Trace fossils are the records of biological activity left in rock, that is, evidence that organisms were active there. They do not include hard parts, a.k.a. "body fossils"

The oldest ichnofossils are thought to be as old as 3.5 b.y. and microtraces in sea-floor basalts.[1] Stromatolites are also trace fossils, and some are equally old.

1) Banerjee, et al., **Direct dating of Archean microbial ichnofossils** Geology 2007 35: 487-490

Stromatolites in the Mississippian Windsor Gp, New Brunswick, S. Earle

Neoichnology is the study of modern traces in sediments, and it is an important aspect of paleoichnology as the present is the key to the past.

Most trace fossils have long temporal ranges *- they are not useful as indicators of age*

Most trace fossils are largely facies dependant *- they are very useful as indicators of depositional environment*

Biogenic sedimentary structures, where preserved intact, are closely related to the environment in which they formed *- they are not transported as some body fossils can be*

Trace fossils may be common in rocks that otherwise are unfossiliferous.

The causative organisms are typically not preserved.

after G. Pemberton, U. of Alberta *– my additions in italics*

Different organisms may produce a single structure, and the same individual or species can produce different structures corresponding to different behaviour *– it can be very difficult to know what made the trace*

The same individual may produce different structures corresponding with identical behaviour but in different substrates *– interpreting environments from trace fossils can be difficult*

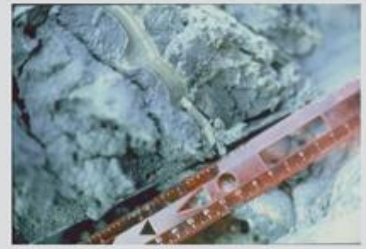
Identical structures may be produced by the activity of systematically different trace-making organisms where behaviour is similar *(and similar ichnofossils can be formed by organisms from different periods that have similar behaviours)*

after G. Pemberton, U. of Alberta *– my additions in italics*

The Conceptual Framework of Ichnology

A. Biogenic structures represent the activity of soft-bodied organisms that are not generally perserved. Such organisms (include many entire phyla) are commonly the dominant conponent of the boimass of many environments.





B. Biogenic structures are commonly enhanced by diagenesis and can be used in horizons where physical sedimentary structures have been masked. In the example below from the Cayman Islands the coral head has been dissolved by perculating ground water and the borings having a more resistant cement were not affected and are preserved.


C. Biogenic structures can be associated with faciess that do not contain any other fossils. In many siliciclastic regimes, diagenesis dissolves most of the shelly fauna and trace fossils represent the only clue as to the original biogenic component of the unit.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The Conceptual Framework of Ichnology

D. Biogenic structures can be used for the paleoecological reconstruction of depositional environments.

In the McMurray Formation IHS beds are interpreted as the lateral accretion deposits of meandering channels. The trace fossils indicate that the channel was probably esturine in origin.

E. Biogenic structures are sensitive to fluctuations in sedimentary dynamics. Bioturbation patterns are important in recognizing event beds and sedimentation patterns.

In clastic regimes episodic depositional events are common including: turbidtes, tempesities, seismites, phyto-detrital pulses, lateral delta lobe switches and inundites.

F. Biogenic structures are sensitive indicators of substrate coherence. The *Trypanites*, *Glossifungites* and *Teredolites* ichnofacies are substrate-controlled and are emerging as important elements in the evolving concepts of sequence stratigraphy.

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The Conceptual Framework of Ichnology

G. Biogenic structures ordinarily cannot be transported and therefore represent the original environmental position of the trace making animal.

In Drumheller the transgression is marked by the *Teredolites* ichnofacies that is incised into the exposed peat bed. Commonly such transgressions bottom out on peats because they are difficult to erode.

H. Biogenic structures are sensitive to changes in certain ecological parameters that are otherwise difficult to ascertain. Trace fossil models are emerging to recognize changes in such parameters as salinity and oxygen levels.

In the Mannville Group of Southern Alberta, a monospecific *Gyrolithes*-dominated assemblage is present in many of the deposits. This assemblage is commonly associated with the interpretation of brackish water environments.

I. An integrated approach utilizing physical, chemical, biological and ichnological lines of evidence constitutes a powerful tool for facies interpretation.

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Ichnologists have given names to:

<u>ichnofacies</u> (depostional environments that <u>ichnofossils</u> are thought to represent)

to a wide variety of ichnofossils (that are divided into ichnogenera and ichnospecies), and

to the different types of behaviours that produce ichnofossils

- **Domichnia**, dwelling structures reflecting the life position of the organism that created it.
- **Fodinichnia**, three-dimensional structures left by animals which eat their way through sediment, such as deposit feeders;
- **Pascichnia**, feeding traces left by grazers on the surface of a soft sediment or a mineral substrate;
- **Cubichnia**, resting traces, in the form of an impression left by an organism on a soft sediment;
- **Repichnia**, surface traces of creeping and crawling.

