INVESTIGATION OF THE PILOT INDUSTRIAL WORKS EFFICIENCY ON THE INFILL WELL SPACING ON THE BASHKIRIAN DEPOSITS OF SOKOLKINSKY FIELD WITH THE USE OF THE GEOLOGICAL-TECHNOLOGICAL MODEL

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Abstract. In this paper, to assess the effectiveness of pilot industrial works on the infill well spacing in the Bashkirian deposits of Sokolkinsky field, factors affecting the final technological indicators are identified. It is possible to refer the following factors to such category: the number of simultaneously commissioned wells in the element; selection of the optimal development element (five-point, nine-point, etc.); organization of the reservoir pressure maintenance system (the ratio of production and injection wells); the time interval for the reservoir pressure maintenance system in the development element. The proof of this fact is the results analysis of the three options considered, which makes it possible to determine how the development system, the ratio of production and injection wells, and the time of wells transfer for injection affect the production of oil.

Key words: infill well spacing, pilot industrial works, development element, flow filtration lines, interference, efficiency, geological-technological model

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Justification of site selection for the pilot works

The deposit II of the Sokolkinsky uplift was considered to carry out studies for the efficiency of pilot works on the infill well spacing. The deposit II is located in the southern part of the field, confined to the Sokolkinsky uplift and penetrated by 73 wells. Up to seven separate effective carbonate interlayers are distinguished in the carbonate stratum, the total oil-saturated thickness of which varies from 0.8 m to 14.2 m.

In wells Nos. 775, 787 and 913, an interval testing of the Bashkirian sediments was carried out; industrial oil inflows were produced with a flow rate of 3.2 to 6.1 tons per day. Water-oil contact is determined from the bottom of the lower oil-saturated layer in the well No. 808 at an absolute elevation minus 648.5 m. Analysis of the geological and geophysical data shows that the oil-water contact has not been established in the deposit. All effective carbonate interlayers contact the tight rocks. The highest position of the aquifer roof (wells Nos. 787, 2764, 2798) and the lowest hypsometric position of the bottom of the oil-saturated interlayer (wells No. 2810, 2814) were recorded at an absolute mark of minus 648.5 m. As a result of all of the above, the absolute elevation of water-oil contact is set at minus 648.5 m. The size of the deposit II is 2.95×2.4 km, the oil net pay is 34.6 m (Pereschet zapasov nefti .., 2009) (Fig. 1).

In order to improve the accuracy of predictive calculations of development options, a geological and technological model of the Bashkirian deposits of the Sokolkinsky field was constructed (Dopolnenie k tekhnologicheskoi skheme ..., 2015).

Filtration modeling was carried out with the help of computational programs realizing the numerical solution of the equation system describing the filtration of formation fluids and injected agents taking into account their interaction with the rock.

The hydrodynamic model was built using ROXAR's Irap RMS software packages – Tempest 7.2.

Geometric parameters of the resulting grids are presented in Table 1. Using the filtration model to adapt the development to the known dynamics of oil and water production, the functions of the modified phase permeabilities for each development object are selected.

The general view of the model on the example of a cube of porosity, permeability and initial oil saturation is shown in Fig. 2.

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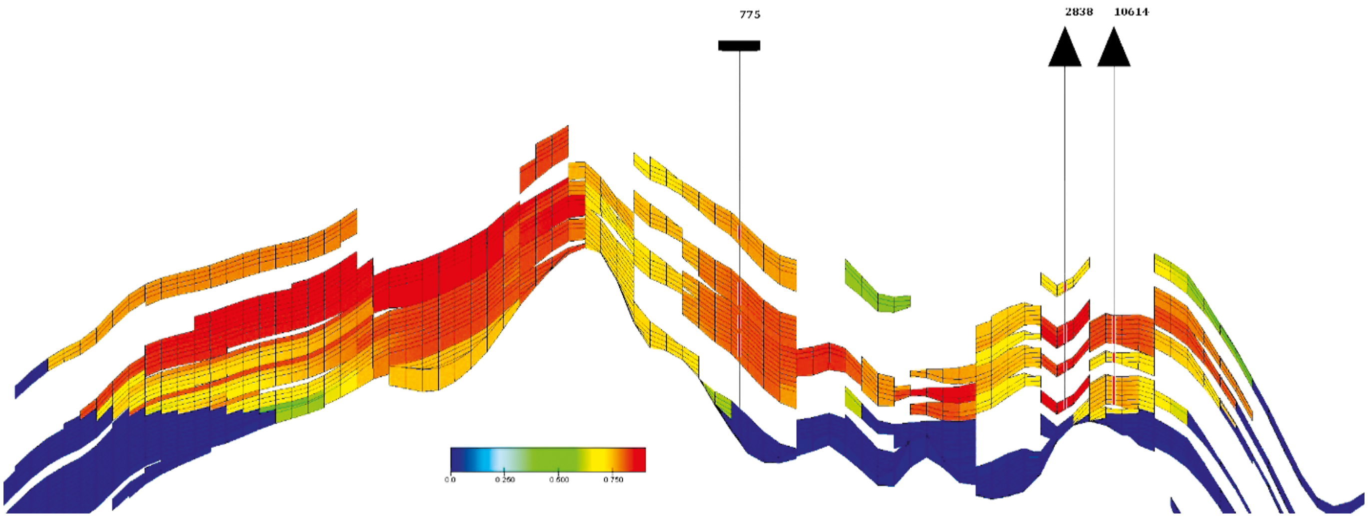
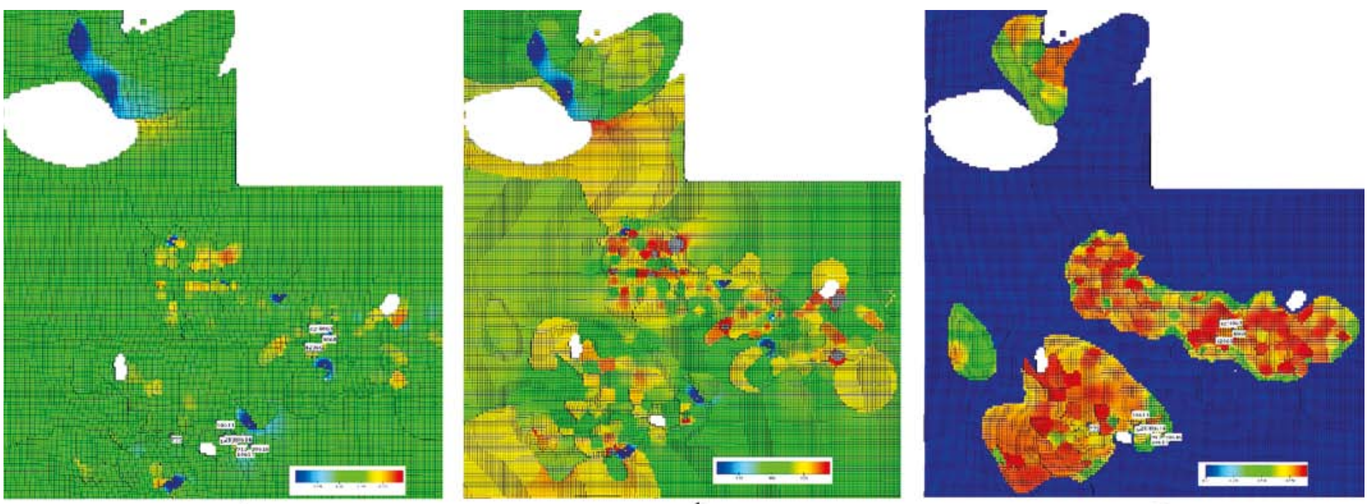


