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DEVELOPMENT MODELING OF THE NEFT DASHLARI FIELD WITHIN THE SOUTH CASPIAN BASIN

(***Представлено членом редакційної колегії д-ром геол. наук, проф. Володимиром МИХАЙЛОВИМ***)

Background. ***The paper examines the current state of development of the productive horizons within the South Caspian Basin, focusing on Block IV of the Neft Dashlari field. As one of Azerbaijan's largest offshore fields, Neft Dashlari possesses significant hydrocarbon reserves. This study systematizes extensive geological and field data to provide a reliable description of the field's geological and technological characteristics, including stratigraphy, tectonics, fluid hydrochemistry, and current reserve status.***

Methods. ***The study is based on the analysis of historical production data since the field's discovery in 1949. Statistical and geological modeling was used to evaluate the 26 discovered oil-bearing layers. The research focuses on the distribution of industrially significant residual oil reserves within the upper and lower stages of the Productive Series (PS) sediments.***

Results. ***Since the commencement of operations, cumulative production has reached 168,787.1 thousand tons of oil, 243,913.2 thousand tons of total liquid, and 13,090.4 million cubic meters of dissolved gas. Current annual production stands at 812 thousand tons of oil with an average water cut of 38.2 %. The average daily well yield is 7.2 tons of oil and 11.7 tons of liquid. The utilization rate of recoverable reserves is 87.3 %. The current oil recovery factor (ORF) is 0.440, while the ultimate ORF is estimated at 0.504. To maintain pressure and enhance recovery, water injection has been employed since 1953, specifically targeting the VII and X horizons, as well as the Fasila and Kirmaki suites of Block IV.***

Conclusions. ***Development models for Block IV indicate that micellar flooding is a highly effective Enhanced Oil Recovery (EOR) method for extracting residual reserves. The use of microemulsions allows for the revitalization of flooded layers, potentially increasing the ORF to 50–60 %. Furthermore, it is recommended to increase reservoir sweep efficiency, reduce water cut, and optimize the well stock through sidetracking (drilling of lateral boreholes). To further enhance recovery at the final stage of development, the implementation of Water-Alternating-Gas (WAG) injection and the transfer of flooded wells to higher productive horizons are proposed.***

Keywords: ***oil recovery factor, exploitation, water injection method, development indicators of the horizons, oil production, gas production, development rate.***

Background

Analysis of the latest research and publications. The global surge in oil demand has created a pressing need to optimize the production of existing oil fields, given the decreasing number of new discoveries. Due to the maturity of most of these large fields, it is essential that reservoir management and development strategies be implemented with care to maximize recovery factor (RF) and economic return, and minimize the negative impact on the environment.

By employing innovative technologies and implementing robust reservoir management practices, the industry can unlock untapped potential and extend the lifespan of existing oil fields. Such strategies not only contribute to meet the growing energy demands but also promote sustainable resource utilization and minimize the need for exploration in environmentally sensitive areas.

So, oilfield development optimization plays a vital role in maximizing the potential of hydrocarbon reservoirs. Decision-making in this complex domain can rely on various objective functions, including net present value (NPV), expected monetary value (EMV), cumulative oil production (COP), cumulative gas production (CGP), cumulative water production (CWP) (Auref Rostamian et al., p. 13, 2024).

As noted by Szklarz et al., (p. 45, 2024) the optimization framework used relies on modern methods to enable robust optimization over an ensemble of model realizations in a computationally efficient. This allows the optimization framework to be easily employed in a variety of problems, ranging from the support of different types of field development decisions to assisting in the design of renewable energy systems.

According to Leandro et al., (p. 587, 2024) the hydrocarbon extraction process is complex and involves numerous design variables and mitigating risks. Numerous time-consuming simulations are required to maximize objective functions of a particular field while contemplating a significant representation of uncertainty scenarios and various production strategies. Production strategies searches may result in a high-dimensional search space which can yield sub-optimal reservoir economical exploration. As a solution, appropriate optimization algorithms selection and tuning may provide good solutions with lesser simulations.

The purpose of modeling the development process (building development curves) is to track the efficiency and evaluate the progress of field development within the South Caspian basin in the case of the Neft Dashlari field. Development curves visualize and analyze the progress of the development project, identify deviations, and make informed decisions to optimize the process, identify problems at an early stage and take corrective measures, identify potential risks and problems (water cut, pressure drop in the development facilities, etc.) that may arise during the development process.

Problem statement. Modeling the development process, tracking the efficiency and evaluation of the field development progress and selecting appropriate oil recovery methods. Identifying distribution areas of residual oil reserves.

Methods

Short information about of the field

The Neft Dashlari field is one of the largest fields of Azerbaijan located within the South Caspian basin (Pogorelova et al., 2024, p. 51; Pogorelova, Abbasova, & Abdulla-zada, 2024, p. 365; Rzayeva, Abdullayeva, & Tagiyev, 2024, p. 556), in terms of the volume of oil and gas reserves including other components. About seventy-five years from 1949 this field was covered by development process and 160 mln. tons of oil and 12.3 billion m^3 of gas were obtained from productive layers of this field. Today, there are 377 wells in operation and an average of 5 tons of oil is obtained from each one per day. Every day, 5–6 new wells are drilled in the Neft Dashlari field, and each of them has the ability to produce 15–16 tons of oil per day in the initial period of development (Wikipedia, the Encyclopedia, 2024). It should be noted that there is a high effect of the Neft Daslari field on the development of the oil industry in Azerbaijan. Geologically the Neft Dashlari is a very interesting field. It is multilayered and consists of 26 productive horizons (Wikipedia, the Encyclopedia, 2024; Namazov et al., 2024, p. 116). In addition, the volume of the remaining recoverable oil reserve over 20 mln tons are estimated here.

The results of the conducted prospecting-exploration work and the development process of the objects made it possible to obtain important geological-field information about the field. The collection and systematization of these data allows for a reliable description of the geological-technological characteristics of the field. Thus, based on this geological-field information the stratigraphy, tectonics, oil-gas-bearing, reserves, hydrochemistry of fluids, etc. of the field was studied. The study of data allowed us to obtain the following information about this structure:

Stratigraphy of the field. Productive series (Middle Pliocene-₽) – the lithological composition of the PS, as in most structures located in the South Caspian basin, consists of a rhythmic alternation of sand, sandstone, siltstone and clay. The maximum thickness of these sediments is 2400 m and they are divided into two stages: lower stage including Gala (GaS), Pre-Kirmaki (PK), Kirmaki (KS), Post-Kirmaki sandy (PKS), Post-Kirmaki clayey (PKC) suites, and upper stage including Fasila (FaS), Balakhani BaS), Sabunchi (SaS), Surakhani (SuS) suites (Gasanov, Gurbanov, & Abbasova, 2022; Karimov, Sharifov, & Zeynalova, 2023, p. 276).

