

Re-Evaluation of the Geophysical Interpretation for Groundwater Exploration at Wadi Elassiuti

Sultan Awad Sultan Araffa¹, Hassan S. Sabet², Ahmed M, El Zahar³

¹ National Research Institute of Astronomy and Geophysics, 11722, Helwan, Cairo, Egypt.

² Geology Dept. Faculty of Science, Al-Azhar University, Cairo, Egypt

³ General Company for Researches and Ground water 19 Emad Elden, Cairo, Egypt.

Abstract

Assiut basin constitutes one of the most promising desert areas for the future development, especially in the Eastern Desert side of the basin at Wadi El-Assiuti area, due to its water potentials and reclaimable soils. Magnetic and geoelectric methods were used in this investigation to determine the groundwater aquifers, detecting the thickness of the sedimentary deposits, defining the depth of the basement rocks and delineating the subsurface structural elements in the study area. The aeromagnetic data used in the present investigation is a part from sensitive aeromagnetic survey over the Eastern Desert of Egypt conducted for the Egyptian General Petroleum Company (EGPC) by Aero Service Division, Western Geophysical Company. The data were processed by using Oasis Montaj. Reduction to the Pole (RTP), Euler Deconvolution, 2D and 3D magnetic Modeling were established to construct basement relief map. The depth to the basement rocks in the study area is ranging from about 2000 m to over 400 m. The major trends of the study area are E-S and NE-SW and NW-SE. Twenty-Nine Vertical Electrical Sounding were measured to estimate the groundwater aquifer in the study area. The results of quantitative interpretation indicated the presence of water-bearing layer which composed of sand, clayey sand and sandy clay intercalations (Quaternary Aquifer) with variable thickness ranging from 150 m to 250m.

Introduction

Wadi El-Assiuti is one of the most important wadies in the Eastern Desert of Egypt its entrance lies to the east of Assiut City, east the Nile flood plain. The area of study is bounded by latitude $27^{\circ} 5'$ and $27^{\circ} 20' N$ and longitudes $31^{\circ} 15'$ and $31^{\circ} 30' E$ with general E-W direction (Fig.1). The Width of Wadi El-Assiuti at its gorge is about 14 km, decreasing gradually upstream. It has about 186 km length and about 10 km width and covers an area of about 7127m². Topographically, the low land ranges between contour lines 50 and 180 m and is surrounded by the high land which represents the carbonate plateau. It ranges in elevation between 200 and 450 m above main sea level. Different geological, geophysical and hydrogeological studies were carried out by many authors on the area of the study and its neighborhood such as Said (1962), Youssef et al., (1977). Elbassyony (1978), Bakheit (1989), El-Gamili (1964), (1986) Rizkalla (1989). And many others.

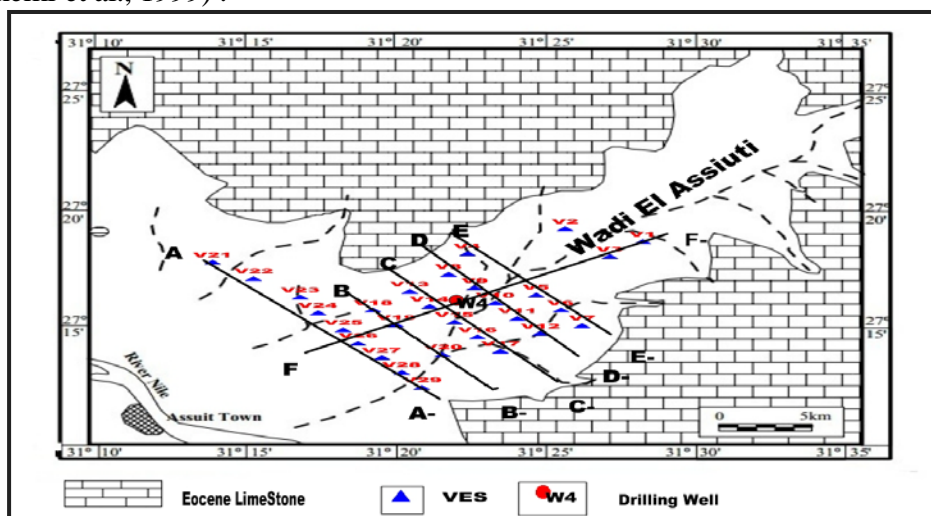
Geologic setting

Stratigraphically, Wadi El-Assiuti is mainly covered by Plio-Pleistocene sediments concealing Lower Eocene limestone bed rock (Fig.2). It is bounded by the Eocene limestone scarps from the north, south and east, and by the Nile flood plain from the

west. The wadi drains southwestward into the present River Nile. According Said (1981&1990), Mansour and Philobos (1983) the litho stratigraphic unit as follows:

1. **HOLOCENE:**The Holocene Sediments(Fig .3) include (a) Recent wadi deposits comprise the sand and gravel of wadi filing , out - wash and fanglomerate. These sdiments cover the great part of the surface of Wadi El –Assiuti.(b) Arkin Formation is made up of silty clay layer with a maximum thickness 20 m ,silty clay layer forms the traditional agriculture clay layer in the Nile Valley of Assiut area.
2. **MIDDLE - UPPER PLEISTOCENE :**The Middle and Upper Pleistocene rocks comprise the Abbasia , Dadara, and Qena Formations (Fig 3). The Abbasia Formation consists of gravel with little sand.Tha Dandara Formation is built up of sand silt intercalated with silt. The Qena Formation comprises cross-bedded, graded sand and gravel with clay lenses. the Middle and Upper Pleistocene sediments unconformable underlain the previously silt clay layer and are considered as the main Quaternary aquifer in Assiut area. These sediments are also exposed at the mouth of Wadi El-Assiuti (Fig. 2).
3. **LOWER PLEISTOCENE :**The Lower Pleistocene rock comprise The Issawia, Armant, and Idfu Formations (Fig 3). Issawia Formation is built up of sand and clay beds capped by red breccia and travertine layers. The Armant Formation is composed of clay, sand, and conglomerate beds. Both the Armant and Issawia Formations are exposed in Wadi El-Assiuti (Fig.2) The Idfu Formation consists of cobbles and gravel in clayey matrix.
4. **PLIOCENE :**The Pliocene rocks are highly enriched in clay facies with few sand beds . These rocks are located at the central part of Wadi El-Assiuti.
5. **EOCENE** The Lower and Middle Eocene rocks consists of limestone and chaiky limestone with chert bands. The rocks which form the plateau bounds the Nile Valley from both sides (Fig.2 and Fig .3).

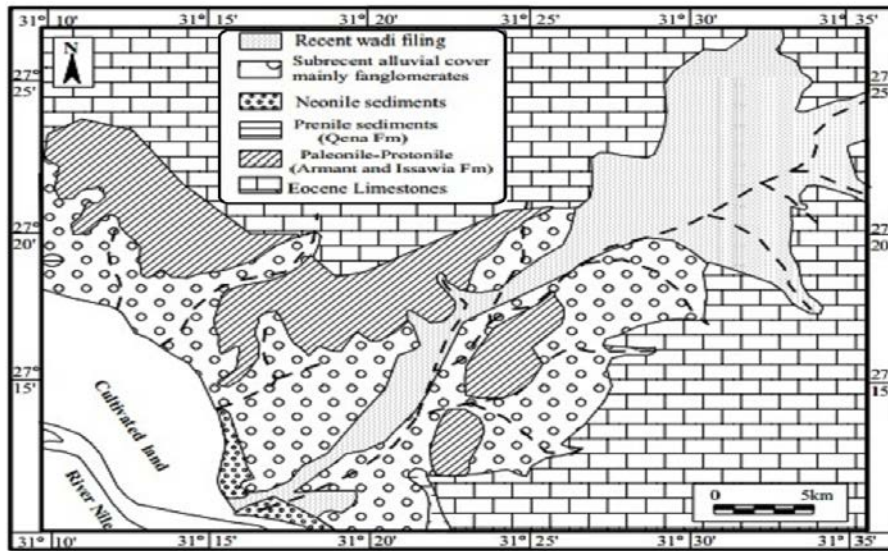
Structurally the study area is a part of the Nile Valley and lies within the stable shelf of Egypt (Said 1961and 1962) where the major surface features are reflection of basement lines and the main fault systems are NW, NE and NS (Youssef, 1968 and El-Shemi et al., 1999) .














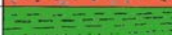
(Fig.1): Location Map of The Study Area

Methodology

Two geophysical tools ; Aeromagnetic and Vertical Electrical Sounding have been carried out on the study area . Aeromagnetic method was applied to delineate the structural element and the depth of the basement rocks which refers to the thickness of sedimentary cover of the study area. Twenty - nine vertical electrical soundings (VES's) [with AB/2 ranged between 1.5 m and 500 m] were carried out in the area of study by using JESSE electric through Wadi El-Assiuti project by RIGW staff to detect the depth of water bearing formation (Quaternary aquifer).



