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# Seismic Interpretation for Investigating the Structural Style and Main Stratigraphic Horizons of Bahariya Formation in Nader Field, Shushan Basin, North Western Desert, Egypt

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**Abstract:** The northern section of the Western Desert of Egypt, is an important source of hydrocarbon production. A comprehensive search for hydrocarbon potential in the Western Desert reveals a region with real long-term deposits that has yet to be fully explored. The great progress in seismic acquisition techniques and processing are a major advantage for revealing tiny traps. The unsuccess explored regions has been attributed to poor resolution and limited coverage of earlier seismic data. The current study is carried out in order to evaluate the structural style and main stratigraphic horizons of the upper and lower parts of Bahariya formation in Nader field. Bahariya Formation represent a section of the Upper Cretaceous epoch. This investigation has been carried using the accessible 2D seismic reflection data (Twenty 2D seismic profiles) and 4 deep wells and State- of- the- art analysis and interpretation of the seismic reflection data in Nader area. Seismic interpretation was done to investigate the interested horizons. Velocity analysis was employed to determine the depth values of the upper and lower Bahariya formation that have been detected in the range from 4560 to 5760 ft. The Lower Bahariya depth contour map displays values from 4940 ft to 5920 ft, showing several normal faults dissecting the Bahariya Formation with a NW-SE trend. Some of these faults have downthrown side towards northwest direction while other towards southeast, forming a graben and horst structures. The constructed structural contour maps have been established for both parts of Bahariya Formation reveal the existence of these normal faults that are related to the dextral concourse between Africa and Eurasia during the Late Cretaceous time (Cenomanian age). The study area affected by two primary fault trends; the first is almost orientated E-W attributed to the Paleozoic tectonic activity (Paleozoic rifting) in the northwestern Desert. The second fault trend has a NE-SW contemporaneous to the Jurassic rifting in the north Western Desert. Relay ramps are prevalent in normal fault systems which consist of an area of reoriented bedding between two major normal faults that overlap in map view and have the same dip direction. Moreover, a large-scale rollover folds are noticed in the most area of dipping antithetic normal fault.

**keywords**: Seismic interpretation, Bahariya Formation, Nader Field, Shushan Basin, Western Desert.

## 1.Introduction

The Northwestern Desert covers an area of around 216,000 $km^2$ and is covered with Neogene deposits. The Western Desert's northern basins began as a distinct rift and have since evolved into a pull-apart structure **(1)**. Hydrocarbon production in the Western Desert is entirely centered in Aptian and Cenomanian-Turonian carbonate and clastic reservoirs. Since 1990, several assessments on the Western Desert's petroleum resources have shown that around 90% of oil and 80% of gas resources permanent unexplored **(2)**. Nader Field is placed in the north Western Desert, at the south western part of Shushan basin. It is sited between latitudes 30° 34' 40", 30° 32' 40" N and longitudes 26° 57' 36", 26° 55' 12" E **(Fig. 1).**

Seismic data is usually interpreted and analyzed to gain a better understanding of the subsurface structural features. It is essential to figure out some precise relationships between desired aims and measurable qualities to grasp various components of the Earth. Moreover, Seismic data play an important role in both oil and gas exploration and production. The equilibrium between the expense of the seismic and the profit expected from it determines the type and quality of data obtained **(3).**

The primary goal of this research is to assess the structural style and main stratigraphic horizons in Nader field using the obtainable 2D seismic and wells data and State- of- art analysis and interpretation.

