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Features of grouping low-producing oil deposits in carbonate reservoirs for the rational use of resources within the Ural-Volga region

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Abstract. A methodology has been developed and a procedure for selecting homogeneous groups has been implemented using a set of parameters characterizing the properties of formation fluids, layering conditions, geological and physical properties of formations at different levels of the hierarchy. An algorithm for identifying deposits for monitoring and justifying measures to improve the efficiency of development management is proposed. A justification for the selection of associative groups of long-term developed objects using the parameters of geological heterogeneity according to different tectonic-stratigraphic elements is presented. To reduce the degree of uncertainty in the evaluation of objects by the degree and nature of geological heterogeneity, the parameters reflecting the degree of uncertainty of the system using complex characteristics are proposed. For different deposit associations, a different influence of the features of the object structure on the degree of their division has been established. In the process of deposit drilling, as additional information about development objects is obtained, it is necessary to specify the nature of the distinguished groups of objects first of all based on the use of characteristics of geological heterogeneity. Comparison of various grouping options shows the need to take into account the geological heterogeneity of objects during their drilling. The identification of groups of objects using a limited number of parameters is approximate, but at the stage of drafting the first design documents, it is possible to solve certain tasks aimed at determining the strategy for the development of deposits.

Key words: low-producing deposit; carbonate reservoir; grouping; deposits identification; differentiation; main component interpretation

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Introduction. Significant reserves of oil production in Russia are deposits in carbonate reservoirs of the Volga-Ural oil and gas-bearing province (VUOGP) [3, 18]. The objects are low-producing, characterized by complicated geological structure, sealed deposits at the water-oil interface, fractured reservoir rocks [17, 29]. This determines the low efficiency of their development, which is expressed in a high cost of the extracted products, a low degree of reserves recovery, long periods of deposits exploitation at the limit of economic profitability [5, 13]. At the same time, the deposits are characterized by significant residual oil reserves, and some of them have achieved high development indicators, comparable to those in terrigenous reservoirs [7, 8].

In these circumstances, it is important to find ways and means to improve the efficiency of deposit management based on the analogy method, which allows for justified decision-making, replication of best practices, and reduction in the risks of making erroneous decisions [11, 19, 21].

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At the same time, it is important to identify (group) deposits according to the parameters that have a predominant influence on the development of oil reserves [25, 26]. It is necessary to identify deposits depending on the amount of initial geological and production information (i.e., the stage of field development) [28].

Grouping of deposits for possible identification under conditions of a significant number of objects and parameters characterizing them is possible with the use of methods of factor analysis [6, 20, 23]. This procedure allows taking into account the degree and nature of similarity of different groups and the similarity itself when determining trends in increasing the efficiency of oil reserve recovery [12, 31].

A differentiated approach to the design, analysis, control and regulation for the development of these objects would improve the management efficiency of the main assets of oil companies in the VUOGP area [1, 4, 22].

Previously, such large-scale work – identification and grouping of deposits with hard-to-recover reserves in VUOGP carbonate reservoirs, determining the degree of influence of the initial information volume on deposit differentiability, development of algorithms for deposit identification at the stage of field exploration completion and after complete drilling-out – has not been carried out by other researchers.

Methodology. Around 600 VUOGP sites, sufficiently studied based on hydrodynamic, laboratory and geophysical investigations of wells, densely drilled and under development for a long time, have been selected for grouping.

Stratigraphically, the objects are confined to productive horizons from the Sakmaro-Arta deposits of the lower Permian to the Eifelian deposits of the Devonian. Tectonically, the sites are confined to the Tatar, Permian-Bashkirian, Zhigulevo-Orenburgian vaults, Permian, Belskaya, Verkhnekamskaya, Melekesskaya depressions, Abdullinsky trough, the south-eastern slope of the Russian platform.

The main component method algorithms, discriminant analysis and different combinations of geological and physical parameters were used to identify homogeneous groups of objects [14, 16, 27].

In the first option, the parameters that have a major impact on oil reserve recovery, which are determined with a sufficient degree of accuracy at the stage of the first project documents, were used. The choice of this set of parameters is caused by the necessity to create a grouping algorithm to use the analogy method at the stage of the field exploration completion [10, 30].

Results and discussion. Eighteen groups of objects have been identified. Using discriminant analysis, canonical variable equations have been derived, which together with the use of a situation map (Fig.1), allow identification of oil production objects already at the stage of exploration completion and identification of analogues that are in operation to determine the development strategy:

$$y_1 = 43.51 + 0.034m_g + 0.056m_r - 2.666K_{oil} + 0.025\mu_{oil} - 0.048\mu_r + 0.004\rho_{oil} - \\ - 0.006H_{dep} + 0.129P_{sat} + 0.016G - 0.178P_{fr} - 0.004K_{per} - 0.121t_{fr};$$

$$y_2 = -32.42 + 0.034m_g - 0.010m_r + 0.215K_{oil} + 0.015\mu_{oil} - 0.098\mu_r - 0.019\rho_{oil} + \\ + 0.0001H_{dep} + 0.438P_{sat} + 0.011G - 0.040P_{fr} - 0.002K_{per} - 0.057t_{fr};$$

$$y_3 = 14.97 - 0.025m_g - 0.014m_r - 0.596K_{oil} - 0.107\mu_{oil} + 0.212\mu_r - 0.024\rho_{oil} - \\ - 0.002H_{dep} + 0.373P_{sat} + 0.054G + 0.090P_{fr} + 0.008K_{per} + 0.013t_{fr};$$

$$y_4 = -3.05 - 0.260m_g - 0.210m_r - 5.465K_{oil} + 0.023\mu_{oil} - 0.025\mu_r + 0.013\rho_{oil} + \\ + 0.001H_{dep} + 0.399P_{sat} + 0.005G - 0.285P_{fr} - 0.003K_{per} + 0.009t_{fr},$$

