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Integrated Geophysical Interpretation On The Groundwater Aquifer (At The North Western Part of Sinai, Egypt)

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Abstract

Different geophysical tools such as magnetic, gravity and geoelectric have been applied to detect groundwater potentiality and structural elements, which controlled a geometry of the groundwater aquifers in the study area.

The first method is Magnetic Method to determine the depth of basement rocks, which indicates on the thickness of sedimentary cover in the study area. Fifty-seven ground magnetic stations have been measured to cover the study area. The results of magnetic interpretation indicate that the basement depth have value between 1484 m to more than 5425 m in the study area.

The second method is the Gravity method to determine the structural elements, which affected on the subsurface layers in the study area. Sixty-three gravity stations carried out using Auto–Grav gravity meter. The corrected gravity values plotted to represent a Bouguer gravity anomaly map, the Bouguer gravity anomaly map is separated directly into regional and residual components, the residual gravity anomaly map used for delineation of the fault elements, the area effected by many faults which take different direction specially NE-SW direction.

The third method is Electrical method, the resistivity method is used for detecting groundwater presence and differentiating subsurface layers. Twenty vertical electrical soundings measured using ABEM SAS 4000 equipment through Schlumberger configuration of AB/2 ranged from 1.5 to 1000 m. The results of quantitative interpretation used to construct five geoelectrical cross-sections, which indicate that the subsurface sequence of the study area consists of five geoelectrical units.

From these geophysical methods, the area has many good sites for drilling wells to get out the groundwater which necessary for living, Agriculture, and development for Sinai.

Introduction

The Vertical Electrical Soundings (VESes) together with the gravity and the magnetic methods could be integrated to provide reasonable results and clear picture about the subsurface formations. The electrical resistivity method is one of the most promising geophysical tools, which is used for groundwater investigation due to its ability to provide useful information about the subsurface structure and lithology at reasonable depths mainly due to the close relationship between electrical conductivity and some hydrological parameters. Gravity method is used in groundwater exploration and in the detection of structural trends controlling the regional geometry of the groundwater aquifers (Murty and Raghavan, 2002). Magnetic method is an important tool to detect the upper surface of the basement and indirectly the thickness of the sedimentary cover. Many geophysical investigations have been carried out around the study area. Sultan and El Sorady, 2001 and Ibrahim et al, 2004 were studied groundwater potentiality at the northern and eastern parts of the study area.

Study area is located at the eastern bank of the Suez canal of northwestern part of Sinai around Al Qantara East and lies at latitudes 30° 29′ 35″ and 30° 56′ 43″ N and longitudes 32° 22′ 34″ and 32° 43′ 06″ E and represents an area of 1,648 km2 as shown in (Fig. 1)

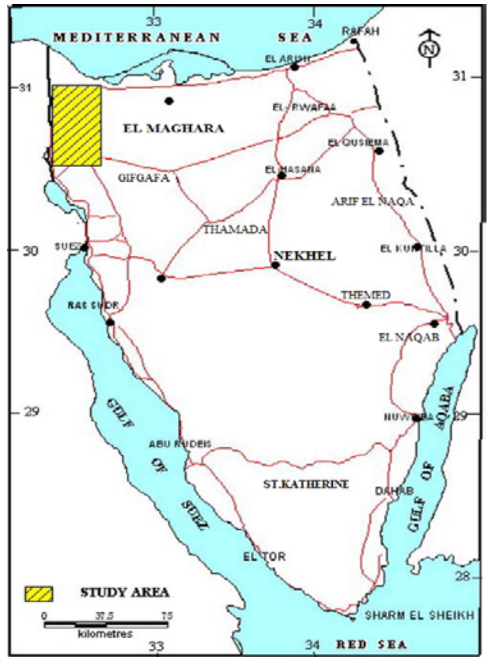

Fig.1: Location Map of the Study Area

Geology and Hydrogeological setting of the study area:

The surface geology has been described through a geological map of Sinai (Fig.2), which was constructed by UNSECO Cairo Office, 2005. The geologic units belong to Quaternary deposits were divided into Holocene and Pleistocene. Holocene include two Formations, the first is Sabakha located at western part of the area beside the eastern bank of Suez Canal and at the northwestern part of the area. The second formation is represented by sand sheet and sand dunes, where it covers most of the study area. The Pleistocene deposits represented by two Formations, the first is Al Qantara Formation which consists of sand and grill with minor clay inter-beds and the second Formation is Sehl Al Tinah Formation.

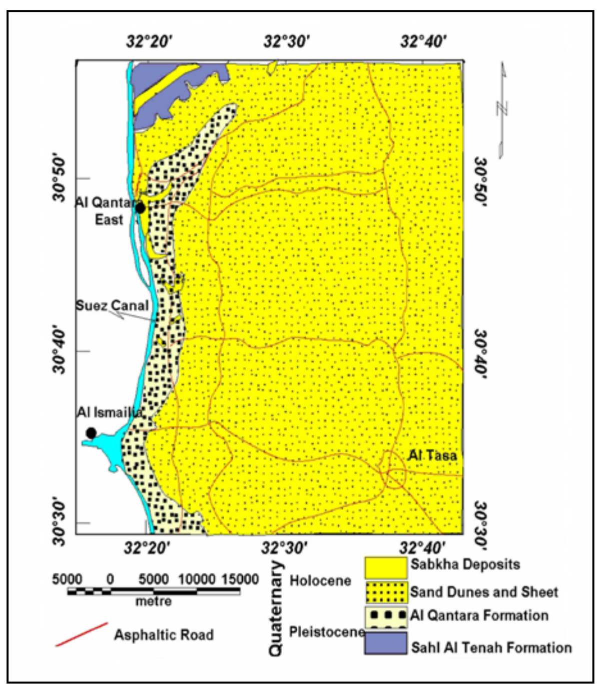

Fig. 2: Geologic Map
(Modified after UNSECO Cairo Office, 2005)

The Quaternary deposits (Holocene and Pleistocene) constitute the important water-bearing formations in the northwestern Sinai area. These deposits consist mainly of loose sand with few clay intercalations .The thickness of such deposits increases towards the west. The Quaternary groundwater exists under free water table condition. Generally, the groundwater is flowing towards the northwest. The water salinity increases in the direction of groundwater flow, the low water salinity is due to direct recharge from El-Sheikh Zayed Canal which supply fresh water to this area, also rainfall is the principal source of groundwater recharge. The average annual rainfall ranges between 80 mm/year to 90 mm/year. The study area is bounded from its northern and western sides by the Mediterranean Sea and Suez Canal (including the bitter lakes) respectively. The presence of such big salt water exposures affects greatly the groundwater regime of the study Area. There are two aquifers, the first aquifer at the second geoelectrical units with thickness range from (4.5 m to 75 m), the lithology of this layer consists of sandstone. The second aquifer at the fourth units with thickness range from (9 m to 137 m) and consists of clayey sand.

Methodology

Three geophysical tools; magnetic, gravity and electrical resistivity, have been carried out on the study area. Magnetic method was applied to determine the depth of basement rocks which refers to the thickness of sedimentary cover of the study area. Gravity tool was applied to detect the structural elements dissecting the study area. Electrical resistivity method was applied to detect groundwater potentiality and differentiating subsurface layers in the study area.

Magnetic data

Magnetic data acquisitions.

Fifty seven ground magnetic stations have been measured to cover the study area, using Envi-mag proton magnetometer (Scintrex) of sensitivity 1nT, two instruments were used, one for field work measurements and the other one for base station recording to estimate diurnal variation correction. After making data acquisition, we must make different corrections as Diurnal variation correction and (IGRF) geomagnetic corrections to reduce the noise. Then the corrected data are stored in the computer to carry out the gridding and contouring processes by Oasis Montaj Programs, 2008 to produce the total intensity magnetic map with contour interval of 10 gammas (Fig. 3)
The total intensity land magnetic map has magnetic anomalies values between 42003.1 nT to maximum value 42240.6 nT. The total intensity magnetic anomalies can be grouped into different types according to their magnetic anomalies values. High magnetic anomalies which concentrated in the north and east part of the study area ,and one spot in the south part, their values between (42240.6 nT- 42225.9 nT), the high magnetic anomaly indicates for thin sedimentary cover and shallow basement relief in this part of the study area. Low magnetic anomalies which concentrated in the southeastern part and southwestern part of the study area, and one spot in the west part, their value between (42143.9 nT – 42003.1 nT), these low magnetic anomaly is high frequency and indicates for thick sedimentary cover and deep basement relief in this part of the study area.

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In other parts are moderate magnetic anomaly which have value between (42225.9 nT – 42143.9 nT).

Magnetic data interpretation

A general outlook to the reduced to the magnetic pole map (Fig.4) in comparison with the original total intensity magnetic map (Fig.3) reflects the northward shift in the positions of the inherited magnetic anomalies due to the elimination of the inclination of the magnetic field at this area.

2-D 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 and 3-D magnetic modeling. Nine 2-D magnetic profiles were applied on RTP magnetic map. Six profiles from west to east and three profiles from south to north (Fig.6).

