Egyptian Geophysical Society
EGS Journal, Vol. 16, No. 1, 43-51 (2018)

THE ROLE OF SEISMIC INTERPRETATION AT SOUTHWEST ABU SENNAN AREA, ABU GHARADIG BASIN, EGYPTIAN NORTHWESTERN DESERT

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الخلاصة: عادة ما يستخدم التفسير السيزمى بطريقة تقليدية للتنقيب عن النفط، استخدام الطرق غير التقليدية يمكن أن يؤدي إلى تحقيق نتائج إيجابية وتقليل مخاطر الحفر. الصورة تحت السطحية تصبح أكثر موضوعية حين دمج الطرق التقليدية وغير التقليدية معاً، مثل استخدام السمات الزلزالية مع الطرق التقليدية، لتسليط الضوء على العناصر الهيكلية. حساب الخصائص الزلزالية متعددة الأبعاد، جنبا إلى جنب مع استخدام شرائح الوقت يعطى نتائج تعتبر فعالة لتحديد الهيكل التحت سطحى لمنطقة الدراسة. وهذا يعني أنه ليس بالضرورة استخدام تفسير اعتيادى مسبق.الهدف الرئيسي من هذه الورقة هو تحديد التكتونيات الهيكلية لمنطقة الدراسة باستخدام الطريقة التقليدية جنباً إلى جنب مع الأساليب غير التقليدية مع احترام الخلفية الجيولوجية لمنطقة الدراسة. تسطيح الطبقات المتتبعه، قبل الطباشيري داخل مكعب سيزمى ثلاثي الأبعاد أثبت أن الأماكن التى كانت تعتبر واعدة وتنتمى للعصر الجوراسي المحفورة في منطقة جنوب غرب أبو سنان جافة بسبب إنخفاضها الهيكلى خلال العصر الجوراسي قبل الحدث التكتوني أثناء العصر الطباشيري المتأخر الذي جلب الصخور الجوراسية عالية حسب الوضع الحالي. و قد تم عمل خرائط عمق للعضو أبو رواش **G** وتكوين خومان لإظهار مجموعات الفوالق الرئيسية، مجموعة شمال غرب - جنوب شرق المهيمنة ومجموعة تتجه شمال شرق-جنوب غرب الناتج عن حدث القوس السوري.

ABSTRACT: *Structural interpretation is considered as a conventional method for oil exploration and commonly used. The use of unconventional methods could lead to achieve significant results and reduce the drilling risk. The subsurface image is completely objective, while merging the unconventional tool, like seismic attributes and the conventional seismic interpretation workflow, to highlight the structural elements, which matched together. Also to identify the general prospective area of interest, the multi-dimensional seismic attributes computation, along with the use of time slices, are both independent of interpretation.This means that no prior interpretation is necessarily required and no interpretational bias to the seismic attributes results. Seismic attributes were used to enhance fault image and enhance the continuity of picked horizons. The main objective of this paper is to determine the structural tectonics of the study area using, the conventional method combined with the unconventional methods with respecting the geological backgroundof the study area. Upon the horizon flattening, the encountered pre-Cretaceous faults within the vertically animated three dimensional seismic cube were better imaged and picked carefully. Drilled Jurassic plays within Southwest Abu Sennan (SWS) area were dry, due to low structural plays during the Jurassic before the Late Cretaceous tectonic event which brought the Jurassic rocks high as per the current day situation. AR/"G" Member and Khoman Formation depth structure contour maps were generated to show the main fault sets, a dominant northwest-southeast set and a set trending northeast-southwest due to Syrian arc structure system.*

GENERAL GEOLOGICAL SETTING

SWSdevelopment lease is located at the centralsouthern part of Abu Sennan area, and about 20 km south of Abu Gharadigarea, 370 km of Qattara depression and delineated by latitudes 29°32' to 29°35' N, and longitudes 28°30' to 28°35' E (Figure 1). SWS structure was discovered by The General Petroleum Company (GPC) in 1985.The northern limit of the area is neighboring to the external southern reaches of Abu Gharadig oil and gas area.Abu Gharadig Basin is considered standout amongst the most important depositionalbasins,that developed during the Late Cretaceous.

Most of the commercial and non-commercial hydrocarbon accumulations, as well as the oil and gas shows have been found in the northern part of the Western Desert, particularly in the Abu Gharadig basin (Azzam and El- Sherbeny, 2002). AbuGharadig roughly is a progression of highs and lows having a general NE-SW trend.These faults were probably rejuvenated from old faults of the same orientation. NW oriented faults that are parallel to the Gulf of Suez were formed during the Early Paleozoic and combined with the E-W to ENE oriented faults in controlling the depocenters of the Miocene basins. Faults activity diminished, after the Late Cenomanian in the Abu Gharadig basin, but continued through The Miocene in the surrounding areas of Northern Egypt. (Abdelaal and Moustafa, 1988).

The major tectonic events of the Abu Gharadig basin extended from The Paleozoic to The Tertiary periods (Awad, 1984). The structural features can be differentiated into folds, different dip tilted faulted blocks, faults and unconformities. Therefore, the seismic expressions and criteria for recognizing these structural elements have to be established, to facilitate the interpretation of the given seismic data (Abedi and El-Toukhy, 1990), The E-W to ENE-WSW was originally formed during the Tertiary time during the rifting of Africa-Arabia (Moustafa& Khalil, 1989), where they formed the passive continental margin of the Neotethys.