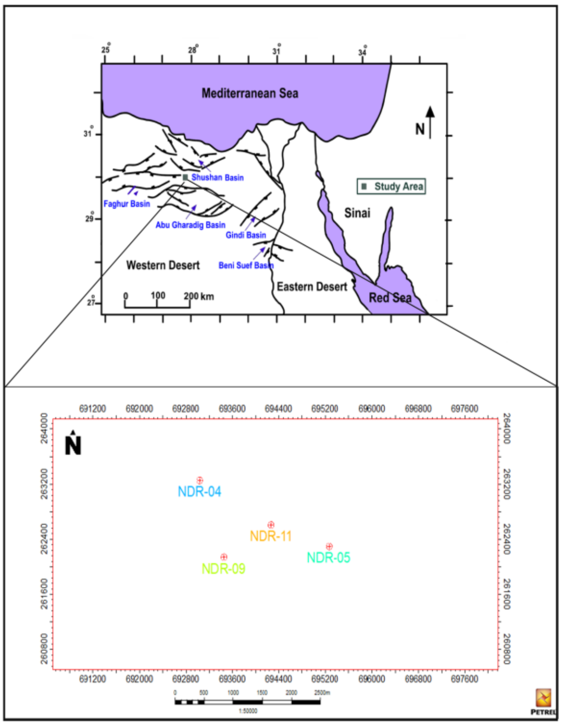


**Fig. 1:** Location map of the Nader Oil Field at the southern western part of Shushan Basin.

## 2. Geological and tectonic setting

Many researchers have looked at the underlying geology of the northern region of the Western Desert such as **(4), (5), (6), (7), (8), (9), (10), (11), (12).**

The sedimentary succession in the North Western Desert stratigraphic column extended from the Pre-Cambrian to Recent **(Fig. 2)**. Despite occasional irregularities, the overall thickness increases progressively to the north and northeast, from roughly 6000 feet in the south to around 25,000 feet towards the coast **(13)**. It spans the deposits sequence from Pre-Cambrian to Holocene. Many carbonate and sandstones clastic alternations define the area **(14)**. Unstable shelf area's stratigraphic column is separated into three parts, beginning with clastics from the Cambrian through the pre-Cenomanian. It is distinguished by extensive carbonate facies from Cenomanian to Eocene. Moreover, clastic facies predominate from Oligocene to Recent **(15)**. In the northern part of the Western Desert, several transgressive and regressive cycles alternate Deltaic and non-marine units define the Paleozoic-Mesozoic and Cenozoic cycles, which, at the end of each cycle, are surpassed by marine carbonates and shales. In older cycles, onshore deposits predominate, whereas marine sediments predominate in younger cycles **(16)**. The late Cretaceous sequence of the North Western Desert is separated into three lithostratigraphic formations from the oldest Bahariya to Abu Roash and Khoman formations **(17)**.

Northeast Africa's tectonic development has been widely studied by numerous authors including **(15, 18, 19).** Geotectonic plate movements provide an overall framework for understanding basinal evolution in northeast Africa **(20)**. The Egyptian platform in the Western Desert is separated into four parts from south to north. These are the Hinge Zone and Unstable Shelf in the north while the Stable Shelf and the Nubian/Arabian Cratons in the South **(15).**

## 3. Data and Methods of Study

The data used to carry out this investigation includes twenty two-dimensional seismic lines, four wells having logging data set (gamma ray, caliper, resistivity, density, neutron, and sonic and a check-shot data). **(Fig. 3)**. The Schlumberger Petrel software was used for the seismic data interpretation that was started by constructing the synthetic seismogram to detect the identified horizons. Before being employed in the seismic tying operation, sonic logs must be calibrated using seismic data from wells (check shot surveys). This is done because the sonic velocities obtained from seismic reflectors within the well frequently differ **(21, 22).** Then the regional prominent reflectors were identified, and picked to form a grid for each horizon on basis of reflectors attributes to make the interpretation easily. There are many distinct seismic attributes can be used to enhance the identification of the geologic features of the current data, and provide the basis for the automation of certain interpretation tasks such as a cosine phase shift, an instantaneous frequency and variance (edge detection). Posting of picked time was carried out to construct horizons surface map. The velocity was estimated using available well data and picked time to construct horizons velocity maps then construct horizons depth maps. This is to evaluate the structural style of Nader field according to the workflow chart **(Fig.4)**.

