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IMPROVEMENT OF OIL RECOVERY FACTOR FROM GEOLOGICAL PERSPECTIVES

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A b s t r a c t

At a late stage of development of any oilfield, there are big number of factors that affect recovery factor. One of them is related to presence of isolated zones, that were caused by combination of poor reservoir and oil properties of a rock. To solve the given problem variety of workover operations and enhance oil recovery (EOR) methods can be appled for the complex reservoirs such as Tevlinsko-Russinskoe oilfield. The number of particular studies were presented by reviewing of field data, construction of heterogeneity zones, revision of workover operations and selection of EOR methods. It has obtained that the reservoir has the lenticular structure, consists from 9 different facies and presented by 4 classes of heterogeneity. The immiscible gas injections of Nitrogen were selected as the most suitable EOR method for the given oilfield. Application of different composition of brine water was reccomended for wettability alteration.

Keywords:
Enhance oil recovery;
Heterogeneity;
Facies;
Workover optimaztions;
Recovery factor.

1. Introduction

Tevlinsko-Russinskoe oil field is related to the north-eastern slope of Surgut arch area and the Tevlinsky dome-shaped uplift within the Khanty-Mansiysk autonomous okrug of the Tyumen oblast [1-6]. The geologic profile of this field is presented by sandy-silty-clay sediments of the Mesozoic-Cenozoic sedimentary cover overlying with angular stratigraphic unconformity on the rocks of the pre-Jurassic basement. The oil-bearing strata is presented by Sortymskaya formation. The productive horizon BS10-2/3 is presented by a hydrodynamic system that ensures reservoir connectivity of vertical and lateral heterogeneities within the system. This horizon is characterized by sandy clinoforms that subsequently are pinched out to the east and form connections for isolated form of blocks [1, 6-8]. The horizon consists of sandstones and siltstones, cement pore-film, pore, hydroslude-chlorite, less often chlorite-kaolinite and very rarely carbonate composition of cement.

In order to find out how complex is the given petroleum reservoir, there was a structured review of field data. It started with a general geological model using IRAP RMS and TEMPEST Roxar Program package. Then applying electrometric facial models, the characterization of the reservoir by various facies had a place to be. Once it was sorted out, deep research was conducted to split up this reservoir by different zones according to their level of heterogeneity. And the final step was to conduct analysis of completed number of workover operations for the given oilfield and to find out a universal classification of upgraded EOR screening criteria.

This way, the main objective of this paper is to study all factors that affect a production rate for Tevlinsko-Russinskoe oil field and find out any kind of workover operations or EOR methods that can change more desirably.

2. Material and methods

2.1. Review of field data

The review was based on the reading of logs, production history data, and checking of lithology that was described during petrography analysis

The construction of geological models was developed in IRAP RMS and TEMPEST Roxar Program package at the School of Geology and Exploration of Oil and Gas Fields, USPTU.

Electrometric facial models are presented on the data from spontaneous potential and gamma logs. In order to eliminate a misinterpretation of the results, relative changes in SP log were considered as well.

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2.2. Characterization and modelling of heterogeneity

Computational geoscience and mathematical statistics were presented by the method of scaling, correlation, and regression analyses to ensure characterization and modelling of heterogeneity by different zones.

2.3. Revision of workover operations and selection of EOR methods

Analysis of workover operations was completed and structured using field data.

The study of EOR methods was based on observations of the database that is presented by 652 projects around the world. This approach was conducted in order to reduce the probability of error in the EOR selection criteria process and as a result, pick up suitable EOR techniques for Tevlinsko-Russinskoe oil field [9-13].

The database was built using the data from The Oil and Gas Journal [14-17] and SPE publications [18-21]. Then it was eventually presented as updated screening criteria by Al Adasani & Bai [22]. The criteria was determined by various parameters that are presented by several projects, oil properties, and reservoir characteristics. It is highly important to say that the higher is the number of existing projects, the more accurate representation of the other parameters such as viscosity, depth, and temperature. To simplify the application of this concept for the given oilfield, only average values of oil properties and reservoir characteristics were considered. A comparison of average values of oil properties and reservoir characteristics for Tevlinsko-Russinskoe oil field with the screening criteria [22] was completed using a special assumption. This assumption was based on a technique when matching numbers or average values of the given parameters might not differ from each other more than on 10%. To choose the most appropriate EOR methods for the given oilfield, only methods with at least 5 matching parameters were discussed.

