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EXPLORATION PERSPECTIVES OF THE KARABAKH FIELD IN THE SOUTH CASPIAN BASIN

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Summary. The Karabakh field, situated in the northern Absheron Archipelago within the South Caspian Basin, presents significant hydrocarbon potential, primarily in the Lower and Upper Kirmaki formations. Initially, the field was discovered in 1998 by the Caspian International Operating Company consortium. The project was suspended in 1999, when the oil price was 25–26 dollars per barrel. Despite the discovery of the fields, the project was closed due to the oil and gas reserves being deemed economically unfeasible for development. However, in 2018, its development began within the framework of a contract signed between SOCAR and Equinor.

Geological studies, including stratigraphy, well logging, and petrophysical interpretations, were conducted on data from three wells (KPS-1 to KPS-3) with notable production test success in KPS-2. Positive gas and condensate results were identified from both the Lower Kirmaki and Upper Kirmaki sandy intervals highlighting the commercial viability of the field.

The structural complexity of the region marked by asymmetric folds, thrust faults, and lithological variability–poses significant exploration and drilling challenges. Stratigraphic assessments reveal a thick sequence of sandy-argillaceous formations, with key reservoirs demonstrating high porosity (up to 22%) and sand content (up to 75%). Drilling operations have been impeded by unstable pore pressures, clay swelling, and overpressure zones, particularly in the Gala and Miocene Formations. The presence of montmorillonite-rich clays further complicates borehole stability.

Comparative regional analysis and historical data from the adjacent fields support the Karabakh potential but underscore the need for further appraisal. Recommendations include the targeted drilling, enhanced seismic analysis, updated petrophysical interpretation, and rigorous pressure management. Addressing these technical and geological uncertainties is essential to unlock the full economic potential of the Karabakh field and ensure safe, efficient offshore development.

Keywords: *The South Caspian Basin, oil and gas exploration, petrophysical log analysis, lithology, stratigraphy, drilling*

Introduction

The Karabakh field is located in the northern sector of the Absheron Archipelago, within the North Absheron uplift zone of the South Caspian Basin (Ronchitelli, 1999). Geographically, it lies approximately 120 km southeast of Baku and 85 km offshore from the Absheron Peninsula. It is situated 20-25 km northeast of the Neft Dashlari and Guneshli oil fields. The region features moderate sea depths ranging from 130 to 180 meters and is underlain by modern Caspian sediments, including clay sands, sandstones, and shell debris. Deeper geological intervals are predominantly composed of compact clays (Fig. 1).

Following the State Program for the Development of the Petroleum and Energy Complex of Azerbaijan, adopted in 2005, SOCAR began design work in 2006 for the development of the Karabakh field, which was originally discovered by the CIPCO Consortium in 1998. Proven hydrocarbon reserves in the field are estimated at 16 million tons of oil and 20 billion cubic meters (BCM) of gas.

SOCAR commissioned its Caspian Offshore Oil and Gas Project Institute to develop a comprehensive project plan, including the design of a drilling and production platform and associated subsea pipelines. The project includes the construction of a drilling and production platform equipped for 12 wells (8 gases and 4 oils). The development plan was submitted to SOCAR for review and approval in February 2007. Following the contractual phase – covering platform and pipeline construction, drilling equipment procurement, and other tangible assets – oil and gas production was projected to begin in late 2008 or

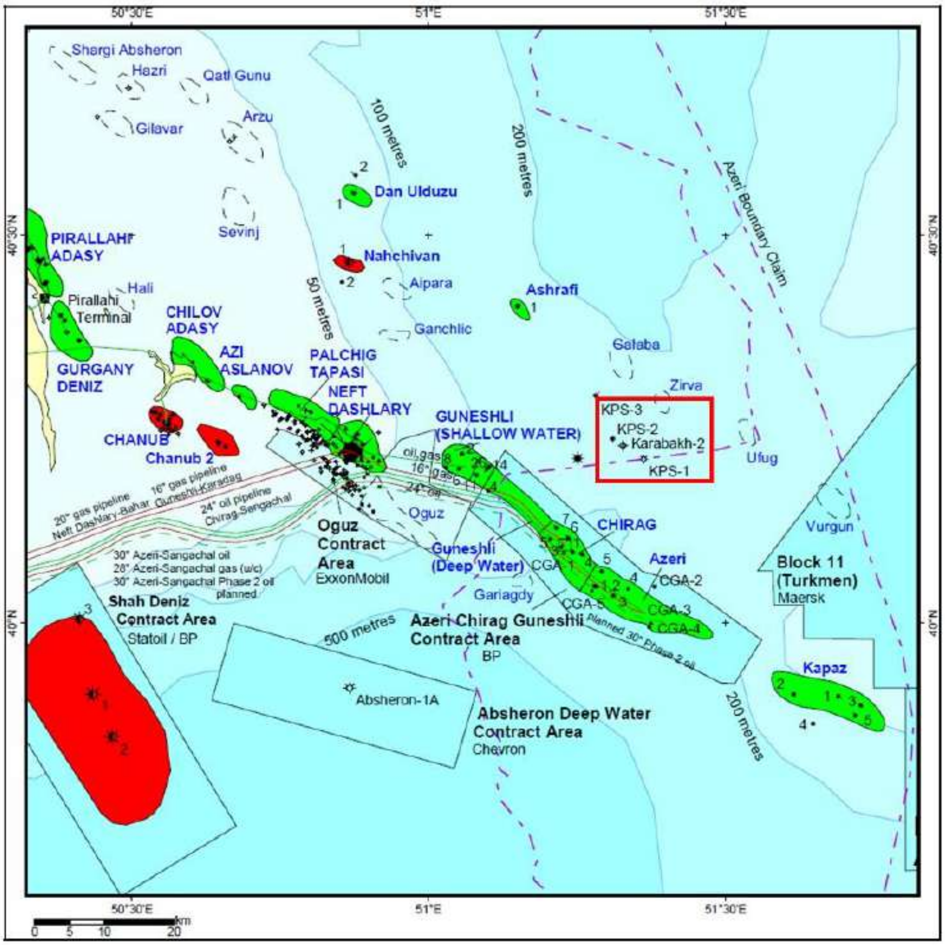

Fig. 1. Karabakh location map

early 2019. In its initial phase, the project was expected to significantly increase SOCAR's hydrocarbon production.

SOCAR opted not to employ advanced drilling and production technologies such as horizontal drilling or open-hole gravel packs at the Karabakh field. Preliminary estimates set the capital expenditure for full field development at approximately $200 million. Despite the potential of the project, few foreign oil companies have expressed willingness to co-finance and co-develop the field with SOCAR. The status of these negotiations remains unclear (Azerbaijan Petroleum Industry Review, 2007).

On May 31, 2018, SOCAR and Equinor signed a Risk Service Contract in Baku for the development of the Karabakh field. The agreement was ratified by the National Assembly of Azerbaijan on June 29, 2018, and entered into force on July 5. The project was to be carried out through a jointly operated company with a 50/50 ownership structure (Caspian Barrel, 2019). However, in 2024, Equinor divested all its remaining assets in Azerbaijan to SOCAR, making SOCAR the sole operator of the project.

Wells KPS-1, KPS-2, and KPS-3 were drilled using the “Dada Gorgud” rig. The elevation of all three wells was 22 meters, with water depths of 180 m for KPS-1, 176 m for KPS-2, and 181 m for KPS-3. The rig was positioned on August 5, 1997. Drilling operations commenced on KPS-1 on August 8, 1997, and concluded on November 21, 1997. KPS-2 was drilled from April 8 to July 1, 1998, and KPS-3 from September 21 to November 3, 1998. The KPS-4 well was also drilled using the same rig (Photo 1)**.**

Materials and Methods

Between 1997 and 1998, biostratigraphic consultancy was provided to CIPCO Operation Company for a study based on cuttings and core samples obtained from three deep exploration wells in the Karabakh region (Table 1).

Photo 1. "Dada Gorgud" rig
(https://www.caspiandrilling.com/browse.php?sec_id=12)

In 2007, during the course of the Ashrafi-Karabakh project conducted by the German company Wintershall, official well log data were acquired from SOCAR. These data were originally available only in paper format but were subsequently digitized and edited by Petrologic Data Services GmbH. The finalized dataset was delivered in LAS digital format with a sampling interval of 0.1524 meters. Rigorous quality control of the log data for the Karabakh-2 and Karabakh-3 wells was carried out by Mr. Richard Culpman, confirming their reliability. For other intervals, only low-resolution composite logs were accessible. As a result, the detailed analysis and achievement of the project objectives were primarily feasible for the Karabakh-2 and Karabakh-3 wells, whereas interpretations of the Karabakh-1 well were considered qualitative rather than quantitative.

Petrophysical interpretations of the Karabakh wells were performed in collaboration with Mr. Culpman. All formation tops in the logs were corrected manually. A standard deterministic interpretation was conducted using Interactive Petrophysics software under Mr. Culpman's supervision.

Prior to 1997, biostratigraphic analyses were carried out on five shallow engineering drilling wells during offshore exploration work at SOCAR. These studies aimed to provide a detailed understanding of Quaternary sea-bottom sediments, focusing on their composition, microfauna, stratigraphy, thickness, and physical properties. Such analyses were essential for improving the efficiency and safety of geological exploration and for addressing engineering and geotechnical challenges related to offshore field development (Akhmedov et al., 1998).

A comprehensive exploration incorporating petrophysical interpretations, core and cutting analyses, and seismic data review was undertaken to evaluate the hydrocarbon potential of the Karabakh prospective structure.

Between 1997 and 1998, I served as a biostratigraphy consultant for CIPCO Operation Company, contributing to a study based on cuttings and core samples obtained from three deep exploration wells in the Karabakh region (Table 1).

In 2007, during my tenure at the German company Wintershall, I led the Ashrafi-Karabakh project. As part of the project, the company officially acquired well log data from SOCAR. These data were initially available only in paper format but were later digitized and edited by Petrologic Data Services GmbH. The final dataset was delivered in LAS digital format with a sampling interval of 0.1524 meters. I extend special thanks to my former colleague, Mr. Richard Culpman, whose rigorous quality control confirmed the reliability of the log data for the Karabakh-2 and Karabakh-3 wells. For other intervals, only low-resolution composite logs were available. Consequently, the detailed analysis and fulfilment of the project objectives were achievable primarily for the Karabakh-2 and -3 wells, while interpretations for the Karabakh-1 well should be regarded as qualitative rather than quantitative.

In collaboration with Mr. Culpman, we conducted petrophysical interpretations of the Karabakh wells. All formation tops in the logs were corrected by me. A standard deterministic interpretation was carried out using Interactive Petrophysics software under the supervision of Mr. Culpman.