GaS lithologically consists of clays, alternating with interlayers of aleurite and sand. In some cases, the thickness of sand and aleurite interlayers reaches 20–25 m.

Based on the logging diagram, 8 sandy layers are noted along the section of GaS. It should be noted that the lithological structure of the GaS differs in different blocks. For instance, in block II, along the wells numbers of 229, 256, 1591, 1667, 2072, six sand layers, and in block IV, along the well number of 900 seven sand layers are noted.

In the south-west limb of the Neft Dashlari structure, on which the Neft Dashlari field is located, oil-bearing of GaS_5, GaS_6, GaS_7, and GaS_8 layers were not discovered.

The thickness of the interlayers of GaS is different. For instence, between the GaS_2, and GaS_1 layers, its thickness is 10–25 m, between GaS_5, and GaS_4 is 10–15 m, between GaS_6, GaS_7 is 30–40 m. The thickness and lithological composition of sand layers and clay interlayers do not remain constant along the area. The sand content of GaS increases from bottom to top. However, GaS_1, GaS_2, GaS_4, GaS_5 oil-bearing layers are sandier. While the total thickness of GaS is 190 m in the crest, it is 900 m in the south-east periclinal of the structure (well 1841).

The section of the PK consists of gray sand and sandstone deposits layers, as well as thick clay layers. Clay content of suite is 30 %. Clay layers are situated in the middle and lower parts of the section. Sands are mainly medium and coarse-grained. In the logging diagrams, its value is up to ρ_k = 100 Ohm·m, and in some cases more (Kerimova, Samadzadeh, 2023). In addition, by SP curve sands are better differentiated. 4 sandy layers are separated along the section of PK suite including $PK_{2\text{-lower}}$, $PK_{2\text{-upper}}$, PK_1, PK_{upper}, on which are separated by clay layers of 5–12 m (sometimes 20 m) thick. The oil-bearing of these layers varies along the others blocks. Thus, the $PK_{2\text{-lower}}$ in blocks Ia, II, IV, V is oil-bearing, $PK_{2\text{-upper}}$, PK_1 are oil-bearing in all blocks, and $PK_{2\text{-upper}}$ is oil-bearing only in block II. Sand content of the PK suite is 70% and decreases from the crest to the limb. The thickness varies between of 70–130 m, on average is 120 m.

Lithologically KS consists of alternating fine-grained sand and sandstone, clay and clayey sands. The thickness of the sand layers increases downward to the bottom of the section and reaches 10 m. In the logging diagrams, the suite is characterized by a low value: ρ_k = 2–4 Ohm m; at the bottom, relatively sandy part of the section, ρ_k up to 50 Ohm·m is noted. The sand content of the suite is 20–35 %. In the bottom of the section with high sand content, there are 3 layers: KS_2, KS_1, KS_{upper}, and they are separated by clay interlayers with a thickness of 5–10 m. These layers are oil-bearing in all blocks of the structure. The thickness of KS sediments is 165 m in the crest of the structure, while it increases in the north-east and south-west limbs up to 275 m and 400 m, respectively.

The lithological composition of the PKS suite sediments consists of medium- and coarse-grained sand (with sandstone) layers; sometimes clay layers are also found. In the sand and sandstone layers, pebbles with a diameter of 1–2 mm are also present. The sand content of the suite is very high; it is 70–90 %. There are two peaks along the logging diagram: the lower part of the section is characterized by a high value of ρ_k, where up to 90 Ohm m is noted, while the upper part is characterized by value of ρ_k, where between of 10–20 Ohm·m is noted. It is expressed positively along of the SP curve. The PKS suite exploited as a single object and is oil-bearing in blocks Ia, II, III, IV, V. The thickness of the suite is between 15–50 m, on average is 25 m.

The lithological composition of the PKC consists of clays, aleurite, sand and sandstone interlayers are also found. Compared to other fields of the South Caspian basin, the sand content here is relatively high (up to 40 %). The lower, relatively sandy part of the suite along the logging diagram is characterized by 10 Ohm·m of AR (ρ_k), while the upper part consists mainly of clays. The PKC suite is oil-bearing in blocks II, III, IV and V of the field. The thickness of the suite is varying in the range of 90–220 m, while on average is 135 m thick.

FaS consists of medium- and coarse-grained quartz sands and sandstones, rarely thin clay interlayers are found along the section. There are pebbles with a diameter of 8 mm in the sands; sand content of suite is 65–70 % and increases toward crest of the structure. In the logging diagram, ρ_k between 100–125 Oh·m is noted, sands are well differentiated by SP curve (Kerimova, & Samadzadeh,

p. 148, 2023). FaS is oil-bearing in blocks II, III, IV and V. The thickness of the suite varies in the range of 60–130 m, on average is 75 m.

BaS suite consists of medium- to coarse-grained quartz sands and sandstones with clay interlayers. Sand content of the suite varies in the range of 50–60 %. X, IX, VIII, VIIa, VII, VI, V sandy horizons are found along the BaS section.

The horizon X is composed of fine-medium-grained sands and sandstones. By the logging diagrams the AR of sands (ρ_k) 100 Ohm·m is noted. The SP curve is well differentiated. The horizon is oil-bearing in blocks II, III, IV, V of the structure. It varies 30–70 m in thickness, on average is 50 m.

The horizon IX consists of sand and sandstone with clay interlayers, sands are fine- and medium-grained, consists up to 60 %. The pk-m value is recorded up to 175 Ohm·m in the logging diagrams. Horizon is oil-bearing in the III, IV, V blocks; the thickness of its of 38–70 m, on average is 55 m.

The horizon VIII consists of medium- and fine-grained sand, sandstones and clays. In the logging diagrams, the value of ρ_k up to 170 Ohm·m is recorded, while the SP curve is well differentiated. It varies from 35 to 70 m thick, on average it is 55 m, in addition, it is oil-bearing only in blocks III, IV, V.

