Estimation of the Forecast Hydrocarbon Resources of the North-Eastern Arctic Shelf of Russia

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Abstract. In the northeastern part of Russia, the shelves of the Laptev, East Siberian and Chukchi seas are promising for hydrocarbon raw materials. This article presents the predicted hydrocarbon reserves on the eastern Arctic shelf of Russia by various authors. The oil and gas potential of the northeastern part of the Republic of Sakha (Yakutia) is shown to provide an opportunity for prospecting and the discovery of predicted hydrocarbon deposits, which will significantly optimize the fuel and energy balances of the Arctic regions of the Republic of Sakha (Yakutia).

1. Introduction
The comprehensive socio-economic development of the Arctic zone of the Russian Federation provides for the improvement of the system of state administration, improvement of the quality of life of the indigenous population and social conditions of their economic activity in the Arctic [1,11,13-17]. The Arctic regions include 13 regions of the Republic of Sakha (Yakutia), their territory occupies 52.56% of the total territory of the republic. Fuel delivery to the Arctic regions is associated with large financial costs. Carrying out exploration and discovery of predicted hydrocarbon deposits in close vicinity to potential consumers will significantly optimize the fuel and energy balance of the Arctic and northern regions of the Republic of Sakha (Yakutia).

The Arctic shelf of the Russian Federation on open reserves, prospective and projected resources is a unique reserve of hydrocarbons (HC) (87 % of the initial total resources (ITR) HC of the entire continental shelf of the Russian Federation) [8].

2. Objects and research methods
The methodology of the study is based on a comprehensive synthesis and analysis of all available data from different years on the oil and gas industry of the Russian Federation. The theoretical and methodological basis of the study was the works of Russian scientists on the theoretical and practical problems of the oil and gas complex. To obtain the results, methods of theoretical analysis of information sources, compilation and comparison of information on the studied question were used. Conducted comparative and statistical analysis. Used tabular and graphical methods for presenting research results.
3. Results and discussion
Transit zones of the shelf of the East Arctic seas of Russia occupy vast areas and contain 3,350 million tons of initial total resources (ITR). These resources belong to D2 category and are distributed extremely unevenly. The main prospects of oil and gas bearing capacity of transit zones are connected with the extensive, with the area up to isobath of 20 m about 145 thousand square kilometers, Laptevskaya oil and gas bearing province (POGBP). Even larger area is occupied by the transit shelf strip of the East Siberian and Chukchi Seas, where the main part of the coastal lowland and shallow waters are formed by folded structures of mesozoides with relatively low thickness of normal sediments overlaying them.

The resource assessment of the transit zone of the East Siberian Sea has been made; its total geological resources are estimated to be about 11 % of the total resources, including about 87 % associated with Mesozoic and about 13 % with Cenozoic (Paleogene). The main resources are assumed to 3 km depths (89 %) with a clear predominance of free gas (Table 1). Such an assessment does not contradict the assumed by balance calculations approximately equal ratio of oil and gas in the total resources of the East Siberian Sea shelf, since the main oil resources are associated with the structures of the East Arctic APGP outside the transit zone [18].

Table 1. Distribution of inferred and prospective oil and gas resources of the transit zone of the East Siberian Sea, by sea depths, geological systems and depths of occurrence (million tons, billion m$^3$).

| HC type | Resources | Total | C$_3$+D | by sea depth, m | by geological age | by depth of occurrence, km | geological | recoverable |
|---------|-----------|-------|---------|--------------|------------------|---------------------------|------------|-------------|
|         |            |       |         |              |                  |                           |            |             |
| HC      | amount     |       |         | 0-10         | 10-20            | KZ                        | MZ         | up to 3     | 3-5        |
| D$_2$ C$_3$+D | 1050      | -     | 1050    | 137          | 913              | 934                       | 116        |             |
| (ITR)   | 853        | -     | 853     | 111          | 742              | 759                       | 94         |             |
| C$_3$+D | 1050       | -     | 1050    | 137          | 913              | 934                       | 116        |             |
| (ITR)   | 853        | -     | 853     | 111          | 742              | 759                       | 94         |             |
| Incl. oil | D$_2$     | 252   | -       | 252          | 33               | 219                       | 224        | 28          |
|         | 78         |       | 78      | 10           | 68               | 69                        | 9          |             |
| Gas     |            |       |         | 0-10         | 10-20            | KZ                        | MZ         | up to 3     | 3-5        |
| C$_3$+D | 788 768    | -     | 788     | 104          | 684              | 710                       | 78         |             |
| (ITR)   | 768        |       | 768     | 101          | 667              | 690                       | 78         |             |
| D$_2$   | 788 768    | -     | 788     | 104          | 684              | 710                       | 78         |             |
| Incl. condensate | C$_3$+D | 10   | -       | 10           | 10               | 10                        | -          | 10          |
| (ITR)   | 7          |       | 7       | -            | 7                | -                         | -          |             |
| D$_2$   | 10         | -     | 10      | -            | 10               | -                         | -          | 10          |
|         | 7          |       | 7       |              | 7                |                           | -          |             |

