Egyptian Geophysical Society
EGS Journal, Vol. 9, No. 1, 191-208 (2011)

APPLICATION OF GEOELECTRIC AND GROUND PENETRATING RADAR TECHNIQUES TO ESTIMATE SHALLOW SUBSURFACE FEATURES AT EL BANAFSEG DISTRICT, NEW CAIRO CITY, EGYPT

H. El Kadi [(1)], D. Hamed [(1)], T.H. Abdelhafeez[(1)],
A. Saad[(1)] and S. Abd El Kawi[(2)]
(1) Geology Department, Al-Azhar University, Cairo, Egypt
(2) Ministry of Education, Saudi Arabia.

تطبيق التقنيات الجيوكهربية و الجيورادارية لتقدير الملامح التحتسطحية الضحلة لحى البنفسج – القاهرة الجديدة – مصر

الخلاصة: موقع الدراسة بحى البنفسج بالجزء الشمالى من القاهرة الجديدة بمصر قد تعرض للعديد من المشاكل و المخاطر التى تلت الانشاءات و هذه المشاكل مرتبطة بوجود بعض التشققات فى طبقة الحجر الجيرى و طبقات الطفل التى تسبب الانتفاش.

تم اجراء ١٤ جسة جيوكهربية رأسية بهدف التعرف على الظروف التحتسطحية السائدة بالمنطقة. اتضح من تفسير بيانات المقاومة النوعية وجود تتابع تحتسطحى شائع يتكون من الطبقات الجيوكهربية الآتية: (١) الطبقة السطحية التى تعتبر غطاءً سطحياً يتكون من الرمال و خليط الرمال مع الحصى و الحجر الوملى و الرمال الطفلية و الحجر الجيرى الرملى و التى لها مدى مقاومة نوعية واسع النطاق (يتراوح من ٥٠ أوم.متر الى ١٨٠ أوم.متر. (٢) الطبقة الجيوكهربية الأولى التى لها مدى مقاومة نوعية من ١٠ أوم.متر الى ١٠٠ أوم.متر بسماكة من مترين الى ٦٦ متراً و تتكون من الرمال الطفلية مع تداخلات الطفلة والطين و هذا النوع من السحنات يمكن البناء فوقه باحتياطات هندسية و هذه الطبقة لها سعة تحمل ممكنة تتراوح من ١,٥ كيلوجرام/سم٢ الى ٣ كيلوجرام/سم٢. (٣) الطبقة الجيوكهربية الثانية و التى لها مقاومة نوعية تتراوح من ٠,٥ أوم.متر الى ١٠ أوم.متر بسماكة من ٤ أمتار الى ٦٥ متراً و هذه الطبقة تتكون من الطفلة وهذا النوع من السحنات يسبب مشاكل و معوقات هندسية عند البناء عليه. (٤) الطبقة الجيوكهربية الثالثة و التى لها مقاومة نوعية تتراوح من ١٠٠ أوم.متر الى ٧٣٠ أوم.متر و هذه الطبقة تتكون من الحجر الجيرى الرملى.

تم اجراء مسح جيورادارى يشمل ٢٠ بروفيلاً وقد فسرت البيانات الجيورادارية فى ضوء المعايير التى تم تطبيقها على مناطق مماثلة ومن ثم تحديد بعض المشاكل مثل وجود التشققات و الفواصل ووجود طبقات الطفلة. وقد أظهرت القطاعات الجيورادارية بعض مناطق الشذوذ و التى تتميز بأنواع مختلفة من انعكاسات الموجات حيث تضمحل الاشارات الجيورادارية مع وجود أسطح انعكاسات ضعيفة وقد تمت المعالجة الجيورادارية للبيانات الرقمية بواسطة نظم برمجيات الحاسوب.

وبإجراء مقارنة لكل من التقنيتين المستخدمتين اتضح وجود مشاكل هندسية مثل وجود طبقات الطفلة و الفواصل السطحية و التشققات التى يمكن تفاديها أو معالجتها لتقليل النفقات و الوقت و المال.

ABSTRACT: *A site located at El Banafseg District, northern part of New Cairo City, Egypt, has been suffered under complicated and different aspects of hazards and risks following constructions. These complications are connected with the problem of limestone fracturing and clay layers, which cause clay swelling. A surface geoelectric resistivity consists of 14 vertical electrical resistivity soundings (VES) are conducted with the aim of identifying the prevailed subsurface conditions at the study area.*

The interpretation of the collected resistivity data reveals a common subsurface earth succession, that consists of following resistivity layers: 1) Surface layer; which is the surface cover around the area composed of sand and often a mixture of sand with gravels, sandstone, shaly sands, and sandy limestone in some places with wide range of resistivity values (from 50 to180 Ohm.m) . 2) First geoelectric layer that has resistivity values ranging from 10 to 100 Ω.m, and thickness varying from 2 to 66 m, consisting of shaly sand with shale or clay intercalations. This type of facies is relatively suitable for direct foundation above them. It also has allowable bearing capacity between 1.5 and 3 kg/cm^2. 3) Second geoelectric layer has resistivity value ranging from 0.5 to 10 Ω.m, and thickness varying from 4 m to 65 m. This layer is composed of shale bed. This shale type may cause some engineering troubles. 4) Third geoelectric layer that has a resistivity value ranging from 100 to 730 Ω.m. This layer is composed of sandy limestone facies.

Ground Penetration Radar survey was carried out in which twenty profiles are conducted. Interpretation of the ground penetrating radar sections has been done in the light of the in-situ calibration and utilizing previously published GPR works on similar areas. The surface observed fractures, joints and shale bed are detected by ground penetrating radar method. These sections revealed anomalous zones characterized by different types of reflections and zones, where the radar signals are highly attenuated with the presence of very weak reflection surfaces. Processing the digitally acquired radar data was achieved via system software. A comparative study of the resolution of the applied geophysical techniques may detect shale layers, surface joints, fractures, and help in reducing the cost and saving the time and money.

Keywords: *Geoelectric method, GPR, geotechnical problems, Greater Cairo*

INTRODUCTION

During the last few years the Egyptian construction strategies aiming towards setting new urban areas as extensions for the already existed communities. This strategy accommodates the ever increasing population in Egypt. As a consequence, several geological and geo-technical problems were arisen and take a great attention and valuable economic importance from engineering point of view.

The Banafseg area is situated in the northern part of the New Cairo City “settlements No I” between latitudes 30° 02′ 11″ N and 30° 04′ 13.12″ N, and longitudes 31° 27′ 24.10″ E and 31° 28′ 30″ E, (Fig. 1).

The new urban areas around the Greater Cairo, usually sited on limestone bedrocks, that have encountered the problem of fracturing or sited on clay which reported construction damage due to swelling process, (Fig. 2). It became inevitable that high resolution near surface geophysical techniques be employed to detect and help delineating and assessing these hazardous problems. At highly developed countries, the application of geophysical techniques is constrained for solving the engineering and geo-technical problems. This thesis introduces confirmative geophysical studies of different tools for solving and giving a clear picture for these problems to be constrained by the engineering viewpoint in Egypt.

GEOLOGIC SETTING

The New-Cairo City is bounded between Cairo-Suez desert road from the north, El-Qattamiya-Ain Elsokhna road from the south, ring road from the west, Gebel Al-Anqabiyah from the east. The New-Cairo City is considered as a part of Cairo-Suez district and can be considered as the eastern extension of Cairo. It is about 15 km far from Maadi and Darrasa, 10 Km from Nasr City and well connected with the existing road network.

Eastern Great Cairo (New Cairo area) is essentially built of sedimentary rocks in addition to some patches of basaltic flows in several localities ranging in age from Middle Eocene to Upper Miocene (Fig. 3). The stratigraphic units exposed in the study area are all sedimentary rocks. The general stratigraphic succession is summarized in Figure (4).

GEOELECTRIC RESISTIVITY SURVEY

A total of 14 vertical electrical soundings (VES) (Fig. 5) were carried out at the under Banafseg using Schlumberger electrode configuration with maximum half spacing (AB/2) of 500 meters. A digital, computer-operated, high resolution resistivity- meter (ABEM terrameter SAS 1000C as Swedish apparatus) was used to acquire the field resistivity data.

Qualitative interpretation:

Iso-apparent resistivity contour maps:

Seven iso-apparent resistivity contour maps at AB/2=1, 3, 5, 10, 30, 100, and 200 was prepared to represent the lateral variation in the apparent electric resistivity at different depths. The apparent resistivity values varies from about 3 Ω.m to about 220 Ω.m. Composite of some iso-apparent resistivity maps (Fig.6) shows the lateral variation at different levels in the Banafseg area.

Quantitative interpretation:

The process followed in interpreting the collected apparent resistivity curves consist of two simultaneous steps; in the first step the master curve technique was to estimate an initial earth model for each sounding and in the second step, an iterative automatic technique (ITC, 1988) was applied to calculate the final earth model.

Eight geoelectric resistivity cross–sections are constructed to demonstrate the distribution of the calculated resistivity parameters (true resistivity and thickness) across the Banafseg area (Fig. 5). These sections are illustrated in figures from 7 to 14.

Three geoelectrical layers have been identified in addition to the surface one:

1- Surface layer; It is the surface cover around the area with a mixture of sand and sand with gravels, with range of different resistivity values between 50 and 180 Ohm.m, and thickness varying from 1 m to 7 m.

