

CHAPTER V

GEOELECTRICAL METHOD

V. 1. Introduction

Goelectrical methods are applied for mapping the resistivity structure of the underground. Rock resistivity is of special interest for hydrogeological purposes: it allows, e.g., to discriminate between fresh water and salt water, between soft-rock sandy aquifers and clayey material, between hardrock porous/fractured aquifers and low-permeable claystones and marlstones, and between water-bearing fractured rock and its solid host rock (Kirsch, 2006).

Goelectric exploration consists of exceeding diverse principles and techniques, and utilizes both stationary and variable currents either artificial or by natural processes. One of the most widely used methods of goelectric exploration is known as the resistivity method. In this method, a current (a direct or very low frequency alternating current) is introduced into the ground by two or more electrodes and the potential difference is measured between two points (probes) suitably chosen with respect to the current electrodes. The potential difference for a unit current sent through the ground is a measure of electrical resistance of the ground between the probes (Battacharya and Patra, 1968). Goelectrical methods detect the surface effects produced by electric current flow in the ground. Using electrical methods, one may measure potentials, currents, and electromagnetic fields that occur naturally or are introduced artificially in the ground.

In addition, the measurements can be made in a variety of ways to determine a variety of results. There is a much greater variety of electrical and electromagnetic techniques available than

in the other prospecting methods, where only a single field of force or anomalous property is used. Basically, however, it is the enormous variation in electrical resistivity found in different rocks and minerals that makes these techniques possible (Telford et al., 1976).

In the present study, geoelectrical methods are carried out by Schlumberger configuration to detect the subsurface geologic section by constructing the geoelectric cross sections and also, to determine the thicknesses of the different lithologic layers through the subsurface section. Added, constructing the contour maps of the top surface of the different layers, isopah maps for the different subsurface layers

V. 2. Basic principles

Resistivity of the ground is measured by injected currents and the resulting potential differences at the surface. The general field layout is sketched in (Fig. 44) Two pairs of electrodes are required: electrodes A and B are used for current injections, while electrodes M and N are for potential difference measurements. The apparent resistivity ρ_a (unit: ohm*meter, Ωm) as the relevant petrophysical parameter can be calculated from the current I and the potential difference ΔV by

$$\rho_a = K \cdot \frac{\Delta V}{I} \quad \dots\dots\dots (V.1)$$

Where, K is called geometric factor (unit: meter) and can be calculated from the electrode spacing by

$$K = \pi \frac{((AB/2)^2 - (MN/2)^2)}{MN}$$

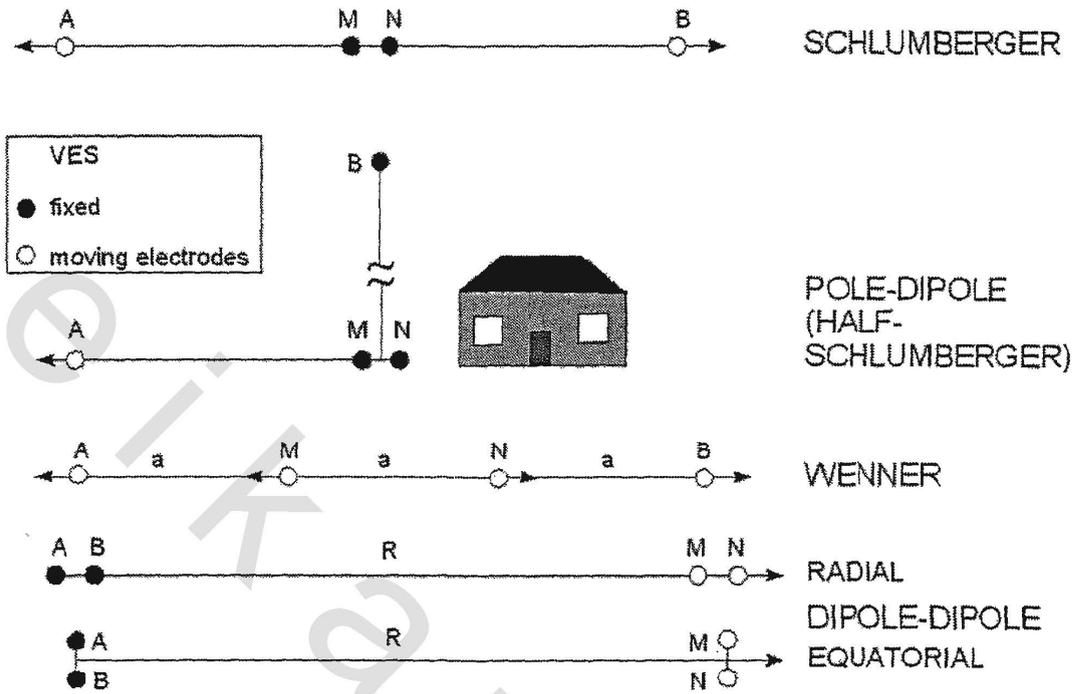


Figure (44): Electrode configurations: Schlumberger, Half Schlumberger, Wenner, and dipole-dipole spread.

The Vertical electrical soundings (VES), Schlumberger configuration are applied to a horizontally or approximately horizontally layered earth, geological targets may be, e.g., sedimentary rocks of different lithologies, layered aquifers of different properties, sedimentary rocks overlying igneous rocks, or the weathering zone of igneous rocks. In the most favorable case, the number of layers, their thicknesses and resistivities are the outcome of a VES survey. The basic idea of resolving the vertical resistivity layering is to stepwise increase the current-injecting electrodes AB spacing, which leads to an increasing penetration of the current lines and in this way to an increasing influence of the deep-seated layers on the apparent resistivity ρ_a (Fig. 45) the stepwise measured apparent resistivities are plotted against the current electrode spacing in a log/log scale and interpolated to a continuous.

V. 3. Field Work and Instrumentation

The vertical electrical sounding (VES) measurements are carried out by using Russian electronic compensator, type AE-72. The VES stations have current electrodes spacing (AB) of 3000 m. The resistivity measurements are recorded twice, after changing the supply voltage. The mean relative measuring error is found to be 2 %. By this way, seventeen vertical electrical soundings are measured in the local area under investigation (Fig. 46). The well known Schlumberger configuration of electrode separation ranging from $AB / 2 = 1.5$ m to $AB / 2 = 1500$ m used for measuring 17 VES stations.

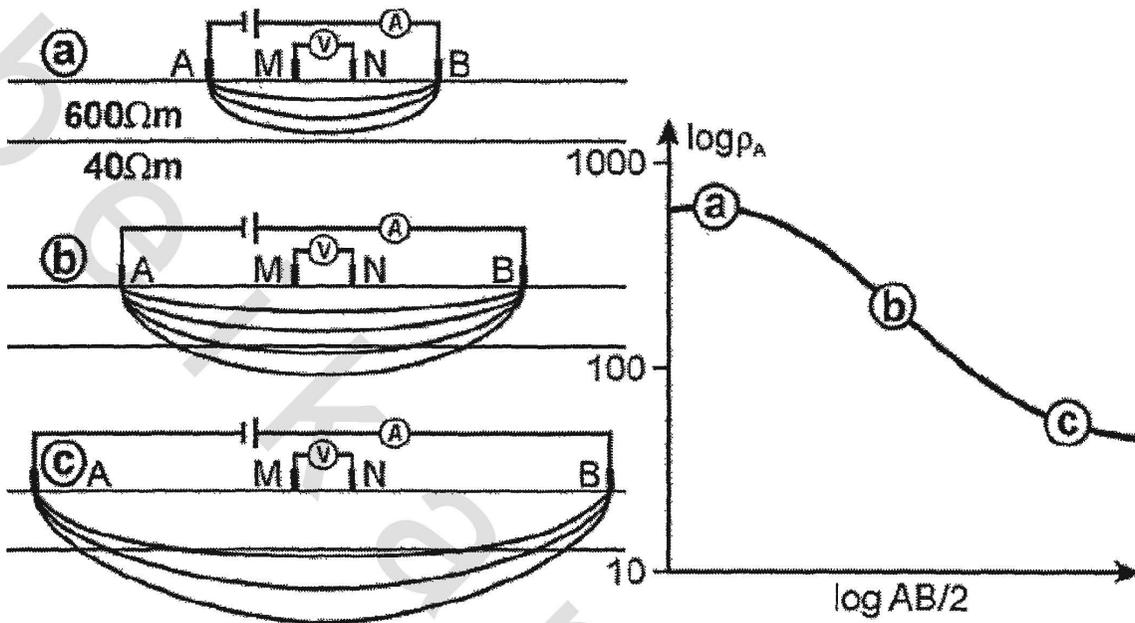


Figure (45): Apparent resistivity measurements with increased current electrode spacing leading to increased penetration depths of the injected current. Results are compiled in the sounding curve.

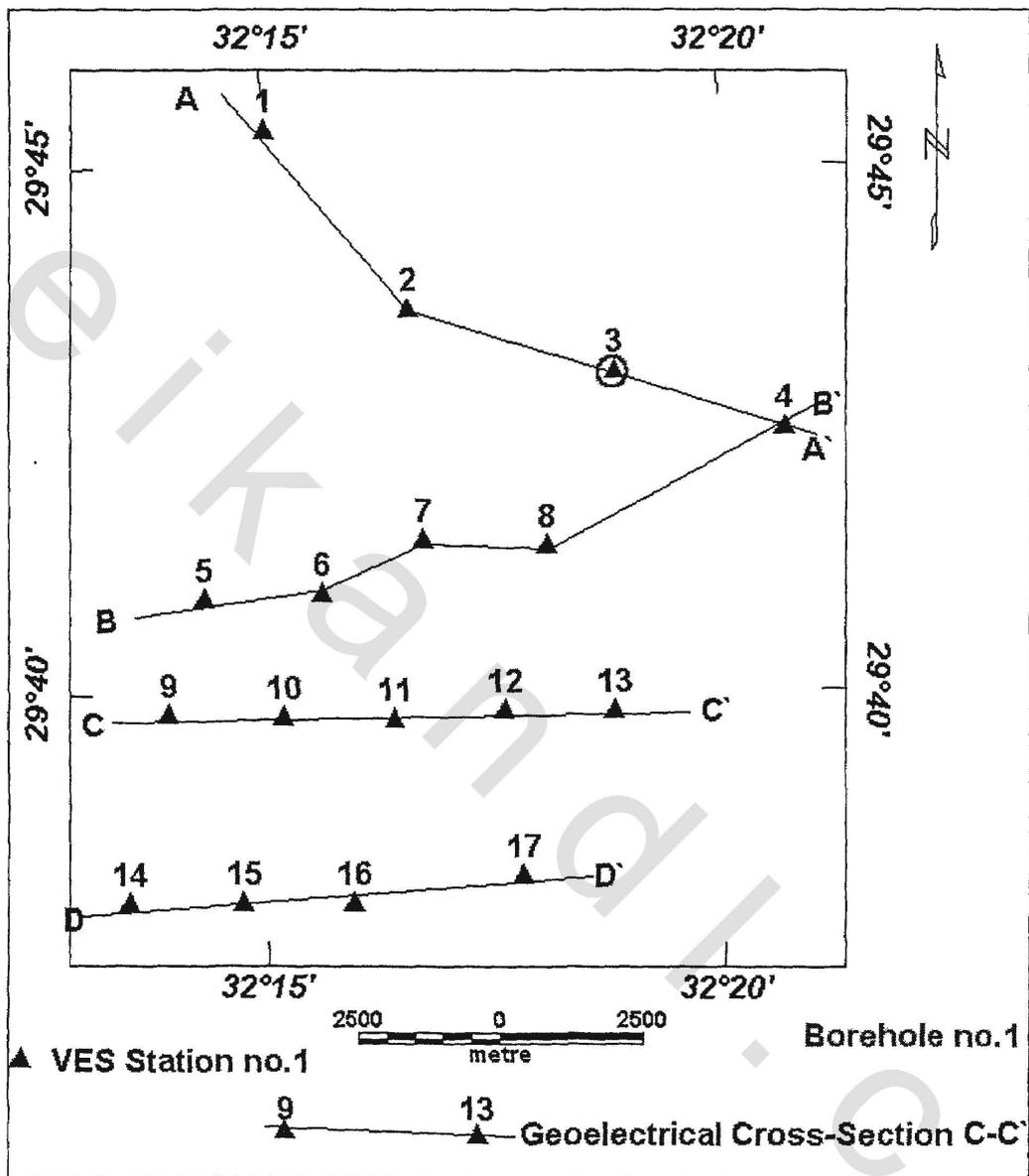


Figure (46): Location map showing the VES stations and geoelectrical cross sections of the study area.

V. 4. Quantitative Interpretation:

The aim of the quantitative interpretation of the vertical electrical soundings is to determine the thicknesses and true resistivity values of the successive strata below the different stations, utilizing the measured field data, which are represented by plotting the apparent resistivity values against $AB/2$ spacing. This plotted data are called the vertical electrical curves. There are several methods for the quantitative interpretation of electrical data. Some of them are graphical and the more complicated ones are the analytical methods, which depend on using digital computers. In the present study, a graphical method is carried out using the two layers curve and the generalized Cagniard graphs (Kofoed, 1960) to convert the values of $(AB/2)$ and apparent resistivity values (ρ_a) into a number of layers model of thicknesses and true resistivity values.

Another technique of quantitative interpretation is the analytical method (computer program), which is defined as IPI2WIN program. The obtained results of the manual interpretation were used as initial models for the analytical methods. The IPI2WIN program has been designed by a scientific group in Moscow state university, Russian at 2000. This program deals with VES curves in man-computer interactive regime and draws theoretical and field curves on a display screen together with $Rho(z)$ model curve. The quantitative interpretation has been applied to determine the thicknesses and true resistivities of the stratigraphic units below each VES stations (Figures 47, 48, 49, 50, 51 and 52), the final results used for construction the geoelectrical cross-section which exhibits the different geological units represented in the study area.

