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GEOLOGY AND PROSPECTS OF HYDROCARBONS IN THE TRANSITION ZONE OF THE SHALLOW WATER OF THE APSHERON FIELD

The Apsheron field area presents the most promising prospect within the Shallow Water Transition Zone of the Apsheron archipelago across all potential reservoir levels. This assessment aims to identify the exploration potential of the area and the associated new business opportunities. The region encompasses water depths ranging from 10 to 20 meters. Methodologically, we utilized available new seismic data, evaluated reference well data, and considered other geological factors within the *Petrel* program. Individual recoverable resource volumes per reservoir layer were calculated using the Monte Carlo program. The total consolidated resource volume of the Productive Series in the entire Bank-Apsheron area is 80.3 million barrels (MMBBL). Additionally, the consolidated resource volumes for the Mesozoic across the entire Bank-Apsheron area amount to 21.4 MMBBL. Specifically, the Gosha Dash area accounts for 16.1 MMBBL of the consolidated resource volumes. Notably, this area remains undrilled. The Gosha Dash structure is viewed as a potential target for field extension, contributing to the remaining exploration potential of Bank-Apsheron and West-Apsheron. The Mesozoic deposit within this area has been identified via 2D seismic data at approximately 2000 meters depth. Consequently, this section of the structure is not categorized solely for exploration purposes but also serves as an appraisal and development target for future wells.

Key words: South Caspian; Bank-Apsheron; offshore deposit; oil and gas; seismic data interpretation; geology; forecast of oil and gas content.

Introduction

The Caspian Basin is renowned as one of the largest continental lake systems globally. The recent geological sequence is typified by fluvial deltaic sandstones and lacustrine shales [BP Report, 2020]. Within the study area, the relief of the seafloor is characterized by underwater and above-water rock formations, cones, banks, and depressions. Among the prominent morphological units are Gosha Dash, Apsheron Bank North, East Apsheron, and West Apsheron, comprising a group of underwater mud volcanoes. The predominant hydrocarbon reservoirs in the South Caspian Basin are found in Middle Pliocene clastic formations [Narimanov, 1993] (Fig. 1).

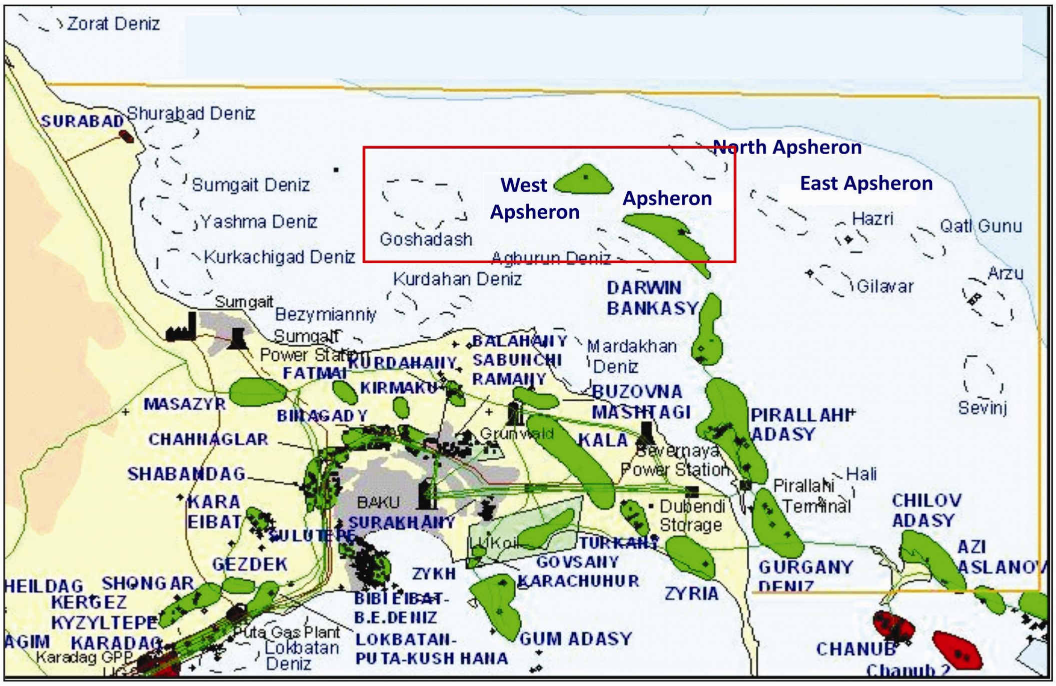

Fig. 1. Schematic location map of Apsheron Trend Shallow water & Transition zone.

In the north, Gosha Dash consists of two ridges protruding above sea level, separated by a strait. The water depth in this area varies between 5 to 20 meters. West of Gosha Dash lies the Shurabad onshore/off-shore field.

The Apsheron Bank is situated along the 10-meter isobaths, spanning 10 kilometres in length and 2.5 kilometers in width. The sea depth above the bank reaches a maximum of 2-3 meters. To the north of the Apsheron Bank lies North Apsheron, while West Apsheron is positioned to its west, and East Apsheron is located to the east. The Gilavar, Khazri Arzu, Noukhany, Gatl Qunu, and Sevinj prospects form a single anticline zone extending eastward from the Apsheron Bank field.

To the south and southwest of the Apsheron Bank field are the Kurkhachidag Sea, Sumgait Sea, Kurdakahni Sea, and Mardakan Sea.

Purpose

The work aims to present a comprehensive overview of the exploration potential for oil and gas in the transition zone of the Apsheron shallow waters in Azerbaijan. It highlights key areas of interest, such as the Bank-Apsheron, West-Apsheron, and Gosha Dash regions, detailing their estimated resource volumes and exploration activities. Additionally, we attempt to discuss the significance of the Mesozoic interval as a potential exploration target and emphasize the need for specialized approaches, including 3D seismic surveys and horizontal drilling techniques, to optimize exploration efforts and mitigate risks. Furthermore, it underscores the importance of past drilling experiences and the adoption of advanced technologies to enhance geological assessments and improve exploration success rates in the region. Overall, the paper aims to provide valuable insights for stakeholders involved in oil and gas exploration in the Apsheron shallow waters.

West Apsheron discovery

The West Apsheron oil discovery is situated 20 kilometers offshore in the western sector of the Apsheron – Dan Ulduzu – Karabakh Trend in the Caspian Sea. Moving southeastward, towards the Azi Aslanova and Neft Dashlari fields, the sea depth gradually increases from 30 to 100 meters (Fig. 2).

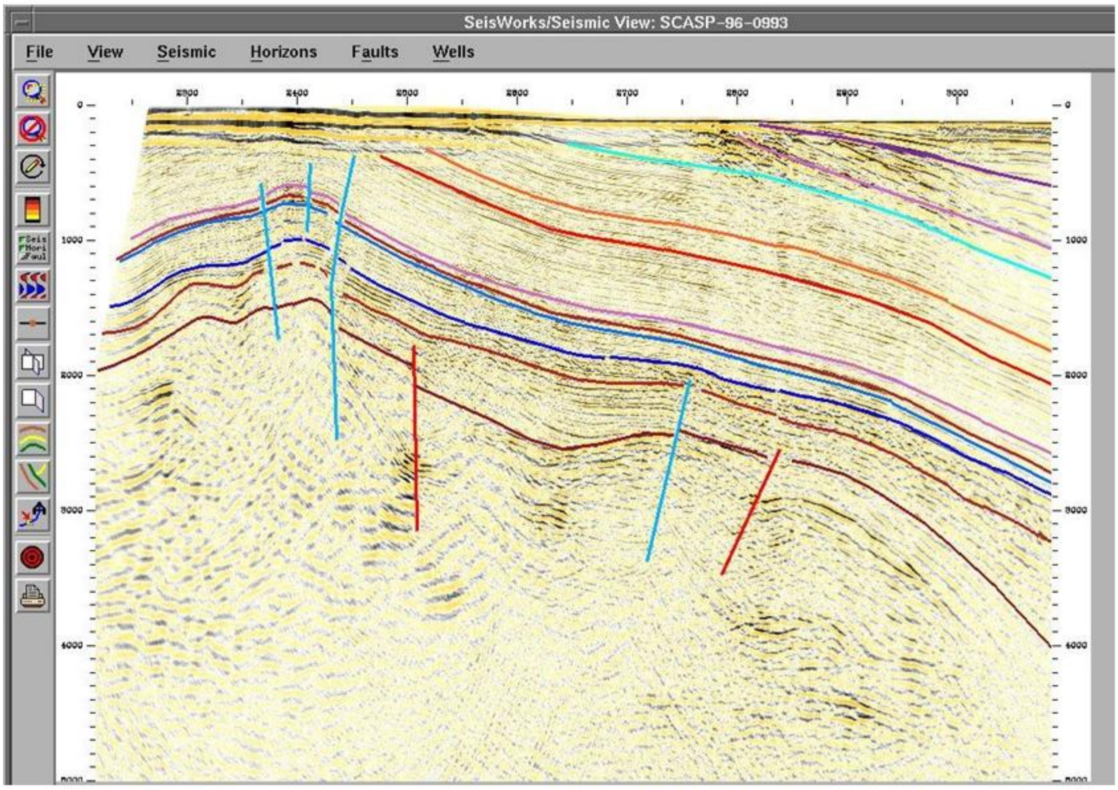

Fig. 2. West Apsheron seismic section. Profile A-A” (relatively new seismic survey profile).

The seabed relief is relatively smooth, consisting of grey sand and silt with shells. It represents the structurally less-defined western culmination of a single large NW-SE trending anticline measuring 30 kilometers by 12 kilometers. This anticline features two structural culminations, with West Apsheron in the west and Apsheron in the east. The structural style of the anticline is typical of many fields in Azerbaijan: a major fault zone runs along its axis, dividing it into two asymmetrical flanks, while several smaller dip faults further compartmentalize it into fault blocks.

The West Apsheron field witnessed the discovery of a small oil accumulation in 1986 when an oil flow was produced in well 85 from the Kirmaki (KS) Suite

(901-908 meters interval). In 1990, another minor oil pool was discovered in a clastic reservoir in the Lower Kirmaki (LK) Suite of the Productive Sequence. Covering an area of 11 kilometers by 2.5 kilometers, the field's stratigraphy encompasses sediments from the Oligocene-Lower Miocene Maykop Suite to the Productive Sequence. The upper part of the Productive Sequence has been eroded from the crest, with the Sequence unconformably overlying the Diatom Suite and the Pontian. At the crest of the anticline, the Supra Kirmaku Mudstone Suite is exposed. The Productive Sequence comprises alternating sands and mudstones, with the latter predominating, and has a total thickness ranging from 1,800 to 2,000 meters.

The productive sand layer at West Apsheron boasts a net thickness of 11 meters, with a porosity of 24% and an average permeability of 75 millidarcies (mD), reaching a maximum of 180 mD. It exhibits a water saturation of 20 %. Initial estimates suggest that West Apsheron holds approximately 17 million barrels (mmbbl) of oil in place, accompanied by 1.1 billion cubic feet (bcf) of solution gas. Wood Mackenzie has categorized reserves that are unlikely to be recovered under the current development scenario as technical reserves. [Wood Mackienzie, 2005]

Foreign participation in the West Apsheron field is absent; the field is operated solely by the Apsheronneft Oil & Gas Production unit of the State Oil Company of Azerbaijan Republic (SOCAR). Production at West Apsheron commenced in 1989, with an initial rate of 20 barrels per day (b/d). However, production ceased five years later due to additional requirements of the platform and production facilities. As of now, the field remains undeveloped.

Apsheron Bank field

Gas seeps on the seafloor along the fault trace instigated seismic surveys in the Apsheron area during various periods: 1947–51, 1952–54, 1958–59, and 1966–67. Shallow drilling operations were conducted on the Apsheron anticline from 1950 to 1952. The initial exploration well, drilled in 1951 to a total depth of 1,140 meters, did not encounter any hydrocarbon shows. In 1964, two exploration wells (N2 and N4) were completed. Well 4, situated on the southwestern flank of the Apsheron field, tested 3.5–5.2 million cubic feet per day (mmcfd) of gas and 68-95 barrels per day (b/d) of condensate from the Kala Suite (KaS) at a depth of 1,661–1,667 meters. In 1965, well 11 was drilled on the northeastern flank of the field to a total depth of 803 meters. This well tested 204–238 b/d of oil from the Kirmaku Suite (KS). Subsequently, the oil accumulation was confirmed by wells 21, 24, and 25. In May 2002, a new gas exploration well, number 23, was drilled to a depth of 2.005 meters using the Khazar-4 jack-up drilling rig. The well tested an initial flow rate of 5.4 mmcfd. Between February and November 2004, SOCAR drilled two exploration wells to a depth of 800 meters each using the semi-submersible rig Apsheron. In 2005, SOCAR drilled another exploration well and proceeded to construct and install a stationary 12-slot drilling platform at the Apsheron Bank.

