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# Tight Oil Accumulation and Enrichment of Chang 7 Oil Layer in Chenghao Area, Ordos Basin Research on Factors

Lu Yin [1, 2], Xiong Ma [1, 2], Feng Wang [1, 2]

[1] School of Earth Sciences and Engineering, Xi'an Shiyou University, Xi'an Shaanxi, 710065, China

[2] Shaanxi Key Laboratory of Petroleum Accumulation Geology, Xi'an Shiyou University, Xi'an Shaanxi, 710065, China

## Abstract

**The study of accumulation and enrichment factors for tight oil is a key focus in unconventional petroleum geology. This paper takes the Chang 7 tight oil reservoir of the Yanchang Formation in the Chenghao area, Ordos Basin, Utilizing data from well logging, drilling, and laboratory analysis, it analyzes the conditions of the source rock, reservoir, and caprock, as well as their controlling effects on the quasi-continuous tight oil distribution, to predict favorable zones. Research indicates that the pores in the Chang 7 reservoir in the Chenghao area are predominantly secondary dissolution pores, with an average total plane porosity of 2.5%. Porosity ranges from 0.7% to 12%, with an average of 8.2%, a median of 7.1%, and the main distribution range being 6% to 12%. Permeability ranges from (0.023–1.68)×10^(-3) μm², with an average of 0.16×10^(-3) μm², a median of 0.1×10^(-3) μm², and a main distribution range of (0.1–0.15)×10^(-3) μm², classifying it as a tight reservoir. The reservoir type is quasi-continuous, characterized by lateral connectivity and vertical stacking. The mudstone thickness and hydrocarbon generation intensity of the source rock exhibit significant control over the Chang 7 tight oil, followed by TOC. The porosity and shale content of the caprock show a clear controlling effect on tight oil, followed by permeability, and finally, individual sand body thickness. The shale content of the caprock has a significant controlling effect on tight oil, followed by caprock thickness. Finally, the enrichment factor of the oil layer was used to predict favorable zones for tight oil.**

## Keywords

**Tight Reservoir; Accumulation Model; Chang 7; Yanchang Formation; Enrichment Factors; Ordos Basin; Favorable Zone.**

## 1. Introduction

Tight oil refers to oil accumulations formed in low-permeability sandstone reservoirs that are not source rocks, with reservoir air permeability generally less than 1×10^(-3) μm² and porosity less than 12%[1-5]. As an important alternative field in global unconventional oil and gas resources, the successful development of tight oil in basins like the Bakken and Eagle Ford in North America has driven changes in the energy industry in recent years. China is rich in tight oil resources, mainly distributed in the Ordos, Songliao, and Sichuan Basins. Among them, the Chang 7 oil reservoir member in the Ordos Basin has become a key exploration target due to its extensive source rocks and large-scale reservoirs[6]. With breakthroughs in horizontal well fracturing technology, the development potential of tight oil is enormous. However, constrained by factors such as low porosity and permeability and strong heterogeneity, its enrichment mechanisms still require in-depth investigation to support efficient exploration and development.

The Chang 7 oil reservoir member in the Chenghao area of the Ordos Basin has shown good conditions for tight oil accumulation. Historically, research has focused more on the Chang 6 and Chang 8 members, with relatively less on Chang 7[7]. However, with shifts in exploration strategy, the Chang 7 member has become a focal point and has achieved significant breakthroughs[8]. Previous studies have conducted in-depth research on the source rock characteristics, reservoir characteristics, caprock characteristics, and favorable zone prediction of the Chang 7 tight oil in the Ordos Basin. Research indicates that: (1) The organic matter in the Chang 7 source rock is mainly Type II and I, with high organic matter abundance. The Total Organic Carbon (TOC) content can reach over 10% in high-value areas, generally ranging from 2% to 4%, is in the peak oil generation stage, and is widely distributed. (2) The reservoir pores in the Chang 7 member are mainly secondary dissolution pores. Porosity ranges from 0.7% to 12%, with an average of 8.2%; the average permeability is $0.16\times10^{(-3)}\ \mu m^2$, with a median of $0.1\times10^{(-3)}\ \mu m^2$, classifying it as a tight reservoir. (3) The Chang 7 tight oil reservoir type is quasi-continuous, characterized by lateral connectivity and vertical stacking. However, most of these studies have focused on the geological evaluation of source rock, caprock, and reservoir conditions separately, without examining the relationship between these three factors and the distribution of the Chang 7 tight oil reservoir. Simultaneously, predictions of favorable zones often did not incorporate parameters related to the caprock and source rock, leading to incomplete assessments[9].

Therefore, this paper takes the Chang 7 tight oil reservoir in the Chenghao area of the Ordos Basin as the study object, analyzes the conditions of the source rock, reservoir, and caprock, discusses the controlling effects of these three factors on tight oil enrichment, and uses their parameters for objective assignment to predict favorable zones, providing a more robust basis for predicting favorable exploration areas for tight oil in this region.