(Fig.2) Geologic Map of the Study Area (After Said 1981)

Age		River stages	Formation	Lithology	Description	
Quaternary	Holocene	Neogene	Wadi out-wash		Gravel And Sand	
			Arkin		Silty Clay of Cultivated Lands	
	Pleistocene	Middle - Late	Preneogene	Abbassia II		Conglomerate
				Dandara		Sandy Silt and Silt
			Abbassia I		Conglomerate	
			Qena		Massive Cross- bedded Sand With clay lenses	
		Early	Proto./Preneogene	Issawia		Tuff, red breccia and sand
				Armant		Clay ,Sand, and conglomerate
	Tertiary	Pliocene	Paleogene	Idfu		Cobbles and Gravels in red Clayey Matrix
				Madamud		Red Brown Clay ,Sand, Silt and Marl
Early			Marine sequence		Clay and Sand	
Eocene	Early-Middle				Chalky Limestone bed with Cherty Babns	

(Fig.3): Composite Stratigraphic Cross Section of the Study Area (After Said 1981 and 1990)

Aeromagnetic data acquisitions

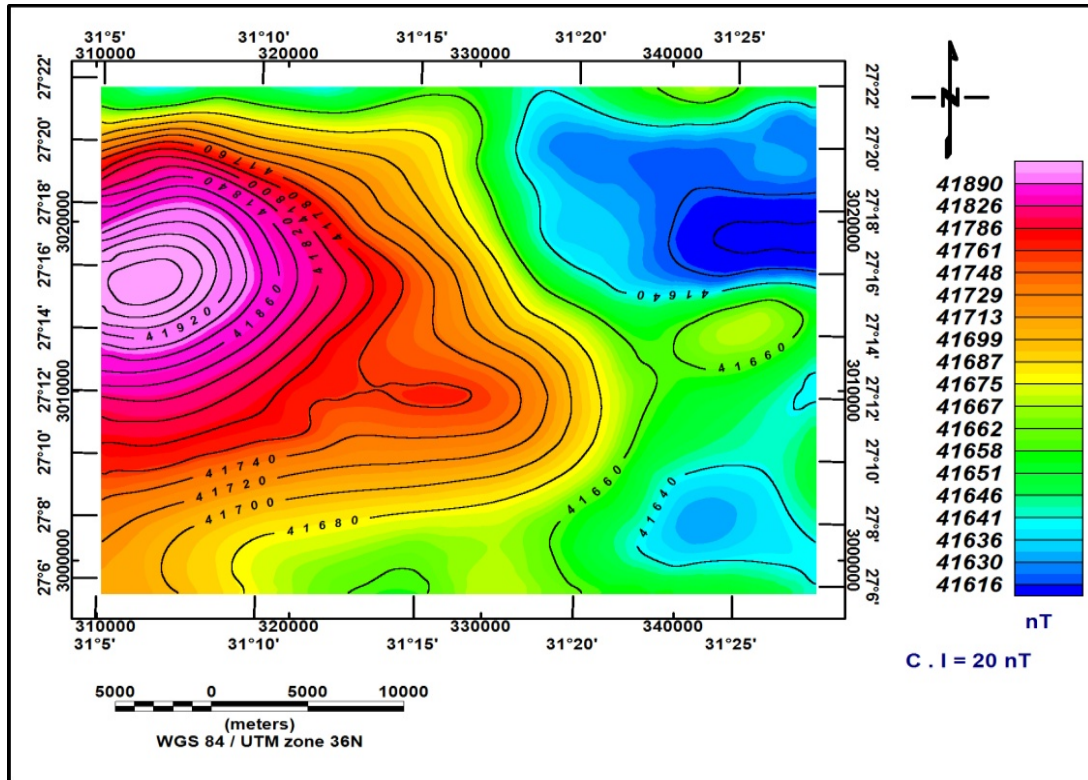
The aeromagnetic data is provided by the Western Digital Company (1983). These data were corrected prior to our working with them. Different processing methods are applied to the aeromagnetic data. The processing in this study was preliminary carried out by reduction of the magnetic northern pole (RTP), in order to overcome the undesired distortion of the shapes, sizes and locations of the magnetic anomalies; an average magnetic inclination of 39° was used for the area, to eliminate the obliquity of the inclination of the earth's magnetic field. Euler deconvolution were used to delineate the structures affected on the area. The analysis and processing of the aeromagnetic data were done through specialized computer program Geosoft: (Oasis Montaj version 7.0.1, 2008). The total intensity aeromagnetic map (Fig. 4a) has magnetic anomalies values between 41610 nT to maximum value 41920 nT. The northwestern and central parts of the area reveals high magnetic anomalies due to presence of the basement rocks at shallow depth, where the while the northeastern part exhibits low magnetic anomalies where the basement rocks are at greater depths.

Magnetic data processing and Interpretation

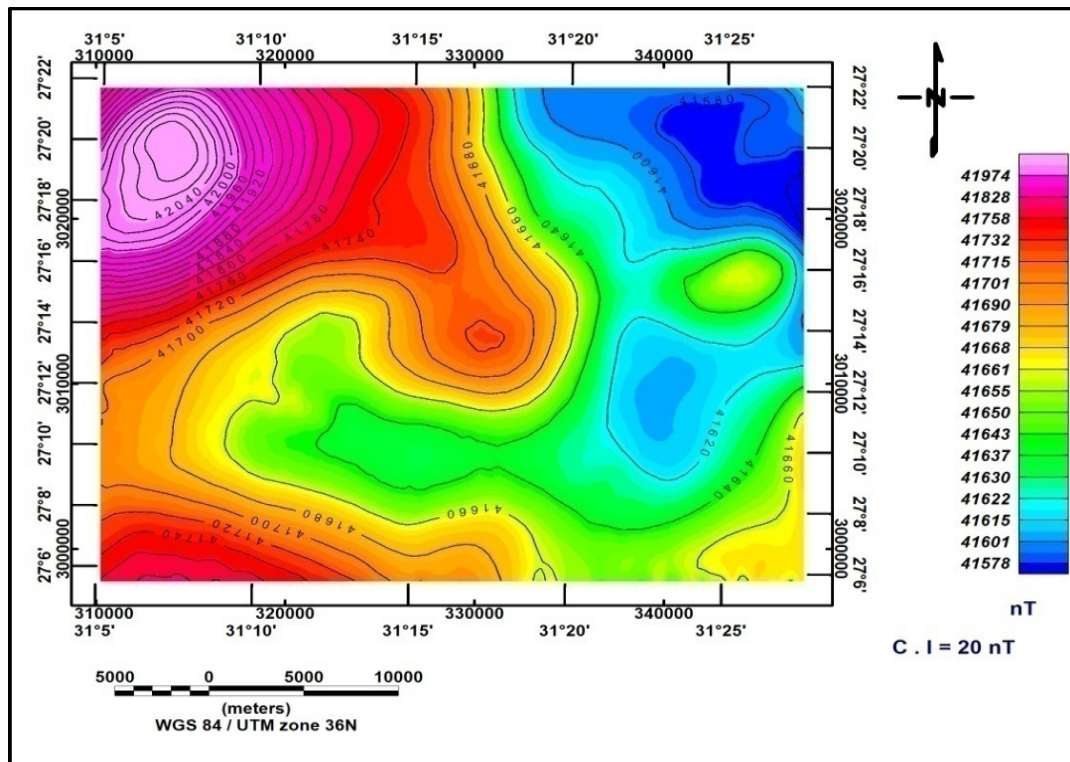
Reduction to The Magnetic Pole (RTP): The total intensity magnetic data were reduced to the magnetic pole (Fig. 4b) to overcome the distortion in anomaly appearance. This appearance depends on the magnetic latitude of the survey area and depends on the dip angle of the magnetization vector in the body by using magnetic parameters such as inclination (39°), declination (2°) and magnetic field strength (41715 nT). This mathematical procedure was first described by Baranov (1957), Baranov and Naudy (1964), Bhattacharyya (1965–1967) and Baranov (1975).

A general outlook to the reduced to the magnetic pole map (Fig. 4b) in comparison with the original total intensity magnetic map (Fig. 4a) reflects the northwestern ward shift in the positions of the inherited magnetic anomalies due to the elimination of the inclination of the magnetic field at this area. The RTP map exhibits different magnetic anomalies while ranging from 41578 nT to 41974 nT. The northwestern and southwestern parts of the area reveals high magnetic anomalies where the northeastern part exhibits low magnetic anomalies.

