The role and significance of the stratigraphic factor in the identification of oil fields

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Abstract. Based on the procedure for identifying oil deposits in Western Siberia, the following was established: oil deposits confined to various large stratigraphic elements have their own distinctive features of the geological structure, which must be taken into account when designing their development; the stratigraphic factor does not give an unambiguous assessment of the belonging of oil deposits to a particular group and requires taking into account the tectonic confinement; in the absence of representative information about oil deposits at an early stage of their exploration, the factor of stratigraphic confinement can be used to determine the development strategy for new deposits.

1. Introduction

Effective management of any process is based on the necessary and sufficient amount of information to justify and make certain management decisions aimed at achieving the target function.

The specificity of the oil industry is, on the one hand, the insufficient density of information about deposits and the processes occurring in them, and on the other, its excessive volume, and often the information is contradictory, which creates significant problems when making decisions [1–6].

All this requires a systematic approach when creating, for example, the geological and technological foundations of development management, which would allow not only increasing the density, but also filtering out redundant, insignificant information about deposits [7–10].

Differentiation, grouping and identification of objects underlie the creation of such a system and make it possible to effectively solve the assigned tasks.

2. Materials and methods

The West Siberian petroleum basin (WSPB) was selected as a mega-object. The choice is due to the presence of a powerful resource base, objective and subjective conditions for increasing the efficiency of its use. The province is characterized by significant:

- geological reserves of oil;
- residual recoverable reserves for deposits that have been in development for a long time and that are becoming difficult to recover;
- reserves classified as non-recoverable [11–12].
According to forecasts, WSPB will determine the main share of production in the country for many years to come.

Within the province, in order to generalize the development experience and solve the set range of tasks, objects were identified:
- which are in development for a long time;
- drilled quite tightly by wells for various purposes;
- sufficiently fully studied based on the results of geophysical, laboratory, hydrodynamic and field studies of wells.

Taking into account the formulated requirements, more than 500 of WSPB facilities were selected. Stratigraphically, the objects are confined to two levels of oil and gas content. Lower (pre-Jurassic) is associated with deposits found in the rocks of the transitional complex, folded basement base. The upper level of oil and gas content (Jurassic-Cenozoic) is formed by rocks of the sedimentary cover accumulated in rifts, over-rift troughs, depressions.

In conditions of a significant number of grouping objects and parameters characterizing them, methods were used based on logical and mathematical analyzes: factorial, cluster and discriminant.

Since grouping is the basis on which the experience of exploration and development of deposits is systematized with the aim of using it in the future to improve the efficiency of development management, it is important to choose the right parameters. These parameters should:
- largely determine the efficiency of the process;
- used in the preparation of project documents at various stages of development;
- to be determined reliably enough already at the stage of geological exploration and drawing up the first project documents;
- determined by the same methods and methods [13–16].

Based on this, the following parameters were selected:
- $H_{\text{form}}$, formation depth, m;
- $H_{\text{tot}}$, total thickness of the formation, m;
- $H_{\text{e}}$, effective oil-saturated formation thickness, m;
- $m_g$, coefficient of porosity, unit fraction;
- $K_o$, oil saturation coefficient, unit fraction;
- $K_{\text{perm}}$, permeability coefficient, $10^{-3} \mu m^2$;
- $K_{\text{net}}$, net-to-gross ratio, unit fraction;
- $K_c$, coefficient of compartmentalization;
- $t_{\text{res}}$, initial reservoir temperature, ºC;
- $P_{\text{res}}$, initial reservoir pressure, MPa;
- $\mu_o$, oil viscosity in reservoir conditions, mPa∙s;
- $\rho_o$, oil density in reservoir conditions, kg/m$^3$;
- $\beta$, volumetric coefficient of oil;
- S, hydrogen sulfide content in oil, %;
- P, wax content in oil, %;
- $P_{\text{sat}}$, pressure of oil saturation with gas, MPa;
- G, gas content in reservoir oil, m$^3$/t;
- $\mu_w$, viscosity of water in reservoir conditions, mPa∙s;
- $\mu_{\text{rel}}$, relative viscosity of oil, unit fraction.

