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Contents

Sedimentary characteristics and distribution patterns of the Cambrian microbial mound-shoal system in the Tarim Basin, NW China

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Abstract

The Tarim Basin is a large superimposed sedimentary basin located in the Xinjiang Uygur Autonomous Region, NW China. Voluminous oil and gas resources have been found in the Cambrian and Ordovician marine carbonate rocks in the Tarim Basin, and marine carbonate reservoirs are significant hydrocarbon exploration targets in this region. Microbial carbonate rocks are newly-identified and important types of hydrocarbon reservoir in both the Tarim Basin and worldwide, and recent exploration practices demonstrate their favorable economic potentials. Due to the special sedimentary characteristics and reservoir formation process, marine microbial carbonate rocks have become research hotspots.

Multiple types of microbialites and microfacies occur in the Cambrian microbial mound system in the Tarim Basin, and these microbialites are also important hydrocarbon reservoirs in this region. Many studies have been conducted on sedimentary fabrics of Cambrian microbial mound outcrops in northwestern parts of the basin. However, there are still some unresolved issues with respect to microbial

types, characteristics and sedimentary patterns, and reservoir controlling factors and distribution patterns. These issues hinder the further hydrocarbon exploration in microbialite reservoirs in the Tarim Basin. Understanding sedimentary characteristics and spatial distribution patterns of microbial mound can not only have theoretical significance but also benefit hydrocarbon exploration in this region.

Based on outcrop, drill-core, seismic and well logging data, this study analyzes rock types, characteristics, sedimentary characteristics and evolution patterns of the Cambrian microbialites in the Tarim Basin, and predicts the distribution patterns of favorable reservoir zones. Following conclusions are obtained:

1. Types and sedimentary microfacies of microbialites in the study area are identified. There are seven kinds of microbial dolomites and their related granular dolomites are identified in the Gucheng district of the Tarim Basin.

2. The microbial mound can be further divided into microfacies including mound base, mound core, mound flat, front mound and back mound, and geological and geophysical features of each microfacies are characterized. The Cambrian microbial mound in the Gucheng-Xiaotang area is a marginal platform, and the sea level decreased continuously during the Middle and Late Cambrian. There were five stages of platform margin reef beaches occurred in this area. The evolution pattern of sedimentary microfacies in the study area is established.

3. The lithofacies paleogeographic map of the study area is compiled, and the favorable reservoir facies belt of the eastern Tarim Basin is predicted. In the Gucheng area, the high energy microfacies is the basis for the development of class I and class II high-quality reservoirs. Cores and flat microfacies within microbial mounds mainly contain fractures and caves as major pore spaces, which have greater storage capacity compared to fractures and pores in the shoal microfacies. Additionally, there are strong heterogeneity with respect to reservoir qualities in the Cambrian microbial mound-shoal system in the Tarim Basin.

Key words： Tarim Basin; Cambrian; microbialite; microbial mound; carbonate type and distribution

Reservoir genetic mechanism and microfacies characteristics of microbial mounds and shoals in Ediacaran Sichuan Basin

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Abstract

Microbialites widely occur in the geological history, and are common products of interactions between sedimentary environments and biochemical reactions. Microbialites record critical details of paleo-environmental evolution, and have appreciable capacities of generating and capturing hydrocarbons. Therefore, understanding formation mechanisms of microbialite microfacies and hydrocarbon reservoirs within microbialites can provide useful insights for theoretical studies as well as guides for hydrocarbon exploration. The Ediacaran Dengying Formation in the Sichuan Basin contains large quantities of microbialites, which are major hosts for trillion cubic meters of natural gases in the central Sichuan Basin. This study investigated types and characteristics of microbialites within the Dengying Formation in the Sichuan Basin using outcrop, drill-core, and thin section analysis. Microfacies of microbial mounds and shoals are identified, and controlling factors and formation mode of reservoirs within microbial mounds and shoals are explored in the study area. Following conclusions are obtained via this study:

(1) Ediacaran microbialites in the Sichuan Basin mainly contain five groups and ten sub-groups of rocks, including stromatolite dolomites, clotted dolomites, oncolite

dolomites, sponge stones, and microbial bindstones. Different types of microbialites occur in environments with distinctive hydrodynamic conditions and microfacies.