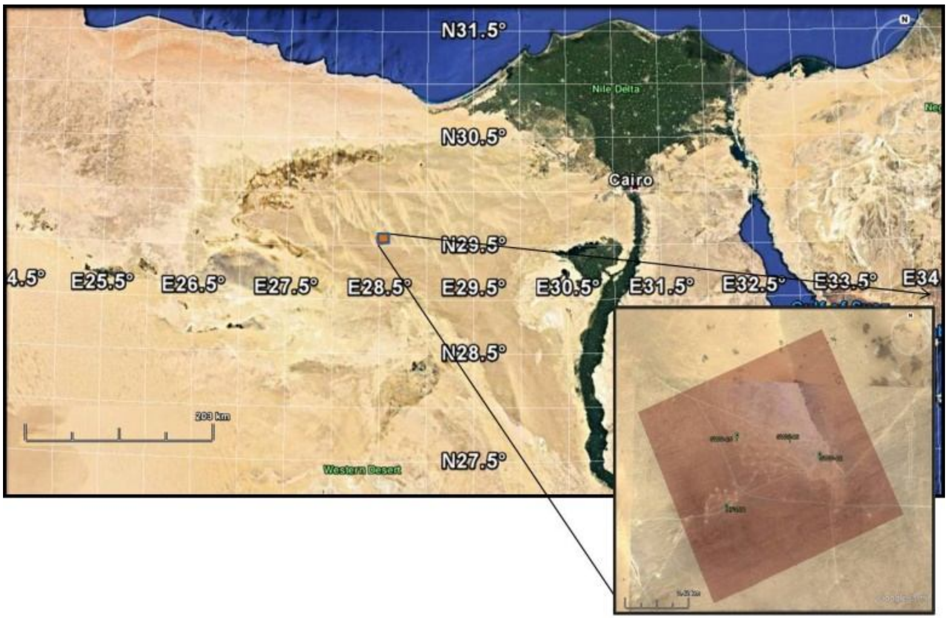

Figure 1: (a) Location map of South West Abu Sennanarea, Abu Gharadig Basin, northwestern Desert, Egypt.

METHODOLOGY

The workflow (Figure 2) chart is to understand the subsurface model of the study area, which is challenging due to the seismic data quality.During the work flow, the conventional and unconventional seismic interpretationtechniques are used to understand the structural pattern and basin evolution. Seismic attributes represent a part of the unconventional seismic interpretation. This means that, it is a part of the seismic interpretation, but unconventional used normally in the case of having bad quality seismic data. In the presence of good quality, conventional seismic interpretation is sufficient.

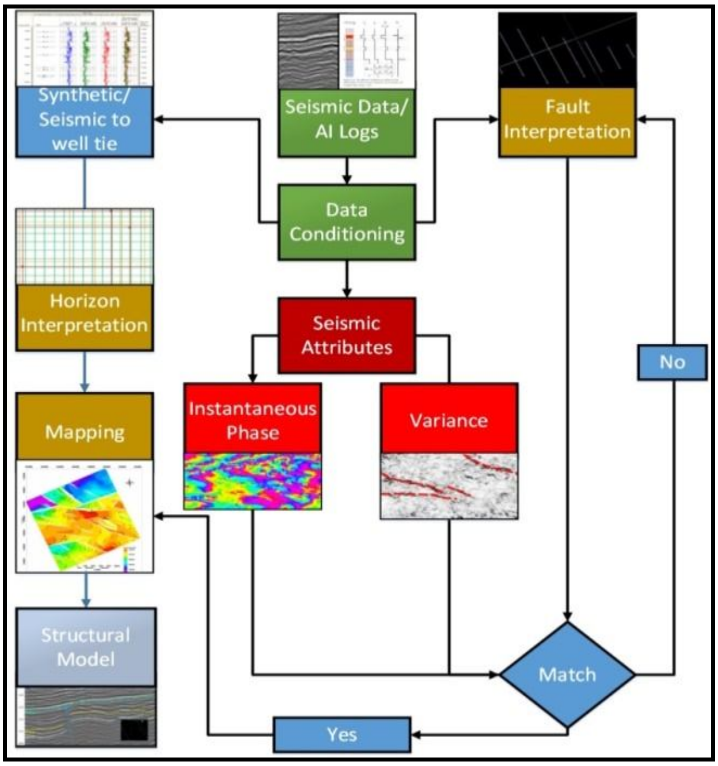

Figure 2: Undertaken methodology scheme, that arrange the steps followed in the conventional and the unconventional seismic interpretation approach. The unconventional approach was to check the occurrence of faults.

