[PS]Architecture Characterization of Braided River Reservoir Based on Dense Well Pattern in Daqing Oilfield, China*

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Abstract

The western Sa-zhong Block of the Daqing Oilfield is located in the Songliao Basin in northeastern China and has 2573 wells in a 9.04 square km area, which is a very high well density. Data are abundant and include core data, horizontal wells, logging data, production data and surveillance data, all of which are used for this fluvial reservoir characterization study. The fluvial types of Sa-Pu reservoir groups, the main oil-bearing formation, are classified as meandering river, braided river, and delta distributary channel deposits.

Using P1-3 small layer as a target layer, according to fine-grained interbeds of flood plain in single wells, the stages of multiple stacking braided channels are divided and correlated vertically. Based on identification of a single channel, rules of geostatistics and production monitoring data analysis, the width of a single channel in this area is determined to be 110-550 m. There are 3 types of single sand bodies: mid-channel bar, braided channel and flood plains, which are identified in each stage with the method of 'identification in single wells, boundary lateral division, and plane combination', and the distribution pattern of single sand bodies in a sandy braided river is summarized. Based on the interpretation of single sand bodies the internal interbeds are also identified, which are mainly classified as fall-siltseam, mudstone between bars, and string groove filling. Guided by modern sedimentation theory and outcrops study, the distribution of architecture boundary surfaces in the mid-channel bar are predicted based on multiple well correlations. Accordingly, a 3D model of the interbeds inside the mid-channel bar was built with stochastic modeling. The results show that the interbeds in the thick sand body of braided river reservoir, which are associated with the bounding surface, are always unstable in the center part of the mid-channel bar. The research provides an accurate geological basis for production dynamic analysis and remaining oil potential tapping.

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1. INTRODUCTION

The study area is one of the development blocks in Daqing Oilfield, which is located in Songliao Basin in northeast China, with about 2500 wells in a 9.04km^2 area(*Fig.1*), has the maximum welling density, 250 wells/km^2 on average in China. Data are abundant and includes core data, horizontal wells, logging data, production data and surveillance data, all of which are used for fluvial reservoir characterization study. The fluvial types of Sa-Pu reservoir groups, the main oil-bearing formation, are classified as meandering river, braided river, and delta distributary channel.

In this study, we mainly focus on architecture characterization of braided river reservoir, which was studied few in the past.
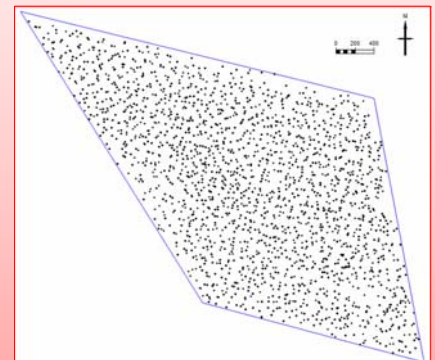

Fig. 1 The wells location of the study area

2. CASE STUDY

2.1 Composite sedimentary microfacies characterization

In order to analyze the composite braided channel distribution of PI3 layer, we first identify the microfacies according to the small layer logging curve (natural potential, natural GR, implants and the gradient) amplitude and spinning back characteristics based on the single wells *(Fig.4)*. Then under the guide of braided fluvial river depositional model *(Fig.2, Fig.3, Fig.5)* and the sequence of the laws, we can further analyze the sand body thickness *(Fig.6)* and the composite sedimentary microfacies surface exhibition *(Fig.7)*.

