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Determination of petrophysical parameters of reservoirs in promising horizons and formations of the Bulla-Deniz field based on integrated well data (using Techlog software)

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The Bulla-Deniz field which is characterised by deep wells has not been fully explored despite its commissioning since 1975. Consequently, the intersection of the Productive Series (PS) deposits has been drilled to the top of the Kirmaky group. The deposits of the sub-Kirmaky and Gala formations have not been exposed in the field area. The Bulla-Deniz field is located in the northern portion of the oil-gas region of the Baku archipelago, which is part of the Azerbaijani sector of the Caspian Sea. The structure was investigated through a comprehensive geophysical exploration program which included mapping, structure-search and logging datas.

The Bulla-Deniz structure is described in these materials as an asymmetric brachyanticline, extending in a northwest-southeast direction. Its dimensions are given as 27×9 km along the roof of the VII horizon and up to 1400 m high. The Bulla-Deniz fold is further complicated by the presence of longitudinal and transverse tectonic faults, which divide it into a number of tectonic blocks. The northeastern wing is divided into six tectonic blocks by six transverse faults. Two transverse fractures are noted in the southwestern wing, which divides the wing into 3 blocks (A, B and C blocks). In the geological cross-section of the Bulla-Deniz field, the sediments of the PS, Agcagil and Quaternary periods were identified in wells. The presence of Miocene sediments, as evidenced by excavations in the cross-section of neighboring deposits, is beyond doubt. The Miocene sediments have not been subjected to drilling studies. In consideration of the area's geological tectonic structure, it can be postulated that the sediments underlying the PS may start at with the Pont floor, which is estimated to be 150 to 200 m thick. The intersection of the PS sediments was exposed by drilling wells to the top of the Kirmaky formation. The Sub-Kirmaky and Gala formations were not subjected to field investigation. In accordance with the classification system utilized by the Absheron division, the VIII horizon is identified as the Kirmaky sandy formation. Two sand-siltstone layers are observed in the lower and upper portions of the horizon. The VII horizon is equivalent to the «Fasilah» formation, as defined by the Absheron division. It is primarily composed of sandstones. Horizon V (corresponding to horizons VIII-IX according to the Absheron division) was represented by alternating layers of thick sand, sandstone and shale. The oil and gas in the Bulla-Deniz field are located within the V, VII, and VIII horizons of the PS. However, since these horizons in the southwestern wing have not been accessed through wells, their oil and gas content remains unknown. From this point of view, important issues such as detailed study of the Bulla-Deniz field, evaluation of its horizons and strata in terms of productivity, determination of its petrophysical parameters and calculation of reserves are still valid today.

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The article deals with the determination of petrophysical parameters of reservoirs, calculation of oil reserves and determination of oil-water contact using complex well logging data on promising horizons and reservoirs of the productive series of the Bulla-Deniz field.

To solve the problem, the Techlog software was used to study the total and effective porosity, clay content, permeability, oil and gas saturation and water saturation of reservoirs in perspective reservoirs in terms of productivity on the basis of integrated log data from 6 well sections of the Bulla-Deniz oil and gas condensate field characterised by deep wells. The total volume of oil by wells in blocks A and B, separated by faults, was calculated according to our parameters, intervals of oil-water contact were determined and correlation by reservoirs was made for wells belonging to each block.

The density logging data were used to calculate the values of total and effective porosity of reservoirs for each well section and to construct curves characterising variations of these parameters over the survey interval. Given that these parameters are dynamic parameters of reservoir layers, the intervals of reservoir layers along the section were determined using these curves.

In the course of the research work for each well section we investigated, using electric logging data and Techlog software, we determined the intervals of the oil-water contact, determined oil- and water saturation parameters and established curves of their variation by depth. The curves were used to determine the intervals of water-bearing and oil-bearing layers in the section. Determination of the oil-water contact is of scientific and practical importance in determining the nature of the boundaries of the oil and water zones in the reservoir and identifying watered productive layers.

In this article, using the average values of parameters determined in the Bulla-Deniz field, the oil volume for blocks A and B separated by the fault and the total oil volume for the studied area were also calculated.

As well as in the detailed determination of petrophysical parameters, in determining the relationship between them, in the more precise calculation of reserves at the fields.

Key words: well, logging, Techlog, interpretation, density, porosity, effective porosity, saturation, shale, oil-water contact.

Introduction. The Bulla-Deniz field is located 55 km south of Baku, in the northern part of the Baku archipelago, 10 km southeast of the Sangachal-Deniz—Duvanni-Deniz—Bulla island field. The structure of the field was analyzed through complex geophysical survey work, mapping, structure exploration, deep exploration, and operational excavation materials. The Bulla-Deniz structure is oriented in the northwest-southeast direction. The geological section of the Bulla-Deniz field contains Productive Series (PS) of the Agcagilian and Quaternary deposits, which have been confirmed by drilling. Additionally, the presence of Miocene deposits in neighboring sections has also been confirmed, beyond any doubt. The Absheron and Kuryan facies expose the sediments of the Productive Series [Yusifov, Aslanov, 2018; Salmanov et al., 2023].

