Application of fine analysis technology for gas-source on condensate gas reservoirs in the Dinan Uplift

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Abstract. Some researches on the distribution of Carboniferous source rock in the Dinan uplift, Junggar Basin, has been clear that the Songkaersu Formation (C1s) is relatively implement, but that of the Dishuiquan Formation (C1d) is still uncertain. The acknowledgment and conclusion of the hydrocarbon generation and gas generation capacity of C1d source rocks are fairly limited, and thus the contribution of this set of source rock to the natural gas in the southern Dinan uplift exists a certain dispute. In this paper, based on the predecessors’ research work, the fine-scale comparison of fingerprint characteristics between the two sets of source rocks in Carboniferous by using monomer hydrocarbon carbon isotope technique, and at the same time, the condensate oils which were associated with Carboniferous natural gas in this region were also compared in detail. As such, the contribution of Carboniferous C1s and C1d source rocks was determined.

1. Work area overview
The Kelameili gas field is the largest one of gas fields currently discovered in the Junggar Basin, which is located on the Dinan uplift in the eastern part of Junggar Basin. And the Dinan uplift is located in the northeastern part of the central depression of Junggar Basin. The uplift is distributed in a narrow east-west direction in structure, which is adjacent to the Dishuiquan sag in the north and the Dongdaohaizi sag and the Wucaiwan sag in the south. On the whole, the uplift is a nose-like structure with a high east and low west, and there is a series of near east-west faults are developed, and its structure is very favorable. In the past few years, the south belt of the Dinan uplift in the area has continuously achieved breakthroughs. It has obtained industrial Carboniferous oil flow in the first exploration of the DT1 well, the M6 well and the M8 well.

2. Samples and methods
The source rock samples from the Dishuiquan Outcrop (C1d) and the DX8 well (C1s) in the Junggar Basin and some Carboniferous crude oil samples, including DX21 well, D201 well, DX10 well, and D403 well, were selected in this paper. The difference of the samples’ organic carbon content, the hydrogen index and rock pyrolysis parameters Tmax are analyzed (Table 1). The samples were firstly physically crushed to about 200 mesh and a small amount of the powder was taken for total organic carbon (TOC) contents and Rock-Eval pyrolysis analysis. Each samples about 100g was taken to get the chloroform-extractable bitumen through soxhlet extraction. Then the extractable organic matter
and the crude oil samples were separated by group composition, and the saturated hydrocarbons were analyzed by gas chromatography (GC). After that, the carbamide complexation experiment was conducted, and the n-alkanes were finally obtained for GCIRMS analysis.

Table 1. Rock-Eval pyrolysis and TOC parameters of source rocks

| Sample number | Depth (m) | Formation | TOC (%) | HI (mg/g) | Tmax (°C) |
|---------------|-----------|-----------|---------|-----------|-----------|
| DSQ S22       | outcrop   | C1d       | 1.3     | 119.2     | 490       |
| DSQ S47       | outcrop   | C1d       | 1.33    | 94.3      | 483       |
| DSQ S53       | outcrop   | C1d       | 1.70    | 108.4     | 467       |
| DSQ S55       | outcrop   | C1d       | 1.47    | 113.0     | 471       |
| DSQ S58       | outcrop   | C1d       | 1.68    | 122.7     | 464       |
| DX 8          | 3407.3    | C1s        | 7.45    | 160.1     | 448       |
| DX 8          | 3511.8    | C1s        | 13.19   | 238.0     | 446       |
| DX 8          | 3605.6    | C1s        | 3.47    | 106.0     | 453       |

3. Comparison of hydrocarbon generation characteristics between two sets of Carboniferous source rocks (C1s,b, C1d)

According to the latest stratigraphic classification scheme, the carboniferous source rocks in the Dinan Uplift were reclassified, and the Carboniferous source rocks of C1s and C1d formation were evaluated. The results indicate that the TOC values of the drilled downhole source rocks from C1d are in a range from 0.44% to 6.28%, and the petroleum generation potential that PG equals S1 plus S2 values range from 0.13 mg/g-3.70 mg/g, both of which manifest that the C1d samples belong to general to good quality source rocks. On top of this, the organic matter is mainly type III and in the highly mature evolution stage. While, the distribution of the organic matter in C1s source rocks are relatively dispersed, with the TOC values ranging from 0.23% to 6.03% and the PG values distributing between 0.07 mg/g and 31.04 mg/g, but some carbonaceous mudstones have high abundance of organic carbon. So the C1s samples belong to common-good quality with type II2 to type III kerogen, highly mature to over-mature.

4. Determination of the source of condensate gas reservoirs in the Dinan Uplift

4.1 Geochemical characteristics of the Carboniferous natural gas

The composition data of Carboniferous natural gas shows that the north part of the Dinan Uplift is dominated by wet gas and partly dry gas. The adjacent Wucaiwan Gas Field contains mainly wet gas. However, the methane drying coefficient C1/C1.5 of the south part of uplift is in the range of 0.90-0.99, which means a partial-dry to dry gas.

