УДК 550.83:553.98 DOI: https://doi.org/10.24028/gj.v44i4.264849

Study of the interrelation between the geneseses and reservoir properties of productive series deposits in Pirallahi field on the basis of oil-field geophysical data

K.A. Kerimova, N.E. Aliyev, 2022

Azerbaijan State Oil and Industry University, Baku, Republic of Azerbaijan
Received 21 September 2021

Petrophysical properties of reservoir rocks are also influenced by a certain relationship between the lithological-mineralogical composition of rocks and the reservoir properties. For this reason, the study of the relationship between the genesis of Productive Series deposits and reservoir properties provides a basis for predicting the regularity of distribution of sand particles throughout the field and making some judgments about the development of porous and permeability zones. This, in turn, is of more scientific and practical importance while identifying variation of reservoir properties of rocks in sedimentary cover.

The paper offers a rational approach that determines the relationship between the genetic origin of sedimentary rocks and their reservoir properties and expounds on the study results.

As a research area, we chose «Qirmakiustu clay», «Qirmakiustu sand», Qirmaki and Qirmakialty series of Productive Series sediments studied in sections of conventional X_1, X_2, X_3, X_4, and X_5 well sections located on one profile of Pirallahifield and their sedimentation environment and facies origin have been studied in more detail.

In the section of well under the study, the average value of effective porosity ($K_{av.p.}$), average thicknesses of sandy and clayey layers ($H_{av.cl.}$, $H_{av.sand}$), and the relative thickness of sand bodies ($H_{rel.sand}$) were calculated for intervals at which the facies of flow, bar, and beach plain origin were identified. The curves of these parameters' variation across the profile were drawn.

At the same time, the curves of thicknesses of flow, bar, and beach plain origin facies were drawn for the interval identified for each well section. These curves were compared and analyzed separately for each facies.

A study of the sedimentation environment and genesis of sedimentation and a comparative analysis of lithofacial and reservoir properties may be important for accurately evaluating oil and gas presence in the study area.

Key words: genesis of sedimentary rocks, porosity, thickness of sediments, streamflow, bar, facies.

Introduction. Studies of sedimentation environment, the genesis of rocks, and the analysis of lithofacies and reservoir properties of rocks have a significant value for the prediction of oil and gas presence in any area. In this respect, the study of interrelations between the genesis of Productive Series deposits and their reservoir properties generates a basis for predicting the regularity of sand grains distribution across the study area and making an opinion on the generation of porous and the transition zones in the area. This has both scientific and practical value for research on the variation of reservoir properties of rocks within the sedimentary cover. The paper is devoted to studying the genetic origin of sedimentary rocks, their reservoir properties, and the interrelation between them across the selected geological line. To fulfill the task, the rational approach is proposed within the framework of this study with a description of the achieved results [Mamedov et al., 2015; Kerimova, 2009; Shilov, Jafarov, 2001].

As the study area, we have considered Qirmakyustu clay, Qirmakyustu sand, Qirmaky, and Qirmakyalty series of Productive Series by analysis of sections of wells conditionally named X_1, X_2, X_3, X_4, and X_5 and located over a line across a Pirallahi field. Facies origin of these layers has been analyzed based on the well logging data (Fig. 1). For each well section along the line, we have outlined intervals of the same origin of facies, and calculated the effective porosity of layers within those intervals with further evaluation of their average values [Kerimova, Ganiyeva 2019].

Regarding reservoir properties, the studied facies included streamflow, bar, beach plain, and coastal plain facies as relatively more perspective facies.

Facies of this origin have been studied by several researchers, who designed their typical models [Kerimova, Khalilova, 2020].

Methods. In the facies of streamflow origin, the sand bodies are characterized by the composition of grains of various sizes and the quantity regularly decreasing upward while the content of clay and aleurite increases in the same direction. In facies of this kind, the interrelation of rocks with underlying and overlying deposits is very important. Typically facies of this kind overlie the rocks by eroded surfaces (paleo flow), causing active relations with underlying layers and gradual penetration into the upper rock grains [Kerimov et al., 2020].

In facies of bar origin, the sand grains basically under active hydrodynamic conditions vary in the vertical direction and are relatively coarse on top and finer at the foot. This, to a degree, makes conditions required for the generation of sand bars. Sand grains of bar enter in clearly traced interrelation with overlying rocks with further gradual penetration into the layers below [Kerimov et al., 2018; Hein, 2017].

Accumulation of sand bodies in facies of beach plain origin is mostly stipulated by active hydrodynamic and relatively stable environmental conditions. Sand bodies here are not subjected to sharp variation and, therefore, are rather evenly distributed across the host layer. Due to this, the SP curves are symmetric in the fore part of layers, straight in the central part, and have sharp low and upper borders [Mustayev et al., 2016; Guliyev et al., 2018].

