Braided river sandstone reservoir characterization in Kumkol South Oilfield, South Turgai Basin

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The differences of remaining oil distribution between two types of braided river are studied. WCNB braided river is mainly composed of the tongue-like bars and wide channels. The width ratios of wide channels and the tongue-like bars are relatively large. And the length ratio of the long axis and short axis of the tongue-like bars is large. The mud interlayers of the tongue-like bars are slant space downstream one after one. The distribution range and the angle of the mud interlayers of tongue-like bars are large. The NCWB braided river is characterized by the narrow braided channel and oval bars. The width ratios of narrow braided channels and oval bars are small. And the length ratio of the long axis and short axis of the oval bars are relatively small. The mud interlayers of the oval bars overlapped space vertically one by one. The distribution range and the angle of the mud interlayer of oval bars are small.

[Key words: South Turgai basin, Kumkol South Oilfield, braided river, architecture characterization, channel sandstone]

Introduction

Braided river sedimentary is an important part of the fluvial delta sedimentary systems in lacustrine basin\textsuperscript{1}. The sandstone architecture and the mud interlayer distribution of braided river has important functions in influencing the waterlogged characteristics, the remaining oil distribution and the water flooding exploitation in high water-cut sandstone reservoirs\textsuperscript{2,3}. Based on the study of reservoir architecture classification\textsuperscript{4,5}, the international and domestic academics have built multiple patterns of different types of braided river by studying outcrops and modern sedimentary\textsuperscript{6,8}. By using seismic and well log data, the underground braided river sandstone distribution between wells is studied\textsuperscript{9,21}. And a series of methods for braided river sandstone reservoir characterization is widely used\textsuperscript{22,22}. The influence of the sandstone reservoir architecture on the remaining oil distribution is studied\textsuperscript{23,25}. The survey found that the prior studies on braided river sandstone reservoir characterization are mainly focus on the well logging and inter-well reservoir prediction of the inner sandstone units and mud interlayer. The studies to compare the differences of the braided river sandstone reservoir architecture characteristics and sedimentary mechanic are rare. Therefore, this article takes the Layer MII of Cretaceous in Kumkol South Oilfield in South Turgai Basin for example. By using the core and well logging data, the differences of distribution pattern and sedimentary mechanic between deep-channel braided river and shallow-channel braided river are studied. The influences of different types of braided river architecture characteristics on remaining oil distribution are studied. This article will lay the foundation for remaining oil exploitation in different braided river sandstone reservoir.

Materials and Methods

Kumkol South Oilfields which locates in the south of South Turgai Basin in Kazakhstan is an edge-bottom water reservoir. It is surrounded by hydrocarbon-rich Arystum Depression with rift complicated by faults is a large drape structure over the Pre-tertiary uplifts on the pre-Jurassic basement (Fig. 1). The well space is wide (average well space is 250m) and the 3D seismic data is of high quality (the dominant frequency is nearly 50 Hz) in Kumkol South Oilfields. This oilfield has high-porosity and high-permeability reservoirs and higher heterogeneity. The stratum of Kumkol South oilfield includes Quaternary, Tertiary, Cretaceous, Jurassic, and pre-Jurassic basement from top to bottom. There are several regional unconformities includes the regional
unconformity between Aryskum Group and Akshabulak Group, the regional unconformity between Mid-Jurassic and Upper Jurassic, the regional unconformity between Lower Cretaceous and Upper Cretaceous. Aryskum Group formed by two parts, Layer MI and Layer MII. Layer MII which includes MII-2 and MII-3 is the main hydrocarbon bearing layer and buried at the depth between 950-1200. The Layer MII-2and Layer MII-2 were formed in the early stage of basin subsidence and developed the braided river sedimentary. From 1990 until now, the composite water cute in this oilfield is over 80%. And the water sweeping efficiency has been affected by sandstone reservoir architecture boundaries increasingly important. Therefore, it is important that the braided river sandstone architecture characterization is increasingly important in study area.

Results and Discussion

The composite braided channels architecture characterization

The research of composited braided belts is equal to sedimentary microfacies. It is the first step of braided river sandstone architecture characterization. Boundaries of composite braided channels are equivalent to the fifth level architecture boundaries. Based on the Miall river types classification, Layer MII-3 develops deep-channel braided river and Layer MII-2 develops shallow-channel braided river by the core and well logging data. And these braid channels have different architecture characteristics.

