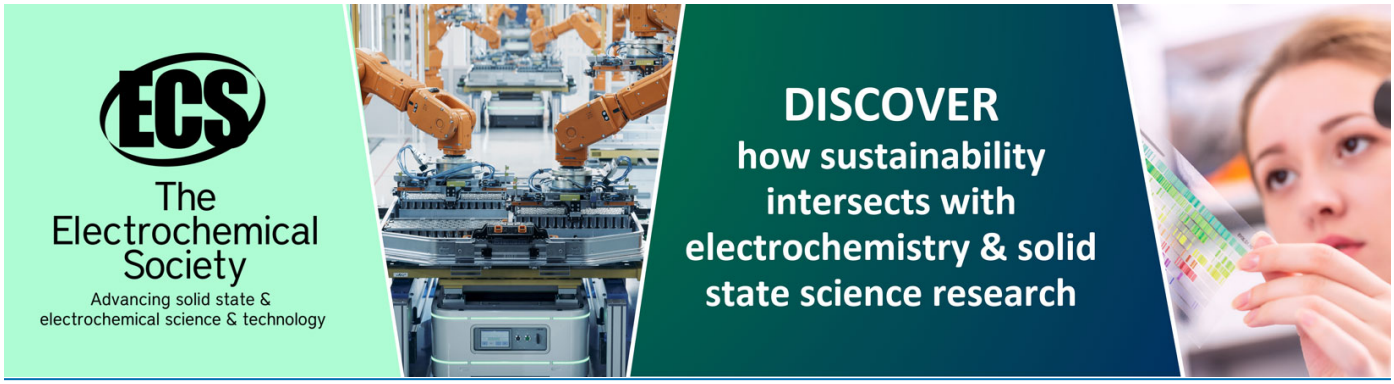
Features of the Geological Structure and Estimation of the Extraction Potential of the Sediments of the Bazhenov Formation in the Territory of Khanty-Mansiysk Autonomous Okrug



Features of the Geological Structure and Estimation of the Extraction Potential of the Sediments of the Bazhenov Formation in the Territory of Khanty-Mansiysk Autonomous Okrug

A A Sevastianov[1], K V Korovin[1], O P Zotova[1], D B Solovev [2, 3]

[1]Faculty of Development and Operation of Oil and Gas Fields of the Institute of Geology and Oil and Gas Production Industrial University of Tyumen, 38, Volodarskogo street, Tyumen, 625000, Russia
[2] Far Eastern Federal University (FEFU), 8, Sukhanov St., Vladivostok, 690950, Russia
[3] Vladivostok Branch of Russian Customs Academy, 16, Strelkovaya St., Vladivostok, 690034, Russia

E-mail: contact@ogtcentre.ru, solovev.db@dvfu.ru

Abstract. The work uses lithological analysis and a method of statistical analysis of the distribution of the main counting parameters, drained reserves and fishing indices of the development of the deposits of the Bazhenov formation. An analysis of the geological features of the structure and composition of rocks of the Bazhenov suite in the territory of the Khanty-Mansiysk Autonomous Okrug was carried out. Types of reservoirs and features of fluid filtration are considered. The characteristics of the properties of oil and kerogen are presented, the data on the formation of liquid hydrocarbons upon initiation of pyrolysis are given. The analysis of the operational experience of the wells was carried out, two groups of wells with different nature of the development of reserves were identified. The well performance indicators for oil and gas bearing areas of the Khanty-Mansiysk Autonomous Okrug – Ugra have been estimated. The forecast of oil production from the Bazhenov formation has been carried out for these deposits for a long-term perspective, taking into account the experience of developing foreign analogues. The assessment of oil production prospects based on the use of proven modern technologies in this paper indicates a limited potential. Mass drilling through regular well nets is not practical.

