MINISTRY OF EDUCATION AND SCIENCE OF THE REPUBLIC OF KAZAKHSTAN

СӘТБАЕВ УНИВЕРСИТЕТІ SATBAYEV UNIVERSITY

School of Geology, Petroleum and mining engineering

Department of Petroleum Engineering

Duzbayeva G.B.

Improving the development efficiency of carbonate oil reservoirs using physical chemical methods of production stimulation

DIPLOMA PROJECT

5B070800 - Oil and gas engineering

Almaty 2021

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APPROVED FOR DEFENSE

Head of the Petroleum
Engineering Department
Dairov Zh. K., MSc
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DIPLOMA PROJECT

Topic: « Improving the development efficiency of carbonate oil reservoirs using physical chemical methods of production stimulation »

5B070800 - Oil and gas engineering

Performed by Duzbayeva G.B.

Academic adviser
Imantayeva A.K.

Almaty 2021

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НАЗВАНИЕ:
X field: Investigating the impact of formation geomechanical properties on wellbore stability

АВТОР:
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MINISTRY OF EDUCATION AND SCIENCE OF THE REPUBLIC OF KAZAKHSTAN

School of geology, petroleum and mining engineering

Department of Petroleum Engineering

CONFIRM

Head of the Petroleum
Engineering Department
Dairov Zh. K., MSc
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TASK

For completing the diploma project

For student Duzbayeva G.B.
Topic: « Improving the development efficiency of carbonate oil reservoirs using physical chemical methods of production stimulation »
Approved by the order of university rector № 762-b from 24 November 2020
Deadline for completion the work: 18.05.2021.
Initial data for the diploma project:
Summary of the diploma project: negotiation of difficulties in development of the carbonate reservoirs, application of the oil recovery mechanisms, increasing of the oil recovery factor.
Recommended main literature:

1. V.N. Kirkinskaya and E.M. Smekhova, (1981). Carbonate oil and gas reservoir rocks.

2. K. I. Bagrintseva, (1999). Formation conditions and properties of carbonate oil and gas reservoirs

3. Report (2018), *Analysis of the current field development*

SCHEDULE

for the diploma project preparation

Name of sections, list of issues being developed	Submission deadline to the Academic adviser	Notes
Literature overview	25.01.2021	Task completed
Finding the issues in N field's oil production system	15.02.2021	Task completed
Application of the oil recovery mechanisms	15.04.2021	Task completed
Conclusion	15.05.2021	Task completed

SIGNATURES

Of consultants and standard controller for the completed diploma project, indicating therelevant sections of the work (project).

The section titles	Consultant name (academic degree, title)	Date	Signature
Theoretical part	MSc, Imantayeva A.K.	25.01.2021	[signature]
Main part	MSc, Imantayeva A.K.	15.02.2021	[signature]
Technical part	MSc, Imantayeva A.K..	15.04.2021	[signature]
Conclusion	MSc, Imantayeva A.K.	15.05.2021	[signature]

Academic Adviser MSc, Imantayeva A.K.

The task was accepted by students: Duzbayeva G.B.

Date «18» May 2021

Task: Investigate the carbonate oil field, find the best way to improve the development system of the deposit

Purpose of the work: To consider various methods of enhancing oil recovery in carbonate reservoirs, and to determine the most optimal one in the ‘N field, tracing the history of the application of these methods in analogous fields.

Key words: carbonate reservoir, development system oil recovery mechanisms, EOR, multilaterals.

ANNOTATION

An increase in the country's raw material base is possible subject to knowledge of the laws of nature and theoretical justification for predicting development zones of high-capacity reservoirs, reliable assessment of parameters, and identifying zones of complex types of reservoirs confined to great depths. Currently, more than 40% of world oil production is associated with carbonate deposits. However, prospecting, exploration, appraisal and development of these deposits are significantly complicated due to the complexity of the structure of carbonate complexes, ambiguity of the types and properties of reservoirs within the reservoir, uncertainties a number of critical issues in assessing fracturing and the parameter of its spatial variability.

This diploma project dedicate the suggestion for solution of production challenges of the carbonate reservoir. Features and difficulties of the carbonate field development were distinguished. Different types of the oil recovery mechanisms were considered in this work. The theoretical application of most effective methods on the 'N' field were considered in this work.

АННОТАЦИЯ.

Увеличение сырьевой базы страны возможно при условии знания закономерностей природы и теоретического обоснования прогноза зон развития высокопроизводительных коллекторов, достоверной оценки параметров и выявления зон сложных типов коллекторов, приуроченных к большим глубинам. В настоящее время более 40% мировой добычи нефти связано с карбонатными месторождениями. Однако поиск, разведка, оценка и разработка этих месторождений значительно усложняются из-за сложности структуры карбонатных комплексов, неоднозначности типов и свойств коллекторов внутри коллектора, неопределенности ряда критических вопросов при оценке трещиноватости и параметра его пространственной изменчивости.

Этот дипломный проект посвящен решению возникающих в ходе разработки карбонатных коллекторов. Различные особенности таких месторождений были освящены в этой статье. Рассмотрены методы увеличения нефтеодачи пласта. Был проведен анализ возможности применения наиболее эффективных из них на карбонатном месторождении ‘N’

АҢДАПТА.

Еліміздің шикізат базасын ұлғайту табиғат заңдылықтарын білу және жоғары өнімді су қоймаларын дамыту аймақтарының болжамын теориялық негіздеу, параметрлерді сенімді бағалау және шектеулі су қоймаларының аймақтарын анықтау шартымен мүмкін болады. үлкен тереңдікке Қазіргі кезде әлемдік мұнай өндірісінің 40% -дан астамы карбонат кен орындарымен байланысты. Алайда, бұл кен орындарын іздеу. барлау, бағалау және игеру карбонатты кешендер құрылымының күрделілігіне, су қоймасының ішіндегі су қоймаларының типтері мен қасиеттерінің түсініксіздігіне, бағалау кезіндегі бірқатар маңызды мәселелердің белгісіздігіне байланысты едәуір күрделі. сыну және оның кеңістіктегі өзгергіштік параметрі.

Бұл дипломдық жоба карбонатты қабаттың өндірістік мәселелерін шешуге арналған. Карбонатты кен орнын игерудің ерекшеліктері мен қиындықтары атап өтілді. Бұл жұмыста мұнай өндіру механизмдерінің әртүрлі түрлері қарастырылды. Бұл жұмыста ең тиімді әдістердің теориялық қолданылуы қарастырылды.

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INTRODUCTION

This work is aimed at studying methods of enhancing oil recovery in carbonate reservoirs, as well as the necessary conditions for their application.

Due to the complexity of their structure, carbonate deposits exhibit unpredictable behavior under certain impacts on the formation. This factor does not allow the use of traditional methods of enhanced oil recovery, which are successfully carried out in terrigenous reservoirs. Moreover, each carbonate field has certain characteristics and properties that distinguish it from another, and not always the techniques working on one can be applied on another carbonate reservoir.

The above factors are the reason that each specific type of such a reservoir requires in-depth analysis.

Therefore, this work is focused on tracing the history of EOR application on carbonates in general and checking whether they work in the "N" field. Also identify possible existing development problems and possible solutions.

1.Carbonate reservoirs

Carbonate reservoirs - reservoirs of huge thickness, composed of carbonate rocks, often represented by limestone (CaCO3) dolomite (CaMg (CO3) 2), etc. Their main difference from terrigenous reservoirs is the presence of macro- and microcracks, caverns, erosion channels, which can both improve and worsen the reservoir properties of the reservoir. This leads to various problems in the development of the field. Although they account for about 30-50% of the total oil reserves in the world, for the most part they are difficult to recover.

1.1 Difficulties during the development of the carbonate reservoirs

1) Large reservoir thickness.

Carbonate reservoirs usually buried deep underground and have large reservoir thickness with a lot of interconnected oil layers. That kind of oil hard to recover. It is hard to involve all of that interlayers so in many cases only one layer with greater net pay zone is drained.

2) Features of the void space formation

Not only biogenic but tectonic processes influence on the voids formation due to the fragility of the carbonate rocks. As a result macro- and microfractures are created. They are the sourse of the dual porosity and permeability. High permeable canals can lead the loss of circulation. So it is needed to use mud with high viscosity. Furthermore oil flows very fast through this fractures causing the high liquid rate at the beginning followed by a sharp decline. As a result the water cut increases very fast leaving a lot of oil trapped.

Orientation of this fractures is another important thing. Before drilling the seismic attribute analysis is needed. Using it the information about orientation, location, conductivity is obtained.

3) Features of minerals in reservoir composition.

The calcite and dolomite are mostly widespread carbonate rocks.

During the dolomitisation when calcite is replaced by dolomite the the porosity and permeability can be increased or decreased. It depends on quantity of voids that were closed. So the dolomites can be divided into two groups: ‘Good dolomites’ and ‘Bad dolomites’ . they can be indicated using geophysical surveys.

Carbonates are able to interact with water creating erosion channels. This channels can be very large in volume even creating karsts. During the drilling if this karst is uncovered the well wall collapse can occur.

2.General information about 'N' field

This field was discovered in 1889 and commissioned in 1992. It lies at a depth of 2900-3200 meters. Reservoir oil is low-viscosity, light and highly paraffinic. Initial geological reserves amount to 12 954 thousand tons of oil and 0.3 billion cubic meters of gas, while initial recoverable reserves amount to 605 thousand tons of oil. At the moment, production is carried out by 16 wells, 13 of which are vertical, 3 are horizontal. Remaining reserves amount to 1990 thousand tons with the current oil recovery factor of 4,7%.

2.1 Geological characteristics of the 'N' field

The 'N' field is represented by a carbonate reservoir, the productive strata of which are represented by rocks of the Middle and Lower Triassic.

Middle Triassic deposits are represented by two strata of different lithological composition (from bottom to top): volcanic-carbonate and volcanic-argillic. In the section of the volcanic-carbonate strata, two members are distinguished: volcanic-dolomite and volcanic-limestone, to which the productive horizons T2B and T2A are confined, respectively.

The volcanic-dolomite member unconformably overlies the Lower Triassic deposits and is represented mainly by dolomites, calcareous dolomites, dolomitic limestones, oolitic, oolitic-detrital, fine-grained brownish-dark gray colors with fragments of ostracod shells. Present in the form of interlayers of tuff sandstone, tuff aleurolite, tuff mudstone, gray tuffite with a greenish tint, crystal- vitroclastic, carbonated.

The volcanic-limestone member is composed mainly of dark gray, black fine-grained limestones with interlayers of tuff mudstones, tuff siltstones and tuff sandstones, with ostracod detritus and fragments of fish scales.

The field has 2 horizons T3 and T2, to which 4 deposits are confined.

Deposit T3. Western semi-vault

Deposit T2A. Western semi-vault

Deposit T2B. Central semi-vault

Deposit T2B. The main semi-vault.

Deposit T2B. The main semi-vault.

Which accounts for the main production of hydrocarbons, therefore, information on it will be provided in the future.

Oil reservoir T2B of the Main semi-flood was established as a result of sampling a volcanic-dolomite member of the Middle Triassic in well 1, from which a gushing oil flow was obtained with a flow rate of 144 m3 / day and gas of 30 thousand m3 / day at an 8 mm choke with a depression of 9.36 MPa. Subsequently, the commercial oil-bearing capacity of the productive unit was confirmed by testing wells 3, 11, 13.

Well 12 was drilled in the western part of the half-rise, which was abandoned for geological reasons without running the production string, due to the absence of productive deposits in the exposed section. In the well there are 12 reservoirs of cavernous-pore type, with which the deposit is associated and oil reserves were estimated, neither by core nor by materials of geophysical studies of the well were found.

The reservoirs of the T2B deposit are of the cavernous-porous type: the lower limit of permeability is 0.1 * 10-3 μm2, the lower limit of open porosity is 9%.

Fractured reservoirs containing deposit B are represented by oolitic, lumpy, detrital, pelitomorphic dolomites, pelitomorphic limestones, and tuffs. Cracks of various directions are noted.

Horizon T2B of the Main semi-drive has been developed since 1992 after the commissioning of production well No. 3. There are 19 wells in the field.

In the process of commissioning wells. Most of them stop gushing during the year, as a result, it is necessary to organize activities to create a depression on the formation. Further, the wells are introduced in a mechanized way, namely the sucker rod pump.

2.2 'N' field's characteristic

The mode of the field is elastic-gas pressure, in this mode the design oil recovery factor is 20%. Characteristics of reservoir oil, density -0.834 g / cm3, light oil, since it has a high gas content, namely 148 m3 / t. Also, the temperature is 1000, which is a fairly high indicator, providing good performance for oil. The viscosity is low, since the oil is deep enough, μ-0.9 cP. The paraffin content was 19%, which classifies it as highly refined. Effective thickness 30.6 meters, dissection factor 11.6. The initial reservoir pressure is 32 MPa.

This field is characterized by low reservoir properties, according to well test data, open porosity is 17%, the lower permeability threshold is 0.5 mD.

2.3 Reservoir oil properties

Reservoir oil of the Main half-water has a high gas content and is undersaturated with gas. The high gas content of 120 m3 / t and the reservoir temperature, as well as the light composition of the oil, led to a good filtration characteristic of the reservoir oil - the oil viscosity in reservoir conditions does not exceed 1.0 mPa * s.

