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***Research Article***

# Trace fossils of the Maastrichtian phosphate series of the Agadir Basin, Western High Atlas, Morocco

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***Abstract –*** The study of the Maastrichtian epoch within the Agadir basin, situated in the Western High Atlas region of Morocco, has brought to light an abundance of distinct trace fossils scattered throughout the investigated section. This research places a particular emphasis on the identification of trace fossils, also known as ichnofacies—an important concept in the field of geology and paleontology. Ichnofacies plays a crucial role in understanding past environments by studying the fossilized traces left behind by living organisms. Essentially, ichnofacies refer to the specific set of fossilized traces found in a given geological or paleontological setting.

Within the Maastrichtian phosphate series of our study area, a remarkably diverse assortment of trace fossils is evident. This assemblage encompasses a variety of Thalassinoïds, Arenicolites, and Lockeia-type traces, contributing to the richness of the region's paleontological findings. The ichnofacies prevalent in this region assumes a crucial significance in determining the paleoenvironment during the Maastrichtian epoch. Through an examination of these fossilized traces, we can glean insights into the intricate interplay between ancient organisms and their surroundings, being able to fully understand the ecological dynamics during the Maastrichtian.

*Keywords – Ichnofacies, Paleoenvironment, Maastrichtian, High Atlas, Morocco*

## [1] INTRODUCTION:

The meridional aspect of the occidental sector of the High Atlas region, specifically denoted as the "Souss-Ouarzazate Gulf" (illustrated in Figure 1), manifests a discernible geological configuration resultant from the orogenic uplift of the High Atlas Range. This locality also manifests a gradual transition from marine to lagoonal and subsequently continental sedimentary environments along a west-to-east transect (Algouti et al., 1998, 2015, and 2022; Hadach et al., 2015 and 2017). The examination of the Maastrichtian strata within the Western High Atlas has yielded invaluable insights into biostratigraphy, lithostratigraphy, ichnology and paleogeography. The primary focus of

ichnological inquiries has predominantly revolved around the discernment of trace fossils, as Thalassinoïds. The studied region encompasses the Agadir basin to the occidental side, the Erguita basin in the central sector, and various smaller basins on the oriental side, influenced by laguno-brackish influences, and acting as morphological trap conducive to phosphate precipitation (Jdaba et al., 2023).

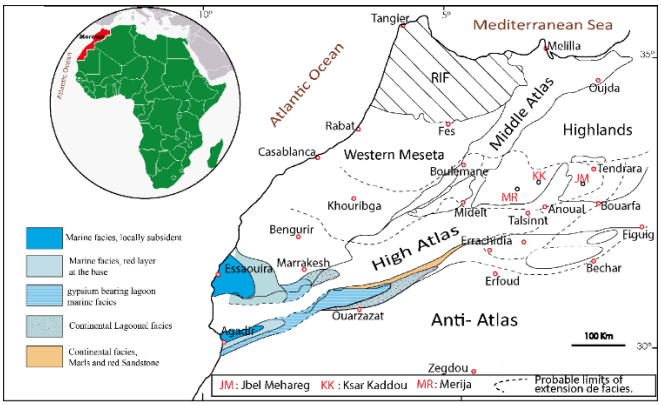



*Figure 1: A schematic map illustrating the distinct facies within the study sector. (Modified after Choubert and Faure-Muret 1960-62)*

[2] ICHNOFACIES:

***Trace Fossils:***

Trace fossils, also known as ichnofossils, are geological records of biological activity that are left behind by living organisms. Unlike body fossils, which preserve the actual remains of organisms, trace fossils provide evidence of the behavior and activities of ancient life forms. These fossils can include tracks, trails, burrows, nests, and other structures created by organisms.

***Ichnofacies:***

"Ichnofacies" refers to a set of trace fossils that are often found together in a specific environment or sedimentary deposit. The term is used to characterize the suite of trace fossils associated with particular ecological conditions. Each ichnofacies represents a distinct suite of trace fossils that are indicative of the environmental and depositional conditions in which they formed.

Different environments, such as shallow marine, deep marine, continental, or freshwater settings, may support specific ichnofacies. The types of trace fossils present can provide insights into factors like water depth, sediment type, energy levels, and the types of organisms that were present in a particular habitat.

By studying ichnofacies, paleontologists and geologists can gain a better understanding of past environments, ecological interactions, and the conditions under which sediments were deposited. This information contributes to the reconstruction of ancient ecosystems and helps scientists interpret the geological history of a given region.