2- First geoelectric layer has resistivity value ranging from 10 to 100 Ohm.m, and thickness varying from 2 m to more than 25 m. This layer corresponds to shaly sand bed, with some clay intercalations.

3- Second geoelectric layer has a low resistivity value ranging from less than 1 up to 10 Ohm.m, and thickness varying from 4 m to 65 m. This layer corresponds to shale bed.

4- Third geoelectric layer has a relatively wide range of resistivity values from 100 up to730 Ohm.m. This layer refers to sandy limestone facies.

Panel diagram bounded the Banafseg area has been constructed to demonstrate the 3D variation in the stratigraphy of the area (Fig.15).

Interpretation of the geoelectrical resistivity maps:

The true resistivity map of the surface layer is constructed as shown in Fig.16a. The first resistivity values ranges between 17 Ω.m and 268 Ω.m. This map indicates a relatively general increase in the electrical resistivity towards the southern part of the area. The true resistivity map for the first layer is constructed as shown in Fig. 16b. The resistivity values ranges between 1.5 Ω.m and 260 Ω.m. The study of this map indicates general increase in the electrical resistivity towards the northern part of the area.

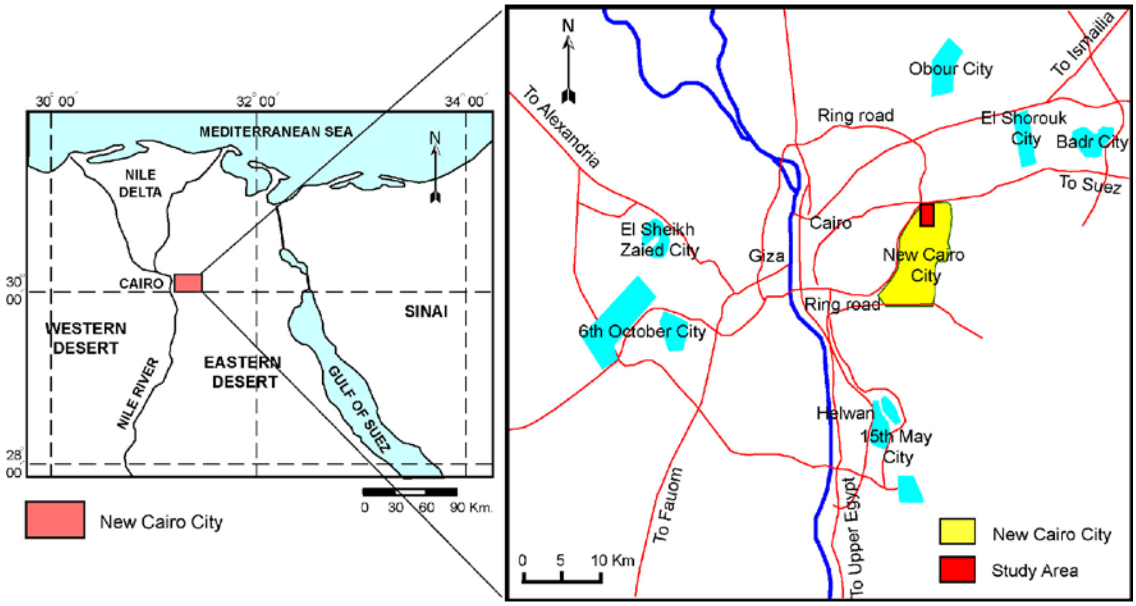


Fig. (1): Location map of New Cairo City.

Fig. (2): Problems causing construction damages.

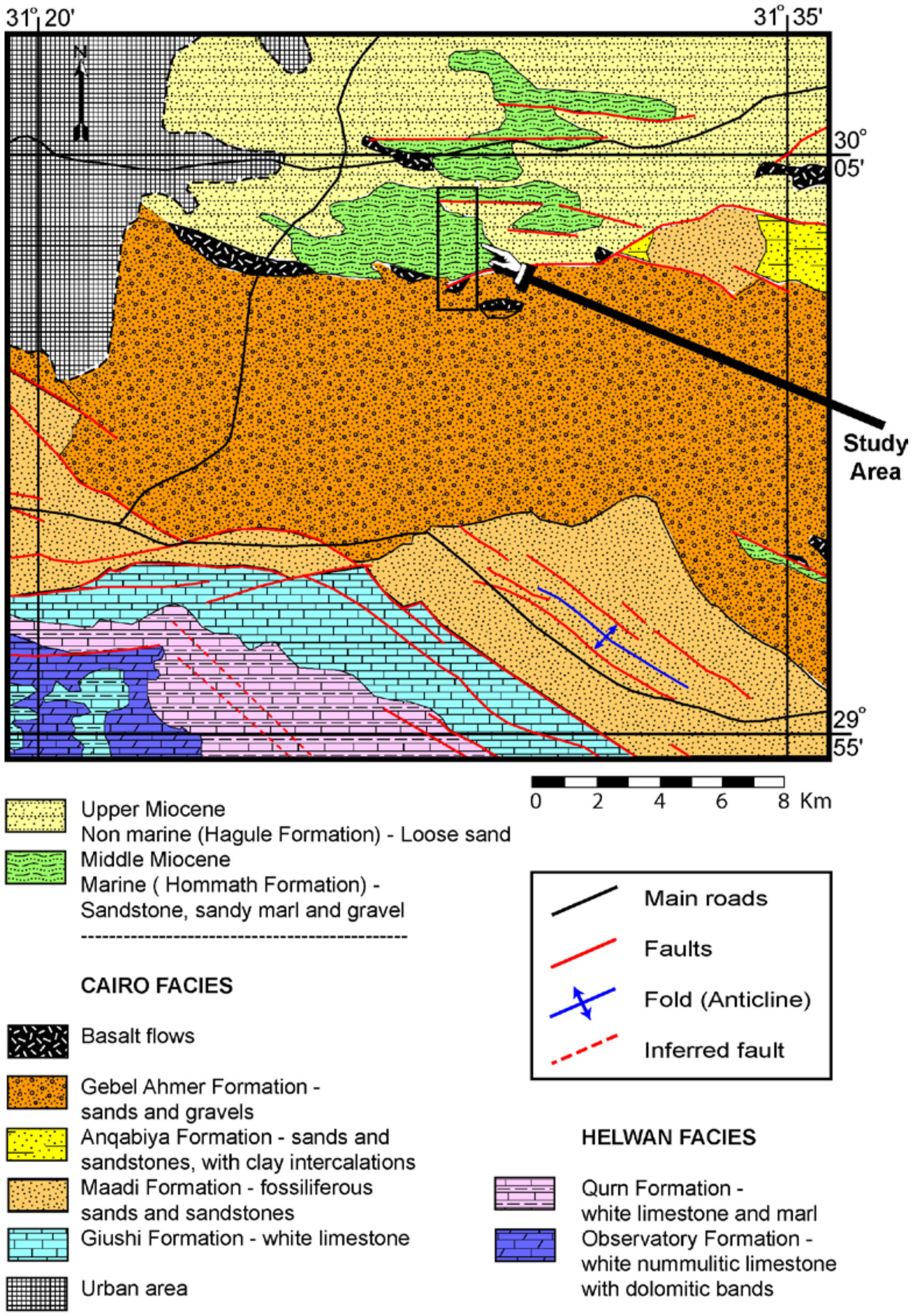


Fig. (3): Geological map of the New Cairo City (after EGSMA,1983).

