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AN INTEGRATED GEOPHYSICAL STUDY FOR DELINEATING THE STRUCTURE AND RESERVOIR PROPERTIES AT RAS FANAR, GULF OF SUEZ, EGYPT

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دراسة جيوفيزيقية متكاملة لتحديد النموذج التركيبي والخزان بحقل رأس فنار، خليج السويس، مصر

الخلاصـــة: تقع منطقة الدراسة على الجانب الغربي من خليج السويس على بعد ٣,٥ كم شرق ساحل رأس غارب.تم اكتشاف حقل رأس فنـــار فـــي ١٩٧٨ بحفر بئر KK84-1 .وقد اخترق البئر طبقة رقيقة من العصر الميوسيني المتقدم بالإضافة إلى متبخراته وتم اختراق طبقة ســميكة حاملــة للزيت في العصر الميوسيني العلوي. ويهدف البحث الى تحديد المناطق المحتملة الحاملة للزيت باستخدام البيانات السيزمية ثلاثية الأبعاد مع اســتخدام البيانات المغناطيسية الجوية و مقارنتها ببيانات الآبار عن الخواص البتروفيزيقية للخزان.وقد تم تحديد أعماق صخور القاعدة باستخدام طيــف الطاقــة ومطابقتها بنتائج التفسيرات السيزمية ونتائج الآبار. وتم عمل تكامل بين المغناطيسية و السيزمية لتحديد العناصر التركيبية وامتداد الخزان لحساب كمية الزيت المحتملة بداخله.

ABSTRACT: *The study area is located on the offshore part of the western side of the Gulf of Suez, 3.5 Km east of Ras Gharib shoreline. The Ras Fanar field was explored in 1978 by drilling well KK 84-1, it penetrated relatively thin post Miocene clastics, Miocene evaporites and found a thick sequence of oil bearing carbonate rock built-up; the pre-Miocene strata were uplifted, faulted and deeply eroded during Oligocene times. The target of this investigation is to deduce newly oil prospects in this area by using available magnetic, seismic, and reservoir data. Power spectrum is used to determine depth ranges of basement structure. Seismic interpretation integrates with magnetic to confirm the structural elements using Petrophysical analysis to determine the prospect areas.*

INTRODUCTION

Ras Fanar field is considered as one of the main oil-bearing carbonate reservoirs in the Gulf of Suez (Fig.1). The field produces from the middle Miocene carbonate reservoir. Magnetic method is an important method to detect the surface of the basement. The magnetic data were processed by using Oasis Montaj software. Seismic method is used to estimate the relief of top Belayim, Nubia, and Basement rocks. Seven seismic sections were selected to make interpretation on top Belayim, Nubia, and Basement. TWT and depth converted maps were constructed. The main aim of the study is determining the prospectus area with using the petrophysical parameters interpreted from logs of KK84-1 well.

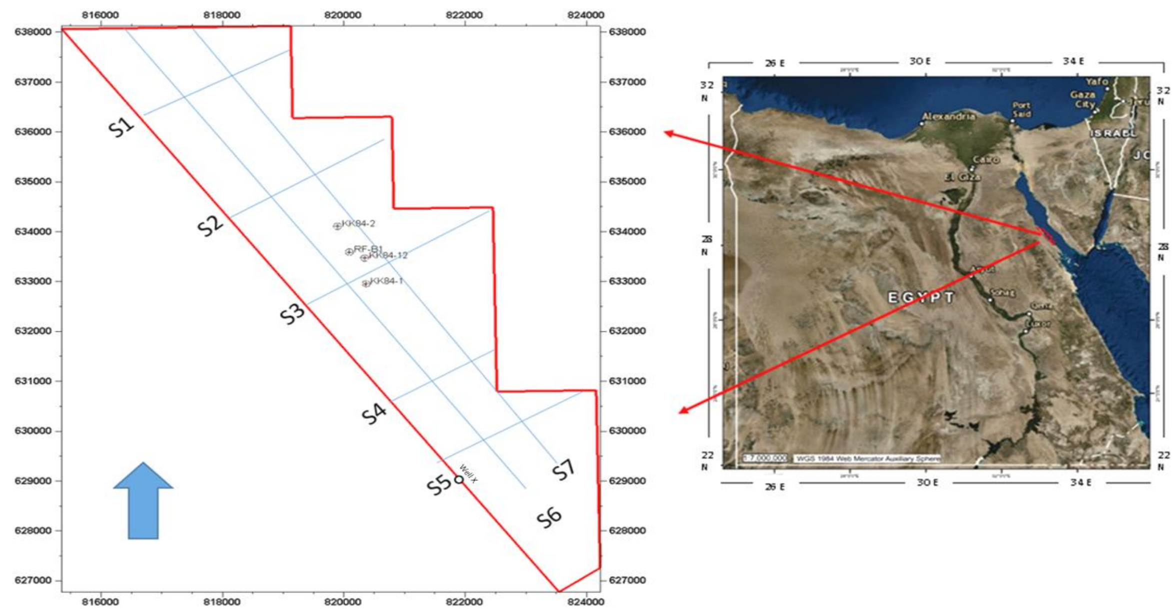

Fig. 1: The location map of the studied area.

2. Geologic setting:

The NW Red Sea-Gulf of Suez rift system *(*Fig.2) was initiated during Late Oligocene time and underwent extension in a N65°E direction (Younes et al., 2010). Analysis of fault geometries, fault kinematics and sedimentation patterns indicates that rift-normal extension predominated throughout the Late Oligocene-Early Mid-Miocene evolution of the rift. Reactivation of the Precambrian basement fabrics was the main factor controlling the fault architecture, fault linkage and evolution of the NW Red Sea-Gulf of Suez rift. The faults that were initiated in Gulf of Suez trend affected intensively the Ras fanar field. This implies that the major faults in Ras fanar field will be Gulf of Suez trend.

The Ras Fanar field exploration started in 1977 during the drilling of Sheab Gharib WELL-1 by the GPC, where the offshore JJ and KK84/85 prospects were under evaluation by a group of oil companies. Ras Fanar is geologically located in the eastern part of the Gharib horst block, which is characterized by a northeast dip direction (Meshref and Abu El Karamat, 1988; Salem et al., 1994). This field has intensive faulting and the cross faults may shift or terminate these blocks (Moustafa, 1976; Sultan and Moftah, 1985).

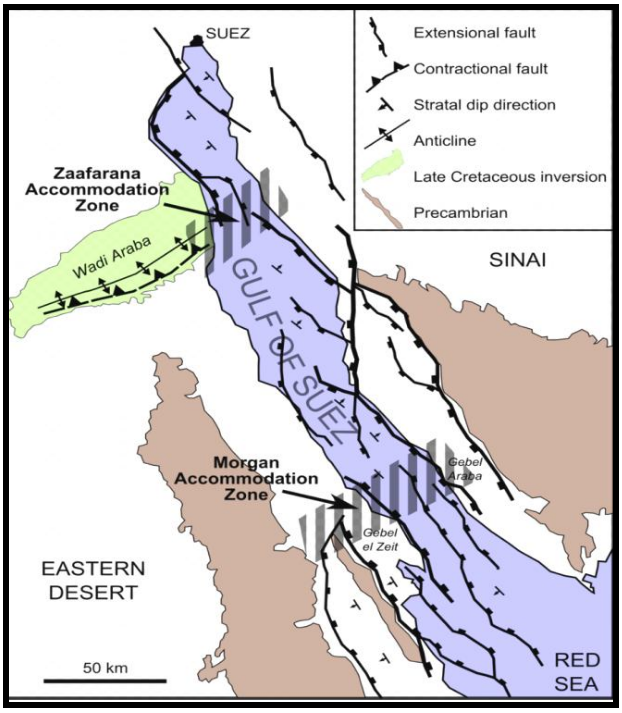

Fig. 2: Structure map of Gulf of Suez (Younes et al., 2010).

