Oil Source of Fuyu Reservoir in Xingbei Region of Songliao Basin and the Process and Mode of Oil Accumulation

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Abstract

This paper made full use of data about geochemical, coring and logging to analyze the oil source and hydrocarbon supplying ability of Fuyu reservoir in Xingbei region of Songliao basin and set the process and mode of oil accumulation of the region. Research indicated that the crude oil of Fuyu reservoir in northern placanticline migrated laterally from Qing1 source rocks in southern Qijia sag. In key hydrocarbon generation period (the late period of the Mingshui Formation), oil that have been generated and discharged from first member of Qingshankou Formation in Qijia-Gulong sag was carried by formation overpressure through oil-migrating faults which communicated with Qing1 source rocks and underlying Fuyu reservoir and was active and open during the period, and migrated to lower Fuyu reservoir of Qijia-Gulong sag. Under the influence of residual pressure and buoyancy, the oil and gas migrated laterally to low potential area in the east--Fuyu reservoir of Daqing placanticline, through combined channels of faults and sand bodies. Certain amount of hydrocarbon accumulation generated when the oil and gas met a sealing fault during the migration. When the amount of hydrocarbon accumulation exceeded sealing capacity of sealing faults, the oil and gas passed through and migrated to higher part.

Keywords

Xingbei region; Fuyu reservoir; oil accumulation process; mode.

1. Source analysis of oil and gas

Gas chromatography–mass spectrography (GS–MS) analysis and gas chromatography–mass spectra–mass spectra (GS–MS–MS) analysis [4,9] of saturated hydrocarbon was used to trace the origin of oil and gas in the research area.

Researchers used GS–MS to analyze the distribution characteristics of terpane and sterane, then traced the origin of oil and gas in Fuyu reservoir of Xingbei region. Xingbei region is near northern Qijia region geographically. Because of the low maturity of source rocks, low abundance of organic matter and low potential of hydrocarbon generation in Qing1 Formation this region, northern Qijia region and Qijia sag became the potential oil source area. The comparison between the characteristics of biomarkers of the crude oil in Fuyu reservoir of Xingbei region and Qing1 source rocks in two regions revealed that, on the distribution characteristics of terpane, the tricyclic terpane in the crude oil of Fuyu reservoir in Xingbei region, unknown compound X and the distribution characteristics of 17α (H) rearranged hopane and 18α(H)–30–norneohopane, the relative content was lower than that in northern Qijia region, which was similar to Qing1 source rocks in Qijia sag. On the distribution characteristics of sterane, the content of C27 rearranged sterane in the crude oil of Fuyu reservoir in Xingbei region was lower than that in northern Qijia region, which was similar to the source rocks of Qijia sag, while the content of αββ C27 sterane was higher than the source rocks in Qijia sag. This shows that the migration effect of crude oil was very likely to enter the placanticline by short distance lateral migration and migrated toward north laterally along the placanticline. The crude oil in Fuyu reservoir of Xingbei region differs quite a bit from that in Qing1 source rocks this region, but is similar to that in Qing1 source rocks of Qijia sag, which shows that the oil in Fuyu reservoir of Xingbei region was migrated from Qijia sag.

The reliability of the qualitative and quantitative research of complex compounds was improved because two levels of mass spectrometry were put in series in GS–MS–MS. By useing GS–MS–MS to identify hopanes and steranes to study oil-source rock correlation, researchers analyzed the oil source of Qijia-Gulong sag.

First, in view of the maturity parameters of crude oil, the ratios of Ts/Tm, rearranged hopane/hopane, rearranged sterane/sterane and the 20S/(20S+20R) and ββ/(αα+ββ) of sterane increased with the deepening of horizons generally, which conforms the general evolution rules of maturity. The ratios of Putaohua reservoir and Gaotaizi reservoir are relatively higher, especially the ratios of Putaohua reservoir. In Putaohua reservoir, Ts/Tm is greater than 2, the rearranged hopane/hopane is generally greater than 0.2, the rearranged sterane/sterane is generally greater than 0.4, the 20S/(20S+20R) of sterane is generally greater than 0.4, the ββ/(αα+ββ) of sterane is generally greater than 0.5, the gammacerane/C30 hopane is greater than 0.14, the C29Ts/C29 hopane is greater than 0.24 and the 24-C26 sterane/27-C26 sterane is higher, it is between 1.63 and 2.41.

