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PROPERTIES OF ARCTIC PARAFFIN OIL

Research article

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Abstract

A comparative analysis of the properties of paraffinic oils in the Arctic zone of Russia and in the non-Arctic territory of Russia has been carried out. It has been shown that Arctic oils are of higher quality in terms of chemical characteristics and differ from non-Arctic oils by a lower content (approximately 2 times) of sulfur, resins, asphaltenes and nitrogen. A comparison of the properties of paraffinic oils in the European and Asian parts of the Russian Arctic showed that European oils have a higher content of sulfur, asphaltenes, nitrogen, vanadium and nickel and a lower content of paraffins. The physic-chemical properties of paraffinic oil from the Arctic are considered, depending on the permeability and porosity of productive formations. It is shown that oils in medium-permeable reservoirs, compared with oils from low-permeability reservoirs, have a lower content of sulfur, paraffins, resins and asphaltenes.

Keywords: Arctic zone of Russia; paraffin oils; physic-chemical oil properties; hard-to-recover reserves; oil deposit; oil-gas-bearing basin.

СВОЙСТВА АРКТИЧЕСКОЙ ПАРАФИНИСТОЙ НЕФТИ

Научная статья

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Аннотация

Проведен сравнительный анализ свойств парафинистой нефти в арктической и неарктической территории России. Было показано, что арктические парафинистые нефти по своим химическим свойствам более высокого качества и отличаются от неарктических нефтей меньшим содержанием (примерно в 2 раза) серы, смол, асфальтенов и азота. Сравнение свойств парафинистых нефтей в европейской и азиатской частях Российской Арктики показало, что европейские нефти имеют более высокое содержание серы, асфальтенов, азота, ванадия и никеля и более низкое содержание парафинов. Рассмотрены физико-химические свойства арктической парафинистой нефти в зависимости от проницаемости и пористости продуктивных пластов. Показано, что нефти из среднепроницаемых коллекторов, по сравнению с нефтями из низкопроницаемых коллекторов, имеют более низкое содержание серы, парафинов, смол и асфальтенов.

Ключевые слова: Арктическая зона России, парафинистые нефти, физико-химические свойства, трудно-извлекаемые запасы, нефтегазоносный бассейн.

Introduction

The development of promising Arctic oil and gas fields in the Russian Arctic is considered as the basis for the increase in hydrocarbon production in the Russian Federation in the coming decades. Large-scale development of oil and gas resources in the Arctic zone of Russia, accompanied by the development of the infrastructure of the northern territories, greatly contributes to the socio-economic development of the Arctic territories [1], [2], [3].

Hard weather and climatic, complex mining geological and l conditions predetermine the complexity of the implementation of projects for the development of hydrocarbon resources in the Arctic [4]. According to its physical and chemical properties and/or conditions of occurrence, oil from Arctic fields belongs to the type of hard-to-recover reserves [5], [6], [7], [8] and requires fundamentally new technological solutions for their development and significant financial investments. When developing deposits in the Arctic zone of Russia (AZR) in conditions of low temperatures, the risks of complications in the production and transportation of hydrocarbons are especially high. One of the significant risks is the formation of paraffin deposits on the elements of submersible and surface equipment. This worsens the technological parameters of equipment operation, increasing the cost of producing oils with a high paraffin content and creating significant production risks, including environmental risks [9], [10], [11]. Paraffinic oils (POs) make up a big part of the oil resources of the AZR. Their properties are little studied [12], [13]. The insufficient knowledge of their properties makes it difficult both to assess the prospects for their development and to develop technological solutions in the field of production and transportation of Arctic oil. Therefore, a more complete and consistent study of the features of the physicochemical properties of Arctic POs becomes an important task. The aim of the work is to study the features of the physicochemical properties of oils with a high content of paraffins in the Arctic zone of Russia.

Materials and methods

The studies were carried out on the basis of information from the database (DB) on the physical and chemical properties of the oils of the world [6]. BD contains informational descriptions of more than 45,000 samples of 7000 oilfields from 195 oil-gas-bearing basins (OGBs) on different continents. The object of study is Arctic oil with a high content of paraffins (more than 6 wt. %), which, in accordance with the classification of oils [8], will be further called paraffinic oils (POs).

