Analogies method application to increase the involvement degree in the deposits development of the Jurassic oil and gas complex in Western Siberia

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Abstract. About 250 objects of the Jurassic and Paleozoic ages of four oil and gas regions of the West Siberian oil and gas province under development were identified and grouped. Eight groups of objects were identified based on the use of data on tectonic-stratigraphic confinement and data on the bedding conditions, geological, physical, and physicochemical properties of the strata and the fluids saturating them. The dominant influence of tectonic-stratigraphic confinement of objects in the formation of the features of the geological structure of deposits and their filtration-capacitive properties is established. The selected groups of objects are ranked according to the degree of similarity and difference in the multidimensional space of parameters that have a collective effect on the process of reserves development. Clusters are presented that make it possible to use the accumulated experience of developing deposits of the Jurassic and Paleozoic ages not only within the considered oil and gas regions but also regions adjacent to them. The results obtained made it possible to create a methodological base for searching not only objects but also groups of similar objects for deposits leaving exploration to engage in active development and increase the degree of oil reserves development in the Jurassic oil and gas complex deposits.

1. Introduction

The current state of the oil industry is characterized by continually decreasing production at significant facilities that have been under development for a long time; insignificant gains of proven reserves; a significant increase in the cost of production due to the deterioration of the structure of oil reserves. In the context of the need to maintain the achieved level of oil production in the country, it is essential to involve in the active development of oil deposits confined to areas with developed infrastructure and characterized not only by a low degree of involvement in the development but also by a low degree of development of oil reserves and a low level of economic profitability of developing these deposits [1-3].

2. Materials and methods

One of the objects of interest for research is the deposits of the upper and middle Jurassic of Western Siberia. This field is characterized by the share of residual recoverable oil reserves of which in the
structure of total current recoverable reserves as a whole is 11.1% and 13.4%, respectively. Deposits are fragmented in the development. Reserves of the Upper Jurassic oil and gas complex are involved in the development process by 76.7%, the selection rate from the currently recoverable reserves is 2.4%, the multiplicity of reserves is 42 years. The degree of involvement of reserves of the Middle Lower Jurassic oil and gas complex is 49%, the selection rate is 1%, and the multiplicity of reserves is more than 200 years.

The degree of development of reserves of these facilities varies within an extensive range, and the expected forecasted final utilization rate of reserves for facilities put into development amounts to about 0.2 with the adopted development systems. However, it reaches 0.4 or more for individual facilities. The reasons for this are, in part, the characteristic of the infrastructure, determined by the distance from the field to the nearest main oil pipeline, the presence of rich deposits of chalk deposits in the geological section. Chalk deposits in the geological section occur at lower depths, have, as a rule, better filtration-capacitive properties and, accordingly, are characterized by a more significant potential with perspective development perspectives than Jurassic sediments.

But the main reason is the low quality of the reservoir and the productivity of the well, a wide variety of deposits according to the geological and physical properties of the reservoirs and fluid. In this connection, there is a need for a differentiated approach when choosing development systems using experience in developing fields for which high technical and economic indicators are obtained, and also determining the need to stimulate their input into development [4–6].

An essential step in increasing the degree of involvement of deposits in development is the use of the analogy method. The analogy method assumes that through the creation of clusters of objects that are closest in geological and physical properties and have been in development for a long time, representative geological and field material has been accumulated, and various generalizations of development experience have been made [7, 8].

It is these clusters that allow for objects that are in the stage of geological exploration, the preparation of the first design documents, as well as in the initial stages of development [9, 10]:
- determine the strategy and set the trend for active development;
- to search for the missing values of parameters, dependencies and other information necessary for the preparation of project documents;
- conduct an examination and determine the reliability of the values of various parameters obtained from the objects using the “templates” of well-studied deposits;
- reduce the degree of risk and uncertainty in solving the problems of exploration and development of objects;
- monitor and reveal the reasons for the decline and search for ways and means to improve development efficiency;
- respond flexibly to changing perceptions of deposits as additional information is obtained, making good use of the empirical estimates obtained from other group objects;
- assess the potential levels of production, oil recovery, the use of methods to increase the degree of development of reserves;
- a priori justify the adoption of the right management decisions to optimize development;
- reduce the time and improve the quality of design work, and accelerate the commissioning of deposits in active development;
- to seek and offer options for transferring assets into the category of profitable, including taking into account energy prices.