The most probable volumes of initial resources of hydrocarbons (HC) of northeast Arctic shelf of Russia academician Kontorovich A.E. and others estimate the following volumes: Laptevskaya OGBZ (oil and gas bearing zone): oil (recovered) - 2.3 billion tons, free gas - 4.2 trillion m$^3$. The East Arctic OGBZ: oil (recovered) - 6.0 billion tons, free gas - 4.7 trillion m$^3$; Novosibirsk-Chukotka OGBZ: oil (recovered) - 0.7 billion tons, free gas - 1.1 trillion m$^3$ (table 2) [7].
Table 2. Initial resources of oil, gas, condensate in the Russian Arctic waters.

| Oil and gas-bearing zones (areas) | Oil (extract), billion tons | Associated gas, (extract), billion m³ | Free gas, trillion m³ | Condensate (extract), million tons |
|----------------------------------|-----------------------------|----------------------------------------|----------------------|----------------------------------|
| Laptevskaya                      | 2.3                         | 63.0                                   | 4.2                  | 15.0                             |
| East Arctic                      | 6.0                         | 18.0                                   | 4.7                  | 17.0                             |
| Novosibirsk-Chukotka             | 0.7                         | 19.0                                   | 1.1                  | 8.0                              |
| Total                            | 9.0                         | 100.0                                  | 10.0                 | 40.0                             |

To assess the resource base of oil and gas in the Arctic shelf of Russia, Eremin N.A., Kondratyuk A.T. and AN Eremin operate on the following indicators: the area of the shelf and continental slope of Russia - 6.2 million km²; a shelf with an area of at least 4 million km², a continental slope and deep-water zones with an area of 0.4-0.5 million km² are promising for oil and gas, where 20 large offshore oil and gas provinces and basins have been identified, of which 10 are with proven oil and gas content [4].

The initial geological hydrocarbon resources on the Russian shelf, according to their estimates, amount to 136 billion tons of standard fuel, and the initial recoverable hydrocarbon resources reach 100 billion tons of standard fuel, including: 13 billion tons of oil and 87 trillion tons of oil equivalent m³ of gas [4]. The largest sedimentary basins in the Arctic part of Russia include: East Barents, South Kara, Laptev, East Siberian and Chukotka. Prospective hydrocarbon resources of the Russian Arctic waters are shown in Table 3.

Table 3. Prospective hydrocarbon resources of the Russian Arctic waters.

| Sea                  | Oil, (billion tons) | Associated gas, (billion m³) | Free gas, (trillion m³) | Condensate, (million tons) | HC, (ton of oil equivalent) |
|----------------------|---------------------|-----------------------------|------------------------|---------------------------|-----------------------------|
| Laptev               | 0.724               | 273.12                      | 1.555                  | 199.50                    | 2392.82                     |
| East Siberian        | 0.016               | 6.71                        | 0.173                  | 14.75                     | 175.52                      |
| Chukchi              | 0.391               | 111.22                      | 0.510                  | 58.20                     | 947.96                      |
| Arctic Ocean (remaining) | 0.187            | 60.80                       | 0.226                  | 29.11                     | 447.22                      |
| Total                | 1.318               | 451.85                      | 2.464                  | 301.56                    | 3963.52                     |

The same authors in their work as an alternative assessment of prospective hydrocarbon resources of the Arctic seas of Russia cite the data of the USGS (2008) [4], which in comparison with the above volumes Kontorovich and others [7] differ in values many times less with respect to oil and gas and, as for condensate - on the contrary many times more.

