Organic carbon, bitumen content and maturity of Lower Cambrian source rocks in the northern margin of Tarim Basin

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Abstract. The lower Cambrian source rocks in the Keping area of the northwest basin ranges 1.49%-14.07%, and the content of bitumen ranges 7.73-24.53 mg / g • TOC. However, the organic carbon content of the lower Cambrian outcrop samples in the Sugetebulake section ranges from 0.93% to 7.90%, and the soluble organic matter content from 0.73 to 5.89 mg / g • TOC. The TOC of Lower Cambrian source rocks in the Keping area of the northwest basin ranges from 0.75% to 1.42%, and the content of bitumen is between 2.97-3.94 mg / g • TOC. In terms of organic matter abundance, the Cambrian source rocks developed in gentle slope facies are better than those in deep-water shelf facies. The measured reflectance (Ro%) of Shairik shallow drilling samples is between 1.0% - 1.7%, with an average of 1.45%. The Ro% of Sugatebulak samples is between 1.4%-1.75%, with an average of 1.55%, indicating that the overall maturity of the source rocks in the northwest is in the condensate wet gas stage. The measured reflectance of the Cambrian source rocks in the Yardangshan and Kuruktag sections in the northeast of the basin is between 1.5-2.5% RO, with an average of 1.75% ro. The overall maturity of the source rocks in the northeast of the basin is relatively higher, suggesting a wet gas stage.

1. Introduction
The lower Paleozoic in Tarim Basin is the key area for deep oil and gas exploration, and the lower Cambrian source rock is the focus of current research (He Zhiliang et al., 2000; Jia et al., 2002; Jin Zhijun, 2011; Wang Zhaoming et al., 2014; Zhu et al., 2018). However, due to the deep burial depth,
there are few samples of Lower Cambrian source rocks revealed by drilling, which greatly restricts the study of Lower Cambrian source rocks (Zhu Guangyou et al., 2017; Zhu et al., 2018). The lower Cambrian source rocks are widely exposed in the northwest of the basin, which provides a good condition for the study of source rocks. In this paper, the organic geochemistry of three sections and a shallow drill sample from Aksu Area in the northwest and Kuruktag area in the northeast of the basin has been systematically analyzed. This paper mainly studies the organic carbon content, organic matter type and maturity of source rocks, aiming to provide useful information for the evaluation of Lower Cambrian source rocks.

2. Study area and method

There are two sections in Aksu Area in the northwest of the basin: Sugetebulak section and Shierke section. In both sections, Sinian and Cambrian strata are exposed to surface. From the bottom to the top the exposed strata are the dolomite of Sinian Qigebulake Formation, the mudstone siliceous rock of lower Cambrian Yuertusi Formation, and the dolomite of Xiaoerbulak Formation, while in the Yardang mountain section of the Northeastern Tarim Basin, the main exposed strata include Sinian Shuiquan formation, the lower Cambrian Xishanbulake formation and Xidashan formation. The Cambrian section and stratigraphic distribution of the northern Tarim Basin are shown in Fig. 1. We have systematically collected samples in these three sections, and carried out shallow drilling work in the Shierke section for providing the shallow drilling samples for comparison.

![Figure 1. Cambrian sections and stratigraphic distribution in northern Tarim Basin (from [3])](image)

In this paper, the organic geochemistry of the lower Cambrian samples collected from outcrops and shallow boreholes in the basin are systematically analyzed and compared with those from Yingdong 2, Milano 1, Tazhong 12, LT 1, etc. The main analysis includes RockEval analysis, bitumen extraction, kerogen preparation and analysis, asphalt reflectance measurement and laser Raman spectroscopy analysis. RockEval 6 pyrolysis analyzer was used for rock pyrolysis analysis. Soluble organic matter was extracted by Soxhlet extraction method with chloroform as solvent, and the bitumen content was determined after constant weight. The bitumen reflectance was measured by using microphotometer (Model 3Y Leica DMR XP). Each sample is scanned to ensure that the number of measuring points is about 20-50. Finally, the median average value of maturity data is selected as the maturity of corresponding samples (Xiao Xianming et al., 1991; Liu Dehan et al., 1994). A micro laser Raman spectrometer (HORIBA-JY 37) is used for laser Raman spectrum analysis. Bitumen is selected for measurement under the same microscopic field of view. Five points are generally tested for each sample, and the average value is taken as the final result.
3. Results and discussion