The carbon isotopic composition of natural gas in the Dinan Uplift is generally heavy, and it is humic gas reaching the mature to highly mature stage. While, the carbon isotopic composition values of ethane are lighter than that of Wucaiwan mature gas, which indicates natural gas in the two regions have differences in bio-precursors.

4.2 Comparison of carbon isotopic composition of individual hydrocarbons between Carboniferous source rocks and condensate oils

The carbon isotopic composition of n-alkanes with different carbon numbers extracted form Carboniferous C1s and C1d source rocks were analyzed by using carbon isotopic analysis of individual hydrocarbons technology, and there were obvious fingerprint differences between them. From the test of samples from the Dishuiquan profile and a large number of Carboniferous source rocks in the DX8 well, the individual hydrocarbons characteristics of Carboniferous C1d source rocks
have generally a descending trend, and the carbon isotopic compositions are lighten with the increase of carbon number. While the C$_1s^b$ source rocks show a mild ascending trend, that is to say, they firstly become heavier and then lighter. The two sets of source rocks have significant differences in the carbon isotopic composition of individual hydrocarbons, which means C$_1s^b$ and C$_1d$ have some differences in bio-precursors. In addition, the carbon isotopic characteristics of individual hydrocarbons of Carboniferous condensate oil, such as the DX21 well, the D103 well and the DX10 well, are similar to that of C$_1d$ source rocks, indicating that the condensate oils mainly come from C$_1d$ source rocks (Figure 1 and Figure 2).

**Figure 1.** Characteristics of monomeric hydrocarbons in Carboniferous C$_1d$ and C$_1s^b$ source rocks (quoted from Shuang Yu)

**Figure 2.** Carboniferous C$_1d$ hydrocarbon source and crude oil monomer hydrocarbon characteristics

The Carboniferous crude oil in the southern part of the region is associated with condensate oil. Among them, the DX33 well is a typical well whose oil and gas come from the Lower Carboniferous
C1s rock, and the source rock is C1s dark gray mudstone. The reservoir rock is a volcanic rock mass developed inside C1s, and the volcano rock is wrapped in a large set of dark mudstone. By comparison, the characteristics of C1s crude oil in M8 well and the DX33 well are consistent. The Pr/Ph is larger, the crude oil carbon isotope is more heavy, which of the crude oil in the northern part of the Dinan uplift is slightly smaller, and the carbon isotope value is slightly lighter than the Carboniferous crude oil in the DX33 Well(Table2). So It shows the relative preference of hydrocarbon-generating parent materials of Carboniferous crude oil in the southern belt of the Dinan uplift.

Table 2. Geochemical characteristics of Carboniferous condensate in Dinan sag.

| Well  | Layer | Depth (m) | Density | Pr/Ph | Pr/nC17 | Ph/nC18 | δ13C |
|-------|-------|-----------|---------|-------|---------|---------|-------|
| D103  | C     | 3050-3062 | 0.781   | 2.12  | 0.25    | 0.14    | -25.59|
| D403  | C     | 3824-3840 | 0.787   | 1.63  | 0.23    | 0.16    | -27.05|
| DX14  | C1s   | 3652-3674 | 0.772   | 1.66  | 0.24    | 0.16    | -27.15|
| DX17  | C2b   | 3633-3670 | 0.780   | 1.79  | 0.21    | 0.14    | -28.05|
| DX18  | C1s   | 3510-3530 | 0.769   | 1.93  | 0.14    | 0.19    | -26.35|
| DX10  | C1s   | 3025-3048 | 0.769   | 2.55  | 0.23    | 0.11    | -25.44|
| M8    | C1s   | 4557-4593 | 0.801   | 2.82  | 0.21    | 0.09    | -23.97|
| DX33  | C1s   | 3518-3526 | 0.749   | 3.86  | 0.20    | 0.07    | -23.49|
| C54   | C2b   | 2984-3060 | 0.773   | 4.29  | 0.23    | 0.07    | -23.25|
| C55   | C2b   | 3348-3358 | 0.764   | 2.57  | 0.21    | 0.09    | -23.46|
| C27   | C2b   | 2778-2790 | 0.772   | 2.84  | 0.22    | 0.08    | -24.46|

5.Conclusions
The carbon isotopic characteristics of individual hydrocarbons of the C1s and C1d source rocks extractions can be used as an efficient index to divide these two sets of source rocks. What’s more, compared the carbon isotopic characteristics of individual hydrocarbons of Carboniferous condensate oils associated with natural gas with source rocks, the C1d source rocks have an important contribution to the Carboniferous natural gas in Dinan Uplift, and it should be a mixture of hydrocarbons derived from both C1s and C1d.

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