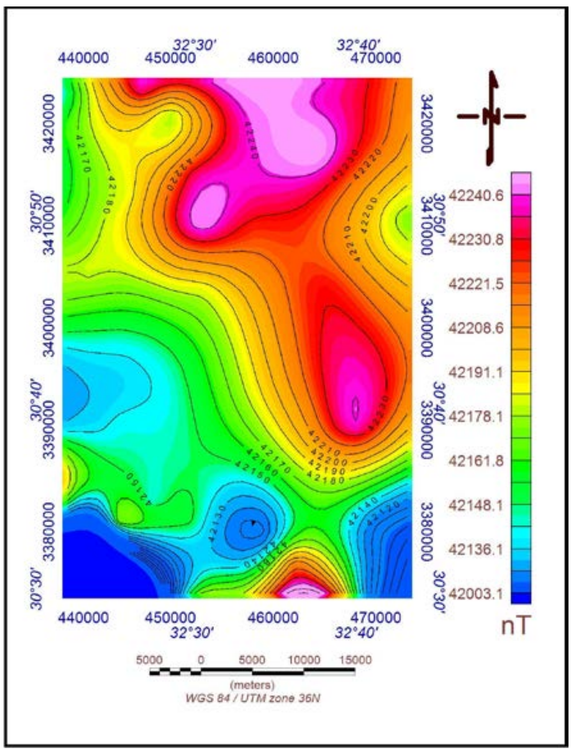

Fig. 3 : Total intensity magnetic map

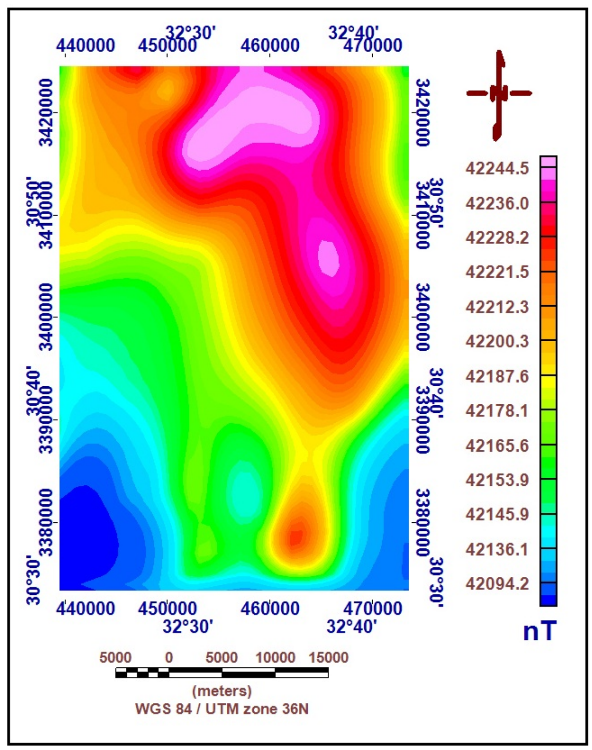

Fig. 4: Total Intensity Magnetic Map Reduced to the Pole (RTP Map)

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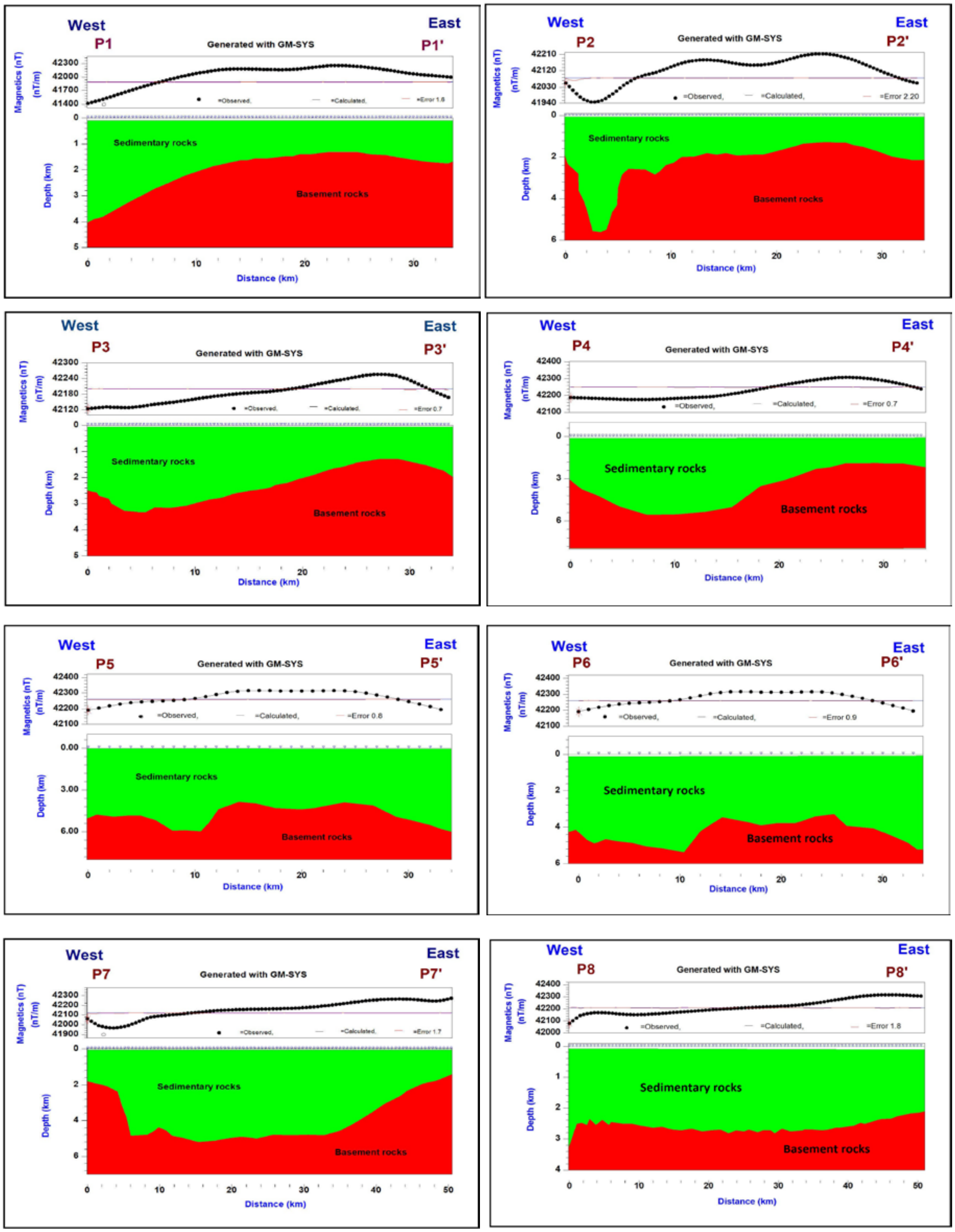

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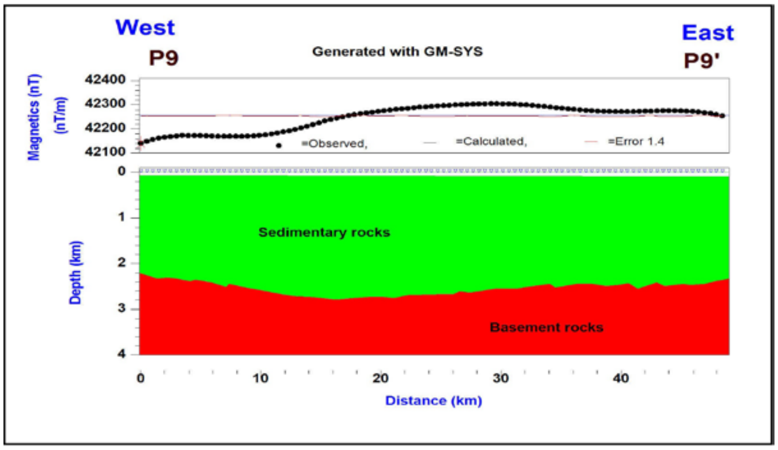
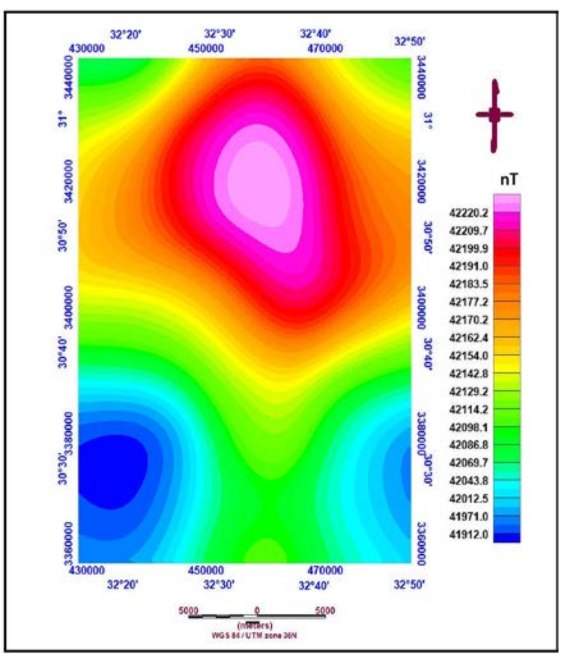
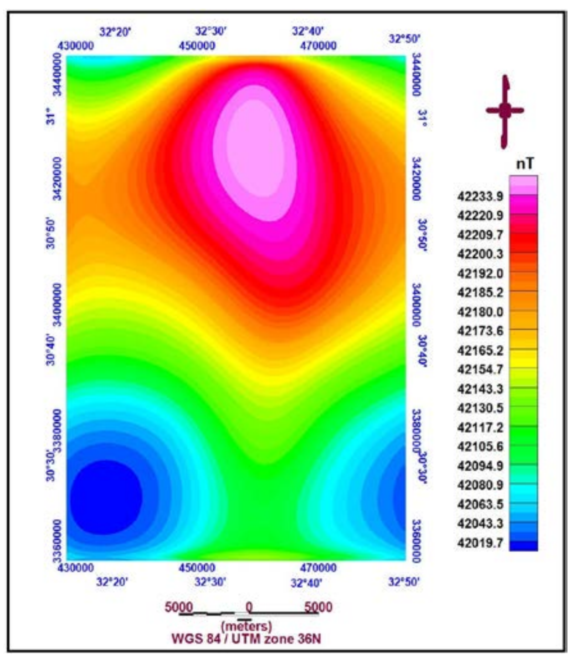


Fig.6: 2D Magnetic modeling along profiles from profile P1–P1’ to profile P9– P9’.