According to a source from SOCAR, the Apsheron field spans 15 kilometers by 9 kilometers at the top of the Kirmaku Suite (KS). The anticline exhibits asymmetry, featuring a gently dipping southwestern limb (25–30°) and a steep northeastern limb (48-50°), trending WNW-ESE. This structure is intersected by two longitudinal thrust and wrench faults, along with normal transverse faults, dividing it into several blocks. In the crestal part, faulting is accompanied by diapiric clay intrusions associated with deep-seated Miocene-Pliocene clayey sections. Notably, oil and/or gas accumulations have thus far been identified solely in blocks located in the northeastern limb. The trap mechanism is further linked to lateral facies changes, particularly shale-outs.

The field stratigraphy of the Apsheron field encompasses sediments ranging from the Oligocene-Lower Miocene Maykop Suite to the Productive Sequence. Erosion has affected the upper part of the Productive Sequence, which uncomfortably overlies the Diatom Suite and the Pontian. At the crest of the anticline, the Supra Kirmaku Mudstone Suite is exposed [Babaev, et al., 2006]. The Productive Sequence consists of alternating sands and mudstones, with mudstones predominating, reaching a total thickness of 1.800–2.000 meters. Commercial hydrocarbon accumulations have been identified in two reservoirs within the Apsheron field: oil in the Kirmaku Suite (KS) reservoir and gas in the Kala Suite (KaS). The specific gravity of the oil averages 0.914 gr/cm³.

Commercial oil production from the Apsheron field commenced in 1971, with peak oil production recorded in 1985, reaching over 380 barrels per day (b/d). Gas production peaked at 3.7 million cubic feet per day (mmcfd) in 1992. Of the 21 development wells drilled in the Apsheron field, only five remain active. The average flow rate of oil wells is 18 b/d of liquids, of which 14 b/d is oil, with a water cut of 25.9 %. Additionally, two wells are known to be producing free gas in this field.

Volume estimation for the producing part of the Apsheron bank has not been implemented as the field is under development by SOCAR.

Gosha Dash (old name Kamni Dva Brata) prospect

The Gosha Dash uplift represents a marginal northwest structure within the studied area of the Caspian Sea. Its stratigraphic and lithological characteristics align with the surface layers in this region, indicating an independent uplift that extends northwest to southeast. This uplift is positioned as part of the continuation of the Tengin-Beshbarmak uplift. In 1950–1951, there was a weak local maximum observed in the Gosha Dash uplift, indicating the proximity of the Mesozoic core to the surface.

The Gosha Dash area is situated in the northwestern region of the Apsheron archipelago, approximately 48–50 km northwest of Artiom Island. The seabed topography in this area is characterized by a dissected landscape, particularly evident in the Stones area. Here, an uplifted section is prominent in the central region, where sea depths range from 2 to 4 m. Stone outcrops on the seabed form a range extending in a northwest-southeast direction, spanning approximately 80 m in length and 7–10 km in width. Moving away from the stone outcrops, the sea depth rapidly increases to 30–35 m at some distance.

At the 20 m isobath, the shallow uplifted part measures 6 km in length and 2 km in width. Seismic surveys conducted in 1950–1951 revealed the presence of far northeast and southwest limbs of an anticlinal high in this area. However, no reflections were obtained from the crests, leaving approximately a 4 km wide blind zone in seismic profiles. Subsequent aerial surveys in the Gosha Dash area yielded no results.

In 1953, structure test drilling helped outline the southwest limb of the uplift, while further drilling in 1955 aimed to elucidate the tectonic and stratigraphic relations between Gosha Dash and the Apsheron and Tsurupa banks. This effort identified the northwest pericline of the uplift and identified faulting in the southwest limb. Subsequent work provided insights into almost the entire structure, although wells drilled on the northeastern uplift were unable to provide data due to the depth of the sea and submarine currents. The geology of Gosha Dash is primarily composed of the Productive series.

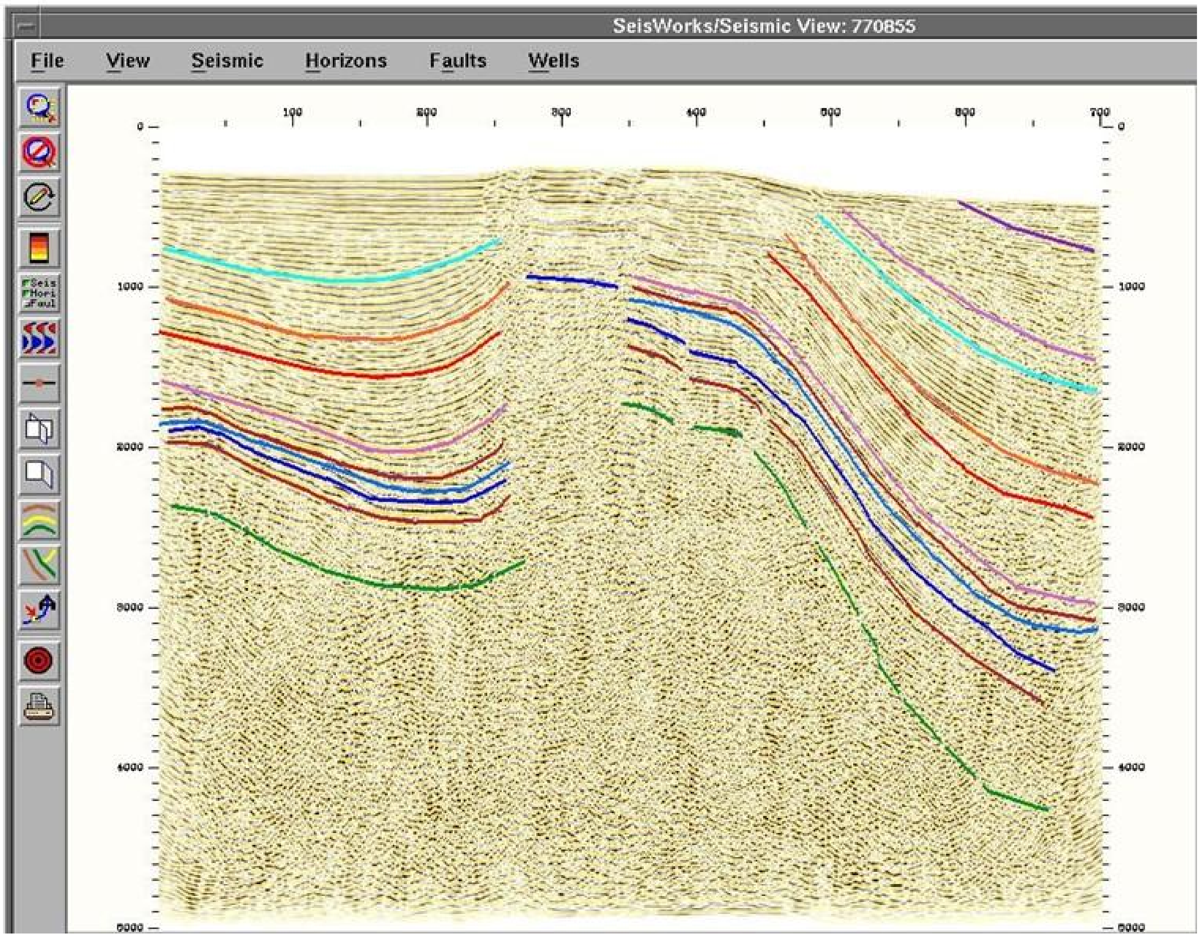

Fig. 3. Gosha Dash seismic section. Profile B-B” (old seismic survey profile).

The geological formations in the Gosha Dash area include deposits from the PS (Productive Series), Akchagylian, and Apsheronian epochs, as well as modern Caspian drifts. Notably, modern drifts are absent in the crest of the fold, but they become more prominent further from the crest, particularly evident in the presence of fine- and mid-grained quartz sands.

At the crestal position, PS rocks are exposed on the seabed, characterized by poorly sorted and light-grey coarse-grained sandstones interspersed with black cherty pebblestone nodules. The light fraction of these rocks primarily comprises quartz, feldspar, and rock fragments.

Seismic data reveals that Gosha Dash is situated at the confluence of two axes, as depicted in Fig. 3.

One axis of the Gosha Dash uplift plunges south-eastward, while the other trends east-south-eastward, though it does not converge with the fold axis of the Apsheron Bank, instead shifting to the south of the bank. A small but distinct saddle lies between the periclinal closures of the Gosha Dash and Apsheron Bank folds.

Geological mapping delineates the Gosha Dash uplift as a brachyanticline trending from west-north-west to east-south-east. At its summit, the Productive Series (PS) forms a fold measuring 13×7 km, hosting PS deposits at the crest and Akchagylian and Apsheronian stages at the limbs. PS crop outs are primarily concentrated along the northwest pericline of the fold, mainly comprising sandstones in the middle section, suggesting erosion of the PS down to the lower intervals. The fold displays slight asymmetry, with the southwest limb exhibiting steeper angles (dipping at about 20–25°) compared to the northeast limb (with a maximum dip of 10-12°).

Near the northwest pericline of the Gosha Dash fold, the southwest limb is characterized by lowering and complexity due to faulting. Horizontal displacement of rocks near the northwest pericline measures 1.5 km, while in the southwest limb, it is 400 m. The faulting contributes to high dip angles, reaching up to 65–70° in the northwest pericline and 28–30° in the southwest limb. These faults are evident on the surface, extending north-west-south-eastward, with one fault shifting south-south-eastward. Further east-south-eastward, another transverse fault is observed in the southwest limb, associated with significant displacement and high dip angles (75–80°).

PS deposits extend southwestward from the uplift to the shoreline along the coast, stretching from Kilyazi Cape to Kechaldag. The PS deposits are bordered by Akchagylian crop outs. Conversely, onshore structures along the coastline consist of older deposits ranging from the Pontian to Cretaceous periods, with Cretaceous formations emerging at the Sovetabad uplift crest.

The periclines of folds to the south of the Tengin-Beshbarmak anticlinorium are composed of Pontian deposits, which are absent in the seabed. This suggests that these folds flatten south-eastward, towards the sea, aligning with known offshore folds such as the Gosha Dash, Apsheron, and Tsuryupa Banks.

Currently, seismic surveys are underway in the Gosha Dash area. Given the nearly complete erosion of the PS in this structure, Gosha Dash holds potential as a target for Mesozoic oil and gas exploration.

In 2012 SOCAR drilled exploration well N 1 in Gosha dash north-northeast flange of structure. In 2013 the same block of structure was drilled for exploration well No. 2. Both wells did not reach the planned well depth and were liquidated for technical reasons. Volume estimation of this structure is implemented and attached.

Stratigraphy

The geology of the north coast of the Apsheron peninsula remains relatively understudied. However, it is known that the primary oil- and gas-bearing suite in this region is the Middle Pliocene Productive Series, as identified by Huseynov et al. (2007). Additionally, small oil accumulations have been identified in Mesozoic deposits, which are considered prospective given the presence of oil fields onshore. The offshore area of the Apsheron peninsula comprises deposits ranging from the Jurassic to the Quaternary period, as documented by Alizadeh et al. (1972). Wells penetrated the interval from Lower Cretaceous to Quaternary deposits, providing valuable insights into the geological composition of the region (Fig. 4). The primary oil fields within the Absheron province were discovered through drilling numerous wells in the North Absheron uplift zone (Apsheron-Dan-Ulduzu-Karabakh) and in the fields of the Absheron-Pribalakhan uplift zone. The thickness of the productive strata reaches up to 3,800 m in the Absheron area, extends up to 6,500 m in the Baku Archipelago, and, based on seismic data, exceeds 12 km in the deeper parts of the sea basin (Javadova, 2005).

