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Reservoir Characterization Using the Seismic Reflection Data: Bahariya Formation as a Case Study Shushan Basin, North Western Desert, Egypt

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Abstract

Herein, a package of 2D reflection seismic lines of good quality set is ordinarily interpreted to disclose the structure controls of the Shorouk field, in the North Western Desert of Egypt. The geological and geophysical information are helped to facilitate creating a number of maps and cross sections that clarify the tectonic fabric. The study focuses attention on tops of the Lower and Upper Bahariya members which act as major hydrocarbon reservoirs in Shushan basin. The seismic reflection interpretation aims to review and bring insight into the basin architecture, which may increase the chances for developing and/or exploring the entrapments. The work steps involve identification, picking and correlation of reflectors, closing loops, fault detection, constructing geo-seismic cross sections, time, and depth structural maps. The reservoir quality was confirmed through constructing the correlation charts between wells. The results indicate that the Shorouk field lies on a fault-bounded high feature. The structure at Bahariya Formation is affected by an anticlinal horst, cut across the central area in the WNW-direction, and bounded by normal faults down-step to the north and south. These bounding faults seem to be inherited from older ones along lines of weakness and grow up into the overburdens. The seismic lines investigation gives no evidence to support the presence of any salt ridges or magmatic flows into fractures. Matching the well data with seismic events of Bahariya revealed that the seismic depths are deeper than the actual, with ~100m static shift. The dip-reversals along flanks of the central closures are the most potential traps at Bahariya Formation.

Introduction

North Western Desert is tectonically subjected to various geologic events causing a structural complexity that largely affects the hydrocarbons potentiality. Such a complex framework is mainly attributed to the Tethyan Sea movement (African plate relative to Europe) which led to continued rejuvenation of old trend patterns along the pre-existing zones of weakness (Meshref, 1982) [1]. The drilling based on structural considerations led to many petroleum explorations, most of these oil fields in the northern province and coastal troughs were discovered based on structural traps, which most probably are productive. However, the Western Desert of Egypt still has a significant hydrocarbon potential as recent oil and gas discoveries have suggested (Dolson et al., 2001) [2]. Perhaps 90% of undiscovered oil reserves and 80% of undiscovered gas reserves in Egypt are located in the Western Desert (Zein El-Din et al., 2001) [3]; (Barakat and Nooh,2017) [4]. The fill-sedimentary basins in the North Western Desert are in many cases underestimated and still questionable. The modern technology, as well as improvements in equipment and processing techniques give a hope for finding structural traps containing hydrocarbons. This may encourage further geophysical activities for solving some difficulties of geologic significance.

The northern part of the Western Desert comprises a number of sedimentary basins that received a thick succession of Mesozoic-Cenozoic sediments.

Shushan, which is the largest of the coastal basins, is one of the most prolific basins in the northern part of the Western Desert of Egypt. It lies to the south of Matruh basin and is bounded from west by Libyan borders. Shushan basin is a half-graben system with a maximum thickness of 7.5 km of Jurassic Cretaceous,

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and Paleogene sediments (Hanter, 1990) [5]. Like Matruh basin, Shushan basin witnessed Jurassic and Early Cretaceous extension followed by Late Cretaceous Early Tertiary inversion (El Awdan et al., 2002) [6].

Many oil and gas fields which are charged by source rocks of Mesozoic Era have been discovered in Shoushan basin e.g. (Shorouk, Umbarka, Kahraman, El-Qasr, Khepri, Sethos, Renpet, Kalabsha, Buchis, Heqet, Shams, Qamar, Amoun, Falak, Meleiha, Emry, Aman, Lotus, Tut, Salam) (Moustafa, 2008) [7]. These sub-basins have attracted the interest of numerous researchers and oil companies due to the existence of the huge subsurface sedimentary section, which includes important thickness of reservoir rocks. The Lower Bahariya Formation (LBF) and Upper Bahariya Formation (UBF) act as main hydrocarbon reservoirs in most of these basinal areas. Numerous studies deal with the structure, stratigraphy and tectonics in coastal basins (Said, 1962) [8]; (Said, 1990)[9]; (Sestini, 1984) [10]; (Abedi, 1990) [11]; (Abu Shady, 2003) [12]; (El-Khadrgy et al., 2010) [13]; (Abu El Yazid, 2011) [14]; (El Khawaga, 2012) [15]; (Abd El Hady et al., 2014) [16]; (Barakat et al., 2019) [17]; (Nabawy et al., 2022)[18].

The Shorouk field, which forms the scope of this study, considered as the most important oil fields in the eastern side of Shushan basin. The concession lies at ~85km from the Mediterranean Sea, confined between latitudes 30° 30° 40'' N– 30° 33' 20'' N and longitudes 26° 54' 40'' E–27° 00' 00'' E (Fig. 1).

One of the prime interests and the main task of our geophysical analyses is in the search for the structural traps containing hydrocarbons. Information obtained from well data indicate that Shorouk field is a very prospective area for further oil accumulations. The work is devoted to revaluating the hydrocarbon potentiality of the Cretaceous reservoirs, with certain emphasis put on LBF and UBF, which in many cases are productive. Oil, gas and condensate are tested from several localities in this region, but reservoir quality is found to be very variable. Structurally, the field is correlated with a fault-bounded high feature (NW-SE oriented inversion anticline) of pre-Cretaceous movement, that almost continued during and after Bahariya deposition. The region is greatly deformed by the WNW-to-NW oriented faults which largely control the basin architecture and form the main structural traps in this area. Stratigraphically, the area is characterized by progressive changes from non-marine sand to marine carbonate, interrupted by many small fluctuations of the depositional environments.

The Bahariya Formation was deposited in shallow marine to coastal environments, consistings mainly of fine tight sandstone with intervening siltstone and shale and occasional more porous sandstone units (Sultan and Halim, 1988) [19].

The study ultimately aims to clarify the subsurface configurations that are probably favourable for the hydrocarbon accumulations. To do that, several geophysical methods and treatment techniques were applied, and their outputs were discussed in terms of the geology of North Western Desert. The approach is based on logs data which are the most common tool for identifying lithology, reservoir parameters and predicting reservoir distribution by correlating units between wells. Seismic reflection is the most preferable between wells and has sufficient resolution to identify areas of good reservoir quality. Seismic mapping can provide more information about factors control the reservoir architecture and demarcate large faults which are active during the late Jurassic-early Cretaceous. Isopachs, lithology maps and correlation charts can be used to clarify lateral thicknesses and stratigraphic variation of reservoirs and pay zones.

