Egyptian Geophysical Society
EGS Journal, Vol. 12, No. 1, 97-112 (2014)

SEISMIC DATA INTERPRETATION FOR THE FARAFRA AREA, WESTERN DESERT, EGYPT

A.M. Hassan*, K. Farhoud**, S. E.M. Sharaf Eldin* and W.M. Mabrouk*

** Geophysics Dept., Faculty of Science, Cairo university, Giza, Egypt*
***Gujarat State Petroleum Corporation, Egypt.*

تفسير المعطيات السيزمية فى منطقة الفرافرة بالصحراء الغربية بمصر

الخلاصة: يتناول هذا البحث دراسة جيوفيزيقية متكاملة لواحة الفرافرة بالصحراء الغربية في مصر و تتضمن علي مراجعة عامة للدراسات الجيولوجية السابقة لمنطقة الدراسة بالإضافة إلى تحليل بتروفيزيقي لبئر أمونيت و هى أقرب بئر لمنطقة الدراسة ثم التفسير للبيانات السيزمية لهذه المنطقة، و تم تحديد أربع فواصل بين التتابعات الجيولوجية المختلفة و ربطها ببيانات الآبار، كما تقدم هذه الدراسة التي يمكن أن يتركز بها البترول بهذه المنطقة.

ABSTRACT: *This paper represents an integrated geophysical study for the Farafra area, Western desert, Egypt including a general review for the different geological data and studies carried out over this area, followed by the petrophysical analysis for Ammonite-1 well which is the nearest well for this area. An interpretation of the available seismic reflection data was carried out by picking four different sequence boundaries and tying them with the well data. The available data were in the form of : well logs for an offset well (Ammonite-1) and 20 reprocessed seismic lines distributed over the study area.*

The paper covers the geological setting of the study area including the stratigraphic sequence and the dominating structures through a review for the previous geological studies. It also discusses the log interpretation data of Ammonite-1 well and builds up the formation rock model so that at each depth the volume of shale, matrix, water and hydrocarbon can be determined. This model provides direct method for the quantitative interpretation of the petrophysical parameters such as: shale, porosity and saturations (Sw and Sh), which are the most important for the geologists, geophysicists, petrophysicists, and engineers.

Finally, the interpretation of the seismic reflection data over the study area where four different sequence boundaries are picked and a synthetic seismogram was created for Ammonite-1 well to tie between the well data and the seismic lines. Two way time (TWT) maps for each boundary were the average velocity was used for the depth conversion to draw the depth maps. Finally the new leads are determined for drilling the new wells.

Till this moment, there is no clear petroleum system that could work in this area unless the Silurian and Devonian shales could be proved in the area. They represented in situ petroleum system and that leads to make the Paleozoic play the only chance like in Libya, Algeria, Saudi Arabia and Jordan which will be discussed by this paper.

1. INTRODUCTION

The Farafra exploration area covers about 37,678 (km2) in the Western Desert of Egypt Figure (2). It was explored together with the adjacent South Siwa and Dakhla blocks in 1970 by Conoco (Continental Sahara Oil Company). The program culminated in 1979 with the drilling of Ammonite-1 and Foram-1 exploration wells, both of which encountered Tertiary, Mesozoic and Paleozoic sections and bottomed in commercial basement without oil or gas shows.

1.1 Geological Settings of the Farafra Area:

1.1.1 Geography:

The Farafra depression is the second biggest depression by size located in Egypt and the smallest by population, It is located at latitude 27.06° North and longitude 27.97° East in the Western Desert of Egypt, approximately at the mid-way between Dakhla and Bahariya, as shown in figure(1).

1.1.2 Geomorphology and Topography:

According to the geomorphologic system of Egypt, the Farafra oasis lies within an oval shaped depression, which is bounded by scarps from the eastern, northern and western sides where, it is open to the south. The longer axis of the depression is 102 km, whereas, its east-west axis measured near the middle of the depression is about 90 km. The floor of the depression is covered by the Dakhla Formation in southern part. Northward it is covered by chalk of Maestrichtian age (Khoman chalk), and sand sheet with some sief dunes on top covering the eastern part of the depression. Hence, erosional processes are mainly due to the wind action, temperature variation and occasional low rainfall.

The general relief of the area is relatively low. The maximum height is about 353 m above sea level at El Quss Abu Said south western part of the area, and the minimum reaches about 32 m above sea level at WadiHennis, Ain El Wadi and Wadi El Maqfi areas. These parts are coverd by wet sabkha, as shown in figure (2).

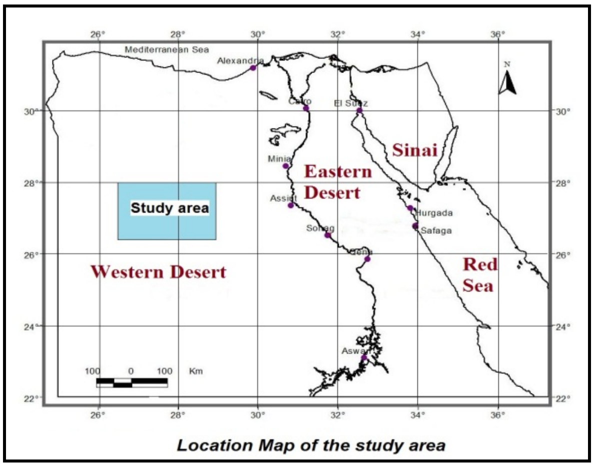

Figure (1): Location of Farafra oasis in Egypt.

1.1.3. Subsurface Geology Of Farafra:

1.1.3.1 The Paleozoic sediments:

- Cambrian to Early Carboniferous is characterized by very mature clastic sediments of braided rivers and very shallow and rapid transgressions.
- Cold climates prevailed in the Early Carboniferous and paleosols are rare to absent.
- Late Carboniferous- Early Jurassic is characterized by very cold to moderate climates sediments and most of them are immature, the paleosols are abundant above the basal glacial formations.

1.1.3.2 Mesozoic:

- The sediments are of moderate to very warm, moist to little bit dry.
- TuronianTaref Formation contain windblown sand.
- Paleosols are common, fluvial sandstone in common is of high to moderate maturity.

The expected Stratigraphic Column for Farafra area as per the nearby out crops that has been explained above (Sources include: Said (1990), EGPC (1992), Selley (1997), Mahmoud and Moawad (1999), Tawadros (2001), Arthur et al. (2003) and Maky and Ramadan (2008):

- KarkurTalhFormation (Ordovician).-Um Ras Formation (Ordovician).
- Tadrart Formation (Silurian).
- Wadi Malik Formation(Carboniferous).
- Lakia Formation (Permian- Late Jurassic).
-Six Hills Formation (Late Jurassic).
- Abu BallasFormation (Aptian). -Sabaya Formation (Albian- Early Cenomanian).
- Maghrabi Formation (Cenomanian).
- Taref formation(Turonian).
- WadiHennis (Early-Middle Campanian).
- El Hefhuf formation (Upper Campanian).
- Dakhla Formation (Maastrichtian).
- Tarawan Formation (Lower Paleocene).
- Esna formation (Upper Paleocene).
- Farafra formation (Ypresian, Lower Eocene).
- Naqb Formation (Lower Eocene).

1.1.4. Description of the Geologic structures:

The Farafra area is distinguished from Dakhla by its relatively more intense tectonics, as it represents the southern extension of the Syrian arc system, more fully developed in Bahariya to its north east. Faults, joints and foldsindicate movements in the basement, but these are faintly distinguished on the surface due to the relatively thick sedimentary cover (Barakat& Abdel Hamid 1973). The sedimentary record in this sector reflects the occurrence of a number of tectonic movements at different times. These movements produce four gently folded structures (Hermina 1990) . Two anticlines (Farafra&AinDalla anticlines) alternate with two synclines (El Quss Abu Said & El Ghard synclines). Rather dense faulting and very prominent jointing resulted from these tectonic disturbances. A prominent set of faults of north east strike is detected parallel to the northern escarpment of the depression. Although individual faults have been traced for a considerable distance, none of these faults was found to extend completely across the whole scarp.

The Farafra main (central) anticline is doubly plunging anticline, trending northeast – southwest with steeper plunge on the northeast. The flanks show gentle dips 2 to 3 degrees, increasing to 7 degrees near the fault. Clastic rocks of the WadiHennisFm. (Campanian) are the oldest rocks exposed on the Central part of the anticline in the area of Ain El Maqfi and WadiHennis.Some faults of a north eastern trends cut obliquely across the Farafra anticline in the area between Guna North and Ain El Maqfi.The eastern flank of the farafra anticline constitutes a huge monoclinal structure covered by limestone. of the Thebes group, which are persistently dip gentely to the southeast. El Ghard syncline extends to the south east of Farafra anticline whose axis also trends north east-southwest in the dune area between BirKarawein and QurZugag(Hermina 1990).

The north west flank of the Farafra anticline is defined by a double plunging syncline of El Quss Abu Said, which in turn is defined by AinDalla minor anticline on its north-west flank. The latter, however, is an ill-defined structure due to the vast cover of sand in the area (Hermina 1990).. The bounding faults extend in a northwest-southeast direction on the plateau areas from Abu Minqar toward El Kharafish.