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where m_g – porosity coefficient by geophysics, %; m_r – porosity coefficient of rock sample, %; K_{per} – permeability coefficient, 10^{-3} μm^2; K_{oil} – oil saturation coefficient, %; μ_{oil} – formation oil viscosity, mPa·s; μ_r – relative viscosity of oil; ρ_{oil} – formation oil density, kg/m^3; P_{sat} – saturation pressure of oil by gas, MPa; G – gas content of formation oil, m^3/t; H_{dep} – formation depth, m; P_{fr} – initial formation pressure, MPa; t_{fr} – initial formation temperature, K.

Table 1 shows the percentage of objects in selected groups from the total number of objects (K_1) and their belonging to the corresponding group (K_2). It can be seen that the percentage of objects grouped correctly varies by groups from 69 to 100 and on average is 91 %.

Table 1

Grouping indicators

Parameter, %	Group objects																		
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	1-18
K_1	2	8	3	22	4	9	2	3	5	5	10	4	8	7	3	1	2	2	100
K_2	100	90	100	91	100	69	100	93	85	78	92	95	100	94	100	100	91	100	91

The canonical correlations of the resulting equations that characterize the division degree of objects into groups vary from 0.86 to 0.97, which is a high indicator of performance.

The second option grouped 304 low-productive (K_{prod} < 10 t/days/MPa) objects according to 29 parameters, which can be attributed to five geological and physical factors [33]: layering conditions, formation thickness properties, specific heterogeneity coefficients, permeability and porosity properties, physical and chemical properties of formation fluids.

For a complete characterisation of the factor of formation thickness properties, the following was additionally used: effective oil-saturated thickness of the drilling zone H_{ef}^{r}, mean square deviation $\sigma_{h_{ef}}$, variation $W_{h_{ef}}$, entropy $E_{h_{ef}}$, relative entropy $\overline{E}_{h_{ef}}$ of effective oil-saturated thickness; mean square deviation σ_{h_p}, variation W_{h_p}, entropy E_{h_p}, relative entropy $\overline{E}_{h_p}$ of oil-saturated interlayers thickness. The factor of permeability and porosity properties of the formation additionally includes: mean square deviation σ_m, variation W_m, entropy E_m, relative entropy $\overline{E}_m$ of porosity. To describe the new factor – special heterogeneity coefficients – the following were used: integrated heterogeneity index K_{het}, share of reservoir rocks in the total formation thickness K_r, stratification coefficient K_s.

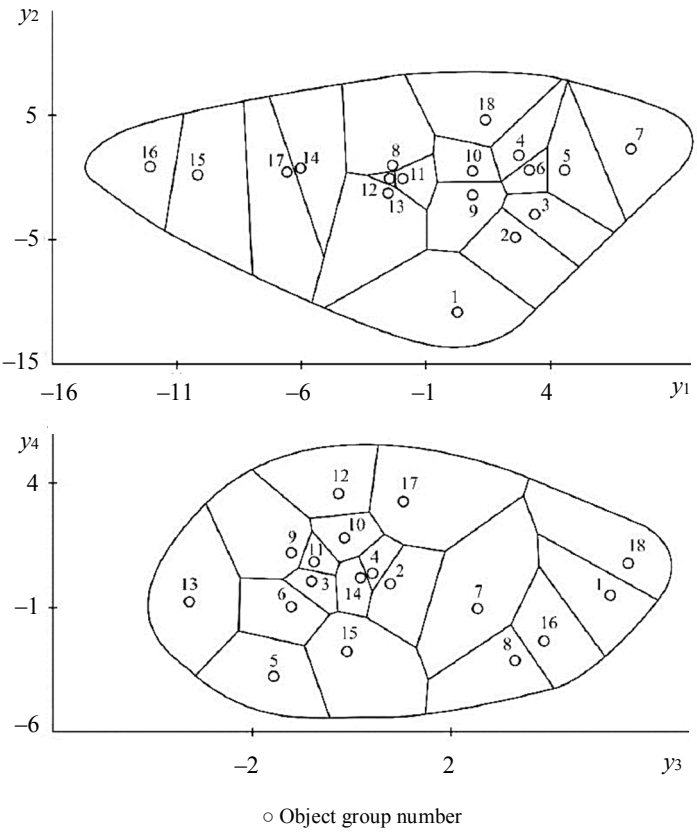


Fig.1. Situation map: grouping centers code

To calculate these indicators, geological and geophysical investigations data from 6000 wells of various purposes were used.

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Reliable characterization of the geological heterogeneity of development targets becomes possible after a field is drilled by dense net of wells. Therefore, the main task of grouping by a set of parameters discussed is a comprehensive comparison and consideration of peculiarities for geological structure of deposits. It allows solving the tasks associated with analysis, control and regulation of development in order to increase the efficiency of oil production [9, 15, 34].

The grouping, using the main component method, identified 14 groups of objects.

When characterizing the objects and their groups, one can not limit oneself to considering only the principal components, because the parameters compri-sing them are united into an inseparable whole by certain correlations and rela-tions, which condition the integrity of the system, i.e. they manifest emergent properties (Fig.2) [2].

