DOI: 10.24996/ijs.2022.63.3.17

ISSN: 0067-2904

Using 2D Resistivity Imaging Technique to Detect and Delineate Shallow Unknown Cavities In Al-Haqlaniyah Area, Western Iraq

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Received: 5/1/2021 Accepted: 10/8/2021

Abstract

Basal breccia unconformity layer between Anah and Euphrates Formations in Al-Haqlaniyah area, Western desert, include enormous sinkholes and cavities usually cause severe damages to any kind of engineering facilities built over it. Two-dimensional resistivity imaging has been applied to detect the depth and extent of the subsurface caves at five stations. The dipole-dipole array is chosen with an electrode spacing of 2 meters. 2D Dipole-dipole imaging inverse models show the resistivity values have a big variation between the anomalous background resistivity of rocks and part of cavities. These models showed shallow cavities at 1 to 3 m depth and others at 5to 6 m depth and extending to a depth of 23 m. The unconformity layer is less cohesive than the rocks beneath and above it. So it was the best area for the caves to be formed as a result of dissolving its rocks by leaking rainwater and groundwater. Therefore, it must be a pre-engineering preparation before starting any urban construction of the population in the study area or adjacent areas to avoid risks.

Keywords: 2D imaging technique, Dipole-dipole array, cavity, Western desert, Haditha area, Iraq.

استخدام تقنية التصوير بالمقاومة ثنائية الأبعاد لاكتشاف وتحديد التجاويف الضحلة المجهولة في منطقة حديثة ، غرب العراق

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الخلاصه

طبقة عدم التوافق القاعدية بريشيا بين تكوينات عنة والفرات في منطقة حديثة ، الصحراء الغربية ، تحتوي على مجاري ضخمة وكهوف عادة ما تسبب أضرارًا جسيمة لأي نوع من المنشآت الهندسية المبنية فوقها. تم تطبيق التصوير المقاومة النوعية ثنائي الأبعاد لاكتشاف عمق ومدى الكهوف الجوفية في خمس محطات. تم اختيار مجموعة ثنائية القطب مع تباعد قطب كهربائي يبلغ 2 متر. تُظهر النماذج العكسية للتصوير ثنائي القطب ثنائي القطب أن قيم المقاومة لها تباين كبير بين مقاومة الخلفية الشاذة للصخور وجزء من التجاويف. أظهرت هذه النماذج تجاويف ضحلة على عمق 1 إلى 3 أمتار وأخرى على عمق 5 إلى 6 أمتار وقد تمتد إلى عمق 23 مترًا. طبقة عدم التوافق أقل تماسكًا من الصخور الموجودة تحتها وفوقها. لذلك كانت أفضل

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منطقة تكونت فيها الكهوف نتيجة إذابة صخورها عن طريق تسريب مياه الأمطار والمياه الجوفية. لذلك ، يجب أن يكون تحضيرًا هندسيا قبل البدء في أي إنشاء منشئات عمرانية للسكان في منطقة الدراسة أو المناطق المجاورة لتجنب المخاطر.

Introduction

Cavities are found in carbonate rocks formed as a result of dissolving their rocks by leaking rainwater and groundwater [1]. They cause severe troubles for civil engineering and environmental management. The main type is the sinkholes, which have been developed in various shapes and dimensions [2]. Canals and voids would develop by penetrating the groundwater through weak areas of limestone [3]. All resistivity techniques were used in the delineation of the subsurface cavities, voids, fractures, and weak zones characteristics, such as, [4- 7] used 1D electrical resistivity techniques to detect the cavities and fracture zones. [8; 9; 10] applied the 1D azimuthal resistivity technique to determine the characteristic fracture patterns. [11- 14] used 2D resistivity imaging technique to delineate the subsurface fracture characteristics. Some authors have used integrated 1D resistivity, and 2D and 3D imaging (by parallel 2D) surveys for the detection of subsurface structures, such as [15- 19].

Haditha region is characterized by the presence of many caves visible within the rocky outcrops. Some caves were observed to have a height of 5 meters (Figure 1). In addition, lead many small openings lead to sub-surface caves. In the study area, there is also a cave opening approximately three meters wide, formed as a result of a bulldozer's work to level the ground for the construction of a primary school. The foregoing indicates that the study area represents a risk area. Therefore, it was necessary to conduct an electrical survey to inspect the subsurface caves to take safety measures by the concerned authorities when constructing buildings in the area.

Materials and methods

Description site and stratigraphy

The study area is located south of Haditha city at Al-Haqlaniyah town, western Iraq. It is located between latitude 34° 4'49.66" to 34° 4'44.82"north and longitude 42°21'12.45" to E42°21'46.11" east (Figure 2).

The study area is built up of sedimentary rocks ranging in age from lower Oligocene to Pliocene, with different types of Quaternary deposits (Pleistocene-Holocene),. The stratigraphic sequences of geological formations in the area of study as fellows [20]. Shurau and Sheikh Alas formations (Lower Oligocene) are composed of limestone recrystallized (Figure 3).

Figure 1- photograph of a cave in the Haditha area

Anah formation (Lower Oligocene) consists of massive very hard limestone and dolomite limestone. Euphrates formation is the oldest rocks outcropped in the studied area. It consists of limestone, dolomite in addition to layers of basal conglomerate [21]. The formation is exposed along both banks of the Euphrates River and in the deep valleys to the south of the Euphrates River. It is divided into two units: [22- 24]. The lower unit consists mainly of conglomerate, gravels followed by layers of limestone that contains fossils; the thickness of this unit ranges from 15-20 meters. The upper unit consists of a sequence of Brescia, limestone, dolomite with horizontal lenses and layers of green shell. The thickness of this unit ranges from 7-15meters.

