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Lithofacies analysis of the Productive Series deposits in the Bulla-Deniz oil and gas condensate field (Azerbaijan)

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The study of the Bulla-Deniz Field by geological and geophysical methods began in the 1950-sand continues up today. Since the oil-and-gas bearing objects of the field have a complex geological setting at considerable depth, their penetration, sampling and development are one of the most important problems of today. Therefore, a detailed study of the geological structure of the field is very relevant.

The object of our investigation is the Bulla-Deniz Field, located in the north-western part of the Baku Archipelago. Exploration works revealed here oil-and-gas condensate bearing successions of V, VII and VIII horizons of the Productive Series. The objective of the study was to refine the geological structure and depositional conditions of these Productive Series horizons as well as to assess their reservoir properties based on well log data.

Sequence stratigraphy is an important method in geological and geophysical research. This method can be used to improve significantly the prediction of the studied fields, as well as to reveal unconventional reservoir types. The facies analysis, one of the stages of sequence stratigraphic analysis, is applied for studying the facies predictions from log data. Since the beginning of the oil production era, the main objects of hydrocarbon exploration have been medium and large anticlinal traps. These have been actively developed; as a result, their potential as primary exploration targets is being gradually exhausted. Therefore, the main exploration objects are non-anticlinal traps, low-amplitude uplifts, and stratigraphic wedges. The modern integrated approach allows tracing the conditions of the formation of sedimentary basins and improving the very understanding of sedimentation conditions.

We applied to the sequence stratigraphic analysis, the Emery method, and the cyclostratigraphic analysis to the study area. Sedimentation conditions were established and analysed, and lithofacies analysis was carried out. Hydrocarbon-rich reservoirs were found to be predominantly in the low sea-level tract and, slightly less frequently, in the transgressive system tract. In most cases, deposits formed during the aggradation and retrogradation periods have good reservoir properties.

Key word: sequence stratigraphy, non-anticlinal trap, system tract, depositional environment, reservoir, horizon.

Introduction. The oil-and-gas bearing objects in the Bulla-Deniz structure lie at great depths and in complex geological conditions. It has made the penetration, testing, and exploitation of these objects one of the most important tasks of our time. Due to the high prospectivity of the research direction, the mentioned structure is in the focus of the strategic development plan of the Azerbaijan republic. In recent years, large-scale drilling operations have created conditions for core sampling and geophysical well logging (WL) in drilled exploration wells.

Many studies have been devoted to the study of the geological structure and oil-and-gas bearing complexes of the Bulla-Deniz

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Field [Yusubov, Guliev, 2015; Shikhmammadova, Yusubov, 2016; Ahmadov, Miriyeva, 2020; Shekerov, Abbasov, 2022; Salmanov et al., 2023; Pogorelova, Abdulla-Zada, 2024; Ismayilov et al., 2024; Kerimova, Samadli, 2024; Nasibova et al., 2024]. These works mainly focus on the study of the geological structure of the deposit and the reservoir properties of Early Pliocene deposits. For instance, [Yusubov, Guliev, 2015] explores the possibility of reconstructing paleohydrodynamic conditions and determining the genesis of the Fasila Suite deposits based on the interpretation of electric WL data from the Garadagh, 8 March, Sangachal-Deniz, Duvanny-Deniz, Khara-Zira Adasi, and Bulla-Deniz Fields.

The study by T.N. Shikhmammadova and N.P. Yusubov [Shikhmammadova, Yusubov, 2016] is devoted to the identification of the main lithotypes of the geological section and the construction of petrophysical models for horizons V and VII of the Productive Series within the Sangachal-Deniz—Bulla-Deniz uplift zone, based on the processing and interpretation of geophysical WL data. This work presents a synthesis of the geological properties of the section and reveals patterns of their variation in the three-dimensional space.

In another study focused on the Bulla-Deniz area, [Ahmadov, Miriyeva, 2020] examine the seismic attribute analysis aimed at refining the geological structure of the Lower Pliocene deposits.

The study by Kh.I. Shekerov and J.S. Abbasov [Shekerov, Abbasov, 2022] is dedicated to the reservoir properties of near-surface rocks within the Sangachal-Deniz—Bulla-Deniz anticlinal zone based on core data. The authors investigate rocks of various grain-size compositions and construct depth-related parameter variation plots.

In the works of Salmanov et al. [2023] and Ismayilov et al. [2024], the sections devoted to the Bulla-Deniz Field present the geological and production data, the field's geological, tectonic, and lithofacial features, as well as a detailed analysis of development indicators.

The study by E. Pogorelova and M. Abdulla-Zada [Pogorelova, Abdulla-Zada, 2024] analyses the hydrocarbon-bearing complexes and the lithostratigraphic structure and evaluates the lithological composition and petrophysical characteristics of the Pliocene deposits of the Bulla-Deniz Field based on geophysical and geological data.

The results of determining the petrophysical parameters of reservoirs in prospective horizons and formations of the Bulla-Deniz Field, based on integrated well data and using Techlog software, are presented in the article by K.A. Kerimova and U.Ya. Samadli [Kerimova, Samadli, 2024].

Finally, the study by G. Nasibova et al. [2024] assesses the geological risk associated with variations in reservoir parameters — such as porosity, permeability, heterogeneity, thickness, fracturing, and seal integrity — as a function of burial depth across various fields of the Baku Archipelago, including Bulla-Deniz.

To summarise, despite the considerable number of works devoted to the geological features of the Productive Series in the Bulla-Deniz area and adjacent fields, the origin (genesis) of these deposits remains insufficiently understood. Many articles highlight the complexity of the facies structure and the variability of reservoir properties, indicating heterogeneous depositional conditions.

Further investigation of the depositional conditions of the Productive Series remains a crucial task, particularly with the application of modern methods. This will not only contribute to a more accurate understanding of the geological structure of the study area but also make hydrocarbon prospectivity assessments more robust for the region as a whole.

A distinctive feature of the present study is the integrated application of a sequence stratigraphic approach, along with facies and cyclostratigraphic analysis methods, based on WL data, aimed at refining the depositional conditions of the reservoir units within the Productive Series.

The object of study was Bulla-Deniz Field, located about 55 km south-east of Baku (Fig. 1). Geophysical works of 1952 confirmed the Bulla-Deniz uplift. In 1965, deep exploration drilling was started at the uplift. The field

