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PETROPHYSICAL ASPECTS OF DEEP RESERVOIRS IN THE ABSHERON AND BAKU ARCHIPELAGOS

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ПЕТРОФИЗИЧЕСКИЕ ОСОБЕННОСТИ ГЛУБОКОЗАЛЕГАЮЩИХ КОЛЛЕКТОРОВ АПШЕРОНСКОГО И БАКИНСКОГО АРХИПЕЛАГОВ

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Based on the recent information about oil and gas production potential in Azerbaijan, a geological and geophysical assessment of deep formations has been made. Scientific criteria have been prepared in order to use them as a basis for new researches. It has been highlighted that the main oil and gas fields are associated with the South Caspian and Kura basins, which were subjected to intense sinking during the Mesozoic Era. The high production potential of the central part and deep formations has not been sufficiently shown in terms of quality and quantity.

It is known that the exploration, production and assessment of oil and gas field potential strongly depend on the information collected about petrophysical parameters of the formation. Researches shall be conducted concerning the oil and gas regions in the Absheron and Baku archipelagos, where Mesozoic and Cenozoic sediments are widely spread.

Various geological, geophysical and physical aspects that had been influencing the reservoir potential of oil, gas, and gas condensate fields in that region have been studied. The conducted researches demonstrate that there is a thin layer of Pliocene anthropogenic deposits of 100 to 200 m in the paleoprofiles formed along the Kurdakhan – Shah Deniz offshore field in the northwest. The thickness increases towards Kum Adasi up to 3600 m and reaches 6000 m in Shah Deniz. Along the edges of the synclinal folds, the thickness of the abovementioned deposits reaches 3000 m in the northwest and about 10,000 m in Shah Deniz. Therefore, without sufficient knowledge about reservoir properties of the layer, it is impossible to assess the hydrocarbon accumulations and production volumes and change the exploration direction. In addition to geological and geophysical researches conducted in the area, lithologic, petrographic and reservoir properties have been studied in order to identify changes in the correspondence of carbon content, porosity, permeability, density, grain size distribution and sound wave velocity along the area to the properties of the abovementioned layer. For this reason, a table with the field reservoir properties has been prepared. It contains upper, intermediate and lower boundaries of physical characteristics, analyses the reservoir property interdependences and determines the formation depth and other physical aspects.

The researches show that physical characteristics of coeval and homonymous rock change due to geological and physical processes and lead to different results. The reservoir characteristics of productive strata have been studied. A table has been prepared to show physical parameters of the area depending on time and place and to display different types and frequency of geological characteristics pertaining to the reservoir rock.

Ключевые слова:
породы, свита, пористость, глубина, скважина, плотность, петрофизика, мезокайнозой, горизонт, бурение, геофизика, нефтегазонакопления, коллектор, карбонатность, скорость продольных волн.

Недавно на основе сведений о перспективах добычи нефти и газа в Азербайджане была проведена геологическая и геофизическая оценка глубоких слоев. Были подготовлены научные критерии, которые могут быть основанием для будущих исследований. Отмечено, что основные месторождения нефти и газа связаны с Южным Каспием и Курским бассейном, которые подвергались интенсивному углублению во время мезозойской эры. Высокая перспективность центральной части и глубоких слоев не была количественно и численно выражена должным образом.

Известно, что разведка, добыча и оценка потенциала нефтяных и газовых месторождений сильно зависят от собранной информации о петрофизических характеристиках слоев. Исследования должны проводиться в нефтяных и газовых регионах Апшеронского и Бакинского архипелагов, где отложения мезозоя и кайнозоя широко распространены.

Исследованы различные геолого-геофизические и физические аспекты, которые влияли на коллекторный потенциал нефтяных, газовых и газоконденсатных месторождений в данном районе. Проведенные исследования показывают, что в палеопрофилях, образованных вдоль Кюрдакхан-Шах-Дениз шельфового месторождения Шах-Дениз на северо-западе, были залежи плиоцен-антропогенных скоплений тонким слоем – от 100 до 200 м. Толщина увеличивается к Кум адасы до 3600 м и в Шах-Денизе до 6000 м. По краям синклинальных складок толщина упомянутых скоплений достигает 3000 м на северо-западе и около 10 000 м в Шах-Дениз. Таким образом, не имея достаточно знаний относительно коллекторных характеристик страты, невозможно оценить залежи углеводородов и объемы производства, а также поменять направление обследования. Помимо геолого-геофизических исследований, проведенных в этой области, были изучены литологическо-петрографические и коллекторные характеристики для определения изменений соответствия вдоль области содержания углерода, пористости, проницаемости, плотности, гранулярного состава и скорости звуковых волн вышеупомянутой страты. Соответственно, была составлена таблица, отражающая коллекторские характеристики месторождения, в которой были указаны верхние, средние и нижние границы физических характеристик; проанализированы зависимости коллекторских характеристик друг от друга, определены глубина залежей и другие физические аспекты.

