Petrophysical analysis of well logs data for identification and characterization of the main reservoir of Al Baraka Oil Field, Komombo Basin, Upper Egypt

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Abstract

The current study presents the log analysis results from two vertical onshore wells in Al Baraka oil Field, Komombo basin, upper Egypt. The Geophysical logs comprising gamma ray (GR), caliper (Cali), resistivity (LLD, LLS, and MSFL), photoelectric effect (PEE), neutron (NHPH) and density (RHOB) are used to study the petrophysical characteristics of the main identified reservoirs in this field. The key purpose of well logging analysis and interpretation is to obtain petrophysical properties of reservoirs such as shale volume, porosity, hydrocarbon saturation, net pay thickness, etc., for hydrocarbon exploration. Petrophysical analysis of well logs reveals that Al Baraka wells consist of three types of lithology: sand, shale, and siltstone. The obtained results show that there are two hydrocarbon-bearing zones named (S-E) and (S-D) zone for Al Baraka-4 well and Al Baraka-14 well, respectively; both had hydrocarbon reservoir bearing oil and lie in Six Hills Fm of the Lower Cretaceous. The generated cross-plots showed that the main reservoir lithology is composed of shaley sandstone to sandstone. The computed petrophysical parameters for the identified and characterized reservoir layers reveal that they have a total porosity range of 18.2–20.1%, water saturation of 57.7–36.6%, shale volume of 20–8.5% for (S-E) and (S-D) zone, respectively. The hydrocarbon saturation reaches to 42.5% for (S-E) zone and 36.6% for (S-E) zone; both hydrocarbons in these zones are movable. The net reservoir pay thickness is high in (S-E) zone reach to 24 ft. Below and above the oil-bearing reservoirs, there is a thick shale bed which acts as potential source rock or as a seal rock. The overall results indicated that the sandy reservoir units of 'Al Baraka' Field have the potential to contain significant accumulations of hydrocarbon, essential oil. It is recommended to integrate more wells and seismic data to better evaluate the reservoirs.

Keywords Reservoir · Petrophysical parameters · Well log analysis · Hydrocarbon-bearing zones Komombo basin

1 Introduction

Petrophysical analysis of well logs is one of the most useful and important tools for reservoir rock characterization. The productivity of wells in hydrocarbon-bearing reservoirs depends on petrophysical properties which include lithology, porosity, water saturation, permeability, and saturation [1]. Generally, the petrophysics framework here is termed as formation evaluation, which is the process of

using borehole measurements to evaluate the characteristics of subsurface formations [2]. Well logs data, such as gamma ray, density, neutron porosity log, photoelectric effect values, and resistivity (LLD, LLS, and MSFL) logs, were used to achieve this task. The proposed study aims to interpret the well logs data and quantitatively evaluate the petrophysical properties to identify promising zones for hydrocarbon accumulation with depth and thickness

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of these zones and to distinguish the interfaces of oil, gas, or water in parts of Al Baraka oil field.

Based on the history of petroleum exploration and production in Egypt, most of the hydrocarbon fields concentrated in three main regions: the Gulf of Suez, the North-Western Desert, and the Nile Delta. Southern Egypt has only attracted separate interest since 1990 with success finally arriving by drilling within Komombo concession. In 2007, drilling of the Al Baraka-1 well was a success, and there was establishment of the Al Baraka Field by Dana Gas Company [3]. Komombo Basin is an extensional rift basin, which covers an area of 186 km² in the southwestern Desert of Egypt [4] Fig. 1a. Komombo basin is filled with a Cretaceous–Cenozoic sedimentary sequence, which is underlain by the Pre-Cambrian basement rock. This succession is approximately reaches 4 km thick in the deepest parts (depocenter area) [5]. The topography of the Komombo area, which lies west of Faris village and northwest of Aswan city, is relatively gentle to the almost flat desert with no indications of the oil and gas activities Fig. 3.

Al Baraka oil field is present in the eastern part of Komombo Basin Fig. 1a, b. This field is located in the

southwestern Desert of Egypt north of Aswan city and covering area of 50 km², which is currently producing heavy oil from sandstone reservoirs. The main oil field, where most of Al-Baraka wells were drilled, is located approximately 12 km West of Faris village Fig. 3. The oil of the Al Baraka field is believed to be generated from potential lacustrine shales (high thermal maturity and rich TOC%) containing mixed terrigenous and marine organic matter, which was deposited in a moderately oxidizing sedimentary environment [3].