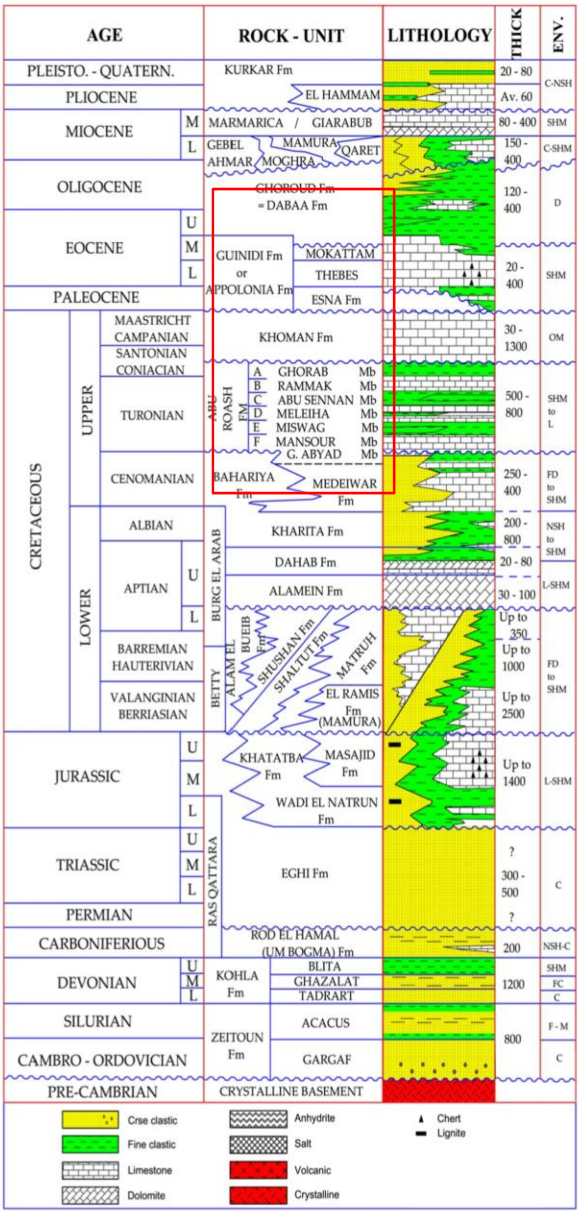


**Fig. 2:** Idealized stratigraphic column representing Northwestern Desert **(23)**.

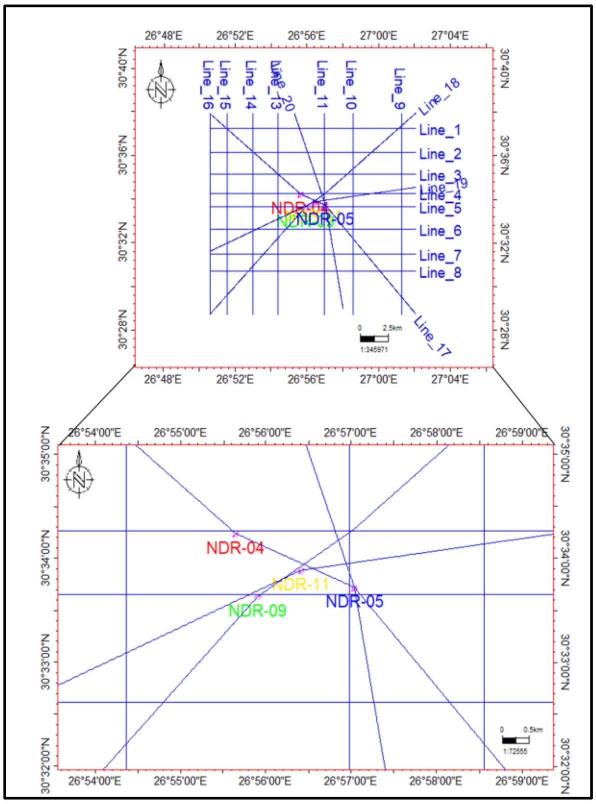


**Fig.3:** Base map of obtainable seismic lines and 4 drilled wells in Nader Field.

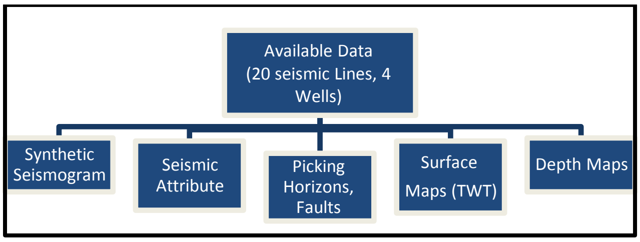


**Fig. 4:** The general workflow used in the present study.

### 3.1. <u>Synthetic Seismogram</u>

Synthetic seismogram is synthesized reflection record formed from velocity logs by converting the depth of the sonic log to a reflectivity function in time, then, using a purportedly adequate wavelet or source pulse, convolve this function **(9)**. The seismic action to vertical propagation of an imagined source wavelet is represented by a model of the subsurface made up of a series of horizontal layers with varying acoustic impedance **(24)**. The aggregate of various reflections in their right travel-time connections makes up the synthetic seismogram for NDR-04 well as shown in **(Fig. 5)**.

Convoluting the reflectivity with a seismic wavelet that represents the amplitude spectrum and phase of the reflectors is the following procedure before they are analyzed to genuine seismic lines **(25)**. Wavelets with zero phase are often preferable because they provide the most quality **(26).** By comparing marker beds or other correlation locations on well logs with prominent reflections on the seismic section, interpretations of the data can be modified. The quality of the resemble between a synthetic seismogram is determined by the quality of the well log, the quality of seismic data analysis, and the ability to extract a representative wavelet from seismic data **(27).**

