*Egyptian Geophysical Society*
*EGS Journal, Vol. 15, No. 1, 39-46 (2017)*

# DELINEATING OIL SHALE OCCURRENCES USING MAGNETIC AND RESISTIVITY TECHNIQUES AT SOUTHWEST OF QUSEIR AREA, EASTERN DESERT, EGYPT

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## تحديد أماكن تواجد الطفلة الزيتية باستخدام تقنيات المغناطيسية والمقاومة الكهربية النوعية بجنوب غرب منطقة القصير، الصحراء الشرقية، مصر

**الخلاصـــة:** تأتي الأهمية الاقتصادية للطفلة الزيتية من حقيقة أنها تحتوي على مواد عضوية وكميات كبيرة من الكيروجين والتي يمكن اســتخلاص سائل الهيدروكربون من خلالها. أما إذا كانت غير ناضجة فيمكن أن يتم استخدامها بعد حرقها، كمصدر للطاقة في محطات توليد الكهربــاء. وتــزداد أهميتها الاقتصادية اذا ما بلغت قيمتها الحرارية أكثر من ٨٠٠ كيلو كالوري / كجم عند حرقها.

منطقة الدراسة تتميز بوجود إمتدادات كبيرة من الطفلة الزيتية داخل تكوين الداخلة، هذا التكوين يحتوي على كميات كبيرة من الكيروجين والذي مــن خلاله يمكن استخلاص الهيدروكربونات السائلة، وقد أظهرت تقنيات المغناطيسية والمقاومة الكهربية النوعية بأن سمك تكوين الداخلة الطفلي يزيد نحو الشمال والشمال الغربى من منطقة الدراسة ومحصور داخل طية مقعرة غير متماثلة حيث يبلغ سمكه الأقصى (٦٢) مترا.

**ABSTRACT:** *The economic importance of the oil shale comes from the verity that it contains organic matter and substantial amounts of kerogen from which liquid hydrocarbons can be constructed. If it is immature it can be used after burning, as a source of energy in the production of electricity.*

*The study area is characterized by the presence of considerable extensions of oil shale within Dakhla shale as deduced from geological studies. This formation contains significant amounts of kerogen from which liquid hydrocarbons can be manufactured. Magnetic and resistivity techniques are used to delineate the subsurface occurrences of the oil shale. Interpretation of the field measurements show that its thickness increases towards N and NE of the study area and restricted by an asymmetrical synclinal fold with a maximum of (62) m.*

## INTRODUCTION

The area of study is a part of the Central Eastern Desert of Egypt, about 15 Km to the southwest of Quseir Town on the Red Sea Coast. It lies between latitudes 25o 57′ 49.29″ N & 25o 58′ 27.91″ N and longitudes 34o 17′ 25.92″ E & 34o 18′ 11.31″ E,Fig.(1). The previous geological, geophysical and geochemical studies proved that Quseir area is rich with considerable extensions of the black shales (oil shales) either on the surface or in the subsurface(Mustafa and Ghaly (1964), El-Kammar (1993), Temraz (2005), El-Kammar and El-Barkooky (2006), Muhammad, et al. (2011)). The black shale, which belongs to the Dakhla Formation that overlies a uranium-bearing phosphate layer belonging to the Duwi Formation. The economic importance of the oil shale comes from its content of organic matter as significant amounts of kerogen from which liquid hydrocarbons can be manufactured.

Moustafa et al. (2014) concluded that Quseir-Safaga area is a commercial field for oil shale production which has a reserve of five billion barrel of oil in place, while the estimates by Troger (1984) for the oil shale in that area were 4.5 billion barrel. It is also noticed that the economic importance of the oil shale increases when the calorific value of the black shale is more than 800 KCalory/Kg during burning, (Dyni, 2003).

Some oil shales can also be used for uranium and other rare chemical element production. During 1946-1952, a marine variety of Dictyonema Shale was used for uranium production in Sillamäe, Estonia, and during 1950–1989 alum shale was used in Sweden for the same purpose (Dyni, 2006).

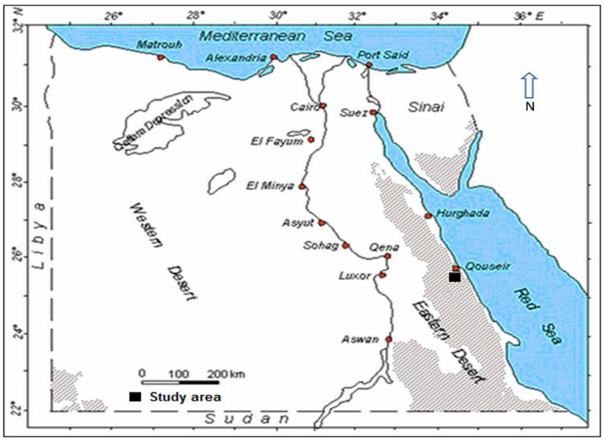


**Fig. (1): Location map of the study area, southwest of Quseir, E. D., Egypt.**

### Geological and Structural settings:

The geology of the area under study and its vicinity is described by many authors such as Baron and

Hume (1902), Ball (1916), Beadnell (1924), Youssef (1957), Faris and Hassan (1959), Akkad and Dardir (1966), Abdel Razik (1972and1967), Issawi et al., (1971and 1969), Tarabili (1969and 1966) and Gindy et al., (1976and 1973).The geology of the study area consists of metagabbro, younger granite, Duwi Formation, Dakhla Shales (oil shale bearing formation), Tarawan Chalk and Quaternary sediments (Fig. 2). The Precambrian rocks in the area are represented mainly by the metagabbro and younger granites. The phosphates of the Duwi Formation conformably overlie the Quseir variegated Shale and underlie the Dakhla Shale. A carbonate bed equivalent to the Tarawan Chalk overlies the Dakhla Formation in this area. The Quaternary sediments bound the different rock units in the study area and fill the main wadies.

