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Analysis of Petrophysical Studies of Deep Oil and Gas Reservoirs of Onshore and Offshore Fields in Azerbaijan

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Анализ петрофизических исследований глубокозалегающих нефтегазовых коллекторов сухопутных и морских месторождений Азербайджана

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The paper presents results of generalized laboratory studies from an array of petrophysical parameters of reservoir rocks (potential hydrocarbon reservoirs). The study is targeted at well-known horizons of productive strata of the Meso-Cenozoic sedimentary basin. The area under study includes oil and gas onshore and deep offshore fields in Azerbaijan that have been under active continuous developments. The development of these natural hydrocarbon accumulations has over a century-long history, which has shown that the major oil and gas deposits are associated with the South Caspian and Kura depressions subjected to an intensive submersion over the Meso-Cenozoic period. Although many of the fields in these depressions have been exploited for a long time, the commercial potential is high enough, especially in deep-seated areas. Nonetheless, problems associated with extracting oil and gas therefrom are pending final resolutions. Subsoil developments in the region are currently performed at an intensive rate at depths above 4-4.5 km, since most oil and gas deposits have already been explored at shallow and moderate depths (even in hard-to-reach areas). As known in oil industry, the wells with a depth of over 4 km are referred to deep wells, while those with a depth of over 6 km are referred to ultra-deep wells. Moreover, drilling of such wells is associated with serious cost-related challenges. For example, the cost of developing deep and even ultra-deep wells is high enough, ranging from $ 2-3 to $ 9-12 million. This fact emphasizes the need to enhance efficiency of such operations, which requires a high-scale geological reasoning of a field's potential and choice of a good location.

Ключевые слова:
петрофизика, плотность, распространение ультразвуковых волн, пористость, скважина, породы, глубина, нефть, газ, залежь, критерии, карбонатность, прогиб, бурение, геофизика, нефтегазонакопления.

Изложены результаты аналитического обобщения данных лабораторных исследований комплекса петрофизических параметров пород-коллекторов – потенциальных резервуаров углеводородов. Объектом исследований являлись хорошо известные горизонты продуктивной толщи мезокайнозойского седиментационного бассейна. В исследуемую территорию вошли активно и длительно разрабатываемые нефтегазовые сухопутные, а также морские глубоководные месторождения Азербайджана. Более чем вековая история разработки этих природных скоплений углеводородов показала, что основные залежи нефти и газа связаны с Южно-Каспийской и Куринской впадинами, которые подвергались интенсивному погружению в течение мезокайнозойского времени. Несмотря на то что многие месторождения указанных впадин длительное время эксплуатировались, промышленная перспективность достаточно высока, особенно в глубокозалегающих частях. В то же время проблемы, связанные с извлечением из них нефти и газа, еще не разрешены окончательно. В настоящее время в регионе интенсивно проводится освоение недр на глубинах свыше 4–4,5 км, так как на малых и умеренных глубинах большинство залежей нефти и газа уже разведаны (даже в труднодоступных районах). Как известно, в нефтедобывающей промышленности скважины глубиной более 4 км называют глубокими, а более 6 км – сверхглубокими. При этом, помимо чисто технических сложностей, проходка таких скважин сопряжена с серьезными экономическими проблемами. Так, стоимость разработки глубоких, а тем более сверхглубоких скважин достаточно высока и варьируется от 2–3 до 9–12 млн долларов. Этот факт обусловливает необходимость повышения эффективности работ, что требует высокой степени геологического обоснования перспективности месторождения и выбора места заложения скважины.

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Introduction

The conducted analytical generalisation of a large corpus of research results on geological and geophysical characteristics of rocks that determine reservoir potentials of sediments and their contents of oil, gas and gas condensate accumulations of the Meso-Cenozoic age demonstrate the relevance of the data obtained. In general, data on petrophysical characteristics, such as carbonate contents, porosity, permeability, density, grain-size composition, screening and elastic properties (P-wave velocity in the medium) of rocks are the most important productivity indicators of oil and gas reservoirs and fields. Average values of physical characteristics, correlations between reservoir properties and depth, and relationship between physical parameters were also determined in the course of studies.

The study results for the respective areas presented in the tables below reflect variations in the physical properties of different types of the reservoir rocks over time and space, including regularities in their changes through the section of productive strata. The preliminary assessments have shown that the physical properties of coeval and eponymous rocks change significantly because of geological and physical processes.

Materials and Methods

A considerable amount of geological and geophysical exploration activities has been recently carried out in many well-known oil and gas fields in Azerbaijan due to active studies of the oil and gas potential of sedimentary covers of deep-seated strata. The results of these operations have shown that the major oil and gas deposits in the region are attributed to deep reservoirs of the South Caspian (SCD) and Kura depressions. Accordingly, we have analysed a large bulk of data based on the results of studies of the geological and geophysical characteristics of rocks that determine the reservoir potential of the sediments and their content of oil, gas and gas condensate accumulations of the Meso-Cenozoic age. The studies have covered the largest onshore deposits in Azerbaijan (Kura Depression), such as the areas of Muradkhanly, Zardab, Tarsdallyar, Kursangya, Dzhafarly, and others. As for the known offshore SCD fields, we involved data for such fields as Neft Dashlary, Sangachal-Duvanny-Khara-Zira, Gunashli, Palchig Pilpilasi, Gurgan-deniz, etc.

Analysis of Petrophysical Studies of Deep Oil Reservoirs

The sections of onshore fields are composed of deposits ranging from the Upper Cretaceous to the Quaternary [1]. In particular, a review of the physical properties of the rocks involved in the geological structure of the Muradkhanly deposit shows that the deep-seated oil reservoirs in the area can be associated with the Upper Cretaceous formations (11 % porosity), Eocene carbonates (marl and limestone (9.6-10.9 % porosity), as well as porous terrigenous rocks of the Eocene-Maykopian series (siltstone and sandstone, 15-19.5 % porosity) [2]. The rocks exposed by exploration wells in the Zardab area relate to the Meso-Cenozoic era. Volcanogenic and sedimentary rocks (limestone, carbonate clay, argillite and siltstone) of the Upper Cretaceous were studied in detail. Geologically, the structure of the Dzharly Saatly oil and gas bearing area in the Middle Kura depression is composed of sediments of the Quaternary, Absheronian, Akchagylian, the productive strata (Upper Pliocene of the productive strata), Sarmatian, Chokrakian, Maykopian series, as well as cretaceous and volcanogenic formations of the Cretaceous age. Drilling logs from the Sor-Sor and Karadzhaly areas in the north-western Kurdamir extension proved o have the identical geological structure of the section over the entire tectonic zone here. At the same time, the Dzharly-Sor-Sor-Karadzhaly structural zone has an essentially different geological structure compared to the Muradkhanly rise (upland), while volcanogenic formations in the Dzharly and Sor-Sor areas have no direct contact with oil and gas producing formations of the Paleogene-Neogene system [3-9].