To study the features of the physico-chemical properties of paraffinic oils, methods of statistical data analysis and geographic information systems were used. To study the properties of paraffinic oils we formed a sample of BD of 1578 samples of paraffinic oils in Russia. According to the information from the database, 550 oilfields with paraffinic oils have been found in Russia in 11 oil-gas-bearing basins: Baltic, Volga-Ural (VUB), Yenisei-Anabar, West-Siberian, Leno-Vilyuisky, Leno-Tungussky, Okhotsky, Caspian, Prepacific Oceanic, North-Caucasian and Timan-Pechora ones. There are 97 oilfields in the AZR, of which: 2 – in the Yenisei-Anabarskoye, 46 – in the West-Siberian (WSB), 1 – in the Leno-Vilyuiskoye, 3 – in the Prepacific Oceanic, 45 – in the Timan-Pechora basin (TPB).

Results and discussion

3.1. Comparative analysis of physic-chemical properties of paraffinic oils from Arctic and non-Arctic fields

Table 1 presents information on the average values of the physicochemical characteristics of the POs from Arctic and non-Arctic deposits. The average values are traditionally calculated as the arithmetic mean of the considered oil indicators from the formed sample sets. The database contains 379 POs samples from 97 Arctic deposits and 917 samples from 345 oilfields in non-Arctic regions. Oils from the AZR show noticeable differences in physicochemical properties from non-Arctic oils (Table 1).

Table 1 - Average values of physicochemical characteristics of paraffinic oils from Arctic and non-Arctic fields

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Physico-chemical indicator	Russia (non-Arctic)	Sample size	AZR	Sample size
Density, g/cm^3	0.8480	830	0.8431	343
Viscosity at 20°C, mm^2/s	71.90	543	94.47	136
Viscosity at 50°C, mm^2/s	7.40	349	11.67	38
Pour point, °C	-3.28	283	11.56	85
Sulfur content, wt. %	0.98	710	0.41	312
Paraffin content, wt. %	10.80	917	10.25	379
Resin content, wt. %	7.40	792	4.13	295
Asphaltene content, wt. %	1.81	724	1.22	260
Nitrogen content, wt. %	0.16	210	0.08	44
Gas content in oil, m^3/t	108.32	305	133.01	99
Coking capacity, wt. %	3.22	170	1.12	11
Vanadium content, wt. %	0.0046	42	0.0013	29
Nickel content, wt. %	0.0008	17	0.0017	28

It has been established that Arctic PNs differ from non-Arctic ones, according to the classification of oils [8], by a lower content of sulfur (more than 2 times), resins (almost 2 times), asphaltenes (by 33%), nitrogen (2 times), vanadium (3 times). Arctic POs are more viscous both at 20 °C and at 50 °C. They have an average positive pour point, which obviously worsens the rheological parameters of the oil and leads to problems in their production and transportation. The AZR oils are low-sulfurous and, compared to non-Arctic oils, they are more saturated with petroleum gas and have a higher nickel content (approximately 2 times). On average, arctic oils are characterized as oils with high viscosity and high paraffin content (above 10%). They are low resin (resin content less than 8%), low asphaltenes (less than 3%), low gas content (less than 200 m^3/t) and depleted in metals.

3.2. Comparative analysis of the properties of paraffinic oils from deposits in the European and Asian parts of the AZR

The Asian part of the AZR includes the oil and gas bearing territories of the Yenisei-Anabar, West-Siberian, Lena-Vilyui, Leno-Tunguska, Pacific Ocean basins, and the European part is represented by the Timan-Pechora basin. Data on the physic-chemical properties of oils from the Asian and European parts of the Russian Arctic are presented in Table 2.

Table 2 - Average values of the physicochemical characteristics of Asian and European Arctic paraffinic oils

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Physico-chemical indicator	Asian part of Arctic					European part of Arctic
	Yenisei-Anabar	West-Siberian	Lena-Vilyui	Prepacific Oceanic	Average value	Timan-Pechora
Density, g/cm^3	0.8425	0.8417	0.8614	0.8371	0.8457	0.8448
Viscosity at 20 °C, mm^2/s	36.10	11.04	-	4.04	17.06	141.96
Pour point, °C	-	1.05	-	23.60	12.33	14.57
Sulfur content, wt. %	0.08	0.15	0.05	0.11	0.10	0.71
Paraffine content, wt. %	9.52	9.01	12.31	17.25	12.02	11.14
Resin content, wt. %	2.71	3.27	7.58	5.30	4.72	4.89
Asphaltene content, wt. %	0.95	0.36	0.34	1.25	0.73	2.02
Nitrogen content, wt. %	0.11	0.08	-	-	0.10	0.15
Gas content in oil, m^3/t	-	254.82	-	67.18	161.00	121.92
Coking capacity, wt. %	-	0.66	-	1.90	1.28	1.78
Vanadium content, wt. %	-	0.0001	-	0.00001	0.00006	0.0020
Nickel content, wt. %	-	0.00005	-	0.00002	0.00004	0.0026

