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Probabilistic and Statistical Assessment of Zonal Oil and Gas Potential of the Perm Arch based on Geochemical Criteria

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Вероятностно-статистическая оценка зональной нефтегазоносности Пермского свода по геохимическим критериям

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probability, statistical analysis, linear statistical model, multidimensional statistical model, correlation coefficient, oil and gas content, statistical criteria, oil and gas geochemistry, organic matter, geochemical and bituminological characteristics.

A zonal probabilistic-statistical assessment of the generation potential of deposits that form the oil and gas potential of the territory of the Perm arch was carried out. To assess the oil and gas content, databases were used on the geochemical and bituminological characteristics of dispersed organic matter in the Upper Devonian-Tournaisian carbonate, Lower Visean terrigenous and Middle Carboniferous (Oka-Bashkirian) carbonate deposits. Statistical models were built on the basis of the following parameters: organic carbon content (C_{ORG}, %); organic matter (OM, %); composition of dispersed organic matter (content of bitumoids, %: chloroform (B_{CL}), petroleum (B_{PE}), alcohol-benzene (B_{AB}), humic acids (HumA, %), insoluble residue (IR, %) and DOM conversion characteristics (ratio of concentrations of chloroform bitumoid to alcohol-benzene (B_{CL}/B_{AB}), bitumoid coefficient (β). To determine the information content of these characteristics in relation to oil and gas potential, Student's statistical criteria – t and Pearson's – χ^2 were used, which made it possible to develop one-dimensional and multidimensional linear regression models. With the help of step-by-step multidimensional regression analysis, a complex criterion was developed that took into account the influence of both each geochemical indicator separately and their combinations. This made it possible to construct a distribution scheme for the probability of oil and gas content for the Perm arch territory. The analysis of the constructed scheme showed that the most favorable geochemical conditions for the formation of oil and gas potential due to the dispersed organic matter of the studied deposits were observed in the northeastern part of the Perm arch, which limited the isoprobability to more than 0.5.

Ключевые слова:
вероятность, статистический анализ, линейная статистическая модель, многомерная статистическая модель, коэффициент корреляции, нефтегазоносность, статистические критерии, геохимия нефти и газа, органическое вещество, геохимические и битуминологические характеристики.

Выполняется зональная вероятностно-статистическая оценка генерационного потенциала отложений, формирующих нефтегазоносность территории Пермского свода. Для оценки нефтегазоносности использованы базы данных по геохимическим и битуминологическим характеристикам рассеянного органического вещества в верхнедевонско-турнейских карбонатных, нижневизейских терригенных и среднекаменноугольных (окско-башкирских) карбонатных отложений. Статистические модели были построены по следующим показателям: содержание органического углерода ($C_{ОРГ}$, %); органического вещества (ОВ, %); состав рассеянного органического вещества (содержание битумоидов, %: хлороформенных ($Б_{ХЛ}$), петролейных ($Б_{ПЭ}$), спиртобензольных ($Б_{СБ}$), гуминовых кислот (ГумК, %), нерастворимого остатка (НО,%) и характеристики преобразования РОВ (отношение концентраций хлороформенного битумоида к спиртобензольному ($Б_{ХЛ}/Б_{СБ}$), битумоидный коэффициент (β). Для определения информативности этих характеристик в отношении нефтегазоносности использованы статистические критерии Стьюдента – *t* и Пирсона – χ^2. При построении моделей прогноза зональной нефтегазоносности территории Пермского свода использовались одномерный и многомерный пошаговый регрессионный анализы, что позволило разработать одномерные и многомерные регрессионные линейные модели. С помощью пошагового многомерного регрессионного анализа разработан комплексный критерий, учитывающий влияние как каждого геохимического показателя в отдельности, так и их сочетаний. Это позволило построить схему распределения вероятности нефтегазоносности для территории Пермского свода. Анализ построенной схемы показал, что максимально благоприятные геохимические условия формирования нефтегазоносности за счет рассеянного органического вещества изучаемых отложений наблюдаются в северо-восточной части Пермского свода, с ограничивающей изовероятностью больше 0,5.

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Introduction

The standard methods of oil and gas content assessment do not always allow identifying the local sites that will contain oil accumulations. Many authors propose to use various quantitative or qualitative criteria for zonal forecast of oil and gas content.