The average value of effective porosity ($K_{av.p.}$) of layers within intervals outlined in the above-mentioned facies, the average thickness of sandy-clayey layers ($H_{av.clay}$, $H_{av.sand}$), and the relative thickness ($H_{rel.sand}$) of sand bodies were calculated. Based on calculated values, we have drawn curves of their varia-

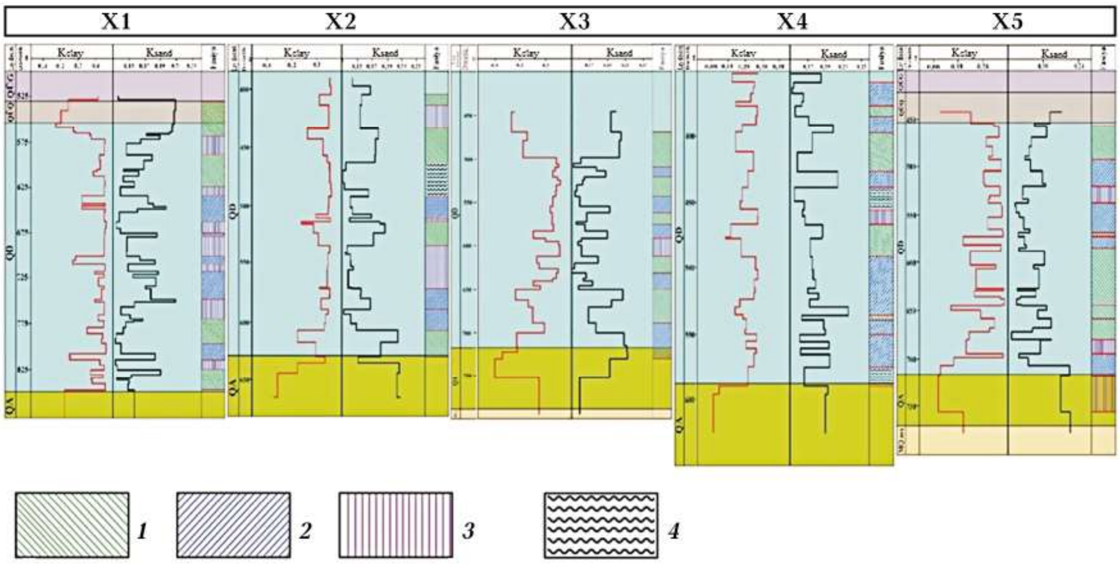

Fig. 1. Analyzing graph of sedimentary rocks' lithofacial properties on the basis of Productive Series deposits in the Pirallahi field: *1* — Bar origin, *2* — Streamflow origin, *3* — Beach plain, *4* — Coastal plain.

T a b l e 1. Evaluation of $H_{rel.sand}$, H_{flow}, and $K_{av.p}$ parameters for facies in outlined intervals (streamflow, bar, beach plain, coastal plain) of Productive Series deposits across Pirallahi field

Well number	Facies of streamflow origin			Facies of bar origin			Facies of beach plain origin			Facies of coastal plain origin		
	$H_{av.sand}$, m	$K_{av.p}$	H_{flow}	$H_{av.sand}$, m	$K_{av.p}$	H_b	$H_{av.sand}$, m	$K_{av.p}$	$H_{beach.p.}$	$H_{av.sand}$, m	$K_{av.p}$	$H_{c.p.}$
X_1	0,973	0,137	93,35	0,976	0,24	117,6	0,972	0,15	100,5	—	—	—
X_2	0,965	0,16	54,46	0,966	0,18	81,68	0,965	0,17	60,01	0,974	0,16	28,9
X_3	0,967	0,18	107,9	0,971	0,176	132,95	0,976	0,16	22,37	—	—	—
X_4	0,97	0,19	122,2	0,958	0,169	66,11	0,985	0,168	11,1	0,961	0,17	36,67
X_5	0,96	0,173	95,29	0,972	0,172	134,33	0,95	0,19	70,15	—	—	—

tion along the selected line. Simultaneously, within the interval defined for each well section, we have evaluated the thickness of facies of streamflow, bar, and beach plain origin with the following drawing of appropriate curves of their variation along the line. Acquired intermediate data are displayed in Table 1.

For each well section, the thickness of the reservoir portion (H_1) of the layer has been calculated according to the formula (1):

$$H_1 = \frac{H_{av.clay} + H_{av.sand}}{2}. \quad (1)$$

Here, H_1 is the thickness of the reservoir in the horizon, $H_{av.clay}$ and $H_{av.sand}$ are average thicknesses of clay and sandy layers, respectively [Kerimov. et al., 2018].

Applying the formula below

$$H_{rel.} = \frac{H_1}{H_{total}} \quad (2)$$

we have evaluated the relative thickness of the reservoir within the horizon for facies of streamflow, bar, beach plain, and coastal plain type [Almedallah, Walsh, 2019].

Here we have $H_{rel.}$ — relative thickness of reservoir, H_1 — thickness of reservoir in layer, H_{total} — the total thickness of the layer in the outlined interval.

