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Evaluation of Pole-dipole technique (Bristow's method) to detect the dimension of K-3 cave in Haditha area -west Iraq- Case study

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ABSTRACT

K-3 solution cavity is located within Haditha area, Western Iraq. The measurements of Graphical Bristow's method were carried out by using Pole-dipole array, to evaluate the method to detect the dimension of a relatively large natural cave. The cave resulted due to the dissolve of carbonate rocks within Euphrates Formation (Miocene). The actual depth and height of the cave are 38.8m and 29.5m respectively.

Two traverses with a-spacing equal to (5m) and length of about 100m are achived, in South- North and West -Eest direction above the cave site. The data interpretation detect the cavity elongate along West -Eest traverse of 58.6m and indicate an error not exceeded 3% in depth and 2% in height values. The results are concluded that this method is useful to be able to detect subsurface cavities and voids.

Keywords: *Bristow's method, Pole-dipole array, Electrode spacing-a, Cavities.*

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تقيم تقنية قطب- قطبين(طريقة برستو) في استكشاف إبعاد كهف كي ثري في منطقة حديثة-غرب العراق(دراسة واقعية)

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الملخص

تقع منطقة الدراسة جنوب مدينة حديثة غرب العراق. آخذت القياسات بطريقة برستو بالاعتماد على ترتيب قطب –قطبين ،وذلك لتحديد الشذوذ الناتج عن تأثير كهف K-3 ضمن صخور تكوين الفرات الكربونية (عمر المايوسين). يصل عمق الكهف حوالي (38.8متر) وارتفاع (29.5متر). توزعت القياسات على امتداد مسارين ،الأول باتجاه جنوب–شمال والأخر بأتجاة غرب–شرق فوق موقع الكهف بفاصلة قطبية (a) تساوي (5متر) وطول (100متر). أستطاع تفسير المعطيات الملحوظة من تمييز شذوذ الفجوة بنسبة خطأ لا تتجاوز 3% للعمق و نسبة خطأ 2% للارتفاع،والكشف عن امتداد الكهف باتجاه المسار غرب–شرق بطول (58.6متر). النتائج دلت على ان هذه الطريقة مفيدة في الكشف الكهوف والقنوات التحت سطحية.

الكلمات الدالة: طريقة برستو، ترتيب قطب–قطبين، الفاصلة القطبية (a)، كهوف.

1.INTRODUCTION

Detection and delineation of subsurface cavities and abandoned tunnels using geophysical methods have gained wide interest in the last few decades. The most widely used surface methods include electrical resistivity, electromagnetic, gravimetric, seismic techniques and recently GPR method. Of these methods, the resistivity methods is the Bristow's technique. There are some researches such as [5], which applied the Pole-dipole electrode array in a manner which allowed direct resistivity has been the most extensively used [1, 2, 3, 4, 5, and 6].One of the graphical interpretation of the cavity targets in approximate depth, position and size. Using this method in field studies, Bristow was able to describe the approximate position of several known passages over karst terrains. [7] were able to detect both air-filled and mud-filled cavities, and [8] successfully delineated air-filled cavities, all of which are confirmed by drilling. [9], [10], [11], [12], and [13] concluded that the Bristow method is a powerful tool not just for detection, but also for delineation of cavities, and it is probably the most sensitive electrical resistivity technique advanced for those purposes. There are few previous studies in Iraq that used resistivity method for detecting cavities; for example [14] used Wenner array to detect the cavities in Hamam Al- Aleel, north Iraq. The resistivity map was drawn which appeared high positive anomalies, where that present of the cavities within gypsum rocks. [15] Achieved two electrical sounding survey, one over known cave 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 which resistivity measurements were carried out using Wenner, Schlumberger and Pole-dipole (Bristow's method) array configurations. It is concluded that the best result was obtained from the Pole-dipole array configuration by using the graphical Bristow method.

