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ESTABLISHING THE DEPTH MAPS TO DELINEATE THE POSSIBLE TRAPS, PROSPECTS AND LEADS OF OIL RESERVOIR ZONES OF THE UPPER CRETACEOUS FORMATIONS OF GANNA FIELD, NORTHERN WESTERN DESERT, EGYPT

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استخدام خرائط العمق لتحديد المصائد والخزانات البترولية المُحتملة في العصر الطباشيري الأعلي بحقل جنة بشمال الصحراء الغربية من مصر

الخلاصة: يقع حقل جنة فى الجزء الجنوبى الغربى من منطقة امتياز شمال البحرية للبترول التى تقع جنوب شرق حوض أبو الغراديق الذى يقع فى شمال الصحراء الغربية على بعد حوالى ١٥٠كم غرب مدينة القاهرة، تم التعاقد مع شركة خدمات جيوفيزيقية لعمل مسح سيزمى ثلاثى الأبعاد لمنطقة امتياز شمال البحرية للبترول فى أغسطس ٢٠٠٤، تضمن هذا المسح منطقة مساحتها حوالى ٣١٢ كم٢.

الهدف الأساسى من هذه الدراسة هو تحديد الخصائص التركيبية و الإستراتيجرافية لمنطقة الدراسة ويتم هذا باستخراج معلومات كاملة عن الجيولوجيا التحت سطحية وعمل خرائط تركيبية للتراكيب الموجودة بالطبقات ذات الأهمية و الصدوع التى تحويها وعلاقتها بالبيئة الترسيبية وعمل مضاهاة جيولوجية للطبقات لتوضيح العلاقات الجيولوجية وذلك لإختيارمواقع جديدة لآبار جاهزة للإختبار بهدف الإستكشاف ووضع خطط تنموية لزيادة الإنتاج وذلك باستخدام المضاهاة الجيولوجية ، التفسير السيزمى و تحليل التسجيلات الكهربية.

ABSTRACT: *Ganna field is located in the south western part of North Bahariya Concession which lies southeast of Abu Gharadig Basin in the Northern Western Desert and is about 150 km West of Cairo city. WesternGeco was contracted to conduct a 3D land seismic survey in North Bahariya concession in August 2004. The survey covered a surface area of approximately 312 km^2 and the shooting geometry was orthogonal patch with symmetrical split-spread layout.*
The main objective of the present study is to delineate the structural and stratigraphic characteristics of the study area, to select new locations to be tested for exploration and to preparing development plans for increasing the production.
Geologic correlation, seismic interpretation and well log analysis, can create many chances for exploratory and development wells. This can be achieved by the interpretation of the available 2D seismic lines extracted from 3D seismic data and innovative approaches for the integration and interpretation with the borehole geophysical data.
To extract complete subsurface geo-information, the borehole geophysical data and the related geologic data are used. A variety of geologic maps such as the structure depth maps, that showed the depths of unit contacts or other surfaces of interest are created. Relevant faults will be an integral part of mapping. The structural model is to be analyzed and related to the deposited sediments. Constructing geological cross sections was carried out to clarify the complex relations between the seismic and well logging data. A correlation between log interpretation results and seismic analysis are made; distinguishing the chrono-stratigraphic boundaries and their correlations with the seismic and well log data was made.

1. INTRODUCTION

The present study area (Ganna field) is located in the south western part of North Bahariya Concession which lies southeast of Abu Gharadig Basin in the Northern Western Desert and is about 150 km West of Cairo city (Fig. 1). Ganna Field lies between latitude 29°35′00" to 29°38′ 00" N and longitude 29°21′00" to 29°27′00" E and covers an area of about 42 Km^2. The study area is characterized by a flat surface, with only local high features. The ground elevation ranges between 160m to 230m.

WesternGeco was contracted to conduct a 3D land seismic survey in North Bahariya concession in Egypt in August 2004. The survey covered a surface area of approximately 312 km^2 and the shooting geometry was orthogonal patch with symmetrical split-spread layout. The total number of recorded swaths was 12 and the number of receiver lines per swath was 12; each receiver line had 120 live channels of 50m spacing and 250m receiver line spacing while the source energy was Vibroseis with 50m shooting interval and 150m source line spacing which gave a nominal fold of 120. The field seismic data was recorded in 6 seconds length and a sampling rate of 4ms. However, the geometry of the spread used (2975m-25m-0-25m-2975) revealed a Max, Useable offset of 3000 m which negatively affect the resolution of deep parts that could not be treated by re-processing.

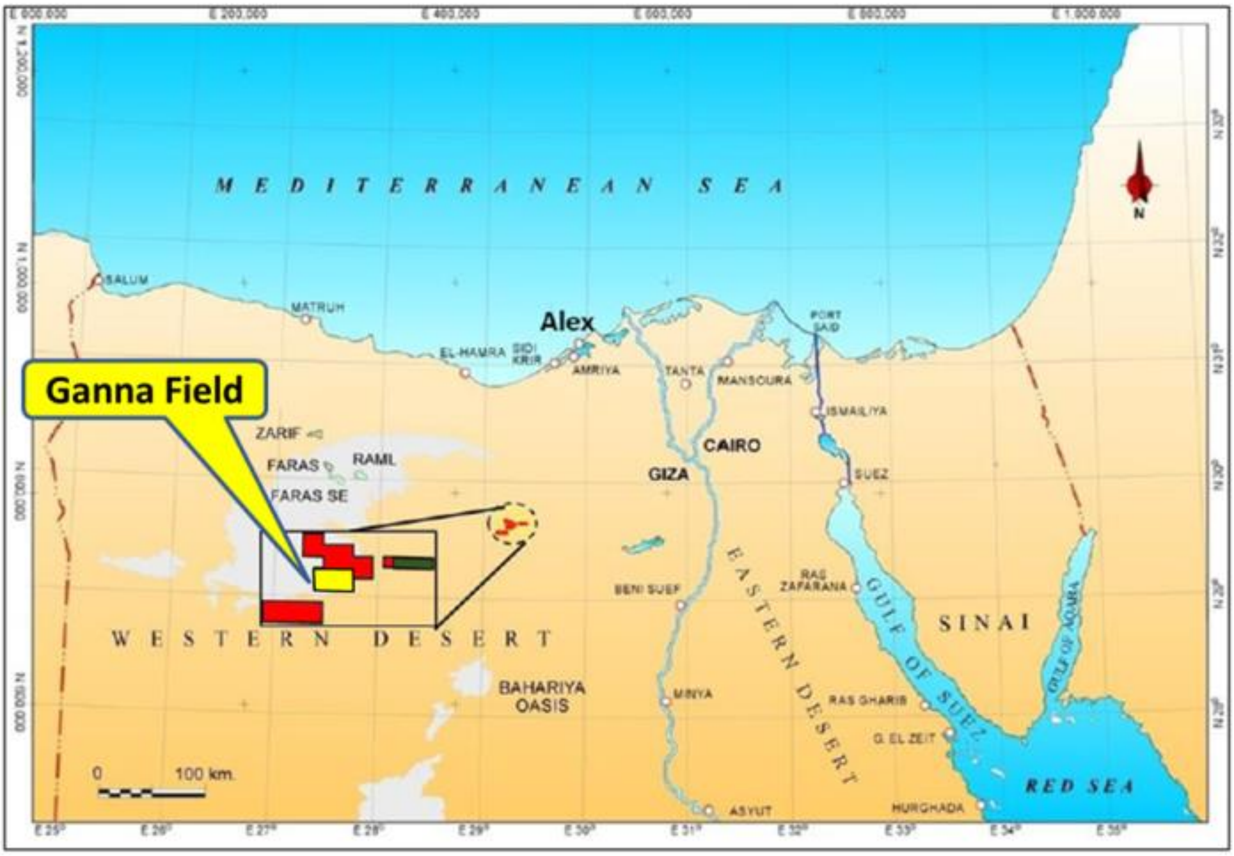

Fig. 1: Location Map of Ganna Field, North Western Desert.

