Iraqi Journal of Science
ISSN: 0067-2904
GIF: 0.851

Delineation of K-3 Cavity Using 2D Imaging Resistivity Technique in Haditha Area (Western Iraq)

Ali Mishaal Abed[1*], Jassim M. Thabit[2]
[1]Department of Applied Geology, College of Science, University of Al- Anbar, Ramadi, Iraq
[2]Department of Geology, College of Science, University of Baghdad, Baghdad, Iraq

Abstract
The 2D imaging survey was conducted across an unknown K- 3 cavity that is located in Haditha area-Western Iraq.2D measurements are collected along two intercrossing traverses above the cavity with 105m length of each one. Dipole-dipole array is performed with n-factor of 6 and a-spacing equals to 5m. The inverse models of 2D imaging technique showed clearly that the resistivity contrast between the anomalous part of cavity and background resistivity of rocks is about 800:100 Ωm .In addition, the invers models showed that the depth from ground surface to the upper roof of cavity approximately equals to 11m near the cavity operator. So, the K-3 cavity is well defined from 2D imaging with Dipole –dipole array in comparison with the actual depth of this cavity which equals to 11.5m approximatly.It is concluded that the 2D imaging is a useful technique and more effective for determining and mapping subsurface cavities, when the suitable a-electrode spacing and n-factor for the Dipole –dipole array are taken in consideration.

Keywords: 2D imaging technique, Dipole-dipole array,K3- cavity, Haditha area,Iraq.

تحديد فجوة K3 بأستعمال المسح التصويري الثنائي البعدين في منطقة حديثة غرب العراق

علي مشعل عبد[1*]، جاسم محمد ثابت[2]
[1]قسم علم الأرض، كلية العلوم، جامعة بغداد، بغداد، العراق
[2]قسم الجيولوجيا التطبيقية، كلية العلوم، جامعة الأنبار، الرمادي، العراق

الخلاصة
تم أجراء المسح الثنائي البعدين فوق فجوة K-3 الواقعة في منطقة حديثة- غرب العراق . أخذ ت القياسات للمسح الثنائي البعدين بأمتداد مسارين متقاطعين فوق الفجوة ويبلغ طول كل مسار 105 مترا". وأستعمل ترتيب ثنائي القطبين (Dipole-dipole array) وتم تحديد المسافة القطبية (a) والعامل (n) وكانا يساويان 5 مترا" و6 مترا" على التوالي . أظهرت الموديلات المعكوسة الثنائية البعدين وجود فرق واضح في المقاومة النوعية بين الفجوة والصخور المحيطة بها وكان بحدود 800 : 100 أوم.متر، كذلك أظهرت هذه الموديلات أن العمق الى السطح العلوي للفجوة يساوي 11 متراً تقريبا قرب فتحة الفجوة وهذا العمق يساوي العمق الحقيقي الى الفجوه والذي كان بحدود 11.5 متراً. وتم التوصل الى أن التصوير الثنائي البعدين يمكن أن يكون مفيد وفعال في تحديد الفجوات تحت السطحية عندما يؤخذ بنظر ألأعتبار أختيار القيم المناسبة للفاصلة القطبية (a) والعامل (n) الى الترتيب الثنائي القطبين.

*Email:ali_mishal2001@yahoo.com

Introduction:

In construction civil engineering,it is necessary to identify any cavities beneath the construction area, these cavities could cause undesired effects at the ground surface such as subsidence or collapse [1-6].K-3 cavity is located in Haditha area-western Iraq Figure-1. It is caused by bulldozer when it leveled the ground to build a primary school. This cavity is developed in karst area with 35m depth to the bottom ,and it is located in area with dry ground surface and high lateral inhomogeneity of sediments Figure-2. Hazard situation comes from the increased need to detect subsurface cavities and map depth to bedrock for geotechnical applications such as foundation planning and construction. Detection and delineation of subsurface cavities and abandoned tunnels using geophysical methods have gained wide interest in the last few decades.