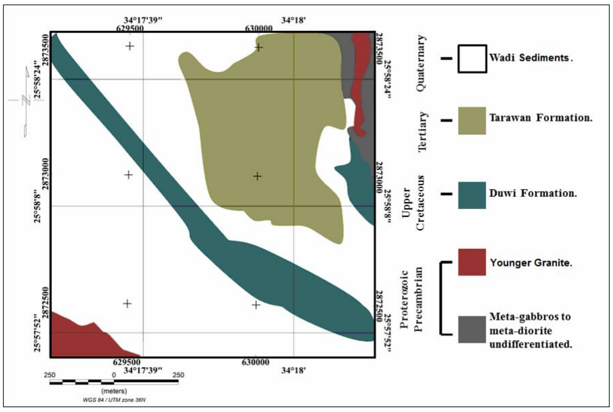


**Fig. (2): Surface geologic map of the study area, southwest of Quseir, E. D., Egypt (after Sabet, et al., 1976).**

The subsurface lithostratigraphic setting of the study area was described by Centrium Company (2008) using a drilled Well No. 5. The lithostratigraphic column (Fig. 3) of the drilled well No. 5 inside the study area gives detailed description of the subsurface units recorded from the ground surface until 400m depth. It starts from bottom with the Duwi Formation, then Dakhla Formation and followed upwardly with Tarawn Formation.

According to Khalil and McClay (2002), the study area and its vicinityare affected by the Red Sea rift system which exhibitsexcellent outcrop examples of kilometric scale and extensional fault-related folds. The faults of the Red Sea rift border fault system consist of a series of WNW and NW-trending segments. The hanging-wall structure of the border fault system is characterized by a series of offset large, doubly-plunging, asymmetric hanging-wall synclines with non-linear axial traces sub-parallel to the faults. These folds result from along-strike displacement variations on the individual fault segments together with extension-related fault-propagation folding as the faults propagated upwards through a highly anisotropic pre-rift sedimentary section. The hanging-wall synclines and their relationships to fault displacement indicate that they are formed by extensional fault propagation folding rather than by frictional drag along the fault surface. These structural elements are in accordance with the field evidences and observations at the study area that show the presence of NW trending asymmetrical syncline as a trough between two ridges of Precambrian rocks to the east and west of the study area, Fig. (2).

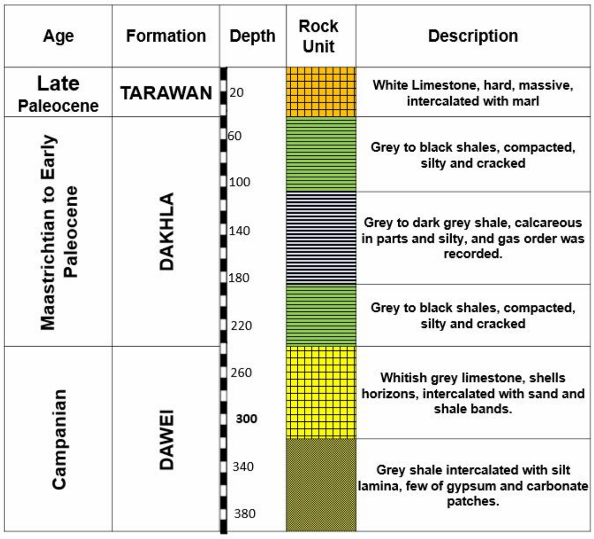


**Fig. (3): Litho-stratigraphic column of Well No. (5) inside the study area, southwest of Quseir, E. D., Egypt. (after Centrium Company (2008)).**

**Field survey and Data processing:**

Magnetic field measurements carried out along (26) profiles trending N-S.Each profile was (1250 m) with a separation of (50m) while the station separation was (25m) Fig. (4).

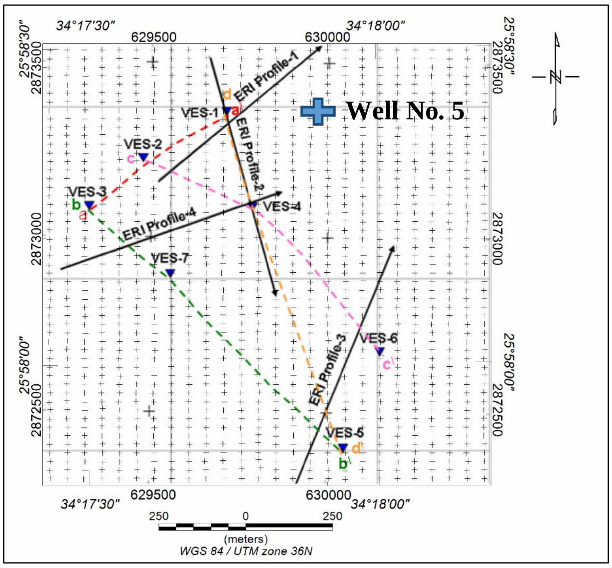


**Fig. (4): Electrical and magnetic surveys Layout map of the study area, southwest of Quseir, E. D., Egypt.**

The observed data was corrected for the diurnal variations and levelled using tie lines to produce the total magnetic intensity map (Fig. 5). This map was reduced to the north magnetic pole using I$^{o}$ (inclination angle) = (38$^{o}$)& D$^{o}$ (declination angle) = (3.7$^{o}$) at the survey date to obtain the reduced to the north magnetic pole map (RTP) (Fig. 6). This RTP map was treated by power spectrum technique using FFT (Fast Fourier Transform)and the resulted spectrum is shown in Fig. (7). It is used to separate the shallow magnetic sources (residual magnetic map), Fig. (8), from the deep seated ones (regional magnetic map), Fig.(9). The 3D Euler deconvolution with structure index of (0, magnetic contacts) technique was applied to the regional and residual magnetic maps in order to locate the magnetic sources and their depths as shown in (Figs.10 and 11), respectively.

