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Spatial and temporal changes of density and chemical composition of heavy oils of Eurasia

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Abstract
Paper is devoted to analytical review of regularities of spatial and temporal changes of chemical composition and density of heavy oils of Eurasia, which are envisaged as main reserve of world’s oil production industry for future years. The contents of sulfur, paraffin, resin, asphaltene and light fraction in heavy oils and their density were analysed statistically with use the global database on petrochemistry created by Institute of petroleum chemistry. The database includes above 3,660 samples of heavy oils from 62 principal oil-bearing basins in Eurasia. The basic regularities of regional distribution of heavy oils are considered. It is shown that the heaviest oils of Eurasia are in oil-bearing basins of Southern Europe and Southern Asia. The regularities of heavy oil density changes depending on occurrence depth are given. It is shown oil density decreases with depth growth. Maximum values of density of heavy oils are observed in Cenozoic rocks and their minimum values are in Proterozoic rocks. In average, heavy oils are sulfur, high resin, high asphaltenes ones containing small paraffin and small light fractions.

Keywords: Chemical composition of oils; Occurrence depth; Petrochemistry; Reservoir rock age; Heavy oils.

1. Introduction

An increase of hard-to-recover reserves in the structure of the raw oil production is an important feature of the world’s oil production industry. In developed countries, these reserves are envisaged not only as a reserve for oil production but also as the main base for its development for the years to come [1]. Heavy oils are one type of hard-to-recover oils. The world’s research community envisages heavy oil as one of the main raw materials for the power industry of the 21^{st} century. So it is necessary to carry out a review of spatial-and-temporal changes of chemical composition and the regional distribution of heavy oils in Eurasian territory, which has become the objective of the present work.

Oils with density more 0.88 g/cm^3 are named heavy ones [2, 3]. These reviews are based on analysis of some published papers and results of new studies carried out using the global database on petroleum chemistry [4-9]. The database has been developed at the Institute of Petroleum Chemistry, Siberian Branch of Russian Academy of Sciences on base of the geoinformation technologies. Now the database on petroleum chemistry (DBPC) involves above 19,000 information units connected with about fifty physical-chemical, geochemical and geological characters and data on the geographic location of oil fields and oil-bearing basins. Laboratory analysis at the bulk level can fractionate crude oils into a light fraction, organic - sulfur molecules, paraffin wax, resins and asphaltenes. In particular, 75 samples of oils from Assam, Kambay and Kach-Katiavarsky oil-bearing basins in Indian territory are represented into the database on petroleum chemistry. More full description of the database on petroleum chemistry is given in our book [9]. This database contains above 3,660 information units about properties of heavy oils of Eurasia.

2. Methodical questions of analysis completed

Data array on Eurasian heavy oils has been formed on base of information from the global DBPC to make an analysis of spatial and temporal changes of density and chemical composition of oils. Because of spatial character of information on oil fields distribution spatial changes analysis of heavy oil density was carried out using geostatistical approach [8-10] to data analysis. This approach is based on combination of methods of statistical analysis and spatial one. Spatial analysis of geodata is of ten realized using tools of geoinformation systems (GIS) and GIS-technologies. So this analysis is named GIS-analysis. Thereby digital thematic maps are used both for carrying out spatial analysis of geodata and for visualization and cartographic representing the analysis results on the computer maps.

For statistical procession of oils data, it is necessary to classify the oil samples by their phisico-chemical indices. As for our paper purposes, the most suitable classification of oils may be generalized scheme (Table 1), which is based on accounting main physical characteristics and chemical composition indices of oils [9]. The values of classification intervals in Table 1 were determined on base of analysis of the information from DBPC.

Table 1. Classification types of oils for different indices of chemical composition

Chemical component [wt %]	Class name	Values interval [wt %]
Sulfur	low-sulfur oils	< 0.5
	middle-sulfur oils	0.5 - 3
	high-sulfur oils	> 3
Paraffin	low-paraffin oils	< 5
	middle-paraffin oils	5 - 10
	high-paraffin oils	> 10
Resin	low-resin oils	< 8
	middle-resin oils	8 - 13
	high-resin oils	> 13
Asphaltene	low- asphaltene oils	< 3
	middle-asphaltene oils	3 - 10
	high-asphaltene oils	> 10
Fraction b.p. 200 ^oC	with low content	< 20
	with middle content	20 - 30
	with high content	> 30
Fraction b.p. 300 ^oC	with low content	< 25
	with middle content	25 - 50
	with high content	50 - 75

In order to make the regional analysis of heavy oils it is necessary to develop the detailed scheme of heavy oils classification by density. So full interval of heavy oil density changes was divided in three subintervals:

a) 0.88 – 0.92 g/cm^3,
b) 0.92 – 0.96 g/cm^3,
c) more 0.96 g/cm^3 ,

for each of which the heavy oils will be named accordingly

a) mildly heavy oils,
b) super heavy oils,
c) bituminous oils.

