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The Analogy Method Usage for the Western Siberia Jurassic Oil and Gas Bearing Complex Deposits' Involvement into Development Degree Increasing

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Abstract

The identification and grouping of about 250 Jurassic and Paleozoic-age targets under development of the West Siberian oil province the four oil and gas bearing areas have been carried out. Basing on the tectonic and stratigraphic data, the mode of occurrence, geological, physical and chemical properties of the strata and the information about saturating fluids the eight groups of objects have been singled out. The prevailing influence of tectonic and stratigraphic geology is established in the deposits' geological structure formation and their reservoir porosity and permeability properties. The selected object groups are ranked by the similarity and discrepancy degree in the multidimensional space of parameters that have a dominant impact on the reserve recovery process. Clusters enabling the accumulated experience in Jurassic and Paleozoic ages reserves development not only within the considered oil areas but also in adjacent areas are presented. This allows for the deposits similar to those under study by their geological features: to establish the strategy and set the trend of effective development; to search for the missing parameter values, dependencies, and other information necessary for project documents; to carry out an examination and determine the values validity of various obtained by the objects parameters using "patterns" of well-studied fields; to reduce risks and uncertainties in the exploration and development of fields; to monitor and investigate the causes of decline and to search for ways and means to improve development effectiveness; to respond flexibly to changing assumptions as more information is obtained, while using the empirical estimates obtained from other group sites in a reasonable manner; to assess the production capacity, oil recovery potential, reserve recovery enhancement techniques application; a priori, to justify the correct management decisions for development optimization adoption; to shorten the time and quality of project work and accelerate the deposits into active development involvement; to search for and propose options for asserts categorization as paying, including taking into account energy prices.

The results made it possible to create a methodological base for not only targets searching but also groups of analogical targets for the deposits that are out of exploration to engage them in active development and increase the Jurassic oil and gas complex oil reserves production.
Keywords: analogous targets, tectonic and stratigraphic confinement, the degree of reserves development, involvement in active development.

Under the conditions of need to maintain the attained oil production level in the country with: a constantly declining production in the main objects, which have been under development for a long time; a moderate increase in the developed reserves; an apparent increase in the cost of the extracted products due to oil reserves deterioration, it is important to involve oil deposits confined to the areas with extended infrastructure and characterized not only by a low degree of involvement into development, but also by a low oil reserve recovery degree and low economic efficiency of these deposits' development, into the active development [4, 7, 17-19].

One of such objects is the deposits of the Upper and Middle Jurassic of Western Siberia, the share of remaining recoverable oil reserves of which within the total remaining recoverable reserves as a whole is 11.1% and 13.4%, respectively. The deposits are involved into the development fragmentarily. Reserves of the Upper Jurassic oil and gas bearing complex (OGC) are involved into the development process by 76.7%, the current rate of remaining recoverable reserves is 2.4%, the reserves-to-production ratio is 42 years. The involvement degree of the Middle-Lower Jurassic OGC's reserves is 49%, the current rate is 1%, the reserves-to-production ratio is more than 200 years [2, 16, 19, 31].

The reserve recovery degree of these objects varies between very wide ranges, and the expected predicted ultimate reserve utilization ratio (RUR) for the objects brought into development is about 0.2 with the adopted development systems, although it reaches 0.4 and more for some objects.

To a certain extent, the reasons for this are, as noted in [19], the infrastructure characteristic, determined by the distance from the field to the nearest oil trunk pipeline, the availability of the productive Cretaceous deposits in the geological section, which occur at shallower depths, and, as a rule, they have the best reservoir properties and, respectively, are characterized by the higher potential in terms of the future developments than the Jurassic deposits. But the main reason is a low reservoir quality and well productivity, a wide variety of deposits by their geological and physical properties of reservoirs and fluids, which requires a differentiated approach when choosing development systems based on the field development experience, which provided the high technical and economic indicators, as well as when determining the need for stimulating their bringing into development [1, 3, 10, 19, 21, 23, 24].

The important stage in a way to increase the degree of the deposit involvement into development is the use of the analogy method through creation of clusters from the objects, which are the most similar in geological and physical properties and have been under development for a long time, upon which the meaningful geological and commercial material was gathered and different development experience generalizations were carried out [12, 22, 25, 27].

