



# Deducing the subsurface geological conditions and structural framework of the NE Gulf of Suez area, using 2-D and 3-D seismic data



Hesham Shaker Zahra <sup>a,\*</sup>, Adel Mokhles Nakhla <sup>b</sup>

<sup>a</sup> Department of Geology, Faculty of Science, Banha University, Egypt

<sup>b</sup> Petropel oil company, Egypt

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## KEYWORDS

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data;  
Step faults

**Abstract** An interpretation of the seismic data of Ras Budran and Abu Zenima oil fields, northern central Gulf of Suez, is carried out to evaluate its subsurface tectonic setting. The structural configuration, as well as the tectonic features of the concerned area is criticized through the study of 2D and 3D seismic data interpretation with the available geological data, in which the geo-seismic depth maps for the main interesting levels (Kareem, Nukhul, Matulla, Raha and Nubia Formations) are depicted. Such maps reflect that, the Miocene structure of Ras Budran area is a nearly NE–SW trending anticlinal feature, which broken into several panels by a set of NWSE and NE–SW trending faults. The Pre-Miocene structure of the studied area is very complex, where Ras Budran area consists of step faults down stepping to the south and southwest, which have been subjected to cross faults of NE–SW trend with lateral and vertical displacements.

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## 1. Introduction

Ras Budran field is located in the northern of Abu Rudeis off-shore area, approximately 4 km from the eastern coast of the Gulf of Suez at a water depth of about forty-two meters. Appraisal drilling of EE85-2, RB-C1 and RB-A1 wells confirmed the presence of a major field with estimated seven

hundred million-barrels of oil-in place. The field, which developed from three wellhead platforms, has been producing since 1983. To date, twenty-nine wells have been drilled in the area.

Abu Zenima field is located between the oil fields of Rudeis–Sidri, October and Ras Budran. The concession occupies an area of almost 180 km<sup>2</sup> (Fig. 1). In this concession, twelve wells are drilled without any commercial discovery. South east Abu Zenima development lease by Petrobel occupies an area of 14 km<sup>2</sup> in the South eastern corner of Abu Zenima exploratory concession, between Ras Budran and Rudeis–Sidri oil fields, where two producing wells were drilled (AZ 13-1 and AZSE-1).

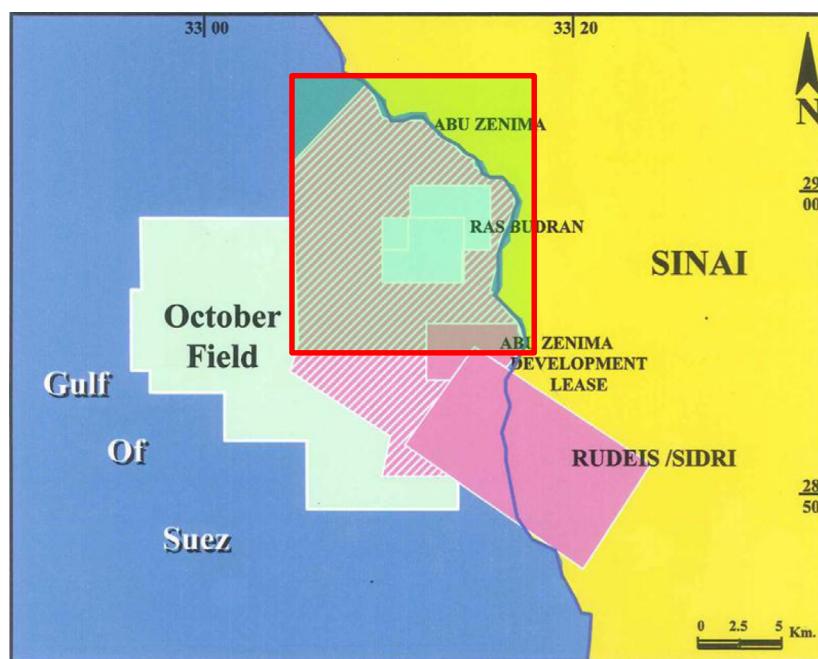
Abu Zenima area is covered by about 1500 km of 2D seismic lines acquired by GUPCO and SUCO companies in 1976, 1979, 1988 and 1989. The reprocessing of 86 seismic lines for a

\* Corresponding author.

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**Figure 1** Location map of the study area.

total of 1050 km started in August 1994 and was completed in March 1995, to improve the quality and resolution of both the Miocene and Pre-Miocene reflectors, to get a better definition of the structural elements and to attenuate the multiples in a good way.

The 2D and 3D seismic surveys were performed in Ras Budran area. Due to the poor quality data, the deepest continuous and reliable seismic event was always believed to be the top Kareem or top Rudeis. The interpretation of the 3D deep marine survey (1980) showed that, this survey was not reliable. The seismic interpretation of the new 3D survey was performed at 1997. The discrepancy between the seismic prognosis and the actual well results indicates that, even the last 3D interpretation is still not reliable.

The geophysical problems in Ras Budran area are due to small acoustic impedance contrasts at all levels below top Rudeis, the absorption of most seismic energy at the shallow evaporitic sequence and the difficulties with effective multiple attenuation due to the thick sequence of interbedded shales, sands, salts and anhydrite of the Miocene section.

Generally, the interpretation of the 2D seismic lines covered the investigated area on the tops of different Miocene horizons (South Gharib, Belayim, Kareem, Rudeis and Nukhul formations) showed a very good quality, as those Miocene horizons (Kareem and Nukhul formations) are easily picked and mapped over the whole area. The quality of the Pre-Miocene seismic data is fair to poor due to multiples and diffractions.

As far as the interpretation is concerned, the main problems were encountered in the imaging and definition of the Pre-Miocene horizons. All the Pre-Miocene reflectors are completely obscured by over-migrated disturbs and often, especially in Abu Rudeis, seismic horizons appear to have an opposite inclination with respect to the interpretation of the well data. The seismic interpretation allowed the production, by means of the workstation based on Zycor software of the

TWT contour maps. The well velocity data were used to execute the needed depth conversions.

The velocity survey data of the Miocene and Pre-Miocene rocks were detected from some drilled wells. Also, the reprocessing of seismic lines was done and achieved some improvement in the resolution of the Pre-Miocene horizons. As a result of the above mentioned steps, the picking of the Pre-Miocene horizons in most of the seismic lines was controlled by plotting the Pre-Miocene well data. The Lower Senonian and Nubia horizons were picked and mapped.

## 2. Geological setting

The stratigraphic sequence of the area under investigation represents an ideal succession of the central part of the Gulf of Suez. Such a succession is observed not only on the surface outcrops at the different locations in the eastern side of the Gulf of Suez, but also in the drilled wells scattered in the area. A sedimentary sequence ranging in age from Paleozoic to Recent with non-depositional and erosional hiatuses was penetrated in the area of consideration. Fig. 2 shows the stratigraphic column of the area, as well as the tectonic events which affected the deposition of the various rock units.

The Gulf of Suez is an elongated tectonic basin that separates the Pre-Cambrian ridge of Sinai with its overlying sedimentary platform from the main Egyptian Craton on the western side. The central part of the basin is covered by waters of the gulf, but the maritime plains on either side are blanketed by sedimentary Miocene and younger strata, that overly the Eocene and Cretaceous and probably the older rocks in depth. Several elongated fault blocks of Pre-Cambrian basement and younger sediments (Paleozoic and younger) flank both sides of the coastal strip. Throughout most of its geological history, the gulf was essentially an elongated embayment of the old Tethys

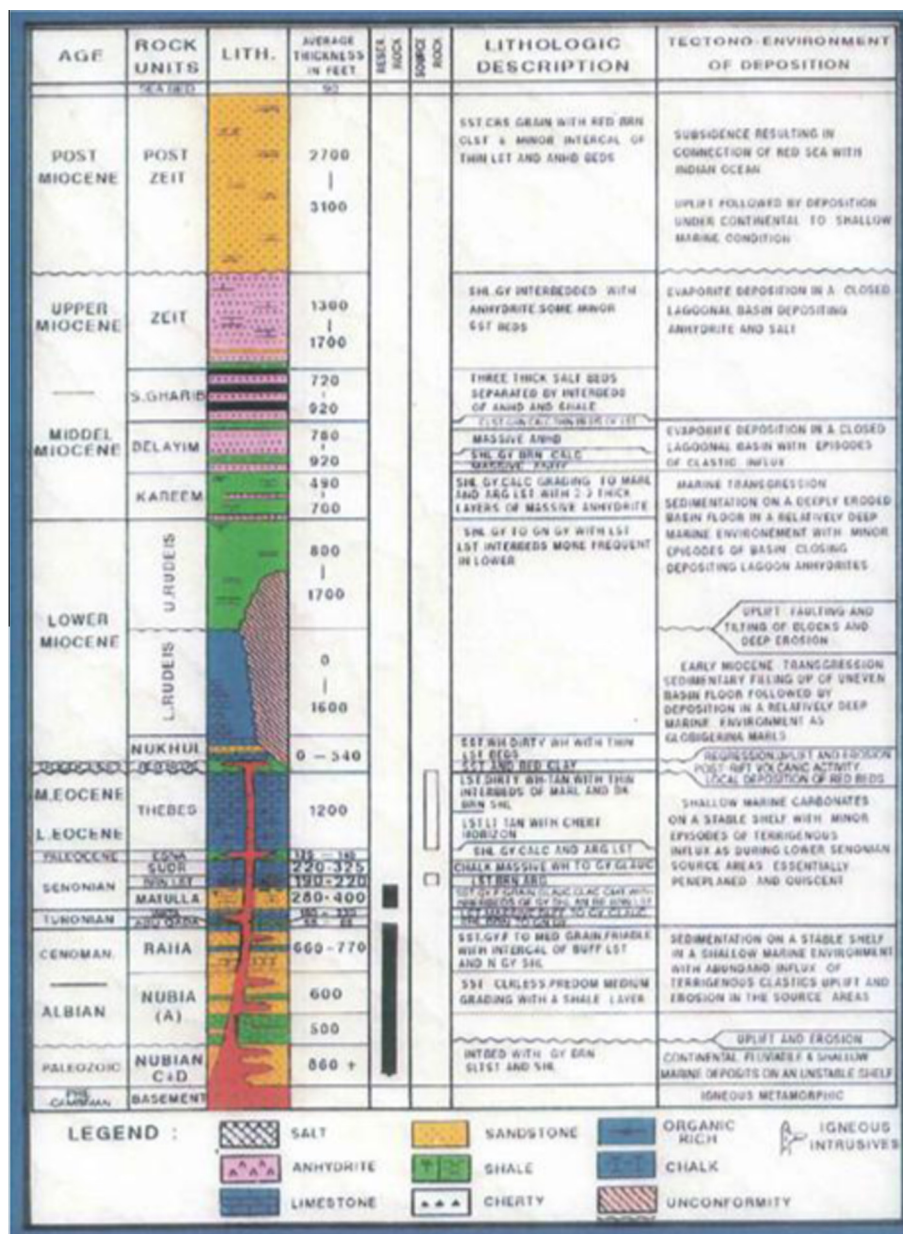


Figure 2 Generalized stratigraphic column of Ras Budran–Abu Zeneima fields.

Sea. The latter was essentially destroyed during the Pliocene phase of the Alpine orogeny and in the Pleistocene taphrogenic movements resulted in the present-day Mediterranean Sea and the Gulf of Suez (Abdel Gawad, 1969).

The central province of the Gulf of Suez is characterized by shallow Pre-Miocene structures bounded by east–west extensional faults (Clysmic faults), whose systems provide the up dip traps by sealing the Cretaceous and Pre-Miocene reservoirs against the syn- and post-extensional shales and evaporites. The severe erosion of these structural highs, led to a re-deposition of the sediments in the Early Miocene low areas, whereas in the Middle Miocene, reefal limestone developed on the Pre-Miocene highs.

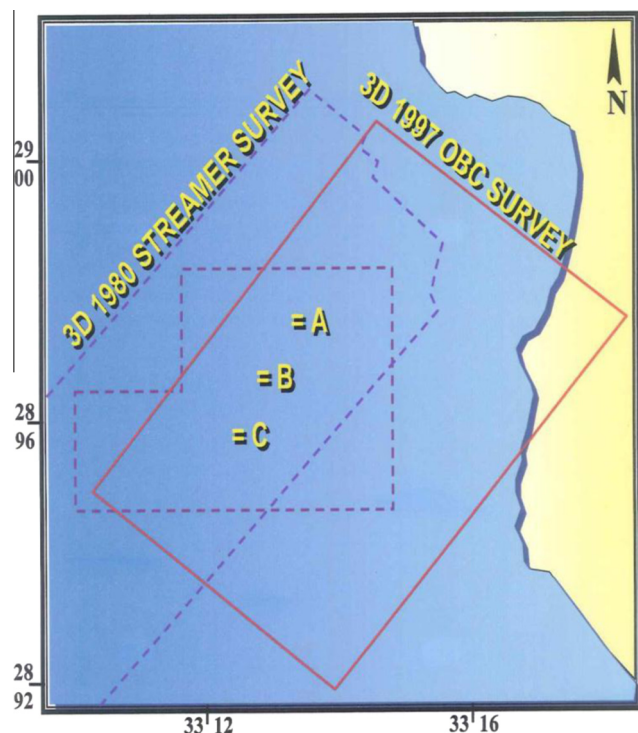
The Gulf of Suez rift is a northern branch of the Red Sea rift and elongated in a NNW–SSE direction. The geological relationship between this rift and the opened basin of the

Red Sea to the south is well known for a long time. On the contrary, only very recent works highlighted clear evidences of the northern extension of the Gulf of Suez rift in the Nile Delta offshore area (Mosconi, 1996).

