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Contents

Characteristics and research status of the Carboniferous marine environment

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Abstract

During the Carboniferous, rapid changes in atmospheric composition and climate coincided with increased rates of tectonic plate reorganization and key events of biological evolution. As one of the most important climatic events in Phanerozoic, the Late Paleozoic Ice Age (LPIA) lasted through the all Carboniferous and influenced the atmosphere, oceans, and biotic evolution. The latest emergent view for the LPIA defines the glaciation as a more dynamic icehouse interval which was a series of shorter, discrete glacial episodes of 1~8 Myr in duration alternating with nonglacial/interglacial phases similar duration. This appears to be more in line with the regular oscillations of the marine environment during the period, even providing a novel insight for studying the Carboniferous marine environment. The Carboniferous was overall characterized by strong faunal provincialisms and persistently low diversity of marine invertebrates, nevertheless, there are the marine ecological crisis of a range of coral reefs and benthic animals, while some marine species and genera rose to the peak, especially foraminifera diversity. Numerous scholars argue that the biotic impact coupled so closely with the

LPIA is prima facie evidence that they were causally connected, and we don't think this is just a simple coupling. Therefore, we have a deeper understanding of the marine environment from the aspects of sea-surface temperature (SST), redox state, and salinity based on previous studies.

Late Paleozoic ice age witnessed the coldest climate over the past 500 Ma, smaller SST variations in tropical oceans during the glacial-interglacial cycles and there were notable tropical SST oscillations; Regional upper ocean temperatures are very similar in the glacial and interglacial; Affected by variables such as seawater upwelling, relatively lowered SSTs in the interglacial case compared to temperatures along the same latitude; Temperature gradient to increase between the equator and polar during glacial compared to interglacial; In contrast to greenhouse biological events, Carboniferous Serpukhov extinction events as well as CPBE were caused by climate change-induced SST changes during the glacial-interglacial cycle, both of which were primarily related to cooler SST triggered by glacier. With a step-change in surface oxygen levels and ocean dissolved oxygen during the Carboniferous, the sea-surface temperature oscillations become larger; There is a surprising dynamic redox history during the Carboniferous perhaps given the prevalence of the development of ocean anoxia during LPIA; The obvious underlying issue is whether there are fundamental differences in redox regulation and in the potential to develop anoxia under a glacial climate state (icehouse) versus for an ice-free greenhouse state. The salinity of paleoseawatwer has been elusive during the Carboniferous, but the spatial gradient of salinity controls the composition of ocean chemical elements to a certain extent and has a profound effect on thermohaline circulation. These environmental changes can be linked to Marine life events, biodiversity, and even the size of individual organisms. In addition, the changes in these factors are basically related to the temperature changes at that time, therefore the climate changes during the glacial-interglacial cycle of LPIA are the key factors that trigger the marine biological events.

Key words: Sea-surface temperature; Redox; Salinity; Marine organism; Carboniferous; LPIA

Sedimentary characteristics of Carboniferous and Heshlafu Formation coral reefs in the southwestern margin of Tarim Basin

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Abstract

Lower Carboniferous coral reefs are found in the Altash area of the southwestern margin of the Tarim Basin, and the reefs are mainly developed in the stratigraphy of the Lower Carboniferous and the Heshlafu Formation. The reefs are considered to be patch reefs within the open terrace through field profile observation and identification of microscopic thin sections. It is uplifted geomorphologically, spreading laterally in the direction of NEE, with an overall width of about 400 m and a thickness of about 50 m, dominated by vertical accretion, and with clear subphases such as reef base, reef core, and reef cover. The reef-building organisms are mainly groups of Tetracoralla, including tube corals and stromatolites, and there are many species of attached reef organisms, mainly brachiopods, gastropods, crinoids, and flies. According to the differences in the external appearance of the reefs, they are divided into two categories, including high-raised reefs and low-raised reefs. Combined with the development characteristics of coral reefs in the study area, paleogeomorphology and the evolution of sea level, it is suggested that: high-raised reefs are developed in the geomorphological uplift position within the plateau, due to the decline in sea level exposure of the death, mainly composed of coral skeleton tuffs, bioclastic granular tuffs;

low- raised reefs for the development of reefs in the inner part of the plateau in the more low-lying parts of the reefs, the reefs are limited by the characteristics of the reef base rocky and the depth of the water, resulting in limited growth of corals, reef body The outer appearance is flat, lens-shaped, due to the rapid rise in sea level was drowned, its depositional environment compared to the former water body is deep, mainly by coral skeleton tuff and bioclastic mud crystal tuff composition. It also summarizes that the coral reefs in the southwest margin of the Tarim Basin are the internal patch reef pattern of the open terrace in the shallow sea.