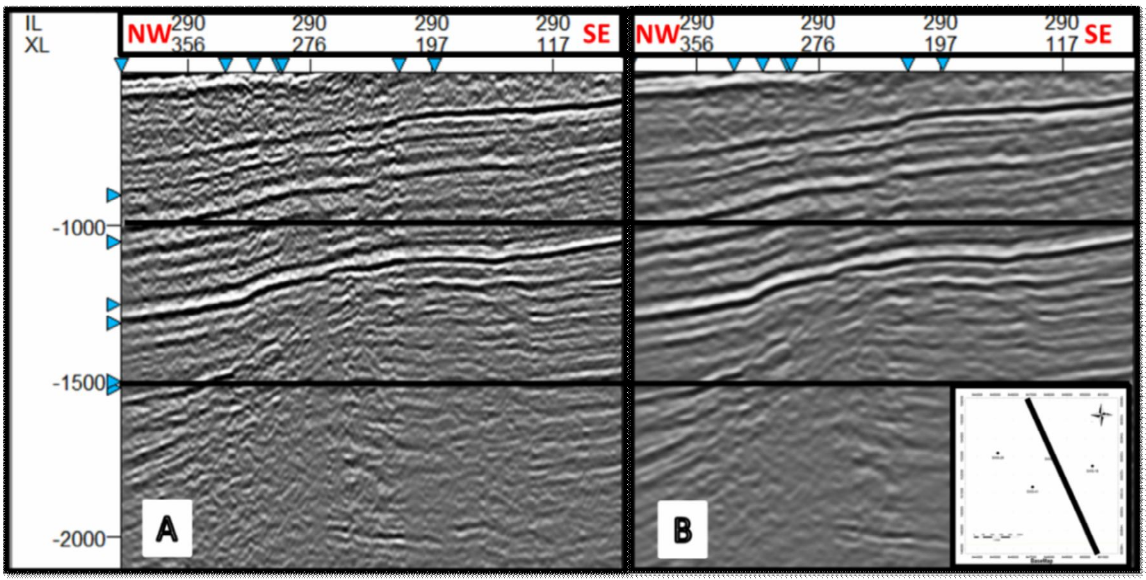

Figure 3: (A) Seismic line with noises associated and poor amplitude connection between the traces, due to sampling problems, (B) the attribute structural smoothing produces an aggressive noise cancellation and improves the continuity of the seismic events while existed faults still clear to be detected.

SEISMIC DATA INTERPRETATION

There are several ways to tackle a structural interpretation, Interpretation of the faults first, then horizons or Interpretation of the horizons first, then faults or Interpretation of horizons and faults (preferred)consecutively, that's about conventional seismic interpretation.Post-stack attributes ex. instantaneous attribute, are the attributes computed from the complex seismic trace. Butterworth type band-pass filters are used to generate the real and imaginary parts of the complex trace. The band-pass filter suppresses the very high and the very low frequency content, of seismic traces to generate a stable Hilbert transformed trace.Using Petrel software, for structural interpretationpurposes, in order to enhance the continuity of seismic events and structural smoothing, has been used (Figure 3). This attribute produces an aggressive noise cancellation, improving considerably the continuity of the reflectors, and helps to sharpen the edges of reflectors and remove the cross-cutting coherent and random noises (Chopra and Marfurt, 2007). The main objectives of the attributes are to provide accurate and detailed information to the interpreter on the structural, stratigraphic and lithology parameters of the seismic prospect. Seismic attributes are divided into two general classifications physical and geometrical attributes (Taner et al, 1994).

Seismic attributes provide a sufficient way to track the trends of faults. Information from different seismic attributes used to form fault geometry and can generally be used to propose well locations. Physical attributes are the seismic measurements that directly related to wave-propagation, lithology and other physical parameters.Instantaneous attributes are computed sample by sample and indicate continuous change of attribute along the time and space axis, one of the effective physical attributes is the instantaneous phase.The instantaneous phase attribute is a physical attribute and can be effectively used as a discriminator for geometrical shape classifications (Taner et al, 1994).

Instantaneous Phase

Instantaneous phase enhances both the weak and strong seismic events, due to the invariant nature of the attribute in terms of amplitudes. It highlights reflection geometry in the seismic volume and hence may be helpful in revealing faults(Figure 4). Some uses the instantaneous phase to show amplitudes discontinuities, that has no amplitude information, hence all events are represented. They visualize stratigraphic elements, devoid of amplitude information, to determine the sequence boundaries the detailed visualization of bedding configurations(Figure 5).This attribute has proven results enhancing reflectors continuity, discontinuities, faults and pinch-outs. Seismic stratigraphic patterns (e.g. on-laps and off-laps) are easily identified with this attribute, allowing the interpreter to deduce more easily the sedimentary processes that affected the area (Taner et al., 1979). This attribute has proven results enhancing faults.

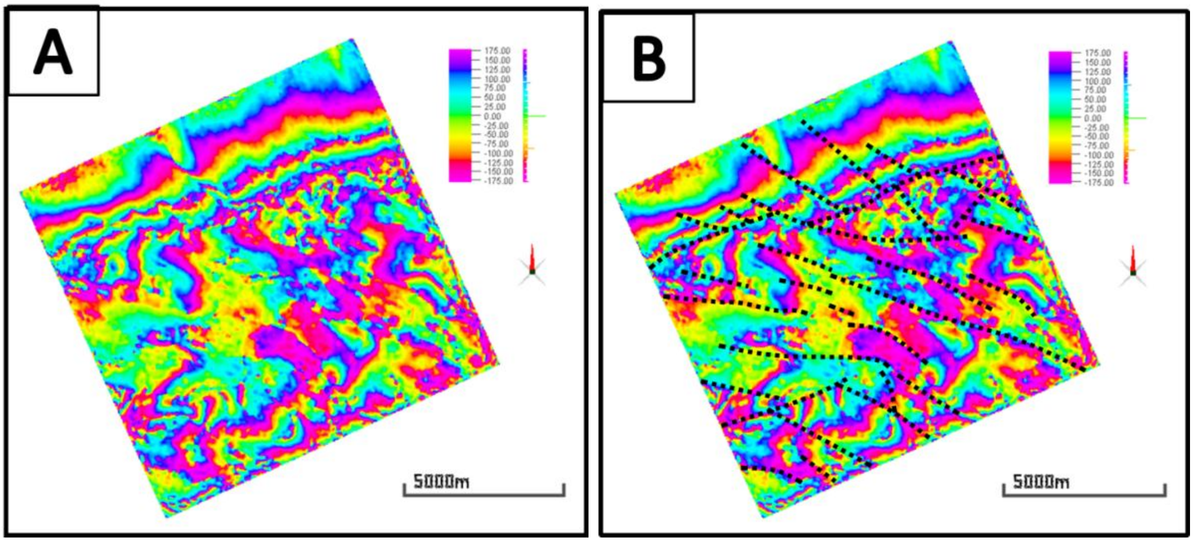

Figure 4: Results of instantaneous phase extracted cube spotting on faults detection enhancement. (A) Time slice at level 1300 mSec. (B) Structural interpretation after enhancing reflectors continuity, discontinuities, faults, black dashed lines describe faults and boundaries.