In the research the zonal probabilistic-statistical assessment of the deposit generative potential forming oil and gas content sedimentary section of the Perm arch was performed. To solve this problem probabilistic-statistical methods were used. Applying them in the construction of one-dimensional and multidimensional linear statistical models was possible by using elements of mathematical statistics and probability theory, which are fully described in Russian and foreign works [1–36].

In the Perm arch, as well as in the entire Perm Krai territory, the typical source rock interval is the deposit of the Upper Devonian-Tournaisian carbonate (D_3-C_{1t}) complex. Its potential description, including statistical methods for estimation oil and gas content potential is given in the following research [37-47]. In this article, the characteristics of dispersed organic matter (DOM) of Visean terrigenous and Middle Carboniferous (Oka-Bashkirian) carbonate deposits are used in the construction of mathematical models for zonal forecast of oil and gas content based on probabilistic-statistical methods. We consider that applying the obtained data will allow to solve the problem of oil and gas content zonal forecast in the Perm arch.

The databases on geochemical and bituminological characteristics of deposit's DOM, identified in wells of the Perm arch were used.

The geological and geochemical features of the deposits have been studied in detail for the entire territory of Perm Krai [37–43]. It should be noted that in these studies little attention is paid to the peculiarities of DOM distribution in the Perm arch. We think that using probabilistic-statistical methods will make it possible to estimate the relationship between the DOM characteristics and oil and gas content of the Perm arch.

Construction of one-dimensional models

The samples from wells located within the Perm arch boundaries were analysed. Initially, the parameters characterising DOM in the studied deposits were divided into two groups. The first group includes DOM measurements from wells located within the field limits, and the second one includes those from wells located outside the oil fields. These parameters will be analysed for Upper Devonian-Tournaisian carbonate (D_3-C_{1t}), Lower Visean terrigenous (C_{1v}) and Middle Carboniferous (Oka-Bashkirian) carbonate (C_2) deposits. These deposits we call geochemical complexes (GCC).

The first statistical tool for assessing the degree of variation between the parameters for two samples is the test of hypotheses on the differences or their absence in the mean values of the considered DOM characteristics, using Student's *t*-criterion. The statistical calculation data of mean values (*t*-criterion and achieved significance level *p*) of geochemical and bituminological parameters for the studied deposits are given in Table 1, as well as the statistical characteristics of geochemical parameters for GCC in wells of the Perm arch.

Quantitative mean values are compared by using Student's *t*-criterion (Table 1).

In some cases data analysis shows statistical differences in mean values. We consider the technology of linear probabilistic models construction used to forecast the zonal oil and gas content of the studied area. The detailed methodology of building one-dimensional probabilistic models for oil and gas content estimation is described in the analyzed papers [14, 16, 43, 44].

As an example of using the methodology, we will examine the order of individual one-dimensional probabilistic model construction of B_{CL}/B_{AB} on GCC D_3-C_{1t}. For this purpose distribution densities of B_{CL}/B_{AB} within the oil fields are studied – class 1, $n_1 = 61$, and data outside the oil and gas content areas – class 2, $n_2 = 167$. It is necessary to divide the B_{CL}/B_{AB} complex (set) into objects belonging to class 1.

Density distributions on B_{CL}/B_{AB} for classes 1 and 2 are given in Table 2.

According to the data in each variation interval the probabilities of belonging to the oil fields – $P(B_{CL}/B_{ABi})$ are calculated. Then they are compared with the average interval values of B_{CL}/B_{ABi}. The matching correlation coefficient r is calculated from the values of $P(B_{CL}/B_{ABi})$ and B_{CL}/B_{AB} and then a regression equation is constructed. Subsequent adjustment of the constructed models is carried out considering that the mean value of probabilities for the oil field should be more than 0.5, and for the outside of oil field – less than 0.5. The probability model on B_{CL}/B_{AB} and other parameters is given in Table 3.

The data in Table 3 show that the regression equations have both positive and negative types. In terms of IR, C_{org}, OM, B_{CL}, B_{AB}, and $H_{um}A$ parameters, they have multidirectional correlations for the studied GCC. For the B_{PE}, B_{CL}/B_{AB} and β parameters they have unidirectional types for all GCC.

