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Research Article

Hard-to-recover, high quality oils in the Russian Arctic

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Abstract

The paper presents an analysis of the physico-chemical properties of hard-to-recover, high quality oils in the Russian sector of the Arctic. In view of the insufficient knowledge of the properties and conditions occurrence of hard-to-recover, high-quality oils in the Russian Arctic, the new results provided in the article on the properties of such oils determine the scientific novelty of the work. The main aim of the study is to study the physico-chemical properties and occurrence conditions of hard-to-recover, high quality oil in the Arctic zone of Russia based on information from the global database on the physico-chemical properties of oils. Based on the quality index and generalised petroleum classification proposed by the authors, a large collection of nearly 3,000 samples of hard-to-recover high-quality oils from the fields of the Russian Arctic was analysed. The features of the physico-chemical properties of hard-to-recover high-quality oils have been studied. It has been shown that hard-to-recover, high quality oil is generally of light or medium density, has medium or high viscosity and, as a rule, is impoverished by petroleum gas, sulphur and heavy metals. It is established that the content of resins and asphaltenes is minimal in the oil of the West Siberian basin and the maximum in the oil of the Leno-Tungusskiy basin. The results of the research are of great practical interest and can be used in developing new and improving existing methods and technologies for oil production, transport and processing of hard-to-recover high-quality oils from the localities of the Russian Arctic.

Keywords

hard-to-recover oils, oil classification, oil-gas-bearing basin, geoinformation systems, physico-chemical oil properties, index of oil quality, oil quality class

Introduction

The relevance of the work is determined by the lack of knowledge of the physico-chemical characteristics of hard-to-recover oils, considered as the main base of oil production growth in the medium term owing to depletion of easily accessible oil reserves (Ibraev 2006; Lisovskiy and Khalimov 2009; Lukyanov et al. 2008; Purtova et al. 2011; Yakuzeni 2005). This makes it difficult to assess the prospects for and determine the directions of development of the domestic oil and gas complex.

Russia is one of the leading Arctic countries in terms of hydrocarbon reserves, accounting for almost 3/4 of the world's Arctic reserves (Harsem et al. 2011; Sidortsov 2016). The Russian Arctic, being a region of special geopolitical, scientific and socio-economic interest to the Russian Federation, constitutes an important oil and gas reserve of the state, which requires serious attention and large investments in the next 10–20 years (Askhabov et al. 2014; Bortnikov 2014; Kaminskii et al. 2011, 2014; Kontorovich 2014; Kontorovich at al. 2010; Laverov et al. 2016; Piskarev and Shkatov 2012; Rudskij 2015; Tkachev 2015).

Materials and methods

The physico-chemical properties of hard-to-recover high quality oils in Russian sector of the Arctic were analysed using the petroleum chemistry database of Institute of Petroleum Chemistry, SB RAS, Tomsk, Russia (Yashchenko and Polishchuk 2014), which contains over 32,940 oil types. Special attention was paid to studying the physico-chemical properties of Arctic oils with a high gas content, with a high reservoir temperature and oils in permafrost.

Methods used in the study: statistical analysis and classification of data to study the characteristics of viscous and heavy oils and geoinformation system methods for spatial analysis of data on the physico-chemical properties and conditions of their occurrence in various oil-bearing basins in the Arctic zone.

Results

According to information from the database (DB), more than 700 fields are located in the Russian Arctic within the boundaries of the Barentsevo-Karskiy, East Arctic, Yeniseysko-Anabarskiy, West Siberian, Leno-Vilyuiskiy, Leno-Tungusskiy, Penzhinskiy, Pritikhookeanskiy, Timano-Pechorskiy, Ust-Indigirskiy and Yuzhno-Chukotskiy oil and gas basins. Among the oil fields on the territory of these oil and gas basins (OGBs), the following unique, large deposits in their reserves should be noted: Pakhtusovskoe in the Barentsevo-Karskiy basin, Urengoyskoye, Russkoye, Severno-Komsomolskoye, Sutorminskoye, Vankorskoye, Samburgskoye, Novoportovskoye, etc. in the West Siberian basin, Naulskoye, Vozeyskoye, Layavozhskoye, Kharyaginskoye, Yaregskoye, Medynskoye-More, etc. in the Timano-Pechorskiy basin, Baykalovskoye in the Yeniseysko-Anabarskiy, Olenekskoye in the Leno-Tungusskiy basin, etc.

Based on geoinformation technologies, the database has been functioning for more than two decades and contains over 32,940 descriptions of oil samples of the world, almost 3,000 of these being oil of the Arctic zone of Russia (AZR). Some results of the analysis of the properties and conditions of hard-to-recover oils (HRO) in Russia on the basis of the quality index proposed by the authors and the generalised classification of oils are provided in (Ibrahim Asaad et al. 2013; Kritsky and Chizh 2013; Polishchuk and Yashchenko 2002; Polishchuk and Yashchenko 2003, 2006; Yashchenko and Polishchuk 2014, 2015, 2017). Analysis of the distribution of reserves of HRO of different quality classes in general in Russia, and in the AZR in particular (Fig. 1), indicates that the share of high quality HRO reserves in Arctic fields is significant.