The seismic data volume has been processed three times; the first processing done in 2004 by Petroleum Geo-services (PGS) to accurately image the whole shallow, deep reflectivity and fault patterns with special emphasis on zones of interest in Abu Roash, Bahariya Formations and deeper potential in Alam El Bueib, Alamein and Khatatba Formations for future potential. In 2007, Petroleum Geo-services (PGS) was contracted to calibrate the 3D land seismic data in North Bahariya concession after drilling several wells; In 2015, the reprocessing was performed in CGG - Cairo center to improve the signal to noise ratio and enhance the stack resolution to enhance the image of the deep reflectivity. The seismic interpretation is done on a set of 30 selected lines in the Post-Stack depth migration (PSDM) of this vintage to achieve high accuracy percentage due to the recent updated data.

The present work is based on the available 2D seismic data, well logging data and subsurface borehole geological cross sections. All the evaluations and interpretations have been established through IP and Petrel softwares.

2. GEOLOGICAL SETTINGS

Six major geotectonic cycles or phases can be recognized in the Western Desert (Meshref, 1990); these are: The Caledonian cycle (Cambrian - Devonian), Variscan- Hercynian (Late Paleozoic), Cimmerian / Tethyian (Triassic - Early Cretaceous), Sub Hercynian - Early Syrian Arc (Turonian - Santonian), Syrian Arc main phase (Paleogene) and the Red Sea phase (Oligocene- Miocene). The Western Desert can be subdivided, from south to north, into four tectonic areas (Fig. 2) Craton and Stable Shelf, Unstable Shelf, Hinge Zone and Miogeosyncline (Schlumberger, 1984).

Early Cretaceous rifting led to the development of WNW-ESE and NW-SE oriented normal faults, a completely different trend compared to the Jurassic faults of NE-SW to ENE-WSW and NNE-SSW trends.

Relative motion of Africa with respect to Eurasia based on reconstruction of seafloor spreading data (Giraud et al., 1999) indicates that such movement during the Early Cretaceous to Santonian time (142-84 Ma) was NE-SW, perhaps exerting an extension in this direction on the plate boundary leading to the development of the WNW-ESE oriented normal faults of the study area.

The sedimentary basins of the north Western Desert occupy two provinces separated by the E-W to ENE trending Ras Qattara-North Sinai uplift. The Northern Province includes the Shushan, Matruh, Alamein basins of Late Jurassic– Early Cretaceous age. The southern province, south of the uplift includes mainly of the Abu El-Gharadig basin of Late Cretaceous and younger age (Fig. 3).

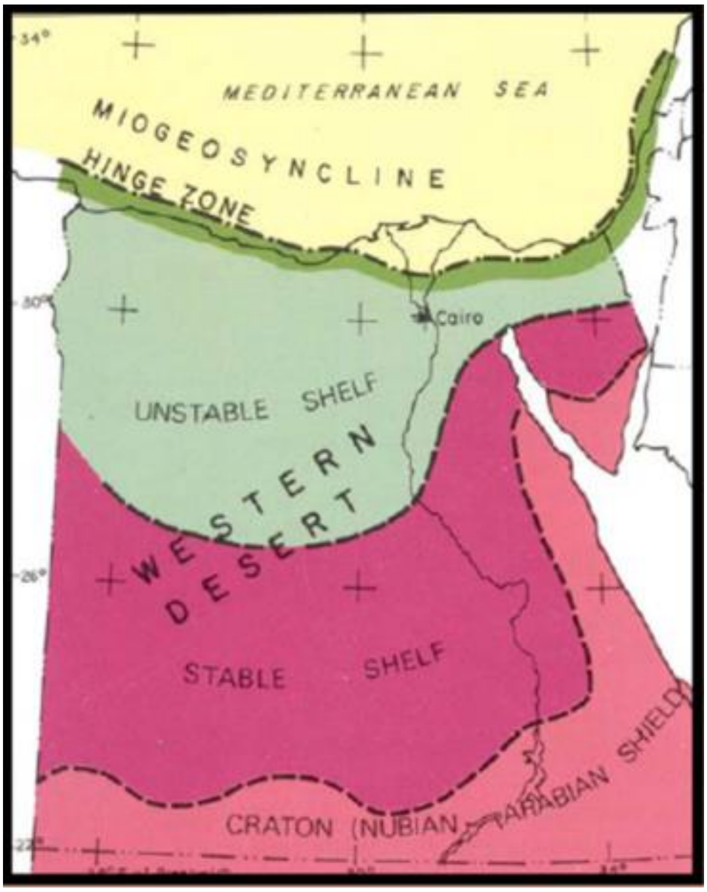

Fig. 2: Sketch of the structural aspects of the Western Desert (Schlumberger, 1984).

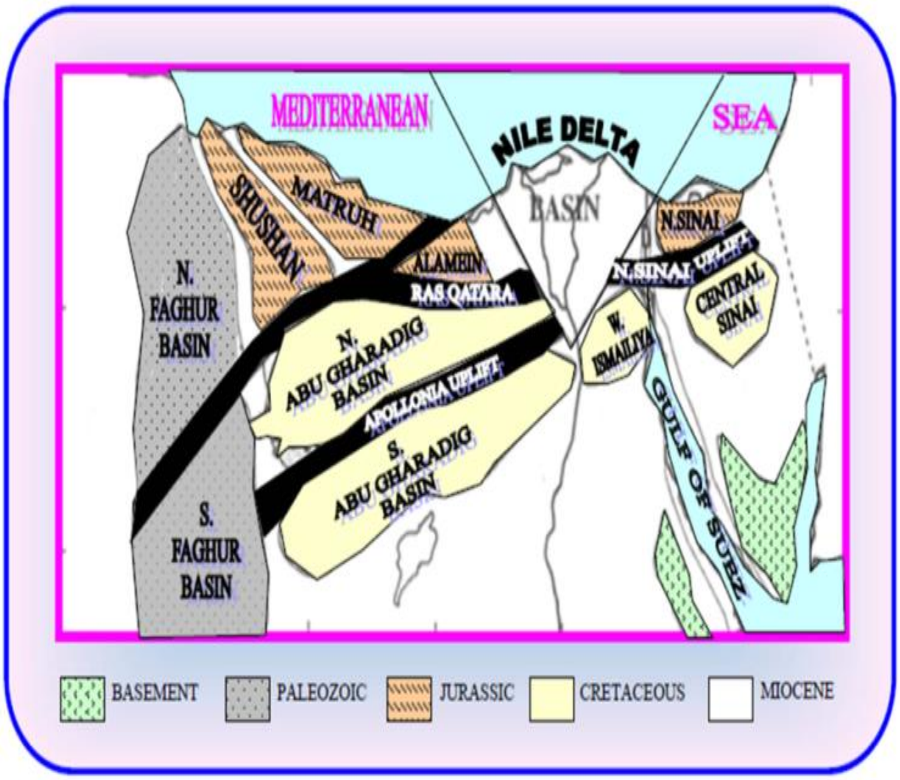

Fig. 3: The basins of the Western Desert (Meshref, 1996).

