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Tofik AKHMEDOV, DSc (Geol. & Mineral.), Prof.
ORCID ID: 0000-0003-0634-5600
e-mail: ahmedovtofiq47@gmail.com
Azerbaijan State Oil and Industry University, Baku, Azerbaijan

Lala KHALILOVA, PhD (Geol. & Mineral.), Assoc. Prof.
ORCID ID: 0000-0003-0411-3216
e-mail: khalilovalala55@gmail.com
Azerbaijan State Oil and Industry University, Baku, Azerbaijan

HYDROCARBON PROSPECTIVITY OF THE ZYKH FIELD ASSOCIATED WITH PLIOCENE–MIOCENE DEPOSITS IN VIEW OF NEW 3D SEISMIC SURVEY DATA (ABSHERON OIL AND GAS BEARING REGION, AZERBAIJAN)

(*Представлено членом редакційної колегії д-ром геол. наук, доц., Георгієм ЛІСНИМ*)

Background. *The hydrocarbon potential of the Zykh-Hovsan area is predominantly associated with the Lower Pliocene deposits of the Productive Series. However, at present, the main hydrocarbon-bearing unit in the Zykh-Hovsan field is the Qala Suite (QaS). The Miocene deposits underlying the Qala Suite have also been of particular interest in recent years. The present seismic studies were conducted in the view of new 3D seismic survey data.*

The purpose of the studies was to detail the geological models of the Zykh structure, to identify and trace the zones of development of faults and to identify oil and gas prospects of both the Qala Suite and Miocene.

Methods. *Seismic stratigraphy and sequence stratigraphy methods were chosen as the main research methods. Attribute analysis was also carried out.*

Results. *In order to expand the resources of the Zykh field, recommendations were prepared for drilling of exploratory and appraisal well №2 based on 3D seismic survey data. Geological and geophysical materials were prepared and analyzed to justify the selection of the location of exploratory wells. After analyzing the seismic cubes, 3 location points of the project prospecting wells were selected, from which the first priority well – Zykh-2 – was selected and recommended for drilling. The recommended exploratory well Zykh-2 is located on the eastern steep slope of the Zykh uplift, in an area where prospective seismic facies in the Qala Suite intervals and prospective targets in the Miocene section are reliably and confidently identified in the section. The presence of well-defined seismic attributes as well as seismic classes in the predicted part of the section all indicate the presence of probable traps here. The well solves the task of both searching for the lower part of the sedimentary cover not explored by drilling and exploring the peripheral (eastern) part of the reservoir of the Sub Kirmaky Suite.*

Conclusions. *The studies have shown that the prerequisites for oil and gas bearing capacity on the eastern slope of the Zykh uplift are the existing favorable regional conditions of petroleum system development, and also local favorable conditions, which consist in the presence of a screening formation elongated in the submeridional direction. The negative factors include the steep eastern slope of the Zykh uplift. Taking into account the results obtained and analytical data, the Zykh-2 exploratory well is recommended for drilling in the project location.*

Keywords: *oil and gas content, seismic facies, seismic attribute, project well, Qala deposits, Miocene deposits, 3D seismic survey.*

Background

Zykh-Hovsan area is located in Surakhany district, southwestern part of Absheron Peninsula, in close proximity to the eastern edge of Baku, Republic of Azerbaijan (Fig. 1).

The first exploratory well was placed within Surakhany-Karachukhur (Karachukhur area) back in the 19th century, from that moment the study of the Zykh-Hovsan area began.

In 1937–1941, 1945–1949, 1949–1951 and 1955 seismic surveys were carried out using the reflected wave (RW) method, in 1977–1978. – in 1977–1978 by the common depth point (CDP) method.

Generalizations of geological and geophysical materials of the Absheron oil and gas bearing region, including the considered Zykh-Hovsan area, have been repeatedly carried out. The results of generalizations were presented in the published literature (Akhmedov, 2017; Ahmedov, Kerimova, & Khalilova, 2024; Akhmedov, & Khalilova, 2024; Akhmedov, Khalilova, & Kerimova, 2024).

Based on the results of geological and geophysical surveys and deep drilling, two fields have been discovered within the study area: Zykh in the west and Hovsan in the eastern part. Until recently, the Zykh field was at the late stage of development. To date, the Zykh field has been placed on reserve.

The Zykh field was discovered and commissioned in 1935. Drilling of well №12 resulted in the first commercial oil production from the IX horizon of the Balakhany Suite. In 1936–1940 oil deposits were discovered in the lower part of the (Productive Series) PS suites, namely UKS (Upper Kirmaky Sandy), KS (Kirmaky Suite), SKS (Sub-Kirmaky Suite) and QaS (Qala Suite). A total of 235 wells of various purposes have been drilled in the field, including 80 exploratory wells, 154 production wells and 1 appraisal well. As of 2001, there were 10 wells in the producing well stock.

CDP method – 3D seismic surveys were carried out in the Zykh-Hovsan area (Abdullayev, Riley, & Bowman, 2012).

Lithologic and stratigraphic characteristics of the section within the Zykh-Hovsan area are studied based on deep drilling data. There are mainly Neogene deposits of the ancient Caspian Sea, rocks of the Absheron and Akchagyl stages, Productive Series and partially Pontus deposits. Below the Pontus deposits lie Miocene rocks (Mamedov, 2008).