Examples of the constructed models' graph on B_{CL}/B_{AB} for GCC of D_3-C_{1t}, C_{1v}, and C_2 are given in Fig. 1.

It is seen that the dependencies of $P(B_{CL}/B_{AB})$ on B_{CL}/B_{AB} for GCC are significantly different. It should be noted that for C_{1V} and C_2 the probability values have a larger range than for D_3-C_{1t}. The models were used to calculate values for all analysed data and to determine mean values for oil and "empty" fields, which in the first case are greater than 0.5, in the second one are less than 0.5.

Construction of multidimensional models

In the next step of zonal forecast, a complex criterion was calculated from the values of individual probabilities using the following formula:

$$P_{\text{comp}} = \frac{\mathrm{P}^{m}_{j=1} P(W_1 \mid X_j)}{\mathrm{P}^{m}_{j=1} P(W_1 \mid X_j) + \mathrm{P}^{m}_{j=1}(1 - P(W_1 \mid X_j))},$$

where $P(W_1 \mid X_i)$ – individual probabilities of wells belonging to the class of oil zones; P – their product. Calculations are performed for each complex separately.

The $P^{\text{GCC}}_{\text{comp}}$ values were then used separately in the construction of multidimensional models on the GCC.

The model for the Upper Devonian-Tournaisian GCC has the following form:

$$P^{\text{GCC D3–C1t}}_{\text{comp}} = -3.288 + 0.97038\,P(\text{IR}) + 1.00461\,P(B_{cl}) + 0.41960\,P(C_{org}) + 0.94026\,P(\beta) + 1.00515\,P(B_{CL}/B_{AB}) + 1.04776\,P(B_{PE}) + 1.02328\,P(B_{AB}) + 1.16665\,P(\text{OM}),$$

at $R = 0.999$, $p < 0.0000$, the forecast error is 0.0032.

This model is used to calculate $P^{\text{GCC D3–C1t}}_{\text{comp}}$ values for all geochemical samples taken from these deposits. The name of areas, well numbers and $P^{\text{GCC}}_{\text{comp}}$ values are given in Table 4.