The arch and southwest flank of Bulla-Deniz are complicated by a parallel and reverse fracture. As a result, the southern wing of the structure gradually dips to the south. The northeastern wing is blocked by cross-cutting fractures (Fig. 1). Taking into account that the blocks remaining between these fractures have a high probability of being dredge traps suitable for oil and gas accumulations, the research objects of the article are the A (conditional wells Nos. 1, 2, 3, 4) and B (conditional wells Nos. 5 and 6) blocks of reservoir layers. Determining the petrophysical parameters, calculating the volume of oil for each block using their average values, determining the intervals of the water-oil connection for each well section, as well as conducting correlation on the well sections characterizing the distribution of sandiness, clay and porosity on the field. is set.

The increase in the volume of geophysical surveys and the deepening of wells has resulted in an excessive amount of time being required for the interpretation of the data from the wells. During the exploration process, interpreters try to interpret only those depth intervals that are considered important

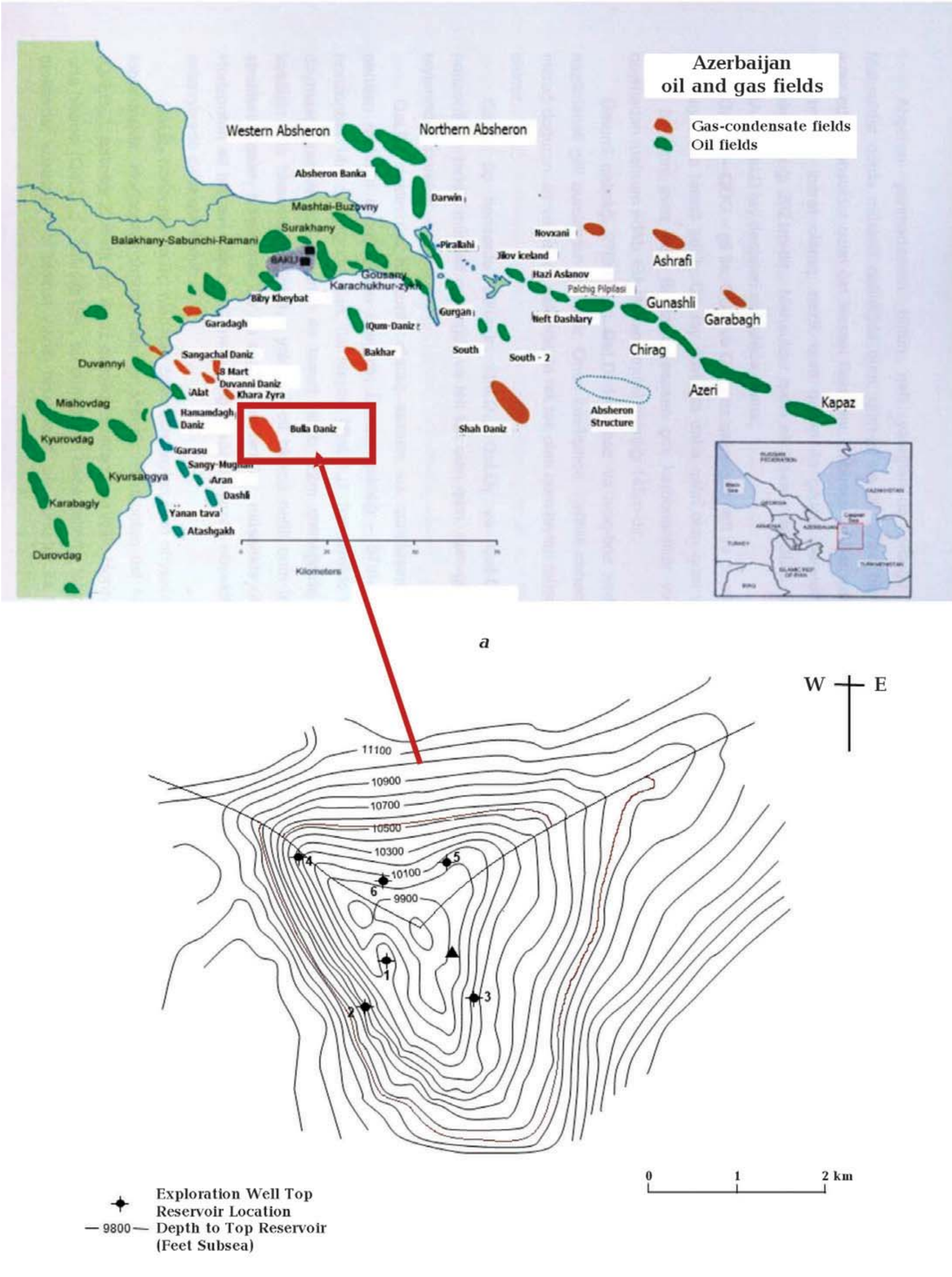

Fig. 1. Map of Azerbaijan's oil and gas fields (*a*); structural map of the researched area of the «Bulla-Deniz» field (well sections 1, 2, 3, 4 of Block A, well sections 5, 6 of Block B) (*b*).

to learn about [Seyidov, Khalilova, 2023]. This is because the data obtained must be interpreted as quickly as possible. This results in missing reservoirs containing thin oil, which means a significant economic loss. Therefore, the use of modern software packages remains important for the interpretation of well data, the detailed determination of petrophysical parameters of prospective reservoirs, the accurate calculation of oil volumes in the exploration area and the precise determination of oil-water contact intervals (software.slb.com). Therefore, this paper discusses the solution of the problems we identified for the 6-well intersection of the Bulla-Deniz oil condensate field characterized by deep wells using Techlog software [Schlumberger, 2015].

