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# Reservoir architecture of braided river and remaining oil distribution in YSM oilfield

*As a case study, YSM oilfield has high water cut and high recovery factor. With various approaches, such as dynamic analysis, reservoir architecture study, simulation and well monitoring, the difference of seepage between planes, interlamination and interior layers can be evaluated, as well as the factors both from geological aspects, such as small structural high, updip sand pinch-out and fault sealing, and engineering aspects such as non-perforation, poor well status which impacted the formation and distribution of remaining oil. The research results suggest that the seepage flow difference is a critical geological factor for the formation and distribution of remaining oil. The vertical seepage to the upper inner differences make the remaining oil mainly distributed in the mid-upper sections of positive rhythm sands. And laterally, sand body splicing zone on plane and the marginal area of main sand body, normally the relatively low permeability area, the local micro tectonic highs and fault sealing affect the distribution of remaining oil in the oil spill area. The vertical distribution of remaining oil is affected by sedimentary rhythm, single sand bottom seriously flooded upper residual oil, residual oil in general oil sand top 1-2 meters. The coupling between geological factors, such as the scale and shape of the sand and the permeability difference between inter layers, and drilling factors such as well pattern design leads to uncompleted or inefficient injection and production pattern, which ends in a variety of remaining oil distribution patterns, such as the planar retention area, undeveloped reservoir and reservoirs with high pressure holding back.*

***Keywords:*** *Braided river deposits, reservoir architecture, remaining oil, distribution disciplinarian, Da Gang oilfield.*

## Introduction

The geological oil reserve in fluvial reservoir takes 36.9% of proved reserves in China, however, the recovery factor is only 23% out of the 36.9% [1-6]. Those developed fluvial reservoirs have come into the stage with high water cut and high recovery factor in succession, which requires further improvement on production performance based on confirmed remaining oil distribution and the optimization of suitable method to enhance oil recovery[7-22].

YSM oilfield in Da Gang is an uncompacted sand reservoir with edge-bottom water. The main producing interval is Guantao formation. After 40 years' production, the average water cut is 94.61%, yet the recovery factor is only 31.93%, which is extra-high water cut stage[3-5].

On the basis of the characteristic of YSM oilfield, this paper performs comprehensive study on the remaining oil distribution of YSM oilfield by referring to the dynamic simulation data, and through some researches on the architecture of braided river and the construction of fine models.

## 2. Architecture study of braided river reservoir

### 2.1 Regional depositional environment

The study of regional deposition suggests that Guantao channel of YSM oilfield was formed during the sedimentation of Huanghua depression [13-15]. Due to being close to provenance, and with sufficient river flow energy, the limited lacustrine basin at early stage spread the channels on the fluvial plain during Guantao formation. This particular depositional environment shapes the special sedimentary characteristic of braided channel sand. Therefore, Guantao formation in YSM oilfield is braided channel sand sediments.

### 2.2 Reservoir architecture study of braided channels

After identifying the sedimentary environment of YSM oilfield as braided river, there normally are two steps to evaluate the architecture of braided channel based on the architecture study of coring wells and the sedimentary study of tight well patterns. Firstly, taking the well coring as basis, and for a specific braided channel type, the logging data responding to reservoir lithology variation are analyzed to build a logging facies model. Then taking a single sand from the main producing interval as a unit, the sand distribution contour and sedimentary facies map are accomplished. What is next, with the log data of tight well pattern, seismic and production data, it could reveal the architecture of single sand body and its geometrical morphology, which further helps the generation of fine architecture maps of oil-bearing

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sands and main producing patterns. For major and thick producing intervals, the architecture is the basis to quantitatively analyze the distribution of barriers within layers. Accordingly, the interlamination heterogeneous model of braided channel is constructed.

This study shows that several architecture units are identified in YSM oilfield, which is braided channel, braid bar, sediment layer, dam channel, overbank and flood plain.

