Geochemical Characteristics and Source Identification of Oil in Block M, Junggar Basin

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Abstract. Block M in the central area of the Junggar Basin holds abundant shallow oil and gas resources with enormous exploration potential. However, exploration practices have indicated the presence of multiple sets of hydrocarbon-rich source rocks in Block M, making it difficult to identify the sources of oil and gas in the Cretaceous strata, which in turn affects future exploration directions. To address this issue, geological data, on-site samples, and experimental tests were utilized to analyse the physical and chemical components, carbon isotopic characteristics, and biomarker compounds of the Cretaceous strata in Block M. The results are as follows: (1) Block M primarily contains two sets of hydrocarbon source rocks from the Jurassic and Permian periods, with biogenic oil as the main type; (2) The API gravity of the crude oil ranges from 38.0 to 56.6, with an average of 44.0, and the gas-oil ratio ranges from 139.0 to 5044.0 m^3/m^3, with an average of 2274.5 m^3/m^3, indicating that the crude oil is predominantly light condensate; (3) The carbon isotopic values of the crude oil are relatively low, with an average of -30.4‰, suggesting a source primarily from sapropelic materials. The abundance and arrangement of biomarker compounds indicate that the oil originates from the Permian source rocks. This study provides valuable guidance and reference for comparative studies on oil and gas accumulation in areas with similar geological characteristics.

Keywords: Geochemical characteristics; Oil-source; Permian source rocks; Block M; Junggar Basin.

1 Introduction

As exploration and development continue to deepen, the Junggar Basin has become the primary battleground for oil and gas exploration, storage enhancement, and production in western China.in western China. Currently, in the middle and shallow layers, significant oil and gas fields such as Shixi, Shinan, Luliang, and Mosuowan have been discovered, demonstrating immense exploration potential. Block M, located in the central part of the Junggar Basin, mainly contains oil and gas reservoirs from the Permian and Cretaceous strata. However, most research has focused on the tectonic mechanisms and distribution patterns of the Permian reservoirs, while the study of oil and gas in the

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Cretaceous strata, especially regarding their sources, is lacking. This gap seriously hampers the development of oil and gas exploration in the study area. In recent years, with increasing discoveries of oil and gas in the Cretaceous strata, the importance of oil sources has been recognized. Wang et al. concluded from a comprehensive comparison of crude oil sources in the central Junggar Basin that some of the oil in Block M comes from Permian source rocks, while the majority originates from Permian source rocks [1]. Chen et al. analyzed the geochemical characteristics of oil and gas in the central Junggar Basin and suggested that the oil and gas in Block M primarily come from Permian source rocks, with a possible contribution from Carboniferous source rocks [2-3]. Further studies by Kuang et al. and Ma et al. indicated that the oil sources come from various Permian source rock layers [4-6].

To address the above issues, this study conducts a comparative analysis of the physical properties, geochemical composition, individual hydrocarbon carbon isotopes, and biomarker characteristics of the crude oil in Block M to explore its origin and reveal the laws of oil and gas accumulation, providing valuable references for the overall evaluation and optimization of exploration targets in the study area.

2 Geological Background

Block M is located in the central depression of the second-level tectonic unit, Mosuowan uplift, in the Junggar Basin (Figure 1). It is bordered to the east by Dongdaohaizi sag, to the west by wellbore 1 in the Xi sag, to the south by Fukang sag, and to the north by Mobei uplift, forming a typical depression-anticline configuration [7-8]. Vertically, the study area mainly consists of two sets of Permian and Cretaceous source rock layers [9-10], providing abundant material basis for oil and gas accumulation.

