Quantitative study on the proportion of oil sources of Wuerxun-Beier Depression, Hailaer Basin, China

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Abstract. There are many petroleum-rich areas which are characterized by hydrocarbon charging from multiple source rocks and subsags. It is significant to analyze the contribution ratio of subsags for the oil resource potential of depression and the scope of petroleum migration. In this study, the absolute quantitative technique of biomarker compounds is applied to oil source correlation for Huoduomoer Oilfield, Sudeerte Oilfield, Huhenuoren Oilfield and Surennuoer Oilfield in Wuerxun-Beier Depression. Firstly, we determined crude oil from which subsags. The second is what biomarker compounds are suitable for calculating the mixed proportion. Through the analysis of the research, we selected on behalf of the compounds of maturity of Tm and Ts, on behalf of the compounds of organic matter sources of terpane and sterane, and on behalf of the compounds of sedimentary environment of β-carotene and gammacerane to establish theoretical plot. After the calculation, it is precise to know the contribution ratio of subsags for crude oil of the four oilfields. The research method of this paper not only clarifies the proportion of oil Sources of petroleum-rich areas with hydrocarbon charging from multiple source rocks and subsags, but also provides the basis for exploration and deployment.

1. Introduction
The Hailaer Basin is located in the northeastern China (figure 1). It is one of the most important petroliferous basins in the Daqing exploration areas and is located in the Inner Mongolia Autonomous Region. The maximum buried depth of sedimentary rocks is about 6000 m. The petroleum geological conditions are complicated in Hailaer Basin. The basin is composed of 16 depressions with a total area of 25260Km\(^2\). Wuerxun and Beier are the two depressions which have discovered most oilfields to date in the Hailaer Basin.

The Wuerxun-Beier Depression contains six main sedimentary sequences resting on Paleozoic metamorphic basement, which are listed from bottom to top as follows: Xinganling Group (J\(_2\)x), Tongbomiao Formation (K\(_1\)t), Nantun Formation (K\(_1\)n), Damoguaihe Formation (K\(_1\)d), Yimin Formation (K\(_1\)y), and Qingyuangang Formation (K\(_2\)q). To date, the petroliferous horizons in the Wuerxun-Beier Depression are mostly found in the Nantun Formation (K\(_1\)n).

Previous studies confirmed that four sets of source rocks exist in the Wuerxun-Beier Depression, namely, the K\(_1\)d\(_1\) member (the first member of the K\(_1\)d Formation), K\(_1\)n\(_1\) member (the second member of K\(_1\)n Formation), K\(_1\)n\(_1\) member (the first member of the K\(_1\)n Formation) and K\(_1\)t Formation. The lithology of source rocks is characterized by dark mudstones. The K\(_1\)d source rock contains thermally
immature, dominantly Type III organic matter, the K_1n source rock contains mature, dominantly Type I and II organic matter, and the K_1t source rock contains mature to postmature, dominantly Type II and III organic matter. The K_1n has high organic carbon abundance, and is main source rock. Petroleum-rich areas in the depression are characterized by hydrocarbon charging from multiple source rocks and subsags. So the genetic relationships between the crude oils and the source rocks remain controversial.

2. Samples and methods

2.1. Samples

Two hundreds and twenty samples were used in organic geochemistry experimental analysis, including 77 core samples (source rocks) and 59 crude oil samples from the Wuexun Depression and 43 core samples (source rocks) and 41 crude oil samples from the Beier Depression. Most samples were from the K_1n Formation. They were analyzed using gas chromatography–mass spectrometry (GC–MS) to assess their molecular characteristics.

2.2. methods

The core samples were cleaned using redistilled water. The samples were subsequently dried at 60 °C and ground to powder. The powder samples were analyzed (using Rock–Eval 6) for total organic carbon (TOC), hydrogen index (HI), and hydrocarbon generation potential (S_1+S_2). Bitumen was extracted from source rocks using a Soxhlet apparatus. All extracts and oils were separated into saturated, aromatic, and resin fractions using column chromatography. GC–MS analyses were performed for the saturated fraction in the oils and source-rock extracts. Chemometric methods were applied to oil–oil and oil–source rock correlations in the Wuexun-Beier Depression.

3. Results and discussion

In this study, the absolute quantitative technique of biomarker compounds is applied to oil source correlation for Huoduomoer Oilfield, Sudeerte Oilfield, Huhenuoren Oilfield and Surennuoer Oilfield in Wuexun-Beier Depression. First determine oil from which a few subsags. The second is what biomarker compounds are suitable for calculating the mixed proportion.

Taking the Sudeerte Oilfield as an example, there are the Beixibei Subsag on the west and the Bei18 Subsag on the north, which are effective source kitchens. There are obvious differences in the two subsags by chromatography, mass spectrometry, isotope and other parameters. The oil and source rock in the Beixibei Subsag are characterized by high content of C_{27} and C_{29} rearranged steranes ‘figure 2’, high maturity and low content of β-carotene, but the oil and source rock in the Bei18 Subsag are characterized by low content of C_{27} and C_{29} rearranged steranes, low maturity and high content of β-carotene. The crude oil of Sudeerte oilfield is more similar to that of the Beixibei Subsag, which is the
characteristics of high content of C_{27} and C_{29} rearranged steranes, low content of β-carotene. The maturity of crude oil in Sudeerte oilfield is between that of Beixibei Subsag and Bei18 Subsag. Therefore, We selected on behalf of the compounds of the maturity of the Tm and Ts, on behalf of the compounds of organic matter sources of terpane and sterane, and on behalf of the compounds of sedimentary environment of β-carotene and gammacerane to establish theoretical plot ‘figure 3’. After the calculation, 77% of the crude oil in Sudeerte Oilfield is from the Beixibei Subsag and 23% of the crude oil is from the Bei18 Subsag.

According to this method, 85% of the crude oil in Huoduomoer Oilfield is from the Beixibei Subsag and 15% of the crude oil is from the Bei18 Subsag, 100% of the crude oil in Huhenuoren Oilfield is from the Beixibei Subsag ‘figure 4’, 65.5% of the crude oil in Surennuoer Oilfield is from the Wubeinan Subsag and 34.5% of the crude oil is from the Wubeibei Subsag.
4. Conclusions

Based on Rock-Eval pyrolysis data, source rocks of the K1n Formation have moderate to high hydrocarbon generating potential, which are wide distribution and large thickness. 89% of the Crude oil in Wuerxun-Beier Depression is contributed from source rock of the K1n Formation. Source rocks of the K1n Formation in each subsags have their own characteristics of biomarker compounds. Therefore the absolute concentration of the biomarker compounds differences in the subsags can be used for oil source correlation.

Select biomarker compounds and establish theoretical plot. After the calculation, it is precise to know the contribution ratio of subsags for crude oil. We can know that the hydrocarbon from each subsags to surrounding migration range and distance. Taking the Sudeerte Oilfield and Huhenuoren Oilfield as examples, 77% of the crude oil in Sudeerte Oilfield is from the Beixibei Subsag and 23% of the crude oil is from the Bei18 Subsag, eastward migration distance is about 3-15Km; 100% of the crude oil in Huhenuoren Oilfield is from the Beixibei Subsag, southward migration distance is about 12-24Km.

The research method of this paper not only clarifies the proportion of oil Sources of petroleum-rich areas with hydrocarbon charging from multiple source rocks and subsags, but also provides the basis for exploration and deployment.

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