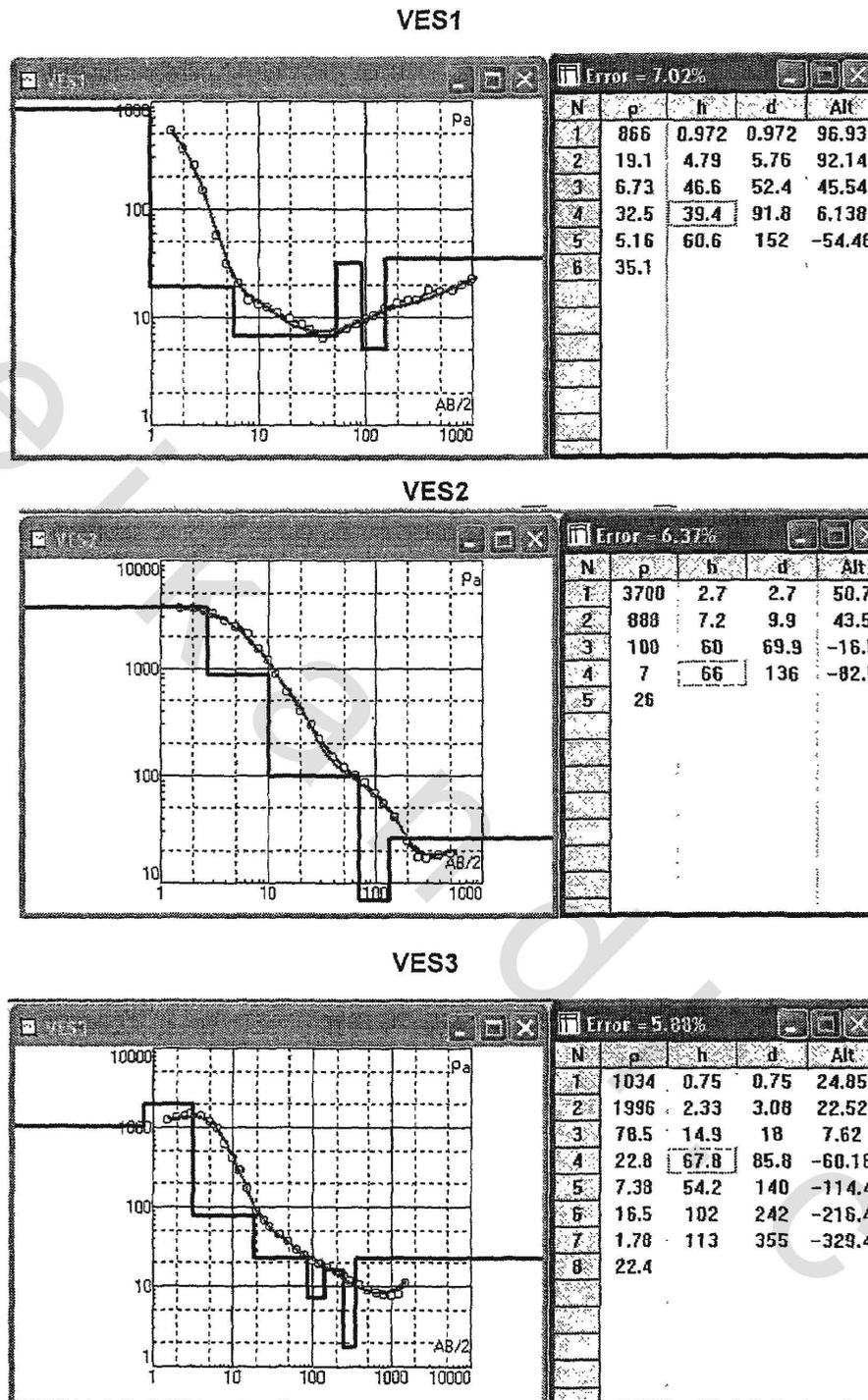


Figure (47): Interpretation of VES station no.1, 2 and 3 (Using IPI2win software).

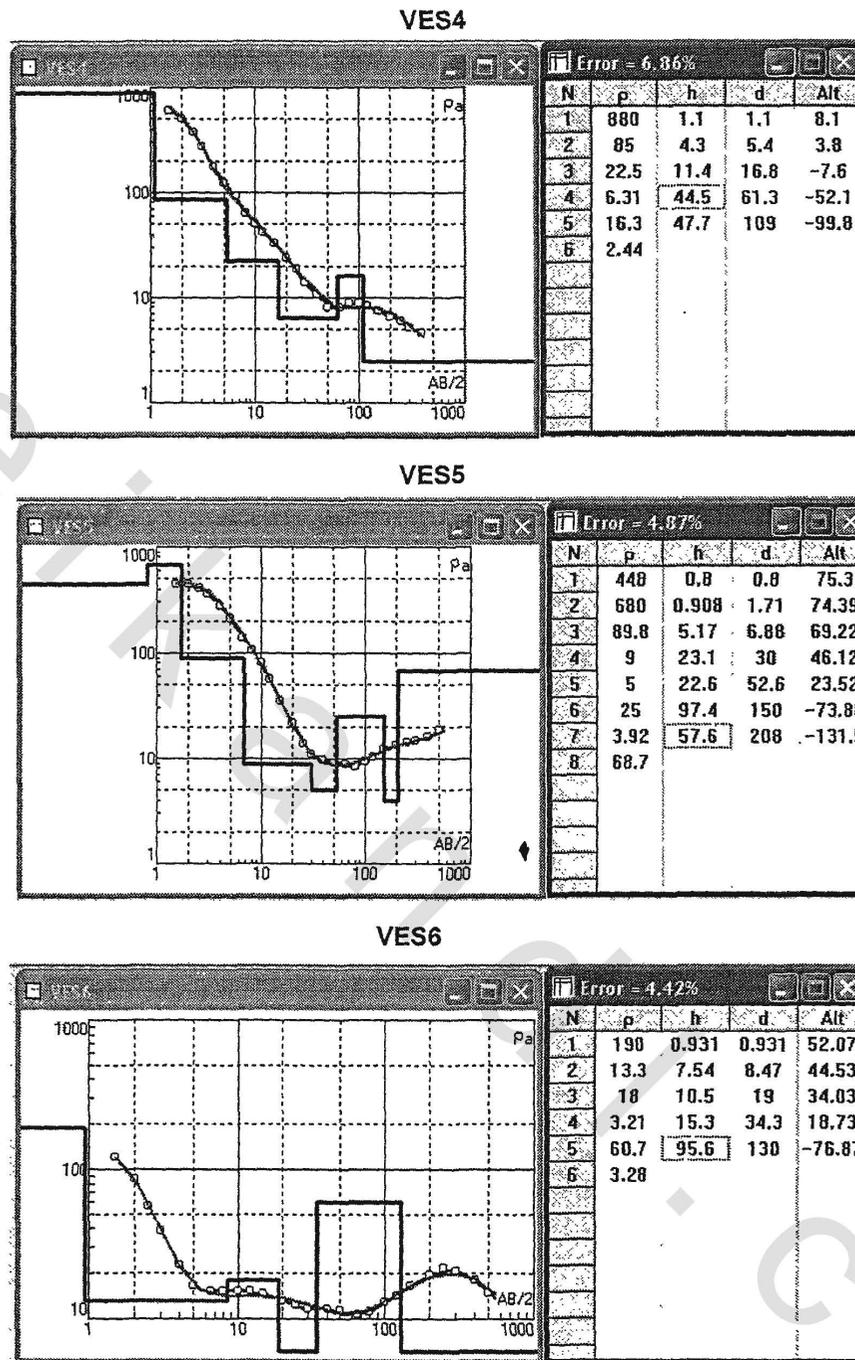


Figure (48): Interpretation of VES station no.4, 5 and 6 (Using IPI2win software).

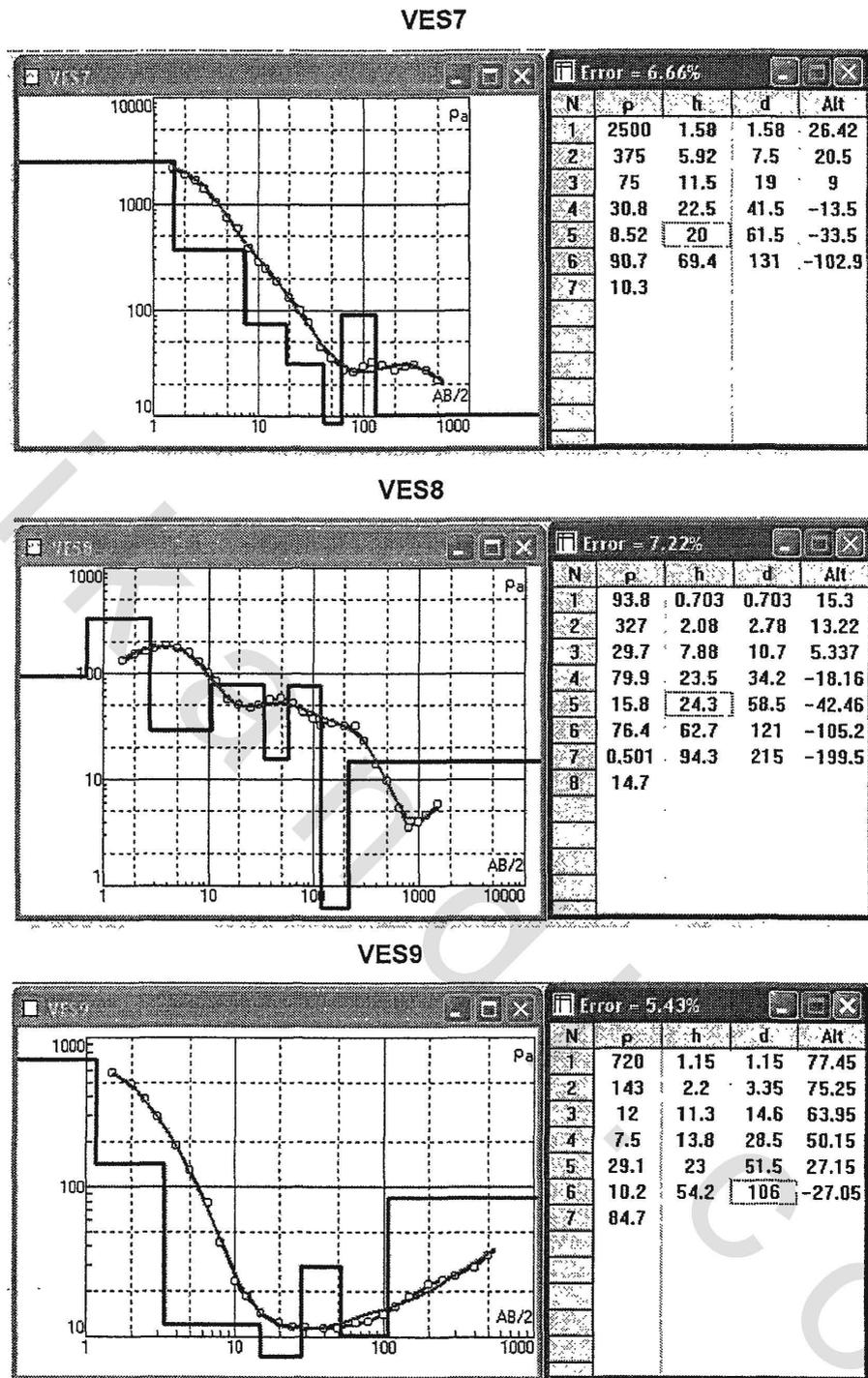
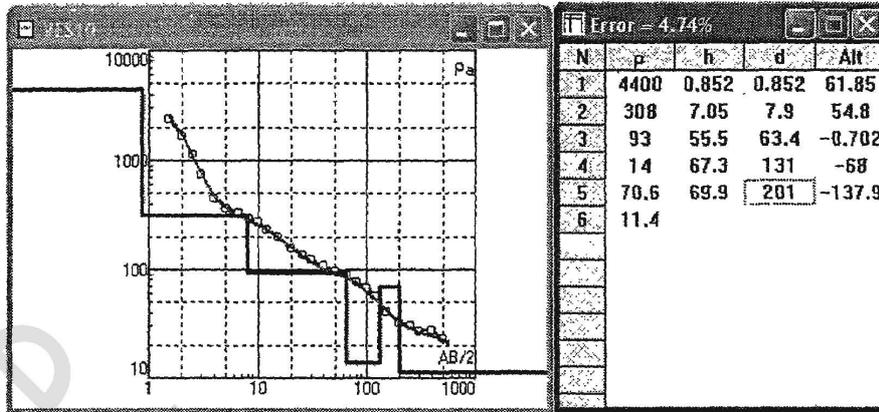
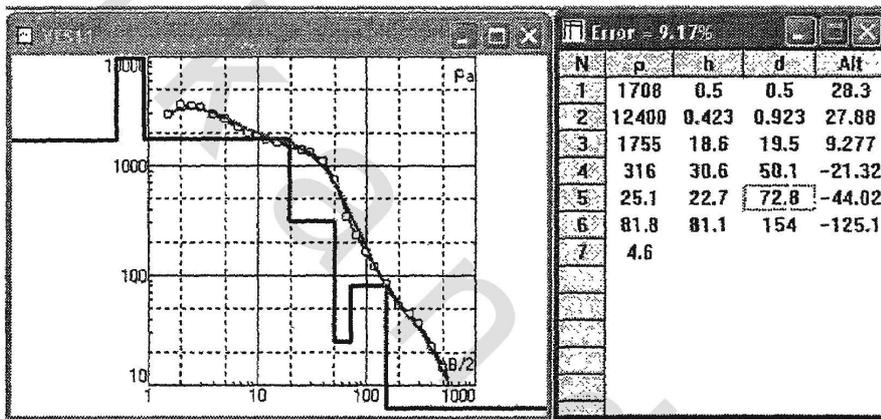


Figure (49): Interpretation of VES station no.7, 8 and 9 (Using IPI2win software) .

VES10



VES11



VES12

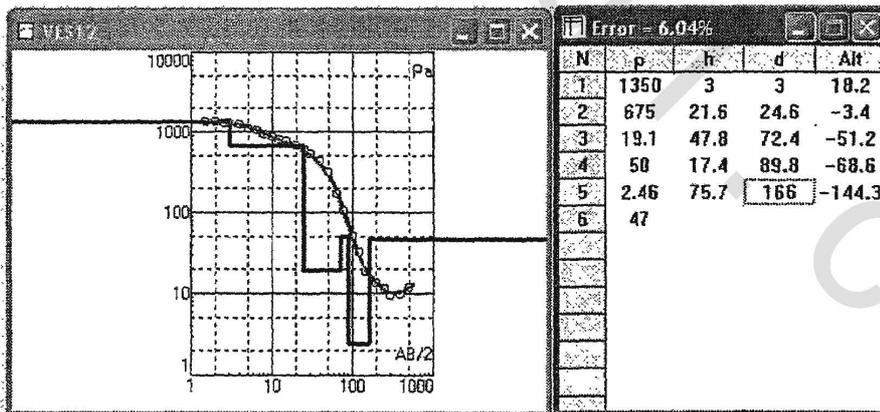


Figure (50): Interpretation of VES station no.10, 11 and 12 (Using IPI2win software).