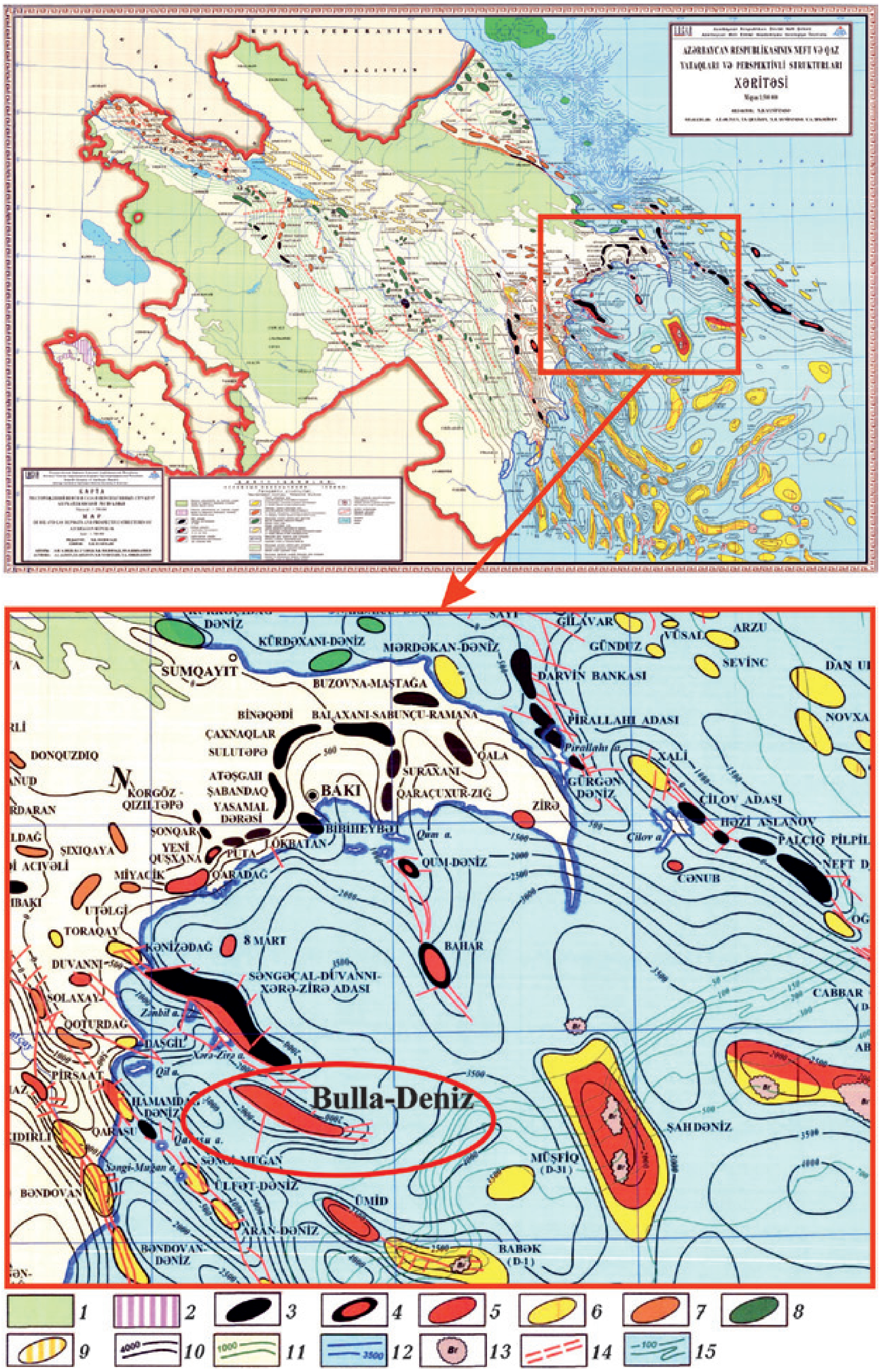

Fig. 1. Bulla-Deniz Field on the map of oil and gas fields in the Baku Archipelago (map of oil and gas deposits and prospective structures of the Republic of Azerbaijan. Editor X.B. Yusifzade. Authors: A.I. Aliyev, I.S. Quliyev, X.B. Yusifzade, Y.A. Shikhaliyev): *1* — Mesozoic deposits outcrop; *2* — Paleozoic deposits outcrop; *3* — oil fields; *4* — oil and gas fields; *5* — gas-condensate fields; *6*—*9* — Prospective Structures (*6* — on Pliocene deposits (based on the seismic survey); *7* — on Paleogene-Miocene deposits (based on the seismic survey); *8* — Mesozoic erosion scarp; *9* — on Pliocene deposits (based on the geological survey)); *10* — hypsometric curves on Productive Series top; *11* — Mesozoic erosion hypsometric curves; *12* — hypsometric curves on Mesozoic seismic horizon; *13* — mud volcanoes (based on the seismic survey); *14* — faults; *15* — isobath.

was put into exploitation in 1975. Its depth varies between 4600 and 5800 m. Gas deposits in the lower part of the structure are limited by a narrow strip of oil belt [Salmanov et al., 2023; Ismayilov et al., 2024].

In the geological section of the study areas, the wells penetrated deposits of the Productive Series, Akchagylian Stage and Quaternary period.

The Bulla-Deniz structure is located in the depression zone between the Sangachal-Khara-Zira Island anticlinal zone in the north-east and the Pirsaat-Sabail anticlinal zone in the south-west. According to structural and seismic exploration data, the Bulla-Deniz structure is a brachianticline extending in the NW and SE directions (Fig. 2).

The uplift has a complex, asymmetric structure. It is complicated by longitudinal and transverse tectonic faults and is divided into a number of tectonic blocks [Salmanov et al., 2023]. Two longitudinal tectonic faults along its strike are observed in the dome part of the fold (Fig. 2, 3). They divide the fold into three parts: the northeastern flank, the central part, and the southwestern flank. As a result, the central part is lowered and the northeastern flank is uplifted relative to the central part and the southwestern flank.

Oil-saturated gas outcrops, oil and gas occurrences, sandstone breccias, and the oil curtain as a result of mud volcanic eruptions have been observed in the Bulla-Deniz area. A large amount of deep drilling has been carried out in the study area, finding the oil and gas condensate fields in the V, VII, and VIII horizons of the PS. Deposits of the Kirmaky Suite (KS), Lower Kirmaky (LK), and Qala Suites (QaS) of the Productive Series in the Bulla-Deniz Field area have not been penetrated.

The Bulla-Deniz structure, with an abnormally high reservoir pressure in the Baku Archipelago, provides most of the republic's gas, domestic and exported. In recent years, active production of gas and gas condensate from depths corresponding to VII—VIII horizons of PS in wells № X2, X4, and X5 drilled at the Bulla-Deniz Field indicates high hydrocarbon reserves.

The objective of the study was to identify genetically related facies within the chronostratigraphic boundaries and to clarify their depositional environments.

Methods. As is known, classical stratigraphic methods do not suit practical problems of geology, as they lack resolution and require complex studies and additions. The biostratigraphic method supplemented by the paleoenvironmental method allows comparison of relatively large stratigraphic subdivi-

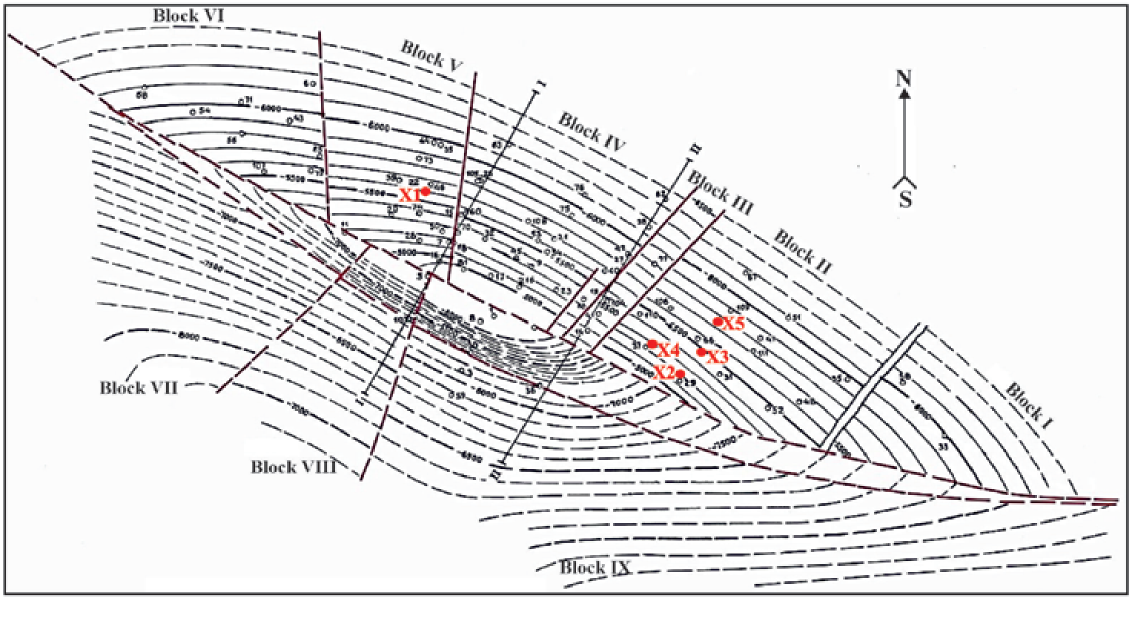

Fig. 2. Structural map of the top of the VII horizon of the Productive Series. Bulla-Deniz Field [Salmanov et al., 2023].

