NRIAG Journal of Astronomy and Geophysics (2015) 4, 222–235

National Research Institute of Astronomy and Geophysics

NRIAG Journal of Astronomy and Geophysics

www.elsevier.com/locate/nrjag

REVIEW ARTICLE

Prospect evaluation of BED 3 and Sitra oilfields, Abu Gharadig Basin, North Western Desert, Egypt

Ibrahim Salem [a,*], **Hosni Ghazala** [b], **Waleed El Diasty** [b]

[a] *Badr El Din Petroleum Company (BAPETCO), Cairo, Egypt*
[b] *Geology Department, Faculty of Science, Mansoura University, Egypt*

Received 5 May 2015; revised 4 September 2015; accepted 14 September 2015
Available online 16 October 2015

KEYWORDS

BED 3 and Sitra oilfields;
Abu Gharadig Basin;
Prospect evaluation;
Egypt

Abstract The occurrence of hydrocarbons is closely linked to the elements of petroleum system history of the BED 3 and Sitra 8 oilfields, which has created multiple reservoir and seal combinations. BED 3 Field and Sitra concessions occupy the northwestern part of the Abu Gharadig Basin and extends between latitudes 29°45′ and 30°05′N and longitudes 27°30′ and 28°10′E. The comprehensive integration of the geo-related data and the interpretation of the well logging, geochemical, seismic data in time domain and depth and sealing mechanisms explain the occurrence of hydrocarbons in some certain reservoirs during cretaceous age and other reservoirs in the same fields don't have any hydrocarbon accumulation. Detailed seismic data interpretation was performed for the target units of BED 3 and Sitra 8 oilfields in time domain and converted to depth domain. Sitra 8 Field is a three-way dip closure bounded by NW–SE faults while BED 3 field is represented by a WNW–ESE trending horst dipping to the east.

The Albian–Cenomanian Kharita Formation has a high energy shallow marine shelf environment and considered as the main pay zone in the BED 3 oilfield. On the other hand, Kharita sands are dry in the Sitra 8 Field. Also, the shallow marine shale, sandstone, limestone and dolomite interbeds of the Abu Roash G Member are another hydrocarbon bearing reservoir in the Sitra 8 Field.

Sealing mechanisms were applied to explain why certain reservoirs have hydrocarbon and others don't. Allan's juxtaposition diagram for the main faults in the study area shows that Kharita sands in BED 3 area have excellent juxtaposition as Kharita juxtapose to upper Bahariya and intra Bahariya, which consist of shale and limestone. Abu Roash G sands in BED 3 area have bad juxtaposition as the Abu Roash G juxtapose to Abu Roash C sand (sand juxtaposed sand). Allan's diagram shows that the Abu Roash G reservoir (main target) in Sitra 8 is juxtaposing Abu Roash D which is

* Corresponding author.
E-mail address: I.Salem2@bapetco.simis.com (I. Salem).

Peer review under responsibility of National Research Institute of Astronomy and Geophysics.

Production and hosting by Elsevier

http://dx.doi.org/10.1016/j.nrjag.2015.09.002

composed of limestone and shale, which acts as very good seal rock, while the Kharita reservoir is juxtaposing Abu Roash G sand (sand juxtaposed sand) from the crest position which can explain the bad juxtaposition.

Contents

1. Introduction

The study area occupies the northwestern part of the Abu Gharadig Basin and covers Badr El Din specially BED 3 and Sitra concessions (Fig. 1). It extends between latitudes 29°45′ and 30°05′N, and longitudes 27°30′ and 28°10′E.

The Abu Gharadig Basin is ENE–WSW oriented basin. It extends for about 300 km long and 60 km wide and represents 3.6% of the Western Desert district, with an age ranges from Late Jurassic to Early Cretaceous (EGPC, 1992). The major Abu Gharadig Basin extends between the Qattara Depression to the west and the Kattaniya horst to the east (Meshref et al., 1980). The Abu Gharadig Basin is bounded by two basement uplifts to the north and south (Meshref et al., 1988): the northern uplift (Sharib–Sheiba–Rabat platform), and the southern bounding structure (Cairo–Bahariya uplift).

The Badr El Din Petroleum Company was started a Joint Venture between EGPC 50% and Shell 50%. The Sitra development lease is located in the Western Desert and it was awarded to Shell in December 1985 following the hydrocarbon discoveries in Sitra 1-1 at (1982), Sitra 3-1 at (1983) and Sitra 5-1 at (1985) in the Abu Roash reservoirs. The BED 3 field is located in the Egyptian Western Desert some 300 km west of Cairo. It was discovered in 1983 when the BED 3-1 well tested gas and condensate from the Cretaceous Kharita sandstone reservoir at 3500 m depth. The most important reservoirs in the study are Abu Roash G, and the good quality sands with great thickness of Kharita reservoir in Sitra 8 and BED 3 oilfields.

2. Geological framework

2.1. General stratigraphic framework for Western Desert

The greater part of the north Western Desert formed a platform which was characterized by comparatively mild subsidence and situated near actively subsiding basins or depocenters. During the Paleozoic, most of the area were located in the east of the active Paleozoic basin and occupying the Siwa-Kufra, Libya area (the Kufra Basin). During the Jurassic substantial tilting shifted the center of the basin to northeastern Egypt leaving part of the Western Desert in the form of a platform. With the onset of the Early Cretaceous and up to the Recent, the active part of the basin shifted to the north occupying the present Mediterranean offshore area parallel to the present shore line. During these times, the north Western Desert formed a platform which was located in the south of the offshore basin to the north. During different periods, however, local depocenters of limited dimensions developed in different places over this platform. The narrow pullapart basins that straddle latitude 30°N are Betty, Abu Gharadig and Gindi (Faiyum) basins. These basins were particularly active during Late Cretaceous–Early Tertiary times.

Recent active exploration of oil exploration work including, seismic, geological studies, drilling, aeromagnetic and gravity measurements has explored the presence of a thick subsurface stratigraphic column, which ranges in age from Paleozoic to Recent. The sediments occur in a number of basins with varying degrees of subsidence (Said, 1990) (Fig. 2).

The whole thickness, stratifies some anomalies, increases gradually to the north–northeast from about 1829 m in the south up to an estimated 7620 m of section over the coastal area.

There are five cycles composed the stratigraphic section of alternating deposition between clastics and carbonate rocks.

1. Clastics Sedimentation prevails the oldest sedimentary rocks including Paleozoic and Lower Jurassic formations.
2. Upper and Middle Jurassic rocks composed of carbonates.
3. Lower Cretaceous up to Early Cenomanian contains mainly clastics cycle.

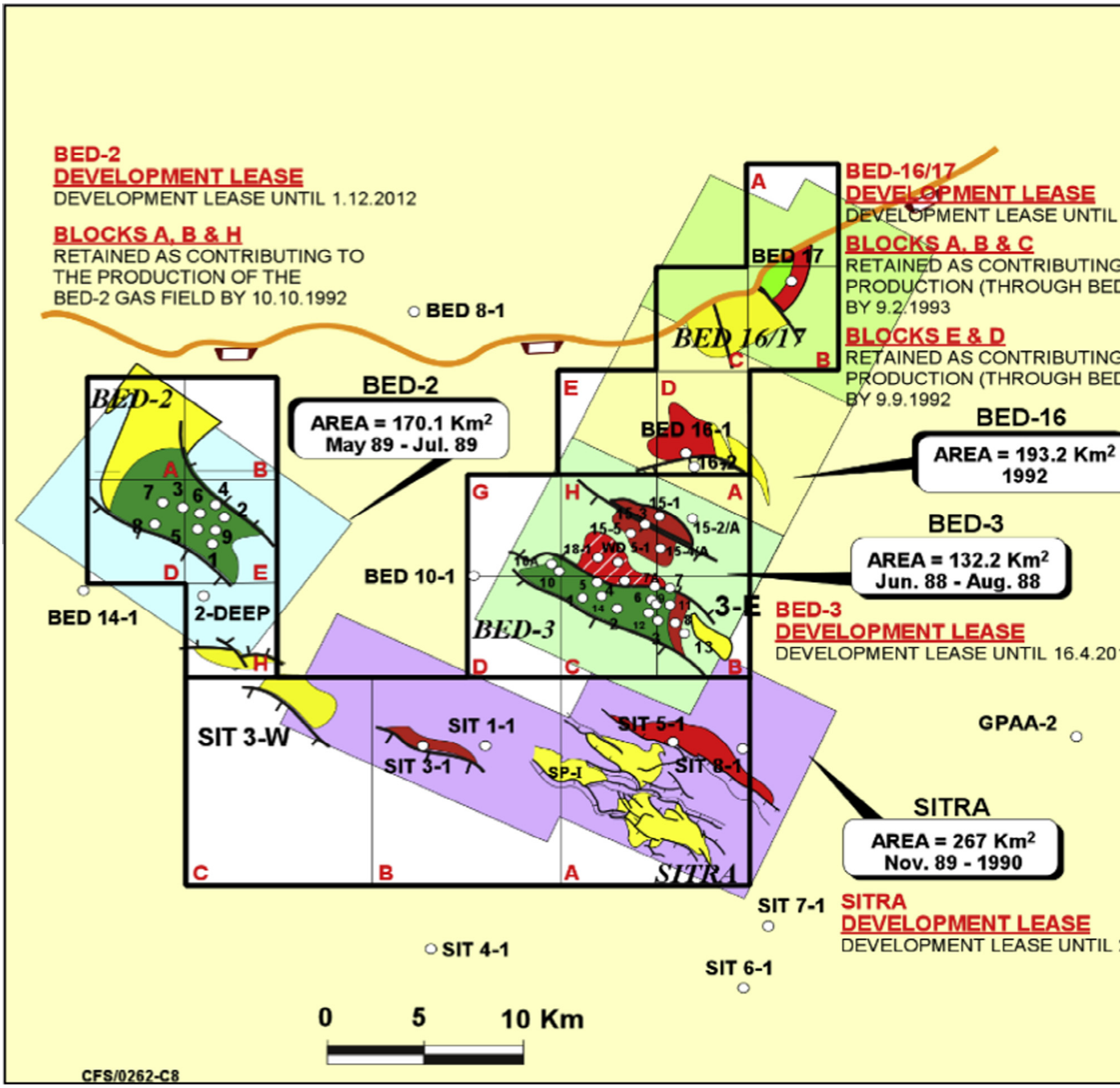

Figure 1 Location map of the study area (Sitra and BED 3). This dataset belongs to Badr Petroleum Company.

