UDC 550.83:553.98
DOI: http://doi.org/10.17721/1728-2713.110.02

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STUDY OF SEDIMENT GENESIS BASED ON BOREHOLE LOGGING DATA AND EVALUATION OF THE RELATIONSHIP BETWEEN SEDIMENT GENESIS AND RESERVOIR PROPERTIES

(*Представлено членом редакційної колегії д-ром геол. наук, проф. О.М. Карпенком*)

Background. *The Bulla-Deniz field is one of the most promising from the point of view of oil and gas content in the South Caspian Trough. It is located in the northern part of the Baku Archipelago. Despite the fact that the Bulla-Deniz field, characterized by deep wells, has been in operation since 1975, it has not yet been fully explored. Its geological structure has been studied on the basis of complex geophysical exploration works, structural mapping, exploration drilling and production material. The wells have penetrated the sediments of the Productive Series (PS) only up to the upper part of the Kirmaky Suite. Deposits of the Sub-Kirmaky and Qala Suites have not been penetrated in the field area. Oil and gas content within the Bulla-Deniz field is confined to horizons V, VII and VIII of the PS. VIII horizon, according to Apsheron stratigraphic scheme, corresponds to the Upper Kirmaky Sandy complex and is represented by two sandy-silty strata in the bottom and top parts. Horizon VII corresponds to the Fasila Suite and is composed predominantly of sandstones. The V horizon (in accordance with the Apsheron section corresponds to horizons VIII–IX) is represented by alternation of thick layers of sand, sandstone and clay.*

Such major issues as assessment of sedimentation conditions and genesis of the rocks forming these horizons, as well as establishing the relationship between the genetic origin of rocks and their reservoir properties, remain relevant at present.

One of the most urgent goals today is to conduct geophysical research related to oil and gas field prospecting and exploration using more advanced methods and introducing new technologies. It allows to determine the internal structure of oil and gas bearing structures and oil-bearing horizons with greater accuracy on the basis of field geophysics data.

Methods. *Due to intensification of prospecting and exploration works aimed at identification of oil and gas bearing formations and horizons of Productive Series, there is need to apply modern methodological and interpretative approaches – tectonic, eustatic, stratigraphic and genetic analyses – as an alternative to expensive drilling. From this point of view, determination of sedimentation conditions of horizons and reservoir complexes of the Productive Series is important for a targeted search for oil and gas deposits not associated with anticlinal traps, identification of stratigraphic, lithologic, paleogeomorphologic, epigenetic and other hard-to-recognize traps, as well as for assessment of oil and gas bearing prospects of the studied region and analysis of the distribution of potentially interesting objects within sedimentary basins.*

On the other hand, there is a definite relationship between the lithological and mineralogical composition of rocks and their reservoir properties, which ultimately manifests itself in the petrophysical characteristics of reservoir rocks. For this reason, the study of the relationship between the genesis of sediments of the productive strata and their reservoir properties makes it possible to predict the patterns of distribution of sandy material over the area, as well as to draw conclusions about the nature of the development of porous and permeable zones. This, in turn, has important scientific and practical significance for assessing the nature of changes in the reservoir properties of sedimentary rocks.

It is from this point of view that the article proposes a rational approach to identifying the relationship between the genetic origin of sediments and reservoir properties of rocks on the basis of quantitative interpretation of complex well data using the "quantitative model of log facies". Horizons V, VII and VIII of the Productive Series of the Bulla-Deniz field were considered as the object of the research. The results of the research are presented and analyzed from the point of view of assessing the genesis of sediments and their influence on the filtration-capacitance properties of rocks.

Results. *Using a quantitative log facies model, lithofacies interpretation of well sections X1, X2, X3, X4 and X5 of the conditional area of the Bulla-Deniz field was carried out. During the analysis alluvial stream facies, bars, coastal-beach and shelf (coastal-marine) formations were identified. The relationship between the genetic origin of sedimentary rocks and their reservoir properties was established. The results showed that the physical properties of the studied rocks are directly related to their genesis. Histograms reflecting changes in average relative sandiness and porosity, as well as variation in the thickness of stream facies, bars and beach deposits along the sections of the studied wells were also constructed.*

Conclusions. *A comprehensive lithofacies and seismic facies analysis was carried out for the Bulla-Deniz field using data from wells X1–X5 and seismic profiles. Facies of stream, bar, coastal-beach, and shelf origin were identified. A clear relationship was established between the genetic origin of sediments and their reservoir properties, particularly in stream and bar facies, where effective porosity and sand body thickness show strong correlation. In contrast, coastal-beach facies exhibit chaotic variation, lacking such correlation. Additionally, seismic facies analysis within the Lower Pliocene interval revealed fluvial, marine, and mixed sedimentation environments, indicating a complex depositional history in the study area.*

Keywords: *facies composition, stream, bar, coastal-beach environment, reservoir properties.*

Background

The South Caspian Trough is a regional depression with a complex geological and tectonic structure, active geodynamic processes and is characterized by high seismicity and widespread development of mud volcanoes. According to gravimagnetic, seismic and electrical studies, the thickness of the sedimentary cover within the trough exceeds 25 km and is divided into blocks by regional tectonic faults.

The South Caspian Trough (SCT) is extremely rich in hydrocarbon resources. Over the last 25 years Azeri, Gunashli, Chirag, Bahar, Bulla-Deniz, Shahdeniz, Umid, Babek, Apsheron, Karabakh and other fields have been discovered here. The conducted geological and geophysical studies allow us to forecast the presence of significant oil and gas reserves also in the promising structures of the region. In the near future there are very encouraging prospects for discovery of rich oil and gas deposits in deeper horizons of the South Caspian Trough (Khalilova, & Seyidov, 2023; Ahmedov, & Khalilova, 2024).

Since most of the identified oil and gas fields within the South Caspian Trough are associated with terrigenous deposits, successful discovery of new deposits depends largely on determining the genesis of these terrigenous formations. Establishing the conditions of sedimentation in the terrigenous strata allows us, first of all, to predict the distribution patterns of sand bodies, to reach conclusions about their morphology, as well as to study the development patterns of porous-permeable strata (Kerimova et al., 2024; Kerimova, & Samadzadeh, 2023; Samadzadeh, 2023).

Determination of rock genesis and analysis of reservoir properties by area are important for both assessment and clarification of oil and gas content of the territory. In this connection, the study of the relationship between the genesis of the sediments of the productive strata and their reservoir characteristics contributes to the identification of patterns of distribution of sandy material, as well as the formation of ideas about the nature of porous and permeable intervals in the section (Seidov et al., 2024; Akhmedov, & Aghayeva, 2022).