The electrical resistivity survey was carried out using ELREC-T tool and consists of (7) vertical electrical soundings (VES) using Shlumberger array with AB/2 values ranging from 500 to 600 m (Fig. 4). The field data was processed using Ato program of Zohdy (1989) to obtain the multi-layer model, and IPI2Win (Moscow State University, 2001) to obtain the layering model where the automatic curve-matching computer program results in a geoelectric model (Fig. 12). Moreover, four 2-D earth resistivity images using a Wenner array with profile length ranging between 550 and 800 m (Fig. 4). The observed data was processed using RES2DINV program (Loke and Barker, 1996 and Loke, 2002) (Fig. 13-16).

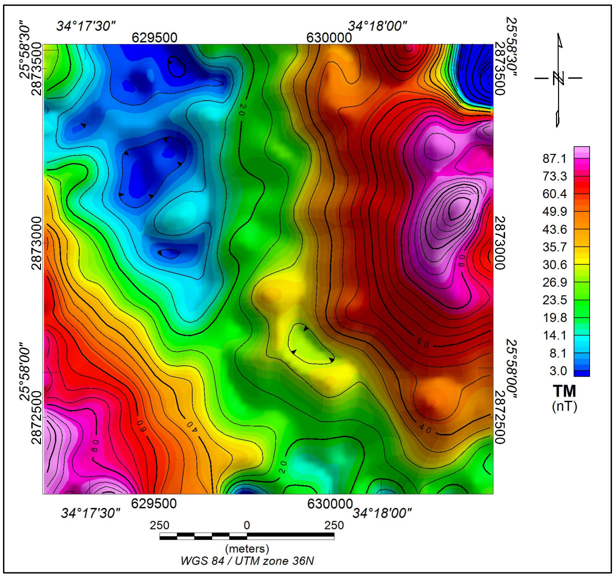


**Fig. (5): The total intensity magnetic map of the study area, southwest of Quseir, E. D., Egypt.**

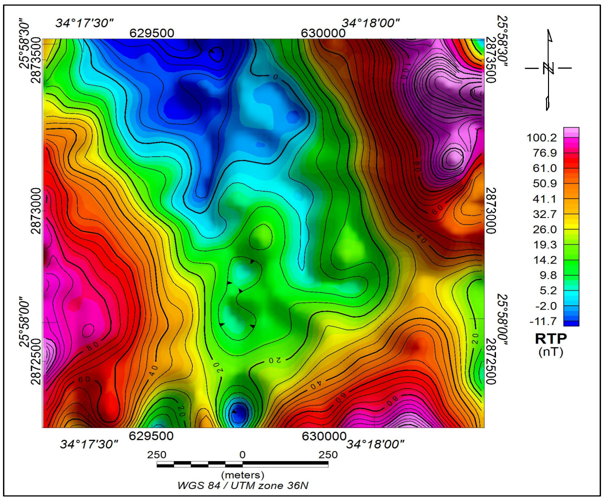


**Fig. (6): The RTP map of the study area, southwest of Quseir, E.D., Egypt.**

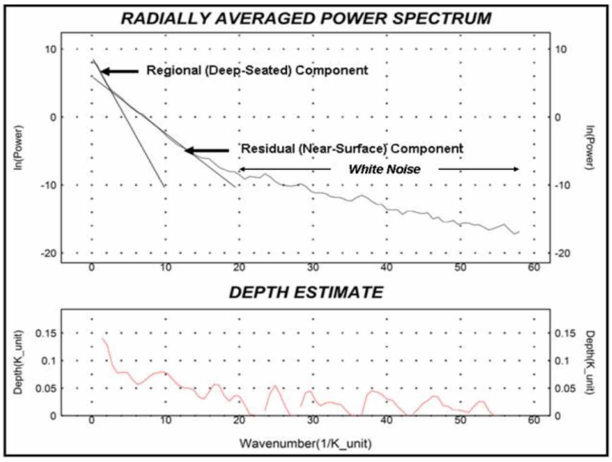


**Fig. (7) Radially averaged power spectrum and depth estimate of the RTP magnetic map of the study area, southwest of Quseir, E. D., Egypt.**

