Prediction of narrow channel sand body by dynamic and static data

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Abstract—At present, a description method has been formed for prediction of the sand body in narrow underwater distributary channel in delta inner front intrafacies. Usually, static data, such as core data and well logging data, are used to predict the sand body distribution in narrow channel. However, dynamic data are inconsistent with static data during dynamic analysis based on the description results. In this paper, a narrow channel was predicted and depicted by combining dynamic and static data, resulting in not only theoretical deduction and genetic interpretation based on static data, but also improvement and verification based on dynamic data. Thus, the geological prediction results are more compliant with the underground conditions. A method for prediction of narrow channel sand body based on dynamic and static data is formed.

1. Introduction
The understanding of delta inner front intrafacies sedimentary sandbody is further strengthened through potential tapping based on water flooding and study on sedimentary characteristics of infill well pattern; delta inner front sedimentation model are recognized and improved through combination of seismic data and logging data; a facies diagram of delta inner front narrow channel sand body is plotted based on dynamic and static data through analysis of typical oil reservoir, and a plotting method and operation procedure for combination of dynamic and static data are prepared.

The significance and purpose of this project is to make full use of all kinds of data to carry out sedimentary facies zone map, especially the delineation and prediction of channel sand is a trend and necessity of drawing map sheet with higher and higher requirements for reservoir description results in oilfield development.

2. Definition of Narrow Channel
During oilfield development, narrow channel sand body is often mentioned. However, narrow channel sand body is not well defined. Based on the reservoir development scale, channels are roughly divided into five categories, i.e. extra small channel, small channel, medium channel, large channel, and extra large channel. In terms of channel scale, a narrow channel refers to a small or extra small channel, and “narrow” refers to “channel width”, and small refers to “channel development scale”.
Narrow channels mainly develop in the delta inner front intrafacies and form by underwater deposition. They are not only main objects of EOR from Class II reservoirs and tertiary infill adjustment of Class II reservoirs, but also an important guarantee for sustained stable production.

3. Recognition of sedimentary characteristics of dense well pattern
According to the macro sedimentary environment of the study area, the sedimentary model and development scale of various sand bodies have changed to a certain extent after well pattern infilling. With the increase of well pattern density, the distribution of various sand bodies, especially the distributary channel sand bodies of delta inner front facies and unstable sand bodies of delta outer front, has changed. In general, different microfacies distribute more complicatedly on the plane, and the sand bodies of different genetic types change to different extents on the profile. The comparison shows that the drilling ratio of channel sand decreases continuously, tabulated reservoirs increases slightly, untabulated reservoirs increases and the mudstone decreases.

3.1. Variation rule of sand body after densification
The comparative analysis of sand body distribution under several well patterns shows that with the increase of well pattern density, the distribution of all kinds of sand bodies has changed, especially the small-scale distributary channel sand body of delta inner front facies and unstable sand body of delta outer front. In general, the distribution of different microfacies is more complex on the plane, and the variation degree of sand bodies of different genetic types is obviously different on the profile. Before and after comparison, the drilling encounter rate of channel sand decreased continuously, the drilling encounter rate of in table reservoir increased slightly, the rise amplitude of off table reservoir was larger, and the drilling encounter rate of mudstone continued to decline.

(1) The geometry of sand body has been improved to varying degrees, continuity and directivity have changed, and the distribution of sand body is complicated;
(2) The results show that the drilling rate of channel sand body is reduced, and there are a certain scale of sand body inside and outside the surface between channel sand or edge zone, which makes the development scale of channel sand body smaller on the plane;
(3) In most cases, all kinds of sand bodies are small and scattered, and the plane phase transformation is rapid. The geometric morphology of sand bodies is characterized by alternating and staggered distribution of various sand bodies.

