Geophysical assessment and hydrocarbon potential of the Cenomanian Bahariya reservoir in the Abu Gharadig Field, Western Desert, Egypt

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Abstract

In this study, the sandstones of the Bahariya Formation in the Abu Gharadig Field, which is a promising oil reservoir in the Abu Gharadig Basin, Western Desert, Egypt, were assessed. The wireline logs from three wells (Abu Gharadig-2, Abu Gharadig-6, and Abu Gharadig-15) were studied using seismic and petrophysical analyses. Based on seismic data, the study area contains an ENE–WSW anticlinal structure, which is divided by a set of NW–SE normal faults, reflecting the effect of Late Cretaceous dextral wrench tectonics on the northern Western Desert. The visual analysis of the well logs reveals a potential zone within well Abu Gharadig-2 located between depths of 10,551 and 10,568 ft (zone A). In contrast, potential zones were detected between depths of 11,593–11,623 ft (zone B) and 11,652–11,673 ft (zone C) in well Abu Gharadig-6. In well Abu Gharadig-15, potential zones are located between depths of 11,244–11,251 ft (zone D) and 11,459–11,467 ft (zone E). The quantitative evaluation shows that the intervals B and C in well AG-6 are the zones with the highest oil-bearing potential in the Abu Gharadig Field in terms of the reservoir quality. They exhibit the lowest shale volume (0.06–0.09), highest effective porosity (0.13), minimum water saturation (0.11–0.16), lowest bulk volume of water (0.01–0.02), high absolute permeability (10.92–13.93 mD), high relative oil permeability (~ 1.0), and low water cut (~ 0). The apex of the mapped fold represents that the topmost Bahariya Formation in the Abu Gharadig Field for which the drilling of additional wells close to well AG-6 is highly recommended.

Keywords Abu Gharadig Basin · Bahariya Formation · Seismic interpretation · Well logging evaluation

Introduction

The Abu Gharadig Basin is the most significant and largest oil-producing basin in the northern Western Desert of Egypt (Fig. 1a). Numerous geological and geophysical studies have been performed in the Abu Gharadig sedimentary basin (e.g., Labib 1985; Bayoumi and Lotfy 1989; Abd El Aal 1988; Awad 1984; El Sayed et al. 1993; Khaled 1999; El Diasty and Moldowan 2012; Nabawy and ElHariri 2008; El Gazzar et al. 2016; Sarhan and Collier 2018; Sarhan 2017a,b,c; Elmahdy et al. 2020; Sarhan 2020).

Hydrocarbons are frequently extracted from structural traps in the Abu Gharadig Basin and other basins in the

Western Desert, which are related to Syrian arc tectonics (Moustafa 2008; Dolson et al. 2001; Abu El Naga 1984). These traps exhibit three- or four-way closures in addition to fault block structures, particularly NW–SE- and NE–SW-trending faults (Abd El Aal 1988; Sultan and Abd El Halim 1988).

Jurassic and Cretaceous deposits are the essential source rocks of petroleum in the Abu Gharadig Basin (Shahin 1992). However, the sandstone beds of the Bahariya Formation are the utmost hydrocarbon reservoirs in most sedimentary basins of the Western Desert (e.g., Sarhan et al. 2017), particularly in the Abu Gharadig Basin (EGPC 1992; Sestini 1995). The Bahariya and Abu Roash formations contain more than 90% of the recognized hydrocarbon reserves in the Western Desert (Richardson et al. 1998).

The study area of this work is the Abu Gharadig Field, which is in the middle of the Abu Gharadig Basin between 28.3° and 28.5° E and 29.5° and 29.7° N (Fig. 1a). The aim of this study was to determine the hydrocarbon potential

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Fig. 1 **a** Map showing different basins in the Western Desert and the location of the Abu Gharadig Field (simplified from Bosworth et al. 2008); **b** seismic lines and location of the examined wells within the Abu Gharadig Field

of Bahariya sandstones in the Abu Gharadig Field based on the integration of seismic and well-log data from three wells, that is, Abu Gharadig-2, Abu Gharadig-6, and Abu

Gharadig-15. The objectives include the seismic mapping and petrophysical assessment of the entire sandstone layers of the Bahariya Formation in these wells.

Geologic setting

The Abu Gharadig Basin is part of the “Unstable Shelf” area in Egypt (Said 1990). Its rift was initiated in the Jurassic–Early Cretaceous. It comprises a thick sedimentary sequence ranging in age from Jurassic to Tertiary. This basin was affected by dextral wrench tectonics until the Late Cretaceous (e.g., Sarhan 2017b), which were due to the westward movement of the African Plate compared with the Laurasian Plate based on the faster opening of the northern Atlantic Ocean compared with its central part (Smith 1971; Biju-Duval et al. 1977).

However, in the Santonian, the movement of the African Plate shifted into the northern direction, which led to large-scale inversion tectonics affecting the subsurface sedimentary sections in the northern Western Desert (Guiraud and Bosworth 1997). This inversion affected the Abu Gharadig Basin until the Early Tertiary (Moustafa 2008). The inversion phase influenced the former normal faults in the Abu Gharadig Basin (Moustafa 2008; Lünig et al. 2004; Bayoumi and Lotfy 1989) and a series of NE–SW-trending folds formed, that is, the Syrian arc fold system (e.g., Moustafa and Khalil 1990; Ayyad and Darwish 1996; Moustafa et al. 1998; Moustafa 2002).

The inversion tectonics were associated with a large uplift phase and led to the erosion of Upper Cretaceous strata in the extremely inverted zone, whereas deeply buried anticlines in the south of this zone did not breach but entrapped the hydrocarbons (Moustafa 2008).

The Bahariya Formation has attracted the attention of numerous geologic researchers (e.g., Afify et al. 2015; Ela et al. 2018; Abdelwahhab and Raef 2020; Mansour et al. 2020; Farrag et al. 2021; Wanas and Assal 2021). It represents the Cenomanian age (Fig. 2) and was deposited under near-shore to shallow marine environment in the beginning of the Late Cretaceous transgression in the Western Desert (Said 1990; El Ayouty 1990; Wahdan et al. 1996). It contains several sedimentary facies including barrier bars, distributary channels, point bars, and mouth bars (El Sayed et al. 1993).

Data and techniques

Seventeen seismic SEG-Y profiles in time unit within the Abu Gharadig Basin were examined and interpreted. These seismic sections were tied to three wells (Fig. 1b): Abu Gharadig-2 (AG-2), Abu Gharadig-6 (AG-6), and Abu Gharadig-15 (AG-15). The seismic data comprise twelve NNW–SSE crosslines with a length of 25 km, and five

ENE–WSW inline sections extend over 55 km. Digital seismic data were interpreted, and a structure map was constructed using Petrel Software (version 2009.1).

Conventional wireline logs from the three examined wells were analyzed using Techlog software (version 2011.1.0). These data consist of: Caliper (CALI), Bit Size, Density Correction (DRHO), Gamma Ray (GR), Sonic (DT), Shallow Resistivity (RS), Deep Resistivity (RD), Medium Resistivity (RM), Density (RHOB), and Neutron (NPHI) logs, as shown in Figs. (3, 4, 5, 6 and 7). The formation logs for wells AG-2, AG-6, and AG-15 and the composite log for well AG-6 were used in the present study. Also, the check-shot data for the examined wells are available to perform the seismic-well tying.

First, the seismic horizon corresponding to the topmost Bahariya Formation was selected, which is next to the fault segments over the seismic line grid (Figs. 8, 9 and 10). The selected horizon and associated faults were mapped (Fig. 11) and then converted from time into depth units (Fig. 12). The mapped structures were analyzed in terms of the tectonic setting of the Abu Gharadig Basin during the Late Cretaceous.

Subsequently, the digital logs of the wells were qualitatively and quantitatively analyzed. This step is important because it involves the detection of potential hydrocarbon-bearing zones within the Bahariya Formation. The results indicate a potential zone in well AG-2 between depths of 10,551 ft and 10,568 ft (zone A). Potential zones in well AG-6 occur between depths of 11,593–11,623 ft (zone B) and 11,652–11,673 ft (zone C). In contrast, in well AG-15, potential zones were discovered at depths of 11,244–11,251 ft (zone D) and 11,459–11,467 ft (zone E).

The qualitative criteria used for the identification of the five zones include: high resistivity, confirming the occurrence of non-conductive oil; low gamma radiation, indicating the purity of the examined sandstone (i.e., low shale content); and deflection of the neutron log and density curve to the right and left, respectively, forming a crossover feature that characterizes the sandstone matrix.

The wireline logs of the potential zones (A, B, C, D, and E) were quantified. The fundamental petrophysical parameters were calculated, which is mandatory for assessing the potentials of hydrocarbon reservoirs. The following parameters were calculated: shale volume, total porosity, effective porosity, water saturation, bulk volume of water (BVW), absolute permeability, and irreducible water saturation. The results are displayed in Tables 1, 2, 3, 4, and 5 for zones A, B, C, D, and E, respectively. The applied cutoff values for the examined parameters in this study are: shale volume < 30%, porosity > 10%, water saturation < 50%, BVW < 0.05, and permeability > 0.1 mD.

