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Study on oil and gas filling and migration and accumulation in synclinal reservoir area

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Abstract. In recent years, the focus of oil and gas exploration in western Daqing has changed from a single large structural high point packaged reservoir to a diversified complex structural low point syncline reservoir. Such reservoirs are mainly lithologic traps, with complex rules of oil and gas filling, migration and accumulation, and irregular oil-water distribution, resulting in unclear understanding of the formation and distribution of syncline lithologic traps.The typical GLN area dominated by lithologic reservoirs is selected as the research object. The oil and gas filling research under the condition of reservoir forming power is carried out by using the source reservoir pressure difference. Based on the plane distribution of crude oil density, the secondary migration and accumulation rule of oil and gas is studied.It is considered that GLN can contain oil in a large area, but oil and gas can not migrate in a long distance. The low value area of crude oil density is the breakthrough of primary migration and the starting point of secondary migration, and its formation is controlled by the principle of phase potential coupling. The sand body is highly heterogeneous and the oil-water distribution is complex, while the sheet sand is mainly pure oil layer, and the water layer is formed only in the parts far away from the breakthrough and poor physical properties.

Keywords: Syncline reservoir, Lithologic reservoir, Source storage pressure difference, Reservoir forming power, Oil and gas filling, Migration and accumulation rule.

1. Introduction

In the past, there were three basic theories of syncline reservoir accumulation: Zhao Wenzhi and Zou Caicai's "full sag oil-bearing theory of oil and gas rich sag" [1], Wu Heyong and Liang Xiaodong's "syncline retention reservoir formation theory" [2] and Zhuo Qingong's "concealed dredging and episodic replacement theory" [3]. These three views complement each other and complement each other. As a complete process, oil and gas migration and accumulation is divided into primary and secondary migration, but these three theories do not consider the primary migration and filling of oil and gas, that is, the migration of hydrocarbons from source rock to reservoir, and the specific research methods and means of secondary migration are not pointed out. At the same time, there is a lack of research on the influencing factors of oil-water distribution law.

Glj-qn oil layer in the north of Daqing basin is mainly located in the middle of Songhua depression, and glj-qn oil layer is mainly located in the south of Songhua depression. There are many reservoir types in this area, and channel sand with rapid lateral change and stable sheet sand are developed; The law of oil-water distribution is complex. There are different sandstone lithologic reservoirs with the same oil source, cap and trap conditions, but the degree of oil-gas enrichment is very different. Pure oil wells, oil-water co production and pure water wells are distributed alternately, and there is no regularity to follow; There are all types of structures. There are both GL and MX synclines and xzo, xZn and an nose structures around the depression. On the basis of these three kinds of syncline reservoir forming theories, taking Gln area as the research object, develop and improve the oil and gas filling, migration and accumulation mechanism of syncline reservoir, explore the research methods of primary and secondary migration of oil and gas, and clarify the law of oil-water distribution.

2. Geological conditions of oil and gas filling and migration and accumulation

According to the "from source to reservoir" [4] process of oil and gas accumulation, and according to the idea of reservoir-forming dynamics [5], it is necessary to study the oil and gas geological conditions such as hydrocarbon expulsion and compaction characteristics of source rocks, fluid potential evolution, that is, structural evolution characteristics, secondary migration and transportation conductors of oil and gas, that is, deposition and sand body characteristics.

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2.1 Reservoir-forming dynamic characteristics

Firstly, the pressure energy is studied. According to Zou Cai, Jia Chengzao and Zhao Wenzhi (2005) [6], "overpressure is usually distributed in source rocks, and undercompaction and hydrocarbon generation pressurization are the dominant factors." In order to find out the reservoir-forming dynamics, the hydrocarbon expulsion and mudstone compaction of source rocks in the first member of Qing Dynasty were studied. Using the material balance method to calculate the hydrocarbon expulsion intensity of the source rocks in the first member of Qing Dynasty [7], two hydrocarbon expulsion centers, GL syncline and MX syncline, are obtained, and the hydrocarbon expulsion intensity is about 300×104t/km2 and 200×104t/km2 respectively. From the south-north mudstone compaction curve running through MX syncline, it can be concluded that the main overpressure develops in the source rocks of Qingshankou Formation, which provides power for oil and gas to enter the low porosity and low permeability reservoir, and the undercompaction range of the formation is also the largest.