Table 1. Basic comparative characteristics of a three-dimensional reservoir model

Deposit	Model	Size of modeling area, km	Number of grid cells in three directions			Horizontal size of grid block, m	Vertical size of grid block, m	Number of active model blocks
			NX	NY	NZ			
Bashkirian	Geological	9×10	181	208	73	50×50	0,01-0,34	360 445
	Filtration	9×10	181	208	73	50×50	0,01-0,34	360 445

Fig. 1. Distribution of current oil saturation in a section along the line of wells Nos. 775,2838,10614



a b c

Fig. 2. Distribution of parameters (top view): a) porosity; b) permeability; c) initial oil saturation

Based on the results of adaptation of the geological and technological model, maps of current mobile reserves have been constructed (Fig. 3).

The analysis shows that in the southwest of the deposit II of the Sokolkinsky uplift, a site with rather high current mobile reserves prevails.

The site chosen for pilot works for infill well spacing within a six-meter isohypses will cover 1292 thousand m3 with geological reserves of 1550 thousand tons.

For the most complete development of residual oil reserves in this section of deposit II, drilling of 34 producing wells along a 150 x 150 m fill-in pattern Δ was proposed (Dopolnenie k tekhnologicheskoi skheme ..., 2015).

A schematic location of the project wells is shown in Figure 4.

Analysis of pilot works for the hydrodynamic modeling on the infill well spacing

With a view to calculating the forecasted technological development indicators, a development period was determined up to 2050. In 2016, 16 wells were to be introduced from infill drilling: in the following, in 2017 – 11, 2018 – 4, 2019 – 3. The results of the first forecast hydrodynamic calculations showed that drilling of 34 design wells leads to a sharp drop in reservoir pressure both in the calculated area and over the entire deposit II of the Sokolkinsky uplift.

