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Characteristics of Chang 61 Reservoir in Hengshan area of Ordos Basin and its Control on Oil-Bearing Property

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Abstract

The Chang 61 reservoir in Hengshan area of Ordos Basin has obvious regionalization. On the basis of core observation, combined with a large number of fluorescence photos, casting thin sections, scanning electron microscopy, mercury injection data and conventional physical property analysis and test data, the reservoir petrology, physical properties and pore characteristics are studied. The reasons for the differences of reservoir physical properties in different blocks of Chang 61 are analyzed, and the influencing factors of reservoir oil-bearing property differences are clarified.

Keywords

Reservoir characteristics; Reservoir oil-bearing ability; Controlling factors; Chang 61 reservoir; Ordos Basin.

1. Introduction

Ordos Basin, located in central and Western China, is a multi cycle superimposed basin developed on the basis of the Paleozoic North China stable craton basin, and is one of the most abundant oil and gas resources in China(Sun,1980;Li 2004;Wang 2011;Bai 2013). Among them, the high-quality source rocks and multiple sets of thick reservoir sand bodies developed in the Triassic Yanchang formation are widely distributed, which jointly control the formation of large-scale tight reservoirs in the Yanchang formation (Zou 2013; Zou 2013;Chen 2019). Large scale reservoirs have been discovered in Chang 8, Chang 7, Chang 6 and Chang 4 + 5. As the main oil-bearing series in Ordos Basin, Chang-6 oil-bearing formation is characterized by wide oil-bearing range, large reservoir thickness, low porosity and permeability, and belongs to typical low-permeability tight reservoir.

Hengshan oilfield is located in the middle of Shanbei slope, Ordos Basin, and the edge of hydrocarbon generation sag. It has abundant oil source and favorable reservoir forming conditions. According to the theory of low permeability sandstone reservoir formation (Liu 2012; Zhao 2012), Chang 6 reservoir in the study area should be widely distributed in large area. However, according to the current exploration results, the oil reservoirs in this area are mainly distributed in the Chang 61 sub oil layer group and mainly distributed in clusters, and the reservoirs are mainly distributed in weijialou, Shuangcheng and bailangcheng generation. In addition, during core observation, it is found that many cores contain oil in one section and no oil in the other section. What kind of privacy controls the oil-bearing difference of reservoir is still unclear. At present, there are many researches on Chang-6 oil-bearing formation at home and abroad, but they mainly focus on single factors such as sedimentary environment, reservoir characteristics and densification origin, diagenetic facies, sand body structure, relationship between reservoir four properties and provenance system. The main

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controlling factors of oil-bearing property of reservoir are not clear, which can not meet the needs of oilfield development. In this paper, the Chang 61 sub oil formation with the best oil-bearing property in Chang-6 oil-bearing group is taken as the object. Through the basic data of petrology, physical property data, mercury injection data, fluorescent thin section and cast thin section, the reservoir characteristics are studied, and the main controlling factors of the difference of oil and gas properties are determined, so as to provide theoretical basis for the next oil and gas exploration and development in this area.

2. Geological setting

Ordos Basin is located in the west of the North China Craton block. It crosses Wuergelan bedrock uplift in the north and is adjacent to Hetao Basin, and the southern part crosses Weibei fold belt and faces Weihe basin. In the East, it connects with the West Shanxi fold belt and Luliang Uplift, and in the west, it confronts Liupanshan Yinchuan basin through the overthrust structure belt. The surface morphology is a rectangular basin with a north-south distribution, about 700km in length and 400km in width from east to west, the total area is about $25 \times 10^4 km^2$ (Li 2004).

The study area is located in the middle of the Northern Shaanxi Slope of the secondary structural unit in Ordos Basin (Fig. 1), reaching Macha Township in the East, Shuangcheng in the west, bailangcheng in the South and weijialou in the north. The exploration area is about $550km^2$. After years of exploration, a large number of oil and gas resources have been found in the middle and south of the study area. Chang 6 in the study area belongs to delta depositional system and develops distributary channel sand body in delta plain. The Chang-6 oil-bearing formation of Yanchang formation can be divided into three sub groups: Chang 6_1, Chang 6_2 and Chang 6_3, of which Chang 6_1 is about 42 ~ 44m thick, Chang 6_2 is about 39 ~ 41m thick, and Chang 6_3 is about 38 ~ 40m thick. This study mainly selects Chang 61 low permeability reservoir with relatively high enrichment degree for analysis.

