THE JUSTIFICATION OF ZONAL OIL AND GAS POTENTIAL OF THE TERRITORY OF VISIMSKAYA MONOLINE BY GEOCHEMICAL CRITERIA

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ОБОСНОВАНИЕ ЗОНАЛЬНОЙ НЕФТГАЗОНОСНОСТИ ТЕРРИТОРИИ ВИСИМСКОЙ МОНОКЛИНАЛИ ПО ГЕОХИМИЧЕСКИМ КРИТЕРИЯМ

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The paper presents the zonal probability and statistical assessment of the generation potential of deposits that form oil and gas potential of the territory of Visimskaya monoline. Databases on geochemical and bituminological characteristics of dispersed organic matter (DOM) in Domanicoid type deposits of the Upper Devonian-Tournaisian formation were used. The following indicators were used: content of organic carbon $S_{org}$, %; organic matter OM, %; composition of DOM (content of bitumoids: % – chloroform – CBE, petroleum – PB, alcohol-benzene – ABB, hemic acids – HumA, %, insoluble residue – IR, %) and characteristics of DOM conversion (ratio of chloroform bitumen to alcohol-benzene one – CBE/ABB, bituminoid coefficient – B), as well as the conversion factor for $S_{org} – K_c$. In order to determine the informativeness of these characteristics, the Student’s ($t$) and Pearson’s ($\chi^2$) statistical criteria were used. When building models for predicting the zonal oil and gas potential of the territory of Visimskaya monoline, one-dimensional and step-by-step multidimensional regression analyses were used, which allowed to construct one-dimensional and multidimensional regression linear models. Using the step-by-step multidimensional regression analysis a complex criterion was developed taking into account influence of each geochemical indicator separately and their combinations. This made it possible to construct a scheme for distribution of probability of petroleum potential of the territory of Visimskaya monoline. Analysis of the scheme showed that the most favorable geochemical conditions for the formation of petroleum potential due to DOM are observed in the central part of Visimskaya monoline (within the Maykorskoye field and surrounding area, bounded by the likelihood more than 0.5). Besides, areas in the south of Visimskaya monoline in the territories where $P_{z,org}^{max} > 0.5$ are of particular interest in terms of zonal oil and gas potential. North of Visimskaya monoline probably has a certain interest as well.

Key words: probability, linear statistical model, multidimensional statistical model, correlation coefficient, oil and gas potential, statistical criteria, geochemical and bitumen characteristics, organic matter, geochemistry.

В статье выполняется зональная вероятностно-статистическая оценка генерационного потенциала отложений, формирующих нефтегазоносность территории Висимской моноклинанали. Использованы базы данных по геохимическим и битуминологическим характеристикам рассеянного органического вещества (РОВ) в отложениях доманикоидного типа верхнедевонско-турнейской толщи. Были использованы следующие показатели: содержание органического углерода $S_{org}$, %; органического вещества ОМ, %; состав РОВ (содержание битумоидов: % – хлороформ – CBE, нефтяное – PB, спиртобензольные – ABB, гемные кислоты – HumA, %, нерастворимый остаток – IR, %) и характеристики преобразования РОВ (отношение хлороформного битумина к спиртобензольному – CBE/ABB, битуминоидный коэффициент – B); а также коэффициент пересчета для $S_{org} – K_c$. Для определения информативности этих характеристик использованы статистические критерии Стьюдента ($t$) и Пирсона ($\chi^2$). При построении моделей прогноза зональной нефтегазоносности территории Висимской моноклинанали использовались одномерный и многошаговый многомерный регрессионный анализ, что позволило построить одномерные и многошаговые регрессионные линейные модели. С помощью погашенного многомерного регрессионного анализа разработан комплексный критерий, учитывающий влияние каждого геохимического показателя в отдельности, так и их сочетаний. Это позволило построить схему распределения вероятности нефтегазоносности для территории Висимской моноклинанали, анализ которой показал, что максимально благоприятные геохимические условия формирования нефтегазоносности за счет РОВ наблюдаются в центральной части Висимской моноклинанали (в пределах Майкorskого месторождения и территории вокруг него, ограниченной изовероятностью больше 0,5). Также определенный интерес с точки зрения зональной нефтегазоносности представляют участки на юге Висимской моноклинанали, где $P_{z,org}^{max} > 0.5$. Вероятно, определенный интерес имеют территории и на севере Висимской моноклинанали.