Miocene deposits within the Hovsan area were penetrated by drilling (well №1870). According to drilling data, these deposits are represented by plastic clays with sand interlayers. On seismic sections, the deposits are confined to (seismic horizon) SH-VI and SH-V, tentatively identified with the rocks in the inner and upper Miocene, respectively.

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The lower part of the PS is represented by the Qalin Suite (QaS), Sub-Kirmaky Suite (SKS), Kirmaky Suite (KS), Upper Kirmaky Sandy (UKS), and Upper Kirmaky Clayey (UKC) Suites.

The Qala Suite (QaS) is the basement suite of the Productive Series and occupies only the southern and southeastern part of the Absheron Peninsula. Its thickness increases from 0 to 385 m in the southern direction down the dip of the strata and reaches its maximum within the Bina-Hovsan depression.

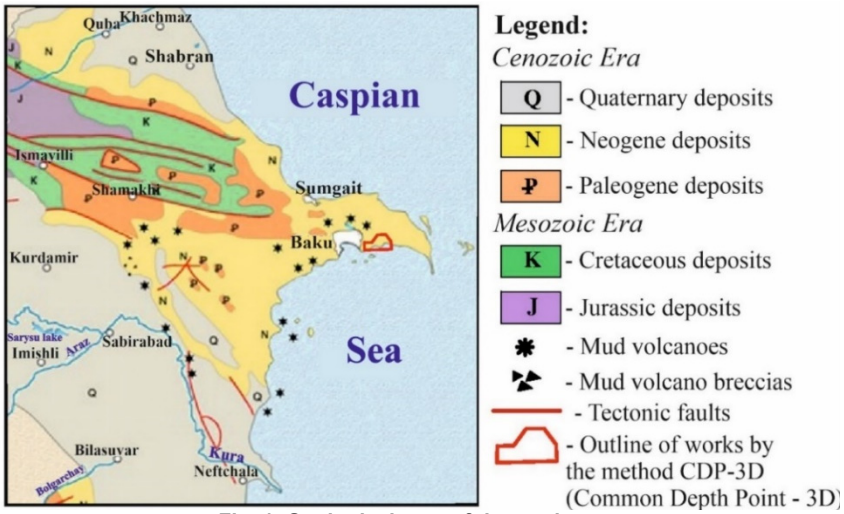


Fig. 1. Geological map of the study area (Geological map of Azerbaijan, 2010; Akhmedov, & Khalilova, 2024)

Here, geological prospecting and exploratory works have revealed a decrease in the thickness and, in some places, wedging upward along the uprise of the Qala Suite strata, which lie on the eroded surface of the Pontus deposits with a strongly pronounced angular unconformity. To the north of the sedge separating the Surakhany uplift from the Balakhany-Ramany uplift, no Qala Suite sediments are observed throughout the Absheron Peninsula. They are also absent in the appropriated parts of the folds.

The increase in thickness of the Qala Suite is due to the stratigraphic increase in its section as a result of new strata in the bottom of the suite (Alizade, Guliyev, & Mamedov, 2018).

Lithologically, the Qala Suite is characterized by alternating interbeds of clayey and sandy rocks. Sandy and silty rocks are represented by gray, light gray, in some places dark gray and yellow varieties. According to the data of granulometric analysis, sandy-siltstone rocks of the Qala Suite are poorly sorted. Clayey rocks are well thinned and contain only a small admixture of silty material; they are mainly gray, dark gray, thinly layered. The lower part of the formation is relatively more clayey.

The Zykh-Hovsan area is part of the East-Absheron syncline and covers the Zykh section of the Karachukhur-Zykh anticline, and the Hovsan area, partially, the Bina-Hovsan syncline.

The Karachukhur-Zykh anticline is the southernmost onshore uplift of the Sarygayabashy-Shah-deniz anticlinal zone, to which the largest oil and gas fields of Azerbaijan are confined. The Karachukhur-Zykh uplift in Pliocene deposits is an anticlinal fold of submeridional spreading with steep (45–500), long eastern and relatively smooth (22–250), short western flanks. The fold is sharply asymmetric in longitudinal section: the northern pericline is short, separated from the Surakhany fold by a well-defined wedge; the southern pericline is strongly elongated, dipping toward the sea, and can be traced to Gum Adasi. The length of the fold along the 2700 m isoline (PS top) is about 4.5 km, width – 3.5 km. The structure is complicated by two main longitudinal faults with an amplitude of 90–100 m. Transverse faults with an amplitude of 10–20 m are traced in the vault part of the fold. The Zykh uplift is the southern periclinal dip of the Karachukhur-Zykh anticline. In the area of Lake Zykh, the structure of the same name is complicated by a fossil mud volcano, which causes complex tectonics of the Zykh fold.

Thus, despite the fact that numerous wells have been drilled and geophysical surveys have been carried out using various methods in the Zykh-Hovsan area under study, many issues of the deep tectonics of the territory and the conditions for the formation of oil and gas deposits have not been fully elucidated.

The work area is located within the Absheron oil and gas bearing area of the Tersko-South Caspian oil and gas bearing province. Oil and gas bearing deposits are unevenly distributed here. The fields under development are concentrated in the central, southwestern, southern and eastern parts of the Absheron Peninsula and further south-eastward to the sea.

The main oil fields are located in the lower part of the Productive Series, to a greater extent in the Kirmaky, Sub-Kirmaky and Qala Suites.