This classification of heavy oils using in our paper for subsequent analysis is adjusted with some classifications of other researches, for instance [11, 12].

3. Regional analysis of spatial distribution of heavy oils depending on its density

There are 3,663 samples of heavy oils in the DBPC, which are taken from 62 Eurasian oil-bearing basins. Table 2 represents general information about distribution of heavy oils by oil-bearing basins with mean-basin density of oils more 0.88 g/cm^3. The individual oils were classified using the weight % categories given in Table 1. As it is shown in Table 2, in average, the most of heavy oils in Eurasia are oils of Sicilian and Adriatic basins in Southern Europe and oils of Bohai Bay and Fang basins in Southern Asia.

Table 2. Distribution of heavy oils in main oil-bearing basins of Eurasia

Number	Name of basin	Number of oils in basin	Number of heavy oils in basin	Mean-basin oil density [g/cm^3]
1	Adriatic	35	12	0.9409
2	Akvitanian	17	5	0.8861
3	Akita	13	4	0.8889
4	Afghan-Tajik	506	125	0.8670
5	Bohai Bay	49	9	0.9569
6	East - Gobian	28	19	0.8884
7	East - Mediterranean	7	2	0.9009
8	Prealpian	14	4	0.8807
9	Precaspian	823	419	0.8856
10	North - Chinese	4	4	0.8845
11	Sicilian	7	3	0.9913
12	Songliao	13	10	0.8992
13	Fang	4	2	0.9145

Analysis of regional distribution of Eurasian oil-bearing basins containing the heavy oils has been carried out. According to above-mentioned, there are 62 oil-bearing basins with heavy oils in Eurasian territory. Regional distribution of these oil-bearing basins represented at map of Eurasia is given in Figure 1. The cartographic scheme shows almost uniform distribution of oil-bearing basins at territory of Eurasia. It is interesting to study regional distribution of Eurasian oil-bearing basins with heavy oils depending on density.

