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Study on Evaluation of Chang-6 Tight Sandstone Reservoir Characteristics in Zhangjiatan, Ordos Basin

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Abstract

The resource potential of the Triassic Yanchang Formation's Chang 6 reservoir in the southeastern part of the Ordos Basin's slope is large, whereas it is poor levels of exploration, and reservoir evaluation is not perfect enough, so that, limiting future exploration in this area. It is underpinned by core of detailed observations and descriptions of the Chang 6 reservoir system, typical samples of various sample, oil-bearing properties, and sedimentary structures were collected, and further analytical tests such as reservoir physical properties, casting thin section, scanning electron microscopy, high-pressure mercury compression, and so on. The macro and micro analyses were performed to analyze the controlling role of the reservoir on the distribution of Chang 6 reservoir characteristics. The results show that the Zhangjiatan Chang 6 reservoir is mainly fine-grain feldspar sandstone with low porosity and very low permeability, and the secondary pore is predominant. The pore structure is mainly divided into two categories. Sedimentary facies and diagenesis together affect the accumulate performance of the reservoir.

Subject Areas

Tight Sandstone Reservoir Characteristics, Geoscience

Keywords

Reservoir, Chang 6 Member, Ordos Basin

1. Introduction

The world oil and gas exploration has entered the period of both conventional and unconventional. In the process of tight oil exploration and development, the study of reservoir has become a crucial step, and the search for high-quality "sweet spot" reservoirs in relatively tight reservoirs has become the main goal of oil and gas exploration [1]-[6]. The Ordos Basin is one of the typical representatives of tight sandstone reservoirs in China and is rich in dense oil resources, which are mainly located in the Chang 6 and Chang 8 oil formations of the Mesozoic Triassic Yanchang Group in the longitudinal direction and concentrated in the lake basin sediment center of the Triassic Yanchang Group in the planar direction, with great exploration potential [7] [8]. In previous studies of tight oil in Ordos Basin [9] [10] [11] [12], a lot of research work was carried out for the center of the lake basin.

The southeastern area located at the edge of the lake basin of the Yanchang Group is adjacent to the outcrop development area, and the previous studies mainly focused on hydrocarbon source rock distribution, geochemical characteristics and oil source comparison [13] [14] [15], lacking in-depth studies from the reservoir perspective, thus further restricting the next step of exploration and development. In view of this, this paper takes the Chang 6 oil formation in Zhangjiatan area, which is located in the southeastern part of the Ordos Basin, as an example, and focuses on analyzing the reservoir characteristics in this area, which can provide some geological basis for the next oil exploration and favorable area prediction in this area.

2. Geological Background

Zhangjiatan area is located in the eastern part of northern Shaanxi slope in Ordos Basin, The Ordos Basin is a relatively stable polycyclic craton basin located in Midwest of mainland China. It is the second largest sedimentary basin in our country. The basin is in a steep and gentle asymmetrical structure in the east and west, and covers Shaanxi, Gansu, Ning, Mongolia and Shanxi provinces. According to the tectonic characteristics and evolution law, it can be divided into six tectonic units: Yimeng uplift, Jinxi flexural fold belt, Weibei Uplift, western margin thrust belt, Tianhuan depression and Yishan slope [16] [17] [18]. The Zhangjiatan area in the study area is located in the east of Qilicun oilfield (**Figure 1**), In terms of structural position, it spans two tectonic units, namely the Jinxi fold belt and Yishan slope. The Chang 6 reservoir group is the most importantoil-bearing layer in the Yanchang oil field. From the bottom up, the Chang 6_4, Chang 6_3, Chang 6_2 and Chang 6_1 subgroups can be divided into four reservoirs. The sedimentary period of Chang 6 oil formation was the main construction period of delta deposition of "lake sand retreating and advancing", and the Chang 6 period in the study area was delta facies, in which Chang 6_4-6_2 was delta front subfacies deposition and Chang 6_1 was delta plain subfacies deposition [19]. The lithology is composed of gray-green, gray-black mudstone, argillaceous siltstone, silty mudstone and light gray, brown gray, light gray green fine sandstone and siltstone interbedded [20], In terms of structural position, it spans two tectonic units, namely the Jinxi fold belt and Yishan slope, At present, the