Prior to 1997, during my service as an offshore exploration geologist at SOCAR, I performed biostratigraphic analyses on five shallow engineering drilling wells. These studies aimed to achieve a detailed understanding of Quaternary sea-bottom sediments, focusing on their composition, microfauna, stratigraphy, thickness, and physical properties. Such insights are critical not only for enhancing the efficiency and safety of geological exploration but also for addressing engineering and geotechnical challenges associated with offshore field development (Akhmedov et al., 1998).

A comprehensive exploration encompassing petrophysical interpretations, core and cutting analyses and a review of seismic data facilitated an assessment of the hydrocarbon potential of the Karabakh prospective structure**.**

Geological and Geophysical Exploration

Initial exploratory activities commenced in 1993 with two wells drilled by the State Oil Company of the Azerbaijan Republic (SOCAR). Well No. 1 targeted the Pliocene Gala Formation at a projected depth of 4200 meters but was abandoned at 720 meters due to technical difficulties. Well No. 2, also targeting the Gala Formation, was terminated at 1567 meters upon reaching the Surakhany suite for similar reasons (Javadova, 2005).

Subsequent exploration between 1996 and 1998 involved 3D seismic surveys by international operators and the drilling of three additional wells (KPS-1, KPS-2, and KPS-3) by a foreign consortium. These wells intersected sedimentary sequences ranging from the Quaternary to the Miocene (Fig. 2).

- **KPS-1** (central axis): drilled to 3840 m; targeted Productive Series.
- **KPS-2** (southwestern flank): reached 3809 m.
- **KPS-3** (northern flank): drilled to 3766 m.

The primary objective was to evaluate the hydrocarbon potential of the Balakhany (Horizons X, IX, and VIII) and Fasila Formations. Due to limited reservoir quality and hydrocarbon shows in these zones, deeper secondary targets in the Lower and Upper Kirmaki formations were also evaluated.

Table 1

List of the studied core and cutting materials

Structure/ field name	well №	Penetrated well depth	number of core sample and sludge cuttings	Core intervals (m)
Karabakh	8	0-150	10	0-5; 10-20;35-38; 38-43; 40-55; 60-65; 75-80; 80-85; 90-100; 145-150
	3	0-200	8	0-5; 5-10; 20-30; 55-60; 190-200; 970-975; 976-980; 1055-1065
	24	0-150	5	0-10; 20-30; 30-40; 90-100; 140-150
	4	0-100	4	0-10; 40-50; 70-80; 90-100
	2	755-900	6	655-665; 680-690 ; 690-1000 ;1050-1060; 1060-1070;1100-1110
	KPS-3	330-3723	core - 2; cuttings - 617	cuttings: 330-1000 m every 10 m;.1003-3425 m every 5 m; 3425-3445 m every 3 m; 3445-3766 m every 5 m; Core: 3701-3712.20 m; 3712.20-3723 m
	KPS-2	3407-3419	5	3407-3408 m; 3408-3409 m; 3409-3416 m; 3416-3418 m; 3418-3419 m
	KPS-1	1000-3840	cuttings - 95; core - 29	cuttings 328-1000 m every 10 m; 1000-3485 m every 3 m; core: 3610-3619 m; 3753-3762 m; 3762-3840 m every 3 m

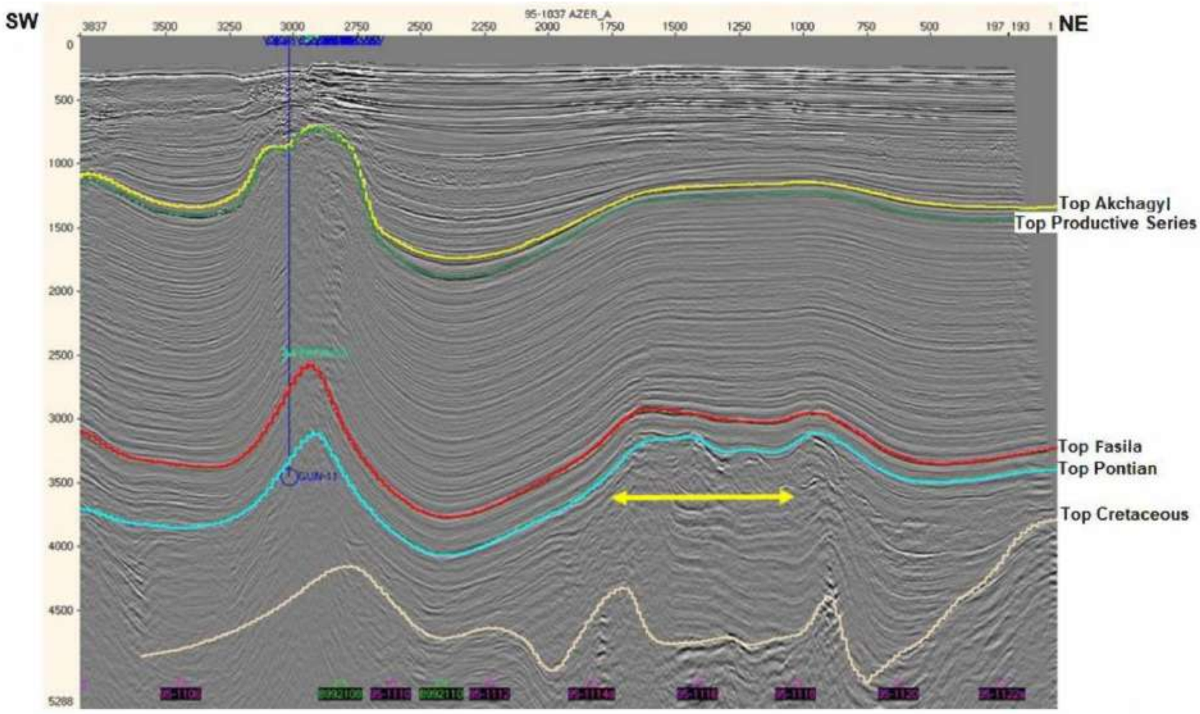

Fig. 2. Seismic section over Karabakh field

Tectonic Setting

- Tectonically, the Karabakh field lies within the North Absheron uplift zone, a region characterized by intense Neogene folding and faulting. All local structures of the zone where the located Karabakh field are characterized by small sizes (5-10x12 km), inconsiderable amplitudes (100-200 m), flanks of least dip (up to 7-12°) and their echelon joint. The arches of the structures are usually broad and without faults. Their structure gets more complex with depth (Babayev, Gadjiev, 2006). Structural geometries of the Karabakh field include asymmetrical and locally overturned anticlines segmented by longitudinal (thrust and strike-slip) and transverse faults. The Karabakh fold trends NW–SE and comprises two domal culminations (Javadova, 2019).

The structure is further complicated by latitudinal and longitudinal fault systems, particularly in its axial part, where the amplitude of displacement ranges from 50 to 120 meters. The southwestern flank exhibits dips of 18-20°, whereas the northeastern flank dips at 9-10°, increasing with depth. These structural features suggest a syndepositional tectonic regime and pose challenges for uniform geological prediction across the field. (La Bella et al., 1996) (Fig. 3).

Stratigraphy and Lithological Characteristics

The stratigraphic column of the Karabakh area can be subdivided into four main intervals (Fig. 4):

1. **0-700 m (Quaternary):** Unconsolidated sandy-argillaceous sediments with drilling difficulties due to low compaction.
2. **700-2220 m (Absheron–Akchagyl and Upper Productive Series):** Transitional sequence with increasing lithological stability.
3. **2220-3500 m (Productive Series):** Comprising the lower Surakhany, Sabunchu, Balakhany, Fasila, and Upper Kirmaki formations.

>3500 m: Lower Kirmaki sediments and deeper sequences.

The lithology predominantly consists of hard, grey sandstone-siltstone interbeds with compact plastic clays. Reservoir properties of key formations are summarized below:

Formation	**Sand Content (%)**	**Average Porosity (%)**
Balakhany	60	19.0
Fasila	65	20.2
Upper Kirmaki (Sandy)	75	22.0

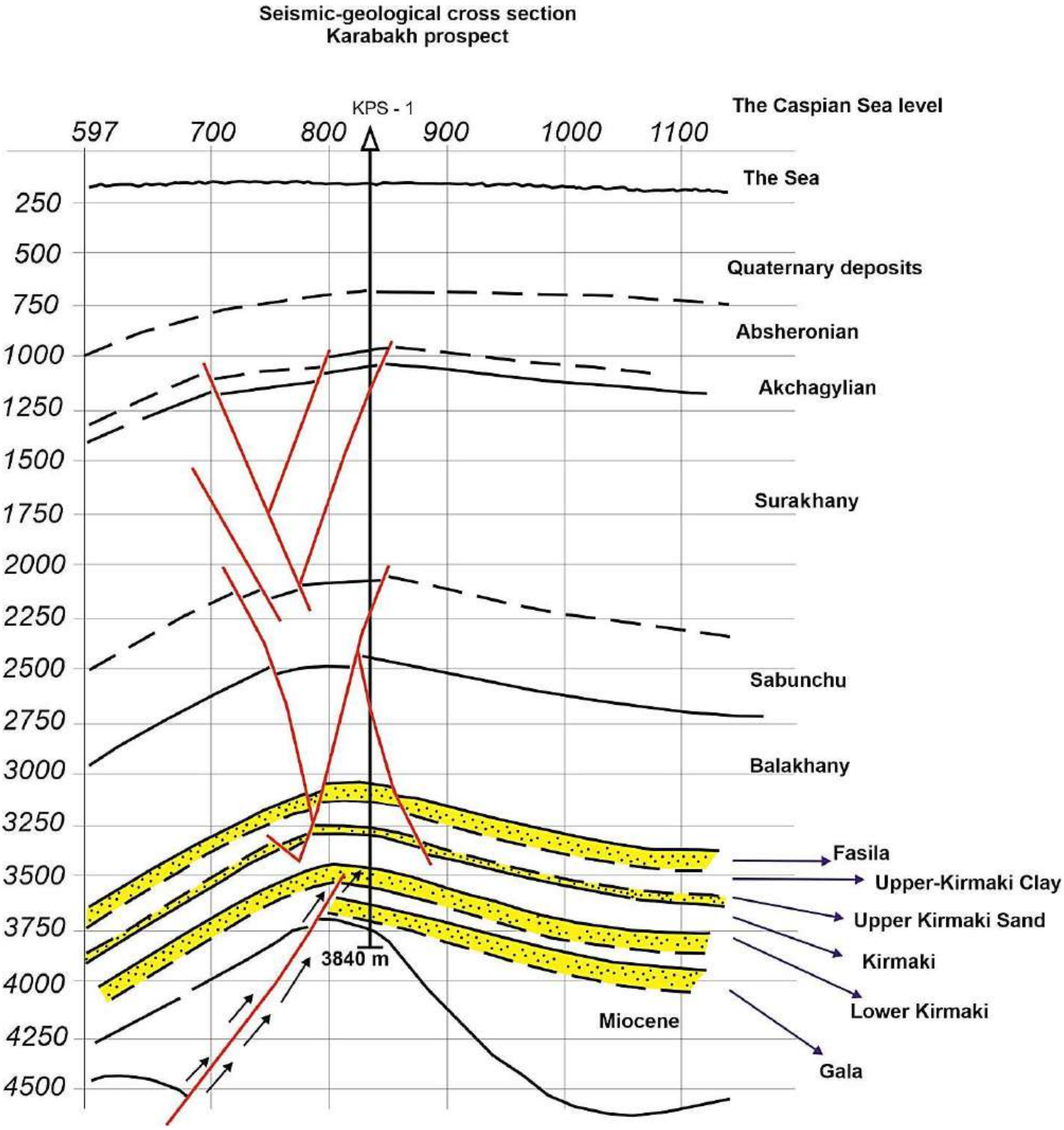

Fig. 3. Seismic-geological cross section Karabakh prospect

From a lithological perspective, several important characteristics of the layers merit attention. Clay-rich intervals, particularly below the Surakhany suite, exhibit swelling behavior that complicates drilling operations and wellbore stability.