The Qala Suite is the lowest deposit of the Pliocene Productive Series and is separated from the upstream SKS formation by a 4 m clay interbed. The total thickness of the QaS is 60 m at an average depth of 2,600 m; the weighted average oil saturated thickness is 7.5 m. Drilled wells have penetrated only the upper part of the Qala Suite. The first commercial oil was obtained in well 91 with oil flow rate of 98.5 tons per day and water flow rate of 14.2 tons per day.

Currently, the only oil and gas bearing object in the Hovsan-Zykh field is the Qala Suite. Since the beginning of development, the field has produced 4315.6 thousand tons of oil, 14720.7 thousand m^3 of water, 1560.3 million m^3 of dissolved gas, 27.3 million m^3 of free gas. Annual oil production at the field was 58.3 thousand tons, condensate production – 6.9 thousand tons, water – 556.1 thousand m^3, dissolved gas – 1.6 million m^3 (Salmanov et al., 2023).

In 2015, a deep well was drilled in the Hovsan area, adjacent to the Zykh field, which confirmed the assumptions about the oil and gas content of Miocene deposits and produced a fountain with a daily flow rate of about 100 tons per day (Ahmadov, 2025).

It should be noted that the available deep drilling data and seismic material do not allow us to determine a detailed geological model of oil traps in the Qala Suite and Miocene of the Zykh area.

Oil accumulation is presumably associated with lateral-facial alteration and low-amplitude faulting. These problems can be solved by detailed tracing of individual horizons and by using seismic and facies analysis of 3D seismic survey data with a clear relation to oilfield data.

Method

The Zykh field of Absheron Peninsula of Azerbaijan has been exploited since the 30s of the last century. The explored reserves of the field can be said to have been put into operation and they are running out. In order to expand the resource base, recommendations for drilling were prepared on the basis of geological and geophysical materials with the involvement of 3D seismic survey data. The entire volume of seismic material, as well as seismic attribute cubes, was analyzed when selecting options for the location of deep exploratory wells on the eastern slope of the field. In recent years, the works of many researchers have proposed new approaches to the application of seismic stratigraphy and sequence stratigraphy methods (Alekseeva, & Vazaeva, 2023; Seidov, & Khalilova, 2023). Seismic facies analysis and sequence-stratigraphic analysis are two powerful approaches in seismic interpretation, each providing unique insights into geologic history, reservoir distribution, and reservoir prediction (Leila et al., 2022; Sheriff, & Geldart, 1987). Both seismic facies and sequence-stratigraphic interpretation approaches were used to analyze the wave pattern, taking into account the quality of the seismic material achieved during processing.

In the seismic interpretation process, absorption and spectral energy attributes are used to extract additional information about geologic structures and fluid saturations. They are part of attribute analysis of seismic data, where derived attributes are calculated from the original seismograms to improve visualization or interpretation (Chopra, 2009). Absorption and spectral energy were chosen to perform seismic attribute information analysis.

Interval spectral energy maps were obtained in the interval of Qala Suite deposits and Miocene deposits. Interval spectral energy maps, which, as mentioned above, are a mean of attribute analysis of seismic data, made it possible to visualize the frequency behavior of the reflecting horizons in the interval between the reflecting surfaces. The location of this drilling point was chosen taking into account a favorable hypsometric position.

After analyzing the seismic cubes, 3 location points of the project exploratory wells were selected, from which the first priority well – Zykh-2 – was selected and recommended for drilling.

Results

Despite the fact that numerous wells have been drilled in the Zykh-Hovsan area under study and geophysical surveys have been carried out using various methods, many issues of the deep tectonics of the territory and the conditions for the formation of oil and gas deposits have not been fully elucidated.

As noted above, the Zykh field was discovered and put into operation in 1935 by well №12, which penetrated the Balakhany oil field of the IX layer. The oil bearing capacity of the field is confined to eight objects of the Productive Series: Qala Suite (QaS), Sub-Kirmaky Suite (SKS), Kirmaky Suite (KS), Upper Kirmaky Clayey (UKC) and Balakhany Suite (formations VI, VII, VIII, IX).

The deepest wells in the East Hovsan field, which is located to the east and not far from the Zykh field, are: № 1855, № 1856 and № 1864. Thus, while drilling well № 1855, 2 reservoirs with high gas values were discovered. Well №1856 also penetrated sandy formations below the established oil-bearing formations of the QaS2+QaS3 group and indexed as QaS4 and QaS5. Deep well №1864 penetrated a section similar to that of well №1855. It was also found that when the section below QaS3 is penetrated, the formation pressure reaches values that are attributed to Abnormal Formation Pressure (AFP), and the pressure anomaly coefficient reaches a value of 2.0 or more. As is known, according to the international classification, a section where the formation pressure exceeds hydrostatic pressure by 30% or more belongs to the AFP category. At the same time, it should be noted that according to the mining and geological conditions, the QaS4 and QaS5 formations are incompatible with the overlying QaS2-3 formations (Ahmedov, 2019).

The main volume of oil produced so far corresponds to the deposits of the Productive Series of the Lower Pliocene. But nowadays geologists and geophysicists are interested in oil and gas content of deeper deposits of Miocene, Eocene and Upper Cretaceous. The field under consideration is not an exception (Ahmadov, 2019).

The main objectives of the present studies are:
a) detailing geological models of the Zykh structure;
b) identification and tracing of zones of development of discontinuities, as well as areas of rock unconsolidation in the interval of the entire sedimentary cover section;
c) identification of oil and gas prospective objects.