1. Introduction

Bazhenov formation is a unique geological complex, which is located almost throughout the entire territory of Western Siberia, including the Khanty-Mansiysk Autonomous Okrug – Ugra, is indexed to the Jurassic reservoir J0. Its area of distribution is about 1200000 km2, including 220000 km2 in the territory of KhMAO-Ugra. Many scientists believe that the Bazhenov formation has a significant mining potential, and at the same time is characterized by a number of factors that make it difficult to involve it in development. The study of the Bazhenov is reflected in the works of I.I. Nesterov [1], A.E. Kontorovich [2], M.Yu. Zubkov [3, 4], V.S. Melik-Pashaev and E.M. Halimov [5], Tereshchenko Yu.A. [6], Gurari FG [7, 8], on the objects having a similar geological structure, it is necessary to single out the works of foreign authors [9-10]. The study of geological features and operational experience of wells makes it possible to determine the features in the development of sediments of the Bazhenov formation, to fulfill the forecast of oil production, to evaluate the possibility of using modern technologies of long-term impact on the reservoir.

The peculiarity of the deposits of Bazhenov suite is that they are not controlled by the structural plan, their productivity is associated with zones of rock fracture, disjunctive unconformities, characterized by anomalously high initial reservoir pressure and temperature. The reservoir is characterized by thin-film and leafy clayey rocks with lenticular interlayers of organic matter [1].

Hydrocarbons of the Bazhenov formation are contained in two forms [2, 3]: in the form of light oil, in organic matter – kerogen. The oil-bearing rocks of the Bazhenov formation are mainly represented by three rock-forming components:

• minerals of silica (opal, chalcedony, quartz), whose share in the volume of the formation is 0.36;
• clay minerals – 0.27 in the volume of the formation;
• carbonate minerals (calcite, dolomite) with a share in the volume of the formation 0.33 d.

Kerogen is represented as follows: in clays – 0.185. Units, in carbonates – 0.11. Units, silica – 0.1.

An important feature of the Bazhenov formation is a significantly different rock composition, depending on the region of occurrence.

Clay rocks of the Bazhenov formation are hydrophobic, areas with hydrophilic properties appear perpendicular to the layering. Characterized by increased radioactivity due to uranium, its values exceed the background by 20-50 times.

In the rocks of the Bazhenov formation there are three types of collectors: pore-fractured, fractured and cracked-cavernous:

• The porous-fractured collector - is represented mainly by silica (with a fraction of silicon oxide in the total elemental composition of the rocks to 75.0-85.0%), practically impermeable, microcracked has a micro-laminate structure, is essentially clogged. Conductors of oil to the wells are cracks, draining matrix pores.

• The fracture type of the reservoir is related to carbonates by differences and dense silica. Collectors have a significant degree of heterogeneity due to the high concentration of carbonate microstimulations from a few millimeters to 2-3 cm.

• The fractured-cavernous reservoir (macro-fractured) is confined mainly to carbonate rocks subjected to intensive leaching, layers of reservoirs of this type are located predominantly in the lower part of the formation section at the boundary with the underlying rocks of the Abalak (George's) suite, possess permeability that can reach up to units of Darcy.

According to the specialists of the National Academy of Sciences of the National Academy of Sciences. V.I. Shpilman [11], type I of the reservoir is more developed in the section and confined mainly to microlayered kerogen claystones, type II of the reservoir is associated with dense silica and carbonates. Collectors of the III type are located mainly in the lower part of the formation section at the boundary with the underlying rocks of the Abalak (George) suite.

The greatest development in the section of Yu_0 has a collector of type II - containing 55.0% of light oil reserves, type I - 34.0% and type III - 11.0%. By productivity, the greatest contribution is made by type II and III reservoirs.

In general, the beds of the Bazhenov formation are characterized by the following filtration-capacitive properties: the matrix permeability is of the order of 1 mD, the permeability of cracks is up to 1 D, the oil saturation is 80.0-90.0%. The porosity index of 2.0-4.0% corresponds to the entire section of the Bazhenov formation on the developed deposits in the territory of KhMAO-Ugra . The productive part of the section is characterized by porosity indices of 6-8%, in some cases reaching 10.0%. Oil is light, low-sulfur. The viscosity of liquid hydrocarbons varies from 0.29 to 6.00 mPa.s, the density is 0.82-0.87 g /sm^3, the total content of resins and asphaltenes varies from 2.0 to 13.2%. For the deposits of the Bazhenov formation twill, abnormally high reservoir pressures (Ka from 1.3 to 1.8), temperatures (up to 135 ° C) are characteristic.

