Prototype geological model of distributary channel based on the high density well pattern

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Abstract. The western part of the central zone lies in the middle of the Saertu anticline structure. It can be divided into 77 sedimentary units, with the permeability ranging from less than 10 mD to more than 1000 mD. Diversity of plane sand body morphology, phase change frequently. Based on the high density logging data in the west of the central district, the prototype geological model of distributary channel sand body is studied, and 6 sedimentary models of distributary channel in 3 sedimentary environments are established. The Upper plain was mainly developed: composite type. The lower plain is mainly developed: the split-band type and the interwoven network type; the delta front is furcated dendritic, single continuous and discontinuous type. Geometric parameters of different distributary channels are obviously affected by the sedimentary environment, and the scale, curvature and width-thickness ratio of distributary channels along the sedimentary direction all decrease from large to small.

1. Introduction

Accurate description of the real appearance of underground reservoir is a research subject throughout oilfield development [1-7]. Many scholars have studied reservoir prototype model base through field outcrop and modern deposition [8-17]. However, modern sedimentation and field outcrop studies are greatly influenced by topography, the formation and distribution of reservoir in three - dimensional space cannot be obtained. Moreover, the sedimentary conditions, sedimentary environment and stratigraphic similarity between outcrop and oilfield are uncertain. Therefore, the high density well pattern data are considered to establish the prototype model[18-19]. The density of well network in the densest block of Daqing oilfield can reach 300/km², and the minimum spacing of wells is only 20 meters[20]. It has the condition of prototype geological model research and can reflect the actual geological condition of oil field, which opens up a new way for reservoir prototype model research.

The western part of the central zone lies in the middle of the Saertu anticline structure. The S P G reservoir is an interlayer of sand and mudstone deposited by a large inland lake-river delta from the middle and late Qingshankou Formation to the early Nenjiang Formation. It can be divided into 77 sedimentary units, with the permeability ranging from less than 10 mD to more than 1000 mD. Diversity of plane sand body morphology, phase change frequently.
The establishment method of the prototype model of dense well pattern

2.1. Vertical (one-dimensional) subdivision of a single well into a single sand

In this study, the most dense well pattern block in the west of Saertu oilfield is selected as the target area. In vertical using well logging curves and core data for unit fine division, into a single sand layer. Single sand layer is 4-5m average formation thickness, the smallest is only 2 m, 26 small layer down to 40 sedimentary unit, through to the small layer on the unit division. The vertical division accuracy is further improved, and the average single sand layer thickness is 2-3m, is the smallest unit to control the oil and water movement.

2.2. Single sand body was identified in the horizontal section (two-dimensional)

In the section, a fine small section with 3 vertical and 50 horizontal logging correlation was made. The regional stability standard layer was selected and the horizon tracking of each single sand layer was conducted according to the levelling of the standard layer, and height difference analysis, connection relation discrimination and classification of microfacies among different single sand bodies were carried out (figure. 1). The characteristics of single sand body boundary can reflect the differences in horizon, microfacies, thickness and curve morphology [4]. On the plane, based on the boundary profile feature recognition of single sand body, the high density well pattern data are used to conduct the single sand body plane combination guided by the deposition pattern.

2.3. Establish detailed geological model in space (three-dimensional)

In space, based on the identification results of two-dimensional single sand body of reservoir, a 3D geological model with a grid accuracy of 20×20×0.1m is established, with a total net node of 50.5 million, which can display the distribution characteristics of microfacies, lithology and properties of reservoir from any angle, so as to realize the three-dimensional description of reservoir and form an all-round 3d prototype geological model.

3. Distribution characteristics of distributary channel prototype model

3.1. Distributary channel sand body deposition type

According to the sedimentary environment and genetic types of sand bodies, the classification scheme of distributary channel in delta was established (table 1). The distributary channel sand bodies in three sedimentary environments were divided into six categories.

The mosaic compound distributary channel is mainly developed in the upper plain on the delta. Distributary channels are distributed in a large area, which are actually composed of multiple distributary channels' migration swing and lateral superposition (figure. 2a). Single distributary channel is highly curved, ranging in width from 40 to 760m, usually less than 300m.

The lower plain distributary channel mainly includes two types: one is "split-band type" split distributary channel (figure. 2b), it develops wide band distributary channel sand body, and the other is more suitable straight narrow channel deposition. The broad ribbon main channel is formed by the
lateral tortuous and splicing of 2-3 distributary channels. The single channel is about 200 meters wide. Straight river is mostly the main channel crevice channel, about 100 meters. The other is the "intertwined network" distributary channel (figure. 2c). The distributary channel branches step by step from upstream to downstream, forming a network pattern. The number of channels increases gradually, with different wideness and narrowness.

