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Application of 2D and 3D Electrical Resistivity Imaging Techniques for Site Investigation in Ramadi City, Western Iraq

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Abstract. Ramadi city, western Iraq, is considered an area with risks resulting from the presence of gypsum soil near the surface and the water table on shallow depth which facilitates the solubility of the soil and creates a weak area. So a dipole-dipole array with an n factor of 6 and a -spacing of 2 m was used. Ten 2D resistivity imaging traverses and 3D resistivity imaging station were done. The robust constrained inversion method is used to obtain 2D and 3D models. The results show that the topsoil layer extends to 2m depth with resistivity of 800 to 4000 Ωm. This is caused by high inhomogeneities in the deposits. The weakness zones and Depositional lenses appears after 2m depth and extent to 9m with resistivity value extend from 200 to 800 Ωm. Finally, it is concluded that four main reasons for civil engineering failure in Ramadi city. These reasons may be the inhomogeneity of the underground deposition material. In addition, the existence of weak areas and sedimentation lenses, and the change of water table.

1. Introduction

The Ramadi area is covered with a shallow layer of gypsum soil, posing risks to the environment and civil engineering. Gypsum soil cause some problems in the stability of urban structures, especially when the water level is near the ground. This problem occurs during the process of dissolving gypsum, leaving weak areas, leading to rupture and collapse of projects and streets [1]. The subsurface water level in Ramadi City is shallow and seeps into the surface in some places. Especially in the season when the amount of water is increasing, causing many problems in civil engineering, environmental and social health. Electrical resistivity methods are one of the most effective geophysical methods used to image the subsurface using differences in measured electrical resistivity at the surface [2]. The application of these imaging techniques, in engineering investigation, very useful for determining underground geology and underground structures (such as cavities, voids, and soil stability) [3,4,5 and 6]. The study aims to used, 2D and 3D resistivity imaging for engineering site investigation to designing the building foundation and for choosing the safe areas and roads in Ramadi city.

2. Materials and Methods

2. 1. Site description

The study area located within Ramadi city, center of Anbar governorate, western Iraq(Fig.1). stratigraphy, the surface soil consists of gypsiferous soil, and gypcrete, Injana Formation and Fatha Formation [7] (Fig. 2). Injana formation consists of brown claystone, pinkish pale claystone, siltstone, and fine sandstone with secondary gypsum. Most civil engineering projects in Ramadi city do not care about the impact of subsurface water levels on gypsum soil layers, which caused cracks of the building, and it collapsed in a hole in the center of Omar bin Abdul Aziz Street (Fig.3).

