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Characteristics and Main Controlling Factors of Chang 8 Tight Reservoir in Zhijing Area

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Abstract

In order to study the physical properties and main controlling factors of the reservoir in the Chang 8 member of the Zhijing area of the Ordos basin, the petrological characteristics, physical properties, pore types, pore throat structure characteristics of the reservoir were studied by analyzing core photos, sedimentary microfacies, combined with casting thin section, scanning electron microscope, mercury intrusion, clay mineral analysis and other test techniques. The results show that the sandstone types of the Chang 8 member in the study area are mainly feldspathic sandstone and lithic feldspathic sandstone, Pore fillers are mainly chlorite, iron calcite and illite; The pore types are mainly intergranular pore and feldspathic dissolved pore, in which the average porosity of Chang 8 section is 9.38% and the average permeability is 0.48×10^{-3} μm^2, generally, it belongs to low porosity, ultra-low porosity and ultra-low permeability reservoir; Sedimentary microfacies are the key factors to control the physical properties of the reservoir, compaction is the main factor leading to the compaction of the reservoir, and cementation and dissolution are the fundamental reasons for the difference of the reservoir seepage relationship; According to the criteria of reservoir classification and evaluation, the Chang 8 member in Zhijing area is divided into three types. Class I and II reservoirs with large porosity and good permeability can be used as key exploration areas.

Subject Areas

Petroleum Geology

Keywords

Ordos Basin, Sedimentary Microfacies, Main Control Factors, Tight Reservoir

1. Introduction

The pore structure of tight sandstone reservoir is complex and diverse, its heterogeneity is stronger than that of conventional reservoir, and its exploitation is difficult. Only through large-scale fracturing can the productivity be improved and the large-scale development of the reservoir be realized. Ordos Basin is the second largest oil and gas bearing basin in China, with rich oil and gas resources. Among them, the Triassic Yanchang Formation is rich in tight oil resources, and the reservoir is characterized by "low permeability, low pressure and low abundance". Its reservoir characteristics are as follows: no obvious oil-water interface, low oil saturation, alternate distribution of oil-water in the same layer, poor oil layer, oil layer and dry layer, and oil-water inversion in local areas.

The Chang 8 member of Yanchang Formation in Zhijing area is controlled by multi-source hydrocarbon supply, near-source reservoir formation mode and favorable reservoir distribution. The reservoir distribution is quite different, with small layers found in the vertical direction and uneven distribution in the horizontal direction. The sedimentary environment in this area is mainly delta front. Affected by sedimentary microfacies, the size of sand body changes rapidly, the physical property of reservoir changes greatly, and the vertical and horizontal heterogeneity of pore structure is obvious; It brings great difficulties to the optimization of exploration targets and the submission of reserves. In particular, its low porosity and low permeability characteristics have been restricting the efficient development of oil and gas [1] [2]. Therefore, it is particularly important to explore the tight factors of tight reservoirs and search for relatively high permeability areas [3] [4]. In the past, the refinement study of tight reservoirs in the Chang 8 member of the Ordos Basin was mostly limited to the study of its single mineral, and the relationship between the single factor and the physical properties of the reservoir, but the compactness of the reservoir was caused by multiple factors [5]-[9]. Therefore, combining the basin structural history, sedimentary environment, analysis of petrological characteristics, physical properties, pore type, pore structure, diagenesis and other methods to systematically study the factors of reservoir densification will make further breakthroughs in the study of densified reservoirs.

Zhijing area is located in the middle of the Ordos basin. The oil and gas in the Chang 8 member of the area is rich, but the distribution of oil and gas is irregular, and the oil-bearing property of each part varies greatly [10]-[15]. Based on the previous research results on the tight reservoir of Chang 8 in the Ordos Basin, through the analysis of sedimentary microfacies and the use of logging, logging, physical property analysis, casting technology, etc., the tight reservoir of Chang 8 in the Zhijing area of the Ordos Basin is analyzed, and the factors affecting the relatively high permeability of the reservoir are analyzed, in order to provide a basis for the subsequent exploration and development of the "sweet spot area" of Chang 8 in the Zhijing area.