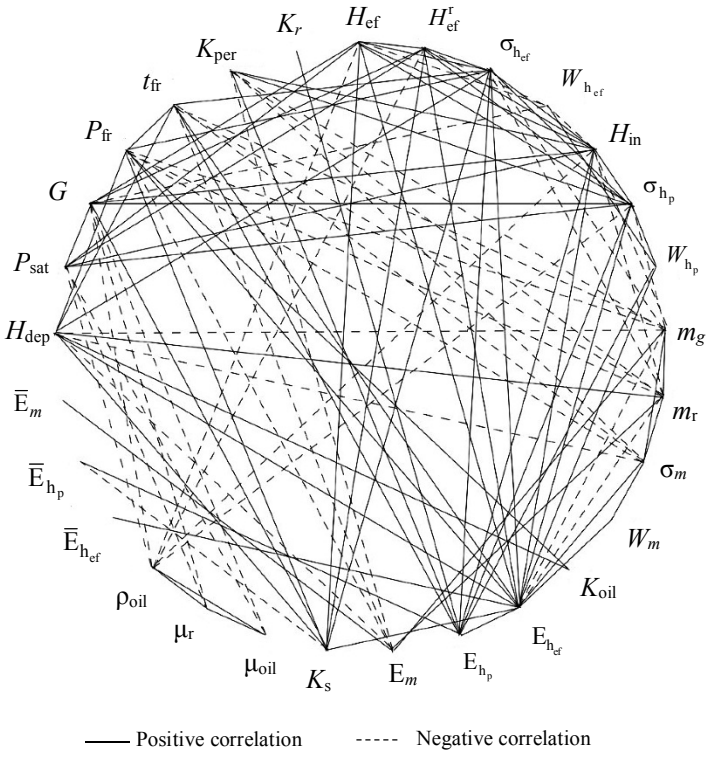


Fig.2. Graph of significant relationships between the parameters of the investigated objects obtained based on paired correlation and regression analysis

Identifying the relationships between different geological parameters is not only of theoretical interest, but also of practical interest both in solving geological problems and in oil field development [32].

Analysis of relationships between parameters shows that as effective oil-saturated thickness increases, so does geological heterogeneity in that parameter, reflected by mean square deviation and entropy; average thickness of oil-saturated interlayers increases and heterogeneity reflected by mean square deviation; oil density decreases, gas content and saturation pressure increase. This explains why, for various fields, the effect of effective oil-saturated thickness on oil recovery differs not only in magnitude but also in sign. On the one hand, increasing effective oil-saturated thickness in analyzed deposits lowers oil density and viscosity that should positively influence oil recovery, but on the other hand, it increases heterogeneity, which worsens recovery conditions.

As the layering depth of objects increases, porosity decreases as a result of rock compaction and permeability increases because of the increasing role of fractures in the oil filtration process. As the share of reservoir rocks in the total formation thickness increases, heterogeneity in the thickness of the oil-saturated interlayers increases, reflected by entropy. Effective oil-saturated thickness and heterogeneity in it, etc. increase with the stratification coefficient. The presence of such correlations and relationships between the parameters and the different effect of these parameters on the processes occurring in the formation, require a comprehensive approach in their consideration [24].

The parameters reflecting geological heterogeneity also have a complex relationship with each other, which is stochastic, making it difficult to compare objects by geological heterogeneity reflected by different indicators. Therefore, the parameters are introduced, which include some or other estimates of geological heterogeneity:

- for porosity

$$\mathrm{P}_m = \sigma_m W_m \mathrm{E}_m \bar{\mathrm{E}}_m;$$

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- for effective oil-saturated thickness

$$P_{h_{ef}} = \sigma_{h_{ef}} W_{h_{ef}} E_{h_{ef}} \bar{E}_{h_{ef}};$$

- for oil-saturated interlayers thickness

$$P_{h_p} = \sigma_{h_p} W_{h_p} E_{h_p} \bar{E}_{h_p}.$$

Consideration of empirical laws of distribution for parameters of geological heterogeneity by groups of objects according to the second option allowed identifying characteristic intervals of change for these parameters (Fig.3).

The first group of objects, confined to the Kizelovsky horizon of the Turnei stage in the Birskaya saddle, are characterized by great depth and belong to the type of massive.

The characteristics of the objects in the second group are mostly the same as those of the first group. The main difference is that the effective oil-saturated thickness of the objects in the second group is characterized as medium, reservoir rocks have low oil saturation, and the deposits are highly stratified and heterogeneous in effective oil-saturated thickness.

The objects of the third group are confined to the Kizelovsky horizon of the Turnei stage and are part of the Almetyevsk and Belebeyevsko-Shkapovskaya peaks of the Tatar arch and the Birskaya saddle.

The objects of the fourth group are distinguished by the fact that they have average values of stratification coefficient and are characterized by high values of heterogeneity parameter in thickness of oil-saturated interlayers. The objects of this group are located within Belebeyevsko-Shkapovskaya peak and are confined to reservoirs of Kizelovsky and Zavolzhsky horizons of Turnei stage.

The deposits of the Cherepetsky horizon on the southeastern slope of the Russkaya platform are attributed to the objects of the fifth group; they are massively layered and located at greater depths than objects of groups 1-4.

The objects of the sixth group are also located within the southeastern slope of the Russkaya platform, but are confined to the Kizelovsky Horizon of the Turnei Stage. The deposits in this group are very deep and are predominantly vaulted and massively layered.

The deposits of the Upper Famennian Stage of the Belebeyevsko-Shkapovskaya peak constitute the seventh group of objects; they are massive, confined to biogerm protrusions and are located at great depth.

