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NEAR-SURFACE GEOPHYSICAL INVESTIGATIONS AT TUSHKA AREA, EGYPT

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فحوصات جيوفيزيقية ضحلة فى منطقة توشكى، مصر

الخلاصة: تم انجاز عدد من الفحوصات الجيوفيزيقية الضحلة والمتمثلة بالقياسات السيزمية الانكسارية الضحلة والجسات الكهربية الرأسية بالاضافة الى نتائج حفر الآبار فى منطقة توشكى بهدف فحص الجزء الضحل من القطاع الجيولوجى وذلك لأغراض استصلاح وتنمية التربة الزراعية وأيضا لتصور ما اذا كانت هناك ضرورة لتنفيذ نظام الصرف الزراعى من عدمه وهذا مهم جدا بالنسبة للهندسة الزراعية. البحث عن المياه الجوفية ليس هو الغرض من هذا البحث وانما التصور العلمى للطبقات السطحية الصالحة للزراعة هو الهدف. لذلك تم عمل تحليل البيانات المقاسة بهاتين الطريقتين وضوهيت بنتائج الحفر لاعطاء نتائج موثوق بها. وتعكس نتائج تفسير البيانات عن وجود قطاع للتربة مكون تقريبا من خمس طبقات تصل الى متوسط عمق حوالى ٤٠ مترا. وأظهرت النتائج أيضا وجود صدع رئيسى يقطع منطقة الدراسة ويتجه شمال شرق- جنوب غرب ويقسم المنطقة الى كتلتين رئيسيتين فى الشرق والغرب. وتمثل الكتلة الغربية جانب الرمية السفلى للصدع ومكونة من طبقة سطحية تعلو طبقة الطين والطين الغرينى والطين الرملى الغرينى والحجر الرملى الغرينى ، بينما تمثل الكتلة الشرقية جانب المرمى العلوى وهى مكونة من طبقة سطحية تعلو حجر رملى غرينى وحجر رملى شديد الصلابة. ويجب عمل نظام الصرف الزراعى على المدى القريب فى الجزء الغربى من المنطقة وذلك لوجود طبقة سطحية رفيعة فوق طبقة طينية سميكة وعمله على المدى البعيد فى الأماكن من الجزء الشرقى التى بها الطبقة السطحية رفيعة تعلو صخرا أو اذا كانت سميكة تعلو طينا ولا حاجة إلى الصرف الزراعى على الإطلاق فى الأماكن التى بها طبقة سطحية سميكة تعلو صخرا.

ABSTRACT: *Near-surface geophysical investigations represented by shallow seismic refraction and Vertical Electrical Sounding (VES) measurements, in addition to borehole drilling have been carried out at Tushka area aiming at the examination of the shallower part of the geological section for topsoil reclamation and agricultural soil development purposes, and also for drainage system implementation that is very useful for agricultural engineering. Searching for groundwater is not the target of this work. Data analysis of these two geophysical tools was done and checked with the borehole data to provide reliable results. The results of data interpretation reveal a soil profile composed of almost five layers with an average depth of investigation of about 40 m. A major fault dissecting the study area and running in the northeast-southwest direction is also detected from both seismic refraction and electric methods. This fault divides the area into two different blocks; the western block represents its down thrown side and it is mainly composed of topsoil overlying clay, silty clay, sandy silty clay, and silty sandstone, while the eastern one represents the up thrown side and it is mainly composed of topsoil overlying silty sandstone and very hard sandstone.*

A drainage system should be done for a short-term at the western part due to the occurrence of thin topsoil layer overlying thick clay and it can be done for a long-term at the eastern part in areas of thin topsoil layer overlying a rock and/or thick topsoil overlying clay. The drainage may not be done at all in areas of thick topsoil overlying a rock.

INTRODUCTION

Tushka area lies in Aswan governorate about 950 km south of Cairo in the Western Desert as shown in the location map (Fig. 1). Ground elevation map is shown in Fig. 2 that is very useful for elevation correction during seismic data processing. The arrows on this map show the locations of seismic profiles. The purpose of this study is the reclamation and development of the agricultural soil, lithological description from the drilled boreholes, geological structure and determination of the rock physical properties such as seismic wave propagation velocity and electrical resistivity and layer thicknesses that are needed for the implementation of the drainage system in Tushka area. This drainage system should be done for a short-term in areas of thin topsoil overlying clay at the western part and it can be done for a long-term in areas of thick topsoil overlying clay or thin topsoil overlying rock. Shallow seismic refraction data and Vertical Electrical Soundings (VES's) were measured as well as several boreholes were drilled all over the study area to achieve this goal.

SEISMIC REFRACTION AND VERTICAL ELECTRICAL SOUNDING DATA ACQUISITION

During field survey 12-Channel SmartSeis Geometrics Seismograph with built in compatible computer was used for acquiring seismic refraction data. In-line geophone spread was used as a system of seismic measurements with two end-on shotpoints and one middle shotpoint. This spread type is preferred for shallow refraction investigations (Herbest et al., 1998). As a source of seismic energy a sledgehammer was used hitting vertically a steel striker plate laid on the ground. The locations of the acquired seismic profiles (207) and the drilled boreholes covering the study area are shown in Fig. 3 with a profile B-B$^{/}$ of the geologic section along boreholes 18, 16 and 19 from east to west.

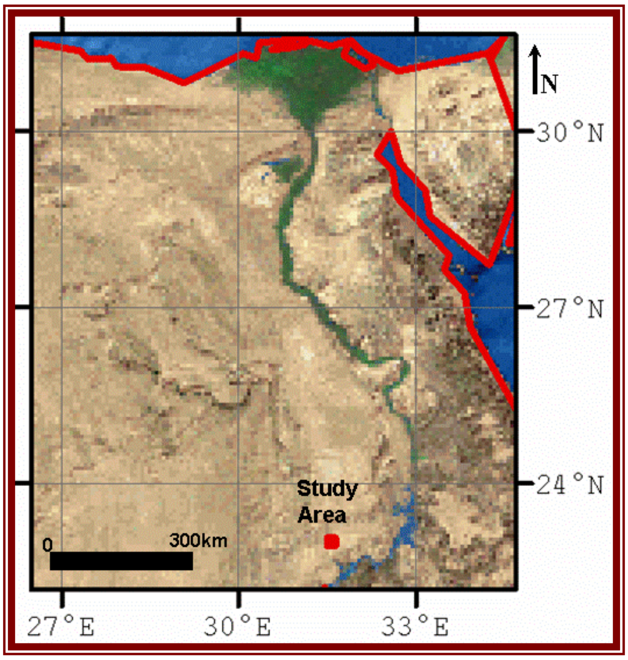

Fig. 1: Location map of the study area.