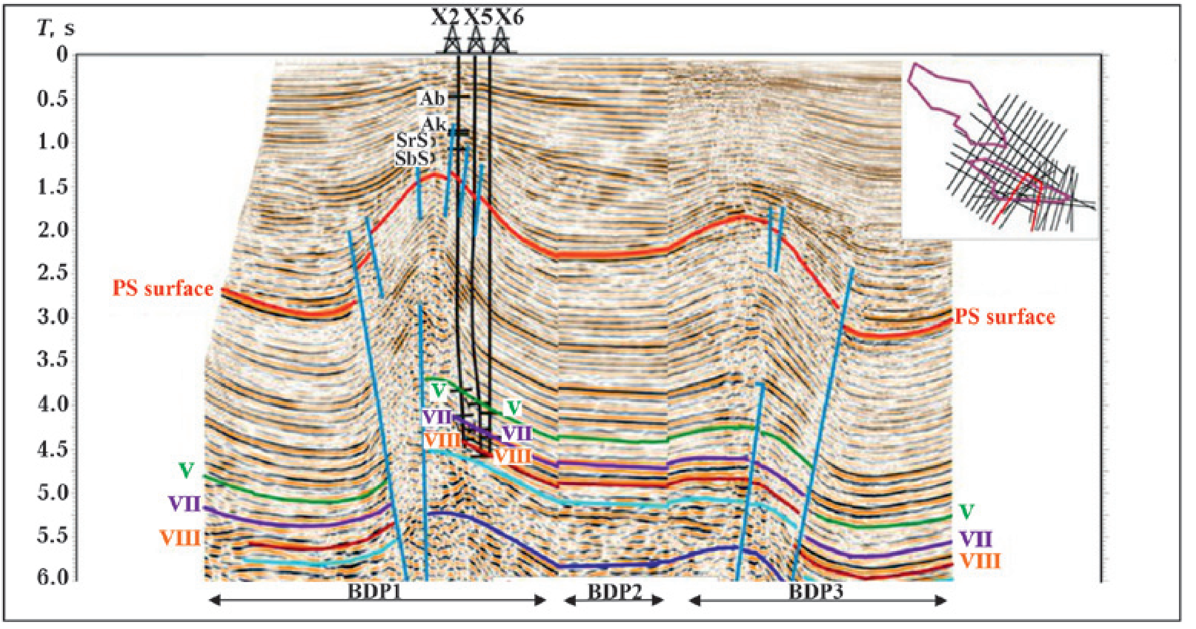

Fig. 3. Correlation of seismic horizons to wells (Compiled by SOCAR). BDP1 —Profile1 of Bulla-Deniz; BDP2 — Profile 2 of Bulla-Deniz; BDP3 — Profile 3of Bulla-Deniz; Ab — Absheron stage (Quarternary); Ak — Akchagyl stage (Upper Pliocene); SrS —Surakhani suite of Productive Series; SbS — Sabunchi suite of Productive Series; PS surface — Productive Series surface; V, VII, VIII—V, VII, and VIII horizons of the Productive Series.

sions. However, this is not sufficient to solve current problems. The modelling of sedimentary bodies required by modern applied geology requires detailed 3-dimensional stratigraphic correlation and detailed description and clear delineation of geological bodies at the reservoir level. In this connection, a new scientific trend — sequence stratigraphy — has been rapidly developing over the last two decades. Recently, the technique has been widely used to study the structure of the Early-Pliocene PS [Mamedov et al., 2017; Khalilova, Kerimova, 2022; Seidov, Khalilova, 2023; Akhmedov et al., 2024]. For example, the study by Mamedov et al. presents the sequence stratigraphic analysis of the Lower Productive Series deposits in the Northern Absheron uplift zone. The facies analysis of the PS deposits in the Pirallahi area, based on WL data, are discussed by Khalilova and Kerimova. Sequence stratigraphic analysis of the Galmaz area using WL data is the focus of the study by Seidov and Khalilova. The article by Akhmedov et al. analyses the seismic stratigraphic and sequence stratigraphic interpretations aimed at clarifying the genesis of the Qala Suite deposits of the PS in the Hovsan-Zykh area.

Reviewing the published works indicates that research of this kind has not previously been conducted either in the Bulla-Deniz area or nearby within the Baku Archipelago.

In the Bulla-Deniz study area, sequence stratigraphic, facies, and cyclostratigraphic analyses were based on gamma ray log data obtained in wells № X1, X2, X3, X4, and X5. Due to its sensitivity to lithology, high resolution, and continuous recording capability, gamma ray logging is indispensable for identifying facies changes, stratigraphic boundaries, and cyclic variations in sedimentary rocks. It candeeply and accurately interpret the section, making it one of the main tools in modern stratigraphic analysis.

The focus of the investigation was deposits of V, VII, and VIII PS horizons. According to the Apsheron subdivision, the V horizon corresponds to the VIII-IX horizons of the Balakhany Suite, the VII horizon — to the Fasila Suite, and the VIII horizon — to the Upper Kirmaky Sandy Suite.

During the interpretation of gamma ray

logging (GR) curves of all the above wells, sequence boundaries, transgression surfaces, and maximum flooding were identified. The point at which the rate of accommodation space formation due to relative sea level rise exceeds the rate of sedimentation to fill the space is called the transgression surface. As the rate of sea level rise slows, the accommodation space begins to be filled with sediment. This greatest extent of the shoreline is called the surface of maximum flooding. The delineation of these surfaces and boundaries subsequently helps in determining the types of sedimentary system tracts at different depths of the specified wells.

Once sedimentary system tracts were delineated, facies depositional environments were established based on the Emery electrometric models.

The Emery electrometric model (Emery method) is a geophysical method for interpreting WL data, based on the correlation of electrical and gamma-ray logging curves. The method was developed by C. Emery to identify facies zones and stratigraphic cycles. Comparing these curves allows to plot lithofacies changes and enables a qualitative analysis of sedimentary environments.

Based on the models, cyclic types of sedimentary sequences can be distinguished, such as aggradation, progradation, retrogradation, and others. Aggradation is vertical sediment accumulation occurring when the rates of sedimentation and relative sea-level rise are approximately equal. Progradation refers to the seaward advance of the shoreline if sedimentation rates exceed the rate of relative sea-level rise. In stratigraphic sections, it is expressed as a vertical succession of facies transitioning from deeper to shallower water upwards. Retrogradation is a type of sedimentary sequence characterized by landward facies shifts due to a rise in sea level that outpaces sediment supply. In the stratigraphic record, this is reflected by a transition from near shore to deeper-water facies in an upward direction.

Further cyclostratigraphic analysis was based on the changes in the deposits' grain size distribution within the studied PS horizons.

Cyclostratigraphic analysis is a method of stratigraphic interpretation based on the identification of repetitive (cyclic) sedimentary sequences that reflect fluctuations in relative sea level, tectonic activity, and other geological processes. It is used to define stratigraphic cycles, correlate sedimentary sections, and reconstruct depositional environments.

A number of derivative terms have been developed from the concept of cyclicity, including cyclites, procyclites, recyclites, and others.

A cyclite is an elementary cyclic sequence of sedimentary rocks formed as a result of short-term changes in sedimentation conditions. Cyclites may reflect facies transitions from deeper to shallower environments (or vice versa) and serve as indicators of sequential sediment accumulation within stratigraphic sections.

A procyclite (progressive cyclite) represents the retrogradational part of a sedimentary cycle, during which a landward shift of facies is observed. In stratigraphic sections, it is expressed as a transition from coastal or shallow-marine deposits to deeper-water facies. This stage reflects transgression, caused by a rise in relative sea level that exceeds the rate of sedimentation.

A recyclite (regressive cyclite) corresponds to the part of a sedimentary cycle when which facies progressively shift seaward. In the stratigraphic record, this is characterized by an upward transition from the deeper-water to the shallower-water deposits. This stage is associated with marine regression or a sedimentation rate exceeding the rate of sea-level rise.

Here, the reservoir properties of deposits of the studied horizons were also evaluated.