## 2. Regional Geological Overview

The Chenghao area is located in the central part of the lacustrine sedimentary basin of the Yanchang Formation, structurally situated in the southwestern part of the Shaanxi North Slope of the basin, covering an area of approximately 7500 $km^2$[10]. The Mesozoic primarily develops two sets of oil-bearing strata: the Triassic Yanchang Formation and the Jurassic Yan'an Formation. The Triassic Yanchang Formation is dominated by lacustrine, deltaic, and gravity flow sediments[11]. The reservoir types are mainly lithologic reservoirs and structural-lithologic reservoirs, primarily developed in the Chang 6, Chang 7, and Chang 8 oil reservoir members. The Jurassic Yan'an Formation is dominated by fluvial and deltaic sediments, with reservoir types being lithologicand lithologic-structural reservoirs controlled by paleogeomorphology[12].

The Chenghao area on the southwestern Shaanxi North Slope of the Ordos Basin achieved significant breakthroughs in exploration in the Chang 6 member, discovering multiple wells with industrial oil flow[13]. Since 2010, exploration in the Chang 7 member in the Chenghao area has discovered tight oil reservoirs (with permeability generally less than 0.3 mD), initially forming a certain scale and demonstrating good exploration prospects, making it the main target for increasing reserves and production in the study area[14].

Therefore, this paper focuses on the Chang 7 tight oil reservoir of the Yanchang Formation in the Chenghao area, Ordos Basin, analyzing the source rock, reservoir, and caprock conditions to investigate their controlling effects on tight oil enrichment, aiming to study the accumulation and enrichment factors of tight oil in this area [15].

# 3. Reservoir Characteristics

## 3.1. Oil Layer Distribution Characteristics

Statistics from production tests of 108 wells in the Chang 7~1~ sub-layer of the study area show 81 industrial oil wells, accounting for 75%. Wells with production rates of 4-10 t/d are the most numerous, at 58 wells, accounting for 53.7%. Wells with 10-20 t/d account for 14 wells (12.96%), and wells with more than 20 t/d account for 8.33%. Low-productivity oil wells number 17, accounting for 15.74% of the total tested wells. There are 10 dry wells and water wells combined. Statistics from production tests of 63 wells in the Chang 7~2~ sub-layer show 44 industrial oil wells, accounting for about 70%. Wells with production rates of 4–10 t/d are the most numerous, at 29 wells, reaching 46.03%. Wells with 10-20 t/d account for 8 wells (12.7%), and wells with more than 20 t/d account for 11.11%. Low-productivity oil wells number 13, accounting for 20.63% of the total tested wells. There are 6 water wells and no dry wells.

Based on the analysis of oil saturation from well log interpretation, oil saturation distribution ranges from 3.1% to 90.7%, with an average of 71.6%. Among them, Chang $7_1$ has the highest oil saturation.