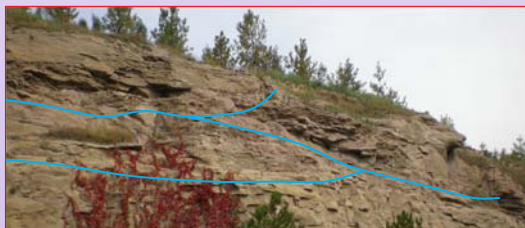*Fig. 2 Modern braided river in Alaska（McCutcheon，1996）*

Fig. 3 The braided fluvial river sedimentary outcrop profile in Datong, Shanxi Province

Plane----The mid-channel bars of braided channel set each other as large width of big ribbon sand bodies.
Vertical----The later channel sand bodies often directly add to the earlier stage sand bodies, which leads to a large thickness of composite sand bodies.
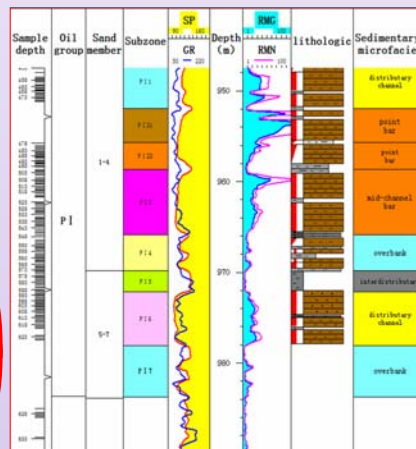

Fig. 4 A single well facie analysis chart of cored well in study area
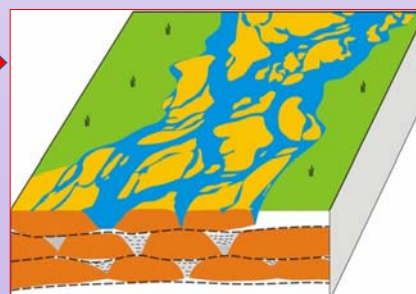

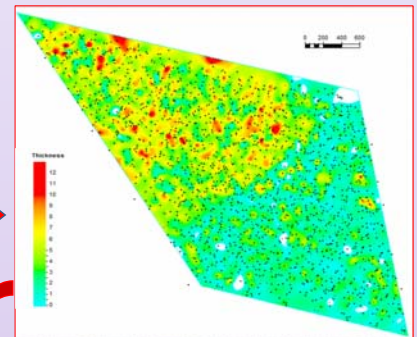
Fig. 5 Depositional pattern of braided river

Fig. 6 Sand body thickness of PI3 layer in study area. The braided channel sand body is relatively thick and even flake, while the overbank sand body is relatively thin in this picture
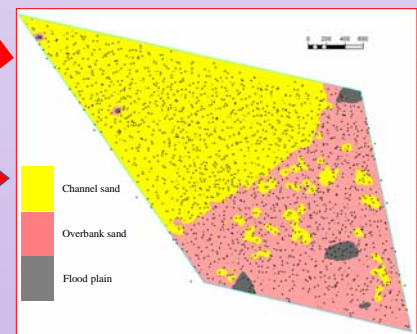

Channel sand
Overbank sand
Flood plain

Fig. 7 Composite sedimentary microfacies surface exhibition of PI3 layer

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2.2 Identification of single mid-channel bar

The braided fluvial river channels changed quickly, which causes more sand bodies in the vertical and lateral connected to each other, forming a widespread thick sandstone. The sand body types of reservoir are mainly the channel and mid-channel bar. The recognition of a single mid-channel bar sand body is the key point to analyze the architecture characterization of braided river reservoir, also is the premise of anatomy of the single mid-channel bar sand body. According to the coring wells material, the mid-channel bar is filled with cross bedding sandstone or block sandstone *(Fig.8)*.
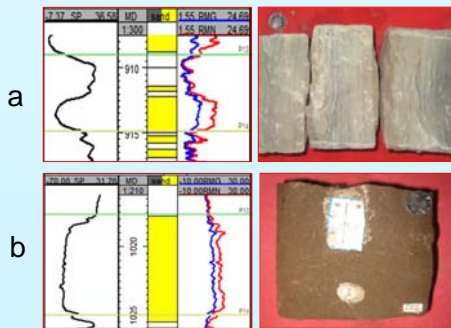

a

b

Fig. 8 *Logging response curve and corresponding core of the braided channel and mid-channel bar. a.braided channel, b. mid-channel bar*

Based on the single well recognition and the principle of the delimitation according to the lateral. The boundary identification marks of the mid-channel bars are mainly according to the distribution patterns of bars (the mid-channel bars in geometric shape, the scale and superposition relations). By the distribution patterns of bars, we can obtain five kinds of boundary identification marks of a single bar in the research area *(Fig.9)*.