Results. Within the PS of the Bulla-Deniz Field, five productive objects have been identified in the productive section: Upper V, Lower V, Upper VII, Lower VII, and VIII horizons. These deposits are represented by layered, tectonically and lithologically shielded sequences. Only the Upper V horizon shows the presence of gas condensate. The remaining horizons are characterized not only by gas condensate but also oil [Salmanov et al., 2023].

Results of the lithofacies analysis of the deposits of horizon VIII of the Productive Series. According to the sampling and WL data, Horizon VIII is an oil-and-gas bearing one with industrial significance. Lithologically, Horizon VIII, penetrated by numerous wells in the northern part of the Baku Archipelago, is represented by grey fine-grained sand and sandstone with interlayers of clays of total formation thickness in the range of 44—90 m.

Horizon VIII in well № X1 is 21 m thick (Fig. 4). Within the depth interval of 5818—5839 m, three oil-and-gas bearing reservoirs were identified. Porosity of oil-and-gas bearing formations varies within 0.223—0.229. The maximum value of oil-and-gas saturation coefficient K_{og}=0.754 is observed in the middle part of the studied interval represented by the sandstone and siltstone alternation. In Horizon VIII, only the low sea level standing system tract was identified. Against the lowstand system tract, aggradation is predominantly observed. The cylindrical shape of the GR curve observed here is characteristic of sandy deposits that are under high energy conditions of sedimentation. This shape reflects the build-up of sandy material in the indicated system tract. The sedimentation environments identified during aggradation are fluvial and tidal bars. The entire horizon, within which all oil-and-gas bearing facies were identified, covers the lower (initial) part of the procyclite, identified by cyclostratigraphic analysis. This procyclite finds its completion already in the bottom part of the Araliq Suite.

In Horizon VIII of well № X2 within the observed system tract of low sea level stand,

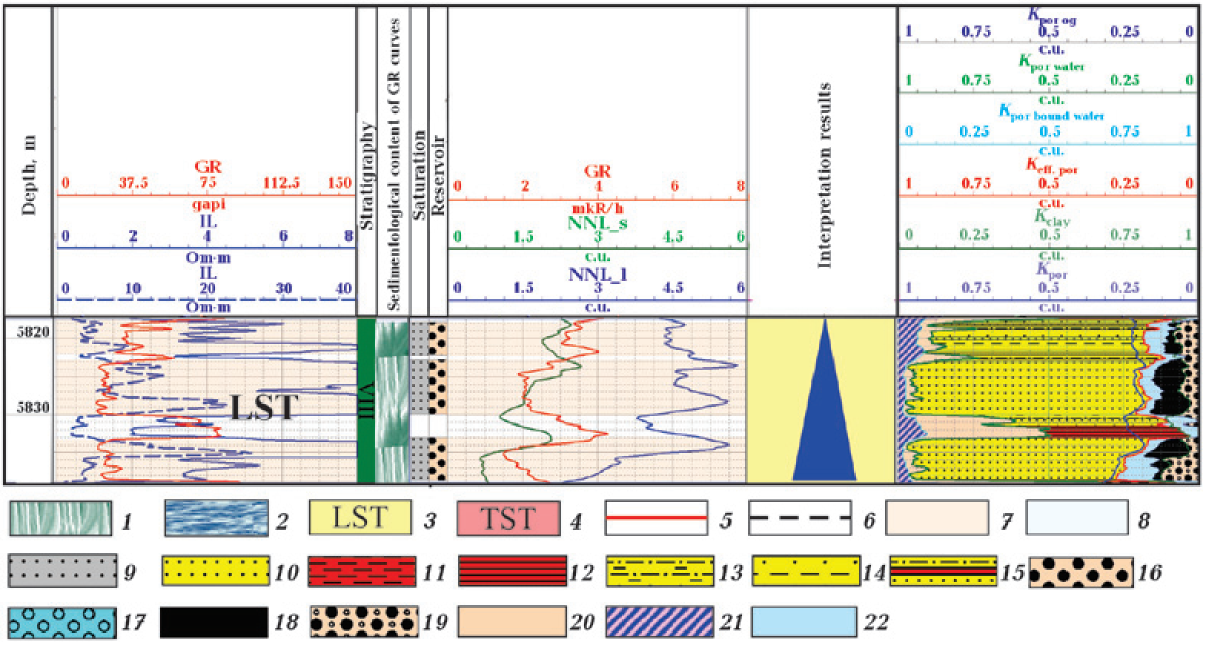

Fig. 4. Interpretation of well sections from the sequence stratigraphy (Bulla-Deniz Field, well №X1, Horizon VIII): *1* — aggradation; *2* — pro-retrogradation; *3* — LST-lowstand system tract; *4* — TST-transgressive system tract; *5* — sequence boundary; *6* — transgression surface; *7* — hydrocarbon-bearing reservoirs; *8* — aquifer reservoirs; *9* — reservoir; *10*—*15* — Lithology (*10* — sandstone, *11* — clay, *12* — clayey sandstone, *13* — silty clayey sandstone, *14* — silty sandstone, *15* — clayey silty sandstone); *16*, *17* — Saturation (*16* — oil-saturated, *17* — water-saturated); *18*—*22* — Total Saturation (*18* — oil-and-gas bearing, *19* — effective porosity, *20* — shaliness, *21* — bound water, *22* — free water); GR (1) — Gamma Ray Logging (while drilling); IL (1) — Small radius Induction Logging; IL (2) — Large radius Induction Logging; GR (2) — Gamma Ray Logging; NNL_l — Neutron-Neutron Logging (long spacing); NNL_s — Neutron-Neutron Logging (small spacing); LL (1) — Three-electrode Lateral Logging; LL (2) — Seven-electrode Lateral Logging; LL (3) — Nine-electrode Lateral Logging; K_{porog} — Porosity coefficient of oil and gas; $K_{por\ water}$ — Porosity coefficient of water; $K_{por\ bound\ water}$ — Porosity coefficient of bound water; $K_{eff.\ por}$ — Effective porosity coefficient; K_{clay} — Clay coefficient; K_{por} — Total porosity.

we identified 1 oil-and-gas bearing and 2 water-bearing reservoirs. The oil and gas saturation coefficient of the oil-and-gas bearing reservoir is K_{og}=0.668. The reservoirs were formed during the aggradation period. As in well № X1, the lower part of the procyclite is distinguished in this interval, within which sand-rich material accumulation is observed.

In the bottom and top parts of Horizon VIII of well № X3 there is a system tract of low sea level stand, while in the middle part there is a transgressive system tract. There are 6 oil-and-gas bearing reservoirs in the studied interval with porosity within the range of 0.154—0.229. The oil-gas saturation coefficient (K_{og}) varies in the range of 0.756—0.854. Oil-and-gas bearing reservoirs were formed predominantly within the lowstand system tract during aggradation. Pro-retrogradation is prominent within the transgressive system tract. Reprocyclites are formed during the pro-retrogradation period. Reprocyclites are characterised by a symmetrical shape of the GR curve. Here, the funnel-shaped shape of the GR curve smoothly transforms into a bell-shaped one. From the bottom and top of the layer to the middle, there is a gradual increase in the grain size of rocks. The depositional environment within Horizon VIII is represented in the top and bottom part by fluvial and tidal bar facies, and in the middle part by coastal bar facies and regressive-transgressive coastal deltaic facies. Cyclostratigraphic analysis identified procyclitesin the bottom and top parts, and reprocyclite in the middle part.

In Horizon VIII of well № X4 a pattern is similar to wells № X1 and № X2. Here 5 reservoirs were identified, 3 of which are oil-and-gas bearing, the rest are water-bearing (Fig. 5).

A pattern similar to the picture in well № X3 is observed in Horizon VIII of well № X5. In this interval 10 reservoirs were identified — 3 oil-and-gas bearing and 7 water-bearing reservoirs. Oil-bearing reservoirs were formed during the aggradation period in the lowstand system tract.