2. Geological Overview

Zhijing area is located in the middle of Yishan slope in Ordos basin, with an area of about 1×10^4 km^2 (**Figure 1**), the study area has 10 small sections, from the top to the bottom is the Chang1 to the Chang 10. The Ordos basin is in the early Chang 8 period of lake retrogression, the sand body is in a strip shape, and the overall direction is northeast to southwest. The study area is mainly in the delta front facies zone, and the landform of the Chang 8 formation period is flat and the sedimentary body accumulation is stable, and there is no gravity flow deposition development. The structure of the study area is stable, and there is no fault development [16] [17] [18], The Chang 8 member can be divided into Chang 8_1

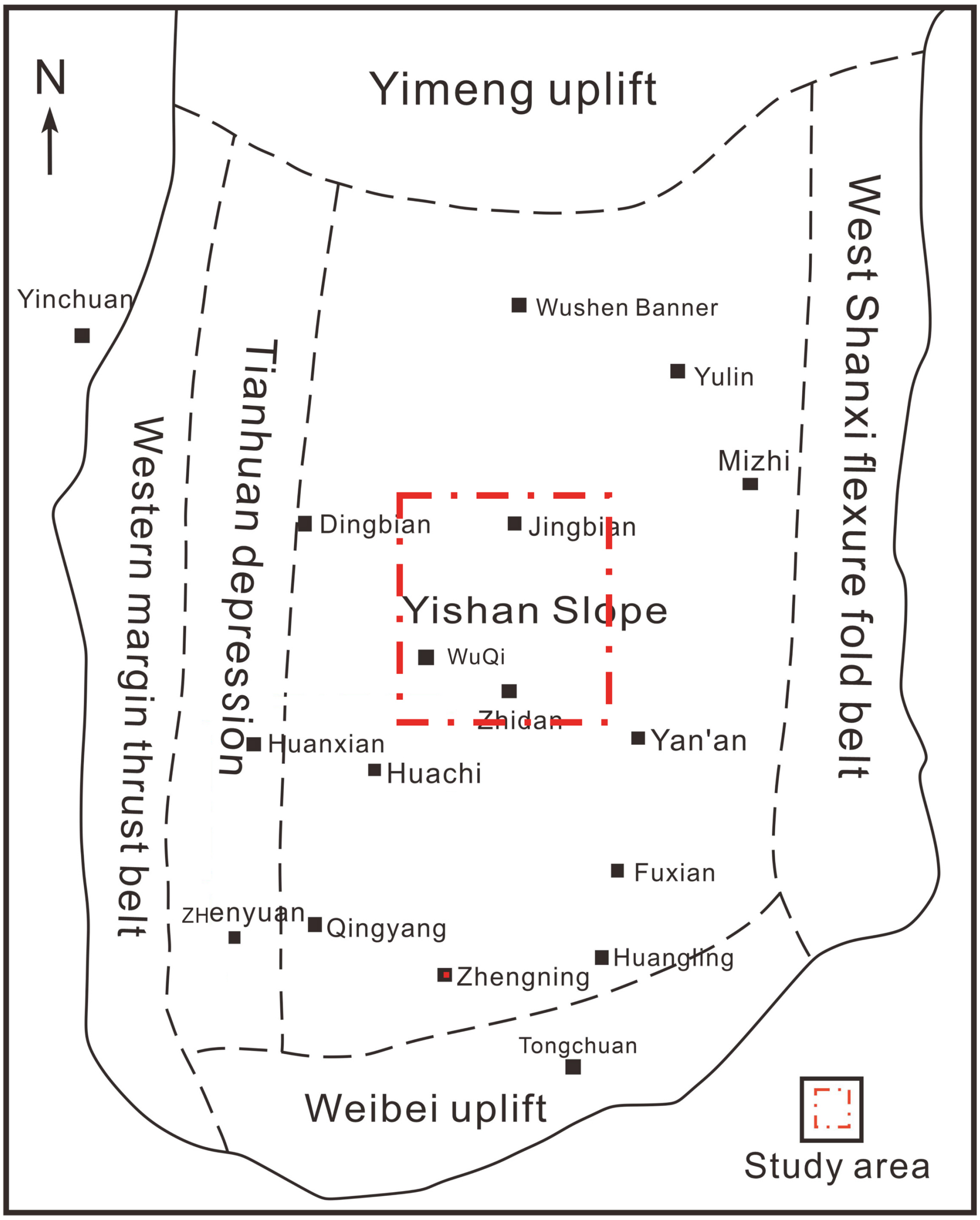

Figure 1. Regional location of Zhijing area.

and Chang 8_2 segments. The Chang 8_1 sand body has less shale content, and the sand body is well developed. The Chang 8_2 sand body is thick, but has more shale content.