3.1 Content of organic carbon and bitumen

The contents of organic carbon and soluble organic matter in source rocks are shown in Table 1. The organic carbon content of the lower Cambrian source rocks in the Keping area of the northwest basin is between 1.49% and 14.07%, and the content of soluble organic matter is between 7.73 and 24.53 mg / g • TOC. However, the organic carbon content of the lower Cambrian outcrop samples from the Shierke and Sugetbulak sections ranges from 0.93% to 7.90%, and the soluble organic matter content ranges from 0.73 to 5.89 mg / g • TOC. The organic carbon content of Lower Cambrian source rocks in Yardang mountain area of the northeastern basin is low, ranging from 0.75% to 1.42%, and the content of soluble organic matter is between 2.97 ~ 3.94 mg / g • TOC. The organic carbon content of Cambrian source rocks in well LT 1, northern Tarim Basin, is between 0.33% and 10.13%, and that of soluble organic matter is 26.42-91.07 mg / g • TOC. The organic carbon content of LT1-3 and LT1-4 cores of two limestone sections is relatively low (0.33-0.53%). The organic carbon content of Cambrian source rocks in well Milan 1 and well Yingdong 2 in the east of the basin is between 0.57% and 2.02%, and the content of soluble organic matter is between 7.12 and 21.43 mg / g • TOC. The lower Cambrian source rocks in the western part of the basin belong to the upper gentle slope sedimentary facies; the Cambrian in LT 1 well in Tabei area belongs to the lower gentle slope sedimentary facies; in the East, Milan 1, Yingdong 2 and Tadong 2 belong to Deep-water shelf sedimentary facies. In terms of organic matter abundance, the Cambrian source rocks developed in gentle slope facies are better than those in deep-water shelf facies.

| Section /well | Depth m | Layer | Bitumen A ppm | Bitumen A mg/g. TOC | TOC % | Saturate % | Aromatic % | Resin % | Asphaltene % |
|--------------|----------|-------|---------------|---------------------|-------|------------|-----------|---------|---------------|
| Shierke      | 2.00     | C1y   | 549           | 9.53                | 5.76  | 12.91      | 31.88     | 35.56   | 19.65         |
| Shierke      | 3.00     | C1y   | 1244          | 8.84                | 14.07 | 19.82      | 31.82     | 34.99   | 13.37         |
| Shierke      | 4.00     | C1y   | 224           | 14.59               | 1.54  | 30.11      | 22.29     | 23.68   | 23.92         |
| Shierke      | 5.00     | C1y   | 1244          | 8.31                | 6.86  | 23.90      | 27.08     | 32.64   | 16.38         |
| Shierke      | 6.00     | C1y   | 274           | 12.96               | 2.12  | 31.76      | 18.10     | 32.94   | 17.19         |
| Shierke      | 7.00     | C1y   | 550           | 11.13               | 4.94  | 12.94      | 30.20     | 37.37   | 19.48         |
| Shierke      | 8.00     | C1y   | 290           | 16.08               | 1.81  | 46.61      | 15.43     | 19.43   | 18.53         |
| Shierke      | 9.00     | C1y   | 301           | 16.10               | 1.87  | 35.84      | 20.09     | 31.03   | 13.05         |
| Shierke      | 10.00    | C1y   | 410           | 24.53               | 1.67  | 51.65      | 13.40     | 20.11   | 14.84         |
| Shierke      | 11.00    | C1y   | 294           | 13.95               | 2.11  | 35.52      | 10.15     | 29.84   | 24.49         |
| Sugetbulak   | 1.00     | C1y   | 45            | 4.82                | 0.93  | 40.05      | 5.47      | 41.26   | 13.22         |
| Sugetbulak   | 2.00     | C1y   | 50            | 3.93                | 1.26  | 27.40      | 2.74      | 49.59   | 20.27         |
| Sugetbulak   | 3.00     | C1y   | 53            | 5.40                | 0.98  | 19.18      | 11.64     | 54.35   | 14.83         |
| Sugetbulak   | 4.00     | C1y   | 26            | 0.73                | 3.61  | 5.49       | 27.74     | 50.00   | 16.77         |
| Sugetbulak   | 5.00     | C1y   | 46            | 2.89                | 1.59  | 19.78      | 10.55     | 59.12   | 10.55         |
| Sugetbulak   | 6.00     | C1y   | 37            | 1.17                | 3.12  | 18.75      | 1.30      | 68.23   | 11.72         |
| Sugetbulak   | 7.00     | C1y   | 46            | 1.08                | 4.29  | 2.65       | 4.65      | 87.96   | 4.74          |
| Sugetbulak   | 8.00     | C1y   | 31            | 3.22                | 0.95  | 91.94      | 3.80      | 4.10    | 0.09          |
| Shierke      | 1.00     | C1y   | 84            | 2.79                | 3.02  | 19.40      | 3.62      | 65.30   | 11.68         |
| Shierke      | 2.00     | C1y   | 43            | 1.12                | 3.88  | 40.82      | 3.47      | 45.04   | 10.67         |
3.2 Maturity

