THE GEOCHEMICAL CHARACTERISTICS AND PRODUCTION GEOCHEMISTRY OF TIGHT OIL IN JIMUSAR DEPRESSION, CHINA

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Introduction

The Lucaogou Formation of the Permian in the Jimusar depression of the Junggar Basin is an important area of tight oil exploration and production. Jimusar tight oil is characterized by relatively high density (average value of 0.8919 g/cm³) and high viscosity (average value of 92.18 mPa•s), which is different from that in the US. This paper shows the geochemical characteristics for the source and formation mechanism of the tight oil. Gas chromatography oil fingerprinting technology plays an important role in calculating production allocation of separate zones of commingled oil wells. However, the conventional gas chromatography method cannot meet the analysis demands of heavy tight oil. Therefore, a series of optimization experiments were conducted to figure out the main gas chromatogram conditions. The fingerprint peaks by optimization were significantly improved for production geochemistry of vertical wells and horizontal wells.

Results

The effective geochemical parameters for properties of tight oil-bearing reservoirs include $S_1$, $S_1$/TOC, chloroform bitumen A, TPI, and $S_1$/S₂. The criteria of sweet spot of tight oil of the Lucaogou Formation in the Jimusar depression were established as follows: $S_1$/TOC > 100 (mg oil/g TOC), $S_1$ > 10mg/g, TPI > 0.12, $S_1$/S₂ > 0.22, and chloroform bitumen A > 0.7%. The properties of tight oil-bearing reservoirs are related to lithology, sedimentary facies, hydrocarbon expulsion, oil migration, porosity, and permeability. The oil-bearing property of siltstone, dolomite, dolomitic mudstone, and silty mudstone reservoirs is superior to that of pure shale reservoirs. It can be divided into the “upper” and “lower sweet spot intervals” based on the geochemical parameters and logging. The maximum thickness of the “upper sweet spot interval” (upper interval) is 77 m and that of the “lower sweet spot interval” (lower interval) is 73 m.

The different sources of crude oil of the upper interval and lower intervals lead to the variation in oil property. The crude oil from the upper interval has relatively lower density than that from the lower interval. The mudstones and dolostones of the Lucaogou Formation are considerable source rocks. The maceral composition is mainly sapropelinite. The source rocks are of high quality with high abundance of organic matter. The crude oil and soluble organic matter in the reservoirs are rich in β-carotane and other biomarkers (Fig.1). It shows that the sedimentary environment of the source rocks of the Lucaogou Formation was a saline reducing environment. The Pr/Ph of the crude oil from the upper interval is between 1.21 and 1.56 and that from the lower interval is between 0.94 and 1.08. More β-carotane was identified in the crude oil from the lower interval. The overall geochemical characters of crude oil show that the source rocks in the lower interval had a more saline environment than that from the upper interval. The algae source input for the source rock is also different. It can be discriminated for the crude oil from the upper interval and the lower interval using $C_{35}/C_{34}$ hopane, Pr/Ph, and gammacerane/($C_{30}$hopane+gammacerane). Therefore, the “upper sweet spot interval” is more suitable for tight oil production.

There is an obvious short-distance migration phenomenon of tight oil. Oil is enriched in siltstones, dolomites, dolomitic mudstones, and silty mudstones. Shales and dolomites are high-quality source rocks. The main factors for tight oil enrichment of the Lucaogou Formation are as follows: 1) the source rock is in the mature stage with large thickness and high abundance of organic matter. 2) The reservoir porosity and permeability are relatively large and the oil saturation of the reservoirs is high.
3) The mudstones are interbedded with dolostones. The source rocks of the saline environment result in the earlier oil generation.

A series of optimization experiments were conducted on programmed temperature rates, injection mode and the inlet temperature to explore an optimum experimental method for whole oil gas-chromatography of tight oil. The optimum method is: DB-5ht capillary column connected with a 5 meters’ guard column before the inlet, split injection mode with a 20:1 split ratio, the inlet temperature of 350°C, FID temperature set at 370°C, the oven temperature starting from 40°C for the initial isothermal period of 3 min, then raised to 230°C at a rate of 4°C/min, and then raised to 370°C at a rate of 10°C/min for the final isothermal period of 20 min.

The 50 fingerprint peaks were chosen from 148 fingerprint peaks between nC₉ and nC₂₅ for tight oil production allocation based on the basic principles of universality, diversity, and stability. By using the partial least squares method (PLS), the production of various layers has been calculated. The results show that the commingling crude oil of the upper interval and the lower interval mainly was generated from the upper interval. The fingerprints of P₂l₂3-1, P₂l₂3-2 and P₂l₂3-3 of the upper interval are different and the tight oil in P₂l₂3-1 is the main contribution layer for commingling tight oil production in the area of wells 37 and 171. The P₂l₂3-2 is the primary contribution layer for commingling tight oil production in the area of wells 173 and 25. The commingling oil in well 174 was the major P₂l₂3-1 contribution layer in 2015 and had a more P₂l₂3-2 contribution for commingling tight oil production in 2017. The main reason has been analyzed on the basis of the geochemical logging. Tight oil production of horizontal well has been also analyzed and the main crude oil was dominantly generated from P₂l₂3-2.

![Figure 1 RIC of the tight oil of in well 301(a) in the upper sweet spot interval and in well 31(b) in the lower sweet spot interval](Image)