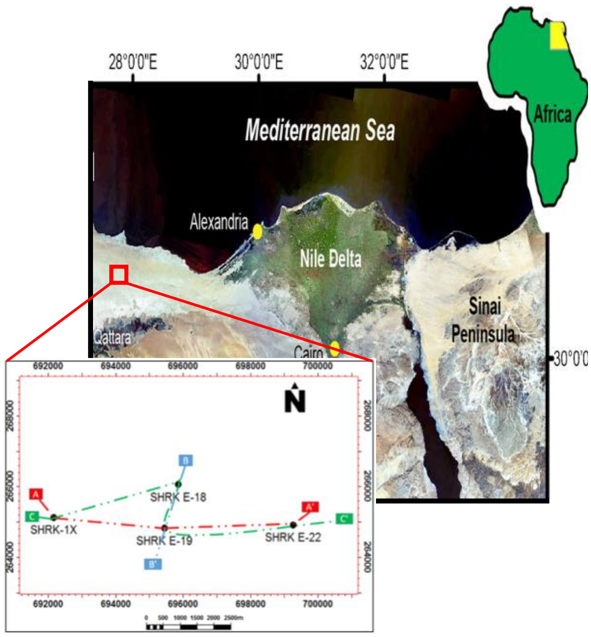

Figure 1 Location map of the study area showing the location of the drilled wells in Shorouk field, directions of correlation charts.

Geological Setting

The general stratigraphic section in the North Western Desert ranges in age from Paleozoic to Cenozoic (Neogene) as summarized in Fig. 2. The post-Paleozoic succession in this area comprises four sedimentary cycles of Lower to Upper Jurassic, Lower Cretaceous, Upper Cretaceous, and Eocene to Miocene (Schlumberger, 1995) [20].

Said, 1990 [9]: subdivided the Cretaceous into two units, the Lower unit made up primarily of clastics and the Upper unit made up mainly of carbonates. Lower Cretaceous Kharita Formation represents the Albian series of the Early Cretaceous (Barakat, 1982) [21] and is composed of massive quartzose sandstone interbedded with shales and siltstone. It conformably overlies the Dahab Formation and underlies the Bahariya Formation. The Kharita Formation is most probably, deposited in an extensive shallow marine shelf in a high energy (mainly littoral) environment and includes frequent gas-prone carbonaceous shales with good source potential for gas generation (EGPC, 1992) [22].

The Late Cretaceous marks the beginning of a major marine transgression which resulted in the deposition of a dominant carbonate section. In the North Western Desert, the main calcareous rocks of the upper Cretaceous age are particularly developed in the Abu-Gharadig basin where they form a number of oil reservoirs. These are divided into three rock units which are from bottom to top: the Bahariya, Abu Roash, and Khoman formations.

Bahariya Formation was firstly published by Said, 1962 [8] who stated that the type locality is in Gebel El-Dist, Bahariya Oasis. The Cenomanian Bahariya Formation consists mainly of fine to medium-grained quartzitic sandstones, colorless to pink, medium to coarse-grained with thin streaks of shales and carbonates inclusions (Soliman and El Badry, 1980) [23].

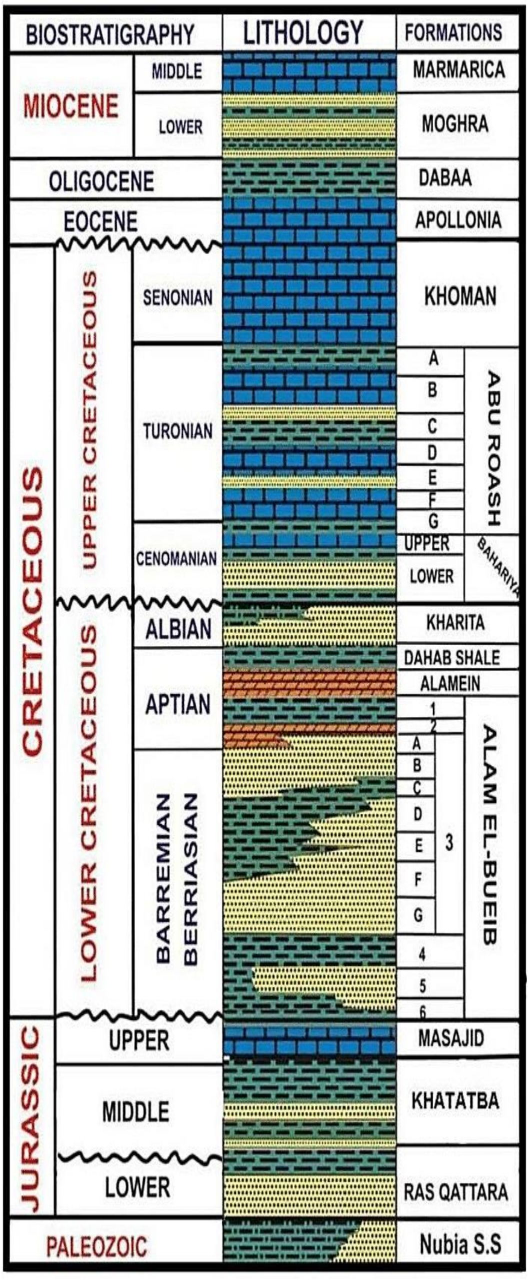

Figure 2 Generalized stratigraphic column of the North Western Desert (Sultan and Halim, 1988) [19]; (Schlumberger, 1995) [20].

Abu Roash Formation attains a thickness ranging from 1440 ft to 2628 ft. The type of section was designated by (Norton, 1967) [24] at Abu Roash locality. El Gezeery and O'Conner, 1975 [25] subdivided the Abu Roash Formation into seven informal members which are A, B, C, D, E, F and G members from top to bottom. It is deposited on a wide shallow marine shelf during several sedimentary cycles.

These sediments have type II kerogen, Khoman Formation overlies the Abu Roash Formation with marked unconformity. It consists of a sequence of massive chalky limestone. The type of section is located at Ain Khoman, Southwest of the Bahariya Oasis in the Abu El Gharadig basin. The Environment of deposition of the Khoman Formation is considered to be Upper Bathyal. The Khoman Formation is not considered as reservoir or seal or as source rocks (EGPC, 1992) [22].

