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# INTERRELATION BETWEEN PROPERTIES OF VISCOUS OILS AND THE LEVEL OF THERMAL FLUX IN TERRITORIES OF THE VOLGO-URALSKIY, WESTERN SIBERIAN AND TIMANO-PECHORSKIY POOLS

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*Fluctuations of basic properties of viscous oils of the Volgo-Uralskiy, Western Siberian and Timano-Pechorskiy oil-and-gas-bearing basins have been investigated depending on the level of thermal flux. The gaging analysis of spatial distribution of a thermal flux in territory of basins has been carried out. The dependence between thermal flux level and oil viscosity is established. It is shown that oil viscosity decreases with increase in thermal flux level. Interrelations between different contents of sulphur, paraffin, pitches and asphaltenes in oils and thermal flux level are studied. It is shown that with increase of thermal flux level the content of sulphur, pitches and asphaltenes decreases and the content of paraffin increases.*

## Introduction

Owing to an essential exhaustion of oil deposits of small and average viscosity in the world the problem of increase in volumes of oil recovery by involving into the development of hard to recover oil stocks, including viscous oils which stocks are estimated by experts of more than 800 billion tons, sharply arises [1]. In Russia significant stocks of viscous oils (VO) are concentrated in more than 400 deposits which are mainly located in territory of three main oil-and-gas-bearing basins (OGB) – Volgo-Uralskiy, Western-Siberian and Timano-Pechorskiy. Stocks of VO in these OGB amount to than 90 % from the all-Russian stocks of viscous oils (table 1).

***Table 1.*** *Distribution of main stocks of VO in territories of Volgo-Uralskiy, Western-Siberian and Timano-Pechorskiy basins [1, 2]*

| Region | Stocks of VO, billion tons | Share from total stocks of VO in Russia, % |
|---|---|---|
| Western-Siberian basin | | |
| Tyumenskaya Oblast | 2,329 | 37,3 |
| Volgo-Uralskiy basin | | |
| Republic Tatarstan | 1,163 | 18,7 |
| Republic Udmurtiya | 0,285 | 4,6 |
| Samarskaya Oblast | 0,284 | 4,6 |
| Permskaya Oblast | 0,237 | 3,8 |
| Republic Bashkortostan | 0,151 | 2,4 |
| Timano-Pechorskiy basin | | |
| Republic Komi | 0,897 | 14,4 |
| Arkhangelskaya Oblast | 0,498 | 8,0 |
| Total: | 5,845 | 93,7 |

The knowledge of distribution laws of such oils and fluctuation of their physical and chemical properties depending on the level of thermal flux (LTF), characterizing power resources of thermal flux as one of the major factors of oil-and-gas formation, is of a great importance in problems of increase of survey efficiency and extraction of viscous oils. Therefore the study of distribution laws of viscous oils depending on the level of thermal flux represents significant interest for survey of oil basins. Some results of the study of spatial changes of physical and chemical properties of viscous oils are stated in a number of our works [3–5]. Separate results of the study of changes of physical and chemical properties depending on the level of thermal flux are published in our works [6–9].

The main purpose of the present work is carrying out of the comparative analysis of changes of physical and chemical properties of viscous oils of Volgo-Uralskiy (VUOGB), Western-Siberian (WSOGB) and Timano-Pechorskiy (TPOGB) basins depending on the level of thermal flux. The basis The global database (DB) on physical and chemical properties of oil, including descriptions of more than 17300 samples of oil, created in Institute of Oil Chemistry of the Siberian Branch of the Russian Academy of Sciences, is the basis of researches of laws of spatial and time changes of VO properties [10, 11].

## General characteristic of data and methods of their analysis

As it is known from the references [12-14], samples of oils with viscosity of mPa·s or 35 $mm^2/s$ and higher is accepted to attribute carry to viscous oils. Viscosity is hereinafter is considered at 20 °C. The resulted values of oil viscosity correspond to the limit, behind which complications at extraction, transportation, oil refining and growth of its cost price begin. We shall briefly characterize the thermal flux in territories of the specified basins (Fig. 1).