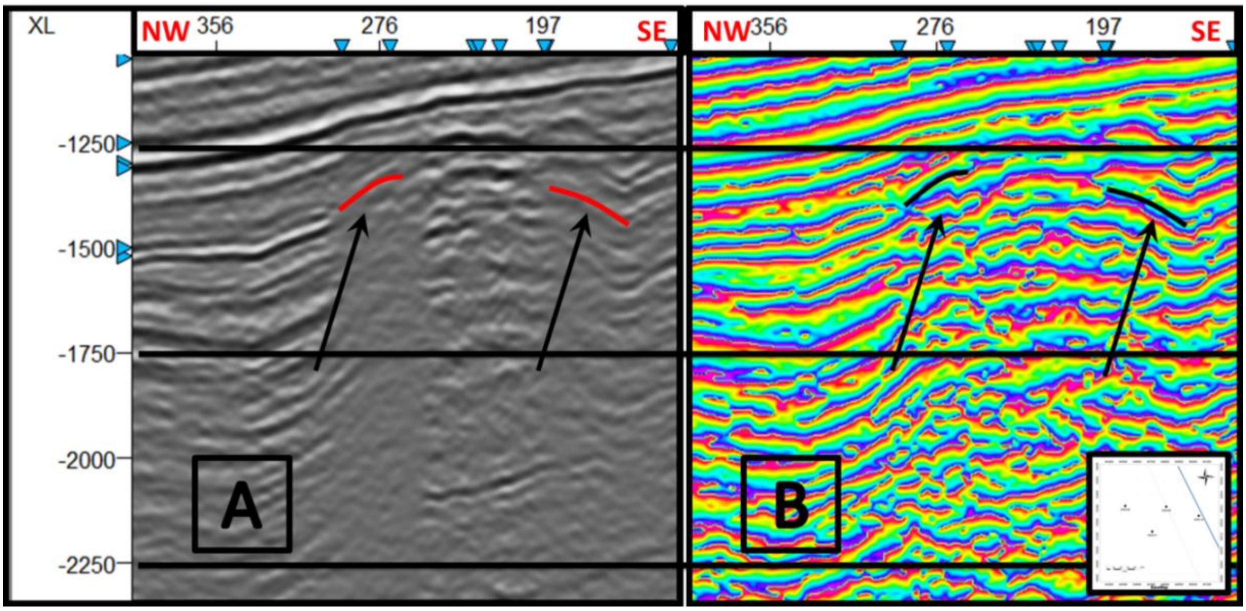

Figure 5: Analysis of instantaneous phase attribute spotting on continuity enhancement, a comparison between the original seismic inline #415(A) and its corresponding instantaneous phase attribute. (B) Interpretation of dimmed continuous (red Picking) reflectors after enhancing the reflectors continuity, discontinuities, faults. Bad continuity observed by black arrows.

Variance

The variance attribute is a geometrical attribute and can be effectively used as a very good fault detector; it is a reliable tool for delineating geological boundaries. Previous observations, using the physical attribute the instantaneous phase, demonstrated the power of seismic attributes for delineating the discontinuities. However, there are still areas of uncertainty, where the fault shadow effect and noisy data are remains an issue. Variance attribute, which is an edge detector attribute, can be defined as the measure of trace to trace similarity of the seismic waveform within a small analysis window used to improve the resolution of faults (Figures 6, 7 and 8).

