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To the experience of Shkapovsky oilfield development

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Abstract. The article formulates the main conclusions about the development of a large Shkapovsky oil field with an emphasis on the results of the development of the main objects – horizons DI and DIV of the terrigenous Devonian. The field was commissioned following the neighboring Tuimazinsky and Serafimovsky fields, taking into account the experience of a scientifically organized system for the development of these large platform oil fields in the Volga-Ural oil and gas region. It is shown that this experience was not taken into account much, especially in relation to the unsecured needs of oil production with capital construction, material and technical supply and social facilities.

The potential of the field was realized in 18 years. Intra-contour and focal flooding, production technologies using electric centrifugal pumps (ESP), chemicalization of oil extraction processes, primary collection and transportation of products, oil, gas and water treatment technologies, etc., accelerated the development. Shkapov engineers and scientists own a number of innovations: realizing high development rates, means of preventing and eliminating salt-paraffin deposits, the introduction of double-barrel drilling, the development of high-performance ESPs, separate development of facilities, etc. At the same time, tasks were solved on eliminating ecological imbalance in the bowels and the environment, housing and public works.

The current urgent problem of the field's additional development is the activation of the production of residual oil reserves from oil and watered zones drilled with an unreasonably rare grid of wells. The final oil recovery coefficients of the Devonian objects are expected to be high, but, according to the author of the article, could reach CU 0.6.

Keywords: oil field, oil and gas reserves, in-circuit flooding, marginal flooding, development pace, oil recovery

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The large Shkapovsky oil field is characterized by an extremely uneven distribution of oil reserves across the section: 98 % of the total initial recoverable reserves (IRR) was concentrated in the Devonian terrigenous strata (production horizons DI and DIV), and only 2.0 % accounted for the remaining six objects. Of these six, the most significant IRRs were in the strata of the Lower Carboniferous (1.0 %). The share of five carbonate objects was about 1.0 % of the initial total IRRs.

In connection with this circumstance, the priority decisions in the design of the development of the field were aimed at the scientific and methodological support of the maximum development of reserves from the terrigenous Devonian objects. Scientifically based decisions on the development of the remaining objects were formed after the completion of the main development period of horizons DI and DIV, which amounted to 18 years.

The development of the Shkapovsky field took place "without proper infrastructure support" (according to the terminology of Prof. V.N. Schelkachev): in the undeveloped forest-steppe area for the first 12 years (1955-1967), they got maximum oil production under pressure from decision-makers, without ensuring elementary oil field facilities and social facilities. The government did not have the necessary material and monetary funds, but unreasonable calculations of oil production wishes existed beyond measure. As a result, after the mentioned 12 years, they received an intensive drop in current oil production. People in power were not interested in the experience of the neighboring unique Tuymazinsky field, where development and commissioning were much more reasonable. The indicated experience allowed a world-famous scientist V.N. Shelkachev to be qualified as the "Academy of the Oil Industry" (Schelkachev, 2004). But when developing the Shkapovsky field, this experience did not seem to exist.

With intensive drilling and development of the Shkapovsky field, a shortage of the most essential was constantly revealed: in drill and tubing, cement, chemicals, electric and sucker rod pumps, etc. They introduced advanced double-barrel drilling technology when two wells were drilled from one base. But the resulting time savings were often not able to use due to the lack of casing for lowering the conductor or production casing. In a number of completed wells, run-off conductors were not cemented at all, and sometimes they were removed to equip newly drilled wells. Such «innovations» turned into technological and, most importantly, environmental harm to the bowels and the environment. Almost half of the families of the working village Priyutovo, where the oil producers of Shkapovo lived, lived in barracks in difficult social conditions. There was also not enough money for housing construction. People lived and set records for production indicators, showing real heroism (this word cannot be replaced with any other suitable word) in the liquidation of accidents in pipelines and other facilities.

Only through the prism of the foregoing is it necessary to judge the pros and cons of developing the legendary field.

Despite the noted costs, the main development period of the Shkapovsky field turned out to be short: over 18 years, 75 % of the total IRRs were extracted (Lozin, Akhmerov, 2017). For large deposits, such terms are unknown to the author of the article. Once again, it has been proved that it is rational to put a field into development in one stage. Infill drilling has confirmed the correctness of the scientific concept of the optimal grid arrangement of wells. The necessity of thickening the grid to the optimum in certain areas has been proved (Lozin, Akhmerov, 2017). Infill drilling was born in the USA and was a real answer to the opinion of M. Musket regarding the uncertainty of the existence of a connection between the grid arrangement and oil recovery (Maloyaroslavtsev et al., 1969). By the way, this statement was formulated 80 years ago and has been no longer relevant, including in the United States. The development of the Shkapovsky field with closed drilling and the corresponding development of the waterflooding system proved the indicated relationship and at the same time showed that in a real heterogeneous formation the grid of wells should be irregular due to local compaction in individual sections. At the same time, it was proved that development with water flooding leads to a noticeable increase in the oil-water factor even in low-viscosity oils.