2.4 Field development history

Follow dynamic pattern shows the change of the main development parameters.

At this graph we can see that oil production rates are high starting from 2003 year. It is due to the hydraulic fracturing of the production wells. Then starting from 2012 year the peak of the production rate is observed. The setting of the new wells is the reason of that leap.

Starting from the 2015 year the oil production decreases sharply causing the increase in water cut. The oil recovery mechanisms are needed to be applied.

The amplitude between the oil production line and liquid production line is very low which means that the quantity of produced water is small.

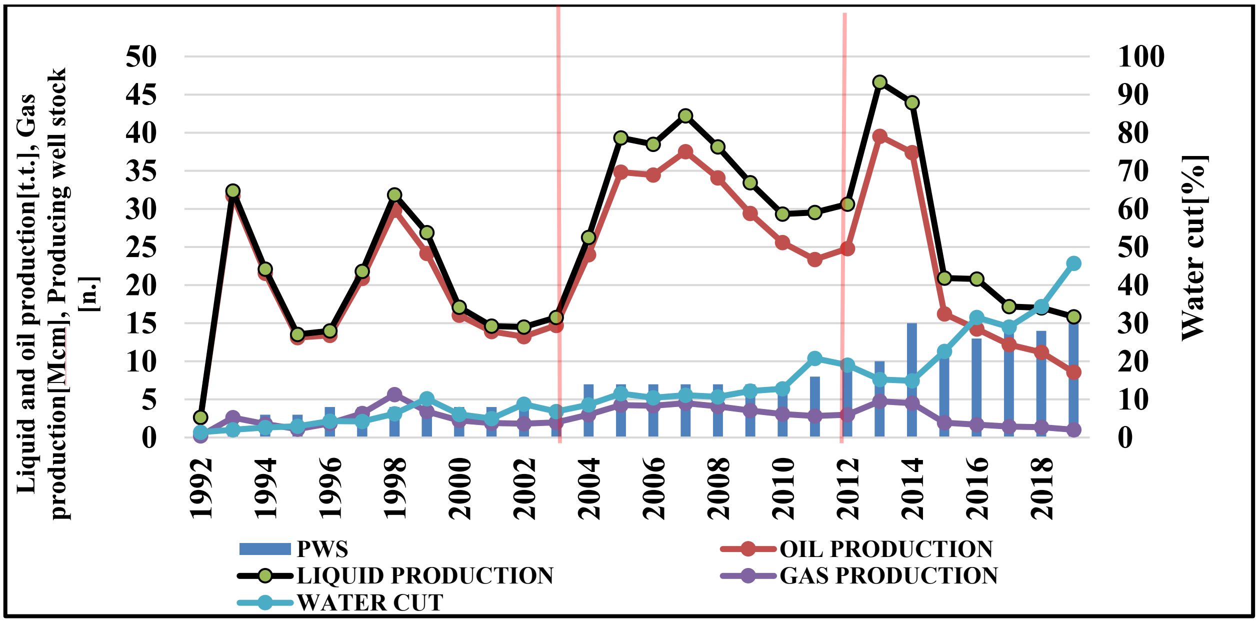

Figure 1. Main development parameters

2.5 Wells location

Figure 2. map of drilled and planned wells

2.6 Features of the 'N' field

1. As our field is presented by carbonate rocks the information about presence dual porosity and permeability is needed. Well testing of the 3 wells were carried out.

Follow picture shows the example of dual porosity on the record of the build up test.

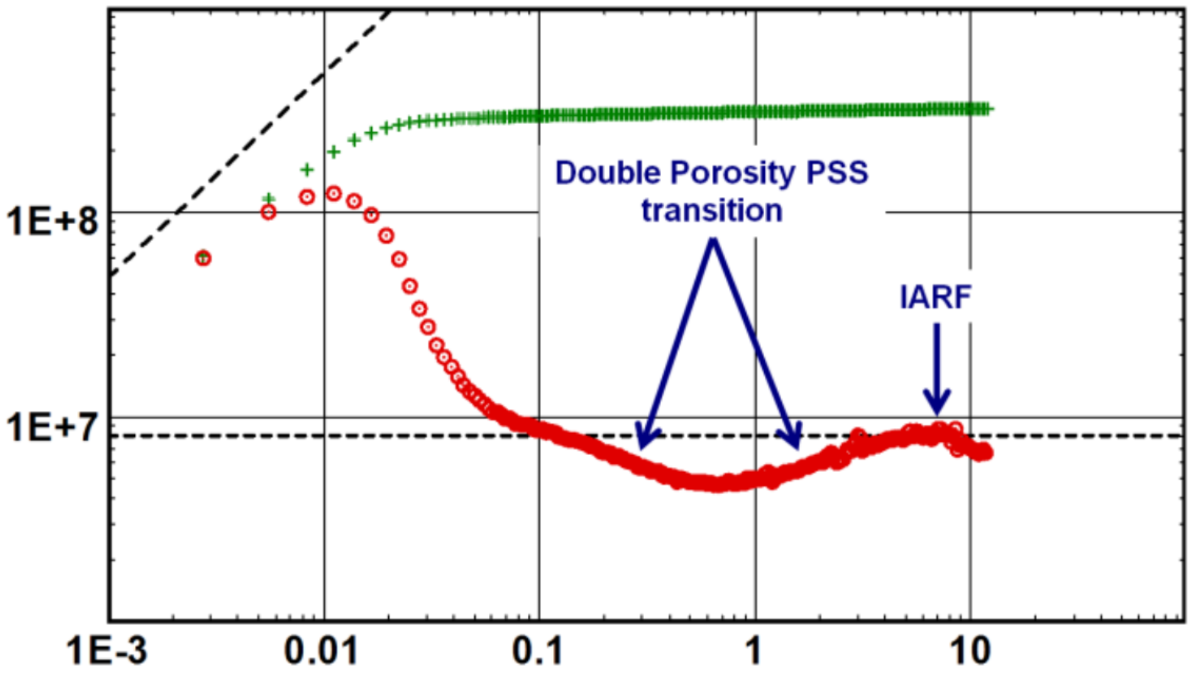

Figure 3. Example of indicating dual porosity on the diagnostic plot

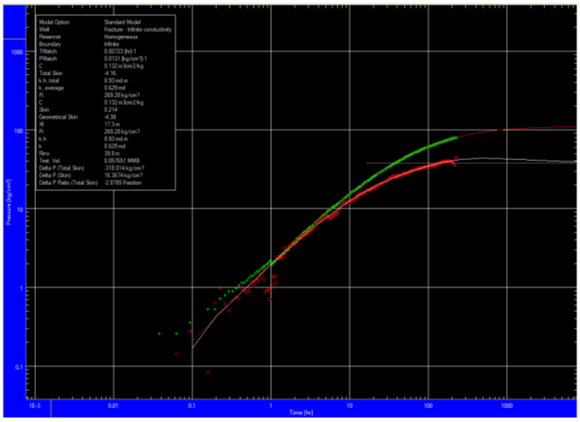

Figure 4. The results of build up test of well#1

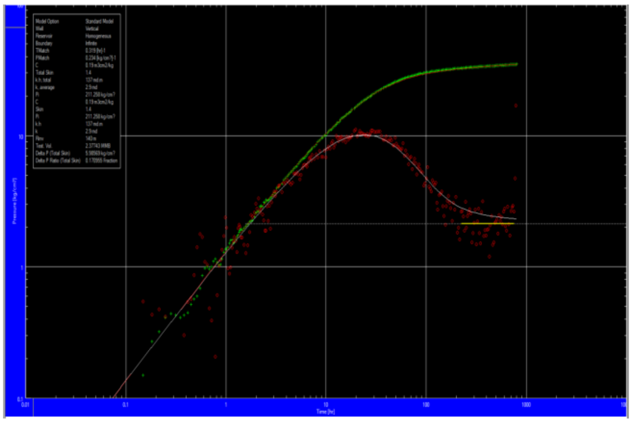

Figure 5. The results of build up test of well#2

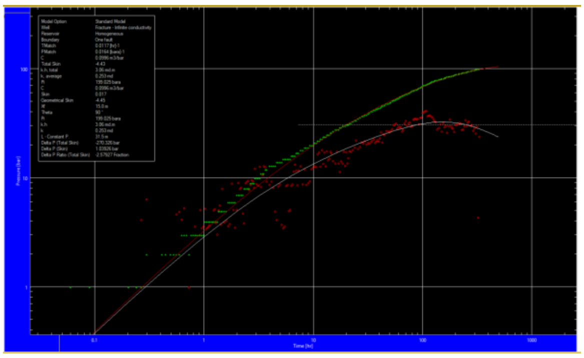

Figure 6. The results of build up test of well#1

This researches identifies the absence of the dual porosity and permeability. Which means that our reservoir contains the fractures which are not connected with each other.

Due to the deep burial depth, the vertical stress is larger than the maximum horizontal and minimum horizontal stresses. This factor is cause of the vertical orientation of those fractures.

This factor can cause high heterogeneity of permeability.

This supposition can be confirmed by the pressure dynamic of the each well

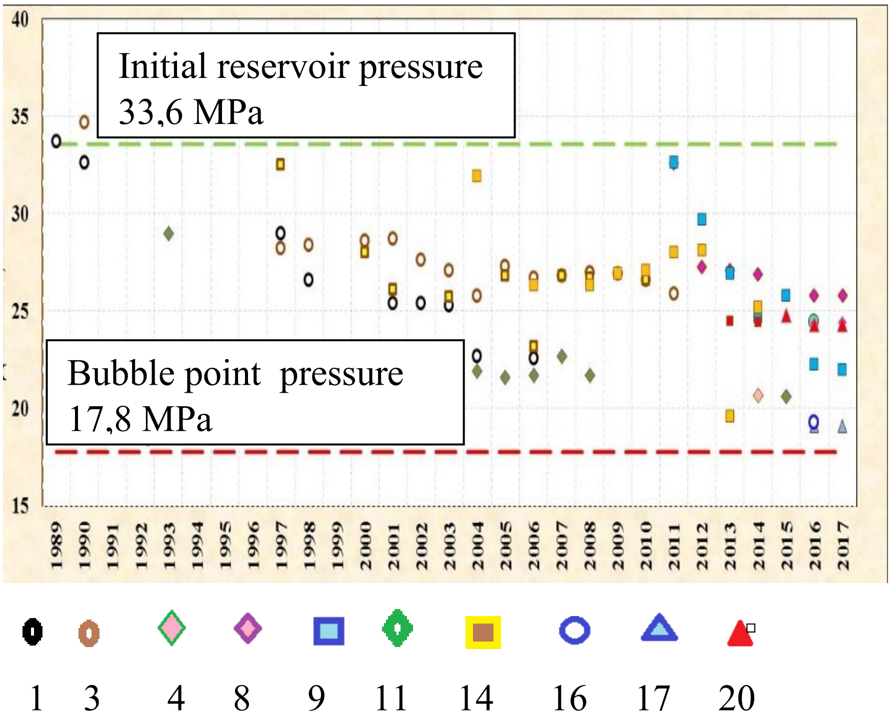

Figure 7. Pressure of each well

Significant spread of the pressure values identify absence of the hydrodynamic connection between majority of them.

But if we look at pressure decreasing of the № 11 and №3 wells we can see the similarity of those trends. The №3 well were set earlier that № 11 and the initial pressure of this well is smaller than initial pressure of the №3 well. So we can suppose that there is connection between those wells.

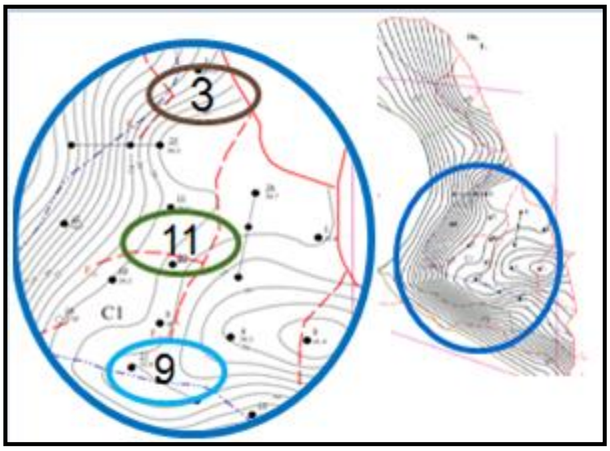

Figure 8. Wells № 3, 11, 9 on the map

This factor makes it possible to assume the fracture orientation from Northeast to Southwest.

3 Overview of the oil recovery mechanisms

Oil recovery mechanism is needed at the mature oil fields when the nature energy s not enough to extract oil to the surface.

The main purpose of oil recovery mechanisms is to increase the oil recovery factor, which varies depending on the oil production methods used, which are subdivided into 3 groups:

Primary methods use only the natural energy of the formation reach the recovery factor of no more than 20-30%,

Secondary methods associated with maintaining in-situ energy by injecting water and gas into the reservoir usually reach the recovery factor of 30-50%,

Tertiary methods are carried out by changing the physical and chemical properties of oil.