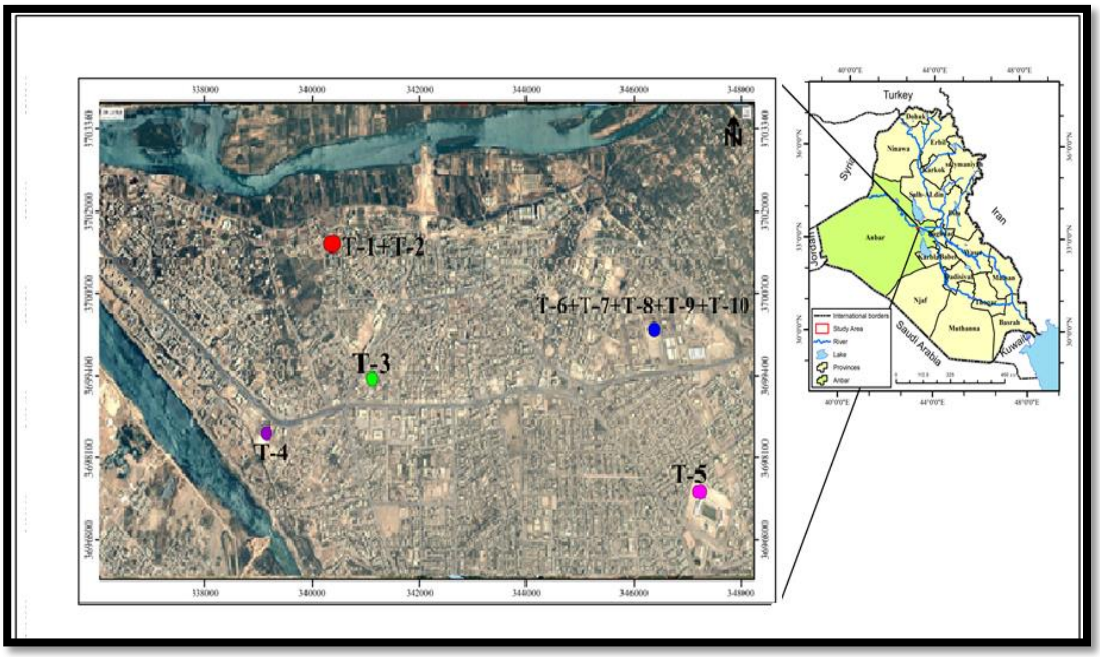
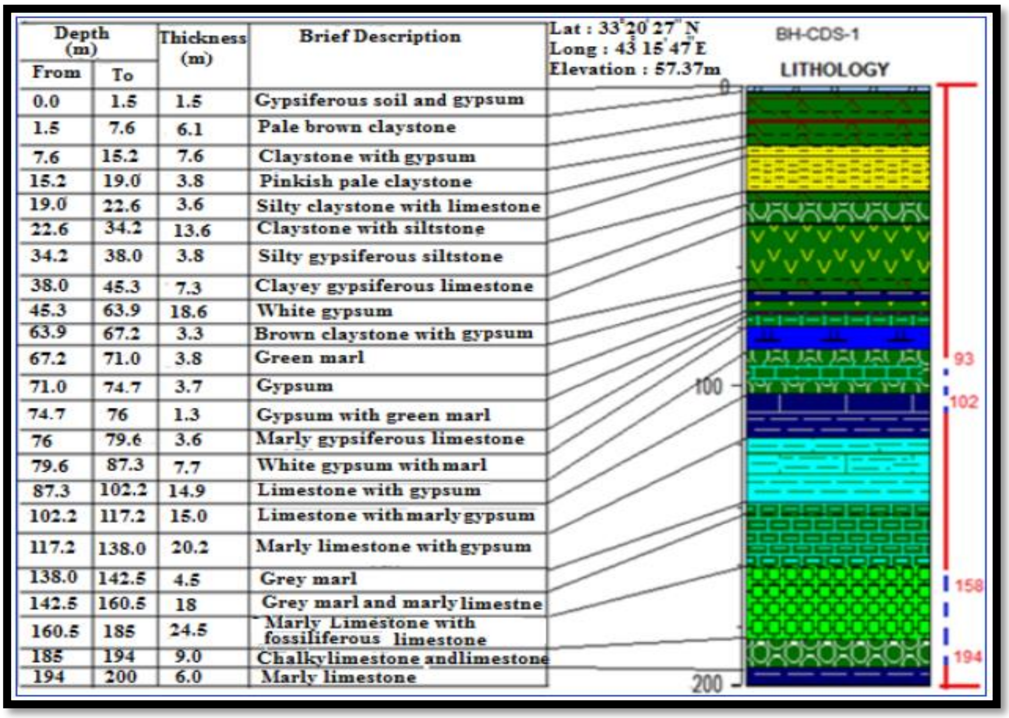