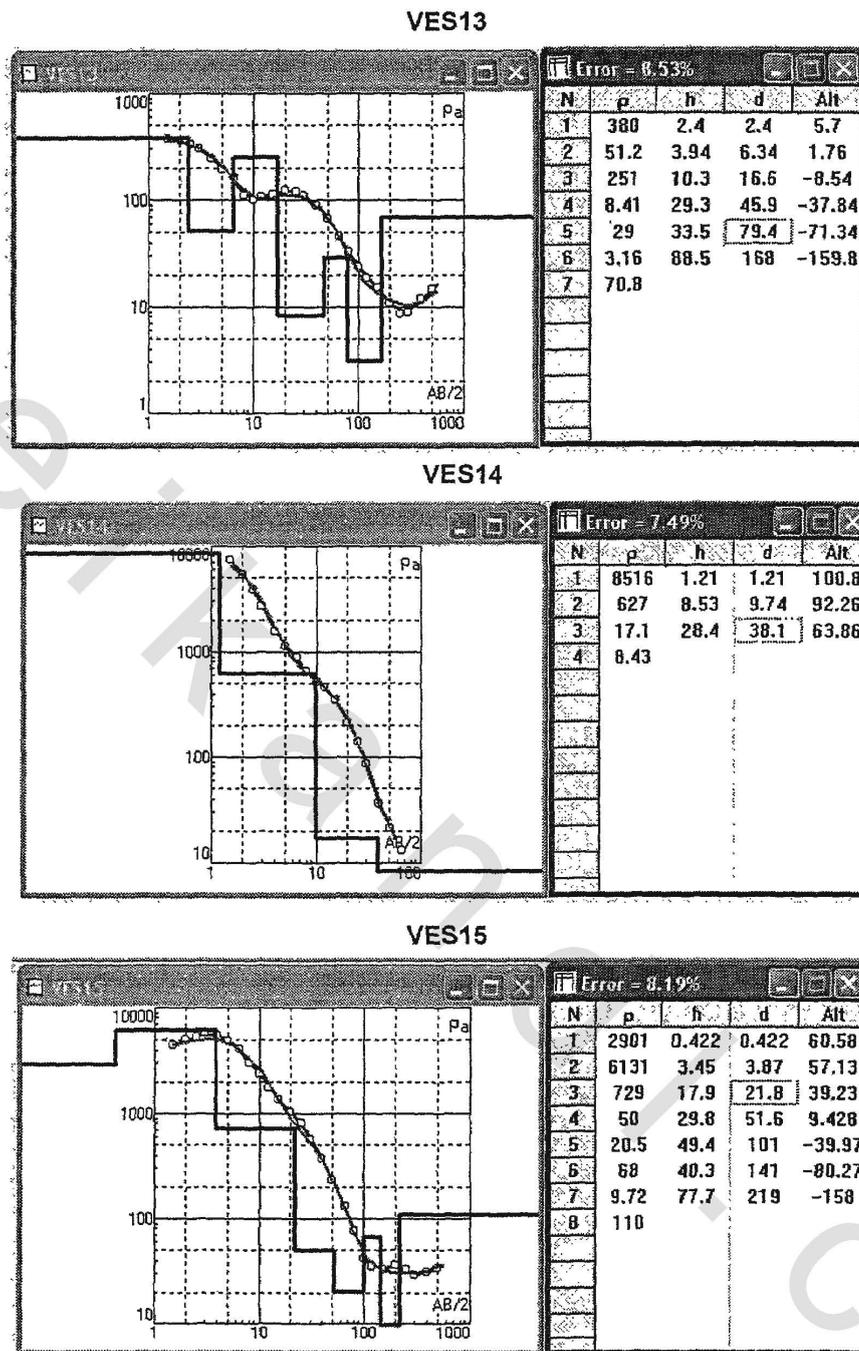
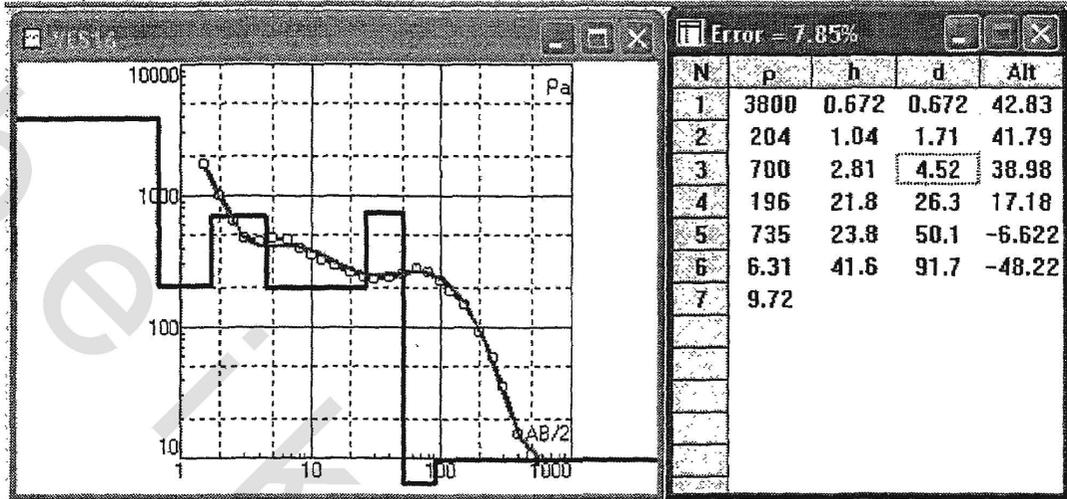


Figure (51): Interpretation of VES station no.13, 14 and 15 (Using IPI2win software).

VES16



VES17

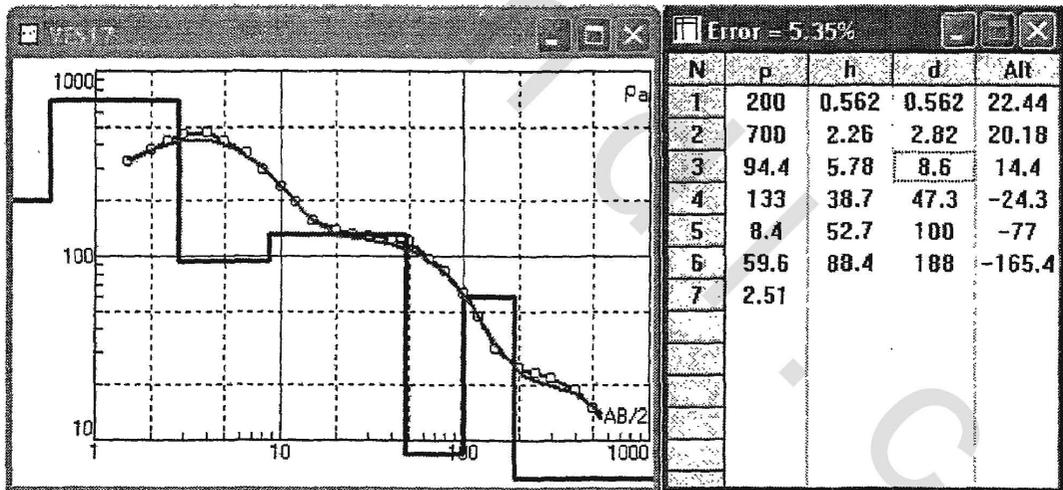


Figure (52): Interpretation of VES station no.16 and 17 (Using IPI2win software).

V. 4. 1. Geoelectrical Cross Sections

1- Geoelectrical cross sections along profile A-A`.

The geoelectrical cross-section A-A` (Fig. 53) reveals six geoelectrical units; the first unit represent the Quaternary gravel and sand of high resistivity values and thickness of about few meters. The second geoelectrical units exhibits moderately resistivity values ranging from 23 ohm.m to 100 ohm.m and represent the fresh water aquifer in the study area, the thickness ranging from 4.5 m at VES station 1 to 67 m at VES station 3, the lithology of this layer consists of sandstone and limestone which belong to Upper Miocene. The third geoelectrical units composed of sandy clay and limestone which belongs to Middle Miocene deposits and reveals low resistivity values ranging from 6-7 ohm.m and thickness ranged from 44.5 m at VES stations 4 to 66 m at VES station 2, this layer represent the second aquifer (brackish water). The fourth geoelectrical cross-section consists of limestone and clayey limestone which belong to Lower Miocene deposits and exhibit moderately resistivity values ranging from 16 at VES station 4 to 33 at VES station 1, the thickness of this unit ranged 47 m at VES station 4 to 102 m at VES station 3 and undetected at VES station 2, this layer represent the third aquifer (brackish water). The fifth geoelectrical unit reveals very low resistivity values 2-5 ohm.m and consists of clay and sandstone of Oligocene and Upper Eocene deposits, the thickness determined only at VES stations 1 and 3 with 61 and 113 m respectively. The sixth geoelectrical unit is the end unit in the section and the upper surface detected only at VES stations 1 and 3 and exhibits moderately resistivity values 22-35 ohm.m and consists of limestone of Middle Eocene deposits.

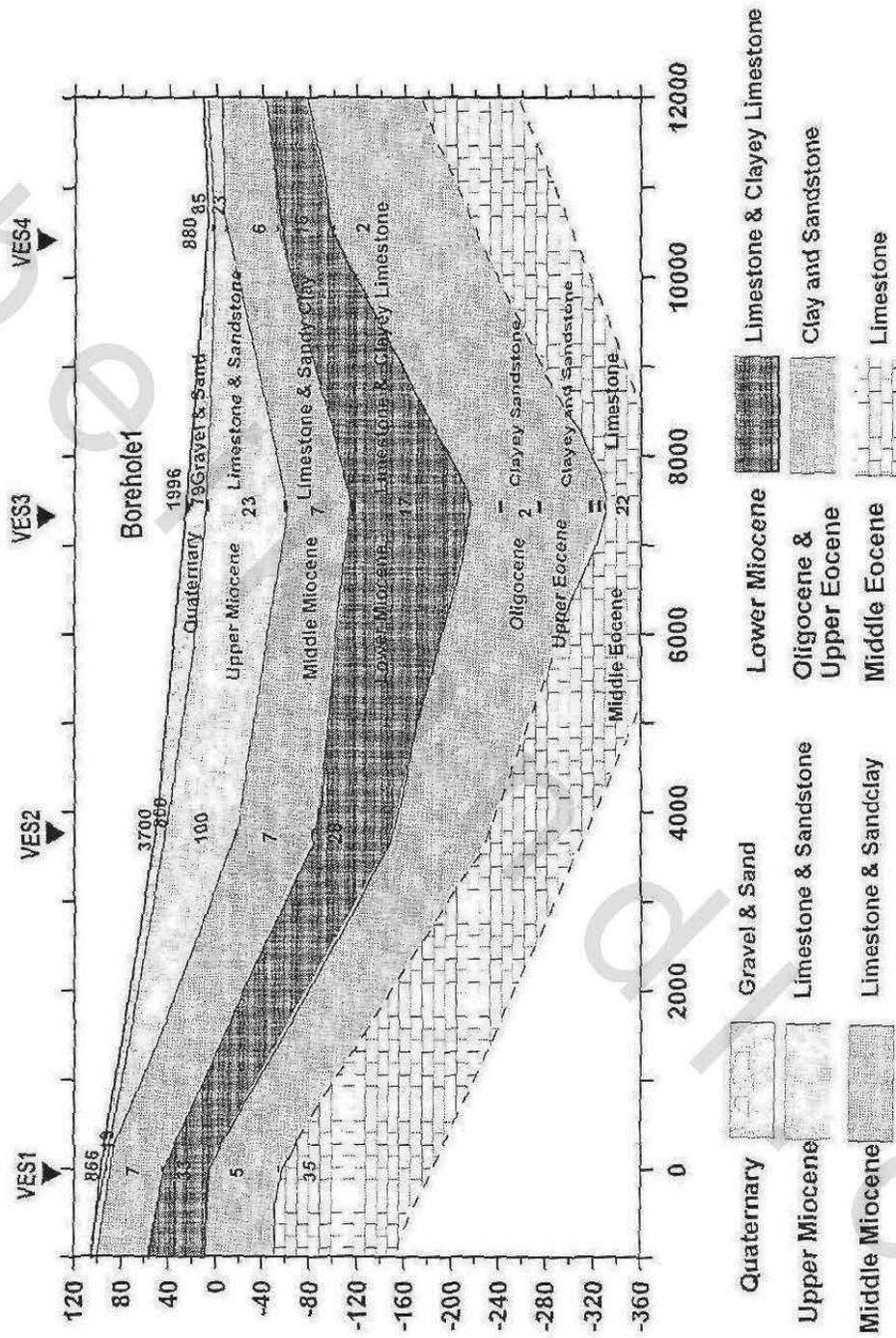


Figure (53): Geoelectrical cross-section along profile A-A

2- Geoelectrical cross-section along profile B-B.'

The geoelectrical cross-section along profile B-B' (Fig. 54) is constructed to involve VES no. 5, 6, 7, 8, and 4. It is characterized by the presence of six geoelectrical units; the first unit represents the Quaternary gravel and sand of high resistivity values and thickness of about few meters. The second geoelectrical units exhibit moderately resistivity values ranging from 9 ohm. m to 80 ohm. m, the thickness of this unit is about 25m. It mainly consists of limestone and sandstone which belong to Upper Miocene and represent the fresh water aquifer in the study area. The third geoelectrical units having resistivity values ranging from 3 to 18 ohm m and thickness of about 40 m and composed of limestone and sandy clay which belong to Middle Miocene deposits, this layer represents the second aquifer (brackish water).

The fourth geoelectrical unit consists of limestone and clayey limestone which belong to Lower Miocene deposits and exhibits moderately resistivity values ranging from 16 at VES station 4 to 91 at VES station 7, the thickness of this unit ranging from 40 m at VES station 4 to 90 m at VES station 5, this layer represents the third aquifer (brackish water). The fifth geoelectrical unit reveals very low resistivity values 1-16 ohm.m and consists of clay and sandstone of Oligocene and Upper Eocene deposits, the thickness ranging from 40 to 70 m. The sixth geoelectrical unit is the end unit in the section and exhibits moderately resistivity values 15-67 ohm.m and consists of limestone of Middle Eocene deposits.

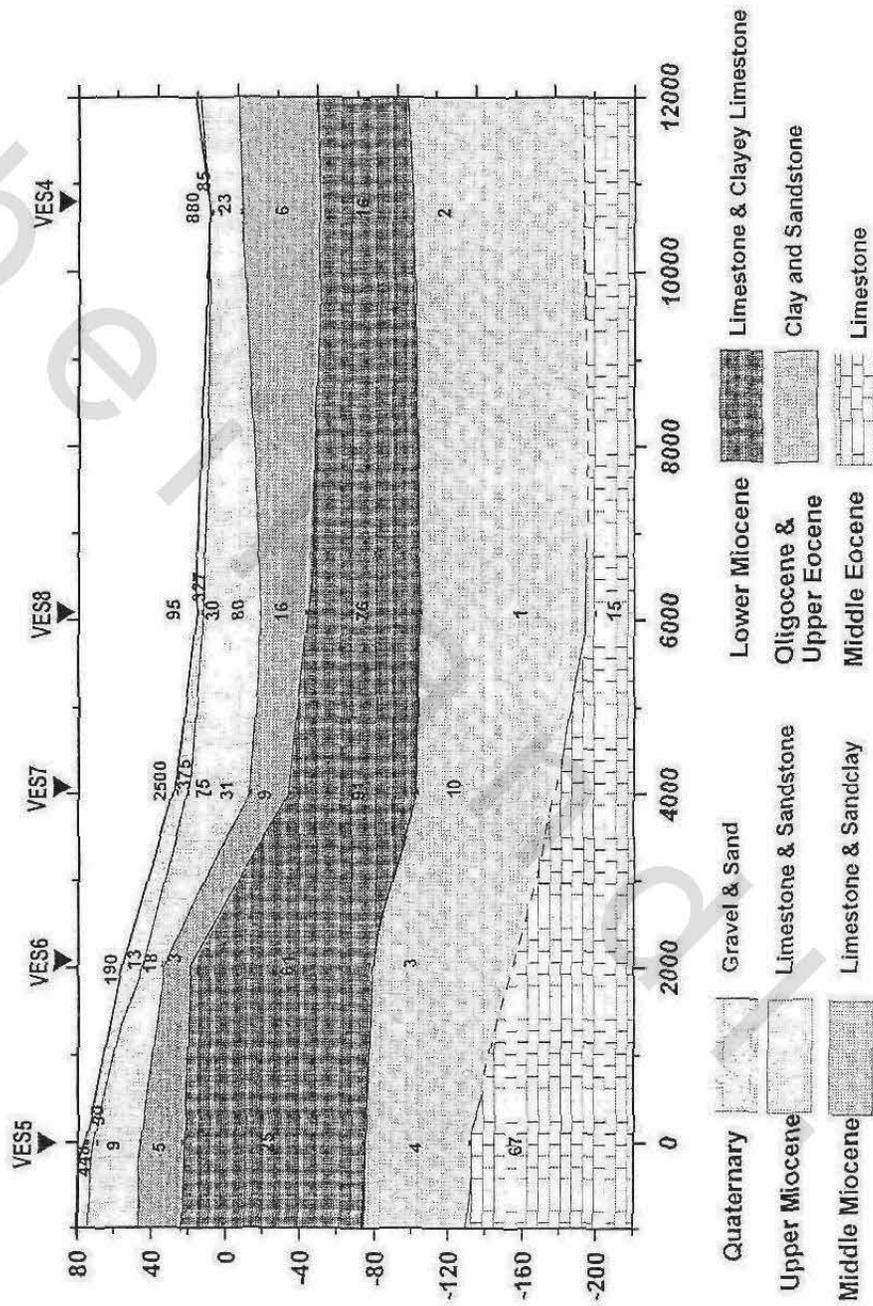


Figure (54): Geoelectrical cross-section along profile B-B

3- Geoelectrical cross-section along profile C-C.'