3.2. Re understanding of the specific changes of sand bodies
According to the high-density well pattern in the study area, the specific changes of sand body after reservoir infilling are re recognized

 Changing position
According to the statistics of sand body changes before and after drilling, the sand body changes are mainly concentrated in three locations: the prediction of channel trend, the opening and end of river channel, and the merging of river bifurcations.

(1) When the predicted distance is more than 2 well spacing, the channel sand is easy to be drilled out due to the lack of information points. When the prediction distance is too long, the width, curvature and direction of the channel have multiple solutions, especially when the predicted distance is greater
than two well spacing, the possibility of channel sand drilling is relatively large. In the future, it is necessary to avoid well layout in areas with long predicted distance and reduce drilling risk.

(2) In the opening and end of the channel, there is no well point control at the edge of the oilfield, and the wide swing range of the river channel makes it easy to drill out the channel sand. Because the local swing direction of the river is not easy to determine, it is found that the extension direction of the river channel changes or deviates after drilling, resulting in channel sand drilling empty. In well layout, for the wide channel with channel width greater than 2 well spacing, the probability of encountering channel sand is high; for narrow channel controlled by single well spacing, the drilling risk is increased.

(3) At the confluence and confluence of river channels, the locations of confluence points and distributary points of multiple rivers and the combination mode of river channels are diversified, which makes it easy to drill out the channel sand. Through the analysis, when at least two wells meet the channel sand and the channel sand is thick, the river is relatively wide and the probability of encountering the river channel is high; when only one well meets the channel sand and the channel sand is thin, especially when the whole unit belongs to the intermittent straight narrow strip type channel sand of the trunk Delta, the channel sand body at the merging place is not It's going to be wide. When determining the boundary of river course at the junction of bifurcations and merges, it is necessary to follow the law of river sedimentation, that is, the center of the channel is thick sand body, and the sand body on both sides of the river channel becomes thinner, and the river boundary should be close to the thin sand body or the sand body with the characteristics of toothed riverside, which makes the prediction of river channel boundary more reasonable.

According to the well layout plan and actual statistics, the predicted river channel outside the river boundary has a high proportion of actual non drilling. According to the cause analysis, for the narrow channel, the fluctuation range of the river is about 25m. When the channel sand is predicted horizontally at 50m greater than the river boundary, the drilling risk is increased. Therefore, the well layout position should be controlled within the river fluctuation range.

Since the channel width of the inner front facies is narrow after drilling, most of the channel widths are within a well spacing. The curvature and boundary position of the river can only be predicted by the parameters such as inter river sand and thickness of adjacent wells, which is difficult to accurately control. There are many channel migration phenomena after drilling. According to the law of river sedimentation, small wave mapping should be adopted for the narrow sand body of Gaotaizi oil layer. When the well location is within a well spacing, it can be located near the adjacent well line.

2 Types of change
The change types of channel sand are analyzed and classified

(1) The width of the river increases with the local expansion. There are two main cases of channel sand body widening after drilling: one is that it occurs at the edge of wide channel sand body, which is local wave. The horizontal fluctuation range is large and the longitudinal fluctuation range is small, which mostly occurs on the convex bank of the river. The other is that it occurs at the edge of narrow channel sand body. The channel is widened as a whole, with small horizontal fluctuation range, less than one well spacing and large longitudinal fluctuation range. The common characteristics of the two cases are that the sand body at the widened position is thick and the logging curve is box shaped or bell shaped.

(2) The channel shrinks and its width narrows. There are two kinds of channel contraction: one is local shrinkage, which occurs at the bifurcation and merging position of several narrow channels. Especially for two tributaries with poor continuity and small width, the sand body at their confluence is not necessarily very wide, which often occurs after drilling. The other is that the overall width becomes narrower, which mainly occurs in the straight and straight distributary, underwater distributary and crevasse channel. For the narrow sand body less than a single well spacing, the control degree is weak when the well pattern density is small, and the width becomes narrow after the well pattern is densified. The channel is mostly flat bell shaped or finger shaped on the logging curve.