4. Carbonate Rocks are again deposited over northern Western Desert from Upper Cenomanian and to the Middle Eocene.
5. The upper clastic cycle includes the Upper Eocene–Oligocene, Miocene and younger section (EGPC, 1992). The stratigraphic succession of the Abu Gharadig Basin does not differ large from that of the generalized one of the north Western Desert. The main observation is the lithological local changes and unconformities.

2.2. Structural framework

The Abu Gharadig Basin is probably initiated during the Paleozoic (EGPC, 1992) but mainly developed as a result of deep crustal extensional tectonics that affected northern Egypt during the Mesozoic. The Abu Gharadig Basin was opened at the end of Early Cretaceous by right-lateral diagonal slip movement on right stepped, en-echelon faults of the E–W to ENE oriented normal fault set. It might also be formed in Jurassic times and affected by N–S to NE–SW extension, which led to the rejuvenation of E–W pre-Jurassic basement faults (EGPC, 1992).

This deep basinal area is almost bifurcated into southern and northern sub-basins by an east–west direction trending positive features or horst. The southern sub-basin has an excess of 15,000 ft of sedimentary section and the northern sub-basin as much as 35,000 ft. In profile, this basin has a half graben form in which the depth to reach to the basement exceeds 35,000 ft. The sedimentary section is

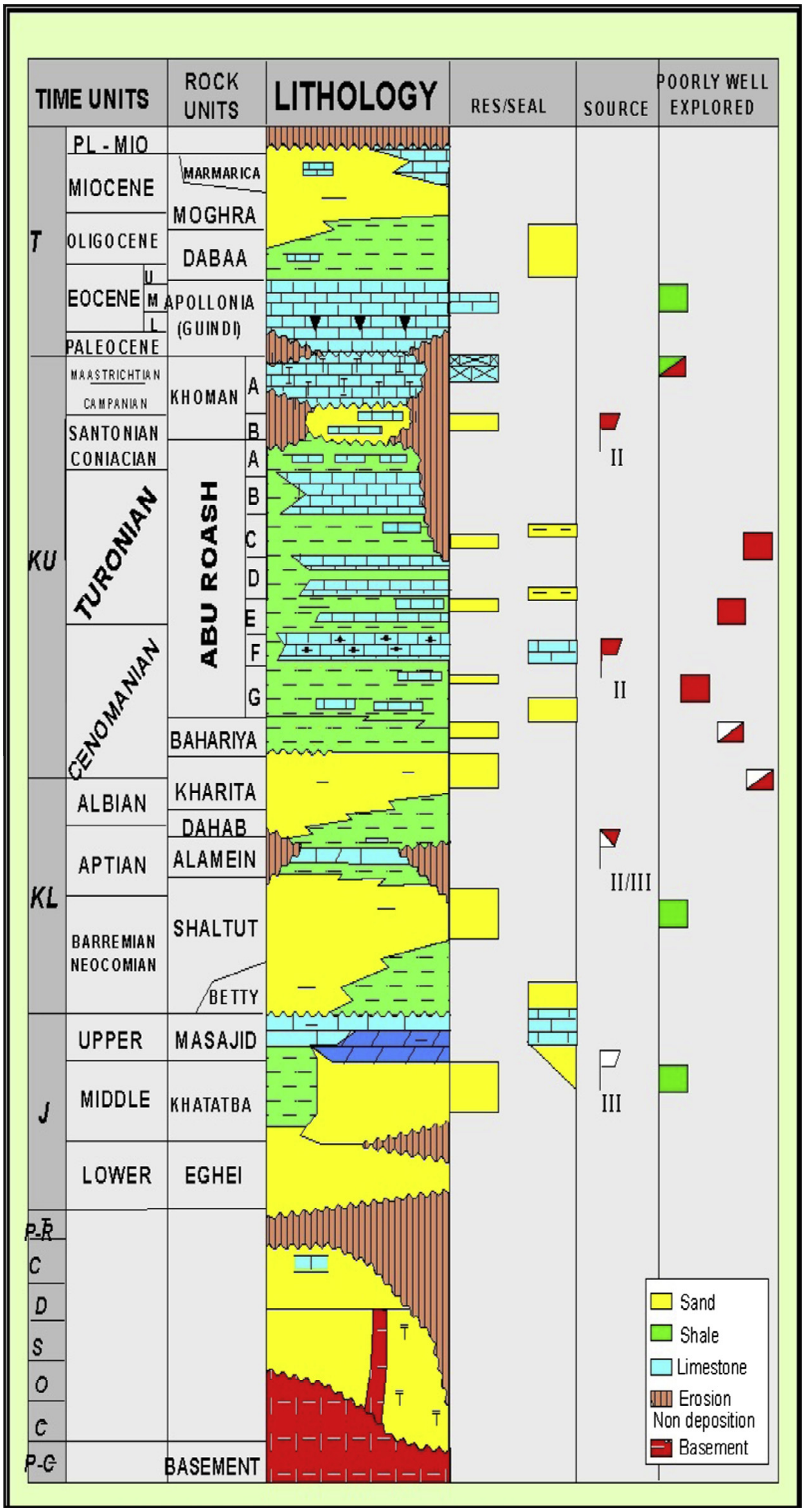

Figure 2 Stratigraphic summary of the Abu Gharadig Basin, Western Desert, showing the position of reservoir, seal and source rock horizons (Wahdan et al., 1996).

overprinted by NE trending compression ridges cut by NW normal faults. The northern margin of this basin is marked by a major border fault zone which upthrows basement to about 10,000 ft forming the Sharib–Sheiba ridge (Schlumberger, 1984).

The southern boundary of the Abu Gharadig Basin is called Sitra platform. The basin is considered to have been started during the Hercynian orogeny. The major faults of the Abu Gharadig province were initiated as simple tensional normal faults but then developed as a strong right lateral component.

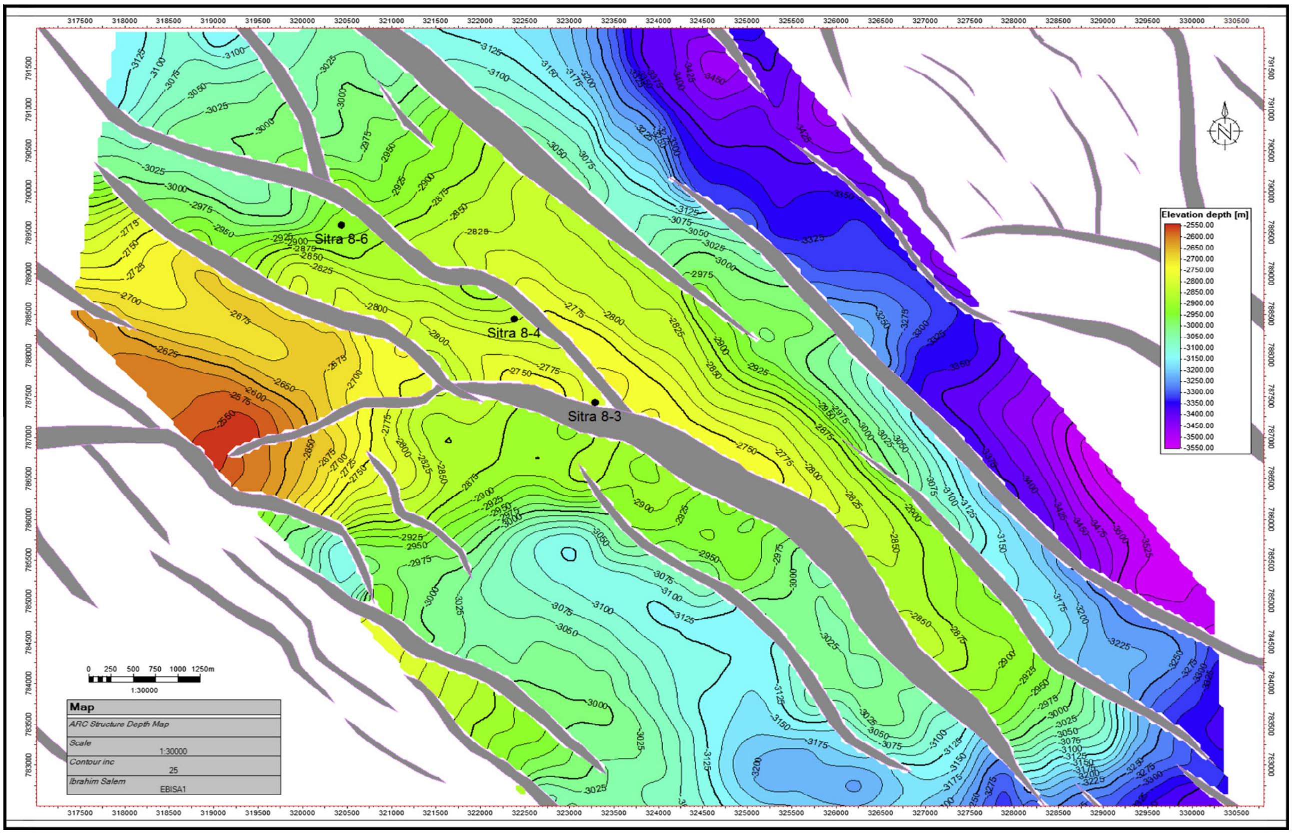

Figure 3 Structure contour map on the top of the Abu Roash C Sitra 8 Field.