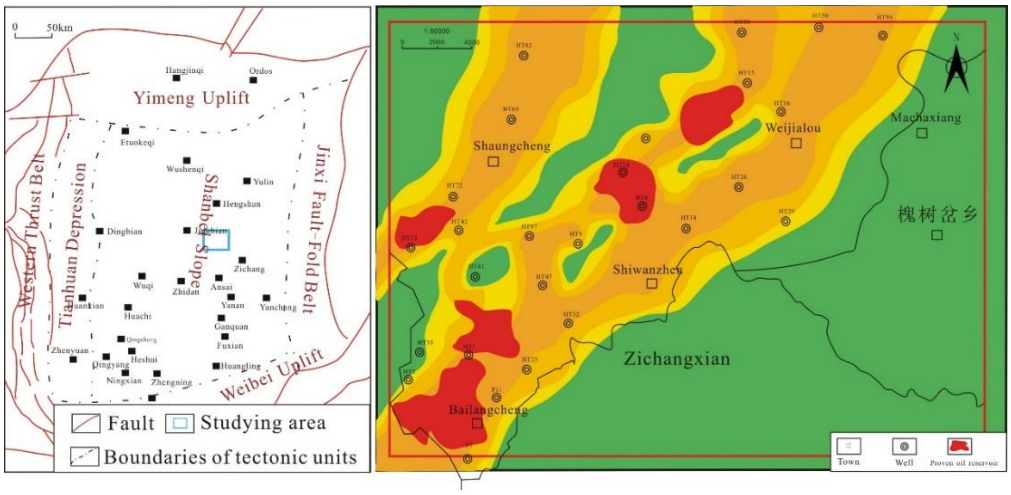

Fig.1 Location map and reservoir distribution map of the study area

3. Characteristics of low porosity and low permeability sandstone reservoir

3.1 Petrological characteristics

In Hengshan area, delta plain is divided into channel sandbodies. The lithology is mainly grayish white massive ~ thick layered medium fine sandstone, accounting for about 80% of the total sandstone, followed by silty fine sandstone and siltstone, accounting for about 20% of the total sandstone.

Based on the statistical analysis of 214 samples from 27 coring wells of Chang 6_1 oil layer subgroup in the study area, it is found that sandstone clastic composition is mainly feldspar, quartz and cuttings.

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The percentage of feldspar is 44.26 ~ 51.33%, with an average of 44.63%, mainly orthoclase, followed by acid plagioclase; the percentage of quartz is 25.44 ~ 30.08%, with an average of 27.82%; the percentage of rock debris is mainly distributed in the range of 8.73 ~ 11.28%, with an average of 9.2%, in which the igneous rock debris and metamorphic rock debris are the main debris, and the sedimentary rock debris content is very high The other components are mainly heavy minerals, with an average of 4.43%, ranging from 1% to 11.23%.

Table 1 Statistics of clastic composition and content of Chang 6_1 reservoir in study area

Content	Clastic rock composition						Other components(%)	Number
	Quartz (%)	Feldspar (%)	Debris(%)					
			Igneous rock	Metamorphic rock	Sedimentary rock	Total		
Max	30.08	51.33	7.76	5.87	/	11.28	11.23	214
Min	25.44	44.26	3.11	3.52	/	8.73	1	
Average	26.32	49.72	4.78	5.01	/	9.2	4.43	