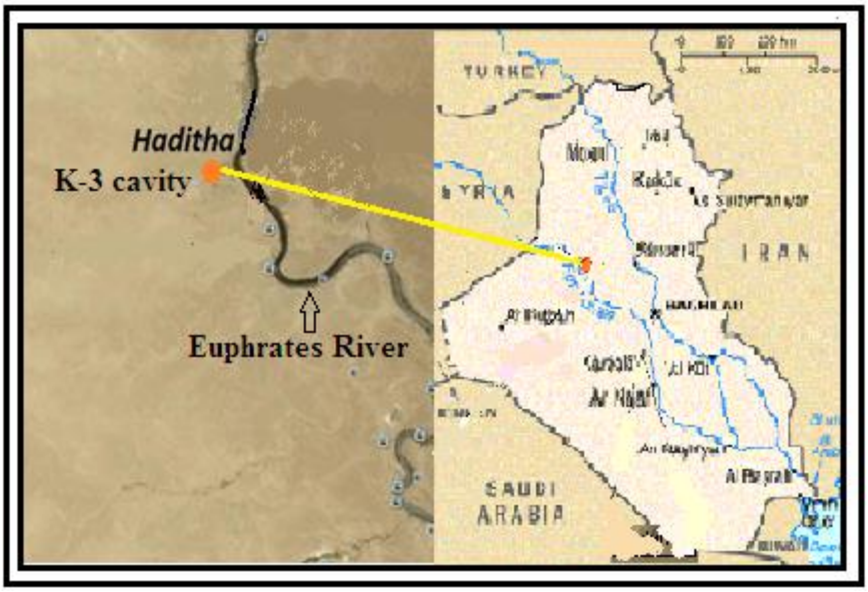

Figure 1- location map of the studied area.

Figure 2-Photograph of the operator K-3 cavity in Hadith area.

Euphrates and Fatha Formations include enormous sinkholes and cavities within gypsum and carbonate rocks. Anah Formation was defined by [7] from the Euphrates valley about 15 km west of Al-Nahiyah village near Anah[8]. The lithological section comprises of grey brecciated, recrystallized, detrital, and coralline limestone. Figure-3 shows the stratigraphic succession of the formations in Haditha area, also Figure-4 shows photograph of the stratigraphic succession of formations in the same area.Euphrates Formation is the most widespread formation of the sequence.

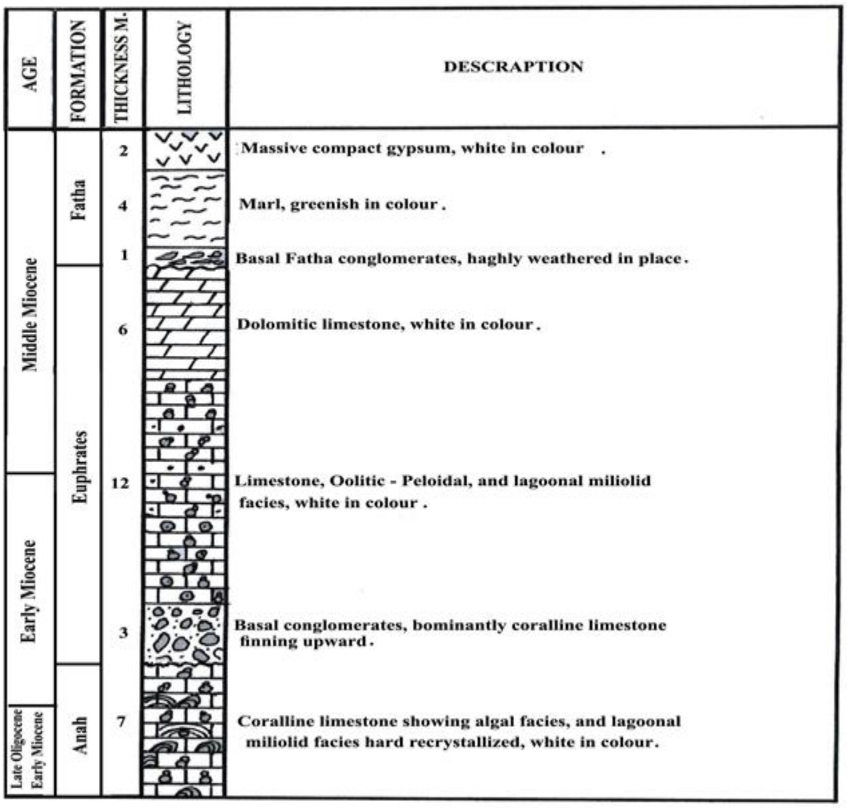

Figure 3- Lithological section of the Haditha area[8].