Purpose. This research aims to confidently determine the total and effective porosity, shale volume, oil-gas, and water saturation of the reservoir layers in horizons V, VII, and VIII of the Productive Series of the Bulla-Deniz field using complex logging data. Furthermore, we will calculate the oil volume in the fractured A and B blocks and the total oil volume for 6 wells in the research field, as well as determine the oil-water contact using the determined parameters.

Methods. So, this research confidently analyzes the petrophysical properties of reservoirs of 6 wells in the Bulla-Deniz field that is divided into 2 blocks (A and B). The logs are available in digital format (LAS) and were directly imported into Schlumberger Techlog software (version 2015.3).

Quality control was meticulously applied to all logging measurements through two steps to ensure the utmost accuracy of the output.

Calculation of total and effective porosity based on density log data. The property was calculated accurately using the density log at in-gauge intervals. Equation 1 was used in order to calculate total porosity (∅) from density log [Pashayev, 2010; Samadzadeh, 2023]:

$$\varnothing = \frac{\rho_{ma} - \rho_b}{\rho_{ma} - \rho_f}, \quad (1)$$

where ∅ — total porosity; ρ_{ma} — the matrix density (sandstone=2.65 g/cc), ρ_b — the formation bulk density; ρ_f — the fluid density (equal to 1.0 g/cc for fresh mud).

The effective porosity ($\varnothing^e$) which represents our target in this step, was calculated from the following equation:

$$\varnothing^e = \varnothing^t - 0.35 V_{sh}, \quad (2)$$

where $\varnothing^e$ — effective porosity, $\varnothing^t$ — total porosity, (shale porosity is 0.35 for Azerbaijan), V_{sh} — shale volume [Seyidov, Kerimova, 2018].

In the evaluation of hydrocarbon potential, $\varnothing^e$ is the most important petrophysical parameter. The structural element can have an effect on the evolution of $\varnothing^e$, which has a large influence on the $\varnothing^e$ [Lyaka, Mulibo, 2018].

Shale volume calculation. Using gamma log results from 6 well sections, Techlog software and the following formula, the shale volume was determined in a similar manner:

$$V_{sh} = I_{GR} = \frac{GR_{kar} - GR_{min}}{GR_{max} - GR_{min}}, \quad (3)$$

where I_{GR} — the intensity of gamma-ray, GR_{kar} — intensity in front of the designated layer. GR_{max}, GR_{min} — the value of intensity corresponding to maximum and minimum values across the respective layer.

Saturation calculation. The oil-gas saturation coefficient is one of the main parameters characterizing the reservoir properties. It is well known that high shale content in the field and large variations in porosity lead to close resistivity values of oil-bearing and water-bearing layers, which in turn create difficulties in distinguishing between oil-bearing and water-bearing reservoirs [Kerimova 2023]. Archi method has been used to calculate water saturation in the Bulla-Deniz field for the true zone (S_w) [Archie, 1952]:

$$Sw^n = \frac{aRw}{\varnothing^m Rt}, \quad (4)$$

where, S_w — water saturation of the uninvaded zone, a — Archie's exponent, it is normally 1, n — saturation exponent, which varies from 1.8 to 4.0 but normally is 2.0, R_w — downhole water resistivity, R_t — deep resistivity, it was determined as 0.066, ∅ — porosity, m — ce-