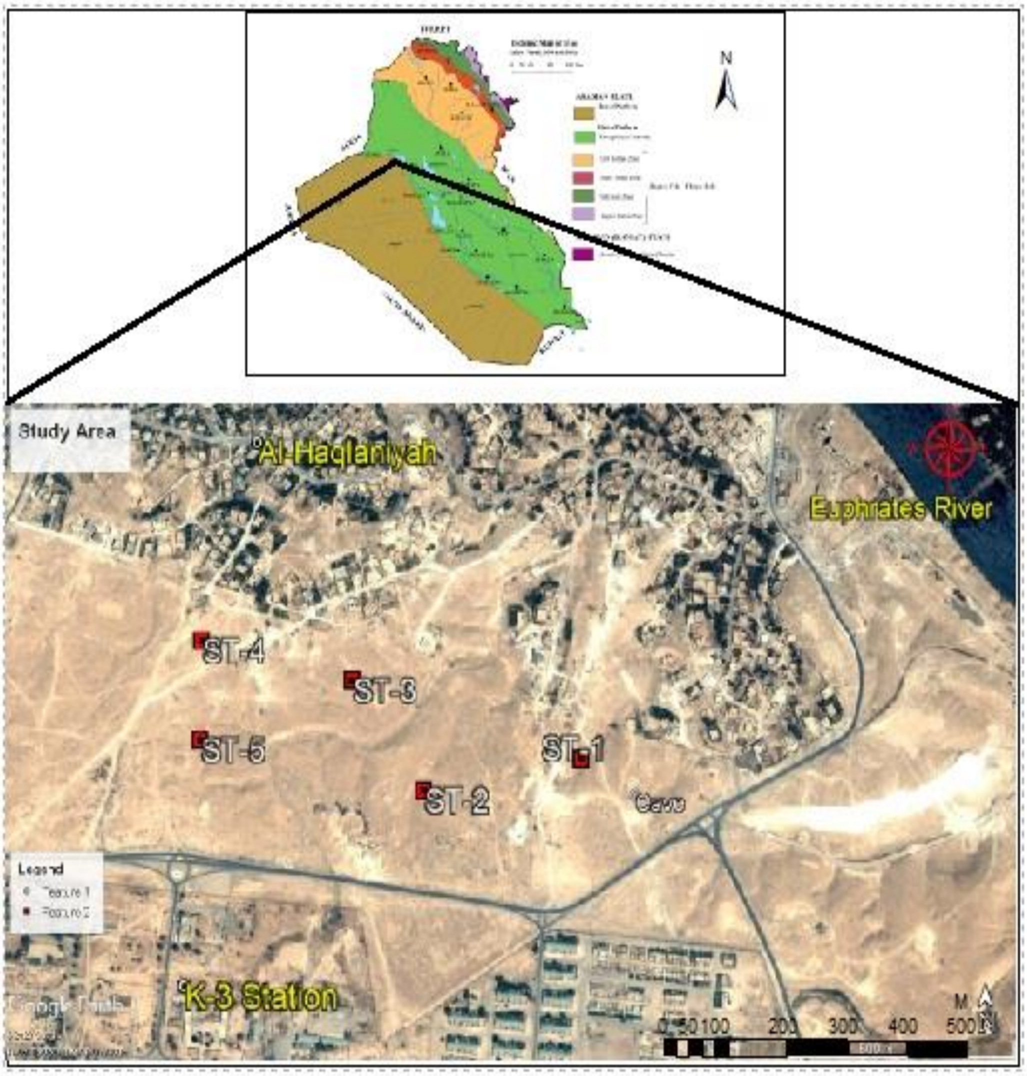

Figure 2- Study area map

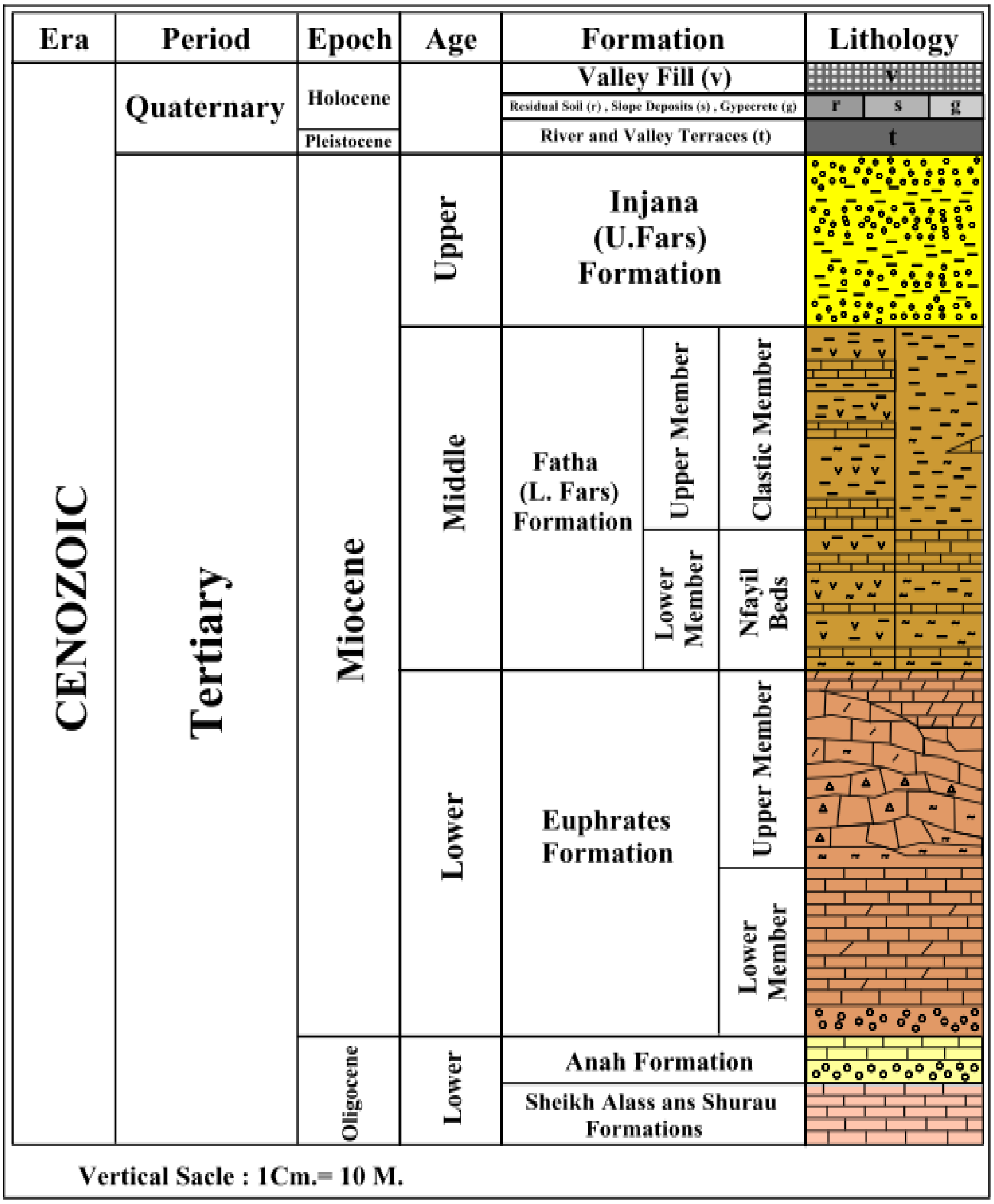

Figure 3- Stratified sequence of geological formations in the studied area [20].

Data acquisition

ABEM Terrameter SAS 4000 was used in the current survey. The measurements of the 2D survey were collected at five stations (Figure 2) using a Dipole-dipole array with an electrode spacing (a-spacing) of 2 (a=2) m and an n-factor equals to 6. The forward sequence of apparent resistivity(ρa) measurements was designed by a survey line consisting of 42 electrodes at station 1and station 5 and 22 electrodes at stations 2, 3, and 4. The 2D stations were selected within the planned areas of new civilian facilities added to the Urban planning of the study area.

Results and discussion

2-D data was interpreted by RES2DINV ver. 4.9.15 software [25]. Using standard least-squares and robust constraint options. The standard least-squares method is used for data to produce a model with smooth boundaries due to layering. While, the robust constraint method is used when there were sharp borders such as cavities, voids, and fractures [26].

