Academic Journal of Emerging Technologies
ISSN Print: 3104-4417
ISSN Online: 3104-4425
CD ISSN: 3104-4433
https://doi.org/10.63313/AJET.9015

Reservoir Characteristics of the Chang 6_3 Sub-member in the Daluogou Area

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How to cite this paper: Jiang, S. S. (2025). Reservoir characteristics of the Chang 6_3 sub-member in the Daluogou area. Academic Journal of Emerging Technologies, 1(2), 100-109. ISSN Print: 3104-4417; ISSN Online: 3104-4425.
https://doi.org/10.63313/AJET.9015
Published: 2025-10-31

Abstract

The Chang 6 reservoir is characterized by "five lows and one strong": low porosity, low permeability, low temperature, low pressure, low oil saturation, and strong heterogeneity. With the continuous and in-depth development of the tight oil reservoir in the Chang 6 formation of the Dagugou area, the natural energy depletion development method has led to severe formation energy deficit, rapid production decline, and difficulties in maintaining stable production, which have become "bottlenecks" restricting the sustainable development of this area. Deepening the understanding of the Chang 6 formation in the Dagugou area through reservoir characteristic research is an effective approach to break through the development bottlenecks and achieve increased and stable production. This study utilizes scanning electron microscopy, cast thin sections, high-pressure mercury intrusion, physical property analysis, oil-water two-phase flow experiments (unsteady-state), and nuclear magnetic resonance movable fluid experiments to investigate diagenesis, reservoir physical properties, and pore structure. It analyzes the microscopic pore structure characteristics of different parts of the sand body and different sand belts, examines the controlling factors influencing reservoir physical properties, conducts a comprehensive reservoir evaluation, and maps the planar distribution of reservoir physical properties to determine the distribution patterns of high-quality reservoirs. This provides theoretical guidance for the subsequent development of the tight oil reservoir in the Chang 6 formation of the Dagugou area.

Keywords

Reservoir characteristics; Petrology; Diagenesis; Reservoir evaluation; Reservoir physical properties

1. Introduction

As an important unconventional oil and gas resource, tight oil is widely distributed in China across numerous strata, with the most abundant reserves found in the Chang 6 oil layer of the Yanchang Formation, Ordos Basin [1-2]. In recent years, the crude oil production from the Chang 6_3 reservoir in the Daluogou area of the Suijing Oilfield has continuously increased, and the exploration and development regions have been expanding. However, the natural energy depletion development method has led to a severe deficit in formation energy, resulting in rapid production decline and great difficulties in maintaining stable production. These issues have become a "bottleneck" constraining the sustainable development of this area and are detrimental to the long-term sustainability of the oilfield. Gaining an in-depth understanding of the reservoir characteristics of the Chang 6_3 layer is of great significance for increasing reserves and production and ensuring long-term stable development of the oilfield. Taking the Daluogou area of the Suijing Oilfield as an example, and supported by data from core observation, thin section analysis, SEM, X-ray diffraction experiments, and other analysis, this paper comprehensively analyzes the petrological characteristics, pore structure characteristics, physical property characteristics, and diagenesis characteristics of the Chang 6_3 reservoir. Furthermore, it summarizes various influencing factors on the reservoir physical properties, aiming to provide theoretical guidance for the subsequent development of tight oil reservoirs in the Chang 6 layer of the Daluogou area.