For solving the clustering problem, about 250 objects were selected that have been under development for a long time or have been drilled quite tightly for various purposes, confined to the Jurassic (Bazhenov (U0) stratum, Upper Jurassic (J3), Middle Jurassic (J2)), pre-Jurassic (Paleozoic weathering crust (PWC) of the Shaismky deposits (SD) and Verkhnyepursky shafts (VSh); Verkhne kondinsky (VP), Sherkalinsky (ShP) and Yarsomovsky (YP) troughs; Krasnoleninsky (KS), Surgut (SUS), Nizhnevartovsk (NS) vaults; Severo-Vartovskaya (SVM), Severo-Surgutskaya (SSM) monoclines.
The discriminant and cluster analyzes were used as tools for solving the problem. Differentiation of objects and their integration into clusters was carried out according to parameters that largely determine the technical and economic indicators of development [8, 9, 11, 13-15]:

- depth ($H_{sn}$, m);
- initial reservoir pressure ($P_{res}$, MPa) and temperature ($t_{res}$, °C);
- total ($H_{tot}$, m) and effective oil-saturated ($H_{e}$, m) formation thickness;
- coefficients of porosity ($m_{por}$, unit), oil saturation ($K_{sat}$, unit), permeability ($K_{perm}$, 10$^{-3}$ microns$^2$), sandiness ($K_{sand}$, unit), dissection ($K_{dis}$);
- density ($\rho_{oil}$, kg/m$^3$), viscosity ($\mu_{oil}$, MPa · s), relative viscosity ($\mu_{rel}$) of reservoir oil;
- volumetric coefficient ($\beta$, unit), gas content (G, m$^3$/t) and saturation pressure ($P_{sat}$, MPa) of oil, the content of hydrogen sulfide (S, %) and paraffin (P, %) in oil, formation water viscosity ($\mu_{w}$, MPa · s).

3. Results and discussion

An analysis of the distribution of the object in the axes of canonical discriminant functions depending on the stratigraphic and tectonic confinement showed a reasonably clear separation. About 70% of objects are classified correctly by tectonic confinement, and about 75% are classified by stratigraphic confinement. In other words, it was the sedimentation conditions that determined the main features of the objects of study. At the same time, about a quarter of objects are classified incorrectly. The search for similar objects for deposits emerging from exploration must first be sought among objects similar to those sought for by tectonic-stratigraphic confinement.

On the other hand, about 20% of objects are an exception. In essence, these are objects of the marginal zones of tectonic elements, objects whose formation conditions in different tectonic-stratigraphic elements were close. This factor must be taken into account during the identification procedure. Besides, many of the selected groups turned out to be similar in terms of the occurrence and the geological, physical, and physicochemical properties of the strata and the fluids saturating them. All this served as the basis for further “manual adjustment” of the allocation of clusters of relatively homogeneous groups of objects based on tectonic-stratigraphic confinement.

8 groups of objects were allocated. The following 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:

$$y_1 = -981.6 + 0.015H_{str} + 0.262H_{tot} + 0.138H_e + 1232m_{por} - 66.9K_{sat} + 0.029K_{perm} - 11.47K_{sand} - 2.77K_{dis} + 4.65t_{res} + 1.49P_{res} - 8.74\mu_{oil} + 1160\rho_{oil} + 200.7\beta + 19.73S + 1.214P + 11.55K_{sat} + 0.26G + 188.7\mu_{w} + 11.12\mu_{rel};$$

(1)

$$y_2 = -977.4 + 0.026H_{str} + 0.324H_{tot} + 0.414H_e + 1236m_{por} - 97.9K_{sat} + 0.014K_{perm} - 21.4K_{sand} - 3.265K_{dis} + 4.66t_{res} + 0.797P_{res} - 5.044\mu_{oil} + 1171\rho_{oil} + 202.9\beta + 18.59S + 0.674P + 11.27P_{sat} + 0.28G + 113.8\mu_{w} + 10.34\mu_{rel}.$$  

(2)

The values of these functions in the groups' centroids, the percentage of the object in groups depending on the tectonic-stratigraphic confinement, are presented in the table. It can be seen that each group consists of necessary objects confined to some fundamental tectonic-stratigraphic element, and separate objects adjacent to other elements adjoin it, which is extremely necessary to consider when searching for an object or groups of analogous objects. So, for example, the objects of the first group mainly comprise deposits of the Upper Jurassic of the Shaimsky shaft, and only a tenth of them are deposits of similar age of the Sherkalinsky Depression (the marginal part of the ShD).