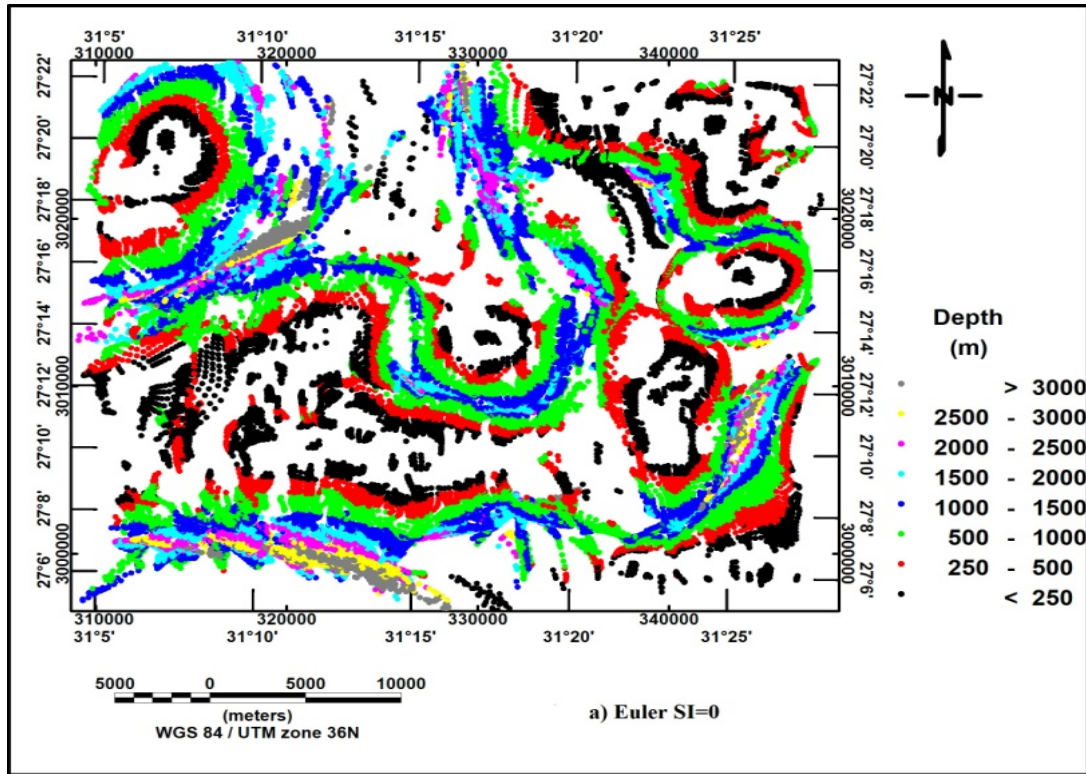
Euler Deconvolution: Euler deconvolution technique is a tool for potential field interpretation that is mainly used to determine the depths of the gravity and magnetic anomalies. Euler deconvolution technique is based on Euler's homogeneity equation. The Euler's homogeneity equation relates the field (gravity or magnetic) and its gradient components to the location of the source, with the degree of homogeneity N , which may be interpreted as a structural index (Thompson, 1982). It was applied to RTP map for different structure indexes (SI). If SI equals to zero, it refers to sill, dyke, ribbon, and step, if SI equals to 1, it refers to cylinder and pipe, and if SI equal to 2, it refers to sphere, Geosoft program (Oasis Montaj, 2008). Euler deconvolution technique was carried out on the study area by using $SI = 0, 0.5, \text{ and } 1$ providing different solutions. The best solution at $SI = 0$ (Fig 5a) which indicate on many structures as Sill, Dyke, Ribbon, and Step structure in the study area. Rose diagrams (Fig. 5e) were constructed for the interpreted structural lineaments (Fig. 5d) in order to assist in defining the principal structural trends in the prospect area of study. The general results obtained from rose diagrams of the traced structural lineaments at shallow and deep depths (Fig. 5e) can be summarized as follows: the major trends of the study area are E-S and NNE-SSW. There is also another trend N E-SW, and NW-SE.



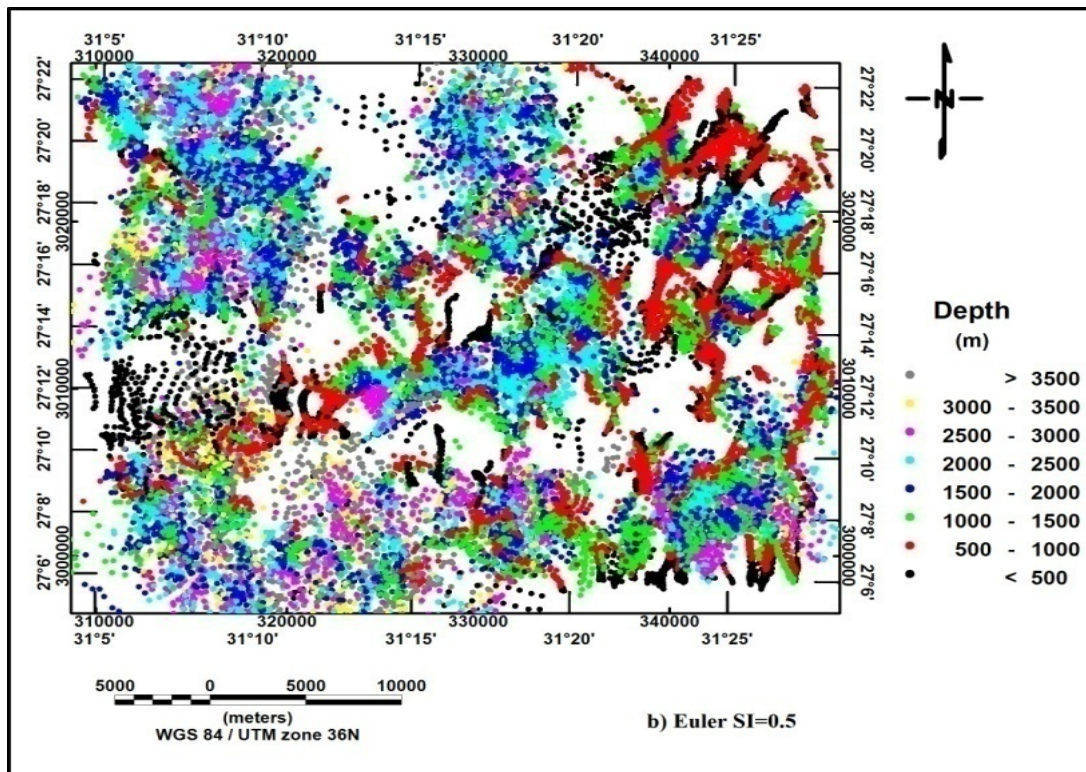
(Fig. 4a): The Total Magnetic Intensity map (TMI)



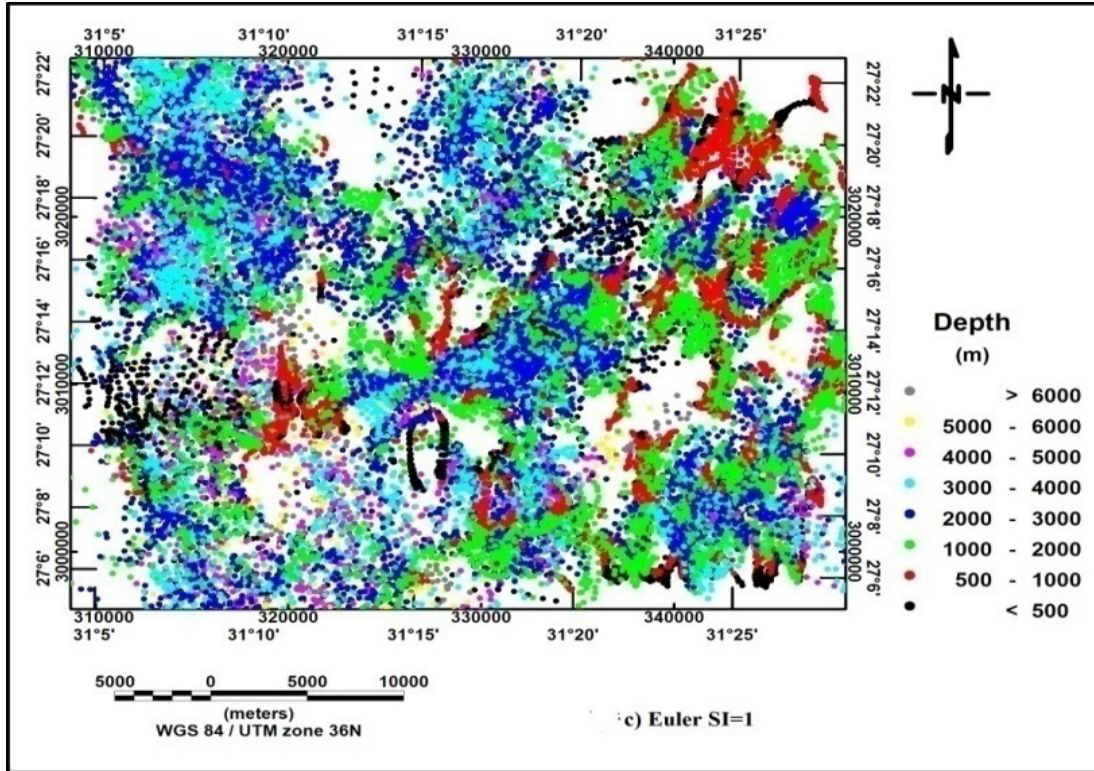
(Fig.4b): The Reduced to the magnetic Pole map (RTP)



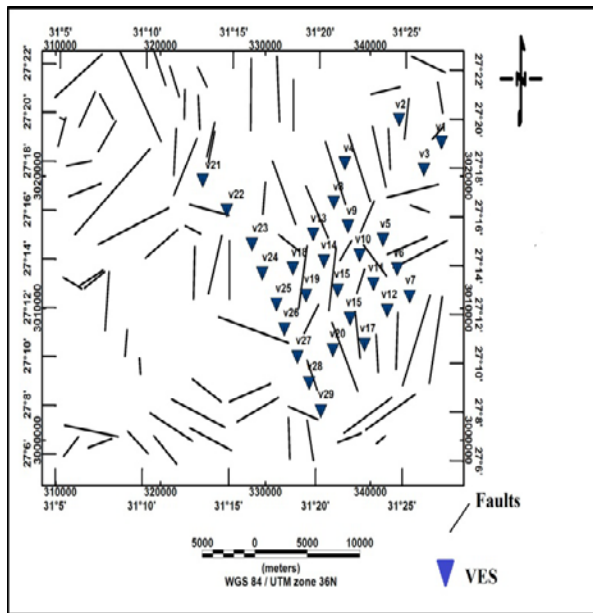
(Fig. 5a): Euler solution with SI=0.