Fig. 9 *a. braided channel: according to the cause of mid-channel bar, within the braided channel, each channel represents an end of a single bar.*

Fig. 9 *b. flood plain: two river channels appear to bifurcate, and river diverted process often leaves traces of the flood plain. The unconnected-distribution of flood plain is sign of boundary of the different single bars.*
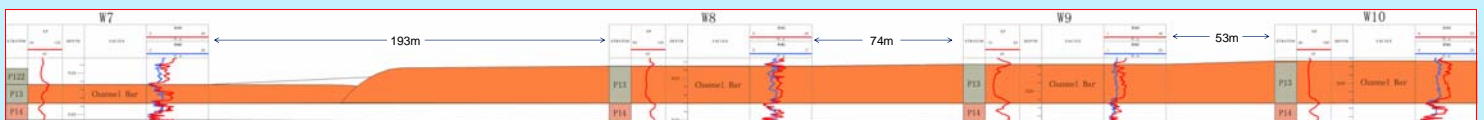

Fig. 9 *c. curve characteristics: different mid-channel bars formed by different water power and different flow velocity, so the scale of the bars cause different logging curves of the different characteristic.*

In addition to the above three identification marks, there are two other signs as follows.

d. elevation difference of sand bodies : at the same time unit (a single layer) there are different periods of mid-channel bars. Since the growing time of each bar is different, the distance from the top of sand body to the formation interface (or mark layer) may be very different.

e. "thick-thin-thick" features: in profile, if the thickness of mid-channel bars is present as continuously "thick-thin-thick" features at the same time stratigraphic units, the boundary of single mid-channel bars certainly exists in it.

With the identification of single bars, we can probably get the distribution of mid-channel bars in the plane *(Fig.10)*.
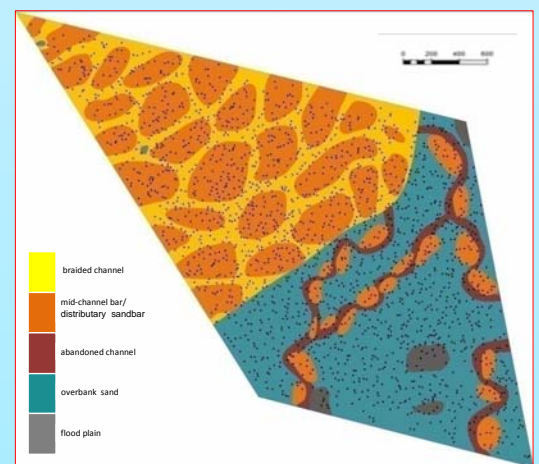

braided channel

mid-channel bar/ distributary sandbar

abandoned channel

overbank sand

flood plain

Fig.10 *The distribution lof single mid-channel bars of PI3 layer*

single sand body	length	width	thickness	shape
mid-channel bar	400m-730m	250m-350m	3.1m-7.8m	elliptic
braided channel	-	45m-109m	2m-4.5m	narrow ribbon

Table.1 *The statistics of single sand bodies of PI3 layer*

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2.3 Internal architecture anatomy of mid-channel bar

Internal architecture anatomy of mid-channel bar is to analyze the multi-stages of vertical overlay bodies distribution in three dimensional, and finally we can build the 3D model. A single mid-channel bar is separated by thin interbeds. The interlayer in the bars was mainly deposited after the flood and was preserved as fine-grained sediments, which present level distribution in the space. In the study area, we found two kinds of interbeds in PI3 layer（ *Fig. 11* ）.

