

Studies of the hydrodynamic connection presence between the terrigenous Bobrikovian and carbonate Tournaisian objects on the basis of the geological-technological model of the site of the field

M.A. Saifutdinov¹, I.N. Khakimzyanov^{1*}, V.N. Petrov², R.I. Sheshdirov², L.M. Mironova³

¹Oil and Gas Production Department Nurlatneft Tatneft PJSC, Nurlat, Russian Federation

²Institute TatNIPneft Tatneft PJSC, Bugulma, Russian Federation

³Nauka LLC, Bugulma, Russian Federation

Abstract. The authors suggest improvement of oil deposit development systems in Tournaisian and Radaevskian-Bobrikovian sediments in zones of erosion incisions with permeable types of reservoirs using the example of the Ashalchinsky oilfield.

Indicator studies were conducted in the experimental section of the Ashalchinsky field in 2014 to determine the hydrodynamic connection between the terrigenous Bobrikovian deposits and carbonate Tournaisian deposits. The presence of an indicator in the production well stock in the Radaevskian-Bobrikovian sediments inside the incision, when injected into the carbonate Tournaisian deposits over the side of the incision, indicates that there is hydrodynamic connection between the enclosing Tournaisian carbonates and the terrigenous Bobrikovian-Radaevskian formations that form the incisions. It follows that the filtration from the carbonate reservoir into the terrigenous, both laterally and vertically, occurs faster and more intensively when the terrigenous reservoir is imposed to the carbonate reservoir in the incision zone.

In order to confirm the presence of a hydrodynamic connection between the terrigenous Bobrikovian and carbonate Tournaisian objects, modeling studies were carried out to design the development of the site of the field. Based on the results of geological and technological modeling, it was revealed that the accumulated oil production from the wells of the Radaevskian-Bobrikovian production well stock may exceed the average well stock by 1-3 times.

Keywords: hydrodynamic connection, carbonate, terrigenous reservoirs, erosion incisions, oil recovery coefficient, indicator studies, fluorescein, filtration current lines

Recommended citation: Saifutdinov M.A., Khakimzyanov I.N., Petrov V.N., Sheshdirov R.I., Mironova L.M. (2018). Studies of the hydrodynamic connection presence between the terrigenous Bobrikovian and carbonate Tournaisian objects on the basis of the geological-technological model of the site of the field. *Georesursy = Georesources*, 20(1), pp. 2-8. DOI: <https://doi.org/10.18599/grs.2018.1.2-8>

In the Republic of Tatarstan, oil deposits in the Tournaisian sediments on all tectonic elements except for the outermost south-eastern part of the Oil and Gas Production Department Bavlyneft Tatneft PJSC area are more or less violated by erosion incisions. In this article, the authors consider complicated reservoirs filled with oil and disrupted by incisions, that is, oil deposits with such structure.

The enclosing rocks are the permeable carbonate rocks of the Tournaisian stage, and the filling rocks are terrigenous highly permeable sandy-siltstone formations of the Radaevskian-Bobrikovian horizon. In the zones of erosion of the Tournaisian deposits in the sections of

the wells there are completely no clay formations of the Elkhovskian horizon. The reservoir of the Radaevskian-Bobrikovian age directly lies on the Tournaisian deposits.

The hydrodynamic connection between the enclosing and filling rocks, proved on the basis of instrumental studies, modeling and analysis of the technological performance of the wells, can be used in the design of deposits, including the arrangement of the project well stock, the development of geological and technical measures, taking into account the use of a highly permeable channel – naturally occurred incision, for a more effective development of oil reserves from weakly permeable Tournaisian reservoirs, organizing the displacement from them of oil into the higher incision channel¹ (Bazarevskaya et al., 2011).

* Corresponding author: *Ilgizar N. Khakimzyanov*
E-mail: khakimzyanov@tatnipi.ru

© 2018 The Authors. Published by Georesursy LLC
This is an open access article under the CC BY 4.0 license
(<https://creativecommons.org/licenses/by/4.0/>)

¹Gubaydullin A.A., Bazarevskaya V.G., Yudinsev E.A. (2010). Geology of carbonate complex reservoirs of the Devonian and Carboniferous of Tatarstan. Report, Academy of Sciences, Kazan: FEN, 283 p.

Such a channel, carried out by terrigenous formations, can be used to improve technologies for the most complete development of oil reserves from weak permeable carbonate rocks in existing development systems². At the same time, the oil recovery factor increases from low permeability carbonate rocks.

The existence of a hydrodynamic connection between the Carbonate deposits of the Tournaisian stage and sandy-siltstone deposits of the Radaevskian-Bobrikovian horizon has been contested so far by many scientists who maintain that the zone of erosion of the Tournaisian deposits is a stratigraphic and lithological screen (Khayretdinov N., Aminov L., etc.).