Fig.1. Location of study area



Depth (m) From	To	Thickness (m)	Brief Description
0.0	1.5	1.5	Gypsiferous soil and gypsum
1.5	7.6	6.1	Pale brown claystone
7.6	15.2	7.6	Claystone with gypsum
15.2	19.0	3.8	Pinkish pale claystone
19.0	22.6	3.6	Silty claystone with limestone
22.6	34.2	13.6	Claystone with siltstone
34.2	38.0	3.8	Silty gypsiferous siltstone
38.0	45.3	7.3	Clayey gypsiferous limestone
45.3	63.9	18.6	White gypsum
63.9	67.2	3.3	Brown claystone with gypsum
67.2	71.0	3.8	Green marl
71.0	74.7	3.7	Gypsum
74.7	76	1.3	Gypsum with green marl
76	79.6	3.6	Marly gypsiferous limestone
79.6	87.3	7.7	White gypsum with marl
87.3	102.2	14.9	Limestone with gypsum
102.2	117.2	15.0	Limestone with marly gypsum
117.2	138.0	20.2	Marly limestone with gypsum
138.0	142.5	4.5	Grey marl
142.5	160.5	18	Grey marl and marly limestne
160.5	185	24.5	Marly Limestone with fossiliferous limestone
185	194	9.0	Chalkylimestone andlimestone
194	200	6.0	Marly limestone

Fig.2. Lithological section of well [7]

Fig.3 collapsed in a hole in the center of Omar bin Abdul Aziz Street

2.2. Data acquisition

The data acquisition along the ten 2D and 3D resistivity traverses in Ramadi city, using SAS 4000 instrument. The 2D survey is performed by the dipole-dipole array with the number of electrodes used are (42), a-spacing is equal to (2m) and n-factor equal to 6. Therefore, the total length of the measurement line is (82m), and the data coverage of the entire station is equal to (685) readings. This array was choosing because most research has been done to determine which array the best response when imaging shallow targets under different conditions, indicating greater resolution and great sensitivity to geological details for shallowly exploration [8,9 and 10]. In addition, when the noise intensity is high, the dipole-dipole subset provides the lowest (feasible) data on the resistivity area of the recording point [11 and 12]. In this study, measurements of five parallel two-dimensional lines used to build 3D model with line distance of 4 meters (Fig.4). The measurements of these five lines were collected in one file prepared for the RES3DINV program. In this study, we manually performed 2D and 3D measurements without a multi-core cable, where the current cable and the potential cable were moved from pole to pole along the measurement line. The data was organized into a file prepared for RES2DINV and RES3DINV. The two-dimensional apparent resistivity of the 5 lines is uniformly sorted using the RES2DINV program data files that can be accepted by RES3DINV software

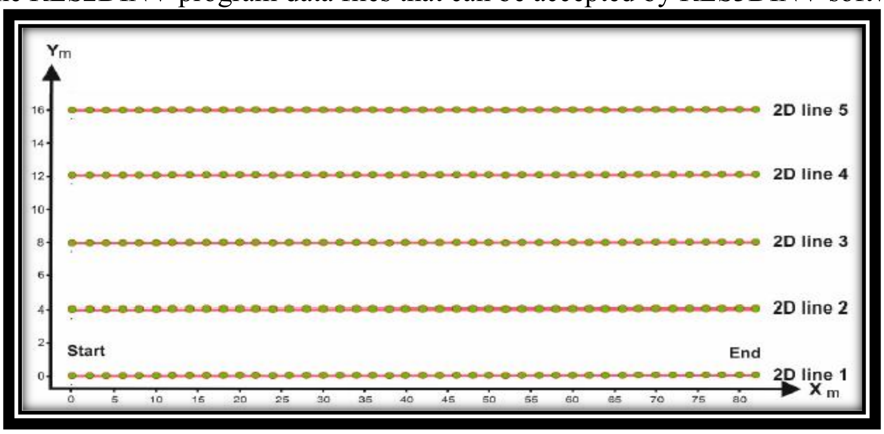


Fig.4. 3D imaging technique by parallel 2D lines.

3. Results and Discussion

3.1. 2D resistivity model

The 2D resistivity data generated by robust inversion method (Fig.5.6.7.8 and 9). This method is able to define clearly the weakness zones in sharp boundaries. The dipole-dipole arrays cause high error rates because the potential electrodes move at different distances outside the current electrodes as well as the inhomogeneity of near-surface deposition so the reading between the potential electrodes is very small [13].