The essence of the application these methods basically boils down to two tasks:

1) better displacement of oil from the reservoir

2) an increase in the drainage zone without drilling additional wells, that is, the use of secondary and tertiary methods.

3.1 Primary methods

Primary methods depend only on the natural energy state of the formation.

In this paper, we will consider secondary and tertiary oil production methods.

3.2 Secondary methods

It is possible to maintain reservoir pressure only by pumping a working reagent, it can be water, gas, etc.

Let's consider the simplest type of reservoir pressure maintenance - waterflooding. Water is one of the most economically profitable resources used in the organization of the reservoir pressure maintenance system.

But in the case of carbonate reservoirs, the use of water can lead to the following complications.

Firstly, most carbonate reservoirs are hydrophobic. Water entering such a reservoir does not wet it, with an increase in water saturation, the relative permeability of water sharply increases. As a result, it becomes more mobile than oil, and quickly breaks through to the bottom of the wells, leading to tongue formation and increasing water cut in the wells.

Secondly, carbonates have a system of fractures, which are highly permeable areas. Water entering such a channel, due to its low viscosity, quickly passes through it. In this situation, the orientation of the fractures plays a special role, where it is directed, and water will go there, not always the research results can give specific values for a certain point, therefore, it becomes difficult to regulate the direction of propagation of the injected water.

Thirdly, when the injected and produced water interacts, a reaction can occur, as a result of which a sediment occurs, which reduces the value of the effective porosity as a consequence, worsening the FES, therefore, analyze the reservoir and injected water and check them for compatibility.

Gas is another type of working agent.

Gas injection is used in cases when it is necessary to reduce the viscosity of oil and increase its mobility, mainly solvents are injected into the reservoir - liquefied natural gases: butane, propane and their mixture. Another solvent option is carbon dioxide (carbon dioxide CO_2), which also dissolves well in oil. At the same time, there are a number of criteria of applicability for gas injection, which will be described below.

3.3 Tertiary methods (EOR)

Tertiary methods also known EOR methods include: steam injection, miscible gas injection and chemicals injection.

Thermal methods oriented to decrease oil viscosity to make oil more movable. The water is injected into the reservoir heated it and transform into steam. This steam increase the reservoir temperature and decrease oil viscosity.

Miscible gas injection is applied when the reservoir pressure is higher than minimum miscible pressure. Gas mixes with oil resulting reduction in oil viscosity and helps to extract heavy oil by decreasing its density.

Injection of the chemicals is used to decrease the interferential tension between wetting and non-wetting phases, with decrease the amount of residual oil.

3.4 Bottom hole zone treatment

Acid treatment . Acid is injected into the formation at a pressure below the fracture pressure of a certain concentration, which, reacting with the matrix, forms voids, caverns, and corrosion channels.

Also, there is a method that combines the two previous ones, acid fracturing, that is, acid is pumped under high pressure.

The problems of organizing hydraulic fracturing in carbonate fields include:

- uneven distribution of horizontal and vertical stresses, that is, difficulties arise in setting the required orientation, that is, a man-made fracture can go anywhere without affecting oil-saturated layers, which greatly reduces the success of this event.

- vertical orientation of fractures, a drawing is needed, which significantly reduces the coverage area of oil-saturated strata

- the effect of hydraulic fracturing usually does not last long, since carbonates mainly lie deep underground and have large thicknesses, the formed fractures quickly close under the weight of the overlying rocks.

3.5 Drilling new wells

In addition to using EORs to increase oil recovery, it is possible to compact the grid of wells.

Drilling new wells helps to increase the radius of the drainage zone.

The problems of this method include the high cost of drilling, since it was said earlier that carbonates occur at a considerable depth. It is very important to note here the fact that carbonate rocks interacting with water can form large karsts. By drilling a well into karst, you can get a well collapse.

3.6Mechanical methods

1) Hydraulic fracturing

Among the methods responsible for increasing the drainage zone, one can single out hydraulic fracturing, the essence of which is the creation of man-made fractures, due to the injection of the fracturing fluid under a pressure exceeding the fracture pressure, as well as fixing the fractures with the help of proppant.

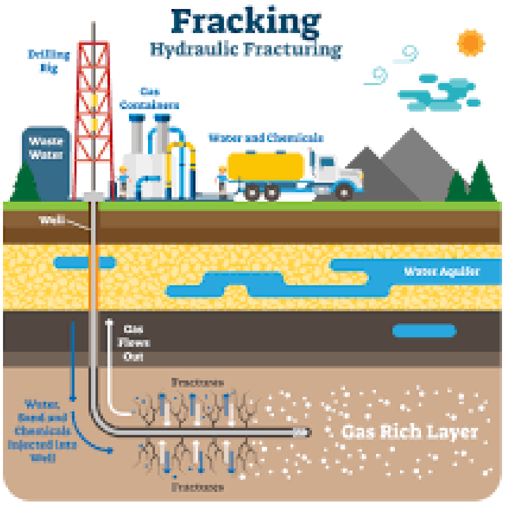

Figure 9. Hydrauilic fracturing

2) Drilling the sidetracks

Drilling the sidetracks is an effective technology that allows you to increase oil production at old fields and increase the oil recovery factor (ORF) from formations, to return to production oil wells that could not be returned to the existing fund by other methods.

By drilling sidetracks, previously unused areas of the reservoir are involved in development, as well as hard-to-recover oil reserves (TREs), the production of which was not previously possible.

Application of sidetracking technology contributes to increased oil recovery and actually replaces well consolidation.

Appropriate technologies help save the well and save on well completion costs.

3.6 Drilling new wells

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Drilling new wells helps to increase the radius of the drainage zone.

The problems of this method include the high cost of drilling, since it was said earlier that carbonates occur at a considerable depth. It is very important to note here the fact that carbonate rocks interacting with water can form large karsts. By drilling a well into karst, you can get a well collapse.

4 Application of the oil recovery mechanisms on the 'N' field

4.1 Primary mehods

1) The reservoir of interest is mature oil field so primary mechanisms can not be applied

4.2 Secondary methods

4.2.1Gas injection

The following gas injection methods are considered:

1) Horizontal miscible displacement with N_2 or combustion gas injection
2) Vertical miscible displacement with CO_2 injection
3) Vertical miscible displacement with hydrocarbon gas injection
4) Horizontal miscible displacement with N_2 or combustion gas injection
5) Horizontal miscible displacement with CO_2 injection
6) Horizontal miscible displacement with hydrocarbon gas injection
7) Vertical immiscible displacement

The most optimal gas injection method for current conditions is horizontal miscible displacement with hydrocarbon gas injection. But the current reservoir pressure has already dropped below the minimum mixing pressure (MMP) at which gas dissolves in oil. Therefore, this mining method also does not meet the applicability criteria. Parameters that do not meet the applicability criteria are highlighted in red in the table, and they are in green.

Parameter	**Unit**	**Value**	**Screening Criteria**
Vertical immiscible displacement			
Oil density	API	39	>10
In situ oil viscosity	cP	0,87	<600
Depth	m	2985	<760
Vertical permeability	mD	0,02	>100
Current reservoir pressure	atm	187	<MMP(267)
Oil saturation		0,76	>0,35
Incidence angle	angle	1	>10

Horizontal miscible displacement with hydrocarbon gas injection

Oil density	API	39	>30
In situ oil viscosity	cP	0,87	<3
Depth	m	2985	1220<<4880
Vertical permeability	mD	0,02	<100
Current reservoir pressure	atm	187	>MMP(267 атм)
Oil saturation		0,76	>0,3
Oil density	API	1	<10

Horizontal miscible displacement with CO_2 injection

Oil density	API	39	>22
In situ oil viscosity	cP	0,87	<10
Depth	m	2985	>760
Vertical permeability	mD	0,02	<100
Current reservoir pressure	atm	187	>MMP(267)
Oil saturation		0,76	>0,2
Oil density	API	1	<10

Horizontal miscible displacement with N_2 or combustion gas injection

Oil density	API	39	>40
In situ oil viscosity	cP	0,87	<0,4
Depth	m	2985	>3050
Vertical permeability	mD	0,02	<100
Current reservoir pressure	atm	187	>MMP(267)
Oil saturation		0,76	>0,4
Oil density	API	1	<10

Vertical miscible displacement with hydrocarbon gas injection

Oil density	API	39	>30
In situ oil viscosity	cP	0,87	<3
Depth	m	2985	1220<<4880
Vertical permeability	mD	0,02	>100

Current reservoir pressure	atm	187	>MMP(267)
Oil saturation		0,76	>0,3
Oil density	API	1	>10

Vertical miscible displacement with CO_2 injection			
Oil density	API	39	>22
In situ oil viscosity	cP	0,87	<10
Depth	m	2985	>3050
Vertical permeability	mD	0,02	>100
Current reservoir pressure	atm	187	>MMP(267)
Oil saturation		0,76	>0,2
Oil density	API	1	>10

Horizontal miscible displacement with N_2 or combustion gas injection			
Oil density	API	39	>40
In situ oil viscosity	cP	0,87	<0,4
Depth	m	2985	>3050
Vertical permeability	mD	0,02	>100
Current reservoir pressure	atm	187	>MMP(267)
Oil saturation		0,76	>0,4
Oil density	API	1	>10

None of the gas injection methods meet the applicability criteria

4.2.2 Water injection

Water injection is the most intensive and cost effective way to stimulate the oil reservoir.

To determine the efficiency of the RPM, it is necessary to conduct pilot tests.

The following results were obtained:

1 mode - pressure 200 atm, water consumption 0.3 m3 / min, injectivity 432 m3 / day;

2 mode - pressure 220 atm, water consumption 0.85 m3 / day, injectivity 1080 m3 / day;

3 mode - pressure 350 atm, water consumption 1.6 m3 / day, injectivity 2160

m3 / day.

Laboratory studies were carried out to analyze the compatibility of injected water and reservoir water.

Based on the results of laboratory tests

1.The Albsenomanian water of the Asar deposit is sulphate-sodium with a total mineralization of 11150 mg / l and a density of 1.006 g / cm3. The water contains a high amount of sulfates - 2388 mg / l, the content of barium, strontium and iron, respectively, 0.2; 15 and 3.5 mg / l.

2. The formation water of the 'N' field belongs to the calcium chloride type with a total salinity of 34811 mg / l. The content of sulfate ions is 18.9 mg / l, strontium and barium is 75 and 6.8 mg / l, respectively, hydrocarbonates - 890.6 mg / l.

3.Albian-Cenomanian water of the Asar field is compatible with the formation water of 'N' field: at a temperature of 90 ° C, the largest amount of sediment is formed in the formation water - 253.5 mg / l, the least - in the Albsenomanian water, 38.5 mg / l. The sediment is 90% of the mass of calcium carbonate (calcite), 10% is iron oxide (Fe_2O_3), strontium carbonate ($SrCO_3$) and barium carbonate ($BaCO_3$).

It is recommended to consider well № 11, in which the maximum volumes of oil were produced without additional geological and technical measures, as a candidate for pilot testing to organize reservoir pressure maintenance. Based on the results of earlier work to determine the injectivity of wells, the injection pressure at the wellhead was quite high, which must be taken into account when planning field operations:

In № 3 well, the discharge pressure was 15.0-18.4 MPa, injectivity - 432 m3 / day, with an increase to 22.5-24 MPa - 864 m3 / day, up to 24-25 MPa - 1296 m3 / day

At the ‘N’ field, work was carried out to inject water into the reservoir. The diagram of parameters for water injection into well SAK_0003 is shown in the figure below. Injection pressure ranged from 16 to 25 MPa. The duration of the injection was 1 hour 51 minutes. Injection volume in each mode: mode 1 - 16.08 m3, mode 2 - 14.94 m3, mode 3 - 31.53 m3, total - 62.55 m3; injectivity in each mode: 1 mode

- 464 m3 / day, mode 2 - 861 m3 / day, mode 3 - 1259 m3 / day

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- 464 m3 / day, mode 2 - 861 m3 / day, mode 3 - 1259 m3 / day.