BIOSTRATIGRAPHY		LITHOLOGY	FORMATIONS	ENV.	SOR.	RES.	SEAL
MIOCENE	MIDDLE		MARMARICA	SM			⊕
	LOWER		MOGHRA	OM			
OLIGOCENE			DABAA	OM			
EOCENE			APOLLONIA				⊕
CRETACEOUS	UPPER CRETACEOUS	SENONIAN	KHOMAN	OM			⊕
		TURONIAN	A	D to SM	●	●	⊕
			B				
			C				
			D				
			E				
			F				
			G				
		CENOMANIAN	UPPER BAHARIYA	FD to SM		●	
	LOWER CRETACEOUS	ALBIAN	KHARITA	NS		●	
		APTIAN	DAHAB SHALE	SM		●	⊕
			ALAMEIN	SM		●	
		BARREMIAN BERRIASIAN	1	FD to SM	●	●	
			2				
			A				
			B				
			C				
			D				
JURASSIC	UPPER		MASAJID	SM			⊕
	MIDDLE		1 A ↓ F	D-SM	●	● ●	
	LOWER		2 KHAZATBA				
			RAS QATTARA	C	●	● ●	
			Nubia S.S				
PALEOZOIC							

SM= Shallow Marine OM= Open Marine NS = Near Shore

D = Deltaic F = Fluvial C = Continental

FD = Fluvial Deltaic ENV. = Environment SOR = Source rock

RES = Reservoir rock

● = Source ● = Reservoir / oil ● = Reservoir / gas

⊕ = Seal

Fig. 2 Regional stratigraphic column of the northern part of the Egyptian Western Desert comprising Abu Gharadig Basin (modified by Shalaby et al. 2011 after; Schlumberger 1984, 1995)

Fig. 3 Well logs with interpretation for zone A in well AG-2

Fig. 4 Well logs with interpretation for zone B in well AG-6

Results

Seismic interpretation

The seismic horizon corresponding to the top of the Bahariya Formation exhibits a relatively strong amplitude reflector intersected by many normal faults (Figs. 8, 9, and 10). The structure maps for the inspected surface display that the ENE–WSW asymmetrical anticline is oriented toward the northeast. This anticline detached by numerous NW–SE normal faults varies in length between 8 and 15 km (Figs. 11 and 12).

The presence of the anticline (compressional structure) as well as normal faults (extensional structure) is evidence

for the effect of the Late Cretaceous dextral wrench tectonics on the Abu Gharadig Basin. This dextral wrench was caused by the NW movement of the African Plate compared with the Laurasia Plate.

Well-log evaluation

Based on the neutron–density cross-plots of Schlumberger (1972) for the investigated zones, the plotted points cluster on and around the sandstone line, reflecting the sandy matrix of these porosities, as shown in Fig. (13). Water saturation–effective porosity cross-plots (after Asqith and Gibson 1982) were created to assess the grain size in interesting zones, as displayed in Fig. (14). These plots show that the sand in these zones is coarse-grained.

Fig. 5 Well logs with interpretation for zone C in well AG-6

Fig. 6 Well logs with interpretation for zone D in well AG-15

Fig. 7 Well logs with interpretation for zone E in well AG-15

Fig. 8 Interpreted TWT seismic line No. 5240 (see Fig. 1b for line location)

Fig. 9 Interpreted TWT seismic section No. 5340 (see Fig. 1b for line location)

Fig. 10 TWT seismic profile No. 5440 with interpretation (see Fig. 1b for line location)

Shale volume (V_{sh})

The amount of clay in the inspected zones was determined based on GR logs, that is, based on the linear equation of Asquith and Gibson (1982), as demonstrated in Figs. (3, 4, 5, 6 and 7).

The volume calculated for the shale in the study area is low. The maximum shale volume (24%) was detected in zone D, and the minimum value (6.0%) was obtained in zone B.

Total porosity (ϕ_T)

The total porosity reflects the total volume of voids in a rock, which can be of primary or secondary origin. The total porosity was calculated from the neutron–density logs using the equation of Asquith and Gibson (1982) as shown in Figs. (3, 4, 5, 6 and 7).

The highest average total porosity (18%) was recorded in zone A, and the lowest value (11%) was obtained in zone E.

Effective porosity (ϕ_e)

The effective porosity measures only the interconnected voids based on which fluids can be transmitted (Asquith and

Gibson 1982). It can be determined by using the equation of Asquith and Gibson (1982) as presented in Figs. (3, 4, 5, 6 and 7).

The highest average effective porosity (13%) was recorded in zones A, B, and C, whereas the lowest value (5%) was obtained in zone E.

Absolute permeability

The absolute permeability of the examined zones was determined using the equation of Wyllie and Rose (1950) as displayed in Figs. (3, 4, 5, 6 and 7).

The average values of the absolute permeability are high in zones A (10.26 mD), B (13.93 mD), and C (10.29 mD), whereas they are low in zones D (0.43 mD) and E (0.35 mD).

Water saturation (S_w)

The water saturation of the zones was computed using the Indonesia model (Poupon and Leveaux 1971).

The calculated water saturation is displayed in blue in Figs. 3, 4, 5, 6, and 7; the green color marks the hydrocarbon saturation.

Fig. 11 Time–structure map for the topmost horizon of the Bahariya Formation in the study area

The highest average water saturation of 40% (i.e., the hydrocarbon saturation equals 60%) was recorded in zones D and E, whereas a low water saturation was detected in zones A (26%), B (16%), and C (11%).

Figure (15) presents the water saturation–effective porosity plots for the studied zones. These plots clearly display that zones A, B, and C are the most promising zones with respect to the hydrocarbon reservoir potential because they have the highest ϕ_e and lowest S_w .

BVW

The BVW was determined by multiplying the water saturation with the porosity. If the calculated BVW values are low and constant in a specific zone, water-free hydrocarbon production can be predicted for this zone. The BVW can be determined with the equation of Buckles (1965).

The calculated BVW values are presented in blue in Figs. (3, 4, 5, 6 and 7). The maximum BVW (0.03) was detected in zone A, and the minimum value (0.01%) was obtained in zone C. However, zones B, D, and E have a BVW of 0.02.

Relative permeability and water cut

The fluid through production process of a hydrocarbon reservoir can be determined based on the measurement of different parameters including K_{ro} (relative permeability to oil), K_{rw} (relative permeability to water), and Wc (water cut), which refers to the amount of water associated with the produced oil. All parameters are controlled by the S_{wirr} value (irreducible water saturation). The S_{wirr} of an individual zone primarily depends on the formation factor (Tables 1, 2, 3, 4, and 5).

Fig. 12 Depth–structure map for the topmost horizon of the Bahariya Formation in the study area. Note that the area outlined by the red polygon represents the crest of the mapped anticline for which the drilling of more wells close to well AG-6 is highly recommended

Several cross-plots display the correlation between water saturation (S_w) and irreducible water saturation (S_{wirr}) in the examined zones (after Asquith and Gibson 1982), which have been constructed to represent the quality of the Bahariya reservoir in the investigated wells. These plots reveal that zones B and C have the highest oil potential because they contain the most points (above $k_{ro} = 1$, Fig. 16; below $k_{rw} = 0$, Fig. 17; and close to $W_c = 0$, Fig. 18).

Zones B and C display similar hydraulic characteristics because they represent the same flow units (FZI; Amaefule et al. 1993; Fig. 19). Both zones have the same rock quality and a similar r_{35} value (Winland 1972 and 1976), which exceeds 2μ , reflecting a better flow quality compared with zones D and E (Fig. 20).

The results of this study were verified with the results of drill stem tests (DST) for wells AG-2 and AG-15. The DST