2D inverse models has distinguish the existence of variation resistivity zones. The first zone idealizes top soil layer which extend to 2 m depth approximately with resistivity values from 400 to 4000. This difference is caused by present the difference lenses which consists of sand, silt with secondary gypsum and sometime is filled with the water. this layer shows present some void which is filled with sediments due to dissolve secondary gypsum by sewage and surface water. This zone causes many problems for civil engineering projects. Weakness zones which caused by dissolved secondary gypsum within claystone layer of the injana formation are at a depth 2 m and extends at depth 10 m with resistivity of 0.54 to 400 Ωm. High RMS error, it rang between 19.9 % - 27.1 % of these models, which may be due to sediments inhomogeneity and variation of water depth. The anomalies in all travers are variation resistivity value due to change water level.

3.2. 3D resistivity model

The horizontal section of the 3D imaging models obtained from five 2D traverses (T6, T7, T8, T9, T10) in the eastern part of the study area. The text editor is used to merge all 2D data files into one file. This editor file can be read by RES3DINV software because it is read manually on site. For production data files, it manually uses many text editor programs, such as NOTEPAD, WORDPAD, Surfer, and Microsoft Office Excel programs. Fig (10) shows the 3D inversion model of the robust constraint option. It shows the 3D distribution of true resistivity.

3D model show a highest resistivity data of the top soil revealed an uneven layer. The first seven slices represent the change in resistivity to a depth of 8.85 m. This represents the weak area below the ground surface. The parts at depths of 0-0.80 m, 0.80- 1.72 m, 1.72-2.78 m, 2.78-3.99 m, 3.99-5.39 m, 5.39-7 m and 7-8.85 m clearly show large changes in resistivity values. The last 5 slices from 8.85-11 m to 19.5-23.2 m depth showed that the resistivity value decreased with depth.