Bitumen is the main form of organic matter in highly mature marine source rocks, and its reflectance is an effective maturity index of marine source rocks (Xiao Xianming, 1991; Liu Dehan et al., 1994). In this study, 8 samples of outcrop and shallow drilling in Shierky, Suguteblak and Kuruktag sections in the north of the basin were observed and reflectance of organic matter was measured. The results of four source rock samples of Yuertusi formation are shown in Fig. 3. It can be seen that the source rocks of Yuertusi formation contain a lot of bitumen. Besides the dispersed bitumen, there are also lumps and strips of bitumen, which indicates that the source rocks of Yuertusi formation have experienced strong hydrocarbon generation. The relatively large pitch shows size of tens of microns, which provides a good sample for the measurement of reflectance. The measured reflectance of Shairik shallow drilling samples is between 1.0% - 1.7% Ro, with an average of 1.45% Ro. The measured reflectance of Sugate Bulak samples is between 1.4% - 1.75% Ro, with an average of 1.55% Ro, indicating that the overall maturity of the source rocks in the northwest is in the condensate to wet gas stage. The measured reflectance of the Cambrian source rocks in the Yardangshan and Kuruktag sections in the northeast of the basin is between 1.5 - 2.5% Ro, with an average of 1.75% Ro. The overall maturity of the source rocks in the northeast is in the wet gas stage. This result is also consistent with the results of early tectonic and thermal studies (Wang et al., 2010; Qiu et al., 2012).

|         |         |        |        |        |        |        |        |        |
|---------|---------|--------|--------|--------|--------|--------|--------|--------|
| Shierke | C1y     | 3.00   | 4.00   | 5.00   | 6.00   | 7.00   | 8.00   | 9.00   |
|         | 97      | 63     | 272    | 172    | 287    | 132    | 195    | 61     |
|         | 1.83    | 1.22   | 3.32   | 2.76   | 5.10   | 4.81   | 3.70   | 4.62   |
|         | 5.28    | 5.21   | 8.20   | 6.22   | 5.62   | 2.74   | 5.26   | 3.01   |
|         | 35.42   | 17.80  | 9.06   | 21.71  | 24.45  | 7.83   | 5.84   | 9.50   |
|         | 7.61    | 54.55  | 3.99   | 56.63  | 13.23  | 5.64   | 2.56   | 66.46  |
|         | 42.89   | 16.79  | 47.39  | 8.60   | 38.88  | 54.66  | 43.27  | 20.48  |
|         | 14.08   | 10.86  | 39.57  | 16.34  | 23.44  | 31.88  | 48.33  | 19.95  |