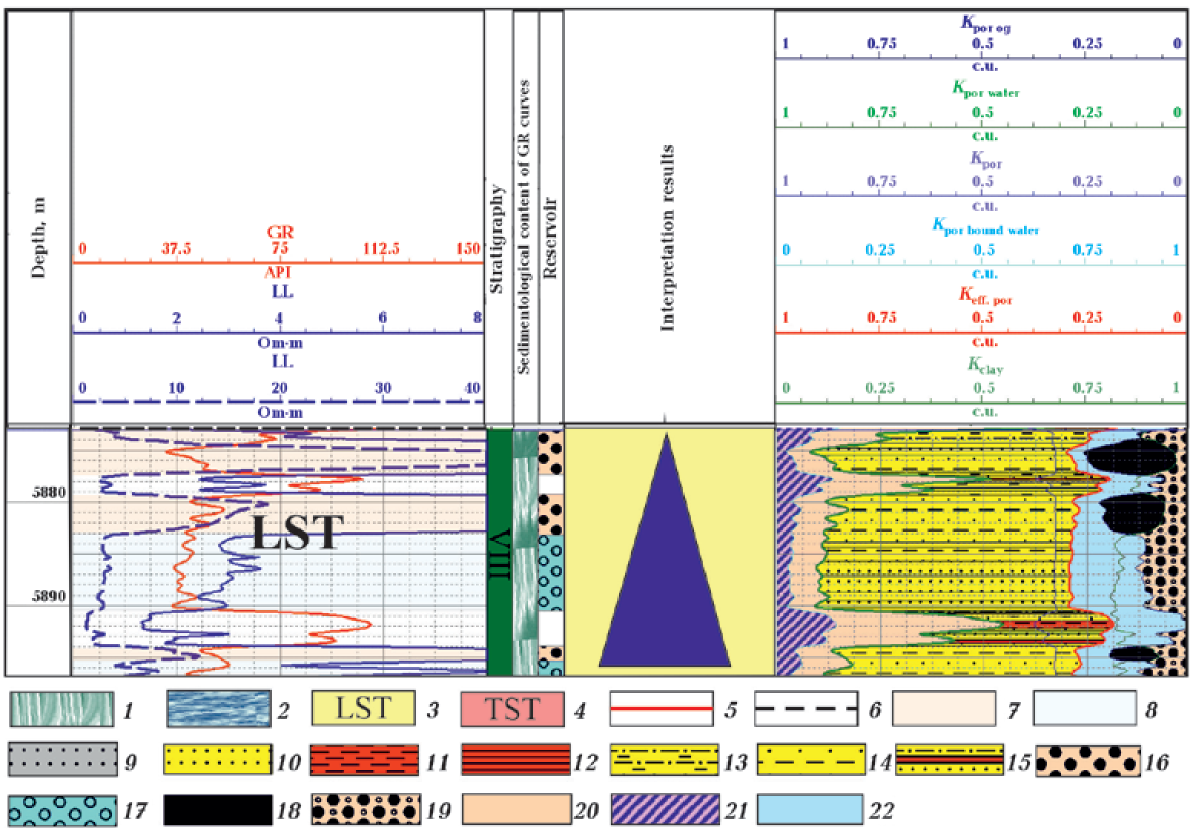

Fig. 5. Interpretation of well sections from the position of sequence stratigraphy. Bulla-Deniz Field, well № X4, Horizon VIII. Symbols as in Fig. 4.

Results of lithofacies analysis of the deposits of Horizon VII of the Productive Series. Horizon VII has been penetrated in many wells. Lithologically, it has alternating grey, medium and fine-grained quartz, weakly cemented sandstones, quartz sands, and dark grey clays (Fig. 6—8). The horizon's thickness and lithological composition are variable. As mentioned above, there are 2 objects in this horizon, namely VII Upper and VII Lower.

In the Horizon VII of well № X1 (Fig. 6), 3 incomplete sequences are observed, within which both lowstand system tracts and transgressive system tracts are distinguished. Ten reservoirs were identified, 9 of which are oil-and-gas bearing. Their porosity varies between 0.187—0.226. The maximum oil saturation coefficient K_{og}=0.81 is observed in the reservoir located at a depth of 5482 m. 8 oil-and-gas bearing reservoirs were formed in the top and bottom parts of the horizon within the lowstand system tract during the aggradation period. These intervals are represented by fluvial and tidal bar facies. During the retrogradation period, according to the Emery method, procyclites are formed. The procyclites are characterised by a bell-shaped anomaly of the GR curve; it reflects marine transgression, weakening of the energy environment of sedimentation and a decrease in the grain size of the rocks from the basement to the top. This interval is represented by the

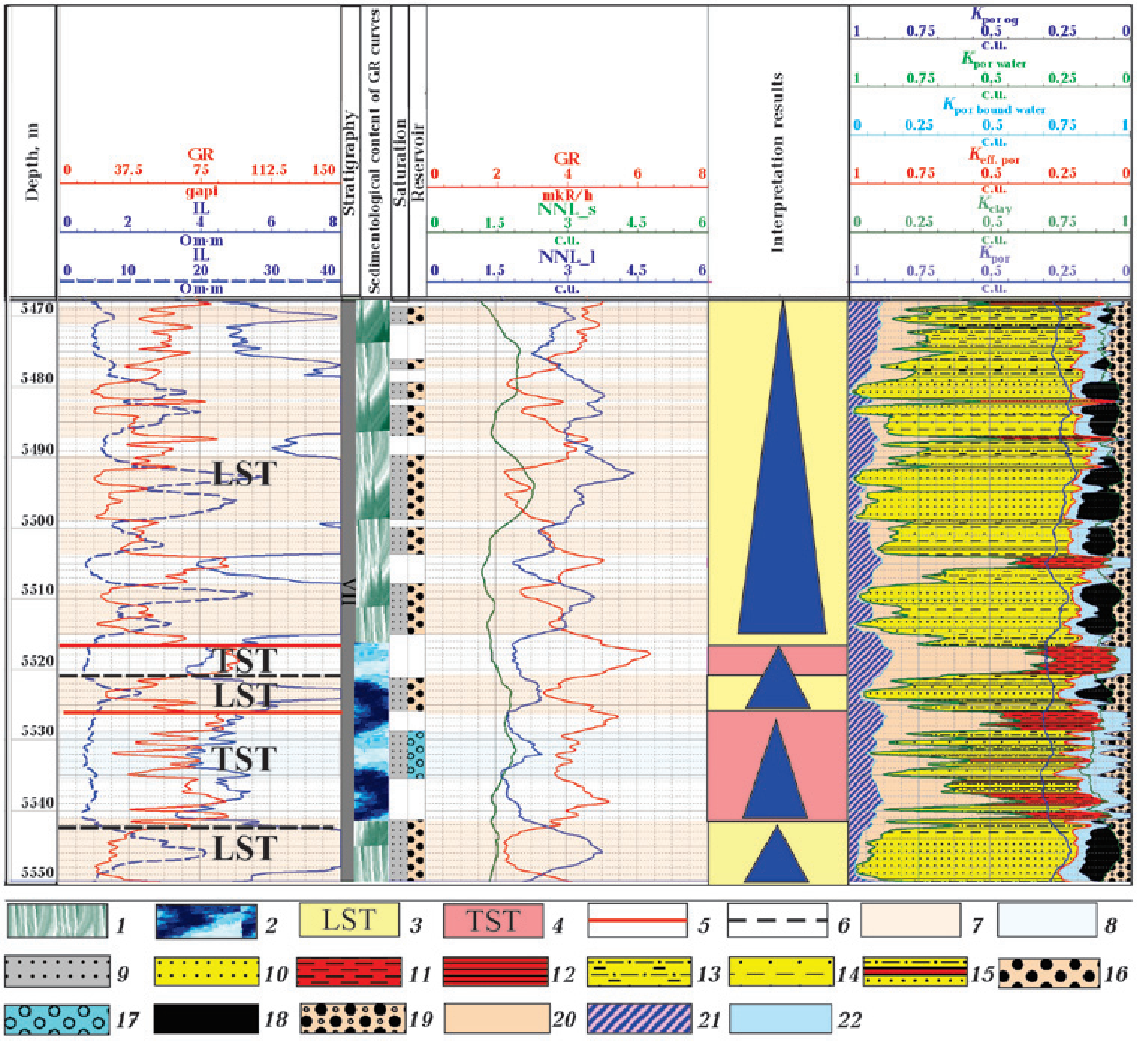

Fig. 6. Interpretation of well sections from the position of sequence stratigraphy. Bulla-Deniz Field, well № X1, Horizon VII. Main symbols see in Fig. 4. *2* — retrogradation.

facies of the estuarine coastal ramparts and the delta front. According to cyclostratigraphy, 4 procyclites were identified here.

