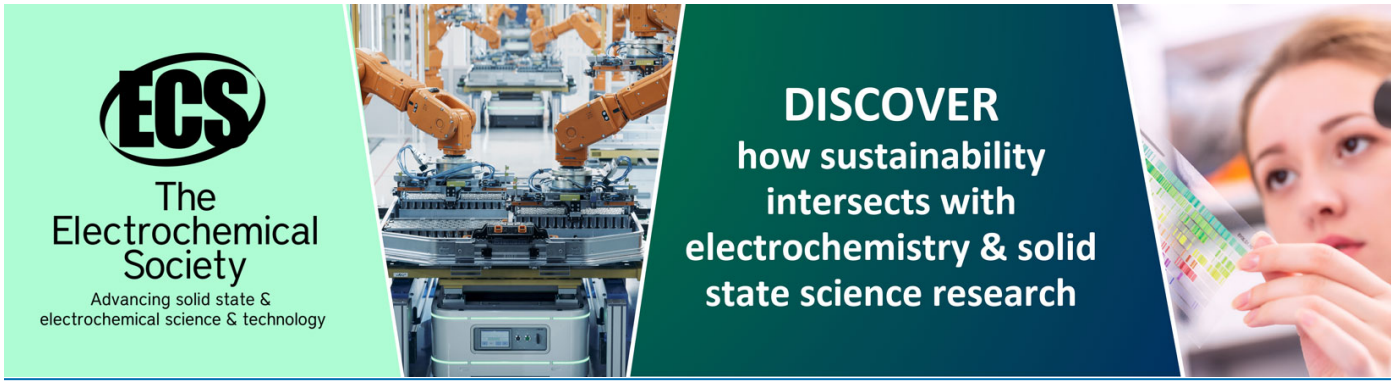
# Rationale for the production of hard-to-recover deposits in carbonate reservoirs





# Rationale for the production of hard-to-recover deposits in carbonate reservoirs

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**Abstract**. Based on the study towards oil recovery by deposits in the carbonate reservoirs of the Volga-Ural oil and gas province of Kashiro-Podolsk age, an express method is proposed for estimating recoverable oil reserves and service life through the parameters that can be determined at the stage of geological exploration with a sufficient degree of precision. As a follow-up to a series of feasibility studies, the method provides a rationale for the need to stimulate the production of similar deposits with hard-to-recover reserves.

## 1. Introduction

For the purpose of tax regulation, it is important to know the potential productivity of deposits with a view to enhancing the resource base. This primarily concerns low-productive objects currently tempered by economic profitability [1–4]. One of such objects is oil deposits in the carbonate reservoirs of the Volga-Ural oil and gas province, where significant (about 30%) hydrocarbon reserves are concentrated.

These objects feature:

- low reservoir properties;
- high geological heterogeneity in various parameters;
- deposits sealed near the water-oil surface;
- fractures and cavern porosity;
- wide ranges of geological-physical and physico-chemical values of formations and saturating fluids;
- lenticular structure of reservoir rocks.

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

- intensive reduction in reservoir pressure in the absence of water injection;
- initial low oil production rates and subsequent significant decrease over a rather insignificant period of time, both due to a drop in reservoir pressure and a rapid breakthrough of water either through lithological windows or existing cracks;
- almost no effect of water injection followed by increased production rates in production wells.

However, in some cases, with the right choice of foci for water injection, 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 when the deposits are developed under natural conditions [5–7].

All this requires a differentiated approach to managing the development of such complex and

controversial objects, when the risks of making certain decisions are high, and the use of traditional production methods allows oil production around the limits of economic profitability. Moreover, the creation of preferences, including tax benefits (or subventions as their successive versions, or government investments into infrastructure projects), is of great importance to encourage oil companies to explore this significant oil production reserve.

In the context of a significant number of uncertainties related to the development of such objects, it is important to be aware of that minimum oil production to be ensured through conventional production technologies. Moreover, it is necessary to ensure this assessment prior to the preparation of the first design documents, even better prior to the acquisition of licenses by the subsoil user.