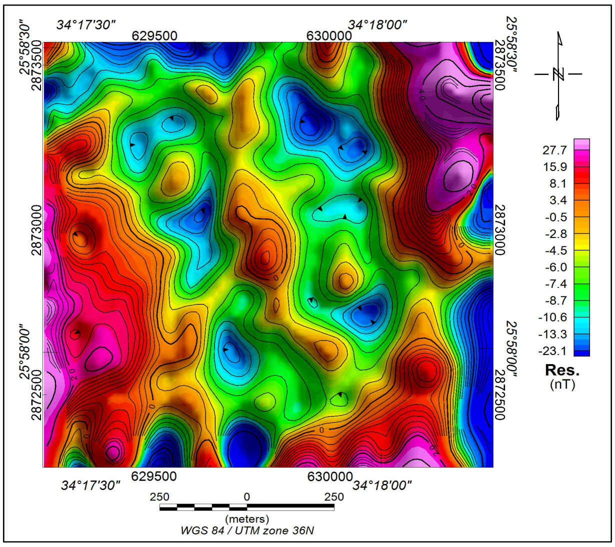


**Fig. (8): The residual RTP magnetic map of the study area, southwest of Quseir, E. D., Egypt.**

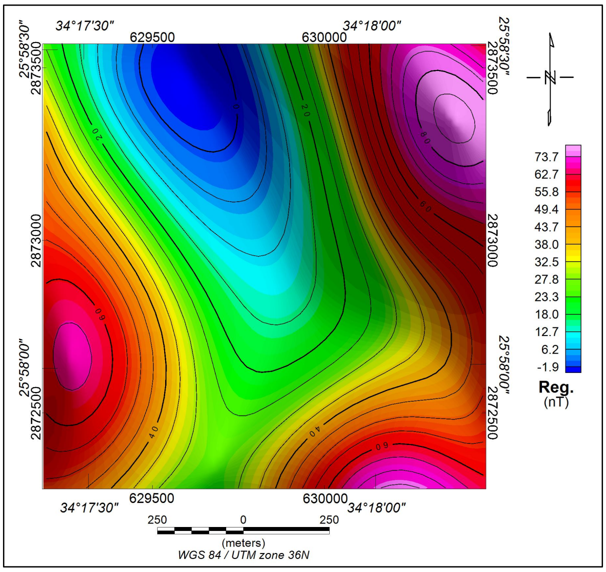


**Fig. (9): The regional RTP magnetic map of the study area, southwest of Quseir, E. D., Egypt.**

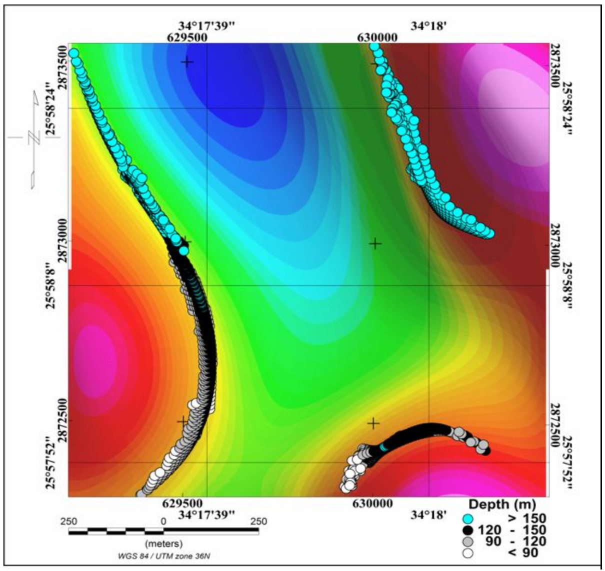


**Fig. (10): Euler solutions (SI= 0) superimposed on the regional map of the study area, southwest of Quseir, E. D., Egypt.**

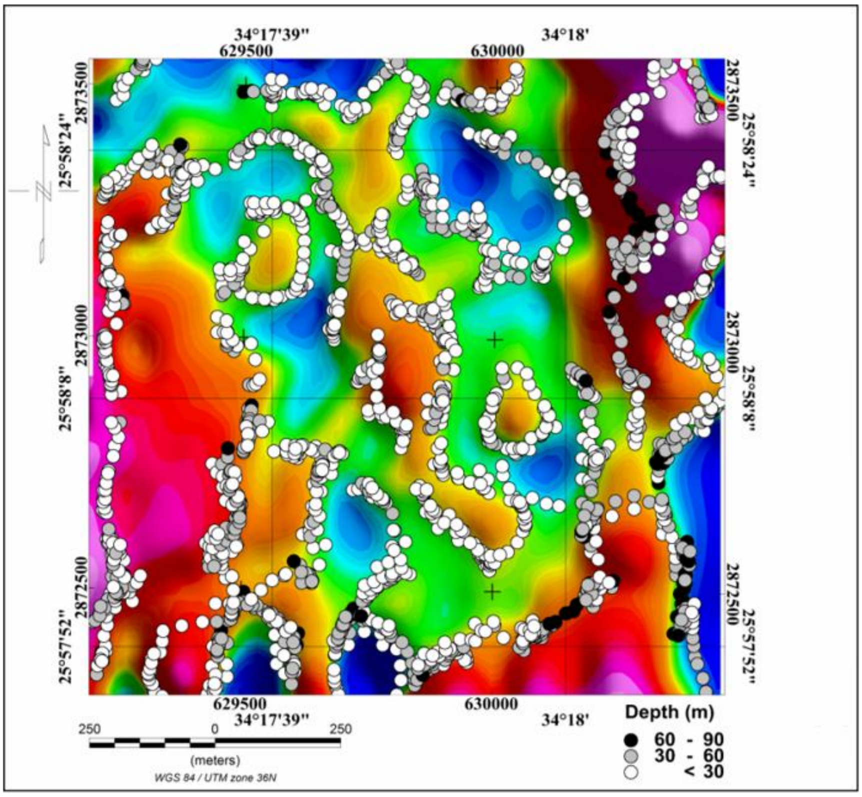


**Fig. (11): Euler solutions (SI= 0) superimposed on the residual map of the study area, southwest of Quseir, E. D., Egypt.**