3. Chang 8 Reservoir Characteristics

3.1. Petrological Characteristics

According to the observation and statistical analysis of 416 cast thin sections of rocks in the study area, it is found that the content of various rock components is relatively high in the Chang 8 section, and the reservoir rocks in the Chang 8 section of the basin are mainly feldspathic sandstone and lithic feldspathic sandstone (**Figure 2**). Due to the provenance of Chang 8 period from the northeast, controlled by provenance, the feldspar content of Chang 8 section in the study area is generally higher than that of quartz, and the content of quartz, feldspar and rock debris in Chang 8_1 and Chang 8_2 sub-sections are not significantly different (**Table 1**).

The content of interstitial material in Chang 8_1 sandstone in the basin is 16.88%, mainly composed of chlorite (4.68%), calcite (3.98%) and illite (3.79%), followed by siliceous, turbidite and reticulated clay. The interstitial material of Chang 8_2 sandstone in the basin is similar to that of Chang 8_1, with a content of 16.80%, mainly composed of chlorite (3.75%), iron calcite (4.53%) and illite (3.01%). The feldspathic content of Chang 8 section is relatively small (**Figure 3**). The separation of Chang-8 section is mainly medium and good; The grain

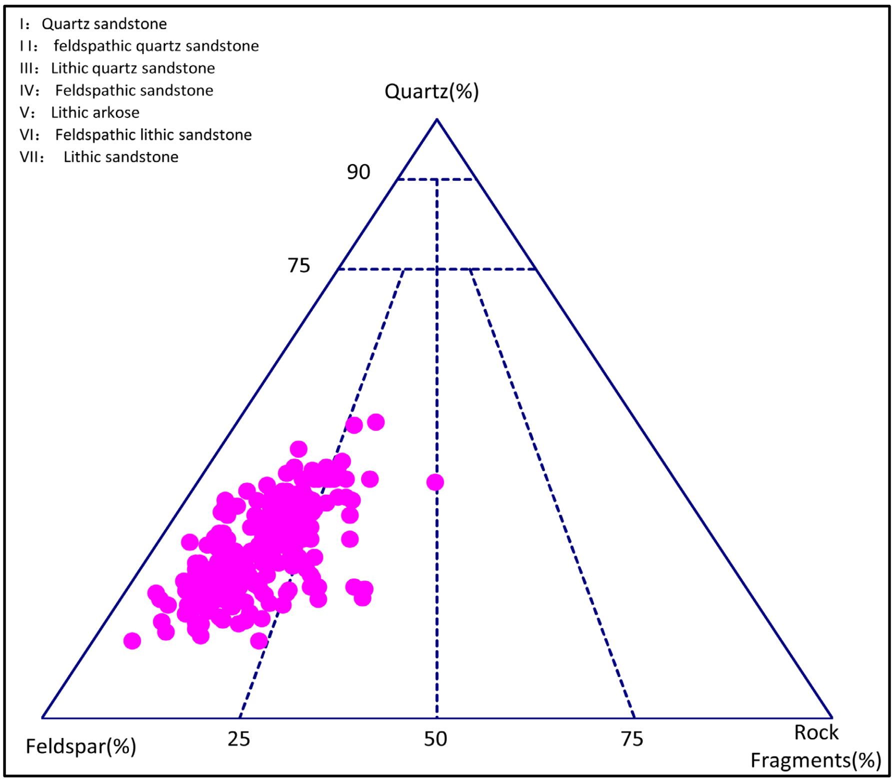

Figure 2. Triangle diagram of rock types of Chang 8 in Zhijing area.

