Baku State University Journal of Earth Sciences & Environment **2026**, v 3 (1), p. 101-108

journal homepage: http://bsuj.bsu.edu.az/en

LITHOLOGICAL-PETROGRAPHIC CHARACTERISTICS OF OIL AND GAS-BEARING MESO-CENOZOIC SEDIMENTS OF THE MIDDLE KURA DEPRESSION

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https://doi.org/10.30546/209805.2026.3.1.2058

Abstract

The exploration of oil and gas fields, their development, and the assessment of reserve potential are considered among the main and necessary conditions for obtaining reliable information about the reservoir properties of rocks forming the geological section.
The Kura depression, which has significant oil and gas potential, is characterized by a complex structural-tectonic structure and specific sedimentation conditions. This area has been comprehensively studied for a long time using various geological and geophysical research methods.
Based on the conducted studies, analyses were performed according to different empirical regularities. Oil and gas production in these fields is carried out from various horizons of the Upper Cretaceous, Eocene, Productive Series, Aghchagil and Absheron deposits, which have been under long-term exploitation. The geological structure of these fields has been studied using numerous geophysical and well logging methods, with each field divided into separate blocks and still under development. At the same time, the necessity of applying petrophysical approaches for more accurate prediction of oil and gas content is emphasized.
Keywords: *Meso-Cenozoic sediments, lithological-petrographic characteristics, oil and gas reservoirs, physical properties of rocks, reservoir rocks.*

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INTRODUCTION

The rock samples obtained from the Muradkhanli field are represented by porphyrites, quartz andesites, porphyritic breccias, trachyandesites, plagioclase andesites, and other rock types. Tuffaceous marls and tuffaceous argillites with organogenic-pelitomorphic structures are also observed along the section. The composition of rock samples obtained from the Kursangi and Kharabakhli fields primarily consists of fine- and medium-grained sandstones. In addition to quartz, feldspars, microquartzite, and mica-chlorite schist fragments, small amounts of volcanogenic rock fragments are also present in the composition of these rocks.

The rocks belonging to the Tarsdallar field are characterized by tuffaceous marls, tuffaceous sandstones, tuffaceous siltstones, and tuffaceous argillites. In the Jafarli field, the rock composition mainly includes marls, weakly calcified tuffs, tuffaceous sandstones, and argillites. Samples obtained from the Garali field are composed of marl, limestone, tuff, and altered basalt rocks. The rock complex of the Shikbaghi field consists of calcareous sandstones and calcareous-sandy clay rocks.

The article investigates the physical properties of core samples obtained from exploration wells drilled in the Middle and Lower Kura depression—specifically density (\sigma, g/cm^3), porosity (K_m, %), ultrasonic wave propagation velocity (V, m/s), granulometric composition (%), carbonate content (%), and permeability (10^{-15} m^2)—under both atmospheric and thermobaric conditions (Dortman, 1976: 213; Volarovich, Bayuk, Efimova, 1975: 84).

In the geological section of the Muradkhanli field, which is distinguished by its complex geological structure, clay, siltstone, sandstone, dolomite, limestone, tuff, and porphyrite-type rocks belonging to the Upper Cretaceous–Quaternary sediments were studied.

The density of the clays participating in the geological section of the field varies between 2.10–2.28 g/cm^3, while the porosity index maintains a balance between 21–38\%; magnetic susceptibility is practically not observed. The density of sandstones varies between 2.12–2.40 g/cm^3, porosity between 11–21\%, ultrasonic wave propagation velocity is 1740 m/s, and magnetic susceptibility ranges from (20–200) \cdot 10^{-6} CGSM. Across the field, the average density of carbonaceous clays was determined to be 2.30 g/cm^3, and the density of clayey siltstones was 2.48 g/cm^3, with porosity varying in the 9.9–14.8\% range. Dolomite rocks encountered in the deep horizons of the studied area are characterized by higher density (2.65 g/cm^3) and relatively lower porosity (6.8\%).