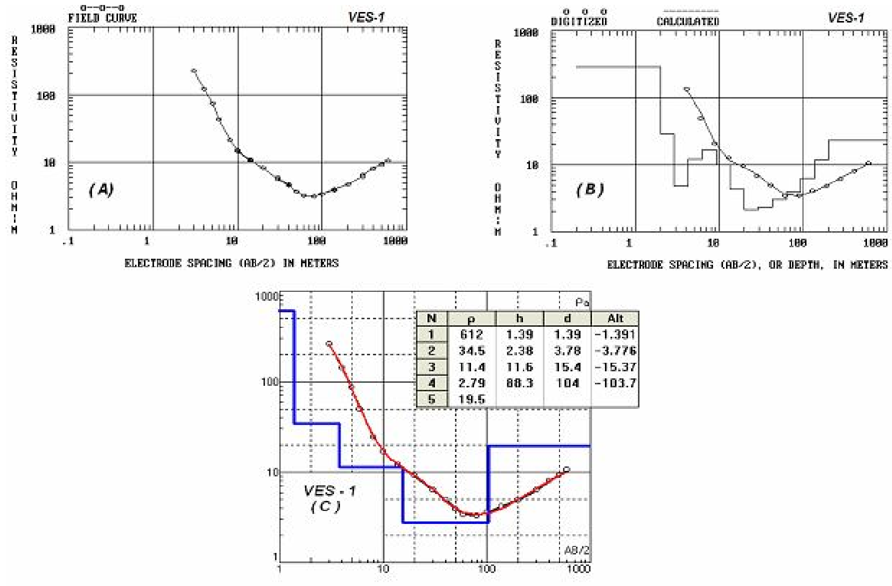


**Fig. (12): Analysis of VES No. 1 (a) smoothed field curve, (b) multilayer model of Zohdy, and (c) layering model of IPI2Win.**

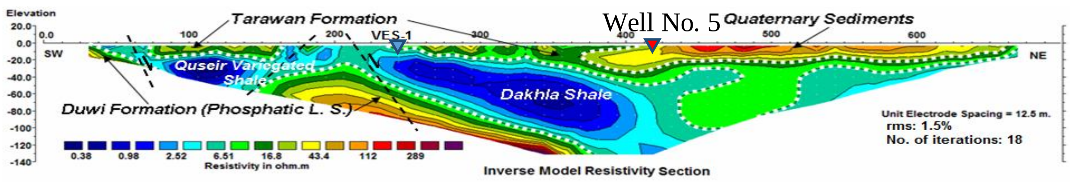


**Fig. (13): Interpreted resistivity inverse model of profile No. 1 (as assigned in Fig. 11).**

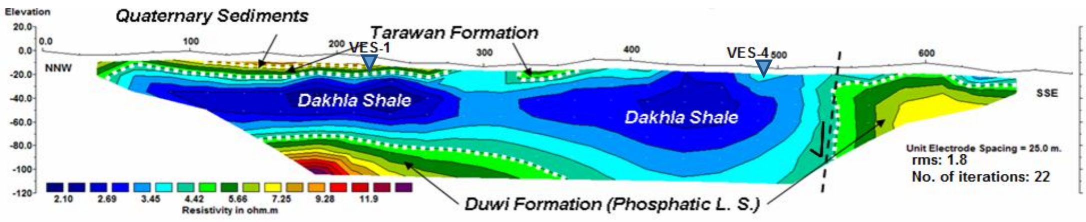


**Fig. (14): Interpreted resistivity inverse model of profile No. 2 (as assigned in Fig. 11).**

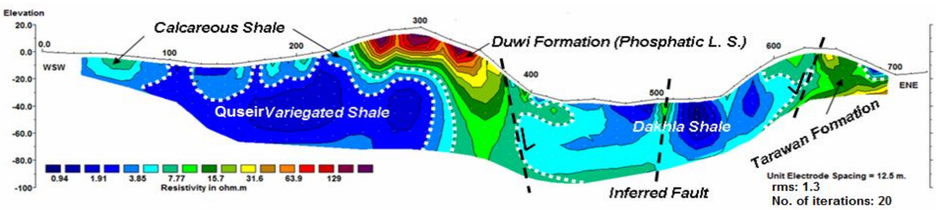


**Fig. (15): Interpreted resistivity inverse model of profile No. 3(as assigned in Fig. 11).**

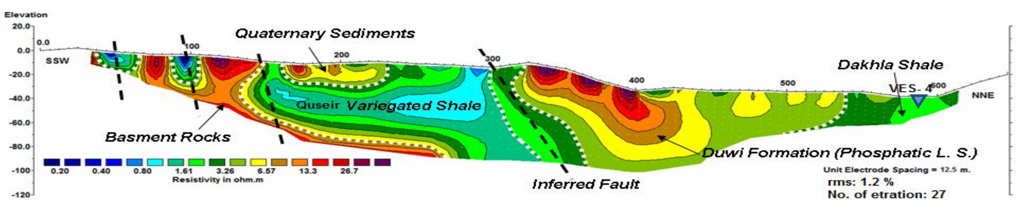


**Fig. (16): Interpreted resistivity inverse model of profile No. 4 (as assigned in Fig. 11).**

**Data interpretation and discussion**

The reduced to the north magnetic pole map (RTP) (Fig. 6) shows three high positive magnetic anomalous zones in the northeast, southeast and western portions of the mapped area. They range in magnetic intensity values from (25 to 220 nT) which emphasizes the presence of the basement rocks at these locations. The other zones of the study area show a low magnetic anomaly ranging in magnetic intensity values -33 to 10 nT which represents a sedimentary basin of down faulted blocks.