Figure 4- Photograph shows the stratigraphic succession of formations in Haditha area.

Two supplementary type sections were described in Chabbab valley, 39km West of Anah, and in Rabi valley, 20km of Husaiba. The first section is 110m thickness and represents the lower and middle units of the formation. The second is 25m thickness and represent the upper unit of the formation.The combined section comprises:

1. Lower unit: 20m thick basal conglomerate sub rounded boulder and cobbles of limestone derived from the underlying Oligocene Anah Formation, followed by 10m of recrystallized fossiliferous limestone grading into coralline limestone. Sinkholes and caves are well developed in a brecciate zone, which representing the contact between Anah Formation and Euphrates Formations.
2. Middle unit: 90m of hard fossiliferous limestone and pseudo-oolitic limestone beds.

3. Upper unit: 25m thick soft fossiliferous bluish green marl, inter bedded with thin beds of shelly, recrystallized limestone or shelly oolitic limestone.Fatha Formation comprises of anhydrite, gypsum, and salt deposits, interbedded with limestone and marl[9].

There are few previous studies in Iraq that used resistivity method for detecting subsurface cavities, such as [10] used Wenner array to detect the cavities in Hmam Al-Alel, north Iraq.The Resistivity map was drawn, and displayed high positive anomalies of cavities were present within gypsum rocks of Fatha Formation. Al-Gabery[11] measured two sounding stations, one over the known cave in Rawa area (W- Iraq), and the other at a distance of 80m west of the cave were carried out using Wenner and Schlumberger arrays. Also, twelve horizontal profiles, along each profile the resistivity measurements were carried out using Wenner, Schlumberger and Pole-dipole (Bristow's method) arrays. The best result was obtained from the Pole-dipole array by using graphical Bristow method. Abed [12] compared between Bristow's method and 2D imaging technique to detect the accurate depth and shape of subsurface cavities in Haditha-Hit area.It is found that the Graphical Bristow's method and 2D imaging surveys have different ability in detecting subsurface cavities.

Thabit and Abed [13] evaluated different electrode arrays in delineation subsurface cavities by using 2D imaging technique .It is concluded that all electrode arrays can detect the subsurface cavity with different shape and accuracy. But, the Dipole –dipole array is the best. Thabit and Abed [14] applied 3D resistivity imaging survey to delineate Um El-Githoaa cavity in Hit area, Western Iraq.The 3D resistivity imaging survey was delineated Um El-Githoaa cavity at depths ranges from 3 to 6 m. It is concluded that, the dense measurements along 2D lines in small area can be increasing the 3D imaging resolution.

Most 2D (Two Dimension) imaging surveys had been used for shallow engineering and environmental studies, and in the following some previous studies are used in detection of subsurface cavities in the world[3,15-27].

2D imaging is considered as one of the most powerful techniques to detect cavities in karst region, due to low coast and high resistivity between cavity and background formation[17,28, 29].The purpose of this study is used 2D resistivity imaging technique in detecting and delineating subsurface cavity in area with dry ground surface and high lateral inhomogeneity of sediments.

Field work:

ElectrePro program is used to select the parameters such as a-spacing, n-factor, and depth of investigation before carrying out the field work (this program is designed by IRIS Instruments, and it is a software allowing us to create 2D /3D and borehole sequences of resistivity measurements). The most important parameters are a-spacing and n-factor of array. The main object of these parameters is to select the suitable sequence to achieve real subsurface imaging. In 2D imaging each array has advantages and disadvantages for investigation depth, data coverage, signal strength, and sensitivity function to vertical and horizontal change in resistivity [17,30].