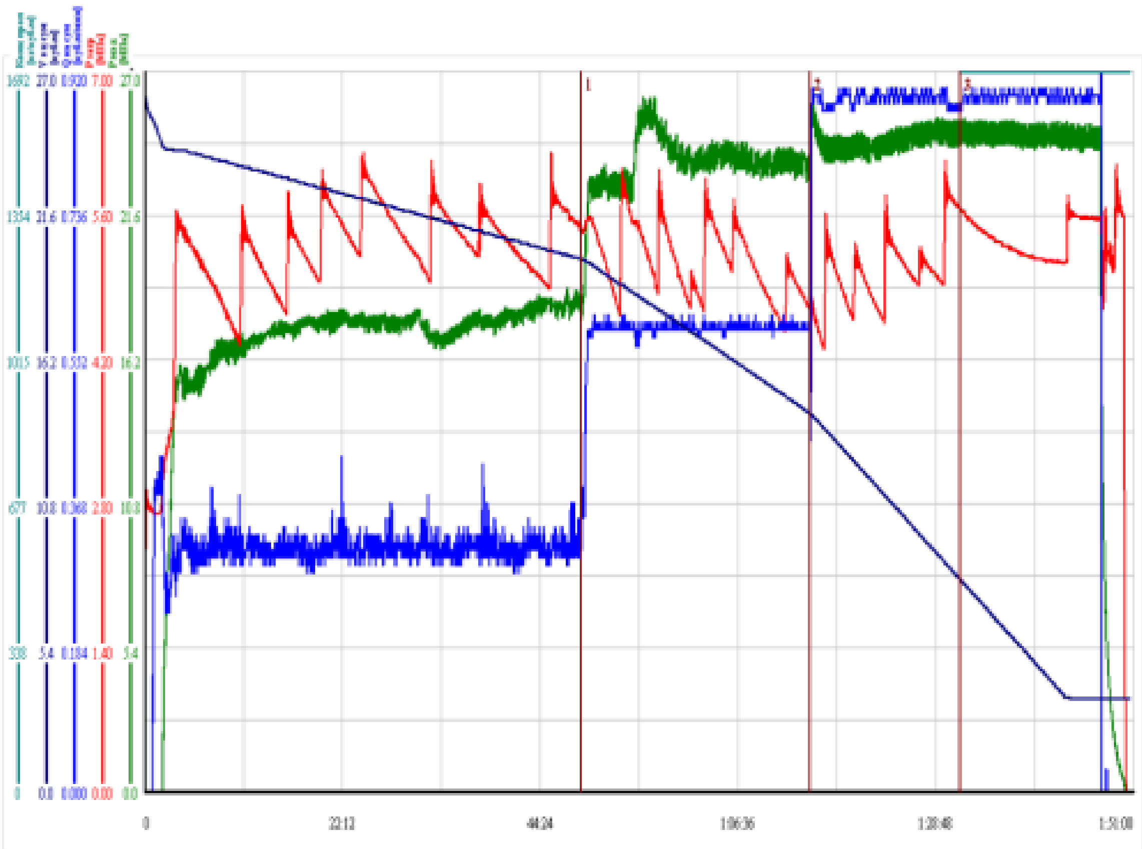

Figure 10. Graph of the water injectivity

In addition, the calculation of injectivity for the well was carried out, from which it follows that with a wellhead injection pressure of 173 atm, the injectivity will be 182 m3 / day, which would be sufficient for the implementation of a pressure maintenance system at the 'N' field. The actual injectivity was 464 m3 / day, which is even more. Uncertainty lies in how long a given injectivity will last.

As the result the water injection was failed due the high content of mechanical admixtures.

The water flooding can be used at this field provided the provided the quality of the injected water specifically content of the mechanical admixtures less than 14 mg/l.

4.3 Tertiary methods

4.3.1.Thermal methods

Follow table shows the screening criteria for using thermal methods

Table 1. Screening criteria for thermal methods

criteria for thermal methods				
Property	**CSS**	**Steamflooding**	**SAGD**	**Hot Water Inj.**
Oil Gravity (API)	8-35	8-20	7-12	10-35
In-situ Oil Viscosity (cP)	10^3-10^6	10^3-10^4	4000-10^6	10^3-10^4
Reservoir Depth (ft)	400-3000	400-4500	250-3000	<3000
Pay Thickness (ft)	>20-150	15-150	50-100	>20
Average Horz. Perm. (mD)	>250	>250	>5000	>2500
Reservoir Pressure (MPa)	2,8-10,3	<10,3	High	>13,8
Oil Saturation (%)	>50	>40	>50	>50

4.3.2 Chemical methods

Follow table shows the screening criteria for using chemical methods

Table 2. Screening criteria for chemical methods

Criteria for chemical methods EOR		
Property	**Polymer Flooding**	**ASP**
Oil Gravity (API)	>15	>20
In-situ Oil Viscosity (cP)	10^1-10^3	<35
Reservoir Depth (M)	244-2744	152-2744
Average Horz. Perm. (mD)	>100	>100
Reservoir temperature (^{0}C)	<76	<93
Oil Saturation (%)	>30	>45
Formation Salinity (ppm)	<3000	<200

As we can see none of the tertiary methods can be used at this field

4.4 Bottom hole zone treatment

Acid treatment

Well № 25 was subjected to hydrochloric acid treatment (07.2014). To assess the effectiveness of the measures taken for the well, the dynamics of fluid, oil and water cut production was analyzed, covering the period before and after the acid treatment.

It should be noted that at well № 25, no positive results were obtained from the application of the RMS, the average parameters of the wells remained practically at the same level: oil production averaged 0.9 t / day, liquid 1.1 t / day, water cut decreased from 19 to 12 %.

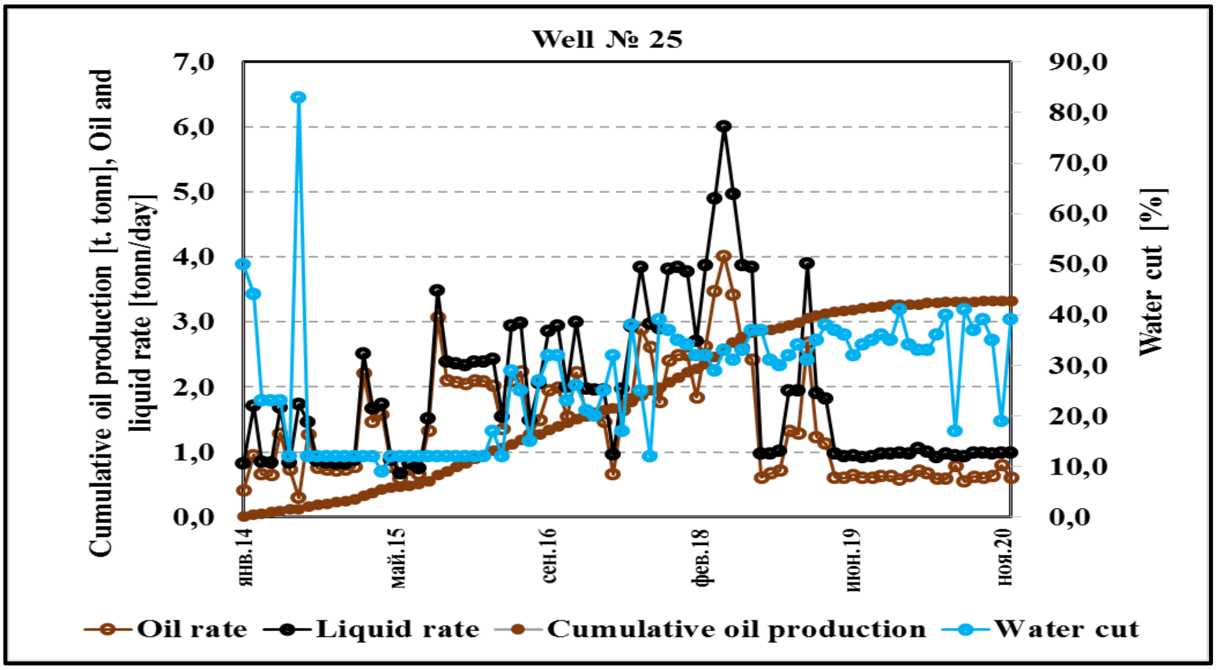

Figure 11. Development parameters of the well № 8

It should be noted that the lack of effect from the DIS depends on a number of factors, the main of which is compliance with the technology.

Also, with an increase in the depth of the well, there is a rapid neutralization of acid in the immediate vicinity of the bottom of the well, as well as swelling of clay minerals in neutralized solutions, which causes a decrease in reservoir permeability. All this makes it difficult to create a good hydrodynamic connection between the wellbore and the formation.

In order to slow down the reaction rate of the acid, its deeper penetration into the formation and, accordingly, increase the efficiency of treatments, it is necessary to introduce acid activity inhibitors into the acid composition. In addition, the effectiveness of acidizing oil wells depends significantly on the quality of the hydrochloric acid used. The presence of even an insignificant amount of iron ions and other impurities in it leads to a sharp decrease in the efficiency of acidizing the bottomhole formation zone and a significant decrease in the planned increase in oil production of the well.

According to the results of the studies performed, the optimal concentration of acid solution for treatment of the bottomhole formation zone in order to increase the productivity of wells in complex carbonate reservoirs of oil of the fields is 12% HCl + 5% (CH_3COOH).

4.5 Drilling new wells

Drilling new wells can increase the drained area.

The wells density grid is 32 ha/well. But if we consider low value of permeability a large amount of oil is not involved in development.

In chapter 2.4 the effectiveness of this method is seen on the graph where peak of oil production is related to the setting of the new wells. So the down-spacing can help to involve more oil reserves. As were mentioned in chapter 2.6 the fractures have vertical orientation which prevents good horizontal conduction. In this case the setting horizontal wells is the best way to cover larger oil saturated zone.

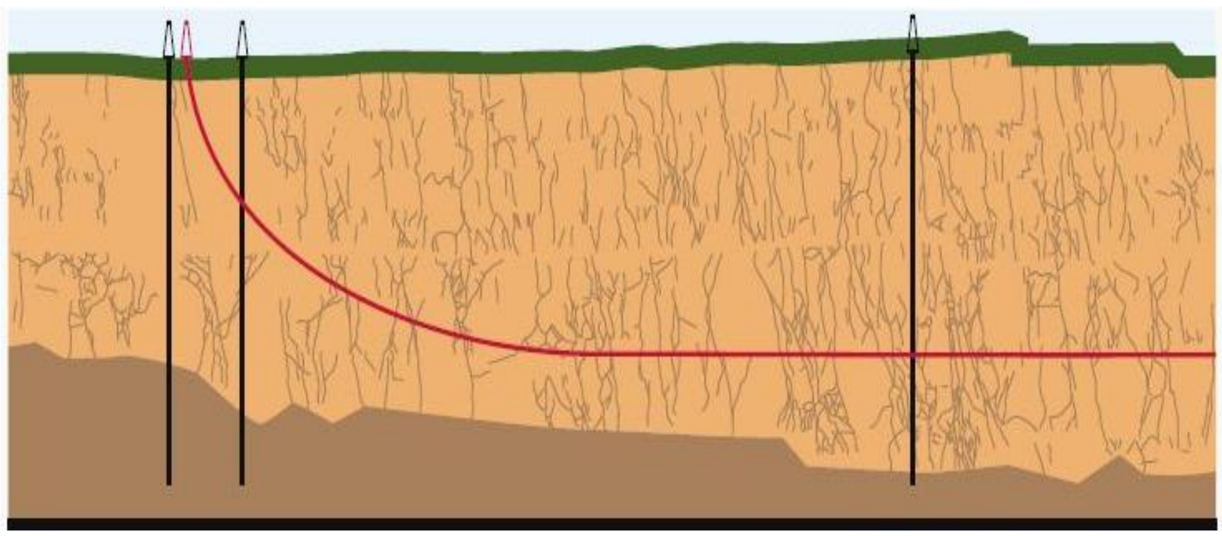

Figure 12.. Fracture orientation on carbonate fields

If we consider the drilling of the new wells one of the attractive adaptation of the horizontal well is the multi-laterals. Follow picture shows different types of multilaterals.

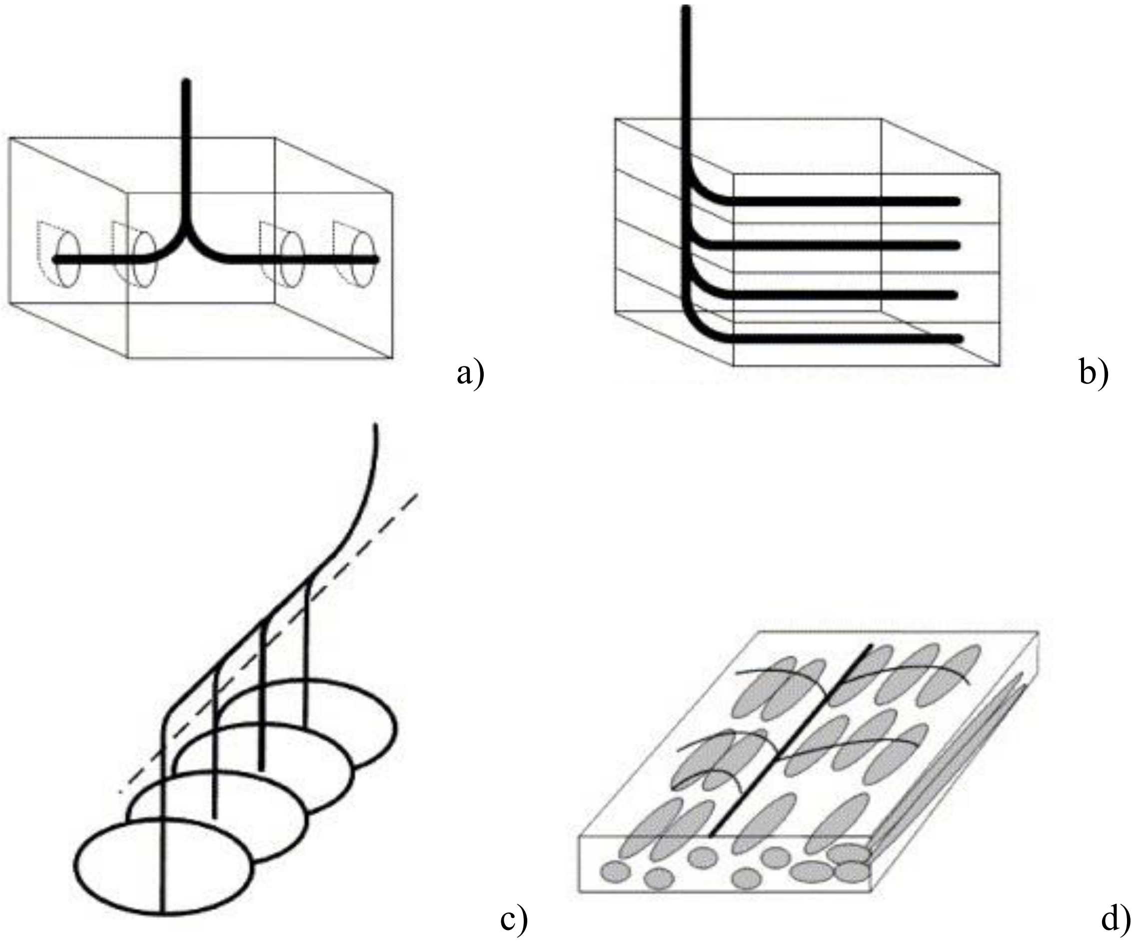

Figure 13. Types of multilaterals a) dual opposing laterals for poorly consolidated/thin formations. b) multilateral wells for heavy crudes in thick formations. C) multibranch well with fractures vertical branches. d) multilateral wells for isolated pockets of oil.