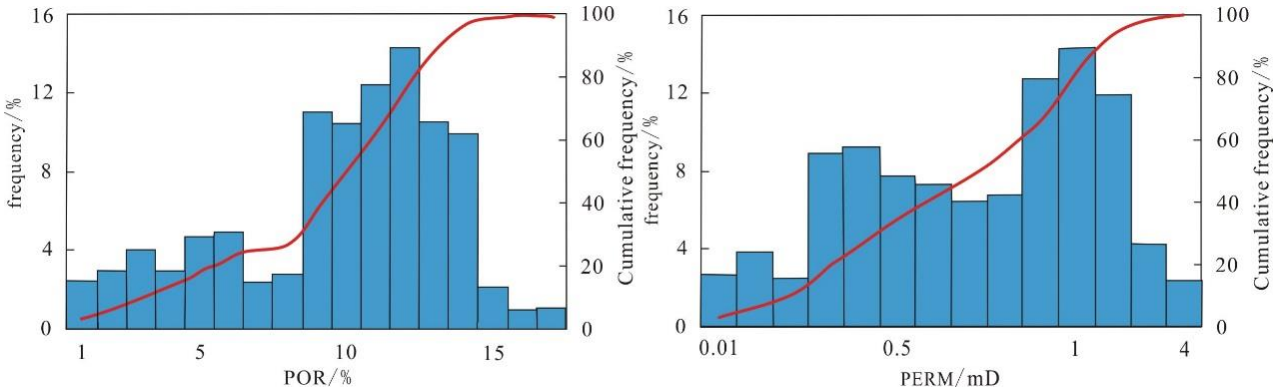

Fig. 2 Reservoir physical property distribution histogram of Chang 6_1 member in study area

3.2 Physical characteristics

Based on the physical property test and analysis data of 100 rock samples in the study area, the porosity distribution of Chang 6 reservoir group is 2% ~ 15.5%, and the average value is 11.21%; the permeability distribution is between 0.1 ~ 4.68 mD, with an average of 1.38 mD. In addition, combined with the frequency distribution histogram of porosity and permeability in the study area, it can be seen that porosity is mainly distributed between 9% and 14%, accounting for 68.5% of the total, while permeability is mainly distributed in (0.3 ~ 2) mD, accounting for 84.8% of the total. The reservoir in the study area belongs to low porosity and ultra-low permeability reservoir.

3.3 Pore characteristics

2.3.1 Pore type

According to the analysis of cast thin section and scanning electron microscope of sandstone in the study area, the pore types of Chang-6 oil-bearing formation sandstone in Hengshan area are various, mainly including intergranular pore, feldspar dissolved pore, lithic dissolved pore, intergranular dissolved pore and micro fracture (Fig. 3). According to the results of image pore analysis, the pores of Chang 6 sandstone reservoir in this area are relatively well developed, the porosity is generally between 4% and 12%, and the average porosity is 8%. The dissolution pore (mainly feldspar dissolved pore) is the main pore type, and its porosity accounts for 73% of the total porosity; the residual intergranular pore takes the second place, and its porosity only accounts for 17% of the total porosity, while the mold pore and intercrystalline micropore are the most important pore types Other pores account for about 10%, indicating that intergranular pores and feldspar dissolved pores are the two main pore types in the study area.

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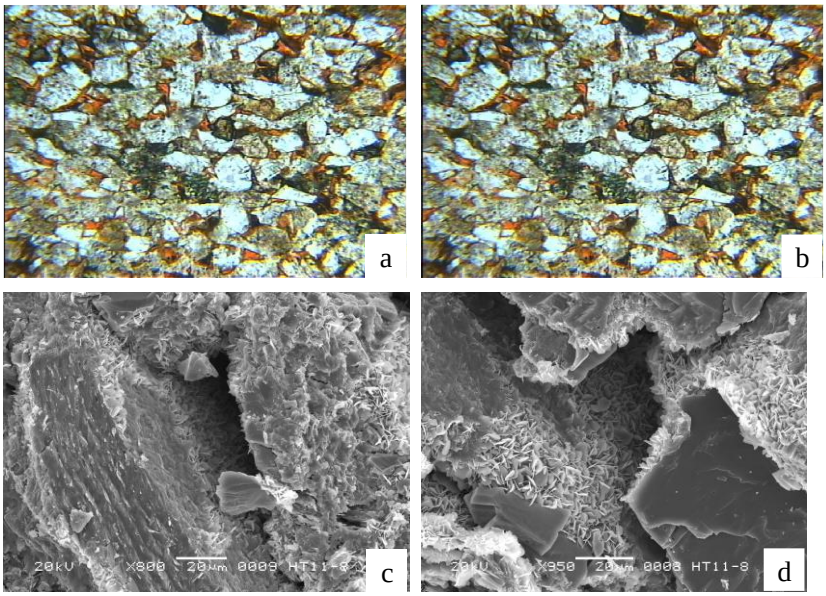

Fig. 3 Pore types of Chang 6_1 reservoir in Hengshan area

a. HT18 well, 1031 m, intergranular dissolution pore, dissolution feldspar and chlorite cement formation; B.HT14 well, 781.01m, intragranular dissolved pore after feldspar dissolution; C.HT14 well, 776.48m, residual intergranular pore, in which blade like chlorite vertical growth on the particle surface; D.HT14 well, 774.24m, intergranular dissolution pore morphology is irregular, the edge is Bay shaped, chlorite and albite are seen Crystal.