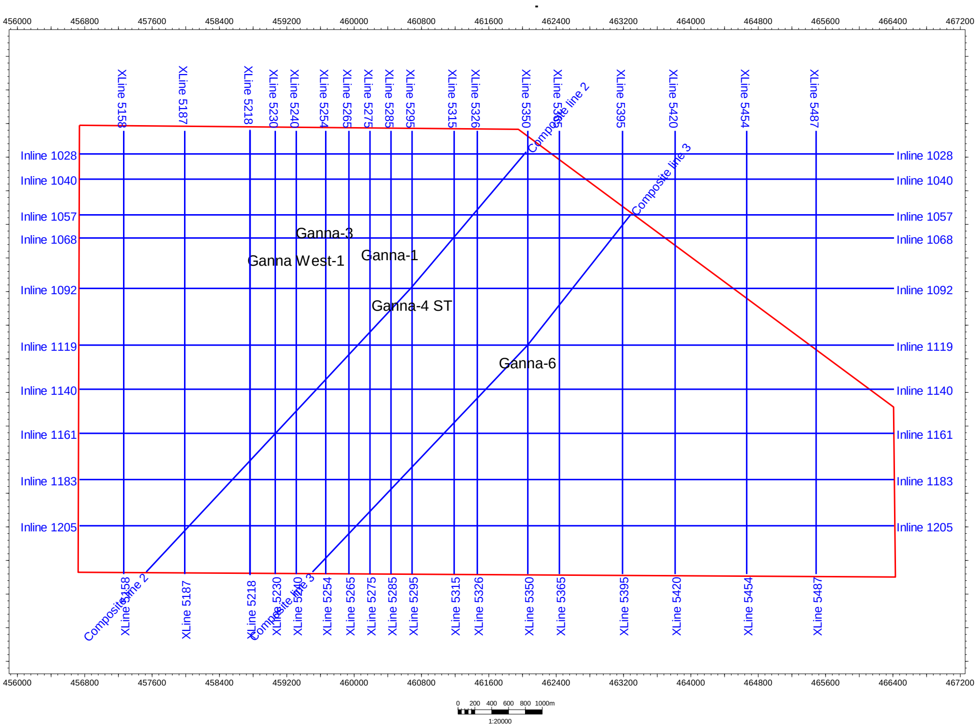

Fig. 4. Base map showing cross-lines, in-lines, Arbitrary lines and well locations in the study Area.

Two main tectonic forces affected the region: the first is a sinistral shear, which resulted in a regional NW tectonic affected both provinces in Jurassic – Early Cretaceous age. The second is a dextral shear, which resulted in a regional ENE tectonics affected the southern provinces (Meshref, 1996).

The primary productive zones in Ganna Field are the Upper Cretaceous Formations Abu Roash 'G', 'E' and Upper Bahariya.

3. METHODOLOGY

A detailed seismic interpretation of Ganna field was done on the depth domain data by using Petrel software for the seismic data after the reprocessing which was performed by CGG - Cairo Center in May 2015.

A set of 30 2D seismic lines were chosen and selected from the 3D seismic survey (18 N-S oriented Cross-lines, 10 E-W oriented In-lines and 2 NE-SW oriented arbitrary lines) (Fig.4), in addition to the data of five wells used for carrying out the seismic interpretation. The main aim of the structural-seismic interpretation is to achieve a coherent structural framework (faulted-horizons) model, and to define the geological features interrupting its continuity, as well as to assess the fault pattern where the products of a structural interpretation of the area, a set of seven interpreted seismic markers (horizons) have been chosen to pick, as identified from the well to seismic tie. The structure setting ranges from a two-way dip closure to a three-way dip closure.

4. RESULTS AND DISCUSSIONS

The picked seismic horizons are chosen from shallow to deep horizons, to trace the fault ages in the geological history. Some of the picked horizons are non-reservoirs like Khoman Formation and A/R "A" Member to control the Package of Abu Roash Formation (Figs. 5 & 6). Most of the picked horizons are related to the main reservoirs in the study area including A/R "E" Member, A/R "G" Member and its subdivisions (Upper, Middle and Lower) and Upper Bahariya Formation (Figs. 7, 8, 9, 10 & 11).

After finalizing the depth interpretation, it is concluded that the structure settings of the northern part of Ganna Field is a tilted horst block dipping to the southeast direction and it has a closed fault corner to the northwest direction where faults of opposite thrown direction are dissecting each other at that part. This horst is bounded by NW-SE fault trending throwing to the north and southwest directions; the Southern part of Ganna field is part of the larger tilted fault block structure that is the Karama North Field. the structure is bounded to the south by a WNW-ESE trending normal fault. The fault block dips down to the north and west.

Then, the examination of these maps searching for the structural closures, which may contain hydrocarbon accumulations in which the structures can be easily defined from the maps and after determining the oil down to best knowledge for the extension of this hydrocarbon then new locations for prospects could be chosen to test in the future for more developments of Ganna field as follows:

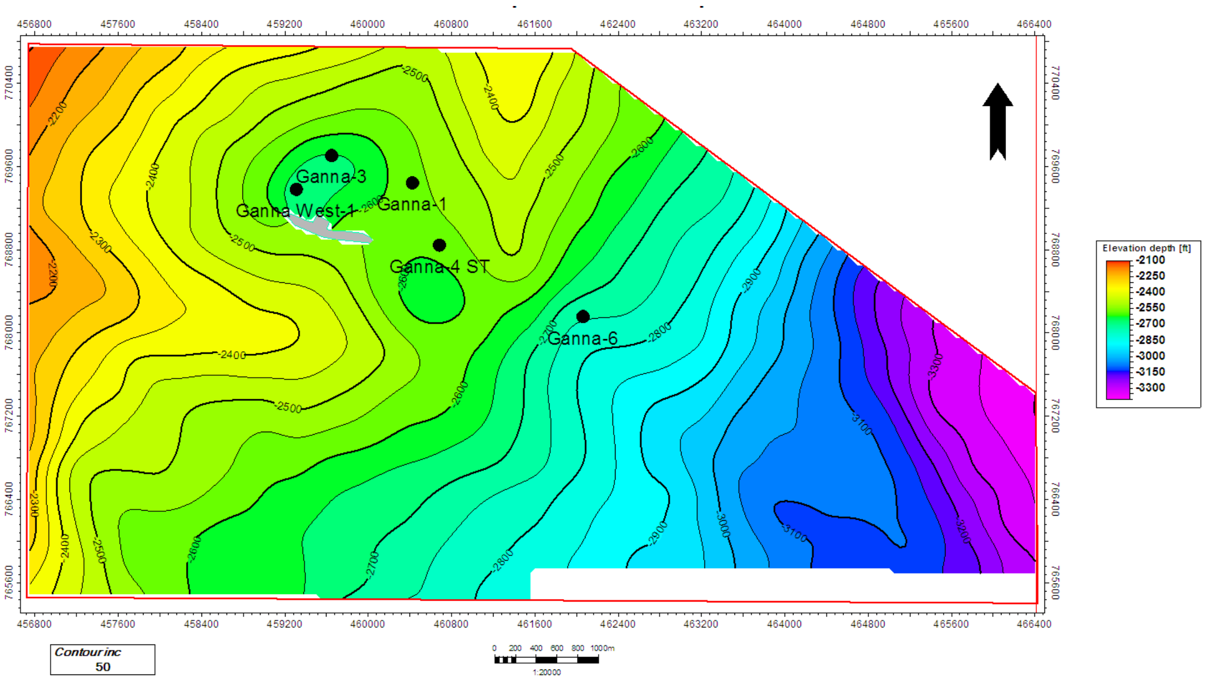

Fig. 5. Depth structure contour map on top Khoman Formation.