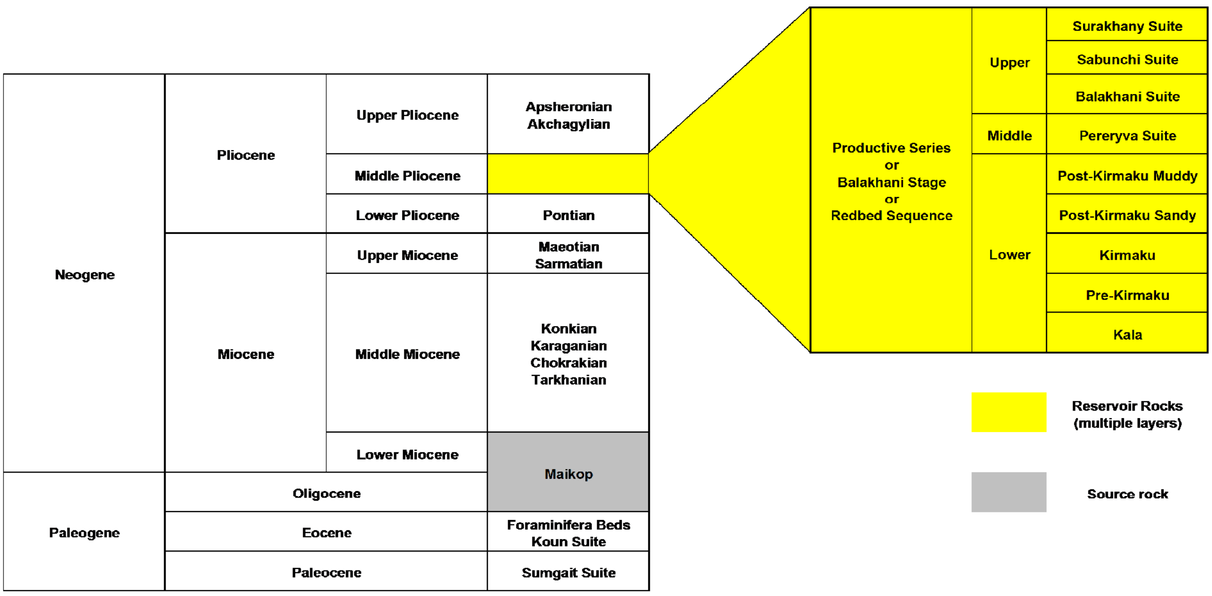

Fig. 4. Generalised Stratigraphy of the Tertiary. Modified after A. Javadova (2005).

General Tectonic Framework

According to S. A. Alieva and B. M. Averbukh (2010), the onshore Dibrar oil and gas region is an independent geological feature situated southeast of the Greater Caucasus meganticlinorium, encompassing the Khizy and North Gobustan prospects as well as the North Absheron oil and gas area. Previously, the North Absheron oil and gas area was erroneously categorized within the Absheron-Pribalkhan zone of the South Caspian oil and gas province, which was inconsistent with geological evidence. However, most geological studies affirm that tectonically, the area in question is part of the anticlinoria of the Apsheron archipelago, occupying its northwest portion.

The Apsheron archipelago, also known as the north-Apsheron Trend, constitutes an independent and complex structural element of the Southeast Caucasus. Its geological evolution has been influenced by two distinct tectonic factors. One of these factors is of Mesozoic origin, leading to the development of large structures with a latitudinal strike and significant subsidence of the Caspian depression during the early Paleogene. This resulted in the pronounced subsidence of Cretaceous structural elements, subsequently overlain by Tertiary deposits and the formation of structures with a meridional strike.

The uplifts within this zone exhibit a highly complex structure, which is primarily attributed to the interaction between deeply seated Mesozoic layers and the formation of Pliocene folding. This complexity arises from the combination of fold-forming movements influenced by both latitudinal (associated with the general Caucasian Trend) and meridional (related to the Caspian Trend) forces.

The Greater Caucasus meganticlinorium extends in a northwest-southeast direction within the mainland and comprises several structural units arranged from south to north: Altyagach-Kurkachidag anticlinoria, Dibraro-Yashminski synclinoria, Germiane uplift, Khizinski synclinoria, Tenginski-Beshbarmak anticlinoria, and Kusar-Divichin synclinoria. There is a prevailing viewpoint suggesting that within the broader tectonic framework of the South-Eastern Caucasus, the Apsheron Archipelago forms a part of the Apsheron periclinal trough. This trough is a component of the Caucasian-Balkhan interpericlinal trough, which developed during the subsidence process of the bends of meganticlinoria in the Greater Caucasus and the Greater Balkhan. Tectonically, the northwest portion of the anticlinoria within the Apsheron Archipelago is linked with the Tenginski-Beshbarmak anticlinoria. The tectonic positioning of the uplifts in the northwest part of the anticlinoria within the Apsheron Archipelago is influenced by the folding of the axial zone in the southeastern Caucasus and the folding in the Apsheron region. Consequently, this leads to challenges in delineating the southeastern continuation of the folding [Alixanov, 1978].

The studied area lies within the North-Apsheron Trend, which is of significant interest due to favorable tectonic conditions conducive to the accumulation of commercial oil and gas deposits. Brachy-folds have been identified in the Pliocene deposits such as Gosha Dash, Apsheron bank, Agburun Deniz, Gilavar, and Mardakyany-deinz, sometimes exhibiting structural complications of a terrace type. In the Apsheron bank, alongside oil and gas seepages associated with faults and presumed mud volcanoes, oil and gas deposits have been identified in the Kirmaki and Kalin Suites of the Middle Pliocene.

Considering the tectonic position and the elevated Mesozoic surface (as indicated by drilling data), along with the presence of structures in these deposits (as observed in geophysical data), occurrences of light oil and gas fountains from the Mesozoic (such as in Shurabad and Keshchai) as well as structural formations in the northwest of the Apsheron Archipelago should be regarded as targets for the exploration of oil and gas in the Mesozoic deposits.

All known and potentially new structural formations are likely to contain oil and gas reserves. This assumption is grounded in their proximity to developed fields such as Darvin, Pirallahi-north fold, and Pirallahi-south fold, as well as their alignment with tectonic elements in the southeast of the Greater Caucasus that are considered prospective for oil and gas deposits in the Mesozoic formations (such as Keshchai and Shurabad).

Deposits of the Productive Series (PS) on the western side of the South Caspian Basin were formed after folding processes and before the formation of tectonic faults. Hydrocarbon deposits were situated within structural arches. During the late Pliocene-Quaternary period, the formation of tectonic faults resulted in the separation of single arch deposits into individual tectonic blocks.

Tectonic disturbances affecting the structures within the "Apsheron Trend" play both negative and positive roles. In some cases, these disturbances contribute to the destruction of deposits, as observed in the Khala structure. Conversely, under favorable geological conditions, they can prevent such destruction, as seen in Chilov Island.

The sediments underlying the Productive Series (PS) are exposed by wells to shallow depths. Given the extensive erosion of PS deposits on the uplift crests, it is recommended to position wells here to investigate Mesozoic deposits.

The geological evolution of the north-western part of the Apsheron Archipelago is shaped by two primary factors: a) the continuous uplift of the Greater Caucasus mountain chain, and b) the significant downwarping of the Caspian depression. This geological history has led to the shallow occurrence of Mesozoic rocks along the uplift crests, accompanied by the accumulation of a thick series of Middle Pliocene rocks in areas experiencing strong subsidence.

The thinning or complete absence of Upper Cretaceous deposits towards the arches (such as Agburun Deniz and Apsheron Bank) suggests that these areas were once elevated above the seafloor as underwater cordilleras due to erosion at the boundary between the Lower and Upper Cretaceous.

During the Eocene, intensive downwarping of the basin floor led to the accumulation of primarily clayey deposits of the Konian Suite, which unconformably overlay the Cretaceous deposits in areas like Apsheron Bank and Agburun Deniz. This downwarping process persisted into the Oligocene and Maycopian periods, resulting in the formation of uplifts within the Apsheron region. The significant folding activity during this period led to a notable reduction in the thickness of the Maycopian Suite on the anticline crests.

The Chockrak age is characterized by a regression of the sea, as evidenced by the absence of Chockrak horizon deposits in the arches and their presence on the slopes of most structures in the Apsheron Archipelago.

Sedimentation, primarily comprising clayey formations of the Diatomite Suite, commenced during the Karagan stage period and persisted until the Meotian period. Tectonic movements with a meridional orientation, driven by the downwarping of the Caspian depression during the Meotian period, became predominant toward the end of the Diatomite Suite.

At the onset of the formation of the Productive Series deposits, there was a regression of the Lower Pliocene Sea. This regression led to the emergence of the Kalin Suite (KaS) within the Pontian deposits, characterized by angular unconformity. The extent of the Kalin Sea basin was relatively small, primarily covering the southeast pericline of the Apsherons bank uplift. Evidence of this is observed in various wells, such as N 3, 4, 5, 8, 10, and 14. Conversely, most of the northeast slope comprised land and Diatomite rocks, as indicated by the absence of KaS and the unconformable occurrence of KS rocks within the Diatomite layers in wells like N 11, 13, 16, and 19.

The diminishing sedimentation basin of the KaS is further evidenced by its absence in the section of well N1 in the Gilavar uplift, where KS deposits directly underlie Maycopian rocks. In well 19, situated in the far subsidence of the southeast pericline of the Mardakyany-Deniz uplift, KaS deposits up to 56 m thick were eroded.

The onset of sedimentation of the Lower Kirmaki (LK) Suite marked a phase characterized by the expansion of basin margins, encompassing the near-arch portion of Agburun Deniz, as well as the southwest slopes and east periclines of both the Apsheron bank and Agburun Deniz. However, as we move northwards from the studied wells, there is a noticeable reduction in the thickness of the LK Suite, eventually leading to its pinching out.

For instance, the thickness of the LK Suite in well 15 measures 24 meters, whereas in wells N23, 13, 2, and 17, these deposits are absolutely absent. As the Kirmaki period commenced, the sedimentation basin significantly expanded, encompassing the entire northwestern region of the Apsheron Archipelago.

Upon examining the thickness map, it becomes evident that the arches of the uplifts exhibit minimal thickness of the KS, while the maximum thickness is observed in the subsidence areas of the structures.

The overlying deposits in the upper division of the PS exhibit significant erosion within the arches of the uplifts, with preservation primarily occurring in the far subsidence areas of the uplifts and adjacent synclines. The clayey nature of the Balakhany Suite deposits, along with the thickness of its formations within the Apsheron Archipelago, suggests relatively tranquil geotectonic conditions throughout the entire Balakhany Suite period.

Furthermore, the increase in clay content in the deposits of the upper division of the PS in the ascending stratigraphic succession suggests a decline in fold-forming processes during that time.

The thickness and composition of the upper Pliocene deposits, predominantly consisting of clayey rocks, indicate their deposition in the synclines and subsidence areas of the anticlines, aligning closely with the tectonic framework of the studied region. Consequently, the sedimentation of the PS within the archipelago, as in the broader Apsheron oil and gas region, was intricately linked with the evolutionary processes of the folds.

A notable aspect of the Apsheron Archipelago's structural evolution is the distinct development of two categories of anticlinal structures. One group hosts oil deposits (e.g., Apsheron Bank), while the other comprises buried uplifts containing gas condensate accumulations (e.g., Janub). This distinctive feature arises from the formation of the flange framing around the Caspian depression and the regional dip of the strata from the flanges toward its central region.

Mamedov (2004) correctly emphasizes that the base of the PS is situated on an unconformity, truncating sediments ranging from the Pontian to the Cretaceous in age. This discontinuity in deposition becomes more pronounced towards the northwest, primarily due to the lower formations of the Productive unit being absent from the section and the deeper erosion of the underlying rock layers [Mamedov, 1989].

Analysis of the geological evolution history of the northwest of the Apsheron Archipelago leads to the following conclusions and results:

1. The geotectonic evolution of the area is influenced by the uplift of the Greater Caucasus and the subsequent downwarping of mountain structures during various geological periods. This led to the absence of appropriate deposits in the arches of the uplifts. Conversely, the downwarping of the Caspian depression resulted in the accumulation of these deposits in the subsidence of the structures and in the synclines that separated them.

2. The formation and evolution of the structures occurred concurrently with the active manifestation of the Alpine folded system. The growth of positive structures occurred against the backdrop of a general subsidence of the basin along with sedimentation, indicating a predominantly compressional tectonic regime.

3. The geological evolution history during the Upper Cretaceous epoch suggests the presence of a complete section of Cretaceous deposits in the subsided areas of structures such as Apsheron Bank, Agburun Deniz, Gosha Dash, and others.

