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On the Issue of Dispersed Organic Matter Differentiation in the Upper Devonian-Tournaisian Strata at the Perm Krai

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К вопросу о дифференциации рассеянного органического вещества Верхнедевонско-Турнейской толщи территории Пермского края

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One of the aspects of the formation of the hydrocarbon potential of the main oil and gas source rock (OGSR) of Upper Devonian-Tournaisian age in the context of the sedimentary cover of the Perm Krai was considered. The subject of study was the basic chemical and bituminological characteristics of dispersed organic matter (DOM) of source rocks. The sample of parameters collected to study the thickness contained more than 4300 definitions. The main goal of the study was to differentiate the dispersed rocks organic matter depending on the distribution of bitumen coefficient values and the enrichment degree of strata with organic carbon. According to the conditions of formation, the Upper Devonian-Tournaisian rock was characterized by the maximum development in this territory of favorable geochemical facies, under the conditions of which the DOM transformation into petroleum hydrocarbons occurs. Statistical analysis of the average values of chemical and bituminological parameters confirmed the syngenetic nature of the DOM to the containing rock with a high degree of transformation and enrichment in migratory bitumens, which allowed considering this strata to generate oil and gas and ensured the formation of the oil and gas content. Further, based on fundamental research, in particular the Uspensky-Vassoevich relationship, the differentiation of DOM of the Devonian-Tournaisian formation into syngenetic, mixed and epigenetic was for the first time quantitatively substantiated. By studying the sample using regression and discriminant analysis methods, it was shown that the identified types of DOM were statistically different in the ratio of the parameters C_{org} and β, which proved their relationship to bitumen of different types. For each identified type of DOM within the stratigraphic units of the main OGSR, different types of relationships between the studied parameters C_{org} and β were also statistically established. As a result of the research, the author established the individual percentage distribution of DOM types for each horizon of the Upper Devonian-Tournaisian oil and gas source rock and statistically proved their difference in the ratio of C_{org} and β, which characterized the individual intensity and direction of converting bitumen into micro-oil. It was established that in this sequence the Domanik horizon itself was characterized by the widest development of epigenetic bitumen.

Ключевые слова:
химико-битуминологические характеристики, статистический анализ данных, Верхнедевонско-Турнейская толща, преобразование ров, нефтегенерирующий потен-циал, дифференциация ров, доманиковый горизонт, эпигенетичные биумоиды.

Рассматривается один из аспектов формирования углеводородного потенциала основной нефтегазоматеринской толщи (НГМТ) верхнедевонско-турнейского возраста в разрезе осадочного чехла территории Пермского края. Предметом изучения являются основные химико-битуминологические характеристики рассеянного органического вещества (РОВ) пород данной толщи. Выборка параметров, собранная для изучения толщи, содержит более чем 4300 определений. Основной целью исследования является дифференциация рассеянного органического вещества пород в зависимости от распределения величин битумоидного коэффициента и степени обогащенности толщ органическим углеродом. По условиям формирования верхнедевонско-турнейская толща пород характеризуется максимальным развитием на данной территории благоприятных геохимических фаций, в условиях которых происходит преобразование РОВ в углеводороды нефтяного ряда. Статистический анализ средних значений химико-битуминологических параметров подтвердил сингенетичность РОВ вмещающей породе с высокой степенью преобразованности и обогащенности миграционно-способными битумоидами, что позволяет считать данную толщу нефтегазогенерировавшей и обеспечившей формирование нефтегазоносности разреза. Далее, опираясь на фундаментальные исследования, в частности зависимость Успенского-Вассоевича, была впервые количественно обоснована дифференциация РОВ девонско-турнейской толщи на сингенетичное, смешанное и эпигенетичное. Исследуя выборку методами регрессионного и дискриминантного анализов, было показано, что выделенные типы РОВ, статистически различны по соотношению параметров $C_{орг}$ и β, что доказывает их отношение к битумоидам различного типа. Для каждого выделенного типа РОВ в объеме стратиграфических подразделений основной НГМТ были также статистически установлены различные типы соотношений исследуемых параметров $C_{орг}$ и β. В результате проведения исследований автором установлено индивидуальное процентное распределение типов РОВ для каждого горизонта верхнедевонско-турнейской нефтегазоматеринской толщи и статистически доказано их различие по соотношению $C_{орг}$ и β, характеризующих индивидуальную интенсивность и направленность процессов преобразования битумоидов в микронефть. Установлено, что в этой толще максимально широким развитием эпигенетических битумоидов характеризуется собственно доманиковый горизонт.

