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Assessment of the deep oil and gas bearing potential onshore in the west of Azerbaijan (Tarsdallar area)

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Abstract. The Tarsdeller oil and gas field, which has a brachyoanthicline structure, is the most promising area of the oil-gas region (OGR) in the Kura-Gabirri interfluve. **Goal:** Based on the reservoir characteristics of rock samples obtained from exploration wells drilled in the area adjacent to the field, petrophysical models have been compiled, reflecting the spatial variation in porosity and permeability of oil-containing reservoirs. **Objects:** Consideration of the petrophysical properties of core samples taken in the study area made it possible to confirm the oil and gas potential of deep-seated reservoirs. **Methods:** This analyzed the values and variation of petrophysical properties by depth, age and various physical factors. The observed wide range of changes in the reservoir properties of rocks in the study area is mainly due to tectonic changes, lithological heterogeneity of the sedimentary complex, differences in the depth of bedrocks, as well as the complexity of tectonic conditions. As a result, to predict the oil and gas content in deep reservoirs of the same structures, it is advisable to use the methods of exploration geophysics, as well as the results of changes in the reservoir characteristics of rocks, determined by petrophysical data. At the same time, it is most expedient to focus on the study of Paleogene-Cretaceous tectonics for the search for oil and gas objects using prospecting and exploration (preferably aerial-photo-space) works at the field. **Results:** Models made in 3D format illustrate the predicted oil and gas potential and patterns of distribution of productive horizons involved in the geological structure of oil and gas deposits, along the depths and stratigraphic units. It is shown that although the permeability of the rocks in the area is low, the porosity values are favorable for the industrial accumulation of hydrocarbons. Fractured carbonate reservoirs of the Upper Cretaceous are the most promising among the Mesozoic sediments in the OGR between the Kura and Gabirri rivers. Deep-seated structural uplifts complicated by large-amplitude fractures are recommended as the priority targets for further geological exploration. However, the real potential of the Eocene deposits, which are widespread in the NGR between the Kura and Gabirri rivers, remains unexplored by deep drilling. This is due, on the one hand, to the incomplete opening of the Eocene section in the structures prepared for deep drilling, structural-tectonic and lithofacies features, as well as insufficient knowledge of drilling for oil and gas, and on the other hand, poor development of promising intervals of the section.

Key words: reservoir properties, oil and gas saturation, porosity, permeability, petrophysical models.

Оцінка глибинного нафтогазоносного потенціалу суші на заході Азербайджану (площа Тарсдалляр)

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Анотація. Нафтогазове родовище Тарсделляр, що має структуру брахіантикліналі, є найбільш перспективною ділянкою НГР міжріччя Кура-Габирри. Мета: На основі колекторських характеристик зразків гірських порід, отриманих з розвідувальних свердловин, пробурених на прилеглій до родовища території, складено петрофізичні моделі, що відображають просторову варіацію пористості та проникності нафтовмісних колекторів. Розгляд петрофізичних властивостей зразків керна, відібраних у районі досліджень, дозволив підтвердити потенціал нафтогазоносності глибоко занурених колекторів. При цьому аналізувалися значення та варіація петрофізичних властивостей за глибиною, віком та різними фізичними факторами. Широкий спектр змін колекторських властивостей гірських порід у районі дослідження, що спостерігається, пояснюється, в основному, тектонічними змінами, літологічною неоднорідністю осадового комплексу, відмінностями в глибині залягання корінних порід, а також складністю тектонічних умов. Внаслідок цього, для прогнозування нафто-газоносності в глибинних колекторах тих самих структур доцільно використовувати методи розвідувальної геофізики, а також результати зміни фільтраційно-ємнісних характеристик гірських порід, що визначаються петрофізичними даними. При цьому найбільш доцільно зосередитися на вивченні палеоген-крейдової тектоніки для пошуків нафтогазовмісних об'єктів з використанням пошуково-розвідувальних (бажано аеро-фото-космічних) робіт на родовищі. Складені моделі, виконані у 3D форматі ілюструють прогнозний нафтогазоносний потенціал та закономірності розподілу продуктивних горизонтів, залучених до геологічної будови нафтогазових родовищ, за розрізом та стратиграфічними одиницями. Показано, що хоча проникність порід на родовищі низька, проте величини пористості сприятливі для промислового накопичення вуглеводнів. Найбільш перспективними серед мезозойських відкладень у НГР міжріччя Кура та Габирри є тріщинуваті карбонатні колектори Верхньої крейди. Як першочергові об'єкти геологорозвідувальних робіт рекомендуються глибоко закладені структурні підняття, ускладнені тріщинами великої амплітуди. Проте, реальний потенціал еоценових відкладень, поширених у НГР міжріччя Кура і Габирри, залишається не вивченим глибоким бурінням. Це пояснюється, з одного боку, неповним розкриттям розрізу еоцену в структурах, підготовлених для глибокого буріння, структурно-тектонічними та літофаціальними особливостями, а також недостатньою вивченістю буріння на нафту та газ, а з іншого – слабким освоєнням перспективних інтервалів розрізу.

