MIGRATION ASPECT IN THE OIL-BEARING CAPACITY OF THE DOMANIC FORMATION IN TATARSTAN

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Abstract. The article highlights the problem of oil bearing of the Domanic formation on the territory of the Republic of Tatarstan. Comparing the geochemical characteristics of bitumen of the Semilukskian horizon and oils of the Eifelian-Frasnian terrigenous complex, it was concluded that in the Semilukskian horizon, mobile bitumen are present along with the syngenetic dispersed matter, which, according to gas-liquid chromatography, are identical to the oil of the underlying terrigenous deposits of the Pashian and Timanian horizons.

These bitumens are migratory and reflect the process of upward vertical oil migration, which is responsible for the formation of industrial deposits in the Semilukskian, Sargaevskian, and Rechitskian horizons in those areas where the lithological features of the rocks and the development of superficial fracturing in them make it possible to create a collecting space. The rocks of the Domanic facies should be considered as accumulation or accumulation-generation system, oil deposits of which were formed due to oil systems generated in other sources. New methods of search are needed that allow us to quickly assess the content of migratory hydrocarbons and syngenetic organic matter. This is possible on the basis of a rapid study of the sludge, which will allow to assess the presence of mobile hydrocarbons and their quantity during drilling. An analysis of the spatial distribution of migratory hydrocarbons will allow localizing oil migration channels.

Keywords: Domanic formation, organic matter, bitumen, vertical oil migration, oil deposits, search methods, resources assessment, accumulation system

DOI: https://doi.org/10.18599/grs.19.4.7

For citation: Plotnikova I.N., Ostroukhov S.B., Laptev A.A., Gazizov I.G., Emel'yanov V.V., Pronin N.V., Salikhov A.D., Nosova F.F. Migration Aspect in the Oil-Bearing Capacity of the Domanic Formation in Tatarstan. *Georesursy = Georesources*. 2017. V. 19. No. 4. Part 2. Pp. 348-355. DOI: https://doi.org/10.18599/grs.19.4.7

Introduction

Despite the high degree of geological study of the central part of the South Tatar arch and its slopes, as well as the large number of oil fields discovered here, the question of oil source in the productive complexes of the sedimentary cover remains unsolved. The active study of high-carbon deposits of the Semilukskian and Rechitskian horizons in recent years has made it possible to address this problem again using new results of geochemical studies of oils and dispersed organic matter.

The widespread opinion that enriched with organic matter rocks of the Semilukskian and Rechitskian horizons are the source for oil generation of the entire sedimentary cover of the Ural-Volga region, including the territory of the South Tatar arch, has long been dominant. However, studies of recent decades convincingly prove the existence of at least two sources of hydrocarbons (Gordadze et al., 2005, Kayukova et al., 2009).

Gordadze G.N. and Tikhomirov V.I. have allocated two genotypes of oils by the composition of hydrocarbons-biomarkers – "Under-Domanic" and "Above-Domanic" – associated with the terrigenous deposits of the Middle Devonian and carbonate, terrigenous deposits of the Upper Frasnian, Famennian, Carboniferous, Permian (Gordadze et al., 2005).

Later on, based on the geochemical differentiation of oils in the Samara region (Romanov et al., 2010), three geochemical groups were identified as part of the two oil genotypes: "Under-Domanic" and "Above-Domanic" oils and a mixed one (the third group representing a mixture of the first two). Two years later, similar results were published by Kiseleva Yu.A. and Mozhegova S.V., who also pointed to the existence, including in the territory of Tatarstan, of two genotypes of oil associated with sources in carbonate and terrigenous complexes (Kiseleva et al., 2012).

Due to the fact that the main oil reserves of Tatarstan are associated with the terrigenous deposits of the Lower Frasnian – with the so-called "Under-Domanic"

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part of the sedimentary cover – the source of its origin, supposedly associated with the terrigenous strata, remains unclear. The question of the formation of industrial deposits in the Sargaevskian, Semilukskian and Rechtskian horizons remains open. Low catagenetic maturity of organic matter (end of PC_3, beginning of MC_1), indicating lack of generation potential of dispersed organic matter (OM), low permeability and high lithological heterogeneity of rocks, local distribution of oil content, which is not related to structural traps and controlled by a fractured reservoir of complex shape – all this indicates that the classical scheme of generation-migration-formation of the deposit, in this case, does not work, and the formation of deposits in dense rocks of high-carbon sequences of the Sargaevskian, Semilukskian and Rechtskian horizons is controlled by other factors and involves the use of other search criteria.

