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Contents

A Study on the siliceous origin of good source rocks at the bottom of Cambrian and Its relationship with sedimentary environment and source rock development

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Abstract

The shale of the Lower Cambrian Niutitang Formation is rich in organic matter and is a good hydrocarbon source rock, and many progress has been made in the research of the Niutitang Formation, but the siliceous in the process of organic matter enrichment or preservation is not understood, and there is a lack of fine comparative research between siliceous rock and siliceous shale. A total of 68 pieces of 3.2m thick siliceous rock system at the bottom of the Cambrian Niutitang Formation in the Yangtiao profile in the Kaili Majiang area of Guizhou Province were sampled layer by layer at high frequency, and according to the idea of sedimentary environment-biological composition-source rock formation, elemental geochemistry, petrology, organic petrology, etc. were used as theoretical guidance, and the identification and analysis under optical microscope and scanning electron microscopy, combined with organic carbon content, main elements, and silicon isotopes and other analysis and testing methods. The biological composition and TOC content of organic carbon were

analyzed in detail, the relationship between sedimentary environment and source rock development was discussed, and siliceous rocks and siliceous shales were compared and studied. The results showed that benthic algae were mainly composed of benthic algae in siliceous rock system, and a large number of grid-like and hive-like benthic algae were often found in siliceous rocks, and the biological composition of the profile was diverse, including planktonic algae, benthic macroalgae, acritarchs, sponge spicule, pogonophora, etc., and could be summarized into three major categories of biological microfacies: planktonic algae, benthic algae, and other biological types. The TOC content of source rocks of different bio microfacies was different, including benthic algae (average 3.50%)> planktonic algae (average 1.46%) > other organisms (average < 1.0%)(Fig 1). The discovery of sponges and sponge spicule, a small number of circular radiolaria fossils, indicates the presence of siliceous organisms. Studies have shown that sponges are more resistant to dissolution than radiolaria, with a preservation rate of 45.2±27.4% in sediment and 6.8±10.1% in radiolaria. Therefore, it is believed that the conservation mechanism of siliceous organisms in the Majiang Yangtiao Niutitang Formation is considered to be more contributed, and sponge spicule needles contribute more.

A large number of sponge spicule and pogonophora were found in the siliceous rock samples of this profile, indicating that the source rocks of the Cambrian bottom Niutitang Formation were repeatedly affected by hot water during the formation process. sponge spicule biomicrofacies and pogonophora biomicrophase samples strongly affected by hot water events had the lowest TOC. It was indicated that hydrothermal activity may have certain adverse effects on the development of source rocks in this profile.

Through the correlation analysis of the organic carbon content and the main element characteristics, the results show that there is no obvious linear relationship between SiO_2, $SiO_{2excess}$, Al_2O_3 content and TOC. The correlation analysis of $SiO_{2debris}$, $SiO_{2\ hydrothermal}$ and $SiO_{\ 2biology}$ with TOC was carried out according to the simulation method(Fig 2). The results indicate that terrigenous detrital input has many effects on the enrichment of organic matter in shale, and the dilution of hydrothermal solution is also an important factor affecting the enrichment of organic matter in Marine shale. Biosilicon is positively correlated with organic matter. In order to explore the influence mechanism of siliceous on the potential of organic hydrocarbon generation, further simulation studies should be carried out.

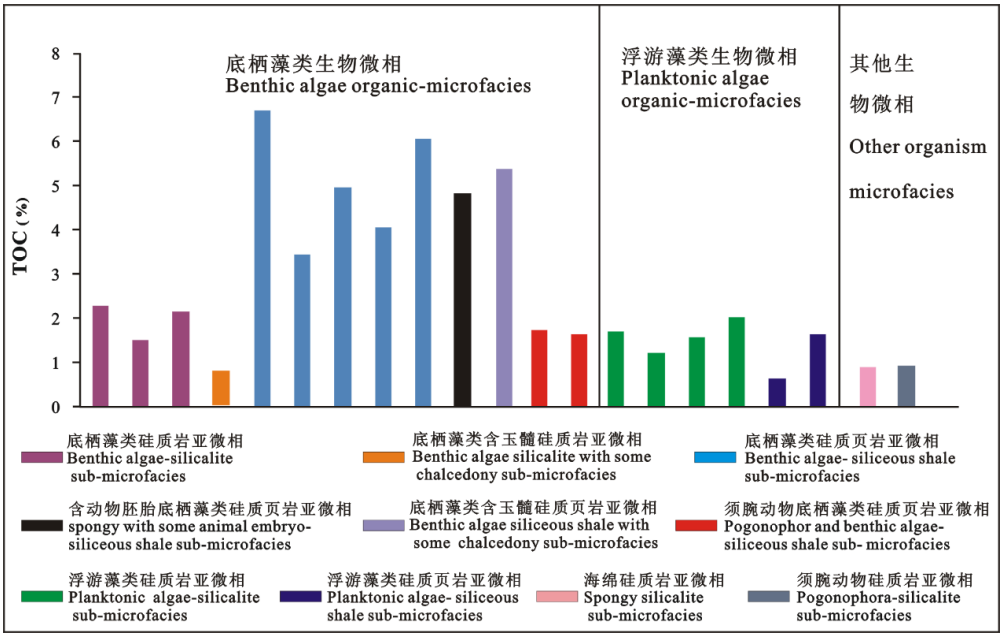

Fig. 1 TOC content and biological composition of the siliceous rock series in The Yangtiao Niutitang Formation, Guizhou province

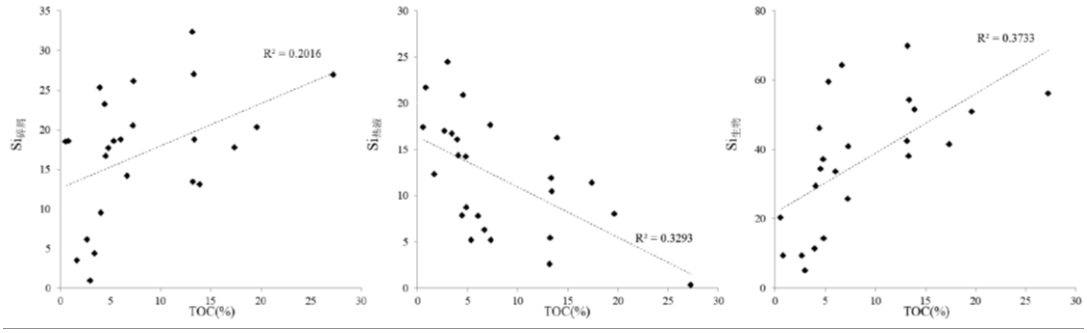

Fig. 2 Correlation between TOC and SiO_2 debris, SiO_2 hydrothermal and SiO_2 organisms in The Yangtiao Nutitang Formation

Keywords: Niutitang Formation; Sedimentary environment; Siliceous origin;Organic matter preservation; Source rock development

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Geochemical characteristics and formation mechanism of source rocks of the Wufeng-Longmaxi Formation—A case study of Weiyuan area

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Abstract

Marine shale gas resources in southern China have great potential in petroleum industry. In order to achieve efficient shale gas development, organic-rich black shale samples from the Upper Ordovician Wufeng Formation-Lower Silurian Longmaxi Formation in the Weiyuan area were used as research objects to analyse the depositional patterns, biocompositions, and characteristics of the high-quality hydrocarbon source rocks of the Upper Ordovician Wufeng Formation-Lower Silurian Longmaxi Formation in the context of the change of the oceanic environment by applying analytical and testing methods of geochemistry, organic petrology and so on.

The results show that the high-quality hydrocarbon source rock section of the Wufeng-Longmaxi Formation shale in the Weiyuan area has a high TOC content (1.78%-4.72%) The TOC content of the Longmaxi Formation shows a general trend of increasing with depth, and is the highest in the small layer of Long-1_1^1, with the highest

TOC value of 4.72%. Organic matter type Ⅰ or Ⅱ$_1$, the hydrocarbon source rock has reached the over-mature stage. The equivalent specular body reflectance is mainly distributed in the range of 2.0 % to 3.0 %, which is in the stage of high - over-mature evolution, dominated by the production of dry gas.

