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Retraction

Retracted: Geochemical Characteristics of Crude Oil in Member 7 of Yanchang Formation in Yanchang Oilfield

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This article has been retracted by Hindawi following an investigation undertaken by the publisher [1]. This investigation has uncovered evidence of one or more of the following indicators of systematic manipulation of the publication process:

(1) Discrepancies in scope

(2) Discrepancies in the description of the research reported

(3) Discrepancies between the availability of data and the research described

(4) Inappropriate citations

(5) Incoherent, meaningless and/or irrelevant content included in the article

(6) Peer-review manipulation

The presence of these indicators undermines our confidence in the integrity of the article's content and we cannot, therefore, vouch for its reliability. Please note that this notice is intended solely to alert readers that the content of this article is unreliable. We have not investigated whether authors were aware of or involved in the systematic manipulation of the publication process.

Wiley and Hindawi regrets that the usual quality checks did not identify these issues before publication and have since put additional measures in place to safeguard research integrity.

We wish to credit our own Research Integrity and Research Publishing teams and anonymous and named external researchers and research integrity experts for contributing to this investigation.

The corresponding author, as the representative of all authors, has been given the opportunity to register their agreement or disagreement to this retraction. We have kept a record of any response received.

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[1] W. Li, Z. Gao, Y. Wang, J. Pu, H. Cheng, and F. Theon, "Geochemical Characteristics of Crude Oil in Member 7 of Yanchang Formation in Yanchang Oilfield," *Journal of Chemistry*, vol. 2022, Article ID 2797655, 7 pages, 2022.

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Research Article

Geochemical Characteristics of Crude Oil in Member 7 of Yanchang Formation in Yanchang Oilfield

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Oil is an important primary energy for national production and life and national defense, and China is the key to rapid development. It is of great strategic significance to ensure the safe and efficient production of the oil industry. Yanchang Oilfield is located in the main position of oil and gas accumulation in Ordos Basin, China, and the seventh member of the Yanchang Formation is the area with the richest crude oil output at present. Studying the geochemical characteristics of its crude oil exploitation is of great engineering significance for the exploration of oil and gas content in similar terrain and the continuous improvement of oil extraction and refining technology. On the other hand, it also provides first-hand data and important technical references for the exploration and exploitation of oil and gas resources in other areas of the Ordos Basin. Firstly, this paper points out the important strategic significance of the petroleum industry for China's development, and briefly describes the basic situation of Yanchang Oilfield and the basic characteristics of crude oil. The power and diversion system of the Yanchang Formation in Yanchang Oilfield are studied, and the main factors of formation and flow of deep reservoirs in the Yanchang Formation are explored, as well as the regional geological survey of the Yanchang Formation No. 7 in Yanchang Oilfield. The characteristics of crude oil and its maturity evaluation system are emphatically discussed, and the changes in crude oil characteristics under the action of microorganisms are comparatively studied. In this paper, Yanchang Oilfield, the main reservoir area of the Ordos Basin, is taken as the research object, and the formation mechanism of the oil reservoir and the geochemical characteristics of crude oil in the 7th member of the Yanchang Formation are deeply explored, so as to provide a preliminary theoretical study for the research of crude oil exploitation in reservoirs and other oilfields in the Ordos Basin.

1. Preface

Oil, known as "industrial blood" and "black gold," is one of the most critical primary energy sources in the world. Although the concept of environmental protection is deeply rooted in people's hearts, with the increasing demand for energy from human development, the oil output will remain stable and rise in the future [1–3]. According to the information disclosure of British Petroleum, BP, the annual growth rate of global oil and gas in the recent ten years is about 8.17%. Oil has important strategic significance in the world, so the development of the oil industry is not only influenced by resources, market, technical level, and other factors but also interfered with by international political situation [4, 5].