## 3.2. Reservoir Distribution Characteristics

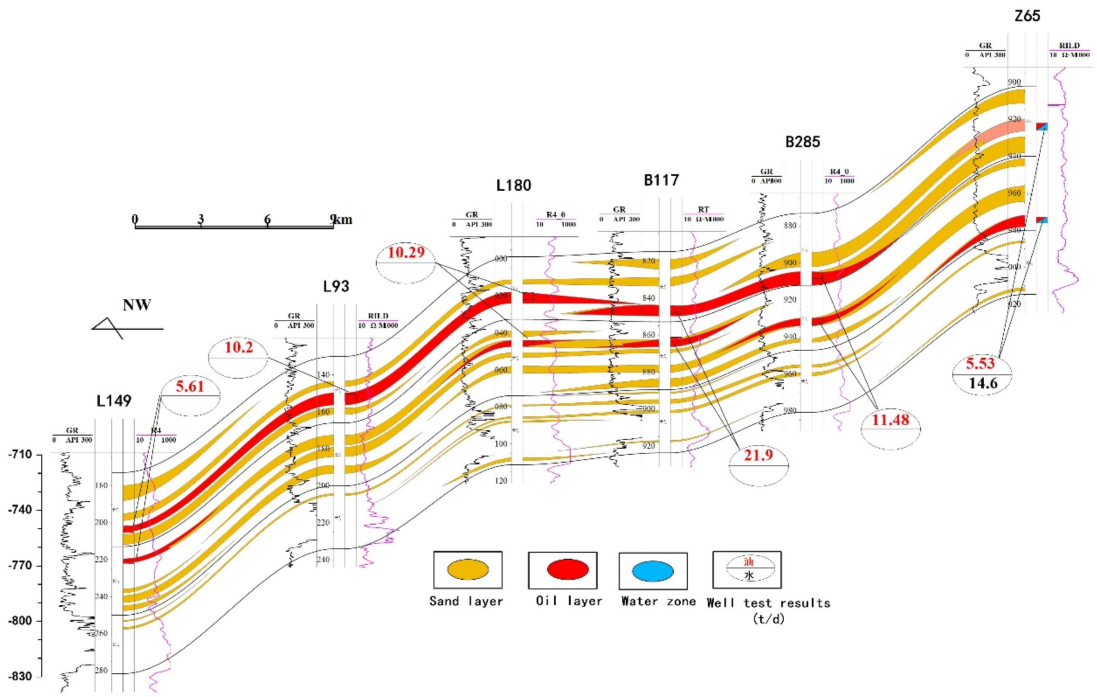


**Figure 1.** Reservoir Profile of the Chang 7 Oil Reservoir Member along Well L149 –Z65 in the Chenghao Area

The Chang 7 tight oil reservoir sand bodies in the Chenghao area are gravity flow depositional sand bodies. There are numerous sand body trap types, including lithologic pinch-out traps, lens-shaped traps, and diagenetic traps. Oil-water differentiation is not obvious, with no edge water or bottom water; oil is produced through fracturing. The reservoirs are characterized by lateral connectivity and vertical stacking, belonging to the quasi-continuous reservoir type. They are not controlled by structural conditions but are controlled by sand body distribution, reservoir physical properties, and diagenesis. The crude oil properties of the Chang 7 member (Yanchang Formation Chang 7 oil reservoir member) in the Chenghao area, Ordos Basin, are characterized by low density, low viscosity, low sulfur, and medium-high wax content, belonging to typical crude oil of continental lacustrine basin origin.

The reservoir profile characteristics of the Chang 7 oil layer along the Li 48 well - Bai 125 well in the Chenghao area are as follows. The oil layers show multi-layer stacked distribution, with no obvious oil-water contact within the oil layers. Oil and water are stored and produced together. Both mudstone and siltstone can act as barriers for the reservoir.

## 4. Tight Oil Accumulation Factors

### 4.1. Source Rock Conditions and Controlling Factors

**1) Spatial Distribution Characteristics of Source Rock**

Through core observation and electric property calibration, the lithology of the Chang 7 source rock in the Chenghao area includes shale, mudstone, and silty mudstone. The TOC value distribution range for the Chang $7_1$ and Chang $7_2$ source rocks is 1.24%–6.5%, mainly distributed between 2%–4%, with an average of 3.1%, exhibiting characteristics of being higher in the north and lower in the south. The TOC value distribution range for the Chang 7~3~ sub-layer source rock is 4.2%–16.2%, mainly distributed between 6%–12%, with an average of 9.5%. The overall characteristics are similar to those of the Chang $7_1$ and Chang $7_2$ sub-layers.

**2) Hydrocarbon Generation Intensity (Q)**

The hydrocarbon generation intensity of source rock is a comprehensive indicator for evaluating its hydrocarbon generation capacity. Based on source rock thickness, lithological density, organic carbon content, maturity, and hydrocarbon generation rate data, the hydrocarbon generation potential of the Chang 7 source rock in the Chenghao area is evaluated. According to the hydrocarbon generation formula, the hydrocarbon generation intensity of the Chang 7 source rock in the Chenghao area ranges from (200–700)×10^4^ t/km$^2$, with an average of about 430×10^4^ t/km$^2$. The intensity is high in the north, mostly exceeding 500×10^4^ t/km$^2$; it exceeds 500×10^4^ t/km$^2$ in the central part; and the intensity in the south is less than 400×10^4^ t/km$^2$, mostly below 300×10^4^ t/km$^2$.

### 4.2. Controlling Effects of Source Rock

**1) Mudstone Thickness**

Mudstone thickness has a relatively obvious controlling effect on the enrichment of Chang 7 tight oil. As shown in Figure 7, as mudstone thickness increases, production shows an increasing trend. When the mudstone thickness is less than 38 m, the production of Chang 7 increases; when the mudstone thickness is greater than 38 m, the change in Chang 7 production is not significant. As shown in Figure 7, as mudstone thickness increases, oil saturation first increases and then decreases.

**2) TOC**

TOC has a relatively weak controlling effect on the distribution of Chang 7 tight oil.

**3) Hydrocarbon Generation Intensity**

Hydrocarbon generation intensity is a comprehensive parameter for source rock evaluation, and it has a significant controlling effect on the distribution of tight oil in the lower assemblage. As shown in the figure below, there is a clear positive correlation trend between the two. As hydrocarbon generation intensity increases, production test yields also show an increasing trend. As shown in the figure below, the two show a positive correlation trend; as hydrocarbon generation intensity increases, oil saturation also increases. These data indicate that hydrocarbon generation intensity has a stronger controlling effect on tight oil enrichment than mudstone thickness and TOC.