Very interesting for comparison are the data on the geological structure and oil and gas content of the Arctic part of the North American continent [21], which is very similar to the territory of the water areas of the Eastern Arctic seas of Russia, especially of the East Siberian and Chukchi seas in terms of the lithology, stratigraphy, tectonics and oil and gas content preconditions. As the authors show, more than 160 deposits of oil, gas and gas condensate have been discovered in the basin of the Arctic slope of Alaska. For the most part, these are small deposits with recoverable reserves of 1.7-17 million tons of oil and 0.5-70 billion m³ of gas. At the same time, in the coastal part of the Umiat Depression, the supergiant Pradho Bey field with recoverable oil reserves of 1.35 billion tons and gas reserves of 728 billion m³ was discovered in 1968. The expected increase in oil and gas reserves according to foreign estimates for the years 2005-2050, borrowed by the authors [5,21].
Table 4. Expected growth of gas and oil reserves in Arctic Alaska for 2005-2055.

| Territories                   | 2005-2015          | 2015-2055          | 2005-2055          |
|-------------------------------|--------------------|--------------------|--------------------|
|                               | Oil, million tons  | Gas, billion m³    | Oil, million tons  | Gas, billion m³    | Oil, million tons  | Gas, billion m³    |
| Colville Depression           | 151                | 280                | 281                | 652                | 432                | 932                |
| Beaufort Sea                  | 89                 | 28                 | 589                | 560                | 678                | 588                |
| Chukchi sea                   | -                  | -                  | 1301               | 1400               | 1301               | 1400               |
| Alaska National Oil Reserve   | 151                | 28                 | 740                | 840                | 891                | 868                |
| Arctic uninhabited territories| -                  | -                  | 925                | 56                 | 925                | 56                 |
| General for the territory of Arctic Alaska | 391 | 336 | 3836 | 3508 | 4227 | 3844 |

In general, the potential HC resources in Arctic Alaska are estimated: oil - 10-12 billion tons, gas - 20-25 trillion m³.

As we can see from the above, the promising resources of the oil and gas regions of the water area of the Eastern Arctic seas of Russia (the Laptev, East Siberian and Chukchi seas), assessed by a team of prominent scientists of the country [7] are quite comparable to the potential hydrocarbon resources of Arctic Alaska.

As of 01.01.2012, the initial total resources of the Arctic water areas are estimated at 113.9 billion tons of conventional hydrocarbons (HCF), of which 95.1 billion tons of HCF (83.5%) of the NSR is free gas, 13 billion tons of HCF (11.4%) - oil, 4.5 billion tons of HCF (4%) - condensate and 1.3 billion tons of HCF (1.1%) - dissolved gas [19,20].

The total volume of hydrocarbon reserves (category AB₁C₁ + B₂C₂) accounted for in the Arctic waters is estimated at 9.7 billion tons of hydrocarbon, of which 71.2% is in the distributed subsoil fund. The explored part (reserves of category ABC₁ + B₂C₂ + cumulative production) includes only 5.7% of the hydrocarbon reserves of the Arctic waters of the continental shelf of the Russian Federation.

Arctic waters are characterized by extremely poor exploration of hydrocarbon potential [19]. For example, the exploration rate for free gas is only 8.6%, oil - 1.0% and condensate - 2.2%.

Over the entire period of exploration work on the Arctic shelf of the Russian Federation, 5 oil fields have been discovered (4 in the Pechora Sea and 1 in the Laptev Sea), 2 oil and gas condensate (1 in the Pechora and 1 in the Barents Sea) and 1 oil and gas (in the Barents Sea), 5 gas (3 in the Barents Sea, 2 in the Pechora and bays of the Kara Sea) and gas condensate open (1 in the Pechora, 2 in the Barents Sea, 2 in the Kara Sea, 3 in the Pechora and bays of the Kara Sea) [7, 19] with current recoverable reserves of oil AB₁C₁ - 120.8 million tons and 509.7 million tons for B₂C₂, gas 3692.3 billion m³ for AB₁C₁ and 2972.1 billion m³ for B₂C₂, condensate AB₁C₁ - 80.0 million tons and for B₂C₂ - 58.7 million tons [8].

As of 01.01.2019, the initial total resources in the water area of the East Siberian Sea were estimated according to cat. D₂ in 5583.0 million tons of hydrocarbon hydrocarbons, of which 30.8% is oil, 3.1% is dissolved gas, 59.9% is free gas and 6.2% is condensate.

Currently, on the Arctic shelf, geological exploration for oil and gas by subsoil companies (PJSC NK Rosneft, PJSC Gazprom, PJSC Gazprom Neft, PJSC NK LUKOIL, PJSC NOVATEK, etc.) [6] are carried out at 79 license areas, including 17 transit licenses. Of these licenses were issued: for geological exploration, including prospecting and assessment of mineral deposits (NP) - 4; for geological study, exploration and production of minerals (combined, HP) - 52; for exploration and production of minerals (NE) - 23.
In 2017, PJSC NK Rosneft discovered a large Central Olginskoye oil field located in the Khatanga Bay of the Laptev Sea, with total oil reserves of cat. C₁ + C₂ 80.4 million tons.