The most important is the Miocene sequence, which is represented by a relatively thick massive carbonate succession overlaid by the upper units of the Evaporites Group. This massive carbonate constitute the main built-up of the Nullipore reservoir and is classified into different zones each of which attains its own petrophysical characters and special different fossil content (Lashin et al. 2005).The sediments of this sequence are of prime interest, as they are usually well developed and accumulated in the Gulf of Suez basin, between the two shoulders of the basin. They include mature source and excellent reservoir rocks and provide suitable cap rocks for most oil fields. Several erosional and/or nondepositional hiatuses are recorded. The subsurface stratigraphic column in Ras Fanar (El Naggar, 1988) ranges from Paleozoic to Pliocene (Fig. 3). The well correlation between four wells was constructed (Fig.4) between KK84-1, 2, 12 and RF-B1 wells.

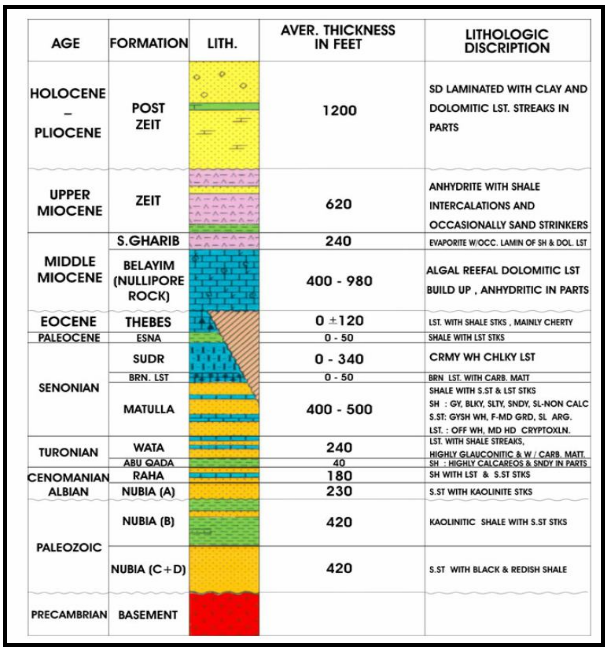

Fig. 3: Stratigraphic Column of Ras Fanar Field (El Naggar, 1988).

3. Available data:

The RTP magnetic data was acquired with flight line spacing 0.5 tie Km and 1 Km transverse tie lines in 1981. Four well data were used in the study. A set of logs (kk84-1) includes resistivity, gamma ray, and caliber were used to determine water saturation, average porosity and net/gross. The four wells were selected to make well correlation. Seven seismic sections were selected to make interpretation on top Belayim, Nubia, and Basement rocks. RF-B1, KK84-1, KK84-2 wells are used in velocity analysis. The repeated formation test of Well X is only used to calculate the recoverable oil. This well locates at the southwest of Ras Fanar field

4. Magnetic study:

Magnetic measurements contain contributions from sources of interest at shallow depths as well as contributions from source at greater depth. Magnetic anomalies were used to define the origin of the structures that cause the anomalies to map faults.

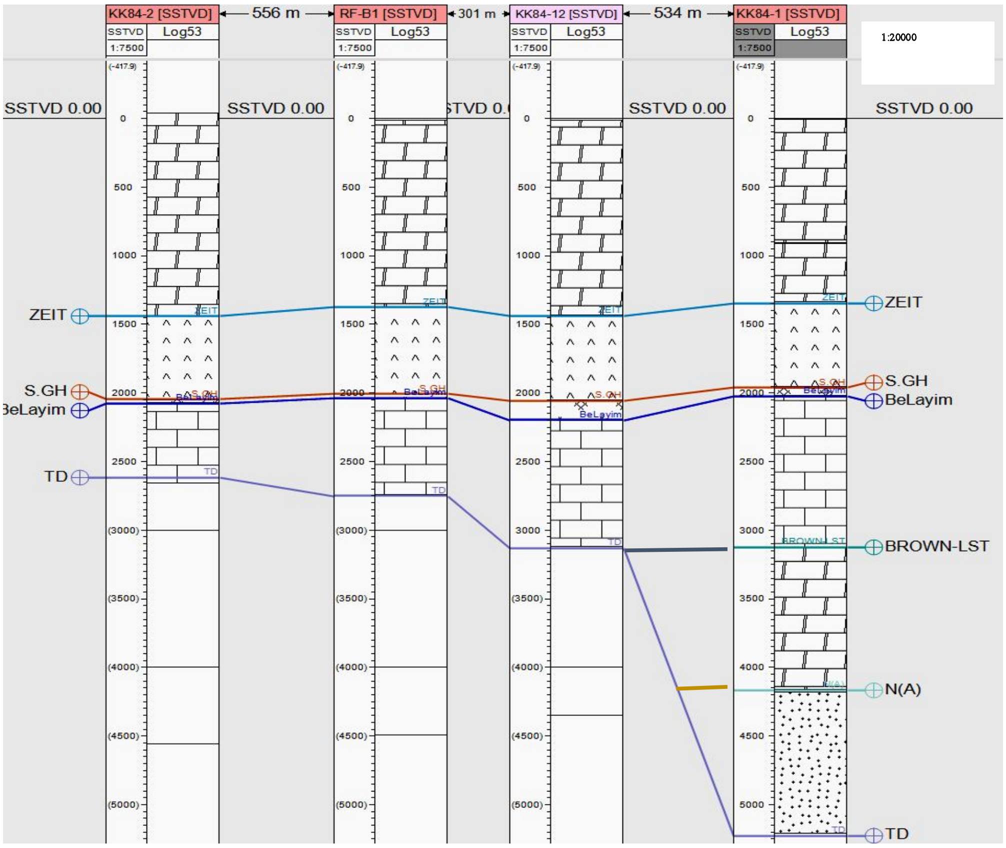

Fig. 4: Correlation between 4 wells in Ras Fanar Field.

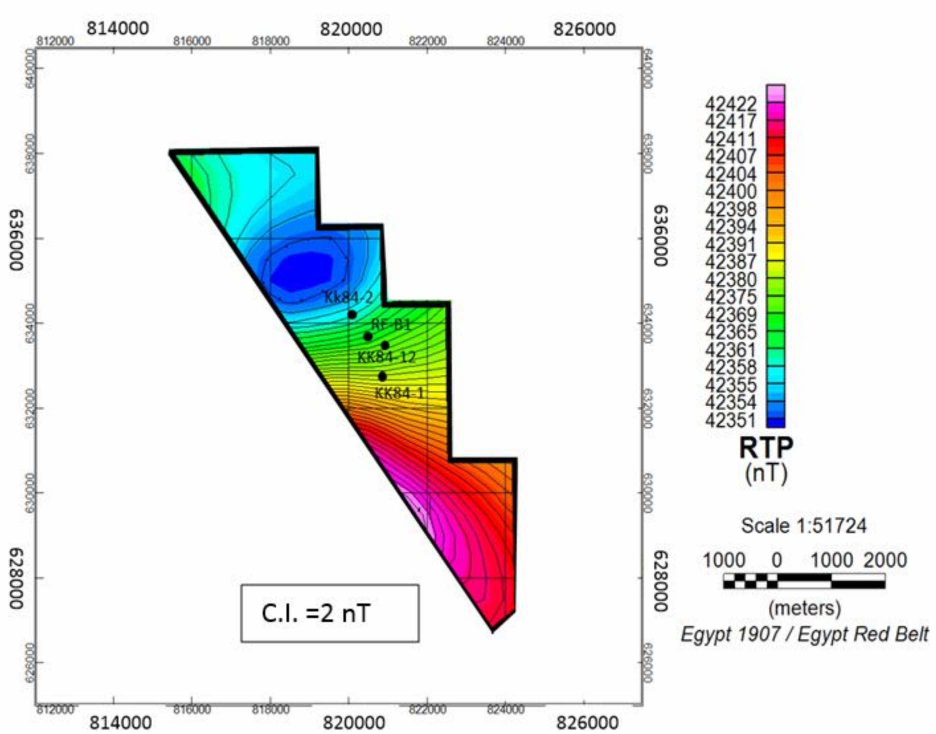

Fig. 5: Reduced to pole Map in Ras Fanar Field.