Materials and Methods

The structural evaluation of the Shorouk field depends mainly on twenty seismic lines shot through 1997-1999, acquired in a closed grid-like pattern; fourteen dip-oriented lines (N-S inlines) and six strike-oriented lines (E-W crosslines). The selected seismic sections attain a total length of ~137 km long and cover an area of ~49 Km2. The 2D seismic lines are subsequently stacked, migrated. and displayed in two-way travel time (max. 4 Sec.). All these time-migrated seismic sections are reliable, while few are ranked between fair to poor. They represent the best quality of seismic reflection data in the Shorouk field. The SEG-Y format time-migrated seismic sections are tied with four drilled wells: Shorouk-1X, Shorouk E-18, Shorouk E-19, and Shorouk E-22. All available data as well as the density, neutron, gamma ray, resistivity, caliper, and sonic log data are supplied by the authority of the EGPC, courtesy of Khalda Petroleum Company. Formal rock stratigraphic and parastratigraphic units are used to delineate succession by representing changes in lithology. Three correlation charts are constructed to give a better idea about Bahariya Formation and its configuration.

The ordinary seismic lines interpretation was started with seismic-to-well tie to precisely identify UBF and LBF reflectors. The check-shot data of boreholes and synthetic seismograms are helped to trace the seismic reflectors that coincide with these tops. By using the Petrel™ (version 2016) of Schlumberger Inc., picking horizons, correlation of the seismic events, tying their times, closing their loops, fault detection, velocity mapping, time to depth conversion is performed as basic steps (Coffeen, 1984) [26]; (Barakat, 2010) [27]; (Abdullah et al.,2021) [28]; (Barakat et al., 2021) [29].

Accordingly, the interpreted two-way times are digitized at equidistance, gridded, and contoured for each lithostratigraphic top to produce two isochronous reflection maps (structural contour maps in terms of time, rather than depth) on tops of LBF and UBF. Subsequently, the fault cut-outs are picked and posted at their locations at the seismic shot-point location map, to establish the fault pattern for each top. The conversion of these time maps into depth maps was carried out using the estimated average

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velocities. Moreover, the statistical trend analysis was executed on faults dissecting these tops to deduce the major tectonic trend patterns complicating the Cretaceous age. Both length (L%) and number (N%), in classes of 10^{o} of arc are calculated along interpreted faults and displayed as arose diagram.

Furthermore, the interpretation of lithology of the Bahariya reservoir was accomplished utilizing the Interactive Petrophysics (IP) software version 3.5. also, all the logs registered through a systematic approach from the available four wells and consequently three correlation charts are carried out to shows the equivalency of stratigraphic units, and the thickness variations on the basis of changing the physical lithologic characteristics or any break in the depositional continuity of Bahariya reservoir.

Results and Discussions

The structural study in Shorouk field was carried out utilizing twenty seismic lines, interpreted to shed light on the main structural elements and oil entrapment styles. The ordinary steps of analysis are accomplished through integration of available geological and geophysical information utilizing a number of maps and cross sections. The process started with tying the geological control into the seismic data (seismic in time-to-well in depth) to find events (seismic reflections) that correspond to LBF and UBF. The process was done by using the check-shot data; time-depth pairs, and/or the synthetic seismogram (Badley, 1985) [30]; (Barakat and Dominik, 2010) [31].

Both synthetic seismograms as well as the VSP data (vertical seismic profiling) can be used to give an accurate tie between well and seismic data (Bacon et al., 2003) [32]. The time-depth curve is the simplest method of tying well data to seismic. A check-shot measures the amount of time it takes for the first arrival of a seismic wave to travel from surface to source near the well to a receiver lowered down the wellbore. It is used to convert the tops from the logs data from time to depth and post the equivalent horizons on the seismic section at the proper times. Fig. 3 shows an increase of check-shot measurements recorded at Shorouk-1x well with depth. Matching the well data with the seismic events of LBF and UBF revealed that the seismic depths are deeper than the actual ones, with about 100m static shift.

Fig. 4 shows an example of seismogram charts at SHR 1-X well, where tops of LBF and UBF have been marked. The Petrel^{TM} (version 2016) of Schlumberger Inc. is used to create the synthetic seismograms in order to tie the reflection time-domain (seismic event) to depth-domain (composite log) by merging over the velocity profile. Synthetic seismogram is created for the available wells, from the sonic-log (formation velocity) and bulk density logs, to accurately estimate the seismic reflections at Bahariya levels. The process permits easy trace and follow the marker horizons from line to line with good certainty. The good quality of the seismic lines and well data allow good correlation of reflectors away from the wells. Tops of LBF and UBF are annotated on synthetics to help identify their seismic events. Most factors affect the quality of the match between seismic data and synthetics is the shale, which is creating erroneously low velocity and low-density values on the logs. As well, many wells are drilled very close to normal faults or crossed them, which weakened the seismic signal near the well, unfavourably affecting the tie quality.

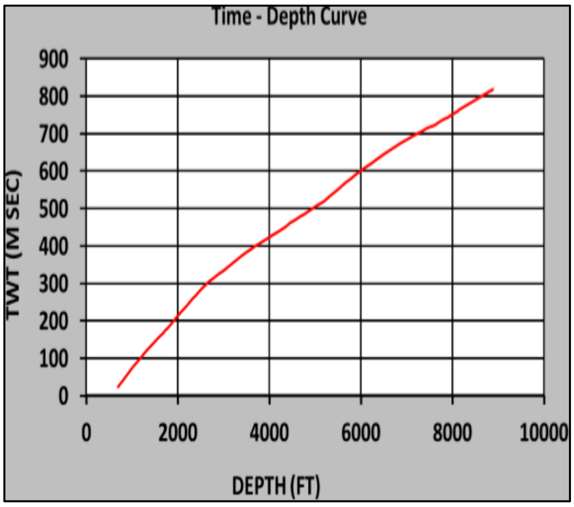

Figure 3 Two-way time versus depth that obtained from check-shot data at Shorouk-1X well.

The induced logs are made from velocity logs by conversion of the velocity log in depth to a reflectivity function in time and by convolution of this function with a certain wavelet or source pulse (Dobrin and Savit, 1988) [33]. The main type of synthetic seismogram represents the seismic response to vertical propagation of an assumed source wavelet through a model of the subsurface composed of a series of horizontal layers of differing acoustic impedance. Some energy is reflected to the surface by rock layers, the amplitude and polarity of the reflection being determined by the acoustic impedance contrast.