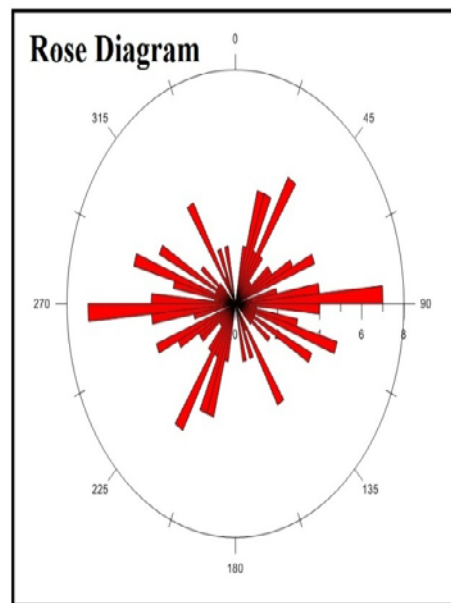
(Fig. 5b): Euler solution with SI=0.5



(Fig. 5c): Euler solution with SI=1

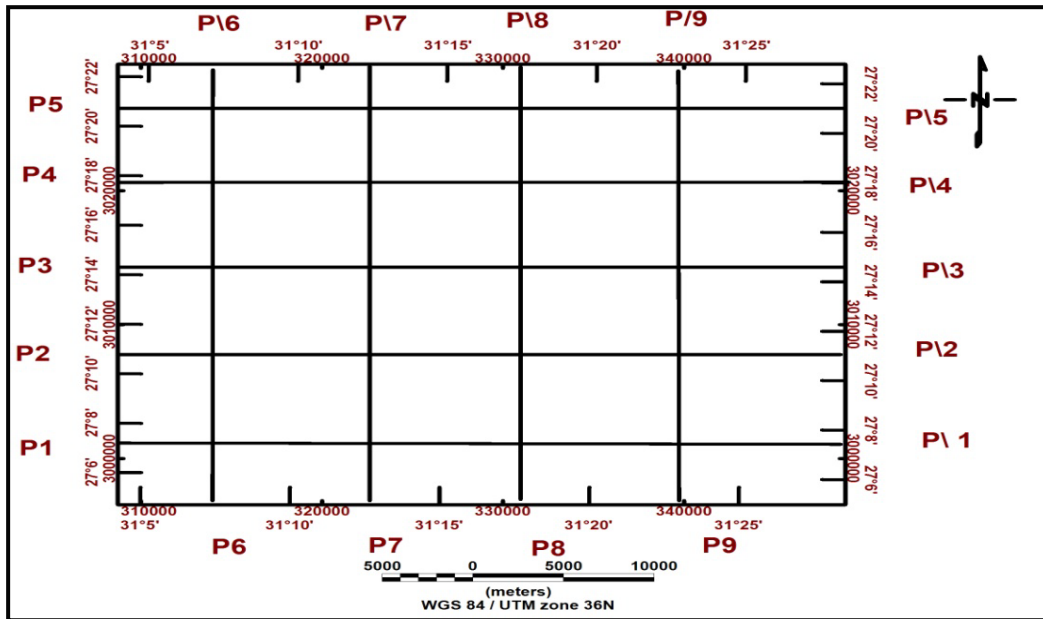


(Fig.5d): Structural lineaments as Interpreted from Euler with SI=0

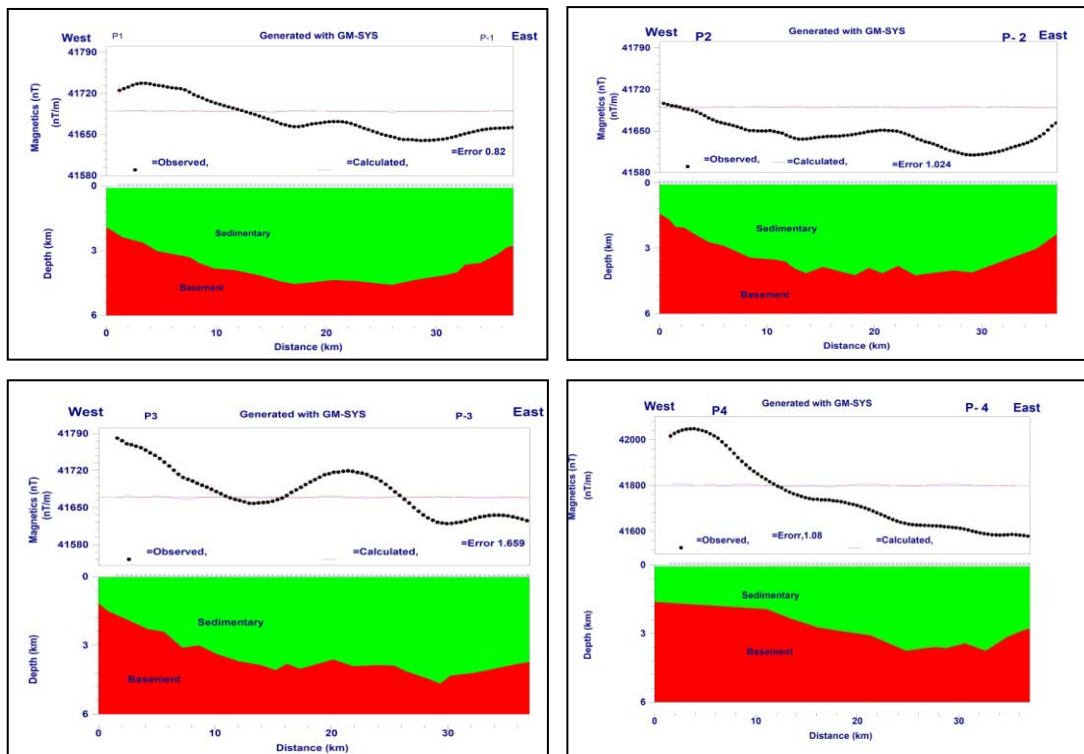


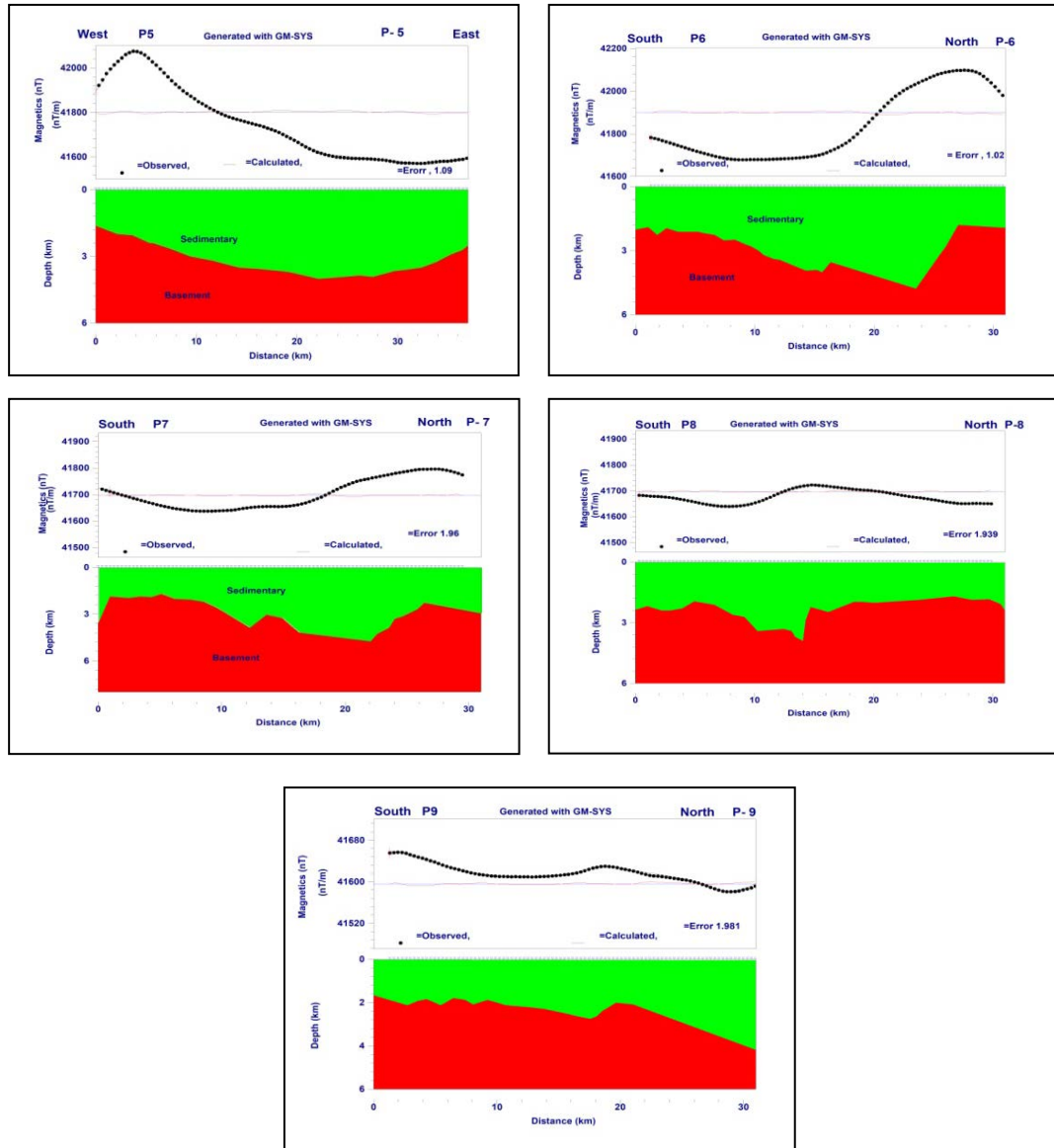
(Fig.3-14): Major Trend Faults Dissecting from Euler with SI=0

2D magnetic modeling. The quantitative interpretation of the reduced to the pole magnetic map is carried out by GM-SYS Program (2008)(Oasis Montaj, 2008). It is used to estimate the depth of the magnetic bodies by using average magnetic susceptibility 0.00075 CGS units to carry out 2-D magnetic modeling. Nine magnetic profiles were applied on RTP magnetic map (Fig. 6a). Five profiles are taken with direction from West to East, and four profiles were taken with direction from South to North. The five profiles (W–E direction) have the same length of 37 km with range of depth of basement rocks is ranging from 1680 to over 4500 m. The four profile (S–N direction) has length 31 km and depth of basement rocks range (1900–4950). So the thickness of sedimentary deposits decrease northwestern ward (Fig. 6b).