Another resistivity method is 2D (Two Dimension) imaging surveys, which have been used for shallow engineering and environmental studies, and in following some previous 2D imaging studies are used in detection of subsurface cavities in the world [16, 17, and 18].However, 2D imaging has a high cost in comparison with Bristow technique.

In the present study, Bristow's method technique is applied in detecting a natural-formed subsurface cavity, which is called K-3 within carbonate rocks, Euphrates Formation, western Iraq Figure (1) and (2). The cavity caused by bulldozer when it prepare the area to build primary school. Its actual dimensions of depth and height at the cavity fracture were (35.80m), (28.5m), respectively. Euphrates Formation is the most widespread formation of the sequence. Two supplementary type sections were described in Wadi Chabbab, 39km W of Anah, and in Wadi Rabi, 20km of Husaiba. In Haditha area the first section is 110m thick and represent the lower and middle units of the formation. The second is 25m thick and represent the upper unit of the formation. This is most widespread Miocene unit occurring along, and west of, the Euphrates River. The bedding in the limestone is often contorted especially along the Abu Jir fault. This contorted bedding may have formed soon after sedimentation due to fluid movement or mud thixotropic due to earthquake along the fault [19, 20]. The purpose of this study was to evaluate the usefulness and suitability of the

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Bristow's technique for detecting and imaging the dimensions of these types of subsurface cavities.

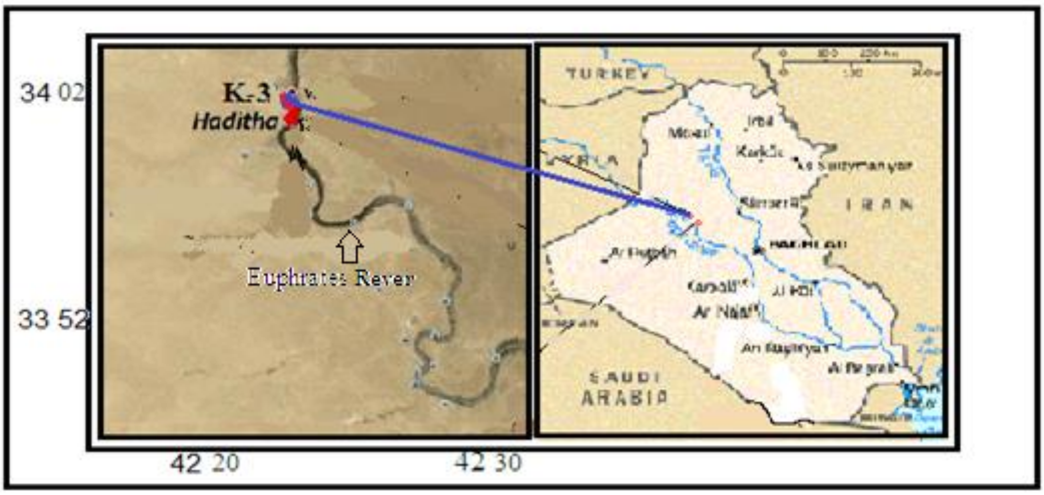

Figure (1): Location of the study area.

Figure (2): K-3 cavity within carbonate rocks in Haditha area.

2.TRADITIONAL BRISTOW'S METHOD

An early application of the resistivity method is described by [21], in reference to the location of subterranean caves. This method employed a symmetrical four-electrode configuration in which the half-array electrode spacing ratio was held constant as the array was expanded to provide depth sounding. Bristow modified the pole-dipole electrode array in a manner which allowed direct graphical interpretation of the cavity targets in approximate

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depth, position, and size [5]. Using this method in the field studies, Bristow was able to describe the approximate position of several known passages over karst terrains. Moreover, he discovered two cavities and verified their existence through boring and excavation. [6] has applied Bristow's method to delineate a number of known cavities, after making some slight modification; he was also able to locate a relatively small target cavity. The successful results achieved by [6] indicated that Pole-dipole method was potentially applicable to the issue of locating shallow cavities in soil associated with sinkhole formation and underground mud flows in karst terrain. Several field examinations of Bristow's method have been conducted with various degrees of success by [7, 8, 9, 10, 13, and 22].