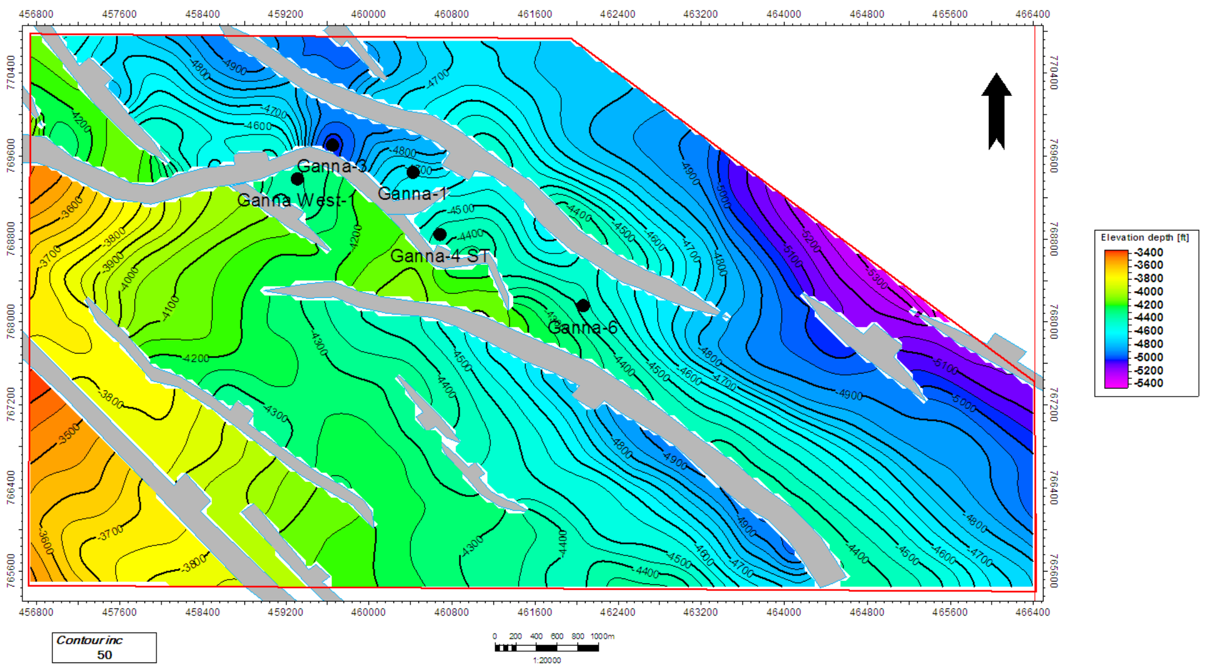

Fig. 6. Depth structure contour map on top A/R "A" Member.

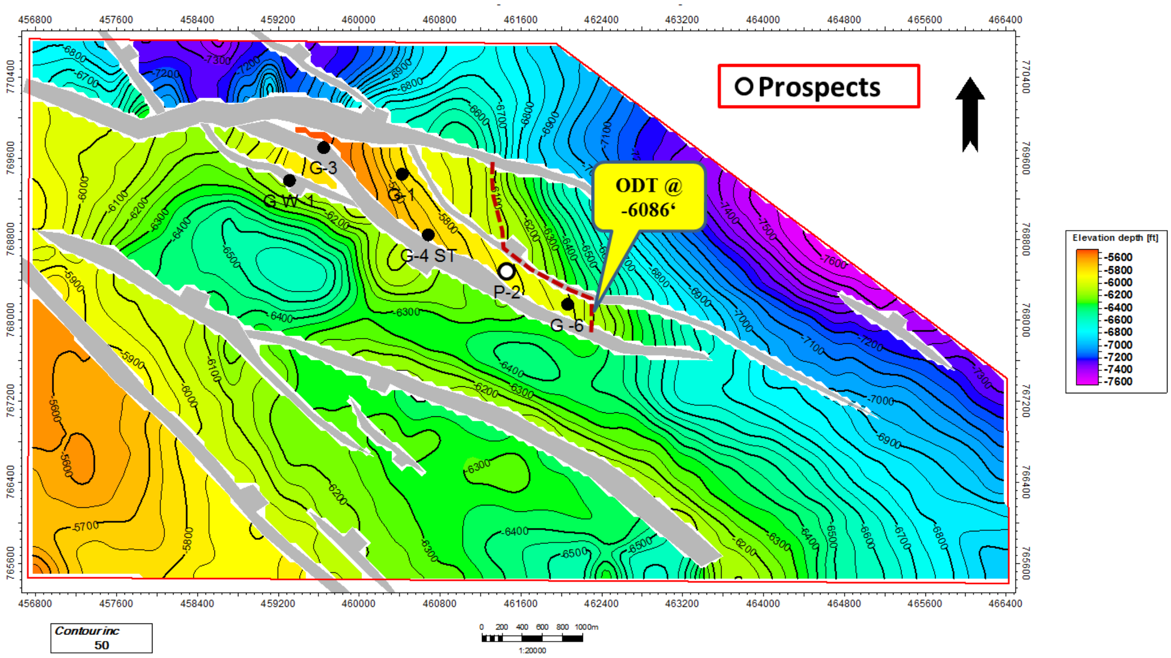

Fig. 7. Depth structure contour map on top A/R "E" Member.

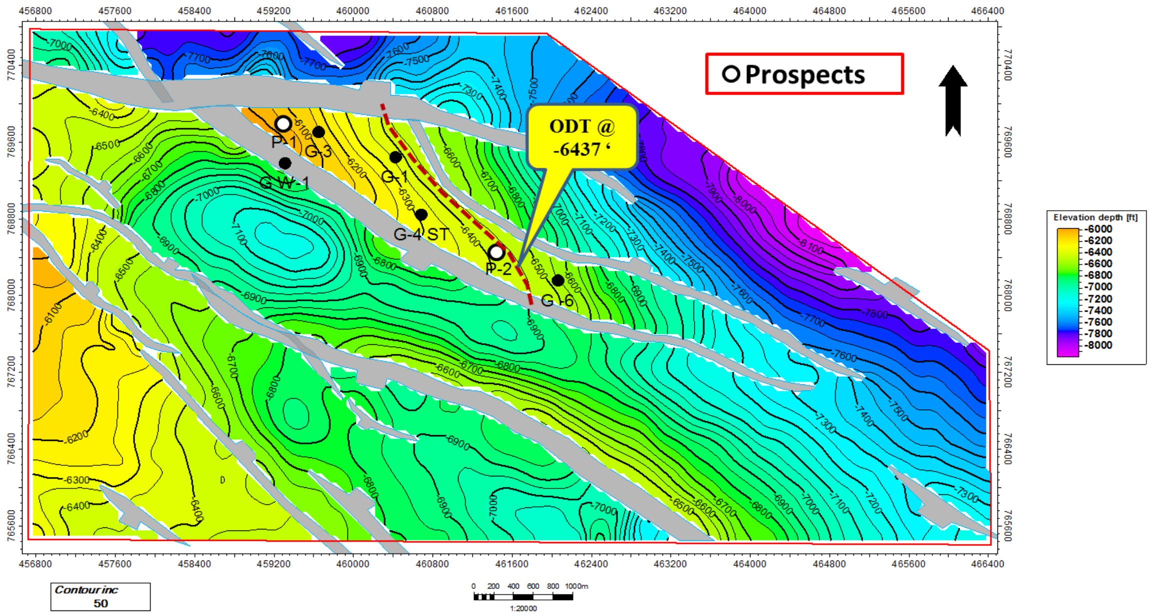

Fig. 8. Depth structure contour map on top Upper A/R "G" Member.

