Available free online at www.medjchem.com

Mediterranean Journal of Chemistry **2012**, 2(1), 382-387

Analysis of chemical composition of high viscous oils

Irina Germanovna Yashchenko and Yury Mikhailovich Polishchuk *

Institute of Petroleum Chemistry, Siberian Branch of Russian Academy of Sciences,
4, Akademichesky Ave., 634021, Tomsk, Russia

Abstract: The spatial distribution of viscous oils which are considered as an important reserve for oil-production in future were studied on base of information from global database on oil physical and chemical properties. Changes in chemical composition of viscous oils in different basins and continents were analyzed as well. It is shown, on average, viscous oils are sulfur-bearing, low paraffin, highly resinous oils with an average content of asphaltenes and low content of the fraction boiling at 200 °C. Study results of viscous oils peculiarities of Canada, Russia and Venezuela are given. The analysis results can be used to determine the optimal layouts and conditions of oil transportation, to improve the search methods of geochemical exploration, and to solve other problems in the oil chemistry.

Keywords: viscous oils, oil chemical composition, spatial distribution, Canada, Russia, Venezuela.

Introduction

In recent years, the world production of hard-to-recover oils with anomalous physical properties, particularly high viscosity, increases due to depletion of light oil reserves in the world. These oils comprise one-tenth of the world production, which is increasing every year. If the increment in oil production in the world remains at the current rate then a fourfold increase in the production of difficult-to-recover oil could be expected by 2030.The oils with a viscosity above 35 mm^2/s at 20 °C falls into the category of viscous oils. The need in these oils increases in connection with the expected oil depletion in many oil fields[1]. In this regard, the study of chemical composition and regularities of spatial distribution of viscous oils (VO) is of great interest[1, 2].

A large volume of information on chemical composition of heavy, viscous, waxy, sulfur and resinous oils, which is necessary for the study of the peculiarities of hard-to-recover oils, has been accumulated at the Institute of Petroleum Chemistry, SB RAS (Tomsk). The global database on chemical composition and physical properties of oils[3,4], created at the IPC SB RAS, includes now above 20,000 oil sample descriptions. Information for database was collected from above 600 different sources, for instance[5-12], Distribution of viscous oils depending on rock age and occurrence depth has been studied in[13, 14]. The purpose of this paper is to analyze the spatial distribution of viscous oils and to study the spatial changes in their chemical composition.

**Corresponding author: Yury Mikhailovich Polishchuk*

E-Mail address: sric@ipc.tsc.ru
DOI: http://dx.doi.org/10.13171/mjc.2.1.2012.30.08.08

Spatial distribution of viscous oils

Nowadays the database currently contains 2,100 descriptions of viscous oil samples from oil bearing basins in the world. Their properties have been characterized in the database. It is obvious from Figure 1, showing the results of geographical zoning oil-gas bearing area, the basins of viscous oil are distributed everywhere on the continents. And 41 oil-gas bearing basins contain viscous oils, which is more than a quarter of the total number of basins in the world represented in the database. The most part of basins with viscous oils is located in the territory of Eurasia. The information on the continental distribution of viscous oils is shown in Table 1.