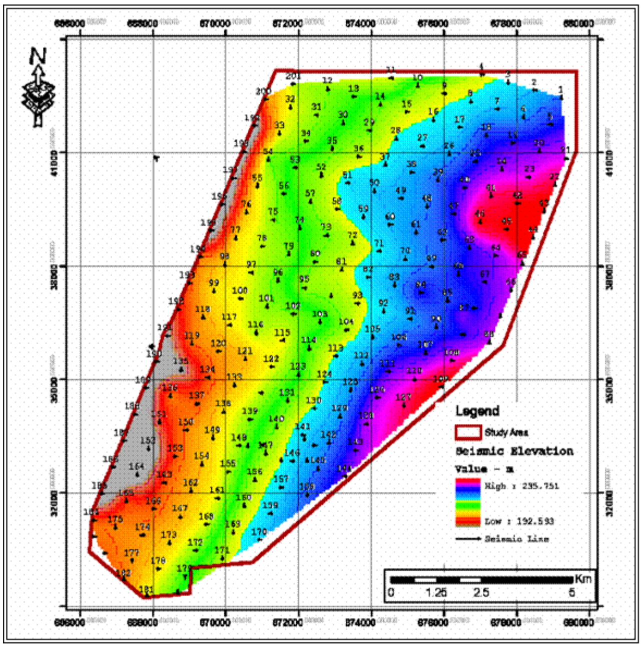

Fig. 2: Ground elevation map.

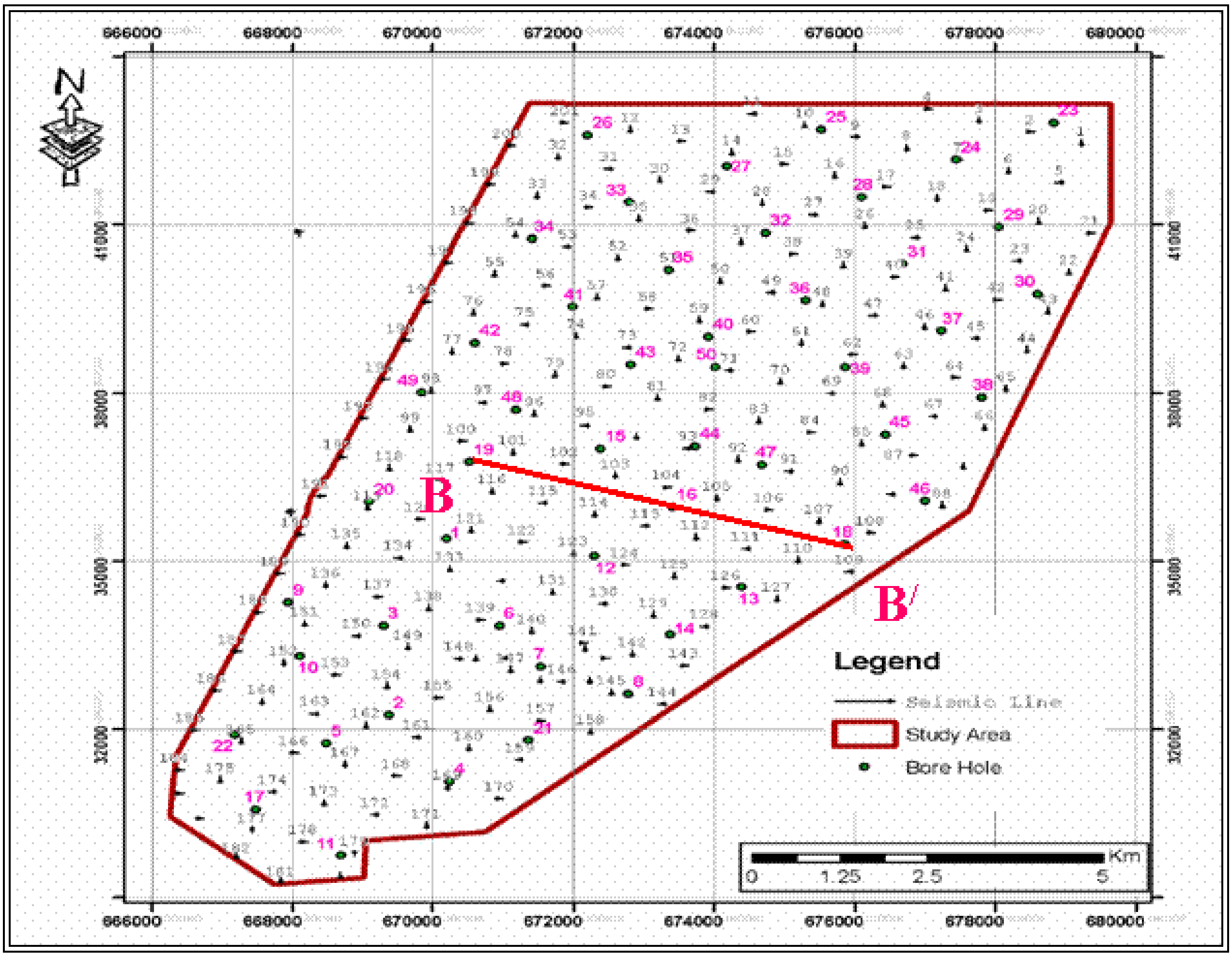

Fig. 3: Seismic profile and borehole location map.

The length of each interpreted seismic profile was 130 m with 10 m geophone interval. Also, Vertical Electrical Soundings (103 VES's) were conducted and their locations were represented by solid dots over each layer resistivity map. The field data of these resistivity soundings were acquired using a digital, signal enhancement, computer-operated resistivity-meter (model SAS1000, Sweden made). The applied maximum current electrode (AB/2) spacing was 200 meters allowing an average depth of investigation of about 40 meters. The schlumberger four electrodes array was applied in carrying out the field measurements. In this array, the potential electrodes are placed at a fixed spacing which is no more than one-fifth of the current electrode half spacing. The current electrodes are placed at progressively larger distances. When the measured voltage between the potential electrodes falls to very low value, the potential electrodes are spaced more widely apart. The measurements are continued and the potential electrode separation increased again as necessary until the VES is completed.

GEOLOGICAL CROSS-SECTION

The lithological correlation of the boreholes 18, 16, and 19 from east to west along profile B-B/ helped in the construction of the shallower part of the geological cross-section (Fig. 4). This section will support the geophysical data interpretation providing reliable results. According to the soil description of borehole data the topsoil is composed mainly of graded-grained sands and gravels, the second layer is composed of clay and silty clay, the third layer is composed of sandy silty clay, the fourth layer is mainly composed of silty sandstone, and finally the fifth layer is composed of very hard sandstone. In the eastern part of the study area, the topsoil is overlying directly the fourth layer and both of second and third layers are missing due to the existence of a normal fault between boreholes 19 and 16.

SEISMIC REFRACTION AND VES'S DATA INTERPRETATION

Advanced methods were applied for seismic refraction data interpretation based on delay time, plus-minus, generalized reciprocal method (GRM) and ray tracing. These methods are well explained in literature such as Hagedoorn, (1959), Redpath (1973) and Palmer (1980 & 1990) which are collected together in a package of SIP software. The output of this software is represented by an average velocity value for each layer and thickness beneath each geophone in the form of geoseismic cross-section. Five sedimentary layers have been identified from the interpreted results of seismic method.

GEOSEISMIC CROSS SECTIONS

Geoseismic cross-sections or ground models which represent the output of seismic methods were constructed beneath each profile showing almost five velocity layers with four dipping interfaces. An average depth of penetration of seismic wave within these layers reaches about 40 m. A comprehensive inspection of these sections shows a very wide range of velocities and thicknesses all over the area of study reflecting the existence of strong heterogeneity. Some of these geoseismic sections have been affected by a major fault dissecting the study area and running in the northeast-southwest direction (Fig. 5: left) where the up thrown side is located in the eastern block and the down thrown side is located in the western block, while others were not affected (Fig. 5: right) This fault was confirmed from the lithological correlation of the boreholes. A fault location map detected from seismic survey is shown in Fig. 6, on this map the solid rectangles are located on the down thrown side and a solid line A-A/ showing the direction of a geoelectric cross-section.