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Introduction

Differentiation and typification of rock dispersed organic matter (DOM) in the Upper Devonian-Tournaisian sourse rock of the sedimentary cover in the Perm region was carried out according to the predominance degree of epigenetic bitumen (micro-oil) in it as the most mobile, migratory part of the syngenetic DOM. This geochemical criterion may be an additional search factor for areas with a low degree of exploration or deep-lying promising complexes [1–4]. The objects of this study are chemical and bituminological indicators (more than 4300 definitions) assessed in samples taken from wells penetrated Upper Devonian-Tournaisian deposits (*D3f2–C1t*) in the Perm Kama region. According to the author's opinion, these characteristics reflect the processes of DOM transformation and hydrocarbon (HC) generation in this deposit [5, 6]. To solve the differentiation problem chemical and bituminological indicators were studied using statistical analysis methods. Among the indicators involved in the analysis there is the percentage content of insoluble residue (I.O.), organic carbon (C_{org}), organic matter (OM), petroleum (B_{Pe}), chloroform (B_{Chl}), alcohol-benzene (B_{ab}) bitumoids and humic acids (HumA); and coefficients: neutrality (Kn) and bitumen (β). The use of geochemical DOM characteristics to solve problems of assuming oil and gas content in various formation intervals and territories has been repeatedly studied by scientists and presented in works [7–11].

The generation and emigration capabilities of Domanik type source rock which is the Upper Devonian-Tournaisian one (*D3f2–C1t*) in this area are beyond doubt and confirmed by many authors [12–15]. Sediments of the Upper Devonian-Tournaisian age which have the maximum oil and gas source potential in the Perm region are developed mainly within the uncompensated paleo-trench of the Kama-Kinel system (KKSP) [16–19]. According to structural and formational analysis performed by researchers of different years (O.M. Mkrtchyan, R.O. Khachatryan, I.K. Korolyuk, V.G. Kuznetsov, A.A. Aksenov, E.S. Larskaya, S.G. Neruchev, G. M. Parparova, S.I. Vaksman, V.N. Sharonov, T.V. Belokon, etc.), these deposits are usually divided into two formations: 1) Domanik type which is close to the stratotype and distinguished in the volume of the Semiluksky (Domanik) horizon of the Upper Devonian, developed within an uncompensated paleo-trench, and 2) Domanikoid type which is associated with the deposits as a whole depression facies in the axial parts of the KKSP from Upper Frasnian to Tournaisian [20–22]. In general, from the history of the deposit formation it can be noted that sediments of the Frasnian stage in the Perm region are widespread with the exception of the extreme northwestern regions. At this time it was that biggest part of the region territory which was characterized by the maximum development of relatively deep-water facies, favorable for the accumulation of Domanik deposits and their non-bituminous analogues. The thickness of the stage deposits is up to 350 m.

Distribution and the thickness of the Famennian stage sediments corresponds to the distribution of geochemical shallow-marine and relatively deep-water facies which existed in the southern and eastern region parts inherited from the Frasnian time. The thickness of Famennian stage sediments in the southern and southeastern regions increases to 500 m, that indicates a deeping of Famennian basin bed. In Tournaisian time, due to significant basin shallowing and reduction of deep-water and shallow-water shelves areas, the geochemical conditions of sediment

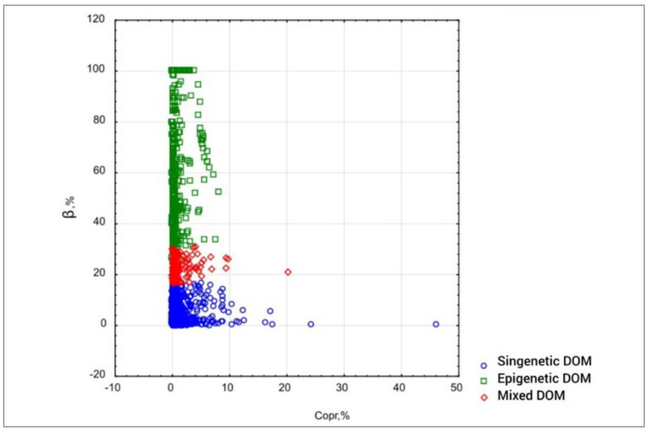

Fig. 1. Correlation field between the C_{org} and β parameters with identified D3f2–C1t DOM types

