Research and application of distribution characteristics of depositional sand bodies in delta-front facies under the condition of large area dense well pattern

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Abstract. Geological reserves in sedimentary unit of small channel sand developed in Gaotaizi reservoir cover 38% of their proved reserves, about 50% of penetration wells are perforated, most of the oil is not recovered, it seriously affects the development effect, in order to produce remaining oil, increase reservoir producing degree, and realize Gaotaizi reservoir fine potential tapping. This paper researches distributing feature of sedimentary sand bodies of in Gaotaizi reservoir and water control and the method for potential tapping by sue of core data and abundant well logging curves, based on analysis of sedimentary facies and logging facies, boundaries of sedimentary units of Gao I reservoir group 1-9 are unified through stratigraphic correlation. The microfacies of the studied area are divided into such three types: subaqueous distributary channel microfacies, sheet sand and subaqueous interdistributary channel microfacies. Based on the detailed study of reservoir thickness, logging curve features, lithologic character, sandbodies and depositional genesis, subaqueous distributary channel and delta front sheet sand microfacies are subdivided into 4 relatively homogeneous units, so as to further reveals the channel sand and sheet internal heterogeneity. Six plane maps sedimentary microfacies of the studied area are drew. It reveals connecting relation of sandbody and describes the sandstone distribution, which can establish geological foundation for identification of high water channel, analysis of injection - production problem and development adjustment scheme design. These methods are used to guide for water control and potential tapping, and the obvious effect of stabilizing oil production by controlling water-cut is shown.

Key Words: sedimentary microfacies, small channel sand, remaining oil.

1. Characteristics of depositional sand bodies in delta-front facies

In recent years, every inland sandstone oilfield combined with geological conditions, based on the river-delta sedimentary model, predicted the distribution of sedimentary sand bodies, and used them to guide the control water exploitation in the later stage of the oilfield [1-3]. However, along with the encryption of the well network, it is found that the predicted sand body distribution, especially the drill encounter rate of narrow-channel river sand body in the delta inner edge, is relatively low, which is less than 60%, and there is a phenomenon that dynamic and static are inconsistent in the development dynamics, which
is the understanding of the sedimentary model needs to be further deepened, or is the forecasting method needs to be further improved? This paper will be combining with the modern sedimentary environment and energy evolution law, make full use of the large area (about 110Km$^2$) dense well pattern conditions (drilling 18000 ports), and combine with seismic attribute data, predict the distribution of sand bodies and reveal the macroscopic evolution law of long distance (10 km) of the sand body along sediment source. At the same time, for which the oilfield enters the late stage of high water cut, the remaining oil distribution is extremely scattered and complicated, the oil layer is used less, and the conventional small layer sedimentary facies zone map is difficult to meet the current situation various conditions that the demand of the remaining oil potential. By further refining the river sand and the mat sand according to the energy unit, and describing accurately the distribution of single sand bodies, to guide the improvement of the relationship between injection and exploitation of single sand bodies, and to determine the corresponding measures of the control water exploitation[4-8].

2. Overview of the study area

The study area is located in the middle of the Saertu Oilfield in Daqing placanticline, the Sazhong Development District, is about 110Km$^2$. The study layer is a group of GI1 ~ GI9 units in the inner delta frontal subfacies. It mainly develops three sedimentary microfacies of underwater distributary channel, mat sand and underwater distributary inter-channel mud, and drills about 18,000 wells. The average well density is 163/Km$^2$, and the well density is up to 270/Km$^2$, which provides favorable conditions for the study of sand body sedimentation characteristics.

3. Deposition characteristics of the frontal sandstone in the inner delta

3.1. Cored well facies analysis

Through careful observation of the rock cores of the J1 and J2 cored well in the study area, comprehensive and detailed analysis of sedimentary features from various aspects such as color, composition, structure and lithology, and combining with logging data, regional geological background and predecessor research results to determine the frontal sub-facies depositional characteristics of the GI1 ~ GI9 unit in the GI stratum[2]. The general characteristics are: the color of the mudstone is mainly gray-green, and the lithology of the reservoir is dominated by siltstone. The whole is characterized by extremely thin mudstone and sandstone interbedded[9-12].

3.2. Deposition time unit division and fine contrast

Using the theory of river sedimentology and the new theory of high-resolution sequence stratigraphy, "the combination of the river flood surface series under the control of the standard layer based on the regional skeleton closed section, the sedimentary model - the guidance of the contemporaneous fault model, the stepwise priority approximation, etc. Comprehensive comparison, and stepwise partitioning and gradual push-opening, and finally the cause of the transition of the river facies oil layer comparison method, to achieve the boundary of the study area G I1 ~ G I9 a total of six sedimentary units [1].

3.3. Logging facies mode

Based on the lithology analysis of the cored wells and the characteristics of the well logging curve, and establish the logging facies models of various microfacies which are the underwater distributary channel, the sheet sand and bay mud between distributary channels .

