Properties of the organic matter of the Bazhenov suite in the Yugansk Megadepression based on Rock-Eval Pyrolysis

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Abstract. The article provides the Rock-Eval analysis data of rock samples and a broad description of the organic matter of the Bazhenovsk suite of the Yugansk megadepression. The authors have designed and compared kinetic models for immature and mature organic matters.

1. Introduction
Nowadays, the Bazhenov suite is widely recognised as the main oil-and-gas source formation in West Siberia. In spite of the fact that there had been a great interest in this formation during the 70s and 80s of the last century, even today this interest is predominate. A 50-year study resulted in the thorough analysis of its petroleum potential. The progress in the global shale oil production in recent years demonstrated a growing interest in further exploration and production of the Bazhenov suite.

The presence of organic matter is the governing factor and main principle in evaluating oil source rock. In this case, the Rock-Eval pyrolysis is the best standard method to identify the organic carbon content in the rock, its potential residual generation, and the catagenetic organic matter maturity. The range of standard parameters determined by this method describes broadly the organic matter properties in rocks. Pyrolysis in combination with kinetic, geological and other data is the starting point for basin modelling.

This article describes the organic matter in the Bazhenov suite of the Yugansk megadepression based on pyrolysis data.

2. Location and geological setting
The Yugansk megadepression (Figure 1) is in the central part of West-Siberian oil-and-gas bearing basin and is confined to the Middle Ob oil-and-gas bearing region. The largest West Siberian oil deposits (Samotlorsk, Fyodorovsk, etc.) are located here. This main oil and gas potential region consists of Jurassic and Lower Cretaceous sediments.

The Yugansk megadepression forms a complicated internal structure (Figure 2), which is divided into two depressions (Fainsk and Kulunsk), two troughs and Yuzhno-Kinyaminsk swell. The southern megadepression edge involves two ridges separated by ravines, while on the south-east facing edge- a monocline (Yuzhno-Vartovsk) and terrace (Negusynsk). The Yarsonovsk trough is situated in the north of the megadepression.

The Bazhenov suite (Yugansk megadepression) contains carbonate-siliceous clay sediments enriched by organic matter which range from the Volgian of Upper Jurassic to the Lower Berriasian substage (Lower Cretaceous). For a more detailed examination 198 core samples were retrieved from 13 wells within the Bazhenov formation section.
3. Methodology

The Rock-Eval 6 Turbo tool is the latest version of the Rock-Eval product line, being the best method for its high analysis accuracy [1]. Rock-Eval analysis is a quick and common method for initial evaluation of geochemical characteristics of source rocks.

The samples were pulverised, and about 30 mg of each sample were analysed by using the Rock-Eval 6 Turbo (Bulk Rock method). Thus $S_1$, $S_2$, $S_3$, $T_{\text{max}}$, TOC and MinC values were obtained. $S_1$ is the amount of free hydrocarbons (mg HC/g rock) in rock pore space at 300°C. Peak $S_2$ is the amount of hydrocarbon released during thermal cracking of kerogen (mg HC/g rock) and heavy hydrocarbons at 300–650°C and heating rate 25°C/min. (temperature-programmed pyrolysis). This parameter represents the residual oil-generating potential. The temperature complying with the maximum amount generated hydrocarbons $S_2$ is termed $T_{\text{max}}$. $S_3$ is the CO$_2$ amount formed as a result of the decomposition of carboxyl groups and other oxygen-containing kerogen compounds at 300 to 400°C. Total organic
carbon (TOC) and mineral carbon (MinC) content is determined by the oxidation of organic matter after pyrolysis (850°C in air). Hydrogen index (HI) is the \( S_2 \) value \( (S_2/TOC) \) expressed in mg HC/g TOC. Oxygen index (OI) is related to the oxygen amount in kerogen and is the normalised value \( (S_3/TOC) \). Production index (PI) shows the level of thermal maturation PI=\( S_1/(S_1+S_2) \).

Chloroform was used in sample extraction for kinetic investigation in the Soxhlet extractor during 72 hours. After extraction, the samples were dried at 70°C for 8 hours and further analysed in the Rock-Eval 6 Turbo (Optkin method) at heat rate of 5, 15 and 25°C/min. Kinetic parameters were calculated by the Optkin 3.0.3 program. Optkin is based on the kinetic model of Tissot and Espitalie which predicts the amount of hydrocarbons generated by the primary cracking of kerogen when temperature increases through time [2].