It should be noted that the Upper Kirmaki sandy formations in the Absheron archipelago areas are characterized by lithological stability, it can be assumed from well KPS-1 data that the Upper Kirmaki sandy formation did not undergo any considerable lithofacial changes in the Karabakh prospect.

Clay-rich intervals, particularly below the Surakhany suite, exhibit swelling behavior that complicates drilling operations and wellbore stability (Table 2).

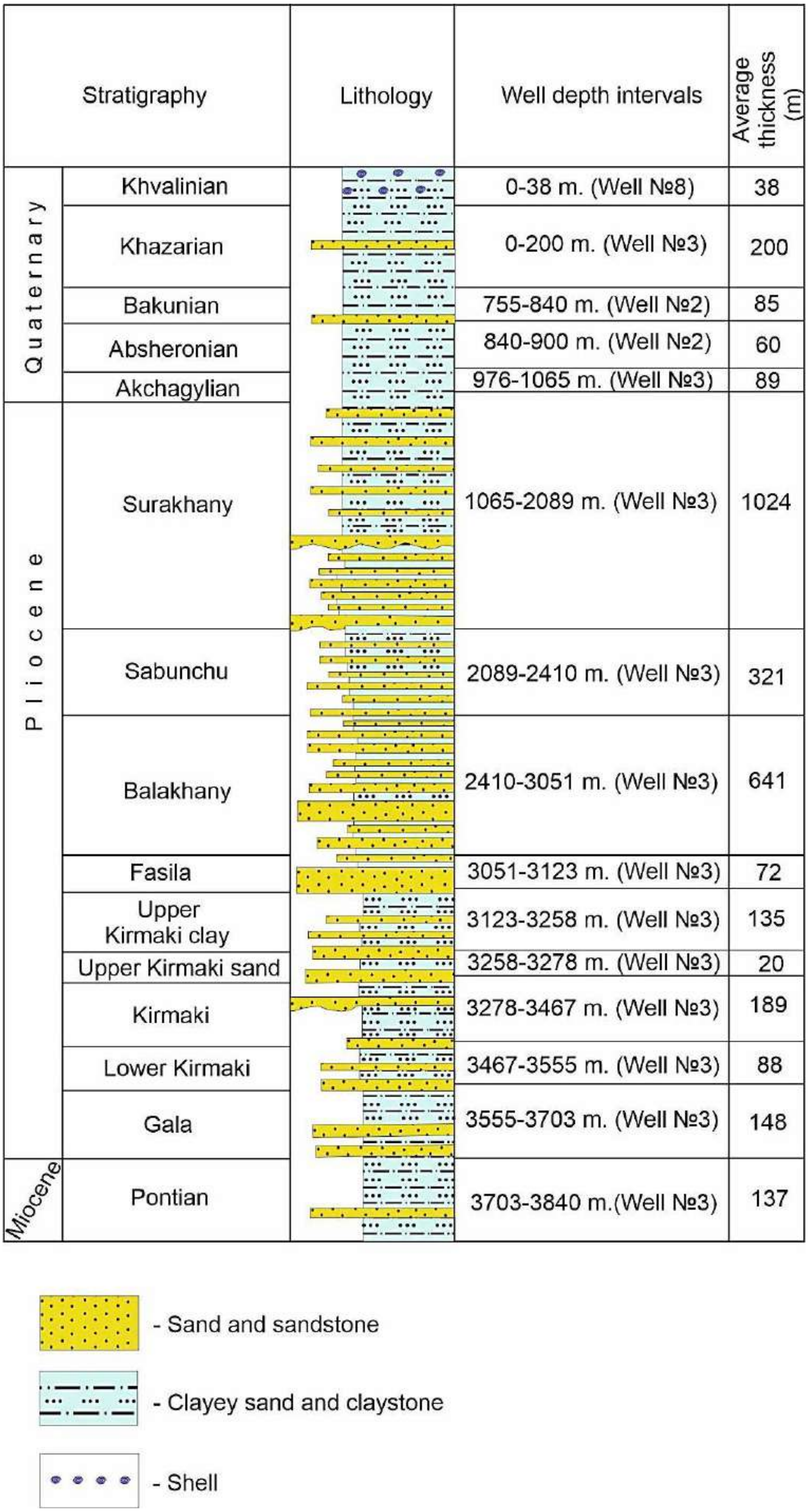

Fig. 4. Stratigraphy chart of the Karabakh field

Table 2

Formation top and lithology of Karabakh wells

Stratigraphy		KPS-1			KPS-2			KPS-3		
		depth, in m	thickness in m	lithology description	depth, in m	thickness in m	lithology description	depth, in m	thickness in m	lithology description
Quaternary	Pleistocene+ Holocene	202-328	126	No samples	198-330	132	No samples have been collected	203-330	127	No samples have been collected
Quaternary	Pleistocene+ Holocene	328-705	377	Claystone grey, plastic, soft, sticky, locally silty to sandy with fossil fragments	330-728	398	Clay/claystone, light grey to grey, plastic, soft, sticky, water sensitive, locally silty, to sandy with fossils fragments	330-728	398	Clay/claystone, light grey to grey, plastic, soft, sticky, water sensitive, locally silty, to sandy with fossils fragments
Quaternary	Absheron	705-976	271	Claystone grey, plastic, soft, sticky, locally silty to sand	728-1046	321	Clay/claystone, grey, plastic, soft, sticky, water sensitive, locally silty to sandy	728-1061	333	Clay/claystone, grey, plastic, soft, sticky, water sensitive, locally silty to sandy
Upper Pliocene Akchagyl		976-1065	89	Claystone dusky yellow, variable grey, locally silty with trace of Pyrite	1046-1145	84	Clay/claystone; grey to dark grey, light brown in parts , soft, to firm with streaks, of siltstone; light brown, to beige, soft to firm, pyritic in parts	1061-1145	84	Clay/claystone; grey to dark grey, light brow, in parts, pyritic in parts
Middle Pliocene Productive strata (upper part)	Surakhany	1065-2089	1024	Claystone dusky yellow, olive grey, plastic, soft, sticky with common anhydrite stringers and intercalated. Sandstone quartzose is very fine to fine-grained, subrounded to subangular, loose, friable, moderately well sorted, calcareous cement, argillaceous matrix	1145-2257	1112	Claystone: grey, to dark grey, brown, orange, soft to firm, blocky with common, gypsum/anhydrite stringers, and intercalated Sandstone: quartzose, very fine, to fine grained, subrounded, to subangular, loose, friable, poor to moderately, sorted, calcareous/dolomitic, cement. Traces of pyrite are associated with the sandstone throughout the section	1145-2257	1112	Claystone: grey, to dark grey, gypsum/anhydrite stringers with intercalated Sandstone: quartzose, very fine, to fine grained, subrounded, to subangular, loose, friable, poor to moderately, sorted, calcareous/dolomitic, cement.

	Sabunchu	**2089-2449**	**360**	**Claystone brownish, grey, blocky to platy, partly soft, soft, plastic, sticky with interbeds of sandstone: quartzous, very fine grained, subrounded to subangular, fairly sorted, calcareous cement, argillaceous matrix**	**2257-2511**	**254**	**Claystone brown, to dark brown, reddish in part, moderately hard, silty. Siltstone light brown, to beige, reddish in part, firm grading to very fine, sandstone. With streaks of sandstone: quartzose, light brown, to beige, off white in part, friable, very fine grained, subangular to subrounded, it moderately sorted, calcareous cement, argillaceous matrix**	**2257-2558**	**301**	**Claystone/Silstone from olive grey, to brown, and dark brown, with interlayers of Sandstone quartoze, light brown, to beige, off white in part, friable, very fine grained, subangular to subrounded, light brown, to beige, off white in part, friable, very fine grained, subangular to subrounded,**
	Bala-khany-V	**2449-2547**	**98**	**Claystone olive grey, dusky yellow, yellowish brown, firm, blocky, with sandstone, interbeds, which become progressively thinner and more frequent with depth. Sandstone: quartzous, very fine to fine-grained, partly medium, subrounded to subangular, grained, poorly sorted, calcareous cement, argillaceous matrix. Traces of pyrite are associated with the sandstone throughout the section**	**2511-2596**	**85**	**Claystone/Siltstone olive Grey, dusky yellow, yellowish brown, firm blocky with sandstone interbeds which become progressively thinner and more frequent with depth. Sandstone quartoze, white, cream, colorless, fine to medium grained, subangular to subrounded, moderately sorted, calcareous/dolomitic cement. Traces of pyrite are associated to the sandstone throughout the section**	**2558-2649**	**91**	**Claystone oil grey , with thin interlayers of sandstone quartoze, medium grained, subangular to subrounded, moderately sorted, calcareous cement, argillaceous matrix**
	Balakhany-VI	**2547-2624**	**77**		**2596-2658.5**	**62.5**		**2649-2701**	**52**	
	Balakhany-VII	**2624-2707**	**83**		**2658.5-2737**	**78.5**		**2701-2791**	**90**	
	Bala-khany-VIII	**2707-2830**	**123**		**2737-2952**	**215**	**claystone with sandstone streaks**	**2791-2981**	**190**	**Sandstone with interlayers of claystone**
	Bala-khany-IX	**2830-2957**	**127**		**2952-3102.5**	**150.5**	**claystone with thin sandstone layers**	**2981-3120**	**139**	
	Balaka hny-X	**2957-3051**	**94**		**3102.5-3177**	**74.5**		**3120-3214**	**94**	**Two horison of sandstone with interlayers of claystone, Sandstone quartoze, white, cream, colorless, fine to medium grained, subangular to subrounded, moderately sorted, calcareous/dolomitic cement**
	Fasila	**3051-3150**	**99**	**Two sandstone bodies with an intermediate and basal claystone development. Sandstone: quartzous, very fine to medium-grained, locally coarse, garined, subrounded to subangular, unconsolidated, traces**	**3177-3287**	**110**	**Sandstone with shale beds**	**3214-3311**	**97**	