Separate development of horizons DI and DIV was also sustained (with rare exceptions due to insecurity of pumping equipment after the cessation of well flowing). This result should be considered as confirmation of one of the cornerstones of the rational development of oil fields, namely: scientifically sound allocation of development objects and their participation in the development of oil reserves. Passion for combining a number of formations into one object, often with sharply different reservoir properties, is not a rational principle of scientifically organized development.

Regarding other principles of field development

Regarding forced fluid withdrawal (FFW). The point of view is known that the development of the terrigenous Devonian of the Shkapovsky field was carried out at accelerated rates of fluid withdrawal. Liquid withdrawal from the DI horizon per one well was increasing and reached a maximum in the 90s. of the last century at the level of 175-208 tons/day. In the modern period, this indicator remains at the level of 170 tons/day. Similar dynamics are observed along the horizon DIV. At present, the selection for 1 well ranges from 150-170 tons/day. The figures cited indicate relatively high selections caused by high productivity coefficients (Musket, 1953). The following calculations indicate how figures given relate to the FFW. The potential production rates of wells of horizons DI and DIV calculated by the Dupuis formula are from 150 to 1200 tons/day. The realized production rates for individual wells reached 700-800 tons/day, and the average did not exceed (see above) 208 tons/day, i.e. ranged from 100 to 25 % of potential. The maximum possibilities of the FFW were not used, but it is indisputable that in some cases the FFW has been used. An analysis of the development indicators of areas with a FFW using many methods does not indicate cases of irregular growth in the current water cut. On the contrary, in some cases, a short-term decrease in water cut was observed. The constructed displacement characteristics (DC) confirm the technological effect.

The total technological effect of the FFW has never been calculated, but the point is that in the areas where the FFW was actually produced, the effect in the form of additional oil production is visible in the DC.

Studies have been performed showing that increasing the fluid withdrawal rate to a recovery factor = 0.4 allows increasing oil production accordingly, and then the connection is lost. An increase in fluid withdrawals at a subsequent stage allows a decrease in the rate of decline in oil production, while at the final stage the connection "recovery rate – oil recovery" does not appear.

Regarding development regulation. To maintain high production rates when stopping the flowing of wells, there was a problem of equipping them with high-performance submersible electric centrifugal pumps (ESPs) due to the lack of the required standard sizes. Domestic high-performance ESPs did not have a high pressure (and there was lack of them). Only after the purchase of imported high-performance ESPs with high-pressure characteristics, the problem was partially solved (due to the limited number of indicated ESPs). Needs were not provided for pipes for laying water conduits to newly mastered injection wells. New injection wells were connected to one conduit due to its extension from the «old» wells. Studies have proven that such a solution did not meet the provision of proper throttle response. Sometimes new production wells were mastered by connecting working wells to flow lines. What kind of development regulation could be discussed if design technological operation modes were not ensured? But the regulation «for the most part» was nevertheless ensured due to the geological and technical measures.

Regarding the water flooding. Waterflooding has passed all stages of improvement – from the contour (marginal) to the in-line contour (cutting rows into blocks) to focal-selective flooding. Under the conditions of real geological heterogeneity, confirmation has been received about the effect of injection at limited distances from the source (injection well) to the nearest and remote production, about rational injection pressures and the «rigidity» of the waterflooding system.

Regarding the well stock. This indicator ensures the fulfillment of all other indicators of oil production and field development, primarily economic ones. The quantitative expression of the well stock – production, injection and observation (piezometric) – in the design documents is determined by calculations. But in practice, distortions are observed. The category of wells "awaiting liquidation" is not regulated at all. The indicated category sometimes turns into a "pocket", where wells are placed for a long time that really require physical liquidation, but for various reasons, staying in this quality for a long time. At the early stages of the development of oil fields in the Volga-Ural province, studies were carried out aimed at obtaining production data on the average standard life expectancy of wells drilled 70, 60, 50 years ago. But this problem now does not seem to exist, and its important environmental content is obvious, including for the design of further development. In economic calculations, the complete drilling of old wells is laid, but there are no clear technical and technological regulatory boundaries. This is especially true for wells where deviations were allowed in the structures for cementing conductors, intermediate and production casing.

