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Geophysical investigation for shallow subsurface geotechnical problems for eastern part of 15th May City, Cairo, Egypt.

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Abstract

Twelve VES stations of AB/2 ranging from 1-200 m are carried out. The results of quantitative interpretation of the 1-D resistivity (VES) data indicate that the subsurface section of the study area consists of four geoelectrical layers, which composed of fractured marl, marl, clayey marl and limestone respectively. Also, the interpretation of 1-D resistivity refers to the study area dissected by two normal faults of NW-SE direction. Seven dipole–dipole sections of different lengths ranging between 150 and 490 m and electrode spacing 10 m are applied on the study area to delineate the low resistivity zone which refers to clayey marl unit which are saturated with groundwater. The quantitative interpretation of 2-D electric resistivity tomography indicates different zones of clayey marl which causes some problems for the constructions in the study area. Also, these sections reflect high resistivity zones regarding to fractures which also have direct effect on constructions and causes some damages for the buildings in the study area. Thirty one shallow seismic spreads have been measured by using geophone spacing 2 m. The results refer to the subsurface consists of 3-4 layers which composed of fractures of limestone and marl, marl, clayey marl and limestone, some sections reflect normal faults dissecting the study area. Also, some geotechnical analyses for 14 samples collected from different locations and core samples extracted from seven boreholes drilled in study area have been carried out to estimate some geotechnical parameters in the study area. The RQD (rock quality designation) test at most of the boreholes (up to 10 m depth) demonstrates the very poor to poor soil category. The swelling test for the claystone samples reflects its swelling ability reaching a value of 140% specially, at Quarters 26 and 27.

Keywords: ERT, Shallow seismic refraction, boreholes, Geotechnical analysis.

1-Introduction :

The study area lies at southeastern part of Cairo about 12 km east of Helwan City lies between latitudes 29° 48` 57`` & 29° 49` 40`` N. and longitudes 31° 22` 35`` & 31° 23` 20``E and represents an area of 1.44 km^2. The study area suffers from different geotechnical problems which have direct effects on the building and constructions especially at the Quarters 26, 27, 28 and 29. Two building no.40 and 41 in Quarter 27 have been empty from the people due to the governorate of Cairo evacuated the population according to big fractures and cracks in these buildings. Different sources for the geotechnical problems come from subsurface structures such as fault zones, fractures and caves, clay layer which is the main sources for subsidence and cracks for the building and constructions in the study area. Many geophysical and geological works are carried out to investigate the shallow subsurface sections such as Araffa et al 2014 , Araffa, 2010, Mohamed et al 2012, Basheer et al,2012, Tealeb et al. 2000, Abdel-hafez, 2004, Atya et al, 2010, El–Behiry et al, 1999, Osman, 2003. The present study aims to investigate the subsurface sections by using integrated geoelectrical , shallow seismic refraction and geotechnical data to differentiate the weak and unsuitable zones for constructions (Fig.1a).

2- Geology of the area

The geology of Helwan area in general and 15th May city especially was discussed by Awad et al. (1953), Shukri (1953), Said (1962, 1971), Farag and Ismail (1955, 1959), Ismail and Farag (1960), and Moustafa et al. (1985), finally Mohamed et, 2012 studied the geology and structures of the study area in detailed. These studies, with field observations of the authors, represent the bases of the discussion around the study area; that touches the geology, the geomorphology, stratigraphy, and the structure. Fig (1b). is the geologic map of the area east Helwan including the study area. The constructed geological map reveals that most of the area consists of deposits of Pliocene and Upper Eocene. The 15th of May City. The Upper Eocene deposits are represented by Wadi Garawi and Qurn Formations. Wadi Garawi Formation is distributed at the south and southwestern parts of 15th of May City and consists of marl and marly limestone with clay intercalation at the upper part of the formation with thicknesses ranging from 50 to 80 m. Qurn Formation belongs to the Upper Eocene, covers most of 15th of May City, and is composed of five geological units (Fig.1b).

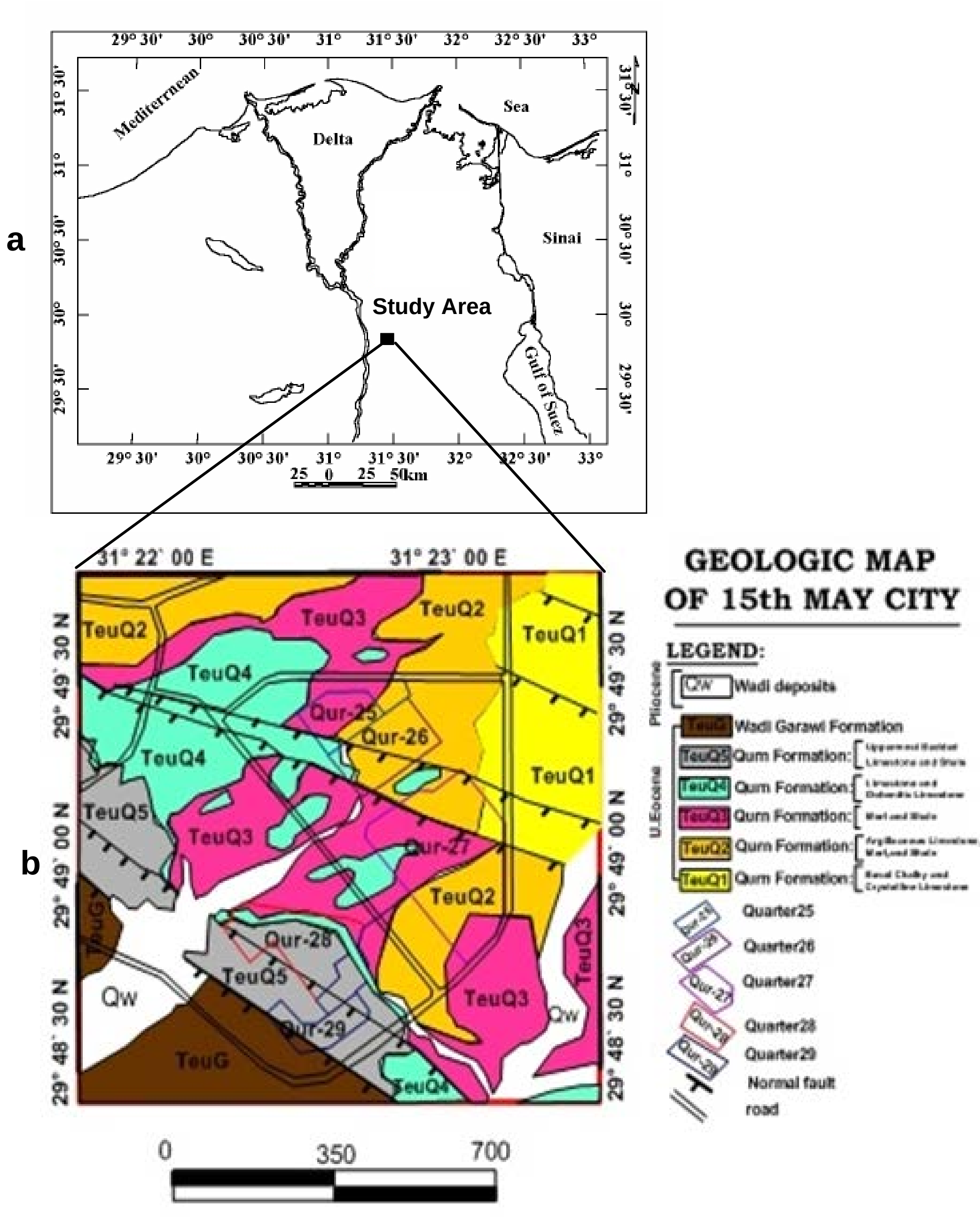

Figure (1):a: Location map of the study area, b: Geological map of the 15^{th} of May City (modified after Mohamed et al, 2012).