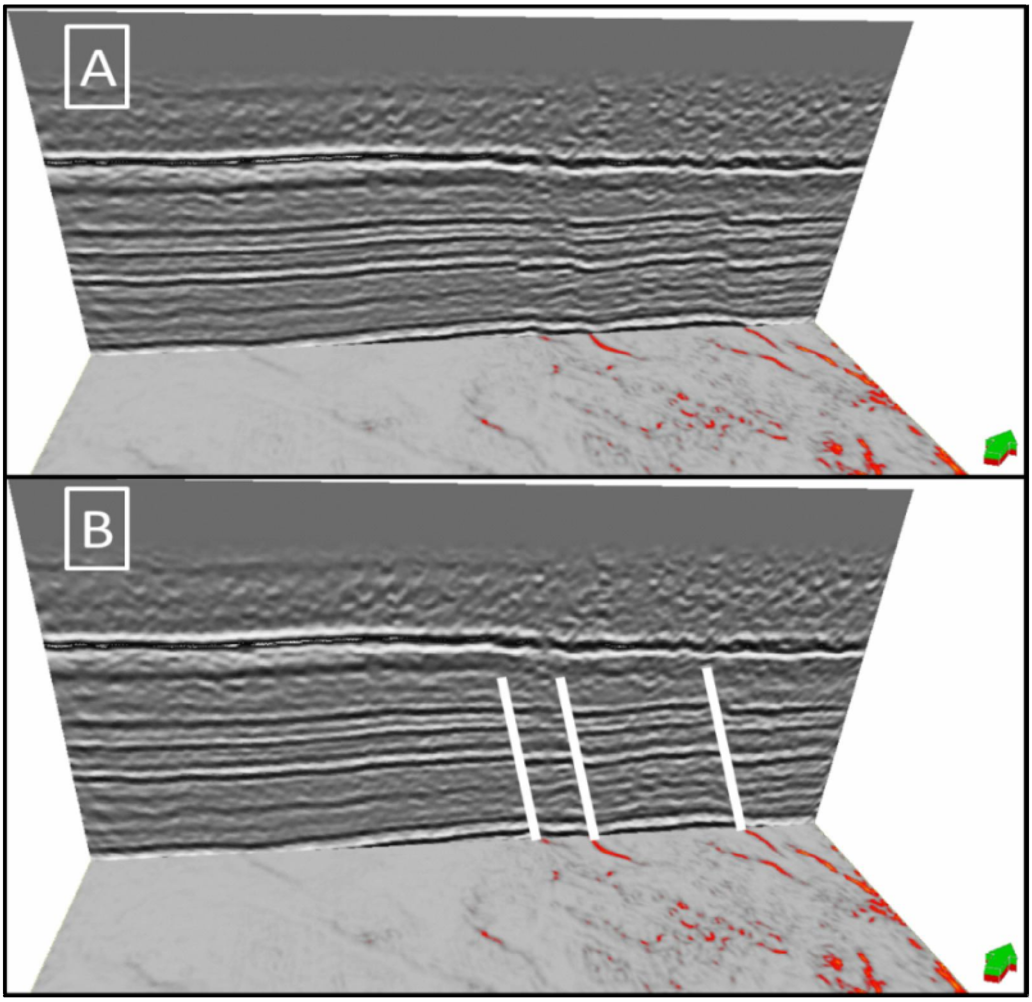

Figure 6: (A) Seismic inline intersected by a variance attribute time slice at level 1000 mSec. To tie the faults between seismic sections and time slice extracted from the variance attribute volume. (B) Shows the normalfaults with white color trending NW-SE and its extension on the variance attribute time slice with red color.

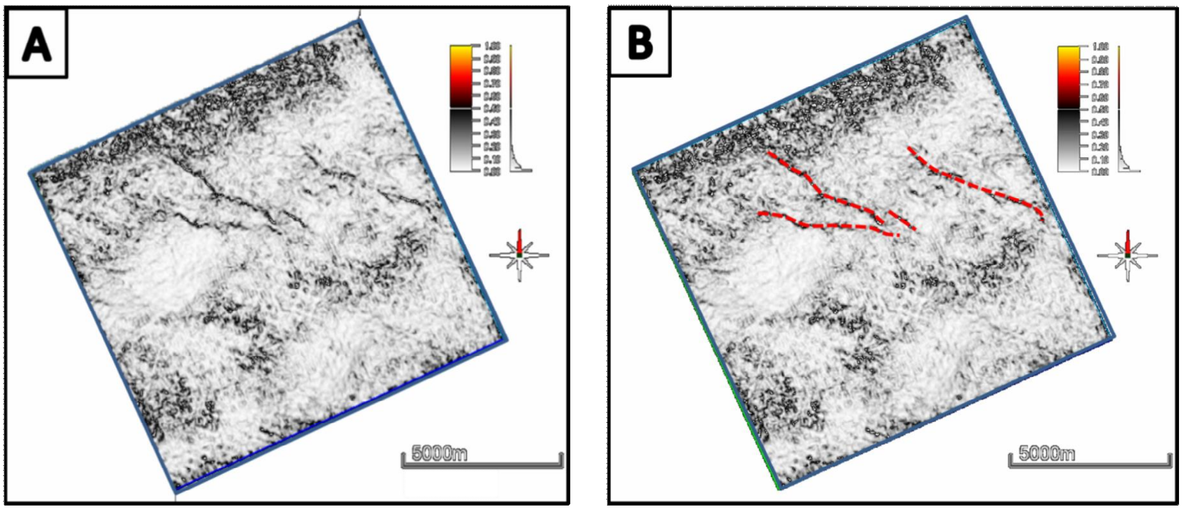

Figure 7: Analysis of Variance extracted cubespotting on the faults detection. (A) Time slice at level -700 mSec.without interpretation. (B) Time slice analysis after enhancing reflectors continuity, discontinuities, faults, red dashed lines describe faults and boundaries, Interpretation highlighting areas with highly faulted areas, Notice that the definition of faults has been improved.

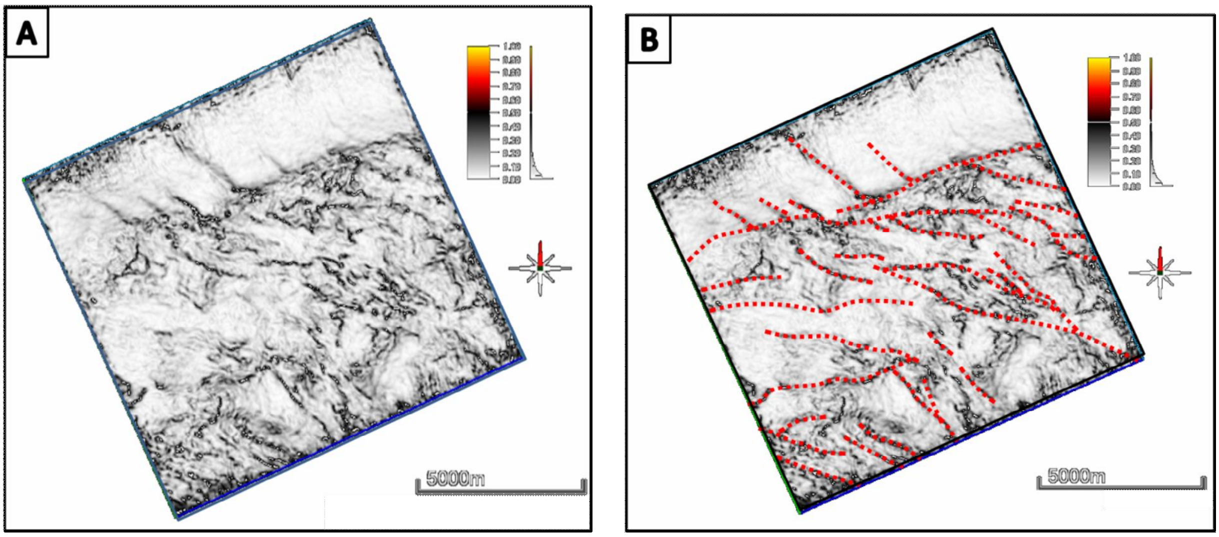

Figure 8: Analysis of Variance extracted cubespotting on the faults detection. (A) Time slice at level -1300 mSec.without interpretation. (B) Time slice analysis after enhancing reflectors continuity, discontinuities, faults, red dashed lines describe faults and boundaries, Interpretation highlighting areas with highly faulted areas, Notice that, the definition of faults has been enhanced.