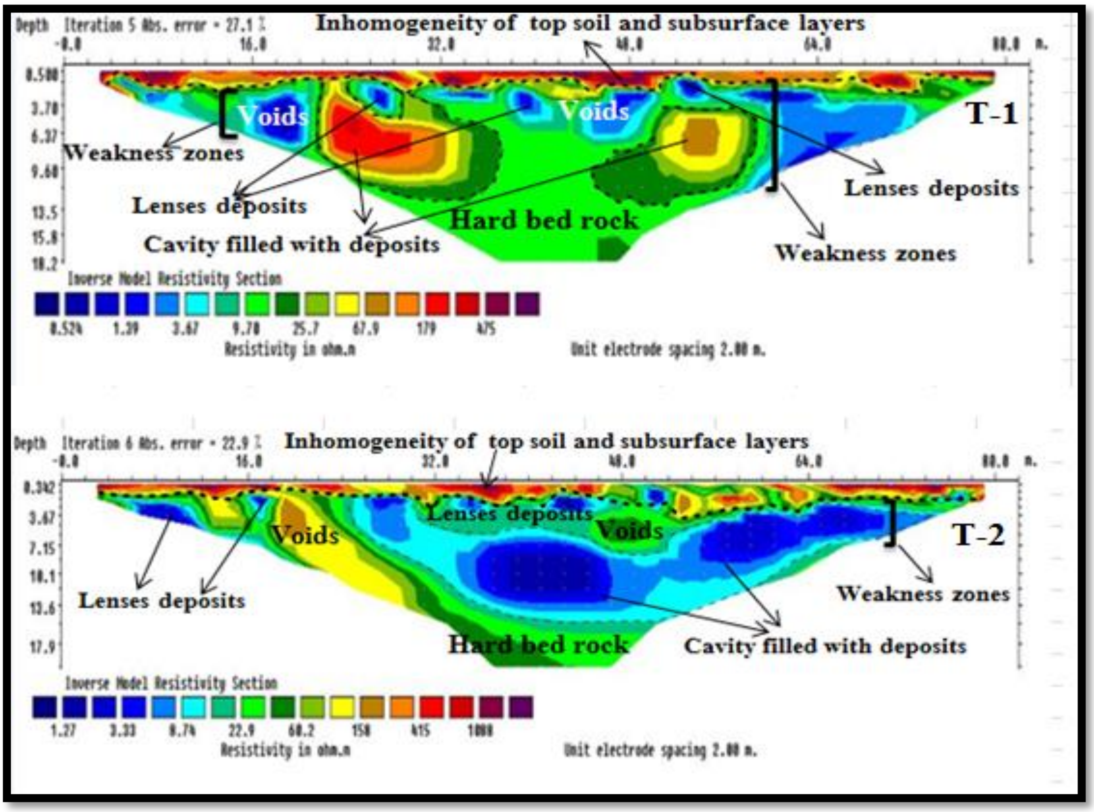


Fig.5. 2D resistivity imaging models for the Traverses 1and 2

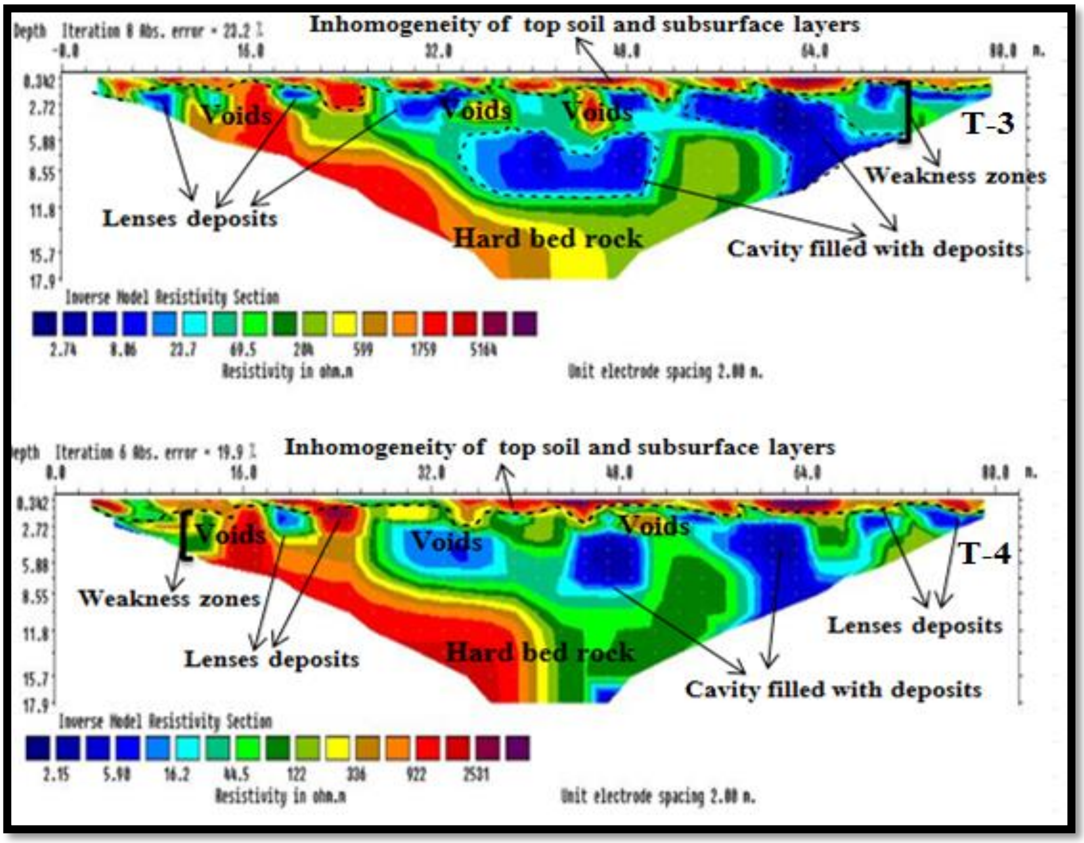


