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The distribution, causes and scientific significance of the global red layer

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Abstract

Red strata, as a special type of sedimentary rock layer, are mainly composed of red sandstone, mudstone and shale, and are widely distributed worldwide. This paper, through in-depth research on existing literature, analyzes the distribution characteristics and genetic mechanisms of the ocean red layer and the continental red layer, which respectively represent sedimentary processes in Marine and terrestrial environments, providing a new perspective for studying the significance of the global red layer.

Keywords

Red layer Distribution characteristics; Ancient ocean Paleoclimate.

1. Introduction

The red layer refers to the clastic sedimentary rock strata with red as the main color, which are widely distributed in the southwest, northwest, central south and southeast regions of China. Generally, it is composed of alternating red conglomerate, sandstone, siltstone, sandy shale and argillaceous rock, etc. Due to its short diagenination time and poor consolidation degree, its particles are prone to breakage, have low strength, and are prone to disintegration and softening when exposed to water[0].

2. Ocean red layer

Ocean red strata refer to the widely distributed red Marine sediments in the world's major oceans. They are formed in deep-water oceanic and semi-oceanic environments and are characterized by sediments under oxygen-rich conditions, rich in chromogenic minerals such as iron oxides or manganese-containing calcite, including limestone, marl, calcareous shale, shale, mudstone and siliceous rock. The ocean red layer is widely developed in the world's oceans and has a certain distribution ratio. The ocean red layer, with its unique color and wide distribution, has become an important carrier for studying the evolution of ancient oceans, ancient climates and ancient geography. It is particularly worth noting the oceanic red layers of the Cretaceous period, which are closely related to the greenhouse climate, featuring a high sedimentation rate and extremely low organic matter content, representing the Marine environment and climatic conditions at that time.

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2.1. Causes and Distribution Characteristics

2.1.1. The causes of the ocean red layer

The ocean red layer, as a special type of Marine deposition, represents a typical oxygen-rich sedimentary environment and holds significant scientific research value. Its genesis is closely related to deep-sea sedimentation[2]. The formation mechanism of the ocean red layer is multi-faceted and involves multiple fields such as geochemistry, biogeochemistry and sedimentology. At present, the scientific community generally believes that the formation of the ocean red layer is related to the following key factors:

(1) Oxidation conditions are one of the key factors in the formation of the ocean red layer. In an oxygen-rich sedimentary environment, the red color in the magenta layer is mainly caused by iron oxides (hematite and goethite), which form chromogenic minerals in an oxidizing environment, giving the sediment a red appearance. At the sediment-water interface, when the dissolved oxygen content in the bottom water is relatively high, iron exists in the form of Fe3+, thereby forming red iron oxides [3]. This oxidation condition may be formed by the combined effect of dissolved oxygen in seawater, seabed currents, volcanic activities and other factors.

(2) Low sedimentation rate: Under conditions of a low sedimentation rate, the organic matter content in the sediment is low and insufficient to consume the dissolved oxygen in the underlying water body, resulting in the iron in the sediment being retained in an oxidized state and forming red sediment.

(3) Biogeochemical processes: The red substances in the ocean red layer mainly originate from biological deposits, such as the remains of microorganisms like siliceous sponges, radiolarians, and foraminifera. Iron bacteria may promote the precipitation of iron oxides through biogeochemical processes under hypoxic or microoxic conditions. This mechanism may lead to the formation of a red layer in certain specific environments.

(4) Regional environment and provenance: The mineral and elemental composition of the ocean red layer is influenced by the regional environment and provenance sources. For instance, in deep-sea basins far from the continents, there is relatively little terrigenous input, and the main components are clay and fine-grained minerals brought in by wind and dust. These factors jointly influence the geochemical characteristics of the ocean red layer. Meanwhile, in some areas of the ocean, due to special geological conditions, hot water activities on the seabed are frequent. Hot water carries a large amount of metal ions and sulfate ions, which combine with the sulfate ions in seawater to form red metal sulfide deposits.

2.1.2. Distribution of the ocean red layer

The ocean red layer is widely distributed around the world, accounting for 31% of the total area of the world's oceans. It is not only found in structurally active regions such as continental margins and island arcs, but also in structurally stable regions such as mid-ocean ridges and deep-sea basins, such as the Pacific Ocean, the Atlantic Ocean, and the Indian Ocean. Its global distribution characteristics reflect the paleomarine environment and paleoclimatic conditions during its formation period. The ocean red layer began in the Middle Ediacaran period and ran through the entire Phanerozoic Eon, appearing in multiple geological periods. The distribution of these red layers has a good correlation with oceanic anoxic events and usually occurs after anoxic events. The manifestation of the ocean red layer varies in different geological periods. For instance, the distribution of the ocean red layer in the Early Cretaceous was relatively limited, while the Late Cretaceous was the peak period for its formation.

(1) Modern oceanic red clay is mainly distributed in the North Pacific, especially in deep-sea basins in non-tropical and upwelling areas with a water depth of over 4.5 km. The deposition rate in these areas is extremely low, usually below the CCD interface, and the carbonate content is relatively low.

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(2) The Cretaceous ocean red layer is distributed globally, especially with significant sedimentary records in the Tethys Sea area. These red layers usually occur immediately after oceanic anoxic events, suggesting that their formation may be related to global environmental changes.

The distribution of the ocean red layer is not only influenced by global climate change but also by regional factors such as tectonic events, provenance, and changes in productivity.