The lithological composition of the horizon VII consists of an alternation of sand and clay; sands are abundant. The value of AR of sands in the logging diagram is recorded up to 75–125 Ohm·m. At the bottom of the horizon, a sand layer with a thickness of 30–75 m (VIIa) is found. ρ_k in front of the VIIa horizon in the logging diagrams is expressed very high value, reaching 215 Ohm·m. In the III, IV, V blocks of the field, the horizon VII is oil-bearing, and in the II, III, IV, V blocks, the VIIa oil is found. The total thickness of the VII + VIIa horizon is 110–120 m.

The horizon VI consists of alternating sand-clay layers. ρ_k up to 260 Ohm·m along logging diagrams. It varies from of 100 to 150 m thick, while on average is 125 m, and it is oil-bearing in blocks IV and V of the field.

Lithologically horizon V consists of alternating sand-clay layers. In front of sand layers, the ρ_k expressed by 80 Ohm·m. The thickness of the horizon varies between of 70–100 m, while on average is 80 m.

The lithological composition of SaS consists of alternating sand and clay layers; the amount of sand is 50 %. These sediments are found on the limbs of the fold and in the south-east periclinal. The thickness of the suite is 250 m; there are IV, III and II sand horizons found along the section.

The thickness of the IV horizon varies from 110 to 155 m; on average it is 140 m thick. it is oil-bearing in the III and V blocks of the field. Along logging diagrams $\boldsymbol{\rho_k}$ indicates by 95 Ohm·m.

The III horizon consists of an alternation of sand and clay layers according to the lithological composition; sands are prevailing. The thickness of the horizon on average is 30 m, it varies in the range of 20–45 m; ρ_k up to 16 Ohm·m is noted.

The horizon II consists of an alternation of sand and clay in lithological composition; sands are prevailing. The thickness of the horizon on average is 35 m, it varies in the range of 30–55 m. This is oil-bearing in blocks III and IV of the field. ρ_k up to 7 Ohm is recorded.

SuS consists of an alternation of sand and clay in lithological composition; clay layers are prevailing. Sand horizons I and I^1 are found in the bottom part of the suite, which lithologically consists of fine-grained sands. These sediments cover the limbs of the structure and the far southeast periclinal. The value of the ρ_k in front of reservoirs of the I and I^1 horizons are of 30–50 and 74 Ohm·m, accordingly. The thicknesses of I and I' horizons are 30 and 35 m, respectively, and vary in intervals of 25–40 and 30–40 m. According to geophysical data, it is assumed that these horizons are oil-bearing in block III of the field.

The interpretation of the stratigraphy of the field allowed singling out 26 development objects along its section.

Field tectonics. The Neft Dashlari field is a brachyanticlinal structure. It is asymmetric and extended from the north-west to the south-east with a length of 11 km and 6 km width. The field is complicated with longitudinal and latitudinal faults and divided into 6 tectonic blocks. Conducted studies show that tectonic faults are screen type. Anyway all blocks are isolated from each other by fault plains. So, each block is developed individually.

Oil-bearing and water charachteristics of the field. The suites and horizons of the Neft Daslari field are mainly oil-bearing and exploited for a long time. The data characterizing the potential of the field were determined. Using this information, it is possible to regulate of development process of the target objects.

The initial balance, recoverable reserves, cumulated reserves, as well as the volume of remaining reserves of individual objects were collected and systematized. Preliminary studies show that the current potential of the field is mainly related to the V and IV blocks, which we will analyze.

According to the presented hydrochemical information, the mineralization of formation waters changes from 720.2 mg-eq/100g (Absheron stage) to 48.0 mg-eq/100g (GaS). The degree of mineralization of waters gradually decreases with depth. If chloride-magnesium and chloride-potassium waters are found in the upper horizons of the PS, starting from the PKS to the bottom of the GaS there are hydrocarbonate-sodium type waters in the lower stage. According to the genetic characteristics, the "transitional" waters in the Fasila suite of PS are found. Alkaline waters are also found along the sections of GaS, PK, KS and PKS.

Character of the regimes of individual deposits under development is based on the changes of the parameters of these deposits during exploitation, as well as the nature of the edge water zone energy. For this purpose, the absence of a gas cap, initial layer pressure exceeding the dissolution pressure, the amount of the gas factor, the rate of drop of the layer pressure, the movement intensity of the contour waters, the waterflooding characteristics of the marginal wells, etc. factors are taken into account. Due to the fact that the specified factors and parameters do not remain constant during processing, the layer regime is also changed.

Thus, the information characterizing the Oil Stones field is described in special tables, which will be used in the next stages of the work.

Results

The Neft Dashlari field was discovered in 1949, put into exploitation in 1950. The first industrial oil flow from GaS of the field was obtained. 26 oil layers were discovered in the geological section of the Neft Dashlari field. At present, the industrially significant remaining oil reserves of these exploitation facilities are concentrated in the upper and lower stages of the PS sediments.

At the beginning of development, 168787.1 thousand tons of oil, 243913.2 thousand tons of liquid, 13090.4 mln.m^3 of dissolved gas were extracted from the field. Annual oil production of the field was 812 thousand tons, liquid production was 1313.8 thousand tons, and dissolved gas production was 57.1 million cubic meters. The current gas factor is 70.3 m^3/t. The water cut of the product was 38.2 %.

In addition, the average production per well is 7.2 t of oil and 11.7 t of liquid.

Utilization of recoverable oil reserves is 87.3 %. The current oil recovery factor for the field is 0.440, and the ultimate oil recovery factor is 0.504.

In order to increase the oil recovery factor in the field, the method of water injection on the productive layers was applied (Bagirov, 2003). The injection process started in 1953. This process was applied to the VII, X, FaS and PK-2 horizons of the IV block, which is the object of the study (Bagirov,1982, p. 36). Based on the analysis of the development data of the IV block, it was determined that 19 horizons are under development in this block. Of these, 14 horizons were injected by water. The development process is being carried out in the 15 horizons at current period. During the development process, 76 wells were drilled into this horizon. In total, 32531.5 thousand tons of oil, 15228.2 thousand m^3 of water, 2896.8 mln. m^3 of dissolved gas was produced. In particular, these indicators are noted for 2011 in the following order: 120.3 thousand tons of oil, extracted water is 161.9 thousand m^3, gas dissolved in oil 8.5 million. m^3 is estimated. 4 injection wells were drilled into horizon. 235.3 mln m^3 of water per day were pumped by these wells.