Therefore, the experiments have shown that in the central part of the Kura Depression, at a depth of 8-10 km, the elevated crustal block by its material composition can be represented by unmodified andesite.

The Kura Depression's central part was essentially studied using the Saatly and other ultra-deep wells as an example; the results are based on a comprehensive study of the core samples collected at drilling to a depth of 8,267 m.Table 1

Changes in physical properties of rocks with the stratigraphic depth in Dzharly-Saatly region

Stratigraphic unit	Depth interval, m	Lithology	Carbonate content, %	Porosity, %	Permeability, $10^{-15}m^2$	Density σ, g/cm^3	Elastic wave velocity *V*, m/s
Ancient Caspian	2,100–2,585	Sandy clayey siltstone	–	15.0–30.0 / 22.5(2)	Impermeable	2.2–2.3 / 2.25(2)	2,000–2,300 / 2,100
Absheronian	2,590–2,595	Clayey siltstone	–	11.0	–	2.40	2,800
Akchagylian	2,700–2,720	Clayey sandy siltstone	–	20.0	Impermeable	2.30	2,200
Productive strata	2,710–2,874	Silt sandstone	8.6–24.6 / 15.8(8)	11.2–24.6 / 17.9(8)	0.6–444.1 / 150.0(4)	2.01–2.28 / 2.19	1,900–2,050 / 1,950(4)
Miocene	2,879–2,971	Argillaceous sandstone	17.8–98.5 / 77.2(6)	5.7–29.8 / 19.7(4)	Impermeable	2.08–2.30 / 2.22	2,100–2,300 / 2,100
Eocene	2,780–2,925	Calcareous sandstone	–	4.0–14.0 / 8.6(7)	Impermeable	2.2–2.7 / 2.5(7)	4,000–5,000 / 4,660(3)
Maastrichtian	3,033–3,138	Arenaceous limestone, Andesite porphyrite	87.6–99.0 / 93.9(3)	0.9–4.4 / 2.65(2)	Impermeable	2.48–2.76 / 2.68	3,200–3,800 / 3,500
Conacian	3,174–3,178	Andesite porphyrite	96.9	5.3	Impermeable	2.65	3,300
Cenomanian	3,271–4,609	Andesite porphyrite	1.2–75.2 / 26.1(5)	1.2–17.7 / 6.3(10)	Impermeable	2.68	3,500
Upper Cretaceous	2,950–5,965	Silt limestone, basaltic andesite	–	1.0–14.0 / 4.9(39)	Impermeable	2.4–2.9 / 2.7(38)	3,000–5,000 / 4,300(26)

N o t e : extreme values are given in the numerator, average values are given in the denominator.

The studies of the physical properties of the crust section penetrated by ultra-deep drilling and using a geophysical well logging suite and petrophysical methods enabled us to identify principal regularities between the material composition of the sedimentary and volcanogenic formations and their physical properties.

The main background is comprised of acidic volcanic rocks with a subordinate amount of andesite that seems to contain concordant and discordant basalt bodies.

Brief petrophysical characteristics of the rocks from the crust section of the Dzharly-Saatly oil and gas region given in Table 1 show that all types of the sedimentary rocks from the Eocene to the ancient Caspian are represented by terrigenous varieties, except for the Eocene that also includes limestone. In turn, the Upper Cretaceous rocks are dominated by volcanic rocks of andesite and basalt composition, alternating with sandstone, siltstone and limestone.

Volcanic rocks of all types were found to pertain to intermediate and basic rocks of normal alkalinity. The studies show that the physical features of coeval and eponymous rocks change under the influence of geological and physical processes, bringing about different results. Reservoir properties of the productive strata rocks were studied.

Based on the data given in Table 1, a petrophysical graph reflecting the reservoir properties of the area was plotted. A certain tension is formed over depth in the reservoir properties of rocks, i.e. an increase in the density and velocity of ultrasonic wave propagation is accompanied by a decrease in the porosity. This results from the degradation of the rocks' reservoir properties in deep layers, as compared to upper layers. As it follows from the graphs (see Table 2), the density of the rocks increases over depth. This process is relatively intense in the Absheronian-Miocene sediments represented by terrigenous varieties, and it is more intense in the Albian-Aptian formations consisting of sandstone and limestone. Further down from the Barremian, the section is represented by carbonate-terrigenous strata up to the Upper Jurassic, while the Jurassic section is represented exclusively by the volcanics consisting of andesite and basalt. Despite such a diversity in the rock types, their density increases relatively uniformly and fairly little over depth. The seismic wave velocity correlates with the density change graph, subject to the stratigraphic depth. Overall, in both cases, there is a depth-dependent increase in the given parameters, with an almost identical geometry of their plots. In turn, the depth-dependent porosity change graph mirrors the above plot, i.e. there is an inverse relationship between the rock density, seismic wave velocity and porosity regardless of rock type and occurrence depth [10-18].

The rocks in natural conditions at great depths are known to be susceptible to forces caused by a range of physical and chemical phenomena. Mainly, these include lithostatic pressure in the pore space, and temperature increasing over depth.

Based on the generalisation of the experimental data obtained from the well log surveys and petrophysics, the volcanogenic strata down to 8,000 m deep can be divided into several intervals, according to the rock material composition.

In the Peri-Caspian-Guba oil and gas region, reservoir properties of the rocks sampled from deep layers and producing deposits were examined. The density of the productive strata clayey sandstone located in relatively upper parts was studied in a dry and wet form, and was confirmed to vary in a wide range (1.94-2.36 g/cm^3) for these rocks. Their porosity ranges between 7 and 30 %, while the ultrasonic wave velocity falls within 2,500-3,000 m/s. The sandy argillite rock density falls in the range of 1.78-2.29 g/cm^3 (dry) and 2.68-2.98 g/cm^3 (wet), the porosity is 6.15-30.0 % and the ultrasonic wave velocity is 1,800 to 2,200 m/s. However, reservoir properties of the rocks are diverse, differing dramatically over depths.

Geological and geophysical activities have been recently carried out in Azerbaijan on a large scale due interests in the oil and gas potential of deep-seated sediments. Based on this fact, the criteria are developed to form the basis for future works. It is noted that the oil and gas deposits mainly pertain to the Meso-Cenozoic era. Although researchers have no doubt that the central part and great depths of these deposits are very promising, still a quantitative solution has not been implemented.

Drilling operations identified a promising outlook of the Kura and Gabirry interfluve area, as well as certain difficulties and issues in studying structural features of local uplifts and predicting their oil and gas potential.