Ключові слова: колекторські властивості, нафтогазоносність, пористість, проникність, петрофізичні моделі.

Introduction

As is known, the oil and gas potential of the territory of Azerbaijan is mainly associated with thick terrigenous sediments of well-formed reservoirs and zones of oil and gas accumulation, as well as Mesozoic and Paleogene-Miocene deposits with sufficient hydrocarbon (HC) potential (Klett et. al., 2010; Kopp, 1997; Yusifov and Aslanov, 2018; Salmanov, Suleymanov, Maharramov, 2015). Although large oil and gas fields are not being developed in the Mesozoic and Paleogene-Miocene deposits, earlier in a number of oil and gas regions of the republic (Caspian-Guba, Absheron, Shemakha-Gobustan, Ganja, Muradkhanli, Kura-Gabirri, etc.) hydrocarbon deposits were observed, and intensive oil and gas manifestations and significant inflows from drilled wells indicate the prospects of these strata. However, it should be noted that the geological structure and oil and gas bearing of the Mesozoic complex have not yet been sufficiently clarified by exploration drilling, so hydrocarbon resources have not yet been fully exploited. In particular, according to the authors (Aliyarov, et al., 2018; Hasanov, et al., 2017; Gurbanov, et al., 2020; Guliyev, et al., 2014), Cretaceous and Jurassic terrigenous-carbonate reservoirs in the complex are characterized by more favorable conditions for the search for new oil and gas fields in the northwestern part of the country. Thus, according to (Hasanov, et al., 2017; Hasanov, Ganbarova, 2019), the maximum thickness of deposits (1117 m) in the territory of the Kura-Gabirri oil and gas region was identified in the areas of Mammadtapa(1037 m) and Tarsdallar. Here, the Eocene deposits are divided into three series (lower, middle, and upper), differing from each other in lithological properties. In the southwest of the region, the Lower Eocene is composed mainly of sandy-argillaceous deposits. It is shown that deposits of the Middle Eocene accumulated on the southwestern slopes of the Kura and Gabirri rivers. The deposits of the Upper Eocene fall on the coastline of the basin and almost coincide with the Middle Eocene. In terms of oil and gas potential, the Eocene deposits here are of the Lower and Middle Eocene age. Commercial oil rates were obtained from the Middle Eocene section at the Damirtapa-Udabno, Tarsdallar and Gurzundag fields. So, in well No. 9, drilled at the Tarsdallar field, tuff cores extracted from the Upper Cretaceous are saturated with light oil. In general, the main oil and gas horizons in the oil and gas region of the Kura-Gabirri interfluve are deposits of the Upper Cretaceous, Eocene and Oligocene-Miocene. These deposits are dominated by reservoirs of terrigenous (argillaceous, sandy, silty), carbonate, volcanic-sedimentary and volcanic rocks (Khuduzade, et al., 1976; 2015; Karimov et al., 2020; Morton, et al., 2003).

From 1976 to 1993, the area of the field was almost completely covered by regional and detailed seismic surveys to depths of 5-6 km using various seismic survey methods (CDP, MCDP). Accurate gravimetric measurements were made in 1975, 1981, 1987. Based on these studies, it was possible to identify and maping the regional tectonic elements of the region (Akhundov and Ganiyev, 2016; Hasanov, et al, 2017).