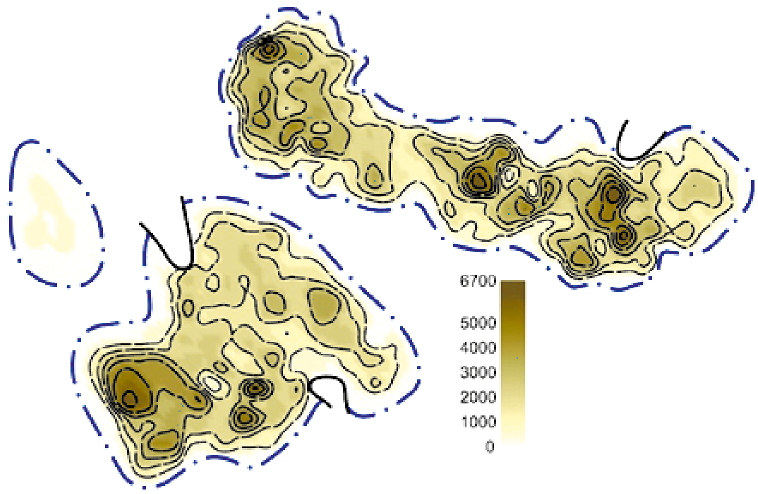


Fig. 3. Distribution of density of current mobile reserves

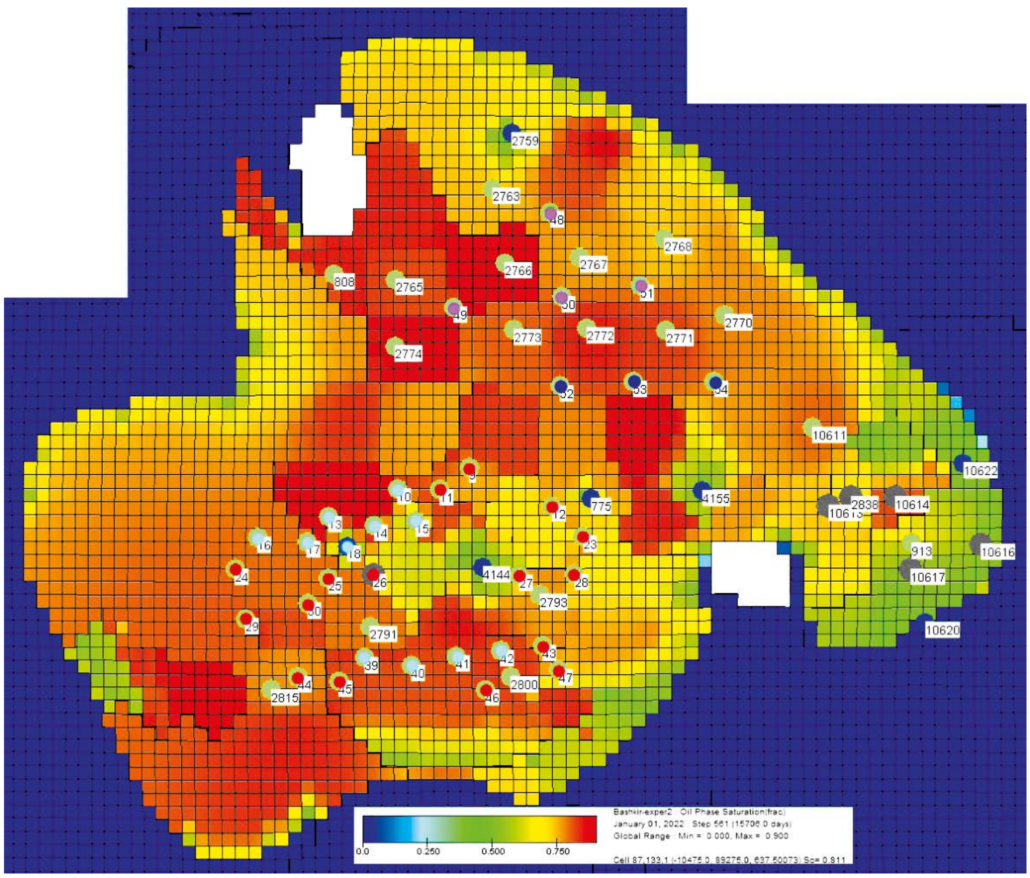


Fig. 4. Schematic location of project wells for drilling by years

Based on this, the option was considered for transferring 15 wells to water injection at certain intervals, depending on the pressure drop and the drop in oil production. In the upper part of the reservoir, wells are planned to be placed along a 5-point development system; in the lower part (area of well No. 775) focal flooding is planned. The layout of the development elements is shown in Fig. 5.

To assess the effectiveness of a particular development option, it is necessary to consider a number of factors that affect the final technological indicators, i.e. on accumulated oil production (Abdulmazitov, 2004; Zakirov, 2002; Shchelkachev, 1984).

The following factors can be attributed to this category:

- the number of simultaneously commissioned wells in the element;

- selection of the optimal development element (five-point, nine-point, etc.);

- organization of the reservoir pressure maintenance system (the ratio of production and injection wells);

- the time interval for the reservoir pressure maintenance system in the development element.

The proof of this fact is the analysis of three options considered, which makes it possible to determine how the development system, the ratio of production and injection

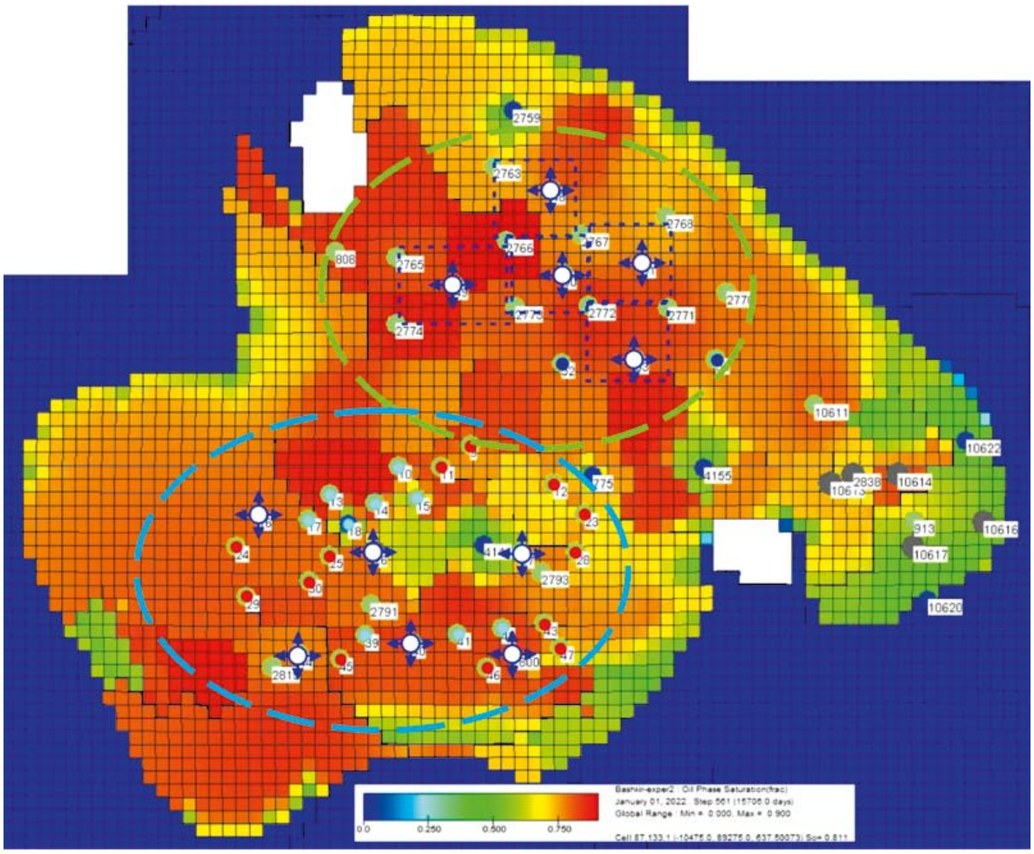


Fig. 5. Layout of the development elements

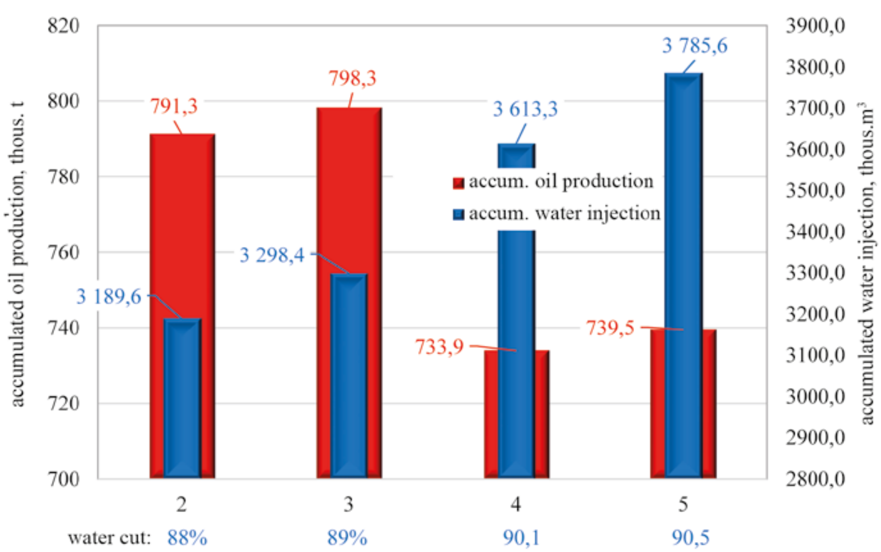


Fig. 6. Dynamics of accumulated production by groups of wells put into operation for certain years

wells, and the time of transferring wells into injection affect the production of oil. Figure 6 shows the dynamics of accumulated oil production and accumulated water injection wells in the Sokolkinsky uplift by the options. It can be noted that the commissioning of a group of fill-in wells, as well as the transfer of wells into injection, significantly affect the accumulated oil production and water cut (Abdulmazitov, 2004, Obobshchenie opyta razrabotki ..., 2005).

In the options with the organization of reservoir pressure maintenance system at the initial stage of development (options 4,5) the accumulated oil production is less than in the options with the transferring group of wells into injection in the middle stage of development (options 2,3). Accordingly, in options 4 and 5 water injection into the reservoir is greater than in options 2 and 3. The distribution of oil saturation at the end of development (2050) by options is shown in Fig. 7a-d.

It is believed that when filling-in the existing well pattern by drilling additional wells, interference occurs between the wells, i.e. wells depending on the geological structure (distribution of porosity, permeability) create interference in oil production (Zakirov, 2002; Schelkachev, 1984).