3. Interpretation of the seismic data covering the Farafra area:

Total seismic coverage interpreted is about 1114.958 line-km of regional 2D seismic data which were acquired by Continental Sahara Oil Company in 1978 and mainly trending northwest-southeast and were reprocessed in Cairo. Among the 20 reprocessed seismic lines, there are 14 along the northwest-southeast regional direction and 6 lines trending northeast-southwest and are tying most of the other regional lines as shown in Figure (4).

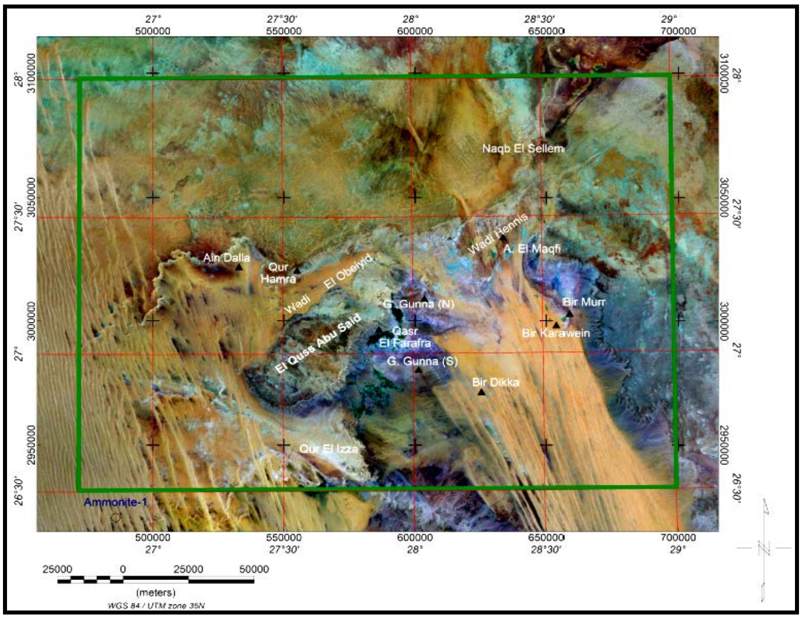

Figure (2): Satellite image with the boundary showing the study area (Farafra oasis).

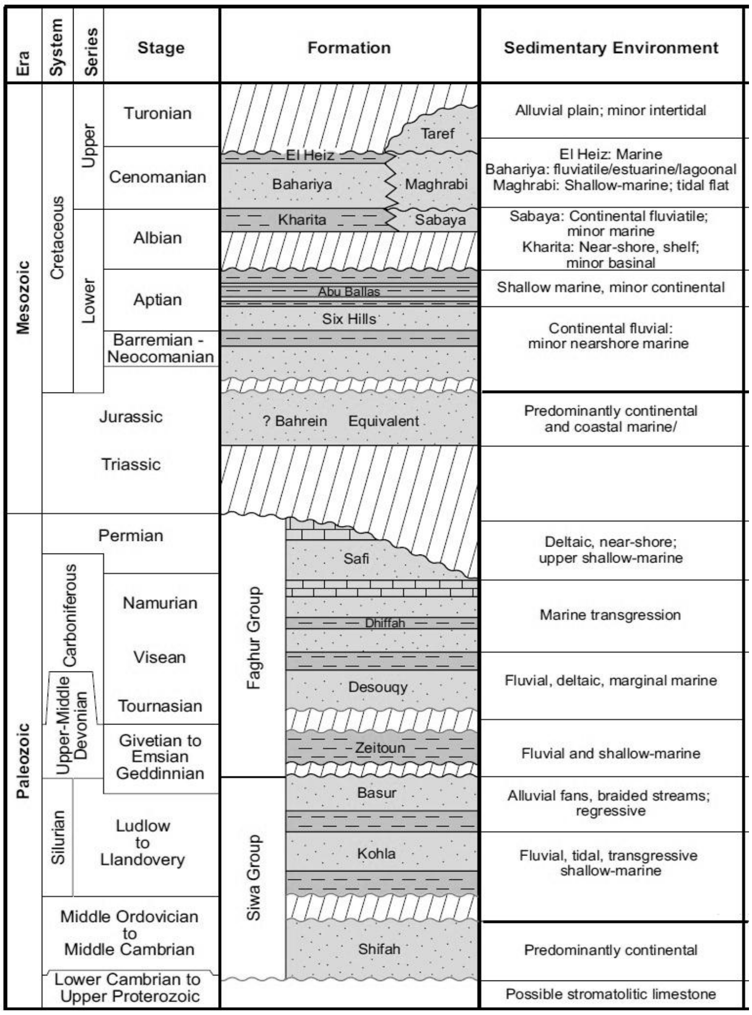

Figure (3): Simplified Mesozoic and Paleozoic stratigraphy predicted to occur in Farafra area, Sources include: Said (1990), EGPC (1992), Selley (1997), Mahmoud and Moawad (1999), Tawadros (2001), Arthur et al. (2003) and Maky and Ramadan (2008).

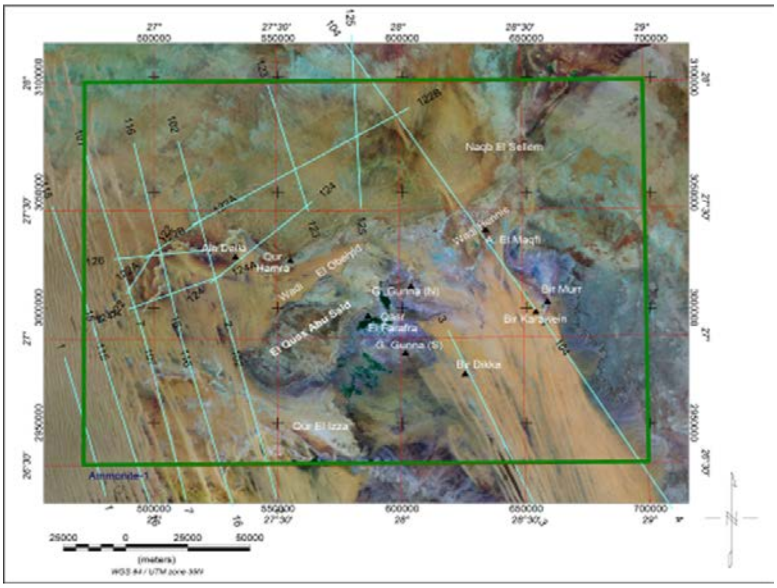

Figure (4): Satellite image showing the boundary of the study area , the 2D reprocessed seismic lines used in the present study and Ammonite-1 well.

3.1 2D seismic interpretation work flow:

The 2D seismic interpretation starts by studying all the data available from the wells and the interpretation of the well logs and correlating them with each other. Then the sonic and density logs are used to create the synthetic seismogram needed for the well to seismic tie then the formation tops are posted from the wells to the seismic section to start picking the horizons of interest with the fault interpretation across them. After that the two way time maps are contoured for each horizon then the velocity function at each horizon is used for the depth conversion to get finally the depth maps on which the new leads and prospects are detected (plate 1).

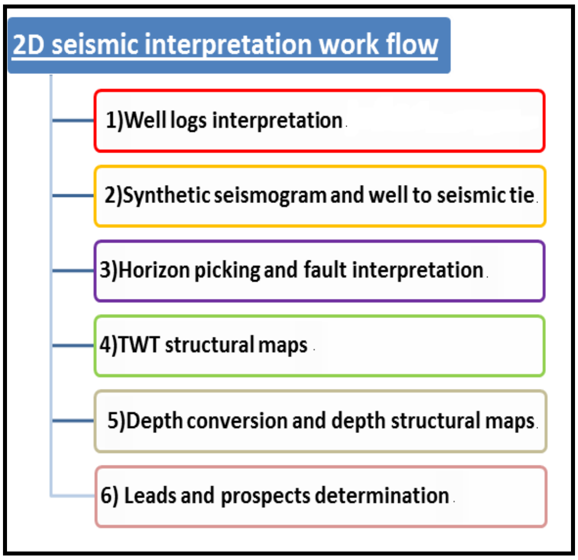

Plate (1): 2D Seismic interpretation work flow.