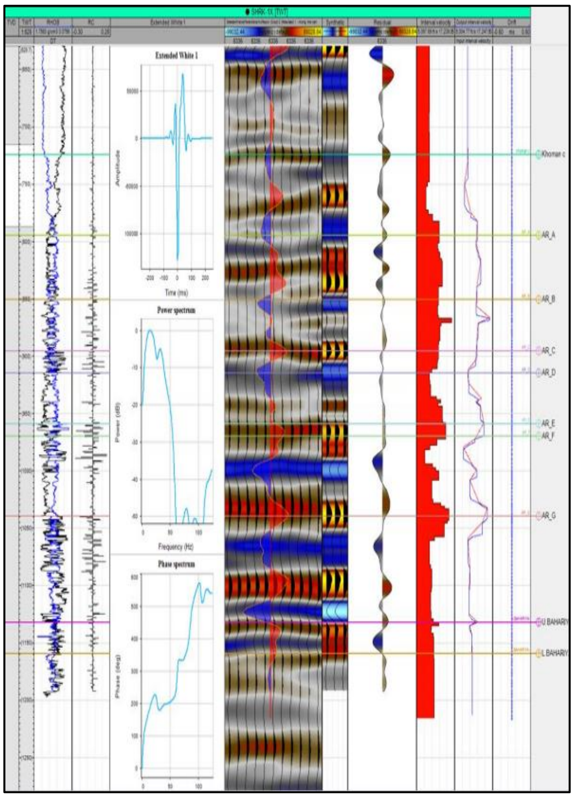

Figure 4 Synthetic seismogram chart that carried out using Shorouk-1X well data.

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Seismic lines Interpretation

The shot-point location map (Fig. 5) comprises a package of 20 seismic sections acquired in two different trends, covering the study area in the N-S and in the E-W directions. This filtered stack migrated version permit easy identifications of Bahariya reflectors, which are followed and traced from line to line with good certainty. Close investigation of these lines leads to identifying the major seismic elements on tops of UBF and LBF. The characteristic along seismic lines involves, the continuity, geometry, arrangement, and the relation between reflectors.

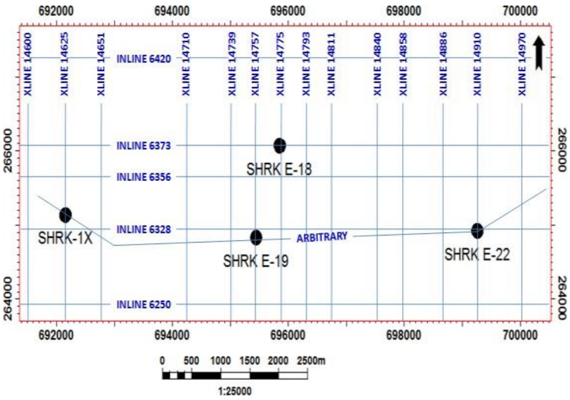

Figure 5 Base map of seismic lines and wells in the study area.

Fig. 6 shows an example of the interpreted seismic lines which run in the S-N direction. This section (Xline-14757) passes through Shorouk E-19 well, where two picked horizons on tops of LBF (green line) and UBF (Yellow line) are precisely traced. The two horizons on the seismic line are running in parallel sequence and show a uniform thickness with gentle northeast dip direction. The stratigraphic continuity is generally good and the reflection on different tops could be easily recognized. The two reflectors are cut by three main faults F7, F8 and F15 from west to east, down-throw toward the north, with relatively small vertical displacements. The faults display nearly the same orientation, tilts, and magnitude of throws, which suggest they originated from the same tectonic event. The structure indicate that the faults are inherited from older ones along zones of weakness and have been rejuvenated into the overburdens with time. There are no magmatic flows, or salt diapairs could be recognized along this trend.

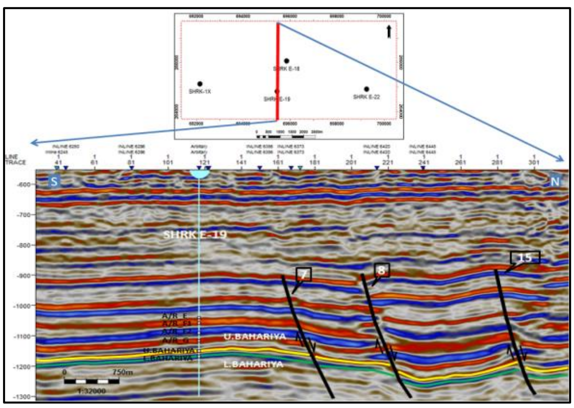

Figure 6 Interpreted seismic line (Xline 14757) passing through Shorouk E-19 well.

Fig. 7 displays another example of the vertical seismic line (Xline-14910) shot in the north-south direction. The two interpreted reflectors of tops LBF and UBF are picked on by tying with the Shorouk E-22 well. Generally, the seismic events are good, and there is no difficulty to trace or interpret the sequence continuity. The structure reveals a nearly constant thickness for both reflectors, with a regional dip regime to the north. The two reflectors are crossed by three normal faults: F12 to the west and F10, F11 to east, with different tilts forming positive structure in the central area. These lines of deformation seem to be of deep-seated origin, grow up and die out into younger formations.

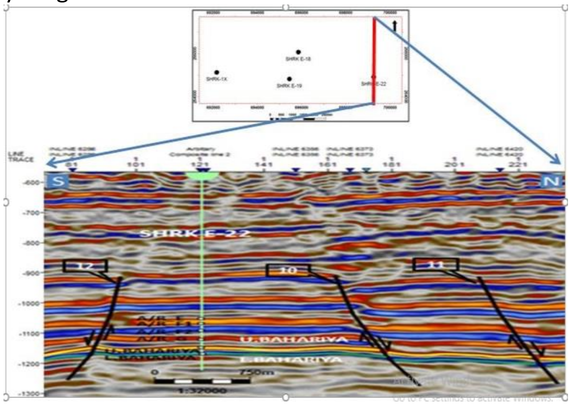

Figure 7 Interpreted Seismic line (Xline 14910) passing through Shorouk E-22 well.

Fig. 8: Shows third example of the N-trending seismic sections (dip direction). The seismic line (Xline-14625) lies to the west of the study area, passing through Shorouk E-22 well. The regional structure along this trend illustrates a larger number of the westerly oriented faults (F1, F2, F3, F4 F5), that cross the two horizons of Bahariya Formation. These normal faults are running parallel to each other and down-throwing toward the north, forming a step-like form, with a regional dip regime to the north.

