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New Understanding of Pebbled Sandstone Reservoir Development

Jie Zhong*, **Jing Shen, Yan Xia**

The fourth Oil Production Plant of Huabei Oilfield Branch, PetroChina, Langfang, Hebei, China.

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***Corresponding author:** Jie Zhong, The fourth Oil Production Plant of Huabei Oilfield Branch, PetroChina, Langfang, Hebei, China.

Abstract

The X22 fault block in the study area belongs to a layered fault block structural oil reservoir surrounded by faults and structurally fractured. The main oil bearing series is the Lower Sha si Member of the Shahejie Formation in the Lower Tertiary, which is divided into three oil formations: V, VI, and VII. This reservoir has the characteristics of significant differences in physical properties between horizontal and vertical reservoirs, as well as significant differences in production conditions. The fault block has been explored for more than thirty years. The multiple oil layer extraction has been jointly produced for many years. In recent years, the complex situations due to Multi-layer mining appeared frequently. This article focuses on the new understanding of the development of the VII oil formation in the gravel sandstone reservoir. Starting from the analysis of the remaining oil and oil-water interface, targeted measures are taken to improve the recovery rate of the VII oil formation and achieve the redevelopment of the gravel sandstone reservoir.

Keywords

Conglomerate-bearing sandstone reservoir, oil and gas field exploitation, residual oil

1. Block geological characteristics

The X22 block was put into development in 1985. After four development stages of elastic driving, water injection development, rolling edge expansion, and comprehensive adjustment, the fault block currently has a comprehensive water content of 84.7% and has entered a high water content stage.

The X22 block belongs to a layered structural reservoir and the main oil-bearing formation is lower fourth section of Tertiary System Shahejie group, which can divided intoⅤ, Ⅵ, Ⅶ three oil layers. There are 22 oil-bearing layers in total, the thickness of which is up to 303 m. The oil layers are stable, and all of them are combined formation exploitation in the early stage. At present, after exploring the remaining oil potential of each set of reservoirs, it has been found that there are significant differences in the geological characteristics of each set of reservoirs, and combined layer mining is not conducive to improving the remaining potential between layers. Therefore, each set of reservoirs is studied separately, and the seventh and fourth sub layers are gravel bearing sandstone reservoirs. The following will provide a detailed description of this set of reservoirs.

2. Characteristics of pebbled sandstone reservoir

2.1 Geological feature

The reservoir characteristics of theⅦ4 layers in the lower part of Sha Si are characterized by high electrical resi s-tance. The thickness of high resistance pebbled sandstone is 4-21m, and the grayish brown gravelly sandstone (some with a gravel diameter of 1-6cm) mixed with purple red mudstone has an apparent resistivity value of 45 ohms per meter (0.4 meter potential) in this section.

According to the core physical property analysis data of Wells X22-14 and X22-17, the average porosity and air permeability of Section VII_4 are 17.3% and 159×10-3μm2.The average porosity of oil groups V and VI is 20.1% and the average air permeability is 55.6×10-3μm2.

Table 1. Statistical table of reservoir physical property of X22 fault block

Well	Oil group	Porosity(%)	Permeability($\times 10^{-3}\mu m^2$)		Throat diameter(μm)		Homogenization of pore throat	Threshold pressure(MPa)
			Air	Effective	(>0.1)	(>0.5)		
X22-14	VII_4	17.3	162	130.9	0.88	0.603	7.74	0.03
X22-17	V、VI	20.1	56.3	55.6	0.497	0.329	5.6	0.18

The difference of lithology and physical property is great. The sectionVII4 has better physical properties than the V and VI oil groups. Section VII4 is a medium-porosity and medium-permeability reservoir.

The VII oil formation is composed of four sedimentary time units. The sedimentary microfacies are mainly composed of braided channels and inter channels in braided river delta plain, and the thickness of single sand body is generally about 5m.

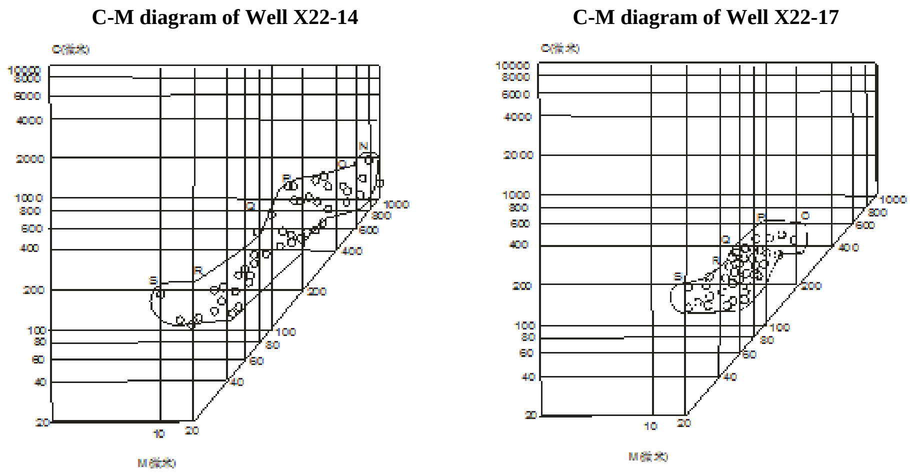

Figure 1. X22 Block C-M Diagram.