It should be noted that along with light oil, the Bazhenov formation has a generation potential due to the presence of kerogen.

When the core samples of the Bazhenov formation with kerogen are heated under inert gas conditions, a pyrolysis process takes place to form liquid hydrocarbons, and the oil begins at 270-290 °

C. The bulk of hydrocarbons (90.0-95.0%) leaves the samples at a temperature of 360-420 ° C. The volume of liquid hydrocarbons from generation is estimated in the range (20.0 - 80.0) l / t of rock.

The generation potential can be realized through the use of currently known technologies of in-situ combustion and additional scientific developments aimed at accelerating the processes of converting kerogen to light hydrocarbons.

On the territory of the KhMAO-Ugra , the development of deposits of the Bazhenov formation was carried out in 39 fields, and 368 wells have oil production experience. The largest number of wells is operated at six fields – Ai-Pimsky, Galyanovsky, Zapadno-Sakhalinsk, Krasnoleninsk, Salym and Sredne-Nazym. In the remaining deposits, the development of the Bazhenov formation is carried out by single wells.

The accumulated oil production from the Bazhenov formation amounted to 8.54 million tons, of which oil production in 2015 was 0,6 million tons. In 2015, 188 wells with an average oil production rate of 13.4 tons a day were in operation at the Bazhenov suite, for fluid – 16,9 tons a day. The bulk of oil production (66.0%) and operating wells (59.0%) falls on the fields of JSC Surgutneftegaz [12]. During the analysis of field data it was revealed that all wells are divided into two groups according to the dynamics of fluid extraction.

In the first group, the well flow rates are characterized by a steady downward trend and obey an exponential law that follows from the material balance equation for the elastic regime [13].

The wells of the second group are characterized by alternating increases and decreases in oil production, which indicates the activity of cracks as a result of changes in effective pressure. With a decrease in bottom hole pressure, oil pick-ups increase, then the reservoir pressure in the bottom-hole zone decreases, the conductivity of the cracks changes and, as a consequence, the production rate decreases. The main results of the analysis are presented in table 1. The main experience of operating the Bazhenov formation consists of two OGRs: Salym (Pravdinsk-Salym group of deposits) and Priobsky (Aim-Pim and West Sakhalin deposits). Salym OGR shows large median indicators for drained reserves, accumulated oil production, drainage area and current average oil production rate.

Table 1 – Median indicators of wells Bazhenov suite in KhMAO-Ugra

Параметр	Oil and gas regions of KhMAO-Ugra						
	Krasnoleninskii	Priobskii	Surgutskii	Laminskii	Salymskii	Vartovskii	Iuganskii
Number of wells	64	102	37	25	115	21	2
Drained oil, thousands tons	4,3	17,9	14,4	15,4	31,5	1,1	15,6
Accumulated oil, thousands tons	2,2	9,6	4,8	9,8	12,9	0,8	5,9
Drainage area, hectare	21	32	50	32	118,0	4,0	74
Current average oil production rate, ton/day	5,2	17,2	3,8	7,4	35,0	3,3	24,7
Initial average oil production rate, ton/day	7,8	19,4	9,1	10,8	12,7	6,3	21,3

Based on the results of well production analysis, 80% of the stock had drainable oil reserves of less than 30 thousand tons, which does not make profitable the exploitation of the Bazhenov suite. Accumulated production of oil over 30 thousand tons per well was recorded for 20% of wells, the

drainage area for them exceeds 150 ha / well, which indicates the location of their bottom holes in the vast zones of rock fracture.