The mineral composition of shale in the Wufeng-Longmaxi Formation in Weiyuan area is mainly quartz and clay minerals, with small amounts of feldspar, calcite, dolomite and pyrite, etc. Penstocks, biotite and other biotite shells can also be identified. The content of brittle minerals is high at 60%~82%, with an average of 74%, which is favourable for late fracturing in shale gas extraction.

The V/Sc and U/Th ratios indicate that the sedimentary waters of the Wufeng-Longmaxi Formation were reducing environments; the U-Mo covariance patterns and Mo/TOC ratios indicate that the Wufeng-Longmaxi Formation was a medium-strongly stagnant, closed water environment with a high degree of reduction, thus favouring the formation of anoxic water conditions conducive to the preservation of organic matter.

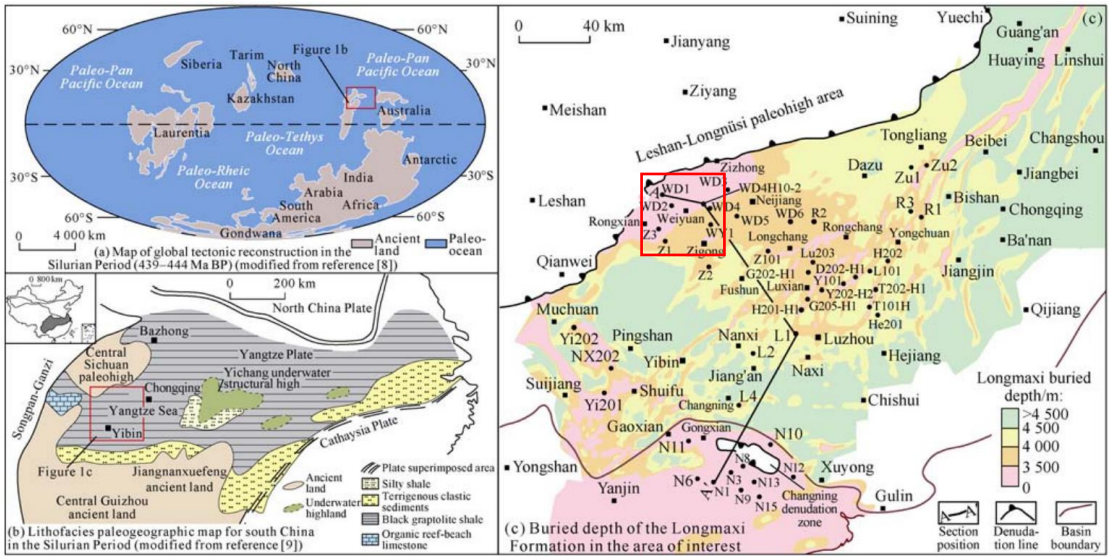

Fig. 1 Geologic setting in the area of interest. (MA,2020)

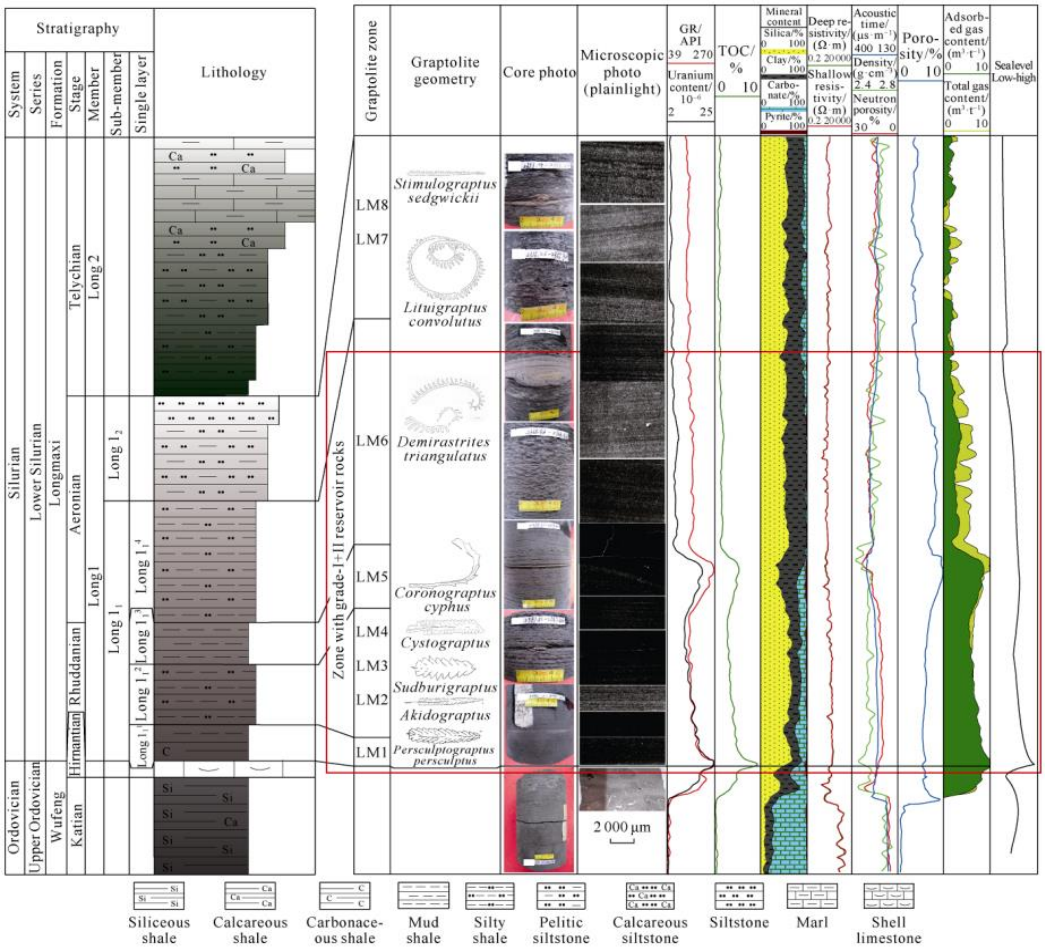

Fig. 2 Generalized geologic column for coring well. (MA,2020)

Key words: source rocks; Geochemical characteristics; wufeng-longmaxi formation; shale gas

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Main controlling factors and accumulate modes of organic matter accumulation in lacustrine shales of Dongyuemiao Member of Lower Jurassic in Sichuan Basin, China

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Abstract

The lacustrine shale of the Lower Jurassic Dongyuemiao Member is a new target for continental shale oil and gas exploration in the Sichuan Basin. In order to explore the accumulation characteristics of organic matter in the lacustrine shale of the Dongyuemiao Member, this paper reconstructs the paleo-redox conditions, paleo-climate changes, paleo-salinity, biological productivity and terrigenous input of lacustrine waters in the Sichuan Basin during the Dongyuemiao Period based on the petrological and geochemical data of core samples from the Dongyuemiao Member, discusses the main controlling factors of organic matter accumulation, and established an organic matter accumulation model. The results show that the organic matter of the shale of the Dongyuemiao Member in Sichuan Basin is mainly type II, and the parent material is mainly derived from zooplankton, algae, and terrestrial higher plants. The TOC content of the shale ranges from 0.25 to 3.17%, with an average of 1.31%. During the Dongyuemiao period, the Sichuan Basin was a continental freshwater (local saline) lake basin in a semi-dry-semi-humid climate. The lake has medium productivity, anoxic bottom water environment and high terrestrial input. Organic matter accumulation is mainly controlled by paleoclimate and influenced by terrestrial input and redox conditions. The organic matter enrichment model shows that in the early and late Dongyuemiao period, the source of organic matter in the lacustrine basin is mainly terrigenous input, and the lake has medium-low productivity. The organic matter is

preserved in shallow water-low oxygen environment and shallow water-brackish water-low oxygen environment (distant provenance region); in the middle Dongyuemiao period, the source of organic matter is mainly from the lake itself. The lake has high productivity, and the organic matter is preserved in the deep water-low oxygen environment. This period is ideal for the accumulation of organic matter. Currently, the lake itself has a high proportion of organic matter, high productivity, and excellent preservation conditions.