				of pyrite. Claystone olive brown, yellowish brown, firm, blocky, to subfisssile, locally silty to sandy.						
Middle Pliocene Productive strata (Lower part)	Upper Kirmaki clayey	3150-3258	108	Claystone grey to dark grey, firm, subblocky, becoming very fissile, to splintery, calcareous, locally silty	3287-3403	116	Claystone grey, to dark grey, firm, subblocky, becoming very fissile, to splitery, slightly, calcareous, locally, silty, Traces of micromicaceous materials.	3311-3426.5	115.5	Claystone, locally silty
	Upper Kirmaki sandy	3258-3467	209	Claystone dark grey, to grey, firm, fissile, to splintery, concave, calcareous, silty in part, becoming very silty, downward, grading to siltstone, locally sandy, with interbeds of sandstone: quartzous, very fine to coarse, grained, unconsolidated, subrounded to subangular, to subrounded, poorly sorted, argillaceous, matrix, calcareous cement	3403-3432.5	29.5	Sandstone with thin shale layers	3426.5-3469	42.5	Sandstone with interlayers of claystone. Claystone grey, to dark grey, firm, subblocky
	Kirmaki suite	3284-3467	183		3432.5-3618	185.5	Claystone pale to light, grey, soft, firm, subblocky, platy, rare, subfissile, silty in parts, grading to siltstone, calcareous	3469-3652	183	Claystone dark grey, to grey, calcareous,
	Lower Kirmaki-1 sand	3467-3518	19		3618-3643	25	Sandstone quartzose, colourless, smokey, grey, very fine grained, subangular to subrounded, well sorted, calcareous, cement, argillaceous, matrix, poor, visible porosity. Interbedded with claystone: pale grey, soft subblocky, silty, in parts, slightly to very calcareous.	3652-3672	20	Well-sorted sandstone, subangular, to subrounded, with interlayers of claystone, calcareous, traces of pyrite, plastic, argillaceous, matrix, calcareous cement
	Lower Kirmaki-2 sand	3486-3518	32		3643-3673	30	Sandstone with claystone layers	3723-3750	27	
	Lower Kirmaki-3 sand	3518-3553.5	35.5		3673-3691	18		3672-3723	51	
	Gala suite	3553.5-3597	43.5	Claystone dark, to light grey, soft, firm, blocky, platy , rare sub fissile, silty in parts, grading to	3691-3737	46	Claystone pale grey, soft to firm subblocky, silty in parts, slightly to very calcarous. Traces of pyrite, with streaks of sandstone: quartzose,	3723-3750	27	

				siltstone, calcareous			colourless, very fine-grained, subangular, to subrounded, well sorted, calcareouse cement, argillaceous matrix, poor visible porosity.			
	Gala suite sandy	3597-3703	106	Claystone dark grey, to grey, firm, fissile, to splintery, concave, calcareous, silty in part, with thin interbedded of sandstone: quartzose, very fine-grained, subangular, to subrounded, well sorted traces of pyrite	3737-3769	32				
	Pre Gala suite	3703-3840	137	Claystone is dark to light grey, light green, soft, firm, blocky, sub-fissile, very calcareous, and silty in part grading to siltstone. With thin beds of sandstone: quartzous, very fine to fine grained, raree medium grained, subangular, to subrounded, poorly sorted, traces of pyrite.	3769-3795	26	Claystone pale grey to dark grey, occasionally pale, grey brown, soft to firm, subblocky, to platy, silty in parts, slightly to very calcareous. Traces of carbonaceous materials and pyrites			
					unconformity					
Mio-cene	Meotian				3795-3809	14				

During drilling of the Gala suite and Miocene Formations in the KPS-1 well, the extrusion and leakage of a plastic, lutea-like material from the open borehole zone were observed. This material appears to have formed due to the saturation of siltstones and compacted clays with high-pressure water and hydrocarbons that migrated into the overlying clay layers from underlying deposits. Swollen clay facies are particularly common in fluid-conducting fracture zones within the clay cap rock. These clays tend to concentrate along the migration paths of high-pressure fluids and are primarily extruded into the wellbore. Additionally, they swell further under the influence of drilling mud filtrate, increasing in plasticity and susceptibility to creep.

To assess the wellbore stability of the KPS-1 in the 3750-3840 m interval, pre-stressed clay rocks in this section were studied. Potential time windows for the onset of drilling issues were also identified. Comparative analysis indicates that such problems are not typical at shallower depths, such as in the Lower Kirmaki suite (3500-3550 m) or the Gala suite (3600-3700 m).

The borehole narrowing, clay extrusion, and formation of clay lumps observed during drilling of the Gala suite and Miocene Formations are attributed to the widespread presence of montmorillonite clays. Notably, in the adjacent Guneshli area, montmorillonite content reaches up to 30% in the Upper Kirmaki sandy, Kirmaki, and Lower Kirmaki suites, and up to 40% in the Gala suite. It is likely that similar montmorillonite concentrations exist in these suites within the Karabakh area as well. A sharp increase in montmorillonite content (up to 20-30%) in loose clay sludge is considered indicative of the proximity to a large, high-pressure hydrocarbon accumulation.

Comparative analysis of subsurface conditions in Karabakh and adjacent fields

Regional data analysis reveals that the stratigraphic layers in the lower part of the Productive strata are characterized by unstable pore pressure, even within individual layers. For instance, in the Fasila suite at the adjacent Chirag field, pore pressure in well No. 6 ranges from 35.5 to 44.6 MPa. Similarly, in the Upper Kirmaki sandy, pore pressure in well No. 4 varies from 38.6 to 51.3 MPa, with corresponding changes in pore pressure gradients in the clay formations.

These variations in fluid pressure between adjacent intervals of differing lithology are attributed to the differing influence of overlying rocks on impermeable clay layers versus permeable reservoirs with a rigid framework. Such localized instability in pore pressure across narrow depth intervals often results in wellbore erosion.

Abnormally high reservoir pressures are consistently observed in the same stratigraphic layers of the lower Productive Series – specifically in the Upper Kirmaki sandy, Kirmaki suite, and the basement complex – across all nearby wells, including Chirag No. 4 and No. 6, Novkhany No. 1, Arzu No. 2, and Karabakh KPS-1.

Actual data obtained during well targeting in the Novkhany prospect (formerly Nakhchivan), well No. 1; Guneshli No. 5; Chirag No. 4 and No. 6; Hazri No. 4; Gilavar No. 2; and Karabakh KPS-1 provides a basis for predicting potential drilling challenges in any future planned new wells at the Karabakh prospect. These challenges primarily relate to reservoir overpressure and hydraulic fracture pressures.

Experience from exploration well targeting in these prospects demonstrates that, if appropriate technologies and procedures are followed, drilling can generally proceed without significant issues up to the Kirmaki Formation. However, due to the geological and structural differences in location, the drilling conditions of any newly designed wells in the Karabakh prospect may vary from those encountered in KPS-1.

In the 325-700 m interval, the presence of unconsolidated formations may result in lost circulation. Additionally, shallow epigenetic overpressure zones may be encountered, leading to potential water and gas shows during drilling.

The 700-2100 m interval correlates stratigraphically with the Lower Quaternary deposits of the Absheron and Akchagyl stages of the Surakhany Formation. Within this zone, minor gas and water shows may occur due to aquifer penetration or the presence of localized hydrocarbon accumulations.

Mud filtrate invasion into permeable units can lead to wellbore constriction (tight hole conditions). The interval between 2100-3300 m corresponds to the Sabunchu, Balakhany, Fasila, Upper Kirmaki Clayey, and Upper Kirmaki Sandy formations. Within these formations, drilling may encounter water and gas shows, sloughing, and further tight hole issues due to mud invasion.

Petrophysical Analysis and Hydrocarbon Potential

Well log analysis and formation testing indicate that the Lower Kirmaki formation is predominantly water-bearing (Fig. 4). However, the Upper Kirmaki sandy unit exhibited positive gas log responses, though no direct formation tests were performed at this interval. Tables 3 and 4, along with Figs 5, 6, 7, 8, 9, 10 and 11 show the petrophysical interpretation results of Karabakh wells. The clay volume was determined using the GR log. The porosity was calculated from the sonic log. Where available (in Karabakh 3 only), the neutron porosity has been used. The lithology model contains shale and sandstone. Primary interest is that an oil-water contact can be seen at 3450 m MD in the Upper Kirmaki sandy in Karabakh 3.

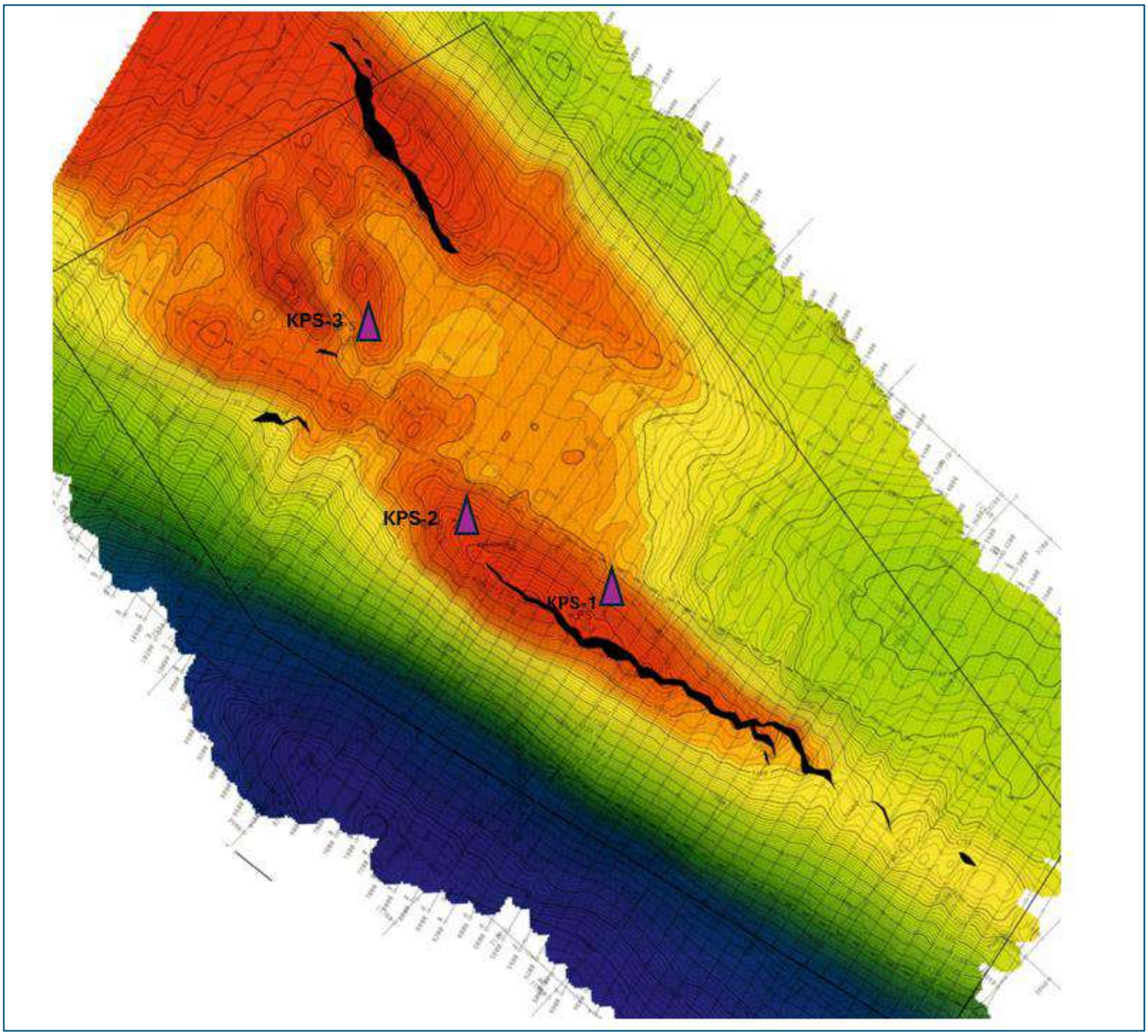

Fig. 5. Base Productive depth map with location of the drilled wells in Karabakh field (modified after Azerbaijan Petroleum Industry Review, 2007)