(3) The river course swings in the direction. In the opening direction of the river channel or the prediction of the river channel, the accuracy of the prediction of the river direction is affected by the
lack of information, so it is difficult to control the curvature change of the channel, and the channel will swing after drilling.

(4) New river course is encountered. Due to the low control degree of well pattern on sand body of narrow strip channel, especially the fractured channel and underwater distributary sand body, the number of river channels will increase with the increase of well pattern density. One is at the junction of intermittent channels, the other is in the protruding part of the main channel, which is prone to crevasse. The results show that both the width and the continuity of the newly drilled channel are basically controlled within the river channel with high degree of well pattern control described at present. The probability of encountering channel sand in inter river sand and pinch out area is low, but the specific shape and width have a further narrowing trend, about 100m. At present, it is still very difficult to predict the narrow sand body, which indicates that the serious plane heterogeneity is still the biggest difficulty in reservoir prediction.

4. A method for prediction and plotting of narrow channel by combining dynamic and static data

The description process of combining the data of any two well points is geological prediction. However, it is difficult to ensure that the prediction results are more compliant with the underground conditions. Following the idea of “Easy first and then difficult”, narrow channels are predicted and depicted according to core data, logging data, seismic data and dynamic data.

4.1. Prediction and depiction based on static data

(1) Determination of channel scale. The channel scale is determined by combining logging data and seismic data, providing a basis for judgment of the sand body continuity between well points.

(2) Prediction of channel continuity and direction. The deposition of various channel sand bodies is controlled by the one-way water flow of the channel. The channel is continuous, and most of the sand bodies deposited in the channel are continuous, too. However, sometimes the channel is too narrow and the well pattern is difficultly controlled, always resulting in the false appearance of discontinuous distribution, such as isolated lump or intermittent strip, of channel sandstone.

(3) Prediction of channel sand body boundary. According to the facies classification based on single well logging data, the most suitable geometric shape is found between a series of well points with different well pattern density at the closest facies change to the well spacing by the gradual approximation method based on the understanding of channel width and the prediction of curvature. The geometric shape and interwell boundary of sand body can be predictively plotted by smooth and smooth curves, and the boundary of sand bodies in some complex areas can be improved by branching, crevasse and tangent.

(4) Improvement of channel combination method. When the confluence point involves 1-2 wells and the two merged channels have poor continuity and small thickness, Y-shaped drawing method is used instead of the H-shaped drawing method, which should be avoided at the confluence point, in order to separate the confluence point from the branching point.

4.2. Verification and improvement based on dynamic data

The dynamic data, including solution preparation, injection, liquid production, water cut, perforation, numerical simulation-assisted profile, etc., are added during plotting of sedimentary facies map. The dynamic data plot is established separately. The channels are predicted and depicted by combining dynamic and static data according to the dynamic response characteristics of injection and production wells, such as water absorption and liquid production, during plotting of channel sand body.

The narrow channel sand bodies are precisely predicted and the result are verified during application based on well logging data and seismic data, i.e. dynamic and static data, in the study area. The method and procedure for plotting of narrow channel sand body is prepared based on "model guidance, facies control of well point, prediction and plotting, and dynamic verification"
5. Conclusion and Recognition

5.1. Two conclusions
(1) The sedimentary model of Gaotaizi reservoir is reconstructed to lay a foundation for description of Gaotaizi reservoir;
(2) The method and procedure for prediction of the narrow channel sand body by combining dynamic and static data is prepared to further describe reservoirs and meet the demand for adjustment and potential tapping.

5.2. Recognition of three aspects
(1) The reservoir description idea and method need to be developed continuously in order to accurately describe the reservoirs;
(2) The recognition accuracy of sedimentary microfacies and combination of dynamic and static data are the bottlenecks of reservoir description;
(3) On completion of skeleton sand body prediction, how to describe the underwater distributary deposition with abundant sedimentary microfacies is the key point for fine drawing of sedimentary facies map.

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