Next, in view of the associated parameters of source rocks, the source rocks of Nenjiang Formation differs a lot from Qingshankou Formation mainly in the following respects: the gammacerane/C30 hopane in source rocks is generally less than 0.1 in Nenjiang Formation, while it is generally greater than 0.1 in Qingshankou Formation; the C29Ts/C29 hopane in source rocks is less than 0.28 in Nenjiang Formation, while it is generally greater than 0.3 in Qingshankou Formation; the rearranged hopane/hopane in source rocks is generally less than 0.1 in Nenjiang Formation, while it is generally greater than 0.1 in Qingshankou Formation; the rearranged sterane/sterane in source rocks in Nenjiang Formation is less than that in Qingshankou Formation generally. According to the result of oil-source rock correlation, the crude oil in Putaohua reservoir, Gaotaizi reservoir and Fuyu reservoir is similar to that in the source rocks of Qingshankou Formation.

Besides, Wang Xue et al. in Daqing oilfield used Pr/nC17 and Ph/nC18 parameters to divide the oil population in Daqing placanticline and Fuyu reservoir in Qijia sag and found that the crude oil in southern Qijia sag and Fuyu reservoir in the placanticline is obviously of the same type (Fig 1).

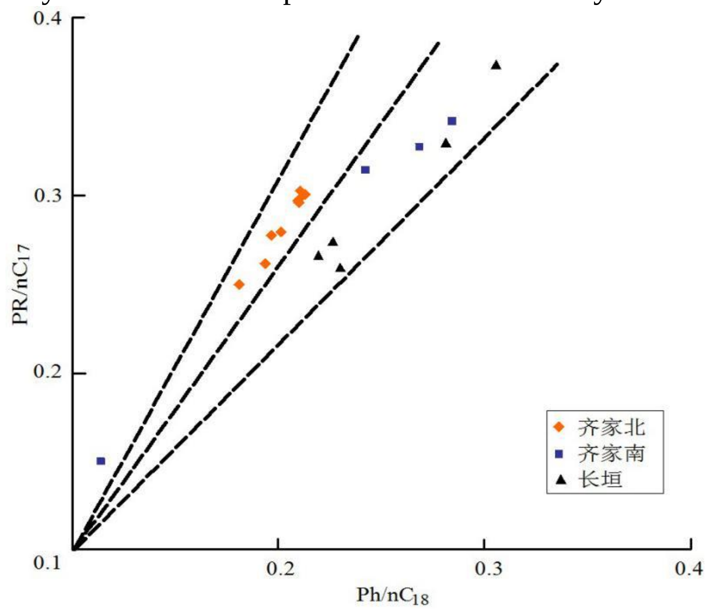

Fig1 Parameter relation graph between Pr/nC17 and Ph/nC18 in crude oil (According to WangXue)

The oil-source rock correlation of C27 ββ/(αα+ββ) sterane, C27 rearranged sterane/sterane, 17α(H) rearranged hopane/C30 hopane and 18α (H)–30–norneohopane/C30 hopane and some other biomarkers shows that: the change rules of four parameters of southern Qijia sag and the source rocks of northern placanticline, the source rocks have a affinity (Fig 2), which shows that the crude oil in

Fuyu reservoir of northern placanticline mainly migrated laterally from the Qing1 source rocks in southern Qijia sag.

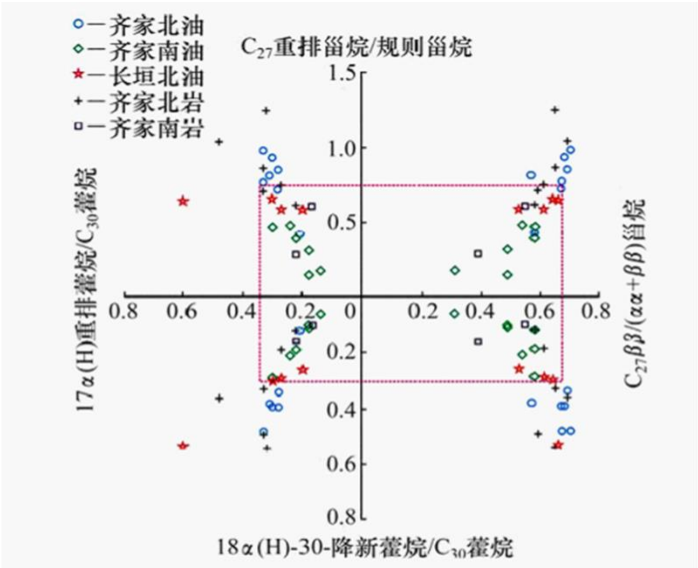

Fig.2 The correlation between reservoir and lithology in Fuyu reservoir in Daqing placanticline (According to Wang Xue, 2006)