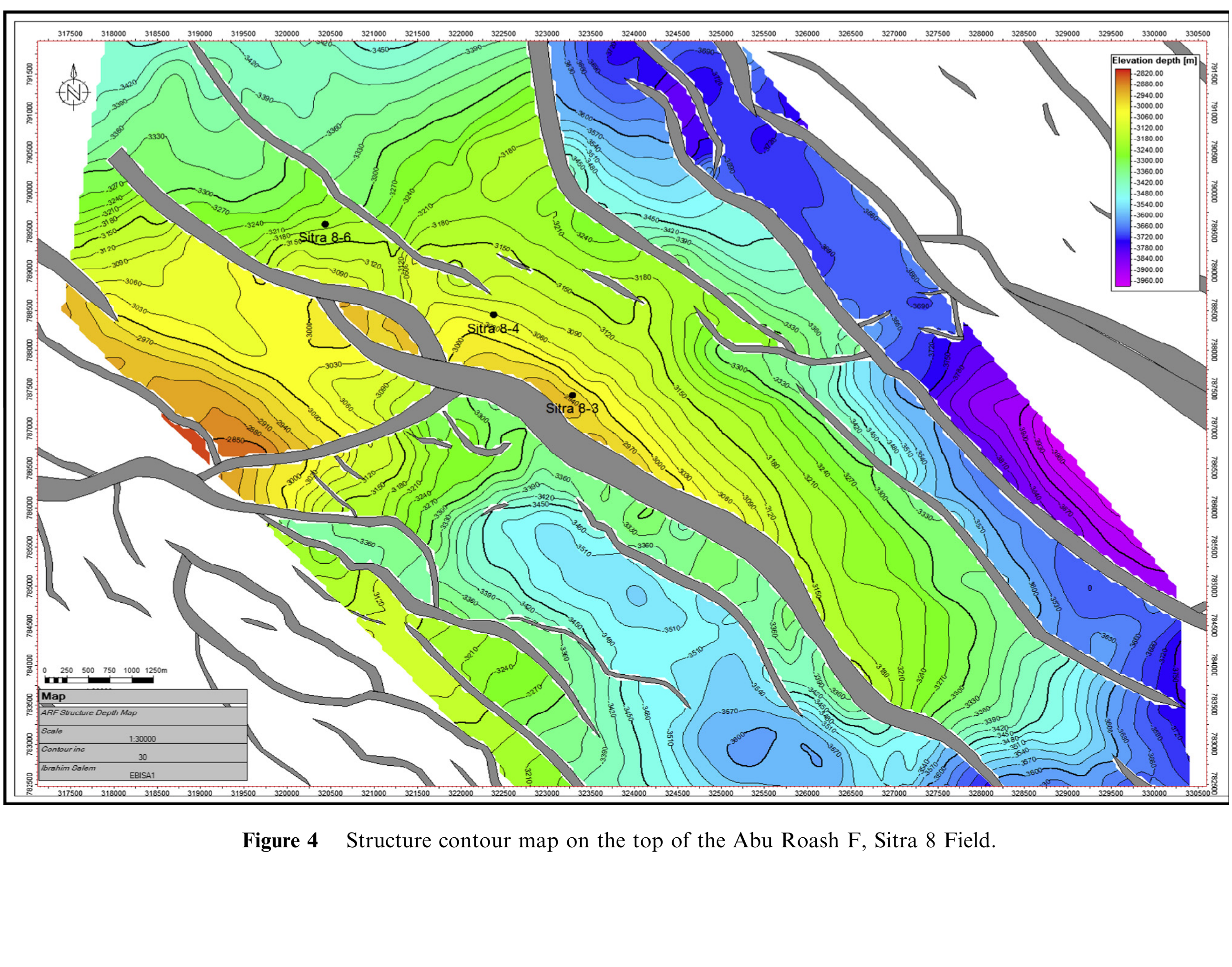

Figure 4 Structure contour map on the top of the Abu Roash F, Sitra 8 Field.

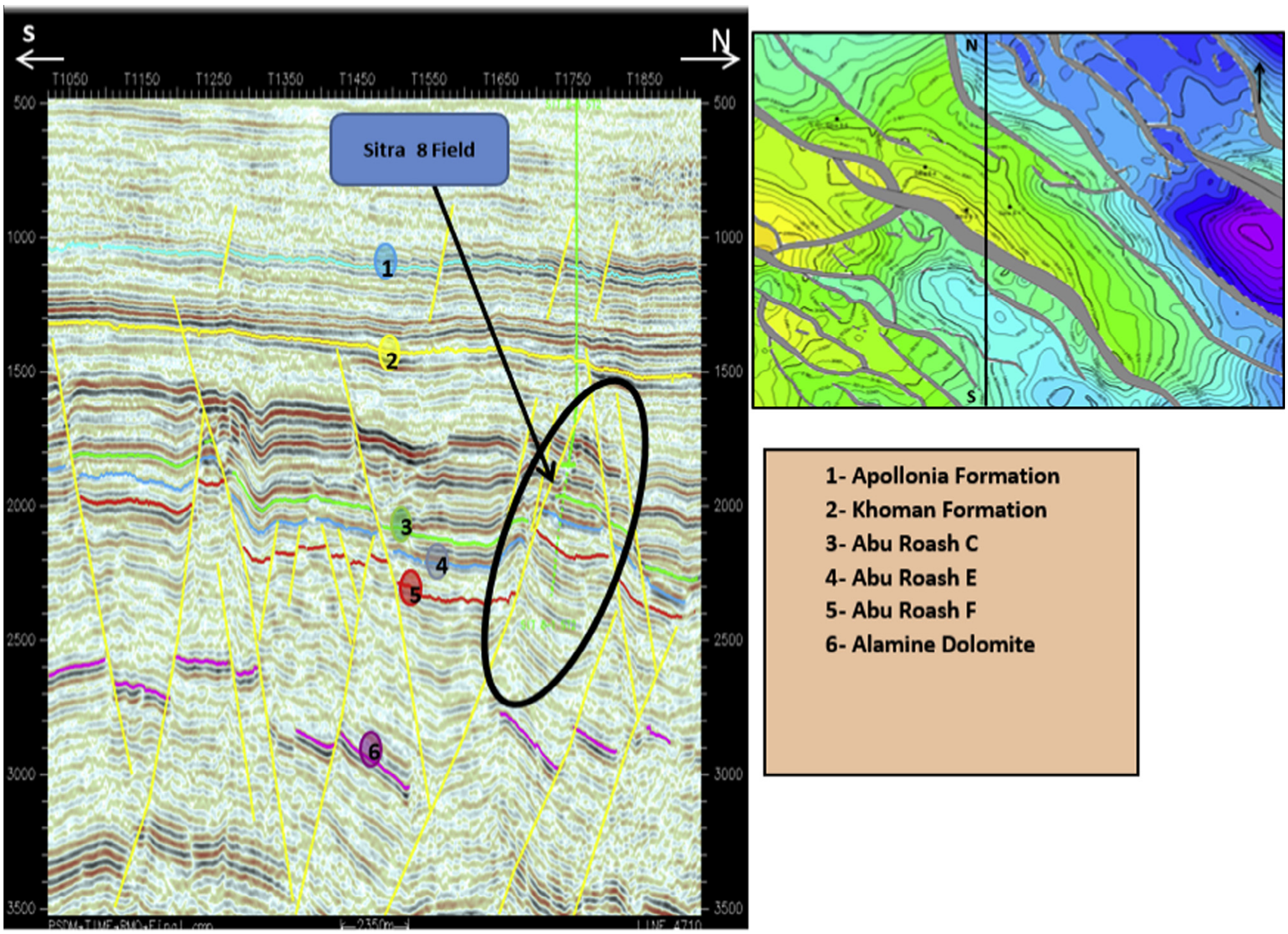

Figure 5 N–S seismic line (4710) through Sitra 8 Field.

This may be resulted from a stress pattern which relates to the opening of the North Atlantic from Turonian times (90 Ma) to Paleogene (60 Ma). Accordingly, a complete reversal of tectonic style resulted, with dextral shear replacing sinistral shear. The NE trending anticlines were developed in direct response to a regional dextral mega shear stress. All the significant hydrocarbon discoveries to date seem to be associated with NE–SW trend (EGPC, 1992).

3. Methods and techniques

The interpretation was done by using seiswork package of land mark software based on 3D seismic survey which was acquired in 2008 for Bapetco covering the study area (Sitra and BED 3) and the maps were created by Petrel software to recognize on the structure in the area of study and to identify the main prospects in the study area and evaluate the structural framework of the subsurface formation utilizing TWT and structural contour maps.

Wireline logs such as gamma ray and sonic logs were used for correlation and discriminate reservoir from non-reservoir units. Neutron-Density logs were used to identify main reservoir intervals. Correlation panels were done by using landmark to evaluate reservoir intervals in the study area and study the distribution of sand.

Based on the structure contour maps that were created and the lithology information from the well data, the sealing mechanism has been done by using Allan juxtaposition diagrams.