The Pole-dipole electrode array Figure (3) incorporates two current and two potential electrodes arranged linearly. One current electrode is placed at an effective infinity, which may be greater than five to ten times the length of distance (P1C1) of the survey line. The two potential electrodes are located at a fixed separation equal of spacing (a). The potential difference is measured between two potential electrodes, by moving current electrode (C1) incrementally with (n=1, 2 ...) for a distance (na) equal approximately to (10a) on either side of the local current electrode (C1), and along the traverse. The measured resistivity profiles will overlap, and the voltage measurements are then expressed as apparent resistivity values. These resistivity values are indicated by the measured voltage given the relative positions of the electrodes, and assuming the ground has invariant electrical properties throughout [12].Therefore, the apparent resistivity values are plotted against the potential electrode at midpoint position, as shown in Figure (4) to detect the probality location of a cavity.

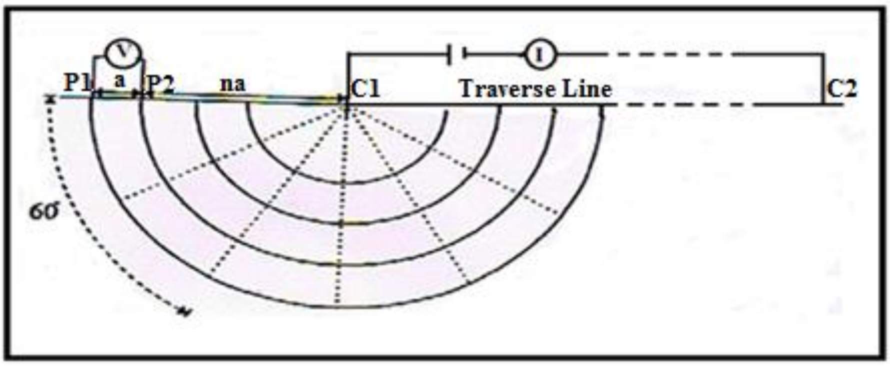

Figure (3): Geometry of the Pole-dipole array of resistivity measurements[13]

On a scale drawing of the vertical section along the survey line, an intersection of two or more equipotential hemispherical shells having radii corresponding to the current to potential electrode separation distance at which resistivity anomalies are observed will locate the subsurface cavity. When this method is applied with sufficient overlap of the resistivity profiles, the subsurface zone of intersection can provide a reasonably good indication of the cavity target, such as cross-section size and depth [23].

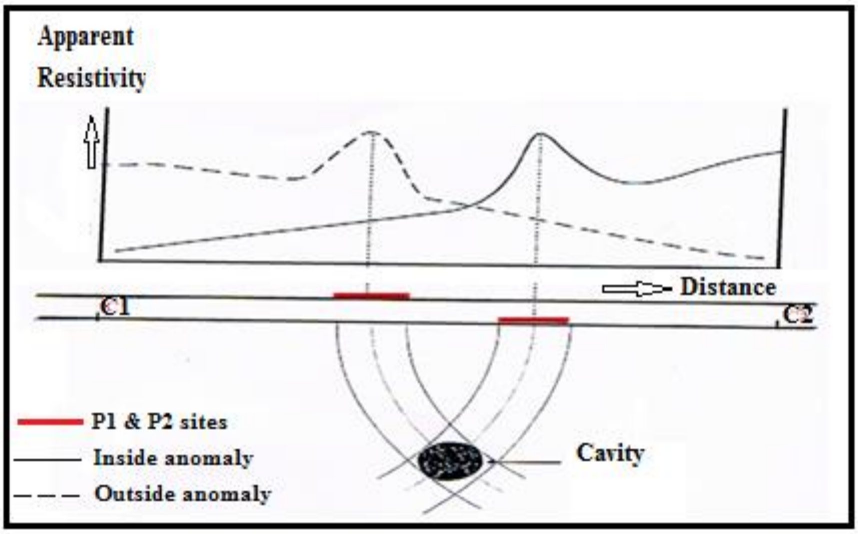

Figure (4): Graphic interpretation procedure of Pole-dipole (Bristow's method) resistivity data