The first station (ST-1) is located on the eastern side of the study area. The inverse model

The inverse model shows the existence of the main cave located in the middle of the path, at a depth of 3 meters and extending to a depth of 23 meters. There are also several small caves to the right and left of the main cave, some of which contain leaky groundwater, which is characterized by low resistivity values (Figure 4). This model produced by the standard least-squares method has a gradational boundary for the cavity wall. In comparison, the model produced by the robust model inversion method (Figure 5) has sharper and straighter boundaries. So, The least-square inversion method is used in the interpretation of other 2D resistivity data because the cavity shape is irregular.

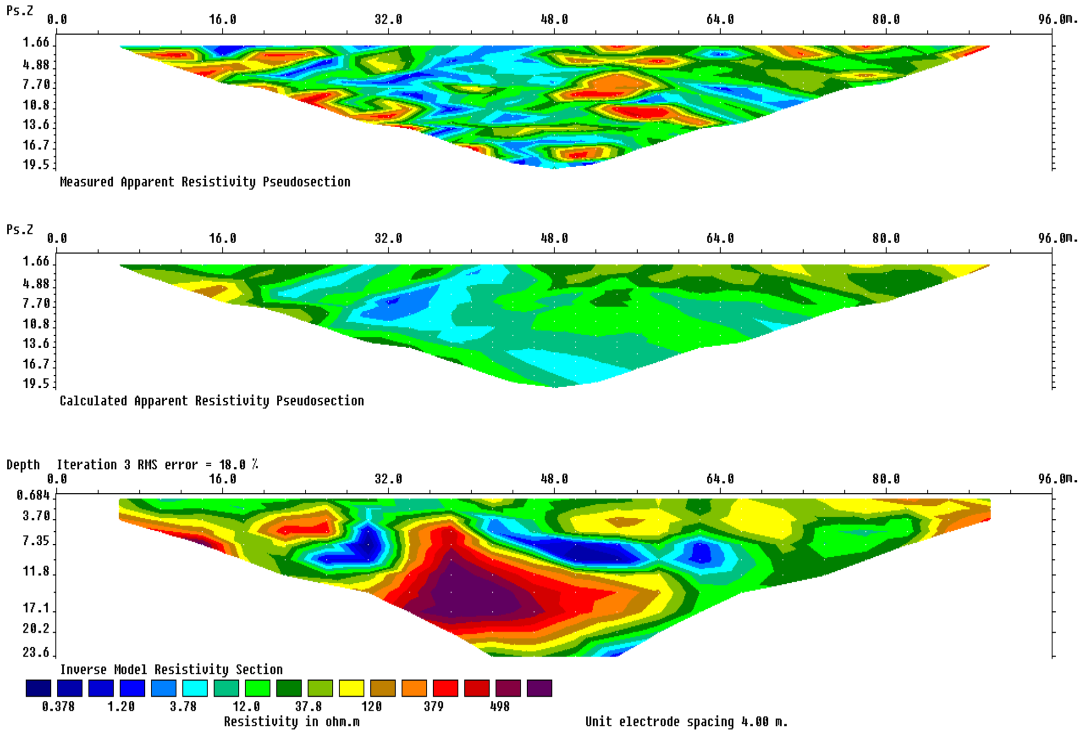

Figure 4- Measured and calculated pseudo sections and inverse model Dipole-dipole resistivity section at ST-1 (Standard least-squares method smoothing constrain).