4. Anticline folds exhibiting structural complexities are situated to the north and northwest of the Apsheron Bank uplift. Before the sedimentation of Middle Pliocene deposits, these folds evolved independently. However, during the deposition of the PS, their growth diverged significantly from that observed in the Apsheron Bank region. Consequently, these folds underwent deformation, and in the current middle Pliocene structural framework, they represent structural terraces and low-amplitude (up to 50 m) anticlinal structures.

5. Regional dislocations that complicate the arches of structures such as Gosha Dash, Agburun Deniz, and Apsheron Bank have a long history of development. They were formed prior to the sedimentation of the Middle Pliocene and exerted significant influence on sedimentation patterns.

6. From the Upper Cretaceous to the Middle Pliocene, the arch of the uplift B occupied the highest hypsometrical position, corresponding to Agburun Deniz. However, since the late Middle Pliocene, this position has been taken over by the uplifted Apsheron Bank.

7. The erosion of upper Pliocene and Anthropogenic deposits in the elevated areas of structures such as Mardakyany-Deniz, Gosha Dash, Apsheron Bank, and Agburun Deniz impedes the reconstruction of their evolution during the post-Pliocene epoch. Additionally, the sections of the Akchagyl and Apsheron stages in the subsided areas of these uplifts are predominantly represented by deep-water facies, showing a lack of significant differences in sediment composition. This consistent lithofacial composition suggests that the upper Pliocene basin lacked large islands. Consequently, the erosion of Upper Pliocene deposits in the near-arch areas of these structures occurred after the Baku tectogenesis, which marked a significant uplift of these structures and the complete formation of their current structural configuration.

8. Despite the known hydrodynamic conditions in the sea within the studied area, erosion processes continue to affect Gosha Dash, Apsheron Bank, and Agburun Deniz. However, it is noteworthy that the isobaths of the shallowest depths contour the near-arch areas of the brachyanticlines. This suggests that weak ascending movements may still be ongoing in these areas.

Reservoirs and Source Rocks

In the Apsheron shallow & transition area, the uplifts are highly raised and deeply washed out, resulting in the presence of oil contained only in suites of the lower section (KaS, LK, KS, UKS, and Pereriva Suite) of the Productive Series (PS), which belongs to the Lower Neogene period. This geological setting indicates that the mature source rocks, primarily the Maykop Suite of the Oligocene-Lower Miocene, are the likely primary source for the oil and gas discovered in the Productive Sequence within this region. Additionally, the intraformational shales of the Productive Sequence are also believed to possess significant source potential.

Given the relatively young age and cool temperature conditions of the South Caspian Basin, the Oligo-Miocene source rocks continue to generate oil at burial depths exceeding 6 km. However, significant volumes of gas are mainly generated in the deeper parts of the basin where source rocks are sufficiently deeply buried. While the exact proportions of oil and gas generated in these deeper areas remain uncertain, the discovery of gas in Shah Deniz has led many industry experts to anticipate similar gas prospects in many of the deeper water basins within the South Caspian Basin.

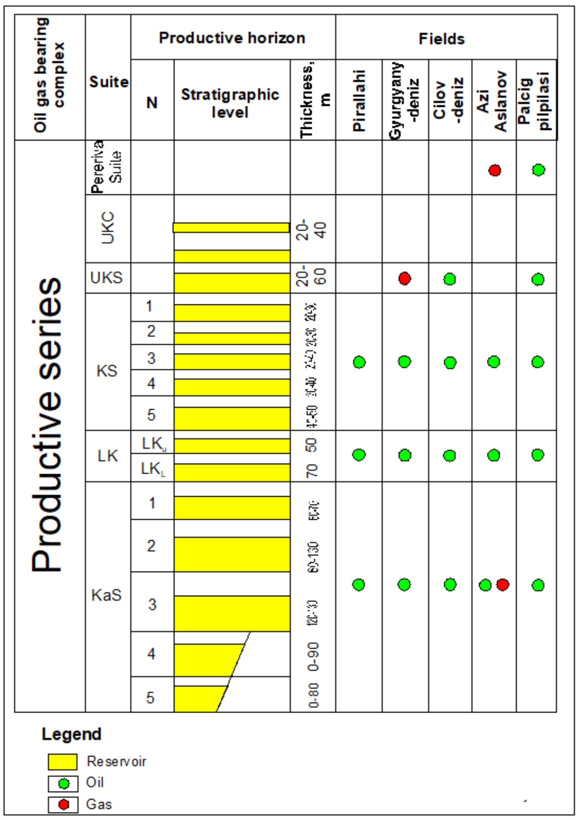

Fig. 5. Shallow water transition zone of Apsheron Trend. Main oil and gas contained fields.

KaS is lithologically variable by area and section. LK Suite contains oil in sandstone benches in the lower and upper parts of the section. KS is one of the main oil and gas-containing objects in Chilov-Deniz, A. Aslanov fields. Gyurgyan-Deniz field has deposits only in the lower KS. On Pirallakhi only four objects are oil and gas bearing- KS_2-KS_5. The commercial oil and gas content of the UKC Suite is determined only on separate blocks of A. Aslanov and Palchyg Pilpilyasi fields. The rhythmic sequence of reservoirs and intra-formational clayey Seals created favourable HC conditions for saturation of most of the section as well as pre-determined a possibility for the preservation of gas-condensate and oil deposits even in tectonically dislocated and deeply washed-out structures.

In the Shurabad structure, two Santonian-Campanian gas-bearing sandstone reservoirs have been tested. The upper interval, tested in the Shurabad 54 well in 1937, lies between 132 m and 135 m, while the lower interval, tested in the Shuraabad 8 well in 1936, is situated between 180 m and 183 m.

The Oligocene-Lower Miocene bituminous shale and marls of the Maykop Group, along with some clays and carbonates of the Middle Miocene Chokrak and Karagan formations, are considered to be the main source rocks in this area. These bituminous shale and clays, deposited in a strongly reducing environment, exhibit a high organic carbon content ranging from 0.5% to 5% and are predominantly of sapropelic type.

In addition to the source rocks mentioned earlier, the Miocene formations in the area have an average organic carbon content of 1.55%. Reservoirs in the area include granular reservoirs from the Middle Jurassic, fractured-granular reservoirs from the Valanginian and Hauterivian stages of the Lower Cretaceous, and granular reservoirs from the Upper Miocene Maykop formation. Seals comprise carbonate and non-carbonate clays from Cenozoic to Mesozoic deposits. The traps in the region are primarily fault-blocked and stratigraphic traps (Xuduzadeh, 2010).

Well and Seismic database

For estimation of reserves, well-log analysis of the following wells: West Apsheron – 3 wells (18, 46, 47); Apsheron Bank – 11 wells (7, 8, 9, 10, 14, 15, 16, 18, 19, 41, 50); West Apsheron correlation1 – 3 wells (6, 15, 17); Apsheron Bank – correlation – 3 wells (18, 11, 7); Kalin Zaliv – 2 wells (13, 14); North Apsheron – 4 wells (1, 2, 3, 5); Mardakyan – 2 wells (13, 16); Noukhany – 1 well (1); Gilavar – 2 wells (1; 2); Khazri – 2 wells (3, 4); Arzu-1 well (1); Kurkachidag-1 well (1); Yashma Sea-1 well (1); TOTAL: 36 well logs.

The interpretation of the regional seismic grid, with a width of 10 km and locally increased to 5 km line spacing, provides valuable insights into the geological structures of the Gosha Dash – West Apsheron prospect (Fig. 6). This seismic data, oriented in NW-SE and SW-NE directions, allows for the identification of structures at various intervals, including the Mesozoic deposits. It was fitting to recall A. Narimanov's (2011) remarks here. He emphasized that despite some Mesozoic wells yielding significant industrial inflows of both oil and gas, the total oil reserves identified in Mesozoic rocks accounted for only 0.2% of the overall oil reserves. Consequently, the modest results of exploration efforts targeting Mesozoic oil have diminished confidence among researchers. However, can we now assert with certainty that the pursuit of industrial oil accumulations in Mesozoic rocks is a futile endeavour? In particular, the Gosha Dash structure at the Mesozoic interval has been identified on the 2D seismic data which we evaluated. However, it is important to note that this structure poses significant exploration risks due to several factors. Firstly, there is an expectation of severe internal compartmentalization within the structure. Additionally, there is limited knowledge regarding the charge mechanism for the Mesozoic reservoir properties. Unfortunately, a recently drilled well in Gosha Dash was unsuccessful due to technical reasons. That is why the information regarding this well remains inconclusive.

Furthermore, the entire Mesozoic section below the Bank-Apsheron area remains undrilled to date, with only one well penetrating the Mesozoic at the edge of this structure in a very down-dip position. Given these uncertainties and risks, estimating reserves in such areas requires sophisticated methodologies.

For the estimation of reserves, the Monte Carlo method has been employed. This method involves generating numerous random samples of input parameters and running simulations to assess the range of possible outcomes. By considering various scenarios and uncertainties, the Monte Carlo method provides a robust approach to reserve estimation in complex geological settings like the Mesozoic deposits of the Gosha Dash – West Apsheron prospect.

Resource volume estimation

The calculation of resource volumes is a comprehensive process that involves several key elements to ensure accuracy and reliability. These elements include depth maps, formation tops derived from reference wells, petrophysical evaluations, and assessments of fault seal and top seal risks. Additionally, reservoir property data specific to the potential Mesozoic play is crucial for this estimation.

In the estimation process, column height estimates play a significant role. For this purpose, a lognormal distribution is applied, with specific percentiles chosen for the calculation. In this case, the P99 percentile corresponds to the crest of the structure, representing the highest point of the reservoir. Conversely, the P1 percentile is set at a conservative value of 300 meters, providing a lower estimate for the column height.

To achieve a trustworthy estimation of resource volumes for the potential Mesozoic play in the Gosha Dash – West Apsheron prospect, it is essential to incorporate all the necessary elements into the estimation process. This includes geological data, reservoir properties, and risk assessments. The approach ensures that uncertainties and risks are appropriately addressed, leading to more informed decision-making in exploration and development activities (Fig. 7).

Methodology

Deriving area depth graphs from key formation tops such as Top Fasila/Pereriva, Top NKP, and Top Mesozoic reservoir is essential for understanding the structural and stratigraphic framework of the reservoirs within the studied area. These depth graphs provide valuable insights into the depth variations of the reservoir formations across the prospect.

In addition to the main reservoir layers, intercalated reservoir layers are also considered in the analysis. These layers, when included in the Monte Carlo program, contribute to a more comprehensive understanding of the reservoir architecture and distribution, allowing for more accurate volume estimations.

Furthermore, interpretation of faults plays a crucial role in defining reservoir compartments. By combining all interpreted faults from various reservoir levels into a general fault trend map, the structural integrity of the reservoir can be assessed. This helps in identifying potential compartments within the reservoir system, which is vital for reservoir management and development planning.

Overall, the integration of area depth graphs, intercalated reservoir layers, and fault trend maps in the Monte Carlo program enhances the accuracy and reliability of reservoir characterization and volume estimation in the Gosha Dash – West Apsheron prospect (Fig. 8-19).

In the structural modeling process, a model incorporating N-S trending faults was superimposed to delineate the structural features within the prospect area. This model, combined with the last closing contour and well data, was used to define polygons or compartments within the reservoir system.

The reservoir input parameters were derived from petrophysical interpretation conducted for both the Productive Series and the Mesozoic deposits. Given that the Productive Series comprises five stacked reservoir layers, each layer was individually evaluated and characterized. The petrophysical properties such as porosity, permeability, water saturation, and net pay thickness were assessed for each reservoir layer.