2. Geological Overview

The Daluogou area is located in the north-central part of the Shaanbei Slope, Ordos Basin. The primary target layers within the Triassic Yanchang Formation in this area are typical reservoirs characterized by low porosity and low to ultra-low permeability. The top structure is a gentle west-dipping monocline, where structural traps are not developed, with only local nose-like uplifts formed by differential compaction present. The Yanchang Formation is divided from top to bottom into ten oil-bearing layers, designated as Chang 1 to Chang 10, among which the Chang 6, Chang 7, and Chang 8 members are the principal source rocks and reservoirs. The Chang 6 member can be further subdivided into three sub-members: Chang 6_1, Chang 6_2, and Chang 6_3[4]. After more than a decade of exploration and development, numerous oil and gas shows have been encountered in the drilled wells targeting the Lower Jurassic Yanchang Formation and the Upper Triassic Yanchang Formation. Hundreds of wells have yielded high-productivity industrial oil flows during testing in the oil-bearing layers of the Yanchang Formation. Through long-term detailed development, the area has achieved a high annual production level and created significant economic benefits. "Chang 6_3" refers to a specific stratigraphic subdivision within the Upper Triassic Yanchang Formation, fully named the "Chang 6_3 sub-member", and is one of the most important hydrocarbon reservoir layers in the Ordos Basin [3]. This paper focuses on the Chang 6_3 oil reservoir group in this area.

3. Petrological Characteristics of the Reservoir

Reservoir petrological characteristics refer to the combination of intrinsic properties of rocks—such as mineral composition, texture, and structure—that are closely related to hydrocarbon storage and seepage capacity. The fundamental purpose of studying these characteristics is to evaluate and predict the physical properties of the reservoir and its dynamic response during development, thereby guiding oil and gas exploration and production. The reservoir sandstone is predominantly fine-grained feldspathic sandstone with low compositional maturity and moderate textural maturity. The detrital grain content ranges between 65% and 93%, averaging 87%, and the composition is primarily feldspathic sandstone with diverse types of lithic fragments [5].

Based on core observation, thin section analysis, SEM, and X-ray diffraction experimental analysis, the Chang 6_3 reservoir sandstone in the study area is mainly composed of fine-grained feldspathic sandstone, with a minor amount of medium-grained sandstone. The primary grain size distribution ranges from 0.05 mm to 0.20 mm, with an average grain size of 0.15 mm and a maximum grain size of 0.40 mm. The composition is predominantly feldspar, with content ranging from 32% to 62% and an average of 49.4%, followed by quartz and lithic fragments. The rock exhibits low compositional maturity. The detrital grains are moderately sorted and moderately rounded, appearing sub-angular to sub-rounded.

4. Pore Structure Characteristics of the Reservoir

Pore structure describes the geometry, size, distribution, and interconnectedness of the pore spaces and throats within reservoir rocks. The study of pore structure represents a refinement and quantification of reservoir petrological characteristics. It reveals the microscopic essence governing reservoir physical properties (especially permeability), explains the micro-scale causes behind many macro-scale phenomena observed during hydrocarbon production (such as water channeling and low recovery rates), and directly provides a scientific basis for the efficient development of oil and gas fields.

4.1. Pore Types

4.1.1. Main Pore Types in the Study Area

Observation and analysis of data from cast thin sections of core samples, core examination, and scanning electron microscopy (SEM) reveal that the Chang 6_3 reservoir sandstone in the Baiyushan-Daluogou area develops various pore types. These mainly include residual intergranular pores, dissolved intergranular pores, dissolved intragranular pores, micropores, and micro-fractures. Dissolved intergranular pores, residual intergranular pores, and dissolved intragranular pores are the most dominant pore types in the study area.

Given that dissolution is intense and widespread in the sandstone reservoirs of the study area, the pores can be categorized into four types for statistical analysis: intergranular pores, dissolved intergranular pores, dissolved intragranular pores, and other pores (including micro-fractures, intercrystalline pores, and micropores within interstitial material).

4.1.2. Characteristics of Pore Types in a Typical Well - Well Y2

The Chang $6_3{}^1$ and Chang $6_3{}^2$ reservoirs in Well Y2 are primarily composed of fine-grained feldspathic sandstone with relatively low maturity. Feldspar grains are the main components subjected to dissolution. The pore assemblage is primarily composed of: intergranular pores + dissolved intergranular pores + dissolved intragranular pores. Specifically, intergranular pores account for 50-65%, dissolved intragranular pores for 10-25%, and dissolved intergranular pores for 5-15%.