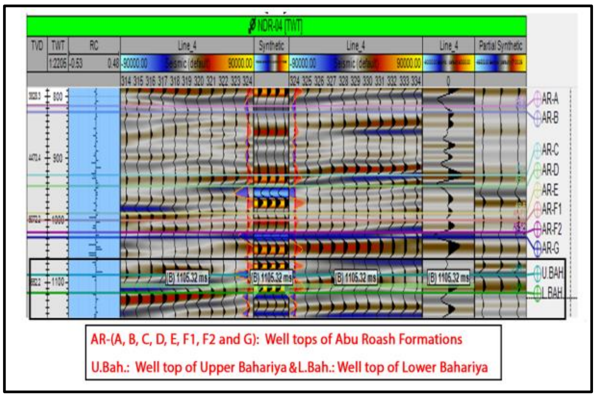


**Fig.5:** Synthetic seismogram generated using data of NDR-04.

## 4. Results and Discussion

### 4.1. Picking The Horizons and Faults

Identification of the important reflectors and horizons on the seismic section is interpreted by picking. The use of seismic picks in conjunction with well log formation tops, enhances and increase the certainty of the interpretation **(28)**. The horizons were determined through the tying process and were selected by correlating seismic occurrences with all available seismic lines. By using different types of attributes as a cosine phase shift, an instantaneous frequency and variance (edge detection) to show the continuity and discontinuity in the reflectors and make the picking easily. Horizons are picked in the seismic sections (Upper and Lower part of Bahariya). Line-17 is arbitrary line aligned NW-SE direction as shown in **Figs (6 and 7)**. This seismic line passes through the wells (NDR-04, NDR-05, NDR-09 and NDR-11) which are located at the upthrown side of the faults (F1 and F16). Six normal faults are (F18, F17, F16, F1, F8 and F4) from SE to NW. Faults (F4, F8, F1 and F18) have downthrown side towards northwest direction and faults (F16 and F17) extend downthrown side towards southeast. Faults (F16 and F17) and (F17 and F18) generate a graben structure. Faults (F16, F17 and F18) pass through picked horizons (Apollonia, Khoman, Upper Bahariya and Lower Bahariya formations), faults (F1 and F4) pass through (Abu Roash-C) and fault (F8) passes through (Upper Bahariya, Lower Bahariya and Alamien Formations).

