

Hydrocarbon accumulation model of Fuyu Oil layer in 401 block, Sanzhao Depression, Songliao Basin

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Abstract

This paper takes Sanzhao Depression in Songliao Basin as the research target, analyzes the hydrocarbon accumulation process of Fuyu oil layer. This paper proposes: 1.The oil accumulation of Fuyu oil layer was under the control of tectonic evolution. Oil migration and accumulation can be divided into two periods: End of Nenjiang Formation sedimentary period and End of Mingshui Formation sedimentary period. 2.There are three accumulation models of Fuyu oil layer : Horst Model, Stair Model and Graben Model.

Keywords

Songliao Basin; Sanzhao Depression; Fuyu oil layer; accumulation model.

1. Introduction

Songliao Basin is one of the oil & gas richest continental sedimentary basins all around the world. The exploration of Fuyu Reservoir in Sanzhao Depression was initiated in 1962. The first exploratory well Zhao 1 was drilled down to Fuyu Formation in 1962 and oil shows appeared, but no oil reservoir was interpreted. From then the exploration of Fuyu oil layer was essentially begun. The first pilot well Fang 16 was drilled and completed in 1978 in this area and test was performed from 956.4 m to 1959.6 m in Fuyu oil layer. Daily oil production was 1.81 tons and daily water production was 0.12 m³ with gas lift. It was identified as industrial oil flow with water production.

After years of exploration, people has achieved certain understanding about the reservoir forming mechanism and oil distribution of Fuyu oil layer in Sanzhao Depression. It is a system of generational seal in above and accumulation in below. The main hydrocarbon source rock is in the 1st member of Qingshankou formation and over-pressurized oil migrated down to Fuyu Formation below through the opened faults [1]. The source rock of the 1st member of Qingshankou formation entered oil window at later period of the 2nd member of Nenjiang formation was sedimenting and Ro value of the 1st member of Qingshankou formation in Sanzhao Depression generally exceeded 0.5% at end of Nenjiang Formation sedimentary period, which indicated the peak of oil generation. The thermal maturity of organic in hydrocarbon source rocks continued to grow from late Nenjiang sedimentary period to late Mingshui sedimentary period [2]. The main expulsion stages of the source rock in Qingshankou Formation is the over-pressured releasing period after the hydrocarbon generation threshold was achieved. The over-pressured release took place once in late Nenjiang deposition and once during later Mingshui deposition [3].

This paper deeply investigated the hydrocarbon accumulation process in Fuyu oil layer. The study provides strong supports and directions for future exploration of Fuyu oil layer.

2. Geological setting

Sanzhao Depression is located in the northern part of Songliao Basin. It's a secondary tectonic units of central depression, B401 block located in southern part of Zhaozhou nose structure in Sanzhao Depression. It,s the main oil and gas enrichment zone, with area about 82km² (Fig. 1).

The target layer is in 4th member of Quantou formation in lower Cretaceous. The lower Cretaceous is composed of Huoshiling, Shahezi, Yingcheng, Denglouku and Quantou Formations in the study area, while the upper Cretaceous is composed of Qingshankou, Yaojia, Nenjiang, Sifangtai and Mingshui Formations.

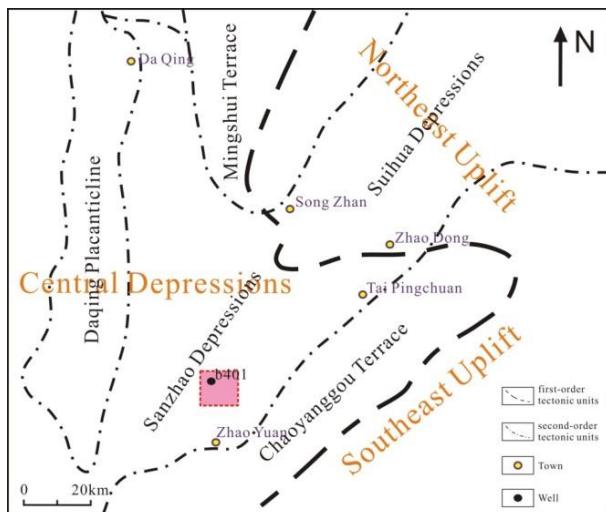


Fig. 1 Geographic location of the study area

3. Accumulation Model

The accumulation model in study area is dominated by the combination of pressure difference and potential difference. The overpressure from the 1st member of Qingshankou formation pushed the petroleum moved vertically to Fuyu oil layer through open faults, and the different potential in the reservoir pushed the petroleum move horizontally and accumulate in the reservoir [4].