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Introduction

Conventional methods for estimating oil and gas potential do not always allow identifying those local objects that could contain oil accumulations. Many authors propose the use different quantitative or qualitative criteria for zonal prediction of oil and gas content.

The paper presents the zonal probability and statistical assessment of the generation potential of deposits that form oil and gas potential of the territory of Visimskaya monocline. As for entire Perm region, there are conventional oil and gas source formations presented by sediments of the Upper Devonian-Tournaissian carbonate \((D_3-C_1t)\) complex \([1-12]\).

In order to overcome this challenge, we used databases on geochemical and bituminological characteristics of dispersed organic matter (DOM) of the Upper Devonian-Tournaissian carbonate sediments determined in wells in the Visimskaya monocline.

The following indicators were used: the content of organic compounds in the rock (organic carbon \(C_{\text{org}}, \%\), and organic matter OM, \%); DOM composition (bitumoid content, \% – chloroform – \(B_{\text{CBE}}\), petroleum – \(B_{\text{PP}}\), alcohol-benzene – \(B_{\text{ABB}}\), humic acids – \(\text{HumA}\), insoluble residue – IR) and characteristics of DOM conversion (ratio of chloroform bitumen to alcohol-benzene one – \(B_{\text{CBE}}/B_{\text{ABB}}\), bitumoid coefficient – \(\beta\) as well as the conversion factor for \(S_{\text{org}} – K_c\).

Statistical analysis was performed according to 325 core tests on geochemical characteristics.

Oil and gas source formation In the Upper-Devonian-Tournaissian oil and gas complex are of the Domanicoid type, which are currently associated with the formation of the main volume of oil and gas deposits in the entire sedimentary cover of the northeastern Volga-Ural oil and gas province, which includes the Visimskaya monocline. Earlier, various authors reviewed the geochemical features of each stratigraphic unit of these sediments, revealed their generating role, and carried out studies on the prediction of oil and gas content. Geological and geochemical features of these deposits were studied by the authors in sufficient detail for the entire territory of the Perm region \([1-8]\). It should be noted here that in works mentioned little attention has been paid to the peculiarities of the distribution of DOM over the territory of the Visimskaya monocline. This is largely due to the fact that there are currently few oil and gas fields discovered in this area, while in a rather limited stratigraphic range. According to the authors of this article, the use of mathematical methods will allow to assess the relationship between the characteristics of DOM and the oil and gas potential of the territory of the Visimskaya monocline.

Methods to build geological and mathematical models for solving various problems are given in \([13-38]\). Elements of mathematical statistics and probability theory were used in constructing one-dimensional and multidimensional linear statistical models. Those elements are described in detail in the works of both domestic and foreign authors \([1, 11, 20, 27, 29, 30, 39-46]\).

Construction of one-dimensional models

Results of studies of samples from wells located within the boundaries of the Visimskaya monocline and near by are analized. Initially, indicators characterizing DOM on the studied deposits were conventionally divided into two groups. The first group includes tests on DOM for wells located near the fields and directly in their contours. The second one includes tests from wells located outside the oil fields.

The first statistical tool for estimating the degree of difference of parameters for two samples is to test hypotheses about differences or non-differences between the mean values of DOM characteristics under consideration using Student's \(t\)-test:

\[
t_p = \frac{|X_1 - X_2|}{\sqrt{\frac{1}{n_1} + \frac{1}{n_2}} \left(\frac{(n_1-1)S_1^2 + (n_2-1)S_2^2}{n_1 + n_2 - 2}\right)},
\]

where \(X_1, X_2\) – average values of DOM for oil and “empty” areas respectively; \(S_1^2, S_2^2\) – dispersion of indicators. Differences in mean values are considered statistically significant if \(t_p > t_r\). The \(t_r\) values are determined depending on the amount of compared data and the level of significance \((\alpha = 0.05)\).