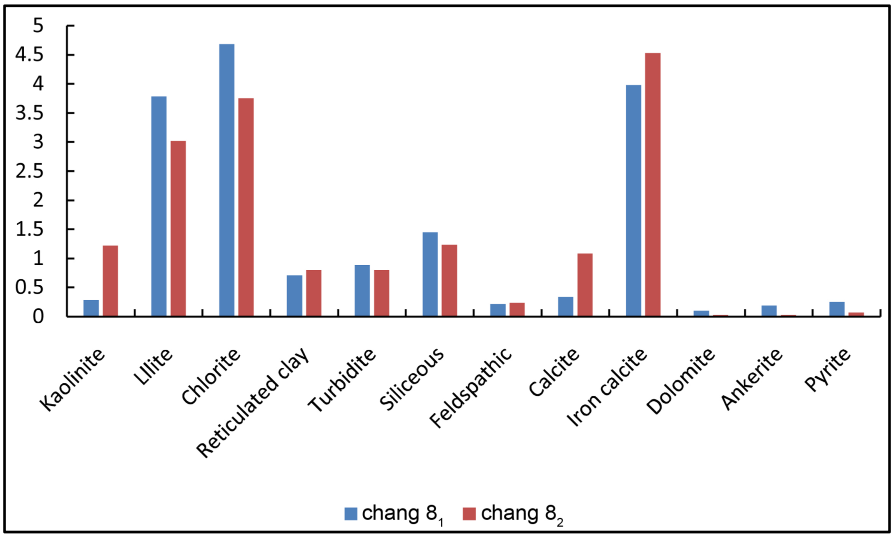

Figure 3. Histogram of interstitial materials of Chang 8 in Zhijing areak.

Table 1. Average content of sandstone clastic components of Chang 8 reservoir in Zhijing area.

Position	Detrital composition (%)			Cuttings composition (%)			Mica (%)
	Quartz	Feldspar	Rock Fragments	Igneous Rock	Metamorphic Rock	Sedimentary Rock	
Chang 8_1	28.25	37.77	13.32	5.04	7.43	0.59	5.89
Chang 8_2	28.09	38.98	11.54	4.18	7.06	0.3	4.88

size is mainly fine-medium and very fine-fine; Debris particles are mainly sub-angular and sub-angular to sub-rounded.

3.2. Reservoir Physical Properties

The porosity of Chang 8_1 reservoir in the study area is between 4.1% and 15.2% (**Figure 4**), and that of Chang 8_2 reservoir is between 2.38% and 18%. The porosity of Chang 8_1 and Chang 8_2 is relatively close to 9.37% and 9.39% respectively; Among them, Chang 8_1 has good permeability, ranging from (0.02 - 3.87) × 10^{-3} μm^2, and the permeability of length 8_2 is (0.01 - 3.01) × 10^{-3} μm^2.

3.3. Pore Type

The pore types of Chang 8 member in the study area are mainly intergranular pores and feldspar dissolved pores (**Figure 5**), and the total porosity rate of Chang 8_1 is 3.5%, in which intergranular pores (2.36%) are developed, the intergranular pores are irregular under the microscope (**Figure 5(a)**), feldspar dissolved pores (0.79%) are relatively developed (**Figure 5(b)**), the cuttings dissolved pores (0.18%) are slightly developed, the cuttings particles are rarely broken (**Figure 5(c)**), the intergranular pores (0.08%) (**Figure 5(d)**) and micro-cracks (0.06%) are generally small. The contribution to the reservoir is small.