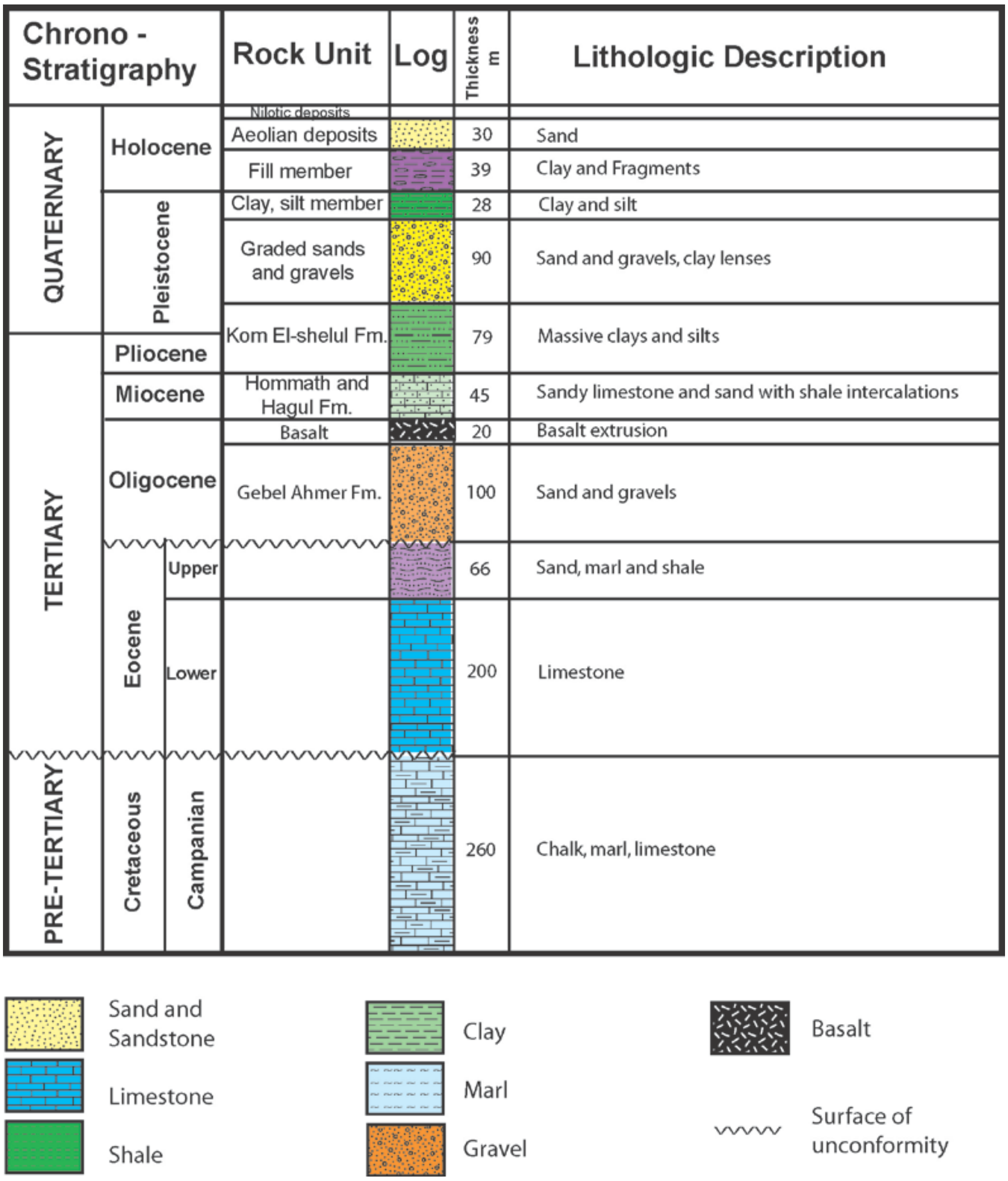


Fig. (4): Composite lithostratigraphic section of the New Cairo area, (Modified after Abd El-Aal, 1982).

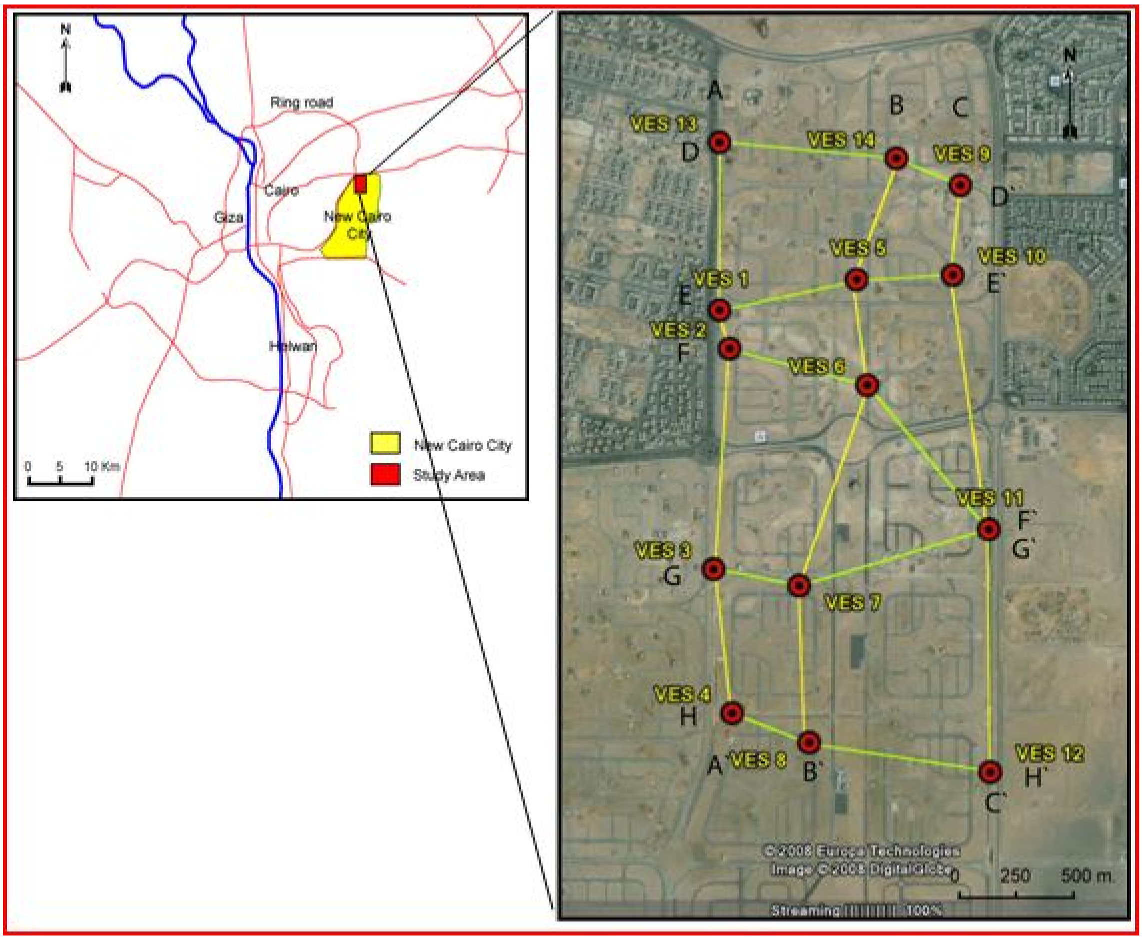


Fig. (5): VES location map with cross-sections.

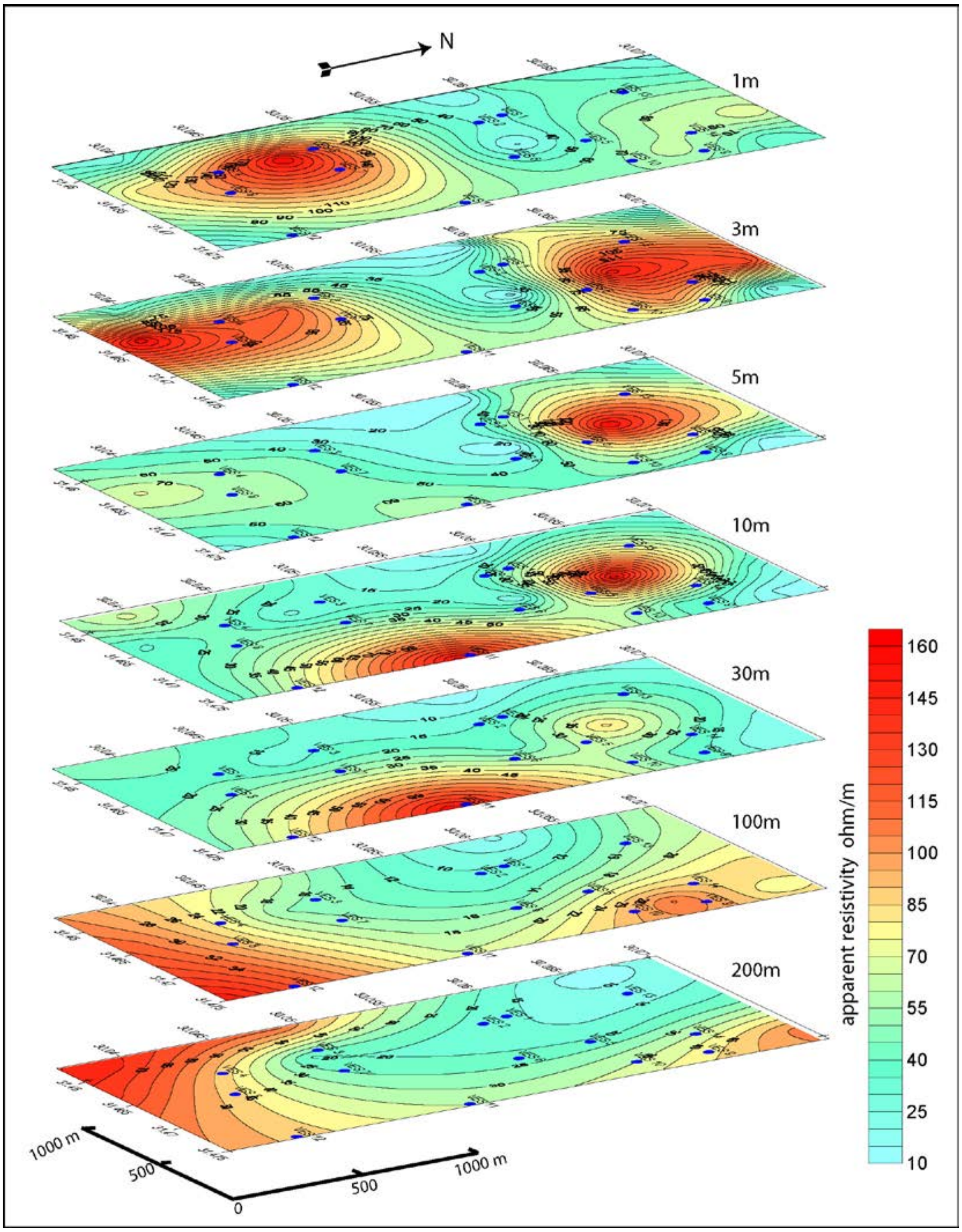


Fig. (6): Iso-apparent resistivity contour maps illustrating different levels.