The amount of accumulated production using technologies of horizontal well (HW) with multi-stage hydraulic fracturing (MHF) of the reservoir on production targets the analogues of "shale oil" abroad reaches a level of 13-15 thousand tons per well, which also does not fundamentally change the efficiency of reserve recovery. The rate of decline in production at the North American fields of Bakken and Eagle Ford is 25.0-40.0% per year; their operation can pay off in 7-10 years, provided that the input oil rates and oil prices remain at $ 73 per barrel, which is currently not a realistic scenario.

Based on the evaluation of drained reserves, the drainage area, the actual rates of decline in oil production from wells, the increase in the production well stock, as well as the data on the application of hydraulic fracturing and the GS with the MGRP, the authors carried out a forecast of oil production levels for objects on the state balance, taking into account the application modern technologies of impact on the reservoir (Figure 1). The forecast was carried out using the algorithms described in [14-16].

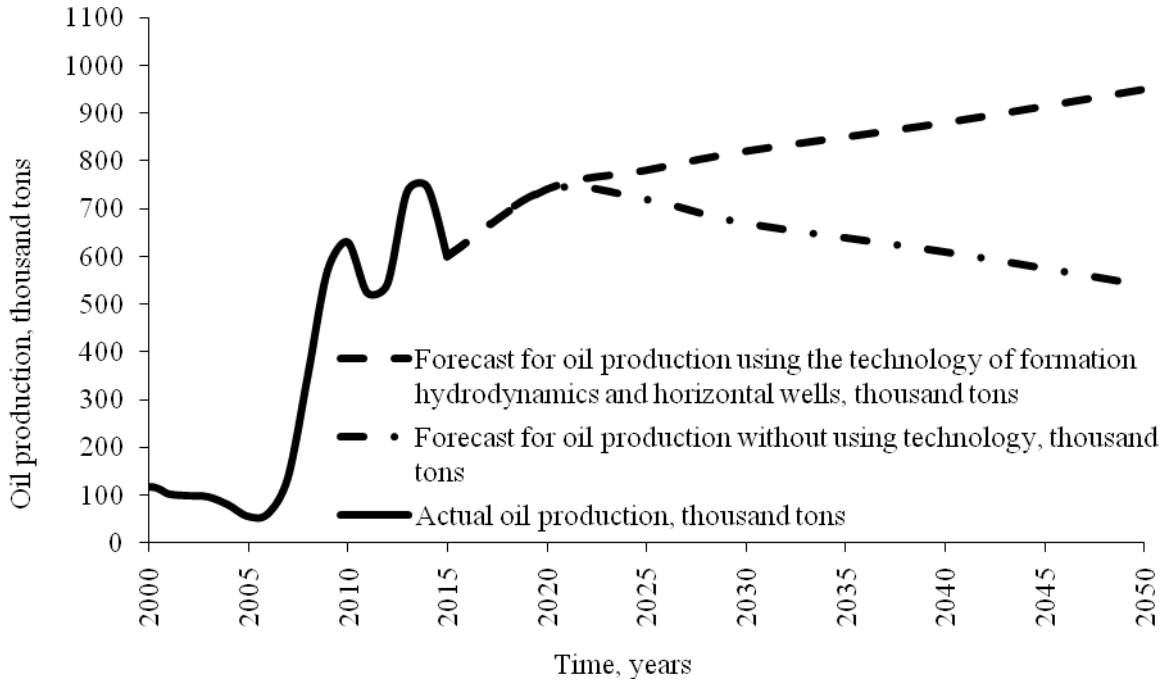


Fig. 1. Forecast of oil production from the Bazhenov formation of KhMAO-Ugra

In general, the results of the forecast, as well as data on the development of foreign analogs, indicate that the assessment of the prospects for oil production from the Bazhenov formation should be approached more restrainedly. It is obvious that mass drilling on regular well screens is impractical.

Conclusions

According to the forecast in the work, the oil production rates, both with the use of well construction technologies with horizontal termination and hydraulic fracturing, and without them, are estimated in the range of 700-800 thousand tons per year until 2030. This suggests that without the introduction of technologies for converting kerogen to light hydrocarbons, the Bazhenov formation can not be an important part of the Russian oil industry.

