Forecasting the use of enhanced oil recovery methods in oilfields of Bashkortostan

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Abstract. Today oil and gas complex in Bashkortostan is characterized by a deterioration in the quality of raw material base, which is associated with a significant degree of highly productive fields. It is a long-term operation, resource increment due to the discovery of fields unconventional oil, which are confined to low-permeable and weakly thick reservoirs oil deposits with extensive underwater gas and waterfowl zones. At the current stage of unconventional oil development of Bashkortostan oilfields, the urgent tasks are to study the experience of their development; identify peculiarities of the influence of geological and technological factors on the development efficiency of productive layers reserves; geological and commercial substantiation of various methods for enhanced oil recovery. The classification of development objects is based on the methods of mathematical statistics. Recommendations to improve the impact effectiveness on residual and unconventional oil reserves are based on the criteria-based analysis of enhanced oil recovery. The paper describes characteristics of reservoir systems and results of object grouping for oilfields development in Bashkortostan. Taking into account the established criteria for effective use of enhanced oil recovery and geological and field conditions of selected groups of objects with similar characteristics, there are some recommendations to increase the efficiency of oil recovery with targeted formation effects technologies.

1. Introduction

The analysis of more than 100 oilfields in Bashkortostan (686 oil deposits) showed that there is a variety of deposits types, reservoir characteristics, and physical and chemical properties of oil, gas and water. Oil deposits are located in a wide range - from the Middle Devonian to the Lower Carboniferous, for which a significant amount of information was obtained on the geological and technological conditions of their operation.

The current state of oilfield development requires a detailed geological field analysis of dynamics for main technological indicators of exploitation objects under conditions of significant variation for geological and physical characteristics of reservoir systems and technological parameters of impact
systems. Such analysis purposes the selection of development objects with similar geological and physical parameters of reservoir systems [1-4].

In this situation, when a natural decline in oil production is not compensated by a corresponding increase in geological reserves due to the discovery of new fields, an alternative way to maintain oil production at the level achieved is the large-scale introduction of advanced methods of enhanced oil recovery into the practice of oil production [5-10].

2. Research Methods

Any method to improve the efficiency of oil recovery process is not universal for "all cases". The method effectiveness largely depends on geological, physical and oilfield conditions in which it is used [11–14].

In the conditions of objects consideration, the operation to identify (group) acquires special significance, that is, the selection of relatively homogeneous groups of objects.

Grouping helps to solve some of the most important tasks of oil and gas geology and development. It gives the way to assess the similarities and differences of productive layers in identifying development objects, justify development systems and methods for enhanced oil recovery, establish measures for control and regulation, etc. [1, 3].

When selecting homogeneous groups in conditions of a significant number of objects of study and parameters characterizing them, the process of effective and reliable grouping becomes possible only with the use of a method based on logical and mathematical analysis.

Currently, there are widely used methods from the theory of pattern recognition — factor analysis, principal component method, discriminant analysis, cluster analysis, etc. The choice of one method or another is determined by problem statement and method's advantages.

When solving a similar series of problems in geology and development of oil and gas fields, the method of principal components and discriminant analysis finds the greatest application.

The choice of principal component method to solve the problem of grouping objects is due to the following reasons:
- grouping of research objects is carried out according to generalized, independent indicators (main components) and is more objective than grouping according to separate initial parameters;
- grouping is made depending not only on general peculiarities of a deposit geological structure, but also on combinations of parameters, which to a greater extent affect the efficiency of development process;
- research objects are described by a number of factors (main components), significantly smaller than the number of initially taken parameters, that is, multidimensional space is compressed, within which grouping is extremely difficult;
- main components adequately reflect the original parameter and, at the same time, contain more information than individual parameters;
- studying the factors structure (main components) helps you to test existing and put forward new hypotheses about the causes of the relation between the parameters, give a causal interpretation of results, and develop and adopt a scientifically based control effect that contributes to the efficiency of oil development processes;
- main components are not mutually correlated, which greatly simplifies the task to construct various models of development process according to the obtained main components.

The paper does not describe in detail the essence of principal component method, but many researchers' works describe this method [1-4].

3. Results and Discussion

The results analysis of principal component method solution showed that out of 15 main components, the first four account for 76.3% of the total dispersion of parameters, that is, when selecting relatively homogeneous groups of objects, it is enough to consider them in the space of only these components. Each of four main components is informative, amenable to semantic interpretation, reflecting a
particular property characterizing occurrence conditions, reservoir-filtration, physicochemical properties of layers and fluids saturating them, current state of development of these objects.

The first component reflects the properties of reservoirs and fluids, since sandiness ratio (15.9%), oil recovery ratio (14.7%), effective oil-saturated thickness (13.9%) and oil density (13.3%) add up to 57.6% of total dispersion of parameters in this component.

The second component is characterized by 56.9% technological parameters and conditions of occurrence of operational facilities: average annual water content of extracted products is 17.2%; inventory utilization rate - 16.5%; reservoir temperature - 11.7%; porosity - 11.5%.

The third component at 55.7% reflects physicochemical properties of oil - viscosity (19.6%), sulfur content in reservoir oil (18.2%), and type of reservoir (17.9%).

In the fourth main component, the greatest contribution is made by paraffin content in oil reservoir (18.1%) and reservoir temperature (14.8%).

As you can see, each component reflects geological and technological peculiarities of object development at one or another hierarchical level.