4.1 The processing and the interpretation of magnetic data:

Magnetic data should be processed to get clear data before interpretation. As the raw magnetic data can't be directly interpreted. Magnetic measurements need a removal of noise to enhance the anomaly presentation. Processing techniques were used in structure interpretation. Processing techniques pass through many steps which include: power spectrum (El Sayed, 2015).

4.1.1 Reduced to pole:

It is transformation the data to a definite location just above the magnetic pole of the earth (Fig.5). This transformation is performed to avoid the latitude variation which comes from the dipole of the magnetic field.

The convolution is usually complicated in the space domain but in the frequency domain it can be expressed by a simple output. It means that measured anomalies of the frequency spectra of Fourier transform are multiplied by the corresponding transform operator, and inversely transformed, then the desirable results are attained.

4.1.2 Power spectrum technique:

The average depth to the different sources of anomalies is defined by Spectral analysis of the magnetic anomaly field. The spectrum of the magnetic anomalies contain two parts, one in the low frequency and the other is high frequency trend. This technique was used to determine the average depth in regional and residual trends as shown in Fig. 6.

From Fig. 6 the slope for regional and residual component can be calculated (slope 1 and slope 2).

$$\text{Slope 1} = \frac{5-0.5}{0.05-0.2} = -30$$

$$\text{Slope 2} = \frac{-3+6}{0.4-0.6} = -15$$

By applying the following equation:

H=-slope/4*3.14 (1)

Where

H is the depth value. It exists 2 slopes one for regional component and the other for residual component .The slope 1 for regional component is -30, while the slope 2 for residual component is -15.05. After applying the slopes in equation (1) the regional depth estimation is 2.4 km while the residual depth estimation is 1.2 km.

5. Interpretation of seismic method:

The seismic data was acquired using one gun (2D) and a single cable of 96 channels with a maximum cable length of 1250m. The shooting interval was 12.5m while channel interval was 12.5m. The inter sail-line spacing was 12.5m and sometimes 25m. The Ras Fanar field was covered by a 3D seismic survey that was shot mostly using shallow single streamer, with a 60-channel telemetry spread with 25m channel spacing and 50m shooting interval. This was used to partially undershoot two platforms.

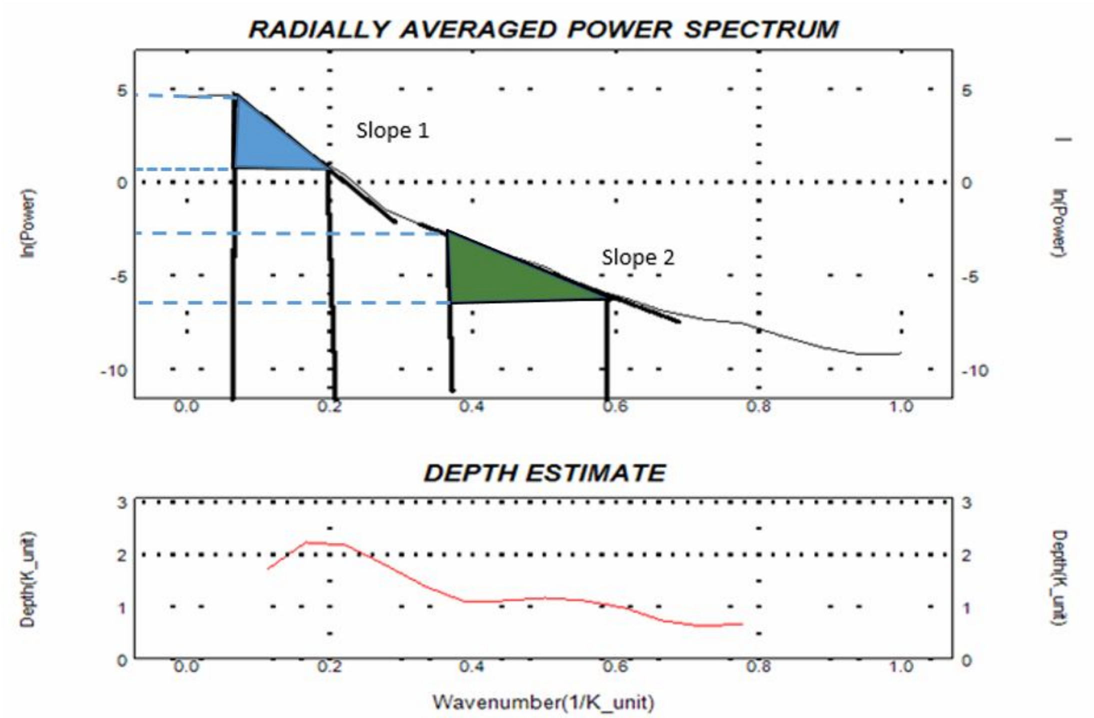

Fig. 6: Power spectrum curve of Ras Fanar Field.

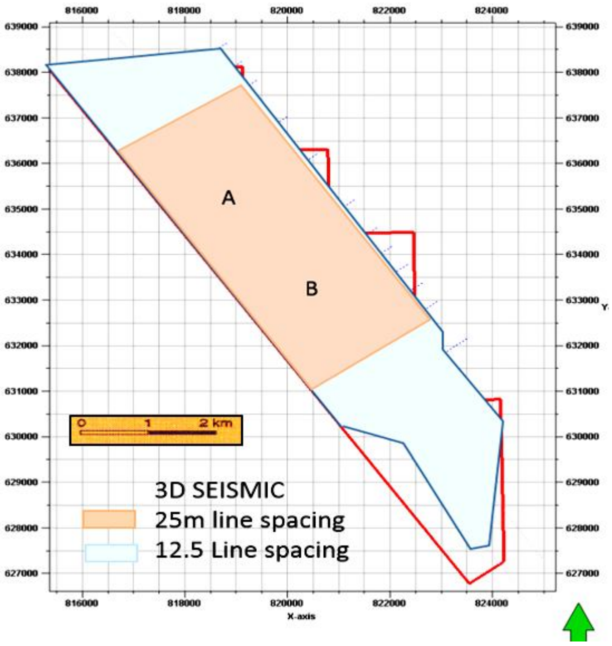

Fig. 7: 3D seismic acquisition of Ras Fanar Field.

The depth processing of the 3D marine seismic data that was acquired over Ras Fanar is covering a surface area of 38.4 km2.

The seismic reflection data used in this study consists of 7 processed seismic profiles covering the study area and three drilled wells used in the tying of seismic grid. One of the principle aims of seismic interpretation is to identify the important seismic reflectors that represent lithological and stratigraphical boundaries, and identify the subsurface structures affecting these reflectors.

5.1 Time interpretation:

The important reflectors are picked on the basis of well markers as the resolution of seismic is very low and the picked reflectors tied together around the network of the seismic lines (looped process).

The seismic interpretation technique is applied to seismic data to enable us to identify a number of regional reflectors (as shown from Fig. 8 to Fig. 14).