The Bulla-Deniz field, located in the northern part of the Baku Archipelago, was chosen as the object of study (Fig. 1). From the tectonic point of view, the structure is elongated in the northwest-southeast direction, its length is about 27 km and width is about 8 km. The main object of field development are horizons V, VII, VIII of the Productive Series, as well as clay deposits of the Upper Kirmaky Subhorizon (Pogorelova, & Abdulla-zada, 2024).

At the Bulla-Deniz field, oil and gas content is confined to horizons V, VII and VIII of the Productive Series. Horizon VIII, according to Apsheron dissection, corresponds to the Upper Kirmaky Sandy complex. Two sandy-siltstone beds are distinguished in the bottom and top parts of the horizon. Horizon VII (corresponding to the Fasila Suite according to the Apsheron section) is composed mainly of sandstones (about 70 %) and has an average thickness of 94 meters. In the section it is divided into two objects – VII_{upper} and VII_{lower}, with thicknesses of 47 m and 25 m, accordingly. These objects are separated by an interbed clay interval with a thickness of about 22 m. Horizon V (in accordance with the Apsheron partitioning corresponds to horizons VIII–IX) is represented by alternating thick layers of sand, sandstone and clay. Sands and sandstones are characterized by fine and fine grain size and contain carbonate material. The total thickness of the horizon is 129 meters. Within the horizon there are two objects – V_{upper} and V_{lower}, 21 m and 30 m thick respectively, between which there is a 21-meter thick clay interbed. Within the field, oil-and-gas bearing capacity has been identified in these horizons of the Productive Series. However, in the southwestern section of the structure these horizons have not been penetrated in wells, and, accordingly, their oil and gas content remains unknown. No commercial oil and gas deposits were recorded above the V horizon in the geological section of the field (Salmanov et al., 2023).

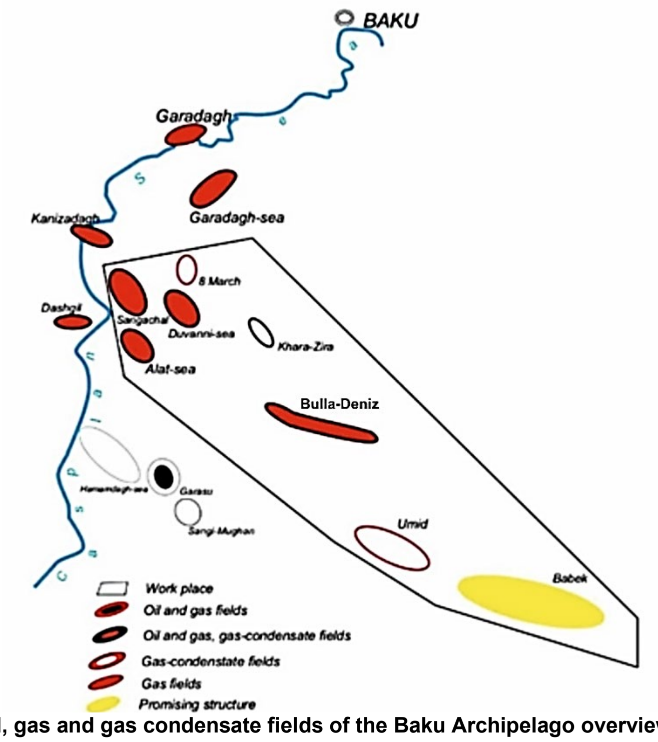

Fig. 1. Oil, gas and gas condensate fields of the Baku Archipelago overview diagram

It is well known that oil and gas reservoir forecasting is largely based on facies analysis of rock formation conditions. In this connection, the reconstruction of conditions of deposit accumulation in the Productive Series by the method of logging facies in the study area remains relevant (Nasibova et al., 2024).

The purpose of this paper aims to study the genetic origin of sediments of horizons V (according to Balakhany Suite lithostratigraphy – horizons VIII–IX), VII horizon (Fasila Suite) and VIII horizon (Upper Kirmaky Sandy complex) of the Productive Series of the Bulla-Deniz field, selected as the object under study. The relationship between the genetic origin of sediments and their reservoir properties is also analyzed, with a comparative analysis of these horizons. In addition, the objective is to construct three-dimensional spatial models showing the variation of the following parameters for horizons V, VII and VIII over the study area: stream facies, bar and coastal-beach conditions, sandiness, effective porosity, estimated resistivity and volumetric clay content.

Methods

The Bulla-Deniz fold is complicated by longitudinal and transverse tectonic faults and is dissected into a number of distinct blocks. In the northeastern flank there are 6 transverse faults, which divide it into 6 tectonic blocks. Two transverse faults are recorded in the southwestern flank, resulting in its subdivision into 3 blocks. Taking into account that the Bulla-Deniz field is a complex oil and gas bearing zone with numerous tectonic faults, each of the identified blocks can be considered as a potential oil and gas trap. In this regard, the article uses integrated logging data from five wells located along one geological profile within the Bulla-Deniz field (Fig. 2) (Kerimova, & Samadli, 2024).

Based on the results of quantitative interpretation of complex data for each well, the method of "quantitative logging facies model" was applied, which allowed us to study the conditions of sedimentation and facies origin of deposits of horizons and formation complexes within the study area.