In this regard, the properties of the Paleogene and Eocene deposits involved in the geological structure of the Tarsdallyar structure are studied. The Paleogene is represented by siltstone, marl, limestone and tuff siltstone. The marl density is 2.16 g/cm^3, the porosity is 2.5%, the magnetic susceptibility is very low, and the ultrasonic wave velocity is 3,500 m/min. The Paleogene limestone is almost diamagnetic, with the density of 2.56 g/cm^3, the porosity of 5.1%, and the ultrasonic wave velocity up to 3,000 m/min. The Eocene siltstone density is 2.45 g/cm^3, the porosity is 50%, and the ultrasonic wave velocity is 1,300 m/min. The limestone density is 2.65 g/cm^3, the porosity is 5.74 %, and the ultrasonic wave velocity is 2,950 m/min, with no magnetic susceptibility. The argillite density is 2.25 g/cm^3, the porosity is 15.5 %, the magnetic susceptibility is very low, and the ultrasonic wave velocity is 2,700 m/min.

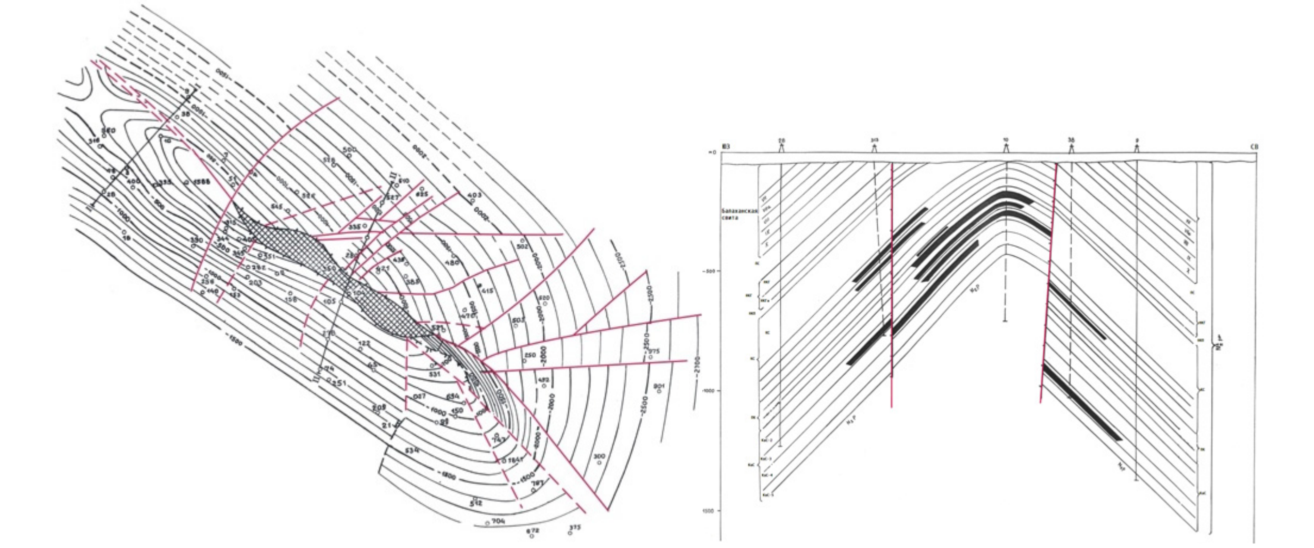
To establish a correlation between the Kura and Gabirry's interfluve subsurface geology and the physical parameters of the sedimentary cover rocks, the data on changes in the density and velocity of elastic waves by area and depth have been analysed. The study covered sandy clayey rocks of the Miocene-Paleocene sediments in the Kura and Gabirry interfluve. A considerable change in the values of physical parameters of the Upper Miocene sediments was observed from the north-west (Armudlin Rise) to the south-east (Gyrakhkesaman-Khatunly Rise). The values of the physical properties of the Eocene sediment sandy clayey rocks also decrease significantly from the north-west to the south-east and increase again in the Ganja area.

In the Kura and Gabirry interfluve, the Maykopian clay on the surface has a lower specific gravity compared to the Sarmatian clay. The specific gravity values for different rock units of the Kura and Gabirry interfluve change equally over depth, differing only in the initial values. The depth-dependent change in P-wave velocity in the Sarmatian clay and sandstone is not identical for the Maykopian rocks [19-28].

A review of Azerbaijan offshore field data shows that the Neft Dashlary field is located within the Absheron archipelago, in the near-axis zone of Absheron-Balkhan structural mega-saddle and is oriented in the general Caucasian direction. The field structure is complicated by two longitudinal and multiple transverse faults (Fig. *a*).

Longitudinal faults form a wide zone of disjunctive dislocations here, composed of strongly deformed breccia sediments of the Oligocene-Miocene age. In the south-east of the structure, a mud volcano is located at the intersection of epy longitudinal and transverse discontinuous faults. Here, there are numerous gryphons with continuous oil and gas seepage at the sea bottom. The Neft Dashlary field is characterised by tabular, depositional and deformational oil traps (Fig. *b*). The density of clayey rocks here is 2.20-2.48 g/cm^3, the porosity is 8.3 to 17.0% (up to 25% in some cases), and the velocity of ultrasonic waves is 2,150-2,200 m/s.

The siltstone density varies between 2.13-2.60 g/cm^3, the porosity ranges from 15 % to 28 %, and the ultrasonic wave velocity is 1,300-2,200 m/s. The sandstone density lies between 2.00 and 2.50 g/cm^3, and the porosity varies



a *b*

Fig. Neft Dashlary field. Structural map of Kirmakin formation top of productive strata (*a*) and geological profile (*b*)

between 7.2 and 22.0%. In all rocks, the velocity of ultrasonic waves, depending on the lithological composition, ranges from 850 to 2,800 m/s. The density of the productive strata carbonate clay is 2.02-2.59 g/cm^3, the porosity ranges between 8.5 and 30%, and the ultrasonic wave velocity is 2,100 to 3,500 m/s [29-31].

The grain-size composition of the productive strata sediments in the Neft Dashlary area is mainly represented by siltstone facies, i.e. the particle size ranges from 0.1 to 0.01 mm. This indicates that the siltstone facies are dominating over other facies in the section. To identify the nature of the depth-dependent change in reservoir properties of the productive strata sediments, a limit of variations in physical parameters was specified. In particular, the rock carbon content varies from 5.27 to 24.6 %, and the permeability ranges from 1.3 to 214.9·10^{15} m^2 at the porosity values of 9.02 to 21.4 %.

According to the generalised data (see Table 2), it can be assumed that the changes in physical characteristics of the Neft Dashlary productive strata rocks attribute to the quantitative extent of lithological varieties, diversity of rocks, their mineralogical composition and tectonic formation conditions.

