Introduction to Ichnology

The Use of Trace Fossils in Paleontology and Related Geosciences

Marine Environment
What is Ichnology?

ICHNOLOGY is the study of organism behaviour and its products: **trace fossils**

**TRACE FOSSIL** is the product of an organism interacting with a **substrate** in an **environment** that generates a **three-dimensional physical structure** (Hasiotis & Roberts, 2005).

Interactions are via behavior: dwelling, feeding, crawling, hiding, resting, grazing, cultivating, reproducing, escaping and multifunctional.
**Organism** - Prokarya & Eukarya

**Substrate** - grains, sediments, rocks and organisms

**Environment** - an area with distinct physical, chemical and biological characters that is found in the continental, transitiona or marine setting.

**Three-dimensional physical structure** - tracks, trails, burrows, nests, rooting patterns, biolaminates, borings and etched surfaces from nanometer to kilometer-scale features.
The Conceptual Framework and Principles of Ichnology

- Most trace fossils are largely facies dependant
- No secondary displacement or transport
- Trace fossils are common in rocks that otherwise are unfossiliferous (siliciclastics, shorelines)
- Non-preservation of the causative organism
- Multiple architects may produce a single structure
- The same individual can produce different structures corresponding to different behaviour
- The same individual may produce different structures corresponding with identical behaviour but in different substrates
- Identical structures may be produced by the activity of systematically different organisms where behaviour is similar
- Abundance - one animal, especially if mobile, can make many traces during its lifetime, whereas it may or may not have its body preserved in the fossil record
Trace Fossil Identification

Criteria:

A. Basic morphology
   1. burrow wall
   2. burrow lining
   3. backfill structure (meniscae)
      4. spreite structure
   5. tunnel (horizontal tube)
   6. shaft (vertical tube)
   7. root pattern (tapering)
   8. branching (Y, T, intersections)

B. General Recognition Criteria
   1. resemble body form or body part an organism
   2. uniform dimensions or continuity of structure
   3. downward tapering dimensions and circular cross section
      4. lack of current alignment
   5. preservation in relief
   6. morphologic traits
   7. association with body fossil
      8. pellets
   9. delicate morphological features
A single animal may produce several sort of traces, as illustrated (redlichid trilobite)

The same burrow preserved in contrasting manners because of slight differences in level of burrowing relative to the clay-sand interface

Preservational terms based on Seilacher’s classification (1964)

Four contrasting types of animals exhibiting the same behavior in the same sediment and thereby producing similar traces

Principles of Ichnology
Trace fossil taxonomy

ETHOLOGICAL CLASSIFICATION
- Ethologic categories of trace fossils, clockwise from the top:
  - repichnia = locomotion traces
  - cubichnia = resting traces
  - domichnia = dwelling traces
  - pascichnia = grazing traces
  - fodinichnia = feeding burrows

Coprolites?

LINNAEAN CLASSIFICATION
Ichnotaxa = Ichnogenus + Ichnospecies
- for example,
  Lithophaga sp. = Gastrochaenolites isp.

PRESERVATIONAL CLASSIFICATION
- full relief, semirelief, epi-relief, hyporelief...

PALEOENVIRONMENTAL CLASSIFICATION
- trace fossil associations (“ichnofacies”) - Trypanites!
▲ Three ichnospecies representing similar crustacean domicinia

▲ The basic differences between burrow and boring

► Different shape of same human footprints depend on substrate water saturation
Seilacher's Concept of Recurring Ichnofacies

TRACE FOSSILS ► BEHAVIOUR ► ENVIRONMENT

Trace fossils are a manifestation of behaviour which can be modified by the environment.

ECOLOGICAL CONTROLS

The distribution and behaviour of benthic organisms is limited by a number of interrelated ecological controls, including:

1. Sedimentation Rate
2. Substrate Coherence
3. Salinity
4. Oxygen Level
5. Turbidity
6. Light
7. Temperature
8. Water Energy

Distribution of Common Marine Ichnofacies

Population strategies among burrowing organisms

**Equilibrium** (*K*-selected) trace fossils flourish in high-diversity assemblages under very stable and predictable conditions.

**Opportunistic** (*r*-selected) trace fossils rise to prominence in low-diversity assemblages under extremely variable and unpredictable conditions. (Modified from Ekdale 1985.)
Seilacher's Concept of Recurring Ichnofacies

Trace fossils are a manifestation of behaviour which can be modified by the environment.

ECOLOGICAL CONTROLS
The distribution and behaviour of benthic organisms is limited by a number of interrelated ecological controls, including:

1. Sedimentation Rate
2. Substrate Coherence
3. Salinity
4. Oxygen Level
5. Turbidity
6. Light
7. Temperature
8. Water Energy

Distribution of Common Marine Ichnofacies
Spreite Burrows and Other Ichnostructures
Evolution of Spreiten Burrows

Cladogram of spreiten burrows, represents an evolutionary progression beginning with a simple vertical shaft and culminating with a very complex burrow.
Diplocraterion
Upper Eocene of Benkovac area, Croatia
Zoophycos
Upper Eocene of Benkovac area
Ophiomorpha
Upper Eocene of Benkovac area, Croatia
Spongeliomorpha
Lower Campanian, Medvednica, Croatia. Detail shows characteristic scratch marks.
Scolicia - spatangoid traces
Upper Eocene of Benkovac area, Croatia
Gastrochaenolites
Middle Miocene, Donje Orešje, Croatia
Graphoglyptids

or highly organized 'agrichnia'

Helminthorhaphe
Glockeria
Protopaleodictyon
Dendrotichnium
Paleomeandron
Lorenzinia

Spirorhaphe

Paleodictyon
Paleomeandron (Squamodictyon)

Cosmorhaphe

Paleodictyon (Glenodictyum)

Oscillorhaphe

Belorhaphe

Desmograpton

Acanthorhaphe
SPIRAL GRAPHOGLYPTIDS

Spirorhaphe and Nereites
Upper Eocene of Istria, Croatia
MEANDERING GRAPHOGLYPTIDS

Urohelminthoida
Upper Eocene of Istria, Croatia
Glockerichnus
Upper Eocene of Benkovac area, Croatia
Paleodictyon
Upper Eocene of Benkovac area, Croatia
Cruziana
Lower Cambrian, Oman

Median Furrow

Oblique Scratch Marks

movement direction
Core samples

Rosselia

Scolicia

Trypanites at hardground
Sauropod trackways, Kirmenjak formation, Upper Jurassic, Istria, Croatia

movement direction (shoreline direction?)

Sauropod trackways, Kirmenjak formation, Upper Jurassic, Istria, Croatia
**GSSP for the Precambrian - Cambrian Boundary**

**Definition:**
The base of the Cambrian System is defined in a coastal section near the town of Fortune in southeastern Newfoundland, Canada. The level is marked by the first occurrence of Phycodes pedum (a trace fossil).

**Phycodes and Harlaniella (secondary marker, together with Palaeopascichnus)**

**1835 Sedgwick?**

References: