THE GEOLOGICAL STRUCTURE AND THE ANALYSIS OF THE REGULARITY OF THE CHANGE IN THE RESERVOIR PROPERTIES OF THE NEFT DASHLARI DEPOSIT

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Abstract

At the Neft Dashlari deposit, in order to study the lithologic-petrographic and reservoir properties of deep-seated formations, as well as the regularity of their changes with depth, carbonate content, porosity, permeability, density, grain size distribution and speeds of propagation of longitudinal seismic waves from samples taken from exploration and prospecting wells. The minimum, average and maximum limits of the physical properties of the rocks were established. The dependence of reservoir properties and other physical factors on the depth of occurrence of the latter is considered. Our analysis of the influence of physical parameters of rocks on their permeability allows us to conclude that the main influence on permeability is exerted by the lithofacial composition, degree of sorting, carbonate content and type of porosity. However, the increased carbonate content of rocks can stimulate the appearance of fracturing in them, as well as cavernous leaching voids in the case of circulation of water in the formed cracks. These processes have a positive effect on reservoir properties, mainly on the permeability of high-carbonate rocks. Analyzing the results of these researches, it is possible to predict the oil and gas potential of deep-lying layers along with those already exploited.

Keywords: deposits, suit, porosity, deep, well, density, petrophysics, horizon, drilling, geophysics.

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1. Introduction

Seeing the investigation of the oil and gas potential of the deep-lying sediments of the sedimentary cover of the South Caspian Depression (SCD), geological exploration and geophysical work was carried out in Azerbaijan in a significant amount. Scientific criteria have been prepared, which can serve as the basis for future geological research. It has been noted that the main deposits of oil and gas in the region are associated with the South Caspian and the Kura Depressions, which were subjected to intense submersion during the meso-cenozoic time.

In spite of the high perspective of the central part of the SCD, its deep-seated strata, the problems associated with the extraction of oil and gas from them have not yet been finally resolved.

2. The aim and objectives of research

In determining oil and gas objects and prospective structures, one of the important tasks is the study of reservoir properties of rocks. Rich oil and gas fields have been identified and commissioned in Azerbaijan, however, to obtain more accurate information on the oil and gas potential of some structures and clarify their geological structure, one of the urgent tasks is to study the petrophysical properties of rocks. The article presents the results of a comprehensive study of rock samples taken from exploration wells drilled at the Neft Dashlary field.

The study of the material composition, structure and reservoir properties of rocks at various depths in the earth's crust with the help of ultra deep drilling opens up great prospects for developing methods for reliable geological interpretation of seismic and other geophysical research results.

Changes in reservoir properties of rocks in the area of Neft Dashlary for clarification of what is mainly due to the depth of occurrence of rocks, with the tectonic activity of the region. To determine the physical properties of rocks of the selected areas of Neft Dashlary. Within the limits of the studied offshore fields, the change in the petrographic properties of the values is mainly due to lithological heterogeneity, depth, and structural-tectonic conditions of bedding.

The change in the density of rocks and the speed of ultrasonic waves with depth are clarified. The results of petrophysical studies establish an increase in the speed of propagation of ultrasonic waves with an increase in the density of rocks and a decrease with a depth of their reservoir properties. In order to predict oil and gas potential in the deeper layers of the structure, optimal geophysical methods are used.

3. Methods and tasks

The local uplifts of individual structural elements of the SCD have developed mainly with the activity of the same folding mechanisms, and their overwhelming part is the injection structures. These include local uplifts of the entire anticline zone of the Absheron-Pribalkhan structural mega-gap, to which the rise of Neft Dashlari is also associated (**Fig. 1**). This anticlinal zone originates in the northwest from the Goshadash uplift and further through the structures of Pirallahi-Gyurgyan-deniz-Darwin kupesi-Khali-Neft Dashlari-Azeri, etc. extends to the east until the Cheleken-sea rises. Developing in the conditions of Absheron-Pribalkhan non-classical (residual) subduction. A characteristic feature of the structures of this anticlinal zone is their formation by longitudinal and transverse bending mechanisms with the dominance of the former.

As a result, most of them are linear and elongated braces, complicated by mud-volcanism. Petrophysical researches were carried out in a number of areas in the Absheron archipelago. Their goal is obtaining detailed information on reservoir rocks, their lithologic-petrophysical features, refinement of hydrocarbon resources and, on the basis of the obtained results, to determine further directions for prospecting and exploration.

For this purpose, the geological, geophysical and physical characteristics of the rocks are investigated, which influenced the reservoir potential of the Mesozoic-Cenozoic deposits containing oil, gas and gas-condensate clusters in the SCD. Such works were carried out at the Neft Dashlari deposit of the North-Absheron archipelago.

The fold of Neft Dashlari is asymmetric along its strike and crosswise. Its northwestern periclinal is shortened, the angles of incidence here are 33–45º, the southeastern periclinal has an elongated shape, the layers lie at an angle of 22–29º. The set of fold displaced towards the northwestern periclinal to the southeast of the longitudinal tectonic disturbance (**Fig. 1, 2**) and is deeply blurred. As a result, deposits of the kirmaky suite, lying in the core of the fold, are exposed on the surface of the seabed [1, 2].

The arch of the uplift is complicated by a large longitudinal rupture, which is essentially a broad zone of intense disjunctive dislocation, composed of strongly crumpled brecciated deposits of the oligocene-miocene age. In general, the fold is complicated by two longitudinal and a large number of transverse ruptures (**Fig. 1**). In its southeastern part, a mud volcano is located at the intersection of disruptive disturbances. Here, on the seabed, there are numerous griffins continuously emitting oil and gas [1].

The southwestern wing of the fold is steeper with the dips mainly of 35–40º, and the northeast is relatively shallow. Here the layers lie at an angle of 27–30º. In the northeast wing, closer to the southeastern periclinal, the dip of the layers are 45–50º. However, in some areas, in the near-axis of the northeastern wing, in the tectonic block between the axis longitudinal ruptures, the dips of incidence of the layers reach 72º (**Fig. 2**). Seismic prospecting has established that within the southeastern periclinal the hinge of the fold is ramified, and it from the north is connected with the Guneshli structure from the north through a shallow saddle, and from the south – with the rise of Neft Dashlari-2. In the north-west it separates from the fold of the Palchyg Pilpilyasi with a weakly expressed saddle.