The obtained regularities in depth-dependent variations in the reservoir petrophysical characteristics can also be proven in the neighbouring areas subject to their similarity in paleo-geography, and structural and tectonic formation profiles.

Within the Baku archipelago, we analysed petrophysical characteristics of the rocks composing its northern structures – Sangachaly-deniz, Duvanny-deniz and Bulla-deniz, where the productive strata sediments were represented fairly well [3]. Here, the total productive strata thickness (3,950-4,000 m) was entered in the Sangachaly-deniz area and in the north-east of other areas. The productive strata thickness on the dome and in the crest positions of the local uplifts of Sangachaly-deniz and Duvanny-deniz is 2,960-3,600 m. Tectonically, the Sangachaly-deniz rise is an asymmetric brachy-fold separated by a long yet shallow saddle from the north-west of the Kyanizadag rise. In the productive strata sediments in the south-east, the fold pericline is represented topographically by a shallow yet short saddle separating it from the Duvanny rise.

The rocks composing the Sangachaly-deniz and Duvanny-deniz deposits were studied by deep-hole drilling from recent sediments down to the Mesozoic. The productive strata is exposed in the north of the rise, while in the near-axis part it is eroded away to a depth of 750-800 m. The lithologic section of the rocks is mainly represented by the alternation of sand, sandstone and clay. The maximum thickness of the productive strata sediments entered by wells is 3,950-4,000 m, and the minimum thickness is 3,000 m. The geology of the area includes the sediments of productive strata, Akchagylian, Absheronian and Quaternary formations. The

Table 2

Range of variation, average values of physical properties, and permeability degree of productive strata sediments of Neft Dashlary field

Depth interval, m	Lithology	Carbonate content, %	Density, σ, g/cm^3	Elastic wave velocity *V*, m/s	Porosity, %	Permeability, 10^{-15} μm^2	Permeability degree
430–480	Sandy clayey siltstone	8.3–12.8 9.7	2.42–2.50 2.45	2,200–2,600 2,400	11.6–20.1 16.3	28.5–79.4 59.7	Good
480–600	Silt clay	4.9–26.8 19.14	2.36–2.56 2.50	2,000–3,100 2,650	12.4–17.0 11.0	2.6– 8.1 5.35	Very week
640–690	Clayey sandy siltstone	5.8–12.4 7.53	1.6–2.34 2.20	1,700–2,400 1,980	11.0–33.6 16.92	0.1–95.7 40.68	Good
690–930	Clayey sandy siltstone	8.9–9.9 9.37	2.01–2.10 2.05	2,400–2,600 2,500	19.5–22.9 21.4	0.1–95.7 2.20	Very week
930–940	Sandy clayey siltstone	8.2–9.4 8.8	2.01–2.47 2.37	2,300–3,200 3,000	9.9–25.7 15.5	1–3.5 2.3	Very week
940–1,130	Clayey siltstone	4.5–6.0 5.27	2.37–2.67 2.56	2,500–3,000 2,800	6.0–16.0 9.57	214.9	High
1,130–1,400	Clayey sandy siltstone	23.4–25.8 24.60	2.38–2.53 2.44	2,100–3,200 2,580	9.7–11.1 10.40	2.25–6.23 4.24	Very week
1,500–1,550	Clayey siltstone	3.0–11.0 7.0	2.40–2.47 2.44	2,300–2,400 2,350	12.6–14.9 13.75	0.6–2.0 1.3	Zero
1,600–2,050	Clayey siltstone	3.8–15.7 11.8	2.47–2.56 2.51	3,500–3,600 3,550	7.6–10.8 9.02	56.9	Good
2,050–2,200	Sandy clayey siltstone	4.1–14.6 9.79	2.36–2.43 2.40	3,150	13.6–17.9 14.8	12.5	Moderate
2,200–2,500	Clayey siltstone	3.8–15.7 11.8	2.47–2.56 2.51	3,500–3,600 3,550	7.6–10.8 9.02	56.9	Good
2,550–3,550	Clayey siltstone	7.8–8.7 8.1	2.43–2.60 2.56	3,600	8.5–10.0 9.9	66.9	Good
3,550–4,600	Clayey sandy siltstone	2.8–10.8 6.8	2.58–2.64 2.61	4,000	5.3–14.2 9.57	60.5	Good

Note: minimum and maximum values are given in the numerator, average values are given in the denominator.

productive strata section is mainly composed of clay, sandstone and siltstone. The clay rock density is 1.95-2.20 g/cm^3, the porosity is 7.5-25.5 %, and the ultrasonic wave velocity varies between 1,950 and 2,300 m/s. Unlike clay, the sandstone density is 2.15-2.50 g/cm^3, and the ultrasonic wave velocity in these rocks is 1,200 to 3,000 m/s. The siltstone density is 2.06-2.56 g/cm^3, the porosity is 5.5-30 %, and the ultrasonic wave velocity is 1,950-2,800 m/s.

The permeability value determined from the core samples is relatively low. A correlation was assessed to determine permeability as a function of porosity. However, this correlation is somewhat conditional, since any permeable rock is known to have porosity, but not each rock that is porous can be permeable.

As it follows from the above analysis, in the considered granular reservoirs in the area under study, the rock porosity and, especially, permeability are conditioned largely by the quantitative content of psammitic siltstone and psammitic facies. Such a dependence of the rock reservoir properties signifies low or zero secondary porosity associated with fracturing, cavernosity, etc.

In turn, the low carbonate content eliminates the possibility of leaching that increases reservoir properties mainly in carbonate rocks. The absence of this process in the rocks under consideration is proven by their low carbonate content, as well as their low reservoir properties.

Due to the direct relationship between the rock density change and ultrasonic wave velocity, these parameters correlate well with each other. However, there is no more or less distinct correlation between the rock lithofacies, reservoir and studied physical parameters in this case [32-45].

Proceeding from the above, to specify the oil and gas bearing potential of certain structures of the Baku archipelago, additional geological, geophysical exploration and survey activities (gravity-magnetic, electrometric and seismic surveys and petrophysical studies) will be conducted followed by locating deep exploration wells. These operations will enable a more efficient study of the reservoir properties of deep-sunk oil and gas bearing strata, as well as tectonics structure of the considered areas.