Table 2 shows that, according to the classification [8], oils from both parts of the AZR belong to the type of oils with an average density (from 0.84 to 0.88 g/cm^3). Oils from the Timan-Pechora basin correspond to high-viscosity oils, oils from the West Siberian basin correspond to medium-viscosity oils, and oils from the Prepacific Oceanic basin correspond to low-viscosity oils. All Arctic POs have an average positive pour point.

According to the sulphur content, the arctic oils of WSB are characterized as low-sulphurous (less than 0.5% wt.), and the oils in TPB are medium-sulfurous (sulfur content from 0.5 to 1%). Oils with the highest paraffin content include oils from the Prepacific Oceanic and Leno-Vilyui oil-gas fields, and a lower paraffin content is typical for the West-Siberian POs. The oils of the Yenisei-Anabar basin have the lowest content of resins and asphaltenes. The nitrogen content is the lowest in West-Siberian oil, which has the highest gas saturation. And the highest metal saturation is observed in the Timan-Pechora oils.

Consequently, European Arctic POs are more viscous and have a higher content of sulfur, asphaltenes, nitrogen, vanadium and nickel. WSB oils are, on average, more paraffinic and more gas-saturated. However, in terms of density, resin content and degree of oil coking, oils from these two parts of the AZR practically do not differ.

3.3. Analysis of the dependence of the properties of paraffinic oils on the age of rocks and depth of occurrence

The analysis of changes in the concentration of PO paraffins depending on the geological age of oil-bearing rocks was based on an array of 847 PO samples with known age (73% of information for the territory of Russia without the Arctic, 27%

of information for the Arctic). In areas outside the Arctic, the largest number of POs are concentrated in Paleozoic sediments – 64% of samples, and the majority of Arctic POs are found in Mesozoic sediments – 61%.

To carry out a statistical analysis of the patterns of changes in the content of PO paraffins depending on age, the data arrays of the Paleozoic, Mesozoic and Cenozoic are divided into subarrays according to stratigraphic systems (Fig. 1 a and b). From Fig. 1 a shows that the maximum number of samples is located in the Devonian, Carboniferous and Jurassic stratigraphic systems. The dependence of paraffin content on age shows a tendency for paraffin concentration to increase with decreasing age of rocks – from 10% in the Vendian to 15% in the Neogene. This dependence is approximated by a 5th order polynomial curve with an approximation reliability value of 0.992.

In the Arctic (Fig. 1 b), the maximum number of PO samples is concentrated in the Devonian, Jurassic and Cretaceous stratigraphic systems. The course of the dependence of the paraffin content in Arctic PN is similar to the course of the curve in Fig. 1 a – an increase in the paraffin content in oils with a decrease in the age of sediments (from the Silurian to the Neogene – from 8% to 17%, respectively, an increase in the paraffin concentration by more than 2 times). The dependence curve of paraffin content in Arctic PO (Fig. 1 b) is approximated by a 6th order polynomial curve, the reliability value is 0.769.