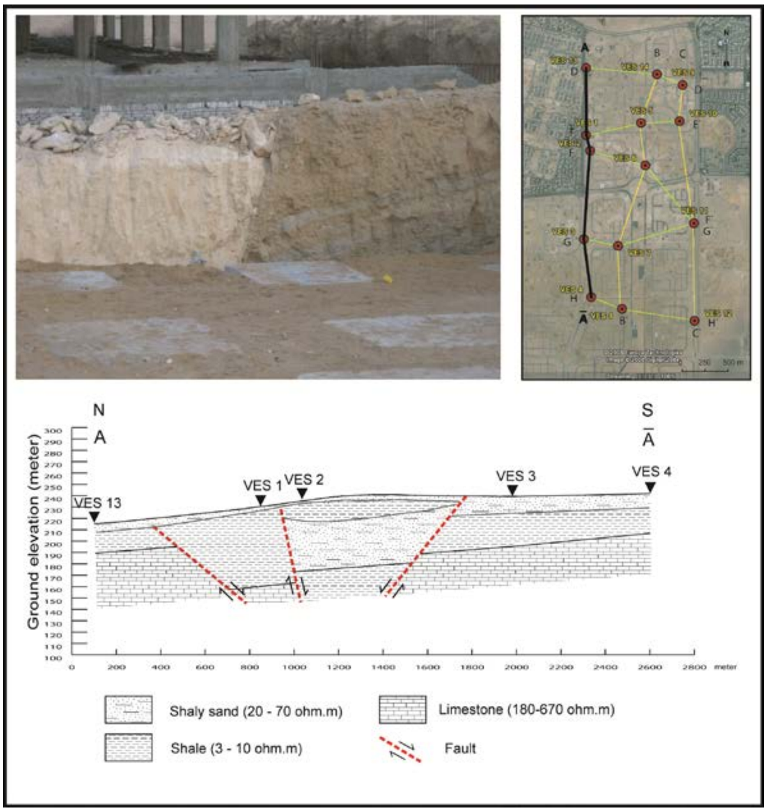


Fig. (7): Geoelectric resistivity cross–section (A–A`).

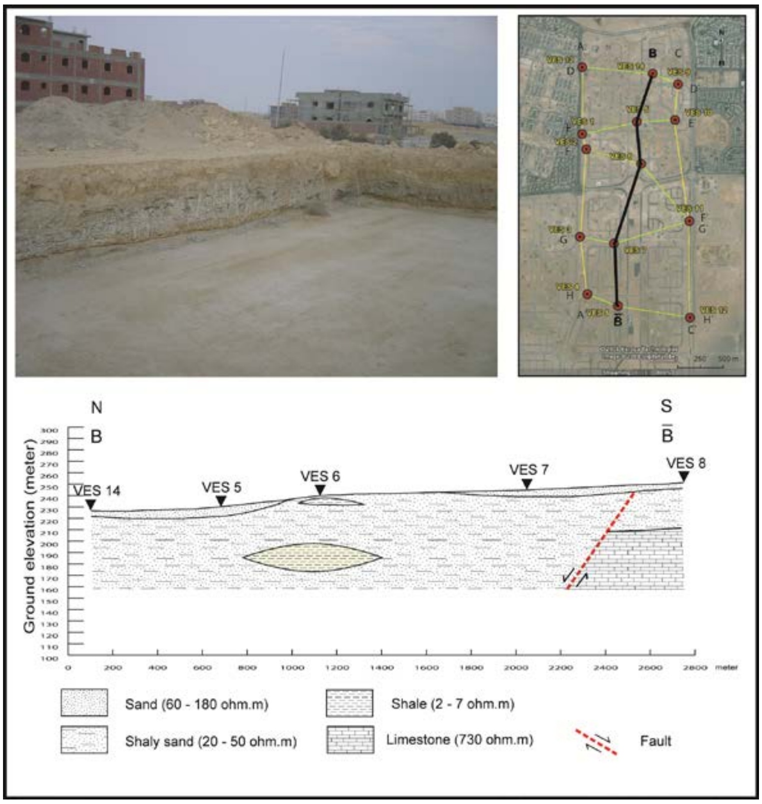


Fig. (8): Geoelectric resistivity cross–section (B–B`).

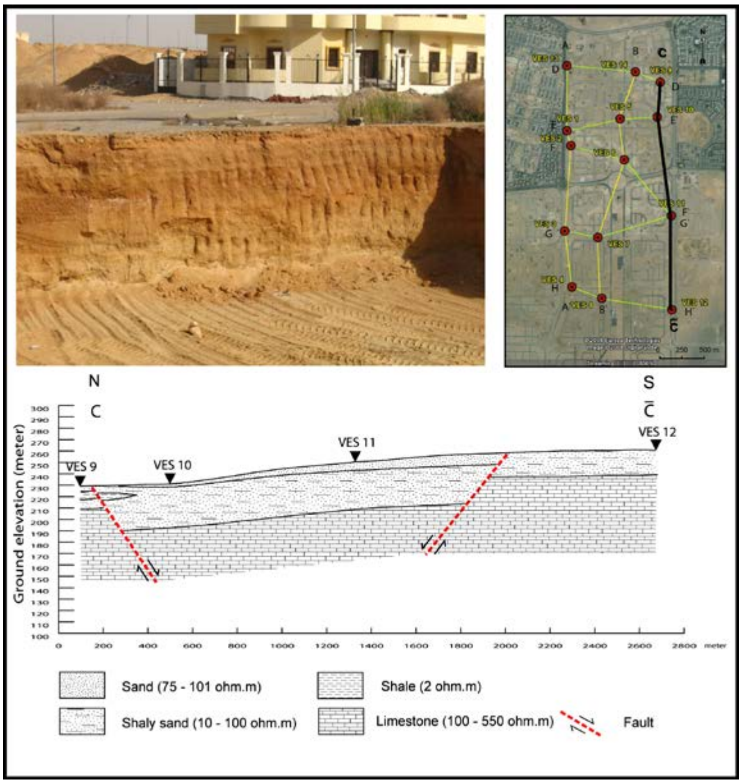


Fig. (9): Geoelectric resistivity cross–section (C-C`).

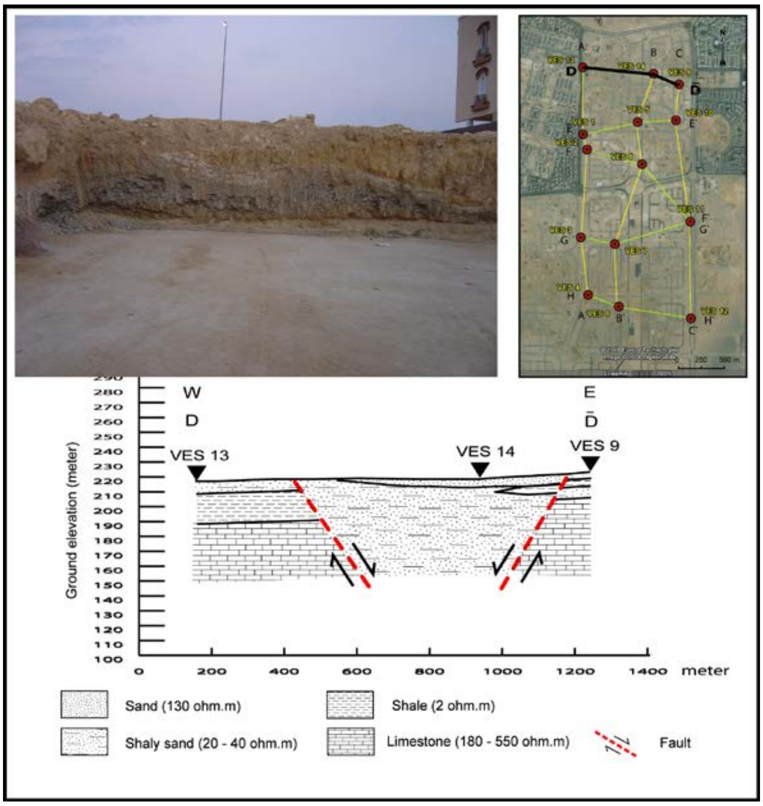


Fig. (10): Geoelectric resistivity cross–section (D-D`).