accumulation were much worse than for the underlying sediments and the degree of OM transformation was quite low. In Late Tournaisian time the system of uncompensated depressions is gradually leveled out by overlying sediments and ceases to exist. Thus, the Upper Devonian-Tournaisian source rock existed in favorable geochemical conditions for the source rock formation at the diagnosis stage [23–25].

At the beginning of the research a statistical analysis of the used indicators average values was performed for the entire complex of *D3f2–C1t* deposits. High average numbers of concentrations in the C_{org} and DOM rocks, reaching 0.98 and 1.12% respectively, characterizes it as an oil and gas source one [26, 27]. The average concentrations ratio of different compositions bitumen: B_{Chl} – 0.217 %, B_{ab} – 0.181 % and B_{pe} – 0.023 %, shows that the Upper Devonian-Tournaisian source rock is distinguished by high concentrations of the most migratory of them: B_{Chl} and B_{ab}. Bitumen extracted from DOM with petroleum-ether solvents (B_{pe}) constitute a small proportion in this deposit. The average content of non-bituminous components (HumA) in the deposit is low and amounts to 0.001 %. The content of insoluble OM in the rock is relatively low and averages 18.07 %. The neutrality coefficient (K_n) for the whole rock is 1.25 ea. which allows us to speak about the predominance of mobile, migratory bitumen in the deposit. The DOM transformation characteristic which is indicated by the bitumen coefficient β for a given deposit amounts to 23.50 %. That mostly indicates about the syngenetic nature of DOM containing oil source rock.

Thus, the studied rock belongs to the category of oil and gas generating ones and, in the opinion of many authors, could provide the entire Paleozoic oil and gas content in the sedimentary cover of the Perm region [28, 29].

Objectives for distinguishing types of DOM and conformity study of relationships between the C_{org} and β parameters generally in the rock

The basis for studying the degree of DOM differentiation of the main oil and gas generating source rocks in the Perm Kama region formation was based on the fundamental research by N.B. Vassoevich, V.A. Uspensky, according to which the relationship between the C_{org} content and the value of the bitumen coefficient β is a criterion for dividing DOM into syngenetic and epigenetic [30, 31]. To prepare the data for quantitative assessment all the C_{org} percentage determinations were generated from maximum to minimum values and then it was used the linear regression method analysis in the Statistica program [31–33]. Consistently, by adding parameter values to the analysis, linear equations were constructed for the dependence of β on C_{org} content (6522 models), the first of which was based on 3 parameters, the next model was obtained with n = 4, and so on up to n = 6524. Constructed models graphical representation is shown in Fig. 1 taking into account the nature of the relationship between the C_{org} and β parameters for the Upper Devonian-Tournaisian source rock.

The established range of C_{org} values has a statistically significant inverse correlation with the coefficient β, and it is the boundary parameter between syngenetic and epigenetic DOM types.

In the correlation field three groups of different relationships between the C_{org} and β parameters are highlighted in color characterizing the DOM differentiation into syngenetic, epigenetic and mixed in the given deposit rocks. The given graph is characterized by significant nonlinearity and certain patterns of changes in the values of β from C_{org} at different ranges of changes in its C_{org} concentrations. This allows us to consider, on the one hand, the process of DOM transformation in a given deposit, passes according to a general scheme; on the other hand, the process intensity will be determined by different C_{org} concentrations [35–38].

Statistical studies of DOM selected groups is performed in order to prove its differentiation at the level of the whole studied deposit. An average values comparison of the C_{org} and β parameters using the Student's t test at a given significance level of $p \leq 0.05$ for the three DOM identified types is given in Table 1.