3. Results and discussion

3.1. Review of field data

Analysis of workover operations was completed and structured using field data.

Analysis of field data provided that the given oilfield is characterized as a structurally complex reservoir since it is presented by pinch-out zones and lateral and vertical heterogeneity of the reservoir characteristics. These features were caused by paleographic distribution of the sediments that are related to a distinct change of lithofacies [23,24] within the given formation. The geological model of this oilfield is presented on figure 1. As one can see, the given reservoir is characterized by it's a lenticular structure.

The study of seismic attributes, well logs and thin sections resulted in identification of facies of the given oilfield.

Sedimentary facies are presented by shoreface, longshore sandbars and barrier islands, dunes and submerged bars. Also, it found out a presence of gaps that were formed by rip currents in breaker bars and a presence of transgressive units of sand bars. All faces are related to littoral and sublittoral zones. It was observed that this division on facies has been correlated with the other authors as well [25-28].

The recognition of sedimentary facies of the given oilfield was based on geological correlation that involved the data from 678 wells, using their electrometric facial models the map of facies was constructed for oil-bearing BS10-2/3 strata. This map is presented on figure 2.

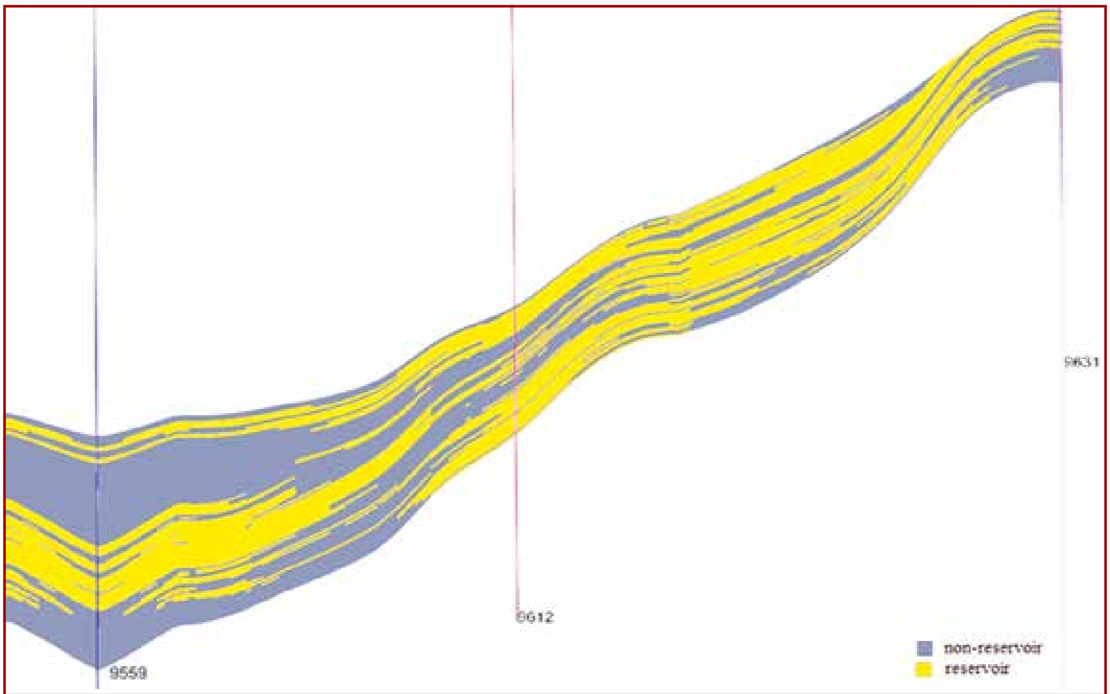

Fig. 1. The lenticular structure of the reservoir of the BS10-2/3 Tevlinsko-Russkinsky field.