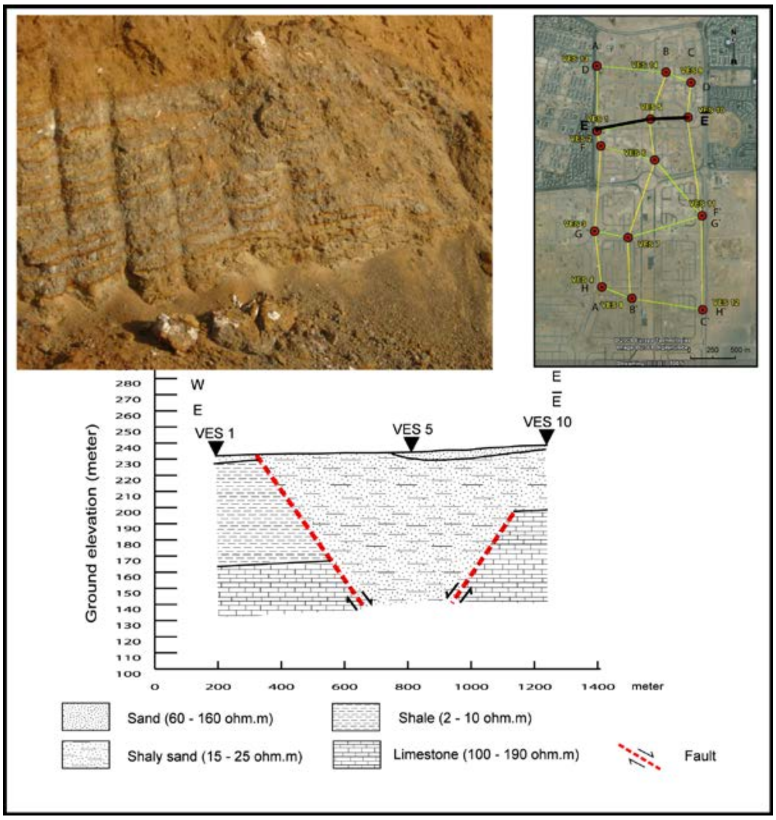


Fig. (11): Geoelectric resistivity cross–section (E-E`).

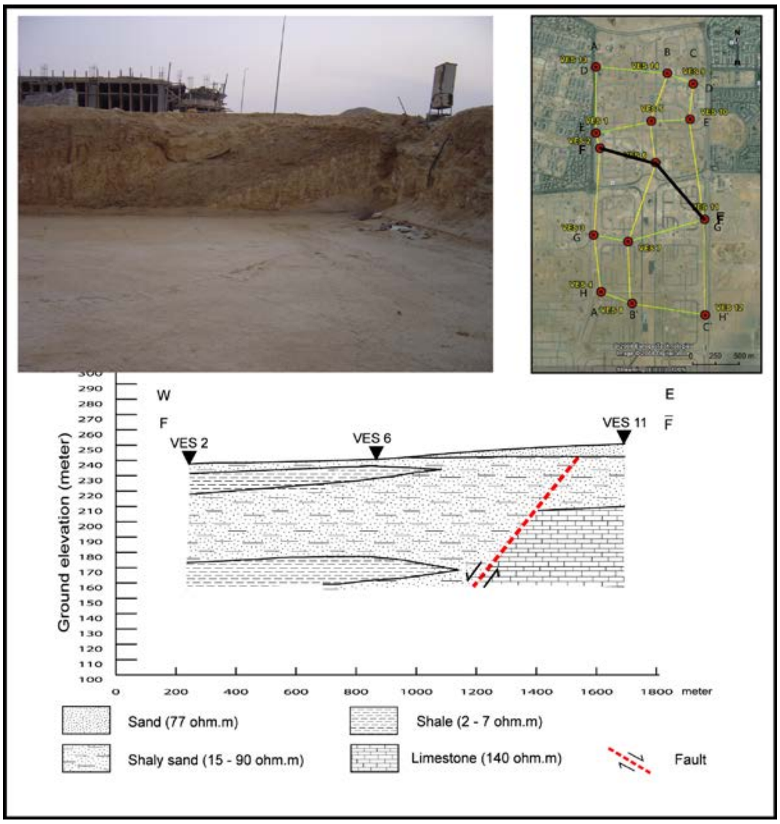


Fig. (12): Geoelectric resistivity cross–section (F-F`).

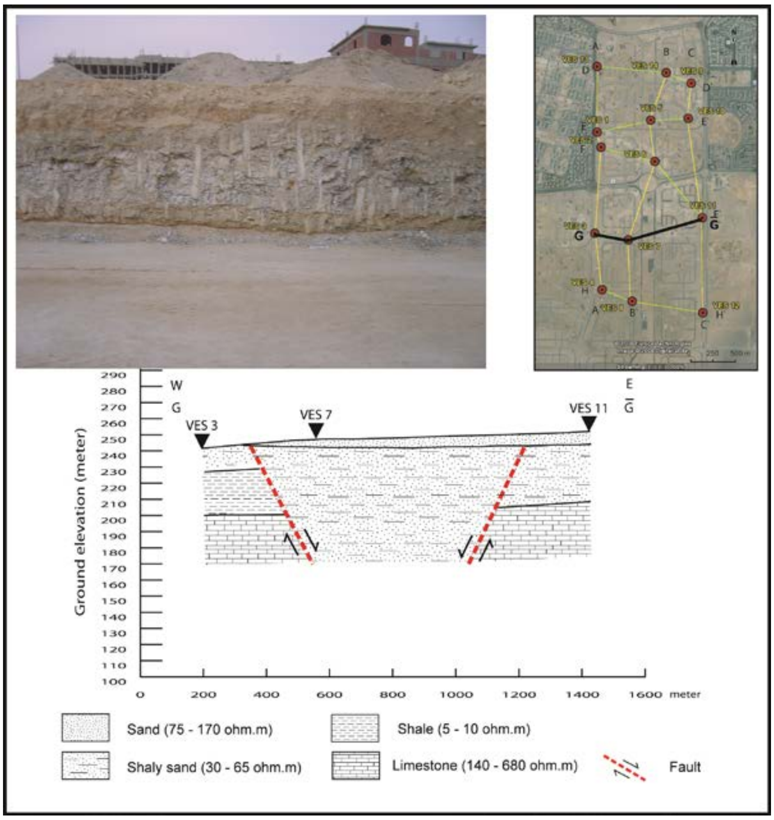


Fig. (13): Geoelectric resistivity cross–section (G-G`).

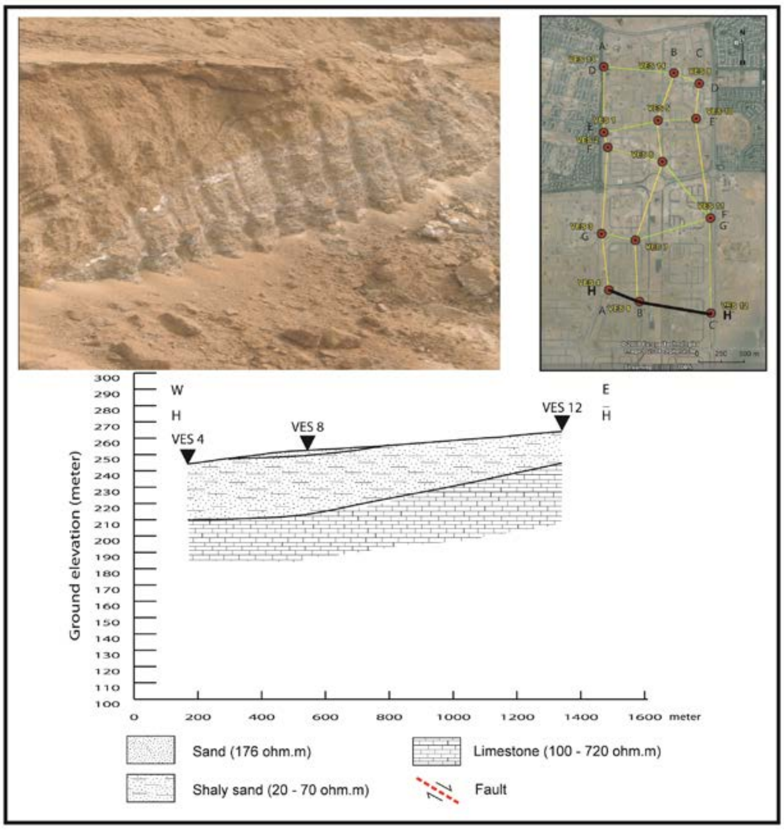


Fig. (14): Geoelectric resistivity cross–section (H-H`).