On a greater part of Timano-Pechorskiy OGB (north, east and south of the basin) the thermal flux changes within the limits of 30...40 $mWt/m^2$, and in its western part a low level of thermal flux is observed within the limits of 20...30 $mWt/m^2$. As it apparent from Fig. 1, within the limits of the Volgo-Uralskiy basin the level of thermal flux (LTF) changes in wider limits – from 20 $mWt/m^2$ in its northern part up to 50 $mWt/m^2$ in the south of the basin. A great part of the basin pool has LTF within the limits of 30...40 $mWt/m^2$.

The thermal flux in territory of Western-Siberian basin noticeably differs from higher level of thermal flux in comparison with the considered above basins [15]. Areas of the highest level of thermal flux (more than 60 $mWt/m^2$) are observed in Nyurolskaya and Khanty-Mansiyskaya megadepressions, in Ust-Tymskaya depression and in Berezovskaya monoclonal. High values of LTF (more than 50 $mWt/m^2$) are recorded in western part of the peninsula Yamal and along the Koltogorsko-Urengoyskiy megadepression. Lower level of thermal flux (30...40 $mWt/m^2$) is marked in the south of WSOGB (Fig. 1), to the west the area of the low thermal

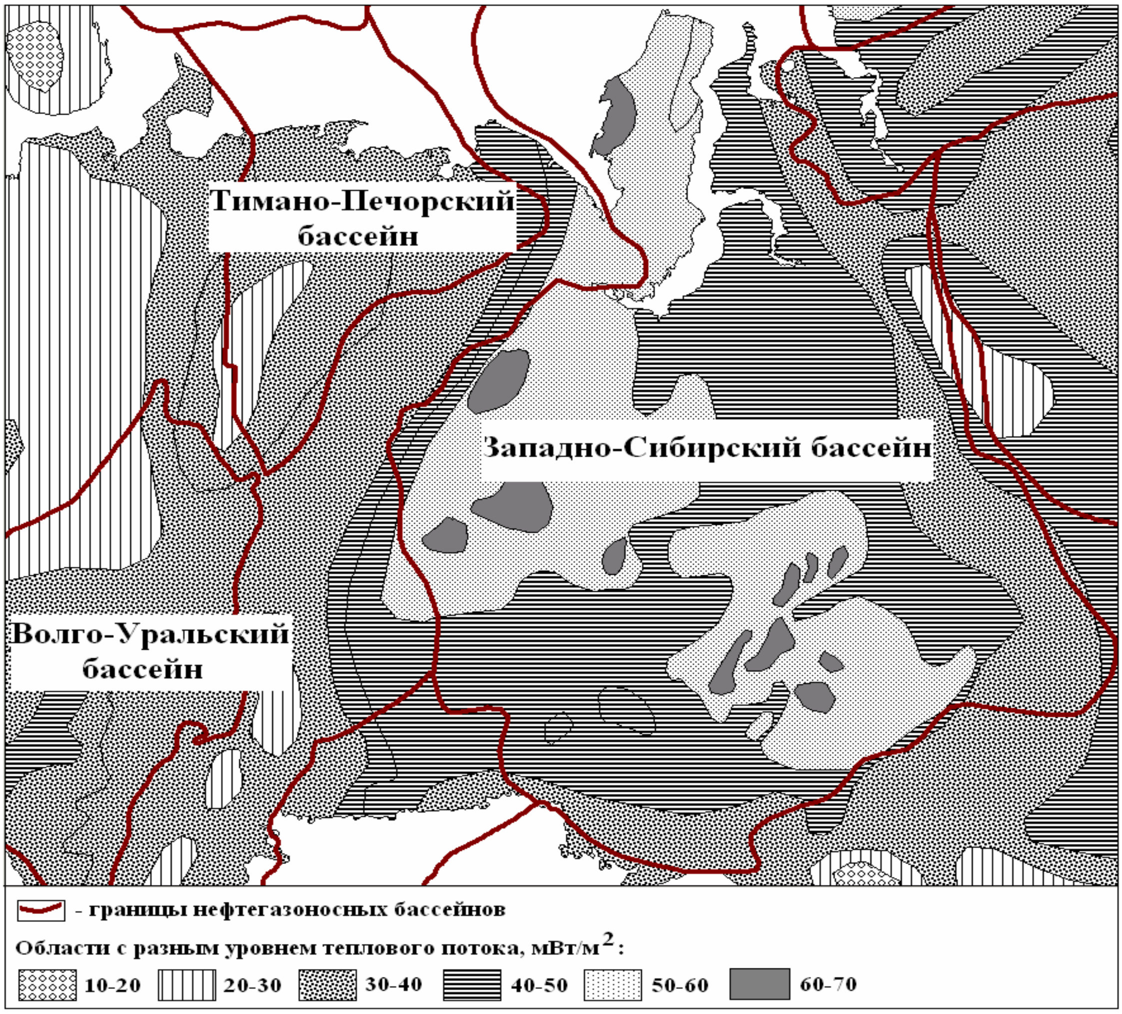


***Рис. 1.*** *Geozoning of territories of Volgo-Ural, Western-Siberian и Timano-Pechora basins by the level of thermal flux*

flux extends, grasping all southwest of Western-Siberian plate and adjacent with it areas of Northern Kazakhstan and Southern Urals.