Both the Suez rift and Aqaba system do not show any evidence of oceanic material, in particular the first can easily be seen as a failed arm of the Red Sea oceanic spreading. The ages of the extension in the Gulf of Suez and Red Sea are quite similar, starting from the Oligocene–Lower Miocene time. But, when the Aqaba transform zone activation decouples the two rifts (during the Middle-Late Miocene time), no more tectonic extension takes place north of the Sinai triple junction, while the extension is still active (up to day) in the Red Sea area.

The Suez continental rift results to be controlled by longitudinal normal faults and tilted blocks, offset by transverse



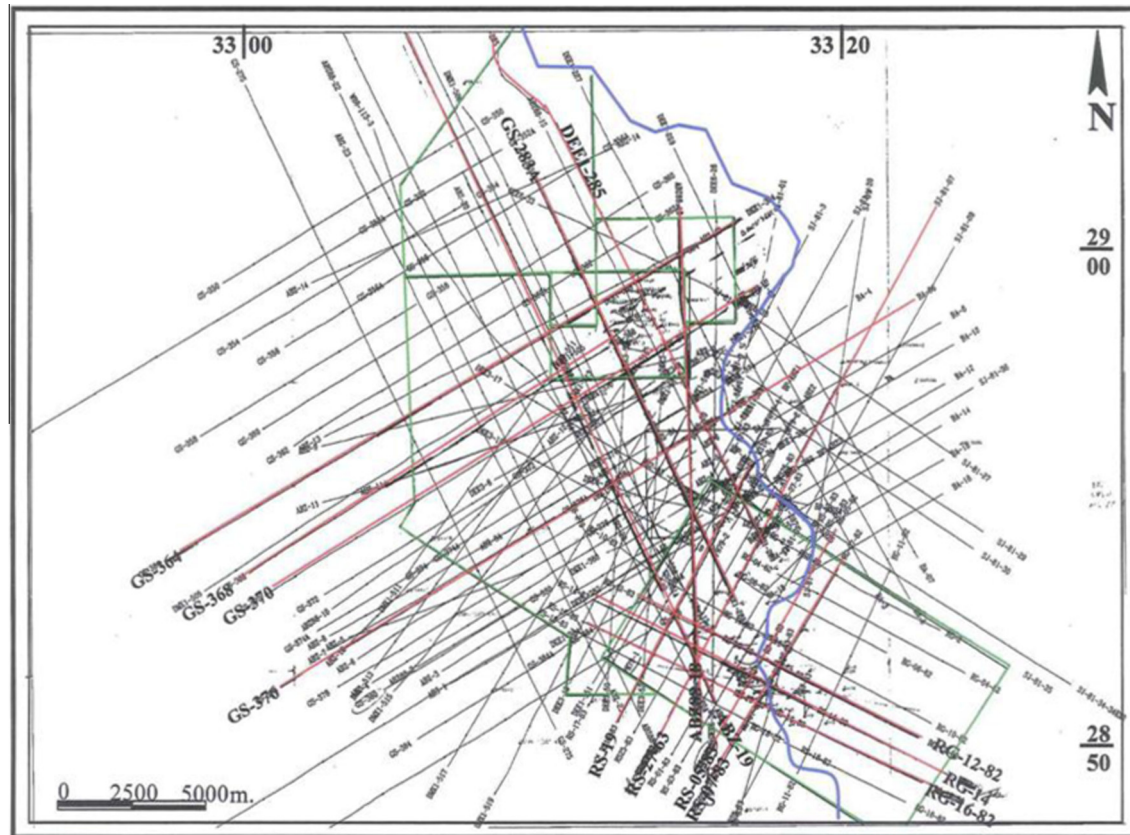


**Figure 3** Seismic base map showing the 3D surveys in Ras Budran field.

features, usually called “cross-elements”, which are responsible for the change in a symmetry in the sub-basins, and, along the “twist” (Colletta et al., 1988) or “accommodation zone” (Bosworth, 1985 and Rosendahl et al., 1986), for the change of the regional dip. The presence of two accommodation zones allows subdividing the Gulf of Suez into three provinces: the Northern and the Southern provinces with SW dip and the central with NE dip. Abdel Magid (1976) named these provinces, W Araba and Amal provinces with SW dip and Belayim province with NE dip. The central province represents one of the interesting tectonic domains, which is characterized by a long history of tectonics.

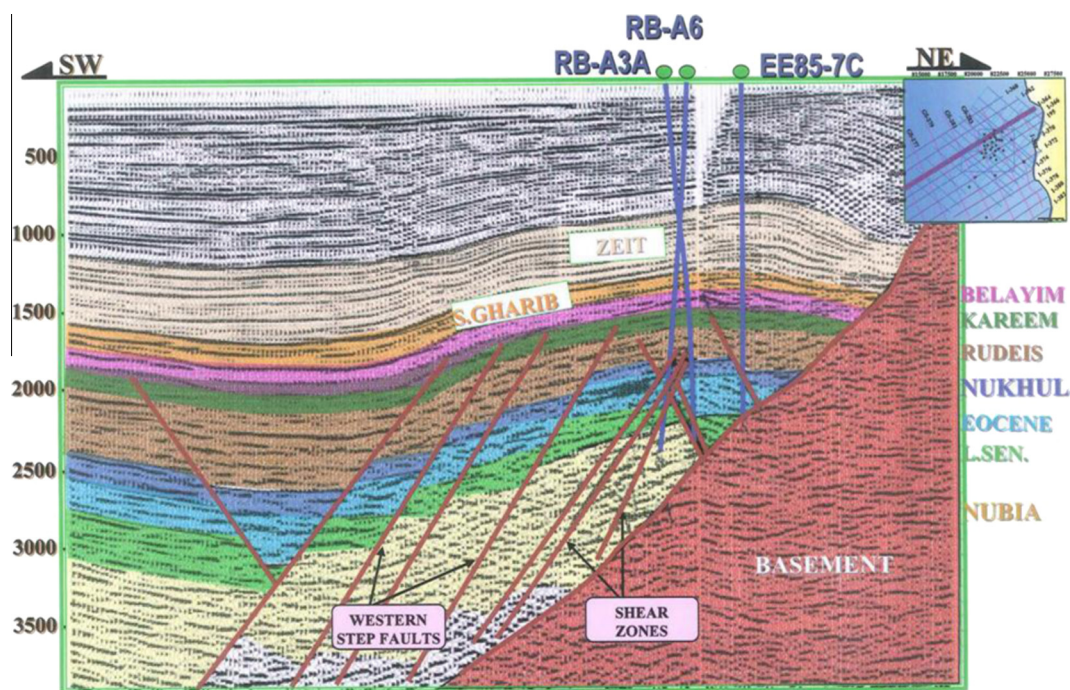
Harding (1984) made a study on the rift sequences of several basins all over the world and came up with the sedimentary sequences of the rift basins as three main depositional phases related to the tectonic history of the basins. So, the tectonic setting and depositional history of the central part of the Gulf of Suez can be classified into three major tectonic and depositional phases namely: Pre-Rift, Syn-Rift and Post-Rift tectonic phases that controlled the deposition and the sedimentary sequences in the Gulf of Suez.

*The Pre-Rift phase:* comprises the sedimentary units overlying the basement to Eocene. It is made up of initially clastic sediments associated with continental and fluvio-marine environments, which form the Nubia Sandstone sequence of Cambrian–Lower Cretaceous. This was followed by the marine sediments of Upper Cretaceous till the Late-Middle Eocene. The Nubia Sandstone indicated thickness



**Figure 4** 2D seismic base map covering the studied area, highlighted the interpreted seismic lines.



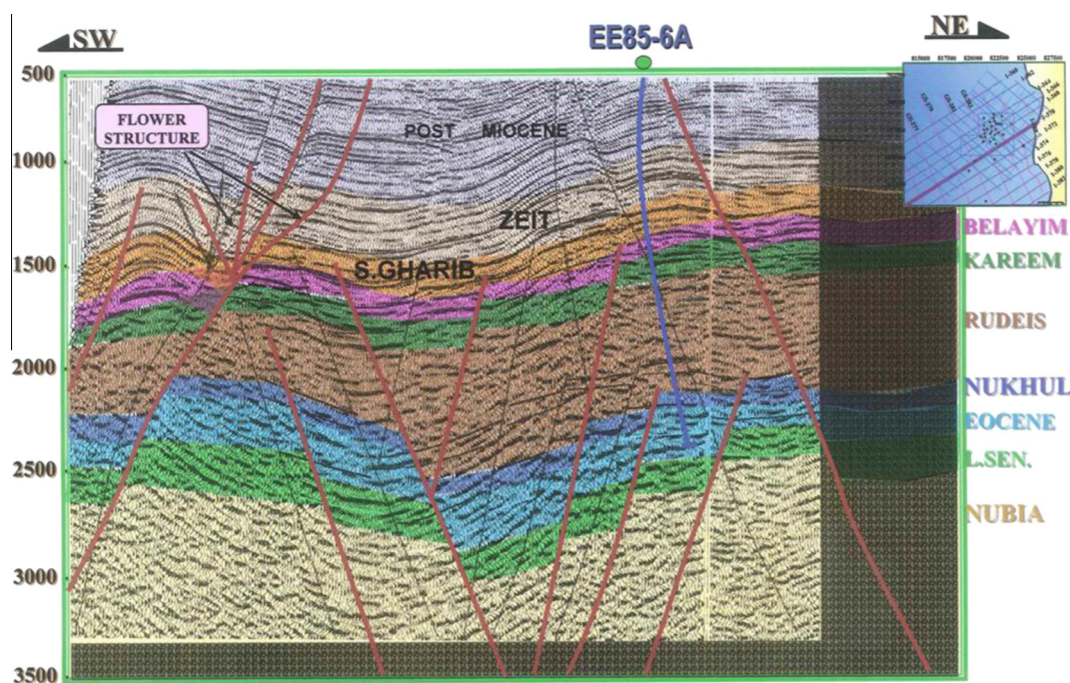


**Figure 5** Interpreted 2D seismic line (DEE1-364) in northern part of Ras Budran field showing shear zones and western step faults.

and facies changes. The Pre-Miocene sediments reveal a great homogeneity in thickness all over the central part of the Gulf of Suez. Facies changes resulting in generally more marine conditions are not related to any tectonic activity in the Suez rift (Garfunkel and Bartov, 1977). Basaltic igneous activities affected the area occurred during the Oligocene–Early Miocene are related to the initial faulting of the

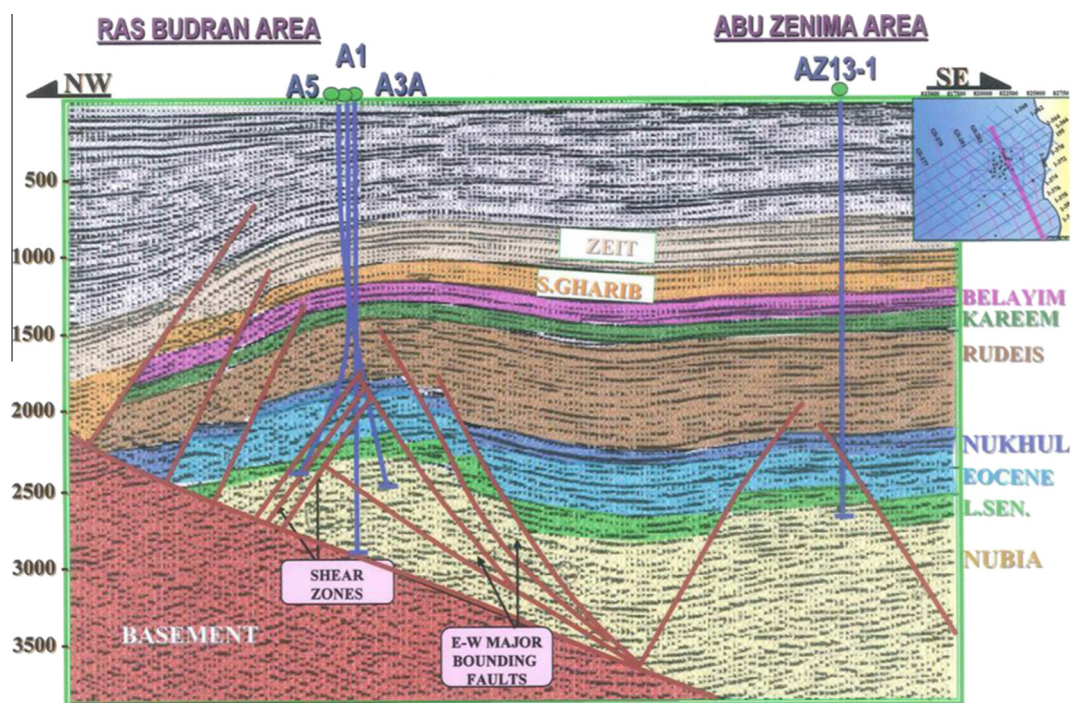
Suez rift. Dykes generally trend NW, sub-parallel to the rift trend.

