ISSN: 2472-3703 DOI: 10.6911/WSRJ.202312_9(12).0020

On the Development and Application of Trace Fossils

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Abstract

In recent years, the progress of vestige fossil is more and more remarkable. It is not only the evidence of biological activities and evolution on earth, but also the sedimentary structure that can be used to analyze the formation conditions of lithofacies and explain the sedimentary environment. Biological disturbance can not only reconstruct and break the sediments, but also reconstruct the sediments, which is an important part of sedimentology research. Nowadays, only the analysis and classification of the morphology and habits of vestige fossils cannot meet the requirements. Many scholars have begun to pursue a broader study of vestige fossils. For example, the birth of relic fabric has brought the study of relic fossils into a new world. In addition, the analysis and reconstruction of the paleoenvironment, paleowater depth, paleoclimate and paleotemperature by using the remains fossils are also the top priorities of current research.

Keywords

Vestige fossil; Sedimentary environment; Paleoclimate.

1. THE RESEARCH SIGNIFICANCE OF TRACE FOSSILS

Trace fossils, also known as vestigial fossils, are formed by the filling and burial of various life activities left by ancient organisms in the bottom layer or at the bottom layer, followed by later diagenesis and petrification. There are generally 10 ways in which ancient organisms can leave traces of life activities: first, running, which can be divided into intra layer escape and intra layer running; Secondly, walking around; The third is crawling, where organisms use their toes or appendages for crawling movements, often without touching the ground; The fourth is peristalsis, where a part of the biological body contacts the ground; Fifth, rest; Six is foraging; Seven is eating; Eight is residence; Nine is swimming; Ten is flying. The traces left by these biological activities on the bottom layer may form various types of trace fossils (trace fossils), and the trace fossils produced by these biological activities are different from solid fossils.

Trace fossils are very important for the analysis of ancient environments. The group of trace fossils buried and preserved together represents the living communities in situ, and the ancient environment they reflect is the original living environment of their traceable organisms. Therefore, they are reliable reference fossils. Therefore, trace fossils have become an important discriminant indicator for analyzing ancient environments.

The study on the relationship between trace fossils and trace fabrics with sedimentary environment and sequence stratigraphy has described a large number of trace fossils and established various local trace facies. Trace facies is not only a component of lithofacies and paleogeography, but also an important aspect of ichnology. It explores and analyzes ancient sedimentary environments by studying the formation mechanism, preservation conditions and methods, as well as spatiotemporal distribution patterns of biogenic structures. It has the

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advantages of simple methods, high reliability, and accuracy, and has broad application prospects in geological exploration of oil, gas fields, and coal fields.

2. THE DEVELOPMENT AND APPLICATION OF TRACE FOSSILS

The earliest scientific confirmation of trace fossils can be traced back to the early 20th century, but only descriptions of some vertebrate footprints (such as dinosaurs) and carnivorous bite marks, while many true trace fossils are classified as pseudofossils and suspicious fossils; Early research also treated relics as plants (seaweed) and some animals. In the 1920s and 1930s, German paleontologists Abel and Richter observed and studied biogenic structures in modern unconsolidated sediments, confirming that many similar structures in ancient strata were caused by biological activities, greatly improving people's understanding of relic rocks during geological history.

In the 1950s and 1960s, a series of works by German paleontologists Hantzschel and Seilacher made ichnology truly an independent discipline, which still affects the thinking of many contemporary researchers. Seiacher first proposed an environmental model of the distribution of marine trace fossils with depth, which has led to a significant amount of effective research. The study of trace fossils has multiple meanings, and their interpretation of sedimentary environment is an important aspect. Trace fossils (except for fecal fossils) are all preserved in situ, reflecting both biological behavior habits and the substrate that organisms rely on for survival. These two are directly controlled by environmental factors, and therefore closely related to sedimentation. The environmental interpretation of trace fossils relies on the distribution patterns in known geological environments and the study of modern trace distribution. The combination of these two aspects provides a broad set of ichnographic standards for evaluating environmental parameters. It is generally believed that changes in the type or combination of trace fossils can reflect the properties of sedimentary basement, environmental energy, sedimentation rate and changes, bottom hydrochemical properties, and water depth. Due to the unique advantages of trace fossils (facies) in environmental interpretation, this research has attracted the attention of the oil and gas exploration community, and a large amount of research work is closely related to global oil and gas exploration work. Seilacher's pattern has been tested, supplemented, and revised, and a more comprehensive solution has been proposed.