3. Results and Discussion

The use of the method of principal components and analysis of the results obtained for all the selected objects and parameters showed that of the nineteen principal components, the first four ($Z_1$–$Z_4$) account for 63.5% of the total variance of the parameters, which makes it possible to reduce the multidimensional space to four-dimensional and even to two-dimensional one, since the first two components account for 43% of the total variance, which is quite sufficient taking into account the errors in determining the initial parameters.
Each of the first four main components is meaningful. The first characterizes the conditions of occurrence and the viscous properties of reservoir fluids, since the main contribution to it is made by: the depth of occurrence, initial reservoir pressure and temperature (30%); oil viscosity and relative viscosity, formation water viscosity, oil saturation pressure and gas content of formation oil (39%). The second reflects the composition of the reservoir oil, including the density of the reservoir oil, the volumetric ratio, the content of sulfur and waxes in the oil (50%). The third one to the greatest extent reflects the thickness properties of oil-and-gas-water-saturated reservoir rocks, since about 40% of the contribution to it is made by the total thickness of the reservoir and the net-to-gross ratio. The fourth characterizes the heterogeneity of the oil-saturated volume of deposits. About 56% of the total dispersion of the parameters in the component is provided by the net pay thickness and the compartmentalization factor. The parameters reflecting the reservoir filtration properties are evenly distributed over the first three components. So, the contribution of porosity coefficients to the first component is 9%, oil saturation in the second is 8%, permeability in the third is 7%. There is no single capacitive filtration component, which must be borne in mind when carrying out further analysis.

Consideration and analysis of the distribution of objects in the axes of the first four main components, taking into account their stratigraphic confinement to the Lower Cretaceous system, and the Jurassic system and the Paleozoic shows the following (see Figures 1–3):

- a fairly stable tendency towards division of objects based on stratigraphic confinement.
- Significant differentiation of objects in certain areas of the factor plane is explained by a specific set of parameters in the conditions of various systems, as well as by the influence of tectonic confinement;
- the presence of zones of unambiguous presence of objects of a particular system (zones I and III in Figures 1–3), which allows, in the conditions of objects confined to these zones, using with a high degree of reliability the principles of development formed for the corresponding objects that have been in development.

The reason for this is the proximity of objects of different systems in terms of geological and physical properties of layers, especially near the border of separation of these systems.

**Figure 1.** Distribution of objects in the axes of the main components Z₁–Z₂: □ are the objects of the Jurassic and Paleozoic; ○ are the objects of the Lower Cretaceous; I) zone of concentration of objects of the Jurassic and Paleozoic; III) zone of concentration of objects of the Lower Cretaceous; II and IV) zone of joint concentration of objects of the Lower Cretaceous, Jurassic and Paleozoic.
Figure 2. Distribution of objects in the axes of the main components $Z_1$–$Z_3$: □ are the objects of the Jurassic and Paleozoic; ○ are the Lower Cretaceous objects

Figure 3. Distribution of objects in the axes of the main components $Z_1$–$Z_4$: □ are the objects of the Jurassic and Paleozoic; ○ are the Lower Cretaceous; I) zone of concentration of objects of the Jurassic and Paleozoic; II) zone of joint concentration of objects of the Lower Cretaceous, Jurassic and Paleozoic; III) zone of concentration of objects of the Lower Cretaceous