The most extensively studied rocks in the Muradkhanli field consist of volcanogenic tuffaceous sandstones, argillites, and sandstones belonging to Upper Cretaceous sediments, reaching a thickness of approximately 2000 m (Table 1). In this section, altered porphyrites, which form the upper part of the effusive rocks, are more widespread and are considered characteristic of the Muradkhanli field. Porphyrites are divided into three groups based on density indicators: low density (2.22 g/cm^3), medium density (2.22–2.53 g/cm^3), and high density (greater than 2.57 g/cm^3).

Table 1

Thickness of rocks studied in Muradkhanli area

Areas	Stratigraphy	Lithology	$\frac{\sigma_{or.}}{\sigma_{\min}-\sigma_{\max}}$	$\frac{M_{or.}}{M_{\min}-M_{\max}}$	$\frac{V_{or.}}{V_{\min}-V_{\max}}$	$\frac{\chi_{or.}}{\chi_{\min}-\chi_{\max}}$
Muradkhanli	Top Chalk	argillite	$\frac{2,46(13)}{2,37-2,52}$	$\frac{4(13)}{3,5-4,5}$	1650(1)	$\frac{2,46(13)}{2,37-2,52}$
		Tuflu Sandstone	2,40(1)	28(1)	0950(1)	40(1)

		sandstone	$\frac{2,53(9)}{2,50-2,56}$	$\frac{3,5(4)}{3,0-4,0}$	3100(1)	180(10)
Zardab	Top Chalk	argillit	$\frac{2,55(8)}{2,52-2,58}$	$\frac{4,3(5)}{3,5-5,2}$	$\frac{3200(4)}{2900-3500}$	$\frac{110(13)}{2900-1800}$
		alevrolite	$\frac{2,32(6)}{2,0-2,57}$	$\frac{16(4)}{12-24}$	$\frac{1820(4)}{1430-2210}$	$\frac{1800(6)}{1700-2100}$
		mergel	2,15(1)	18,0(1)	1420(1)	420(1)
		limestone	$\frac{2,54(2)}{2,53-2,55}$	$\frac{4(3)}{2,0-6,0}$	2950(1)	0-10

Notes:

- **sigma%**: Density (%g/cm^3%)
- **M%**: Porosity (%)
- **V%**: Ultrasonic wave propagation velocity (%m/s%)
- **kappa%**: Magnetic susceptibility (%10^{-6}% CGSM)

In some cases, the density of the rocks can increase up to 2.70 g/cm^3%. Due to the variation in these indicators, differences are also observed in the porosity and ultrasonic wave propagation velocity of the rocks. In some samples of altered tuffaceous porphyrites, porosity increases up to 33.2\%. Tuffs and tuffaceous breccias are also frequently observed in the geological section. These rocks demonstrate variability in the ranges of 1.98–2.63 g/cm^3% for density, 3.4–23.7\%% for porosity, (100–6200) \cdot 10^{-6}% CGSM for magnetic susceptibility, and 1300–3770 m/s% for ultrasonic wave propagation velocity.

Samples taken from deep exploration wells drilled in the **Zardab** field belong to Meso-Cenozoic sediments. In this area, the physical properties of Upper Cretaceous volcanogenic and sedimentary facies rocks—limestones, carbonaceous clays, argillites, and siltstones—have been studied in detail. Based on the results of the research, the average density of limestones was determined to be 2.54 g/cm^3, the porosity index 4.2\%, and magnetic properties were found to be at a low level. Carbonaceous clays have an average density of 2.15 g/cm^3, porosity of 19.4\%, magnetic susceptibility of 420 \cdot 10^{-6} CGSM, and an ultrasonic wave propagation velocity of \$1420 m/s\$. The density of argillite rocks varies in the range of \$2.50–2.60 g/cm^3. For these rocks, porosity is relatively low, varying between 3.4–5.2\%, while the ultrasonic wave propagation velocity fluctuates between 2030–3440 m/s. The density of siltstones varies from 2.00–2.57 g/cm^3, porosity from 12.3–23.7\%, and ultrasonic wave velocity from 1430–2210 m/s (Sultanov, Najaf-Kulieva, Abbasova, 2014: 10).

