ISSN 2706-655X Vol. 7, Issue 1: 9-13, DOI: 10.25236/IJFET.2025.070102

The Pore Structure Characteristics of the Chang 2 Formation in the Dongxigou Production Area of Qingpingchuan Oil Production Plant

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Abstract: *Through detailed observation and experimental analysis of core samples from the Chang 2 reservoir in the Dongxigou mining area of Qingpingchuan Oil Production Plant, the pore types, pore structure characteristics, and reservoir physical properties, among other key parameters, have been revealed. The study found that the reservoir in this area has diverse pore types, mainly intergranular pores and dissolution pores, with uneven pore size distribution but predominantly small to medium pores. The pore connectivity is good, which is beneficial for the seepage and extraction of oil and gas. The reservoir physical properties are dually controlled by sedimentation and diagenesis, with intergranular pores being dominant, poor pore connectivity, and low permeability. Reservoir classification evaluation indicates that Type I reservoirs are mainly distributed in the Chang 211, Chang 221, and Chang 223 sublayers, while Type II and Type III reservoirs are widely distributed. Diagenesis has a significant impact on reservoir physical properties, with compaction and cementation leading to deteriorated reservoir performance, and dissolution improving reservoir storage capacity to some extent. A thorough analysis of the pore structure characteristics of the Chang 2 reservoir helps optimize development plans, improve oil and gas recovery rates, and is of great significance for promoting the sustainable development of Qingpingchuan Oil Production Plant.*

Keywords: *Pore Structure Characteristics, Chang 2, Qingpingchuan, Northern Shaanxi*

1. Introduction

Qingpingchuan Oilfield is located in the area of Donggou and Xigou villages, Guanzhuang Town, to the west of Yanchuan County, Shaanxi Province, and structurally belongs to the middle-southern segment of the eastern slope of the Northern Shaanxi Slope [1]. The Chang 2 oil-bearing formation in the Dongxigou production area is one of the important oil and gas reservoirs in Qingpingchuan Oilfield, but the research on its pore structure characteristics is still insufficient [2], which restricts further exploration and development. Therefore, this paper conducts a detailed study on the pore structure characteristics of the Chang 2 reservoir in the Dongxigou production area of Qingpingchuan Oil Production Plant through systematic thin section identification, scanning electron microscopy, mercury injection experiments, and physical property analysis, aiming to provide a theoretical basis for subsequent exploration and development.

2. Overview of Geological Background

Qingpingchuan Oilfield is located in the middle-southern segment of the eastern slope of the Northern Shaanxi Slope. The regional structure is a gentle west-dipping monocline with a slope gradient of less than 10m per kilometer. In the early exploration phase, a large number of wells have shown signs of oil and gas, and a certain number of industrial oil flow wells have been obtained, indicating good exploration potential. The Dongxigou production area belongs to the Chang 2 oil-bearing formation of the Upper Triassic Yanchang Formation, with relatively simple tectonics and mainly developed lithologic and structural-lithologic reservoirs [3].

The overall thickness of the Chang 2 oil-bearing formation varies little and can be subdivided into

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three sub-formations: Chang 21, Chang 22, and Chang 23. Since most wells in the area have not penetrated the Chang 23 sub-layer, this study mainly focuses on the Chang 21 and Chang 22 sub-layers, which are further divided into six smaller layers: Chang 211, Chang 212, Chang 213, Chang 221, Chang 222, and Chang 223. The Chang 2 oil-bearing formation belongs to the delta depositional system, mainly developing delta plain subfacies distributary channels, natural levees, and interdistributary bays and other sedimentary microfacies. Among them, the delta plain distributary channel microfacies mainly control the range of high-quality reservoir development [4, 5].