In general, 34 local uplifts have been identified in the oil and gas bearing region of the Kura-Gabirri interfluve, including the Tarsdallar oil and gas field, as well as Sajdag, Boyuk Palantokan, East Gurzundag, West Gurzundag, Molladag, Agtapa, Jahandar. The Tarsdallar oil and gas field, which is currently the single object for development of the Kura and Gabirri interfluve, was discovered by prospecting and exploration work carried out in 1983 in the area. The main oil and gas bearing horizon here is the Middle Eocene, represented by deposits of carbonate and tuff-sedimentary facies. The revealed diversity of the mineral composition of the exposed volcanogenic-sedimentary rocks, with their inherent complexity of the void space, which includes pores and caverns of various sizes connected to each other, connected by thin capillaries and cracks, necessitated a comprehensive analysis of the data of modern well logging systems and the results of core study. In particular, according to well logging and core data, it was found that, in general, tuffaceous rocks of the Middle Eocene are distinguished by porosity, which varies over a fairly wide range from 1.5% to 26.6%, carbonate content from 0% to 25%, and clay content from 11.6% to 29%. Among the studied samples, limestones are characterized by the highest density (p_{av}=2.68 g/cm^3) and the lowest porosity (K_p=4.9%). They are also characterized by high wave velocities (υ_{av} = 3240 m/s). In addition, in the section of the Middle Eocene there are mudstones with relatively low density (p_{av}=2.23 g/cm^3), open porosity (K_p=15.5%), longitudinal wave velocity of 2700 m/s, relative permeability of 0.001 10^{-15}m^2 and carbonate content of 50, 76%.

According to the data obtained, the tuffaceous reservoir of the Middle Eocene age is distinguished here by the complex structure of the void space, which is due to the development of porosity and fracturing of different genesis. The nature of the common void space of the studied reservoir rocks is associated, firstly, with the primary matrix intergranular pores; secondly, with secondary pores that appeared as a result of authigenic transformation of the original tuffaceous material, as well as with a network of secondary micro- and macrofractures that determine the filtration properties of the volcanogenic-sedimentary matrix of rocks. According to local and foreign studies (Geology of Azerbaijan, 2005; Morton, et al., 2003; Lyberis and Manby, 1999; Khain, et al., 2009; Pilchin and Eppelbaum, 2020), the oil and gas bearing of the region can be refined using wells drilled in the Eocene and Upper Cretaceous.

However, modeling of the deep sections of the zone based on the available data also makes it possible to express a certain opinion about the prospects of geological objects (Hasanov and Gakhramanli, 2019; Hasanov, et al., 2018; Yusifov and Aslanov, 2018; Kauerauf and Hantschel, 2009). For this purpose, we have carried out studies that allow us to assess the deep oil and gas bearing potential of the onshore territory of western Azerbaijan (Tarsdallar area).

Results

In particular, we summarized the petrophysical data obtained from the ancient deposits of the Meso-Cenozoic sedimentary complex (Upper Cretaceous) discovered by drilling within the oil and gas bearing area (OGR) of the Kura and Gabirri interfluve (Fig. 1).

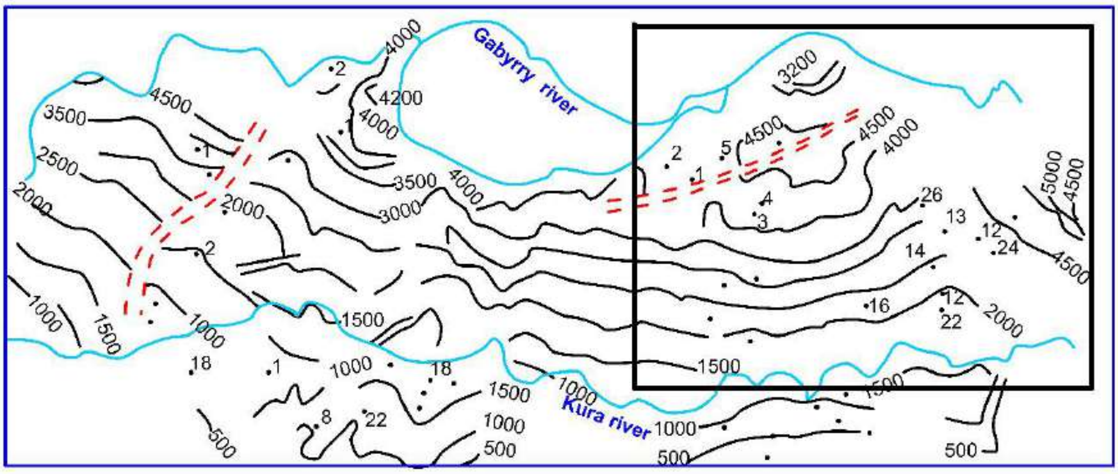

Fig. 1. Structural map to Mesozoic of the Kura-Gabirri interfluve OGBR (Tarsdallar region) (Geology of Azerbaijan 2005).

