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© J.F. Shırıyev*, G.R. Muradov[2], K.S. Mammadov[1], S.A. Musayeva[1], M.A. Azımov[3], 2025.

[1]Baku Higher Oil School, Baku, Azerbaijan;
[2]SOCAR,"Azneft" Production Union, Geological Supervision Department of Drilling Operations, Baku Azerbaijan;
[3] Institute of Geology and Geophysics of the Azerbaijan National Academy of Sciences, Baku Azerbaijan.
E-mail: cavid.shiriyev@bhos.edu.az

PROSPECTİVİTY ASSESSMENT OF DEEP SEDİMENTS İN PİRSAAT, LOWER KURA DEPRESSİON

Shiriyev Javid — Doctor of Technical Sciences, Associated Professor at Baku Higher Oil School, Baku Azerbaijan,
E-mail: cavid.shiriyev@bhos.edu.az, https://orcid.org/ 0000-0002-7262-4176;
Muradov Galib — SOCAR,"Azneft" Production Union, Geological Supervision Department of Drilling Operations, Senior Geologist, Baku Azerbaijan,
E-mail: qalibmuradov6@gmail.com, https://orcid.org/ 0009-0002-3701-867X;
Mammadov Kanan — PhD Student in Oil and Gas Reservoir Exploitation, Lecturer at Baku Higher Oil School, Baku Azerbaijan,
E-mail:kanan.mammadov@bhos.edu.az, https://orcid.org/ 0009-0004-9645-306X;
Musayeva Samira — Doctor of Technical Sciences, Head of Petroleum Engineering Department at Baku Higher Oil School, Baku Azerbaijan,
E-mail: samira.musayeva@bhos.edu.az, https://orcid.org/0000-0001-6767-5713;
Azimov Muslim — Institute of Geology and Geophysics of the Azerbaijan National Academy of Sciences, Baku Azerbaijan.
E-mail: muslim113@gmail.com, https://orcid.org/0009-0008-3654-1411.

Abstract. The Lower Kura Depression, located in the northeastern South Caspian Basin, is separated from the Middle Kura Depression by the Talysh-Vandam uplift and from the Shamakhi-Gobustan region by the Lankaran-Alat uplift. Its deep structure has been investigated through seismic surveys, seismology, gravimagnetic and electrical exploration, and borehole geophysics. Numerous anticlinal and non-anticlinal structures have been identified, many containing long-producing oil and gas fields within the Lower Pliocene Productive Series. Secondary depressions include Upper Shirvan, Lower Shirvan, and Mughan-Salyan. Four major anticlinal

zones—Pirsaat-Hamamdagh, Kelameddin-Mishovdagh-Bandovan, Kursangi, and Kurovdagh-Neftchala—trend northwest–southeast, with outcrops of Akchagyl, Absheron, and Baku deposits. Uplifts such as Kelameddin, Great and Small Harami, Mishovdagh, and Bandovan form asymmetric anticlines complicated by major faults and mud volcanoes. In the Pirsaat-Hamamdagh zone, the Hamamdagh anticline shows up to 900 m of erosion, while nearby segments expose Akchagyl, Absheron, and Ancient Caspian sediments. In the Pirsaat field, oil and gas accumulations are concentrated in the upper sandy horizons of the Productive Series. Using well lithology and 2D seismic data, seismo-geological profiles were created and the structural map of the VII lower horizon was updated. Based on well tests, oil-gas-water contacts were defined, with Category C1 reserves assigned to the VII horizon and C3 to the QA group. Lower horizon fields are mainly tectonically screened and lithological-type, with justified strategies for further exploration and development.

Key words: Productive Series, structural map, tectonically screened fields, exploration-development activities, correlation, lithological section, calculation plan

© Дж.Ф. Шириеев*, Г.Р. Мурадов[2], К.С. Маммадов[1], С.А. Мусаева[1], М.А. Азимов[3], 2025.

[1]Баку жоғары мұнай мектебі, Баку, Әзірбайжан;

[2]Әзірбайжан Мемлекеттік мұнай компаниясы (SOCAR), «Азнефть» ӨБ, Бұрғылау операцияларының геологиялық бақылау басқармасы, Баку, Әзірбайжан;

[3]Әзірбайжан Ұлттық ғылымдар академиясының Геология және геофизика институты, Баку, Әзірбайжан.

E-mail: cavid.shiriyev@bhos.edu.az

ПИРСАТ АЙМАҒЫНДАҒЫ ТЕРЕҢ ШӨГІНДІЛЕРДІҢ ПЕРСПЕКТИВТІЛІГІН БАҒАЛАУ, ТӨМЕНГІ ҚҰРА ОЙЫСЫ

Шириев Джавид — техника ғылымдарының докторы, Баку жоғары мұнай мектебінің доценті, Баку, Әзірбайжан,
E-mail: cavid.shiriyev@bhos.edu.az, https://orcid.org/0000-0002-7262-4176;
Мурадов Ғалиб — SOCAR, «Азнефть» ӨБ, Бұрғылау операцияларының геологиялық бақылау басқармасы, аға геолог, Баку, Әзірбайжан,
E-mail: qalibmuradov6@gmail.com, https://orcid.org/0009-0002-3701-867X;
Маммадов Кенан — мұнай және газ кен орындарын пайдалану мамандығы бойынша PhD докторант, Баку жоғары мұнай мектебінің оқытушысы, Баку, Әзірбайжан,
E-mail: kanan.mammadov@bhos.edu.az, https://orcid.org/0009-0004-9645-306X;
Мусахеева Самира — техника ғылымдарының докторы, Баку жоғары мұнай мектебінің Мұнай-газ инженериясы кафедрасының меңгерушісі, Баку, Әзірбайжан.
E-mail: samira.musayeva@bhos.edu.az, https://orcid.org/0000-0001-6767-5713;
Азимов Муслим — Әзірбайжан Ұлттық ғылымдар академиясының Геология және геофизика институты, Баку, Әзірбайжан,
E-mail: muslim113@gmail.com, https://orcid.org/0009-0008-3654-1411.