Table 1

Mean values of geochemical parameters on geochemical complexes

Value	GCC			Student's criterion $\frac{t}{p}$
	D_3–C_{1t}	C_1v	C_2	
IR, %	$\frac{38.99 \pm 41.29}{94}$	$\frac{81.34 \pm 25.44}{73}$		$\frac{-7.6977}{0.000000}$
		$\frac{81.34 \pm 25.44}{73}$	$\frac{27.17 \pm 30.56}{67}$	$\frac{11.42838}{0.000000}$
	$\frac{38.99 \pm 41.29}{94}$		$\frac{27.17 \pm 30.56}{67}$	$\frac{1.985389}{0.048821}$
C_{org}, %	$\frac{0.39 \pm 0.72}{116}$	$\frac{6.56 \pm 16.19}{50}$		$\frac{-4.2490}{0.000028}$
		$\frac{6.56 \pm 16.19}{50}$	$\frac{0.24 \pm 0.31}{67}$	$\frac{3.19403}{0.001811}$
	$\frac{0.39 \pm 0.72}{116}$		$\frac{0.24 \pm 0.31}{67}$	$\frac{1.575542}{0.116878}$
OM, %	$\frac{0.50 \pm 0.90}{116}$	$\frac{8.73 \pm 21.54}{50}$		$\frac{-4.1196}{0.000060}$
		$\frac{8.73 \pm 21.54}{50}$	$\frac{0.33 \pm 0.44}{67}$	$\frac{3.19069}{0.001830}$
	$\frac{0.50 \pm 0.90}{116}$		$\frac{0.33 \pm 0.44}{67}$	$\frac{1.380581}{0.169110}$
B_{PE}, %	$\frac{0.0017 \pm 0.0079}{234}$	$\frac{0.00021 \pm 0.00045}{123}$		$\frac{2.0739}{0.038807}$
		$\frac{0.00021 \pm 0.00045}{123}$	$\frac{0.00225 \pm 0.014}{156}$	$\frac{0.122420}{0.122420}$
	$\frac{0.0017 \pm 0.0079}{234}$		$\frac{0.00225 \pm 0.014}{156}$	$\frac{-0.477432}{0.633332}$
B_{CL}, %	$\frac{0.045 \pm 0.117}{247}$	$\frac{0.030 \pm 0.046}{126}$		$\frac{1.3247}{0.186094}$
		$\frac{0.030 \pm 0.046}{126}$	$\frac{0.017 \pm 0.102}{157}$	$\frac{1.30703}{0.192272}$
	$\frac{0.045 \pm 0.117}{247}$		$\frac{0.017 \pm 0.102}{157}$	$\frac{2.392633}{0.017186}$
B_{AB}, %	$\frac{0.081 \pm 0.129}{232}$	$\frac{0.065 \pm 0.084}{125}$		$\frac{1.2390}{0.216158}$
		$\frac{0.065 \pm 0.084}{125}$	$\frac{0.025 \pm 0.082}{156}$	$\frac{4.03537}{0.000070}$
	$\frac{0.081 \pm 0.129}{232}$		$\frac{0.025 \pm 0.082}{156}$	$\frac{4.805095}{0.000002}$
$H_{um}A$, %	$\frac{0.0014 \pm 0.0035}{245}$	$\frac{0.038 \pm 0.134}{175}$		$\frac{-4.3410}{0.000018}$
		$\frac{0.038 \pm 0.134}{125}$	$\frac{0.001 \pm 0.005}{156}$	$\frac{3.45518}{0.000635}$
	$\frac{0.0014 \pm 0.0035}{245}$		$\frac{0.001 \pm 0.005}{156}$	$\frac{-0.133462}{0.893896}$
B_{CL}/B_{AB}, RU	$\frac{0.488 \pm 0.381}{228}$	$\frac{0.518 \pm 0.304}{125}$		$\frac{-1.7501}{0.080972}$
		$\frac{0.518 \pm 0.304}{125}$	$\frac{0.584 \pm 0.658}{156}$	$\frac{-1.03703}{0.300622}$
	$\frac{0.488 \pm 0.381}{228}$		$\frac{0.584 \pm 0.658}{156}$	$\frac{-2.54602}{0.011288}$
β, %	$\frac{13.63 \pm 16.13}{112}$	$\frac{3.83 \pm 9.04}{48}$		$\frac{3.94801}{0.000118}$
		$\frac{3.83 \pm 9.04}{48}$	$\frac{5.84 \pm 11.69}{67}$	$\frac{-0.99566}{0.321543}$
	$\frac{13.63 \pm 16.13}{112}$		$\frac{5.84 \pm 11.69}{67}$	$\frac{3.448253}{0.000705}$

Note: * – numerator - mean values and standard deviation, denominator - number of data.

Table 2

Distribution of B_{CL}/B_{AB} values of D_3-C_1 domanic deposits

Class of features	B_{CL}/B_{AB} variation intervals, unit fraction			
	0.0–0.50	0.5–1.0	1.0–1.5	1.5–2.0
Areas within the field, $n_1 = 61$	0.672	0.262	0.016	0.049
Areas outside the field, $n_2 = 167$	0.796	0.161	0.035	0.006

Table 3

Individual models for zonal oil and gas content forecast on GCC of D_3-C_{1t}, GCC -C_{1v} and GCC of C_2

