Egyptian Geophysical Society
EGS Journal, Vol. 18, No. 1, 35-45 (2020)

THE USE OF 3D SEISMIC ATTRIBUTES FOR IMAGING THE POTENTIAL GAS REMAINS AT FARASKOUR REGION, THE EASTERN PART OF ONSHORE NILE DELTA, EGYPT

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إستخدام السمات السيزمية ثلاثية الأبعاد لتصوير بقايا الغاز المحتملة فى منطقة فارسكور - الجزء الشرقي من دلتا النيل - مصر

الخلاصة: الهدف الرئيسي من هذه الدراسة هو تحديد البقايا المحتملة لتواجد الغاز ولتحديد الخصائص التركيبية–الطبقية في منطقة فارسكور في الجزء الشرقي من حوض دلتا النيل, وذلك بإستخدام بيانات الانعكاس الزلزالي النموذجية وتحليل السمات. وقد أضاف الاستخدام المتكامل للسمات الزلزالية (التماسك ونمذجة وتحليل السعة مع المسافة وإستخراج السعة) معلومات هامة تفيد فى حسابات الناحية الكمية عن إمكانات تواجد الهيدروكربون والسحنات و التراكيب الجيولوجية الثانوية. ارتبطت نتائج التفسير الزلزالي ثلاثي الأبعاد التي تم الحصول عليها و مقارنتها بالتراكيب الإقليمية المعروفة في الجزء الشرقي من حوض دلتا النيل وأظهرت مطابقة مرضية , و أضافت المزيد من التفاصيل عن مصائد الهيدروكربون و أعطت احتمالات جديدة لوجود احتياطى الغاز بمنطقة الدراسة.

ABSTRACT: *The main objective of the present study is to identify the possible remains of gas potentiality and to delineate the structural-stratigraphic characteristics at the on-shore Faraskour Region, in the eastern part of the Nile Delta Basin (NDB), using modeled seismic reflection data and attributes analysis. The integrated use of seismic attributes (coherency, AVO modeling and analysis, and amplitude extraction) added significant quantitative information about the hydrocarbon potentiality, facies and the minor geological structures. The obtained three dimensional (3D) seismic interpretation results were correlated with the known regional structural–stratigraphic fashion of the western NDB and showed a satisfied matching, added more details about hydrocarbon trapping and gave a new possible gas reserve at the study area.*

1. INTRODUCTION

In the last decade, Dana Gas Egypt Limited explored more than 13 discoveries, containing commercial volumes of gas and condensates, from which 4 discoveries belong to the present study area. The awarded development leases, which are in-production, covering the following fields; El-Basant, Azhar Delta, Sharabas, and Faraskur fields. All have produced wet gas through the South El-Manzala Plant (Fig. 1). So, it was highly important to work on the remaining gas fields in the area.

2. SEISMIC INTERPRETATION

A synthetic seismogram was created using extracted wavelet from the PSTM seismic data for El-Basant-1 stratigraphic control well with a good correlation coefficient of 0.712 (Fig. 2), the only available well which has a complete set of logs and VSP, good-quality seismic data with a resolved well tying. The typical interpreted seismic cross section (Fig. 3) explains how the seismic data fit with both the synthetic seismogram and gamma ray logging results in a good matching.

The 3-D Seismic data acquired and processed on 2006. The quality of the PSTM seismic data was ranged between a good to fair in the deeper part and a good all over the shallow part, where they can easily picked up. The quality of the interpreted stratigraphic horizons and geological faults was mainly controlled by the seismic data quality, depending on the working depth-level within the study area. The typical interpreted seismic cross-section # 1339 (crossline direction) is extended from east to west, passing through El-Basant-1 well and showing clearly the major structure as N–S trend of fault series which have relatively large throws and (Fig. 4). All these faults are affected by the same strong geologic events with a high magnitude and at the same time within Sidi Salem Formation (Tortonian–Serravalian). The N–S fault trend is mainly controlling El-Basant field and Azhar fields in the western side of the study area. The eastern part of seismic cross-section showed another fault trend, oriented in NE–SW direction, in Faraskour area and controlling the whole Faraskour field.

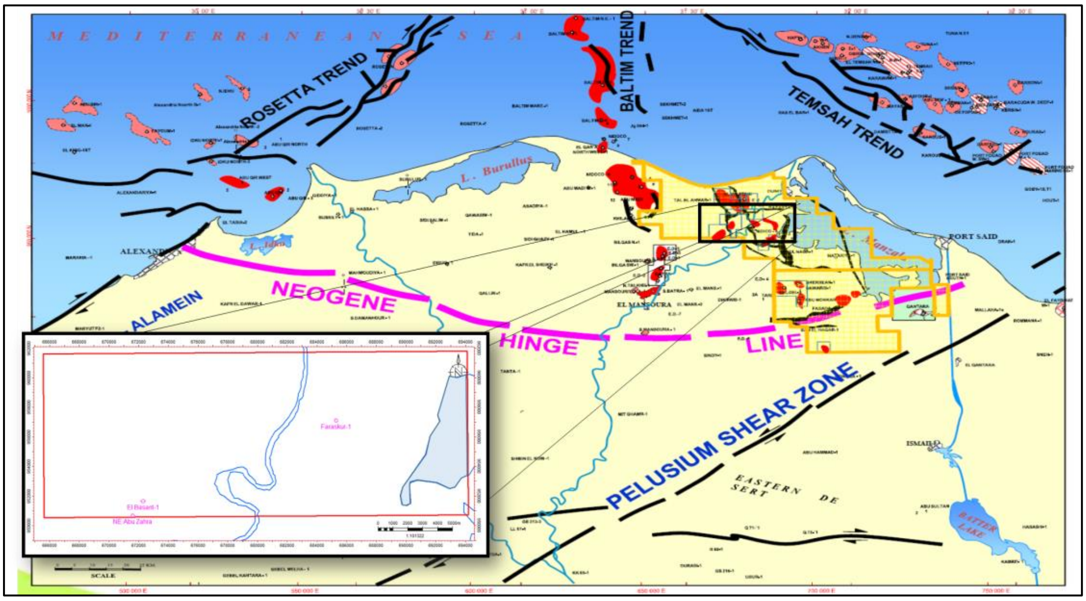

Fig. 1: Regional subsurface structure trends and the discovered gas fields at the northern part of the NDB.