Аннотация. Төменгі Кура ойпаты Каспий теңізінің солтүстік-шығысында орналасқан және Орта Кура ойпатынан Талыш-Вендам көтерілуімен, ал солтүстікте Шемаха-Гобустаннан Ленкоран-Алят көтерілуімен бөлінген. Оның терең құрылымы сейсмология, сейсмикалық барлау, гравимагниттік, электрлік зерттеулер және ұңғымалық геофизика арқылы зерттелген. Көптеген антиклиналды және антиклиналды емес құрылымдар анықталған, көбінде төменгі плиоцен өнімді қабаттарында бай мұнай және газ қоры шоғырланған. Екінші деңгейлі ойпаттар: Жоғарғы және Төменгі Ширван, Мұған-Сальян. Солтүстік-батыстан оңтүстік-шығысқа төрт антиклиналды белдеу созылады: Пирсаат-Хамамдаг, Келәмеддин-Мишовдаг-Бандован, Курсанги, Куровдаг-Нефтчала. Келәмеддин, Үлкен және Кіші Харами, Мишовдаг, Бандован асимметриялық антиклинальдар, ірі жарылыстар мен батпақ жанартауларымен күрделенген. Хамамдаг антиклиналы 900 м эрозия көрсетеді, ал басқа сегменттерде Ақчагыл, Апшерон және Ежелгі Каспий шөгінділері ашық көрінеді. Пирсаат кен орнында мұнай мен газ қорлары Өнімді қабаттардың жоғарғы құмды горизонттарында шоғырланған. Ұңғымалардың литологиясы және 2D сейсмикалық деректер негізінде сейсмо-геологиялық қималар жасалып, VII төменгі горизонттың құрылымдық картасы жаңартылды. Ұңғыма сынақтары нәтижесінде мұнай-газ-сулы шекаралар анықталып, VII горизонтқа C1 санатындағы қорлар, ал QA тобына C3 санатындағы қорлар тіркелді. Төменгі горизонттағы кен орындары негізінен тектоникалық экрандалған және литологиялық типке жатады, әрі оларды әрі қарай барлау мен игеру үшін негізделген стратегиялар ұсынылған.

Түйін сөздер: өнімді қабаттар, құрылымдық карта, тектоникалық тұрғыдан оқшауланған кен орындары, барлау және игеру жұмыстары, корреляция, литологиялық қимасы, есептеу жоспары

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[1]Бакинская Высшая Школа Нефти, Баку, Азербайджан;
[2]ГНКАР, Производственное объединение «Азнефть», Управление геологического контроля буровых работ, Баку, Азербайджан;
[3]Институт геологии и геофизики Национальной академии наук Азербайджана, Баку, Азербайджан.
E-mail: cavid.shiriyev@bhos.edu.az

ОЦЕНКА ПЕРСПЕКТИВНОСТИ ГЛУБОКИХ ОТЛОЖЕНИЙ В ПИРСААТЕ, НИЖНЕКУРИНСКОЙ ДЕПРЕССИИ

Шириеев Джавид — доктор технических наук, доцент Бакинской Высшей Школы Нефти, Баку, Азербайджан,
E-mail: cavid.shiriyev@bhos.edu.az, https://orcid.org/0000-0002-7262-4176;
Мурадов Галиб — старший геолог Производственного объединения «Азнефть» ГНКАР, Управление геологического контроля буровых работ, Баку, Азербайджан,

E-mail: qalibmuradov6@gmail.com, https://orcid.org/0009-0002-3701-867X;
Маммадов Канан — аспирант по эксплуатации нефтяных и газовых месторождений, преподаватель Бакинской Высшей Школы Нефти, Баку, Азербайджан,
E-mail: kanan.mammadov@bhos.edu.az, https://orcid.org/0009-0004-9645-306X;
Мусаева Самира — доктор технических наук, заведующая кафедрой нефтегазового дела Бакинской Высшей Школы Нефти, Баку, Азербайджан,
E-mail: samira.musayeva@bhos.edu.az, https://orcid.org/0000-0001-6767-5713;
Азимов Муслим — Институт геологии и геофизики Национальной академии наук Азербайджана, Баку, Азербайджан,
E-mail: muslim113@gmail.com, https://orcid.org/0009-0008-3654-1411.

Аннотация. Нижне-Куринская впадина, расположенная на северо-востоке Южно-Каспийского бассейна, отделена от Средне-Куринской впадины Талыш-Вандамской поднятой зоной, а на севере — Ленкорань-Алятской поднятой зоной. Глубинное строение изучено методами сейсмологии, сейсмических съёмок, гравимагнитной и электрической разведки, а также геофизики скважин. Выявлены многочисленные антиклинальные и неантиклинальные структуры с богатым нефтегазовым потенциалом в коллекторах нижнего плиоцена. Вторичные впадины представлены следующими сегментами: Верхне-Ширванская, Нижне-Ширванская, Мугань-Сальянская. Четыре антиклинальные зоны — Пирсаат-Хамамдаг, Келямеддин-Мишовдаг-Бандован, Кюрсанги, Куровдаг-Нефтчала — имеют выходы акчагыльских, апшеронских и бакинских отложений. Поднятия Келямеддин, Большой и Малый Харами, Мишовдаг, Бандован представляют собой асимметричные антиклинали с крутыми юго-западными и пологими северо-восточными крыльями, осложнённые разломами и грязевыми вулканами. Антиклиналь Хамамдаг характеризуется эрозией до 900 м, а другие сегменты имеют различную структурную направленность. На Пирсаатском месторождении скопления нефти и газа сосредоточены в верхних песчаных горизонтах продуктивной толщи. На основе литологических данных скважин и 2D-сейсмики были построены сейсмо-геологические разрезы и обновлена структурная карта нижнего горизонта VII. По данным испытаний скважин определены нефтегазоводные контакты: категории запасов C1 присвоены горизонту VII, а C3 — группе QA. Залежи нижних горизонтов преимущественно тектонически экранированные и литологического типа, с обоснованными стратегиями дальнейшей разведки и разработки.