Table (1). Summary of logs interpretation:

<table>
<tr><td colspan="6">Shale</td></tr>
<tr><td colspan="2">Volume evaluation from single log
GR Log</td><td colspan="2">Shale corrections
Steiber (1973)
$V_{sh} = 0.5X / (1.5-X)$</td><td colspan="2">Shale types
Illite& Kaolinite
$CEC = 10^{(1.9832 \times V_{sh} - 2.4473)}$</td></tr>
<tr><td colspan="6">Effective porosity (ϕ_{eff}.)</td></tr>
<tr><td colspan="6">$\Phi eff. = \Phi t - (\phi_{sh} * v_{sh})$</td></tr>
<tr><td colspan="6">Water Saturation</td></tr>
<tr><td colspan="4">Shaly zones (v_{sh}>10%)
$S_W = \frac{\left[\left(\frac{-V_{sh}}{R_t}\right) + \sqrt{\left(\frac{-V_{sh}^2}{R_{tsh}^2}\right) + \frac{\phi_T^2}{0.2R_tR_W(1-V_{sh})}}\right]}{\frac{\phi_T^2}{0.4R_tR_W(1-V_{sh})}}$</td><td colspan="2">Clean zones (v_{sh}<10%)
$S_W^n = \frac{FR_W}{R_t}$</td></tr>
<tr><td colspan="6">Bulk volume</td></tr>
<tr><td colspan="3">Bulk volume water
$BVW = \Phi_{eff}.{*}S_w$</td><td colspan="3">Matrix volume
$V_{ma} = 1- (V_{sh} + \Phi_{eff.})$</td></tr>
<tr><td colspan="6">Formation rock model (figure 5)</td></tr>
</table>

3.1.1 Well logs interpretation:

From the interpretation the following results are concluded:

1. From the matrix identification plots the most dominating lithologies are silica and shales.
2. From the hydrocarbon indicators it is clear that this well is a dry well and there is a fresh water aquifer extends from depth 1700 to 3200 ft.

Ammonite-1 well

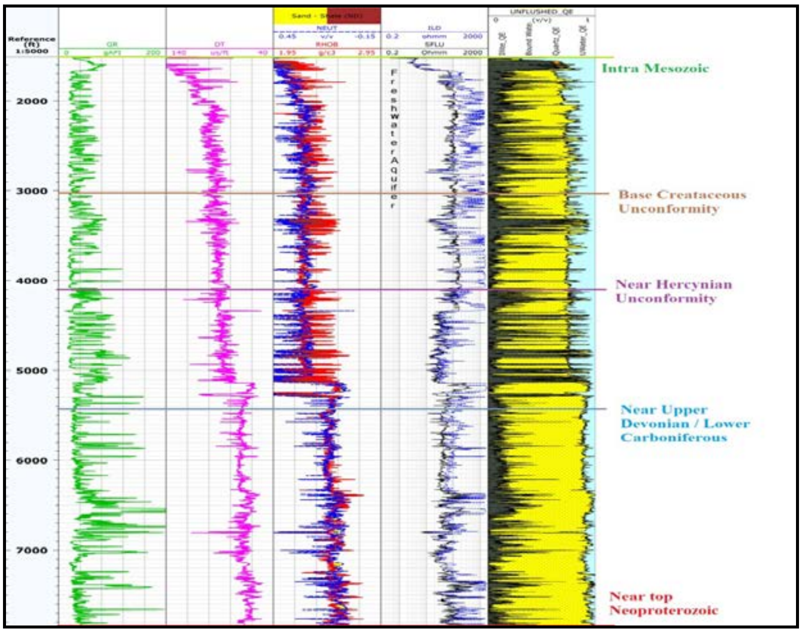

Figure (5): The formation rock model for Ammonite-1 well, Farafra area, Western Desert, Egypt.

3. The shale volume is calculated from a single log which is the gamma ray log and corrected by Steiber equation (1973).
4. The shale types are illites and kaolinites with average densities 2.4 – 2.53 gm/cc.
5. The water saturations were calculated by Sclumberger equation (1975) for the shaly zones and by Archie equation (1942) for the clean zones.
6. The quantitative interpretation can be summarized as follows table (2.5)

The electric well logs for Ammonite-1 well were interpreted to determine the lithologies and formation tops.

3.1.1.1. Petroleum Potentiality:

Farafra area located at the transit between two provinces northern western Desert and southern Western Desert. The northern Western Desert “this term always refer to the area above latitude 28 degree while the south western desert refer to the area south of latitude 28 degree, where the petroleum play is almost well understood in term of petroleum elements, basically in regional sense the source rocks among one of Abu Raosh “F” (ARF) and Khatatba coal.

ARF Upper Cenomanian worked mainly in the central basins of the Western Desert as in El Gindi Basin along with many parts of Abu Gharadig prolific basin, and there is lean of ARF towards the north of Western Desert.Khatatba “Zahra, Upper Safa, Kabrit& lower Safa” Callovian-Bathonian is the second major source rock in the northern Western Desert. North western Desert contains variety of reservoirs but most of the production of the northern western desert is coming from the CenomanianBahariya Formation. Now a days there are good discoveries regarding the Jurassic “KhatatbaFormation”.

The surface section north of latitude 28 degree is almost Tertiary and start with Lower Tertiary at latitude 28 degree and reaches Early to Middle Miocene towards the Mediterranean shore line. This surface section overlaying big section of Late Cretaceous carbonate, all together gives superior regional ultimate seal rock. Traditional thought about south Egypt is that this part of the Western Desert (south of latitude 28) affords excellent exposures of cretaceous and lower Tertiary. This fact was the reason for most of the oil companies to avoid south Egypt from hydrocarbon exploration, where the top seal carbonate and shale in the northern western desert is eroded or not deposited.

As per geologic history and the previous study over the concerned area it seems that there is no chance to catch the Cretaceous play represented by Bahariya , Abu Raoash formations at northern Western Desert and this due to the lack of retention of the hydrocarbons due to the absence of the potential seal or cap rock. Most of the cretaceous formations appear on the outcrops of the surface.

Till this moment there is no clear petroleum system could work in this area unless the Silurian and Devonian shales could be proved in the area which represented in situ petroleum system and those leads to make the Paleozoic play the only chance like in Libya, Algeria, Saudi Arabia and Jordan.

3.1.2. Synthetic seismogram and well to seismic tie:

Synthetic seismogram:

Synthetic seismograms are the bridge between geological information (well data in depth) and geophysical information (seismic data in time).

This essentially involves a two-step process:

- Time converting the wells by means of check shot data or sonic logs.
- Generating synthetic seismograms from density logs, sonic logs and a seismic wavelet by calculating acoustic impedance and reflection coefficients, which are then convolved using a Synthetic seismogram is created by convolving the reflection coefficient log (derived from the well logs) with a defined wavelet. The wavelet will be added at each point in the RC (reflection coefficients) log with an amplitude equivalent to the size of the reflection. These are then summed to give the synthetic seismogram, figure (6).

Well to seismic tie:

We create a Synthetic Seismogram to know the accurate location of the formation tops of interest horizon then tie it with the seismic section. Synthetic indicates also that if the horizon response is peak or trough.

From the well, we know the depth of the event (Formation tops).

From plotting the values of depths and times, we can extract the time valuesfor certain depth (to mark these depths on seismic section).We must know the datum of survey (datum survey in seismic called Seismic reference datum). We must know the type of well depth (TVD, MD, or TVD subsea).

3.4.1.3 Horizon picking and fault interpretation:

The rules followed in selection of horizons for Picking are as follows:

- Geologically, the picked horizons, as per the geological understanding of the geology and, in regional seismic tie between the data sets.
- Horizons that possibly representing reservoirs.

The picked horizons have been tied with the Ammonite well synthetic seismogram, to confirm the represented geological formations.

These horizons from younger to older are as of follow:

1- Intra Mesozoic horizon.

2- Near Hercynian unconformity horizon.

3- Near Upper Devonian horizon/Lower Carboniferous.

4- Near top Neoproterozoic horizon.

Horizons Polarity:

In Farafra area, the only available well data is Ammonite -1X well synthetic seismogram and all horizons picked according to the signature given from this well all over the block.The seismic signature of the horizon is constant in all cases is peak or trough represented by black or red color in the seismic section except the Hercynian unconformity marker which selected to represent strong truncation according to the unconformable relation with the other reflections, however in most cases it is represented by strong trough.

Horizons Picking and Distribution:

Intra Mesozoic:

This horizon is sharp and strong negative reflector separating between two regional seismic packages, characterized by nearly constant signature all over the survey area, with smooth close to be flat low relief structure character, and it is assumed to be one of the major unconformity surfaces.This horizon is located possibly in the middle of the expected Mesozoic section, and defining boundary of high frequency, high amplitude package which appeared to be a constant phenomenon covering all the surveyed area, with the exception of the part of bad quality seismic data within the protected area white desert park.

Near Hercynian unconformity:

The most clear and defined reflector in the block, expressing a regional unconformity surface separating between the Paleozoic and Mesozoic deposits.Clearly there is severe increase of the velocity just below the unconformity surface which is reflected by strong seismic reflector, where this reflector separating between two different packages the deeper and high frequency low amplitude transparent package, and the upper is higher in both amplitude and frequency content.

Moreover this horizon is separating between different reflections angles, the shallower section and the one beneath thereof which nearly horizontal facies on lapping on the Paleozoic of gentle dipping reflectors. It is quite clear to follow it in the block and in the available 2D seismic lines than the other horizons all over the seismic data, even in the bad quality area.

Near Upper Devonian / Lower Carboniferous horizon:

It is a strong clear marker within the possibly Paleozoic package, this horizon is well defined as a strong positive amplitude and high frequency marker continue all over the block with the same character, eroded/ truncated on Hercynian unconformity and absent due to erosion/non deposition in the northern part.It represents the middle Paleozoic (Silurian age) which characterized by the Paleochannels as shown in (figure 9). This Paleo Channels formed during the Silurian as the earth rotate near to the northern pole so the ice cap of the earth has been formed then at the end of the Ordovician age the earth move toward north so the melting occur during the Deglaciation time. This melting of ice formed channels on the surface called paleochannels appear on the section as an evidence of the silurian age.