3.1 Transport System

The oil transport system includes the vertical transporting through open faults and lateral transporting through sand bodies within the reservoir.

Vertical Transporting (Primary Migration)

The faults near T2 was reopened as a vertical transporting pathway because of the crack of overpressure box at the end of Nenjiang Formation sedimentary period and the reverse tectonic movement occurred at the end of Mingshui Formation sedimentary period. Meanwhile the source rock in Qingshankou 1st was mature enough to generate and expulse hydrocarbon. The synchronization of these accumulation events is the key to form this "Downward flow" migration model.

Lateral Transporting (Secondary Migration)

Compared with the source rock, the reservoir can be used as the main lateral transporting path because of its larger aperture, larger pore space, lower fluid pressure, lower stratum temperature and weaker adsorption power. For the study area, oil migrated laterally from higher potential zone to lower potential zone through sand bodies within the reservoir.

3.2 Migration and Accumulation

Fuyu oil layer takes the source rock of the 1st member of Qingshankou formation as its petroleum source. Its rule of oil migration and accumulation performs as a combination of "upper generate-lower accumulate" and "sideward migration and accumulation"[5].

Source rock of the 1st member of Qingshankou formation started generating hydrocarbon when Nenjiang group was depositing, and reached peak when the 1st member of Mingshui formation was depositing. It started expulsing hydrocarbon at the end of Nenjiang formation was depositing, and expulsing hydrocarbon massively at the end of Mingshui formation was depositing [6] (Fig. 2). Oil migration and accumulation can be divided into two periods: End of Nenjiang Formation sedimentary period and End of Mingshui Formation sedimentary period.

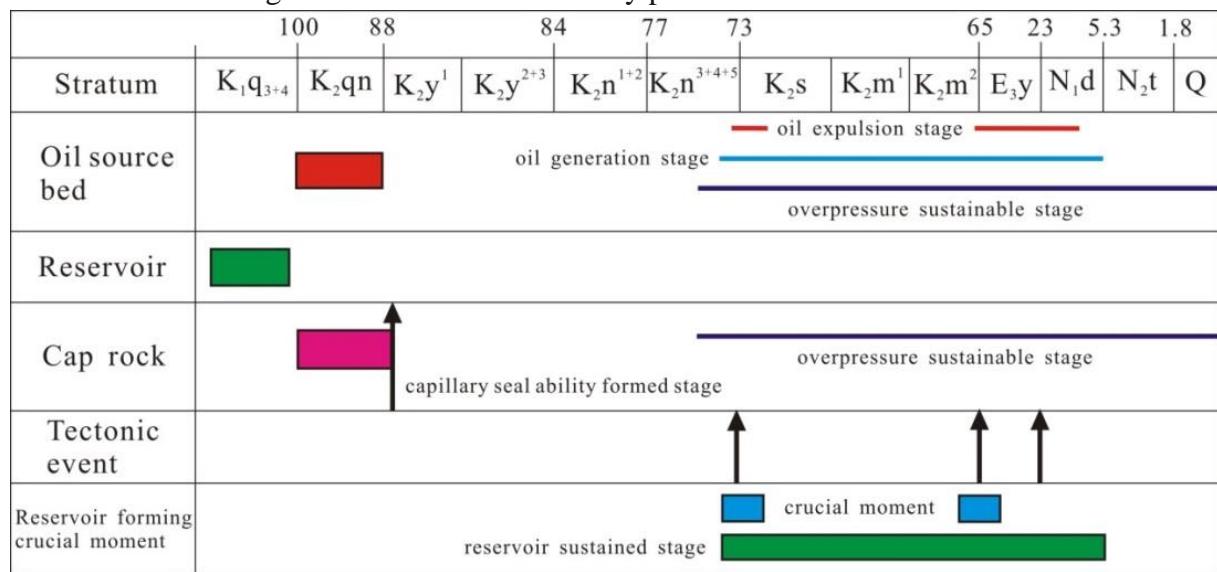


Fig. 2 Accumulation events

End of Nenjiang Formation sedimentary period

The overpressure box which formed in Qingshankou Formation sedimentary period, was cracked due to volume shrinking at the end of Nenjiang Formation sedimentary period. The crack leads to T₂ faults opened in a certain way with short extension. These faults were opened too narrow to connect the source rock of the 1st member of Qingshankou formation and overlying Putaohua oil layer at this time, thus cannot be used as a path for oil migrating upward [7]. So the contribution to Putaohua oil layer reservoir forming is very limited.