Statistics from cast thin sections of core samples indicate that the Chang $6_3{}^1$ and Chang $6_3{}^2$ sandstone reservoirs in the study area are dominated by intergranular pores and dissolved intragranular pores (mainly in feldspar), with minor development of laumontite dissolved pores, micro-fractures, and intercrystalline pores. Intergranular pores constitute approximately 60% of the total porosity, followed by dissolved pores (approximately 35% of the total porosity), including dissolved intragranular pores in feldspar and lithic fragments, and dissolved intergranular pores in laumontite. Micropores, micro-fractures, and intercrystalline pores together account for about 5% of the total porosity. The plane porosity of Chang $6_3{}^1$ samples generally ranges between 6% and 15%, with an average of 8.9%; the plane porosity of Chang $6_3{}^2$ samples generally ranges between 6% and 13.5%, with an average of 8.4%.

4.2. Pore Structure Characteristics

Analysis of 55 cast thin section samples and mercury injection capillary pressure (MICP) data from 18 sandstone samples from the Chang $6_3{}^1$ and Chang $6_3{}^2$ layers indicates that the capillary pressure curves of the Chang 6_3 reservoir are generally characterized by low displacement pressure, coarse skewness, relatively good pore-throat sorting, and good connectivity. The average throat diameter in the Chang 6_3 reservoir of the study area is 0.18 μm. Thin section analysis reveals that the pore diameters are predominantly distributed in the range of 15-40 μm. Comprehensive analysis suggests that the Chang 6_3 interval in the study area is primarily characterized by medium pores with fine throats, and fine pores with very fine throats. The physical properties related to the pore structure of the Chang 6_3 reservoir sandstone show relatively poor pore-throat sorting and a relatively complex pore structure. The displacement pressure typically ranges from 0.09 to 0.25 MPa, and the median pore-throat radius generally falls between 0.1 and 0.50 μm, classifying it as a relatively poor reservoir. The high median pressure indicates tight rock with fine grains.

5. Physical Characteristics of the Reservoir

Porosity and permeability are the two most fundamental parameters reflecting reservoir performance and filtration conditions [6,7]. The quality of porosity directly determines the volume of hydrocarbons a rock layer can store, while the quality of permeability controls the productivity of the fluids contained within the reservoir [7,8].

According to the statistical results from core physical property analysis data of the Chang 6_3^1 layer in the study area, the porosity of the Chang 6_3^1 sandstone reservoir is mainly distributed between 9% and 13%, with an average porosity of 10.05%. The permeability distribution ranges from 0.05 to $5\times10^{-3}\mu m^2$, primarily concentrated in the intervals of $0.05\text{-}0.4\times10^{-3}\mu m^2$ and $1\text{-}2\times10^{-3}\mu m^2$, with an average permeability of $1.26\times10^{-3}\mu m^2$.

Statistical results from the core physical property analysis data of the Chang 6_3^2 layer indicate that its porosity is mainly concentrated in the 10% to 13% range, with an average porosity of 10.76%. The permeability distribution ranges from 0.05 to $6\times10^{-3}\mu m^2$, primarily concentrated between 0.05 and $0.2\times10^{-3}\mu m^2$, with an average permeability of $1.26\times10^{-3}\mu m^2$.

Based on the evaluation criteria for sandstone reservoirs of the Yanchang Formation in the Northern Shaanxi area, the Chang 6_3 reservoir in the study area is classified as having low porosity and low to ultra-low permeability.

6. Factors Influencing Reservoir Physical Properties

The Chang 6_3 reservoir in the study area is a typical tight sandstone reservoir, inherently characterized by significant reservoir heterogeneity. Furthermore, the study area is located in a transitional zone between the delta plain and delta front subfacies of a continental lacustrine basin, where facies change rapidly. Coupled with intense diagenetic alteration, these factors lead to substantial variations in reservoir physical properties within the study area. Therefore, analyzing the main factors influencing reservoir physical properties is of great importance for conducting accurate reservoir evaluation and prediction.