*Syn-Rift phase:* Garfunkel and Bartov (1977) concluded that, the major structural characteristics of the Suez area were produced during the Miocene and only moderately modified by the later movements. The rifting that formed the Gulf of Suez graben occurred during the Oligocene.

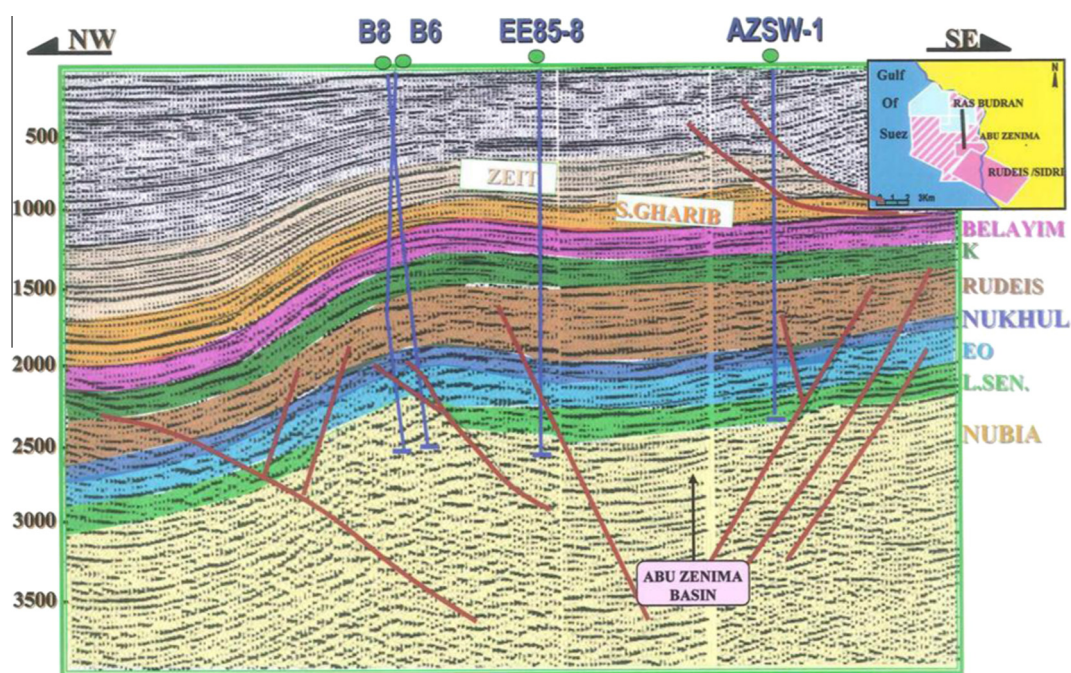


**Figure 6** Interpreted 2D seismic lines (GS-370 and DEE1-370) between southern part of Ras Budran field and Abu Zenima basin. It shows the western flower structure.





**Figure 7** Seismic line (DEE1-285) extends in NW–SE direction between Abu Zenima and Ras Budran, showing graben between them and the shear zones affecting Ras Budran field.



**Figure 8** Seismic line (DEE1-283a) covering the western part of Ras Budran and showing Abu Zenima basin separated between Ras Budran and Abu Rudeis.

Normal faulting occurred in multiple stages. Initial pervasive stretching resulted in relatively closely spaced faults, with predominantly moderate displacement. The faulting was accompanied by the rotation of the fault blocks, causing deep erosion at some block edges (Harding, 1984).

However, the tectonic activity during this pre-mid Cyclic phase was moderate, resulting in a low-relief basing floor. The basal Miocene marine sediments (Nukhul Formation) lie on the Middle Eocene (Thebes Formation) or younger rocks. By the Early Miocene, the rift system



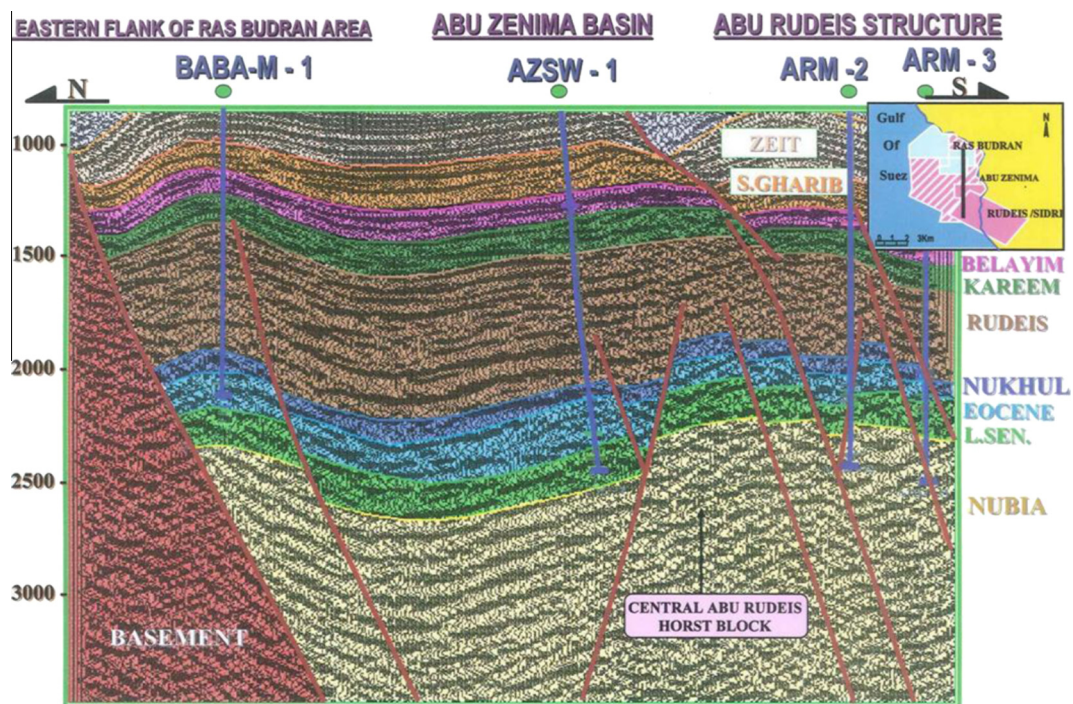


Figure 9 Regional 2D seismic line (ABZ88-18) extends through Ras Budran–Abu Rudeis area.

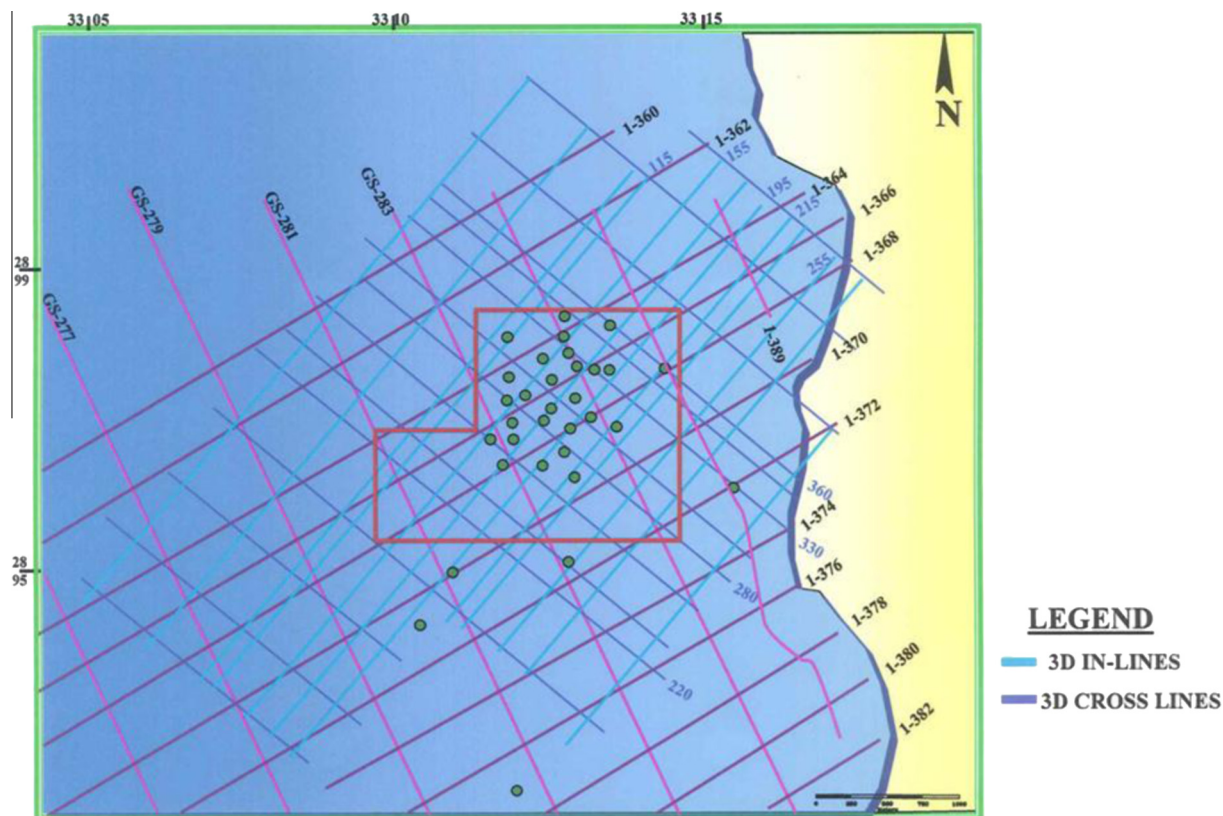
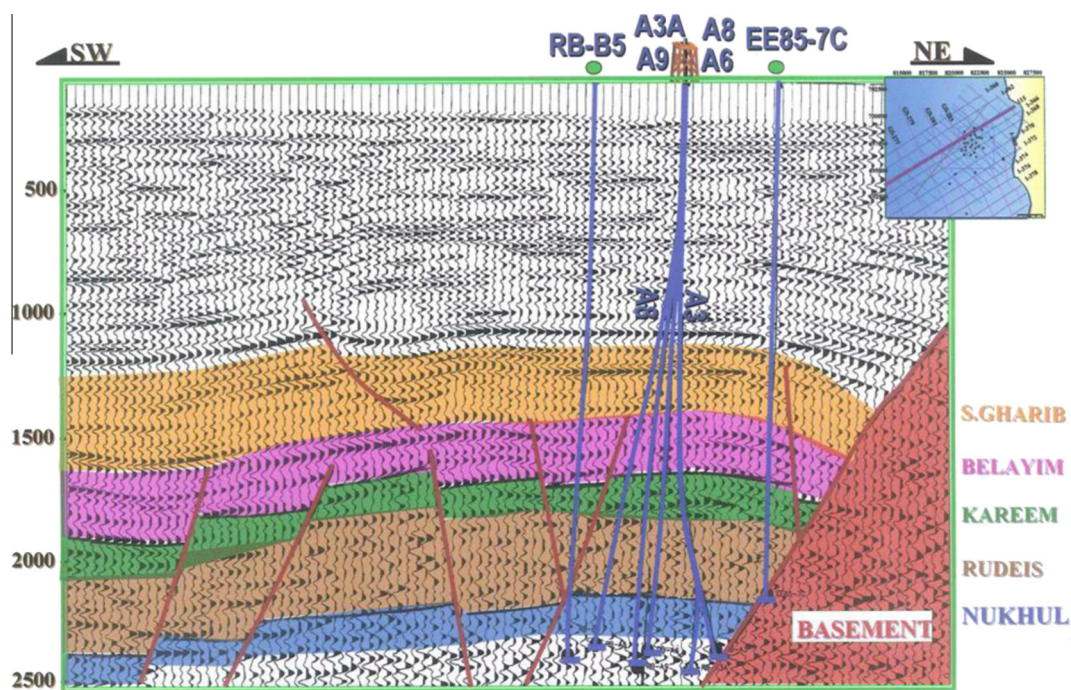
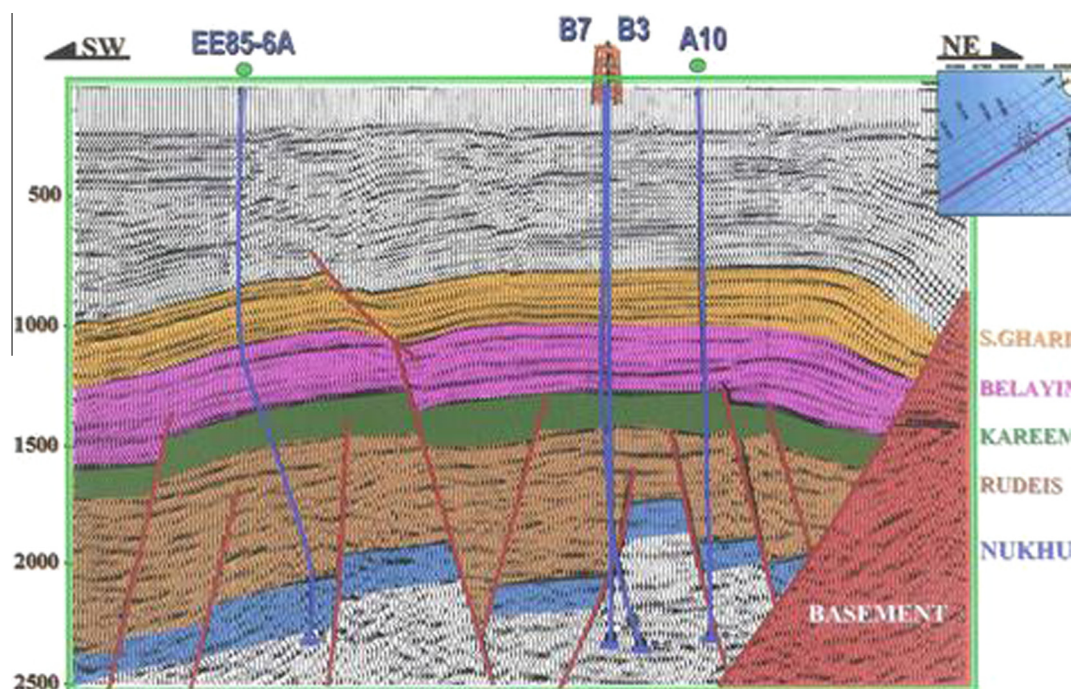


Figure 10 3D seismic base map of Ras Budran field showing the locations of interpreted key seismic lines.