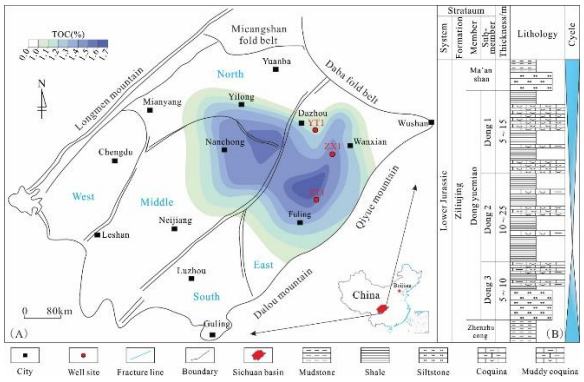

Fig. 1 Structural division of Sichuan Basin and TOC contour map (A) and stratigraphic histogram of Dongyuemiao Member (B).

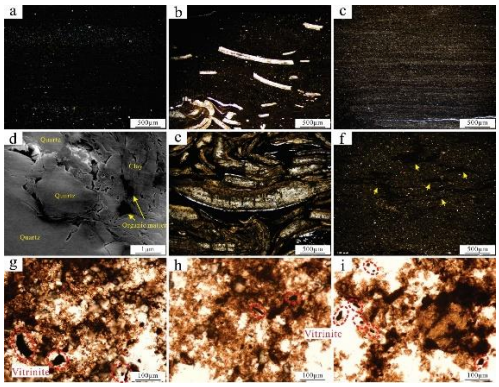

Fig. 2 Microscopic characteristics of shale lithofacies, main minerals and organic matter in Dongyuemiao member of Sichuan Basin.

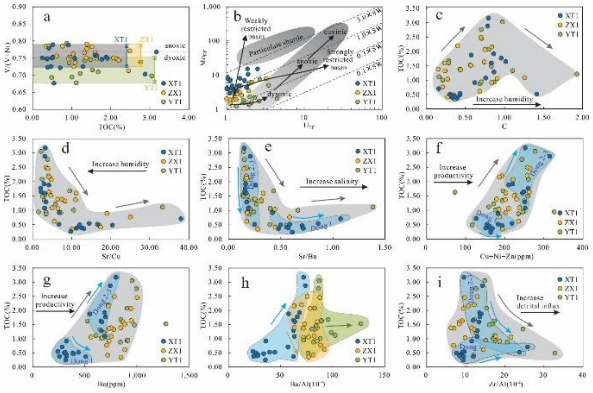

Fig. 3 Correlation diagram between paleoenvironmental indicators and total organic carbon (TOC).

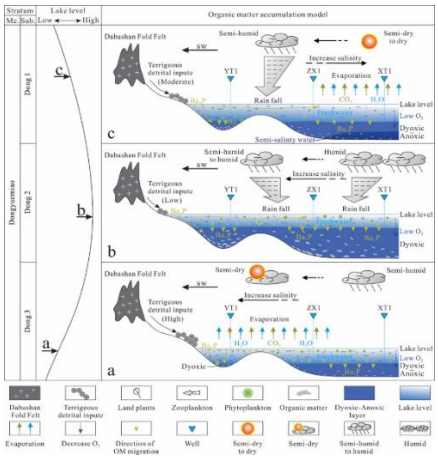

Fig. 4 Organic matter accumulate model of Dongyuemiao Member in Sichuan Basin

Keywords: main controlling factors of organic matter accumulation; organic matter accumulation mode; Sichuan Basin; Dongyuemiao member; lacustrine shale

The characteristics comparisons of Cambrian source rocks in South China and Alum Shale in Europe

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Abstract

The Lower Cambrian Niutitang Fm in south China, hosts a shale gas target, namely the Alum Shale. This interval is over-mature, and its hydrocarbon generation potential cannot be easily evaluated. The characteristics of Alum Shale with low maturity (0.4-0.5%Ro) and high TOC content (11.16-12.24%), could be referenced for Lower Cambrian shale evaluation in south China. In this study, the organic matter composition and the depositional palaeoenvironment of Alum Shale were carefully studied. The maceral composition is dominated by lamalginite and vitrinite-like macerals (VLM) (Fig.

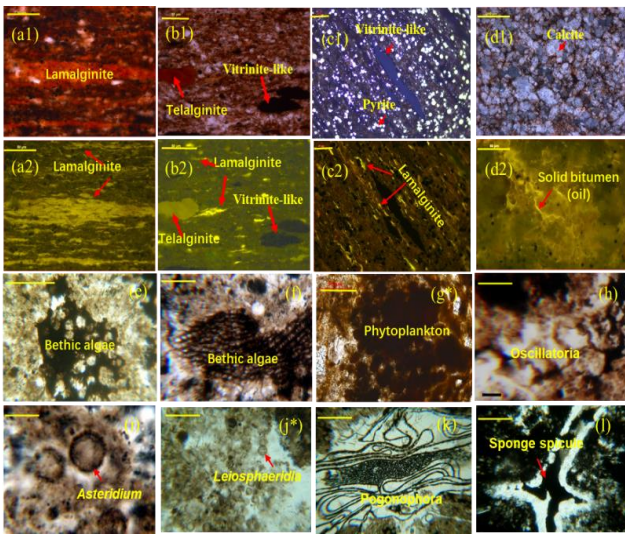

Fig. 1 Photomicrographs of the organic matter in Alum Shale (a-d) and Niutitang Fm shales in South China (e-l). (g* and j* from Xie et al. (2015, 2021, respectively).

1) deposited in an euxinic or even sulfur-rich (TS= 4. 30 ～ 5. 31%) marine sedimentary environment; this was also confirmed by the size-distribution (<0.5 μm) of pyrite particles.

The TOC content (up to 30%) of the Cambrian shales in South China, which contained syngenetic hydrothermal silica fluid deposition at the bottom, is much higher than this of the Alum Shale. The precursors of the organic matter in Lower Cambrian were mainly multi-cellular macro-benthic algae, planktonic algae and some zooplankton (Fig. 1). The organic matter is well-preserved due to the syngenetic hydrothermal silica fluid input, which has silicified organisms rapidly. This can explain the lack of solid bitumens. The well-preserved organic matter contains organic carbon but probably without hydrocarbon generation potential. This was the result of the instant fossilization of the organisms in Lower Cambrian; the organisms did not experienced biodegradation and maturation. Therefore, the shale gas potential cannot depend on the content and type of organic matter, but the organic matter evolution process would be also important for hydrocarbon (HC) generation potential analysis. The characteristics of Alum Shale with low maturity provided a clue for resources evaluation, and the artificial maturation provided quantitative analysis for the HC generation. This is helpful for analyzing the organic matter in Lower Cambrian shales, but the characteristics of hydrocarbon generation potential and resources evaluation were difficult or used with cautions to apply in the gas shale resources evaluation in China.

Key words: Niutitang Formation; Alum Shale; Organic matter composition; depositional palaeoenvironment

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Geochemical characterization of hydrocarbon source rocks in the third member of the Shahejie Formation in the western depression of Qinnan Sag

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Abstract

Qinnan Sag is a marginal depression with the lowest degree of exploration in the Bohai Bay Basin. In 2009, the QHD29-2/E oil field was discovered in the Southeast Depression, but there has been no significant breakthrough since then. Hydrocarbon source rocks' development and resource potential are the basis for oil and gas exploration. In recent years, Bohai Oilfield has drilled a new well on the north side of Western depression, revealing a shale section of the Es_3 with a thickness of over 300m, which provides a possibility for a reasonable understanding of the distribution and resource potential of the source rocks in the Es_3 of Western depression. This article takes this well as an example to reunderstand the source rocks' characteristics in the West depression area of the Qinnan Depression. This well drilled and exposed nearly 400m of shale in the third section of the Shahejie Formation. The detailed geochemical test results indicate that the TOC of the Es_3 ranges from 0.4% to 9.5%, with an average of 2.7%. The organic matter type is mainly I-II_1, and the Ro has reached around 0.6%, entering the oil

generation threshold (Fig 1). It is speculated that the development scale and quality of deep source rocks will be better. Therefore, the material foundation for the formation of large-scale oil and gas fields in the Western depression area of the Qinnan Depression has broken the understanding shackles of poor development of source rocks in the early stage of the Western depression.