Исследования показывают, что физические особенности одновозрастных и одноименных пород изменяются в результате геолого-физических процессов, приводя к разным результатам. Были изучены коллекторские свойства пород продуктивной толщи. Создана таблица, отражающая физические свойства данной площади во времени и пространстве, а также различные типы геологических особенностей пород-коллекторов и закономерность их распространения.

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Introduction

The reservoir properties of rock are crucially important to study when determining the formation potential in terms of oil and gas content and estimating the reserves at proven fields. In addition to this, the oil and gas industry currently demand to update and intensify the development processes applied at oil and gas fields.

For this reason, the geological and geophysical rock characteristics influencing reservoir potential of the deposits containing oil, gas and gas condensate accumulations of the Meso-Cenozoic Era have been studied.

Deep Reservoirs in the Absheron Archipelago

The Absheron archipelago features the Neft Dashlary fold located in the near-axial zone of the Absheron-Prebalkhan mega-arch structure and stretched in the general Caucasian direction. The fold is complicated by two longitudinal and multiple transversal fractures.

The longitudinal fractures represent a wide area of disjunctive dislocations built by strongly broken brecciate deposits of the Oligocene-Miocene Era. In the southeastern part of the fold, at the intersection of longitudinal and transversal fractures, there is a mud volcano. There, the sea bottom is characterized by multiple springs continuously emitting oil and gas.

It is known that the oil and gas potential of rock depends on its petrophysical characteristics. To determine the petrophysical characteristics in deep layers, the carbonate content, porosity, permeability, density, grain size distribution and P-wave propagation velocity have been assessed in the rock samples taken from exploratory wells drilled in the area of Neft Dashlary. Moreover, we have determined the average values of sample physical characteristics and the dependence of reservoir properties on the formation depth and rock physical parameters. The petrophysical and reservoir properties of the rock have been summarized in a table prepared by the authors (Table 1) [1–12].

The Neft Dashlary field is characterized by anticline, lithologic, and tectonic petroleum traps.

The local argillaceous rock has a density of 2.20–2.48 g/cm^3, a porosity of 8.3–17 % (in some cases, it reaches 25 %), and an ultrasonic wave propagation of 2150–2200 m/s. In siltstone, the density varies within 2.13–2.60 g/cm^3, the porosity is 15–28 %, and the ultrasonic wave propagation varies within 1300–2200 m/s. In sandstone, the density ranges from 2.00 to 2.50 g/cm^3, and the porosity is 7.2–22.0 %. In all types of rock, the ultrasonic wave propagation varies within 850–2800 m/s depending on the lithological composition. In the limestone clay comprising the productive strata, the density is 2.02–2.59 g/cm^3, the porosity is 8.5–30 %, and the ultrasonic wave propagation is 2100–3500 m/s.

Grain-type deposits in the productive strata of the Neft Dashlary area are mainly represented by silt facies, i.e. the grain size varies from 0.1 to 0.01 mm. This indicates silt prevalence over other types of facies in the section.

To understand how the reservoir properties change when the productive strata deposits are deepening, the change limits for the correlated physical parameters have been studied. Thus, Table 1 shows that the rock carbonate content varies from 5.27 to 24.6 %, and the permeability varies from 1.3 to 214.9·10^{15}m^2 μm², while the porosity is in the range of 9.02–21.4 %.

According to Table 1, we can assume that the changes in physical characteristics of the productive strata rock in the Neft Dashlary area are related to the quantified amount of rock types, rock variety, rock mineralogical composition and tectonic conditions.

The Chilov Island field represents a sloping fold that extends from the northwest to the southeast for 10 km having a width of up to 4 km and steep angle wings (up to 55–80°). The fold crest is water-worn till the diatomaceous suite and is complicated by a thrust fault, the outlet of which is seen at the bottom of the sea almost for 15 km. The vertical displacement amplitude is 500 m. The fold is also complicated by seven transversal and two longitudinal fractures having vertical displacement amplitude of up to 250 m. It has a complex structure and is split into 10 blocks by several longitudinal and transversal irregularities [13–23].

