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Control function of Sedimentary Facies on Tight Oil Distribution—Taking Gaotaizi Oil Layer in Qijia Area as An Example

To cite this article: Haiyan Wang and Hui Jin 2019 *IOP Conf. Ser.: Mater. Sci. Eng.* **585** 012029

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Control function of Sedimentary Facies on Tight Oil Distribution—Taking Gaotaizi Oil Layer in Qijia Area as An Example

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Abstract. In order to find out the controlling factors of tight oil distribution in Gaotaizi oil layer, Qijia area, the authors consider that the sediment facies is shallow delta in G3-G4 oil layer through the fine study of sedimentary characteristics, and develops delta plain, delta front and prodelta subfacies from north to south. Multiple and small scale transgressions during with the base level falling cause the multistage superposition between delta outer front with prodelta mud, and the terminal of delta inner front with the mud of delta outer front, which provide the premise of source and storage match for inner source tight oil. Then, the authors analyze the control action of sediment facies on tight reservoir, high quality oil layers and the matching relationship between them, and point that there exist two kinds of tight oil reservoir in Qijia area, tight reservoir of distal bar in the rear of delta inner front, tight reservoir of sheet sand in delta outer front. By comparing the superiority of the three conditions, the former is better in reservoir condition, hydrocarbon source rock condition and source storage matching, which is the most important tight oil reservoir type. Finally, it is pointed out the tight reservoir of distal bar in rear of delta outer front is the most favorable microfacies in the next tight oil exploration in southern Qijia area.

1. Introduction

At present, tight oil has become a new bright spot in global unconventional oil exploration. Most of the world has found tight oil resources, especially in North America, which has a tight oil resource of about 10 billion tons and is the largest area in the world. Global oil production is expected to increase by 16.1 million barrels per day by 2030, nearly half of which comes from tight oil [1, 2]. China is also rich in tight oil resources. It has been proved that its prospective resources are $(70-90) \times 10^8$ t, which are mainly distributed in Songliao, Ordos and Sichuan Basin [3-6]. Great breakthroughs have been made in tight oil exploration in Songliao Basin in recent years. The potential of 100 million tons of tight oil resources has been found in Fuyu reservoir in Daqing placanticline and Gaotaizi reservoir in Qijia area. Especially in Gaotaizi reservoir in Qijia area, the potential of tight oil resources is huge, but the current exploration and development and related research are still in the preparatory stage. Relevant literatures mostly discuss the formation conditions of tight oil; seldom study the distribution law of tight oil from the aspect of sedimentary facies. In fact, sedimentary facies not only affect the lithology and physical properties of reservoirs, but also control the distribution of tight oil sources. It is very important for predicting favorable areas of tight oil and guiding the next exploration.



2. Sedimentary Facies Characteristics

By making full use of core observation, seismic, drilling, logging and geological and geochemical data, the sedimentary facies types of Gao 3 and Gao 4 reservoirs in Qijia area are shallow water delta facies, including delta plain, delta front and front delta, among which delta front can be further subdivided into inner front and outer front. Each subfacies microfacies have its own characteristics in lithology, rhythm, sedimentary structure and electricity.

During the sedimentary period of Gao 3 and Gao 4 reservoirs, influenced by tectonic movement, the surrounding basin was continuously uplifted and the lake area shrank. A set of shallow water delta facies deposits were deposited in Qijia area. The north-south sedimentary profile clearly reveals the vertical evolution characteristics of Gaotaizi reservoir: controlled by the northern provenance, Delta plain, delta front and front delta subfacies are developed from north to south in Qijia area. From the bottom to the top, along with the gradual decline of the sedimentary base level, the delta front advances southward gradually, and the sedimentary range of the front subfacies expands gradually (fig.1).