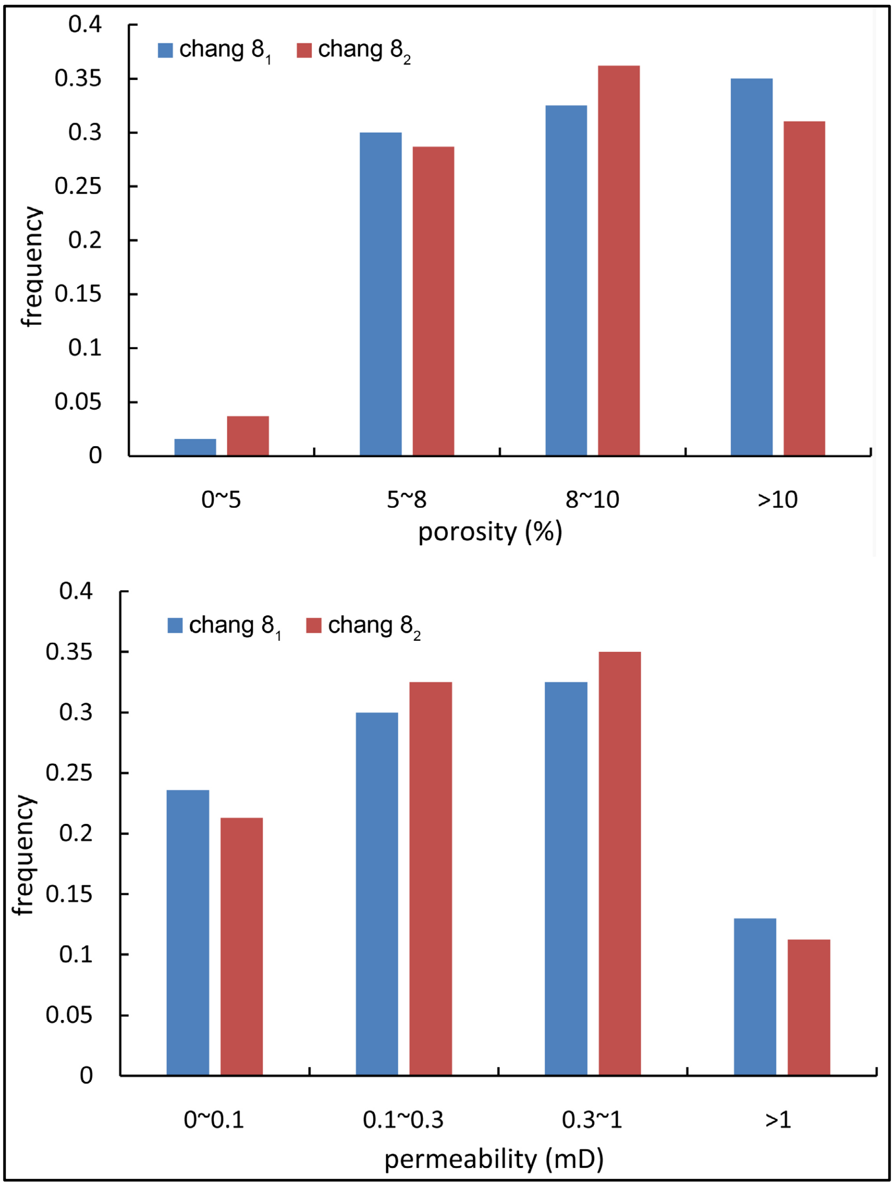

Figure 4. Frequency distribution histogram of porosity and permeability.

The total porosity of Chang 8_2 is 3.61%, the intergranular pores (2.41%) and feldspar dissolution pores (0.83) are longer and 8_1 are more developed (Figure 5(e) and Figure 5(f)), and the cuttings dissolution pores (0.18%), intergranular pores (0.09%), and microfractures (0.07%) are generally small, but they are still of constructive significance for reservoir seepage.

3.4. Pore Throat Feature

Pore throat characteristics through mercury injection analysis of the samples in the study area, the shape of the capillary pressure curve of the reservoir are obtained. Combined with the characteristics of seepage parameters and microscopic thin section observation, the pore structure in the study area is subdivided into three types.