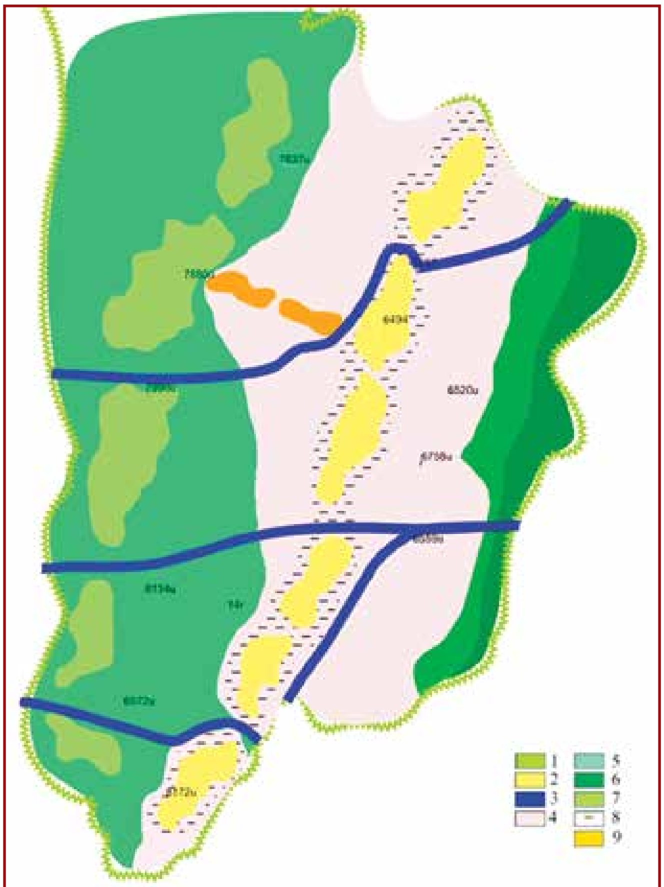

Fig.2. Facies map distribution of BS10-2/3, where 1 – submerged bars; 2 – longshore sandbars and barrier islands, transgressive units of sand bars; 3 – gaps that were formed by rip currents in breaker bars; 4 – beach facies; 5 – shoreface; 6 – lagoonal facies; 7 –coastal lagoons; 8 – longshore gaps; 9 – dunes.

3.1. Characterization and modelling of heterogeneity

Analysis of production history data identified that production of oil is mostly controlled by a reservoir heterogeneity in a vertical and a lateral direction [29]. These variations of properties are caused by the deposition of sediments that went through stages of deformation and diagenesis [1]. Microheterogeneity was presented by changes of reservoir rock properties, while macroheterogeneity was presented as distribution of permeable and impermeable rock in oil bearing strata.

For the reliability of the implementation of the geological model, the study of core data and a review of literature sources on the formation of sediments were carried out.

The results of the core analyses allowed us to establish the predominance of siltstone and fine-grained sand components in the wells. Bioturbation, the inclusion of fossils, textural and structural features, and mineralogical composition, it was found that the deposits of the BS10/2-3 formation are medium and are represented by well-sorted gray sandstones with oblique stratification. The formation of sediments was due to tidal channels and alluvial sand bodies. The sediments contain the remains of bivalves. In some wells, there is a violation of the texture due to intensive bioturbation of the plains.

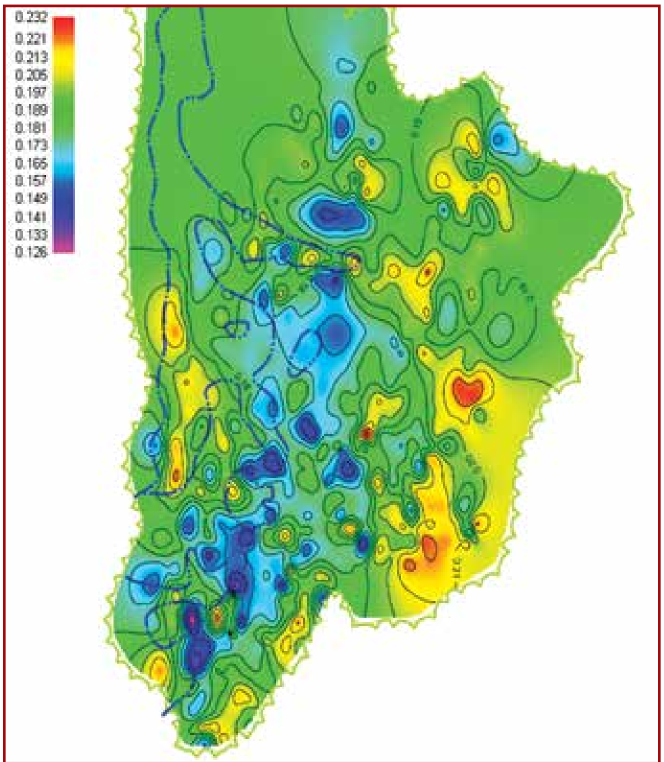

Fig.3. Porosity map of oil-bearing strata BS 10-2/3

Porosity and permeability maps were plotted to understand the distribution of rock properties within the reservoir (fig.3 and 4).