The RTP map was subjected to the FFT to produce a power spectrum represents the RTP map in form of frequency domain to separate the shallow magnetic sources (residual component) from the deeper ones (regional component) (Bird, 1997; Sadek et al., 1984; Treital et al., 1971; Spector and Grant, 1970). The spectrum shows near-surface (residual) magnetic component mapat a depth of about 92 m and the deep-seated (regional) magnetic component map at a depth of about 148 m depth,(Fig. 7).

3-D Euler Deconvolution technique is applied on filtered magnetic maps (Figs. 10&11)using a structural index of (0) to locate the magnetic contacts and their proper depths (Thompson, 1982 and Reid et al., 1990).Euler solutions of good clustering along linear segments trending in NW, NE and NS directions. Moreover, the Euler solutions provide depth estimation to these structures. These depths estimated for the near-surface structures range from 30 to 90m. Meanwhile, depths range from 90m to more than 150m for the deep-seated structures with the general increase to wards the northwest, Figures (10 and 11).

Structural interpretation according to Dobrin and Savit (1988) and Afflek (1963) was done by careful examination of the RTP, regional and residual magnetic maps (Figs. 6, 7, 8&9) and provide a structure tectonic map represents the structural lineaments of the study area, Fig.(17). Such lineaments are presented statistically through rose diagram to delineate the major and minor structural lineaments affecting the area under study, Fig. (18). It shows structural elements that are oriented mostly in NNW, NW, N-S, NE and NNE directions as predominant trends and WNW and ENE as secondary trends. It is evident from these results that, the outlined interpreted magnetic structural lineaments at the near-surface level are still highly recognized at the deep-seated one at the study area.

The four imaging profiles (Figs. 13- 16) proved that the Tarawan, Dakhla and Duwi formations increase in thicknesses towards north and northeast and vanished towards the western parts where the calcareous shale and Quseir variegated shale appear. All 2D- resistivity sections indicate that the area is affected by faults in different directions. These faults are in accordance with that deduced from the ground magnetic maps of the study area proving the existing of several faults in different directions including NW, NNW, N-S, NNE and NE.

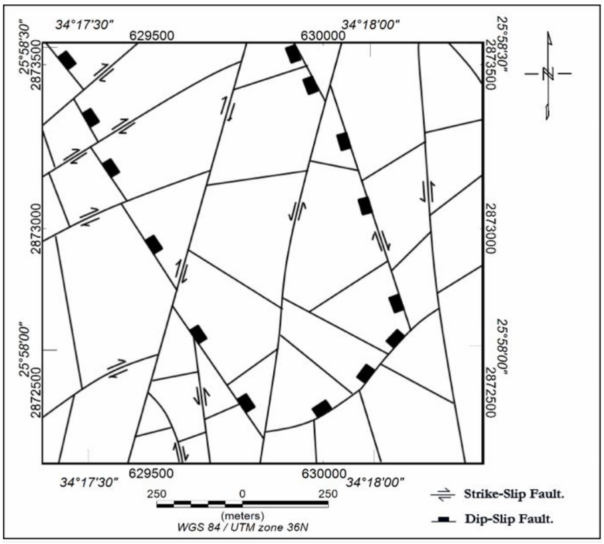


**Fig. (17): Interpreted tectonic map of the study area, southwest of Quseir, E.D., Egypt.**

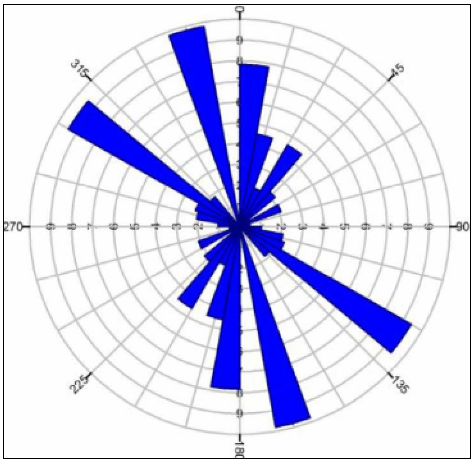


**Fig. (18): Rose diagram of structural elements measured in the study area, southwest of Quseir, E.D., Egypt.**

The geoelectric layers obtained from the IPI2win program are represented as resistivity and depth bar sections beneath their sounding locations (Figs.19 - 22).The interpreted geoelectric models (Figs.19 - 22)pointed that the area has five to six geoelectric layers. Generally, the area attains low to moderate resistivity values with some exceptions for the bedrock layer. The uppermost layer is interpreted as Quaternary sediments which is characterized by moderate to high resistivity values with an average value of 137.5 Ω-m. Its thickness ranges between 0.5 and 15m.

The second layer mostly represents the Tarwan Formation with an average resistivity of 13.2 Ω-m and an average thickness of 22.5m with a general increase towards the North and Northeast. The third layer recorded remarkable decreasing of average resistivity to 2.5 Ω-m, representing the black shale forming Dakhla Formation with an average thickness of about 61.9m. There is a general increase in the thickness of this layer toward the north and northeast. The phosphatic limestone of the Duwi Formation represents the fourth layer which indicates relative increasing of the resistivity values compared with those of the third layer to reach 10.9 Ω-m as an average value. It was observed that this layer disappears at the locations of soundings 3, 5 and 7 to the west and southwest of the area. The fifth and six layers represent the calcareous shale and the Quseir variegated shale. The fifth layer has 3.7 Ω-m with relatively moderate average thickness of about 17m, while the variegated shale layer attains an average thickness of about 73m and average resistivity of 1.6 Ω-m. The bedrock is observed at the locations of soundings 3, 5, 6 and 7 with a high to very high resistivity values. It is shallow at sounding No. 7 while it became deeper at soundings 3, 5 and 6, respectively.