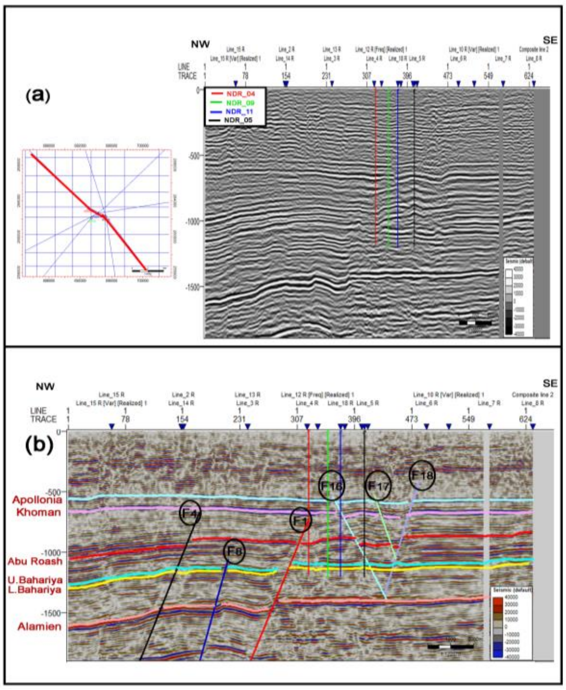


**Fig. 6:** (a) Uninterpreted seismic arbitrary- 17 and view line in map window. (b) Interpreted seismic arbitrary line passing through (NDR-04, NDR-05, NDR-09, NDR-11) wells.

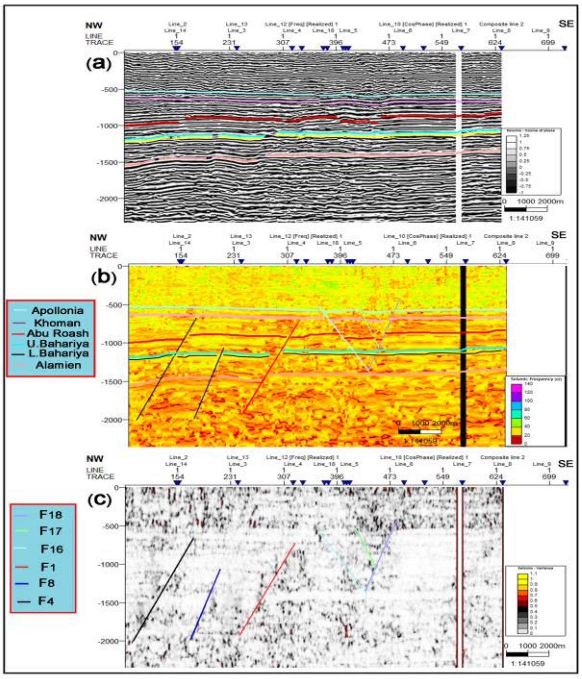


**Fig. 7:** Interpreted seismic arbitrary- 17 with different attributes (a) Cosine phase shift, (b) Instantaneous frequency and (c) Variance attribute.

### 3.1. Velocity and Depth conversion

Because seismic data is created in real time, and wells depends on seismic interpretations are in depth, the seismic interpreter is concerned with depth conversion. To correlate well data and do volume calculations, you may translate data from one domain to another, such as seismic data in time, by using depth conversion **(29)**.

Surface (TWT) structural contour map has been established for the Upper Bahariya Formation (**Fig. 8a).** The area under investigation is dissected by an irregular distribution pattern with a maximum value towards north direction and reaches its maximum value of 1300 ms at downthrown of fault (F1), while the time eliminates decreases towards the south direction with a maximum value of 1030 ms. This map clarifies the predominance of a group of normal faults in two different directions. All these faults have downthrown side towards northeast direction at the selected region except faults (F7 and F3) have downthrown side towards southwest directions. The top of Upper Bahariya Formation has normal faults and related to the dextral concourse between Africa and Eurasia during the Late Cretaceous time (Cenomanian age).