On the territory of Tatarstan, the most widespread erosion disturbances are observed on the eastern side of the Melekess depression² (Kozina, 1978). A striking example is the Ashalchinsky field, where, in fact, every uplift that controls oil deposits has been subjected to erosive disturbances of the sediments of the Elkhovskian horizon and the Tournaisian stage (Figure 1).

By the time of the deposition of terrigenous Tulsian formations, the incision is completely compensated and the structural plan on the bottom of the Tulsian stratigraphic object, as a rule, repeats the paleostructural plan of the Tournaisian stage (Figure 1). With the purpose of revealing the existence of the hydrodynamic

connection in the Tournaisian and the Radaevskian-Bobrikovian deposits, we consider the results of the indicator injection and geological and hydrodynamic modeling on the example of one of the fields of the Republic of Tatarstan³ (Salakhova, 2012).

1. Indicator studies

Indicator studies were conducted in the experimental section of the Ashalchinsky field in the pilot site in 2014 to determine the hydrodynamic connection between the terrigenous Bobrikovian deposits and carbonate Tournaisian deposits (Figure 2).

According to the results of the research, it was established that the concentration of the indicator in the flow of produced products and the time of its arrival to the production well depend not only on the filtration properties of the reservoir, but also on the current operating modes of the operating wells stock, that is why the investigations were carried out under steady-state operating conditions of the wells. Evidence are based on the results of determining the content of the eosin and fluorescein indices in the produced water of produced wells, located in the vicinity of the injection well No 4742, located outside the incision. Indicators were recorded in the well production samples in separate batches, which indicates the presence of