3 D Modeling

3D models are defined by a number of surface grids with a density distribution (and/or susceptibility & remanent magnetization distribution) assigned to each layer. Layer density may be specified using either a constant density, a vertical density-depth profile relative to a “reference surface”, or a laterally-varying density distribution defined by a grid. Layer susceptibility may be specified using either a constant susceptibility and remanent magnetization, or a laterally-varying susceptibility distribution.





(a) **(b)**

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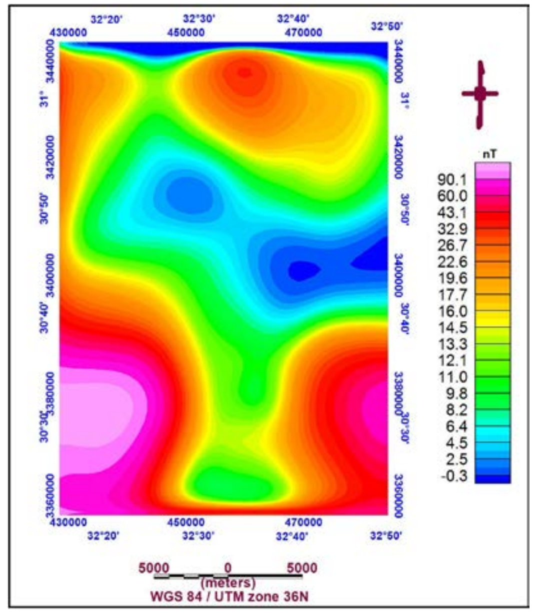
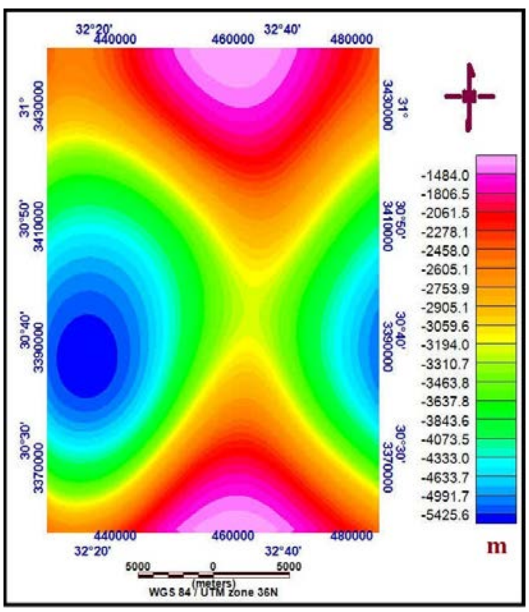
Fig. 7 (a,b and c) : Outputs of GMSYS-3D modeling; a observed anomalies, b calculated anomalies and c deviation between calculated and measured anomalies (error)

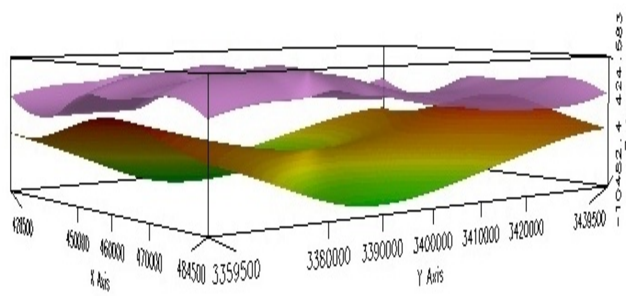


(c)

3-D magnetic modeling were used to construct the basement relief map (Fig. 8 a,b)



(a)



(b)

Fig. 8.(a and b) : 3D-Basement relief map.

From the results of 3 D modeling the basement depth ranges from about 1484 m to about 5425 m and these results are compatible with the results of 2 D modeling. The depth of basement found in western and eastern parts of the study area is very deep which have values more than 5000 m, which is indicate for thick sedimentary cover, but it decrease gradually in southern and northern directions to reach depth have values less than 1500 m.

Gravity data

Gravity data acquisitions

Sixty-three gravity stations carried out using Auto-Grav (CG3) gravity meter of sensitivity of 0.01 mGal .The measured gravity values corrected to different gravity corrections such as, drift, tide, free-air, Bouguer, latitude and topographic corrections.

The corrected gravity values used to plot Bouguer anomaly map using Oasis Montaj, 2008 (Fig. 9). The Bouguer anomaly map is separated directly into regional and residual components (Fig.10 and 11) by using low and high pass filter technique of wave number 0.0178 cycles/k-unit.

The regional- residual separation technique carried out to filter the regional component, which related to deep-seated sources and residual component, which related to local sources.

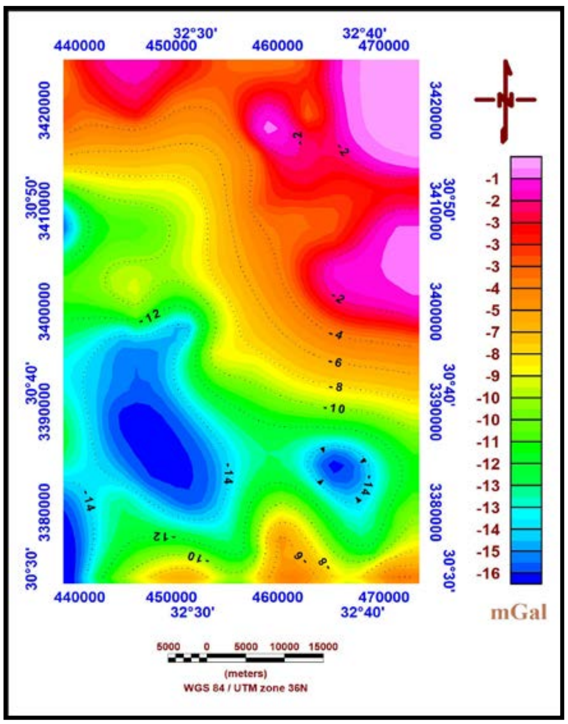


Fig. 9 : Observed Bouguer anomaly map

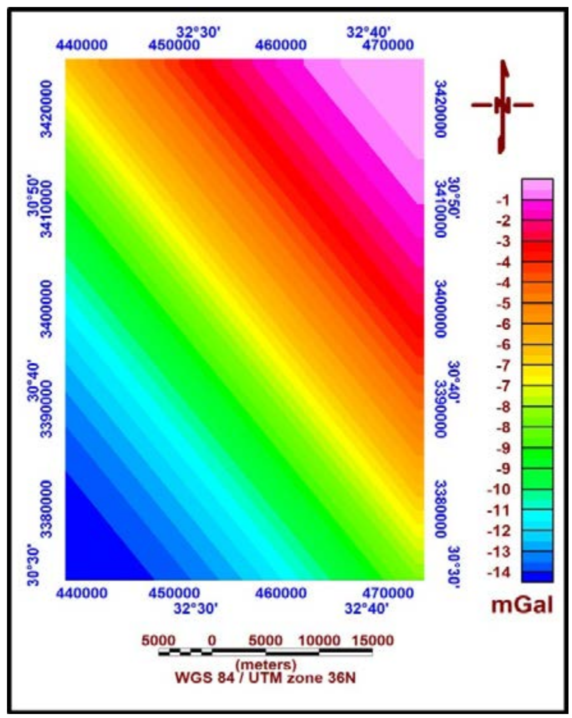


Fig.10: Regional Gravity Anomaly Map

The residual gravity anomaly map (Fig.11) represents actually the distribution of the gravity field at a shallow depth after removing the regional effect. The critical characteristics of the residual gravity anomaly map in the study area can be summarized in the following: The residual gravity anomaly field in the study area ranges between a maximum value (3.2m.gal) at NW, NE,S, E of central part of study area and a minimum value (-4.3 m.gal) at E part which have coordinates long.32°37'E
and between lat.30°32'N and lat.30°40'N and W part which have coordinates long.32°30'E and between lat.30°47'N and lat.30°51'N and central part of study area which have coordinates between lat.30°34'N and lat.30°44'Nand between long.32°26'E and long.32°34'E and SW part of the study area. The positive gravity anomaly is mainly due to uplift of denser basement rock, while the lower gravity values indicate sedimentary basins.

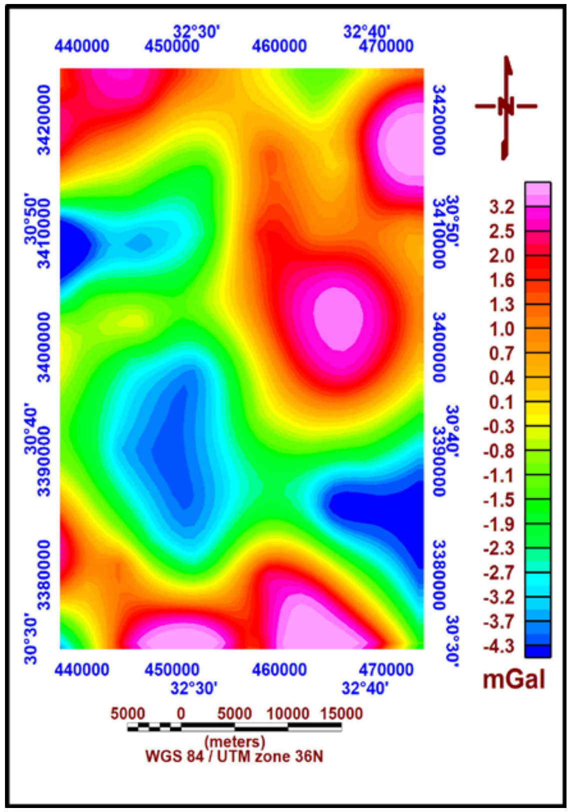


Fig.11: Residual Gravity Anomaly Map.

