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.

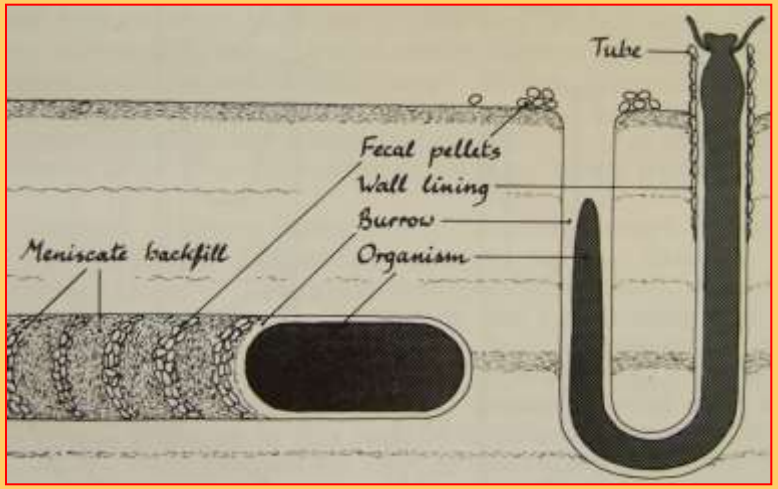
The Conceptual Framework and Principles of Ichnology

- Most trace fossils are largerly 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 behavior 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:

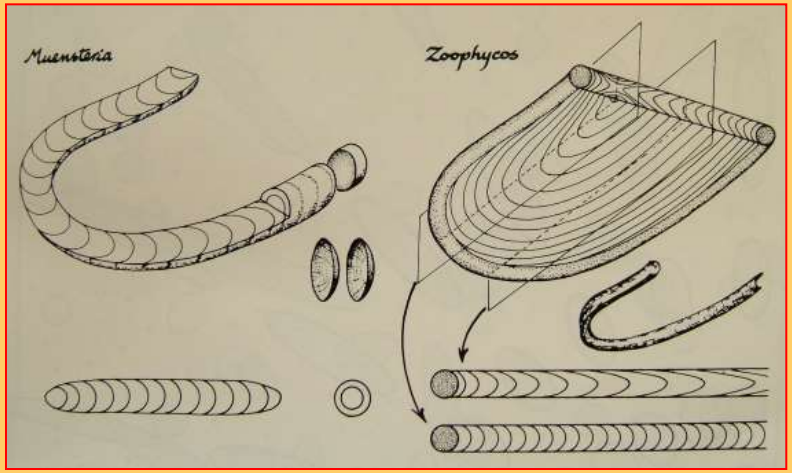
A. Basic morphology

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)



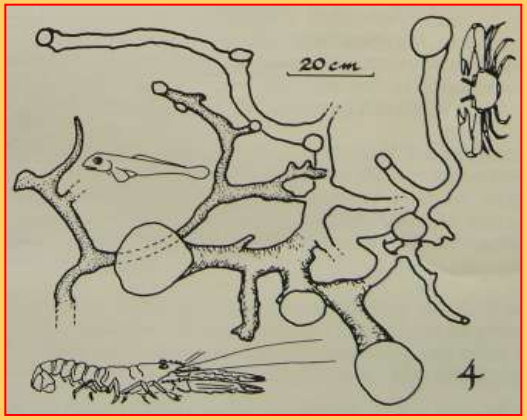
B. General Recognition Criteria

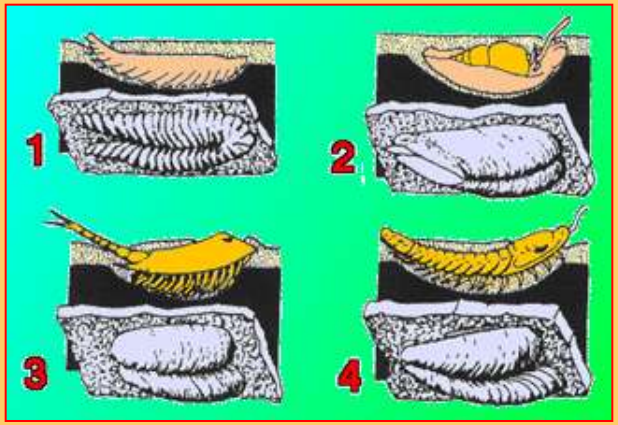
1. resemble body form or body part an organism
2. uniform dimensions or continuity of structure
3. downward tapering dimensions and circular cross section
4. lack of current alignment
5. preservation in relief
6. morphologic traits
7. association with body fossil
8. pellets
9. delicate morphological features

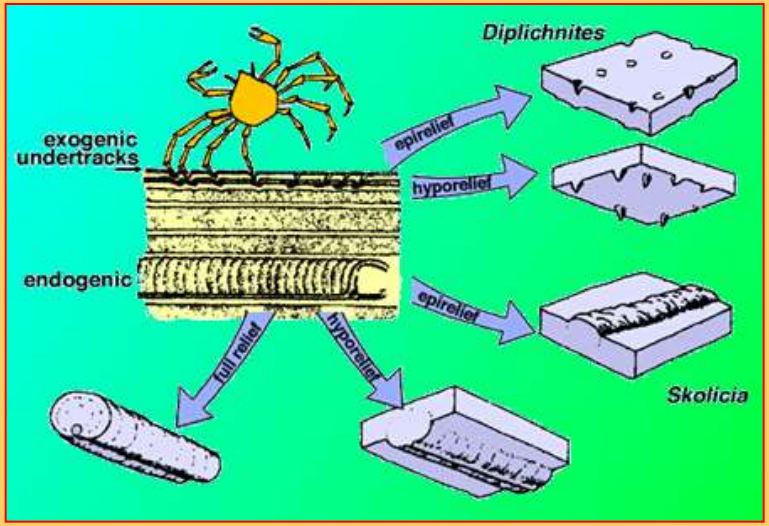


Principles of Ichnology

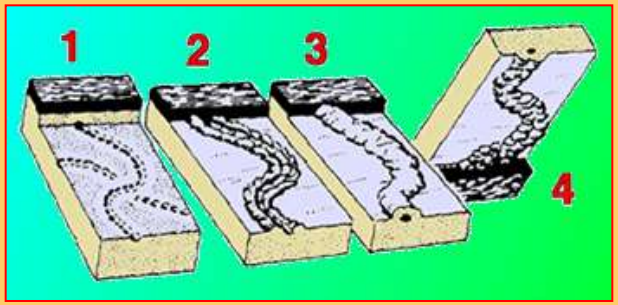
Four contrasting types of animals exhibiting the same behavior in the same sediment and thereby producing similar traces ►