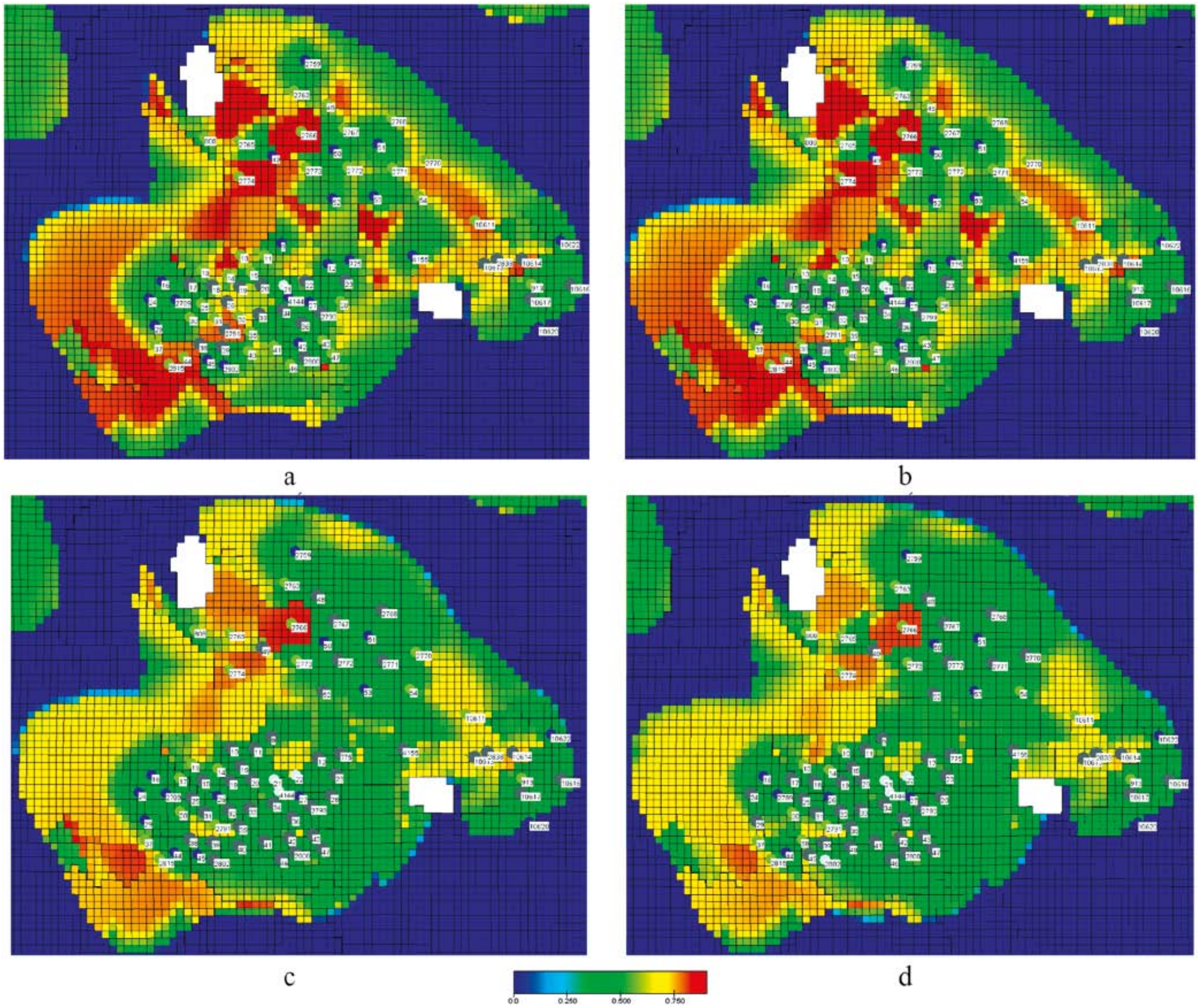


Fig. 7. Distribution of oil saturation at the end of the development by options (top view): a) 2, b) 3, c) 4, d) 5

Confirmation of this fact is in detailed analysis of the development of pilot sections of oil-bearing oil deposits with infill drilling (Yamashinsky, Bureikinsky and Shegurchinsky fields), which show the influence of interference on oil well flow rates (Abdulmazitov, 2004, Obobshchenie opyta razrabotki ..., 2005).

Proceeding from this, we will construct maps of the flow filtration lines depending on the time of input of project wells and wells transferred from other objects. Figures 8a-e show the dynamics of the change in the oil flow filtration lines depending on the year of drilling and introduction of wells into commissioning. Fig. 8a shows the flow filtration lines of the active wells in the deposit, Fig. 8b – at the time of commissioning of the first 16 design wells (01.2017), Fig. 8c – 11 wells (01.2018), Fig. 8d – 4 wells (01.2019), Fig. 8e – 3 wells (01.2020), Fig. 8f – transfer of the first wells into injection.

In order to identify interference between the wells, we shall discuss the results of the three options, where we select 2 sections, as shown in Fig. 9a-b.

At the 1 site, we will select the area of wells Nos. 10,13,14,15,17,18,24,25,26. It should be noted that the wells are put into operation at different times: Nos. 24,25,26 – 02.2016, Nos.10,13,14,15,17,18 – 02.2017. The schedule of oil flow rates (Fig. 9a) shows that for the period of 02.2016 – 12.2020, the introduction of wells Nos.10,13,14,15,17,18 into operation influenced the increase in flow rates of wells No. 24,25,26. For example, the flow rate of oil in well No.24 increased by 0.29 t/day, well No.25 – by 0.32 t/day, well No.26 – by 0.27 tons per day, with an average increase of 21.2%.

In the future, with the fall in reservoir pressure, the oil flow rates of wells Nos. 10,13,14,15,17,18 decrease, but subsequently, after the transfer in August 2018 of well No.26 for injecting water, there is a noticeable increase. For example, in the well No. 13 oil production grew by 0.13 tons per day, in wells No.14 – at 0.48 tons per day in the well No. 15 – by 0.19 t /day, in well No. 17 – by 0.07 t / day and in well No. 18 – by 1.25 tons per day.

The arrangement of water injection also affected the flow rate of oil in well No. 25, the increase was 1.64 tons/day. Filtration lines of oil flow in wells Nos. 10, 13, 14, 15, 17, 18, 24, 25, 26 of this section are shown in Fig. 10a-d.