For Fuyu oil layer, the hydrocarbon source rock of the 1st member of Qingshankou formation is very close, which is just on top of it. The opening distance of these faults is short but a function bridge between hydrocarbon source rock and Fuyu oil layer. As it's difficult for fluid to migrate upward, so the only way to release overpressure is migrates downward to Fuyu oil layer, which provided a perfect condition for oil "migrate downward". Oil will migrate and accumulate to heading wall priority and form lithologic-structural traps, then migrate to hanging wall and form structural -lithologic traps (Fig. 3).

End of Mingshui Formation sedimentary period

Another overpressure forming time in Sanzhao Depression is when Mingshui formation was depositing. The source rock of the 1st member of Qingshankou formation approached the peak of hydrocarbon generation and massive of oil was generated. The overpressure released at the end of Mingshui group. Under the background of intense tectonic reverse movement, T2 and T1-1 faults selectively reopened which becomes a bridge among source rock of the 1st member of Qingshankou formation, Fuyu oil layer and Putaohua oil layer.

For Putaohua oil layer, oil can migrate upward from source rock into overlying Putaohua oil layer to accumulate through reopened faults.

As for Fuyu oil layer, oil migrated under the force of overpressure through reopened faults to Fuyu oil layer, then migrated sideward through sandstone and accumulated in reservoir. The important point is that the faults which became the path for oil migrating downward to Fuyu oil layer should be opened in small scale (only connect source rock and underlying Fuyu oil layer, but not connect with overlying Putaohua oil layer) at this time. On the other side, the large scale opened faults which

extended to Putaohua oil layer lead oil in Fuyu oil layer migrating upward to Putaohua oil layer and shows certain damage to Fuyu oil layer (Fig. 4).

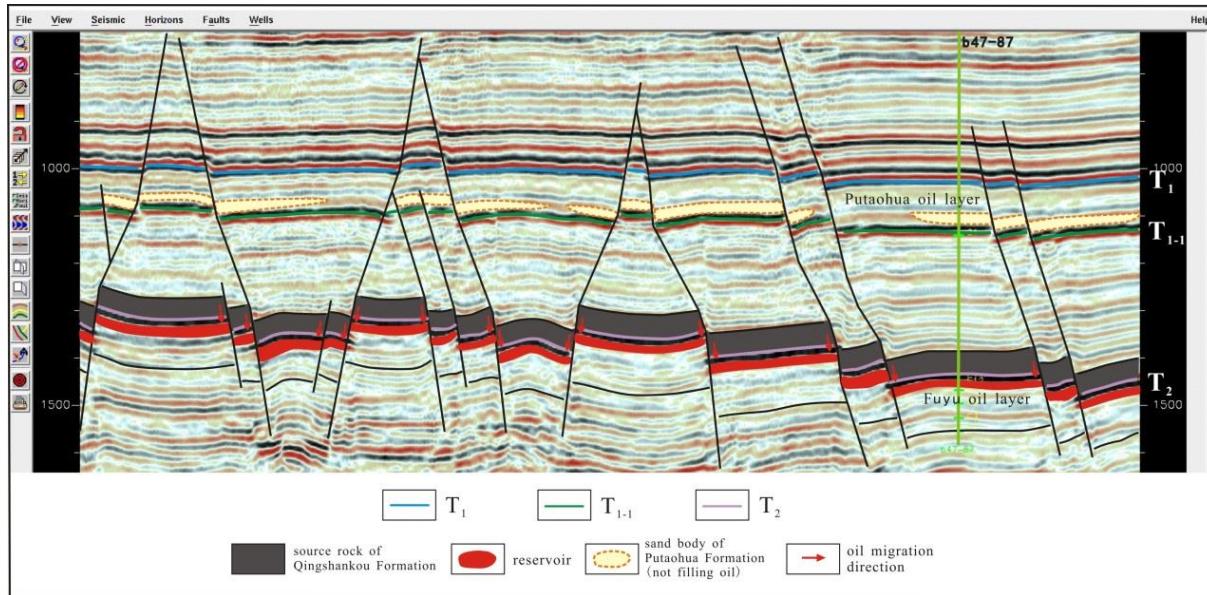


Fig. 3 Oil migration and accumulation of Fuyu oil layer
(End of Nenjiang Formation sedimentary period)