In Horizon VII of wells № X2, X3, X4 and X5, similar to well № X1, two system tracts were identified (Fig. 7, 8): a lowstand system tract and a transgressive system tract. In well № X2, 16 reservoirs were identified, 10 of which are oil-and-gas bearing and 6 water-bearing. In well № X3 we identified 18 reservoirs, 17 of which bear oil and gas and one, water. In well № X4, 13 reservoirs (5 oil-and-gas bearing and 8 water-bearing). In well № X5, 10 oil-and-gas bearing reservoirs. In the sections of all wells in Horizon VII, a pattern is similar to well № X1. In wells № X2 and № X3 oil-and-gas bearing reservoirs were formed mainly during aggradation and retrogradation periods. In wells № X3 and № X4, unlike the other wells in the studied interval, progradation periods were also identified, when oil-and-gas bearing horizons were also formed. The recyclites are characterised by a funnel-shaped shape of the GR curve, which reflects the onset of land on the sea. An increase in the grain size of rocks is observed from the bottom to the top. During this period, fluvial facies associated with branched tidal channels are formed.

Results of lithofacies analysis of the deposits of Horizon V of the Productive Series. Horizon V is represented by alternating layers of thick sands, sandstones, and clays. Sand and sandstone are fine, fine-grained, carbonate. Sandiness in the section reaches 46 %. In the Horizon V section, the V Upper and V Lower have good permeability and their thickness is 21 and 30 m, respectively.

Horizon V of well № X1 (Fig. 9) is an 85-m-long formation consisting of silt-clay sandstone with 14 water-bearing layers. Two system tracts were also identified here: low stand and transgressive. A small area of retrogradation in the bottom is replaced by progradation, which in turn changes to aggradation. According to the cyclostratigraphic analysis, procyclites were identified in this horizon within the lowstand system tracts and recyclites in the transgressive systemic tract.

The Horizon V of well № X2 is confined to two system tracts: low sea level and transgressive. There are 21 reservoirs in this formation, only one of which is oil-and-gas bearing. In the studied interval 3 incomplete sequences succeed each other. From bottom to top, aggradation is replaced by pro-retrogradation, which in turn transitions to progradation and further in the horizon top is completed by pro-retrogradation. The oil-and-gas bearing reservoir is located within the lowstand system tract and was formed during progradation in the facies of fluvial fulfilment of branched tidal channels.

In the Horizon V of well № X3, 15 reservoirs were identified, of which only one is oil-and-gas bearing. In the Horizon V of well № X4, 19 reservoirs were delineated, of which only one is oil-and-gas bearing. In the Horizon V of well № X5 (Fig. 10), 14 water-bearing reservoirs were also detected. In the sections of all wells in Horizon V, the pattern is similar to well № X2. The oil-and-gas bearing reservoirs identified in wells № X3 and X4 within the low sea level system tract were formed during the retrogradation period. In well № X2, the oil and gas bearing reservoir was formed during the progradation period.

Cyclostratigraphic analysis made it possible to determine the types of sedimentary rocks and their alternation in the well sections. The facies analysis carried out by the Emery method allowed us to determine the nature of sedimentation of the studied sections. It should be noted that the results of the Emery method are consistent with cyclostratigraphic analysis.

Conclusions. The main accumulations of hydrocarbons in the Productive Series of the Bulla-Deniz Field are in Horizons VIII and VII, which are analogues of the Upper Kirmaky Sandy Suite and the Fasila Suite (according to the Apsheron subdivision). Among the studied wells, Horizon VII accounts for the largest number of oil and gas bearing reservoirs. The vast majority of oil-and-gas bearing reservoirs belong to the lowstand system tract, but there were oil-and-gas bearing reservoirs belonging to the transgressive system tract.

Facies analysis using the Emery method was used to determine the nature of sedimen-

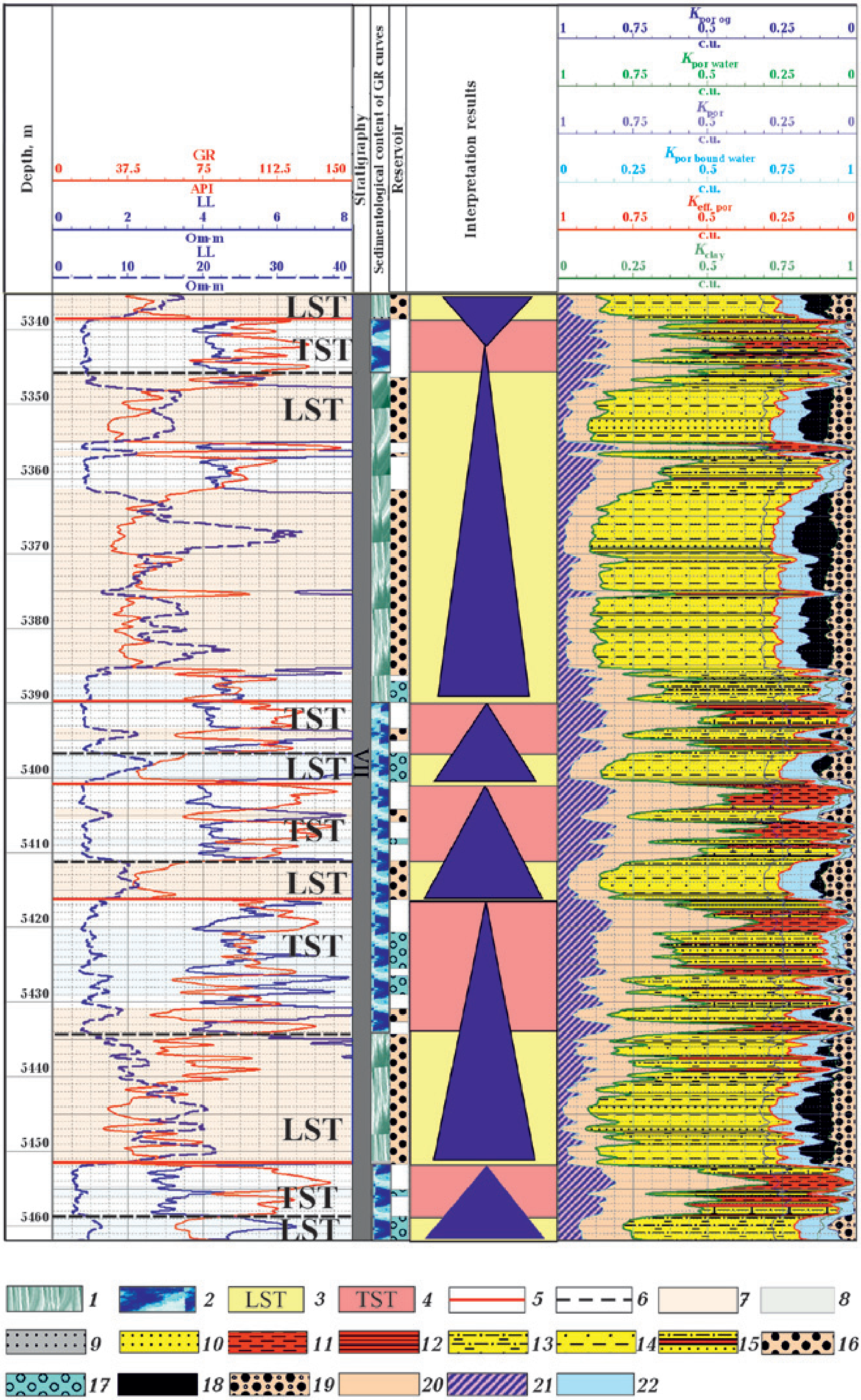

Fig. 7. Interpretation of well sections from the position of sequence stratigraphy. Bulla-Deniz Field, well № X2, Horizon VII. Main symbols as in Fig. 4. *2* — retrogradation.