Table 1. Classification scheme of delta distributary channel types.

| Sedimentary environment | Depositional model           | Basic characteristics                                                                 |
|-------------------------|------------------------------|---------------------------------------------------------------------------------------|
| Upper plain             | Mosaic compound              | Complex lateral and vertical cutting, large thick lamellar composite sand body          |
| Lower plain             | Wide band type, intertwined network | Plane crevasse, network connection, small and medium-sized wide band or network skeleton sand body |
| Inside front            | Furcated dendritic, single continuous | Subaqueous extension of shore-bank branching channels, narrow bands or dendritic skeleton sand bodies |
| Outside front           | Intermittent isolated        | Channel sand body is transformed by wave action and distributed in cuspate shape or pod intermittently |

There are two main types of distributary channels in the inside front delta: one is the “furcated dendritic” narrow and small distributary channels (figure. 2d), which diverge step by step from upstream to downstream, with few conversions. This type of distributary channels shows that the number of single distributary channels gradually increases and the width becomes narrow, and they develop in the near shore part of the front delta edge. The second is "single continuous" narrow banded distributary channel (figure. 2e) mainly developed relatively straight narrow channel sand bodies, with less number and furcation of channels and mainly with sand-sheets. However, the single distributary channel has good continuity and develops in the middle and far bank of the delta front.

The outer front of the delta is mainly developed with "intermittent isolated" narrow and small distributary channels (figure. 2f). The channels are few in number, small in scale and poor in continuity, most of them are distributed in cuspate shape at the outer edge of the delta.

Figure 2. Morphological characteristics of distributary channels under different sedimentary environments.
3.2. Geometric parameters of different types of distributary channels

According to the geological model of dense well pattern prototype for all kinds of sand body geometry parameters for the actual measurement, the measurement of the four main sedimentary environment of distributary channel distribution parameter characteristics (table 2), from complex to isolate furcated type, channel width decreases from 287 to 130-62-42 meters, the curvature from 1.8 to 1.5-1.2-1.0, also decreases, and width-thickness ratio ranges from 97.4 to 47.4-26.0-19.5.

Table 2. Distribution table of geometric characteristic parameters of distributary channels.

| Sedimentary environment | width (m) | thickness (m) | curvature | furcated Angle (°) | Channel width-thickness ratio |
|-------------------------|-----------|---------------|-----------|-------------------|-----------------------------|
| Upper plain              | 287       | 3.1           | 1.8       | 48.7              | 97.4                        |
| lower plain              | 130       | 2.7           | 1.5       | 39.1              | 47.4                        |
| Inside front             | 62        | 2.3           | 1.2       | 36.3              | 26.0                        |
| outside front            | 42        | 2.1           |           |                   | 19.5                        |

3.3. Heterogeneity of distributary channel reservoirs

Generally speaking, it has the following characteristics:

First, the narrow width of sand body and the rapid face transition in plane
From different sand body width distribution, the single channel width is small, the biggest only 287 meters, the minimum of 42 meters, from the different distance transformation face statistics, within the scope of 30 meters, the upper plain face change rate is 6.5%, the lower plain face change rate is 28.9%, inside and outside front face change rate is about 50%. Thus the distributary channel has a strong heterogeneity.

Second, the control degree of sand body well is low and the control rate of sparse well pattern is high
Data of different well pattern stages in the study area is used to analyze the control degree of wide-band and narrow-strip distributary channel sand body [2]. For the wide band type sand body, out of control rate is 55% when the well spacing density is 10.3 wells /km²; when the well spacing density is 50.3 wells /km², out of control rate is 20%. As well pattern density increases further, the control rate changes little. For the narrow strip sand body(defined above: furcated dendritic, single continuous, intermittent isolated), out of control rate is 90% when the well pattern density is 10.3 wells /km², 60% when the well pattern density is 119.4 wells /km², and 30% when the well pattern density is 315.9 wells /km², showing a continuous downward trend.

Third, there are many new sand bodies between wells with infill well pattern, which has a certain residual potential
Generally speaking, due to the narrow distributary channel sand body, the drilling encounters of sand bodies in SIII group with different well distances of 250m, 126m, 66m and 42m were calculated; as well spacing decreases, the number of channel sand bodies drilled increases gradually, and the width of channel sand bodies decreases gradually, so the understanding of channel sand body width is more and more close to the actual situation (figure 3). It indicates that the control degree of distributary channel sand body is lower than that of sparse well pattern, and the potential of improving single sand body injection-production system by infill well pattern or stratified well pattern reconfiguration is greater.

4. Conclusion

Characteristics of delta distributary channel are controlled by sedimentary environment. There are six sedimentary modes can be refined in four sub-environments: upper plain, lower plain, inside front and outside front. The upper plain is mainly developed as a mosaic compound type, while the lower plain is mainly developed as a wide-band type and an intertwined network type, the inside front is mainly
developed as a furcated dendritic type and a single continuous type, and the outside front is mainly intermittent and isolated type.

![Diagram of distributary channels](image)

**Figure 3.** Profile comparison of distributary channel characterization results with different well spacing conditions.

The knowledge base of delta distributary channel parameters is quantified. Along the sedimentary trend, the scale and curvature of distributary channels decrease gradually. The single channel width in the upper plain is less than 300 meters, and the channel curvature is 1.8. The width of a single channel in the lower plain is more than 100m, and the curvature of the channel is 1.5. The width of a single channel at the inside front is about 60m, and the curvature of the channel is 1.2. The width of the outside front channel is about 40m.

The distribution characteristics of distributary channels in delta are deepened. With narrow sub water channel width, rapid face change, low well controlling and large potential, the residual potential can be further explored through combination of reservoir system and well pattern optimization.

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