GROUNDWATER EXPLORATION BY USING 1-D RESISTIVITY TECHNIQUE AT ABU ZENIMA AREA, SOUTHWESTERN PART OF SINAI, EGYPT

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ABSTRACT

Sinai Peninsula is considered one of the attracted regions where, the government set a national plan for its sustainable development. The aim of this work is focused in defining the groundwater occurrences along WadiTayiba, WadiThal, WadiIseila, Wadi Abu- Ideimat, WadiRewikna, Wadi El-Garf and WadiRewis El- Ghanam at Abu Zenima area. Twenty six Vertical Electrical Soundings (VES) were measured in the study area by using AB/2 ranging from 1.5-1000 m, on two areas A and B. The results of quantitative interpretation of resistivity data at area A indicated that the subsurface section of the study area consists of five geoelectrical units , the first geoelectrical unit is characterized by very high resistivity values and is composed of coarse sand and gravels, .The second geoelectrical unit is represented by sand and gravels which exhibits resistivity values ranging from 300-550 Ohm.m and represents the Quaternary aquifer in the study area.The third geoelectrical unit is represented by resistivity values ranging from 13-108 Ohm.m. corresponding to Rudies-Nukul Formation of Lower Miocene The fourth geoelectrical unit reflects low resistivity values ranging from 5-12 Ohm.m .The fifth geoelectrical unit is beneath of resistivity values ranging from 18-19.5 Ohm.m corresponding to Thebes Formation. The results of quantitative interpretation of resistivity data at area B indicate that the subsurface of this area consists of four geoelectric units. The first geoelectrical unit is coarse sand and gravels that belong to the surface layer; it composed of sand and gravels of the Quaternary deposits. The second geoelectrical unit is composed of sand and gravels that belongs to the Quaternary deposits. The third geoelectrical unit is correlated with sandstone that belongs to Paleozoic rocks. The fourth geoelectrical layer is correlated with the basement rocks.

Keywords: *Resistivity; Groundwater and Faults*

INTRODUCTION

Sinai Peninsula covers an area of about 61000 km^2. It is triangular in shape with its apex formed by the junction of the Gulf of Aqaba and the Gulf of Suez, and its base by the Mediterranean coastline. The southern part of the Sinai consists of an intricate complex of very rugged mountains formed by igneous and metamorphic rocks.

The middle and northern parts of the peninsula comprise a massively developed limestone plateau on lapping the basement rocks. The prevailing drainage system is formed to the north by the Wadi El-Arish with its many effluents. The eastern and the western edges are dissected by deep gorges draining into the Gulf of Aqaba and Gulf of Suez respectively. In the northern part, the regional dip slope is broken up into many large hills followed northwards by a belt of low lands, with high sand dunes along the Mediterranean coast. The plains or low lands along the east and the west coast of the Gulf of Suez are part of its structural and depositional province. El-Qaa plain and El-Tur plain along the central and southeastern coast are separated by an East-West trending subsurface high. Its presence is expressed by a regional southwest dip of the formations in El-Tur plain and by a northwest dip of the strata in El-Qaa plain. The area of study "Abu Zenima" is located between Lat. 29º 00`-29º 15`N and Long. 33º 00`-33º 40`E.

Many authors worked on the area such as Ghorab (1961) who introduced formational names and described the stratigraphy of the Cretaceous rocks at west central Sinai. Geophysica (1963) gave an investigation on water and soils resources using geophysical methods and made groundwater potentialities in central Sinai. Youssef and Abdel-Malik (1969) studied the geologic succession of the Tayiba-Feiran area, west central Sinai, and classified it into eleven lithostratigraphic units. Abdallah and Abu-Khadra (1977) studied the geomorphology of Sinai Peninsula and its associated rocks and discussed some geomorphological and hydrogeological aspects on it. Garfunkel and Bartov (1977) reported that, the faulting took place on Paleozoic rocks and increased in intensity and aerial extension progressively reached its Climax in Oligo-Miocene period. Hammad (1980 and 1985) studied the hydrogeological aspects in southwestern Sinai and made planning for water resources in it. Issawi *et al.* (1981) studied the stratigraphy of west central Sinai, and they classified the Cretaceous-Lower Eocene rocks from bottom to top. Barakat *et al.* (1986) studied the sandstone section of Malha Formation and classified it into different rock units and assigned it to Permo-Triassic to Early Cretaceous. Abdeen (1988) studied the structure of the area from HammamFaraun to El-Tur, and described the folds and faults and their direction and extension. Okiel (1995) studied the Hydrology of the area between WadiSidri and WadiGharndal and concluded that, the Carboniferous sandstone is the main aquifer in this area. El-Kelani et al. (1999 and 2003) studied the lithostratigraphic of Paleozoic and Mesozoic in southwestern Sinai, and gave the description about their lithology and made lithostratigraphic sections. JICA (1999) classified the geomorphology of south Sinai Peninsula into eight categories by LANDSAT image analysis aerial photograph interpretation and field survey. El-Shayeb (2001) studied the area of WadiSudr at west Sinai area and made geophysical studies to help in groundwater potentiality and concluded that, there are three main aquifers (Quaternary aquifer, Upper Cretaceous aquifer and Lower Cretaceous aquifer). Youssef *et al*. (2004) studied the groundwater occurrences along Wadi Gharandal and its tributaries. These studies revealed that the subsurface succession consists of 11 geoelectrical units, some of these units are considered as water bearing formations. Also, the subsurface faults play an important role in the groundwater occurrences along Wadi Gharandal. Sultan *et al.* (2009) studied the groundwater occurrences along Al qantara East, North Western Sinai, Egypt. Al A bassy (2010) studied the area east of Suez Canal and made geophysical hydrogeological studies to help in groundwater potentiality

MATERIAL AND METHODS

1.1. Geology of the study area

Geomorphology:

Generally Sinai Peninsula can be divided into two main parts: The southern part (dominated by Precambrian igneous and metamorphic rocks) and the northern part (dominated by Paleozoic to Cenozoic sedimentary rocks). Hammad (1980) divided Sinai into seven geomorphological units. These are; southern elevated mountainous district, central plateaux district (El-Tih and El-Egma), hilly district, north and northwest coastal plain district, marshy and sabkhas district, alluvial coastal plains district and lakes. The investigated area is part of the central plateau's district and the alluvial coastal plains district.

Stratigraphy:

The area of study is covered by exposed rock units varying from Lower Cretaceous to Quaternary, where most of these rock units are considered as water bearing formations. *Quaternary Deposits* are unevenly distributed in WadiIseila and WadiThal as dark patches. They cover the floor of wadis from Abu-Zenima town up to the downstream area of WadiNukhul and occupy the downstream portions of the wadis (Fig.2).