2- Methodology

2.1. Electrical Resistivity Tomography (ERT)

In the present study, seven Electric Resistivity Tomography (ERT) profiles have been carried out by using dipole–dipole array, the space between current electrodes and potential electrodes are equal (a=10 m) The processing and interpretation of the obtained data have been done using RES2DINV, (2001) program, the data are measured by using Syscal-R2 Instrument with different lengths ranging between 150 and 490 m. These sections are P1–P1', P2–P2', P3–P3', P4–P4', P5–P5', P6–P6' and P7–P7'. The dipole–dipole cross sections Figs (2-4) exhibit large variation of resistivity values corresponding to lateral variation in the subsurface lithological units. The inverted models for the seven sections indicate that the subsurface section consists of more than three geological units represented by limestone, marl and clayey marl. Also, the dipole–dipole section along profile P1–P1' reveals a fractural zone at the end of the section which exhibits high resistivity values.

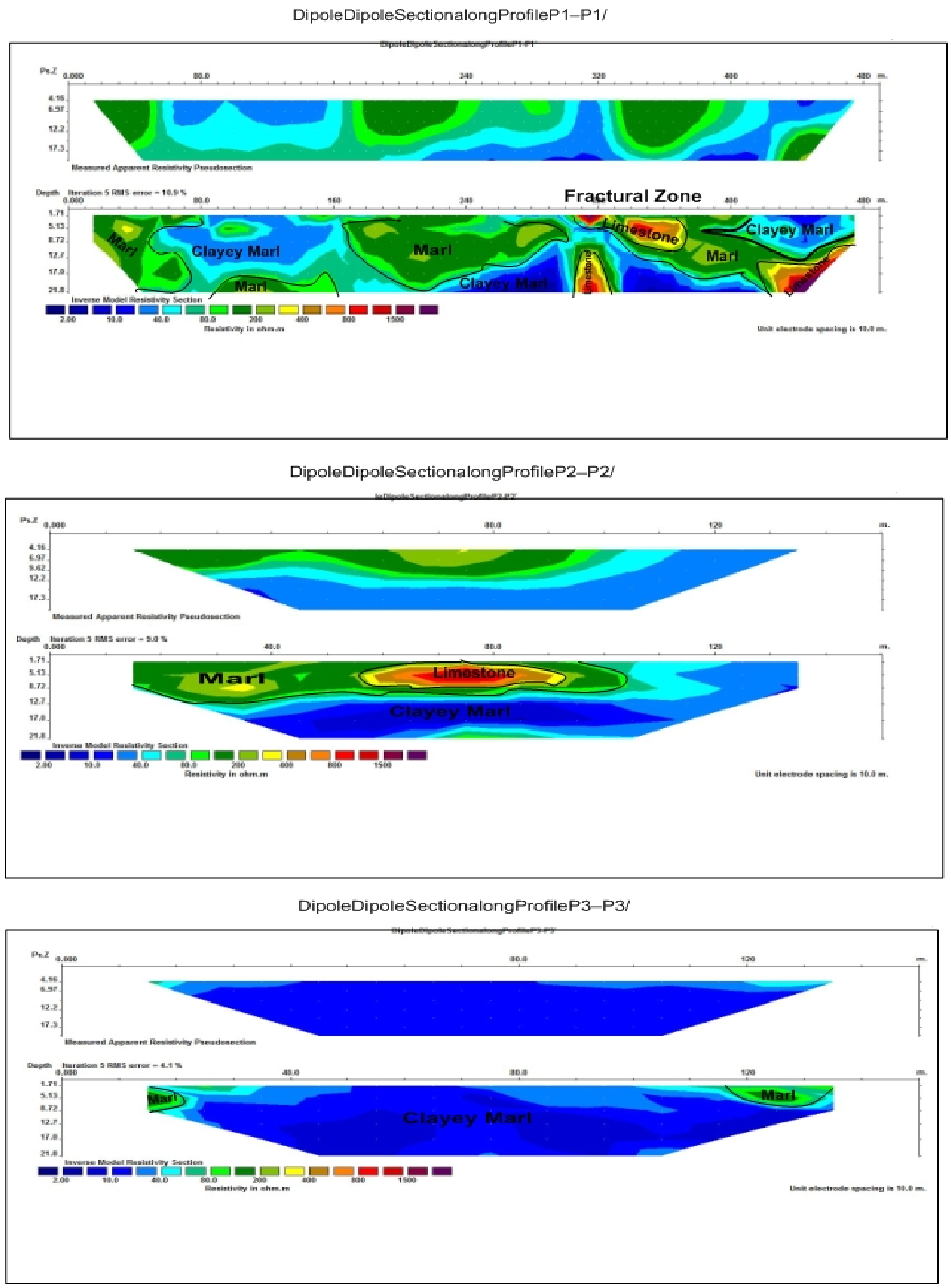

Fig.(2): Dipole-Dipole sections along Profiles P1–P1', P2–P2' and P3–P3'.