## 2. Materials and methods

In this formulation, the problem was solved for the conditions of deposits in the carbonate reservoirs of the Kashir-Podolsk age, confined to the Birsk saddle and the Bashkir peak. The objects were explored mainly in natural conditions, and only in some relatively highly productive areas water was pumped into the reservoir. The results of waterflooding were contradictory. Along with the effect achieved, it was completely absent, and there was even a negative impact on the production of reserves.

By means of factor analysis, the objects were divided into three groups, within which their geological and commercial characteristics were similar.

For each group the sites yet produced with no water injection were selected to study the changing oil production in the wells within conditionally allocated drainage zones due to the absence of interference between the wells, up to distances of 250-300 meters between them. Similar conclusions were drawn in [8–11]. The effect of parameters on a change in the flow rate of wells was also explored. The parameters can be determined at the stage of geological exploration.

In practice, the values of productivity coefficients are often used to predict flow rates and their changes over time. However, the “instability” and change in this important integral indicator over time make its use difficult and sometimes problematic in terms of forecasting recoverable oil reserves ($Q_{rec}$).

## 3. Results and discussion

The generalization and analysis of geological production material for the selected groups provided the following empirical equations for estimating recoverable reserves when deposits are developed in a natural mode and with a well grid density of 9 ha/well or over:

- for objects in 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 objects in the second group

$$Q_{rec} = N\left[\left(0{,}24\sqrt{H_E m_P}/\sqrt{H_L} - 1{,}6\sqrt{\mu_H}/\sqrt[3]{H_E/n} + 0{,}93\sqrt{m_P}/\sqrt[3]{H_E/n}\right)\mathrm{x}\sum_{i=1}^{t_{total}} 0{,}124 - 447\ln t_i\right]; \quad (2)$$

- for objects in the third group

$$Q_{rec} = N\left[\left(3{,}56\sqrt{m_P} - 0{,}5\mu_O^2\sqrt{m_P/H_E G}\right)\sum_{i=1}^{t_{total}} 0{,}127 - 421 t_i\right], \quad (3)$$

where $t_i$ is the time from the start of well operations, year; $t_{total}$ is the total life of the wells to the limit of economic profitability, year; $H_E$ is the average value of the effective oil-saturated thickness, m; $H_L$ is the average thickness of oil-saturated layers, m; $m_P$ is the average value of the porosity; $n$

is the average number of oil-saturated layers; $\mu_O$ is the viscosity of reservoir oil, mPa.s; $G$ is gas content in reservoir oil, $m^3/t$; $N$ is the number of estimated production wells.

According to the actual data, $t_{total}$ is determined from the equations with a sufficient degree of precision:

- for objects in the first group

$$t_{total} = 498\, e^{-0,141 Q_{\text{H}\,min}/0,91 H_E/\sqrt{n}}; \quad (4)$$

- for objects in the second group

$$t_{total} = 447\, e^{-0,124 Q_{\text{H}\,min}/\left(\frac{0,24\sqrt{H_E m_P}}{\sqrt{H_L}} - 1,6\sqrt{\mu_O}/\sqrt[3]{H_E/n} + 0,93\sqrt{m_P}/\sqrt[3]{H_E/n}\right)}; \quad (5)$$

- for objects in the third group

$$t_{total} = 421\, e^{-0,127 Q_{\text{H}\,min}/\left(3,56\sqrt{m_P} - 0,5\mu_O^2\sqrt{m_P/\text{H}_E G}\right)}, \quad (6)$$

where $Q_{H\,min}$ is minimum profitable flow rate, t/year.

## 4. Conclusion

The studies resulted in an express method for estimating recoverable oil reserves and service life through the parameters that can be determined at the stage of geological exploration with a sufficient degree of precision. The method provided the rationale for the need to stimulate the production of hard-to-recover deposits.

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