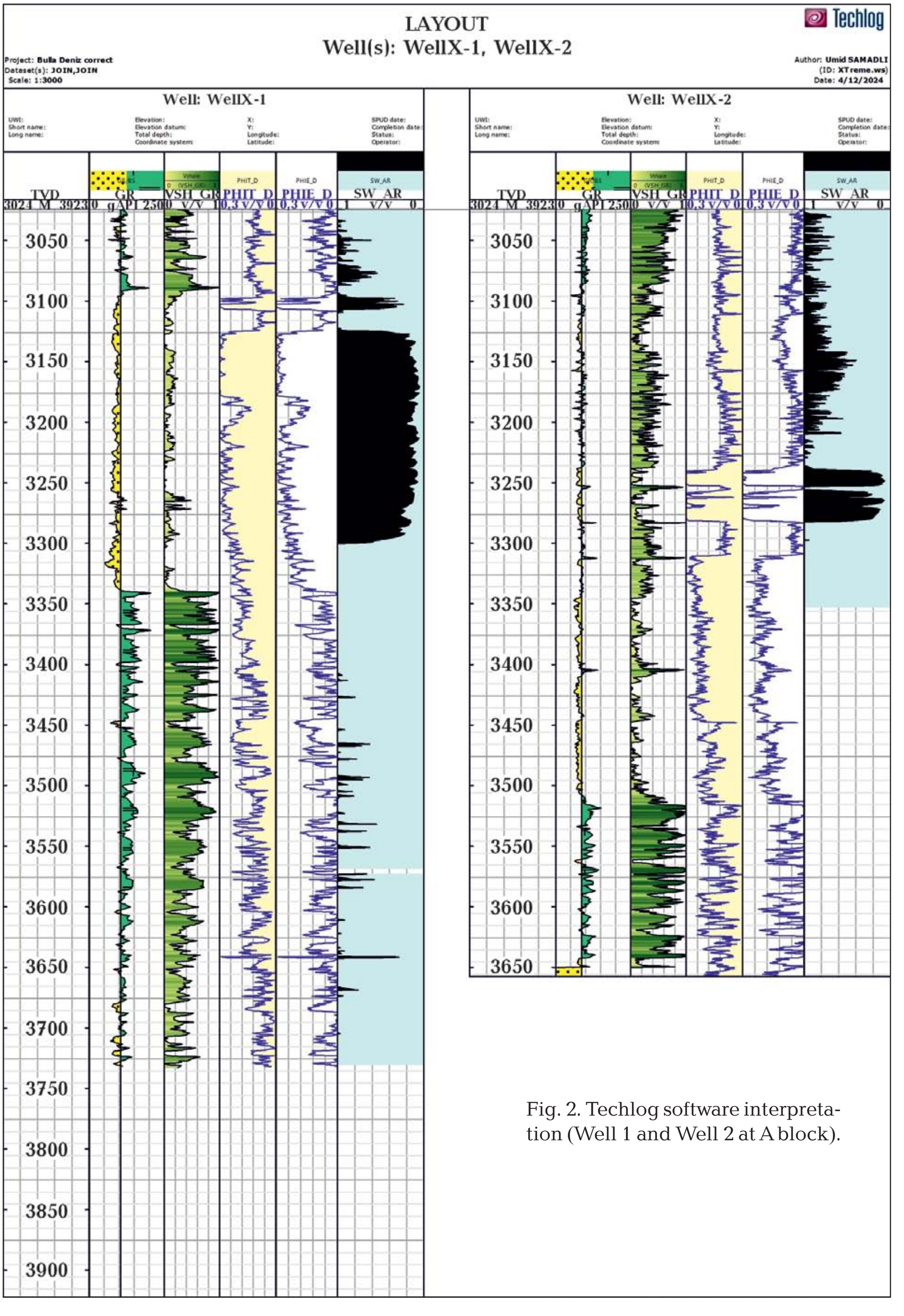

Fig. 2. Techlog software interpretation (Well 1 and Well 2 at A block).

mentation exponent, which varies from 1.7 to 3.0 but normally is 2.0.

Also, after determination after saturation oil-water contacts were identified for all wells. The calculated results presented in Figs. 2—4 and Table 1 for the study wells. Moreover, the average results of this interpretation are shown in Table 1 for the study wells.

Stock Tank Oil Initially in Place (STOIIP) calculation. In this paper Stock Tank Oil Ini-

