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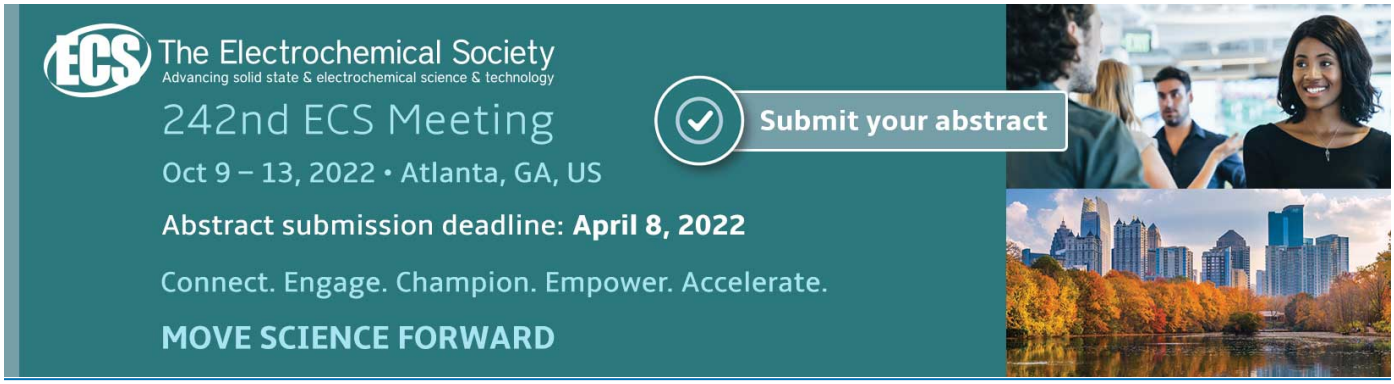

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Comparative analysis of lithological and geochemical features and conditions for the formation of oil and gas source rock strata

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Abstract. The typification according to the lithological and geochemical characteristics of the deposits that make up the sections of the two oil source strata: Domanik and Bazhen was carried out . Lithotypes are revealed. For each of the objects of study, a complex of laboratory studies of rocks and contained fluids was carried out. The relationships were revealed between the mineral composition of rocks, the content and types of contained organic matter, the degree of organic matter maturity,the chemical composition of the inorganic and component composition of the organic parts of study strata.

1. Introduction

The relevance of the study of sedimentary formations, often called oil and gas source rocks and black shales, is due to the reduction of active hydrocarbon reserves in traditional regions of their production, as a result of which the need to assess unconventional reservoir rocks increases [1]. According to the US Energy Information Administration (EIA), shale oil production by 2035 will reach 20.5% of the total oil production [2]. If you pay attention to the production of hydrocarbons in the United States and China in recent years, you can easily notice the actively growing production of shale oil and gas, which from zero at the beginning of the century reached almost 30% of the total production of hydrocarbons (figure 1).

In Russia, such objects include oil and gas source deposits of the Semiluksky horizon of the Frasnian stage of the Upper Devonian of the east of the East European platform (domanikite) and the Bazhenov formation of the Tithonian-Berriasian stages of the Jurassic-Cretaceous systems of Western Siberia (bazhenite) [3].

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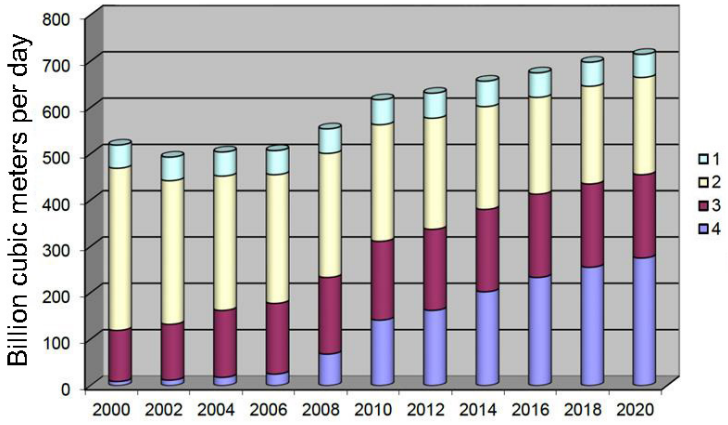