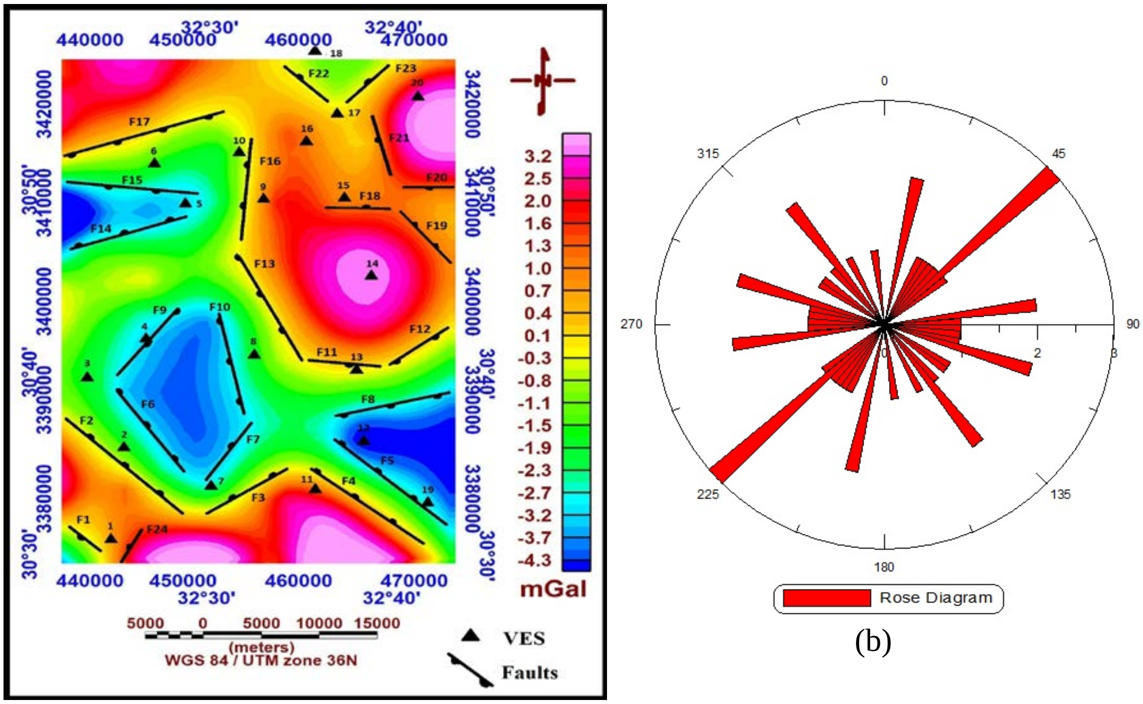
Delineating of structure elements

The faults locations and they directions have been detected by two ways: the first way by the residual gravity anomaly map to determine the faults which affecting in the study area and the second way by

Euler Deconvolution.

The residual gravity anomaly map (Fig.11) used to detect and trends of the faults dissecting the study area. The location of faults can be detected between high and low gravity anomalies and the downthrown of faults towards low anomalies. This map (Fig.12) dissected by about 24 faults. These faults take different directions N-S, E-W, NE-SW, and NW-SE trend.

Euler deconvolution or Euler depth deconvolution is a tool for potential field interpretation. This method used to determines the depth of source of anomaly and structural index of a list of anomalies. The Euler deconvolution process is applied at each solution. The best solutions which make the data are concentrated at some places in the study area "not distributed all over the area". In the present study the structural index which applied, structural index 0, 0.5 and 1 to select the best solution, The structural index 0 (Fig.13) gives better solutions than structural index 0.5(Fig. 14) and 1 (Fig. 15), because the solutions are concentrated at some places in the study area not distributed all over the area as SI=0.5 and SI=1. Finally, the two ways, from the residual gravity anomaly map and Euler Deconvolution give similar results.



(a)

Fig.12 (a and b) : a)Fault Elements Dissecting the Study Area, b)Rose Diagram for the Major Trend Faults detecting from residual anomaly map.

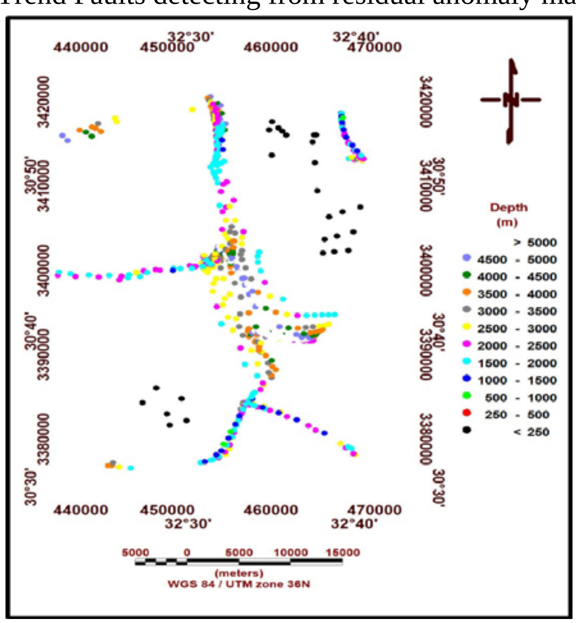


Fig.13: Euler Solutions of Structural Index = 0.

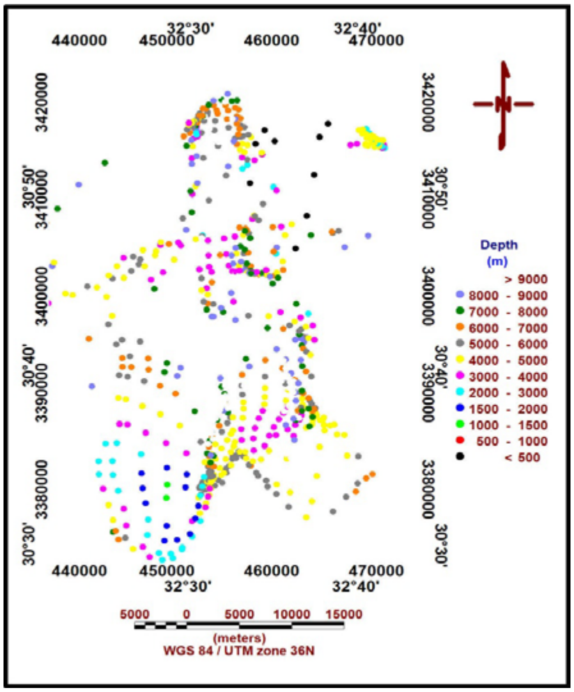


Fig.14: Euler Solutions of Structural Index=0.

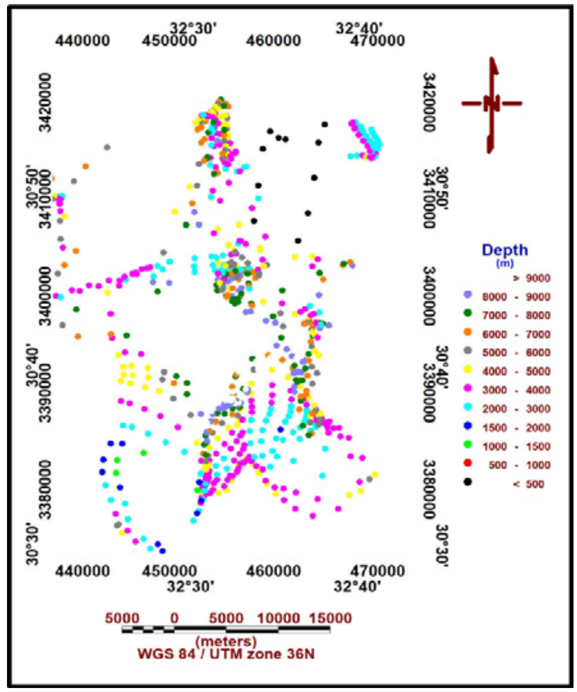


Fig.15: Euler Solutions of Structural Index = 1

Geoelectric method

Geoelectrical data acquisition and interpretation.

The resistivity method is used for detecting ground water presence and differentiating subsurface layers. The data of resistivity were Twenty Vertical Electrical Sounding (VES) (Fig.16), Two VES stations have been done beside two boreholes for correlation between resistivity data and boreholes data. The first borehole is Al Awsat Well and the second borehole is Al Shohat Well. Then the interpretation applied using the IPI2WIN program. The quantitative interpretation has been applied to determine the thicknesses and true resistivity of the stratigraphic units beside each VES station (Fig. 17,18 and 19). The results of the interpretation of the resistivity data for the two VES station, which measured beside the two boreholes, indicate good similarity for the results of the borehole data. As shown in (Fig.16) the results of VES interpretation are used to construct five geoelectric sections A, B, C, D and E.