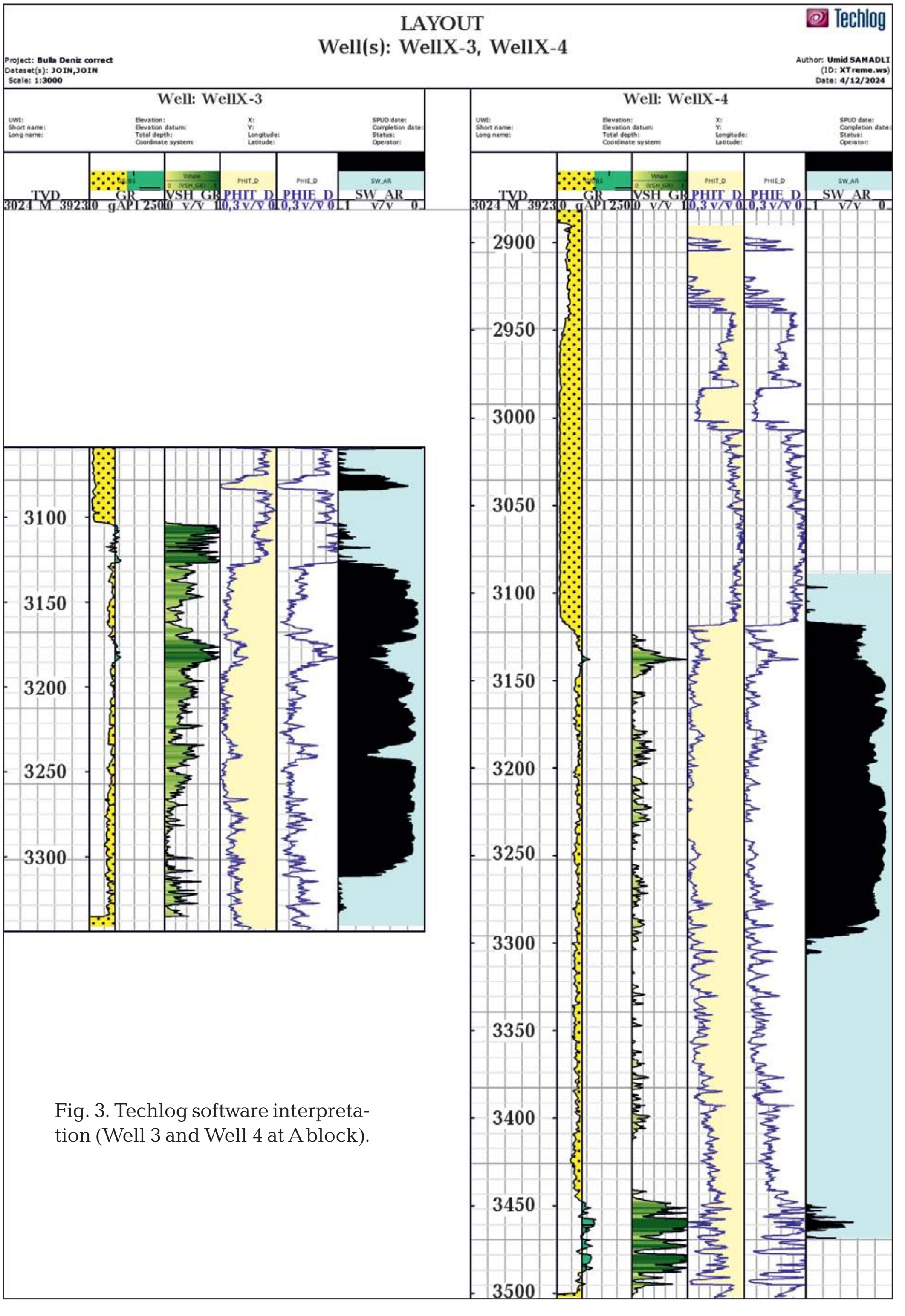

Fig. 3. Techlog software interpretation (Well 3 and Well 4 at A block).

tially in Place value was determined using formula 5 for A and B block [Dandekar, 2013]

$$\text{STOIIP} = 7758\frac{GRV\dfrac{N}{G}\varnothing\left(1-S_w\right)}{B_o}, \qquad (5)$$

where STOIIP — stock tank oil in place, *GRV* — gross rock volume, m^3, $\varnothing$ — rock porosity, %, S_w — water saturation, %, B_o — oil formation volume factor, 7758 — conversion factor, *N/G* — Net-to-gross ratio is the fraction of the