Cretaceous deposits are widespread in the region (Khuduzade et al., 2015; Geology of Azerbaijan, 2005) and are represented by volcanic (Turonian-Lower Coniacian) in the lower part, volcanic-sedimentary (Upper Coniacian-Lower Santonian) in the middle part, and carbonate lithofacies in the upper parts (Upper Santonian-Maastrichtian). Volcanogenic rocks are mainly composed of porphyries, basalts, andesites and their derivatives and are classified as vuggy-porous reservoirs due to their capacity and permeability (Hasanov, et al., 2017). Table 1 shows data covering the lower, upper and middle limits of the physical properties of rocks of different ages taken from different depths (the number of samples studied is indicated in brackets).

Consideration of the generalized data shows that the Paleogene and Eocene deposits involved in the geological structure of the Tarsdallar structure are mainly characterized by siltstones, marls, limestones and tuff siltstones. The density of marls is 2.16 g/cm^3, the porosity is 2.5%, the magnetosensitivity is very low, and the propagation velocity of longitudinal elastic waves is 3500 m/s. Paleogene limestones are practically non-magnetic, their density is 2.56 g/cm^3, porosity is 5.1%, and the propagation velocity of longitudinal elastic waves reaches 3000 m/s. Based on the results of laboratory studies of rock samples, the following assessments of the physical properties of Eocene rocks were made (Hasanov, et al., 2017).

Table 1. Characteristics of reservoirs in the Tarsdallar section

Well №	Stratigraphy	Interval,m	Carbon content ,% min-max/mid	Porosity/% min-max/mid	Permeability, % $10^{-15}m^2$	Density,g/cm²		The speed of propagation of waves	
						Dry $\sigma_{min}-\sigma_{max}/\sigma_{mid}$	Wet $\sigma_{min}-\sigma_{max}/\sigma_{mid}$	Dry $V_{min}-V_{max}/V_{mid}$	Wet $V_{min}-V_{max}/V_{mid}$
1	Chokrak	1695-2900	1,6-32.7/13.3(4)	10.0-17.9/14.34(5)	0.1-2.1/1.4(3)	2.16-2.33/2.25(2)	2.34-2.46/2.40(2)	2874	2750-3100/2920(2)
3	Upper Eocene	1613-1623	0	21.5-21.5/12.5(2)	-	2.09-2.12/2.11(2)	2.18-2.35/2.27(2)	570	1950-2780/2360(2)
5	Upper Eocene	2625-2823	11.5-73.6/50.76(7)	3.53-18.1/8.2(10)	0.001(8)	2.38-2.58/2.46(6)	2.41-2.61/2.52(7)	1090-4180/1900(7)	1760-2540/2150(5)
	Upper Cretace.	2915-2941	28.8-92.4/74.0(4)	4,01-5.75/5.09(7)	0.001-0.003	2.54-2.72/2.63(8)	2.63-2.73/2.68(6)	2720-4300/3440(4)	2720-3750/3240(2)
9	Middle Eocene	2906-3169	0.8-81.7/32.45(64)	1.7-20.1/8.85(69)	0.001-0.04/0.01(40)	2.29-2.56/2.43(15)	2.33-2.72/2.52(18)	2560-3740/3040(9)	2215-4040/3280(9)
	Upper Cretace.	3155-4012	1.0-83.9/27.06(29)	2.23-30.0/8.32(33)	0.01-385.0/27.6(15)	2.17-2.82/2.48(17)	2.27-2.90/2.70(17)	2560-4770/3800(9)	2450-4360/3070(13)
11	Middle Eocene	2485-3705	1.0-85.4/17.8(22)	6.0-15.6/14.1(36)	0.001-0.05	2.15-2.58/2.38(24)	2.19-2.65/2,43(19)	1580-2950/2550(13)	2630-3660/3000(7)
24	Upper Eocene	3243-4236	0.6-51.2/16.3(19)	3.7-13.2/9.8(9)	0,01(6)	2.22-2.33/2.27(2)	2.27-2.48/2.35(12)	2500-3580/2850(10)	2780-3100/2940(2)
	Upper Eocene	4276-4342	1.0-78.7/38.7(10)	4.3-18.4/11.7(10)	0.01-8.5	2.37-2.56/2.46(4)	2.45-2.69/2.52(4)	2700-3400/3100(4)	3150-3780/3370(4)
	Lower Eocene	4395-4452	16.1-38.0/26.8(6)	8.0-12.5/11.2(5)	0.01-0.07/0.03(5)	2.41-2.51/2.46(2)	2.56-2.58/2.57(2)	2750/-	3400(2)
26	Upper Eocene	3335-3476	7.5-33.2/21.7(5)	3.1-19.1/8.9(5)	0.01-0.03	2.17-2.37/2.27(2)	2.36-2.47/2.41(2)	-	2800-3100/2950(2)