The data of statistical calculations of average values \((t\text{-criterion and attained significance level } p)\) of geochemical and bitumen parameters in groups for deposits of the Domanic type of Upper-
Devonian-Tournaisian deposits (D3-C1) are given in Table 1.

The statistical significance of differences in the average values of geochemical and bitumen characteristics of the DOM of the Upper Devonian-Tournaisian sequence was established for three indicators: $K_c$, $B_{ABB}$, $B_{CBE}$. The maximum statistical difference by criterion $t$ is obtained for $B_{CBE}$, minimal – OM. In order to assess the possibility of the formation of the petroleum potential of the Visimskaya monocline according to the DOM characteristics of the Upper Devonian-Tournaisian formation, individual forecast models were constructed for them to assess the petroleum potential. The method of constructing such models is described in sufficient detail in work [1].

Consider the construction of individual probabilistic models.

### Table 1

| Indicator | Statistical characteristics of indicators | Student's criterion | Top line – the equation of probability of belonging to a class of territories within the contours of deposits; medium line – scope of the model; lower line – range of probability change |
|-----------|------------------------------------------|---------------------|----------------------------------------------------------------------------------------------------------------------------------|
| IR, %     | 47.4 ± 42.4 0.501 ± 0.002 | $-1.21853$ 0.22424 | $P(IR) = 0.502 - 0.0005 IR$ 0.35–99.75 % 0.497–0.502 |
| $C_{org}$, % | 0.64 ± 1.23 0.501 ± 0.003 | 0.61471 0.53933 | $P(C_{org}) = 0.499 + 0.00425 C_{org}$ 0.02–23.33 % 0.499–0.602 |
| OM, %    | 0.81 ± 1.54 0.501 ± 0.003 | 0.54493 0.58631 | $P(OM) = 0.499 + 0.00321 OM$ 0.03–32.36 % 0.499–0.603 |
| $BPB$, % | 0.006 ± 0.018 0.511 ± 0.072 | 3.49030 0.10690 | $P(BPB) = 0.488 + 3.9047 BPB$ 0.000–0.08 % 0.488–0.800 |
| $B_{CBE}$, % | 0.056 ± 0.258 0.504 ± 0.038 | 1.61845 &nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&n

Note: * – in the numerator – average values of the indicator and standard deviation in the class, in the denominator – the average value of the probability and standard deviation in the class.

### Table 2

| Feature class | Variation interval $B_{CBE}$/$B_{ABB}$, rel. units |
|---------------|---------------------------------------------------|
| Territories within the contours of deposits ($n = 95$) | 0.00–2.0 2.0–4.0 4.0–6.0 6.0–8.0 8.0–10.0 10.0–12.0 12.0–14.0 14.0–16.0 More 16.0 |
| $B_{CBE}$/$B_{ABB}$ | 0.886 – 0.031 0.031 – 0.010 0.010 – 0.001 0.001 – 0.007 0.007 – 0.009 0.009 – 0.010 0.010 – 0.015 0.015 – 0.030 0.030 – 0.045 0.045 – 0.060 0.060 – 0.080 0.080 – 0.100 0.100 – 0.120 0.120 – 0.140 0.140 – 0.160 More 16.0 |
| Territories outside the contours of deposits ($n = 142$) | 0.922 0.036 0.021 0.007 0.007 0.007 – 0.010 0.010 – 0.015 0.015 – 0.030 0.030 – 0.045 0.045 – 0.060 0.060 – 0.080 0.080 – 0.100 0.100 – 0.120 0.120 – 0.140 0.140 – 0.160 More 16.0 |
As an example, let’s perform a statistical analysis on the $B_{CBE}/B_{ABB}$ indicator for samples taken within the contours of deposits and beyond. Comparison of the average values given in Table 1 shows that the average value for territories within the contours of the deposits is 1.634, for the territories beyond the contours of the deposit 0.782. According to the criterion $t$, the mean values are not different, since $p = 0.07962$.