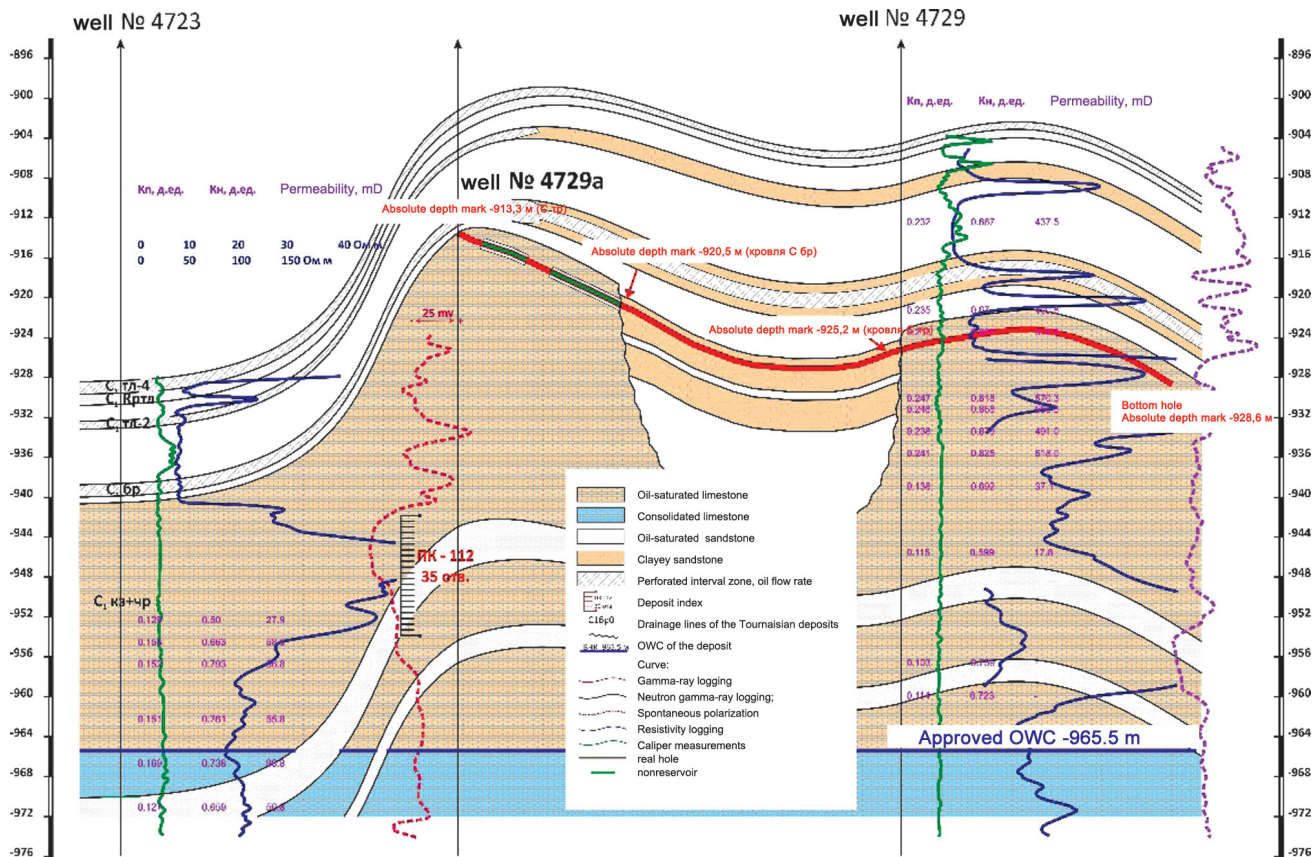


Figure 1. Compilation from the Lower Carboniferous section at the Ashalchinsky site of the Ashalchinsky field with the position of the actual trajectory of the horizontal section of the well trunk with horizontal end No 4729a

² Nureeva N.S. (2006). Technological scheme for the development of the Ashalchinsky oil field. Report. TatNIPIneft, Bugulma.

³ Antonov G.P. et al. (2014). Investigations of the mutual influence of injection and production wells on the Tournaisian stage of the Ashalchinsky field by means of indicator studies. Report. LLC «Nauka», Bugulma.

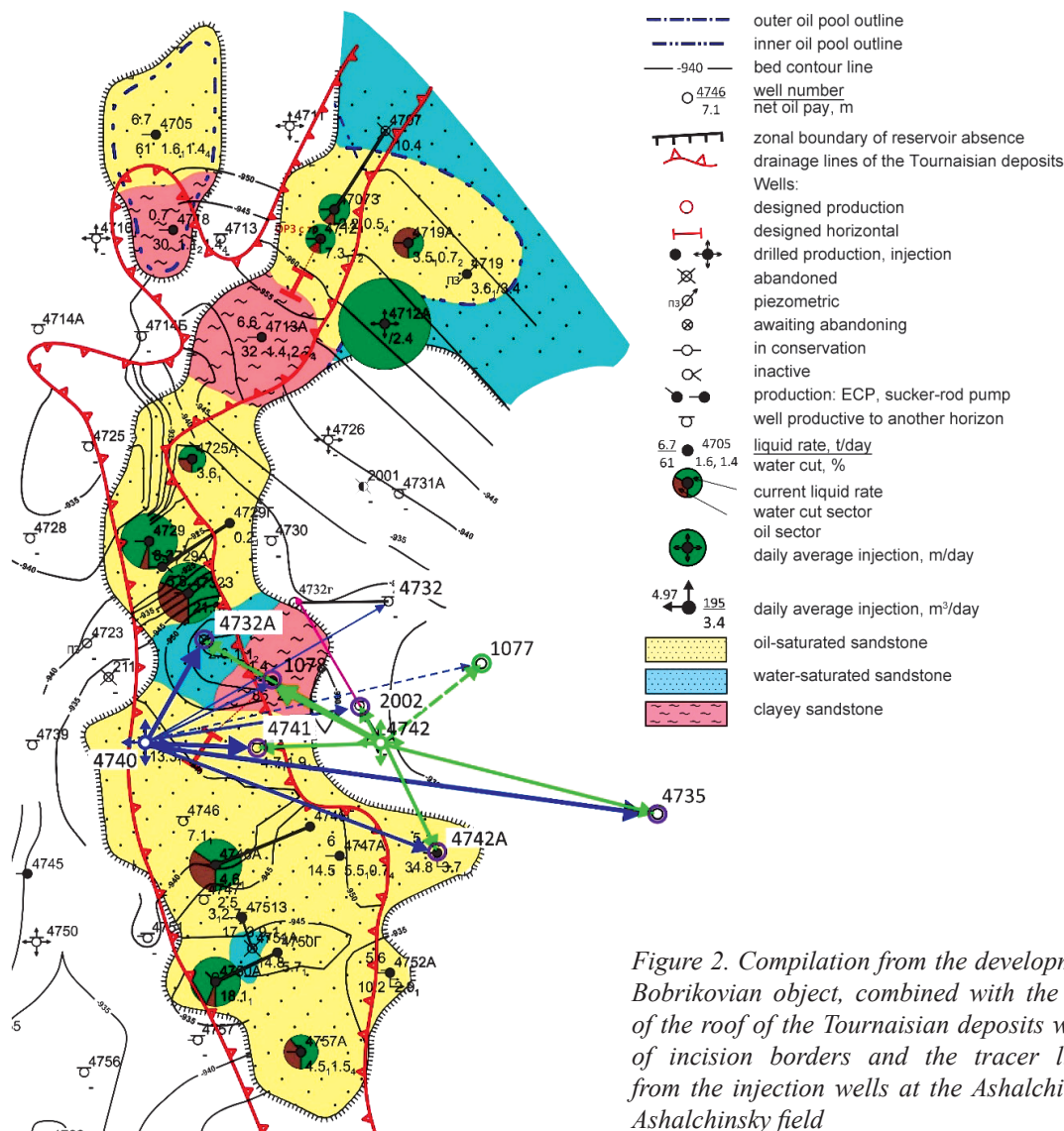


Figure 2. Compilation from the development map of the Bobrikovian object, combined with the structural map of the roof of the Tournaisian deposits with designation of incision borders and the tracer lines movement from the injection wells at the Ashalchinsky site of the Ashalchinsky field