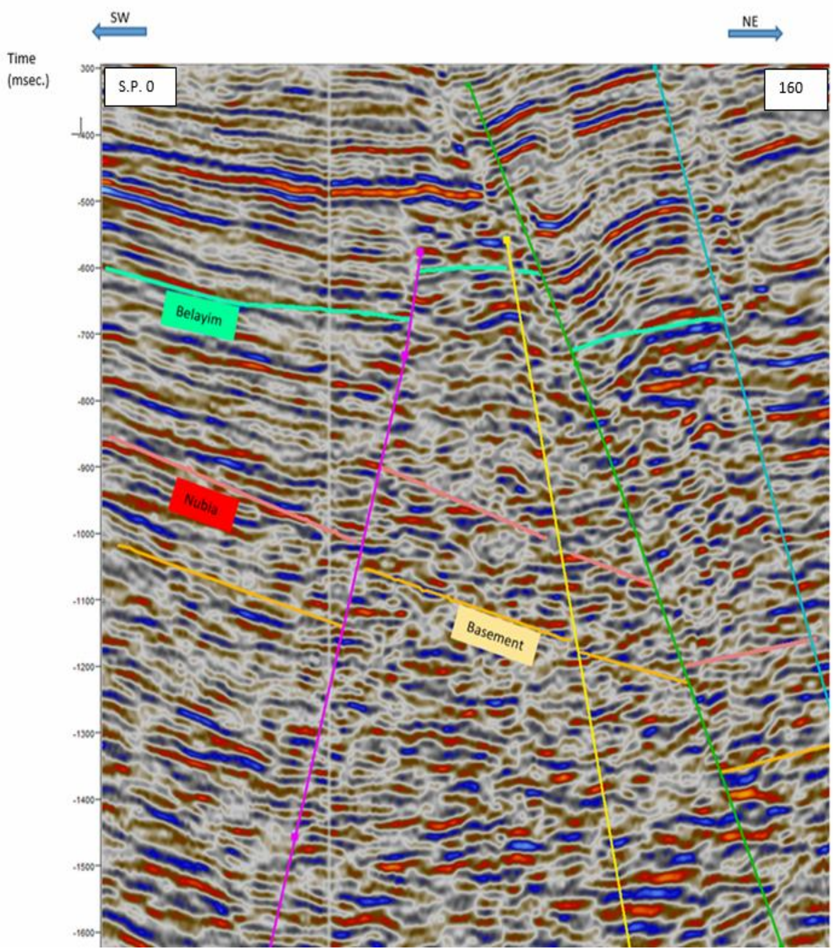

Fig. 8: Interpretation of seismic section in NE-SW direction (line S1) in the northern part of the field with the interpreted three horizons.

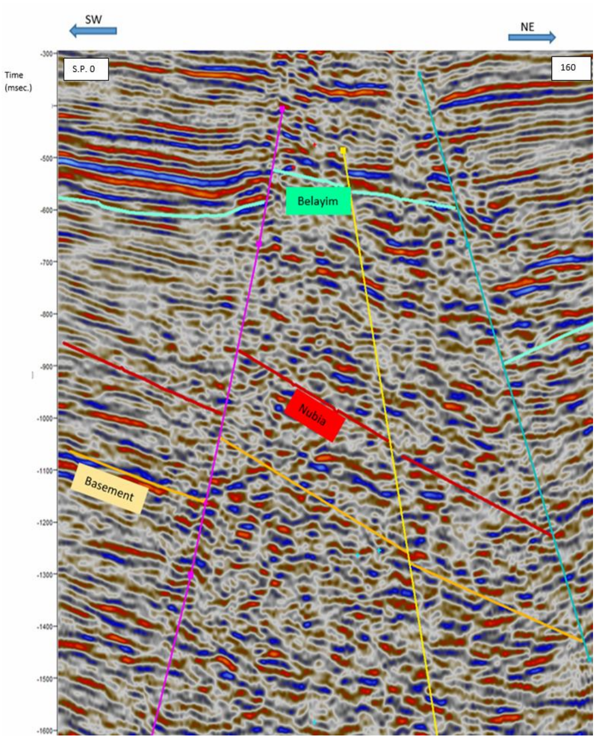

Fig. 9: Interpretation of seismic section in NE-SW direction (line S2) in the northern part of the field with the interpreted three horizons

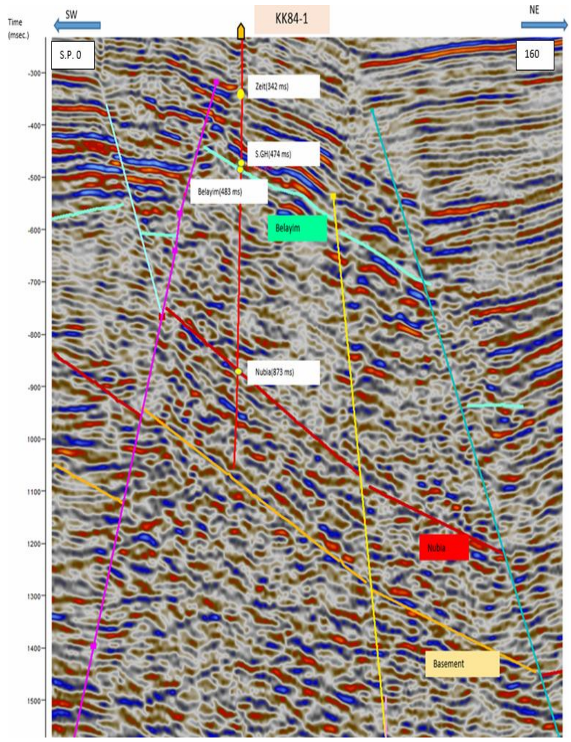

Fig. 10: Interpretation of seismic section (line S3) in NE-SW direction passing through KK84-1 with the interpreted three horizons

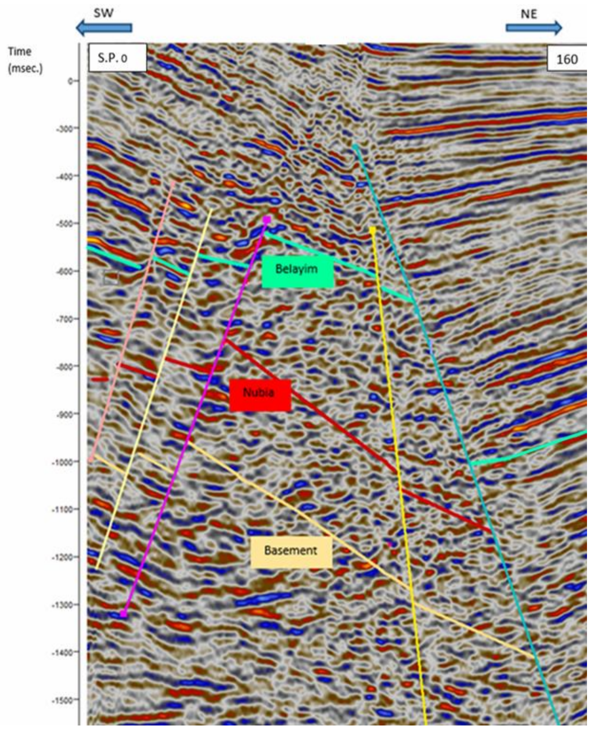

Fig. 11: Interpretation of seismic section in NE-SW direction (line S4) in the southern part of the field with the interpreted three horizons.

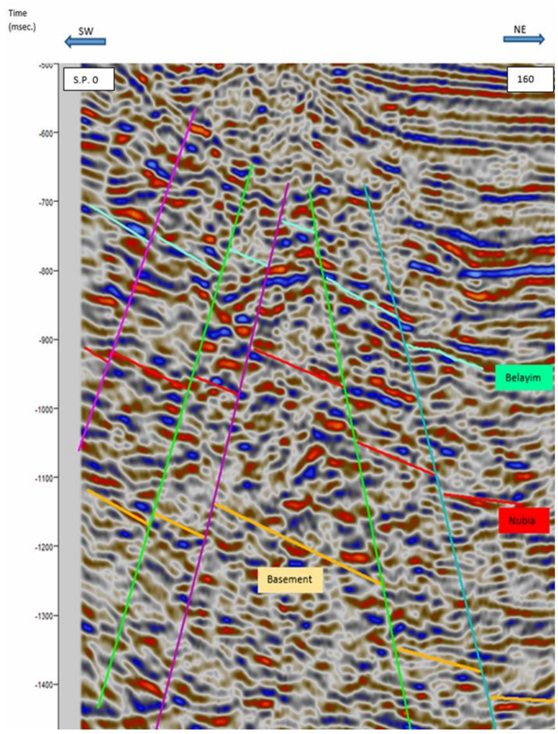

Fig. 12: Interpretation of seismic section in NE-SW direction (line S5) in the southern part of the field with the interpreted three horizons.