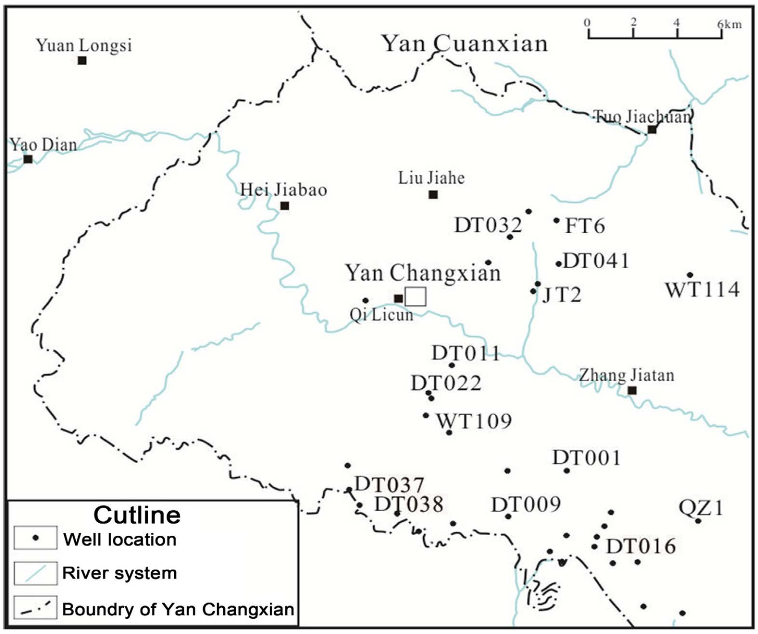

Figure 1. The location map of Zhangjiatan area in Ordos Basin.

main production layer is the Chang 6 oil layer group. Industrial oil flow is found in the oil test, which proves that the tight oil resources in this area are potential.

3. The Petrographic Characteristics of the Reservoir

3.1. Rock Types

By observing the field core in Zhangjiatan area, the rock characteristics were analyzed by using the collected sheet data and the video logging data. The particle size of the Chang 6 oil layer group is mainly distributed in 0.1 - 0.4, which belongs to the category of fine grain. Then, the statistics of the reservoir sandstone debris components show that the sandstone types in the study area are mainly fine granular feldspar sandstone (Figure 2). According to the analysis of thin sections, the types of quartz in the study area are mainly quartz and chert, the types of feldspar are mainly potassium feldspar and plagioclase, and the main debris are eruption rock, quartzite, schist, phyllite, and so on. Quartz content is mainly distributed in 20% - 27%, with an average of 24%. Feldspar content is mainly distributed in 40% - 55%, with an average of 50%. The content of debris is mainly distributed in the range of 4% - 10%, with an average of 7.6%, 5% of metamorphic rock debris, 2.4% of igneous rock debris and 0.25% of sedimentary rock debris. The content of interstitial material is mainly distributed in 10% - 20%, with an average of 13.4%.

3.2. Characteristics of Interstitial Material

The content of interstitials in Chang 6 Formation in the study area ranges from 2% to 21%, with an average of 11.21%. The main components of interstitial materials include hydromica, chlorite, ferric dolomite and ferric calcite, which

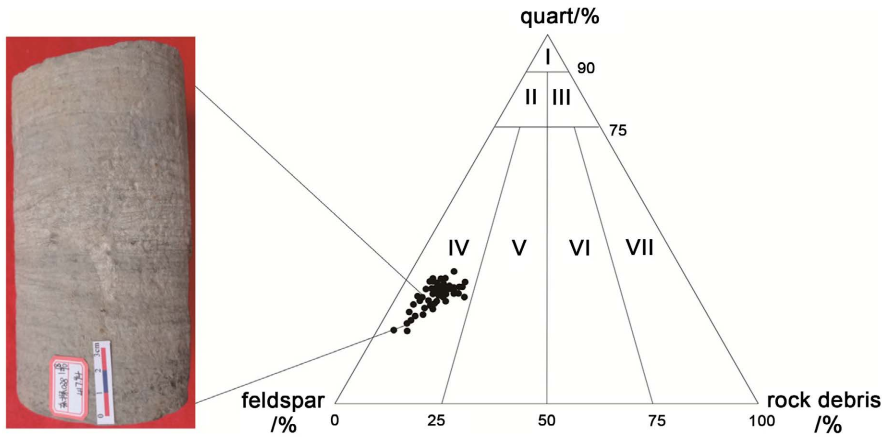

Figure 2. Triangular diagram of sandstone types of the Chang 6 formation in Zhangjiatan area.

account for more than 80% - 90% of the total interstitial materials and play a very important role in sandstone reservoir performance [21]. In addition, there are a small amount of rhombus and turbidite. Chlorite is the most common reservoir interstition, with an average content of 4.12% (1% - 10%). It was followed by hydromica (1% - 57%, mean 2.47%) and iron calcite (1% - 10%, mean 3.65%). The interstiticles of Chang 6 reservoir are mainly chlorite and hydromica with relatively high content, while the content of calcite and iron calcite is the second, and other minerals are relatively few.