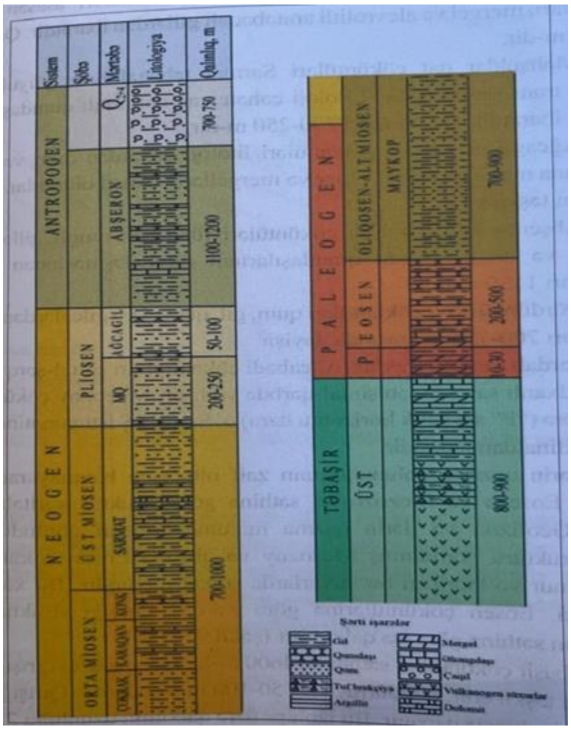

Figure 1. Zardab field. Generalized geological section.

Senonian sediments in the field are mainly composed of marl, porphyrite, and tuffaceous breccia rocks. The statistical average density of marls is 2.54 g/cm^3, porosity is 8.0\%, ultrasonic wave velocity is 4140 m/s, and magnetic susceptibility is extremely weak. Porphyrites of basaltic origin have an average density of 2.32 g/cm^3, porosity of 15.6\%, magnetism of 1600 \cdot 10^{-6} CGSM, and an ultrasonic wave velocity of 4220 m/s. The porosity index of tuffaceous siltstones can rise up to 20\%, while density varies in the 2.40–2.50 g/cm^3 range.

Eocene marl rocks are characterized by a relatively low density index, with an average density value of 2.23 g/cm^3. These rocks have a porosity of 11.0\%, an ultrasonic wave velocity of 1600 m/s, and magnetic susceptibility is practically not observed.

In the **Muradkhanli** field, the Maikop series is primarily represented by clay and siltstone-type rocks. These rocks are characterized by very weak magnetic susceptibility, a density of 2.18 g/cm^3, and a porosity of 17.9\%.

The physical properties of Paleogene and especially Eocene rocks participating in the geological structure of the **Tarsdallar** structure have been studied. Paleogene sediments are represented by siltstone, marl, limestone, and tuffaceous siltstone rocks. Marls have a density of 2.16 g/cm^3, porosity of 2.5\%, very weak magnetic susceptibility, and an ultrasonic wave velocity of $3500 m/s$. Paleocene limestones are distinguished by the almost total absence of magnetic properties. These rocks have a density of 2.56 g/cm^3, porosity of 5.1\%, and an ultrasonic wave velocity of up to 3000 m/s (Yusubov, Guliyev, 2008: 25).

Eocene siltstones have a density of 2.45 g/cm^3, porosity of 5.0\%, and an ultrasonic wave velocity of 1300 m/s. Limestones showed a density of 2.65 g/cm^3, porosity of 5.24\%, and an ultrasonic wave velocity of 2950 m/s, with no magnetic susceptibility observed. For argillites, the density was determined at 2.25 g/cm^3, porosity at 15.5\%, magnetic susceptibility at a weak level, and ultrasonic wave velocity at 2700 m/s.