After more than one hundred years of development, the petroleum system has formed a perfect industrial system and solutions to various engineering and technical problems and has spawned a series of supporting chemical and electric power industries and specialized talent training schools

[6, 7]. With the continuous progress of technology, unconventional oil and gas exploitation such as offshore oil and shale gas has also entered a new historical stage. China is rich in oil and gas resources, with a vast territory and abundant resources. There are more than 500 sedimentary basins including Bohai Bay Basin, Sichuan Basin, and Ordos Basin, which have formed a unique oil and gas distribution area [8–10]. Since the founding of the People's Republic of China, the revolutionary ancestors have worked hard for more than half a century. China has built a complete and independent oil industry system, fundamentally removed the hat of a poor oil country, and ensured national oil security [11, 12].

Yanchang Oilfield is located in Ordos Basin (Qilicun Township, Yanchang County, Shaanxi Province)-the eastern slope of northern Shaanxi. It has been the first well in China since 1907. The basement of the Ordos Basin is composed of Archean and Proterozoic metamorphic rocks, while the sedimentary cover is composed of middle-upper Proterozoic and lower Paleozoic marine carbonates [13–15]. In Cenozoic, Ordos Basin began to subside again (thickness about 50~100 m). Tight oil content in Ordos Basin ranks first in China, and it is predicted that its total amount is about $35\sim40\times10^8$ tons, while Yanchang Oilfield is located in the central and southern part of the basin, and its tight oil is mainly distributed in the western and southern exploration areas. Chang 6, Chang 7, Chang 8, and Chang 9 are the main development strata in tight oil, with an estimated total amount of about 3.7×10^8 tons [16–18]. Among them, the Chang-8 member lake basin is small and mostly swamped, and the lake generally presents a shallow water environment, with relatively flat terrain and a dry climate [19]. The sedimentary type of the lake is still mainly shallow lake delta, and the semideep area and deeper area are limited. The sixth member is mainly distributed in 50~70 m, and it is mainly the delta front deposit [20, 21]. The 7th member is mainly distributed in the range of 10~40 m, mainly oil shale and turbidite, and its auxiliary reservoir is a gravity flow turbidite fan, with a sand thickness of 5~25 m [22].

Oil is a viscous, colored, and odorous combustible in the liquid phase, but it is mainly composed of two elements carbon (C, content of about 83%~87%) and hydrogen (H, content of about 10%~14%), and some trace elements such as oxygen, nitrogen, and sulfur exist in the form of mixtures [23–25]. Its density varies greatly with temperature, and it is stipulated in China that its density is the standard density at 20°C [26]. When the temperature changes at 5°C, its variation curve can be linear locally, which can be described as $\rho 20 = \rho t + \gamma(t - 20^\circ\text{C})$, where $\rho 20$ is the density at 20°C (g/ml) and γ is the average temperature coefficient (g/ml) and the petrochemical structure is different, and its density also changes greatly [27]. For example, the density of aromatic hydrocarbon is much higher than that of alkane under the same number of carbon atoms, and the density is also affected by different producing areas (raw materials) [28–30]. The petroleum density of major producing areas in China is shown in Table 1.

The geochemical characteristics of crude oil are the direct reflection of reservoir address information. By studying the characteristics of crude oil in the 7th member of the Yanchang Formation in Yanchang Oilfield, the accuracy of underground rock structure research can be effectively proved [31–33]. At the same time, combined with reservoir description, the target oil production area can be accurately screened, providing reliable research data for the exploration and exploitation of tight oil and other oil and gas resources in the Ordos Basin, promoting the development of geological exploration and oil exploitation technology in China and helping the iterative updating of national oil and gas technology.

Table 1: Oil density of different producing areas in China.

Serial number	Place of production	Density (g/ml)	Type
One	Xinjiang Wuerhe	0.96	Heavy quality
2	Gaosheng of Liaohe River	0.96	Heavy quality
Three	Dagang Yangsanmu	0.94	Heavy quality
Four	Shengli Gudao	0.94	Heavy quality
Five	Liao	0.88	Mesoplasm
Six	Win	0.88	Mesoplasm
Seven	Grand Celebration	0.86	Light
Eight	Changqing	0.84	Light