2.1. Application of Trace Fossils in Sedimentary Environment Analysis

The interpretation of sedimentary environments using trace fossils relies on the distribution patterns of known geological environments and some research on the living and distribution habits of modern biological forms. The types and combinations of trace fossils can reflect some properties and changes in sedimentary basement, sedimentary rate, environmental energy, etc. during the sedimentary process. The emergence of trace fabrics marks the beginning of a new stage in the study of trace fossils. Many scholars are no longer limited to analyzing the characteristics of trace fossils, but have begun to explore various biological activity structures, including biological disturbances, and explore more aspects of research.

The significance of trace fossils in sequence stratigraphy research is increasingly attracting the widespread attention of many experts both domestically and internationally. There is a close relationship between the two, but their combination research is still in the exploratory stage. Research has shown that trace fossils have a sensitive indicating effect on environmental changes caused by dynamic sea levels, known as "trace fossil events", providing important evidence for the division of sedimentary system tracts and the identification of sedimentary environments.

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Trace fossils are quite sensitive to the environment, and the same combination of trace fossils often appears under the same sedimentary environment conditions. If influenced by periodic sedimentation, the same type of trace fossils will repeatedly appear in the vertical sequence, indicating the characteristics of periodic changes. This feature is helpful for analyzing the cyclicity of stratigraphic sequence, especially suitable for high-frequency cycle research. In addition, as mentioned earlier, trace fossils have a sensitive indicating effect on the properties of the basement. Therefore, the vertical changes in trace fossil types can indicate a series of changes in the sedimentary basement from soft basement to solid basement to hard basement. This can reveal the missing sedimentary surface, which is also of great significance in sequence analysis.

2.2. On Trace Fossils in River and Lake Sediments

Non marine trace fossils include two types: terrestrial and underwater. Land-based trace fossils have the following characteristics: ① many burrows have no wall lining, and the boundaries are concave and convex; ② There are many marks of etching, scratching, or digging on the inner wall of the burrow; ③ Opened cavities; ④ The filling material has loose fabric and lacks active filling characteristics; ⑤ Symbiotic with terrestrial exposed sedimentary markers such as dry cracks and rain marks; ⑥ Save as upper or full float marks. There is not much difference between underwater remains and marine remains, except for differences in differentiation and individual size. Except for large perennial lakes with water depth zones similar to the ocean, many other sedimentary environments do not have this condition, making it difficult to classify relic facies zones based on water depth factors.

Since the early 1980s, research on river sedimentary ichnography has greatly increased. Trace fossils in river sediments are considered non diagnostic and their distribution is not related to any specific environment. A characteristic of the fluvial facies relic fabric is that the disturbance depth of tracers is greater than that of tracers in lake environments, and the disturbance intensity is generally lower. The tracemaking organisms of river and lake facies trace fossils are mainly insects and their larvae, arthropods and their larvae. The evolution trend of terrestrial relic fabric is a supplement and improvement to the ecological content of terrestrial benthic organisms. Identifying prototype, repetitive, or Seilacherian relic facies on a continental scale has always been a controversial topic, and by the 1990s, the invertebrate prototype relic facies of continental sediments had gained widespread recognition in the scientific community.

The fossils identified in river sediments mainly involve invertebrate trace fossils and so-called prototype vertebrate fossils. Other recently proposed features, according to the current definition, lack progressive features of prototypes. The lake environment is a relatively complex system in which the distribution of animals and plants is influenced by the interaction of non biological factors (such as energy, light, oxygen, temperature, salinity, substrate, and nutrition) and biological factors (such as competition, grazing, predation, and symbiosis). The lake system is different from the ocean system in some aspects, including the volume of sediment in the lake, the direct connection between water level and sediment supply in the lake, and the possibility of coastline migration not only due to degradation.

2.3. Trace Fossils and Paleoclimate

Global climate change and its impact on Earth's biodiversity and ecosystems are cutting-edge issues in scientific debate and international government decision-making in the 21st century. Geological records are the best archival records on how life and ecosystems respond to global cooling or warming, but most people's attention is focused on the Cenozoic era. This is because ice rock cores, tree rings, corals, pollen, and other climate records are the best and most continuous preserved sedimentary records in the past one million years or so.