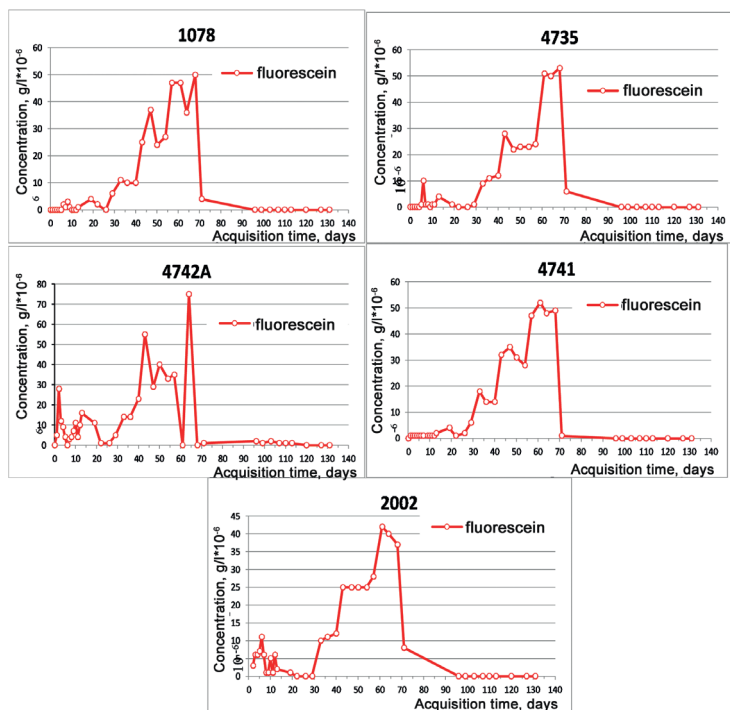


Figure 3. The dynamics of fluorescein release from the reservoir with some of the reacting surrounding wells

filter paths of different length and permeability, that is, high heterogeneity of the object (Figure 3). When interpreting the results of indicator studies, all geological, geophysical and fishery information was used: geological data, logging data, field data.

The identity in the time recording and concentration of the indicator in the surrounding producing wells on the maxima indicates the presence in the rock mass of the most permeable interlayers, regardless of their lithotype, and having a hydrodynamic connection during the path of filtration of labeled water from the injection to surrounding producing wells.

The presence of an indicator in the production stock of the reservoir in the Radaevskian-Bobrikovian sediments within the incision when injecting into the Tournaisian carbonate deposits outside the incision shows that there are hydrodynamic connections between the enclosing carbonates of the Tournaisian Stage (in well No. 4742) and filling terrigenous formations of the Bobrikovian-Radaevskian age. The relatively rapid appearance of an indicator in production of producing wells from high

concentrations indicates that there are abnormally high permeable filtration channels in the formation.

A small fraction of the indicator extracted from the reservoir characterizes the low degree of influence of the injection well No 4742 to surrounding extracting plants, in which the fluorescein and eosin indicators are recorded. After the passage of the trailing edge of the labeled rim, the indicator in the adjacent produced waters of the surrounding wells was not recorded. It is possible that the main mass of the indicator has migrated to the lower-lying aquifers of the Tournaisian Stage, which are characterized by higher reservoir properties. The absence of an indicator in a number of producing wells indicates that there is no hydrodynamic connection of these wells with injection wells.

Thus, this proves that the filtration from the carbonate reservoir to the terrigenous one both laterally and vertically occurs faster and more intensively, when the terrigenous reservoir is superimposed on the carbonate reservoir within the incision zone⁴.

2. Geological and hydrodynamic modeling

In order to confirm the existence of a hydrodynamic connection between the terrigenous Bobrikovian and carbonate Tournaisian objects, modeling studies were conducted to design the development of the field site. The calculated grid in the geologic-technological model of the oil deposit was $130 \times 121 \times 399$ cells, further, a section with a calculated grid of $35 \times 40 \times 399$ cells was cut out. Vertically, the objects were divided into a certain number of cells (Bobrikovian – $1 \div 10$, Bobrikovian (incision) – $12 \div 193$, Tournaisian – $194 \div 399$).