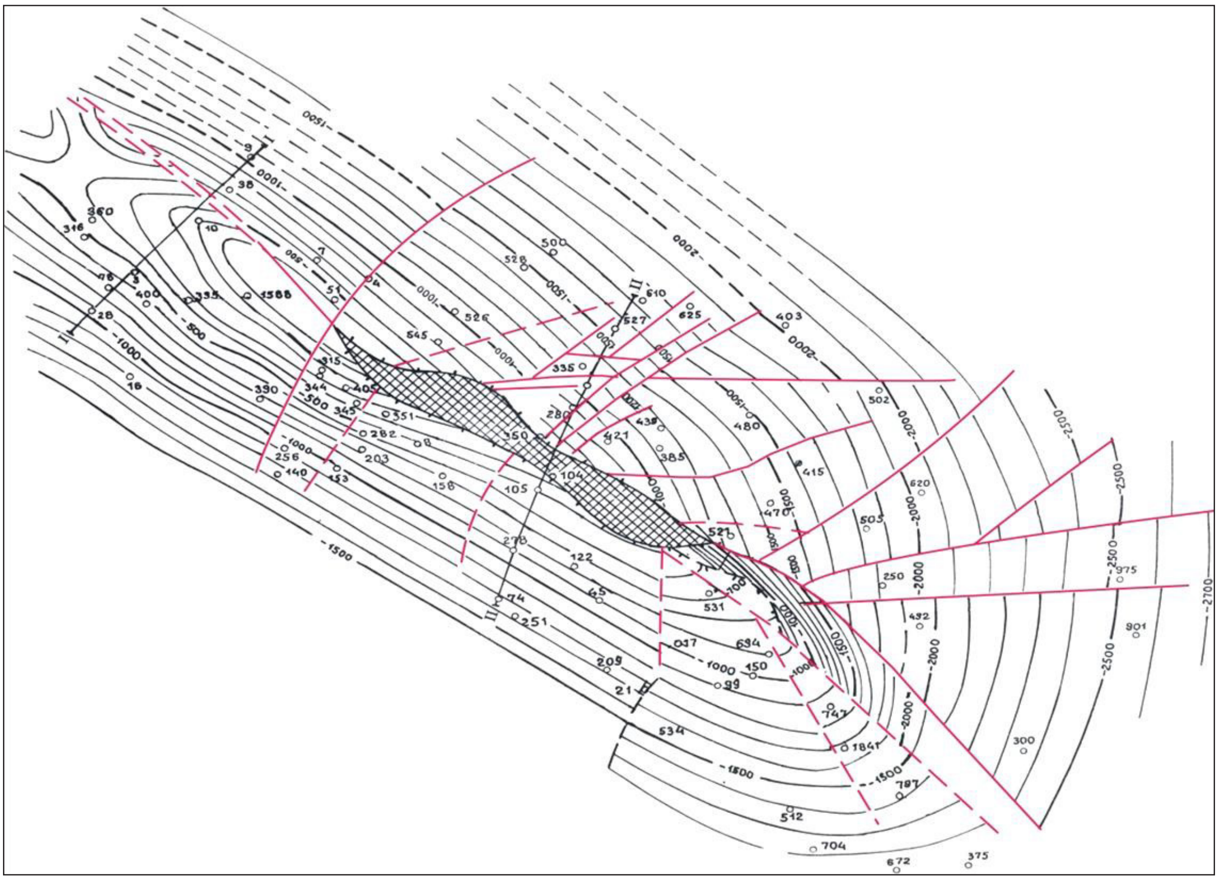


Fig. 1. The Neft Dashlari deposit. Structural map on the roof of kirmaky suite of PS

