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ЭНЕРГЕТИЧЕСКАЯ ОСНОВА ОСВОЕНИЯ МИНЕРАЛЬНО-СЫРЬЕВЫХ РЕСУРСОВ АРКТИЧЕСКИХ РАЙОНОВ ЯКУТИИ

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Аннотация: обозначена необходимость поиска и разведки углеводородных энергоресурсов для эффективного освоения богатых минерально-сырьевых ресурсов Арктической зоны Республики Саха (Якутия). Построена схема размещения основных объектов минерально-сырьевой базы арктических районов Республики Саха (Якутия) и перспективных на нефть и газ территорий. На западном секторе Арктической зоны Республики Саха (Якутия) в качестве первоочередного объекта выделено Южно-Тигянское месторождение тяжелой нефти. Сделан вывод о большом потенциале наращивания сырьевой базы месторождения, который можно реализовать в краткосрочной перспективе. Оленекское месторождение природного битума предлагается рассмотреть, как перспективный объект добычи нефтепродуктов в долгосрочной перспективе. На восточном секторе Арктической зоны Республики Саха (Якутия) предложено заложить глубокую поисково-оценочную скважину в пределах Тастахского прогиба, расположенного в непосредственной близости от Северного морского пути. Отмечена необходимость проведения тематических исследований по перспективам нефтегазоносности Индигиро-Зырянского прогиба с учетом всех возможных причин получения отрицательных результатов бурения. Для освоения остальных отдаленных районов восточного сектора Арктической зоны Республики Саха (Якутия) предложено рассмотреть вопрос получения моторного топлива из бурых углей.

Ключевые слова: освоение ресурсов Арктической зоны, минерально-сырьевая база, месторождение, нефтегазоность, энергообеспечение, уголь, моторное топливо.

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The energy basis for the development of mineral resources in the Arctic regions of Yakutia

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Abstract: The necessity of search and exploration of hydrocarbon energy resources for effective development of rich mineral resources of the Arctic zone of the Republic of Sakha (Yakutia) is outlined. The layout of the main sites of the mineral resource base of the Arctic regions of the Republic of Sakha (Yakutia) and promising oil and gas territories was constructed. In the

western sector of the Arctic zone of the Republic of Sakha (Yakutia), the Yuzhno-Tigyanskoye field of heavy oils is identified as a priority object. The conclusion is made about the great potential of increasing the raw material base of the field, which can be implemented in the short term. Olenek natural bitumen field is proposed to be considered as a promising object of oil products production in the long term. In the eastern sector of the Arctic zone of the Republic of Sakha (Yakutia) it is proposed to lay a deep exploration and appraisal well within the Tastakh trough, located in close proximity to the Northern Sea Route. The necessity of carrying out thematic studies on the prospects of oil and gas content in the Indigiro-Zyryansky Trough was noted, taking into account all possible reasons for the negative results of drilling. For the development of other remote areas in the eastern sector of the Arctic zone of the Republic of Sakha (Yakutia), it is proposed to consider the issue of obtaining motor fuel from lignite.

Key words: development of resources of the Arctic zone, mineral resource base, deposit occurrence, oil-and-gas-bearing capacity, energy supply, coal, motor fuel.

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Introduction

The Arctic zone of the Republic of Sakha (Yakutia) covers the territory of 13 districts and occupies more than half of the entire territory of the republic. Only 67674 people lived on this vast territory as of 01.01.2019 [1]. Extreme climatic conditions causing long heating seasons, absence of reliable year-round transportation system, high cost of imported life-supporting cargoes, low income level of population and expensive decentralized power supply make the Arctic regions extremely depressive for human habitation.

The basis for qualitative improvement of human life in the Arctic regions can only be full-scale effective development of rich mineral resources of the territory [2, 3]. There are large and unique deposits of diamonds, gold, non-ferrous and rare-earth metals, coal, fossil mammoth bone, etc. The effective development of the extractive industry is impossible without solving the issue of energy supply and, above all, affordable motor fuel.