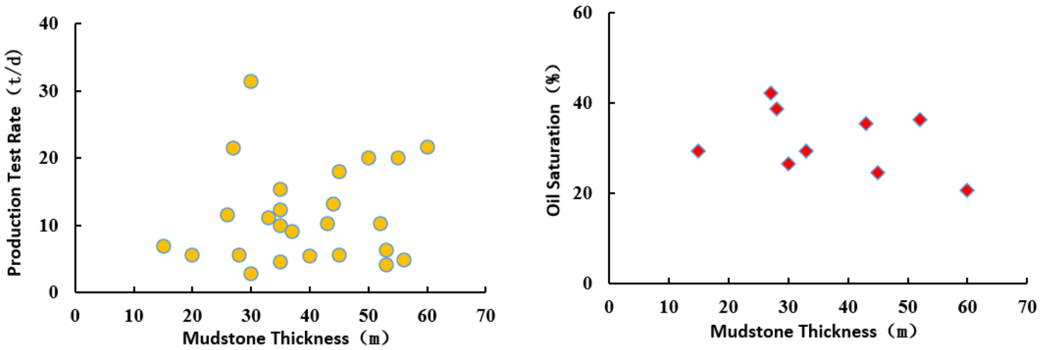


**Figure 2.** Crossplot of production test yield, oil saturation, and mudstone thickness in the Chenghao area

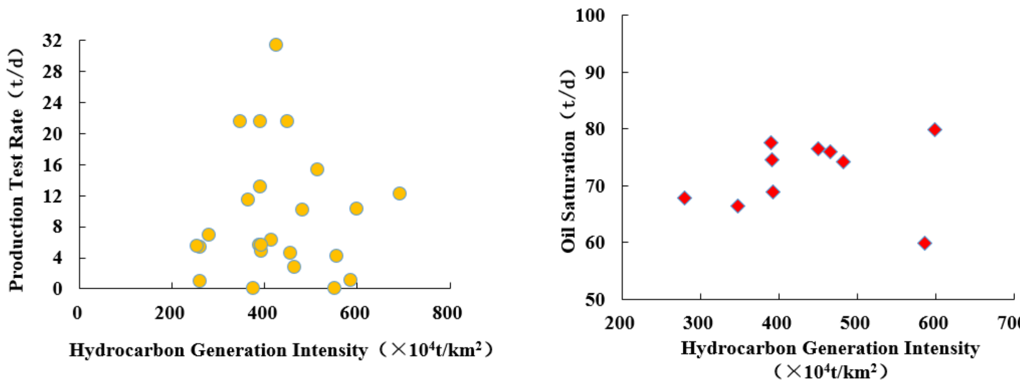


**Figure 3.** Crossplot of production test yield, oil saturation, and hydrocarbon generation intensity in the Chenghao area

## 4.3. Reservoir Conditions and Controlling Effects

### 4.3.1. Reservoir Conditions

#### 1) Lithological Characteristics

Based on core analysis from cored wells, the lithology of the Chang 7 member is relatively fine, including fine sandstone, argillaceous fine sandstone, muddy fine sandstone, silty fine sandstone, and fine sandstone with silt, with argillaceous fine sandstone and silty argillaceous fine sandstone being the most common.

#### 2) Reservoir Space Types

The reservoir space in the Chenghao area of the Ordos Basin is primarily pores. According to casting thin section identification results, the pores in the Chang 7 reservoir of Well Cheng 96 are mainly secondary dissolution pores. Chang 7~1~ is dominated by feldspar dissolution pores; while Chang 7~2~ pore types include intergranular pores, intergranular dissolution pores, feldspar dissolution pores, lithic dissolution pores, moldic pores, etc.

#### 3) Sand Body Thickness of Chang 7 Tight Oil Reservoir

The thickness distribution of individual sand bodies in the Chang 7 oil reservoir member ranges from 6 to 28 m, mainly distributed between 10 and 20 m, characterized by greater thickness in the east and smaller thickness in the west. The sand body thickness distribution range for the Chang 7~1~ sub-layer in the Chenghao area is between 3 and 28 m, with the main range being 10–20 m. The sand body thickness distribution range for the Chang 7~2~ sub-layer in the Chenghao area is between 0 and 32 m, with the main range being 0–15 m.

