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

V Sh Mukhametshin

Ufa State Petroleum Technological University, Branch of the University in the City of Oktyabrsky, 54a, Devonskaya St., Oktyabrsky, Republic of Bashkortostan, 452607, Russia

E-mail: vsh@of.ugntu.ru

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

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

(1)

- for objects in the second group

$$Q_{rec} = N \left(0.24 \sqrt{H_E m_p} / \sqrt{H_L} - 1.6 \sqrt{\mu_p} / \sqrt{H_E / n} + 0.93 \sqrt{m_p} / \sqrt{H_E / n} \right) x \sum_{i=1}^{t_{total}} 0.124 - 447 \ln t_i \right);$$

(2)

- for objects in the third group

$$Q_{rec} = N \left[3.56 \sqrt{m_p} - 0.5 \mu_p / \sqrt{H_E G} \right] \sum_{i=1}^{t_{total}} 0.127 - 421 t_i \right].$$

(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; \( \mu_0 \) 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, \( t_{\text{total}} \) is determined from the equations with a sufficient degree of precision:

- for objects in the first group

\[
t_{\text{total}} = 498 e^{-0.141 Q_{\text{H min}}/0.91 H_E/\sqrt{n}},
\]

- for objects in the second group

\[
t_{\text{total}} = 447 e^{-0.124 Q_{\text{H min}}/(0.024 H_E^{mp}/\sqrt{H_E}-1.6 \sqrt{\mu_0}/\sqrt{H_E/n}+0.93 \sqrt{mp}/\sqrt{H_E/n})},
\]

- for objects in the third group

\[
t_{\text{total}} = 421 e^{-0.127 Q_{\text{H min}}/(3.56 \sqrt{mp}-0.5 \mu_0^2 \sqrt{mp}/H_E G)},
\]

where \( Q_{\text{H min}} \) 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.

References

[1] Economides J M and Nolte K I 2000 Reservoir stimulation (West Sussex, England: John Wiley and Sons) 856 p

[2] Mukhametshin V V and Kuleshova L S 2019 Justification of Low-Productive Oil Deposits Flooding Systems in the Conditions of Limited Information Amount SOCAR Proceedings 2 16–22 DOI: 10.5510/OGP20190200384

[3] Johansen A, Eik-Andresen P and Ekambaram A 2014 Stakeholder benefit assessment – Project success through management of stakeholders Procedia – Social and Behavioral Sciences 119 581-590

[4] Khokhlov V I, Galimov Sh S, Devyatkova S G, Kotenev Yu A, Sultanov Sh Kh and Mukhametshin V Sh 2019 Justification of impact and planning of technology efficiency on the basis of limy-emulsion formulation in low-permeability highly-rugged reservoirs of Tyumen deposits IOP Conference Series: Earth and Environmental Science 378(1) 012114 DOI: 10.1088/1755-1315/378/1/012114

[5] Behrenbruch P 2000 Waterflood Residual Oil Saturation – The Buffalo Field, Timor Sea SPE Asia Pacific Oil and Gas Conference and Exhibition (Brisbane, Australia, 16-18 October 2000) pp 1-15 DOI: 10.2118/64282-MS

[6] Kuleshova L S, Kadyrov R R, Mukhametshin V V and Akhmetov R T 2019 Auxiliary equipment for downhole fittings of injection wells and water supply lines used to improve their performance in winter IOP Conference Series: Materials Science and Engineering 560(1) 012071 DOI: 10.1088/1757-899X/560/1/012071

[7] Watson R W and Boukadi F H 1990 Effect of surface area and pore-size distribution on oil recovery at breakthrough, on oil recovery at infinite water-oil ratio, on residual oil saturation
4

and on wettability (Paper SCA 9007) Proceedings of the Society of Core Analysts, Fourth Annual Technical Conference (Dallas, Texas, USA, 1990)

[8] Kuleshova L S and Mukhametshin V V 2019 Estimation of the wells hydrodynamic drag level based on wells geophysical survey data Atlantis Highlights in Material Sciences and Technology 1 727–729 DOI: 10.2991/isees-19.2019.145

[9] Mukhametshin V V and Kuleshova L S 2019 Prediction of production well flow rates using survey data IOP Conference Series: Earth and Environmental Science 378(1) 012116 DOI: 10.1088/1755-1315/378/1/012116

[10] Kuleshova L S, Kadyrov R R, Mukhametshin V V and Safiullina A R 2019 Design changes of injection and supply wellhead fittings operating in winter conditions IOP Conference Series: Materials Science and Engineering 560(1) 012072 DOI: 10.1088/1757-899X/560/1/012072

[11] Stenkin A V, Kotenev Yu A, Mukhametshin V Sh and Sultanov Sh Kh 2019 Use of low-mineralized water for displacing oil from clay productive field formations IOP Conference Series: Materials Science and Engineering 560(1) 012202 DOI: 10.1088/1757-899X/560/1/012202