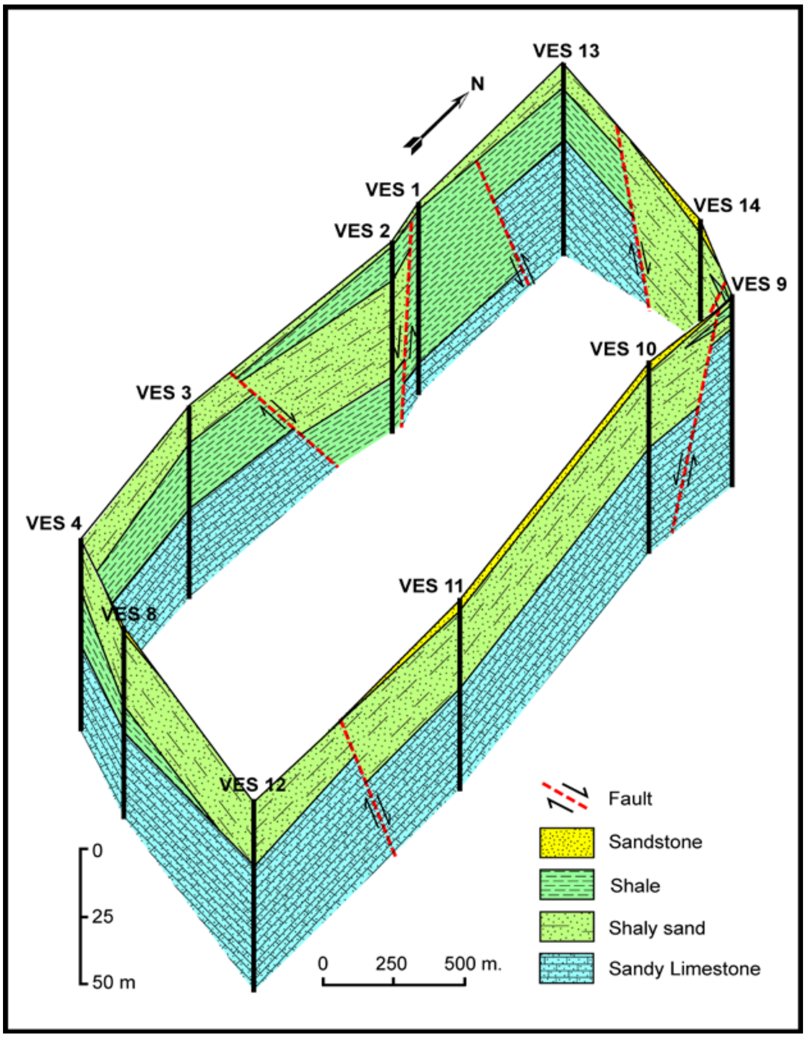
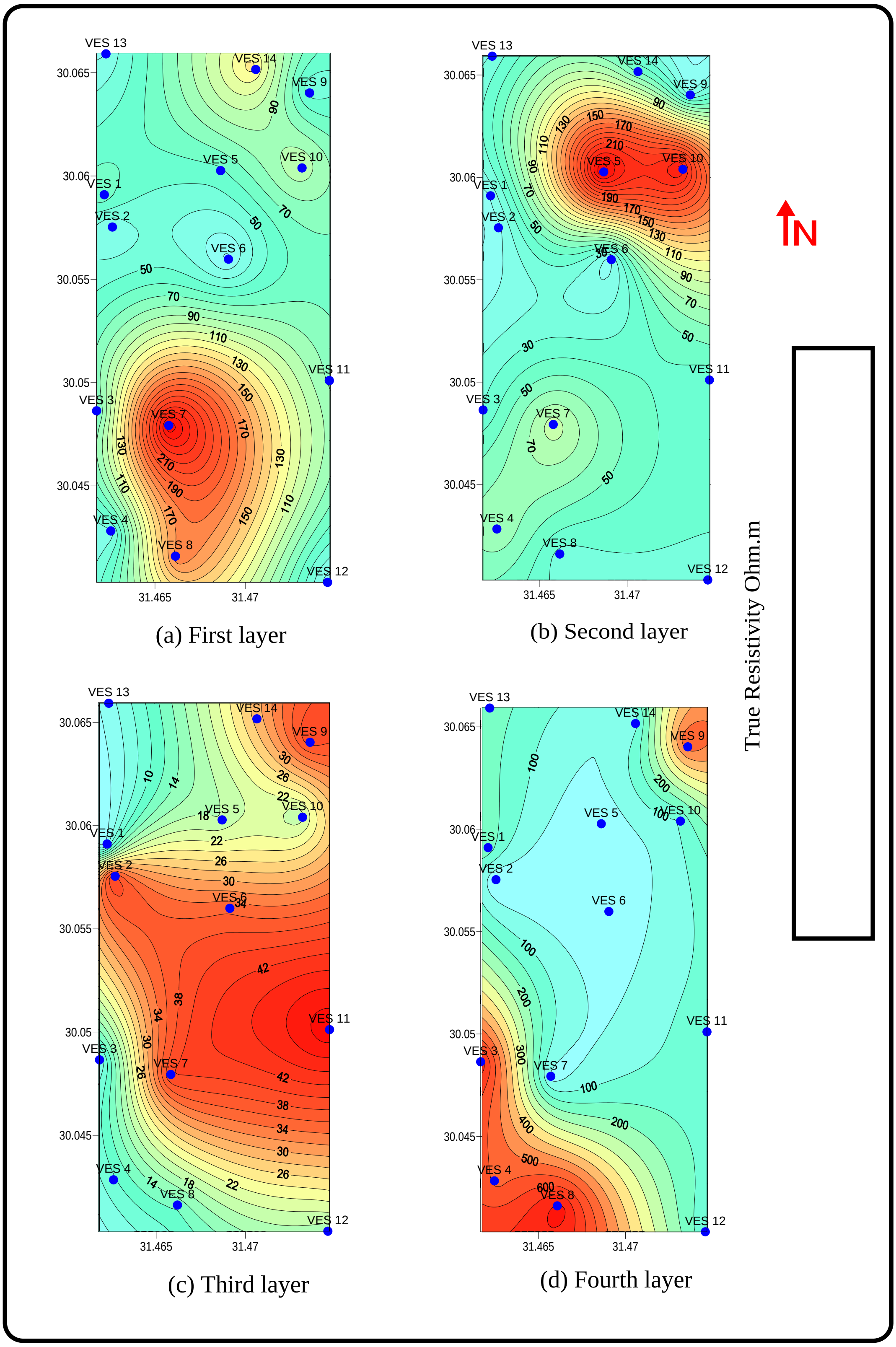


Fig. (15): Panel diagram showing subsurface facies change.



(a) First layer

(b) Second layer

(c) Third layer

(d) Fourth layer

Fig. (16): True geoelectrical resistivity maps.

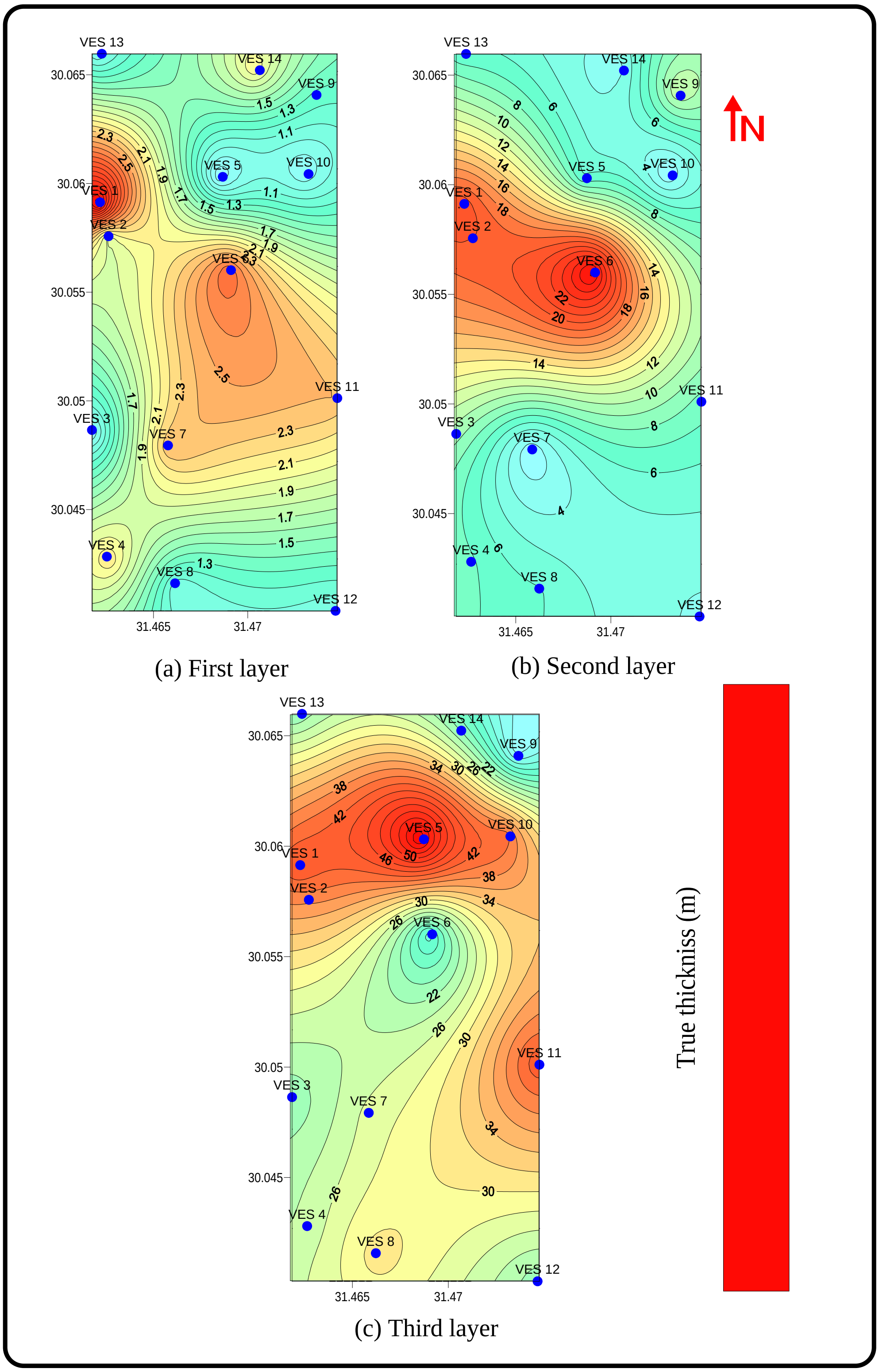


Fig. (17): True thickness maps.