4. Results and discussion

4.1. Seismic data interpretation

The evaluation work was carried out on the pre stack time migration (PSTM) processed 3D seismic data (2008/2009), and the total interpreted area approximately amounts to 700 km^2. The interpretation of seismic data was done for two horizons, and well to seismic matches were done using the Sitra 8 wells. Two seismic reflectors were interpreted and mapped which are Abu Roash C and Abu Roash F. The top Abu Roash C reflector represents an acoustically hard to soft transition (soft kick) and is displayed as a positive black loop on the workstation. At Abu Roash C level, the Sitra 8 closure is bounded and dissected by several NW–SE trending faults resulting in an accumulation with several (isolated) compartments (Fig. 3). The Abu Roash F reflector is an acoustically soft to hard transition (hard kick) and is mapped on the workstation as (negative) red loop. For Abu Roash F level, the Sitra 8 accumulation is a fault/dip closure bounded to the SW by a NW–SE trending south fault as shown in Fig. 4.

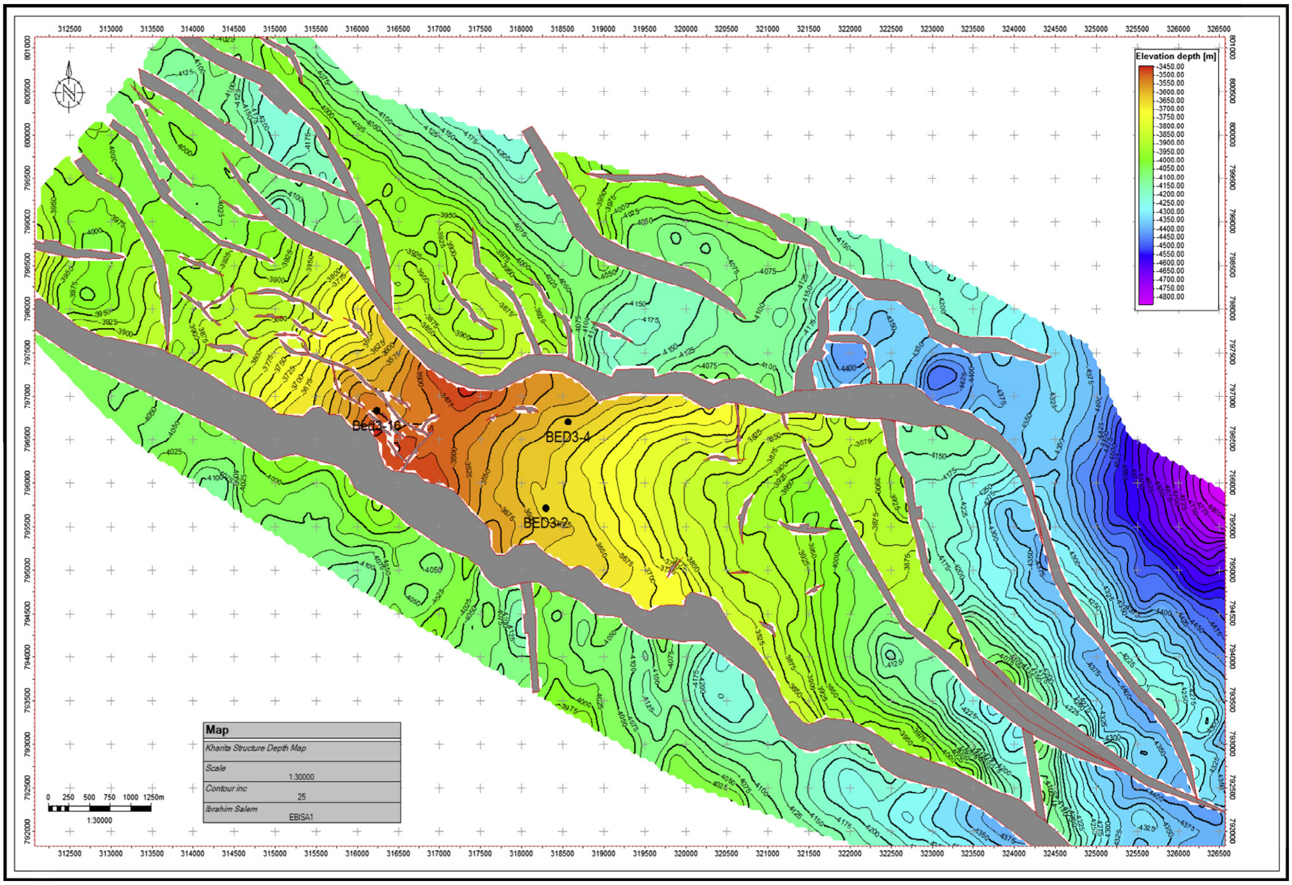

Figure 6 Kharita structure depth map in BED 3 area.

Sitra 8 Field is the main prospect in Sitra development leases. It is the largest one in the area. It is 3-way dip closure bounded by NW–SE fault. Twenty-five wells have been drilled in that field and the main target is the upper Abu Roash G sand. The closure area in Sitra 8 Field is the biggest closure in the greater Sitra areas. It is around 15 km^2 bounded by NW–SE faults. The relief of Sitra 8 closure is around 400 m.

Fig. 5 shows the structural regime of the Sitra 8 area using a seismic line that runs N–S direction. The pronounced structure that can be inferred from this line is the presence of a horst block bounded by two normal faults in NW–SE direction as a result of Cretaceous rifting (Fig. 5). Six seismic reflectors are picked on this seismic line, and these include Apollonia, Khoman, Abu Roash C, Abu Roash E, Abu Roash G and Alamein Dolomite rock units.

The main faults affect the Cretaceous sequences appear to be in two sites where the NW–SE main fault and the NE–SW minor faults present and interact with each other. The Apollonia and Khoman reflectors appear as strong and continuous, dissected with few numbers of the normal faults forming small grabens and horsts.

The structural features inherited in the reflection maps of the studied stratigraphic units reflect the Cretaceous trends of local structures that are believed to be produced as a result of comparable systems of regional structural deformations affecting the surrounding regions. The Cretaceous trend is oriented WNW–ESE, which is related and thought to be developed due to plate divergence between Africa and Asia and sea floor spreading within the Red Sea that initiated the Mediterranean Sea system of faults and folds during Late Tertiary (Azzam and El-Sherbeny, 2002).

In BED 3 field, only the Kharita horizon was interpreted over a control grid of dip and strike lines. The top Kharita reflector is an acoustically hard to soft transition (soft kick) and displayed on the workstation as a positive black loop. The top Kharita horizon was mapped over the entire BED 3 field area. The picking confidence is less over the northwestern part of the BED 3 field due to the intense and complex faulting regime (Fig. 6).

Fig. 7 is a seismic line runs in an N–S direction at the BED 3 area to show the structural in the area. The structure in BED 3 from this line is a horst block bounded by two normal faults in NW–SE direction as a result of the Cretaceous rifting (Fig. 7). Seven seismic reflectors are picked on these seismic lines, that include Khoman, Abu Roash C, Abu Roash E, Abu Roash G, Intra Bahariya, Kharita and Alamine Dolomite. The main faults affect the Cretaceous sequences and appear to be in two sites, the first, where the NW–SE main fault and the NE–SW minor faults present and interact with each other. Khoman reflector appears as strong and continuous, dissected with few numbers of the normal faults forming small grabens and horsts. BED 3 field is a NW–SE fault-bounded horst block (some 9 km long and 4 km width), which is representing an asymmetrical anticline with steeper dip in its western flank. The main accumulation of BED 3 field is in the Kharita reservoir.

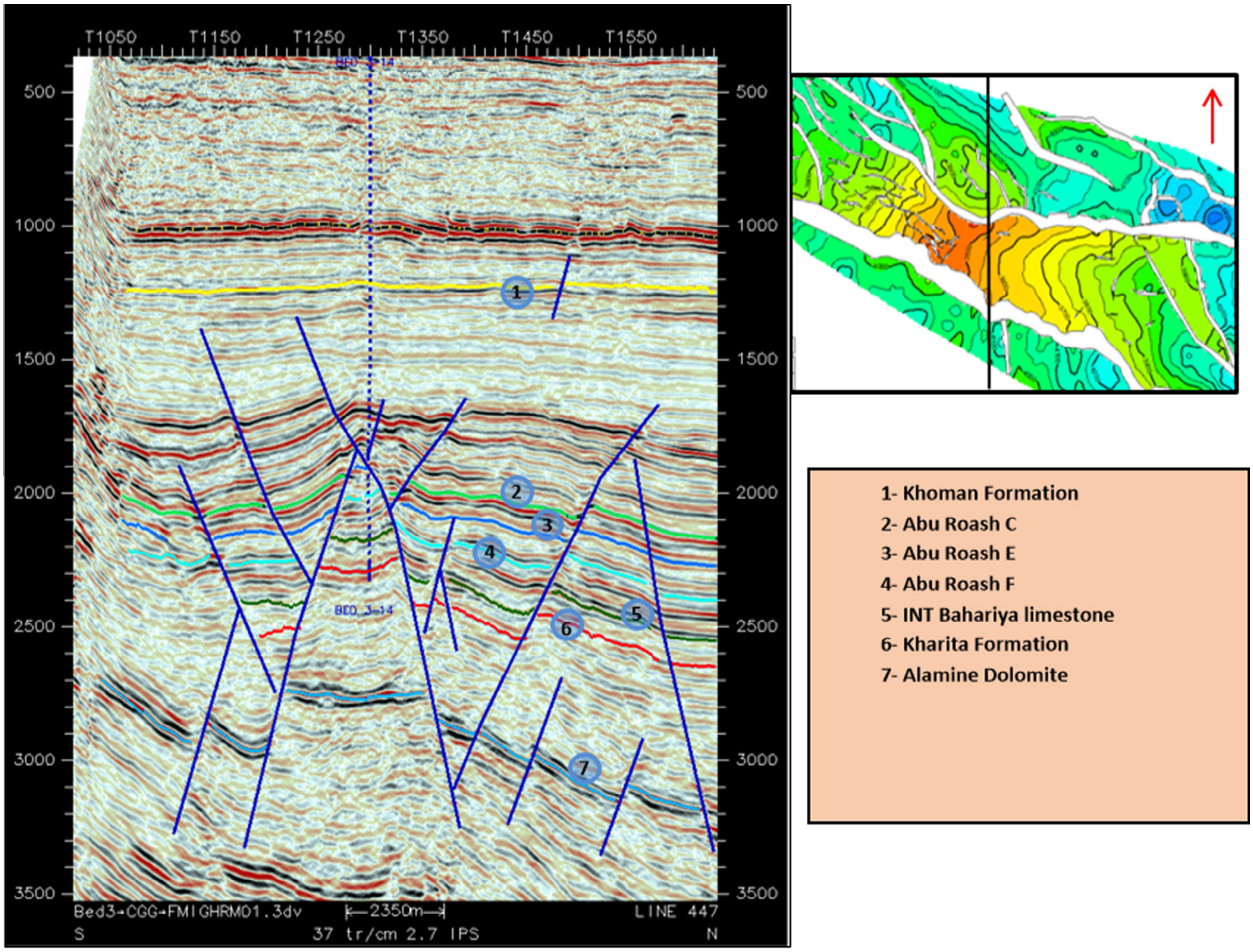

Figure 7 N–S seismic line (447) through BED 3 Field.

