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Detection of Haqlaniyah cave within carbonate stratigraphic sequence rocks using 2D resistivity imaging technique, Haditha, western Iraq

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Detection of Haqlaniyah cave within carbonate stratigraphic sequence rocks using 2D resistivity imaging technique, Haditha, western Iraq

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Abstract The western desert of Iraq is characterized by a widespread karst phenomenon and caves. The study area is a site for the establishment of a primary school inAl- Haqlanighah village Haditha area, during leveling the land with a bulldozer, the ground collapsed, causing a hole with a diameter of up to two meters. Two-dimensional resistivity imaging has been applied to detect the depth and extent of the subsurface cave within carbonate rocks and along two cross-image lines in the array of Dipole-dipole and an electrode distance of 5 meters, each length of 105m. 2D Dipole-dipole imaging technique is obtained the inverse models which shows the resistivity variation between the anomalous of background resistivity of rocks and part of cavity is about 750:100 Ω.m. These models showed that the depth 11m at the cavity operator to the roof of cavity. While the actual depth at same location of this cavity measured of 11.35m approximately. The results of this study showed that the extension of the cave along the first track is 52 meters in a direction of west-east, 11 meters depth to the ceiling of the cave, 31-35 meters to the bottom of the cave. While the extension of this cave along the second track is 20 meters in a direction south-north, and the depth to the ceiling of the cave is 12 meters and 32-34 meters to the bottom of the cave. The stratigraphic succession of the study area, starting from bottom withAnah Formation, overlain by unconformity brecciated bed, ranging from 6 to 30m meters in thickness, followed by Euphrates Formation in the top. 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 rain water 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.

1. Introduction

The presence of natural voids and cavities in subsurface carbonate rocks cause severe troubles for civil engineering and environmental management [1].The most plentiful cavities are generated by dissolution in limestone, dolomite, salt, gypsum, and anhydrite. The downward filtered meteoric water is formed Karst features [2].The main type is the sinkholes, which are developed in different shapes and dimensions [3].Channels and voids will develop by penetrated groundwater through weak zones in limestone [4].A final stage is reached, where roof of the cavity space will no longer support the weight of the overburden and other foundations. Sinkholedevelopment has negative and meteoric effects on shallow and deep foundations. The presence of such cavernous features leads to circumscribes in land employment and causes variable geotechnical hazards like ground surface subsidence, collapsing of surface structures and cracks and fissures in the surface buildings [4 and5].

Enormous sinkholes and cavities are found within limestone sediments for Euphrates Formation. Solution of evaporates and carbonate rocks has formed considerable karst areas and cavernous features in Iraqi desert region. Usually, in limestone the shape of the sinkholes is more uniform and larger in comparison to those developed in gypsum [3]. In the former, they are usually circular or elliptical, whereas the walls are either vertical or inclined in different slopes. These give the shape of a cylinder or as a spoon to the sinkhole. In the latter they are very irregular without a distinct shape. The diameter of sinkholes, in limestone ranges from 1-30m, exceptionally may exceed 100m, whereas, the depth ranges from 1-15m, exceptionally exceed 50m[3].

The composition of the Euphrates consists of solid fossil limestone and the family is non-mystical limestone of 90 meters long, thick soft green marble embossed an internal bed with thin beds of Shelly, monocrystalline limestone of 25 meter. The content of the Fatah formation that sits upward from the anhydrite, gypsum and salt sediments is interfered with limestone and sand [6].

Most 2 Dimension imaging surveys have been used for shallow engineering and environmental studies, and in some of the following studies they have been used to uncover subsurface cavities in the world [7, 8, 9,10,11,12 and 13].