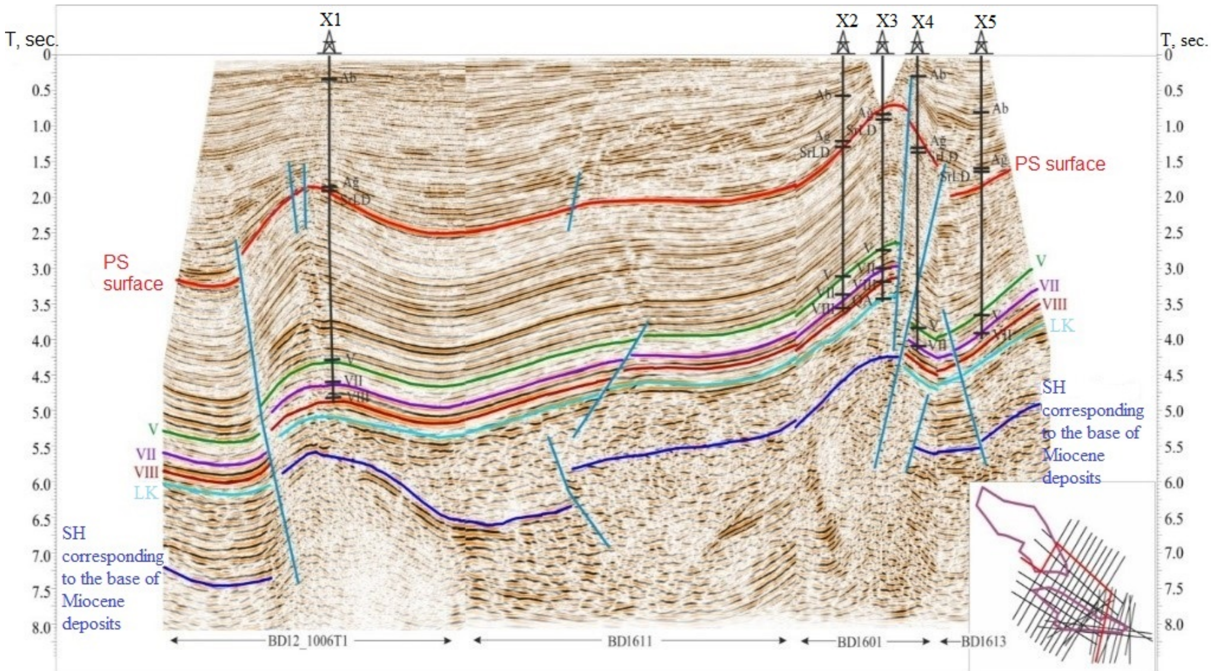

Fig. 2. Stratigraphic referencing of seismic horizons in the Bulla-Deniz field

Based on the results of quantitative interpretation of complex well data, the values of effective porosity and volumetric clay content of the formations were determined and histograms of their changes by depth were constructed. Histograms of effective porosity and volumetric clay content variation by depth were used to analyze and interpret the genetic origin of sediments (Fig. 3).

Results

As can be seen from the figure, in well X1 (conventionally accepted) of the Bulla-Deniz field, the genetic origin of sediments varies by depth (from top to bottom) as follows: In the 5650–5700 m depth interval, a facies of bar origin is identified; In the interval 5700–5713 m – a facies of coastal-beach conditions; In the interval 5713–5829 m a successive change of facies of stream, coastal-beach zone and bar is traced; In the 5829–6100 m interval, there is an alternation of stream, bar, coastal-beach zone, shelf and again coastal-beach facies. This facies succession reflects the dynamics of sedimentation and indicates a complex sedimentary history within the study area.

In the conditional well X2 in the depth interval 5568–5742 m, a sequential change of facies (from top to bottom) is observed in the following order: bar – stream – stream – coastal-beach zone – stream – bar – stream – bar. In the interval 5742–6018 m, alternation of facies of bar, coastal-beach, shelf, coastal-beach and again shelf origin is recorded. In the deeper interval – 6018–6346 m – the sequence of facies is traced: stream – coastal-beach zone – bar – coastal-beach zone – shelf – coastal-beach zone. As for conditional well X3, in the interval 5080–5164 m there is an alternation of facies of coastal-beach and bar origin, in the interval 5164–5555 m – facies of coastal-beach zone prevail, in the interval 5555–5626 m – facies of bar origin, and in the interval 5626–5900 m the facies of coastal-beach genesis prevail again. This facies variability reflects the complex morphodynamics of the sedimentary environment within the Bulla-Deniz field and indicates the alternation of different sedimentary settings within one stratigraphic section.

According to the results of interpretation of conditional well X4, the facies sequence in the section is as follows: In the interval 4832–4909 m from top to bottom there is an alternation of facies: coastal-beach zone – stream – coastal-beach zone – stream – coastal-beach zone – stream. In the interval 4909–5146 m, a change of facies is recorded: bar – coastal-beach zone – bar – coastal-beach zone. In the interval 5146–5388 m the sequence: stream – coastal-beach zone – stream – coastal-beach zone is recorded. In the interval 5388–5669 m the sequence: bar – coastal-beach zone – bar – coastal-beach zone – stream – coastal-beach zone is observed. In the interval 5669–5849 m the following facies alternation is observed: bar – stream – coastal-beach zone – stream. Such a detailed facies interpretation indicates a complex sedimentary environment characterized by frequent change of facies environments (bar bodies, streams, beach and shelf zones), which directly affects the variability of reservoir properties of rocks within the section.

According to the results of interpretation of the section of conditional well X5, the facies composition of sediments at depth (from top to bottom) changes as follows: In the interval 5016–5166 m, a successive facies change is observed: shelf (coastal) environment – coastal-beach zone – bar formation. In the 5106–5387 m interval, the following alternation is traced: stream – coastal-beach zone – stream – bar – stream. In the interval 5387–5610 m, facies of shelf zone, coastal-beach zone and bar formation are recorded. In the 5610–5944 m interval, a facies sequence is observed: stream – coastal-beach zone – stream – coastal-beach zone. Such facies change indicates alternation of conditions with different hydrodynamic activity and energy of sedimentation, which has a significant impact on the lithology of rocks, their porosity-permeability properties and, accordingly, on the prospects of oil and gas bearing within this area.