The true resistivity map for the second layer is constructed as shown in Fig. 16c. The resistivity values ranges between 2.6 Ω.m and 49.8 Ω.m. The study of this map indicates a relatively general decrease in the electrical resistivity towards the northwestern and the southwestern parts of the area. The true resistivity map for the third layer is constructed as shown in Fig. 16d. The resistivity values ranges between 0.4 Ω.m and 727 Ω.m. The study of this map indicates a relatively general increase in the electrical resistivity towards the northeastern and the southwestern parts of the area.

True Thickness Maps:

The true thickness map of the surface layer is constructed as shown in Fig. 17a. The first thickness map values are ranged between 0.8 m. and 7 m. The study of this map indicates a relatively general increase in thickness towards the northwestern part of the area.

The thickness map of the first layer is constructed as shown in Fig. 17b. The thickness values of this layer are ranged between 2 m. and 25 m. The study of this map indicates a relatively general increase in the thickness towards the western and central parts of the study area.

The thickness map of the second layer is constructed as shown in Fig. 17c. The thickness values of this layer are ranged between 7 m. and 58 m. The study of this map indicates a relatively general decrease in the thickness towards the northwestern part of the study area.

Shale layer distribution map:

The recognized clay layers in the study area especially these layers which have shallow depth to the surface mast be taken in consideration for engineering purposes. These units detected under most VES stations with thickness ranges from 0.7 m to 66 m. The other clay layers are detected to deeper depths that are of less danger for engineering purposes. Fig.18 shows contour map of thickness to first clay layer. This layer has dangerous effects of the building or any establishment. This danger related with the building height, depth of foundation, type of this establishment and its sensitivity or resistance for falling down or swelling when water infiltrate to clay layer.

GROUND PENETRATING RADAR SURVEY

Ground penetrating radar is a very useful geophysical method used in near surface mapping studies. It can be used to study subsurface structures (faults, fractures, and cavities), all of which pose potentially dangerous engineering and geotechnical problems.Geophysical surveys can play an important role in defining the subsurface geology. Interpretation of the ground penetrating radar sections has been done in the light of the in site calibration and utilizing previously published GPR works on similar areas (as El–Behiry, 1999). From the 20 radar profile lines conducted in the studied area (Fig.19), a preliminary inspection of these sections revealed anomalous zones characterized by different types of reflections and zones, where the radar signals are highly attenuated with the presence of very weak reflection surfaces.

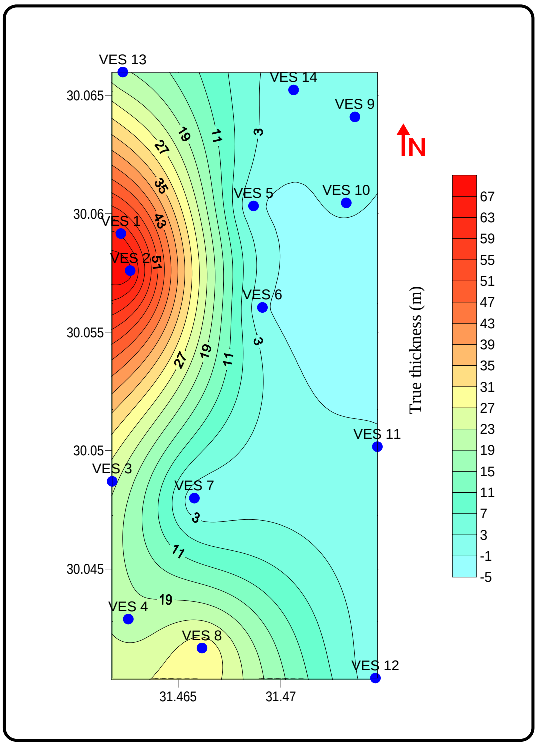


Fig. (18): Thickness distribution map of the shale layer.

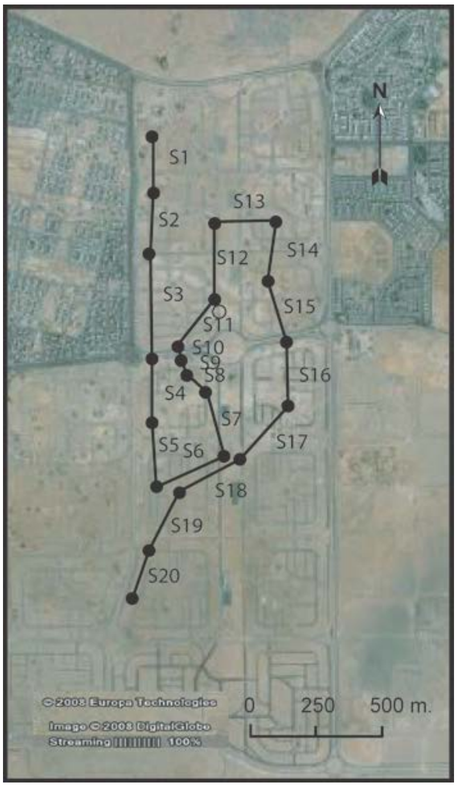


Fig. (19): Location map of GPR profiles.

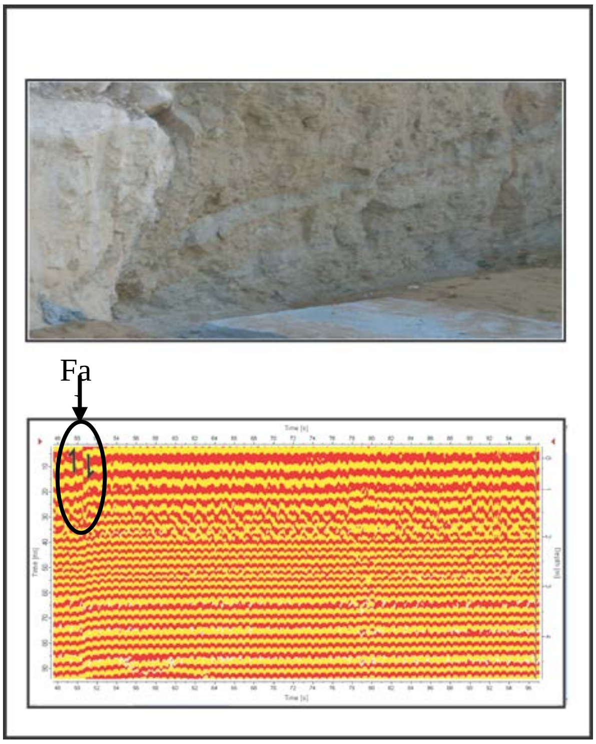


Fig. (20): GPR section showing fault.

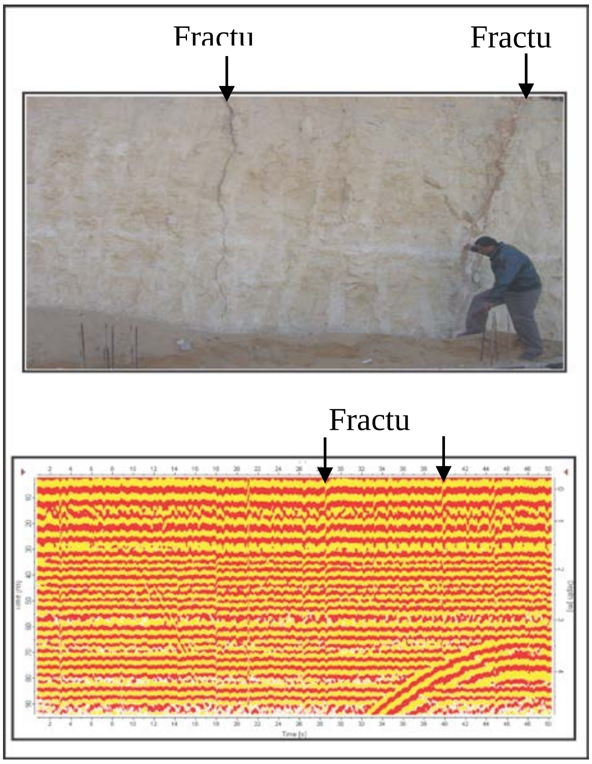


Fig. (21): GPR section showing fractures.

Data Processing:

Processing the digital acquired radar data was achieved via system software. The processing sequence consists of three main steps: data display, data filtering, and data presentation (plotting). Although, data filtering is an important step in the processing of the georadar data, some of the acquired GRR–data of the present investigation were clear enough that need no processing. The filter of the main menu applied to the data collected in the present study includes; Ringing Filter to eliminate multiples and Ringing and Band pass Filter, Time Varying Gain Filter to compensate for signal suppression, Finite–Impulse Response (FIR) filter is a band pass filter in time domain, Averaging Filter to suppress noise and smooth the image, and Moving Average Filter, which is applied to retain non–horizontal structures and remove others.

After the data was filtered and an acceptable image was obtained for interpretation, the filtered image was plotted to mark on it the locations of subsurface inhomogeneities. Interpretation procedures followed in interpreting the present GPR–data are adopted (Fenner, 1992; Daniels et al., 1996; Papakakis et al., 1996).

Output results*:*

The analysis and interpretation of the acquired GPR records are straightforward. Figures from (20) to (24) show some of interpreted georadar records for surveyed GPR lines, using the 100 MHZ antenna. The drawn dashed arrows, rectangle, solid lines, circles and ellipses indicate the location of the vertical fractures , faults and shales, in addition to pipes and cables. The observed primary arching of higher mplitude, reflection pattern was interpreted as the interface between bedrock and fractures. The ground penetrating radar profiles show the diffraction patterns; which are interpreted to be due to fractures in the subsurface with depth estimate of about 1-4 m.

