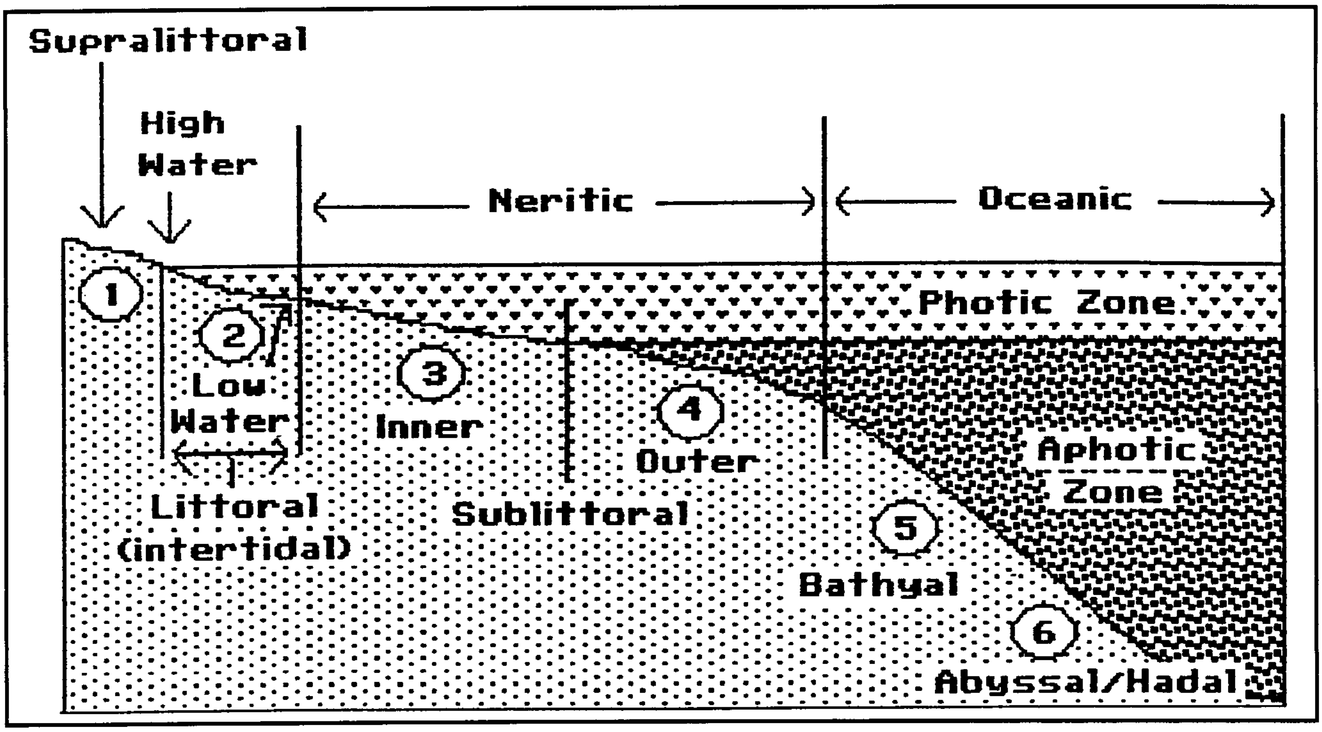

Figure 2. Classification of marine environments and the associated ichnofacies. 1) Supralittoral (Fluvial, Lacustrine — Scoyenia; 2) Littoral (Rock Shore — Trypanites), (Semiconsolidated Substrate — Glossifungites), (Sandy Shore — Skolithos); 3, 4) Inner/Outer Sublittoral — Cruziana; 5) Bathyal — Zoophycos) 6) Abyssal/Hadal — Nereites. Modified from Davis (1977, p. 241) and Ekdale et al., (1984, p. 187).

cal traces do exist in this zone. This is reflected in the horizontal repichnia (e.g., *Cruziana, Aulichnites,* etc.) and cubichnia (e.g., *Asteriacites, Lockeia,* etc.) which dominate this zone.