Ключевые слова: продуктивная толща, структурная карта, тектонически экранированные залежи, разведочно-добычные работы, корреляция, литологический разрез, план подсчёта

Introduction: The Lower Kura Depression is one of the largest oil and gas-producing and most promising hydrocarbon regions in Azerbaijan's onshore territory. Rich oil and gas fields have been discovered in the Pliocene sediments here and are currently under production. The oil and gas fields identified in the

Lower Kura petroleum region are mainly associated with the upper horizons of the Productive Series (PS), which are characterized by high sand content. Although the sand content in the lower section of the Productive Series decreases significantly, several thick sandy layers are also encountered in this interval.

At present, exploration wells drilled in various parts of the depression have partially studied not only the lower section of the Productive Series but also the underlying Miocene sediments. In the studied sections of the depression, the upper division of the PS contains up to 20 sandy horizons separated by clay layers, according to the Neftchala stratigraphic subdivision. The basal horizon of the upper division, Horizon XX, is considered analogous to the «Facies» layer group in the Absheron petroleum region. In the electric log diagrams of deep wells in the Lower Kura Depression, the lower division of the PS (comprising PK, KS, NKP, and NKG layer groups) is clearly distinguishable below Horizon XX.

Among the 37 exploration wells that have penetrated the lower division of the Productive Series in the Lower Kura Depression, testing operations were not conducted in 19 wells due to the lack of hydrocarbon indications, as determined by geophysical data. Ten wells were not tested due to technical reasons. In the remaining wells, testing operations yielded low-flow water with no signs of oil or gas from the PK, KS, and NKP layer groups.

The analysis and generalization of drilling data for the hydrocarbon potential of Horizon VII (as per the Garadagh subdivision) across various areas indicate that exploration wells in the Kurovdagh-Neftchala anticlinal zone (Kurovdagh, Garabaghly, Babazanan, Khilly, Neftchala) have shown limited industrial significance. Among 40 wells that penetrated the Facies layer group, only three (located in the Neftchala field) yielded industrial oil flows (Huseynov et al, 1983, Yusif et al, 1984, İbrahimov et al, 1987). In the Pirsaat area, 16 exploration and 4 appraisal wells were drilled between 1964 and 1972, with 8 wells abandoned for technical reasons. Four wells produced industrially significant oil and gas-condensate flows from the sandy layers of Horizon VII of the Productive Series. In the Bandovan area, the full thickness of Horizon VII, analogous to Horizon XX, was penetrated by 7 deep exploration and appraisal wells. One well was abandoned due to technical issues, while others yielded minimal water or no flow during testing. In the Qalmaz and Mishovdagh areas, Horizon XX of the Productive Series was reached by drilling; however, due to the absence of flows during testing, the wells were abandoned for geological reasons.

Objective: Industrial accumulations of oil and gas in the Pirsaat field are primarily associated with the upper sandy horizons of the Productive Series. However, significant oil and gas flows have also been recorded during drilling and testing from the lower horizons of the Productive Series in deep exploration wells in various parts of the region. The analysis of existing geological and geophysical data, along with the integrated study of deep drilling results, indicates that the lower horizons of the Productive Series have not been uniformly explored across the

region. Their structural, tectonic, and lithological characteristics vary significantly. Therefore, comprehensive scientific research is necessary to fully evaluate the hydrocarbon potential of the lower section of the Productive Series and to determine effective strategies for exploration and development activities.

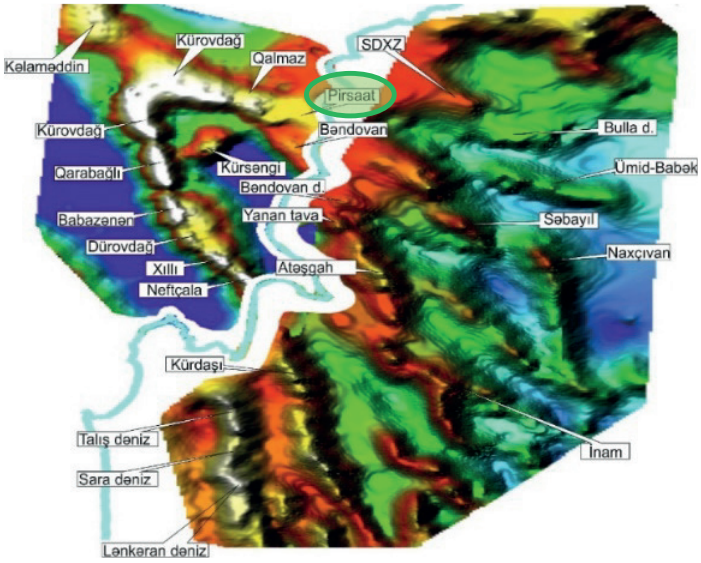

Figure 1. Overview scheme of the Pirsaat deposit located in the Lower Kura Depression

Methods: The Pirsaat oil-gas-condensate field is located in the northeastern part of the Kura Depression, along the Caspian Sea coast, 76 km southwest of Baku (Figure 1). Industrially significant oil was first discovered in 1936 from the II Pirsaat layer group at a depth of 1,255 meters in Well No. 27, with a production rate of 300-350 tons/day. Testing of wells drilled after 1938 confirmed the presence of hydrocarbons in the Absheron stage, as well as in the I, II, and III Pirsaat layer groups, and the Hamamdagh layer group. Since 1935, a total of 127 wells have been drilled in this area. Of these, 82 wells were abandoned due to technical issues, while 45 wells were successfully completed.