Seilacher's Concept of Recurring Ichnofacies

TRACE FOSSILS ➡ BEHAVIOUR ➡ ENVIRONMENT

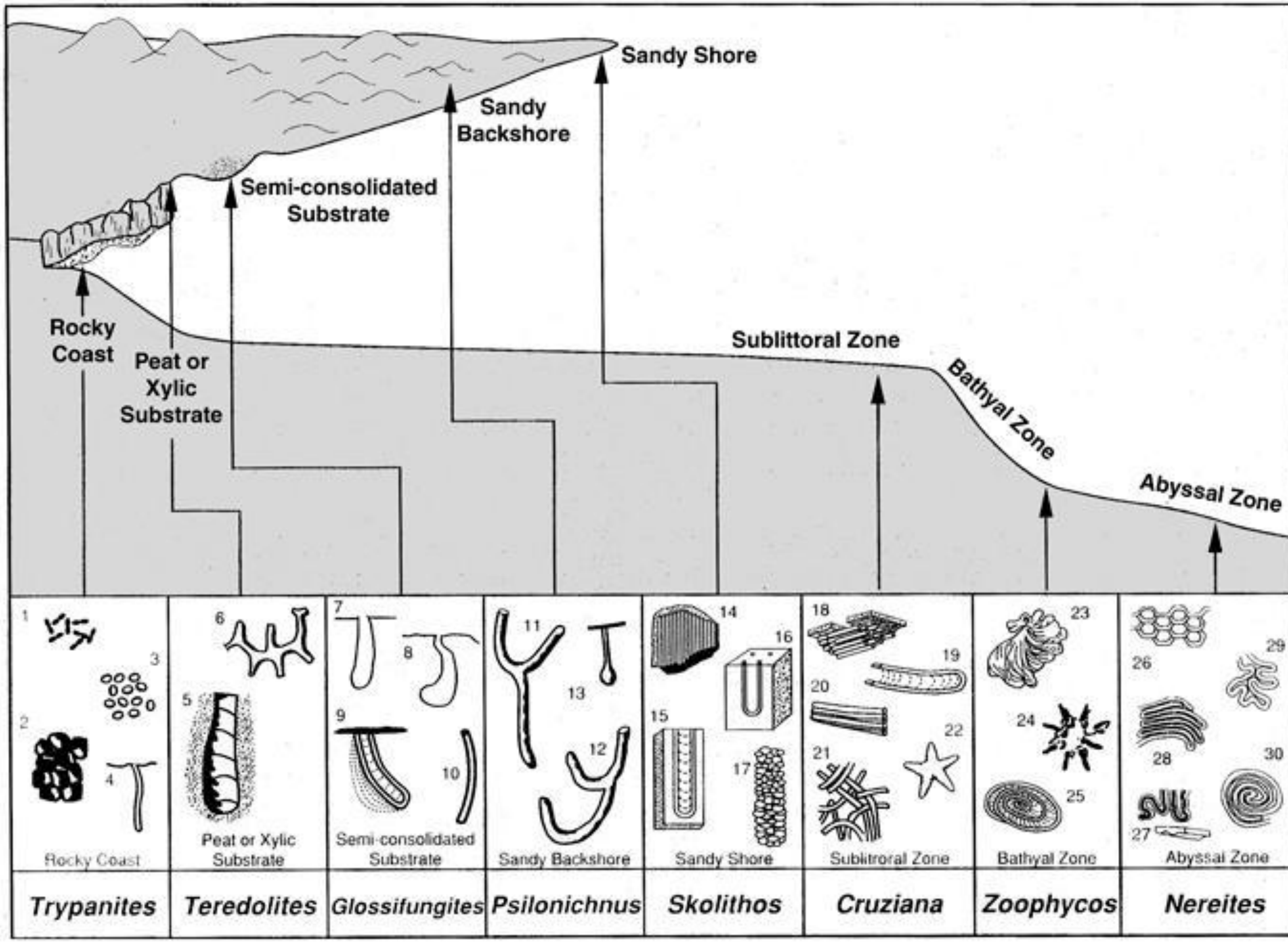
Trace fossils are a manifestation of behaviour which can be modified by the environment.

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**

From G. Pemberton, U. of Alberta

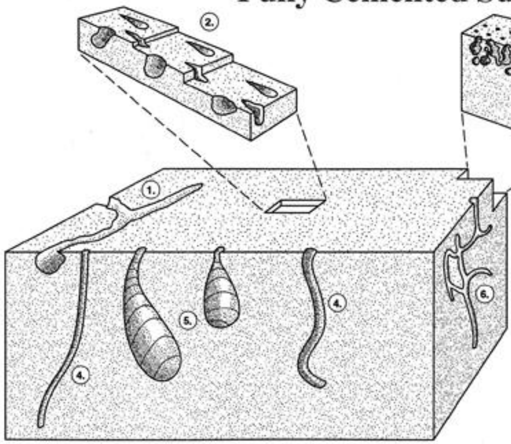


Distribution of Common Marine Ichnofacies

From G. Pemberton, U. of Alberta

TRYPANITES ICHNOFACIES

Fully Cemented Substrates



1. Echinoid Grooves
2. Barnacle Borings
3. Sponge Borings
4. Polychaete Boring
5. Bivalve Boring
6. Sipunculid Boring
7. Polychaete Boring