Structure:

According to Shata (1956); Youssef & Abdel-Malik (1969) and Garfunkel and Bartov (1977), the major structures of the investigated area are dominated by normal and step faults. Generally, the downthrow of the faults ranges between few centimeters to several hundreds of meters. These faults may be related to the synthetic type comprises all faults which are parallel to the Red Sea Graben, and the antithetic type that include the faults which are parallel to the Gulf of Suez and Gulf of Aqaba (Fig.2).

2-Methodology:

2.1. Geoelectric data acquisition:

Geoelectrical survey described in the work is representing by DC resistivty sounding. A total of 27 of Vertical Electrical Sounding (VES) stations were carried out in the study area as a grid pattern. 14 of these sounding stations were measured at the area "A" is located in the Western part of studied area and the others (12 VESes) were measured at the area "B" which located in the Eastern part of studied area. Some of these sounding stations were measured near hand dug wells to estimate the geophysical parameter available for verifying the geoelectrical interpretation. The distribution of the sounding stations and the trend of geoelectrical profiles are shown in (Fig. 3, 4).

The Schlumberger configuration is used in this work with electrode spacing from AB/2=1.5m to AB/2=1000m, The "SYSCAL R1"resistivity meter made in France was used for measuring the apparent resistivity of high accuracy. The topographic survey was carried out with the purpose of determine the location (latitudes and longitudes) of the sounding stations on topographic map by using the GPS apparatus and concluding the ground elevations. VESes locations were chosen according to the following:

a) The VESes stations must be far away from water channels as can as possible and should be arranged in a grid form.
b) The VESes stations must be far away from any source of electricity such as electrical cables and high potential lines to avoid external electrical field.
c) The tilting of land surface at VESes locations must be less than 30º to be conformable with the iterative method of interpretation (Zohdy, 1989).

2.2. Geoelectric Data Interpretation:

2.2.1. Quantitative interpretation of VES stations:

The quantitative interpretation was proceeded using the computer program "RESIST" (Van Der Velpen, 1988) & IPI2WIN Program (2010) for non- automatic iteration method in which the measured field data are compared with data calculated from an assumed model. The initial models were constructed depending on the available data from drilled wells in the investigated area and the geologic map (G.S.E., 1994). The interpreted values of the true resistivity and thickness of the subsurface layers are recorded in Table (1). The quantitative interpretations provide the geoelectrical parameters, i.e., the true resistivities and the corresponding thicknesses of the encountered geoelectrical layer at each sounding station. The interpreted resistivities and thicknesses of the soundings were compared with the available geological and hydrogeological data that come from the drilled wells and the geologic map to assign these resistivities to geoelectrical layers. These geoelectrical layers were grouped as geoelectrical units to be equivalent to the geological formations. The lateral and vertical distribution of the geoelectrical succession, subsurface geologic structures and groundwater occurrence were clarified through the construction of 6 geoelectrical cross sections along the studied area (Fig 2&3).

Table (1): True resistivity and true thickness obtained from the interpretation of the resistivity curves.

VES #	Area (A)								
	True resistivity (Ohm.m)					True thickness (m)			
	ρ_1	ρ_2	ρ_3	ρ_4	ρ_5	h_1	h_2	h_3	h_4
1	437	350	13	9	29	1.2	18	135	149
2	650	325	13	7	31	6.4	8.6	195	290
3	670	447	17	7	15	0.8	5	8	35
4	1000	225	15	10	25	1.4	2.6	10	140
5	825	330	15	5	19.5	0.9	4.5	104	
6	375	300	108	12		1	8.5	55	.....
7	730	580	15	5	16.5	1.2	4.7	18.8	64.6
8	550	220	11	5	19	1.1	7.4	67.8	160
9	1900	190	15	10	26	1	4.2	15	120
10	1100	550	13	5	18	1	1	96	130
11	394	315	27	11		1.7	16.2	59.4	.....
12	1300	650	16	7	24	1	3.2	16.5	103
13	580	116	17	6	16.3	1	5	12	33
14	500	180	15	5	19	1.3	3.3	17	110

VES #	Area (B)						
	True resistivity (Ohm.m)				True thickness (m)		
	ρ1	ρ 2	ρ 3	ρ 4	h1	h2	h3
15	318	188	...	8900	5	15.3	.....
16	134	58.5	160	5550	4.5	25	160
17	443	64	....	4415	0.5	4.5	.....
18	510	107	93.6	2734	2.55	8.45	30
19	850	136	94	3155	3.5	22.5	95
20	456	84	31.5	8000	4.2	15.8	150
21	667	102	....	1460	0.5	8.5	.....
22	280	76	31	5326	2.2	12	68
23	2009	759	.....	3106	0.4	5	.....
24	183	37.3	......	3579	0.5	9.5	.....
25	235	125	38	8900	0.6	4.4	60
26	350	195	43	4126	0.7	28.3	25

2.2.2. Geoelectrical Cross-sections:

2.2.2.1 Geoelectric cross-sections of area A

2.2.2.1.1.1 Geoelectric.Cross-section A1-A`1:

The geoelectrical cross-section (A1-A1`) passes a cross the sites of VESes 10, 5, 11 and 6, It shows four geoelectrical units beneath VES 5, 11 and 6 and five geoelectrical units under the VES-10. (Fig.5). The first geoelectrical unit occurred at all VESes with nearly homogeneous thickness ranging from 1.5-2m. It is characterized by very high resistivity values and is composed of coarse sand and gravels, this unit represented by Wadi deposits. The second geoelectrical unit appeared at all VESes with thickness ranging from 4.5-15m, its resistivity values ranging from 300-550 Ohm.m.The third geoelectrical unit is represented under all VESes but with different thickness between VES-5 and VES-10 due to the presence of interpreted fault between them. This unit has resistivity values ranging from 13-108 Ohm.m.The fourth geoelectrical unit occurs under all VESes with large thickness and low resistivity values ranging from 5-12 Ohm.m.The fifth geoelectrical unit is beneath under VESes-10 and 5 with extending vertically to undetermined depth and the resistivity values ranging from 18-19.5 Ohm.m.

2.2.2.1.1. 1 Geoelectric Cross-section A2-A2`:

The geoelectric cross-section A2-A2` passes across the sites of VESes 10, 1, 2, and 12, it shows five geoelectrical units beneath all area under study (Fig.6). The first unit represented by alluvial deposits of high resistivity and few meters of thickness. The second unit represented by sand and gravel with change of resistivity values from 325-650 Ohm.m and change of thickness under the VESes. The third unit is characterized by low resistivity which ranging from 13-16 Ohm.m and change of thickness with present interpreted fault.