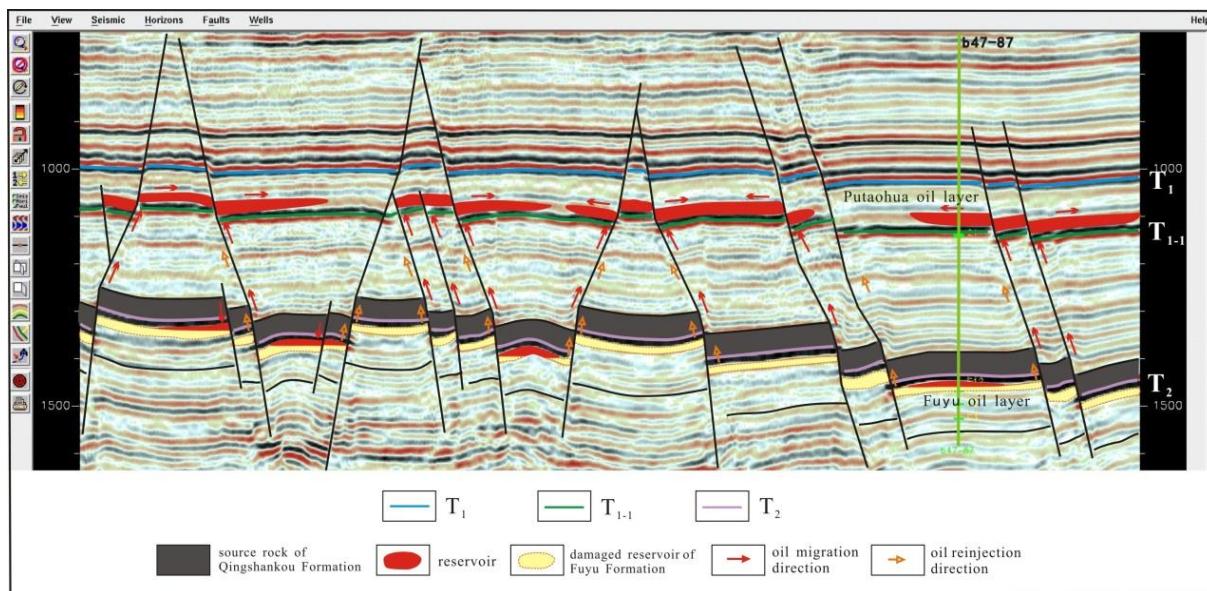


Fig. 4 Oil migration and accumulation of Fuyu oil layer
(End of Mingshui Formation sedimentary period)

3.3 Accumulation Model

Three accumulation models were established after the analysis of the exploration wells and the rule of oil migration and accumulation (Fig. 5). These three models are: a.Horst Model, b.Stair Model, and c.Grabon Model.

(1)a. Horst Model: Reservoir locates at the high block. This location is the closest one to overlying source rock of the 1st member of Qingshankou formation and has minimum distance for "Downward-flow" which is helpful to hydrocarbon forming. The trapping system can be structural trap or lithologic-structural trap (Fig. 6a).

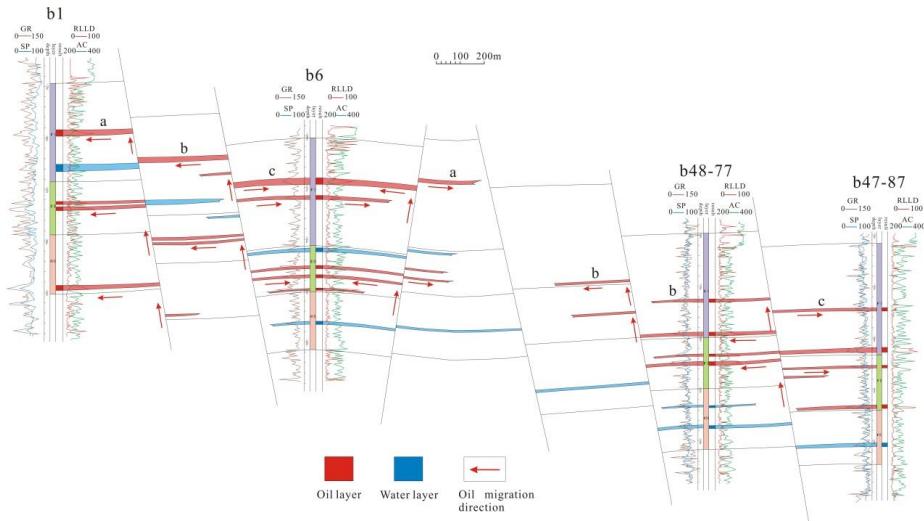


Fig. 5 Oil reservoir profile(b1~b6~b48-77~b47-87)