The distribution of permeability, porosity and initial oil saturation along the site of the deposit (top view) for each of the objects is shown in Figures 4-6.

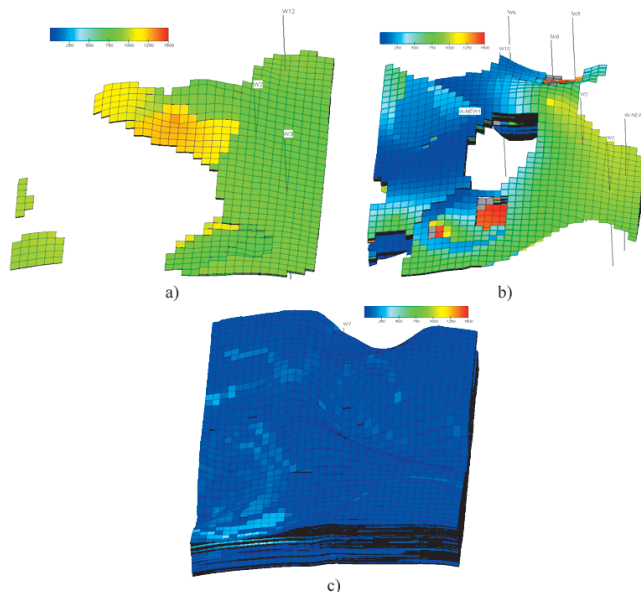


Figure 4. 3D distribution of permeability along the site of the field (top view) along the following objects: a) Bobrikovian, b) Bobrikovian-incision, c) Tournaisian

10 vertical wells are in operation in the area under consideration (w2, w3, w6, w7, w8, w9, w10, w12, w-new1, w-new2).

For the study, 2 options for further development of the reservoir section were considered: 1 – development without a system of reservoir pressure maintenance and 2 – with a system of reservoir pressure maintenance by pumping water into well w7 to the Tournaisian object for 15 years.

Analyzing the results of the hydrodynamic forecast calculations of the technological indicators of the site development and comparing the accumulated oil

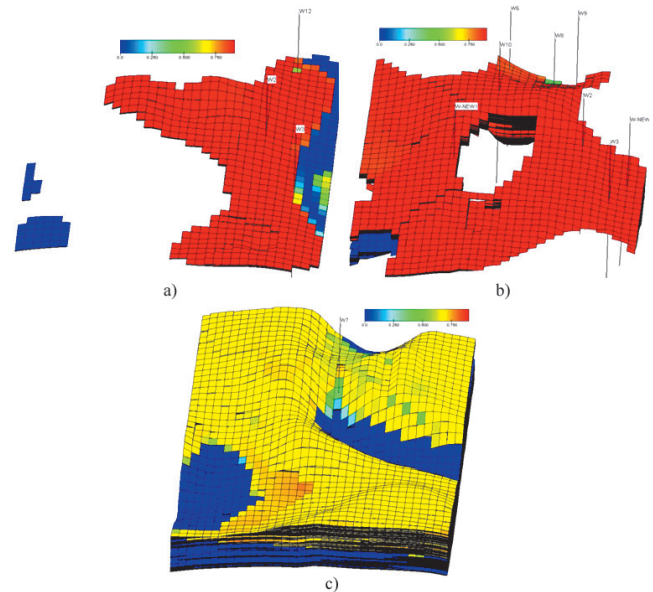


Figure 5. 3D distribution of the porosity along the field site (top view) along the following objects: a) Bobrikovian, b) Bobrikovian-incision, c) Tournaisian

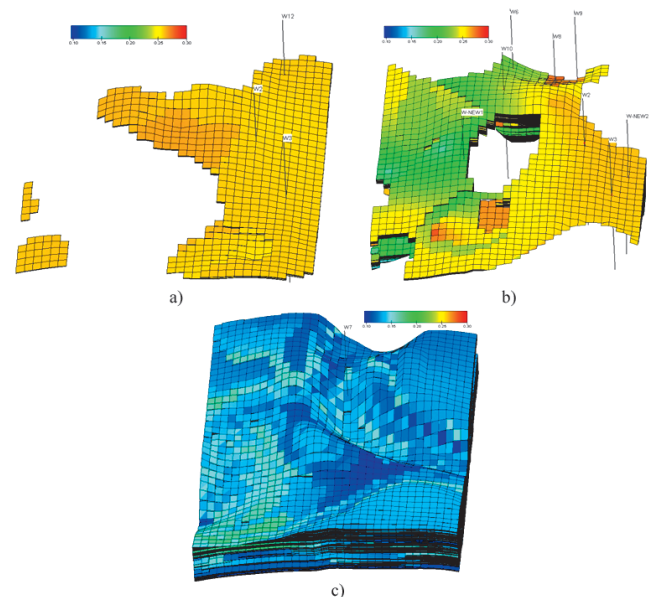


Figure 6. 3D distribution of the initial oil saturation along the field site (top view) along the following objects: a) Bobrikovian, b) Bobrikovian-incision, c) Tournaisian

