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THE EFFECT OF THE INTENSITY OF THE IMPACT ON THE PRODUCTION OF OIL RESERVES DURING IN-CIRCUIT FLOODING UNDER VARIOUS CONDITIONS TECTONIC AND STRATIGRAPHIC ELEMENTS

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A B S T R A C T

The article is devoted to a comprehensive study of the processes of oil extraction during in-circuit flooding using the example of various tectonic and stratigraphic elements of carbonate reservoir deposits in the Volga-Ural oil and gas province. As a criterion for the efficiency of the production of residual oil reserves, the possibility of introducing into the processes of analysis and interpretation of geological and field data an impact factor on deposits, defined as the product of the current density of the well grid and the ratio of producing wells to injection wells, is considered. The choice of this coefficient is due to both the possibility of interpreting data and making appropriate design decisions in conditions of uncertainty, and its high informativeness, taking into account the specifics of the placement of wells within the studied area of the field. Additionally, in order to improve scientific and methodological approaches to evaluating the effectiveness of the current development system using computer modeling systems, it is recommended to take into account the values of productivity coefficients obtained at the time of stabilization of the optimal flow rate of wells after cleaning the bottomhole formation zone and determined by multidimensional regression models for certain tectonic zones, stratigraphic elements or, in general, objects. Conclusions are drawn about the existence of a close correlation between the oil recovery coefficient and various technological indicators, in particular with the proposed coefficients of impact on deposits, which allows us to apply the results obtained in solving various fundamental problems of oil field development.

Keywords: intra-contour flooding; tectonic and stratigraphic elements; well grid density; oil recovery coefficient; deposits of the Volga-Ural oil and gas region; production of residual oil reserves.

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Introduction

The wide variety of oil deposits in terms of parameters reflecting the geological structure of the deposits and the properties of reservoir fluids is the reason for the use of various flooding systems of productive formations [1-3]. At the same time, the most important task is to choose a system that would allow achieving maximum compliance of the flooding system with the features of the geological structure of deposits [4-8]. The results of generalizing the experience of developing fields in oil and gas producing regions of the world show that reservoir flooding has different efficiencies [9-12]. Along with an increase in technical and economic indicators, compared with the development in natural modes, there is a decrease in these indicators up to the absence or receipt of a negative effect [13-17]. A significant amount of work has been devoted to the issue of effective drilling [18-20], however, updating knowledge, systematizing it and solving new issues related to changing the structure of oil reserves require additional research.

The results of these studies allow, in conditions of deposits that have been in operation for a long time, to determine the need for: drilling, transferring and disconnecting production and injection wells, using a transit fund [21-24]; using cyclic, non-stationary flooding in order to change the direction of filtration flows [25-27]; regulating selection and injection, choosing a flooding system after determining stagnant zones and zones of decompression [28-31]. And this is far from a complete list of issues to be solved on the basis of generalizing the experience of developing deposits using flooding [32-34].

Materials and methods

In this regard, the study of the oil recovery process in the deposits of the Volga-Ural region in carbonate reservoirs, which have been in development for a long time, characterized by high values of residual oil reserves separately by tectonic and stratigraphic elements, was carried out.

The values of the final oil recovery coefficient were calculated and used for each deposit (ORC_i^1) when developing

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deposits using in-circuit flooding. Values ORC_1^1 they were calculated at the time of the analysis using the A. V. Kopytov method, which allows for the tangent of the angle of inclination of a straight line in coordinates $(\sum Q \cdot t) - t$, where $\sum Q$ – accumulated oil production; t – the time since the beginning of the development of the object. The choice of the method was determined by its wide use and high reliability of the forecast, noted by various researchers. It is known that the most significant parameters affecting oil recovery are the parameters of the impact on oil deposits during their development using flooding – the density of the well grid (*DWG*) [35, 36] and the ratio of the number of producing wells (N_1) to the injection (N_2) [37, 38]. That is why, at the first stage, the influence of these parameters on ORC_1^1. The parameter of the intensity of exposure when using in-circuit flooding was presented in the following form:

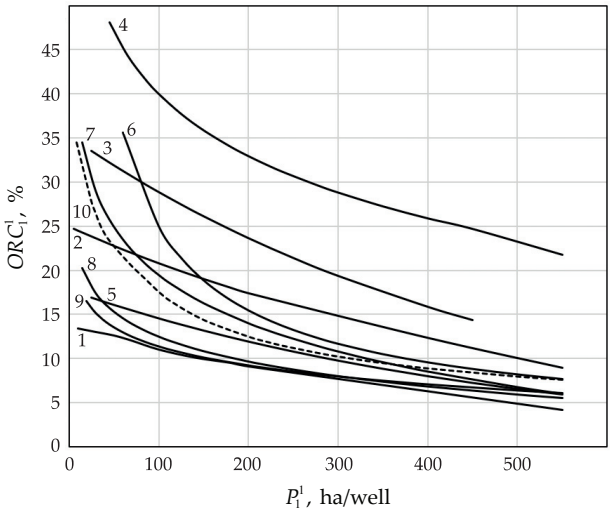
$$P_1^1 = DWG\frac{N_1}{N_2} \quad (1)$$