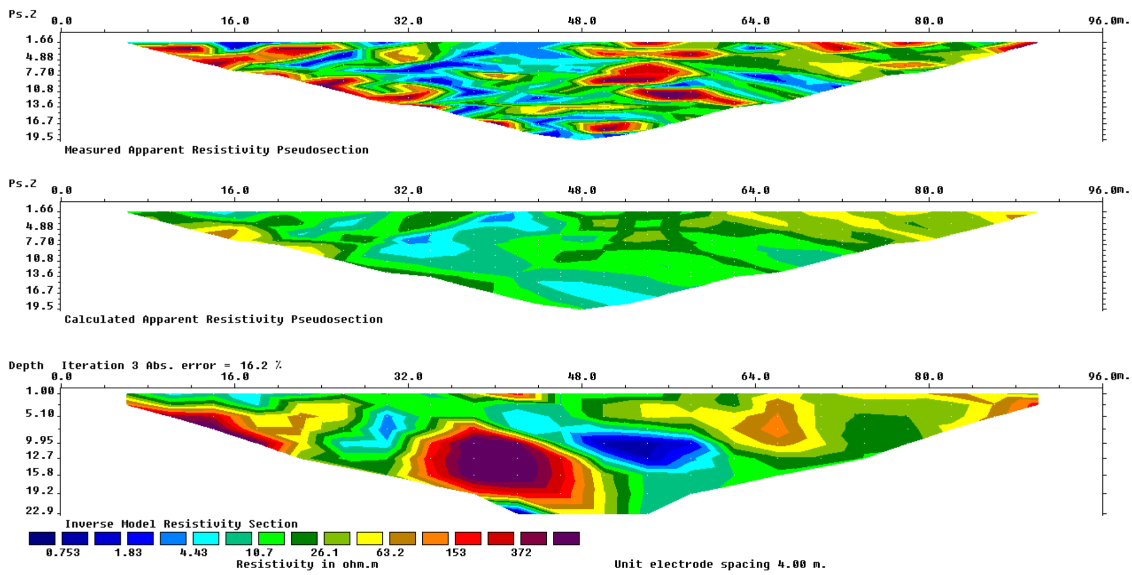

Figure 5- Measured and calculated pseudo sections and inverse model Dipole-dipole resistivity section at ST-1(Robust inversion model constrain).

At station 2, the inverse model of 2D data produced by the standard least-squares method has a gradational boundary for the cavity wall. This model indicates the existence of a large cave extending a distance equal to thirty meters and a depth of two meters from the surface. The bottom of this cave extends to the bottom. We could not determine the depth of the bottom of the cave. The lower part of the cave was distinguished by its low resistivity values, through which it can be concluded that there is water below the cave at a depth of six meters (Figure 6).

Figure 7 shows the same inverse model but by the Robust inversion, model constrain method. In this model, the edges of the cave appear sharp and straight.

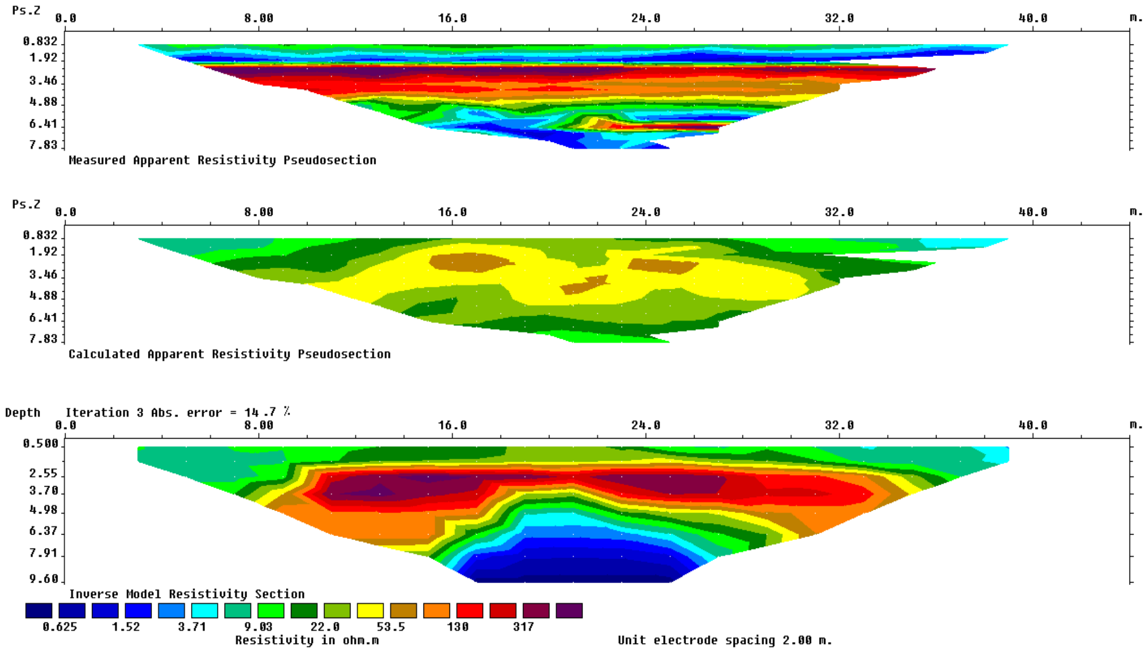

Figure 6- Measured and calculated pseudo sections and inverse model Dipole-dipole resistivity section at ST-2 (Standard least-squares method smoothing constrain).