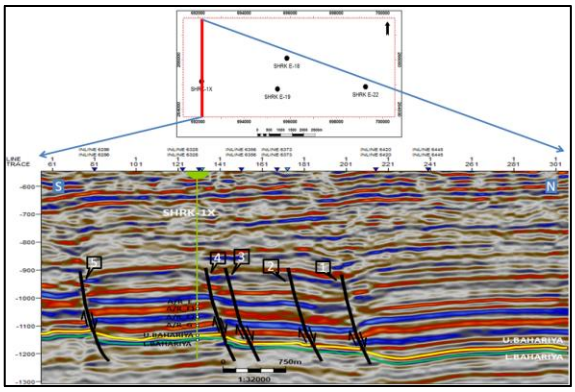

Figure 8 Interpreted seismic line (Xline 14625) passing through Shorouk E-22 well.

Fig. 9 shows an arbitrary seismic line, extending horizontally from east to west along the central area. The picked markers top of LBF and UBF are controlled through tying with SHRK 1-X, SHRK E-19 and SHRK E-22, from west to east. The two horizons flattened laterally, with slight changes in depth, thickness, and geometry. The interpreted horizons seem to be simple in structure with no dense deformation. The structure exhibits one fault (F6) toward the west with low dip angle and small magnitude of throw to the east.

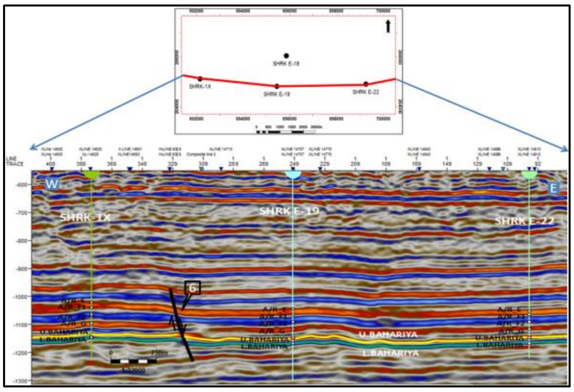

Figure 9 Interpretation of arbitrary seismic line passing through Shorouk E-22, Shorouk E-19 and Shorouk E-18 wells from east to west direction.

Fig. 10 shows the interpreted seismic inline-6373, passing through Shorouk E-18 well which was used as a guide point to detect the seismic events of LBF and UBF. These two marked horizons are dissected by five normal faults (F3, F7, F8, F9, F10), which are running parallel and down-stepping gently toward the east. The five faults seem to be inherited from older lines of weakness and renewed with time into the overlying sediments.

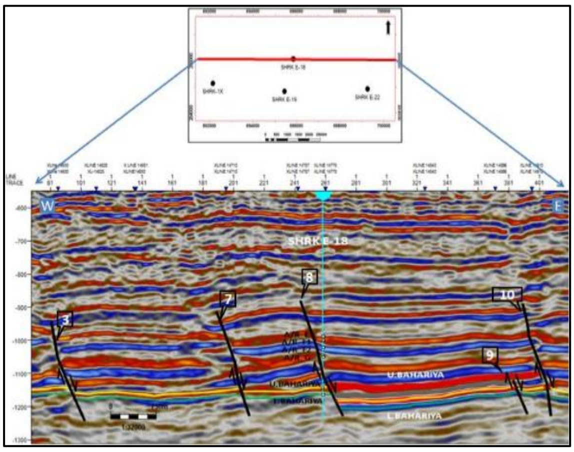

Figure 10 Interpreted seismic line (Inline 6373) passing through Shorouk E-18 well.

Velocity maps

Velocity plays an essential role in seismic reflection studies. Herein, the average velocity (Vav) is calculated to convert the two-way time to depth. Depth conversion makes it possible to convert seismic data from time domain into depth domain. so erroneous velocity estimation leads to mistakes in determining the geological picture of the study area. Average velocity is simply defined as the velocity over a certain reflecting surface below the seismic reference datum (SRD) and can be expressed as: Vav = D/t, where: D is the depth to the reflecting surface from the seismic reference datum (SRD), and t is the one-way time.

The average velocity contour maps are already established on tops of LBF and UBF. They illustrate a similar pattern of distribution of velocity, with a gradual increase in values from east to west as shown in Figs. 11 and 12.

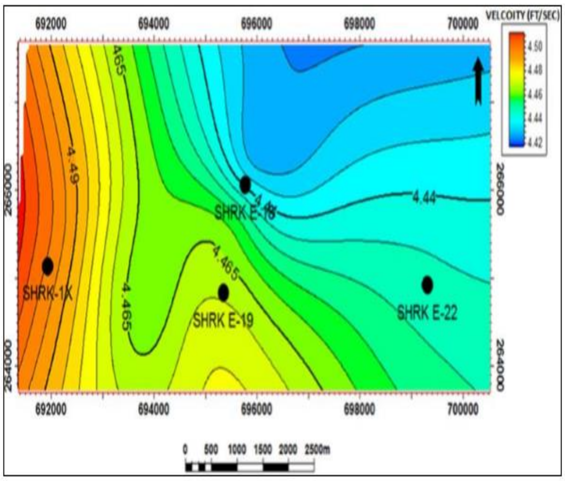

Figure 11 Average velocity map for UBF horizon, C.I. 0.005 ft/msec.

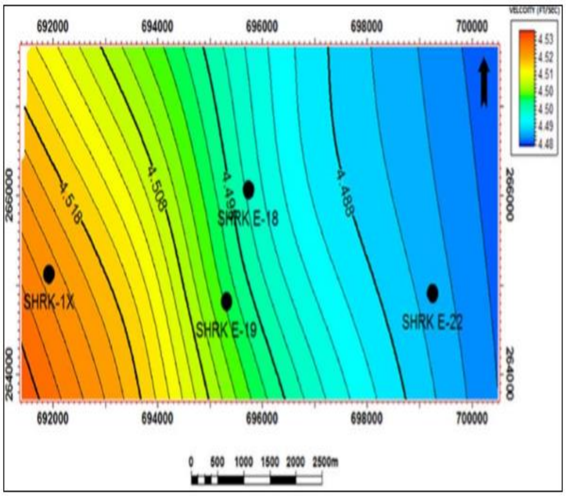

Figure 12 Average velocity map for Lower Bahraiya horizon, C.I. 0.0025 ft/msec.

Two-way time and depth structure maps

The structural analysis of the seismic records via picking the two-way reflection times of the target formations was achieved and used to establish two isochronous maps on tops of Bahariya Formation.

Subsequently, depth conversion is carried out which is a fundamental procedure after interpretation where the seismic data are made in time while the well data are in depth. These maps were created to evaluate the geometry of the Bahariya Formation and identify the structural traps and closures suitable for hydrocarbons accumulation. The fault segments are posted on the base map of the study area to construct time/depth-structure maps for UBF and LBF.