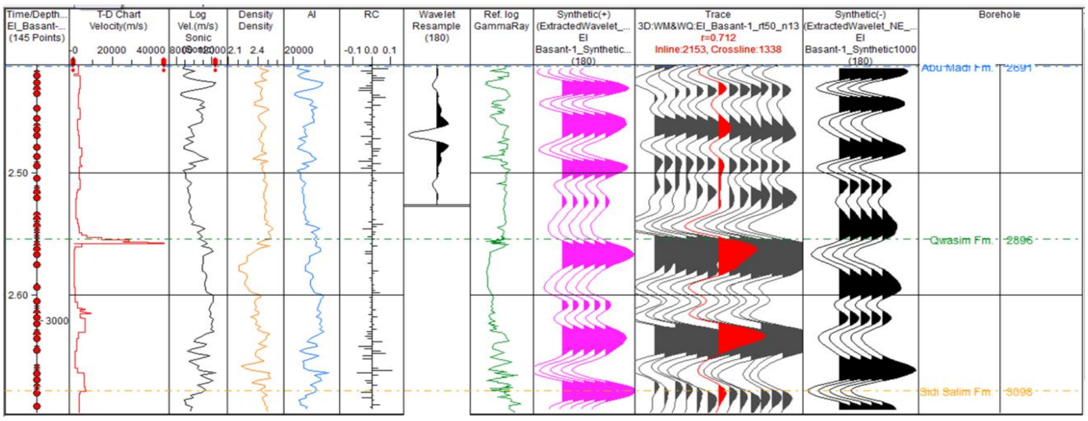

Fig. 2: The obtained synthetic seismogram at El-Basant-1 well with a correlation coefficient = 0.712.

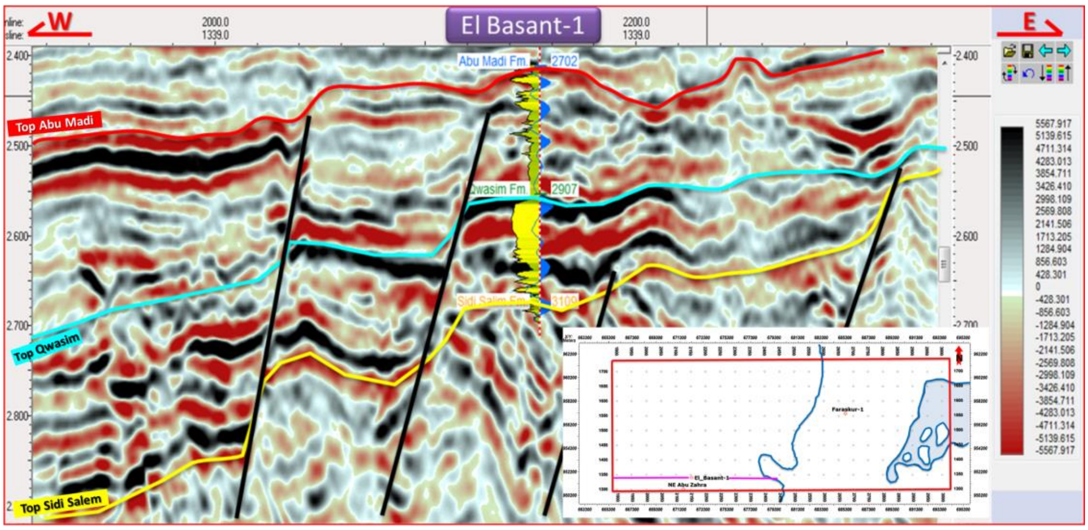

Fig. 3: The obtained formation tops, along the interpreted seismic cross-section # 1339 (crossinline direction), using the created synthetic seismogram results. The interpreted stratigraphic boundaries are shown, from top to bottom, with red, cyan and light yellow colors.

The interpretation of top Sidi Salem Formation was straightforward because it has a clear angular unconformity between low-angle dip Qwasim or Abu Madi Formations and steep-dip angle of Sidi Salem Formation (Fig. 5). The onlape of Qwasim on Sidi Salem Formation and in some where Abu Madi on Sidi Salem Formation is very clear (Fig. 5) from north to south which also explains the filling sediments for the paleo-low-relief of Sidi Salem Formation as pinch-out of Abu Madi and Qwasim Formations. The pinch-out is only present from the eastern direction and thickening towards the western direction (Fig. 4).

The interested zones which containing hydrocarbons in El-Basant field are called Qawasim pay 1 and 2 (QP1 and QP2). The interpretation done for these two intervals on the pre-stack time migration (PSTM) and far-angle stack seismic data sets (Fig. 6) for calculating root-mean square (RMS) seismic amplitude maps. The two target horizons have two-way time (TWT) ranges of about 2400 and 2800 mSec., respectively, and characterized with high (zero-crossing) 'amplitude anomalies' on the far-angle seismic stacks which could be considered as direct hydrocarbon indicators (DHI) due to the presence of gas remains. Notably, these bright seismic events showed an exact matching with the target formation tops at the drilled wells.

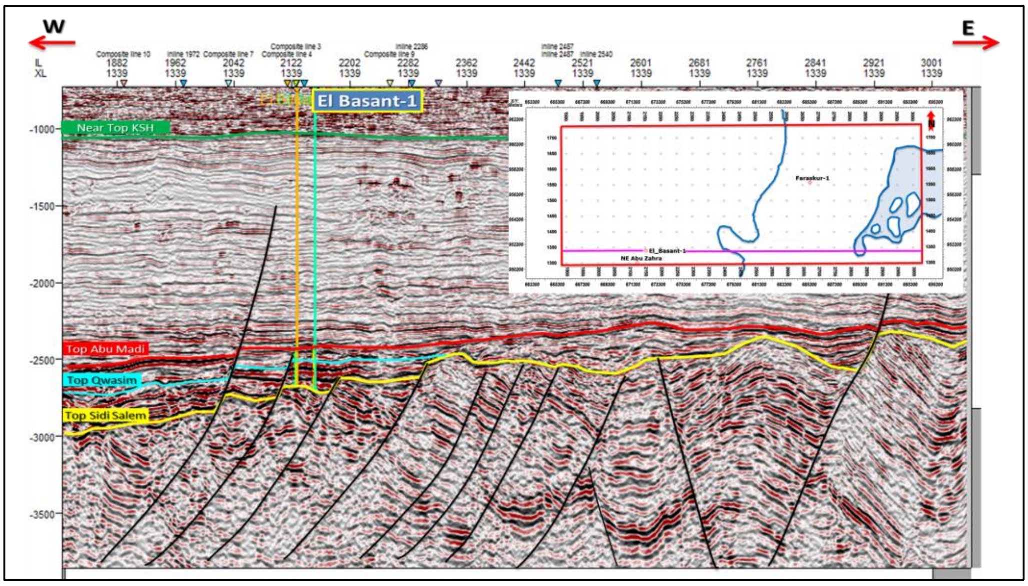

Fig. 4: The whole interpreted seismic cross-section # 1339 (crossinline direction), extending E–W, passing through El-Basant-1 well and showing the regional structure of Sidi Salem Formation.