In selecting options for the location of deep exploratory wells on the eastern slope of the Hovsan field, the entire volume of seismic material was analyzed, as well as cubes of seismic attributes of both mono-attributes and complex attributes (Alsadi, 2017; Fraser et al., 2008; Kirilov & Zakrevsky, 2014; Shimansky et al., 2011; Urupov, 2004).

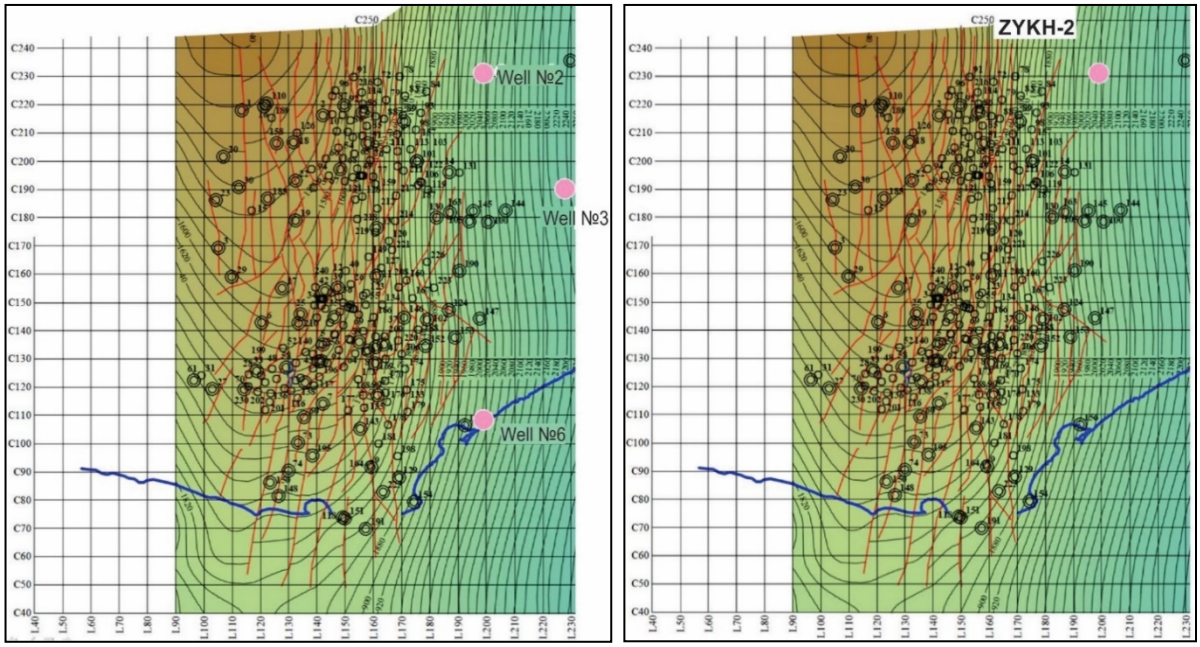
Such interpretation approaches as seismic-facies and sequence-stratigraphic were used to analyze the wave pattern, taking into account the quality of seismic material achieved during processing.

After analyzing the seismic cubes, 3 location points of the project exploratory wells were selected (Fig. 2a), from which the first-priority well – Zykh-2 was selected and recommended for drilling (Fig. 2b).

Exploratory well № 2 (Fig. 2a) is located on the eastern tectonic block of the Zykh uplift (crossline 230, Inline 200). The status of the well is exploratory, project depth for penetration of objective horizons is 3100–4300 m, project horizons are SKS, QaS, Miocene. Project bottom hole is 4500 m.

Exploratory well № 3 (Fig. 2a) is located on the eastern tectonic block of the Zykh uplift (crossline 190, Inline 230). The status of the well is exploratory, the project depth for penetration of objective horizons is 3100–4200 m, the project horizons are QaS, Miocene.

Exploratory well № 6 (Fig. 2a) is located on the eastern tectonic block of the Zykh uplift (crossline 110, Inline 200). The status of the well is exploratory, the project depth for penetration of objective horizons is 3000–3900 m, the project horizons are SKS, QaS, Miocene.



a *b*

Fig. 2. Location options for exploratory wells at the Zykh field (a) and project well № 2 at the Zykh field (b)

The recommended exploratory well Zykh-2 (Fig. 2b) is located on the eastern abrupt slope of the Zykh uplift and is characterized by the following features:

• is located in an area where the section reliably and confidently identifies promising seismic facies in the Qala Suite intervals and perspective objects in the Miocene section;

• the presence of well-defined seismic attributes as well as seismic classes in the predicted part of the section all indicate the presence of probable traps;

• the well solves the task of both exploration of the lower part of the sedimentary cover not explored by drilling and exploration of the peripheral (eastern) part of the reservoir formation of the Sub-Kirmaky Suite.

Figs. 3–4 show seismic and geologic sections of the eastern flank of the Zykh fold, indicating the expected trap types confined to the Qala Suite (IIIa, IV) and Miocene (V, VI) that may be penetrated by the projected well.

Types of traps expected to be penetrated by the Zykh-2 well (Fig. 5a and 5b):

1 – stratigraphic, wedging upward along the uprise (Qala Suite formations);

2, 3 – stratigraphic, replacement, screened by clay diapir (Miocene deposits).

3 – lithologic, weathering crust.

When analyzing, the informativity of seismic attributes, absorption and spectral energy were selected. Figures 6–7 show maps of interval spectral energy in the interval of Qala Suite deposits and Miocene deposits. The location of this point was chosen taking into account the favorable hypsometric position.