Incised Valleys:

The regional geological background in nearby area, for instance Middle East along with North Africa indicating the presence of channels within the lower Silurian as result of climate / environmental changes taken place after the Ordovician de-glaciations and melting of the huge bodies of the glaciers followed by regional scales streams which cutdown through the late Ordovician sediments and producing ENE-WSW incised valleys.

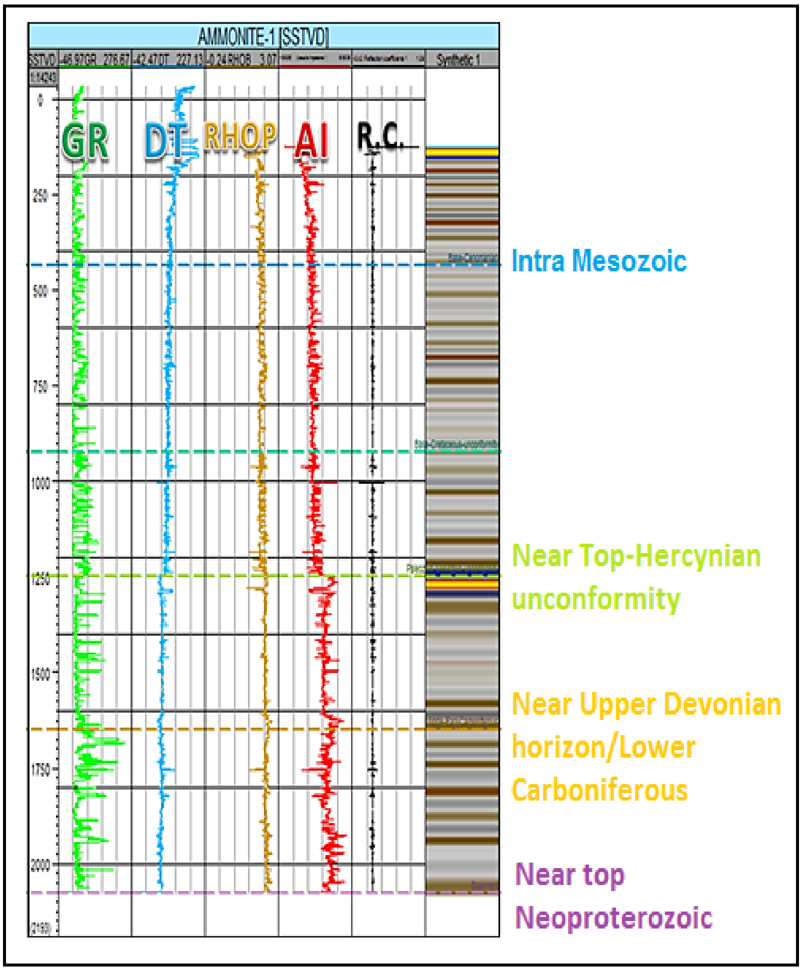

Figure (6): Synthetic seismogram for Ammonite-1 well with the formation tops.

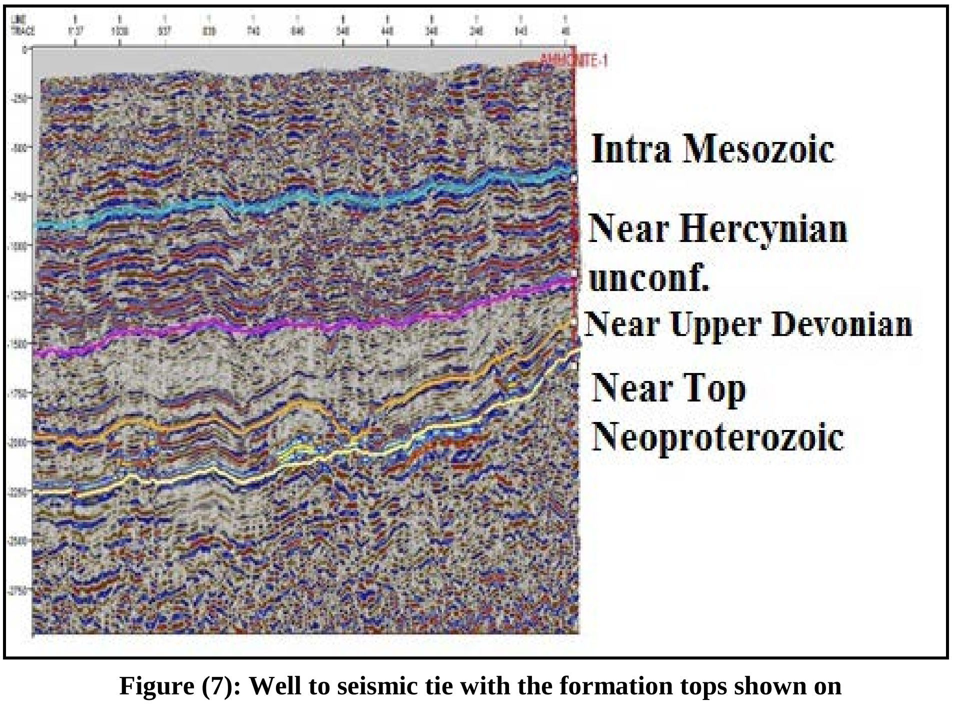

Figure (7): Well to seismic tie with the formation tops shown on the seismic section and denoted to the right.

These valleys are detected in this block and outlined according to the available data, where, taking in account that the accuracy of these old data.These channels complex are limited regionally to base Silurian package and according to the available data the incisions are terminated by the Upper Silurian package. The outline of above mentioned valleys/ channel-like might and possibly will be changed after acquisition of new 3D but still the effect of the valleys/ channel-like are clear and matching the identified regional directions. In general, the valley geometry is defined by the characteristic shape and its terminations of reflections in both sides of the boundary thereof, the regional character of the Lower Silurian package is low frequency, medium amplitude and fair to good continuity reflections, this package are intersected by high amplitude, high frequency packages with different extension laterally and vertically (figure 9).

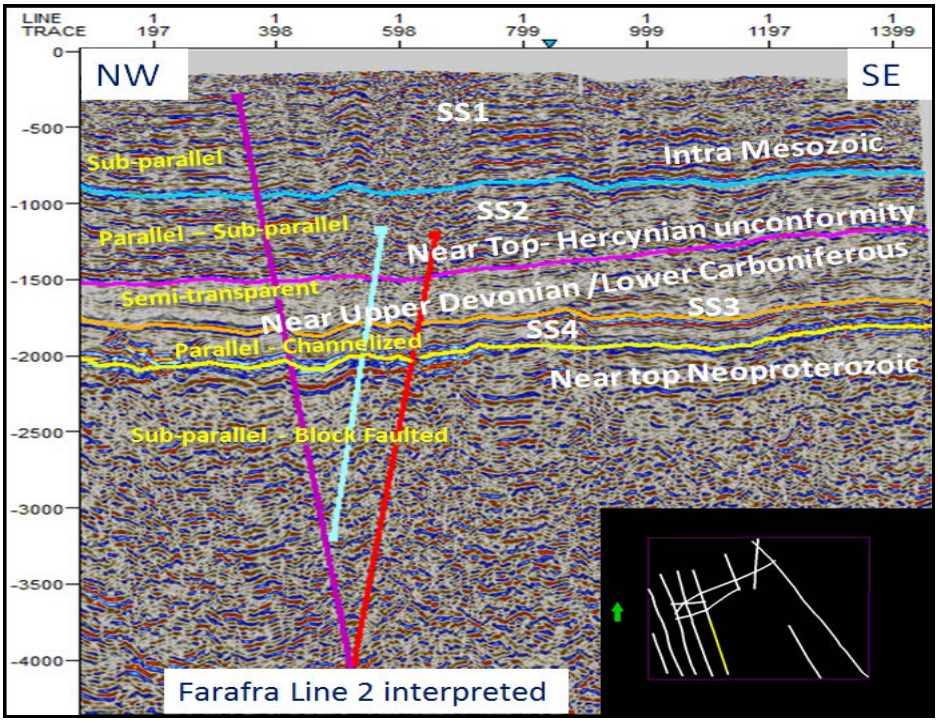

Figure (8): Interpreted seismic Line-2 showing the picked horizons and the structural interpretation.

