

# Assessment of the Need to Stimulate the Development of Hard-to-Recover Reserves in Carbonate Reservoirs

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**Abstract.** The subject of research is the process of oil recovery from the Kashira and Podolsky formations of the Volga-Ural Basin. The sites have some specific features including low degree of recovery, difficulties in applying secondary and tertiary methods to increase oil recovery factor and high production costs. Significant resources of these hard-to-recover oil reserves can be considered as a large pool for hydrocarbon extraction. It is important to assess the need to stimulate the development of these fields. The key issue to address herein is the estimation of recoverable oil reserves and the timing of development in primary production. Summing up the experience concerned with the development of separate oil deposits being in operation for a long time, a rapid assessment method for these indicators at the geologic exploration stage is proposed. Further technical and economic calculations make it possible to assess the necessity to stimulate the development of sites similar to those studied against their geological properties. It is proposed to solve these problems in context based on different groups of homogeneous sites not only in the Volga-Ural province but in neighboring oil and gas regions as well.

## 1. Relevance

Tax regulation as to stimulate resource expansion requires the awareness of mining potential of the deposits. Today this has much more to do with low-productive sites whose commissioning and active development is hampered by economic viability constraints [1-8]. One of such sites is oil deposits in carbonate reservoirs of the Volga-Ural oil and gas province where significant hydrocarbon reserves (about 30%) are concentrated.

The features of these facilities are:

- low reservoir properties;
- high geological heterogeneity against various parameters;
- closed deposits near oil-water contact surface;
- fissuring and cavern porosity of different degrees;
- wide ranges of changes in geological, physical and chemical values of zones and saturating fluids;
- lenticular structure of reservoirs.

Under these conditions, the development of deposits is often accompanied by:

- intensive pressure reduction if no water is injected into the reservoir;
- low initial oil rates and resulting substantial decrease within a fairly small period of time due to both formation pressure depletion and rapid water inrush through lithological windows or through the existing cracks;



- frequent lack of waterflooding effect resulting in an increase in production rates.

However, in some cases, when the foci for water flooding is selected properly, it is possible to stabilize oil production and increase the oil recovery factor (ORF) to 0.3-0.4, which is 2-3 times higher than that obtained in primary production.

## 2. Objective

All this requires a differentiated assessment to manage the development of such complex and contradictory sites, when decision-making risks are high, and the use of traditional development methods makes it possible to extract oil at a level to reach economic viability limit. At the same time, establishing the system of preferences that include various tax incentives like subventions, state investments in infrastructure projects, etc., is of great importance to encourage oil companies to use this significant oil production reserve.

Given a significant number of uncertainties [9-11] around the development of such sites, it is important to know what minimum oil production will be provided using traditional development technologies. Moreover, it is necessary to carry out such assessment, as noted in [12-17], before drafting the first design documents, even better prior to acquiring licenses by subsoil users.

## 3. Methods and Materials

In this statement the problem was solved for the Kashira and Podolsky carbonate reservoirs confined to the Birsk Saddle and the Bashkir Arch. The primary production was mainly carried out at these sites and water injection was organized just in a few relatively high-productive formations. The results of waterflooding are quite contradictory. There can or can be no visible effect at all and even a negative impact on the oil production can be observed.

The sites using factor analysis were split up into three groups, within which they are much alike in terms of geological and field characteristics.

## 4. Results

Within each group, in non-injected zones, the change in oil production within the nominally allocated drainage zones was studied due to the lack of interference between the wells, up to 250-300 meters between them. Besides, the study was conducted as to how the parameters that can be determined at the exploration stage affect the change in well flow rates.

In practice, the productivity values are often used to predict production rates and their changes in time. However, the "instability" and the change in this important integral index in time make its application difficult and sometimes problematic in terms of forecasting recoverable oil reserves ( $Q_{rec}$ ).

The summary and analysis of field geological material for the selected groups made it possible to obtain the following empirical equations for estimating the recoverable reserves in the primary production and given a well grid density of 9 hectares per well and over:

- for the first group

$$Q_{rec} = N \left( 0.91 H_E / \sqrt{n} \sum_{i=1}^{t_{total}} 0.141 - 498 \ln t_i \right); \quad (1)$$

- for the second group

$$Q_{rec} = N \left[ \left( 0.24 \sqrt{H_E m_g} / \sqrt{H_{oi}} - 1.6 \sqrt{\mu_o} / \sqrt[3]{H_E / n} + 0.93 \sqrt{m_g} / \sqrt[3]{H_E / n} \right) \times \sum_{i=1}^{t_{total}} 0.124 - 447 \ln t_i \right]; \quad (2)$$

- for the third group

$$Q_{rec} = N \left[ \left( 3.56\sqrt{m_g} - 0.5\mu_o^2 \sqrt{m_g/H_E G} \right) \sum_{i=1}^{t_{total}} 0.127 - 421t_i \right], \quad (3)$$

where  $t_i$  is the elapsed time from the start of well operation, year;;

$t_{total}$  – total life of wells to the limit of economic viability, year;

$H_E$  – average value of the effective oil-saturated portion of the formation, m;

$H_{oi}$  – average thickness of oil-saturated interlayers, m;

$m_g$  – average porosity;

$n$  – average number of oil-saturated interlayers;

$\mu_o$  – viscosity of reservoir oil, mPas;

$G$  – gas/oil ratio, cubic meter per tonne;

$N$  – number of estimated production wells.

According to the actual data  $t_{total}$  is determined from equations with reliable accuracy:

- for the first group

$$t_{total} = 498 e^{-0.141Q_{E\ min}/0.91H_E/\sqrt{n}}, \quad (4)$$

- for the second group

$$t_{total} = 447 e^{-0.124Q_{E\ min}/\left(\frac{0.24\sqrt{H_E m_g}}{\sqrt{H_{oi}}} - 1.6\sqrt{\mu_o}/^3\sqrt{H_E/n} + 0.93\sqrt{m_g}/^3\sqrt{H_E/n}\right)}, \quad (5)$$

- for the third group

$$t_{total} = 421 e^{-0.127Q_{E\ min}/\left(3.56\sqrt{m_g} - 0.5\mu_o^2 \sqrt{m_g/H_E G}\right)}, \quad (6)$$

where  $Q_{E\ min}$  – minimal economic rate, tonne per year.

## 5. Conclusions

The conducted studies made it possible to obtain an express method for estimating recoverable oil reserves and service life using parameters that can be determined at the stage of geological exploration with a reasonable accuracy. The method enables to identify the need to stimulate the development of hard-to-recover reserves.

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