It is these clusters allow to draft the first project documents, and also at the initial development stages, for the objects that are under the prospecting stage [5, 6, 20, 26, 28-30]:

- to establish the strategy and set the trend of effective development;
- to search for the missing parameter values, dependencies, and other information necessary for project documents;
- to carry out an examination and determine the values validity of various obtained by the objects parameters using "patterns" of well-studied fields;
- to reduce risks and uncertainties in the exploration and development of fields;
- to monitor and investigate the causes of decline and to search for ways and means to improve development effectiveness;
- to respond flexibly to changing assumptions as more information is obtained, while using the empirical estimates obtained from other group sites in a reasonable manner;
- to assess the production capacity, oil recovery potential, reserve recovery enhancement techniques application;
- a priori, to justify the correct management decisions for development optimization adoption;
- to shorten the time and quality of project work and accelerate the deposits into active development involvement;
- to search for and propose options for asserts categorization as paying, including taking into account energy prices.

To solve the clustering problem, about 250 objects that were under development for a long time or drilled sufficiently densely by different-purpose wells confined to the Jurassic (Bazhenov (Yu0) formation, Upper Jurassic (J3), Middle Jurassic (J2), pre-Jurassic (the Paleozoic weathering crust (WC)) sediments of the Shaimsky (ShB) and Verkhnepursky (VB) banks; Verkhne-Kondinsky (VKD), Sherkalinsky (ShD) and Yarsomovsky (YaD) downfolds; Krasnoleninsky (KA), Surgutsky (SA), Nizhnevartovsky (NA) arches; North-Vartovsk (NVM), North-Surgut (NSM) monoclines.

Discriminant and cluster analyzes were used as problem-solving tools. Object differentiation and clustering were carried out by the parameters that largely determine the production and economic performance [8, 9, 11, 13-15]: a formation depth (N_{form}, m); initial formation pressure (R_{form}, MPa) and temperature (t_{form}, °C); total (N_{total}, m) and net oil stratum thickness (N_n, m); porosity factors (m_g, unit fraction), oil- saturation factors (K_{sat}, fr.unit), permeability factor (K_{perm}, 10^{-3} μm^2), sand factors (K_s, fr.unit), sand-to-shale ratio (K_{ss}); density (ρ_d, kg/m^3), viscosity (μ_v, mPa·s), relative viscosity (μ_r) of the crude oil; formation volume factor (β, fr.unit), gas/oil ratio (G, m^3/t) and oil saturation pressure (R_{sat}, MPa), hydrogen sulfide content (S,%) and paraffin content (P, %) in an oil, local water viscosity (μ_{vws}, mPa·s).

The analysis of object distribution in the canonical discriminant function axes depending on the stratigraphic and tectonic confinement, showed a fairly clear separation. About 70% of the objects are classified correctly by the tectonic confinement and about 75% - by the stratigraphic confinement. In other words, it was the sedimentation conditions that determined the main features of the examined objects. However, about a quarter of the objects are classified incorrectly. The analysis showed that, with shared use of the tectonic-stratigraphic factor, upon which about 25 groups of objects were distinguished, 82% of the objects are correctly classified, i.e. the object-analog search for deposits emerging from exploration firstly, should be carried out among the objects similar to the one sought by the tectonic-stratigraphic confinement.

On the other hand, about 20% of objects are an exception - they are the objects of marginal tectonic element zones: the objects whose formation conditions in different tectonic-stratigraphic elements were similar. This factor must be taken into account when carrying out the identification procedure. Besides, many distinguished groups were similar in storage conditions and geological, physical and physico-chemical stratum properties and fluids saturating them. All that was used as a basis for further "manual regulation" of clusterization for relatively homogeneous object groups based on the tectonic-stratigraphic confinement.