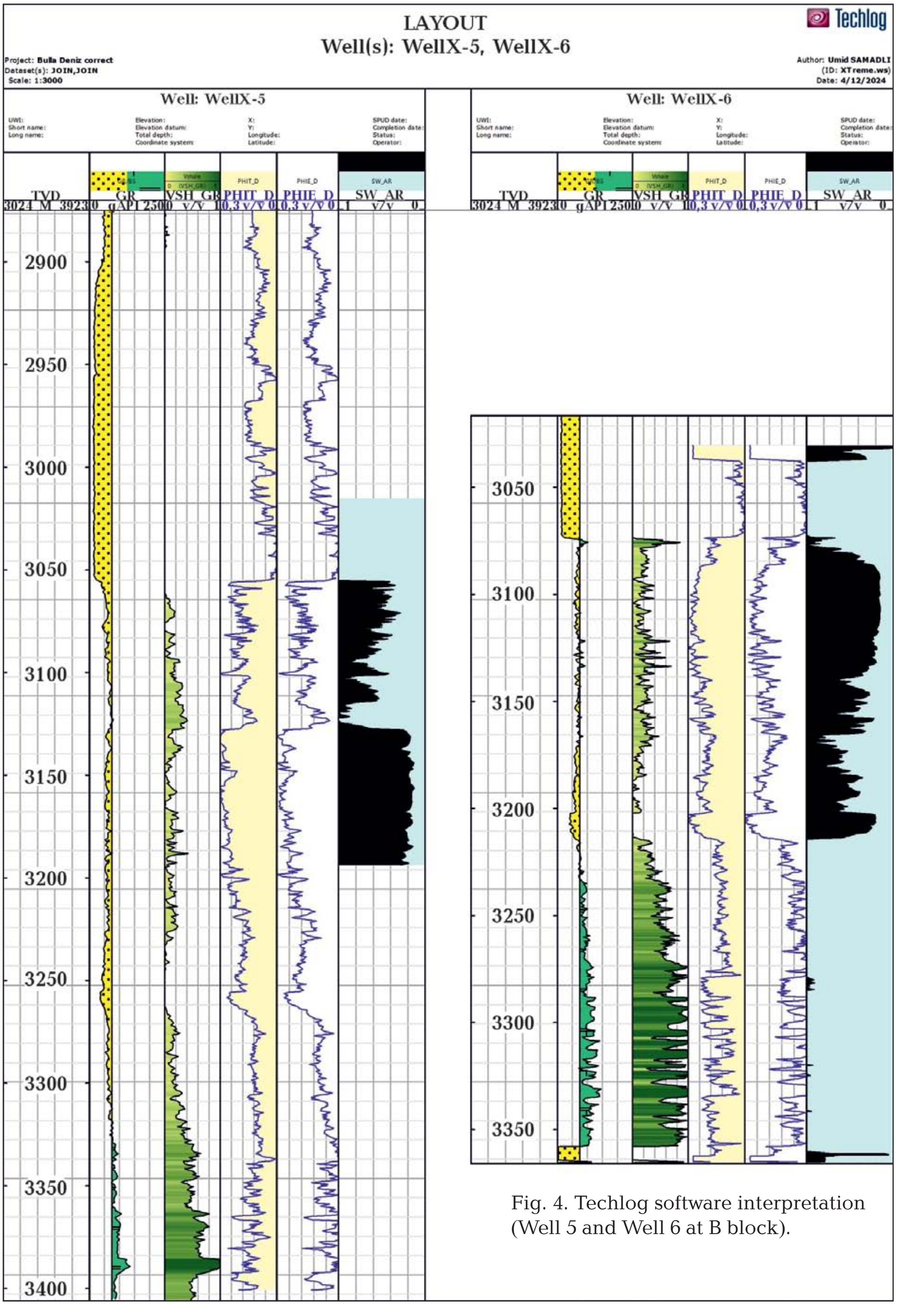

Fig. 4. Techlog software interpretation (Well 5 and Well 6 at B block).

gross reservoir thickness that is net reservoir thickness.

Net reservoir thickness is the sum of the thicknesses of the zones that meet the petrophysical cutoffs. Gross reservoir thickness is the total thickness of the reservoir interval, including non-reservoir zones. *N*/*G* reflects the reservoir continuity and heterogeneity. It is usually expressed as a percentage or a decimal fraction. The results of this calcula-

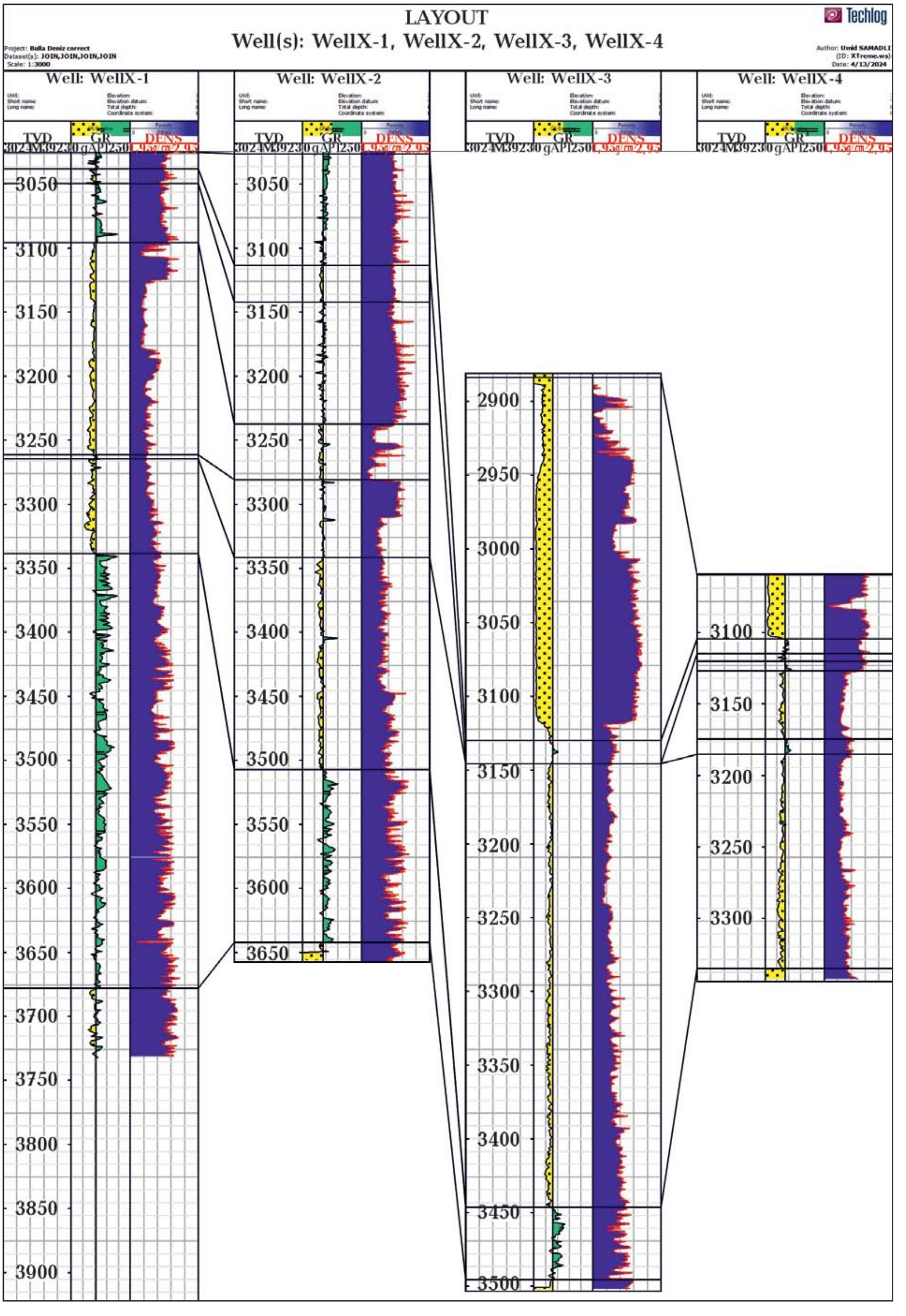

Fig. 5. Correlation for wells of A block.

tion are shown in Table 2 for A and B blocks.