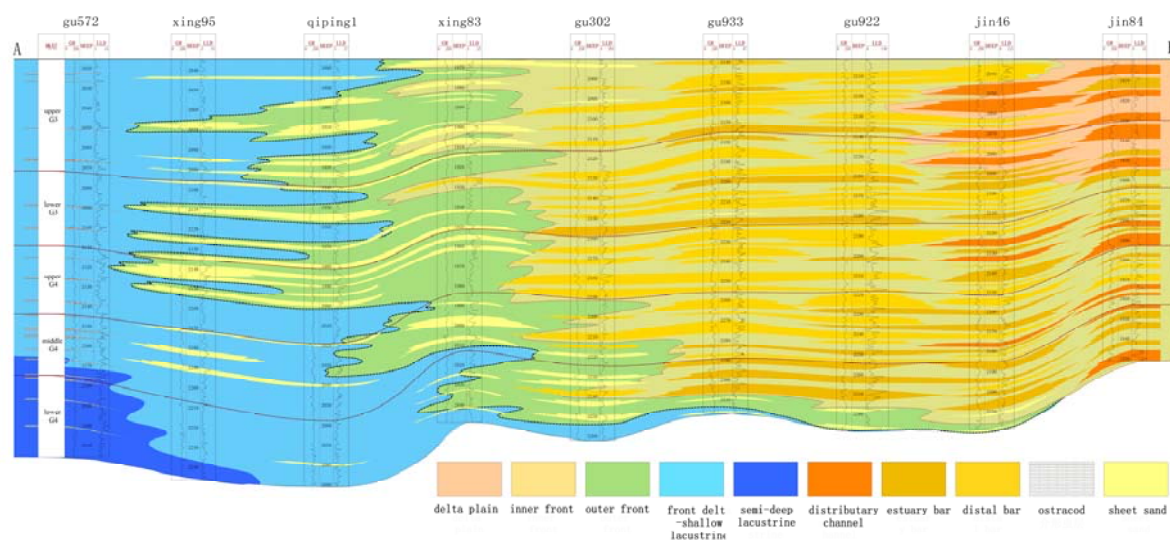


Figure 1. Profile of sedimentary facies in G3-G4 oil layers of Qijia area

3. Tight Oil Characteristics

The mechanisms of tight reservoir formation and exploration practice have proved that tight reservoir is different from conventional reservoir in oil-water relationship. The physical properties of conventional reservoir are better. The fluid flow pattern follows Darcy's percolation law, and the reservoir is generally water-bearing. The tight reservoir is characterized by non-Darcy's law because of its compactness and non-Darcy's law of fluid flow, and the reservoir is characterized by pure oil. In order to clarify the distribution characteristics of tight oil in Qijia area, the oil-water distribution laws of all wells in Gao 3 and Gao 4 reservoir groups in Qijia area are counted, and the distribution characteristics of tight oil are preliminarily found out: the oil-water relationship in northern Qijia area is complex, the reservoir is generally water-bearing, belonging to the conventional oil development area; the oil-water relationship in southern Qijia area is relatively simple, Pure oil layer and dry layer are developed, belong to tight oil development area. Based on the analysis of sedimentary facies, the distribution of different types of reservoirs is in good agreement with different sedimentary microfacies: conventional reservoirs are mainly developed in the distributary channel and estuary bar microfacies in northern Qijia; compact reservoirs are mostly developed in the distal bar and sheet sand microfacies in southern Qijia. The author will analyze the three conditions of the formation of tight oil and find out the relevant reasons for the formation of this coincidence (fig.2).