The fourth unit represented under all VESes and characterized by very low resistivity values ranging from 5-9 Ohm.m. The fifth unit shows resistivity from 18-25 Ohm.m and extended under the area and represented of Thebes formation.

2.2.2.1.1. 2 Geoelectric Cross-section A3-A3`:

The geoelectrical cross section (A3-A3`) involves VESes number 7, 13 and 4. *(Fig.7)* it is characterized by the presence of five geoelectrical units. The first unit represented by alluvial deposits of high resistivity and thickness of about few meters. The second geoelectrical unit exhibits resistivity ranging from 116-580 Ohm.m with change of thickness. The third geoelectrical unit may be very few change of resistivity where the resistivity ranging from 15-17 Ohm.m and have about 20m thickness. The fourth geoelectrical unit change in thickness may be indicated on interpreted fault under VES-13 and have resistivity values ranging from 5-10 Ohm.m. The fifth geoelectrical unit has resistivity values ranging from 16-25 Ohm.m with change in thickness affected by the interpreted fault under VESes. The geoelectrical cross sections at the area A reveal a five geoelectrical units, which include: The 1st (surface) geoelectrical unit has been detected at all stations with changing of thickness and characterized by a wide range of resistivity values which reflects lithological heterogeneities. This unit is mainly alluvial deposits of Quaternary age. The 2nd geoelectrical unit has change of thickness and resistivity values, it mainly consists of sand and gravels represented Quaternary aquifer of the studied area. The 3rd geoelectrical unit: mainly consists of sandstone and clay stone represented by Rudies - Nukhul Formation of early (lower) Miocene age. The 4th geoelectrical unit: mainly consists of clay stone, sandy marl and sandstone which represented late (upper) - Middle Eocene age. The 5th geoelectrical unit: mainly consists of limestone of Thebes Formation which represented by Early (lower) Eocene age.

2.2.2.2 Geoelectric cross-sections of area B

2.2.2.2.1 . Geoelectric.Cross-section B1-B1`:

The geoelectric cross-section B1-B1` *(Fig. 8)* is constructed depending on the interpretation of VESes 16, 19 and 22 from NE to SW direction; it is characterized by four geoelectrical units. The first geoelectric unit is beneath all VESes with thickness ranging from 0.5-5m and characterized of high resistivity values ranges from 134-850 Ohm.m. The second geoelectric unit is recorded under all VESes with resistivity values ranging from 58.8-136 Ohm.m and has thickness ranges from 5-25m. The third geoelectric unit is recorded under all VESes with large thickness about 170m under VES-16 and resistivity value between 31-160 Ohm.m. The fourth geoelectric unit is recorded under all VESes with high resistivity values ranging from 3155-5550 Ohm.m and extended with undetermined depth.

2.2.2.2.2 . Geoelectric.Cross-section B2-B2`:

The geoelectric cross-section B2-B2` passes through VESes 15, 18 and 21 from NW to SE direction (*Fig 9*). It is characterized by four geoelectric units. The first geoelectric unit is surface layer; it has resistivity values ranging from 318-667 Ohm.m with thickness ranging from 0.5-5m. The second geoelectric unit has resistivity values ranging from 102-180 Ohm.m with thickness ranging from 8-15 m. The third geoelectric unit recorded under VES-18 but missing under VESes 21 and 15 which form a lens under VES 18 it has resistivity value 93 Ohm.m with thickness about

8.5 m. The fourth geoelectric unit has high resistivity values ranging from 1460-8900 Ohm.m and extended with undetermined depth and represented by igneous rocks.

2.2.2.2.3 . Geoelectric.Cross-section B3-B3`:

The geoelectric cross-section B3-B3` passes through VESes 22, 21, 24 and 23 from NE to SW direction (Fig. 10) and it is characterized by four geoelectrical units. The first geoelectrical unit with thickness about 0.5m and resistivity values ranging from 183-2009 Ohm.m. The second geoelectrical unit has thickness ranging from 4-10m and has resistivity values ranging from 37-750 Ohm.m. The third geoelectrical unit is recorded under VES-22 and missed under VESes 21, 23 and 24 effected by interpreted fault and has about 70m thickness. The fourth geoelectrical unit has resistivity values ranging from 1460-5326 Ohm.m and extended with undetermined depth. The geoelectrical cross sections at the area B from the electrical surveying with correlation with borehole No.2 reveal that: The first geoelectrical unit is coarse sand and gravels that belong to the surface layer; it composed of sand and gravels of the Quaternary deposits. The second geoelectrical unit is composed of sand and gravels that belongs to the Quaternary deposits. The third geoelectrical unit is correlated with sandstone that belongs to Paleozoic rocks. The fourth geoelectrical layer is correlated with the basement rocks.

2.2.3. Iso-resistivity maps:

The Iso-resistivity contour maps may give a primary outline of the fault zones, which are characterized by anomalies of considerable aerial extension along a given direction and have a maximum horizontal gradient. In the present work, we have two areas (A and B).

2.2.3.1. Iso-resistivity maps: of area A:

At this area, 4-four Iso-resistivity maps are constructed to cover the most of the succession penetrated by the electric current. First geoelectric unit shows resistivity values are ranging from 300-1800 Ohm.m, the maximum resistivity represented in the Central part and Southwest corners while minimum resistivity at Southeast corners. This can be attributed to lithological heterogeneities (Fig. 11). Second geoelectric unit shows resistivity values are ranging from 50-600 Ohm.m, the maximum resistivity represented in the East part of the studied area and decreases to West direction, but we can recognize a clear difference than the previous map due to general decrease in resistivity values w`ith depth. (Fig.12). The third and the fourth geoelectric units, shows low resistivity values ranging between 10-100 Ohm.m at the most West area while the low values occur at the Northwest corner of the studied area (Figs. 13&14).

From Iso-resistivity maps, we can recognize the values are decreasing with depth, essentially at the Western part of the studied area

2.2.3.2. Iso-resistivity maps: of area B:

Four Iso-resistivity contour maps are constructed to indicate the variation of the resistivity values for different layers that to differentiate the lithology of these units. First geoelectrical unit shows resistivity value ranged from 50-1800 Ohm.m. This can be attributed to lithology heterogeneities. At general trend it is clear that, the higher resistivity values are obtained at west part of the study area and the lower resistivity values are represented at the East part (Fig. 15). This indicates that the electrical current at the encountered depth may be introduced the Quaternary aquifer, which consists mainly of sand and gravels and contains water as encountered from the subsurface. Second and third geoelectrical units resistivity's are decrease with depth at all area, the values of resistivity ranging between 50-100 Ohm.m with second unit but more decrease at third unit and give resistivity value from 20-170 Ohm.m (Figs. 16 and 17) the maximum value of resistivity at west direction but decrease at Northeast direction and give low resistivity at north part with third unit. Fourth geoelectrical unit shows very high resistivity values with increasing the depth. The resistivity values increasing in all directions and ranging from 1000-8000 Ohm.m which indicate that the electrical current at the encountered depth may be intruded to the basement rocks (Fig. 18).