6.1. Relationship Between Sedimentary Facies and Reservoir Physical Properties

During the Chang 6_3^1 period, the study area, specifically along the Daluogou-Huaziping axis, was dominated by delta front subfacies deposits in the southwestern part, where underwater distributary channels and inter-channel bays were well developed. The extensive northern and eastern regions were occupied by the delta plain subfacies, primarily consisting of distributary channel and inter-channel bay microfacies. In the subsequent Chang 6_3^2 period, following the Daluogou North-Huaziping South line, delta front subfacies deposits developed in the southwest, with developed underwater distributary channels and inter-channel bays. The vast northern and eastern areas remained dominated by the delta plain

subfacies, mainly featuring distributary channel and inter-channel bay microfacies.
Statistical results indicate that for the Chang 6_3 reservoir in the study area, the sandstone porosity in distributary channels ranges from 5% to 13.5%, averaging about 9.7%, with permeability ranging from 0.01 to 4.5 $\times 10^{-3}\mu m^2$ and an average of 0.59 $\times 10^{-3}\mu m^2$. In contrast, the sandstone in underwater distributary channels exhibits a porosity range of 5% to 15.5%, with an average of 10.9%, and permeability ranging from 0.01 to 5.1 $\times 10^{-3}\mu m^2$, averaging 0.71 $\times 10^{-3}\mu m^2$. This demonstrates that the sand bodies of underwater distributary channels in the front subfacies have better sorting and lower content of plastic grains and argillaceous material compared to those in distributary channels. Consequently, the reservoir physical properties are superior in the underwater distributary channel sand bodies. Furthermore, within the reservoir sand bodies, the physical properties are relatively better in the main channel areas and gradually deteriorate towards the channel margins.

6.2. Impact of Diagenesis on Physical Properties

During the burial process of the clastic sandstone in the study area, the reservoir physical properties are continuously altered by various diagenetic processes. Compaction causes the rearrangement of detrital grains and the expulsion of pore water, leading to increased sandstone density and the degradation of reservoir porosity and permeability. Cementation generates various authigenic minerals that fill pore spaces and block throats, thereby damaging reservoir quality. Replacement and recrystallization affect the reservoir properties by altering the mineral composition and rock fabric. In contrast, dissolution selectively removes unstable components within the reservoir sandstone, effectively enhancing pore space and storage capacity.
Due to the continuous accumulation of overlying sediments, the static load pressure on the reservoir increases. Consequently, both compaction and cementation tend to deteriorate the physical properties, whereas dissolution correspondingly increases porosity and permeability, thereby modifying the overall reservoir characteristics.

6.2.1. Mechanical Compaction

Compaction occurs continuously during the burial of reservoir sandstones. As the burial depth of the oil layer increases, the overlying sedimentary load causes loose sediments to be progressively compacted, expelling pore water and reducing porosity. In the study area, compaction manifests mainly as: deformation of plastic components in minerals, such as the bending of plastic mica fragments; the contact relationships between detrital grains shift from point contacts to line contacts, locally to concave-convex and sutured contacts, while quartz and feldspar develop secondary overgrowths; mudstone fragments are squeezed and deformed, forming pseudomatrix; and mineral grains become oriented. Compaction and pressure dissolution lead to a significant reduction in primary reservoir porosity, which is an important reason for the deterioration of reservoir physical properties.