In this aspect, the most relevant, from our point of view, is the study, first of all, of the paleofacial conditions for the formation of Dominicites, since this will allow restoring the paleotectonic conditions and the geodynamic regime in which sediments were formed and identify factors that determine the uneven distribution of organic matter in the rock, both spatially and by section. Secondly, it is necessary to find out what types of bitumen are present in the pore space of Dominicites at the present moment and how much they are mobile. Carrying out a correlation between the bitumen of high-carbon sequences and oil of fields is also an important task, since the formation of industrial oil accumulations in the carbonate complex, starting from the Sargaevskian horizon and upper, as a result of the dominant upward vertical oil migration, was established for Tatarstan fields over 40 years ago and subsequently it was repeatedly confirmed in practice (Emelyanov et al., 2014; Plotnikova et al., 2013; Ostroukhov et al., 2014; Ostroukhov et al., 2017).

The purpose of this research was to study and compare bitumen of the Semilukskian horizon and oil of the Timanian and Pashian horizons of the Pervomaisky and Bondyzhsky fields.

The objects of research were 25 samples of bitumen from the Semilukskian horizon of the Pervomaisky field from the interval 1662.0-1685.0 m (Figure 1) and 7 samples of oil from the Bondyzhsky and Pervomaisky fields.

The rocks of the Semilukskian horizon are represented by the uneven alternation of calcareous silicate and siliceous limestones (according to the classification of I.G. Teodorovich, 1958).

Methods of the research

The performed analytical works included the determination of group composition of chloroform

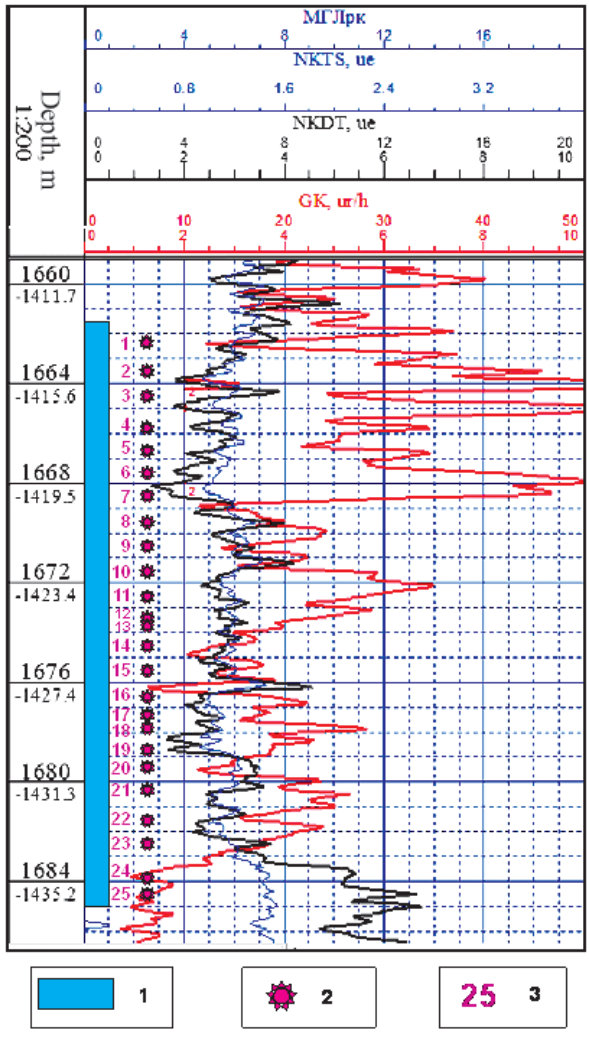

Figure 1. Scheme of sampling cores from the well 467-D for geochemical studies. 1 – core sampling interval, 2 – sampling points, 3 – sample numbers

bitumen A and oils on the basis of generally accepted methods. The first stage was dehydration of oils, and then the polar components of petroleum – oils, resins and asphaltenes were separated. The oil fraction of petroleum was obtained by the method of eluent liquid-adsorption chromatography on silica gel. Petroleum was divided into a number of relatively homogeneous chemically analytical groups that combine compounds of similar physical and chemical properties – oils, resins and asphaltenes. Chromatographic studies were performed on a Crystal 2000M device using the capillary GC method in the temperature programming mode from 100 °C to 300 °C. In the temperature range from 100 °C to 150 °C, the rate of determination of the test substance varies at a rate of 10 °C per minute and in the range from 150 °C to 300 °C – 3 °C per minute, respectively (hydrogen is used as the carrier gas). Pyrolytic studies were conducted on a HAWK instrument.