In the current conditions, the approach to the development of the deposits of the Bazhenov formation in the territory of the KhMAO-Ugra should be selective, with the location of wells in the

zones of crushing rocks that have increased productivity and drainage capacity, which involves the search for and application of methods for localizing zones of increased productivity based on analysis of the amplitude-frequency characteristics of the seismic survey of the Bazhenov formation.

References

[1] Nesterov I I 1985 *Oil vole clay bituminous rocks, the structure and oil and gas content of the bazhents of Western Siberia* (Tyumen: Zap Sib NIGNI).
[2] Kontorovich A E Nesterov I I Salmanov F K 1975 *Geology of oil and gas in Western Siberia* (Moscow: Nedra) p. 680.
[3] Zubkov M Ju Pormeyster J A Bondarenko P M 2002 *Forecast of fractured reservoirs in the sediments of the Bazhenov and Abalak formations on the basis of the results of tectonophysical modeling The ways of realizing the oil and gas potential of KhMAO* (Khanty-Mansiysk: Proc. of the V scientific conference) pp. 244–253.
[4] Zubkov M Ju 2005 *Criteria for assessing regional prospects for oil and gas potential and local forecasting of hydrocarbon deposits in sediments of the Bazhenovo and Abalak formations of Western Siberi vol 6* (Moscow: Gornye vedomosti) pp. 30–51.
[5] Halimov Je M Melik-Pashaev V S 1980 *About the search for industrial oil accumulations in the Bazhenov suite* (Moscow: Oil and gas geology) pp. 1–9.
[6] Stepanov A I Tereshhenko Ju A 1985 *Type of reservoir and conditions for the formation of oil deposits in sediments of the Bazhenovaya Formation of the Salym field* (Moscow: Oil geology of deposits with hard-to-recover reserves) pp. 80–93
[7] Gurari F G 1979 *On the conditions of accumulation and oil content of the Bazhenov suite of Western Siberia* (Tyumen: SNIIGGiMS) pp. 153–160.
[8] Gurari F G Vayc Je Ja Melenevskiy V N Moskvin V I 1988 *Formation conditions and methods of searching for oil deposits in the argillites of the Bazhenov suite* (Moscow: Nedra) p. 197.
[9] Burnham A K 2017 *Porosity and permeability of Green River oil shale and their changes during retorting* (Fuel) pp. 208–213.
[10] Conkright M E Sackett W M Peters K E 1986 *Application of the pyrolysis-carbon isotope method for determining the maturity of kerogen in the Bakken shale* (Organic Geochemistry) pp. 1113–1117.
[11] Kuzmin Ju A Sudat N V 2005 *Features of the geological structure, assessment and accounting in the state balance of hydrocarbon reserves in the sediments of the Bazhenov Formation of the Khanty-Mansiysk Autonomous Okrug – Ugra* (Khanty-Mansiysk)
[12] Korovin K V, Pecherin T N 2016 *Analysis of the results of wells operation from the deposits of the Bazhenov suite in the territory of the Khanty-Mansiysk Autonomous Okrug-Ugra* (Yekaterinburg: International Scientific and Research Journal) pp. 91–94.
[13] Sevastianov A A Korovin K V Zotova O P 2016 *Development of deposits with hard-to-recover oil reserves* (Tyumen: TIU)
[14] Medvedsky R I Sevastianov A A Korovin K V 2005 *Forecasting the development of reserves from the double environment strata* vol 15 (Khanty-Mansiysk: Bulletin of the subsoil user of the Khanty-Mansiysk Autonomous Okrug) pp. 49–53.
[15] Sevastianov A A Korovin K V Zotova O P Zubarev D I 2016 *Features of the structure and assessment of the potential of achimov deposits in KHMAO-Yugra* vol 8 (Moscow: Successes of modern natural science) pp. 195-199.
[16] Sevastianov A A Korovin K V Zotova O P Zubarev D I 2016 *Prospects for the development of sediments Tyumen suite in the KhMAO-Yugra* vol 12-2 (Moscow: Successes of modern natural science) pp. 44–48.