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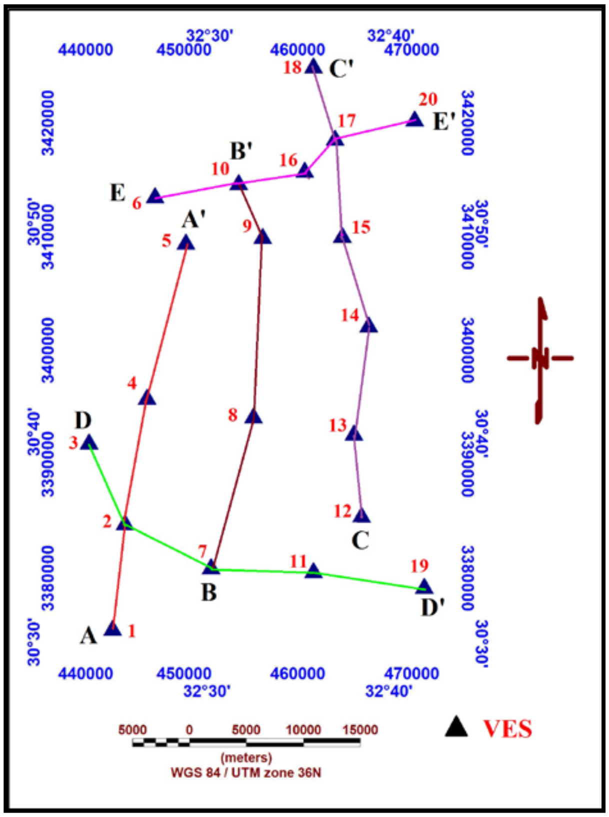

Fig. 16: Location of Resistivity Soundings and Direction of the Constructed Profiles.

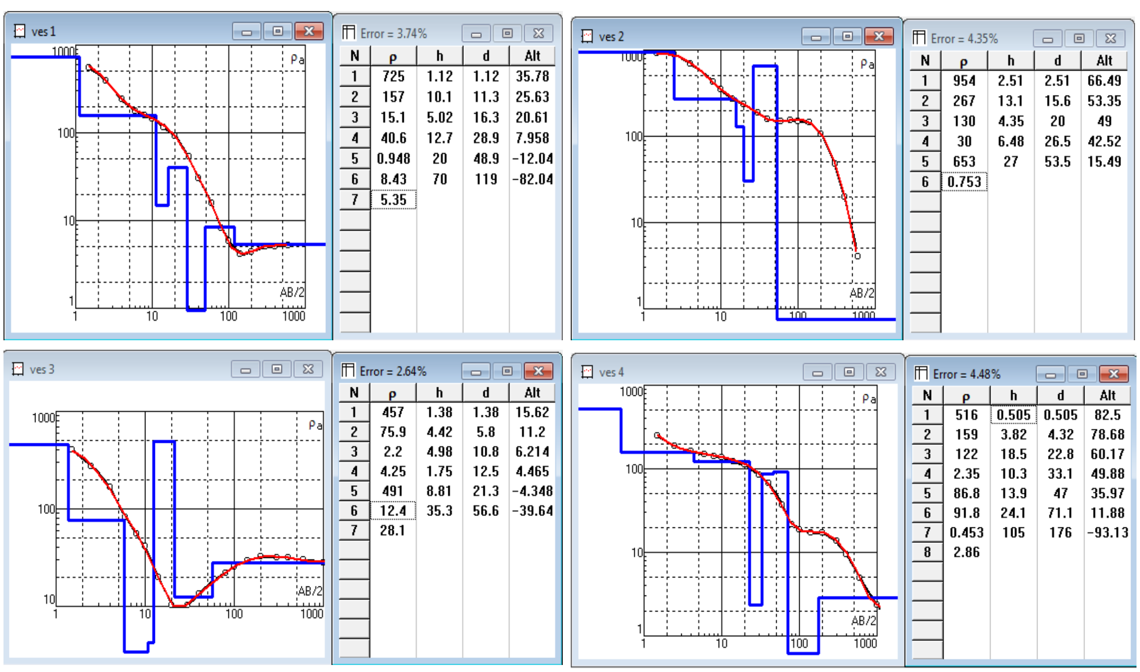

Fig. 17: Interpretation of VES stations no. 1, 2, 3 and 4 (Using IPI2win software).

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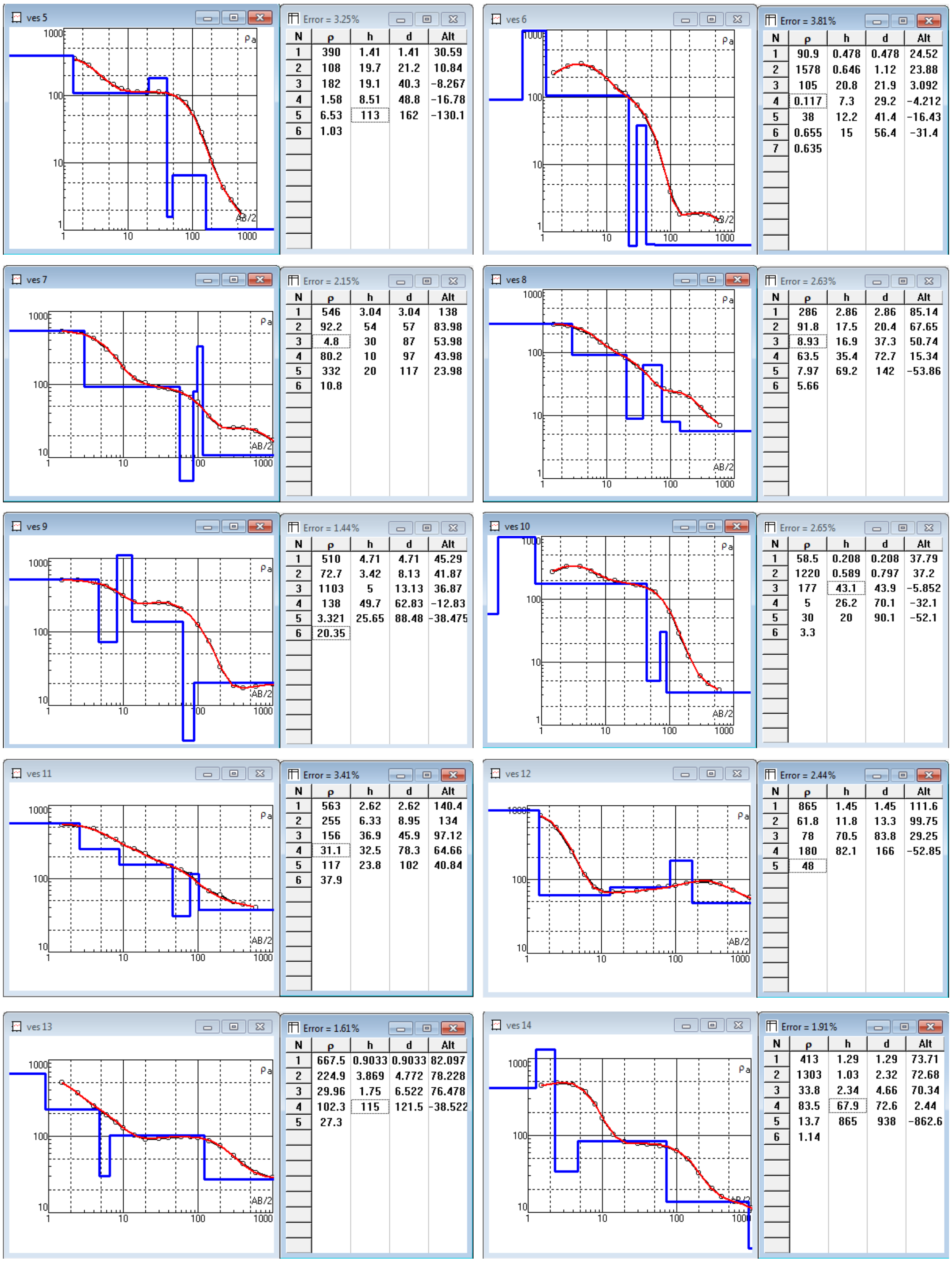

Fig. 18: Interpretation of VES stations no.5, 6, 7, 8, 9, 10, 11, 12, 13 and 14 (Using IPI2win software).