In the system of longitudinal disturbances identified on the fragment of the map of the predicted trap contour in Miocene deposits (Fig. 8), it can be seen that the project well Zykh-2 is located at a sufficient distance from the disturbance zone.

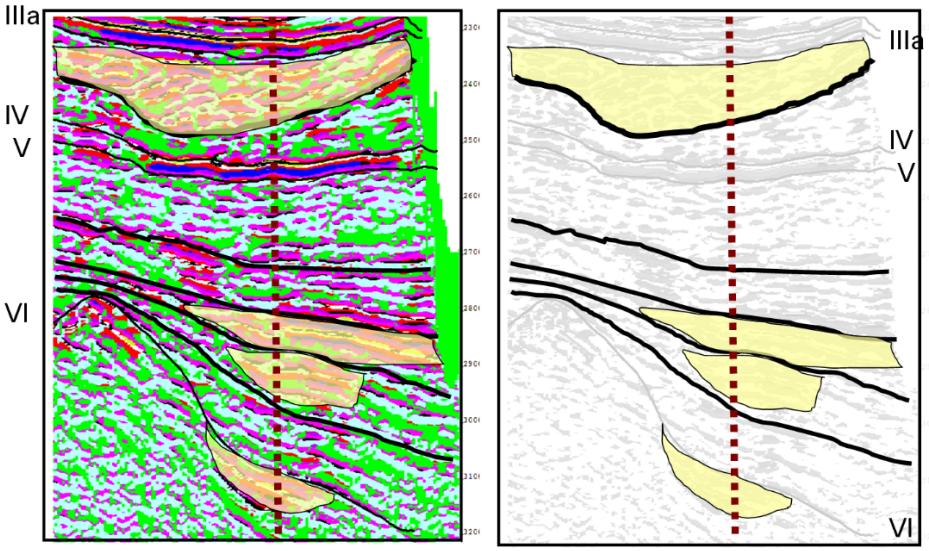


Fig. 3. Seismic-geologic section along Inline 200 showing the eastern flank of the Zykh fold: seismic horizons confined to the Qala Suite (IIIa, IV) and Miocene (V, VI)

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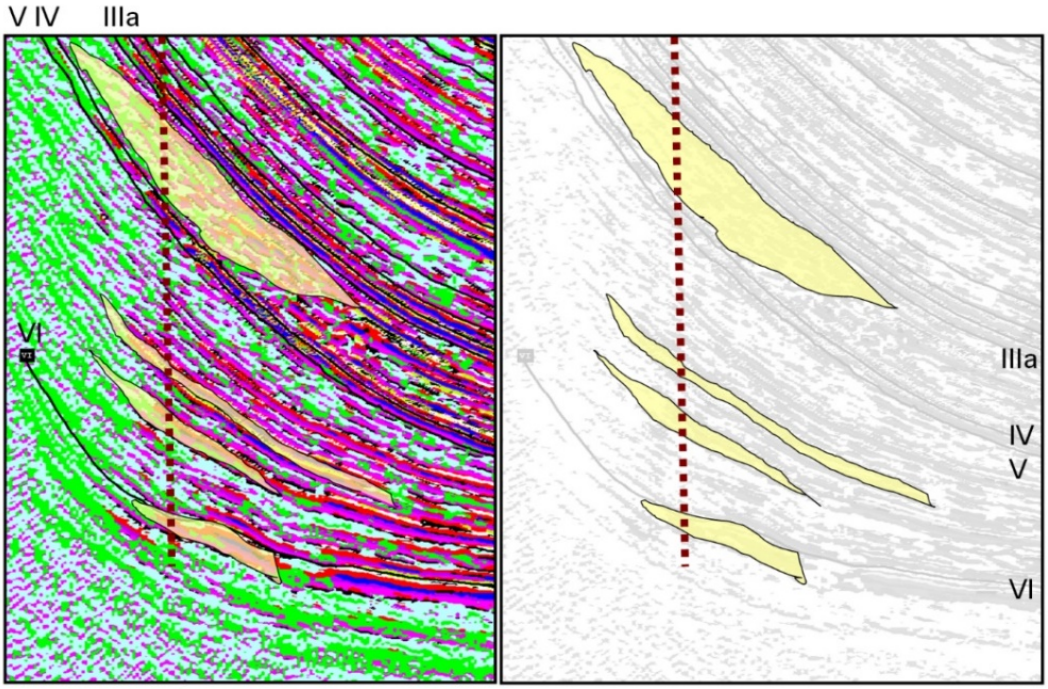

Fig. 4. Seismic-geologic section along fold 230 showing the eastern flank of the Zykh fold: seismic horizons confined to the Qala Suite (IIIa, IV) and Miocene (V, VI)