Fig.6. 2D resistivity imaging models for the Traverses 3 and 4

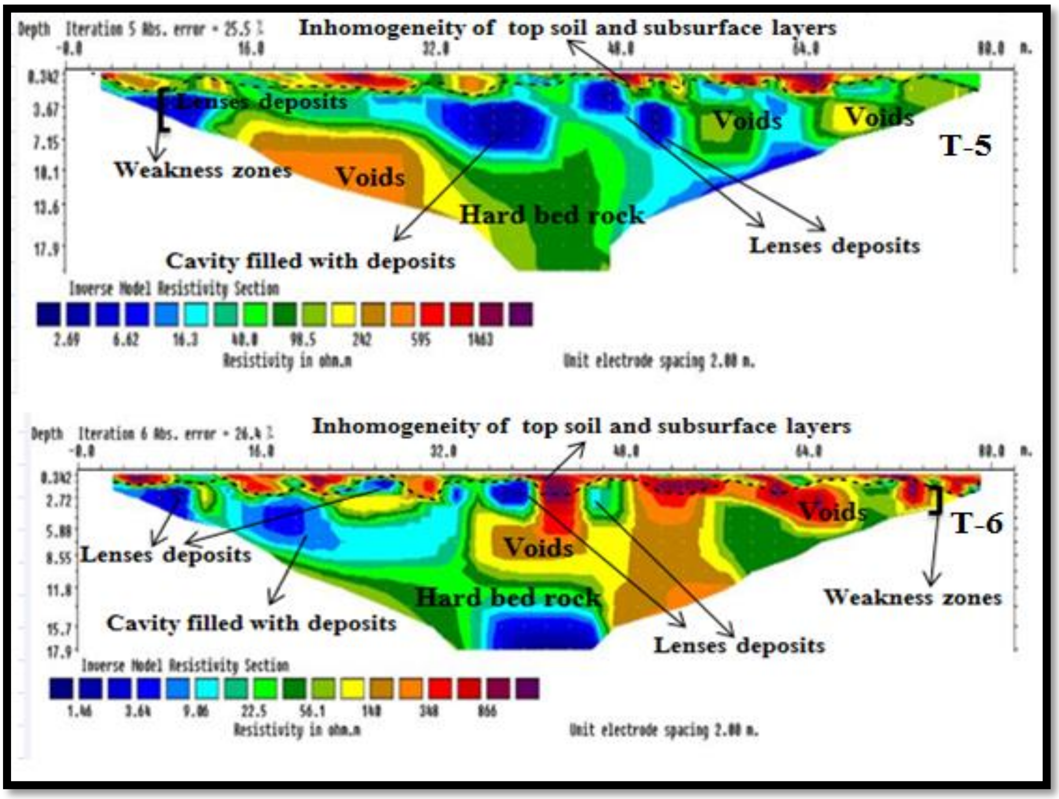


