Toward the problem of oil and gas bearing capacity of the East Tom-Kolyvan structural zone (Western Siberia)

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Abstract

The vast depression in the east Tom-Kolyvan folded zone (West Siberia) has been identified by the geophysical data. The well which uncovered 4000 m deep profile of the Jurassic and Paleozoic deposits has been drilled. The relevance of the research is the oil/gas-bearing capacity evaluation of the discovered depression in this West Siberia area.

Introduction

The target of the research is to obtain geologic characteristics of the profile deposits. Lithological, petrographical, bituminological, X-ray fluorescence- microscopy, geochemical, nuclear-physics methods have been used during the analyses.

By the comprehensive research data the lithologic column and lithology-geochemical Paleozoic profiles of the deep well have been made. According to the obtained results the following conclusions have been drawn:

- the most ancient deposits of the depression are introduced by the volcanogenic-clastic rock sequence of the andesite-basalt composition with the moderately alkaline reduction;
- the younger rocks relate to the sedimentary sequence formed during various facial conditions: marine, coast-marine and lacustrine-swampy;
- in the marine environments the clayey deposits of the domanik facies are formed. These are characterized by the kerogen of type II, halo shows of the singenetic bitumoids of the mixed composition (from asphaltogenus to oily-resinous), and by the liquid hydrocarbon seeps;
- in the coast-marine and lacustrine-swampy environments the aleurite mudstones with the coal streaks are formed;
- the crust of weathering deposits are in the closure of the profile;

The conclusion for further research of the deposits has been made. This is due to possible oil/gas-generation domanik deposits extent in the vast area and future oil/gas field exploration.

Methodology

To address the problem of oil and gas-bearing capacity of the east Tom-Kolyvan structural zone, a parametric well Vostochnaya in the south-west of the West Siberia plate was drilled. It is located in the megadepression of about 300 km², to the depths of 4007 m.
The relevance of the work and the goal are due to the need to obtain a detailed lithologo-petrographical and geochemical information on the deposits of the Paleozoic basement in the center of the depression. Currently it is the only deep drilling object in the new oil-gas bearing area.

To achieve the goal, 138 core samples were selected from the basement rocks in the range of 3400 - 4007 m. All of them were examined visually and with the use of a binocular microscope. Petrographic thin sections were made out of 42 samples. For the detailed studies the following methods were used: petrographic, nuclear geochemistry, bituminologic, X-ray fluorescence. The selected set of methods allows understanding the processes of sedimentogenesis, postsedimentogenesis changes of the studied deposits, as well as tracing the fluids migration, including hydrocarbon ones. For all specimens were given the lithologic and petrographic descriptions, besides, the names of rocks by the modern classifications and classification of [4-5]. Petrographic thin sections were studied by the polarized light microscope POLAM 213M, by the ultraviolet light microscope MICMED-2 and LUMAM-2M. Elementary and chemical composition of basaltoids in clastic material was identified by the analyzer XGT-7200. All samples were studied on the basis of the research nuclear reactor of Tomsk Polytechnic University by the delayed neutrons method. The concentrations of uranium and aluminum were identified, and lithgeochemical profiles were made.

The results of petrographic and nuclear-geochemical studies have shown that the basement in the major part, mainly, in the low part of the profile is characterized by a volcanogenic-clastic sequence of the basic rocks. From the depth of 3394m it is accompanied by the interlayers of high-carbon content, mainly argillaceous rocks.

Volcanogenic-clastic sequence is represented by the tuffs and consists mainly of basaltoid fragments. The textures of the clastic rocks are psammitic psephitic, and aleurite. The upper profile section is made of coarse rock fragments varieties, the low profile section - is of less coarse fragments. These are dense, uniform, well - lithified. Basaltoid rocks are often almond-shaped. Volcanic rocks are predominantly ophitic: poikilophitic, doleritic which occur in the upper part of the profile; anamesite, hyalo-ophitic textures are common in the low part of the profile. The changed plagioclase, pyroxenes and relict minerals occur in the rock composition. Besides, there are minerals that replace them and take part in the amygdules composition: chlorides, siliceous minerals and titanium minerals.

It is an important fact that potassium feldspars occur in a number of basaltoid rock composition. They are found in the plagioclase interstitials and partly replace them (figure 1-a). The presence of potassium feldspar is confirmed by the X-ray fluorescent analysis (figure 1-b). The determined amount of potassium can pertain the basic rocks to moderately alkaline, mainly potassium ones.

Figure 1 (a, b). Basaltoids: a) the mineral composition: 1-microliths alteration. 2-orthoclases. 3-chlorites (HC. 10 x, N +); b) element composition of basaltoid fragments: high level of potassium and calcium, sodium.
Judging by the amount of potassium K$_2$O (average content 2.64%), some basalt belongs to moderately alkaline, i.e. trahybasalt [5].