The density siltstones is 2.45 g/cm^3, porosity is 5.0%, ultrasonic wave velocity is 1300 m/s, the density of limestone is 2.65 g/cm^3, porosity is 5.24%, ultrasonic wave velocity is 2950 m/s, the magnetosensitivity is missing. Density of argillites is 2.25 g/cm^3, porosity is 15.5%, magnetosensitivity is low, velocity of propagation of ultrasonic waves is 2700 m/s. In the section of the field, as a whole, cover deposits of the Upper Cretaceous, Paleogene, Neogene and Agjhagil, Absheron strata are represented. Paleocene sediments resting on carbonate rocks of the Upper Cretaceous are composed of gray and light gray marls, intermediate layers of sand and clay. The bottom of the Middle Eocene is composed of breccias and conglomerates; also, layers of clay and marl are found in the section. The thickness is 200-250 m. Upper Eocene sediments are composed mainly of medium sandy clays, less often marls. The thickness is 130 m. The Maikop series of deposits 1000 m thick in the lower part of the section is composed mainly of clays, sometimes with intermediate layers of sand and volcanic materials. Miocene deposits with a thickness of 700-750 m are composed of sandy-argillaceous rocks. The lower part of the section is composed of interlayers of marl and dolomite. The thickness of the layers of Agjhagil and Absheron, composed of sandy-clayey deposits, ranges from 130-560 m. According to borehole data, it was determined that in some cases the physical properties of rocks similarly-named and of the same age changed as a result of geological and physical processes and had different values. These phenomena have also been the target of petrophysical studies carried out under the influence of pressure and temperature (Dortman, 1976; Khuduzade, et al., 2015).

A review of the values of the physical characteristics of rocks and other geophysical materials that reflect the reservoir properties of rocks suggests the absence of a single view over the entire area of the Tarsdallar field, which, according to the authors (Akhundov and Ganiyev, 2016; Hasanov, et al., 2017) semi-closed anticline bounded by faults. However, since the density of rocks and the velocity of propagation of longitudinal elastic waves depend mainly on depth and tectonic processes, the values of density and velocity were considered taking into account the depth of the rocks (Table 1). These and subsequent analytical generalizations are based on statistical data from the study of 191 samples of core material extracted from drilled wells (Table 2, Figure 2). In particular, our petrophysical models of the productive horizons of the Tarsdallar field indicate that the reservoir properties of rocks in some parts of the environment remain quite high, despite the general trend of decreasing porosity with depth (Figure 3).

Table 2. Generalized values of reservoir characteristics in the section of Tarsdallar

№ well (samples)	Interval, m	Av. depth, m	**Кр, %**	**Carbon cont., %**	**Permeab., 10^{-15} m^2**	**Density, g/cm^3**	**Velocity, m/c**
3 (2)	1613;1623	1618	12.5	0	-	2.11	0.57
1 (5)	1695;2900	2297.5	14.34	13.3	1.4	2.25	2.87
5 (10)	2625;2823	2724	8.2	50.76	0.001	2.46	1.9
5 (7)	2915;2941	2928	5.09	74	0.02	2.63	3.44
9 (69)	2906;3169	3037.5	8.85	32.45	0.01	2.43	3.04
11 (36)	2485;3705	3095	14.1	27.06	27.6	2.48	3.8
26 (5)	3335;3476	3405.5	8.9	17.8	0.0255	2.38	2.55
9 (33)	3155;4012	3583.5	8.32	16.3	0.01	2.27	2.85
24 (9)	3243;4236	3739.5	9.8	28.7	4.255	2.48	3.1
24 (10)	4276;4342	4309	11.7	26.8	-	2.46	-
24 (5)	4395;4452	4423.5	-	-	-	-	-

In general, it should be noted that the Mesozoic sedimentary complex within the oil and gas bearing region of the Kura and Gabirri interfluve is characterized by significant oil and gas content. However, the small scale of the geological exploration work carried out here to study the oil and gas potential of these deposits did not allow obtaining satisfactory results. Thus, deep wells drilled in the Mammadtapa area (parametric well number 1) and Tarsdallar (prospecting-exploratory wells number 9 and 27) in this area managed to study (Aliyarov, et al., 2018) only sections of carbonate, tuffaceous-sedimentary and volcanic deposits of the Upper Cretaceous up to a depth of 1000 m.