If large oil reserves are discovered in the waters of the East Siberian Sea, the Laptev Sea, the Chukchi and Bering Seas, their development will be carried out after 2040.

The first quantitative assessment of the prospects for the oil and gas potential of the Indigiro-Zyryansky trough in the north-east of Yakutia was carried out by VNIGRI in 1972 [3]. The calculation was carried out by various methods with an orientation, mainly, on gas resources. When using the volumetric statistical method, the predicted gas resources in the Lower Cretaceous sediments of the trough are determined at 1.16 - 1.20 trillion m³. Application of the method of geological analogies gave a more significant scatter of estimates - from 1.8 to 3.9 trillion m³. Taking into account the conventionality of many of the parameters used, the authors of the calculation took the predicted hydrocarbon resources (hydrocarbon gases) in the amount of 1.0-1.2 trillion m³ as the resulting estimate.

In 1987, the calculation of predicted hydrocarbon resources in the northeastern regions of the YaASSR (Yakutsk Autonomous Soviet Socialist Republic), including the territory of the Zyryansky trough, was carried out by the Yakutskgeofizika trust [2]. The same methods were used as before. The results of this calculation (830-870 billion m³) are slightly lower than the previous estimates.

Along with the conventionality of the accepted analogies, given the poor knowledge of the object of calculation itself, the indicated discrepancies are probably due to the difference in the choice of promising intervals (reservoirs). In the first case, the section of the Lower Cretaceous deposits was considered completely, in the second - only the Silyap and Ozhoginskaya formations (the Buorkemysuska formation was distinguished in this case as a screen). In addition, VNIGRI data covered the entire Momo-Zyryan basin, including the Zyryan trough and the Momskaya depression [3].

It should also be noted that the total estimate of the geological reserves of the UHF as of 01.01.1984, prepared by VNIGRI by the assignment of the USSR Ministry of Geology and approved by the Interdepartmental Expert Commission, is 742 billion m³ for the Zyryan trough [12].

Within the limits of the Omulevsky uplift, bordering with the Indigiro-Zyryansky trough from the south, the Omulevsky possible oil-and-gas bearing area is distinguished. Using according to the geological analogy, the Turukhano-Norilskoye oil and gas bearing area as a benchmark, the author performed the initial HC resources forecast for the 4 promising areas he outlined and for the POGBZ (possible oil and gas bearing area) as a whole. HC density of the Turukhano-Norilskaya POGBZ (14.5 t/km²), taking into account unfavorable factors established within the boundaries of the Omulevskaya POGBZ: widespread development of magmatism, a high degree of catagenetic transformation of sedimentary formations, intensive disjunctive tectonics, the author reduced by three times. The results of hydrocarbon resources calculation are shown in Table 5 [9].

| №  | Site name   | Area, km² | UHC, mln.t |
|----|-------------|-----------|------------|
| 1  | Uyarinsky   | 460       | 9.2        |
| 2  | Iryudi      | 150       | 3.0        |
| 3  | Supkaninsky | 340       | 6.8        |
| 4  | Urultunsky  | 520       | 10.4       |
|    | In total for 4 sites | 1470 | 29.4       |
|    | Total for Omulevskaya POGBZ | 95000 | 72.5       |

A brief review of the study of the territory in question shows that in recent decades, in Russia and abroad, more and more attention has been paid to the study of the Arctic oil and gas bearing belt. At the same time, geological and geophysical exploration of the East Arctic seas (Laptev, East Siberian and Chukchi) is very low, in particular seismic survey, and deep drilling has not been conducted there.
Volumes of seismic exploration, its density, the number of identified local objects in the territory in question in comparison with other seas of the Russian Arctic are given in Table 6 [6,10].

| Seams of the Russian Arctic | Exploration | Number of local objects |
|----------------------------|-------------|-------------------------|
|                            | Seismic exploration (SE), thousand km | SE density, km / km² |                      |
| Laptev                     | 52.91       | 0.08                    | 40                    |
| East Siberian              | 24.44       | 0.03                    | 10                    |
| Chukchi                    | 19.51       | 0.06                    | 23                    |

Geological exploration work is carried out on the Arctic shelf of the Russian Federation both at the expense of the federal budget and at the expense of subsoil users. The share of budget funding in 2018 amounted to 2% of total costs.

Seismic exploration, carried out at the expense of the federal budget in the Arctic waters, made it possible to create a significant fund of identified structures. However, due to the low density of the worked-out profiles, many of the identified oil and gas promising objects are contoured conditionally and require further additional study.