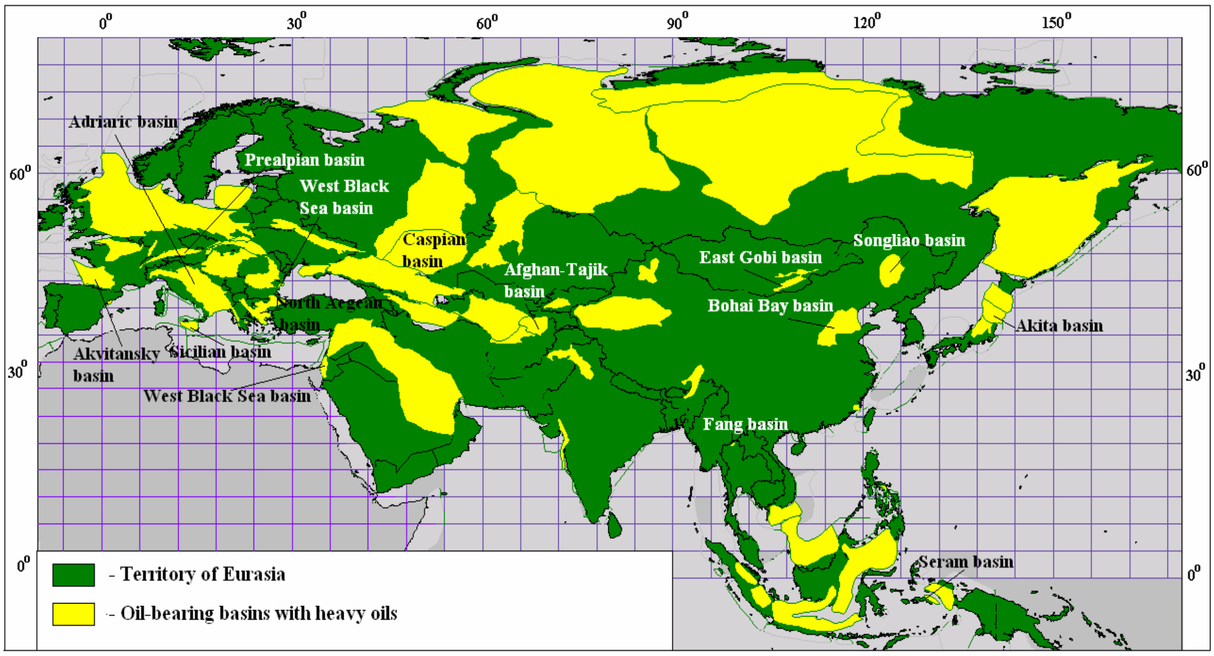

Figure 1. Regional distribution of oil-bearing basins with heavy oils in Eurasia

In accordance with above-mentioned, heavy oils are divided by density into three subclasses: mildly heavy, super heavy and bituminous oils. As it is shown on base of analysis of 3,164 samples of heavy oils of the Eurasian oil-bearing basins, heavy oils of Eurasia are distributed by subclasses according to Figure 2. Widening geologic searches of heavy oils in Eurasia may lead to correction of Figure 2 in future.

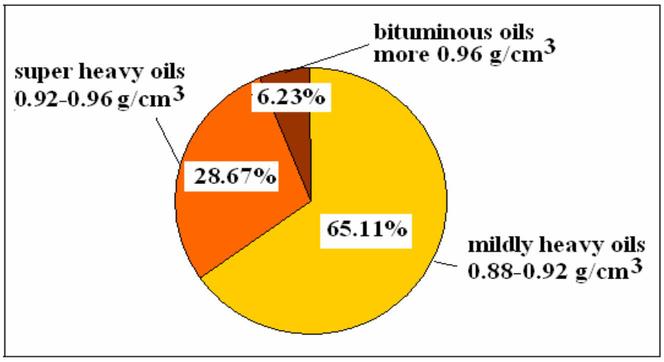

Figure 2. Distribution of Eurasian heavy oils depending on density

4. The relationship between the oil density and occurrence depth

Relationship between the oil density and occurrence depth have been considered in [13]. Below are results of the same analysis for Eurasian heavy oils based on the examination of more 2,640 samples of heavy oils of Eurasian basins. The distribution of the data on density depending on occurrence depth is shown in Figure 3. Most of heavy oils of Eurasia (above 45 %) occur at the depth 1,000 – 2,000 m. About 1/3 of them are at the depth less 1,000 m. Therefore, as it is shown from Figure 3, about ¾ Eurasian heavy oils are at the depth less 2,000 m.

Figure 4 shows oil density changes depending on occurrence depth for the heavy oils of the principal oil-gas bearing territories of Eurasia. Black squares show oil density values averaged in intervals of occurrence depths. The occurrence depth of Eurasian heavy oils is limited to 5,000 m and the heaviest oils occur at the depth less 1,000 m. It is noted that density of Eurasian heavy oils is less then density of heavy oils in the world on average in the corresponding depths [14].