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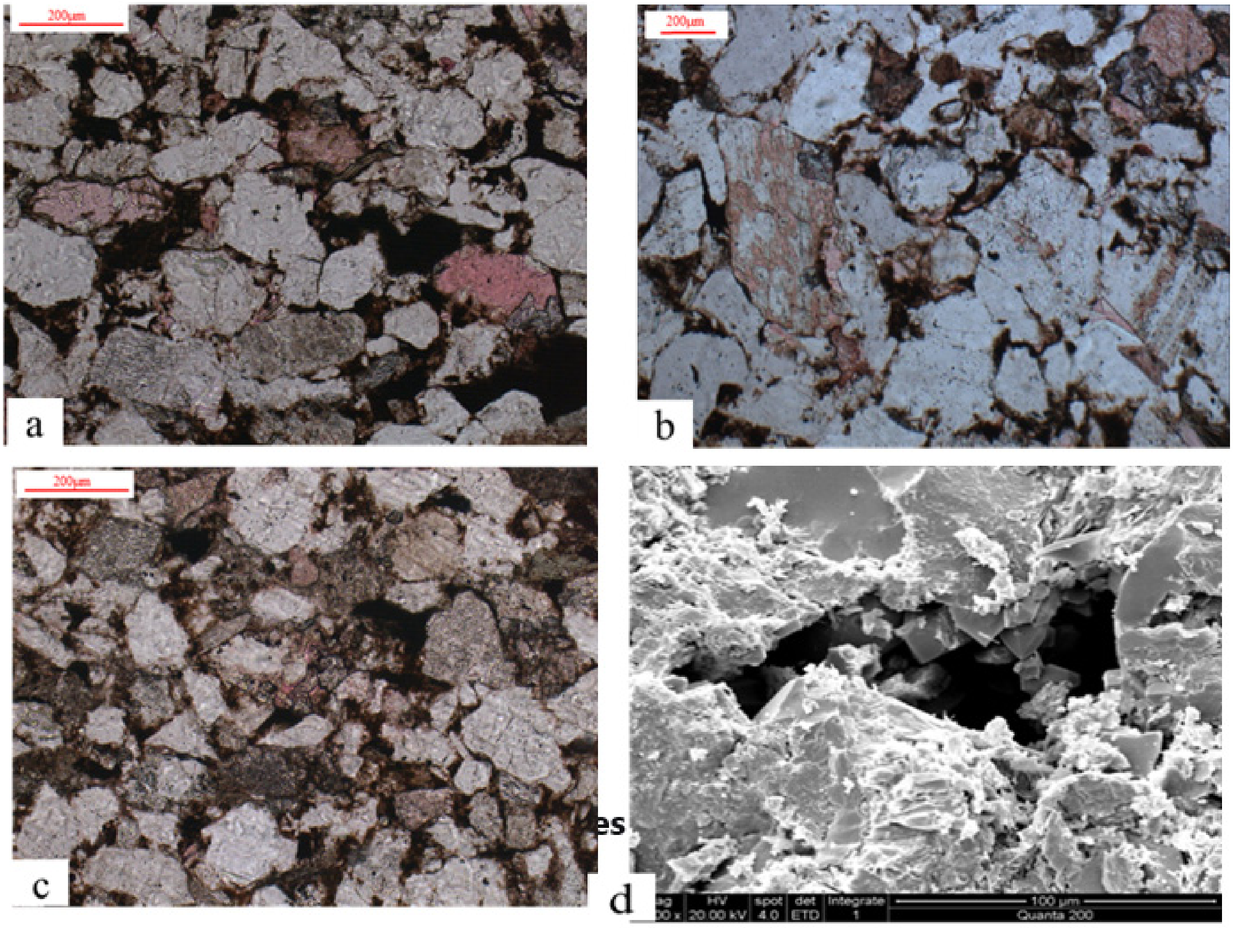


a. Well Cheng 96, Chang 7~1~, 2003.76m, intragranular dissolution pores, moldic pores; b. Well Cheng 96, Chang 7~2~, 2003.87m, intragranular dissolution pores, intergranular pores; c. Well Cheng 96, Chang 7~2~, 2004.79m, lithic dissolution pores; d. Well Cheng 96, Chang 7~2~, 2028.99m, residual intergranular pores.

**Figure 4.** Main pore types in the Chang 7 member

According to rock thin section statistics, in the Chang 6~3~ - Chang 7~2~ sandstone, quartz content ranges from 18% to 56%; feldspar content ranges from 7% to 28%; lithic fragment content ranges from 9.5% to 39%, among which metamorphic rock fragment content ranges from 1% to 18% (average 9%), and igneous rock fragment content ranges from 1.5% to 15% (average 3.2%), with metamorphic rock fragments being dominant. Interstitial material content ranges from 4% to 47.5%. Quartz content is high, followed by feldspar and lithic fragments. Analysis based on the sandstone classification triangle diagram shows that the Chang 6~3~ - Chang 7~2~ sandstone is basically feldspathic litharenite, with a small amount of lithic arkose.

### 4) Reservoir Physical Properties

The Chang 7 reservoir is a tight reservoir. Porosity ranges from 0.5% to 12.3%, with an average of 7.14%, a median of 7.5%, and the main peak between 6% and 12%. The main permeability values range from (0.02–7.83)×10^(-3) μm$^2$, with an average of 0.17×10^(-3) μm$^2$, a median of 0.1×10^(-3) μm$^2$, and the main distribution range being (0.05–0.2)×10^(-3) μm$^2$. The physical property analysis results indicate that the Chang 7 member is a typical tight reservoir. Porosity and permeability are positively correlated; samples with permeability below 0.2×10^(-3) μm$^2$ show a clear positive correlation between porosity and permeability.