2. Hydrocarbon supplying analysis of source rocks

The research of Research Institute of Exploration and Development of Daqing Oilfield has shown that (Fig 3) the Qing1 source rocks of Qijia-Gulong sag is rather thick, the northern source rocks of sag is 100m thick; the middle source rocks of sag is 90m thick at most; the southern source rocks of sag is relatively minor, but it also reaches 60m-80m. Hence, in view of the thickness of source rocks, the Qing1 source rocks of Qijia-Gulong sag have great hydrocarbon generation potential. [1,3,8,10-11]

Table 1 Geochemical characteristics of source rocks in Qijia-Gulong sag (According to Chen Fangwen)

Horizons	Organic carbon TOC/%	Hydrocarbon generation potential S_1+S_2/(mg/g)	Chloroform bitumen “A”/%	Vitrinite reflectance R_0/%
Tender section (K_1n1)	2.47 (716)	38.32 (397)	0.55 (251)	0.53 (124)
	0.19~6.66	0.02~53.04	0.01~1.43	0.38~0.88
Green two or three paragraphs (K_1qn^{2+3})	1.27 (1673)	28.08 (488)	0.57 (284)	0.81 (145)
	0.08~6.56	0.01~55.40	0.01~1.40	0.41~1.39
Green section (K_1qn^1)	2.50 (1816)	42.45 (193)	0.49 (101)	0.84 (358)
	0.11~6.95	0.04~65.33	0.01~1.75	0.37~1.42

From the research of Cheng Fangwen, Lu Shuangfang et al. (Table 1), the TOC of Qing1 source rocks in Qijia-Gulong sag ranges from 0.11% to 6.95%, the content of hydrocarbon generation potential (S_1+S_2) ranges from 0.04 mg/g to 65.33mg/g, the numerical value of chloroform asphalt "A" ranges from 0.01% to 1.75%. This illustrates that the source rocks have high abundance of organic matter and reach the standard of good-high quality source rocks; the type of organic matter is Type II_1 and Type I, the source rocks are favorable for oil generation; the vitrinite reflectance have averaged 0.84%, the source rocks are in the low mature-mature stage. Hence, combined with the analysis of source rock thickness of Qijia-Gulong sag and their geochemical characteristics, it is observed that the first member of Qingshankou Formation in Qijia-Gulong sag has better hydrocarbon supplying ability, it can be an adequate supply of oil and gas for Xingbei region.

Through the oil generation and expulsion intensity simulations of the Qing1 source rocks in Qijia-Gulong sag, it is obvious that there are two high-value regions of oil generation and expulsion intensity in northwest and southwest Xingbei region of Daqing placanticline (Fig 4, Fig 5). Specifically, the high-value of oil generation intensity of northwest source rocks reaches 400-1500t/km^2, the oil expulsion intensity reaches 400-1280t/km^2, the high-value of oil generation intensity of southwest source rocks reaches 400-800t/km^2, the oil expulsion intensity reaches 400-560t/km^2, oil mainly migrated from the two regions. While the oil generation and expulsion intensity of source rocks of northwest region is stronger than that of southwest region, so the northwest region is the preponderant region for oil and gas supplying. The results are consistent with the analysis of Research Institute of Exploration and Development of Daqing Oilfield. Hence, the Qing1 source rocks of western Qijia-Gulong sag in Daqing placanticline can supply adequate oil and gas for Fuyu reservoir in Xingbei region (Fig 6).