4.2. Reservoir evaluation

One of the most important parameter in the petroleum system is the presence of productive reservoir. So, it is necessary to know and evaluate the reservoirs in the area of study and detect which intervals act as a good reservoir for oil accumulation. The analysis of well logs is the best task for any well after drilling, to detect the reservoir rocks among all drilled successions. The well logs also help to know the physical characteristics of rocks such as porosity, water saturation, permeability, lithology, and pore geometry.

The well logging data are always used to measure thickness and depths of the productive zones, differentiate between gas, oil, or water for the reservoir, and to evaluate hydrocarbon reserves. Also, geological maps which are produced from the interpretation of logs help to determine drilling locations and facies relationships (Pirson, 1963).

The primary reservoir in Sitra 8 area is Abu Roash G sand. The thickness of the Abu Roash G Member, which was deposited during Cenomanian age, ranges between 130 and 160 m. The Abu Roash G Member is subdivided into two main units, the Upper and Middle/Lower units separated by the transgressive Intra-Abu Roash G carbonate marker which is a laterally very extensive layer in the Abu Gharadig Basin. The Abu Roash G upper sand unit is considered as the main reservoir in the studied area. The hydrocarbon bearing sand in Sitra 8 area is variable with thickness ranging from 3 m to 14 m. The net sand thickness of the lower Abu Roash G is about 5 m and considered as a hydrocarbon bearing unit (Fig. 8).

Kharita Formation composed of fine to coarse sandstone with small beds of grayish green shales with some carbonates. Although Kharita reservoir has a very good quality sand with great thickness, it is not an effective and productive reservoir in the Sitra 8 area, but it is always a water bearing zone due to the bad juxtaposition along the faults that control the trap.

The primary reservoir in BED 3 area is the Kharita reservoir and the reservoir intervals are laterally extensive and can be correlated across the area. The Kharita reservoir in BED 3 greater area can be subdivided into five main units. Kharita-A unit is the upper most reservoir unit of the Kharita Formation with gross thickness ranging from 60 to 70 m and the net sand ranging from 25 m to 35 m. Kharita-B unit is dominated by sandstone with few shale intercalations. The gross thickness of this unit ranges from 50 to 75 m and net sand ranging from 50 m to 65 m. Kharita-C unit composed of shale and siltstone with few meters of sandstone. The gross thickness of this unit ranges from 100 to 120 m. Kharita-D

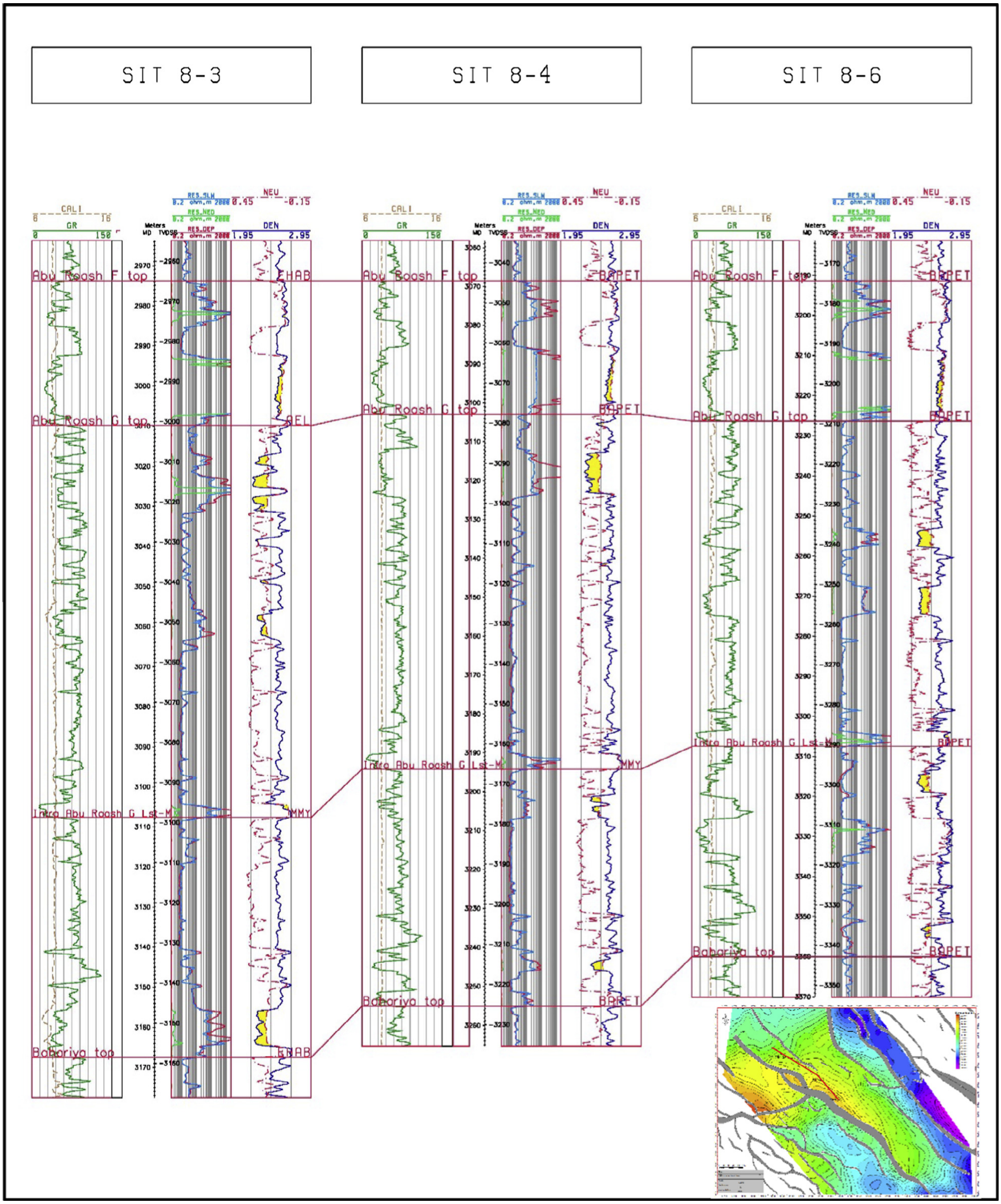

Figure 8 Correlation panel showing the main reservoir (Abu Roash G) in Sitra 8 Field.

unit composed of an alternation of clean quartz arenites separated by thin shales. The total thickness of this unit ranges from 33 to 48 m and net sand ranging from 40 m to 44 m. Kharita-E unit composed of siltstone and shales deposited in a low energy flood basin. The average thickness of this unit is 139 m. All Kharita reservoirs in BED 3 area are hydrocarbon bearing reservoirs due to the good sealing and juxtaposition along the faults (Fig. 9).

In the study area there is no problem with reservoirs because Sitra 8 and BED 3 areas have multi-reservoirs, but the problem is that some of these reservoirs are water bearing horizons.