Distribution of $B_{CBE}/B_{ABB}$ values over the Domanic deposits is given in Table 2. That shows that distribution of $B_{CBE}/B_{ABB}$ values for the territories of oil fields and beyond them is significantly different. For oil filed areas $B_{CBE}/B_{ABB}$ values in the range of 0.0-4.0 fractions of units are found with a frequency of 0.886, while for areas beyond the fields – 0.956. In the range of 2.0-10.0 in the first case 0.041, in the second – 0.042, i.e. there is a practical equality of the values of the frequency. With $B_{CBE}/B_{ABB} > 12.0$ for the territories of oil fields, the frequency is 0.063; there are no such high values beyond the oil fields. The performed evaluation of differences by criterion $\chi^2$ showed that the distributions are statistically different. This allowed the use the characteristic to build a probabilistic model.

In accordance with the methodology used at the first stage of constructing a probabilistic model in each interval, the probabilities of belonging to the territories of oil fields are determined ($P(B_{CBE}/B_{ABB})$). Next, interval probabilities of belonging to the $1^{st}$ class are compared with the average interval values $B_{CBE}/B_{ABB}$. By magnitude of $P(B_{CBE}/B_{ABB})$ and $B_{CBE}/B_{ABB}$ the pair correlation coefficient $r$ is calculated and the regression equation is constructed. The subsequent adjustment of the models built is carried out from the condition that the average value of the probabilities for the territories of oil fields must be greater than 0.5, and for the territories outside the oil fields less than 0.5. Thus, linear models built for a given strata allowed to evaluate the individual informativity of each geochemical indicator with respect to oil and gas content. An example of a graphic image of the constructed linear model in terms of $B_{CBE}/B_{ABB}$ is shown in Fig. 1.

This shows that with increasing values of $B_{CBE}/B_{ABB}$ from 0 to 21 shares, $P$ value ($B_{CBE}/B_{ABB}$) increases from 0.494 to 0.617.

![Dependance $P(B_{CBE}/B_{ABB})$ on $B_{CBE}/B_{ABB}$](image)

**Building of multidimensional models**

In the next step in forecasting estimates, the authors of the work justified a complex criterion that takes into account the constructed linear individual probabilistic models of each geochemical indicator for this complex. The criterion was calculated by the following formula:

$$P_{com} = \frac{\prod P_{ind}}{\prod P_{ind} + \prod (1 - P_{ind})},$$

where $P_{ind}$ – individual probabilities of $P(K_c), P(IR), P(C_{org}), P(OM), P(BPB), P(B_{CBE}), P(HumA), P(B_{CBE}/B_{ABB}), P(\beta)$, and $\Pi$ – their multiplication.

A combination of $m$ probabilities was used while calculating a complex criterion $P_{com}$ for the Upper Devonian-Tournaisian oil and gas complex. Mean values of probabilities $P_{com}$ in groups are the most statistically different (Table 3).

Combinations of probabilities selected in this way, calculated by geochemical indices from $m = 2$ to $m = 10$, are given in Table 3. It can be seen from the Table 3 that in the first step of building the model, with $m = 2$, the values of $P(B_{pn})$ and $P(B_{ABB})$ were used, when $m = 3$ the $P(K_c)$ probability was included in the model, then following probabilities were consistently included in the model $P(B_{CBE}/B_{ABB}), P(B_{CBE}), P(IR), P(HumA), P(\beta), P(C_{org}), P(OM)$.

Dependence of $P_{com}$ values on $m$ is given on the Fig. 2.

It is showed that with $m$ increasing from 1 to 6 the average value of $P_{com}$ for territories within the field contours regularly grows from 0.515 to 0.533 and remains constant when $m > 6$. There is a
tendency to decrease in values for territories beyond field contours with $m$ increasing. In order to develop a method for calculating $P_{\text{com}}^m$ values for the sediments based on the indicators we will use the values $P_{\text{com}}^m$ at $m = 7$. This is caused by the fact that there is a maximum value of the criterion $t$ with this combination.

