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Accumulation Characteristics of Tight Sandstone Oil below Source Rocks and Its Major Controlling Factors: Fuyu Oil Layer in Da'an Area in Songliao Basin, NE China

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1 Introduction

Tight sandstone oil generally refers to the oil accumulated in tight sandstone reservoir rocks, with in-situ permeability less than $0.1 \times 10^{-3} \mu\text{m}^2$ (or surface permeability lower than $1 \times 10^{-3} \mu\text{m}^2$). Under normal conditions, there is no oil natural capacity in the well, or natural capacity is lower than the threshold of industrial capacity. But under special economic and technical conditions, it can reach to the industrial capacity (Jia et al., 2012; Hu, 2013). Tight sandstone oil has become the most realistic highlight field in unconventional hydrocarbon exploration and development in the world (Pollastro R M et al., 2008; Zou et al., 2012). Many petroliferous basins of china have favourable geological conditions for the occurring of tight sandstone oil. And it shows a great resource potential (Zou et al., 2013). However, the research results mainly focus on tight sandstone gas in the world, including hydrocarbon accumulation conditions, hydrocarbon accumulation pattern and distribution characteristics (Holditch S A, 2006). There are few studies on tight sandstone oil, and there is scope to go much further. Da'an area is located in low slope in the southern Da'an sag of Songliao basin, NE China. Fuyu oil layer is the fourth section of Lower Cretaceous Quantou Formation. The major reservoir sandbody of Fuyu oil layer is the channel sandbody. It is distributed widespread from NW to SE, and Its porosity and permeability are generally low (most of the porosity less than 10%, most of the permeability less than $1 \times 10^{-3} \mu\text{m}^2$), which can be ascribed into three reasons: First, the deep burial depth; Second, the very strong diagenesis of rocks; Third, the high shale content and plastic debris content in sandstone.

Exploration practice shows that Fuyu oil layer of Da'an area is rich in oil resources (Sun et al., 2009). However, the tight sandstone oil accumulation and distribution controlling factors are still unclear.

2 Accumulation Characteristics of Tight Sandstone Oil in Fuyu Oil Layer

2.1 Sandstone reservoir rocks and Source-reservoir combination

The porosity range is from 1.1% to 13.5% in Fuyu oil layer (Fig. 1), with an average porosity value of 7.27%. The porosity mainly distribute between 4% and 10%. The permeability varies from $0.01 \times 10^{-3} \mu\text{m}^2$ to $16.00 \times 10^{-3} \mu\text{m}^2$ (Fig. 2), and averaged at $0.25 \times 10^{-3} \mu\text{m}^2$. The permeability mainly distribute between $0.01 \times 10^{-3} \mu\text{m}^2$ and $0.3 \times 10^{-3} \mu\text{m}^2$. According to the standard of reservoir rocks classification in China Petroleum industry (SY/T6285-1997), the reservoir rocks of the Fuyu oil layer is ultra-low porosity and ultra-low permeability or tight sandstone reservoir rocks.

Oil and source rocks correlation show that tight sandstone oil in Fuyu oil layer was from the first section of Lower Cretaceous Qingshankou Formation, which was above the Fuyu oil layer (Zou et al., 2005). They constituted the source-reservoir combination which was the typical style of upper source rocks and lower reservoir rocks. And it can be further classified as superimposed source-reservoir combination and conterminous source-reservoir combination (Fig. 3). Superimposed source-reservoir combination is improved by means of close contact with the reservoir rocks at the top of Fuyu oil layer and source rocks of Qingshankou Formation. The reservoir rocks at the lower of Fuyu oil layer was not

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directly exposed to source rocks, and conterminous source-reservoir combination was formed under the condition of fault connectivity.

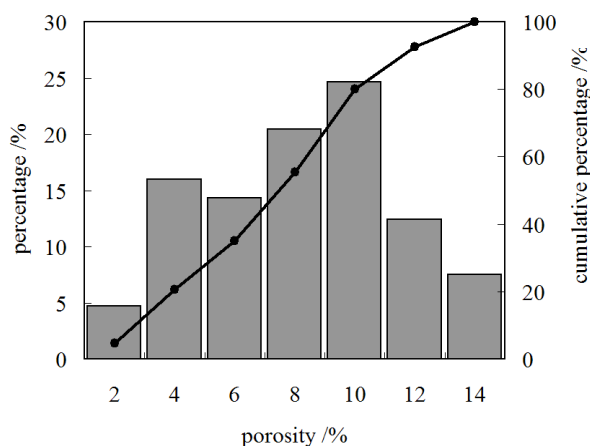


Fig. 1. Distribution of routine porosity values from tight sandstone of Fuyu oil layer in Da'an area.