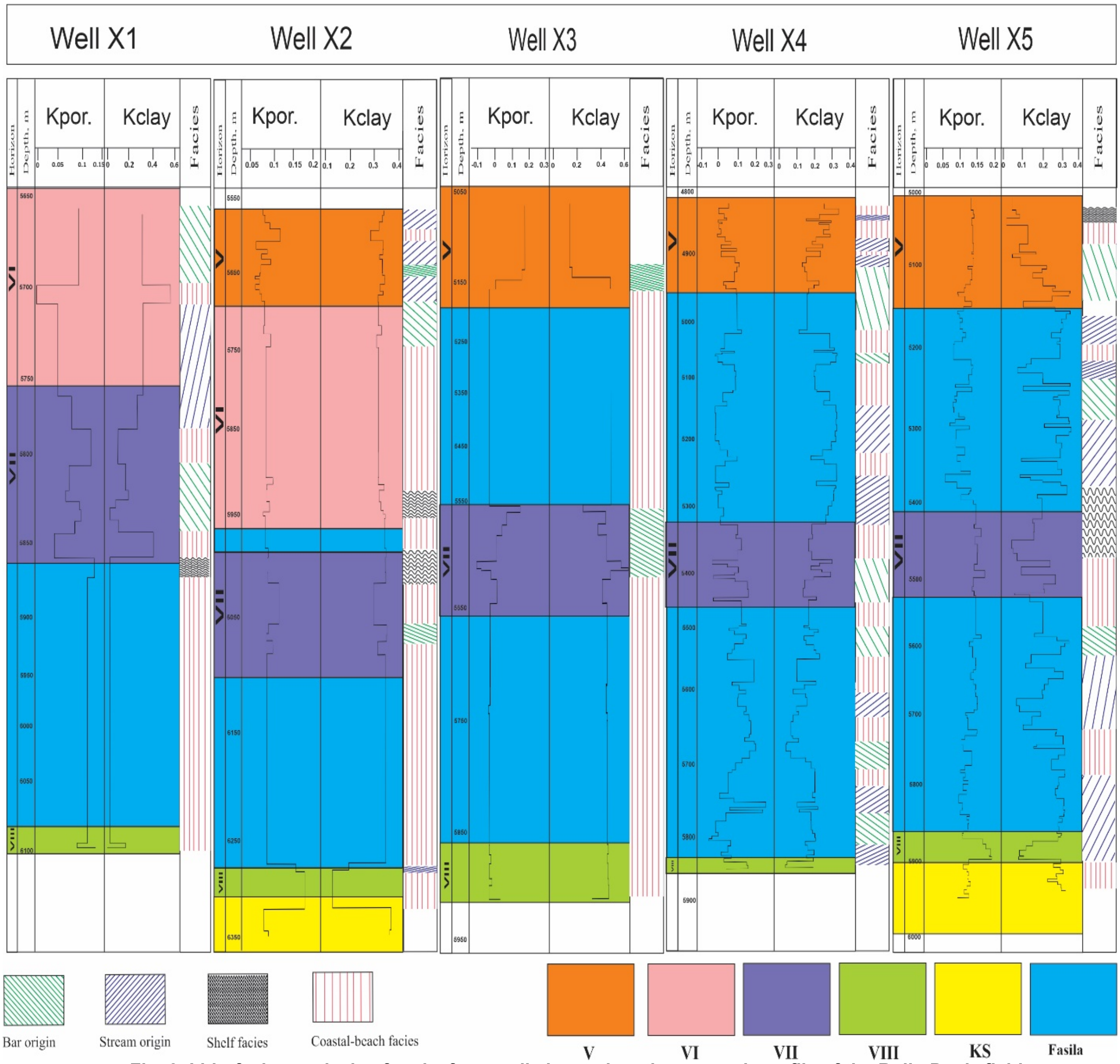

Fig. 3. Lithofacies analysis of rocks from wells located on the research profile of the Bulla-Deniz field

As part of this research, the following parameters were calculated for each well section in intervals where stream, bar, and coastal-beach facies were identified: mean value of effective porosity of the formations ($K_{por.mean}$), average thickness of sandy ($H_{clay.ave.}$) and clayey ($H_{sand.ave.}$) beds, relative thickness of sandy bodies ($H_{rel.sand}$). For each of these parameters, graphs of variation by well were plotted. For this purpose, within each well section, in the intervals of distribution of stream, bar, coastal-beach and shelf facies, the reservoir thickness within the total reservoir thickness (H_1) was calculated using the following formula (1):

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

here H_1 – thickness of the reservoir part by horizon; $H_{clay.ave.}$– average thickness of clay layers; $H_{sand.ave.}$– average thickness of sandy strata.

Using formula (2), the relative reservoir capacity by horizon was estimated for stream facies, bars, and coastal-beach conditions:

$$H_{rel.} = H_1/H_t \quad (2)$$

here $H_{rel.}$ – relative reservoir thickness, H_1 – thickness of the reservoir part within the formation, H_t – total thickness of the reservoir within the selected interval (Kerimova, Aliyev 2022; Kerimova, Khalilova, 2020).

Using formula (3) for each well section, they were calculated separately: mean value of effective porosity of formations ($K_{por.mean}$), relative thickness of sand bodies by horizon ($H_{rel.sand}$) in intervals where stream, bar, and coastal-beach facies were identified. The results of these calculations are summarized in Tab. 1.

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

Table 1

Estimation of parameters Hrel.sand, Hstream and Kpor.mean on facies origin of sediments of horizons V, VII and VIII of the Productive Series of the Bulla-Deniz field

Well №	Stream origin facies			Bar origin facies			Coastal-beach origin facies		
	Hrel.sand, m	Kpor.mean	Hbar	Hrel.sand, m	Kpor.mean	Hbar	Hrel.sand,m	Kpor.mean	Hbar
X1	0,632	0,248	97,16	0.489	0.169	28.6	0.633	0,175	70,5
X2	0.545	0.202	55.84	0.554	0.205	22.23	0.563	0.215	93
X3	0.582	0.183	12.66	0.615	0.197	29	0.544	0.186	233
X4	0.612	0.182	75.58	0.496	0.185	89.23	0.586	0.189	33.55
X5	0.534	0.215	180.7	0.537	0.203	120.4	0.622	0.180	109.6

Note: On the basis of the data in Tab. 1, the corresponding graphs reflecting the peculiarities of the parameters variation by wells located on the studied geological profile were constructed (Fig. 4, Fig. 5, Fig. 6).

Based on the comparative analysis of the curves of change of parameters $H_{rel.sand}$, H_{stream} and $K_{por.mean}$ along the studied profile, the following was established: From well X1 towards well X2, there is a general decrease in all three parameters: thickness of the facies of stream origin decreases from 97.16 m to 55.84 m, the relative thickness of sand bodies decreases from 0.532 to 0.545, mean effective porosity decreases from 24.8 % to 20.2 %. In the direction from well X2 to X3: stream facies thickness decreases to 12.6 m, the mean effective porosity decreases to $K_{por.mean}$=18.3 %, in contrast, the relative thickness of sand bodies increases to $H_{rel.sand}$=0.582 m. In the interval from well X3 to X4: the thickness of the facies of stream genesis increases again and reaches H_{stream}=75.58 m, the mean effective porosity continues to decrease to $K_{por.mean}$=18.2 %, relative thickness of sand bodies increases to $H_{rel.sand}$=0.612 m. These changes indicate the variability of sedimentation conditions and reservoir properties along the profile, which indicates the complex facies and lithologic heterogeneity of the studied area of the Bulla-Deniz field.

The section of conditional well X5 shows a significant increase in the thickness of the stream facies, which reaches 180.9 m. At the same time: mean effective porosity is $K_{por.mean}$=21.5 %, relative thickness of sand bodies decreases and makes $H_{rel.sand}$=0.534 m.

When considering all three curves separately, we can conclude that for facies of stream origin, the curves $H_{rel.sand}$ and $K_{por.mean}$ generally follow each other along the profile. This indicates that there is a certain regularity in the variation of these parameters along the profile. Thus, it can be stated that the change in the relative thickness of the sand reservoir ($H_{rel.sand}$) along the profile is, to a large extent, equivalent to the change in the thickness of the stream facies. In other words, the thicker the stream facies, the higher the proportion of sandy material and, consequently, the higher the effective porosity is (Fig. 4). This relationship confirms the importance of facies analysis in predicting reservoir properties and indicates a direct relationship between the genetic type of sediments and their reservoir potential.