Table 1 Well-log data and output for zone A in well AG-2

Input well-log data										Output						
Depth (ft)	Bit Size (IN)	Caliper (IN)	Gamma Ray (API)	Sonic (US/F)	Medium Resistivity (Ωm2/m)	Deep Resistivity (Ωm ² /m)	Neutron Porosity	Density (G/C ³)	CALI-BS (IN)	Shale volume	Total porosity	Effective porosity	K (mD)	Water Saturation	Bulk Volume of Water	Irreducible water saturation
10,551	8.63	9.28	29.64	78.51	10.97	17.92	0.17	2.41	0.65	0.22	0.17	0.11	4.55	0.32	0.03	0.21
10,551.5	8.63	9.69	27.84	78.91	12.00	18.59	0.17	2.40	1.07	0.20	0.18	0.12	7.18	0.29	0.03	0.19
10,552	8.63	10.10	26.03	79.31	12.52	19.25	0.17	2.38	1.48	0.18	0.18	0.13	10.84	0.27	0.04	0.17
10,552.5	8.63	9.49	24.83	79.11	12.88	23.30	0.18	2.39	0.86	0.16	0.18	0.14	12.72	0.24	0.03	0.17
10,553	8.63	8.87	23.63	78.91	13.24	27.35	0.18	2.39	0.24	0.15	0.19	0.14	14.73	0.22	0.03	0.16
10,553.5	8.63	8.70	25.43	78.41	13.75	25.15	0.19	2.39	0.07	0.17	0.19	0.14	13.30	0.23	0.03	0.16
10,554	8.63	8.53	27.23	77.91	14.03	22.95	0.19	2.39	-0.10	0.19	0.19	0.13	11.86	0.24	0.03	0.17
10,554.5	8.63	8.47	28.64	77.61	14.40	21.20	0.19	2.39	-0.16	0.21	0.19	0.13	9.27	0.26	0.03	0.18
10,555	8.63	8.40	30.04	77.31	14.55	19.45	0.19	2.40	-0.23	0.22	0.19	0.12	7.21	0.28	0.03	0.19
10,555.5	8.63	8.45	27.64	78.01	14.70	20.49	0.18	2.42	-0.18	0.20	0.18	0.12	6.85	0.28	0.03	0.19
10,556	8.63	8.49	25.23	78.71	14.85	21.53	0.17	2.44	-0.14	0.17	0.17	0.12	6.51	0.28	0.03	0.19
10,556.5	8.63	8.51	25.23	79.62	15.00	22.22	0.16	2.41	-0.12	0.17	0.17	0.12	7.36	0.27	0.03	0.19
10,557	8.63	8.52	25.23	80.52	15.03	22.90	0.16	2.39	-0.11	0.17	0.17	0.12	8.71	0.26	0.03	0.18
10,557.5	8.63	8.53	26.83	80.52	15.07	23.55	0.17	2.39	-0.10	0.19	0.18	0.12	8.19	0.26	0.03	0.18
10,558	8.63	8.54	28.43	80.52	15.05	24.20	0.18	2.39	-0.09	0.20	0.18	0.12	7.69	0.25	0.03	0.19
10,558.5	8.63	8.57	25.63	80.02	15.04	24.72	0.17	2.38	-0.05	0.17	0.18	0.13	11.73	0.23	0.03	0.17
10,559	8.63	8.60	22.82	79.52	14.99	25.23	0.16	2.36	-0.03	0.14	0.19	0.14	17.25	0.22	0.03	0.15
10,559.5	8.63	8.64	22.62	78.62	14.95	25.75	0.16	2.36	0.01	0.14	0.19	0.14	17.16	0.22	0.03	0.15
10,560	8.63	8.67	22.42	77.71	14.83	26.27	0.16	2.36	0.04	0.14	0.19	0.14	17.04	0.22	0.03	0.15
10,560.5	8.63	8.61	21.42	76.01	14.77	26.24	0.17	2.36	-0.02	0.13	0.19	0.15	21.09	0.21	0.03	0.15
10,561	8.63	8.54	20.42	74.30	14.72	26.21	0.18	2.36	-0.09	0.12	0.19	0.16	25.82	0.20	0.03	0.14
10,561.5	8.63	8.53	21.02	75.00	14.67	26.01	0.18	2.40	-0.10	0.12	0.18	0.14	15.02	0.22	0.03	0.16
10,562	8.63	8.52	21.62	75.70	14.40	25.80	0.17	2.45	-0.11	0.13	0.16	0.13	9.18	0.25	0.03	0.18
10,562.5	8.63	8.52	21.02	76.31	14.18	25.60	0.16	2.43	-0.11	0.12	0.16	0.12	8.70	0.25	0.03	0.18
10,563	8.63	8.52	20.42	76.91	13.95	25.40	0.14	2.42	-0.11	0.12	0.16	0.12	8.90	0.26	0.03	0.18
10,563.5	8.63	8.59	21.02	76.81	13.69	25.20	0.15	2.43	-0.04	0.12	0.16	0.12	7.96	0.26	0.03	0.18
10,564	8.63	8.65	21.62	76.71	13.43	24.99	0.15	2.44	0.03	0.13	0.16	0.12	7.09	0.27	0.03	0.19
10,564.5	8.63	8.72	22.42	77.71	13.04	25.28	0.15	2.43	0.09	0.14	0.16	0.12	6.74	0.27	0.03	0.19
10,565	8.63	8.78	23.22	78.71	12.52	25.57	0.16	2.43	0.15	0.15	0.16	0.12	6.41	0.27	0.03	0.19
10,565.5	8.63	8.71	24.03	78.91	12.08	26.01	0.16	2.42	0.08	0.16	0.17	0.12	7.18	0.26	0.03	0.19
10,566	8.63	8.63	24.83	79.11	11.77	26.45	0.16	2.41	0.01	0.16	0.17	0.12	8.02	0.25	0.03	0.18
10,566.5	8.63	8.61	25.23	76.51	11.46	24.58	0.17	2.40	-0.02	0.17	0.18	0.12	8.99	0.25	0.03	0.18
10,567	8.63	8.59	25.63	73.90	10.78	22.71	0.17	2.39	-0.04	0.17	0.18	0.13	10.05	0.25	0.03	0.17
10,567.5	8.63	8.67	30.04	74.80	10.18	18.72	0.18	2.40	0.04	0.22	0.18	0.11	5.33	0.31	0.03	0.20
10,568	8.63	8.75	34.45	75.70	9.64	14.72	0.18	2.41	0.13	0.27	0.18	0.09	2.62	0.38	0.04	0.24
Average										0.17	0.18	0.13	10.26	0.26	0.03	0.18

Table 2 Well-log data and output for zone B in well AG-6

Input well-log data										Output								
Depth (ft)	Bit Size (IN)	Caliper (IN)	Density Correction (G/ C3)	Gamma Ray (API)	Sonic (US/F)	Shallow Resistivity (Ωm2/m)	Medium Resistivity (Ωm2/m)	Deep Resistivity (Ωm2/m)	Neutron Porosity	Density (G/C ³)	CALI-BS (IN)	Shale volume	Total porosity	Effective porosity	K (mD)	Water Saturation	Bulk Volume of Water	Irreducible saturation
11,111,593	8.63	9.55	0.01	23.17	65.78	53.53	39.30	46.13	0.15	2.49	0.93	0.15	0.14	0.09	2.52	0.24	0.02	0.24
11,111,593.25	8.63	9.55	0.01	21.86	65.88	59.58	38.62	51.07	0.13	2.48	0.92	0.13	0.13	0.10	2.73	0.23	0.02	0.23
11,111,593.5	8.63	9.55	0.01	20.55	65.98	65.62	37.94	56.00	0.12	2.47	0.92	0.12	0.13	0.10	3.26	0.21	0.02	0.23
11,111,593.75	8.63	9.54	0.01	18.15	66.07	71.66	37.26	60.93	0.11	2.45	0.92	0.09	0.13	0.11	4.20	0.20	0.02	0.21
11,111,594	8.63	9.54	0.01	15.75	66.17	77.70	36.58	65.86	0.09	2.45	0.91	0.06	0.13	0.11	4.60	0.19	0.02	0.21
11,111,594.25	8.63	9.54	0.02	16.06	66.21	83.79	34.36	75.28	0.09	2.45	0.91	0.07	0.13	0.11	4.31	0.18	0.02	0.21
11,111,594.5	8.63	9.54	0.02	16.36	66.25	89.88	32.14	84.69	0.09	2.45	0.91	0.07	0.13	0.10	4.03	0.17	0.02	0.21
11,111,594.75	8.63	9.54	0.02	15.89	66.28	95.97	29.92	94.11	0.09	2.45	0.91	0.07	0.13	0.11	4.41	0.16	0.02	0.21
11,111,595	8.63	9.54	0.02	15.42	66.32	102.05	27.70	103.52	0.09	2.44	0.91	0.06	0.13	0.11	5.27	0.15	0.02	0.20
11,111,595.25	8.63	9.54	0.02	14.95	65.95	109.53	27.79	108.43	0.09	2.43	0.91	0.06	0.13	0.12	6.69	0.14	0.02	0.19
11,111,595.5	8.63	9.54	0.01	14.48	65.59	117.01	27.89	113.34	0.09	2.42	0.91	0.05	0.14	0.12	8.38	0.13	0.02	0.18
11,111,595.75	8.63	9.54	0.01	13.80	65.22	124.48	27.99	118.24	0.10	2.41	0.91	0.04	0.14	0.13	10.73	0.12	0.02	0.17
11,111,596	8.63	9.54	0.01	13.13	64.85	131.96	28.08	123.15	0.10	2.41	0.91	0.03	0.15	0.14	12.73	0.11	0.02	0.17
11,111,596.25	8.63	9.54	0.01	12.45	64.71	132.63	29.42	127.27	0.10	2.41	0.91	0.03	0.15	0.14	14.73	0.11	0.02	0.16
11,111,596.5	8.63	9.54	0.01	11.78	64.57	133.31	30.77	131.40	0.11	2.40	0.91	0.02	0.15	0.14	17.00	0.10	0.01	0.15
11,111,596.75	8.63	9.53	0.01	12.13	64.43	133.98	32.11	135.52	0.11	2.40	0.91	0.02	0.15	0.15	17.74	0.10	0.01	0.15
11,111,597	8.63	9.53	0.01	12.47	64.29	134.66	33.45	139.65	0.11	2.39	0.90	0.03	0.16	0.15	19.18	0.10	0.01	0.15
11,111,597.25	8.63	9.53	0.01	13.28	68.96	143.92	38.97	147.82	0.12	2.39	0.91	0.04	0.16	0.15	19.28	0.09	0.01	0.15
11,111,597.5	8.63	9.54	0.01	14.08	73.63	153.19	44.49	156.00	0.12	2.38	0.91	0.05	0.16	0.15	19.36	0.09	0.01	0.15
11,111,597.75	8.63	9.54	0.01	14.62	78.29	162.46	50.00	164.18	0.12	2.37	0.91	0.05	0.17	0.15	19.91	0.09	0.01	0.15
11,111,598	8.63	9.54	0.02	15.17	82.96	171.72	55.52	172.36	0.12	2.37	0.91	0.06	0.17	0.15	20.46	0.08	0.01	0.15
11,111,598.25	8.63	9.55	0.02	15.22	80.11	187.84	53.66	160.99	0.12	2.36	0.93	0.06	0.17	0.15	22.04	0.09	0.01	0.15
11,111,598.5	8.63	9.56	0.02	15.28	77.27	203.95	51.80	149.62	0.12	2.36	0.94	0.06	0.17	0.16	23.75	0.09	0.01	0.14
11,111,598.75	8.63	9.57	0.02	15.38	74.42	220.06	49.94	138.26	0.12	2.35	0.95	0.06	0.18	0.16	25.08	0.09	0.01	0.14
11,111,599	8.63	9.58	0.02	15.47	71.57	236.17	48.09	126.89	0.12	2.36	0.96	0.06	0.17	0.15	22.79	0.10	0.01	0.14
11,111,599.25	8.63	9.59	0.02	15.57	72.81	210.61	44.81	121.76	0.12	2.36	0.96	0.06	0.17	0.15	20.34	0.10	0.02	0.15
11,111,599.5	8.63	9.60	0.02	15.67	74.06	185.04	41.54	116.63	0.12	2.37	0.97	0.06	0.17	0.15	18.09	0.11	0.02	0.15
11,111,599.75	8.63	9.60	0.02	15.35	74.68	159.48	38.27	111.50	0.12	2.38	0.98	0.06	0.16	0.14	17.29	0.11	0.02	0.15
11,1600	8.63	9.61	0.02	15.03	75.30	133.92	35.00	106.37	0.12	2.39	0.98	0.06	0.16	0.14	16.35	0.11	0.02	0.16
11,1600.25	8.63	9.61	0.03	14.71	75.92	121.44	34.44	103.63	0.12	2.40	0.98	0.05	0.16	0.14	15.46	0.12	0.02	0.16
11,1600.5	8.63	9.61	0.03	14.39	76.54	108.97	33.89	100.90	0.12	2.41	0.98	0.05	0.15	0.14	14.61	0.12	0.02	0.16
11,600.75	8.63	9.60	0.03	13.75	79.44	96.50	33.34	98.16	0.12	2.42	0.98	0.04	0.15	0.14	14.67	0.12	0.02	0.16