Currently, the most convenient and reliable fossil raw materials for energy supply and motor fuel production are hydrocarbons. For allocation of potential clusters on development of Arctic regions it is necessary to consider comprehensively a condition of a mineral-raw-material base and prospects of oil-and-gas bearing capacity of northern territories.

Major mineral and raw material projects

The Arctic regions of the Republic of Sakha (Yakutia) are notable for their poor geological and geophysical knowledge due to their complex natural and climatic conditions and lack of reliable transport infrastructure. At the same time, even the existing mineral resource base, prepared mainly in the Soviet era, makes it possible to outline large investment projects (Fig. 1).

On August 14, 2020, the Strategy of socio-economic development of the Arctic zone of the Republic of Sakha (Yakutia) for the period up to 2035 was approved [1]. The baseline scenario involves the implementation of priority measures for the development and exploitation of the mineral resource base, as well as transport and energy.

Thus, extensive development and exploitation of the mineral resource base is expected in the Anabar and Olenek districts. In the short term, the development of the world's largest deposit of rare-earth metals (niobium, terbium, yttrium and scandium) will begin. As

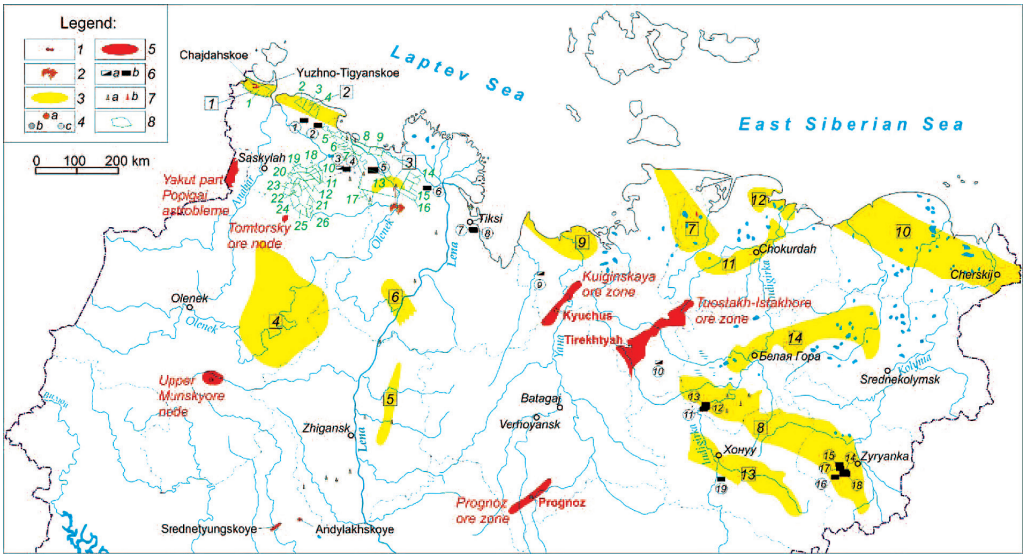

Fig. 1. Layout of the main objects of the mineral and raw material base of the Arctic regions and promising oil and gas areas.

Legend: *1* — oil and gas fields; *2* — Olenekskoye deposit of natural bitumen; *3* — promising areas for oil and gas: *4* — deposits: a — gold, б — silver, *3* — tin; *5* — ore zones; *6* — coal deposits: a — lignite coal, б — hard coal; *7* — wells: a — drilled, б — recommended; *8* — hydrocarbon feedstock

Promising territories for oil and gas (Fig.s in the square): *1* — Yuzhno-Tigyanskoye field, *2* — Pronchishchevsky swell, *3* — Tyumetinsky protrusion, *4* — Sukhonskaya depression, *5* — Sobolokh-Mayan swell, *6* — Kyutyungdik block, *7* — Tastakh trough, *8* — Indigiro-Zyryansky trough, *9* — Nizhneyansky trough, *10* — South Anyu suture zone, *11* — Berelekhsky trough, *12* — Goose depression, *13* — Momsky trough, *14* — The Alazeian-Indigir system of depressions.