4. Results and discussion
The average Rock-Eval parameter values of rock samples from each of the 13 wells are presented in table 1.

| Well No | Quantity of samples | Depth (m)   | \( S_1 \) (mgHC/g rock) | \( S_2 \) (mgHC/g rock) | PI | \( T_{\text{max}} \) (°C) | HI (mgHC/g TOC) | OI (mgCO\(_2\)/g TOC) | TOC (wt%) | MinC (wt%) |
|---------|---------------------|-------------|-------------------------|-------------------------|----|--------------------------|-----------------|---------------------|-----------|------------|
| 1       | 10                  | 2480-2490   | 3.16                    | 67.65                   | 0.04 | 423                      | 652             | 1                   | 10.42     | 1.37       |
| 2       | 7                   | 2713-2718   | 5.26                    | 87.31                   | 0.06 | 423                      | 636             | 0                   | 13.63     | 0.86       |
| 3       | 23                  | 2924-2941   | 5.26                    | 70.87                   | 0.07 | 430                      | 668             | 0                   | 10.61     | 0.65       |
| 4       | 4                   | 2846-2857   | 8.32                    | 87.30                   | 0.09 | 432                      | 638             | 0                   | 13.73     | 0.82       |
| 5       | 3                   | 2794-2795   | 3.35                    | 44.12                   | 0.08 | 433                      | 6.33            | 0                   | 6.64      | 0.31       |
| 6       | 4                   | 2780-2782   | 4.16                    | 42.29                   | 0.09 | 434                      | 631             | 0                   | 6.62      | 0.17       |
| 7       | 47                  | 2846-2874   | 7.25                    | 69.48                   | 0.10 | 434                      | 619             | 0                   | 11.12     | 0.99       |
| 8       | 17                  | 2867-2878   | 6.43                    | 51.87                   | 0.11 | 435                      | 621             | 0                   | 8.24      | 0.82       |
| 9       | 19                  | 2830-2844   | 6.29                    | 61.29                   | 0.10 | 436                      | 624             | 0                   | 9.79      | 0.26       |
| 10      | 20                  | 2902-2981   | 8.58                    | 73.11                   | 0.10 | 436                      | 602             | 0                   | 12.18     | 0.75       |
| 11      | 14                  | 2739-2749   | 5.97                    | 48.75                   | 0.11 | 437                      | 608             | 0                   | 7.91      | 1.61       |
| 12      | 20                  | 2964-2974   | 9.11                    | 63.92                   | 0.13 | 438                      | 537             | 0                   | 11.81     | 2.76       |
| 13      | 10                  | 2812-2825   | 7.44                    | 60.08                   | 0.12 | 439                      | 568             | 0                   | 10.46     | 0.54       |

Table 1. Average values of Rock-Eval parameters for rocks in the wells under study

Bazhenov suite rocks in all the studied wells have an excellent generation potential \( (S_2) \). Low OI is typical for organic matter accumulating in reduction conditions. HI–\( T_{\text{max}} \) Diagram (figure 3) shows that the samples are influenced by the evolution of I-II type kerogen which generates oil [3].

According to catagenesis level, rocks from Wells 1-3 are immature. This fact is confirmed by low PI (PI< 0.10) and \( T_{\text{max}} \) (423–430°C), which responds to catagenesis level MC\(_1^1\) [4]. Rocks from wells № 4-13 are mature and have already entered the main oil generation phase ("oil window"). Their \( T_{\text{max}} \)
varies from 432 to 439°C, which responds to catagenesis level MC$_1^2$ [4]. Increased PI values (PI≈0.10) prove this fact.

Figure 3. HI–T$_{\text{max}}$ diagram.

Figure 4 shows the distribution of energy activation of an immature sample from well № 2, and a mature sample from well № 13. Comparing the histograms in figure 4, it can be observed that the mature sample has already reached its generation potential, which, in its turn, corresponds to the chemical bonds with activation energy 48 kcal/mol and equal to 130 mgHC / gTOC or about 20% of initial 660 mgHC / gTOC.

Figure 4. Activation energy distribution.
The dependence of oil source potential in immature rock from well № 2 to temperature increase (figure 5) proves the fact that within the temperature range of 430-440°C, kerogen embraces 14-23% of its oil source potential.

5. Conclusions
Based on the results of Rock-Eval pyrolysis of rock samples retrieved from Yugansk megadepression, it was concluded that

- all examined source rocks have not only an excellent generating potential ($S_2$) but also high total organic carbon (TOC);
- rock organic matter is related to kerogen type I-II, which is the major source in the generation of liquid hydrocarbons;
- catagenesis level alters from $\text{MC}_1^1$ to $\text{MC}_1^2$;
- the most mature source rocks in the investigated area have only reproduced 20% of its oil-generating potential.

References

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