By use of formula (3) for each well section, we have calculated the average values of effective porosity ($K_{av.p.}$) and relative thickness of sand bodies ($H_{rel.sand}$) within the horizon borders for intervals with identified facies of flow, bar and beach plain type. The curves

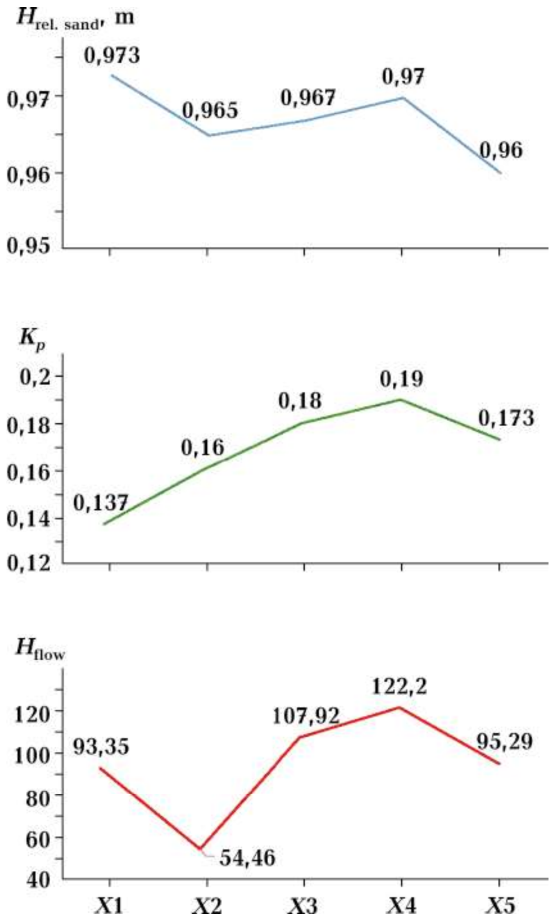

Fig. 2. The graph of comparative analysis of $K_{av.p}$, $H_{rel.sand}$, H_{flow} curves drawn for facies of streamflow origin.

characterizing variation of these parameters through wells located along the study line have been drawn [Kerimova, 2011]

$$H_{rel.sand} = 1 - H_{rel.} \quad (3)$$

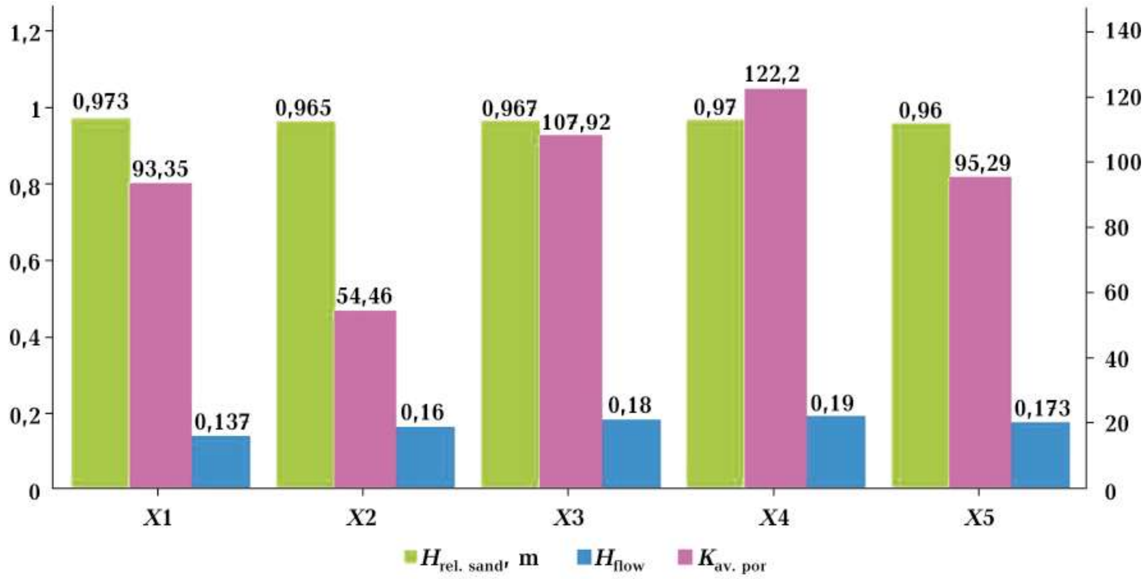

Fig. 3. The graph of $H_{rel.sand}$, $K_{av.p.}$ and H_{flow} parameters' variation in flow originated facies in wells under the study.

Based on a comparative analysis of curves drawn for parameters $H_{rel.sand}$, H_{flow}, and $K_{av.p.}$, it has been made clear that the facies of streamflow origin across the section of well X_1 are traced by 93.35 m thickness in the Qirmaky series within depth intervals of 632.25—662.5 m; 675—678.9 m; 700—708.5 m; 715.8—750 m; 798.7—815.7 m and in the section of well X_2 by 54.46 m thickness within depth intervals of 491.2—509.48 m and 569.49—606.17 m (Fig. 2). From the curve of $K_{av.p.}$ parameter, it can be seen that while the average value of effective porosity of layers across the section of well X_1 is $K_{av.p.}$=0.137, the value of this parameter in the section of well X_2 increases as $K_{av.p.}$=0.16.