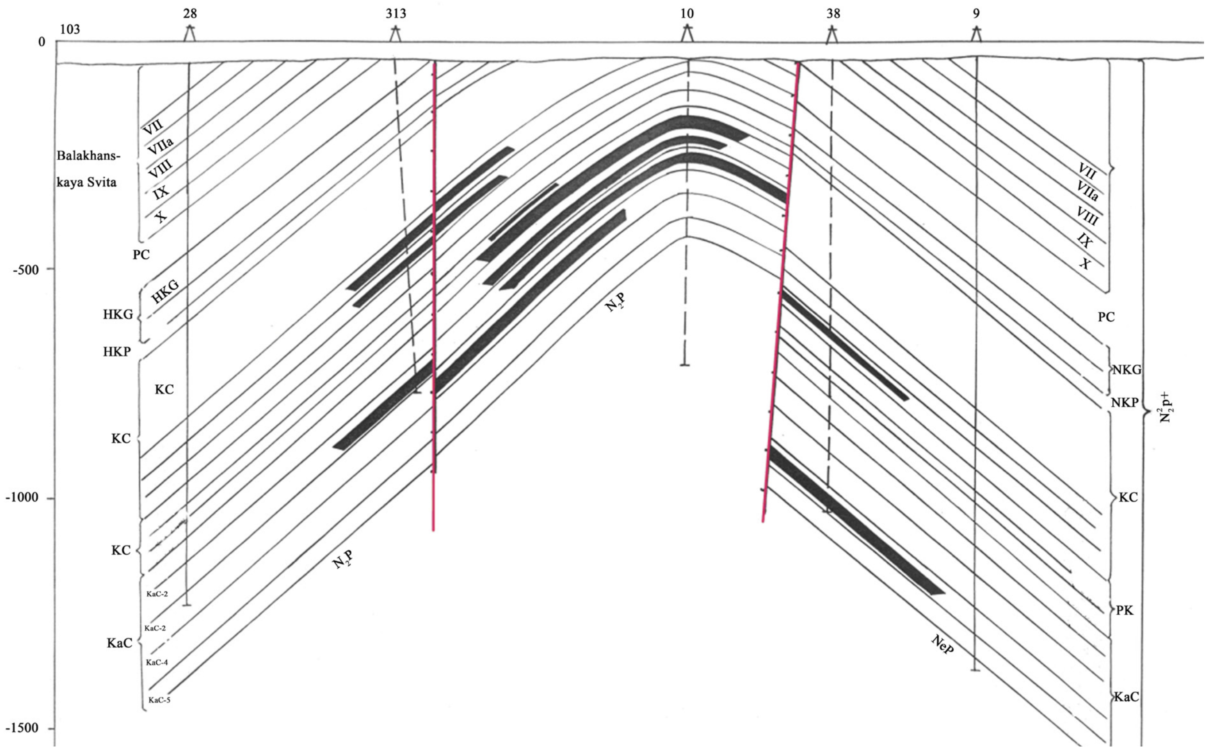


Fig. 2. Transverse geological profile through the field of Neft Dashlari. PS Suites: KaS-kalinin suite; UK – underkirmaky suite; KS – the kirmaky suite; OKS - overkirmaky sandstone suite; KS-1 – first, KS-2 – second horizon of the kirmaky suite

The sedimentary section of the deposit of Neft Dashlari is studied from the kone suite to quaternary sediments inclusive. Deep exploration wells were discovered and studied sediments of the cones, Maikop series, middle, upper miocene and pliocene. The maximum thickness of these deposits is 4650 m. Maikop series is opened by a well, in the arch of the fold, it consists of sands and clays with layers of volcanic ash and plant residues. A variety of oil-bearing horizons are revealed in the section of the Productive strata (PS-N'_2). Kalinin plantar suite of PS is represented by siltstones and clayey deposits with interlayers of fine-grained sands and sandstones. Sands are quartz, medium-fine grained, clays are slightly sandy and weakly calcareous. The composition and thickness of the sandy horizons and clay interlayers that separate them are not stable in area. The sandiness of the cut from the bottom to the top of the suite and from the wings to the arch of the fold increases to 70 %. The suite is divided into 4 oil and gas bearing horizons. In the lower horizon, in a further number of blocks are allocated 4 subhorizons [2]. To determine the reserves of the operational object over the area, it is necessary to analyze the accumulated geological, geophysical, field materials and the integrated use of their results. Based on the materials of each well, the values of such parameters as effective thickness, porosity, and oil saturation are interpreted and determined. The used technique is realized according to the program of algorithms [3].

4. Research results and discussion

It is known that prospecting and exploration of oil and gas fields, their development and assessment of the potential of oil and gas potential of reservoirs depends on the petrophysical characteristics of the deposits that make up the section of the area. To determine the physical and reservoir properties, as well as their changes with depth in the area of Neft Dashlari, a table and graphs were compiled reflecting the petrophysical characteristics of the rocks (**Tables 1, 2**) [5, 6].

The field is characterized by reservoir, lithological and tectonic types of traps and contains 26 oil-bearing objects confined to the suite and horizons of the PS. The underlying PS sediments (the kone suite – pontic stage) in terms of their oil and gas potential are of interest from data from more than 25 wells. In oil-bearing objects, gas accumulations are found in a dissolved form. However, in some cases, there is its independent access. The oil potential of the kalinin suite is established in all tectonic blocks of the structure.

As follows from Table 1 and graphs (**Table 2**) in the depth interval 430–480 m, rocks are sandy-argillaceous siltstones with a carbonate content of 9.7 %, a porosity of 16.3 % and a permeability of $59.7 \cdot 10^{-15}$ mkm^2. Obviously, a low percentage of carbonate content and the presence of a certain number of open pores contributed to the formation or preservation of good permeability at an average rock density of 2.45 g/cm^3 and a seismic speed of 2400 m/sec.