Conclusions

Based on the petrophysical and reservoir data generalisation, a comparative analysis of the deep-seated rocks in the South Caspian and Kura depressions was conducted. It follows from the results that the wide-range changes in the properties of the study objects are mainly attributable to heterogeneous lithology of rock units, rock type and tectonic conditions. Furthermore, there is a certain correlation between porosity and permeability. The development and interpretation of petrophysical and field geophysical data has revealed that some of the productive strata horizons have the greatest oil and gas bearing potential. And some aspects should be taken in account. Firstly, at onshore fields, wide-range changes in reservoir properties of the rocks in the area are mainly associated with lithogenesis conditions, heterogeneous lithological composition of sedimentary complexes, rocks' occurrence depth, as well as peculiarities of local uplift development. Secondly, ultrasonic wave velocity is increasing in limestone and, less frequently, in rocks with higher carbon content, also subject to the change in figures with stratigraphic depths. Thirdly, when predicting the oil and gas bearing potential in deep-seated strata of the areas under study, apart from exploration and geophysical methods, it is advisable to use findings on depth-related changes in the porosity and permeability properties of rocks established through petrophysical studies, as well as the data on ultrasonic wave velocity patterns.

References

1. Ali-zade A.A., Akhmedov G.A., Akhmedov A.M., Aliev A.K., Zeinalov M.M. Geologiia neftianykh i gazovykh mestorozhdenii Azerbaidzhana [Geology of oil and gas fields of Azerbaijan]. Moscow: Nedra, 1966, 390 p.

2. Akhmedov A.M., Guseinov A.N., Khanlarova Sh.G. Novye dannye glubokogo bureniia na ploshchadi Dzharly [New deep drilling data in Jarly area]. *Azerbaidzhanskoe neftianoe khoziaistvo*, 1973, no. 12, pp. 9-13.

3. Gasanov A.B., Kiazimov R.R., Mamedova D.N., Mutallimova O.M. Variatsii plastovogo davleniia i fil'tratsionno-emkostnye svoistva kollektorov glubokozalegaiushchikh mestorozhdenii Iuzhnogo-Kaspiia [Variations in reservoir pressure and reservoir properties of deep-seated deposits in the South Caspian]. *Geologiia, geodinamika i geoekologiia Kavkaza: proshloe, nastoiashchee i budushchee. Materialy nauchno-prakticheskoi konferentsii.* Makhachkala, 2016, pp. 242-247.

4. Gurbanov V.Sh., Narimanov N.R., Sultanov L.A., Babaev M.S. Geologicheskoe stroenie i kollektorskie svoistva mezokainozoiskikh otlozhenii Dzharly-Saatlinskogo neftegazonosnogo raiona na bol'shikh glubinakh [Geological structure and reservoir properties of meso-cenozoic deposits of Dzharly-Saatli oil and gas region at great depths]. *Izvestiia Ural'skogo gosudarstvennogo gornogo universiteta*, 2016, no. 2 (42), pp. 25-27. DOI: 10.21440/2307-2091-2016-2-25-27

5. Kerimov K.M., Rakhmanov R.R., Kheirov M.B. Neftegazonosnost' Iuzhno-Kaspiiskoi megavpadiny [Oil and gas potential of the South Caspian megawall]. Baku, 2001, 317 p.

6. Gadirov V.G. Magmaticheskii vulkanizm srednekurinskoi vpadiny Azerbaidzhana i ego rol' vskoplenii uglevodorodov [Magmatic volcanism of the Middle Kura depression of Azerbaijan and its role in hydrocarbon accumulation], available at: http://sinp.com.ua/work/679254/Magmaticheskij-vulkanizm-Sredne-kurinskoj-vpadiny (accessed 12 January 2017).

7. Khain V.E. Tektonika neftegazonosnykh oblastei Iugo-Vostochnogo pogruzheniia Bol'shogo Kavkaza [Tectonics of oil and gas areas of the South-East immersion of the Greater Caucasus]. Moscow: Gostoptekhizdat, 1958, 224 p.

8. Hasanov A.B., Balakishibayli Sh.A. The influence of recent geodynamics on the physicomechanical state of the geological environment of the sedimentary cover. *Evaluation of synthetic elastic parameters of reservoirs, fluid phase saturation and temperatures in the depths. Materials of international workshop*. Baku, 2010, pp. 101-108.

9. Gurbanov V.Sh., Sultanov L.A. O neftegazonosnosti mezozoiskikh otlozhenii Azerbaidzhana [On oil-and-gas content of Mesozoic deposits in Azerbaijan]. *Vestnik Permskogo natsional'nogo issledovatel'skogo politekhnicheskogo universiteta. Geologiia. Neftegazovoe i gornoe delo*, 2015, no. 16, pp. 7-13. DOI: 10.15593/2224-9923/2015.16.1

10. Uspenskaia N.Iu., Tauson N.N. Neftegazonosnye provintsii i oblasti zarubezhnykh stran [Oil and gas provinces and regions of foreign countries]. Moscow: Nedra, 1972, 283 p.

11. Gurbanov V.Sh., Gasanov A.B., Narimanov N.R., Sultanov L.A., Ganbarova Sh.A. Fizicheskie kharakteristiki i FES perspektivnykh neftegazonosnykh gorizontov v nizakh PT na sukhoputnykh ploshchadiakh Azerbaidzhana (na primere mestorozhdeniia Kalamaddin) [Physical and reservoir properties of potential oil and gas bearing intervals at the bottom of productive thickness onshore in Azerbaijan (at the example of Kalamaddin field)]. *Vestnik Permskogo natsional'nogo issledovatel'skogo politekhnicheskogo universiteta. Geologiia. Neftegazovoe i gornoe delo*, 2017, no. 3, pp. 204-214. DOI: 10.15593/2224-9923/2017.3.1

12. Salmanov A.M., Suleimanov A.M., Magerramov B.I. Paleogeologiia neftegazonosnykh raionov Azerbaidzhana [Paleogeology of oil and gas regions of Azerbaijan]. Baku, 2015, 470 p.

13. Kozhevnikov D.A. Petrofizicheskaia invariantnost' granuliarnykh kollektorov [Petrophysical Invariance of Granular Reservoirs]. *Geofizika*, 2001, no. 4, pp. 31-37.

14. Rakhmanov R.R. Zakonomernosti formirovaniia i razmeshcheniia zon neftegazonakopleniia v mezozoiskikh otlozheniiakh Azerbaidzhana [Patterns of formation and distribution of oil and gas accumulation zones in the Mesozoic deposits of Azerbaijan]. Baku, Elm, 1985, 108 p.

15. Kerimov K.M. Glubinnoe stroenie i neftegazonosnost' depressionnykh zon Azerbaidzhana i Iuzhnogo Kaspiia [Deep structure and oil and gas potential of the depressed zones of Azerbaijan and the South Caspian]. Baku, 2009, 440 p.