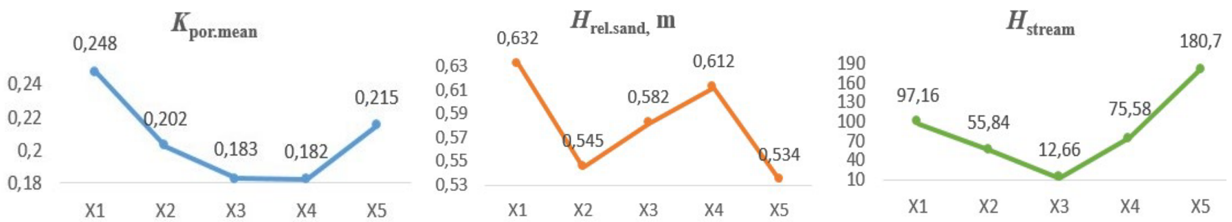

Fig. 4. Comparative plot of variation of $K_{por.mean}$, $H_{rel.sand}$ and H_{stream} parameters along the profile for the stream origin facies

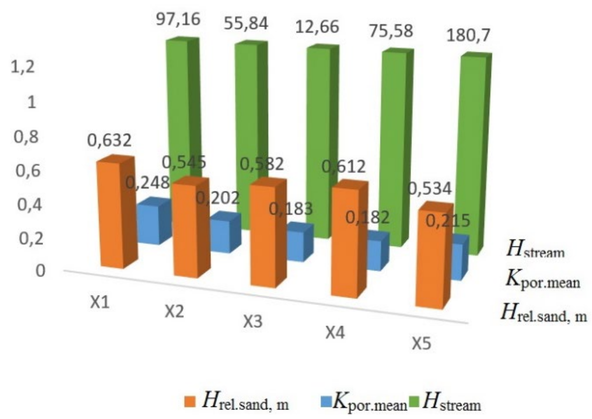

Fig. 5. Histogram of the distribution of parameters $H_{rel.sand}$, $K_{por.mean}$ and H_{stream} across wells for the stream origin facies

The growth of $K_{por.mean}$ (mean effective porosity) may indicate the compaction of rocks under the action of gravity, as well as the heterogeneity of reservoirs. Analyzing all three curves separately, we can conclude that for the stream facies, the plots of $H_{rel.sand}$ (relative sand reservoir thickness) and $K_{por.mean}$ plotted along the profile are mutually correlated and follow a similar trend. This indicates that there is a consistent pattern between the sandiness of rocks and their filtration-capacity properties within the stream sediments.

Histograms of the distribution of parameters $H_{rel.sand}$, H_{stream} and $K_{por.mean}$ across wells were constructed (Fig. 5).

Similar studies were also used to determine the intervals of distribution of bar and coastal-beach facies in deposits of V, VII and VIII horizons of the Productive Series for each well section along the selected profile. The following parameters were calculated for each interval where these facies were identified: mean value of effective porosity ($K_{por.mean}$), facies thickness (respectively H_{bar} – for bars and $H_{coast.b.}$ – for coastal-beach deposits), relative thickness of sand bodies ($H_{rel.sand}$). On the basis of these data, plots of parameter variation along the profile (Figs. 6 and 7), histograms of parameters distribution along wells (Figs. 8 and 9) were plotted.

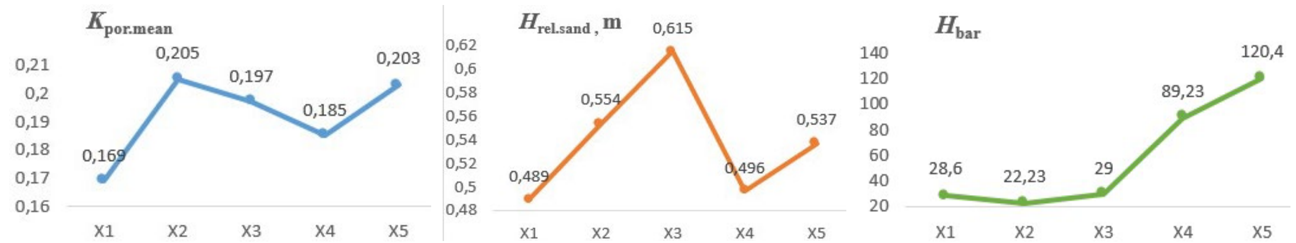

Fig. 6. Comparative plot of variation of parameters $K_{por.mean}$, $H_{rel.sand}$ and H_{bar} along the profile for facies of bar origin

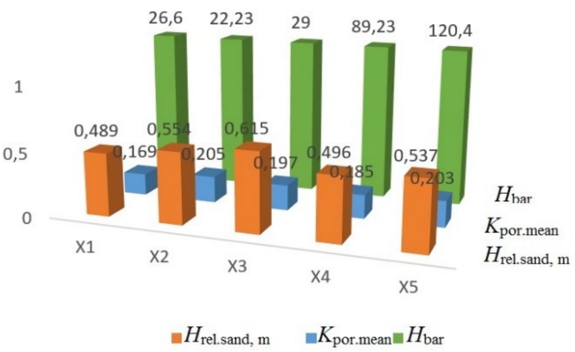

Fig. 7. Graph of distribution of parameters $H_{rel.sand}$, $K_{por.mean}$ and H_{bar} across wells for the bar origin facies

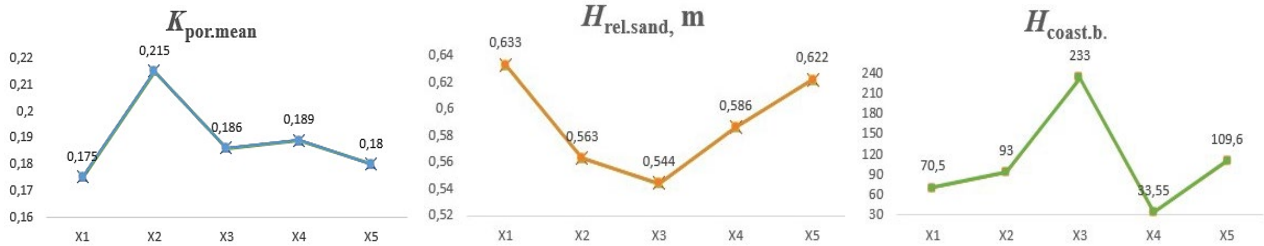

Fig. 8. Comparative plot of variation of parameters $K_{por.mean}$, $H_{rel.sand}$ and $H_{coast.b.}$ along the profile for the facies of coastal-beach origin