Thus, the amount of water (Karimov, et. al., 2023, p. 276) injected into the horizon since the beginning of the impact was 45967.9 thousand m3, additional oil production since the beginning of the impact was 16276.0 thousand tons.

The development of the X horizon of block IV started in 1966. From the beginning of development, 1080.9 thousand tons of oil and 2008.6 thousand m^3 of water were extracted from the horizon. The utilization rate of recoverable oil reserves is 61.9 %. In 2017, annual oil production on the horizon was 8.9 thousand tons, water production was 16.3 thousand m^3, the current gas factor was 70.8 m^3/t, and water production was 65 %. Average oil production per well per day is 3.7 tons. The number of operating wells is 8, the number of injection wells is 1, the development rate is 0.51 %.

Water injected into the horizon since 1971 and is being continued intermittently until now. The volume of water injected since the beginning of the pumping was 707.5 thousand m^3. Currently, the annual volume of water injected into the horizon is 28.3 thousand m^3 (Table 1). The development period of the layer consisted of two stages (I and IV). The first stage lasted until 1972, and in the following years, with a sharp drop in production, it moved to the IV stage. Currently, the layer is in the final stage of development (Fig. 2) (Bagirov, 1982; 2003, p. 38).

The development of the Fasila suite (FaS) of block IV started in 1956. From the beginning of development, 3080.3 thousand tons of oil and 2439.2 thousand m^3 of water were extracted from the horizon. In 2017, annual oil production on the horizon was 7.1 thousand tons, water production was 6.8 thousand m^3. The utilization rate of the recoverable initial oil reserve was 92.3 %, the current gas factor was 70.9 m^3/t, and the water production of the product was 48.9%. Average oil production per well per day is 3.4 tons. The number of operating wells is 7, the development rate is 0.21 %.

Based on the well data collected by studies, the distribution areas of the remaining oil reserves were determined. The area with the most distribution of hydrocarbon accumulations is the zone of well number of 1931 located in the northwestern part of the field (Fig. 1) (Eminov et al., 2022, p. 20; Maharramov, Karimov, & Sharifov, 2022, p. 514).

The second remaining oil reserve is located in the west of the field, in the zone of wells 2216 and 2218. In addition, another area is located in the east of the field (Fig. 2).

For obtaining remaining oil reserve, it is necessary to increase the coverage of the layer by displacement, to reduce the water cutting of the production, and reconstruction of the well stock by sidetracking well hole.

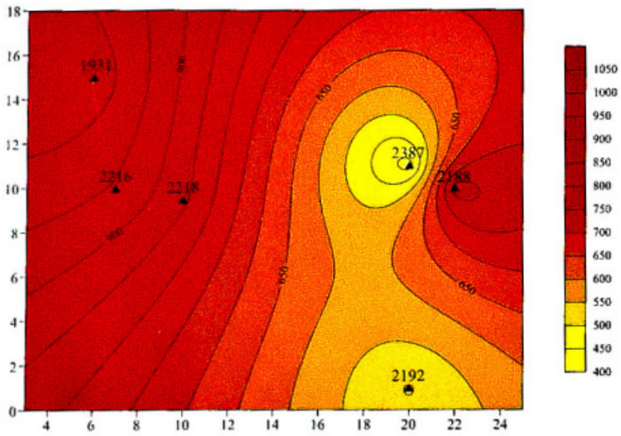

Fig. 1. Distribution areas of residual oil reserves (Eminov et al., 2022, p. 21)

The injection process in horizon started in 1961 and continued until 2013. The volume of injected water since the beginning of the injection was 8330.6 thousand m^3 (Table 2).

The development period of the layer consisted of three stages (I, III and IV). The first stage lasted until 1972, the stage III lasted until 1981, and in the following years it passed to stage IV due to a sharp drop in production. Currently, the layer is in the final stage of development (Fig. 3) (Bagirov, 1982, p. 37).

The development of the PK-2 horizon of block IV started in 1954. According to the data of 01.01.2018, 2343.5 thousand tons of oil and 855.4 thousand m^3 of water were extracted from the horizon (Table 3). The utilization rate of the recoverable initial oil reserve is 90 %. Annual oil production on the horizon was 9.9 thousand tons, water production was 16.7 thousand m^3. Current gas factor was 69.3 m^3/t, and water product was 62.8 %. Average oil production per well is 5.5 tons. The number of operating wells is 6, the number of injection wells is 1, the rate of development is 0.38 % (Fig. 4) (Kərimov, Sharifov, & Zeynalova, 2023, p. 277).

The figure shows how to use the production decline curves to diagnose the production performance of a well, where the solid line (red) in the figure represents a gradual decline of the reservoir pressure along the development process of the horizons. In the period of late development stage, the real production skews and gradually moves downwards, it indicates that there is interwell interference, which reduces the original oil (gas) in place of the wells.

The lifetime of a field development and the shape of the production curve are often related to the type of hydrocarbon that is produced. For example, natural gas flows very easily and can be extracted almost all at once, which results in high decline rates in extraction.

To illustrate the development process, the production curve used to illustrate dominant features is given below in Figure 2, 3, 4, in which production rate increases linearly with time until the production rate reaches its maximum value.

The production curves clearly show how oil production is affected by differences of water injection. With water injection, curve shows the rapid decline of oil, gas production that occurs just after water breakthrough the pore volume of reservoir had been injected (see, Fig. 2, 3, 4).

Effective extraction of hydrocarbons from target objects that are at a late stage of development and are heavily flooded is an urgent problem that oilmen face every time during the development process. As can be seen from the models, high water cut is observed at operational facilities. The causes of this situation can be analyzed from two factors: natural and technological. Natural factors exclude the rise of the oil-water contact, uneven floods of the layers, and the presence of highly permeable interlayers within fields. Technological factors exclude the breakthrough of pumped water into facilities.