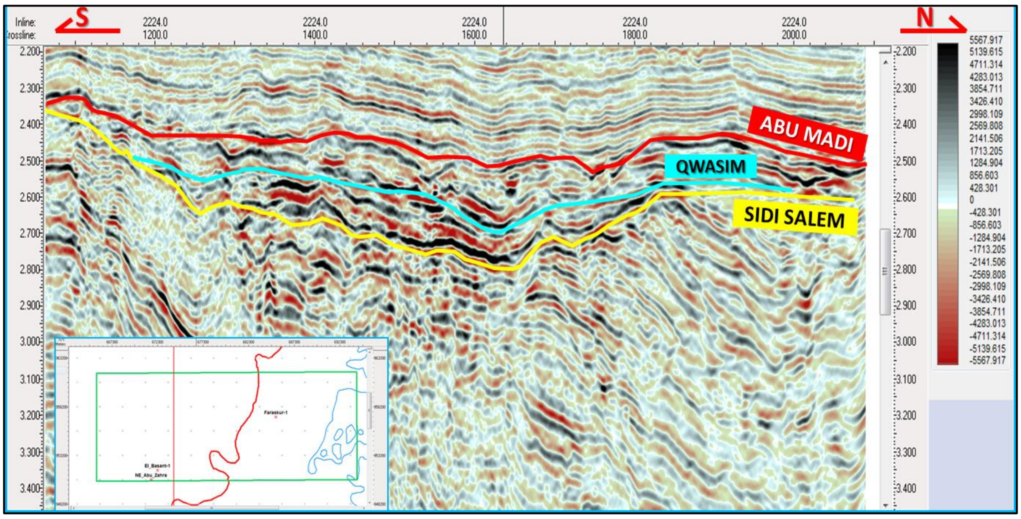

Fig. 5: The whole interpreted seismic cross-section # 2224 (inline direction), extending S–N explaining the onlap of both Abu Madi and Qwasim Formations over Sidi Salem Formation.

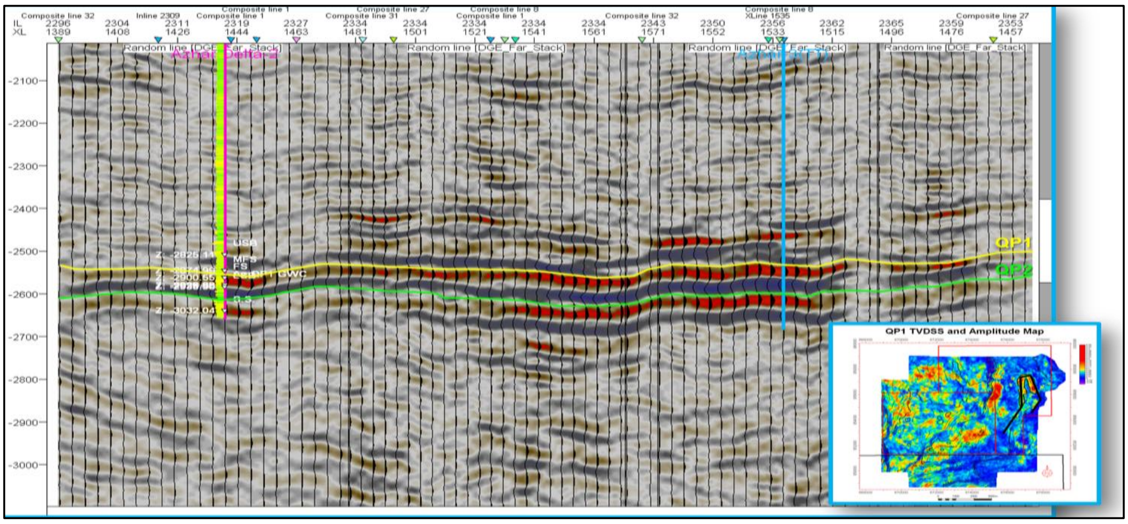

Fig. 6: The far-stack seismic cross-section (composite seismic traces), following up the 'bright seismic events' or 'amplitude anomalies', with the interpreted horizons of zero-crossing amplitude for Qawasim pay 1 and 2 (QP1 and QP2).

3. SEISMIC ATTRIBUTES

Coherency is usually achieved as one of the best discontinuities attributes which can distinctly compare the adjacent seismic traces, using the seismic cross-correlation technique, and clearly reveal buried deltas, river channels, reefs, dewatering features, faults and even fracture zones. The typical coherency slice at the study area (Fig. 7) showed the main structure trend for Sidi Salem Formation which is generally oriented in N–S direction and extended to the shallower Qwasim and Abu Madi Formations. Fig. 7 also shows the meander channels trend which is oriented perpendicular to the existing geologic faults trend, indicating that they have been existed before the deposition time. The variance attribute has been applied (Fig. 8), particularly for the picked base-Pliocene horizon, to explain the changing in the meander channels from E–W to N–S (Bednar, 1998).

The gas sands of the reservoirs are characterized by low velocity and density ranges, compared with the surrounding shale. Interestingly, both the top and base of reservoirs have a 'bright' seismic amplitude response. The key challenge of the reservoirs is to understand the depositional environment with respect to the amplitude and acoustic impedance geometry from the processed–interpreted 3D seismic data with the aid of seismic facies and depositional pattern cross-correlation. The AVO analysis was performed, using the common-depth point (CDP) seismic gathers and the modeled AVO gas response on the created well logging offset gathers, to quantitatively interpret the pay zone extension with a help of 3D amplitude cut-off far from the well location and to volumetrically calculate the possible gas remain anomalies.

The first step of AVO analysis is the selecting of CDP gathers in the vicinity of the available well locations and preconditioning of such CDP gathers to optimize the analysis results. The preconditioning of seismic data include both the noise filtering for removing their high-frequency content and normal moveout (NMO) correction using the trim statics process. The AVO analysis of seismic CDP gathers at the stratigraphic-control well 'El-Basant-1' showed that the top of hydrocarbon zones is sensationally 'seismic trough' while the base is 'seismic peak'. The preconditioned CDP gathers at the stratigraphic-control well 'Faraskur-1' showed that the amplitude increases with offset and the gradient–intercept cross-plot (Fig. 9) presents the top and base of gas within the third and first quarters, respectively, and far from the wet trend, i.e. ideal class–III gas remains at Abu Madi Formation level.

The second step of AVO analysis is the AVO modelling for the well logging results after preconditioning (Shuey. 1985). The positive pressure gradient between the drilled well wall and the formation causes some mud liquids penetration into the permeable zones, displacing original fluids near the well wall. The simplest and most common technique for such a fluid substitution or replacement is to apply Biot–Gassmann equation (Biot, 1956 and 1962; Walls and Carr, 2001). (Figs. 10 and 11) showed the typical example of AVO analysis of the gas zone for Qawasim pay 1 (QP1) within the study area at the 'El-Basant-1' well where the brine and gas models can be distinctly differentiated with a satisfied correlation coefficient between the zero-offset synthetic and actual CDP seismic gathers, along with the expected amplitude increase with offset.