From the C-M diagram of Well X22-14, it can be seen that the crude oil in this area has good properties, characterized by low specific gravity, low viscosity, low sulfur content, low gum asphalt, and high solidification point. Ground crude oil density is 0.8178-0.8329g/cm3, an average is 0.8218g/cm3, a viscosity is 2.95-3.88mPa S, a freezing point is 29-33 ℃, a wax content is 14.5-20.6%, sulfur content is 0.067-0.295%, a colloidal asphaltene is 2.3-9.83%, and an initial boiling point is 80-94 ℃.

The underground crude oil density is 0.6989-0.6998 g/cm3, viscosity is 0.6-1mPa·S, and volume coefficient is 1.3215.

3. Mining characteristics

3.1 In the initial stage of production, single well has high yield and long flowing period

The initial production layer of X22 fault block is the layer VII4, pebbly feldspar sandstone, medium porosity and medium permeability reservoir with good physical property. The oil Wells are all spontaneous injection, and the initial production is higher by 30-50 tons. The spontaneous injection period is 13-19 months, and the gas-oil ratio is 60-160 m3/t. Total oil production of 105,300 tons during the water-free period. In just two years after the development, the degree of recovery has reached 28.4%.

3.2 Production variance in infill well pattern

There are six adjustment wells deployed in this reservoir in 1990, mainly concentrated in the central and western parts of the fault block. The well spacing has been reduced from 250 meters to 180 meters, and the controlled reserves of a single well have been adjusted from 87900 tons to 44000 tons. There are significant differences in the initial production situation. The sand bodies in the western region are well developed compared to the central and eastern regions, with a thick sand layer and a production capacity of over 30 tons. There is one self spraying well with a self spraying period of 2 months. The central part is affected by the edge and bottom water, and the production of Well X22-18 is relatively high, with a self spraying period of 3 years. The production of wells X22-19 and X22-21 at the high part of the broken ridge is less than 10 tons, and the sand body of wells X22-40 becomes denser towards the east. After the transformation of natural production capacity and low-pressure fracturing, the production capacity has been effectively improved.

3.3 The yield increased significantly after waterflood development

After water injection development, the improvement of the eastern well network in the early stage of production of the seventh and fourth sub layers was relatively high, with an effective time of 12-102 days and an efficiency of 100%. After the effective period, the average daily increase in liquid was 12.4 tons, and the daily increase in oil was 12.1 tons. The degree of effective increase in oil was relatively high, with a cumulative increase in oil per well exceeding 2000 tons. Due to the influence of physical properties, water injection has a fast effect and good oil increase effect, but the water content increases rapidly. Taking the eastern X22-14 well group as an example, with a daily water injection volume of 140 cubic meters, the corresponding oil well X22-15 has a significant increase in production after being converted to pumping. A larger water injection volume not only brings fast oil well effectiveness, but also a monthly water content increase rate of 8.4%, resulting in rapid water flooding of the oil well.

By analyzing the water flooding situation of the reservoir, it was found that there are multiple and unevenly developed interlayers in the reservoir, with strong heterogeneity within the layer. The fractures within the layer are developed, and the water flooding direction is along the direction of the high permeability layer. For example, the water injection in the seventh and fourth layers of X22-14 well corresponds to the oil wells X22-15 and X22-7, although they are not on the unified mainstream line, their water injection efficiency is still significant. This layer has strong water absorption capacity, resulting in the upper layer not absorbing water or having very little water absorption when combined with the upper layer [1].

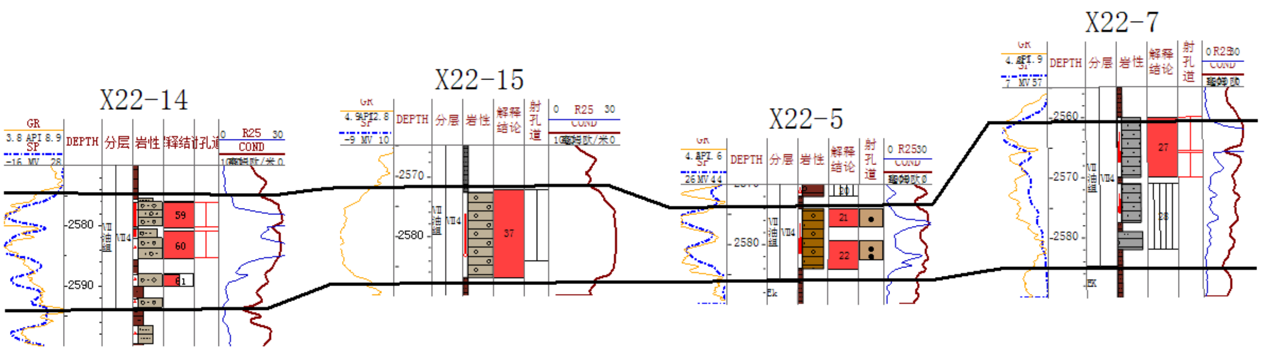

Figure 2. X22-14 Well Cluster Comparison Diagram.