The K-3 cavity is located at Haglania village within Haditha area. It is situated in an area surrounded by carbonate rocks within the Euphrates Formation. Near the cavity operator the average depth from the ground surface to the roof of the cavity is 11.5m, and to the bottom is 35m approximatly.

Two-dimension imaging survey is done along two intercrossing traverses (1 and 2) which run over the cave room Figure-5. The Terrameter SAS 4000 instrument was used for measuring apparent resistivity in the field. The 2D imaging survey was carried out by Dipole-dipole array for n-factor equal to 6.When the data is collected by this array the maximum electrode spacing (a) is equal to 5m with a total array expanding of 105m.We selected Dipole -dipole array depending on previous studies [12,13] who applied 2D imaging survey with Pole-dipole, Schlumberger, and Dipole-dipole arrays above Um El-Githoaa cavity near Hadith area. It is found that all electrode arrays can detect the subsurface cavity with different shape and accuracy. But, the Um El-Githoaa cavity is well defined from 2D imaging of Dipole –dipole array.

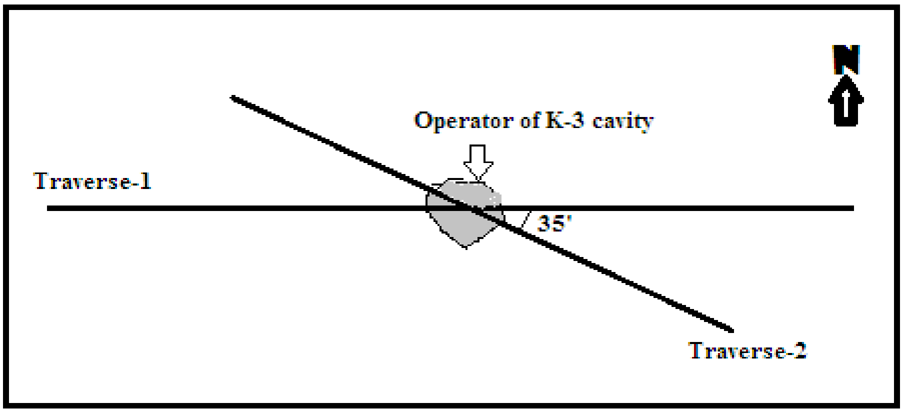

Figure 5-Sketch showing locations of the traverse survey lines above the K-3 cavity

Data Processing:

The bad data is usually more common with the Dipole-dipole array arrays,which have very large geometric factors, and thus very small potential measurements for the same current.

The conventional least-squares method will attempt to minimize the square of difference between the measured and calculated apparent resistivity values [31,32]. This method normally gives reasonable results if the data contains random noise comes from the effect of telluric current. However if the data set contains nonrandom(systematic)noise from sources such mistakes or equipment problems, this situation is less satisfactory, and such data points could have a great influence on the resulting inversion model.To reduce the effect of such data points, an inversion method where the absolute difference (or the first power) between the measured and calculated apparent resistivity values is minimized can be used [33].

In general, before carrying out the inversion of a data set, it should first take a look at the data as a pseudosection plot Figure-6a as well as a profile plot Figure-6b. In measured apparent resistivity pseudosection, the bad data points with systematic noise is shown up as spots with unusually low or high resistivity values Figure-6a. In profile form, they stand out from the rest and can be easily removed from the data set Figure-6b. The bad data in profile form of Dipole-dipole array contains random noise may come from sources such as mistakes in measurements or equipment problems, or due to lateral inhomogeneity of sediments which is considered the main reason of noise,and it removed from data of the two traverses. The bad data along traverse-2 less than traverse-1.

Apparent resistivity measurements of 2D imaging need to further process to model the true distribution of resistivity values for the specific geology. The Inversion programs use mathematical algorithms to produce a subsurface resistivity model that will best fit the apparent resistivity data set. To overcome the problem of non-uniqueness (many models fit the data equally well), the regularized least-squares optimization method is commonly used in the inversion algorithms[31] .