To determine the strategy for the development of new objects, it is necessary to calculate the values of the principal components using the obtained empirical formulas, in which the values of the parameters are normalized according to the following formulas:

$$Z_1 = 0.14H_{form} + 0.02H_{tot} + 0.03H_e - 0.13m_g - 0.02K_s - 0.10K_{perm} - 0.01K_{ntg} + 0.03K_c + 0.12t_{res} + 0.14P_{res} - 0.13\mu_o - 0.09\rho_o + 0.11\beta - 0.02S - 0.08P + +0.13P_{sat} + 0.13G - 0.08\mu_w - 0.11\mu_{rel};$$

$$Z_2 = 0.18H_{form} - 0.01H_{tot} - 0.07H_e - 0.06m_g - 0.17K_s - 0.06K_{perm} - 0.02K_{ntg} + 0.06K_c + 0.11t_{res} + 0.17P_{res} + 0.06\mu_o + 0.17\rho_o - 0.23\beta + 0.26S - 0.18P - 0.11P_{sat} - 0.19G - 0.08\mu_w + 0.09\mu_{rel};$$

$$Z_3 = -0.02H_{form} - 0.29H_{tot} - 0.37H_e - 0.12m_g - 0.16K_s - 0.16K_{perm} - 0.22K_{ntg} - 0.35K_c - 0.04t_{res} - 0.03P_{res} - 0.02\mu_o - 0.01\rho_o + 0.02\beta - 0.06S + 0.06P + 0.01P_{sat} + 0.001G + 0.03\mu_w - 0.03\mu_{rel};$$
\[ Z_4 = 0.12H_{\text{form}} - 0.32H_{\text{tot}} - 0.02H_e + 0.15m_g + 0.03K_s + 0.21K_{\text{perm}} + 0.34K_{\text{ntg}} - 0.16K_c \\
- 0.09t_{\text{res}} + 0.13p_{\text{res}} + 0.19\mu_o - 0.02\rho_o + 0.15\beta + 0.08S - 0.23P + 0.18p_{\text{sat}} + 0.15G \\
- 0.004\mu_w + 0.20\mu_{\text{rel}}. \]

and determine their position on the factor planes. If an object falls into the zone of uncertainty in the coordinates \( Z_1 - Z_2, Z_1 - Z_4 \), it is necessary to determine which of the two groups of objects it is closer to. To obtain an answer to this question, as well as to reduce the size of the zone of uncertainty, a discriminant analysis was carried out. The canonical discriminant function is obtained in the following form:

\[ y_1 = -740.6 + 0.16H_{\text{form}} + 0.24H_{\text{tot}} + 1.19H_e + 835.2m_g - 3.92K_s - 0.03K_{\text{perm}} \\
- 24.1K_{\text{ntg}} + 0.66K_c + 1.84t_{\text{res}} - 9.7p_{\text{res}} - 27.7\mu_o + 746.0\rho_o + 242.3\beta + 9.02S \\
+ 4.12P + 3.37p_{\text{sat}} - 0.20G + 299.2\mu_w + 15.5\mu_{\text{rel}}. \]

The distribution of the values of this function and the values of the centroids are shown in Figure 4.

Evidently, the number of objects that have fallen into the uncertainty zone has significantly decreased (down to 14% of the total number, while in the PCA on the uncertainty zone falls more than 70%), and by calculating the CDA for a specific object falling into the uncertainty zone, one can easily determine which group of objects it is closer to by comparing the distances to the centroids of the groups. In a situation where the objects of one system are closer to the centroid of the other, there is a reason to consider the issue of combining productive horizons into one production facility with, for example, a low density of oil reserves for each reservoir;

- the presence of rather significant areas of uncertainty and the ratio of the number of objects in them to the total number of objects of study, which requires further identification and grouping procedures already separately by stratigraphic systems and taking into account territorial and tectonic factors.

4. Conclusion

Based on the studies carried out, it was established that:

- oil deposits, confined to various large stratigraphic elements, have their own distinctive features of the geological structure, which must be taken into account when designing a development;
- the stratigraphic factor does not give an unambiguous assessment of the belonging of oil deposits to a particular group and requires taking into account the tectonic confinement;
– in the absence of representative information about oil deposits at an early stage of their exploration, the factor of stratigraphic confinement can be used to determine the development strategy for new deposits.

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