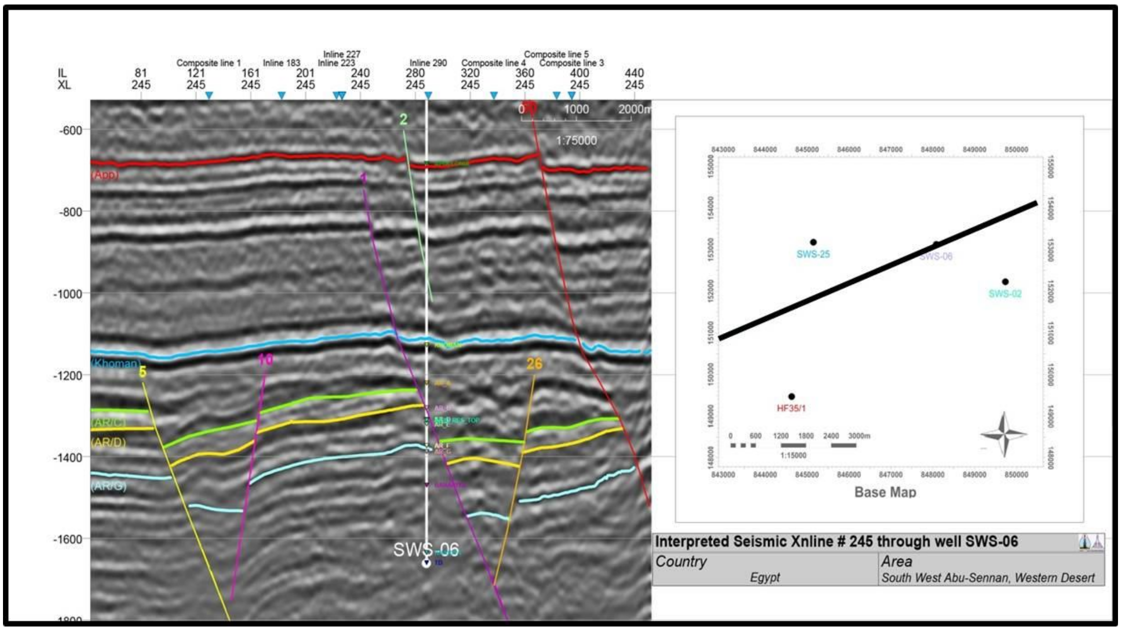

Figure 9: NE-SW seismic section shows the dominant structure elements and also picked horizons, thatguided by the seismic attributes and interpreted horizons of the SWS area, tracked horizons names represented at the left hand side to each one.

HORIZONS AND FAULT INTERPRETATION

Horizons are mapped during the integrated interpretation process. The interpretation of SWS appeared to be challenging. To interpret these horizons, tied wells were connected with each other by composite lines to check the stratigraphy correlation. The horizons are well interpreted in the middle of the survey and have some limitations to the northeastern margins of the survey.The initial horizon interpretation was performed by tracking 5 strong reflectors throughout the entire length of the seismic survey. APOLLONIA, KHOMAN, AR/ “C”, AR/ “D” and AR/ “G” (Figure 9).

After catching the main fault pattern, using the seismic attributes, it’s important to recognize and interpret faults in the seismic data to complete the image. The interpreted faults (NW-SE or E-W) are often normal thrown, except the Syrian arc structural systemtrending towards the NE-SW direction and throwing towards the south direction.These faults represent the initiation of seismic interpretation in the study area, this structure affecting the Abu Roash Members in-between range from 950 to 2000 mSec., in two-way time seismic sections.