The geoelectrical cross-section along profile C-C.' (Fig. 55) involve VES no. 9, 10, 11, 12 and 13. It characterized by the presence of six geoelectrical units; the first unit represents the Quaternary gravel and sand of high resistivity values thickness of about few meters. The second geoelectrical unit exhibits moderately resistivity values ranging from 29 ohm. m to 675 ohm. m, the thickness of this unit ranging from 10 to 40 m. It mainly consists of limestone and sandstone which belong to Upper Miocene and represent the fresh water aquifer in the study area. The third geoelectrical units having resistivity values ranged from 8 ohm m at VES station 13 to 25 ohm m at VES 11 station and thickness ranges between 40 and 60 m and composed of limestone a sandyclay which belong to Middle Miocene deposits, this layer represent the second aquifer (brackish water).

The fourth geoelectrical units consists of limestone and clayey limestone which belong to Lower Miocene deposits and exhibits moderately resistivity values ranging from 29 at VES station 13 to 82 at VES station 11, the thickness of this unit ranging from 20 m to 80 m at VES station 12, this layer represent the third aquifer (brackish water) . The fifth geoelectrical unit reveals very low resistivity values 3-11 ohm.m and consists of clay and sandstone of Oligocene and Upper Eocene deposits, the thickness. The sixth geoelectrical units is the end unit in the section and detected only at VES stations 12 and 13, exhibits moderately resistivity values 2 ohm.m at VES stations 13 and 47 at VES stations 12 and consists of limestone of Middle Eocene deposits.

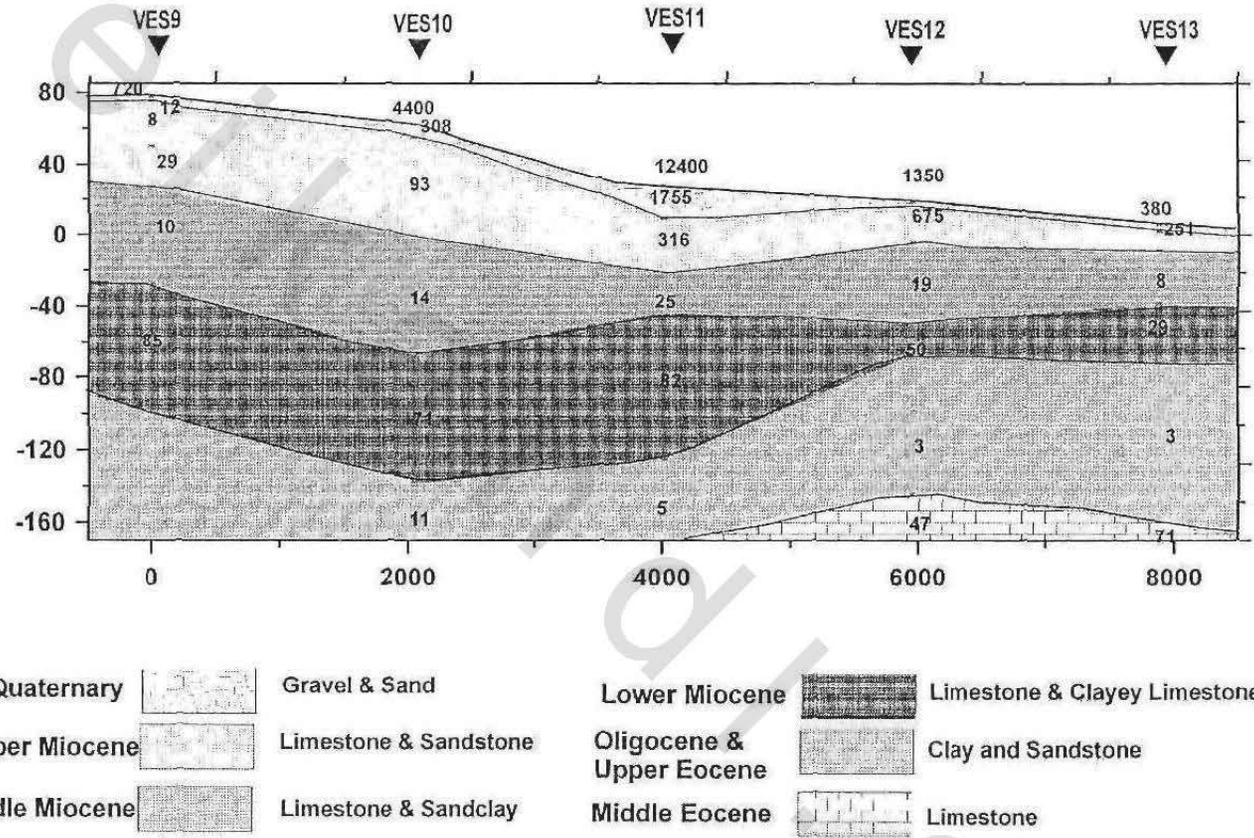


Figure (55): Geoelectrical cross-section along profile C-C.

4- Geoelectrical cross-section along profile D-D'.

The geoelectrical cross-section along profile **D-D'** (Fig 56) involves VES no. 14, 15, 16 and 17. It is characterized by the presence of six geoelectrical units; the first unit represents the Quaternary gravel and sand of high resistivity values with a thickness of about few meters. The second geoelectrical unit exhibits moderately resistivity values ranging from 17 ohm. m at VES station 14 to 735 ohm. m at VES station 16, the thickness of this unit is about 40 m. It mainly consists of limestone and sandstone which belong to Upper Miocene and represent the fresh water aquifer in the study area. The third geoelectrical unit having resistivity values ranging from 6 ohm m at VES station 16 to 21 ohm m at VES station 15 and thickness ranges between 40 and 100 m and composed of limestone and sandy clay which belongs to Middle Miocene deposits, this layer represents the second aquifer (brackish water).

The fourth geoelectrical unit consists of limestone and clayey limestone which belongs to Lower Miocene deposits and exhibits moderately resistivity values ranging from 19 at VES station 16 to 66 at VES station 17, the thickness of this unit ranging from 45 m at VES station 15 to 105 m at VES station 17, this layer represents the third aquifer (brackish water), this layer represents the second aquifer (brackish water). The fifth geoelectrical unit reveals very low resistivity values 3-10 ohm.m and consists of clay and sandstone of Oligocene and Upper Eocene deposits, the thickness is about 80m. The sixth geoelectrical unit is the end unit in the section and not detected at VES stations 17, exhibits moderately resistivity values 110 ohm.m at VES stations 15 and consists of limestone of Middle Eocene deposits.

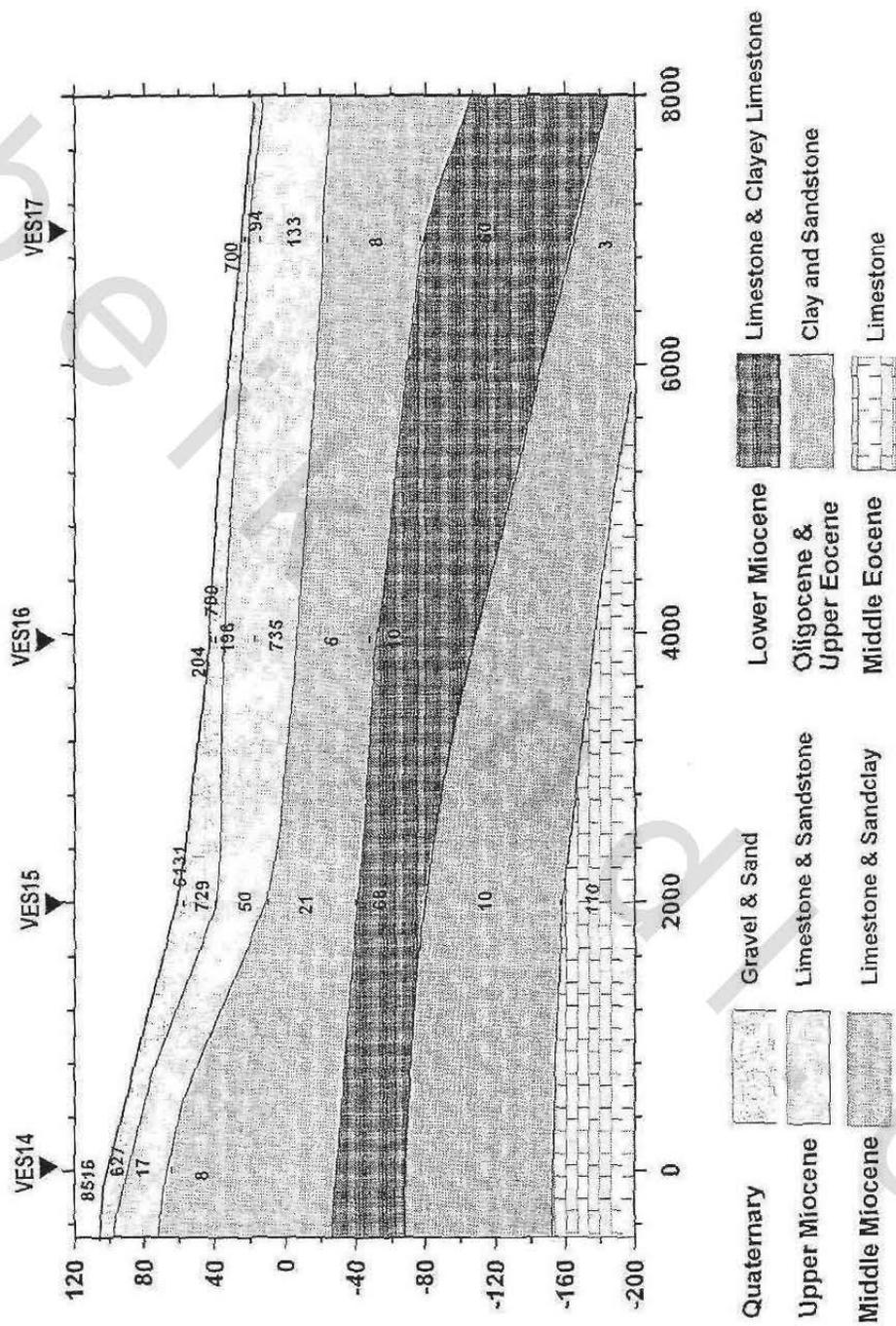


Figure (56): Geoelectrical cross-section along profile D-D.

V. 5. Depth Maps:

The depth maps (Figs. 57, 58, 59, 60, and 61) described the variation of depth for the different layers of geoelectrical unit.

1- Depth map of the second geoelectrical unit

The depth of the second geoelectrical unit (Fig. 57) shows shallow depths at the northwestern part and southeastern part of the study area (1-5 m) but the northeastern and southwestern parts reveal deep depths (20-25m).

2- Depth map of the third geoelectrical unit

The depth of the third geoelectrical unit (Fig. 58) shows shallow depths at the northwestern part and southeastern part of the study area (5-10 m) but in the northeastern part reach to maximum depth (80 - 100 m) and in southwestern part the depth about (20-60m).

3- Depth map of the fourth geoelectrical unit

The depth of the fourth geoelectrical unit (Fig. 59) shows shallow depths at the northwestern part and southeastern part of the study area (5-10 m) but in the northeastern part reach to maximum depth (150- 180 m) and in southwestern part the depth about (70-90m).

4- Depth map of the fifth geoelectrical unit

The depth of the fifth geoelectrical unit (Fig. 60) shows shallow depths at the northwestern part and southeastern part of the study area (70-100 m) but in the northeastern part reach to maximum depth (210- 260 m) and in southwestern part the depth about (150m).

5- Depth map of the sixth geoelectrical unit

The depth of the sixth geoelectrical unit (Fig. 61) shows shallow depths at the northwestern part and southeastern part of the study area (130 - 160 m) but in the northeastern part reach to maximum depth (300- 370 m) and in southwestern part the depth about (200 – 220 m).

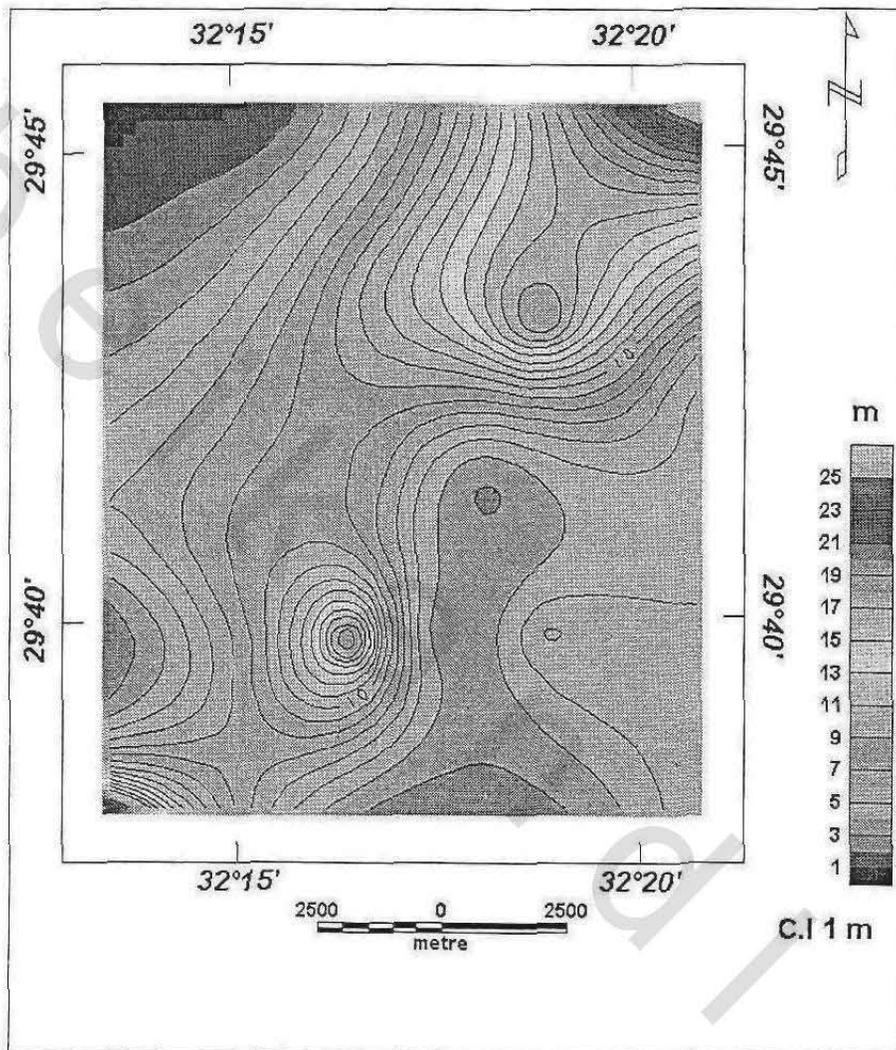


Figure (57): Depth map of the second geoelectrical unit.