The interval of depths of 480–600 m is composed of silty clay with a carbonate content of 19.14 %. In this case, the clay composition and relatively high carbonation of rocks with an average density of 2.50 g/cm^3 and a seismic speed of 2550 m are characterized by a very weak permeability of $5.35 \cdot 10^{-15}$ mkm^2 (**Tables 1, 2**). With the clay composition, the increase in carbonate content probably contributed to the formation of cracks, that is, the secondary porosity, which became the main reason for the appearance of insignificant. At depths of 640–690 m lie clayey sand aleurolites. The clays were partially replaced by sands, the carbonate content dropped to 7.53 %, and the porosity increased to 16.92 %, respectively, and the permeability improved to $40.68 \cdot 10^{-15}$ mkm^2 at a density of 2.20 g/cm^3 and a seismic speed of 1980 m/s. The relatively low density and speed of seismic waves, as well as good permeability, seem to indicate that there is a primary open porosity in these rocks. The depth interval 690–930 m is expressed by clay-sand aleurolites with carbonate content of 9.37 % and porosity of 21.4 %. However, the permeability actually disappeared ($2.20 \cdot 10^{-15}$ mkm^2), and the density decreased 2.05 g/cm^3, although the speed of seismic waves increased significantly (2500 m/sec) (**Table 1**). Obviously, the increase in porosity relates to their subcapillary when the variety is closed, which does not contribute to an increase in the permeability of rocks. At depths of 930–940 m lie sandy-argillaceous aleurolites with carbonate to 8.8 % and 15.5 % porosity to a density of 2.37 g/cm^3 and a relatively high speed of seismic waves is 3000 m/s. As in the previous case, despite sufficient porosity, rocks are virtually devoid of permeability ($2.3 \cdot 10^{-15}$ mkm^2), apparently with the development of mainly sub-capillary porosity.

The next depth interval of 940-1130 m consists of clay aleurolites with low carbonate content (5.27 %) and low porosity in (9.57 %). The density is relatively high 2.56 g/cm^3, and the speed of seismic waves is 2800 m/sec. The permeability of rocks is 214.9·10^{-15} mkm^2, which may be due to the relatively good development of supercapillary porosity, or with the appearance of its secondary variety.

Clayey sand aleurolites compose a depth interval of 1130–1400 m with carbonate content of 24.6 %, porosity of 10.4 %, density of 2.44 and a seismic speed of 2530 m/s. With sufficient porosity, a very weak permeability (4.24·10^{-15} mkm^2) can be associated with high carbonation and, apparently, with the development of mostly closed or sub-capillary porosity. The depth interval 1500–1550 m is represented by clay aleurolites with a carbonate content of 7.0 %, a porosity of 13.75 %, and the density and speed of seismic waves is the same as in the previous interval. In this case, practically no permeability (1.3·10^{-15} mkm^2) indicates that the existing porosity is subcapillary or closed. The rocks of the depth interval 1600–2050 m are clayey aleurolites with a carbonate content of 11.8 % and a porosity of 9.02 %, with a density of 2.51 g/cm^3 and a seismic speed of 3550 m/s. Their permeability is 56.9·10^{-15} mkm^2. A good indicator of permeability may be associated with the development of primary or secondary supercapillary open pores.

The depth interval 2050–2200 m is represented by sandy-argillaceous aleurolites with a carbonate content of 9.79 % and a porosity of 14.8 % (**Tables 1, 2**). With a density of 2.40 g/cm^3 and a seismic speed of 3150 m/s, these rocks have a permeability of 12.5·10^{-15} mkm^2, which indicates its average level associated with the presence of a certain amount of supercapillary porosity in the rocks.

Clay aleurolites with a carbonate content of 11.8 % and a porosity of 9.02 % lie at depths of 2200–2500 m. These rocks, with a density of 2.51 g/cm^3 and a seismic speed of 3550 m/s, have good permeability (56.9·10^{-15} mkm^2), which indicates the presence of a sufficient number of super-capillary open pores in them.

The depth interval 2550–3550 m is composed of clay aleorolites with a carbonate content of 8.1 %, a porosity of 9.9 %, a density of 2.56, a seismic speed of 3600 m/s, and a good permeability of 66.9·10^{-15} mkm^2 (**Tables 1, 2**), which can be connected, as in the previous cases, to the presence of open capillary and supercapillary pores in them. At depths of 3550–4600 m, the rocks are clayey-sand aleurolites with a carbonate content of 6.8 %, a porosity of 9.57 % at a density of 2.61 g/cm^3, and a seismic speed of 4000 m/sec. With such a petrophysical characteristic, their permeability is 60.5·10^{-15} mkm^2, which is obviously related to the presence of open capillary and supercapillary porosity. The presented analysis of the influence of the physical parameters of rocks on their permeability allows to conclude that the main influence on permeability is exerted by the lithofacies composition, the degree of sorting, the size of the carbonate content and the type of porosity. At the same time, the value of the total porosity has no direct effect on the quantitative index, and the carbonate content in most cases is inversely proportional to the permeability. However, increased carbonate rocks can stimulate the appearance of them in the event of fracture as a thermobaric stringent conditions and dynamic stresses, as well as cavernous leaching voids in the case of water circulation in the formed cracks. These processes have a positive effect on the permeability of high-carbonate rocks.