2.3.2 Pore structure characteristics

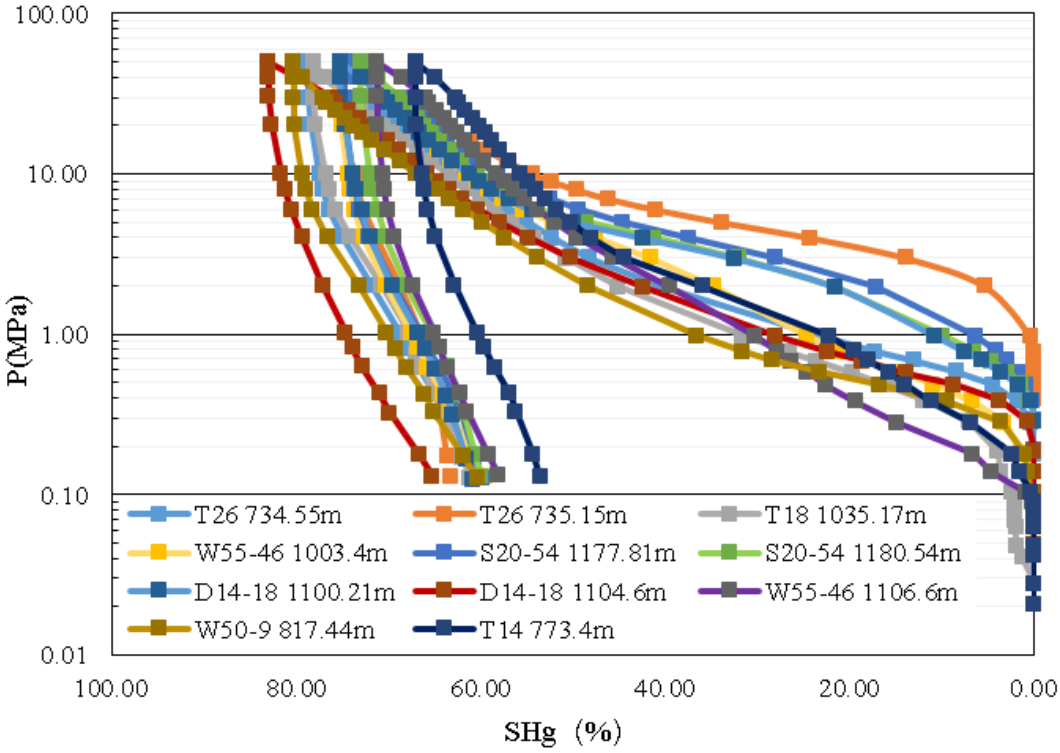

Fig.4 Mercury injection curve characteristics of Chang 6_1 reservoir in Hengshan District

According to the characteristics of high-pressure mercury injection curve of Chang-6 reservoir in the study area (Fig. 4), the displacement pressure distribution range of Chang-6 sandstone in the study area is wide, mainly distributed in the range of 0.14-1.93 MPa, with an average of 0.55 MPa. The

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average pore throat radius distribution range of reservoir rock is 0.143-2.672 μm, and the average pore throat value is about 1.07 μm (Table 2), indicating that the throat heterogeneity of Chang 6 reservoir in the study area is strong, while mercury injection curve is relatively strong The gentle section of the line is longer, indicating that the pore throat sorting is better. In Chang 6 sandstone of the study area, small pores are dominant, accounting for 74.3%, followed by fine pores and medium pores; throat is mainly micro throat, accounting for 72.7%, followed by micro throat and fine throat. It can be seen that the pore throat structure of Chang 6 sandstone in the study area is mainly of small pore and micro throat type.