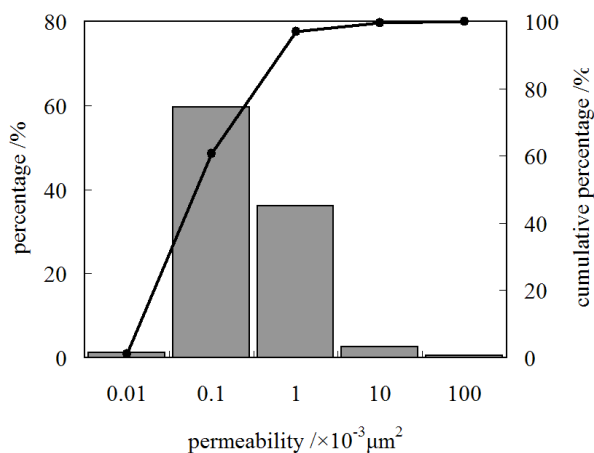


Fig. 2. Distribution of routine permeability values from tight sandstone of Fuyu oil layer in Da'an area.

2.2 Hydrocarbon Accumulation Dynamics

Movable water is rarely in tight sandstone, which lead to a small effect of buoyancy and hydrodynamics. Therefore, the buoyancy and hydrodynamics are not hydrocarbon accumulation dynamics. The overpressure generated by the hydrocarbon generation of source rocks in the Qingshankou Formation is mainly hydrocarbon accumulation dynamics. The overpressure value in Da'an area is from 12 MPa to 25MPa at the end of the Mingshui formation (Chi et al., 2000). The entry pressure of Fuyu oil layer varies from 0.38 MPa to 20.0 MPa (Fig. 4) and its value mainly distribute between 0.38 MPa and 3.63 MPa, which is about 82%. Therefore, the entry pressure is much

less than the overpressure. This shows that the overpressure generated by the hydrocarbon generation can promote the oil entering into the tight sandstone and migrate.

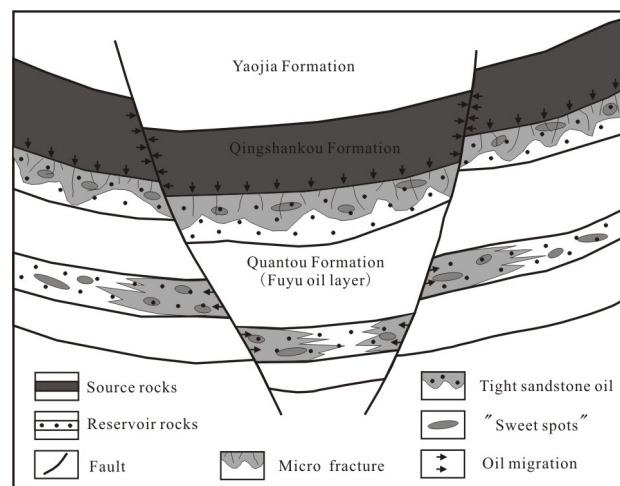


Fig. 3. Source-reservoir combination of tight sandstone oil in Da'an area.

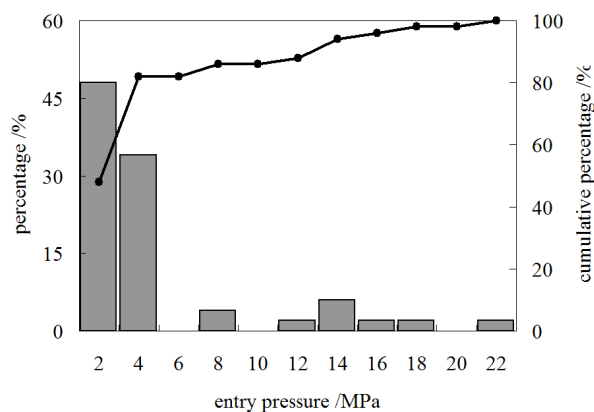


Fig. 4. Distribution of entry pressure values from tight sandstone of Fuyu oil layer in Da'an area.