Studies have shown that the physical properties of rocks of the same type and age change under the influence of geological-physical processes, resulting in different values. Petrophysical studies conducted under pressure and temperature conditions have confirmed these results. Analysis of tables showing rock reservoir properties and other geophysical materials indicates that in the Tarsdallar field, which has a semi-closed anticlinal structure bounded by faults, there is no single or constant regularity for the entire area. However, since rock density and ultrasonic wave velocity indicators mainly depend on depth and the influence of tectonic processes, the values of these parameters demonstrate wide-range variability as depth increases (Salekhli, Sultanov, 1975: 34).

As previously mentioned, to study the reservoir properties of the Tarsdallar field, which has a tectonic structure complicated by various faults, geological-geophysical studies conducted in the area were analyzed; simultaneously, core samples obtained from drilled wells were researched and analyzed under laboratory conditions.

The physical properties of Paleogene and Eocene rocks in the geological structure of the Tarsdallar structure were investigated. Paleogene sediments are mainly represented by siltstone, marl, limestone, and tuffaceous siltstone-type rocks. Marls have a density of 2.16 g/cm^3, a porosity index of 2.5\%, very low magnetic susceptibility, and an ultrasonic wave velocity of 3500 m/s. Paleocene limestones possess almost no magnetic properties; their density is 2.56 g/cm^3, porosity is 5.1\%, and ultrasonic wave velocity rises up to 3000 m/s.

Rocks form and exist at great depths under the influence of high temperature and pressure conditions. Since the studied rocks have a porous structure and pores are filled with fluid under natural conditions, the influence of the pore medium on the physical properties of the rocks must be considered. This necessitates evaluating the role of pore pressure during research. The effect of pore pressure on ultrasonic wave velocity was specifically studied in silty-tuffite rock samples with a porosity index of 20\%. During measurements, a slight decrease in wave propagation velocity was initially observed, followed by the recovery of the velocity indicator toward its initial state (Gadirov, 2007: 38; Gurbanov, Narimanov, Mansurova, 2013: 16).

The comprehensive study of porosity and density indicators of the given rocks under high-pressure conditions showed that these parameters undergo quite significant changes. Therefore, it is essential to consider these factors during the analysis of geological and geophysical data. In the pressure interval of 0–60 MPa (corresponding to a depth of approximately 5–6 km), the elastic deformation of the rock pore volume varies in the range of 30–50\%.

A characteristic feature of the pressure-dependent change in the porosity of sandstones and siltstones is that in the 20–30 MPa pressure interval, the gradient of change of the porosity coefficient (K_n) reaches its maximum value, and then gradually decreases due to increasing pressure, approaching zero at high pressure levels like 60 MPa.

In the initial stage, a small relative change in the porosity coefficient is considered more typical for clayey sandstones and siltstones with high porosity. Conversely, in rocks with low initial porosity and a high clay content index, the relative change in the porosity coefficient may take on larger values.

Generally, as clay content decreases and the degree of grain sorting increases in sandy reservoir rocks, the storage and filtration capacity of the rocks improve; therefore, it is observed that the relative change in the porosity coefficient (K_n) is lower in rocks with high porosity.

One of the main factors influencing the change in porosity in rocks is the composition and character of their cementing material. When the amount of cement is constant, the change in porosity in clayey rocks is observed at a minimum level. Low variation in porosity is characteristic of sandstones with carbonate cement; meanwhile, in clayey rocks, porosity increases relatively evenly under the influence of pressure. In rocks with basal-pore type cement, the increase in porosity becomes more noticeable. The elastic variability of density in rocks can be evaluated based on the dynamics of change in the porosity index. For sandy-silty rocks, the maximum change in density is approximately 1–2\%.