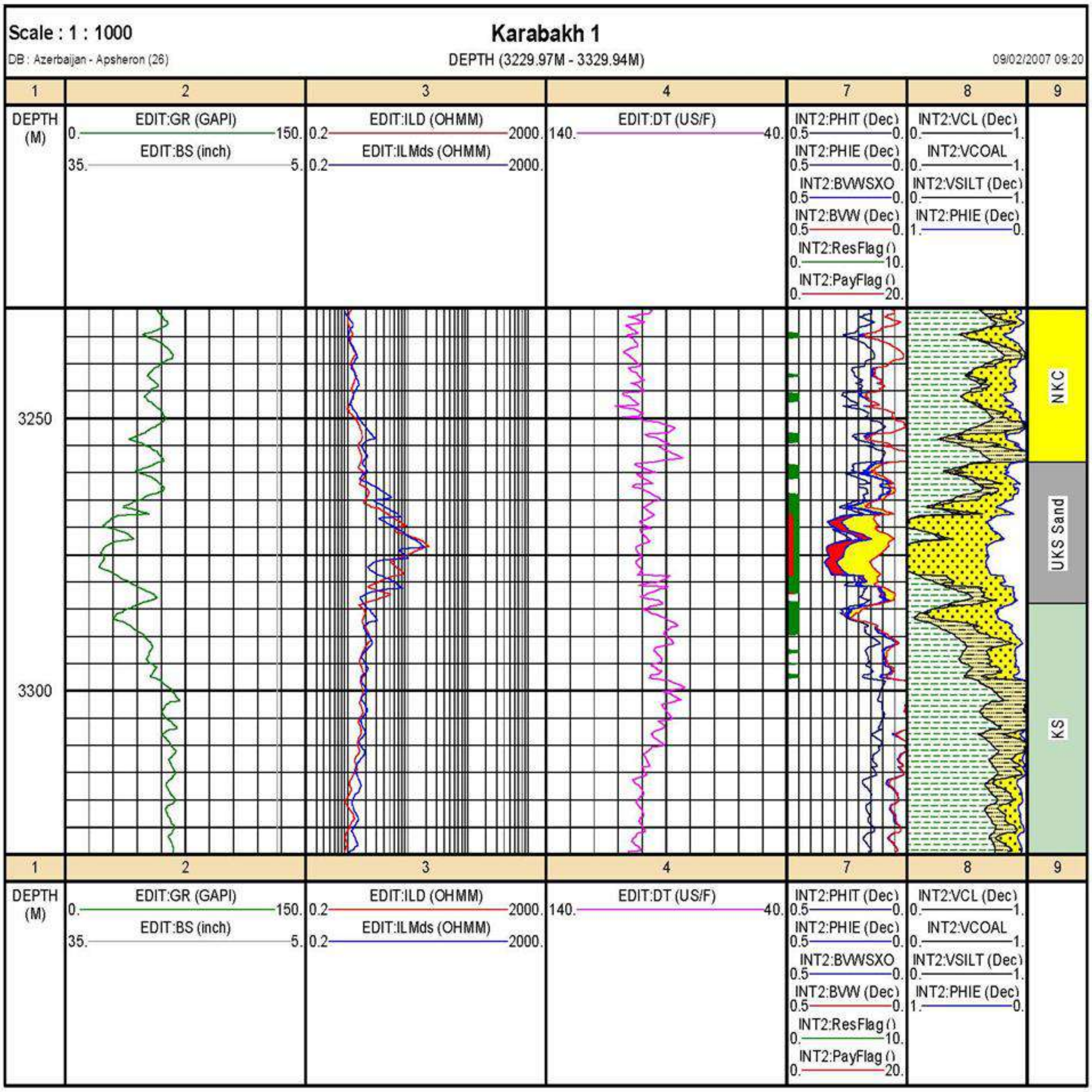

Fig. 6. Karabakh KPS-1 well log at Upper Kirmaki sandy (UKS) level

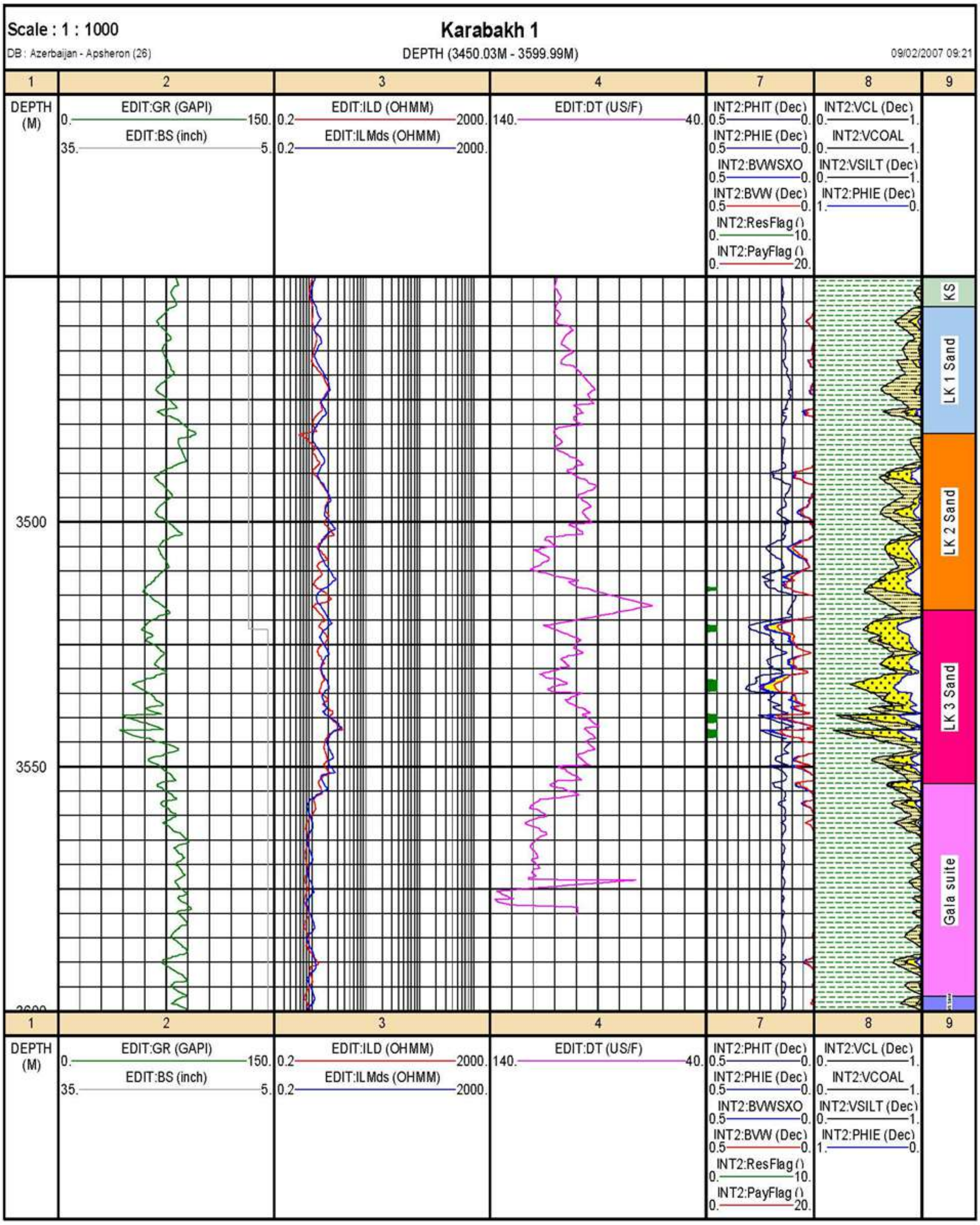

Fig. 7. Karabakh KPS-1 well log.at Lower Kirmaki (LK) level

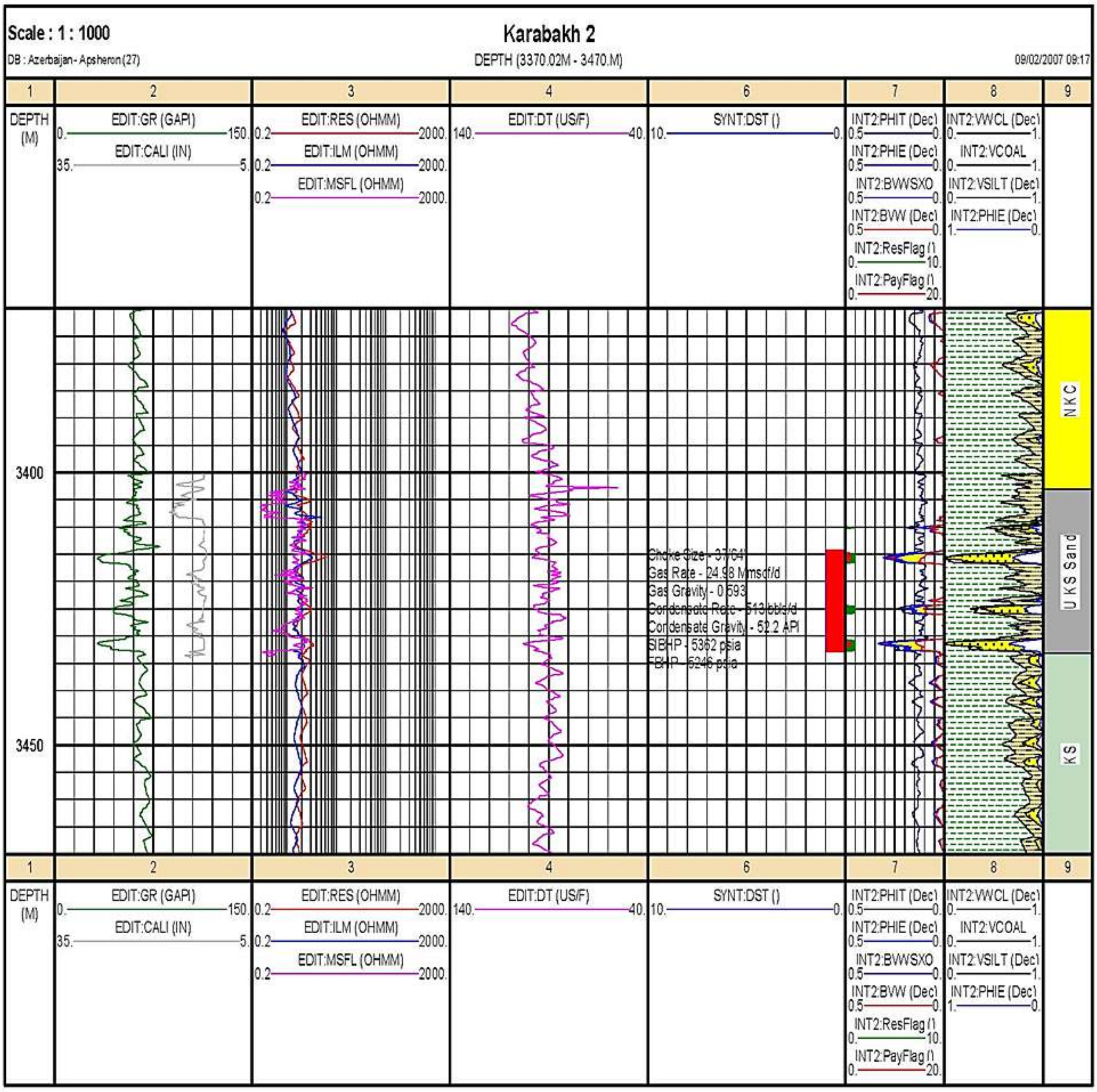

Fig. 8. Karabakh KPS-2 well log at Upper Kirmaki sandy (UKS) level

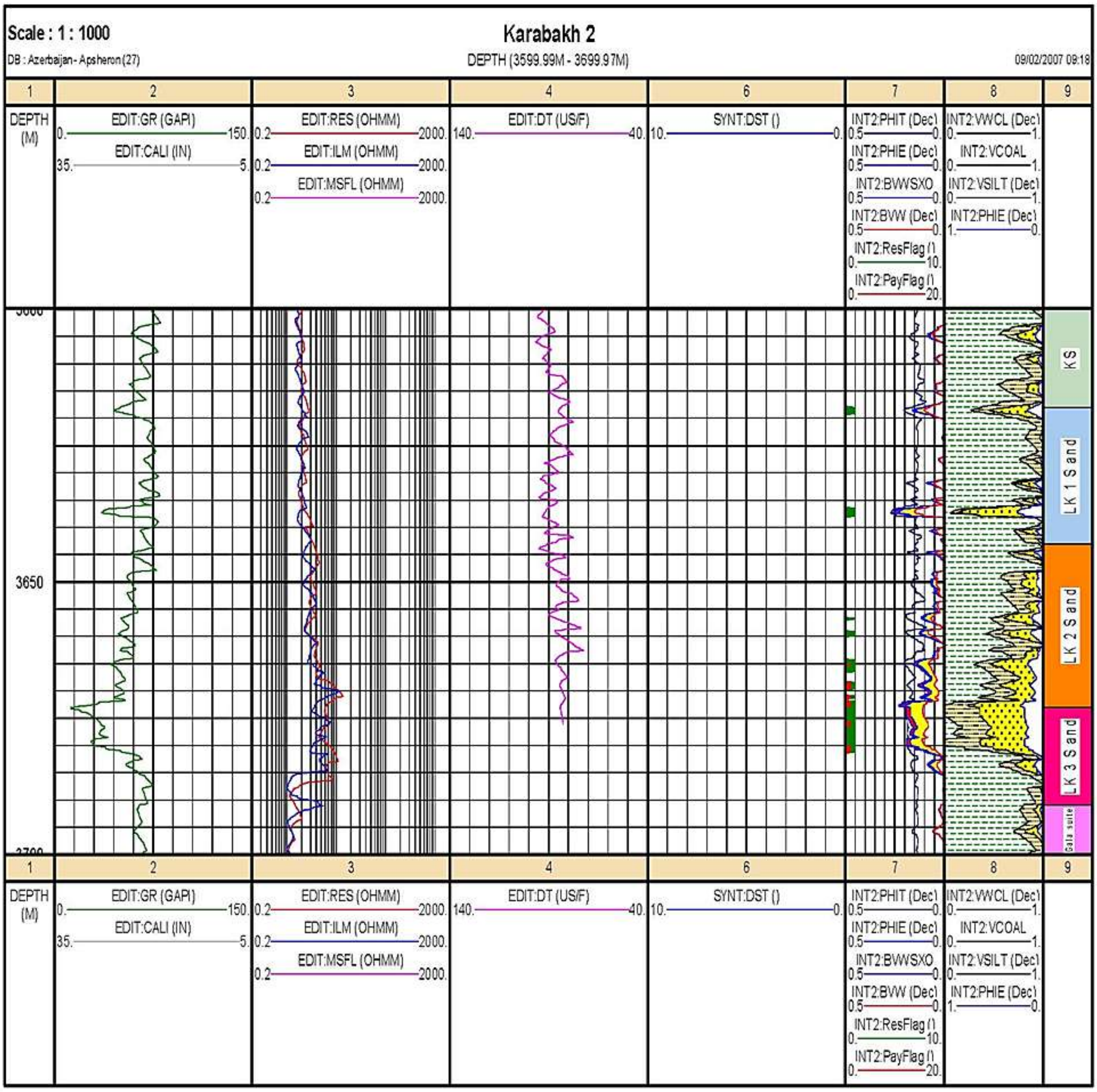

Fig. 9. Karabakh KPS-2 well log at Lower Kirmaki (LK) level

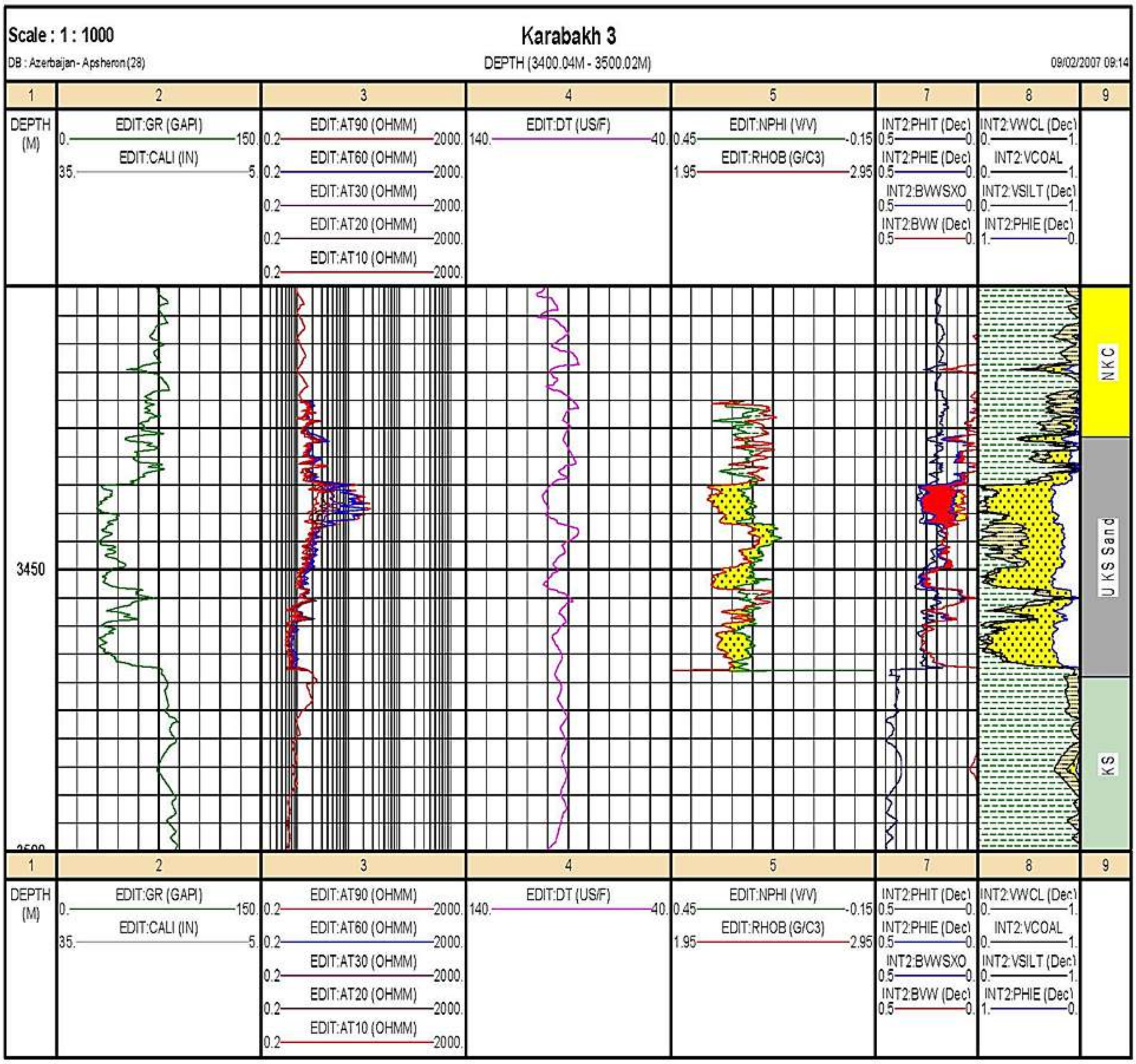

Fig. 10. Karabakh KPS-3 well log at the Upper Kirmaki sandy (UKS) level

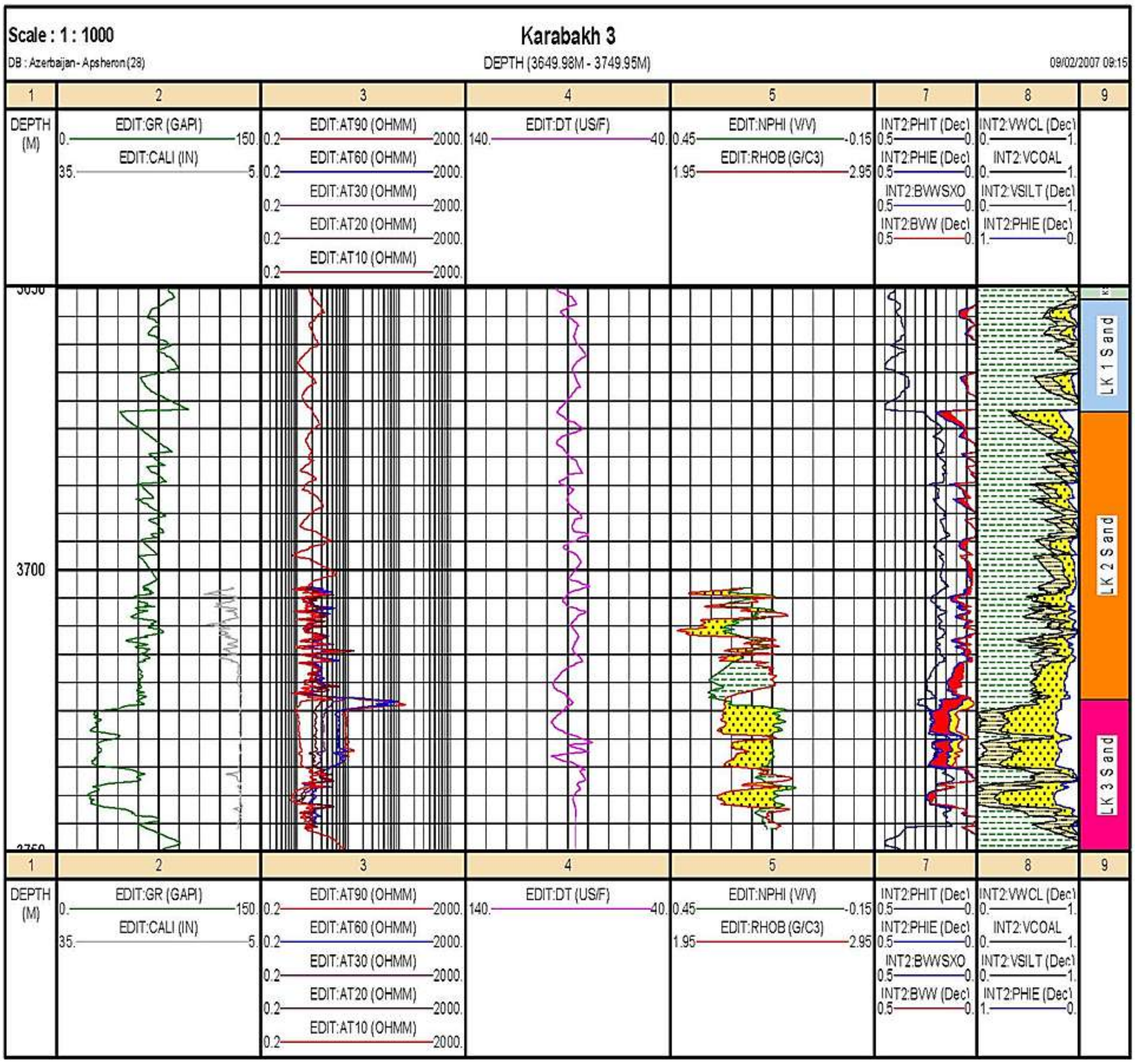

Fig. 11. Karabakh KPS-3 well log at the Lower Kirmaki (LK) level

Table 3

Reservoir summary of Karabakh wells

Reservoir summary

Well	Zone Name	Type	Units	Top	Bottom	Gross	Net	N/G	Av Phi	Av Sw	Av Vcl	Phi*H	PhiSo*H
Karabakh 1	Fasila	MD	m	3048.61	3150.00	101.39	62.03	0.61	0.23	1.00	0.17	14.35	0.04
Karabakh 1	UKC	MD	m	3150.00	3258.00	108.00	4.57	0.04	0.17	0.94	0.42	0.75	0.05
Karabakh 1	UKS Sand	MD	m	3258.00	3284.00	26.00	21.04	0.81	0.23	0.53	0.19	4.78	2.26
Karabakh 1	**KS**	**MD**	**m**	**3284.00**	**3455.98**	**171.98**	**6.85**	**0.04**	**0.17**	**0.97**	**0.26**	**1.16**	**0.04**
Karabakh 1	LK 1 Sand	MD	m	3455.98	3481.88	25.90	0.00	0.00	---	---	---	---	---
Karabakh 1	LK 2 Sand	MD	m	3481.88	3518.00	36.12	0.61	0.02	0.11	---	0.49	0.07	---
Karabakh 1	LK 3 Sand	MD	m	3518.00	3553.50	35.50	6.71	0.19	0.19	0.82	0.38	1.28	0.23
Karabakh 1	**All Zones**	**MD**	**m**	**3048.61**	**3553.50**	**504.89**	**101.80**	**0.20**	**0.22**	**0.88**	**0.21**	**22.40**	**2.60**
Karabakh 2	Fasila	MD	m	3177.00	3287.00	110.00	65.84	0.60	0.22	0.97	0.13	14.56	0.40
Karabakh 2	UKC	MD	m	3287.00	3403.00	116.00	0.00	0.00	---	---	---	---	---
Karabakh 2	UKS Sand	MD	m	3403.00	3432.50	29.50	5.10	0.17	0.22	0.50	0.18	1.11	0.55
Karabakh 2	**KS**	**MD**	**m**	**3432.50**	**3618.00**	**185.50**	**0.94**	**0.01**	**0.14**	**0.74**	**0.45**	**0.13**	**0.03**
Karabakh 2	LK 1 Sand	MD	m	3618.00	3643.00	25.00	3.10	0.12	0.19	0.60	0.23	0.60	0.24