2 Location map and geological setting

Al Baraka oil field occupies the eastern part of the Komombo basin. It is located 800 km south of Cairo and lies between latitudes 24° 38' and 24° 40' 30" N, and longitudes 32° 46' and 32° 50' 30" E [6] Fig. 1b.

2.1 Location map of the study area

The study area is located in the south of Egypt in the eastern part of the Komombo basin, where the discovered

Fig. 1 **a** Komombo concession index map in Upper Egypt; **b** map showing the location of the Al Baraka oil field in Komombo Basin [4]

Al Baraka oil field is present. This field includes two wells named Al Baraka-14 (Cg 78-14) and Al Baraka-4 (Cg 78-4). Figures 2 and 3.

2.2 Regional geological setting

Komombo basin is a half-graben system filled with thick non-marine sediments deposited during Early Cretaceous (Hauterivian to Barremian) followed by marine deposition during Albian/Cenomanian (argillaceous sandstones and shales) and later shales and marine limestones during Late

Cretaceous and early Tertiary [7]. Stratigraphic boundaries and lithostratigraphic sequences are based on wireline logs lithofacies description, microscopic examination of ditch cutting samples for drilled wells, and biostratigraphic analysis. The stratigraphic sequences of the komombo basin are characterized by two major sedimentary breaks (non-deposition or erosional phases), represented by the gap in time between the Pre-Cambrian Basement rock and the Neocomian sediments and between the Cretaceous sequence and the overlying Paleocene sediments due to the regional uplift event on the area. Also, this

Fig. 2 Location map of the two studied wells

Fig. 3 Google earth image showing the location of the study area in Al-Baraka field with respect to the Faris Village

sequence has two minor inter-formational stratigraphic gaps; hiatus were detected between Neocomian and Barremian around three million years, and between Aptian and Albian sequences of around fourteen million years [8].

Sedimentation effectively terminated in the upper cretaceous (Santonian/Campanian) simultaneous with the earliest development of the Red Sea which bounds the eastern side of the Western Desert basin.

The Cretaceous succession in the Komombo basin Concession as shown in Fig. 4 generally consists of six formations from top to the base: Dakhla, Quseir, Taref, Maghrabi, Sabaya, Abu Ballas, Six Hills formation [9]. Six Hills formation is subdivided into seven members from base to top (A-G); also it provides the main source rock which is dark shale rich in an organic matter especially in B member of Six Hills formation [8] Fig. 4.

The primary targets for hydrocarbon exploration in North and Central Africa are the Mesozoic Rift basins [10, 11]. In the southwestern Desert of Egypt Bouguer gravity and aeromagnetic data show large elongated structural lows, grabens, and half-grabens [6, 12]. The Komombo Basin is considered an extensional rift basin, which appears to be a half-graben [13] Fig. 5, probably developed in an extensional stress regime originated in Central and North Africa with the opening of South Atlantic, which is started from the Late Jurassic–Early Cretaceous age and terminated in the Late Cretaceous by the Syrian Arc inversion in southern Egypt [14]. This rift basin is filled with sedimentary sequences that reach 4 km thick ranging from non-marine lacustrine facies to fully marine systems Fig. 4. The main bounding fault of the Komombo Basin is located to the northeast and trending NW–SE, while the subordinate faults are mainly synthetic and of the same trend [6, 13] Fig. 5.

3 Materials and methods

Understanding and knowing the subsurface comes primarily from drilling, which is a very expensive process. Wireline logging offers an opportunity to determine the composition, variability and physical properties of the rocks around the well, thereby enabling a proper good method for the understanding of subsurface at a cheaper cost.

3.1 Available data

The Wireline logs data for this study were collected from Ganoub El Wadi Petroleum Holding Company. The available drilled boreholes are Al Baraka-4 and Al Baraka-14, each well has main logs like gamma ray (GR), spontaneous potential(SP), caliper (CL), density(RHOB), neutron

Fig. 4 Stratigraphic column of Komombo Basin, upper Egypt (modified) [9]

Fig. 5 **a** Un-interpreted NE–SW 2D seismic section (05-01-Cf 77-08) crossing the Komombo basin, Upper Egypt. **b** Interpreted NE–SW 2D seismic section showing the half-graben basin and the main seismic horizons in the study area [13]

(NPHI), photoelectric effect (PEE), resistivity logs [deep resistivity (LLD), shallow resistivity (LLS), medium resistivity (LLM)]. These logs are used for calculating the petrophysical parameters as no core data is available; these logs are delivered as soft copies (Las files (as shown in Table 1. The Techlog version 2015.1 and Petrel version 2015.5 software was used to integrate all the available data to interpret and compute the input of the different petrophysical properties to deliver a more realistic and accurate formation evaluation.