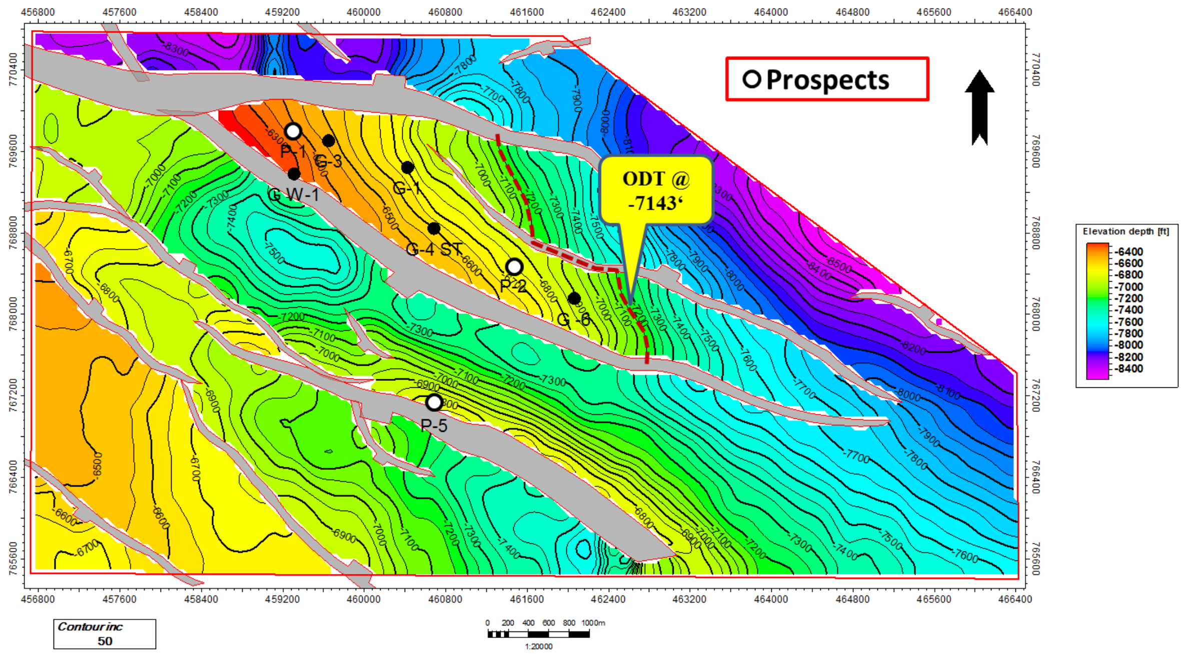

Fig. 9. Depth structure contour map on top Middle A/R "G" Member.

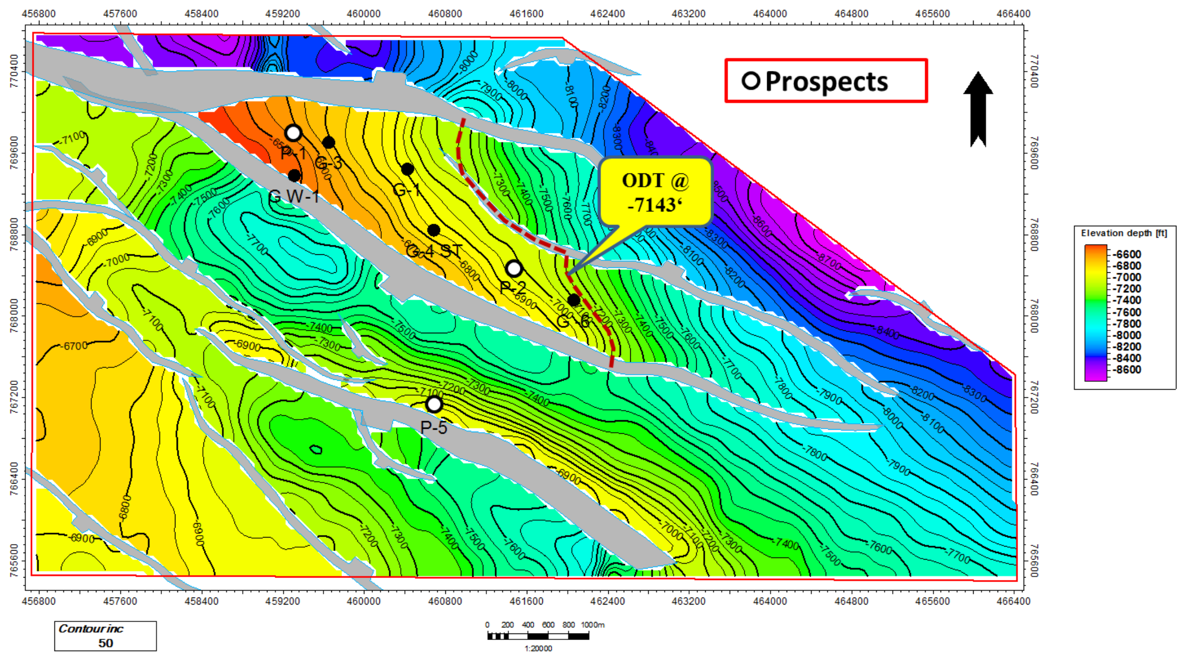

Fig. 10. Depth structure contour map on Lower A/R "G" Member.