The results of the preliminary analysis of the properties of oils of different quality classes in the Russian Arctic are provided in (Yashchenko and Polishchuk 2017). High-quality oils with relatively large reserves are of interest to specialists of both oil-producing and oil-refining complexes. In this respect, the aim of the work is a more detailed study

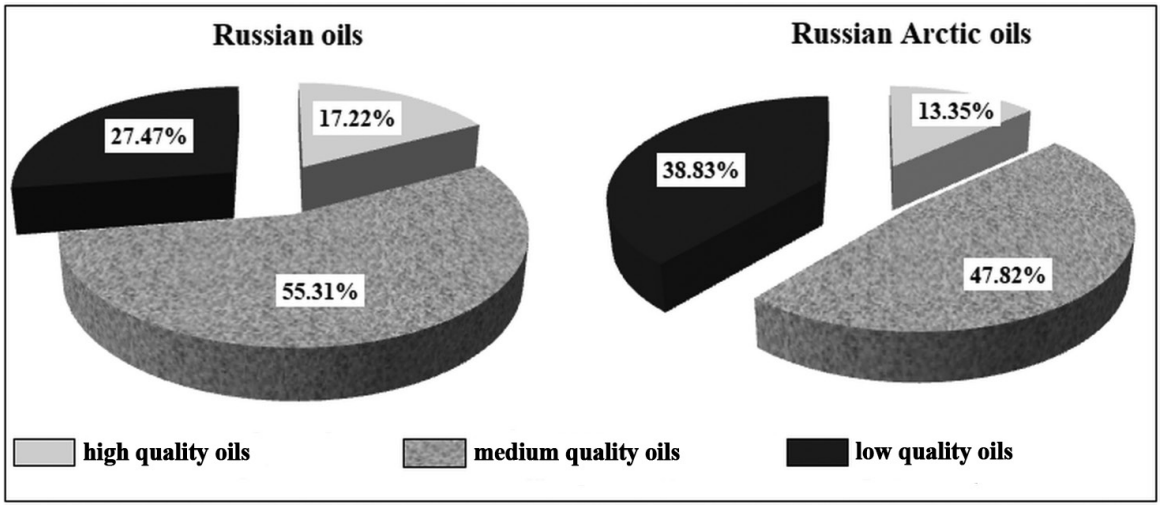

Fig. 1. Analysis of distribution of hard-to-recover oil stocks in Russia by quality class

of the physico-chemical properties and conditions of sedimentation of hard-to-recover high-quality oils located in the AZR.

Discussion

Analysis of the location of Arctic, high quality, hard-to-recover oils

In the article (Yashchenko and Polishchuk 2017), we proposed using a comprehensive index to assess the quality characteristics of oils in oil fields and OGBs. This approach, successfully applied in analysing the physico-chemical properties of different quality classes of HRO, made it possible to study the geographical features of the occurrence of different types of HRO in oil-bearing areas and to make a map of the spatial distribution of HRO of different quality classes, in particular in the Russian Arctic (Yashchenko and Polishchuk 2017).

The methods of statistical analysis and classification of data for studying the physico-chemical characteristics of hard-to-recover, high quality oil and of geoinformation system methods for spatial analysis of data on the properties of oils and conditions of their occurrence were used in the research. Owing to the lack of data in the scientific literature on the properties of hard-to-recover oil in the Russian Arctic, the new results on the properties of such oil determine the scientific novelty of the work.

It has been demonstrated that most of the fields are located in the West Siberian basin – 60, 27 fields are in the Yeniseysko-Anabarskiy basin, 16 are in the Timano-Pechorskiy basin and 4 fields are in the Barentsevo-Karskiy and Pritikhookeanskiy basins. Table 1 presents quantitative characteristics of high-quality Arctic HRO on the basis of information from the database.