The need to build a multidimensional model is caused by the fact that the studied indicators have a different effect on the complex criterion $P_{\text{com}}^m$ both in strength and in direction.

The influence of all the studied parameters was investigated by calculating the correlation coefficients $r$, defined in three options: the first option – according to all data, second – according to geochemical samples taken within the contours of the fields, third – beyond the contours of fields. The results of calculations of the values of $r$ are given in Table 4.

Table 4 shows that the values of the correlation coefficients $r$ between the studied parameters are different. For example, the correlation between $P_{\text{com}}^m$ and $\beta$ for samples taken within field contours has a statistically positive relationship, whereas for samples taken outside field contours, it is also statistically significant, but inverse.

Differences in the direction and closeness of correlations for two classes under the study are also observed between $P_{\text{com}}^m$ and other geochemical indicators (see Table 4). It should also be noted that there are different statistical relationships between the indicators that form values $P_{\text{com}}^m$ for two classes under the study. For example, the correlation between $B_{PB}$ and $B_{CBE}$ for samples taken within the fields’ contours has a statistically positive relationship, whereas for samples taken outside the contours of deposits, it is practically absent.

### Table 3

| Probability | Combination of probabilities with different $m$ |
|-------------|-----------------------------------------------|
|             | 2    | 3    | 4    | 5    | 6    | 7    | 8    | 9    | 10   |
| $P(\text{IR})$ | $+$  | $+$  | $+$  | $+$  | $+$  | $+$  | $+$  | $+$  | $+$  |
| $P(\text{C}_\text{or}g)$ | $+$  | $+$  | $+$  | $+$  | $+$  | $+$  | $+$  | $+$  | $+$  |
| $P(\text{OM})$ | $+$  | $+$  | $+$  | $+$  | $+$  | $+$  | $+$  | $+$  | $+$  |
| $P(B_{Bm})$ | $+$  | $+$  | $+$  | $+$  | $+$  | $+$  | $+$  | $+$  | $+$  |
| $P(B_{Bm})$ | $+$  | $+$  | $+$  | $+$  | $+$  | $+$  | $+$  | $+$  | $+$  |
| $P(B_{hum})$ | $+$  | $+$  | $+$  | $+$  | $+$  | $+$  | $+$  | $+$  | $+$  |
| $P(B_{Hum})$ | $+$  | $+$  | $+$  | $+$  | $+$  | $+$  | $+$  | $+$  | $+$  |
| $P(\beta)$ | $+$  | $+$  | $+$  | $+$  | $+$  | $+$  | $+$  | $+$  | $+$  |
| $P(K_c)$ | $+$  | $+$  | $+$  | $+$  | $+$  | $+$  | $+$  | $+$  | $+$  |

Mean value of the probability of the territories within field contours

| Probability | Mean probability value for territories beyond the field contours |
|-------------|---------------------------------------------------------------|
|             | 0.515 0.529 0.531 0.532 0.532 0.532 0.532 0.532 0.532 0.532 |
|             | 0.486 0.470 0.470 0.468 0.469 0.468 0.467 0.467 0.467 0.467 |

Mean probability value for territories beyond the field contours

$t$ and $p$:

| $t$   | $p$    |
|-------|--------|
| 4.267 | 0.00002|
| 4.3953 | 0.00017|
| 4.6082 | 0.00007|
| 4.7188 | 0.00004|
| 4.7591 | 0.00003|
| 4.7792 | 0.00003|
| 4.7542 | 0.00004|
| 4.7511 | 0.00004|
| 4.7445 | 0.00004|
All these data show that there are statistical differences in both the distributions and correlations for samples taken within the contours of deposits and beyond their contours. Consequently, the oil and gas potential of the Visimskaya monocline depends on the geochemical characteristics of the DOM of the Upper Devonian-Tournaisian sediments. According to the authors of this work, these indicators can be used to produce the zonal oil and gas potential of the study area.