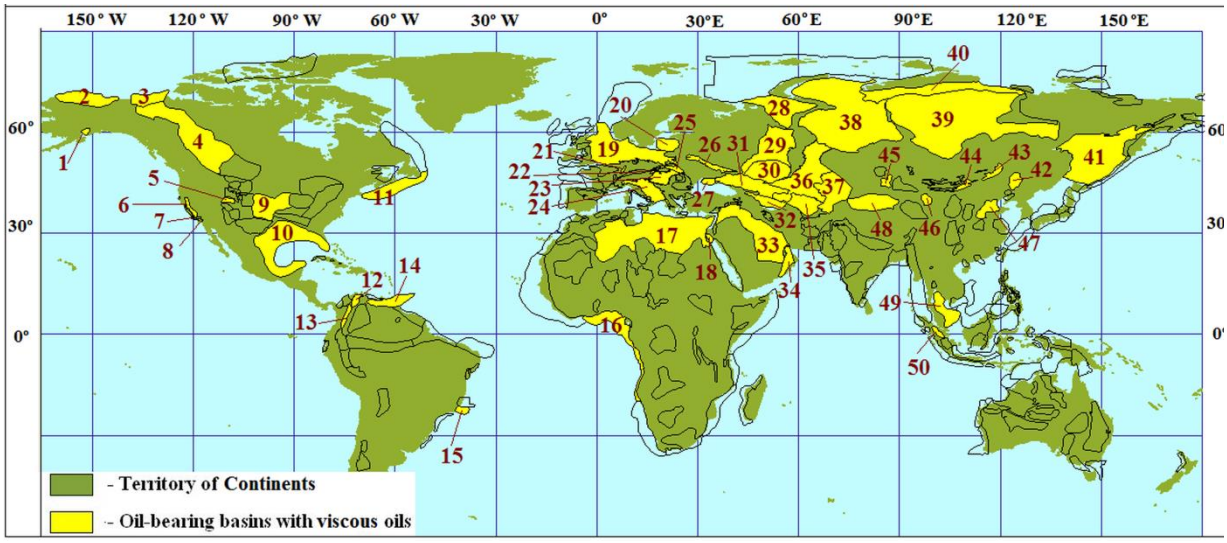

Figure 1. Oil-gas bearing basins with viscous oils on the territories of continents. Designations of oil-gas bearing basins: 1 - Cook Inlet, 2 - Arctic Slope of Alaska, 3 - Boforta,4 - Western Canadian, 5 - Winter Patience, 6 - Great Valley, 7 - Santa Maria, 8 - Los Angeles, 9 - Western Internal, 10 - Gulf of Mexico, 11 – Novoshotlandsky, 12 - Maracaibo, 13 - Upper and Middle Magdalena-14 - Orinoco, 15 – Campos, 16 - Gulf of Guinea, 17 - Sahara-Libyan, 18 - Gulf of Suez, 19 - Central European, 20 - Baltic, 21 - Rhein, 22 - Vienna, 23 - Pannonian, 24 - Adriatic, 25 - Carpathian, 26 - Dnieper-Pripyat, 27 - North-Crimean, 28 - Timan-Pechora, 29 - Volga-Ural, 30 - Pre-Caspian, 31 - North Caucasian, 32 - South Caspian, 33 - Persian Gulf, 34 - Omani-Macran, 35 - Amu Darya, 36 - Turan, 37 - Afghano-Tajik, 38 - West Siberian, 39 - Lena-Tunguss, 40 - Enisey-Anabar, 41 - Okhotsky, 42 – Songliao, 43 – Hailar, 44 - East Gobi, 45 – Dzungarian, 46 - Pre-Nanshang, 47 - Bohai, 48 - Tarim, 49 - Siam, 50 - Central Sumatra

Table 1. General characteristics of data on viscous oils

Location	Database sampling volume	Number of basins with VO	Number of viscous oil fields	Number of VO samples in the database	Share of VO in worldwide reserves (%)
Africa	479	3	7	7	0.44
Eurasia	18,509	33	714	2,034	30.64
Northern America	1,299	12	38	50	61.81
South America	332	4	12	18	7.11

An analysis of the database information showed that the main world resources of viscous oils (57 %) are located in the Western Canada Basin (Canada). The viscous oil resources of

Russia are about 12 %. Venezuela ranks third in the world in viscous oil resources, where their total share is more 6.8 %.

Analysis of chemical composition of viscous oils

Oil composition analysis was carried out using generalized classification of oils[4]. The individual oils were classified using the weight % categories given in Table 2. The classification limits are determined for contents of sulfur, paraffin, resin and asphaltene which are considered as basic indexes of oil chemical composition[4].

Table 2. Classification types of oils depending on contents of basic indexes of chemical compositions

Chemical component	Class name	Values interval, %
Sulfur	low-sulfur oils	0 – 0.5
	middle-sulfur oils	0.5 - 3
	high-sulfur oils	> 3
Paraffin	low-paraffin oils	0 - 5
	middle-paraffin oils	5 - 10
	high-paraffin oils	> 10
Resin	low-resin oils	0 - 8
	middle-resin oils	8 - 13
	high-resin oils	> 13
Asphaltene	low- asphaltene oils	0 - 3
	middle-asphaltene oils	3 - 10
	high-asphaltene oils	> 10

Table 3 represents the statistical characteristics of physical and chemical indexes of average world viscous oils. Confidential intervals for the average values of these indexes were calculated for probability 95 %. Large volume of data used for evaluating mean values of these indexes determines small values of the confidential intervals. As shown in Table 3, according to the above-mentioned classification (Table 2), viscous oils are on average middle-sulfur, low-paraffin, high-resin, middle-asphaltenes oils with low content of the fraction boiling at 200 °C given in[4].