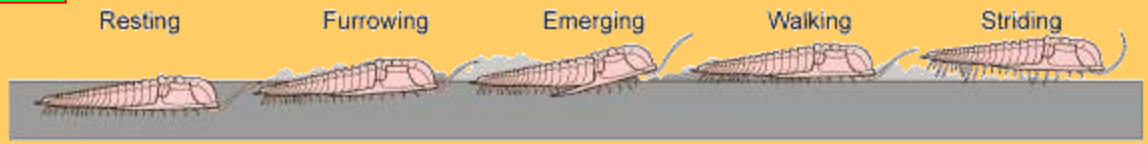




The same burrow preserved in contrasting manners because of slight differences in level of burrowing relative to the clay-sand interface ►

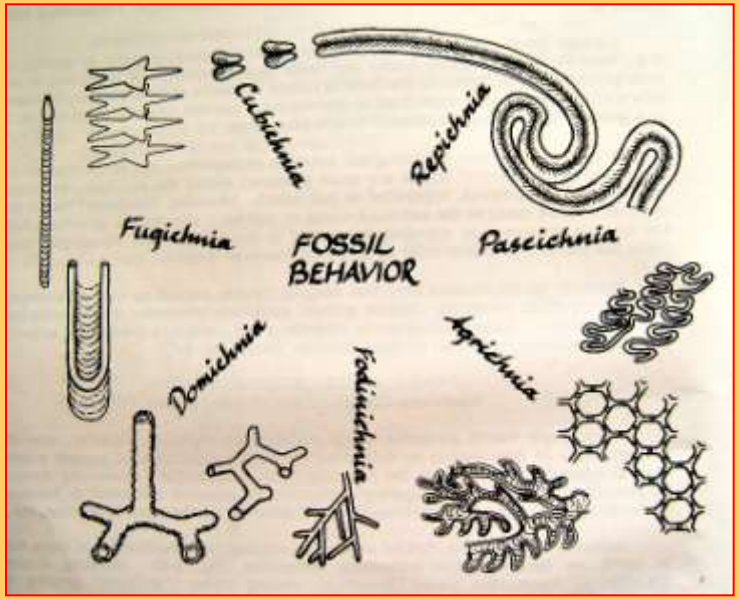


◄ Preservational terms based on Seilacher's classification (1964)



A single animal may produce several sort of traces, as illustrated (redlichid trilobite) ►

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,

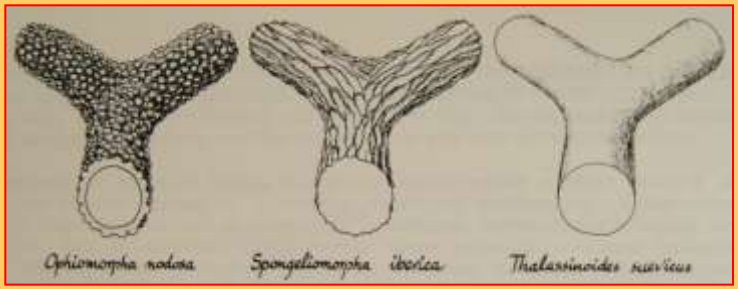
Lithophaga sp. = Gastrochaenolites isp.

PRESERVATIONAL CLASSIFICATION

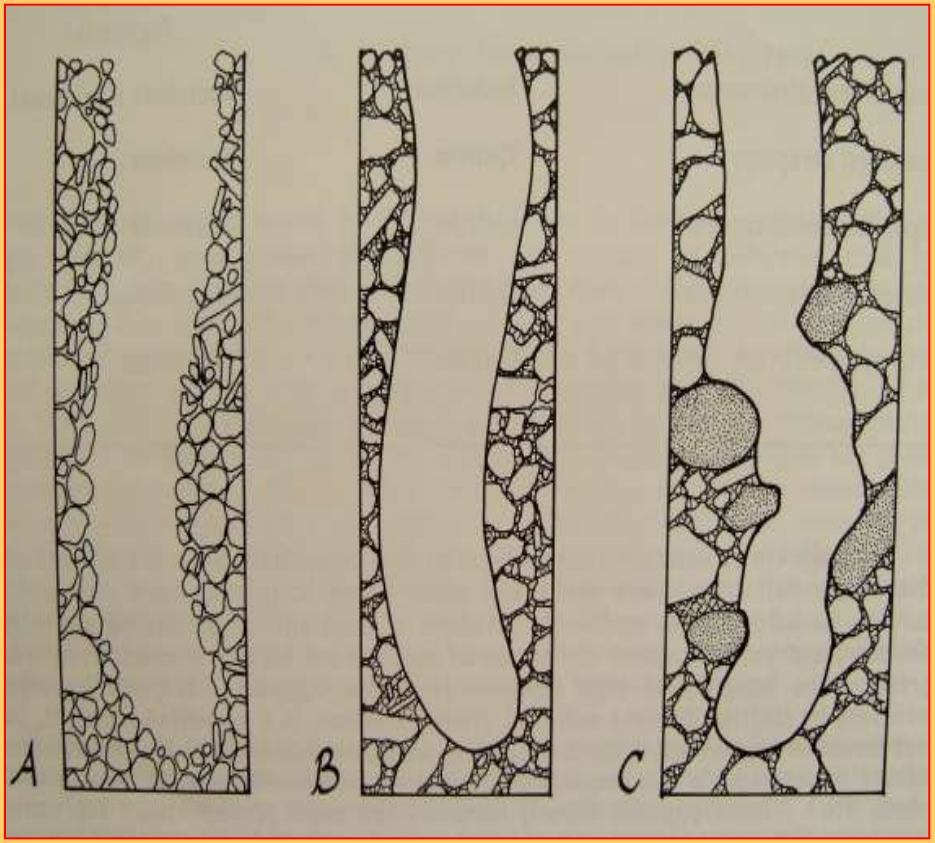
-full relief, semirelief, epirelief, hyporelief…

PALEOENVIRONMENTAL CLASSIFICATION

-trace fossil associations ("ichnofacies") – Trypanites!