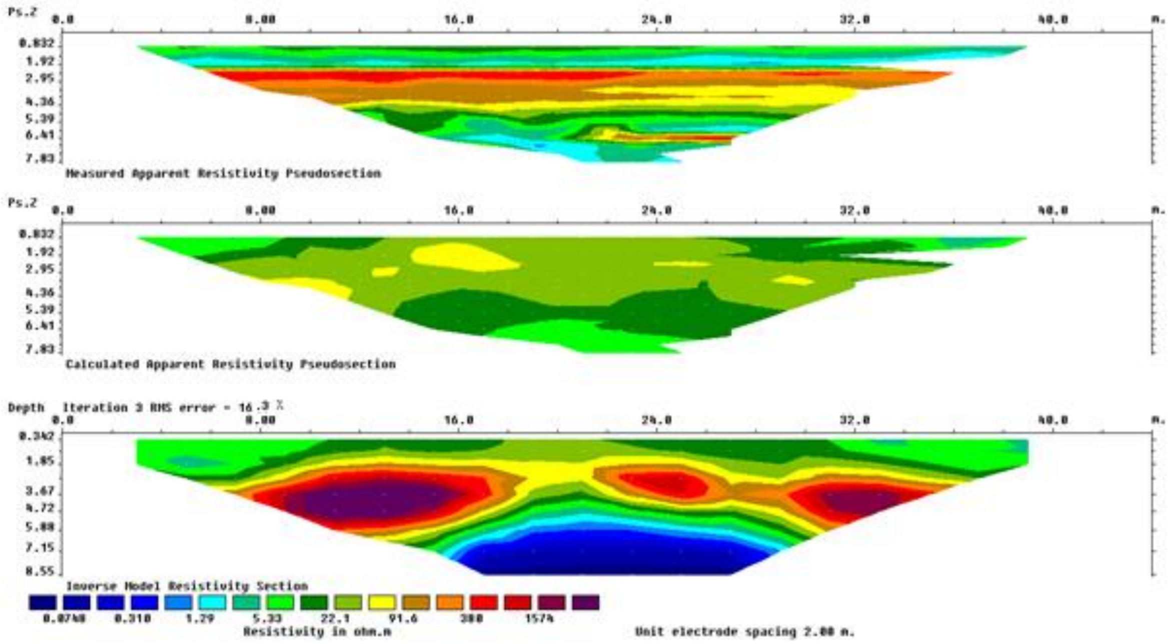

Figure 7- Measured and calculated pseudo sections and inverse model Dipole-dipole resistivity section at ST-2(Robust inversion model constrain).

The third station is located in the middle of the study area. Where it was found that there is the main cave extending from the center of the Traverse to the south of the study area. This cave is characterized by high resistivity values of 7 ohm. meters, being empty, and a depth of 5 meters. This cave is surmounted by a small cave with a depth of half a metro. In the north, a small cave appears at a depth of one meter and is characterized by high resistivity values of five hundred ohm-meters, indicating that the cave is empty (Figures 8, and 9).

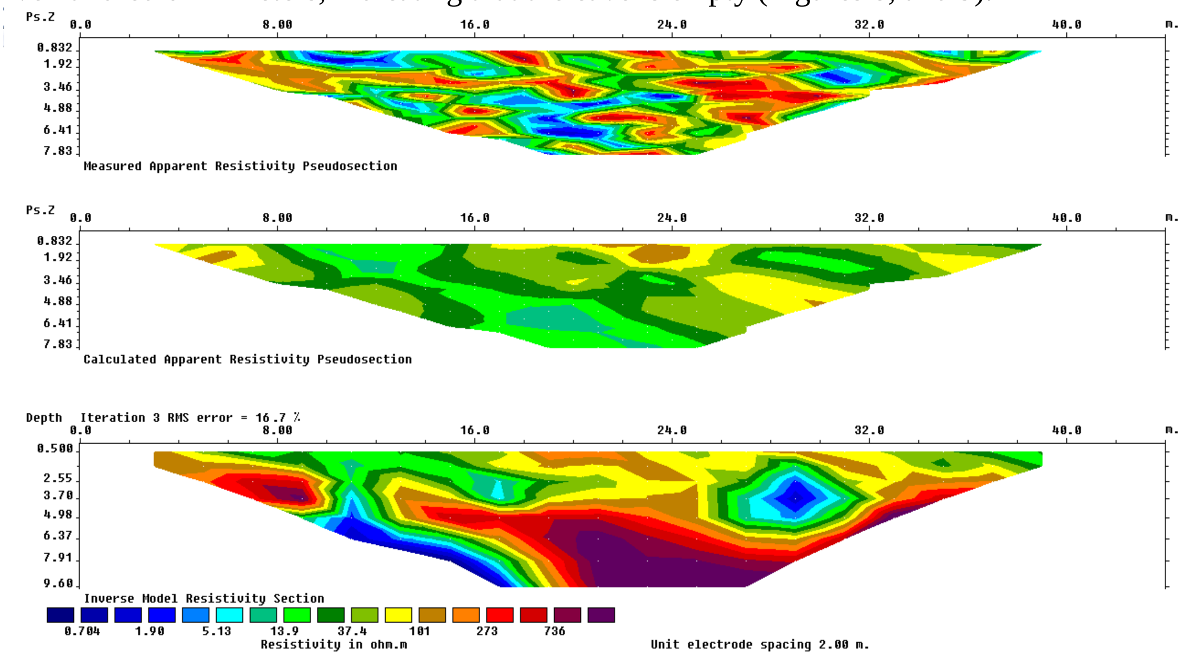

Figure 8- Measured and calculated pseudo sections and inverse model Dipole-dipole resistivity section at ST-3 (Standard least-squares method smoothing constrain).