3. Petrological Characteristics Analysis

Through observation of reservoir sandstone thin sections and cast thin sections, the rock types of the Chang 2 reservoir in the Dongxigou production area of Qingpingchuan Oilfield are mainly fine-grained and siltstone-fine-grained feldspathic sandstones, with a small amount of lithic feldspathic sandstones. The petrological characteristics are similar, with low compositional maturity and moderate textural maturity [6].

The pore types developed in the feldspathic sandstones are mainly primary intergranular pores, accounting for about 92% of the total pore space, while feldspar dissolved pores and lithic dissolved pores occupy a smaller volume of pore space. The formation of intergranular pores is closely related to the sedimentary processes of the rock, while the dissolved pores are mainly influenced by diagenesis.

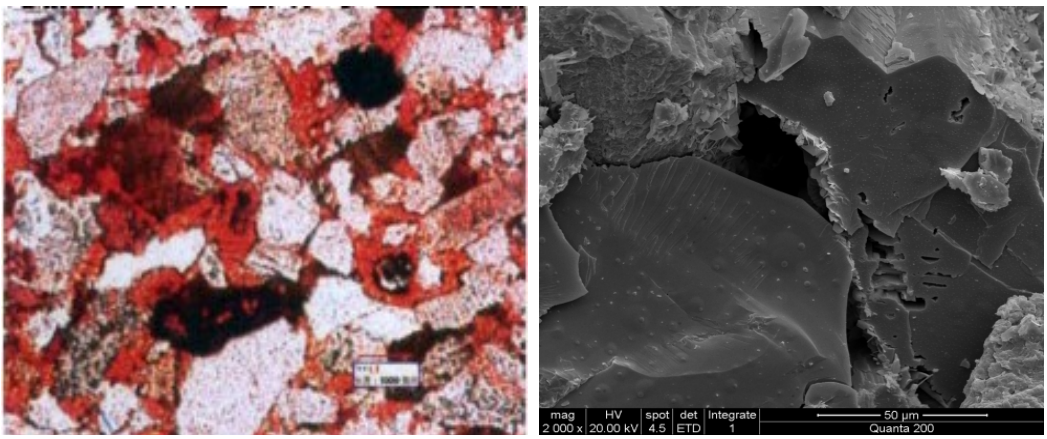
4. Pore Structure Characteristics

4.1 Pore Types

Due to the shallow burial depth of the Chang 2 oil-bearing formation in the study block of the Yanchang Formation, compaction and pressure dissolution effects are reduced, and primarily primary pores are developed.

(1) Intergranular Pores

These are the remaining primary intergranular pores after mechanical compaction, secondary enlargement of feldspars and quartz, and filling by various cementation processes, also known as residual intergranular pores or remaining intergranular pores. They include residual intergranular pores after early thin-film chlorite and illite cementation, residual intergranular pores after secondary enlargement of quartz and feldspars [7], and residual intergranular pores after filling and cementation by calcite and clay minerals (see Figure 1).



A. Chang 2, Primary Intergranular Pores B. Chang 2, Feldspar Secondary Enlargement, Chlorite, Residual Intergranular Pores Approximately 25µm

Figure 1: Well B95 in Dongxigou Area

(2) Dissolved Pores

Dissolved pores are a common pore type in the Yanan Formation of this area, second only to intergranular pores. During the diagenesis process, at different diagenetic stages, the acidity or alkalinity of pore water varies. When the acidity of pore water increases, some acid-soluble minerals