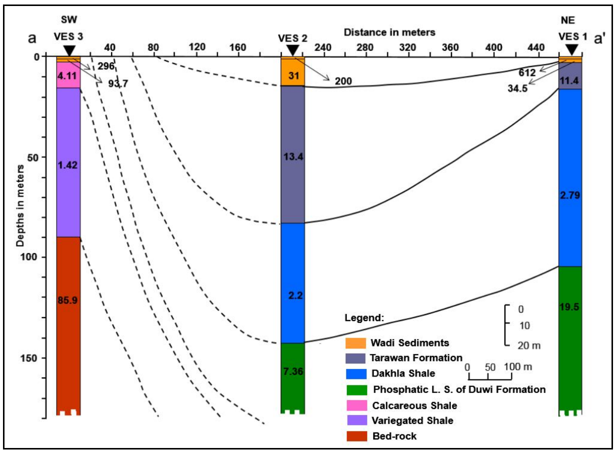


**Fig. (19): Geoelectric bar-section (a-a') of VES's 3, 2 and 1.**

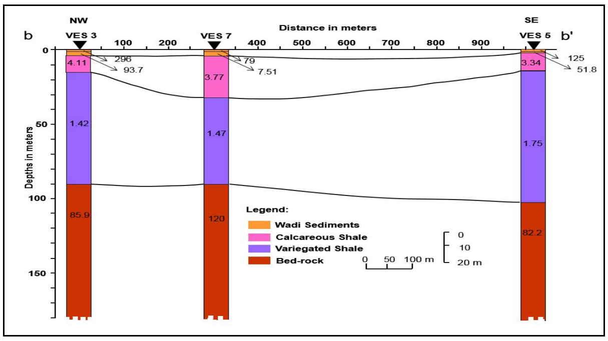


**Fig. (20): Geoelectric bar-section (b-b') of VES's 3, 7 and 5.**

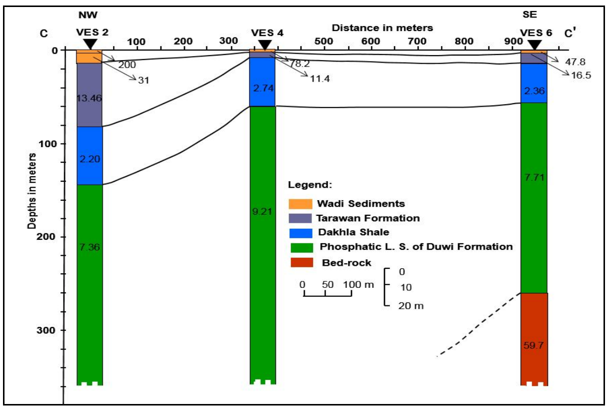


**Fig. (21): Geoelectric bar-section (c-c') of VES's 2, 4 and 6.**

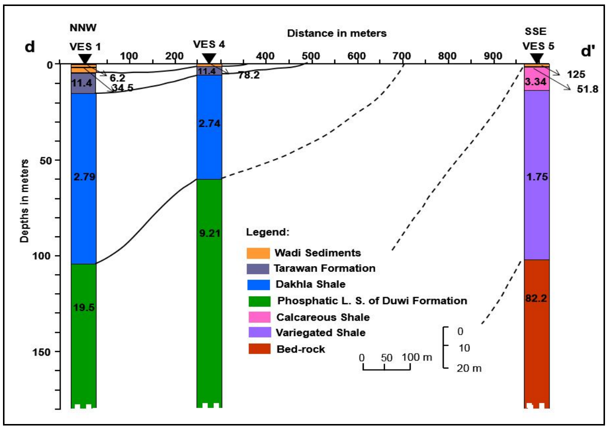


**Fig. (22): Geoelectric bar-section (d-d') of VES's 1, 4 and 5.**

## SUMMARY AND CONCLUSION

The ground magnetic data shows the structural elements in the study area that are oriented mostly in NNW, NW, N-S, NE and NNE directions as predominant trends and WNW and ENE as secondary trends. Also the 3D Euler deconvolution emphasis that the thickness of the basin increases toward the north and northwest of the study area as the estimated depths reach greater than 150 m.It is restricted by the asymmetrical synclinal fold coincides with the increasing in the thickness of the Tarawan, Dakhla and the Duwi formations. The Dakhla shale (oil shale bearing formation) is found beneath the central and northern parts of the study area as deduced from the geo-electrical observations reaches to 88m in thickness and extends horizontally to 700m, while the Quseir variegated shale is mainly occurred along the western part of the study area.

## REFERENCES

**Abdel Baki, A.M.A., (1983):** “Hydrogeological and hydrogeochemical studies in the area west of Rosetta branch and south El-Nasr canal” PH.D. Thesis, Fac. Sci., Ain Shams Univ. 156p.

**Abd El Rahman, A.A., (1996):** “Geophysial study on the groundwater conditions in the area southwest of the Nile Delta between Abu Raoash and El Khatatba road” M.SC. Thesis, Fac. Sci. Ain Shams Univ. 116p.