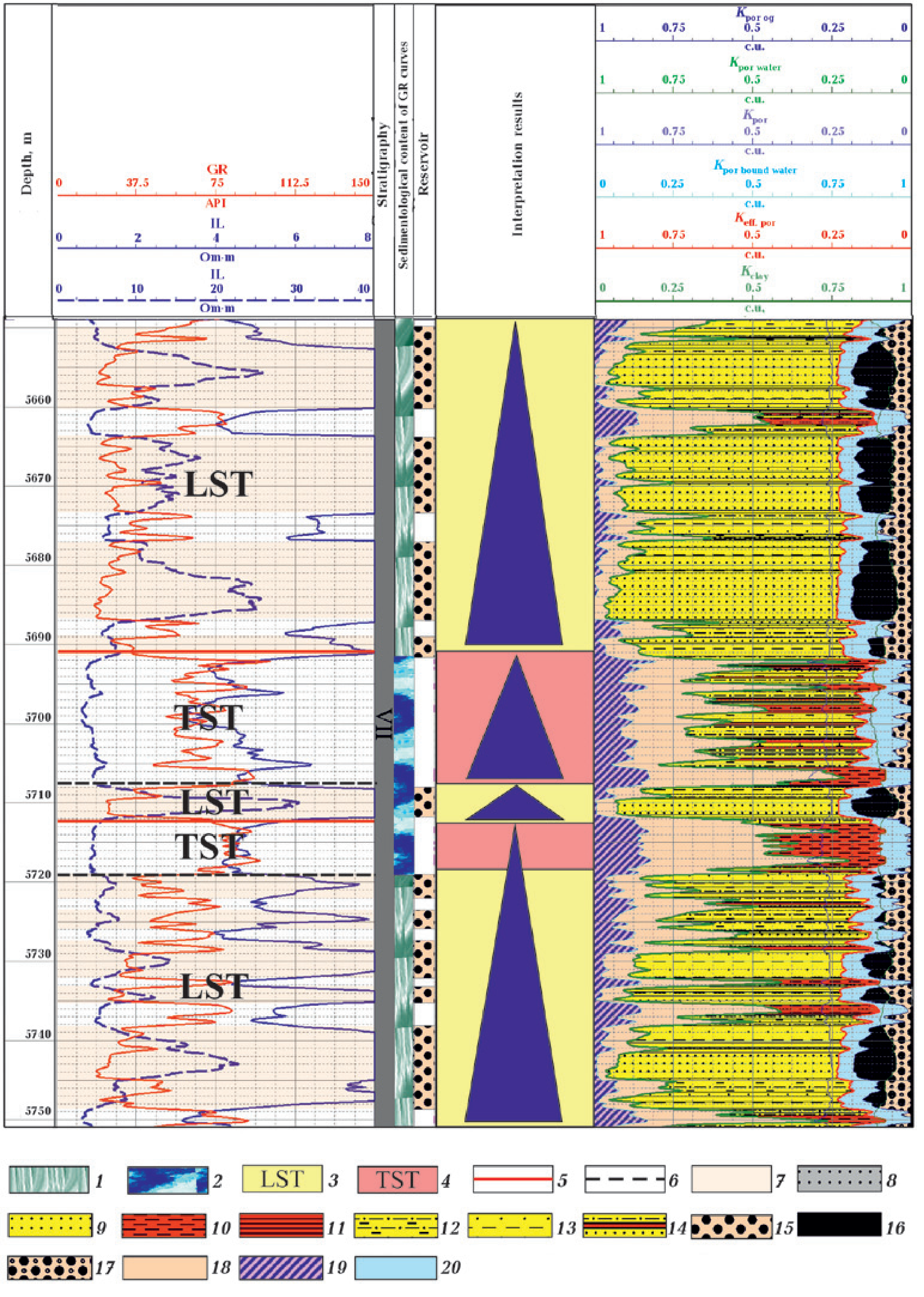

Fig. 8. Interpretation of well sections from the position of sequence stratigraphy. Bulla-Deniz Field, well № X5, Horizon VII. Main symbols as in Fig. 4. *2* — retrogradation.

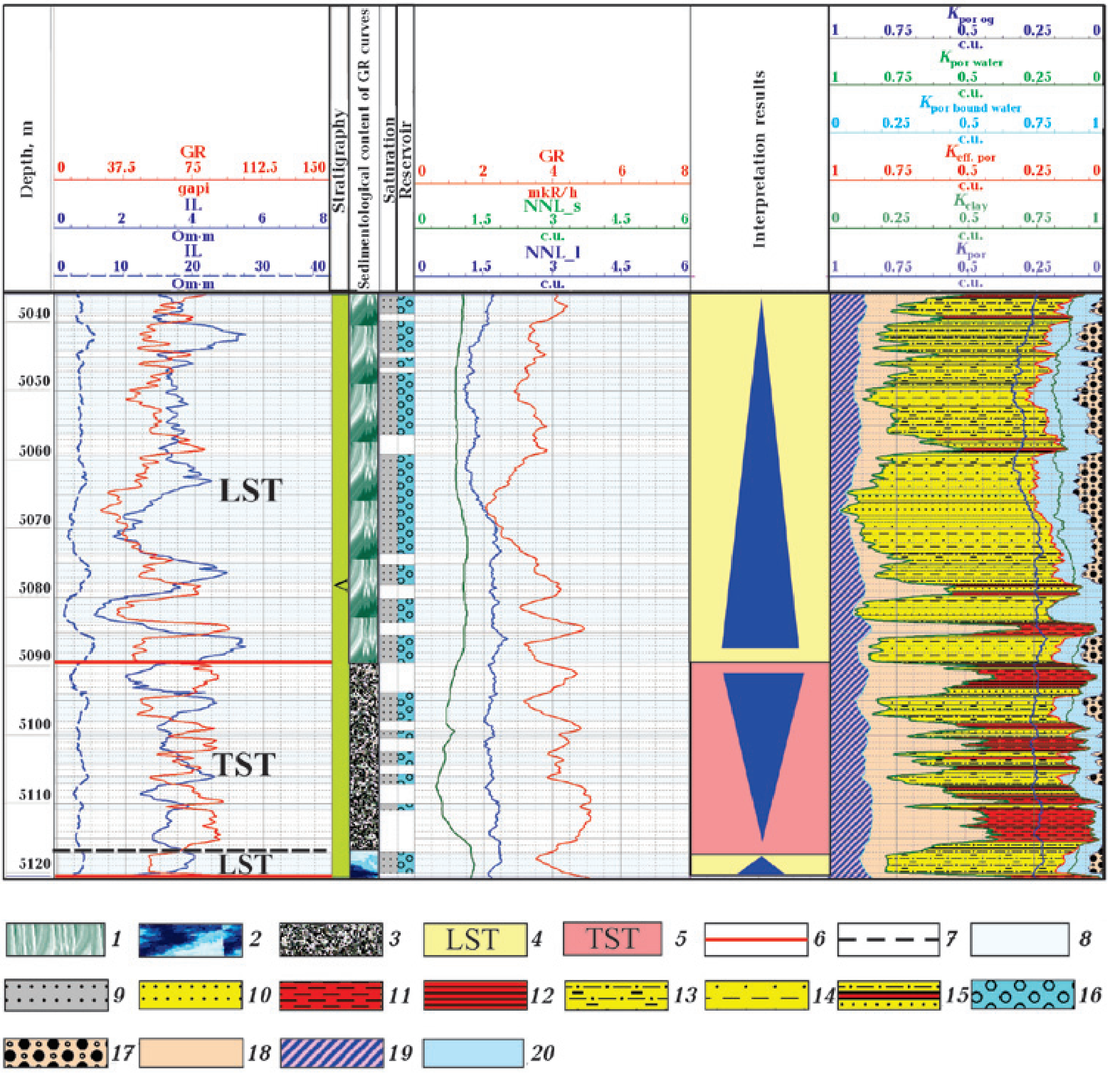

Fig. 9. Interpretation of well sections from the position of sequence stratigraphy. Bulla-Deniz Field, well № X1, Horizon V. Main symbols as in Fig. 4. *2* — retrogradation; *3* — progradation.

tation of oil and gas saturated reservoirs. In many cases, sand layers formed during aggradation and retrogradation have good reservoir characteristics. Very rarely oil and gas bearing reservoirs are found during progradation. The main oil accumulations are confined mainly to the facies of fluvial and tidal bars, estuarine coastal ramparts, and the delta front. Both oil and gas bearing and water-bearing reservoirs were formed predominantly under conditions of constant high-energy conditions of sedimentation, resulting in the continuous accumulation of sandy-rich material.