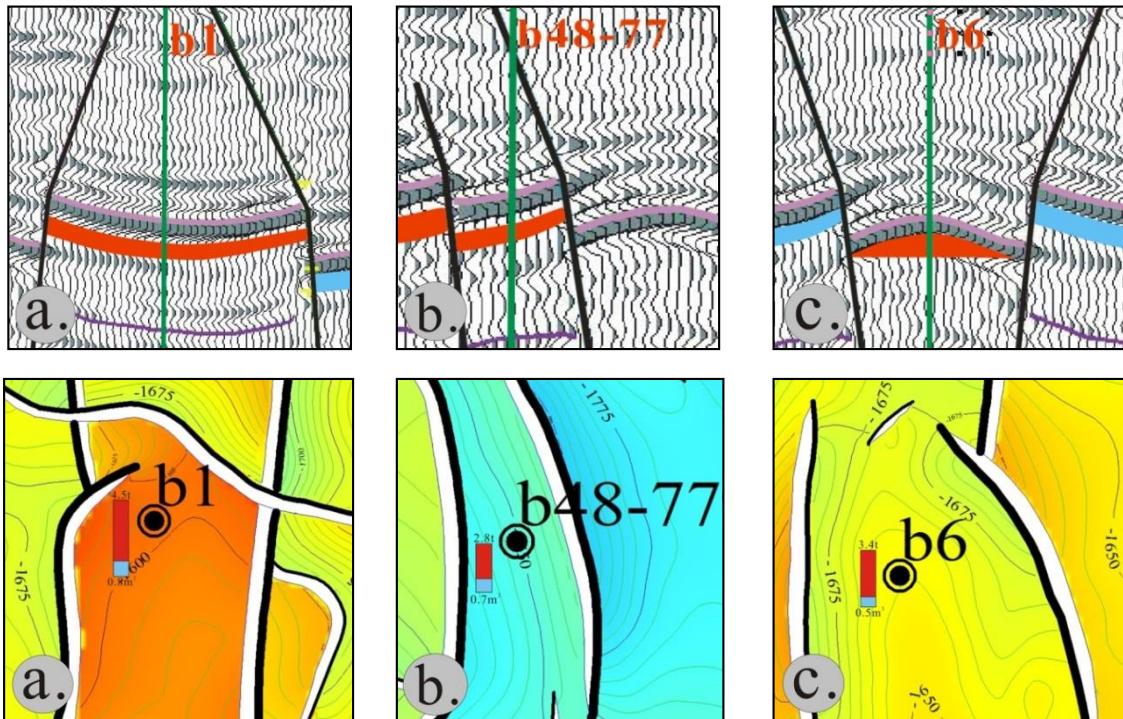


Figure 6 Reservoir-forming Model

a. Horst Model b. Stair Model c. Graben Model

(2)b. Stair Model: The reservoir location is usually tilted in a stair shaped fault block between horst and graben. The trapping system can be structural trap or structural-lithological trap (Fig. 6b).

(3)c. Graben Model: The reservoir locates in the graben where the stratum uplifts in the middle and dip down at the edge. The typical method of “uplift in graben” keeps oil and gas accumulating at the center top even in a lower level stratum. The trapping system is structural trap (Fig. 6c).

4. Conclusion

1. The oil accumulation of Fuyu oil layer was under the control of tectonic evolution. Oil migration and accumulation can be divided into two periods: End of Nenjiang Formation sedimentary period and End of Mingshui Formation sedimentary period. End of Nenjiang Formation sedimentary period: Huge overpressure forced the faults nearby T₂ axis to open, but the opening distance was small in vertical direction. It formed a path for hydrocarbon to migrate from the 1st member of Qingshankou

formation downward to nearby Fuyu Oil layer but contributed nothing to far distance Putaohua Oil layer. End of Mingshui Formation sedimentary period: The peak of hydrocarbon generation in the 1st member of Qingshankou formation occurred during this period and the oil was released due to the huge overpressure. Meanwhile T₂ and T₁₋₁ faults were reopened by the intensive tectonic reverse movement. The small scale reopened faults are favorable to the accumulation of Fuyu oil layer, but the large scale reopened faults which extended to Putaohua oil layer shows certain damage to Fuyu oil layer.

2. Three accumulation models were established: Horst Model, Stair Model and Graben Model.

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