The Zoophycos ichnofacies, according to Seilacher (1967, p. 415), occupies the outer sublittoral and bathyal zones well below storm wave base. The environments are outer continental shelf and upper continental slope, and sediments may include proximal turbidites. However, this ichnofacies occurs in both shallower-water and deeper water zones as well. This is an example of how trace fossils cannot be used as strict indicators of bathymetry. According to Ekdale et al. (1984, p. 26), the Zoophycos ichnofacies may reflect low-oxygen conditions. Typically, this ichnofacies' trace fossil diversity is low, even monospecific, although burrows may be abundant. Complex fodinichnia of systematic, infaunal deposit feeders (e.g., *Zoophycos)* are especially characteristic.

The Nereites ichnofacies, as defined by Seilacher (1967, p. 415), represents the abyssal and hadal zones. The sedimentary environments represented by these zones are hemipelagic muds and distal turbidite deposits. The ichnofacies is characterized by a high diversity of horizontal pascichnia (e.g., *Nereites, Helminthoida,* etc.) and agrichnia *(e.g., Paleodictyon, Cosmorhape,* etc.), usually occurring on turbidite bedding planes. Vertical burrows are almost totally absent.

The Glossifungites ichnofacies is characterized by firm, compacted mud or silt substrates within the marine intertidal or shallow subtidal zones and thereby limits the type of creature that can live in this environment. This ichnofacies is represented by domichnia *(e.g., Glossifungites, Thalassinoides,* etc.) and plant root penetration structures (rhizoliths); other behavioral types of traces are typically absent.

The Trypanites ichnofacies is typified by rocky and/or cemented substrates which extend from shorelines to bathyal depths. Such substrates are referred to as "rockgrounds" and "hardgrounds." This ichnofacies is characterized by a highly diverse assemblage of fauna, most commonly being represented by domichnial borings of worms *(e.g., Trypanites),* bivalves (e.g., *Gastrochaenolites),* barnacles (e.g., *Rogerella)* and sponges *(e.g., Entobia).* This ichnofacies, like Glossifungites, is different from most of those previously mentioned due to the fact that the substrate is the controlling factor.

The Scoyenia ichnofacies is characterized by fresh water (e.g., fluvial and lacustrine) environments in which ichnospecies diversity is lower than in marine environments, but higher than in terrestrial environments. It is typically characterized by simple horizontal fodinichia (e.g., *Scoyenia, Muensteria,* etc.), which may be quite abundant locally, especially in sand and silt.

Terrestrial environments contain sparse trace fossils due to the decreased preservation potential for these deposits. Most trace fossils found in terrestrial environments consist mainly of domichnia and repichnia of insects and vertebrates. Terrestrial ichnofacies are currently unnamed. Much interest has been generated in the last 10 years over the large number of dinosaur footprints discovered and the information they have provided. This particular area of ichnology is referred to as vertebrate ichnology. It is not the intent of this paper to address vertebrate ichnology and the reader is referred to the following recent works: Gillette and Lockley, 1989; Lockley, 1991; Morris, 1980: and Baugh