### 4.3.2. Controlling Effects of the Reservoir

**1) Porosity**

Porosity is an important parameter characterizing reservoir physical properties and has a significant controlling effect on the distribution of Chang 7 tight oil. As shown in the figure, as porosity increases, production test yield also increases; when porosity is greater than 6%, the increasing trend for Chang 7 is not significant. As shown in the figure, as porosity increases, oil saturation shows an increasing trend, which is relatively obvious.

**2) Permeability**

Permeability has a relatively obvious controlling effect on tight oil distribution. As shown in the figure, as permeability increases, yield first increases and then decreases. The inflection point is approximately 0.12×10^(-3) $\mu m^2$. When permeability is less than 0.12×10^(-3) $\mu m^2$, the production test yield of Chang 7 increases with increasing permeability; when permeability is greater than 0.12×10^(-3) $\mu m^2$, the production test yield of Chang 7 shows a decreasing trend. As shown in the figure, permeability and oil saturation show a positive correlation trend; as permeability increases, oil saturation also increases. These data indicate that reservoir permeability has a certain controlling effect on oil enrichment.

**3) Shale Content**

Shale content has a significant controlling effect on the distribution of tight oil in the lower assemblage. Based on the relationship between production test yield, oil saturation, and shale content, there is a clear negative correlation trend. As shown in the figure, as shale content increases, yield relatively decreases. As shown in the figure, as the shale content of the reservoir increases, oil saturation also decreases.

**4) Individual Sand Body Thickness**

Individual sand body thickness has a weak controlling effect on the distribution of tight oil in the lower assemblage. As shown in Figure 9a, there is a relatively good positive correlation between individual sand body thickness and yield. As sand body thickness increases, yield also increases, with an inflection point at 17 m. When sand body thickness is less than 17 m, yield gradually increases; when sand body thickness is greater than 17 m, the change in yield is not significant, or even decreases slightly. As shown in Figure 9b, overall, it shows a trend of first increasing and then decreasing, with no significant change in oil saturation.

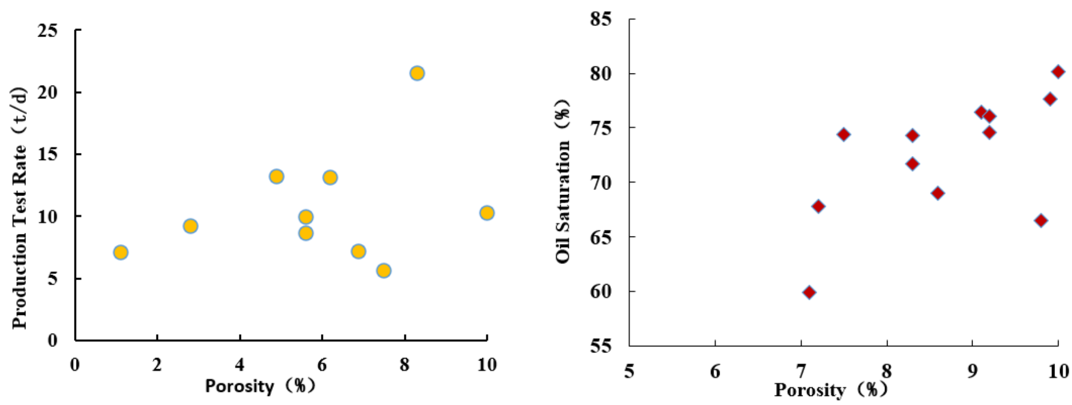


**Figure 5.** Crossplot of production test yield, oil saturation, and porosity in the Chenghao area

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## 4.4. Caprock Conditions and Controlling Effects

### 4.4.1. Caprock Conditions

The thickness distribution of the caprock for the Chang 7 oil reservoir member in the Chenghao area ranges from 5 to 30 m, mainly distributed between 10 and 25 m, characterized by greater thickness in the east and smaller thickness in the west.

The shale content distribution of the Chang 7 caprock ranges from 50% to 85%, mainly distributed between 60% and 75%.