The density of the medium and the speed of seismic waves are indirect indicators of permeability, being in inverse relationship with it and in a straight line with each other.

All that has been said can also be seen on the graphs (**Table 2**), on which the relationship between carbonate and permeability is relatively more clearly traced than between porosity and permeability.

On the area of Neft Dashlari, the maximum thickness of the PS, discovered by four wells, is 4600 m. In some sections of the field deep exploratory wells, at great depths, some horizons of PS are opened. The density of clay rocks here is 2.20–2.48 g/cm^3, a porosity of 8.3–17 % (in some cases reaches up to 25 %), the propagation of ultrasonic waves is 2150–2200 m/s. The density of siltstones is 2.13–2.60 g/cm^3, the porosity varies between 15–28 %, the propagation of ultrasonic waves varies between 1300–2200 m/s. The density of sandstones varies from 2.00 to 2.50 g/cm^3, the porosity varies between 7.2–22.0 %. In all rocks, depending on the lithological composition, the propagation of ultrasonic waves varies within 850–2800 m/s. Carbonate clays of PS changed

and their physical properties are characterized by the following values: density 2.02–2.59 g/cm^3, porosity 8.5–30 % and propagation speed of ultrasonic waves 2100–3500 m/s.

Table 1
Limits of change, average values of physical properties and the degree of permeability of sedimentary rocks of the PS field of Neft Dashlari

Depth intervals, m	Lithology	Carbon-ate, % min – max / average	Density, σ, g/cm^3 min – max / average	Speed of propagation of elastic waves, V, m/sec. min – max / average	Porosity, % min – max / average	Perme-ability, 10^{-15} mkm^2 min – max / average	Degree of permeability
430–480	sandy-argillaceous aleurolites	8,3 – 12,8 / 9,7	2,42 – 2,50 / 2,45	2200 – 2600 / 2400	11,6 – 20,1 / 16,3	28,5 – 79,4 / 59,7	good
480–600	aleurite clay	4,9 – 26,8 / 19,14	2,36 – 2.56 / 2,50	2000 – 3100 / 2650	12,4 – 17,0 / 11,0	2,6 – 8,1 / 5,35	very weak
640–690	clayey sandy aleurolites	5,8 – 12,4 / 7,53	1,6 – 2,34 / 2,20	1700 – 2400 / 1980	11,0 – 33,6 / 16,92	0,1 – 95,7 / 40,68	good
690–930	clayey sandy aleurolites	8,9 – 9,9 / 9,37	2,01 – 2,10 / 2,05	2400 – 2600 / 2500	19,5 – 22,9 / 21,4	0,1 – 95,7 / 2,20	very weak
930–940	sandy-argillaceous aleurolites	8,2 – 9,4 / 8,8	2,01 – 2,47 / 2,37	2300 – 3200 / 3000	9,9 – 25,7 / 15,5	1 – 3,5 / 2,3	very weak
940–1130	clayey aleurolites	4,5 – 6,0 / 5,27	2,37 – 2,67 / 2,56	2500 – 3000 / 2800	6,0 – 16,0 / 9,57	214,9	high
1130–1400	clayey sandy aleurolites	23,4 – 25,8 / 24,60	2,38 – 2,53 / 2,44	2100 – 3200 / 2580	9,7 – 11,1 / 10,40	2,25 – 6,23 / 4,24	very weak
1500–1550	clayey aleurolites	3,0 – 11,0 / 7,0	2,40 – 2,47 / 2,44	2300 – 2400 / 2350	12,6 – 14,9 / 13,75	0,6 – 2,0 / 1,3	missing
1600–2050	clayey aleurolites	3,8 – 15,7 / 11,8	2,47 – 2,56 / 2,51	3500 – 3600 / 3550	7,6 – 10,8 / 9,02	56,9	good
2050–2200	sandy-argillaceous aleurolites	4,1 – 14,6 / 9,79	2,36 – 2,43 / 2,40	3150	13,6 – 17,9 / 14,8	12,5	medium
2200–2500	clayey aleurolites	3,8 – 15,7 / 11,8	2,47 – 2,56 / 2,51	3500 – 3600 / 3550	7,6 – 10,8 / 9,02	56,9	good
2550–3550	clayey aleurolites	7,8 – 8,7 / 8,1	2,43 – 2,60 / 2,56	3600	8,5 – 10,0 / 9,9	66,9	good
3550–4600	clayey sandy aleurolites	2,8 – 10,8 / 6,8	2,58 – 2,64 / 2,61	4000	5,3 – 14,2 / 9,57	60,5	good