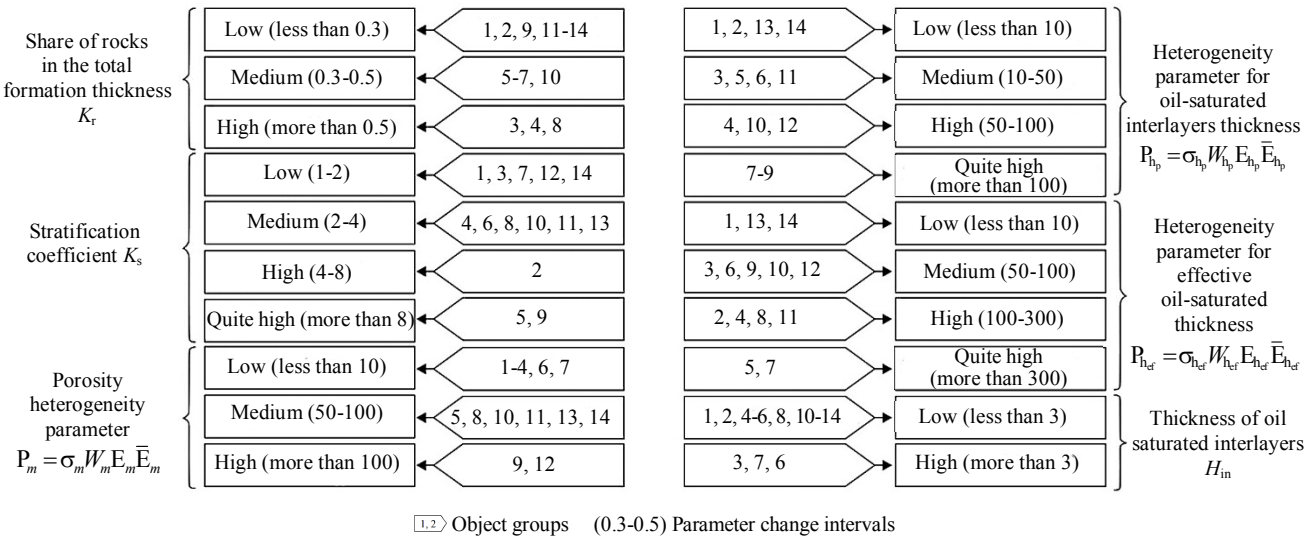


Fig.3. Characterization of "average" hypothetical deposits of objects by geological heterogeneity

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The objects of the Famennian Stage of the southeastern slope of the Russkaya platform, included in the eighth group, differ significantly from the objects of the seventh group. They are characterized by quite large depth, being massive and confined to the biogerm protrusions.

The ninth group of objects is represented by the reef massive structures of the Belskaya depression, confined to the Artinsky, Asselian and Sakmarian stages and located at medium depth.

The objects of the group 10 include the deposits of V_2 Vereisky formation, located within the Bashkirian peak, which are mainly formation vaults and located at a low depth.

Group 11 comprises objects of the Bashkirian stage of the Bashkirian peak. The deposits are mostly massively layered and located at medium depth.

Group 12 includes formation, vaulted, lithologically screened, low-depth objects confined to the Kashirsky (KSh_1) and Podolsky (P_3) horizons of the Birskaya saddle.

Group 13 objects include deposits of the Kashirsky (KSh_1, KSh_4) and Podolsky (P_2, P_3) horizons of the Birskaya saddle.

Oil deposits in the Vereisky (V_1, V_2, V_3) and Kashirsky (KSh_1, KSh_2, KSh_3, KSh_4) horizons of the Bashkirian peak comprise group of objects 14. Characteristics of this group are similar to those of groups 10, 12, 13. However, there is a specific set of considered parameters, which allowed distinguishing these objects in an independent group.

Based on the characteristics of the objects, two groups are distinguished, significantly different from each other. The first group includes objects of Lower Permian and Middle Carboniferous systems (groups 9-14), the second – Lower Carboniferous and Upper Devonian systems (groups 1-8). Objects of the first group compared to the second have approximately 1.5 times less layering depth and formation pressure, are more homogeneous in terms of thickness properties, stratification and share of reservoir rocks in the total formation thickness; permeability of objects is almost two times lower, but porosity and heterogeneity in it are almost 1.5 times higher. Viscosity of formation oil in objects of the second group is twice as high with lower (1.5 times) gas content.

In order to obtain a clearer picture on the division of the 14 groups of objects, to check whether objects are correctly assigned to one or another group according to the parameters under consideration and to identify the parameters most involved in dividing the groups, a discriminant analysis was conducted separately for groups 1-8 and 9-14.

Figure 4 shows a clear division of the object groups. The percentage of correctly grouped objects ranges from 90 to 100, with an average of 95, indicating little error in distinguishing them.

The identification of the parameters taking the largest part in the division of the groups of objects was carried out by using the values of F – statistics (Fisher's criterion) for multivariate comparison of group mean variables entered in the equations of canonical variables. The F-criterion values are given in Tables 2 and 3.

Table 2

Values of Fisher's criteria in a multivariate comparison of group mean variables in objects of Lower Permian and Middle Carboniferous systems

Parameter	F-criterion	Parameter	F-criterion	Parameter	F-criterion	Parameter	F-criterion
H_{ef}^{r}	280	P_{fr}	94	σ_m	74	ρ_p	66
P_{sat}	153	K_s	87	W_m	70	K_r	64
K_{per}	121	W_{h_p}	83	m_g	69	μ_{oil}	64
σ_{h_p}	108	H_{dep}	77	$\sigma_{h_{ef}}$	66	μ_r	62

As seen in Table 2, the most informative parameters in division of Lower Permian and Middle Carboniferous objects groups are: effective oil-saturated thickness, saturation pressure and permeability

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coefficient. The least informative parameters are viscosity and density of formation oil. The relative viscosity of formation oil indicates insignificant difference between groups of objects according to these parameters. Uninformative parameters were: thickness of oil-saturated interlayers, gas-oil ratio, coefficient of oil saturation, entropies and relative entropies by different parameters, formation temperature.