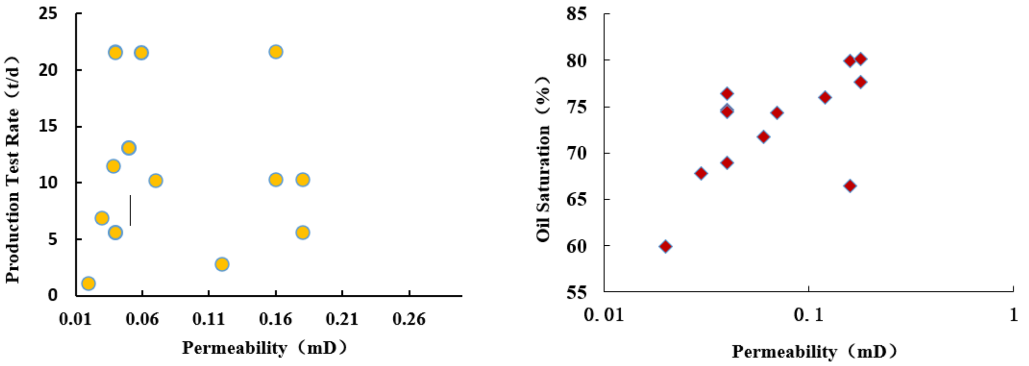


**Figure 6.** Crossplot of production test yield, oil saturation, and permeability in the Chenghao area

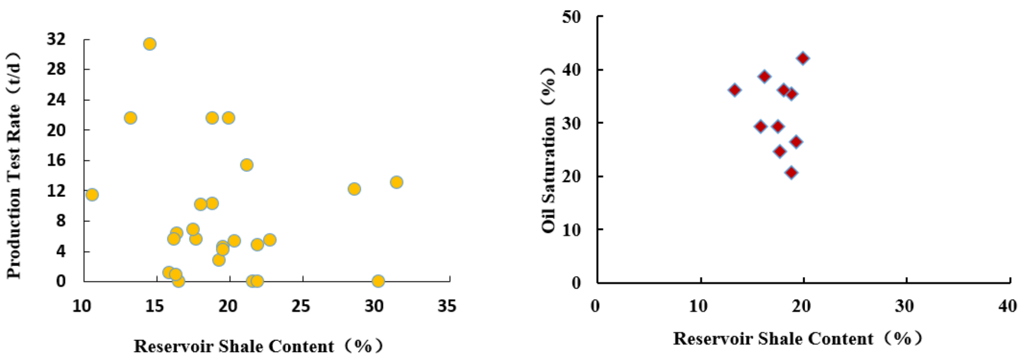


**Figure 7.** Crossplot of production test yield, oil saturation, and reservoir shalecontent in the Chenghao area

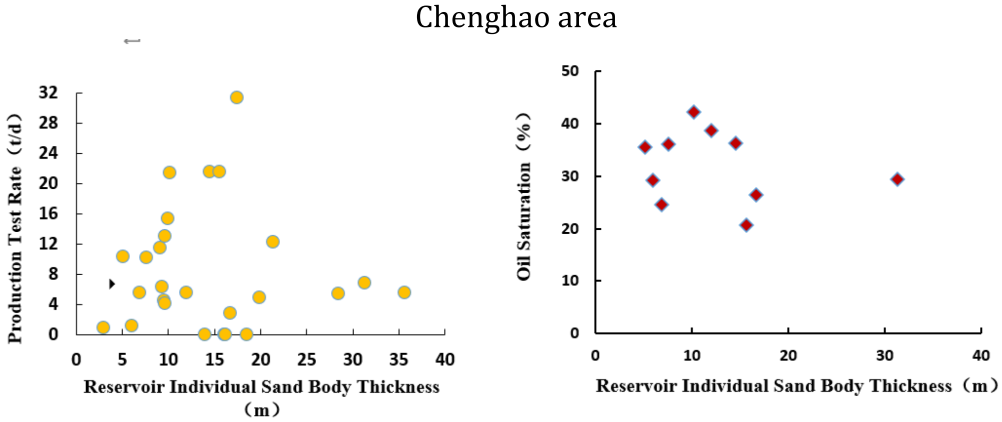


**Figure 8.** Crossplot of production test yield, oil saturation, and individual sand body thickness in the Chenghao area

### 4.4.2. Controlling Effects of the Caprock

**1) Caprock Thickness**

Caprock thickness has a weak controlling effect on the distribution of Chang 7 tight oil. As shown in the figure, the correlation between caprock thickness and production test yield is poor. When caprock thickness is greater than 5 m, it is conducive to forming high production. As shown in the figure, as caprock thickness increases, oil saturation also increases, but the increasing trend is not significant. These data indicate that the increase in production test yield and oil saturation is also controlled by other parameters.

**2) Shale Content of the Caprock**

The shale content of the caprock has a significant controlling effect on the distribution of Chang 7 tight oil. As shown in the figure, there is a positive correlation between caprock shale content and production test yield; as shale content increases, production test yield also increases. The inflection point is 63%. When shale content is less than 63%, the increase in yield is slow; when shale content is greater than 63%, the production test yield increases rapidly. As shown in the figure, as the shale content of the caprock increases, oil saturation shows a clear increasing trend. These data indicate that the shale content of the caprock has a stronger controlling effect on Chang 7 tight oil enrichment than caprock thickness.