4. Physical Properties of Reservoir

4.1. Porosity and Permeability

Based on the analysis of 406 reservoir physical property samples of the Chang 6 reservoir in Zhangjiatan area, the minimum porosity of the Chang 6 reservoir is 1.62%, the maximum value is 13.5%, the average is 8.39%, and the main body distribution is between 6% and 10%. The minimum permeability was 0.01×10^{-3} μm^2, the maximum was 2.66×10^{-3} μm^2, the average was 0.36×10^{-3} μm^2, and the main distribution was between $(0.1 - 1) \times 10^{-3}$ μm^2. According to the pore-permeability correlation analysis, the porosity of the Chang 6 reservoir group has a certain positive correlation, and some data points show the characteristics of low porosity and high permeability, which is presumed to be related to local fractures. (Figure 3) Chang 6 reservoir belongs to low porosity and extremely low permeability, and the distribution range of porosity and permeability is relatively concentrated and has a positive correlation.

4.2. Pore Throat Structure

The pore throat structure in Zhangjiatan area mainly includes primary porosity, secondary pores and fractures, and there is little difference in the proportion of primary porosity and secondary pores.

The secondary pores are slightly higher and dominate, which are mainly dissolved pores and intergranular pores, etc. The throat types of reservoir in the

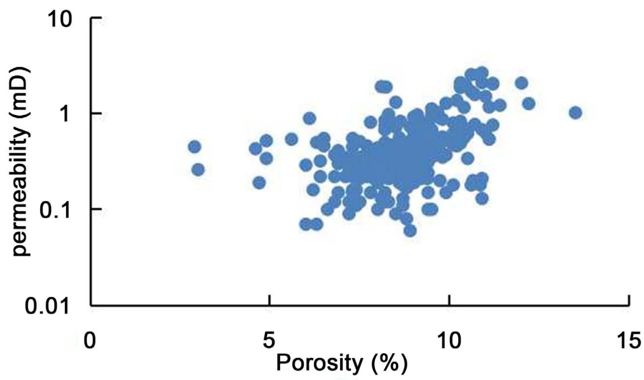

Figure 3. The correlation of porosity and permeability in the Zhangjiatan area.

study area are mainly shrinkage throat type, followed by curved and flake type, and the connectivity between pores is moderate to poor. There is no throat connection between local pores.

According to the classification standard of low permeability tight sandstone reservoirs by Zhao Jingzhou (2007) [22], the mercury injection curves can be divided into the following two types (**Figure 4**):

Class I consists of 14 samples, accounting for 82.35% of the total number of samples, with an average porosity of 7.78% and an average pore permeability of 0.1068×10^{-3} μm^2. It has significant capillary curve platform, good porosity and permeability, good overall sorting and uniformity, and good pore-throat connectivity. It belongs to the reservoir type with good reservoir property and seepage capacity. The porosity is 73.52 times of the permeability, indicating that there is strong heterogeneity between the porosity and permeability.

The second category is fine-micro-porous, micro-larynx. There were 3 samples of this type, accounting for 17.65% of the total number of samples, with an average porosity of 7.23% and an average pore permeability of 0.05×10^{-3} μm^2. The overall sorting of pore-throat was poor and uneven, and the connectivity of pore-throat was poor. It is a type of reservoir with poor reservoir property and seepage capacity. The porosity is 154.2 times of the permeability, indicating that there is a strong heterogeneity between the porosity and permeability, and the pore-throat is difficult to be effectively identified.

5. The Factors Affecting the Petrophysical Properties of Reservoir Were as Follows

5.1. The Effect of Sedimentary Facies on Reservoir Property

By drawing the continuous well-by-source direction profile analysis of the well DT038-WT 109-DT011-JT 2-FT6 passing in the north-east direction (**Figure 5**), the Chang 6 is the fan delta front, with good overall connectivity of channel sandbodies and multi-phase superposition of underwater distributary channels. The Chang 6_2 has good connectivity and large thickness of sand bodies. Typical characteristics of the distributary channel deposits are box shape, toothed box