2. Materials and Methods

2.1. Power and Diversion System of Extension Group. The hydrocarbon-generating capacity of source rocks is not only the material basis for the formation of oil and gas but also an important index reflecting the formation of organic matter content. Oil shale and mudstone are the main source rocks in the Ordos basin, and the current evolution degree is the peak stage of oil production. Influenced by many factors, such as crustal movement and groundwater dynamics, the stratum is in different states of deposition and compaction, and the deposition is unidirectional, so the pressure distribution of underground rock structure is unknown and complicated. According to the knowledge, the excess pressure in the Ordos Basin is in a "NW-SE" trend as a whole, with a pattern of "uplift-depression interaction" in the plane distribution. The main components of the western and southern rock formations are mudstone and oil shale, so the overall process pressure is also high. The parts of the Yanchang Formation with high excess pressure are all located on the slope where the source rocks are well developed. This geographical structure provides a prerequisite for the formation and multidirectional migration of oil and gas in the reservoir. The oil and gas in the reservoir are gradually transferred and accumulated into oil and gas reservoirs in favorable areas driven by the process pressure. Among them, the thick mudstone distribution in the central and western Ordos Basin is the main factor leading to the sudden change of pressure structure. In the vertical distribution, there is only an abnormal high-pressure distribution between Chang 7 and Chang 9 members. Chang 7~Chang 8 also have some abnormal high pressure in the north-south direction, so it is also a favorable area for oil and gas formation. The residual pressure of rock formation is the active power source for the accumulation and movement of oil and gas in the reservoir, and it is of great significance to explore its dynamic characteristics for the exploration of oil and gas resources.

According to the residual power of the underground reservoir, the oil and gas accumulation area is not the location of oil and gas generation but is formed by oil and gas generation and multiple movements to favorable positions. Therefore, to study the characteristics of oil and gas itself, it is necessary to consider the path of its reservoir underground diversion system, which is not only related to the formation pores of the reservoir underground sedimentary environment but also directly related to physical and chemical reactions such as dissolution and cementation. In the early stage of Ordos Basin formation, on the basis of the recovery of the permeability characteristics of the Yanchang Formation, the late superimposed action affected the formation of the present sand body distribution. Especially after the oil and gas movement, the existing reservoir gap will be enlarged, and residual substances will be left. With the accumulation and increase of substances, a solid structure with larger particles will be formed, and then the reservoir diversion system will be affected.

2.2. Main Factors of Deep Reservoir in Yanchang Formation. The formation of oil and gas reservoirs is influenced by many factors, among which the excess pressure of rock strata and strata movement are the most significant. The main function of the excess pressure of rock stratum is to form density space between reservoir-cap medium and surrounding rock wall, so as to seal oil and gas and change it into the present oil and gas reservoir through long-term underground pressure. However, the excess pressure of the rock stratum is one of the main factors for the formation of oil and gas reservoirs. According to the statistical law, we can compare and analyze the geological environment of oil and gas-rich areas, find their common characteristics and analyze their key factors, and finally get the distribution of oil and gas reservoirs in geological relations. On the one hand, by analyzing the proven areas rich in oil and gas, it is clear that the areas with higher excess pressure are richer in oil and gas reservoirs; On the other hand, oil and gas enrichment will be formed at the corresponding low-pressure funnel of two adjacent oil and gas-rich reservoir areas in areas with high excess pressure. It can be seen from the above analysis that the residual pressure has a certain influence on the formation and content of oil and gas reservoirs.

Paleotectonic factors are also one of the key factors for the formation and enrichment of oil and gas, and its structural high point value is the key representation that directly affects the degree of oil and gas enrichment. Wuchangpu block of Yanchang Oilfield is a typical case of a paleotectonic-controlled reservoir, and its high-productivity well (Well Wu 45#) belongs to the paleotectonic high point value in the Early Cretaceous. At the same time, well Wu 9#, a high-yield well located in the same location as well Wu 45#, is found to have normal excess pressure, so it can be concluded that the excess pressure is not the only factor for the formation of oil and gas reservoirs, nor is it the main control factor here. Paleostructure plays a key role in oil and gas migration from the aspect of geographical profile and can ensure oil and gas communication horizontally.