Multilateral well drilled in favorable location may be much more efficient than several wells built using traditional technologies. Since in this case, the efficiency of work increases, there is a reduction in construction costs, the volume of oil coming from the reservoir. Literate the use of multilateral drilling technology allows for better quality field development. Drilling multilateral wells can be effective for the development of fields with depleted reserves or for the operation of reservoirs with low reservoir pressure

The advantages of this drilling method are: increased coverage ratio formation, reducing overall drilling costs and completing wells, increasing productivity, ensuring a more effective oil flow, ensuring an increase in the oil recovery factor. Production volumes world oil increases significantly over multilateral well construction.

A. Grigoryan tested his method at the Ishimbayneft field he drilled well 66/45.

The main wellbore was drilled to a depth of 575 meters. Branches like tree roots were drilled from the main open trunk. The drilling was carried out without installing cement bridges, without diverters, without any special tools. As a result, he received 9 boreholes in this well, while the maximum deviation from the vertical was 136 meters, with a total effective length of 32 meters.Drilling cost 2 times more than usual, but an increase in production rates was obtained, and even 120 m3, while before that production rates were 7 m3 / day.

Oil in the desired field is distributed non-uniformly throughout the reservoir, for example, the geophysical characteristics of the reservoirs in well №7 are given in follow picture.

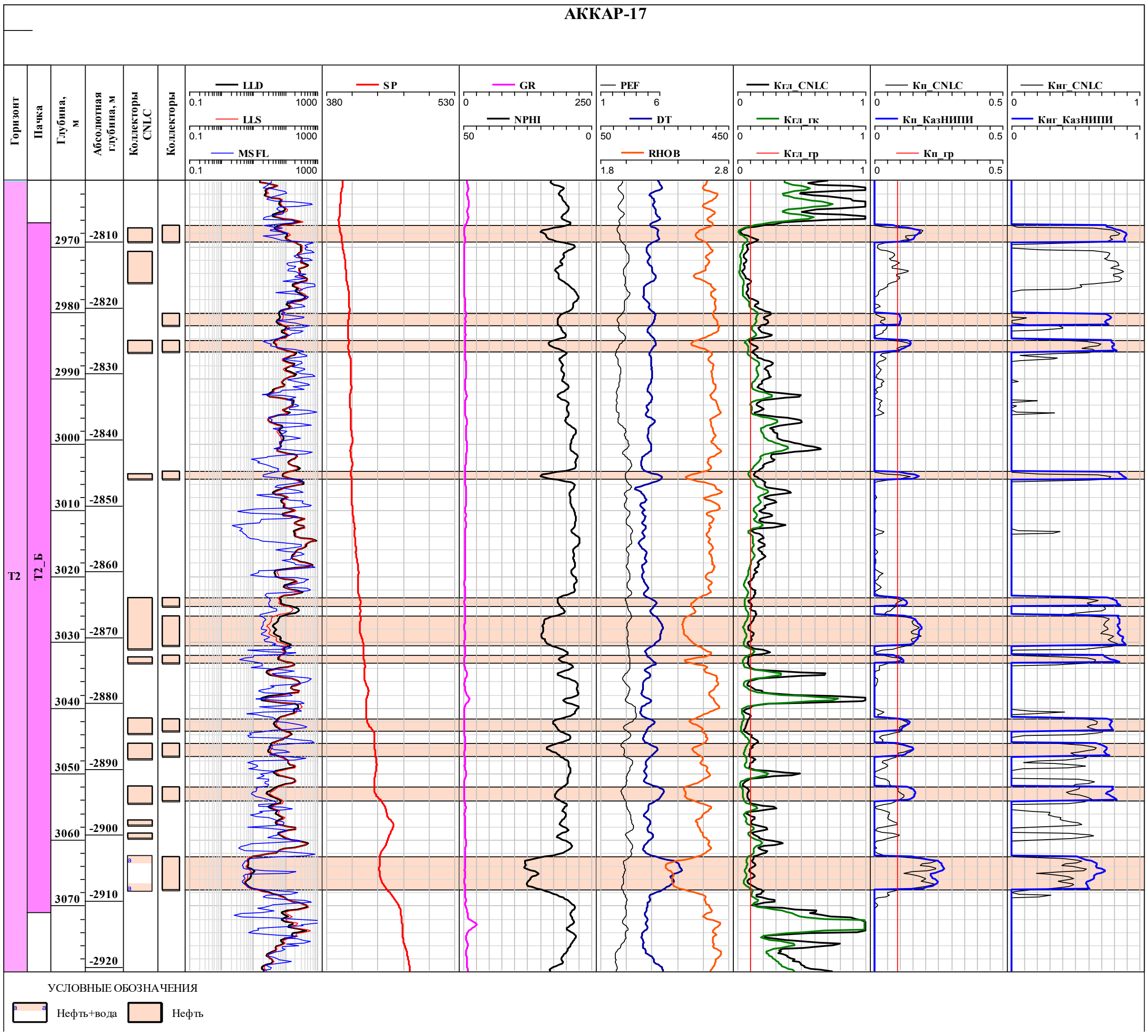

Figure 14. Geophysical characteristics of the reservoirs in well №

As can be seen from this figure, oil in interlayer is not connected with each other. It should be noted that the draining new wells regarding other methods is costly process. It can be used in the case of absence cost-effective alternate.

4.6 Mechanical methods

4.6.1 Hydraulic fracturing

Well №8 in April 2013 with hydraulic fracturing. Well operation parameters before and after hydraulic fracturing are shown in Figure 8.2.

Oil flow rate before hydraulic fracturing averaged 1.5 tons / day, after - 24.6 tons / day. and in the following months increased to 45.3 tons / day. The water cut after hydraulic fracturing decreased from 16.8 to 12% and stabilized at this level. The effect of hydraulic fracturing in the well lasted 21 months. Further, in February 2015, there is a sharp decline in oil production to 2.8 tons / day. As of the date of analysis, the oil production rate was 4.6 tons / day, liquid - 6.9 tons / day, water cut 34%.

To assess the effectiveness of hydraulic fracturing at well 8, an analysis was made of changes in the predicted and actual values of cumulative oil production before and after hydraulic fracturing.

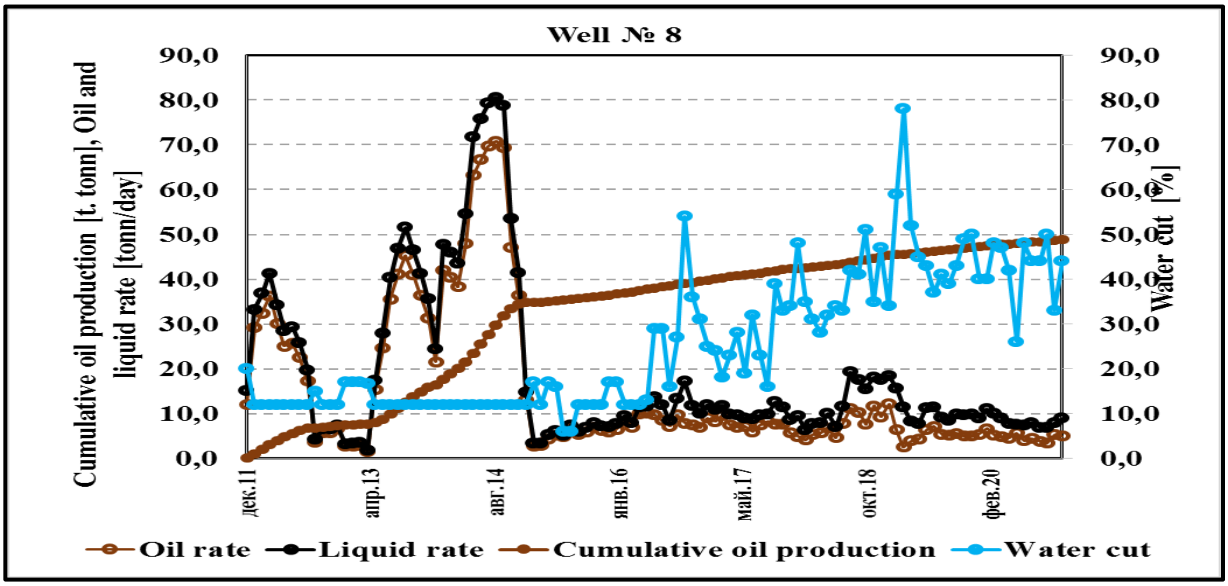

Figure 15. Development parameters of well № 8

The well №16 in September 2013 was fractured.

Oil flow rate before hydraulic fracturing averaged 2.2 t / day, after -32.3 t / day. The water cut after hydraulic fracturing decreased from 23 to 12% and stabilized at this level. The effect of hydraulic fracturing in the well lasted 6 months.

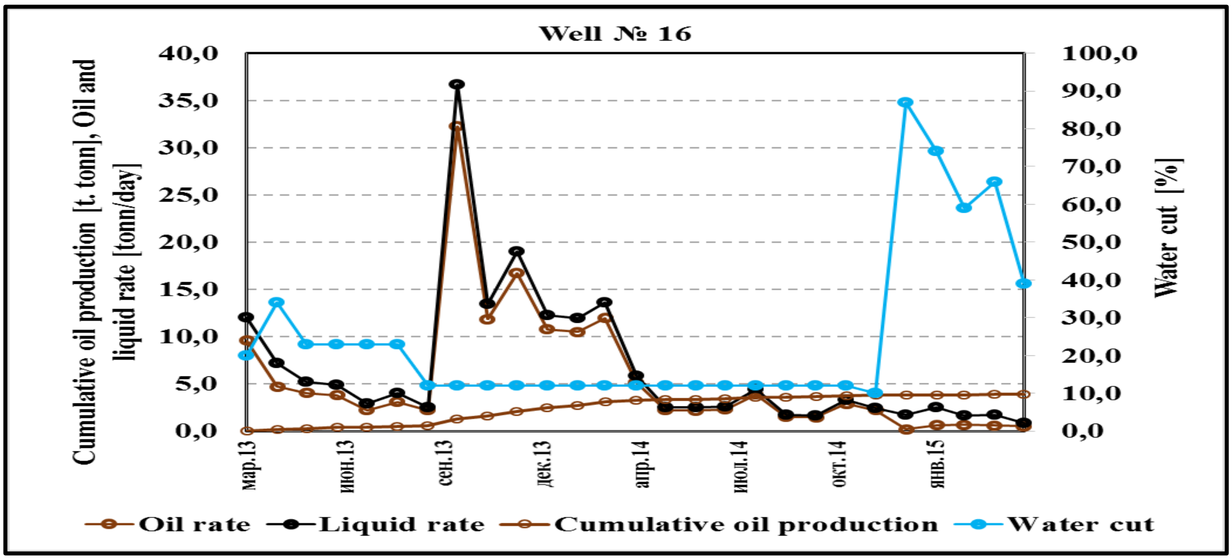

Figure 16. Development parameters of well № 16

As the result we can see the hydraulic fracturing had positive effect and can be used further.

4.6.2 Drilling the sidetracks

Multiple sidetracking is modification of the multilateral well. This method saves on vertical drilling, which has a positive effect on the economic component.

Follow steps help to investigate the effect of using this method making theoretical application on the 'N' field.

Step1. Selection of wells-candidates

Step2. Calculate the additional production

Step3. Calculate the recovery factor taking into account additional production.

Step4. Comparison with other methods.

Step1. Firstly, it is necessary to select wells candidates for sidetracking.

3 criteria were emphasized.

1) Maximum structure height
2) Maximum oil Net pay zone
3) High reservoir pressure

1)Maximum structure height

The sidetrack has to be drilled as far as possible from the bottom of the reservoir to avoid breakthrough of the underlying water if there is long vertical fracture. Furthermore the remoteness from the water will give possibility to make hydraulic fracturing if the well will be damaged.