8 object groups were distinguished. The further discriminant analysis showed that about 90% of the objects are classified correctly. The equations of the first two canonical discriminant functions have the following form:

$$y_1 = -981{,}6 + 0{,}015\mathrm{N}_{form} + 0{,}262\mathrm{N}_{total} + 0{,}138\mathrm{N}_n + 1232\mathrm{m}_g - 66{,}9K_{sat} + 0{,}029K_{perm} - \\ -11{,}47K_s - 2{,}77K_{ss} + 4{,}65\mathrm{t}_{form} + 1{,}49\mathrm{R}_{form} - 8{,}74\mu_v + 1160\rho_d + 200{,}7\beta + \\ +19{,}73\mathrm{S} + 1{,}214\mathrm{P} + 11{,}55\mathrm{R}_{sat} + 0{,}26\mathrm{G} + 188{,}7\mu_{vws} + 11{,}12\mu_r; \quad (1)$$

$$y_2 = -977{,}4 + 0{,}026\mathrm{N}_{form} + 0{,}324\mathrm{N}_{form} + 0{,}414\mathrm{N}_n + 1236\mathrm{m}_g - 97{,}9K_{sat} + 0{,}014K_{perm} - \\ -21{,}4K_s - 3{,}265K_{ss} + 4{,}66\mathrm{t}_{form} + 0{,}797R_{form} - 5{,}044\mu_v + 1171\rho_d + 202{,}9\beta + \\ +18{,}59\mathrm{S} + 0{,}674\mathrm{P} + 11{,}27\mathrm{R}_{sat} + 0{,}28\mathrm{G} + 113{,}8\mu_{vws} + 10{,}34\mu_r. \quad (2)$$

The values of these functions in the group centroids, the object percentage in the groups depending on the tectonic-stratigraphic confinement, are given in the table. It is apparent that each group consists of basic objects confined to some basic tectonic-stratigraphic element, and it is adjoined by separate objects confined to other elements, that is extremely important when searching for an object or object-analog groups. So, for example, the first-group objects are, mainly, the Upper Jurassic deposits of the Shaimsky bank and only a tenth of them are the deposits of the same age of the Sherkalinsky downfold (the SD's marginal part). The fifth-group objects, on the contrary, consist mainly of the Middle Jurassic deposits of the Sherkalinsky downfold and only a tenth of them are confined to the Shaimsky bank (as well as the marginal part).

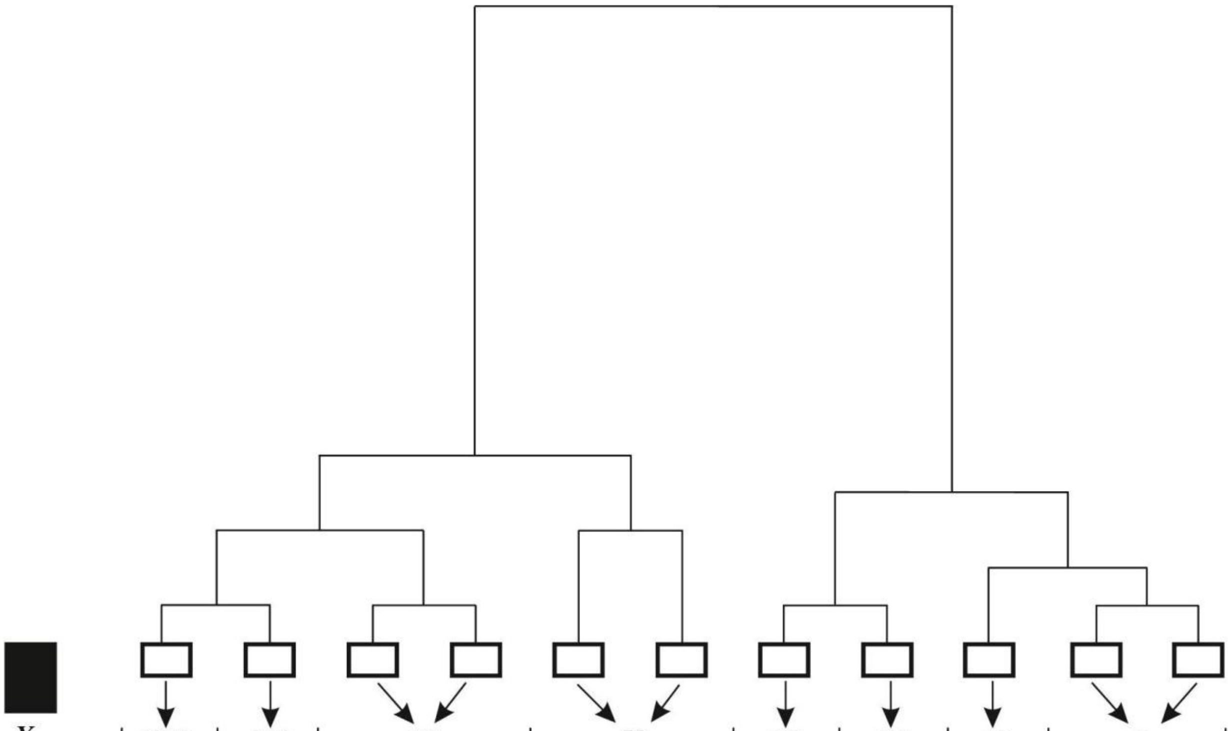
Table 1. Values of canonical discriminant functions in the group centroids and tectonic-stratigraphic confinement of the object groups