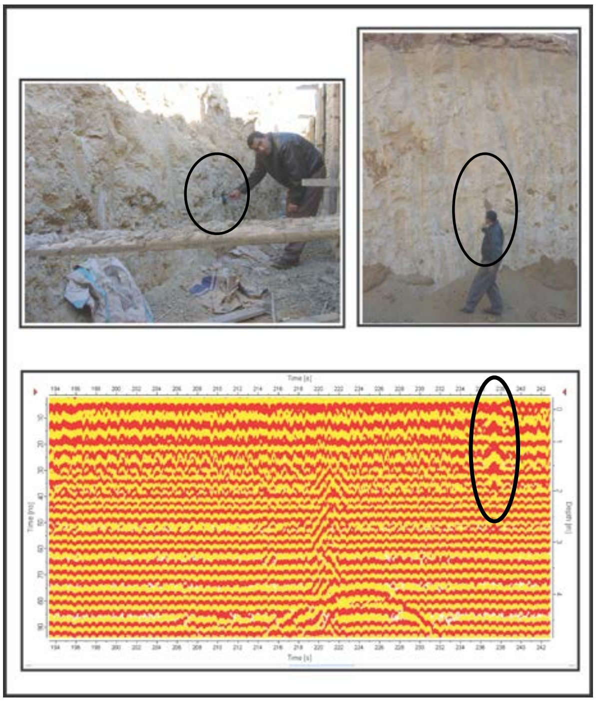


Fig. (22): GPR section showing voids.

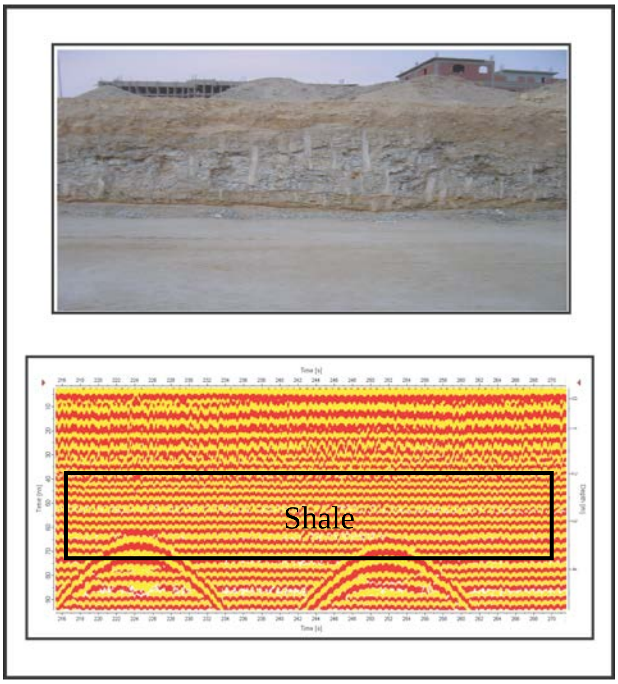


Fig. (23): GPR section showing shale layer overlain 2 pipes.

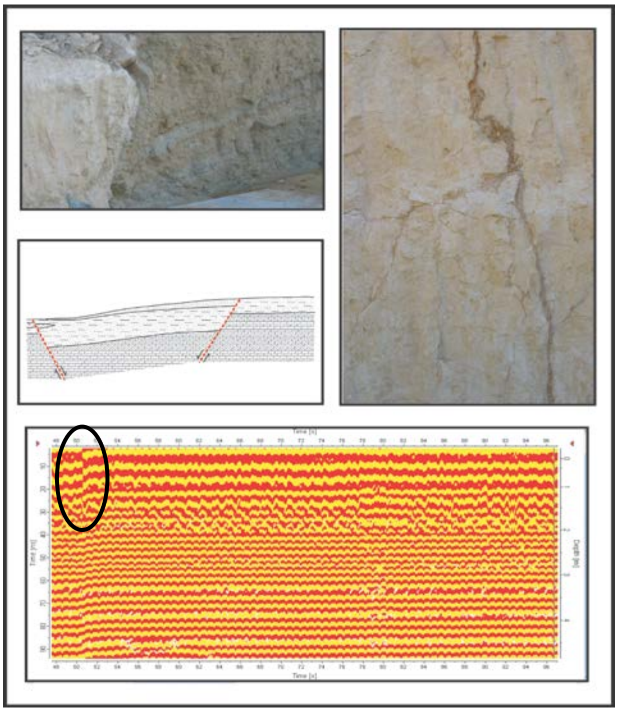


Fig. (24): Combined figures showing fractures.

SUMMARY AND CONCLUSIONS

The Banafseg area is situated in the northern part of New Cairo City beside settlement No1 between latitudes 30° 02′ 11″ and 30° 04′ 13.12″ N, and longitudes 31° 27′ 24.10″ and 31° 28′ 30″ E.

Geoelectrical resistivity survey has been accomplished by carrying out 14 Schlumberger Vertical Electrical Soundings (VES's), with a maximum current electrode separation of 400 meters. These resistivity soundings were qualitatively evaluated using an automatic iterative algorithm. The results of these studies can be summarized as follows:

Geoelectric resistivity sounding data is interpreted qualitatively as well as quantitatively. The qualitative interpretation of these data, including a set of apparent resistivity contour maps and a construction of eight resistivity pseudo-sections, which give a preliminary impression of the homogenous subsurface layers of near-surface rocks. On the other hand, these VES`s were interpreted quantitatively. The output data has been used in constructing eight geoelectrical cross-sections, isopach and depth maps for the near-surface layers.

Three geoelectric resistivity layers have been identified as:

1- Surface layer; sand with gravels, (from 50 to180 Ω.m).

2- First geoelectric layer, shaly sand bed with some clay intercalations, (from 10 to 100 Ω.m).

3- Second geoelectric layer, shale bed, (from 0.5 to 10 Ω.m).

4- Third geoelectric layer, sandy limestone facies. (from 100 to 730 Ω.m).

Ground penetration radar survey was carried out, where twenty radar profiles are conducted in the study area. Interpretation of the ground penetrating radar sections has been done in the light of the in-situ calibration and utilizing previously published GPR works on similar areas. The surface observed fractures, joints and shale bed are detected by ground penetrating radar method. These sections revealed anomalous zones characterized by different types of reflections and zones, where the radar signals are highly attenuated with the presence of very weak reflection surfaces. Processing the digitally acquired radar data was achieved via software.

REFERENCES

Aaltonen, J. (2000): A short introduction to geoelectrical investigations, (Short note). Land and Water Resources, Stockholm, 4p.

Abd El-Aal, M.E. (1982): Hydrogeological evaluation of the ground water resources in Cairo district (A.R.E.) M.S.C Thesis, Geol. Dept. Fac. Sci., Ain Shams Univ., 131 p.

Abu EI-Ata A.S. and Hassanein A.G. (1990): A Comparative study of the geoelectric characteristic and water qualities in the Cairo-Ismailia, Cairo-Suez and Cairo-Sukhna roads, eastern Desert, Egypt. Geol. Dept. Fac. Sci., Mansoura Univ., Egypt, V. 17, No. I, Supplement, pp. 511-532.

Egyptian Geological Survey and Mining Authority, EGSMA, (1983): Geological map of greater Cairo area, scale 1: I000,000. Geological survey of Egypt.

El-Behiry, M.G., (1990): Geophysical Analysis of Some Shallow Sediments: Ph. D. Thesis, Faculty of Science, Cairo Univ., Egypt, 224p.

Hossin, H.H. (2003): Integrated Geophysical and Geological Study of the New Cairo City, Cairo Suez Road, Using Geoelectrical, Remote Sensing and GIS Techniques. Ph.D. thesis, Geol. Dept., Fac. Sci., Ain Shams University, 257p.

Loke, M.H., and Barker, R.D., (1996): Rapid least squares inversion of apparent resistivity pseudo-sections by a quasi-Newton method. , Geophysical Prospecting 44, pp. 131-152.

Parasnis, D.S. (1997): Principles of applied Geophysics: Fourth Edition. Chapman and Hall, pp. 371-373, 137-150.

Saad, A.M. (2005): Identification of Shallow Facies at New Cairo City Through Their Petrophysical Characteristics, Using Compiled Geophysical, Engineering and Sedimentological Researches. Ph.D. thesis, Geol. Dept., Fac. Sci., Al Azhar University, 217p.

Salloum, G.M., Abu EI-Leil I. and E1 Ghanary M.N. (1988): Structural development of the Cairo-Suez District, Egypt. 5th Symp. Phanerozoic developed Egypt, Nat Committee Geol Sci., IGCP, Egypt, p.213.

Swedan, A.H. (1991): A note on the geology of Greater Cairo area. Annals of the geological survey of Egypt, V. X. VII, PP. 239-251.

Van Der Velpen, B.P.A. (1988): «RESIST", version 1.0, a package for the processing of the resistivity sounding data. M.Sc. research Project, Netherlands, pp. 345-364.

Zohdy, A.R., (1989): A new method for the automatic interpretation of Schlumberger and Wenner sounding curves: Geophysics, Vol. 54, No. 2. pp. 245-253.