The above-mentioned two major factors of reservoir formation have been explained, and there is a third type of reservoir-"excess pressure-paleostructure" double-acting type in the proven reservoirs, which is jointly acted by the two factors. Its characteristics are as follows: (1) excess pressure, as the power source of oil and gas movement, drives oil and gas to flow in the reservoir; (2) the flow direction is the structural high point of paleostructure rather than the pressure low point of "excess pressure reservoir"; (3) oil and gas flow to the closed circle with the highest structural value of paleotectonic point to form oil and gas reservoirs. Songshan oil area and Danba 446 well area in Yanchang oilfield belong to this kind of oil reservoir, but due to the double factors, there is some oil-water mixing in this oil area, which brings difficulties to crude oil exploitation.

2.3. Geological Survey of Yanchang Group 7 Area in Yanchang Oilfield. Ordos Basin, where Yanchang Oilfield is located, belongs to the central part of northern China, and its status is described as E106 20′~E110 30′, N34 00′~N41 30′, with a large administrative span (Shaanxi, Gansu, Ningxia, and Jinmeng). Structurally, it belongs to a large depression area in North China, and the present Ordos Basin is a residual basin after multistage reconstruction. Based on rock density and magnetism, it can be divided into six structural units, which are as follows: (1) Northern Shaanxi Slope; (2) Tianhuan depression; (3) West Shanxi fold belt; (4) thrust belt in the western margin; (5) Yimeng uplift; (6) Weibei Uplift, Yanchang Oilfield studied in this paper is located in the northern Shaanxi slope structural belt, which belongs to the main body of oil and gas accumulation in the basin. Figure 1 shows the distribution of the Ordos Basin and its neighboring Mesozoic and Cenozoic basins. The development of the Yanchang Formation has gone through five stages, among which the first stage is the oil layer (thickness 250~350 m) corresponding to Chang 10 at the bottom. As the initial stage of the lake basin, it is mainly composed of coarse-grained rocks such as feldspathic sandstone, which is flesh-red in color and mixed with mudstone layers. The second stage corresponds to the oil layers of Chang 9 (80~110 m) and Chang 8 (75~90 m), with large-scale delta deposition; The third stage is the main stage of development, including 7 segments, 6 segments, 4 segments, and 5 segments, the thickness of which is about 110~130 m at the sixth segment, and about 80~90 m after entering the fourth segment and 5 segments. The fourth stage consists of the Chang 2 oil layer (90~110) and the Chang 3 oil layer (120~1500). The lido of the Chang 3 oil layer is relatively small, while the Chang 2 oil layer is coarser. The fifth stage is corresponding to the oil layer (0~240 m) of Chang-1 member, which is affected by extensive weathering, and the lakes gradually disappear to form swamps, and carbonaceous mudstone gradually develops.

3. Results

3.1. Composition and Maturity Evaluation of Crude Oil. Figure 2 shows the composition of crude oil. Crude oil is a mixture of organic matter, including the corresponding normal alkanes, which were acyclic sort defensibly diene