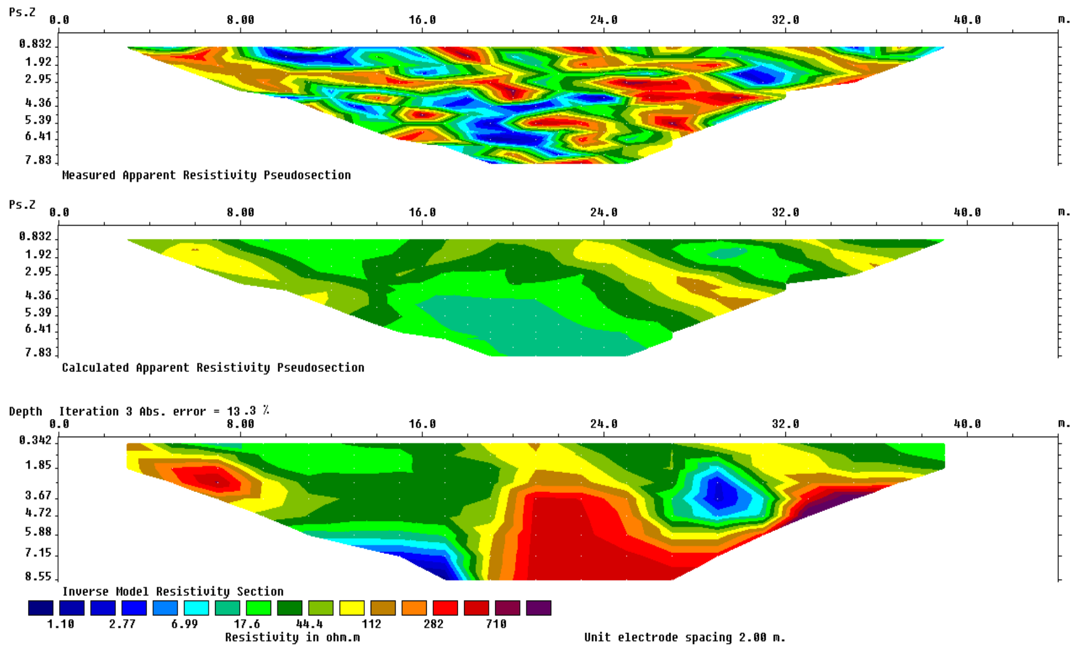

Figure 9- Measured and calculated pseudo sections and inverse model Dipole-dipole resistivity section at ST-3(Robust inversion model constrain).

The fourth station is located in the west of the study area. Figure 10 shows the presence of two caves in the middle of the path and west of the study area, at a depth of 3 and 1 meters, respectively. They are characterized by high resistivity values ranging from 400 to 550 ohm. meters. While Figure 11 shows the same caves but by the Robust inversion model constrain method.

The fifth station is characterized by several small caves spread near the surface, and this indicates that the southern part of the study area has more risks for the buildings to be built in the area (Figure (12, 13).

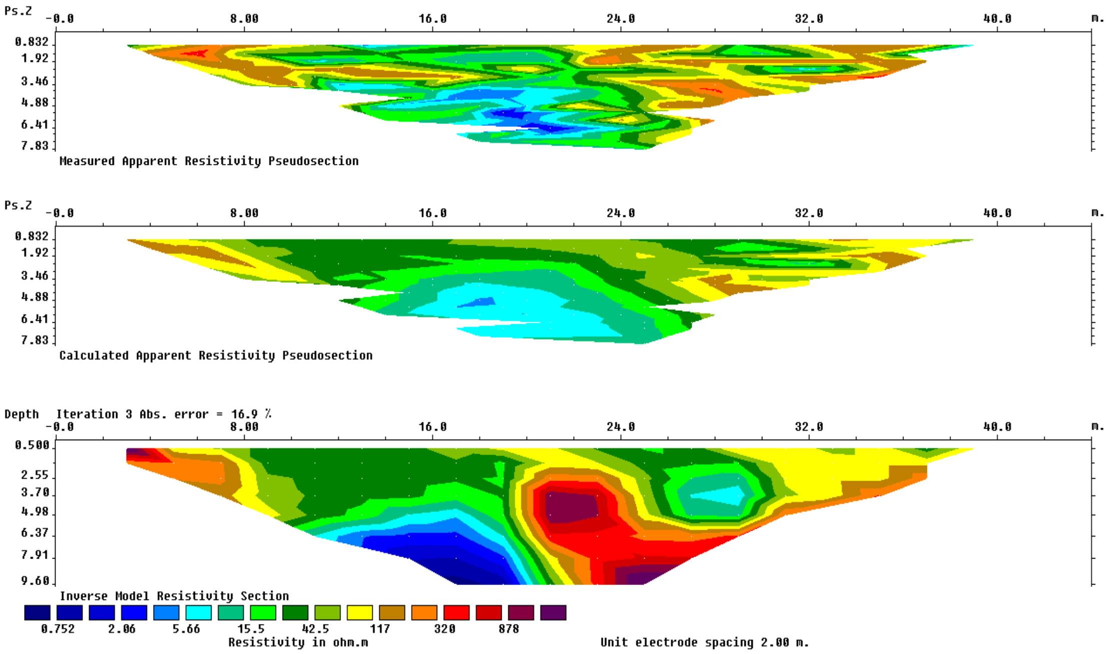

Figure 10- Measured and calculated pseudo sections and inverse model Dipole-dipole resistivity section at ST-4 (Standard least-squares method smoothing constrain).