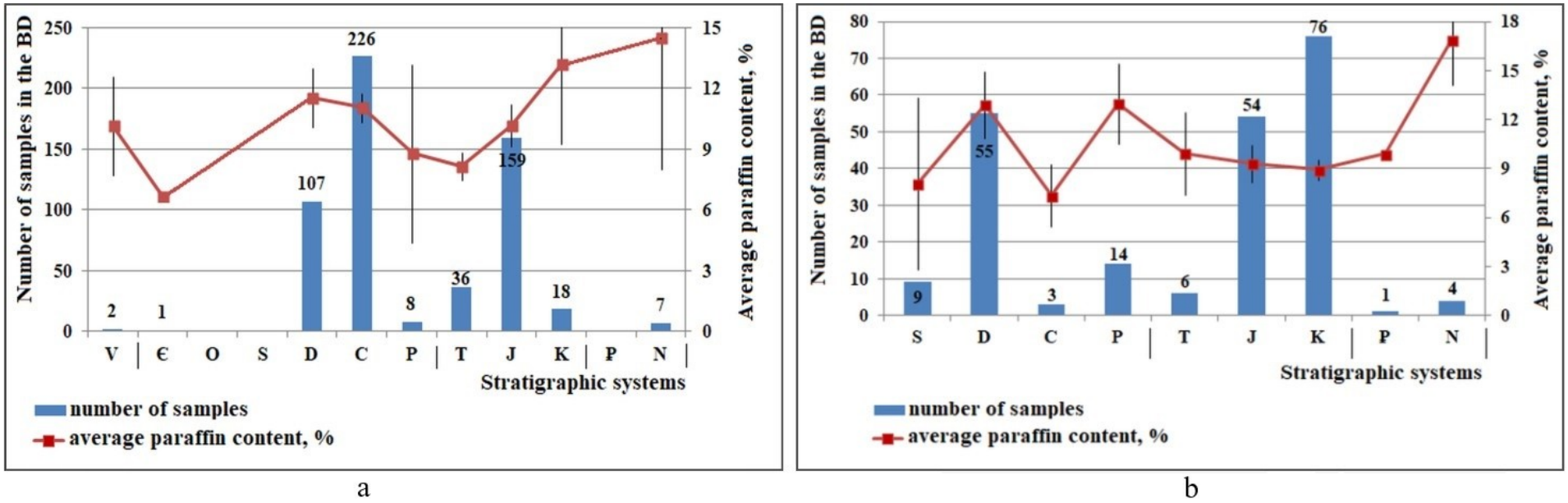

Figure 1 - Dependence of the paraffin content in paraffinic oils on the age of rocks in the non-Arctic (a) and Arctic territories of Russia (b)
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Note: segments of vertical straight lines – the width of intervals with a confidence probability of 0.95

The analysis of changes in the paraffin content in oil deposits depending on the depth of occurrence is based on a study of 761 oil samples with a known depth of occurrence. The distribution of actual material is shown in Fig. 2 (74% of information for the non-Arctic territory (Fig. 2 a), 26% – information on Arctic PO, Fig. 2 b). To conduct research, the entire data array from the database was divided into subarrays according to Fig. 2. It has been established that for the non-Arctic and Arctic territories of Russia, the largest number of POs are concentrated at a depth of 2000-3000 m, which in total amounts to 51% of the total number of POs with a known occurrence depth. In each of the specified depth intervals, the average value of paraffin content was determined. From Fig. 2 a and b it is clear that the dependence of the paraffin content on the depth of occurrence indicates a tendency for the concentration of paraffins to decrease with increasing depth of occurrence – in the non-Arctic territory of Russia, the paraffin content from 10-11% at shallow and medium depths decreases to 8% in deep-lying layers (5000- 6000 m). Similarly, in the Arctic, the paraffin content ranges from 11-13% at shallow and medium depths to 8-10% at great depths (3000-4000 m). These dependencies are approximated by third-order polynomial curves with approximation reliability values of 0.951 and 0.999, respectively.