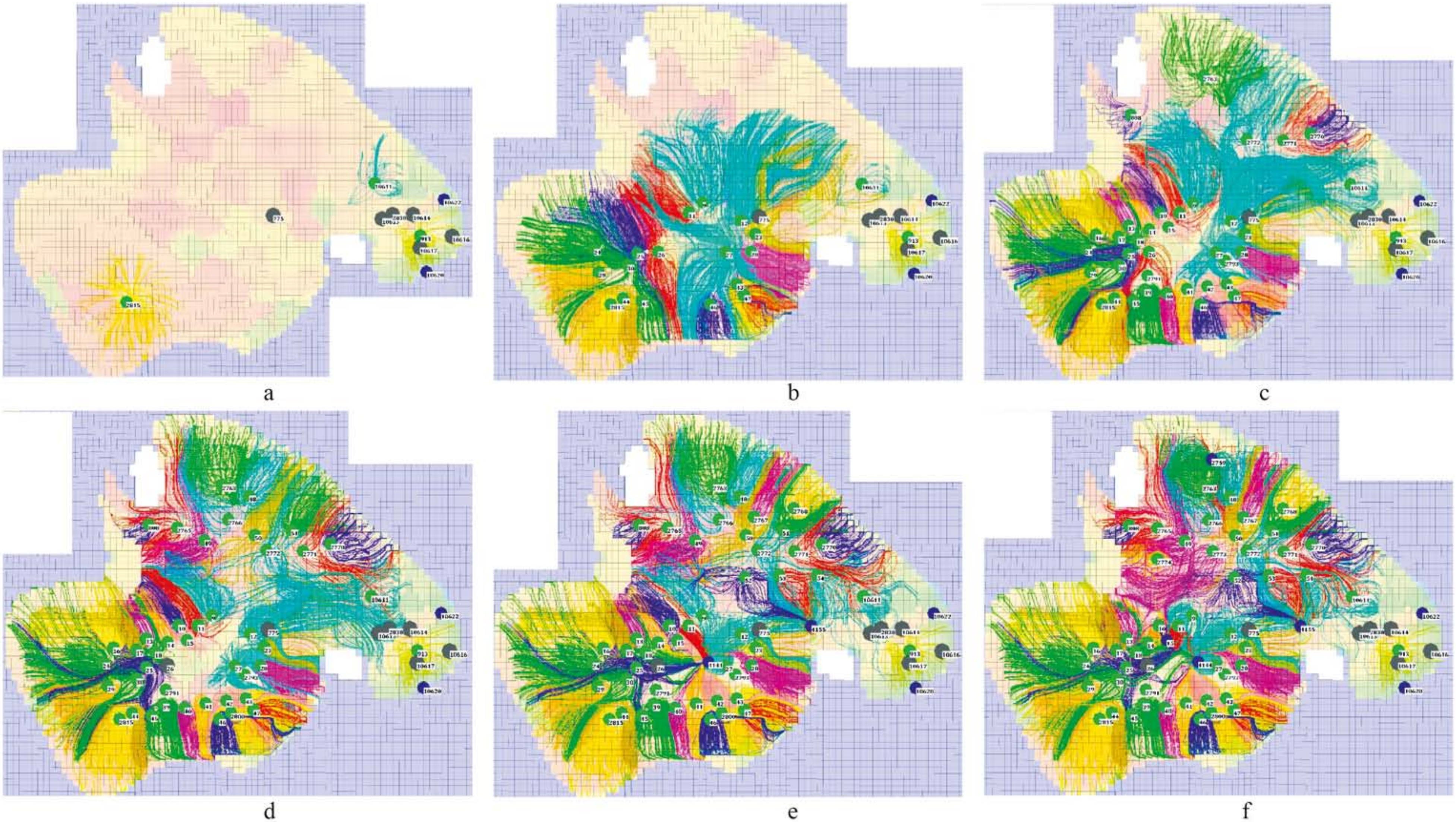


Fig. 8. Dynamics of the filtration lines of oil flow as on:
a) 01.2016, b) 01.2017, c) 01.2018, d) 01.2019, e) 01.2020, e) 01.2021

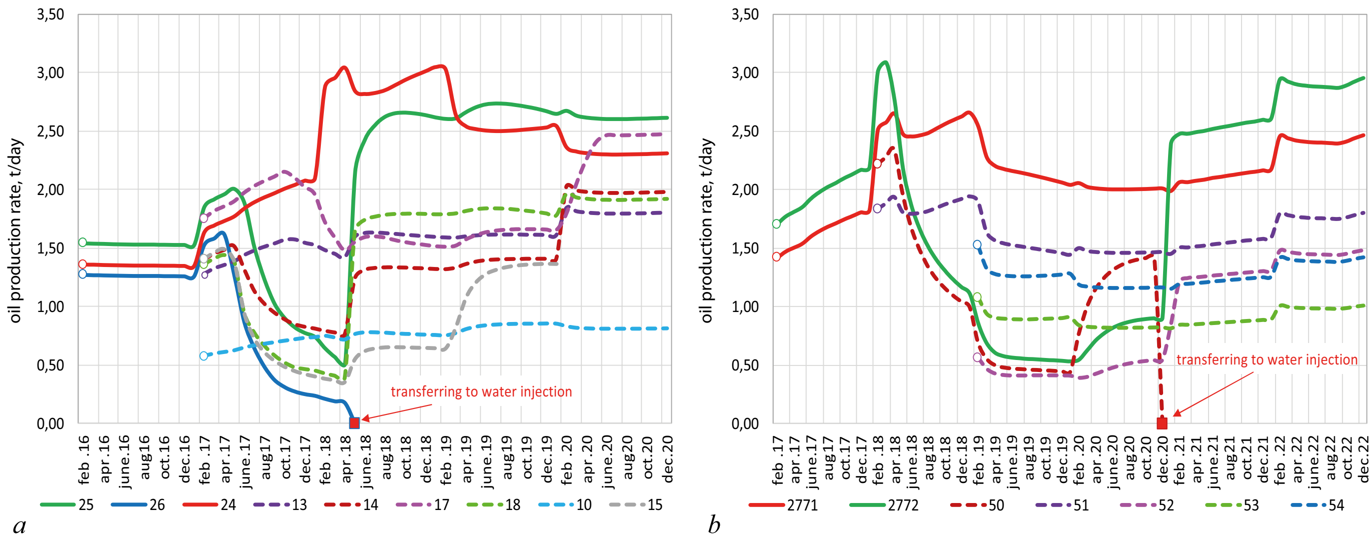


Fig. 9. Dynamics of oil production rates: a) for section 1 of 02.2016 – 12.2020, b) for section 2 of 02.2017 – 12.2022