TWT surface are generated for the top Lower Bahariya Formation. **Figure (9a)** reflects TWT structural contour map for the top of the Lower Bahariya Formation. The current study is dissected by an irregular distribution pattern having a maximum value (1320 ms) towards north direction at the downthrown side of faults of graben (F6 and F7) at the northeast and in the upper part of northwest, while the time reduces towards the south direction and reached its minimum time value of 1110 ms. This map demonstrates the prevalence of a group of normal faults structure having two different directions. Such faults have downthrown side towards northeast direction except both F7 and F3 faults have downthrown side towards southwest directions.

The conversion of time to depth is accomplished using velocity information. A time interpretation's depth conversion is straightforward and done anytime whenever data is available. The physical quantity that accelerates the passage of time is velocity. The P-wave velocity in the vertical direction is necessary for converting time to depth. It can be directly calculated in a well, indirectly from surface seismic data, or as a result of a mix of seismic and well data **(30)**. In this situation, the velocity data was derived from the check shot survey recordings. for Upper Bahariya **(Fig. 8b)** and **(Fig. 9b)** for Lower Bahariya. Upper Bahariya depth values have been detected from 4560 to 5760 ft **(Fig. 8c)**. Lower Bahariya depth contour map displays values from 4940 ft to 5920 ft **(Fig. 9c).**

Generally, in the study area, there are two main fault trends, the first fault trend is nearly oriented E-W direction and is attributed to the Paleozoic tectonic movement (Paleozoic rifting) in the north Western Desert. The second fault trend is oriented NE-SW which is related to the Jurassic rifting in north Western Desert. Relay ramps are prevalent in normal fault systems. They consist of a region of reoriented bedding that is between two normal faults with the same dip direction and overlap in map view **(31)**. The white arrows in depth maps **(Figs. 8, 9 (c))** reveals to the overlap zone in relay ramp structure.

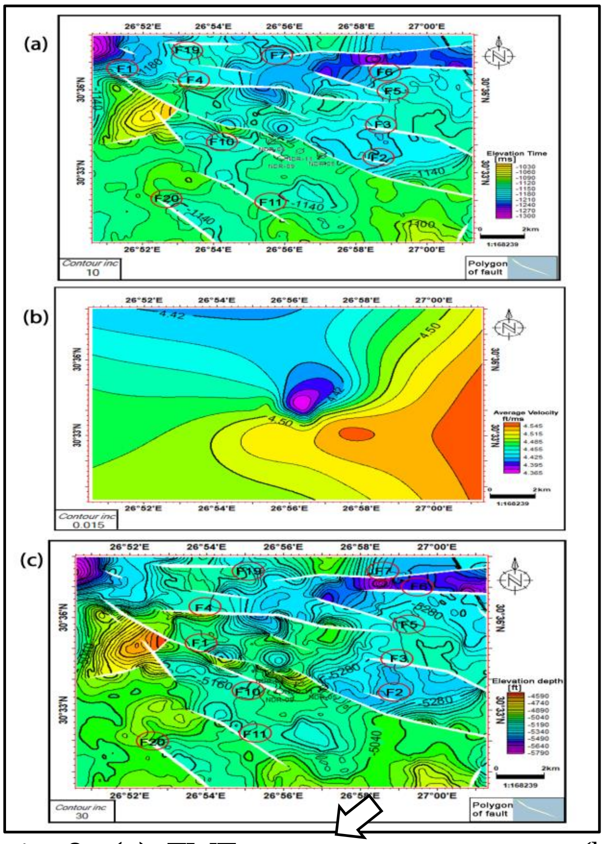


**Fig. 8: (a)** TWT structure contour map, (b) Average velocity contour map and (c) Depth

structure contour map of upper part of Bahariya Formation.