Key words: Tarim Basin; Lower Carboniferous; coral reefs

Characteristics and roles of the peloidal micrites in the Late Carboniferous (Moscovian) microbial reefs of southern Guizhou, China

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Abstract

Peloids considered here to include all micro- and cryptocrystalline micrite components that have a pelleted aspect, generally appear as subangular to well-rounded, spheroidal, ellipsoidal, to irregular in shape. Studies on the origin and role of peloids are significant in discussing the environment and construction processes of Late Paleozoic reefs. In the Houchang area (southern Guizhou, China), the Late Carboniferous microbial reefs are well preserved, providing an opportunity to study the characterizations and roles of the peloidal micrites for this time interval in reef facies.

Three types of peloids are differentiated: microbial, lithic, and bioclastic peloids. Microbial peloids generally range from 20 to 100 μm with fuzzy margins and are good sorting, which were generated by microbial metabolic activities with possibly some contribution from organomineralization. Lithic peloids have sharp margins and irregular shapes, and exhibit variable diameters from 50 to 800 μm, whereas locally they may reach up to 1300 μm. They were derived from erosion and redeposition of the micrite matrix caused by bottom turbulence. Bioclastic peloids mostly are ellipsoidal and spheroidal, with variable sizes from 60 to 600 μm, and generated by fully

micritized fragments of skeletons as well as shells. Quantitative analysis is applied to estimate the contents of micrite, cement, debris, and peloids from the Lumazhai microbial reef. Three growth stages of the reef could be divided. The results show that the microbial peloids and cement are mainly developed in stage Ⅰ, and their content gradually reduces as the reef grows, which is contrary to the debris. The volume of lithic peloids is greater in stage Ⅱ, Ⅲ than in stage Ⅰ, while the bioclastic peloids are less variable in content. The distribution of the various peloidal types and other components suggest that the stage Ⅰ of the microbial reef accreted within the shallow marine setting with good water circulation. The microbial peloids are not only a significant source of sediments in the reef, but also enhance the stability of the framework. The increase in the content of lithic peloids and debris reflects the enhancement of wave energy and the fall of sea level. The sedimentary of the Lumazhai microbial reef indicates a dynamic balance between destructive versus constructional processes, providing an example for the study of microbial reef growth at low latitudes during the Late Paleozoic Ice Age with frequent sea-level fluctuation.

Key words: Late Carboniferous; Microbial reef; Peloids; Sea-level fluctuation; South China

Distribution of skeletal grains and implications for environment factor and bioconstructions: A case study of Moscovian-Gzhelian section in southern Guizhou

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Abstract

Multiple bioconstructions have been found in the Lumazhai section of the Houchang Town, Guizhou Province, southern China, ages from Moscovian to the Gzhelian. The Upper Carboniferous strata were well-preserved and continuously exposed. This study identifies ten microfacies types, whose vertical evolution indicates significant changes in the depositional environment related to relative sea-level fluctuations. Skeletal grains are widely present in these facies. Among them, foraminifera, algae, bryozoans, crinoids, and *Tubiphytes* are the most common and exhibit distinct distribution characteristics in various environments. They play important roles as environmental indicators. Thus, their relative abundance and distribution patterns have been studied by using quantitative analysis to provide insights into the complex interactions between organisms and their surrounding environment. Based on the relevant analysis, it is suggested that hydrodynamic conditions and the presence of bioconstruction significantly influenced the distribution patterns of the organisms. The findings of this research reveal environmental conditions and

ecosystem functioning, contributing to our understanding of climate change events and their effects on biological communities.

Key words: Marine environment; Marine biological; Carboniferous; LPIA

Sedimentary Evolution and Sea-Level Fluctuation of Late Pennsylvanian Carbonate Platform in Southern Guizhou Province, South China

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Abstract

The Late Pennsylvanian is the one of main icehouse intervals of the Late Paleozoic Ice Age. The advancement and retreat of the ice cap triggered sea-level fluctuation and climate change in the mid-low latitudes globally. Numerous of reefs are widespread and well exposed in Southern Guizhou Province, South China, providing a good opportunity to study climate change and sea level fluctuation during Late Pennsylvanian. This study focuses on the reef-bearing shallow water succession in Lumazhai village and the deeper-water succession in Zhuanchang village in Southern Guizhou Province, South China. Field observation and petrographic analysis document 19 facies and indicate evolutional facies of a carbonate margin within Lumazhai section and carbonate ramp within Zhuanchang section. The depositional environment evolution indicates sea level fluctuations, which reflects global climate changes. The