| Shierke | C1y     | 10.00  | 11.00  | 12.00  | 13.00  | 14.00  | 15.00  | 16.00  |
|---------|---------|--------|--------|--------|--------|--------|--------|--------|
|         | 139     | 148    | 139    | 148    | 139    | 148    | 139    | 148    |
|         | 3.70    | 4.62   | 3.01   | 4.81   | 3.70   | 4.62   | 3.01   | 4.81   |
|         | 5.26    | 5.26   | 5.84   | 2.74   | 5.26   | 5.26   | 5.84   | 2.74   |
|         | 5.84    | 9.50   | 2.56   | 66.46  | 5.84   | 9.50   | 2.56   | 66.46  |
|         | 42.89   | 42.25  | 43.27  | 48.33  | 42.89  | 42.25  | 43.27  | 48.33  |
|         | 14.08   | 31.88  | 48.33  | 19.95  | 14.08  | 31.88  | 48.33  | 19.95  |

3.2 Maturity

Bitumen is the main form of organic matter in highly mature marine source rocks, and its reflectance is an effective maturity index of marine source rocks (Xiao Xianming, 1991; Liu Dehan et al., 1994). In this study, 8 samples of outcrop and shallow drilling in Shierky, Suguteblak and Kuruktag sections in the north of the basin were observed and reflectance of organic matter was measured. The results of four source rock samples of Yuertusi formation are shown in Fig. 3. It can be seen that the source rocks of Yuertusi formation contain a lot of bitumen. Besides the dispersed bitumen, there are also lumps and strips of bitumen, which indicates that the source rocks of Yuertusi formation have experienced strong hydrocarbon generation. The relatively large pitch shows size of tens of microns, which provides a good sample for the measurement of reflectance. The measured reflectance of Shairik shallow drilling samples is between 1.0% - 1.7% Ro, with an average of 1.45% Ro. The measured reflectance of Sugate Bulak samples is between 1.4% - 1.75% Ro, with an average of 1.55% Ro, indicating that the overall maturity of the source rocks in the northwest is in the condensate to wet gas stage. The measured reflectance of the Cambrian source rocks in the Yardangshan and Kuruktag sections in the northeast of the basin is between 1.5 - 2.5% Ro, with an average of 1.75% Ro. The overall maturity of the source rocks in the northeast is in the wet gas stage. This result is also consistent with the results of early tectonic and thermal studies (Wang et al., 2010; Qiu et al., 2012).
4. Conclusions

The organic carbon content of the lower Cambrian source rocks in the Keping area of the northwest basin is between 1.49% and 14.07%, and the content of soluble organic matter is between 7.73-24.53 mg / g •TOC. However, the organic carbon content of the lower Cambrian outcrop samples in the Sugetebulak section ranges from 0.93% to 7.90%, and the soluble organic matter content ranges from 0.73 to 5.89 mg / g • TOC. The organic carbon content of Lower Cambrian source rocks in Yardang mountain area of northeast basin is low, ranging from 0.75% to 1.42%, and the content of soluble organic matter is between 2.97-3.94 mg / g • TOC.

From the perspective of organic matter abundance, the Cambrian source rocks developed in gentle slope facies are better than those in deep-water shelf facies. Relatively speaking, the abundance and preservation of organic matter in the lower Cambrian source rocks of Shairek shallow drilling are better than those of Shierke and Sugetebulak sections.

The measured reflectance of Shairek shallow drilling samples is between 1.0%-1.7%, with an average of 1.45%. The measured reflectance of Sugate Bulak samples is between 1.4%-1.75%, with an average of 1.55%, indicating that the overall maturity of the source rocks in the northwest is in the condensate wet gas stage. The measured reflectance of the Cambrian source rocks in the Yardangshan and Kuruktag sections in the northeast of the basin is between 1.5-2.5% Ro, with an average of 1.75% Ro. The overall maturity of the source rocks in the northeast of the basin is relatively high, suggesting a wet gas stage.

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