1. Cylindrical to vase-, tear-, or U-shaped domiciles.

2. Borings perpendicular to substrates.

3. Suspension feeders or passive carnivores.

4. Raspings and gnawings of algal grazers.

5. Moderately low diversity, although individual borings may be abundant.

Trypanites

Entobia

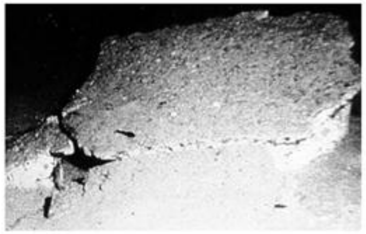
TRYPANITES ICHNOFACIES

Modern examples

Rocky shorelines

Sabellarid worm reefs

Beachrock



Submarine hardgound

Ancient examples

Trypanites at hardground surface, Triassic of Alberta

Discontinuity, Silurian-Devonian boundary in southern Ontario

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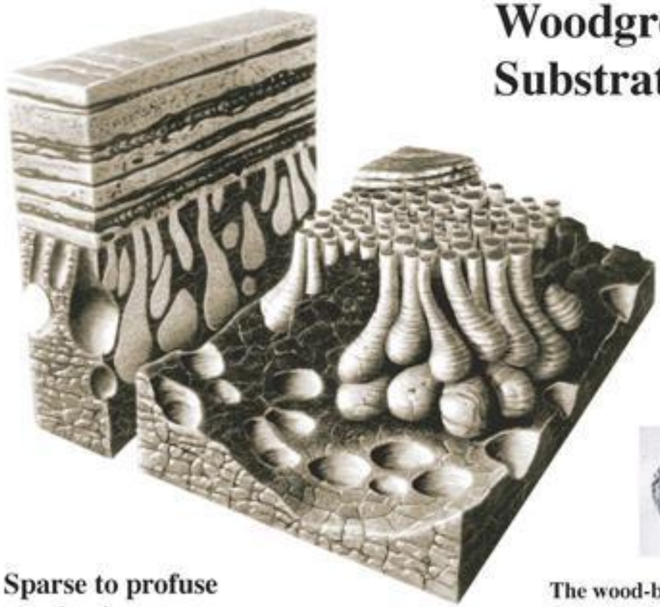
TEREDOLITES ICHNOFACIES

Woodground Substrates



1. Sparse to profuse clavate borings.

2. Dense excavations, but without interpenetrating borings.

3. Walls ornamented with the texture of the host substrate.

4. Elongate sub-cylindrical excavations in marine settings.

The wood-boring bivalve *Martesia* sp., Upper Cretaceous Horseshoe Canyon Fm.

Teredolites clavatus, Upper Cretaceous Horseshoe Canyon Fm., Alberta

TEREDOLITES ICHNOFACIES

Mud-filled channel (dashed and solid line), Upper Cretaceous Horseshoe Canyon Fm., Alberta. *Teredolites* Ichnofacies present where valley incises into peat (solid line).

Detail of contact

Bedding surface view

It is important to stress that the *Teredolites* Ichnofacies represents a mappable surface (left photo), not transportable clasts (center and right photos).

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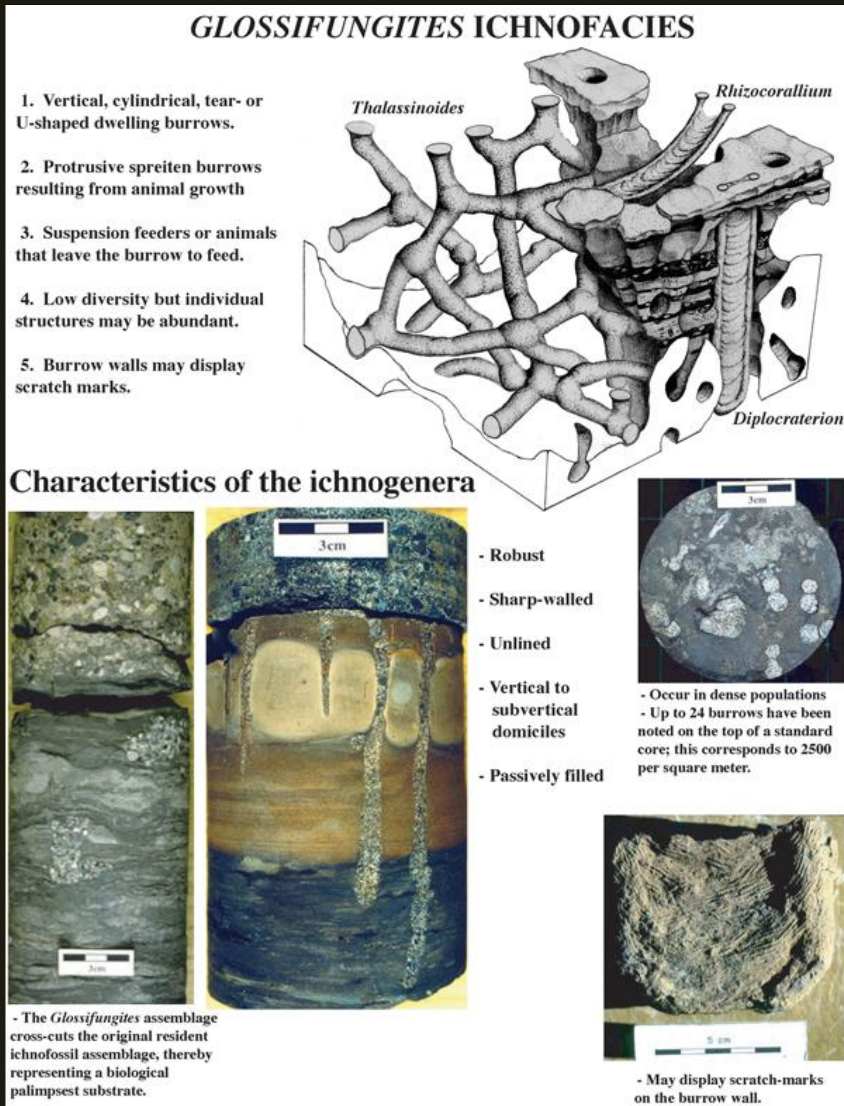