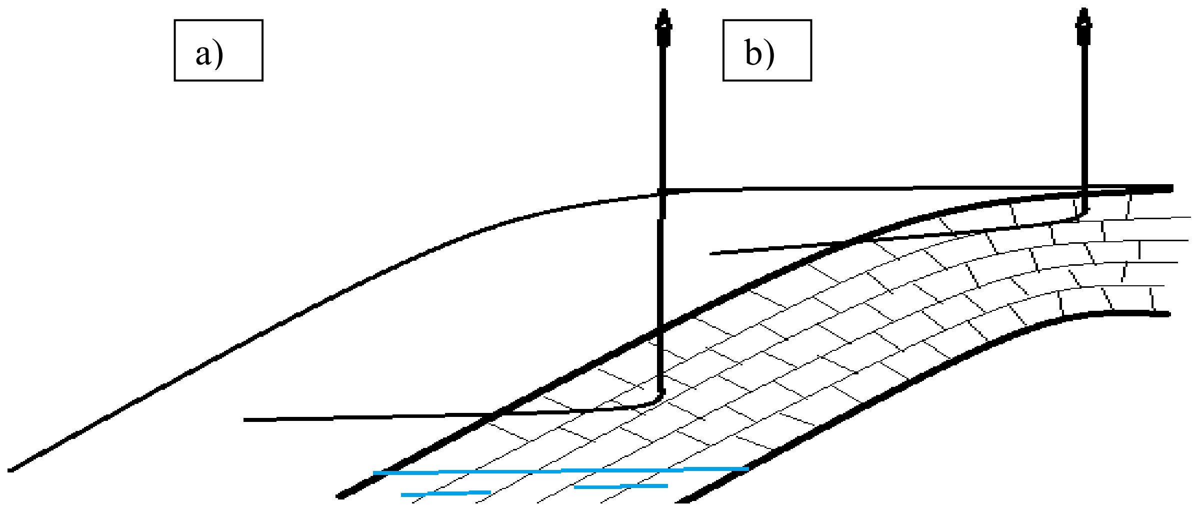

Figure 17. Scheme of the undesirable (a) and desirable (b) well location

By this criteria the wells №1, №8, №4, №11, №20 were selected cause they are located at the top of the anticline.

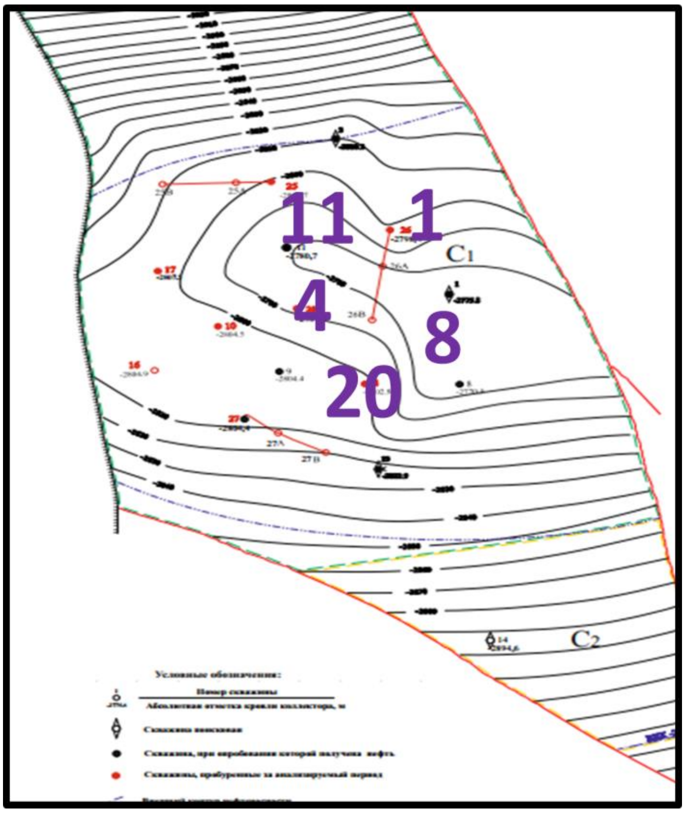

Figure 18. Well- candidates by first criteria

2) Maximum oil Net pay zone

Another important criteria. Large oil net pay zone contains more oil and give the possibility to place more sidetracks in vertical direction increasing the covered area.

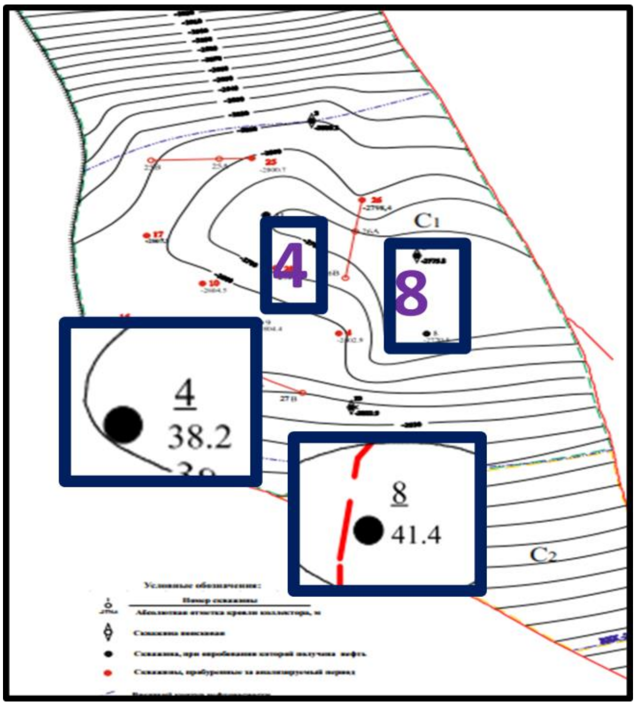

Figure 19. Well-candidates by the second criteria

By this criteria the wells №8, №4 were selected with oil net pay zone 38,2 m 41,4 m respectively.

3) *High reservoir pressure* is the most important criteria. Because sidetracks give very high oil rates proportionally to the amount of them. In this case the reservoir energy will be rapidly depleted.

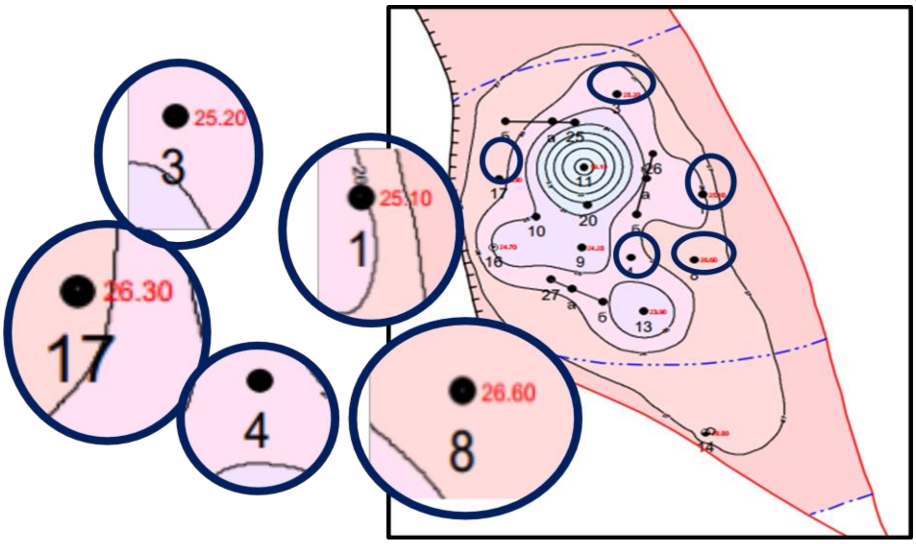

Figure 20. Well-candidates by the third criteria

By this criteria the wells №8 (26,6 Mpa), №17 (26,3 Mpa), №4 (26 Mpa), №3 (25,2Mpa), №1 (25,1 Mpa), were selected.

Generalizing all of the criteria follow table is created

Table 3. Well- candidates by all criteria

	Well number				
1 Maximum structure height	1	8	4	11	20
2 High reservoir pressure	8	4	17	3	1
3 Maximum oil Net Pay zone	8	4			

According to this table №8 well leads the way.

Step2.

Follow formula developed by Y.T. Borisov, V.P. Tabakov were used to calculate the initial oil rate in one sidetrack.

$$q = \frac{2\pi kh}{\mu} * \frac{Pk - Pc}{ln\frac{4Rk}{L} + \frac{h}{L}ln\frac{h}{2\pi rc}}$$

Where:

q- initial oil rate, m^3/day

k- permeability, mD

μ- viscosity, cP

h- reservoir thickness, m

Pk- boundary pressure, Mpa

Pc- bottom hole pressure, Mpa

Rk- radial extent, m

L- sidetrack length, m

r_c- reduced well radius, m $r_c=r_w e^{-S}$

S- skin factor,

$$q = \frac{2 * 3,14 * 41,4}{0,98} * \frac{26,6 - 20}{ln\frac{4 * 200}{250} + \frac{41,4}{250} ln\frac{41,4}{2 * 3,14 * 0,25^4}} = 159,9\, m3/day$$

This value will be doubled if we drill two sidetracks.

$$159,9 * 2 = 319,8\, m3/day$$

Step3.

Follow formula was used to calculate the additional production

We consider the exponential decline rate.

$$q = qi * e^a$$

Where :

q- liquid rate, ton/day

q- initial liquid rate, ton/day

a- rate of the decline, defined from the production history of the well

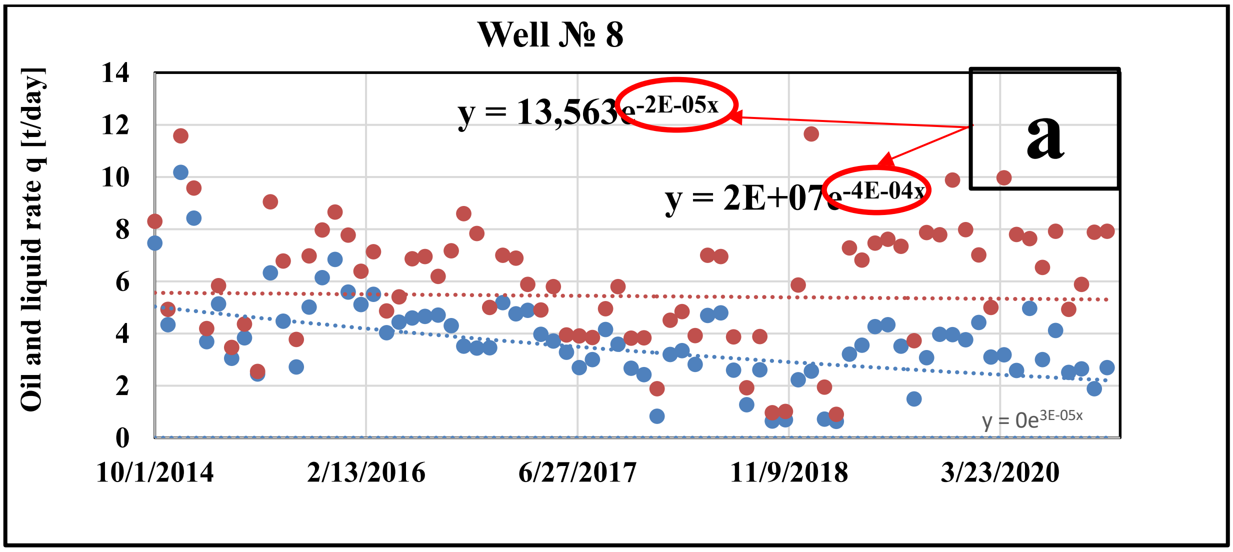

Figure 21. Production history of well № 8

Data for calculation:

Table 4. Initial data for additional production calculation

initial data:	
Field	*N*
Well №	***4***
№ sidetracks	*1*
Well entry date	***01.05.2021***
decline rate of the oil, fraction	*-0,0004*
decline rate of the liquid, fraction	*0,0000*
on-stream factor,fraction	*0,96*
Calculation period, years	*5*
initial oil rate, ton/day	***159,9***
initial liquid rate, ton/day	***202,5***

Calculation by every month during 2021:

Table 5. Additional production of oil by month for 2021 year

	Total	2021							
		May-21	Jun-21	Jul-21	Aug-21	Sep-21	Oct-21	Nov-21	Dec-21
growth of oil rate, ton/day		159,9	159,8	159,8	159,7	159,7	159,6	159,5	159,5
growth of liquid rate, ton/day		202,5	202,4	202,4	202,4	202,4	202,4	202,4	202,4
Working time, days		30	29	30	30	29	30	29	30
additionat oil production, ton	277183	4759	4604	4755	4753	4598	4749	4594	4746
additionat liquid production, ton	354879	6025	5831	6025	6025	5830	6024	5830	6024

Calculation by every month during 2022:

Table 6. Additional production of oil by month for 2022 year

2022											
Jan-22	Feb-22	Mar-22	Apr-22	May-22	Jun-22	Jul-22	Aug-22	Sep-22	Oct-22	Nov-22	Dec-22
159,4	159,3	159,3	159,2	159,1	159,1	159,0	159,0	158,9	158,8	158,8	158,7
202,4	202,4	202,4	202,4	202,4	202,4	202,4	202,4	202,4	202,4	202,4	202,4
30	27	30	29	30	29	30	30	29	30	29	30
4744	4283	4740	4585	4736	4581	4732	4730	4576	4727	4572	4723
6024	5441	6024	5829	6024	5829	6023	6023	5829	6023	5829	6023

Calculation by every month during 2023:

Table 7. Additional production of oil by month for 2023 year

2023											
Jan-23	Feb-23	Mar-23	Apr-23	May-23	Jun-23	Jul-23	Aug-23	Sep-23	Oct-23	Nov-23	Dec-23
158,6	158,6	158,5	158,4	158,4	158,3	158,3	158,2	158,1	158,1	158,0	157,9
202,4	202,4	202,4	202,4	202,4	202,4	202,3	202,3	202,3	202,3	202,3	202,3
30	27	30	29	30	29	30	30	29	30	29	30
4721	4262	4717	4563	4713	4560	4710	4708	4554	4704	4550	4700
6023	5440	6022	5828	6022	5828	6022	6022	5827	6022	5827	6021

Calculation by every month during 2024:

Table 8. Additional production of oil by month for 2024 year

2024											
Jan-24	Feb-24	Mar-24	Apr-24	May-24	Jun-24	Jul-24	Aug-24	Sep-24	Oct-24	Nov-24	Dec-24
157,9	157,8	157,7	157,7	157,6	157,6	157,5	157,4	157,4	157,3	157,2	157,2
202,3	202,3	202,3	202,3	202,3	202,3	202,3	202,3	202,3	202,3	202,3	202,3
30	28	30	29	30	29	30	30	29	30	29	30
4698	4393	4695	4541	4691	4538	4687	4685	4532	4681	4529	4678
6021	5633	6021	5827	6021	5826	6020	6020	5826	6020	5826	6020

Calculation by every month during 2025:

Table 9.Additional production of oil by month for 2025 year

2025											
Jan-25	Feb-25	Mar-25	Apr-25	May-25	Jun-25	Jul-25	Aug-25	Sep-25	Oct-25	Nov-25	Dec-25
157,1	157,1	157,0	156,9	156,9	156,8	156,7	156,7	156,6	156,6	156,5	156,4
202,3	202,3	202,3	202,3	202,3	202,3	202,3	202,2	202,2	202,2	202,2	202,2
30	27	30	29	30	29	30	30	29	30	29	30
4676	4222	4672	4520	4668	4516	4665	4663	4511	4659	4507	4655
6020	5437	6019	5825	6019	5825	6019	6019	5825	6019	5824	6018

Calculation by every month during 2026:

Table 10.Additional production of oil by month for 2026 year

2026											
Jan-26	Feb-26	Mar-26	Apr-26	May-26	Jun-26	Jul-26	Aug-26	Sep-26	Oct-26	Nov-26	Dec-26
156,4	156,3	156,2	156,2	156,1							
202,2	202,2	202,2	202,2	202,2							
30	27	30	29	1							
4653	4201	4650	4498	150							
6018	5436	6018	5824	194							

Additional production by years:

Table 11. Additional production from drilling sidetracks of oil by years

Total by years:	Total	2021	2022	2023	2024	2025	2026
Addit.l oil prod, 10^3 ton	**277,183**	37,558	55,729	55,462	55,348	54,934	18,152
Addit. liquid prod.,10^3 ton	**354,879**	47,614	70,921	70,904	71,081	70,869	23,490

Total additional production of the oil is 277 183 tons for 5 years.

Total additional production of the liquid is 354 879 tons for 5 years.

Step4.

The hydraulic fracturing which showed positive effect were chosen for comparison.

From the practical application it was found out that the average additional oil production from hydraulic fracturing is 17 ton/day with average duration of the effect 282 days. To calculate additional oil production in 5 years, 5 hydraulic fracturing processes were considered with interval 282 day.

Calculation of the additional production from the hydraulic fracturing by every month during 2021:

Table 12. Additional production of oil by month for 2021 year

	Total	2021							
		May-21	Jun-21	Jul-21	Aug-21	Sep-21	Oct-21	Nov-21	Dec-21
Growth of oil rate, ton/day		17,0	17,0	17,0	17,0	17,0	17,0	17,0	16,9
Growth of liquid rate, ton/day		21,5	21,5	21,5	21,5	21,5	21,5	21,5	21,5
Working time, days		30	29	30	30	29	30	29	30
Additionat oil production, to	**29461**	506	489	505	505	489	505	488	504
Additionat liquid production, ton	**37719**	640	620	640	640	620	640	620	640

Calculation by every month during 2022:

Table 13. Additional production of oil by month for 2022 year

2022											
Jan-22	Feb-22	Mar-22	Apr-22	May-22	Jun-22	Jul-22	Aug-22	Sep-22	Oct-22	Nov-22	Dec-22
16,9	16,9	16,9	16,9	16,9	16,9	16,9	16,9	16,9	16,9	16,9	16,9
21,5	21,5	21,5	21,5	21,5	21,5	21,5	21,5	21,5	21,5	21,5	21,5
30	27	30	29	30	29	30	30	29	30	29	30
504	455	504	487	503	487	503	503	486	502	486	502
640	578	640	620	640	620	640	640	620	640	620	640

Calculation by every month during 2023:

Table 14. Additional production of oil by month for 2013 year

2023											
Jan-23	Feb-23	Mar-23	Apr-23	May-23	Jun-23	Jul-23	Aug-23	Sep-23	Oct-23	Nov-23	Dec-23
16,9	16,9	16,8	16,8	16,8	16,8	16,8	16,8	16,8	16,8	16,8	16,8
21,5	21,5	21,5	21,5	21,5	21,5	21,5	21,5	21,5	21,5	21,5	21,5
30	27	30	29	30	29	30	30	29	30	29	30
502	453	501	485	501	485	501	500	484	500	484	500
640	578	640	619	640	619	640	640	619	640	619	640

Calculation by every month during 2024:

Table 15. Additional production of oil by month for 2024 year

2024											
Jan-24	Feb-24	Mar-24	Apr-24	May-24	Jun-24	Jul-24	Aug-24	Sep-24	Oct-24	Nov-24	Dec-24
16,8	16,8	16,8	16,8	16,8	16,7	16,7	16,7	16,7	16,7	16,7	16,7
21,5	21,5	21,5	21,5	21,5	21,5	21,5	21,5	21,5	21,5	21,5	21,5
30	28	30	29	30	29	30	30	29	30	29	30
499	467	499	483	499	482	498	498	482	498	481	497
640	599	640	619	640	619	640	640	619	640	619	640

Calculation by every month during 2025:

Table 16. Additional production of oil by month for 2025 year

2025											
Jan-25	Feb-25	Mar-25	Apr-25	May-25	Jun-25	Jul-25	Aug-25	Sep-25	Oct-25	Nov-25	Dec-25
16,7	16,7	16,7	16,7	16,7	16,7	16,7	16,7	16,6	16,6	16,6	16,6
21,5	21,5	21,5	21,5	21,5	21,5	21,5	21,5	21,5	21,5	21,5	21,5
30	27	30	29	30	29	30	30	29	30	29	30
497	449	497	480	496	480	496	496	479	495	479	495
640	578	640	619	640	619	640	640	619	640	619	640

Calculation by every month during 2026:

Table 17. Additional production of oil by month for 2026 year

2026											
Jan-26	Feb-26	Mar-26	Apr-26	May-26	Jun-26	Jul-26	Aug-26	Sep-26	Oct-26	Nov-26	Dec-26
16,6	16,6	16,6	16,6	16,6							
21,5	21,5	21,5	21,5	21,5							
30	27	30	29	1							
495	447	494	478	16							
640	578	640	619	21							

Additional production by years:

Table 18. Additional production from hydraulic fracturing of oil by years

Total by years:	Total	2021	2022	2023	2024	2025	2026
Addit.l oil prod, 10^3 ton	**29,461**	3,991	5,922	5,896	5,883	5,839	1,930
Addit. liquid prod.,10^3 ton	**37,719**	5,060	7,538	7,534	7,555	7,534	2,498

Total additional production of the oil is 29 481 tons for 5 years.

Total additional production of the liquid is 37 719 tons for 5 years.

This method can be used on the 'N' field but the investigation of fracture orientation has to be observed. Because drilling perpendicular to the fracture orientation can help to involve more fractures which creates are high permeable zones.

5 Technical and economic analysis

To optimize the development system 3 variants were considered.

Average cost of the sidetracking 202316,19 $

Average cost of the hydraulic fracturing 44017,94$

202316,19 $ /44017,94$= 4,6

It means drilling 1 sidetracking is equivalent to 5 hydraulic fracturing

1) Resume the development with the current system
2) Making 5 the hydraulic fracturing
3) Drilling 2 sidetracks in well №4.

1 Variant

Characteristic of the main development parameters of the 'N' field

Table 19. Technological parameters of development system by 1 variant

Years	Oil production, 10^3 tonn	Extraction rate, %		Cumulative oil production, 10^3 tonn	Extraction of recoverable reserves, %	Recovery factor, %
		from initial	from current			
1	*2*	*3*	*4*	*5*	*6*	*7*
2018	12,1039954	0,4	0,5	599,5	18,7	4,957211331
2019	10,05502681	0,3	0,4	609,6	19,0	5,040351953
2020	11,89098757	0,4	0,5	621,5	19,4	5,138673332
2021	10,2188789	0,3	0,4	631,7	19,7	5,223168775
2022	9,984702023	0,3	0,4	641,7	20,0	5,305727912
2023	9,354908027	0,3	0,4	651,0	20,3	5,383079558
2024	9,141333568	0,3	0,4	660,2	20,6	5,45866525
2025	8,932635057	0,3	0,4	669,1	20,9	5,532525305
2026	8,728701176	0,3	0,3	677,8	21,1	5,60469912
2027	8,529423147	0,3	0,3	686,4	21,4	5,675225192
2028	8,334694676	0,3	0,3	694,7	21,7	5,744141139
2029	8,144411896	0,3	0,3	702,8	21,9	5,811483721
2030	7,958473311	0,2	0,3	710,8	22,2	5,877288859
2031	7,776779741	0,2	0,3	718,6	22,4	5,941591651
2032	7,599234273	0,2	0,3	726,2	22,7	6,004426398
2033	7,425742204	0,2	0,3	733,6	22,9	6,065826615
2034	7,256210995	0,2	0,3	740,9	23,1	6,125825052
2035	7,090550217	0,2	0,3	747,9	23,3	6,184453712
2036	6,928671509	0,2	0,3	754,9	23,5	6,241743869
2037	6,770488524	0,2	0,3	761,6	23,8	6,297726079
2038	6,61591689	0,2	0,3	768,3	24,0	6,352430204

Further development of the field with the existing fund and the price of oil is economically impractical.

2 Variant

The recovery factor by using hydraulic fracturing:

Characteristic of the main development parameters of the ‘N’ field by 2 variant

Table 20. Technological parameters of development system by 2 variant

Years	Oil production, 10^3 tonn	Extraction rate, %		Cumulative oil production, 10^3 tonn	Extraction of recoverable reserves, %	Recovery factor, %
		from initial	from current			
1	*2*	*3*	*4*	*5*	*6*	*7*
2018	12,1039954	0,4	0,5	599,5	18,7	4,96
2019	11,05502681	0,3	0,4	610,6	19,0	5,05
2020	11,89098757	0,4	0,5	622,5	19,4	5,15
2021	14,2098789	0,4	0,6	636,7	19,9	5,26
2022	15,90670202	0,5	0,6	652,6	20,4	5,4
2023	15,25090803	0,5	0,6	667,8	20,8	5,52
2024	15,02433357	0,5	0,6	682,9	21,3	5,65
2025	14,77163506	0,5	0,6	697,6	21,8	5,77
2026	10,65870118	0,3	0,4	708,3	22,1	5,86

3 Variant

*The recovery factor by drilling **1 sidetrack:***

Characteristic of the main development parameters of the 'N' field by 3 variant

Table 21. Technological parameters of development system by 3 variant

Years	Oil production, 10^3 tonn	Extraction rate, %		Cumulative oil production, 10^3 tonn	Extraction of recoverable reserves, %	Recovery factor, %
		from initial	from current			
1	*2*	*3*	*4*	*5*	*6*	*7*
2018	12,1039954	0,4	0,5	599,5	18,7	4,96
2019	11,05502681	0,3	0,4	610,6	19,0	5,05
2020	11,89098757	0,4	0,5	622,5	19,4	5,15
2021	47,7768789	1,5	1,9	670,2	20,9	5,54
2022	65,71370202	2,0	2,7	736,0	23,0	6,09
2023	64,81690803	2,0	2,7	800,8	25,0	6,62
2024	64,48933357	2,0	2,8	865,3	27,0	7,15
2025	63,86663506	2,0	2,8	929,1	29,0	7,68
2026	26,88070118	0,8	1,2	956,0	29,8	7,91

*The additional production by drilling **2 sidetracks:***

Additional production by years:

Table 22. Additional production from drilling 2 sidetracks by years

Total by years:	Total	2021	2022	2023	2024	2025	2026
Addit.l oil prod, 10^3 ton	554,368	75,116	111,460	110,924	110,697	109,866	36,305
Addit. liquid prod.,10^3 ton	709,757	95,227	141,841	141,808	142,162	141,738	46,981

*The recovery factor by drilling **2 sidetracks:***

Table 23. Technological parameters of development system by 3 variant (2 sidetracks)

Years	Oil production, 10^3 tonn	Extraction rate, %		Cumulative oil production, 10^3 tonn	Extraction of recoverable reserves, %	Recovery factor, %
		from initial	from current			
1	*2*	*3*	*4*	*5*	*6*	*7*
2018	12,1039954	0,4	0,5	599,5	18,7	4,96
2019	11,05502681	0,3	0,4	610,6	19,0	5,05
2020	11,89098757	0,4	0,5	622,5	19,4	5,15
2021	85,3348789	2,7	3,4	707,8	22,1	5,85
2022	121,444702	3,8	5,1	829,3	25,9	6,86
2023	120,278908	3,8	5,3	949,5	29,6	7,85
2024	119,8383336	3,7	5,6	1069,4	33,4	8,84
2025	118,7986351	3,7	5,9	1188,2	37,1	9,82
2026	45,03370118	1,4	2,3	1233,2	38,5	10,2

The drilling of 1 sidetrack can increase recovery factor till the 7,91 % . two sidetracks can increase that parameter till the 10,2 %.