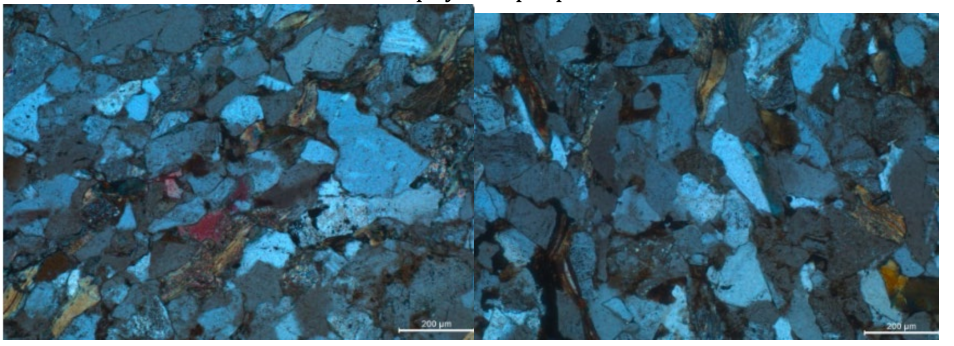

Figure 1. The relationship between compaction and reservoir physical properties

6.2.2. Cementation

Cementation is relatively well-developed in the study area and is one of the key processes destroying primary porosity. The main types of cementation in the study area include carbonate cementation, laumontite cementation, clay mineral cementation, and siliceous cementation.

① Carbonate Cementation

The Chang 6_3 sandstone exhibits two stages of carbonate cementation: an early stage comprising calcite, siderite, and minor ankerite, and a late stage comprising minor ferrocalcite and ankerite. Research results indicate that carbonate cements fill part or most of the pore space, greatly reducing primary porosity. Since the dissolution of carbonate is weak during the late diagenetic stage, this often results in the formation of tight reservoirs with low porosity and low permeability. Porosity and permeability in carbonate-cemented samples show a negative correlation with cement content; higher carbonate cement content corresponds to lower sample porosity and permeability.

Physical property analysis of 29 reservoir sandstone samples from the Chang 63 layer shows that samples with carbonate cement content between 0-5% have a porosity range of 3.3 – 11.1% (avg. 7.9%) and a permeability range of 0.03 – 0.922 $\times 10^{-3}\mu m^2$ (avg. 0.28 $\times 10^{-3}\mu m^2$). Samples with carbonate cement content greater than 5% have relatively lower physical properties, with porosity ranging from 4.5% to 7.7% (avg. 5.9%) and permeability ranging from 0.03 to 0.4 $\times 10^{-3}\mu m^2$ (avg. 0.18 $\times 10^{-3}\mu m^2$).

② Zeolite Cementation

The development of laumontite cementation plays a constructive role in the porosity evolution of the sandstones in the study area. Laumontite formed during the early diagenetic stage precipitates and fills intergranular pores under conditions of weak compaction of detrital grains, which positively contributes to preserving intergranular pore volume during diagenetic evolution. Furthermore, under acidic diagenetic conditions during the late diagenetic stage, it is dissolved by acidic fluids, providing the material basis for the widely developed secondary pores from laumontite cement dissolution. Laumontite cement in the study area has undergone extensive dissolution, forming abundant dissolved intergranular pores.

Measured physical property analysis of sandstones indicates that the porosity of Chang 63 reservoir samples ranges between 3.3% and 11.1%, with an average of 7.7%. Permeability ranges from 0.03 to 1.2 $\times 10^{-3}\mu m^2$, with an average of 0.27 $\times 10^{-3}\mu m^2$. Among these, samples with laumontite cement content greater than 5% and subjected to strong dissolution have a porosity of 8 – 11% (avg. 9.5%) and a permeability of 0.35 – 0.9 $\times 10^{-3}\mu m^2$ (avg. 0.68 $\times 10^{-3}\mu m^2$). Overall, porosity and permeability in laumontite-cemented samples show a positive correlation with cement content; higher laumontite cement content corresponds to higher sample porosity and permeability.

③ Clay Mineral Cementation

Authigenic chlorite in the Chang 6_3 reservoir of this area mostly occurs as grain coatings or pore linings. This chlorite film or lining, to some extent, inhibits quartz cementation. Among the authigenic clay mineral cements, chlorite coatings primarily form during the eodiagenetic stage, enveloping detrital grains before significant compaction occurs. Their development can effectively resist mechanical compaction and inhibit siliceous cementation, thus playing a constructive role in preserving intergranular pores. The development of chlorite clay coatings shows a positive correlation with reservoir physical properties; samples with more developed chlorite coatings generally exhibit better physical properties.