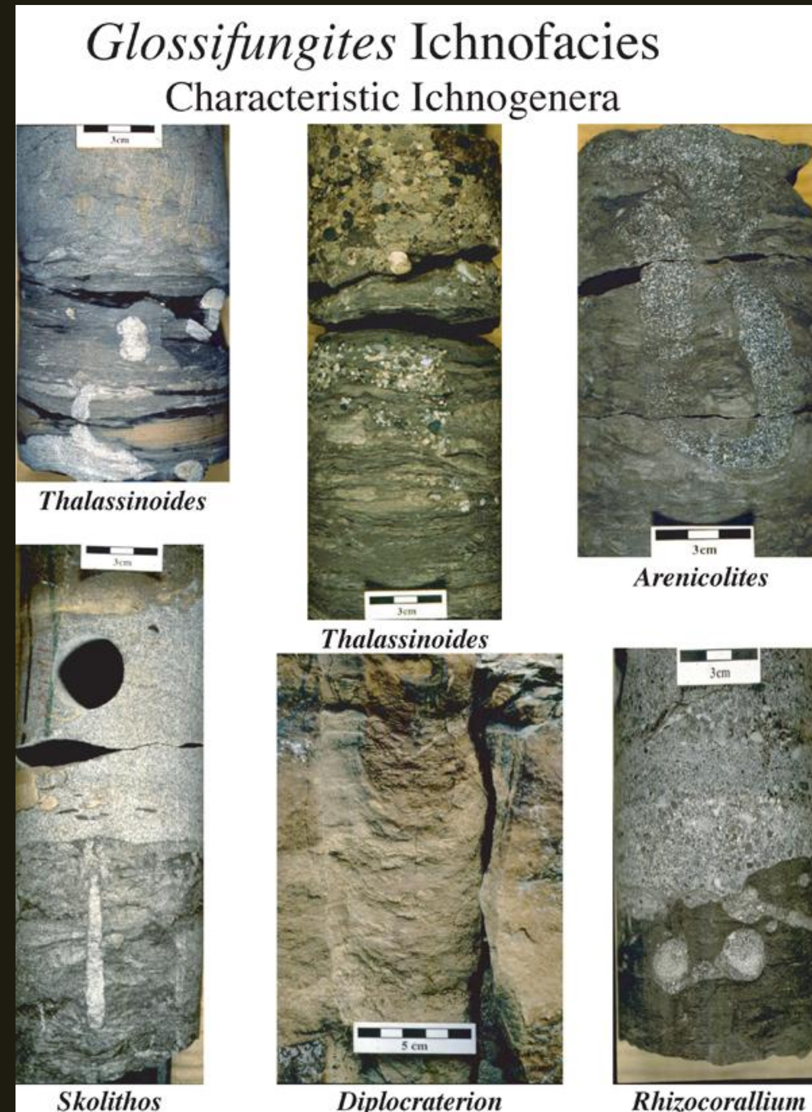

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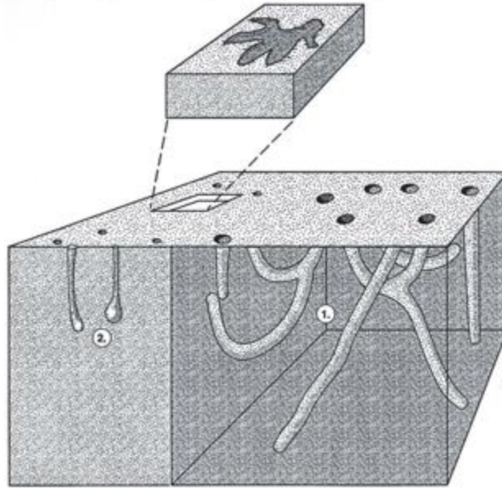
PSILONICHNUS ICHNOFACIES



- Low diversity and abundance.
- Dominated by J-, Y-, or U-shaped dwelling burrows made by ghost crabs.
- Vertical shafts of insects and spiders (Macanopsis).
- Root penetrations are common.
- Horizontal trails formed by the crawling and foraging of insects and tetrapods.
- The ephemeral tracks, trails and fecal pellets of insects, reptiles, birds and mammals; these are predominantly predators and herbivores.