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However, deep paleoclimate records are also important as they provide a record of long-term climate change and the response of organisms and ecosystems to these disturbances. Generally speaking, paleontological, lithological, and geochemical evidence are the main indicators of paleoclimate and global change. Fossils are the most direct, close to biological relationships and empirical forms of paleoclimate indicators. Through the concepts of taxonomy, ecological homogenization, and paleobiogeography, the climate control of continental fossil remains is regarded as a sensitive indicator of paleoclimate. Fully studying and understanding ancient soil can be used to explain ancient climate records. However, the continental remains fossils that appear in many ancient soils have not been fully utilized in this regard. This is because trace fossils have not been effectively linked to the sediments they were discovered, nor are they considered as potential biological archives for paleontological climate data.

There is currently not much research on the relationship between soil relic associations and paleoclimate, but a hypothesis can be proposed that climate sensitive soil relic associations can serve as a catalyst for testing potential paleoclimate indicators. This also means encouraging research that combines neoichnology with soil science and climatology to develop more and older climate indicators. Continental fossil remains not only represent the diversity of organisms buried in situ, but also record the interaction between sedimentary deposits under the strong influence of ancient climate.

2.4. Trace Fossils and Paleosols

Ancient soil (also known as fossil soil), as a product of natural landscapes during geological history, records the impact of factors such as the parent material, climate, biological community, terrain (including drainage conditions), and time during its formation on surface materials. Therefore, some people believe that ancient soil is a relic fossil of the ecosystem during the geological history period and a powerful tool for reshaping the ancient environment. Paleosols are different from sedimentary rocks, as they are the surface zone with a clear soil hierarchy structure after the upper part of the weathered crust is subjected to pedogenesis. This unique hierarchical structure and formation process make paleosols contain geological information that is not easily obtained by sedimentary rocks. It is precisely these special geological information that has sparked geologists' strong interest in paleosols. After years of practice, ancient soil has been widely used in research on ancient terrain restoration, ancient climate analysis, and the evolution of ancient plants. The use value of ancient soil has also been valued by geologists in the division of sequence boundaries, sedimentation rates, time frames, and stratigraphic correlation analysis.

Although there has been an increase in interest in paleosols over the past decade, there is currently no satisfactory classification method.

A commonly used classification today utilizes soil genetic characteristics that have the highest preservation potential in rock records. This classification is based on the relative prominence of six soil forming characteristics or processes, including organic matter content, level, redox conditions, in-situ mineral alteration, deposition of insoluble minerals or compounds, and accumulation of soluble minerals. Among them, 4 orders (organic soil, lime soil, oxidized soil, and humus soil) were borrowed from soil classification, while the other 5 orders (calcareous soil, gypsum soil, gley soil, muddy soil, and native soil) all appeared for the first time. This classification method is relatively easy to apply to rock records and helps to standardize terminology. The current classification of ancient soil is combined with modern soil research and cannot adapt to the inherent changes in rock formation. Therefore, we need to re evaluate based on standards that are more conducive to paleosol research, which is the basis for defining more applicable classification methods in the future.

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3. CONCLUSION

The research methods for distinguishing terrestrial, marine, transitional, and turbidite deposits, interpreting sedimentary environments, determining the relative rates of erosion and sedimentation, determining water flow, and distinguishing the properties of the bottom layer by applying trace fossils or trace fossil combinations have been developed very maturely. Nowadays, the research on trace fossils is not limited to this, and many scholars have made more breakthroughs, such as using trace fossils and trace fabric to analyze the ancient environment, restoring ancient water depth, reconstructing the ancient temperature and climate of the region, etc. At the 15th International Symposium on Ichthyomics, the new progress and applications of ichnography theory were discussed, mainly including the evolution and application of the connotation of ichnography; The application of trace fossils in paleoecology and paleoclimate research; The application of trace fossils in the study of major geological events; The application of new technologies and methods in archaeological research. These will become the focus of future development of trace fossils.

As a unique material reflecting biological and environmental events, trace fossils can play an important role in studying the development process and mechanism of the environment. Although they may not serve as standard fossils like solid fossils, they have high referential significance. Nowadays, trace fossils not only have an impact on the study of ancient biological morphology and habits, but also have become a very important field of work in the study of paleoecology, paleoclimate, and other fields. By studying the rich behavior, burial mechanisms, and characteristics of paleontology, a reasonable systematic classification scheme can be established to explain the interaction between paleontology and sediment, reveal the paleoecological and paleoclimatic characteristics of trace fossils in their developmental stages, and build a bridge between paleontology, sedimentology, and sequence stratigraphy. The research on trace fossils will never stop here, and in the future, more aspects will definitely be explored.

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