Review of these maps has been stated that relatively low values of rock properties had a place to be in the central part of the reservoir, where the permeability of the reservoir rock reached the highest values on the eastern and western sides. The best distribution of rock properties within the oilfield is observed in the form of elongated submeridional stripes with the length over the entire area of research and with the width that is presented as a range from 0.5 km to 2.5 km.

Maps such as net-to-sand-gross-ratio and ratio of permeable layers to impermeable layers in oil-bearing strata BS 10-2/3 are presented on figures 5 and 6.

Summarizing all of these factors it resulted in table 1 and on figure 7, where there was a differentiation of zones according to their level of heterogeneity.

The first class was considered to be related to zones of lagoonal facies, coastal lagoons, and part of shoreface. This class is characterized by it is poor quality of reservoir properties.

The second class is related to zone of beach face. It was concluded that it has relatively small ratio of impermeable to permeable layers in oil-bearing strata BS 10-2/3, however, it has high values of net-to-gross-ratio.

The third class is related to submerged bars, while the fourth class is presented by shoreface and gaps that were formed by rip currents in breaker bars. The third and fourth classes were characterized

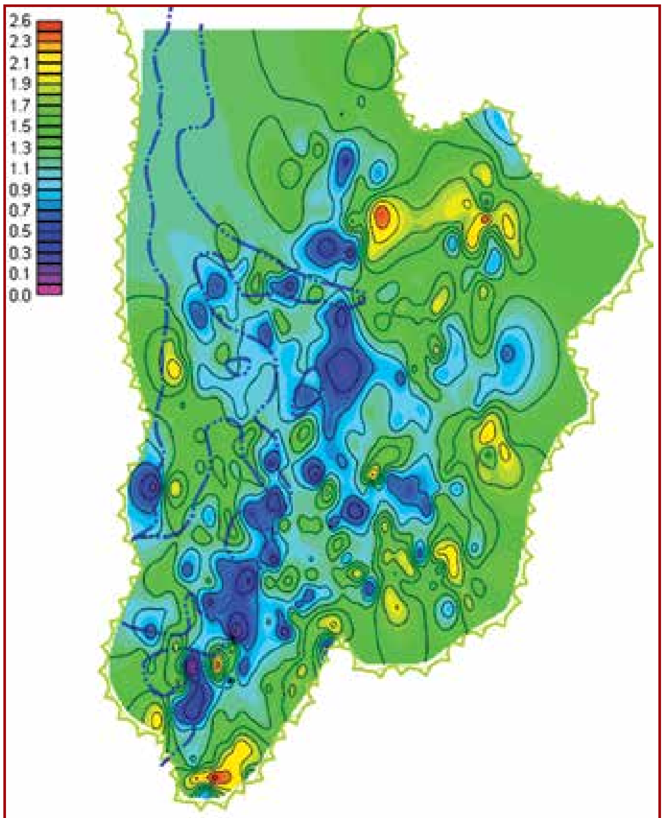

Fig.4. Permeability (log scale) map of oil-bearing strata BS 10-2/3

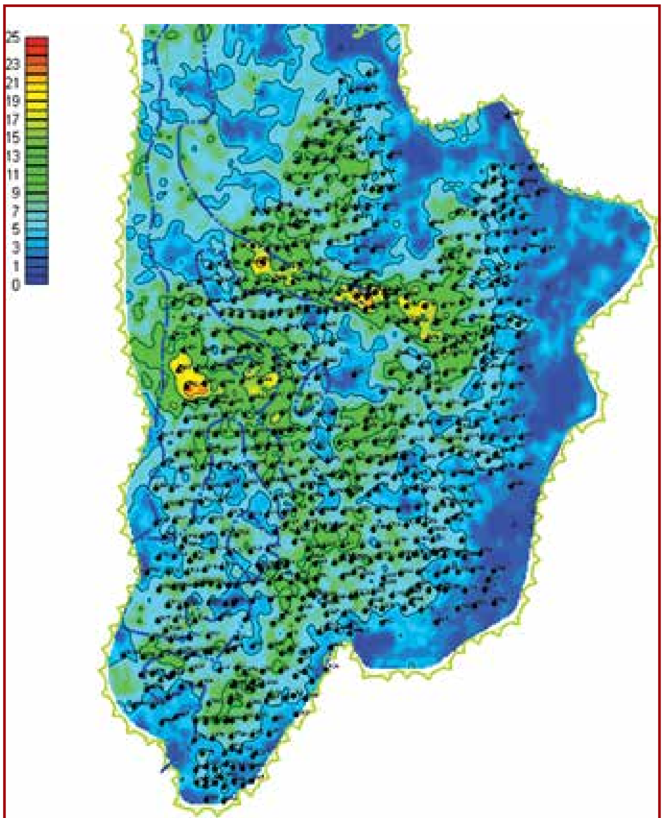

Fig.6. Ratio of impermeable layers to permeable layers in oil-bearing strata BS 10-2/3

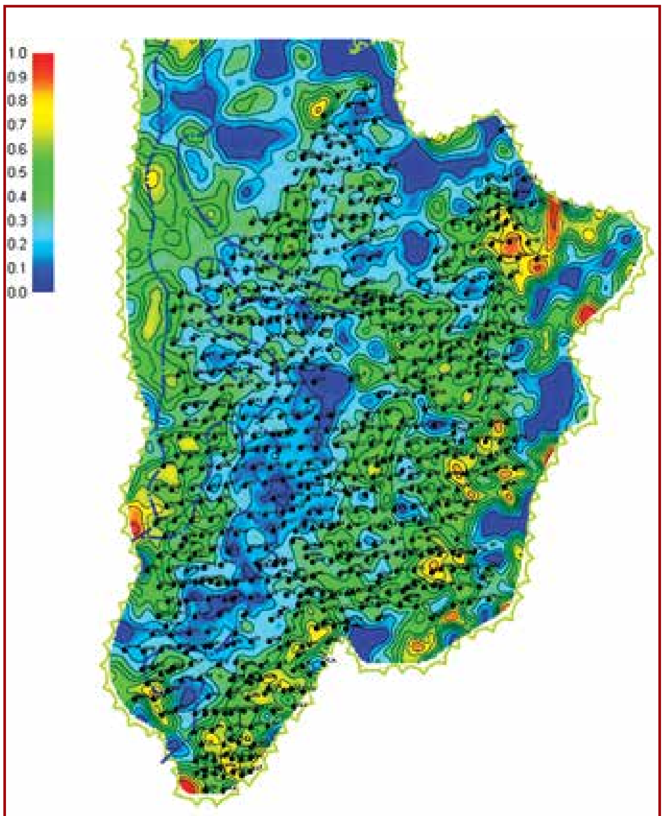

Fig.5. Net-to-gross-ratio map in oil-bearing strata BS 10-2/3

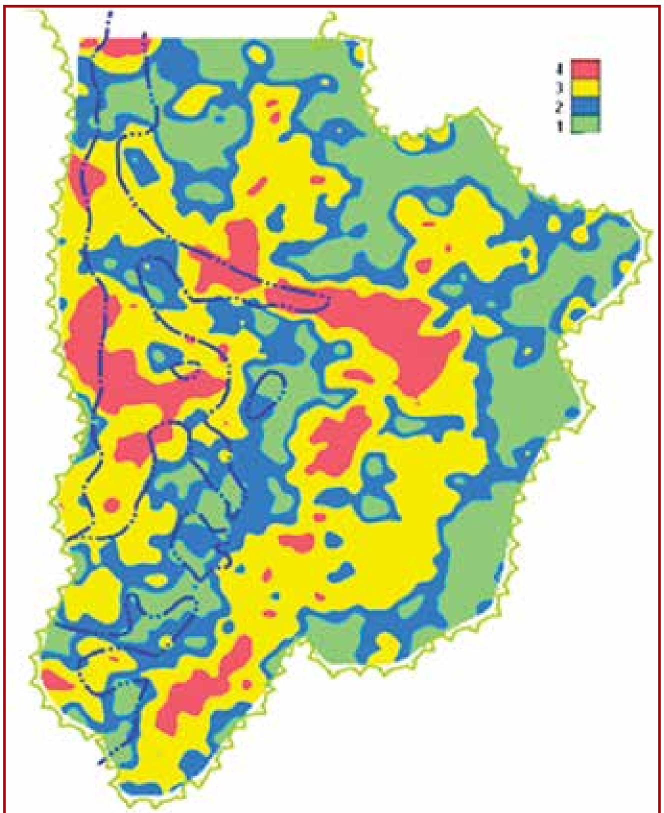

Fig.7. Differentiation of zones according to their level of heterogeneity

as zone of high ratio of impermeable to permeable layers in oil-bearing strata BS 10-2/3 [2,3]. All of these derived facies by zones are completely correlated with fundamentals of lithology [28].