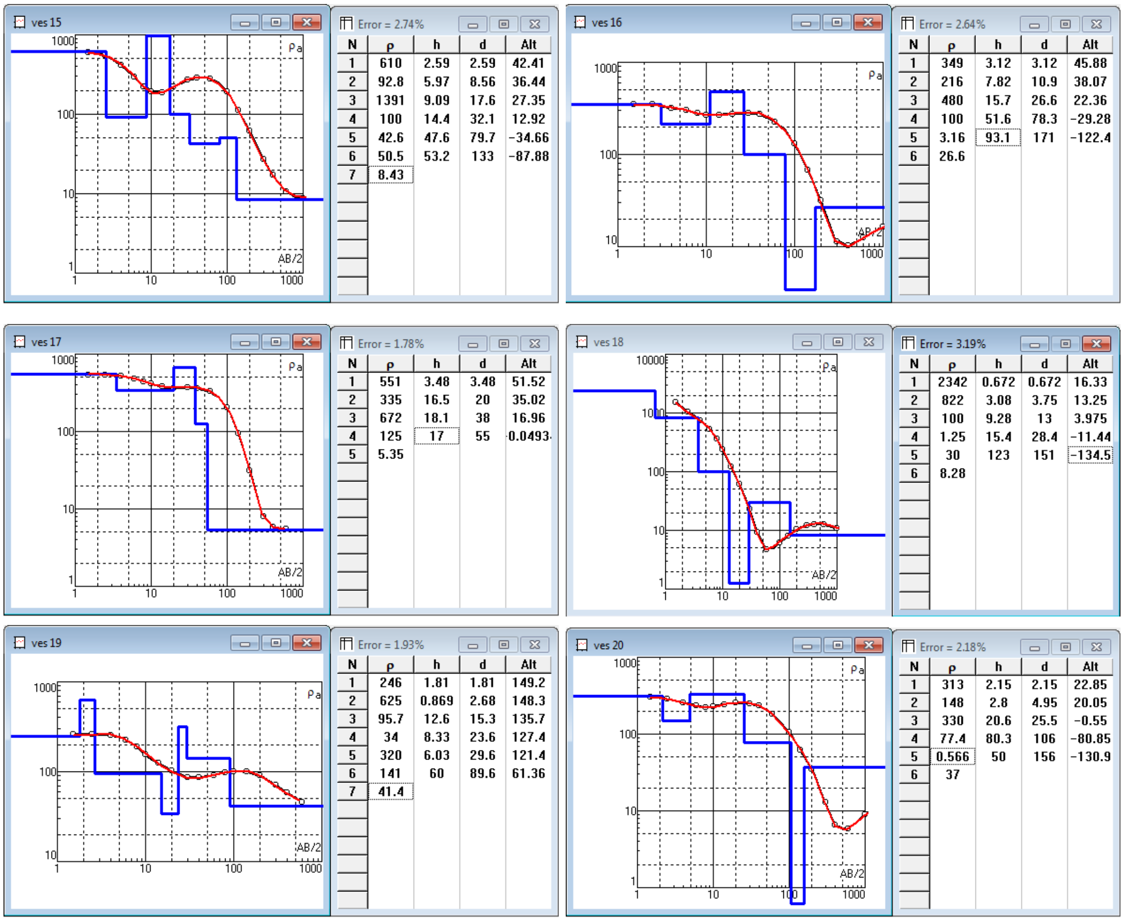

Fig. 19: Interpretation of VES stations no. 13, 14, 15, 16, 17, 18, 19 and 20 (Using IPI2win software).

The geoelectric cross-sections exhibit five geoelectric units (Figs.20 and 21), the first unit is the quaternary sand sheet and sand dunes of high resistivity values, the second unit is the quaternary aquifer and reveals moderately to high resistivity and reflects the presence of fresh water-bearing zone,the lithology of this layer consists of sandstone, the third geoelectrical units composed of clay which reveals low resistivity values, the fourth geoelectrical unit consists of clayey sand and exhibits moderately resistivity values, this layer represent the second aquifer, the fifth geoelectrical unit is the end unit in the sections, reveals very low resistivity values and consists of clay, the faults named in accordance with the residual gravity anomaly map (Fig 20, 21 and 22).

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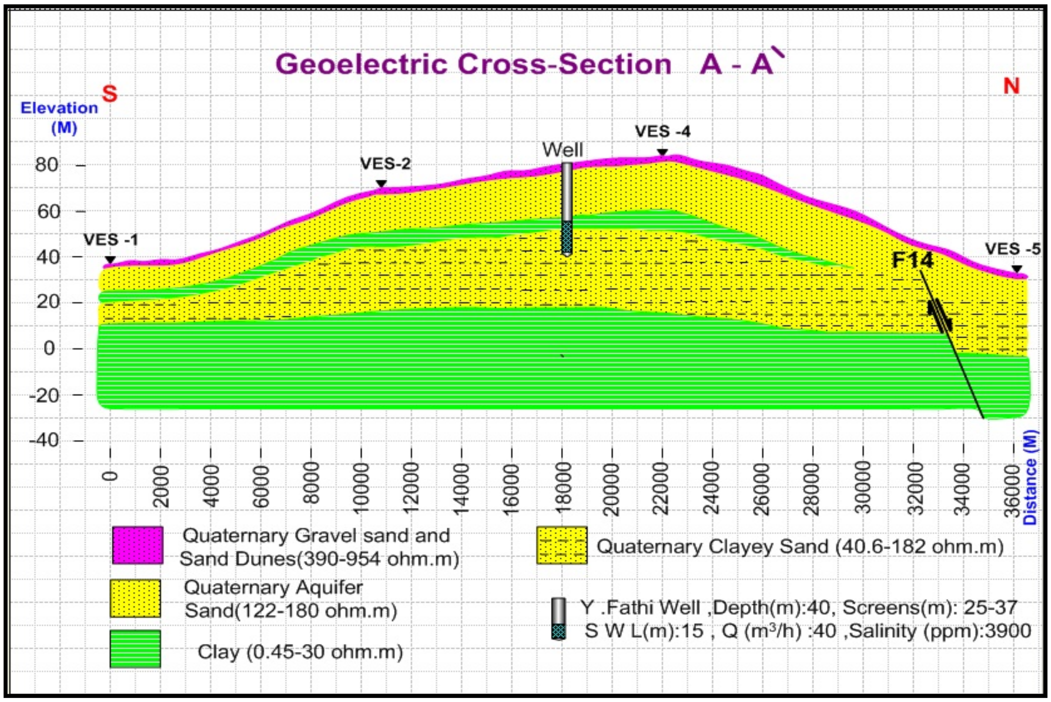

Fig. 20: Geoelectric Cross-Section along Profiles A-A'.

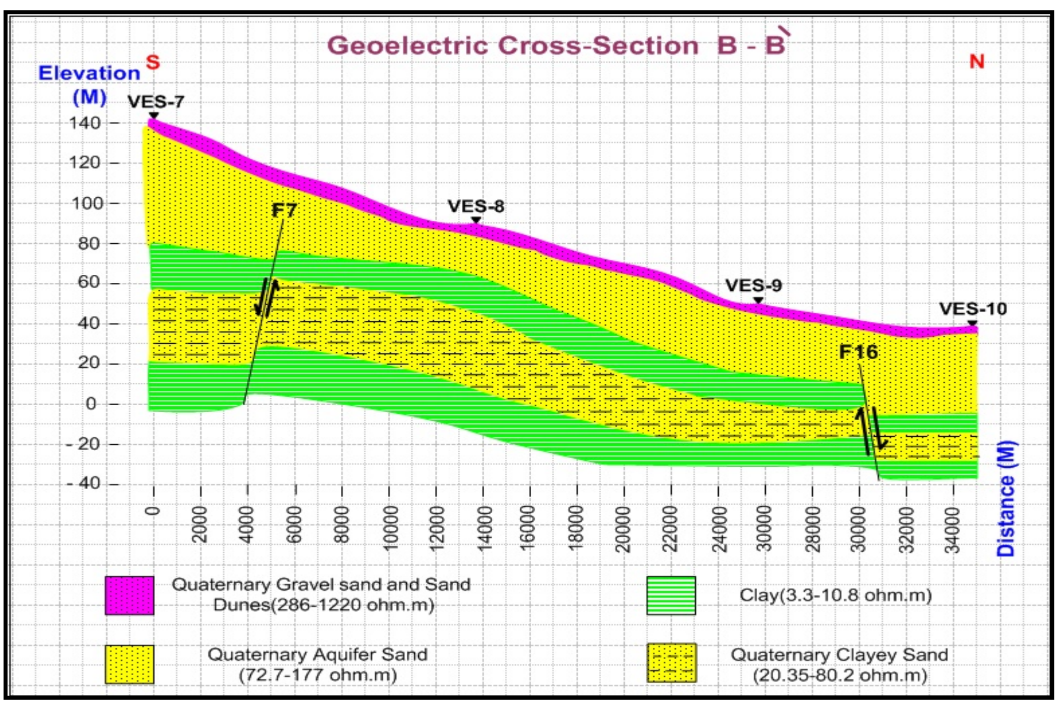

Fig. 21: Geoelectric Cross-Section along Profiles B-B'.