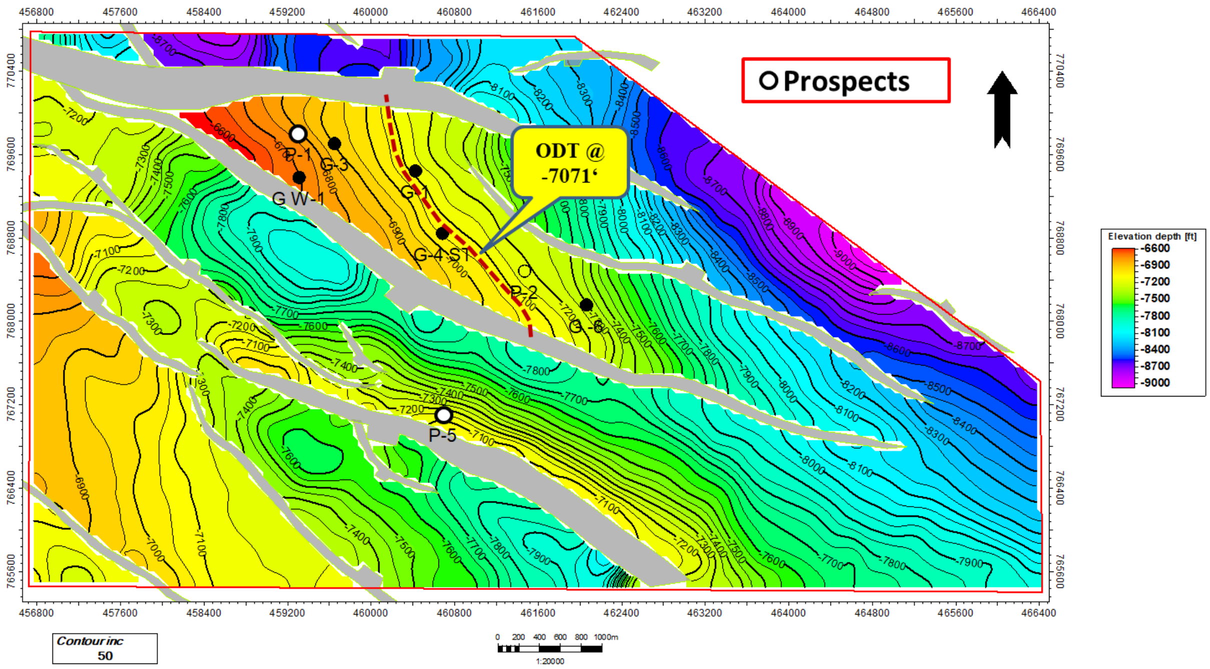

Fig. 11. Depth structure contour map on Upper Bahariya Formation.

Prospect-1 (P-1) is located in the crestal part of a two-way dip closure and targeted the reservoirs of A/R "G" Member (Upper, Middle &Lower) and Upper Bahariya Formation. This prospect is the best location for a good sand quality and has the minimum risk. X-line 5240 is selected perpendicular; IN-line 1057 is selected parallel to obtain the existence of this prospect (Figs. 12 &13).

The interpreted seismic section (cross-line 5240) is located in the western part of the study area passing through prospect P-1 Figure (12). It is oriented in North-south direction. This Section showing three major normal faults; the first fault (F3) striking through the area in E-W direction with a dip direction north, the second fault (F1) striking through the area in northwest-southeast direction with a dip direction southwest, the third fault (F4) striking through the area in northwest-southeast direction with a dip direction south. Other normal faults (F7 and F8) are shown on the section at the eastern side striking northwest-southeast with a dip direction northeast.

All the faults are dissecting the shallower succession from Abu Roash "A" till Bahariya Formation while for the main faults (F1, F3 and F4) it are extended through the deeper succession till the Jurassic formations.

The main normal Fault (F3) which striking through E-W direction seems to be formed at older ages in Jurassic, while the other two main normal faults (F3 and F4) which striking through NW-SE direction seems to be formed in cretaceous age.

F3 and F1 faults are scissor faults forming a horst block with an anticline inside the block while F4 is lying south from these structure forming a three-way dip closure.

The interpreted seismic section (IN-line 1057) is located in the northern part of the study area passing through Prospect P-1 Figure (13). It is oriented in East-West direction. Also this Section showing the same structure regime, where the two major normal faults (F3 and F1) are extended to deeper parts and forming a scissor on shallower targets.

Prospect-2 (P-2) is located within the oil column in a two-way dip closure and targeted the reservoirs of A/R "E", A/R "G" Member (Upper, Middle &Lower) and Upper Bahariya Formation. This prospect is the best location to test all reservoir levels and has low risk. X-line 5326 is selected perpendicular; IN-line 1119 is selected parallel to obtain the existence of this prospect (Figs. 14 &15).

The interpreted seismic section (cross-line 5326) is located in the eastern part of the study area passing through prospect P-2 Figure (14). It is oriented in North-South direction. Also this Section showing the same structure regime with a little bit of variation, while (F2) throw increased and it is extended to a deeper part, while (F3) become weaker.

The interpreted seismic section (IN-line 1119) is located in the northern part of the study area passing through prospect P-2 Figure (15). It is oriented in East-West direction. Also this Section showing the same structure regime, where the two normal faults (F2 and F1) are extended to deeper parts and forming a scissor on shallower targets and a horst on reservoir levels, while the major fault (F3) is disappearing and dying.

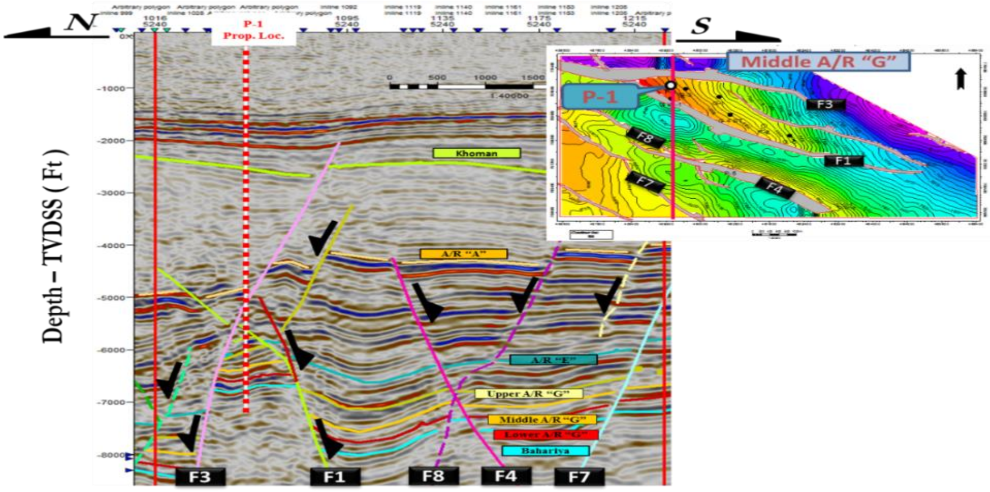

Fig. 12. Cross-line 5240 interpreted seismic section showing Prospect-1 location.

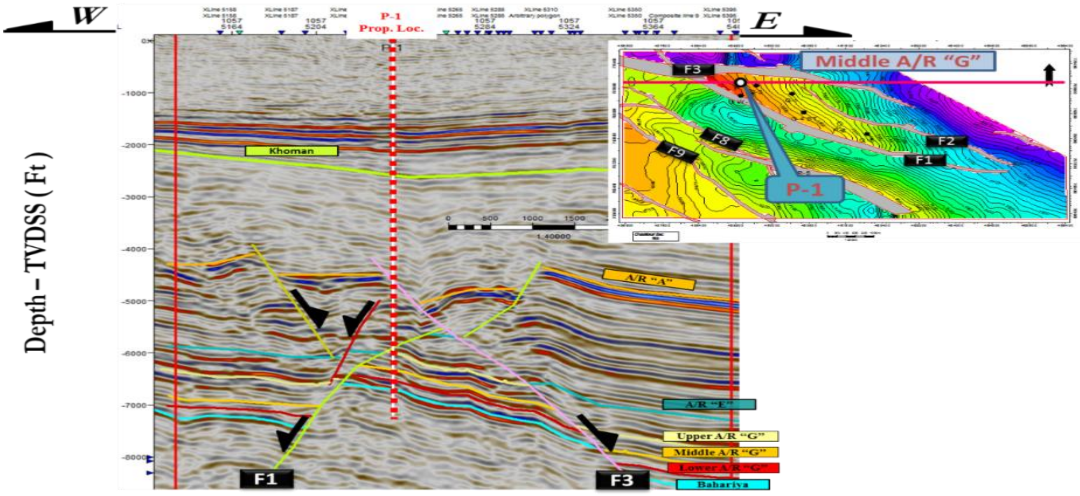

Fig. 13. IN-line 1057 interpreted seismic section showing Prospect-1 location.