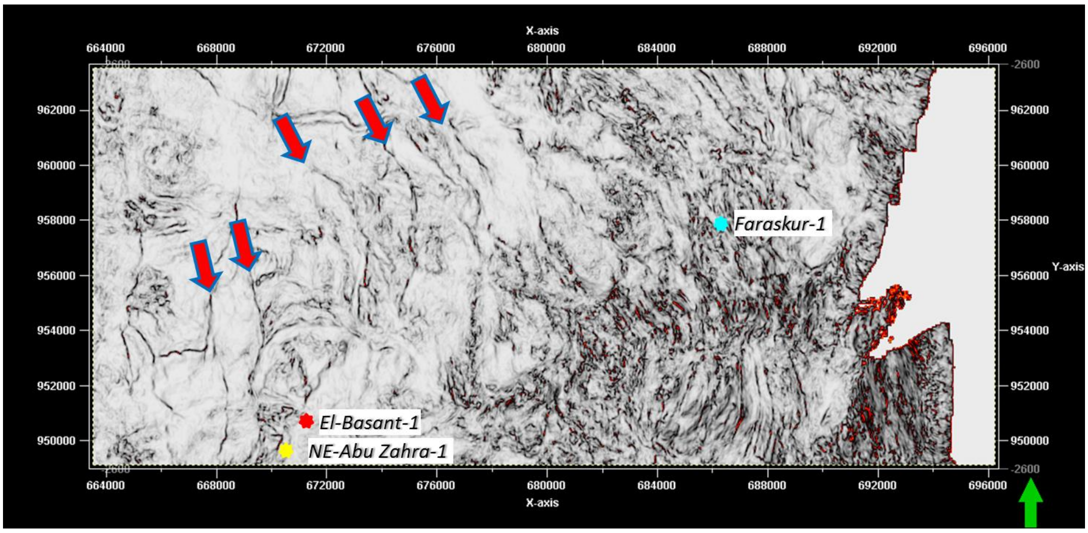

Fig. 7: The coherence time-slice of 2550 mSec. For the present study area showing the regional structure trend which affects the Sidi Salem Formation and extends N–S.

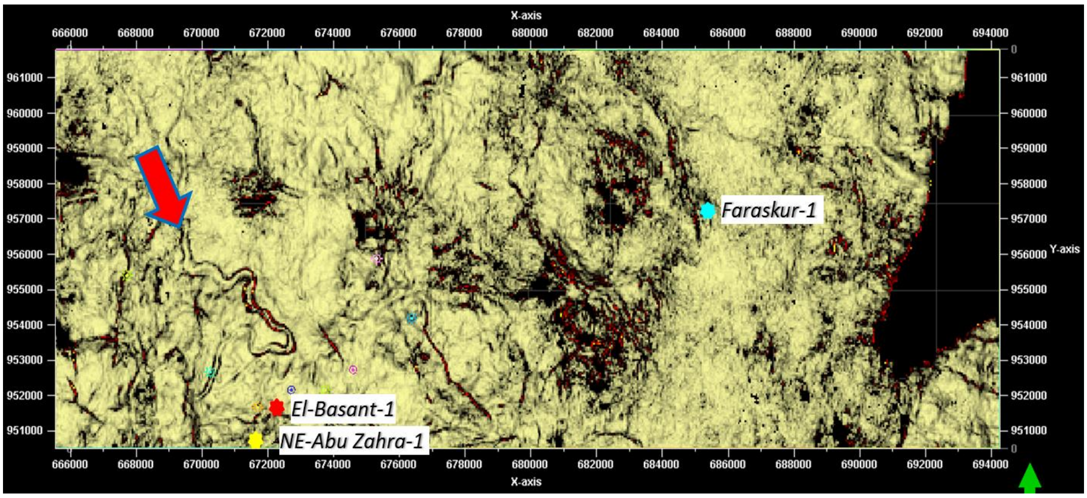

Fig. 8: The variance time-slice for the picked base-Pliocene horizon showing the meander channels and explaining the gentle-slope depositional direction.

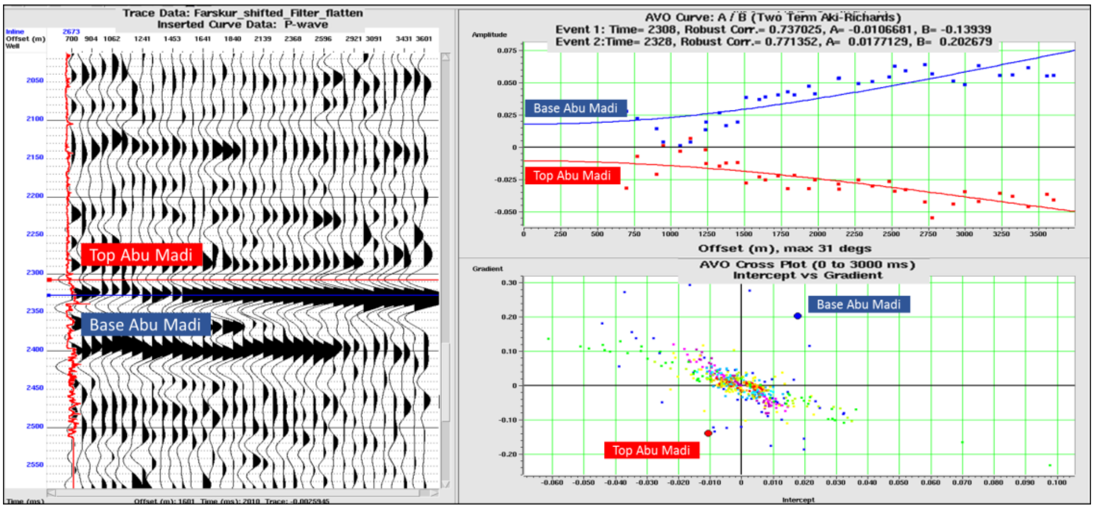

Fig. 9: The preconditioned CDP gathers along the seismic cross-section # 2673 (inline direction) (left) and the gradient–intercept cross-plot (right) showing the ideal class–III gas remains at Abu Madi Formation level in Faraskur-1 stratigraphic-control well location.