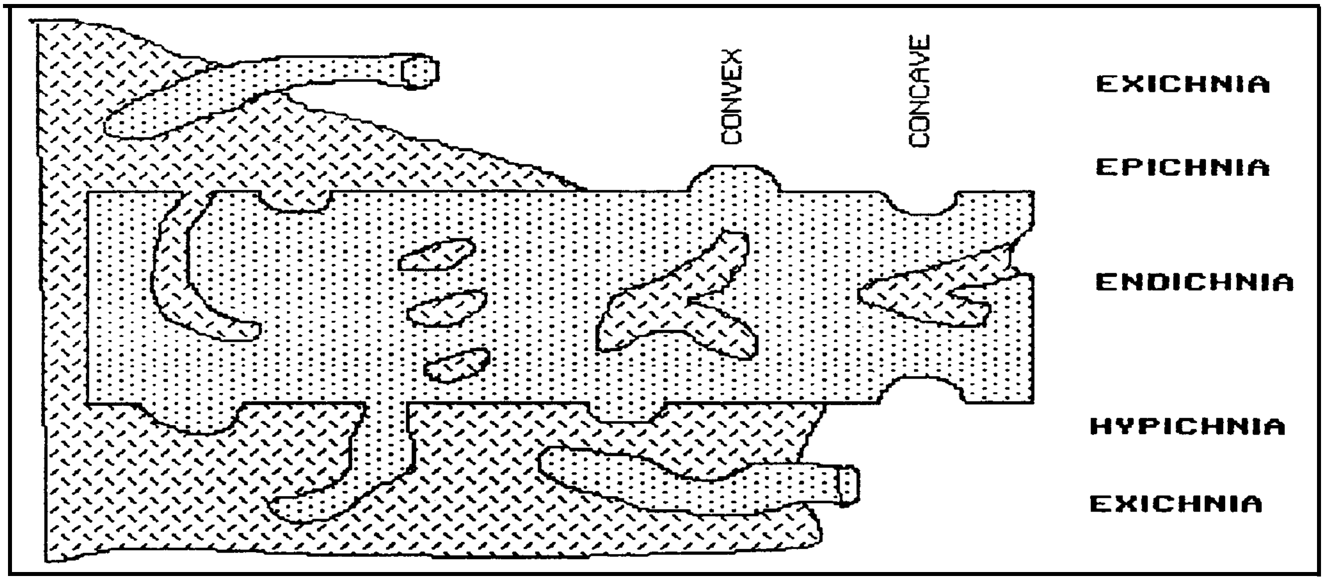

Figure 3. Preservational classification of trace fossils by Martinsson (1970, p. 327). Redrawn from Ekdale et al., 1984, p. 22.

and Wilson, 1987, as well as various *Creation Research Society Quarterly* articles dealing with this subject matter.

Some Principles in Ichnology

Any ichnogenera or ichnospecies which is the name bearer of an ichnofacies can appear in any other ichnofacies. For example, the Skolithos ichnofacies represents a high energy environment where the ichnogenus Skolithos may or may not be found. Conversely, any ichnogenera or ichnospecies that is the name bearer of an ichnofacies may be absent from its own ichnofacies classification. An example of this being the ichnogenera *Ophiomorpha* and *Diplocraterion* are characteristic of the Skolithos ichnofacies and might be the only representatives of that ichnofacies.

Different species of animals can and do leave identical traces (i.e., the same ichnospecies) in the geologic record. However, the same species of animal, or for that matter the same organism itself, can leave more than one type of trace (i.e., multiple ichnospecies). The reason for this change in behavior can be attributed to a change in environmental conditions. Anytime the behavior changes, the morphology of the trace changes, e.g., a resting trace changing to a crawling trace.

The behavioral aspects of a trace fossil are much more important than the identity of the tracemaker, since the traces represent an ecological niche. Identification of what made the trace is possible only if the creature is found in the trace or if the morphology of the trace so closely conforms to the morphology of the tracemaker that the organism can be recognized.

A sediment which has experienced a significant amount of reworking, but has not lost its original sedimentary features, is called an ichnofabric. Within the ichnofabric, traces can be classified to the ichnogenus, or if detailed enough, to the ichnospecies level. Ichnofabric differs from bioturbation, in that the latter is defined as the physical mixing of sediments to such a degree that the sediments, physically and chemically, are often blurred or destroyed in their original physical sedimentary structure(s).

Since the great bulk of trace fossils are found in the marine sedimentary rock record, trace fossils have typically been used for paleoenvironmental reconstruction in marine rocks. Many ichnofacies are found in the sedimentary record at sequence or unconformity boundary surfaces and as such are useful in determining sea levels.

Trace Fossil Preservation

Preservation of trace fossils is dependent upon a variety of factors, the two most important being (1) the type of sediment both in and surrounding the trace fossil(s), and (2) burial of the trace fossil by sufficient sediment to protect it from subsequent erosion. Trace fossil preservation classification is based on the relationship of the structure to a casting medium; the greater the contrast in sediments, the more obvious the trace (Bromley, 1990, p. 165). As preservational features, tracks, trails and burrows are classified into four groups (Martinsson, 1970, pp. 326-329; Frey and Chowns, 1972, p. 26) (Figure 3):

A. **Epichnia** — Traces in primary contact with the upper surface of the casting medium; may appear as a ridge or a groove.

B. **Endichnia** — Traces within the casting medium; i. e., not in contact with the upper surface.

C. **Hypichnia** — Traces in primary contact with the lower surface (sole) of the casting medium; may appear as a ridge or a groove.