Results of the research

Features of the group composition of bitumen and petroleum are reflected in Figure 2. The content of

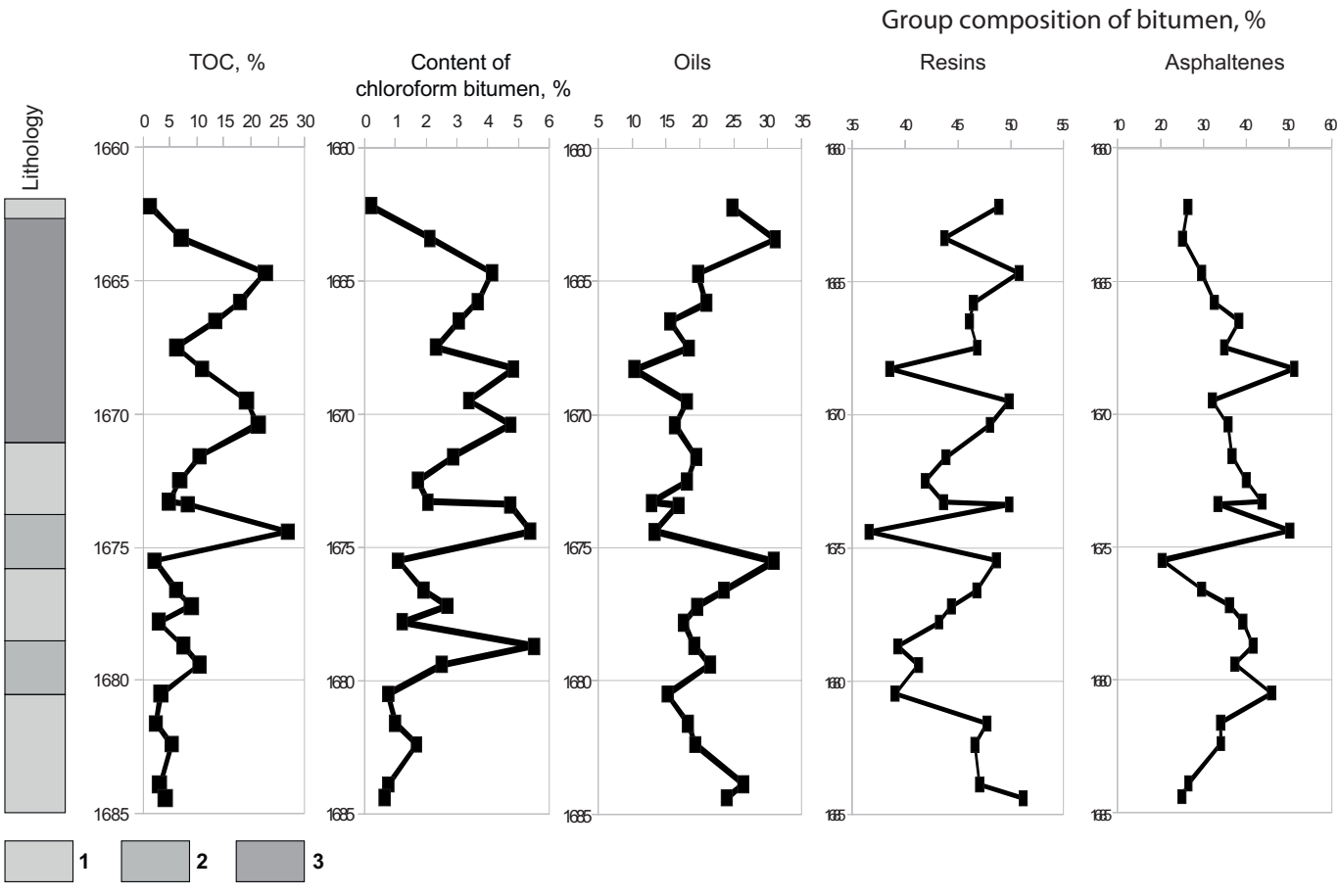

Figure 2. Group composition of bitumen of the Semilukskian horizon. 1 – siliceous limestones, 2 – alternation of silica-limestones and siliceous limestones, 3 – alternation of silica-limestones and siliceous silicates

chloroform bitumen in the composition of domanicites in the investigated range varies from 0.24 to 5.5% (mean – 2.61%) and is unevenly distributed along the section of the investigated interval. The lowest content of chloroform bitumen is characterized by rocks in the roofing part of the interval and its bottom, and the maximum amount is confined to three parts of the middle part of the interval. The bitumen coefficient (BK) in almost all samples exceeds 20, varies from 16.21 to 73.71, and its average value from the results of a study of 25 samples was 31.75.