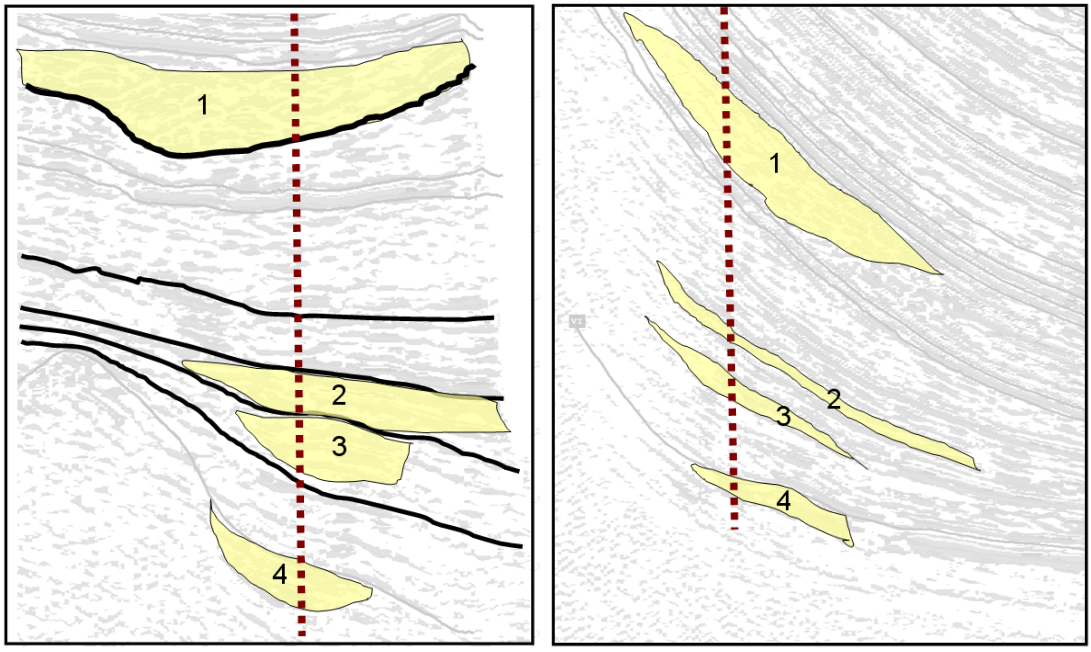

Fig. 5. Hydrocarbon trap types:
a – Inline 200; b – Crossline 230; 1 – stratigraphic, wedging upward along the uplift (Qala Suite formations); 2, 3 – stratigraphic, replacement, screening by clay diapir (Miocene deposits); 4 – lithologic, weathering crust

Discussion and conclusions

Thus, the studies have shown that the prerequisites for oil and gas bearing capacity on the eastern slope of the Zykh uplift are the existing favorable regional conditions for oil system development. And also local favorable conditions, which consist in the presence of screening strata, elongated in the submeridional direction. To the negative factors we include the presence of the abrupt eastern slope of the Zykh uplift. Taking into account the obtained results and analytical data, the Zykh-2 exploratory well is recommended for drilling in the project location.

The main geologic risks to the Miocene deposit we consider to be trap risk and reservoir risk.

The main geologic risks for the Qala Suite formations are mainly trap risk and, to a lesser extent, reservoir risk.