**Figure 11** Interpreted 3D seismic in-line 115 which covers the north western portion of Ras Budran field.



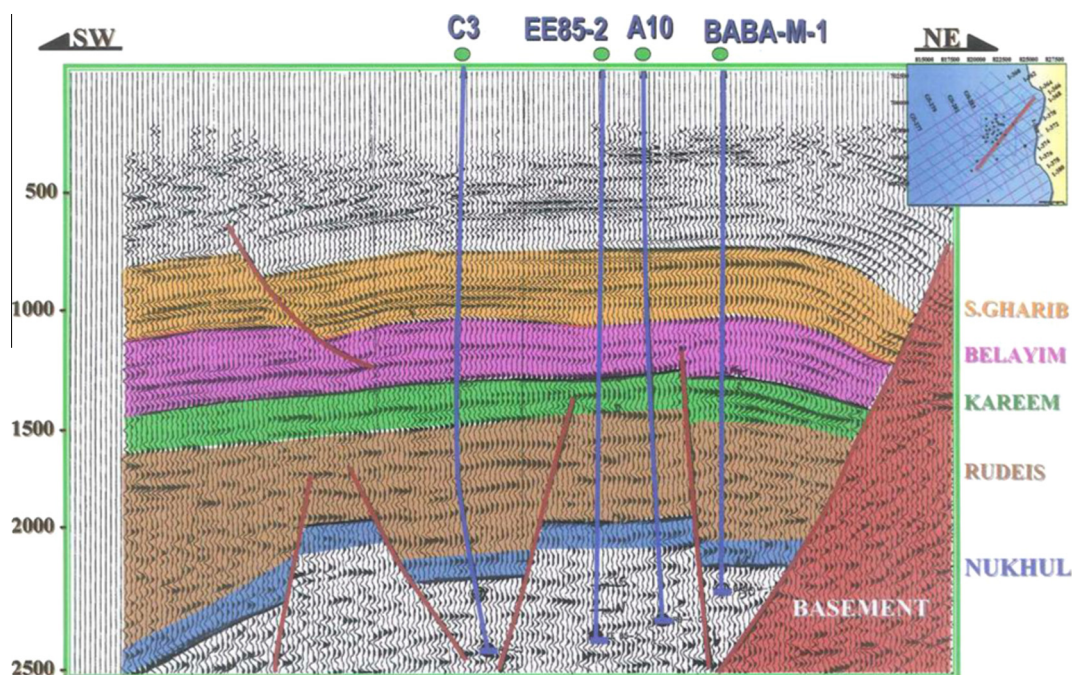
**Figure 12** Interpreted 3D seismic in-line 195 which covers the south eastern portion of Ras Budran field.

was well established and had subsided enough to be inundated by the sea. Shaley-marly sediments of Early Rudeis age were deposited.

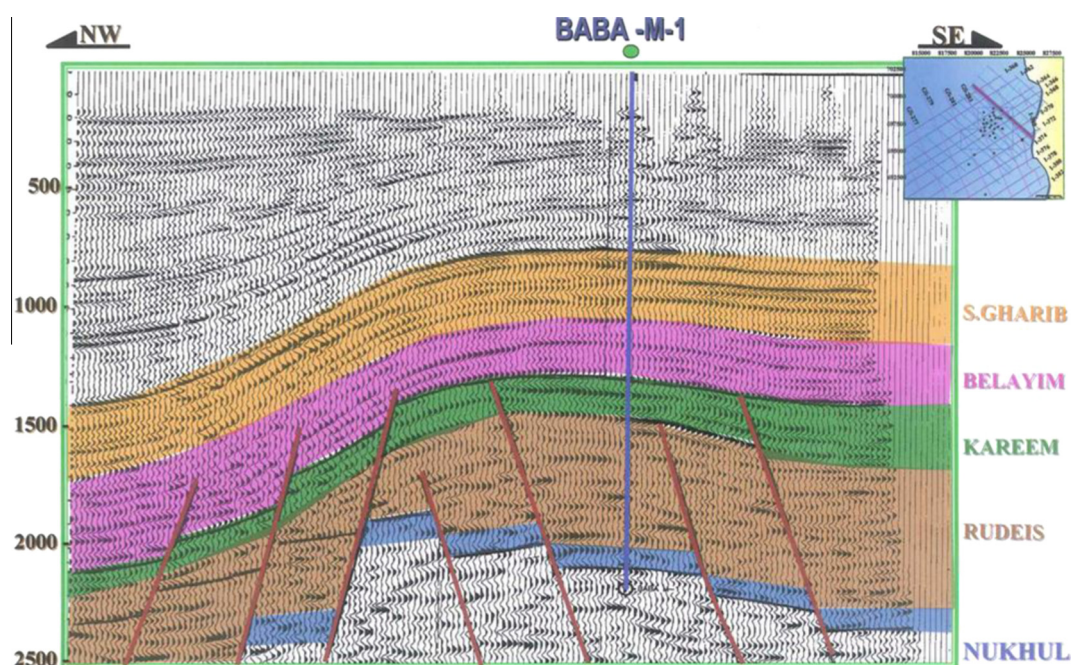
The most intense phase of tectonics within the Gulf was an intra-Rudeis (mid-Clysmic) event. As a result of this phase, the

rift shoulders were elevated and the rift was confined mainly to the central trough (Garfunkel and Bartov, 1977). The structure of the rift is dominated by major NW–SE trend (Clysmic system) and subsidiary NE–SW trending normal faults (Aqaba system). The stretching of the rift is devoid of any compressional structures (Gilboa and Cohen, 1979).





**Figure 13** Interpreted 3D seismic in-line 215 showing the drag of Miocene strata along the main bounding fault and homogeneous Kareem dip.



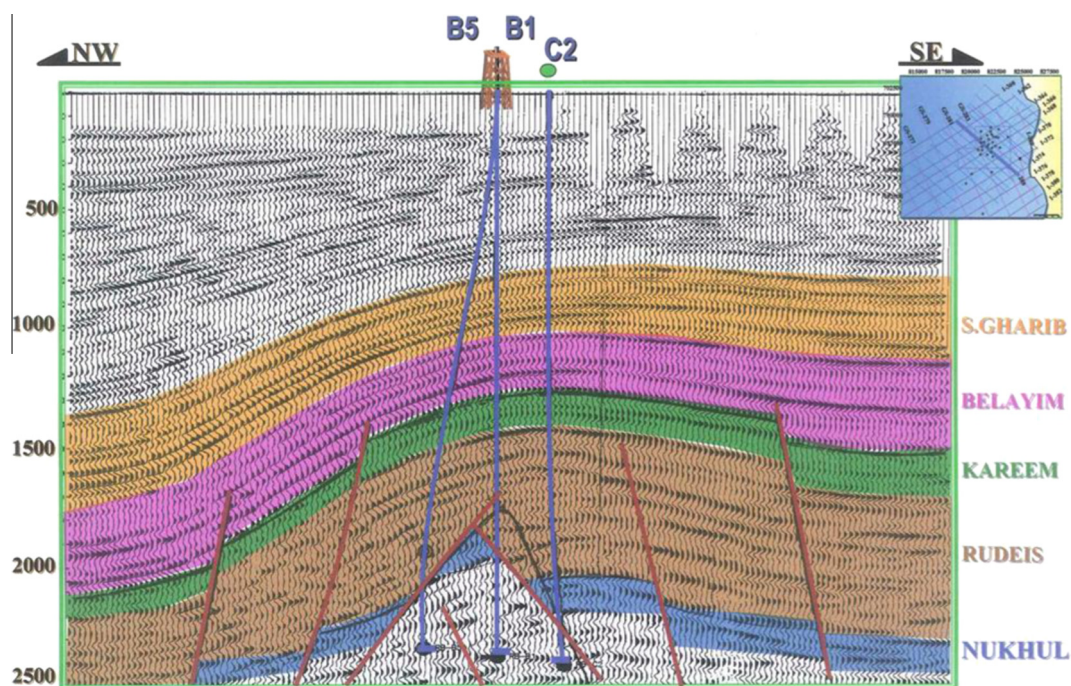
**Figure 14** Interpreted 3D seismic cross-line 360 in NW-SE direction showing the dip change of Miocene strata.

*Post-Rift phase:* It is a period of emergence and tectonic quiescence, which began in the Pliocene and many faults remained inactive. This includes the Pliocene and Pleistocene sediments that accumulated in the rift basin after the gulf activity became quiescence. These are a package of coarse clastics of sandstone and conglomeratic intercalations overlying the top Miocene unconformity surface. Most of the tectonic activity was confined in the central part of the rift and was stronger to the south.

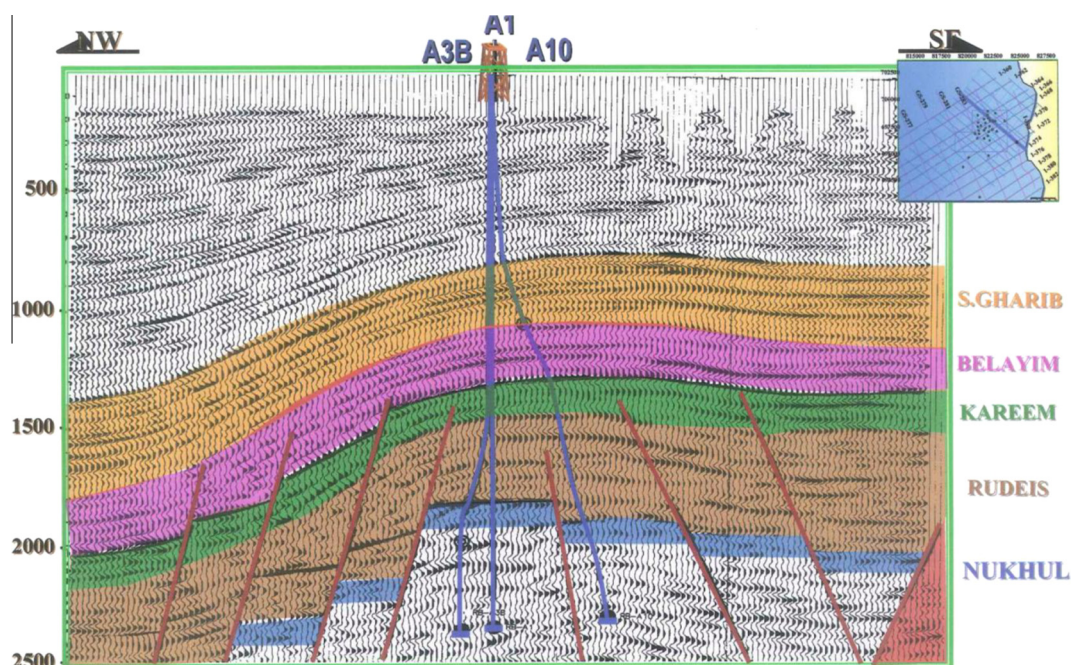
The linkage area between Baba fault system, rift coastal fault and the Master Miocene-bounding (Sidri) collateral faults represents low-stand zone overlapped by syn-rifting sediments and controlled the Miocene basin-morphology and related sedimentation (Abdel Fattah et al., 2002).

Understanding the growth, linkage and death of fault segments and reconstruction of the early rift structure has important implications for subtle trap and reservoir distribution in rift basins (Jackson et al., 2002).





**Figure 15** Interpreted 3D seismic cross-line 280 in NW–SE direction showing the thinning of Miocene strata on the structural crest.



**Figure 16** Interpreted 3D cross-line 330 showing the step faults with opposite throws creating central horst block.

### 3. Seismic data of study area

Several 2D and 3D seismic surveys were acquired in Ras Budran area from 1974 to 1997. From 1976 to 1977, additional seismic data were recorded by Deminex/BP/Shell group in an attempt to delineate the Pre-Miocene structure. The produced data quality for the Pre-Miocene section remained poor to very poor. Using flow-frequency band pass filtering (3–13 Hz) for

the final display, however, permitted structural interpretation for the deeper Pre-Miocene levels. As in many areas in the Gulf of Suez, the deepest reliably mapped horizon was the base of Belayim evaporites and top of Kareem Formation in 1977.