The geometric representation of research objects in coordinate axes of main components $Z_1 - Z_2$, $Z_3 - Z_4$, $Z_5 - Z_6$ helped to distinguish six groups of objects. When selecting groups and drawing boundaries, the condition was fulfilled under which each group of objects must occupy a certain and limited zone in the space of the main components.

Qualitative characteristics and peculiarities of selected groups of objects according to the initial parameters require the calculation of their values for “average” hypothetical deposits. Each of the selected groups of objects has its own peculiarities.

The first group included 130 objects. The group of objects is represented by terrigenous reservoirs of lower Carboniferous deposits and is characterized by the highest values - effective oil saturated thickness of layers, coefficients of porosity, oil saturation, permeability and oil recovery, tar content in reservoir oil and asphaltene; high rates - watering and use of reserves; the smallest indicator of the density of oil.

The second group consisted of 99 objects. The group of objects is represented by terrigenous reservoirs of Devonian deposits with small thickness of productive formations, the highest values of oil density, paraffin content in it and water production of produced products, low values of oil viscosity. Here you can also distinguish two subgroups, in which, by geological field data, different oil recovery factors are identified: 0.48 for large fields and 0.28 for medium and small fields. In the first subgroup, the maximum oil recovery factor was achieved (on average 0.5). For smaller fields, oil recovery factor reached more than 0.37. In group II, a high level of watering was achieved - about 80%.

One hundred and twenty-two objects of the third group are represented by carbonate reservoirs and characterized by the highest values of total thickness of productive sediments, viscosity of reservoir oil and sulfur content, utilization rate of reserves and water content of products produced; the lowest values of porosity coefficient, oil saturation permeability, content of paraffins and asphaltene-resinous compounds, reservoir temperature.

In the fourth group entered 131 objects. The group is also represented by carbonate reservoirs, where the smallest values of oil recovery and use of reserves.

In general, group III-VI include deposits with carbonate reservoirs. Many deposits are developed in natural modes. A low oil recovery factor is planned for all fields of these groups - an average of 0.23, actual ratio is much lower, no more than 0.07–0.08.

Currently, oil deposits in Bashkortostan are being developed quite rationally. However, the main disadvantage of the implementation of field development systems is the use of only one method of oil extraction - flooding.

A differentiated approach to the choice of enhanced oil recovery methods for each group of fields can increase the final oil recovery factor, and the effect is most productive with combined methods.

Based on the criteria-based analysis of the effectiveness of oil-jet device and comparing them with geological and physical characteristics and development characteristics of considered groups of fields,
we can draw preliminary conclusions about the use of enhanced oil recovery methods in oil fields in Bashkortostan.

**Group I** (productive strata are terrigenous reservoirs of Devonian age, low-viscosity oil, fairly homogeneous reservoir). It is advisable to evaluate the effectiveness of the oil recovery devices to increase the rate of displacement - water-gas effect, injection of alternating CO₂ fringes and water, oil displacement by highly concentrated fringes of surfactants. Predicted increase in enhanced oil recovery 4–5 points;

**Group II** (terrigenous reservoirs of coal age with a high degree of macro-inhomogeneity; moderately viscous oil) is promising for enhanced oil recovery, aimed at increasing the rate of sweep, using silicate-alkaline solutions, polymer systems, and vibrational exposure. In addition, a highly developed system to maintain reservoir pressure at facilities of groups I and II makes the use of biometric methods on them relevant. Forecast of growth of oil recovery factor in the group of 3-4 points;

**Group III** (carbonate, mainly fractured collector of Famennian age) - objects to apply hydrodynamic, wave and regulating technologies. Predicted growth of oil recovery factor for a group of 5-7 points;

**Group IV** (pore-type carbonate reservoirs of Kashiro-Podilsky age, medium viscosity oil) - conditions of objects are favorable for the application of water-gas action and forcing out oil with highly concentrated surfactant rims. Predicted growth of oil recovery factor for a group of 4-5 points;

**Group V** (carbonate pore-cavernous reservoirs of Bashkir and Tournaisian age) - use of water-gas effect is recommended at the sites. Predicted growth of oil recovery factor for a group of 5-7 points;

**Group VI** (reef-bearing carbonate reservoir of Sakmaro-Artinsky age with a high oil-bearing floor and a high degree of anisotropy in reservoir properties) - objects are promising for the application of gas technologies (hydrocarbon gases and alternation of hydrocarbon gas lines and BFLH). Forecast growth in oil recovery factor for a group of 7-8 points.

Thus, a wide application of the proposed methods to influence the objects of the selected groups in relation to geological peculiarities of Bashkortostan deposits, and the choice of optimal water flooding system will further extract 5.3-8.1% of initial geological reserves of Bashkortostan’s oil.

4. Conclusion

Based on a detailed geological field analysis of basic indicators dynamics for exploitation in Bashkortostan fields in conditions of significant variation of geological and physical characteristics of reservoir systems and technological parameters of systems affecting development objects using the method of principal components, identification (grouping) of development objects has been carried out on complex of geological field data, which helped to identify six homogeneous object groups with similar characteristics of reservoir systems of objects group and applied development systems.

Typical objects in the selected groups were identified, a criterial analysis of effective use of enhanced oil recovery was performed, and a set of recommendations was proposed to improve the efficiency of producing unconventional oil and residual oil reserves and an additional increase in oil recovery factor was predicted during the implementation of the proposed measures. The increase in oil recovery factor from the implementation of recommendations at operational facilities in the Republic of Belarus will be on average 5-8 points.

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