High water cutting of the horizons led to premature depletion and a decrease in its final oil recovery, as well as to a negative effect on the operation of the reservoir pressure maintenance system. The maximum water cut in the exploitation object horizon X (1989), in the Fasila (Fa) (1999) and in the PK-2 (1991) suites was 81.87%, 67.10 % and 63.64 %, respectively, and this, in turn, affected the annual oil production, which was constantly decreasing. So, if in 1967 oil production was 57 thousand tons along the horizon X, then in 2017 it was 8.9 thousand tons. If in 1972 oil production was 190 thousand tons in the Fasila suite, then in 2016 it was 4,2 thousand tons. If in 1957 oil production by PK-2 was 120.9 thousand tons, then in 2017 it was 9.9 thousand tons (Fig. 1, 2, 3; Table 1, 2, 3).

The analysis of the development of the reservoir shows that the implemented system of maintaining reservoir pressure is not effective enough and cannot provide optimal conditions for the production of reserves. The maintaining reservoir pressure system depends on its modernization (changes in the direction of filtration streams, cyclic injection, etc.).

Table 1

The Neft Dashlari field. Development indicators of horizon X of the IV blok

Year	Oil, t. t.	Water, t. m^3	Well number		Reservoir pressure	Injected water, t. m^3	Liquid, t. m^3	Rate, %	Water cut, %	Year	Oil, t. t.	Water, t. m^3	Well number		Reservoir pressure	Injected water t. m^3	Liquid, t. m^3	Rate, %	Water cut, %
			Production	Injection									Production	Injection					
1966	17		7				17	0,97	0,00	1992	7,9	2,4	5				10,3	0,45	23,30
1967	57	23	12				80	3,26	28,75	1993	15,1	3,2	6				18,3	0,86	17,49
1968	40	25,8	12				65,8	2,29	39,21	1994	14,5	3,2	6				17,7	0,83	18,08
1969	45	49	14				94	2,58	52,13	1996	11,8	6,7	8				18,5	0,68	36,22
1970	45	42,9	6				87,9	2,58	48,81	1997	9,9	17,5	10	1		3,6	27,4	0,57	63,87
1971	43	43,3	13	1	82,31	13,4	86,3	2,46	50,17	1998	12	24,6	12	1		48,6	36,6	0,69	67,21
1972	84	58,6	16	1		30,7	142,6	4,81	41,09	1999	12,6	36	11	1		26,8	48,6	0,72	74,07
1973	50	80,7	16	1		17,5	130,7	2,86	61,74	2000	13,8	44,1	11	1		37,2	57,9	0,79	76,17
1974	29	100,8	12	1		26,9	129,8	1,66	77,66	2001	11,8	46,2	9	1		36,5	58	0,68	79,66
1975	29	68,2	11			7,6	97,2	1,66	70,16	2002	9,5	34,5	8	1		44,8	44	0,54	78,41
1976	22	54,3	11				76,3	1,26	71,17	2003	7,9	33,8	13	1		29,1	41,7	0,45	81,06
1977	24	72,9	12				96,9	1,37	75,23	2004	7,7	30,9	9	1		18,3	38,6	0,44	80,05
1978	26	74,9	10				100,9	1,49	74,23	2005	12,1	42,3	15	1		16,8	54,4	0,69	77,76
1979	26	82,8	12				108,8	1,49	76,10	2006	16,2	51,4	14	1		19,7	67,6	0,93	76,04
1980	31	100,9	12				131,9	1,78	76,50	2007	19,7	32,3	16	1		13	52	1,13	62,12
1981	35	85,4	16				120,4	2,00	70,93	2008	15,6	33,8	15	1		16,7	49,4	0,89	68,42
1982	36	85,1	19				121,1	2,06	70,27	2009	13	21,1	13	1		17,9	34,1	0,74	61,88
1983	35	85,9	18	1		82,3	120,9	2,00	71,05	2010	10,7	16,6	12	1		17,3	27,3	0,61	60,81
1984	24,6	53,9	19	2		31,1	78,5	1,41	68,66	2011	14,3	23,8	10	1		18,1	38,1	0,82	62,47
1985	20	41	16				61	1,15	67,21	2012	11,3	23,6	9	1	39	18,6	34,9	0,65	67,62
1986	16	50,8	14				66,8	0,92	76,05	2013	11,3	25,9	10	1		16,7	37,2	0,65	69,62
1987	19,6	30,4	13				50	1,12	60,80	2014	7,7	28,4	10	1		22,2	36,1	0,44	78,67
1988	12,7	28,9	10				41,6	0,73	69,47	2015	7,4	23,5	9	1	27,6	23,9	30,9	0,42	76,05
1989	3,5	15,8	6				19,3	0,20	81,87	2016	8,1	18	8	1	28,8	23,9	26,1	0,46	68,97
1990	11	8,3	8				19,3	0,63	43,01	2017	8,9	16,3	8	1	28,8	28,3	25,2	0,51	64,68
1991	8,7	4,9	9				13,6	0,50	36,03										