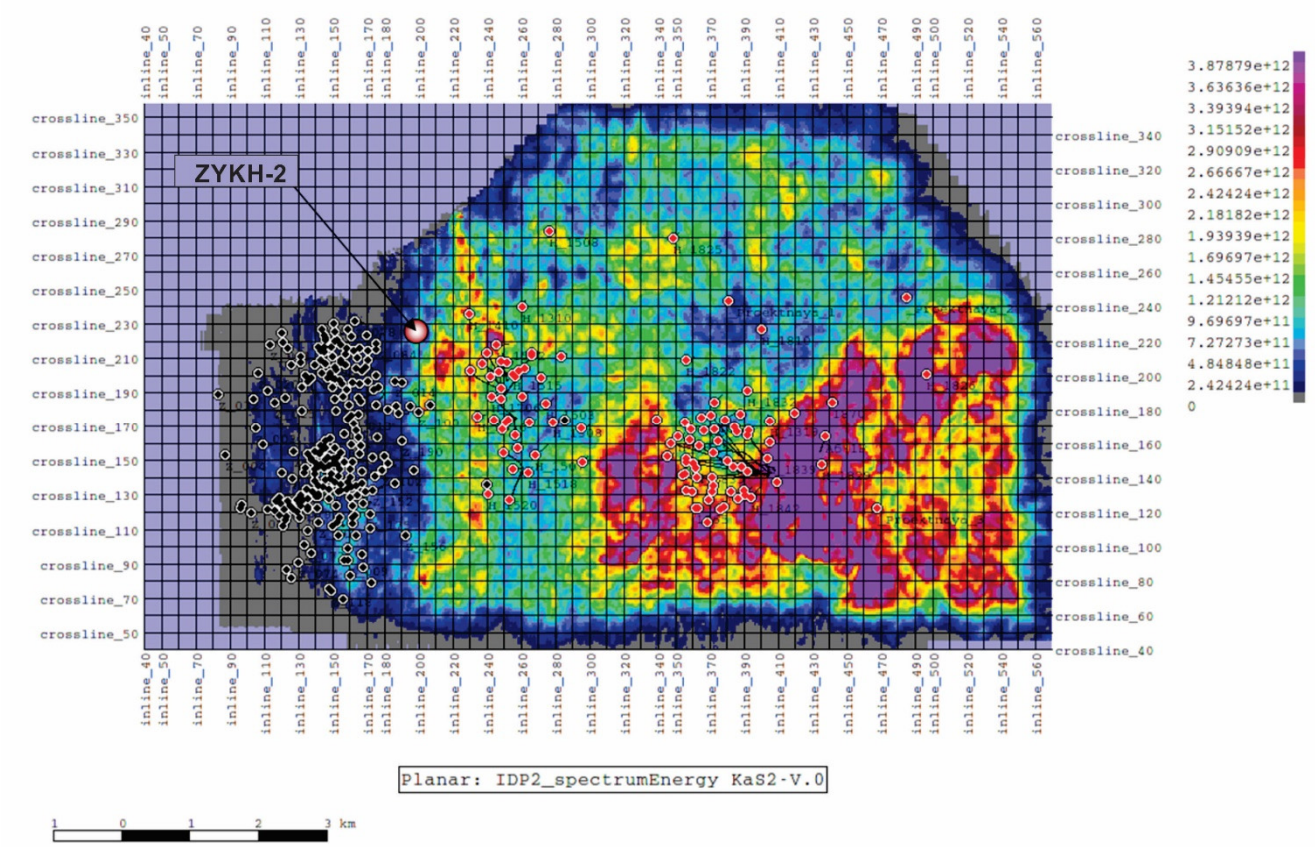

Fig. 6. Map of interval spectral energy in the Qala Suite deposits interval

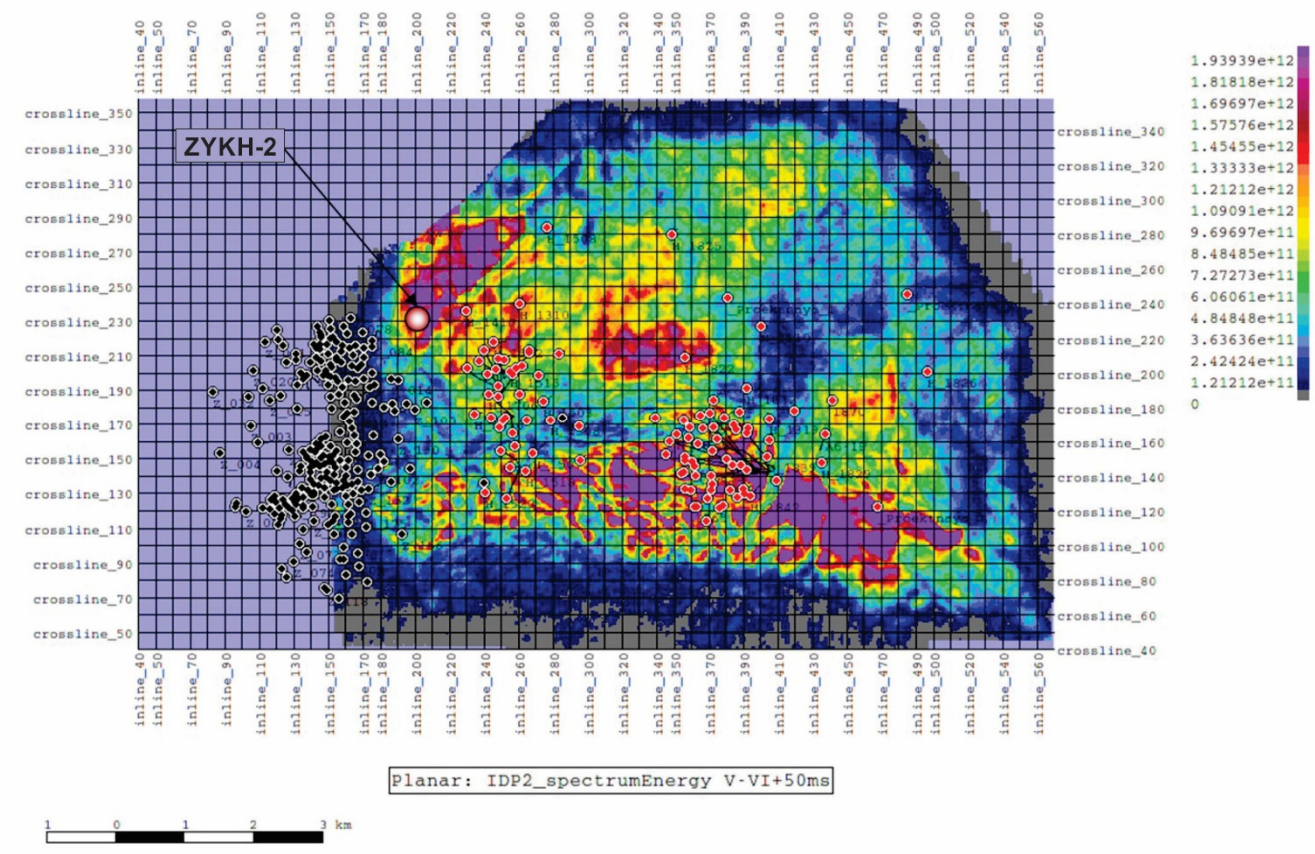

Fig. 7. Map of interval spectral energy in the Miocene deposit interval

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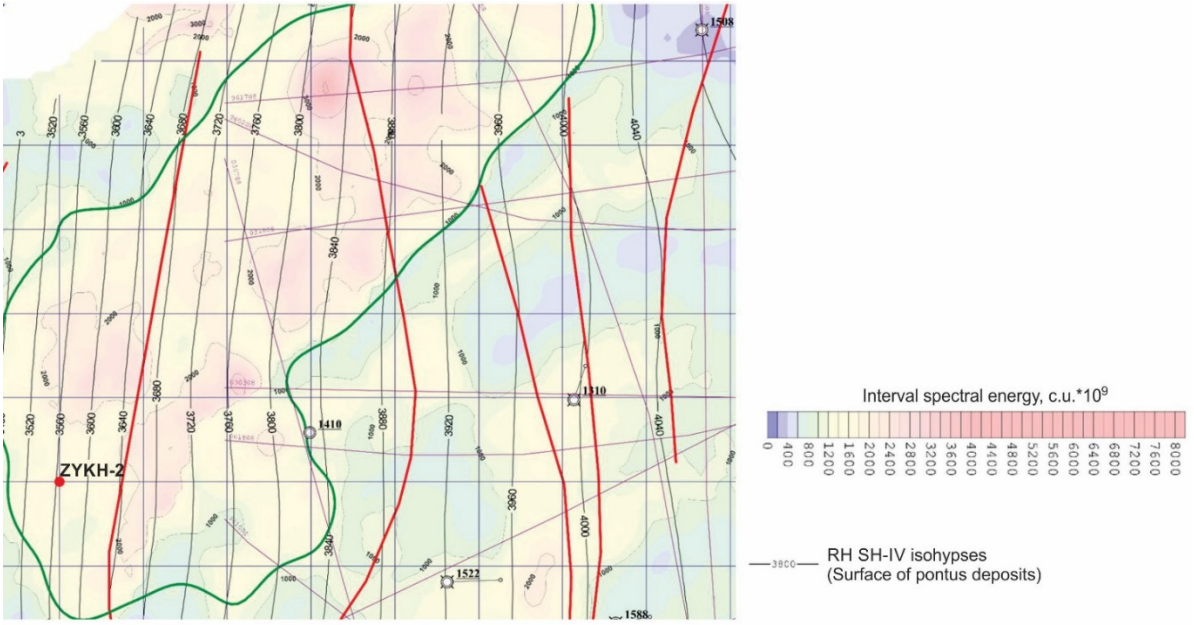

Fig. 8. Map fragment of the predicted trap contour in Miocene deposits

Authors' contribution: Tofik Akhmedov – conceptualization, methodology, writing (original draft), formal analysis; Lala Khalilova – data validation, writing (review and editing).

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Тофік АХМЕДОВ, д-р геол.-мінерал. наук, проф.
ORCID ID: 0000-0003-0634-5600
e-mail: ahmedovtofiq47@gmail.com
Азербайджанський державний університет нафти та промисловості, Баку, Азербайджан

Лала ХАЛІЛОВА, канд. геол.-мінерал. наук, доц.
ORCID ID: 0000-0003-0411-3216
e-mail: khalilovalala55@gmail.com
Азербайджанський державний університет нафти та промисловості, Баку, Азербайджан

ВУГЛЕВОДНЕВА ПЕРСПЕКТИВНІСТЬ РОДОВИЩА ЗИХ, ПОВ'ЯЗАНА З ПЛІОЦЕН-МІОЦЕНОВИМИ ВІДКЛАДЕННЯМИ З ОГЛЯДУ НА НОВІ ДАНІ 3D СЕЙСМОРОЗВІДКИ (АПШЕРОНСЬКИЙ НАФТОГАЗОНОСНИЙ РАЙОН, АЗЕРБАЙДЖАН)

В с т у п . ***Вуглеводневий потенціал Зих-Говсанського району пов'язаний переважно з відкладеннями нижнього пліоцену продуктивної серії. Однак на даний момент основною вуглеводненосною одиницею Зих-Говсанського родовища є калинська свита (QaS). Міоценові відкладення, що лежать під свитою Кала, також становлять особливий інтерес в останні роки. Дані сейсморозвідувальні дослідження було проведено з урахуванням нових даних сейсморозвідки 3D.***

Мета досліджень полягала в деталізації геологічних моделей будови Зих, виявленні та відстеженні зон розвитку розломів і виявленні нафтогазоносних перспектив як калинської світи, так і міоцену.