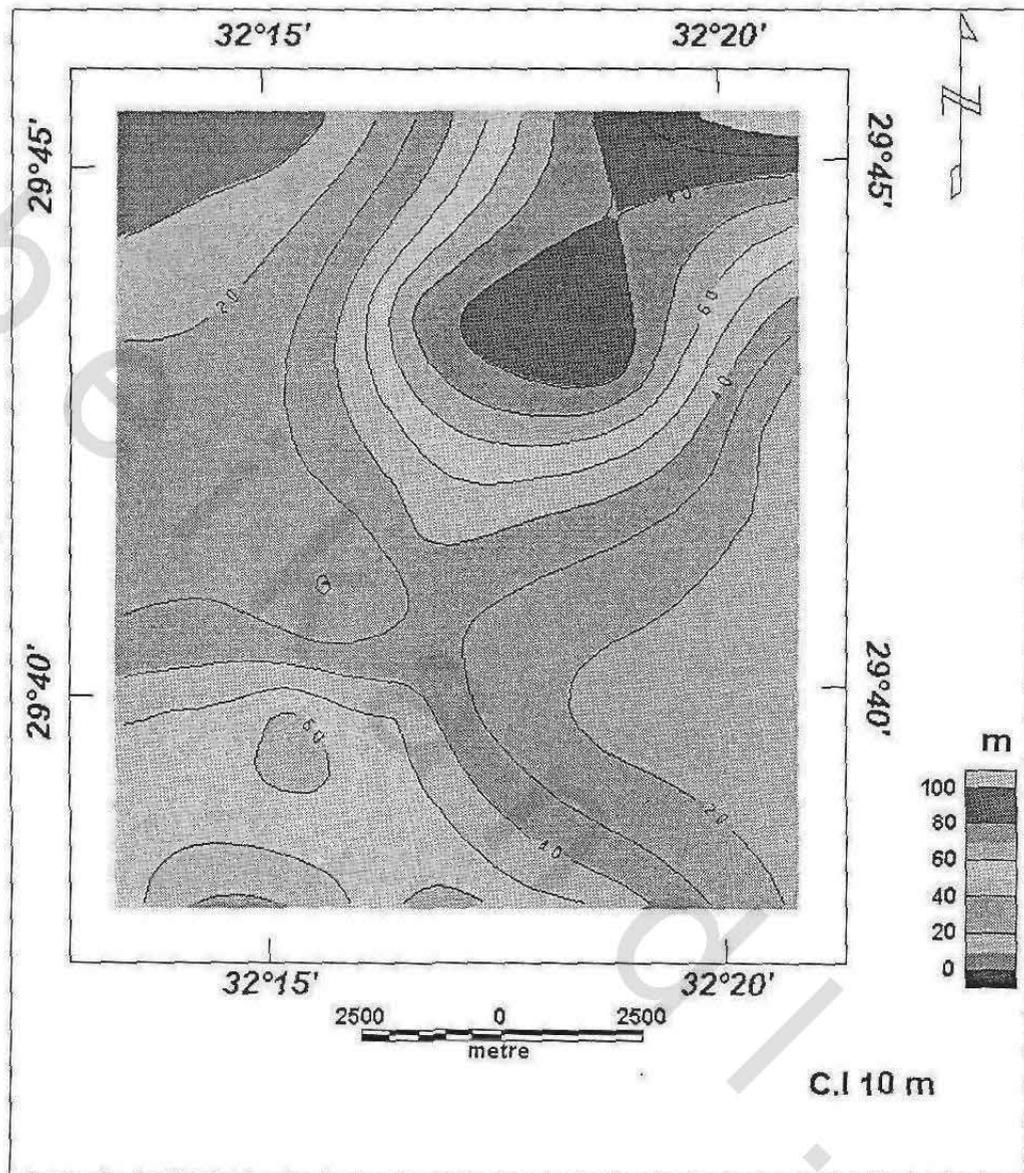


Figure (58): Depth map of the third geoelectrical unit.

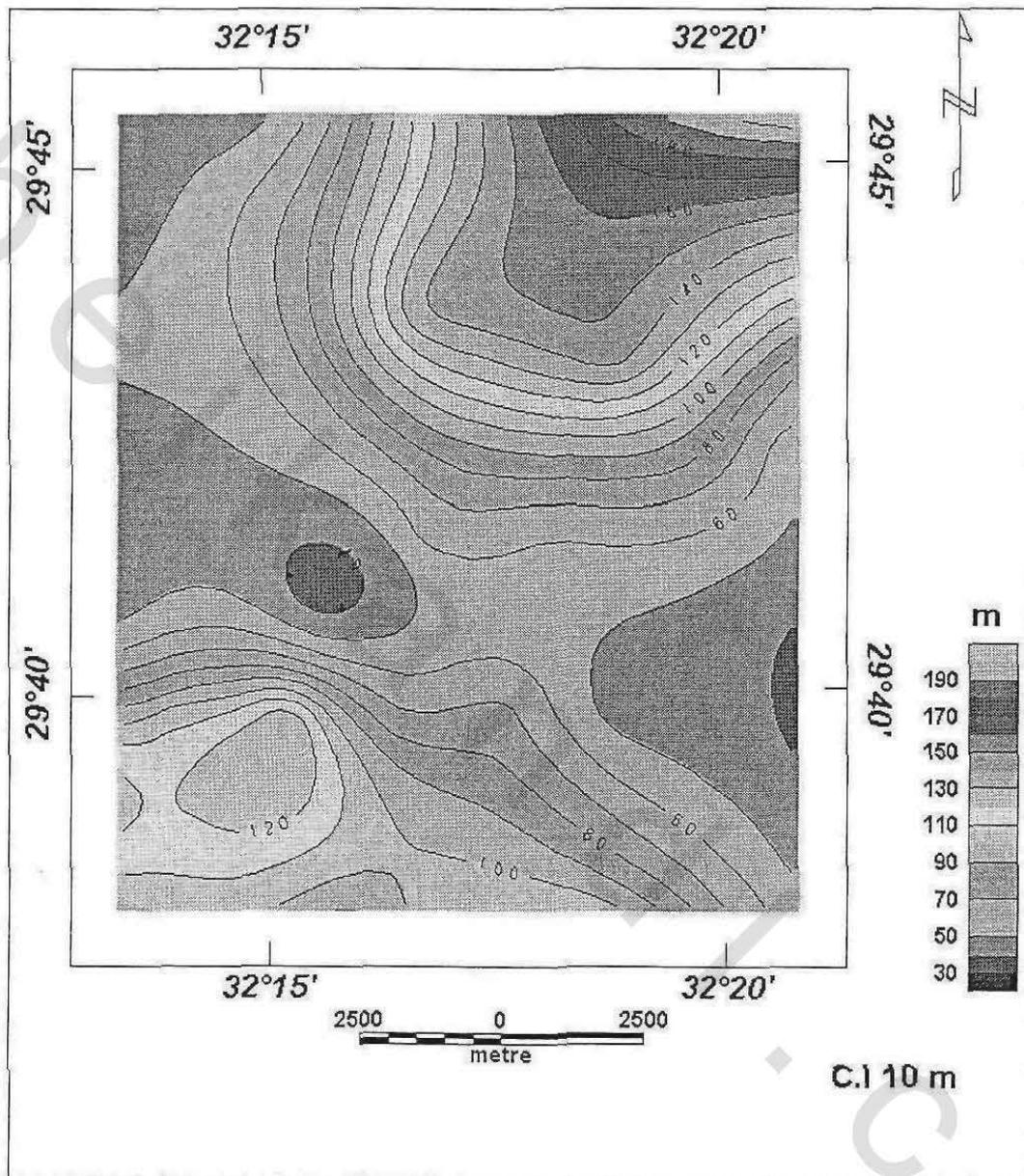


Figure (59): Depth map of the fourth geoelectrical unit

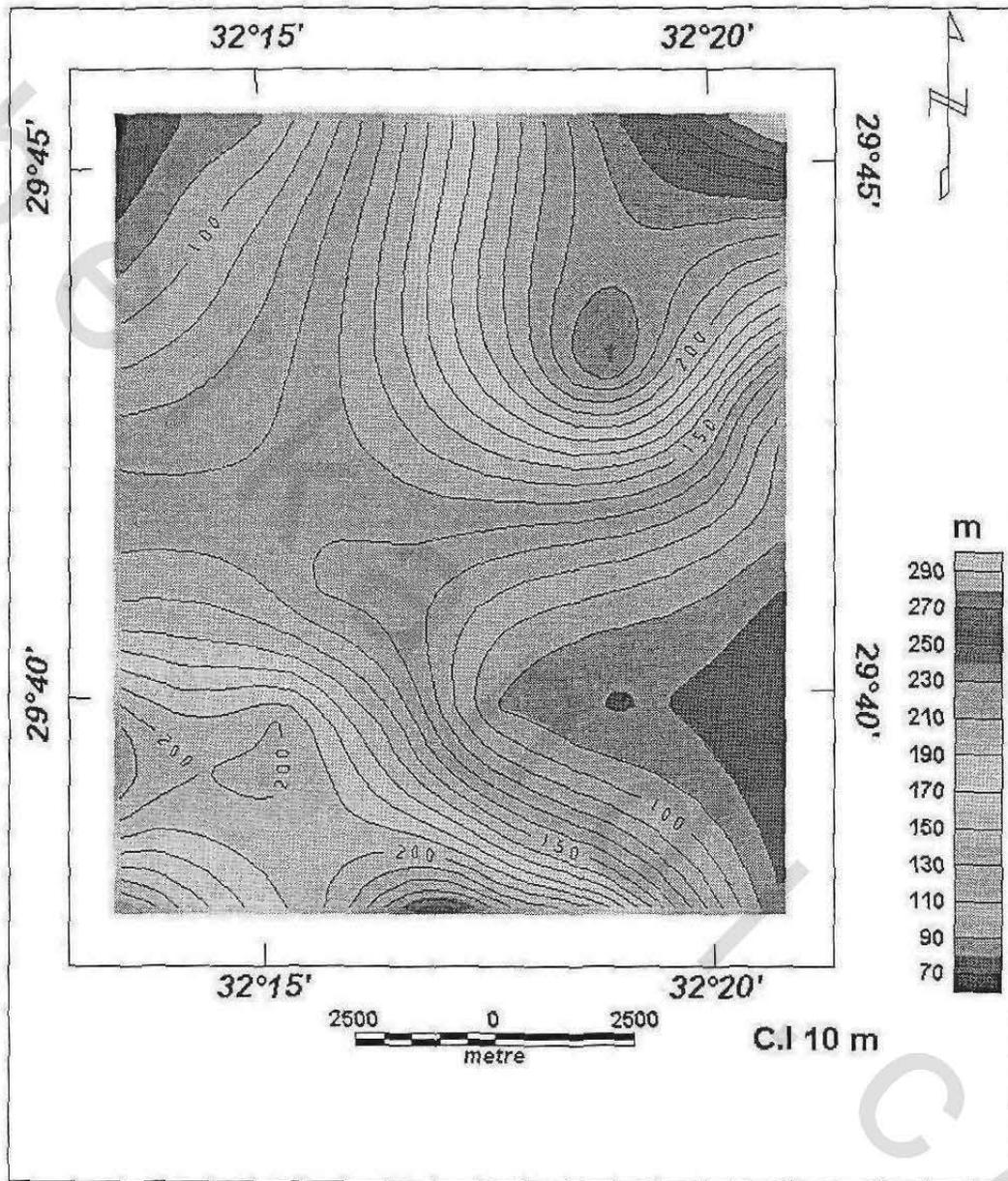


Figure (60): Depth map of the fifth geoelectrical unit.

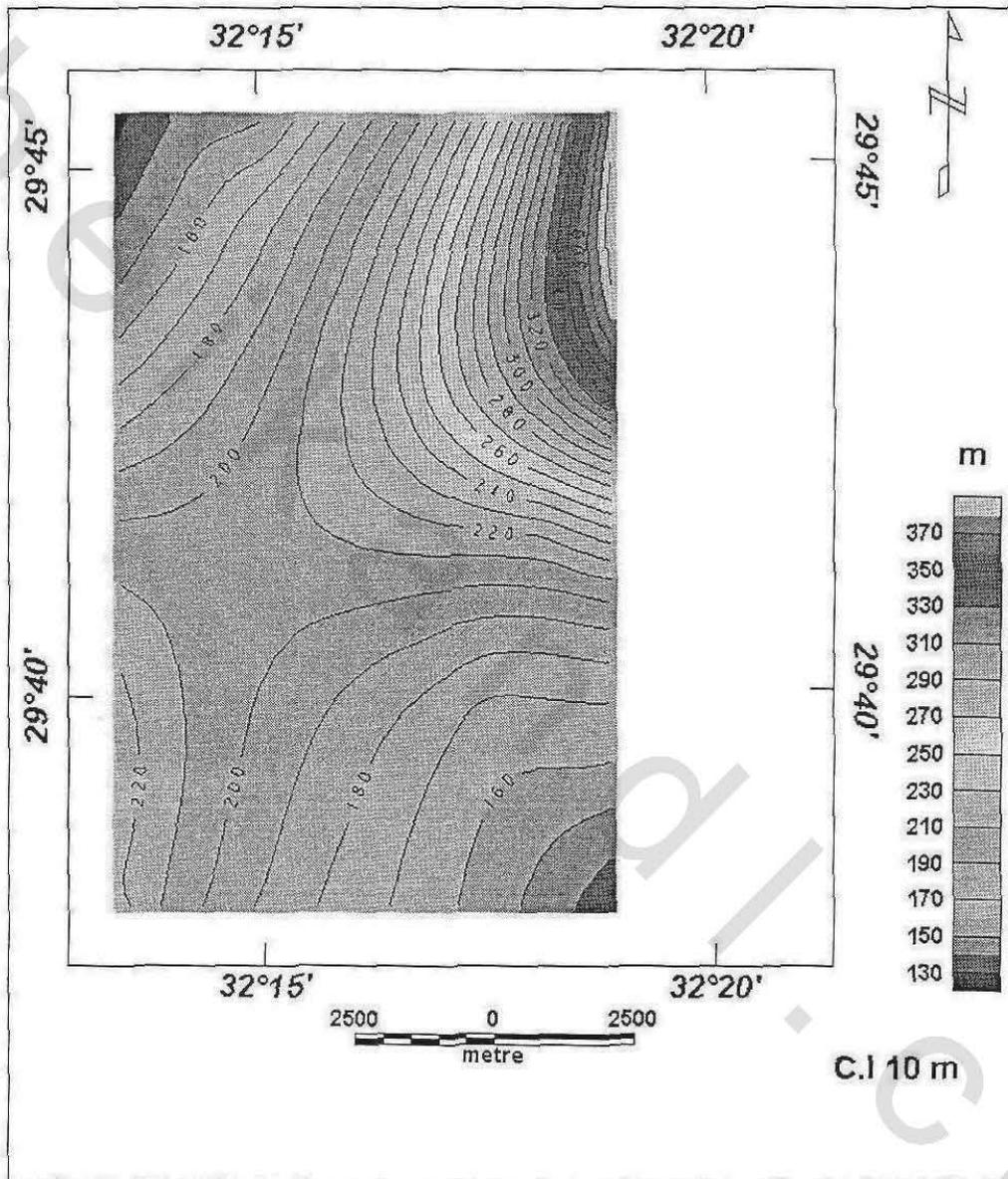


Figure (61): Depth map of the sixth geoelectrical unit.

V. 6. Isopach Maps

The isopach maps (Figs. 62, 63, 64, 65 and 66) are constructed to indicate the variation of the thicknesses of the first, second, third, fourth and fifth unit's respectively.

1- Isopach map of the first geoelectrical unit

The lithology of this layer consists have gravel and sand for Quaternary age. The isopach map shows the thickness ranging from 1 to 25m and its thickness increase toward the northeastern corner 25m and decrease at northwestern corner (Fig. 62).

2- Isopach map of the second geoelectrical unit

The isopach map of this unit exhibits large thickness at the northern part, specially at northeastern part with a thickness reaches 85m, but northwestern part is characterized by small thickness of about 5m. This layer represent the fresh water aquifer in the study area for Upper Miocene age, the lithology of this layer consists of limestone and sandstone (Fig 63).

3- Isopach map of the third geoelectrical unit

The isopach map of this unit reflects that, the thickness values are ranging from 15m at the middle part and 65 m at the north and south part. This layer represent the second aquifer in the study area for middle Miocene age, the lithology of this layer consists of limestone and sandyclay (Fig. 64).

4- Isopach map of the fourth geoelectrical unit

The isopach map of this unit reveals considerable thickness values at western central part and the northeastern corner with a thickness of about 100m, but the small thickness values are located at southern part. This layer represents the third aquifer in the study area for Lower Miocene age, the lithology of this layer consists of limestone and clayey limestone. (Fig. 65).

5- Isopach map of the fifth geoelectrical unit

The lithology of this layer consists of clay and sandstone for Oligocene and Upper Eocene age. The thickness ranges from 50 to 120 m and increase from west to northeastern corner. (Fig. 66).