In the Pirsaat oil-gas-condensate field, the Productive Series sediments have been fully penetrated only in four wells (Nos. 94, 99, 104, and 216), with a thickness ranging between 4,300 and 4,500 meters. The upper division of the Productive Series is subdivided according to the local stratigraphic classification, while the lower division corresponds to the Garadagh subdivision. Lithologically, the field's stratigraphic section consists of alternating terrigenous rocks (sand, clay, sandstone) of varying thicknesses (Figure 2).

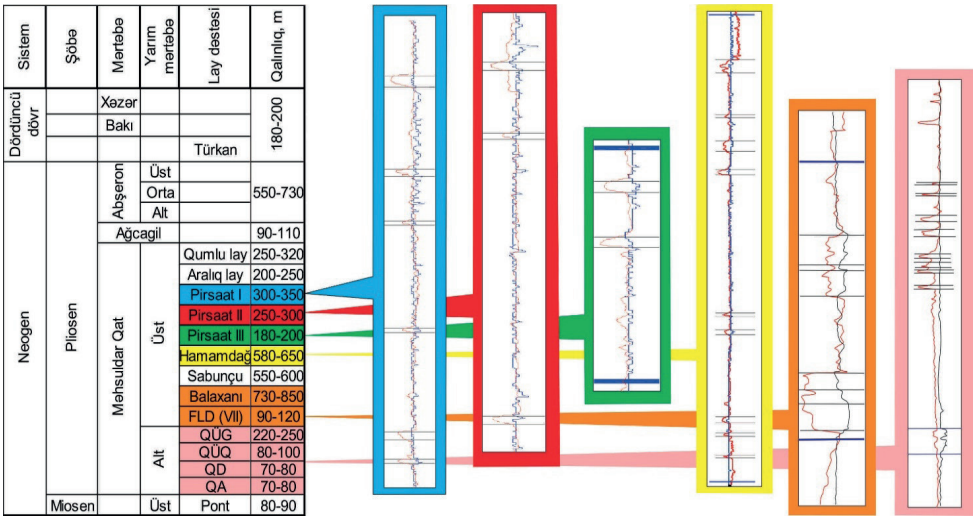

Figure 2. Generalized geological-geophysical section of the Pirsaat oil-gas-condensate deposit

The generalized stratigraphic section of the Pirsaat oil, gas, and condensate field includes Quaternary sediments (180-200 m), Absheron (550-730 m), and Akchagyl (90-110 m) formations, as well as the upper section of the productive layer comprising the Sandstone (250-320 m), Intermediate (200-250 m), I Pirsaat (300-350 m), II Pirsaat (250-300 m), III Pirsaat (180-200 m), Hamamdagh (580-650 m), Sabunchu (550-600 m), and Balakhani (730-850 m) formations. The VII (VII upper, VII middle, VII lower) horizon (90-120 m) and the lower section of the productive layer, which includes the NKG (220-250 m), NKP (80-100 m), KS (70-80 m), and PK (70-80 m) formations, along with Pont sediments (80 m), are also present. The Pont sediments primarily consist of dark and light-colored clays, with rare occurrences of limestone and sandstone. Lithofacies variations in the lower section of the productive layer are much more complex than in the upper section. The lower section is mostly clay. The Lower Kirmaku layer in the lower section and partly the Upper Kirmaku Sandy layer are relatively sandy. The stratigraphy of the upper section of the productive layer mainly consists of variously colored clays, with very thin sand and aleurite layers. The Quaternary sediments are mainly composed of gray and brownish-gray sandy clay layers, alternating with thin sand layers.

Oil and gas presence has been detected in the Absheron horizon, the I, II, and III Pirsaat layers, the Hamamdagh layer, and the VII horizon of the Pirsaat field. The sediments of the I, II, and III Pirsaat layers are of river origin. The burial depth of these layers ranges from 960 to 1650 meters. The thickness of the sands and sandstones in these layers varies from 2 to 12 meters. The sediments of the VII (VII top, VII middle, VII bottom) horizon are of deltaic origin. Three sandy objects—VII bottom, VII middle, and VII top—are clearly distinguishable within the limits of the VII horizon. Only the VII bottom is productive. The burial depth

of these sediments ranges from 3100 to 4400 meters, with the thickness of the sand layer varying between 8 and 14 meters, and its maximum thickness reaching up to 18 meters (Figure 3).

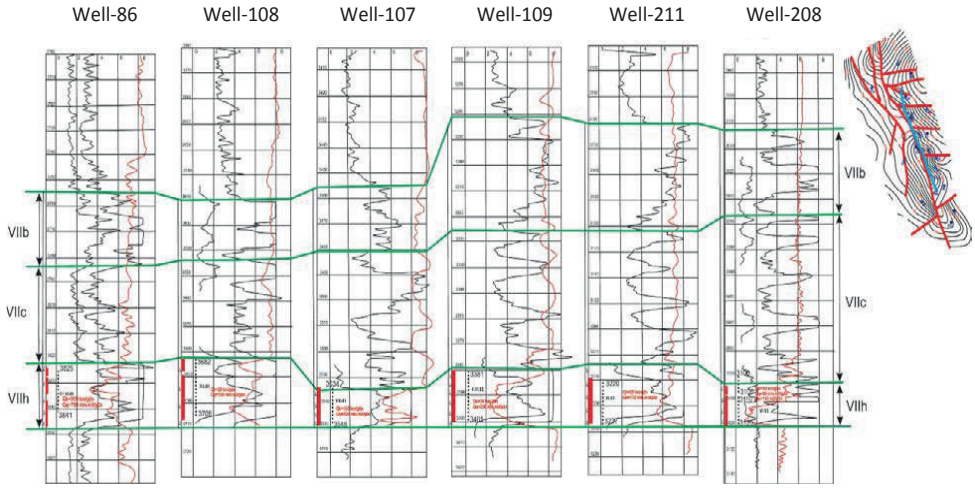

Figure 3. Geological-geophysical correlation diagram of the VII horizon of the Pirsaat field