⁴Monitoring of the use of horizontal technology at the fields of Tatneft PJSC. (2014). TatNIPIneft funds.

production, we find that, in the second variant, pumping water to the Tournaisian object leads to an increase in the accumulated oil production from the Bobrikovian object by 8,000 tons, i.e. part of the reservoirs from permeable carbonates of the Tournaisian object was displaced into highly permeable terrigenous rocks of the Bobrikovian-Radaevskian object.

A comparison of the accumulated oil production by the options for each production well of the site of the Bobrikovian object is shown in Figure 7.

The distribution of initial and final oil saturation in a section along the line of well 7 on the whole for the site of the plant according to the options is shown in Figures 8.

The distribution of initial and final oil saturation in a section along the line of well w7 separately for each object is shown in Figures 9,10.

In Figure 9b, it can be clearly seen that the injection of water into the well 7 leads to a change in the oil saturation in the Bobrikovian object. Comparing Figures 9 and 10, one can also notice a hydrodynamic connection between the Tournaisian and Bobrikovian objects.

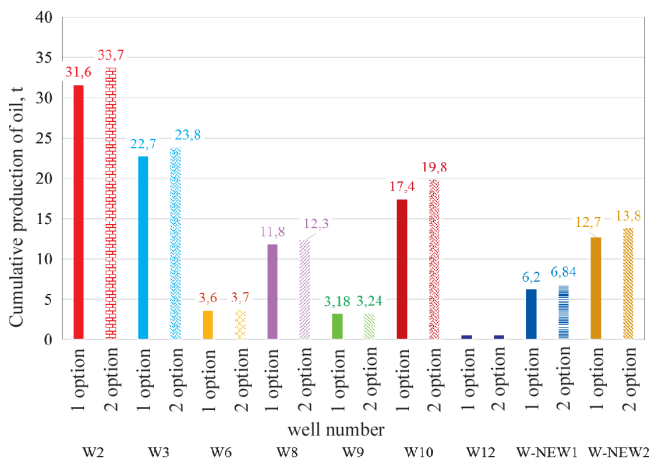


Figure 7. Comparison of cumulative production of oil wells according to options

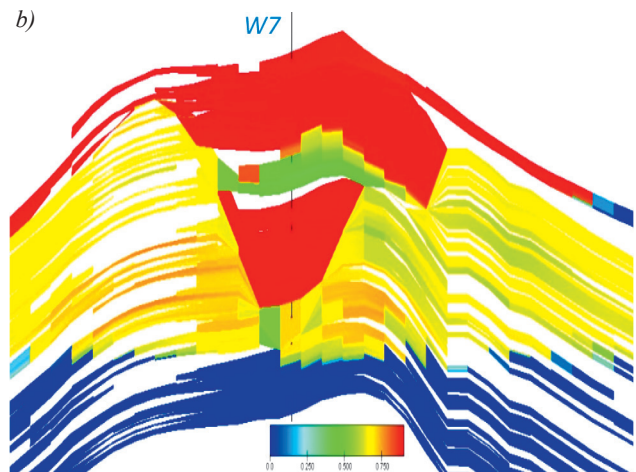
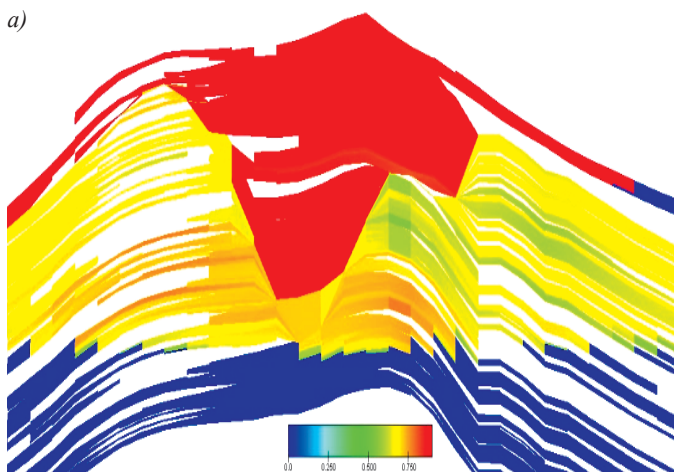


Figure 8. Distribution of oil saturation at the end of the forecast period in the section by options: a) 1 option without reservoir pressure maintenance, b) 2 option with reservoir pressure maintenance

In order to detail the process of the hydrodynamic connection of the Tournaisian and Bobrikovian objects, let us consider the filtration lines of the oil current for each variant.