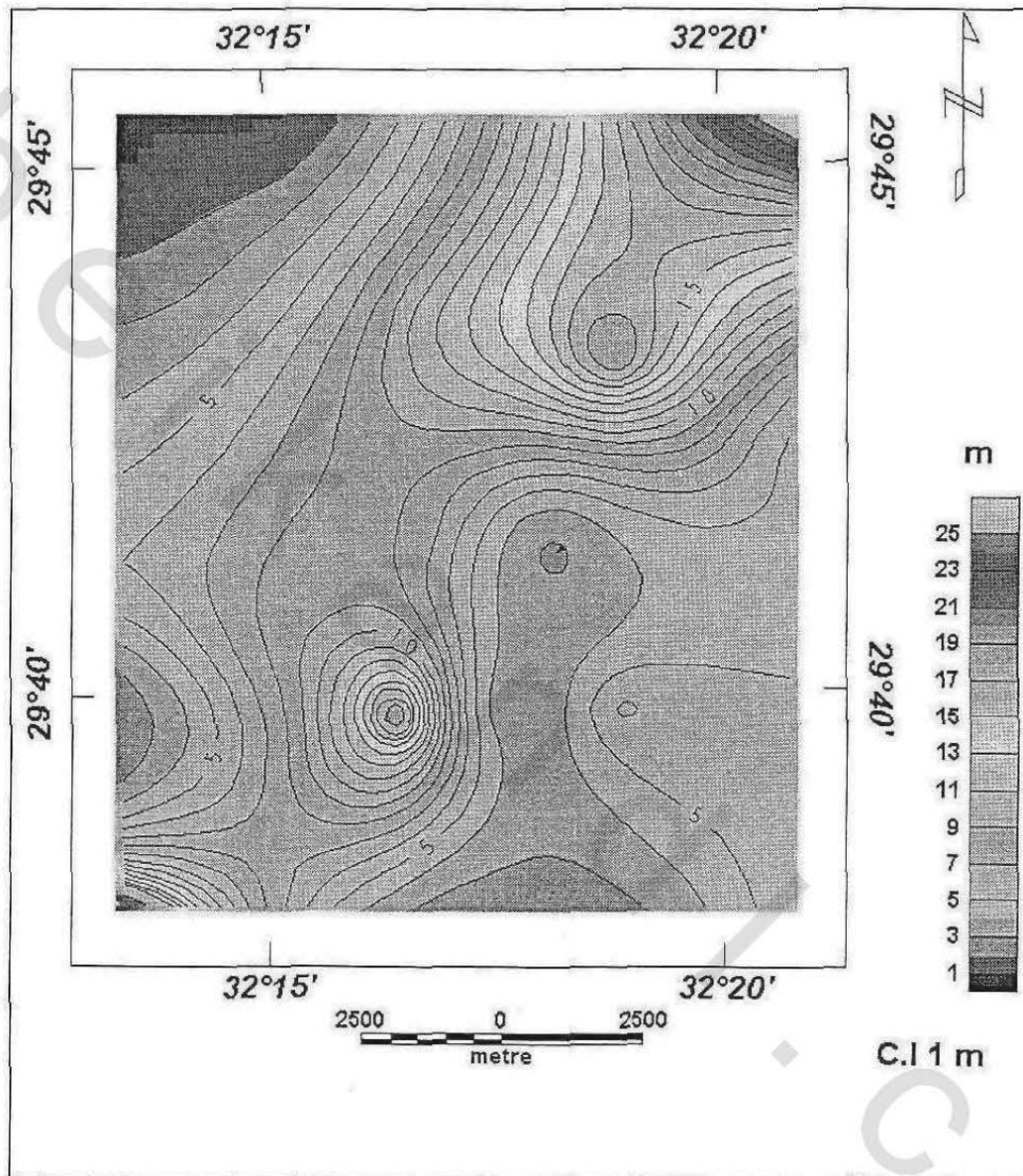


Figure (62): Isopach map of the first geoelectrical unit.

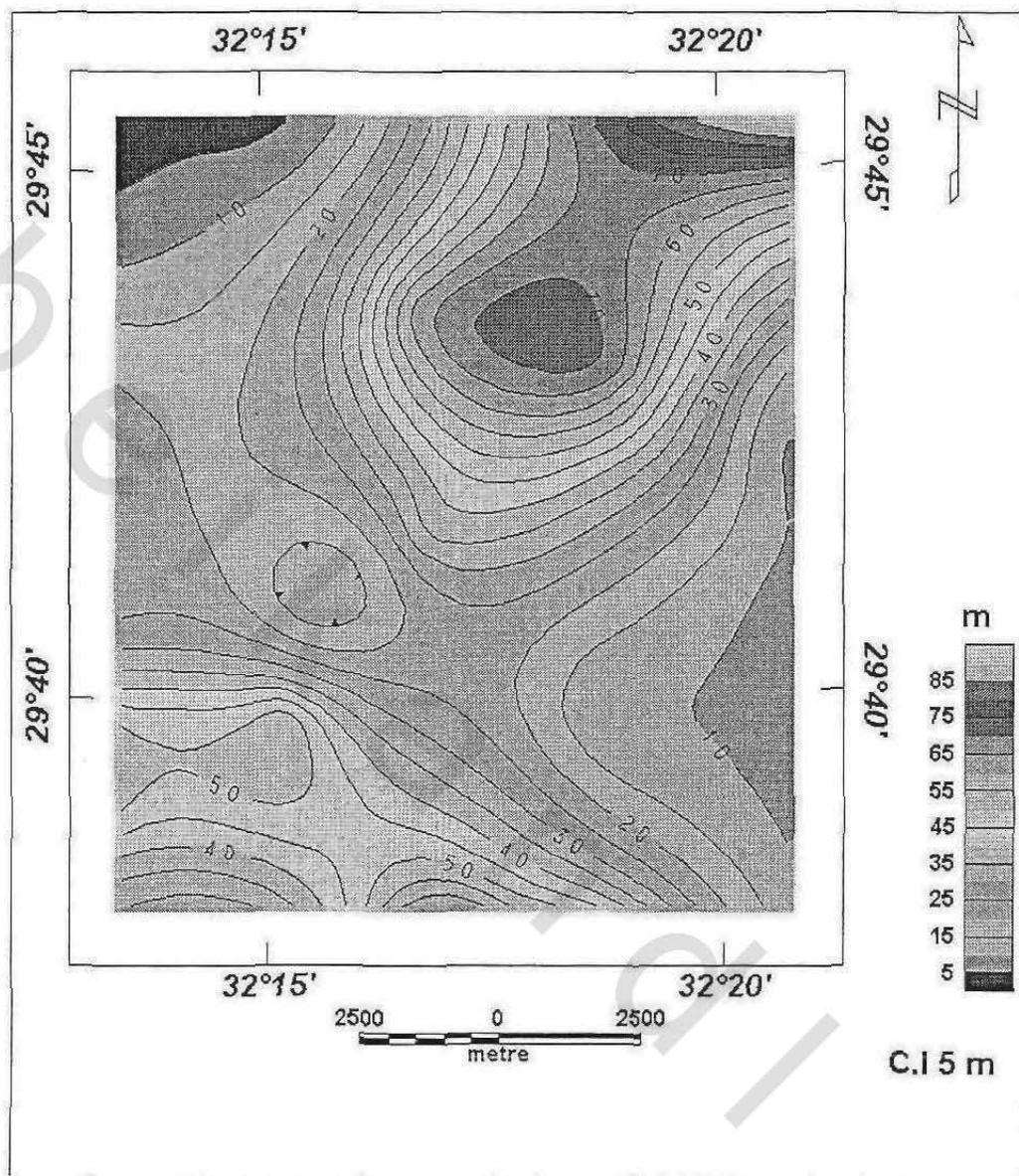


Figure (63): Isopach map of the second geoelectrical unit.

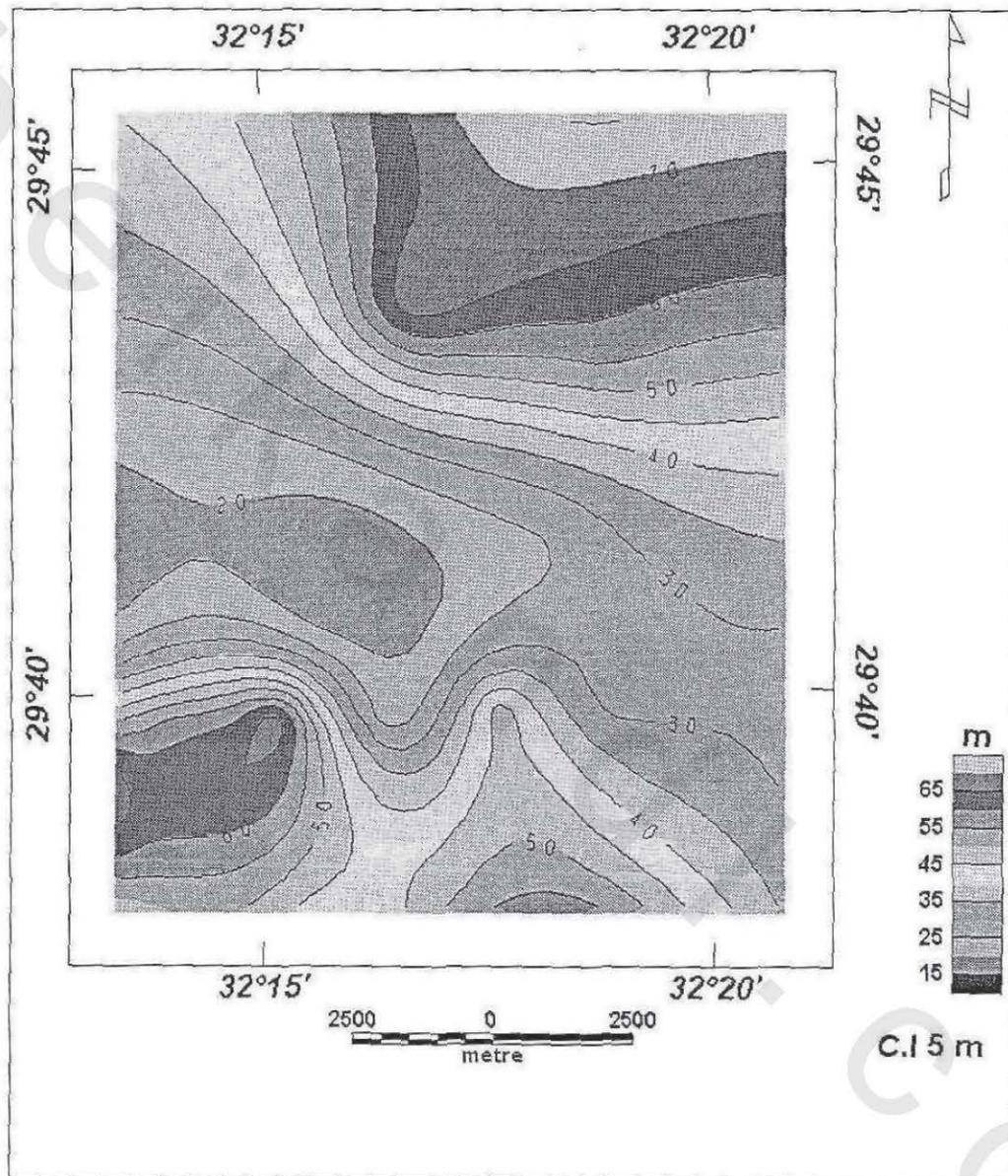


Figure (64): Isopach map of the third geoelectrical unit.

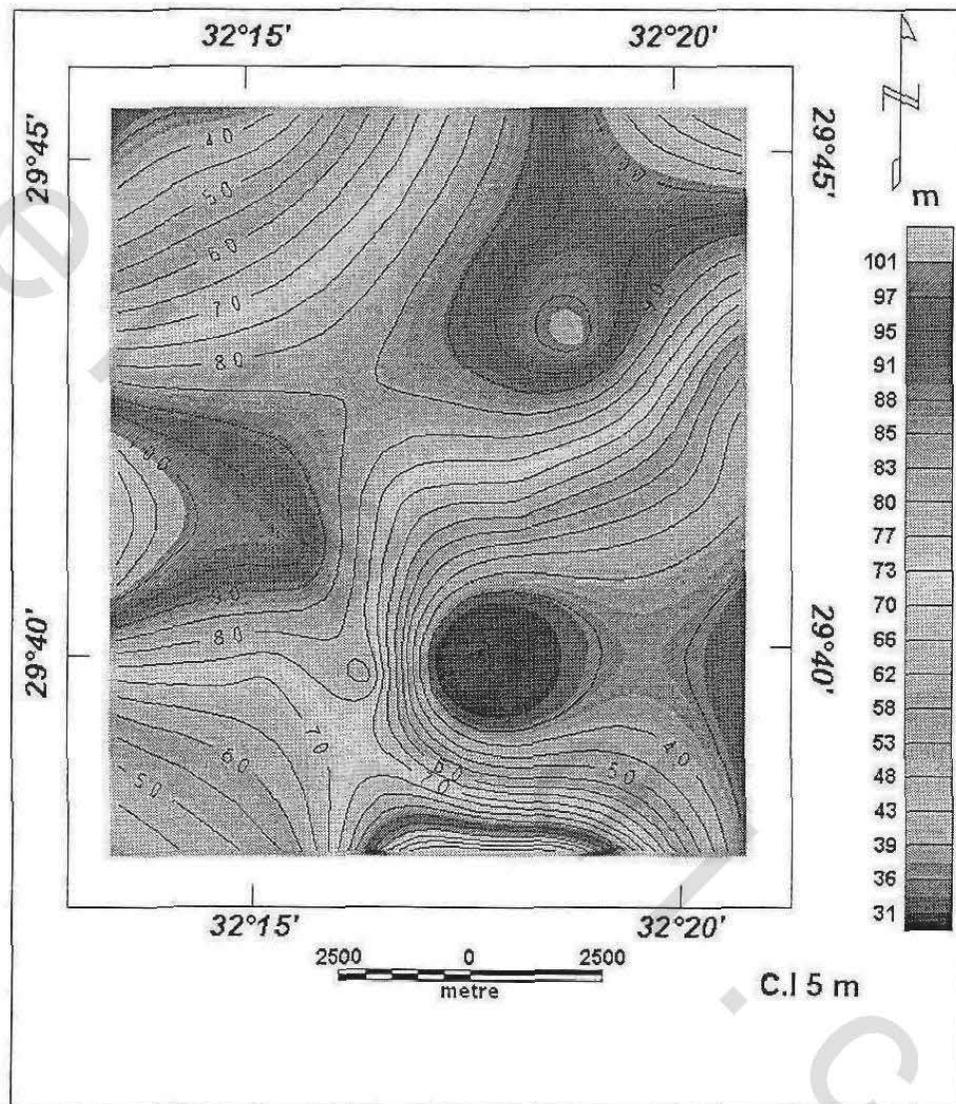


Figure (65): Isopach map of the fourth geoelectrical unit.