▲ Three ichnospecies representing similar crustacean domichnia



▲ The basic differences between burrow and boring

◄ Different shape of same human footprints depend on substrate water saturation

Seilacher's Concept of Recurring Ichnofacies

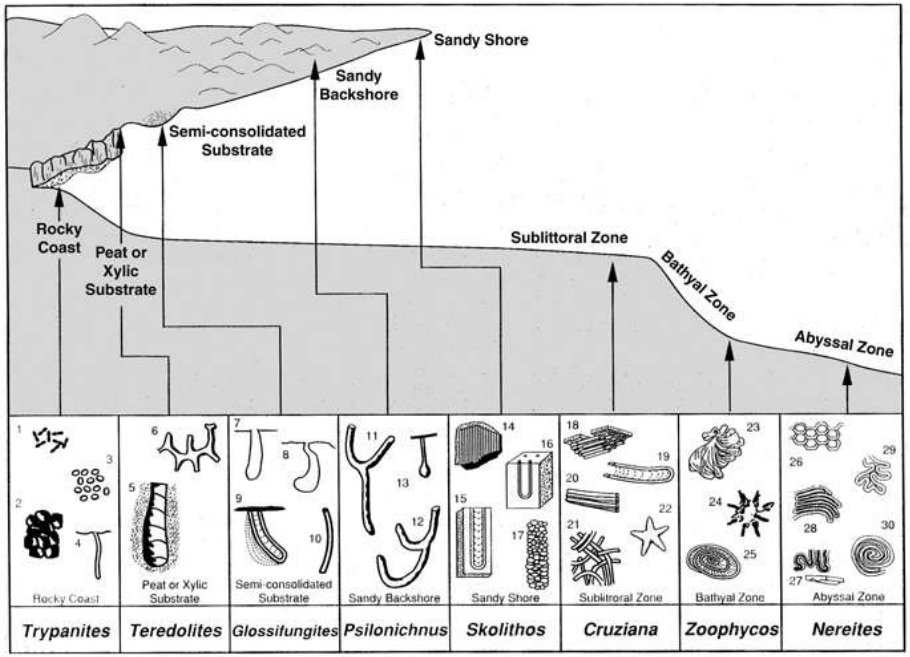
TRACE FOSSILS ➡ **BEHAVIOUR** ➡ **ENVIRONMENT**

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

ECOLOGICAL CONTROLS

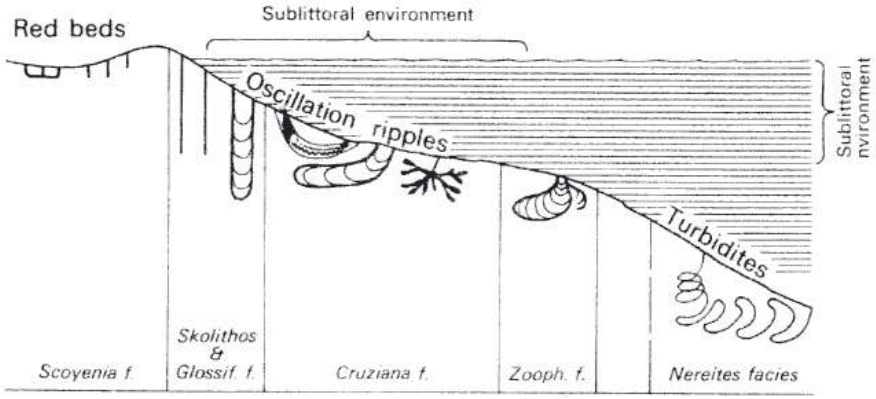
The distribution and behaviour of benthic organisms is limited by a number of interrelated ecological controls, including:

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

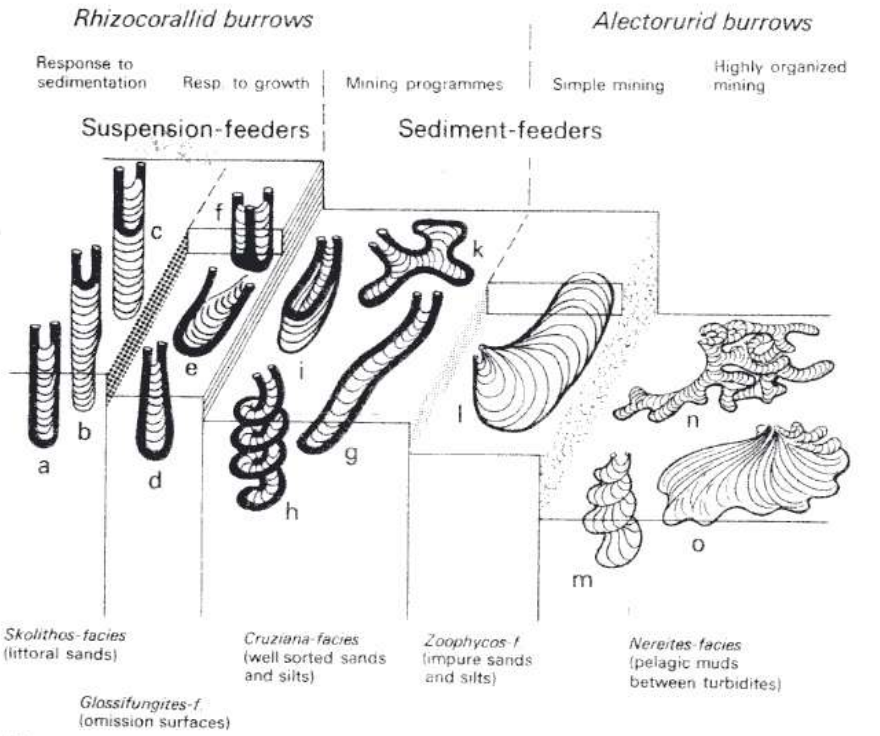


Distribution of Common Marine Ichnofacies

Typical trace fossils include: *1) Caulostrepsis; 2) Entobia; 3) echinoid borings; 4) Trypanites; 5) Teredolites; 6) Thalassinoides; 7, 8) Gastrochaenolites or related genera; 9) Diplocraterion (Glossifungites); 10) Skolithos; 11,12) Psilonichnus; 13) Macanopsis; 14) Skolithos; 15) Diplocraterion; 16) Arenicolites; 17) Ophiomorpha; 18) Phycodes; 19) Rhizocorallium; 20) Teichichnus; 21) Planolites; 22) Asteriacites; 23) Zoophycos; 24) Lorenzinia; 25) Zoophycos; 26) Paleodictyon; 27) Taphrhelminthopsis; 28) Helminthoida; 29) Cosmorhaphe; 30) Spirorhaphe.*