(2) The microbial mound-shoal system in the study area can be further divided into microfacies including mound bases, mound cores, mound flats, and mound wings. The mound base is located in the bottom of mounds, and mainly consists horizontal laminated algae dolomites. The mound core is mainly composed of algae clotted dolomites, wavy stromatolite dolomites, and sponge dolomites. Grape lace structures commonly occur in these rocks. The mound flat is located over the top of mounds, and mainly consists of dolomite breccia.

(3) Three types of microbialite reservoirs are identified in the study area, including the karst reservoir formed by early-stage erosion of mound-shoal dolomites, the superimposed karst reservoir formed by early-stage erosion and epigenetic karstification of mound-shoal dolomites, and the tectonic (fracture)-hydrothermal dolomite reservoirs with dissolution caves as dominant pore spaces. Main controlling factors for the occurrence of microbialite reservoirs in the study area include sedimentary microfacies, high-frequency sequences, and unconformity-related karstification of weathering crusts. Accordingly, formation modes were established for Ediacaran microbialite karst reservoirs in the study area.

Key words: Sichuan Basin; Ediacaran; microbialite; mound-shoal microfacies; reservoir type; reservoir genetic mechanism.

Formation mechanism and controlling factors of microbial reservoirs in the Dengying Formation, Sichuan Basin

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Abstract

The Sinian Dengying Formation is the most important Precambrian gas-bearing stratigraphic unit in the Sichuan Basin. Based on the macro and micro data of drilling cores and outcrop samples, combined with the corresponding geochemical data, the characteristics, formation mechanism and main control factors of microbial dolomite reservoir of Dengying Formation in Sichuan Basin are studied in detail. Following conclusions are obtained via this study: (1) algal thrombolite dolomite, algal dolarenite dolomite, and algal stromatolite dolomite are dominant gas reservoirs within the Dengying Formation; (2) five categories of pore spaces are identified in dolomitic reservoirs of the Dengying Formation, including lattice pores and caves (residual), intragranular dissolution pores, intercrystalline dissolution pores, small- to medium-sized dissolution pores and caves, and fractures; (3) lattice pores and caves and intergranular pores are mainly affected by sedimentary structures of microbialites. Algal thrombolite dolomites and algal dolarenite dolomites have the best porosity and are most well-developed in the platform marginal zone. In intra-platform zone, there are mainly stromatolites, laminated and mud crystalline dolomites, and primary pores are relatively scarce; (4) small- to medium-sized karst caves occur pervasively and are the most important types of pores in the study area. Karstfication can occur during penecontemporaneous, early diagenetic and burial stages, and the early diagenetic

process has the most important influence on the occurrence of karst pores and caves in the study area. Selective dissolutions of microbialites occur during the formation of karts, and this is mainly attributed to heterogeneous microstructures within microbialites. The karst cave system is complex in the study area, which is the combined result of lateral variations in sedimentary facies and topographical features and vertical frequent interbeding of impermeable and permeable layers; (5) there is an obvious negative correlation between gas production yields and distances from faults, suggesting that multi-stage structural fracturing can improve the fluid circulation capacity within reservoirs; (6) there are multiple diagenetic processes occurred within the Dengying Formation. Diagenetic processes such as compaction, cementation, filling and siliceous metasomatism have negative impacts over reservoir qualities; (7) sedimentary geomorphology and syn-sedimentary faults are fundamental controlling factors for the formation of reservoirs within the Dengying Formation because both factors control the spatial distribution of favorable sedimentary facies belt. This would further affects lithological types and occurrence of primary pores, as well as a series of karstification events in the later stages.

Key Words: Microbialite; Reservoir Space; Karst; Sedimentary Geomorphology

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Late Permian reef build-up in the Upper Yangtze region – a case study on typical sedimentary outcrops

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References

The Yangtze region is one of the regions with the best stratigraphic record and the most abundant fossils of the Permian–Triassic in the East Tethys and even in the world. It records the evolution of the Paleotethys, the Permian–Triassic Boundary (PTB) mass extinction, the Emei tafrogenesis and other important geological events. The proposed field trip targets, located in the Upper Yangtze region, including the typical Late Permian platform margin reefs and Early Triassic grain shoals at Jiantianba in Lichuan County, at Panlongtong, in Xuanhan. The Jiantianba outcrop reveals a complete sedimentary succession containing basin, slope, carbonate platform margin, and open-restricted platform deposits, where especially, the platform margin reef cores can be observed with very clear assemblages of architecture units and a variety of identifiable microfacies (e.g., filled-skeleton sponge framestone, open-skeleton sponge framestone, binding-skeleton sponge framestone, segment or cluster bafflestone). Calcisponge is the main reef-building organism with abundant species and various forms. It is one of the most typical Late Permian reefs in The Yangtze region. The platform margin zone across the Permian-Triassic biological mass extinction event is studied at the Panlongdong outcrop, revealing the typical platform margin sedimentary characteristics that the reefs of Changxing stage developed on the lower part while the shoals of Feixianguan stage on the upper part of the section. Platform margin reefs and shoals are superimposed and inherited spatially. The sedimentary evolution succession