The Ghost Crab *Ocyopoda quadrata*, Sapelo Island, Georgia

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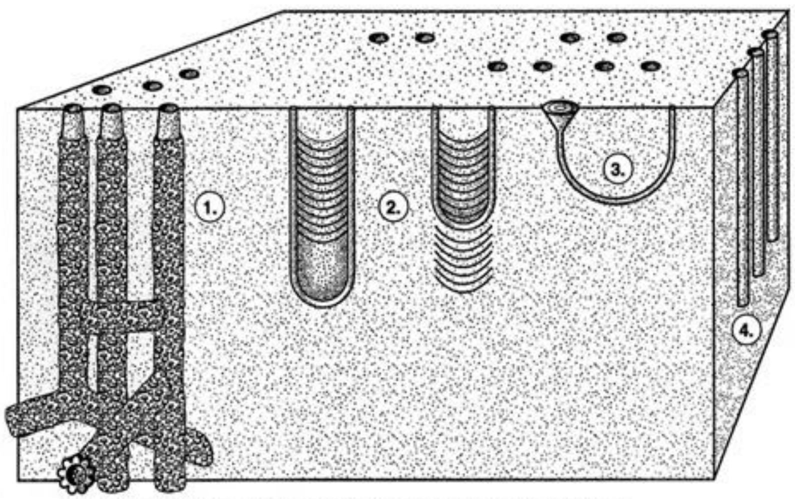
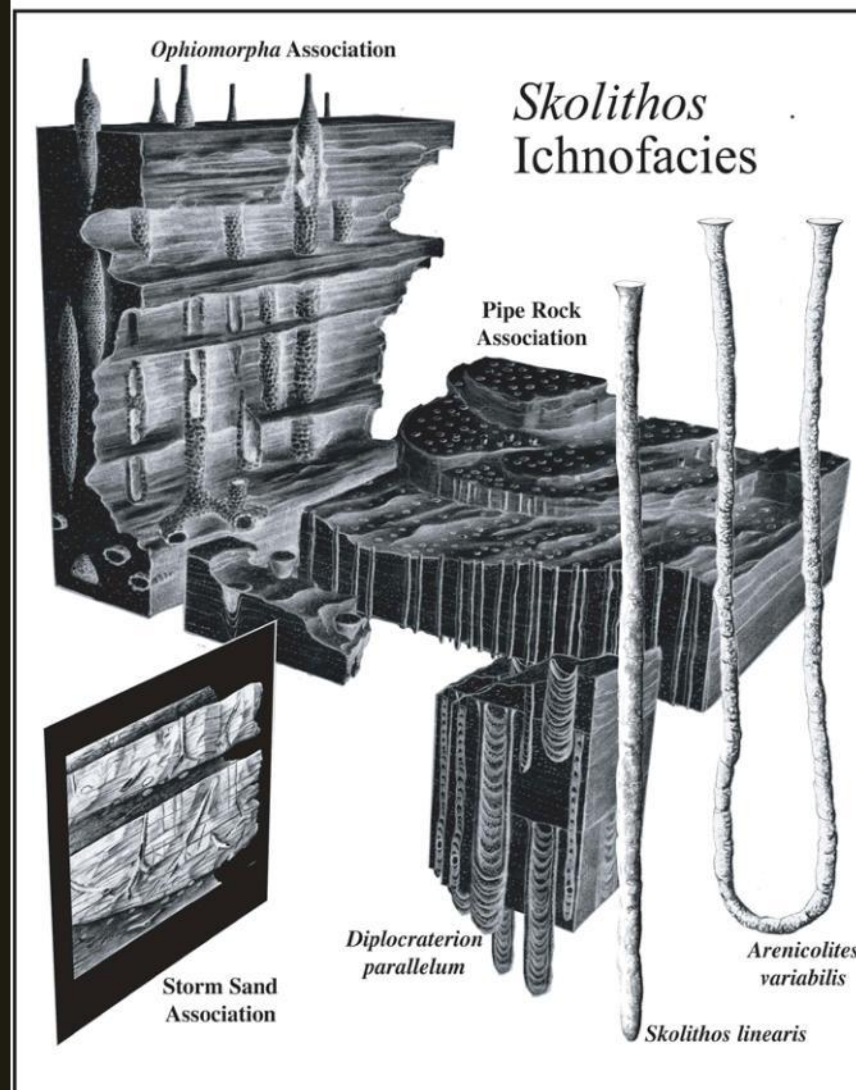
SKOLITHOS ICHNOFACIES