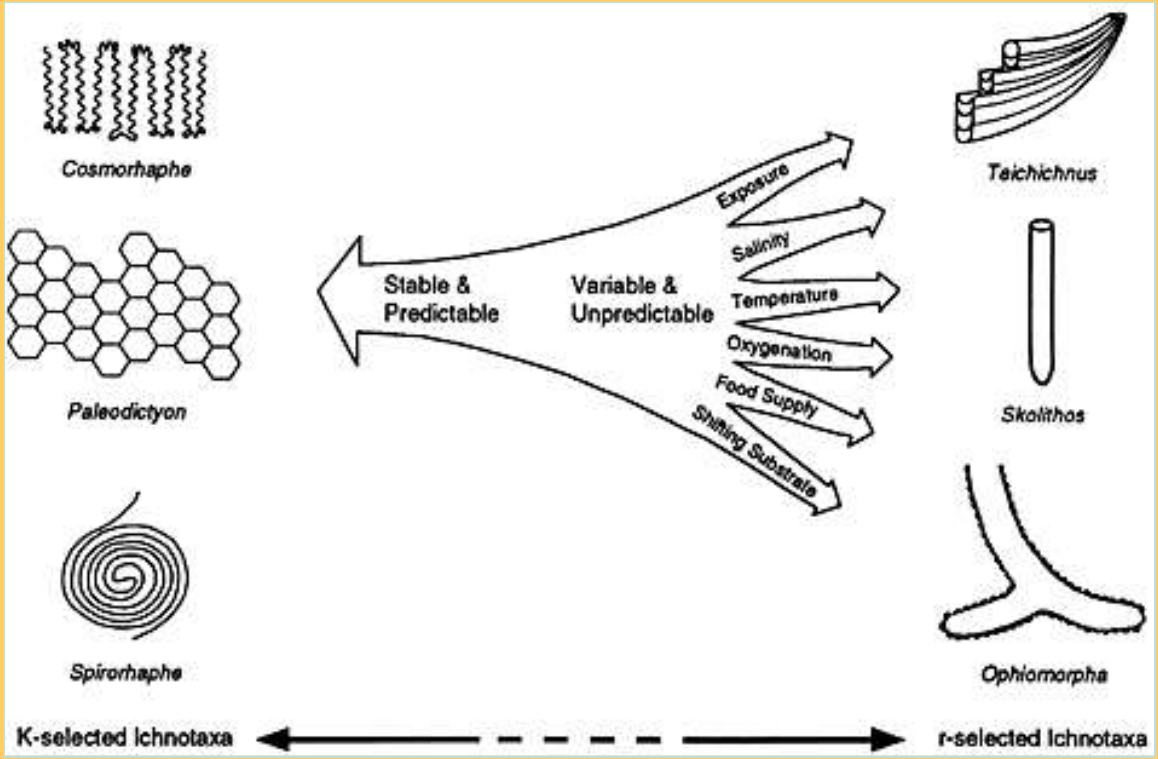


A



B

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.)

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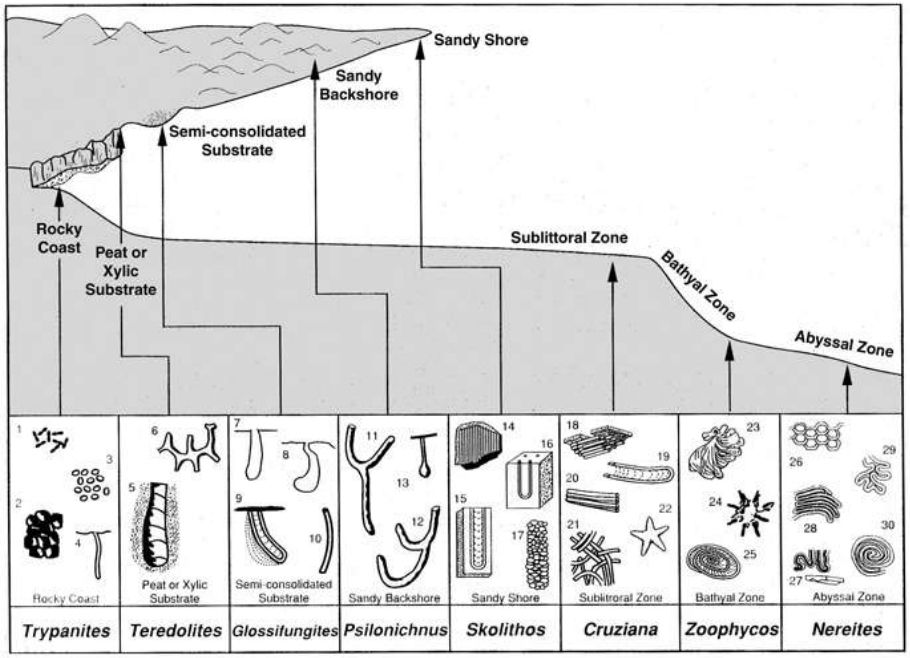