Table 2 (continued)

Input well-log data										Output								
Depth (ft)	Bit Size (IN)	Caliper (IN)	Density Correction (G/ C3)	Gamma Ray (API)	Sonic (US/F)	Shallow Resistivity (Ωm2/m)	Medium Resistivity (Ωm2/m)	Deep Resistivity (Ωm ² /m)	Neutron Porosity	Density (G/C ³)	CALI-BS (IN)	Shale volume	Total porosity	Effective porosity	K (mD)	Water Saturation	Bulk Volume of Water	Irreducible water saturation
111,601	8.63	9.60	0.04	13.11	82.33	84.03	32.78	95.42	0.13	2.42	0.98	0.03	0.15	0.14	15.92	0.12	0.02	0.16
111,601.25	8.63	9.54	0.03	12.62	85.23	78.49	32.22	89.78	0.13	2.42	0.91	0.03	0.15	0.14	16.35	0.13	0.02	0.16
111,601.5	8.63	9.47	0.03	12.13	88.12	72.95	31.66	84.15	0.13	2.42	0.85	0.02	0.15	0.14	16.80	0.13	0.02	0.16
111,601.75	8.63	9.41	0.03	12.94	86.87	67.40	31.10	78.52	0.13	2.42	0.78	0.03	0.15	0.14	15.11	0.14	0.02	0.16
111,602	8.63	9.34	0.03	13.76	85.62	61.86	30.54	72.88	0.13	2.43	0.72	0.04	0.15	0.13	12.49	0.15	0.02	0.17
111,602.25	8.63	9.26	0.02	14.58	84.36	80.45	31.92	69.02	0.12	2.44	0.64	0.05	0.14	0.13	10.16	0.16	0.02	0.17
111,602.5	8.63	9.19	0.02	15.40	83.11	99.04	33.31	65.16	0.12	2.45	0.56	0.06	0.14	0.12	8.19	0.17	0.02	0.18
111,602.75	8.63	9.11	0.02	16.38	83.84	117.63	34.69	61.30	0.12	2.46	0.48	0.07	0.13	0.11	5.62	0.19	0.02	0.20
111,603	8.63	9.03	0.02	17.36	84.56	136.22	36.08	57.44	0.11	2.46	0.40	0.08	0.13	0.10	4.18	0.20	0.02	0.21
111,603.25	8.63	8.97	0.02	17.80	85.29	143.14	37.20	66.14	0.10	2.46	0.34	0.09	0.13	0.10	3.63	0.20	0.02	0.22
111,603.5	8.63	8.90	0.03	18.23	86.01	150.07	38.32	74.83	0.10	2.46	0.28	0.09	0.13	0.10	3.13	0.19	0.02	0.23
111,603.75	8.63	8.84	0.03	18.69	82.67	156.99	39.45	83.53	0.10	2.46	0.21	0.10	0.13	0.10	2.86	0.18	0.02	0.23
111,604	8.63	8.77	0.03	19.15	79.34	163.92	40.57	92.22	0.10	2.45	0.15	0.10	0.13	0.10	3.36	0.17	0.02	0.22
111,604.25	8.63	8.78	0.03	18.66	76.00	168.65	44.55	157.55	0.10	2.43	0.16	0.10	0.14	0.11	4.90	0.12	0.01	0.21
111,604.5	8.63	8.80	0.03	18.18	72.66	173.37	48.54	222.88	0.11	2.42	0.17	0.09	0.14	0.12	6.93	0.09	0.01	0.19
111,604.75	8.63	8.81	0.03	17.42	71.96	178.10	52.52	288.21	0.11	2.40	0.18	0.08	0.15	0.13	9.45	0.08	0.01	0.18
111,605	8.63	8.82	0.03	16.66	71.26	182.82	56.50	353.53	0.11	2.40	0.20	0.07	0.15	0.13	11.36	0.07	0.01	0.17
111,605.25	8.63	8.82	0.03	15.90	70.55	210.12	64.51	324.30	0.11	2.39	0.20	0.07	0.16	0.14	13.61	0.07	0.01	0.16
111,605.5	8.63	8.82	0.03	15.14	69.85	237.43	72.53	295.07	0.12	2.39	0.20	0.06	0.16	0.14	16.19	0.07	0.01	0.16
111,605.75	8.63	8.82	0.04	14.59	69.15	264.73	80.54	265.84	0.11	2.38	0.20	0.05	0.16	0.15	18.12	0.07	0.01	0.15
111,606	8.63	8.82	0.04	14.03	68.45	292.03	88.56	236.61	0.11	2.37	0.20	0.04	0.16	0.15	20.36	0.07	0.01	0.15
111,606.25	8.63	8.81	0.03	13.47	67.74	254.39	77.64	225.58	0.11	2.37	0.19	0.04	0.16	0.15	21.82	0.07	0.01	0.15
111,606.5	8.63	8.81	0.03	12.91	67.04	216.75	66.73	214.55	0.11	2.36	0.18	0.03	0.16	0.16	23.31	0.07	0.01	0.14
111,606.75	8.63	8.80	0.03	11.45	66.76	179.10	55.81	203.53	0.10	2.35	0.17	0.02	0.17	0.16	28.03	0.07	0.01	0.14
111,607	8.63	8.79	0.03	9.98	66.48	141.46	44.90	192.50	0.10	2.35	0.16	0.00	0.17	0.17	32.21	0.07	0.01	0.13
111,607.25	8.63	8.90	0.02	9.62	66.19	135.37	44.22	383.47	0.10	2.35	0.27	0.00	0.17	0.17	34.41	0.05	0.01	0.13
111,607.5	8.63	9.00	0.02	9.26	65.91	129.29	43.54	574.44	0.11	2.35	0.38	0.00	0.17	0.17	36.71	0.04	0.01	0.13
111,607.75	8.63	9.11	0.02	8.90	66.33	123.20	42.85	765.41	0.11	2.34	0.48	0.00	0.17	0.17	39.10	0.04	0.01	0.13
111,608	8.63	9.21	0.02	8.54	66.74	117.12	42.17	956.38	0.12	2.34	0.59	0.00	0.18	0.18	40.51	0.03	0.01	0.13
111,608.25	8.63	9.29	0.02	8.63	67.16	140.39	47.15	782.56	0.12	2.34	0.66	0.00	0.18	0.18	40.51	0.04	0.01	0.13
111,608.5	8.63	9.37	0.02	8.72	67.57	163.66	52.13	608.75	0.12	2.34	0.74	0.00	0.18	0.18	40.51	0.04	0.01	0.13
11,608.75	8.63	9.44	0.02	8.15	68.25	186.93	57.11	434.93	0.12	2.34	0.82	0.00	0.18	0.18	40.51	0.05	0.01	0.13

Table 2 (continued)