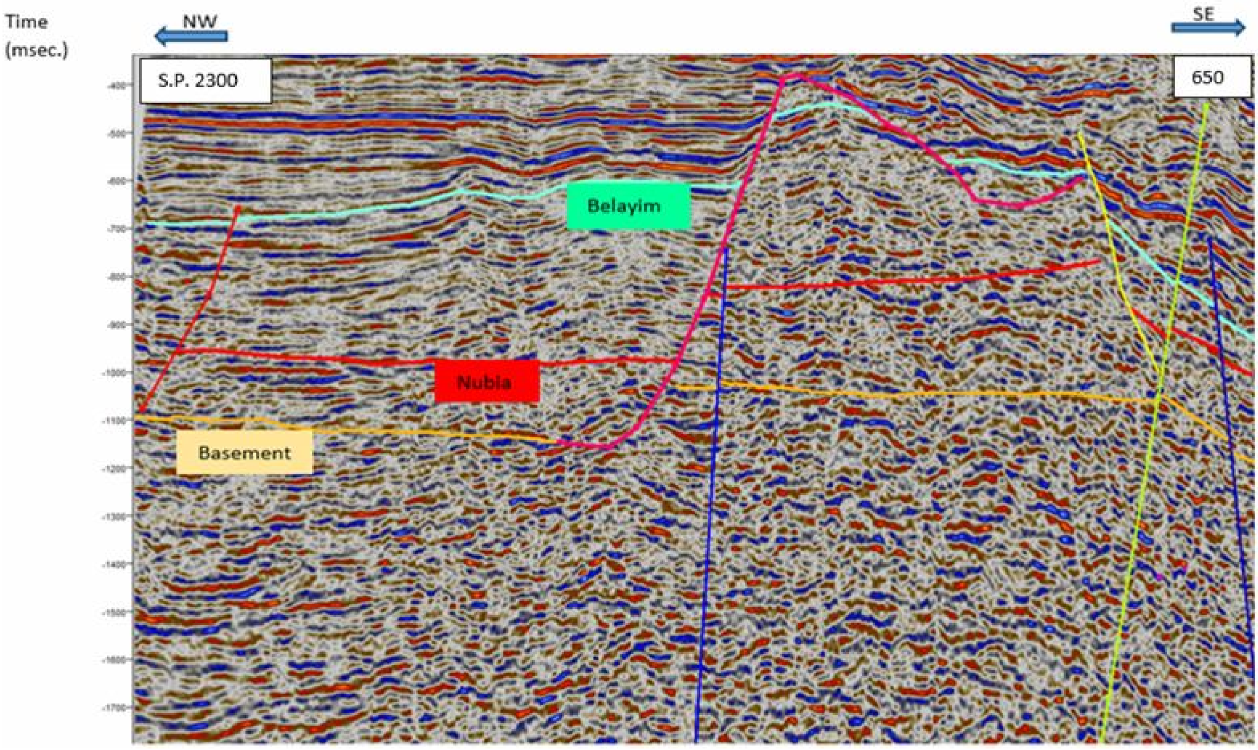

Fig. 13: Interpretation of seismic section in NW-SE direction (line S6) along the field with the interpreted three horizons.

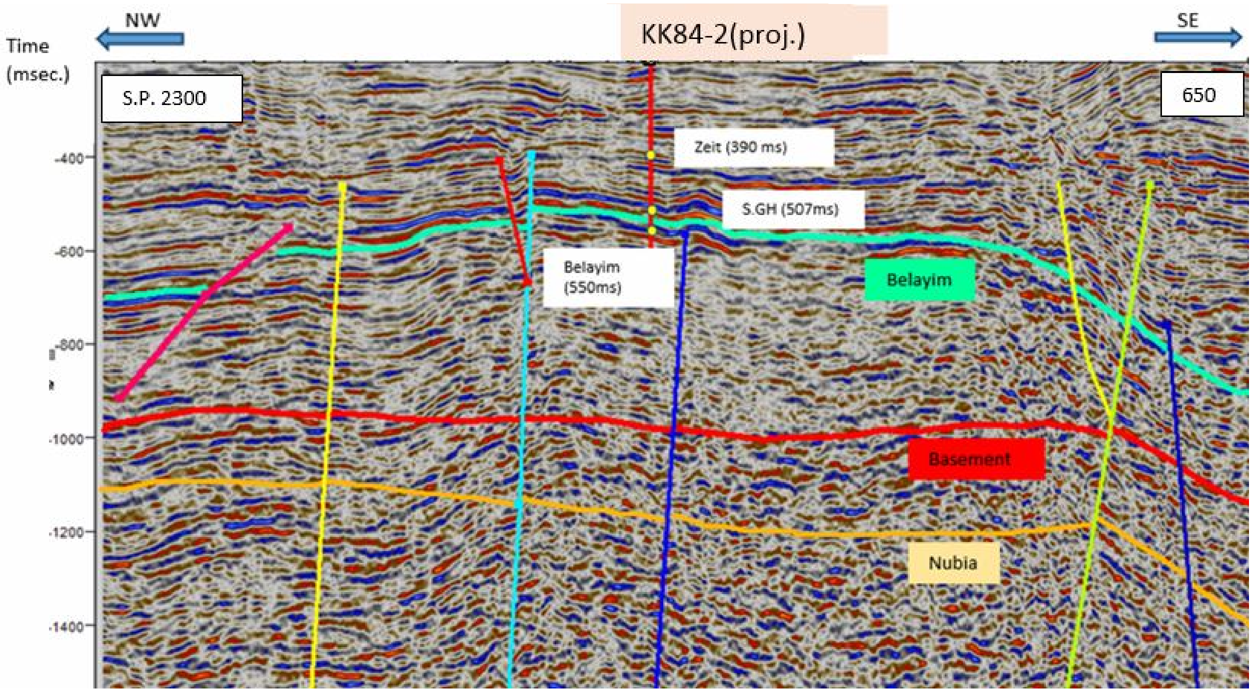

Fig. 14: Interpretation of seismic section in NW-SE direction (line S7) along the field passing through KK84-2 projected 150 m.

After the interpretation of seismic sections, a set of TWT maps are generated (Fig. 15 to Fig.17). These maps include top Belayim, Nubia and basement. The structure of basement is coincidence with magnetic.

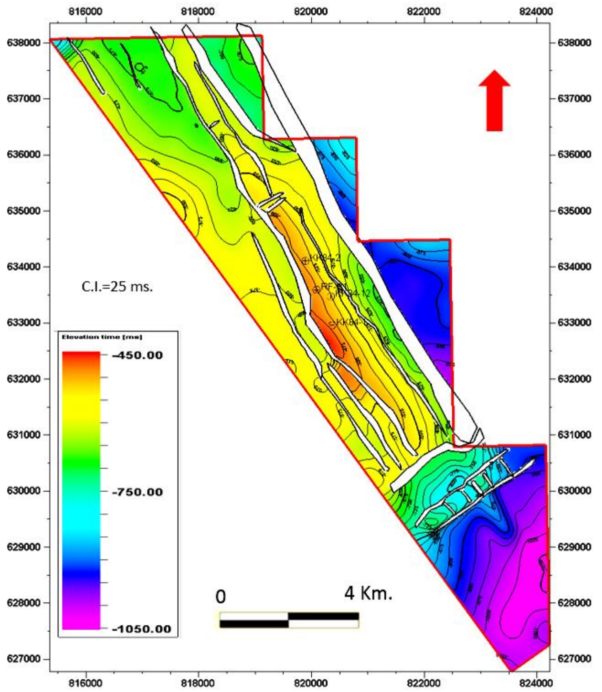

Fig. 15: TWT map on top Belayim formation.

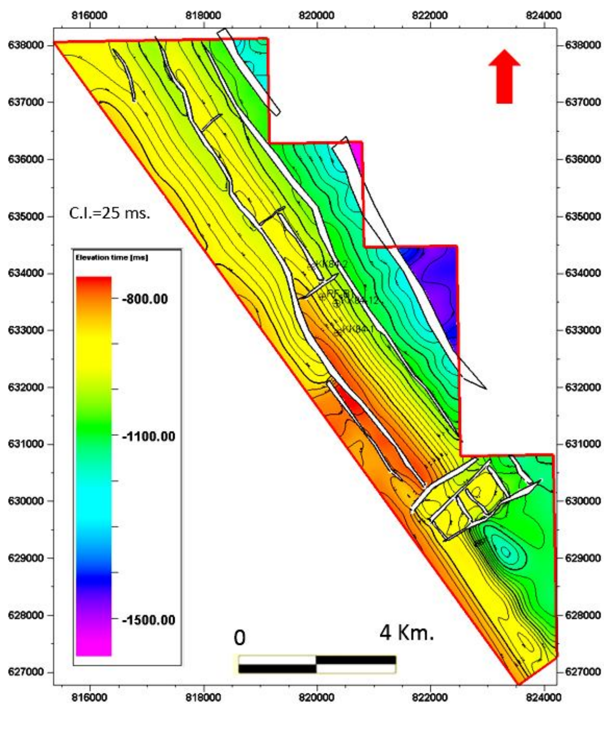

Fig. 16: TWT map on top Nubia rocks.