By studying the core, deep-channel braided river has the obvious distribution characteristics of positive rhythm and binary structure. The coarser retention conglomerate and obvious erosion surface, which reflect the strong water energy, developed at the bottom of the river. As bed load transport, the coarse to medium-grained sandstone cover the upper channel sandstone. The channel sandstone have trough cross-bedding, which reflect the characteristics of the deep channel deposition (Fig. 2). Shallow-channel braided river have less arrested conglomerate and obviously scour surface at the bottom, which reflect the water energy is relatively weak. Main channel sandstone have less St rock facies and develop the visible ripple bedding, parallel bedding, which reflect the depth of the river is shallow. The main channel body have positive rhythm characteristics, which mainly reflect the monistic structure (Fig. 2).

Vertically, the interface between braided channel unit and channel bar unit of shallow braided river is not clear. The fluvial incision is weak, and the braided channel embedded in the channel bar. The interface between braided channel unit and channel bar unit of deep braided river is clear. Channel thickness is very thick. And the braided channel usually shows the...
interval distribution channel with channel bar (Fig. 3). The NCWB braided river have unstable channel, which lead to the widespread channel sandstone. The ratio of width of braided channel and width of channel bar is 1:3-1:4 (Fig. 4). The WCNB braided river have stable channel and channel bar. The ratio of width of braided channel and width of channel bar is 1:2-1:3 (Fig. 5).

Based on the research mentioned above, the depositional mechanism of braided river sandstone distribution is clear with the sedimentary background of study area. The braided river of Layer MII developed in the later stage of basin subsidence. The accommodation is relatively large. The sediments supply is relatively small. The fluvial energy is weak and stable. Therefore, the braided channel is stable. The scale and distribution range of channel sandstone is relative small. The scale and distribution range of channel bar sandstone is relative large. Finally, the distribution pattern of braided river in Layer MII is characterized by narrow channel and wide bar.

The braided river of Layer MIII developed in the early stage of basin subsidence. The accommodation is relatively small. The sediments supply is relatively large. The fluvial energy is strong and unstable. Therefore, the braided channel is unstable. The scale and distribution range of channel sandstone is relative large. The scale and distribution range of channel bar sandstone is relative small. Finally, the distribution pattern of braided river in Layer MIII is characterized by wide channel and the tongue-like bar (Fig. 5).

**Single braided belt architecture characterization**

The research of single braided belts is the second step of braided river sandstone architecture characterization. The boundaries of composite braided channels are equivalent to the forth level architecture boundaries. The reservoir of single braided belts includes braided channel sandstone and channel bar sandstone. Based on the core and well logging data, the braided river of Layer MII-3 is characterized by WCNB. And the braided river of Layer MII-2 is characterized by NCWB. These two types of braided river have unique characteristics.

**WCNB single braided belt architecture characterization**

The width of WCNB single braided belt is between 3500 and 3800m. And the WCNB braided river is characterized by the tongue-like bar and wide braided channel. The ratio of long axis and short axis of channel bar is relative large, between 1/2 and 1/4. The thickness of channel bar is between 6-15m. The length of channel bar is between 3100 and 1500m. The width of channel bar is between 620 and 850m. The channel bar has a tongue-like shape. The braided channel is characterized by the wide and thick channel sandstone. The ratio of width and thickness of channel sandstone is relatively large, between 15 and 100. The width of braided channel is between 200 and
1500m. The thickness of braided channel is between 10 and 15m (Tab.1).

By the depositional mechanism analysis of the WCNB braided river, it is found that the WCNB braided river developed in the condition of small A/S. The energy of flow is relative strong and the fluvial downward incision is strong. The bank is also laterally incised by the river. Therefore, the bank full width and depth is relative large. And abundant of debris which is brought by the river deposited. And the channel sandstone is large. Meanwhile, the wide braided river isolated the channel bar. And the early deposited channel bar is reconstructed by the later powerful river. Specifically, the upstream part and the both sides of the channel bar are scoured by the flow. And the energy of flow is weaker, which make abundant debris deposited in front of the channel bar or overlap on the downstream part of the channel bar (Fig. 6). Therefore, the channel bar is increasingly getting longer by the downstream deposited (Fig. 7) and is increasingly narrower by the lateral scour of flow in the plane (Fig. 8). This architecture characteristic is important for the development of mud interlayer of channel bar.

**NCWB single braided belt architecture characterization**

The width of NCWB single braided belt is between 1800 and 2400m. It is characterized by the wide channel bar and narrow braided channel. The wide channel bar has small length ratio of long axis and short axis, and the ratio is between 1/2 and 1/3. The thickness of channel bar is between 6 and 10m. The length of channel bar is between 800 and 1500m. The width of channel bar is between 500 and 900m. The braided channel sandstone is narrow laterally and thin vertically. The thickness of braided channel bar is between 4 and 10m. The width of channel bar is between 100 and 800m (Tab.1).