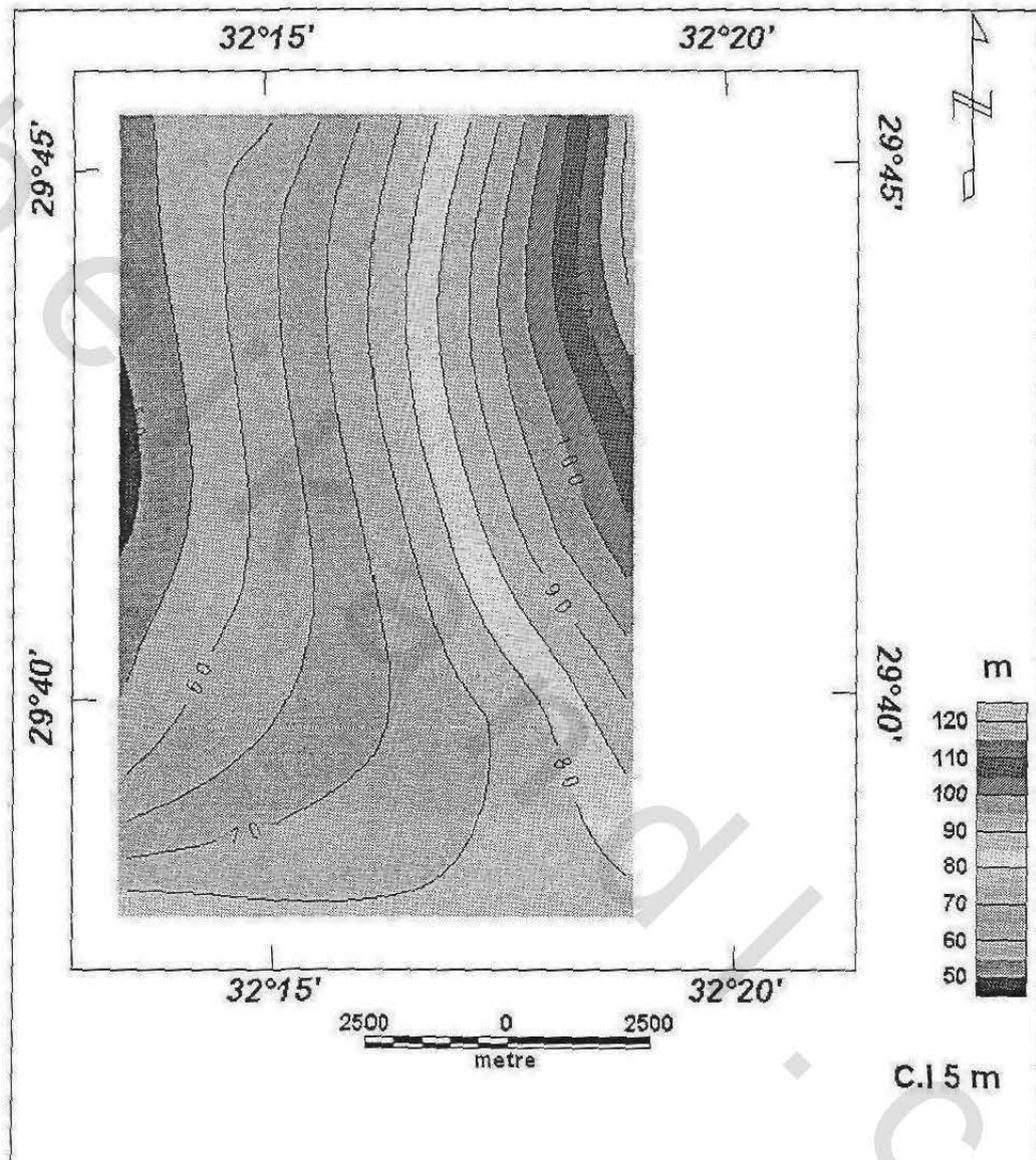


Figure (66): Isopach map of the fifth geoelectrical unit.

V. 7. Isoresistivity Maps

The Isoresistivity maps are constructed to indicate the variation of the resistivity values for different layers (Figs 67, 68, 69, 70, 71 and 72) to differentiate the lithology of these layers specially the water bearing layers where the quality of water in the aquifer depend on the resistivity values, the fresh water has high resistivity and saline water has low resistivity values.

1- Isoresistivity map of the first geoelectrical unit

The resistivity values ranging from 200 ohm.m to 8700 ohm.m, the maximum resistivity at the south western part while minimum resistivity at eastern part (Fig. 67).

2- Isoresistivity map of the second geoelectrical unit

The resistivity values ranging from 0 ohm.m to 600 ohm.m, the maximum resistivity represented with southern part while minimum resistivity represented with northern part of study area (Fig. 68).

3-Isoresistivity map of the third geoelectrical unit

Isoresistivity map of the third geoelectrical unit shows the low resistivity values ranging between 4 ohm.m at the most northern parts while the small part from the southern area occupied by high resistivity 16 ohm.m (Fig. 69).

4- Isoresistivity map of the fourth geoelectrical unit

The fourth geoelectrical unit is characterized by low resistivity values ranging between 10 to 30 ohm.m at the northern part while the most of the southern part represented by high resistivity ranged from 40 to 90 ohm.m (Fig.70).

5-Isoresistivity map of the fifth geoelectrical unit

Isoresistivity map of the fifth geoelectrical unit reveals that the whole area of this unit are characterized by low resistivity values ranging between 1 to 5 ohm.m expect the southwestern corner which have resistivity value of 13 ohm.m (Fig. 71).

6-Isoresistivity map of the sixth geoelectrical unit

Isoresistivity map of the sixth geoelectrical unit shows that the whole area is represented by low resistivity range from 10 to 60 ohm.m. While the small part of southwestern and southeastern corner represented by high resistivity range from 120 to 150 ohm.m (Fig. 72).

Conclusions

The results of resistivity interpretation for depth, thickness and resistivity values for different layers indicated that the fresh water bearing aquifer has thickness from 5 to 85m and depth ranging from 5 to 25m. From these results we can suggest that the best locations of boreholes for ground water (Fig. 73) which can be used for construction, production and human uses.

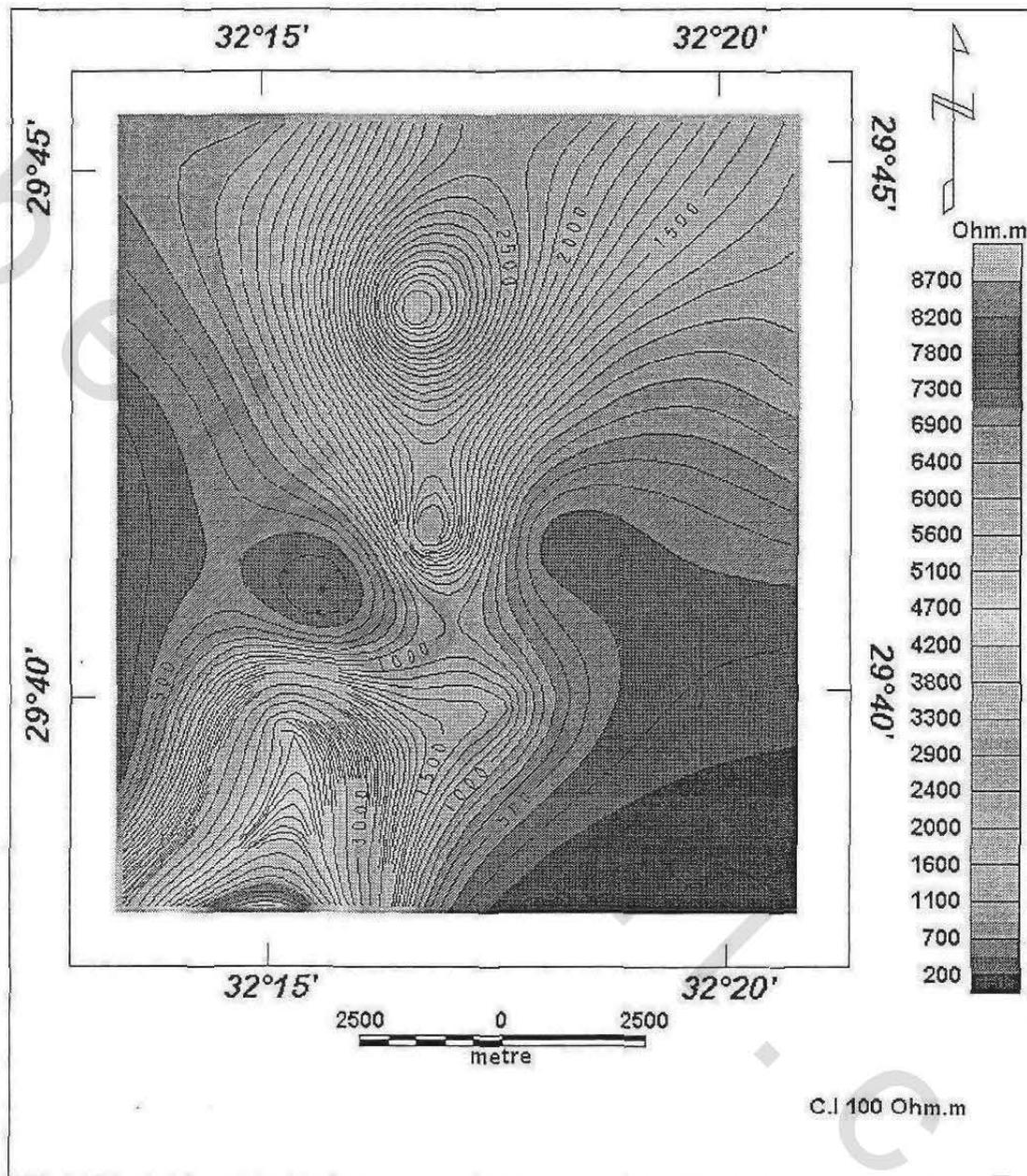


Figure (67): Isoresistivity map of the first geoelectrical unit.

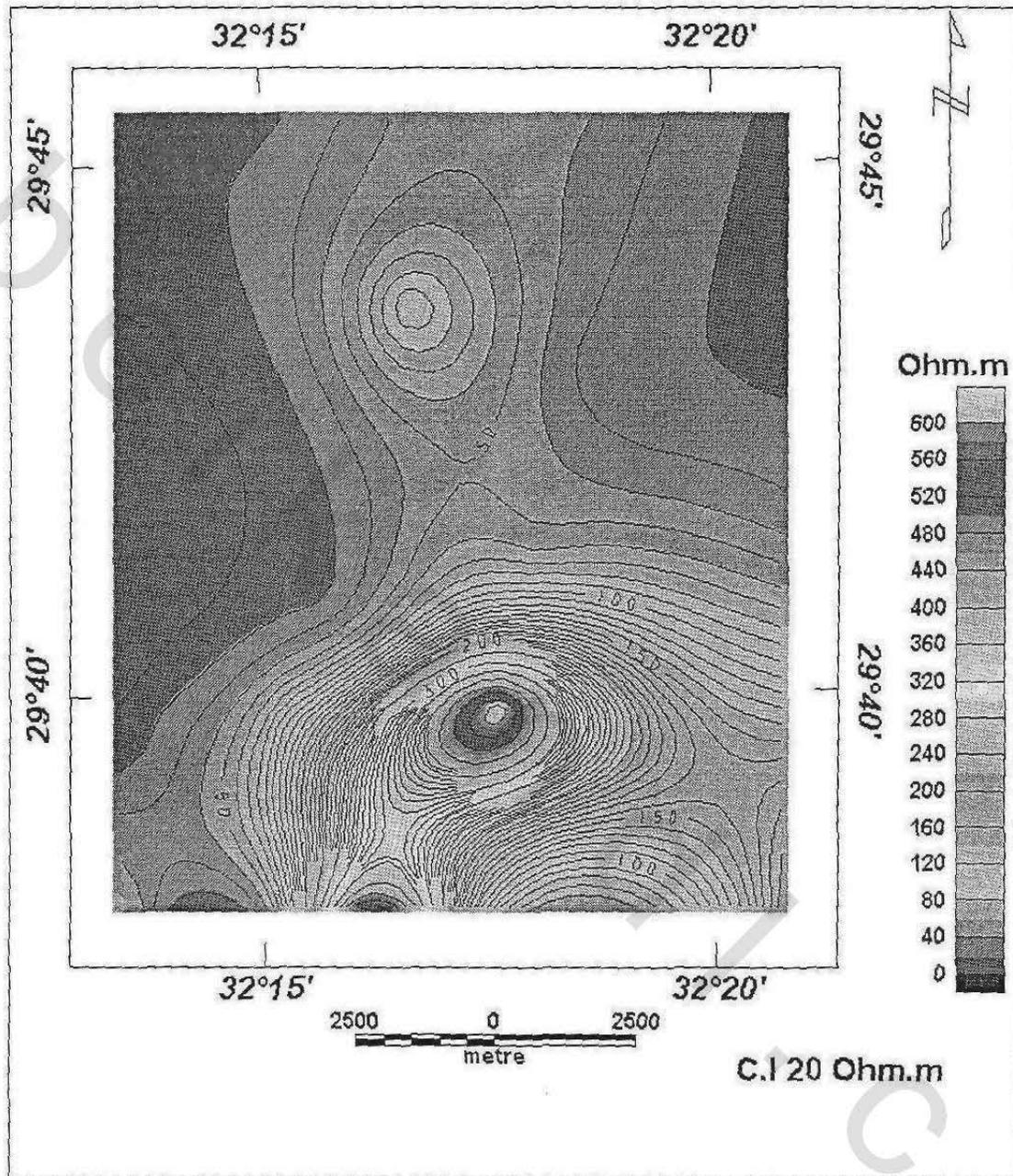


Figure (68): Isoresistivity map of the second geoelectrical unit.

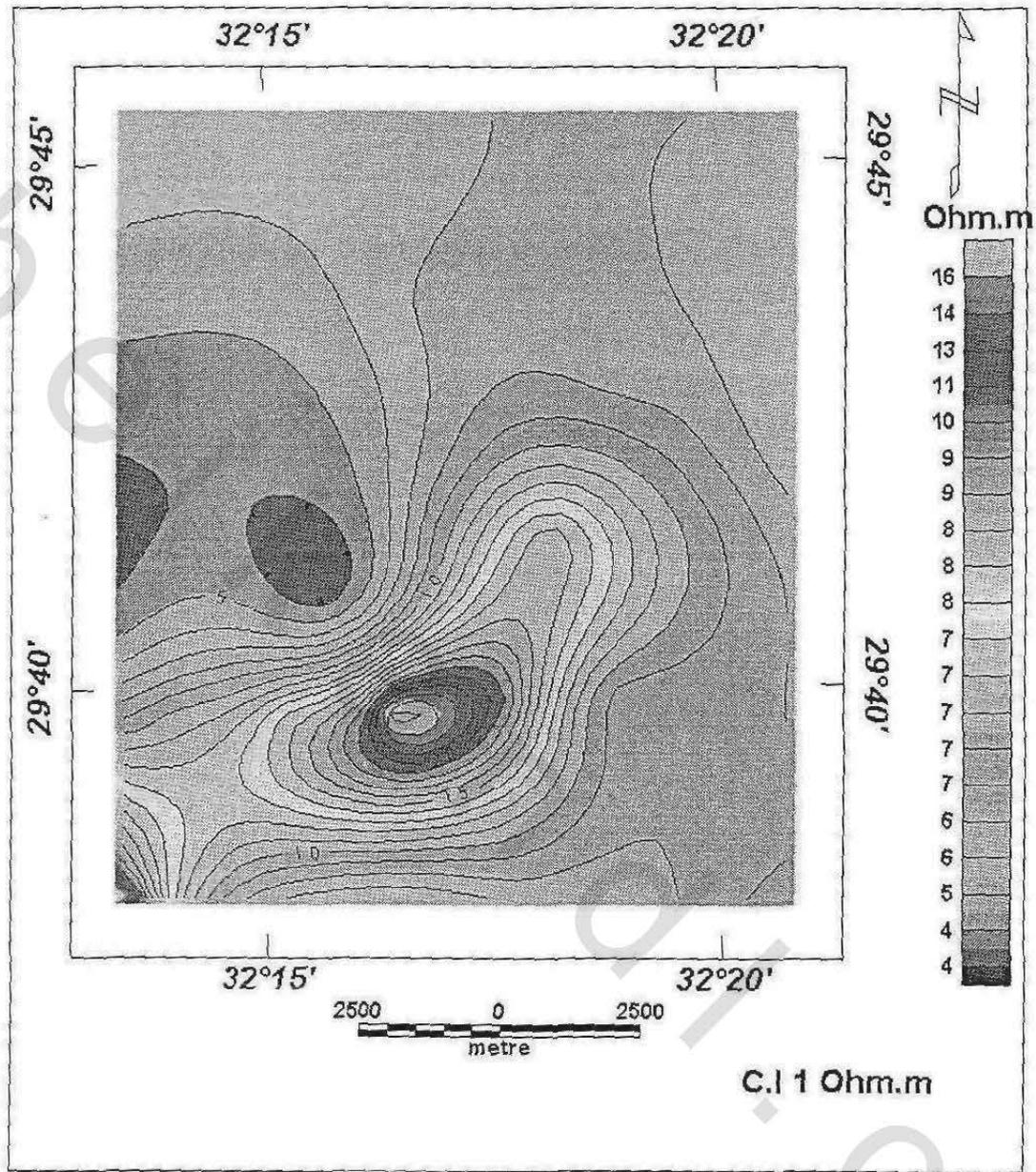


Figure (69): Isoresistivity map of the third geoelectrical unit.