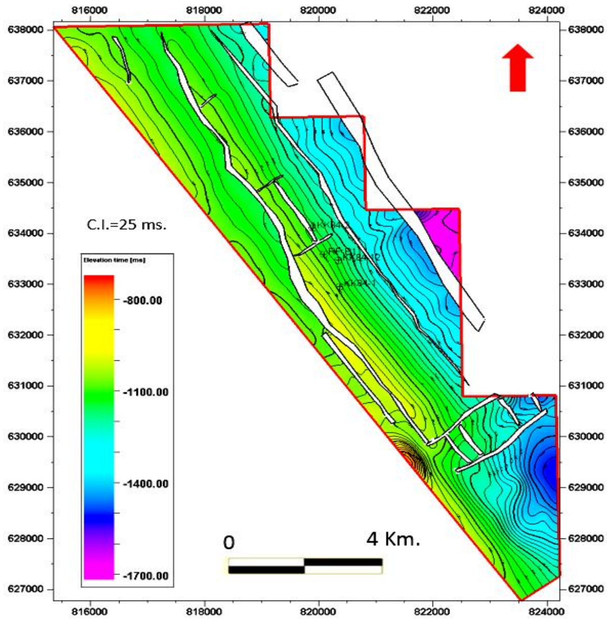

Fig. 17 TWT map on top Basement rocks.

5.3 Velocity Calculation:

The velocities of three formations are calculated which include Belayim, Nubia and basement rocks. The main formula of velocity:

$$\text{Velocity} = Z/OWT, \qquad (2)$$

Where

Z is the depth of a certain layer and OWT is One Way Time of the traveling wave.

5.3.1: Velocity of Belayim formation

Table (1): Velocity calculations of Belayim formation for the three wells.

Well Name	Z(Ft)	TWT(msec)	By applying the velocity law	V(ft/sec)
KK84-1	2021.75	483.47	Velocity= Z/OWT	8364
KK84-2	2073.79	510.74		8121
RF-B1	2035.51	505.58		8052

From the previous data (Table 1) the velocity map on top Belayim formation will be generated

5.3.2 Basement velocity calculation:

- KK84-1 is the only well which encountered top Nubia section with good velocity survey so it is possible to expect the top of basement. Moreover, the depth of Nubia section is at 4165 ft. and the thickness of Nubia section is about 1070 ft so the depth of basement will be around 5235 ft.
- From the plot, the expected average velocity is 10240 ft/sec.

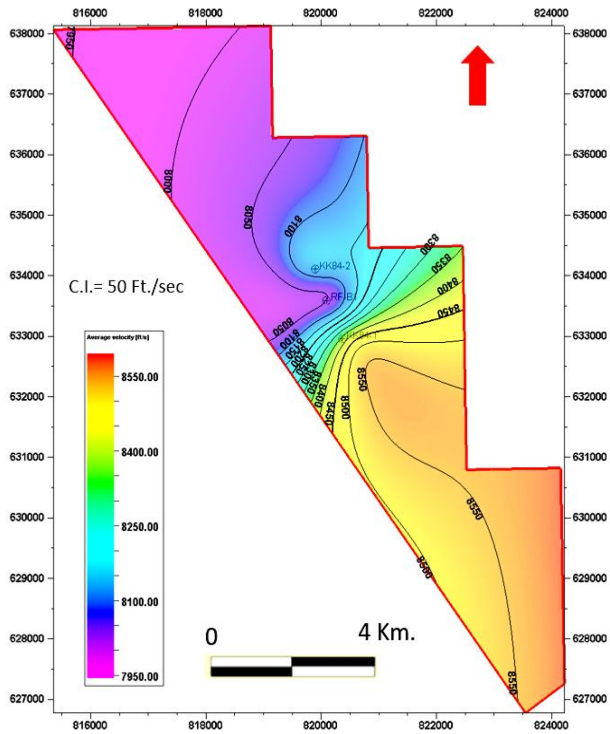

Fig. 18: Average velocity map on top Belayim.

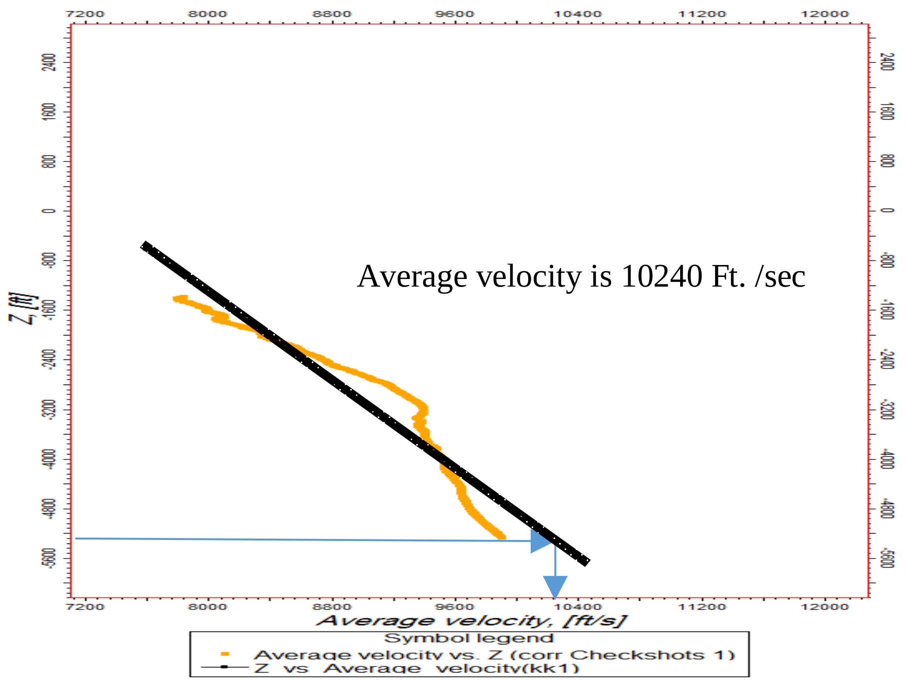

Fig. 19: The calculated velocity of Nubia rocks.

5.3.3 Nubia velocity calculation: it depends only on data of KK84-1 well which encounters Nubia section. By using the formula of equation (2), the velocity will be 9360 ft. /sec as shown in table 2.

Table 2: Velocity calculations of Nubia rocks for KK84-1 well.

Depth(ft.)	OWT(sec)	Velocity(ft./sec)
4165	0.445	9360

5.4 Depth maps generation:

Depth map on top Belayim formation has been generated by multiplying velocity map by time map (Fig. 20 to Fig. 22).

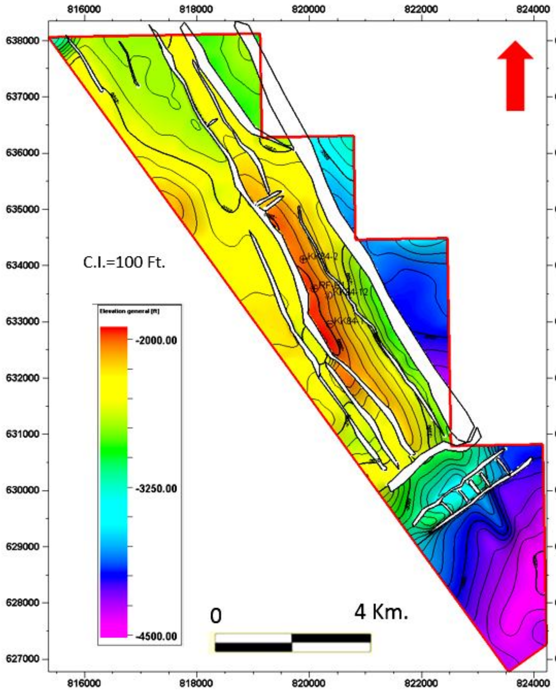

Fig. 20: Depth converted map on top Belayim formation in Ras Fanar Field.