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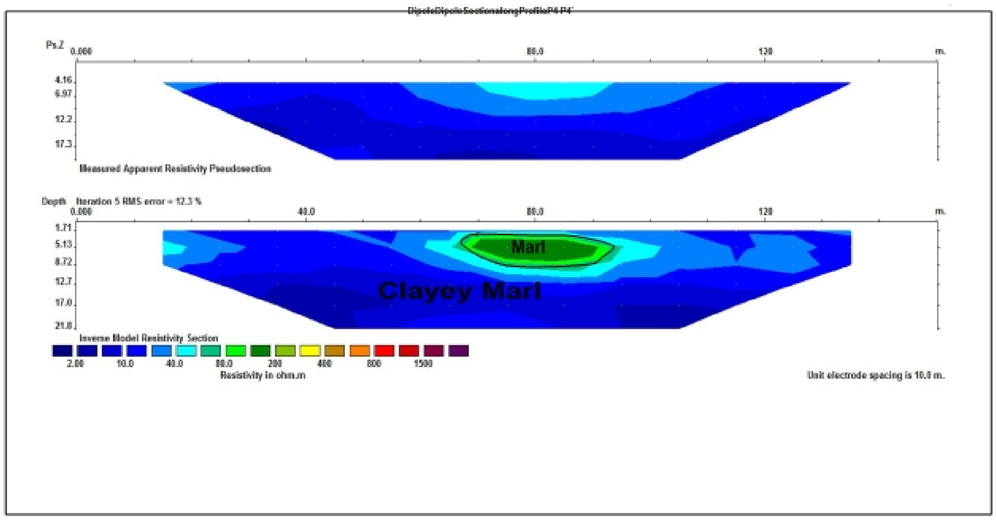
DipoleDipoleSectionalongProfileP4–P4/



DipoleDipoleSectionalongProfileP5–P5/

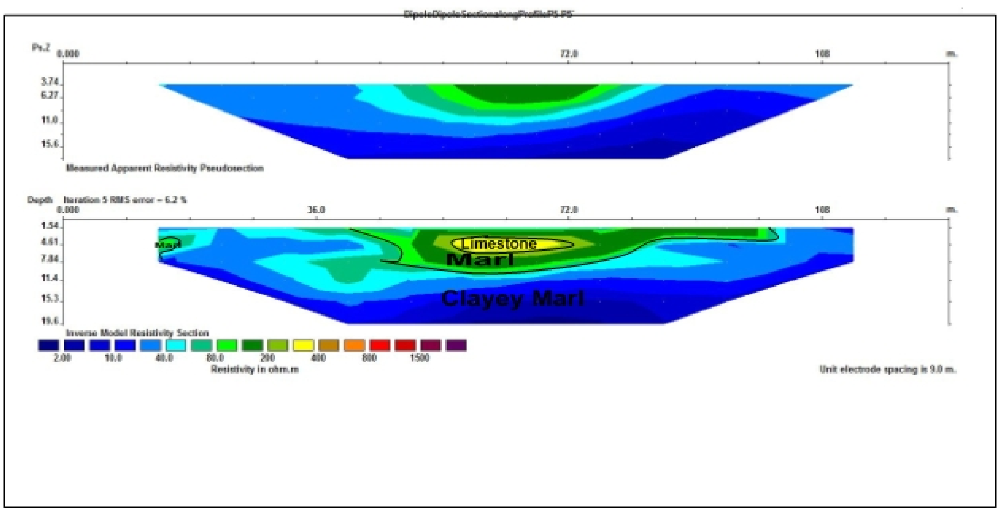


Fig. (3): Dipole-Dipole sectionsalong Profiles P4–P4' and P5–P5'.

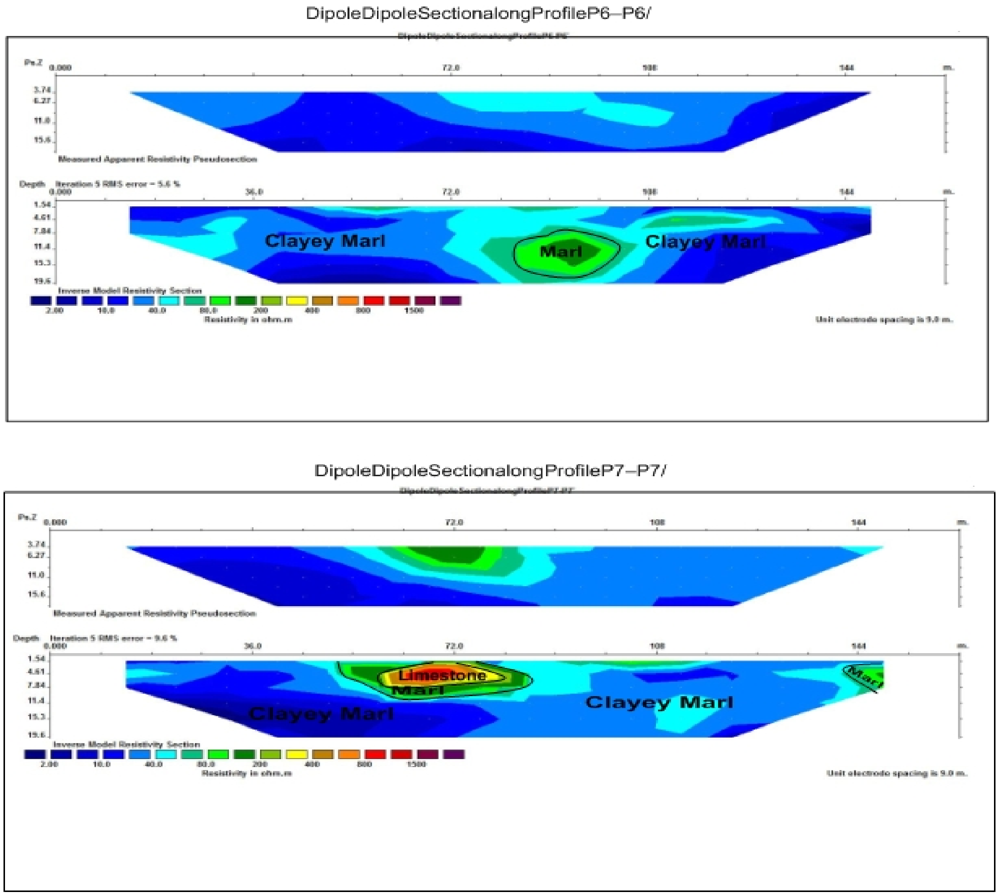


Fig. (4): Dipole-Dipole Sectionsalong Profiles P6–P6' and P7–P7'.

2.2. Vertical Electrical soundings (VES)

Twelve vertical electrical sounding (VES) Fig (5) were measured by using Schlumberger configuration of AB spacing ranges from 2 to 400m. The main target of this work to detect clayey layers and delineating the subsurface structures. The quantitative interpretation was made by using the IPI2WIN program. The quantitative interpretation has been applied to estimate the thicknesses and the true resistivities of the geoelectrical units beneath each VES station Fig (5).

2.2.1. Geoelectrical Cross-sections

The results of inverted data are used for constructing five geoelectric cross-sections to establish the subsurface stratigraphy and geological situation of the area of investigation, which gives an ideal picture about the continuity or discontinuity of the stratigraphic layers. Also, the geoelectriccross-sections reflect the structural implications of the studied area (Fig.6). The geoelectric cross-sections exhibit four geoelectric units, the first geoelectrical unit is composed of fractured limestone, shale and marl. The thickness of this unit is ranging from 1.11 m at VES no. 2 to 14 m at VES no. 9, and it's resistivity value ranges from 13.4 ohm.m at VES no. 6 to 214 ohm.m at VES no. 3.The second geoelectrical unit is composed of marl of thickness ranges from 4.05 m at VES no. 2 to 21.2 m at VES no. 4, and it's resistivity value ranged from 6.83 ohm.m at VES no. 1 to 268 ohm.m at VES no. 5. The third geoelectrical unit is composed of clayey marl. The thickness of this unit is ranging from 32.4 m at VES no. 2 to 86.2 m at VES no. 1, and it's resistivity value range from 0.7 ohm.m at VES no. 8 to 34.8ohm.m at VES no. 1. The fourth geoelectrical unit is composed of limestone of resistivity value ranges from 13.2 ohm.m at VES no. 1 to 30.7 ohm.m at VES no. 3. Most of sections dissected by two normal faults.