Fig.7. 2D resistivity imaging models for the Traverses 5 and 6

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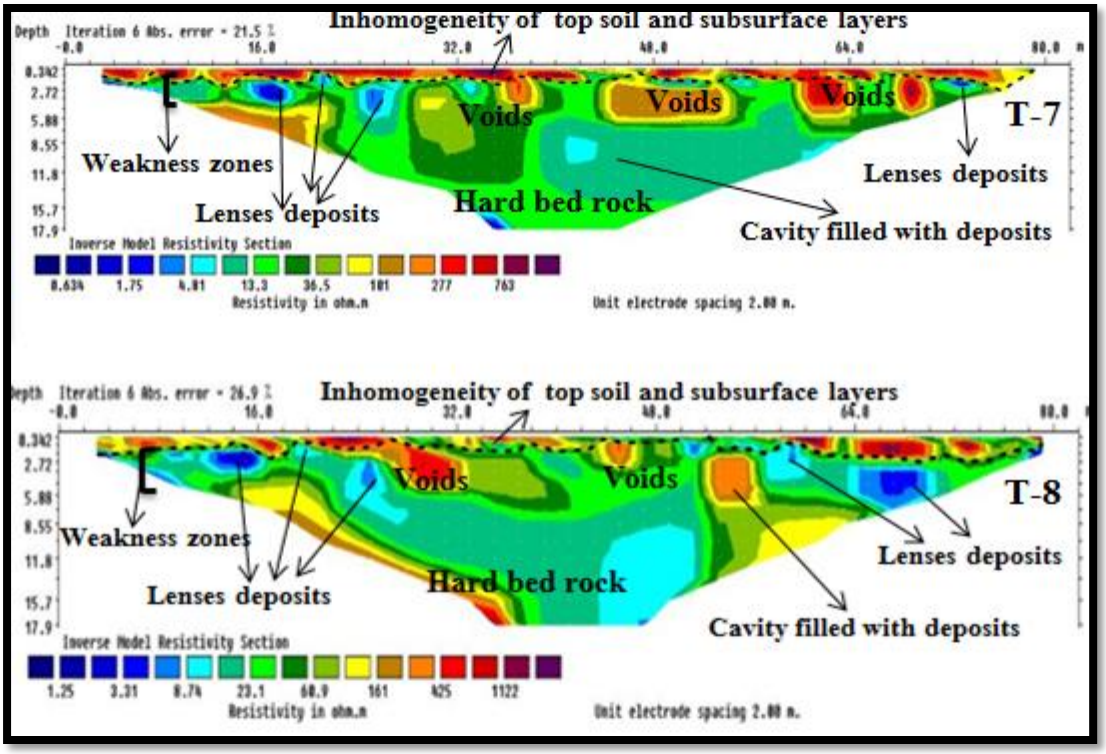