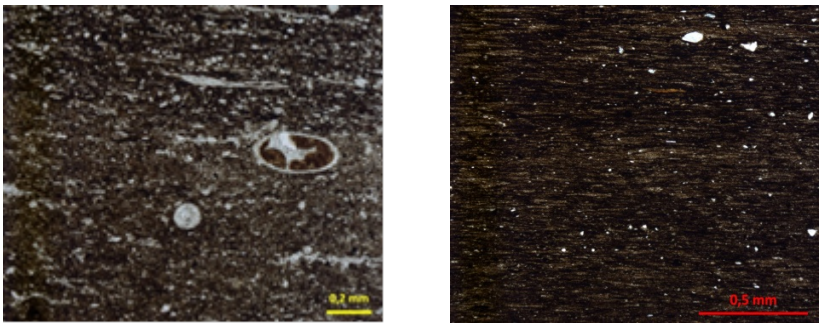
Figure 1. Dynamics of development of hydrocarbon gas production in the USA: 1- coalbed methane, conventional hydrocarbons, 2- traditional hydrocarbons, 3 - tight rock hydrocarbons, 4 - shale hydrocarbons [4].

2. Materials and methods

When working with the Domanikite and Bazhenite core material, at first, a macroscopic study was carried out to reveal their lithological and petrophysical heterogeneity. After that, a selection of main samples was carried out. Samples were sent to laboratory studies: reservoir properties and oil saturation, optical microscopy, X-ray analysis, X-ray fluorescence analysis, electron microscopic analysis, synchronous thermal analysis, pyrolysis by the RockEval method.

3. Results

Optical-microscopic analysis showed a high similarity of the studied objects. All of them are characterized by a predominantly pelitomorphic structure (figure 2), the presence of organic remains, mainly radiolarians, and much less frequently other remains.



Domanikite Bazhenite

Figure 2. Typical NL photographs of thin sections.

A large volume of the studied thin sections shows:

- Clastic fragments in Domanik deposits are practically not found, in Bazhen deposits they are found in rare layers;
- In the sediments of bazhen, sometimes, in addition to sapropel organic matter, coal material is found, which composes thin layers;
- Siliceous organic remains (radiolarians), visible under an optical microscope, are found very rarely, although sometimes they form separate layers.

X-ray analysis, as expected, showed a great similarity of the samples in terms of mineral composition. All of them contain minerals: quartz, calcite, hydromica and feldspar. Additional processing of data on the quantitative mineral composition of the studied samples in the program "Mathematical statistics" made it possible to assess the correlation between the identified minerals (table 1 a, b).

Table 1 a. Correlation of the mineral composition of domanikites (more than 100 samples).

Minerals	Calcite	Quartz	Feldspar	Hydromica
Calcite	1.00	-0.43	-0.46	-0.92
Quartz		1.00	0.39	0.25
Feldspar			1.00	0.42
Hydromica				1.00

Table 1 b. Correlation of the mineral composition of bazhenikites (more than 50 samples).

Minerals	Calcite	Quartz	Feldspar	Hydromica
Calcite	1.00	-0.34	-0.40	-0.28
Quartz		1.00	0.29	0.19
Feldspar			1.00	0.34
Hydromica				1.00

The results shown in the tables show a positive correlation between quartz, feldspar and hydromica; and negative between the named minerals and calcite. Moreover, the degree of both positive and negative correlation is greater for Domanik samples, less for Bazhenov samples. Hence, it can be concluded that there are two genetically different components that make up the strata. On the one hand, it is quartz, feldspars and hydromica, and on the other, calcite.