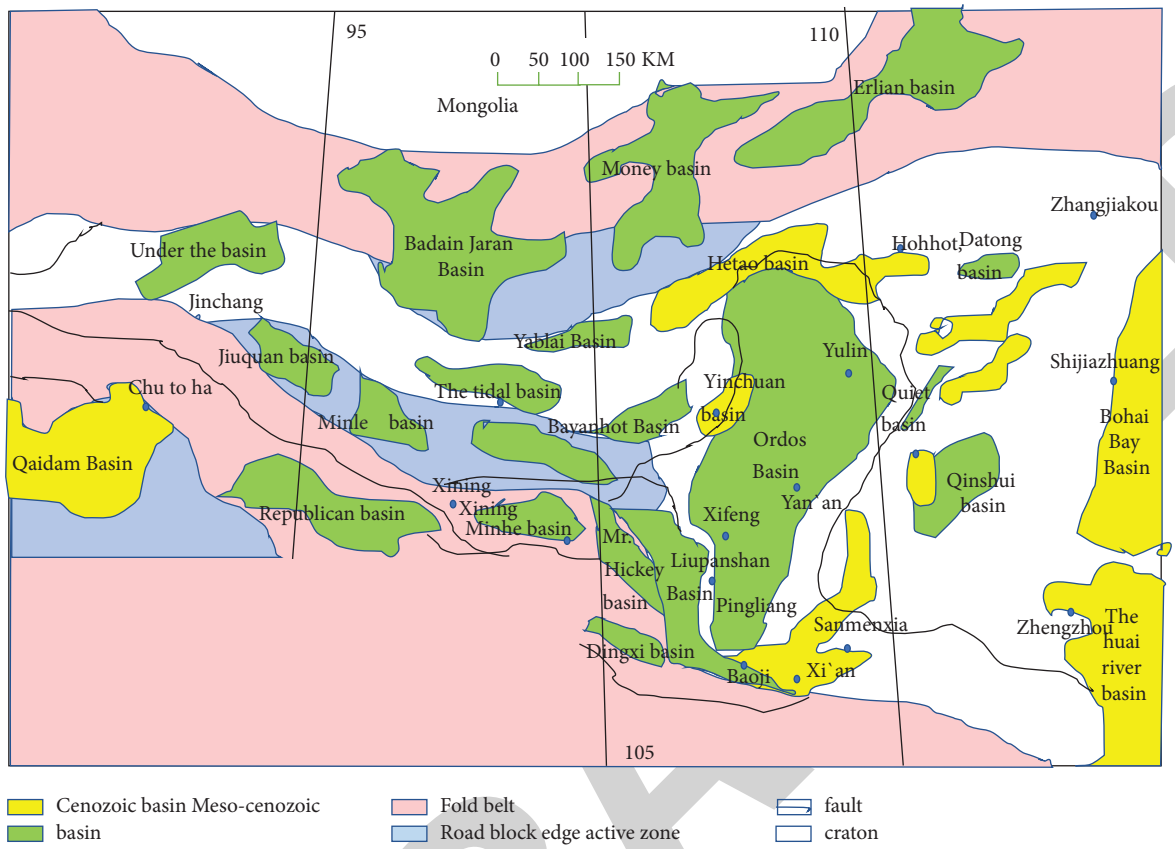

Figure 1: Distribution map of Ordos basin and its neighboring Mesozoic-Cenozoic basins.

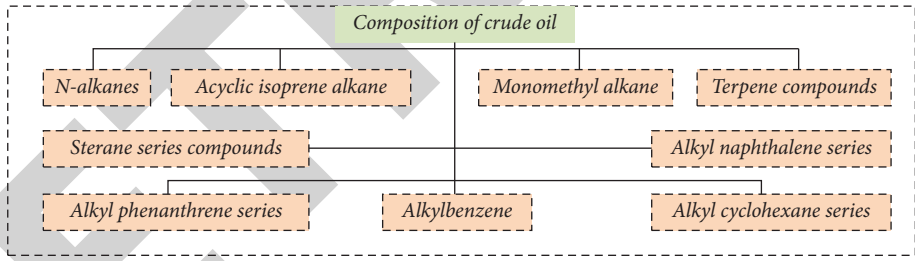

Figure 2: Composition of crude oil.

alkanes, single methyl alkanes, sterane, and terpene series compounds, alkyl benzene, alkyl naphthalene series, alkyl phenanthrene series and so on the many kinds of organic matter, according to the different proportion of different organic matter composition, crude oil also presents various characteristics. The hydrocarbons with the highest content in crude oil are n-alkanes, which are converted from lipid compounds of animals and plants. Lower organisms such as algae and phytoplankton constitute low-carbon n-alkanes, while higher organisms constitute high-carbon n-alkanes. Acyclic isoprenoid alkanes are the core indicators to distinguish different crude oils. Pristane and phytane, which are derived from chlorophyll (where photosynthesis occurs), are used to distinguish the salinity of oxidation and Pr/Ph REDOX environments in sedimentary environments. Monomethylalkanes are the main discriminant basis for the origin of crude oil. Tricyclic terpenes (mainly C19–C30) are widely distributed in crude oil, which are probably derived from microorganisms and algae. Terpenes are mainly used to determine the formation age of crude oil. Steranes (long see C27~C29) are three-carbon steranes, which generally exist in crude oil and hydrocarbon source rocks. It is generally believed that C27 comes from lower aquatic organisms and C29 from higher plants. The crude oil with a different composition also shows different characteristics in the actual inspection. According to these characteristics, the crude oil composition can be better distinguished, so as to provide data basis for crude oil refining.