Braided channels always changed, so only the last stage channel in the braided river could be recognized. During flood period, the sediments carried along the flow rise to the maximal amount. Braided channel, as the main stream line, has strong hydrodynamic force, which erodes the sediments. When the water level decreases, the reduction of current and water amount lead to the maximal deposition, making the aggradation of braided channels. The channels are submerged to a single wide one during flood period. The braid bar exposes to water surface during water falling, braiding the channels. In the drought, the channels abandon, therefore, the last stage channels usually are very narrow. That is why braided river has typical sedimentary characteristic of broad bar and narrow channel.

Channel's architecture unit has three filling styles, sand filling, mud semi-filling, and mud filling (Fig.1). The ratio between the width of the channel and braid bar is 1:4. The ratio between the width of braid bar and the length of braid bar is 1:1:8. Braid bar and channel show the pattern as "broad bar, narrow channel". The length of braid bar is in the range between 1200m to 2000m, and the width is between 800m and 1000m. The width of braided channel is around 120m. The mud semi-fills the upper interval and forms a lateral shelter which prevents the underground fluid motion to some extent.

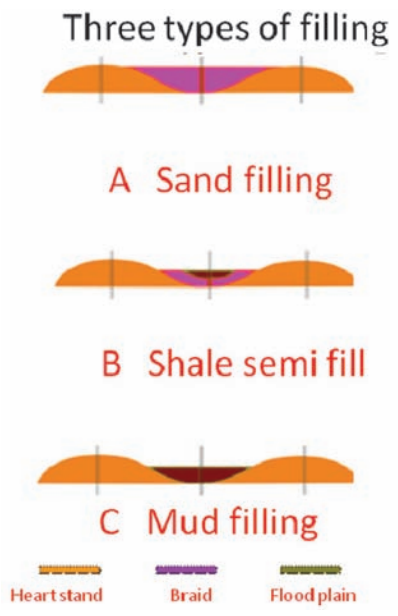


Fig.1 Three styles of filling in braided rivers

Braided river is deep and flows rapidly. The growth of braid bar has complicated direction with fast speed, which gives rise to rapid rechannelling and makes the transformation of braid bar even more complex. Due to water level, the crest of bar is higher than channel. When braided bar grows to a certain extent, most sand will deposit or erode the bar during either flooding or water falling. When braided bar experiences the flood twice or above, the erosion and sedimentation will become rather complicated [16-18].

The mud barrier inside the bar is likely to be created by dam channel and silting, shown as three types, discrete barrier in dam channel, a combination of discrete barrier and locally distributed sediment layer, and extensive sediment layer. Among them three, dam channel has least impact on production. But the sediment layers which are extensively distributed acts as a barrier in its influence zone, restraining the bottom water breakthrough of thick reservoir, which forms a reservoir environment locally similar with edge water reservoir.

Floodplain and overbank deposits distributes sporadically among single braided belt.

### 2.3 Regional depositional environment

On the basis of 3D structural model and sedimentary model, well data are applied, such as architecture interpretation, to carry out three-dimensional forecast and quantitative description of reservoir size, geometry and 3D space, which lays the foundation for reservoir property modelling. 3D architecture model demonstrates the spatial distribution and barrier's characteristic of each facies (braid bar, braided channel, abandon channel, dam channel, silting layer and floodplain, etc.) (Figs.2 and 3). The method of controlling reservoir property modelling by architecture is employed. The model aims at porosity, permeability and oil saturation and its grid size is 10*10*0.5m. With this model, further simulation and remaining oil distribution study can be carried out.