GCC	Probability equation of belonging to a class of territories within the field	GCC	Probability equation of belonging to a class of territories within the field
D_3–C_{1t}	$P(\mathrm{IR}) = 0.558 - 0.0019\ \mathrm{IR}$	D_3–C_{1t}	$P(B_{AB}) = 0.491 + 0.10072\ B_{AB}$
C_1v	$P(\mathrm{IR}) = 0.101 + 0.00506\ \mathrm{IR}$	C_1v	$P(B_{AB}) = 0.539 - 0.5876\ B_{AB}$
C_2	$P(\mathrm{IR}) = 0.346 + 0.00543\ \mathrm{IR}$	C_2	$P(B_{AB}) = 0.502 - 0.1771\ B_{AB}$
D_3-C_{1t}	$P(C_{org}) = 0.486 + 0.0364\ C_{org}$	D_3–C_{1t}	$P(\mathrm{HumA}) = 0.501 - 0.0003\ \mathrm{HumA}$
C_1v	$P(C_{org}) = 0.485 + 0.00232\ C_{org}$	C_1v	$P(\mathrm{HumA}) = 0.486 + 0.34761\ \mathrm{HumA}$
C_2	$P(C_{org}) = 0.622 - 0.5917\ C_{org}$	C_2	$P(\mathrm{HumA}) = 0.502 - 2.395\ \mathrm{HumA}$
D_3–C_{1t}	$P(\mathrm{OM}) = 0.485 + 0.03014\ \mathrm{OM}$	D_3-C_{1t}	$P(B_{CL}/B_{AB}) = 0.481 + 0.0475\ B_{CL}/B_{AB}$
C_1v	$P(\mathrm{OM}) = 0.486 + 0.00175\ \mathrm{OM}$	C_1v	$P(B_{CL}/B_{AB}) = 0.271 + 0.46511\ B_{CL}/B_{AB}$
C_2	$P(\mathrm{OM}) = 0.620 - 0.5117\ \mathrm{OM}$	C_2	$P(B_{CL}/B_{AB}) = 0.361 + 0.21008\ B_{CL}/B_{AB}$
D_3–C_{1t}	$P(B_{PE}) = 0.503 - 1.687\ B_{PE}$	D_3–C_{1t}	$P(\beta) = 0.463 + 0.00263\beta$
C_1v	$P(B_{PE}) = 0.542 - 250.00\ B_{PE}$	C_1v	$P(\beta) = 0.481 + 0.00543\beta$
C_2	$P(B_{PE}) = 0.502 - 1.398\ B_{PE}$	C_2	$P(\beta) = 0.473 + 0.00467\beta$
D_3–C_{1t}	$P(B_{CL}) = 0.492 + 0.17574\ B_{CL}$	–	–
C_1v	$P(B_{CL}) = 0.520 - 0.6667\ B_{CL}$	–	–
C_2	$P(B_{CL}) = 0.504 - 0.4975\ B_{CL}$	–	–

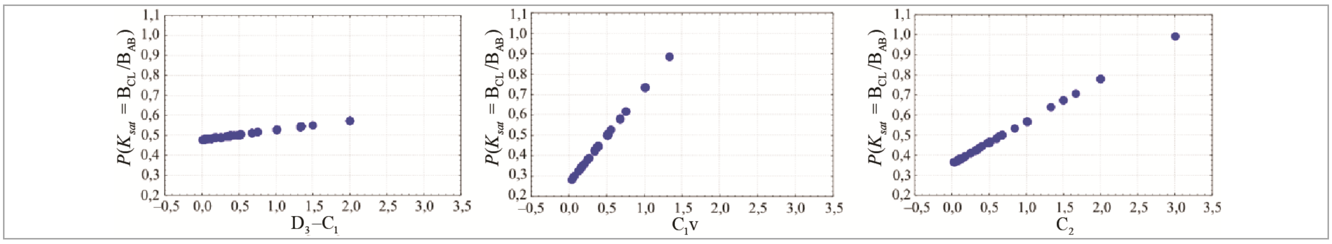

Fig. 1. Dependencies of $P(B_{CL}/B_{AB})$ values on B_{CL}/B_{AB} for GCC; $K_{sat} = B_{CL}/B_{AB}$, RU