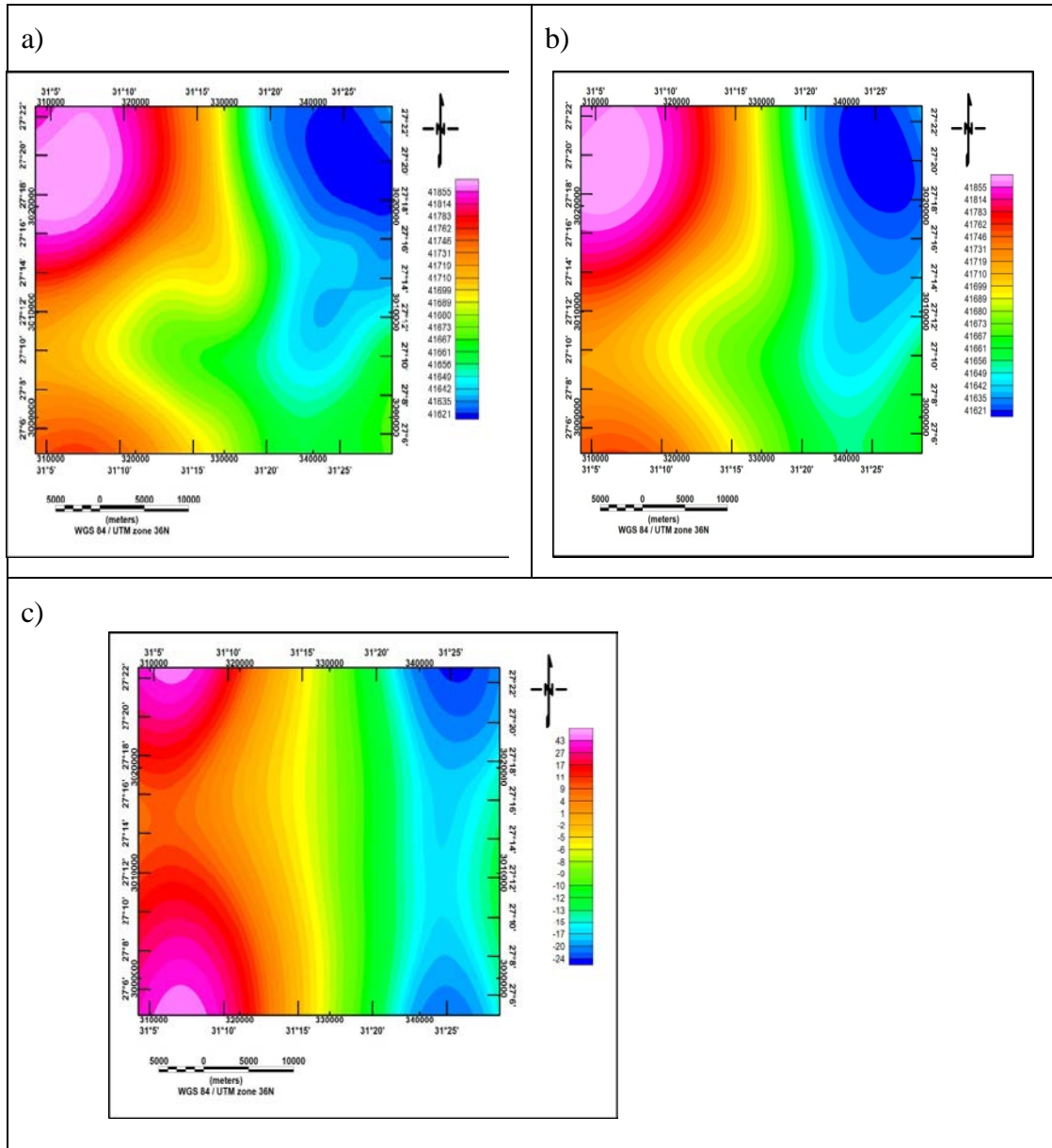
(Fig .6a.) Location of Magnetic Profiles in the Study Area.



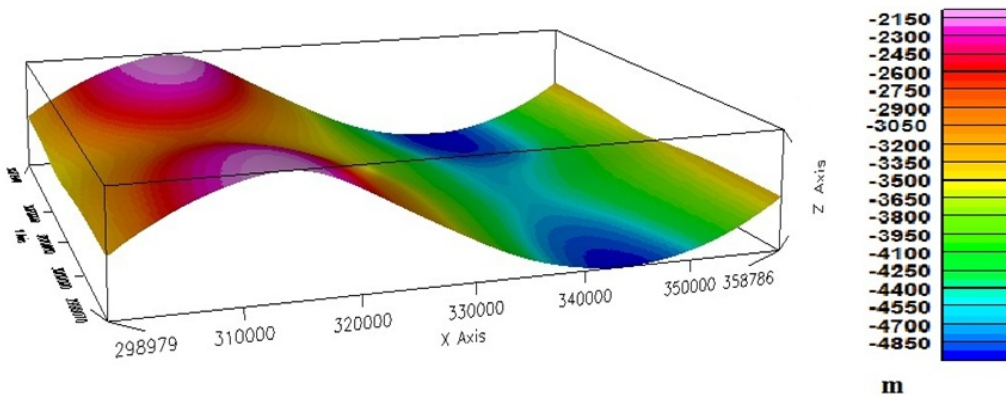


(Fig.6b). Nine Profiles 2-D modeling

3D magnetic modeling: The 3-D modeling has been used in this study the GMSYS-3D software, which is one programs of the geosoft (Oasis Montaj2008). GMSYS-3D is a 3-D gravity and magnetic modeling package for surface-oriented models. A model is defined by a number of stacked surface grids with density, susceptibility and remnant magnetization distributions specified for the layer below each surface. The final model is shown in Figs. 7and8.



(Fig. 7.) Outputs of GMSYS-3D modeling; a) observed anomalies, b) calculated anomalies and c) deviation between calculated and measured anomalies (error).



(Fig.8): The Basement Relief Map from GMSYS-3D Modeling

From the results of 3 D modeling the basement depth ranges from about 2150 m to about 4800m and these results are compatible with the results of 2 D modeling. The depth of basement found in east part of the study area is very deep which have values more than 4500 m which is indicate for thick sedimentary cover, but it decrease gradually in west direction to reach depth have values of about 1800 m.

Geoelectrical data

Electrical data acquisitions:Using Schlumberger array, a Twenty - nine vertical electrical soundings (VES's) [with AB/2 ranged between 1.5 m and 500 m](Fig.1) were carried out in the area of study by using JESSE electric through Wadi El-Assiuti project by RIGW staff at locations permitting the construction of six geoelectric cross sections. Each cross section passes through a number of VES's, added to the available water wells .

Quantitative interpretation of Vertical Electrical Soundings(VES):

Two techniques of quantitative interpretation were used to determine the true resistivity and the thickness values of successive strata of subsurface section. The first technique is the manual interpretation which depends upon matching the plotted field curves through two layers master curves and the generalized Cagniard graphs (Koefoed, 1960; Orellana and Mooney, 1966).The obtained results of the manual interpretation were used as initial models for the analytical methods by the second technique to compute the actual true resistivities and thicknesses by using the IPI2WIN program (2001)as final results (Fig. 9a,9b,9c). The IPI2WIN program was designed by a Russian scientific group in Moscow StateUniversity (MSU). The results of VESes interpretations indicated that, the number of layers in this area is three layers (Figs. 9a,9b,9c), the resistivity values have range from 3.6 to 40000 Ohm m and the thickness ranges from 2 to 150 m. The geoelectric resistivity cross-sections can be considered as vertical slices through the subsurface, which show the lateral and vertical subsurface resistivity distribution (Ismail, 2003). The results obtained from modeling of the vertical electrical soundings (VES) calibrated with all drilled boreholes data and geological information all are used to construct six detailed geoelectric cross-sections (Figure 10 and 11) .