The Pirsaat-Hamamdagh anticline zone is located in the northeastern part of the Lower Kura depression. The Pirsaat structure is characterized by a brachianticlinal fold that extends from the northwest to the southeast, with a length of 12 km and a width of 6 km. Its continuation to the northwest is the Alat fold zone, and to the southeast, it is the Sangimugan marine structure. The Pirsaat anticline is the only land uplift in the Pirsaat-Hamamdagh anticline zone. This brachianticlinal fold, extending in the northwest-southeast direction, is sharply aligned with the Goturdagh anticline to the northwest, which extends in the strike direction, while to the southwest, it is separated by a shallow saddle with weak reflection from the Hamamdagh anticline located in the sea. This has led some researchers to suggest that these two structures form a single anticline. The Pirsaat brachianticline connects in the north with the Dashgil zone and in the southeast with the Hamamdagh marine uplift.

2D seismic exploration has been carried out in the area, and during the interpretation of the seismic exploration, various reference horizons (Pirsaat 1, Pirsaat 2, Pirsaat 3, Hamamdagh LD, VII horizon, and the lower horizons of the PK layer) were traced, and tectonic fractures were clarified. Based on the results of the 2D seismic exploration and data from the drilled wells, seismic profiles were constructed to create seismo-geological profiles (Figure 4).

In the upper parts of the productive layer, the structural zone is complicated by two parallel longitudinal tectonic fractures. As a result, the northeastern wings have subsided by 200-800 m relative to the central blocks, and the central block has subsided by 300-700 m relative to the southwestern wings. The folds are fragmented into tectonic blocks by transverse fractures with amplitudes ranging from 50 to 600 m. The arch-like zone between these two fractures has collapsed into a graben structure. The Pirsaat anticline also has an asymmetric structure, with the northeastern wing being less steep (25°) and the southwestern wing being relatively steep (45°).

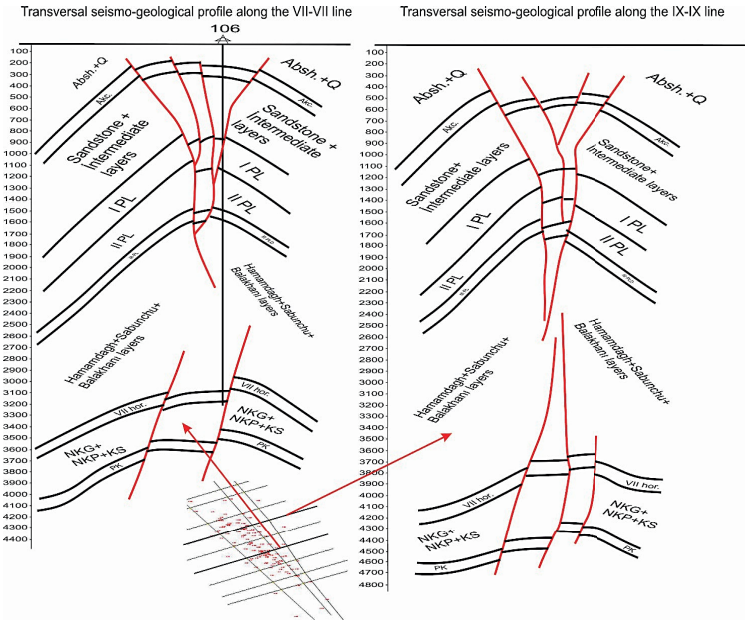

Figure 4. Seismo-geological profiles compiled based on seismic data

In the lower part of the productive layer, the asymmetry of the structure gradually decreases. In the wings, the dip angle of the layers is approximately 24 degrees to the east and approximately 13 degrees to the west. The structure is divided into northeastern, southwestern, and central tectonic blocks by two longitudinal fractures. As shown in the map constructed according to the top of the VII horizon, the fold, both in its wing sections and arch-like zone, is complicated by several transverse fractures (Figure 5).

The industrially significant oil and gas presence in the lower VII horizon of the reservoir was first identified in 1966, when well No. 86 produced 750,000 m³/day of gas and 300 tons of condensate from the interval between 3840-3822 meters. The upper section of the formation in well No. 86, which reaches a thickness of 3200 meters, consists of an irregular alternation of thick gray and brownish-colored sandy clays with poorly cemented fine and medium-grained sand layers.

The stratigraphy of the upper section, from top to bottom, includes the following formations: Sandstone, Intermediate, I Pirsaat, II Pirsaat, III Pirsaat, Pirsaat lower, Hamamdagh, and the Interruption layer.

From well No. 83, drilled southeast of well No. 86, oil, gas (3,000 m³/day), and water (163 m³/day) were obtained from the depth interval of 4114-4130 meters, with a production rate of 74 tons/day. Subsequently, oil and gas were extracted from wells drilled in the northeast and southeast wings of the fold (wells 85 and 91).