The lines of the oil current to the producing wells of the considered deposit of the Bobrikovian object (incision) are shown in Figure 11.

Comparing Figures 11a and 11b, we can see that the injection of water into the well w7 of the Tournaisian object allows us to significantly change the current filtration lines in the area of wells that are perforated in the dome parts of the Bobrikovian (incision) object.

Conclusions

1. In erosion areas of Tournaisian deposits argillaceous formation of the Elkhovskian horizon are completely absent in wells. Reservoir of Radaevskian-Bobrikovian age directly overlies the deposits of the Tournaisian stage.

2. Rocks enclosing the incision are weakly permeable carbonate rocks of the Tournaisian stage; rocks filling the incision are clastic highly permeable sand and silt formation of the Radaevskian-Bobrikovian horizon.

3. On the basis of instrumental studies, geological-technological modeling and analysis of well production technology, the existence of a hydrodynamic connection between the enclosing rocks and rocks the incision has been proved.

4. Identification of hydrodynamic connection can be used to improve the development of the field, including the arrangement of the project well stock, selection of geological and technological measures, taking into account the use of highly permeable channel – incision – created by nature for more efficient highly production of oil from low permeable reservoirs of the Tournaisian stage, organizing the oil displacement into the highly permeable channel of the incision.

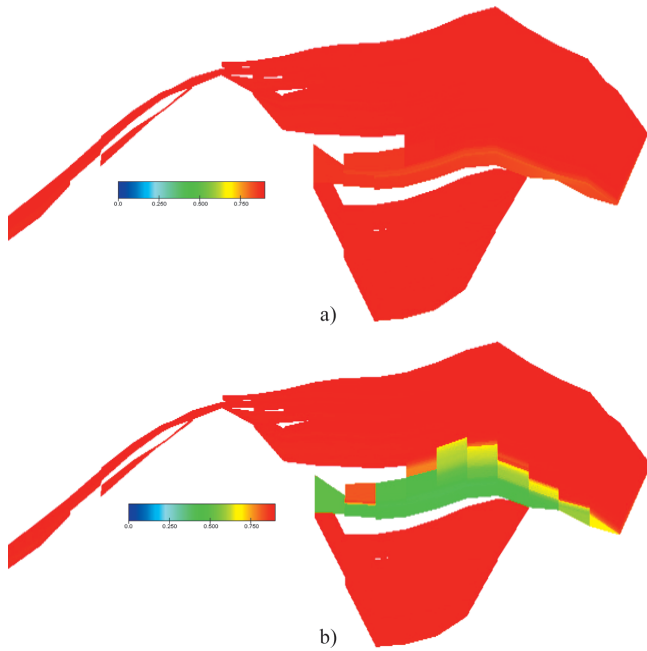


Figure 9. Distribution of oil saturation in the Bobrikovian object in the section by options: a) 1 option without reservoir pressure maintenance, b) 2 option with reservoir pressure maintenance

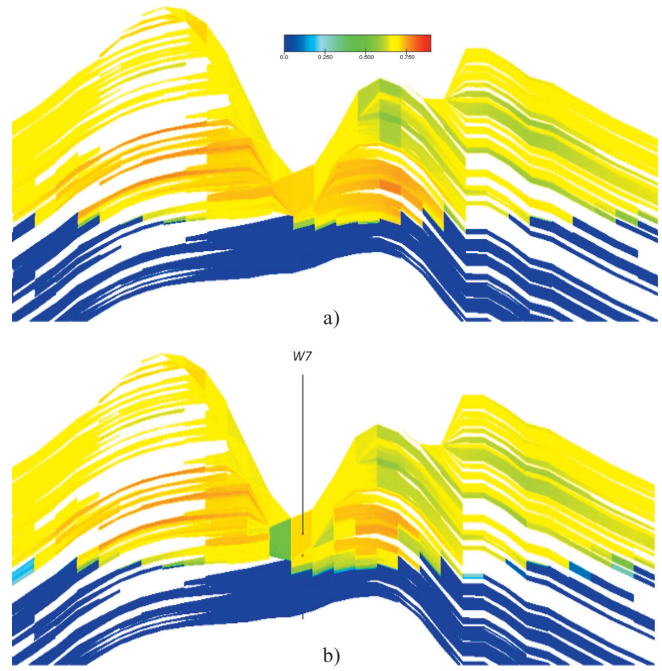


Figure 10. Distribution of oil saturation in the Tournaisian object in the section by options: a) 1 option without reservoir pressure maintenance, b) 2 option with reservoir pressure maintenance