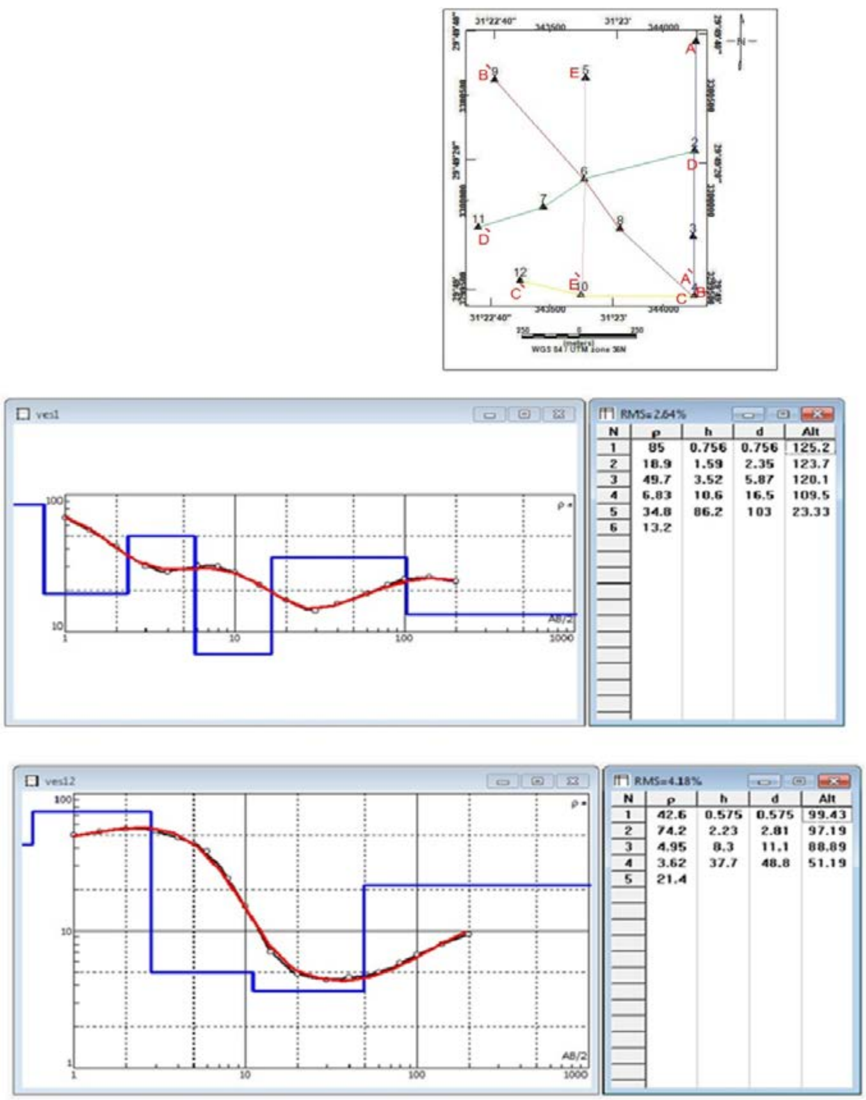


Fig.5 : Location map of VES station and Quantitative Interpretation of VES no.1 & 2 by using IPI2WIN program