1. Ophiomorpha 2. Diplocraterion 3 Arenicolites 4. Skolithos

- **Predominantly vertical, cylindrical, or U-shaped burrows.**
- **Protrusive or retrusive spreiten in some U-burrows, which respond to subtrate aggradation and degradation.**
- **Few horizontal structures.**
- **Few structures produced by mobile organisms.**
- **Low diversity, although individual forms may be abundant.**
- **Mostly dwelling burrows constructed by suspension feeders or passive carnivores.**
- **Vertebrate traces, particularly in low-energy settings.**



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SKOLITHOS ICHNOFACIES

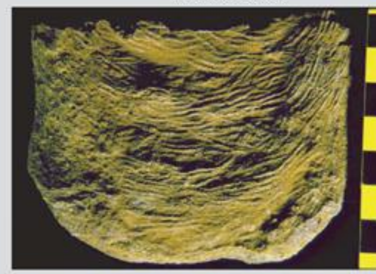
Characteristic Ichnogenera

Skolithos

Rosselia

Vertical
Ophiomorpha

Horizontal
Ophiomorha



Diplocraterion

Conichnus

Arenicolites

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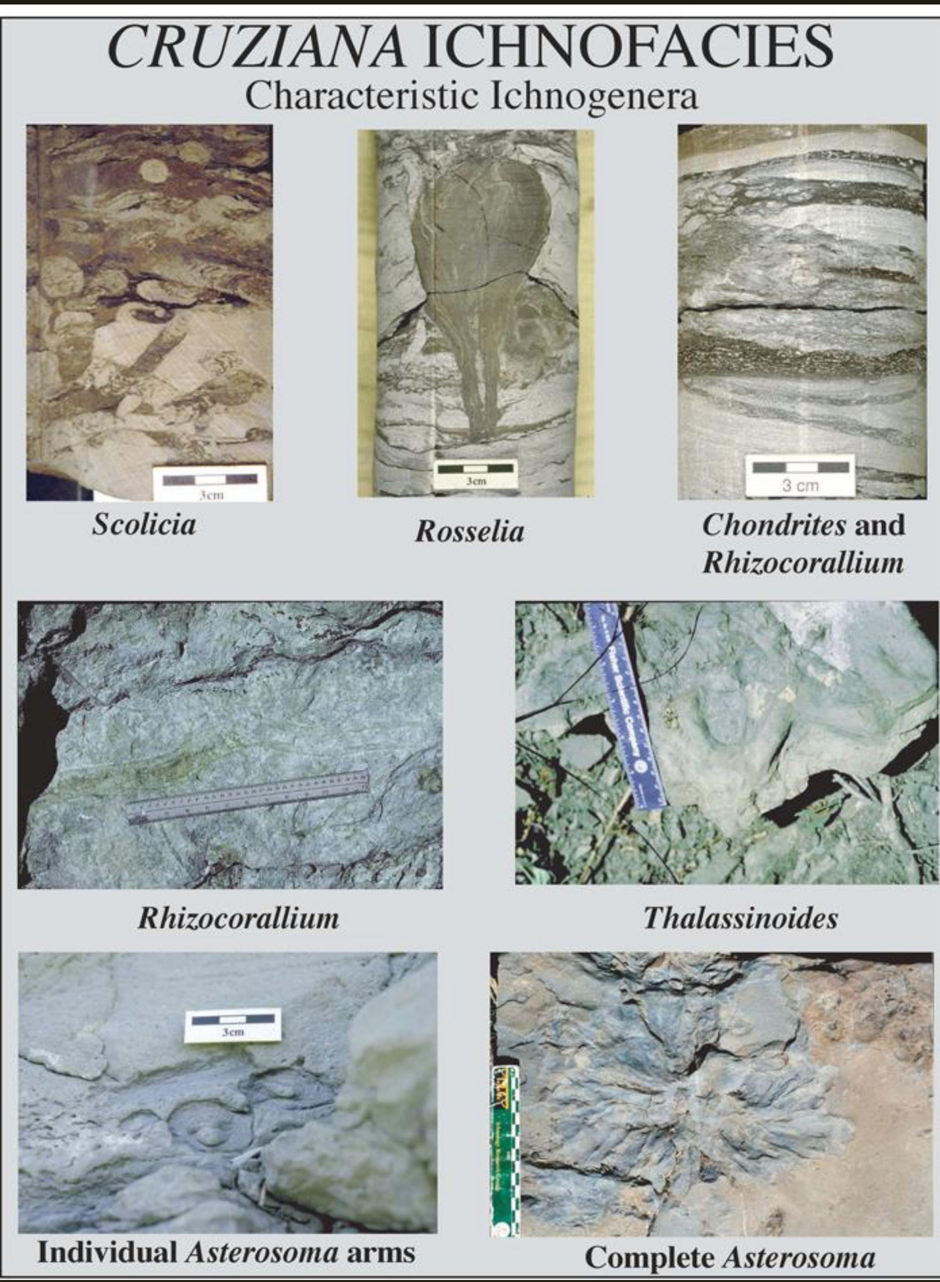