2.3 Oil Migration Distance and Oil-water Differentiation

The distribution characteristics of formation water salinity in Fuyu oil layer is seen in Fig. 5. The salinity increases gradually from southeast to northwest. Within a short distance of 5km, the salinity has jumped from 10000 mg/L to 40000 mg/L, which indicated that fluid exchange interaction in tight sandstone was weak and oil migration distance was short. Oil production testing of 30 single layers in 20 wells shows that the results of 20 single layers are both oil and water. It accounted for 66.7% of the total number of layers. This indicates that the oil-water

differentiation was weak.

2.4 Boundary of the Trap (or Reservoir) and Oil-water Interface

The distribution of oil wells have been drilled is seen in Fig. 6. The reservoir has no obvious boundary and no uniform oil-water interface. And there are many oil-water interface and pressure system. In the plane, the oil distribution is continuous, all wells tested oil production testing (hydraulic fracturing) can produce oil, but the output of oil is very different. In the vertical, oil distribution is superimposed multi-layer, and the height of layer has little effect on oiliness, even all the layers of the whole well contains continuous oil.

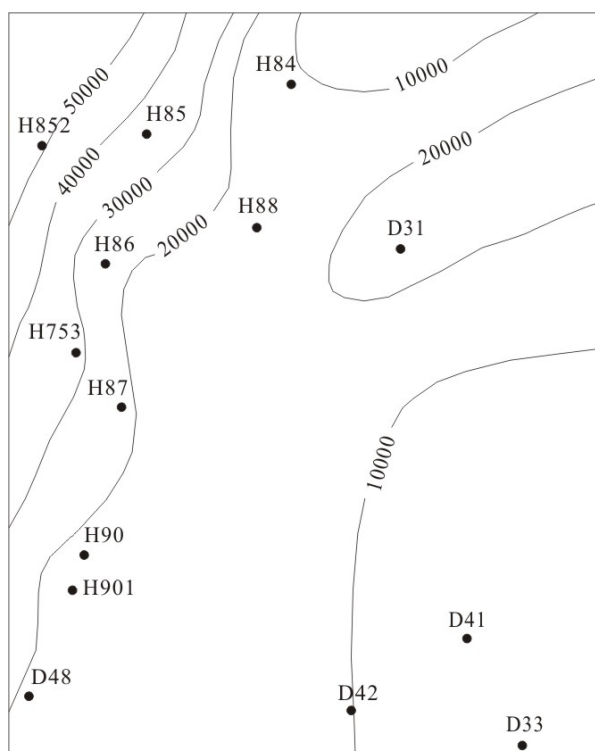


Fig. 5. Distribution of formation water salinity values from Fuyu oil layer of Da'an area.

3 Main Controlling Factors of Tight Sandstone Oil below Source Rocks

3.1 Type of Source-reservoir Combination

Fig. 3 show that superimposed source-reservoir combination involved a direct contact between source rocks and reservoir rocks. Oil generated from source rocks migrated directly into the reservoir rocks along micro fracture and discursive filled. A “continuous” petroleum reservoir was formed. The hydrocarbon accumulation was continuous carried out. Therefore, hydrocarbon charging time is relatively long, and the oil saturation is higher. The

reservoir rocks at the lower of Fuyu oil layer was not directly contact to source rocks in conterminous source-reservoir combination. Oil generated from source rocks migrated into the reservoir rocks under the condition of fault connectivity and filled into multiple tight sandstone. Then, the oil is laterally pushed along the reservoir rocks. An “oil-water inversion” petroleum reservoir was formed. The hydrocarbon accumulation was controlled by fault activity period and was episodic carried out. Forming period of tight sandstone oil was mainly in the end of Cretaceous Nenjiang Formation and Mingshui formation.