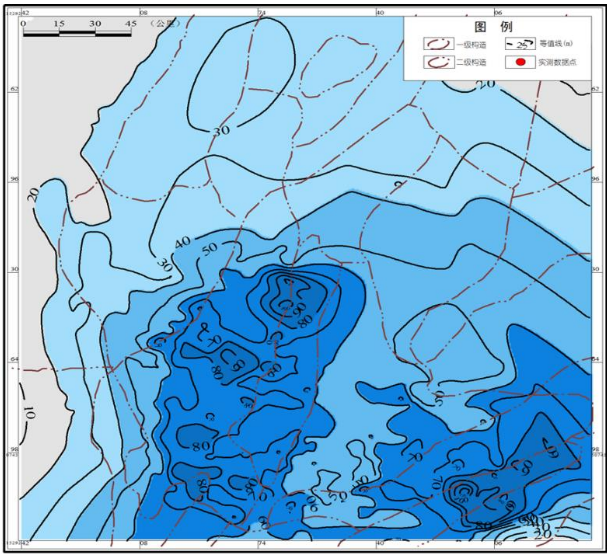

Fig.3 Contour map of mudstone thickness in the first member of Qingshankou Formation in the Northern Songliao Basin (According to Daqing oilfield)

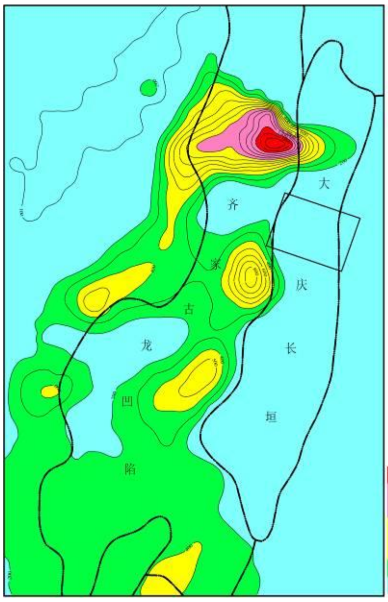

Fig.4 Contour map of oil generation intensity in the first

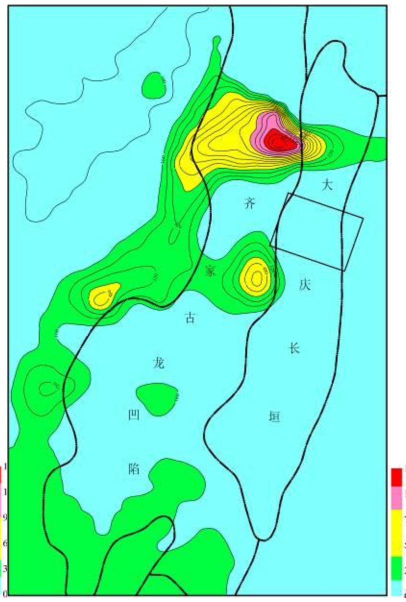

Fig.5 Contour map of oil discharge intensity in the first

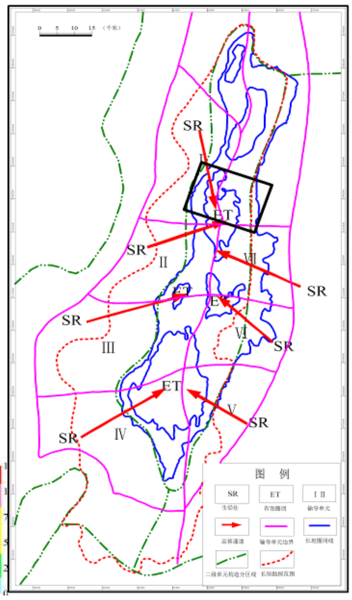

Fig.6 Division of migration and accumulation

3. Process and mode of oil migration and accumulation

The study found that Qijia-Gulong region met the necessary condition of vertically downward migration [2-3,5-7,11]: (1) sufficient oil sources; (2) high enough abnormal fluid pressure; (3) faults that communicates sand bodies with overlying source rocks.

First, the Qijia-Gulong region has sufficient oil sources. According to the analysis of the geochemical characteristics and oil generation and expulsion intensity of first member of Qingshankou Formation, the Qing1 source rocks have better oil conditions, it can supply sufficient oil and gas for the region.