Table 1

Distribution of rock properties according to classes

Parameter/class	1 class	2 class	3 class	4 class
Net-to-sand ratio	min. 0.10 max. 0.20 avg. 0.15	min.0.20 max.. 0.90 avg. 0.55	min. 0.40 max. 0.70 avg. 0.50	min. 0.30 max. 0.45 avg. 0.35
Ratio of impermeable to permeable layers	min. 1.0 max. 4.0 avg. 2.5	min. 4.5 max. 6.5 avg. 5.5	min. 7.5 max. 10.0 avg. 8.8	min. 9.5 max. 25.0 avg.17.3
Porosity	min. 0.01 max. 0.195 avg. 0.1	min. 0.175 max.0.225 avg. 0.19	min. 0.20 max.0.22 avg. 0.21	min. 0.15 max. 0.21 avg. 0.18
Permeability, mkm^2×10^{-3}	min. 0.005 max.0.025 avg.0.0185	min. 0.010 max. 0.150 avg. 0.080	min. 0.015 max. 0.090 avg. 0.058	min. 0.015 max. 0.150 avg. 0.083
Net thickness, m	min. 1.0 max. 4.0 avg. 2.5	min. 8.0 max. 14.0 avg.11.0	min. 10.0 max. 18.0 avg. 14	min. 12.0 max. 37.0 avg. 24.5

3.2. Revision of workover operations and selection of EOR methods

Observations of different workover operations and their level of perfomance are presented in table 2. This study was conducted for productive layers of the BS-BV group and it investigated that production and injection wells were more efficient in longshore bars and barrier islands compare to the other facies. Hydraulic fracture treatment and workover optimization were performed better than the other workover operations for the given productive layers [4].

For hydraulic fracture treatment it can be applied a different composition of water in order to cause wettability alteration.

As one might see that any kind of acid treatment did not work out for the given oilfield since the oil-bearing strata are low permeable and was made a small number of well treatments [30].

These observations proved the initial ideas of Skachek about the intensification of fluid reservoir influx that is fully dependent on the geological structure of a given oilfield [31].

The average values of oil properties and reservoir characteristics for Tevlinsko-Russinskoe oil field showed in table 3. A systematic review of updated screening criteria by Aldanasine & Bai [22] (tabl.4) was conducted in to apply it on this field where the matching parameters are highlighted by green colour.

It was observed that for miscible gas injections the leading technique is presented by Water-Alternating-Gas (WAG), where the 5 matching parameters were identified as gravity, porosity, formation type, net thickness and depth. Moreover, according to [32] application of this method for flooded zones might help to reduce residual oil saturation to 0. However, application of this method should be considered very carefully since EOR criteria for WAG was based only on 3 projects.

For immiscible gas injections the leading technique is presented by Nitrogen where the 6 matching parameters were recognised as gravity, porosity, formation type, net thickness, depth and temperature.

However, application of this method should be considered very carefully since EOR criteria for Nitrogen injections was based only on 8 projects.

The average values of oil properties and reservoir characteristics for the given field could not have at least 5 matching parameters with any kind of chemical or thermal methods. Therefore, application of these techniques was not considered as recommened one.

Miscible gas injections of CO_2 and thermal injections of steam were formed in a separate group since EOR criteria for these methods was based on bigger number of projects compare to the other methods. However, application of these techniques was not considered as recommened one due to lack of enough matching points with a given parameter of oilfield.

Miscible gas injections of CO_2 and thermal injections of steam were formed in a separate group since EOR criteria for these methods was based on bigger number of projects compare to the other methods. However, application of these techniques was not considered as recommened one due to lack of enough matching points with a given parameter of oilfield.

