“Factory-like” horizontal well plan optimization techniques in tight oil exploration—A case study in Fuyu oil-bearing layer of Y63 well block, Northern Songliao Basin

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Abstract. In Zhaoyuan region of Sanzha Depression, Fuyu oil layer is of considerable resource potential, and its tight reservoir is continuous and extensively oil-bearing. How to improve the deliverability of tight reservoir, however, is still a major problem facing explorationists. As for the sweet spot Y63 in Zhaoyuan region, this paper uses well logging, well testing and laboratory test data to identify the geological characteristics of FⅡ1, determines the sand body boundaries of the sweet spot by means of seismic attributes and geostatistical inversion, and then carry out batches of horizontal well plans on the same platform. The drilling result of five horizontal wells shows that the oil layer thickness ranges from 934m to 1177m, with an average of 1080m. By comparison with its adjacent straight wells, the deliverability of horizontal well is improved by a factor of 5-12. This proves the advantage and feasibility of the horizontal well plan proposed in this paper.

1. Introduction
In recent years, tight oil has become a hot spot in unconventional oil and gas field [1-7], which is the main succeeding field of oil exploration in the future. With the deepening of exploration and development in Songliao Basin, conventional oil and gas exploration becomes more and more difficult, and tight oil and gas has broad exploration prospects. However, the natural productivity of tight reservoir drilling is generally low, and large-scale fracturing technology is needed to form industrial productivity. In recent years, Changqing Oilfield has formed a series of tight oil exploration and development technologies with "horizontal well + volume fracturing" as the core, and the tight oil production capacity is increasing[8]. At present, the exploration and development of tight oil at home and abroad are focused on the "sweet spot" area, and the multi well flat bench "factory" production mode is widely used. This mode can implement synchronous fracturing or cross fracturing within the control range of multiple wells in the oil-bearing layer, produce more complex fracture network system, greatly increase the volume of oil layer transformation, enhance the production capacity of the reservoir, and improve the initial production. And ultimate recovery [9]. At the same time, it can also reduce the land occupation, shorten the construction period, reduce the project operation cost, and further reduce the production cost through the collection of surface facilities, which is conducive to the economic and effective use of tight oil resources.
2. Geological characteristics of "desserts" area

Drilling revealed that the thickness of channel sand body of FⅡ1 sand formation in "dessert" area of y63 is 2.6-10.0m, which is box shaped on the curve. Reservoir physical properties are good, porosity is generally between 9.0% - 13.5%, median is 11.8%; air permeability is generally distributed between 0.1md-1.5md, median is 0.55md. The main composition of sandstone is feldspar lithic sandstone, and the main mineral composition is quartz, feldspar and lithic. The average content of quartz, orthoclase, plagioclase, cuttings and argillaceous in the reservoir is 24.5%, 26.5%, 4.3%, 33.6%, 7.9% and 0.04mm-0.25mm respectively. The rock particles are fine and siltstone; the grain sorting is medium, the cementation type is pore regeneration film type, and the cementation is medium dense. Rock brittleness can reflect the degree of rock fracture. The mineral composition of the study area is mainly composed of quartz, feldspar, calcite and clay. Through the analysis of rock mineral composition by drilling coring and comprehensive analysis of logging data, the brittleness of tight sandstone reservoir in Fuyu oil layer is mainly controlled by lithology. The higher the content of silty sand is, the higher the brittleness index is. Generally, the brittleness index of argillaceous rock is less than 35%, and that of siltstone is more than 40%. Generally, the sand group with brittleness index more than 40% calculated by rock mechanics logging is proved to have productivity by oil test. The thickness of mudstone interlayer between sandstones varies from several meters to tens of meters. The brittleness condition of the reservoir is good, and the brittleness distribution range is 40% - 60%, which is easy for later fracturing(Fig.1).

Figure 1. Attribute map of maximum trace amplitude

The range of channel sand body is the "sweet spot" of tight oil in this layer. Due to the large thickness and good physical property of channel sand body reservoir, oil layers can be seen in the drilling within the distributary channel. The width of the channel is 500-2500m, and it is distributed in a NE-SW direction. In this paper, the horizontal well deployment area is the channel sand body section from well y63 to well z261. The structure of this well area is open and simple, and the seismic peak amplitude attribute energy is strong and uniform. It is predicted that the channel sand body is
relatively developed. Due to the stable and consistent seismic waveform characteristics of the channel sand body location, it is speculated that the channel sand body changes less laterally and the reservoir heterogeneity is relatively weak, It is beneficial to the platform "factory" design of horizontal wells.

3. Design of platform type "factory" horizontal well
For tight sandstone horizontal wells, in order to ensure the later fracturing effect and improve the production reserves of single well, the horizontal section in the plane distribution direction of the reservoir must match the in-situ stress distribution. In situ stress refers to the internal stress in crustal rocks. In situ stress is an important factor affecting reservoir fracturing. The maximum principal stress direction of the strata in Sanzhao area is between 80° and 90° (Fig. 2), i.e. nearly east-west direction. The maximum principal stress value is generally between 35mpa-40mpa, the minimum principal stress value is generally between 28mpa-34mpa, and the pressure difference is less than 10MPa, which is conducive to the later large-scale volume fracturing and other engineering transformation. According to the characteristics of rock mechanics, when the reservoir is artificially fractured, the artificial fracture is generally distributed along the direction of the maximum principal stress in the absence of natural fracture interference. When the horizontal well trajectory direction is perpendicular to the maximum principal stress, the artificial fracturing fracture extends vertically to both sides of the wellbore, and the sweep area is the largest; when the horizontal well trajectory direction is 45° oblique to the maximum principal stress, the artificial fracturing fracture direction is 45° oblique to the wellbore, and the sweep area is 0.7 times of the vertical sweep area. In short, the smaller the included angle is, the smaller the sweep area of fracturing is. Therefore, in order to increase the swept area of artificial fracture, the design direction of horizontal well trajectory should be perpendicular to the direction of maximum in-situ stress, that is, nearly north-south direction.