Figure 1 and table 1 show the dependencies, regression equations, and values of the determination coefficients ($R2$) according to groups of objects divided according to the tectonic-stratigraphic principle, characterizing the relationship of the final oil recovery coefficient from the intensity parameter of the impact during the development of deposits in the regime of oil displacement by water.

It can be seen that each group of objects has its own dependencies (obtained by iterating through functions of various types and selecting by the largest values R^2), which indicate a difference in the degree and nature of the influence of the density of the well grid and the ratio of the number of producing wells to injection wells on the degree of reserve production. There is a significant spread of curves (see fig. 1) relative to the general dependence plotted for all objects. High values of the coefficients of determination (see table 1 – equations (2) – (11)) they allow using the obtained dependencies in practice to solve a wide range of development tasks.

It should be noted that the dependence constructed for all objects is characterized by the lowest coefficient of determination, with the exception of objects of groups 2 and 4. Its value (R^2=0.255) 72.6% lower than the average for the objects of the selected groups $(R_1^2 = 0.440)$ and it speaks about the need for a differentiated approach to making management decisions.

Figure 1 also shows that the degree of development of deposits in the most fractured limestones of the Famensk tier of the South Tatar arch is 2 or more times higher than in the conditions of objects of other groups. Also relatively high values ORC_1^1 the limestones of the Blagoveshchensk depression, which have the greatest fracturing of reservoir rocks among the deposits of the Tournaisian tier, are characterized. The greater degree of development of the Famensk and Tournaisian deposits in comparison with objects, for example, the Kashirsky horizon, can also be explained by the lower viscosity of the extracted oil.



The cipher of curves is the number of a group of deposits
1, 2, 3 – the Tournaisian tier, respectively, of the Birskaya saddle, the South Tatar arch, the Blagoveshchenskaya depression;
4 – the Famensk tier of the South Tatar arch;
5, 9, 6 – Vereysky and Kashirsky horizons, Bashkir tier, respectively, of the Bashkir arch;
7, 8 – Kashirsky horizon of the Birskaya saddle and the Upper Kama depression, respectively;
10 – in –general for all objects

Fig. 1. Dependence of the final oil recovery coefficient on the parameter of the intensity of exposure during in-circuit flooding

Table 1

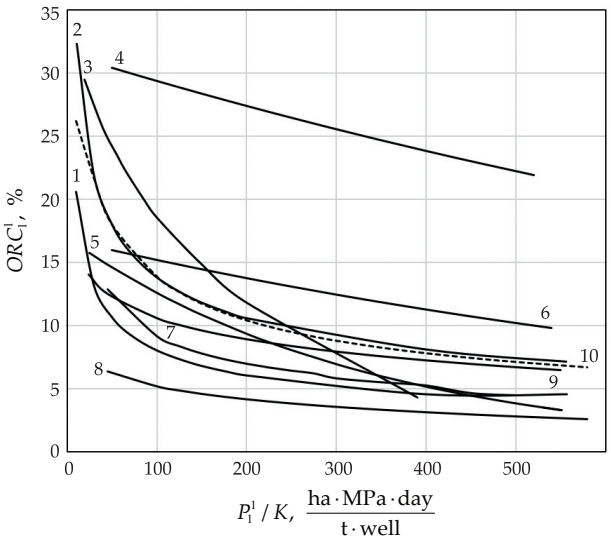
Dependencies that best describe the impact P_1^1 on ORC_1^1

Group of objects	Type of dependency	R^2	Equation number
1	$ORC_1^1 = 97.5577(P_1^1)^{-0.4849}$	0.047	(2)
2	$ORC_1^1 = e^{2.7543-0.0034P_1^1}$	0.516	(3)
3	$ORC_1^1 = 29.16\ e^{-0.007P_1^1}$	0.776	(4)
4	$ORC_1^1 = -4.2765\ln(P_1^1) + 31.4356$	0.228	(5)
5	$ORC_1^1 = 17.775e^{-0.002P_1^1}$	0.638	(6)
6	$ORC_1^1 = 613.11P_1^{1-0.695}$	0.560	(7)
7	$ORC_1^1 = -0.03P_1^1 + 15.2667$	0.317	(8)
8	$ORC_1^1 = -4.271\ln(P_1^1) + 31.187$	0.361	(9)
9	$ORC_1^1 = e^{2.7802-0.0031P_1^1}$	0.542	(10)
10	$ORC_1^1 = 169.59P_1^{1-0.493}$	0.255	(11)

Results

It is known that the productivity coefficient (K) It is a parameter that comprehensively reflects the geological, physical and physico-chemical properties of formations and fluids saturating them and largely determines the degree of production of oil reserves, all other things being equal, field development [39-41].