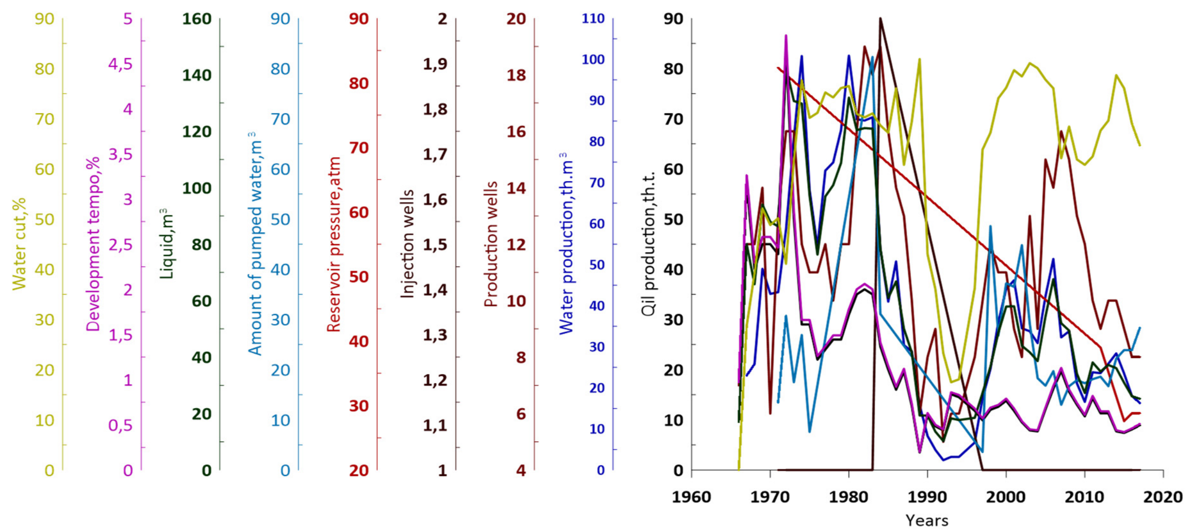

Fig. 2. The Neft Dashlari field. Development model of horizon X of the IV blok

Table 2

The Neft Dashlari field. Development indicators of horizon Fa of the IV blok

Year	Oil, t. t.	Water, t. m³	Well number		Reservoir pressure	Injected water, t. m³	Liquid, t. m³	Rate, %	Water cut, %	Year	Oil, t. t.	Water, t. m³	Well number		Reservoir pressure	Injected water, t. m³	Liquid, t. m³	Rate, %	Water cut, %
			Production	Injection									Production	Injection					
1956	0,9		2				0,9	0,03		1987	43,6	36,5	16	1	54,05	96	80,1	1,31	45,57
1957	11,1		2				11,1	0,33		1988	39	40,3	18	2	54,05	30,5	79,3	1,17	50,82
1958										1989	35	40,3	6		54,05	8,4	75,3	1,05	53,52
1959	1,7		3				1,7	0,05		1990	42,1	47,2	8		54,05		89,3	1,26	52,86
1960	19	0,8	5				19,8	0,57	4,04	1991	44,8	27,7	9		54,05		72,5	1,34	38,21
1961	93,8	4	14	1		9,5	97,8	2,81	4,09	1992	43	33	5				76	1,29	43,42
1962	107,5	10,2	13	3		173,5	117,7	3,22	8,67	1993	57,3	40,9	6				98,2	1,72	41,65
1963	85,2	19	15	5		388,9	104,2	2,55	18,23	1994	33,5	43,5	22				77	1,00	56,49
1964	75,6	20	17	5		507,3	95,6	2,27	20,92	1995	29	52	22				81	0,87	64,20
1965	53,4	21,9	17	5		340,7	75,3	1,60	29,08	1996	27,6	47,9	23				75,5	0,83	63,44
1966	91,8	21,4	19	5		302,5	113,2	2,75	18,90	1997	27,1	45,1	20				72,2	0,81	62,47
1967	87,6	16,3	17	5		294,9	103,9	2,63	15,69	1998	22,9	33,3	15				56,2	0,69	59,25
1968	96,4	24,6	22	6		262	121	2,89	20,33	1999	17,6	35,9	11				53,5	0,53	67,10
1969	72	65,4	18	8		295,8	137,4	2,16	47,60	2000	15,8	24,3	15				40,1	0,47	60,60
1970	102	41,7	20	8		339,9	143,7	3,06	29,02	2001	18,1	17,2	15				35,3	0,54	48,73
1971	89	38,3	22	9	64,9	536,1	127,3	2,67	30,09	2002	17,3	17,9	16				35,2	0,52	50,85
1972	190	77,9	35	7		562,1	267,9	5,69	29,08	2003	22,1	17,4	18				39,5	0,66	44,05
1973	184	93,2	41	7		718,8	277,2	5,51	33,62	2004	22,8	24	18				46,8	0,68	51,28
1974	129	105,7	30	7		440	234,7	3,87	45,04	2005	27	36	18				63	0,81	57,14
1975	74	77,5	21	4		321	151,5	2,22	51,16	2006	30	35,1	17	1		10,3	65,1	0,90	53,92
1976	57	57,6	21	5		310,9	114,6	1,71	50,26	2007	23,5	26,8	14	1		10,8	50,3	0,70	53,28
1977	61	69,5	27	3		307	130,5	1,83	53,26	2008	23	23,9	17	1		12	46,9	0,69	50,96
1978	89	91,5	33	3		246,6	180,5	2,67	50,69	2009	21,4	17,3	13	1		6,5	38,7	0,64	44,70
1979	97	116,2	31	2		382,8	213,2	2,91	54,50	2010	17,5	13,1	12	1		7,7	30,6	0,52	42,81
1980	85	129	31	2		264,1	214	2,55	60,28	2011	15,2	9,7	8	1		7,8	24,9	0,46	38,96
1981	83	101,5	31	2		168,7	184,5	2,49	55,01	2012	13,3	9,8	9	1	42,4	7,9	23,1	0,40	42,42
1982	59	95,4	29	3	58,7	201,1	154,4	1,77	61,79	2013	15,5	17,5	11	1		14,6	33	0,46	53,03
1983	56	93	22	5	54,29	252,6	149	1,68	62,42	2014	8,2	22,4	9				30,6	0,25	73,20
1984	41,5	68,3	21	3		160,3	109,8	1,24	62,20	2015	9,5	9,7	8				19,2	0,28	50,52
1985	49,9	67,1	23	4	53,71	132	117	1,50	57,35	2016	4,2	11,8	7				16	0,13	73,75