4. Residual potential understanding

As of 2010, the oil production wells producing section VII_4 layers have ceased production due to high production liquid and high water content, and the oil well casing has changed. There are no oil well production VII_4 in the study area. By tracing the production situation during the normal production period; it was found that the reservoir had an oil production capacity of 2-3 tons before both the upstream and shutdown periods. Therefore, the regional potential was reanalyzed.

4.1 Further Understanding of Oil Water Interface

After the refinement and adjustment of the well network, there have been significant changes in the structure, and the original oil-water interface is no longer sufficient to explain the regional oil reservoir situation. Therefore, it is necessary to recognize the oil-water interface in different zones. Firstly, the infill wells in the western region were completed from 1993 to 2003. The original oil-water interface was 2620 meters from Well Jing 22-18, and after the edge low water uplift, the oil-water interface in this area was 2600 meters from Well X22-35. In the central region, only high areas have wells for production. Through production tracking, the oil water interface is 2520 meters due to the uplift of low edge water and the impact of water injection; In 2017, one adjustment well was put into operation in the eastern region, producing the seventh and fourth sub layers. After fracturing, the high yield did not produce water, and the oil-water interface was determined to be at 2625 meters.

4.2 Recognition of recovery potential

From the production process of this layer, it can be concluded that the sand body of the wells in the western region has undergone changes, resulting in low production in the early stages of production and a relatively long effective period after water injection. The later stages are all multi-layer combined production and injection, and due to the influence of interlayer water absorption differences, the injection and production are gradually stopped. Therefore, the recovery rate of wells VII and IV in the western region is relatively low, with an accumulated oil production of 4.1 tons and a recovery rate of 32.1%.

This reservoir has a water body with sufficient energy, and the central region has a recovery rate of 38.8% for the seventh and fourth small layers due to low water energy at the edge. The key to implementing the regional oil-water interface is whether there is a rise in the edge low water level. Through the analysis of the production history of X22-18 well in the central region, the top depth of the oil layer in the well is 2618 meters, located near the oil-water boundary. It is exploited with low water energy near the edge. The daily oil production is 29.1 tons, and the daily water production is 11.1 cubic meters, with a water content of 34.1%. After 3 years of self injection, the well is switched to pumping. Dynamic observation shows that the dynamic liquid level drops from 826 meters to 1202 meters, and the liquid production is reduced from 68.9 cubic meters to 39.5 cubic meters. In 2000, the ash seal VII 4 was returned to production. In 2003, the production of X22-32 well in the high part was low after being put into operation. The decreasing speed is fast. The energy of low water on the edge is a decay process, and a longer shutdown time is beneficial for the reset of oil and water in high areas [2-4].

The eastern region has a long production time and water injection development time, but the area is relatively small, with a cumulative oil production of 64300 tons and a recovery rate of 49.4%. All oil and water wells have stopped production and injection. Based on the analysis of production conditions before the shutdown, the daily oil production of the oil wells producing VII 4 is around 2 tons before returning, so the remaining oil in this oil layer is clearly present [5].

4.3 The exploration of water injection mode

The Wells producing small zoneVII4 were all spontaneous injection after being put into operation. After being transferred to pumping, the injection-production well pattern was relatively perfect and the water flooding control degree was 100%. The reservoir had good physical property and sufficient water energy. Early water injection development was operated at high water injection rates, with a daily water injection rate of 100 cubic meters per day for a single well, resulting in sudden flooding of single layer oil wells. Therefore, this type of reservoir is assisted by water injection and operates with low water injection [6].

5. Evaluation of governance effectiveness

Long stop well in the eastern region for re production of layer VII 4, with stable oil well production capacity and a daily oil increase of 2.8 tons/day; Middle adjustment well fracturing VII 4 small layer with high production and no water observed; There are three adjustment wells in the western region, and two wells have been drilled to the seventh and fourth sub layers, with a depth lower than the position where the oil water interface is further recognized. The logging interpretation reflects a water layer, which is consistent with the research and analysis. It should be confirmed that the remaining oil is accurately recognized and the depth of the oil water interface is reliable [7-8].

6. Brief talk to understanding

Gravel bearing sandstone reservoirs have the natural advantage of good reservoir physical properties. Production wells with high sand body thickness have high production capacity for self spraying, while production wells with relatively poor sand body development can also achieve high production after reservoir transformation, with a stable production capacity of about 10 tons and a decline rate of only 3.7%; After water injection development, areas with well-developed sand bodies should operate at low injection production ratios, while areas with poor sand body development should operate at regional injection production ratios to ensure long-term efficiency and high production; After water flooding occurs in the water injection development of this type of reservoir, due to the large thickness of the oil layer, measures such as internal sealing and re perforation can be taken to prolong the production effect of a single well; Developing development policies based on the development of sand bodies is beneficial for the long-term development of this type of oil reservoir [9-10].

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