① Shale interbed with thin thickness, 8cm-10cm on average, more for dark grey or gray, The logging curve response obvious, GR curve is of extremely high value.
② Mud powder interbed is mainly silty mudstones, shale silty sandstone, the color is often hoar, commonly seen in the sand body top rhythm. The response of the logging curves relative to the shale curve response is weak, return to small scale.

Fig.11 Thin interbeds of coring wells in PI3 small layer

According to the well sections of vertical direction of ancient flow and parallel direction of ancient flow, the matching relationship of interface between wells is built （ *Fig. 12* ）.
3D modeling of mid-channel bar is the combination exhibition of interface between wells. According to the result of interpolation prediction between wells, we can get the interface exhibition in 3D model （ *Fig. 13* ）.
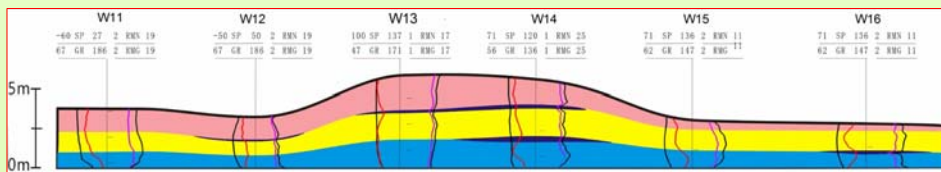

Fig.12 a. The section in vertical direction of ancient flow, the interbeds are nearly flat and with poor continuity
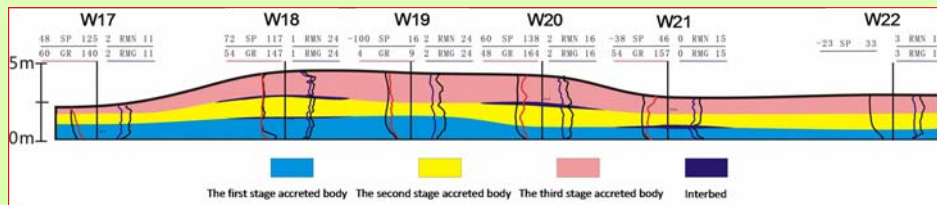
Fig.12 b. The section in parallel direction of ancient flow, the interbeds are nearly horizontal, but the continuity is better than that in vertical direction of flow.
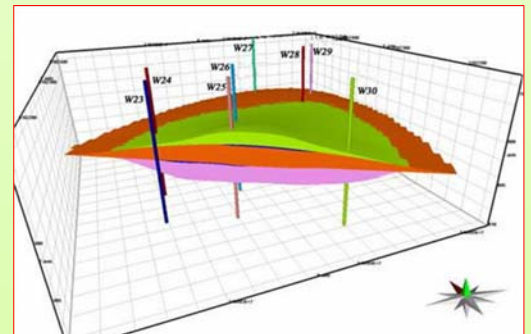
The first stage accreted body   The second stage accreted body   The third stage accreted body   Interbed

Fig.13 The 3D model of interbeds distribution of PI3 layer in the study area

3. CONCLUSION

1. According to fine-grained interbed of flood plain in single wells, the stages of multiple stacking braided channels are divided and correlated vertically. Based on identification of single channel, rules of geostatistics and production monitoring data analysis, we get the composite sedimentary microfacies surface exhibition.

2. There are 3 types of single sand bodies: mid-channel bar, braided channel and flood plains, which are identified in each stage with the method of 'identification in single wells, boundary lateral division, and plane combination', and the distribution pattern of single sand bodies in sandy braided river is summarized. Based on the interpretation of single sand bodies, the internal interbeds are also identified.

3. Guided by modern sedimentation theory and outcrops study, the distribution of architecture boundary surfaces in the mid-channel bars are predicted based on multiple wells correlation. Accordingly, 3D model of the interbeds inside the mid-channel bar is built with stochastic modeling method.

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