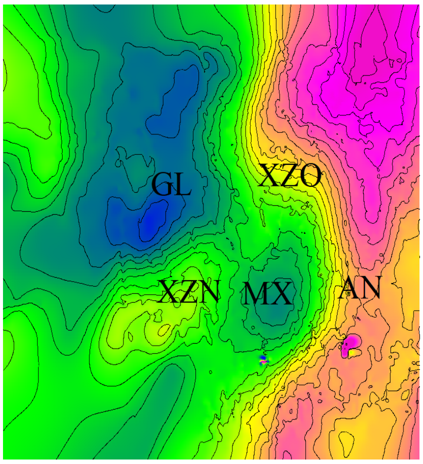

Fig. 1 Top structure of Putaohua oil layer in GLN area

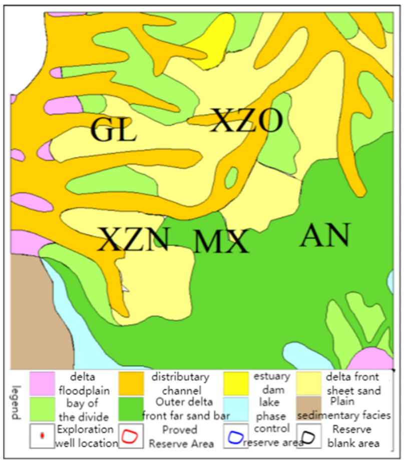

Fig. 2 Sedimentary microfacies of Putaohua oil layer in Gln area

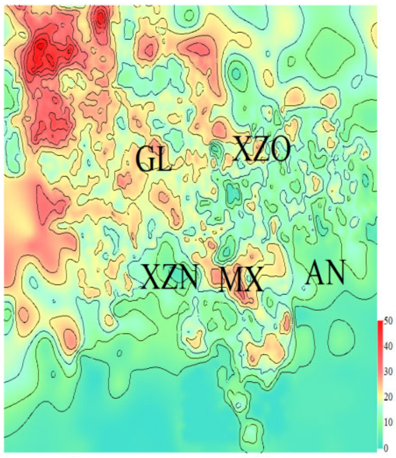

Fig. 3 Seismic prediction results of sandstone (unit: m)

Secondly, the potential energy of reservoir forming period is studied. The back stripping method is used to calculate the development history of the top structure of Putaohua oil layer [8]. The results show that the structural form of oil and gas in the main reservoir forming period is composed of xzo, xZn, an nose structure and the "three nose and two concave" structure of GL and MX syncline (Fig. 1). Analyze the relative potential energy of oil and gas during filling. According to the potential energy formula, the potential energy is also the largest in the central area of the two depressions.

Based on the research results of pressure energy and potential energy in reservoir forming period, in terms of reservoir forming power, the two depressions in Gln area, namely GL syncline and MX syncline, have the largest reservoir forming power.

2.2 Characteristics of sandstone conductor

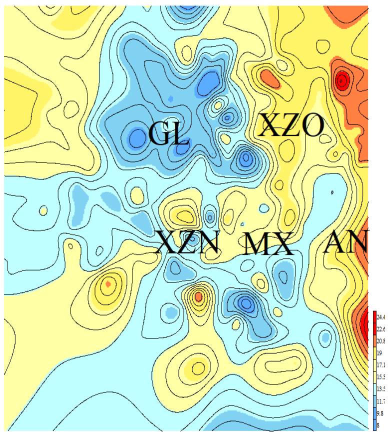

Fig. 4 Porosity contour map of grape flower layer

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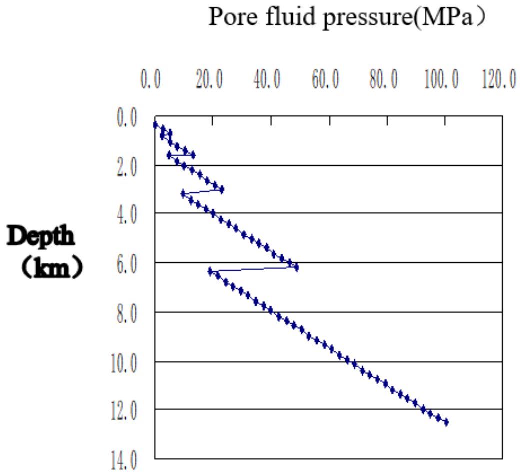