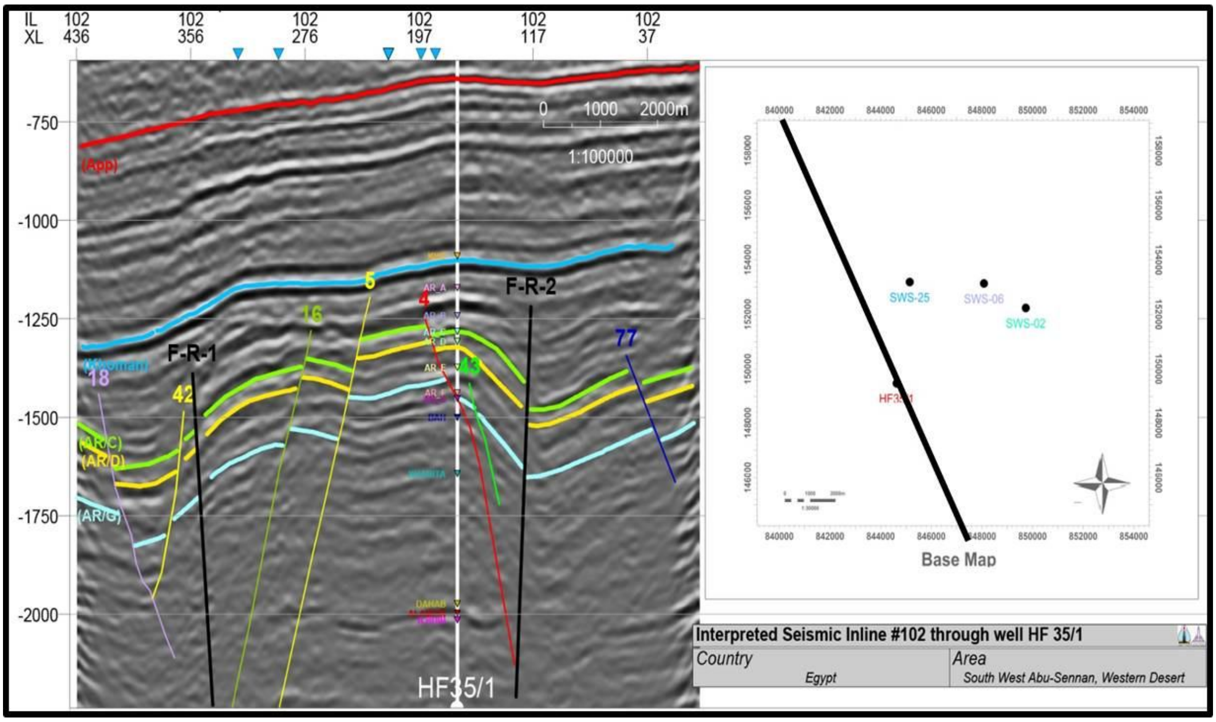

Figure 10: NW-SE Seismic Section shows the main structure guided by seismic attributes and interpreted horizons of the SWS Area.

Seismic lines in the study area are classified into two sets, NE-SW and NW-SE. These two trends (Figure 10) are dip lines. The NE-SW lines are dip lines for the NW-SE faults of post-Tertiary, while the NW-SE lines are dip lines for the NE-SW faults of pre-Tertiary elements. Together, they form a closed loop, which has been used to highlight the structural and stratigraphic elements of the area under consideration. The structure of Abu Roash/ “G”, “D” and “C” Members is similar to each other, because they are all related to the Cretaceous time (Figure 10). The normal faults are the most predominant types and trending mainly E-W, NW-SE and NE-SW, The reverse faults are relatively few with the ENE trend.

HORIZON FLATTENING

Flattening can reveal significant features present at a particular time, duringthe Late Cretaceous time.Such tectonic activity in the form of elevation and folding during theCretaceous caused release for the incremental energy stored in the crust and caused formally reverse faults. Such energy releases transform most of the Syrian arc NE-SW faults from reverse to normal elements. Therefore, most of the NE-SW Syrian arc faults are no normal ones. This fault trend was challenging to be detected, a blank full dynamic range seismic section (Figure 11), which is directed NW-SE was considered to find out the ENE-WSW fault trend, due to Syrian arcstructural system, (figure 12) shows the interpretation of horizons from Dabaa to Masajid and the ENE-WSW fault trend as a dashed black stick.Flattening on the top AR/G (Figure 13) and top Khoman (Figure 14) were carried out to prove the inverted basin structural fashion existence which is considered one of the Western Desert criteriathat indicates the structural inversion process.

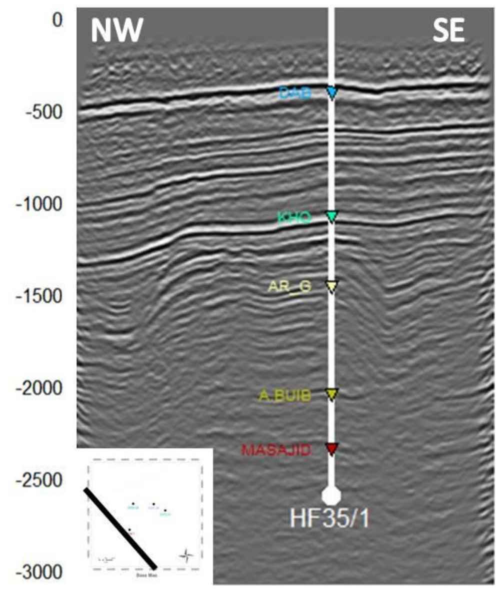

Figure 11: Full dynamic range Seismic Section passing through well HF35/1, section is directed NW-SE, South West Abu Sennan Area, WesternDesert, Egypt.

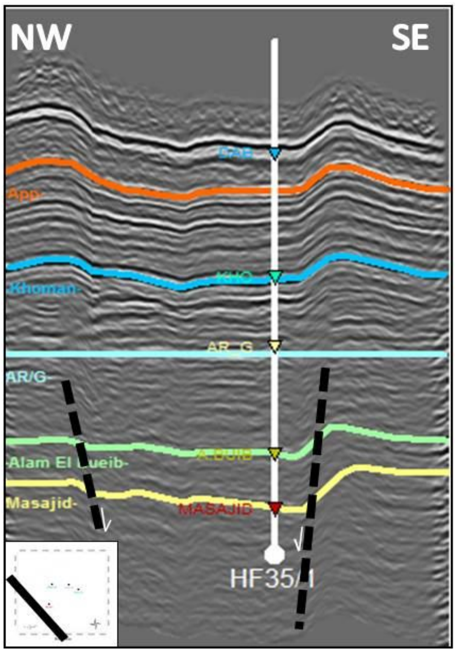

Figure 12: Interpreted full dynamic range NW-SE Seismic Section (Present day time) passing through well HF35/1 shows the main ENE-WSW fault trend, South West Abu Sennan Area, Western Desert, Egypt.

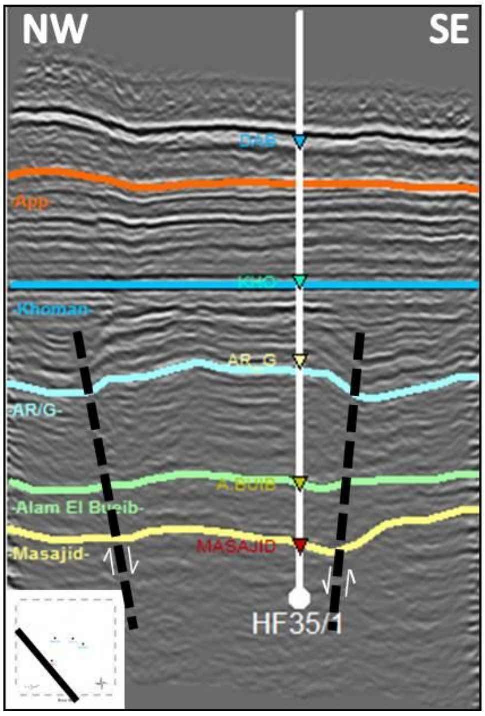

Figure 13: Flattened NW-SE seismic section passing through well HF35/1 on top AR/G.