М е т о д и . ***Як основні методи дослідження обрано методи сейсмічної стратиграфії та секвенційної стратиграфії. Також проведено аналіз ознак.***

Р е з у л ь т а т и . ***З метою розширення ресурсів родовища Зих підготовлено рекомендації щодо буріння розвідувально-оцінювальної свердловини № 2 за даними сейсморозвідки 3D. Підготовлено та проаналізовано геолого-геофізичні матеріали для обґрунтування вибору місця проведення пошукових свердловин. Після аналізу сейсмічних кубів було обрано 3 точки розташування проєктних пошукових свердловин, з яких обрано та рекомендовано до буріння першочергову свердловину – Зих-2. Рекомендована розвідувальна свердловина Зих-2 розташована на східному крутому схилі Зихського підняття, в районі, де в розрізі достовірно і впевнено виділено перспективні сейсмічні фації в інтервалах каланської свити і перспективні цілі в міоценовому розрізі. Наявність чітко визначених сейсмічних атрибутів, а також сейсмічних класів у прогнозованій частині розрізу вказують на наявність тут імовірних пасток. Свердловина вирішує завдання як пошуку нерозвіданої бурінням нижньої частини осадового чохла, так і дослідження периферійної (східної) частини пласта підкірмаківської світи.***

В и с н о в к и . ***Дослідження показали, що передумовами нафтогазоносності східного схилу Зихського підняття є наявні сприятливі регіональні умови розвитку нафтогазової системи. А також локальні сприятливі умови, які полягають у наявності екрануючого утворення, витягнутого в субмеридіональному напрямку. До негативних факторів можна віднести крутий східний схил підняття Зих. Враховуючи отримані результати та аналітичні дані, розвідувальна свердловина Зих-2 рекомендована до буріння на проєктному місці.***

К л ю ч о в і с л о в а : ***нафтогазоносність, сейсмічна фація, сейсмічний атрибут, проєктна свердловина, родовища Кала, міоценові відклади, сейсморозвідка 3D.***

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