Karabakh 2	LK 2 Sand	MD	m	3643.00	3673.00	30.00	3.74	0.13	0.13	0.51	0.36	0.50	0.24
Karabakh 2	LK 3 Sand	MD	m	3673.00	3691.00	18.00	8.91	0.50	0.14	0.32	0.28	1.23	0.84
Karabakh 2	**All Zones**	**MD**	**m**	**3177.00**	**3691.00**	**514.00**	**87.63**	**0.17**	**0.21**	**0.87**	**0.16**	**18.13**	**2.31**
Karabakh 3	Fasila	MD	m	3214.00	3311.00	97.00	70.60	0.73	0.25	1.00	0.13	17.31	0.03
Karabakh 3	UKC	MD	m	3311.00	3426.50	115.50	0.32	0.00	0.16	0.84	0.40	0.05	0.01
Karabakh 3	UKS Sand	MD	m	3426.50	3469.00	42.50	30.31	0.71	0.22	0.75	0.16	6.67	1.69
Karabakh 3	**KS**	**MD**	**m**	**3469.00**	**3652.00**	**183.00**	**0.00**	**0.00**	**---**	**---**	**---**	**---**	**---**
Karabakh 3	LK 1 Sand	MD	m	3652.00	3672.00	20.00	0.15	0.01	0.20	0.63	0.31	0.03	0.01
Karabakh 3	LK 2 Sand	MD	m	3672.00	3723.00	51.00	3.35	0.07	0.14	0.61	0.41	0.48	0.19
Karabakh 3	LK 3 Sand	MD	m	3723.00	3750.00	27.00	15.09	0.56	0.20	0.53	0.07	3.04	1.43
Karabakh 3	**All Zones**	**MD**	**m**	**3214.00**	**3750.00**	**536.00**	**119.83**	**0.22**	**0.23**	**0.88**	**0.14**	**27.58**	**3.36**

Table 4

Pay summary of Karabakh wells

Well	Zone Name	Type	Units	Top	Bottom	Gross	Net	N/G	Av Phi	Av Sw	Av Vcl	Phi*H	PhiSo*H
Karabakh 1	Fasila	MD	m	3048.61	3150.00	101.39	62.03	0.61	0.23	1.00	0.17	14.35	0.04
Karabakh 1	UKC	MD	m	3150.00	3258.00	108.00	4.57	0.04	0.17	0.94	0.42	0.75	0.05
Karabakh 1	UKS Sand	MD	m	3258.00	3284.00	26.00	21.04	0.81	0.23	0.53	0.19	4.78	2.26
Karabakh 1	**KS**	**MD**	**m**	**3284.00**	**3455.98**	**171.98**	**6.85**	**0.04**	**0.17**	**0.97**	**0.26**	**1.16**	**0.04**
Karabakh 1	LK-1 Sand	MD	m	3455.98	3481.88	25.90	0.00	0.00	---	---	---	---	---
Karabakh 1	LK-2 Sand	MD	m	3481.88	3518.00	36.12	0.61	0.02	0.11	---	0.49	0.07	---
Karabakh 1	LK-3 Sand	MD	m	3518.00	3553.50	35.50	6.71	0.19	0.19	0.82	0.38	1.28	0.23
Karabakh 1	**All Zones**	**MD**	**m**	**3048.61**	**3553.50**	**504.89**	**101.80**	**0.20**	**0.22**	**0.88**	**0.21**	**22.40**	**2.60**