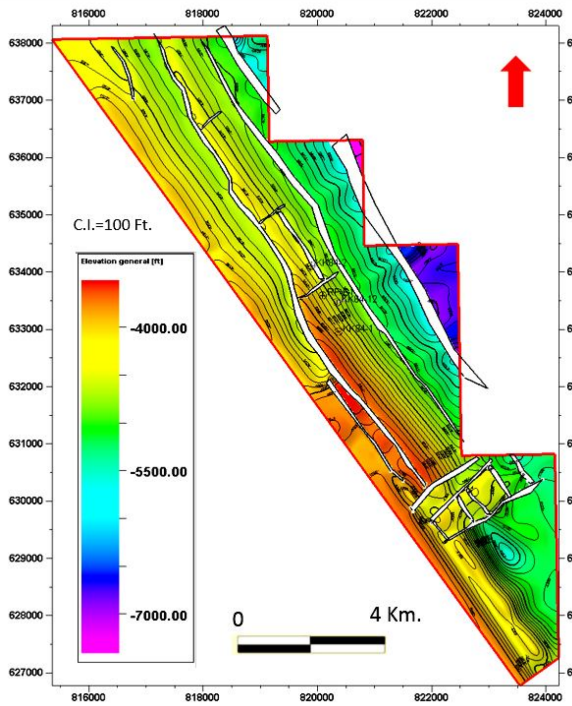

Fig. 21: Depth converted map on top Nubia section in Ras Fanar Field.

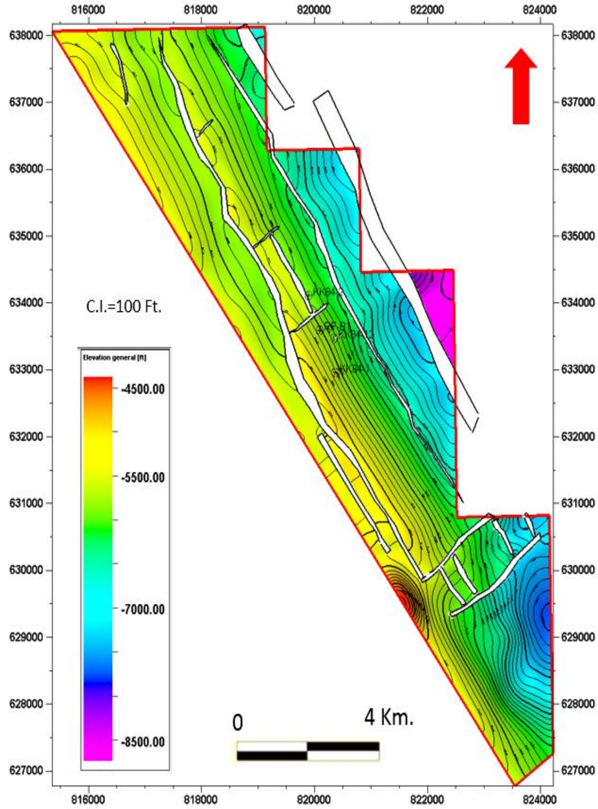

Fig. 22: Depth converted map on top Basement rocks in Ras Fanar Field.

The thickness of Raha formation is created by subtracting 180 ft. (from the stratigraphic column) from top Nubia (Fig. 23).

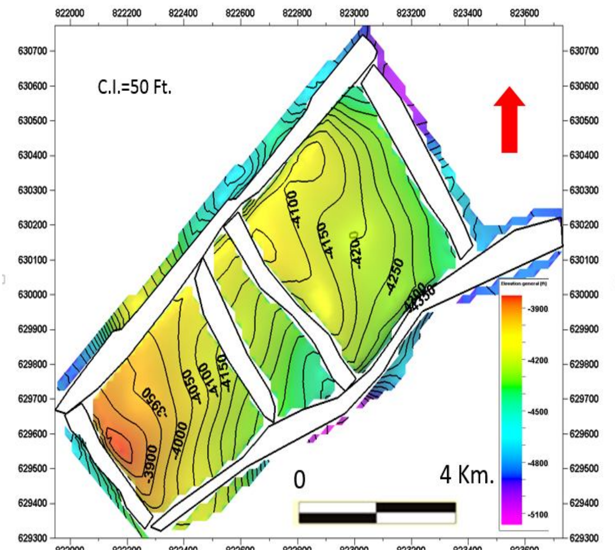

Fig. 23: Depth map on top Raha formation created by thickness subtraction.

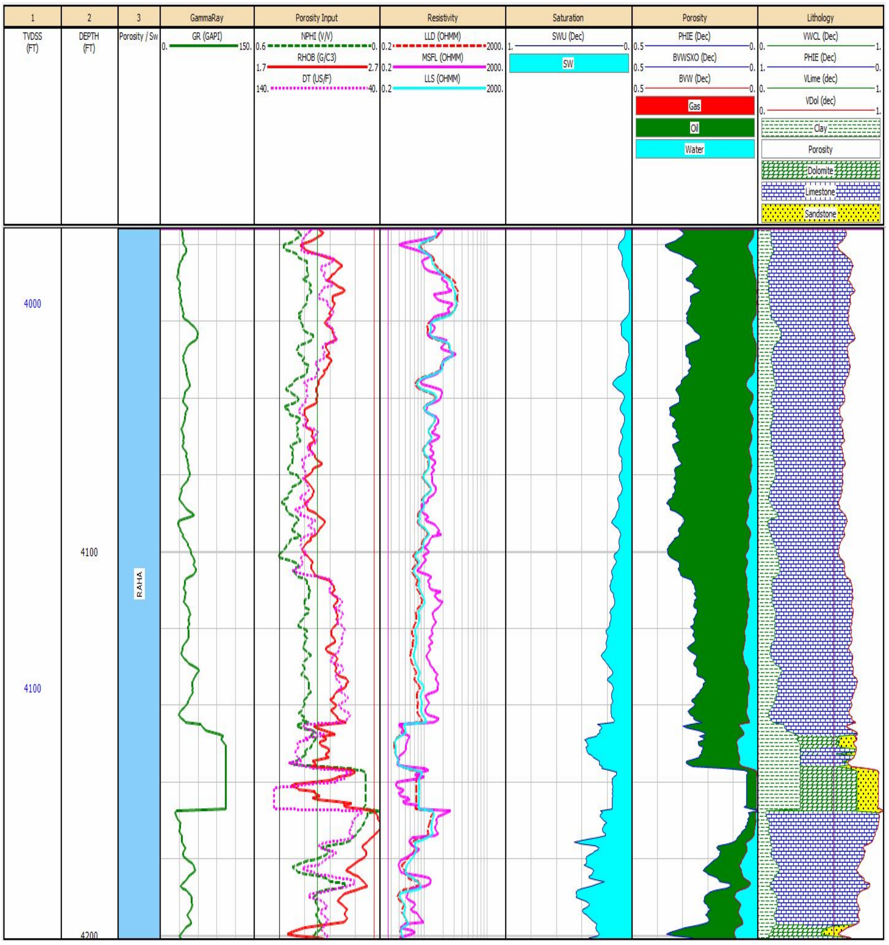

Fig. 24: Estimated Lithology, porosity and fluid saturation for Raha Formation in KK84-1 Well.

6. Petrophysical analysis for KK84-1 Well:

6.1. Top Raha Evaluation:

Three resistivity curves, gamma ray and porosity logs are used to estimate the water saturation and the porosity of Raha Formation (Fig 24).

6.2. Top Nubia Evaluation

Three resistivity curves, gamma ray and porosity logs are used to estimate the water saturation and the porosity of Nubia sandstone in well KK84-1 (fig 25).