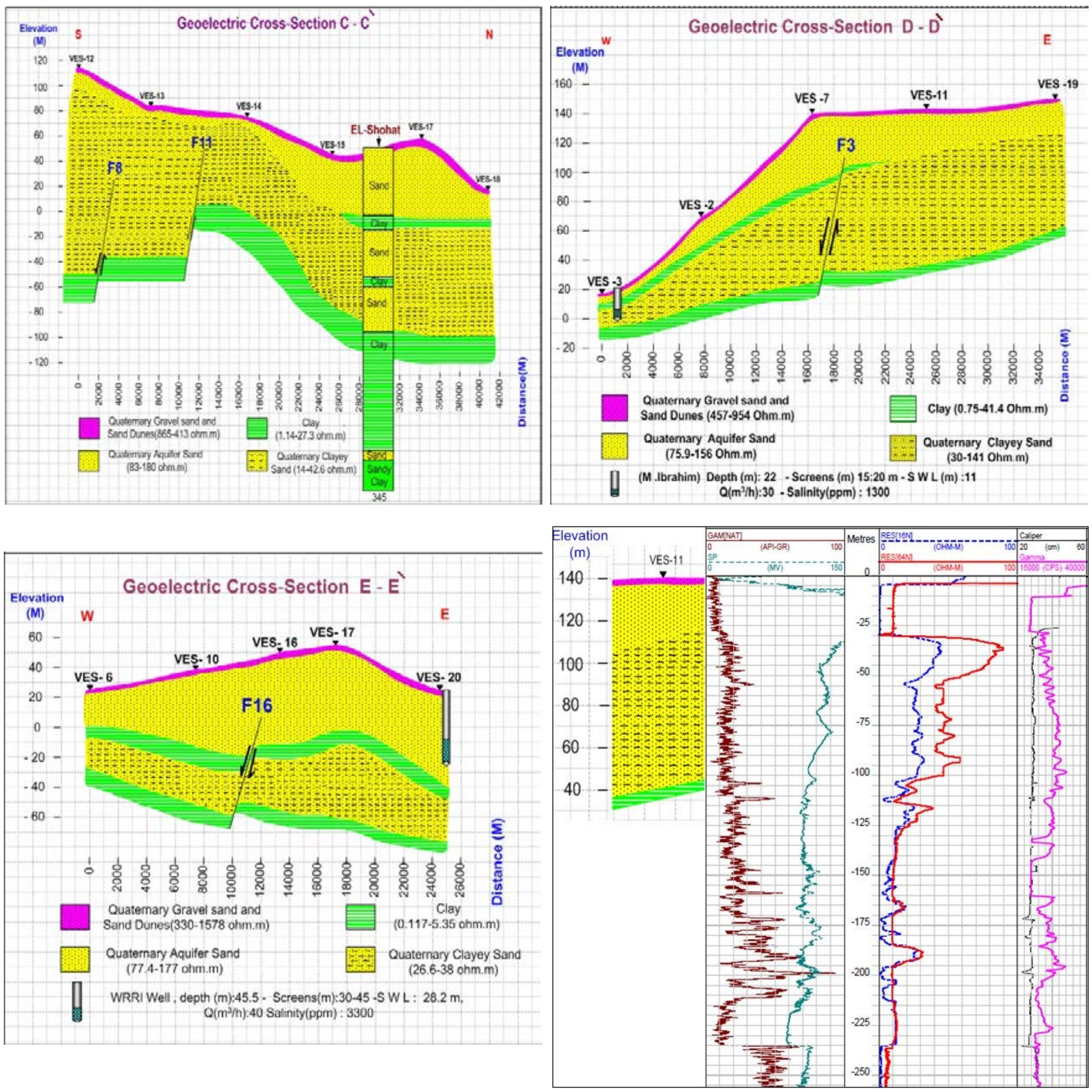

Fig. 22: Geoelectric Cross-Section along Profiles C-C', D-D',E-E' and Correlation between EL Awsat Well (Drilled by Dasco.Co 2008) and cross-section of VES-11

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The Interpreted subsurface maps

True resistivity contour maps of the two aquifers

The second unit is the Quaternary aquifer and considered as the water-bearing unit in addition to the fourth unit. This unit has resistivity values ranging from 70 - 180 □.m, the true resistivity values of the forth unit increase mainly to the southeastern part and around VES-5, and decrease towards northwestern, northeastern and southwestern parts of the study area (Fig.23)

Iso-pach maps for the second and fourth geoelectric units

The thickness of the second geoelectric unit in the study area is varied from 5 to 75 m, the maximum thickness is recorded at VES-16 towards the northeastern part of the study area the thickness increase mainly to the northeast and south parts of the study and decrease mainly to the west, the minimum thickness recorded at Ves-3. The thickness of the fourth geoelectric unit in the study area is varied from 8 to 138 m , the maximum thickness is recorded at VES-12, VES-13 and VES-18, we can say the thickness gradually increase from west to east except around VES-20 (Fig. 24)

Depth contour maps to the second and fourth geoelectric units

The depth of the second geoelectric unit in the study area is varied from 0.51 to 4.7 m, the maximum depth is recorded at VES-9 at the central part of the study area the thickness increase mainly to the central part of the study area also to northeastern part and southeastern part and decrease mainly towards the west and east, the minimum depth recorded at VES-4.The depth of the fourth geoelectric unit in the study area is varied from 12 to 68 m ,the maximum depth is recorded at VES-17 and VES-20 at the northeastern part of the study and the minimum depth recorded at VES-3 (Fig.25)

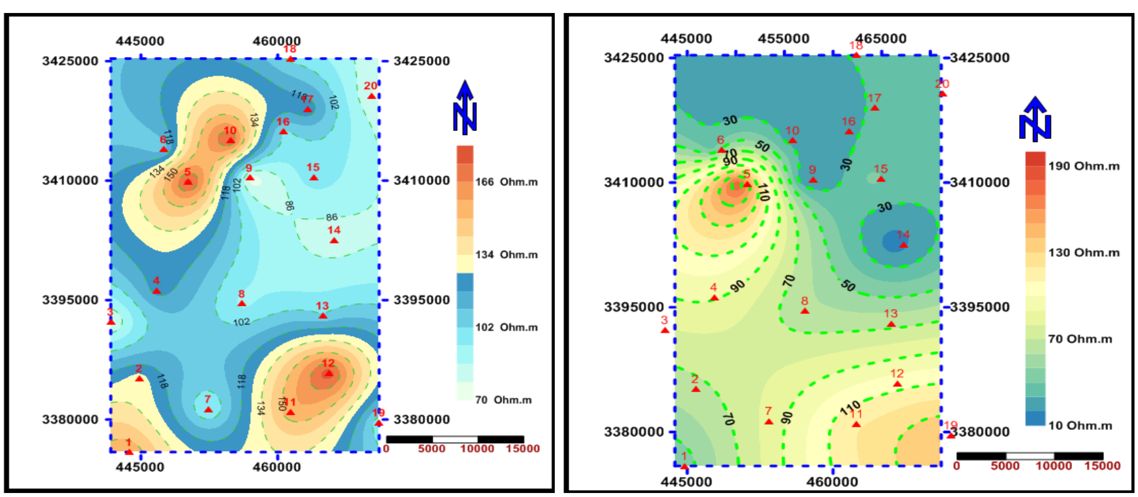

Fig. 23: Second and Fourth Geoelectric Units True Resistivity Maps

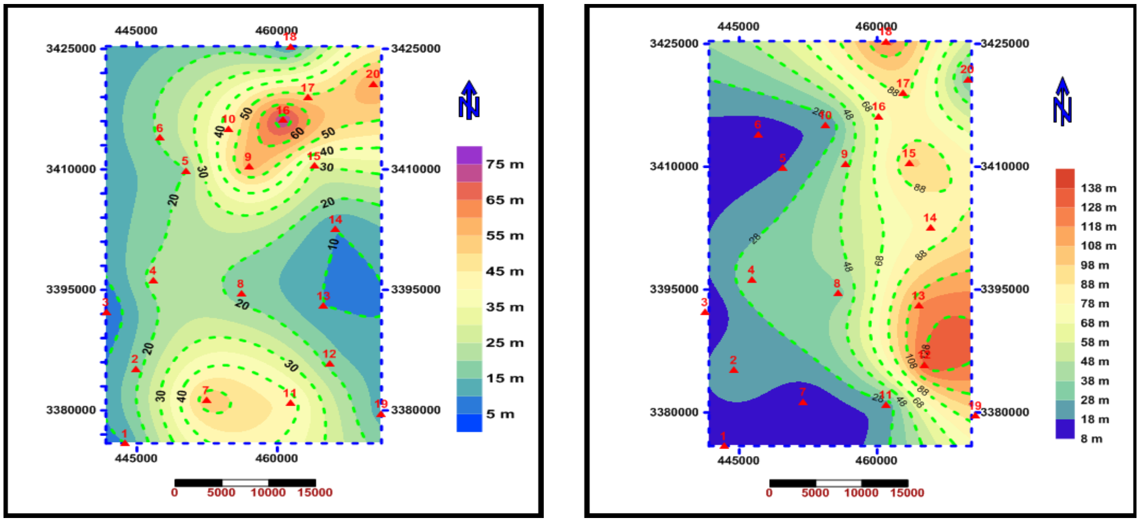

Fig. 24: Iso-pach Maps for the Second and Fourth Geoelectric Units

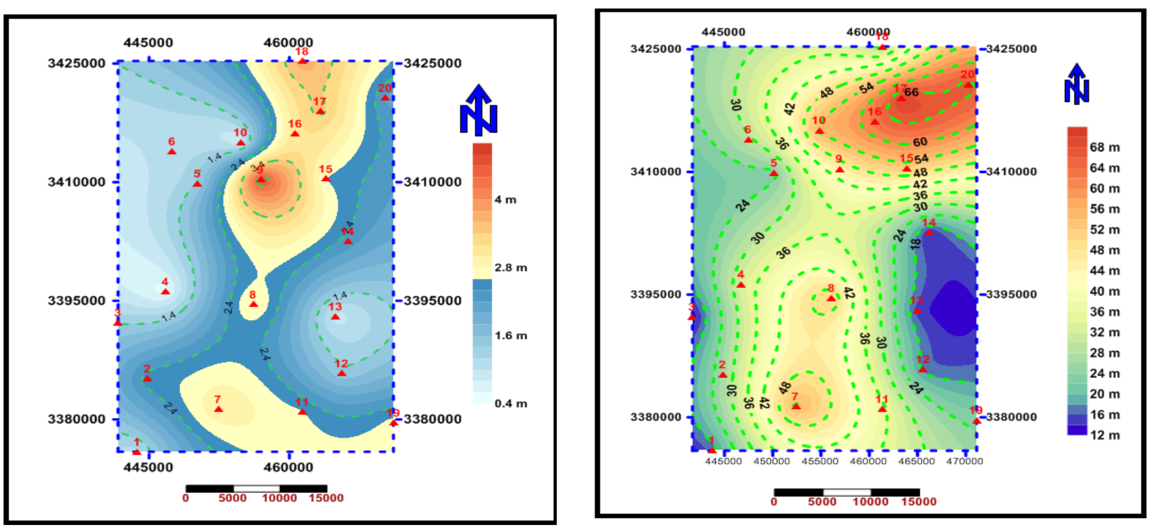

Fig. 25: Depth Contour Maps for the Second and fourth Geoelectric Units

Joint inversion interpretation for gravity and resistivity data.