Table 2 Physical parameters of pore structure of Chang 6 sandstone reservoir in Hengshan area

Well	POR (%)	PERM ($\times10^3\mu m^2$)	Mean pore throat (μm)	Skewness	Sorting coefficient	Threshold pressure (MPa)	Median pressure (Mpa)	Median radius (μm)	Mercury removal efficiency (%)
HT26	10.6	0.75	11.66	-0.5	2.09	0.28	3.42	0.22	23.28
HT26	7.4	0.08	12.7	-0.08	1.32	0.98	8.14	0.09	15.54
HT18	11.6	2.90	11.26	-0.33	2.51	0.05	2.84	0.26	21.71
W55-46	11.2	0.48	11.68	-0.30	2.24	0.10	4.51	0.16	20.74

4. Control of reservoir characteristics on oil bearing difference

Core observation shows that there are continuous sandstone sections in Chang-6 oil-bearing formation in the study area, but there are obvious differences in oil-bearing properties (Fig. 5). Analysis shows that the controlling factor of obvious difference in oil-bearing properties of sandstone in the same section is reservoir physical property difference. Taking 816.36 ~ 819.05m of well Wei 50-9 as an example (Fig. 5a), the oil-bearing section samples and the samples without oil-gas display section were selected for the physical property test (Table 3). The results show that the porosity of the oil-bearing section is generally greater than 7%, and the permeability is greater than $0.22\times10^{-3}\mu m^2$, while the porosity of the oil-gas non display section is less than 7%, and the permeability is less than $0.11\times10^{-3}\mu m^2$. Sandstone has high porosity and permeability, high degree of oil filling and good oil-bearing property, which indicates that physical properties control the oil enrichment degree of sand body.

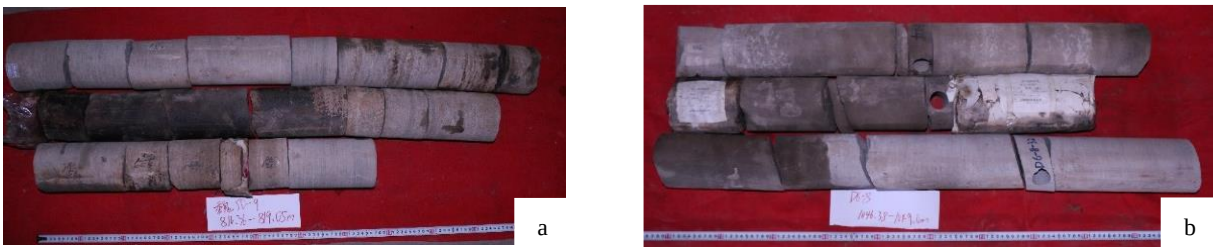

Fig. 5 Core photos of oil-bearing difference of Chang-6 oil-bearing formation in Hengshan area
a. Wei 50-9, 61816.36-819.05m in length, has different distribution of oil-bearing cores;b. D8-38,1046.38~ 1049m in length, has different distribution of oil-bearing cores

Table 3 Physical properties of different oil-bearing cores in 816.36 ~ 819.05m section of well W50-9

Depth	Oiliness	Strata	POR(%)	PERM($10^{-3}\mu m^2$)
817.20	Oil spots	Chang6	8.32	1.13
817.36	Oil spots	Chang6	7.77	0.72
818.10	Oil spots	Chang6	8.84	1.25
816.40	/	Chang6	3.41	0.21
819.00	/	Chang6	4.67	0.28

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Combined with the analysis of sandstone physical properties and fluorescence display, it is found that the sandstone with strong fluorescence display and good oil-bearing property under microscope is generally relatively good, while sandstone with weak fluorescence display and poor oil-bearing property also has poor physical properties, which indicates that physical properties play an important role in controlling the oil enrichment.