In conclusion, the genesis and distribution characteristics of the ocean red layer provide us with a unique perspective for understanding the changes in the ancient Marine environment. Through in-depth research on the ocean red layer, we can better understand oxidation events, climate change and biogeochemical cycles in the history of the Earth. Future research needs to integrate the knowledge and methods of multiple disciplines such as geochemistry, sedimentology, paleoclimatology and paleoceanography in order to gain a more comprehensive understanding.

2.2. Research Significance of the Ocean red Layer

2.2.1. Reconstruction of the ancient Marine environment

The mineralogical and geochemical characteristics of the ocean red layer can reveal the REDOX state of the ancient Marine environment. For instance, the enrichment of iron oxides indicates oxygen-rich sedimentary conditions, while the enrichment of manganese may suggest a specific sedimentary environment[6]. Through these features, scientists can infer the productivity of ancient oceans, ocean current patterns and the structure of biological communities.

2.2.2. Paleoclimate change indication

The global distribution of the ocean red layer is closely related to important climate events in geological history. For instance, the formation of the Cretaceous ocean red layer was related to global cooling, which might be associated with changes in the carbon dioxide content in the atmosphere. Therefore, the study of the ocean red layer is helpful for understanding the ancient records and future trends of global climate change.

2.2.3. Indication of hydrothermal or magmatic activity

The non-aluminium ocean red layer may indicate hydrothermal or magmatic activities in ancient oceans, which had significant impacts on the Marine environment and biological productivity. By studying these red layers, we can better understand the history of Marine plate tectonics and seabed geological activities.

2.2.4. Changes in biological productivity

The changes in the biological content in the ocean red layer can reflect the biological productivity of ancient oceans. For instance, the abundant biological remains in the Cretaceous ocean red layer indicate the prosperity of Marine biodiversity at that time, which is of great significance for understanding biological evolution and ecosystem changes.

3. Prospects for Research on the Red Layer of the Ocean

3.1. Carbon Cycle and Ocean Red Layer

Further research is needed on the role of the ocean red layer in the global carbon cycle, especially its impact on the oxidation of organic carbon and the acidification of seawater. This involves an in-depth analysis of the organic matter content, types and burial efficiency in the ocean red layer.

3.2. Comparative studies of geological history periods

A comparative study of ocean red layers from different geological history periods is conducted to reveal their relationship with global cooling. This requires interdisciplinary collaboration,

integrating knowledge and methods from multiple fields such as geology, geochemistry and paleoclimatology.

3.3. Sea-land interaction

Study the possible connection between the oceanic red layer and the continental red layer, and explore the influence of sea-land interaction on the formation of the red layer. This might involve a comparative analysis of terrestrial and Marine sediments, as well as research on ancient sea level changes and terrestrial weathering.

3.4. Chronology research

Conduct precise chronological studies on the ocean red layer to determine the age at which the expansion of the ocean basin ceased. This requires precise radioactive isotope dating techniques and a deep understanding of Marine geological events.

3.5. Earth System Science research

Incorporate the study of the ocean red layer into the framework of Earth system science and consider its multi-sphere interactions within the Earth system. This includes the interactions among the ocean, atmosphere, biosphere and lithosphere, as well as their responses to global changes.

4. Conclusion

As an important field in Marine sedipology, the study of the ocean red layer not only enriches our understanding of the Earth's history but also provides valuable information for understanding current and future changes in the Marine environment. Through in-depth research on the ocean red layer, scientists can better understand the REDOX state of the ancient Marine environment, climate change, changes in biological productivity, and the history of geological activities on the seabed. However, current understanding of the ocean red layer remains limited, and more research is needed to reveal its full scientific value. Future research should adopt an interdisciplinary approach, integrating the latest technologies and theories of modern earth science, with the aim of achieving greater breakthroughs in this field. Through these efforts, we can not only better understand the past of the Earth, but also provide scientific basis for predicting and responding to future global changes.

References

[1] Xie Jizun, Feng Wenkai, Hu Yunpeng, et al. Mechanical Properties and Damage Deformation Energy Characteristics of Mudstone Under Natural and Water-Saturated Conditions. Hydrogeology & Engineering Geology. 2016, Vol. 43 (No. 3), p. 66-72,78.

[2] Xing Guanyou. Discussion on Safety Measures for Dam Projects in Red Bed Areas of China. Dam and Safety. 1996, (No. 2), p. 1-7.

[3] Guo Yongchun, Xie Qiang, Wen Jiangquan. Distribution Characteristics and Main Engineering Geological Problems of Red Beds in China. Hydrogeology & Engineering Geology. 2007, (No. 6), p. 67-71.

[4] Wang Chengshan, Hu Xiumian. The Cretaceous World and Oceanic Red Beds. Earth Science Frontiers. 2005, (No. 2), p. 11-21..

[5] Lyu Xuan, Liu Zhifei. A Review on the Distribution, Composition and Scientific Significance of Oceanic Red Beds. Advances in Earth Science. 2017, Vol. 32 (No. 12), p. 1307-1318.

[6] Peng Hua, Wu Zhicai. Preliminary Study on the Characteristics and Distribution Patterns of Red Beds. Acta Scientiarum Naturalium Universitatis Sunyatseni. 2003, (No. 5), p. 109-113.

[7] Xu Qiang, Tang Ran. Research on Red Beds and Their Geological Hazards. Chinese Journal of Rock Mechanics and Engineering. 2023, Vol. 42 (No. 1), p. 28-50.

[8] Jia Zhaowen, Ma Ligang. Analysis of Karst Development Characteristics and Engineering Geological Problems of Red Bed Conglomerate: A Case Study of the Danjiangkou Hydropower Station Dam Site. Express Water Resources & Hydropower Information. 2024, Vol. 45 (No. 1), p. 18-22.