![Figure 2. Indicating the maximum horizontal ground stress direction frequencies in Y63 well block](image)

It is difficult to establish an effective displacement system in tight oil reservoir due to the tight sand body and poor reservoir physical properties. In order to expand the swept volume of fracture network system between horizontal wells and realize effective production, it is necessary to determine a
reasonable horizontal well spacing. Under the current large-scale volume fracturing technology, through the microseismic monitoring of four wells zp8, zp12, zp15 and zp20 in Fuyu reservoir of Sanzhao area, it is found that the half length of artificial fracturing fracture in the process of horizontal well fracturing is mainly concentrated in 170-230m. The effective and reasonable horizontal well spacing is 2 times of the half fracture length of artificial fracturing. Therefore, the reasonable horizontal well spacing of Fuyu reservoir in Sanzhao area is 340-460m.

**Figure 3.** Maps indicating horizontal well trajectories in F II 1 sweet spot, Y63 well block

Well y63-z261, the ne channel sand body, is selected as the deployment area of horizontal well design. Well y63 is selected as the reference well for horizontal well design. The thickness of channel sand body is 10.0m, the porosity is 11.5%, and the permeability is 0.63md. For the tight oil "sweet spot" of F II 1 sand group in yuan63 well block, the channel sand body has been predicted by seismic attributes in the previous paper. In order to further implement the plane distribution of "sweet spot" sand body, the geostatistical inversion method is carried out for reservoir prediction. Geostatistical inversion is a more practical method in the area with thin reservoir and fast lateral change [17], The result of inversion prediction is similar to that of seismic attribute prediction. The mutual confirmation of the two prediction methods further confirms the accuracy of seismic prediction of channel sand body. According to the peak maximum amplitude attribute and geostatistical inversion prediction results, the channel sandbody is 8.5km, the channel width is 1.3-2.5km, and the "sweet spot" area of tight oil is 11.3km2. According to the analysis of track direction and well spacing, the optimized track direction is north-south direction, and the well spacing is 340-460m. According to the plane distribution of sand body, the location of stable seismic waveform of track section, large thickness and lateral stability of sand body predicted by inversion section are optimized, and 11 horizontal wells are designed, so that the "sweet spot" sand body of the river can be used as a whole. According to the structural shape of the target formation, the horizontal wells are optimized and combined, and four drilling platforms are designed. The zp22 platform is designed with three horizontal wells, the wellhead is in the north, and the length of horizontal section is 1123-1177m; Two horizontal wells are designed for zp23 platform, the wellhead is in the north, and the length of horizontal section is 1076-1485m; Zp24 platform is designed with 3 horizontal wells, the wellhead is in the south, and the length of horizontal section is 2306-248m; Zp26 platform is designed with 3 horizontal wells, the wellhead is in the north, and the length of horizontal section is 1163-1580m.

**4. Drilling effect**

At present, 6 horizontal wells have been drilled in y63 well block, including 3 wells in zp22 well group, zp23 (East track), zp24 (middle track) and zp26 (middle track). The rest horizontal wells are under drilling, and the length of oil-bearing sand body is 934-1177m, with an average of 1070m. Good drilling results have been obtained, such as well zp22 (middle track), horizontal section length is 1123m, sandstone length is 1123m, and oil-bearing sandstone length is 1090m. Oil immersed siltstone 785m, oil spot siltstone 247m, oil trace siltstone 58m, sandstone drilling rate 100%, reservoir drilling rate 97.1%. Three wells in zp22 well group have been put into operation. The initial oil production of
the pump after fracturing is 4.0-9.6 T/d, compared with the surrounding vertical wells, the productivity is increased by 5-12 times, and good exploration results are obtained. In addition, it can reduce the drilling and fracturing construction period, facilitate the centralized management of multiple wells and reduce the engineering operation cost, which is conducive to the economic and effective use of tight oil resources. Therefore, the deployment mode of platform type "factory" horizontal wells in y63 well block has changed the previous scattered deployment mode of tight oil horizontal wells in Fuyu reservoir of Songliao basin into the integrated and efficient exploration and development mode of platform type "factory" overall deployment and overall production of sweet sand body. The drilling practice in this area has proved the superiority and feasibility of the "sweet spot" sand platform type "factory" horizontal well deployment mode for tight oil.

5. Conclusion
Channel sandbodies control the "sweet spot" area of tight oil. The horizontal distribution of channel sandbodies in Fuyu sand formation is accurately depicted by well seismic combination. The width of channel is 500-2500m, and the channel is distributed in NE-SW direction. The channel sand body is thick, the reservoir physical property is good, the oil is generally contained, and the brittleness distribution range is 40% - 60%. According to the regional in-situ stress analysis and microseismic monitoring results, the optimized trajectory direction is north-south direction, and the well spacing is 340-460m. Combined with the seismic reservoir prediction results, the platform type "factory" design has 4 horizontal well platforms and 11 horizontal wells. At present, 6 horizontal wells have been drilled, and the length of oil-bearing sand body is 934-1177m, which has achieved good drilling effect. Compared with the surrounding vertical wells, the productivity is increased by 5-12 times, which proves the superiority and feasibility of the "sweet spot" sand body platform type "factory" horizontal well deployment mode of tight oil in Fuyu reservoir of Sanzhao area.

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