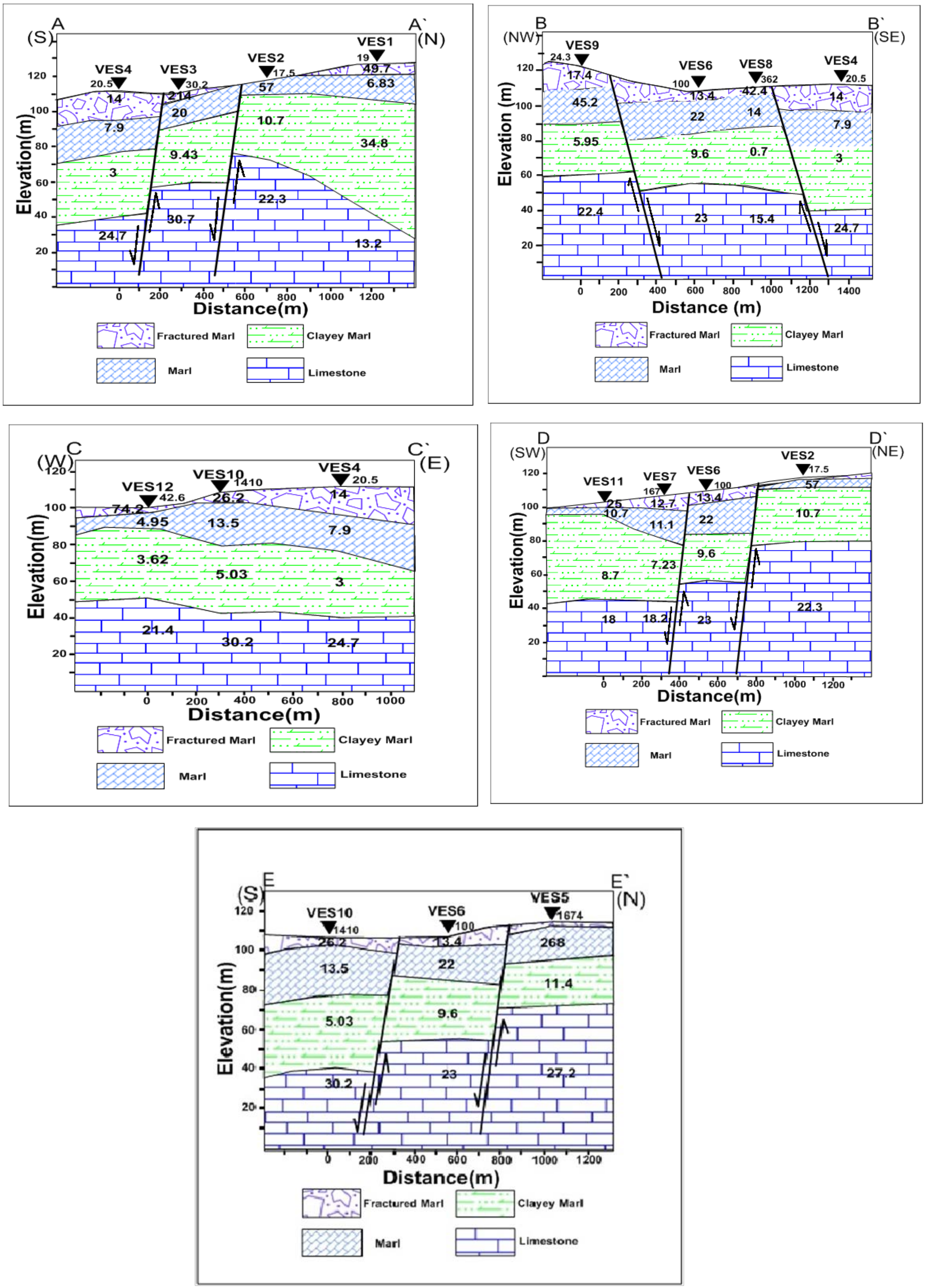


Fig.6. Geoelectric cross-sections

2.3.Seismic data

Thirty-one shallow seismic refraction spreads (Fig. 7) were carried out by using Strata ViewTM 48 channels seismograph manufactured by Geometrics Company to cover Quarters 25, 26 and 27. The acoustic waves were generated by using a hammer of 15 kg weigh as a seismic source. Forty-eight receivers (geophones) of natural frequency of 40 H_z for longitudinal waves and 4.5 H_z for surface waves) are used for receiving the waves with geophone spacing of 2 m. Five shots are carried out; the first shot is the normal one at 5 m before the first geophone, the second shot at the half distance between geophones 13–14, the third one is the midpoint between the geophones 24 and 25, the fourth one between geophones 36–37, and the last shot is the reverse one at 5 m after the last geophone. Thirty-one geoseismic cross sections are constructed, these sections reflect the number of layers penetrated by the seismic waves. Also, the type of lithology of each layer is determined according to the values of velocities of seismic waves through layers and the geologic structures.

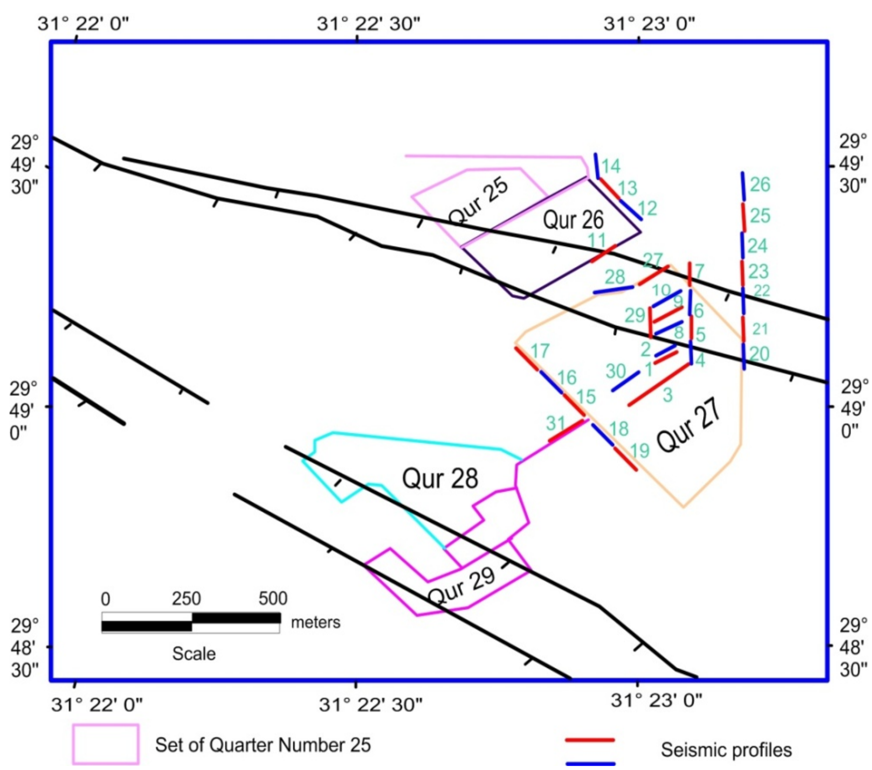


Fig. (7): Seismic Location map of the study area

2.3.1.Seismic Data Interpretation:

The seismic data have been processed and interpreted by using SEISIMAGER (2009) software packages. The interpretation of data is based on iterative ray-tracing technique, in which the ray propagation will be simulated through a model (Scott, 1973). The results of the interpretation for 21 spreads reveal three layers but 10 spreads exhibit four layers, Fig. (8). The P-wave average velocity of the first layer is ranging between 230 and 320 m/s and corresponding to clay and sand of thickness ranging between 0 and 3 m. The second layer has an average velocity value ranging from 400 to 1,300 m/s which consists of fractured marl and limestone of thickness ranging from 0 to 10 m. The third layer reveals a velocity value ranging from 780 to 2,000 m/s and thickness ranging from 1.5 to 22 m corresponding to marl. The Fourth layer exhibits a high velocity value ranging from 1,900 to 3,800 m/s corresponding to clayey marl. According to the fault criteria, the seismic profiles 7, 11, 20, 22, 28 and 29 demonstrate the effects of normal faults. Fig. (9) shows a representative example of the P-wave model which affected by the normal fault. The results of interpretation of seismic data are represented by geoseismic cross-sections and seismic tomography sections.