Table 3

Values of Fisher's criteria in a multivariate comparison of group mean variables in objects of Lower Carboniferous and Upper Devonian systems

Parameter	*F*-criterion	Parameter	*F*-criterion	Parameter	*F*-criterion
μ_{oil}	156	H_{dep}	74	K_r	58
m_r	118	K_{per}	70	μ_r	56
P_{fr}	107	ρ_{oil}	68	G	56
K_s	100	W_{hp}	65	H_{in}	55
t_{fr}	84	K_{oil}	65	H^r_{ef}	53
P_{sat}	76	σ_m	62	E_m	51

Under conditions of Lower Carboniferous and Upper Devonian system objects groups (Table 3), oil viscosity, porosity and formation pressure are the most informative. Effective oil-saturated thickness and entropy of porosity have the least dividing ability. The heterogeneity parameters of effective oil-saturated thickness were uninformative.

The comparison shows that the set of the most informative parameters is largely determined by the stratigraphic confinement factor, which must be taken into account during the development of oil production objects.

The relative entropy of the different parameters is in both cases an uninformative parameter and weakly differentiates objects into groups.

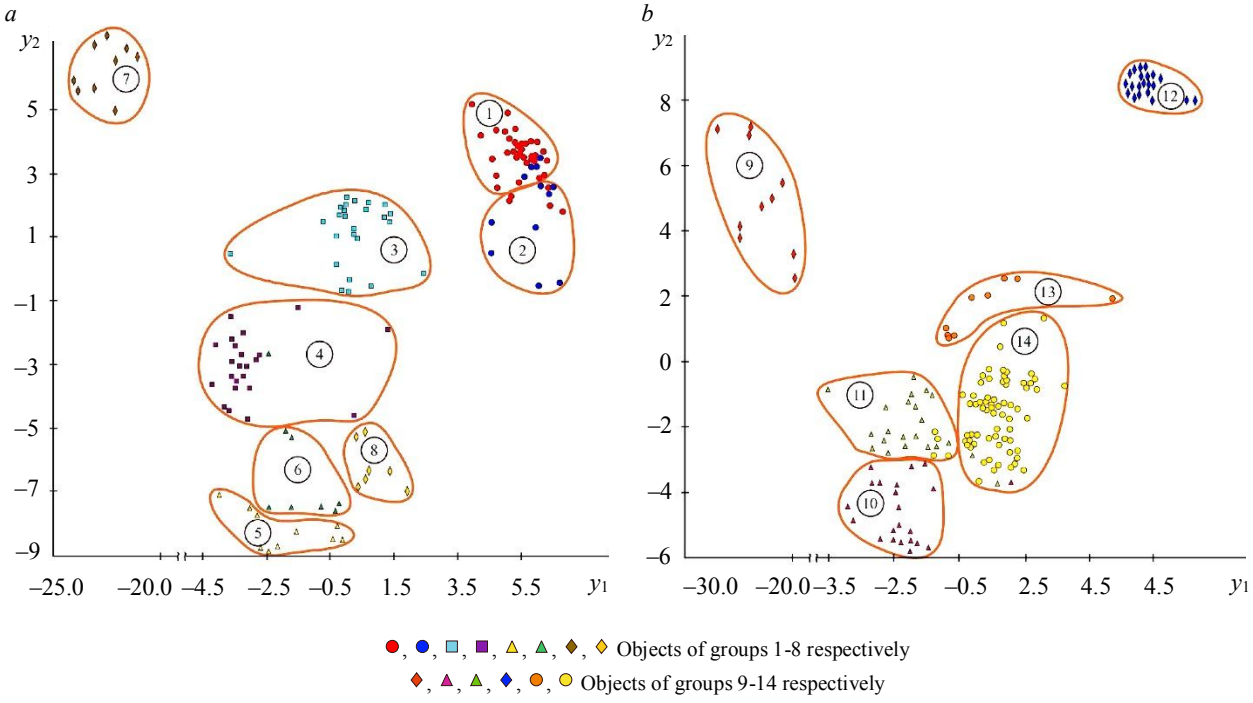


Fig.4. Distribution of investigated objects in canonical variable axes y_1 and y_2:
a – Lower Permian and Middle Carboniferous systems; *b* – Lower Carboniferous and Upper Devonian systems

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Using the resulting canonical variable equations for groups of objects 1-8:

$$y_1 = 158.1 + 0.218H_{ef}^{r} - 1.477H_{in} - 0.043W_{h_p} + 1.494m_r - 0.334\sigma_m - 33.02K_{oil} - 0.689E_m - $$
$$- 0.11K_s + 0.305\mu_{oil} + 0.485\mu_r - 0.126\rho_{oil} + 0.02H_{dep} - 0.448P_{sat} + 0.022G - 0.897P_{fr} -$$
$$- 0.193t_{fr} - 0.016K_{per} + 2.757K_r;$$

$$y_2 = -3.23 - 0.121H_{ef}^{r} + 0.504H_{in} + 0.037W_{h_p} - 0.31m_r - 0.371\sigma_m + 15.13K_{oil} + 1.398E_m -$$
$$- 0.221K_s - 0.165\mu_{oil} + 0.227\mu_r + 0.048\rho_{oil} - 0.002H_{dep} - 0.19P_{sat} - 0.109G - 0.397P_{fr} -$$
$$- 0.122t_{fr} + 0.01K_{per} - 7.68K_r;$$