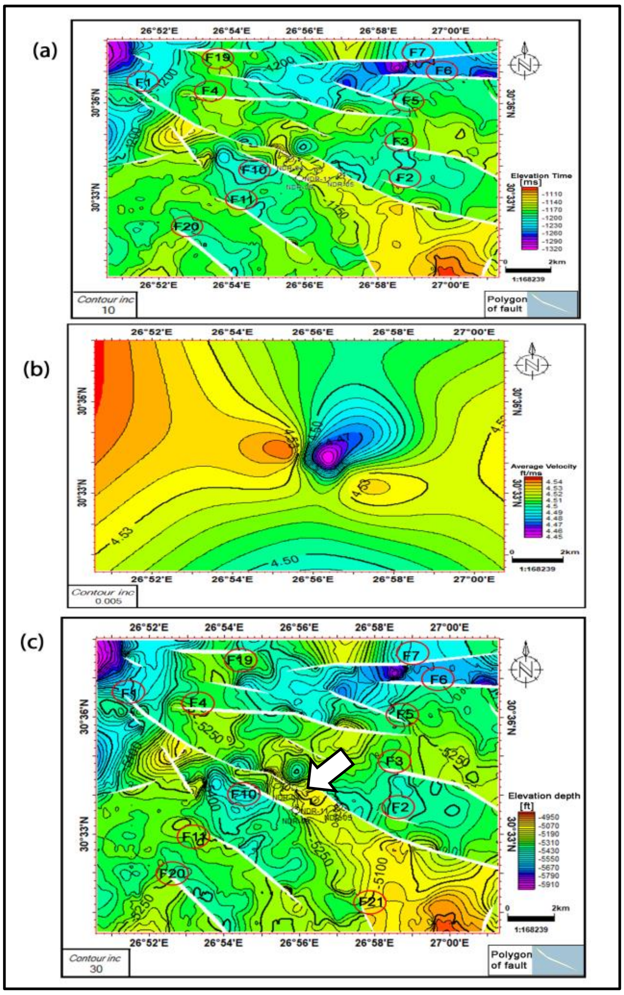


**Fig. 9:** (a) TWT structure structure map, (b) Average velocity contour map and (c) Depth structure contour map of lower part of Bahariya Formation.

## 5. References


1 Abu El Naga, M. 1984. Paleozoic and Mesozoic depocenters and hydrocarbon generating areas, north Western Desert. EGPC 7th Petroleum Exploration Seminar, Cairo. 269-287.

2 Egyptian General Petroleum Corporation (EGPC), 1992. Western Desert oil and gas fields - a comprehensive overview. The Egyptian General Petroleum Corporation, 1-431.

3 Zhou, H. W., 2014. Practical seismic data analysis. Cambridge University Press.

4 El Gezeery, N. H., Mohsen, S. M. and Farid, M. I. 1972. Sedimentary Basins of Egypt & their Petroleum prospects. 8th Arab Petrol. Conf., Algiers, **2**, 83 (B-3), 1-13.

5 Khaled, D. A. M. 1974. Jurassic Prospects in the Western Desert, Egypt. EGPC, 4th Petrol. Expl. and Prod. Conf., Cairo, 214-223.

6 Hanter, G. 1990. North Western Desert. In R. Said, ed., The Geology of Egypt, Rotterdam, Netherlands. A. A. Balkema Publishers, 293-319.

7 Berglund, J.B., Gjelberg, J., El Masry, M. and Skogen, H.J., 1994. The Jurassic Hydrocarbon Habitat of Ras Kanayis Area, North Western Desert. Egypt. EGPC 12th Petrol. Expl. and Prod. Conf., Cairo, 229-237.

8 El-Shaarawy, Z. and Montasser, S. 1996. Positive Flower Structure in the North Western Desert of Egypt and its effect on Hydrocarbon Accumulation. EGPC. 13 Petrol. Expl. and Prod. Conf., Cairo, 87-102.

9 El Kadi, H Hassaneien, I Ghazaly, A 1998. Seismological and Petrophysical Studies for Hydrocarbon Evaluation of Cretaceous Rocks in the north Western Desert. Egypt. EG PC. 14th Petrol. Expl. Prod. Conf. Cairo. 16.

10 Shalaby, M.R., Hakimi, M.H. and Abdullah, W.H. 2012. Organic geochemical characteristics and interpreted depositional environment of the Khatatba Formation, northern Western Desert, Egypt. AAPG bulletin, 96(11), 2019-2036.