16. Gurbanov V.Sh., Sultanov L.A Petrofizicheskie osobennosti glubokozalegaiushchikh kollektorov Apsheronskogo i Bakinskogo arkhipelagov [Petrophysical aspects of deep reservoirs in the Absheron and Baku Archipelagos]. *Vestnik Permskogo natsional'nogo issledovatel'skogo politekhnicheskogo universiteta. Geologiia. Neftegazovoe i gornoe delo*, 2019, no. 3, pp. 204-219. DOI: 10.15593/2224-9923/2019.3.1

17. Sultanov L.A., Narimanov N.R., Samadzadeh A.A. The geological structure of the Neft Dashlari deposit and the analysis of the regularity of the change in the reservoir properties of the productive floor rocks, depending on the depth of their occurrence. *EUREKA: From international journal (Tallinn, Estonia)*, 2019, no. 1, pp. 55-62.

18. Gurbanov V.Sh., Gasanov A.B., Sultanov L.A., Babaev M.S. Vliianie geodinamicheskogo rezhima na formirovanie geologicheskogo stroeniia i petrofizicheskie kharakteristiki pliotsenovykh otlozhenii mestorozhdeniia Khamamdag-Deniz Bakinskogo arkhipelaga [Infuence of geodynamical regime on formation of geological structure and petrophysical characteristics of pliocene sediments in Khamamdag-Deniz field in Baku archipelago]. *Vestnik Permskogo natsional'nogo issledovatel'skogo politekhnicheskogo universiteta. Geologiia. Neftegazovoe i gornoe delo*, 2019, no. 2, pp. 128-137. DOI: 10.15593/2224-9923/2019.2.3

19. Gurbanov V.Sh., Sultanov L.A., Valiev S.A. et al. Litologo-petrograficheskie i kollektorskie xarakteristiki mezokainozoiskikh otlozhenii severo-zapadnoi chasti Iuzhno-Kaspiiskoi vpadiny [The lithophysical and collector characteristics of mesozoic-cenozoic deposits of north-western part of the Caspian depression]. *Vestnik Permskogo natsional'nogo issledovatel'skogo politekhnicheskogo universiteta. Geologiia. Neftegazovoe i gornoe delo*, 2015, no. 17, pp. 5-15. DOI: 10.15593/2224-9923/2015.17.1

20. Kocharli Sh.S. Problemy voprosy neftegazovoi geologii Azerbaidzhana [Problems issues of oil and gas geology of Azerbaijan]. Baku, 2015, 278 p.

21. Mekhtiev U.Sh., Kheirov M.B. Litologo-petrograficheskie osobennosti i kollektorskie svoistva porod kalinskoi i podkirmakinskoi svit Apsheronskoi neftegazonosnoi oblasti Azerbaidzhana [Lithological-petrographic features and reservoir properties of rocks of the Kalinsky and Podkirmakinsky suites of the Absheron oil and gas region of Azerbaijan]. Baku, 2007, part 1, 238 p.

22. Sostavlenie kataloga kollektorskikh svoistv Mezokainozoiskikh otlozhenii mestorozhdenii nefti-gaza i perspektivnykh struktur Azerbaidzhana: otchet Nauchno-issledovatel'skogo instituta geofiziki, no. 105-2009 [Compilation of the catalog of reservoir properties of the Meso-Cenozoic deposits of oil and gas fields and prospective structures of Azerbaijan: report of the Research Institute of Geophysics, no. 105-2009]. Baku: Fondy Upravleniia geofiziki i geologii, 2010.

23. Afandiyeva M.A., Guliyev I.S. Maicop Group-shale hydrocarbon complex in Azerbaijan. *75 EAGE Conference @ Exhibition*. London, 2013, pp. 6-13. DOI: 10.3997/2214-4609.20130979

24. Landolt-Bornstein Tables. Physical properties of rocks. Ed. G. Argenheisen. N.Y., 1983, vol. V, 245 p. DOI: 10.1007/b20009

25. Physical properties of the mineral system of the Earth's interior. International monograph Project 3 CAPG. Praha, 1985, 176 p.

26. Rachinskiy M.Z., Chilingar D.J. Results of geological explorations years of 1990–2005. Geological aspects of perceptivity and numerical assessment. *Journal ANX*, 2007, no. 1, pp. 7-15.

27. Salmanov A.M., Suleymanov A.M., Maharramov B.I. Paleogeology of oiland gas bearing region in Azernaijan. Mars Print, 2015, 471 p.

28. Theoretical and Experimental Investigations of Physical Properties of Rocks and Minerals under Extreme p,T-conditions. Berlin: Academie Verlag, 1979, 210 p.

29. Akhmedov A.M. O geologicheskoi kharakteristiki i perspektivakh neftegazonosnosti ploshchadi Umid [On the geological characteristics and prospects of oil and gas potential Umid area]. *Azerbaidzhanskoe neftianoe khoziaistvo*, 2008, no. 3, pp. 19-22.

30. Sokolov B.A. Evoliutsiia i neftegazonosnost' osadochnykh basseinov [Evolution and oil an]. Moscow: Nauka, 1980, 243 p.

31. Fizicheskie svoistva gornykh porod i poleznykh iskopaemykh [Physical properties of rocks and minerals]. Ed. N.B. Dortman. Moscow: Nedra, 1976, 527 p.

32. Volarovich M.P., Baiuk E.I., Efimova G.A. Uprugie svoistva mineralov pri vysokikh davleniiakh [Elastic properties of minerals at high pressures]. Moscow: Nauka, 1975, 130 p.

33. Hasanov A.B., Melikov Kh.F. 3D model of productive layers according to data geophysics and petrophysics. *Materials of international workshop – The influence of recent geodynamics on the physic-mechanical state of the geological environment of the sedimentary cover*. Baku, Azerbaijan, 2010, pp. 101-108.

34. Lebedev T.S. Model studies of physical properties of mineral matter in high pressure – temperature experiments. *Phys. Earth and Planet. Inter*, 1980, vol. 25, pp. 292-303. DOI: 10.1016/0031-9201(80)90126-0

35. Spravochnik po litologii [Lithology Handbook]. Ed. N.B. Vassoevicha. Moscow, 1988, 509 p.

36. Babaev M.S. Kollektorskie parametry porod vybrosov griazevykh vulkanov Bakinskogo arkhipelaga (na primere o. Duvanny i o. Bulla) [Collector parameters of rocks of emissions of mud volcanoes of the Baku archipelago (on the example of Duvanny Island and Bulla Island)]. *Tematicheskii sbornik nauchnykh trudov*. Baku: Azerbaidzhanskii ИУ, 1991, pp. 82-84.

37. Spravochnik po geologii nefti i gaza [Handbook of Oil and Gas Geology]. Moscow: Nedra, 1988, 480 p.

38. Khizhniak G.P. Ispol'zovanie materialov geofizicheskikh issledovanii skvazhin dlia otsenki pronitsaemosti terrigennykh porod [Data usage of geophysical investigations of wells for permeability estimation in terrigenous rocks-reservoires]. *Neftianoe khoziaistvo*, 2011, no. 6, pp. 86-88.