The amount of data used to characterize the given deposit rock DOM is one of the most significant and evenly covering the formation of the Perm region entire territory. In the selected DOM groups there are 56.33 % definitions for syngenetic, 15.25 % for mixed and 28.41 % for epigenetic ones. As the analysis of six compared pairs of average values shows that only the average C_{org} values are not statistically different in two DOM pairs: syngenetic – mixed and mixed – epigenetic. For parameter β all average values are different, and the maximum level of difference is characterized by syngenetic and epigenetic DOM types. Consequently, the division of DOM into three groups is statistically proven and correct.

To assess the obtained relationships between the C_{org} and β parameters a correlation analysis was carried out to assess the ratio of obtained correlations between the parameters [39, 40]. Equations were derived for the entire sample and separately for the selected DOM types. The derived equations (Table 2) show that, in general, for the entire DOM sample a significant inverse correlation was established (p value ≤ 0.05), and within the identified DOM types there are differences in the parameters ratios. For syngenetic DOM an inverse not statistically significant correlation was also obtained between the C_{org} and β parameters and for mixed and epigenetic DOM the correlations were positive, although not statistically significant.

Thus the DOM differentiation into syn- and epigenetic was substantiated, in general, for the *D3f2–C1t* deposit using linear regression analysis and differences in the average values of the C_{org} and β parameters were established in the identified DOM types. The results of the correlation analysis showed multidirectional relationships between the studied parameters for different DOM types.

In general, weak negative correlations were established for the whole deposit and for the singenetic DOM type, and weak positive ones were established for the mixed and epigenetic type, which corresponds to existing ideas and the dependence of N.B. Vassoevich.

Rationale for distinguishing DOM types and studying the patterns of relationships between the Corg and β parameters for stratigraphic deposit units

Further, the relationship between the C_{org} and β parameters will be studied according to a similar scheme more detailed for the stratigraphic units of the Upper Devonian-Tournaisian source rock – Sargayev, Domanik, Mendym horizons, Upper Frasnian substage, Famennian and Tournaisian stages.

The relationships between the β and C_{org} parameters for all stratigraphic units of the Upper Devonian-Tournaisian source rock are shown in Fig. 2 in the form of correlation fields.

According to the resulting distribution the deposit in Sargayev age is quite lean in terms of C_{org} concentration in the rock. For all DOM types the main number of determinations does not exceed 1–2 %. The main difference between the constructed relationship for the Domanik horizon is the distribution of the C_{org} parameter. A significant range of changes is observed in this parameter for all DOM types. The bulk of the values in syngenetic DOM vary within 0–10 %; C_{org} varies within the same range in mixed DOM and slightly less – up to 8 % – in epigenetic ones. The distribution of the C_{org} parameter in the Mendym horizon changes somewhat due to a decrease in concentrations in the determinations bulk to 1.5–2 % in the group of mixed and epigenetic DOM. Syngenetic DOM is also characterized by a decrease in the range of C_{org} values (0–3 %). The resulting distribution of parameters in the Upper Frasnian substage characterizes an even more reduced C_{org} amount to values of 0.5–1 % in the groups of epigenetic and mixed DOM and up to 2 % in the syngenetic group. For overlying deposits of the Famennian Stage the relationship between the parameters β and C_{org} reflects the minimum C_{org} concentrations (up to 1 %) in groups of epigenetic and mixed DOM; in syngenetic DOM this value increases to 8 %. The C_{org} content in the epigenetic and mixed DOM types of the Tournaisian Stage continues to decrease and does not exceed 0.5 %; in the syngenetic type it mainly varies from 0 to 2 %.

To analyze the differences in the average values of the C_{org} and β parameters in the identified DOM types for all stratigraphic units of the Upper Devonian-Tournaisian source rock, we will conduct an analysis using the Student's t test.

In Table 3 it is shown the average values and standard deviations for C_{org} and β parameters.

The average C_{org} concentrations (%) in the syngenetic, mixed and epigenetic DOM types up the section decrease slightly from the Sargayev horizon to the Tournaisian stage.

Only the Domanik horizon which is characterized by the most favorable recovery sedimentation conditions is characterized by a sharp increase in C_{org} concentrations (%) in all DOM types.

The average values of C_{org} content in all DOM types are close to each other and are statistically indistinguishable for the Sargayev, Mendym horizons, Upper Frasnian substage and Famennian stage.

In the Domanik horizon the average C_{org} concentrations values are statistically different while comparing syngenetic and epigenetic groups as well as mixed and epigenetic DOM types.