Also, the quantitative interpretation of the field sounding curves was carried out using a computer program of Zohdy (1989) to obtain a multi-layer model for each curve providing number of layers equal to the number of the digitized points. Then, these multi-layer models are reduced manually to less number of layers and run by WINSEV 3.4 program for an automatic iterative technique till reach a best fit between the calculated curves and the observed (field) curves. WINSEV 3.4 program is created by GEOSOFT (1997) for assisting in the interpretation of resistivity sounding curves. The final workable results obtained from these programs are in the form of true electrical resistivies and thicknesses of subsurface layers. VES data interpretation is explained in several literature such as Edwards (1977), Zohdy (1975 & 1989) and Ibe Sr and Uzoukwu (2001).

VES'S MODELS

The calculated models represent the final results of the quantitative VES's data interpretation, in which the field apparent resistivity curves, the calculated resistivity models and the corresponding iterated best fit curves are represented for comparison by crosses, block lines and solid lines, respectively (Fig. 7).

GEOELECTRIC SECTION

The quantitative interpretation of the filed curves provides resistivity models that reveal geoelectrical succession. Five geoelectric units can be clearly identified. The thicknesses and true resistivities of these units were used for construction of a geo-electric cross-section along profile A-A/ (Fig. 8) after supporting of the drilling boreholes. On this section a major fault can also be detected from electric as was noticed from both seismic and drilling. The calculated models were helpful for construction of resistivity maps.

SEISMIC VELOCITY AND ELECTRICAL RESISTIVITY DISTRIBUTION MAPS

Seismic wave velocity distribution maps were constructed for the interpreted five layers. The topsoil velocity distribution map (Fig. 9) reveals the existence of lower velocity values of about 300 m/s in the western part of the study area for sands and gravels, while higher values close to 1000 m/sec are occurred in the eastern part due to the occurrence of sandstone rock fragments. The topsoil resistivity distribution map (Fig. 10) manifests lower resistivity values (10 ohm.m) for friable sands high values for rock fragments of very hard sandstone.

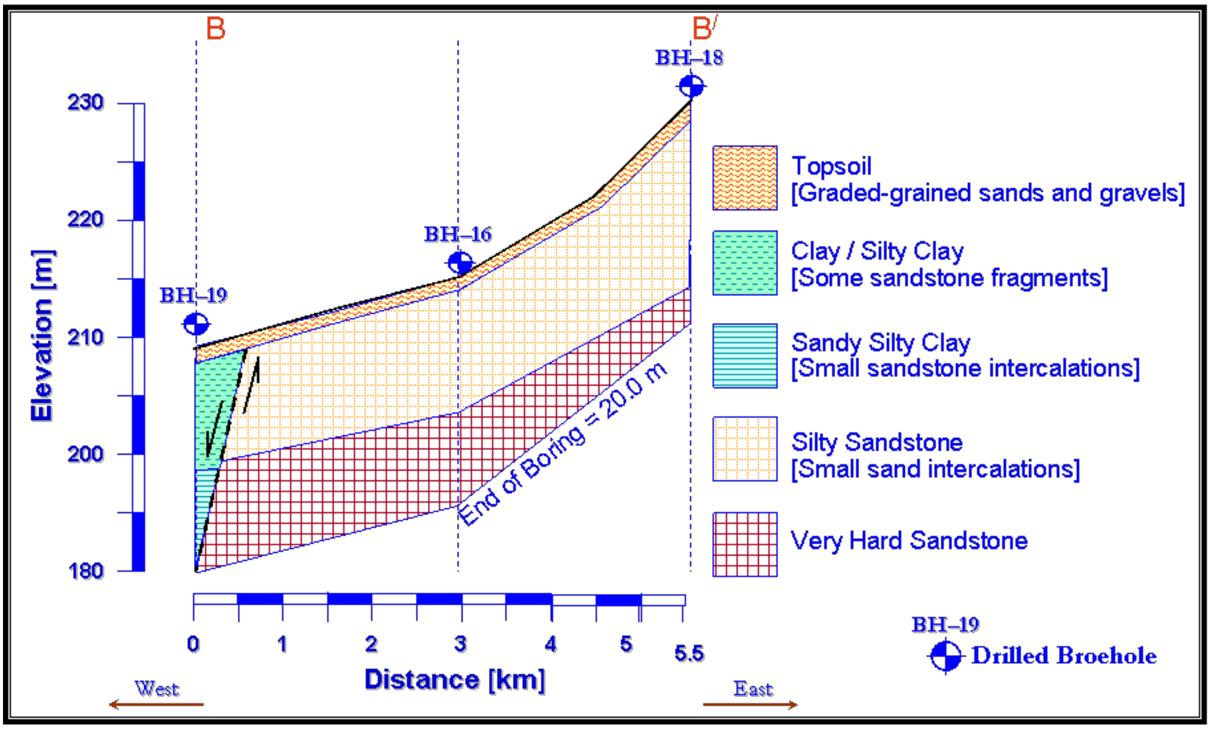

Fig. 4: Geologic cross section along profile B-B'.

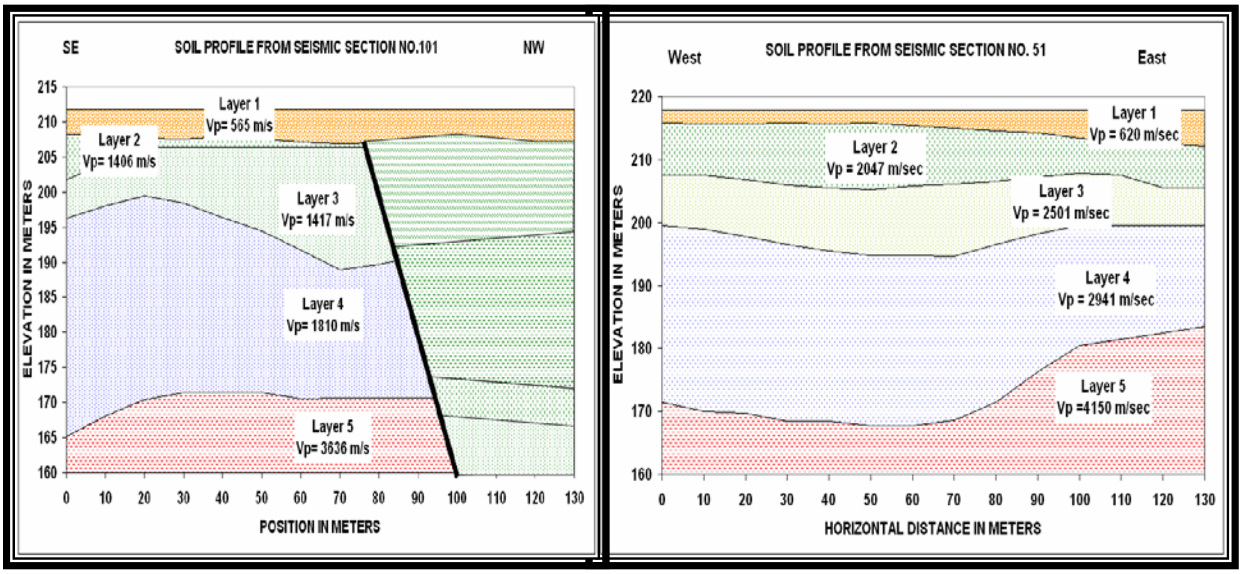

Fig. 5: Selected examples of geoseismic cross-sections; left: seismic section directed NW-SE crossing the fault, right: seismic section (E-W) on the eastern block.