Table 1. Information about Arctic oils of high quality

Types of high quality oils	Oils number in DB	Oil-fields number in different basins
With high gas saturation (gas content in oil of more than 500 m^3/t)	15	9 deposits of the West Siberian OGB
With a high reservoir temperature (above 100°C)	75	27 deposits in the West Siberian OGB
At a considerable depth (more than 4,500 m)	52	25 deposits: 24 – West Siberian OGB, 1 – Timano-Pechorskiy OGB
Located in the zone of continuous permafrost	2810	117 deposits: 60 –West Siberian OGB, 16 – Timano-Pechorskiy OGB, 27 – Yeniseysko-Anabarskiy OGB, 7 – Leno-Tungusskiy, 4 – Barentsevo-Karskiy OGB, 3 – Pritikhookeanskiy OGB

Analysis of the physico-chemical properties of high quality oils

Table 2 presents the physico-chemical properties of high-quality oil with a high gas saturation. This type of oil is represented by the West Siberian oils of 9 fields in the Yamalo-Nenets Autonomous Okrug (Vyngapurovskoye, Vyngayakhinskoye, Yety-Purovskoye, Markovskoye, Novogodneye, Severo-Gubkinskoye, Sutorminskoye, Urengoyskoye and Kharampurskoye). Unique reserves are found at Sutorminskoye and Urengoyskoye fields, other listed fields belong to large fields. In general, these oils are deposited in the reservoirs of the lower cretaceous age at a depth of from 2,309 m (Sutorminskoye field) to 2,939 m (Kharampurskoye field). On average, these oils are very light, with a negative freezing point and low viscosity. By their chemical properties, they are low-sulphur, low-tar, low-asphaltene, medium-paraffin, with a high content of petroleum gas and low content of heavy metals and aggressive components (carbon dioxide and hydrogen sulphide).

Table 2. Physico-chemical properties of Arctic oils with a high gas content

Physico-chemical indicators	Average value	Sample size
Density, g/cm^3	0.7854	5
Viscosity at 20°C, mm^2/s	3.73	4
Sulphur content, wt.%	0.46	4
Paraffin content, wt.%	5.42	4
Resin content, wt.%	3.56	4
Asphaltene content, wt.%	0.55	3
Gas content in oil, m^3/t	892.51	15

We present the results of the analysis of the specific properties of hard-to-recover oils with a high reservoir temperature. 27 fields of the West Siberian OGB on the territory of the Yamal-Nenets Autonomous Area were established. These oils mainly belong to Jurassic sediments and three samples from the Urengoyskoye, Evoyakhinskoye and Yaraynerskoye deposits are Paleozoic. 'Hot oil' lies from a mean depth (starting at 2,770 m, Vyngayakhinskoye field) to great depth (over 4,500 m). The following oils of the West Siberian fields with a high reservoir temperature are deep-lying ones: Bovanenskoye, Geologicheskoye, Zapolyarnoye, Malyginskoye, Medvezhye, Semakovkoye, Shtormovoye, Urengoyskoye, Yubileynoye and Yamburgskoye. Oils of the Yyubileynoye field are found at the greatest depths (5,400–5,480 m).

The average values of the physico-chemical characteristics of the HRO under consideration are presented in Table 3, which shows that the oils with a high reservoir temperature ('hot oils') are characterised by low density (from 0.7700 to 0.8429 g/cm^3) and viscosity values and have a negative low pour point. By the content of sulphur (0.01–0.17%), resins (2.05–7.00%) and asphaltenes (0.50–0.70%), these oils are, on average, low-sulphur, low-tar and low-asphaltene oils and, by the paraffin content (2.78–12.11%), high-paraffin ones. The highest content of paraffins (9.76 and 12.11%) is typical of oils of the West Tarkosalinskoye field, the content of sulphur, resins and asphaltenes in which is minimal: 0.05, 2.05 and 0.60%, respectively.

Table 3. Physico-chemical properties of Arctic oils with a high reservoir temperature

Physico-chemical indicators	Average value	Sample size
Density, g/cm^3	0.8044	17
Viscosity at 20°C, mm^2/s	6.69	2
Gelation temperature, °C	–32.00	2
Sulphur content, wt.%	0.09	9
Paraffin content, wt.%	7.41	9
Resin content, wt.%	4.03	4
Asphaltene content, wt.%	0.60	2
Conversion to coke, wt.%	1.95	2
Vanadium content, wt.%	0.0001	2
Nickel content, wt.%	0.00005	2
Carbon dioxide content, wt.%	0.80	3

As can be seen from Table 1, the AZR has 25 fields (24 fields in the West Siberian and one in the Timano-Pechorskiy basin), the productive deposits of which are confined to depths below 4,500 m. The Samburgskoye and Urengoyskoye fields are unique in their deposits, while the Evoyakhinskoye, Komsomolskoye, Pyakyakhinskoye, Yamburgskoye and Yarudeyskoye fields are the largest. The Vostoch-

no-Sarutayuskoye field from Timano-Pechorskoye OGB is small, with reserves of 0.3 million tonnes. Deposits are mainly gas condensate or gas.

Let us consider the oils belonging to the Arctic fields in the permafrost zone. As can be seen from Table 1, the information in the database amounts to about 3,000 descriptions of oil samples from 117 fields of six OGBs: the Barentsevo-Karskiy, Yeniseysko-Anabarskiy, West Siberian, Leno-Tungusskiy, Pritikhookeanskiy and Timano-Pechorskiy basins. Note that more than half of the Arctic fields belong to the West Siberian OGB (51.3%).