Cyclostratigraphy made it possible to identify cyclites within the studied intervals of the Productive Series section on the basis of the study intervals of variations in lithological composition, the formation of which is associated with the periodic change of depositional environments over in time.

Based on the integrated results of facies, sequence, and cyclostratigraphic analyses conducted using well log data, genetically related facies associated with specific systems tracts were identified within the Productive Series of the Bulla-Deniz Field.

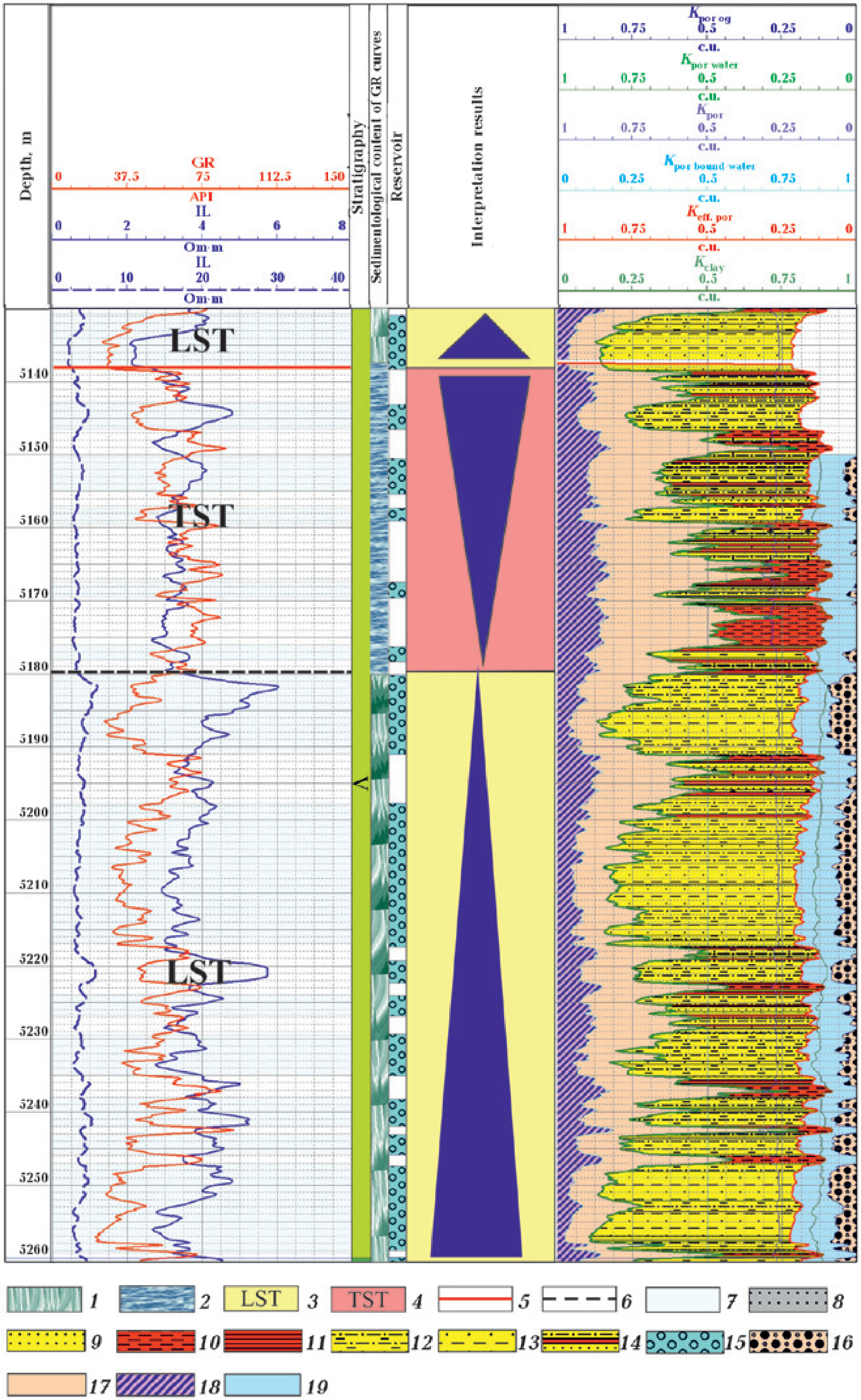

Fig. 10. Interpretation of well sections from the position of sequence stratigraphy. Bulla-Deniz Field, well № X5, Horizon V. Legend as in Fig. 4.

Facies features characteristic of different stages of sedimentation (aggradation, retrograde, etc.) have been established, and the conditions of reservoir formation within chronostratigraphic boundaries have been clarified.

Therefore, the research objective can be considered achieved.

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Літофаціальний аналіз відкладень продуктивної товщі нафтогазоконденсатного родовища Булла-Деніз (Азербайджан)

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Вивчення родовища Булла-Деніз із застосуванням геологічних і геофізичних методів розпочалося у 1950-х роках і продовжується донині. Оскільки нафтогазоносні об'єкти родовища на великій глибині мають складну геологічну будову, їх розтин, випробування і розробка — одна з найважливіших проблем сьогодення. І тому детальне вивчення геологічної будови цього родовища дуже актуальне.

Родовище Булла-Деніз, що є об'єктом досліджень, розташоване в північно-західній частині Бакинського архіпелагу. У результаті проведених на цій площі розвідувальних робіт було виявлено нафтогазоконденсатність V, VII та VIII горизонтів продуктивної товщі. Метою досліджень було уточнення геологічної будови та умов утворення відкладень цих горизонтів продуктивної товщі, оцінка їх колекторських властивостей за даними геофізичних досліджень свердловин.

У геолого-геофізичних дослідженнях одним із важливих методів є метод секвенс-стратиграфії, за допомогою якого можливе значне удосконалення прогнозу родовищ, що вивчаються, а також виявлення нетрадиційних типів колекторів. Фаціальний аналіз є одним із етапів секвенс-стратиграфічного аналізу для вивчення прогнозу фацій за каротажними даними. З початку епохи видобутку нафти основними структурами родовищ вуглеводнів є середні та великі антиклінальні підняття, які активно розробляються, внаслідок чого їхній потенціал як об'єктів первинної розвідки поступово вичерпується. Отже, основними об'єктами розвідки є неантиклінальні пастки, малоамплітудні підняття та стратиграфічні виклинювання. Сучасний комплексний підхід дає змогу простежувати умови утворень осадових басейнів, а також покращити саме розуміння умов накопичення опадів.

Для секвенс-стратиграфічного аналізу досліджуваної території застосовано метод Емері та циклостратиграфічний аналіз. Було встановлено та проаналізовано умови седиментації, а також проведено літофаціальний аналіз. Встановлено, що колектори, насичені вуглеводнями, належать переважно до тракту низького стояння рівня моря та трохи рідше до трансгресивного системного тракту. У більшості випадків хороші колекторські властивості мають відкладення, сформовані в періоди аградації та ретроградації.

Ключові слова: секвенс-стратиграфія, неантиклінальна пастка, системний тракт, умови седиментації, колектор, горизонт.