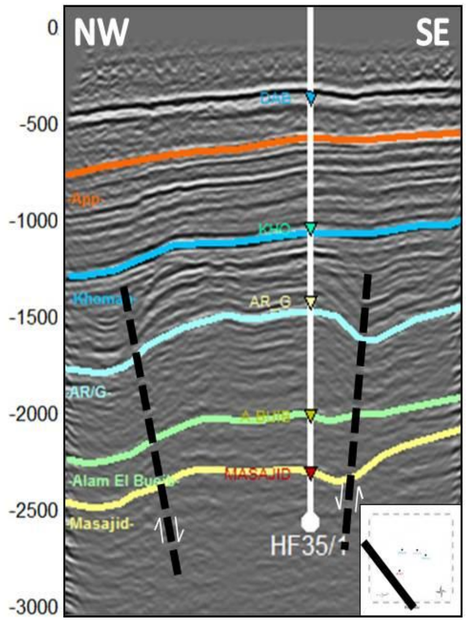

Figure 14: Flattened NW-SE seismic section passing through well HF35/1 on top Khoman.

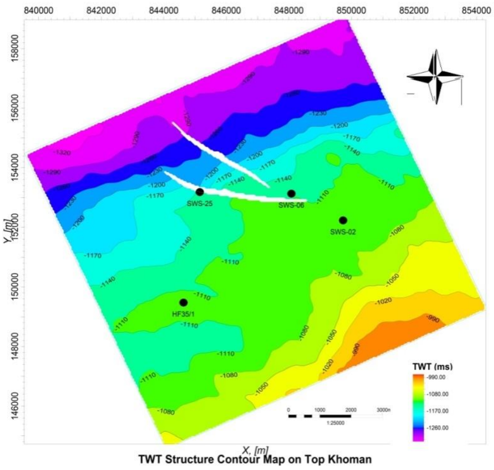

Figure 15: Top Khoman two-way time structural contour map.

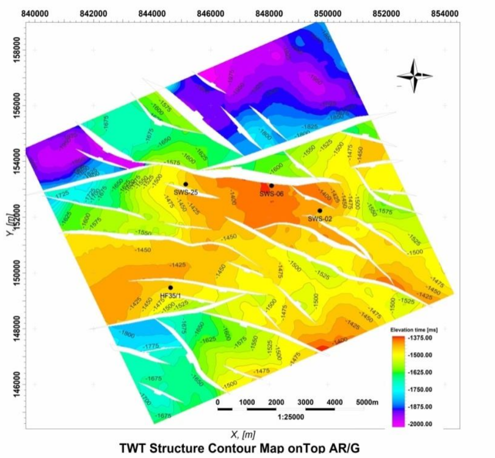

Figure 16: Top AR/"G"two-way time structural contour map.

The highly structural and promising oil potentiality areas were found in both the central and southwestern parts of the SWS area. Flattening is process of dating the generation and rejuvenation of faults, consequently defining the relationship between the hydrocarbon synthesis and the trapping formation. Oil prospecting experience showed that, all inverted structural faults are lacked from hydrocarbons, this is because the reactivation of faults caused the seepage of the already existed hydrocarbons.The flattening of seismic data declared that, the central Cretaceous structural highs have a high oil potentiality, while the central deeper horizons have relatively no potentiality at the time of oil migration.

STRUCTURAL MAPPING

The structural features, inherited in the two-way timestructure contour maps of the studied stratigraphic units, reflect the prevalence of the tectonic trends of local structures that believed to be formed as a result of comparable systems of regional structural deformations affecting the surrounding regions (Abu El-Ata, 1988).

Khoman and AR/"G" structure time maps (Figures 15 and 16) are completely tied exactly with the comparable formation tops across the 3D seismic cube of in-line and cross-line directions. KHOMAN and APOLLONIA maps show the NW-SE fault trend, according to the deformation caused by the rift fault movement in Eocene.The structure of Abu Roash/ "G", "D" and "C" Members is similar to each other because they are all related to the Cretaceous time.Some of the small grabbens and horsts are recorded in the central part of the study area.However the NW-SE trending normal faults trend is the dominant fault trend, because it is the youngest in the study area, that obliterated the older NE-SW Syrian arc structure of folding and faulting.

CONCLUDING REMARKS

1. The study and interpretation of seismic attributes therefore provide us with some qualitative information of the geometry of the subsurface.
2. The general structural style of SWSarea is northeast doubly plunging asymmetrical anticline. Thedominant faults have dissected the area into a number of separate reservoir blocks. These faults are trending in E-W, NW-SE and ENE-WSW directions, resulting from the Late Cretaceous compressive force.
3. Drilled Jurassic plays within the study area were dry, due to being structurally low during the Jurassic times and before the Late Cretaceous tectonic event which brought the jurassic rocks high as per the current situation. This was clear after running flattening exercise in two different full dynamic range seismic sections trending NW-SE for AR/"G"Member and Khoman Formation, respectively.

ACKNOWLEDGMENT

The authors are grateful to both The General Petroleum Company (GPC) and the Egyptian General Petroleum Corporation (EGPC) for providing the raw seismic reflection data of the SWS area to be used for the present study.

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