Table 3. Chemical composition and physical properties of average world viscous oils

Oil parameters	Sample number	Average value	Confidence interval
Density, g/cm^3	2,033	0.9107	0.0020
Viscosity at 20 °C, mm^2/s	2,109	1,300	311.62
Sulfur content, wt%	1,167	1.92	0.09
Paraffin content, wt%	1,055	4.00	0.19
Resin content, wt%	917	16.45	0.57
Asphaltene content, wt%	979	4.63	0.24
Fraction b.p. 200 °C, wt%	385	12.86	0.73
Fraction b.p. 300 °C, wt%	321	29.06	1.09
Fraction b.p. 350 °C, wt%	250	37.82	0.94
Coke content, wt%	597	5.70	0.23

It is clear from Table 4, that the densities of viscous oils from different continents are different: according to the classification in[4], the viscous oil in Eurasia is classified as 'high density oil', in South America it belongs to the subclass 'super-heavy oil', and in North America – 'bituminous oil'. The Eurasian viscous oil is highly viscous, and in America – super-viscous one. According to the classification in Table 2, the viscous oils are on average middle-sulfur, low-paraffin and middle-asphaltene in Eurasia and America, and high-resin in Eurasia and North America.

Table 4. Comparative characteristics of viscous oils properties in different continents

Oil parameters	Eurasia	South America	North America
Density, g/cm^3	0.9098	0.9394	0.9388
Viscosity at 20 °C, mm^2/s	550	29,095	21,738
Sulfur content, wt%	1.92	1.74	1.93
Paraffin content, wt%	4.01	1.40	2.35
Resin content, wt%	16.36	No data	42.57
Asphaltene content, wt%	4.57	7.55	9.38
Fraction b.p. 200 ^{o}C, wt%	12.86	No data	8.00
Fraction b.p. 300 ^{o}C, wt%	29.02	No data	34.65
Coke content, wt%	5.69	No data	12.92

Comparative analysis of oil chemical composition in Russia, Canada and Venezuela

Russia has significant reserves of viscous oils amounting to 7 billion tons[2]. In traditional oil-producing regions (Western Siberia, North Caucasus, Volga-Ural and Timan-Pechora), along with the share of production of hard-to- recover oils with high viscosity. Russia could produce annually up to 25-30 million tons of additional oil through the development of viscous oil reserves.

It is interesting to considered the distribution of viscous oil reserves by oil-gas basins of Russia. The results of a comparison between chemical properties of Russia's viscous oils and of Canada and Venezuela are presented in Table 5, which shows that the Russian oils contain less of asphaltenes, but more paraffins.

Table 5. Chemical composition of Russian, Canadian and Venezuelan viscous oils

Oil parameters	Russia			Canada			Venezuela		
	Sample number	Average value	Confidence interval	Sample number	Average value	Confidence interval	Sample number	Average value	Confidence interval
Sulfur content, wt %	854	2.28	0.08	4	3.84	2.63	3	2.06	1.68
Paraffin content, wt %	758	3.99	0.27	3	2.41	3.09	1	1.10	-
Resin content, wt%	702	17.34	0.65	1	44.80	-	-	-	-
Asphaltene content, wt %	769	4.96	0.29	6	7.78	4.99	1	12.50	-

In what follows, we consider the peculiarities of distribution of oil and gas basins of Russia in accordance with the value of the average-basin oil viscosity. It is revealed that the viscous oil deposits occur almost in all basins of Russia except Lena-Vilyui, Anadyr-

Navarino and Penzhin basins (Figure 1). Average basin oil viscosity is higher 35 mm^2/s for the following 5 basins: Volga-Ural, Dnieper-Pripyat, Okhotsky, North Caucasian and Timan-Pechora basins (Figure 1). On average, the most viscous Russian oils are those of Timan-Pechora basin. It is seen from Figure 1 that one half of the basins with a viscous oil is located on the European territory of Russia (Volga-Ural, Dnieper-Pripyat, Pre-Caspian, North Caucasian and Timan-Pechora) and the other half is situated in the Asian part of Russia (Yenisey-Anabar, West-Siberian, Lena-Tunguss and Okhotsky basins).

As noted above, the main VO resources of Russia are concentrated in the Volga-Ural (48.8 %), West Siberian (27.5 %) and Timan-Pechora (16.9 %) oil-gas bearing basins. Chemical composition of viscous oils in these basins is presented in Table 6, where the average values have been determined by the territories of basins and the confidence intervals for these average values have been found for the probability of 95 %. Table 6 shows that the viscous oils by classification[4] are on average sulphurous, high resinous (except West-Siberian viscous oils, which are middle-resin), but with low content in paraffin and in fraction before boiling at 200 °C, while their content in fraction boiling at 300 °C is average.