In general, the character of the change in ultrasonic wave propagation velocity in all rock samples up to 60 MPa pressure is qualitatively similar. As pressure increases, wave propagation velocity also rises, and the main variability of velocity is observed up to the 40 MPa pressure limit. Up to 30 MPa pressure, the ultrasonic wave velocity mainly increases gradually, but at the 40 MPa pressure level, some sharp changes—meaning breaks—are recorded, which are likely related to internal changes occurring in the structure of the rocks. Under 60 MPa effective pressure conditions, the relative change in wave propagation velocity is observed in the 5–10\% interval. This change amounts to approximately 10\% in sandstones and siltstones, 9\% in limestones and marls, 8\% in tuffites, and up to 7\% in andesites and porphyrites.

The study of the effect of high pressure on wave propagation velocity in sandstones, siltstones, marls, limestones, and volcanogenic rocks shows that changes in pressure lead to significant differences in the velocity-porosity relationship. Therefore, when using velocity-porosity relationships, it is considered more appropriate to apply data obtained in accordance with the natural bedding conditions of the rocks. Comparative analysis of relative changes in velocity and porosity in 20 samples of the same rock type across different pressure ranges shows that the porosity coefficient (K_n) plays different roles in various stress states of the rock.

The effect of porosity on ultrasonic wave propagation velocity is more pronounced at low pressures, as the elastic property of the rock skeleton is weak under these conditions. As pressure increases, since the elasticity of the rock skeleton rises, the effect of porosity on velocity relatively weakens and drops to an insignificant level.

The initial values of the relative increase in velocity ($\Delta V/V$) are determined by the degree of cementation of the rock skeleton. The maximum pressure-determined change in ultrasonic wave velocity is observed in clastic rocks with clayey cementing material. In clastic rocks, the dependence of ultrasonic waves on pressure is determined by the distribution characteristics of the clay component within the rock volume. If the clayey material does not undergo additional loading during skeleton deformation and only fills the intergranular spaces, its effect on the rock deformation process is relatively weak. However, the clay material filling the pore spaces is characterized by a relative clay content index expressed as the pore filling factor (K_{pf}) and causes an increase in the absolute value of velocity based on the average time equation. Consequently, the effect of pore-filling type clay content on the change of velocity under pressure is evaluated in a negative direction (Volarovich, Bayuk, Efimova, 1975: 84).

The liquid or gas phase filling the pore spaces of rocks is one of the factors that significantly influences the wave propagation velocity within them. The effect of the saturating fluid on the ultrasonic wave velocity within the rock is closely related to the rock's porosity; for this reason, the quantitative indicator of the saturation effect is considered proportional to the porosity coefficient. Generally, in clastic rocks without clay and carbonate mixtures, the effect of saturation is relatively weak, especially in low-porosity rocks, and is estimated at around 10\%. In cases where clay or carbonate components are up to 40\% in the composition of sandstones and siltstones, a 100–120\% increase in wave velocity is observed during fluid saturation. Since the fluid filling the rock's pore spaces changes its elastic and strength properties more significantly in the intergranular contact zone, it is accepted that its influence on the pressure dependence of velocity is substantial. However, this mainly manifests under conditions where the rock skeleton has relatively low elasticity. An increase in the degree of rock cementation, a decrease in porosity, or the loading of the rock under the influence of all-around pressure leads to an increase in the skeleton's elasticity, which weakens the effect of the saturating fluid. At the same time, under conditions where the rock skeleton has high initial elasticity, the influence of high all-around pressure on the ultrasonic wave velocity is expected to decrease. Under the influence of pressure, an improvement in the intergranular acoustic contact forming the rock skeleton occurs, and the maximum change in velocity is recorded in high-porosity rocks with low initial elasticity. The maximum change in velocity is also observed in gas-saturated rocks with the same porosity and low elasticity.

CONCLUSION

The results of the conducted research show that the bedding conditions of rocks, the diversity of lithological composition, the characteristics of cementing material, porosity, degree of carbonate content, fracturing, and the state of fluid saturation of pores play an important role in the change of their physical and reservoir properties. Therefore, during the study of rock reservoir properties, it is essential to consider the aforementioned factors individually for each region in the analysis of physical parameters and geological-geophysical data.

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