3.2 Methods

Generally, the wireline logs like GR, SP, and caliper logs were used for the correlation of depth and identification of permeable zones in addition to identifying the same facies in the wells, which have a lack of core data. Porosity logs as (density logs, neutron logs, sonic logs) were used to calculate porosity at each point. Resistivity logs were used

to obtain water saturation. After obtaining water saturation, both oil and gas saturation can be calculated.

The procedure for calculation of petrophysical parameters are as follows:

3.2.1 Lithology determination

The lithology identification is pivotal for reservoir characterization because all of the Petrophysical parameters, such as porosity and permeability depend on facies type. Besides, fluid saturations directly depend on facies types [15]. In this study, lithology across Al Baraka wells was identified by using gamma ray (GR) log, photoelectric factors (PEF) Table 2. Cross-plots are used to define lithology and petrophysical parameters using different types of logs. Neutron–density–gamma ray and also density–photoelectric effect–gamma ray cross-plots indicate lithology and porosity of the formation [1].

Table 1 The available open hole wireline logs and [surface temperature (ST), bottom hole temperature (BHT)] for the two studied wells

Well name	Available well logs	ST (DegF)	BHT (DegF)
Al Baraka-4	GR, Caliper, BSZ, SP, RHOB, NPHI, PE, LLS, LLD and MSFL	80	160
Al Baraka-14		65	165

Table 2 Photoelectric parameters for common lithology in sedimentary rock [16]

Lithology	Sandstone	Dolomite	Shale	Limestone	Anhydrite
PEF value barns/ electron	1.8–2	3.14–4	1.8–6	5	5

3.2.2 Reservoir identification

The reservoir is the only zone, which is the potential for economic interest because it contains storage space for fluid (hydrocarbon or water) to accumulate. A good reservoir rock must be a good porous, permeable and contains hydrocarbon as well [17]. In this study, reservoir rock was identified using the interpretation of the available log data. The gamma ray log was used in the identification of reservoir rock based on the fact that the sandstone reservoir exhibits very low radioactivity because of the low content of radioactive elements. Resistivity logs were also used in the sense that reservoir zones exhibit relatively higher resistivity values than non-reservoir zones. Based on neutron and density logs, reservoir rock was also marked by the presence of neutron–density crossover [1, 16].

3.2.3 Fluid identification

It is very important to identify the interval zone and the type of fluid in the reservoir rock, because reservoirs may contain hydrocarbon (oil and gas), non-hydrocarbon fluid (water), or both. For a reservoir to contain hydrocarbons, so the zone should be porous with resistivity values higher than those of water-bearing zones [18]. In this study, the resistivity log and neutron–density log were used to identify hydrocarbon and non-hydrocarbon-bearing intervals. Hydrocarbons are poor conductors than water and hence show higher resistivity than water-bearing intervals. Based on neutron and density crossover, the gas zone is expected to show a wider negative separation due to low density and low hydrogen index of gas, while the oil zone is also expected to show relatively low negative separation because of relatively high density and hydrogen index compared to gas. A very low separation also was observed in the water zone due to higher density and higher hydrogen index in water.

3.2.4 Volume of shale (Vsh) calculation

Calculation of shale volume is crucial because it helps to calculate formation porosity, fluid content, and overall rock

quality. In this study, the volume of shale was estimated using a gamma ray logs method as the following equation [19]:

$$\text{IGR} = (\text{GR log} - \text{GR min}) / (\text{GR max} - \text{GR min}) \quad (1)$$

where IGR = Gamma ray Index, GRlog = gamma ray reading of the formation, GRmin = minimum gamma ray, maximum density log reading, IGR = Vsh in the linear model.

3.2.5 Net to gross ratio (h/H)

It is very important to determine net pay thickness to calculate original hydrocarbon in place. NTG is the ratio of the thickness of sand bearing hydrocarbon to the total thickness of sand formation [16]. It shows the volume of shale present in the reservoir. Net reservoir thickness (h) can be calculated by using the following formula:

$$h = H - h_{\text{shale}} \quad (2)$$

where H = The gross reservoir thickness, h_{shale} = The thicknesses of the shale and Net/Gross = h/H .