Coal deposits (Fig.s in circles): *1* — Salga, *2* — Chaidakh, *3* — Kumakh-Yuryakh, *4* — Buolkalaakh, *5* — Taymylyr, *6* — Chay-Tumus, *7* — Soyginskoye (Northern), *8* — Soyginskoye (Southern), *9* — Kularskoe, *10* — Uyandinskoe, *11* — Krasnorechenskoye (Sogolokh), *12* — Krasnorechenskoye (Shakhtnoye), *13* — Krasnorechenskoye (Razrez), *14* — Erozionnoe (Buor-Kemyusskoy), *15* — Sibik -*2*, *16* — Kharanga, *17* — Erozionnoe (Zyryanskij), *18* — Buor-Kemyusskoy, *19* — Tikhonskoe.

List of subsoil areas on hydrocarbons (green numbers): *1*. Zapadno-Anabrsky (Anabarneftegaz LLC), *2*. Punchischevsky Western (ARKTika LLC), *3*. Pronchischevsky Central (ARKTika LLC), *4*. Pronchischevsky Eastern (LLC ARKTika), *5*. Tirekhtyakhsky (LLC Taimylyrneftegaz), *6*. Ust-Buolkalaakhsky (LLC Taimylyrneftegaz),*7*. Bulunsky (LLC Yakutskneftegaz), *8*. Bysarsky (OOO Yakutskneftegaz), *9*. Yurdyuksky (OOO Yakutskneftegaz), *10*. Khastyrsky (OOO Olenekneftegaz), *11*. Nuorakhtakhsky (LLC Olenekneftegaz), *12*. Surtakhsky (LLC Olenekneftegaz), *13*. Tyumyatinsky (Surgutneftegaz), *14* Ulakhan-Yuryakhsky (Olonkho Mining LLC), *15*. Kuogastakhsky (Dezhnev Mining LLC), *16*. Kelimersky (Olonkho Mining LLC), *17*. Kyup-Chopkinskiy (Olonkho Mining LLC), *18*. Verkhnekhatygynsky (Dyuglyuneftegaz LLC), *19*. Arakh-Bilirsky, *20*. Verkhne-Balagannakhsky, *21*. Nizhne-Balagannakhsky (LLC Bilirneftegaz), *22*. Bilirsky (LLC Bilirneftegaz), *23*. Grigorievsky (LLC Bilirneftegaz), *24*. Nizhneonnekhoysky (Udyakanneftegaz LLC), *25*. Udyakansky (Udyakanneftegaz LLC), *26*. Verkhneudyakanskiy (LLC Tamalakanneftegaz).

of 01.01.2019, there are 86.4 thousand tons of niobium, 0.43 thousand tons of scandium and 139 thousand tons of rare earths under categories C1 and C2 in the State Balance of the Russian Federation for the Tomtor ore cluster. According to an independent assessment, according to the JORC Code (2012), Tomtor deposit

contains 700 thousand tons of niobium and 1.7 million tons of rare earth oxides, which makes it the world's third largest deposit of rare earth metals [4].

In the Yano-Indigirskiy and Kolyma regions, it is planned to resume and expand mining of ore and alluvial gold, silver, and tin.

The Kyuchus gold ore deposit is located in the lower reaches of the Kyuchus River, a left tributary of the Yana River in the Verkhoyanskiy district. On the state balance sheet as of 01.01.2019, the reserves of the Kyuchus deposit by categories $A+B+C_1+C_2$ are 175.262 tons of gold with an average grade of 7 — 9 g/t.

'Prognoz' silver deposit. The deposit contains large reserves of rich ore. As of 01.01.2019, 9748.6 tons of silver in categories C_1+C_2. by category at an average grade of 560 g per ton of ore. Inferred resources are estimated at 2,320 tons of silver. Expected annual production of silver is 420 tons.

'Tirekhtyakh' alluvial tin deposit is located in the North-Yan tin-bearing district in the territory of the Ust-Yan district. The state balance sheet of the Russian Federation takes into account the reserves for open-pit mining in the amount of 74 268 tons by categories $A+B+C_1+C_2$. Average tin content is 814.13 g/m^3. Expected annual tin production is 3,500 tons.