Table 4

$P_{\text{comp}}^{\text{GC}}$ values on geochemical complexes

№ n/o	$P_{\text{comp}}^{\text{GCC D3–C1t}}$		$P_{\text{comp}}^{\text{GCC-C1v}}$		$P_{\text{comp}}^{\text{GCC-C}_2}$	
	Well	$P_{\text{comp}}^{\text{GC}}$ mean	Well	$P_{\text{comp}}^{\text{GC}}$ mean	Well	$P_{\text{comp}}^{\text{GC}}$ mean
1	Zorinskaya-208	0.519	Kizimskaya-North Geschskaya	0.584	Koltsovskaya-1	0.454
2	Zorinskaya-218	0.429	Kizimskaya-Krasnovisherskaya	0.511	Novo-Talitskaya-20	0.379
3	Zorinskaya-221	0.539	Koltsovskaya-1	0.368	Nytvenskaya-9	0.365
4	Zorinskaya-223	0.545	Nytvenskaya-9	0.323	Rassvetovskaya-2	0.446
5	Zorinskaya-225	0.458	Rassvetovskaya-2	0.416	Rassvetovskaya-6	0.449
6	Zorinskaya-228	0.577	Rassvetovskaya-6	0.468	Rozhdestvenskaya-41	0.454
7	Kizimskaya-1	0.655	Rozhdestvenskaya-41	0.433	Sukhobizyarskay-Yaborovskaya	0.660
8	Kizimskaya-2	0.496	Sukhobizyarskaya-Yaborovskaya	0.578	Sukhobizyarskaya-Ivazhinskaya	0.569
9	Koltsovskaya-1	0.444	Sukhobizyarskay-Yaborovskaya	0.725	Sukhobizyarskaya-150	0.501
10	Koltsovskaya-3	0.297	Sukhobizyarskaya-150	0.507	–	–
11	Lukhovskaya-1	0.417	Sukhobizyarskaya-1	0.414	–	–
12	Novo-Talitskaya-20	0.520	Slutskaya-279	0.542	–	–
13	Nytvenskaya-9	0.447	–	–	–	–
14	Rassvetovskaya-2	0.435	–	–	–	–
15	Rassvetovskaya-6	0.588	–	–	—	–
16	Rozhdestvenskaya-41	0.466	–	–	–	–
17	Severokamskaya-12	0.518	–	–	–	–
18	Sukhobizyarskaya-1	0.567	–	–	—	–
19	Sukhobizyarskaya-2	0.531	–	–	–	–
20	Sukhobizyarskaya-150	0.502	–	–	–	–
21	Shikhovskaya-1	0.517	–	–	–	–
22	Slutskaya-279	0.550	–	–	–	–

Table 5

The sequence of probabilities inclusion into the constructed multidimensional regression equations to calculate $P_{\text{comp}}^{\text{GC}}$ values on geochemical complexes

Probability	Consistency of individual probabilities inclusion into constructed multidimensional models, coefficients at parameters					
	$P_{\text{comp}}^{\text{GCC-D3-C1t}}$	Coefficients	$P_{\text{comp}}^{\text{GCC-C1v}}$	Coefficients	$P_{\text{comp}}^{\text{GCC-C2}}$	Coefficients
$P(\text{IR})$	1	0.97038	2	0.86234	3	0.83277
$P(C_{\text{org}})$	3	0.41960	4	1.75149	5	2.25739
$P(\text{OM})$	8	1.6665	–	–	1	–0.91542
$P(\text{B}_{\text{PE}})$	6	1.04776	3	0.90777	4	0.75568
$P(\text{B}_{\text{CL}})$	2	1.00461	8	1.07995	8	1.50130
$P(\text{B}_{\text{AB}})$	7	1.02328	5	0.76367	–	–
$P(\text{HumA})$	–	–	7	0.71421	6	1.05721
$P(\text{B}_{\text{CL}}/\text{B}_{\text{AB}})$	5	1.00515	1	0.94381	2	0.93010
$P(\beta)$	4	0.94026	6	0.72506	7	0.25492

Table 6

Correlation matrix

Parameter	D_3–C_{1t}	C_{1V}	C_2
D_3–C_{1t}	1.00	–0.91*	–0.77
C_{1V}		1.00	0.96*
C_2			1.00