The maturity of crude oil is a geochemical characteristic parameter reflecting the evolution of the organic chemical composition of crude oil and source rocks. As the maturity of crude oil is difficult to be measured directly by instruments, the maturity of samples to be measured is often characterized by the content of organic components.

Table 2: C29 mature marks of sterane crude oil.

Alkanes C29 class	Immature crude oil	Mature crude oil
C29$\alpha\alpha\alpha$	<0.3	>0.3
C29$\alpha\alpha\beta$	<0.32	>0.32

Table 3: Terpene crude oil maturity mark.

Specific value	Oil generation stage	Balance point	Overripe-over-ripe
Epihopane C31-$\alpha\beta$22S/(C31-$\alpha\beta$22S + C31-$\alpha\beta$22R)	0.5~0.54	0.6	0.57~0.63
β hopane/β α monane	1.0	4.0~7.0	>7.0

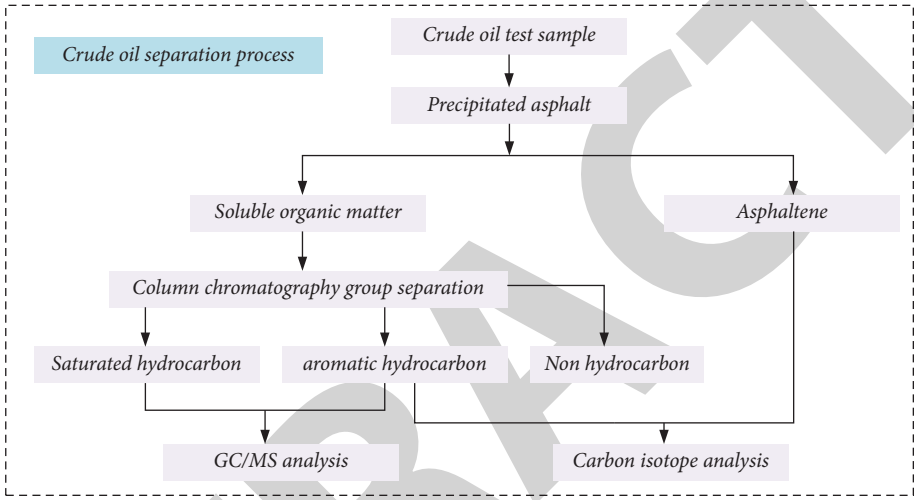

Figure 3: Crude oil separation process.

Generally speaking, with the increase of the maturity of crude oil, the contents of steranes and terpenes will decrease. Firstly, the steranes are C29$\alpha\alpha\alpha$ α and C29$\alpha\alpha\beta$. In immature crude oil, C29$\alpha\alpha\alpha$-20R mainly exists in the form of C29α α-20R. With the increase of crude oil maturity, C29α α-20R will change to C29α α-20s. It is generally believed that the ratio of C29α α to C29$\alpha\alpha\beta$ can be used as an index of crude oil maturity. According to China's "Ninth Five-Year Plan" research results, the definition of crude oil maturity mark can be shown in Table 2.

The content of rearranged steranes is positively correlated with the maturity of crude oil, so the ratio of rearranged steranes/regular steranes can also be used as an index of crude oil maturity. Academics think that the ratio of rearranged steranes to regular steranes is 0.25 as a watershed. If it is greater than 0.25, it is considered mature, otherwise, it is immature. However, its ratio will be affected by the characteristics of rock strata, so it can only be used as an auxiliary judgment condition rather than an independent judgment condition.