39. Gadirov V.G. Prognozirovanie vulkanogennykh obrazovanii mezozoia Srednekurinskoi depressii i ikh neftegazonosnosti po kompleksnym geofizicheskim dannym [Prediction of Mesozoic volcanogenic formations of the Srednekurinsky depression and their oil and gas potential according to complex geophysical data]. Abstract of Ph.D. thesis. Baku, 1991, 22 p.

40. Babazade B.Kh., Putkaradze L.A. O poiskakh zalezhei gaza i nefti v pribrezhnoi morskoi zone Apsheronskogo poluostrova i Bakinskogo arkhipelaga [On the search for gas and oil deposits in the coastal marine zone of the Absheron peninsula and the Baku archipelago]. *Geologiia nefti i gaza*, 1961, no. 10, pp. 7-11.

41. Ali-Zadeh A.A, Salayev S.Q, Aliyev A.I. Scientific evaluation of perceptivity of oil and gas in Azerbaijan, South Caspian and direction of search-exploration operation. Baku: Elm, 1985, 227 p.

42. Iusifzade Kh.B. Primenenie sovremennykh tekhnologii v oblasti razvedki i dobychi neftegazovykh mestorozhdenii v Azerbaidzhane [Application of modern technologies in the field of exploration and production of oil and gas fields in Azerbaijan]. *Azerbaidzhanskoe neftianoe khoziaistvo*, 2013, no. 7-8, pp. 3-13.

43. Gudok N.S., Bogdanovich N.N., Martynov V.G. Opredelenie fizicheskikh svoistv neftevodosoderzhashchikh porod [Determination of physical properties of oil-containing rocks]. Moscow: Nedra-Biznestsentr, 2007, 592 p.

44. Belozerov B.V. Rol' petrofizicheskikh issledovanii pri otsenke nasyshcheniia slozhnopostroennykh kollektorov [The role of petrophysical studies in assessing the saturation of complex reservoirs]. *Izvestiia Tomskogo politekhnicheskogo universiteta*, 2010, vol. 317, no. 1, pp. 110-116.

45. Gadirov V.G. Magmaticheskii vulkanizm srednekurinskoi vpadiny Azerbaidzhana i ego rol' v skoplenii uglevodorodov [Magmatic volcanism in the Middle Kur depression of Azerbaijan and its role in hydrocarbon accumulations]. *Mezhdunarodnyi nauchnyi institut Educatio*, 2001, vol. III (10), pp. 64-69.

Библиографический список

1. Геология нефтяных и газовых месторождений Азербайджана / А.А. Али-заде, Г.А. Ахмедов, А.М. Ахмедов, А.К. Алиев, М.М. Зейналов. – М.: Недра, 1966. – 390 с.

2. Ахмедов А.М., Гусейнов А.Н., Ханларова Ш.Г. Новые данные глубокого бурения на площади Джарлы // Азербайджанское нефтяное хозяйство. – 1973. – № 12. – С. 9–13.

3. Вариации пластового давления и фильтрационно-емкостные свойства коллекторов глубокозалегающих месторождений Южного Каспия / А.Б. Гасанов, Р.Р. Кязимов, Д.Н. Мамедова, О.М. Муталлимова // Геология, геодинамика и геоэкология Кавказа: прошлое, настоящее и будущее: материалы науч.-практ. конф. – Махачкала, 2016. – С. 242–247.

4. Геологическое строение и коллекторские свойства мезокайнозойских отложений Джарлы-Саатлинского нефтегазоносного района на больших глубинах / В.Ш. Гурбанов, Н.Р. Нариманов, Л.А. Султанов, М.С. Бабаев // Известия Уральского государственного горного университета. – 2016. – № 2 (42). – С. 25–27. DOI: 10.21440/2307-2091-2016-2-25-27

5. Керимов К.М., Рахманов Р.Р., Хеиров М.Б. Нефтегазоносность Южно-Каспийской мегавпадины. – Баку, 2001. – 317 с.

6. Гадиров В.Г. Магматический вулканизм Среднекуринской впадины Азербайджана и его роль в скоплении углеводородов [Электронный ресурс]. – URL: http://sinp.com.ua/work/679254/Magmaticheskij-vulkanizm-Srednekurinskoj-vpadiny (дата обращения: 12.01.2017).

7. Хаин В.Е. Тектоника нефтегазоносных областей Юго-Восточного погружения Большого Кавказа. – М.: Гостоптехиздат, 1958. – 224 с.

8. Hasanov A.B., Balakishibayli Sh.A. The influence of recent geodynamics on the physicomechanical state of the geological environment of the sedimentary cover // Evaluation of synthetic elastic parameters of reservoirs, fluid phase saturation and temperatures in the depths: materials of international workshop. – Baku, 2010. – P. 101–108.

9. Гурбанов В.Ш., Султанов Л.А. О нефтегазоносности мезозойских отложений Азербайджана // Вестник Пермского национального исследовательского политехнического университета. Геология. Нефтегазовое и горное дело. – 2015. – № 16. – С. 7–13. DOI: 10.15593/2224-9923/2015.16.1

10. Успенская Н.Ю., Таусон Н.Н. Нефтегазоносные провинции и области зарубежных стран. – М.: Недра, 1972. – 283 с.

11. Физические характеристики и ФЕС перспективных нефтегазоносных горизонтов в низах ПТ на сухопутных площадях Азербайджана (на примере месторождения Каламаддин) / В.Ш. Гурбанов, А.Б. Гасанов, Н.Р. Нариманов, Л.А. Султанов, Ш.А. Ганбарова // Вестник Пермского национального исследовательского политехнического университета. Геология. Нефтегазовое и горное дело. – 2017. – № 3. – С. 204–214. DOI: 10.15593/2224-9923/2017.3.1

12. Салманов А.М., Сулейманов А.М., Магеррамов Б.И. Палеогеология нефтегазоносных районов Азербайджана. – Баку, 2015. – 470 с.

13. Кожевников Д.А. Петрофизическая инвариантность гранулярных коллекторов // Геофизика. – 2001. – № 4. – С. 31–37.

14. Рахманов Р.Р. Закономерности формирования и размещения зон нефтегазонакопления в мезозойских отложениях Азербайджана. – Баку: Элм, 1985. – 108 с.

15. Керимов К.М. Глубинное строение и нефтегазоносность депрессионных зон Азербайджана и Южного Каспия. – Баку, 2009. – 440 с.