By its elemental composition, bitumen is almost of the same type: the carbon content is from 70.9% and up to 83.72% (average – 80.98%), hydrogen – from 8.02 to 10.9% (average – 9.38%) , nitrogen – from 0,94 to 2,26 %% (average – 1,62%). Values of the ratio H/C atom for the majority of samples are located in a narrow range – from 1.5 to 1.68 (average – 1.62), with the exception of one sample with a ratio of 1.82.

Asphaltene components with a content of 69.01 to 87.2 %% (medium – 80.36%) prevail in the composition of bitumen. The resin/asphaltene ratio is within a fairly wide range – from 0.73 to 2.38 with an average value of 1.37. The content of oils varies from 10.3 to 30.98%, the average – 19.64%. Virtually all bitumen are resin-saturated, with the exception of four samples in which the content of asphaltenes slightly exceeds them. The components of the alcohol-benzene fraction prevail in the composition of the resins.

In the group composition of petroleum, oils prevail – from 58.18 to 67.54% (average values – 61.28% and 61.7% respectively in the petroleum of Pervomaisky and Bondyuzhsky fields), and in asphalt-resinous components – resins, from 20.51 to 31.47% (average values – 26.87 and 29.39%, respectively, for the petroleum of Pervomaisky and Bondyuzhsky fields).

Previous studies (Ostroukhov et al., 2017; Plotnikova et al., 2017) made it possible to establish that migratory bitumen with a different source of generation are present in the rocks of the Semilukskian horizon, along with the bitumen of the syngenetic dispersed organic matter.

Undoubtedly, the search for this source is a complex task and requires a wide range of additional studies. However, as a working hypothesis, we can assume that the migratory component of bitumen is the oil of the Pashian and Timanian horizons of the Upper Devonian terrigenous complex, and the variety of geochemical characteristics of the bitumen of the investigated interval is due to the varying degree of mixing the "native" syngenetic organic matter of the Semilukskian rocks and oil brought by vertical upward migration.

To test this assumption, we compared the bitumen of rocks and oils of the underlying productive complexes on the basis of the following geochemical coefficients:

P/Ph – ratio of pristane to phytane;

P/nC$_{17}$ – ratio of pristane to n-alkane C17;

Ph/nC$_{18}$ – ratio of phytane to n-alkane C18;

C$_{27}$/C$_{17}$ – distribution coefficient of n-alkanes in the middle fractions;

$\sum$(C$_{27}$-C$_{31}$)/$\sum$(C$_{15}$-C$_{19}$) – ratio of the number of high-molecular alkanes to low-molecular alkanes. This coefficient is a parameter of catagenetic maturity;

2nC29/C28+C30 – oddness coefficient in the medium-molecular area;

CPI – oddness coefficient in the high-molecular area;

Odd/Even – oddness coefficient;

P+F/C$_{17}$+C$_{18}$ – the ratio of the sum of pristane and phytane to the sum of n-alkanes C$_{17}$ and C$_{18}$.

Comparison of bitumen and oils was carried out by comparing the stellar diagrams. Figure 3 shows a comparison of the Pashian horizon oil from two wells of the Pervomaisky field. The almost absolute identity of the oils allowed us to use the average values of the coefficients for further comparisons.

Comparison of bitumen with each other, on the contrary, indicated the presence of significant differences from each other, which is clearly illustrated in Figure 4, which compares five bitumen located at different depths of the studied interval. Despite the proximity of the oddness coefficients, the bitumen differ significantly in other factors, which is due primarily to the various facies conditions for the formation of individual interlayers.

Comparison of the average values of coefficients for oils and bitumen (Figure 5) revealed differences between them only in general and indicated the need for an individual comparison of oils with each of the 25 investigated bitumen.