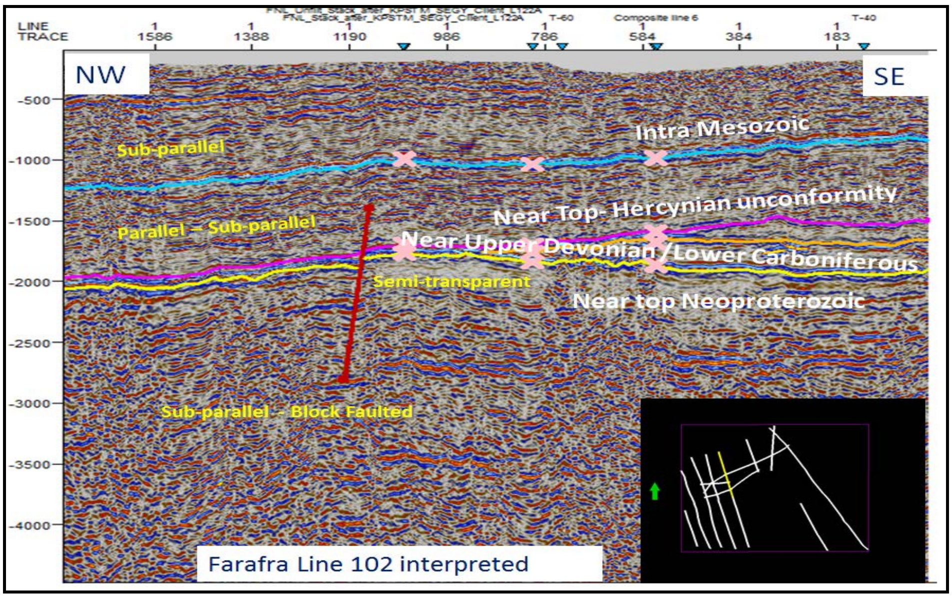

Figure (9): Interpreted seismic Line-102 showing the pinching out of the Near Upper Devonian / Lower Carboniferous Horizon.

Neoproterozoic horizon:

The most clear and quit defined reflector in the block, expressing a regional unconformity surface separating the possibleLower Paleozoic deposits from older sediments of Proterozoic age.This horizon is seismically is sharp, high amplitude low frequency and clear continuity assuming this horizon is the sedimentary-basement boundary.

The most dominating structures in the area are normal planar faults forming grabens and half grabens as shown in figures (7, 8).

Fault criteria on seismic section:

- TWT offsets.
- Reflection character changes.
- Dip changes.
- Amplitude dimming.
- Diffractions. (Sroor 2010).

The 2D seismic coverage is considered of fair quality in the western area of the block; however it is very poor to inadequate in the eastern area. The available 2D seismic data for interpretation is comprised of one old survey that was acquired by Continental Sahara Oil Company probably in 1978. This data set is used in locating Ammonite Well-1X on a pronounced seismic high that is close by the southwestern corner of the block.

Utilizing the Paleozoic to Upper Proterozoic mega-regional stratigraphy along the Gondwana shelf and across North Africa and the Arabian Plate, the four interpreted and tied geo-seismic sequence boundaries are defined as Intra Mesozoic horizon which probably is of Jurassic-Cretaceous age, Near Top-Hercynian Unconformity horizon which is interpreted to be the regional Upper Paleozoic, Near Upper Devonian /Lower CarboniferousHorizon which is interpreted to be near basal Silurian shale sequence, and Near Top Neoproterozoic horizon near what is described in Ammonite well report as Basement however it is believe to be a Pre-Cambrian/top Upper Proterozoic sedimentary section which overlies the crystalline Precambrian Basement.

All of the defined four sequence boundaries are considered mappable in areas of good quality seismic data and as indicated all correlate with the typical Paleozoic stratigraphic sequences described in the Western Desert particularly the Silurian-Devonian major unconformity along with the basal Silurian extremely important sequence boundary with potential petroleum source rocks of the Silurian ‘black hot shale’.

Sample Seismic Line L-102(northwest)/L-2 (extension in southeast) in the western region of the Farafra area (Figures 7,8). The Line Indicates the Nature of the correlated 4 seismic boundaries Intra Mesozoic horizon through, Near Top Neoproterozoic horizon and their encompassed Seismic Sequences SS-1 through SS-4. Notice the drastic change in the seismic isochrones between Near Top-Hercynian Unconformity horizon and Near Top Neoproterozoic horizon along with Intra Mesozoic horizon and Near Top-Hercynian Unconformity horizon.

3.2.1.4 Time Mapping

Maps quality is controlled by:

1- Intensity of data.
2- Accuracy of seismic interpretation.
3- The mapping parameters

All the available data in the new survey are used in interpretation.The data quality is good enough to follow all the selected horizons for picking , the average grid cell of this data is quite suitable in most of the area.The horizons characters are fair to good with limitation of the bad quality over the White Desert park at the north of the studied area. This limitation affecting the horizon and fault interpretation of the above mentioned horizon. The mapping parameters used is the standard petrel software; the maps are tested after mapping by displaying the maps grids on seismic section to avoid any possible effects of the smoothing or grid cell effects.

Time Maps:

Then, we created the two way time maps and depth maps for these seismic boundaries Intra Mesozoic, Near Hercynian Unconformity, Near Upper Devonian /Lower CarboniferousHorizon, Near Top Neoproterozoic Horizon. For the two way time (TWT) map of Intra Mesozoic Horizon the highest value (shallowest) is -560 msec and it is located at the south western part of the area where Ammonite-1x well was drilled, while the lowest (deepest) value is -1400 msec and it is located at the north west part of the map.A major normal fault is shown in this map trending NE – SW with small throw towards the south eastern part of the map figure (10 a).

The two way time (TWT) map of Near Hercynian Unconformity the highest value (shallowest) is -1200 msec and it is located at the south west part of the area where Ammonite-1x well was drilled, while the lowest (deepest) value is -2080msec and it is located at the north west part of the area .Two major normal faults are shown in this map trending NE – SW forming a horst between them as their throws are in opposite directions.Also there are two minor faults trending E – W forming graben and half graben with one of the major faults as shown in figure (10 b).

For the two way time (TWT) map of Near Upper Devonian /Lower CarboniferousHorizon the highest value (shallowest) is -1240 msec and it is located at the south western part of the area where Ammonite-1x well was drilled, while the lowest (deepest) value is -2040 msec and it is located at the north western part of the area .A major normal fault is shown in this map trending NE–SW with small throw towards the south east part of the map and two minor faults trending E-W figure (10 c).The map shows pinching out forming angular unconformity with Near Hercynian Unconformity Horizon and three normal faults forming grabens and half grabens .

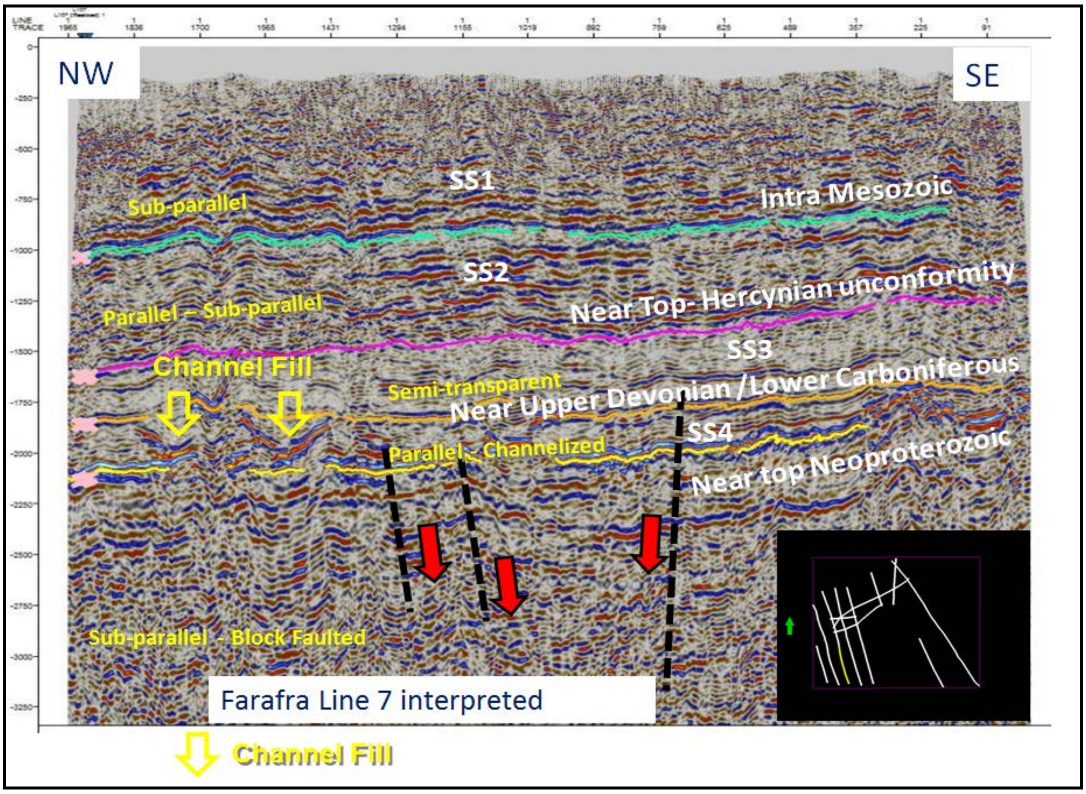

Figure (10): Interpreted seismic Line-7showing probable paleochannels and faulted blocks.