Commonly, the two-way time map on top of UBF (Fig. 13) is generally characterized by a gradual increase in time from north and south toward the central part. The map displays fifteen normal fault lines namely F1-F15, almost down-throwing northward. They differ in their lengths, tilts, and throws, forming a horst-like structure in the central portion. Close inspection of Fig. 13 reveals that the low and high time values (range between 1113 and 1253 mSec.) are consistent with the low and high depths (4970 to 5775 ft) in Fig. 14.

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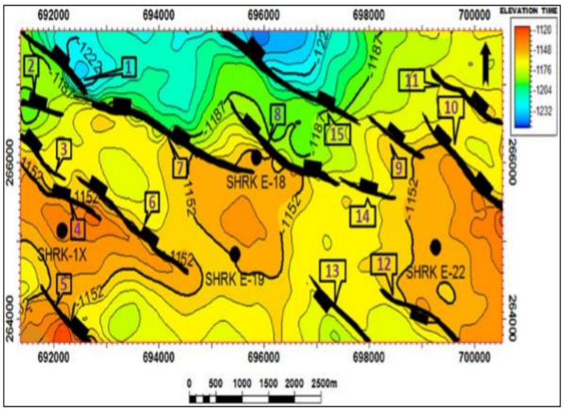

Figure 13 TWT structure map for Upper Bahariya horizon, C.I.: 7 ft.

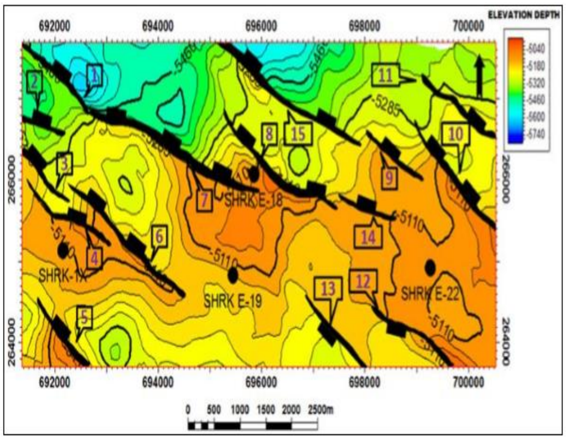

Figure 14 Depth structure map for Upper Bahariya horizon, C.I.: 35 mSec.

Similarly, the TWT map of LBF (Fig. 15) shows a comparable pattern of distribution of reflection time which previously existed in Fig. 13. It reflects a noticeable decrease in time contours values toward the centre. The time variation in Figs. 15 ranges between 1134 and 1270 mSec, while the depth variation in Fig 16 varies from 5075 to 5775 Ft. The images primarily give an impression of a structural high in the central area, sided from the north and south by graben-like features. The two maps suggest a WNW-trending horst in the form of faulted-anticlinal feature. the flanks are generally dipping northward and southward. The structural elements traced on tops of these horizons gave an indication about the active tectonics during the Cretaceous age and feel for some of the deeper structural fabric. The structure encourages to drilling more development and exploratory wells in the central area to enhance productivity in the Shorouk field.

The statistical trend analysis was applied as a method by which the tectonic trends that affected the target formations could be detected. The interpreted seismic faults on tops of LBF and UBF are defined in terms of number and length (measured in the unit of the map-scale). The fault parameters (L%, N%) distributed every 10^{o} spectrum around the north are plotted as rose diagrams. The results on top of UBF (Fig. 17a) show dominance of the northwesterly tectonic trends that largely control the structural regime. Also, the statistical results on top of LBF (Fig. 18b) displays a similar pattern of distribution that existed before. Both L% and N% show nearly the same tectonic trend in the WNW-to-ESE direction, which is considered as the most profound tectonic trend that heavily deforms Shushan basin.

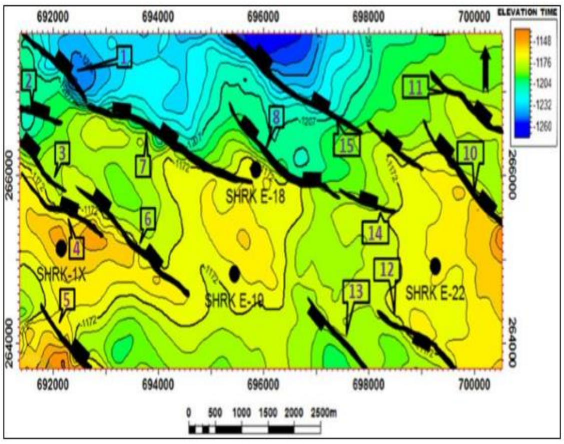

Figure 15 TWT structure map for Lower Bahariya Horizon, C.I.: 7 ft.

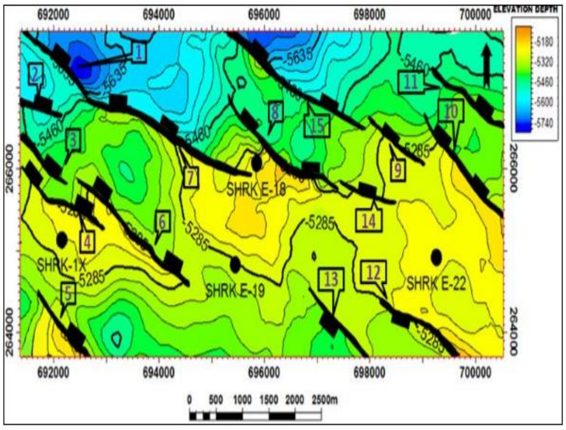

Figure 16 Depth structure map for Lower Bahariya horizon, C.I.: 35 mSec.

Tectonically, the statistical trend analyses show a good agreement between LBF and UBF outputs, as shown in Fig. 17. This indicates that these fault-trends are old lineaments of Pre-Carboniferous (Hercynian orogeny) and have been reactivated with time. This can be attributed to the Tethyan Sea tectonics, the relative movement between the North African Plate and European Plate. The structural elements (folding and faulting) are produced as a result of south easterly compressive force between the north African plate and Europe. The NNW-SSE collision has resulted in regional folding of the north portion of Egypt, which are associated with primary and secondary fracture systems.

Correlation Charts

The Correlation Chart aims to study and organize the strata on the basis of changing the physical lithologic characteristics or any break in the depositional continuity. It shows the equivalency of stratigraphic units, and the thickness variations.