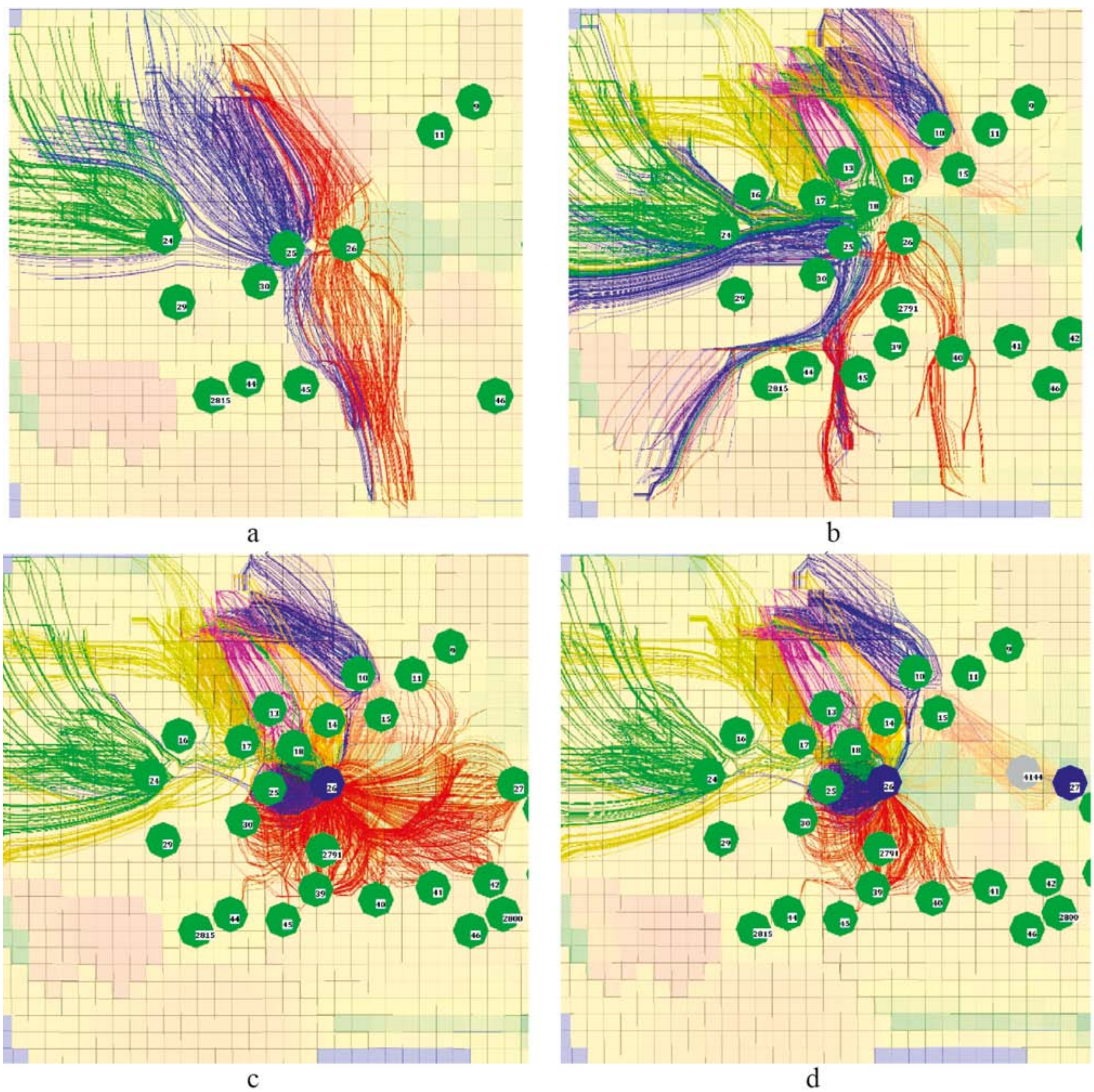


Fig. 10. Filtration lines of oil flow in 1 section as on: a) 01.2018, b) 01.2019, c) 01.2020, d) 01.2021