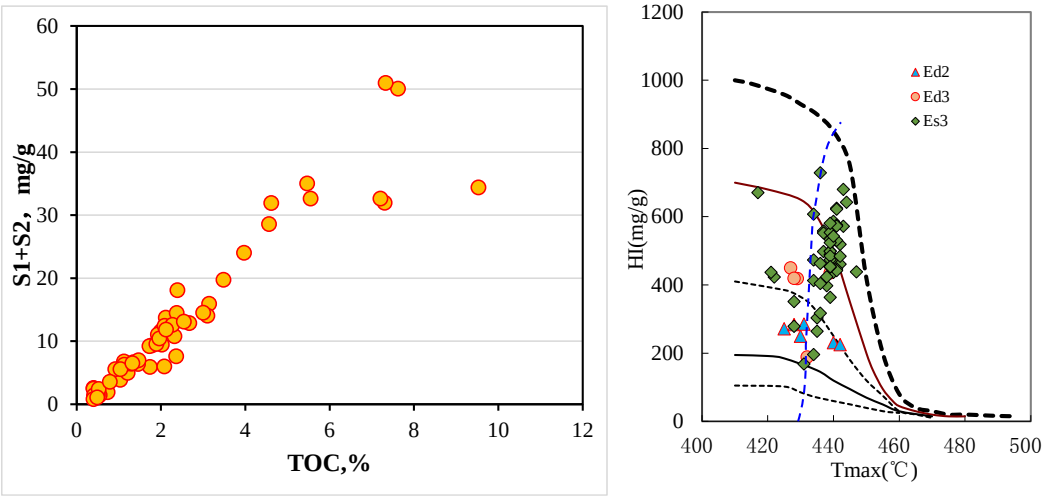

Fig. 1 Abundance and Type of Organic Matter in Source Rocks of a Well on the North Side of Western Depression in Qinnan Sag

In order to further confirm the development scale of hydrocarbon source rocks, based on the measured results, the hydrocarbon source rock logging method is used for prediction. Based on the correlation between measured organic carbon content and logging parameters, the application of the ΔlogR method and multiple regression method to establish an organic carbon content logging prediction model can obtain TOC content curves, which can effectively solve the shortcomings of limited measured TOC data points and unclear characterization of source rocks. Therefore, a random selection of partial data was used for multiple regression modeling. After prediction, blind sample testing was conducted on the remaining data. The evaluation results showed that the use of multiple regression methods can effectively predict the vertical distribution characteristics of hydrocarbon source rocks, providing a foundation for the next step of characterizing the spatial development characteristics of hydrocarbon source rocks (Fig 2).

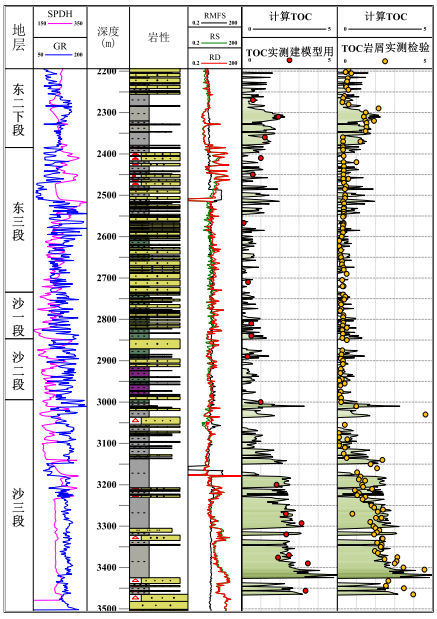

Fig. 2 Prediction Effect of TOC of Source Rocks by Multiple Regression Logging in a Well in Western depression

Key words: Qinnan Sag; Geochemical characteristics; hydrocarbon source rocks; ΔlogR; Logging

curve

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The Influence of Relative Content Composition of Different Bioorganic Matter Sources on the Potential Evaluation of Source Rocks in the Late Triassic Xujiahe Formation Source Rock Sublayers of the Sichuan Basin

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Abstract

The Sichuan Basin experienced strong tectonic activity from the Late Triassic to Jurassic, with drastic changes in climate and environmental conditions, resulting in significant changes in sedimentary characteristics. The Late Triassic Xujiahe Fm. was an important set of hydrocarbon source rocks under this tectonic sedimentary background, and the complex tectonic sedimentary background led to significant differences in organic matter composition in different regions. Therefore, a detailed study of the relative content and composition of different organic matter in its source rocks was of great significance for evaluating its hydrocarbon generation potential. The Xujiahe Fm. was divided into 6 sublayers from bottom to top (T_3x^{1-6}), among which T_3x^1, T_3x^3, and T_3x^5 were important source rock sub layers in the region. In order to

study the influence of the relative content and composition of biogenic organic matter in each sublayer of the Xujiahe Fm. source rock on its hydrocarbon generation potential, this paper comprehensively studied its paleosalinity, paleoredox environment, and paleoproductivity by combining organic petrology and organic geochemistry methods, combined with palynology.

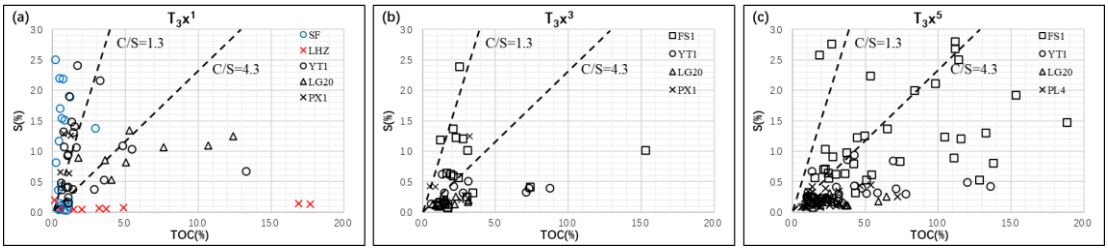

Fig. 1 Relationship between TOC(%) and S(%) in source rocks of the Xujiahe Fm.

Basic geochemical data showed that the average total organic carbon value(TOC) of the T_3x^1 was 7.11%, and the average reflectance of vitrinite(%Ro) was 1.11; The average TOC of the T_3x^3 was 4.04%, and the average %Ro was 1.04; The average TOC of the T_3x^5 was 3.12%, and the average %Ro was 0.96. Therefore, the source rocks of the Xujiahe Fm. had high overall organic matter abundance and moderate maturity, making them good to high-quality source rocks. The organic petrological characteristics showed that the organic matter in this layer was mainly composed of vitrinite (mainly detrital vitrinite), sapropel (layered algae), and secondary components (solid asphalt). The average relative content of these three components in the three sub layers was 45.21%, 32.72%, and 22.07%. Therefore, the microstructure of the T_3x^1 and T_3x^3 was mainly composed of vitrinite, which had a high potential for gas generation; The amorphous algae in the T_3x^5 had a high content and low maturity, and were located within the oil window. The changes in the relative content of biogenic organic matter were constrained by changes in sedimentary environments. Combining petrology and elemental geochemistry studies, it was believed that the T_3x^1 might had been affected by marine invasion events. The main evidence was that (1) biogenic limestone deposits were observed in the T_3x^1 of the Shifang outcrop in the Sichuan Basin, and the ratio of total organic carbon to total sulfur (C/S) was widely distributed, ranging from 0.21 to 26.14. Some samples had a ratio of<0.5, indicating the influence of marine sedimentation; (2) The organic matter kerogen isotopes in the Shifang outcrop were relatively low, with the kerogen isotopes in the biological limestone section as low as -25.51 ‰, indicating that the organic matter mainly came from planktonic algae. Overall, considering the TOC content, organic matter source characteristics, and

maturity evolution, the organic matter in the T_3x^1 and T_3x^3 was mainly derived from higher plants, and the maturity of organic matter had reached the gas generation stage with high gas generation potential. The amorphous organic matter formed by the layered algae in the T_3x^5 had a high content, and the maturity of organic matter was in the stage of oil window. It was a good oil generation layer and might provide research value for the relationship with the overlying Jurassic oil and gas. This study conducted a detailed comparative analysis of the source rocks in each sublayers of the Upper Triassic Xujiahe Fm., expecting to provide basic data and certain references for the exploration and development of oil and gas in the Xujiahe Fm. in the Sichuan Basin.