Table 1

Comparing average values of C_{org} and β parameters by DOM types

Parameters, Units.	Average values			Criteria
	Types of DOM, n – amount of data			t^* / p
	Singenetic, n = 1160	Mixed, n = 314	Epigenetic, n = 585	
C_{org}, %	1,031 ± 2,352	0,804 ± 1,762		1,5892 / 0,11222
	1,031 ± 2,352		0,636 ± 1,231	**-3,7951** / 0,00015
		0,804 ± 1,762	0,636 ± 1,231	1,6671 / 0,09583
β, %	5,374 ± 4,692	22,825 ± 3,744		**-60,9496** / 0,00000
	5,374 ± 4,692		80,900 ± 21,811	**-80,9006** / 0,00000
		22,825 ± 3,744	80,900 ± 21,811	**-29,5303** / 0,00000

N o t e : * – significant criteria characterizing statistical differences in parameters are highlighted in bold.

Table 2

Regression equations between C_{org} and β parameters for DOM types

Group	Values of free terms of regression equations	Coefficient values at C_{org}	Parameters r	Parameters p^*
All data	24,313	–0,918	–0,069	**0,00159**
Singenetic	5,424	–0,075	–0,037	0,1992
Mixed	22,732	0,114	0,054	0,3408
Epigenetic	58,683	1,234	0,070	0,092

N o t e : * – significant criteria characterizing statistical differences in parameters are highlighted in bold.

Table 3

Comparing average values of C_{org} and β parameters for sediments of the D3f2–C1t deposit

Parameter, unit.	Means, standard deviations			Student's t test*
	DOM type, n-amount of data			
	Singenetic	Mixed	Epigenetic	
	Sargayev horizon (n = 72, n = 15, n = 36)			
C_{org}, %	1,202 ± 2,495	0,712 ± 0,849		0,7479
	1,202 ± 2,495		0,951 ± 1,514	0,55537
		0,712 ± 0,849	0,951 ± 1,514	–0,57184
β, %	**4,470** ± 4,436	**22,399** ± 3,292		–14,7957
	4,470 ± 4,436		**57,113** ± 20,942	–20,5163
		22,399 ± 3,292	**57,113** ± 20,942	–6,35035
	Domanik horizon (n = 68, n = 47, n = 76)			
C_{org}, %	3,254 ± 3,563	2,840 ± 3,604		0,6100
	3,254 ± 3,563		**1,910** ± 2,097	2,7911
		2,840 ± 3,604	1,910 ± 2,097	1,8087
β, %	**8,475** ± 5,233	**23,667** ± 3,557		–17,3147
	8,475 ± 5,233		**60,547** ± 21,781	–19,2170
		23,667 ± 3,557	**60,547** ± 21,781	–11,4962
	Mendym horizon (n = 72, n = 15, n = 41)			
C_{org}, %	1,226 ± 1,988	0,830 ± 0,717		0,7598
	1,226 ± 1,988		1,091 ± 1,475	0,3801
		2,840 ± 3,604	1,091 ± 1,475	0,65569
β, %	**6,589** ± 4,859	**22,852** ± 3,990		–12,1216
	6,589 ± 4,859		**59,395** ± 24,655	–17,6373
		22,852 ± 3,990	**59,395** ± 24,655	–5,68074
	Upper Frasnian substage (n = 118, n = 31, n = 41)			
C_{org}, %	0,768 ± 1,443	0,282 ± 0,321		1,8611
	0,768 ± 1,443		**0,310** ± 0,840	1,9205
		0,282 ± 0,321	0,310 ± 0,840	–0,17872
β, %	**5,171** ± 4,623	**21,813** ± 3,391		–18,7398
	5,171 ± 4,623		**60,638** ± 21,401	–26,5690
		21,813 ± 3,391	**60,638** ± 21,401	–9,98987
	Famennian Stage (n = 354, n = 96, n = 218)			
C_{org}, %	0,785 ± 2,955	0,440 ± 0,874		1,1294
	0,785 ± 2,955		**0,310** ± 0,742	2,3252
		0,440 ± 0,874	0,310 ± 0,742	1,3494
β, %	**5,570** ± 4,823	**22,932** ± 3,318		–32,4700
	5,570 ± 4,823		**60,358** ± 21,467	–46,1843
		22,932 ± 3,318	**60,358** ± 21,467	–16,9429
	Turnasian Stage (n = 468, n = 108, n = 173)			
C_{org}, %	**0,892** ± 1,566	**0,412** ± 0,668		3,1126
	0,892 ± 1,566		**0,390** ± 0,623	4,0878
		0,412 ± 0,668	0,390 ± 0,623	0,2784
β, %	**4,783** ± 4,329	**22,628** ± 3,754		–39,5315
	4,783 ± 4,329		**60,638** ± 21,401	–26,5690
		22,628 ± 3,754	**60,638** ± 21,401	–16,5809

