Introduction

The shallow water delta reservoir is widely developed in the Bohai Sea, and the proved geological reserves of crude oil account for 43% of the total geological reserves of the Bohai Sea (Dai et al. 2007). With the continuous development of oilfields, most of them have entered high water cut development stage. Affected by complex contact relationships between single distributary channels and reservoir heterogeneity, the distribution of remaining oil is complex and the shallow water delta oilfield development effect becomes worse at the late stage of waterflooding development. Reservoir description technology is an important means to improve development effect in middle and high water cut period of oilfield (FENG et al. 2012; SONG et al. 2018; JIA et al. 2014). Conventional reservoir characterization techniques are mostly based on high-resolution three-dimensional seismic data, using the principle of seismic sedimentology to complete the fine division and quantitative characterization of reservoirs. However, some reservoirs in the offshore oilfields, i.e., Bohai Sea in northeastern China, are buried deep and have low resolution of seismic data. Compared with onshore oilfields, offshore oilfields have larger well spacing and fewer testing data (Zhang et al. 2016), which further increases the difficulty of reservoir characterization in offshore oilfields.

Method and/or Theory

Taking the QK oilfield in Bohai sea as an example, the reservoir configuration of shallow water delta sand body is studied by using core, well logging and production dynamic data. The classification standard of configuration grade, interface identification method of single channel sand body, shape scale and reservoir configuration mode of shallow water delta reservoir in offshore oilfield are defined, which provides basis for later development adjustment of offshore shallow water delta oilfield.

Conclusions

First of all, referring to Miall's six level configuration interface division scheme and field outcrop observation results (Miall.1985; Fu et al. 2015), combined with the actual development demand and data accuracy of offshore oil field, a 3-6 level configuration interface classification scheme of shallow water delta sand body in the study area is established, as shown in table 1.

Table 1 The classification scheme of shallow water delta reservoir architecture in the study area

<table>
<thead>
<tr>
<th>Configuration unit</th>
<th>Configuration interface</th>
</tr>
</thead>
<tbody>
<tr>
<td>Shallow water delta deposit</td>
<td>Level 6</td>
</tr>
<tr>
<td>Shallow water delta front deposit</td>
<td>Level 5</td>
</tr>
<tr>
<td>Composite channel sand body</td>
<td>Level 4</td>
</tr>
<tr>
<td>Single channel sand body</td>
<td>Level 3</td>
</tr>
</tbody>
</table>

Secondly, using core and logging data, the boundary of single channel is identified from two directions: vertical and horizontal. According to the logging data, the vertical interface is divided into three genetic types (Zhang et al. 2008): ① fine-grained muddy interlayers; ② calcareous interlayers; ③ physical interlayers caused by channel erosion and cutting.

On the basis of vertical interface identification, combined with two methods of "lithologic boundary and thickness model", the single lateral interface in the study area is characterized from both qualitative and quantitative perspectives. The lithologic boundary mainly includes three types: overflow deposit, lacustrine mudstone and abandoned river channel. The thickness model method is mainly based on the "flat top and convex bottom" of the sandbody shape in the single channel (Duan et al. 2014), and the prediction formula of single channel thickness is established: \[ L1=H1\times L/(H-H1) \], \( L1 \) is the distance between the river boundary and the boundary well, m; \( L \) is the distance between the two wells, m; \( H1 \) is the sand body thickness of the boundary well, m; \( h \) is the sand body thickness of the central well, m, as shown in figure 1.
Figure 1 - Quantitative determination model of single distributary channel in the study area

Based on the identification of the vertical and lateral interface of a single channel, the scale of a single channel sand body is quantified from the two directions of profile and plane, and finally the distribution law and configuration mode of single channel sand body in the study area are established. The results of profile comparison show that the thickness and continuity of sand bodies vary greatly in different periods vertically, and the thickness of sand bodies gradually decreases from top to bottom, but the continuity of sand bodies gradually gets better; the thickness of sand bodies in the same period is greatly changed, mostly between 1.0-4.0m, under the influence of channel diversion in the direction perpendicular to provenance, and the thickness of sand bodies is relatively stable in the direction of parallel provenance in the same period. The thickness of sand body in single channel is about 3.0m, as shown in figure 2.

The results of plane distribution show that the composite channel sand body with stable continuous distribution on the plane is actually composed of several single channel sand bodies of different periods. The plane distribution form of sand body changes from flake to strip from the bottom to the top, and the connectivity of sand body gradually becomes poor. In addition, the width and thickness of a single underwater distributary channel increase gradually. The statistical results show that the sand body of a single channel in the study area is 2.0-4.3m in thickness, 220-1530m in width and 110-382 in width thickness ratio, as shown in figure 3.
Figure-3 Plane distributary characteristics of composite and single channel in the study area

Based on the study of the vertical and plane superposition relationship of the distributary channel sand body, the sedimentary and configuration model of the distributary channel type shallow water delta in the study area is established, as shown in Figure 4. The periodic fluctuation of lake level and the supply of material lead to different structures of sand bodies in different periods in the shallow water delta. In the early stage of sand body deposition in the compound channel, the lake level in the study area is the largest, which leads to relatively insufficient sediment supply and thin sand body thickness. At the same time, affected by waves and coastal currents, the sand body is transported laterally, forming overflow deposit between the distributary channels, resulting in better connectivity of the sand body. As the lake level continues to decline until the late stage of composite channel sand body deposition, the sediment supply in the study area is relatively sufficient, and the thickness of channel sand body is thickened. At the same time, due to the increase of suspended substances in the sediment, it is easy to form stable natural levees and other overflow deposits on both sides of the channel, thus forming a stable single distributary channel deposit, and the connectivity between the sand bodies becomes poor. The vertical superposition and lateral contact of single distributary channels in different periods make the composite sand bodies of shallow water delta have strong reservoir heterogeneity, and directly control the distribution of remaining oil. In the process of water injection development, the corresponding relationship between injection and production wells at the bottom of the composite channel is good, resulting in serious water flooding of the sand bodies; while the relationship between injection and production at the top of the composite channel is poor, the degree of water flooding is low, and there is still remaining oil enrichment can enhance the production of remaining oil in the top layer by implementing profile control operation of water injection well and deploying horizontal well.
Figure 4-Sedimentary and architecture model of shallow water delta in the study area

References


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