The relative thickness of sandy reservoirs in the study interval in the section of well X_1 is $H_{rel.sand}$=0.973 m, and in the section of well X_2 is $H_{rel.sand}$=0.965 m.

Results. Analysis of the curves makes it possible to derive the increase of $K_{av.p.}$ values from the section of well X_1 towards the section of well X_2, while we observe the decrease of values of $H_{rel.sand}$ and H_{flow}. It must be noted that the relative thickness of the reservoir within this interval varies equivalently depending on the thickness of the facies and the effective porosity of the layer.

In the section of well X_3 the facies of streamflow origin are observed by 107.92 m thickness within depth intervals of 507.89—518.7 m; 541.07—559.9 m; 573.4—592.1 m;

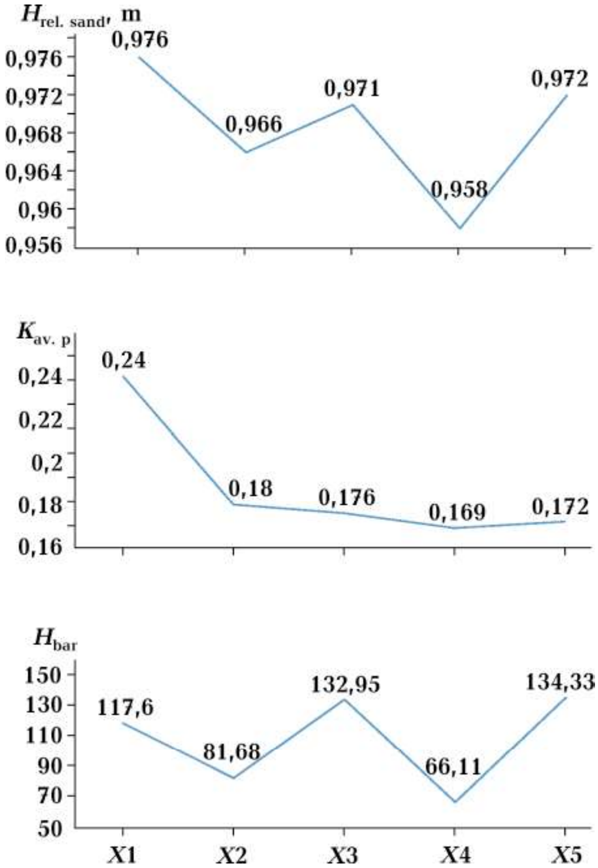

Fig. 4. Comparative analysis of $K_{av.p.}$, $H_{rel.sand}$, H_{bar} parameters' variation for bar originated facies along the study line.

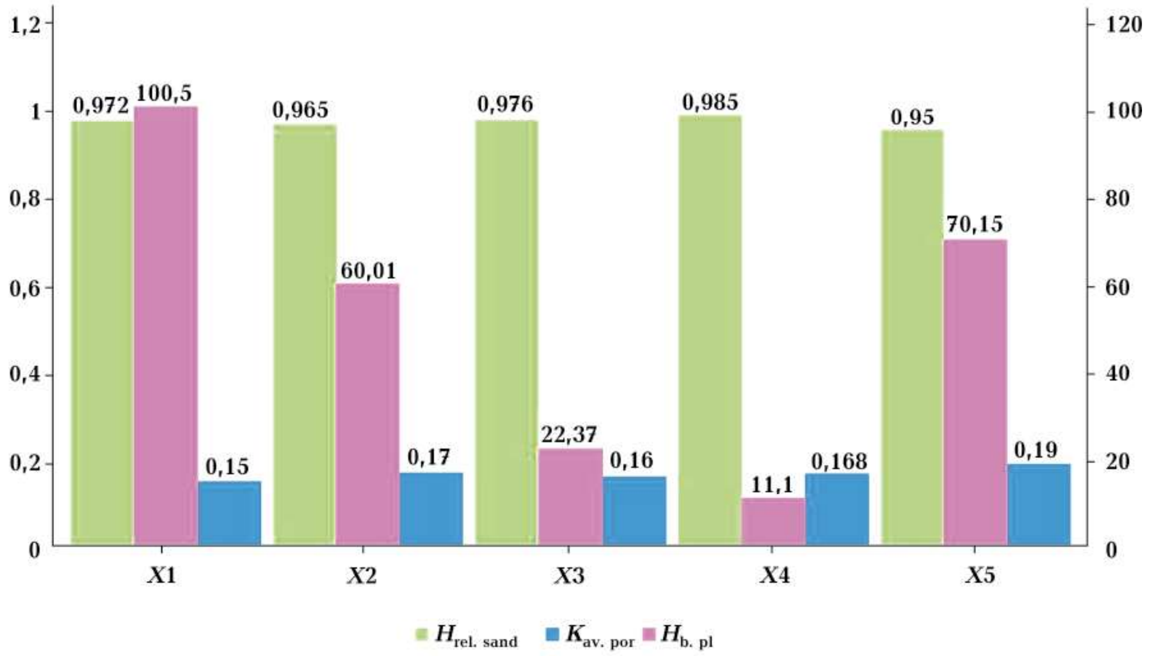

Fig. 5. Variation of $H_{rel.sand}$, $K_{av.p.}$, and H_{bar} parameters of bar originated facies across the studied wells.