There are a few studies that used resistivity method for detecting cavities in Iraq, such as [14] used Wenner array to detect the cavities within gypsum rocks in Hamam Al Alel,north Iraq, Resistivity map was drawn which appeared high positive anomalies; [15] collected two sounding measuring stations one over the known cave and the other at a distance of 80m west the cave were carried out using Wenner and Schlumberger arrays; [16] and [17] study the differences between the two dimension (2-D) imaging resistivity technique and Bristow's method in detecting the accurate dimension of subsurface cavities which is located within Haditha area, western desert,Iraq.Dipole-dipole(n-factor=6 and 8), Wenner-Schlumberger(n=8), and Pole-dipole(n=8) arrays are carried out along traverse over Um El-Githoaa cavity. Another Dipole-dipole(n=6) array is applied along a traverse in Haditha area above WadhahaShamut cavity. [18] carried out 3D resistivity imaging technique above Um El-Githoaa cavity in Hit area, west desert, Iraq. The 2D imaging survey (Dipole-dipole array) was applied with (n) factor and a-spacing of 6 and 2m respectively. Inverted 3D models have got them exposed from standard least-squares method and robust constrain method at Um El-Githoaa cave showed horizontal slices of the 3D resistivity distribution with depth.[19] applied Graphical Bristow's method above K-3 cavity to evaluate the method to image a relatively large natural cavity. The data interpretations detect the cavity elongate along W-E traverse of about 58.6m with an error less than 3% in depth and 2% in height.

The purpose of this study is to use two-dimensional imaging technology to detect and locate Al-Haqlaniyah subsurface cavity in Haditha area, Western Desert, Iraq. And determine the relationship between the formation of this cave and the caves of the surrounding area with the stratified column sequence of the study area.

2. Description site and stratigraphy

The study area is located at southern Al- Haqlaniyah village within Haditha area, western Iraq (Fig. 1). Al- Haqlaniyah cavity, within carbonate rocks of Euphrates Formation (Early – Middle Miocene), is caused by bulldozer when it leveled the ground to build a primary school. The cavity is found in karst area of 35m depth to the bottom, and it is located at dry ground surface and high lateral in homogeneity of carbonate sediments.

Anah Formation (Late Eocene) and Euphrates Formation (Early–Middle Miocene) are the main stratigraphic succession in the study area. Anah Formation consists of varied color of hard, massive, coralline, fossiliferous limestone. This is followed by thick bed (4 to 19 m) of brecciate unconformity with surrounded of limestone boulders and pebbles, mainly derived from Anah Formation [20 and 21]. Euphrates Formation which is overlain the brecciate rocks consist of hard, well bedded, crystalline fossiliferous limestone, followed by white hard dolomitic limestone and green marl in the top. Sinkholes and caves are developed in the unconformity brecciate bed (the contact between Anah Formation and Euphrates Formations).

3. Data acquisition

Parameters of 2D imaging survey, a-spacing, n-factor parameters, and depth of investigation, have got them by ElectrePro program before carrying out the field work (this program is determent by IRIS Instruments, and it is a software allowing us to format 2D /3D and borehole sequences of resistivity measurements).

Near the aperture of the cavity, the average depth from the ground surface to its roof is 11.5m, and to the bottom is 35m approximately.2-D Geoelectrical resistivity imaging technique is used to collect apparent resistivity measurements along two traverses, East-West traverse and a perpendicular traverse in North-South direction above the cavity. The Terrameter SAS 4000 instrument was used to measure apparent resistivity in the field. The 2D imaging survey is done by Dipole-dipole array, n-factor of 6 and a- spacing is equal to 5m. Dipole -dipole array was selected depending on previous studies [17 and 18]. The cavity is well defined from 2D imaging of Dipole –dipole array.