Fig.8. 2D resistivity imaging models for the Traverses 7 and 8

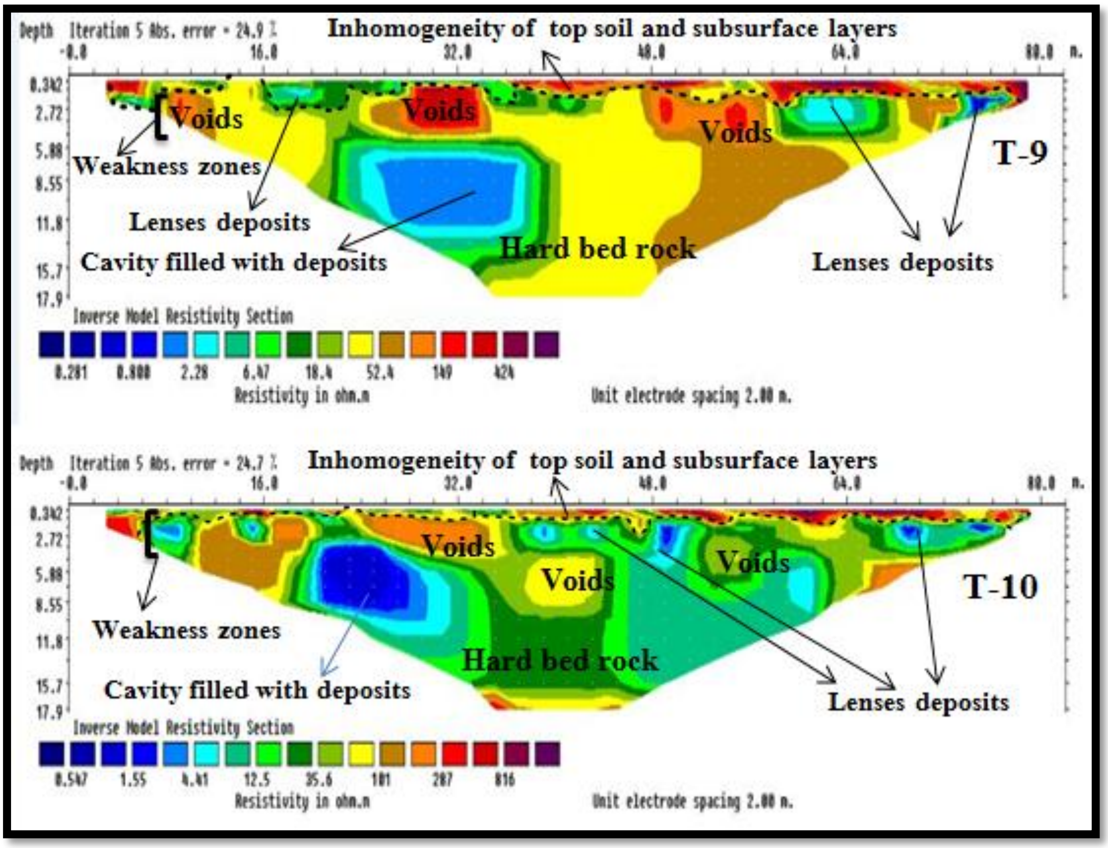

Fig.9. 2D resistivity imaging models for the Traverses 9 and 10

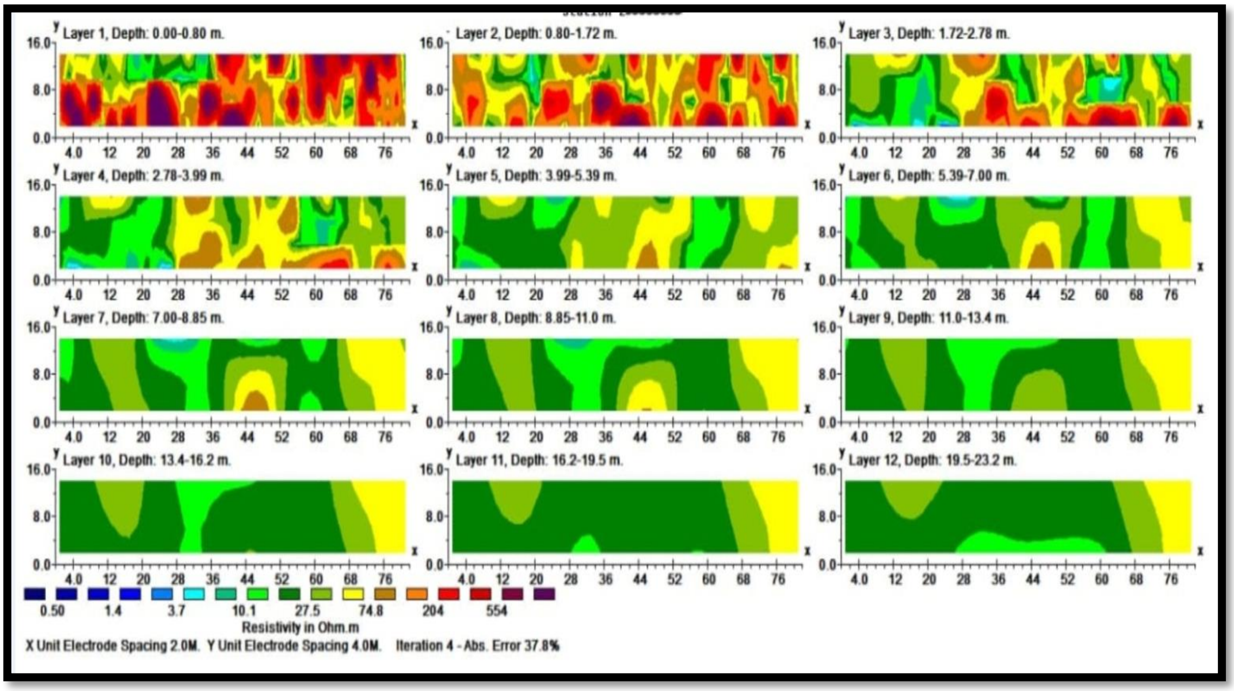

Fig.10. Horizontal section of the 3D resistivity imaging models

4. Conclusion

1.The inverse model of 2D and 3D resistivity produced by robust inversion method which clearly confirm the weak area as clearer and straighter.

2. The maximum investigation depth range is between 17.9 and 18.2 m.

3. The topsoil layer extend to 2m depth with variation resistivity range of 800 to 4000 Ωm and. This caused by high inhomogeneities in the deposits. The weakness zones and Depositional lenses appears after 2m depth and extent to 9m with resistivity value extend from 200 to 800 Ωm

4. The results show that four main reasons for civil engineering failure have been identified. These reasons may be the inhomogeneity of the underground deposition material. In addition, the existence of weak areas and sedimentation lenses, and the change of water table.

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