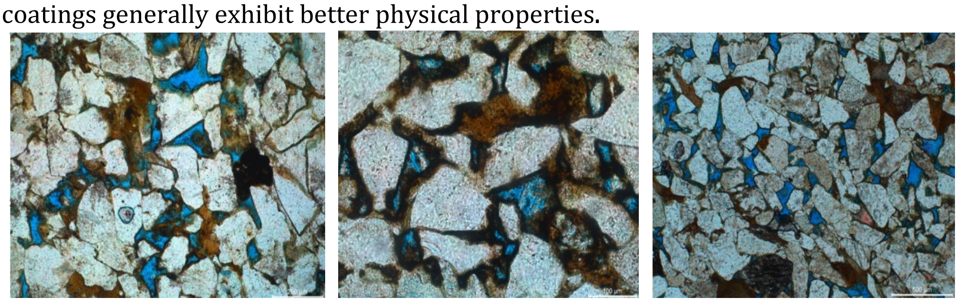

Figure 2. Relationship Between Chlorite Coatings and Reservoir Physical Properties in the Chang 6_3 Reservoir, Study Area

④ Siliceous Cementation

Siliceous cementation in the study area primarily occurs as secondary overgrowth rims and as pore-filling euhedral crystals. While authigenic quartz overgrowths or pore-filling reduce primary porosity and deteriorate sandstone physical properties, the content of siliceous cement in the study area is generally low, typically between 1-3%, resulting in a limited impact on reservoir physical properties.

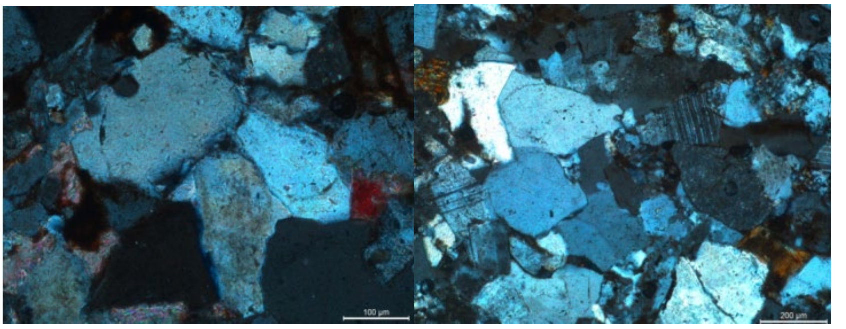

Figure 3. Development characteristics of siliceous cementation in the Chang 6_3 reservoir of the study area

Overall, diagenesis and cementation (e.g., carbonate cementation, siliceous cementation) have severely damaged the reservoir, leading to significant loss of primary porosity, which is the main cause of the reduction in sandstone physical properties.

Based on the analysis of the aforementioned diagenetic processes and main controlling factors on physical properties, the Chang 6_3 reservoir in the study area can be divided into the following diagenetic facies zones:

- "Strong Calcite & Laumontite Cementation, Weak Dissolution; Weak Feldspar Dissolution Facies Zone"
- "Moderate-Weak Calcite & Laumontite Cementation, Weak Dissolution; Weak Feldspar Dissolution Facies Zone"
- "Weak Calcite & Laumontite Cementation-Weak Dissolution; Weak-Moderate Feldspar Dissolution, Weak Chlorite Coating Cementation Facies Zone"

In general, calcite and laumontite cementation gradually weakens from the northeast to the southwest, while dissolution gradually strengthens. On one hand, the distribution of reservoir diagenetic facies zones corresponds well with the distribution of sedimentary facies zones. Secondly, closer proximity to the organic acid source (the hydrocarbon generation center of the basin) in the northeast-southwest direction of the study area correlates with progressively stronger dissolution.

7. Conclusions and Insights

The Chang 6_3 reservoir sandstone in the study area is primarily composed of fine-grained feldspathic sandstone. The dominant component is feldspar, followed by quartz and lithic fragments. The rock exhibits low compositional maturity, with detrital grains displaying moderate sorting and roundness. The interstitial materials mainly consist of clay minerals, carbonate cements, laumontite, siliceous cement, and minor pyrite cement.