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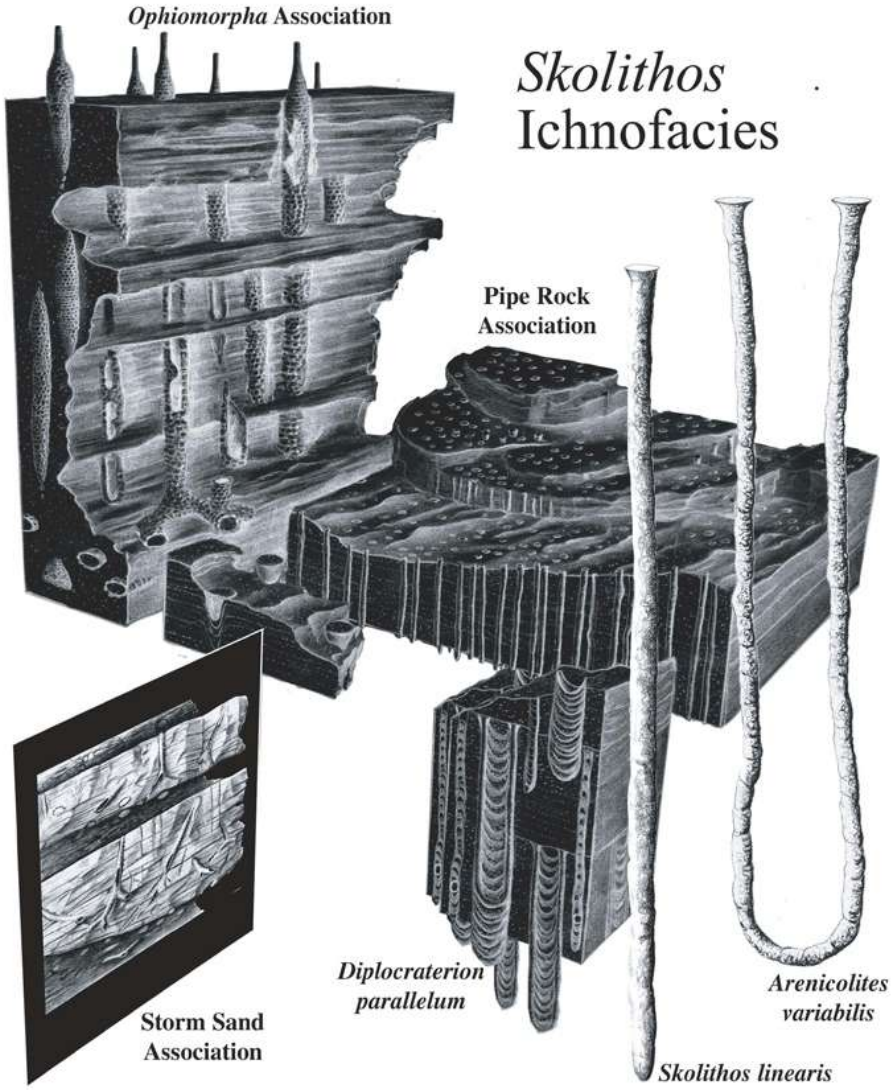
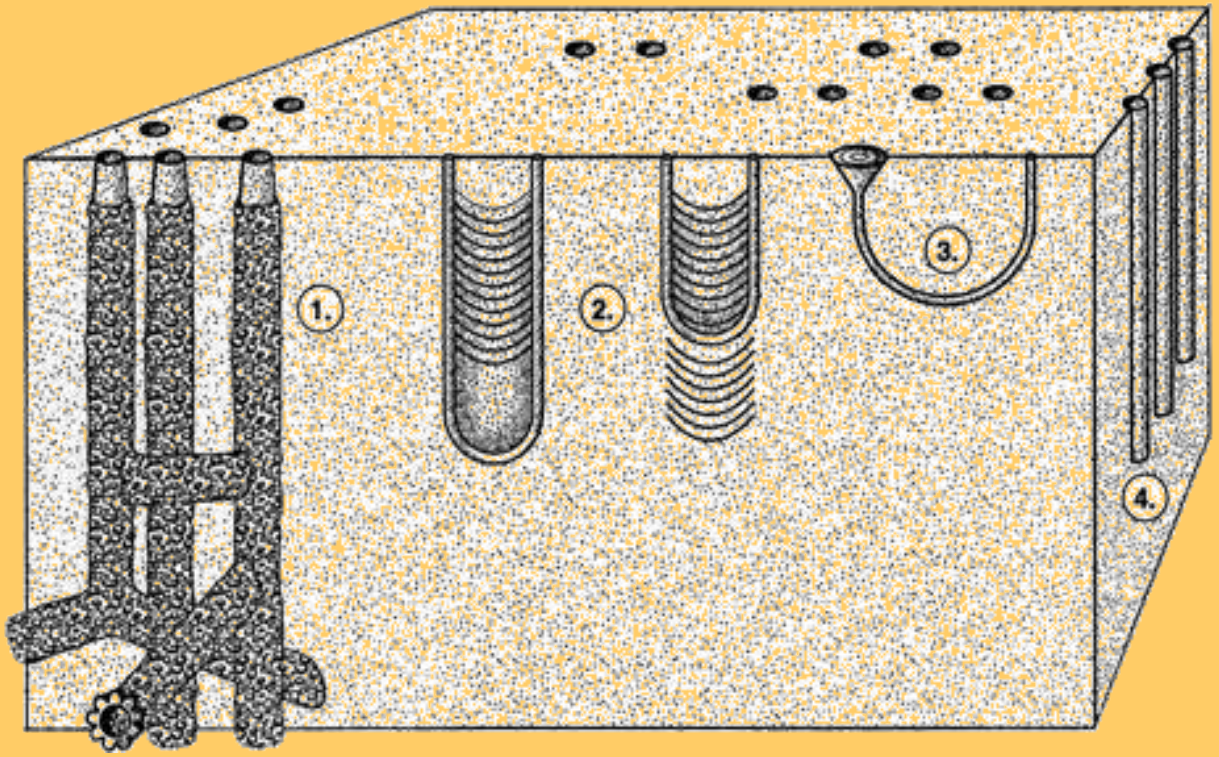
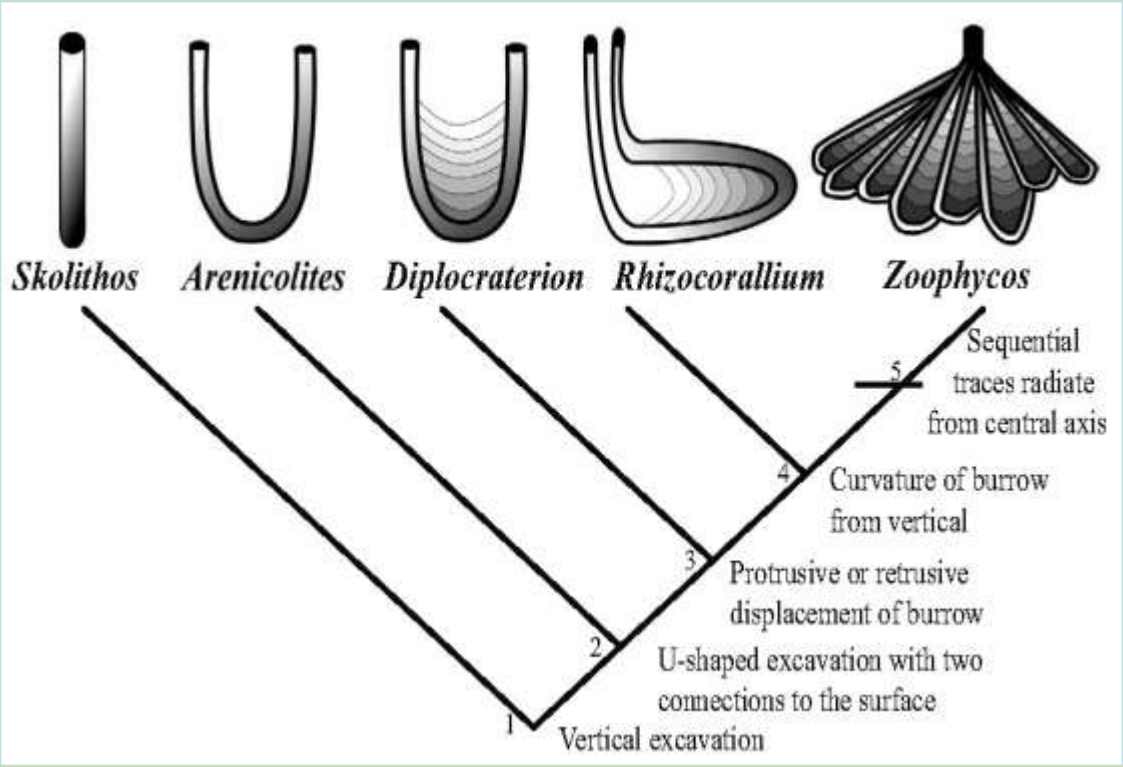


Spreite Burrows and Other Ichnostructures



Evolution of Spreiten Burrows

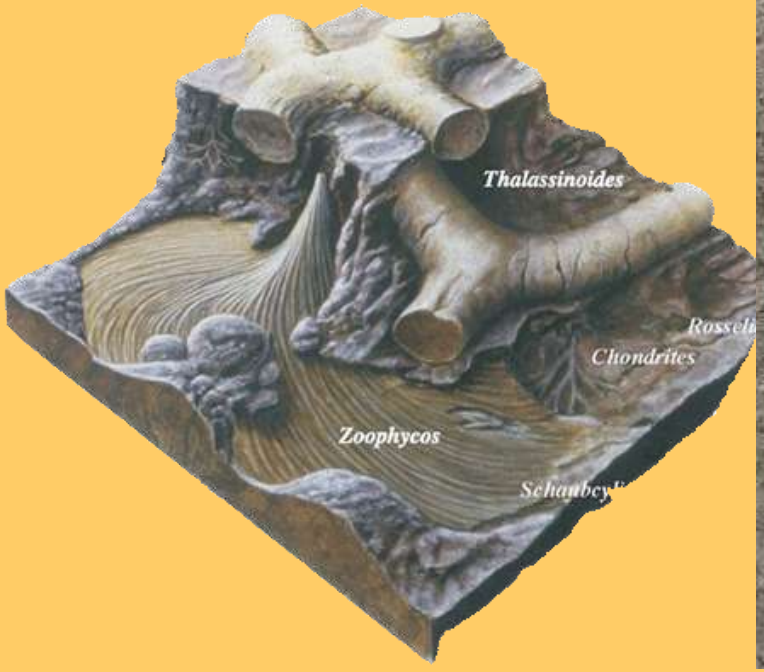
Cladogram of spreiten burrows, represents an evolutionary progression beginning with a simple vertical shaft and culminating with a very complex burrow.