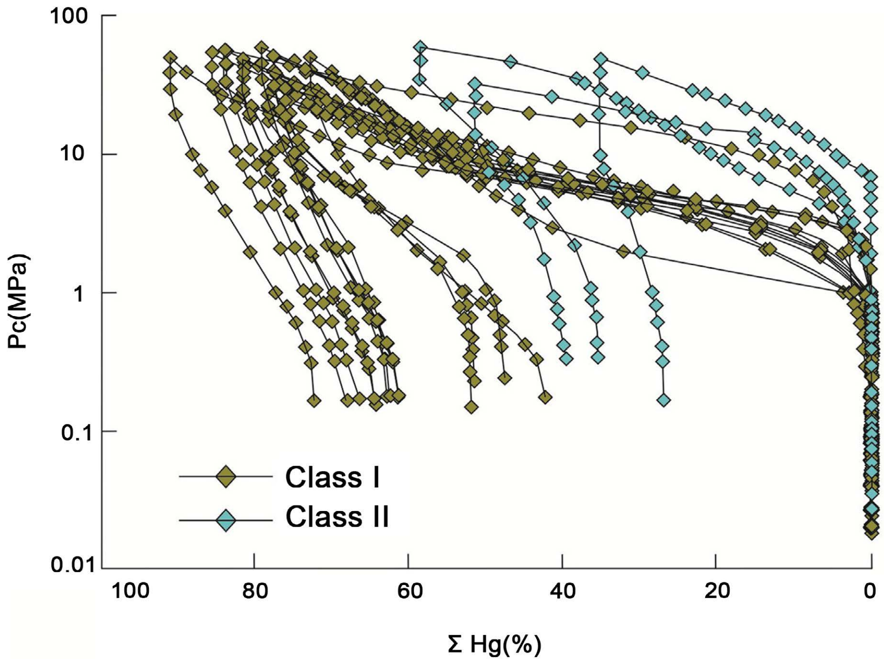

Figure4. Capillary pressure curves in high-pressure mercury experiment of Chang 6 reservoir in Zhangjiatan area.

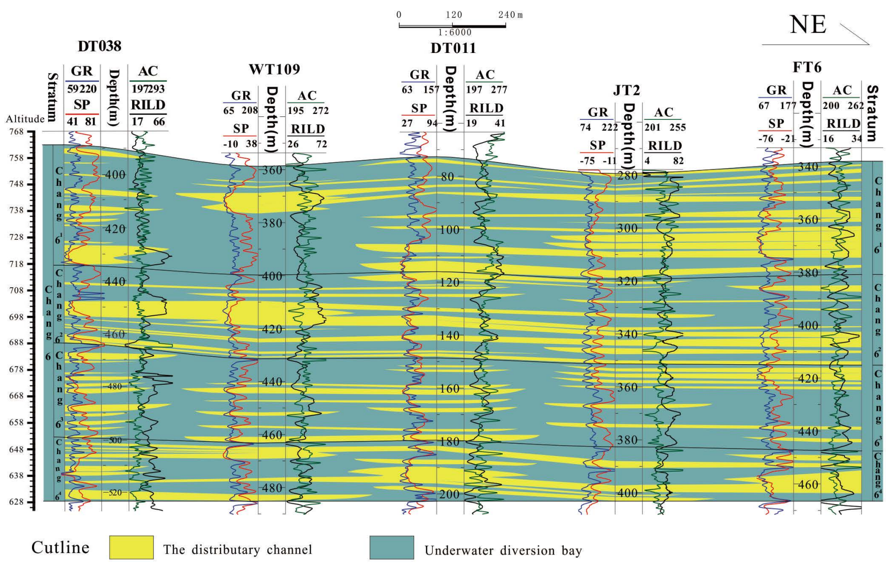

Figure 5. The profile of sedimentary facies of the Chang 6 in Zhangjiatan area.

shape or superposition of two types. The connectivity of the Chang 6_3 sand body is poor and the thickness of sand body is small. High-quality reservoirs are mainly distributed in underwater distributary channels [23], and their lithology is fine sandstone. The sandstone body of subsea interdistributary bay has poor physical property, and its lithology is siltstone and mudstone.

5.2. The Effect of Diagenesis on Reservoir Property

Diagenesis is the most important factor affecting the porosity and permeability of sandstone. According to the observation of the casting film and electron microscope scanning *et al.*, the diagenesis in the study area is mainly compaction, dissolution and cementation.

Compaction occurs in the whole process of burial diagenetic stage. Due to the high content of feldspar and mica, the plastic rock debris is squeezed and deformed with the increase of depth [24] (Figure 6(a), Figure 6(d)), and the rigid clastic minerals are crushed or fractured, which leads to the shrinkage of pore throat and the occupying of pore space, thus worsening the reservoir space.