In addition to the VII horizon, positive results were obtained from other wells during testing. In well No. 85, located below well No. 86 in terms of dip, a liquid flow with a total rate of 150 m³/day was obtained from the 4130-4110 meter interval, which included 20 tons of oil per day. In well No. 91, located in the southeast part of the northeastern wing of the fold, oil (70 tons/day) and gas (250,000 m³/day) were obtained from the 3618-3604 meter interval of the VII horizon. Later, the production rate of the well gradually decreased to 80,000 m³/day of gas and 3 tons/day of oil.

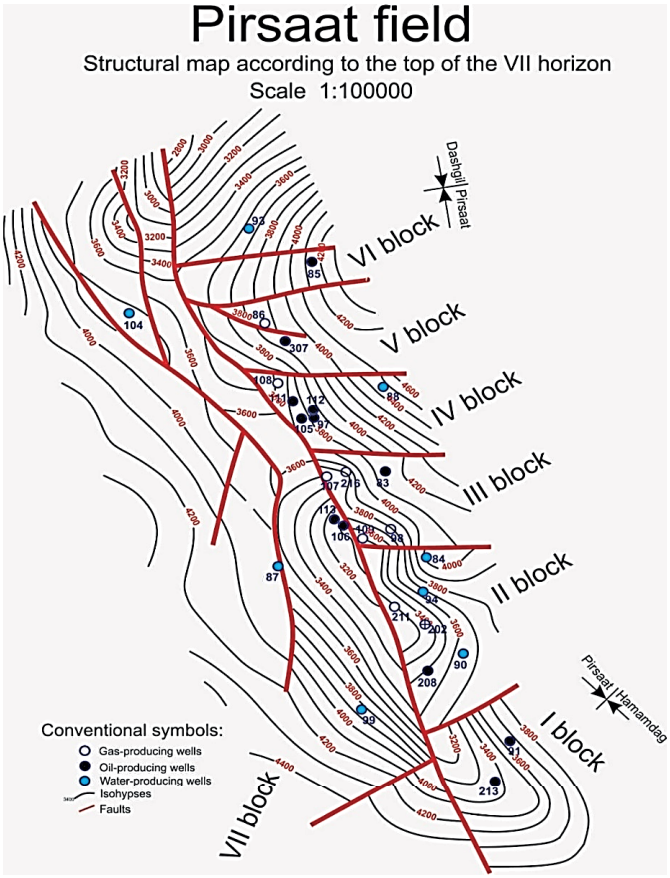

Figure 5. Structural map constructed according to the top of the VII horizon

From the wells drilled into the lower VII horizon of the Pirsaat field (wells No. 97, 105, 106, 107, 108, 109, 111, 112, 208, 211, 213, and 307), industrially significant oil, gas, and condensate have been extracted (Table 1). Additionally, water has been extracted from wells No. 84, 87, 88, 90, 93, 94, 96, 99, and 104 during the development of the lower VII horizon. Development work has not been carried out in well No. 202 for technical reasons, and there is no data available for well No. 101. The karaj indicators of well No. 216 for the lower VII horizon are positively evaluated.

Table 1.

Horizon	Block	Well	Depth of the filter, m	Initial production			
				Oil, t	Gas, thsnd.m3	Cond., t	Wat., m3
VII_{low}	III	83	4130-4114	74	3		163
VII_{low}	VI	85	4130-4110	20	2,1		130
VII_{low}	V	86	3841-3825		750	300	350
VII_{low}	I	91	3618-3604	70	250		4,7
VII_{low}	IV	97	3850-3808	100			5
VII_{low}	IV	105	3650-3641	45-50	40		
VII_{low}	VII	106	3332-3307	25	58		50
VII_{low}	III	107	3548-3536		300	100	
VII_{low}	IV	108	3706-3682		200	25	
VII_{low}	III	109	3401-3381		200	29	
VII_{low}	IV	111	3562-3570	20	2		
VII_{low}	IV	112	3842-3850	60	1026		
VII_{low}	II	208	3100-3120	10	50		140
VII_{low}	II	211	3237-3220		170	20	
VII_{low}	I	213	3154-3149	10	50		50-60
VII_{low}	V	307		150			

Table 1. Initial production results for the VII lower horizon

Oil, gas, and condensate have been obtained from 16 wells drilled into the lower VII horizon. Based on these wells, a calculation plan for the lower VII horizon has been developed by determining the oil-gas and oil-water boundaries (Figure 6). Furthermore, the prospective reserves for the lower VII horizon in the C1 category have been assessed (Figure 7). In Block I, the initial oil production from well No. 91 is 70 tons/day, and gas production is 250,000 m³/day. Based on this well, the oil-water boundary is determined at 3700 m. In Block II, the initial gas production from well No. 211 is 170,000 m³/day, and condensate production is 20 tons/day. The initial oil production from well No. 208 is 10 tons/day, and gas production is 50,000 m³/day. For wells No. 90 and 94, due to water extraction, the gas-oil contour is set at 3425 m, and the oil-water contour at 3600 m. In Block III, since gas-condensate was obtained from wells No. 107 and 109 during testing, the oil-gas boundary is set at 3750 m. Considering that well No. 83 has an oil production of 74 tons/day, gas production of 3,000 m³/day, and water production of 163 m³/day, the oil-water boundary is determined at 4160 m. In Block IV, the initial gas production from well No. 108 is 200,000 m³/day, and condensate production is 25 tons/day. For this well, the oil-gas boundary is set at 3710 m. For wells No. 97, 105, and 112, the oil-water boundary is determined at 3900 m. In Block V, the initial gas production from well No. 86 is 750,000 m³/day, and condensate production is 300 tons/day. The oil-gas boundary for this well is set at 3880 m. Based on the maximum oil flow from well No. 307, the oil-water boundary is set at 3930 m. In Block VI, the initial oil production from well No. 85 is 20 tons/day, and gas production is 2.1 million m³/day. Based on this, the oil-water boundary is set at 4150 m. In Block VII, the initial oil production from well No. 106 is 25 tons/day, and gas production is 58,000 m³/day. The oil-water boundary for this well is set at 3360 m.