Input well-log data										Output								
Depth (ft)	Bit Size (IN)	Caliper (IN)	Density Correc- tion (G/ C3)	Gamma Ray (API)	Sonic (US/F)	Shallow Resistivity (Ωm2/m)	Medium Resistivity (Ωm2/m)	Deep Resistivity (Ωm2/m)	Neutron Porosity	Density (G/C ³)	CALI- BS (IN)	Shale volume	Total poros- ity	Effec- tive poros- ity	K (mD)	Water Satura- tion	Bulk Vol- ume of Water	Irreduci- ble water saturation
11,111,609	8.63	9.52	0.02	7.59	68.93	210.20	62.09	261.11	0.12	2.34	0.90	0.00	0.18	0.18	40.32	0.06	0.01	0.13
11,111,609.25	8.63	9.37	0.02	7.71	69.61	214.30	58.86	222.49	0.12	2.34	0.75	0.00	0.18	0.18	40.13	0.07	0.01	0.13
11,111,609.5	8.63	9.23	0.02	7.84	70.29	218.39	55.63	183.87	0.12	2.34	0.60	0.00	0.18	0.18	39.94	0.07	0.01	0.13
11,111,609.75	8.63	9.08	0.02	7.97	70.69	222.49	52.39	145.24	0.12	2.35	0.45	0.00	0.18	0.18	39.75	0.08	0.01	0.13
11,111,610	8.63	8.93	0.02	8.10	71.09	226.58	49.16	106.62	0.12	2.34	0.31	0.00	0.18	0.18	39.94	0.10	0.02	0.13
11,111,610.25	8.63	8.88	0.02	8.23	71.48	224.18	45.27	130.26	0.12	2.34	0.26	0.00	0.18	0.18	40.63	0.09	0.02	0.13
11,111,610.5	8.63	8.83	0.02	8.36	71.88	221.78	41.38	153.91	0.12	2.34	0.21	0.00	0.18	0.18	41.33	0.08	0.01	0.13
11,111,610.75	8.63	8.78	0.03	8.58	71.91	219.38	37.48	177.56	0.12	2.34	0.15	0.00	0.18	0.18	42.08	0.07	0.01	0.13
11,111,611	8.63	8.73	0.03	8.81	71.94	216.99	33.59	201.20	0.12	2.35	0.11	0.00	0.17	0.17	38.31	0.07	0.01	0.13
11,111,611.25	8.63	8.70	0.03	10.11	71.96	196.84	35.83	180.72	0.12	2.37	0.07	0.00	0.17	0.17	34.02	0.08	0.01	0.13
11,111,611.5	8.63	8.67	0.04	11.42	71.99	176.70	38.08	160.25	0.12	2.38	0.04	0.02	0.17	0.16	27.05	0.08	0.01	0.14
11,111,611.75	8.63	8.64	0.04	12.35	71.85	156.55	40.32	139.77	0.12	2.39	0.02	0.03	0.16	0.15	22.07	0.09	0.01	0.15
11,111,612	8.63	8.61	0.05	13.28	71.70	136.40	42.56	119.30	0.12	2.39	-0.02	0.04	0.16	0.15	19.14	0.10	0.02	0.15
11,111,612.25	8.63	8.60	0.04	13.27	71.63	129.92	42.80	107.32	0.12	2.40	-0.02	0.04	0.16	0.14	17.23	0.11	0.02	0.15
11,111,612.5	8.63	8.60	0.04	13.27	71.56	123.44	43.03	95.34	0.11	2.40	-0.03	0.04	0.15	0.14	15.50	0.12	0.02	0.16
11,111,612.75	8.63	8.59	0.04	13.27	71.48	116.95	43.26	83.37	0.11	2.41	-0.04	0.04	0.15	0.14	13.88	0.13	0.02	0.16
11,111,613	8.63	8.58	0.03	13.27	71.41	110.47	43.49	71.39	0.10	2.41	-0.04	0.04	0.15	0.14	12.76	0.15	0.02	0.17
11,111,613.25	8.63	8.57	0.03	12.90	71.67	104.04	43.54	71.00	0.10	2.41	-0.06	0.03	0.15	0.14	13.07	0.15	0.02	0.16
11,111,613.5	8.63	8.56	0.03	12.53	71.93	97.62	43.59	70.61	0.11	2.42	-0.07	0.03	0.15	0.14	13.37	0.15	0.02	0.16
11,111,613.75	8.63	8.54	0.03	13.22	72.19	91.19	43.64	70.22	0.11	2.42	-0.08	0.04	0.14	0.13	12.22	0.15	0.02	0.17
11,111,614	8.63	8.53	0.02	13.90	72.45	84.77	43.69	69.83	0.11	2.42	-0.10	0.04	0.14	0.13	11.20	0.15	0.02	0.17
11,111,614.25	8.63	8.52	0.03	14.59	72.76	78.75	43.84	67.92	0.11	2.42	-0.11	0.05	0.14	0.13	10.58	0.16	0.02	0.17
11,111,614.5	8.63	8.51	0.03	15.28	73.08	72.72	43.98	66.02	0.11	2.42	-0.12	0.06	0.15	0.13	9.98	0.16	0.02	0.17
11,111,614.75	8.63	8.49	0.03	17.34	73.39	66.70	44.12	64.11	0.12	2.43	-0.13	0.08	0.15	0.12	8.00	0.17	0.02	0.18
11,111,615	8.63	8.48	0.03	19.40	73.70	60.68	44.26	62.21	0.12	2.44	-0.15	0.10	0.14	0.11	5.60	0.18	0.02	0.20
11,111,615.25	8.63	8.47	0.03	20.60	73.54	57.18	41.43	57.81	0.12	2.45	-0.16	0.12	0.14	0.10	3.99	0.20	0.02	0.22
11,111,615.5	8.63	8.46	0.03	21.80	73.39	53.67	38.59	53.42	0.12	2.46	-0.17	0.13	0.13	0.10	2.75	0.22	0.02	0.23
11,111,615.75	8.63	8.44	0.03	21.32	73.23	50.17	35.75	49.02	0.12	2.47	-0.18	0.13	0.13	0.09	2.43	0.24	0.02	0.24
11,111,616	8.63	8.43	0.03	20.83	73.07	46.67	32.92	44.63	0.12	2.48	-0.20	0.12	0.13	0.09	2.27	0.25	0.02	0.24
11,111,616.25	8.63	8.43	0.03	19.68	72.59	44.04	31.43	42.94	0.11	2.48	-0.20	0.11	0.12	0.09	2.24	0.26	0.02	0.25
11,111,616.5	8.63	8.42	0.03	18.53	72.11	41.41	29.95	41.26	0.11	2.49	-0.21	0.09	0.12	0.09	2.20	0.27	0.02	0.25
11,116,16.75	8.63	8.42	0.04	19.00	71.62	38.79	28.46	39.57	0.10	2.50	-0.21	0.10	0.12	0.09	1.66	0.29	0.02	0.26

Table 2 (continued)

Input well-log data										Output								
Depth (ft)	Bit Size (IN)	Caliper (IN)	Density Correction (G/ C3)	Gamma Ray (API)	Sonic (US/F)	Shallow Resistivity (Ωm2/m)	Medium Resistivity (Ωm2/m)	Deep Resistivity (Ωm2/m)	Neutron Porosity	Density (G/C ³)	CALIBS (IN)	Shale volume	Total porosity	Effective porosity	K (mD)	Water Saturation	Bulk Volume of Water	Irreducible water saturation
11,161.7	8.63	8.41	0.04	19.48	71.14	36.16	26.98	37.88	0.10	2.50	-0.22	0.11	0.11	0.08	1.39	0.31	0.03	0.27
11,161.75	8.63	8.41	0.04	20.20	72.98	35.54	25.97	36.51	0.10	2.50	-0.22	0.11	0.11	0.08	1.11	0.33	0.03	0.29
11,161.75	8.63	8.41	0.03	20.93	74.82	34.91	24.96	35.14	0.09	2.50	-0.22	0.12	0.11	0.07	0.87	0.35	0.03	0.30
11,161.75	8.63	8.41	0.03	21.65	76.65	34.29	23.95	33.76	0.09	2.50	-0.22	0.13	0.11	0.07	0.68	0.37	0.03	0.32
11,161.8	8.63	8.41	0.03	22.38	78.49	33.67	22.94	32.39	0.09	2.50	-0.22	0.14	0.11	0.06	0.51	0.39	0.03	0.34
11,161.825	8.63	8.41	0.03	22.44	81.99	34.05	22.53	32.74	0.09	2.50	-0.22	0.14	0.11	0.06	0.50	0.39	0.03	0.35
11,161.85	8.63	8.41	0.03	22.51	85.49	34.44	22.12	33.08	0.09	2.51	-0.22	0.14	0.11	0.06	0.49	0.39	0.03	0.35
11,161.875	8.63	8.41	0.03	21.77	88.98	34.82	21.71	33.43	0.09	2.51	-0.22	0.13	0.11	0.07	0.57	0.38	0.03	0.34
11,161.9	8.63	8.41	0.03	21.03	92.48	35.21	21.30	33.78	0.09	2.51	-0.22	0.12	0.11	0.07	0.64	0.38	0.03	0.33
11,161.925	8.63	8.41	0.04	20.30	89.60	38.13	21.62	35.62	0.09	2.51	-0.22	0.11	0.10	0.07	0.64	0.37	0.03	0.33
11,161.95	8.63	8.41	0.04	19.56	86.71	41.05	21.94	37.47	0.09	2.52	-0.22	0.11	0.10	0.07	0.65	0.36	0.02	0.32
11,161.975	8.63	8.41	0.04	17.58	83.83	43.97	22.26	39.31	0.08	2.52	-0.22	0.08	0.10	0.07	0.85	0.34	0.03	0.31
11,1620	8.63	8.41	0.04	15.59	80.94	46.88	22.58	41.16	0.08	2.51	-0.22	0.06	0.10	0.08	1.46	0.31	0.03	0.27
11,1620.25	8.63	8.41	0.04	14.75	81.77	53.52	24.34	46.15	0.08	2.50	-0.22	0.05	0.10	0.09	2.01	0.27	0.02	0.25
11,1620.5	8.63	8.41	0.05	13.90	82.60	60.15	26.11	51.14	0.08	2.49	-0.22	0.04	0.11	0.10	2.73	0.25	0.02	0.23
11,1620.75	8.63	8.41	0.05	13.94	83.42	66.79	27.87	56.13	0.08	2.47	-0.22	0.04	0.11	0.10	3.18	0.23	0.02	0.23
11,1621	8.63	8.41	0.05	13.98	84.25	73.42	29.64	61.13	0.08	2.48	-0.22	0.04	0.11	0.09	2.64	0.23	0.02	0.24
11,1621.25	8.63	8.41	0.05	14.02	89.35	96.07	33.09	83.84	0.08	2.49	-0.22	0.04	0.10	0.09	2.26	0.20	0.02	0.25
11,1621.5	8.63	8.41	0.05	14.06	94.46	118.71	36.54	106.56	0.08	2.50	-0.22	0.05	0.10	0.09	1.93	0.18	0.02	0.25
11,1621.75	8.63	8.41	0.05	14.51	99.56	141.35	39.98	129.28	0.08	2.51	-0.22	0.05	0.10	0.08	1.52	0.17	0.01	0.27
11,1622	8.63	8.41	0.05	14.96	104.66	163.99	43.43	152.00	0.08	2.52	-0.22	0.06	0.10	0.08	1.26	0.17	0.01	0.28
11,1622.25	8.63	8.41	0.04	15.45	103.29	158.49	50.41	148.84	0.08	2.53	-0.22	0.06	0.10	0.08	1.12	0.17	0.01	0.29
11,1622.5	8.63	8.41	0.04	15.94	101.92	152.99	57.40	145.69	0.09	2.53	-0.22	0.07	0.10	0.08	0.99	0.18	0.01	0.30
11,1622.75	8.63	8.41	0.03	17.10	100.55	147.48	64.38	142.54	0.09	2.54	-0.22	0.08	0.10	0.07	0.77	0.19	0.01	0.31
11,623	8.63	8.41	0.02	18.27	99.18	141.98	71.36	139.39	0.09	2.55	-0.22	0.09	0.09	0.07	0.57	0.20	0.01	0.33
Average												0.06	0.14	0.13	13.93	0.16	0.02	0.20