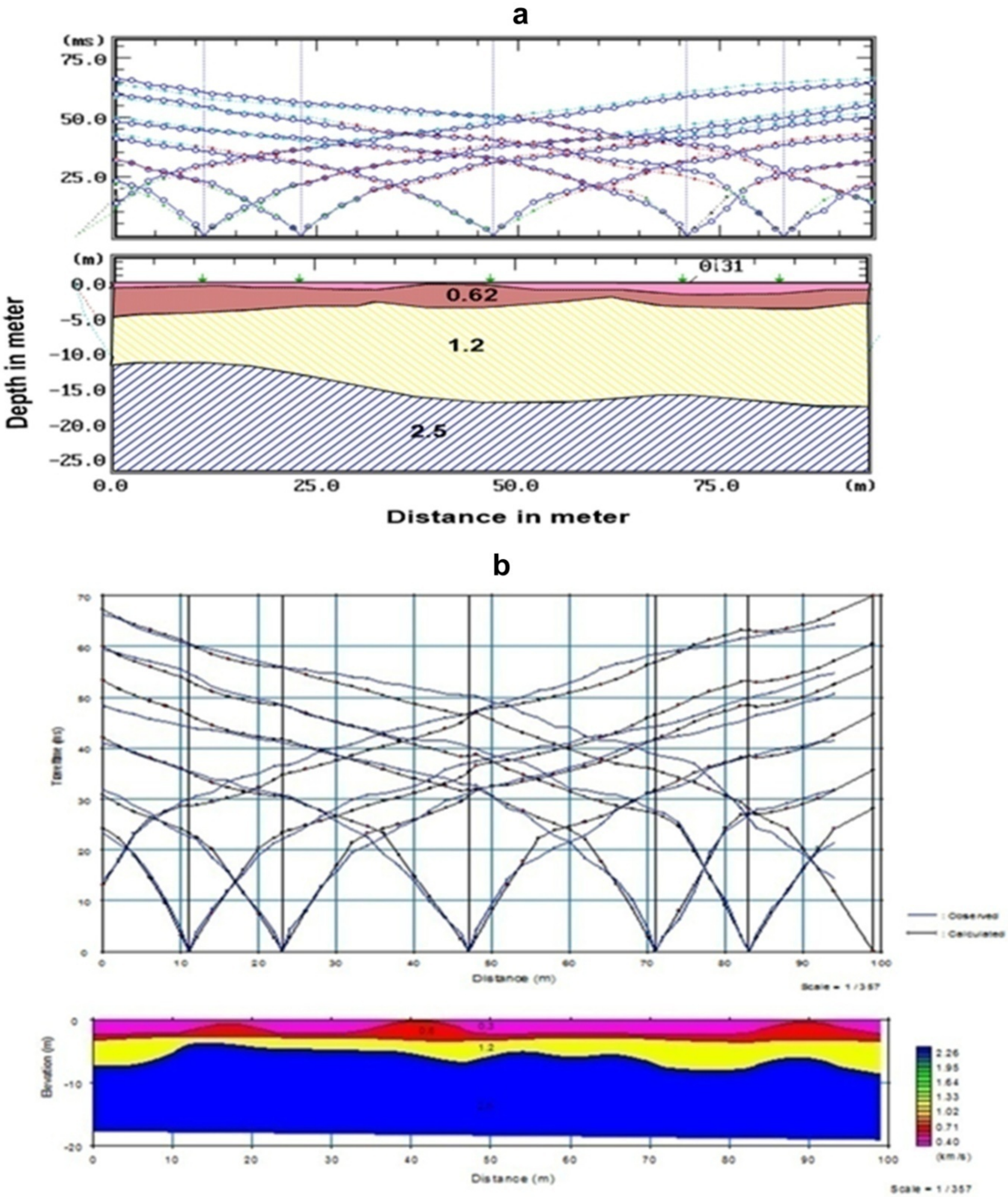


Fig.8 : Seismic interpretation for profile 4 , a ; Geoseimic cross-section, b: Seismic tomography

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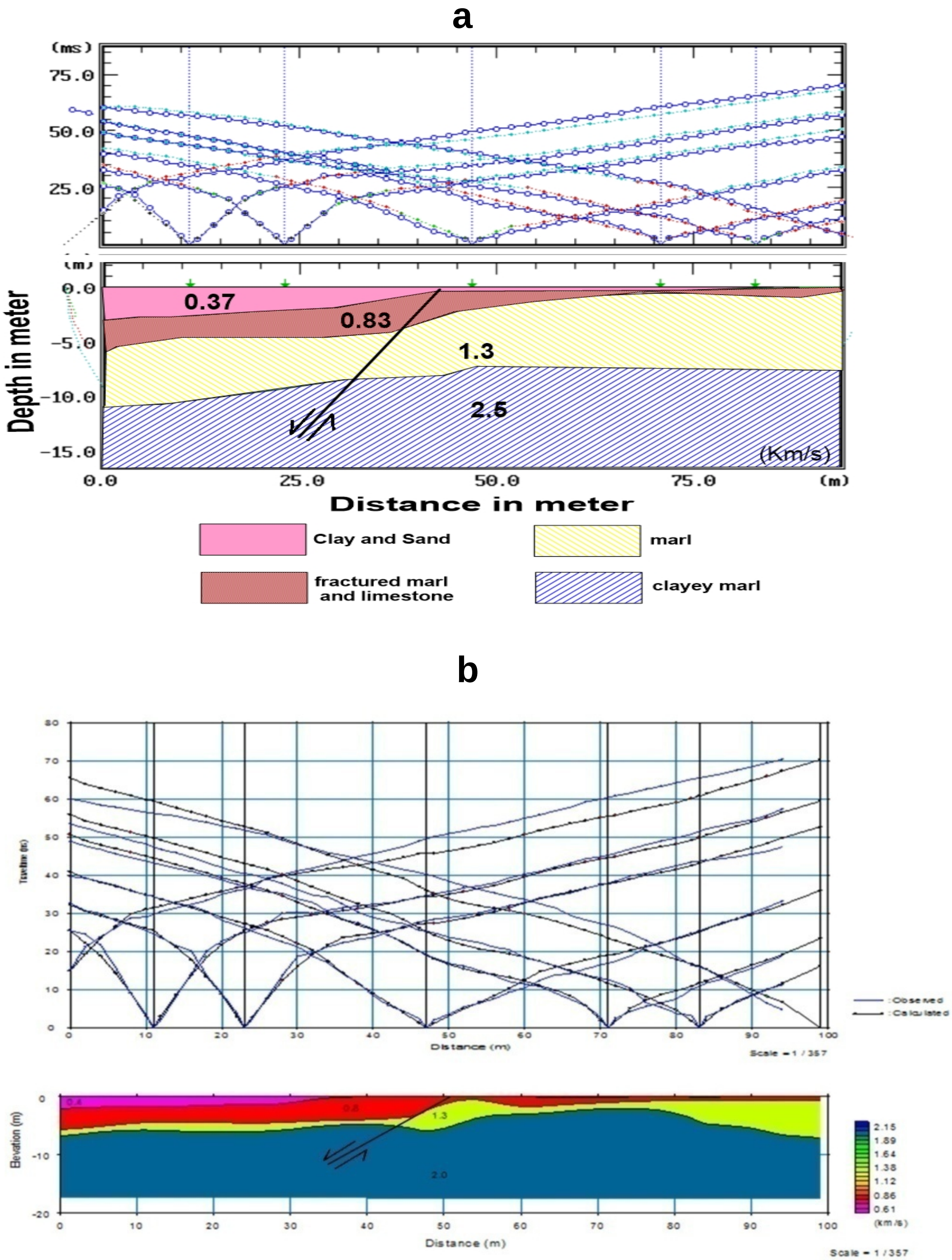