The objects of the fifth group, on the contrary, consist mainly of deposits of the Middle Jurassic of the Sherkalinsky Depression, and only a tenth of them are confined to the Shaimsky shaft (also the marginal part).
Table 1. Values of canonical discriminant functions in group centroids and tectonic-stratigraphic confinement of groups of objects

| Group of objects | 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 SD                           | 67                  | $J_3$                                       | $J_2+ J_3+ PWC$          |
|                  |                                        | 9 VP                            | 33                  |                                             | $J_3$                    |
| 2                | -4.72/0.20                             | 86 SD                           | 94                  | $PWC$                                       | $J_2+ J_3+ PWC$          |
|                  |                                        | 14 VP                           | 6                   |                                             | $J_3+ PWC$               |
| 3                | -3.23/0.78                             | 97 SD                           | 93                  | $J_2$                                       | $J_2+ J_3$               |
|                  |                                        | 3 KS                            | 7                   |                                             | $J_2+ J_3+ KB$           |
| 4                | -3.66/-1.54                            | 79 SD                           | 100                 | $J_2$                                       |                          |
|                  |                                        | 21 VP                           | 100                 |                                             | $J_2$                    |
| 5                | -0.13/-2.37                            | 9 SD                            | 100                 | $J_2$                                       |                          |
|                  |                                        | 91 ShP                          | 100                 |                                             |                          |
|                  |                                        | 4 SVM                           | 96                  | $J_3$                                       |                          |
|                  |                                        | 4 SUS                           | 12                 |                                             | $J_3(U_0)$               |
|                  |                                        | 40                              |                     |                                             | $J_3$                    |
| 6                | 6.52/-0.48                             | 14 YP                           | 33                  | $J_3$                                       | $J_3(U_0)$               |
|                  |                                        | 17                              |                     |                                             |                          |
|                  |                                        | 17                              |                     |                                             |                          |
|                  |                                        | 14 NS                           | 33                  | $J_3$                                       |                          |
|                  |                                        | 50                              |                     |                                             |                          |
|                  |                                        | 14                              |                     |                                             |                          |
|                  |                                        | 50                              |                     |                                             |                          |
| 7                | 5.14/0.12                              | 76 NS                           | 85                  | $J_3$                                       |                          |
|                  |                                        | 15                              |                     |                                             |                          |
|                  |                                        | 11 SUS                          | 100                 | $J_3$                                       |                          |
|                  |                                        | 100                             |                     |                                             |                          |
| 8                | 12.8/14.4                              | 100 VSh                         | 100                 | $J_3$                                       |                          |

The obtained equations of the canonical discriminant functions (1) and (2), as well as the data presented in the table, allow the search procedure to be performed not only for an object but also for a group of analogous objects. This procedure consists in determining the tectonic-stratigraphic confinement and taking into account the peculiarities of the occurrence conditions of objects and their geological and physical properties. The definition of belonging to the group of objects of the desired object is determined by the closest proximity to the centroid of any group in the Euclidean space of the
first two canonical discriminant functions.
To verify the reliability of the procedure for identifying objects, as well as to determine the
direction of the search for analog deposits in other tectonic-stratigraphic elements and adjacent groups.
For expanding the use of advanced technologies, a cluster analysis was carried out, the results of
which are presented in the figure.

**Figure 1.** The dendrogram scheme using the intergroup communication method: X₁ – cluster number;
X₂ – the most representative group of objects in the cluster; X₃ – a percentage of the number of group
objects included in the cluster of the total number of objects included in the cluster; X₄ – a percentage
of the number of group objects included in the cluster of the total number of objects in the group.

There are high average values of the percentage of the number of group objects included in the
cluster of the total number of objects included in the cluster (68%) and the number of group objects
included in the cluster of the total number of objects in the group (70%). These values indicate a high
degree of reliability of the identification and are the basis for expanding the search for analogous
objects with high efficiency of their development.

4. Conclusion
The study allowed, based on clustering, creating a methodological base for the search for analogous
objects to increase the degree of involvement in the development and increase the degree of oil
reserves development of the Jurassic oil and gas complex of Western Siberia.

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