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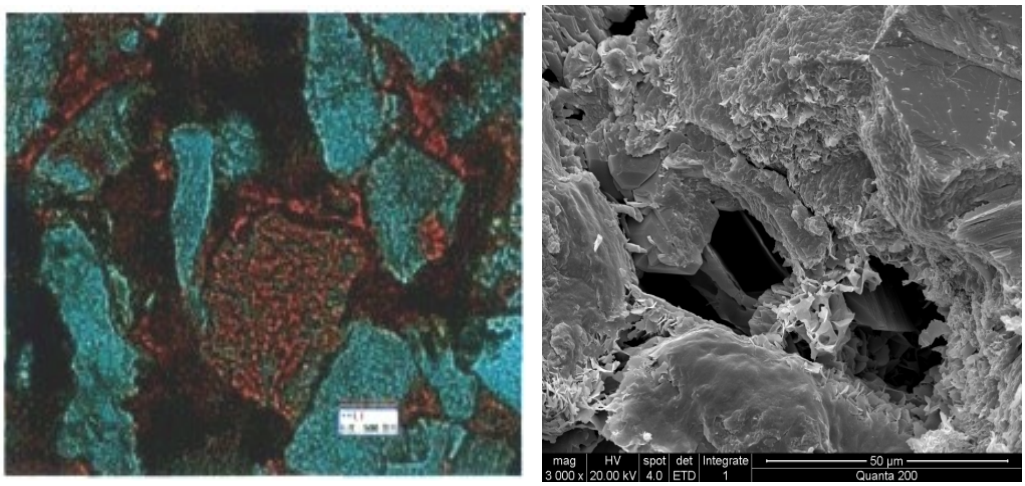
are dissolved by the pore water, often forming dissolved pores (see Figure 2).



A. Chang 2, Feldspar dissolution phenomenon *B. Chang 2, Dissolved pore*

Figure 2: Well K38 in Dongxigou Area

4.2 Pore Structure Characteristics

This study employs the mercury injection method to investigate pore structure. The capillary pressure curve reflects the pore size into which mercury can potentially enter the throat at a given displacement pressure, as well as the pore volume connected by such throats. The capillary pressure curve is not only a function of pore size distribution and pore volume but also a function of the connectivity of pore throats, and furthermore, it is a function of porosity, permeability, and saturation [8]. The capillary pressure curve is used to characterize pore structure: the length of the relatively flat segment in the middle of the capillary pressure curve indicates the concentration and sorting quality of the rock throat distribution. A longer flat segment indicates a more concentrated throat distribution and better sorting. The lower the flat segment, the larger the rock throat radius, the lower the displacement pressure, and the better the rock permeability; conversely, the higher the flat segment, the smaller the rock throat radius, the higher the displacement pressure, and the poorer the rock permeability.

Table 1: Mercury Injection Curve Data for the Chang 2 Formation in the Dongxigou Area

Formation	Well Number	Displacement Pressure (MPa)	Median Saturation Pressure (MPa)	Median Throat Radius (μm)	Mercury Withdrawal Efficiency (%)	Maximum Mercury Saturation (%)
Chang 2	D147	0.34	2.52	0.3	41.32	96.4
	X115	0.2	3.47	0.22	42.29	90.23
	B95	0.18	5.13	0.15	37.93	92.43
	K38	0.13	3.38	0.22	39.98	92.26
	D116	0.04	0.16	4.85	24.97	95.6
	X151	0.1	2.52	0.3	38.39	95.99
	Average	0.19	3.41	0.24	39.98	93.46

Based on the capillary pressure curves and the mercury injection curve data (see Table 1), it can be seen that apart from Well D116, which has a relatively low displacement pressure and a larger median throat radius, the parameters such as displacement pressure, median saturation pressure, and median throat radius for the other wells show little variation. After statistically analyzing the data from the remaining five wells, the average displacement pressure for the Chang 2 formation in Qingpingchuan is 0.19 MPa, the average median saturation pressure is 3.41 MPa, the average median throat radius is 0.24 μm, the average mercury withdrawal efficiency is 39.98%, and the average maximum mercury saturation is 93.46%.

Overall, the Chang 2 reservoir in the study area has a low displacement pressure, which is considered good to moderate, and a high mercury withdrawal efficiency, indicating good reservoir storage and permeability characteristics.