for groups of objects 9-14:

$$y_1 = 52.67 - 0.054H_{ef}^{r} + 0.426\sigma_{h_{ef}} - 3.007\sigma_{h_p} + 0.032W_{h_p} - 0.37m_g + 3.102\sigma_m - 0.471W_m -$$
$$- 0.949K_s + 0.734\mu_{oil} - 0.887\mu_r - 0.036\rho_{oil} - 0.31P_{sat} - 0.041G - 1.092P_{fr} -$$
$$- 0.016K_{per} + 0.95K_r;$$

$$y_2 = 106.73 - 0,099H_{ef}^{r} + 0.936\sigma_{h_{ef}} + 0.002W_{h_p} - 0.027m_g + 1.656\sigma_m - 0.1151W_m + 0.503K_s +$$
$$+ 1.841\mu_{oil} - 1.697\mu_r - 0.119\rho_{oil} - 0.905P_{sat} - 0.047G - 0.601P_{fr} - 0.053K_{per} - 5.229K_r,$$

as well as the distributions of objects in the axes of these variables allow for a search procedure of analogous objects and deep identification of objects, taking into account geological heterogeneity in various parameters to solve different problems of improving efficiency and involvement in the development of both low-producing and low-profitable oil deposits.

Table 4 shows the values of K_1 and K_2. It can be seen that the percentage of objects grouped correctly varies across groups from 90 to 100, averaging 95 %, indicating little error in identifying groups of objects.

Table 4

Grouping indicators

Parameter, %	Objects of group															
	1	2	3	4	5	6	7	8	1-8	9	10	11	12	13	14	9-14
K_1	28	10	19	17	8	6	7	5	100	7	13	14	14	7	45	100
K_2	100	93	100	96	90	100	100	100	95	100	100	92	100	100	91	95

The values of the canonical correlations of the resulting equations vary from 0.841 to 0.986.

The use of parameters and coefficients characterizing geological heterogeneity of investigated objects according to different parameters, as seen in Fig.5, allows in some cases to make a deeper comparison and differentiation of objects groups. For example, if the objects of groups 10, 15, 17, 18, selected according to the first variant of grouping (in the absence of parameters for geological heterogeneity) formed groups 3, 7-9 respectively, with regard to geological heterogeneity, then groups 5, 12, 13 were divided into two subgroups, which differ in parameters of geological heterogeneity. The fifth group, identified according to the first option, split into groups 12 and 13 according to the second option (taking into account geological heterogeneity). At the same time, if the objects of groups 12 and 13 are approximately identical by a share of reservoir rocks in the total formation thickness, they differ in other parameters of geological heterogeneity (Fig.5). The strongest influence of geological heterogeneity parameters in the differentiation is observed under the conditions of objects in the sixth group, obtained in the grouping according to the first option. This group split in the second grouping option into five more groups, each of which differs from the others by a specific set of parameter variation intervals and coefficients of geological heterogeneity.

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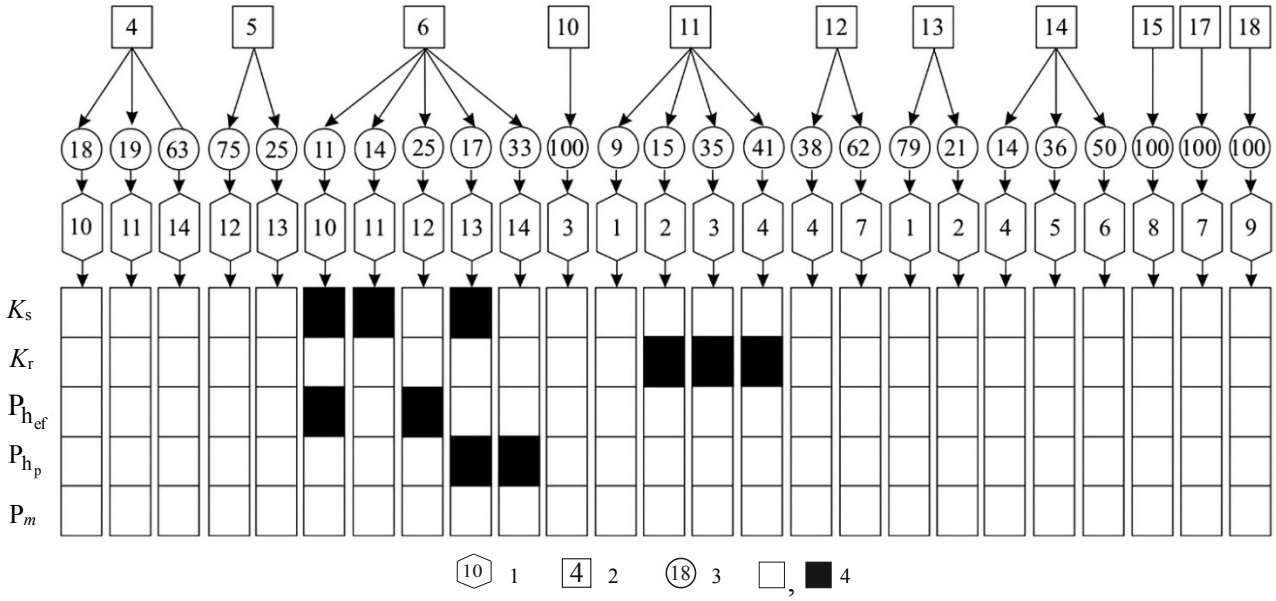


Fig.5. Division of the groups of objects obtained in the grouping according to the first option, taking into account geological heterogeneity

1 – the number for the group of objects obtained according to the second option; 2 – the number for the group of objects obtained during grouping according to the first option; 3 – percentage of the ratio for the number of objects (when grouping according to the second option) to the total number of objects in the group (when grouping according to the first option); 4 – correspondence of intervals for parameters variation of groups of objects (when grouping according to the second option)

Examination of the reverse picture (Fig.6) showed that the groups obtained according to the second option include objects from several groups identified according to the first option.