A regression analysis is a statistical method for studying the dependencies between the dependent variable \( Y \) and one or several independent variables \( X_1, X_2, \ldots, X_p \). A dependent attribute in the regression analysis is called resultant, independent – factorial. Usually, several factors act on a dependent variable. The cumulative effect of all independent factors on the dependent variable is taken into account due to multiple regression.

In the general case, multiple regression is estimated by the parameters of the linear equation

\[
Y = a + b_1 X_1 + b_2 X_2 + \ldots + b_p X_p.
\]

In this equation, the regression coefficients \( (b\text{-coefficients}) \) represent the independent contributions of each independent variable to the prediction of the dependent variable. The regression line expresses the best prediction of the dependent variable \( Y \) with respect to the independent variables \( X_i \).

### Table 4

|   | \( P^{{\text{comp}}}_C \) | \( K_c \) | IR | \( C_{\text{org}} \) | OM | \( B_{PB} \) | \( B_{CBE} \) | \( B_{ABB} \) | HumA | \( B_{CBE}/B_{ABB} \) | \( \beta \) |
|---|----------------|-------|----|-------|----|------------|------------|------------|-----|--------------------|-------|
| \( P^{{\text{comp}}}_C \) | 1.00 | -0.73* | 0.28* | -0.02 | -0.02 | 0.50* | 0.29* | 0.37* | -0.19 | 0.24 | 0.09 |
| 1.00 | -0.85* | 0.22 | 0.14 | 0.13 | 0.54* | 0.35* | 0.35* | -0.00 | 0.51* | 0.42* |
| 1.00 | 0.96* | 0.57* | -0.30* | -0.31* | 0.07 | -0.52* | -0.22 | -0.37* | -0.33* | -0.39 |
| \( K_c \) | 1.00 | -0.53* | 0.16 | 0.17 | 0.16 | 0.23 | 0.21 | 0.10 | 0.03 | 0.28* |
| 1.00 | -0.45* | 0.14 | 0.09 | 0.08 | 0.14 | 0.06 | 0.08 | -0.01 | -0.21 | -0.11 |
| 1.00 | -0.68* | 0.33* | 0.34* | 0.25 | 0.63* | 0.42* | 0.26* | 0.42* | 0.46 |
| \( IR \) | 1.00 | 0.14 | 0.14 | -0.22 | -0.25 | 0.04 | 0.20 | 0.30 | 0.05 | 0.08 |
| 1.00 | 0.25 | 0.25 | -0.24 | -0.24 | -0.04 | 0.38* | -0.52 |
| 1.00 | 0.00 | -0.02 | -0.15 | -0.62* | -0.52 | -0.04 | 0.38* | -0.52 |
| \( C_{\text{org}} \) | 1.00 | 1.00* | 1.00* | -0.04 | 0.10 | 0.28* | 0.15 | 0.11 | 0.11 | 0.11 |
| 1.00 | 1.00* | 0.04 | 0.04 | 0.26 | 0.65* | 0.17 | 0.26 | 0.05 | -0.11 |
| 1.00 | 0.41* | 0.41* | 0.41* | 0.26 | 0.43* | 0.57 | -0.05 | -0.21 |
| \( OM \) | 1.00 | 1.00* | 1.00* | -0.04 | 0.10 | 0.28* | 0.15 | 0.11 | 0.02 | 0.11 |
| 1.00 | 1.00* | 0.04 | 0.04 | 0.26 | 0.65* | 0.17 | 0.26 | 0.05 | -0.11 |
| 1.00 | 0.41* | 0.41* | 0.41* | 0.26 | 0.43* | 0.57 | -0.05 | -0.21 |
| \( B_{PB} \) | 1.00 | 1.00* | 1.00* | -0.04 | 0.10 | 0.45* | 0.64* | -0.09 | 0.31* | 0.33* |
| 1.00 | 1.00* | 0.04 | 0.04 | 0.26 | 0.64* | 0.03 | 0.64 | 0.48* | 0.48* |
| 1.00 | 0.41* | 0.41* | 0.41* | 0.26 | 0.43* | 0.57 | -0.05 | -0.21 |
| \( B_{CBE} \) | 1.00 | 1.00* | 1.00* | -0.04 | 0.10 | 0.41* | 0.00 | 0.26* | 0.32* |
| 1.00 | 1.00* | 0.04 | 0.04 | 0.26 | 0.41* | 0.31 | 0.34 | 0.42* |
| 1.00 | 0.40* | 0.40* | 0.40* | 0.22 | 0.47* | 0.57* |
| \( B_{ABB} \) | 1.00 | 1.00* | 1.00* | -0.04 | 0.10 | 0.01 | -0.03 | 0.15 | 0.01 |
| 1.00 | 1.00* | 0.13 | 0.13 | -0.19 | -0.03 | -0.11 |
| 1.00 | 0.15 | 0.15 | -0.02 | 0.15 |
| \( \text{HumA} \) | 1.00 | 1.00* | 1.00* | -0.04 | 0.10 | 0.66* | 1.00 | 1.00* |
| 1.00 | 1.00* | 0.90* | 0.90* |
| 1.00 | 0.75* | 0.75* |
| \( B_{CBE}/B_{ABB} \) | 1.00 | 1.00* | 1.00* |
| \( \beta \) | 1.00 | 1.00 | 1.00 |