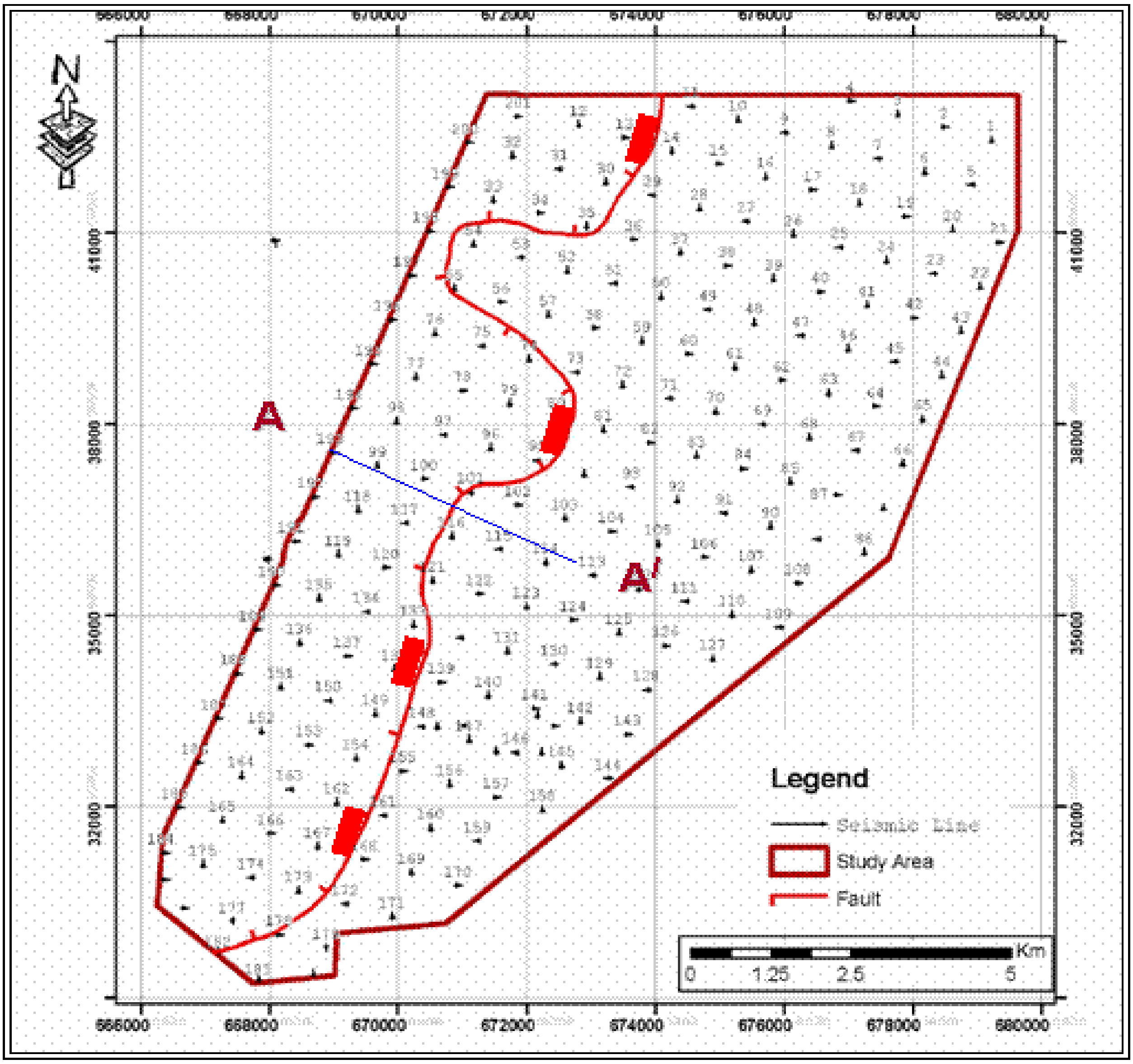

Fig. 6: Fault location map from seismic survey.

