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GEOLOGY

Oil Recovery from Lenticular Reservoirs

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The coefficient of oil recovery (COR) average in our country shows a steady decreasing tendency in recent years. One of the reasons is deterioration of the resource base structure due to increase in the share of hardly recoverable oil reserves in the oil fields put into operation. Many newly discovered fields are initially characterized as hardly recoverable oil reserves.

Oil pools with lenticular reservoirs make up a fairly large share in hardly recoverable reserves. Such pools are found in all oil-producing regions [1–3].

A low degree of oil recovery in lenticular reservoirs is a generally recognized fact. For instance, the COR value is estimated at 10% for lenticular reservoirs in the technical–economic assessment of COR in the Arkutun–Dagin oil field (Project Sakhalin-1). It is evident that we can hardly agree with such a low efficiency of oil reserve development.

Unfortunately, the problem of increasing the COR of lenticular oil reservoirs is discussed in a small number of publications [3, 4]. The analysis of these and other works shows that they solve, but not in full measure, the problem of efficient development of lenticular reservoirs.

Each lens is traditionally regarded as an isolated object. It is assumed that if one producing well penetrates a lens, then the amount of recoverable oil is determined by its elasticity margin. If two or more wells penetrate the lens, the oil can be recovered by its flooding with water.

In any case, the external boundary of the lens is considered impermeable. Such a concept is subjective because it is related to the traditional practice of establishing quality and subquality oil reservoirs. The latter group usually includes reservoirs with a permeability factor equal to or less than 1 mD.

We questioned the validity of the concept mentioned above and initiated a series of investigations, the results of which are described below.

We decided not to exclude subquality reservoirs from consideration and to study their possible influence on indicators of the development of oil pools with lenticular reservoirs. For distinctness, an isolated lens is regarded as a circular body with a diameter of 500 m and bed permeability of 500 mD. The lens is surrounded by a massif of subquality reservoirs with a permeability of 1 mD. Subquality reservoirs are rectangular bodies 10 × 20 km in size. The scheme of the computed model is illustrated in Fig. 1.

The bed thickness and the porosity ratio are similar everywhere and equal to 20 m and 0.2, respectively. We also took into consideration the following input data: oil saturation coefficient in the lens and subquality reservoirs was 0.8 and 0.5, respectively; initial formation pressure, 250 atm; pressure of oil saturation with gas, 150 atm; viscosity of oil and water viscosity under formation conditions, 1 and 0.5 cP, respectively; gas/oil ratio (GOR), 172 m^3/t; and formation volume factor of oil, 1.4.

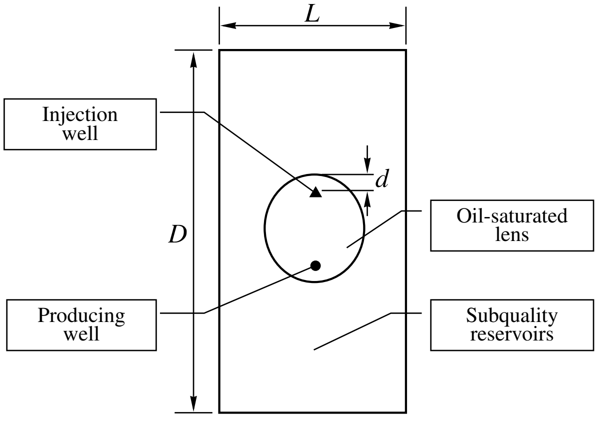

Fig. 1. Analytical scheme of water flooding of oil-saturated lens. $L = 10$ km, $D = 20$ km.

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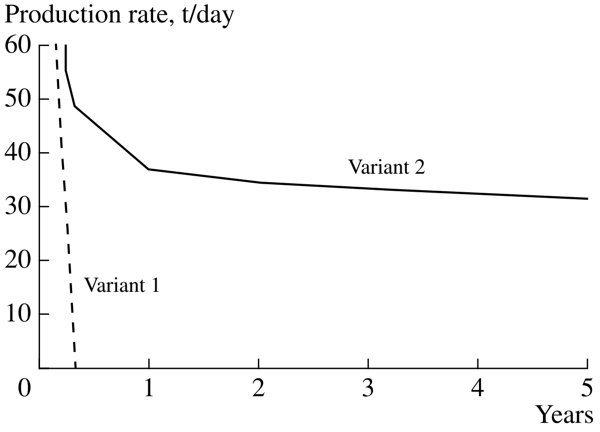

Fig. 2. The time dependence of oil production rate in variants 1 and 2 of the depletion regime.

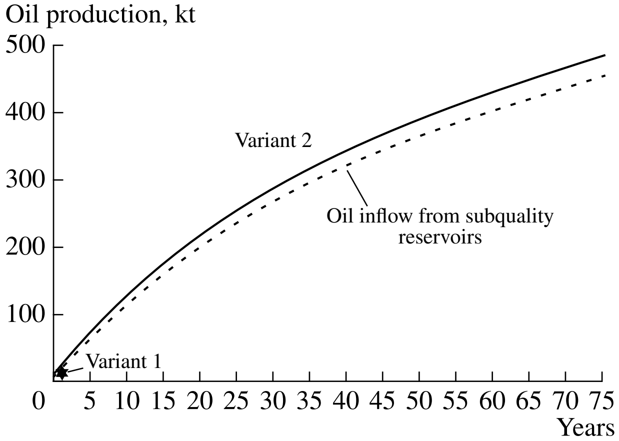

Fig. 3. Dynamics of cumulative oil production in variants 1 and 2 and oil inflow.

With such input data, we investigated the following development variants.

The first (basic) variant reflects the traditional approach. It is assumed that the lens is isolated and drained under natural conditions by one well located in its center.