Correlation. Correlation was tested separately on the well sections in blocks A and B to observe the distribution of sandstone, shale and porosity within each block (Figs. 5—6). When analyzing Fig. 6 it is seem that solid rock is visible in the 2900—3065 m interval on well 5 section included in block B. Notably,

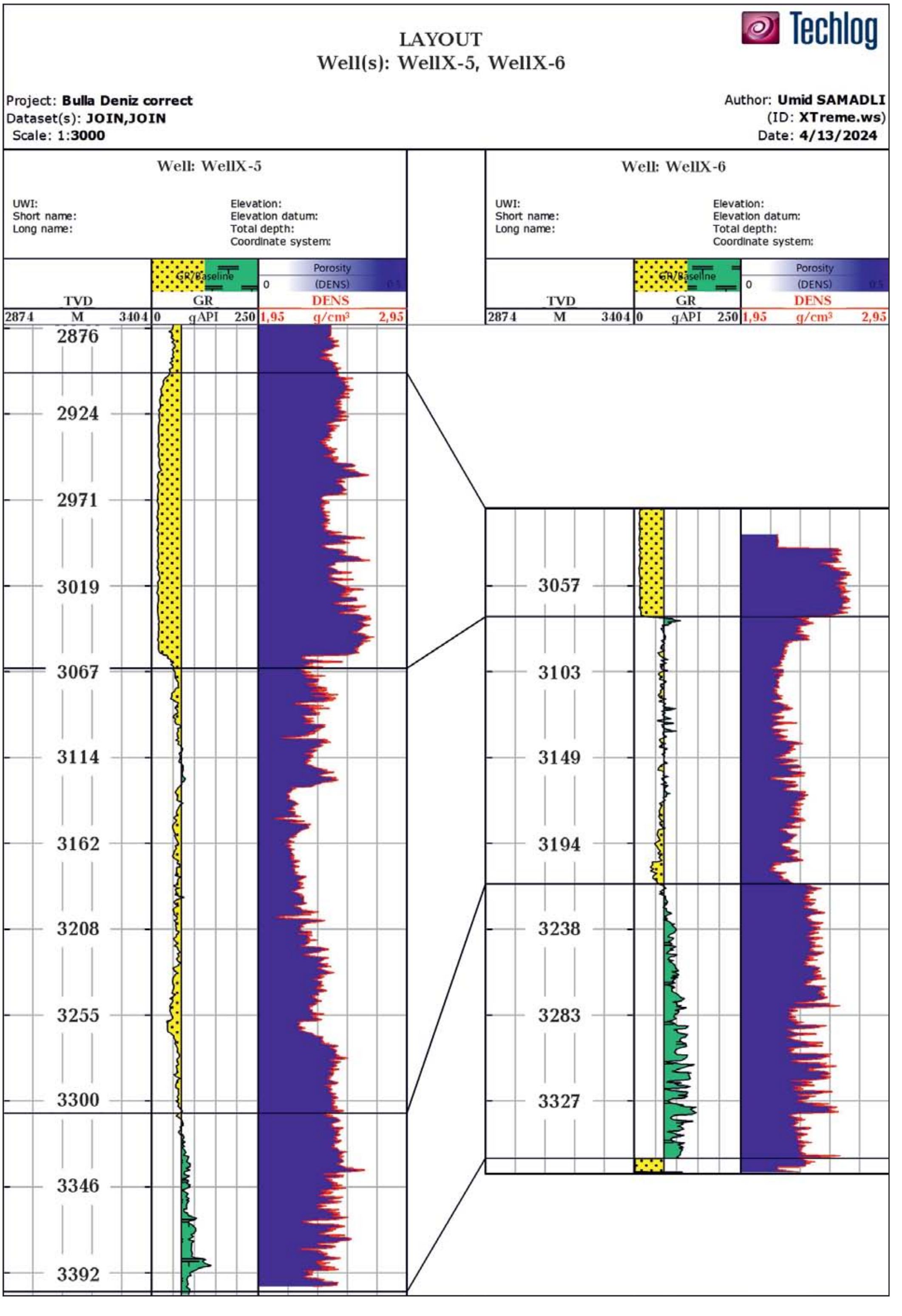

Fig. 6. Correlation for wells of B block.

this interval is shale-free and has total porosity and effective porosity ranges of 0—13 %. A similar scenario is observed in well 6 in the interval 3016—3074 m. Shale was not observed in this interval. The porosity and effective porosity values range 0—9 %. Reservoir layers dominate the 3065—3305 m interval on well 5. The shale content varies from 0 to

Table 1. The results of petrophysical properties as average values

Well	Top depth, m	Bottom depth, m	Oil-water contact depth, m	Average of total porosity, %	Average of effective porosity, %	Average of water saturation, %
1	3124	3367	3300	24.5	24.3	20.1
2	3238	3508	3310	21.7	21.4	26.5
3	3127	3332	3310	25.2	25	25
4	3121	3473	3304	27.7	27.3	19.3
5	3057	3270	3200	22.8	22.4	25.3
6	3078	3218	3216	23.7	23.2	22.9