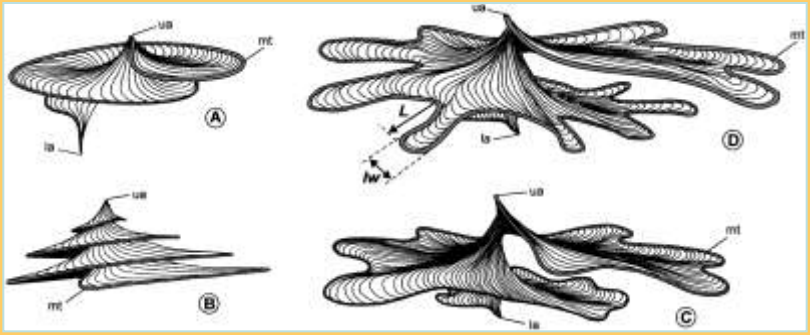


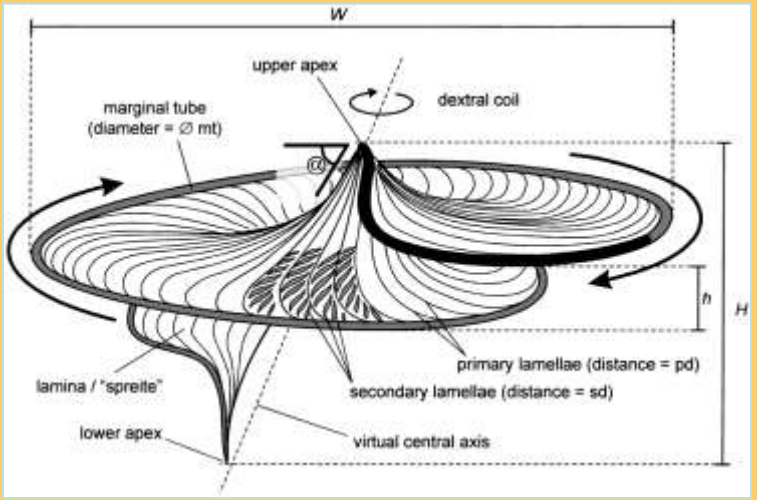
Diplocraterion

Upper Eocene of Benkovac area, Croatia

1 cm



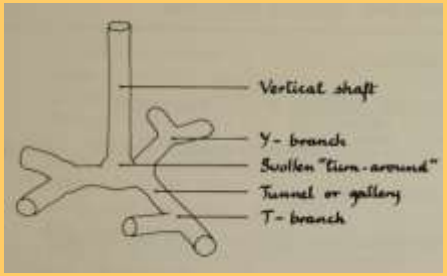


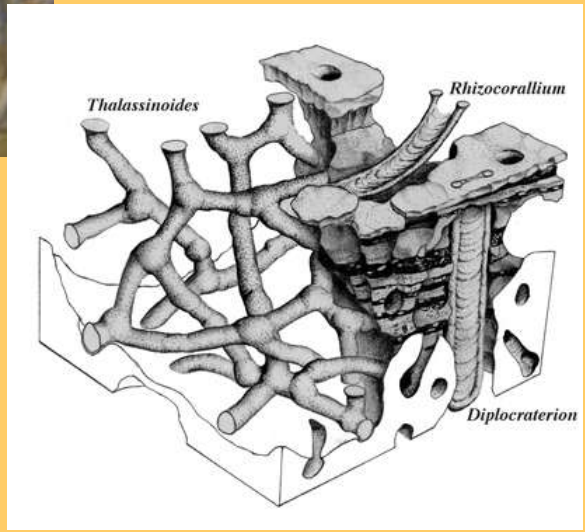


Zoophycos

Upper Eocene of Benkovac area

5 cm





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

5 cm

Gastrochaenolites

Middle Miocene, Donje Orešje, Croatia

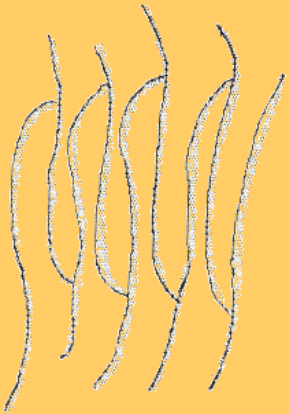
Graphoglyptids

or higly organized 'agrichnia'

Helminthorhaphe

Acanthorhaphe

Protopaleodictyon

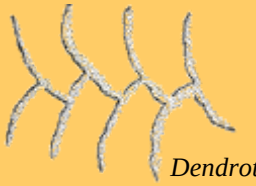


Urohelminthoida

Cosmorhaphe

Paleodictyon
(*Glenodictyum*)

Glockeria



Dendrotichnium

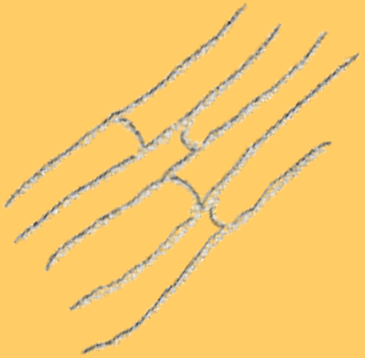
Oscillorhaphe

Paleomeandron

Spirorhaphe

Paleodictyon
(*Squamodictyon*)