Using the calculation plan, the prospective reserves for the lower VII horizon in the C1 category have been calculated at P50 as follows: Gas balance reserves – 1,092.9 million m³, Gas recoverable reserves – 797.3 million m³, Condensate balance reserves – 84.3 thousand tons, Condensate recoverable reserves – 42.8 thousand tons, Oil balance reserves – 10,722.06 thousand tons, Oil recoverable reserves – 3,311.34 thousand tons.

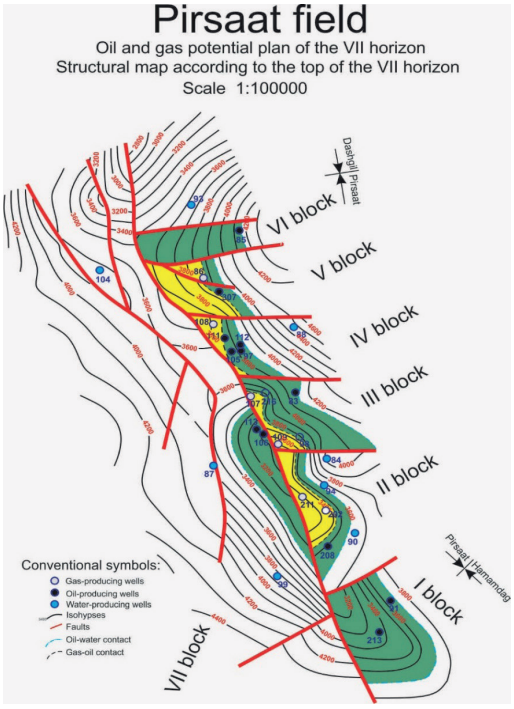

Figure 6. Oil and gas potential plan of the VII horizon

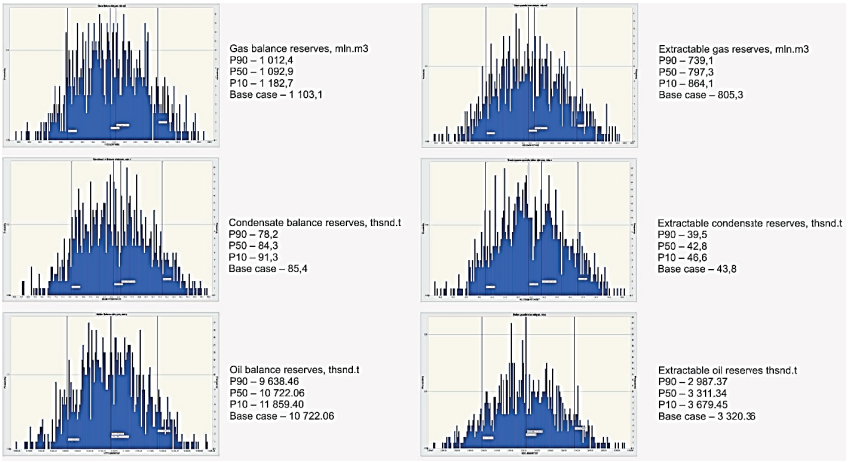

Figure 7. Calculated Prospective Reserves for VII lower Horizon under Category C1

In the exploration and prospecting work carried out in the Pirsaat field since 1970, the aim has been to track the reservoirs in the upper horizons and also to study the Lower Kirmaku layer formation. The Lower Kirmaku layer formation has been encountered in various parts of the field, in wells No. 103, 104, 94, 100, 99 (exploration wells), and No. 207, 216 (prospection wells). Wells No. 104 and 94 were abandoned for geological reasons due to water production during testing, while wells No. 103, 100, and 99 were abandoned for technical reasons. In the central tectonic block of the fold structure, wells No. 207 and 216 were also abandoned due to water production. The total thickness of the sediments opened by the wells drilled into the PK layer formation ranges from 70 to 80 meters. Considering that no positive results were obtained from the Lower Kirmaku layer formation, drilling work in this formation was stopped in 1989.

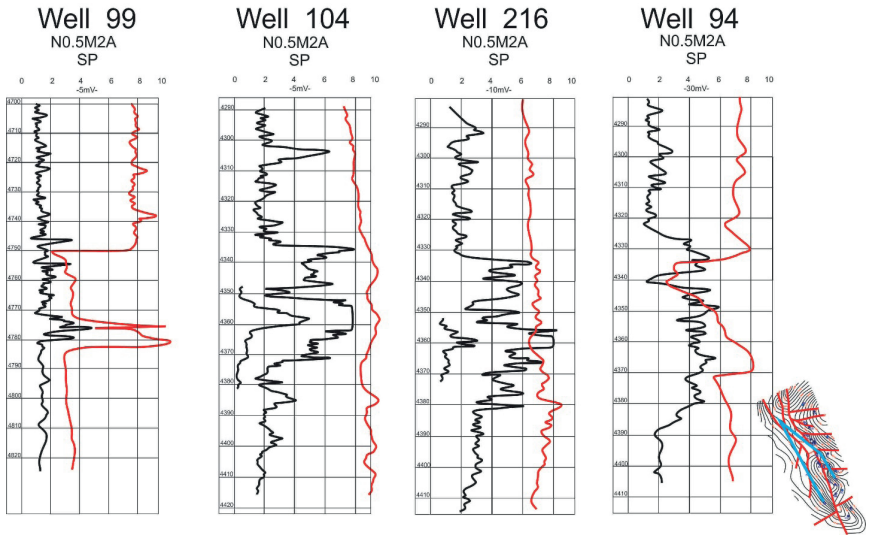

Figure 8. Geological-Geophysical Correlation Scheme of the PK Reservoir Unit

However, these results should not imply that the PK layer set is not prospective. In well No. 99, sands with an oil odor were lifted from the assumed interval of the PK layer set. Additionally, the well No. 216, which opened the PK layer set, has favorable reservoir parameters (Figure 8). The presence of water in the wells opening the PK layer set may be related to drilling into the remote wing sections of the reservoir or falling behind the oil-gas contour.