2.3. Groundwater Occurrence:

In the area, there are two aquifers for groundwater in the studied area: The Quaternary aquifer (Limited groundwater) and Paleozoic (The Carboniferous aquifer).

2.3.1. Groundwater Possibilities at Area (A):

From the results of geological and geophysical exploration for groundwater possibilities at area (A) and from the interpretation of the proposed hydrogeological cross-sections developed from the geological and geoelectrical data the following can be suggested:

1. Poor groundwater possibilities can occur along the directions of every geoelectrical section and are taken at the area due to the presence of many faults, which reduce the thickness of permeable layer and presence of thick impermeable layers.
2. Limited groundwater possibilities within the Quaternary gravels mainly recharge from the infiltrated rainfall.

2.3.2. Groundwater Possibilities at Area (B):

From geoelectrical studies on Wadi El-Garf and the hydrogeological cross sections, the following can be concluded:

1. The first water- bearing layer is equivalent to the second geoelectrical layer. It is recharged from the very little amount of infiltrated rain water at the aquifer belonging to the Quaternary.
2. The second water-bearing layer is equivalent to the third geoelectrical layer, which belongs to Paleozoic rock aquifer.
3. The basement rocks acts as barrier preventing groundwater to escape deeper.

CONCLUSION

Poor groundwater possibilities in area **(A)** are due to the presence of many faults, which reduced the thickness of layers but limited groundwater possibilities within the Quaternary gravels. In area **(B)** groundwater possibilities are within the Quaternary gravels. There is a water-bearing zone equivalent to the Paleozoic aquifer, where the basement rocks make an impermeable layer for groundwater, accordingly; we are recommend drilling for water wells to the top of the confined aquifers under VESes 16, 19 & 22.

FUTURE RESEARCHES

Whereas the Basementrocks in the studied area are highly affects the aquifers thickness and its availability, we recommend applying future investigation using Gravity method to map the basement correctly.

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Figure Captions :

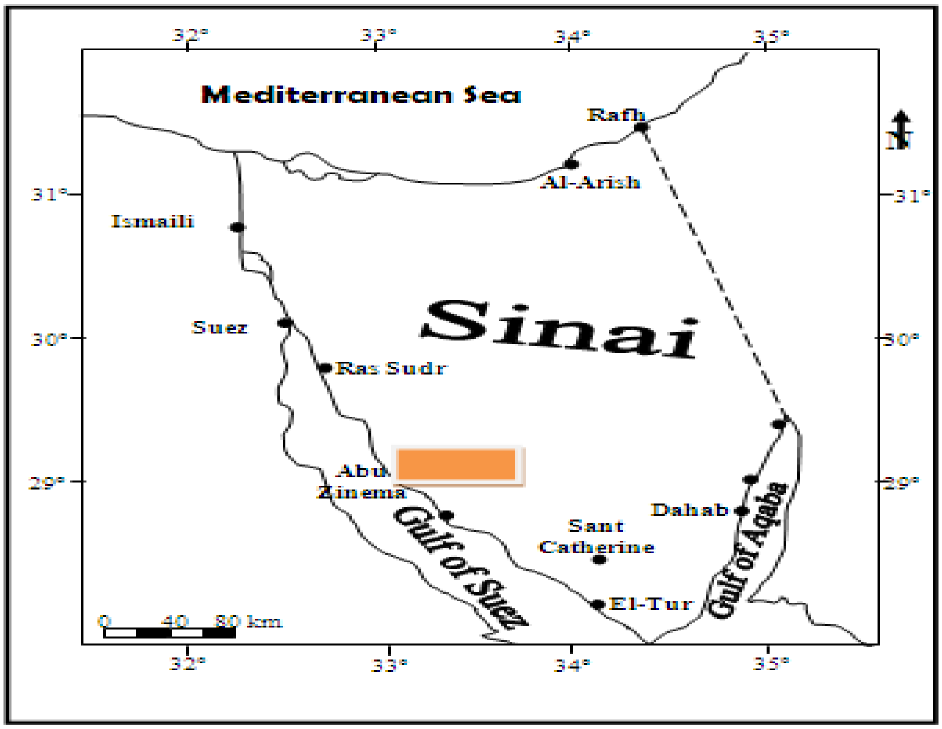

Fig. (1): Location map of the study area.

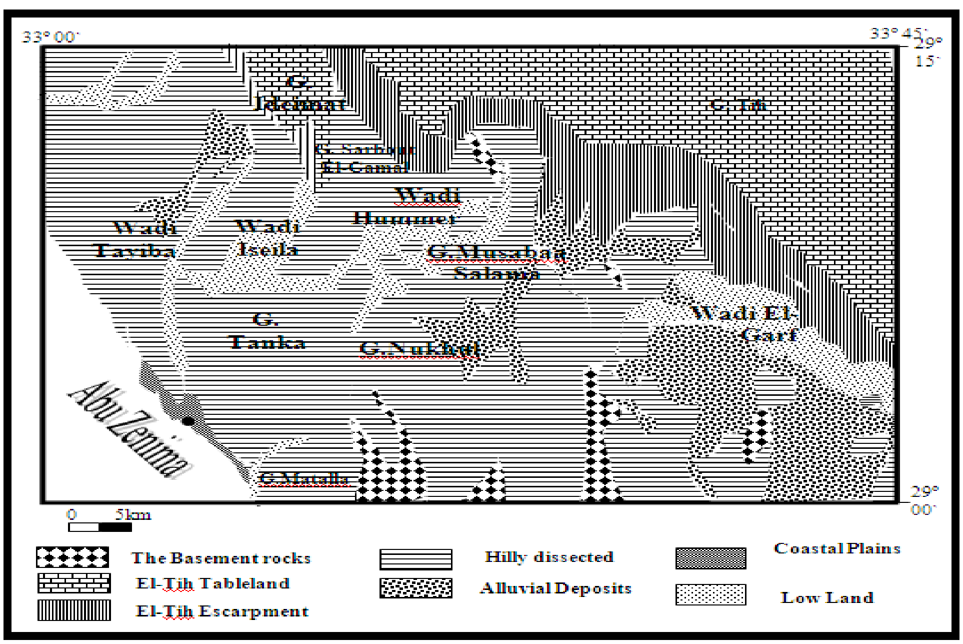

Fig. (2): Geological map of the study area (Modified after Okiel, 1995).