3.2.6 Porosity estimation

Porosity is a very important parameter for the characterization of the reservoir rock as it is used to describe the amount of open space filled with fluid (hydrocarbon or water). In this study, total porosity and effective porosity were calculated as the following:

A. Total porosity calculation

By the combination of neutron–density logs, the total porosity within reservoirs interval was determined. The equation to compute the total porosity from neutron and density logs that may be expressed as:

$$\Phi_{\text{tot}} = (\Phi_N + \Phi_D) / 2 \quad (3)$$

where Φ_N = Neutron porosity, Φ_D = Density porosity, which is calculated from this equation [20]:

$$\Phi_D = (\rho_{\text{ma}} - \rho_b) / (\rho_{\text{ma}} - \rho_f) \quad (4)$$

where ρ_b : bulk density which includes both fluid and rock (read directly from the log), ρ_f : density of the saturating fluid, ρ_{ma} : density of the rock matrix, ϕ : porosity.

According to Baker (21), the criteria for classifying porosity is as follows: $\phi < 0.05$ = Negligible; $0.05 < \phi < 0.1$ = Poor; $0.1 < \phi < 0.15$ = Fair; $0.15 < \phi < 0.25$ = Good; $0.25 < \phi < 0.30$ = Very good, $\phi > 0.30$ = Excellent [21].

B. Determination of effective porosity

The effective porosity is usually based on an adjustment of total porosity by means of estimated shale volume. The equation to compute effective porosity may be expressed as [22]:

$$\varnothing_{\text{eff}} = \varnothing_T - [\varnothing_{\text{sh}} * V_{\text{sh}}] \quad (5)$$

where $\varnothing_{\text{eff}}$ = effective porosity, $\varnothing_T$ = total porosity, $\varnothing_{\text{sh}}$ = porosity reading in a shale zone, V_{sh} = Shale volume.

3.2.7 Water saturation calculation

Water saturation can be defined as the ratio of water volume to pore volume. It is calculated by porosity and resistivity logs. Determining water saturation is crucial because hydrocarbon saturation can be calculated from water saturation. In this study, Archie's model is used to calculate the water saturation of the reservoir rocks. To calculate water saturation from Archie's model, the following equation was used [23]:

$$S_w = (a * R_w) / (R_t * \varphi^m)^{1/n} \quad (6)$$

where S_w = water saturation of the uninvasion zone, a = tortuosity exponent, n = saturation exponent, R_w = formation water resistivity at formation temperature, φ = porosity, m = cementation exponent, R_t = true formation resistivity.

3.2.8 Hydrocarbon saturation

Hydrocarbon saturation (S_h) is the percentage of pore volume in a formation occupied by hydrocarbon. In this study, the hydrocarbon saturation was determined by subtracting the value of water saturation from 100%. Hydrocarbon saturation (uninvasion zone) percentage S_h is given as

$$S_h = (100 - S_w)\% \quad (7)$$

3.2.9 Hydrocarbon movability index calculation

The S_w/S_{xo} value is equal or greater than 1.0 indicates that hydrocarbon is not moveable if the value is less than 0.7 indicate a moveable hydrocarbon condition [19]. Archie's formula has been used for the calculation of the hydrocarbon movability index. The hydrocarbon movability index

is a ratio of the uninvasion zone and flushed zone which estimated by the following equation:

$$H_{\text{cmov index}} = S_w/S_{xo} \quad (8)$$

where S_{xo} = water saturation of the flushed zone, which is calculated from this equation ($S_{xo}^n = (a * R_{mf}) / (\varphi^m * R_{xo})$) [23], a = tortuosity exponent, n = saturation exponent, R_{mf} = mud filtrate resistivity at formation temperature, φ = porosity, m = cementation exponent, R_{xo} = resistivity of the flushed zone.

3.2.10 Net pay

Net pay thickness is the most important factor to calculate hydrocarbon in place calculations because it affects reservoir management and reservoir productivity. Table 3 shows the applied cutoffs in this study.