Belorhaphe



Desmograpton

Lorenzinia

Spirorhaphe and Nereites

Upper Eocene of Istria, Croatia

MEANDERING GRAPHOGLYPTIDS >

Urohelminthoida

Upper Eocene of Istria, Croatia

Glockerichnus

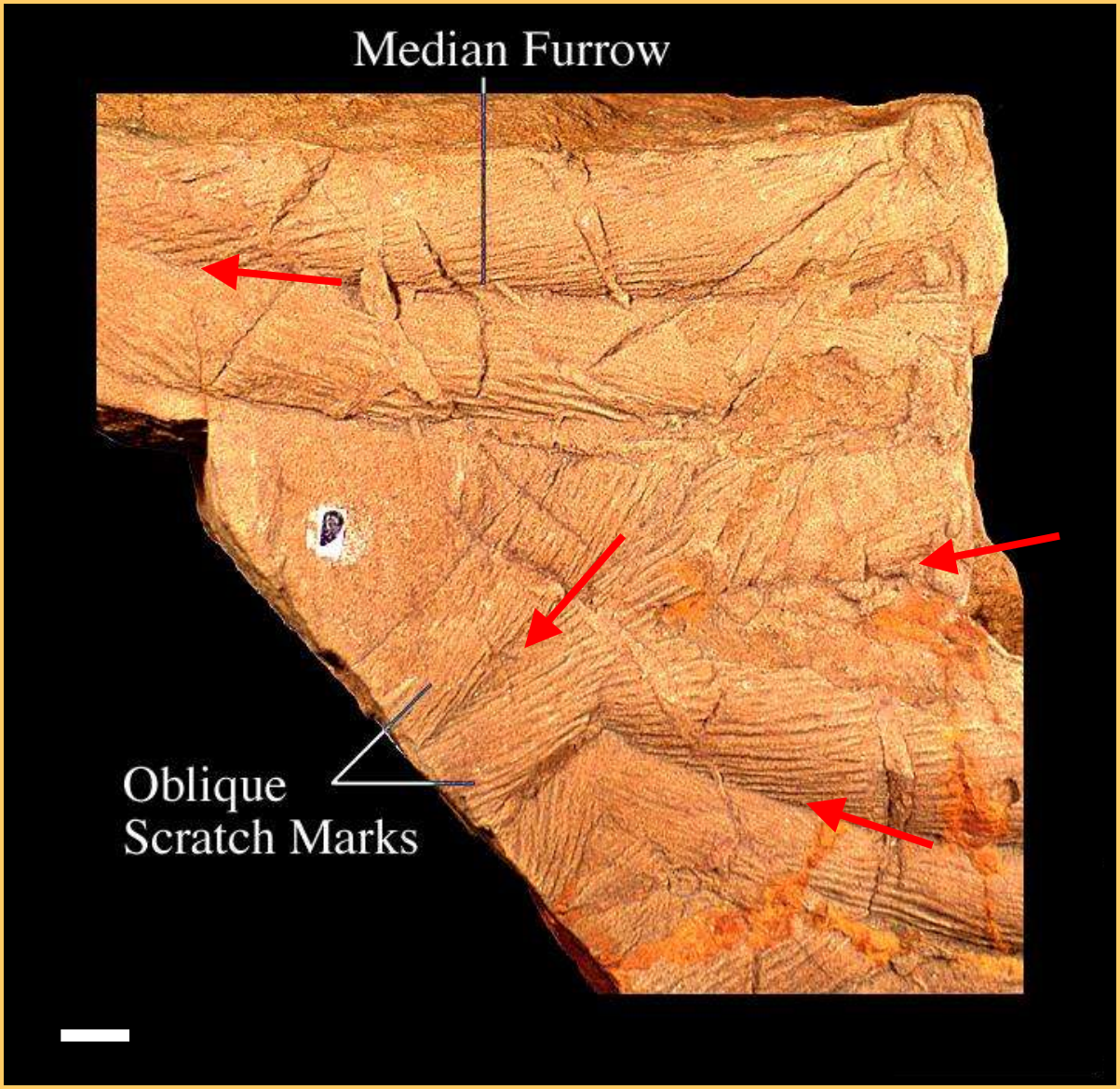
Upper Eocene of Benkovac area, Croatia

Paleodictyon

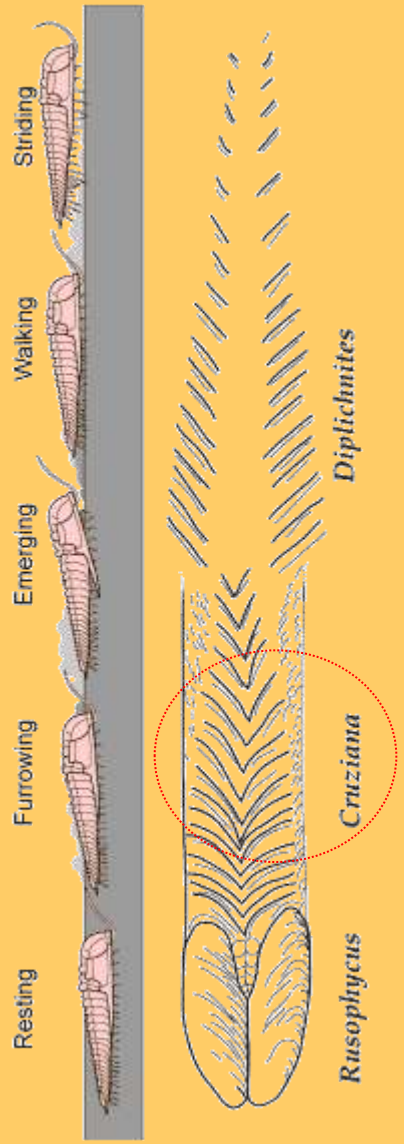
Upper Eocene of Benkovac area, Croatia

Cruziana

Lower Cambrian, Oman



movement direction



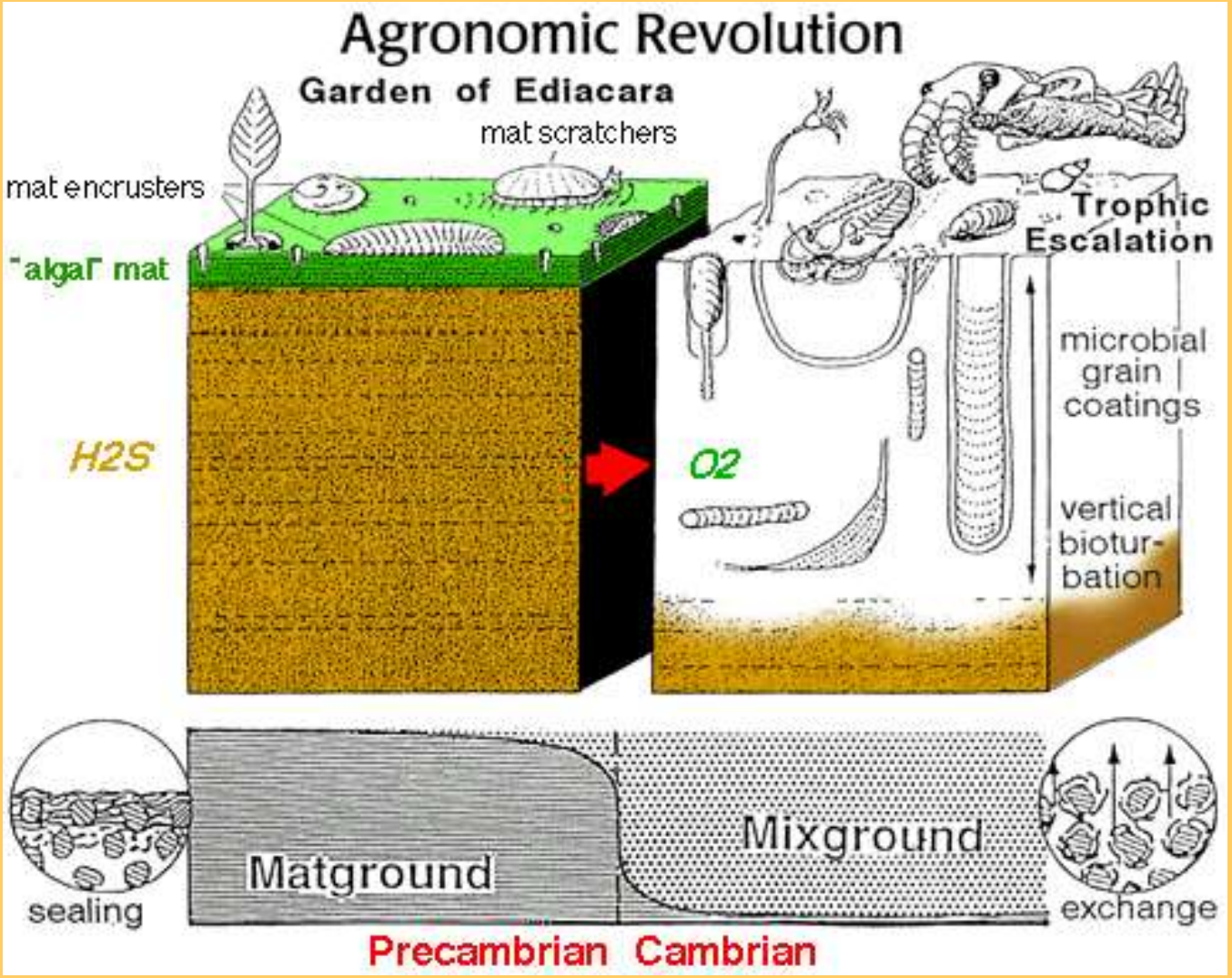
Core samples

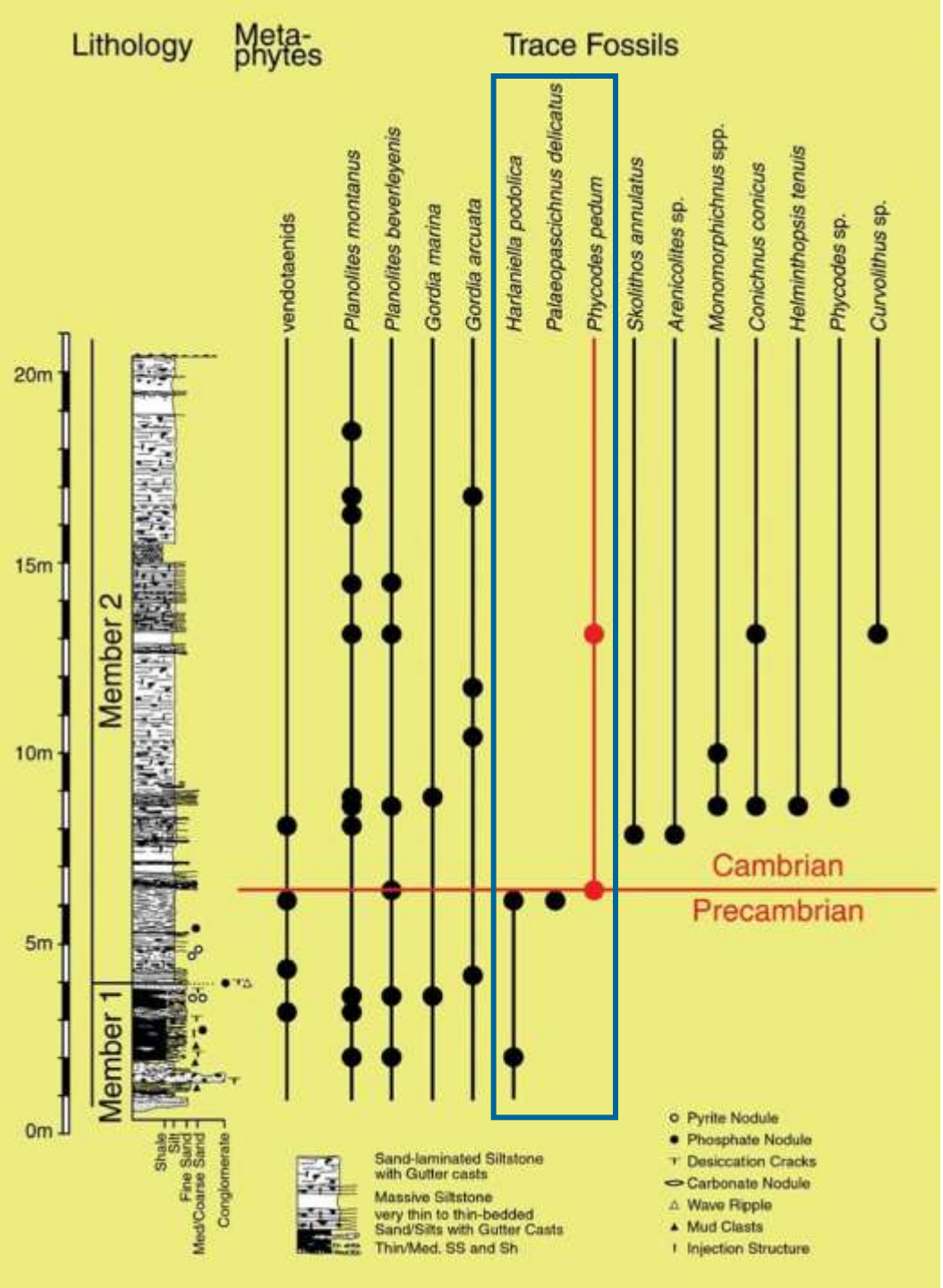
Rosselia

Scolicia

Trypanites at hardground

Sauropod trackways, Kirmenjak formation, Upper Jurassic, Istria, Croatia

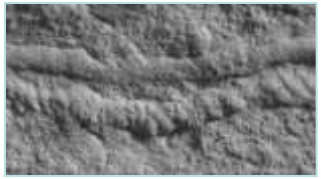

Agronomic Revolution
Garden of Ediacara
mat scratchers
mat encrusters
"algal" mat
H2S
O2
Trophic Escalation
microbial grain coatings
vertical bioturbation
sealing
Matground
Mixground
exchange
Precambrian Cambrian

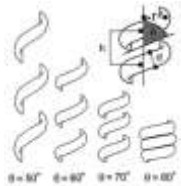


GSSP for the Precambrian - Cambrian Boundary

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:
Brasier, M., Cowie,J., and Taylor, M., 1994. Decision on the Precambrian-Cambrian boundary stratotype. Episodes 17/1&2, p. 95-100.