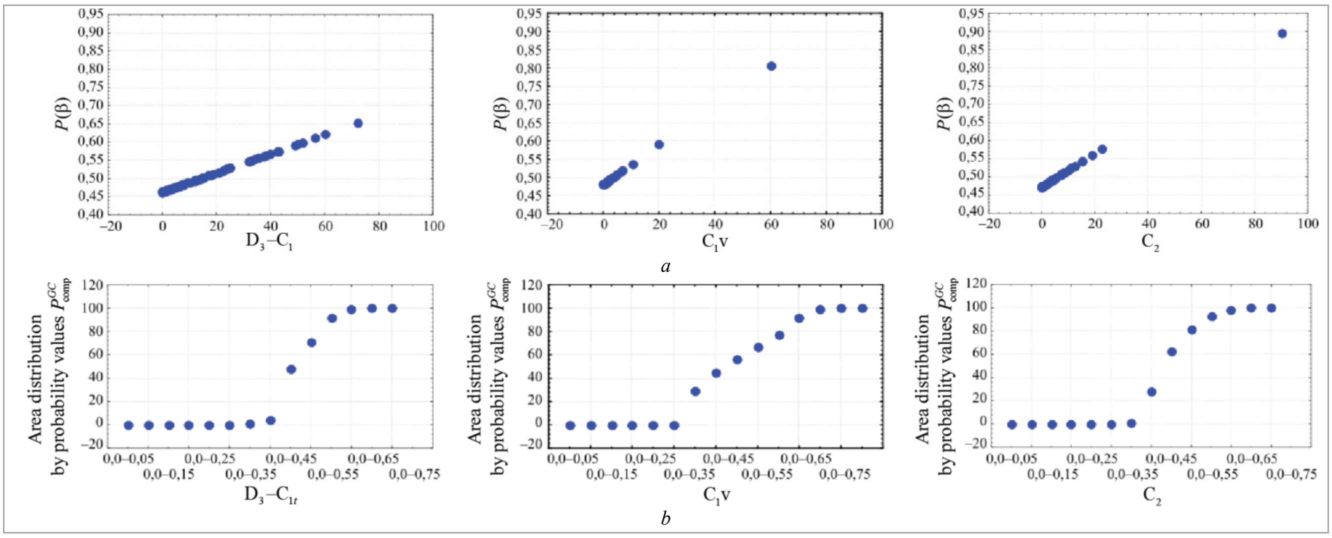

Fig. 2. Dependences of values change: *a* – $P(\beta)$ on β by GCC; β, %; *b* – areas by $P_{\text{comp}}^{\text{GCC}}$ by GCC; $P_{\text{comp}}^{\text{GCC}}$ variation interval

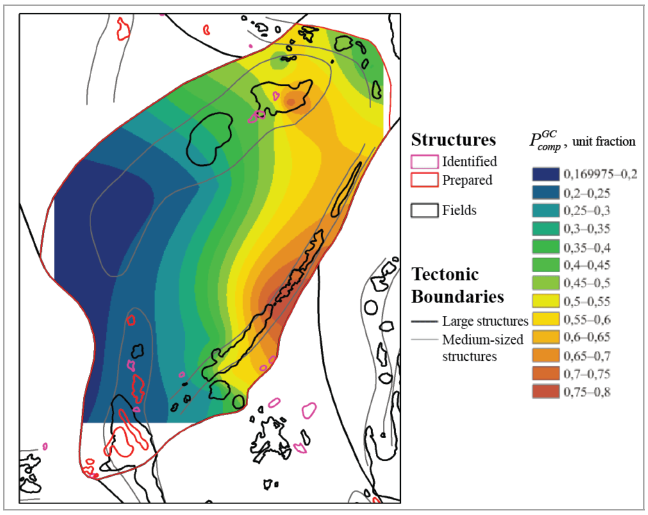

Fig. 3. Distribution diagram of the P^{GC}_{comp} average for the Perm arch territory

Based on the average $P^{GCC\text{-}D3\text{-}C1t}_{comp}$, $P^{GCC\text{-}C1v}_{comp}$, $P^{GCC\text{-}C2}_{comp}$ values in the wells, the probability distribution diagrams of zonal oil and gas content for the Perm arch were constructed. These diagrams were used in further assessments of zonal oil and gas content in the Perm arch.

To understand the process of P^{GC}_{comp} values formation from the values of individual probabilities P(IR), P(C_{org}), P(OM), P(B_{PE}), P(B_{CL}), P(B_{AB}) the sequence of regression equations formation on GCC was analysed (Table 5).

It is seen that the sequence of using individual probabilities when building multidimensional models to calculate P^{GC}_{comp} values differs significantly for the three studied variants. It should be noted that the formation of models is fundamentally different for rocks that are considered to be the main oil source rock – D_3-C_{1t} and covering C_{1V} and C_2. It is obvious from the P(B_{CL}) values which are used for $P^{GCC\text{-}D3\text{-}C1t}_{comp}$ model construction at the second step of model construction, while for $P^{GCC\text{-}C1v}_{comp}$, $P^{GCC-C_2}_{comp}$ – at the last steps of model construction.

The correlation coefficients between the data in the multidimensional regression equations are given in Table 6.