***Types of Ichnofacies:***

The trace fossils have remained in appearance rather constant since Cambrian, even if their producers might have been different. The trace fossil assemblages can be divided according the paleoenvironmental scheme into a number of ichnofacies named after a characteristic trace fossil. The ichnofacies indicate a particular sedimentary facies and can be identified on the basis of its trace fossil assemblage

| Woodground | Rockground | Firmground | | Loose- and softground | | | Sedimentology / environment | | |
|---|---|---|---|---|---|---|---|---|---|
| | | Marine | Freshwater | Freshwater | Marine | | Energy | Bathymetry | Grain size |
| ***Teredolites*** | *Trypanites* | *Glossifungites* | *Scoyenia* | - | *Psilonichnus* | | - | Backshore | Sand |
| | | | | *Rusophycos?* | *Skolithos* | | High | Beach | Sand |
| | | | - | *Arenicolites?* | *Arenicolites* | | Event | Shelf | Sand silt |
| | | | | *Fuersichnus?* | *Cruziana* | | Medium | Lagoon / shelf | Sand, silt |
| | | | | *Mermia* | *Nereites* | | Event | Slope to abyssal | Sand, mud |
| | | | | | *Zoophycos* | | Low | | Mud |

Table indicating relationships of ichnofacies with environment (after Bromley, 1996).

***Nereites Ichnofacies:***

The *Nereites* Ichnofacies is recognized by the presence of **meandering pascichnia** (*Nereites*, *Neonereites* and *Helminthoide*), **spiral pascichnia** (*Spirorhaphe*), and **agrichnia** (*Paleodictyon* and *Spirodesmos*). Vertical burrows are almost entirely absent.

This ichnofacies indicates deep-water environments, including ocean floors and deep marine basins. The trace fossils occur in muds

deposited from suspension, and in the mudstones and siltstones of distal turbidites.

***Zoophycos Ichnofacies:***

The *Zoophycos* Ichnofacies is characterized by complex **fodinichnia** (*Zoophycos*, and sometimes other deep traces such as *Thalassinoïds*) in tiered arrangements.

The ichnofacies occurs in a range of water depths between the abyssal zone and the shallow continental shelf, in normal background conditions of sedimentation. The *Nereites* Ichnofacies may be a matching association found at similar water depths during times of turbidite (event) deposition.

***Cruziana Ichnofacies:***

The *Cruziana* Ichnofacies shows rich trace fossil diversity, with horizontal **repichnia** (*Cruziana* and *Aulichnites*), **cubichnia** (*Rusophycus*, *Asteriacites* and *Lockeia*), and vertical burrows.

This ichnofacies represents mid and distal continental shelf situations, below normal wave base, but may be affected by storm activity.

***Skolithos Ichnofacies:***

The *Skolithos* Ichnofacies can be recognized by a low diversity of abundant vertical **domichnia** burrows (*Skolithos*, *Diplocraterion* and *Arenicolites*), **fodinichnia** (*Op hiomorpha*), and **fugichnia**.

All these traces typically indicate intertidal environments where the organisms have to be able to respond rapidly in stressful conditions. The *Skolithos* Ichnofacies was at first seen as occurring only in the intertidal zone, but it is also typical of other shifting sand environments, such as the tops of storm sand sheets and the tops of turbidity flows.

***Psilonichnus Ichnofacies:***

The *Psilonichnus* Ichnofacies shows a low diversity assemblage of small vertical burrows with basal living chambers (*Macanopsis*), narrow sloping T-shaped and Y- shaped burrows (*Psilonichnus*), root traces, and vertebrate footprints.

This ichnofacies is typical of backshore, dune areas, and supratidal flats on the coast.

***Scoyenia Ichnofacies:***

The *Scoyenia* Ichnofacies is characterized by a trace fossil assemblage that is not diversified, it consists mainly of simple horizontal **fodinichnia** (*Scoyenia* and *Taenidium*), with occasional vertical **domichnia** (*Skolithos*) and **repichnia** produced by insects or freshwater shrimps (*Cruziana*, *Isopodichnus*).

These traces are conserved within fluvial and lacustrine sedimentary deposits, frequently embedded in the silty and sandy layers of redbed sequences. Coexisting subaerial Paleosols and Aeolian sands may harbor domichnia and repichnia of arthropods, as well as footprints of dinosaurs and other tetrapods.

***Glossifungites Ichnofacies:***

The *Glossifungites* Ichnofacies can easily be identified by the presence of **domichnia** (*Glossifungites* and *Thalassinoïds*) and is sometimes characterized by plant root penetration structures. Other behavioural trace fossil types are rare.

These traces can be found in marine intertidal and shallow subtidal zones in firm, but not lithified sediments, such as muds and silts. The firm grounds can be formed in low energy environments like salt marshes, mud bars, high intertidal flats, or shallow marine environments where erosion has stripped away superficial, unconsolidated sediment layers.

***Trypanites Ichnofacies:***

This ichnofacies is characteristic of fully lithified marine substrates such as reefs, hardgrounds, rocky

coasts, beach rock, unconformities and other omission surfaces (Pemberton et al. 1980; Gryszeynski 1986, 1998). The *Trypanites* Ichnofacies is characterized by domichnial borings of worms (*Trypanites*), bivalves (*Gostrochaenolites*), barnacles (*Rogerella*) and sponges (*Entobia*). Bio-erosion traces made by gastropods and echinoids are rarely preserved in ancient cases.