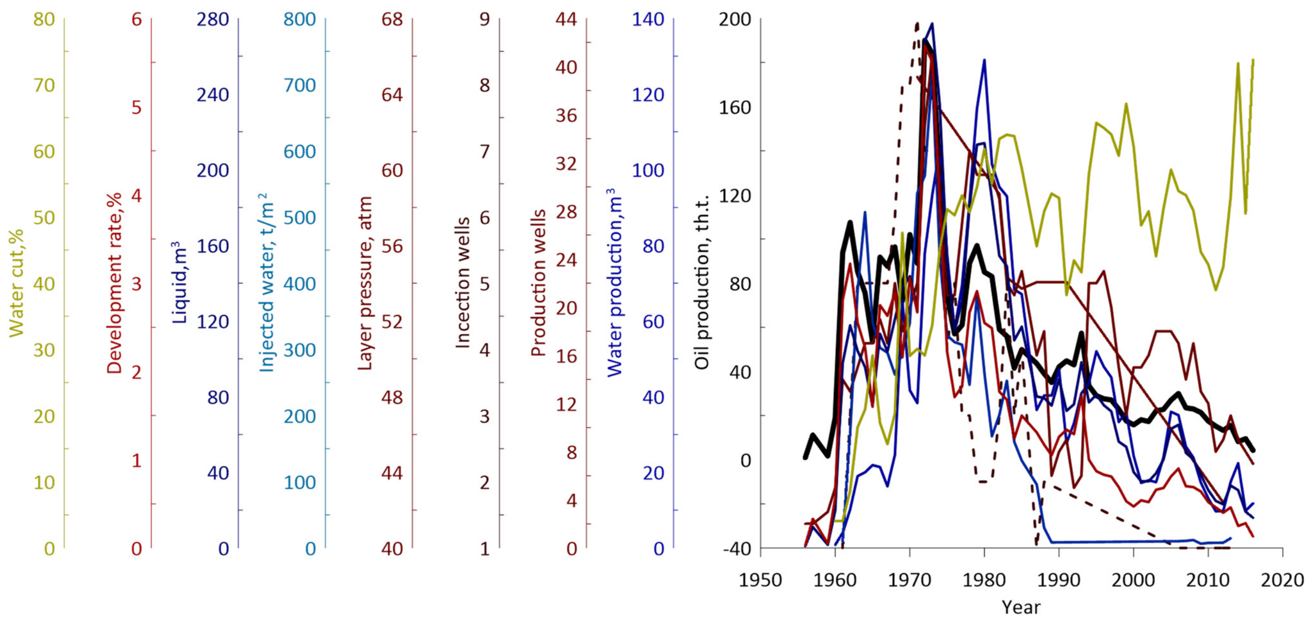

Fig. 3. The Neft Dashlari field. Development model of horizon Fa of the IV blok

Table 3

The Neft Dashlari field. Development indicators of horizon PK-2 of the IV blok

Year	Oil, t. t.	Water, t. m³	Well number: Production	Well number: Injection	Reservoir pressure	Injected water, t. m³	Liquid, t. m³	Rate, %	Water cut, %	Year	Oil, t. t.	Water, t. m³	Well number: Production	Well number: Injection	Reservoir pressure	Injected water, t. m³	Liquid, t. m³	Rate, %	Water cut, %
1954	20,3		2				20,3			1986	25	24	14	1	52,4	3,9	49		48,98
1955	16,7		2				16,7			1987	25	20	14		52,4	0,4	45		44,44
1956	44,4		6				44,4			1988	21	25	15		52,4		46		54,35
1957	120,9		8				120,9			1989	21,4	23,1	14		52,4		44,5		51,91
1958	104,2		8				104,2			1990	10,9	12	16		52,4		22,9		52,40
1959	83,6		9	2		78,4	83,6			1991	10,4	18,2	18		52,4		28,6		63,64
1960	86,6		8	3		123,3	86,6			1992	9,9	9,9	10				19,8		50,00
1961	84,2		8	2		111,8	84,2			1993	9,6	9,6	8				19,2		50,00
1962	92,6		8	2		103,7	92,6			1994	10,5	10,5	9				21		50,00
1963	102,5	1,5	10	2		87,6	104		1,44	1995	9,6	9,6	9				19,2		50,00
1964	112,7	6,2	11	2		88,3	118,9		5,21	1996	10,2	10,2	10				20,4		50,00
1965	91,1	9,8	10	2		51	100,9		9,71	1997	10,8	8,9	9				19,7		45,18
1966	90,7	11,6	13	2		40,8	102,3		11,34	1998	10,2	8,7	8				18,9		46,03
1967	99,4	11	18	5		40,7	110,4		9,96	1999	11,7	14,9	12				26,6		56,02
1968	94,1	10,1	24	4		43,9	104,2		9,69	2000	10,8	19	12				29,8		63,76
1969	90	12,9	27	5		45,5	102,9		12,54	2001	10,5	19,9	11				30,4		65,46
1970	78	25	27	3		53,5	103		24,27	2002	14,8	12	11				26,8		44,78
1971	68	24,1	32	4	54,4	43,3	92,1		26,17	2003	14,5	12,4	9				26,9		46,10
1972	57	19,7	23	2		38,7	76,7		25,68	2004	15,3	14,4	9				29,7		48,48
1973	36	21,5	17	4		72,5	57,5		37,39	2005	16,1	15,4	17				31,5		48,89
1974	35	23,5	20	4		56,8	58,5		40,17	2006	18,8	11,4	10	1		25,2	30,2		37,75
1975	14	13,4	16	5		40	27,4		48,91	2007	18,1	10,3	11	1		36,7	28,4		36,27
1976	23	11,8	17	5		116	34,8		33,91	2008	14,4	11,5	8	1		38,2	25,9		44,40
1977	31	20,4	21	4		119,7	51,4		39,69	2009	10,4	12	9	1		41,4	22,4		53,57
1978	43	11	20	4		177,6	54		20,37	2010	9,2	9,5	9	1		40,1	18,7		50,80
1979	38	15,5	21	4		122,8	53,5		28,97	2011	10,6	13,1	6	1		40,8	23,7		55,27
1980	34	26,1	19	4		113,3	60,1		43,43	2012	13,2	14,9	6	1		40,7	28,1		53,02
1981	29	18,8	15	5		108	47,8		39,33	2013	12	14,8	6	1		35	26,8		55,22
1982	29	21,1	16	5	56,4	90,2	50,1		42,12	2014	10,4	15,3	6	1		30,2	25,7		59,53
1983	25	26,5	14	4	53,1	50,4	51,5		51,46	2015	9,7	16,3	3	1	28,2	26,6	26		62,69
1984	19	28,5	14	1	53,1	30,7	47,5		60,00	2016	9,6	16	6	1	28,2	23,9	25,6		62,50
1985	26	25,9	16	1	52,4	15,8	51,9		49,90	2017	9,9	16,7	6	1	28,2	28,6	26,6		62,78