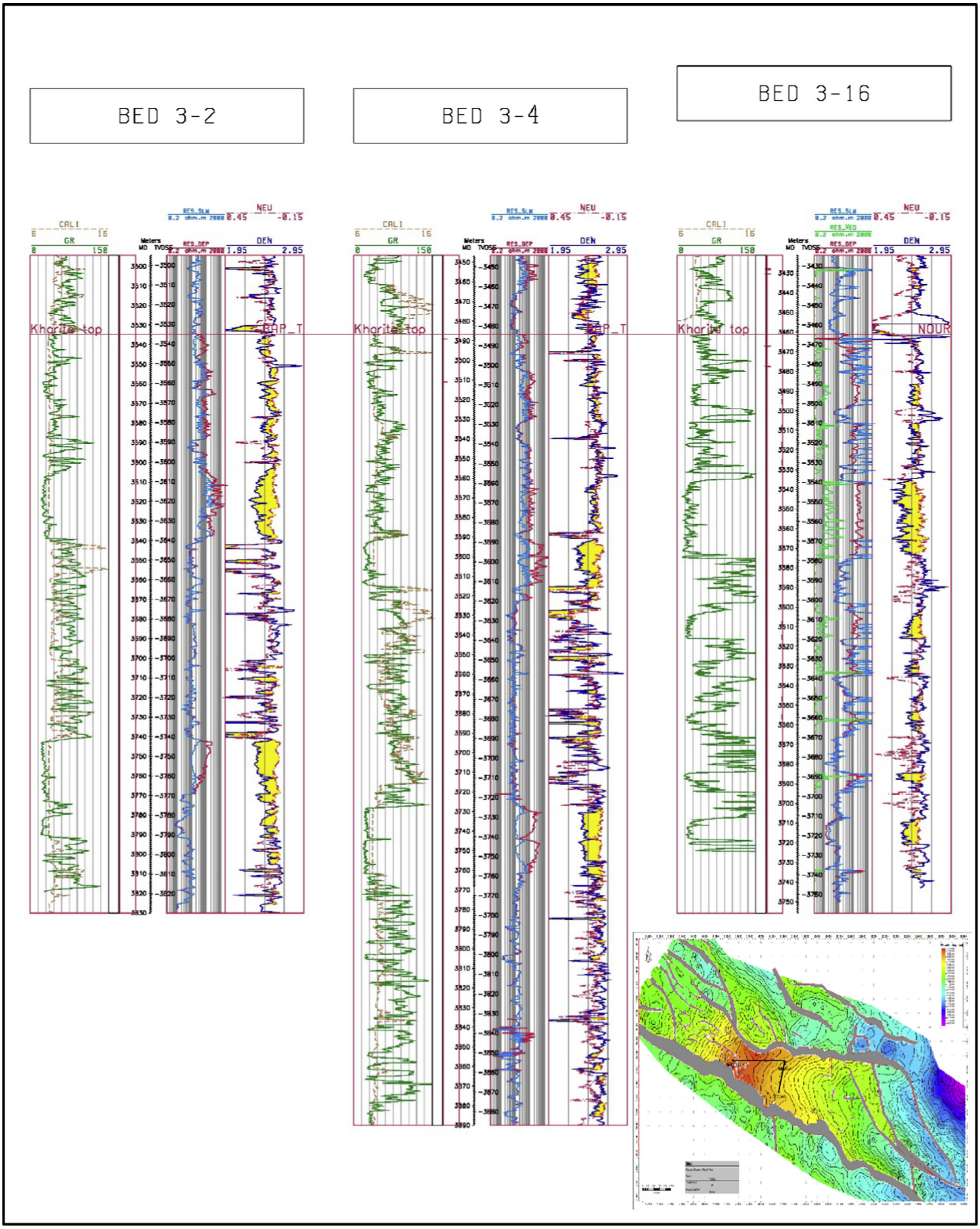

Figure 9 Correlation panel showing the main reservoir (Kharita) in BED 3 Field.

4.3. Source rock

The source rock is defined as any sedimentary rock that has the ability to expel and generate hydrocarbons to compose oil or gas accumulation. The hydrogen content of the organic matter is considered the most important factor controlling oil and gas generation (Kamali and Mirshady, 2004; Maowen, 2006).

The petroleum source rocks are generally shales that have high amounts of organic matter (Tissot and Welte, 1984).

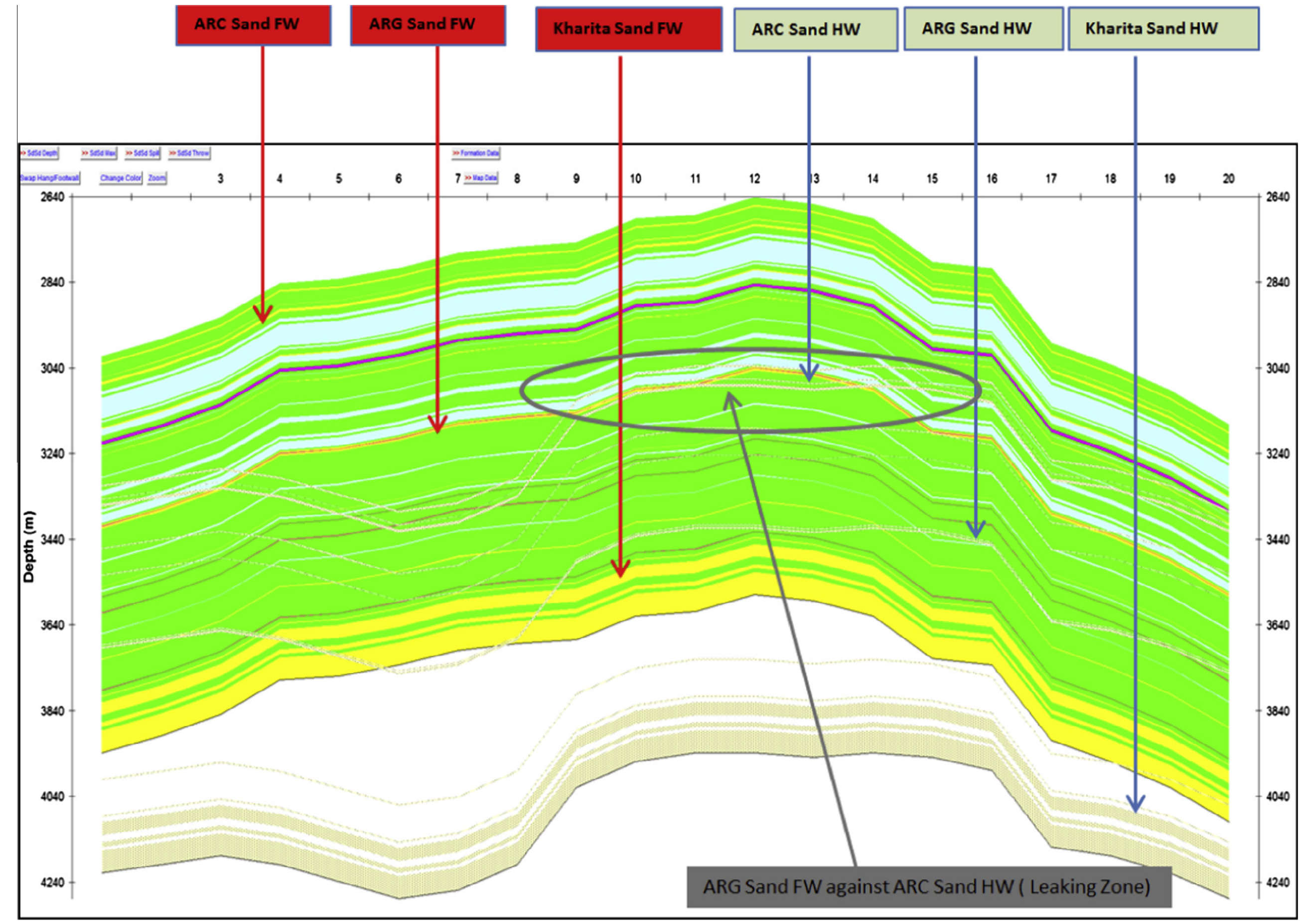

Figure 10 Allan juxtaposition diagram of the main northern fault of BED 3 Field.

Organic matter can be determined directly from laboratory analyses of shale samples, but indirect methods based on wire-line log data. The well logs that can help for source rock evaluations most generally have gamma ray, resistivity, neutron density and sonic (Serra, 1986; Herron, 1988; Luffel, 1992). The Western Desert source rocks are commonly sequences of shales associated with the carbonates of Upper Jurassic and Upper Cretaceous. Some wells have been drilled into the formation below the Mesozoic and, as a consequence, the oil potential of Paleozoic strata is very rare. The hydrocarbons of the Abu Gharadig Basin are a multi-sourced from Cretaceous, Jurassic and possibly Carboniferous rocks (Shahin, 1992).

The main recognized source rocks for the Abu Gharadig area include the "F" Member of the Abu Roash Formation and the shales of Khatatba Formation of Jurassic age. The Abu Roash F Member provided much of the oil generated in the Abu Gharadig Basin, including most of the oil present in the Sitra fields. Presence of charge has been proven by wells in BED 3 and Sitra 8. Oil charge is interpreted to be from Abu Roash F, which is mature to generate oil in Abu Gharadig Basin. Gas charge is from Khatatba, which is mature to generate gas (Shahin, 1992).

Access to charge from the kitchen area to BED 3 and Sitra 8 Fields is by migration through faults.

4.4. Sealing

The petroleum system geographic extent is defined by the occurrences of genetically related hydrocarbons that migrated from a mature source rock. The associated migration ways and related hydrocarbon occurrences, in turn, are limited by the existence of sealing rocks. So if there are no seal rocks, the hydrocarbons will escape through faults to the surface. Therefore, the seal rock is very important element of the petroleum system.

Fault sealing is now recognized as one of the most important factors controlling hydrocarbon reservoir trapping and during production (Bouvier et al., 1989; Harding and Tuminas, 1989; Knipe, 1992a; Knott, 1993; Allan, 1989; Berg and Avery, 1995). Fault seal represents a significant unknown in any prospect evaluation associated with both hydrocarbon exploration and development strategies. Characterization of the properties and distribution of structural heterogeneities, which can form barriers to fluid flow, is a prerequisite for detailed reservoir simulation. Despite the acknowledged importance of fault behavior to reservoir management and development, as well to the role of faults during hydrocarbon migration, the detailed properties of faults remain poorly defined.