Synchronous thermal analysis has provided very important information about the structural state of quartz (figure 3). The analysis was carried out for samples of domanik and bazhen, which were compared with samples of sandstone and jasper. According to the given fragments of differential scanning calorimetry curves of the studied objects, “typical” quartz is found only in a sandstone sample, as evidenced by the endothermic effect at a temperature of ~ 573 ° C. Whereas in none of the samples of Domanik, Bazhen, and hydrothermal-sedimentary jasper, this thermal effect is found, which indicates a high structural imperfection of the quartz present in the samples [5]. In one of the works, such quartz was named nanoquartz, the formation of which is recognized as biogenic [6].

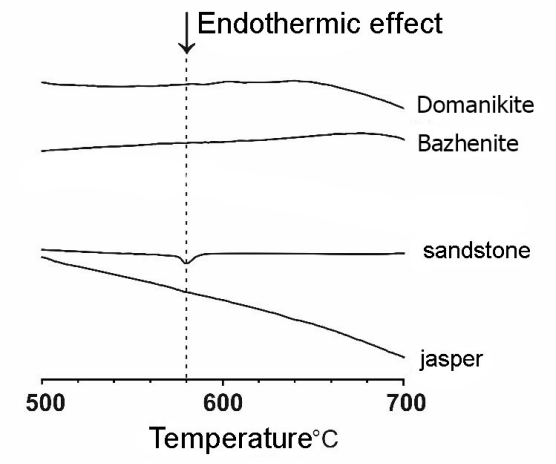
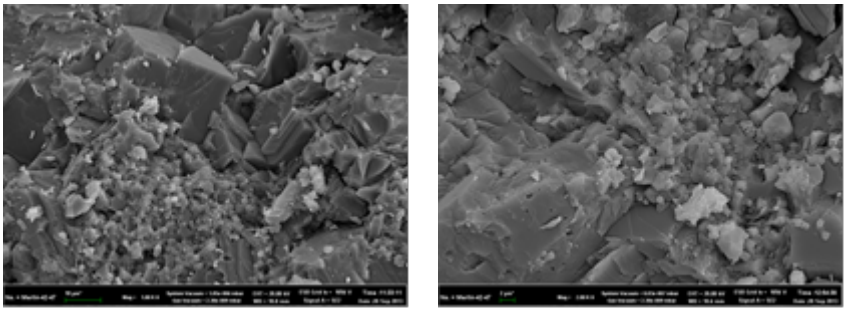


Figure 3. DSC curves of typical samples of Domanik, Bazhen, also sandstone and jasper.

Electron-microscopic analysis of samples of two studied oil and gas source strata made it possible to reliably establish the morphology of the main rock-forming minerals - quartz and calcite (figure 4). All photographs clearly show idiomorphic or hypidiomorphic calcite grains and quartz grains that look like intergrowths of grains close to isometric. The morphology of the latter, according to [7], is due to the biogenic method of its formation. Genesis of calcite, which has undergone recrystallization, cannot be reliably established from the given electron microscopic images, although many prove its biogenic origin in the form of micrite.



Domanik Bazhen

Figure 4. Electron microscopic photographs of typical samples of Domanik (a) and Bazhen (b).

X-ray fluorescence analysis was used to determine the chemical composition of the mineral content of the samples. Based on the results of analyzes in the "Mathematical Statistics" program, an attempt was made to detect correlations between the chemical components present in the samples.

The most successful relationships have been identified for the Domanik deposits (table 2). The established positive correlations between silica and biophilic chemical elements are important [8]. Rather high positive correlations may indicate a single source of input of silica and biophilic chemical elements into the sediment. A negative correlation between the main components of domanikites - SiO_2 and CaO - indicates different sources of their input into the sediment.

Table 2. Correlation relationships between chemical components in domanikite samples.