632.89—650 m and 689.19—731.76 m. From the section of well X_2 towards the section of well X_3, the thickness of flow facies increases to some degree, and the average value of effective porosity reaches $K_{av.p.}$=0.18 in this interval. It can be seen that the relative thickness of sand bodies also increases in this area and constitutes $H_{rel.sand}$=0.967 m.

The thickness of flow originated facies also increases from section of well X_3 in direction to the well X_4 and reaches H_{flow}=122.2 m, and this thickness is observed within Qirmaky series at depth intervals of 358.89—376.67 m; 385—397.72 m; 427.23—440.01 m; 492.23—536.12 m; 540.01—575 m. The effective porosity and relative thickness of sand grains in these intervals increase compared to those in the well X_3 and constitute $K_{av.p.}$=0.19 and $H_{rel.sand}$=0.97 m, respectively.

Considering section of well X_5, facies of flow origin are observed in the Qirmaky series by 95.29 m thickness at depth intervals of 492.54—520.9 m; 536.06—567.91 m; 694.02—717.16 m. A comparison of the average value of effective porosity in the section of wells X_5 and X_4 makes it clear that the value slightly decreases and constitutes $K_{av.p.}$=0.173; the value of the relative thickness of sand bodies also decreases to $H_{rel.sand}$=0.96 m.

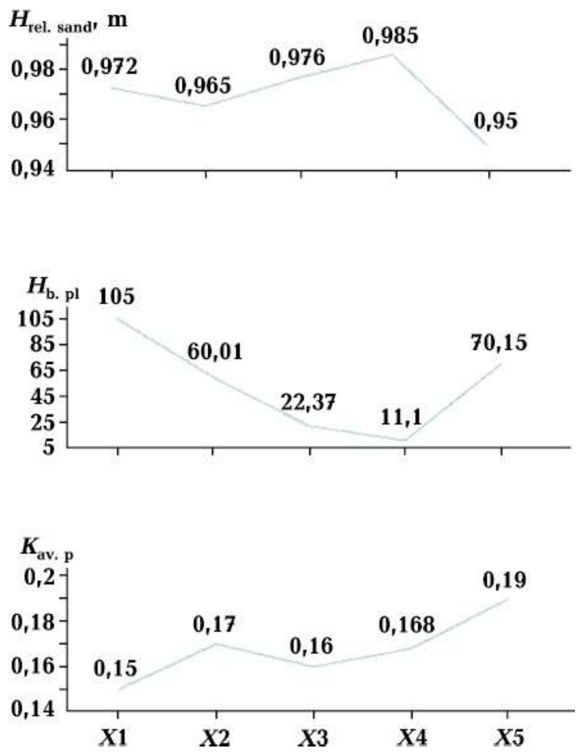

Fig. 6. Comparative analysis of $K_{av.p.}$, $H_{rel.sand}$, $H_{b.pl.}$ parameters variation for beach plain facies along the study line.

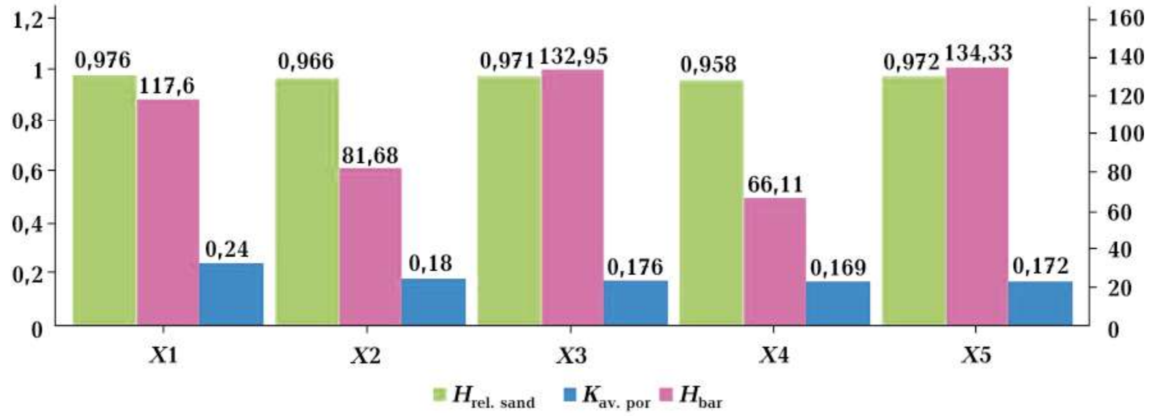

Fig. 7. Variation of $H_{rel.sand}$, $K_{av.p.}$ and $H_{b.pl.}$ parameters of beach plain facies across the studied wells.