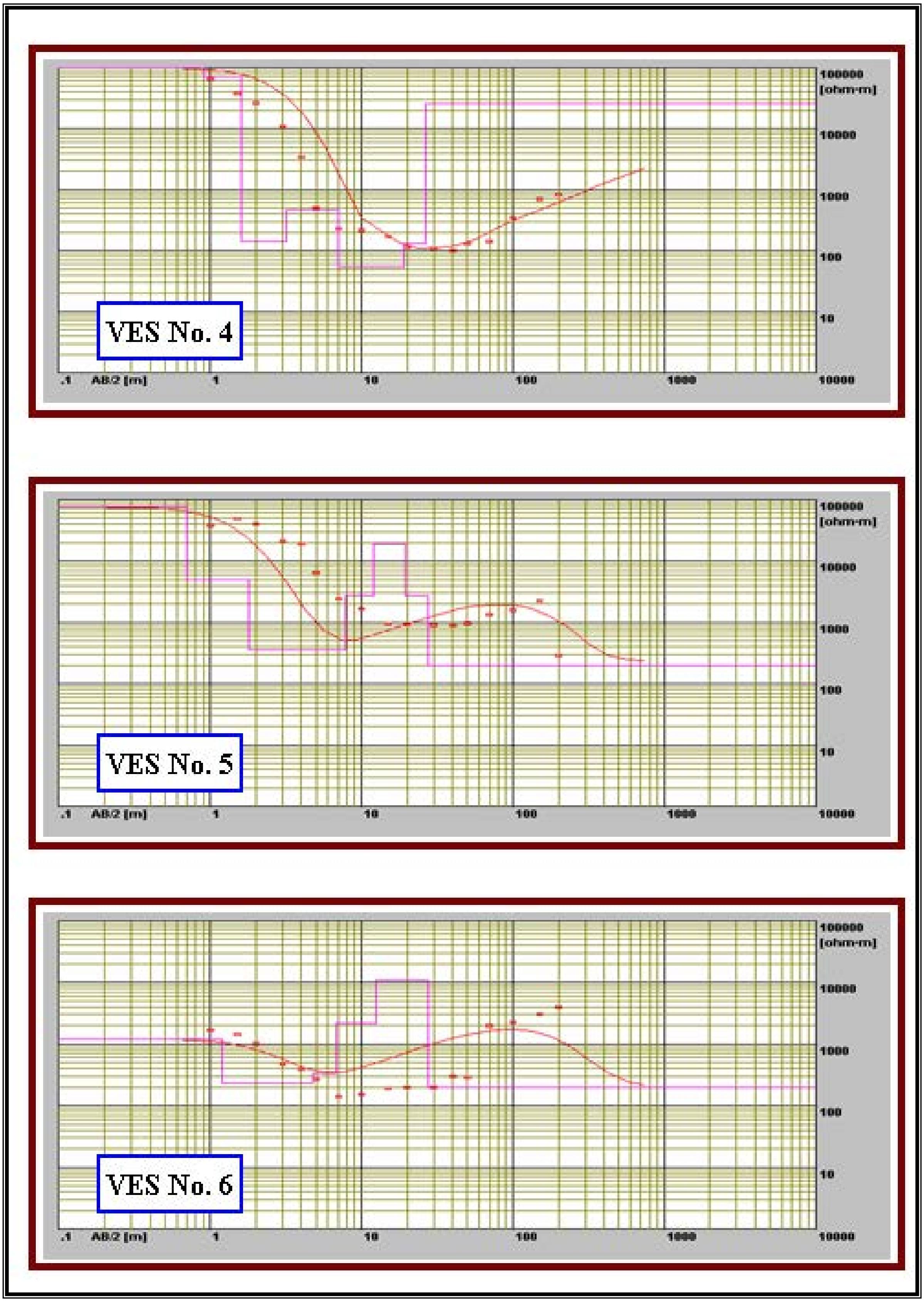

Fig. 7: Some examples of the VES's models.

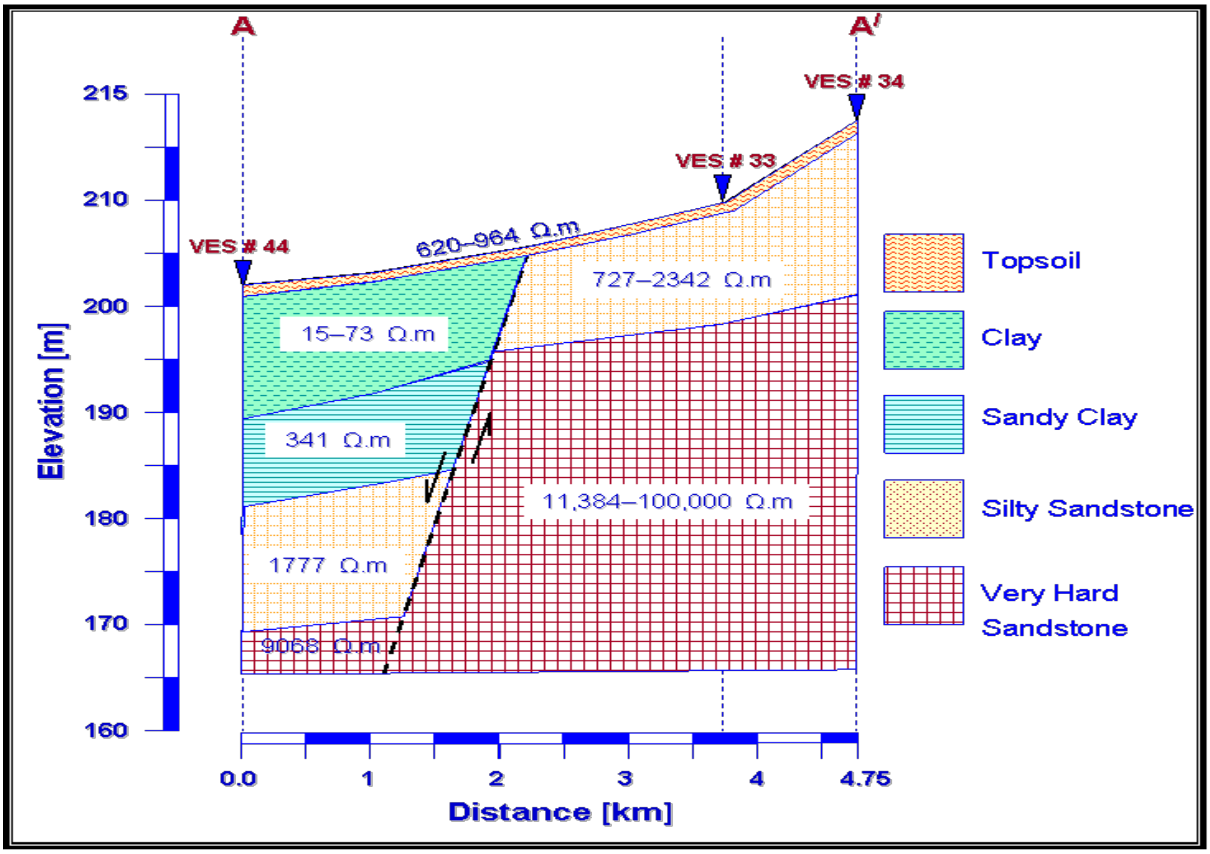

Fig. 8: Geo-electric cross-section along profile A-A'

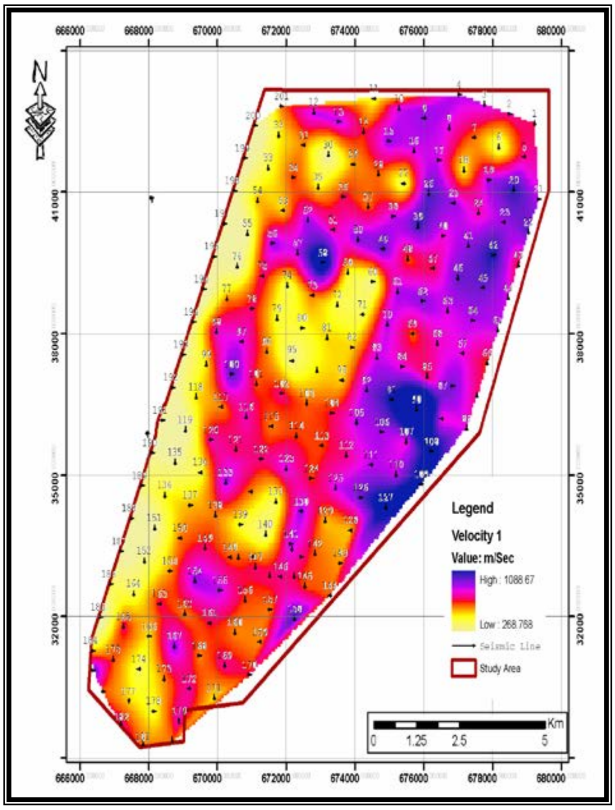

Fig. 9: First layer seismic velocity map.

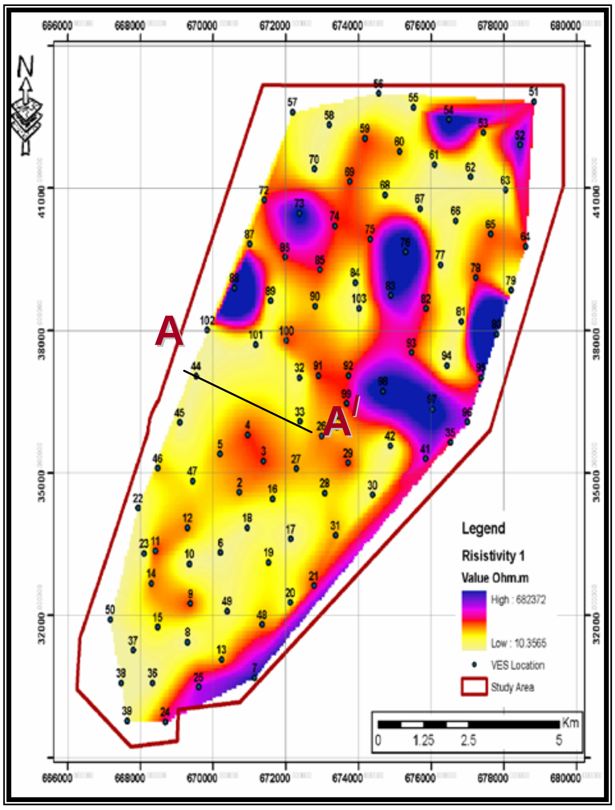

Fig. 10: First layer resistivity map.