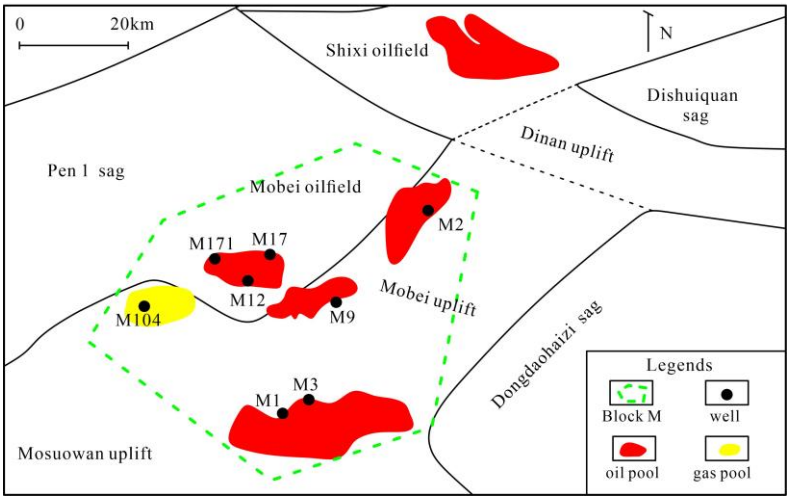

Fig. 1. Location of Block M in the Junggar Basin

2.1 Permian Source Rocks

The Permian strata is the most significant source rock formation in the Junggar Basin, primarily characterized by sapropelic type organic matter. The micro-components mainly consist of sapropelic and calcareous components. The organic carbon content ranges from 0.4% to 4.1%, with an average of 1.4%. The organic matter maturity ranges from 0.8% to 1.5%, indicating a mature to high-mature stage, which is conducive to the abundant generation of oil and gas.

2.2 Jurassic Source Rocks

The Jurassic strata have a wide depositional range and thickness in the study area. The primary type of organic matter is humic. Micro-components mainly include humic and inertinite components. The organic carbon content ranges from 0.5% to 2.0%, with an average of 1.4%. The organic matter maturity mainly ranges from 0.5% to 0.8%, indicating a low maturity stage, resulting in relatively lower oil and gas generation.

3 Data and Methods

3.1 Data collection

The experiment collected 10 samples of crude oil and 7 samples of source rocks. The samples were collected from Block M in Junggar Basin.

3.2 Methods

The physical properties of the crude oil, including density and gas-oil ratio, were tested according to the standard GB/T 1884-2000 "Laboratory Determination of Density of Crude Oil and Liquid Petroleum Products" for density measurement and GB/T 6534-1986 "Gas-Liquid Ratio Determination Method for Gasoline" for gas-oil ratio measurement. Isotope determination was performed using a DELTA PLUS V stable isotope mass spectrometer (model YQ3-12-13), following the standard GB/T 18340.2-2010 "Methods for Organic Geochemical Analysis of Geological Samples - Part 2: Stable Carbon Isotope Determination by Isotope Ratio Mass Spectrometry." Saturated hydrocarbon gas chromatography-mass spectrometry analysis was conducted using a 5977B gas chromatography-mass spectrometer (model YQ3-18-01), following the standard GB/T 18606-2017 "Gas Chromatography-Mass Spectrometry Method for the Determination of Biomarkers in Sediments and Crude Oils." All experimental analyses were performed in the Geochemistry Laboratory at Yangtze University.

4 Results and Discussion

The API gravity is a standard used to categorize crude oil based on its density. Generally, crude oil with an API gravity of less than 10 is considered extra heavy, between

10 to 22.3 is heavy, between 22.3 to 31.1 is medium, and greater than 31.1 is considered light. The density test results for crude oil in Block M indicate that the API gravity ranges from 38.0 to 56.6, with an average of 44.0, suggesting it consists mainly of light crude oil. Additionally, the gas-oil ratio test revealed a range of 139.0 to 5044.0 m^3/m^3, with an average of 2274.5 m^3/m^3, indicating that the crude oil is predominantly light condensate (Table 1). These results suggest that the crude oil in Block M is likely derived mainly from deep source rocks, with a minor contribution from shallow source rocks.