Gravity and resistivity data were used in the present study for groundwater exploration using a joint inversion process to determine the thickness and resistivity distribution of the different geological units in the study area. The results obtained from the inversions of synthetic data indicate that the joint inversion significantly improves the solution decreasing the ambiguity of the models. The results of the joint inverse interpretation revealed the presence of four layers are similar to the results that obtained from resistivity method, Joint inversion was applied along two profiles B-B' (Fig.26) and E-E' (Fig.27).

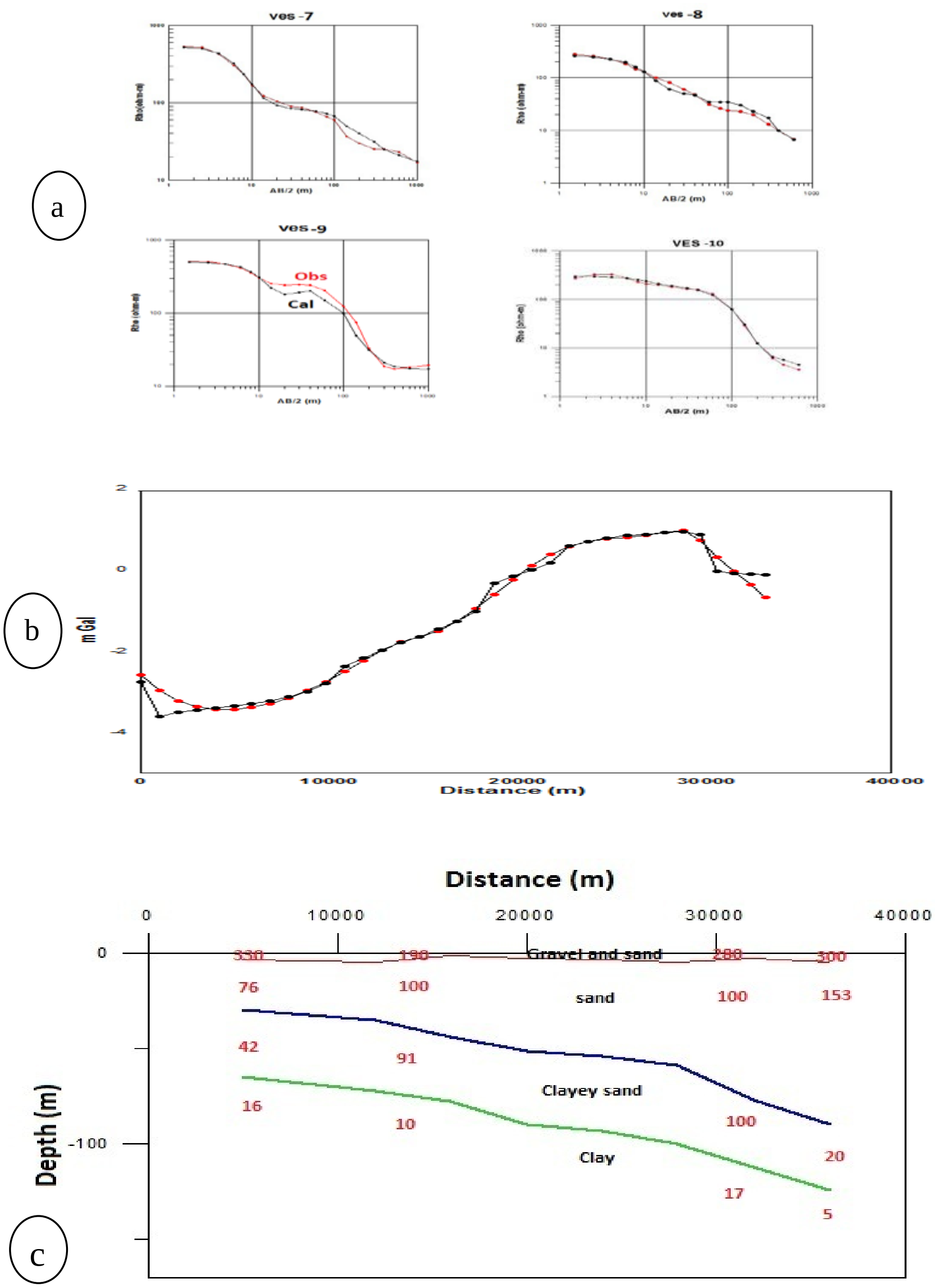

Fig. 26 (a,b and c): Results of joint inversion of gravity and resistivity data along profile B-B' where a) the fit of VES curves in logarithmic scale, b) the fit of the gravity curve and c) the subsurface model shown with true resistivity values in Ωm and density of 2000, 2100 and 2300 kg/m3 for gravel, sand and clayey sand, respectively.

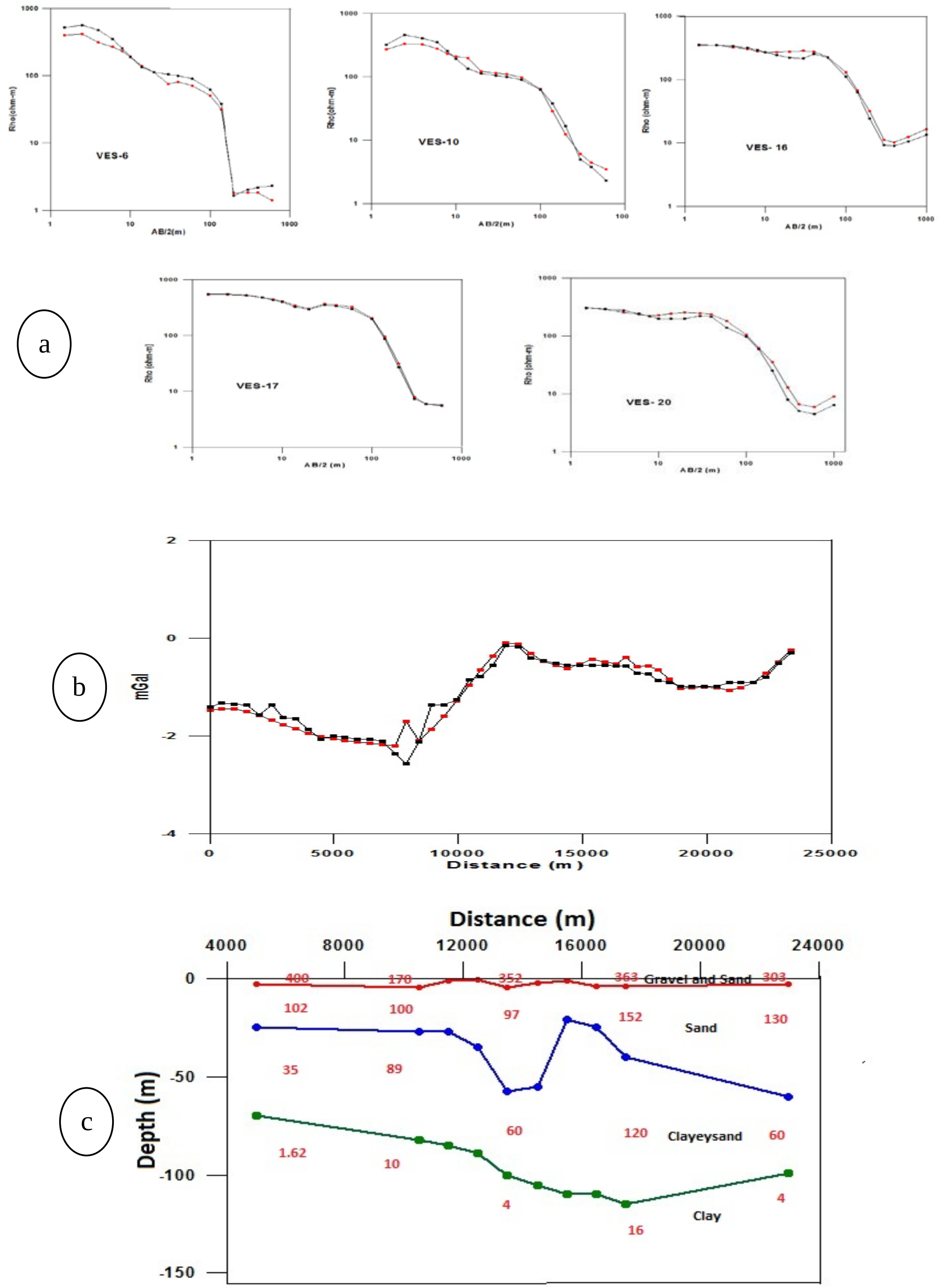

Fig. 27: Results of joint inversion of gravity and resistivity data along profile E-E' where a) the fit of VES curves in logarithmic scale, b) the fit of the gravity curve and c) the subsurface model shown with true resistivity values in Ωm and density of 2000, 2100 and 2300 kg/m3 for gravel, sand and clayey sand, respectively.

CONCLUSION

In finally, from all these geophysical data we can concluded that :-

The depth of basement rocks ranging from 1484 to 5425 m.

The major faults trend which controlling in the study area take direction NE-SW.

There are two aquifers, the first aquifer at the second geoelectrical units with thickness range from (4.5 m to 75 m), the lithology of this layer consists of sandstone. The second aquifer at the fourth units with thickness range from (9 m to 137 m) and consists of clayey sand.

There are two aquifers zones, the first zone along the Mediterranean Sea and Suez Canal, salinity more than 10.000 ppm and the depth to water is about 2 m from the ground surface depends on the topographic surface, this zone is used for fish cultivation. The second zone is relatively far from Mediterranean Sea and Suez Canal, the thickness varying from 20 to 100 m, well depths from 8 to 120m, depth to water from 3 to 55 m from the ground surface, and the salinity ranging from 500 to 4000 ppm, many seasonal and permanent agricultural crops occurred in this zone.

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