The seismic velocity distribution map of the second layer (Fig. 11) possesses also a wide range of velocity. The lower values about 616 m/s for clay and silty clay occupying the western part, while the higher velocity values (3357 m/s) of silty sandstone occur at the eastern part. The electrical resistivity map of the second layer (Fig. 12) shows lower resistivity values with a minimum of 4 ohm.m for possibly clay and silty clay in the western part and extremely high values (> 2000 ohm.m) in the eastern part. The third layer exhibits seismic velocity values in the range of 1024–3865 m/s for both cemented sandy silty clay and fractured sandstone as shown in Fig. 13. The electrical resistivity map of the third layer (Fig. 14) shows lower values with a minimum of 12 ohm.m in the western part and again extremely high values in the eastern part.

The fourth layer shows seismic velocity values in the range of 1458–3975 m/s for silty sandstone (Fig. 15). The electrical resistivity map of the fourth layer (Fig. 16) shows lower values with a minimum of 2 ohm.m in the western part and extremely high values (> 2000 ohm.m) in the eastern part.

The velocity and resistivity distribution maps of the fifth layer are omitted because it is composed of very hard sandstone and laid at greater depth away from the target of this paper which is soil reclamation and agricultural development. However, it has a velocity range of 2187-4435 m/s and again extremely high resistivity values.

THICKNESS DISTRIBUTION MAPS

Thickness maps for four layers of the soil profile were established based on the results of seismic data interpretation and the drilled boreholes (Figs. 17 through 20). The thickness of the topsoil is ranged from 1.0 m to 8.5 m. The calculated thickness of the second layer which is mainly composed of clay in the western side of the fault is ranged from 1.0 m to 15.6 m with its maximum value in the southwestern part. The calculated thickness of the third layer is varied from 2.2 m to 26 m, and finally, the thickness of the fourth layer is ranged from 2.0 m to 28.0 m. It can be noticed that the thicknesses of all soil profile layers have a wide range of variations laterally due to the predominant heterogeneity in the study area.

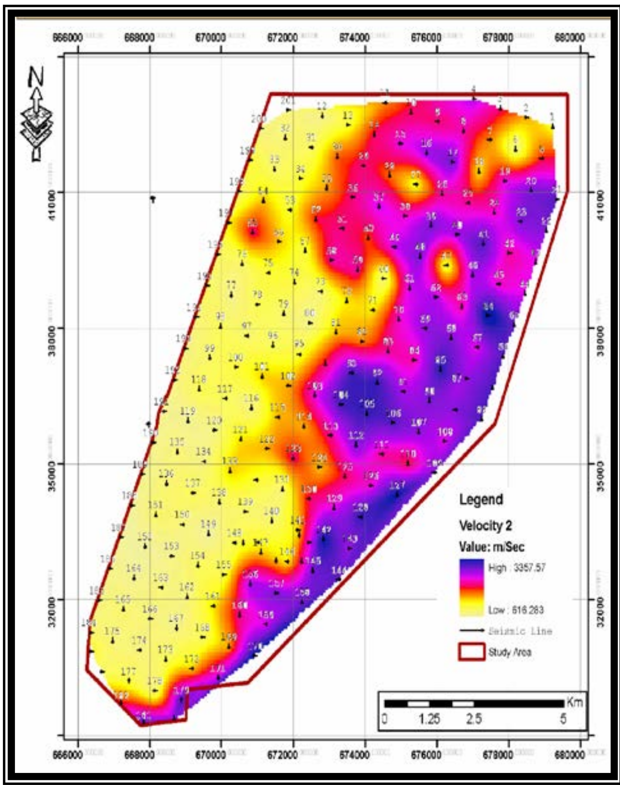

Fig. 11: Second layer seismic velocity map.

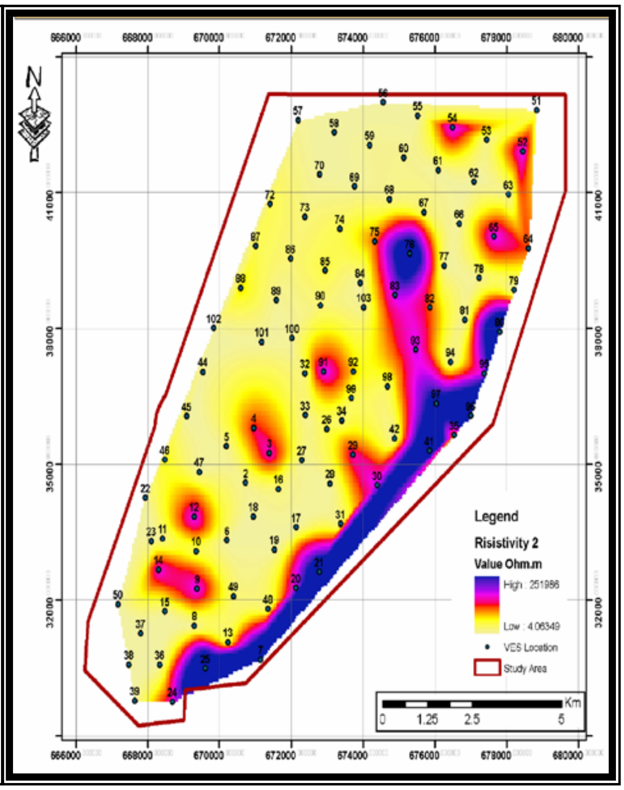

Fig. 12: Second layer resistivity map.

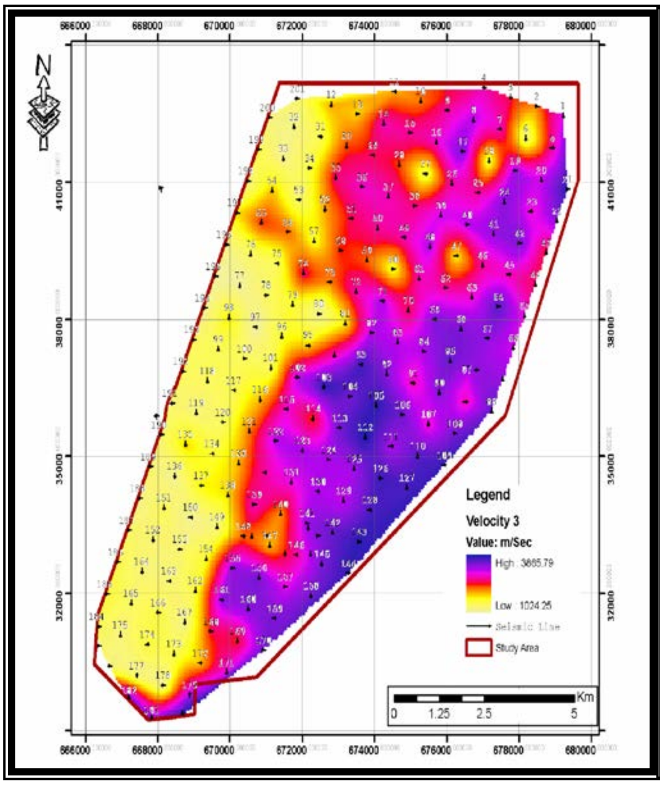

Fig. 13: Third layer seismic velocity map.