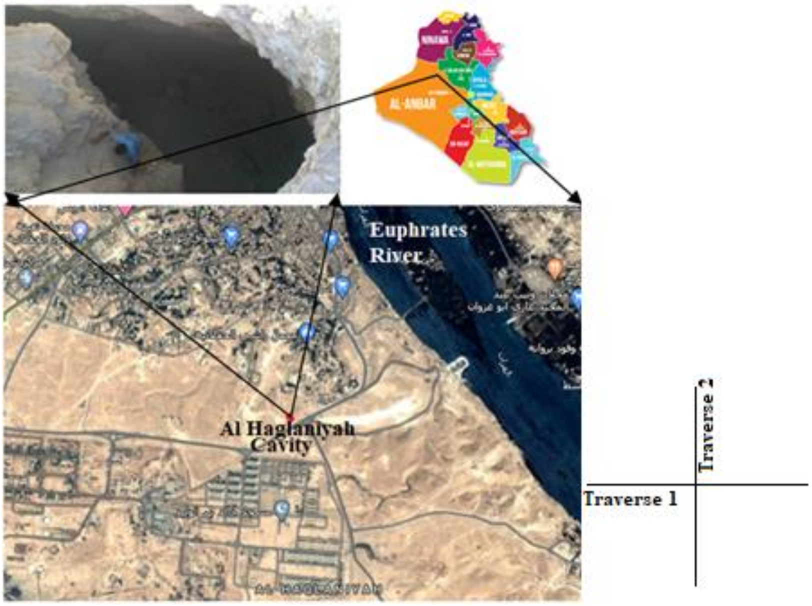

Fig.1 Location map of the studied area

4. Data Processing

The conventional least-squares method will try to lessen the square of leagues between the measured and calculated apparent resistivity values [22 and 23]. If the data has indiscriminate noise it comes from the effect of telluric current this method normally gives plausible results. However if the data set includes systematic noise from sources such equipment quandaries or blunders. This data is fewest satisfactory, and like these data points that could have a great influence on the resulting inversion model. The absolute divergence (first power) between the measured and calculated apparent resistivity values is minimized by an inversion method which can be applied to reduce the influence of the data points [24].

The unsolicited data points with systematic noise is shown up as blotches with unusually low or high resistivity values in the measured apparent resistivity pseudo section and can be readily erased them from the data set .The unsolicited data in section form of Dipole-dipole array contains random noise may come from sources such as mistakes in measurements or equipment problems, or due to lateral in homogeneity of sediments which is considered the main reason of noise, and it removed from data of the two traverses. The bad data along traverse W-E less than traverse S-N.2D measurements fixture to deport process to model the true distribution of resistivity values for the designated geology. The masterminded least-squares optimization method is commonly used in the inversion algorithms to overcome the problem of non-uniqueness [25]. If the data set is too noisy, a larger damping factor is applied. If the data set is the least noisy can be applied a smaller elementarily damping factor [26]. A higher elementarily damping factor could be 0.15, and a higher minimum damping factorof 0.02 and a higher damping factor for the first layer of 2.5.

The filter ratio weight of Vertical / Horizontal flatness was utilized of 1. If the main anomalies in apparent resistivity pseudo section are elongated horizontally, it must choose a smaller weight than vertical filter [23]. So, the flatness filter was chosen weight of 0.5.

The third important parameter is using Robust Inversion. From this the fineness constrains can be selected. The conventional least-squares method will try to reduce the variation square between the measured and calculated reading values. While the robust values constrain option will attempt to curtail the utter difference (or the first power) between the measured and calculated reading data (Claerbout and Muir, 1973).

5. Result and discussion

By RES2DINV program version 3.56.22[27], the 2D resistivity observed data was interpreted. A non-linear least-squares optimization technique is applied for data inversion, while the apparent resistivity values are measured by usage a forward modeling. The inverse model produced by the standard least-squares method has a gradational boundary for the cavity. The cavities boundaries are showed sharper and straighter by robust constrain method. The results of 2D imaging data along two intercrossing traverses as shown in Fig.2 and Fig.3 indicate that the resistivity contrast between the anomalous part of cavity and background resistivity is about 750:100 Ωm.

The inverse model is the true image that is used for interpretation.The RMS error indicates the calculated pseudosection is the best fit to the measured pseudosection, so it is preferable to reduce it as much as possible. Fig. 2 shows depth of the cavity equals to 11m approximately at a distance 54m near the cavity operator in the inverse model of traverse W-E, which is equal to actual depth (11.5m). While Fig. 3 shows the inverse model of traverse S-N , the depth of the cavity at a distance 50m near the cavity operator equals to 10.5m approximately. So, the cavity is well defined in comparison with the actual depth of this cavity at the operator, which is equal to 11.2m. Addition, the obtained information about the subsurface Al-Haqlaniyah cavity along resistivity cross-section was interpreted based on high resistivity values in two traverses.