D. **Exichnia** — Traces outside the casting medium and not in direct contact with it.

Since trace fossils are composed of the same materials as the sedimentological fabric (i.e., sand, silt and clay), transport of trace fossils is rare. The same forces that erode and transport sediments, shells, etc., usually destroy individual trace fossils in the same manner in which laminae, bedding features, etc., are destroyed. Exceptions to the rule of non-transport occur when trace fossils are lithified and retain their integrity during erosion and transport. In these cases, trace fossils may display any number of the same characteristics of any

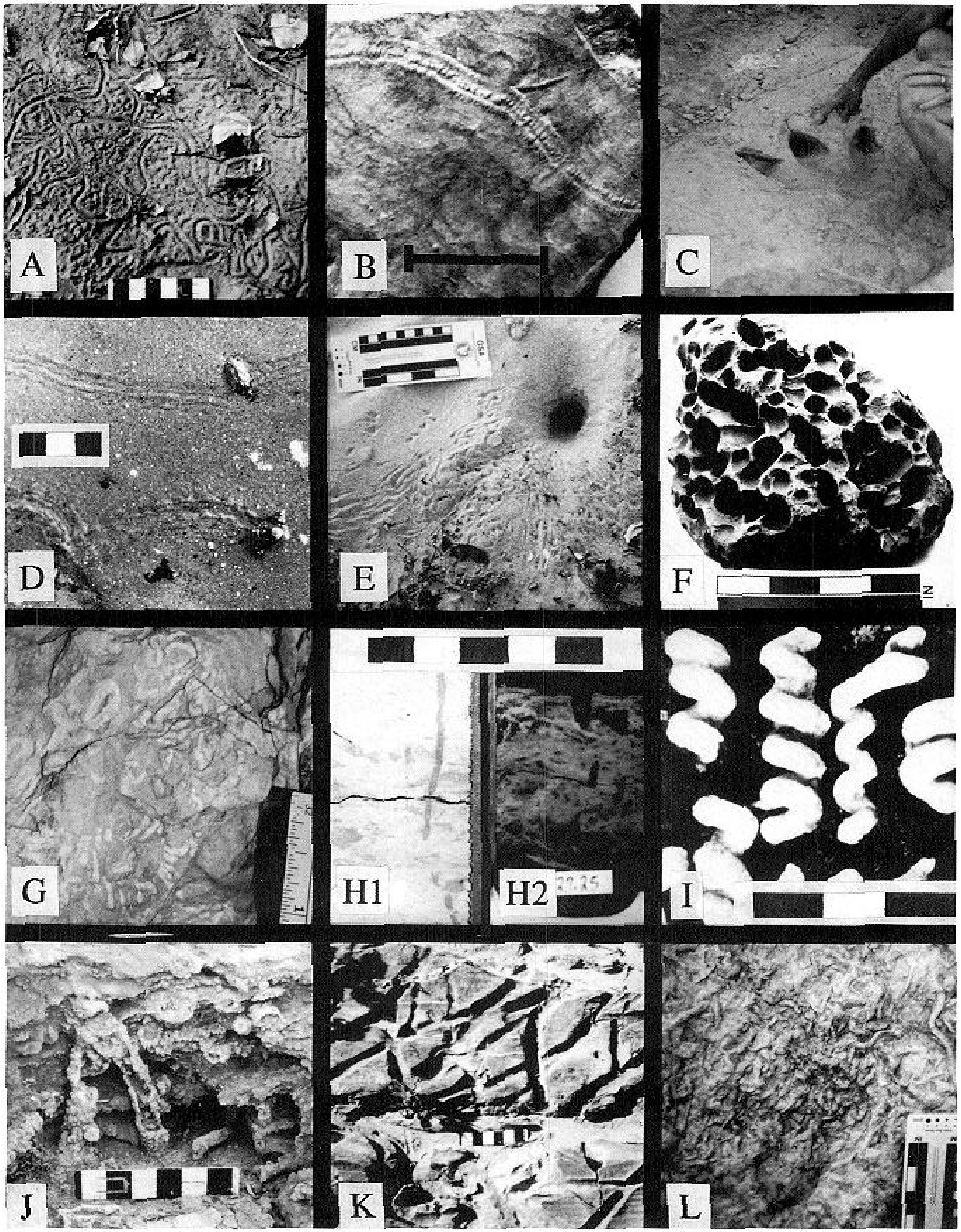

Figure 4. Examples of both ancient and modern trace fossils. (Scale bar unit equals 1 inch for all figures)
A, Concave endichnion insect grazing trails (Pascichnia) in unconsolidated sediments, Scoyenia ichnofacies

(Figure caption continued, top of next page.)