relatively low sea-level accompanied by high-frequency fluctuations, may be related to the expansion of glaciation (GL3), which was correspond to the growth of microbial reefs and phylloid algal reefs during Late Moscovian to Early Kasimovian. Subsequently, the sea level rose gradually during the Kasimovian and experienced a brief rise during the Late Kasimovian, corresponding to the development of coral reefs indicating a short-term global warming. A brief sea-level drop during the Early Gzhelian might indicate the presence of glaciation (GL4), followed by a subsequent rise corresponding to the growth of the large coral reef, indicating another episode of global warming. The abrupt sea-level drop during the Late Gzhelian, accompanied by the reemergence of microbial reef and phylloid algal reefs might be related to glacial increase. The variations in sedimentary facies from deep-water to shallow-water settings in South China reveal the consistency and differences in different settings under the influence of glacial-type sea level changes. The type, scale, and morphology of reefs are coupled with glacial sea-level changes and glaciation, suggesting a relationship between the growth and development of reefs and far-field climate and sea level fluctuations during the Late Paleozoic Ice Age.

Key words: Late Pennsylvanian; South China; Late Paleozoic Ice Age; Sea-level fluctuations; Facies

Influence of microbial carbonate structure on pore characteristics: A case study of Dengying Formation in northeast Sichuan Basin

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Abstract

Microbialite is developed extensively as an important oil and gas reservoirs in the Sinian Dengying Formation in the Sichuan Basin. Microbial texture is an important characteristic of microbial dolomites compared to conventional carbonate rocks. Thus, studying microbial texture is the key to understand the origin and distribution of microbial dolomites. We selected representative microbialite samples of the Dengying Formation in the northeast Sichuan Basin to test their petrophysical properties and pore structures. The test results are correlated with corresponding microbial textures to analyze their influence on pore characteristics. This study suggests that: (1) The microbial dolomites of the Dengying Formation in the northern Sichuan area are mainly divided into four kinds of microbial dolomites, thrombolite dolomite, foam spongy dolomite and oncolite. The reservoir space is mainly composed of framework pores, intergranular pores, intragranular pores and granular mold pores; (2) Microbial structure is the basis for the formation of microbial carbonate reservoirs: the pores type

in the laminated structure are mainly the microbial framework pores, the pore types in the clot structure are mainly the inter-clot pores, and the pore type in the foam spongy dolomite structure is mainly the particle mold pore; (3) The diagenesis such as burial dissolution of the clot structure will lead to the dissolution of the inside of the clot to produce secondary framework pores; (4) The foam spongy dolomite structure is a special composite structure formed by microbial structure coated on the surface of intraclasts composed of unstable minerals, and then subjected to selective dissolution. wherein the intraclasts are all dissolved into particle mold pores, and the inner part is dissolved into intral granular pores; and (5) Sedimentation served as the dominating factor of pore structures with its controls on microbial textures, while diagenesis, under the restriction of microbial textures, changed the pore system mainly on the basis of sedimentation.

Cyclostratigraphy of the Lingshui Formation in Changchang Sag, Qiongdongnan Basin, China, with paleoenvironmental and paleoclimatic analyses based on paleontology

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Abstract

The Qiongdongnan Basin, located in the sea between Hainan Island and the Xisha Islands, is a faulted Cenozoic basin on the northern continental margin of the South China Sea. The Changchang Sag, situated in the eastern part of the central depressional zone in the deepwater area of the Qiongdongnan Basin, exhibits a near E-W striking morphology and represents an important potential target for oil/gas exploration. However, the age of the interface of the Lingshui Formation remains controversial, which hinders a comprehensive understanding of the tectonic evolution and hydrocarbon accumulation pattern in the Changchang Sag. This study focuses on well A, located in the depositional center of the Changchang Sag, and employs cyclostratigraphic analysis to identify cyclic signals of the Milankovitch cycles recorded in the sedimentary strata. Spectral analysis of natural gamma logging data from this well reveals the presence of 405 kyr long eccentricity cycles, 100 kyr short eccentricity cycles, 39.3 kyr obliquity cycles, and 20.58 kyr age precession cycles. By employing astronomical tuning, a "floating" astronomical time scale of the Lingshui Formation spanning 5.483 million years (Myr) is established. The top interface of the Oligocene in the International Geological Time Scale 2020 (GTS2020), with a geological age of 23.03 Ma, is used as the time anchor to establish a high-precision absolute astronomical age framework for the Lingshui Formation. The results indicate

that the bottom interface of the first member of the Lingshui Formation is dated at 23.79 Ma, the bottom interface of the second member is dated at 25.08 Ma, and the bottom interface of the third member is dated at 28.51 Ma.