***Teredolites Ichnofacies:***

The *Teredolites* Ichnofacies encompasses suites of borings excavated into marine or marginal-marine xylic (woody or coaly) substrates.

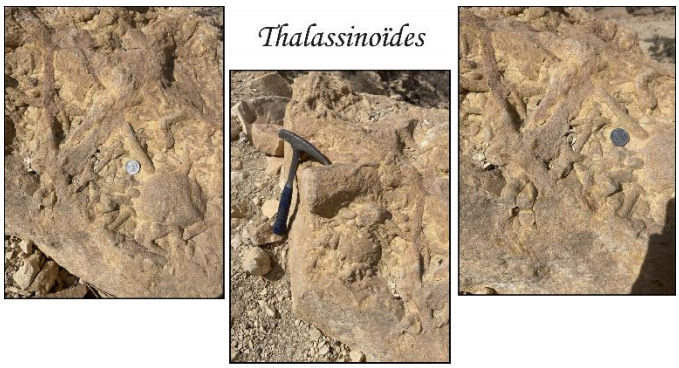
[3] TRACE FOSSILS IN THE STUDY REGION:

The trace fossil assemblage consists of juxtaposed and partly overlapping traces that differ in pattern, size, distribution, and crosscutting relationships. Three trace-types were identified in the Oued Lahouar formation: Thalassinoïds, Arenicolites and Lockeia.

***Thalassinoïds:***

Are a type of trace fossils associated with the activities of burrowing organisms, particularly crustaceans known as thalassinidean decapods. These trace fossils represent the preserved burrows or tunnel system that these organisms create in sediment.

Thalassinoïds burrows are characterized by a U-shaped to J-shaped structure, often with a lined or mottled infill representing the different sediment layers disturbed during burrow construction.

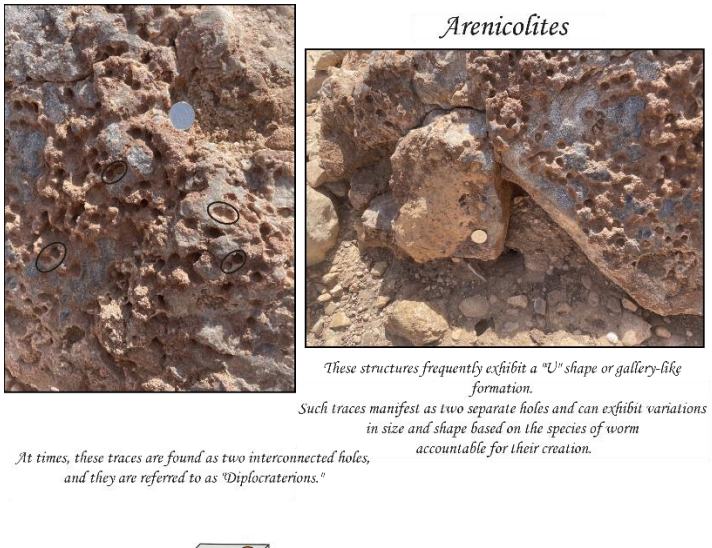



*These structures consist of Y-shaped burrows, filled with coarse detrital and fossiliferous sediments. The substrate is a massive, azoic dolomitic carbonate bed, exhibiting a Mudstone texture, deposited in a very calm environment.*

***Arenicolites:***

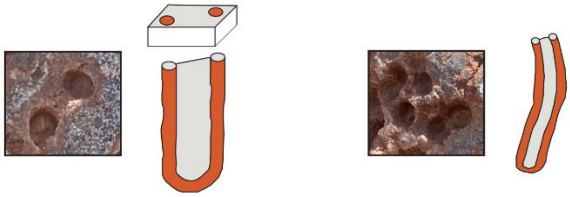
Are a type of trace fossils attributed to the activities of burrowing organisms too, but particularly those created by annelid worms.

Arenicolites trace fossils typically consist of U-shaped or J-shaped burrows in sedimentary rocks, and they are commonly associated with marine environments. These burrows are interpreted as the preserved evidence of the activities of ancient worms that lived in sandy or muddy substrates.




*These structures frequently exhibit a "U" shape or gallery-like formation. Such traces manifest as two separate holes and can exhibit variations in size and shape based on the species of worm accountable for their creation.*

*At times, these traces are found as two interconnected holes, and they are referred to as "Diplocraterions."*



***Lockeia:***

Lockeia traces are typically characterized by a series of interconnected, branching burrows or tunnels in sedimentary rocks. These trace fossils are often associated with the activities of marine invertebrates, such as arthropods or worms, that lived in ancient seafloor environments. Lockeia is commonly found in rocks of various ages, ranging from the Paleozoic to the Cenozoic eras.

## [4] CONCLUSION:

These traces and burrows are found in various sedimentary rocks, providing valuable information about the paleoenvironment, the behavior of ancient organisms, and the conditions of the substrate in which they lived. Relying on them, we can conclude that the study region is a calm marine environment, with a massive substrate that consists of azoic dolomitic carbonate beds, the burrows are filled with fossiliferous coarse detrital sediments.

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