If the data set is very noisy, a relatively larger damping factor is used. If the data set is less noisy can be used a smaller initial damping factor [34]. Here a higher initial damping factor was used to be 0.15, and a higher minimum damping factor equal to 0.02. Additionally a higher damping factor was used for the first layer to be 2.5.The inversion subroutine will generally reduce the damping factor after each iteration.

Another important sub option is (Vertical / Horizontal flatness filter) ratio weight of 1. If the main anomalies in apparent resistivity pseudo section are elongated horizontally, it must choose a smaller weight than vertical filter[30] . So, the flatness filter was used weight of 0.5.

The third important parameter is selecting Robust Inversion. From this the smoothness constrains can be selected. It must be either (the standard least-squares method) or (robust constrain method). The conventional least-squares method will attempt to minimize the square of difference between the measured and calculated apparent resistivity values. The robust data constrain option will attempt to minimize the absolute difference (or the first power) between the measured and calculated apparent resistivity values[33] .

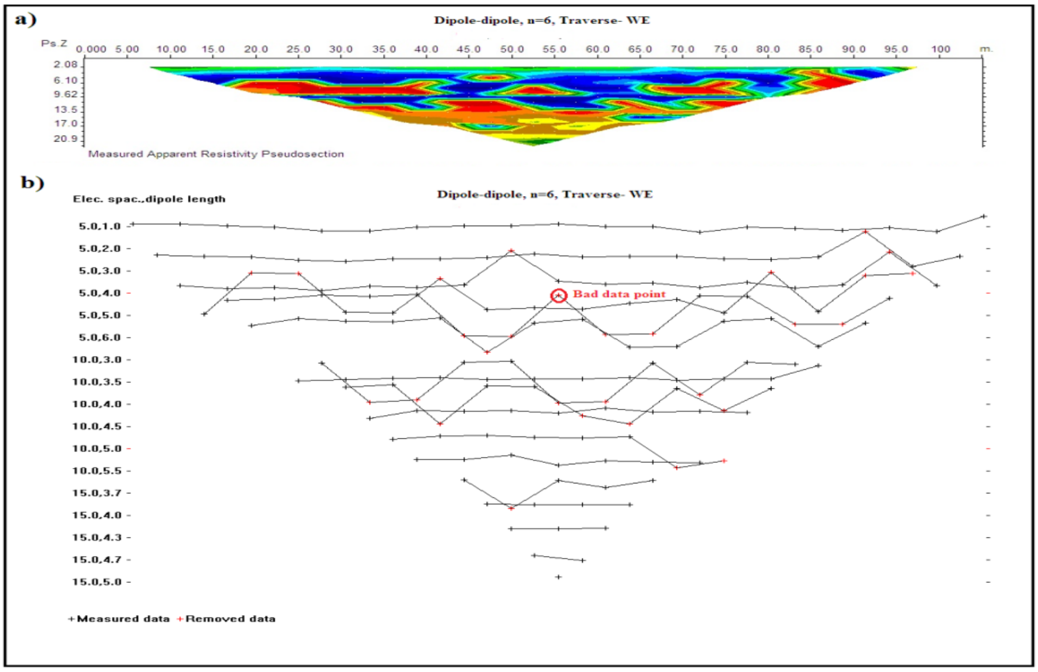

Figure 6- Field data set with a few bad data points of Dipole-dipole array along traverse-1 (WE) above K-3 cavity. The apparent resistivity data in (a) pseudosection form, and in (b) profile form.

Interpretation and Results:

The 2D resistivity data were interpreted using the RES2DINV program [35]version 3.56.22. A forward modeling is used to calculate the apparent resistivity values, and a non-linear least-squares optimization technique is used for inversion of data.The inverse model produced by the standard least-squares method has a gradational boundary for the cavity. While, the invers model produced by the robust constrain method has sharper and straighter boundaries.