The following zones with different level of thermal flux with LTF have been allocated for convenience of representation and interpretation of research results:

1. very high (more than 60 mWt/m$^2$),
2. high (from 50 up to 60 mWt/m$^2$),
3. average (from 40 up to 50 mWt/m$^2$),
4. low (from 30 up to 40 mWt/m$^2$),
5. very low (from 20 up to 30 mWt/m$^2$).

### The analysis of laws of spatial distribution of viscous oils depending on the level of thermal flux

The massif of DB files on 1061 samples of viscous oils, 114 of which are Western-Siberian, more than 900 are Volgo-Uralskiy and 38 are Timano-Pechorskiy samples, is used for the analysis. We shall consider the distribution of VO depending on the level of thermal flux in all the territory of basins. As it is apparent from Fig. 2, in the 1$^{st}$ and the 2$^{nd}$ zones with very high and high LTF there is the smallest quantity of VO (50 samples of oils), in the 3$^{rd}$ zone with average LTF (40...50 mWt/m$^2$) the quantity of VO has increased up to 170 samples, and in the 4$^{th}$ and the 5$^{th}$ zones with the lowest LTF there are more than 800 of such oils. Thus, the quantity of VO in zones with low and very low LTF has increased by more than 16 times in comparison with their quantity in zones with high and very high LTF (Fig. 2).