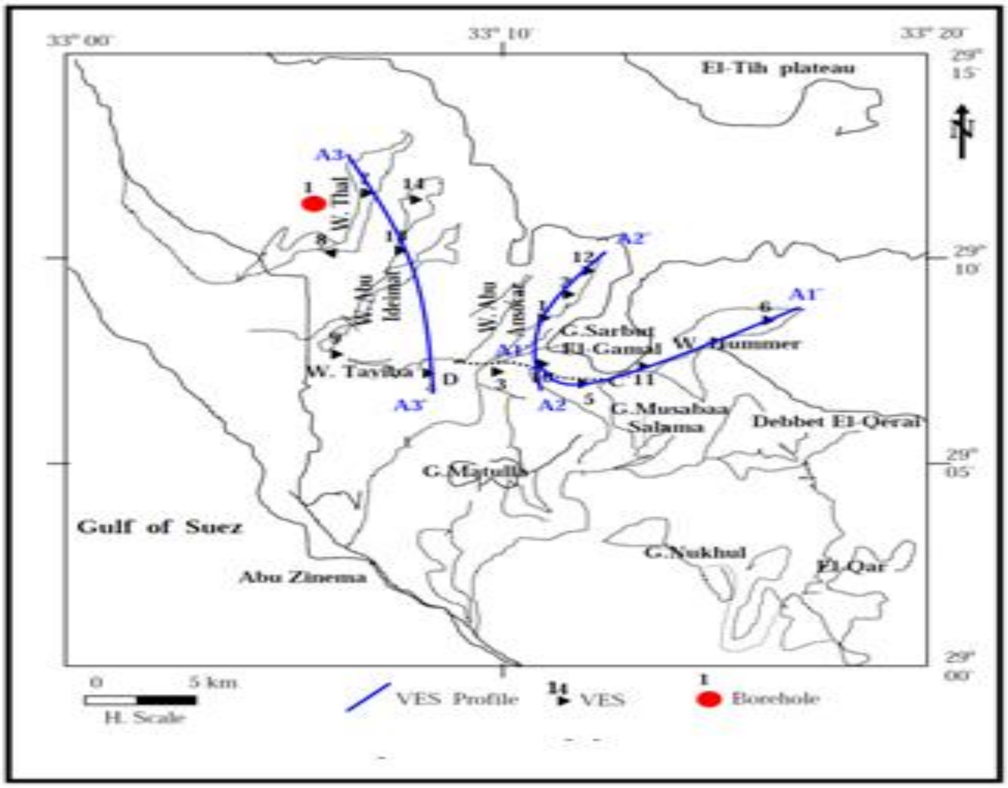

Fig. (3): Location map of the VES station and geoelectric cross-sections of area A.

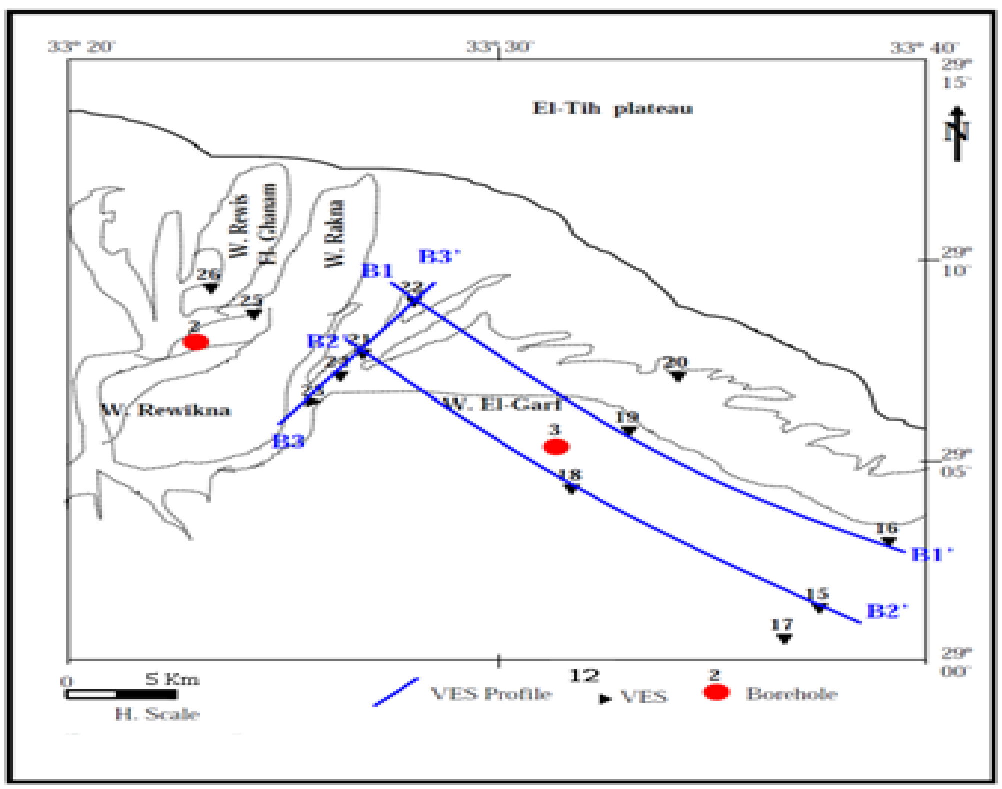

Fig. (4): Location map of the VES station and geoelectric cross-sections of area B.