Figure 4 caption (continued).
B, Convex epichnion locomotion trail (Repichnia) in indurated sediments, possible Cruziana or Nereites ichnofacies (Used with permission of M. J. Hartnett).
C, Concave epichnion bipedal vertebrate track (Repichnia) in indurated sediments, Scoyenia ichnofacies (photo courtesy of J. C. Meredith).
D, Concave epichnia locomotion trails (Repichnia) of land hermit crabs *(Coenobita clypeatus)* in unconsolidated sediments, Skolithos ichnofacies.
E, Unconsolidated trackway (Repichnion) and dwelling (Domichnia) of ghost crab *(Ocypode quadrata).*
F, Indurated, highly bored (Endichnion) mudstone, Trypanites ichnofacies (specimen from Santa Monica Beach, California, USA. Used with permission of R. O. Howard, Jr.).
G, Indurated endichnia of uncertain origin ("graphoglyptids" or Agrichnia). Possibly the Cruziana, Zoophycos, or Nereites ichnofacies.
H, Interbedded mudstone and fine grained sand (Endichnion) with Skolithos vertical dwelling (Domichnia) burrow trace, possible Skolithos or Cruziana ichnofacies (Athabasca oil sand core—McMurray Formation, Alberta, Canada).
H2, Interbedded bioturbated shale (light) and bitumen saturated sands (dark) with several distinct *Planolites* dwelling (Domichnia) burrow traces, possible Skolithos or Cruziana ichnofacies (Athabasca oil sand core—McMurray Formation, Alberta, Canada).
I, Casts (Exichnia) of *Xenohelix* vertical dwelling (Domichnia) burrows possible Skolithos or Cruziana ichnofacies.
J, Casts (Exichnia) of *Ophiomorphia nodosa,* vertical and horizontal dwelling (Domichnia) burrow tubes, possible Skolithos or Cruziana ichnofacies.
K, Indurated sandstone casts (Exichnia) of *Thalassinoides suevicus(?)* horizontal dwelling (Domichnia) burrow tubes, possible Skolithos or Cruziana ichnofacies.
L, Indurated hypichnion of a community of trace makers. Possibly the Cruziana, Zoophycos, or Nereites ichnofacies.

transported material, such as imbrication, abrasion, etc. Lithification of trace fossils may result from various chemical and/or physical conditions in the animal's environment or from the animal itself, such as secretions.

Additionally, trace fossils in driftwood (Teredolites ichnofacies) are an example of trace fossils that can be transported.

Figure 4 depicts some examples of different types of traces (modern and ancient) that have been found in the rock record. Additionally, these traces have been identified using both their preservational and ichnofacies classifications.

Not every feature resembling trace fossils is a result of biogenic activity. Pseudo-traces, which do not originate from animal behavior, can be confused with actual traces. These false or misleading traces are the result of physical and/or chemical processes such as tool marks, sedimentary overburden features (i.e., ball-and-pillow structures), convolute bedding structures, water escape structures, slump structures, turbidity current marks, gas bubbles, lightning strikes, faulting, shrinkage cracks, precipitation, diagenesis, and plant root casts (Boyd, 1975, pp. 6589).

Ichnology Related to the Creationist Model

The authors believe that trace fossil information in the rock record is another "arrow in the quiver" for creationist earth scientists to use in deciphering the geologic record left in God's Creation and in reconstructing the earths history. The creationist model presented below is in a brief, generalized form. Only four major timeframes will be examined, those being the Antediluvian, the Flood event, the Post-Flood (including the Ice Age) and the Present Age.