Using the calculation plan of the VII-alt horizon and the preliminary test results from wells No. 103, 207, 216, and 94 drilled into the Lower Kirmaku layer set, we have established a calculation plan for the PK layer set (Figure 9). Based on this calculation plan, the prospective reserves for the PK layer set in the C3 category have been evaluated (Figure 10).

For the PK layer set, prospective reserves in the C3 category have been calculated

with P50 as follows: gas balance reserves – 3,895.4 million m³, recoverable gas reserves – 2,841.5 million m³, condensate balance reserves – 300.5 thousand tons, and recoverable condensate reserves – 153.0 thousand tons.

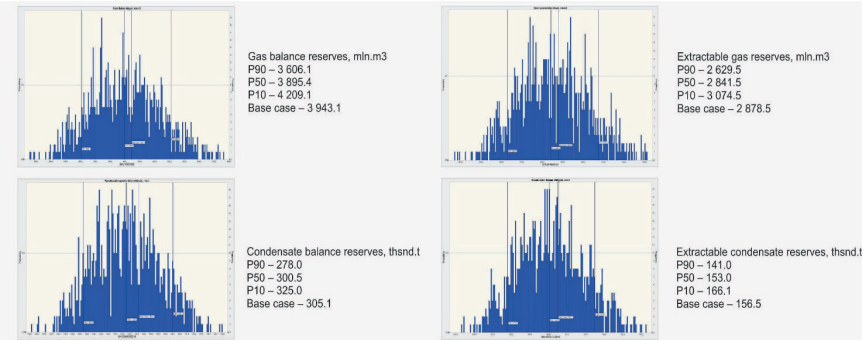

Figure 9. Oil and gas potential plan of the PK layer

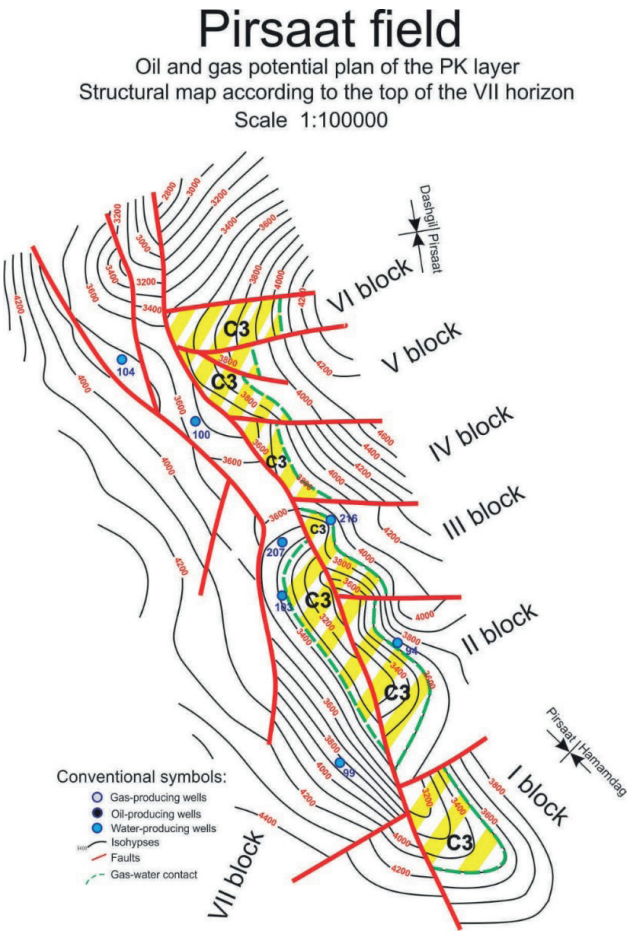

Figure 10. Calculated Prospective Reserves for the PK Reservoir Unit under Category C3

The positive evaluation of the reservoir parameters of well No. 216, drilled from the III tectonic block to the Lower Kirmaku layer set in the eastern wing of the Pirsaat anticlinal, suggests that the layer set could potentially be oil and gas-bearing under favorable structural-tectonic conditions. Therefore, it is considered appropriate to drill an exploration well in this block to study the oil and gas potential of the PK layer set at the near-crest section to a depth of 4400 m. Additionally, drilling exploration wells from the near-crest section of blocks II, IV, and V located on the eastern wing at an average depth of 4350 m is deemed suitable.

Conclusion. Using the data from the wells drilled in the Pirsaat field and the two-dimensional (2D) seismic exploration work, the lithological generalized geological-geophysical profile of the field has been refined, seismic-geological profiles cutting the field in different directions have been constructed, and the structural map based on the roof of the VII alt horizon has been updated.

Using the preliminary test results from the drilled wells, the initial oil-gas-water contour has been determined, and a calculation plan has been developed. Based on this, the prospective reserves for the VII alt horizon were evaluated in the C1 category, and for the PK layer set, in the C3 category.

The oil, gas, and condensate reservoirs discovered in the lower horizons of the Pirsaat field are mainly tectonically enclosed and lithological in nature.

There is a possibility of gas-condensate reservoirs in the productive horizon of the Lower Kirmaku layer set.

The efficient direction of exploration and survey work for the Pirsaat field has been substantiated based on new data.

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