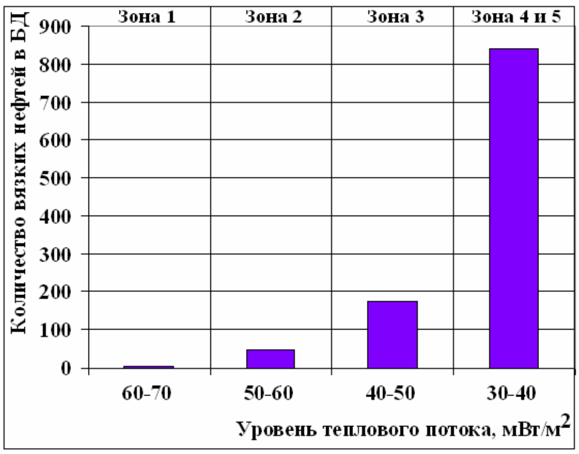


***Fig. 2.*** *Changes in quantity of VO depending on LTF*

***Table 2**. Fluctuation of oil viscosity depending on the level of thermal flux*

| Zones of LTF | Volgo-Uralskiy basin | | | Western-Siberian basin | | | Timano-Pechorskiy basin | | |
|---|---|---|---|---|---|---|---|---|---|
| | Sample volume | Average value of oil viscosity, mm$^2$/s | Confidence interval | Sample volume | Average value of oil viscosity, mm$^2$/s | Confidence interval | Sample volume | Average value of oil viscosity, mm$^2$/s | Confidence interval |
| 1 | – | – | – | 100 | 11,20 | 6,08 | – | – | – |
| 2 | – | – | – | 530 | 14,71 | 1,84 | – | – | – |
| 3 | 109 | 85,30 | 4,43 | 217 | 50,14 | 19,27 | – | – | – |
| 4 | 803 | 101,14 | 2,29 | – | – | – | 158 | 1099,43 | 113,08 |
| 5 | 2 | 154,60 | – | – | – | – | 3 | 10590,10 | 1035,40 |

Let's further consider the distribution of deposits with viscous oils in territories of Volgo-Uralskiy, Western-Siberian, and Timano-Pechorskiy basins. The total number of deposits in territory of three pools amounts to 390 which are distributed among the basins as follows: 339 deposits with VO are allocated in VUOGB, 34 deposits in WSOGB, and 17 of such deposits are revealed in TPOGB. It is possible to show that with reduction of LTF the quantity of deposits with viscous oils also increases. In territory of WSOGB in the 1$^{st}$ zone only 2 deposits (Tolumskoe and Southern-Tolumskoe) have viscous oils, from them the most viscous are oils of the Southern-Tolumskiy deposit (Khanty-Mansiyskiy Autonomous Okrug). In the 2$^{nd}$ zone of such deposits there are 19, and the most viscous for this zone are oils of the Gerasimovskiy deposit (Tomsk Oblast). In the 3$^{rd}$ zone of deposits with viscous oils there are a lot of them as well – 13, in this zone the most viscous are oils of the Russkiy deposit (Yamalo-Nenetskiy Autonomous Okrug).

In territory of VUOGB the situation is similar: in the 3$^{rd}$ zone a total of 48 deposits with VO are revealed and the most viscous oils are located in the Maksimovskiy (Samarskaya Oblast) and Krasnoyarskiy (Orenburgskaya Oblast) deposits, and in the 4$^{th}$ zone of such deposits there are 291, in this zone the most viscous are oils of Aksubaevo-Mokshinskiy deposit (Tatarstan). In TPOGB the most viscous are oils of the Yaregskiy deposit (Komi) which is located in the 5$^{th}$ zone. Generalizing the obtained data, it is possible to tell that in the 1$^{st}$ and 2$^{nd}$ zones with high and very high LTF 21 deposits with VO are established, which is more than 5 % from the total quantity of deposits with viscous oils, in the 3$^{rd}$ zone with the average level of thermal flux there are 61 of such deposits which makes about 17 % from their total quantity, and in zones with low and very low LTF (the 4$^{th}$ and the 5$^{th}$ zones) there are 308 deposits, i. e. about 80 % from the total quantity of deposits with viscous oils.

In table 2 the data on change of oil viscosity in each basin is presented, distributed by the corresponding zones with different level of thermal flux. As it is apparent from table 2, the average values of viscosity on territories of VUOGB, WSOGB, and TPOGB increase with reduction of the level of thermal flux. The confidence interval was defined for the probability of 95 %.

In table 3 the general fluctuations of viscosity of viscous oils in corresponding zones with various LTF is presented. As it is apparent from table 3, the viscosity of VO sharply increases with reduction of the level of thermal flux – from the value 37, 7 mm$^2$/s in the 1$^{st}$ zone up to 10 thousand mm$^2$/s in the 5$^{th}$ zone.