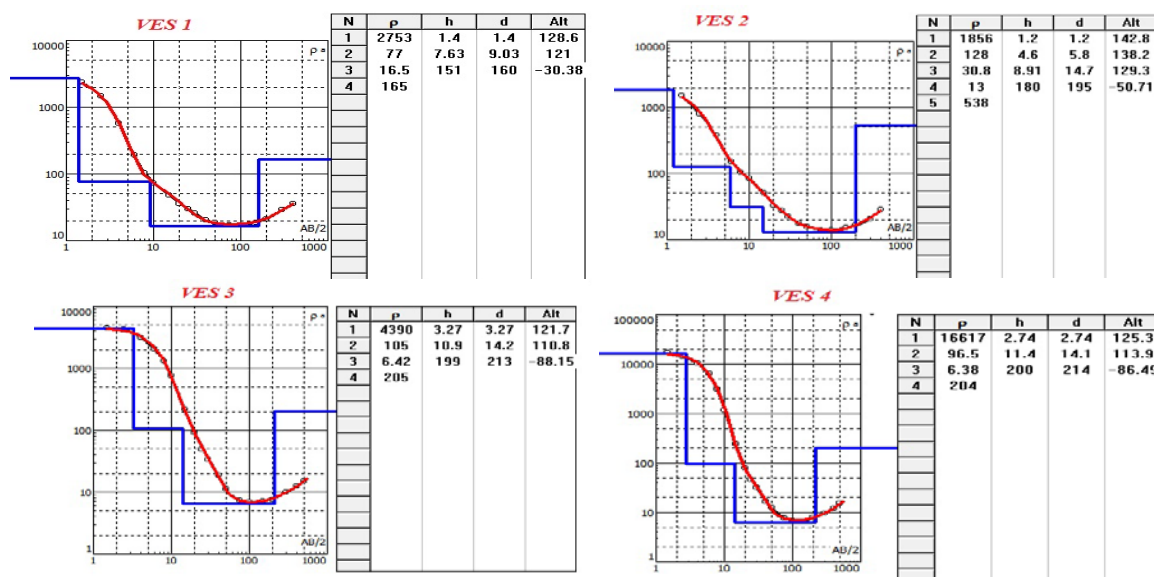
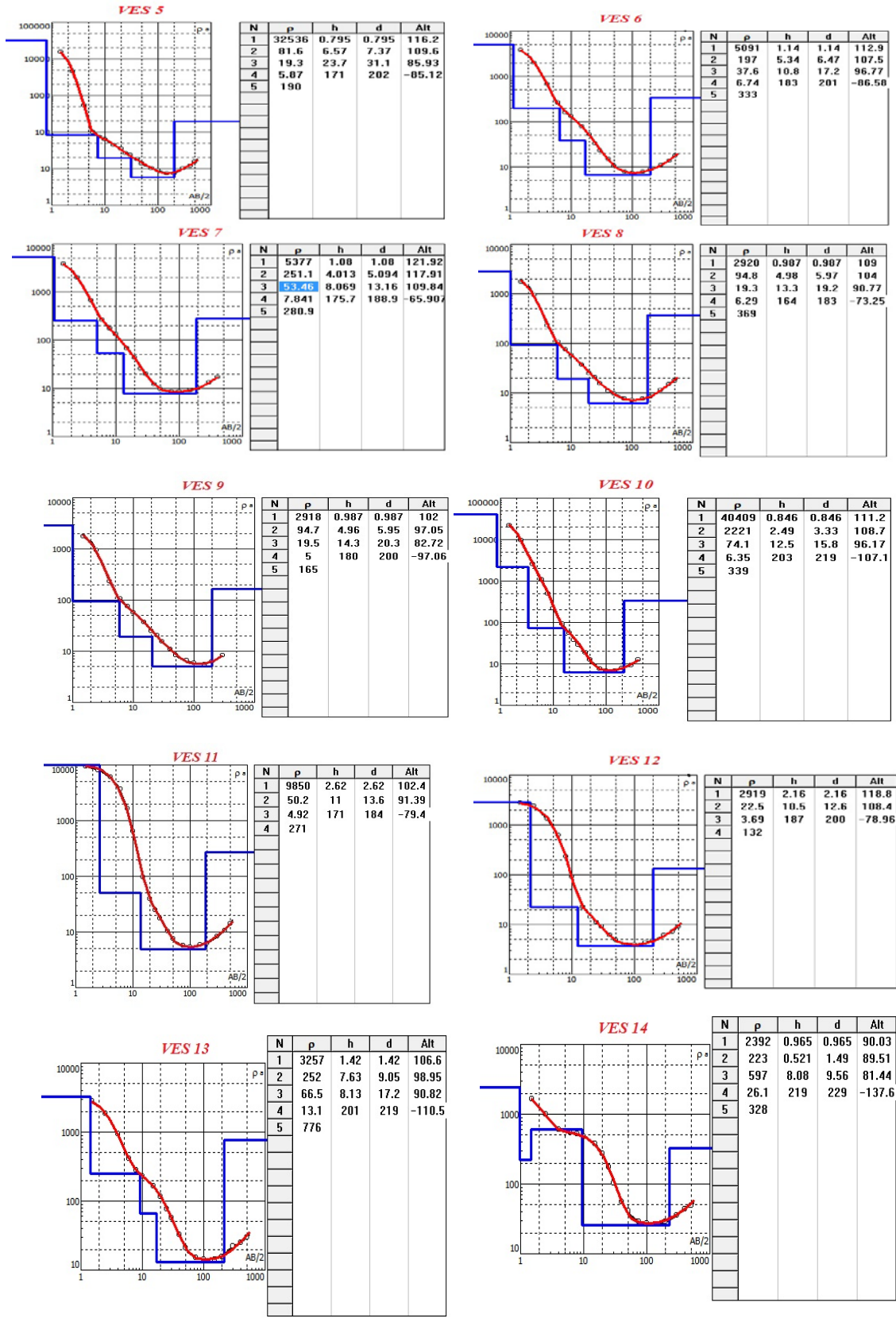


Fig.9a. Interpretation of VES Stations (Using IPI2win software)



(Fig.9b). Interpretation of VES Stations (Using IPI2win software).