The depositional mechanism of the NCWB braided river is analyzed. It is found that the NCWB braided river developed in the condition of large A/S. The energy of flow is relative weak and the fluvial downward incision is weak. The bank is hardly incised by the river. Therefore, the bank full width and depth is relative small. The flow carries fewer amount of debris in small braided channel. Therefore, the size of braided channel sandstone is relative small. The distribution density of channel bar is relative large. Because of the weak flow, the early deposited channel bar is hardly reconstructed by the later powerful river. Specifically, the debris carried by flow will deposit on and around the channel bar when the flow is blocked by the channel bar (Fig. 9), which make the channel bar grow in short axis (Fig. 10) and long axis direction (Fig. 11).

![Image](image_url)

**Fig.6 — Satellite picture of modern tongue-like bar**

**Fig.7 — Long axis profile of Tongue-like bar**

**Fig.8 — Short axis profile of Tongue-like bar**

<table>
<thead>
<tr>
<th>Grade</th>
<th>Fifth</th>
<th>Forth</th>
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<tbody>
<tr>
<td>Unit</td>
<td>Width/m</td>
<td>Channel bar</td>
</tr>
<tr>
<td>WCNB</td>
<td>3500-3800</td>
<td>620-850</td>
</tr>
<tr>
<td>NCWB</td>
<td>1800-2400</td>
<td>500-900</td>
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Table 1 — Architecture unit size of braided river
Inner single channel architecture characterization

The research of inner single braided channel is the third step of braided river sandstone architecture characterization. The boundaries of inner single braided channel are equivalent to the third level architecture boundaries. The single channel sandstone is the basic unit for the store and transportation of oil and gas. The mud interlay in single channel sandstone is the main flow barriers. Thus, the shape, size and distribution of mud interlayer is important for the water flooding and remaining oil distribution. Therefore, this article will study the architecture characteristics of mud interlayer of WCNB and NCWB braided river.

Inner single channel architecture of WCNB braided river

WCNB braided river is formed by narrow channel bar and wide braided channel. Because of the different depositional mechanism, the mud interlayers developed in narrow channel bar and wide braided channel are different in shape and size. The mud interlayer in narrow channel bar has tongue-like shape which is the same as channel bar. The length of mud interlayer in channel bar is between 800 and 2900 m. The width of mud interlayer in channel bar is between 600 and 800. And the sizes of mud interlayers increase from bottom to top of the channel bar vertically. The thickness of mud interlayer is between 0.15 m and 0.6 m. The frequency of mud interlayer (the number of mud interlayer /the thickness of channel bar sandstone) is between 0.06 and 1. The density of mud interlayer (the sum of mud interlayers /the thickness of channel bar sandstone) is between 0.03 and 0.5. The incline angle of mud interlayer is between 0.6° and 4.5° (Tab. 2). The position of mud interlayer move increasingly downstream from bottom to top in channel bar (Fig. 7). The depositional mechanism of mud interlayer in tongue bar is analyzed. It is found that the channel bar is composed by multiple accretion sand bodies which deposit during multiple flood periods. And there will be a large flood period among multiple small flood periods. And the mud interlayers deposited in the large flood periods. Because the later vertical accretion sand bodies deposit further downstream than early vertical accretion sand bodies in single channel bar, the upper mud interlayer is further downstream than the lower mud interlayer vertically in single channel bar (Fig. 12).

<table>
<thead>
<tr>
<th>Architecture units</th>
<th>Interlayer thickness/m</th>
<th>Flow direction</th>
<th>Vertical flow direction</th>
<th>Frequency (num/m)</th>
<th>Density (m/m)</th>
<th>Incline angle/°</th>
</tr>
</thead>
<tbody>
<tr>
<td>WCNB braided river</td>
<td>0.1-0.4</td>
<td>300-800</td>
<td>100-1000</td>
<td>0.02-0.4</td>
<td>0.02-0.3</td>
<td>0.2-0.5</td>
</tr>
<tr>
<td>Tongue-like bar</td>
<td>0.15-0.6</td>
<td>800-2900</td>
<td>600-800</td>
<td>0.06-1</td>
<td>0.03-0.5</td>
<td>0.6-4.5</td>
</tr>
<tr>
<td>Narrow channel bar</td>
<td>0.1-0.2</td>
<td>500-1000</td>
<td>50-600</td>
<td>0.03-0.2</td>
<td>0.03-0.15</td>
<td>0.3-0.4</td>
</tr>
<tr>
<td>Oval bar</td>
<td>0.1-0.5</td>
<td>600-1000</td>
<td>300-700</td>
<td>0.06-0.8</td>
<td>0.03-0.4</td>
<td>0.4-1.5</td>
</tr>
<tr>
<td>NCWB braided river</td>
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</table>
The mud interlayer of wide braid channel distribute along the channel. The length of mud interlayer is between 300 and 800. The width of mud interlayer is between 100 and 1000m. The thickness of mud interlayer is between 0.1 and 0.4. The frequency of mud interlayer (the number of mud interlayer / the thickness of channel bar sandstone) is between 0.02 and 0.4. The density of mud interlayer (the sum of mud interlayers / the thickness of channel bar sandstone) is between 0.02 and 0.3. The incline angle of mud interlayer is between 0.1° and 0.5° (Tab.2). The depositional mechanism of mud interlayer in single braided channel is analyzed. The flow of wide braided channel is strong, so the length and width of mud interlayer is small. But the wide braided channel is relatively stable and the diversion is relatively rare, the frequency of mud interlayer is relative high.