***Table 3**. Fluctuation of viscosity of VO depending on the level of thermal flux*

| Zones of LTF | Sample volume | Average value of viscosity of VO, mm$^2$/s | Confidence interval |
|---|---|---|---|
| 1 | 2 | 37,65 | 0,10 |
| 2 | 49 | 69,97 | 9,78 |
| 3 | 173 | 108,30 | 20,62 |
| 4 | 837 | 302,27 | 21,46 |
| 5 | 3 | 10633,53 | 1026,91 |

### The analysis of interrelation of the chemical compound of viscous oils and the level of thermal flux in territory of oil-and-gas-bearing basins

Researches of fluctuation of a chemical compound of viscous oils of the considered basins depending on the level of thermal flux are carried out. On the basis of the analysis of more than 900 samples of Volgo-Uralskiy, 114 of West-Siberian and 38 of Timano-Pechorsky VO the interrelation of changes in chemical compound of VO from the level of thermal flux is investigated. It is established that with increase in the level of thermal flux the content of sulphur, pitches and asphaltenes in viscous oils of three basins decreases, and the content of paraffins, on the contrary, increases. Namely, on the territory of WSOGB with increase of LTF the content of sulphur and pitches in viscous oils decreases by more than 4 times, asphaltenes by 5 times, and the content of paraffins increases by almost 2 times. A similar interrelation of change of the content of sulfur, pitches, asphaltenes and paraffins from the level of LTF is revealed and for Volgo-Uralskiy VO, namely, the content of sulphur decreases by 3 %, pitches by 4 %, asphaltenes by 5 %, and the content of paraffins increases by almost 8 % with increase of LTF. For Timano-Pechorskiy VO the established laws are characteristic – with increase of LTF the content of sulphur decreases by 23 %, pitches by 2 times, asphaltenes by 5 %, and the content of paraffins increases by almost 2 times.

The data of the general fluctuation in content of sulphur, paraffins, pitches and asphaltenes, depending on the level of thermal flux in zones with various LTF, are presented in table 4. As it is apparent from table 4, the average content of sulphur from the value of 0,3 % in the 1$^{st}$ zone with a very high LTF increases up to 1,9 % in the 5$^{th}$ zone with a very low LTF, i.e. more than by 6 times, the average content of pitches increases from the 1$^{st}$ zone to the 5$^{th}$ zone by more than 5 times, similarly the average content of asphaltenes increases by 40 times, and the content of paraffins decreases by almost 9 times. The confidence interval was defined for the probability of 95 %, for zones 1 and 5 the confidential interval was not defined because of a small volume of sample of viscous oils in these zones.

***Table 4**. Fluctuation of content of sulphur, pitches, asphaltenes and paraffins in viscous oils depending on the level of thermal flux, %*

| Zones of LTF | Sulphur | | Pitches | | Asphaltenes | | Paraffins | |
|---|---|---|---|---|---|---|---|---|
| | Average value | Confidence interval | Average value | Confidence interval | Average value | Confidence interval | Average value | Confidence interval |
| 1 | 0,30 | – | 3,30 | – | 0,40 | – | 6,70 | – |
| 2 | 1,11 | 0,13 | 9,21 | 1,21 | 2,79 | 0,52 | 5,03 | 0,76 |
| 3 | 2,22 | 0,18 | 14,91 | 1,75 | 3,79 | 0,64 | 3,92 | 0,41 |
| 4 | 1,53 | 0,08 | 12,86 | 0,73 | 5,39 | 0,36 | 1,34 | 0,15 |
| 5 | 1,90 | – | 17,00 | – | 16,00 | – | 5,50 | – |

### Conclusion

On the basis of the carried out analysis it has been established that within the limits of the main oil-extracting basins of Russia (Volgo-Uralskiy, Western-Siberian, and Timano-Pechorskiy) the quantity of deposits of viscous oils in this territory increases with reduction of the level of thermal flux. On the example of deposits of the considered basins the authentic interrelation between viscosity oils and the level of thermal flux is established. In zones with a high level of thermal flux the oil appear less viscous and with reduction of the level of thermal the average values of viscosity of viscous oils increases.