The Antediluvian world existed from the "Creation" to the "Flood." This time period is not exact (Vis, 1950, p. 242) but could be estimated (using inexact biblical "generations") as being approximately 1,200 to 1,656 years in duration (Whitcomb and Morris, 1961, p. 26). The Antediluvian earth had mountains (Genesis 7:20), rivers (Genesis 2:10-14) and seas (Genesis 1:10 & 22), and so must have experienced geological activities similar to today with several exceptions, most notably that it did not rain (Genesis 2:5) [modified from Whitcomb and Morris, 1961, p. 215]. Created bodies of water existed in the antediluvian world with creatures designed and placed there by the Creator (Genesis 1:20-25). Antediluvian subaqueous surfaces (both freshwater and marine) would provide the substrate for contemporaneous ichnospecies. The amount of time postulated here is sufficient for all levels of ichnofacies development, including bioturbation and escape structures (fugichnia).

The authors believe that the beginning of the Flood resulted in the first occurrence of rain. However this point remains controversial among creationists today. Additionally the beginning of the Flood also marked the breaking up of the earths surface resulting in the release of subterranean waters. This created an erosional environment on the continents and depositional environments in the lakes and seas and along the continental shelves and slopes in the oceans. These sedimentary deposits buried and filled (where possible) any traces during this event. Ichnofacies exposed to erosion associated with this event would have been destroyed.

Genesis 7:20 tells us that the Flood water covered the earth to a depth of at least 15 cubits (approximately 22 ft) within the first 46 days. This depth would not have prevented marine life from reestablishing itself on the substrata while the water covered the Earth. The earth, underwater at that time, did not have an underwater surface of equal depth and this uneven underwater surface would have promoted diverse environmental conditions and would have provided new opportunities for trace fossil development and diversity.

Then winds blew across the face of the earth as the waters receded (Genesis 8:1). Winds are recognized as a source of currents and this action may have resulted in the resuspension and/or winnowing of some subaqueous sediments. Trace fossil development during this time would result in the formation of escape structures or the burial of whole ichnofacies with a subsequent reestablishment of the same or perhaps different ichnofacies once deposition had ceased. This would have resulted in the generation of new niches for diverse trace makers to colonize.

During the latter stages of the Flood, tectonic forces, still incompletely understood, created basins into which waters flowed, thereby exposing earths surface. Lowering of the water level would have created new opportunities for ichnofacies to develop. Sea level would continue to drop, possibly as a result of the continental plate's spreading with the cooling and the sinking of the oceanic basalt accommodating greater volumes of water (Schopf, 1980, p. 48). Sea levels would also continue to fluctuate due to the ensuing Ice Age. The time from maximum Flood water depth to Noah's departure from the ark has been calculated as being 221 days (Whitcomb and Morris, 1961, p. 8).

The authors support the single "wet" ice age as outlined by Michael Oard (1990) and believe that the combination of tectonic forces coupled with climatic instability contributed to glacial disequilibrium resulting in the rapid rise and fall of sea level over the timeframe of the Post-Flood and Ice Age and subsequently thereafter (approximately 700 to 1000 years in duration). This change in sea level could create opportunities for the development of the various ichnofacies. The Post-Flood timeframe probably marked the time of greatest ichnofacies development. The earth was stabilizing to Post Flood conditions and the catastrophic processes which occurred during the Flood were no longer in operation. Changes in environmental conditions, such as changes in sea level, would subject the ichnofacies to tremendous stresses and change could occur from one ichnofacies to another very rapidly.

Modern traces, in many cases, are similar to those produced in the past (see Figure 2). However, there are many traces that do not have modern representatives. Today's sea level is estimated to reflect anywhere from 4,900 to 7,000 years of more nearly stable conditions (Dolan and Lins, 1986, p. 13; Curray, 1965, p. 733), which is consistent with the creationist's model (especially if the earth is no older than 10,000 years). This stability has allowed the reestablishment of ichnofacies at all levels of oceanic depth and has made possible the study and extrapolation of traces from the present back into earth's past.

Discussion

Trace fossils occur in almost all sedimentary rocks and have been found at all levels of the stratigraphic record as far back as the "Precambrian." According to Crimes (1975, p. 113):

> The earliest recorded trace fossil is a burrow system considered to have been made by a worm-like organism, probably an annelid, found in the Grand Canyon Series (U.S.A.) and suggested to be more than a billion years old.