Table 3 Well-log data and output for zone C in well AG-6

Input well-log data										Output								
Depth (ft)	Bit Size (IN)	Caliper (IN)	Density Correction (G/ C3)	Gamma Ray (API)	Sonic (US/F)	Shallow Resistivity (Ωm ² /m)	Medium Resistivity (Ωm2/m)	Deep Resistivity (Ωm ² /m)	Neutron Porosity	Density (G/C ³)	CALI-BS (IN)	Shale volume	Total porosity	Effective porosity	K (mD)	Water Saturation	Bulk Volume of Water	Irreducible water saturation
11,652	8.63	8.44	0.03	29.03	74.42	60.48	27.72	38.62	0.15	2.40	-0.19	0.21	0.17	0.10	4.10	0.23	0.02	0.21
11,652.25	8.63	8.45	0.03	32.00	74.36	61.50	28.93	40.48	0.15	2.37	-0.17	0.24	0.18	0.11	4.62	0.21	0.02	0.21
11,652.5	8.63	8.47	0.03	34.98	74.30	62.51	30.15	42.34	0.15	2.37	-0.15	0.28	0.18	0.10	3.12	0.21	0.02	0.23
11,652.75	8.63	8.49	0.03	35.46	74.22	63.53	31.36	44.19	0.15	2.36	-0.13	0.28	0.18	0.10	3.00	0.21	0.02	0.23
11,653	8.63	8.51	0.03	35.95	74.15	64.54	32.57	46.05	0.15	2.36	-0.11	0.29	0.18	0.10	2.74	0.21	0.02	0.23
11,653.25	8.63	8.51	0.03	33.47	74.07	63.33	37.20	54.62	0.14	2.36	-0.11	0.26	0.18	0.10	3.74	0.19	0.02	0.22
11,653.5	8.63	8.51	0.03	31.00	73.99	62.12	41.84	63.19	0.14	2.37	-0.12	0.23	0.18	0.11	4.75	0.17	0.02	0.21
11,653.75	8.63	8.51	0.03	28.91	73.91	60.92	46.47	71.75	0.14	2.37	-0.12	0.21	0.18	0.11	5.67	0.16	0.02	0.20
11,654	8.63	8.51	0.03	26.83	73.84	59.71	51.10	80.32	0.13	2.37	-0.12	0.19	0.18	0.12	7.34	0.14	0.02	0.19
11,654.25	8.63	8.51	0.03	23.83	73.76	64.94	53.67	285.86	0.13	2.36	-0.12	0.15	0.18	0.13	10.36	0.07	0.01	0.17
11,654.5	8.63	8.51	0.03	20.83	73.68	70.16	56.24	491.39	0.13	2.38	-0.12	0.12	0.17	0.13	11.63	0.05	0.01	0.17
11,654.75	8.63	8.51	0.02	19.96	73.60	75.39	58.81	696.93	0.12	2.39	-0.12	0.11	0.16	0.13	10.29	0.05	0.01	0.17
11,655	8.63	8.51	0.02	19.09	73.53	80.62	61.38	902.46	0.12	2.40	-0.12	0.10	0.16	0.13	10.25	0.04	0.01	0.17
11,655.25	8.63	8.50	0.02	19.54	73.45	86.93	62.98	1101.63	0.12	2.40	-0.12	0.11	0.16	0.13	9.20	0.04	0.00	0.18
11,655.5	8.63	8.50	0.02	19.99	73.37	93.25	64.57	1300.80	0.12	2.40	-0.12	0.11	0.16	0.13	9.30	0.04	0.00	0.18
11,655.75	8.63	8.50	0.03	20.69	73.30	99.57	66.17	1499.97	0.12	2.39	-0.12	0.12	0.16	0.13	9.14	0.03	0.00	0.18
11,656	8.63	8.50	0.03	21.39	73.22	105.88	67.77	1699.14	0.12	2.39	-0.12	0.13	0.16	0.12	8.64	0.03	0.00	0.18
11,656.25	8.63	8.49	0.03	20.63	73.15	107.43	66.93	1668.24	0.12	2.39	-0.13	0.12	0.16	0.13	10.19	0.03	0.00	0.17
11,656.5	8.63	8.48	0.03	19.88	73.07	108.97	66.10	1637.34	0.13	2.38	-0.14	0.11	0.17	0.13	11.89	0.03	0.00	0.17
11,656.75	8.63	8.47	0.03	20.18	73.38	110.51	65.26	1606.44	0.13	2.38	-0.15	0.11	0.17	0.13	12.31	0.03	0.00	0.17
11,657	8.63	8.46	0.03	20.49	73.68	112.05	64.42	1575.54	0.14	2.38	-0.16	0.12	0.17	0.13	12.43	0.03	0.00	0.17
11,657.25	8.63	8.46	0.03	20.62	73.99	110.44	61.44	1316.92	0.14	2.38	-0.17	0.12	0.17	0.13	12.18	0.03	0.00	0.17
11,657.5	8.63	8.46	0.02	20.75	74.29	108.82	58.45	1058.29	0.14	2.39	-0.17	0.12	0.17	0.13	11.51	0.04	0.00	0.17
11,657.75	8.63	8.46	0.02	20.88	74.41	107.21	55.47	799.67	0.14	2.39	-0.17	0.12	0.17	0.13	10.87	0.04	0.01	0.17
11,658	8.63	8.46	0.02	21.00	74.52	105.59	52.48	541.04	0.14	2.40	-0.17	0.12	0.17	0.13	10.20	0.05	0.01	0.17
11,658.25	8.63	8.46	0.02	20.35	74.64	103.15	51.14	466.37	0.14	2.40	-0.17	0.12	0.16	0.13	10.32	0.06	0.01	0.17
11,658.5	8.63	8.46	0.02	19.70	74.75	100.70	49.80	391.69	0.13	2.39	-0.17	0.11	0.17	0.13	12.02	0.06	0.01	0.17
11,658.75	8.63	8.45	0.02	20.52	74.66	98.26	48.46	317.02	0.13	2.38	-0.17	0.12	0.17	0.13	11.88	0.07	0.01	0.17
11,659	8.63	8.45	0.02	21.33	74.58	95.81	47.12	242.34	0.13	2.39	-0.17	0.13	0.17	0.13	10.13	0.08	0.01	0.17
11,659.25	8.63	8.45	0.03	22.15	74.49	93.78	47.08	227.74	0.13	2.39	-0.17	0.14	0.16	0.12	8.39	0.09	0.01	0.18
11,659.5	8.63	8.45	0.03	22.97	74.40	91.74	47.05	213.13	0.13	2.38	-0.17	0.14	0.17	0.12	8.20	0.09	0.01	0.18
11,659.75	8.63	8.45	0.03	21.55	74.34	89.70	47.01	198.53	0.12	2.38	-0.17	0.13	0.17	0.13	10.41	0.09	0.01	0.17

Table 3 (continued)