The interpretation results of 2D imaging of Dipole-dipole data along two intercrossing traverses as shown in Figures-7 and 8 , they clearly indicate that the resistivity contrast between the anomalous part of cavity and background resistivity is about 800:100 Ωm. The inverse model produced by the robust model inversion method has sharper and straighter boundary for the cavity.

The inverse model is the true image that is used for interpretation.The RMS error indicates how well the calculated pseudosection is fit to the measured pseudosection, so it is preferable to reduce it as much as possible. But in some cases this is not true, especially if there is a high amount of geological noises, and the noise is usually more common with Dipole –dipole array that have a very large geometric factor, and thus very small reading between potential electrodes [31,30]. From the inverse model of traverse-1 (Figure-7), the depth of the cavity equals to 11m approximatly at a distance 55m near the cavity operator, which is equal to actual depth (11.5m).

The inverse model of traverse-2 (Figure-8) shows that the depth of the cavity at a distance 50m near the cavity operator equals to 10.5m approximately. So, the K-3 cavity is well defined from 2D imaging with Dipole –dipole array in comparison with the actual depth of this cavity, which is equal to 11.2m.

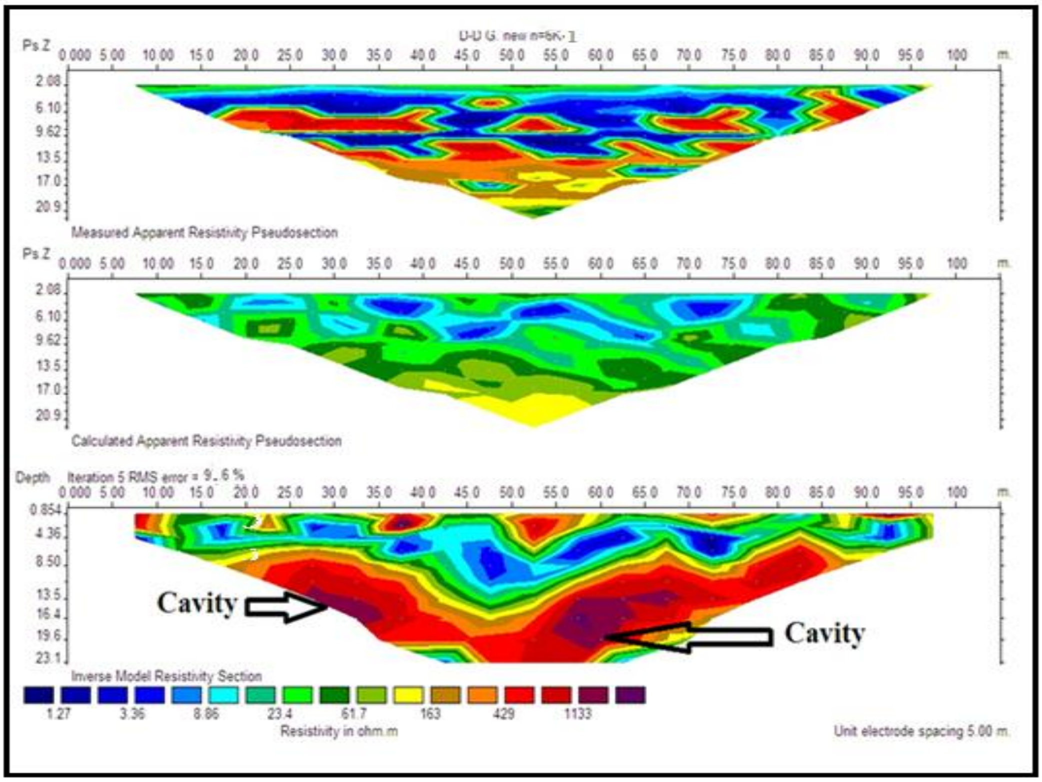

Figure 7- Measured and calculated pseudo sections and inverse model of Dipole-dipole resistivity section along traverse-1in direction(E-W).