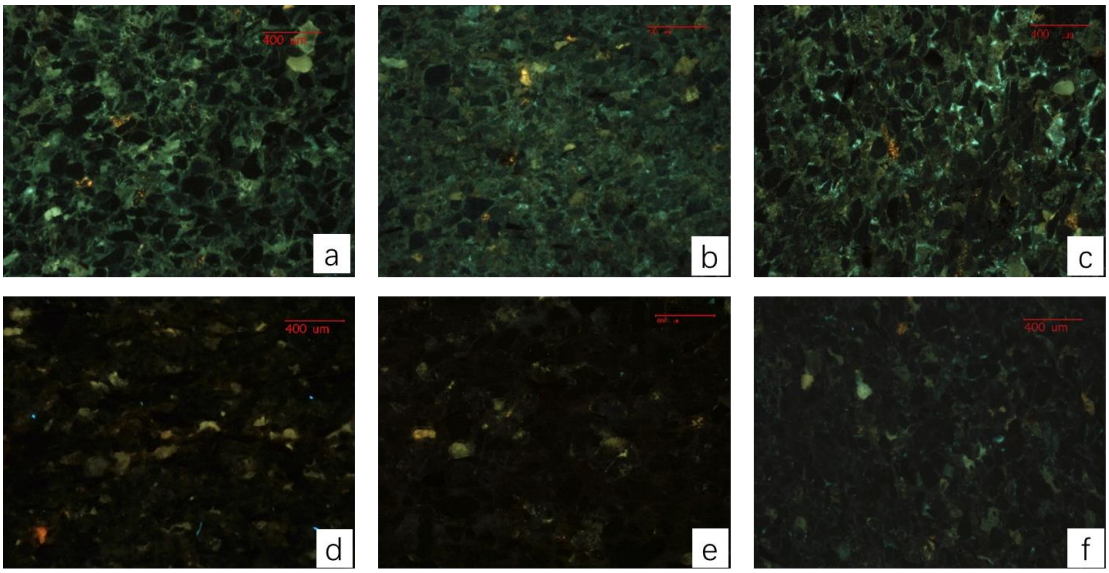

Fig. 6 Fluorescence photos of Chang 61 reservoir in Hengshan area

For the sand bodies in the crude oil enrichment area of the study area, the porosity and permeability of different types of sand bodies are analyzed according to the oil test conclusion (oil-water same layer, water layer and dry layer) (Fig. 7). The results show that the porosity and permeability of oil-bearing sand body in Chang-6 oil-bearing group are the best, with average values of 12.9% and 1.25 $\times 10^{-3}\mu m^2$, respectively; while the porosity and permeability of dry layer sand body are the best 2% and 0. $27\times 10^{-3}\mu m^2$. The higher the porosity and permeability of the reservoir, the higher the degree of crude oil enrichment, indicating that physical properties have an obvious control on the enrichment degree of reservoir crude oil.

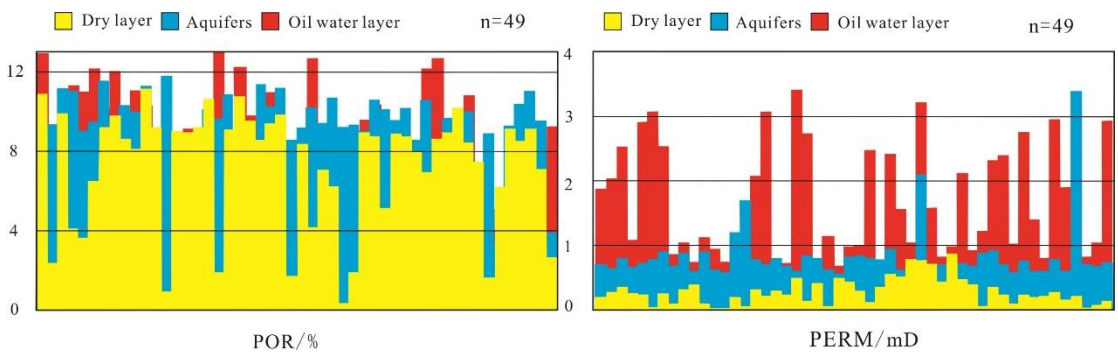

Fig. 7 Physical and petroleum properties of Chang 6 reservoir in Hengshan area

5. Conclusion

(1) The lithology of Chang 6_1 reservoir in Hengshan area of Ordos Basin is mainly gray white massive thick layered medium fine sandstone. The pore types are mainly intergranular dissolution pore and feldspar dissolution pore, and a small amount of lithic dissolution pore is developed. The average

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porosity is 11.21%, the average permeability is about 1.38md, and the pore throat structure is mainly small pore and micro throat.

(2) According to core observation, fluorescence photos and relevant physical property data statistics, the higher the porosity and permeability of the reservoir, the higher the degree of oil enrichment, indicating that physical properties have an obvious control effect on the enrichment degree of reservoir crude oil.

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