Notes: In the numerator – the minimum and maximum values, in the denominator – the average values

When investigating the granulometric composition of the rocks of the PS complex of the Neft Dashlari area, it is established that the grain diameter changes mainly from 0.1 to 0.01 mm. This indicates that the aleuric facies prevail in the section relative to other terrigenous differences. As it was noted, the field of Neft Dashlari is multistory. To determine the reservoir properties of deposits with depth, it is necessary to correlatively analyze the limits of changes in physical parameters.

Researches make it possible to assume that changes in the physical characteristics of rocks are associated not only with lithological heterogeneity of rocks, carbonate content, but also with tectonic activity of the medium. As a result, the regularities of the change in the coefficients of porosity and permeability are established [7–12].

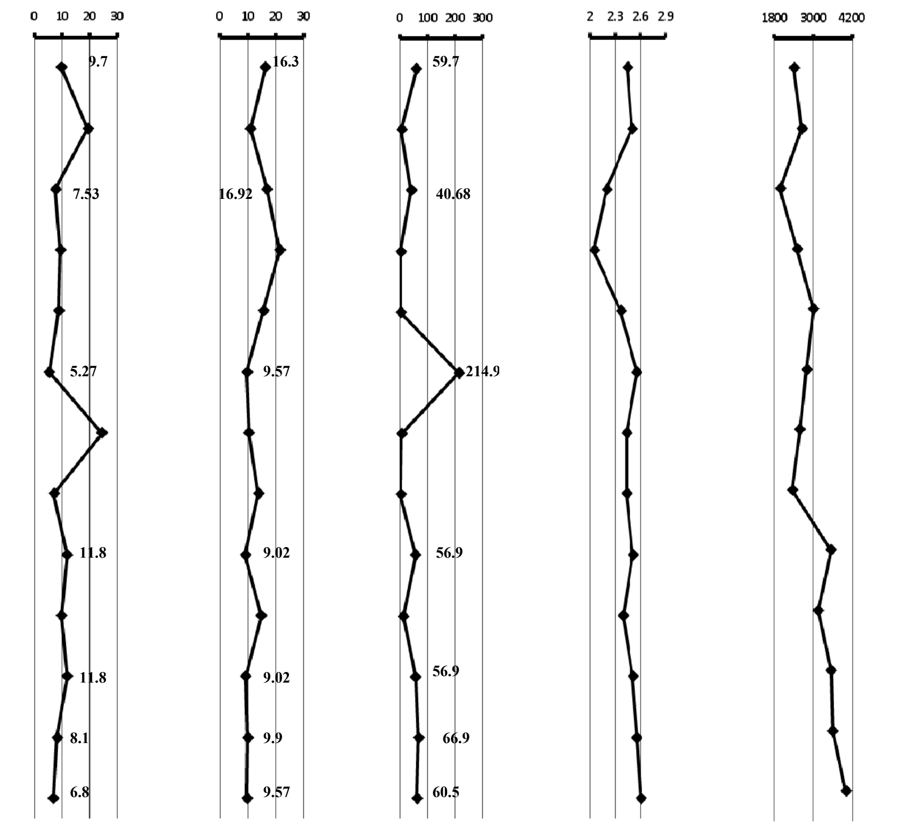
From **Table 1**, the constructed graphs (**Table 2**) and their analysis, it can be seen that the reservoir properties of rocks within the depths under consideration vary from impermeable to highly permeable, regardless of the depth of their occurrence, which makes it possible to predict the presence of collectors at relatively large depths. In some cases, in connection with petrophysical changes, certain regularities are violated. his is evident from the graphs of the change in the limits of values of reservoir rock characteristics (**Table 2**).