Average values of the physico-chemical characteristics of the HRO of the type under consideration are presented in Table 4. This table shows that such oils in different basins have significant differences in physico-chemical properties. Oils in the Leno-Tungusskiy basin, for instance, are heavy (with a density of more than 0.88 g/cm^3), while in other basins the average oil densities are very light (Barentsevo-Karskiy OGB), light (West Siberian and Pritikhookeanskiy OGB) or medium (Yeniseysko-Anabarskiy and Timano-Pechorskiy OGB). By viscosity, the oils of the Timano-Pechorskiy basin correspond to ultra-viscous oils; high-viscosity oils include the Yeniseysko-Anabarskiy basin, extraviscous – oils of the West Siberian basin, with medium viscosity – oils of the Leno-Tungusskiy OGB, while oils of the Barentsevo-Karskiy and the Pritikhookeanskiy basins are low-viscous. A positive pour point is a peculiar feature of the Pritikhookeanskiy and Timano-Pechorskiy OGB. By sulphur content, the Arctic oils of the Barentsevo-Karskiy, West Siberian and Pritikhookeanskiy basins are characterised as low-sulphur (less than 0.5%), the highest sulphur content being found in the oil of the Leno-Tungusskiy basin (1.45%). High-paraffin oils (content more than 6%) include oils of the Pritikhookeanskiy and Timano-Pechorskiy OGB. The content of resins and asphaltenes is minimal in the oil of the West Siberian basin, and maximal in the oil of the Leno-Tungusskiy OGB.

Consequently, on the basis of Table 4 data, it can be concluded that, on average, Arctic hard-to-recover high-quality oils are light or medium-density (with the exception of oil of the Leno-Tungusskiy OGB), with a medium or high viscosity (with the exception of oil of the Barentsevo-Karskiy and the Ptitikhookeanskiy OGB), have low oil gas, sulphur and heavy metal content (with the exception of the Timano-Pechorskiy basin oil).

Conclusions

The paper presents a new analysis of the physico-chemical properties of hard-to-recover high quali-

Table 4. Physico-chemical properties of Arctic oils in permafrost

Physico-chemical indicators	Average value					
	Yeniseysko-Anabarskiy	Barentsevo-Karskiy	West Siberian	Leno-Tungusskiy	Pritikhookeanskiy	Timano-Pechorskiy
Density, g/cm^3	0.8567	0.7921	0.8192	0.8847	0.8169	0.8763
Viscosity at 20°C, mm^2/s	101.85	1.40	38.06	31.08	2.48	1008.53
Gelation temperature, °C	–27.67	–54.00	–25.76	–58.00	23.60	3.56
Sulphur content, wt.%	0.80	0.04	0.20	1.45	0.10	1.43
Paraffin content, wt.%	2.36	–	4.27	0.95	15.11	7.30
Resin content, wt.%	10.81	–	4.05	11.58	7.14	7.09
Asphaltene content, wt.%	5.20	–	0.62	5.58	2.56	3.41
Gas content in oil, m^3/t	–	–	161.89	–	67.18	85.48
Conversion to coke, wt.%	5.36	–	1.56	–	1.90	1.37
Vanadium content, wt.%	–	0.00001	0.00034	0.0277	0.00001	0.0051
Nickel content, wt.%	–		0.00020	0.0066	0.00002	0.0099
Carbon dioxide content, wt.%	0.63	0.36	0.82	–	1.15	0.74
Hydrogen sulphide content, wt.%			0.56			2.09

ty oils in the Russian sector of the Arctic. The analysis is carried out using an extensive array of data on the properties of oil obtained from the database of the Institute of Petroleum Chemistry of the Siberian branch of the Russian Academy of Sciences. The total sample consisted of 2,952 oil samples. During the analysis, the total data set on the studied high-quality oils was divided into subsets, including samples of HRO with a high gas content, a high reservoir temperature and located in the zone of continuous permafrost. For each of the data subsets, the average values of the physical and chemical characteristics were determined, a comparison of which revealed the specific properties of the types of HRO under consideration.

It has been demonstrated that most of the oils with a high oil gas content are located in the West Siberian basin: on average, they are very light, with a negative freezing point and low viscosity. By their chemical properties, they are characterised by a low content of sulphur, resins, asphaltenes, heavy metals and aggressive components and an average content of paraffins. On average, the physico-chemical properties of 'hot oils' do not differ from those of oil with a high gas content. Oils in the permafrost zone are located in six OGBs and have significant differences in physico-chemical properties, depending on their location in the OGB.

The results of the study can be used for developing new and improving existing methods and technologies of oil production, transport and processing, as well as for assessing the prospects for and determining the directions of development of the domestic oil and gas production complex in the Arctic zone of Russia.

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