The available well data are used to construct three correlation charts constructed in different trends to describe the Bahariya reservoir configuration. Borehole data from four composite logs are used to

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construct three correlation charts oriented in the NE-SW, W-E and NW -SE directions. The location of these profiles is displayed in Fig. 1, with different colours. These charts have been constructed in order to show the subsurface geological structures and stratigraphy of the target formation.

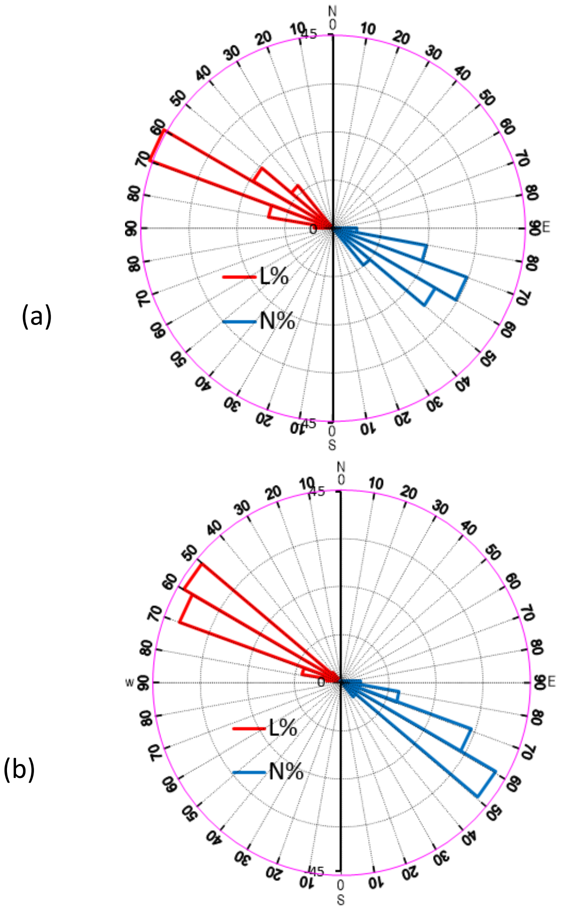

Figure 17 Results of statistical trend analysis on tops of (a) Upper Bahariya Formation and (b) Lower Bahariya Formation.

The first correlation chart (A-A') extends along W–E direction and passes through SHRK-1X, SHRK E-19 and SHRK E-22 wells. The chart (Fig 21) shows two units, namely UBF and LBF arranged from top to bottom respectively. The correlation chart shows the difference in lithology and petrophysical parameters from UBM to LBM. They indicate that lithology of UBF and LBF consists mainly of siltstone, sandstone, shale, and some intercalation of limestone. In UBM, there is abundance of sandstone in (SHRK E-19) (South direction) but suddenly this hydrocarbon bearing sand became intercalated by argillaceous sediments (siltstone and shale) toward the (SHRK-1X and SHRK E-22) (East and West directions). In LB, there is abundance of sandstone in (SHRKE-22) (East direction) then decreased gradually in SHRK E-19 (South direction) then increased again in SHRK-1X (the West part). The top of UBF and LBF are higher in SHRK E22 well (in the Eastern part) than in the other wells, this result supported by depth structure map. Fig. 19 shows the stratigraphic correlation for the studied wells flatten on Bahariya Formation. It exhibits the thickness of UBF in the central area, with slight thinning toward the east (SHRK E-22) and west (SHRK 1-X).

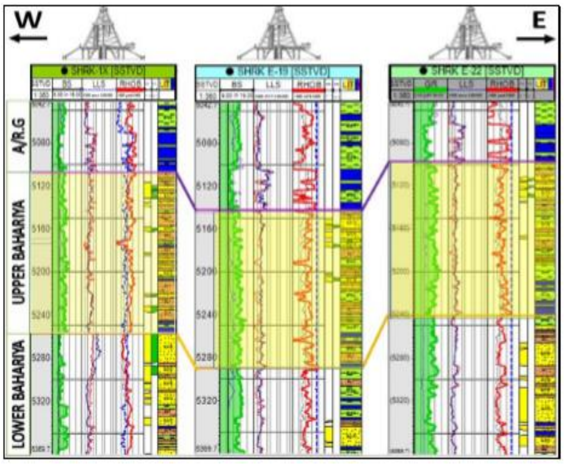

Figure 18 Correlation chart along the profile (A-A').

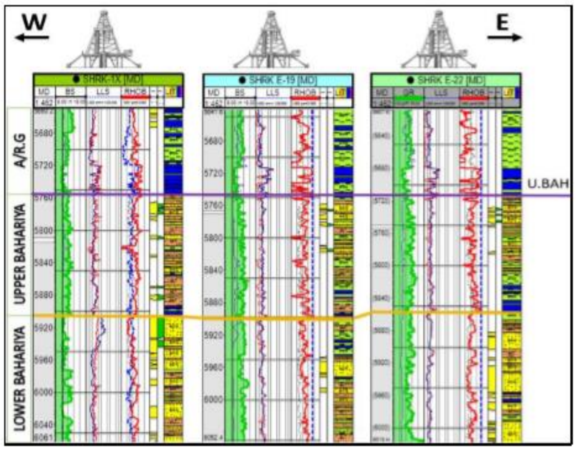

Figure 19 Stratigraphic correlation for the studied wells flatten on Bahariya Formation applied on the profile (A-A').

Fig. 20 shows the second correlation chart (B-B') that was constructed in the NNE–SSW direction, between SHRK E-18 and SHRK E-19 wells. It reveals that the stratigraphic top of UBF reservoir is higher in SHRK E-18 (northward) well than in SHRK E-19 well (southward). Fig. 21 reveals that UBF in SHRK E-18 well is relatively less in thickness than in SHRK E-19 well, by a small percentage. It is characterized by gradual southward deepening of the target formations. Lithologically, UBF predominantly consists of sandstone and siltstone with subordinate intercalations of shale and limestone. Meanwhile, LBF formed of siltstone and shale with subordinate intercalations of sandstone and traces of limestone. In the LBF the thickness of sandstone gets thicker in SHRK E-19 well than in SHRK E-18 well.