Fig. 5 Evolution of pore fluid pressure in source rock of GSY well

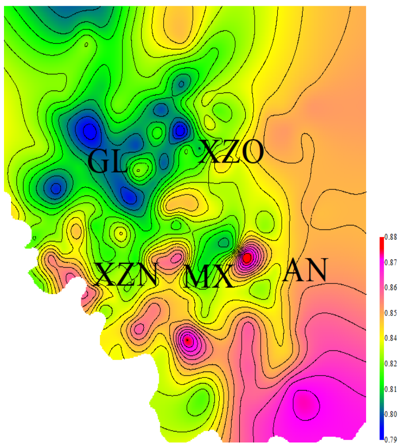

Fig. 6 Isogram of crude oil density

Firstly, the types of sandstone are analyzed. Putaohua oil layer in Gln area is jointly controlled by the northern and Western sedimentary systems, mainly delta facies. The two provenances gradually transition from the underwater distributary channel of the inner front of the Delta in the provenance direction to the center of the lake basin into the deposition of sheet sand of the inner front and far sand bar of the outer front of the Delta, and the stability of the reservoir gradually becomes stronger (Fig. 2). The ends of the two sedimentary systems are mainly located in an oilfield and MX syncline. The reservoir type is mainly distal bar microfacies at the outer front of the Delta, and the reservoir development is very stable (see Table 1).

Table 1 Sedimentary environment and sandstone types of different blocks in Daqing GLN area

Sedimentary environment / provenance direction	Delta inner front channel sand	Delta inner front sheet sand	Far sand bar at outer front of delta
Western provenance	GL syncline, xzo Oilfield	XZn Oilfield	
Northern provenance		Xzo Oilfield	
Sedimentary end			An oilfield and MX syncline

Secondly, the thickness of sandstone is analyzed. According to the seismic prediction results of sandstone thickness in the whole region (Fig. 3), it corresponds well to sedimentary micro. In the GL syncline dominated by underwater distributary channel microfacies deposition in the inner front of the Delta, the thickness of the high value area of sandstone is distributed in strips, and the direction is consistent with the provenance direction. It is preliminarily judged as the main body of channel deposition, with a thickness of about 20m and the thickness of inter river reservoir of about 10m; The MX syncline sandstone, which is dominated by the sheet sand sedimentary microfacies of the inner front of the Delta and the far bar deposits of the microfacies of the outer front of the Delta, is relatively thin and about 10m thick, but the distribution is relatively uniform. Only some well points have high value areas, which is consistent with the recognition that the sand body type of the two sedimentary areas is sheet sand.

Finally, the physical properties of sandstone are analyzed. From the plane distribution map of reservoir porosity (Figure 4), it can be seen that the physical properties of the reservoir gradually get better from syncline position to high structure position. And the reservoir physical properties in glmx syncline area are relatively poor, with a permeability of about 1.0md, ANd the permeability of XZN, XZO and an oilfields in high structural positions is basically above 2.0 MD.

3. Oil and gas filling and migration and accumulation law

3.1 Oil bearing and migration conditions

According to the above-mentioned principle of oil and gas migration and accumulation, the research is carried out from three aspects: the large area of hydrocarbon source and the development of faults can ensure that all kinds of sand bodies can effectively contact the source rock; The lake basin fluctuates and the sand and mudstone frequently interact with each other, especially the GL syncline and xzo block in the sedimentary part of the inner front of the delta can form various lithologic and stratigraphic sealing rings; The physical properties of the reservoir are poor, especially in xZn oilfield with sheet sand at the front edge of the Delta and MX syncline at the end of the deposition. The reservoir permeability is basically about 2Md. Under the condition that the fluid pressure difference and buoyancy cannot overcome the resistance formed by the capillary action of the reservoir [9], various physical property sealing rings can be formed. It is concluded that the study area has the conditions to form a large area of oil-bearing, but the oil and gas under single-stage filling and reservoir forming do not have the conditions for long-distance migration.