4 Results

4.1 Qualitative analysis

4.1.1 Lithology and potential reservoir identification

The petrophysical analysis of well logs and according to the low gamma ray response, photoelectric effect values and neutron and density crossover, we recognize the main lithology of Al Baraka wells, which consist of three types of lithology: sand, shale and siltstone. Generally, the neutron–density logs combination and resistivity logs (MSFL and LLD) were used for the identification and characterization of various fluids in the reservoir zone. After well log interpretation and eliminate uninterested zones (high gamma ray and low deep resistivity). There are two main permeable interesting zones identified, One for AB-4 well named (S-E) and other for AB-14 well named (S-D) Figs. 6 and 9. These zones were characterized by the low gamma ray response, relatively high porosity, neutron–density crossover, and high resistivity value Figs. 12 and 13. The photoelectric effect values in Tables 2 and 4 and neutron–density response show the dominant reservoir lithology is from shaley sandstone to sandstone. Also, the generated cross-plots indicate that the main lithology is sandstone

Table 3 The applied cutoffs for net pay calculations

Categories	Vsh	Vsh and porosity	Vsh, porosity and water saturation
Cutoff equation	$0\% \leq V_{\text{sh}} \leq 45\%$	$10\% \leq \varnothing > 50\%$ $0\% \leq V_{\text{sh}} \leq 45\%$	$0\% \leq S_w \leq 60\%$ $10\% \leq \varnothing > 50\%$ $0\% \leq V_{\text{sh}} \leq 45\%$
Zone name after the cutoff	Net sand	Net reservoir	Pay zone

Fig. 6 The interval depth with the Composite log response and lithology interpretation of the hydrocarbon-bearing zone (S-E) in Al Baraka-4 well

Table 4 Summary of two sandstone main reservoir zones identified from well logs data

Well name	Main reservoir interval (ft)	Type of reservoir lithology	Type of hydrocarbons	Zone name	Thickness (ft)	Formation name	Photoelectric effect value range (b/e)
Al Baraka-4	4377–4451	Shaley Sandstone	Oil	S-E	74	Six Hills Fm	1.89–3.84
Al Baraka-14	4962–4973	Sandstone		S-D	10		1.78–2.95

in the S-D zone Figs. 10 and 11 and shaley sandstone in S-E zone Figs. 7 and 8. The reason for categorizing the two sand units as two different potential reservoir zones were based on eliminating thick shale beds between reservoirs and low value of deep resistivity so as to reduce the effect of both increasing shale volume and high-water saturation when computing other petrophysical parameters.

4.2 Quantitative analysis

The two reservoir zones have been selected across Al Baraka wells interpretations lie at depth interval from 4377 to 4451 ft for S-E zone and from 4962 to 4973 ft for S-D zone with thicknesses ranging from 74 to 10 ft, respectively, Figs. 6 and 9. The two selected zones were analyzed quantitatively to estimate the values of shale volume, porosity, and water saturation, net pay by using empirical formulas as described in the methodology

part. The average total and effective porosity results of the delineated in S-E and S-D reservoir zones range from 14.3 to 17.1% and 18.2 to 20.2%, respectively. The average shale volume estimated from the gamma ray log was found to be 0.20 (v/v) and 0.085 (v/v) for S-E and S-D, respectively. The calculated value of average water saturation from the arhi equation is 57.5% for S-E and 36.4% for S-D. On the other hand, we used the average water saturation values to estimate the value of hydrocarbon saturation, which is ranged from 42.5% for S-E and 63.6% for the S-D zone; these hydrocarbons have movability index low than 0.7 and is between 0.58 and 0.61. After applying cutoff in Table 3, the net pay thickness range from 8ft for the S-D zone to 24 ft for the S-E zone. All petrophysical parameters estimated for the hydrocarbon-bearing zones and net pay are shown in Tables 5 and 6 and Figs. 12 and 13.

Fig. 7 Density-neutron-gamma ray cross-plot of the main reservoir (S-E zone) in Al Baraka - 4 well

5 Discussions

5.1 Petrophysical parameters assessment from qualitative analysis

The well logs analysis of Al Baraka wells indicates that the subsurface lithostratigraphy consists of three types of lithology, which are sand and shale interbedding. Based on the interpretation of wireline logs, there are two permeable interesting zones considered as the main potential reservoirs identified and evaluated, both in Six Hills Fm of lower cretaceous, One for AB-4 well named (S-E) and other for AB-14 well named (S-D). Neutron-density and density-photoelectric effect cross-plots strongly show the dominant reservoir lithology is Shaley sandstone to sandstone. The location shale formation related to the identified reservoirs could thus be potential source rock or act as a seal rock.

