Developing the efficiency of low-productivity oil deposits via internal flooding

N N Soloviev¹, V Sh Mukhametshin² and A R Safiullina²

¹ LLC Gazprom VNIIGAZ, Staraya Basmannaya St., 20, b. 8, Moscow, Russian Federation
² Ufa State Petroleum Technological University, Branch of the University in the City of Oktyabrsky, 54a, Devonskaya St., Oktyabrsky, Republic of Bashkortostan, 452607, Russian Federation

E-mail: vsh@of.ugntu.ru

Abstract. The article studies geological and technological parameters’ impact on degree and nature of production wells. The wells influence the water injection into wells in the carbonate reservoirs of the Tournaisian stage of the Birsk saddle. The study presents an algorithm with substantiating technological solutions to increase the efficiency of developing low-productive deposits via internal flooding. It also considers the development of facilities for hard-to-recover reserves with high production costs and low profitability. This is made in order to use the resource base of the Volga-Ural oil and gas provinces more efficiently.

1. Introduction
To meet the country's needs for liquid hydrocarbons one should make a more complete and efficient use of the resource base of deposits with hard-to-recover reserves in the carbonate reservoirs of the Volga-Ural oil and gas province (VUOGP).

This resource base consists of two large groups:
- the first group includes relatively high-productive facilities of large and medium deposits developed for a long time with a high degree of development of recoverable reserves;
- the second group includes low-productivity small deposits not developed enough and drilled with a rare grid of wells. There is poorly organized water, and the degree of oil recovery from the bowels is several percent of geological reserves.

Scientists and industrialists are more interested in the second group due to the following reasons:
- significant total oil reserves and a low degree of involvement in development;
- location in a relatively positive climatic zone;
- confinement to territories with developed social and industrial infrastructures;
- provision of enterprises with human resources of high professional training;
- the ability to use wells drilled at other development sites, and the use of the created material base.

Thus, these objects are considered to have good perspective for good oil production in the region.

However, it is necessary to find ways and means of reducing costs of extracted products and ensure product profitability [1–6].
2. Materials and methods
One of such objects is massive deposits in the carbonate reservoirs of the Tourmaisian stage of the Birsk saddle and objects similar to them in terms of geological and production characteristics, confined to other VUOGP tectonic elements.

Lithologically, the oil deposits are composed of gray and light gray biomorphic, biomorphic-detrital, clot-clumpy and pelitomorphic-clot limestones with insignificant interlayers of dolomites. In the structure of reservoir rocks, intergranular (granular) porosity plays a decisive role, similar to the rocks of the terrigenous series by the type of structure of the void space. Fracturing has a limited distribution, increasing the connectivity of voids in cavernous-porous areas. There are 3 structural types of collectors distinguished: 1 - pore; 2 - fissure-pore; 3 - fissure-cavernous-pore.

The first type of reservoir dominates sharply, determining the productivity of the deposits. The main reservoir rocks are clot-lumpy and detrital-biomorphic limestones, characterized by the highest porosity and permeability. Fracturing of limestone is expressed by the following average values of parameters: fracture porosity 0.02–0.2%, fracture permeability - up to 10 • 10^(-11) m² and bulk density of cracks - 20-50 m⁻¹.

The reservoir rocks are characterized by the following average values of parameters: porosity - 0.113; oil saturation - 0.80; permeability - 5.2 • 10^(-3) microns²; effective oil saturated thickness - 3.82 m; the thickness of oil saturated layers is 1 m.