The deposits in the geological structure of the Chilov Island field are studied from the modern layers until the diatomaceous suite inclusive. The latter is represented by a frequent alternation of clay minerals, marlstone and siltstone. Its penetrated depth is 290 m. The Pontian deposits mainly consist of clay minerals.

Table 1 shows a significant change in the rock permeability within the studied depths, while the change in the porosity is slight.

In some cases, the changes in rock petrophysical characteristics generate some irregularities. This is seen on the curves visualizing the changes in the rock reservoir properties (Table 2).

In addition, we have studied the relation between the porosity and carbonate content in the rock of the Absheron archipelago areas. As a result, a clear reversible relation between the carbonate content and porosity of the rock has been established.

According to tables 1 and 2, the porosity and carbonate content change step-wise. In some cases, the porosity exceeds 20 %. The maximum porosity is 15.7 % in Gyurgyan Deniz, and 18.0 % in Chilov Island [23–28].

Therefore, in three areas of the Absheron archipelago, studying petrophysical properties of the productive strata reservoirs allowed us to determine the main parameters and track their changes depending on the depth.

The conducted analysis of petrophysical characteristics can be approximated to the neighbouring areas based on their paleogeographic similarity and structural-and-tectonic processes that formed local elevations.

The analysed lithologic and petrographic properties of the deposits in the studied areas and reservoir properties of the rock samples allow us to the predict oil and gas occurrence.

Deep Reservoirs of the Baku Archipelago

We have studied petrophysical characteristics of the rock constituting the northern structures of the Baku archipelago (Sangachal-Deniz, Duvanny-Deniz and Bulla-Deniz), where the productive strata deposits are thick.

Table 1

The petrophysical characteristics of the productive strata rock by its depth in the areas of the Absheron archipelago

Depth interval, m	Lithology	Carbonate content,%	Porosity, %	Permeability, 10^{-15} m^2	Density, σ, g/cm^3	Elastic wave propagation velocity V, m/s
430–480	Sandy-argillaceous siltstone	$\frac{8,3-12,8}{9,7}$	$\frac{11,6-20,1}{16,3}$	$\frac{28,5-79,4}{59,7}$	$\frac{2,42-2,50}{2,45}$	$\frac{2200-2600}{2400}$
480–600	Silty clay	$\frac{4,9-26,8}{19,14}$	$\frac{12,4-17,0}{11,0}$	$\frac{2,6-8,1}{5,35}$	$\frac{2,36-2.56}{2,50}$	$\frac{2000-3100}{2650}$
640–690	Argillo-arenaceous siltstone	$\frac{5,8-12,4}{7,53}$	$\frac{11,0-33,6}{16,92}$	$\frac{0,1-95,7}{40,68}$	$\frac{1,6-2,34}{2,20}$	$\frac{1700-2400}{1980}$
690–930	Argillo-arenaceous siltstone	$\frac{8,9-9,9}{9,37}$	$\frac{19,5-22,9}{21,4}$	$\frac{0,1-95,7}{2,20}$	$\frac{2,01-2,10}{2,05}$	$\frac{2400-2600}{2500}$
930–940	Sandy-argillaceous siltstone	$\frac{8,2-9,4}{8,8}$	$\frac{9,9-25,7}{15,5}$	$\frac{1-3,5}{2,3}$	$\frac{2,01-2,47}{2,37}$	$\frac{2300-3200}{3000}$
940–1130	Clayey siltstone	$\frac{4,5-6,0}{5,27}$	$\frac{6,0-16,0}{9,57}$	214,9	$\frac{2,37-2,67}{2,56}$	$\frac{2500-3000}{2800}$
1130–1400	Argillo-arenaceous siltstone	$\frac{23,4-25,8}{24,60}$	$\frac{9,7-11,1}{10,40}$	$\frac{2,25-6,23}{4,24}$	$\frac{2,38-2,53}{2,44}$	$\frac{2100-3200}{2580}$
1500–1550	Clayey siltstone	$\frac{3,0-11,0}{7,0}$	$\frac{12,6-14,9}{13,75}$	$\frac{0,6-2,0}{1,3}$	$\frac{2,40-2,47}{2,44}$	$\frac{2300-2400}{2350}$
1600–2050	Clayey siltstone	$\frac{3,8-15,7}{11,8}$	$\frac{7,6-10,8}{9,02}$	56,9	$\frac{2,47-2,56}{2,51}$	$\frac{3500-3600}{3550}$
2050–2200	Sandy-argillaceous siltstone	$\frac{4,1-14,6}{9,79}$	$\frac{13,6-17,9}{14,8}$	12,5	$\frac{2,36-2,43}{2,40}$	3150
2200–2500	Clayey siltstone	$\frac{3,8-15,7}{11,8}$	$\frac{7,6-10,8}{9,02}$	56,9	$\frac{2,47-2,56}{2,51}$	$\frac{3500-3600}{3550}$
2550–3550	Clayey siltstone	$\frac{7,8-8,7}{8,1}$	$\frac{8,5-10,0}{9,9}$	66,9	$\frac{2,43-2,60}{2,56}$	3600
3550–4600	Argillo-arenaceous siltstone	$\frac{2,8-10,8}{6,8}$	$\frac{5,3-14,2}{9,57}$	60,5	$\frac{2,58-2,64}{2,61}$	4000