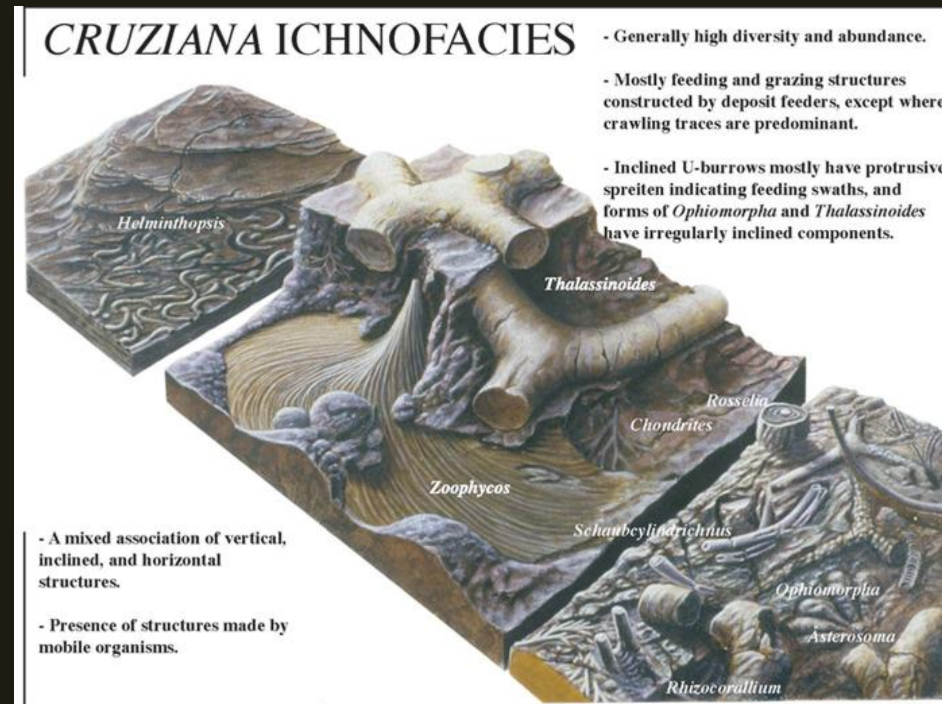

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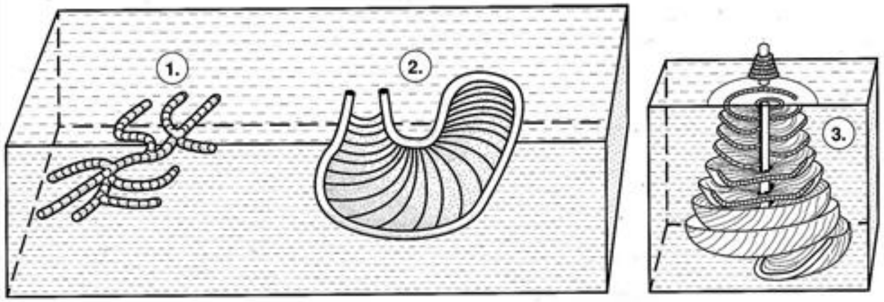
ZOOPHYCOS ICHNOFACIES

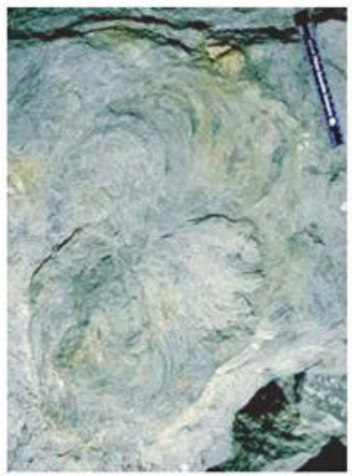


1. Zoophycos 2. Zoophycos. 3. Spirophyton

- Low diversity, though individual traces may be abundant.

- Simple to moderately complex, efficiently executed grazing and feeding structures produced by deposit feeders.

- Horizontal to gently inclined spreiten structures distributed in delicate sheets, ribbons, lobes, or spirals (flattened forms of *Zoophycos* or, in pelitic sediments, *Phycosiphon*).