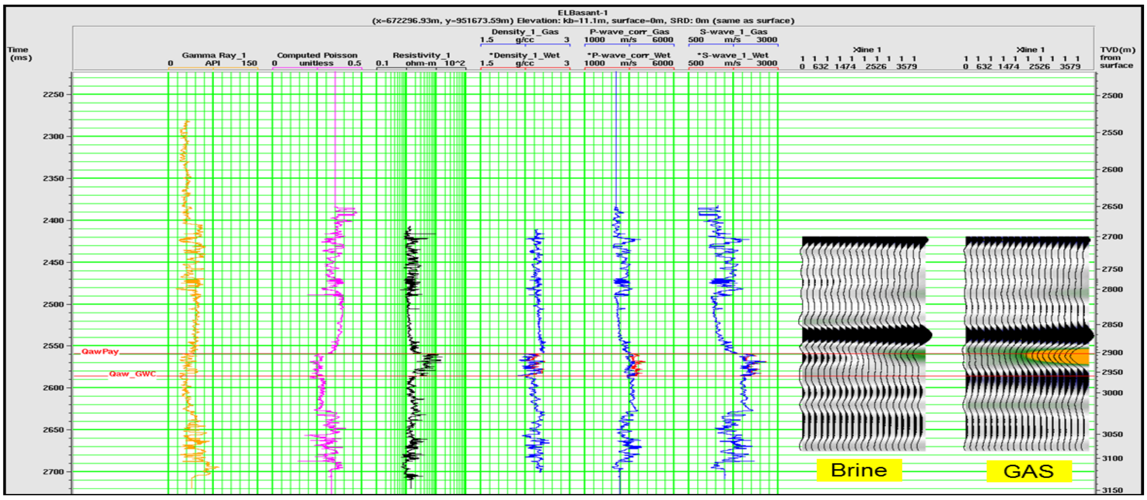

Fig. 10: The obtained final AVO model at the 'El-Basant-1' well upon fluid substitution or replacement process and synthetic offset CDP gather.

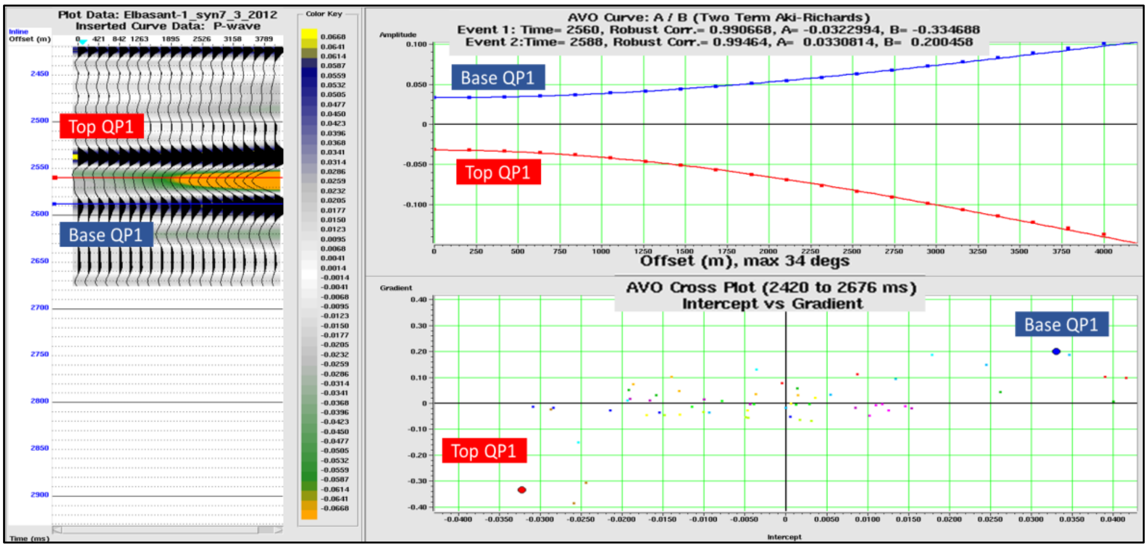

Fig. 11: Gradient–intercept cross-plot for modeled offset CDP gathers at the 'El-Basant-1' showing the ideal class–III gas remains.

The obtained final AVO model confirmed that the top of hydrocarbon zones is sensationally 'seismic trough' while the base is 'seismic peak', representing the ideal class-III gas remains at Abu Madi Formation level.

The obtained satisfying matching between the estimated and modeled offset CDP gathers lead to delineate the amplitude cut-off which was used in the three-dimensional (3D) visualization to detect the rest of the gas potential within the study area. The RMS–TWT amplitude contoured maps were constructed on the picked two horizons of QP1 and QP2 pay zones, which containing hydrocarbon at both the El-Basant field and Azhar fields, as a confirmation tool to insure the presence of gas and its extension (Fig. 12).

4. THREE-DIMENSIONAL (3D) VISUALIZATION

In the past 10 years, the volume rendering tools have been progressively adopted by the geo-seismic community as the emergence of high-end graphics workstations with 3D texture capabilities made real-time volume rendering possible (Engel K., Kraus M., and Ertl T., 2001). Volume rendering tools are now part of most seismic interpretation packages. However, most do not provide better insight into the 3D structures of seismic data because the noise and high spatial frequencies in the data prevent classical volume rendering from capturing relevant information. The cartoon illustration in (Figure 13) simply explains how the opacity tool is working for different purposes.

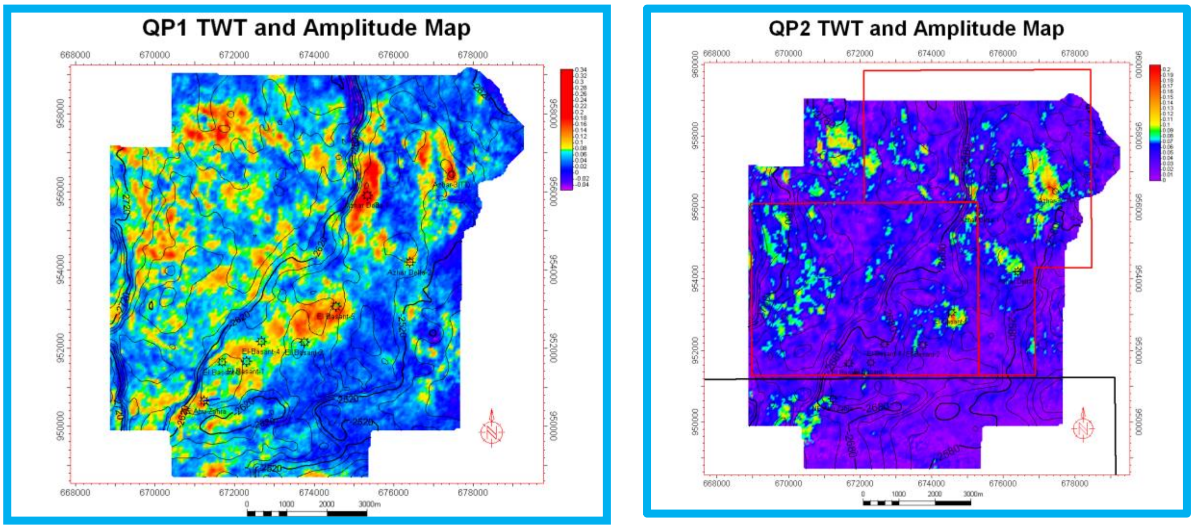

Fig. 12: RMS–TWT amplitude contoured maps for Qawasim pay 1 and 2 (QP1 (left) and QP2 (right)) showing the drilling amplitude and the new opportunity to the northeastern area of Azhar-1 well.