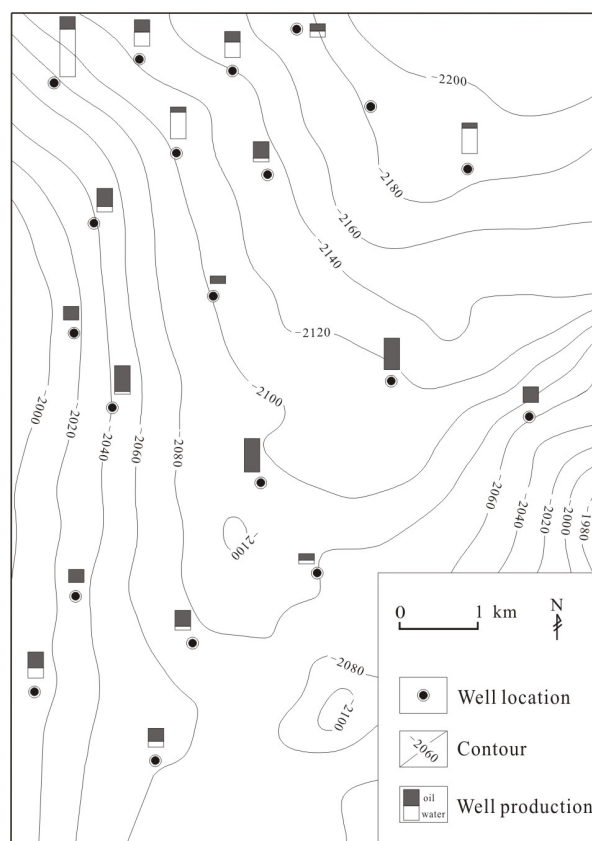


Fig. 6. Distribution of oil wells have been drilled of Fuyu oil layer in Da'an area.

3.2 Pressure Differences between Source Rocks and Reservoir Rocks

The overpressure generated by the hydrocarbon generation is mainly accumulation dynamics of tight sandstone oil. The precondition of filling the oil into the reservoir rocks is that the overpressure is higher than the entry pressure of the reservoir rocks. Namely a pressure difference between source rocks and reservoir rocks was greater than zero. Under the same accumulation dynamics, the oil will give priority to fill into reservoir rocks with relatively small the entry pressure. When the entry pressure of reservoir rocks is more than the hydrocarbon

accumulation dynamics, the oil can not be filled into the reservoir rocks. Due to heterogeneity of the overpressure and the entry pressure, it leads to the differences of oil migration range and distribution layers.

3.3 The Distribution of Tight Channel Sandbody

Fig. 7 show that Effective reservoir rocks of Fuyu oil layers in Da'an area is almost entirely channel sandbody. So the distribution of tight sandstone oil is controlled by the distribution characteristics of the channel sandbody. The boundary of channel sandbody is the outer boundary of tight sandstone oil. The heterogeneity of tight sandstone oil is controlled by channel monosandbody and the relationship of multiple channel monosandbodies.

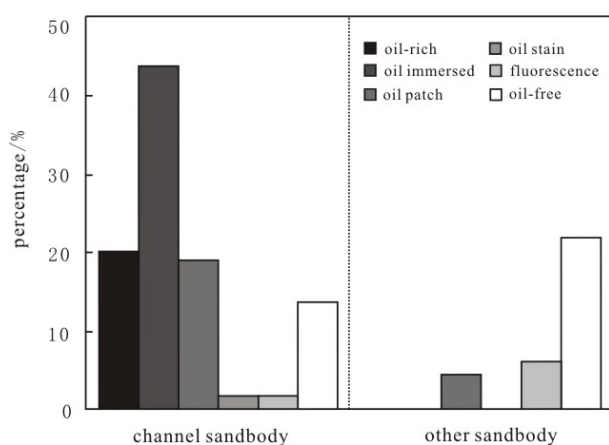


Fig. 7. Comparison of oil bearing grade between channel sandbody and other sandbody.

4 Conclusions

This article is mainly describe the below two issues.

There are six major accumulation characteristics about tight sandstone oil in Fuyu oil layer: the first, tight sandstone reservoir rocks under the source rocks; Second, the overpressure accumulation; Third, short oil migration distance and weak oil-water differentiation; Fourth, no obvious reservoir boundary and no uniform oil-water interface.

Type of source-reservoir combination, pressure differences between source rocks and reservoir rocks, the

distribution of tight channel sandbody are major controlling factors of tight sandstone oil below source rocks.

Acknowledgements

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