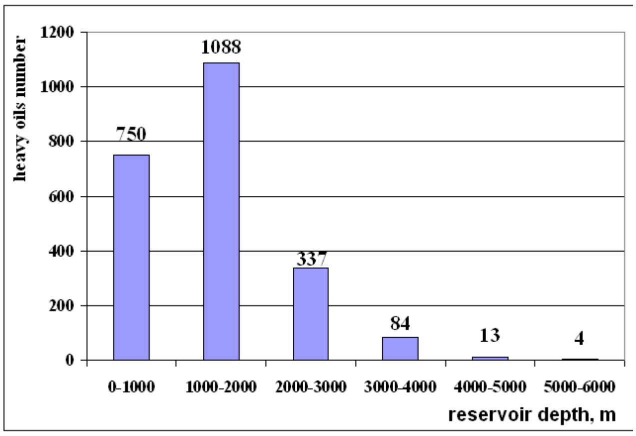

Figure 3. Distribution of Eurasian heavy oils depending on reservoir depth

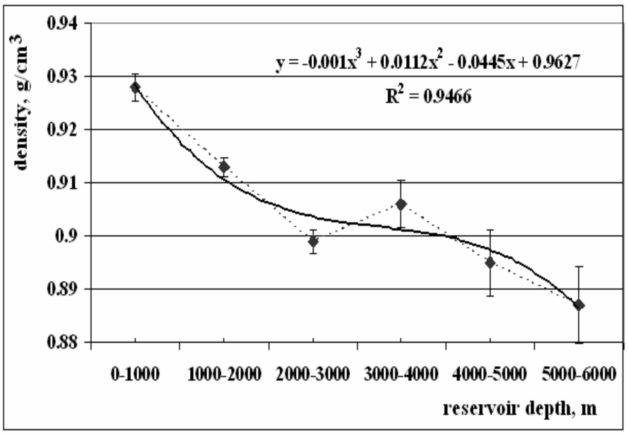

Figure 4. Density of heavy oils of Eurasia depending on occurrence depth

5. The relationship between the oil density and age of the oil-bearing rocks

The global analysis of changes of oil density in relation to the geological age of oil-bearing rocks carried out in our [14, 15] shown relationship between the oil density and rock age. Below are results of the same analysis for Eurasian heavy oils based on the examination of more 2,460 samples of heavy oils of Eurasian basins. The distribution of the data on oil density by geological eras (Cenozoic, Mesozoic, Paleozoic, Proterozoic) is shown in Figure 5.

As it is seen from Figure 5, Eurasian heavy oils of Paleozoic are the most representative. Their number exceeds 45 % of total number of Eurasian heavy oils that is more comparing with world heavy oils [14]. Relative parts of Cenozoic and Mesozoic heavy oils of Eurasia are approximately equal (about ¼ of total number).

As it is seen from Figure 6, the most density of Eurasian oils is in Cenozoic. The average density values of the Eurasian heavy oils in Paleozoic and Mesozoic are very close: 0.909 and 0.910 g/cm^3 respectively. Proterozoic oils are on average the smallest density.

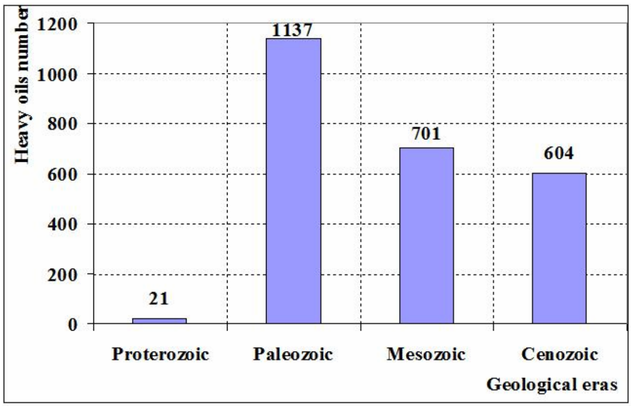

Figure 5. Distribution of Eurasian heavy oils depending on rock age

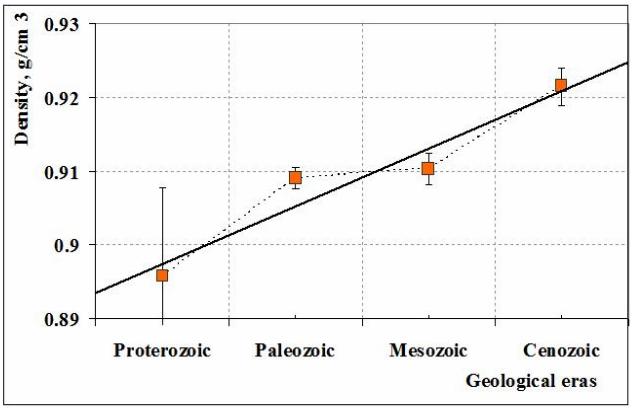

Figure 6. The changes of oil density of Eurasian heavy oils depending on rock age

6. Analysis of chemical composition indices for Eurasian heavy oils

Detailed statistical information on the chemical composition of heavy Eurasian oils is given in Table 3. Confidential intervals were calculated under confidence probability 0.95. Table 3 shows that heavy Eurasian oils are on average middle-sulfur, high-resin, middle-asphaltene and low-paraffin ones accordingly to oil classification given in Table 1. However Eurasian heavy oils are less sulfuric, more resins and asphaltenes ones as compare with world heavy oils [14]. Content of fraction b.p. 200 ^{o}C and 300^{o}C in Eurasian oils are less than in averaged world ones.

Table 3. Statistical indices of chemical composition of Eurasian heavy oils

Oil indices [wt %]	Total number of oil samples in DBPC	Average value [wt %]	Confidence interval [wt %]
Sulfur content	2,465	1.94	0.07
Paraffin content	1,850	3.69	0.14
Resin content	1,820	17.45	0.48
Asphaltene content	1,820	4.77	0.19
Fraction b.p. 200 ^{o}C	693	12.40	1.28
Fraction b.p. 300 ^{o}C	565	28.36	2.31
Fraction b.p. 350 ^{o}C	458	34.81	1.30
Vanadium content	241	0.11	0.01
Nickel content	162	0.02	0.003

7. Conclusion

The paper represents an analytical review on regularities of density and chemical composition changes of heavy oils, which are considered by community as main reserve of world oil production for future years. The analysis of the spatial distribution of heavy oils has demonstrated that above half of the oil-gas bearing basins in Eurasia bear the heavy oils. It is shown that the heaviest oils in Eurasia are in Adriatic and Sicilian oil-bearing basins of Southern Europe and in Bohai Bay and Fang basins of Southern Asia.