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5. Study on Physical Properties

The porosity of the Chang 2 formation in the Dongxigou production area of the Qingpingchuan Oilfield mainly ranges from 10% to 15%, with a secondary range of 15% to 25%. Porosities below 10% and above 25% account for a smaller proportion. The distribution of porosity is dually controlled by sedimentation and diagenesis, with significant influences from different sedimentary microfacies and reservoir thickness. Most of the permeability values are less than $5\times10^{-3}\mu m^2$, with a secondary range of $5\sim50\times10^{-3}\mu m^2$. There are hardly any data points with permeability greater than $50\times10^{-3}\mu m^2$. Permeability is greatly influenced by pore structure, especially the fineness and uneven distribution of pore throats, which result in low permeability. According to the reservoir physical property classification standards, the Chang 2 reservoir in Qingpingchuan is a medium-low porosity, low permeability, and ultra-low permeability sandstone reservoir.

6. Reservoir Classification and Evaluation

Based on the four parameters of sandstone porosity, permeability, reservoir thickness, and oil saturation, the Chang 2 reservoir in the study area is divided into three categories:

•Class I reservoir: High porosity, good permeability, large reservoir thickness, and high oil saturation, mainly distributed in the Chang 211, Chang 221, and Chang 223 sublayers.

•Class II reservoir: Moderate porosity and permeability, moderate reservoir thickness and oil saturation, and widely distributed.

•Class III reservoir: Low porosity and permeability, thin reservoir thickness, and low oil saturation, mainly distributed in poorer sedimentary microfacies areas.

Statistics show that Class II and Class III reservoirs account for a larger proportion in each sublayer of the Chang 2 oil reservoir group. Class I reservoirs are only found in the Chang 211, Chang 221, and Chang 223 sublayers, with the Chang 221 sublayer having relatively more Class I reservoirs compared to the other sublayers.

7. Discussion and Conclusion

7.1 Impact of Diagenesis on the Reservoir

The diagenesis of the reservoir in the study area is intense, and the intensity of diagenesis has a crucial impact on the reservoir's storage and permeability properties. Compaction, cementation, and dissolution are the main types of diagenesis that affect reservoir physical properties. Compaction leads to a decrease in reservoir porosity and a deterioration in permeability; cementation further exacerbates the complexity of the pore structure; and dissolution improves the reservoir's storage capacity to some extent, but the overall impact is limited.

7.2 Development Potential and Technical Policies for Stable Production

Preliminary water injection in the Chang 2 reservoir in the study area has shown positive effects, with good utilization of water-driven reserves. However, there are many issues in the development process, such as a high proportion of low-producing wells, low levels of formation energy maintenance, deteriorating reservoir and fluid properties, and an increasing proportion of high water cuts. To address these issues, the following technical policies for stable production are proposed:

•Adjust water injection intensity by zone to improve water injection effectiveness.

•Optimize water injection processes to improve water injection utilization.

•Improve the injection-production well pattern to enhance formation pressure maintenance levels.

•Tap into remaining oil potential to slow down production decline.

7.3 Conclusion

The Chang 2 reservoir in the Dongxigou production area of the Qingpingchuan Oilfield is a medium-low porosity, low-permeability sandstone reservoir with a complex pore structure and strong

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heterogeneity. Reservoir physical properties are dually controlled by sedimentation and diagenesis, with intergranular pores predominating, poor pore connectivity, and low permeability. Reservoir classification and evaluation indicate that Class I reservoirs are mainly distributed in the Chang 211, Chang 221, and Chang 223 sublayers, while Class II and Class III reservoirs are widely distributed. Diagenesis has a significant impact on reservoir physical properties, with compaction and cementation leading to deteriorated reservoir performance, and dissolution improving reservoir storage capacity to some extent. Corresponding technical policies for stable production have been proposed to address the issues in development, providing a theoretical basis for subsequent exploration and development.

Acknowledgment

This work was supported by Shaanxi Provincial Department of Science and Technology 2024 Natural Science Basic Research Program Project (2024JC-YBQN-0347), Yan'an University Doctoral Research Initiation Project (YAU202303785).

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