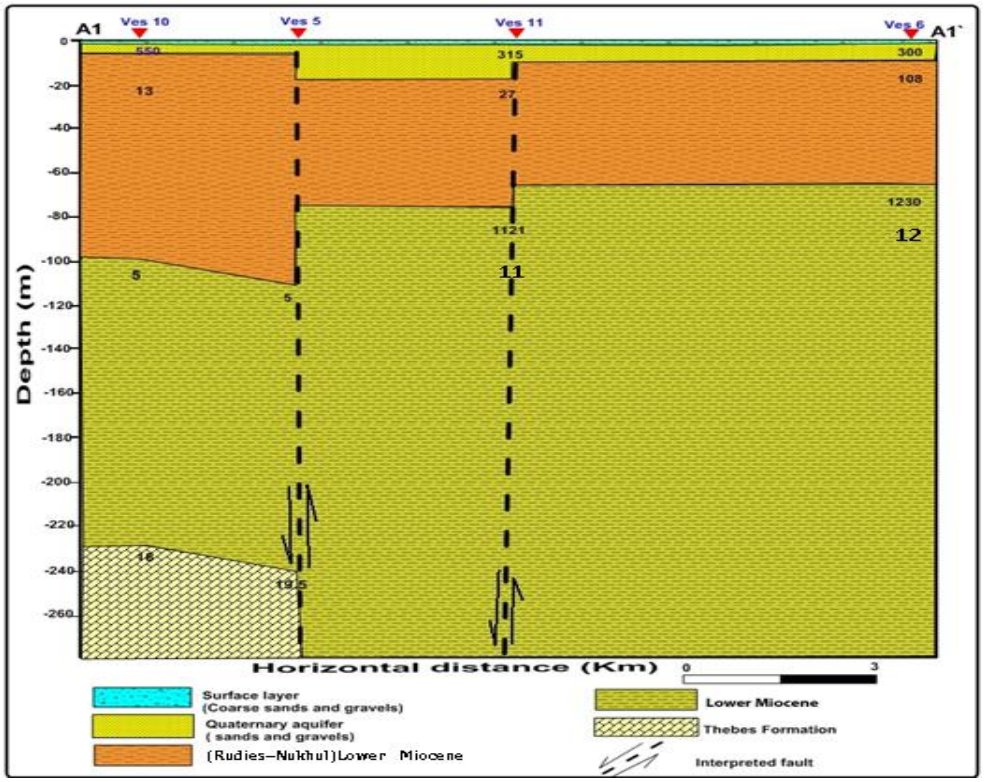

Fig. (5): Geoelectric cross-section A1-A1`.

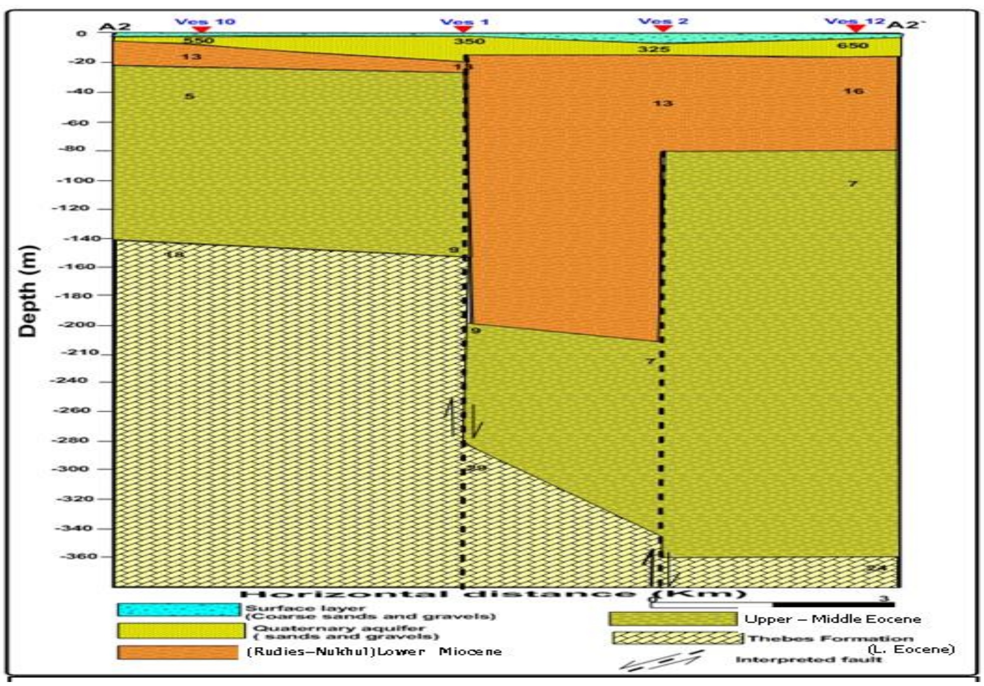

Fig. (6): Geoelectric cross-section A2-A2`.

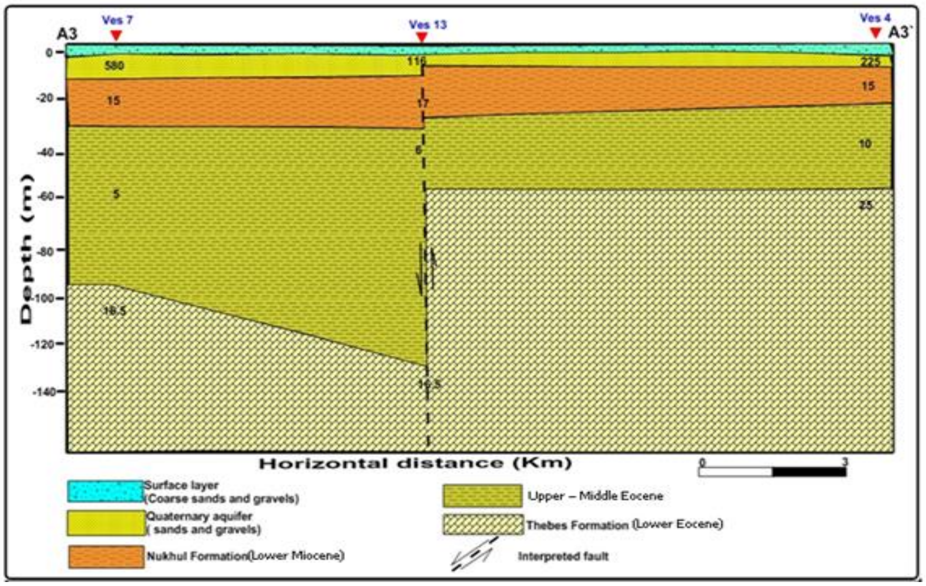

Fig. (7): Geoelectric cross-section A3-A3`.

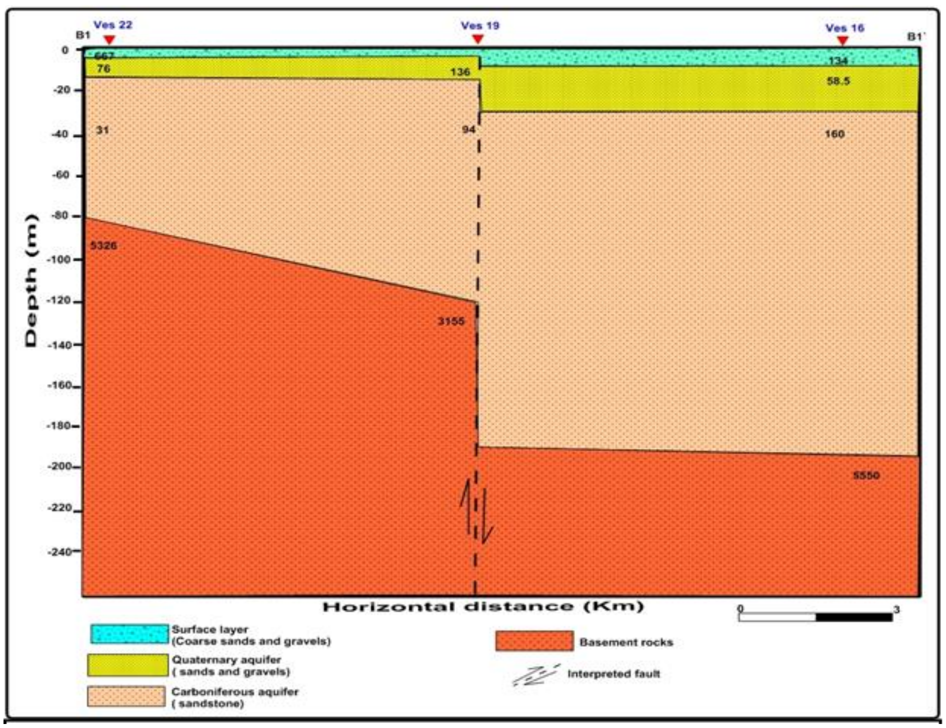

Fig. (8): Geoelectric cross-section B1-B1`.