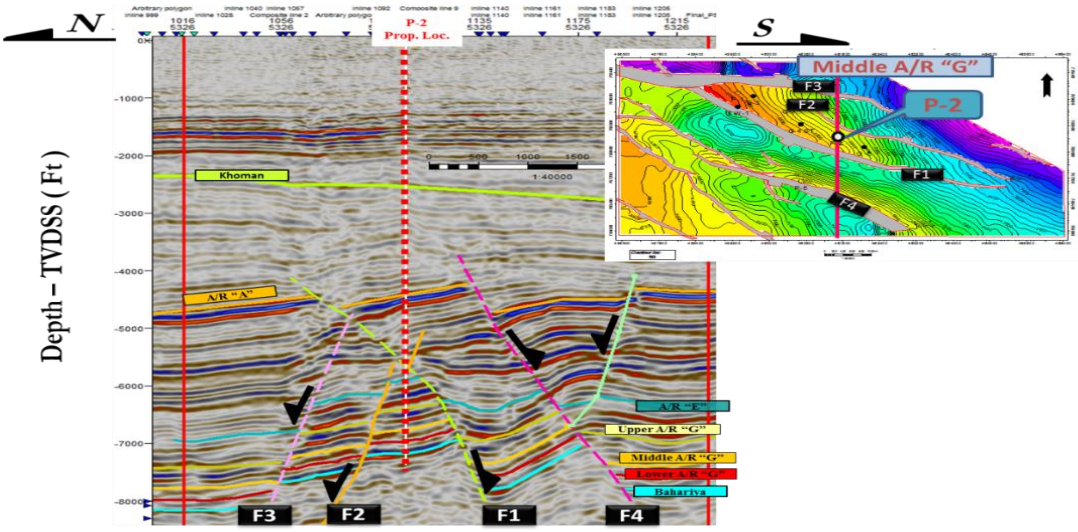

Fig. 14. Cross-line 5326 interpreted seismic section showing Prospects-2 location.

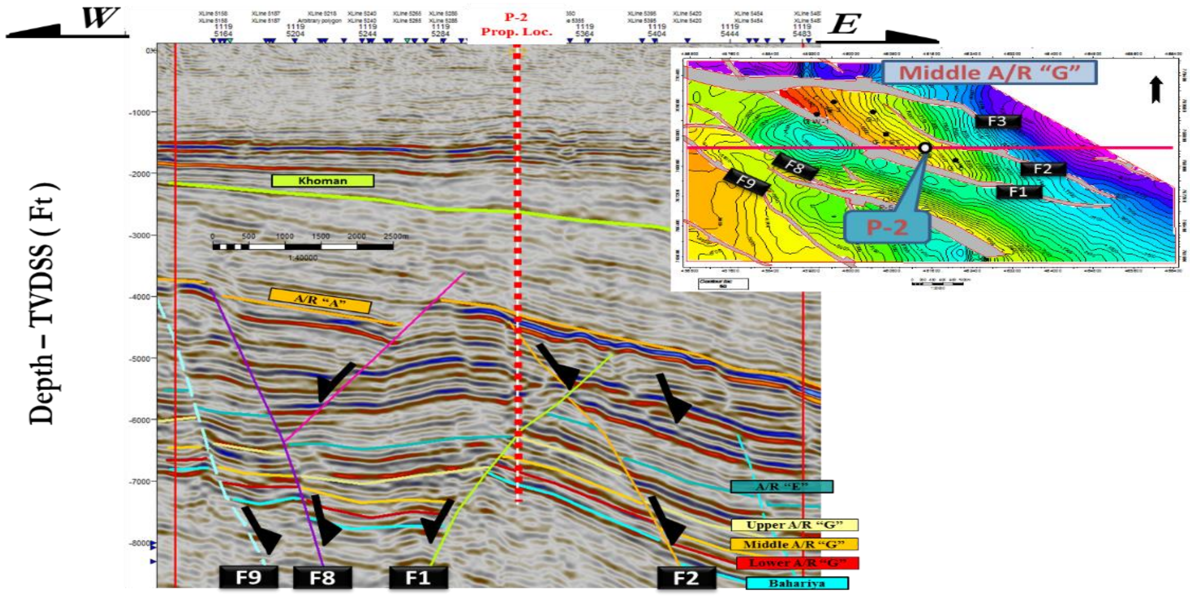

Fig. 15. IN-line 1119 interpreted seismic section showing Prospects-2 location.

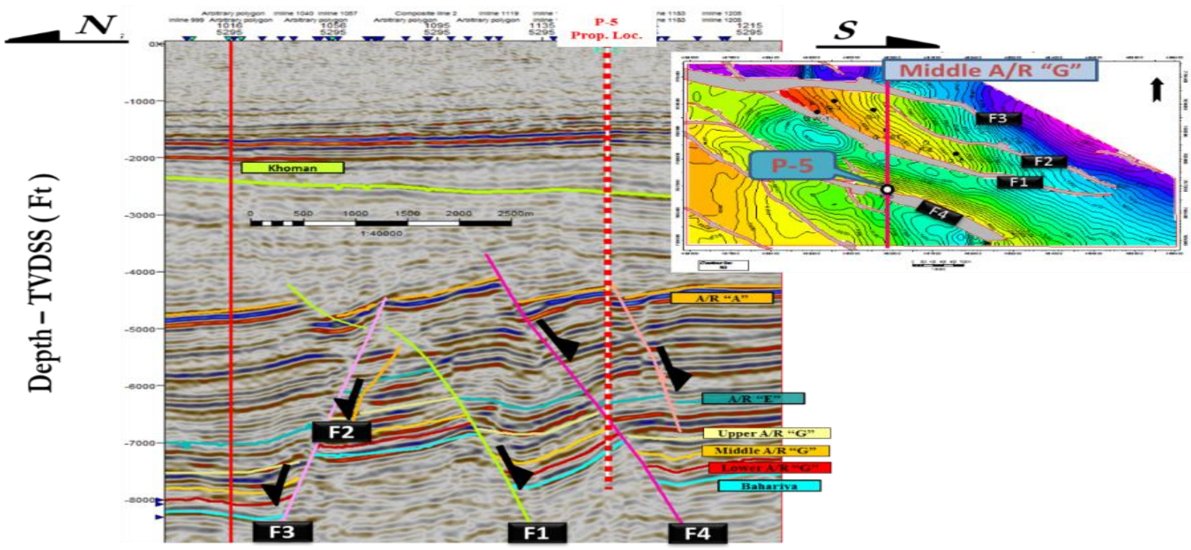

Fig. 16. Cross-line 5295 interpreted seismic section showing Prospect-5 location.

Prospect-3 (P-5) is located on the crestal part of a three-way dip closure and targeted the reservoirs of A/R "G" Member (Middle &Lower) and Upper Bahariya Formation. This prospect is considered an exploratory well to determine the existence of hydrocarbon on it. X-line 5295 is selected perpendicular; IN-line 1161 is selected parallel to obtain the existence of this prospect (Figs. 16 &17).

The interpreted seismic section (cross-line 5295) is located in the center part of the study area passing through prospect P-5 Figure (16). It is oriented in North-South direction. This Section showing the same structure regime and the same fault trends in the northern part, but a new normal Fault (F2) have appeared in the western side of the section on the foot wall of the main fault (F3) and divided the horst block of Ganna structure, it is striking through NW-SE direction with a dip direction northeast. In the southern part of this section where P-5 is lying a three-way dip closure on the major normal fault (F4) striking northwest-southeast and dipping towards the south is founded and needed to be tested.