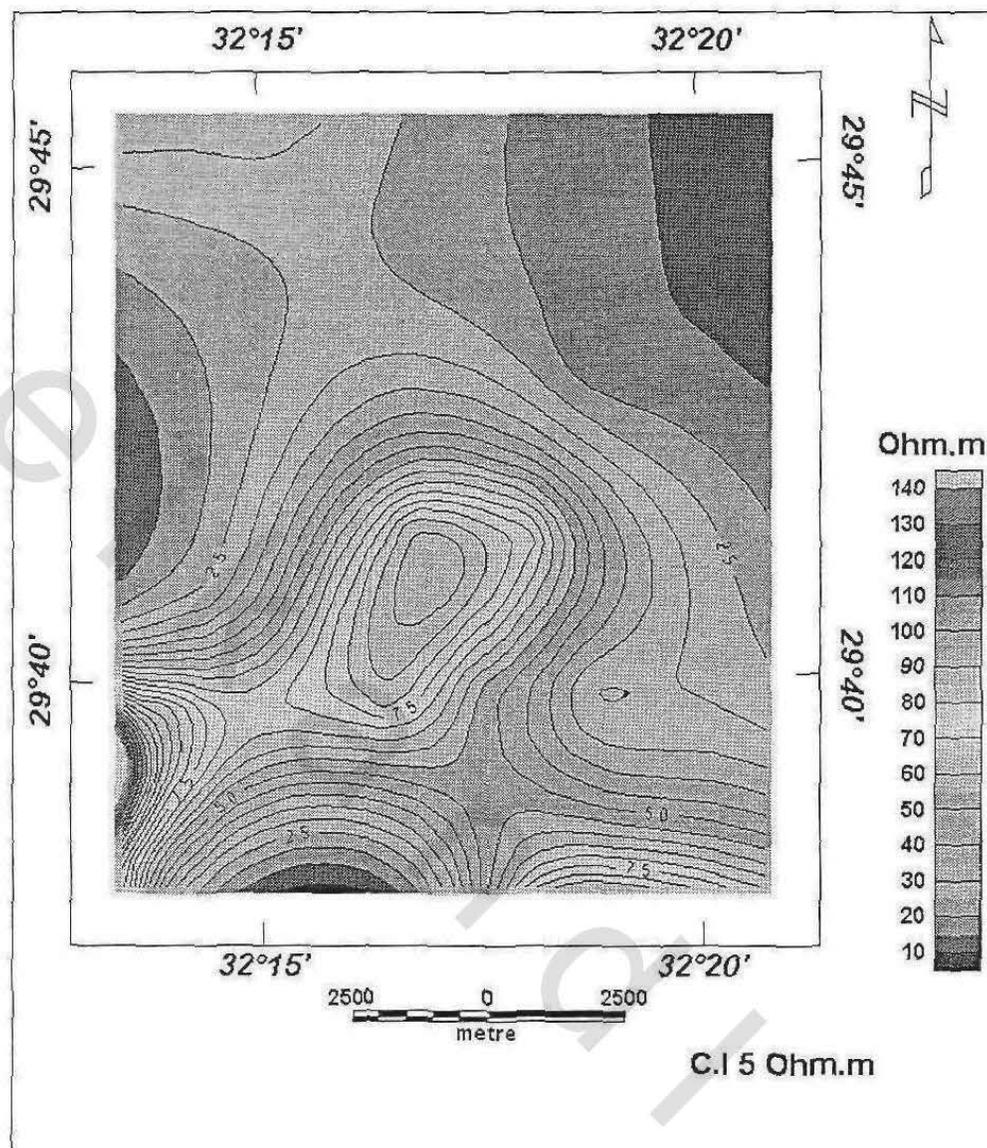


Figure (70): Isoresistivity map of the fourth geoelectrical unit.

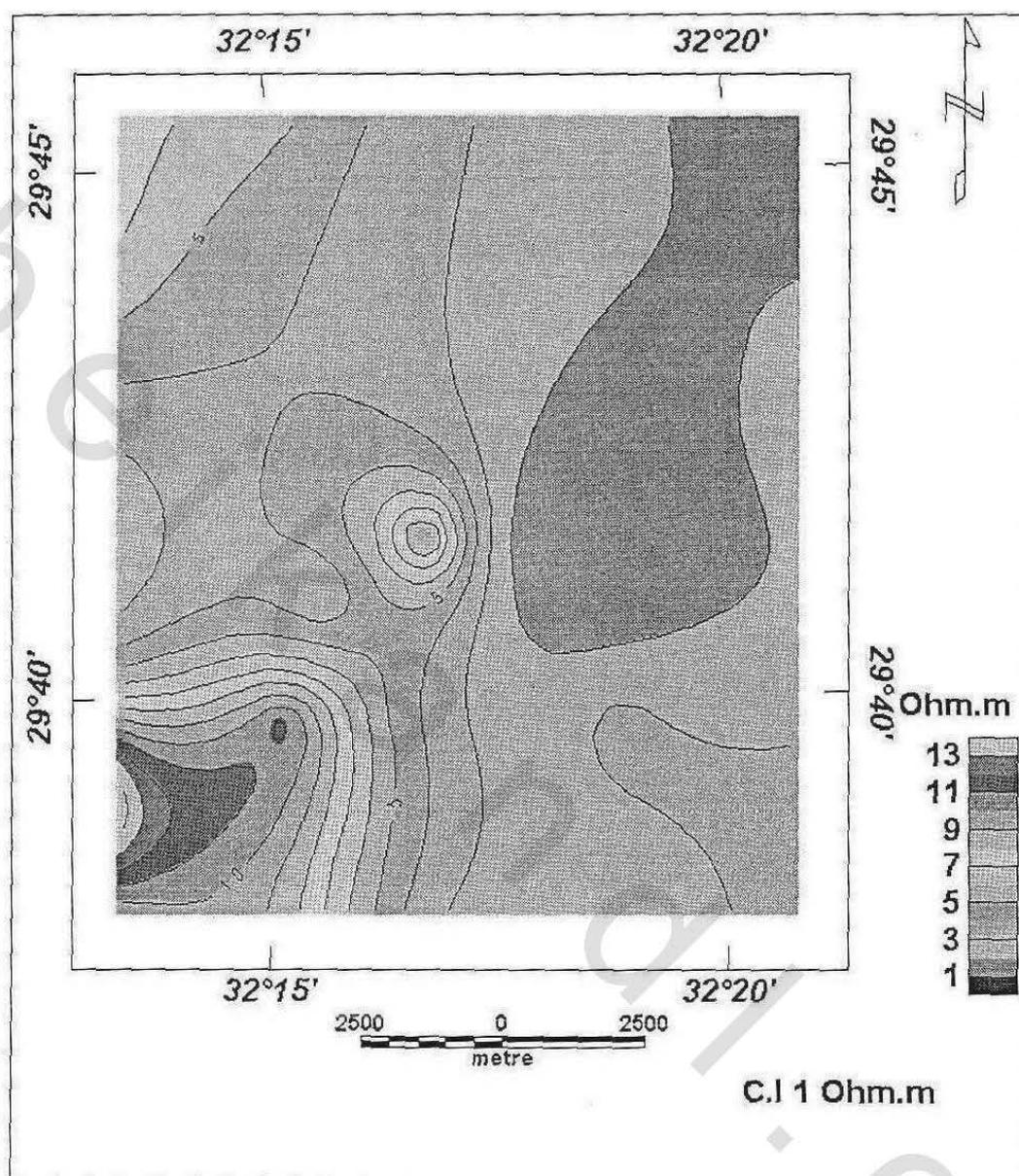


Figure (71): Isoresistivity map of the fifth geoelectrical unit.

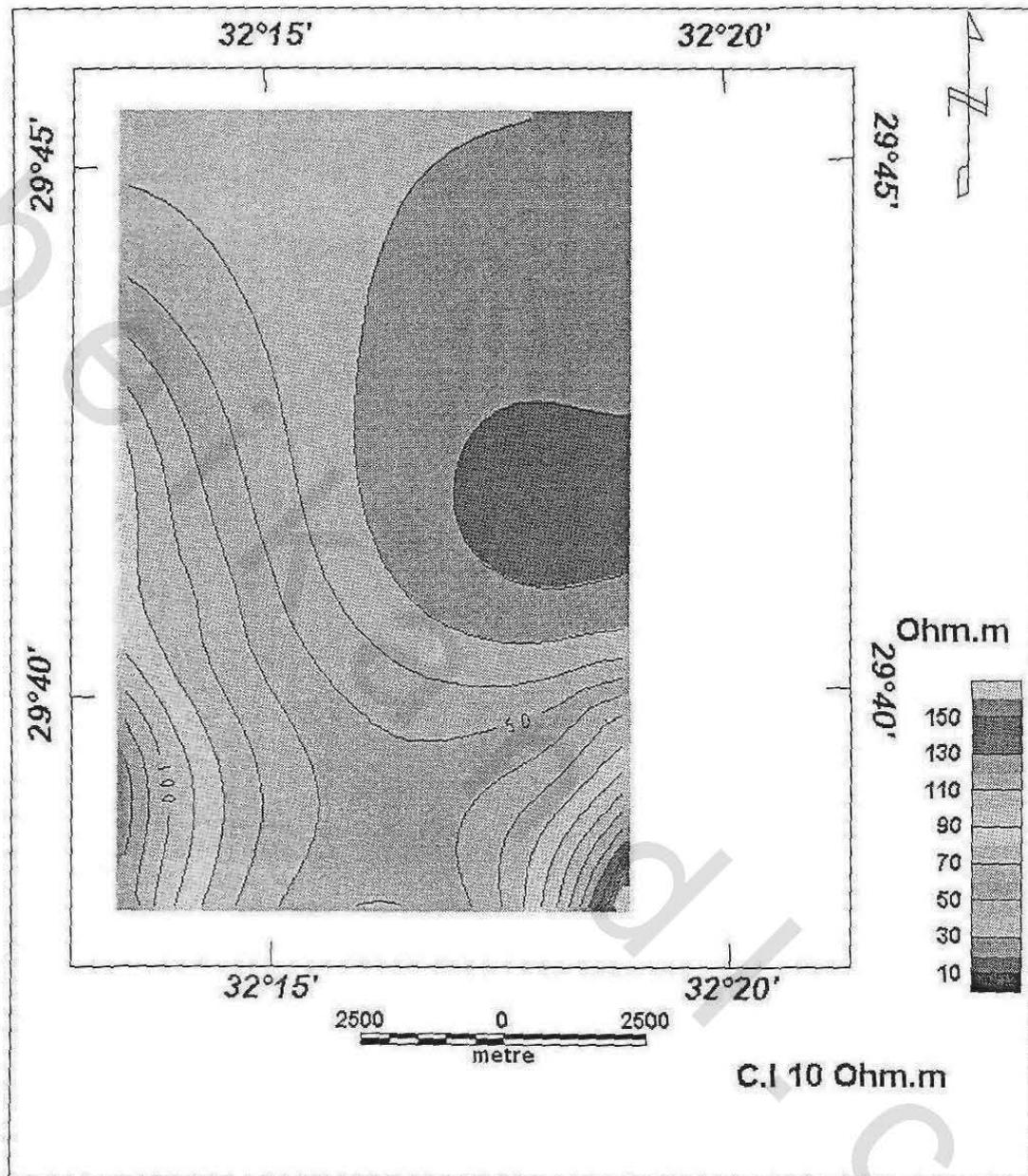


Figure (72): Isoresistivity map of the sixth geoelectrical unit.

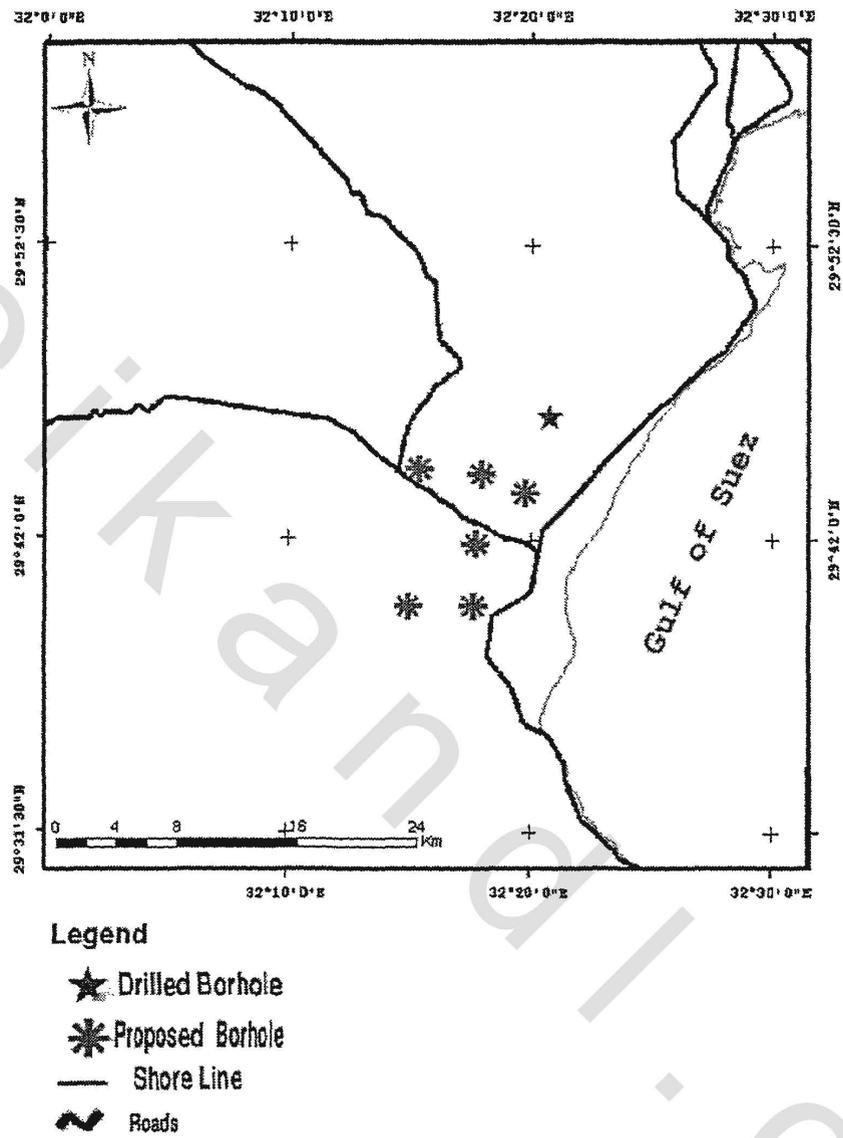


Figure (73): Location map showing drilled and proposal