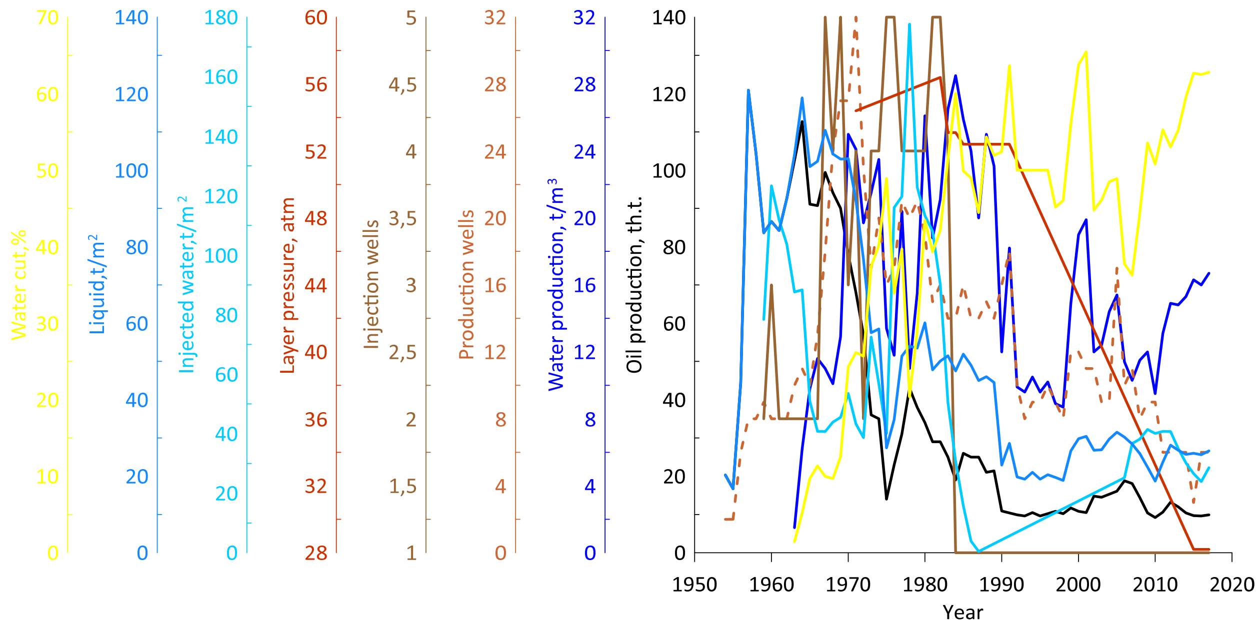

Fig. 4. The Neft Dashlari field. Development model of horizon PK-2 of the IV blok

The process of injection in horizon started in 1959 and continues with interruptions until now. The volume of water injected since the beginning of the injection was 2476 thousand m³. Currently, the volume of water pumped into the horizon is 28.6 thousand m³ (see, Table 3). The development period of the layer consisted of three stages (I, III and IV). The first stage lasted until 1957, it was followed by stage III until 1972 and stage IV with a sharp drop in production in the following years. Currently, the layer is in the final stage of development (see, Fig. 4).

Discussion and conclusions

Thus, the current state of the oil extraction process of the fields worked by the injection method in the IV tectonic block of the Neft Dashlari field was investigated and analyzed. As a result of the studies, it can be noted that:

- According to their current state, all the studied objects are in the final stage of development;
- Longitudinal and latitudinal faults that complicate the structure of Neft Dashlari divide the field into 6 tectonic blocks and are tectonic screen type;

• For extraction of remaining oil reserves from layer the Micellar Solution Flooding method is appropriate. The displacing agent in this method is a micro emulsion with micelles. The use of such emulsion is possible to resume the development of completely flooded deposits and extracting up to 50–60 % of the oil. In addition, it is necessary to increase the coverage of the layer by displacement, to reduce the water cutting of the production, and reconstruction of the well stock by secondary well hole.

• As all the studied objects are in the final stage of development to increase oil recovery in the later stage of the development of the target objects it is recommended to transfer flooded wells to returnable objects, and apply suitable methods to increase the oil recovery of objects in the later stage of development such as a water-gas mixture.

Authors' contribution: Gultar Nasibova– conceptualization, data validation, methodology, writing (original draft); Shura Ganbarova – writing (review and editing), data analysis, methodology.

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МОДЕЛЮВАННЯ РОЗРОБКИ РОДОВИЩА НЕФТ ДАШЛАРІ В МЕЖАХ ПІВДЕННОКАСПІЙСЬКОГО БАСЕЙНУ

В с т у п . ***Присвячено аналізу сучасного стану розробки продуктивних пластів Південнокаспійської западини на прикладі IV блоку родовища Нефт Дашларі. Це одне з найбільших родовищ Азербайджану з потужними запасами вуглеводнів. У роботі систематизовано великий обсяг геолого-промислових даних, що дало змогу уточнити стратиграфічні, тектонічні та гідрохімічні характеристики об'єкта, а також оцінити його поточний стан.***

М е т о д и . ***Дослідження базується на аналізі показників експлуатації 26 нафтових пластів, відкритих з 1949 р. Використано методи статистичного аналізу та геологічного моделювання для оцінки залишкових запасів нафти, які нині зосереджені переважно у верхніх та нижніх відділах Продуктивної товщі (ПТ).***

Р е з у л ь т а т и . ***З початку розробки накопичений видобуток становив 168 787,1 тис. т нафти та 13 090,4 млн м³ розчиненого газу. Річний видобуток нафти становить 812 тис. т за середньої обводненості продукції 38,2 %. Середньодобовий дебіт однієї свердловини становить 7,2 т нафти та 11,7 т рідини. Ступінь виробленості видобувних запасів сягає 87,3 %. Поточний коефіцієнт вилучення нафти становить 0,440, а кінцевий (проєктний) – 0,504. Для інтенсифікації видобутку з 1953 р. застосовується заводнення, зокрема на VII та X горизонтах, фасільській та кірмакійській світах IV блоку.***

В и с н о в к и . ***На основі побудованих моделей розробки обґрунтовано доцільність застосування міцелярного заводнення для вилучення залишкових запасів. Використання мікроемульсій дає змогу відновити експлуатацію заводнених пластів і підвищити КВН до 55–60 %. Додатково рекомендовано збільшити охоплення пластів витісненням, впровадити заходи зі зниження обводненості та провести реконструкцію фонду свердловин шляхом буріння бокових стовбурів. Оскільки об'єкти перебувають на завершальній стадії розробки, запропоновано впровадження водогазового впливу та повернення свердловин на вищезалеглі об'єкти.***

К л ю ч о в і с л о в а : ***коефіцієнт вилучення нафти, розробка, спосіб закачування води, показники розробки горизонтів, видобуток нафти, видобуток газу, швидкість розробки.***

Автори заявляють про відсутність конфлікту інтересів. Спонсори не брали участі в розробленні дослідження; у зборі, аналізі чи інтерпретації даних; у написанні рукопису; в рішенні про публікацію результатів.

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