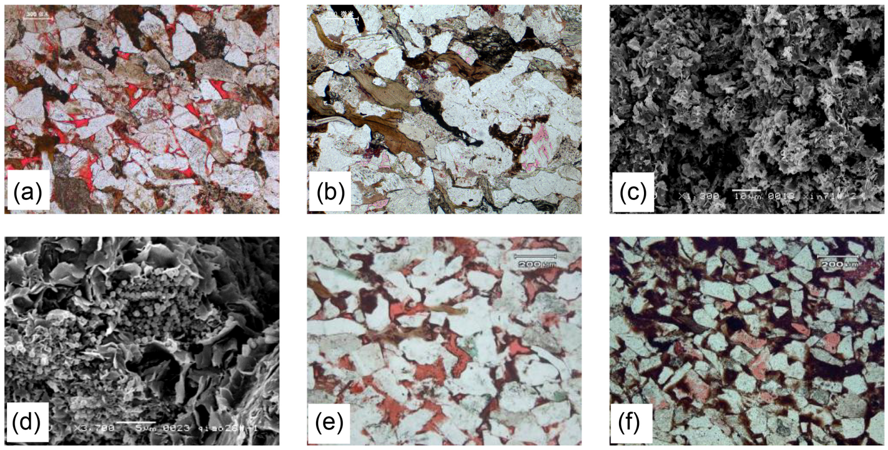

Figure 5. Micrograph of pore type of Chang 8 reservoir in Zhijing area. (a) Well A26, 2030.07 m, chang 8_1, with directional distribution of debris and deformation of mica and rock cuttings. (b) Well A43, 2289.72 m, chang 8_1, with feldspar dissolution hole. (c) Well X71, 2219.7 m, chang 8_1, the cuttings are dissolved and broken. (d) Well Q28, 1079.5 m, chang 8_1, with intergranular pores. (e) Well Q11, 1360.3 m, chang 8_2, with intergranular pores developed. (f) Well D42, 1609.5 m, chang 8_2, feldspar dissolution holes are relatively developed.

Class I pore structure: pore throat size distribution is inclined to coarse pore throat, and curve inclination is small; It has the characteristics of coarse skewness and medium to good separation. The pore type is mainly intergranular pore, and the throat is mainly medium-fine throat. The pore throat size distribution of Class II pore structure is inclined to coarse pore throat, and the curve inclination is small. It is characterized by coarse skewness and medium to good sorting. The pore type is mainly intergranular pore, and the throat is mainly fine throat. The pore throat size distribution of Class III pore structure is inclined to fine throat, and the curve inclination is large. There are many pore types, wide pore range distribution and poor sorting. The throat is mainly fine throat.

4. Factors Affecting Reservoir Development

4.1. Sedimentation

According to core observation, wavy bedding (**Figure 6(a)**), massive bedding (**Figure 6(b)**, **Figure 6(c)**), parallel bedding (**Figure 6(d)**), carbonized plant (**Figure 6(e)**), plant stem (**Figure 6(f)**), wrapped bedding (**Figure 6(g)**) and horizontal bedding (**Figure 6(h)**) are developed in the study area; It is generally characterized by gray-green sandstone under the delta front subfacies. The degree of oxidation of the sand body is low [19] [20] [21], and it is mostly medium-fine sandstone. The common massive bedding and parallel bedding in the Chang 8 period showed strong hydrodynamic characteristics, and the inclusion bedding also showed the characteristics of rapid deposition.

The thickness of Chang 8 single sand body is generally 10 - 20 m, and the overlap of Chang 8_1 multi-phase sand body can reach 40.3 m. The Chang 8_2 composite sand body is longer, 8_1 thick and up to 46.2 m. According to the