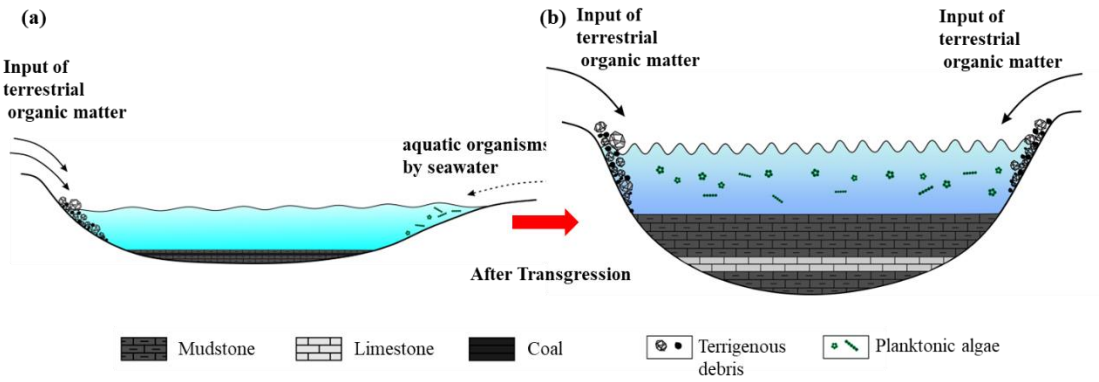

Fig.2 Diagram of the formation mode of hydrocarbon source rocks in the Xujiahe Fm.
(a) Schematic diagram of sedimentary patterns before transgression;
(b) Schematic diagram of sedimentary patterns after transgression

Key words: Sichuan Basin; Xujiahe Formation; Different sources of biological organic matter; Sedimentary environment; Potential evaluation of hydrocarbon source rocks

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Morphological characteristics and paleoenvironmental significance of framboidal pyrite in the Lower Silurian Longmaxi Formation from well WY1 in Weiyuan-Rongxian Area, southern Sichuan Basin

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Abstract

Framboidal pyrite's morphological characteristics can be utilized as an indicator for sedimentary environment and geological conditions of shale gas. The present research used Ar-Ion milling, scanning electron microscopy (SEM), and ImageJ image processing technology to investigate the morphology and particle size of framboidal pyrites in shale samples from the Lower Silurian Longmaxi Formation in well WY1 of Weiyuan-Rongxian Area, which was used to analyze the redox conditions and shale gas conditions with trace elements, organic matter abundance, and gas-bearing property. The findings demonstrate that the framboidal pyrite content in the Longmaxi Formation from well WY1 shale decreases upward. The microcrystalline shapes are mainly truncated octahedrons in the lower part of the First Member and truncated octahedrons with some octahedrons and truncated tetrahedrons in the upper part of the First Member to the Third Member. Framboidal pyrite has an average particle size of 4.02 m, while microcrystalline has an average particle size of 0.45 m. From the First Member to the Third Member, the ratio (D/d) drops as the size of the framboidal pyrite and microcrystalline particles increases. The increased particle size of framboidal pyrite and

microcrystalline from the First Member to the Third Member, negatively correlated with the parameters of trace elements such as V/Cr, Ni/Co, and U/Th, indicates the gradually weakened reducibility from anoxic-sulfide environment to hypoxic environment, nevertheless the particle size of microcrystalline is more sensitive to redox conditions than that of framboidal pyrite. The pyrite content is positively correlated and the particle size of framboidal pyrite and microcrystalline is clearly negatively correlated with organic matter and adsorbed gas content, indicating that the anoxic sulfide environment is favorable for the enrichment of organic matter as well as the production, storage, and preservation of shale gas.

Key words: framboidal pyrite; paleoenvironment; Longmaxi Formation; Weiyuan-Rongxian Area

Study on porosity of shale oil system with different petrographic characteristics and its influencing factors

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Abstract

Shale, as a major reservoir for shale oil and shale gas systems, has been the subject of many studies focusing on petrophysical analyses including porosity, permeability and pore size characteristics. These data are important for assessing shale resource potential, but the matrix pore structure of shale reservoirs is difficult to characterize because a large fraction of the total matrix porosity may be distributed in nanopores associated with organic matter and clay minerals. With the development of extraction techniques, the focus on basic organic matter lithological characteristics has diminished. Few published articles have been written about the combination of petrological and geochemical parameters in lake-phase shale oil systems, which has left the basic mechanisms of hydrocarbon storage and hydrocarbon release from hydrocarbon source rocks unappreciated.

In the Jiyang depression of the Bohai Bay Basin, shale oil is considered to be a very important resource. Against the background of the inadequacy and inaccuracy found in the past in evaluating shale oil from geochemical characteristics alone, the

study of this topic can deepen the understanding of shale oil micro-components and physical parameters, and provide a theoretical basis for the evaluation of shale oil resources and oil and gas exploration. In this paper, shale oil samples of different lithologies were analyzed in terms of petrographic classification, total organic carbon, pyrolysis, and helium permeability determination.

By observing a large number of oil-bearing shale samples under transmitted light, reflected light, and fluorescence under an optical microscope, eight petrographic phases (A-H) were classified according to the criteria of lithology, the presence or absence of grain layer, the difference in hydrocarbon storage mode, and the mineralogical composition, etc., and all but four representative samples were selected for the subsequent pyrolysis analyses and porosity measurements for subsequent discussions.

microscopic petrography	Petrographic characteristics	Hydrocarbon deposition modes
A	Vague lamination, Lime Mudstone or Argillaceous Limestone	Hydrocarbons are stored in matrix state, with a few intra -formational microfractures
B	Clear lamination, Higher clay content than calcium content	Hydrocarbons are dominated by karogen organic matter adsorption, followed by interlayer fracture filling
C	Clear lamination, Higher calcium content than clay content with smaller calcium grain	Filling in interlayer cracks
D	Clear lamination, Higher calcium content than clay content with larger calcium grain and good crystallization	Predominantly hydrocarbons in intergranular pores, more hydrocarbons in interlayer fractures
E	Clear lamination, coarse and fine calcite grain interlayers	Mainly in the coarse calcite grain layer, based on the adsorption of mineral particles on the lipophilic surface and intergranular pore filling
F	Clear lamination, calcite vein contained	Hydrocarbons are stored in calcite vein ： Hydrocarbons dominated by intergranular pores
G	Clear lamination, with bioturbation phenomena	Hydrocarbons in matrix state and fracture -filled hydrocarbons predominate
H	limestone	Less hydrocarbons , fracture filled hydrocarbons, calcite intergranular pore filled hydrocarbons, and hydrocarbons adsorbed on the surface of oleophilic mineral particles
I	Mudstone with gypsum, or lime mudstone with gypsum	Intergranular pores filled with hydrocarbons

Fig. 1 Summary of the 8 different classified microscopic petrography and their characteristics

Through the Rock-Eval and porosity measurements, the data were analyzed and used to discuss the factors affecting the porosity of the shale oil system, which are a) the microphase and petrographic phase of the different rocks themselves: more specifically, the state of hydrocarbon accumulation, i.e., hydrocarbons in the form of matrix accumulation, i.e., the porosity of the shale oil system in petrographic phase A is relatively larger; b) the total organic carbon (TOC) content: generally, the larger the TOC content is, the greater the porosity of its shale oil system is ; c) depth and maturity: the deeper the depth, the greater the maturity, the greater the total porosity.