Note: the top line is all the data, the middle line is the fields’ contour, the bottom line is beyond fields’ contour; * – statistically significant correlations.
Table 5

| Areas                  | Well      | Age      | Number of samples | $p_{GC}^{comp}$ mean | $p_{GC}^{comp}$ min | $p_{GC}^{comp}$ max |
|------------------------|-----------|----------|-------------------|----------------------|---------------------|---------------------|
| Visim-Istokskaya       | 33        | D1f1–C1t| 10                | 0.458 ± 0.164        | 0.369               | 0.887               |
| Visimskaya             | 11        | D1f1–C1t| 7                 | 0.408 ± 0.043        | 0.379               | 0.502               |
| Visimskaya             | 13        | D1–D1f2| 21                | 0.445 ± 0.067        | 0.373               | 0.574               |
| Visimskaya             | 14        | D1f2–C1t| 9                 | 0.467 ± 0.087        | 0.379               | 0.646               |
| Visimskaya             | 15        | D1f2–C1t| 21                | 0.536 ± 0.111        | 0.381               | 0.695               |
| Visimskaya             | 16        | D1f2–C1t| 17                | 0.556 ± 0.157        | 0.397               | 0.972               |
| Visimskaya             | 23        | D1f2–C1t| 2                 | 0.384 ± 0.008        | 0.378               | 0.390               |
| Garinskaya             | 62        | D1–D2f1| 27                | 0.552 ± 0.012        | 0.540               | 0.581               |
| Dmitrievskaya          | 2         | D1f2–C1t| 7                 | 0.545 ± 0.003        | 0.542               | 0.551               |
| Dmitrievskaya          | 5         | D1f2–C1t| 3                 | 0.384 ± 0.015        | 0.369               | 0.401               |
| Invinskaya             | 71        | D1f2–C1t| 6                 | 0.387 ± 0.016        | 0.370               | 0.413               |
| Karnashevskaya         | 90        | D1f2–C1t| 7                 | 0.378 ± 0.021        | 0.363               | 0.410               |
| Kasibskaya             | 15        | D1f2–C1t| 4                 | 0.411 ± 0.013        | 0.393               | 0.421               |
| Kasibskaya             | 2         | D1–D1f2| 2                 | 0.390 ± 0.025        | 0.372               | 0.409               |
| Kuprosskaya            | 9         | D1–D1f2| 13                | 0.552 ± 0.007        | 0.546               | 0.562               |
| Maykorskaya            | 13        | D1f2–C1t| 6                 | 0.794 ± 0.212        | 0.373               | 0.982               |
| Nazarovskaya Durinskaya| 71        | D1f2–C1t| 16                | 0.385 ± 0.022        | 0.346               | 0.442               |
| Nazarovskaya Ivazhinskaya| 17    | D1–D2f1; D1f2–C1t| 30               | 0.434 ± 0.077        | 0.366               | 0.561               |
| Nolystskaya-Urayskaya  | 17        | D1f2–C1t| 14                | 0.434 ± 0.086        | 0.369               | 0.564               |
| Rodnikovskaya          | 12        | D1f2–C1t| 1                 | 0.369                |                     |                     |
| Romanshorskaya         | 1         | D1f2–C1t| 16                | 0.552 ± 0.060        | 0.372               | 0.696               |
| Senkinskaya Belopashkinskaya| 12 | D1–D1f2| 4                 | 0.553 ± 0.015        | 0.533               | 0.576               |
| Slutskaya              | 279       | D1–D3f1; D1f2–C1t| 18              | 0.423 ± 0.062        | 0.375               | 0.558               |
| Tukachevska            | 3         | D1–D1f2| 10                | 0.560 ± 0.015        | 0.546               | 0.584               |
| Ust-Kondasskaya        | 3         | D1f2–C1t| 3                 | 0.489 ± 0.090        | 0.385               | 0.543               |
| Chermozskaya           | 3         | D1–D1f2; D1f2–C1t| 14              | 0.585 ± 0.043        | 0.544               | 0.691               |
| Shatovskaya            | 287       | D1f2–C1t| 22                | 0.524 ± 0.110        | 0.371               | 0.808               |
| Shatovskaya            | 293       | D1f2–C1t| 9                 | 0.412 ± 0.066        | 0.374               | 0.586               |