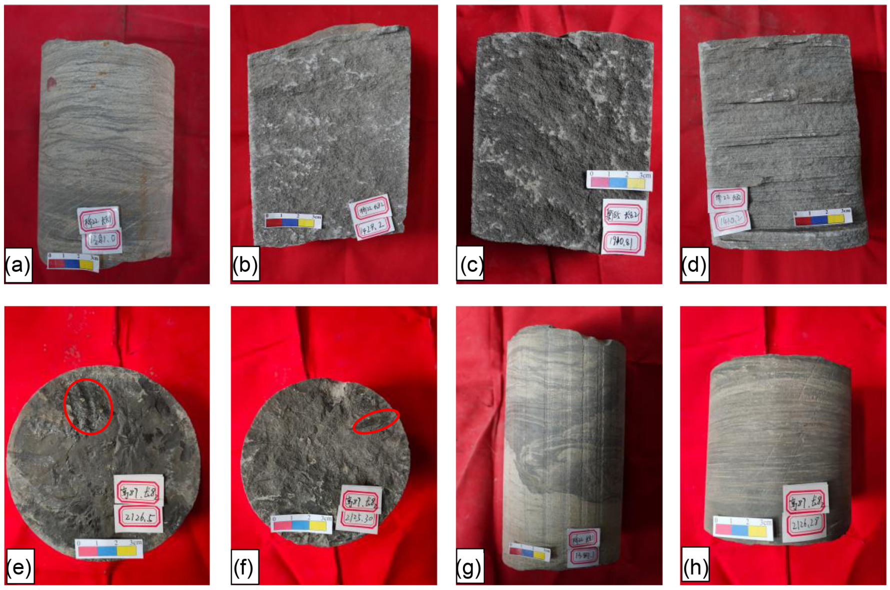

Figure 6. Sedimentary structure characteristics of Chang 8 in Zhijing area. (a) Well Q22, 1381.0 m, chang 8_1, wavy bedding; (b) Well Q22, 1429.2 m, chang 8_2, massive bedding; (c) Well X85, 1910.81 m, chang 8_2, massive bedding; (d) Well Q22, 1410.2 m, chang 8_2, parallel bedding; (e) Well G87, 2126.5 m, chang 8_2, carbonized plants; (f) Well G87, 2125.3 m, chang 8_2, plant stems and leaves; (g) Well Q22, 1387.1 m, chang 8_1, wrapped bedding; (h) Well G87, 2126.28 m, chang 8_2, horizontal bedding.

sedimentary characteristics of the study area and the analysis of logging data, the Chang 8 member is divided into three sedimentary microfacies: underwater distributary channel, underwater natural dike, and interdistributary bay. In the Chang 8_1 period, the shale content is small, the sand body thickness is large, the wavy bedding and horizontal bedding are developed, and the shale content is increased in the Chang 8_2 period. In the Chang 8 period, the underwater distributary channel sediments are mainly sand and silt, the shale content is small, and the sand body particles are large. The sediments of underwater natural levee are mainly fine sand and silty sand, with common crisscross and wavy bedding and thin sand body thickness. The distributary bay has high shale content, weak hydrodynamic force and the worst reservoir physical properties.

4.2. Diagenesis

4.2.1. Compaction

Compaction Compaction seriously damaged the physical properties of the reservoir in the Chang 8 section. Under the microscope, it can be observed that the rock debris particles are deformed due to compaction, the contact area between the particles increases, the porosity decreases, and the permeability decreases (Figure 7(a)).

4.2.2. Cementation

The cementation in the study area is mainly clay mineral cementation and siliceous cementation. The influence of cementation on the reservoir depends on

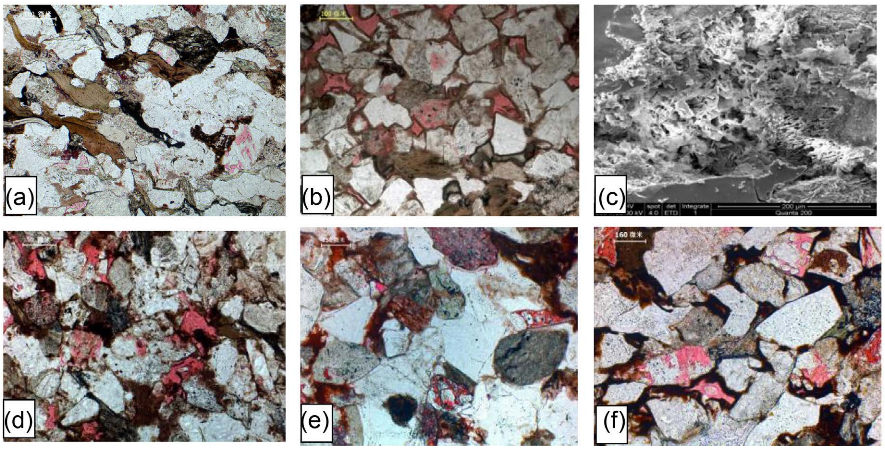

Figure 7. Diagenesis characteristics of Chang 8 in Zhijing area. (a) Well A43, 2289.72 m, chang 8_1, with directional distribution of debris and strong deformation of mica and plastic cuttings; (b) Well Q23, 1074.35 m, chang 8_1, chlorite film filling pore, turbidite slightly soluble; (c) Well X321, 2138.16 m, chang 8_1, inter-grain illite filling; (d) Well G38, 2196.05 m, chang 8_2, quartz increased chimerism, and kaolinite filled pores; (e) Well X37, 2300.11 m, chang 8_1, quartz enlarged chimerism, with a small amount of feldspar dissolved pores; (f) Well X71, 2222.78 m, chang 8_2, with intergranular pores, feldspar dissolution pores and cuttings dissolution pores.

the diagenetic period, and the early diagenesis is generally constructive. The middle and late stage of diagenesis is destructive.