In addition to the major projects outlined in the Strategy, the Verkhnemunskoye diamond mining enterprise will reach its design capacity of 3 million tons of ore per year in the Oleneksky district with reserves until 2041. There are plans to develop the Popigayskoye field of impact diamonds, which is located on the border of the Krasnoyarsk region and Yakutia in the area of Popigayskaya astroblem — a hundred-kilometer meteorite crater. Reliable reserves and inferred resources of impact diamonds in high-diamond-bearing primary rocks on a total area of about 120 km^2 in Popigaysky area are up to 212 billion carats [5]. In addition to this volume in the 50 m layer of impactites on the rest of the area (about 1020 km^2), in addition to the areas of deposits and promising sites, is about 150 billion carats (with a confidence coefficient of 0.5) [6].

All the mentioned large projects have a high investment capacity, which could be significantly reduced if there were available raw materials for energy resources, including motor fuel. In addition, in the Arctic zone of Yakutia 94% of the installed capacity of decentralized energy systems are diesel power plants, 4.5% — mini-CHPs and only 1.3% — renewable energy sources (solar panels and wind installations) [7]. Taking into account the low rates of modernization of remote low-power energy systems, diesel fuel will remain the only source of energy for a long time.

In connection with the above and the planned in the Energy Strategy of the Russian Federation for the period up to 2035 [8] global projects of development of the Arctic, the search for oil and gas fields for the formation of new oil and gas mineral centers becomes an urgent task.

Prospects of oil and gas potential

Western sector

Virtually the entire western part of the Arctic zone of the republic, which belongs in tectonic terms to the northeastern part of the Siberian platform, is in one way or another promising for oil and gas. In this regard, Fig. 1 highlights only the areas where accelerated preparation of raw materials for energy resources is possible. The most promising appears to be the Anabar-Khatanga saddle, where in the 40 — 50s of the last century 5 non-industrial (in our opinion, due to their underexplored) oil fields were discovered — Nordvik, Ilya, Kozhevnikovskoe, Chaidakhskoe and Yuzhno-Tigyanskoe. The last two are