Table 1. Crude oil physical properties of Block M

Sample	Depth/m	API	GOR/m^3/m^3
1	4176.8	54.6	3230
2	4178.5	42.2	327
3	4211.5	56.2	5044
4	4232.5	31.8	2993
5	4232.0	34.8	3758
6	4235.8	37.1	139
7	4239.3	33.7	898
8	4253.5	56.6	385
9	4252.5	55.2	4512
10	4251.3	38	1459

The distribution of carbon isotopes in crude oil corresponds to the type of organic matter in the source rocks [11,12]. Generally, humic organic matter has higher carbon isotope values, while sapropelic organic matter has lower values. The analysis of stable carbon isotopes in the crude oil from Block M shows relatively low values, with an average of -30.4‰, indicating a dominant contribution from sapropelic organic matter, which is similar to the type found in Permian source rocks.

The abundance and arrangement of regular steranes (biomarker compounds) provide valuable indications of whether the source is derived from higher plants [13]. By comparing the characteristics of biomarkers (regular steranes) in the crude oil from Block M with those in Permian and Jurassic source rocks, it is evident that Permian source rocks exhibit a typical pattern of $C_{27}>C_{29}>C_{28}$, with the arrangement forming a "V" shape, indicating a predominance of humic organic matter. On the other hand, Jurassic source rocks show a typical pattern of $C_{29}>C_{27}>C_{28}$, forming an inverted "Λ" shape, indicating a predominance of humic organic matter. The analysis of biomarker characteristics in the Cretaceous crude oil shows a similar pattern to Permian source rocks, also exhibiting a "V" shape, indicating that the Cretaceous crude oil in Block M is primarily derived from Permian source rocks rather than Jurassic source rocks (Figure 2).

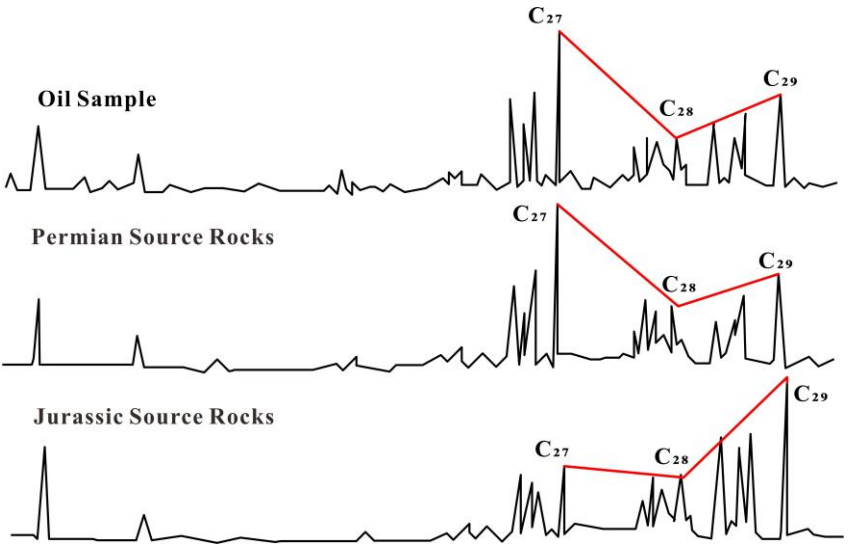

Fig. 2. Biomarkers characteristics of oil sample, Permian and Jurassic source rocks

5 Conclusion

Block M in the Junggar Basin holds abundant oil and gas resources in the Cretaceous strata, demonstrating significant exploration potential. The main hydrocarbon source rocks in Block M are from the Permian and Jurassic periods, characterized by sapropelic and humic organic matter, respectively. The average API gravity of crude oil in Block M is 44.0, and the average gas-oil ratio is 2274.5 m^3/m^3, indicating that the crude oil is primarily composed of light condensate. The carbon isotopes and biomarker fingerprinting of the crude oil suggest that the Cretaceous oil in Block M mainly originates from Permian source rocks.

In the next phase, it is essential to focus on a detailed evaluation of the Permian effective source rocks and assess their resource potential to expand oil and gas exploration in the middle and shallow layers, providing guidance for future exploration directions. Besides, we can use artificial intelligence and big data to establish a decision-making platform for oil and gas exploration, and realize digital and intelligent oil and gas resource exploration.

Acknowledgments

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