Dependences of fluctuation of the content of parameters of a chemical compound of viscous oils depending on the level of thermal flux are established – with increase in the level of thermal flux the content of sulphur, pitches, and asphaltenes decreases, and the content of paraffins decreases, and, on the contrary, increases. The given dependences can testify that processes of oil-and-gas-formation are provided not only by traditional factors of catagenesis, but also by power resources of the thermal flux of the Earth.

The revealed laws can be used for evaluation of quality indicators of oils in once again opened deposits on the basis of the data on the level of thermal flux.

### REFERENCES

1. Maksutov R.A., Orlov G.I., Osipov A.V. Development of stocks of highly-viscous oils in Russia // Technologii TEK. – 2005. – № 6. – P. 36–40.
2. Maksutov R.A., Orlov G.I., Osipov A.V. Technical-technological complexes for development of deposits of highly-viscous oils and natural bitumens // Neftyanoe khozyaistvo. – 2007. – № 2. – P. 34–37.
3. Polischuk Yu.M., Yaschenko I.G. Highly-viscous oils: the analytical review of laws of spatial and time fluctuations of their properties // Neftegazovoe delo. – 2006. – V. 4. – № 1. – P. 27–34.
4. Polischuk Yu.M., Yaschenko I.G. The statistical analysis of viscosity properties of oil of Eurasia // Interval. – 2003. – № 4. – P. 9–12.
5. Polischuk Yu.M., Yaschenko I.G. Laws of regional disposition and fluctuation of properties highly-viscous oils of Western Siberia depending on their age and deposition depth // Tekhnologii TEK. – 2006. – № 1. – P. 10–13.
6. Yaschenko I.G., Polischuk Yu.M., Rikhvanov L.P. The analysis of interrelation of physical and chemical properties of oils with the level of thermal flux // Geologiya nefti i gaza. – 2003. – № 3. – P. 17–24.
7. Yaschenko I.G. The analysis of spatial, time and geothermal fluctuations of viscous oils of Russia // Bulletin of the Tomsk Polytechnic University. – 2006. – V. 309. – № 1. – P. 32–39.
8. Polischuk Yu.M., Yaschenko I.G. The study of connection of oil properties with geothermal characteristics of petroliferous territories // Bulletin of Northeast scientific centre DVO of the Russian Academy of Sciences. – 2005. – № 3. – P. 26–34.
9. Polischuk Yu.M., Yaschenko I.G. The analysis of interrelation of chemical composition and oil density with geothermal characteristics of petroliferous territories // Bulletin of the Tomsk Polytechnic University. – 2006. – V. 309. – № 6. – P. 37–42.
10. Polischuk Yu.M., Yaschenko I.G. Physical and chemical properties of oils: statistical analysis of spatial and time fluctuations. – Novosibirsk: Publishing house of the Siberian Branch of the Russian Academy of Sciences, branch «Geo», 2004. – 109 p.
11. Polischuk Yu.M., Yaschenko I.G., Kozin E.S., An V.V. The database on structure and physical and chemical properties of oil and gas (the DB of oil and gas), registered in Rospatent, certificate № 2001620067 from 16.05.2001.
12. Antoniadi D.G., Valuyskiy A.A., Garushev A.R. Condition of oil extraction by methods of increase of petroextraction in total amount of the world extraction // Neftyanoe khozyaistvo. – 1999. – № 1. – P. 16–23.
13. Gavrilov V.P. The concept of prolongation of the «oil era» Russia // Geologiya nefti i gaza. – 2005. – № 1. – P. 53–59.
14. Zapivalov N.P. Geologic-technologic features of development of hard to recover stocks // Neftyanoe khozyaistvo. – 2005. – № 6. – P. 57–59.
15. Smyslov A.A., Surikov S.N., Wainblat A.B. Geothermal map of Russia. Scale 1:10 000 000 (an explanatory note). – Moscow-Saint Petersburg: Publishing house Goskomvuz, Saint Petersburg Geologic Institute, Roskomnedra, All-Russia Geologic Institute, 1996. – 92 p.

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