11 Aboelhassan, N., Tarabees, E., & Alaa, M. 2017. Reservoir evaluation of Bahariya Formation in tut oil field, north Western Desert, *Egypt. International Journal*, **12(29),** 129-203.

12 Abdelwahhab MA, Raef A. 2020. Integrated reservoir and basin modeling in understanding the petroleum system and evaluating prospects: The Cenomania reservoir, Bahariya Formation, at Falak Field, Shushan Basin, Western Desert, Egypt. *Journal of Petroleum Science and Engineering*, **189**, 12-16.

13 Schlumberger. 1992 Well Evaluation Conference, Egypt. Schlumberger Technical Editing Services, Chester, 57-71.

14 Barakat MK. 2017 Petrophysical Evaluation and Potential Capability of Hydrocarbon Generation of Jurassic and

Cretaceous Source Rocks in Shoushan Basin, North Western Desert, Egypt. IOSR *Journal of Applied Geology and Geophysic*s, **5**, 23-45.

15 Said, R. 1962. The geology of Egypt. Elsevier Publishing Co., Amesterdam, New York, 337.

16 Strauss, R. G., and Aultmann, J. B.1992. Hydrocarbon potential of the South Umbarka Concession, Western Desert, Egypt. Phillips Petroleum Company, Oklahoma, unpublished report.

17 Schlumberger. 1995. Well Evaluation Conference, Egypt. Schlumberger Technical Editing Services. Chester, 57-71.

18 Meshref, W. M. 1990. Tectonic framework. In R. Said, ed., The geology of Egypt Rotterdam, Netherlands, A. A Balkema Publishers, 113-155.

19 Schandelmeier, H., Klitzsch, E., Hendriks, F., & Wycisk, P. 1987. Structural development of North-East Africa since Precambrian times. Berliner Geowissen schaftliche Abhandlungen, Reihe A: Geologie und Palaeontologie, **75**, 5-24.

20 Meshref, W.M., Abd El-Baki, S.H., Abd El-Hady, H. M. and Soliman, S.A. 1980. Magnetic trend analysis m the northern part of the Arabian- Nubia shield and its tectonic implications. Ann. Geol. Surv., Cairo. Egypt. 10. 939-953.

21 Schlumberger. 1984 Well evaluation conference. Egypt. Geology of Egypt, 1-64.

22 Gretener, P.E.F. 1961. An analysis of the observed time discrepancies between continuous andwell velocities surveys. Geophysics, 26, 1-11.

23 Stick, E. 1971. An explanation of observed time discrepancies between continuous and well velocity surveys. Geophysics, **36,** 285-295.

24 Kearey, P Brooks, M Hill, I 2002. An introduction to geophysical exploration, third cd_ Blackwell. 268.

25 Darling, T 2005. Well Logging and Formation Evaluation, Gulf Professional Publishing, 326.

26 Dobrin, M.B., Savit, C.H. 1988. Introduction to Geophysical Prospecting, fourth cd. McGraw-Hill. New York. 867.

27 Abuzaied, M., Metwally, A., Mabrouk, W., Khalil, M. and Bakr, A., 2019. Seismic interpretation for the Jurassic/Paleozoic reservoirs of QASR gas field, Shushan-Matrouh basin north Western Desert, Egypt. *Egyptian Journal of Petroleum*, **28(1),** pp.103-110.

28 Onajite, E. 2014. Understanding seismic interpretation methodology. Seismic Data Analysis Techniques in Hydrocarbon Exploration, 177-211.

29 Berglund, J.B., Gjelberg, J., El Masry, M. and Skogen, H.J., 1994. The Jurassic Hydrocarbon Habitat of Ras Kanayis Area, North Western Desert. Egypt. EGPC 12th Petrol. Expl. and Prod. Conf., Cairo, 229-237.

30 Brown, A.R. 2004. Interpretation of Three-dimensional Seismic Data, sixth ed. AAPG & SEC, 534.

31 Peacock, D.C.P., Knipe, R.J., Sanderson, D.J. 2000. Glossary of normal faults. *Journal of Structural Geology* **22**, 291-305.