The interpreted seismic section (IN-line 1161) is located in the northern part of the study area passing through prospect P-5 Figure (17). It is oriented in East-West direction. This Section a little bit variation in the structure regime where the major two-way dip closure forming by the two normal faults (F3, F2 and F1) are almost disappeared while a three-way dip closure on the major fault (F4) is become obvious and clear.

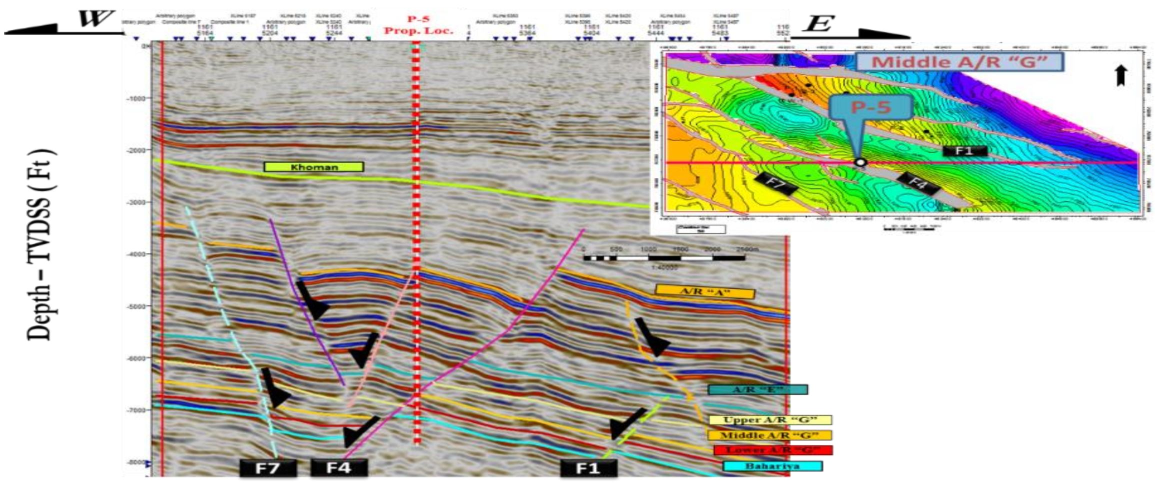

Fig. 17. IN-line 1161 interpreted seismic section showing Prospects-5 location

CONCLUSIONS AND RECOMMENDATIONS

The present study area is located in the northern part of the Western Desert. It is bounded by latitude 29°35’00" to 29°38’ 00" N and longitude 29°21’00" to 29°27’00" E and covers an area of about 42 Km^2. The study area is characterized by a flat surface, with only local high features and covered by Moghra sand. The ground elevation ranges between 160m to 230m. The stratigraphic section penetrated by the boreholes in the study area includes recent sedimentary rocks. The wells drilled in the vicinity of the study area revealed the same stratigraphic column of the northern Western Desert, with few exceptions in the variations of thicknesses and the absence of some rock units.

The study area was covered by 2D seismic lines extracted from the 3D seismic survey in 2004. Seismic data are successfully used to derive structural information about the subsurface and to locate hydrocarbon traps, seven seismic horizons boundaries have been identified and correlated on the seismic and well log data. Furthermore, depth structure maps were constructed and as a result several structural features were identified: normal faults and anticlines.

The work deals with the contribution of the seismic studies and well logs analysis to achieve a comprehensive evaluation of the main reservoirs. The recommendation is to start drilling the available development and exploratory wells to increase the production.

Based on the geochemical analysis of (Ganna-1), the oil discovered in AR/ G (Middle, Lower units) & Bahariya are believed to have been sourced from Terrestrial sediments such as the Jurassic Khatatba shale which is rich with mixed oil and gas prone organic contents in the upper Khatatba section (kerogen type II and III), which, becomes more gas prone in the lower section. The lower Khatatba is characterized by Paralic swamp/deltaic environments, imbedded with coal units and sand bodies. The coal units are moderate to good source for gas generation.

The proven reservoir levels in the North Bahariya area and its surroundings are found in the upper- middle part of the Cretaceous section (Turonian – Albian). These reservoirs include the sandstones of the Abu Roash E and G members, as well as the sandstones of the Bahariya Formation.

The hydrocarbon discoveries in the two and three-way dip closures in North Bahariya Region, prove the excellent vertical sealing, where most of the oil and gas fields discovered in such type of trapping system had been capped by good seal beds, where a thick shale sequence enfold the potential reservoir intervals as in the case of A/R "G" and Bahariya reservoirs.

As well as the vertical seal, the successful hydrocarbon discoveries in the explored three-way structural closures, proved that the lateral sealing is very active specially when the reservoir sand juxtapose non permeable beds, and proof the good lateral seal along the fault plane, (either, due to the nature of the metamorphism or shale smearing within the fault gauge).

Structural traps have been and still are the main type of traps in the northern Western Desert. Folds formed by Late Cretaceous- early Tertiary basin inversion represent the most common structural trap in the northern Western Desert and are in the form of three-way and four-way dip closures. also, tilted fault blocks represent another type of structural trap in the northern Western Desert.

REFERENCES

Guiraud, R., Issawi, B., and Bosworth, W., 1999: Phanerozoic history of Egypt and its surroundings. Memoires du Museum national d’histoire naturelle, Vol. 186, pp. 469-509.

Schlumberger, 1984: Well Evaluation Conference, Egypt, Schlumberger Middle East. S. A. PP.1-64.

Meshref, W.M., 1990: Tectonic framework of global tectonics. In: The geology of Egypt. (Ed. R. Said, 1990), A. A. Blakema, Rotterdam. PP. 439-449.

Meshref, W.M., 1996: Cretaceous tectonics and its impaction on oil exploration in Regional Northern Egypt. Geol. Soc. Egypt, Spec. Publ. No. 2, PP. 199 -241.

Abdel Gawad E.A., Fathy, M. and Attia, M.M., 2016: Subsurface Geological and Petrophysical Analysis of Bahariya Reservoir at Yomna Field, East Bahariya Concession, North Western Desert, Egypt, International Journal of Scientific Engineering and Applied Science (IJSEAS), Vol-2, Issue-6, pp. 309-314.

Abu El Ata, A., 1981: A Study on The Tectonics and Oil Potentialities of Some Cretaceous _ Jurassic Basin, Western Desert, Egypt Using Geophysical and Sub-Surface Geological Data, Ph.D. Thesis. Cairo, Faculty of Science, Ain Shams University, 568.p.

Abu El Naga, M., 1984: Paleozoic and Mesozoic Depocenters and Hydrocarbon Generating Areas, North Western Desert, Egypt. Proc. 7th Petrol. Exploration Seminar, EGPC, Cairo, pp.269-287.

EGPC, 1992: Western Desert, Oil and Gas Fields (A Comprehensive Overview). Cairo: The Egyptian General Petroleum Corporation, 431. p.

Lüning, S., Kolonic, S., Belhadj, M.E., Belhadj, Z., Cota, L., Baric, G. and Wagner, T., 2004: Integrated depositional model for the Cenomanian-Turonian organic-rich strata in North Africa. Earth Science Reviews, Volume 64, Issue 1, pp. 51-117.

Production Geoscience Ltd (PGL), 2000: Instruction manual of the interactive petrophyiscs software. Production Geoscienc Ltd.