Note: here and in Table 2, the numerator indicates the minimum and maximum values, and the denominator indicates average values.

The full thickness of the productive strata (3950–4000 m) was penetrated at the area of Sangachal-Deniz and in the northeastern part of other areas. At the crest and crest positions of Sangachal-Deniz and Duvanny-Deniz local elevations, the productive strata thickness is 2960–3600 m.

The elevation of Sangachal-Deniz tectonically represents an asymmetric brachyaxial fold separated from the northwest Kyanizadag elevation by a long but not deep saddle. In the southeast productive strata, the plunge of the fold is seen in the terrain as a not deep and short saddle separating it from Duvanny elevation.

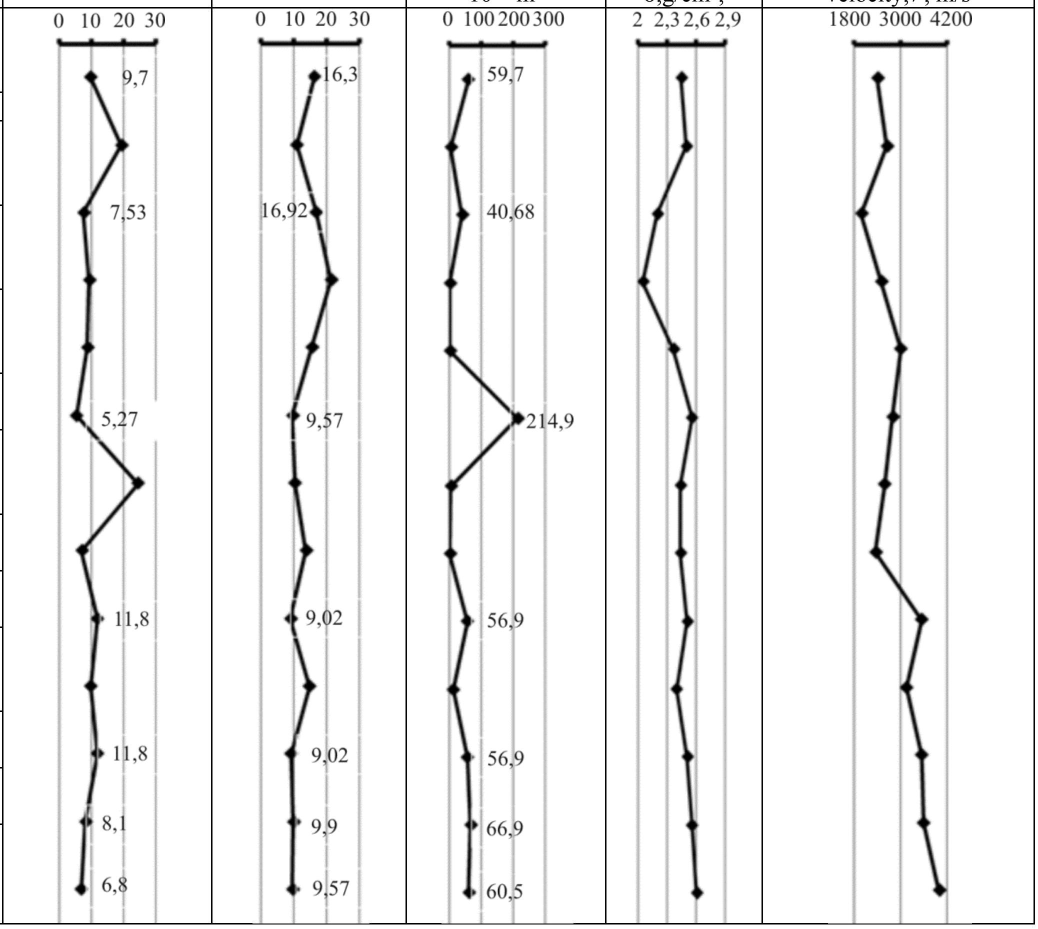
The rock constituting the Sangachal-Deniz and Duvanny-Deniz fields are studied employing deep drilling from modern to the Mesozoic layers inclusive. The productive strata crops out in the northern part of the elevation; in the near-axial zone it is water-worn to a depth of 750–800 m. The lithological section of the rock is mainly represented by the alternating sand, sandstone and clay minerals. The maximum thickness of deposits in the productive strata revealed by the drilling is 3950–4000 m, and the minimum thickness is 3000 m.