Number	Bed	TOC	Type	φ_{S1}	(Φtotal)
LY1-1	Es4	2.43	A	1.45	7.07
L67-8	Es3	4.39	A	0.81	4.61
L67-15	Es3	1.64	C	0.67	2.14
NY1-19	Es4	2.11	A	0.66	2.53

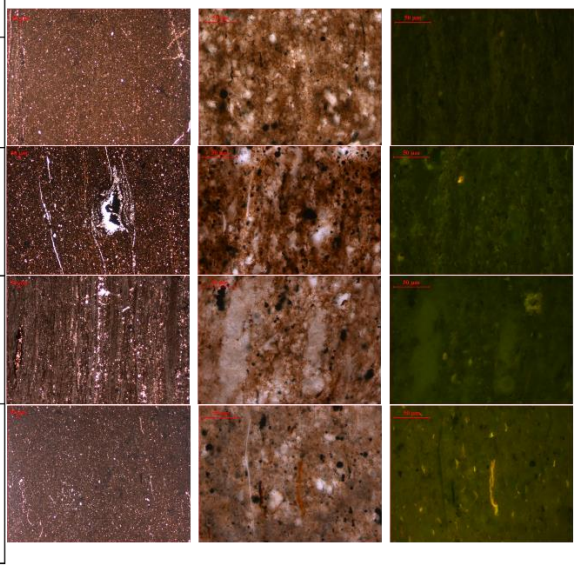

Fig. 2 The result of Rock-Eval and the porosity measurement, combined with their own micro-petrographic phase

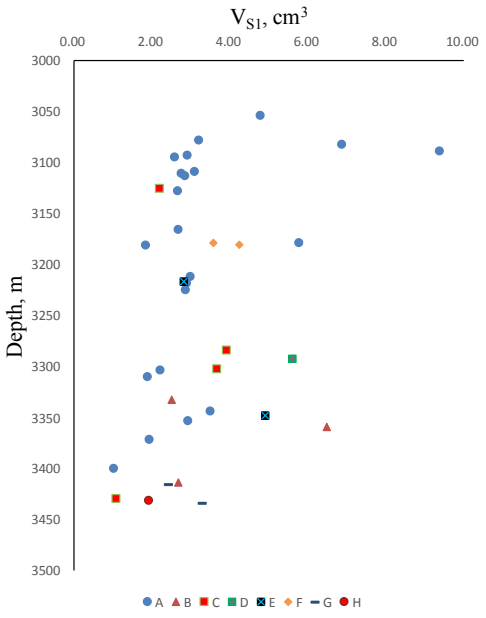

Fig. 3 Take FY-1 as an example, the volume of free hydrocarbons distributed by lithology

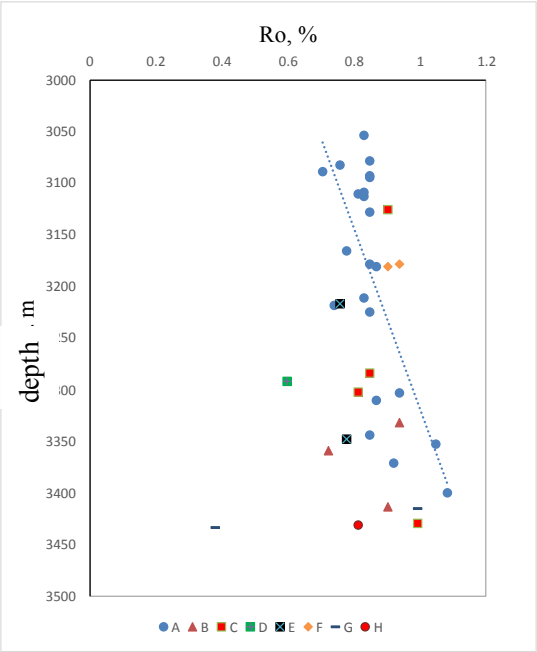

Fig. 4 Take FY-1 as an example, the Ro deduced from the formula

Key words: Bohai Bay Basin; Porosity; Microfacies

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Discovery of algal biosphere in shale oil reservoir of Qingshankou Formation in Gulong Sag and its significance

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Abstract

Shale oil and gas is the current exploitation resources at home and abroad, which has attracted wide attention. The exploration and development of shale oil and gas started late in our country, so there are many problems. Daqing Gulong Sag is rich in shale oil and gas, with resources up to 15.1 billion tons. But at present, many basic geological problems are still unclear, which troubles the exploration and development. Recent studies have found that a good algal biosphere is developed in the shale oil reservoir of Qingshankou Formation in Gulong Sag.

Fig. 1

Multiple geochronology and geothermometers constraint on thermal history: novel insights into the petroleum generation, accumulation and preservation condition of Ordos Basin, North China

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Abstract

Reconstructing the thermal history of petroliferous basins is of vital significance in petroleum exploration, as this evolution history controls petroleum generation and accumulation history in the basin. The Ordos Basin has excellent petroleum exploration prospects, which is one of the large petroliferous sedimentary basins in China. However, the thermal history and it controls on petroleum generation, accumulation and preservation conditions in the basin are unclear. In this work, we integrated multiple

geochronological (carbonate U-Pb dating, AFT/ZFT, K/Ar-Ar dating) and geothermometers (carbonate clumped isotope $T_{\Delta 47}$, vitrinite reflectance (*R*o), AFT/ZFT and fluid inclusions micro-thermometry) to reconstruct thermal history. The calcite U-Pb dating results suggest that the basin might experience four hydrothermal fluid actives at 455±14 Ma (MSWD=13), 245.8±4.1 Ma (MSWD=0.2), 178±13 Ma (MSWD=3.0) and 108±31 Ma (MSWD=3.3). The fault movement and related regional heat flow were the major controls on the thermal and fluid-flow actives at the 455 Ma, 245.8 Ma and 178 Ma, which have little effects on the large-scale petroleum generation. A large-scale tectono-thermal event occurred at the End-Early Cretaceous (110−100 Ma) result into the formation of 108 Ma calcites, which was controlled by lithospheric extension, destruction and thinning. This End-Early Cretaceous event led to the highest paleo-temperatures and thermal maturities and coeval with the peak period of petroleum generation and accumulation. Low temperature thermochronology suggest that the Ordos Basin has undergone rapid and large scale uplift and experienced tectonic overprinting that was strong in the basin margin and weak in the inner part of basin. The strongest overprinting occurred in the southwestern basin. The southern basin experienced a rapid uplift since 40 Ma that could rejuvenate the fault active at 32.8 Ma to 23.7 Ma. The erosion rate was 0.067 mm/y during the ~9 Myr period from 32.8 Ma to 23.7 Ma in the southwestern Ordos Basin. This would activate the Cenozoic faulting, destroy the petroleum reservoir and make the petroleum preservation conditions worse in the southwestern Ordos Basin. These Cenozoic faulting might provide a permeable leakage pathway for petroleum release into the atmosphere. Since the large scale uplift and denudation started at the end of the early Cretaceous, and fault slip may initiate without mineralization (or with no successfully sampled and dated calcite), we can estimate that the petroleum leakage was initiated at or before 32.8±3.3 Ma. In addition, the accelerated uplift and exhumation since 10 Ma to 5 Ma would lead to faulting, which has continued to the present, with slip rates ranging from 0.5 mm/year to 1.0 mm/year. This suggested that the petroleum leakage event could continue after 23.7±7.4 Ma. This work shed light on understanding the petroleum generation, accumulation and preservation condition from a novel thermal perspective, and provide important insights into future petroleum exploration in the Ordos Basin.

Comparison of two sets of source rock organic matter sources and their development control factors in the Permian system of Qimigan profile in southwest Tarim Basin

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Abstract

The Permian source rocks of the Qimeigan profile in the southwest area of Tarim Basin exhibit excellent development and possess significant oil generation potential (Kang et al., 2018). However, there is limited understanding regarding the organic matter sources and developmental influencing factors of the Permian source rocks P_1q and P_1k (Xiao et al., 2002). In order to investigate the disparities in organic matter sources and their controlling factors in the Permian P_1q and P_1k source rocks of the Qimeigan profile in the southwest region of the Tarim Basin, a total of 34 samples were collected (26 samples of P_1q source rocks and 8 samples of P_1k source rocks). A comprehensive study encompassing basic geochemistry, organic petrology, and elemental geochemical analysis was conducted to explore the source characteristics of organic matter and the factors influencing source rock development. The results indicated that the organic matter in the Permian P_1q and P_1k source rocks of the Qimeigan profile originated from higher plants. Elemental geochemical analysis

revealed that the controlling factors for the development of P_1q and P_1k source rocks differed in terms of paleosalinity, paleoclimate, original productivity, and redox conditions.

(1) The climate index "C" of the CIA and the Sr/Cu climate index indication suggest that the paleoclimate during the deposition of P_1q showed a semi-arid to semi-humid climate change, while the paleoclimate during the deposition of P_1k source rock was warm and humid (Fig1).

(2) The paleosalinity indexes Sr/Ba and B/Ga indicate that the sedimentary water environment of P_1q source rock changed from brackish water to salt water, while the environment of P_1k source rock sedimentary water changed from freshwater to salt water (Fig2).