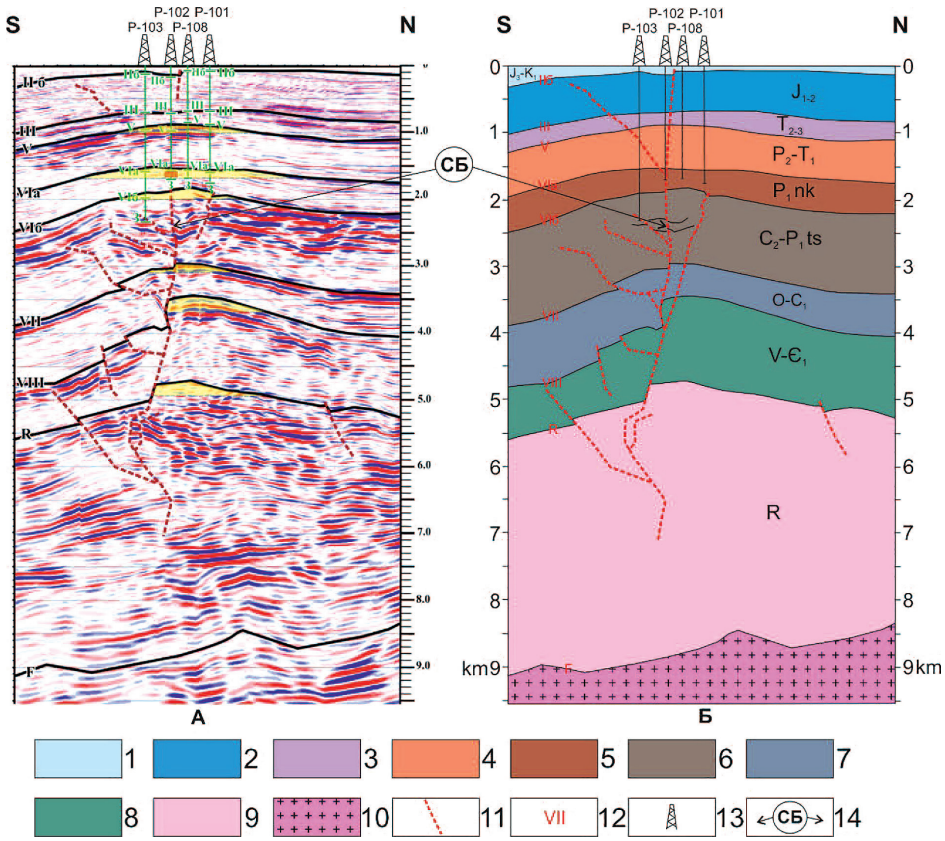

Fig. 2. Seismogeological section along the section of profile 050311 on the Western dome of the South Tigyan structure [8, 9].
Legend: deposits: 1 — upper Jurassic-lower Cretaceous, *2* — lower — middle Jurassic, *3*–, mediumverkhnetarasovka, *4* — upper Permian-lower Triassic, *5* — Nizhnetagilsky Suite lower Permian, *6* — section of upper Carboniferous-lower Permian (custosa Suite), *7* — Ordovician-lower Carboniferous, *8* — Vendian-lower Cambrian, *9* — Riphean; *10* — basement; *11* — faults; *12* — indices of the reflecting horizons; *13* — borehole; *14* — area of transition fault on reset.

located on the territory of the republic within the Zapadno-Anabarsky license area. The only well (No. 102-R) which gives commercial oil flow is located in the Yuzhno-Tigyanskaya area (oil flow rate is up to 15.3 m^3/day and gas flow rate is up to 1,455 m^3/day). Author's estimate of geological reserves of oil from horizon XI was 1.448 million tons by category C_1 [9].

Recent studies [10, 11] have proposed a new model for the structure of the Yuzhno-Tigyan field, suggesting the presence of a major producing accumulation in the lower part of the section (Fig. 2). It is recommended to drill a prospecting and appraisal well with a design depth of 5000 m, which, if successful, will significantly increase the reserves, and if negative, will put the existing reserves on the State balance. The fact that in 2017 Rosneft discovered the Tsentralno-Olginskoye field in Khatanga Bay, which is large in terms of reserves, testifies to the high prospects of the area.

A number of parametric and prospecting wells were drilled within

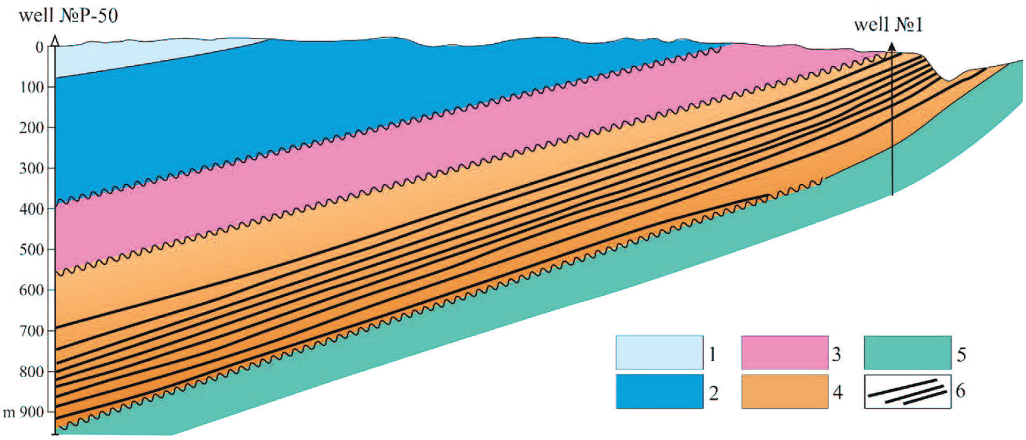

Fig. 3. Schematic profile section of the Olenek natural bitumen field.
Legend: 1 — Middle Jurassic deposits, *2* — Lower Jurassic deposits, *3* — Lower Triassic deposits, *4* — Permian deposits, *5* — Upper Cambrian deposits, *6* — bituminous layers

the Lena-Anabar trough and the adjacent territory of the Predverkhoyanskiy trough in the second half of the 20th century (Fig. 1). Only indications of the oil and gas content of the section (bituminous and gas showings) were recorded. In the short term on these territories of oil and gas deposits discovery is not expected. General characteristics of oil-and-gas bearing capacity of these territories is reflected in work [12].