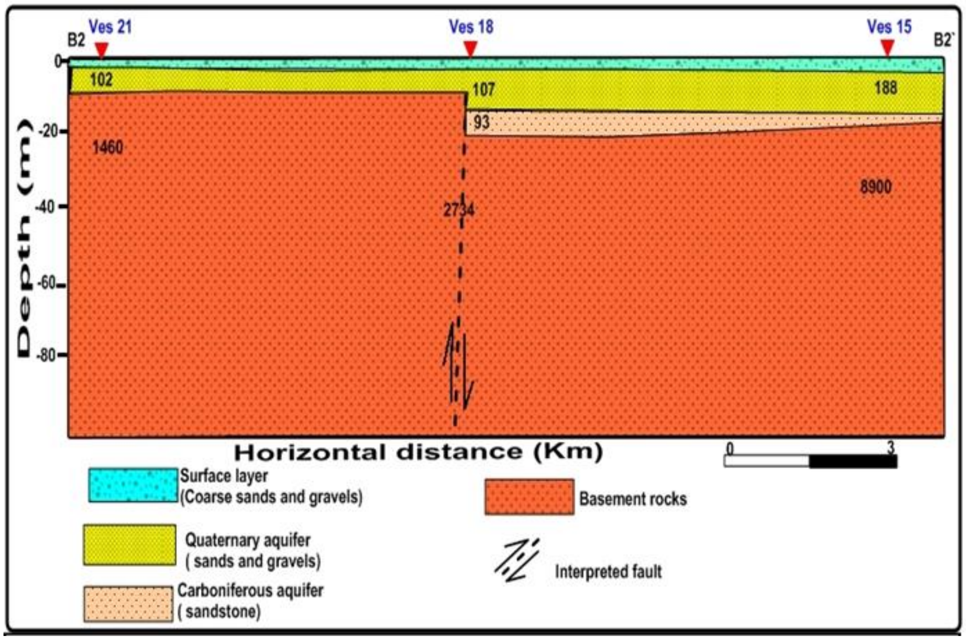

Fig. (9): Geoelectric cross-section B2-B2`.

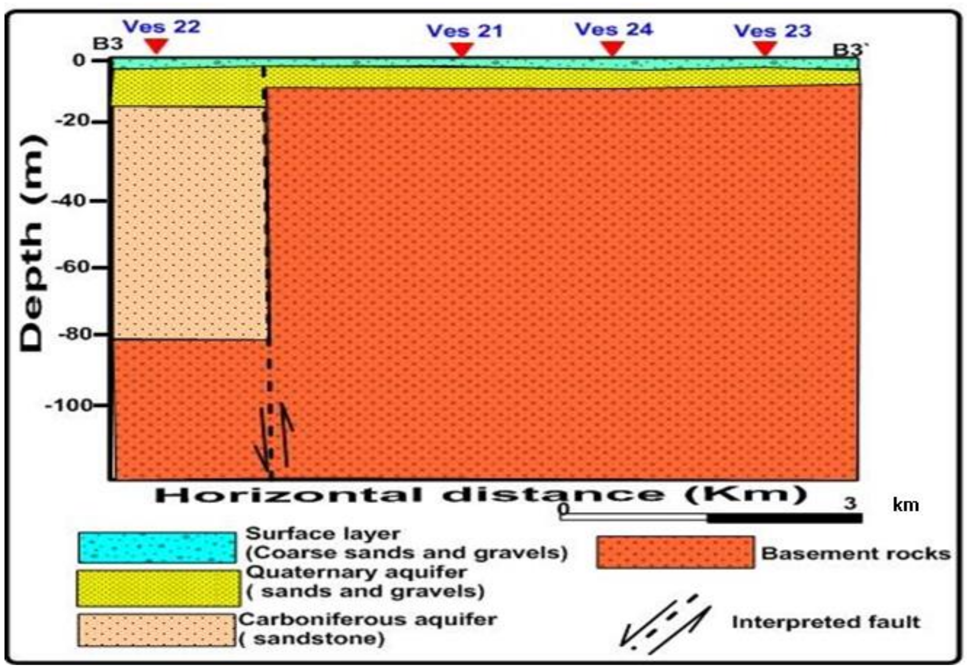

Fig. (10): Geoelectric cross-section B3-B3`.