The Chang 6_3^1 and Chang 6_3^2 sandstone reservoirs in the study area are dominated by intergranular pores and dissolved intragranular pores (mainly in feldspar), with minor development of laumontite dissolved pores, micro-fractures, and intercrystalline pores. Intergranular pores constitute approximately 60% of the total porosity, followed by dissolved pores (about 35% of the total porosity), including dissolved intragranular pores in feldspar and lithic fragments, as well as laumontite dissolved pores. Micropores, micro-fractures, and intercrystalline pores collectively account for about 5% of the total porosity.

The Chang 6_3 reservoir in the study area is classified as having low porosity and low to ultra-low permeability. The porosity of the Chang 6_3^2 layer is mainly concentrated in the 10-13% range, with an average of 10.76%. Its permeability distribution ranges from 0.05 to 6 $\times$ $10^{-3}\mu m^2$, with an average of 1.26 $\times$ $10^{-3}\mu m^2$. The porosity of the Chang 6_3^1 sandstone reservoir is concentrated between 9% and 13%, with an average of 10.05%. Its permeability is primarily distributed in the ranges of 0.05-0.4 $\times$ $10^{-3}\mu m^2$ and 1-2 $\times$ $10^{-3}\mu m^2$, with an average of 0.87 $\times$ $10^{-3}\mu m^2$.

Compaction, pressure dissolution, as well as carbonate and siliceous cementation are the primary causes for the reduction of physical properties in the sandstone reservoirs of the study area. Conversely, the dissolution of feldspar, lithic fragments, and laumontite cement has generated extensive secondary pores, which is a key factor in improving the physical properties of the reservoir sandstone.

The reservoir is dominated by intergranular pores, dissolved intragranular pores (in feldspar), and dissolved intergranular pores (in laumontite), with minor development of micropores, micro-fractures, and intercrystalline pores. The plane porosity generally ranges between 6% and 14%, with an average of 8.6%. The pore structure is characterized by medium-sized pores, small pore throats, and very fine throats. The reservoir exhibits low porosity and low to ultra-low permeability.

The reservoir physical properties are primarily controlled by sedimentary facies, diagenesis, diagenetic facies, and pore-throat structure.

References

[1] Deng Xiuqin. Study on the accumulation mechanism of super-low permeability large lithologic reservoirs in the Triassic Yanchang Formation, Ordos Basin [D]. Northwest University, 2011.

[2] Jiao Fangzheng. Re-recognition of "unconventional" in unconventional oil and gas [J]. Petroleum Exploration and Development, 2019, 46(5): 803-810.

[3] Yang Junjie. Tectonic Evolution and Hydrocarbon Distribution Patterns in the Ordos Basin [M]. Beijing: Petroleum Industry Press, 2002.

[4] Fu Jinhua, Yu Jian, Xu Liming, et al. Formation conditions and distribution patterns of tight oil reservoirs in the Yanchang Formation, Ordos Basin [J]. Acta Petrolei Sinica, 2013, 34(1): 34-41.

[5] Yao Jingli, Wang Yi, Deng Xiuqin, et al. Characteristics and genesis of tight sandstone reservoirs in the Yanchang Formation, Ordos Basin [J]. Geological Science and Technology Information, 2013, 32(5): 1-9.

[6] Luo Zhetan, Wang Yuncheng. Pore Structure of Oil and Gas Reservoirs [M]. Beijing: Science Press, 1986.

[7] Qiu Yinan, Xue Shuhao. Evaluation Technology of Oil and Gas Reservoirs [M]. Beijing: Petroleum Industry Press, 1997.

[8] Tiab, D., Donaldson, E. C. Petrophysics: Theory and Practice of Measuring Reservoir Rock and Fluid Transport Properties (Fourth Edition) [M]. Gulf Professional Publishing, 2015.