Table 6. Chemical composition of the viscous oils in the main Russian basins

Oil parameters	Volga-Ural basin			West Siberian basin			Timan-Pechora basin		
	Sample number	Average value	Confidence interval	Sample number	Average value	Confidence interval	Sample number	Average value	Confidence interval
Sulfur content, wt %	568	2.90	0.08	109	1.20	0.11	64	1.81	0.19
Paraffin content, wt %	492	4.27	0.15	113	4.47	0.52	47	4.08	1.63
Resin content, wt %	471	20.01	0.72	125	10.07	0.79	24	16.53	2.58
Asphaltene content, wt %	542	5.87	0.31	115	2.36	0.30	22	7.31	3.69
Fraction b.p. 200 °C, wt %.	146	15.97	0.70	24	13.55	1.25	4	12.53	7.33
Fraction b.p. 300 °C, wt %.	101	31.32	0.85	23	31.56	1.62	3	30.33	13.11
Fraction b.p. 350 °C, wt %.	88	36.88	1.32	10	39.62	4.39	1	33	-
Gas content in oil, m^3/t	301	19.16	8.12	43	63.12	7.12	19	40.87	25.04
Coke content, wt %.	317	7.16	0.18	25	4.48	0.62	2	8.98	-

From Table 6 is evident, that viscous oils of the Volga-Ural and Timan-Pechora basins according to the classification[4] belong to the class of oils with an average content of asphaltenes. But viscous oils of the West Siberian basin have low content in asphaltenes. West Siberian oils differ from these of the Timan-Pechora and Volga-Ural basins by weaker content in sulfur, resins, asphaltenes (almost 2-fold), and fractions boiling at 200 and 300 °C, but their content of paraffins is higher. At the same time the viscous oils in Volga-Ural basin are distinguished by the greatest content in sulfur, resins, asphaltenes, and fractions boiling at 200 and 300 °C.

Thus, the results of a comparative analysis of chemical composition of viscous oils given in this paper enhance understanding of the peculiarities of viscous oils at the level of continents, countries, and oil-gas basins.

Conclusion

The need to find new ways of prospecting for exploration and development of hydrocarbon deposits in response to increased oil consumption and the need to develop difficult-to-recover oil reserves makes the investigation of changes of their physical and chemical properties and regularities of regional distribution of viscous oils very urgent. We have studied regularities of spatial changes of chemical composition of viscous oils. It has been found that the fifth part of the total number of basins located in almost every continent contain viscous oil, with most of them being located in Eurasia. However, almost 82 % viscous oil reserves are concentrated in areas of North and South America. It is shown, on average, viscous oils are middle-sulfur, low-paraffin, high-resin oils an average content of middle-asphaltenes and with low content of the fraction boiling at 200 °C according to the classification of oils. The revealed in this work the regularities of regional changes in chemical composition of the viscous oils can be used to determine the optimal schemes and conditions of oil transportation, to improve the geochemical methods for their prospecting and exploration, and to solve some problems of environmental prediction for sustainable development of oil-producing regions.

References

1- Danilova, E., The Chemical Journal, **2008**, 12, 34-37. (in Russian).
2- Vartivarian, D., Andrawis, H., Oil&Gas Journal, **2006**, 104, Issue 6, 52-56.
3- Ahn, V.V., Kozin, Ye.S., Polishchouk, Yu.M., and Yashchenko, I.G., Geology of Oil and Gas**, 2000**, 2, 49–51. (in Russian).
4- Polishchuk, Yu.M., Yashchenko, I.G., Physico-Chemical Oil Properties: Statistical Analysis of Spatial and Temporal Variations. Novosibirsk: SB RAS Editions, 'Geo' Branch, **2004**. (in Russian).
5- Polishchuk, Yu.M., Yashchenko, I.G., International Journal of Energy and Environment. **2011**, 2, Issue 4, 717-722.
6- International Petroleum Encyclopedia, Ed. John C. Mc Caslin, Tulsa, Texas: Penn Well Publishing Co., **1979**.
7- International Petroleum Encyclopedia, Ed. John C. Mc Caslin, Tulsa, Texas: Penn Well Publishing Co., **1983**.
8- International Petroleum Encyclopedia, Ed. John C. Mc Caslin, Tulsa, Texas: Penn Well Publishing Co., **1985**.
9- International Petroleum Encyclopedia, Ed. John C. Mc Caslin, Tulsa, Texas: Penn Well Publishing Co., **1989**.
10- Mark Bobra, Sandra Callaghan, A Catalogue of crude oil and oil product properties. Ottawa: Consultchem Ottawa, **1990**.
11- Nickolis, J.H., Luhning, R.W., Journal of Canadian Petroleum Technology, **1977**, 3, 50–61.
12- Speight, J.G., The Desulfurization of Heavy Oils and Residua, New-York – Basel: Marcel Dekker, **1999**.
13- Ahn, V.V., Polishchuk, Yu.M., Yashchenko, I.G., Journal of Organic Geochemistry, **2002**, 33, Issue 12, 1381-1387.
14- Yashchenko, I.G., Polishtchouk, Y.M., Progress in Oilfield Chemistry, Ed. by Istvan Lakatos, **2011**, 9, 277-288.