Table 2. Value of STOIIP and value of all parameters used to calculate STOIIP

Block	A				B	
Well	1	2	3	4	5	6
GRV, m^3	266382				40112	
Porosity, %	23.4				21.2	
N/G	0.87				0.87	
S_w, %	77.3				77	
B_o	1.35				1.39	
STOIIP (MMSTB)	241				32	
Total STOIIP (MMSTB)	273					

40 %, while the porosity and effective porosity values range from 0 to 30 %. This is observed in well 6 at the interval of 3074—3214 m. In this interval, the shale value varies between 0—45 % and the porosity and effective porosity values range between 0—30 %. Well 5 and well 6 both exhibit shale layers dominating the 3305—3402 m and 3214—3355 m intervals, respectively. Within these intervals, shale volume ranges from 0 to 100 %, while total porosity and effective porosity values range from 0 to 18 % and 0 to 12 %, respectively. A correlation analysis was also conducted for the well sections in block A.

Conclusion. The selection of reservoir formations was based on log data from 6 well sections in the Bulla-Deniz field.

The porosity, shale volume, and saturation values of the reservoir layers have been measured and averaged. The total and effective porosity, shale volume, oil-gas saturation and water saturation have been calculated.

Stock Tank Oil Initially in Place (STOIIP) was determined for 4 wells in block A and 2 wells in block B which separated by faults.

Oil-water contacts were determined for each well intersection.

Correlation was conducted to show the intra-block variation of sand, shale and porosity for wells in blocks A and B separately.

The obtained results can be applied to other oil fields of Azerbaijan and in the study of the filtration-capacity characteristics of the reservoir layers in the fields, as well as in the detailed determination of petrophysical parameters, in determining the relationship between them, in calculating the reserves in the field, as well as in the process of exploitation, in determining the nature of the boundaries of the oil and water zones in the field and in the production of diluted productive it gives a reason to form a certain opinion both scientifically and practically in the selection of layers.

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Визначення петрофізичних параметрів колекторів перспективних горизонтів і пластів родовища Булла-Деніз на підставі комплексних свердловиних даних (з використанням програмного забезпечення Techlog)

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Родовище Булла-Деніз, що досліджене глибокими свердловинами, не було повністю розвідано, назважаючи на те, що введено в експлуатацію 1975 р. Отже, свердловинами розкрито перетин відкладів продуктивної товщі (ПТ), пробурено доверху групи Кирмаки. Відклади світ підкирмакинської та гала на території родовища не розкрито.

З цього погляду такі важливі питання, як детальне вивчення родовища Булла-Деніз, оцінювання його горизонтів і пластів з точки зору продуктивності, визначення петрофізичних параметрів та підрахунок запасів актуальні й сьогодні.

У статті розглянуто питання визначення петрофізичних параметрів пластів-колекторів, підрахунку запасів нафти та визначення водонафтового контакту за комплексними даними геофізичних досліджень свердловин на перспективних горизонтах і пластах продуктивної товщі родовища Булла-Деніз.

Для розв'язання задачі за допомогою програмного забезпечення Techlog були проведені дослідження загальної та ефективної пористості, глинистості, проникності, нафтогазононасиченості та водонасиченості колекторських пластів у перспективних пластах за продуктивністю на підставі комплексних даних геофізичних досліджень свердловин шесті розрізів свердловин нафтогазоконденсатного родовища Булла-Деніз. За заданими нами параметрами розрахований загальний обсяг нафти у свердловинах блоків А і Б, розділених розломами, визначено інтервали водонафтового контакту та проведено кореляцію пластів для свердловин, що належать кожному блоку.

За даними щільнісного каротажу розраховано значення загальної та ефективної пористості колекторів для кожного розрізу свердловин і побудовано криві, що характеризують зміну цих параметрів на інтервалі дослідження. З огляду на те, що ці параметри є динамічними параметрами колекторних шарів, інтервали колекторних шарів розрізу визначалися за цими встановленими кривими.

Під час дослідницької роботи для кожної дослідженої ділянки свердловини з використанням даних електричного каротажу та програмного забезпечення Techlog визначено інтервали водонафтового контакту, параметри нафто- і водонасиченості та побудовано криві їхньої зміни за глибиною. За цими кривими визначено інтервали водоносних і нафтоносних шарів у розрізі. Виявлення водонафтового контакту має наукове та практичне значення при визначенні характеру меж нафтової та водної зон у пласті та виділенні обводнених продуктивних пластів.

За середніми значеннями параметрів родовища Булла-Деніз розраховано обсяг нафти окремо у блоках А і Б, розділених розломом, і загальний обсяг нафти у досліджуваній площі.

Отримані результати дають підставу для формування науково-практичної думки щодо фільтраційно-ємнісних характеристик пластів-колекторів тих чи інших родовищ, а також для детального визначення петрофізичних параметрів, взаємозв'язку між ними, безпомилкового розрахунку запасів на родовищах.

Ключові слова: свердловина, каротаж, Techlog, інтерпретація, густина, пористість, ефективна пористість, насиченість, сланець, водонафтове відношення.