Terpene TS and Terpene TM are isomers, and TS has better thermal stability in chemical properties. It is generally believed that TM will gradually transform into TS with the increase of maturity, and the ratio of the two will change correspondingly in this process, so TS/TM is also the core index of crude oil maturity. Generally speaking, TS/TM > 1 is considered as mature crude oil, and vice versa is defined as immature crude oil. Moreover, TS and TM have a great catalytic reaction on clay and are affected by microbial action, so the measurement of carbonate crude oil is not accurate enough. Epihopane C31-$\alpha\beta$22R has the same characteristics as sterane, and will gradually change to C31-$\alpha\beta$22S with the increase of maturity. Its parameters as an indicator of crude oil maturity are shown in Table 3. Similarly, α β hopane β α moane has similar characteristics. β β hopane inherited from organisms is extremely unstable, and it will gradually transform into α β hopane β α moane in the process of maturity, and its ratio indicates maturity, which is also listed in Table 3.

In particular, norhopane C31-$\alpha\beta$22R is different from C29 sterane, and its ratio is not affected by microbial explanation, so it has a quite stable effect.

3.2. Characteristic Changes under the Action of Microorganisms. There are a lot of organic mixtures in crude oil, and aerobic microorganisms are the main reason for degrading crude oil, while anaerobic microorganisms can be neglected because of their slow action. Microbial degradation mainly consumes n-alkanes, and the structures of alkylbenzene and dialkylbenzene are easily destroyed by bacteria, while C19~C45 tricyclic terpenes have a strong

antidegradation ability and are not easily decomposed. Some components used for maturity evaluation are also distinguished according to antimicrobial explanation, such as terpene TS has better degradation resistance than terpene TM, and C29$\alpha\alpha\alpha$-20S has a more stable performance than C29α α-20r. Microbial degradation of crude oil is an extremely complex multistage process, and the order of degraded compounds is also affected by the types and quantities of microorganisms. Although both industrial and academic circles have carried out relevant research on it, there is still no systematic and comprehensive description.

Figure 3 shows the separation process of crude oil group changes before and after the microbial reaction. First, the crude oil test sample needs to be deposited in Petroleum Ether (PE) and filtered, and the asphalt adhered to the filter paper is cleaned with trichloromethane ($CHCL_3$), and its weight is measured. The filtrate was separated by Al_2O_3/silica gel column chromatography and then cleaned by PE, benzene (C_6H_6), and ether ($C_2H_5OC_2H_5$) to obtain saturated hydrocarbons, aromatic hydrocarbons, and nonhydrocarbons. The weight of different organic compounds was tested. Finally, the stable carbon isotope analysis and GC/MS analysis were completed. Finally, the change characteristics of crude oil before and after microbial action were determined.

4. Conclusion

In this paper, taking Yanchang Oilfield, the core area of Ordos Basin, as an example, taking Yanchang Chang 7 crude oil as the research object, the geochemical characteristics of crude oil are studied. In the beginning, it points out the importance of the petroleum industry to a national economy and national security, introduces the basic situation and characteristics of Yanchang Oilfield, focuses on the power and diversion system of Yanchang Oilfield, explores the main factors for the formation of oil and gas reservoirs in Yanchang Formation and the geological survey of Yanchang Formation, especially discusses the characteristics and maturity evaluation indexes of crude oil, and considers the changes of crude oil properties under the action of microorganisms.

With the shortage of primary energy in the world, it is the key point to improve oil recovery technology and oil and gas recovery quality. In this paper, taking the oil from the 7th member of the Yanchang Formation in Yanchang Oilfield as an example, by studying its formation mechanism and geochemical characteristics, the formation principle of oil and gas reservoirs and chemical properties of crude oil are explored, so as to provide basic theoretical research and first-hand engineering data for high-quality oil and gas exploitation and unconventional oil and gas resource exploration. In the next step, practical engineering research will be carried out in combination with other characteristics of crude oil, so as to accumulate experience for upgrading oil and gas exploration and development technology in China.

Data Availability

The figures and tables used to support the findings of this study are included in the article.

Conflicts of Interest

The authors declare that they have no conflicts of interest.

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