At the top of the studied Paleozoic basement profile there revealed intervals (3541.5 ...3544.7, 3546.0 ...3548.6 m.) of the basic sedimentary rocks. They are characterized by the high-content carbon aleurite mudstones with thin coal streaks and remains of plant detritus. In the sample from the depth of 3396.9 m the spores are visible (figure 2-a), which indicate the humus substance taking part in their formation.

![Figure 2(a, b): a) Mudstones: aleurite mudstone (1) with the coal streaks (2) and (3) the spore relics (HC. 10 x N |); b) mudstone with thin interlayers of the phosphate substance (1) (HC. 3 N |).](image)

The thin interlayers of high-carbon content mudstone in the interval of 3541.5-3548.6 m are characterized by saturation. These should be attributed to oil-generated domanik deposits by a number of features [2]. Very thin stratification is one of the properties resulting from the climate aridization. (figure 2-b). The second feature is the clayey composition with microclasts. The main feature is the presence of oil-generated kerogen of type II [6-7]. It is red, amorphous geopolimer with a halo of a bituminous substance. Singenetic shows of type II kerogen and bitumoids are in figure 3. Bitumoids are characterized by a complex mixture of various components: from oily-resinous to asphaltenous ones. (figure 3-b).

It is important to emphasize that in the interval of 3541.5-3550.0 m. oil in a liquid form is found. According to Gribov et.al. research [6], the oil is heavy ($\rho = 0.921$ g/cm$^3$ at $t = 22^\circ$ C), high viscosity oil ($\eta = 0.3$ MPa, 38 $\times$ c), paraffin-base oil (T freezing = 40$^\circ$ C), with the dominance of methane. When testing the horizon with domanik deposits and increased output of the liquid hydrocarbons is represented by the letter "M". The horizon refers to the type of domanik deposits with the thickness of 8.5 m. For the low-thickness domanik deposits it is a traditional one.

![Figure 3(a, b). Mudstone:a) mudstones with the inclusion of type-II kerogen (1) accompanied by a halo of a bituminous (2) (HC. 10 x N +); b) bitumoids in a halo of type-II kerogen: 1-oily - resinous, 2- asphaltenous (HC. 100 x).](image)
The presence of type-II kerogen is easily identified by nuclear-geochemical core sample investigations. Rocks with the increased uranium concentrations up to 6 g/t are in the range of 3541.5–3549.5 m. and belong to domanik deposits.

By the XRF analysis in the horizon M two different environmental facies of mudstone formation are identified: mudstones with organic humus in the range of 3396.9–3430.0 m. and mudstones with organic sapropel, type II kerogen in the range of 3541.5–3544.7 m. By XRF analysis in the organic humus mudstones formed in the oxygen–rich environments (that contain O₂ in different quantities) there is less amount of P, S, Cl, Ti, Cr, Mn, Fe, Cu, Ir, Bi. Sapropel mudstones formed in the sharp reduction environment are characterized by the increased amount of chemical substances. This accounts for the conception of heavy metals accumulation in the absence of hydrogen during the process of diagenesis. [7]

The research of bitumoids distribution peculiarities in rocks of the profile was carried out by two methods: fluorescence microscopy [8] and by the chloroform extract analysis [9]. The results of the second method are in the lithogeochemical profile. Their shows provided the identification of the thickness in the upper section of the Paleozoic profile. Several anomalous concentrations of bitumoids in the interval of 3395-3555 m have been identified: at the depth of 3396.6 m, and in the intervals of 3401.0–3403.4 m., 3422.4–3423.6 m., 3430.1–3432.0 m., 3484.3–3488.8 m., 3541.5–3549.5 m. Bitumoids shows are also confirmed by the fluorescence microscopy method. This method identifies higher quantities of hydrocarbon fluids for the rock marked intervals. The bitumoids largely correspond to medium and heavy, from oily-resinous to resinous-asphaltenous that are most characteristic for syngenetic bitumoids. In the low section of the profile the bitumoid shows are insignificant. They are characterized by the light hydrocarbons distributed through the thin cracks in the rocks, and are referred to the epigenetic bitumoids. (figure 4-a).

The pores and fractures were studied by the microscopic method. The presence of the interstitials was identified through all rocks of the profile. Pores are of irregular shape, they look like leaching pores (figure 4-b) which are not interrelated. At the same time, the schistosity and jointing zones are determined in the profile. Friction planes with bitumoid characteristics occur in some samples of the intervals.

Figure 4 (a, b) peculiarities of the interstitials: a) cracks with traces of light bitumoids; b) leaching voids in basaltoids (1) (HC. 10 x, N |).

Conclusion

The given research concludes: among the basaltoid sequence deposits the interlayers of high-carbon content sedimentary rocks (mostly mudstones in the horizon M) occur. Among them there are
carbonaceous mudstone (mudstones with coal streaks) and domanik deposits with type II kerogen. The identified thickness of the domanik deposits is 8.9 m, with the large promising areas waiting for the core analysis to be performed. Thus, Paleozoic basement sedimentary deposits are considered to be the center of oil/gas generation in the area, and the eastern territory of Tomj Kolyvan structural zone – the promising one.

References

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