Table 2

Average Oil properties and reservoir characteristics of Tevlinsko-Russinskoe oil field

Gravity API	Viscosity, Pa·s	Porosity, %	Oil saturation, %	Permeability, mkm^2	Net thickness, m	Depth, m	Temperature, C°
34.385	0.00118	20	59	0.091	13.4	2395	80

Table 3

Geological- technical operations efficiency distribution			
BS10 Tevlinsko-russkinskoe, BV8 Povkhovsky			
№	**Type of activities**	**Number of ineffective procedures, %**	**Average unit displacement efficiency, tones/operation**
1	Hydraulic Fracture Treatment (HFT)	12	3935
2	Workover Optimization	30	3001
3	Repair and insulation works	40	1885
4	Fluid withdrawal	49	1446
5	Surface Acting Agents	52	1299
6	Mud-acid treatment	71	1098
7	The additional perforation	73	824
8	Acid treatment	74	915
9	Bottom hole treatment	75	641
1	Reperforation	79	1007
1	Accoustic wellstimulation	100	384

Conclusion

- The general geological model was created by IRAP RMS and TEMPEST Roxar Program package and showed that reservoir is presented by the lenticular structure.
- Review of field data helped to identify distribution of faices within the reservoir and concluded that all of them are related to littoral and sublittoral zones.
- Differentiation of zones according to their level of heterogeneity was presented by 4 classes. Porosity, permeability,net-to-gross-ratio and ratio of impermeable to permeable layers of oil-bearing strata BS 10-2/3 played a key role in decision making process.
- Revision of workover operations showed that the most reliable techniques are presented by workover optimization and hydraulic fracture treatment. In order to increase level of efficiency of hydraulic fracture treatment, it was recommended to use a different composition of brine water. Since this action can help to cause wettability alteration and as the result increase oil recovery factor. Also, it investigated that production and injection wells were more efficient in longshore bars and barrier islands compare to the other facies.
- Selection of upgraded EOR screening. criteria helped to choose the most suitable method for Tevlinsko-Russinskoe oil field. The method is presented by immiscible gas injections of Nitrogen. In order to achieve the highest level of efficiency it was recommended to use it for the third and fourth heterogeneity classes.

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Table 4

EOR screening criteria using for particular oil properties and reservoir characteristics [22]

EOR method	№ projects	Oil properties		Reservoir characteristics						
		Gravity,api (range/average)	Viscosity,Pa*s (range/average)	Porosity,% (range/average)	Oil saturation, % PV (range/average)	Formation type	Permeability, mkm² (range/average)	Net thickness,m (average)	Depth,m (range/average)	Temperature,F (range/average)
Miscible gas injection										
CO_2	153	22-45 / 37	0.0350 / 0.00208	3-37 / 15.15	15-89 / 46	Sandstone or carbonate	0.0015-4.5 / 0.20973	Wide range	457.16-4073.45 / 1898.86	27.78-125 / 58.94
Hydrocarbon	67	23-57 / 38.3	18-0.00004 / 0.2861	4.25-45 / 14.5	30-98 / 71	Sandstone or carbonate	0.0001-5 / 0.7262	thin	1231.33-4846.08 / 82543	29.44-165 / 94.56
WAG	3	33-39 / 35.6	0.0003-0.0009 / 0.0006	11-24 / 18.3	-	Sandstone	0.130-1 / 1.0433	thin	2299.6-2708.62 / 2504.36	90-127.78 / 109.67
Nitrogen	3	38-54 / 47.6	0.0002-0 / 0.00007	7.5-14 / 11.2	0.76-0.8 / 0.78	Sandstone or carbonate	0.0002-0.035 / 0.015	-	3047.85-5638.52 / 4460.01	87.78-162.78 / 130.33
Immiscible gas injections										
Nitrogen	8	16-54 / 34.6	180-0 / 2.2568	11-28 / 19.46	47-98.5 / 71	Sandstone	0.003-2.8 / 1.0417	-	518.13-5638.52 / 2412.13	27.78-162.78 /78.34
CO_2	16	11-35 / 22.6	0.592-0.0006 / 0.0655	17-32 / 26.3	42-78 / 56	Sandstone or carbonate	0.30-1 / 0.217	-	350.5-2590.67 / 1031.7	27.78-92.22 / 51.11
Hydrocarbon	2	22-48 / 35	0.004-0.00025 / 0.0021	5-22 / 13.5	75-83 / 79	Sandstone	0.040-1 / 0.52	-	1828.71-2133.5 / 1981.1	76.67-82.22 / 79.44
Hydrocarbon+ WAG	14	9.3-41 / 31	16000-0.17 / 3948.2	18-31.9 / 25.09	Average 88	Sandstone or carbonate	0.040-1 / 0.52	-	2650-9199 / 7218.71	55-130.56 / 92.6
Chemical methods										
Polymer	53	13-42.5 / 26.5	4-0.0004 / 0.1232	10.4-33 / 22.5	34-82 / 64	Sandstone	0.0018-5.5 / 0.8341	-	2883.27 / 213.35 / 1286.77	114-23.33 / 75
Alkaline surfactant polumer (ASP)	13	23-34 / 32.6	6.5-0.11 / 0.8758	26-32 / 26.6	68-74.8 / 73.7	Sandstone	0.596-1.52	-	1188.66-829.93 / 909.63	70-47.78 / 49.78
Surfactant +P/A	4	22-39 / 31.75	0.0156-0.00263 / 0.00708	14-16.8 / 15.6	43.5-53 / 49	Sandstone	0.050-0.060 / 0.5667	-	1615.36-190.49 / 1038.17	68.33-50 / 52.41
Thermal / Mechanical methods										
Combustion	27	10-38 / 23.6	2.77-0.0044 / 0.5048	14-35 / 23.3	50-94 / 67	Sandstone or carbonate	0.01-15 / 1.9815	> 3.05	121.91-3444.07 / 1697.53	18-110 / 79.72
Steam	274	8-33 / 14.61	Average 32.59496	12-65 / 32.2	35-90 / 60	Sandstone	0.001-15.001 / 2.6697	> 6.1	60.96-2743.07 / 502.11	avg 41.06
Hot water	10	12-25 / 18.6	8-0.170/ 2.002	25-37 / 31.2	15-85 / 58.5	Sandstone	0.900-6 / 3.346	-	-	23.89-57.22 / 36.94
Microbial										
Microbial	4	12-33 / 26.6	8.900-0.0017 / 2.9775	12-26 / 19	55-65, avg 60	Sandstone	180-200 / 190	-	479.12-10055.47 / 745.29	30-32.22 / 31.11