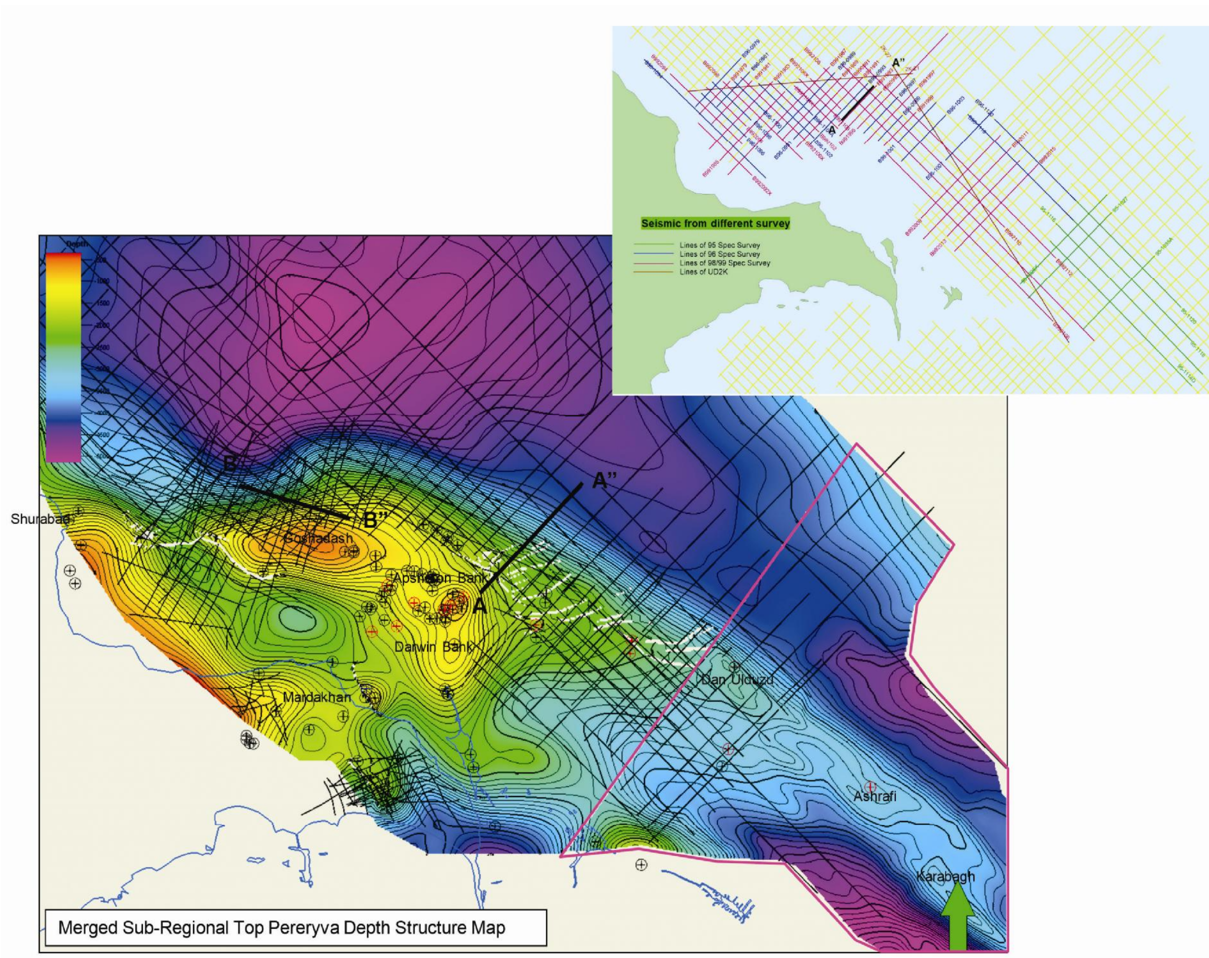

Fig. 6. Location of used Seismic lines along with location of profiles A-A" and B-B".

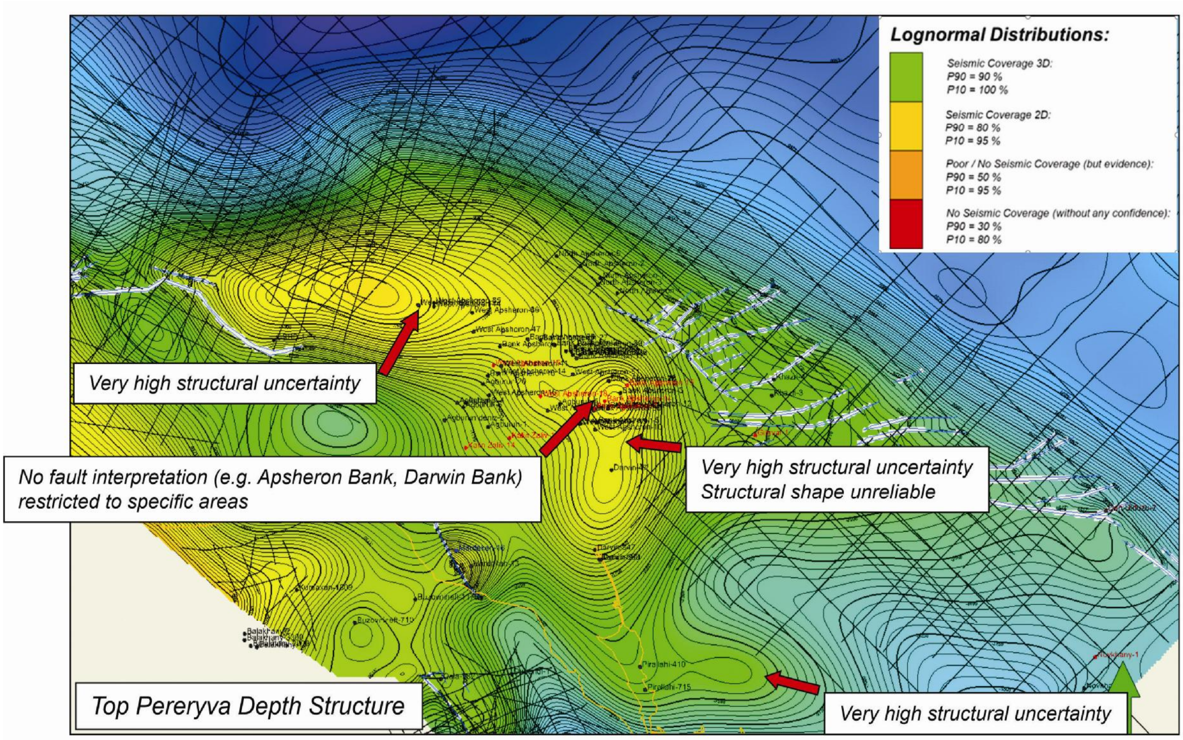

Fig. 7. Volumetric parameters. Area uncertainty.

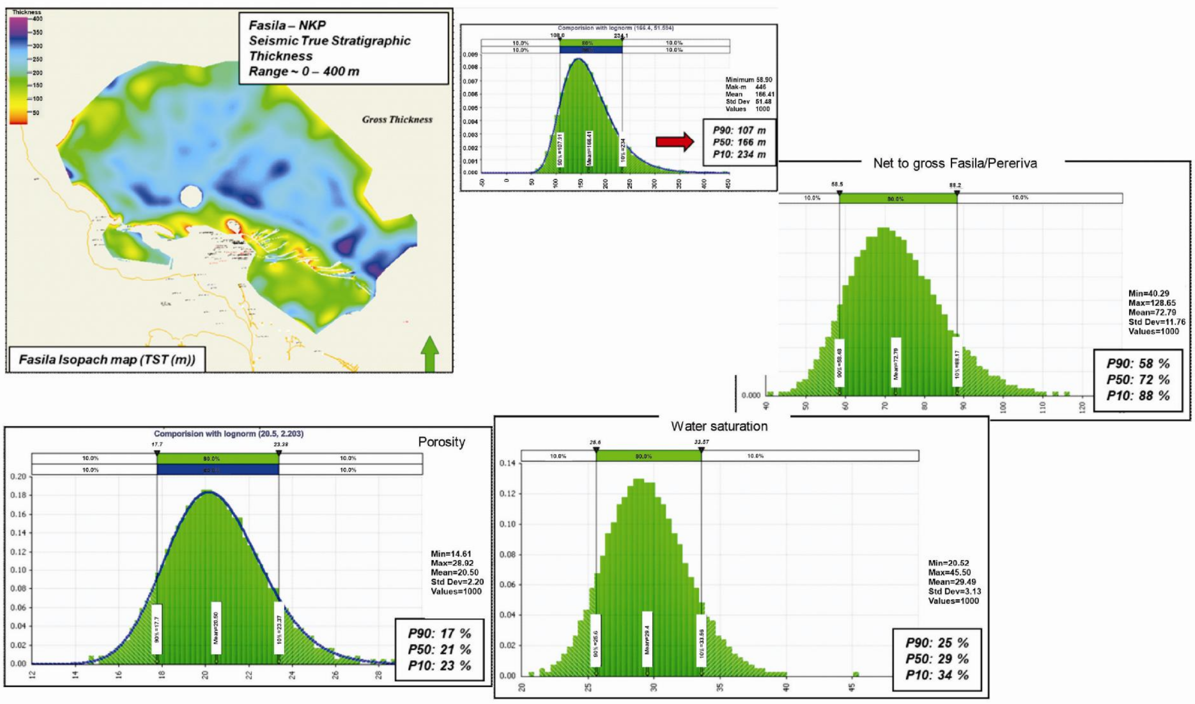

Fig. 8. Fasila/Pereriva Volumetric parameters.

Following the evaluation of individual reservoir layers, the results were consolidated to provide a comprehensive understanding of the reservoir system as a whole. This consolidation process involved combining the petrophysical parameters and reservoir properties for each layer, both at the level of individual polygons or compartments and at the total reservoir level.

By consolidating the petrophysical interpretation results for the Productive Series and the Mesozoic deposits, a detailed characterization of the reservoir properties was achieved. This comprehensive reservoir characterization serves as a crucial input for reservoir modeling, simulation, and ultimately, for making informed decisions regarding reservoir development and management strategies.

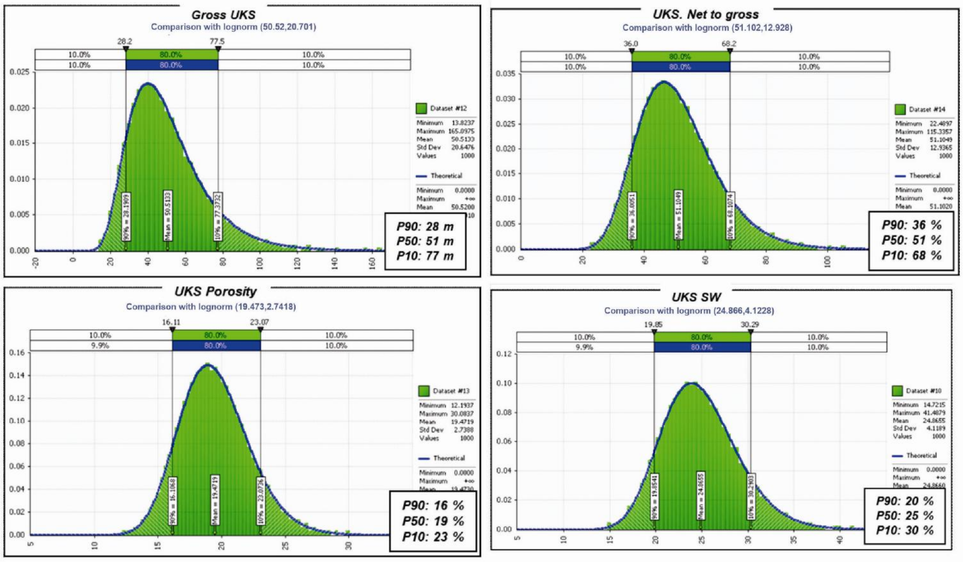

Fig. 9. Upper Kirmaki sandy (UKS) Volumetric parameters.