16. Гурбанов В.Ш., Султанов Л.А Петрофизические особенности глубокозалегающих коллекторов Апшеронского и Бакинского архипелагов // Вестник Пермского национального исследовательского политехнического университета. Геология. Нефтегазовое и горное дело. – 2019. – № 3. – С. 204–219. DOI: 10.15593/2224-9923/2019.3.1

17. Sultanov L.A., Narimanov N.R., Samadzadeh A.A. The geological structure of the Neft Dashlari deposit and the analysis of the regularity of the change in the reservoir properties of the productive floor rocks, depending on the depth of their occurrence // EUREKA: From international journal (Tallinn, Estonia). – 2019. – № 1. – С. 55–62.

18. Влияние геодинамического режима на формирование геологического строения и петрофизические характеристики плиоценовых отложений месторождения Хамамдаг-Дениз Бакинского архипелага / В.Ш. Гурбанов, А.Б. Гасанов, Л.А. Султанов, М.С. Бабаев // Вестник Пермского национального исследовательского политехнического университета. Геология. Нефтегазовое и горное дело. – 2019. – № 2. – С. 128–137. DOI: 10.15593/2224-9923/2019.2.3

19. Литолого-петрографические и коллекторские характеристики мезокайнозойских отложений северо-западной части Южно-Каспийской впадины / В.Ш. Гурбанов, Л.А. Султанов, С.А. Валиев [и др.] // Вестник Пермского национального исследовательского политехнического университета. Геология. Нефтегазовое и горное дело. – 2015. – № 17. – С. 5–15. DOI: 10.15593/2224-9923/2015.17.1

20. Кочарли Ш.С. Проблемы и вопросы нефтегазовой геологии Азербайджана. – Баку, 2015. – С. 278.

21. Мехтиев У.Ш., Хеиров М.Б. Литолого-петрографические особенности и коллекторские свойства пород калинской и подкирмакинской свит Апшеронской нефтегазоносной области Азербайджана. – Баку, 2007. – Ч. 1. – 238 с.

22. Составление каталога коллекторских свойств Мезокайнозойских отложений месторождений нефти-газа и перспективных структур Азербайджана: отчет Научно-исследовательского института геофизики – № 105-2009 // Фонды Управления геофизики и геологии. – Баку, 2010.

23. Afandiyeva M.A., Guliyev I.S. Maicop Group-shale hydrocarbon complex in Azerbaijan // 75 EAGE Conference @ Exhibition. – London, 2013. – P. 6–13. DOI: 10.3997/2214-4609.20130979

24. Landolt-Bornstein Tables. Physical properties of rocks / ed. G. Argenheisen. – N.Y., 1983. – Vol. V. – 245 p. DOI: 10.1007/b20009

25. Physical properties of the mineral system of the Earth's interior. – International monograph Project 3 CAPG. – Praha, 1985. – 176 p.

26. Rachinskiy M.Z., Chilingar D.J. Results of geological explorations years of 1990–2005. Geological aspects of perceptivity and numerical assessment // Journal ANX. – 2007. – № 1. – P. 7–15.

27. Salmanov A.M., Suleymanov A.M., Maharramov B.I. Paleogeology of oiland gas bearing region in Azernaijan. – Mars Print, 2015. – 471 p.

28. Theoretical and Experimental Investigations of Physical Properties of Rocks and Minerals under Extreme p,T-conditions. – Berlin: Academie Verlag, 1979. – 210 p.

29. Ахмедов А.М. О геологической характеристике и перспективах нефтегазоносности площади Умид // Азербайджанское нефтяное хозяйство. – 2008. – № 3. – С. 19–22.

30. Соколов Б.А. Эволюция и нефтегазоносность осадочных бассейнов. – М.: Наука, 1980. – 243 с.

31. Физические свойства горных пород и полезных ископаемых / под ред. Н.Б. Дортман. – М.: Недра, 1976. – С. 527.

32. Воларович М.П., Баюк Е.И., Ефимова Г.А. Упругие свойства минералов при высоких давлениях. – М.: Наука, 1975. – С. 130.

33. Hasanov A.B., Melikov Kh.F. 3D model of productive layers according to data geophysics and petrophysics // Materials of international workshop – The influence of recent geodynamics on the physic-mechanical state of the geological environment of the sedimentary cover. – Baku, 2010. – P. 101–108.

34. Lebedev T.S. Model studies of physical properties of mineral matter in high pressure – temperature experiments //

Phys. Earth and Planet. Inter. – 1980. – Vol. 25. – P. 292–303. DOI: 10.1016/0031-9201(80)90126-0
35. Справочник по литологии / под ред. Н.Б. Вассоевича. – М., 1988. – 509 с.
36. Бабаев М.С. Коллекторские параметры пород выбросов грязевых вулканов Бакинского архипелага (на примере о. Дуванны и о. Булла) // Тематический сборник научных трудов. – Баку: Изд-во Азерб. ИУ, 1991. – С. 82–84.
37. Справочник по геологии нефти и газа. – М.: Недра, 1988. – 480 с.
38. Хижняк Г.П. Использование материалов геофизических исследований скважин для оценки проницаемости терригенных пород // Нефтяное хозяйство. – 2011. – № 6. – С. 86–88.
39. Гадиров В.Г. Прогнозирование вулканогенных образований мезозоя Среднекуринской депрессии и их нефтегазоносности по комплексным геофизическим данным: автореф. дис. … канд. геол.-мин. наук. – Баку, 1991. – 22 с.
40. Бабазаде Б.Х., Путкарадзе Л.А. О поисках залежей газа и нефти в прибрежной морской зоне Апшеронского полуострова и Бакинского арипелага // Геология нефти и газа. – 1961. – № 10. – С. 7–11.
41. Ali-Zadeh A.A., Salayev S.Q., Aliyev A.I. Scientific evaluation of perceptivity of oil and gas in Azerbaijan, South Caspian and direction of search-exploration operation. – Baku: Elm, 1985. – 227 p.
42. Юсифзаде Х.Б. Применение современных технологий в области разведки и добычи нефтегазовых месторождений в Азербайджане // Азербайджанское нефтяное хозяйство. – 2013. – № 7–8. – С. 3–13.
43. Гудок Н.С., Богданович Н.Н., Мартынов В.Г. Определение физических свойств нефтеводосодержащих пород. – М.: Недра-Бизнесцентр, 2007. – 592 с.
44. Белозеров Б.В. Роль петрофизических исследований при оценке насыщения сложнопостроенных коллекторов // Известия Томского политехнического университета. – 2010. – Т. 317, № 1. – С. 110–116.
45. Гадиров В.Г. Магматический вулканизм Среднекуринской впадины Азербайджана и его роль в скоплении углеводородов // Международный научный институт Educatio. – 2001. – Т. III (10). – С. 64–69.

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