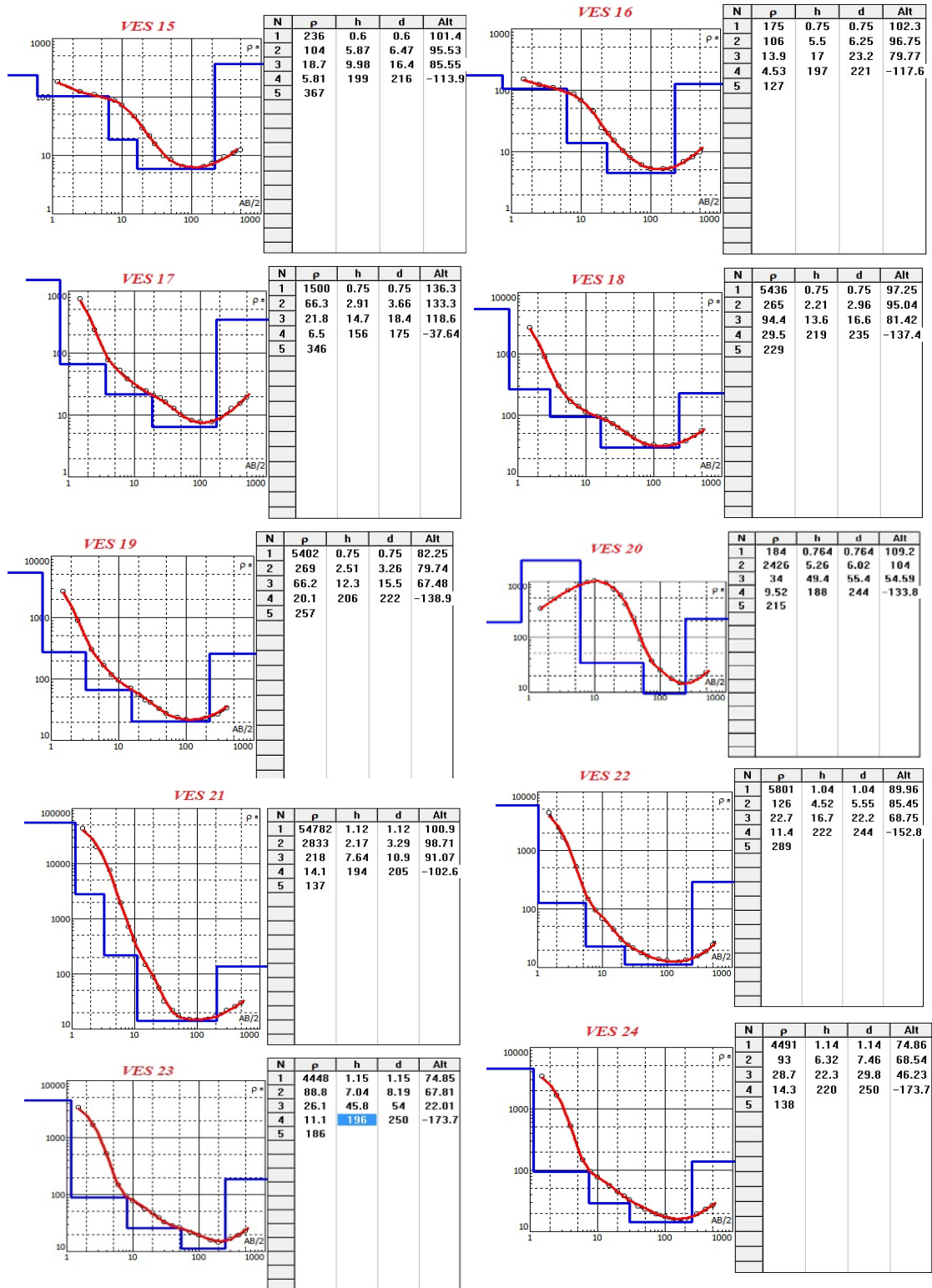
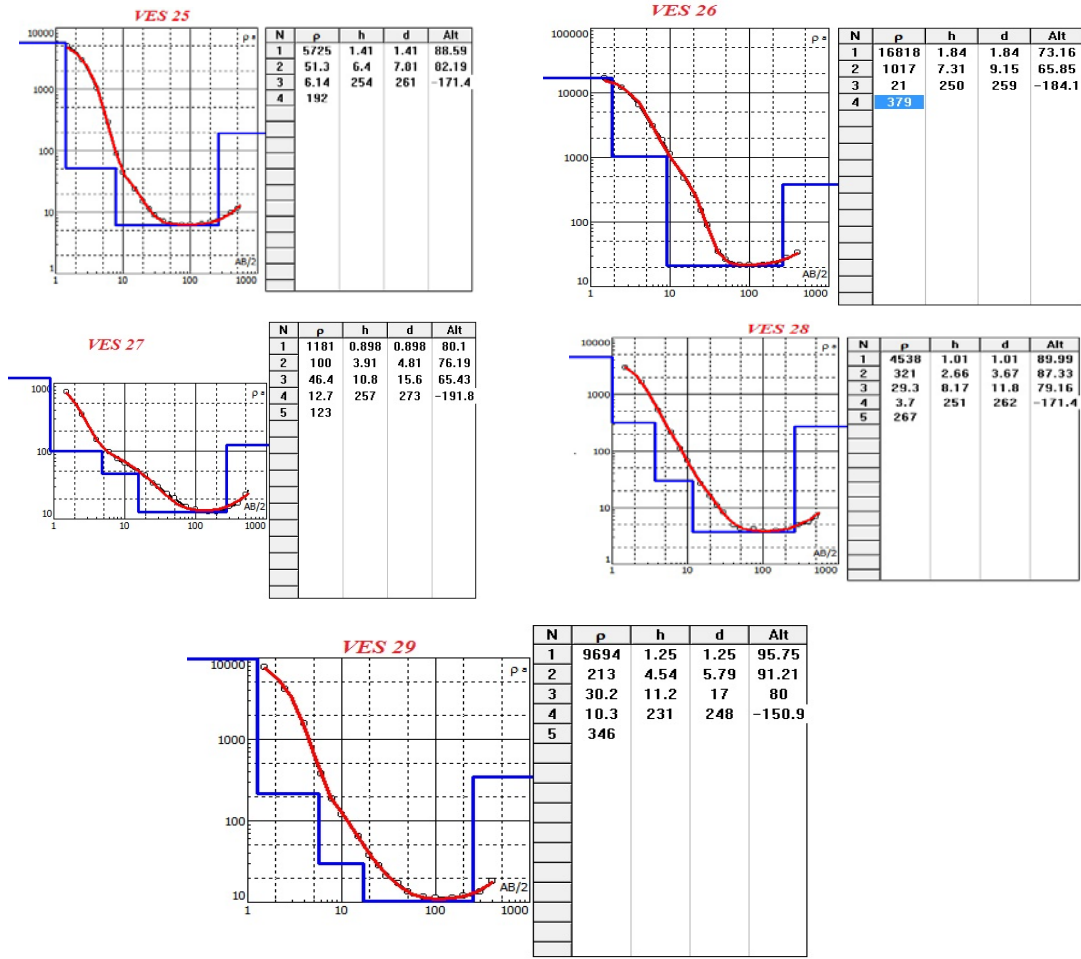
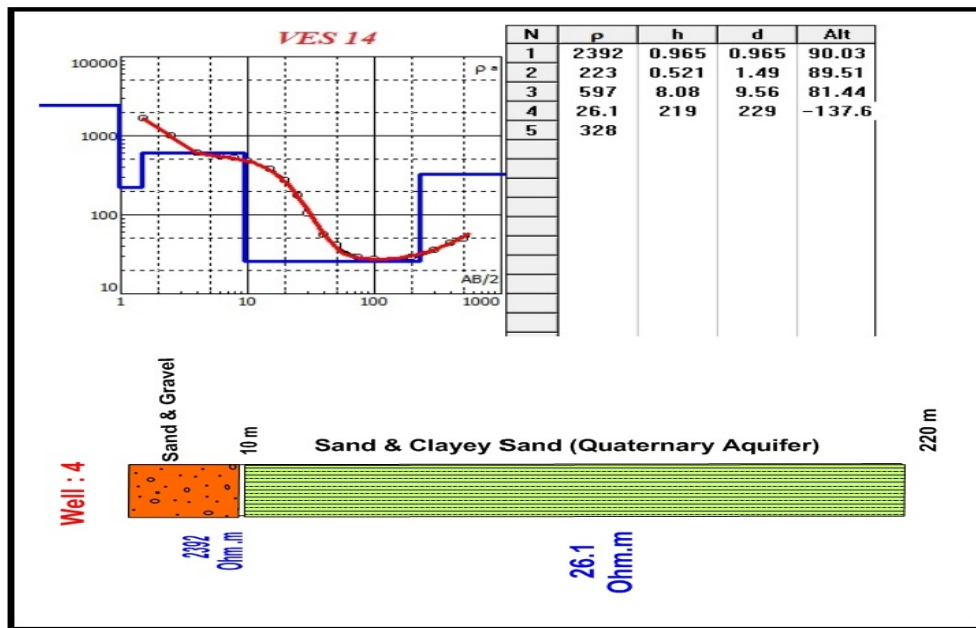


Fig.9b. Interpretation of VES Stations (Using IPI2win software)



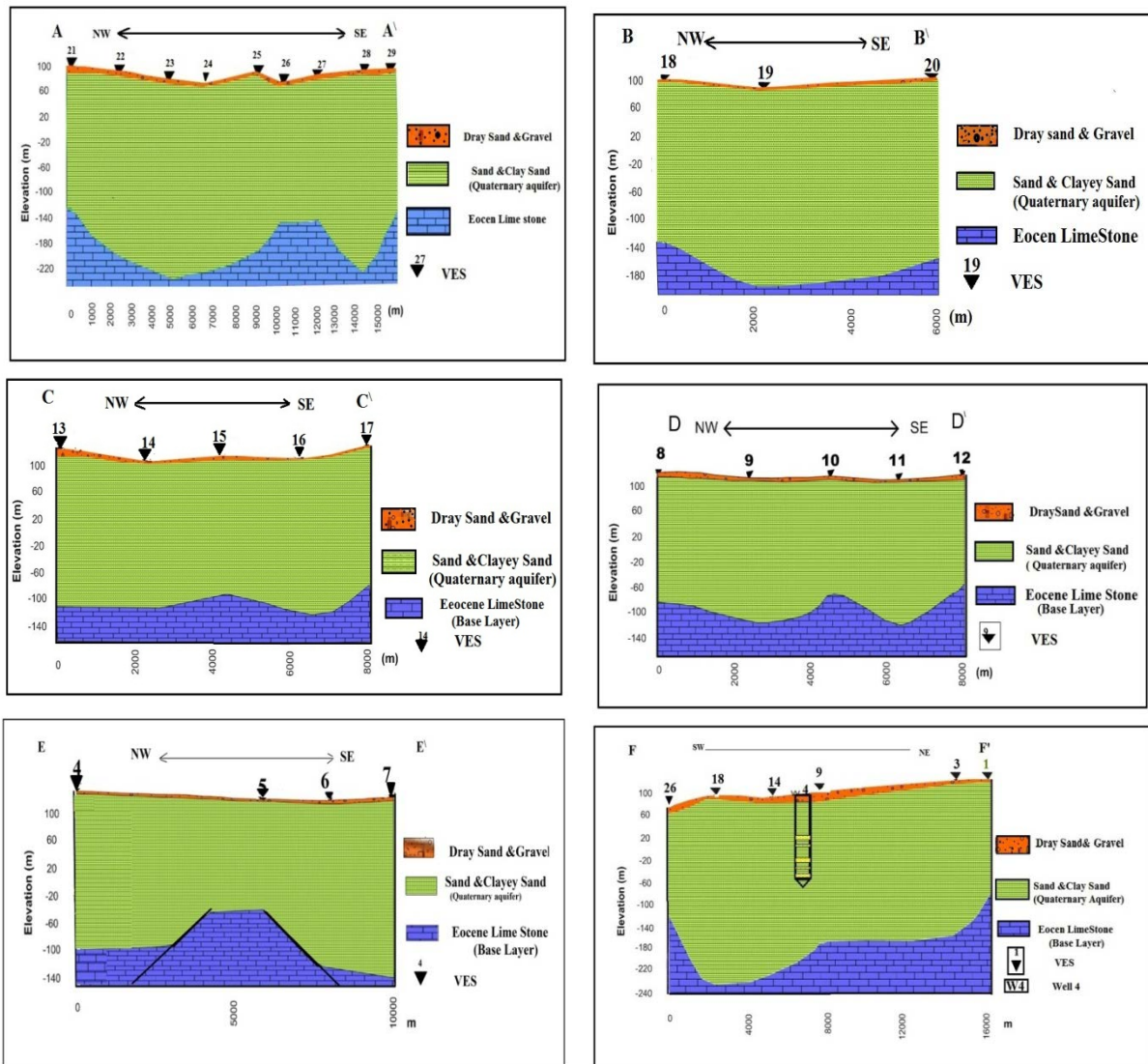
(Fig.9c). Interpretation of VES Stations (Using IPI2win software).



(Fig. 10). Comparison between Well(4) and VES No. 14

These geoelectric cross-sections shown in (Fig.11), were constructed to investigate the lithological distribution succession, these section are A-A', B – B', C-C', D-D', E-E', F-F'. The constructed geological-geoelectric sections along the six profiles lead to safely defining aquifer in Wadi El –Assiuti Area. The geoelectric survey shows that the Aquifer is characterized by three geological –geoelectrical units which are from top to base:

1. The surface one has a very high resistivity value ranging between 46 Ohm.m to 40000 Ohm. m with a thickness varying from 2 m to 17 m , and is related to dry sand and gravel.
2. The intermediate unit has low resistivity value ranging from 3.6 Ohm .m to 37 Ohm.m, and the variable thickness is ranging from 151 m to 260 m. This unit composed of sand and clayey sand and sandy clay intercalations. The drilling water wells indicated this zone to be saturated with ground water which may be present with the sand lenses.
3. The third geoelectric unit has high resistivity values 123 Ohm. m to 776 Ohm .m it is suggested to be of Eocene limestone.