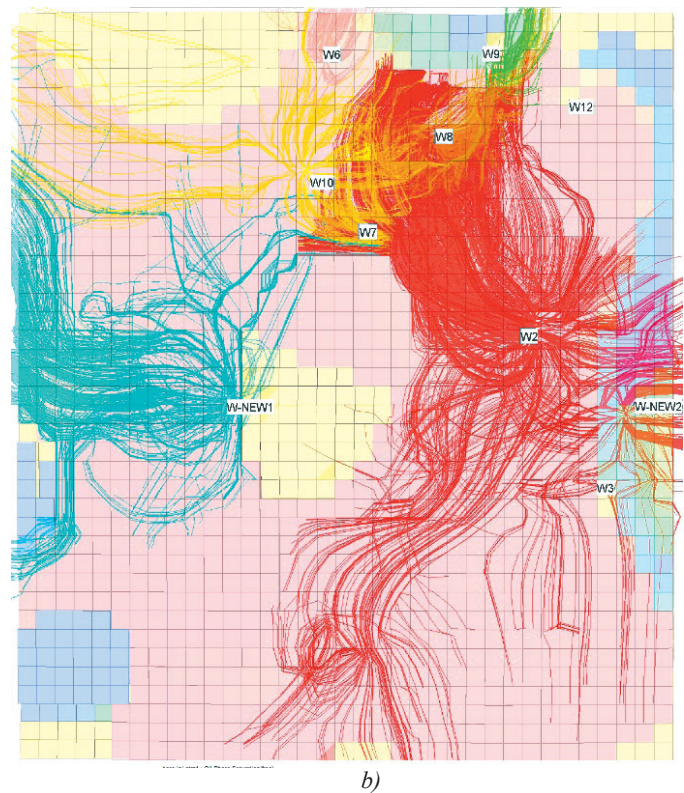


Figure 11. Filtration lines of oil flow in the Bobrikovian object (incision): a) 1 option without reservoir pressure maintenance, b) 2 option with reservoir pressure maintenance

5. By analyzing the technological performance of the wells and the results of geological and technological modeling, it was revealed that the accumulated oil production in the production stock of the Radaevskian-Bobrikovian object may exceed the average well stock by an average of 1-3 times.

References

Bazarevskaya V.G., Tarasova T.I., Timergaleeva R.R., Galimova G.S., Presnyakova A.V. (2011). Analiz gidrodinamicheskoy svyazi pri razrabotke antiklinal'nykh stratigraficheskikh zalezhey [Analysis of connectivity in development of anticlinal stratigraphic deposits]. *Neftyanoe khozyaystvo = Oil industry*, 7, pp. 12-14. (In Russ.)
 Kozina E.A. (1978). Usloviya formirovaniya i zakonomernosti razmeshcheniya karbonatnykh porod-kollektorov turneyskogo yarusy nizhnego

karbona yugo-vostoka Tatarii [Conditions of the formation and regularity of the location of carbonate reservoir rocks of the Turney stage of the Lower Carboniferous of the southeast of Tatarstan]. Avtoref. dis. kand. geol.-min. nauk. [Abstract Cand. geol. and min. sci. diss.]. Bugulma: TatNIPIneft, 21 p.

Salakhova L.N. (2012). Geologo-promyslovoe modelirovanie slozhnopostroyenykh ob'ektov na primere nizhnokamennougol'nykh zalezhey nefi Yuzhno-Tatarskogo svoda [Geological and industrial modeling of complex objects on the example of the Lower Carboniferous oil deposits of the South Tatar arch]. Dis. kand.-geol.-min. nauk [Cand. geol. and min. sci. diss.]. Moscow: Gubkin Russian State University of Oil and Gas, 185 p.

About the Authors

Marat A. Sayfutdinov – Chief Geologist, Oil and Gas Production Department Nurlatneft Tatneft PJSC
100, Sovietsky St., Nurlat, 423042, Russian Federation

Ilgizar N. Khakimzyanov – DSc (Engineering), Head of Laboratory, Institute TatNIPIneft Tatneft PJSC
32, M.Djalil St., Bugulma, 423326, Russian Federation

Tel. +7 85594 78741, e-mail: khakimzyanov@tatnipi.ru

Vladimir N. Petrov – PhD (Engineering), Head of Laboratory
Institute TatNIPIneft Tatneft PJSC
32, M.Djalil St., Bugulma, 423326, Russian Federation

Ramiz I. Sheshdirov – Sector Manager
Institute TatNIPIneft Tatneft PJSC
32, M.Djalil St., Bugulma, 423326, Russian Federation

Lyubov M. Mironova – Head of the Geology Department, Nauka LLC
66, M.Djalil St., Bugulma, 423326, Russian Federation

Manuscript received 10 January 2018;

Accepted 25 February 2018;

Published 30 March 2018