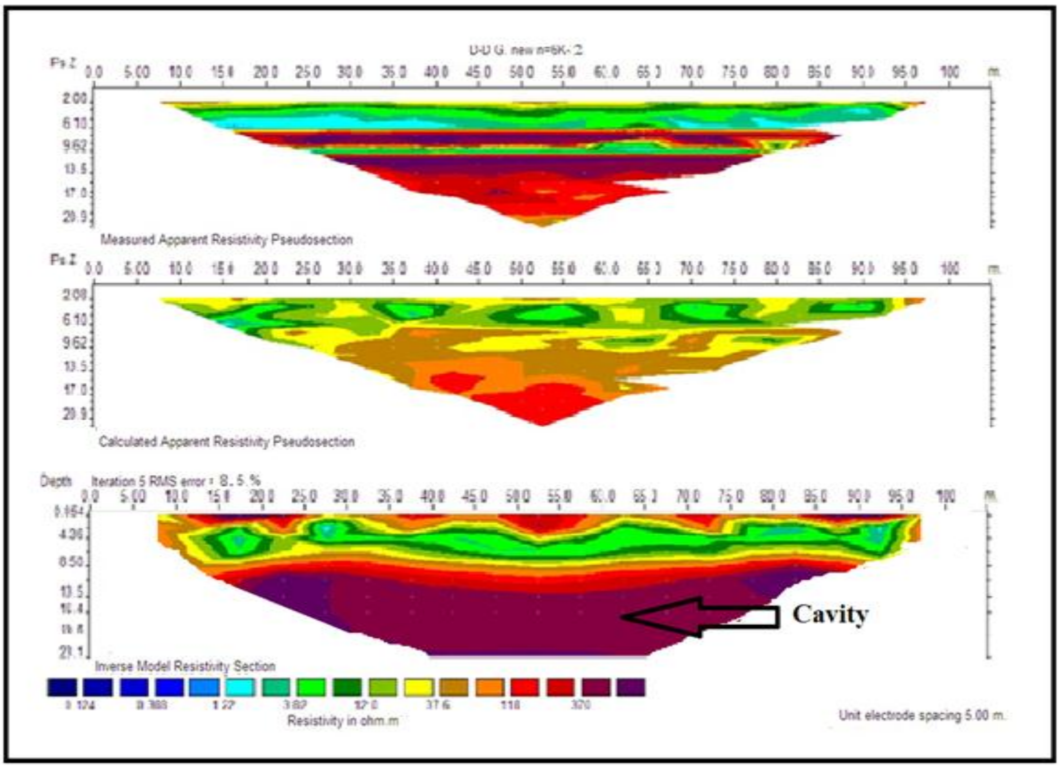

Figure 8- Measured and calculated pseudo sections and inverse model of Dipole-dipole resistivity section along traverse-2 in direction (NW-SE).

The depth of the cavity along this traverse is ranged from 10m to 11m approximatly. The RMS error is fairly high equal to 8.5% with robust model inversion method of this model, which may be a result of lateral inhomogeneity of carbonate rocks, and some of these rocks visible on ground surface.The inverse model along traverse-2 shows the best image of cavity may due to the data measurements less affected by noise especially the lateral inhomogeneity.

Conclusions:

1. The inverse model of Dipole-dipole array clearly shows that the resistivity contrast between the anomalous part of cavity and background resistivity is about 800:100 Ωm.
2. The K-3 cavity is well defined from 2D imaging of Dipole –dipole array, the inverse models showed that the depth from ground surface to the upper roof equals nearly to 11m. This result agree satisfactorily 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 approximatly.
3. We concluded that the 2D imaging survey is a useful technique and more effective for determining and mapping subsurface cavities, when using suitable a-electrode spacing and n-factor for Dipole –dipole array.

Acknowledgments:

The authors are grateful to thank the College of Science and Head of Geology Department – Baghdad University. We would like to thank dean of Science College and the staff of Applied Geology Department – Anbar University for providing requirements for achieving the field work. Finally we would like to thank our friends, senior geologists (Mohammed M. A. Al Hameedawie, and Ahmed Srdah AL-Zubedi), and Baraa Y. Hussein for helping us in the field work and providing necessary information concerning the studied area and this work.

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