During 1980, a 3D deep marine seismic survey was done to cover the central, western and northwestern parts of Ras Budran field. Based on this survey, maps of the Pre-Miocene events are prepared; however, the drilling results showed that,



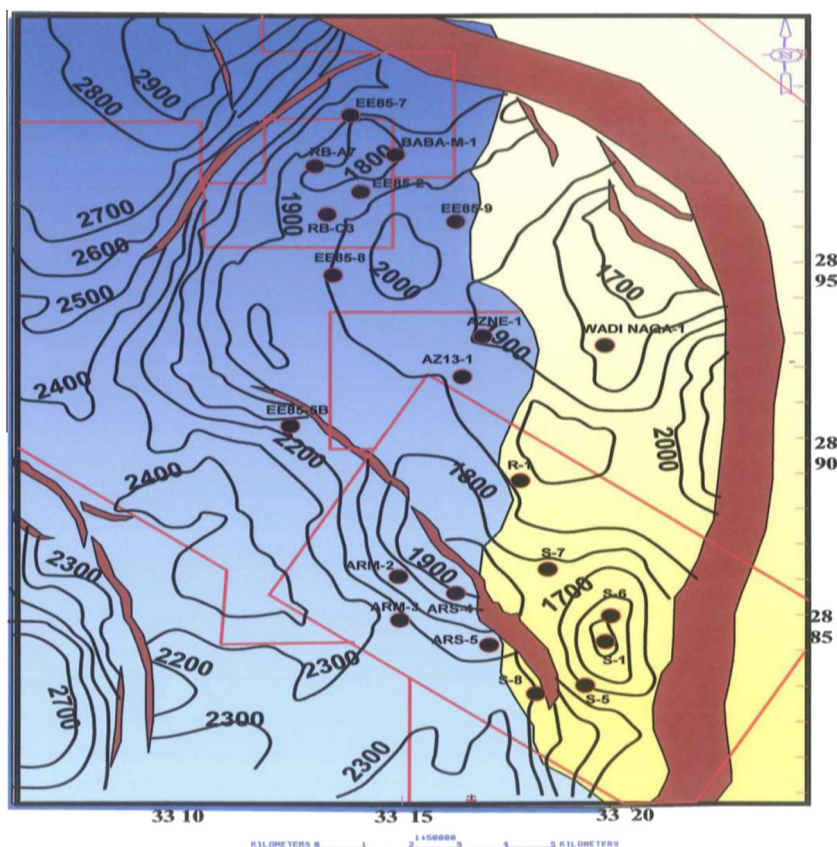


Figure 17 Depth structure contour map on top Kareem.

these maps were not reliable enough. Afterward on 1997, a 3D (OBC) survey was acquired for the purpose of covering the eastern part of Ras Budran and to extend over the onshore area. The fore-mentioned two 3D surveys were processed/reprocessed and merged during 1997 by Western Geophysical Company (Fig. 3).

The quality of the merged 3D seismic survey is fairly good in the OBC/streamer survey overlapping area and the OBC part, whereas the onshore link the NW flank display; some quality deterioration has been occurred, due to offshore-onshore transition zone and to steeply dipping events. As a result, the quality of the Miocene horizons down to the Nukhul Formation is good, whereas the Pre-Miocene exhibits bad quality data, which was tested by RB-A10 well. The well drilled the predicted Miocene sequence. The Pre-Miocene section was encountered much deeper than the expected. The discrepancy between the seismic prediction and the actual well results indicates that, even the last 3D interpretation is still not reliable.

The geophysical problems faced in the Ras Budran area are summarized as follows:

1. The small acoustic impedance contrast at all levels below top Rudeis.
2. The absorption of most seismic energy at the shallow evaporitic sequence.
3. The difficulties arisen from the effective multiple attenuation, due to the thick sequences of interbedded shales, sands, salts and anhydrite in the Miocene section.

#### 4. Interpretation of 2D seismic data

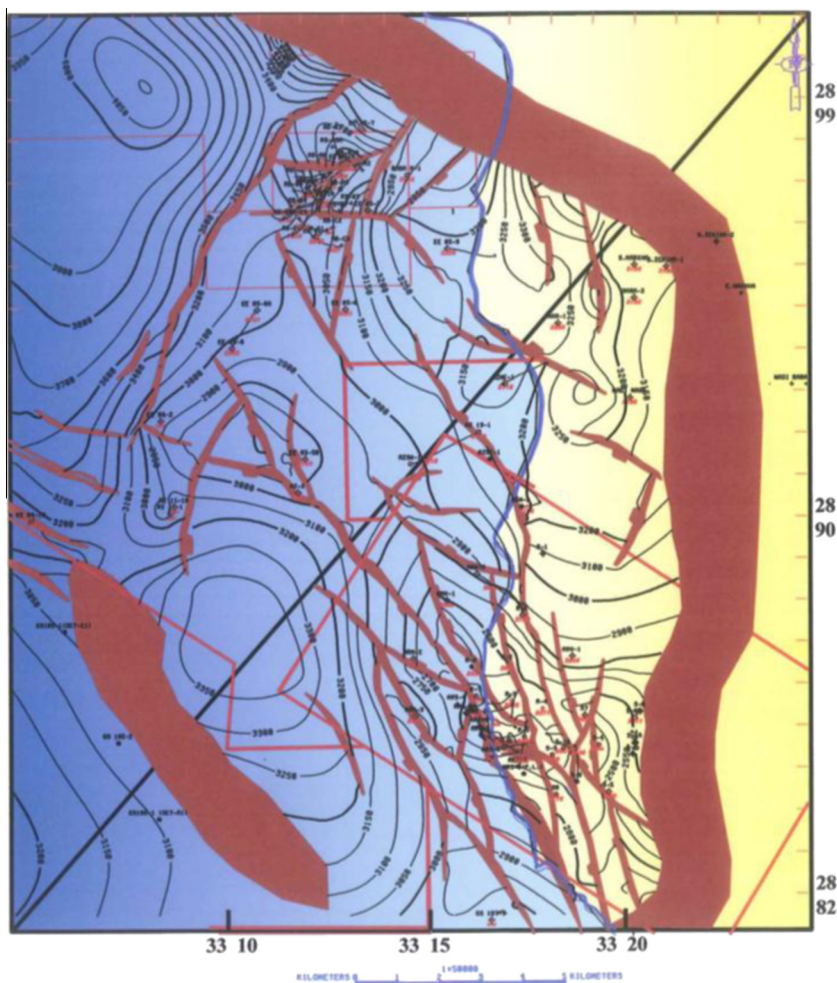
A number of seismic lines were selected and interpreted (Fig. 4) with the help of well velocity surveys and time-depth trace conversion to construct the structural maps characterizing the different levels of the concerned area, as well as to confirm the validity of the established tectonic model.

##### 4.1. Seismic line DEE1-364

This line is located to the north of Ras Budran area (Fig. 5) in the NE-SW direction. The step faults affecting the area and the down stepping to the west are obvious. The shear zone trending NE-SW is clearly demonstrated in the Ras Budran area (east of the section), in addition to the main bounding fault, which is crossing EE85-7C well and getting the basement against the Miocene and Pre-Miocene sections. Three wells are located on this line, these are EE85-7C, RB-A3A and RB-A6. The big graben, which separated Abu Zenima basin from Ras Budran area to the west, can be distinguished.

##### 4.2. Seismic lines GS-370 and DEE1-370

These lines are located to the south of Ras Budran area (Fig. 6) in the NE-SW direction, parallel to the previous one. They extend in the SW direction, from Ras Budran area to Abu Zenima area. The flower structure in the western part is clear.



**Figure 18** Depth structure contour map on top Nukhul.

The extension of the western bounding fault is obvious. This section clarifies the horst of the EE85-6A well block.

#### 4.3. Seismic line DEE1-285

This line extends in the NW direction (Fig. 7) from Abu Zenima area to Ras Budran area. It shows the in-between graben, that separates Abu Zenima area from Ras Budran area. Going to Ras Budran area, the section is cutting by a major shear zone. The main E–W faults down stepping to the south and bounding Ras Budran blocks are clear. In the southeastern part (toward Abu Zenima area), the Miocene section attains its maximum thickness at AZ13-1 well.

#### 4.4. Seismic lines DEE1-283A and GS-283A

They extend in the NW direction, parallel to the previous one (Fig. 8) and passed through the northern part of Abu Rudeis, Abu Zenima and Ras Budran areas. Four wells are located in this line: AZSW-1, EE85-8, RB-B6 and RB-B8. The main fault, crossing the RB-B8 well and bounding the area from south, is clear. Abu Zenima basin, which separated Abu Rudeis area from Ras Budran area, is obvious. The step faults down stepping toward the north can be distinguished.

#### 4.5. Seismic line ABZ-88-18

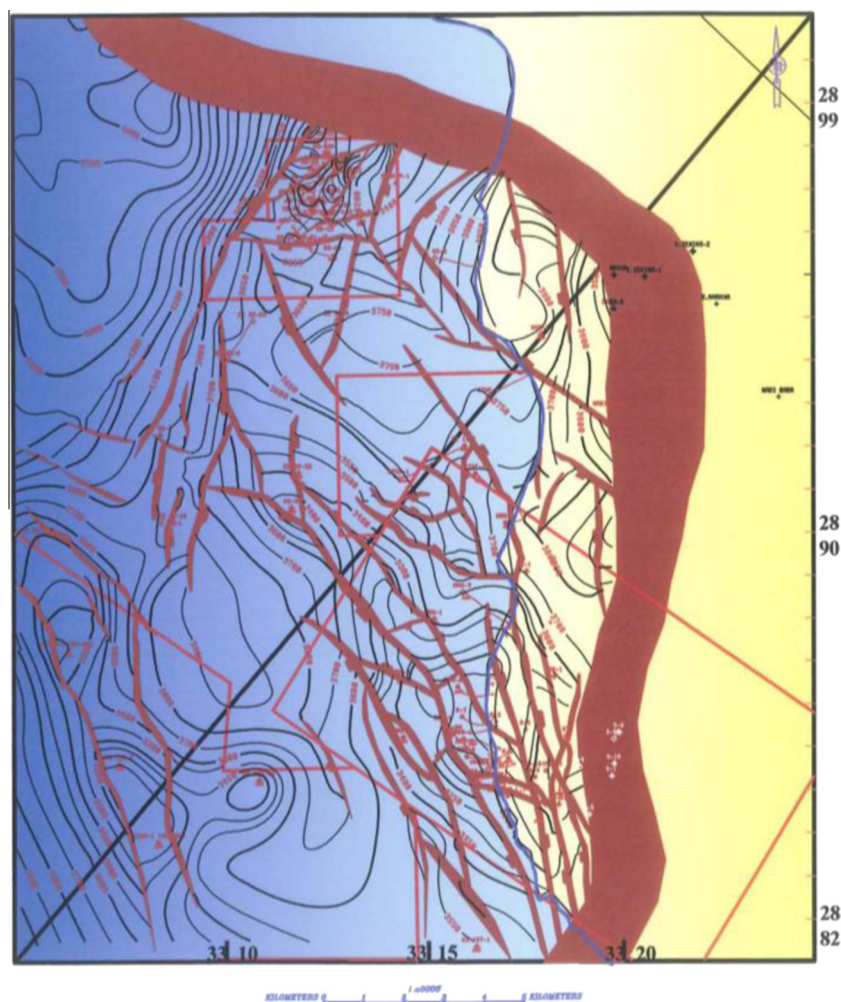
It extends from Abu Rudeis area to Ras Budran area (Fig. 9) in the N–S direction. The wells: ARM-3, ARM-2, AZSW-1 and Baba-M-1 are projected on the line. The central horst, which is running in Clysmic trend and extends from Abu Rudeis area to Abu Zenima area, can be illustrated. In addition, the listric fault, which cuts at shallow Miocene levels, is obvious. The graben of Abu Zenima basin, which occurred between Abu Rudeis area and Ras Budran area to the north, is demonstrated.

### 5. Interpretation of 3D seismic data

Recently on 1997, a 3D survey (OBC-Deep marine) was acquired to cover the eastern part of Ras Budran area and to extend the seismic data over the on-shore area. The relatively bad quality of the 3D seismic data, especially in the Pre-Miocene horizons, does not allow the construction of reliable maps. As a result, the deepest mapped horizon was the base of the Belayim evaporites (top Kareem Formation).

Six 3D seismic key sections (Fig. 10) are selected to illustrate the different structural elements of the reliable horizon (top Kareem Formation).





**Figure 19** Depth structure contour map on top lower Senonian.

### 5.1. Seismic in-line 115

This line passes in the northern part of Ras Budran field (Fig. 11) in the NE direction. On this line, the wells: EE85-7C, RB-A3, RB-A3A, RB-A6, RB-A9, RB-A8 and RB-B5 are projected. The main bounding fault (to the east) and its antithetic effect, in addition to the contact between the basement rocks and the Miocene section are obvious. Also, the listric fault, which was detected from the 2D seismic data interpretation, is clear on the 3D section, but cutting the Miocene levels shallower than the Kareem Formation. The faults dissecting the section are in random form causing horst, graben and step-like fault blocks.

### 5.2. Seismic in-line 195

It is parallel to the previous one (Fig. 12) and extends from the southeastern part of Ras Budran field to Abu Zenima area. The well RB-A10 to the east, added to RB-B3, RB-B7 and EE85-6A wells are located on the section. The eastern down faulted block, in addition to the horst of the main Ras Budran field can be distinguished. The graben separated Ras

Budran area from Abu Zenima area is clear. The Kareem Formation in the central part is of regular dip, which exceeds toward the two flanks of the section in reversal directions.