Table 2. displays the average values of porosity, sand, and clay content of reservoirs in the Qirmaky and Qirmakyalty series in sections of wells conditionally named X_1, X_2, X_3, X_4, X_5 and located in the area under the study

Hori-zon	X_1			X_2			X_3			X_4			X_5		
	K_{clay}	$K_{av.p}$	K_s	K_{clay}	$K_{av.p}$	K_s	K_{clay}	$K_{av.p}$	K_s	K_{clay}	$K_{av.p}$	K_s	K_{clay}	$K_{av.p}$	K_s
QD	0,31	0,18	0,39	0,33	0,18	0,46	0,3я	0,17	0,21	0,3	0,18	0,42	0,3	0,17	0,38
QA	0,15	0,17	0,60	0,21	0,22	0,57	0,18	0,20	0,49	0,17	0,18	0,55	0,1	0,22	0,64

The drop of $K_{av.p.}$ value can be explained mainly by inhomogeneity of reservoirs and compaction of rocks under the impact of gravity.

If we analyze these three curves individually, we can derive that on curves drawn for facies of streamflow origin, $H_{rel.sand}$ and $K_{av.p.}$ are following each other's values along the given line. This indicates that curves of these parameters' variation along the studied line have some regularity between them. Thus, based on considered layer thickness, the relative thickness of sandy reservoir varies equivalently depending on the facies type (Fig. 3).

Performing similar studies, we have outlined intervals with facies of bar and beach plain origin in Qirmakyustu clay, Qirmakyustu sand, and Qirmaky series of Productive Series deposits in the section of each well along the study line. The average value of effective porosity ($K_{av.p.}$), thickness (H_{bar}, $H_{beach.pl.}$), and relative thickness of sand bodies ($H_{rel.sand}$) have been calculated for bar-originated facies and beach plain facies for defined intervals. Appropriate curves of variation of these parameters along the study line have been drawn (Fig. 4—7). According to the studies, the facies of bar origin have been identified in Qirmakyustu sand, Qirmaky deposits of the Productive Series, while beach plain facies have been identified in Qirmaky and Qirmakyalty series.

Applying data from Table 2, the 3D model characterizing porosity, sand, and clay content by their percentage through well sections in the Pirallahi field has been designed (Fig. 8, 9).

Fig. 8 shows the model of porosity distribution through well sections in the Pirallahi field. The model was designed by use of the Petrel software package. Analyzing the data shown in the table based on well logging data, it can be seen that the value of the porosity coefficient in the Qirmaky series varies within the range of 0.17—0.18. This value for the Qirmakyalty series varies from 0.17 to 0.22, respectively. Similarly, the table displays clay content across the studied wells. The value of clay content in the Qirmaky series varies within the 0.31—0.33 range, while for the Qirmakyalty series, this value changes from 0.1 to 0.21. The model has been designed with a wide use of computer aids.

The figure displays the reservoir, non-reservoir model designed for the top of the Qirmaky and Qirmakyalty series. As seen from the table, the percentage of sand in the Qirmaky series is 51 %, the percentage of clay is 49 %, while for the Qirmakyalty series, those are 62 and 38 %, respectively.

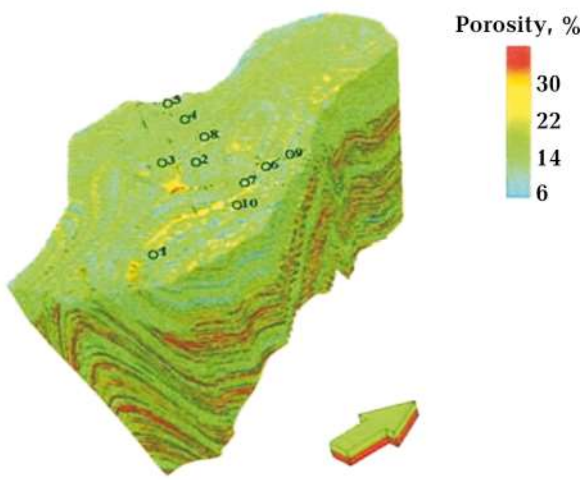

Fig. 8. 3D model of porosity distribution in the study area.

Conclusion. The following results have been gained within the framework of the present study.

1. The dependence of reservoir properties on the genesis of Productive Series deposits in the Pirallahi field has been researched.

A. It can be seen from the graph of parameters ($H_{rel.sand}$, H_{flow}, and $K_{av.p.}$) derived for flow originated facies that the curves of $H_{rel.sand}$ and $K_{av.p.}$ are following each other. This proves the presence of some interrelation between these parameters. The value of the relative thickness of sandy layers varies proportionally to the sedimentary cover thickness and effective porosity of the layer of the same facies.

B. In all wells along the study line, the value of $K_{av.p.}$ parameter for bar-originated facies decreases on the general background values. However, the curves of $H_{rel.sand}$ and H_{bar} variation follow each other.

C. In facies of beach plain origin, no regularity is observed between parameters of $H_{rel.sand}$, H_{flow}, and $K_{av.p.}$ In this case, the parameters vary in a chaotic nature independently from each other.