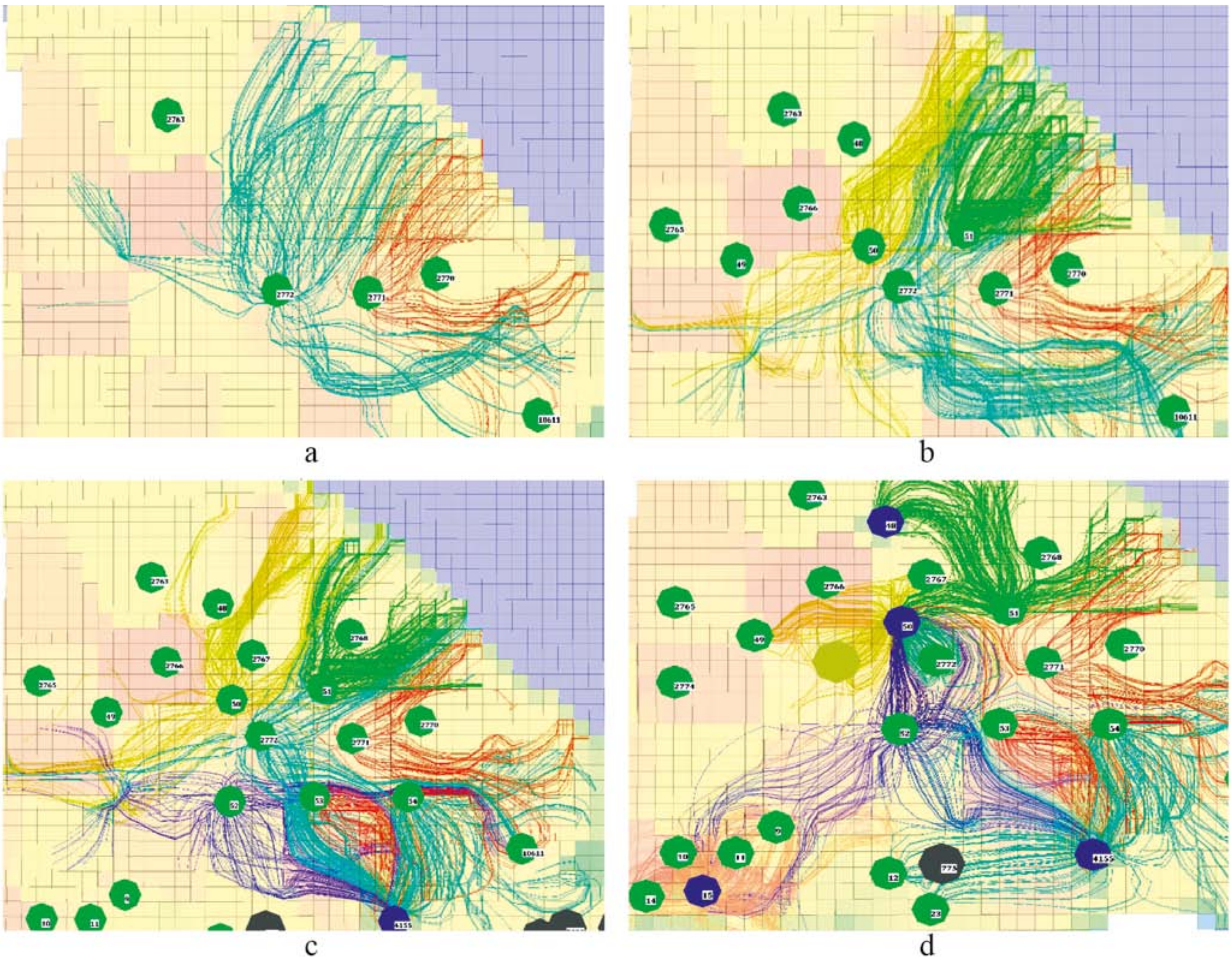


Fig. 11. Filtration lines of oil flow of oil in 2 sections as on: a) 01.2018, b) 01.2019, c) 01.2020, d) 01.2021

On the 2nd section we will select the area of wells Nos. 50,51,52,53,54,2771,2772 and it is worth noting that the wells are put into operation at different times: Nos. 2771,2772 – 02.2017 by transferring from other facilities, Nos. 50.51 – 02.2018, Nos. 52,53,54 – 02.2019. The dynamics of the oil flow rates of this group of wells for the period 02.2017 – 12.2022 is shown in Fig. 9b.

Fig. 9b shows that the introduction of wells Nos. 50,51 into operation significantly (spasmodically) affected the flow rates of wells Nos. 2771.2772. For example, in the well No. 2771 oil production increased by 0.68 tons/day, and in well No. 2772 – by 0.82 t/day, with an average increase of 37.2%.

In the future, with the fall in reservoir pressure, the oil production rate in wells Nos. 2771.2772 began to decrease sharply, by 0.64 t/day and 1.86 t/day, respectively.

In this regard, in February 2020 the well No. 48 and in December 2020 the well No. 50 are transferred into water injection. Wells No. 2772 and No. 52 reacted on the water injection, according to which the oil flow rate increased by 1.49 t/day and by 0.37 t / day, respectively. Fig. 9b also shows that in February 2022 in wells. Nos. 2771, 2772, 51, 52, 53, 54 there is a slight jump in oil flow rate, due to the breakthrough of injected water from wells Nos.15,4155. The filtration lines of the oil flow in the given section are shown in Fig. 11a-d.

Conclusions

1. The choice of the development system and the optimal well spacing are of great importance in the theory and practice of oilfield development. In this regard, a number of important issues remain relevant at all stages of the development of the national oil industry, and they are given constant attention (Abdulmazitov, 2004; Zakirov, 2002, Shchelkachev, 1984, Obobshchenie opyta razrabotki ..., 2005; Takhautdinov et al. 2009).

2. It is promising to establish deterministic permanent mathematical models of oil fields for optimizing the infill well pattern in order to increase oil recovery, with the help of which it is possible to identify poorly drained and stagnant zones of the reservoir, to establish their size and ways of involving them in active development.

3. Currently, in the context of a decline in oil prices, each development option can be characterized by three main indicators: the level of oil production, the economic

indicators of the hydrocarbon field development (net present value) and the oil recovery factor. These three indicators characterize the effectiveness of field development from different sides, often contradict each other, besides, the subsoil user and the government are sometimes interested in achieving the maximum values of various indicators.

In this regard, it is necessary to seek a reasonable compromise between these criteria of rationality, to find the best balance of interests between the subsoil user, the government and the requirements for protection of the subsoil and the environment.

4. The results of geological and hydrodynamic calculations to study the effectiveness of pilot works on the infill well spacing at the Sokolkinsky uplift of the Sokolkinsky field show that when justifying the design well spacing, it is necessary first of all to take into account factors that affect both current and forecast technological indicators:

- the number of simultaneously commissioned wells in the element;
- selection of the optimal development element (five-point, nine-point, etc.);
- arrangement of the reservoir pressure maintenance system (the ratio of production and injection wells);
- the time interval for the reservoir pressure maintenance system in the development element.

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