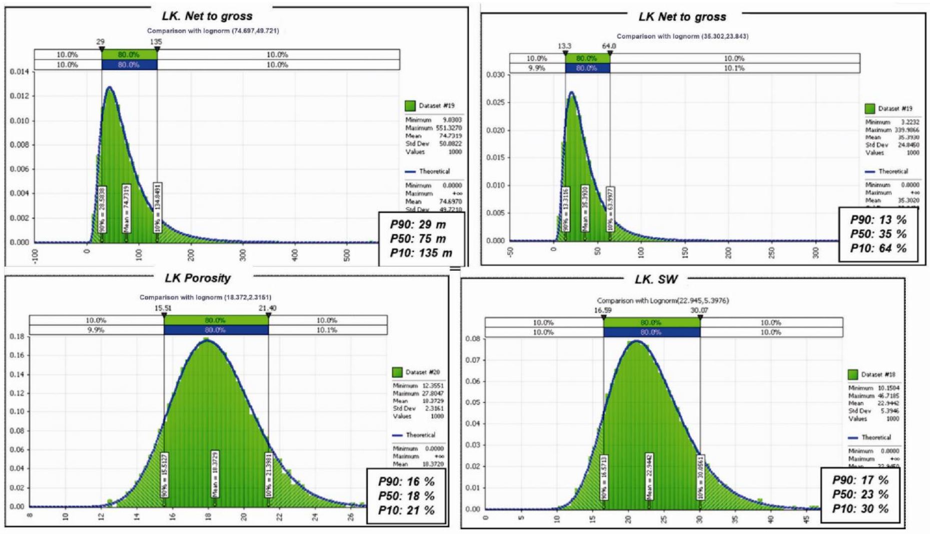

Fig. 10. Lower Kirmaki (LK) Volumetric parameters

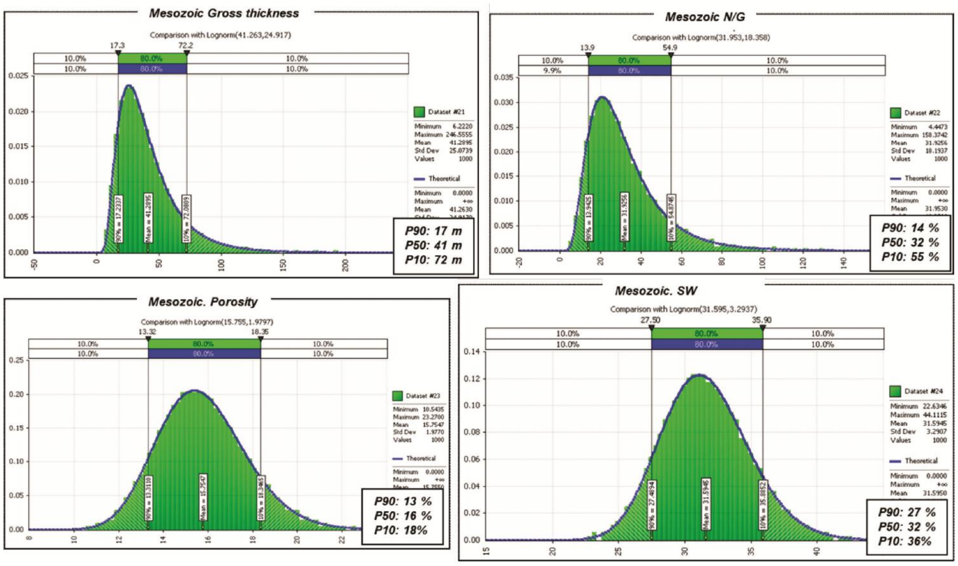

Fig. 11. Mesozoic Volumetric parameters.

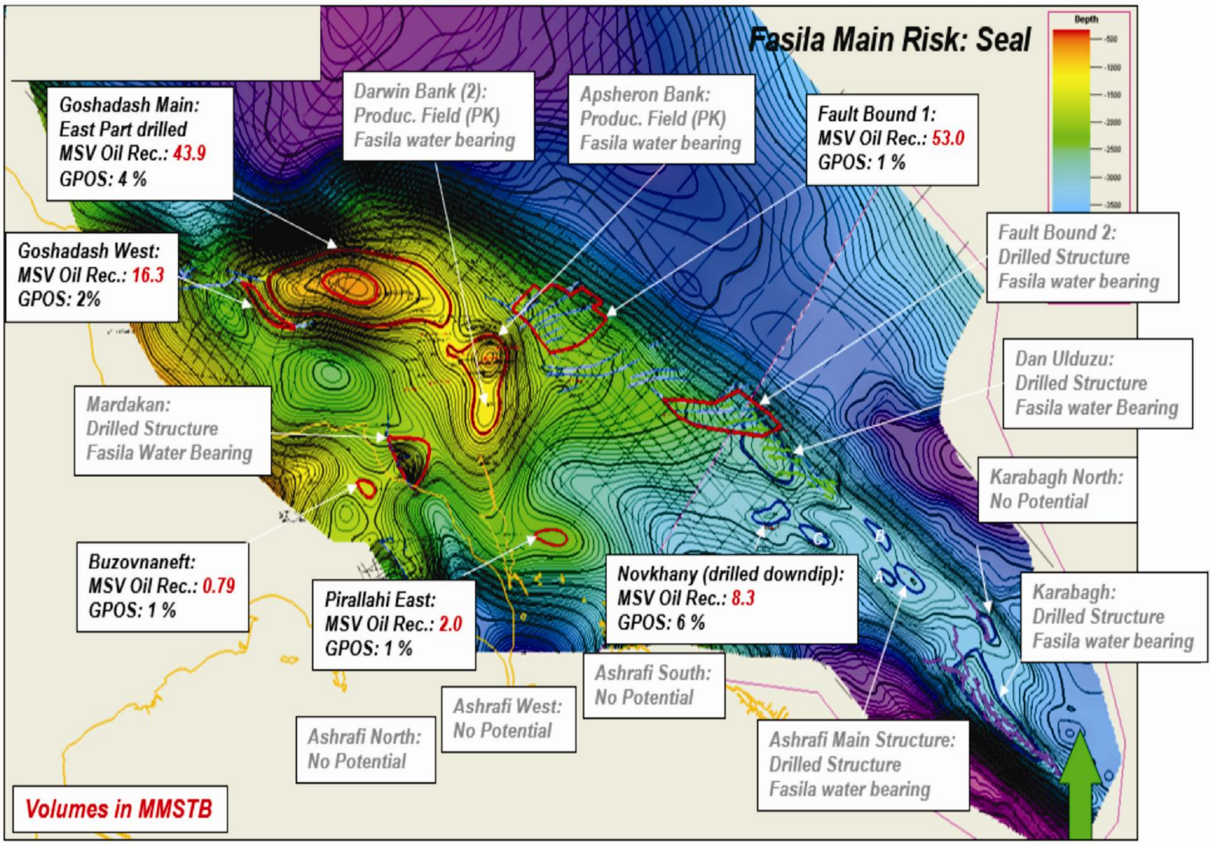

Fig. 12. Fasila/Pereriva Volumetrics & Risking.

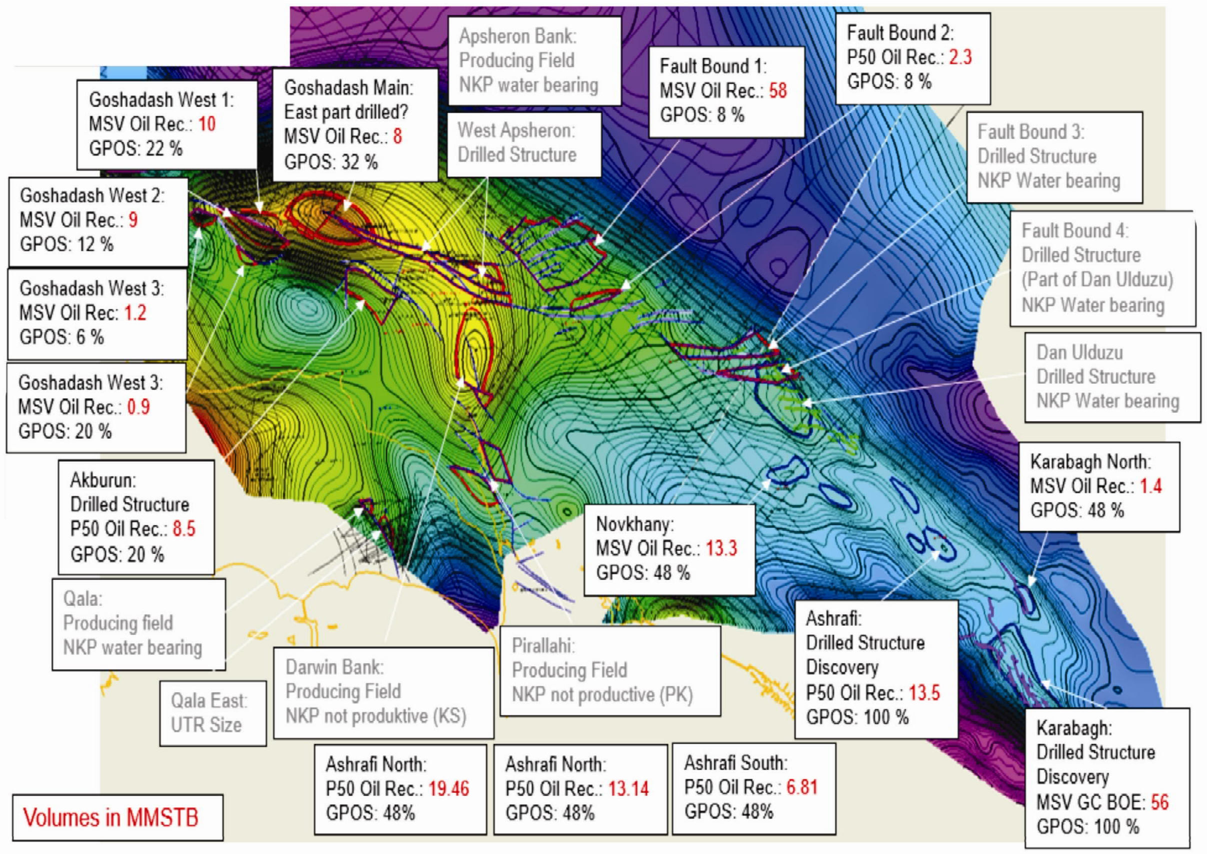

Fig. 13. Upper Kirmaki sandy suite Volumetrics & Risking.

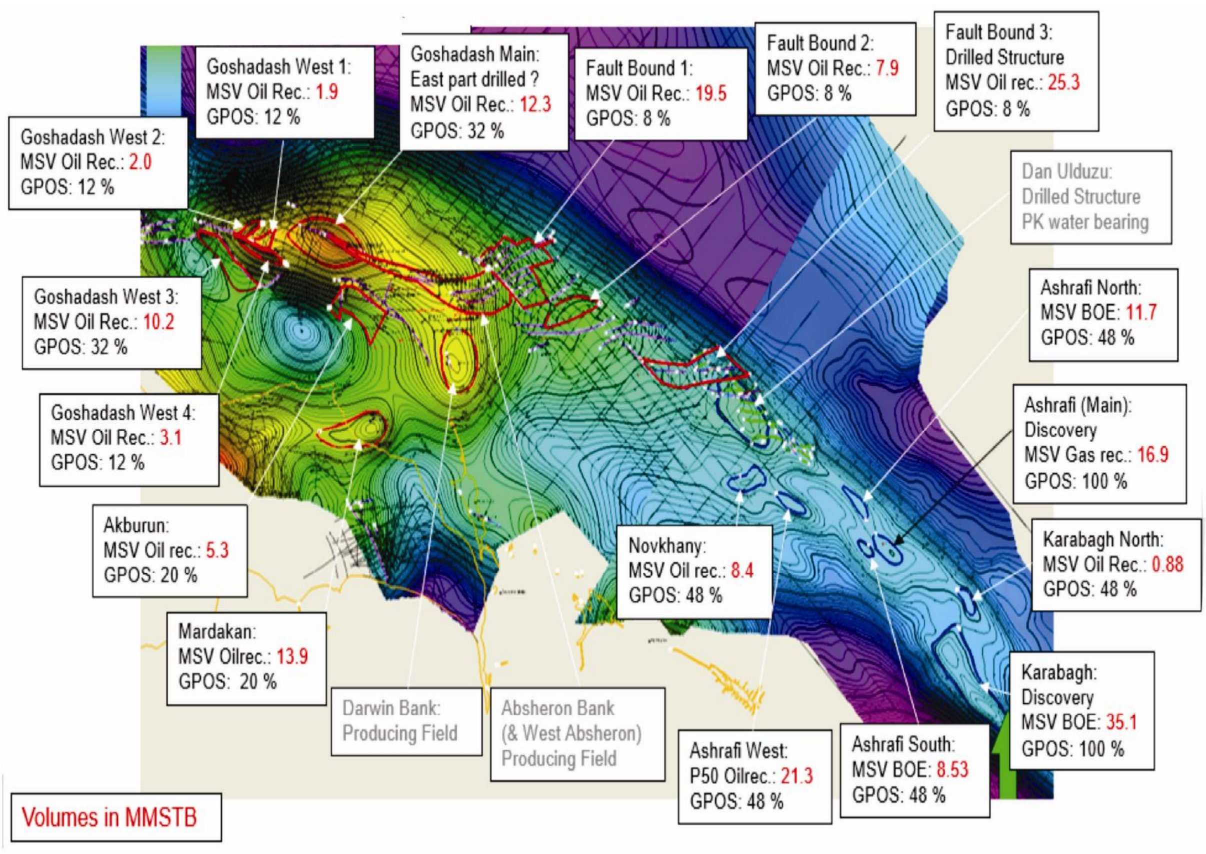

Fig. 14. Lower Kirmaki suite Volumetrics & Risking.