To compare those values the graph of the recovery factor values were created:

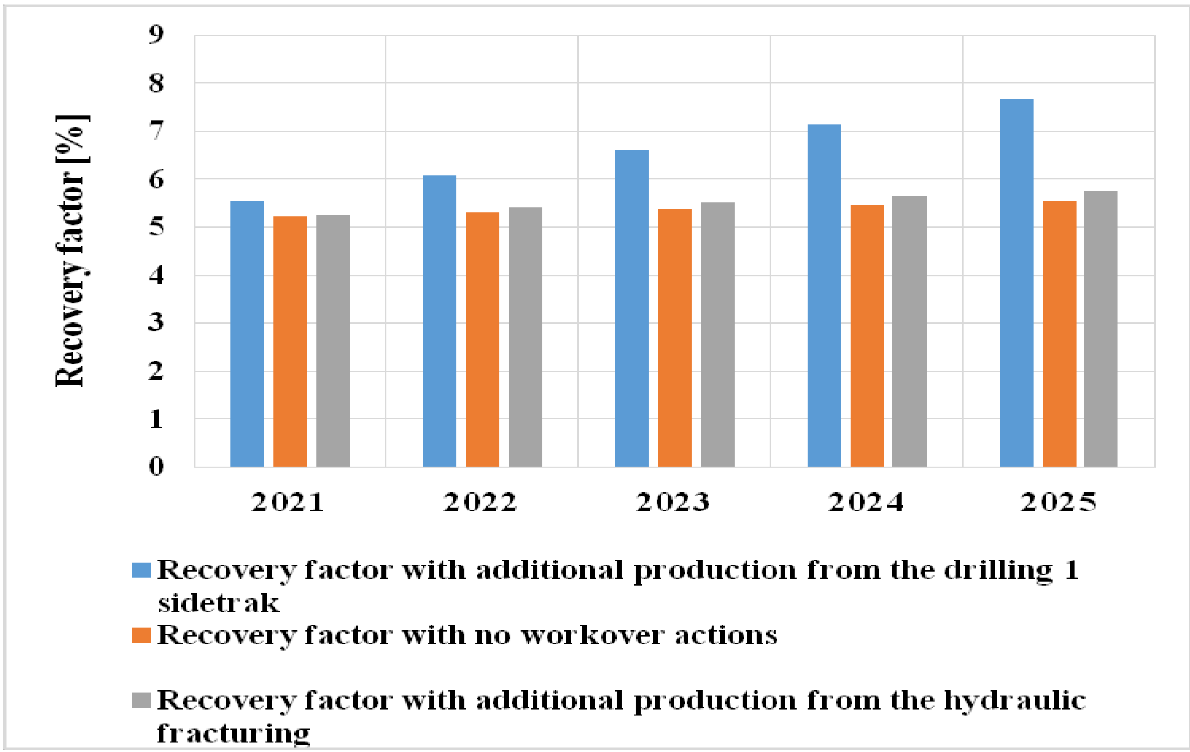

Figure 22. Comparison of the recovery factor using workover actions (1 sidetrack)

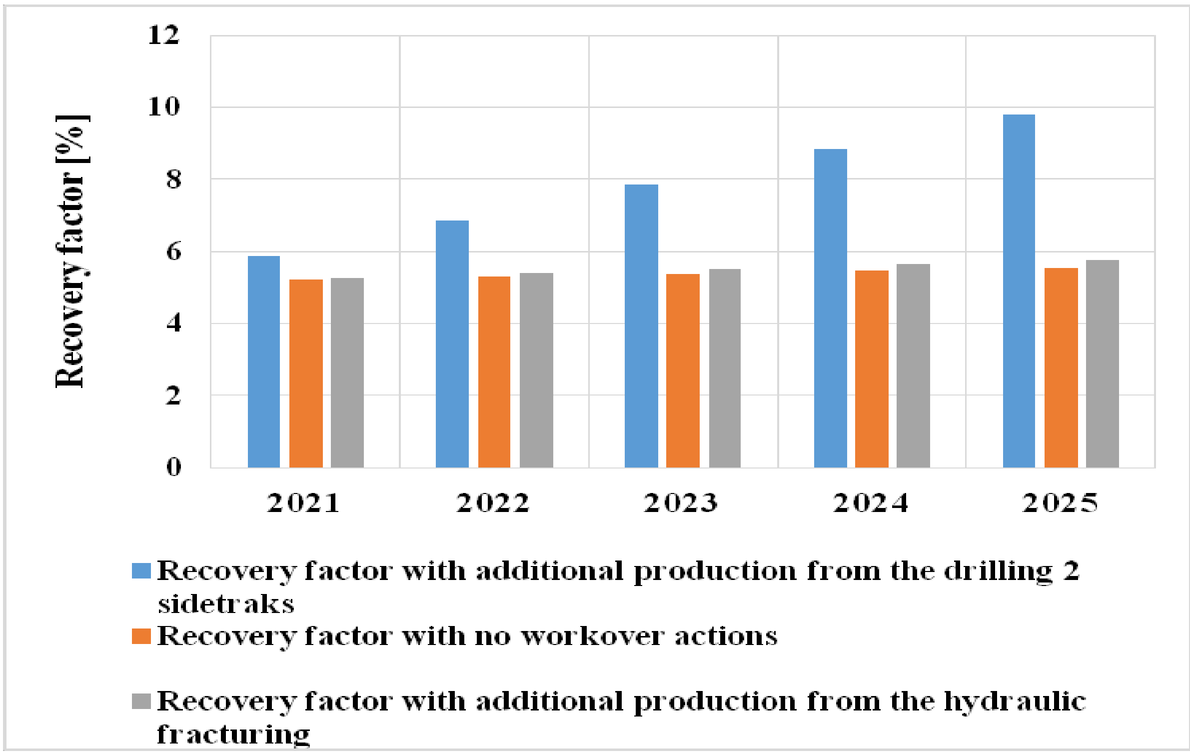

Figure 23. Comparison of the recovery factor using workover actions (2 sidetracks)

According to this graph the *recovery factor is sharply increasing* when the drilling of sidetracks is used comparing with hydraulic fracturing. Recovery factor can be increased *2 times*, from 5,15% to 10,2% during 5 years.

As the result the sidetracking allow to achieve project level of recovery factor quicker that making hydraulic fracturing.

Economic parameters

Based on the data from the forecast of the technological indicators of the well, the total accumulated oil production for 8 years for each well under consideration was obtained.

Taking into account the average cost of Brent crude oil of $ 68.32, as well as the current exchange rate of the US dollar of 423.39 tenge, the company's profit for 8 years for each well is calculated according to the formula:

$$P = \frac{Np * AOP * DR}{0,1364}$$

Where:

P- profit

Np-cumulative oil production in 8 years

AOP- average oil price

DR- dollar rate

Taking into account the average cost of costs for sidetrack cutting and production drilling, the company's net profit from accumulated oil production for 8 years for each well under study was calculated:

$$NP = P - ACE$$

Where:

NP- net profit

P- profit

ACE- average cost of event

In order to improve the economic calculation, the concept of discounting cash flows was introduced, that is, bringing the value of future (expected) cash payments to the current point in time. Discounting cash flows is based on the important economic law of the decreasing value of money.

Discounting cash flows:

$$DCF = \sum_{i=1}^{n} \frac{CFi}{(1+r)^i}$$

Where:

DCF-discounted cash flow or NPV net present value

CF- cash flow

r- internal rate of return

Table 24. Economical analysis of three variant of development

Parameter	1 variant	2 variant	3variant
Investment, $	0	202316,19	220089,7
Cumulative oil production, 10^3 to	677,8	956	796,7
Conversion factor	7,62		
Cumulative oil production, bar	5164836	7284720	6070854
Oil prise, $/bar	68,32		
Profit, $	352861595,520	497692070,400	414760745,280
Net profit, $	352861595,520	497489754,210	414540655,580
i, %	5		
NPV1	58810265,920	82914959,035	69090109,263
NPV2	9801710,987	13819159,839	11515018,211
NPV3	272269,750	383865,551	319861,617
NPV4	7563,049	10662,932	8885,045
NPV5	210,085	296,193	246,807
NPV6	5,836	8,228	6,856
NPV7	0,162	0,229	0,190
NPV8	0,005	0,006	0,005

The Net Present Value didn't took negative value it means that break even point wasn't achieved by all of the variants. They are in profitability zone.

But values of NPV of the 2 variant is higher than other, which means that it is more favorable.

6 Social responsibility.

Social responsibility implies activities aimed at developing new solutions that ensure: the elimination of accidents; the protection of workers ' health; the reduction of harmful effects on the environment; and the economical of non-renewable natural resources. This portion discusses the space of work, the cutting of side boreholes is performed on the bush site X of the field in the open air below any conditions and at any time of the year. A harmful production factor (VPF) is called such the production factor, the impact of which on the worker in certain conditions leads to illness or a reduce in working capacity. Harmful production factors include: * adverse weather conditions; • dust and gas content of the air environment; * exposure to noise, infra-and ultrasound, and vibration; * the presence of electromagnetic fields, laser and ionizing radiation, etc. All risky and harmful production factors in accordance with GOST 12.0.003-74 are divided into physical, chemical, biological and psychophysiological

Risky production factors include, for example, the possibility of falling the altitude of the worker himself, or different parts and objects; electric current of a certain strength; incandescent bodies; equipment operating below pressure above atmospheric pressure, etc.

7 Environment protection

The main types of anthropogenic impacts on nature are:

1) oil pollution of the environment due to imperfect technology, accidental spills and non-compliance with environmental requirements

2) air pollution during gas combustion in flares and losses through leaky equipment in the area of the compressor station, in case of accidents on gas and oil pipelines;

3) pollution of the natural environment by industrial and hohold waste;

4) the development of negative physical and geological processes in the area of construction and operation of facilities (changes in surface runoff, waterlogging , flooding, development of ravines, landslides, erosion, activation of cryogenic processes in the areas of permafrost distribution, salinization by the outlet of Cenomanian waters).

Common environmental protection measures are: - reduction of oil and gas losses;

-expand of tightness and reliability of oilfield equipment; - high degree of utilization of petroleum gas;

- optimization of fuel combustion processes while reducing the formation of toxic combustion products. All oil collection lines and main oil pipelines should be able to withstand soil deformation during the melting period. Any damage to the environment exterior of the development sites must be eliminated.

- pollution of the natural environment by industrial and hohold waste;

- the development of negative physical and geological processes in the area of construction and operation of facilities (changes in surface runoff, waterlogging, flooding, development of ravines, landslides, erosion, activation of cryogenic processes in the areas of permafrost distribution, salinization by the outlet of Cenomanian waters).

Conclusions and recommendations

The ‘N’ deposit is mature oil field. The problem of this field is high anisotropy of permeability and predominance of low permeable regions. Current development system is not enough effective enough achieve project level. It is needed to use oil recovery mechanisms to increase the effectiveness of the development system. Several types of them were considered in this work.

One of the most attractive methods is drilling sidetracks which helps to increase the productivity of the well raising recovery factor and cover more oil saturated area. Additional surveys like seismic analysis have to be conducted to know the fracture orientation. The hydraulic fracturing is one of the effective methods of oil recovery mechanisms but the duration of the effect is lower that above method. Acid treatment is working process on carbonate reservoirs but it is necessary to ensure quality of the acid.

The Pressure maintenance system has to be organized on this field due to the rapid energy depletion in high productive wells. Additional events like water cleaning from mechanical admixtures is needed to use this method.

Other types: gas injection, thermal, chemical methods can't be used on this field.

NOMENCLATURE

EOR-enhanced oil recovery

RF- recovery factor

CSS- cyclic steam stimulation

SAGD- steam assisted gravity drainage

ASP- alkaline-surfactant-polymer flooding

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