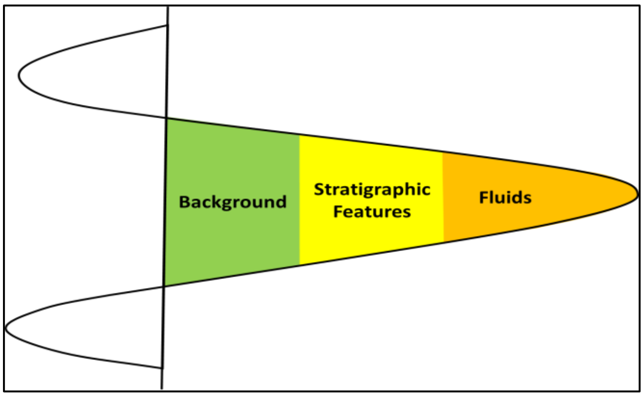

Fig. 13: Cartoon illustration showing classification use of the seismic amplitudes.

One of such a purpose is helping in building more accurate depositional models by dimming all very high or very small amplitudes, which are related to the gas presence, tuning or lithological effect coming from the high velocity layers. The moderate-pass amplitudes are normally referring to the interpreted 3D seismic–stratigraphic features.

Both the volume rendering and opacity tools were applied for the present 3D seismic–stratigraphic interpretation over the coherency volume by dimming the background amplitudes in order to image stratigraphic features and to explain the depositional direction of Abu Madi Formation level which has the same direction of Qawasim channels but with a meandering shape. This means that these paleo low dip-angles for the channels are at the time of deposition (Fig. 14). Additionally, by dimming all the background amplitudes, the high amplitudes were kept and reflected the stratigraphic features as well as the gas remains (Figs. 15 and 16).

Figure 15 shows the 3D volume rendering results for a window of the far-stack seismic volume (Marsh A.J., Kidd G.D., and Furniss A., 2000) , for both the proved (Azhar-1 well) and dry (Azhar-2 well) and gas remains zones in the top part of the figure, within the study area, using the amplitude cut-off of the complete AVO analysis. The easily encountered amplitude anomalies, like the northeastern area of Azhar field, showed several possible gas potentialities. So, it was quantitatively possible to use the opacity tool in extracting the geo-bodies for every reservoir anomaly throughout seismic interpretation. (Figure 16) illustrates the existing gas field as one of discoveries and an adjacent anomaly as one possible gas remains within the study area for QP1 level. Keeping into consideration that it was critical to understand the depositional environments for such reservoir types, i.e. clastic or carbonate reservoirs. The main operational steps for the geo-bodies extraction were as follows: (1) amplitude anomalies identification; (2) anomalies isolation, and (3) final geo-body extraction (Chaves, Michelle U.; Oliver, Flavio; Kawakami, Gregorio; Di Marco, Leandro, 2011).

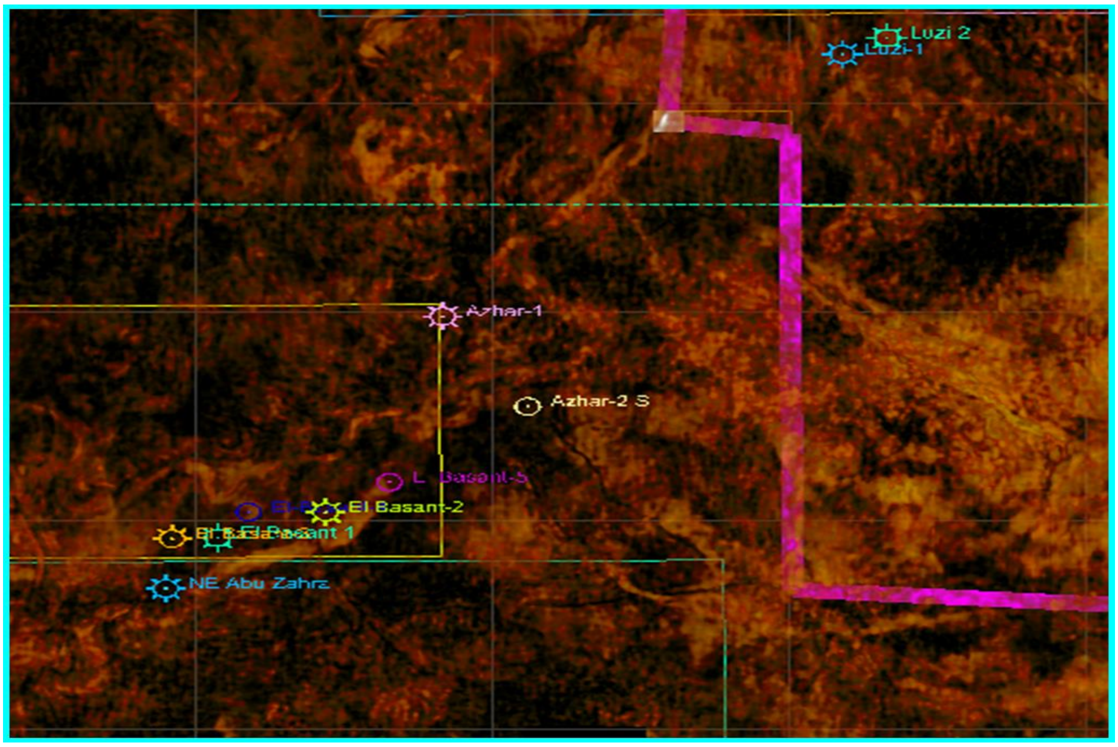

Fig. 14: 3D volume rendering and opacity slides showing how to image the meander channels at Abu Madi Formation level which are directed E–W at El-Basant and Azhar fields.