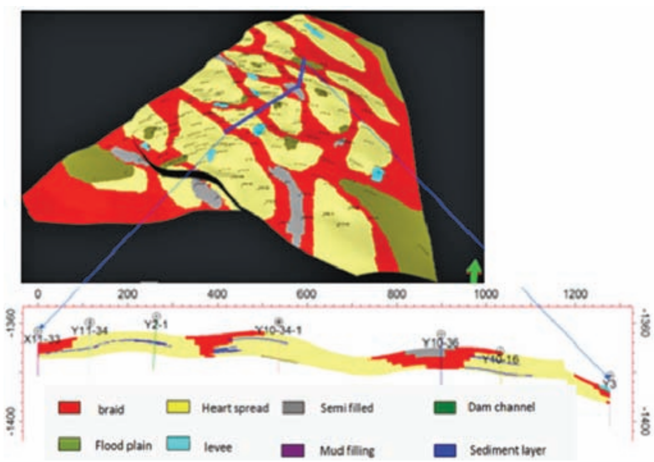


Fig.2 Architecture model of single sand of NgII5-1 in YSM oilfield

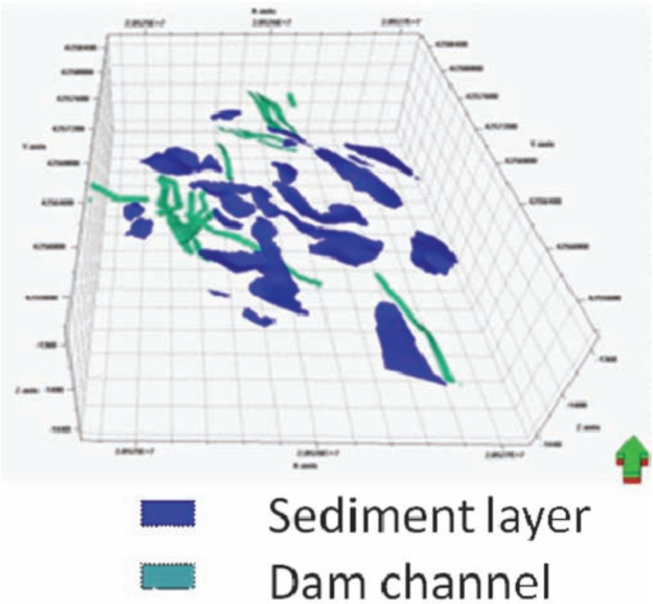


Fig.3 3D display of sediment layer and dam channel in YSM oilfield

## 3 Remaining oil distribution study

### 3.1 Simulation

There are five fault blocks divided in the simulation of YSM oilfield. And the black oil model for oil-water two phase is applied.

Submitted reserve always needs repetitive review and evaluation, therefore, fitting error of the reserve normally is limited within 2% in the simulation. If it appears significant difference between simulated and actual production status, the fitting error range could be reasonably adjusted, yet no more than 10%.

The actual reserve and simulated reserve of each block are in Table 1. It suggests that the fitting error is in the reasonable range and can be treated as simulated reserve.

Table 1 Simulated reserves of each block in YSM oilfield

| Block | Submitted reserve ($10^4$t) | Simulated reserve ($10^4$t) | Absolute error ($10^4$t) | Relative error (%) |
|---|---|---|---|---|
| Y1 | 801.18 | 801.02 | 0.16 | 0.02 |
| Y2 | 312.04 | 311.54 | 0.50 | 0.16 |
| Y3 | 1968.04 | 1975.23 | -7.19 | -0.37 |
| YG1 | 173.74 | 173.25 | 0.49 | 0.28 |
| YG2 | 59.05 | 59.07 | -0.02 | -0.04 |
| Total | 3314.05 | 3320.10 | -6.05 | -0.18 |

History match of each block achieves the requirement of numerical simulation. From a comprehensive view, history match in early development stage is poorer comparing with it in the late stage. The dominant cause is the recording error of water cut in some oil wells. According to simulation result, the remaining oil distribution has been analyzed. Among the unswept area between production wells and faults, the remaining oil has been impacted by some small local structure high and fault sealing (Fig.4).