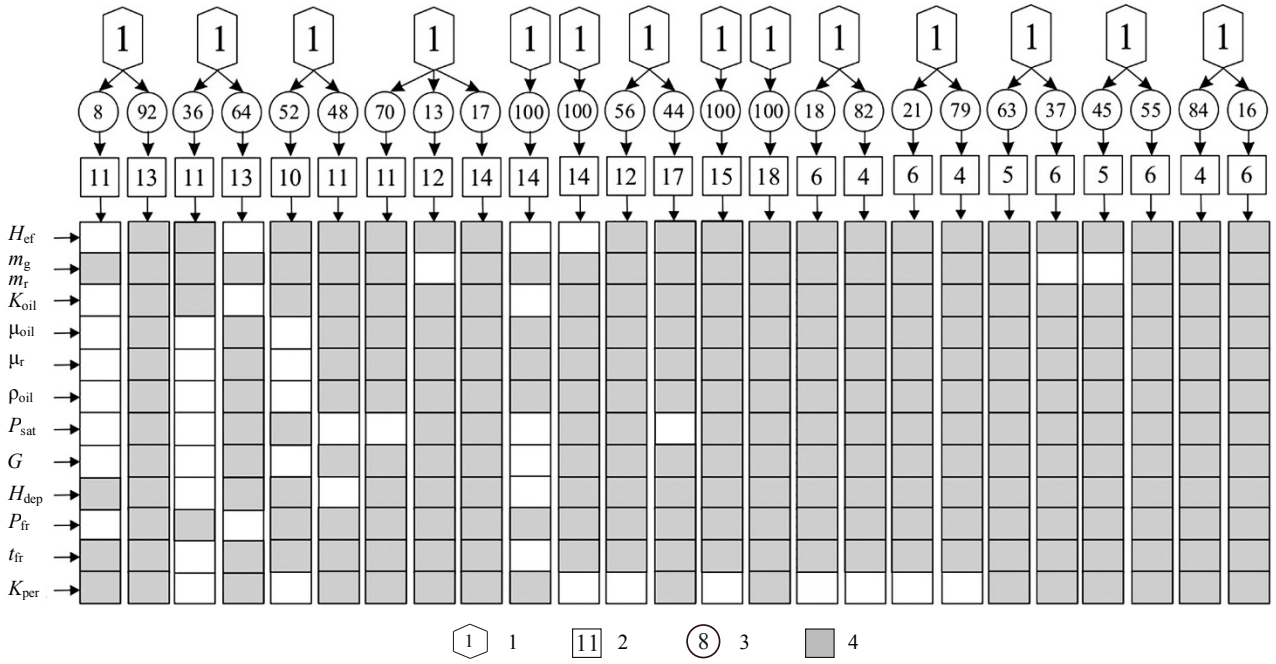


Fig.6. Comparison for intervals of parameters variation for "medium" hypothetical deposits of groups of objects according to the first and second grouping options

1 – the number for the group of objects obtained according to the second option grouping; 2 – the number for the group of objects obtained during grouping according to the first option; 3 – percentage of the ratio for the number of objects (when grouping according to the second option) to the total number of objects in the group (when grouping according to the first option); 4 – correspondence of intervals for parameters variation of the "medium" hypothetical deposits of the groups identified according to the first and second options

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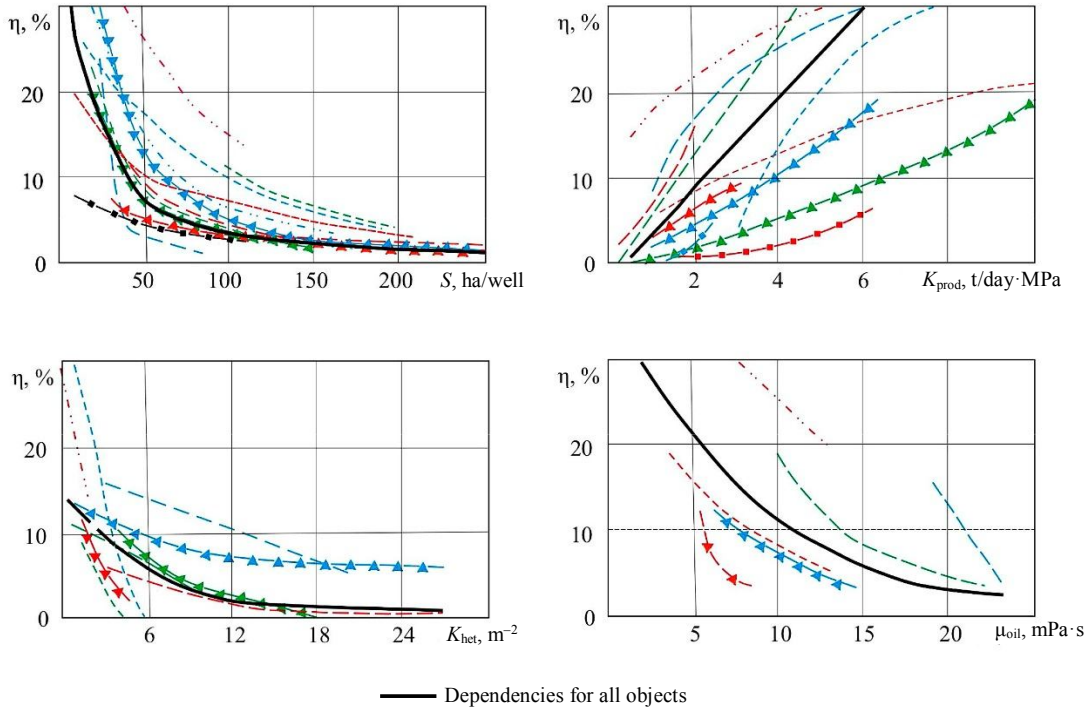