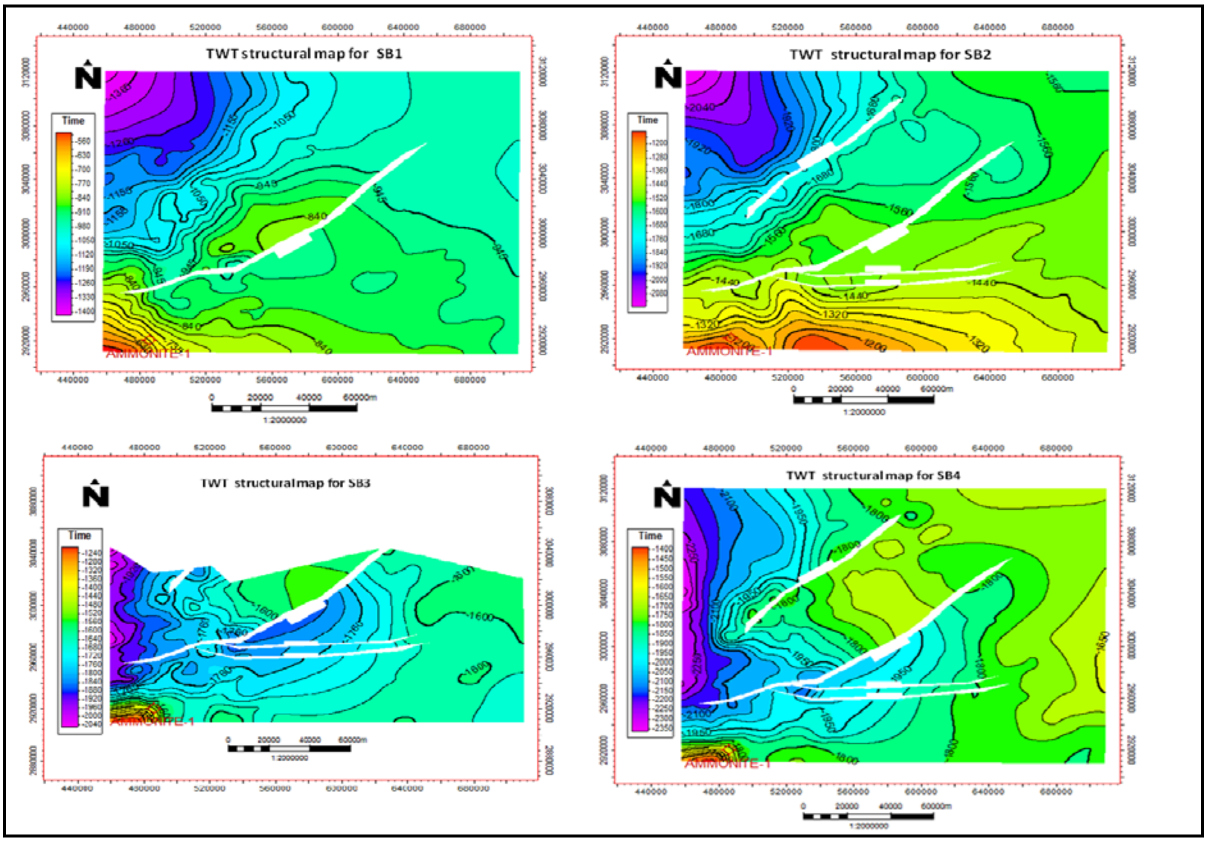

Figure (11): TWT maps for a) Intra Mesozoic b) Near top Hercynianunconf. C) Near Upper Devonian /Lower Carboniferous d) Near Top Neoproterozoic Horizon (Infracambrian Unconformity).

For the two way time (TWT) map of Near Top Neoproterozoic Horizon the highest value (shallowest) is -1400 msec and it is located at the south western part of the area where Ammonite-1x well was drilled, while the lowest (deepest) value is -2350 msec and it is located at the north western part of the area.

Two major normal faults are shown in this map trending NE – SW forming a horst between them as their throws are in opposite directions.Also there are two minor faults trending E – W forming graben and half graben with one of the major faults as shown in figure (10 d).

3.2.1.5 Depth conversion and depth structural maps:

Depth conversion:

Due to the lack of drilled wells in the area and also the lack of check shot data even in Ammonite well which is 12 Km far from the nearest seismic line , accordingly to get the velocity from the sonic log, the following steps have been used.

1) Calculating the instantaneous velocity (Vi=1/DT).

2) Calculate the average velocity from surface to each depth.

With the absence of the well data in the area in addition to the areal extension of the seismic survey, make it mandatory to use the only available velocity which is coming from the only available Ammonite-1X well velocity. The depth conversion of the time maps is achieved using the available average velocity on the interpreted horizons.

Lead	Type and Age	X	Y	Area(km^2)
A	3way dip closure (lower carboniferous)	3028000	512000	31.70
B	3way dip closure (lower carboniferous)	3032000	632000	21.78
E	Channel (lower carboniferous)	2984000	510000	23.47
A_2	3way dip closure (Neoproterozoic)	3036000	492000	110.0
C	4way dip closure (Neoproterozoic)	3072000	562000	144.1
D	4way dip closure (Neoproterozoic)	3084000	612000	159.7

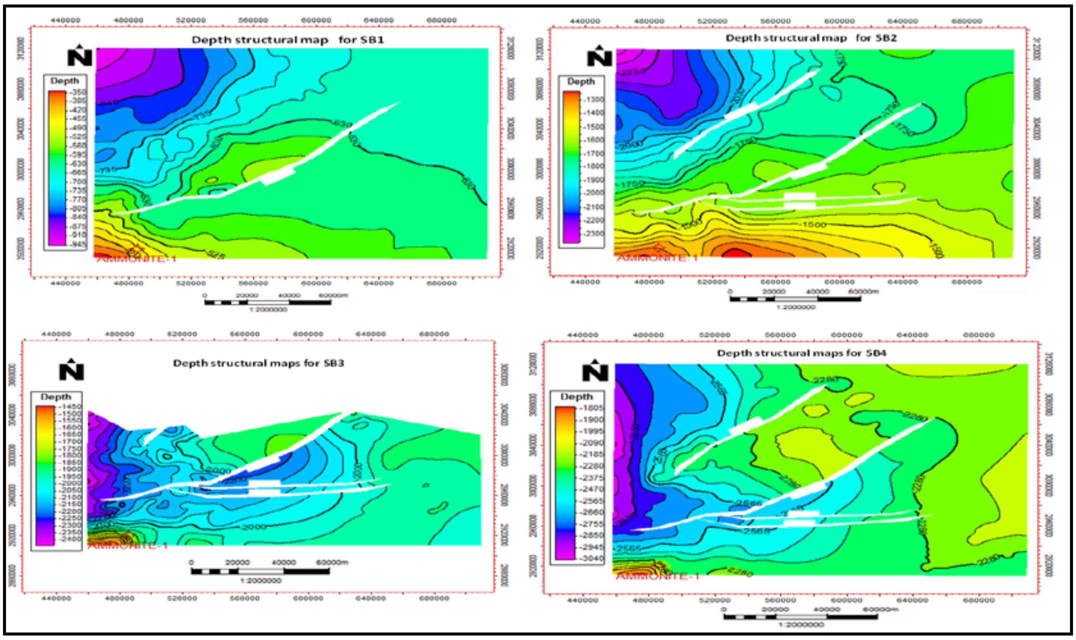

Figure (12): Depth maps for a) Intra Mesozoic b) Near top Hercynianunconf. C) Near Upper Devonian/ Lower Carboniferous d) Near Top Neoproterozoic Horizon (Infracambrian Unconformity).

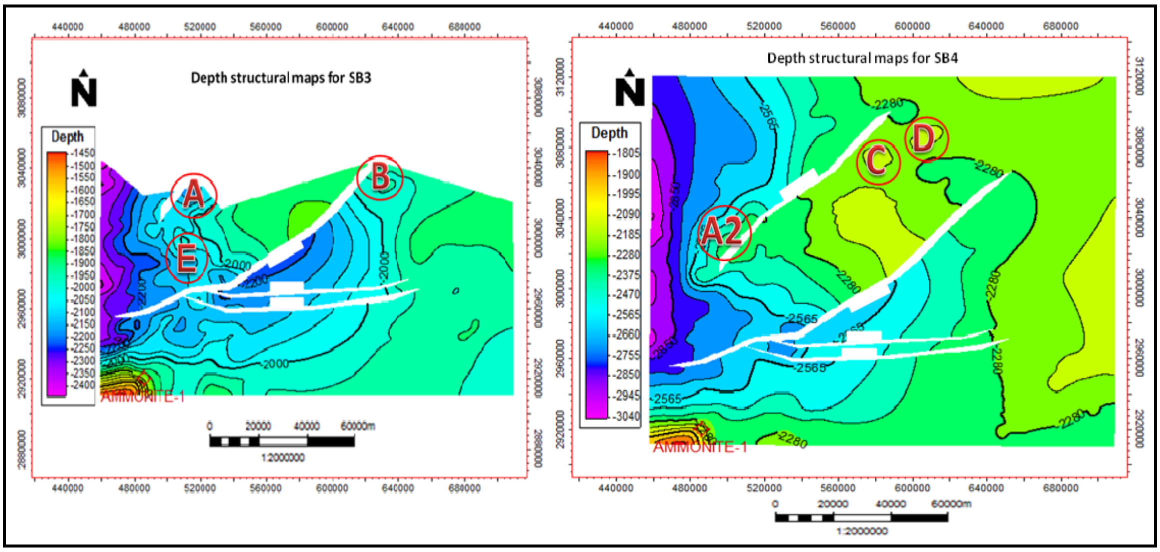

Figure (13): Depth maps for a) Near Upper Devonian Horizon/Lower Carboniferous showing leads A,B,E., b) Near top Neoproterozoic showing leads A2,C,D.