(1) Underwater distributary channel microfacies

It has river features such as bottom flushing or mutation surface, bottom retention, positive rhythm and vertical channel sequence. It has high amplitude, high amplitude difference, typical bell shape (or box shape), medium thick layer, smooth - micro-tooth logging facies characteristics. Referring to characteristics such as reservoir thickness and log curve, it is subdivided into four relatively homogeneous units (energy units), namely, I, II, III, and IV types of underwater distributary channels (Fig. 1).
Underwater distributary channel Ⅰ            underwater distributary channel Ⅱ

Underwater distributary channel Ⅲ             underwater distributary channel Ⅳ

Fig.1 The electrofacies models of underwater distributary channel microfacies

Sheet sand Ⅰ                               Sheet sand II

Sheet sand III                           Sheet sand IV

Fig.2 The electrofacies models of sheet sand

(2) Sheet sand microfacies
It is Mainly siltstone, argillaceous siltstone and silty mudstone that are located in the lower part of the spiral. The overall is a higher amplitude and amplitude difference, is box-shaped or toothed box
shape or a box-funnel composite shape, and the top position abrupt change, bottom position gradual change or abrupt change, and the smooth-micro-toothed feature. Referring to the characteristics of reservoir thickness and log curve, it is subdivided into four relatively homogeneous units, namely, I, II, III, and IV types of sheet sand (Fig. 2).

(3) bay mud between distributary channels
The underwater distributary inter-channel mudstone and the thin mat sand are frequently interbedded, and the mudstone is dark gray, gray, grayish green, and the block mudstone is purer, darker and more homogeneous (Fig. 3). The microelectrode curve shows a low value, with no amplitude difference.

3.4. Logging and seismic are combined to predict sand body
Using the well network data, according to the established logging facies mode, through the layer-by-layer and well-by-well logging microfacies identification and the plane sedimentary microfacies combination, using the pattern drawing method[3]. At the same time, combined with the seismic attribute slicing, the logging and seismic are combined to predict the sand boundary of the river channel, the river course and the disappear position in the end of distributary channel accurately (Fig. 4), and the sand body distribution of each unit is characterized in detail [13-15].

4. The understanding of sand body sedimentary characteristics
Through the logging-seismic combinatio, the large area and tight well network. The single sand body plane distribution (Fig. 5) is finely characterized, and the sedimentary features are recognized as follows:
Directionality of the channel: controlled by the northern sediment source, the river is mainly showed the nearly south-north direction, but the distribution direction of the local channel sand body intersects with the source direction at a high angle, and it’s even nearly east-west direction, with sediment source direction is distributed. The reason for the analysis is that the underwater distributary channel is partially forked, merged, and distributary channel is lateral flow.

Continuity of the channel: from north to south away from the sediment source direction, due to the increase of water depth, the river control effect is weakened, and the transformation effect of the lake wave make the continuity of the channel sand body worse, from continuous branch-mesh, strip-like gradient to isolated Potato-shaped, intermittent strips.

Width of the channel: away from the sediment source direction, due to weak river handling capacity, the top support of the lake, the width of the channel sand body is narrowed, the width of most channels in the north is more than 200m, the width is 400m, and the width of the southern channel is narrow, most of them are 80~150m, more than 200m channel is less.

Thickness of channel sand: The effective thickness of channel sand is thinner. The northern part is mostly the I and II types of channels with effective thickness greater than 2m, and the south part is mostly III types of channel with effective thickness greater than 1m.

(5) Distribution of mat sand: away from the lake shore, the water depth increases, the lake wave transformation effect is enhanced, and the debris transported by the river channel is enhanced by slicing. From the river is centered on the channel, to the both sides or the front end are gradually changed to the continuously mat sand.

After fine anatomy of the tight well network, the continuity, directionality and distribution models of the narrow channel sand body are clearer. The geometry and connectivity of the sedimentary sand body are more in line with the sedimentary law, and the inter-difference between the same micro-facies is clearer after refinement and characterization. It has laid a good foundation for the narrow channel sand body to the control water exploitation.
5. Conclusion

Through the anatomy of the dense well network, the GI1 ~ GI9 units sand body of the Gaotaizi oil layer in the Sazhong development area are finely characterized and the water-flooding control-water exploitation methods were studied. The following conclusions were obtained:

(1) According to the thickness of the reservoir, the characteristics of the electric curve, the type of lithology, the characteristics of the sand body, and the sedimentary genesis, the micro-facies of the underwater distributary channel sand and the mat sand are refined and characterized into four types of relatively homogeneous units (energy units). The difference between the same micro-facies is revealed more clearly, the difference is the potential, and the sand body distribution map after refinement is favorable to guide the remaining oil exploitation.

(2) Accurately predicting the plane distribution of sand bodies in narrow channels, objectively characterizing the distribution of sedimentary sand bodies shows regular changes away from the sediment source, that is, from north to south away from the sediment source, the water body deepens, and the lake wave transformation is enhanced. The scale of the underwater distributary channel sand body becomes smaller, which is characterized by narrowing of the width, thinning of the thickness, fineness of the grain size, deterioration of the continuity of the river channel, and gradual enhancement of the mat sanding.

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