Allan juxtaposition diagrams were carried out for the faults in the study area using Sitra 8 and BED 3 structure depth maps

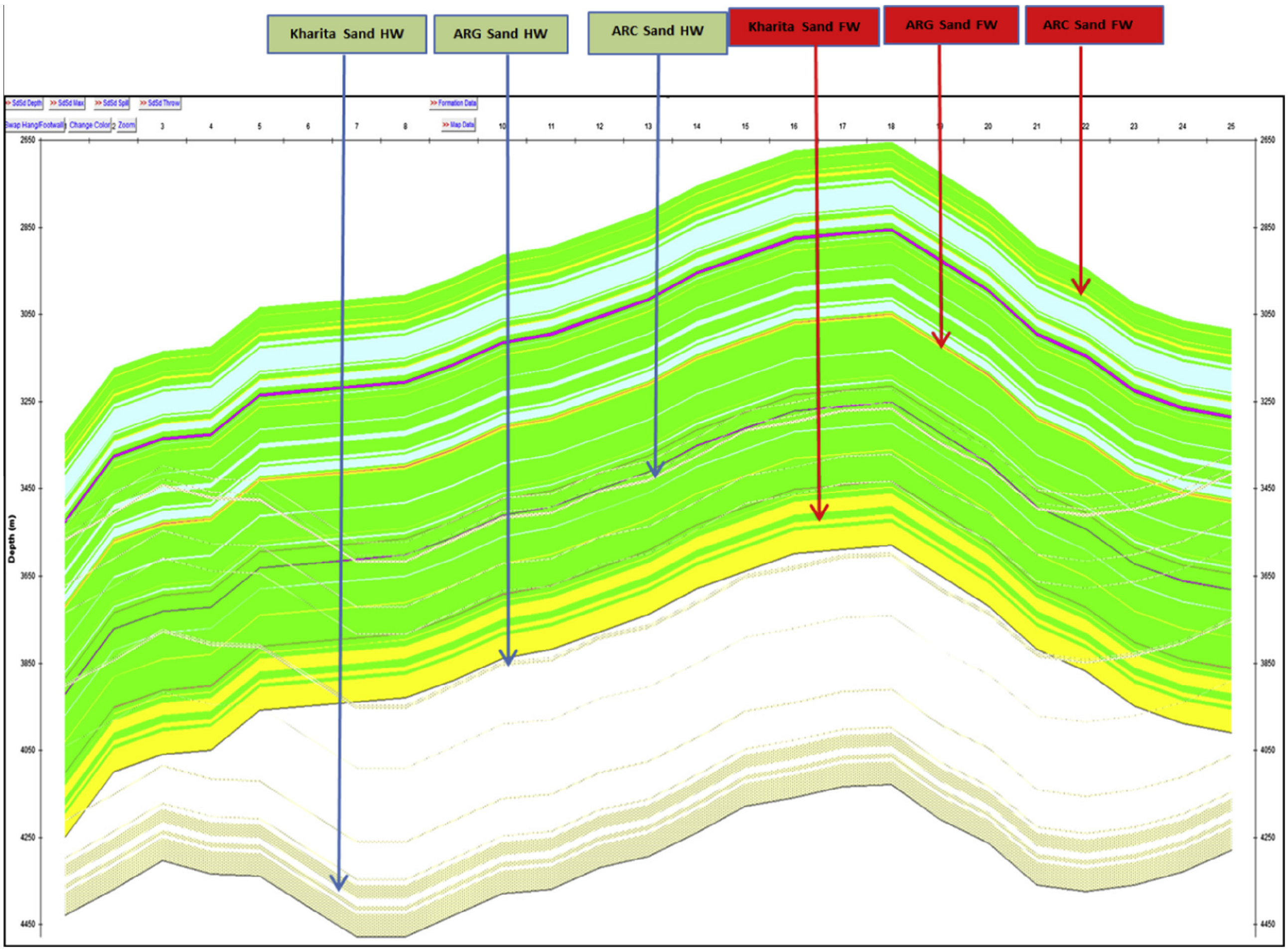

Figure 11 Allan juxtaposition diagram of the main southern fault of BED 3 Field.

to get the values of depths at both sides of the fault (hanging wall and foot wall) by moving perpendicular through this fault and also using well data to get lithologies and thickness. Fig. 10 of the main northern fault of BED 3 shows the lithology of the foot wall and the hanging wall of the fault. The foot wall lithology was colored while sand is yellow color, shale is green and limestone is light blue. The hanging wall is not colored, and only sand is dashed yellow to illustrate the leaking point. Allan diagram shows that the Abu Roash G sand reservoir on the foot wall of the fault is juxtaposing Abu Roash C sand on the hanging wall of the fault (sand juxtaposed sand) from the crest position. Potentially, this is considered as a very bad juxtaposition. It may be have a clear leaking through this fault at this point. This may explain why Abu Roash G reservoir is dry in BED 3 Field. Kharita reservoirs on the foot wall of the fault are juxtaposing upper Bahariya and Intra Bahariya on the hanging wall of the fault. Upper Bahariya is composed mainly of shale and Intra Bahariya is composed of limestone. Shale and limestone act as a very good seal rock. So, this is indicating that Kharita reservoirs on the foot wall have very good juxtaposition. For this reason, Kharita Formation is usually hydrocarbon bearing reservoir. Abu Roash G sand reservoir on the hanging wall of the fault has a very good juxtaposition while juxtaposing shale of the Bahariya Formation on the foot wall of the fault. So, Abu Roash G reservoir may be considered as an excellent target on the hanging wall of the fault if there is a trap.

Allan diagram of the southern fault of BED 3 shows that Abu Roash G reservoir has a good juxtaposition at this fault but may be leaky through the northern fault (Fig. 11). Kharita reservoirs on the foot wall of the fault are juxtaposing to the lower Abu Roash E and Abu Roash F on the hanging wall side of the fault. The lower Abu Roash E Member consists of shale whereas Abu Roash F is composed of limestone. Shale and limestone act as a very good seal rock. Furthermore, Kharita reservoirs on the foot wall have a very good juxtaposition so the hydrocarbon would be prevented from escaping along the other side of the fault. The hydrocarbon would be tapped in the closure due to the good fault sealing.

Allan's diagram of the main Sitra 8 fault (Fig. 12) shows that the Abu Roash G reservoir (main target) on the foot wall of the fault is juxtaposing Abu Roash D on the hanging wall side of the fault. The Abu Roash D is composed of limestone and shale, which acts as very good seal rock, indicating that Abu Roash G sand on the foot wall has a very good juxtaposition, so it is considered as the main target in Sitra 8 Field. Kharita reservoir on the foot wall of the fault is juxtaposing Abu Roash G sand on the hanging wall of the fault (sand juxtaposed sand) from the crest position forming a very bad juxtaposition. This may lead to clear leaking through this fault

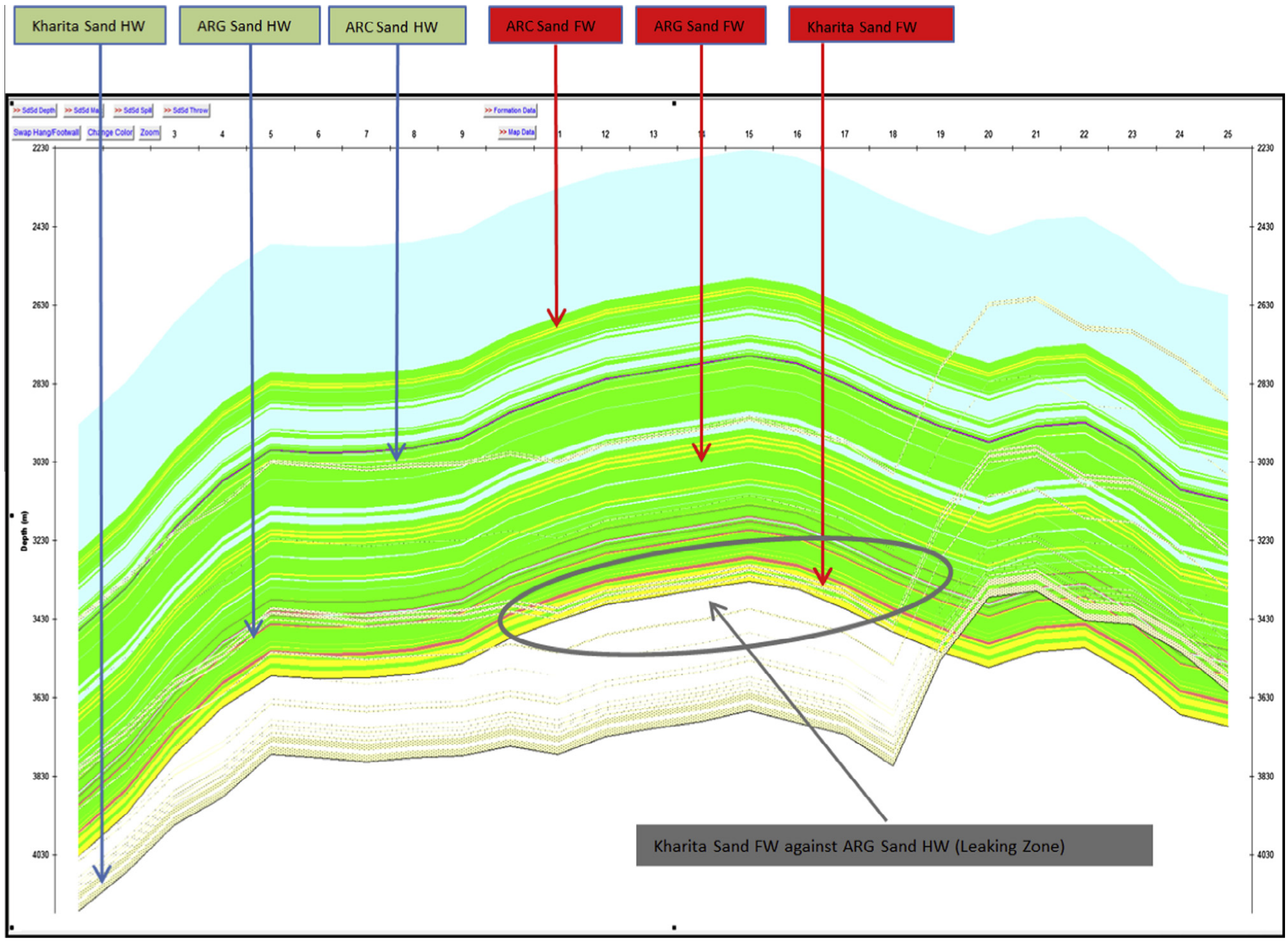

Figure 12 Allan juxtaposition diagram of the main fault of Sitra 8 Field.

at this point and explain why Kharita reservoir is dry in Sitra 8 Field. Due to the leaking from Kharita on the footwall to Abu Roash G on the hanging wall, Abu Roash G sand may be considered as a hydrocarbon bearing in the hanging wall if there is a trap. Juxtaposition mechanism can explain why Kharita reservoir is a water bearing in Sitra 8 Field and Abu Roash G reservoir is a hydrocarbon bearing. Also, it can explain why Abu Roash G reservoir is water bearing in BED 3 field and Kharita reservoir is a hydrocarbon bearing.