Besides, the Qijia-Gulong region has high enough abnormal fluid pressure. The late period of Nenjiang Formation and the late period of Mingshui Formation of Qijia-Gulong sag were both overpressure peaks. The Qing1 mudstone is in the late period of Nenjiang Formation, the fluid pressure gradient is 2.0MPa/100m, reaches the first overpressure peak, the tectonic uplifting pressure drops. In the late period of Mingshui Formation, the fluid pressure gradient is 2.4MPa/100m, reaches the second overpressure peak, then the overpressure relieves for a second time. The alternative variations of fluid pressure gradient in different periods formed the hydrocarbon expulsion mode into overpressure-relief-overpressure- relief.

In the plane, at the first overpressure peak, the highest fluid pressure gradient of Qing1 is in Qijia-Gulong sag (2.0MPa/100m), which is higher than that in Daqing placanticline (1.4-1.5Mpa /100m) and that in Longhupao terrace (1.4-1.7MPa/100m); at the second overpressure peak, the distribution pattern of Qing1 fluid pressure gradient is Qijia-Gulong sag > Longhupao terrace > Daqing placanticline, the numerical values are 2.4MPa/100m, 2.0-2.4MPa/100m, 1.3MPa/100m respectively. Hence, the Qing1 source rocks of Qijia-Gulong sag and nearby region are most favorable for oil downward migration, the depth of hydrocarbon expulsion is 50-100m.

Finally, the Qijia-Gulong region has faults that communicates sand bodies with overlying source rocks. In the late period of Qingshankou Formation, under the influence of regional extensional stress field, a lot of ruptures started to take shape, their effect was to adjust the extension action of floor. In the main hydrocarbon generation stage and the hydrocarbon migration stage (the late period of Nenjiang Formation, the late period of Mingshui Formation and the late period of Paleogene), influenced by the regional stress field, a lot of faults resurrected and opened, becoming the paths for hydrocarbon in Qing1 source rocks to migrate to underlying reservoirs. The finding of the asphaltene in the fracture of Quan4 (Well DA281) near the fault zone proofed faults were the paths of hydrocarbon downward migration. Besides, through the study of characteristics of regional reservoirs, it is obvious that in the vertical, sets of sandstone developed in Fuyu reservoir. The features of sandstone development are: the monolayer is small in thickness (mainly 2-3m), the sandstone does not superpose, it is isolated, adjacent sand horizons are divided by mud, hydrocarbon can not migrate vertically downward through sand bodies over long distance; due to the small vertical fault displacement, the source rocks and sand bodies can contact widely in the lateral, hydrocarbon can not migrate laterally to deep reservoirs through sand bodies directly, in other word, sand bodies can not be the main paths of hydrocarbon migration. Hence, there are faults that communicates sand bodies and overlying source rocks in Qijia-Gulong sag, and the faults are main paths of hydrocarbon migration in Qijia-Gulong sag.

In conclusion, In key hydrocarbon generation period (the late period of the Mingshui Formation), oil that have been generated and discharged from first member of Qingshankou Formation in Qijia-Gulong sag was carried by formation overpressure through oil-migrating faults which communicated with Qing1 source rocks and underlying Fuyu reservoir and was active and open during the period, and migrated to lower Fuyu reservoir of Qijia-Gulong sag. Under the influence of residual pressure and buoyancy, the oil and gas migrated laterally to low potential area in the east–-Fuyu reservoir of Daqing placanticline, through combined channels of faults and sand bodies. Certain amount of hydrocarbon accumulation generated when the oil and gas met a sealing fault during the migration. When the amount of hydrocarbon accumulation exceeded sealing capacity of sealing faults, the oil and gas passed through and migrated to higher part.

4. Conclusion

The crude oil of Fuyu reservoir of Xingbei region in Songliao basin mainly migrated laterally from Qing1 source rocks in southern Qijia sag. In key hydrocarbon generation period (the late period of the Mingshui Formation), oil that have been generated and discharged from first member of Qingshankou Formation in Qijia-Gulong sag was carried by formation overpressure through oil-migrating faults which communicated with Qing1 source rocks and underlying Fuyu reservoir and was active and open during the period, and migrated to lower Fuyu reservoir of Qijia-Gulong sag. Under the influence of residual pressure and buoyancy, the oil and gas migrated laterally to low potential area in the east–-Fuyu reservoir of Daqing placanticline, through combined channels of faults and sand bodies. Certain amount of hydrocarbon accumulation generated when the oil and gas met a sealing fault during the migration. When the amount of hydrocarbon accumulation exceeded sealing capacity of sealing faults, the oil and gas passed through and migrated to higher part.

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