3.2 Characteristics of oil migration

On the basis of Zhuo Qingong's "theory of covert dredging and episodic displacement", it is considered that the study of oil and gas migration can be carried out through the current plane distribution characteristics of crude oil density [10]. There are three main reasons. First, the study area meets the conditions of "covert diversion and curtain replacement". The high-pressure hydrocarbon-water fluid of the lower Qing Member is injected into the upper Putaohua layer through faults, fissures and so on. Under the action of fluid pressure difference and buoyancy, the early oil in sandstone is gradually displaced to the surrounding direction, forming a situation that the early oil is in front and the late oil is behind in the lateral direction. When the episodic hydrocarbon expulsion stops, the oil will stay in the first migration breakthrough until the next episodic hydrocarbon expulsion, and the resulting fluid pressure difference will drive the crude oil to migrate to the surrounding direction again. Second, there are many stages of oil and gas filling and accumulation in the study area. The simulation results of excess pressure evolution of mudstone in Qingshankou Formation of Well GSY (Figure 5) show that the source rocks of the first member of Qing Dynasty have been fractured several times; Third, the density of oil, gas and crude oil generated in the later period of the third source rocks is relatively low.

Based on the above understanding, the statistics of the relative density data of crude oil in this area (Fig. 6) shows that there are great differences in different structural positions, with the minimum of 0.79 and the maximum of 0.88. There are areas with low crude oil density in the high and low parts of the structure, which is poorly matched with the structure, indicating that the secondary migration and accumulation process of oil and gas does not conform to the characteristics of structural reservoirs [11], and the above-mentioned oil and gas cannot migrate on a large scale and over a long distance Oil and gas accumulation is mainly formed by lithology or physical property sealing. The low value area of crude oil density formed in the later stage is mainly concentrated in the center of GL syncline and MX syncline, indicating that this area is the breakthrough point of primary oil and gas migration and the starting point of secondary plane migration.

The principle of phase coupling [12] is specifically: "The main control factor of oil and gas migration and accumulation is the coupling of overpressure+buoyancy (potential) and capillary resistance (phase). When the sum of the components of fluid pressure and buoyancy in the migration direction is greater than capillary resistance, oil and gas will migrate; otherwise, oil and gas will stay and gradually form a large-scale contiguous oil and gas accumulation". And the center of GL MX syncline has poor physical properties, but the pressure energy and potential energy are the largest in the accumulation period. Although the axial parts of XZN and XZO nose structures have small compressive energy and potential energy, their good physical properties lead to the minimum capillary resistance. The faults in XZO slope area are developed, and the oil and gas formed by source rocks can easily communicate with Putaohua reservoir, which leads to the reservoir-forming power of these three positions being greater than the resistance, so the oil and gas migration breaks through here at one time and migrates around.

3.3 Hydrocarbon migration and accumulation law

It can be seen from Figure 1 that the oil-water distribution law of GL syncline and xzo block in the channel sand development area at the front edge of the delta is complex. The reasons are analyzed. Although the two blocks are at the breakthrough of primary oil and gas migration and have a large amount of hydrocarbon expulsion, the reservoir has strong heterogeneity and poor connectivity. Under the action of overpressure, the oil injection capacity is quite different, so it is difficult to form a balanced displacement of the primary water in the reservoir, resulting in the development of water layers and the simultaneous production of oil and water in test wells; However, xZn oilfield, an oilfield and MX syncline developed by sheet sand and far sand dam have small plane change in reservoir thickness, good sand body connectivity and relatively complete oil and water displacement, resulting in pure oil production in test wells. However, a water producing zone is developed in the structural slope zone between an oilfield and MX syncline developed in the far sand bar. The reasons are analyzed: first, it is far away from the oil and gas breakthrough in the center of the syncline, and the power of oil and gas migration and accumulation is weakened over a long distance; Second, the poor physical properties of the reservoir lead to high reservoir forming resistance. The west boundary of proved reserves in an oilfield basically coincides with the porosity contour (Fig. 4), indicating that the reservoir forming resistance controls the lower limit of oil and gas filling in an oilfield. The sand body with strong heterogeneity and complex oil-water distribution, while the sheet sand is dominated by pure oil layer, and the water layer is formed only in the parts far away from the breakthrough and poor physical properties

4. Conclusion and understanding

4.1. GLN syncline oil reservoir area has large oil-bearing conditions, and oil and gas can't migrate long distance in the process of single-stage filling and reservoir formation.
4.2. The low oil density area of GLN syncline reservoir is the breakthrough point of primary migration and the starting point of secondary migration of oil and gas, and its formation is controlled by the principle of phase-potential coupling.

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4.3. The heterogeneity of GLN syncline reservoir has a great influence on the oil-water distribution law, and the oil-water distribution is complex, while the sheet sand is mainly pure oil layer, and only water layer is formed at the parts far from the breakthrough and with poor physical properties.

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