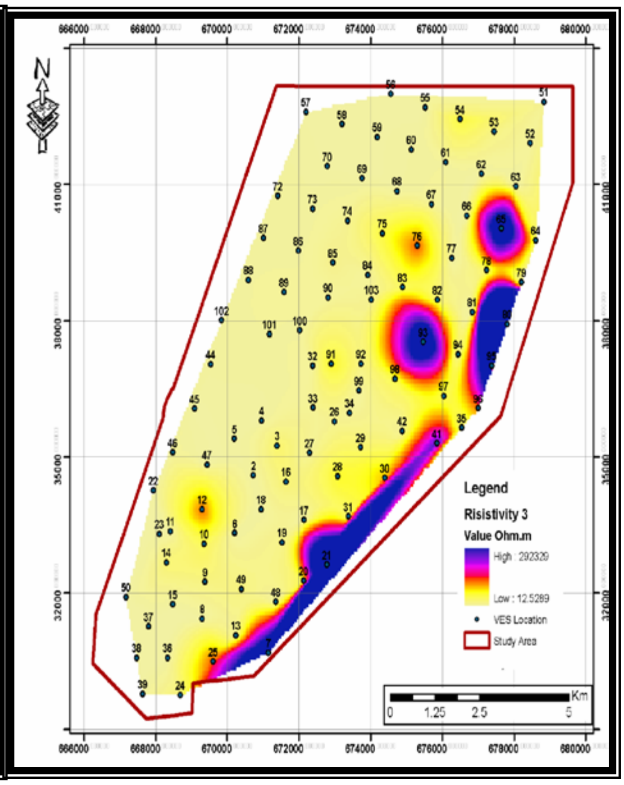

Fig. 14: Third layer resistivity map.

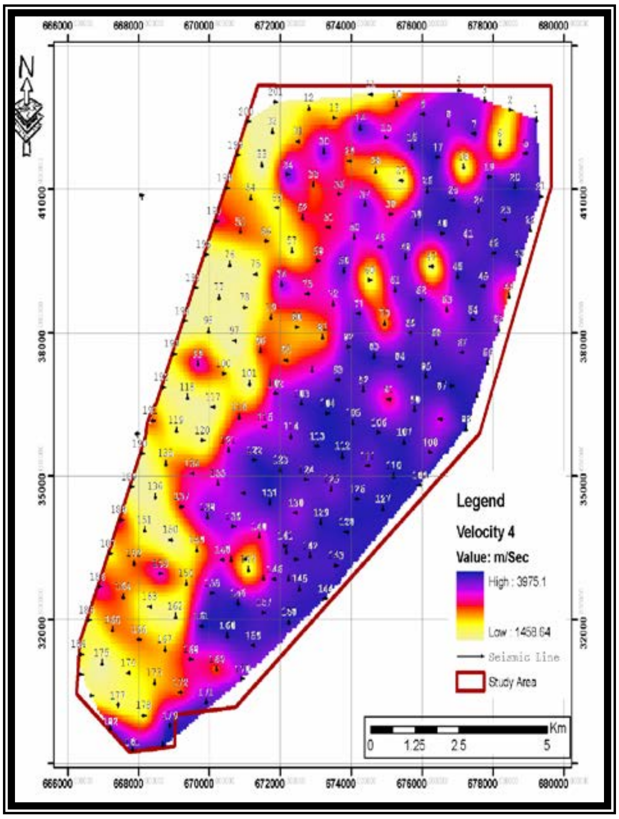

Fig. 15: Fourth layer seismic velocity map.

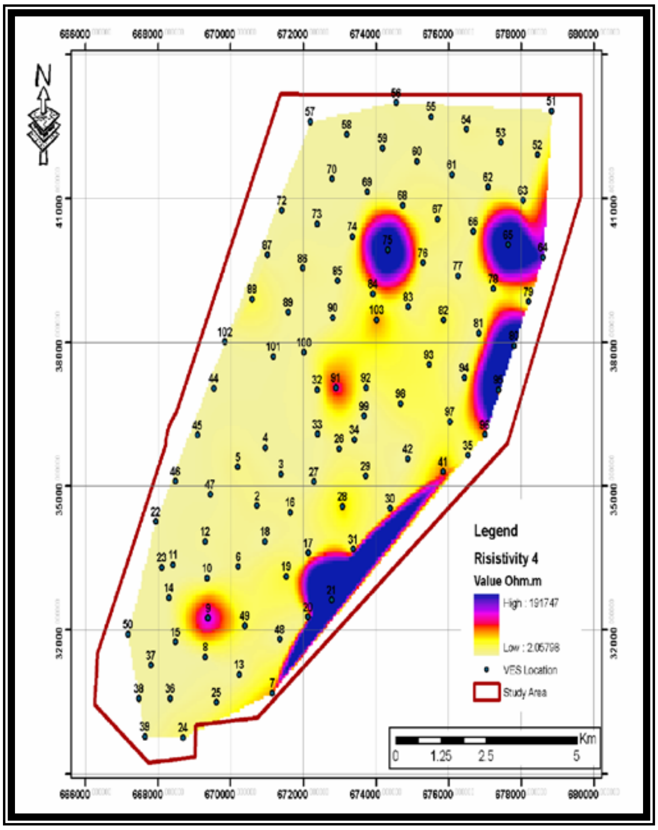

Fig. 16: Fourth layer resistivity map.

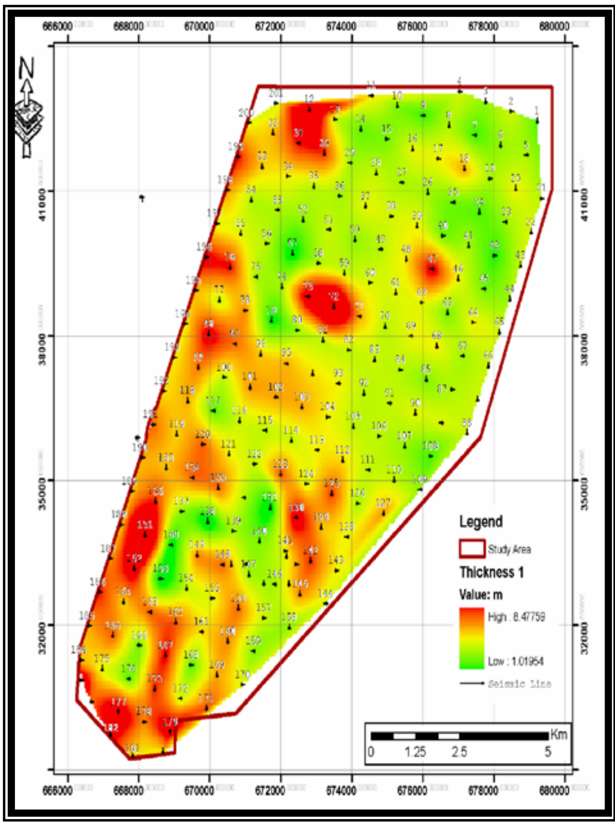

Fig. 17: First layer thickness map.