Investigation of the inverted 2D traverse W-E revealed the cavity at different depths of 8-11m roof depths and 32.2-35.2m bottom depths (Fig. 2). Whereas, it was delineated along traverse W35N, roof and bottom depths are ranges 9-11m and 31-35m respectively(Fig. 3).Lateral in homogeneity of carbonate rocks, and some of these rocks visible on ground surface are caused the RMS error fairly high of19.0% with robust model inversion method of this model.

The stratigraphic study yielded results almost identical to the geophysical study. The stratified column was constructed by calculating the true thickness at the mouth of the cave that resulted from the weight of the bulldozer. Where he started measuring from the bottom of the hole, which was at a depth of 31 meters. The Anah Formation represents the bottom of the hole, which is represented by a visible thickness of 1 m. It consists of limestone recrystalized coral reef, as coral colonies appear in different forms.

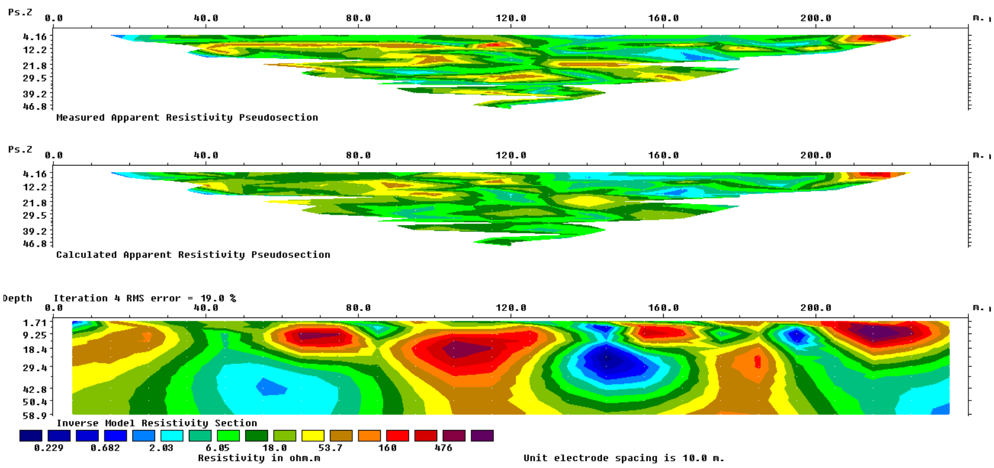

Fig. 2 Dipole-dipole resistivity section along traverse W-E.

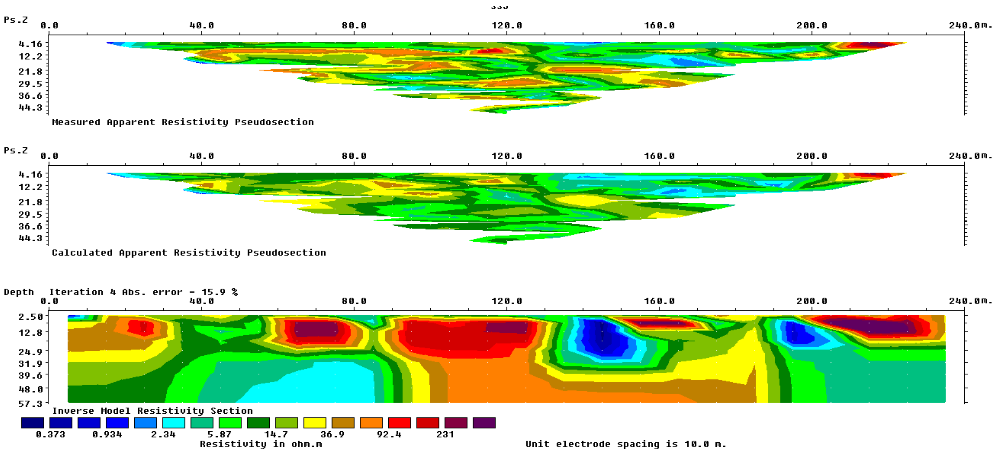

Fig.3 Dipole-dipole resistivity section along traverse W35N.