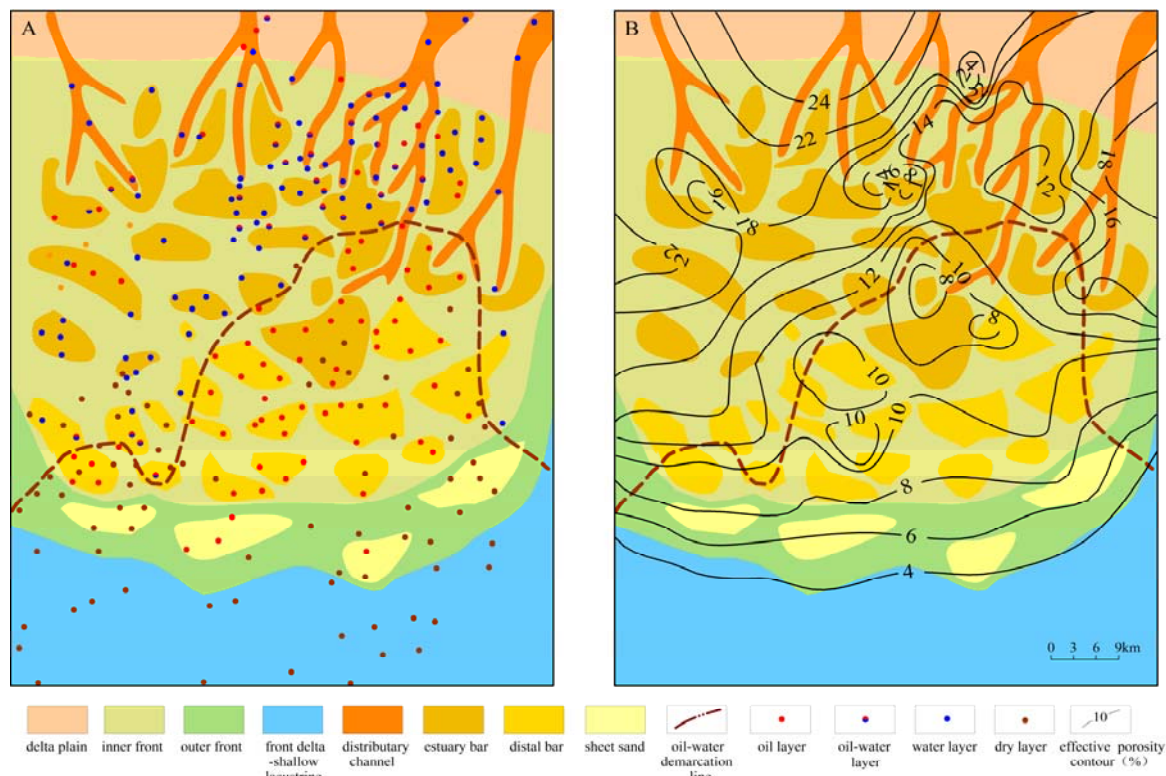


Figure 2. Superposition map of sedimentary facies with oil and water distribution and sedimentary facies with effective porosity (%) in G3-G4 oil layers of Qijia area

Physical property is an important index for evaluating tight oil grade. Based on the comprehensive analysis of core seepage test, reservoir physical property, oil-bearing occurrence and fracturing test results of Gaotaizi Formation in Gao 3 and Gao 4, the upper and lower limits of tight oil reservoirs in Gaotaizi Source in Qijia Area are defined, and the pore distribution range of tight reservoirs in Gaotaizi Formation is determined to be 4%~12%. The permeability is 0.02-1 mD. Among them, porosity is 8%~12%, permeability is 0.05~1 mD, oil-bearing occurrence is mainly oil spot and oil immersion. The pore throat radius of this kind of reservoir is larger, fluidity is better, oil testing is easy to reach industry; porosity is 4%~8%, permeability is 0.02~0.05 mD, oil-bearing occurrence is mainly oil trace and oil spot, and pore throat radius of this kind of reservoir is easy to reach industry. Small, poor fluidity, oil testing is difficult to reach industry. Therefore, the reservoirs with porosity of 8%~12% and permeability of 0.05~1 mD are divided into better compact reservoirs. The reservoirs with porosity of 4%~8% and permeability of 0.02~0.05 mD are divided into poorer compact reservoirs.

There are obvious differences in reservoir conditions of different sedimentary microfacies. Inner front distributary channel and estuary bar microfacies: lithology is mainly fine and siltstone, the thickness of single sand body is generally 2-5 m. Sand body is developed vertically with high concentration and large scale in plane. Especially along the direction of provenance, it can extend more than ten or even dozens km. Reservoir physical properties are good, porosity is generally > 12%, permeability is generally > 1 mD. It belongs to conventional reservoir. Distal bar in the rear of inner front: siltstone is the main lithology, and the thickness of single sand body is generally 0.5~2 m. Sand body is overlapped in vertical layers, with good vertical concentration and wide plane distribution. Sand body extends from several kilometers to more than ten kilometers, with good physical properties and porosity of 8%~12%. Therefore, there are two kinds of microfacies in Qijia area which can be used as tight reservoirs: distal bar and sheet sand, distal bar reservoir conditions are obviously better than sheet sand.