In our case, $p_{GC}^{m=7}$ is a dependent attribute, and values of $K_c$, IR, $C_{org}$, OM, $B_{PB}$, $B_{CBE}$, HumA, $B_{CBE}/B_{ABB}$, $\beta$ as independent factors.

The model derives based on geochemical characteristics of the DOM of the Upper Devonian-Tournaisan sediments has the following formula

$$
\begin{align*}
    p_{GC}^{comp} = & 2.952 - 2.26761K_c + 0.16153B_{CBE} + 0.22506B_{ABB} + \\
                   & 0.000742B_{CBE}/B_{ABB} - 0.45018HumA - 0.00005IR + 0.00005\beta + 0.0001OM \\
\end{align*}
$$

if $R = 0.999$, $p < 0.0000$, forecast error is 0.00311.

The sequence of input of indicators in regression equations was done in a sequence of indicators given in the equation. In the first step of equation formulation, the indicator $K_c$ was included when $R = 0.726$; further, the value of $R$ was changed as follows: 0.956; 0.981; 0.991; 0.994; 0.996; 0.997; 0.998; 0.999.

Using this model, the $p_{GC}^{comp}$ values for all geochemical samples taken from these sediments were calculated. Information on well numbers from which samples were taken, age, their number and $p_{GC}^{comp}$ values is given in Table 5.
According to 29 wells and 322 determinations of DOM indicators, the average value of $P_{comp}^{GC} = 0.480 \pm 0.094$; it varies from 0.346 to 0.982.

According to the Table 5 plotted density distribution of values $P_{comp}^{GC}$ mean, $P_{comp}^{GC}$ min, $P_{comp}^{GC}$ max, are given in Table 6.

This shows that $P_{comp}^{GC}$ values in all three cases change slightly. For example, the mean probability in most cases has values in the range 0.4-0.6 (0.724). The average values in the wells were used to construct a pattern of oil and gas potential distribution for the territory of the Visimskaya monocline (Fig. 3).

**Conclusion**

As a result of the studies performed, it was found that the most favorable geochemical conditions for the formation of petroleum potential due to DOM are observed in the central part of the Visimskaya monocline, within the Maykorskoeye field and the area around it, limited by the probability level greater than 0.5.

 Territories in the south of the Visimskaya monocline where $P_{comp}^{GC} > 0.5$ are of particular interest in terms of zonal petroleum potential. Probably, there is a certain interest in the territory in the north of the Visimskaya monocline. This scheme will be used in further assessments of zonal oil and gas potential of the Visimskaya monocline.

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