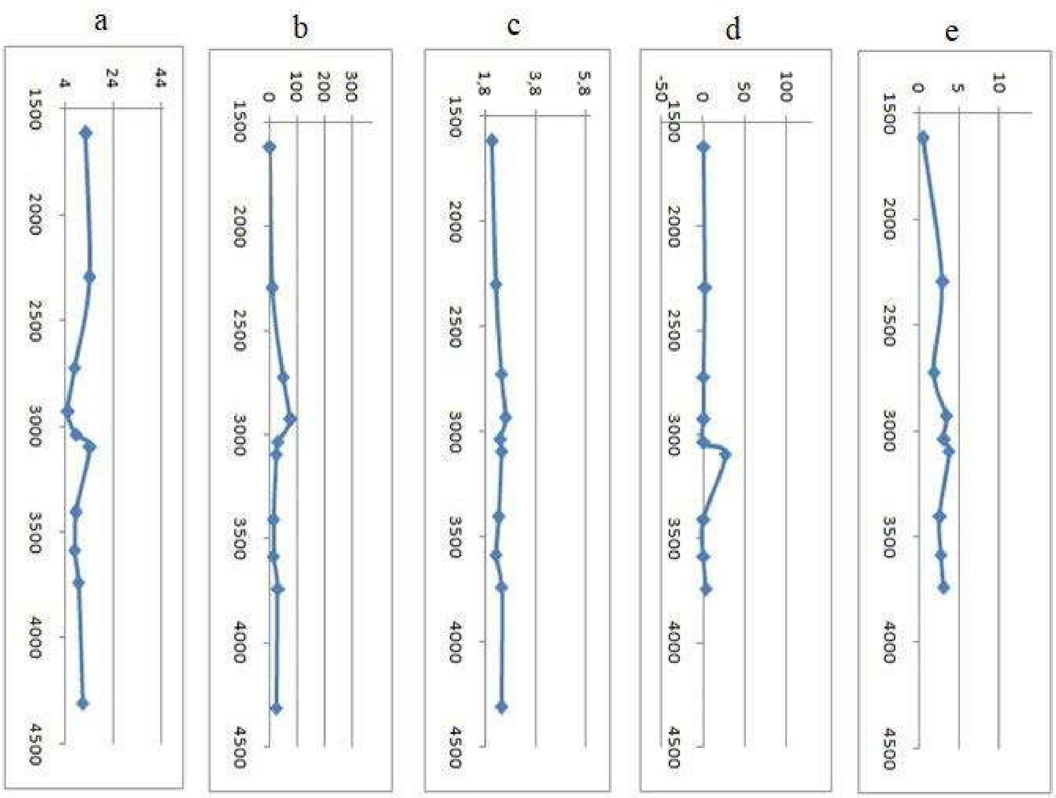

Fig. 2. The values of the physical properties of rocks in the section of the Tarsdeller field. a) Kp – porosity coefficient, %; b) C – carbonate content, %; c) p – density, g/cm^3; d) Kpr – permeability coefficient, *10^{-12}m^2; e) Vp- is the velocity of elastic waves, m/s.