Additionally, many Cambrian-type fossils (i.e., trilobites, worms, etc.) were very well established and active, bioturbating the sedimentary package during this period. So we see that ichnofacies have developed from the earliest (deepest) rocks and are continuing to be developed today. In fact, the "remains" of soft-bodied animals in the form of trace fossils are probably much more common than the remains of animals with hard parts (Ager, 1993, p. 150).

As a tool, ichnology has helped determine depositional and environmental conditions. For example, an ichnofacies consisting of more vertical burrows than horizontal burrows covered and filled by overlying sand deposits, could reflect a high energy (near-shore) ichnofacies which was buried under migrating barrier/spit sands. Another example is a highly bioturbated substrate, which may indicate either a period of low sedimentation with time for the trace makers to work and rework the sediments, or a larger population of trace makers which rework more quickly deposited sediments. These are just a few examples of how ichnology can be used to further define the environment. Ichnology, coupled with other geologic tools (i.e., stratigraphy, sedimentology, paleontology, paleoecology, etc.), offers the opportunity to better support the creationist model.

Conclusions

Ichnology is a tool that can, when properly integrated with other geologic disciplines, greatly aid in the determination of past deposition environments. The application of Ichnology toward the creationist model will help to determine the timeframe the ichnofacies, and the associated ichnogenera and ichnospecies in question, were produced, i.e., the Antediluvian, the Flood event and subsequent receding of waters, the Post-Flood (including the Ice Age), or the present. Once the timeframe is approximated, the creationist modeler should better be able to understand the environment and depositional setting in which the traces occurred. In many cases, Ichnology serves to reinforce the catastrophic nature of the Creation/Flood model. This ichnological information should serve as reinforcement to the premise of the Biblical interpretation of earths historical events. In subsequent articles or notes, the authors will attempt to correlate ichnological evidence using specific sites where traces are present within a creationist young-earth model.

Glossary

Abyssal zone — Oceanic zone of greatest depth, i.e., below 2000 m.

Aphotic zone — Oceanic depths lacking light penetration.

Bathyal zone — In marine ecology it is the region of the continental slope and rise.

Distal turbidites — The turbidite sediments located furthest from the source of origin.

Facies — Sum total of features that reflect the specific environmental conditions under which a given rock was formed or deposited. Can be singular or plural depending upon its usage.

Geopetal structures — A sedimentary fabric which records the way up at the time of deposition.

Hadal zone — The part of the ocean that lies in very deep trenches below the general level of the deep-ocean floor.

Hemisessile — A sea creature which spends half its life floating and the other part attached to a substrate.

Ichnofacies — A characteristic assemblage of trace fossils.

Imbrication — Fabric resulting from the lateral stacking of rock fragments indicating the direction of flow (tilted/leaning against each other like roof shingles).

Morphology — The form and structure of individual organisms.

Littoral zone — In marine ecosystems the shore area or intertidal zone where periodic exposure and submersion by tides is normal.

Neritic zone — The shallow-water or near-shore marine zone extending from low-tide level to a depth of 200 m.

Photic — Relating to levels of light.

Proximal turbidites — The turbidite sediments located close to the source of origin.

Substrate — The base on which an organism lives.

Turbidite — A sedimentary deposit laid down by a turbidity current.

Turbidity current — A variety of density current that flows as a result of a density difference created by dispersed sediment within the body of the current.
Vagile — A sea creature which is free to move about.

Dedication

This article is respectfully dedicated to the late Dr. Robert W. Frey, one the leading trace fossil experts in the world. Bob Frey was Mr. Cowart's major professor while Mr. Cowart worked on his trace fossil thesis for his Master of Science degree in Geology at the University of Georgia. Special appreciation is extended to Dr. S. George Pemberton, now with the Department of Geology, University of Alberta, Canada. While a Professor of Geology at the University of Georgia, Dr. Pemberton obtained a grant which permitted Mr. Cowart to work on his trace fossil thesis in Alberta, Canada.

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QUOTE

Thy righteousness is like the great mountains; thy judgements are a great deep: O Lord, thou preservest man and beast. How excellent is thy loving kindness, O God! therefore the children of men put their trust under the shadow of thy wings. They shall be abundantly satisfied with the fatness of thy house; and thou shalt make them drink of the river of thy pleasures. For with thee is the fountain of life: in thy light shall we see light.

Psalms 36:5-9, KJV