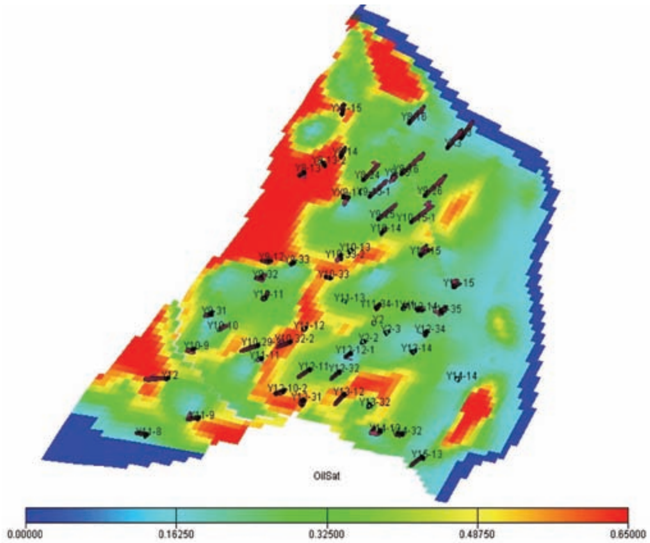


Fig.4 Oil saturation of NgII3-1 single sand in YSM oilfield

### 3.2 Dynamic data

In 1997, two wells cased by glass reinforced plastic were drilled with combination flooding in three fault blocks. Surveillance well Y1 was spudded along the main stream line from injection well Y15-14 to production well Y14-13 on April 23rd, 1997. Surveillance well Y2 was spudded along the sub-stream line from production well Y14-13 to production well Y14-14 on April 12nd, 1997. Two approaches of production logging, resistivity ratio and C/O ratio, were conducted to monitor the oil saturation of remaining oil in the two wells. The analysis indicates that the decrease of oil saturation in a single sand of NgII3-1 is smaller than in NgII3-2 and NgII4. Meanwhile, the saturation of top 1-2m in NgII3-1 sand reduced a little, which means rich remaining oil left.

### 3.3 Remaining oil distribution

The unswept areas between production wells and faults where the remaining oil have been impacted by local structure high and fault sealing. Vertically, they are controlled by sedimentary facies. The bottom of sand are severely watered out, but the upper interval accumulated remaining oil which commonly are found at the top 1-2m.

## 4. Stimulation performance

Surveillance well Y1 and Y2 are designed for monitoring remaining oil of YSM oilfield. Thanks to monitoring results and architecture findings, we find that the upper interval of the NgII3-1 sand has watered out slightly due to protection from mud semi-filling the channels. After analyzing the production history of Y3H12 well area and the formation of the channels which are semi-filled by mud in braided river deposition environment (Figs.5 and 6), we conclude that the southern area of surveillance well Y1 has significant