The deposits of the Akchagyl strata, Absheron strata and Quaternary strata participate in the area geological structure. Here, the productive strata have been penetrated till the top of the Kirmakinskaya suite. The Kirmakinskaya suite is mainly represented by clay minerals, sandstone and siltstone. In argillaceous rock, the density is 1.95–2.20 g/cm^3, the porosity is 7.5–25.5 %, the ultrasonic wave propagation varies within 1950–2300 m/s. In sandstone the density is 2.15–2.50 g/cm^3, and the ultrasonic wave propagation is 1200–3000 m/s. In siltstone, the density is 2.06–2.56 г/см^3, the porosity is 5.5–30 %, and the ultrasonic wave propagation is 1950–2800 m/s.

Table 2

The change in average values of physical parameters
pertaining to productive strata sedimentary rock at the Neft Dashlary field

Depth interval, m	Lithology	Carbonate content,%	Porosity,%	Permeability, $10^{-15}m^2$	Density, σ,g/cm^3,	Elastic wave propagation velocity,V, m/s
430–480	Sandy-argillaceous siltstone					
480–600	Silty clay					
640–690	Argillo-arenaceous siltstone					
690–930	Argillo-arenaceous siltstone					
930–940	Sandy-argillaceous siltstone					
940–1130	Clayey siltstone					
1130–1400	Argillo-arenaceous siltstone					
1500–1550	Clayey siltstone					
1600–2050	Clayey siltstone					
2050–2200	Sandy-argillaceous siltstone					
2200–2500	Clayey siltstone					
2550–3550	Clayey siltstone					
3550–4600	Argillo-arenaceous siltstone					



The conducted researches let us assume that the changes in petrophysical and reservoir properties of the rock comprising the main assemblage of the object under investigation are related to the carbonate content, lithological heterogeneity, various density and tectonic conditions. This allowed us to establish a relationship between the carbonate content, porosity and permeability (Table 3).

Therefore, analysing the rock that forms the geological structure of Sangachal-Deniz, Duvanny-Deniz and Bulla-Deniz, we compiled a table to show the rock petrophysical properties, including the reservoir properties, in the view of areas and sections. The dependence of the rock reservoir properties on its litho-physical properties has been studied.

The investigation results concerning the petrophysical parameters exhibited by the rock in particular areas of the Baku archipelago can be found below.

The petroleum and gas condensate fields of Sangachal-Deniz, Duvanny-Deniz and Hara-Zire Island are located in the north of the Baku archipelago and are included in one anticlinal zone; therefore, they can be regarded as an assemblage. In that place, the productive strata deposits penetrated by drilling have a maximum thickness of 3950–4000 m and a minimum thickness of 3000 m. In the north of the Baku archipelago, in argillaceous deposits, the density is 2.26–2.50 g/cm^3, the porosity is 9.5–18 % (in some cases it reaches 30 %), and the ultrasonic wave propagation is 2200–2300 m/s. In siltstone, the density is 2.16–2.63 g/cm^3, the porosity is 15–30 %, and the ultrasonic wave propagation velocity varies within 1500–2500 m/s. In sandstone, the density is 2.07–255 g/cm^3, and the porosity is 8.2–22.5 %. As in all other rock types, the ultrasonic wave propagation in sandstone depends on the mineralogical composition, cementing material, density and other factors.