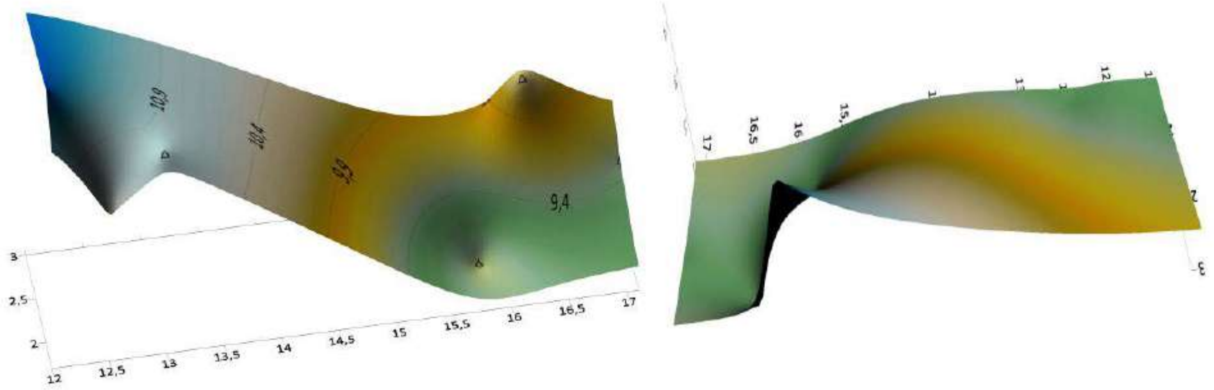

Fig. 3. Variation of reservoir properties (porosity and permeability) of submerged productive reservoirs in the Kura-Gabirri interfluve OGBR

The above conclusions can be confirmed by the fact that our results coincide with the assumptions of previous studies, in particular, the petrophysical model of the Mesozoic section compiled by us in the area of the Kura-Gabirri interfluve OGBR (Figure 4) corresponds to the structural map presented in previously published works (Akhundov and Ganiyev , 2016; Hasanov, et al., 2017).

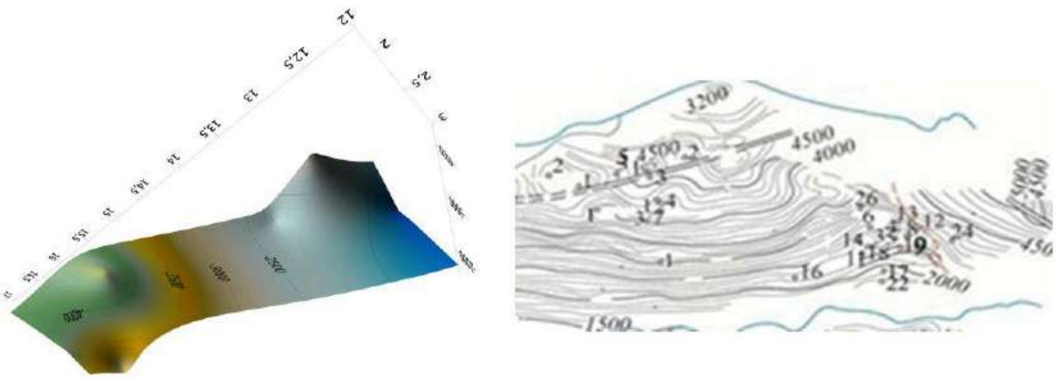

Fig. 4. Reflecting model of the occurrence of the Mesozoic deposits of the Kura-Gabirri interfluve OGBR section on the surface and an overview structural map of the territory.

Conclusions

Summarizing the above, it can be concluded that the prospects of Mesozoic deposits in the Kura and Gabirri interfluves are associated with fractured carbonate reservoirs of the Upper Cretaceous. Deep structural uplifts, complicated by large-amplitude faults, are primarily recommended as promising objects for geological exploration.

In general, the real potential of the Eocene deposits, which are widespread in the Kura and Gabirri interfluves, remains unexplored by deep drilling. This is explained, on the one hand, by the incomplete opening of the Eocene section in the structures prepared for deep drilling, by structural-tectonic and lithofacies features, as well as by the insufficient effectiveness of drilling for oil and gas, and, on the other hand, by the weak development of promising intervals of the section.

Analysis of the petrophysical properties of core samples taken in the study area made it possible to confirm the oil and gas potential of deep-seated reservoirs. At the same time, the values and variation of petrophysical properties by depth, age and various physical factors were analyzed. Summarizing the results of the conducted research, we can draw the following conclusions:

1. It is highly advisable to focus on the study of Paleogene-Cretaceous tectonics for the search for oil- and gas-bearing formation objects using prospecting and exploration (preferably aerial-photo-space) work in the field.

2. A wide range of changes in the reservoir properties of rocks in the study area can be explained mainly by tectonic changes, lithological heterogeneity of the sedimentary complex, differences in the occurrence depth of bedrocks, as well as the complexity of tectonic conditions.

3. To predict the oil and gas content in deep-seated reservoirs of the same structures, it is advisable to use the methods of exploration geophysics, as well as the results of changes in the reservoir characteristics of rocks obtained on the basis of petrophysical information.

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