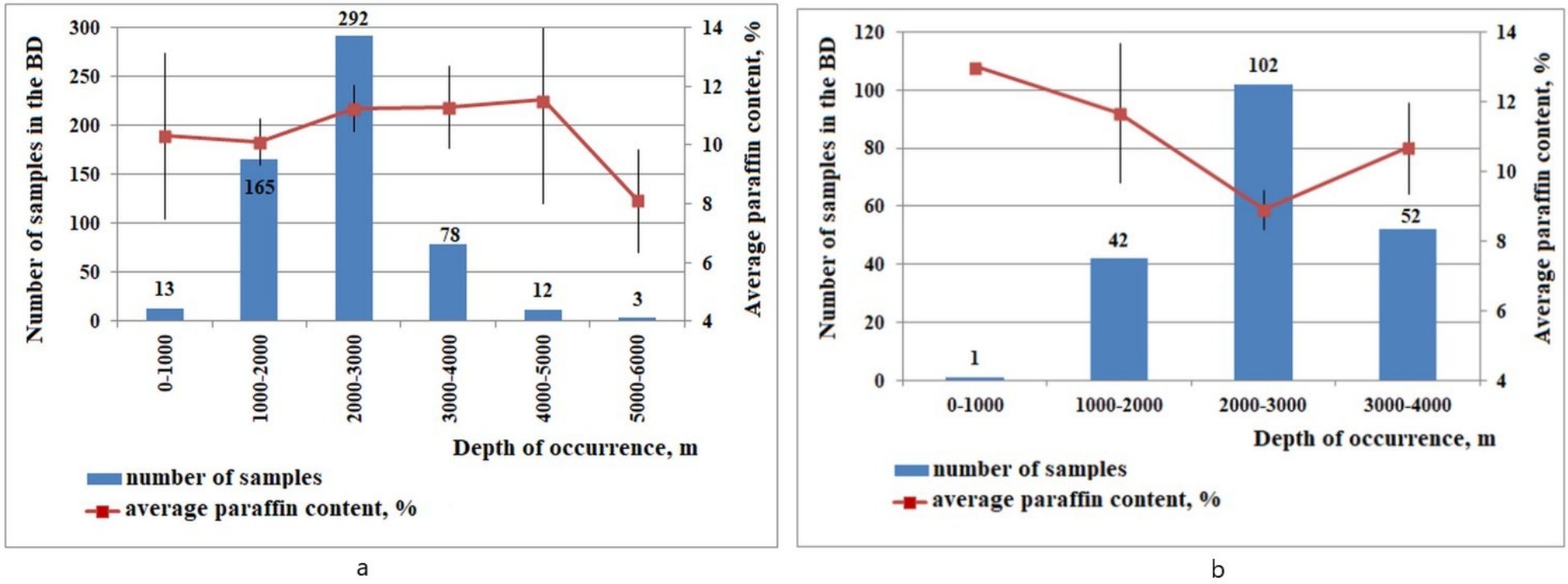

Figure 2 - Dependence of the paraffin content in paraffinic oils on the depth of occurrence in the non-Arctic (a) and Arctic territories of Russia (b)
DOI: https://doi.org/10.60797/CHEM.2024.3.2.4

Note: segments of vertical straight lines – the width of intervals with a confidence probability of 0.95

3.4. Analysis of the properties of arctic waxy oils depending on the permeability and porosity of oil-bearing rocks

The most significant reservoir classification characteristics used to classify oil reserves as hard-to-recover are reservoir temperature, depth, and rock permeability and porosity. Permeability and porosity have a direct impact on the development regime and used oil recovery technologies. It has been established that in the AZR the majority of reservoirs (52.6%) are classified as low-permeability (less than 0.05 μm^2), 40.7% – as medium-permeable (from 0.05 to 0.5 μm^2) and 6.7% – as high-permeability (more than 0.5 μm^2) reservoirs.

Table 3 shows data on the reservoir characteristics of low- and medium-permeability reservoirs, which make up more than 90% of the productive strata of the Arctic fields. The permeability of rocks differs several times, and the differences in other indicators are small (Table 3). Next, we study the features of the properties of arctic paraffinic oils depending on the permeability of the rocks.

Table 3 - Reservoir characteristics of arctic paraffinic oils in low and medium permeability reservoirs

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Reservoir characteristics	Low permeability reservoir	Medium permeability reservoir
Reservoir temperature, °C	74.87	67.98
Formation pressure, MPa	29.01	30.44
Permeability, μm^2	0.025	0.15
Porosity, %	14.58	15.71

Table 4 shows the results of the analysis of the properties of POs occurring in productive formations with different permeability. This table 4 shows that oils in medium-permeable reservoirs are characterized by a lower content of sulfur (by 1.5 times), paraffins (by 11%), resins (by 26%), asphaltenes (by 13%) and nitrogen (by 57%), but with higher values viscosity (by 35%) and gas content (by 13%). In medium-permeable reservoirs, oils have a negative oil pour point.

Table 4 - Average values of the physicochemical characteristics of arctic paraffinic oils in low and medium permeability reservoirs

DOI: https://doi.org/10.60797/CHEM.2024.3.2.6

Physico-chemical indicator	Low-permeability reservoir	Medium-permeability reservoir
Density, g/cm^3	0.8383	0.8348
Viscosity at 20 °C, mm^2/s	8.09	12.60
Pour point, °C	4.50	- 7
Sulfur content, wt. %	0.63	0.38
The content of paraffins, wt. %	11.95	10.62
Resin content, wt. %	4.78	3.52
The content of asphaltenes, wt. %	1.49	1.30
Nitrogen content, wt. %	0.07	0.04
Gas content, m^3/t	142.22	171.92

Below are the results of the analysis of the properties of oils depending on the porosity of the rocks. According to the degree of porosity of rocks, the effective reservoir capacity is divided into small (with porosity less than 5%), medium (with porosity from 5 to 15%) and large (more than 15%). It has been established that only 0.2% of oil from the AZR is located in low-porosity reservoirs (porosity is less than 5%), 16% of Arctic oil is located in medium-porous reservoirs, and the vast majority of oil samples (83%) occur in highly-porous reservoirs with a porosity of more than 15%.