Lead A:

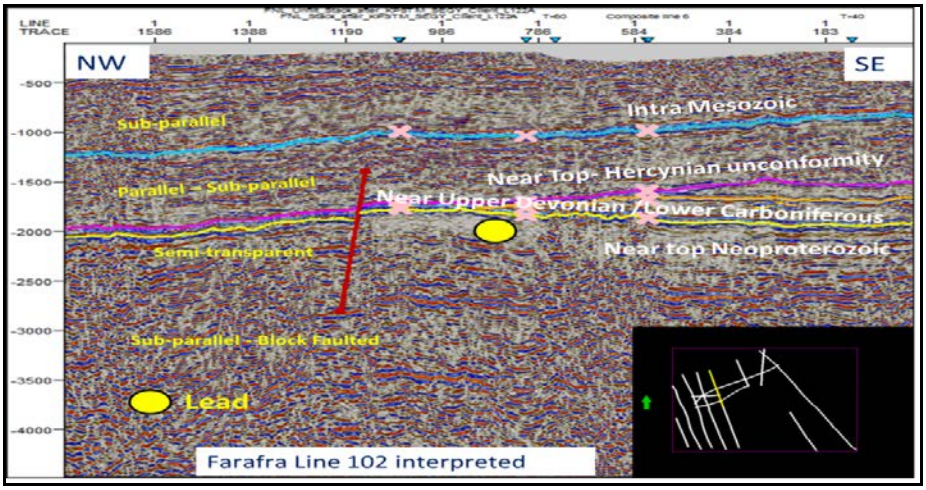

Figure (14): Iterpreted seismic line 102 showing lead A.

Lead B:

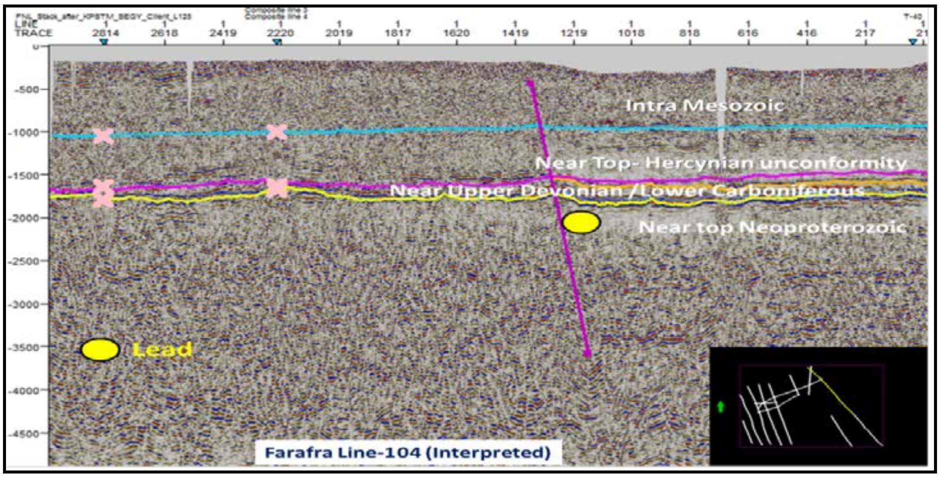

Figure (15): Interpreted seismic line 104 showing lead B.

Lead E:

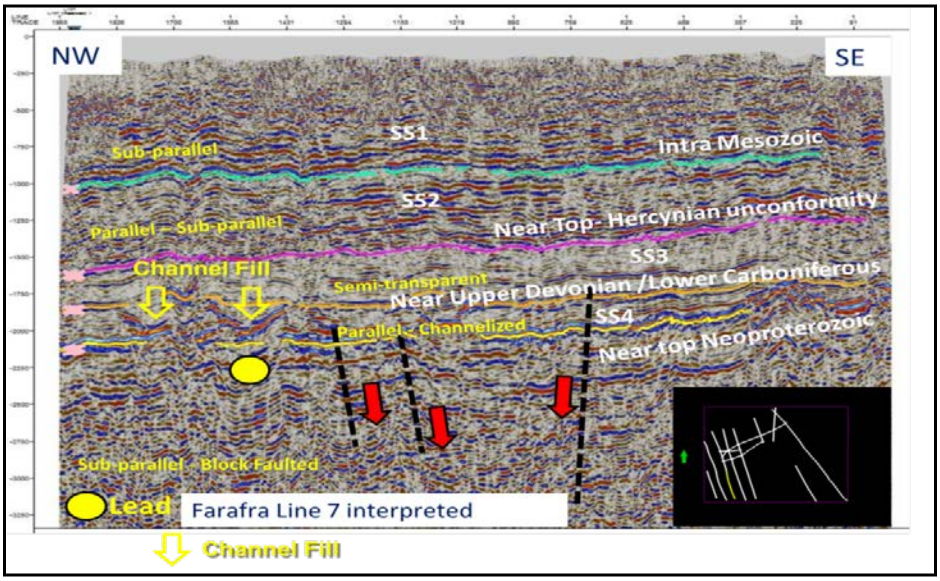

Figure (16) Interpreted seismic line 7 showing lead E (stratigraphic lead due to channels).

Lead A2:

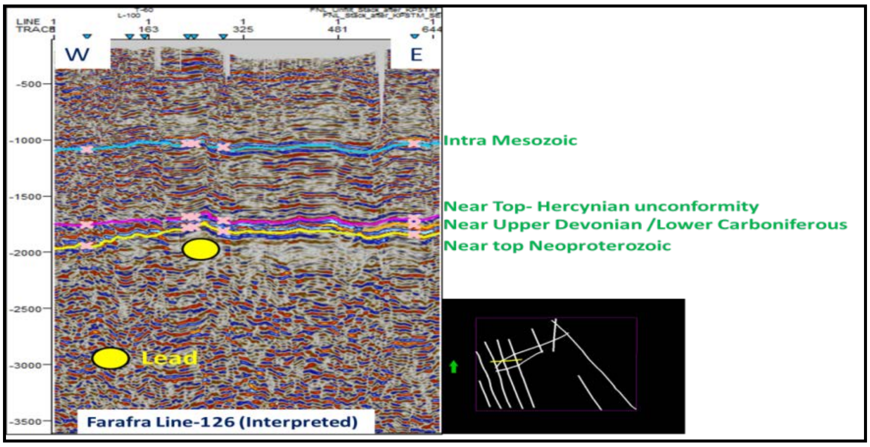

Figure (17) Interpreted seismic line 126 showing lead A2.

Lead C:

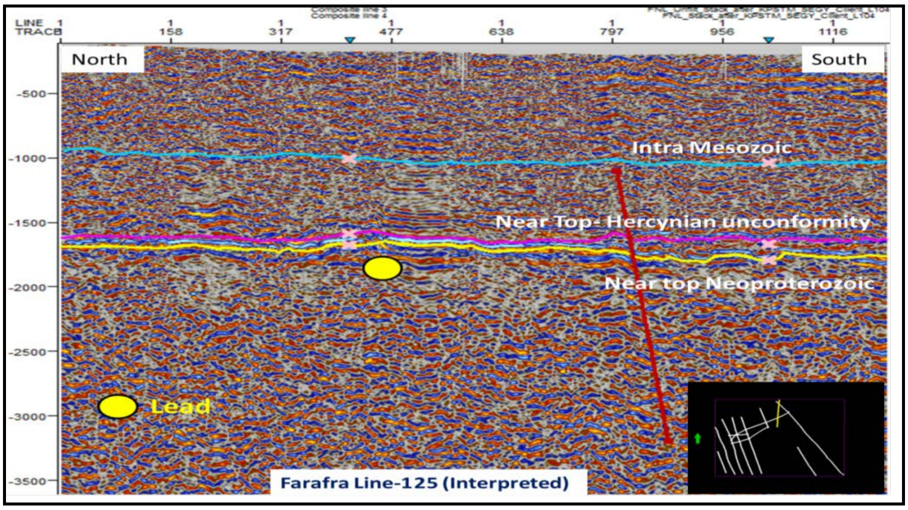

Figure (18) Interpreted seismic line 125 showing lead C.