5.2 Petrophysical parameters assessment from quantitative analysis

The two reservoir zones have been selected across Al Baraka wells interpretations lie at depth interval from 4377 to 4973 ft with the high net to gross value ranging

from 0.94 to 0.95 Table 5. Al Baraka-4 well cross-plots in Figs. 7 and 8 shows that the porosity is ranging from 12 to 25% and also show that gamma ray value mostly is low; so, this proves the S-E reservoir zone contains mostly highly porous sandstone, but in Al Baraka-14 well cross-plots in Figs. 10 and 11 show that the porosity is ranging from 17 to 22% and also show that gamma ray value is low; so, this proves the S-D reservoir zone contains mostly porous sandstone. The average total porosity results of the delineated in S-E and S-D reservoir zones ranging from 18.2 to 20.2%, respectively, which indicates that the reservoir quality ranges from moderate to good porosity. The average shale volume is 0.20 (v/v) and 0.085 (v/v) for S-E and S-D, respectively, that reveal to the low distribution of low permeable shale content in the reservoir zones. The estimated value of average water saturation is 57.5% for S-E and 36.4% for S-D, which indicates that the proportion of void space occupied by water is low consequently with high hydrocarbon saturation (42.5% for S-E and 63.6% for S-D zone). The net pay zone thickness ranges from 8 to 24 ft and characterized by high hydrocarbon saturation, good porosity, very low shale volume that leading to high hydrocarbon production Tables 5 and 6. Related to the values of the mobility index, the hydrocarbon-bearing

Fig. 8 Density–photoelectric effect–gamma ray cross-plot of the main reservoir (S-E zone) in Al Baraka-4 well

Fig. 9 The interval depth with the Composite log response and lithology interpretation of the hydrocarbon-bearing zone (S-D) in Al Baraka-14 well

Table 5 Summary of sum and averages of computed petrophysical parameters for the identified hydrocarbon-bearing zones

Well name	Formation name	Zone name	Interval (ft)	Gross (ft)	Net (ft)	N/G (v/v)	Average porosity (v/v)	Effective porosity (v/v)	Avg shale volume (v/v)	Avg SW (v/v)	Avg So (v/v)	SW/SXO (v/v)	Net pay (ft)
Al Baraka-4	Six Hills	S-E	4377–4451	74	70	0.94	0.182	0.1429	0.201	0.575	0.425	0.583	24
Al Baraka-14		S-D	4962–4973	10	9.5	0.95	0.201	0.1711	0.085	0.364	0.636	0.615	8

Table 6 Summary of averages computed petrophysical parameters for the net pay of two identified hydrocarbon-bearing zones

Zone name	Net pay (ft)	Av_Shale volume (v/v)	Av_Porosity (v/v)	Av_Water saturation (v/v)	Av_Hydrocarbon saturation (v/v)
S-D	24	0.189	0.19	0.281	0.719
S-E	8	0.083	0.199	0.279	0.721

reservoir is distinguished by high movability as shown in Table 5 and Figs. 12 and 13.

6 Conclusion

Generally, by considering all parameters such as permeable zone identify, reservoir thickness, shale volume, porosity, water saturation, net pay thickness and hydrocarbon saturation from the log analysis performed in this study, there are two hydrocarbon-bearing reservoirs present in Six Hills Fm of the lower cretaceous age, which named as S-E zone in AB-4 well and S-D zone in AB-14 well with varying thicknesses identified and evaluated. Different cross-plots are constructed (neutron–density and photoelectric effect–density cross-plots) to display the reservoir lithology. These cross-plots with also well log analysis reflect that the lithology in S-E and S-D zone varies in the available wells from shaley sandstone to sandstone. The hydrocarbon zones were proven by petrophysical analyses that show high porosity, low water saturation, low shale volume, and high net–to–gross ratio. Based on petrophysical parameters obtained, the two selected reservoir zones have moderate to good porosity of 18.2% to 20.1%, the low effect of shale distribution (20% to 8.5%), whereas average hydrocarbon saturation ranged from 42 to 57% with high movability. The study reveals that the hydrocarbon-bearing reservoir is the potential for commercial oil production and accumulation, essential oil. Below and above the oil-bearing reservoirs, there is a thick shale bed which is acted as potential source rock or as a seal rock.

Fig. 10 Density–neutron–gamma ray cross-plot of the main reservoir (S-D zone) in Al Baraka -14 well

Fig. 11 Density-photoelectric effect-gamma ray cross-plot of the main reservoir (S-D zone) in Al Baraka -14 well

Fig. 12 Digitizing of calculated petrophysical parameters of the main reservoir (S-E zone) along the Al Baraka-4 well

Fig. 13 Digitizing of calculated petrophysical parameters of the main reservoir (S-D zone) along Al Baraka-14 well

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Compliance with ethical standards

Conflict of interest On behalf of all authors, the corresponding author states that there is no conflict of interest.

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