Thus, it has been made clear that studies of sedimentation conditions and genesis

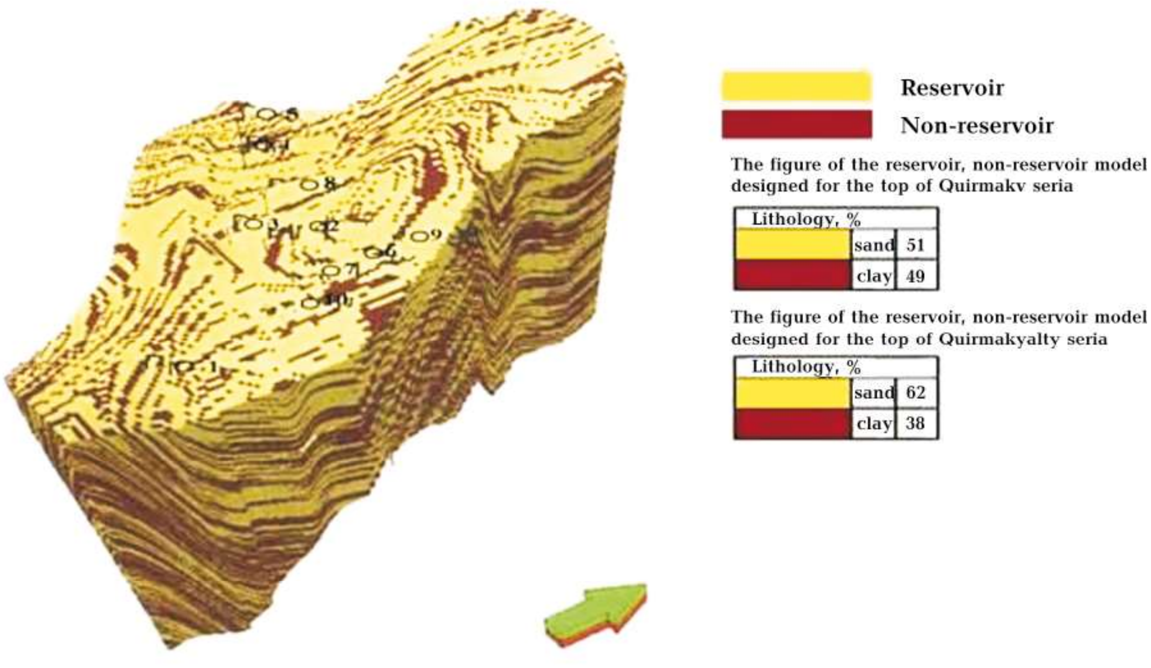

Fig. 9. 3D model of distribution of clay and sand content by percentage.

and research on lithofacies and the reservoir properties make it possible to study in more detail the perspectives of oil and gas presence in the area.

2. The average values of oil and gas saturation of reservoirs, porosity, and clay content have been calculated for the Qirmaky and Qirmakyalty series in the Pirallahi field, and 3D models were designed using Petrel software in order to display these parameters' variation across the wells.

The average value of porosity in the section of well X_1 varies as 17—18 %, for well X_2 as 18—22 %, for well X_3 within 17—20 %, for well X_4 it constitutes 18 %, and for well X_5 varies as 17—22 %. The average value of clay content for well X_1 varies as 15—31 %, for well X_2 as 21—33 %, for well X_3 as18—30 %, for well X_4 as 17—30 %, and for well X_5 as 10—30 %. The value of oil and gas saturation for well X_1 varies within 39—60 %, for well X_2 as 46—57 %, for well X_3 as 21—49 %, for well X_4 as 42—55 %, and for well X_5 as 38—64 %.

References

Almedallah, M.K., & Walsh, S.D.C. (2019). Integrated well-path and surface-facility optimizationfor shallow-water oil and gas field developments. *Journal of Petroleum Science and Engineering, 174*, 859—871. https://doi.org/10.1016/j.petrol.2018.11.025.

Hein, F.J. (2017). Geology of bitumen and heavy oil: An overview. *Journal of Petroleum Science and Engineering, 154*, 551—563. https://doi.org/10.1016/j.petrol.2016.11.025.

Gubina, A.I. (2007). *Bases of facies cyclicity of sedimentary layers based on results of geological-geophysical studies in wells*. Perm: Press time, 271 p. (in Russian).

Guliyev, I.S., Kerimov, V.Yu., Mustayev, R.N., & Bondarev, A.V. (2018). Evaluation of generation potential of shaly low-permeable layers (Caucasian Maikop series). *SOCAR Proceedings*, (1), 4—20. https://doi.org/10.5510/OGP20180100335 (in Russian).

Kerimova, K.A. (2009). Analysis of reservoir properties and genesis of sedimentary rocks of the South-Caspian basin. *Karotazhnik*, (11), 38—47 (in Russian).

Kerimova, K.A. (2011). Genetic model of sedimentary rocks based on integrated geophysical studies of wells in the South Caspian basin. *Dissertation thesis*. Baku, 181 p. (in Russian).

Kerimova, K.A., & Ganiyeva, R.Y. (2019). Study of genesis of productive series based on integrated well data (in case of Pirallahi field). *News of the Ural State Mining University*, (3), 90¾97 (in Russian).