**Ahmed, K.A., (2002):** " Hydrogeological studies on the groundwater aquifers in the northwest Cairo", Ph. D. Thesis, Fac. Sci. Al Azhar Univ. 113P.

**Al Temamy, A.M.M. and Barseem, M.S.M. (2010):** Structural impact on the groundwater occurrence in the Nubia Sandstone aquifer using geomagnetic and geoelectricalalalal techniques, northwest Bir Tarfawi, East El Oweinat area, Western Desert, Egyptian Geophysical Society (EGS) Journal, Vol. 8, No. 1, pp. 47-63.

**Attia, S.H. (1975):** Pedology and soil genesis of Quaternary deposits in the region West of the Nile

Delta (Northeast of Wadi El Natrun Ph.D. Thesis, Fac. Sci. Ain Shams Univ., 228p.

**Bhuyan, K., and Passey, Q.R. (1994):** ”Clay estimation from Grand Neutron-Density logs” Trans. SPWLA 35 th Annual logging symposium. Paper DDD. 12P.

**Continental Oil Company CONOCO (1987):** Geologic Map of Egypt 1:500 000 series, Sheet.

**Desert Research Center (1991-2013):** Geoelectrical studies on some areas of Cairo – Alex. High Way, Egypt. Internal Reports, Publications of the Desert Research Center.

**El Abd, E.A., (2005):** " The geological impact on the water bearing formations in the area southwest Nile Delta,Egypt" Ph.D. Thesis, Fac. Sci., Menufiya Univ., Egypt, 319 p.

**El-Badrawy, H.T. and Soliman, M. R. (2003)**: Subsurface evaluation of south Kharga Oasis area, south Western Desert, Egypt. Egyptian Geophysical Society (EGS) Journal, vol. 1, No. 1, p. 31-41.

**El Ghazawy, E.M. and Attwa, S.M., (1994):** “Contribution of some structural elements to the groundwater condition in the southwestern portion of the Nile Delta” Desert Research Center. Cairo, Egypt. P.

**Ezz El-Deen, H.M. (1999):** “Implication of the subsurface structures on the groundwater aquifers in the area between Km 38 and Km 46, Cairo-Alexandria Desert Road” pp. Bull. E.G.S. Proc. of the 6th Ann. Meet. P.111-130.

**El Shazly, E.M., Abdel Hady, M.A., El Ghawaby, M.A., El Kassas, I.A., Khawasik, S.M., El Shazly, M.M., and Sanad, (1975):** “Geologic interpretation of landsat satellite images for West Nile Delta area”: Remote Sensing Center, Academy of Scientific Research and Technolog, Cairo, Egypt, p.38

**Gomaa, M.A.A. (1995):** Comparative hydrogeological and hydrogeochemical study on some aquifers, West of Nile Delta, Egypt. Ph.D thesis, Fac. Sci., Ain Shams Univ., Cairo, Egypt, p.236.

**IPI2Win Program (2003):** Programs set for 1-D VES data interpretation. Dept. of Geophysics, Geological Faculty, Moscow University, Russia

**Mabrouk, M.A. (1998):** “Possibilities and limitations of recognizing the Tertiary basalt on the apparent resistivity curves, southwest Nile Delta area, Egypt” Mansoura Sci. Bull (C Nat. Sci. and Phys. Sci.), Vol. 25 (1), P. 25-40.

**Omara, S.M. and Sanad, S. (1975):** Rock stratigraphy and structural features of the area between Wadi El Natrun and the Moghara Depression, Western Desert, Egypt. Geol. Jb, Bl. 6, Hannover,: p.46-73.

**Said, R. (1962):** “The geology of Egypt” Elsvier Publishing Co., Amsterdam, New Yourk, 377p.

**Sanad, S. (1973):** Geology of the area between Wadi El Natrun and the Maghra Depression. Ph.D. Thesis. Fac.Sci. , Assiut Univ. , Assuit, Egypt, 184 p.

**Sharaky, A.M., Atta, S.A.; El Hassanein, A.S. and Khallaf, K.M.A. (2007):** "Hydrochemistry of groundwater in the western Nile Delta aquifers, Egypt" 2nd International Conference on the Geology of Tethys, , Cairo University

**Shata, A.A. (1961):** “The geology of groundwater supplies in some arable lands in the desert of Egypt. Internal report, Desert Institute, Cairo, Egypt.

**Shata, A.A., Pavlov, M., and Sanad, K.F., (1962):** “Preliminary report on the geology, hydrogeology and groundwater hydrology of Wadi Ell ?Natrun and adjacent areas”: Internal report desert Institute, Cairo, Egypt, p. 159.

**Shata, A.A., and El fayoumy, I.F., (1967):** “Geomorphological and morphopedological aspects of the West of the Nile Delta with special reference of Wadi Natroun“. Desert d’Egypt; T.XVIII., No.1, p.1-28.

**Steiber, R.G., (1973):** "Optimization of shale volumes in open hole logs.", Jour. Pet. Tech

**Sultan. A.S., Fernando, A.M. and Helaly, A.S. (2011):** "Integrated geophysical interpretation for the area located at the eastern part of Ismailia Canal, Greater Cairo, Egypt. Arab Jour. Geosci. P 735-753.

**Vander Velpen, B.P.A. (1988):** Computer program “Resist“, Version 1.0.t, a package for the processing of the resistivity sounding data, M.Sc. Research project, Delf. Netherlands.