Fig.7. Significant correlations of the final oil recovery on the geological and technological parameters

It should be noted that the parameters used in the first option often coincide. In these cases, the geological heterogeneity that unites these objects into a single group is important.

Comparison of the different grouping options shows the need to account for geological heterogeneity in the drilling process. The identification of groups of objects using a limited number of parameters is approximate, but at the stage of drafting the first design documents, it is possible to solve problems aimed at determining the strategy for the development of deposits.

At the final stage, final oil recovery η was predicted for the considered objects using statistical methods based on the application of displacement characteristics of oil by water and depletion characteristics.

The influence of all considered parameters on η was studied and multivariate models were constructed for each of the selected groups using the method of group accounting for arguments.

As an example, Fig.7 shows significant correlations of η with density of well grid density S, productivity coefficient K_{prod}, integrated heterogeneity index K_{het} and formation oil viscosity μ_{oil}. It can be seen that under conditions of different groups of objects the degree and character of influence for these parameters on oil recovery is different, which indicates the need for differentiation of objects and combining them into relatively homogeneous groups when solving various problems of development.

The need for object differentiation is also indicated by the resulting multivariate models (according to the groups in the second modelling option). Thus, the model for the first group is as follows:

$$\eta = 18.3\frac{P_m^{0.5}P_{h_p}E_{h_p}^{0.5}}{S} - 169\frac{P_{h_{ef}}^{0.5}}{S} + 0.15\frac{S}{P_m^{0.5}P_{h_{ef}}} - 10.9\frac{P_m^{0.5}P_{h_{ef}}}{H_{ef}^{r\,0.5}S};$$

- model for the fourth group:

$$\eta = 910\frac{H_{ef}^{0.5}}{\mu_{oil}^{0.5}S^{0.5}\overline{E}_m^{0.5}\sigma_m^{0.5}W_m^{0.5}} - 78.1\frac{H_{ef}^{0.5}}{P_{fr}^{0.5}E_m^{0.5}W_m^{0.5}};$$

- model for the seventh group:

$$\eta = 21.3\frac{P_{h_p}^{0.5}E_{h_{ef}}^{0.5}}{W_m^{0.5}S^{0.5}} + 0.508\frac{K_{per}^{0.5}P_{h_p}^{0.5}}{S^{0.5}} - 12.5\cdot10^{-2}H_{dep}^{0.5};$$

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- model for the group 13:

$$\eta = 2.19 \cdot 10^{-2} \frac{P_{h_p}^{0.5} G^{0.5} P_{sat}}{\mu_r^{0.5}} - 3 \cdot 10^{-4} \frac{P_{h_p} G^{0.5} P_{sat} S}{\mu_r^{0.5}};$$

- model for all groups of objects:

$$\eta = 7.86 \cdot 10^{-4} \frac{t_{fr}^{0.5} H_{dep} \sigma_{h_p}^{0.5} \sigma_{h_{ef}}^{0.5}}{K_{oil} S^{0.5}} + 9.54 \cdot 10^{-6} \frac{t_{fr}^{2.0} H_{dep}^{0.5} W_{h_p}^{0.5}}{m_r^{0.5} S^{0.5}} - 20.8 \frac{\sigma_{h_p}^{0.5}}{t_{fr}^{0.5}} +$$
$$+ 24.4 \frac{K_{oil}^{0.5} E_{h_p}^{0.5} K_r^{0.5} \sigma_{h_{ef}}^{0.5}}{S^{0.5}} - 8.46 \cdot 10^{-6} \frac{t_{fr}^{2.0} H_{dep}^{0.5} W_{h_p}^{0.5} \mu_{oil}}{m_r^{0.5} S^{0.5}}.$$

Model analysis shows that different groups of objects have their own set of significant parameters that have a predominant impact on the production of oil reserves, while the degree of influence for the same parameters in different groups of objects differs.

The correlation ratio for the obtained models by groups of objects varies from 0.718 to 0.983, while for the model built using all objects is 0.426. The relative uncertainties for the models by groups are on average 15 %, while for the model based on all objects is 34 %.

Conclusion

1. Based on the use of features for the geological structure of deposits characterized by hierarchy level parameters, an algorithm of identifying objects for solving problems of monitoring and management of development is proposed.

2. The use of integrated features to reduce uncertainty in the evaluation of development objects according to various parameters of geological heterogeneity is proposed.

3. Groups of long-term development objects are identified according to the parameters of geological heterogeneity in different tectonic-stratigraphic systems.

4. It has been found that, as deposits are drilled out, it is necessary to refine the values of parameters characterizing the features of the geological structure and to make clarifications about the belonging of objects to one or another group, using the parameters of geological heterogeneity.

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