6.3. Reservoir Results:

The petrophysical parameters (table 3) for both Raha formation and Nubia sandstone will be used in original oil in place calculations.

Table 3: The petrophysical parameters of Raha formation and Nubia sandstone in KK84-1.

Zone	**Net/Gross**	**Av Phi (%)**	**Av Sw (%)**
Name	pay	pay	pay
Raha Formation	0.838	0.272	0.221
Nubia Sandstone	0.247	0.25	0.379

As there is well X in the southern area of Ras Fanar field has repeated formation test at 4200 ft. so the reserve calculation is made on 4200 ft. (the darkest area). (Fig. 26).

7. Estimate OOIP (Original Oil in Place) for an Oil reservoir

Estimate of original oil in place and the recoverable oil for Raha formation and Nubia sandstone is calculated according to (Beaumont, 1999)

OOIP = [7758 Ah phi (1-Swi) (N/G)]/Boi (3)

where:

OOIP - Original Oil in Place (stb)

A - Reservoir Area (acres)

h - Reservoir Thickness (ft.)

Phi - Reservoir Porosity

Swi - Connate Water Saturation

(N/G)- Net/Gross

Boi - Initial formation volume factor (rb/stb) from PED.

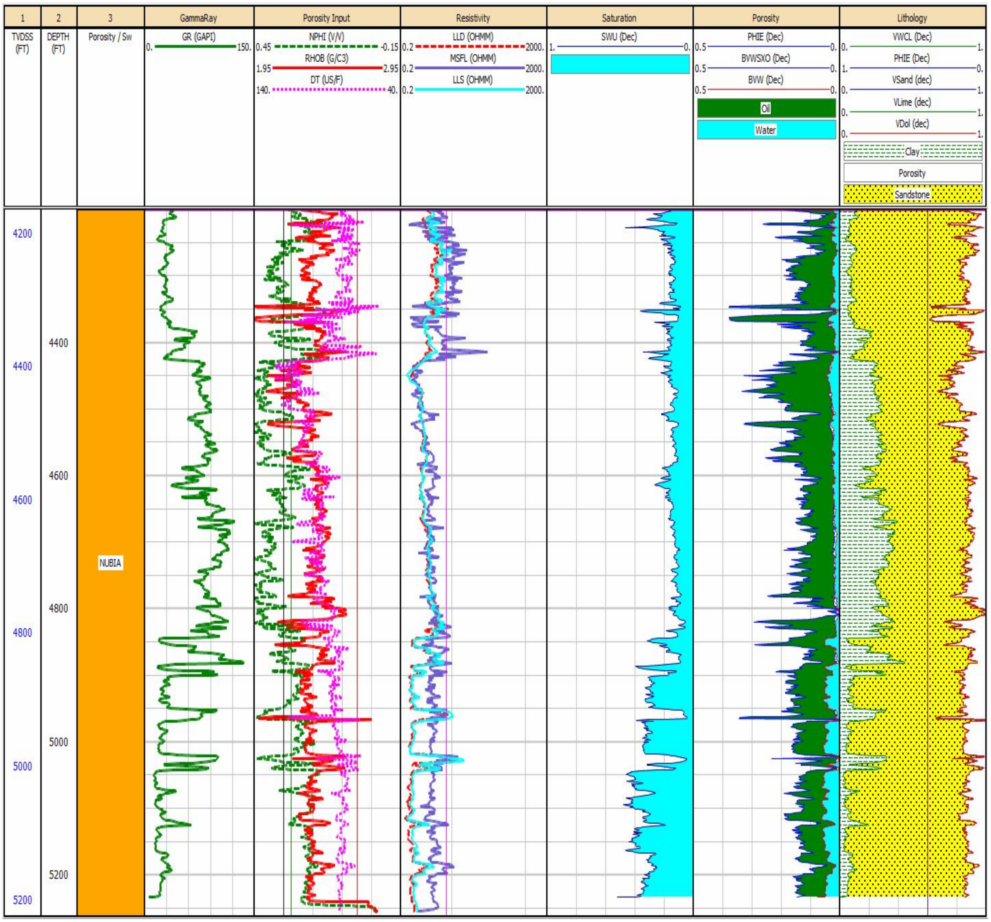

Fig. 25: Estimated Lithology, porosity and fluid saturation for Nubia sandstone in KK84-1 Well.

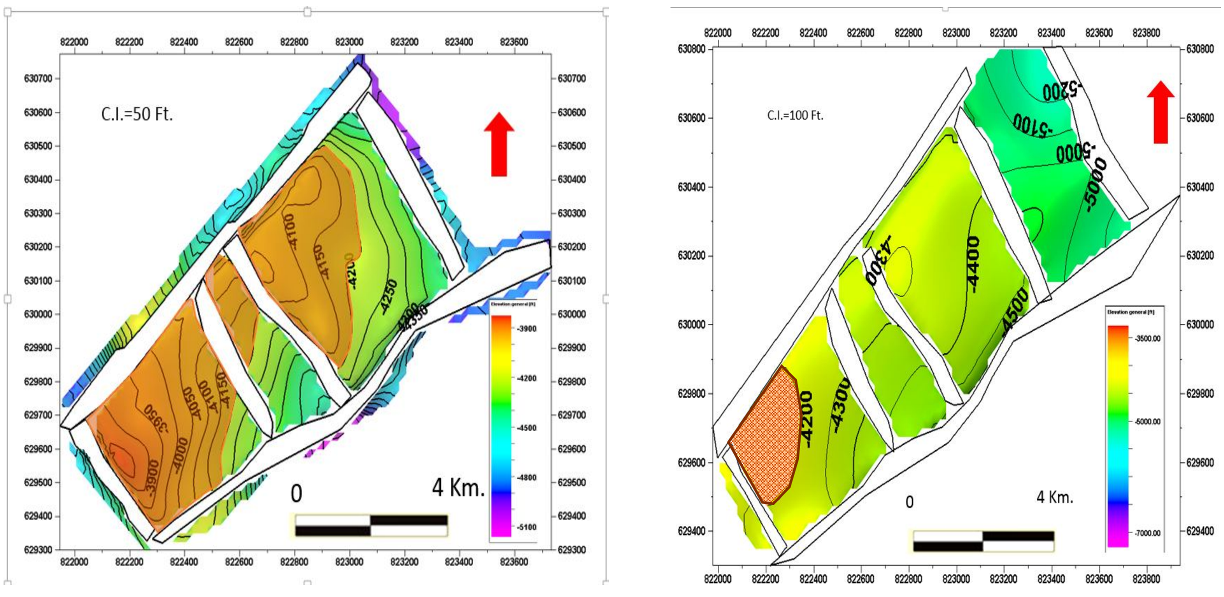

Fig. 26a: top Raha **Fig. 26b: top Nubia**

Fig. 26: Depth Map of top Raha and top Nubia Formations with OWC 4200 ft.

Table 4: calculations of recoverable oil in Raha and Nubia formations.

Formation	AV. Sw(%)	Av PHI(%)	Net/Gross	Volume(ACRE.FT)	Boi	OOIP(MMSTB)	Recoverable(MMSTB)
Raha	22	27	83	10000	1.15	135	5.4
NUBIA	37	25	25	950	1.15	0.3	0.1

The recoverable oil for top Raha is about 5.4 MMSTB and the recoverable oil for top Nubia is about 0.1 MMSTB so the total recoverable of this area will be about 5.5 MMSTB.

Finally, it can be concluded that the southern area is the best area to explore as the recoverable oil is about 5.5 MMSTB.

8. CONCLUSION

The Ras Fanar Field is of great economic interest where it contains some oil prospects in its southern part. The geophysical tools were used in integration to evaluate this area. These tools include magnetic method which is an important tool to detect the structure of the basement rocks and to confirm the structure with seismic surface. Seismic method is used to estimate the relief of carbonate, Nubia and basement surfaces.

TWT and depth maps were converted to conclude structure depth maps. Two major faults trends were detected in NE-SW and NW-SE trends. The petrophysical analysis of KK84-1well logs are performed to determine Net\gross, water saturation and porosity values. 5.5 MMSTB recoverable oil reservoir was explored in the southern area.

9. Acknowledgments

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