(3) The paleoproductivity indexes Cu/Al, Ni/Al, and Zn/Al show that the original productivity of P_1q source rock was higher than that of P_1k source rock (Fig3).

(4) Redox indexes such as V/(V+Ni) and Th/U indicate that the water bodies during the sedimentary period of P_1q and P_1k source rocks were both reducing environments, but the reducibility of P_1k sedimentary water was stronger than that of P_1q .(Fig4)

This study analyzes the differences between Permian source rocks P_1q and P_1k in the southwest margin of the Tarim Basin through comprehensive petrology and geochemistry comparison. It provides fundamental experimental data for further detailed evaluation of the resource potential of Permian source rocks in the southwest Tarim Basin, which is expected to support petroleum geological exploration in this area.

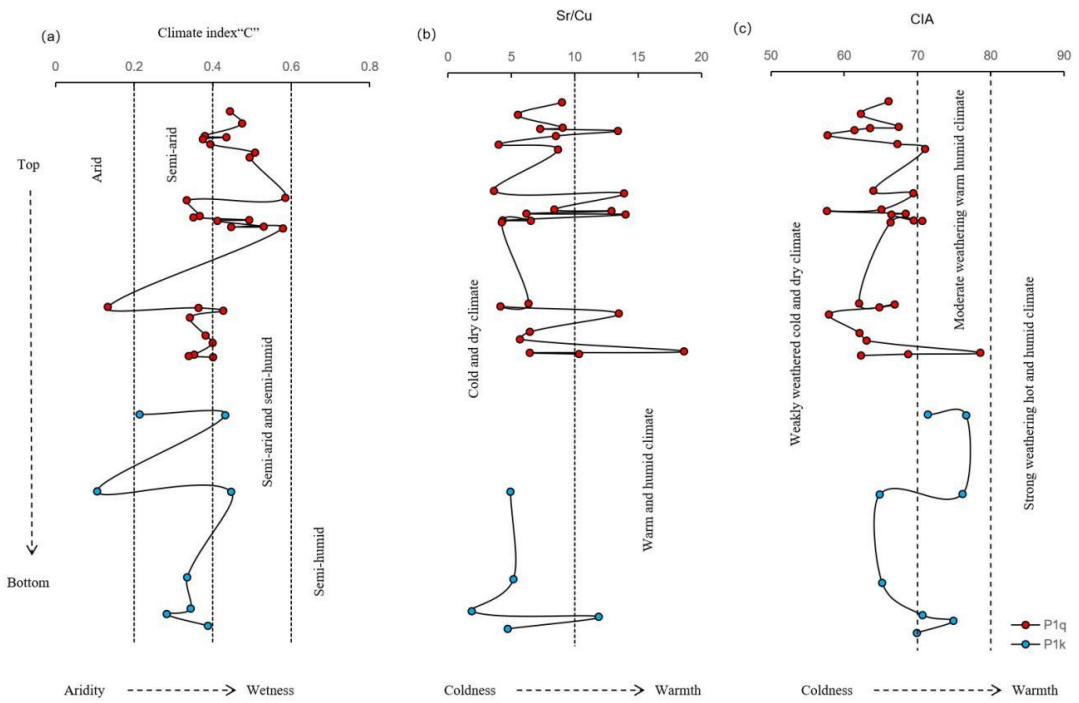

Fig. 1 Permian P_1q and P_1k paleoclimatic map of the Qimigan profile in southwest TarimBasin

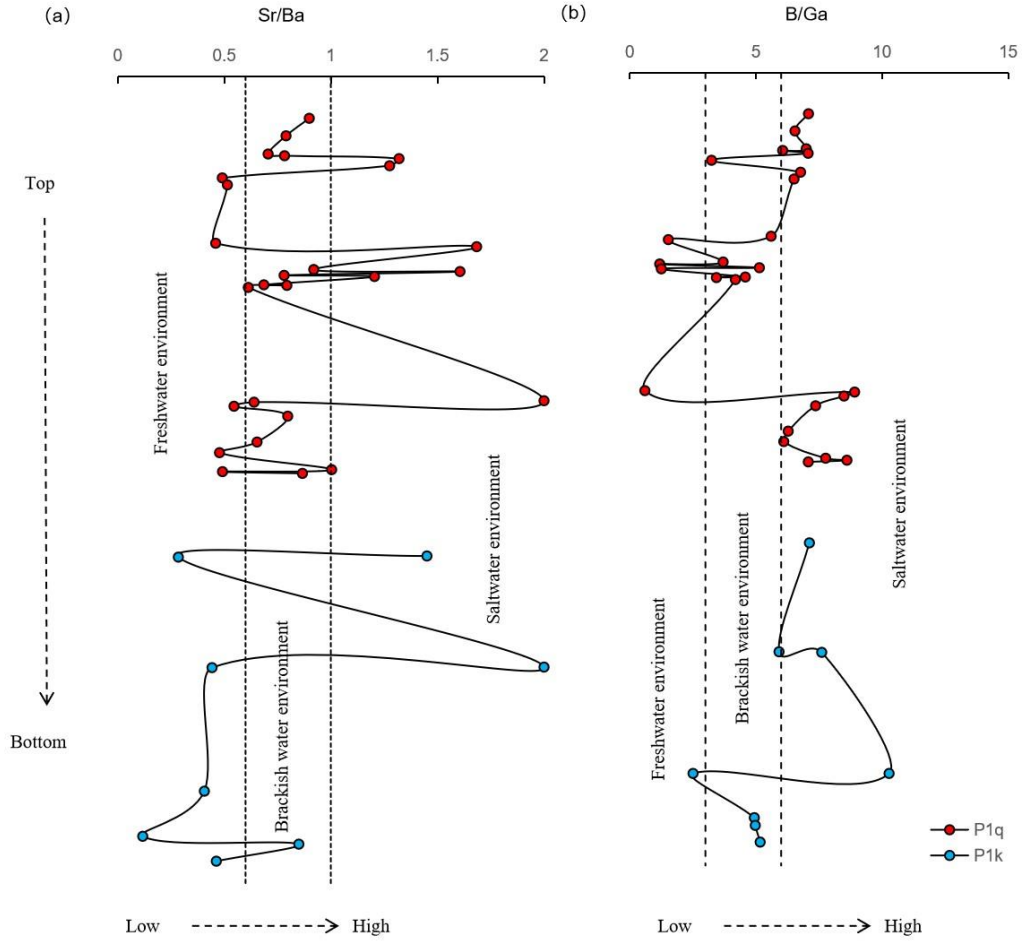

Fig. 2 Paleosalinity changes of Permian source rocks P_1q and P_1k in the Azimekan profile in southwest Tarim Basin

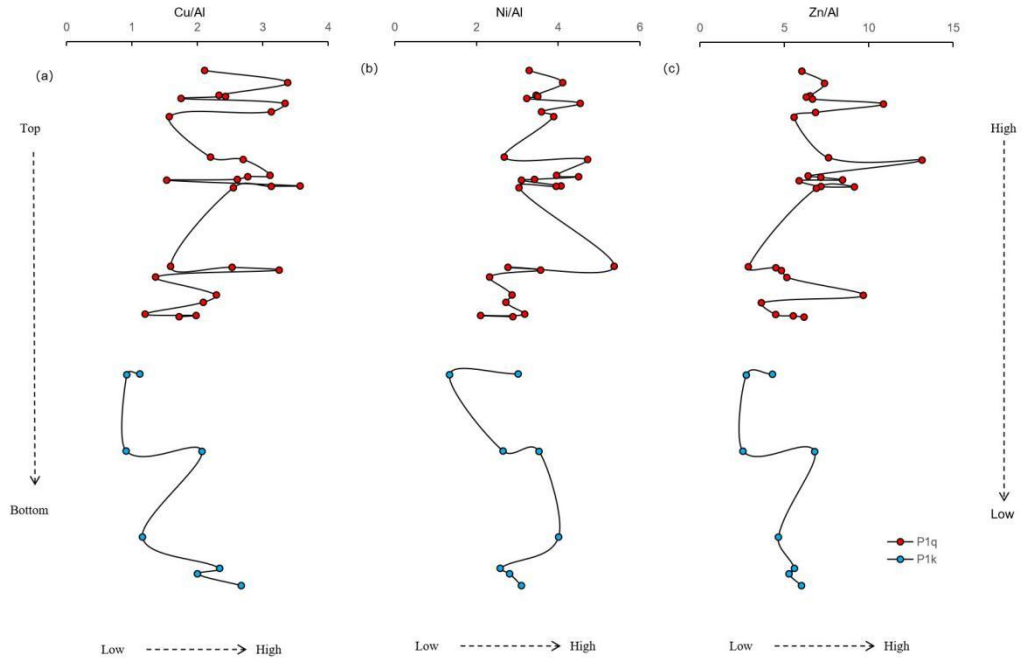

Fig. 3 Changes in paleoproductivity of Permian source rocks P_1q and P_1k in the Qimigan profile in southwest Tarim Basin