Table 3

The petrophysical characteristics of the productive strata rock by its depth in the areas of the Baku archipelago

Interval, m	Particle size, mm				Carbonate content, %	Porosity, %	Permeability, 10^{-15} m^2	Density σ, g/cm^3	Ultrasonic wave propagation V, m/s
	0,25	0,25–0,10	0,1–0,01	0,01					
2522–2564	0–10,6 / 3,18	1,5–37,7 / 20,94	25,2–71,2 / 50,92	15,8–36,5 / 24,83	7,5–14,4 / 9,25	10,0–21,1 / 17,03	6,6–16,7 / 126,40	2,08 – 2,50 / 2,24	2450 – 4000 / 3000
2956–2978	0,4–3,6 / 2,0	26,4–44,7 / 35,5	37,6–38,9 / 38,2	17,1–34,3 / 25,7	6,8–7 / 6,9	15,0–20,6 / 17,8	0,9	2,23 – 2,40 / 2,332	3000 – 3400 / 3200
3292–3348	0,1–0,8 / 0,6(4)	0,9–45,6 / 20,8(4)	30,0–66,6 / 50,1(4)	23,7–32,3 / 28,8(4)	8,2–9,4 / 8,8(2)	9,9–22,7 / 14,5(14)	1–3,5 / 2,3(2)	2,01 – 2,47 / 2,35(15)	2400 – 3400 / 3060(18)
3804–3814	1,9–9,3 / 4,18	41,3–48,8 / 45,95	23,6–32,6 / 26,03	21,3–27,6 / 24,52	6,9–10,1 / 8,25	20,1–22,2 / 21,5	35,6–46,4 / 39,20	2,03 – 2,12 / 2,08	2250 – 2600 / 2450
3814–3982	0–0,6 / 0,3	10,0–50,0 / 31,8	20,7–63,4 / 48,68	15,3–28,7 / 19,95	10,9–13,5 / 11,70	20,0–22,1 / 20,68	46,8–172,0 / 122,20	2,04 – 2,12 / 2,09	2550 – 2600 / 2430
4444–4446	11,8–17,6 / 15,63	46,2–57,2 / 5057	14,9–30,4 / 23,27	9,7–11,6 / 10,53	11,8–15,1 / 13,07	14–17 / 16,0	17,6–20,1 / 18,85	2,23 – 2,35 / 2,24	3000 – 3450 / 3250
4580–4656	0,5–7,5 / 3,23	19,6–57,9 / 43,07	22,7–69,1 / 37,3	10,0–23,9 / 16,6	8,9–9,9 / 9,37	20,4–22,9 / 21,4	0,1–95,7 / 2,20	2,01 – 2,10 / 2,05	2400 – 2600 / 2500
5071–5409	1,0–4,4 / 2,70(2)	57,4–60,0 / 58,70(2)	11,8–19,1 / 15,45(2)	19,9–26,4 / 23,15(2)	5,8–12,3 / 9,05(2)	15,8–19,0 / 17,40(2)	0–19,0 / 9,5(2)	–	–
5175–5232	0,0–2,20 / 1,40	7,2–31,9 / 20,76	32,7–76,2 / 45,8	15,3–38,4 / 32,32	4,3–18,4 / 9,0	5,0–20,9 / 12,26	42,0–94,0 / 59,33	2,08 – 2,28 / 2,18	2400 – 2800 / 2600
5325–5401	0,04–1,3 / 0,46(3)	1,9–18,6 / 7,31(6)	37,5–65,8 / 54,62(6)	26,3–43,9 / 37,78(6)	8,2–20,7 / 15,80(6)	7,2–20,0 / 11,90(5)	0,98–2,4 / 1,55(5)	–	–
5660–5707	–	41,2–43,9 / 42,55(2)	33,3–47,1 / 40,2(2)	11,7–22,8 / 17,25(2)	11,9–15,0 / 13,45(2)	12,6–14,7 / 13,65(2)	156–190 / 173(2)	–	–

As a result of that, it varies within the range of 1950–4000 m/s. The physical properties of limestone clays in the productive strata are characterized by the following parameters: density of 2.05–2.65 g/cm^3, porosity of 8.5–30.0 %, and ultrasonic wave propagation of 2100–4000 m/s. By the results of processing and interpreting the petrophysical, field and geophysical data, we can predict that some particular horizons of the productive strata have a rather high potential, i.e. the oil and gas occurrence in some of them has a bigger potential than expected. The wells drilled in all areas penetrated the complete thickness of the productive strata (3950–4000 m) in the fields of Sangachal-Deniz and Hara-Zire Island. On the hypsometrically high-positioned local structures of Sangachal-Deniz and Duvanny-Deniz, the productive strata thickness is 2960–3600 m.