Based on the results of quantitative analysis of foraminiferal samples from Well A, the boundary between the foraminiferal N4-P22 Zones was determined to be approximately 23.23 Ma. Similarly, the boundary between the P22-P21 Zones is estimated to be around 23.45 Ma, and the boundary between the P21-P19 Zones is approximately 28.2 Ma. Furthermore, based on the quantitative identification of calcareous nannofossils from Well A, the boundary between NN2-NP25 Zones is estimated to be about 23.13 Ma, the NP25-NP24 Zone boundary is around 24.81 Ma, and the NP24-NP23 Zone boundary is approximately 27.43 Ma. The established absolute astronomical time scale derived from astronomical cycle analysis is consistent with the geological age of the foraminiferal and calcareous nannofossil zonation, thereby affirming the reliability of employing astronomical orbital parameters in paleoclimate analysis.

Based on the spore and pollen assemblage characteristics observed in Well A, the proportion and abundance of planktonic foraminifera, along with other paleoclimate proxies, indicate warm and humid climatic conditions during the deposition of the Lingshui Formation. The sedimentary environment was primarily littoral, and the climate exhibited a pattern of warm-cool changes. In conclusion, our comprehensive analysis suggests that the Oligocene climate variations in the Qiongdongnan Basin were driven by the spatial-temporal distribution of solar radiation, which is influenced by changes in Earth's orbital parameters, particularly eccentricity.

Key words: Spore and pollen assemblage
characteristics; Foraminifera; Paleoclimate; Qiongdongnan Basin; Cyclostratigraphy

Morphology of Archaeocyaths from the Shuijingtuo Formation, lower Cambrian of the Yangtze Platform

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Abstract

Archaeocyaths are a group of extinct filter feeders that flourished in the early Cambrian and occupied an important position in the evolution of the basal fauna and the early marine ecosystem, as well as present great significance in the international biostratigraphic correlation. However, the detailed morphological and anatomical information of this group is still unclear due to insufficient fossil material and limited experimental analysis. Here, we report exquisitely preserved phosphatized archaeocyaths fossils from the upper Shuijingtuo Formation (Cambrian Series 2, Stage 3) at the Aijiahe Section of the Three Gorges area, South China. Detailed observation of their external morphological structure by Scanning electron microscopy (SEM) reveals that these fossils have a typical regular double-walled cup structure belonging to the order Ajacicyathida. The inner and outer walls are concentrically distributed, the septa between the two walls are radially arranged, and these structures are perforated. The pores of outer wall have more rows but with a smaller diameter than the inner wall, while the size of the pores on septa has nearly the same number of rows as the outer wall pores. The data of Micro-computed tomography (Micro-CT) analysis show that the different stages of the growth process of the cup have different characteristics. In comparison to traditional thin section analysis, combination of SEM and Micro-CT analysis of phosphatized fossils presented in this research further explored detailed

internal structure and finely reconstructed the microscopic overall morphological structure of Ajacicyathids, which provide important information to help us understanding the systematic taxonomy, anatomy and morphology of archaeocyaths during the Cambrian period.

Keywords: Archaeocyaths, morphology, Cambrian, the Shuijingtuo Formation, Ajacicyathida

Microbialite succession of Lower Ordovician in the middle Yangtze region and its implications for the GOBE--thoughts and prospects

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Abstract

Microbialite-dominated reefs are an important component of Phanerozoic reefs, and their abundance and diversity are closely related to the evolution of metazoan diversity. The mechanism of this association, or the interaction between microbialites and metazoans, or between organisms and environment, is currently a research hotspot. The Early Ordovician was a period of widespread development of microbialites, and it was also a transitional period for the construction of reef ecosystems from microbialites to metazoans. Studying the evolution of microbialites and metazoans, as well as the evolution of ancient environments during this period, can help reveal the causal mechanism of the Great Ordovician Biodiversification Event. There are various types of reefs in the Lower Ordovician of the middle Yangtze region, with a variety and high abundance of fossils. Stromatolites, thrombolites (in-situ growth type), and oncolites (non in-situ growth type) have been discovered. We have completed research on the macroscopic development characteristics of microbialites and the diversity evolution of some metazoan groups (brachiopods, cephalopods, trilobites), and found that the extinction of microbial rocks is accompanied by the radiation of metazoans. A preliminary exploration was conducted on the symbiotic relationship between microbialites and metazoans in the study area. It was believed that microbialites have a certain promoting effect on the development of metazoans, and an increase in metazoan

abundance will affect the morphological development of microbialites. Further research will be conducted on the macro and micro succession patterns of microbialites, as well as environmental influencing factors (paleoclimate, paleomarine environment, sea level changes, etc.), to explore the significance of microbialite succession on the radiation of metazoans.

Keywords: Early Ordovician, microbialite, metazoans, the Great Ordovician Biodiversification Event, the middle Yangtze region