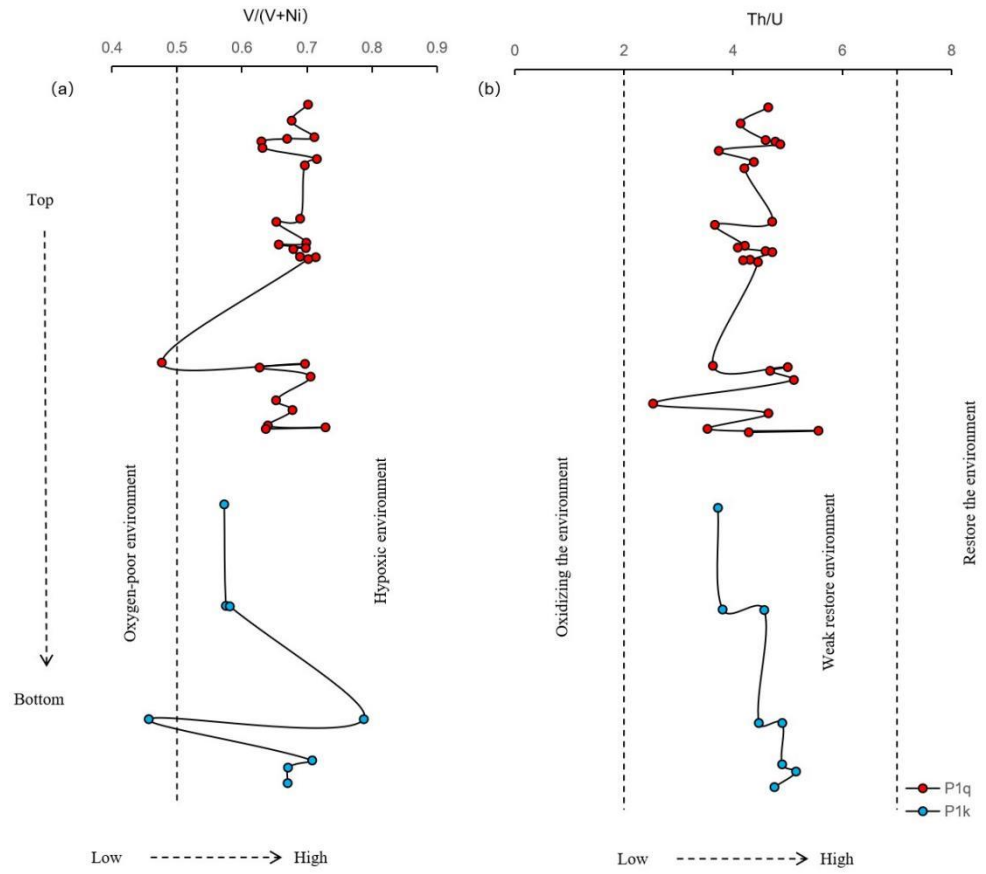

Fig. 4 Environmental changes of P_1q and P_1k source rocks in the Qimigan profile of the southwest region of the Tarim Basin

Key words: Source rocks; Chimeigan profile; Organic petrology; Geochemistry; Master trace

elements

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Source Rock Formation Mechanisms at Depths greater than 10,000 Meters in the Craton Basins of China

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Abstract

The Neoproterozoic-Cambrian is an important period of Earth's biological evolution and environmental change, highlighted by remarkable major geological events, such as the Neoproterozoic snowball Earth, the deposition of cap carbonate, the extreme negative carbon isotope excursion, and the Cambrian Explosion. During this period, three sets of globally distributed organic-rich black shales were deposited, which were important source rocks and material basis for oil and gas exploration at depths greater than 10,000 meters. With the discovery of high-quality source rocks formed during the Nanhua (Cryogenian) interglacial period, we revealed the mechanisms of biological recovery and organic matter accumulation under the warming conditions during the interglacial period by nitrogen isotopes. Hydrothermal activity and interglacial water exchange can play an important role in the organic matter accumulation of the underlying manganese-bearing interval. This research also demonstrated the control of highly stratified redox conditions of the Ediacaran on the formation of high-quality source rocks. The different interpretations for forming the cap carbonate rocks may reflect the global or local marine environmental anomalies following the Snowball Earth glacial period. Copper, zinc, iron, lithium and other isotopes have unveiled the presence of Early Cambrian transgression events and oceanic redox conditions dominated by continuous ferruginous and intermittent sulfidic conditions, and their impacts on the high-quality Lower Cambrian source rocks. The formation mechanism of source rocks has been established. The accumulation of

organic matter is mainly controlled by terrigenous weathering input, upwelling water, submarine hydrothermal, anoxic water and high paleo-marine productivity.

Substrate lithification in early Cambrian carbonates triggered by intense bioturbation

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Abstract

Burrowing organisms in the early Cambrian are well known for disturbing the microbial-mat-dominated seafloor present at the time, promoting the cycling of nutrients and oxygen and mixing the substrate. Here we provide new insights into the capacity of bioturbation to modify substrates in the Cambrian. Dense, morphologically complex burrows (*Balanoglossites*) with thick diagenetic halos are manifest at several horizons (ranging from 10 to 160 cm in thickness) in the Houjiashan Formation, Cambrian Stage 4 of North China. Fragmented burrows and their irregular diagenetic halo recovered from these horizons, and synsedimentary fracturing constraining in their halo indicate early and preferential lithification of the sediments immediately adjacent to the burrow margins. Using quantitative techniques, along with micro-X-ray fluorescence mapping of trace fossils and their associated halos, we identify that erosional surfaces or lithified substrates are coupled with high levels of bioturbation and diagenetic halo volume. This suggests that such burrows possess the capacity, in particular environments and in suitable concentration, to facilitate the gradual

lithification of the soft substrate and to transform the substrate into a firmground or even an incipient hardground by the increasing intensity of bioturbation and their associated halos.

Early Cambrian paleo-marine environments indicated by iron isotope in the Tarim Basin, China

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Abstract

The Ediacaran to Cambrian period is generally considered to be the vital transition in the history of marine redox environment and life evolution on earth. The ocean oxygenation levels during this transition period are still debated in spite of abundant reports of geochemical data. Since iron is widely involved in biogeochemical cycles and undergoes redox cycling both in the seawater and sediments, it has become a significant proxy to reconstruct paleo-marine environment. However, the iron isotopes recorded during the transition period from Ediacaran to Cambrian is insufficient and most of them in previous studies focus on the south China. In order to constrain the paleo-marine redox state in the early Cambrian and provide supplementary data in other area, the iron isotope composition of bulk rock (δ56FeT) is interpreted combining with iron-speciation, redox sensitive elements (Mo, U and V) and pyrite sulfur isotope (δ34Spy) of Yuertusi Formation in Tarim Block. The bulk rock of iron isotope composition is determined by different mineral phases and is mainly controlled by pyrite mineral facies in this study. Based on the mechanism of pyrite generation in different redox condition and corresponding iron isotope fractionation, it is proposed that the paleo-marine environment of the lower Cambrian in the Tarim basin is dominated by anoxic with intermittent euxinic state. The dynamic evolution of redox environment can be divided into three intervals. In summary, the paleo-marine environment of the lower Cambrian Yuertusi Formation in XK1 well evolved from anoxic ferruginous to euxinic and then oxidized continuous. Iron isotope statistics from

geological historical periods indicate that seawater was relatively oxidized after the NOE event but did not reach the oxidation levels of present-day seawater.