Unlike the first variant, the second variant implies that the lens is hydrodynamically related to surrounding subquality reservoirs.

The next four variants imply that the lens is penetrated by two (producing and injection) wells. Variants 3 and 4 imply that the lens is isolated. In variants 4 and 5, the lens is in contact with the surrounding subquality reservoirs. In other words, variants 3 and 4 characterize traditional concepts of the isolated nature of the lens under consideration. In variants 3 and 5, producing and injection wells are located symmetrically about the center. The characteristic distance *d* is equal to 20 m in variants 3 and 5 (Fig. 1) and 60 m in variants 4 and 6. In the water flooding variants, the relative phase permeability for oil and gas was preset on the condition that the oil displacement coefficient equals 0.8.

In all variants, the producing well is exploited at a bottom-hole pressure of 150 atm. Pressure in the injection well is maintained at 250 atm. Prognostic calculations are carried out until achievement of one of the following restrictions: watering of the recoverable products is 98%; oil production rate, 1 t/day; period of oil pool development, 75 yr.

Calculations were made using the 2D/two-phase Eclipse software of Schlumberger.

The calculation results are given in Figs. 2–4. They are nontrivial and indicative of the following characteristic moments.

Flush production rates for oil in the producing well make up 400 t/day in variants 1 and 2. The production rate decreases rapidly in both variants. Oil production in the isolated lens ceases in half a year. It is quite natural, as the oil elasticity margin in the lens is low.

The second variant is characterized by stable oil output in the well at ~30 t/day (Fig. 2). Such productivity extends over five years due to oil inflow to the lens from surrounding subquality reservoirs. In other words, the lens behaves with respect to subquality reservoirs as an enlarged well with a radius of 250 m. As time goes by, a balance sets in between oil recovery from the lens and oil inflow from the surrounding massif.

Fig. 3 illustrates the comparison of cumulative oil production in variants 1 and 2. The figure scale does not make it possible to depict the vanishingly small oil production in variant 1. However, one can see that oil inflow from subquality reservoirs makes up the main share in oil production in variant 2.

Figure 4 demonstrates the COR dynamics for variants 3–6, when oil is recovered from the lens through its water flooding. These data reveal the following interesting features.

First, the water flooding of the lens seems to be highly efficient. Oil production ceases in less than five years. At the same time, all the variants demonstrate a high final COR (75–79%).

Second, apparent advantage of the traditional approach is erroneous, since variants with or without regard for lens communication with subquality reservoirs differ but slightly in finite COR values. Hence, the rapid running process of water flooding does not allow oil inflow from subquality reservoirs to affect cumulative oil production from the lens. Cumulative oil production with water flooding amounts to 8 kt. In the case of lens drainage at the natural regime with the involvement of subquality resources (variant 2), cumulative oil production makes up 484 kt.

Thus, the investigations carried out allow the following conclusions.

1. The modern model of isolated lenses in the massif of so-called nonreservoirs is incorrect. Its nonphysical nature is also explained by the lack of an answer to the question: how did the oil enter the lens?

2. The traditional concept of the efficiency of water flooding oil-saturated lenses is also incorrect.

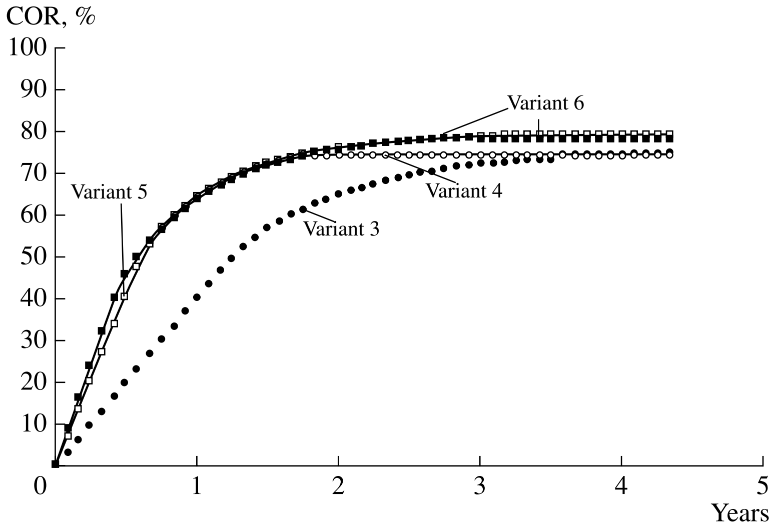

Fig. 4. The time dependence of COR on water flooding of the lens in variants 3–6.

3. It is expedient to develop lenticular reservoirs by a method precisely opposite to traditional approaches. First, it is necessary to take into consideration the communication pattern of lenses with subquality reservoirs. Second, lenses should be regarded as enlarged wells in the massif of subquality reservoirs. Third, it makes sense not to flood them but to produce oil in the regime of reservoir energy depletion. This will allow subquality oil reserves to be involved in draining.

With other input data, it is naturally possible to analyze variants with refining technological solutions.

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REFERENCES

1. V. V. Guzeev, M. P. Sadykov, M. F. Pustovalov, et al., Neft. Khoz-vo, No. 6, 26 (2004).
2. S. N. Varlamov, G. D. Ukhlova, and K. K. Gallyamov, in *Methods of Realization of Oil-and-Gas Potential in the Khanty-Mansi Autonomous Region* (IzdatNaukaServis, Khanty-Mansiisk, 2005), Vol. 2, pp. 186–196) [in Russian].
3. M. Sh. Kayumov, M. M. Salikhov, I. V. Vladimirov, et al., Neftepromysl. Delo, No. 8, 10 (2005).
4. *Manual on Planning the Development and Exploitation of Oil Fields: Development Planning*, Ed. by Sh. K. Gimatudinov (Nedra, Moscow, 1983) [in Russian].