Input well-log data										Output								
Depth (ft)	Bit Size (IN)	Caliper (IN)	Density Correction (G/ C3)	Gamma Ray (API)	Sonic (US/F)	Shallow Resistivity (Ωm ² /m)	Medium Resistivity (Ωm2/m)	Deep Resistivity (Ωm ² /m)	Neutron Porosity	Density (G/C ³)	CALIBS (IN)	Shale volume	Total porosity	Effective porosity	K (mD)	Water Saturation	Bulk Volume of Water	Irreducible water saturation
111,660	8.63	8.45	0.03	20.12	74.29	87.67	46.97	183.92	0.12	2.38	-0.17	0.11	0.17	0.13	11.96	0.09	0.01	0.17
111,660.25	8.63	8.45	0.03	19.66	74.23	86.18	46.38	178.79	0.13	2.37	-0.17	0.11	0.17	0.14	13.25	0.09	0.01	0.16
111,660.5	8.63	8.45	0.03	19.20	74.17	84.70	45.78	173.66	0.13	2.37	-0.18	0.10	0.17	0.14	14.92	0.09	0.01	0.16
111,660.75	8.63	8.45	0.03	18.33	74.28	83.22	45.18	168.52	0.13	2.37	-0.18	0.09	0.17	0.15	17.46	0.09	0.01	0.15
111,661	8.63	8.45	0.04	17.45	74.38	81.74	44.59	163.39	0.13	2.37	-0.18	0.08	0.17	0.15	20.00	0.09	0.01	0.15
111,661.25	8.63	8.45	0.03	17.49	74.49	80.07	44.45	169.06	0.13	2.37	-0.18	0.08	0.17	0.15	19.99	0.08	0.01	0.15
111,661.5	8.63	8.45	0.03	17.53	74.59	78.40	44.30	174.72	0.13	2.37	-0.18	0.08	0.17	0.15	19.34	0.08	0.01	0.15
111,661.75	8.63	8.45	0.03	18.92	74.67	76.73	44.16	180.39	0.13	2.37	-0.18	0.10	0.17	0.14	16.33	0.09	0.01	0.16
111,662	8.63	8.45	0.02	20.31	74.74	75.06	44.02	186.05	0.13	2.37	-0.18	0.11	0.17	0.14	13.69	0.09	0.01	0.16
111,662.25	8.63	8.44	0.02	19.74	74.82	74.12	44.43	181.55	0.13	2.38	-0.18	0.11	0.17	0.14	13.92	0.09	0.01	0.16
111,662.5	8.63	8.44	0.03	19.18	74.89	73.18	44.84	177.05	0.13	2.37	-0.18	0.10	0.17	0.14	14.92	0.09	0.01	0.16
111,662.75	8.63	8.44	0.03	19.39	73.66	72.23	45.26	172.55	0.13	2.37	-0.18	0.10	0.17	0.14	14.71	0.09	0.01	0.16
111,663	8.63	8.44	0.03	19.60	72.43	71.29	45.67	168.05	0.13	2.37	-0.18	0.11	0.17	0.14	13.70	0.09	0.01	0.16
111,663.25	8.63	8.44	0.03	19.82	71.19	69.64	43.76	151.86	0.13	2.38	-0.18	0.11	0.17	0.14	13.65	0.10	0.01	0.16
111,663.5	8.63	8.44	0.03	20.03	69.96	67.99	41.85	135.67	0.13	2.37	-0.18	0.11	0.17	0.14	15.10	0.10	0.01	0.16
111,663.75	8.63	8.44	0.03	20.77	69.12	66.34	39.93	119.47	0.14	2.36	-0.19	0.12	0.18	0.14	15.79	0.10	0.01	0.16
111,664	8.63	8.44	0.03	21.50	68.29	64.69	38.02	103.28	0.14	2.35	-0.19	0.13	0.18	0.15	17.48	0.11	0.02	0.15
111,664.25	8.63	8.43	0.03	19.76	67.45	62.72	36.19	98.49	0.14	2.34	-0.20	0.11	0.19	0.16	23.49	0.11	0.02	0.14
111,664.5	8.63	8.42	0.03	18.02	66.61	60.75	34.36	93.69	0.14	2.35	-0.21	0.09	0.18	0.16	23.88	0.11	0.02	0.14
111,664.75	8.63	8.41	0.04	18.02	66.94	58.78	32.54	88.90	0.14	2.37	-0.22	0.09	0.18	0.15	20.57	0.12	0.02	0.15
111,665	8.63	8.40	0.04	18.03	67.26	56.81	30.71	84.11	0.14	2.37	-0.23	0.09	0.18	0.15	20.33	0.12	0.02	0.15
111,665.25	8.63	8.39	0.05	17.81	67.59	55.22	30.54	86.07	0.14	2.37	-0.24	0.09	0.18	0.15	20.69	0.12	0.02	0.15
111,665.5	8.63	8.38	0.05	17.59	67.91	53.63	30.36	88.04	0.14	2.37	-0.24	0.08	0.18	0.15	21.06	0.12	0.02	0.15
111,665.75	8.63	8.38	0.06	17.37	67.60	52.04	30.19	90.00	0.14	2.37	-0.25	0.08	0.18	0.15	21.43	0.11	0.02	0.15
111,666	8.63	8.37	0.06	17.15	67.29	50.45	30.02	91.97	0.14	2.38	-0.26	0.08	0.17	0.15	19.41	0.12	0.02	0.15
111,666.25	8.63	8.32	0.07	16.18	66.98	51.22	33.23	91.15	0.15	2.40	-0.30	0.07	0.17	0.15	19.17	0.12	0.02	0.15
111,666.5	8.63	8.28	0.07	15.21	66.67	51.99	36.43	90.32	0.15	2.41	-0.35	0.06	0.16	0.15	18.26	0.12	0.02	0.15
111,666.75	8.63	8.23	0.07	13.20	67.11	52.76	39.63	89.50	0.15	2.43	-0.39	0.04	0.16	0.15	19.35	0.12	0.02	0.15
111,667	8.63	8.19	0.07	11.18	67.55	53.53	42.84	88.68	0.15	2.44	-0.44	0.01	0.16	0.15	21.47	0.12	0.02	0.15
111,667.25	8.63	8.21	0.07	11.75	67.98	58.57	42.78	93.23	0.15	2.45	-0.41	0.02	0.15	0.14	17.07	0.12	0.02	0.15
111,667.5	8.63	8.24	0.06	12.31	68.42	63.60	42.72	97.77	0.14	2.48	-0.39	0.03	0.14	0.13	10.66	0.13	0.02	0.17
111,667.75	8.63	8.26	0.06	12.38	68.60	68.63	42.66	102.32	0.14	2.51	-0.36	0.03	0.13	0.12	6.89	0.14	0.02	0.19

Table 3 (continued)

Input well-log data										Output								
Depth (ft)	Bit Size (IN)	Caliper (IN)	Density Correction (G/C3)	Gamma Ray (API)	Sonic (US/F)	Shallow Resistivity (Ωm ² /m)	Medium Resistivity (Ωm ² /m)	Deep Resistivity (Ωm ² /m)	Neutron Porosity	Density (G/C ³)	CALIBS (IN)	Shale volume	Total porosity	Effective porosity	K (mD)	Water Saturation	Bulk Volume of Water	Irreducible water saturation
111,668	8.63	8.29	0.06	12.45	68.78	73.66	42.60	106.86	0.13	2.51	-0.34	0.03	0.12	0.11	6.25	0.14	0.02	0.19
111,668.25	8.63	8.31	0.05	11.02	68.96	75.02	45.77	111.84	0.13	2.51	-0.32	0.01	0.12	0.12	6.81	0.14	0.02	0.19
111,668.5	8.63	8.33	0.05	9.60	69.14	76.38	48.95	116.82	0.12	2.52	-0.29	0.00	0.12	0.12	6.85	0.14	0.02	0.19
111,668.75	8.63	8.36	0.05	9.63	68.79	77.75	52.12	121.80	0.12	2.52	-0.27	0.00	0.11	0.11	6.14	0.14	0.02	0.20
111,669	8.63	8.38	0.05	9.66	68.45	79.11	55.29	126.77	0.11	2.52	-0.24	0.00	0.11	0.11	5.14	0.14	0.02	0.20
111,669.25	8.63	8.37	0.05	9.66	68.10	77.17	51.93	125.08	0.11	2.53	-0.25	0.00	0.11	0.11	4.25	0.15	0.02	0.21
111,669.5	8.63	8.36	0.05	9.66	67.75	75.23	48.58	123.39	0.10	2.54	-0.26	0.00	0.10	0.10	3.50	0.15	0.02	0.22
111,669.75	8.63	8.35	0.05	10.03	68.01	73.29	45.22	121.70	0.10	2.54	-0.27	0.00	0.10	0.10	2.89	0.16	0.02	0.23
111,670	8.63	8.34	0.05	10.40	68.28	71.36	41.86	120.01	0.09	2.53	-0.28	0.00	0.10	0.10	2.83	0.16	0.02	0.23
111,670.25	8.63	8.35	0.04	10.71	68.54	69.00	41.37	124.44	0.09	2.53	-0.27	0.01	0.10	0.10	2.94	0.16	0.02	0.23
111,670.5	8.63	8.36	0.03	11.02	68.80	66.64	40.88	128.87	0.09	2.53	-0.26	0.01	0.10	0.10	2.72	0.16	0.02	0.24
111,670.75	8.63	8.37	0.02	11.32	68.22	64.28	40.38	133.30	0.08	2.53	-0.26	0.01	0.10	0.09	2.51	0.16	0.01	0.24
111,671	8.63	8.38	0.01	11.63	67.65	61.92	39.89	137.73	0.08	2.51	-0.25	0.02	0.10	0.10	3.11	0.15	0.01	0.23
111,671.25	8.63	8.38	0.01	10.82	67.07	67.58	40.39	125.58	0.08	2.49	-0.25	0.01	0.11	0.11	4.57	0.14	0.02	0.21
111,671.5	8.63	8.38	0.02	10.02	66.49	73.25	40.88	113.43	0.08	2.48	-0.25	0.00	0.11	0.11	5.82	0.14	0.02	0.20
111,671.75	8.63	8.38	0.02	10.11	66.14	78.91	41.38	101.28	0.08	2.46	-0.25	0.00	0.12	0.12	6.56	0.15	0.02	0.19
111,672	8.63	8.38	0.03	10.20	65.78	84.57	41.88	89.13	0.08	2.47	-0.25	0.00	0.11	0.11	5.89	0.16	0.02	0.20
111,672.25	8.63	8.39	0.03	11.75	65.43	82.47	41.33	85.88	0.08	2.48	-0.24	0.02	0.11	0.11	4.61	0.17	0.02	0.21
111,672.5	8.63	8.40	0.03	13.30	65.07	80.36	40.78	82.64	0.08	2.47	-0.22	0.04	0.12	0.11	4.25	0.18	0.02	0.21
111,672.75	8.63	8.42	0.03	13.40	64.36	78.25	40.23	79.39	0.09	2.46	-0.21	0.04	0.12	0.11	4.79	0.17	0.02	0.21
111,673	8.63	8.43	0.03	13.50	63.65	76.14	39.69	76.14	0.09	2.46	-0.20	0.04	0.12	0.11	5.01	0.18	0.02	0.20
Average												0.09	0.15	0.13	10.92	0.11	0.01	0.18