Karabakh 2	Fasila	MD	m	3177.00	3287.00	110.00	65.84	0.60	0.22	0.97	0.13	14.56	0.40
Karabakh 2	UKC	MD	m	3287.00	3403.00	116.00	0.00	0.00	---	---	---	---	---
Karabakh 2	UKS Sand	MD	m	3403.00	3432.50	29.50	5.10	0.17	0.22	0.50	0.18	1.11	0.55
Karabakh 2	**KS**	**MD**	**m**	**3432.50**	**3618.00**	**185.50**	**0.94**	**0.01**	**0.14**	**0.74**	**0.45**	**0.13**	**0.03**
Karabakh 2	LK-1 Sand	MD	m	3618.00	3643.00	25.00	3.10	0.12	0.19	0.60	0.23	0.60	0.24
Karabakh 2	LK-2 Sand	MD	m	3643.00	3673.00	30.00	3.74	0.13	0.13	0.51	0.36	0.50	0.24
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Karabakh 2	**All Zones**	**MD**	**m**	**3177.00**	**3691.00**	**514.00**	**87.63**	**0.17**	**0.21**	**0.87**	**0.16**	**18.13**	**2.31**
Karabakh 3	Fasila	MD	m	3214.00	3311.00	97.00	70.60	0.73	0.25	1.00	0.13	17.31	0.03
Karabakh 3	UKC	MD	m	3311.00	3426.50	115.50	0.32	0.00	0.16	0.84	0.40	0.05	0.01
Karabakh 3	UKS Sand	MD	m	3426.50	3469.00	42.50	30.31	0.71	0.22	0.75	0.16	6.67	1.69
Karabakh 3	**KS**	**MD**	**m**	**3469.00**	**3652.00**	**183.00**	**0.00**	**0.00**	**---**	**---**	**---**	**---**	**---**
Karabakh 3	LK-1 Sand	MD	m	3652.00	3672.00	20.00	0.15	0.01	0.20	0.63	0.31	0.03	0.01
Karabakh 3	LK-2 Sand	MD	m	3672.00	3723.00	51.00	3.35	0.07	0.14	0.61	0.41	0.48	0.19
Karabakh 3	LK-3 Sand	MD	m	3723.00	3750.00	27.00	15.09	0.56	0.20	0.53	0.07	3.04	1.43
Karabakh 3	**All Zones**	**MD**	**m**	**3214.00**	**3750.00**	**536.00**	**119.83**	**0.22**	**0.23**	**0.88**	**0.14**	**27.58**	**3.36**

All wells drilled in the Karabakh field – KPS-1, KPS-2, and KPS-3 – were ultimately abandoned due to geological reasons. However, well KPS-2 yielded successful testing results. Two productive intervals were identified:

- From 3665.5 to 3681 m (Lower Kirmaki/LK Suite), the well produced **30 t/d of condensate** and **773,000 m³/d of gas**.
- From 3414 to 3433 m (Upper Kirmaki sandy/ UKS Suite), it produced **82 t/d of condensate** and **700,000 m³/d of gas**.