Table 5 shows reservoir characteristics of reservoirs of different porosity. Note that medium- and high-porosity reservoirs are also medium-permeable at the same time. It can be seen from Table 5 that the values of reservoir temperature and pressure on average decrease as the porosity of the reservoirs increases.

Table 5 - Reservoir characteristics of Arctic oils in reservoirs with different porosity

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Reservoir characteristics	Low porosity reservoir	Medium porosity reservoir	High porosity reservoir
Reservoir temperature, °C	81.00	82.52	44.74

Formation pressure, MPa	41.85	36.374	20.24
Permeability, μm^2	No data	0.096	0.16
Porosity, %	3.00	12.01	21.10

The results of the analysis of the properties of paraffinic oils in layers of different porosity are presented in Table 6, which shows that low-porosity reservoirs contain medium-density POs with an average content of sulfur and asphaltenes and a high content of petroleum gas. In medium- and high-porosity formations, POs are light, with medium viscosity, low-sulfur, low-resin and low-asphaltenes, with low gas content (less than 200 m^3/t) and have a negative pour point.

Table 6 - Average values of the physicochemical characteristics of arctic paraffinic oils in reservoirs with different porosity

DOI: https://doi.org/10.60797/CHEM.2024.3.2.8

Physico-chemical indicator	Low-porosity reservoir	Medium-porosity reservoir	High-porosity reservoir
Density, g/cm^3	0.8645	0.8318	0.8371
Viscosity at 20 °C, mm^2/s	No data	11.49	17.21
Pour point, °C	No data	-8	-7
Sulfur content, wt. %	0.63	0.34	0.48
The content of paraffins, wt. %	9.92	12.63	9.66
Resin content, wt. %	4.99	3.96	4.20
The content of asphaltenes, wt. %	7.30	1.25	0.91
Gas content, m^3/t	490.05	167.04	112.08

Conclusion

Let us present the main conclusions based on the results of the conducted studies, which used information on the properties of POs from 97 fields with paraffinic oil, identified in the oil-bearing territories of the Arctic zone of Russia. The largest number of them is concentrated in the West-Siberian and Timan-Pechora basins. The physicochemical properties of the paraffinic oils are considered for comparison both in the Arctic and non-Arctic territories of Russia. The patterns of changes in the average content of paraffins in PO depending on the age of oil-bearing rock and the depth of occurrence have been studied. It is shown that the Arctic POs differ in chemical characteristics from the non-Arctic ones in lower content of sulfur (approximately 2 times), resins (almost 2 times), asphaltenes (33%), nitrogen (2 times), vanadium (more than 3 times). Arctic paraffinic oils are more viscous than non-Arctic ones and have a positive pour point. A comparative analysis of the properties of Arctic POs in the European and Asian parts of the AZR showed that European oils are more viscous, with a high content of sulfur, asphaltenes, nitrogen, and metals, while Asian Arctic paraffinic oils have a higher content of paraffins and higher gas saturation.

It is shown that the Arctic paraffinic oils are mainly located in low- or medium-permeable and medium- or high-porosity reservoirs. Compared to oils from low-permeability reservoirs, oils in medium-permeable reservoirs are characterized by a lower content of sulfur (by 1.5 times), paraffins (by 11%), resins (by 26%), asphaltenes (by 13%) and nitrogen (by 57%), but with higher viscosity (by 35%) and gas content (by 13%), have a negative pour point. Oils in medium- and high-porosity reservoirs are light, medium-viscous, low-sulfur, low-resinous and low-asphaltenes, with low gas content (less than 200 m^3/t) and with a negative pour point.

The results of the work can be used in the tasks of improving the technologies for the extraction and transportation of the paraffinic oils from the oilfields of the Russian Arctic.

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Конфликт интересов

Не указан.

Рецензия

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Conflict of Interest

None declared.

Review

All articles are peer-reviewed. But the reviewer or the author of the article chose not to publish a review of this article in the public domain. The review can be provided to the competent authorities upon request.

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