Fig.9 : Seismic interpretation for profile 7 , a ; Geoseimic cross-section, b: Seismic tomography

a

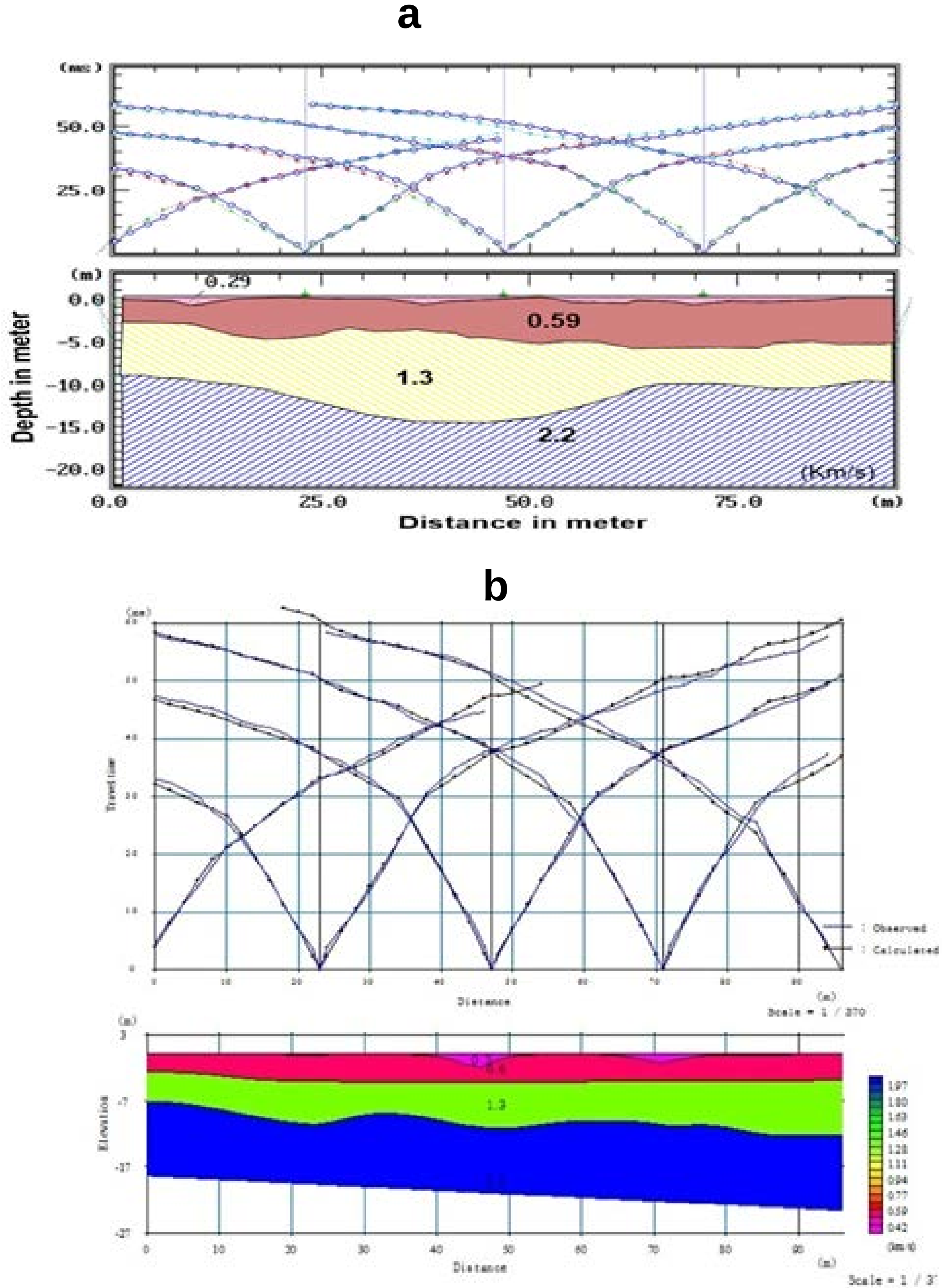

Fig.10: Seismic interpretation for profile 21 , a ; Geoseimic cross-section, b: Seismic tomography

2.4. Geotechnical analysis

Soil mechanics is defined as the application of the laws and principles of mechanics and hydraulics to engineering problems dealing with soil as an engineering material testing refers to the determination of the soil characteristics through two techniques, the first laboratory experiments for samples collecting from field and core samples from drilled boreholes at different localities of the study area (Fig11a). The second technique represents the effect of the surface layer (soil) on the seismic waves.

2.4.1.Laboratory Experiments

2.4.1.1.Samples collecting from different locations in study area

Fourteen rock samples have been collected from six sites covering most study area (tables 1, 2 and 3). The collected samples were tested for mineral compositions by using Distorted X-Ray Instrument (XRD). The result of these analyses indicate that the calcite mineral is the major component for most of samples where the ratio of calcite ranging from 76-100 % but for samples no.1-2, 1-1 and 3-1 the ratio of calcite are 36, 26 and 1% respectively. The kaolinite is recorded in sample no 1-1 and 1-2 with ratio of 56 and 41 %, the quartz mineral recorded with high ratio (98 %) in sample no.3-1. The curves of the laboratory experiments are recorded in the Fig .11b).

2.4.1.2.Borehole samples:

Seven boreholes were drilled in the study area; they reached depths of 10 m (Fig. 11d). The results of boreholes show different geologic units. The boreholes no.1, 2 and three were drilled in the Quarter 26 while boreholes no.5 and 6 were drilled in the Quarter 27 and borehole no. 9 and 10 were drilled in the Quarter 29. The borehole no.1 reflects variation in geological units where the surface layer consists of fragments of limestone with clay intercalation and sand of thickness about 0.5 m overlay a layer of marl intercalated with muddy clay ranging from depth of 0.50 m to 4.5 m. The last layer is marl which have depth ranging from 4.5 m to the end of drilling (10 m). Borehole no.2 indicates variation in lithology where the surface layer composed of fragments of limestone with clay and sand intercalation of thickness of 0.8 m overlay a layer of sand & gravel of depth ranging from 0.8 m to 3.75 m. The last unit is ranging from 3.75 to 10 m is the end of drilling which corresponding to marl intercalated with muddy clay. Borehole no.3 consists of different geological unit, where the surface layer composed of muddy clay and fragments of marl of depth up to 0.8 m overlay a layer of muddy clay intercalated with marl of depth ranging from 0.8 m to 7 m. The last layer consists of marl of depth ranging from 7 m to the end of boring (10 m). Borehole no.5 include different geological units where the surface layer composed of fragments of marl with muddy clay to depth of 0.5 m overlay muddy clay of depth ranging from 0.5 m to 7 m. The last layer consists of marl intercalated with muddy clay of depth ranging from 7 m to the end of boring (10 m). Borehole no.6 indicates variation in lithology where the surface layer composed of fragments of limestone with clay and sand intercalation of thickness of 0.5 m overlay a layer of muddy clay & sand of depth ranging from 0.5 m to 3.15 m. The last unit is ranging from 3.15 to 10 m is the end of drilling which corresponding to marl intercalated with muddy clay. Borehole no.9 consists of different geological units where the surface layer composed of fragments of limestone and muddy clay to depth of 0.5 m overlay limestone intercalated with thin layer of muddy clay depth ranging from 0.5 m to 7.5 m. The last layer consists of muddy clay of depth ranging from 7.5 m to the end of boring (8 m). Borehole no.10 includes different geological units where the surface layer composed of sand to depth of 0.5 m overlay fragments of limestone with muddy clay to depth of 2 m. The last layer consists of limestone intercalated with thin layer of muddy clay and some fragments of depth ranging from 2 m to the end of boring (8m).