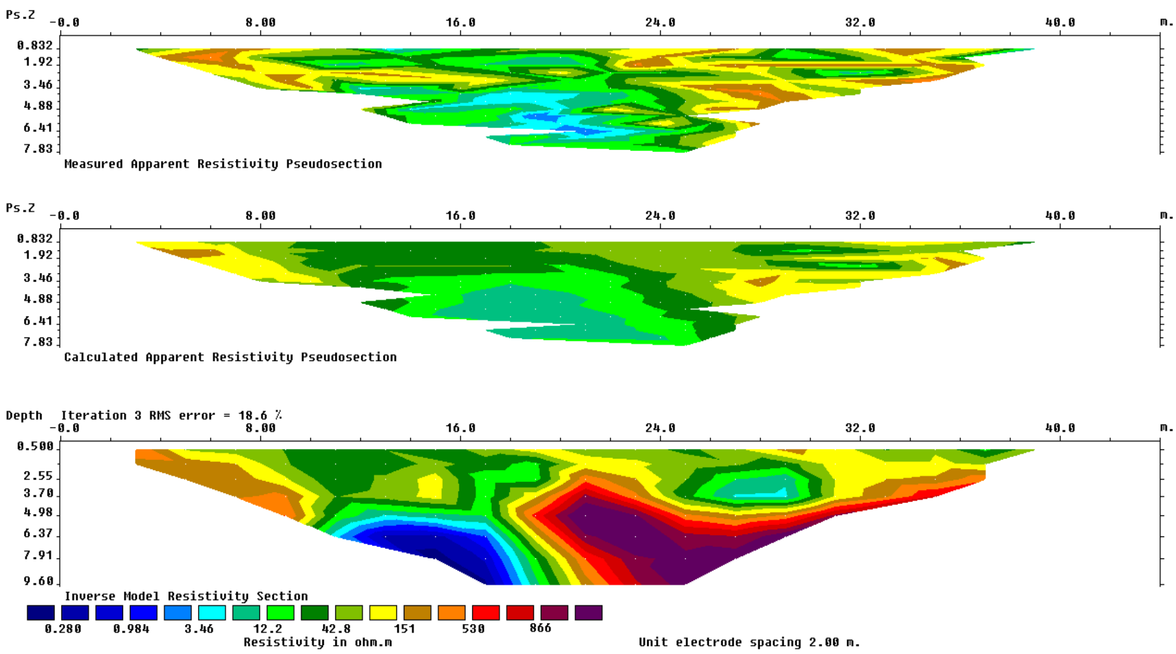

Figure 11- Measured and calculated pseudo sections and inverse model Dipole-dipole resistivity section at ST-4(Robust inversion model constrain).

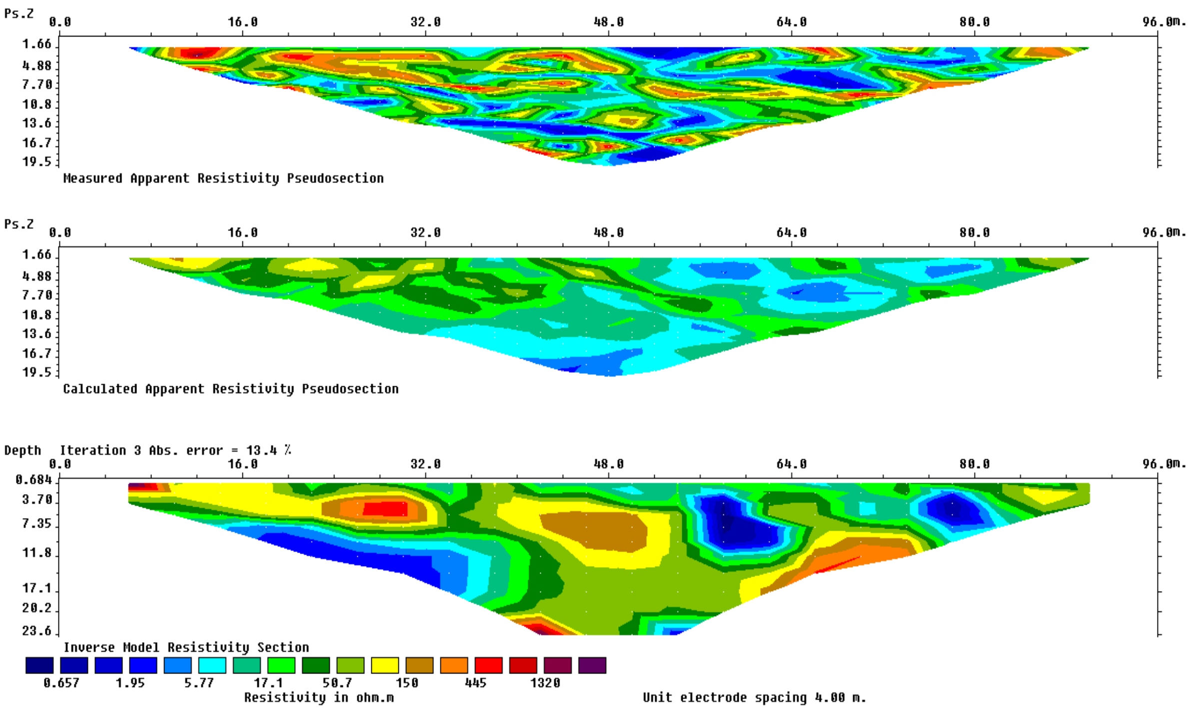

Figure 12- Measured and calculated pseudo sections and inverse model Dipole-dipole resistivity section at ST-5 (Standard least-squares method smoothing constrain).