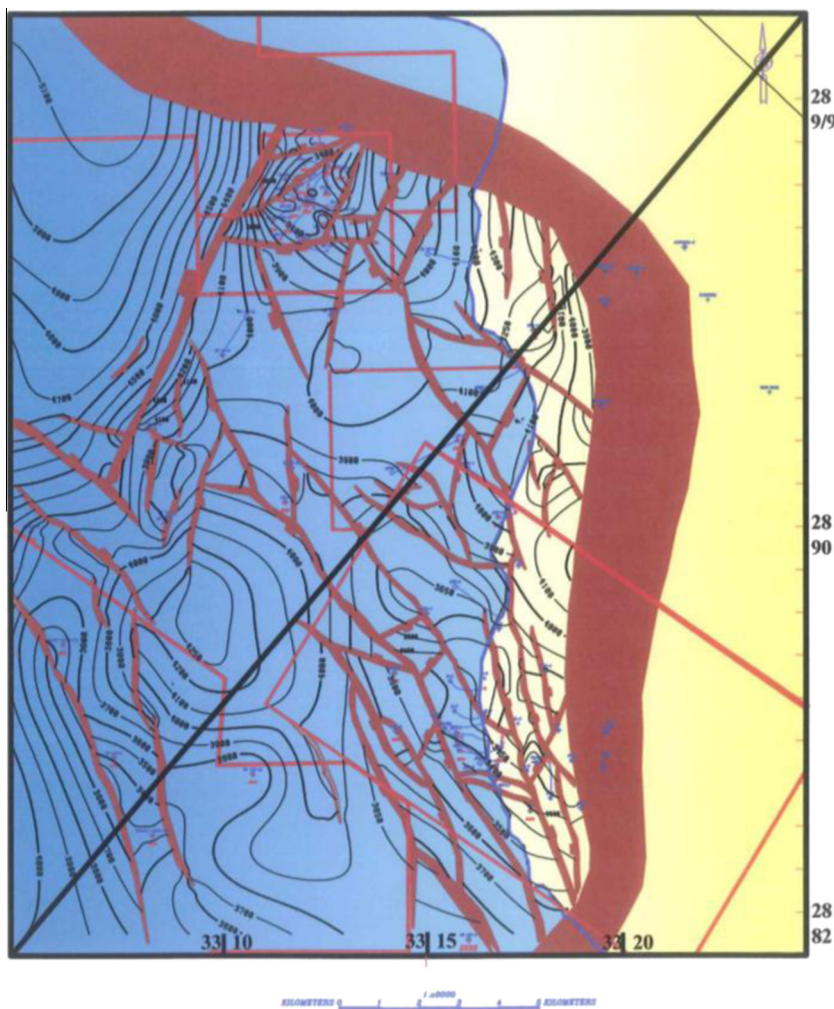
### 5.3. Seismic in-line 215

This line bounds Ras Budran area from the southeast (Fig. 13), in parallel to the two previous lines. The wells: Baba-M-1, RB-A10, EE85-2 to the east, added to RB-C3 in the southern part of Ras Budran field are located on this section. The drag of the Miocene strata along the eastern main bounding fault is clear. The basement rocks juxtaposed the Miocene section by this fault.

### 5.4. Seismic cross line 360

It is in the NW direction of the area and bounded the eastern part of Ras Budran field (Fig. 14). The well Baba-M-1 is located on this section. The Miocene strata in the southern part of the section are flat and very steep in the northern part. The faults down stepping to the north are clear in the northern part of the section.





**Figure 20** Depth structure contour map on top Nubia.

#### 5.5. Seismic cross line 280

It is parallel to the previous one (Fig. 15) in the NW direction. The wells: RB-C2, RB-B1 and RB-B5 are located on this line. The main basin of the area can be distinguished at the northern part of the section. The high block is found in the middle part. The dip reversal on both flanks of the positive structure is clear. The thinning of the Miocene strata on the crustal part of structure and the thickening on its two flanks are obvious.

#### 5.6. Seismic cross line 330

It is parallel to the two previous lines (Fig. 16) in the NW direction. The step faults with opposite throws are interpreted in the form of uplifted (horst) block at the central part. The wells: RB-A10, RB-A1 and RB-A3B are located on this line. The northern basin is clear, giving rise to thick layers.

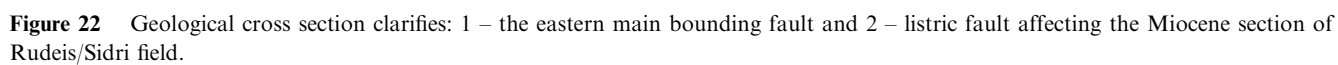
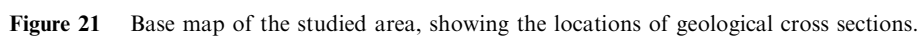
### 6. Structural configuration of study area

As an end product of the interpreted seismic data and the geological integration, the fault and structural patterns were

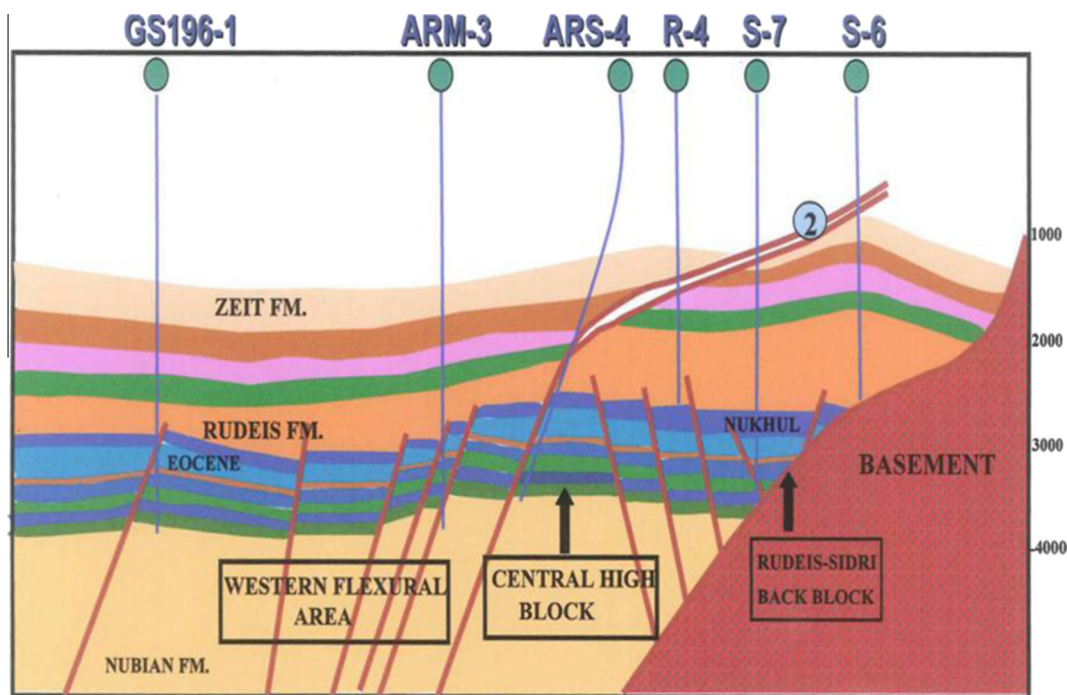
depicted to illustrate the tectonic features characterizing the area. Accordingly, geo-seismic regional depth maps were constructed for the main interesting levels of Kareem, Nukhul, Matulla (Lower Senonian), and Nubia Formations (Figs. 17–20), in addition to six numbers of geological cross sections (Fig. 21).

Generally speaking, the dominant fault system is the NW–SE longitudinal faults (Clysmic trend), that run sub-parallel to the field axis prolongation with general NE dip, which constitutes the prevailing tectonic feature. This trend is associated with an oblique fault system which has varying degrees of shifting from the main NE–SW trend. In addition, the eastern margin of the area is characterized by a major rift border fault, which has considerable throw (+ 5000 m) and get the Miocene and Pre-Miocene sections in juxtaposition with the basement complex (Fig. 22). On the other hand, the western side of the area has distinctly flexural character with a number of faults, each has relative small throw (Fig. 23). In this dip domain, the anti-dip faults (faults throwing to the west) are the main linear structures controlling the oil entrapments.

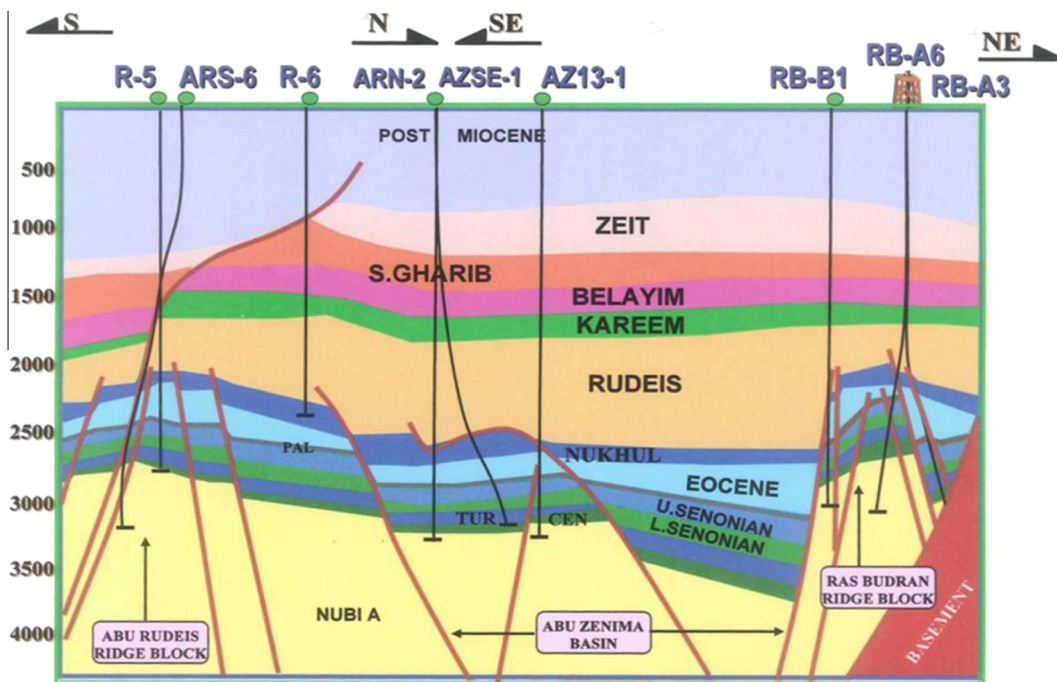
Besides, the structural pattern of the area reveals two main ridges characterizing Rudeis–Sidri and Ras Budran areas, added to a wide basin between them called Abu Zenima basin.







**Figure 23** Geological cross section in the central part of Rudeis-Sidri fields showing: (1) western flexural area, (2) listric fault, (3) central high block and (4) Abu Rudeis back block.



**Figure 24** Geological cross section extended from Rudeis-Sidri to Ras Budran field, showing the two ridges of Abu Rudeis, Ras Budran and Abu Zenima basin between them.



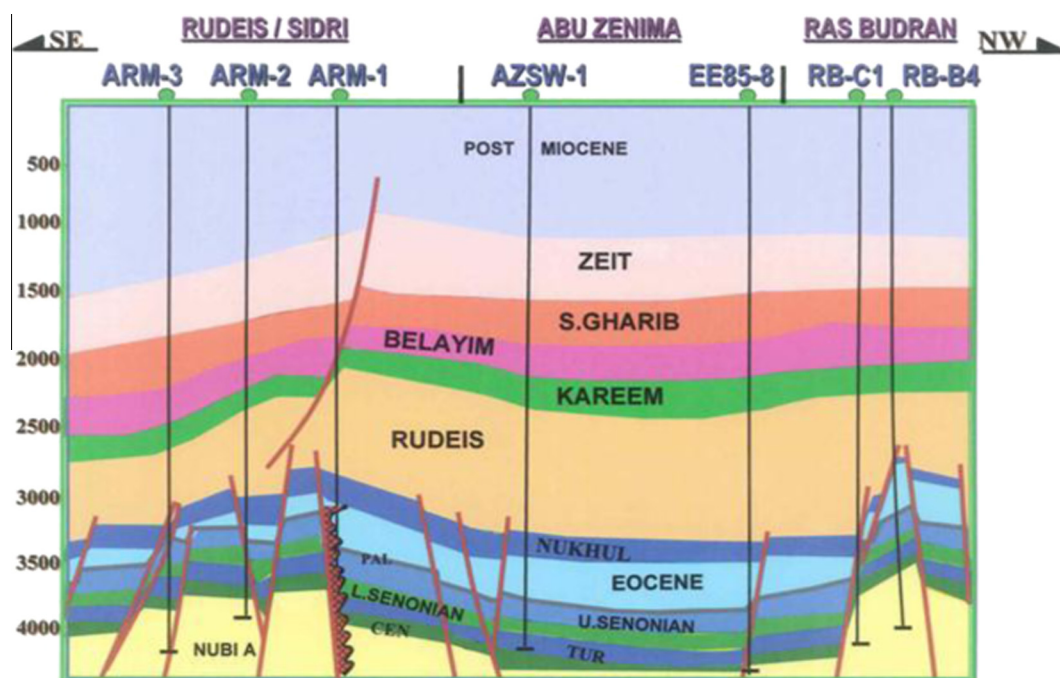


Figure 25 Regional geological cross section between Ras Budran Abu Zenima and Abu Rudeis/Sidri areas.