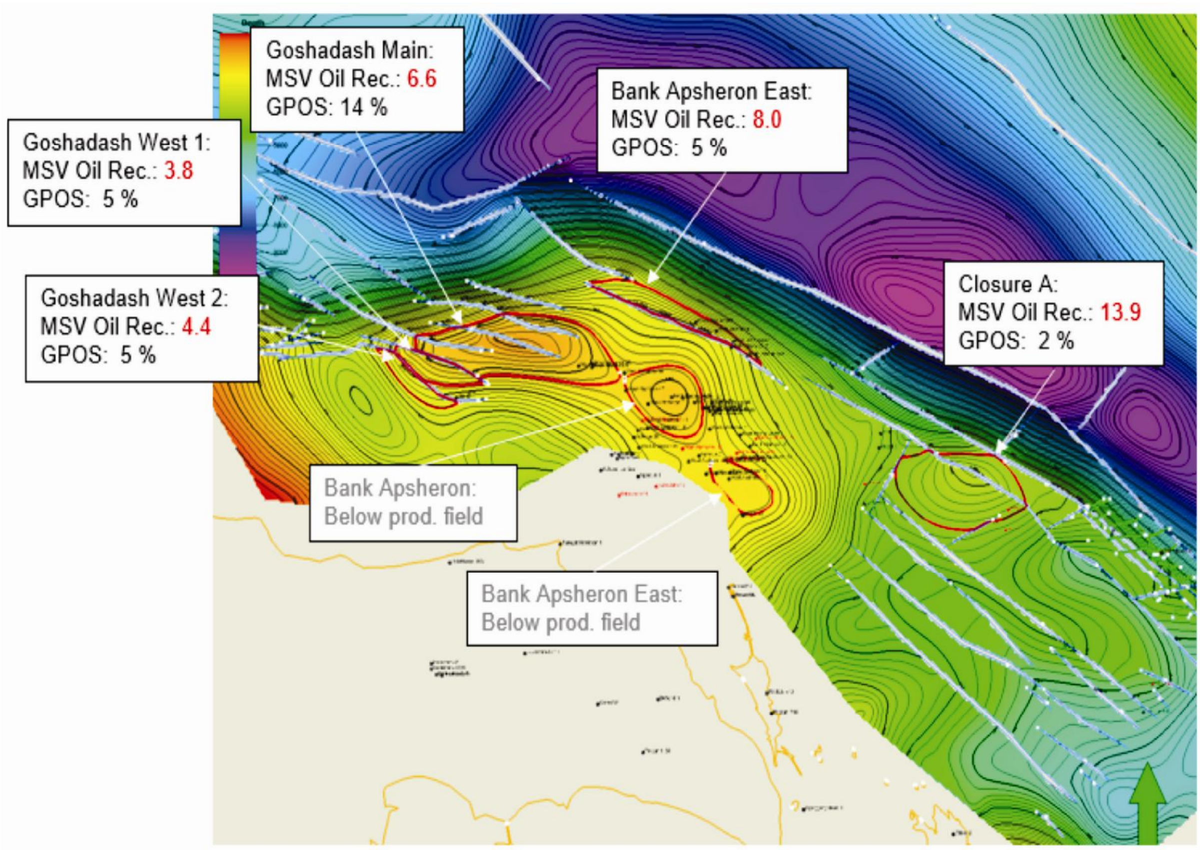

Fig. 15. Mesozoic Volumetrics & Risking.

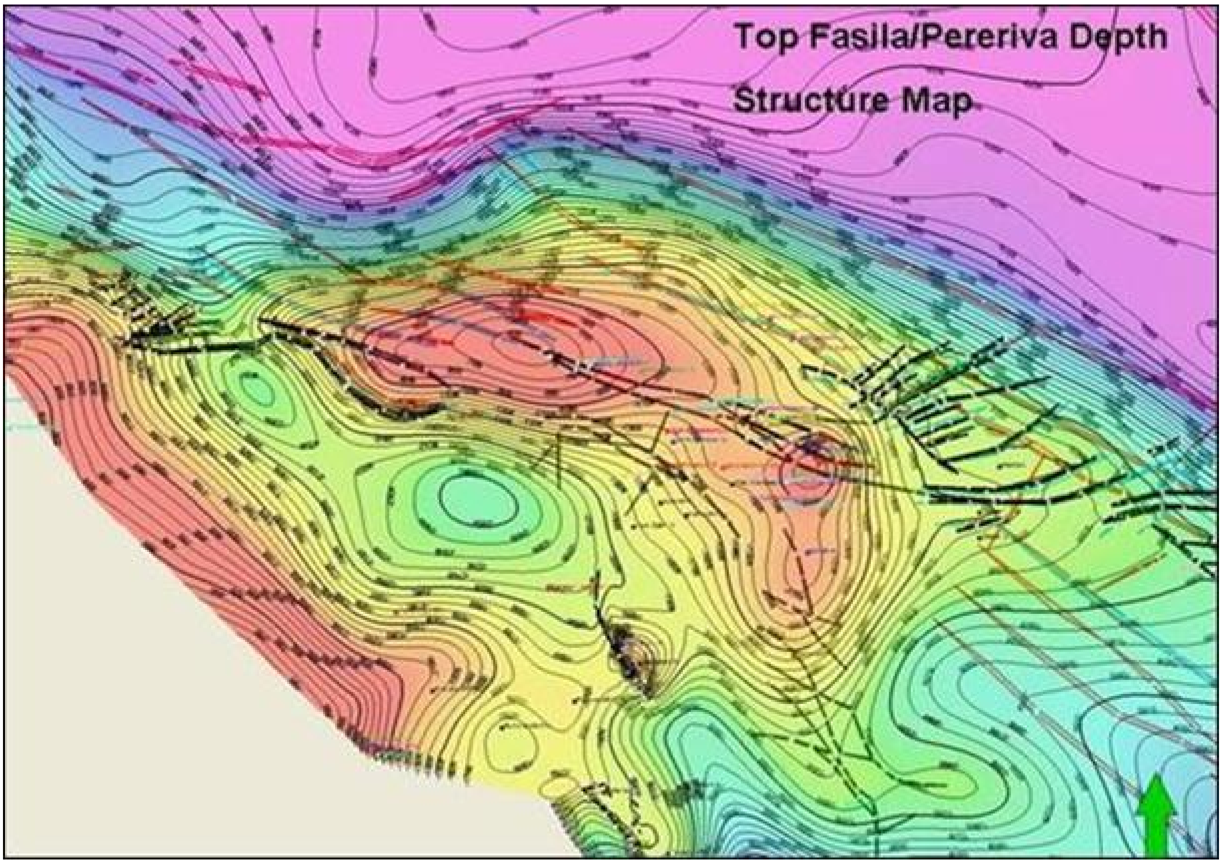

Fig. 16. Top Fasila/Pereriva depth map.

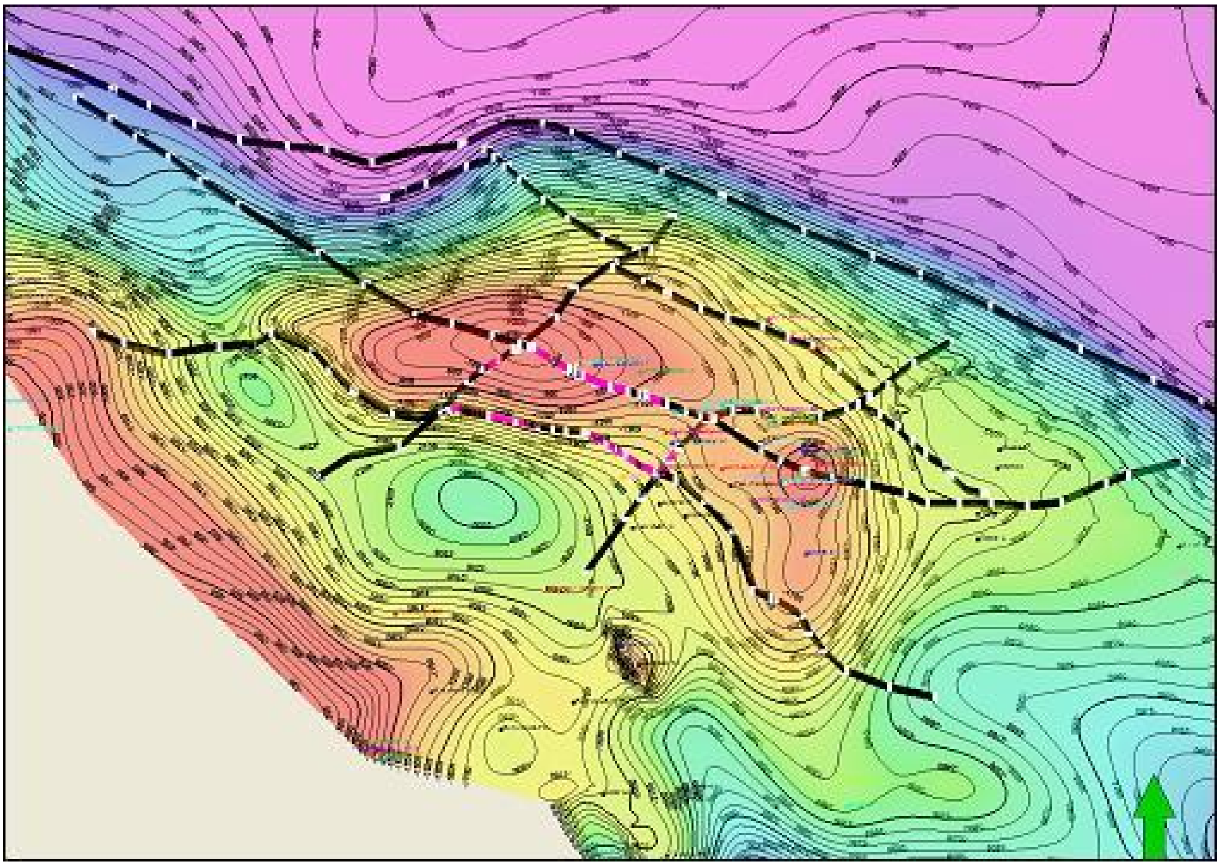

Fig. 17. Top Fasila depth map with lowest closing contour.

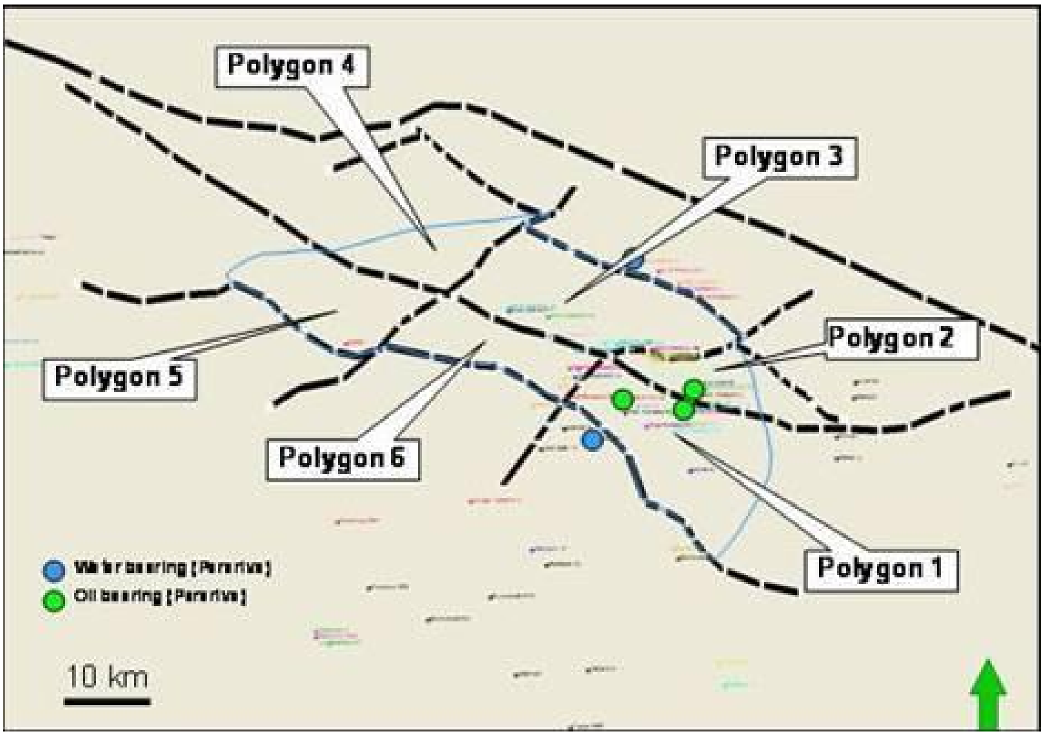

Fig. 18. Definition of reservoir polygons.