Kerimov, V.Yu., Gasanov, A.B., Gurbanov, V.Sh., & Abbasova, G.G. (2020). Petrophysical characteristic of deep oil and gas reservoirs in inland and offshore fields in Azerbaijan. *Eurasian Mining*, (1), 3—8. https://doi.org/10.17580/em.2020.01.01.

Kerimov, V.Yu., Gordadze, G.N., Mustaev, R.N., & Bondarev, A.V. (2018). Formation Conditions of Hydrocarbon Systems on the Sakhalin Shelf of the Sea of Okhotsk Based on the Geochemical Studies and Modeling. *Oriental Journal of Chemistry, 34*(2), 934—947. https://doi.org/10.13005/ojc/340243.

Kerimov, V.Yu., Gordadze, G.N., Lapidus, A.L., Giruts, M.V., Mustayev, R.N., Movsumzade, E.M., Zhagfarov, F.G., & Zakharchenko, M.V. (2018). Physicochemical Properties and Genesis of the Asphaltites of Orenburg Oblast. *Solid Fuel Chemistry, 52*, 59—67. https://doi.org/10.3103/S0361521918020064.

Kerimova, K.A., Khalilova, L.N. (2020). Genesis study of Productive Series sediments based on the results of quantitative interpretation of logging curves (on the example of Binagadi and Balakhani fields). *Ore & metals*, (8), 68¾71 (in Russian).

Lapidus, A.L., Kerimov, V.Y., Mustaev, R.N., Movsumzade, E.M., & Zakharchenko, M.V. (2018). Caucasus Maykopian kerogenous shale sequences: Generative potential. *Oil Shale, 35*(2), 113—127. https//doi.org/10.3176/oil.2018.2.02.

Mamedov, P.Z., Kerimova, K.A., & Mamedova, L.P. (2015). Study of facies composition of the Early Pliocene deposits (Productive Series) of the

South-Caspian basin on the basis of logging data. *Geophysics News in Azerbaijan*, (3-4), 3—7.

Mustayev, R.N., Kerimov, V.Yu., Shilov, G.Ya., & Dmitriyevskiy, S.S. (2016). Modeling of thermal and pressure conditions of formation of hydrocarbon accumulations in shaly low-permeable reservoirs of Khadum suite of Fore-Caucasus. *«Geomodel-2016»: 18th scientific and practical conference on problems of geological survey and development of oil and gas fields. Gelendzhik*. https://doi.org/10.3997/2214-4609.201602185.

Shilov, G.Ya., & Jafarov, I.S. (2001). *Genetic models of sedimentary and volcanogenic rocks and technology of their facies interpretation based on geological-geophysical data*. Moscow: Information center VNİGRİ geosystem, 393 p. (in Russian).

Вивчення взаємозв'язку між генезисом та колекторськими властивостями відкладень продуктивної товщі родовища Піраллахи на основі геофізичних методів

К.А. Керімова, Н.Е. Алієв, 2022

Азербайджанський державний університет нафти та промисловості, м. Баку, Азербайджанська Республіка

Між літолого-мінеральним складом гірських порід та їх колекторськими властивостями існує певний зв'язок, що, у свою чергу, проявляється у петрофізичних властивостях порід-колекторів. Тому вивчення зв'язку між генезисом продуктивної товщі і колекторськими властивостями порід забезпечує основу для прогнозування закономірності розподілу часточок піску в межах усього родовища і дає змогу зробити деякі висновки щодо характеру розвитку пористих зон і зон провідності. Вказане має велике наукове і практичне значення для визначення характеру зміни колекторських властивостей порід осадового шару.

У статті запропоновано раціональний підхід, що визначає взаємозв'язок між генетичним походженням осадових порід та їхніми колекторськими властивостями, наведено результати дослідження.

Досліджено світи «НКГ», «НКП», кірмакинську та підкірмакинську світи продуктивної товщі за розрізами свердловин з умовними назвами X_1, X_2, X_3, X_4 та X_5, що розташовані на одному профілі родовища Піраллахи, і на основі свердловинних геофізичних даних уточнено умови осадонагромадження та їх фаціальне походження.

За розрізом однієї із досліджуваних свердловин розраховано середнє значення ефективної пористості пласта ($K_{ср.п}$), середні потужності піщаних і глинистих пластів ($H_{ср.гл}$, $H_{ср.п}$), відносну потужність піщаних тіл ($H_{отн.п}$), в інтервалах яких були виявлені потокові, барові фації та фації пляжних рівнин, а також побудовано криві їх зміни за профілем.

Криві зміни потужностей потокових і барових фацій та фацій пляжних рівнин побудовані в інтервалах, визначених для кожного розрізу свердловин. Такі криві були порівняні і проаналізовані окремо для кожної фації.

Визначення умов та генезису осадонагромадження, а також порівняльний аналіз літофаціальних та колекторських характеристик можуть мати важливе значення для точного визначення перспектив нафтогазоносності досліджуваної території.

Ключові слова: генезис осадових порід, пористість, товщина відкладів, потік, бар, фація.