N o t e : * – statistically different average values according to the t test with an acceptable significance level of $p \leq 0.5$ are highlighted in bold.

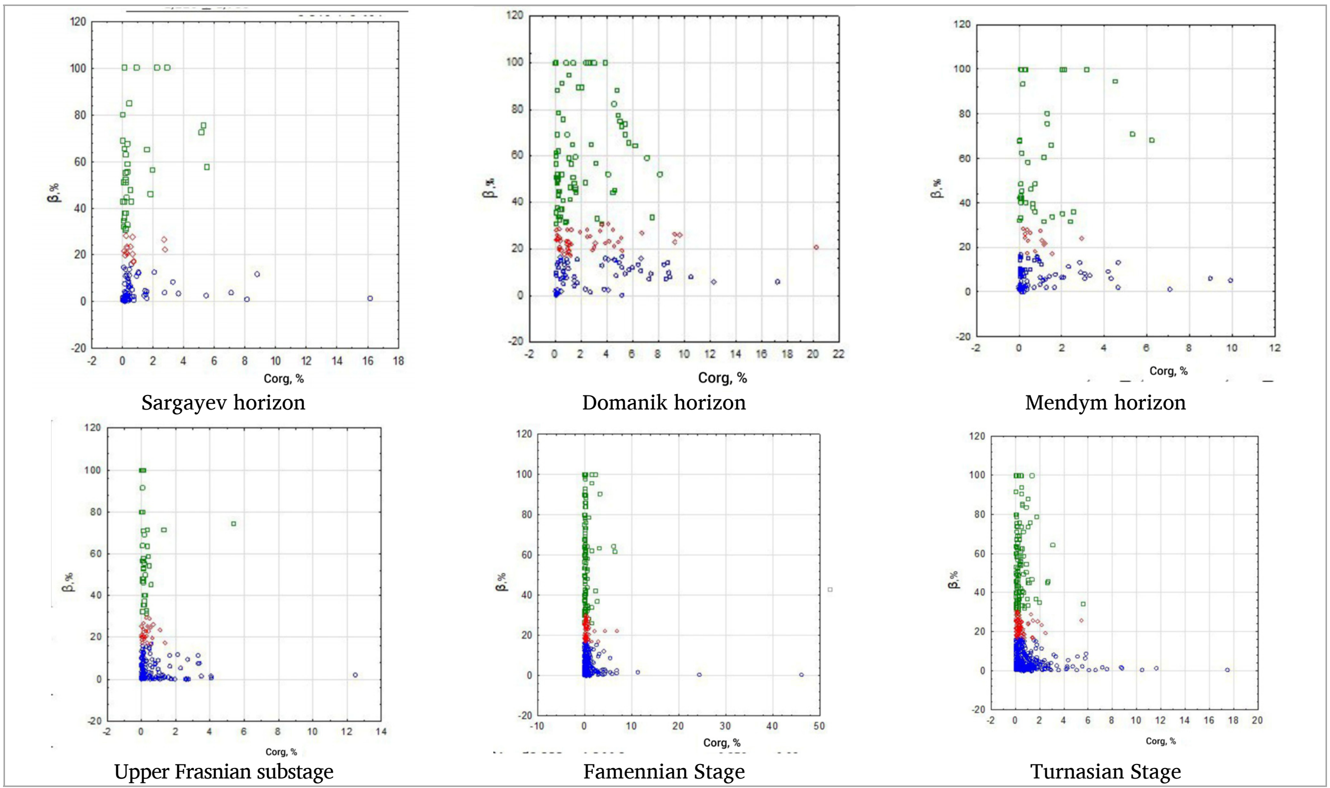

Fig. 2. Correlation fields between the C_{org} and β parameters with selected DOM groups for stratigraphic units *D3f2–C1t* of the deposit