Table 4 Well-log data and output for zone D in well AG-15

Input well-log data										Output								
Depth (ft)	Bit Size (IN)	Caliper (IN)	Density Correction (G/ C3)	Gamma Ray (API)	Sonic (US/F)	Shallow Resistivity (Qm2/m)	Medium Resistivity (Qm2/m)	Deep Resistivity (Qm2/m)	Neutron Porosity	Density (G/C³)	CAL-BS (IN)	Shale volume	Total porosity	Effective porosity	K (mD)	Water Saturation	Bulk Volume of Water	Irreducible saturation
11,244	8.50	8.59	0.02	26.86	66.63	28.60	26.51	25.07	0.08	2.49	0.09	0.19	0.11	0.05	0.22	0.49	0.03	0.42
11,244.5	8.50	8.60	0.02	28.78	68.11	32.17	29.81	27.70	0.08	2.46	0.10	0.21	0.12	0.05	0.22	0.45	0.02	0.42
11,245	8.50	8.60	0.02	29.05	71.61	31.70	31.41	28.56	0.08	2.46	0.10	0.21	0.12	0.05	0.24	0.44	0.02	0.41
11,245.5	8.50	8.61	0.02	28.57	75.37	31.05	30.31	30.38	0.09	2.46	0.11	0.21	0.12	0.06	0.32	0.41	0.02	0.38
11,246	8.50	8.61	0.02	28.87	77.42	31.38	27.93	31.29	0.10	2.46	0.11	0.21	0.12	0.06	0.39	0.39	0.02	0.37
11,246.5	8.50	8.62	0.02	30.45	70.21	36.66	25.67	30.71	0.10	2.44	0.12	0.23	0.13	0.07	0.54	0.36	0.02	0.34
11,247	8.50	8.62	0.02	35.23	71.38	39.21	23.52	30.02	0.11	2.45	0.12	0.28	0.13	0.05	0.17	0.41	0.02	0.44
11,247.5	8.50	8.63	0.02	34.77	72.23	38.98	21.91	29.68	0.10	2.42	0.13	0.28	0.14	0.06	0.37	0.37	0.02	0.37
11,248	8.50	8.63	0.01	32.72	72.98	38.25	20.92	29.16	0.11	2.39	0.13	0.25	0.15	0.08	1.17	0.31	0.02	0.28
11,248.5	8.50	8.64	0.01	31.42	74.11	37.26	21.01	29.18	0.12	2.42	0.14	0.24	0.15	0.08	1.24	0.32	0.03	0.28
11,249	8.50	8.64	0.01	32.54	75.02	36.44	22.30	29.30	0.11	2.44	0.14	0.25	0.14	0.06	0.50	0.36	0.02	0.35
11,249.5	8.50	8.65	0.02	34.69	75.30	37.67	24.63	29.62	0.10	2.41	0.15	0.27	0.15	0.06	0.45	0.36	0.02	0.35
11,250	8.50	8.65	0.02	34.36	74.45	46.82	25.20	29.07	0.10	2.43	0.15	0.27	0.14	0.06	0.31	0.39	0.02	0.38
11,250.5	8.50	8.67	0.04	32.85	73.11	51.48	26.12	27.54	0.10	2.47	0.16	0.25	0.12	0.05	0.13	0.46	0.02	0.47
11,251	8.50	8.68	0.03	31.36	71.30	42.17	26.18	27.89	0.10	2.48	0.18	0.24	0.12	0.05	0.14	0.47	0.02	0.46
Average												0.24	0.13	0.06	0.43	0.40	0.02	0.38

Table 5 Well-log data and output for zone E in well AG-15

Input well-log data										Output								
Depth (ft)	Bit Size (IN)	Caliper (IN)	Density Correction (G/C3)	Gamma Ray (API)	Sonic (US/F)	Shallow Resistivity (Ωm2/m)	Medium Resistivity (Ωm2/m)	Deep Resistivity (Ωm2/m)	Neutron Porosity	Density (G/C3)	CALI-BS (IN)	Shale volume	Total porosity	Effective porosity	K (mD)	Water Saturation	Bulk Volume of Water	Irreducible water saturation
11,459	8.50	9.10	0.02	53.03	73.60	7.76	5.19	7.37	0.22	2.27	0.60	0.48	0.24	0.10	3.03	0.45	0.04	0.23
11,459.5	8.50	8.91	0.01	46.02	70.54	10.92	5.79	11.64	0.19	2.36	0.40	0.40	0.20	0.08	1.22	0.44	0.03	0.28
11,460	8.50	8.71	0.02	38.66	69.24	16.09	6.74	17.73	0.15	2.42	0.21	0.32	0.16	0.07	0.53	0.43	0.03	0.34
11,460.5	8.50	8.69	0.02	30.67	80.37	47.36	9.50	32.17	0.09	2.46	0.19	0.23	0.12	0.05	0.17	0.43	0.02	0.44
11,461	8.50	8.66	0.01	30.71	80.98	61.89	14.42	44.04	0.06	2.51	0.16	0.23	0.09	0.02	0.01	0.58	0.01	0.92
11,461.5	8.50	8.64	0.00	31.21	82.22	76.71	40.22	69.60	0.06	2.52	0.14	0.24	0.09	0.02	0.00	0.55	0.01	1.39
11,462	8.50	8.61	-0.01	30.14	88.24	84.26	975.51	84.38	0.06	2.51	0.11	0.22	0.09	0.02	0.01	0.43	0.01	0.96
11,462.5	8.50	8.59	-0.01	28.51	106.16	90.66	1149.29	90.20	0.06	2.51	0.09	0.21	0.09	0.03	0.02	0.37	0.01	0.74
11,463	8.50	8.57	0.00	27.25	103.95	102.90	851.98	88.76	0.06	2.51	0.07	0.19	0.09	0.04	0.04	0.35	0.01	0.63
11,463.5	8.50	8.55	0.01	25.15	97.88	104.82	250.05	85.67	0.07	2.50	0.04	0.17	0.10	0.05	0.12	0.30	0.01	0.47
11,464	8.50	8.52	0.01	23.22	82.43	94.02	101.54	88.48	0.07	2.50	0.02	0.15	0.10	0.05	0.20	0.28	0.01	0.43
11,464.5	8.50	8.54	0.02	22.54	75.09	91.42	76.35	88.56	0.06	2.52	0.04	0.14	0.09	0.05	0.15	0.30	0.01	0.45
11,465	8.50	8.55	0.01	22.81	72.31	84.03	43.71	80.62	0.06	2.52	0.05	0.14	0.09	0.05	0.11	0.33	0.02	0.49
11,465.5	8.50	8.58	0.01	23.95	80.46	86.30	25.87	81.44	0.06	2.52	0.07	0.16	0.09	0.04	0.07	0.34	0.01	0.53
11,466	8.50	8.60	0.02	25.93	80.16	81.06	23.43	78.82	0.06	2.50	0.10	0.18	0.10	0.04	0.09	0.33	0.01	0.51
11,466.5	8.50	8.62	0.03	28.16	74.28	68.93	19.13	50.61	0.06	2.48	0.12	0.20	0.10	0.04	0.09	0.39	0.02	0.52
11,467	8.50	8.64	0.04	31.57	70.84	51.57	14.45	49.07	0.06	2.47	0.14	0.24	0.11	0.03	0.03	0.44	0.01	0.66
Average												0.23	0.11	0.05	0.35	0.40	0.02	0.59

Fig. 13 Density–neutron cross-plot (after Schlumberger 1972) for the examined zones within the Bahariya Formation in the Abu Gharadig Field

Fig. 14 Water saturation–effective porosity cross-plot (after Asquith and Gibson 1982) showing the grain size distribution in the investigated zones within the Bahariya Formation in the Abu Gharadig Field

Fig. 15 Water saturation–effective porosity plot showing the investigated zones within the Bahariya Formation in the Abu Gharadig Field

Fig. 16 Water saturation versus irreducible water saturation cross-plot (Asquith and Gibson 1982) that can be used to evaluate the relative oil permeability in the examined zones

Fig. 17 Water saturation versus irreducible water saturation cross-plot (Asquith and Gibson 1982) for assessing the relative water permeability in the zones of interest

Fig. 18 Water saturation versus irreducible water saturation cross-plot (Asquith and Gibson 1982) that can be used to calculate the water-cut percentage in the zones of interest

Fig. 19 Correlation chart (the y-axis represents the permeability values, x-axis represents the effective porosity values, and the color reflects the calculated water saturation) representing the flow units (FZI) based on Amaefule et al. (1993). Note that the plotted points

are not based on the microscopic measurements of rock core samples. This figure compares the characteristics of zones B and C (homogeneity and hydraulic characteristics)

Fig. 20 Correlation graph (the y-axis represents the permeability values, x-axis represents the effective porosity values, and the color reflects the calculated water saturation) indicating the r35 value (Winland, 1972 and 1976). Note that the plotted points are not based on

the microscopic measurements of rock core samples. This figure compares the characteristics of zones B and C (homogeneity and rock quality, r35 exceeding 2 μ)

Fig. 21 **a** Bar graph summarizing the calculated petrophysical parameters (shale volume, total porosity, effective porosity, water saturation, bulk volume of water, and irreducible water saturation) for the promising zones. **b** Bar graph displays the calculated absolute permeability (K) for these zones

for zones D and E in well AG-15 confirm the production of condensate with an API of 46.1, whereas zone A in well AG-2 produces gas with traces of condensate. On the other hand, the composite log of well AG-6 shows that the entire sand in zones B and C might be a hydrocarbon-bearing zone. They characterized by the presence of oil satin and display blue fluorescence which reflects the condensate hydrocarbons with API > 45 (Johnson and Pile 2006). The DST data for well AG-6 are not available; therefore, DST should be carried out in zones B and C in this well in the future.

Conclusions

In this study, the reservoir superiority of the sandstone of the Bahariya Formation in Abu Gharadig Field, Western Desert, Egypt, was evaluated. Based on the seismic data and mapping the uppermost surface of the Bahariya Formation, the study area contains a ENE–WSW-oriented anticline, which is cut by NW–SE-trending normal faults.

The qualitative explanation of the well-log data indicates good reservoir characteristics for oil production in zone A (17 ft thick) in well AG-2, zones B (30 ft thick) and C (21 ft thick) in well AG-6, and zones D (7 ft thick)

and E (18 ft thick) in well AG-15. However, the quantitative appraisal shows that zones B and C in well AG-6 are the best intervals in terms of the reservoir performance because they exhibit the lowest shale volume, highest effective porosity, minimum water saturation, lowest BVW, and high absolute permeability (Fig. 21). They also display high relative oil permeability, low relative water permeability, and low water cut.

The crest of the mapped anticline in the topmost of Bahariya Formation in the Abu Gharadig Field is expected to be the optimum site for the installation of new exploratory wells. Accordingly, the drilling of the anticlinal crest is highly recommended including the addition of wells close to well AG-6.

The lack of important measurements that are necessary to describe the reservoir quality (e.g., k_{ro} , k_{rw} , and W_c) might lead to improper decisions regarding the setting of pipes considering only traditional petrophysical parameters (e.g., ϕ , V_{shale} , and S_w).

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Declarations

Conflict of interest Here, I confirm that there is no conflict of interest.

Ethical approval Hereby, I assure that this paper has not been previously published and the manuscript reflects my own research and analysis in a truthful and complete manner.

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