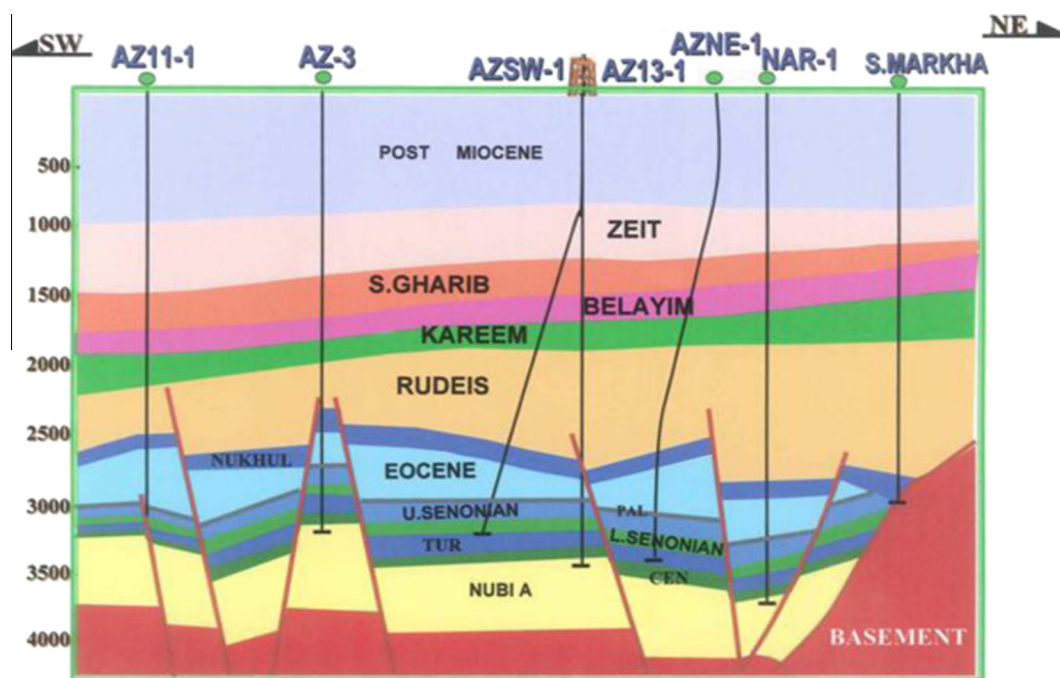


Figure 26 Geological cross section showing the structural configuration within Abu Zenima basin.

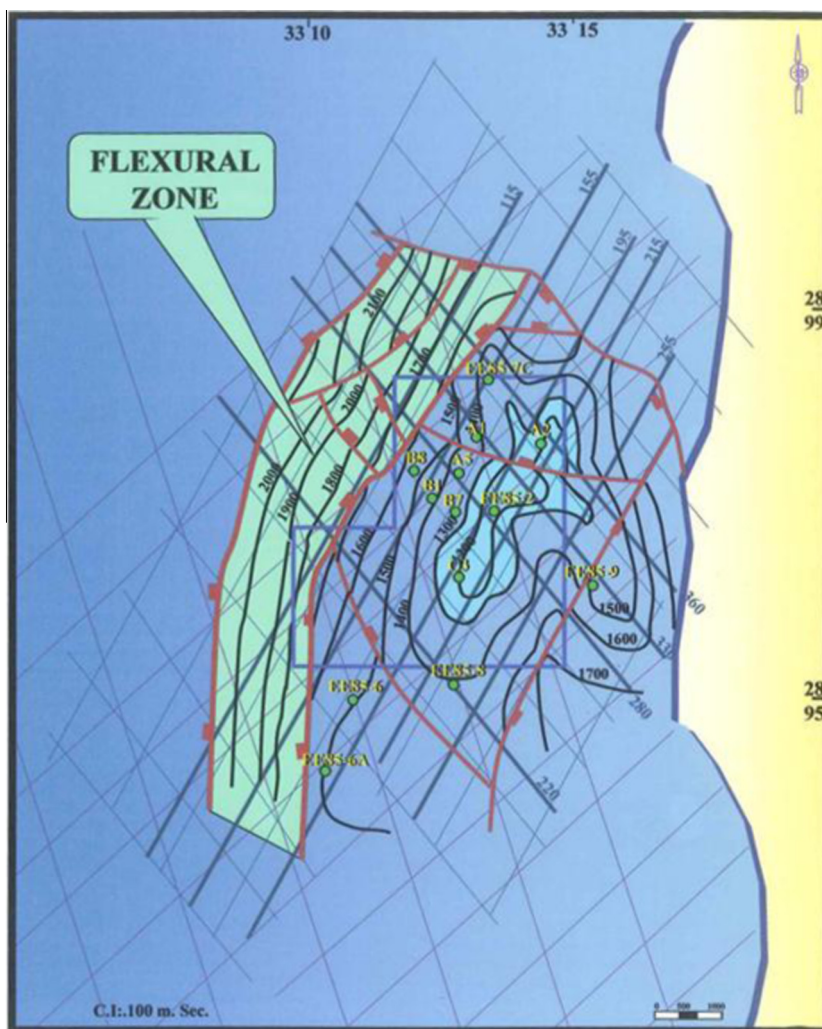
This basin, in turn, is affected by a lot of fault systems dissecting this basin into small horsts, grabens and step-faulted blocks (Figs. 24–26).

Finally, the structural configuration of the studied area is implicated by two structural features superimposing each other, the Miocene (Rift sequence) where the faults trend in a NW direction (Clysmic) and the Pre-Miocene (Pre-Rift

sequence) where the faults trend in a NNE to N–S (oblique) direction.

#### 6.1. Miocene structures

The Miocene structures of Ras Budran area, as seen on the top of Kareem Formation (the deepest and consistently mapped



**Figure 27** Time contour map on top Kareem Fm. incorporating 3D seismic data in Ras Budran field.

2D and 3D seismic reflectors), of Figs. 17 and 27, respectively, are a nearly NE–SW trending anticlinal feature broken into several parallel panels by sets of NW–SE integrated with NE–SW trending faults. The Ras Budran ridge forms the crest of a NE–SW trending broad platform located near the eastern coast of the Gulf of Suez.

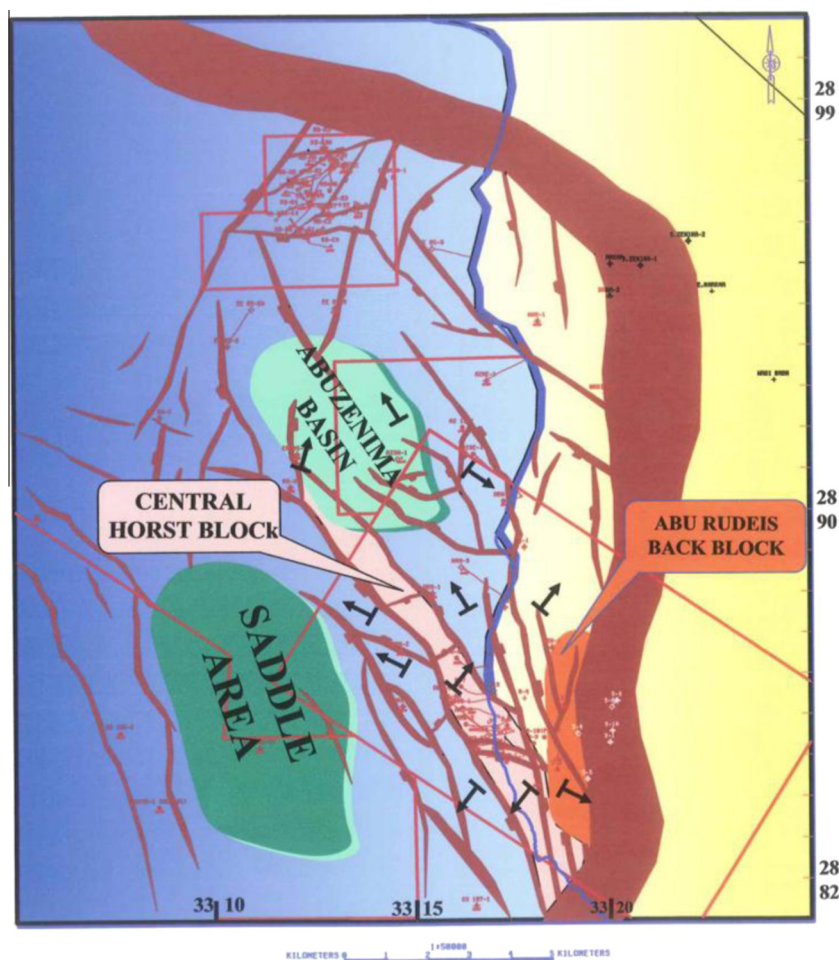
The alignment of Ras Budran structural feature at right angle to the main Clysmic trend (NW–SE) is anomalous and could be interpreted due to the main NNW–SSE tectonic stress synthesizing the produced fold and faults. Structures with similar strikes are restricted toward the eastern coast of the gulf, giving rise to the echo of its tectonics. These structures, showing an Aqaba-like trend, may be related to the strike-slip faulting causing the flexural structural zone to the west (Fig. 27).

Comparing Ras Budran structures, as mapped from the 2D seismic data (Fig. 17) and as mapped through incorporating the 3D seismic data (Fig. 27), reveals significant differences mainly in the occurrence of faults, where none of these faults that interpreted from the 2D seismic data have been penetrated in the well section near top Kareem level. These faults are seen to be present mostly at the Pre-Miocene levels or within the

lower Rudeis. However, the structural configuration of Ras Budran area in both maps reveals a NE–SW trending structural feature with a crustal structural closure. The structural axis of Ras Budran field is oblique to that of Abu Rudeis–Sidri field (Fig. 17) (see Fig. 28).

## 6.2. Pre-Miocene structures

The Pre-Miocene structures of Ras Budran area are fairly well defined. Seismic, however, does not aid much in the delineation of the Pre-Miocene structure, despite both the two-dimensional and three-dimensional surveys, plus the various reprocessing efforts followed by the interactive interpretation of 3D seismic data. Interestingly, none of the faults near top Kareem reflector have been penetrated. On the other hand, faults are present in the well section within the lower Rudeis (Pre-Miocene), as shown in the geological cross sections (Figs. 21 and 25). The Pre-Miocene structures of Ras Budran are very complex, because they are disturbed by severe faulting at different stratigraphic levels and with a variety of orientations (NW, NNW, WSW and NE). In addition, the structural



**Figure 28** Lower Senonian fault pattern and dipmeter interpretation showing the block rotation.

complexity is intricate more by two major tectonic phases within the studied stratigraphic section, Oligocene and intra-Rudeis.

Moreover, based on the interpretation of faults from well data and dip meter analysis, structure contour maps on the tops of Raha (Cenomanian) and Nubia Formations (Figs. 29 and 30) have been constructed. The structure consists of a system of step faults down stepping to the south and southwest, and is finally bounded to the south by a major antithetic fault aligned nearly east–west. To the northeast, the structure is limited by a set of synthetic faults aligned northwest–southeast which along them the basaltic intrusions were observed. These faults are extended toward the north-western part of the field with throws in the opposite direction of the coastal marginal fault system and create a NW aligned graben to the northeast of the structure.

These faults, together with a system of faults down stepping toward the south direction, have been subjected to a younger cross fault system of NE–SW alignment (shear faults), which had divided the field into parallel block segments. These cross faults have combined lateral and vertical displacements, giving rise to left and right lateral components. They also shifted the older gravitational faults with varying lateral offsets (Figs. 31 and 32). Thus, according to this interpretation, the limits of Ras Budran field can be considered as fairly well defined. Three main blocks are delineated: the northern main block

with “A” cluster of wells; the central block with “B” cluster of wells and the southern block with “C” cluster of wells (Figs. 32 and 33).

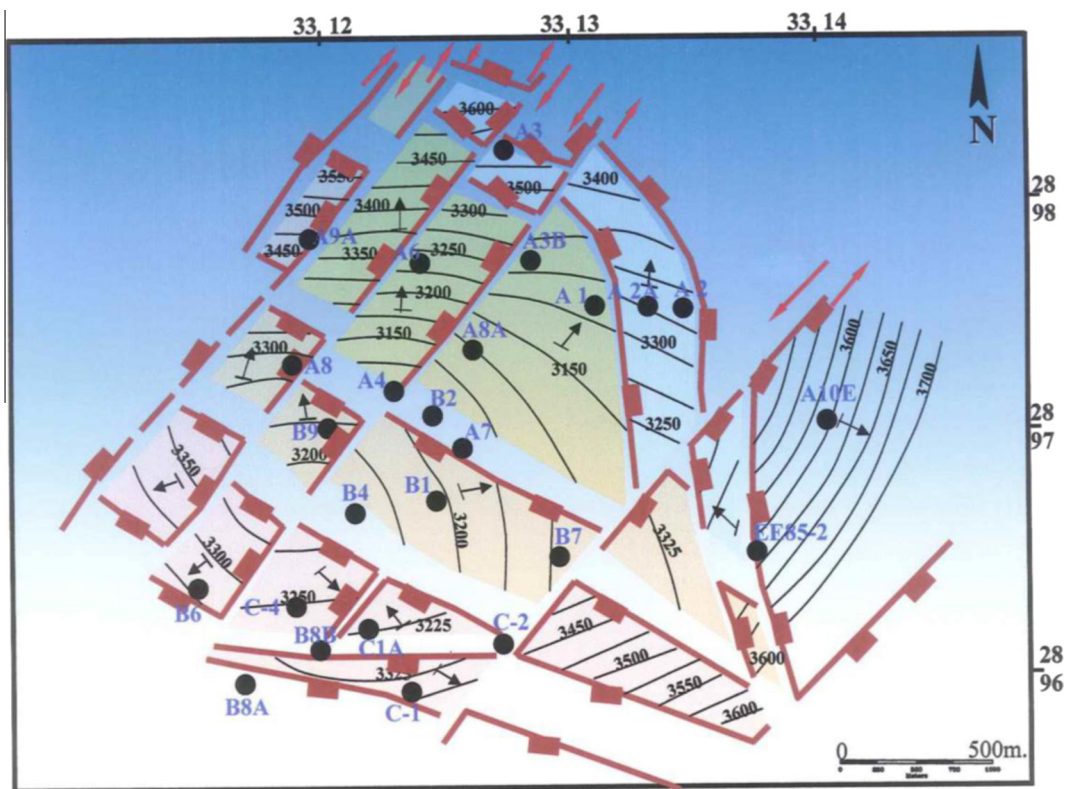
## 7. Summary and conclusions

The present study deals with the interpretation and evaluation of the seismic data of Ras Budran–Abu Zenima Fields in the north central part of the Gulf of Suez, in terms of subsurface geological structures and tectonic pattern prevailing in the area.