Table 4

Regression equations between the C_{org} and β parameters for the *D3f2–C1t* deposit sediments

Stratigraphic divisions	Regression equations for DOM types* 1. All data 2. Syngenetic 3. Mixed 4. Epigenetic	Correlation coefficient and significance level
Sargayev horizon	β1 = 21,916 + 0,139 C_{org}	r = 0,011, p = 0,902
	β2 = 4,502 - 0,026 C_{org}	r = –0,014, p = 0,903
	β3 = 21,949 + 0,632 C_{org}	r = 0,162, p = 0,561
	β4 = 52,388 + 4,966 C_{org}	r = 0,359, p = 0,03
Domanik horizon	β1 = 35,586 -1,0133 C_{org}	r = –0,116, p = 0,110
	β2 = 7,677 + 0,245 C_{org}	r = 0,167, p = 0,173
	β3= 23,493 + 0,061 C_{org}	r = 0,062, p = 0,679
	β4 = 57,519 + 1,585 C_{org}	r = 0,152, p = 0,188
Mendym horizon	β1 = 24,881 + 0,464 C_{org}	r = 0,028, p = 0,103
	β2 = 6,532 + 0,046 C_{org}	r = 0,019, p = 0,874
	β3 = 23,593 – 0,892 C_{org}	r = -0,160, p = 0,568
	β4 = 55,111 + 3,924 C_{org}	r = 0,234, p = 0,568
Upper Frasnian substage	**β1 = 21,657-3,050 C_{org}**	r = -0,151, p = 0,037
	β2 = 5,552-0,495 C_{org}	r = -0,154, p = 0,094
	β3 = 21,602 + 0,746 C_{org}	r = 0,071, p = 0,705
	β4 = 60,144 + 1,590 C_{org}	r = 0,062, p = 0,698
Famennian Stage	**β1 = 26,851-1,281 C_{org}**	r = –0,101, p = 0,008
	β2 = 5,702-0,167 C_{org}	r = –0,102, p = 0,054
	β3 = 23,083-0,343 C_{org}	r = –0,076, p = 0,458
	β4 = 60,413-0,177 C_{org}	r = –0,006, p = 0,928
Turnasian Stage	**β1 = 21,989-3,275 C_{org}**	r = –0,175, p = 0,000
	β2 = 5,201-0,468 C_{org}	r = –0,169, p = 0,0002
	β3 = 22,616 + 0,029 C_{org}	r = 0,005, p = 0,957
	β4 = 59,567-3,739 C_{org}	r = –0,106, p = 0,165

N o t e : * – regression equations characterized by a significant relationship between the parameters are highlighted in bold.

Table 5

Percentage content of DOM types in sediments of the *D3f2–C1t* deposit

Sediments	DOM types,%		
	Syngenetic	Mixed	Epigenetic
Sargayev horizon	58,53	12,19	29,26
Domanik horizon	35,60	24,60	39,80
Mendym horizon	56,25	11,71	32,04
Upper Frasnian substage	62,10	16,31	21,57
Famennian Stage	52,99	14,37	32,64
Turnasian Stage	62,50	14,41	23,09

In the Tournaisian Stage a statistical difference of the average C_{org} values was established in the pairs syngenetic – mixed and syngenetic – epigenetic DOM.

The average values of the bitumen coefficient β which characterizes the transformation degree of organic matter for all DOM types are statistically different in all stratigraphic deposit ranges which is confirmed by the above criteria. The maximum difference in average β values was found between syngenetic and epigenetic DOM types. The widespread development of syngenetic DOM is characteristic of the Domanik horizon itself where the bitumens transformation occurred more intensively. Epigenetic bitumens predominate over other types in all stratigraphic deposit ranges.

Thus, it can be argued that each stratigraphic element of the Upper Devonian-Tournaisian source rock has unique characteristics of DOM types and has a number of features that shape their oil-generating and oil storage potential.