The Alyat-Deniz oil and gas field is located in the northwest of the Baku archipelago. In that area, all suites in the productive strata have been penetrated except for the Kala suite. The productive strata deposits consist mainly of clay minerals, sandstone and siltstone. In argillaceous rock, the density is 1.90–2.20 g/cm^3, the porosity is 7.5–27.0 %, and the ultrasonic wave propagation is 1250–2200 m/s. In sandstone, the density varies within 2.14–2.48 g/cm^3, the porosity is 6.5–20.5 %, and the ultrasonic wave propagation is 1800–3000 m/s. In siltstone, the density varies within 2.06–2.45 g/cm^3, the porosity is 9.1–23.9 %, and the ultrasonic wave propagation is 1900–2100 m/s.

The permeability value determined based on core materials is relatively small. To determine changes in the dependence of this parameter on the porosity, a correlation pattern has been built. However, this relation is rather conditional. It is known that any permeable rock is porous, but not each porous rock can be permeable.

The correlation of the curves showing the changes in the studied petrophysical processes depending on the depth enabled establishing the following dependence of the porosity and permeability on the particle size distribution and carbonate content in the rock (fig. 4).

Table 4 demonstrates that until the depth is 4580 m, the psammitic facies generally show significant growth in the particle size distribution of the rock; whereas the amount of siltstone and pellite fractions decreases, and carbonate content fluctuations remain insignificant. As a result, on the background of the insignificantly increased porosity, the permeability has grown relatively fast (up to (122.0–185.5) 10^{-15} m^2), which is probably due to the abovementioned change in the particle size distribution of the rock. At the same time, at a depth of 2564–3401 m, the rock is characterized by low content of the psammitic facies and increased content of the siltstone and pellite facies. It is evident that such particle size distribution causes almost zero permeability in that layer ((0.9–2.3) 10^{-15}m^2).

Then, at a depth of 3401–4580 m, a strong increase in the psammitic facies up to 66.2 % and a decrease in the siltstone and pellite facies also led to a relatively steep increase in the permeability of the rock (32.2–188.5) 10^{-15}m^2). Beginning with a depth of 4580 to 4656 m, the psammitic facies content in the rock drops to 47.3 % being accompanied with a growth in the siltstone and pellite fractions and carbonate content. Such a change in the particle size distribution led to a sharp drop in permeability to $2.23 \cdot 10^{-15}$ m^2, which can be regarded as typical for granular reservoirs [29–34].

At a depth of 4656–5109 m, the psammitic facies increase again up to 61.4 % being accompanied with a relatively sharp drop in the siltstone content to 15.43 % and a slight growth in the pellite fraction to 15.43 %. Such a combination of fractions in question led to an insignificant reduction in the porosity and a growth in the permeability just up to $9.5 \cdot 10^{-15}$ m^2.

At a depth of 5175–5232 m, there is a sharp drop in the psammite content to 22.16 %, triple growth in the siltstone facies, and almost 10 % growth in the pellite facies, whereas their carbonate content remains relatively low, thus leading to an increase in the permeability to $59.33 \cdot 10^{-15}$ m^2.

Further, at a depth of 5660–5702 m, the psammitic facies content grows again up to 42.65 %; the siltstone content decreases to 40.02, and there is a double reduction in the pellite fraction to just 17.35 %; the carbonate content grows insignificantly. As a result, when the porosity is 13.65 %, the rock permeability grows to $173.0 \cdot 10^{-15}$ m^2.

The conducted analysis shows that in the studied granular reservoirs in the territory under investigation, the porosity and, especially, the permeability of the rock are mainly conditioned by the quantitative content of psammitic-and-siltstone facies and, above all, by psammitic facies. Such dependence of the rock reservoir properties is indicative of insignificant development or full absence of the secondary porosity mainly caused by fracturing and cavern porosity, etc. The low carbonate content, in its turn, excludes the probability of leaching contributing to reservoir properties of carbonate rock. The absence of such a process in the rock in question is evidenced by its low carbonate content, as well as by its low reservoir properties [35–45].

There is a direct relationship between the change in the rock density and the ultrasonic wave velocity; the tables show that they correlate well. However, there is no apparent relation between the lithofacies properties, reservoir properties and mentioned physical properties of the rock in this particular case.

Based on the above, we can say that to further define the oil and gas occurrence in some particular structures of the Baku archipelago, it is necessary to perform additional geological and geophysical work (gravimetric investigations, magnetometric investigations, electrometric investigations, seismic exploration and petrophysical investigations) followed by sinking deep exploratory wells in order to reveal new oil and gas accumulations.