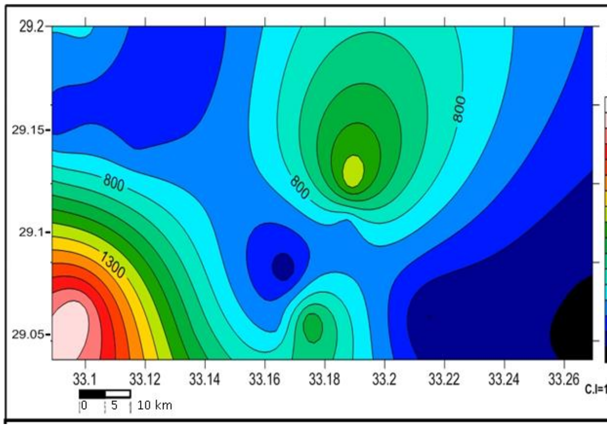

Fig. (11): Iso-resistivity map of the first geoelectric unit for area A

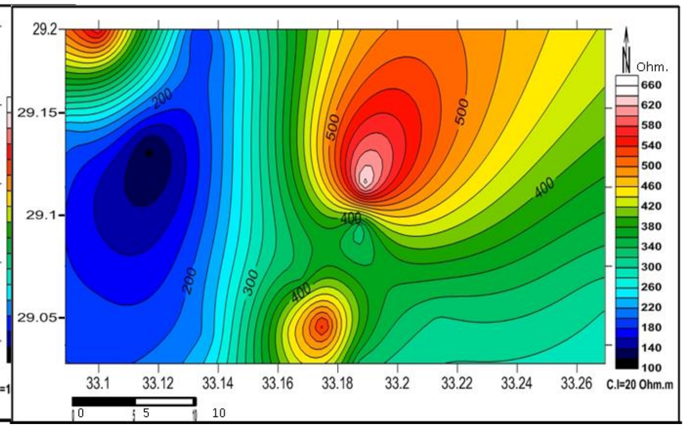

Fig. (12): Iso-resistivity map of the second geoelectric unit for area A

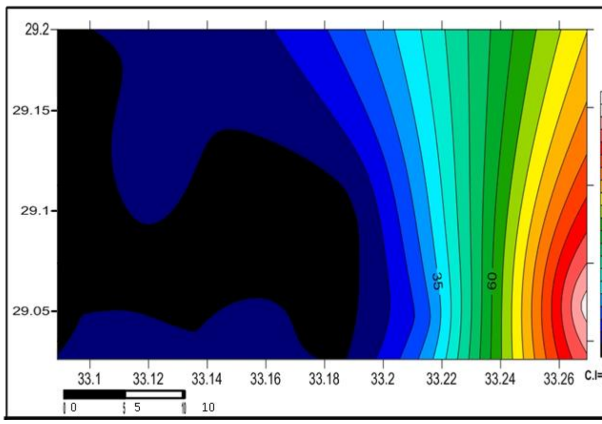

Fig. (13): Iso-resistivity map of the third geoelectric unit for area A

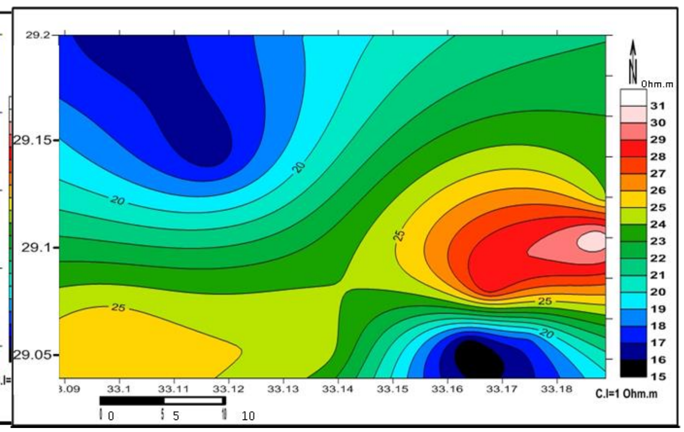

Fig. (14): Iso-resistivity map of the fourth geoelectric unit for area A

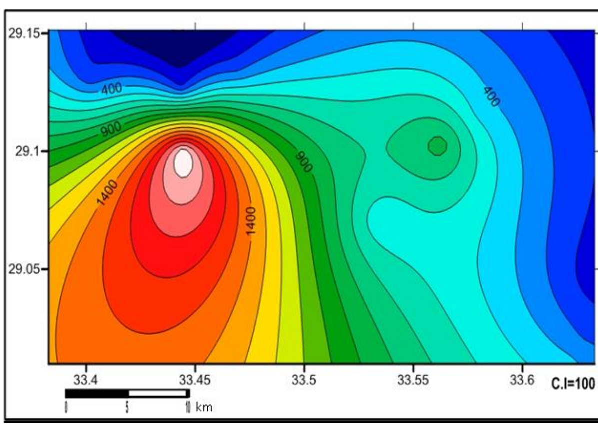

Fig. (15): Iso-resistivity map of the first geoelectric unit for area B

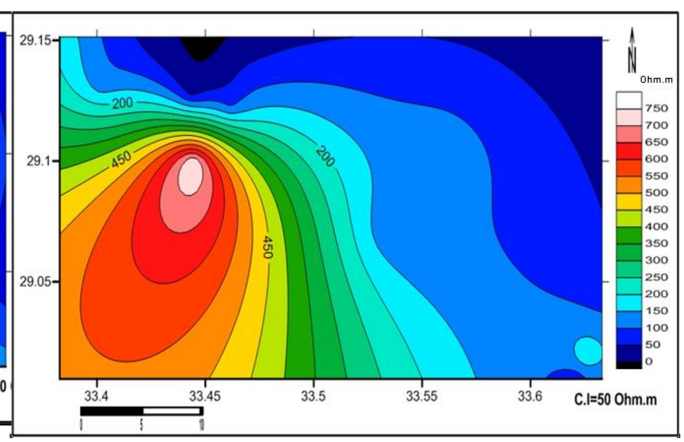

Fig. (16): Iso-resistivity map of the second geoelectric unit for area B

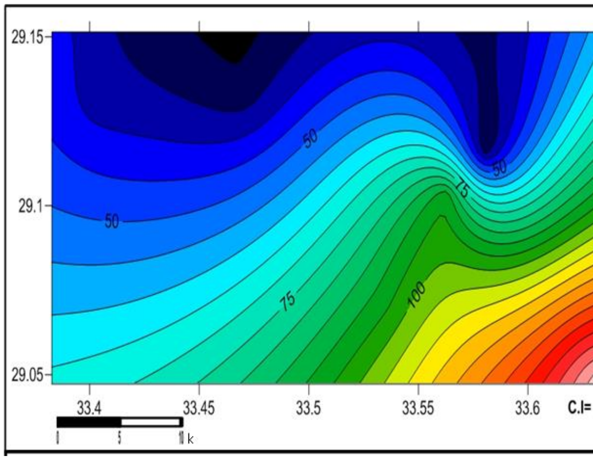

Fig. (17): Iso-resistivity map of the third geoelectric unit for area B

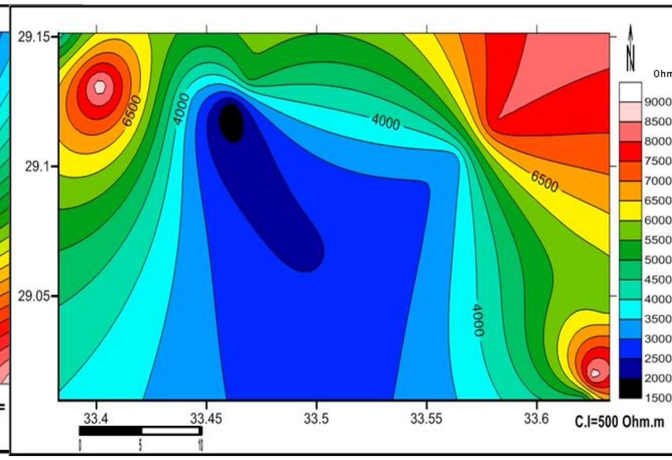

Fig. (18): Iso-resistivity map of the fourth geoelectric unit for area B