The limits of changes in porosity and permeability of rocks in separate areas based on their petrophysical characteristics are also analyzed (**Fig. 3**), indicating that there is no direct relationship between total porosity and rock permeability.

Table 2

Graphs of changes in the mean values of the physical parameters of the sedimentary rocks of the PS field of Neft Dashlari

Depth Intervals, m	Lithology	Carbonate, %	Porosity, %	Permeability, 10^{-15} mkm^2	Density, σ, g/cm^3	Speed of propagation of elastic waves, V, m/sec.
430-480	sandy-argillaceous aleurolites					
480–600	aleurite clay					
640–690	clayey sandy aleurolites					
690–930	clayey sandy aleurolites					
930–940	sandy-argillaceous aleurolites					
940–1130	clayey aleurolites					
1130–1400	clayey sandy aleurolites					
1500–1550	clayey aleurolites					
1600–2050	clayey aleurolites					
2050–2200	sandy-argillaceous aleurolites					
2200–2500	clayey aleurolites					
2550–3550	clayey aleurolites					
3550–4600	clayey sandy aleurolites					



Processing and interpretation of petrophysical and field-geophysical materials in the Neft Dashlari deposit make it possible to establish that some horizons of PS from the point of view of their oil and gas potential are more promising. The analysis of the lithologic-petrographic properties of deposits of the Neft Dashlari deposit and their reservoir properties on the core material allows to conclude that the change in reservoir properties of rocks with depth is a multifunctional appearance. Under certain thermobaric and geodynamic conditions, rocks, especially with increased carbonate content, can acquire or improve their reservoir properties due

to the formation of secondary porosity in them. The result gives the basis to predict oil and gas potential of deep layers.

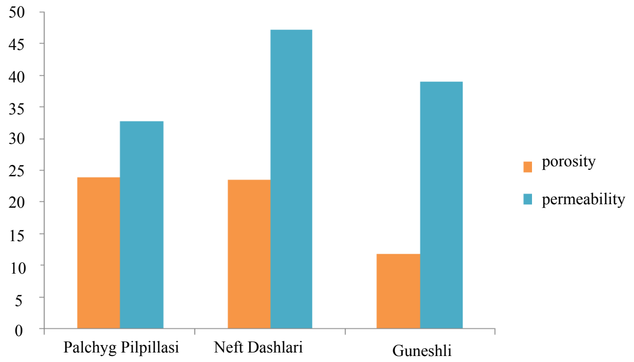


Fig. 3. The character of the change in the average values of porosity and permeability in the areas of Palchyg Pilpillasi, Neft Dashlari and Guneshli

5. Conclusions

1. The change in the wide range of reservoir properties of rocks in the area of Neft Dashlari is associated mainly with the conditions of lithogenesis, with the heterogeneity of the lithological composition of sedimentary complexes, the depths of occurrence of rocks, and the tectonic activity of the region.

2. The speed of propagation of ultrasonic waves increases with increasing density of rocks and a decrease in their speed with an improvement in the reservoir properties of rocks.

3. Carbonate content and permeability of rocks are mostly inversely related, but with relatively stringent thermobaric and dynamic conditions, rocks with high carbonation and clay content can acquire or improve reservoir properties due to the appearance of secondary porosity.

4. Petrophysical studies indicate that there is no direct functional relationship between the reservoir properties of rocks and the depth of their occurrence.

5. When forecasting the oil and gas potential of deep-lying strata, along with exploratory geophysical methods, it is also expedient to take into account the filtration-volume characteristics of rocks and the features of the propagation of seismic waves.

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