**Inner single channel architecture of NCWB braided river**

NCWB braided river is formed by wide channel bar and narrow braided channel. Because of the different depositional mechanism, the mud interlayers developed in NCWB braided river is different with WCNB braided river.

The mud interlayer in narrow channel bar has oval shape which is the same as channel bar. The length of mud interlayer in channel bar is between 600 and 1000m. The width of mud interlayer in channel bar is between 300 and 700. And the sizes of mud interlayers increase from bottom to top of the channel bar vertically. The thickness of mud interlayer is between 0.1m and 0.5m. The frequency of mud interlayer is between 0.06 and 0.8. The density of mud interlayer is between 0.03 and 0.2. The incline angle of mud interlayer is between 0.4° and 1.5° (Tab.2). The mud interlayers overlap vertically in channel bar (Fig.7). The depositional mechanism of mud interlayer in oval bar is analyzed. It is found that the oval bar is composed by multiple accretion sand bodies which overlap one after one vertically during multiple flood periods. And during the large flood period, the mud interlayer deposit. Because the later accretion sand bodies deposit on the early accretion sand bodies in the oval bar, the upper mud interlayer superposed on the lower mud interlayer vertically in the oval bar (Fig.12).

The mud interlayer of narrow braid channel is analyzed. The flow of wide braided channel is weak, so the length and width of mud interlayer is large. But the wide braided channel is relatively unstable and the diversion is relatively usual, the frequency of mud interlayer is relative low.

**Remaining oil distribution controlled by braided river architecture difference**

Because the architecture characteristic between WCNB braided river and NCWB braided river is different, the remaining oil distribution of these two...
types of braided river is different. Overall, the remaining oil of WCNB braided river is relative rich due to the high frequency of mud interlayer. And the remaining oil of NCWB braided river is relative poor due to the low frequency of mud interlayer (Fig. 14, Fig. 15).

The remaining oil distribution characteristic of WCNB braided river is analyzed. It is found that the injection water flow along the bottom of the channel bar sandstone because of positive rhythm of the permeability and porosity of thereservoir. As the time of water flood increasing, the injection water flow upward. Because of the blocking of the mud interlayer, there is remaining oil which is rich under the mud interlayer. Because the mud interlayers aslant space downstream, the remaining oil is mainly rich in the downstream part of channel sandstone (Fig. 16). And the remaining oil of wide braided channel sandstone is rich in the bottom of the channel because of the positive rhythm of the permeability and porosity of

Conclusion

WCNB braided river is mainly composed by tongue-like bar and wide braided channel. Width ratio between braided channel and tongue-like bar is relatively large. Length ratio between long axis and short tongue-like bar axis of tongue-like bar is relatively large. Under the control of downstream deposition, the mud interlayer of tongue-like bar is aslant space downstream. And the incline angle and distribution range of this kind of mud interlayer is large. WCNB braided river is mainly composed by oval bar and narrow braided channel. Width ratio between braided channel and tongue-like bar is relatively small. The length ratio between long axis and short tongue-like bar axis of tongue-like bar is relatively small. By the control of overlapping deposition, the mud interlayer of tongue-like bar is vertical space. And the incline angle and distribution range of this kind of mud interlayer are small. Remaining oil of WCNB braided river is relatively rich because the density of mud interlayer in WCNB braided river is high. And the remaining oil is concentrated in the downstream part of WCNB braided river sandstone because the mud interlayer in WCNB braided river aslant space downstream. The remaining oil of NCWB braided river is relatively poor because the density of mud interlayer in NCWB braided river is low. And the remaining oil is
concentrated in the center part of WCNB braided river sandstone because the mud interlayer in WCNB braided river overlap space vertically. The remaining oil of wide braided channel and narrow braided channel is mainly rich in the top of channel sandstone and under the mud interlayers.

References