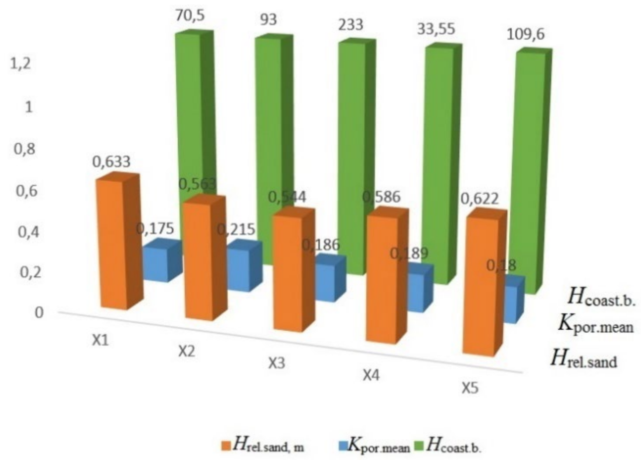

Fig. 9. Graph of distribution of parameters $H_{rel.sand}$, $K_{por.mean}$ and $H_{coast.b.}$ across wells for the facies of coastal-beach origin

Based on the comparative analysis of the graphs of variation of parameters $H_{rel.sand}$, H_{bar} and $K_{por.mean}$ along the profile in the intervals where bar facies are identified, the following was established (Fig. 6): In the direction from well X1 to X2, there is an increase in the values of mean effective porosity ($K_{por.mean}$) and relative thickness of sand bodies ($H_{rel.sand}$), while the thickness of the bar facies itself (H_{bar}) decreases. This indicates that the relative reservoir capacity varies with the combination of effective porosity and facies thickness. From X2 to X3, the bar facies thickness increases slightly, but the effective porosity decreases to $K_{por.mean}$=19.7 %, while $H_{rel.sand}$ continues to increase, reaching 0.615 m. Further along the profile from X3 to X4, the thickness of the bar facies continues to increase and

ISSN 1728-2713 (Print), ISSN 2079-9063 (Online)

reaches H_{bar}=89.23 m. However, a decrease in both effective porosity ($K_{por.mean}$=18.5 %) and relative thickness of sand bodies ($H_{rel.sand}$=0.495 m) is observed in this interval.

In the section of conditional well X5 the mean value of effective porosity and relative thickness of sand bodies in comparison with well X4 increased and amounted, respectively: $K_{por.mean}$=20.3 %, $H_{rel.sand}$=0.537 m. The growth of $K_{por.mean}$ value is explained, first of all, by compaction of rocks under the action of gravity and heterogeneity of reservoirs. Analyzing all three graphs separately, we can conclude that for the bar facies of the profile, the curves describing $H_{rel.sand}$ and $K_{por.mean}$ generally follow the same trend. This indicates that there is a definite regularity between the parameters reflecting the filtration-capacitance properties of the rocks. In well X5, the thickness of the bar facies also reached the maximum value – H_{bar}=120.4 m. Analysis of Figure 7 shows: the highest value of mean effective porosity ($K_{por.mean}$=20.5 %) was recorded in well X2, the minimum value ($K_{por.mean}$=16.9 %) is in well X1. In terms of bar facies thickness: the maximum is in well X5 (H_{bar}=120.4 m), the minimum is in well X1 (H_{bar}=28.6 m). Relative thickness of sand bodies ($H_{rel.sand}$): the maximum value is observed in X3 ($H_{rel.sand}$=0.615 m), the minimum is at X1 ($H_{rel.sand}$=0.489 m).

Based on the comparative analysis of the graphs of variation of the parameters $H_{rel.sand}$, $H_{coast.b.}$ and $K_{por.mean}$ along the profile in the intervals where facies of coastal-beach origin were identified, the following was established (Fig. 8). In the direction from well X1 to X2, there is a decrease in the value of relative thickness of sand bodies ($H_{rel.sand}$), while the mean effective porosity ($K_{por.mean}$) and facies thickness ($H_{coast.b.}$) increase. This indicates that the change in relative reservoir capacity in this interval is a function of the combination of porosity and total facies thickness. In the interval from X2 to X3, the thickness of the coastal-beach facies slightly increases, but the effective porosity decreases to $K_{por.mean}$=18.6 % and $H_{rel.sand}$ also decreases to 0.544 m. In the interval from X3 to X4, the thickness of the coastal-beach facies decreases to $H_{coast.b.}$=53.55 m, while the effective porosity slightly increases to $K_{por.mean}$=18.9 %, and the relative thickness of sand bodies also increases, reaching $H_{rel.sand}$=0.586 m.

In the section of the conditional well X5, compared to X4, there is observed: decrease in average effective porosity to $K_{por.mean}$=18 %, increase in the relative thickness of sand bodies to $H_{rel.sand}$=0.622 m. At first sight, this may seem paradoxical, but the decrease in porosity may be due to compaction of rocks under gravity, and the increase in sandiness may be due to greater thickness of sand beds or their better sorting and stability along the section. Thus, an increase in $K_{por.mean}$ values in other sections may indicate the expansion of pore space and relative homogeneity of reservoirs, while in this case we observe the opposite trend. It follows that there is a definite but indirect dependence between $K_{por.mean}$ and $H_{rel.sand}$ parameters – the character of their change can be both coordinated and multidirectional, depending on sedimentation conditions, lithology and textural properties of rocks. In addition, the relative thickness of the sandy reservoir ($H_{rel.sand}$) varies naturally with the total thickness of the layer, which indicates the importance of taking stratigraphic thickness into account when interpreting reservoir properties.

Analysis of Fig. 9 shows the following key patterns for intervals with coastal-beach facies: the mean effective porosity ($K_{por.mean}$) reaches its highest value in well X2 at 21.5 %, and the lowest value in well X1 – 17.5 %. The thickness of the coastal-beach facies reaches its maximum in well X3 – $H_{coast.b.}$=233 м, and the minimum in well X4 – $H_{coast.b.}$=38,55 м. The relative thickness of sand bodies ($H_{rel.sand}$) shows the highest value in well X1 – 0.633 m, and the lowest value in well X3 – 0.544 m.

Based on the well and seismic data, isopach maps (equal thickness of deposits) and seismofacial maps were also compiled for the interval between the Lower Kirmaky Suite and horizon VII of the Productive Series (Figs. 10 and 11).