Under a certain situation in the world market of hydrocarbons the organization of heavy oil production from the Olenek natural bitumen field may be of interest. It is located in the lower reaches of the Olenek river and is a relic of a giant oil field [13], confined to the zone of wedging of Permian deposits on the northern slope of the Olenek uplift (Fig. 3). According to the results of NIIGA (1966—1967) the bitumen resources of the Olenek field are estimated at a total of 3.5 billion tons. Explored reserves by category C_2 in the Ust-Bur area of 16 km^2 amount to 15.2 million tons [14].

Eastern sector

According to a number of geological assumptions, some territories within the limits of North-Eastern Yakutia are potentially oil and gas-bearing as well (Fig. 1) [15]. These are, first of all, the Indigiro-Zyryansky trough, made by carbonaceous terrigenous-volcanogenic deposits of Jurassic, Cretaceous and Cenozoic age. Four prospecting and appraisal wells were drilled in the western part of the Indigiro-Zyryansky trough. The actual depth of the wells was 1066—1611 m and the total penetration was 5126 meters. No oil and gas discoveries were made upon completion of drilling operations. For the Indigiro-Zyryanskiy Trough, additional case studies should be carried out, taking into account all possible reasons for the negative drilling results. Very likely, gas deposits were missed [16].

Also promising and to some extent prepared for deep drilling in the eastern sector of the Arctic zone is the Tastakh Trough (Fig. 1). Discovery of weakly oxidized oils in the Omulevsk block [17] and high bituminosity of the Selenniakh block [18] give reason to be optimistic about the prospects of oil and gas content of the predicted Middle Paleozoic deposits within the Tastakh Trough as well. This issue will remain open until deep parametric and exploratory drilling. In [19],

it was recommended to make a parametric borehole on the northeastern side of the trough with a depth of up to 4000 m. Here, special prospects are associated with the Middle Paleozoic Domanikoid sediments, which may contain oil deposits. The proximity of the Tastakh Trough to the route of the Northern Sea Route is an important favorable infrastructural and investment factor.

Taking into account the duration of oil and gas prospecting and exploration processes, as well as their preparation for industrial development (15 — 20 years) in the short and medium term it is necessary to consider options of using alternative sources of energy resources and motor fuel. Currently, in the Arctic zone of the Republic of Sakha (Yakutia) the only traditional available raw materials for energy is hard coal (Fig. 1). However, the high environmental requirements in the Arctic [20, 21] and the policy of decarbonization supported at the state level, taking into account the quality indicators of coals [22, 23], are unlikely to allow the use of coal as a direct fuel for mini-cogeneration plants.

At the same time, domestic and world practice has accumulated considerable experience in obtaining liquid fuels from coals [24, 25, 26]. The most acceptable raw material for obtaining synthetic fuel is lignite, which is widespread in the Arctic zone of the republic. The increase in prices of petroleum products due to the increase in the cost of oil production and high transportation costs in the absence of stable transportation schemes can make coal a promising raw material for the production of liquid fuels in remote areas of the Arctic.

Conclusion

In the harsh natural and climatic conditions of the Arctic, energy is becoming a basic indicator of the quality of human life. The energy crisis of autumn 2021 in Europe showed the dominant role of traditional energy sources and the need for a smoother transition to renewable energy sources [27, 28].

For accelerated and integrated development of mineral resources in the Arctic zone of the Republic of Sakha (Yakutia), it is necessary to involve local energy resources. In the short term, the Anabaro-Olenek industrial cluster may become the main point of growth. Here there is an opportunity of accelerated build-up of raw hydrocarbon base — as an energy basis for implementation of major projects. In Yano-Indigirskiy and Kolyma districts it is necessary to carry out priority exploration for oil and gas at the expense of federal funds. Until large deposits of oil and gas are identified, it is advisable to consider options for the use of hard coal as a basis for energy.

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