According to the cast thin sections of core samples and SEM observations, the dissolution in the study area is mainly caused by the dissolution of feldspar and turbidite and the formation of a large number of dissolution pores (Figure 6(b), Figure 6(e)), which can effectively improve the physical properties of the reservoir to a certain extent and form a local relatively high permeability reservoir.

According to scanning electron microscope observation, the cementation types of Chang 6 reservoir in the study area are mainly clay mineral cementation, zeolite cementation and siliceous cementation (Figure 6(b), Figure 6(e)), and the cementation components are mainly turbidite and chlorite, etc. The presence of cementation reduces the pores in sandstone and destroys the primary pores.

6. Conclusion

1) The sandstone reservoir of the Chang 6 oil Formation in Zhangjiatan area of Ordos Basin is mainly fine-grained feldspar sandstone, and the interstitial material is mainly chlorite and hydromica. The cement types in the sandstone

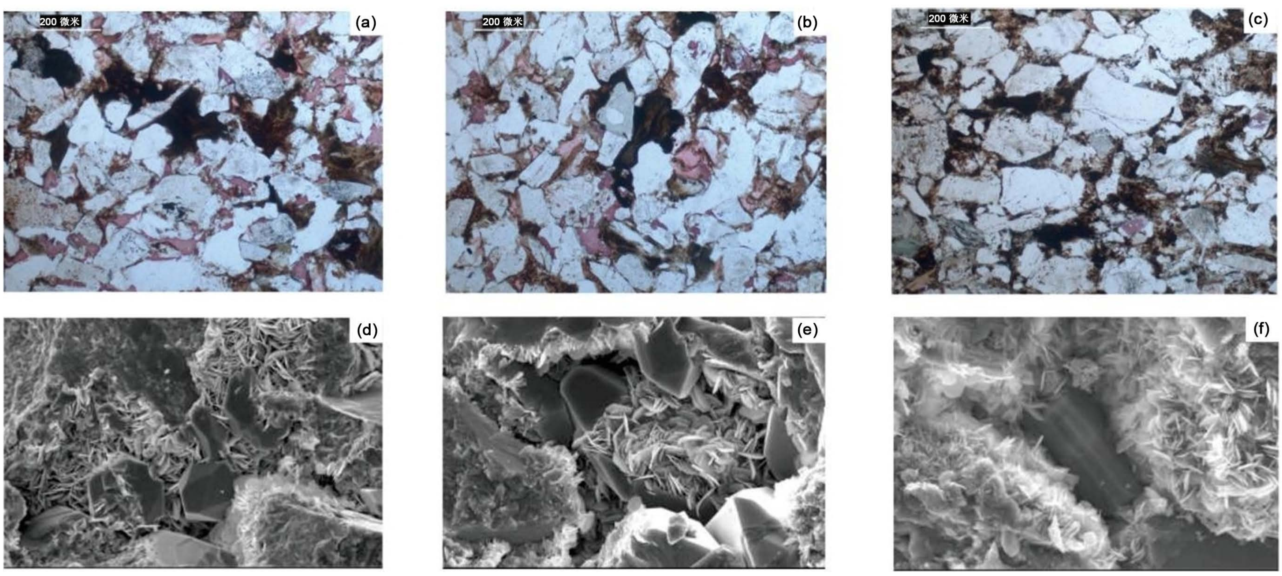

Figure 6. Typical pore types of Chang 6 reservoir in Zhangjiatan area, Ordos Basin. (a) The DT022 well, cast sheet, iron calcite filling pore, mica deformation; (b) The DT022 well, casting sheet, dissolved hole development; (c) The DT022 well, cast sheet, quartz secondary increase, iron dolomite filling pore; (d) The DT022 well, SEM, sheet mica minerals visible curved row deformation; (e) The DT022 well, SEM, turbid zeolite cement dissolution; (f) The DT022 well, scanning electron lens, turbid zeolite closely inset, overall structure compact.

are mainly carbonate, authigenic clay and siliceous cement, and the pore types are mainly residual intergranular pores and inner pores of feldspar dissolved grains.

2) The Chang 6 reservoir belongs to low porosity and ultra-low permeability, and the reservoir is compact. According to the capillary pressure curve morphology, the pore structure can be divided into two types. The I type is micro-pore and micro-throat. Class II consists of fine-micro-porous, micro-larynx, and is dominated by Class I pore structure, which has good porosity and permeability, good overall sorting and uniform, and good pore-throat connectivity. It belongs to the reservoir type with well reservoir property and filtration ability.

Sedimentation and diagenesis are the main factors, causing the poor physical properties of Chang 6 reservoir in this area, and diagenesis has a greater impact on the reservoir property.

Conflicts of Interest

The author declares no conflicts of interest.

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