In well KPS-1, geophysical data indicated a gas-bearing interval between 3265 and 3278 m (UKS Suite), although no production test was reported.

No testing was conducted in well KPS-3. Two primary hydrocarbon-bearing intervals have been delineated:

- **Lower Kirmaki suite (LK)**: Gas-condensate
- **Upper Kirmaki sandy suite (UKS)**: Oil/condensate with a gas cap

Well targeting analysis in adjacent prospects indicates that drilling conditions in the lower part of the Productive strata differ significantly from those encountered in the Karabakh prospect. Exploration in adjacent Ashrafi and Karabakh fields supports the presence of commercial hydrocarbons within these formations (Babayev, Gadjiev, 2006). Nevertheless, due to the limited number of drilled wells and insufficient well testing, spatial variability and reservoir heterogeneity remain unresolved.

Conclusion

1. **Hydrocarbon Potential Confirmed**: The Karabakh field exhibits confirmed gas-condensate and oil/condensate accumulations within the Lower and Upper Kirmaki formations, based on positive log responses and production testing in KPS-2. The UKS suite is particularly promising, showing significant gas and condensate yields.
2. **Stratigraphic and Structural Complexity**: The area presents considerable geological complexity, with asymmetric folding, fault segmentation, and significant lithological variability. These features pose challenges for reservoir continuity predictions and well placement.
3. **Reservoir Quality**: Reservoirs within the Balakhany, Fasila, and especially the Upper Kirmaki formations demonstrate good sand content (up to 75%) and porosity values (~22%), suggesting favorable conditions for hydrocarbon storage and flow.
4. **Drilling Challenges Identified**: Issues related to clay swelling, borehole instability, overpressured zones, and high montmorillonite content were encountered during drilling, particularly in the Gala and Miocene formations.
5. **Pressure Variability**: Abnormally high and variable pore pressures were observed in multiple formations. This highlights the necessity for careful wellbore pressure management and mud weight control during drilling.
6. **Underexplored Structure**: Only three wells (KPS-1, KPS-2, KPS-3) were drilled, with limited testing conducted. This has left significant uncertainty in reservoir characterization, continuity, and lateral extent.

Recommendations

1. **Further Appraisal Drilling**: Additional wells should be strategically placed along the flanks and crest of the structure to improve spatial resolution, validate reservoir connectivity, and better define hydrocarbon contacts.
2. **Comprehensive Testing**: Conduct complete formation testing in future wells, particularly in promising zones identified in KPS-1 and KPS-3, to assess productivity and fluid properties directly.
3. **Enhanced Well Planning**: Implement advanced wellbore stability models that account for clay swelling and overpressured intervals. Pre-drilling geomechanical modelling should be mandatory to mitigate drilling risks.
4. **Extended Seismic Analysis**: Update and refine 3D seismic interpretation to resolve fault systems, dome culminations, and potential trap geometries more accurately. Pay special attention to lateral sealing faults and stratigraphic pinch-outs.
5. **Petrophysical Re-evaluation**: Reassess existing log data using advanced interpretation techniques (e.g., NMR, dielectric logging) to characterize better characterise fluid types,

saturations, and porosity in heterogeneous reservoirs.

6. **Pressure Management Strategy**: Establish a detailed pore pressure prediction and monitoring framework to safely navigate high-pressure zones and reduce the risk of kicks or losses during drilling.
7. **Comparative Regional Study**: Continue integrating regional data from adjacent fields (e.g., Guneshli, Chirag, Ashrafi) to inform predictive models on stratigraphy, pressure regimes, and reservoir behaviour.
8. **Economic Assessment**: Following successful appraisal, initiate an economic feasibility study including development planning, considering offshore infrastructure constraints, potential tie-backs, and phased production scenarios.

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ПЕРСПЕКТИВЫ ОСВОЕНИЯ КАРАБАХСКОГО МЕСТОРОЖДЕНИЯ В ЮЖНО-КАСПИЙСКОМ БАССЕЙНЕ

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Резюме. Месторождение Карабах, расположенное в северной части Абшеронского архипелага в пределах Южно-Каспийского бассейна, обладает значительным потенциалом углеводородов, главным образом в нижне- и верхнекирмакинских толщах. Изначально месторождение было открыто в 1998 году консорциумом Caspian International Operating Company. В 1999 году проект был приостановлен, когда цена нефти составляла 25-26 долларов за баррель. Несмотря на открытие залежей, проект был закрыт, поскольку запасы нефти и газа были признаны экономически нецелесообразными для разработки. Однако в 2018 году началось его освоение в рамках контракта, подписанного между SOCAR и Equinor.

Геологические исследования, включая стратиграфию, каротаж и петрофизическую интерпретацию, проводились по данным трёх скважин (KPS-1 — KPS-3), при этом наибольший успех испытаний был достигнут на скважине KPS-2. Положительные результаты по газу и конденсату были получены из интервалов: подкирмакинская и надкирмакинская песчаная, что подтверждает коммерческую перспективность месторождения.

Структурная сложность региона — выраженная асимметричными складками, надвигами и литологической изменчивостью — создаёт значительные трудности при разведке и бурении. Стратиграфический анализ выявил мощную толщу песчано-глинистых отложений, при этом ключевые коллекторы характеризуются высокой пористостью (до 22%) и песчанистостью (до 75%). Проведение буровых работ осложнялось нестабильными пластовыми давлениями, набуханием глин и зонами аномально высоких давлений, особенно в калинской и миоценовой свитах. Наличие глин, богатых монтмориллонитом, дополнительно ухудшает устойчивость ствола скважины.

Сравнительный региональный анализ и исторические данные по соседним месторождениям подтверждают потенциал Карабаха, но подчёркивают необходимость дальнейшей оценки. Среди рекомендаций — целевое бурение, улучшенный сейсмический анализ, обновлённая петрофизическая интерпретация и строгий контроль давления. Устранение этих технических и геологических неопределённостей является ключевым условием для раскрытия полного экономического потенциала месторождения Карабах и обеспечения безопасного и эффективного освоения на шельфе.

Ключевые слова: *Южно-Каспийский бассейн, разведка нефти и газа, петрофизический анализ каротажных диаграмм, литология, стратиграфия, бурение*

CƏNUBİ XƏZƏR HÖVZƏSİNDƏ QARABAĞ YATAĞININ ÖYRƏNİLMƏSİ PERSPEKTİVLƏRİ

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Xülasə. Qarabağ yatağı Cənubi Xəzər hövzəsinin Şimal Abşeron arxipelaqında yerləşir və əsasən Aşağı və Yuxarı Kirməki laylarında əhəmiyyətli karbohidrogen potensialına malikdir. Yataq ilk dəfə 1998-ci ildə Caspian International Operating Company konsorsiumu tərəfindən kəşf edilmişdir. 1999-cu ildə neftin bir barelinin qiyməti 25-26 ABŞ dolları olduğu dövrdə layihə dayandırılmışdır. Yataqların aşkar edilməsinə baxmayaraq, ehtiyatların iqtisadi baxımdan səmərəsiz hesab olunması səbəbindən layihə bağlanmışdır. Lakin 2018-ci ildə SOCAR və Equinor arasında imzalanmış müqavilə çərçivəsində yatağın işlənməsi yenidən başlamışdır.

Geoloji tədqiqatlar – stratigrafiya, quyu karotajı və petrofiziki interpretasiya daxil olmaqla – üç quyudan (KPS-1-dən KPS-3-ə qədər) əldə edilən məlumatlar əsasında aparılmış, ən uğurlu hasilat sınağı KPS-2 quyusunda qeydə alınmışdır. Həm Alt Kirməki, həm də Üst Kirməki qumlu intervallarından qaz və kondensat üzrə müsbət nəticələr əldə olunmuşdur ki, bu da yatağın kommersiya baxımından perspektivliyini göstərir.

Rayonun struktur mürəkkəbliyi – assimmetrik qatlardan, itələnmə qırılmalarından və litoloji dəyişkənlikdən ibarət olması – kəşfiyyat və qazma proseslərini əhəmiyyətli dərəcədə çətinləşdirir. Stratigrafik qiymətləndirmələr qum-gil ardıcıllığından ibarət qalın layların mövcudluğunu göstərir; əsas kollektorlar yüksək məsaməlilik (22%-ə qədər) və qumluluq (75%-ə qədər) dəyərlərinə malikdir. Qazma işləri qeyri-sabit lay təzyiqləri, gil şişməsi və xüsusilə Qala və Miosen laylarında yüksək təzyiq zonaları səbəbindən çətinləşmişdir. Montmorillonitlə zəngin gil minerallarının mövcudluğu quyu dayanıqlığını daha da mürəkkəbləşdirir.

Regional müqayisəli təhlil və qonşu yataqlardan əldə edilən tarixi məlumatlar Qarabağ yatağının potensialını təsdiqləyir, lakin əlavə qiymətləndirməyə ehtiyac olduğunu göstərir. Tövsiyələrə məqsədyönlü qazma işlərinin aparılması, təkmilləşdirilmiş seysmik analiz, yenilənmiş petrofiziki interpretasiya və ciddi təzyiq nəzarəti daxildir. Bu texniki və geoloji qeyri-müəyyənliklərin aradan qaldırılması Qarabağ yatağının tam iqtisadi potensialının reallaşdırılması və təhlükəsiz, səmərəli dəniz əməliyyatlarının təmin edilməsi üçün vacibdir.

Açar sözlər: *Cənubi Xəzər hövzəsi, neft və qaz kəşfiyyatı, karotaj diaqramlarının petrofiziki təhlili, litologiya, stratiqrafiya, qazma*