According to the geological heterogeneity (estimated by the values of the heterogeneity parameter, which is the product of the standard deviation, variation, entropy and relative entropy of a particular geological parameter), objects can be characterized as relatively homogeneous in effective oil-saturated thickness, oil-saturated interlayers and porosity. The share of reservoir rocks in the total thickness of the reservoir with the values of dissection coefficient 3.8 is 0.21. The operating modes of the deposits are characterized as pressure-elastic with weak backwater of bottom and marginal waters. The sealing of deposits near the surface of the oil-water contact due to the deposition of secondary calcite and viscous bitumen in a fractured-porous medium, the strong dissection of productive formations by dense impermeable differences and the lenticular structure of reservoir rocks. Thus, there appears a sharp drop in reservoir pressure and well flow rates in the absence of produced water in individual sections of the deposits indicating an elastic mode of operation. In view of this, in the absence of measures to maintain reservoir pressure, the operating mode of the reservoir subsequently switches to the dissolved gas mode.

The reservoir oils of the objects are viscous, have high values of density and viscosity at low saturation pressures and gas factors. Formation water is highly saline; the density is 1120–1180 kg/m³. Calcium and sodium chlorides predominate in the salt composition. The first salinity reaches 83%. The concentration of calcium salts is slightly higher than magnesium salts. According to the classification of V.A.Sulin, they belong to the calcium chloride type, the chloride group, and the sodium water subgroup. The formula used for it is Palmer S₃S₂A⁻².

Drilling of objects was conducted extremely unevenly and for a long time. At the same time, the analysis of the objects, the density of the well grid varies over a fairly wide range - from 16 to 240 ha per well in the external oil circuit. In some more productive areas, the density of the well network in the drilling zone reached 10 ha per well, when placing the wells on a uniform triangular and quadrangular grid, with a distance between the wells of 400 m.

Oil production is mainly conducted using natural energy of the reservoir - both due to elastic forces, and the weak backwater of plantar and marginal waters. The final oil recovery in areas developed under natural conditions is determined by the productivity and density of the well network and varies from 3.0 to 35.0% (oil recovery was predicted using field-statistical methods). Oil production rates decrease over time due to both a decrease in reservoir pressure and watering of produced products, and in some areas the reservoir pressure has decreased below the saturation pressure and a dissolved gas regime takes place [7].

In some areas with the most favorable geological characteristics, areal flooding was organized to make development process faster and increase the final oil recovery [8].
3. Results and Discussion
Water flooding analysis proves that along with an increase in the production rates of production wells surrounding injection wells, there is a lack of growth in production rates. In this case, the injection efficiency is determined by the geological structure of the formation and the distances between production and injection wells.

Improving the efficiency of object development considers their further drilling and areal and focal flooding organization in areas with favorable geological characteristics [9]. It is important to know the distance between the wells in areas with different geological characteristics. The producing wells in these places will respond to the injection of water into the injection.

The solution seems to be the use of oil displacement mode in the development of such facilities since the analysis shows, it will double the final oil recovery in a short period of time, as well as introduce similar facilities into development, the oil production of which is currently not profitable.

In this regard, there are areas with focal water flooding identified, and the change in the production rate of wells injection was studied. In this case it is very important to reduce extraneous “noise”. Wells were excluded from the sample, in which there was any effect on the formation or bottomhole zone, which could be affected by injection from two or more injection wells, etc.

Wells were identified that responded to water injection and did not respond. Geological-field analysis showed that the likelihood of a response is largely determined by geological structure of the objects and a distance between the wells (F). Moreover, with water injection pressures less than 0.7 rock pressure, there is no increase of a reaction with an increase in injection volumes. It was revealed that with an increase in effective oil-saturated thicknesses (OSih), average thicknesses of oil-saturated interlayers (OSi), the number of oil-saturated interlayers (n), as well as average weighted porosity values (m) in both production and injection wells, the probability, time, and intensity of response are growing. The response between the wells has a significant effect on response rates. It is important to note that about 75% of the wells experienced injection effects at following values: OSih > 6,5 m; OSi > 2,5 m; m > 0,15;

F < 400 m. The maximum values of the response time and intensity are confined to these intervals.

On the other hand, in areas with low values of parameters characterizing the geological and physical properties of the formation, a decrease in the distance between production and injection wells mitigates the negative impact of natural factors. This fact suggests the need for a differentiated approach to determining the value of F.