It can be seen that between the coefficients at geochemical parameters in multidimensional regression equations for the forecasted P^{GC}_{comp} on D_3-C_{1t} and C_{1V} there is a statistically significant inverse correlation, between D_3-C_{1t} and C_2 – the relation is also negative, but weaker. The correlation between C_{1V} and C_2 is direct and statistically significant. It indicates that the formation of oil and gas content due to the DOM of deposit potential occurred by different mechanisms of its transformation and further migration, which is confirmed by the type of change diagrams in the P^{GC}_{comp} values of D_3-C_{1t}, C_{1V} and C_2. This is quite clearly confirmed by such an important criterion of oil and gas content formation as β, which characterises the degree of hydrocarbon mobility. Dependences of P (β) values on β in the studied deposits are shown in Fig. 2, *a.*

It can be seen that the dependences of P (β) on β for the studied rocks are significantly different. For the Upper Devonian-Tournaisian deposits P (β) values are located in a rather narrow range of values – from 0.463 to 0.653, which indicates a significant syngenetic nature of the DOM. P (β) values vary from 0.481 to 0.807 in the Visean terrigenous and from 0.473 to 0.894 in the Upper Visean-Bashkirian deposits. In addition, fundamental differences are observed in the B_{CL}/B_{AB} parameter. For the Upper Devonian-Tournaisian deposits, this parameter was included in the 5th place of the multidimensional model formation, whereas for the Visean terrigenous and Upper Visean-Bashkirian deposits it was used in the 1st and 2nd places.

According to the diagrams of changes in the $P^{GCC\text{-}D3\text{-}C1t}_{comp}$, $P^{GCC\text{-}C1v}_{comp}$, $P^{GCC\text{-}C2}_{comp}$ values, the distributions of areas within certain ranges of probabilities are built, shown in Fig. 2, *b.*

We can see that $P^{GCC\text{-}D3\text{-}C1t}_{comp}$, $P^{GCC\text{-}C1v}_{comp}$, $P^{GCC\text{-}C2}_{comp}$ values less than 0.3 of the areas occupied by these probabilities are extremely insignificant and quite close in size. In the range up to 0.4 of the areas $P^{GCC\text{-}D3\text{-}C1}_{comp}$ remains insignificant, whereas $P^{GC\text{-}C1V}_{comp}$ and especially $P^{GC\text{-}C2}_{comp}$ are characterised by large values (44.459 % – C_{1V}, 28.006 % – C_2).

Conclusion

The research shows that the zonal oil and gas content of the Perm arch territory was formed due to the combined DOM potential of Upper Devonian-Tournaisian carbonate, Lower Visean terrigenous and Upper Visean-Bashkirian carbonate deposits. This allows us to consider that the developed probabilistic geochemical criteria can be used to estimate the zonal oil and gas content of the entire section of the Perm arch. Stepwise multidimensional regression analysis was used to estimate the quantitative contribution of $P^{GCC\text{-}D3\text{-}C1t}_{comp}$, $P^{GCC\text{-}C1v}_{comp}$, $P^{GCC\text{-}C2}_{comp}$ values to the P^{GC}_{comp}, complex characteristic defined, as before, by the formula of the complex criterion.

The multidimensional regression equation of dependences on $P^{GCC\text{-}D3\text{-}C1t}_{comp}$, $P^{GCC\text{-}C1v}_{comp}$, $P^{GCC\text{-}C2}_{comp}$ has the following form:

$$P^{GC^m}_{comp} = -0.467 + 3.72126\ P^{GCC\text{-}C2}_{comp} +$$

$$+\ 0.64282\ P^{GCC\text{-}C1v}_{comp} - 2.72126\ P^{GCC\text{-}D3\text{-}C1t}_{comp};$$

at R = 0,840, $p <$ 0,45577 forecast error equals to 0.053.

This shows that all the $P^{GCC\text{-}D3\text{-}C1t}_{comp}$, $P^{GCC\text{-}C1v}_{comp}$, $P^{GCC\text{-}C2}_{comp}$ values participated in the values formation in a complex way (Fig. 3). According to the $P^{GC^m}_{comp}$ values, a diagram of value distribution for the Perm arch territory was constructed (Fig. 3).

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