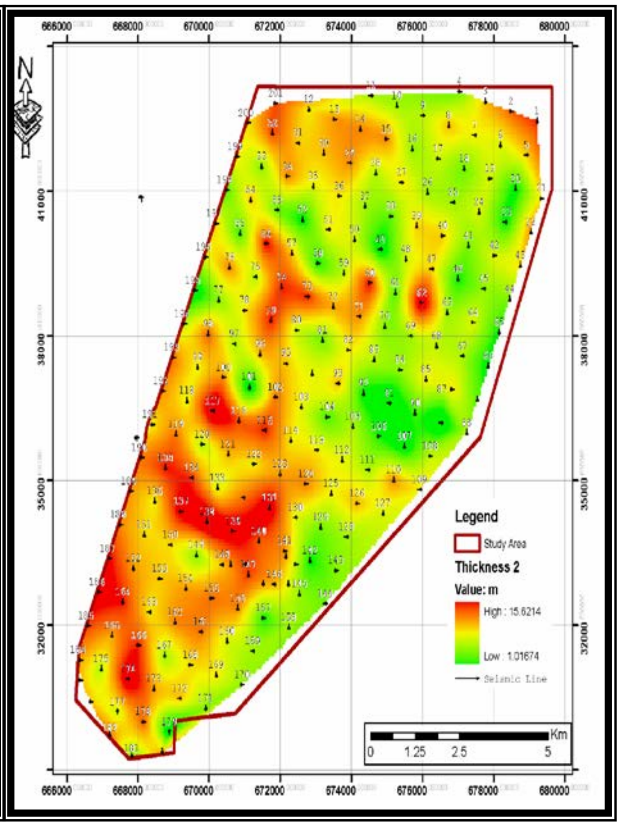

Fig. 18: Second layer thickness map.

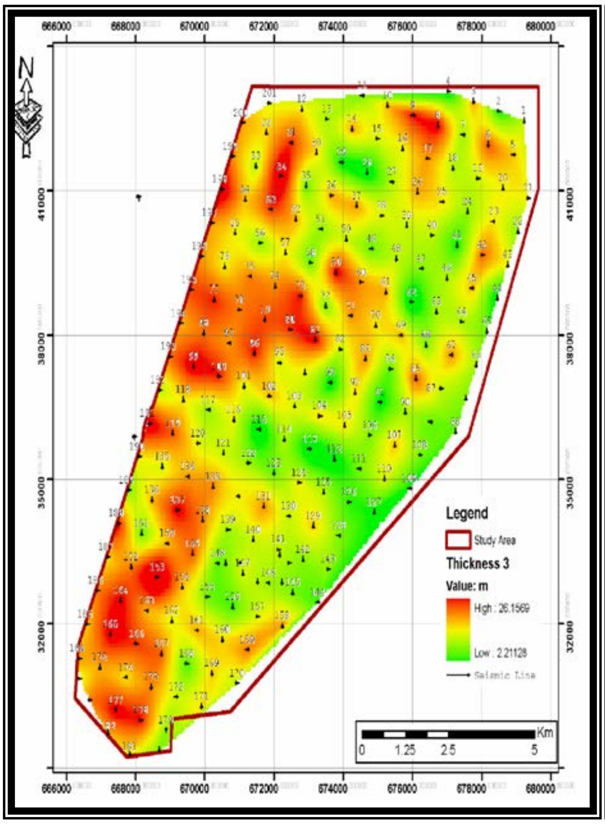

Fig. 19: Third layer thickness map.

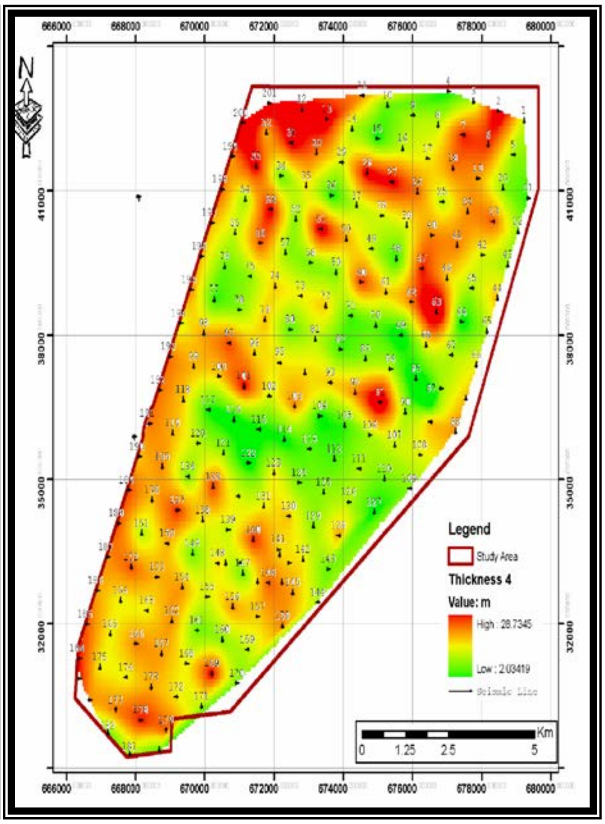

Fig. 20: Fourth layer thickness map.

SUMMARY AND CONCLUSIONS

The lithological composition, the seismic wave propagation velocity, electrical resistivity, layer thicknesses and geological structure were determined using geophysical methods for the near-surface geological section at Tushka area. These physical properties are needed for the reclamation of the topsoil, development of the agricultural soil and the implementation of a drainage system. The obtained results from the seismic and electric methods were supported by the drilled boreholes to provide reliable and confirmed results. Advanced programs were used for processing and interpretation of the acquired geophysical data. Almost five layers were detected from seismic and electric methods reaching an average depth of penetration of about 40 m.

A major northeast-southwest fault dissecting the study area was also detected from both seismic refraction and electric methods as well as from borings. This fault divides the investigated area into two major blocks; the western block which is the down thrown side reveals lower velocity and resistivity values of graded-grained sands and gravels with some rock fragments of sandstone, clay / silty clay, sandy silty clay in the shallower part, while the eastern block which represents the up thrown side reflects higher velocity and resistivity values of silty and very hard sandstone.

Remarkable changes in thicknesses, velocities and electrical resistivities are found within each layer due to the occurrence of strong heterogeneity which is mainly due to lithological variations in Tushka area. Extremely high values of resistivity were also noticed which are referred to the existence of some rock fragments of very hard sandstone within the soil profile.

The search for groundwater was not the target of this paper. However, the purpose is to obtain useful information for agricultural engineering during the implementation of a drainage system in the study area. This drainage system is important for agricultural soil development. For this reason, it is recommended that a drainage system should be done for a short-term in areas of thin topsoil overlying thick clay at the western part of the study area and the drainage can be done for a long-term at the eastern side in areas of thin topsoil overlying a rock or thick topsoil even overlying clay. The drainage system cannot be done at all in areas of thick topsoil overlying a rock.

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