The third correlation chart (C-C') shown in Fig. 22 passes through SHRK-1X (West Direction), SHRK E-18 (North Direction), SHRK E-19 (South Direction) and SHRK E-22 (East Direction) wells. The chart shows that the Bahariya sediments are found at shallow depth in the west direction in SHRK-1X well and becomes slightly deeper toward the north, south and east directions. The Bahariya thickness slightly decreases in the west direction in SHRK-1X well. Also, it shows that sandstone continuity in UBF and LBF decreases in the north direction. By making a stratigraphic correlation for the studied wells flatten on Bahariya Formation (Fig. 23), it is found that there is thinning in the thickness of UBF in SHRK E-22 toward the east direction and thickening in SHRK-1X toward the west direction.

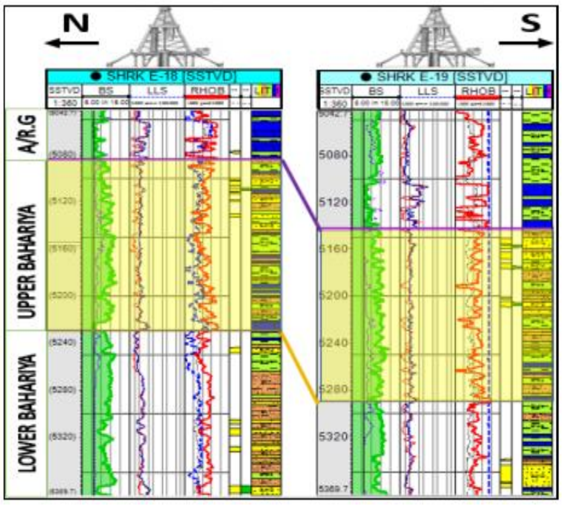

Figure 20 Correlation chart along the profile (B-B').

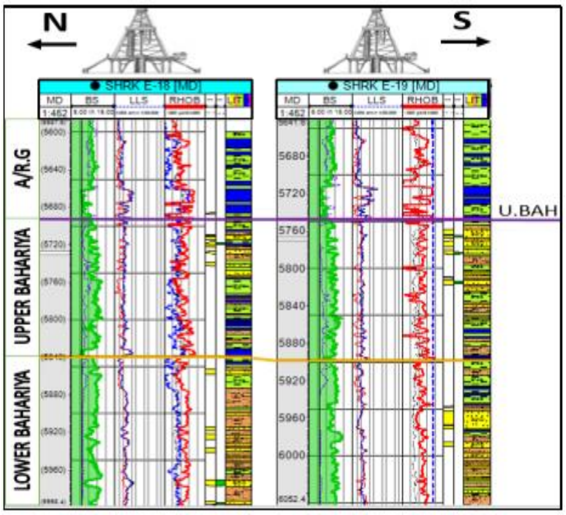

Figure 21 Stratigraphic correlation for the studied wells flatten on Bahariya Formation applied on the profile (B-B').

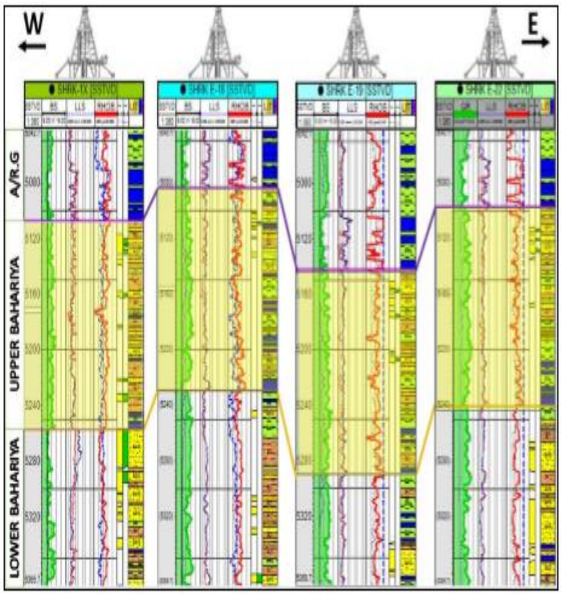

Figure 22 Correlation chart along the profile (C-C').

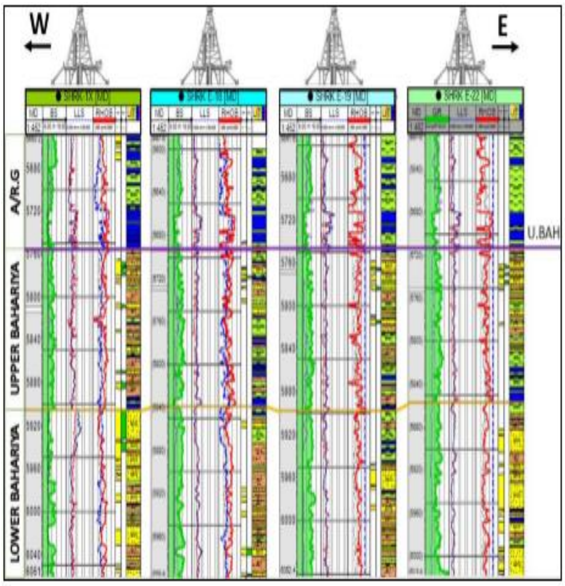

Figure 23 Stratigraphic correlation for the studied wells flatten on Bahariya Formation applied on the profile (C-C').

Conclusion

Seismic reflection interpretation reveals that the Shorouk field is correlated with a fault-bound high feature at Cretaceous level. The axis of this anticlinal horst is oriented in the WNW-direction and bounded by fifteen normal faults more or less in the same trend. The faulted-flanks are subjected to a strong subsidence to the north and south in the form of step-like structure, forming the main structural trap for the surrounding basins.

Most trap possibilities occur via the bounding faults of great throws, where the up-dip faults on the anticlinal flanks act as traps for the thin bed reservoirs. Other structural traps could be expected to be in closures of the horst structure, which provide suitable conditions for hydrocarbons entrapment along the axis of the anticlinal feature. The time and depth structure maps on tops of Bahariya Formation describe these bounding-faults and closures, which play a vital role in new prospect identification.

The structural elements traced on tops of Bahariya gave an indication about the active tectonics during the Cretaceous age and feel for some of the deeper structural fabric. The seismic investigations ascertain a set of WNW-trending faults of different tilt, throws and lengths. These major faults seem to be of deep-seated origin, developed along the pre-existing zones of weakness. Such a deformation may facilitate the hydrocarbons migration from underling pre-Cretaceous sediments.

The structure encourages drilling more development and exploratory wells in the central area to enhance productivity in the Shorouk field. It is recommended to test the axis of the mapped closures, where the hydrocarbons potentiality of the Bahariya reservoirs was enhanced toward the central area, with possible hydrocarbon entrapments may occur.

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Conflicts of interest

There are no conflicts to declare.

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