Components	Na_2O	MgO	Al_2O_3	SiO_2	P_2O_5	K_2O	CaO	TiO_2	V_2O_5	Cr_2O_3
SiO_2	**0.59**	-0.16	**0.55**	1	0.3	0.38	-0.93	0.42	**0.78**	0.27
CaO	-0.49	-0.12	-0.66	-0.93	-0.52	-0.52	1	-0.55	-0.83	-0.31

Note: The most significant positive connections are highlighted in bold.

Similar studies of Bazhen deposits did not reveal the same significant dependences, which is explained by the presence in the latter, according to optical microscopic observations, of an admixture of clastic material.

3.6. Pyrolytic studies carried out to determine the type of kerogen present in sediments with no signs or low clastic material showed the expected results (figure 5). It turned out that type I kerogen is present in the Domanik deposits, while type II kerogen is mainly present in the Bazhen deposits. In addition, the samples of bazhen may contain kerogen of types I and II. Type I kerogen is found in samples in which, according to optical microscopic analysis, no clastic component has been established, and type II kerogen is established in samples with the presence of a clastic material.

It is known that the main differences between kerogens of types I and II are that type I kerogen is composed of phytozooplankton residues, while type II kerogen also contains a humus component, i.e. remains of terrestrial vegetation [9-10].

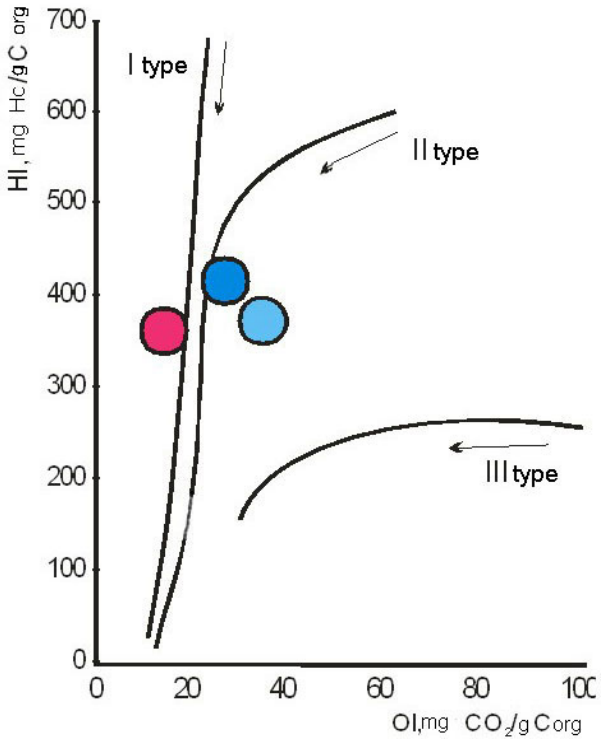


Figure 5. Modified Van Krevelen diagram with pyrolytic results. The circles show the average values of the oxygen index (OI) and hydrogen index (HI) for domanikites (red), bazhenite with almost no clastic material admixture (blue), bazhenite with clastic material admixture (blue).

4. Conclusion

Thus, a review of the two objects of study shows their features:

- Oil and gas source rocks of Western Siberia (bazhenites) occur among clastic deposits, while similar deposits in the east of the European part of Russia (domanikites) occur among carbonate rocks;
- The mineral composition of the two objects of study is close, however, the proportion of the clastic component in domanikites is minimal compared to bazhenites;
- The structure of rocks is predominantly pelitomorphic;
- Biogenic genesis of micro-grained quartz is assumed;
- Organic matter of domanitaks is determined mainly as type I kerogen, bazhenite - type I-II kerogen;
- As the reason for the enrichment of rocks with organic matter, the entry of biophilic chemical elements into the sedimentation zone is considered, which causes high bioproductivity;
- A positive correlation is found between the contents of quartz and organic matter, with other minerals the relationship of organic matter is not established or negative.

Acknowledgments

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