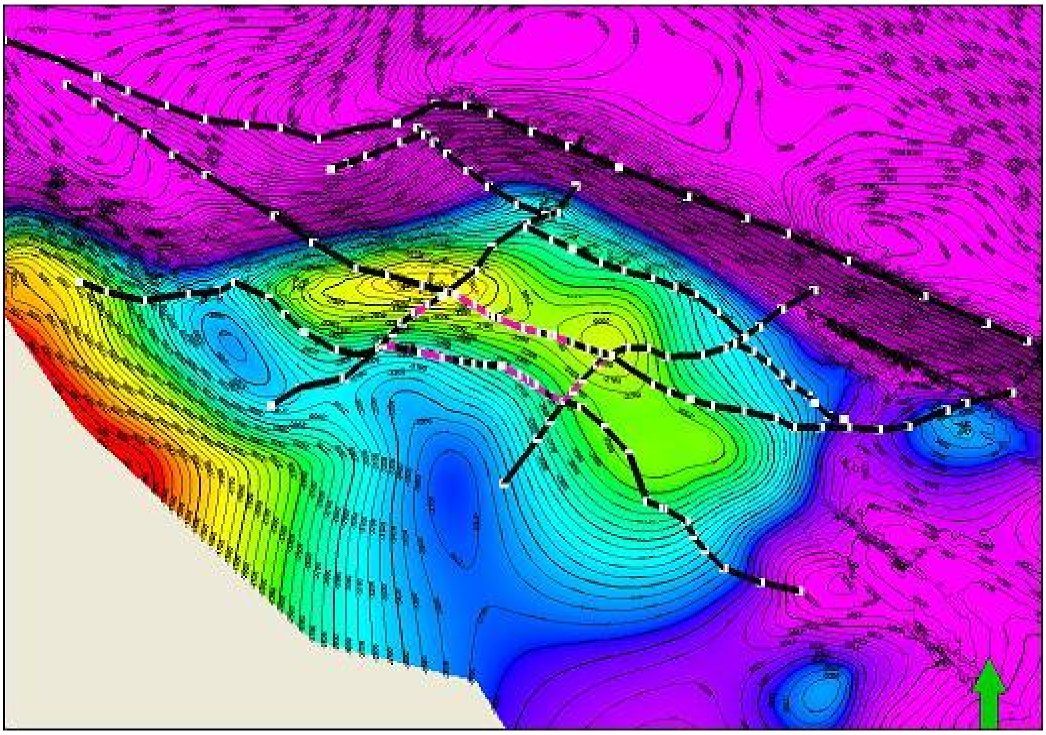

Fig. 19. Top Mesozoic depth map.

Technical Results

Productive Series Interval:

Individual resource volumes per individual reservoir layer and polygon are detailed in Tab. 1.

The overall consolidated resource volumes for the Productive Series across the entire Bank-Apsheron area amount to 80.3 million barrels (MMBBL).

The consolidated resource volumes for the Mesozoic interval across the entire Bank-Apsheron area total 21.4 MMBBL.

Specifically for the Gosha Dash area, which remains undrilled, the consolidated resource volumes are estimated at 16.1 MMBBL. This area is considered an integral part of the Bank- Apsheron structure and is designated as an appraisal and development target for future wells.

Mesozoic Interval:

A structure at the Mesozoic interval has been identified based on 2D seismic data. However, this structure represents a potential exploration target characterized by high risk due to expected severe internal compartmentalization and limited knowledge of the charge mechanism and reservoir properties.

The Gross Prospective Oil Initially in Place (GPOS) is currently estimated to range between 5-10% at maximum.

It's noteworthy that the Mesozoic interval below the Bank-Apsheron area remains undrilled to date, with only one well having penetrated the Mesozoic at the edge of the structure in a very down-dip position.

Our study unveils significant insights into the hydrocarbon potential of the Bank-Apsheron area, particularly within the Mesozoic interval, shedding light on previously unexplored reservoirs. Through meticulous analysis of geological data and seismic interpretations, we have delineated a promising structure within the Mesozoic interval, offering an estimated 21.4 million barrels (MMBBL) of consolidated resource volumes across the region. Notably, the undrilled Gosha Dash area emerges as a focal point, presenting an untapped reserve potential of 16.1 MMBBL, earmarked for future appraisal and development efforts. Moreover, our findings underscore the complexity and inherent risks associated with exploration within the Mesozoic interval, characterized by compartmentalization challenges and limited understanding of reservoir properties and charge mechanisms. This pioneering investigation sets the stage for targeted exploration strategies and underscores the necessity for further research to unlock the vast hydrocarbon reserves concealed within the Bank-Apsheron area's Mesozoic strata.

Table 1

Resource volumes of all reservoir layers in the Bank-Apsheron/Gosha Dash area.

			MMBBL, Recoverable reserves , MSV unrisked	GPOS%	Comment
polygon 1	Productive series	Pereriva/Fasila	1.9	100	
		upper Kirmaki sandy (UKS)	0	100	proved water bearing by well
		Kirmaki	0	100	proved water bearing by well
		lower Kirmaki (LK)	21.3	100	
		Kalinskaya (KaS)	3.04	100	
		Mesozoic (oil case)	13.7	5-10%	
polygon 2	Productive series	Pereriva/Fasila	1.91	100	
		upper Kirmaki sandy (UKS)	0	100	proved water bearing by well
		Kirmaki	0	100	proved water bearing by well
		lower Kirmaki (LK)	14.9	100	
		Kalinskaya (KaS)	1.75	100	
		Mesozoic (oil case)	11.4	5-10%	
polygon 3	Productive series	Pereriva/Fasila	21.5	24	
		upper Kirmaki sandy (UKS)	5.9	12	
		Kirmaki	4.5	12	
		lower Kirmaki (LK)	9.06	30	
		Kalinskaya (KaS)	3.45	30	
		Mesozoic (oil case)	22.4	5-10%	
polygon 4	Productive series	Pereriva/Fasila	23.6	23	
		upper Kirmaki sandy (UKS)	1.95	11	
		Kirmaki	1.21	11	
		lower Kirmaki (LK)	2.71	28	
		Kalinskaya (KaS)	1.01	28	
		Mesozoic (oil case)	34.06	5-10%	
polygon 5	Productive series	Pereriva/Fasila	24.6	23	
		upper Kirmaki sandy (UKS)	3.05	11	
		Kirmaki	1.95	11	
		lower Kirmaki (LK)	4.29	28	
		Kalinskaya (KaS)	1.6	28	
		Mesozoic (oil case)	17.3	5-10%	
polygon 6	Productive series	Pereriva/Fasila	39.3	23	
		upper Kirmaki sandy (UKS)	2.57	11	
		Kirmaki	1.67	11	
		lower Kirmaki (LK)	3.65	28	
		Kalinskaya (KaS)	1.34	28	
		Mesozoic (oil case)	11.3	5-10%	

Conclusions and recommendations

The Bank-Apsheron, West-Apsheron, and Gosha Dash areas exhibit significant potential in the Lower Productive Series (LK, LKS) within the transition zone offshore Azerbaijan, with a total estimated resource volume of 80.3 million barrels (MMBBL).

Recent production activities by SOCAR have focused on the Bank-Apsheron field within the Productive Series. While West-Apsheron has been drilled by SOCAR, it has not yet been developed for production.

Among these areas, Gosha Dash stands out as the only undrilled region within the entire Bank-Apsheron area, holding an estimated resource volume of 16.1 MMBBL. Gosha Dash is considered a prime target for potential field extension, making it an area of interest for further appraisal and development efforts by SOCAR.

Additionally, exploration potential below the Bank-Apsheron and West-Apsheron areas lies in the Mesozoic interval, identified through 2D seismic data at approximately 2000 meters depth. This area represents an opportunity for future exploration endeavors.

The Mesozoic interval in the entire area is estimated to hold 21.4 million barrels (MMBBL) of resources, with a relatively low Gross Petroleum Oil initially in Place (GPOS) ranging from 5-10%. However, after consolidation, the GPOS increases to 32%, indicating a potentially high resource concentration.

To gain a comprehensive geological understanding of the Bank-Apsheron structure, a dedicated 3D seismic survey covering the entire area, focusing on both the Productive Series and the Mesozoic, would be necessary.

Exploration potential exists in the shallow-water Transition Zone of the Apsheron area, particularly in the undrilled areas adjacent to the Apsheron Bank, such as the Sumgait Sea and Kurdakhani Sea. The Kalin Zaliv field, although discovered with oil and gas, remains undeveloped due to infrastructure limitations.

Several wells drilled in prospects such as North Apsheron, Yashma Sea, Kurkachidag Sea, Mardakan Sea, Agburun Sea, Arzu, and Gilavar have not yielded commercial discoveries due to technical and geological challenges.

While gas condensate discoveries have been made in prospects like Khazri and Noukhnay, the absence of infrastructure has hindered their production.

Areas such as East Apsheron, Gosha Dash, Sevinj, Gatl Gunu, Sumgatit Sea, and Kurdakhani Sea remain unexplored as they have not been drilled yet. These areas represent potential targets for future exploration activities.

Indeed, the transition zone of the Apsheron shallow waters holds promising potential for oil and gas exploration. Given the challenges encountered during drilling in the Mesozoic deposits, it is imperative to adopt a specialized approach and thorough preparation for future drilling endeavours. Utilizing modern 3D seismic technology can provide valuable insights into the subsurface geology, helping to identify optimal drilling locations and mitigate risks associated with drilling in complex formations.

Horizontal drilling from the shore, as practiced in other regions like the North Sea, could offer a viable solution for accessing Mesozoic reservoirs while minimizing logistical and operational challenges associated with offshore drilling. This approach requires meticulous planning and coordination to ensure safe and efficient operations.

Past drilling experiences underscore the importance of improving core sampling techniques and conducting comprehensive field geophysical surveys to enhance the accuracy of geological assessments. By adhering to best practices and leveraging advanced technologies, future exploration efforts in the Mesozoic formations of Azerbaijan can be conducted more effectively, potentially unlocking significant hydrocarbon reserves in the region.

Special Gratitude

I would like to express my gratitude to my ex-colleague Dr.Thomas Kraft from the Wintershall company, with whom we worked together on a regional study of the North Absheron Trend. Despite different views on calculating the reserves of individual areas of the Absheron Trend, he played an important role and provided valuable advice on constructing structural maps.

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ГЕОЛОГІЯ ТА ПЕРСПЕКТИВИ ВУГЛЕВОДНІВ У ПЕРЕХІДНІЙ ЗОНІ МІЛКОВОДДЯ АПШЕРОНСЬКОГО РОДОВИЩА

Район Апшеронського родовища представляє найбільш багатообіцяючі нафтогазові перспективи в межах мілководної перехідної зони Апшеронського архіпелагу на всіх потенційних рівнях пластів. Представлені у статті дослідження мають на меті виявити геологорозвідувальний потенціал території та пов’язані з цим нові можливості для бізнесу. Регіон охоплює глибини води від 10 до 20 метрів. Методологічно ми використали доступні нові сейсмічні дані, оцінили дані еталонних свердловин і врахували інші геологічні фактори в рамках програми *Petrel*. Індивідуальні обсяги видобувних ресурсів на пласт-колектор були розраховані за допомогою програми Монте-Карло. Загальний сукупний обсяг ресурсів продуктивної серії на всій площі банки Апшерон становить 80,3 млн барелів (MMBBL). Крім того, сукупні обсяги ресурсів для мезозою по всій площі банки Апшерон становлять 21,4 млн. барелів. Зокрема, на ділянку Gosha Dash припадає 16,1 MMBBL сукупних обсягів ресурсів. Примітно, що ця площа залишається нерозбуреною. Структура Gosha Dash розглядається як потенційий об’єкт для розширення родовища, сприяючи збільшенню залишкового геологорозвідувального потенціалу банки Апшерон і Західного Апшерону. Мезозойські відклади на цій ділянці було виявлено за допомогою сейсмічних даних 2D на глибині приблизно 2000 метрів. Отже, ця ділянка структури не визначається виключно для цілей розвідки, але також служить об’єктом оцінки та розробки для буріння майбутніх свердловин.

Ключові слова: Південний Каспій; банка Апшерон; шельфове родовище; нафта і газ; інтерпретація сейсмічних даних; геологія; прогноз нафтогазоносності.

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