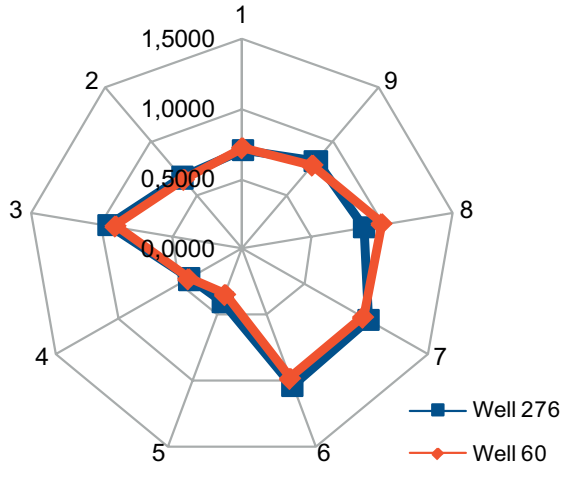

Figure 3. Comparison of the Pashian oils of the Pervomaisky field by geochemical coefficients. Here and further the correspondence of geochemical coefficients to the numbers on the stellar diagram – see in the text

In the course of an individual comparison, very interesting results were obtained.

1. In the Semilukskian section, several bitumens were identified, which by geochemical coefficients are almost identical to the oil of Pashian horizon (Figure 6a). This suggests that in some parts of the section there are traces of upward vertical migration of oil from the underlying horizons of the terrigenous Devonian.

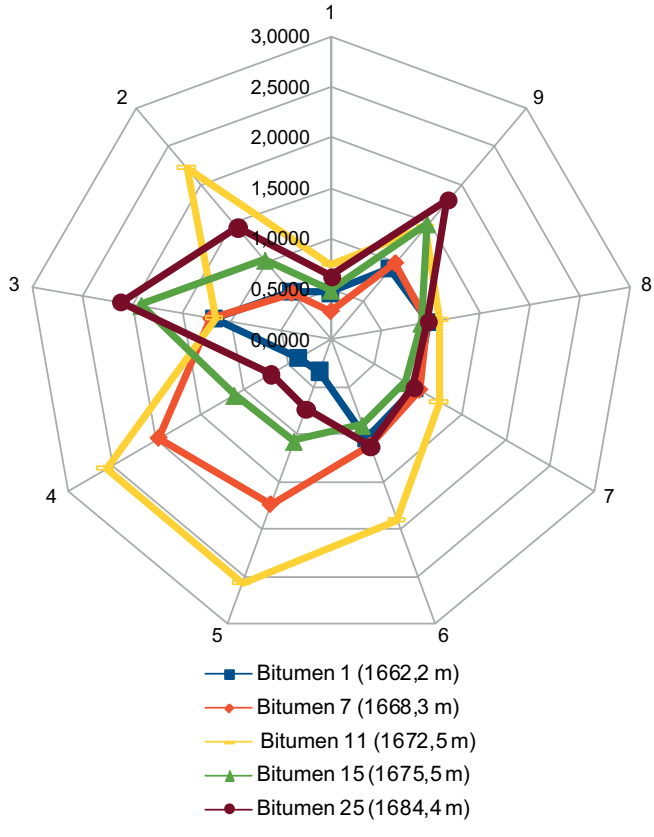

Figure 4. Comparison of bitumen of the Semilukskian horizon from the well 467-D of the Pervomaisky field by geochemical coefficients

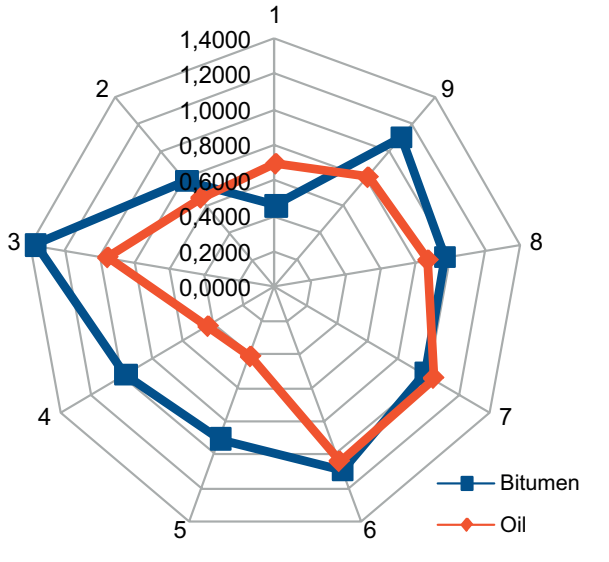

Figure 5. Comparison of bitumen of the Semilukskian horizon from the well 467-D and oil of Pervomaysky fields based on the average values of geochemical coefficients