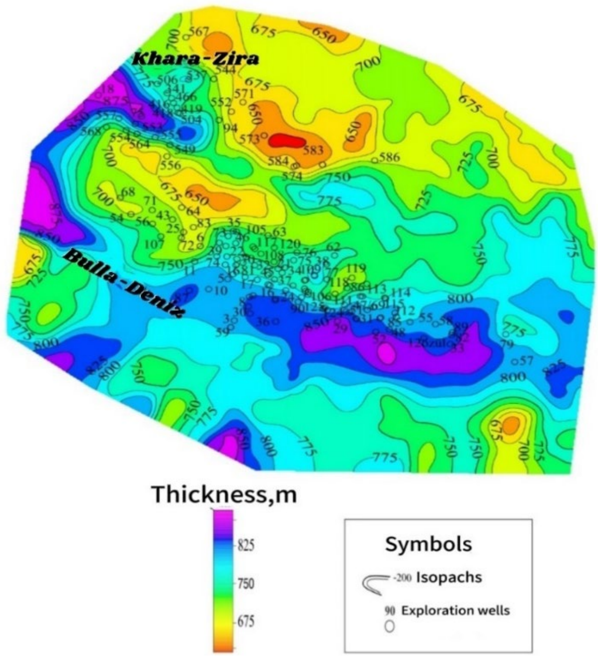

Fig. 10. Map of equal thicknesses (isopach) for the interval between the Lower Kirmaky Suite and horizon VII of the Productive Series

As can be seen from Figure 10, on the isopach map for horizon VII of the Productive Series, the thickness of the studied interval varies within 500–900 m. The most pronounced pattern is a decrease in sediment thickness from the south-western (SW) part of the area toward the north-east (NE). At the same time, localized increases in thickness are observed in the area of wells No. 29, No. 33 and No. 52, which may be related to tectonic or sedimentary features such as localized troughs or zones of enhanced sedimentation.

As can be seen from Fig. 11, three seismic facies were identified on the seismic facies map for the study interval: SF1, SF2, and SF4. SF1 corresponds to shelf conditions of sedimentation, where stable, relatively uniform seismic reflections are observed. SF2 is characterized by low amplitude, which is probably related to changes in the lithological composition of rocks or variability in sedimentation conditions (e.g., transitional environments between the shelf and coastal zone). SF4 represents a facies formed under conditions of high-energy sedimentation, which is reflected in sharper, more contrasting seismic responses. All identified seismic facies were traced over the area on the basis of the seismic facies map, which allows us to conclude about facies zonality and dynamics of sedimentation processes within the studied interval.

The transition from one facies to another may be associated with changes in depositional conditions and a variety of lithologic compositions of rocks. As a result of such facies and lithologic transitions within the studied interval, an increase in sandiness toward the north-eastern (NE) part of the study area is observed. This may indicate the displacement of zones of more intense sedimentation or the stream of detrital material from active feeding sources in this direction.

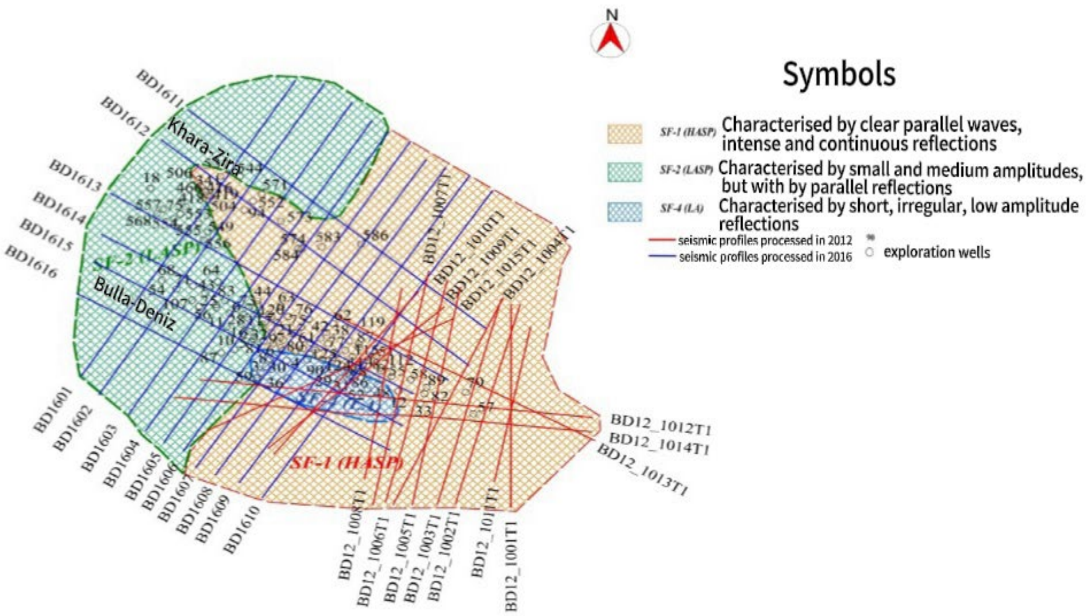

Fig. 11. Seismic facies map for the interval between the Lower Kirmaky Suite and horizon VII of the Productive Series

Discussion and conclusions

A lithofacies analysis of sedimentary rocks from sections of conventionally accepted wells X1, X2, X3, X4 and X5 in the Bulla-Deniz field was performed using a quantitative logging facies model. As a result of the analysis, facies of stream, bar, coastal-beach and shelf origin were identified.

The relationship between the genetic origin of sediments of horizons V, VII and VIII of the Productive Series of the Bulla-Deniz field and their reservoir properties has been studied. According to the results of the research it was found that physical properties of rocks directly depend on the conditions of their formation and genetic type.

a) According to the graph of variation in the values of the parameters $H_{rel.sand}$, H_{stream} and $K_{por.mean}$ for the facies of stream origin along the studied profile, it can be seen that the curves $H_{rel.sand}$ and $K_{por.mean}$ generally repeat each other. This, in turn, indicates that there is a definite relationship between the relative thickness of sand beds and effective porosity. It was found that the value of the relative thickness of sand beds varies in proportion to the total thickness of the sedimentary complex belonging to the same facies and the effective porosity of the corresponding bed. Thus, the higher the porosity and thickness of the facies, the greater the specific thickness of sand reservoirs, which emphasizes the importance of a comprehensive assessment of lithofacies parameters in predicting reservoir properties.

b) For the facies of bar origin along the studied profile there is a general trend of increasing values of $K_{por.mean}$ (mean effective porosity) in all wells. However, the analysis shows that the $H_{rel.sand}$ (relative sand reservoir capacity) and H_{bar} (bar facies capacity) curves generally follow each other.

c) In facies of coastal-beach origin, there is no clear pattern between the parameters $H_{rel.sand}$, $H_{coast.b.}$ and $K_{por.mean}$. Changes in these parameters are chaotic and independent of each other, indicating that there is no stable relationship between facies thickness, sandiness and effective porosity under these conditions.

For horizons V, VII and VIII of the Productive Series of the Bulla-Deniz field, histograms were constructed to show the variation in the following parameters by wells: facies of stream, bar and coastal-beach origin, relative sandiness ($H_{rel.sand}$), mean effective porosity ($K_{por.mean}$).

Based on the dynamic and kinematic characteristics of the seismic wave field observed on time sections, three seismic facies (SF1, SF2, and SF4) were identified within the deposits of the Lower Pliocene – in the interval from the Lower Kirmaky Suite (LKS) to horizon VII. As a result of the seismic facies analysis, sedimentation conditions were studied, which allowed us to conclude about the diversity of genesis of deposits of the Lower Pliocene complex within the study area. The sediments were found to be of fluvial, marine and mixed origin, indicating a change of sedimentation environments during the geologic history of the section formation.