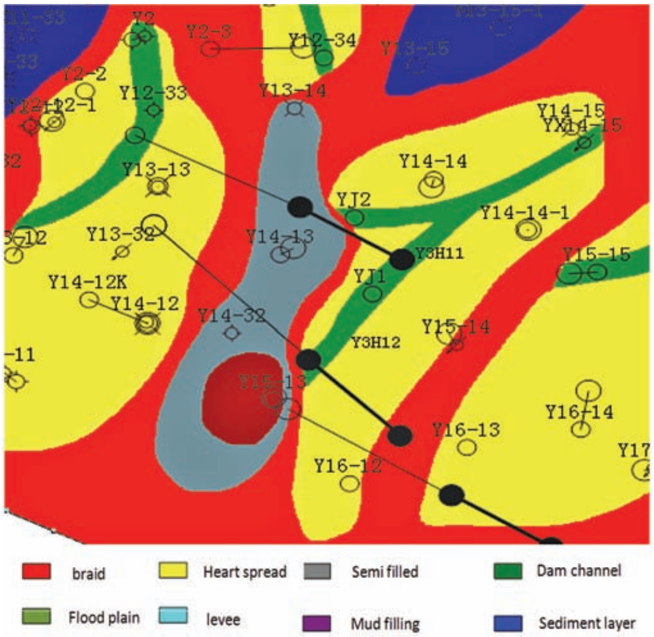


Fig.5 Semi-filled channel sand in Y3H12 well area

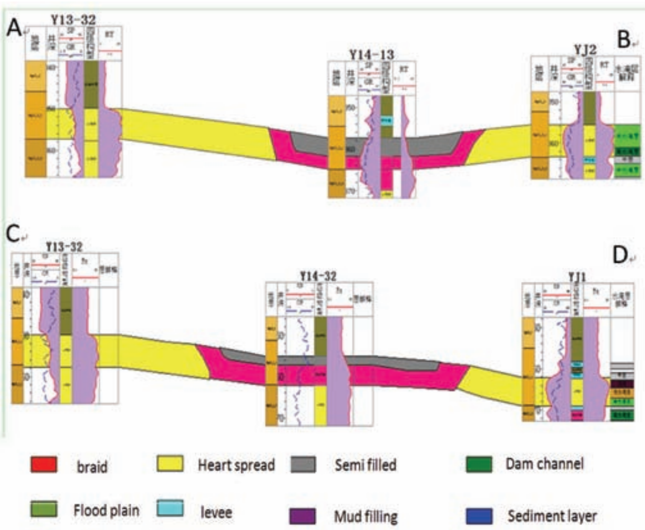


Fig.6 Well section of channel sand with mud semi-filling in Y3H12 well area

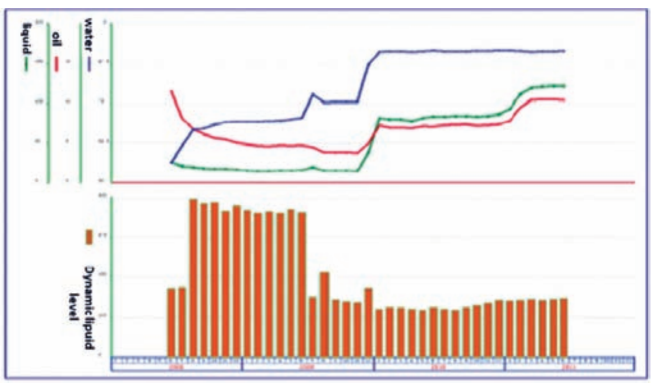


Fig.7 Production performance of well Y3H12

remaining oil since mud semi-filling channels make top interval survived from water-out. Therefore, a horizontal well Y3H12, aiming at producing the remaining oil in the top interval, was placed in the southern area of Y1. It achieves great stimulation performance, which has daily oil production of 8t/d and water cut of 65% (Fig.7).

## 5. Conclusions

Three filling types are found in braided channels, which are sand filling, mud semi-filling and mud filling. The ratio between the width of braided channel and braided bar in deep fluvial deposition is 1:8. The ratio between the width of braided bar and the length of braid bar is 1:1:8. Braided bar and braided channel demonstrate the pattern as "broad bar, narrow channel". The length of braided bar is in the range between 1200m to 2000m, and the width is between 800m and 1000m. The width of braided channel is around 120m. The mud semi-fills the upper interval and forms a lateral shelter which prevents the underground fluid motion to some extent.

The unswept areas between production wells and faults where the remaining oil have been impacted by local structure high and fault sealing. Vertically, they are controlled by sedimentary faces. The bottom of sand are severely watered out, but the upper interval accumulates considerable remaining oil which commonly are found at the top 1-2m.

It is recommended to combine reservoir architecture study and well history production. The favourable area of remaining oil could be better selected to drill infill wells for developing interlamination reserve. On the other hand, to carry out water shut off in wells which have clear internal architecture boundary of single sand will move forward to remaining oil production.

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