of reef base–reef core–reef cap is clear and complete. The platform margin shoal is mainly composed of oolitic, and gravel intraclasts the second, with tabular and wedged cross-bedding developed. Puguang gas field is dominated by the reef and shoal reservoirs with high porosity and high permeability within the Permian Changxing Formation and the Lower Triassic Feixianguan Formation. This discovery is benefited from the breakthrough in sedimentological studies on sedimentary facies and favorable reservoirs. It provides a useful reference for the exploration and development of ultra-deeply buried carbonate gas fields in the world.

Keywords: reef buildup; Late Permian; Upper Yangtze region; sedimentary outcrops

The space and time of Ordovician microbialites

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Abstract

The distribution characteristics of microbialites have been extensively documented in the literature, with stromatolites and thrombolites being the most commonly reported in terms of their spatial and temporal distribution. Stromatolites proliferated from restricted coastal lagoons at the depths of photic zones in the Proterozoic oceans. In the Neoproterozoic oceans, the abundance of stromatolites appears to have decreased, possibly due to the expansion of eukaryotic benthos, but stromatolites remained the dominant in carbonate strata. Since the Cambrian Period, stromatolites have become increasingly restricted to coastal environments and subtidal settings characterized by shifting sands, while traction load-limited subtidal carbonates are marked by the occurrence of thrombolites. The growth forms (mesostructures) of microbialites, therefore, are particularly sensitive to even small fluctuations in relative sea level. The Yangtze Platform in southern China was an epicontinental sea during the Ordovician period. Towards the southeastern margin of the platform, there was an increase in stromatolitic and thrombolytic textures within reefs. The stromatolites

discovered in the lower Tremadocian at Songzi, located in the central Yangtze Platform of southwest Hubei Province, developed within a range from upper intertidal low-energy zones to subtidal high-energy zones. Their morphology varied from laminar to wavy, domal, and ultimately columnar structures. Furthermore, speckled and banded thrombolites were also identified within intertidal zones with certain energy limitations while reticular thrombolites existed in subtidal low-energy zones. The Lithistid sponge-Calathium-microbial reefs were discovered in the lower Setul limestone of the Early Ordovician strata (Floian) in Perlis, northwestern Malaysia Peninsula. These reefs were composed of cylindrical columnar stromatolites and labyrinth-shaped thrombolites, with a small amount of lithistid sponges (anthaspidellids) and highly calcified sponges (Calathium), which grew in the shallow subtidal zone dominated by strong waves and currents. The diversity in macrostructure between stromatolites and thrombolites may reflect subtle changes in the environment (such as deepening of water) during the formation of thrombolites. Nevertheless, the Ordovician microbialites present a clear distinction in most regions worldwide, stromatolites are predominantly found in intertidal to subtidal zones, while thrombolites are more commonly observed in shallow subtidal areas. Briefly, microbialites emerged during the Early to Late Ordovician period. Stromatolites were formed in lower supratidal to intertidal and shallow subtidal zones, displaying with variable morphologies such as stratiform, wavy, domal to columnar structures that reflect an enhancement of hydrodynamic conditions; thrombolites are typically deposited in shallow to deep subtidal zones, as well as reef beach facies, indicating the possible replacement of stromatolites by thrombolites. The primary morphologies of thrombolites include reticular, columnar-branching, domical, and labyrinth-shaped structures.

Key words: microbialites；stromatolites；thrombolites；Ordovician；spatial and temporal distribution

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

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Abstract

Microbialite was 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 were correlated with corresponding microbial textures to analyze their influence on pore characteristics. This study suggest 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. And 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 pores type in the clot structure are mainly the inter-clot pores, and the pores type in the f foam spongy dolomite structure are 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 intraclast composed of unstable minerals, and then subjected to selective dissolution. wherein the intraclast were all dissolved into particle mold pores, and the inner part was dissolved into intra granular pores. (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.