The final stage of studying DOM types differentiation in the context of the main OGSR in the Upper Devonian-Tournaisian age was a study of regression relationships between the C_{org} content and the β value [41, 42]. As it was said before, according to research by N.B. Vassoevich and V.A. Uspensky, there are certain relationship types between C_{org} concentrations and the bitumen coefficient β value [43, 44] between different bitumen types. The constructed regression equations between the C_{org} and β parameters for the identified DOM types of individual stratigraphic units are given in Table 4.

Analysing the obtained regression equations makes it possible to evaluate the various relationships of the studied parameters of the studied deposit horizons and tiers in the selected DOM types. Regression equations obtained for all data without dividing into DOM types show that for almost all formation elements inverse correlations have been established between the β and C_{org} parameters. The exception is the Sargayev and Mendym horizons where the established connection between parameters is weak positive. The Upper Devonian-Tournaisian stratum has high average C_{org} concentrations values and up the section a slight content change in the deposit horizons does not have a significant effect on the process of converting bitumen (β). Regression equations obtained for syngenetic DOM show that for the Mendym and Domanik horizons characterized by maximum β values the C_{org} content influences the DOM transformation degree. Further up to an inverse regression relationship between these parameters was established across the formation.

According to the equations describing the connections for epigenetic DOM type, it has been established that a content increase of the most mobile bitumens (average β values) in the deposit in the upper formation level is based on high C_{org} concentrations.

In this particular case the equations describe positive relationships between the parameters.

While reaching high concentrations of epibitumoids in the Famennian and Tournaisian stages, the relationships change to slightly negative, the influence of C_{org} content on the DOM transformation becomes less.

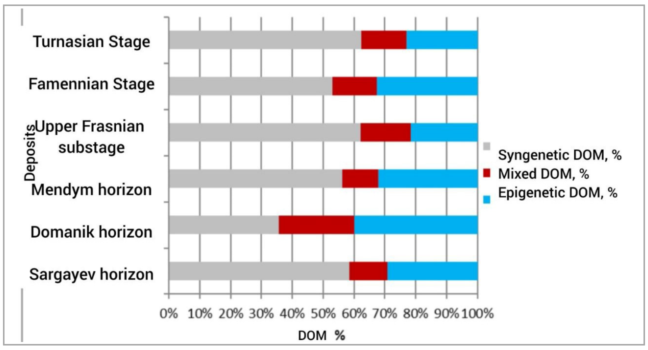

Fig. 3. Relationship between DOM types in sediments of the *D3f2–C1t* deposit

Concluding the analysis of the various DOM types differentiation in the oil and gas source rock in the age *D3f2–C1t*, we present the percentage distribution of DOM types by stratigraphic units (Table 5).

Analyzing the given distribution by DOM types, it should be noted that the concentration of syngenetic DOM in the Domanik horizon sediments is minimal, that indicates its more intensive implementation compared to other deposit elements. The remaining stratigraphic elements are characterized by a higher percentage of syngenetic DOM confirming their oil and gas source potential.

Based on the epigenetic DOM ratio the Domanik horizon is also distinguished, which made the maximum contribution to the process of converting DOM into hydrocarbons.

In general, all other units of the Upper Devonian-Tournaisian source rock are enriched in the most mobile bitumens (micro-oil). A graphical representation of the DOM relationships within the *D3f2–C1t* deposits is shown in Fig. 3.

Conclusion

Thus, the studies performed for the main Upper Devonian-Tournaisian OGSR in relation to the territory of the Perm region showed the following results:

1. The entire currently available body of factual data on the geochemical and bituminological characteristics of dispersed organic matter along the section of *D3f2–C1t* deposit sediments has been generalized and statistically processed.
2. For the first time the boundary values of the Corg and β parameters for different types of bitumens were statistically substantiated and the DOM types in this deposit were differentiated.
3. Using regression analysis methods various relationships between the C_{org} and β parameters were established for the DOM types in each stratigraphic deposit unit reflecting its transformation processes into micro-oil.
4. The individual distribution of DOM types in each stratigraphic deposit unit and the features that form their oil-generating and oil-accumulating potential have been proven.
5. It has been shown that the Domanik horizon of the studied Upper Devonian-Tournaisian source rock is characterized by maximum processes of DOM transformation into micro-oil and the widespread development of epigenetic bitumens.

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