The clay minerals in the Chang 8 member of the study area can be divided into chlorite, illite and kaolinite. The chlorite is mainly uniformly covered on the particle surface as a pore liner. The content of chlorite cement affects the physical properties of the reservoir. The early cementation of chlorite is for constructive diagenesis, and the late is for destructive diagenesis. Under the microscope, the chlorite film is yellowish brown (**Figure 7(b)**) attached to the particle surface.

In the study area, authigenic illite often blocks pores in the form of filiform bridging, or distributes on the surface of particles in the form of clay film, which will have a destructive effect on the porosity and throat of the reservoir. Under the scanning electron microscope, it can be seen that filamentous illite (**Figure 7(c)**) is distributed in feldspar dissolution pores, reducing the physical properties of the reservoir.

In the study area, kaolinite is often distributed in feldspar dissolved pores (**Figure 7(d)**), in the form of pore filling. When the content of kaolinite is high, the area generally has strong dissolution, and there are many secondary pores due to dissolution, so kaolinite has a constructive effect on the reservoir.

The siliceous cementation is mainly divided into two stages. The early siliceous cementation occurs in the early diagenetic stage, mainly the enlarged edge of quartz (**Figure 7(e)**), which is due to the dissolution of feldspar and rock debris to produce SiO_2, resulting in the increase of quartz content. Early siliceous cement occurs before compaction, which can improve the anti-compaction ability of the reservoir. Due to the massive dissolution of feldspar and rock debris, the late siliceous cement produced more SiO_2, which formed quartz grains to fill the pores and was difficult to dissolve.

4.2.3. Dissolution Function

In the study area where the dissolution is developed, it is found through microscopic observation that the dissolution is mostly feldspar dissolution (**Figure 7(f)**), and feldspar dissolution holes account for about 22% of the porosity, greatly improving the physical properties of the reservoir.

5. Conclusions

The sandstone type of Chang 8 member in the study area is mainly feldspathic sandstone and lithic feldspathic sandstone. The filler is mainly chlorite, calcite and illite. Silica cement is common. The pore type is mainly intergranular pore and feldspar dissolved pore.

The porosity of sandstone reservoir in Chang 8 member of the study area is between 4.1% and 15.2%, with an average value of 9.37%; Permeability is (0.02 - 3.87) × 10^3 μm^2, permeability of more than 87% is less than 1 × 10^3 μm^2, the porosity of Chang 8_2 reservoir is 2.38% - 18%, with an average of 9.39%; Permeability is (0.01 - 3.01) × 10^3 μm^2, permeability of more than 89% is lower than 1 × 10^3 μm^2. The reservoir type is low porosity, ultra-low porosity and ultra-low permeability reservoir. The heterogeneity of Chang 8_2 reservoir is strong, and the physical property of Chang 8_1 reservoir is better than that of Chang 8_2. The pore throat structure is characterized by narrow throat.

The reservoir of Chang 8 member is mainly composed of grayish-green-grey sandstone and black mudstone, which shows underwater reduction characteristics. In the sand body whose sedimentary microfacies are underwater distributary channels, massive bedding and horizontal bedding are common, which are characterized by strong hydrodynamic and rapid sedimentation. The sand body has a large vertical thickness and is horizontally distributed in the NE-SW direction. Among them, in the east of Wuqi, the reservoir in the west of Ansai has the best physical properties.

Combined with sedimentary microfacies, pore throat seepage capacity and reservoir physical properties, the Chang 8 member in the study area is divided into three types of reservoirs. Type I reservoir belongs to the main part of underwater distributary channel. Type I pore throat structure, porosity > 10%, permeability > 1 × 10^{-3} μm^2. Class II reservoir belongs to the flank of underwater distributary channel, with II pore throat structure, porosity between 8% and 10%, and permeability between (0.3 - 1) × 10^{-3} μm^2. Class III reservoir belongs to the flank of underwater distributary channel, with pore throat structure, porosity between 5% and 8%, and permeability < 0.3 × 10^{-3} μm^2. Class I and II reservoirs can be used as key areas for oil and gas development.

Conflicts of Interest

The authors declare no conflicts of interest.

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