4. Tight Reservoir Types and Prediction of Favorable Areas

It can be seen from the above that there are roughly two kinds of tight reservoirs in Gaotaizi reservoir in Qijia area: distal bar and sheet sand. There are three kinds of tight oil source rocks: inner front subfacies mudstone, the rear of inner front and outer front mudstone, and front Delta mudstone. From inner front to front delta, the condition of hydrocarbon source rocks is getting better gradually. Different matching relationships between tight reservoirs and oil-generating reservoirs form two kinds of tight reservoirs in Gaotaizi reservoir of Qijia area. Outer front sheet sand tight reservoir: outer front source rock condition is good, and it is superimposed with high-quality source rock of the front Delta for many periods. Source-reservoir matches well. But because of thin sheet sand reservoir and general deviation of physical property, drilling also proves that the sand body is generally characterized by dry layer, only the local physical condition is good, and there are many sets of sheet sand stacks. It can become a compact reservoir with exploration value. Distal bar tight reservoir in the rear of inner front: large reservoir scale, good physical properties, good hydrocarbon generation conditions of mudstone in the rear of inner front, and multi-stage superimposed distribution of oil generating reservoir in the rear of outer front. Source-reservoir matching is good. At present, most of the tight reservoirs are found in the distal bar. In contrast, distal bar tight reservoir in the rear of inner front is the most developed and most valuable tight reservoir in the area. Distal bar microfacies are the most favorable microfacies for the next step of tight oil exploration (fig.3).

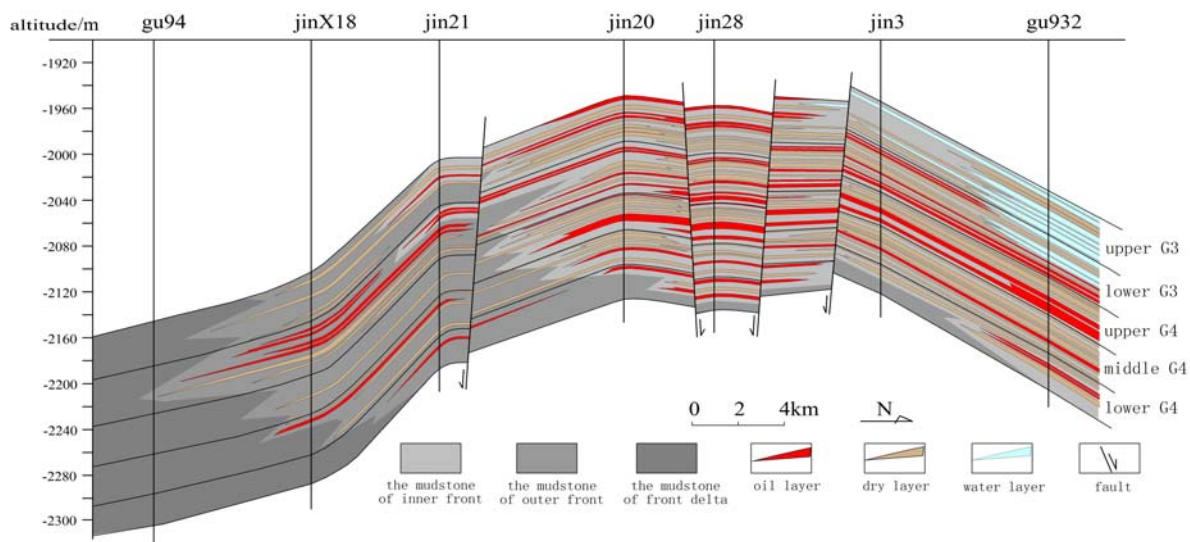


Figure 3. Profile map for tight sand oil of Well gu94-gu932 in G3-G4 oil layers of Qijia area

5. Conclusions

The tight oil resources of Gaotaizi reservoir in Qijia area have great potential. At present, the discovered tight oil mainly distributes in the south of Qijia. Sedimentary facies is the key reason for the distribution of tight reservoirs. The sedimentary facies of Gao 3 and Gao 4 oil reservoirs in Qijia area are shallow water delta facies. The Delta plain, delta front and prodelta subfacies successively develop from north to south. Multiple and small scale transgressions during with the base level falling cause the multistage superposition between delta outer front with prodelta mud, and the terminal of delta inner front with the mud of delta outer front, which provide the premise of source and storage match for inner source tight oil. Controlled by sedimentation, tight reservoirs of different sedimentary microfacies have different advantages and disadvantages, and tight reservoirs of distal bar are better than those of sheet sand. The conditions of tight oil source rocks of different subfacies are different, and the conditions of source rocks gradually improve from inner front to front delta. There are two kinds of tight reservoirs in Gaotaizi reservoir in Qijia area: distal bar tight reservoir in the rear of inner front and Outer front sheet sand tight reservoir. The former is the most important type of tight reservoir in this area because of its large scale, good physical properties, good source rock conditions

and good matching between source and reservoir. Distal bar microfacies in southern Qijia are the most favorable microfacies for the next step of tight oil exploration.

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