Followed by the Euphrates Formation layers, the lower part is compiled by brecciate base layer which consists of limestone with sharp edges of various sizes and is 19 meters thick. Topped with well-bedded, limestone rocks turn into dolomitic limestone rocks of 5 meters thick, followed by chalky limestone rocks with a little shale in the upper parts. This layer is surmounted by a crushed, recrystalized hard rock, with a thickness of 1 m, which is the highest part of Euphrates formation (Fig.4).

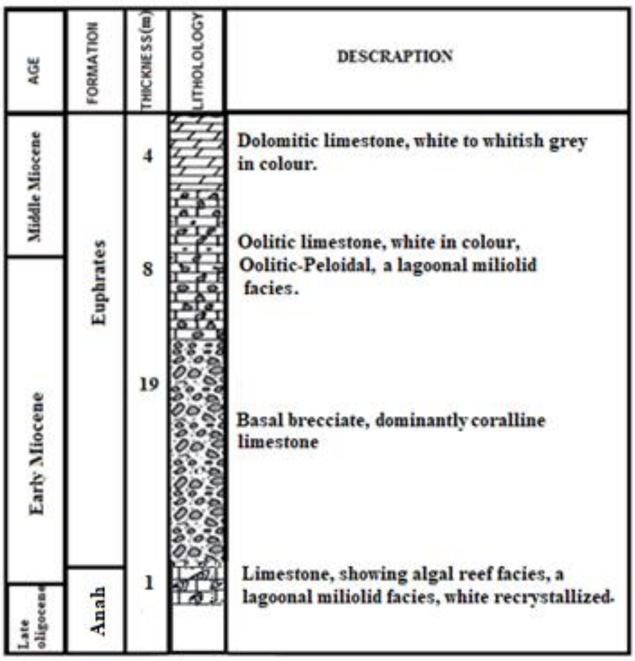

Fig. 4 Stratigraphic column of the study area.

6. Conclusions

The western part of Iraq, which consists mainly of carbonate rocks, has great developing activities. Sinkholes and caves are formed in the unconformity contact, brecciate zone, between Anah Formation and Euphrates Formation. This study shows some important results which are given as conclusions:

1. The resistivity contrast between the cavity anomalous part and resistivity background is equal about 750:100 Ω.m in the Dipole-dipole array inverse model. This reflects the in homogeneity between the rock components surrounding the cave and the space inside it

2. The inverse models showed that the depth from ground surface to the upper roof equals nearly to 11mof the Al- Haqlaniyah cavity. This result agrees with the depth as it is known from the mapping of cavity under the traverses in the field near the cavity operator, which equals to 11.5m approximately.

3. The cavity can be investigated clearly along two traverses W-E and W35N which has range of roof and bottom depths 8-11m and 31-35m respectively. .

4. 2D imaging survey is a handy technique and more operant for detecting and delineating subsurface cavities, by a suitable a-electrode spacing and n-factor for Dipole –dipole array.

5.The Stratigraphic succession of the study area begin with 1m of Anah Formation (Late Oligocene) followed by 19m of unconformity basal brecciate layer represent the void of cave, and is topped with 12 m thick of Euphrates Formation.

6.The cave was resulted from the dissolution of the components of the basal Brecciate layer by groundwater and rain water leaking into the interior. In the Stratigraphical succession, a cave height ranges between 16-19 meters, and extends 55 meters to the west-east.

7.The results of the study show a very close match with the cave height at the aperture site of both techniques: inverse model resulting from the 2D resistivity imaging inverse model resulting from the 2D resistivity imaging technique and the Stratigraphic succession of the study area.

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