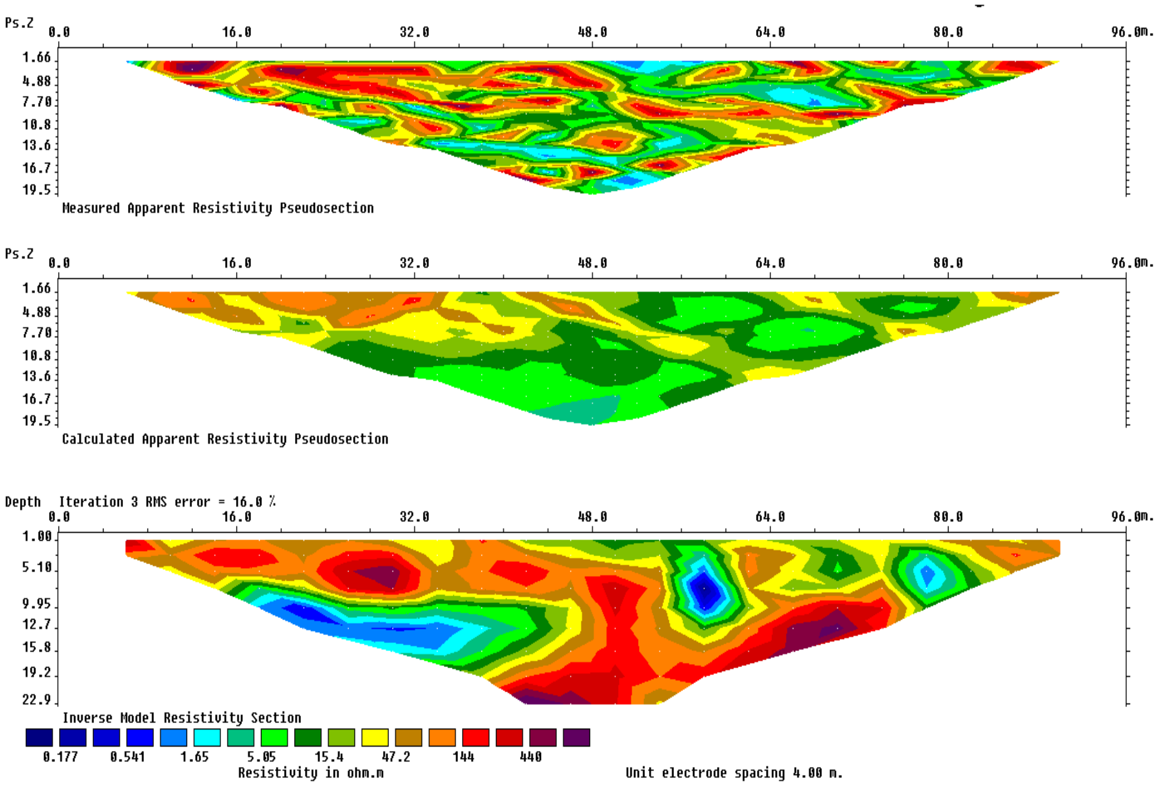

Figure 13- Measured and calculated pseudo sections and inverse model Dipole-dipole resistivity section at ST-5 (Robust inversion model constrain).

From the foregoing, we can conclude that the study area is considered an environmental risk area for buildings represented by citizens' homes or government homes. In other words, the spread of caves near the surface makes the area a dangerous area.

Conclusion

All the 2D Inverse models indicated that the study area was characterized mainly by the presence of many subsurface cavities. These caves are small and shallow, while the large ones extend to great depths, where they are located in the mismatched layer of the Basal breccia unconformity layer between the Anah and Euphrates formations. Two-dimensional resistivity imaging has been applied to detect the depth and extent of the subsurface caves at five stations. The dipole-dipole array is chosen with an electrode spacing of 2 meters. 2D Dipole-dipole imaging inverse models show the resistivity values have a big variation between the anomalous background resistivity of rocks and part of cavities. These models showed shallow cavities at 1 to 3 m depth and others at 5to 6 m depth and extending to a depth of 23 m. Therefore, the RMS and Abs errors of inverse models are distinguished by relatively high values between 14 and 16.9% approximately indicate that the region was characterized by high heterogeneity due to the effect of the random presence of these caves in the area. The standard least- squares and robust constraint methods gave the 2D image of the subsurface with different resolutions. But, the second method shows the expected cavities with more sharp boundaries.

This study confirms that all necessary engineering precautions must be taken before starting any building in the Haditha area. These are technical engineering measures to consider removing the risks of subsurface caves on the foundations of buildings under construction.

Acknowledgments

The authors thanked the Head and members of the Department of Applied Geology for their important geological information when conducting this research. Likewise, they would like to thank the Dean of the College of Science (Anbar University) for providing him with SAS-4000 devices, electrodes, electrode cables, etc., which were necessary for conducting the field survey.

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