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Повышение нефтеотдачи высоконеоднородных пластов

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Реферат

Для месторождений, находящихся на поздней стадии разработки существует большое количество факторов, влияющих на конечный коэффициент нефтеизвлечения. Одним из таких факторов является формирование зон остаточных запасов нефти, формирующихся из-за высокой степени геологической неоднородности и свойств пластового флюида. Для решения данной проблемы применяются различные методы повышения нефтеотдачи пластов (МУН). Обоснование применения тех или иных методов, в данной работе, было проведено путем анализа геолого-промысловых данных, построения и анализа карт неоднородности, ретроспективному анализу проведения геолого-технических мероприятий, проводимых на объекте исследования. Объект исследования имеет линзовидную строение, состоит из 9 различных фаций и представлен 4 классами неоднородности. В условиях данного пласта были предложены наиболее эффективные методы по вовлечению остаточных запасов в разработку.

Ключевые слова: методы повышения нефтеотдачи; неоднородность; фации; обработка призабойной зоны пласта; коэффициент нефтеизвлечения.

Yüksək dərəcədə qeyri-bircins laylarda neftveriminin artırılması

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Xülasə

İşlənmənin son mərhələsində olan yataqlar üçün son neftçıxarma əmsalına təsir edən çoxlu sayda amillər mövcuddur. Bu amillərdən biri də yüksək dərəcədə geoloji qeyri-bircinslilik və lay flüidlərinin xassələri səbəbindən əmələ gələn qalıq neft ehtiyatları zonalarının formalaşmasıdır. Bu problemin həlli üçün layların neftveriminin (LNA) artırılmasının müxtəlif üsullarından istifadə olunur. Məqalədə həmin üsulların tətbiqinin əsaslandırılması geoloji mədən məlumatlarının təhlili, qeyri-bircinslilik xəritələrinin qurulması və təhlili, tədqiqat obyektində aparılan geoloji-texniki tədbirlərin retrospektiv təhlilinin aparılması yolu həyata keçirilmişdir. Tədqiqat obyekti linzayaoxşar quruluşa malikdir, 9 fərqli fasiyadan ibarətdir və 4 qeyri-bircinslilik sinfi ilə təmsil olunur. Verilən lay şəraitində qalıq neft ehtiyatlarının işlənməyə cəlb edilməsi üçün ən effektiv üsullar təklif edilmişdir.

Açar sözlər: neftveriminin artırılması üsulları; qeyri-bircinlilik; fasiya; layın quyudibi zonasının işlənməsi; neftçıxarma əmsalı.