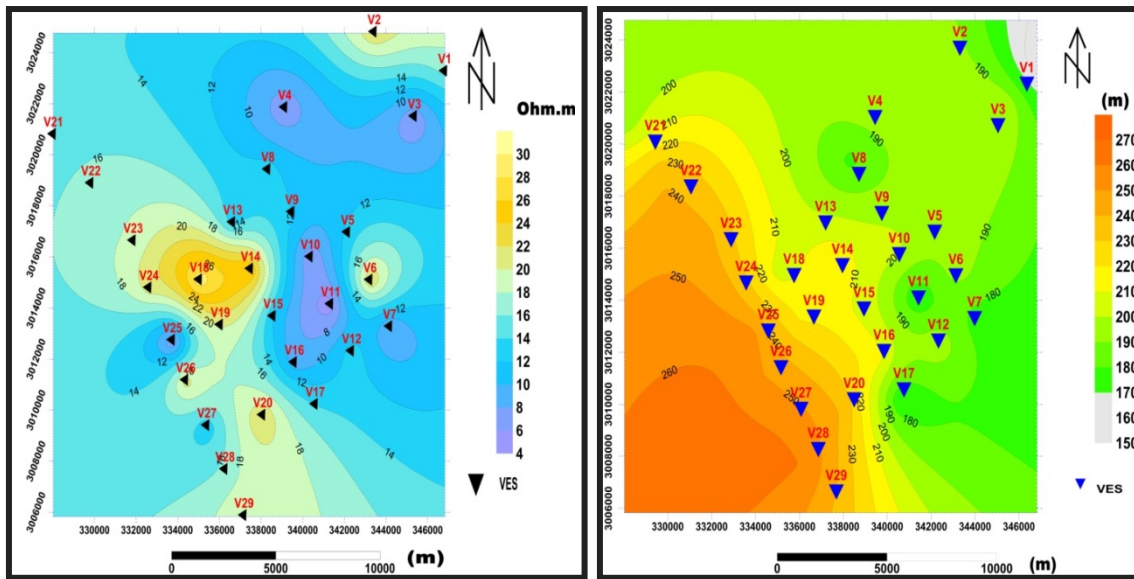
(Fig.11): Six Geoelectric Cross Section

Iso-resistivity and Iso-pach Maps of the Aquifer

The study of iso-resistivity map for Second geoelectric unit (water bearing layer) (Fig.12a). Shows that the true resistivity increase around VES 18 ,VES 19 in the northwestern part of the map due to increasing in sand content and decreasing in the central and northeastern parts of the map due to increasing in clay content .the main lithology of this unit sand and clay.

The study of Iso-pach map of water bearing layer (Fig.12b) shows that:

- 1- In general, the aquifer thickness increases in the direction of downstream of Wadi El-Assiuti and decrease toward the upstream in the east direction.
- 2- The thickest portion in the study area is located around the site VES 28.



(Fig.12 a). True Resistivity Map for Second Geoelectric unit (water bearing layer).

(Fig.12b) Iso-pach map for water bearing layer

Discussion:

The study area is located at Eastern Desert. It is suffering from lack of water. So the authors applied several geophysical methods to detect the structural elements which dissect the sedimentary cover and they recommend locations for new wells. Firstly, the magnetic method was applied to detect the thickness of sedimentary cover in the study area from determine depth of basement complex. After magnetic acquisition and make the necessary corrections to establish total magnetic intensity map reduced to the magnetic pole (RTP) which prepared for quantitative interpretations to detect the depth of basement rocks. The depth to the basement was determine by 2D magnetic modeling and by 3D magnetic modeling the basement relief map was constructed. Euler deconvolutions techniques used to determind the structure elements in the area. it showed that the study area is intersected by many faults , however the major trends of the study area are E-S and NNE-SSW. There is also another trend N E-SW, and NW-SE these faults are well correspond to the surface geological structure.Finally, Twenty-Nine Verticle Electrical Sounding were measured to estimat the groundwater aquifer in the study area . The resistivity record of VES No. 14 show high correspondence with the

boreholes data Busines Well(4) (Fig. 10).Six geoelectric resistivity cross-sections were constructed to show the lateral and vertical subsurface resistivity distribution . The integration between magnetic and electrical resistivity methods used to determine the thickness of sedimenary cover and the faults that affcted on the area .

Conclusion

From the interpretation of geophysical data we can concluded that:

- The depth of the basement rock ranging from 1800 to over 4500m.
- The major trends of the study area are E-S and NNE-SSW. There is also another trend N E-SW, and NW-SE.
- The water bearing layer in the study area (Quaternary aquifer) compsed of sand and clayey sand and sandy clay intercalations. The drilling water wells indicated this zone to be saturated with ground water which may be present with the sand lenses.
- The thickness of the Aquifer is ranging from 150 to 250 m.
- In general, the aquifer thickness increases in the direction of downstream of Wadi El-Assiuti and decrease toward the upstream in the east direction.

References

- Bakheit, A. A., (1989). Geological and Geophysical studies on the areas around wadi El-Assiuti, Eastern Desert, Egypt. Ph. D. Thesis, Geo. Dept. Assiut University., 203. P.
- Baranov, V., (1957). A new method for interpretation of aeromagnetic maps: pseudo gravimetric anomalies. *Geophysics* 22, 359–383.
- Baranov, V., (1975). Potential fields and their transformation in applied geophysics.In: *Geoexploration Monographs*, series1–6.Gebrüder, Borntraeger, Berlin Stuttgart.
- Baranov, V., Naudy, H., 1964. Numerical calculation of the formula of reduction to the magnetic pole. *Geophysics* 29, 67–79.
- Bhattacharyya, B.K., (1965). Two dimensional harmonic analysis as a tool for magnetic interpretation. *Geophysics* 30 (5), 829–857.
- Bhattacharyya, B.K., (1967). Some general properties of potential field in space and frequency domains: a review. *Geoexploration* 5, 127–143.
- El Bassyony, A.A.(1978):Structure of the Northeastern Bahariya Oasis, Western Desert,Egypt.*Geologieen Nijnbouw*,V.52.p.77-86.
- El Gamili, M. M. H (1964) "Geological and geophysical studies on Wadi El Assiuti area, Eastern Desert Egypt. MSc thesis, Dept. of Geo. Assiut University, 185. P.
- El Shemi , A.M., Setto., I., MauritsH, H.I and Abu Helkia , M.M., (1999);The Delineation of Surface and Subsurface Structures in the Area Between El Minia And Assiut , Egypt , *Bull. Fac.Sci. Assiut.Unv.*, 28(2-f) 161-190.
- GM-SYS Programs, 2008. Gravity and magnetic modeling, version 6.4.2 (HJ), Inc Suit 500, Richmound St., West Toronto, ON Canada N5SIV6.

- IPI2WIN program, version 3.1 2: 17. 10. 08 (1990 – 2008): copyright al 1990. 2010, Bobachev A.A, programs set for VEs data interofretion. Dep. Of Geophysics, geological fac. Moseeow state VnV. Fussow, 119899.
- Ismail .A.M.(2003): Geophysical , hydrological and Archaeological Investigation in the East Bank of Luxor, Ph. D. Thesis, Department of Geology and Geophysics, University of Missouri-Rolla. 211p.
- Koefoed, O., (1979): Geosounding Principles Resistivity sounding Measurements, Elsevier. Science Publishing. Company, Amsterdam.
- Mansour, H. H. and Philobbos, I: R., (1983), Lithostratigraphic classification of the surface Eocene carbonate of the Nile Valley, Egypt. Bull. Fac. Sci. Assiut University. (2/2) 129. 153).
- Oasis Montaj 7.0.1, (2008):Geosoft provides data processing and analysis (DPA) software and services for geological, geophysical, geochemical, UXO detection and environmental applications prospecting and remote sensing. Cambridge University Press.
- Orellana, E., Mooney, H.M., (1966). Master table and curves for vertical electrical sounding data. Geophys. Prospect. 8 (3), 459–469.
- Rizkalla. I.R. (1989)"Interpretation of Aeromagnetic Data around Assiut Area, Eastern Desert" Egypt, E. G.S. Proc. A. the 7th Ann. Meet March 1989. PP. 65. 76.
- Said R.(1981) "the Geological evaluation of the River Nilk" springer verlage R. 174.
- Said, R.,(1990) "The Geology Egypt", A.A. Balkeme. RoHerdam – Broof. Field, P. 734.
- Said, R., 1961. Tectonic framework of Egypt and its influence and distribution of foraminifera. Am. Ass. Petrol. Gol. Bull., 45: 198– 218.
- Said, R., 1962. Geology of Egypt. Elsevier Publishing Company, Amsterdam, the Netherlands.
- Thompson D.T.; 1982: EULDPH, A new technique for marking computer assisted depth estimates from Magnetic Data; Geophysics. Vol 47, PP. 31 – 37.
- Youssef M. I: 1968. Structural pattern of Egypt and its interpretation. The Amer. Assoc. of petroleum Geologist Bulktin, V. 52, No 4- PP. 601 – 614.
- Youssef, M.Mi Riad, S. and Mansour, H. H.,(1977) "Surface and subsurface structural study of the Area around Assiut". Egypt, Bull. Fac.sci, Assiut. Univ. PF. 293. 306.