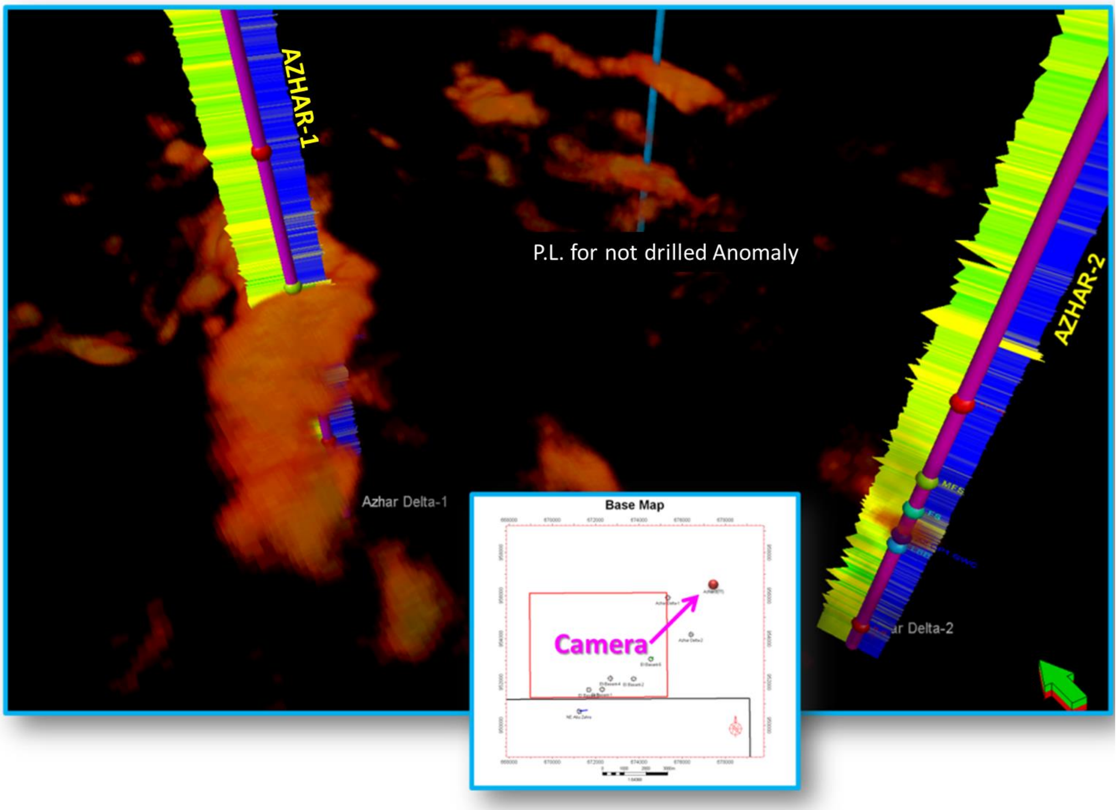

Fig. 15: 3D volume rendering results for the far-stack seismic volume showing the possible gas potentialities at the northeastern area of Azhar field.

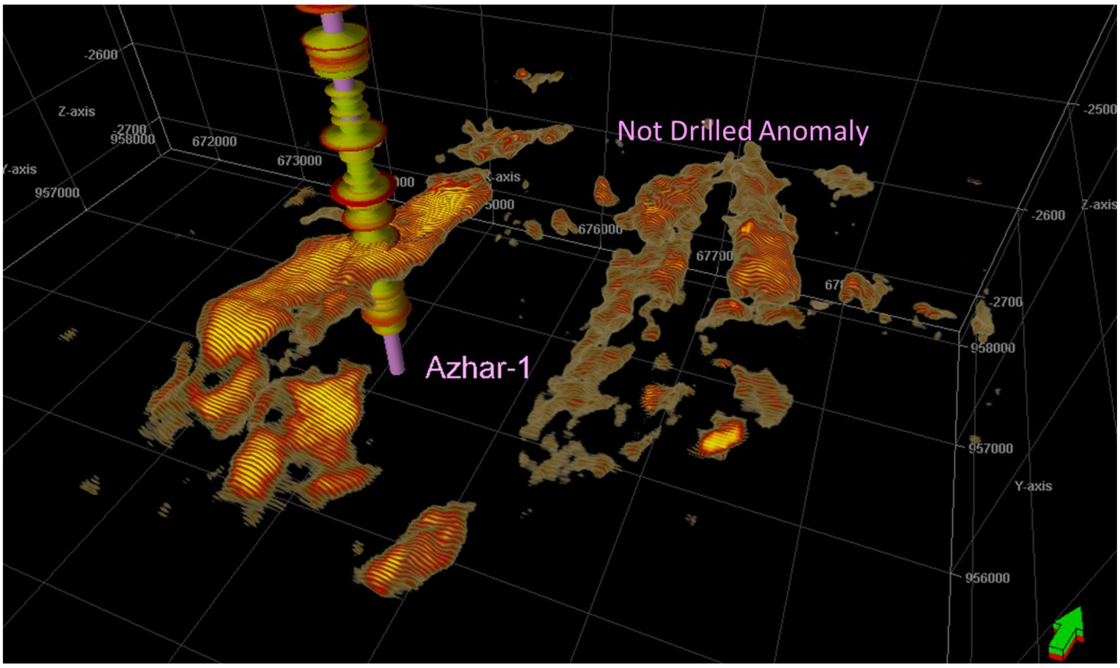

Fig. 16: 3D volume rendering and opacity results for the far-stack seismic volume showing the QP1 sand bodies of Qwasim Formation and possible gas potentialities at the northeastern area of Azhar field.

5. DEPTH-CONVERSION AND MAPPING

The depth-conversion for both the two horizons QP1 and QP2 was executed using the only available VSP in El-Basant-1 well from their average-velocity functions, due to the lack of velocity control points that can be used within this area. Additionally, some apparent-velocity values were used in constructing the velocity contour maps and to critically fit the general form of the modeled TWT structural contour maps (Fig. 17). (Figure 18) shows the obtained depth–structural contour maps for both the two horizons QP1 and QP2, while (Figure 19) shows the final isopach contour map for the horizon QP1, supporting the idea of Qwasim Formation pinching-out and syn-depositional lateral thinning of some adjacent anomalies.

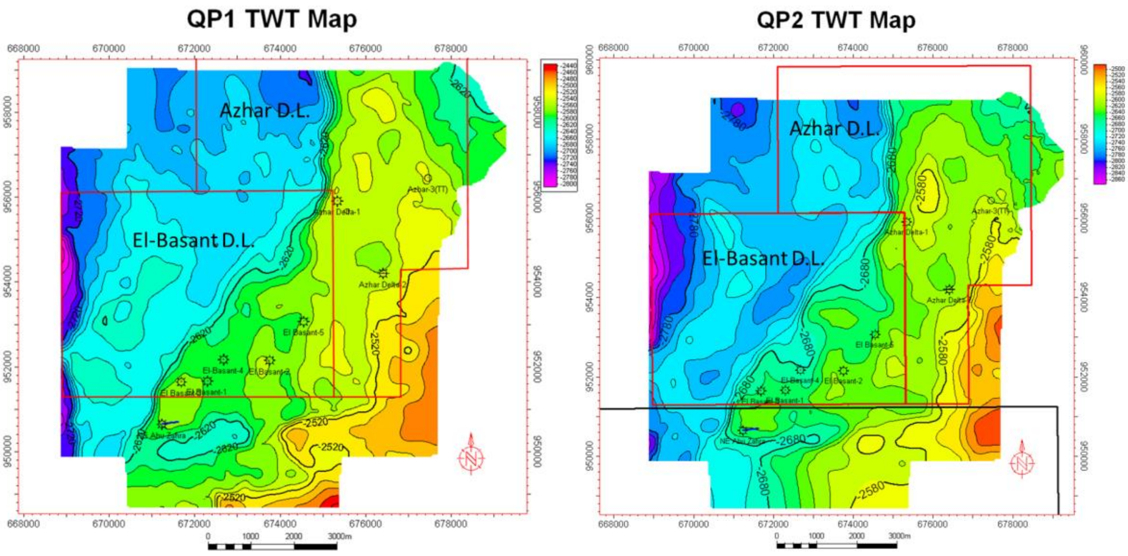

Fig. 17: The obtained TWT contour maps for the two horizons QP1 (left) and QP2 (right) at El-Basant field.