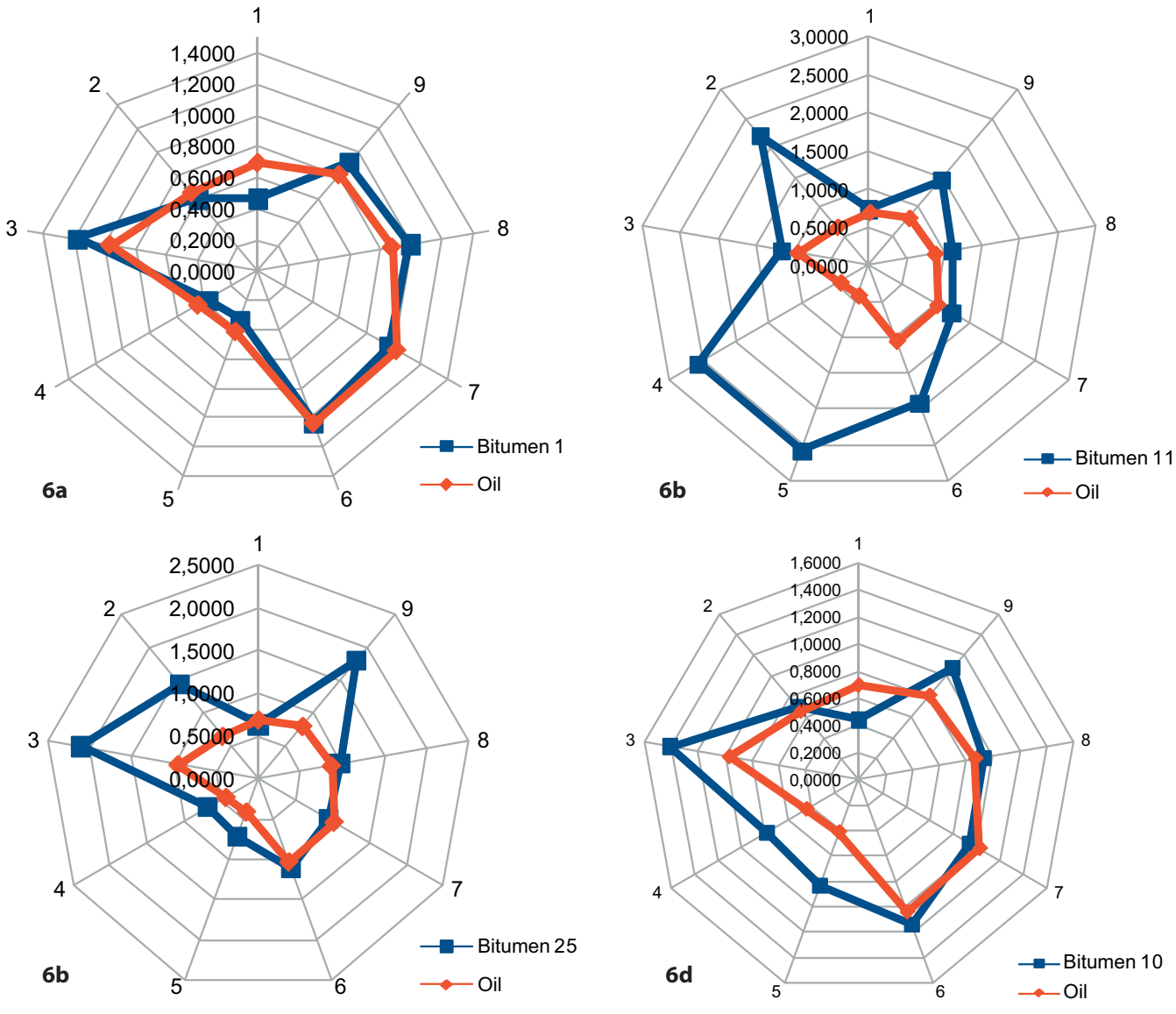

Figure 6. Examples of comparison of different bitumens of the Semilukskian horizon with the oils of the Pashian horizon:a – an example of bitumen, identical to oil; b, c – examples of bitumen that are significantly different from oil; d – an example of bitumen that involves mixing syngenetic organic matter with migration oil

2. In addition to bitumen identical to oil, in the section of the Semilukskian horizon there are bitumens that differ significantly from oils (Figures 6b, 6c) or represent a bias of syngenetic organic matter and Pashian oil (Figure 6d).