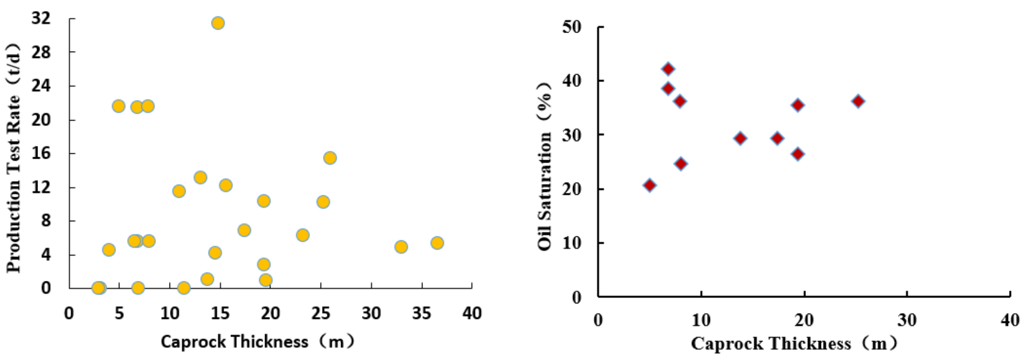


**Figure 9.** Crossplot of production test yield, oil saturation, and caprock thickness in the Chenghao area

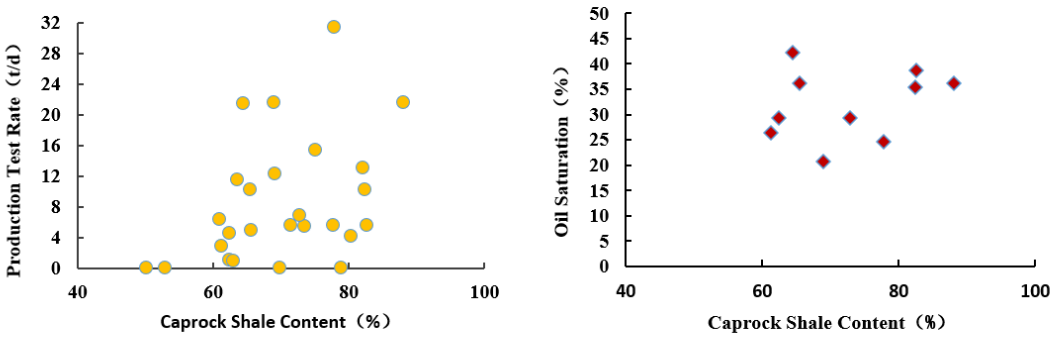


**Figure 10.** Crossplot of production test yield, oil saturation, and caprock shale content in the Chenghao area

## 5. Tight Oil Enrichment Model and Favorable Zone Prediction

### 5.1. Tight Oil Enrichment Model

The Chang 7 reservoir in the study area features integrated source and reservoir, with source rocks and tight reservoirs interbedded. The source-reservoir configuration can be subdivided into five types: lower generation-upper storage, upper and lower generation-middle storage, sand-mud interbeds, thin mudstone-thin sandstone, and thin mudstone-thick sandstone.

Among them, lower generation-upper storage, upper and lower generation-middle storage, and sand-mud interbeds are conducive to the formation and accumulation of tight oil. The Chang 7 member of the Yanchang Formation mainly develops self-sourcing and self-reservoiring shale oil and short-distance migrated lower generation-upper storage shale oil. The high-quality source rock at the bottom of the Chang 7 member in the area is stably distributed, has strong oil generation capability, and is in close contact with sandy debris flow and turbidity current sand bodies, resulting in a favorable source-reservoir configuration.

### 5.2. Favorable Zone Prediction

The prediction of favorable zones is primarily based on the analysis of source rock, reservoir, and caprock conditions. For the source rock, a hydrocarbon generation intensity of 300×10^4^ t/km$^2$ is adopted as the lower limit for high tight oil production, located in the central and northern parts of the study area. For reservoir conditions, reservoir sand body thickness is primarily used, with 10 m selected as the lower limit. The reason is that planar distribution data for reservoir sand body thickness are abundant and cover the entire study area, while data for individual sand body thickness and reservoir shale content are relatively scarce and coarser, and can be used as supplements. Therefore, the prediction of favorable zones for the Chang 7~1~ and Chang 7~2~ sub-layers is mainly based on source rock hydrocarbon generation intensity (300×10^4^ t/km$^2$), reservoir sand body thickness (10 m), and caprock shale content (63%).

## 6. Conclusion

1) The pores in the Chang 7 reservoir of the Chenghao area are mainly secondary dissolution pores, with an average total plane porosity of 2.5%. Porosity ranges from 0.7% to 12%, with an average of 8.2%, a median of 7.1%, and the main distribution range is 6% to 12%. Permeability ranges from (0.023–1.68)×10^(-3) μm$^2$, with an average of 0.16×10^(-3) μm$^2$, a median of 0.1×10^(-3) μm$^2$, and the main distribution range is (0.1–0.15)×10^(-3) μm$^2$, belonging to tight sandstone. The Chang 7 tight oil reservoir sand bodies in the Chenghao area are gravity flow depositional sand bodies, forming a quasi-continuous reservoir type.

2) Hydrocarbon generation intensity of the source rock has a significant controlling effect on tight oil, followed by mudstone thickness. Reservoir porosity and shale content have very significant controlling effects, followed by permeability, and finally individual sand body thickness. The shale content of the caprock has a significant controlling effect on tight oil, followed by caprock thickness.

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