Such activities will allow for a more detailed investigation of the reservoir properties of deep oil, gas, and water-bearing strata, and structural and tectonic aspects of the analysed areas.

Conclusion

The results of the conducted researches allow us to make the following conclusions:

– within the analysed offshore areas the change of petrophysical values in a wide range is mainly caused by the lithological heterogeneity of the assemblages, different formation depths, and structural and tectonic conditions;

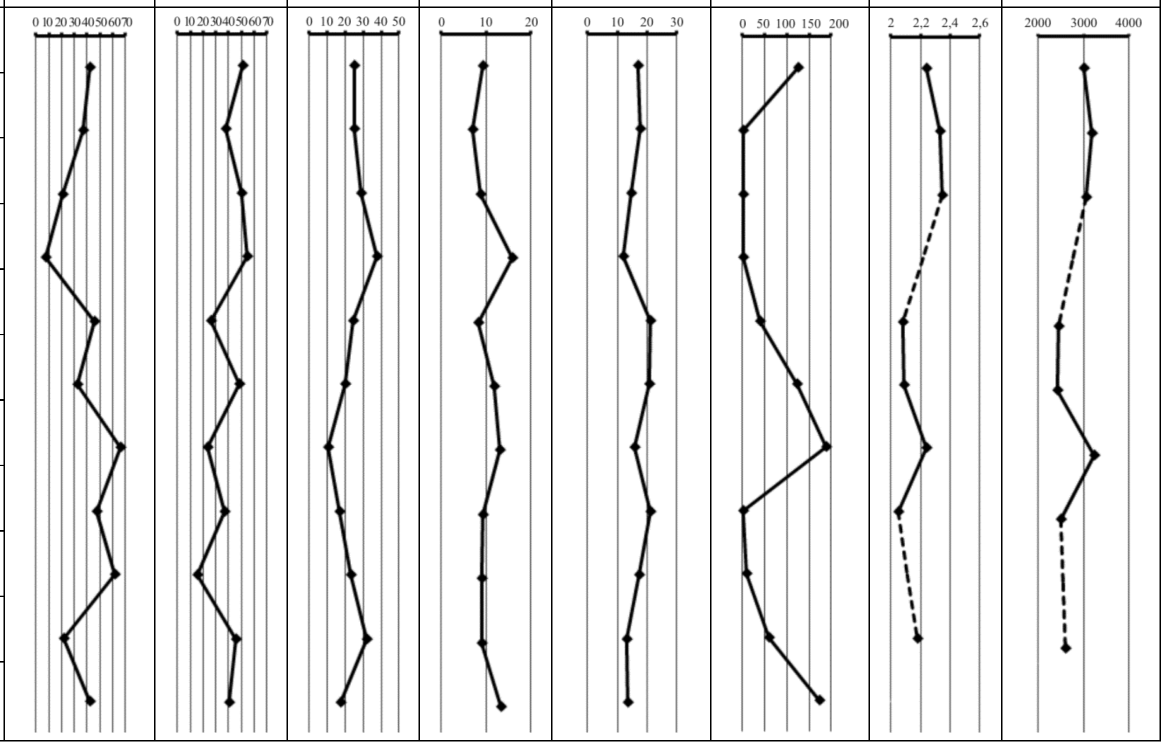
– a good correlation between the porosity and permeability is conditioned by the terrigenous composition, lithofacies identity and close values of the reservoir rock porosity; the relatively high rock permeability is related to an increased content of psammitic-and-siltstone facies;

– when predicting oil and gas occurrence in deep strata of such structures, in addition to the best geophysical prospecting methods, it is necessary to take into consideration porosity and permeability properties of the rock;

Table 4

Northern areas of the Baku archipelago – the change in the particle size distribution and reservoir properties of the productive strata deposits by the depth

Depth interval, m.	Particle size distribution, % Particle size, mm			Carbonate content, %	Porosity, %	Permeability, 10^{-15} m^2	Density σ,g/cm^3	Ultrasonic wave propagation, *V*, m/s
	> 0,25–0,1	0,1–0,01	< 0,01					
2522–2564								
2956–2978								
3292–3318								
3325–3401								
3804–3814								
3814–3982								
4444–4446								
4580–4656								
5071–5109								
5175–5232								
5660–5707								



– the change in the rock density and ultrasonic wave velocity depending on the depth signifies their good correlation and the absence of such correlation between them and the rock reservoir properties, which mainly indicates that the secondary porosity is not characteristic for the reservoir rock.

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