Table 1: show the collecting rock samples for laboratory experiments.

Sample Number	Lithology	Formation	Member	Quarter
Sample 1-1	Argillaceous limestone: pale yellowish white, moderately hard	QurnFm	2nd Unit	26-27
Sample 1-2	Marl: yellow, moderately hard	QurnFm	2nd Unit	26-27
Sample 1-3	Silty limestone: yellow, moderately hard	QurnFm	2nd Unit	26-27
Sample 1-4	Claystone: greenish yellow, weak	QurnFm	2nd Unit	26-27
Sample 1-5	Limestone: white, hard	QurnFm	2nd Unit	26-27

Sample 1-6	Silty dolomitic limestone: greenish yellow, weak	QurnFm	2nd Unit	26-27
Sample 1-7	Limestone	QurnFm	2nd Unit	26-27
Sample 1-8	Dolomitic limestone: pale grayish white	QurnFm	2nd Unit	26-27
Sample 2-1	Limestone: white, hard	QurnFm	1st Unit	26-27
Sample 3-1	Nummulitic limestone: white, hard	QurnFm	3rd Unit	26-27
Sample 4-1	Claystone: greenish yellow, weak	QurnFm	5th Unit	28-29
Sample 4-2	Limestone: white, hard	QurnFm	5th Unit	28-29
Sample 5-1	Oil-tainted limestone: white, hard	QurnFm	5th Unit	28-29
Sample 6-1	Argillaceous limestone: pale yellowish white, moderately hard	QurnFm	3rd Unit	27

Table 2: shows the results of carbonate samples

Sample No.	Calcite %	Dolomite %	Quartz %	Gypsum %	Kaolinite %
S.1-3	91	-	9	-	-
S.1-5	100	-	-	-	-
S.1-6	89	6	5	-	-
S.1-7	76	-	24	-	-
S.1-8	100	-	-	-	-
S.2-1	100	-	-	-	-
S.3-1	1	-	98	1	-

S.5-1	100	-	-	-	-
S.6-1	100	-	-	-	-

Table3: shows the results of Clayey sample where (+) meaning the mineral was detected but value undetermined

Sample Number	S.1-1	S.1-2	S.1-4	S.4-1	S.4-2
Calcite %	36	26	+	+	+
Quartz %	8	33	+	+	+
Gypsum %	-	-	-	-	-
Kaolinite %	56	41	+	-	-
Montmorillonite %	-	-	+	+	+
Illite	-	-	+	+	+

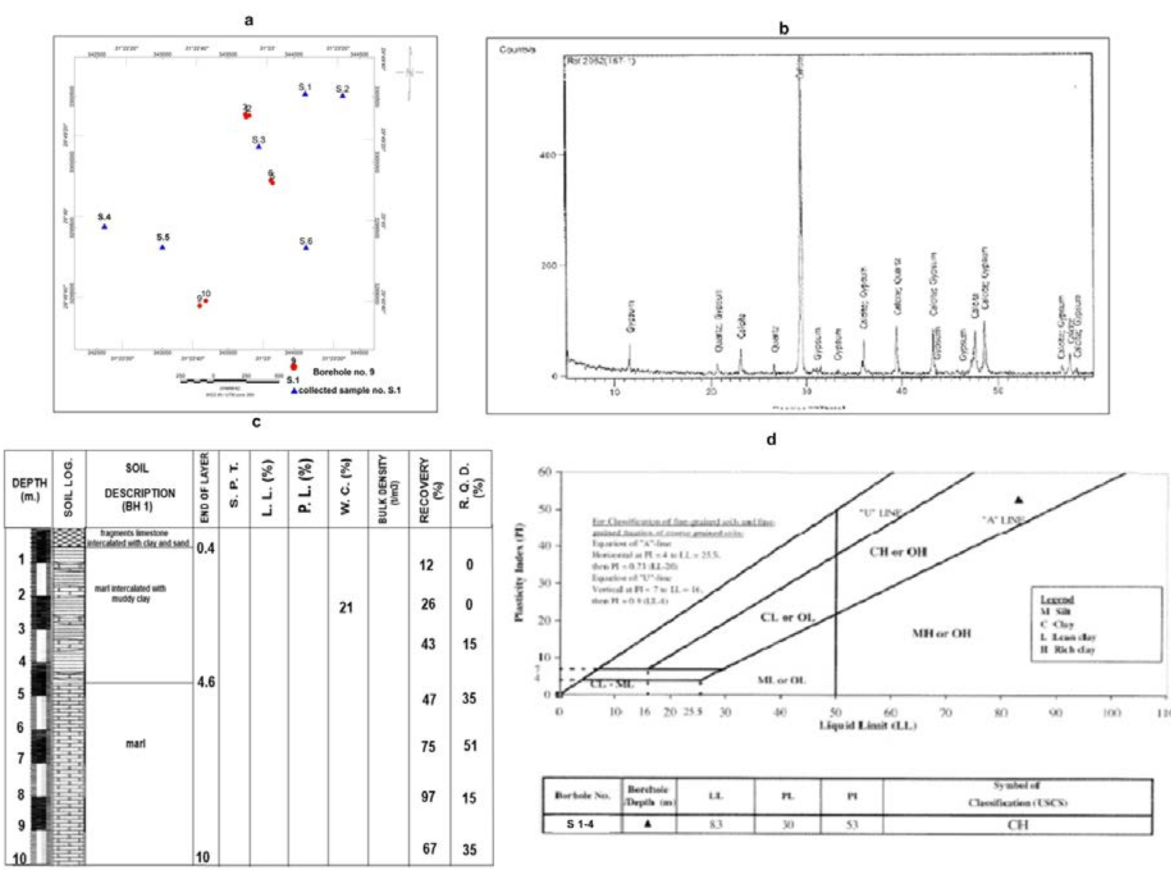

Fig.11 : Geotechnical analysis, a: Location map of collecting samples and boreholes, b: Mineral composition for sample no. s 2-1 by XRD instrument, c: Geotechnical parameters for borehole no. 1, d: Plasticity chart for the sample no s 1-4.

5. Conclusion

From the geologic, geoelectric, shallow seismic and geotechnical data we can concluded that the study area consists of four geologic units , the first unit composed of fragments for gravel, marl and limestone, the second unit consists of marl which is distributed through the area at different depths ranging from near surface to a depth of 50 m. The third geological unit is composed of clayey marl which reveals low resistivity values ranging from 2 to 11 Ωm; This unit represents the main problem in the study area, where the marl and limestone are overlain by a clayey marl unit which causes the most engineering problems due to volume changes in swelling clays as a result of man-made activities that modify the local environments causing most fractures on the limestone and marl. The fourth geological unit is limestone unit which have high resistivity values ranging from 15 to 30.7 Ωm according to the hardness and fractures. The study area dissected by tow normal faults of NW-SE trends. the northwestern part to southeastern part passing by central part are competence parts and have high suitability for any constructions.

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