The analysis showed that within the selected groups of objects, except *DWG* and relationships N_1/N_2 by the amount of N_1/N_2 it also has a significant impact K, defined in the period from the moment the wells reach the maximum optimal flow rate until its decrease by 10-15 %, i.e. during the period when it most closely reflects the real properties of the reservoir at the point of opening by the well [42-47]. Therefore, at the second stage, the combined effect of the exposure intensi-



The curve cipher is similar to the cipher in figure 1

Fig. 2. Dependence of the final oil recovery coefficient on the ratio of the exposure intensity parameter to the productivity coefficient during in-circuit flooding

Table 1

Dependencies that best describe the impact P_1^1 / K on ORC_1^1

Group of objects	Type of dependency	R^2	Equation number
1	$ORC_1^1 = -4.9363\ln(P_1^1 / K) + 33.9074$	0.324	(12)
2	$ORC_1^1 = 81.395(P_1^1 / K)^{-0.385}$	0.379	(13)
3	$ORC_1^1 = 214.0318(P_1^1 / K)^{-0.5718}$	0.679	(14)
4	$ORC_1^1 = 29.678e^{\left(-7\cdot10^{-4}(P_1^1/K)\right)}$	0.373	(15)
5	$ORC_1^1 = 16.974e^{-0.003(P_1^1/K)}$	0.696	(16)
6	$ORC_1^1 = 123.17(P_1^1 / K)^{-0.329}$	0.700	(17)
7	$ORC_1^1 = 44.156(P_1^1 / K)^{-0.319}$	0.467	(18)
8	$ORC_1^1 = -1.483\ln(P_1^1 / K) + 12.007$	0.354	(19)
9	$ORC_1^1 = e^{-2.1784-0.0041(P_1^1/K)}$	0.595	(20)
10	$ORC_1^1 = 94.639(P_1^1 / K)^{-0.417}$	0.432	(21)

ty parameter and the productivity coefficient on the final oil recovery coefficient was studied. When using the values of the product of the ratio of the number of producing wells to injection wells, the density of the well grid and productivity, as can be seen from table 2 (dependencies (12) – (21)), the values of the determination coefficients increase compared to dependencies (2) – (11) obtained without taking into account (*K*) both by groups of objects and in general for all fields. So, on average, for the selected groups of objects, the coefficient of determination increased from 0.432 to 0.507, and in general for all objects – from 0.255 to 0.432, i.e. when solving problems aimed at improving the efficiency of mining deposits using flooding of productive horizons, it is necessary to operate with the value of the specific parameter of the intensity of the impact, reduced to the coefficient of productivity.

The dependencies shown in figure 2 show that, on average, for values $(P_1^1 / K) > 100$ ha·MPa·day/t·well. the influence of the density of the well grid and the ratio of the number of producing wells to injection wells on the production of reserves is decreasing, however, the individual boundary in the conditions of the selected groups of objects has its own values, which indicates the need for a differentiated approach when making certain decisions when optimizing well grids and choosing flooding systems.

Conclusions

Based on the conducted research, the following conclusions are made:

1. In the conditions of groups of objects allocated according to the tectonic-stratigraphic principle, a close correlation has been established between the final oil recovery coefficient and the productivity coefficient determined in the period from the moment the wells reach the maximum optimal flow rate until its decrease by 15%, as well as the density of the well grid and the ratio of the number of producing wells to injection wells during development deposits using in-circuit flooding;
2. It is proposed to effectively solve the problems of analysis, design, monitoring and management of the development of deposits to use the proposed impact intensity parameter, which in combination includes the density of the well grid, the ratio of the number of producing and injection wells and largely determines the degree of production of oil reserves;
3. It was found that in different ranges of changes in the values, the impact intensity parameter has different effects on the oil recovery coefficient, and the degree and nature of the influence of this parameter, as well as productivity on the degree of reserve production in conditions of different groups of objects, are different and indicate the need for a differentiated approach in the implementation of the results obtained;
4. The necessity of joint use of the productivity coefficient and the impact intensity parameter in predicting the final oil recovery coefficient is shown.

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