Object group	**Function values in centroids y_1/y_2**	**Percentage of objects in a group**	**Tectonic confinement**	**Percentage of objects in the tectonic element**	**Stratigraphic confinement**
1	-5,26/1,27	91	SHB	67	J_3
				33	J_2+ J_3+WC
		9	VKD	100	J_3
2	-4,72/0,20	86	SHB	94	WC
				6	J_2+ J_3+WC
		14	VKD	67	WC
				33	J_3+WC
3	-3,23/0,78	97	SHB	93	J_2
				7	J_2+ J_3
		3	KC	100	J_2+ J_3+WC
4	-3,66/-1,54	79	SHB	100	J_2
		21	VKD	100	J_2
5	-0,13/-2,37	9	SHB	100	J_2
		91	SHD	100	J_2
6	6,52/-0,48	60	NMV	96	J_3
				4	J_2
		12	SA	60	$J_3(Yu_0)$
				40	J_2
		14	YAD	17	$J_3(Yu_0)$
				33	J_3
				50	J_2

Object group	Function values in centroids y_1/y_2	Percentage of objects in a group	Tectonic confinement	Percentage of objects in the tectonic element	Stratigraphic confinement
		14	NA	17	$J_3(Yu_0)$
				33	J_3
				50	J_2
7	5,14/0,12	76	NA	85	J_3
				15	J_2
		11	SA	100	J_3
		4	NSM	100	J_3
		9	NMV	100	$J_3(Yu_0)$
8	12,8/14,4	100	VB	100	J_3

The obtained equations of the canonical discriminant functions (1) and (2), as well as the data given in the table, allow to perform a search not only for an object, but also for an object-analog group, which consists in determination of the tectonic-stratigraphic confinement and taking into account the peculiarities of the object storage conditions and their geological-physical properties. The determination of belonging to an object group of the sought object is determined by the closest proximity to the centroid of any group in the Euclidean space of the first two canonical discriminant functions.

The cluster analysis was carried out in order to check the reliability of the carried-out object identification procedure, as well as to determine the search direction for deposit-analogs in other tectonic-stratigraphic elements and related groups, for expansion of use of advanced technologies. Its results are shown in Fig. 1



X_1	VIII	VII	VI	V	IV	III	II	I
X_2	6	7	5	8	3	4	2	1
X_3	63	100	70	50	72	38	80	61
X_4	100	33	52	100	45	71	87	72

Figure. 1 The dendrogram diagram with use of the intergroup relation method:

X_1 – a cluster number; X_2 – the most representative object group in the cluster; X_3 – a percentage of the number of group objects that are included in the cluster from the total number of the objects included in the cluster; X_4 – a percentage of number of group objects that are included in the cluster from the total number of objects in the group.

The high average values of the percentage of the number of group objects, which are included in the cluster from the total number of objects, included in the cluster (68%) and the number of group objects, included in the cluster from the total number of objects in the groups (70%), indicate the high reliability level of the carried-out identification and it is the basis for expansion of the search for object-analogs with the high efficiency of their development.

Thus, the conducted research allowed to create a methodical base for search of the object-analogs in order to increase the involvement into development degree and to increase the oil reserve recovery level of the deposits of the Jurassic oil and gas bearing complex in Western Siberia.

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