The characteristic of density changes of heavy Eurasian oils depending on occurrence depth is given. It is shown oil density decreases with depth growth. The maximal density values of heavy Eurasian oils are observed on average at occurrence depth less 1,000 m. Changes of density of heavy Eurasian oils is studied in respect with geological age of reservoir rock. Maximum values of heavy oils density are observed in Cenozoic rocks and its minimum values – in Precambrian rocks.

Statistical analysis of data on chemical composition of heavy Eurasian oils has been carried out. It is shown that, in average, heavy oils is sulfuric, high resins, high asphaltenes ones and with small content of paraffin and light fractions.

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References

[1] Antoniadi, D.G., Valujsky A.A., Garushev A. R. State of the Enhanced Oil Recovery in the Total Volume of World production. Neftyanoye Khozyajstvo. 1999, 1, 16-23 (in Russian).

[2] Naziev V. Residual but not Secondary. Neftegazovaya Vertikal. 2000, 3, 21-22 (in Russian).

[3] Yashchenko I.G., Polishchuk Y.M. High-viscous oils of Eurasia. Xinjiang Petroleum Geology. 2006, 27(3), 375-382.

[4] Ahn V.V., Kozin Ye.S., Polichtchouk Yu.M., Yashchenko I.G. Geoinformation System for Investigation of Space Distribution Regularities of Oil and Gas Resources. Problems of Environmental State and Natural Resources. 2000, 11, 15 – 24 (in Russian).

[5] Ahn V.V., Kozin Ye.S., Polichtchouk Yu.M., Yashchenko I.G. Database on Oil Chemistry and Prospects of Their Application in Geochemical Studies. Geology of Oil and Gas. 2000, 2, 49 – 51 (in Russian).

[6] Polichtchouk Yu.M., Yashchenko I.G., Kozin Ye.S., Ahn V.V. Database on the Composition and Physicochemical Properties of Oil and Gas (DB OG). Official Bulletin of the Russian Agency for Patents and Trademarks. 2001, 3, 340-341 (in Russian).

[7] Polishchuk Y.M., Yashchenko I.G., Kozin Ye.S., Ahn V.V. Database on the Composition and Physicochemical Properties of Oil and Gas. Registered by Rospatent, Certificate N 2001620067 of May 16, 2001 (in Russian).

[8] Polishchuk Yu.M., Yashchenko I.G. Geostatistical Analysis of Oil Distribution by Physicochemical Properties. Geoinformatika. 2004, 2, 18 - 28 (in Russian).

[9] Polishchuk Yu.M., Yashchenko I.G. Physicochemical Oil Properties: Statistical Analysis of Regional and Time Changes. Novosibirsk: SB RAS Editions, 'Geo' Branch, 2004. (in Russian).

[10] Polishchuk Y.M., Yashchenko I.G. Regularities of oil distribution induced by density and viscosity differences. Progress in Mining and Oilfield Chemistry (Ed. by Istvan Lakatos), Akademiai Kiado, Budapest. 2003, 331-338.

[11] Mulyak V.V., Chertenkov M.V. Technology of high-viscous oils extraction (brief review). Oilfield engineering. 2006, 1, 15 – 20 (in Russian).

[12] Nickolis J.H., Luhning R.W. Heavy oil sand in situ pilot plants in Alberta (Past and Present). Journal of Canadian Petroleum Technology. 1977, 3, 50 – 61.

[13] Ahn V., Polishchuk Y.M., Yashchenko I.G. Some Results Obtained on the Study of Chemical Composition of Eurasian Oils Depending on the Depth and Age of the Reservoir Rock. Organic Geochemistry. 2002, 33(12), 1381 -1389.

[14] Polishchuk Y.M., Yashchenko I.G. Heavy Oils: Analytical Review of Regularities of Spatial and Temporal Changes of Their Properties. Oil and Gas Business. 2005, 3, 21 – 30 (in Russian).

[15] Polishchuk Y.M., Yashchenko I.G. Regularities Governing the Variability of the Content of Resins and Asphaltenes in Oils of Eurasia. Russian Geology and Geophisics. 2003, 44(7), 695 - 701.

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