Lead D:

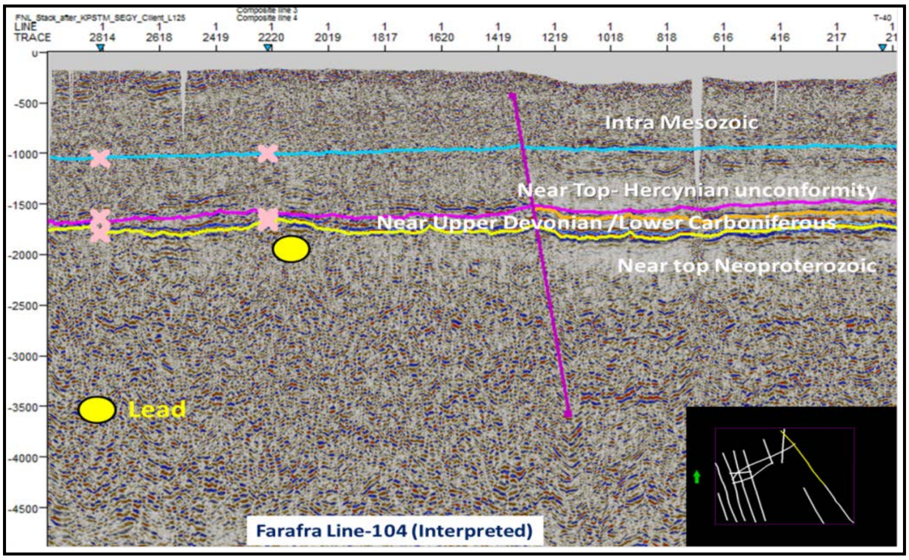

Figure (19) Interpreted seismic line 104 showing lead D.

Conversion methodology

The simple equation (written below) used to convert maps from time to depth:

$$Depth_{map} = V_{average} \times TWT_{map} / 2000$$

Therefore by using average velocity, the depth structural maps have been produced as follows (figure 14):

3.2.1.6 Leads and prospects determination:

In mapping seismic data, one looks for leads, the possibilities of hydrocarbon traps that require more work to define them completely. Although structural leads and local amplitude anomalies may be fairly evident, that interpreter should also be alert for subtle clues, perhaps to channels, that may indicate stratigraphic accumulations. Information from wells in the area may help locate the parts of the section where stratigraphic trapping is most probable.

Dip, reflection character, or amplitude variations may indicate stratigraphic or porosity changes. Careful study of the maps, sections and records plus broad experience and ample imagination will at times disclose accumulations (Sengbush,1987; Scheriff 1992).In this study only few leads could be detected as the area is a new volunteer area where no well is already drilled before, accordingly the following leads are determined.

3.2.1.6.1 Farafra leads location and description:

As per the seismic interpretation along with the current understanding of the area from geological point of view the following locations have been identified for drilling.

3.3 CONCLUSION

The petrophysical interpretation work in this study indicated that the Ammonite Well-1X encountered Jurassic-Cretaceous sequences which were confirmed to be fresh water bearing. As a result, it reduced the potentiality of structural traps exploration plays within the Mesozoic sequences, and accordingly exploring the Pre-Mesozoic sequences became of primary importance in the area.

The detailed seismic data interpretation and geo-seismic horizons picking are based on regional and mega-regional understanding and integration of regional sequence boundaries, i.e. the Upper Paleozoic Hercynian unconformity, base Silurian maximum flooding surface (MFS) and major sequence boundary, Upper Neoproterozoic unconformity sequence boundary, etc., along with synthetic seismic tie with Ammonite Well-1X. In addition, geo-seismic horizons indicated fair to good seismic resolution and few of them may represent hydrocarbon prospective sequences.

The interpreted and picked geo-seismic horizons were as the following surfaces: (1) Intra Mesozoic Horizon, (2) Near Top-Hercynian Unconformity Horizon, (3) Near Upper Devonian Horizon/Lower Carboniferous, (4) Near Top Neoproterozoic.

In the above geo-seismic definitions "Near" indicate that these seismic reflectors are tentative and hypothetical until validated by drilling results of the proposed exploratory-stratigraphic wells in the concession. No considerable difference is noticed between TWT (two-way-time) and depth seismic maps. Also, in general, the two sets of maps showed high level of conformity and accordance. Hercynian unconformity time and depth seismic maps revealed a clear regional northwest-southeast trend with a regional dip towards the northwest.

Near Top Devonian / Lower Carboniferous section is considered one of the most important as the potential basal Silurian organic rich shale might be deposited and preserved. However it should be noticed that the rich black source rocks shale is limited only to the euxinic basins which existed during the earliest Silurian deglaciation period. Those indicated euxinic basins are not validated yet by drilling in the Western Desert of Egypt.

Also, the channels detected in this block and outlined according to the available data, where, taking in account that the accuracy of these old data. These channels complex are limited regionally to base Silurian package and according to the available data the incisions are terminated by the Upper Silurian package. The outline of above mentioned valleys/ channel-like might and possibly will be changed after acquisition of new 3D seismic but still the effect of the valleys/ channel-like are clear and matching the identified regional directions and may be very good reservoirs.

Finally six new different leads are determined some of them are Structural and others are stratigraphic figure (12).

As a summery for hydrocarbon petroleum system, taking in account all what has been explained above, will consider the following:-

Upper Proterozoic Petroleum Habitat

Source:	• Organic-rich shales deposited in restricted sub-basins between the stromatolitic carbonate complexes.
Reservoir:	• Stromatolitic limestone.
Seal :	• Interbedded shales.

Paleozoic Petroleum Habitat

Source:	• Lower Silurian black 'hot shale'. • Upper Devonian.
Reservoir:	• Upper Ordovician–Lower Silurian indurated preglacial deposits. • Less consolidated Upper Ordovician deposits.
Seal:	• Paleozoic interbedded shale in addition to Triassic–Early Jurassic.

Mesozoic Petroleum Habitat

Mesozoic to Early Tertiary charged systems with Triassic–Jurassic shale and evaporite seals in the Mesozoic sag or 'Triassic' Basin.

Mesozoic to Early Tertiary charged systems with intra-Paleozoic shale seals in basins to the south and east of the Triassic Basin.

Due to the fresh-water hydrodynamic flushing of the Mesozoic sequences in the South Diyur region, these classes of petroleum systems is not expected to be present in the Farafra area.

REFERENCES

Bacon, M., Simm R. and Redshaw T. 2003, 3-D Seismic Interpretation, Cambridge University press.

EGPC (Egyptian General Petroleum Corporation) 1987. Geologic map of the Farafra Quadrangle NG35 NE 1:500,000-scale.

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 (1992).

Farooqui et al. 2012, Petroleum potential of the interpreted Paleozoic geoseismicsequences in the South Diyur Block, Western Desert of Egypt.GeoArabia, v. 17, no. 3,p. 133-176.

Franklyn, B. Van Houten, 1980, latest Jurassic-Early Cretaceous Regression facies, Northern Africa Craton AAPG V64, No.6.

G.B. Asquith and C. Gibson, 1982: Basic well log analysis for geologists; Textbook, AAPG, Tulsa, Oklahoma, U.S.A., 216 pp.

George Asquith & Daniel Krygowski – " Basic Well Analysis – Second Edition".

Gindy, A. and El Askary, M.A., 1969, Stratigraphy, Structure, and origin of Siwa Depression, Western Desert Egypt, AAPG V53, No.3.

Hart, B., 2004. Principles of 2-D and 3-D Seismic Interpretation. McGill University.

Hazem Mahmoud , Rami Al Awada, Ahmed Mohsen 2011 , Petrophysical study for some Hydrocarbon bearing formations, Gulf of Suez, Egypt.

Hermina, 1990, the surroundings of Kharga, Dakhla and Farafra oasis, geology of Egypt, Rushdi Said, chapter 14.

Jon Gluyas and Richard Swarbrick, 2004. Petroleum Geoscience, Blackwell Science Ltd.

Kerdany, M.T. and Cherif, O.H., 1990, Mesozoic, geology of Egypt, Rushdi Said, chapter 22.

Klitzsch, E. 1990. Paleozoic. In R. Said (Ed.) Geology of Egypt, Balkema, Chapter 21.

Klitzsch, E. and Squyres C.H. 1990. Paleozoic and Mesozoic geological history of northern Africa based upon new interpretation of Nubian strata, AAPG V74, No. 8.

Klitzsch, E., Harms, J.C., Lejal-Nicol, A., and list, F.K., 1979, Major subdivision and depostional environment of nubia strata southwestern Egypt, V 63, No. 6.

Klitzsch, E. And Schandelmeier, 1990, south western desert, geology of Egypt, Rushdi Said, chapter 13.

Mamdouh, R. Gadallah, Ray Fisher, 2009, Exploration Geophysics, Springer-Verlag Berlin Heidelberg.

Mahmoud Sroor, 2010, Geology & Geophysics in Oil Exploration (unpublished).

Meshref, W. (1990), "Tectonic framework of Egypt", In: R. Said (Editor), The Geology of Egypt, Balkima, The Netherlands.

Ruhovets, N., 1990, A Log analysis technique for evaluating laminated reservoirs in the Gulf Coast area: The Log Analyst. v. 31, no. 5: 294-303.

Scheriff, R.E., Geldart, L.P. 1995. Exploration Seismology, Cambridge University press.

Schlumberger – "Well Evaluation Conference Egypt 1984."

Schlumberger, 1969: Log Interpretation/Charts: Houston, Texas, Schlumberger well Services Inc.

Schlumberger, 1972: Log Interpretation: Volume 1 Principles . Houston, Schlumberger Well Services, Inc**.**

Schlumberger, 1977: Log Interpretation manual.

Schlumberger, 1979: Log Interpretation charts, Houston .

Sulaiman, L. Al-Sulami, Mohammed Ameen, 2010: Characterization of the Hercynian Unconformity, for Prospect Evaluation, Saudi Arabia.