***Zoophycos*, Upper Cretaceous Cardium Formation, Alberta**

ZOOPHYCOS ICHNOFACIES

Characteristic Forms of *Zoophycos*

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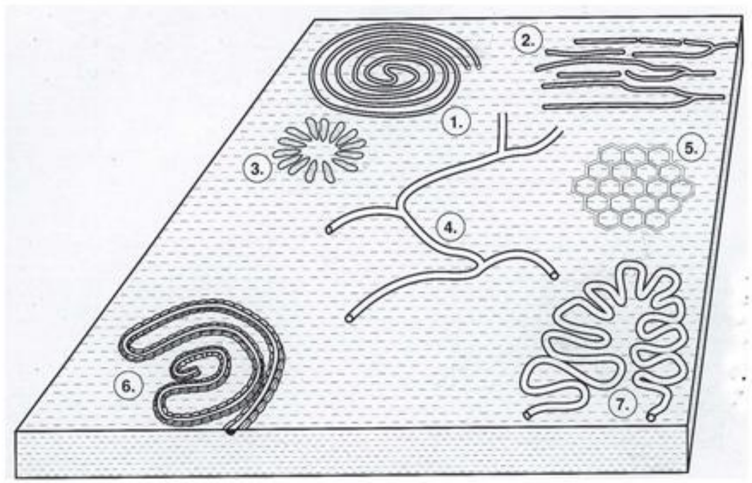
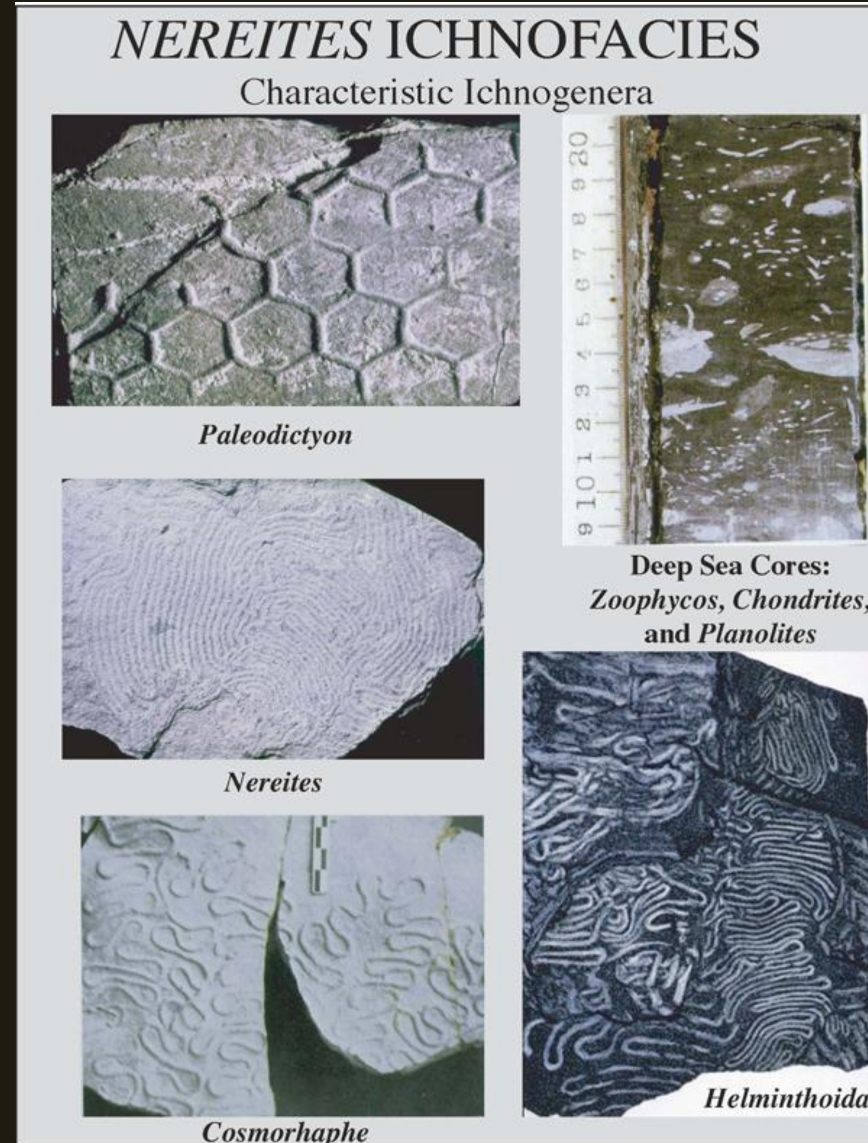
NEREITES ICHNOFACIES



1. Spirorhaphe 2. Urohelminthoida 3. Lorenzinia 4. Megagrapton 5. Paleodictyon 6. Nereites 7. Nereites

- **High diversity but low abundance.**
- **Complex horizontal grazing traces and patterned feeding/dwelling structures reflecting highly organized efficient behaviour.**
- **Spreite are typically nearly planar, although Zoophycos forms are spiraled, multilobed and complex.**
- **Numerous crawling and/or grazing traces and sinuous fecal castings (*Helminthoida*, *Cosmorhaphe*) that are mostly intrastratal.**
- **Structures produced by deposit feeders and scavengers.**
- **Structures associated with trapping or farming microbes within permanent open domiciles (*Paleodictyon*, *Megagrapton*).**



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Macaronichnus

Macaronichnus segregatis: A Feeding Structure of Shallow Marine Polychaetes
H. Edward Clifton, Janet K. Thompsom, *Journal of Sedimentary Research,* Volume 48 (1978)

Macaronichnus isp. (?) from the Gabriola Fm., Gabriola Island

S. Earle, Vancouver Island University


S. Earle, Vancouver Island University


S. Earle, Vancouver Island University