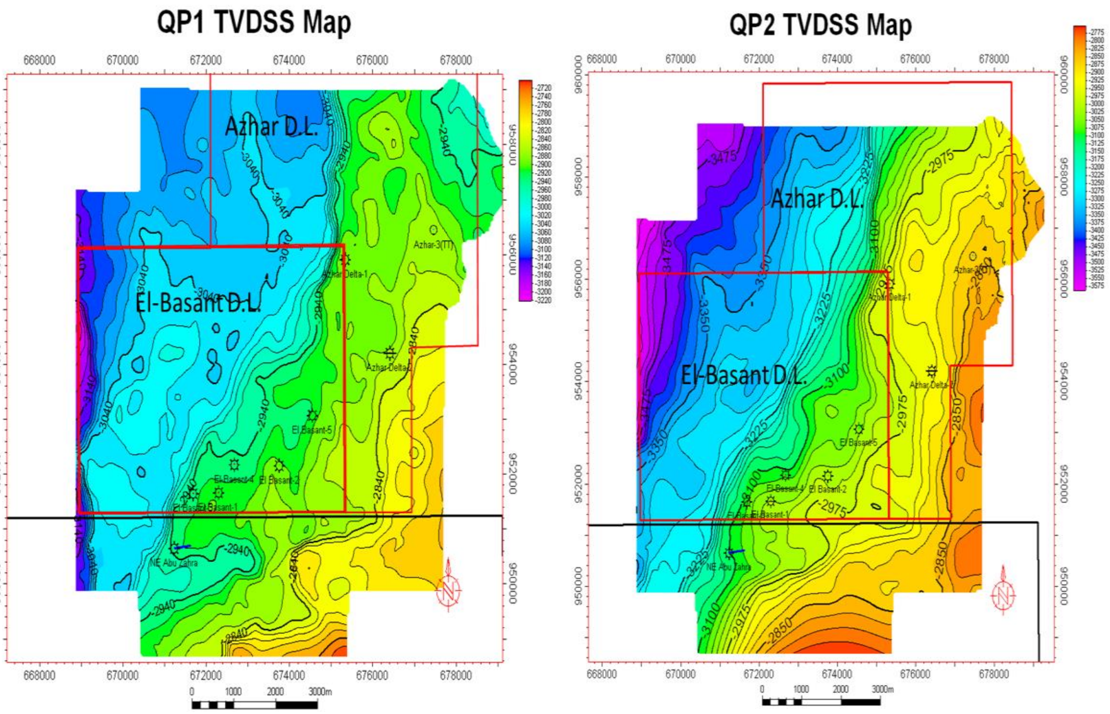

Fig. 18: The obtained depth contour maps to the two horizons QP1 (left) and QP2 (right) at El-Basant field.

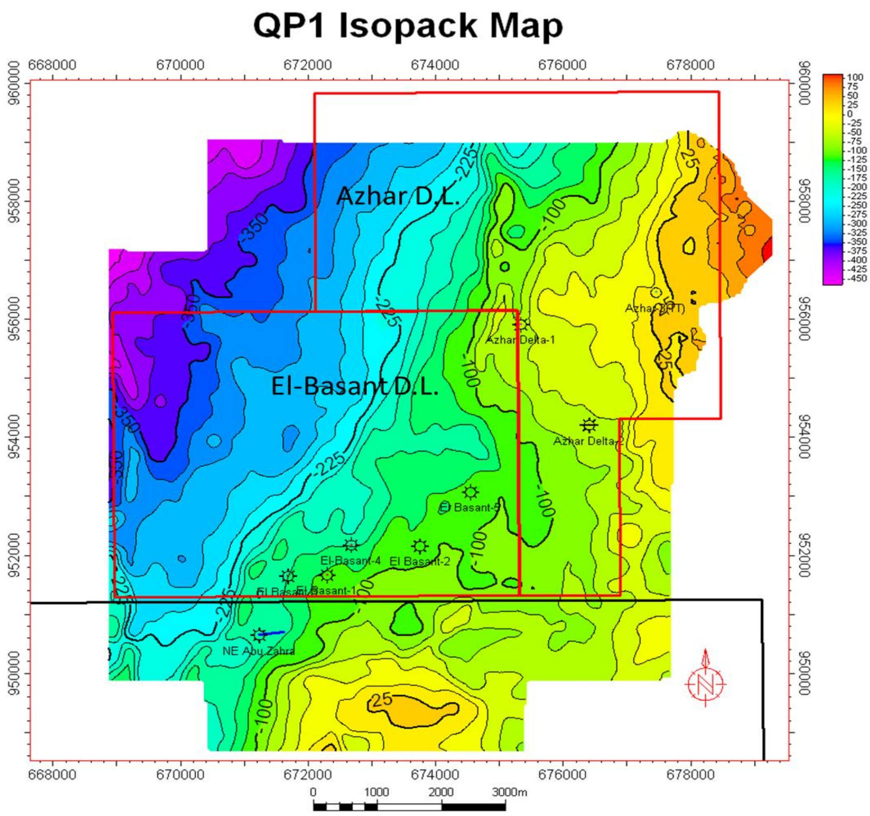

Fig. 19: The obtained isopach contour map of the horizon QP1at El-Basant field explaining the idea of Qwasim Formation pinching-out.

6. CONCLUSIONS

The optimum use of modeled seismic reflection data and volumetric seismic attributes analysis, as well as the integration of both 3D volume rendering and opacity transparency tools within the seismic interpretation, could facilitate the subsurface imaging of the potential gas remains, within their meander sand channels, at the eastern part of Faraskour Region, Nile Delta Basin, and northern Egypt. The operational sand channels extraction workflow, including amplitude anomalies identification, anomalies isolation and final geo-body extraction added some significant information for quantitative calculation about the depositional facies and faulting fashion within the study area, and even the new possible gas potentialities at the northeastern area of Azhar field.

Acknowledgment:

We would like to acknowledge both Dana Gas Egypt Limited, Cairo, Egypt and the Egyptian General Petroleum Corporation (EGPC) for their legal providing the seismic - well logging data and their support throughout the work.

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