Author's contribution: Kİfayet Kerimova – writing, investigation, methodology, formal analysis, conceptualization, data curation, supervision; Lala Khalilova – investigation, writing, visualization, data curation, formal analysis, supervision.

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Отримано редакцією журналу / Received: 17.04.25
Прорецензовано / Revised: 29.05.25
Схвалено до друку / Accepted: 30.06.25

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ВИВЧЕННЯ ГЕНЕЗИСУ ОСАДОВИХ ПОРІД ЗА ДАНИМИ КАРОТАЖУ СВЕРДЛОВИН ТА ОЦІНКА ВЗАЄМОЗВ'ЯЗКУ МІЖ ГЕНЕЗИСОМ ОСАДІВ І КОЛЕКТОРСЬКИМИ ВЛАСТИВОСТЯМИ

В с т у п . ***Родовище Булла-Деніз є одним із найперспективніших щодо нафтогазоносності у Південнокаспійському прогині. Воно розташоване в північній частині Бакинського архіпелагу. Незважаючи на те, що родовище Булла-Деніз, яке розкрите глибокими свердловинами, експлуатується з 1975 року, воно ще не було повністю вивчене. Його геологічна будова досліджувалася на основі комплексу геофізичних методів, структурного картування, пошукового буріння та матеріалів із видобутку. Свердловини пройшли лише до верхньої частини Кірмакинської світи в межах Продуктивної товщі (ПТ). Відклади Підкірмакинської та Ґалинської свит не були розкриті в межах родовища. Нафтогазоносність родовища Булла-Деніз приурочена до горизонтів V, VII та VIII ПТ. Горизонт VIII, згідно з Апшеронською стратиграфічною схемою, відповідає Верхньокірмакинському піщаному комплексу й представлений двома шарами піщано-алевритових відкладів у нижній і верхній частинах. Горизонт VII відповідає світі Фасіла і переважно складається з пісковиків. Горизонт V (відповідно до Апшеронського розрізу – горизонти VIII–IX) представлений чергуванням потужних шарів піску, пісковика та глини.***

Такі важливі питання, як оцінка умов осадконакопичення та генезису порід, що формують ці горизонти, а також встановлення зв'язку між генетичним походженням порід і їх колекторськими властивостями, залишаються актуальними.

Одним із найбільш актуальних завдань є проведення геофізичних досліджень, пов'язаних з пошуком і розвідкою нафтових і газових родовищ із використанням більш сучасних методів і впровадженням нових технологій. Це дає змогу з більшою точністю визначити внутрішню будову нафтогазоносних структур і нафтоносних горизонтів на основі польових геофізичних даних.

М е т о д и . ***У зв'язку з активізацією пошукових і розвідувальних робіт, спрямованих на виявлення нафтогазоносних утворень і горизонтів Продуктивної товщі, виникла потреба у застосуванні сучасних методологічних і інтерпретаційних підходів – тектонічного, евстатичного, стратиграфічного та генетичного аналізів – як альтернативи дорогому бурінню. З цього погляду важливим є визначення умов осадконакопичення горизонтів і колекторських комплексів ПТ для цілеспрямованого пошуку покладів, не пов'язаних з антиклінальними пастками, ідентифікації стратиграфічних, літологічних, палеогеоморфологічних, епігенетичних та інших складно розпізнаваних пасток, а також для оцінки нафтогазоносного потенціалу регіону та аналізу поширення перспективних об'єктів у межах осадових басейнів.***

З іншого боку, існує певний зв'язок між літолого-мінералогічним складом порід і їх колекторськими властивостями, що в кінцевому підсумку проявляється у петрофізичних характеристиках колекторських порід. Саме тому дослідження взаємозв'язку між генезисом відкладів продуктивної товщі та їх колекторськими властивостями дає змогу прогнозувати закономірності поширення піщаного матеріалу на території, а також робити висновки про характер розвитку пористих і проникних зон. Це, у свою чергу, має важливе наукове та практичне значення для оцінки мінливості колекторських властивостей осадових порід.

З цього погляду у статті запропоновано раціональний підхід до виявлення зв'язку між генетичним походженням відкладів і колекторськими властивостями порід на основі кількісної інтерпретації комплексних даних каротажу свердловин за допомогою "кількісної моделі лог-фацій". Як об'єкт дослідження розглянуто горизонти V, VII та VIII Продуктивної товщі родовища Булла-Деніз. Результати дослідження наведено й проаналізовано щодо оцінки генезису відкладів та їх впливу на фільтраційно-ємнісні властивості порід.

Р е з у л ь т а т и . ***За допомогою кількісної лог-фаціальної моделі проведено літолого-фаціальну інтерпретацію розрізів свердловин X1, X2, X3, X4 та X5 умовної ділянки родовища Булла-Деніз. У процесі аналізу виділено фації алювіальних потоків, мілин, прибережно-пляжні та шельфові (морські) утворення. Встановлено взаємозв'язок між генетичним походженням осадових порід і їх колекторськими властивостями. Результати показали, що фізичні властивості досліджуваних порід безпосередньо пов'язані з їхнім генезисом. Крім того, побудовано гістограми, що відображають зміни середньої відносної піщаності й пористості, а також варіації товщини фацій потоків, мілин і пляжних відкладів по розрізах досліджуваних свердловин.***

В и с н о в к и . ***Проведено комплексний літолого-фаціальний і сейсмо-фаціальний аналіз для родовища Булла-Деніз на основі даних свердловин X1–X5 та сейсмічних профілів. Виділено фації потоків, мілин прибережно-пляжного і шельфового походження. Встановлено чіткий зв'язок між генетичним походженням осадів і їх колекторськими властивостями, особливо у фаціях потоків і мілин, де ефективна пористість і товщина піщаних тіл мають тісний кореляційний зв'язок. Натомість прибережно-пляжні фації демонструють хаотичну варіативність без такої кореляції. Крім того, сейсмо-фаціальний аналіз у межах нижньопліоценового інтервалу виявив флювіальні, морські й змішані середовища осадконакопичення, що свідчить про складну історію осадконакопичення в досліджуваному районі.***

К л ю ч о в і с л о в а : ***фаціальний склад, потік, мілина, прибережно-пляжне середовище, колекторські властивості.***

Автори заявляють про відсутність конфлікту інтересів. Спонсори не брали участі в розробленні дослідження; у зборі, аналізі чи інтерпретації даних; у написанні рукопису; в рішенні про публікацію результатів.

The authors declare no conflicts of interest. The funders had no role in the design of the study; in the collection, analyses or interpretation of data; in the writing of the manuscript; or in the decision to publish the results.