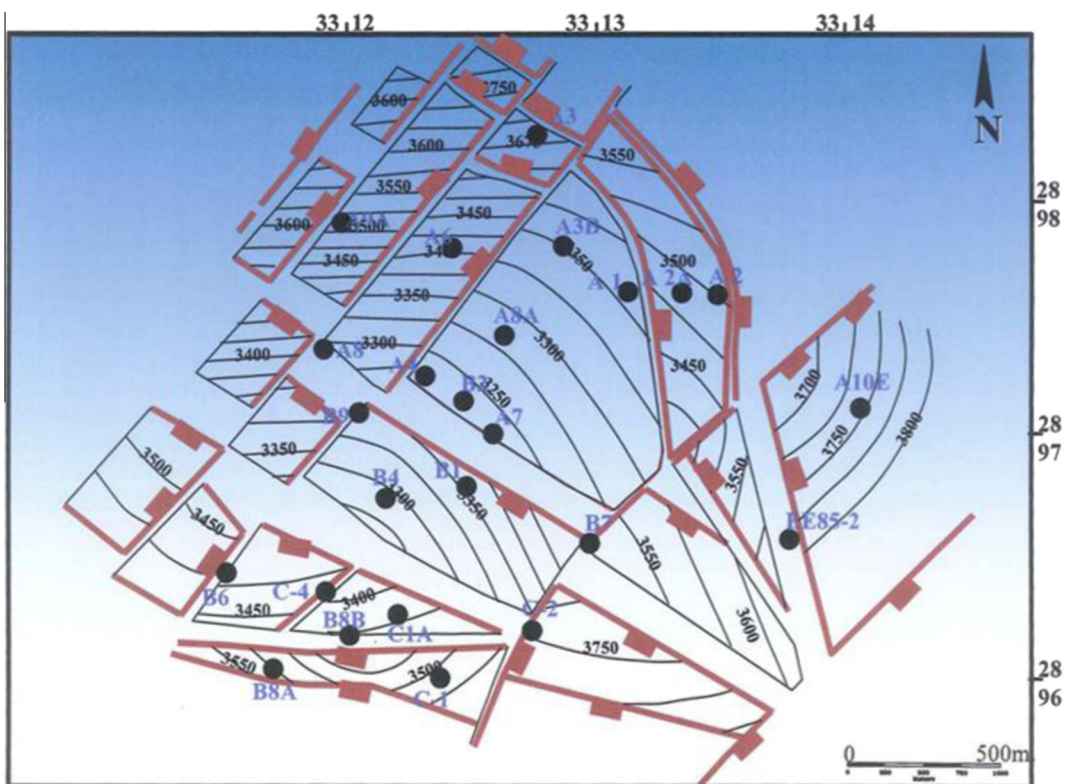
The seismic reflection data (2D and 3D), integrated with the geological data, are worked to define the structural configuration of the area, through a set of structural maps for varying time horizons.

The Miocene structure of Ras Budran Field is a nearly NE trending anticlinal feature broken into several parallel panels by a set of NW faults integrated with NE trending ones. The Pre-Miocene structure of Ras Budran Field consists of a system of step-like faults down stepping to the south and south west, and is finally bounded to the south by major antithetic faults aligned nearly E–W. The structural complexity of the studied area is enhanced by the presence of two major erosional unconformities in the stratigraphic section: One of Post-Eocene and the second of Intra-Rudeis, added to the Post-Carboniferous unconformity.

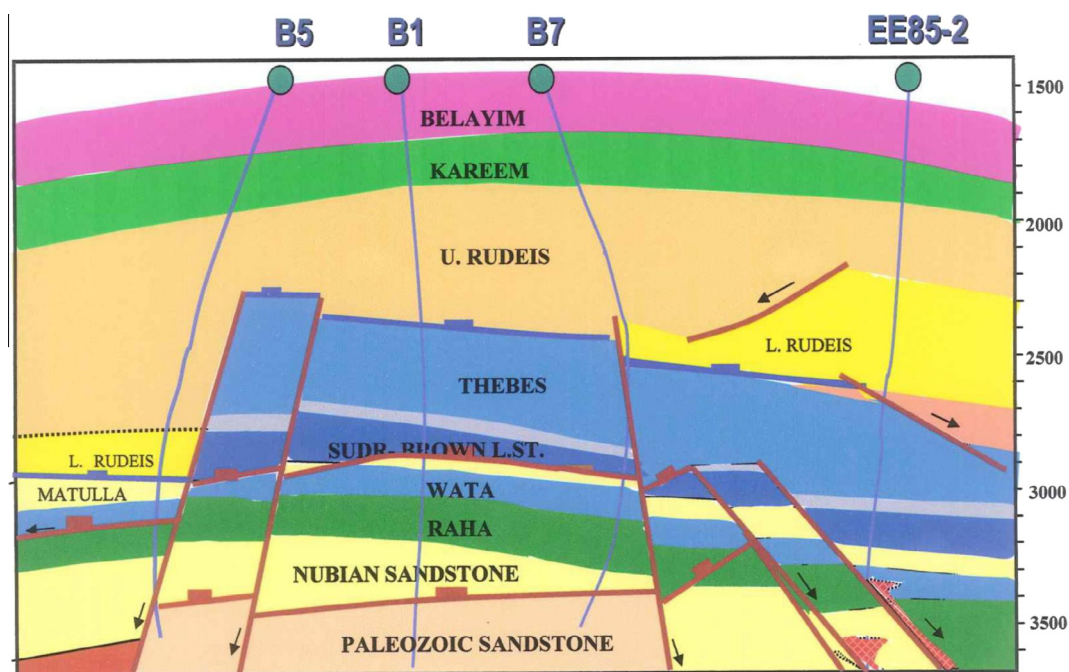




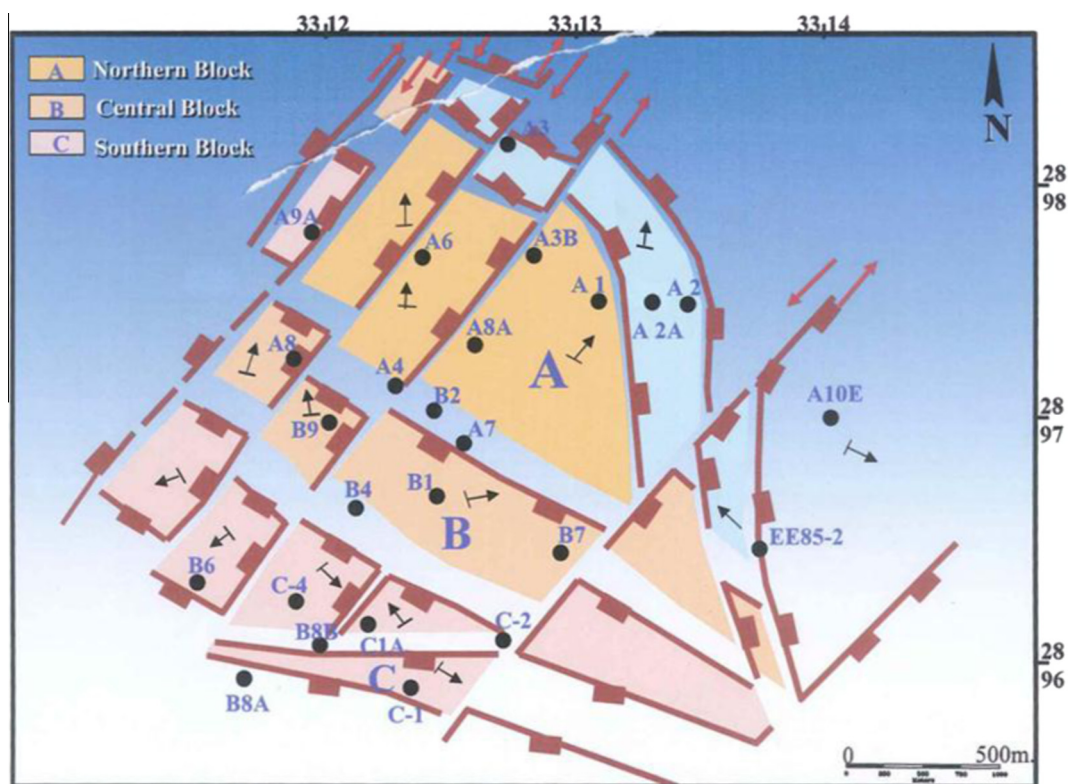
**Figure 29** Structure contour map of Raha Fm. in Rasbudran field.



**Figure 30** Structure contour map of Nubia Fm. in Rasbudran field.



**Figure 31** Geological cross section within Ras Budran field showing the effect of shear fault systems on the NW Clysmic fault system.



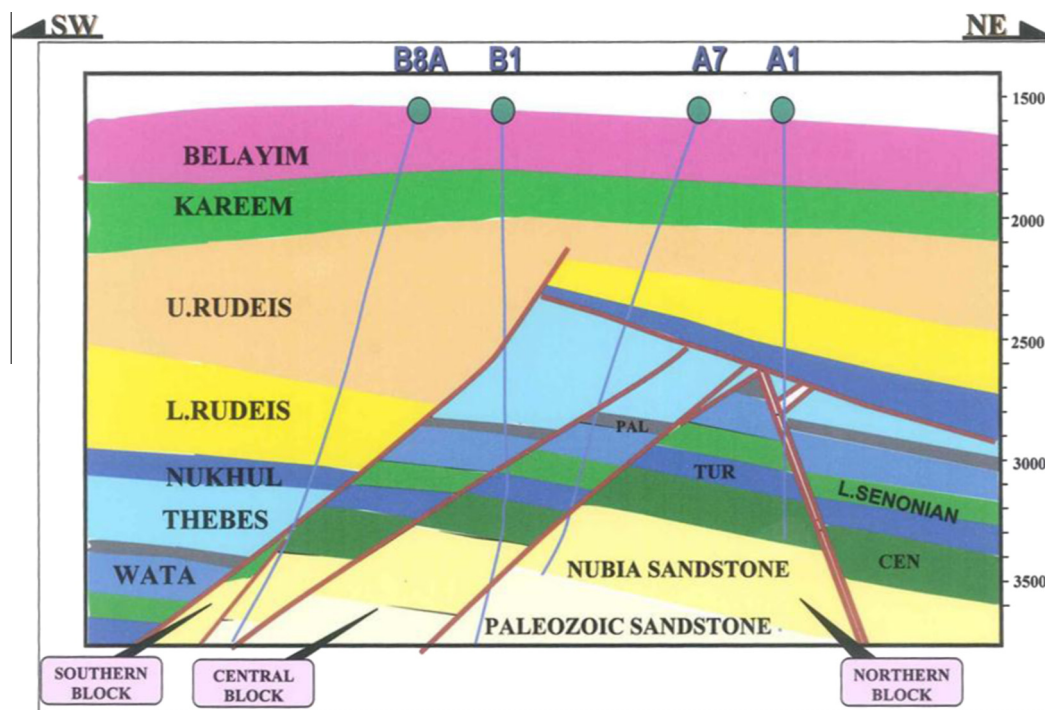
**Figure 32** Upper Raha fault pattern and dipmeter interpretation showing the blocks rotation.

The Pre-Miocene structure of Ras Budran Field has been subjected to a system cross faults of NE-SW alignment (diagonal faults) with lateral and vertical displacements. However, the left and right lateral components are the predominant, in

which they transferred the older gravitational faults through different lateral offsets.

The analysis of the fault systems detected from the structural maps for the studied area, reflects four main fault trends:





**Figure 33** Geological cross section showing the three main blocks of Ras Budran field.

NNW–SSE (older trend), that formed during the Early Paleozoic and rejuvenated in the Oligocene time (rifting phase), NE–SW (oblique) during the Middle Mesozoic–Late Mesozoic time, NW–SE (Clysmic) during the Early Tertiary and NNE–SSW (Aqaba) that formed during the quaternary time. The geological history of the area illustrated that, Ras Budran structure is figured primarily during the intra-Rudeis tectonic phase.

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