5. Summary and conclusions

Sitra 8 Field is the main prospect in Sitra development leases. It is a three-way dip closure bounded by a NW-SE fault. The main target is the Upper Abu Roash G sand. The closure area in Sitra 8 Field is the biggest closure in the greater Sitra areas. It is around 15 square kilometers bounded by NW–SE faults. The relief of Sitra 8 closure is around 400 m. The thickness of the Cenomanian Abu Roash G Member ranges between 130 and 160 m. The Abu Roash G Member is subdivided into two main units, the Upper and Middle/Lower units separated by the transgressive Intra-Abu Roash G carbonate marker, which is a laterally very extensive layer in the Abu Gharadig Basin. The Upper sand of Abu Roash G is considered the main reservoir in the area. The sand development within this unit is variable with sand thickness ranging between 3 m and 14 m and it is hydrocarbon bearing sand in Sitra 8 area. The net sand thickness of lower Abu Roash G is around 5 m and it is hydrocarbon bearing sand. The Abu Roash F Member provided much of the oil generated in the Abu Gharadig Basin, including most of the oil present in the Sitra fields. Oil charge is interpreted to be from Abu Roash F which is mature to generate oil in Abu Gharadig Basin. Access to charge from the kitchen area to Sitra 8 Fields is by migration through faults. Allan diagram of the main Sitra 8 fault shows that Abu Roash G reservoir (main target) on the foot wall of the fault is juxtaposing Abu Roash D on the hanging wall of the fault which is considered excellent juxtaposition. Kharita reservoir on the foot wall of the fault is juxtaposing Abu Roash G sand on the hanging wall of the fault (sand juxtaposed sand) from the crest position. This is considered very bad juxtaposition. It may be having clear leaking through this fault at this point. This may be explaining why Kharita reservoir is dry in Sitra 8 Field.

BED 3 field is NW–SE fault-bounded horst block (some 9 km long and 4 km width) which is representing an asymmetrical anticline with steeper dip in its western flank. The main accumulation of BED 3 field is in Kharita reservoir. The primary reservoir in BED 3 area is Kharita reservoir and the reservoir units are laterally extensive and can be correlated across the BED 3 area. The Kharita reservoir in BED 3 greater area can be subdivided into five main units. Kharita A unit is the upper most reservoir unit of the Kharita FM with gross thickness ranging from 60 to 70 m and net sand ranging from 25 m to 35 m. Kharita B unit is dominated by sandstone with few shale intercalations. The gross thickness of this unites ranges between 50 and 75 m and net sand ranging from 50 m to 65 m. Kharita C unit composed of manly shale and siltstone with few meters of sandstone and it separated between Kharita B reservoir and Kharita D. The gross thickness of this unit ranges from 100 to 120 m. Kharita D unit composed of an alternation of clean quartz arenites separated by thin shales. The total thickness of this units ranges from 33 to 48 m and net sand ranging from 40 m to 44 m. Kharita E unit composed of siltstone and shales deposited in a low energy flood basin. The average thickness of this unit is around 139 m. All Kharita reservoirs in BED 3 area are hydrocarbon bearing reservoirs. The main recognized source rocks for the Abu Gharadig area include the Abu Roash F Member of the Abu Roash formation and the shales of the Jurassic Khatatba formation. Access to charge from the kitchen area to BED 3 and Sitra 8 Fields is by migration through faults. Allan juxtaposition diagram for BED 3 faults can explain why Kharita reservoirs are hydrocarbon bearing and Abu Roash G lacks hydrocarbon shows. Abu Roash G sand reservoir on the foot wall of the fault is juxtaposing Abu Roash C sand on the hanging wall of the fault (sand juxtaposed sand) from the crest position. This is considered very bad juxtaposition. Kharita reservoirs on the foot wall of the fault are juxtaposing upper Bahariya and intra Bahariya on the hanging wall of the fault. Upper Bahariya is composed mainly of shale and Intra Bahariya is composed of limestone. Shale and limestone act as very good seal rock. So this is indicating that Kharita reservoirs on the foot wall have very good juxtaposition. This may be explain why Kharita is hydrocarbon bearing in BED 3 Field.

Acknowledgments

The authors are grateful to the Egyptian General Petroleum Corporation (EGPC) and Badr Petroleum Company for providing the raw material and reports used in this study and permission of publication.

References

Allan, U.S., 1989. Model for hydrocarbon migration and entrapment within faulted structures. Am. Assoc. Pet. Geol. Bull. 73, 803–811.

Azzam, S., El-Sherbeny, S., 2002. Interpreting the seismic reflection data to delineate the structures and tectonics of north Sitra area Western desert Egypt. J. Appl. Geophys. 1, 1–13.

Berg, R.R., Avery, A.H., 1995. Sealing properties of Tertiary growth faults, Texas Gulf Coast. Am. Assoc. Pet. Geol. Bull. 79, 375–393.

Bouvier, J.D., Kaars-Sijpesteijn, C.H., Kluesner, D.F., Onyejekwe, C. C., van der Pal, R.C., 1989. Three-dimensional seismic interpretation and fault sealing investigations, Nun River Field, Nigeria. Am. Assoc. Pet. Geol. Bull. 73, 1397–1414.

EGPC, 1992. Western Desert, oil and gas fields, a comprehensive overview. Paper Presented at the 11th Petroleum Exploration and Production Conference, Egyptian General Petroleum Corporation, Cairo, pp. 1–431.

Harding, T.P., Tuminas, A.C., 1989. Structural interpretation of hydrocarbon traps sealed by basement normal fault blocks at stable flanks of foredeep basins and rift basins. Am. Assoc. Pet. Geol. Bull. 73, 812–840.

Herron, S.L., 1988. Source rock evaluation using geochemical information from wireline logs and cores (abs). AAPG Bull. 72.

Kamali, M.R., Mirshady, A., 2004. Total organic carbon content determined from well logs using DLogR and Neuro Fuzzy techniques. J. Petrol. Sci. Eng., 8–10

Knipe, R.J., 1994. Fault zone geometry and behaviour: the importance of the damage zone evolution. In: Abstracts of Meetings Modem Developments in Structural Interpretation. Geological Society, London.

Knott, S.D., 1993. Fault seal analysis in the North Sea. Am. Assoc. Pet. Geol. Bull. 77, 778–792.

Luffel, D.L., 1992. Evaluation of Devonian shale with new core and log analysis methods. J. Petrol. Technol., 1192–1197

Meshref, W.M., Abu El Karamat, M.S., and El Gindi, M.K., 1988. Exploration concepts for oil in the Gulf of Suez. Paper Presented at the 9th Exploration and Production Conference, vol. 1, Egyptian General Petroleum Corporation, Cairo, pp. 1–23.

Maowen, L., Stasiuk, L., Maxwell, R., Monnier, F., Bazhenova, O., 2006. Geochemical and petrological evidence for Tertiary terrestrial and Cretaceous marine potential petroleum source rocks in the Western Kamchatka coastal margin, Russia. Org. Geochem., 17–19

Pirson, S.J., 1963. Handbook of Well Log Analysis for Oil and Gas Formation Evaluation. Prentice Hall Inc., Englewood Cliffs, pp. 326–327.

Said, R., 1990a. Cenozoic. In: Said, R. (Ed.), Geology of Egypt. Rotterdam, Balkema, pp. 451–486.

Said, R., 1990b. Quaternary. In: Said, R. (Ed.), Geology of Egypt. Rotterdam, Balkema, pp. 487–507.

Said, R., 1990c. Geomorphology. In: Said, R. (Ed.), Geology of Egypt. Rotterdam, Balkema, pp. 9–26.

Said, R., 1990d. Red Sea coastal plain. In: Said, R. (Ed.), Geology of Egypt. Rotterdam, Balkema, pp. 345–360.

Said, R., 1990e. Cretaceous paleogeographic maps. In: Said, R. (Ed.), Geology of Egypt. Rotterdam, Balkema, pp. 439–450.

Serra, O., 1986. Fundamentals of well-log interpretation. In: Acquis. Log. Data, vol. 1. Elsevier, pp. 679–680.

Schlumberger, 1984. Geology of Egypt. Paper Presented at the Well Evaluation Conference, Schlumberger, Cairo, pp. 1–64.

Shahin, A.N., 1992. Undiscovered petroleum reserves in North Western Desert, Egypt. Paper Presented at the 1st Int. Confer., Geology of Arab World, GUPCO, Cairo University.

Tissot, B.P., Welte, D.H., 1984. Petroleum Formation and Occurrence. Springer-Verlag, New York, pp. 966–968.

Wahdan, M., Fahmy, M., Brekelmans, H., 1996. 3D reservoir modelling and simulation in BAPETCO: case studies from the BED 1, 2 and 3 fields, Western Desert, Egypt. In: Proceedings 13th Petroleum Conference, vol. 2, EGPC, Cairo, pp. 250–260.