Almost complete identity with petroleum was found in 5 bitumen out of 25 studied, all of them located in the upper part of the studied interval (Figure 7). Significant differences from oils are also found for 5 bitumens, which are unevenly distributed throughout the interval. The remaining 15 bitumen samples (60%) are a product of mixing syngenetic organic matter (OM) and introduced hydrocarbons. Thus, practically all the studied bitumens are a product of mixing of syngenetic OM and migration component (oil). Since there is no clear relationship between the types of bitumen and the presence of organic matter in the rock, it seems that the share of the migration component and its distribution along the section is controlled by the capacitive properties of the rocks and their fracturing.

This is also confirmed by the absence of a positive correlation between the share of the oil fraction in the bitumen of the rock sample (the lightest and mobile part of the bitumen) and total organic carbon (TOC) in this rock (Figure 8). Moreover, between these two parameters there is a weak inverse correlation (-0.37), rather indicating, that the distribution of migration hydrocarbons in rocks is not related to the distribution of TOC.

Also for bitumen of the first two types (the first is identical to oil, the second is sharply different from it), the differences in pyrolytic parameters are established. In particular, the average values of S_0, S_1 and ΔS_1 (the difference of S1 values before and after extraction) for bitumen of the first type are higher than those of bitumen of the second type (Table 1).

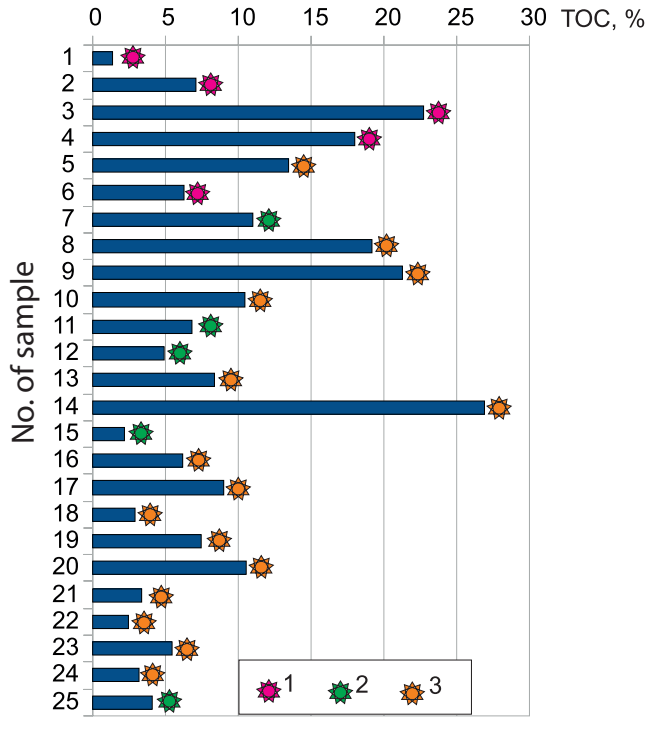

Figure 7. Distribution of different types of bitumen in the section of the studied interval.1 – bitumens identical to oils, 2 – bitumens, significantly different from oils, 3 – bitumens, in which mixing of syngenetic organic matter and migration oil hydrocarbons is supposed

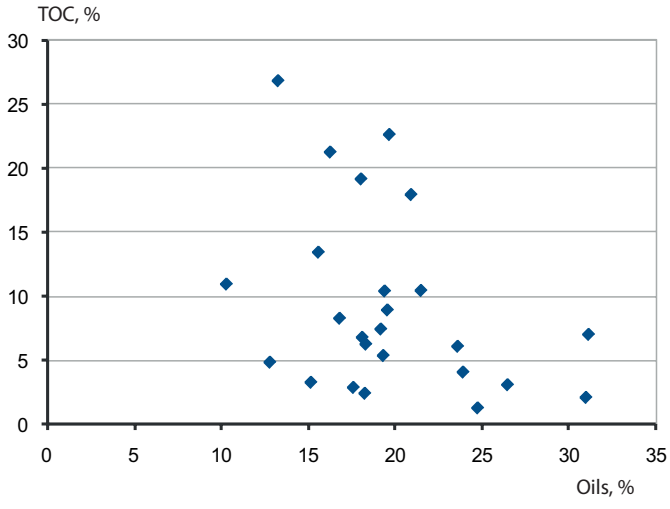

Figure 8. Dependence of the oil fraction content of bitumen from the total organic carbon (TOC) in the rock

Conclusions

The results obtained are fundamentally new and allow us to present the formation of deposits in the Semilukskian horizon in a different way. The main conclusions are as follows:

Mobile lighter bitumoids are present in the Semilukskian horizon, along with the syngenetic dispersed organic matter, which, according to gas-liquid chromatography, are identical to the oil of the underlying terrigenous deposits of the Pashian and Timanian horizons. These bitumens, undoubtedly, are migratory and reflect the process of upward vertical migration of oil, which is responsible for the formation of industrial deposits in the Semilukskian horizon in those areas where the lithologic features of the Domanicites and the development of superficial fracturing in them allow creating a collecting space.