Nonparametric informational criteria revealed the best possible dependence [7, 8]

\[ K = \frac{OS_{ih}^2 \cdot m^2}{F} \]

where \( K \) is a complex parameter characterizing the geological and technological features of flooding as an element of the reservoir; \( OS_{ih}, m \) is the average value of the effective oil-saturated thickness and porosity between production and injection wells.

Based on this, K values were established for the probability of response:
- 0% – (\( K^0 < 1,4 \cdot 10^{-4} \) m);
- 25% – (\( K^{25} = 2,4 \cdot 10^{-4} \) m);
- 50% – (\( K^{50} = 3,4 \cdot 10^{-4} \) m);
- 75% – (\( K^{75} = 4,4 \cdot 10^{-4} \) m);
- 100% – (\( K^{100} > 5,4 \cdot 10^{-4} \) m),

due to the task, this allow scientifically substantiating the choice of wells in the drilled sections for transferring them to injection, transferring wells from other horizons to modify the object development process, planning the grid of wells and the waterflooding system at the developing facilities. In this case, it is necessary to ensure that F is less than \( F^{100} = 1850 \ OS_{ih}^2 m^2 \). If this is not possible for economic and technological reasons, you can use the other options presented.
4. Conclusion

The study and the results obtained suggest the following:
- carry out the substantiation of technological solutions to increase the efficiency of the development of low-productive deposits using internal flooding;
- consider putting into development facilities of hard-to-recover reserves with high production costs and low profitability in order use the resource base of the Volga-Ural oil and gas province more efficiently.

References

[1] Yakupov R F, Mukhametshin V Sh, Khakimzyanov I N and Trofimov V E 2019 Optimization of reserve production from water oil zones of D3ps horizon of Shkapovskoy oil field by means of horizontal wells Georesursy 21(3) 55-61. DOI: 10.18599/grs.2019.3.55-61
[2] 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 (MEACS 2018 – International Conference on Mechanical Engineering, Automation and Control Systems) 560(1) 012071 1-6 DOI: 10.1088/1757-899X/560/1/012071
[3] Mukhametshin V V, and Kuleshova L S 2020 On uncertainty level reduction in managing waterflooding of the deposits with hard to extract reserves Bulletin of the Tomsk Polytechnic University. Geo Assets Engineering 331(5) 140–146 DOI 10.18799/24131830/2020/5/2644
[4] 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 (MEACS 2018 – International Conference on Mechanical Engineering, Automation and Control Systems) 560(1) 012202 1-5 DOI: 10.1088/1757-899X/560/1/012202
[5] Valeev A S, Kotenev Yu A, Mukhametshin V Sh and Sultanov Sh Kh Substantiation of the recovery of residual oil from low-productive and heterogeneous formations in Western Siberia by improving the waterflood system using gas and water-gas impacts IOP Conference Series: Materials Science and Engineering (MEACS 2018 – International Conference on Mechanical Engineering, Automation and Control Systems) 560(1) pp 1–6 DOI: 10.1088/1757-899X/560/1/012204
[6] Andreev V E, Dubinskiy G S, Fedorov K M and Andreev A V 2014 Design and implementation of technology using acid "retarder" for carbonate reservoir treatment Problems of Gathering, Treatment and Transportation of oil and oil products 2 5-14
[7] 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
[8] Akhmetov R T, Kuleshova L S and Mukhametshin V V 2019 Application of the Brooks-Corey model in the conditions of lower cretaceous deposits in terrigenous reservoirs of Western Siberia IOP Conference Series: Materials Science and Engineering (MEACS 2018 – International Conference on Mechanical Engineering, Automation and Control Systems) 560(1) 012004 1-4 DOI: 10.1088/1757-899X/560/1/012004
[9] 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 (MEACS 2018 – International Conference on Mechanical Engineering, Automation and Control Systems) 560(1) 012072 1-5 DOI: 10.1088/1757-899X/560/1/012072