Regarding the rational development of oil-water zones. The gently sloping Shkapovsky brachyanticline, which controls the external and internal oil contours DI and DIV, caused the presence of wide oil-water zones, in which more than 50 % of the total oil IRRs were concentrated. A similar phenomenon was first encountered in the exploration of the giant Tuimazinsky brachiantclinal. Comparing the development of the Tuymazinsky field with the giant US field East-Texas, prof. V.N. Schelkachev consistently emphasized that the oil-water zones at the latter were drilled along a much denser grid. Actually, the Woodbine sand layer with high reservoir properties in the East Texas field over the entire vast area of its monoclinic distribution is lined with bottom water and drilled with an almost hectare grid. At the Tuymazinsky field, the drilling rig of the oil-water zones was 2-3 times less dense compared to the initially completely oil zone, where in turn the grid density averaged 20 ha/well. At the same time, 11 % of the Tuymazinsky area of oil-water zones was occupied by the so-called "contactless" areas, i.e. such, where the oil-unsaturated part is separated from the water-saturated impermeable layer. At the Shkapovsky field there were essentially no "non-contact" sites in the oil-water zones. The situation on large platform deposits is exacerbated by another circumstance. In the annular zones adjacent to the external contour of oil content, oil-saturated thicknesses are 1-3 m with water-saturated from 3 to 10 m.

Such an unfavorable ratio of oil-saturated and water-saturated thicknesses is compounded by increased geological heterogeneity and clayiness of the upper oil-saturated thicknesses. The oil reserves contained here are not produced. This is confirmed by well logging data for new wells.

The authors of the article (Yakupov et al., 2019), who examined the problem of additional development of oil-water zones in platform deposits using the example of Shkapovsky, rightly (following other authors) raise the question of additional development of oil-water zones using horizontal wells and wells with horizontal completion. The following scheme of oil reserves development using the indicated wells is given (Fig. 1):

The above scheme has to be recognized as relevant to modern reality. The high initial oil production rates from the horizontal wells and wells with horizontal completion in oil-water zones with moderate water cut are very rapidly reduced due to the sharp water cut, which casts doubt on the profitability of drilling. This is also shown in the article (Chekushin et al., 2015). The depressed scheme shown indicates a predominant gradient of involvement in the development of the middle and lower parts of the reservoir, which have the best properties compared with the upper and adjacent middle parts. The essence of horizontal drilling consists mainly in creating a cylindrical «funnel» of depression along the axis of the trunk. And this can be achieved

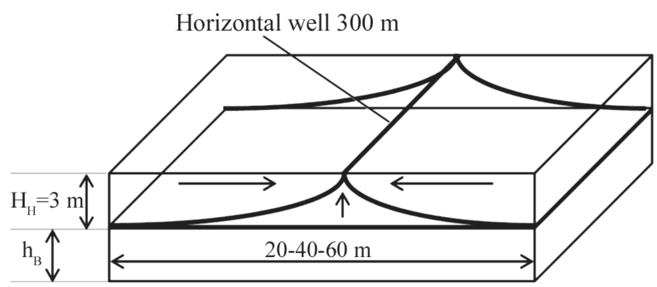

Fig. 1. The scheme for creating depression in water-oil zones in horizontal wells (according to (Yakupov et al., 2019))

only by selecting the technological mode of operation of horizontal wells, and not just by creating conditions for maximum extraction. It is also advisable to investigate the nature of the perforation of the horizontal well in the oil-water zones (maybe there are no perforations to be created below, etc.). This requires scientific research.

For all the expenses outlined today, it is indisputable that the oil recovery factor for the terrigenous Devonian of the Shatapovsky field is at least 0.565: for the DIV horizon – 0.58, for the DI horizon – 0.55, which corresponds to the difference in oil viscosities. In the author's opinion, the oil recovery factor could have been more – not lower than 0.6.

The article does not consider all the development lessons of the Shkapovsky oil field. These include, for example, ideas about the prospects for further development of the field using enhanced oil recovery technologies, of which the most attractive is the technology of exposure using liquid carbon dioxide. There are approximate calculations about the effectiveness of this technology, but this is the topic of another article.

Conclusions

To conclude, the main lessons of the development of the Shkapovsky oil field testify to the viability of the following principles:

1) The feasibility of entering the field in one stage;

2) Equity of separate development of facilities;

3) Selection of the optimal well grid arrangement for a real operational facility with drilling of infill wells in local areas of a heterogeneous geological environment;

4) The rationality of the high pace of development due to reservoir properties of deposits;

5) The inevitability of high water-oil factor during development with water flooding, even for low-viscosity oils;

6) The feasibility of drilling the water-oil zones on dense grids using the capabilities of horizontal wells and wells with horizontal end;

7) Maximum technological efficiency of water-flooding with focal-selective schemes.

8) Creation of a system for monitoring environmental safety, anthropogenic pressure on the subsoil and the environment.

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