The results obtained from the data of gas-liquid chromatography are completely correlated with the results obtained from the distribution analysis in the bituminous hydrocarbons of a number of alkyltoluenes and set forth earlier (Ostroukhov et al., 2017).

The presence of migratory mobile bitumen in the Semilukskian horizon leads to an overestimation of the TOC values in them according to pyrolysis data.

No. of sample	S_0		S_1		ΔS_0	ΔS_1
	Before extraction	After extraction	Before extraction	After extraction		
rocks, contained first type of bitumens (identical to oil)						
1	0,16	-	0,37	0,06	0,16	0,31
2	1,69	-	5,15	0,24	1,69	4,91
3	1,41	-	10,38	0,73	1,41	9,65
4	3,21	-	9,39	0,74	3,21	8,65
6	2,11	-	3,94	0,2	2,11	3,74
average	**1,72**		**5,85**	**0,39**	**1,72**	**5,45**
rocks, contained second type of bitumens (sharply different from oil)						
7	2,09	-	7,32	0,31	2,09	7,01
11	1,83	-	4,53	0,30	1,83	4,23
12	1,69	-	4,11	0,20	1,69	3,91
15	0,74	-	3,1	0,14	0,74	2,96
25	0,74	-	2,12	0,16	0,74	1,96
average	**1,42**		**4,24**	**0,22**	**1,42**	**4,01**

Table 1. Compare of mobile hydrocarbons content in rocks with different types of bitumoids

In this regard, new methodological approaches and analytical techniques are needed to separate and evaluate separately the content in the rocks of mobile migration hydrocarbons and syngenetic organic matter.

Such a method can be created on the basis of an integrated rapid study of sludge (geochemical and mineralogical research in the drilling process). It will be of great practical importance and will allow for an assessment of the presence of mobile hydrocarbons and their number at the stage of drilling out the Domanic Formation. An analysis of the spatial distribution of migratory hydrocarbons, in turn, will allow localizing oil migration canals and identify promising sites for the location of industrial oil deposits in the Semilukskian horizon and the boundaries of their distribution.

Mapping the saturation levels of the Sargaevskian, Semilukskian and Rechitskian horizons by mobile hydrocarbons will be the basis for choosing the location and direction of the inclined and horizontal trunks and will increase the effectiveness of the development of shale strata. The integration of geochemical methods of investigation of sludge and geophysical methods for studying the development of fracturing will make it possible to successfully predict potential sections for the presence of oil deposits. At the same time, promising areas of deposit allocation must be linked, first of all, to the presence of favorable conditions for vertical oil migration (faults, decomposition zones) and its accumulation (a reservoir formed primarily by open fracturing).

Tight high-carbon rocks of the Sargaevskian, Semilukskian and Rechitskian horizons are an unconventional object of oil production, which involves the use of non-traditional new approaches to its prospecting and development. One such approach is the consideration of Domanicites as an accumulation or accumulation-generation system and the assumption that the deposits in these systems could be formed by the accumulation of oil systems generated in other sources. Since at the present time the oil of the Semilukskian, Rechitskian and Sargaevskian horizons is mainly associated with the generation system of the Domanic organic matter, the main search criterion is the presence of organic matter and the degree of its catagenesis in the rocks.

In other words, the basis of the forecast is solely the genetic criteria associated with the dispersed organic matter. However, the high lithological heterogeneity of the rocks, the uneven distribution of OM in them and its low maturity (mainly PC_3) often lead to an overestimate of the resource potential, and the mechanism of migration and accumulation of oil totally does not agree with the low reservoir properties of both Domanicites and the transit zones in contact with them, which in fact are not transit zones.

The use of new methodological approaches, including complex rapid study of sludge and core, will increase the reliability of the separation of productive oil-saturated intervals in the section and allow more accurate estimation and calculation of reserves in tight high-carbon deposits.

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Manuscript received 23 September 2017;
Accepted 03 November 2017;
Published 30 November 2017