Some performance indicators of offshore oil and gas exploration in the Arctic waters are presented in Table 7 [8].

| Seas of the Eastern Arctic | Number of identified potential HC traps | Number of fields |
|---------------------------|-----------------------------------------|------------------|
| Laptev                    | 54                                      | 1                |
| East Siberian and Chukchi | 56                                      | -                |
| The whole region          | 110                                     | 1                |

At the expense of subsurface users, the volume of financing of geological exploration in the Arctic waters in 2018 amounted to 56% of the total costs of subsurface users on the entire continental shelf of the Russian Federation. The main expenses of subsoil users (66%) for geological exploration in the Arctic waters were related to deep drilling. During the year three exploratory wells were drilled with a total volume of 7.3 thousand meters, while no exploratory drilling was carried out.

4. Conclusion
The Arctic shelf of the Russian Federation possesses a colossal resource base of gas and oil, but due to poor exploration this potential has not been realized to a great extent. To accelerate the process of reserve growth and, subsequently, their reproduction, it is most expedient to carry out, at the expense of the federal budget, exploration works to thicken the network of regional profiles in the oil and gas prospective zones, identified by previous studies [9]. To accelerate the development of oil and gas resources of the Arctic shelf it is necessary to develop a program of comprehensive geological study and development of its resource base. Priority activities and works in the Arctic water areas are full digitalization of mapping material (unified GIS-project) on the seas, creation of unified zonal and regional projects based on the results of geological and geological-geophysical works.

5. References
[1] Alekseev N N, Sitnikov V S, Sleptsova M I 2016 J. Scientific Review: theory and practice JSRTP04 008
[2] Arzhakov N A, Obolkin A P, Sitnikov V S J. Oil and gas geology: theory and practice JogiTP 12(4) 020
[3] Chochia N G, Volnov D A, Golbraikh I G 1972 Tectonics and oil and gas content of the eastern USSR: VNIGRI Proceedings (Leningrad) 309 pp 118-132
[4] Eremin N A, Kondratyuk A T, Eremin A N 2010 J. Georesursy Geoenergetics Geopolitics 1 pp 1-11
[5] Houseknecht D W, Bird K. J 2005 U.S. Geological Survey in Alaska: Professional paper 1732-A pp 1-11
[6] Kaminsky V D, Suprunenko O I, Medvedeva T Yu, Chernykh A A 2016 J. Oil and Gas Geology 5 pp 50-57
[7] Kontorovich A E, Epov M I, Burstein L M, Kaminskii V D, Kurchikov A R, Malyshev N A, Prischepa O M, Safronov A F, Stupakova A V, Suprunenko O I 2010 J. Geology and Geophysics 51(1) pp 7-17
[8] Melnikov P N; Skvortsov M B, Kravchenko M N, Agadzhanyants I G, Grushevskaya O V, Uvarova I V 2020 J. Neftegaz 1 pp 22-30
[9] Migursky F A 2007 Prospects of oil and gas bearing capacity of Omulevsky uplift (Novosibirsk) 132 p
[10] Senin B V, Leonchik M I 2013 Mater. of the All-Russian VNIGNI meeting (Moscow: VNIGNI) pp 4-7
[11] Sitnikov V S and Sleptsova M I 2020 IOP Conf. Ser.: Earth Environ. Sci. 459 052005
[12] Sitnikov V S, Spektor V B 1998 Geophysical research in Yakutia (Yakutsk: Yakut State University press) pp 21-31
[13] Sleptsova M I 2012 Future of the oil industry in the Republic of Sakha (Yakutia) J. Russ. Econom. online-journal JREO04(2012)006
[14] Sleptsova M I 2012 Future of the oil industry in the Republic of Sakha (Yakutia) J. Russ. Econom. online-journal JREO04(2012)006
[15] Sleptsova M I 2018 J. International research journal 10(76) pp 55-58
[16] M I Sleptsova 2020 IOP Conf. Ser.: Earth Environ. Sci. 459 052004
[17] Sleptsova M I, Sitnikov V S, Sevostyanova R F 2018 J. Oil and gas geology: theory and practice JogiTP13(4)(2018)014
[18] Sobolev V S 1999 Proc. of the Int. Conf. Development of shelf of Arctic seas of Russia (Saint-Petersburg) pp 165-171
[19] Varlamov A I, Afanasenkov A P, Peshkova I N, Unger A V, Kravchenko M N, Obukhov A N 2017 J. Oil and Gas Eurasia 2 pp 44-51
[20] Varlamov A P, Afanasenkov I N, Peshkova, Lugovaya O V 2013 Proc. of the Conf. on field development in harsh conditions and the Arctic (Moscow)
[21] Zabanbark A, Lobkovsky L I 2013 J. Arctic: Ecology and economy 3(11) pp 64-75