3.ADVANTAGE OF BRISTOWS METHOD

With detection of subsurface cavities, there is a good probability that the geological noise may cause mistakes for cavity conditions. To overcome this problem to a useful extent, the interpretation technique devised of [5], and advanced by [6] and [4]; by using high resolution Pole-dipole array is recommended. Its advantage is that the geological noise is greatest near the ground surface, and is spatially distributed, whereas the cavity target is localized. With this technique, overlapping resistivity profiles can be used to separate noise anomalies near the surface from a cavity target at depth

The usefulness of Pole-dipole resistivity profiles is evident in the survey results, no prior knowledge of the target location is required, and both position and depth of cavity along traverse can be derived from the analysis. By demanding that several circular arc intersections, e.g. Three or more, accumulate at an anomaly of subsurface location before declaring it a suspected target, the redundancy of the survey data is used advantageously to enhance the validity of target interpretation [11]. Practical methods are used to analyze anomalies in apparent resistivity caused by the unknown cavity, this method is based upon direct interpretation techniques.

4.FIELD WORK

The K-3 cavity is located at (N 34° 02' 52'', E 42° 30' 45'') about (5Km) to the west of K-3 oil company. It is situated in an area surrounded by limestone within the Euphrates Formation. The shape of the cavity is ovulate, the actual dimensions of depth and height near the cavity fracture were (35.80m),(29.5m), respectively.

The Bristow's method (Pole-dipole array) is used to collect apparent resistivity measurements along two traverses: traverse in W-E direction and traverse in S-N direction above the cavity Figure (5). The Terrameter SAS (4000) instrument was used for measuring apparent resistivity in the field.

The filed layout of Bristow's method: the Current electrodes(C1,C2) of Pole- dipole were planted along the traverse W-E with (100m) separation, and the potential measurements were collected with interval spacing(a) of potential electrodes(P1,P2) equal to (5m), and moving incrementally over intervals of (5m).

In the Pole-dipole array Figure (3) the potential measurement electrodes are relatively close together, the equipotential lines at each electrode contact on the surface may be considered as the edges of curved equipotential surfaces extending below the surface [11].The restricted subsurface region in which an underground anomaly might have influence on the apparent resistivity as determined from the positions of electrodes C1, P1 and P2, as shown in Figure (4).

The survey of the Pole-dipole array by using Bristow's method employs depth sounding profile measurements, in which the potential electrode pair is moved incrementally away from the current source station, first in one direction and then in the opposite direction along the traverse. Then, by moving the current source location along traverse at incremental distances, so that the measured resistivity profiles will overlap the intersection of two or more equipotential hemispherical shells, having radii corresponding to the current–to–potential electrode separation distances, at which resistivity anomalies are observed, which will locate the subsurface cavity. When this method is applied with sufficient overlap of the resistivity profiles, the subsurface zone of intersection can provide a reasonably good indication of the cavity target, such as cross-sectional size and depth.

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5.INTERPRETATION

The Pole-dipole apparent resistivity measurements are presented as pseudosection to show lateral and vertical variations of resistivity with depths, as shown in Figure (5), and 7). The pseudosection is not a true resistivity cross-section, because the vertical scale is not a true depth. However, these pseudosections show anomalous results with high apparent resistivity, which are considered as an indication of weak zones. The actual size and location of these zones can be delineated by the graphical interpretation of the resistivity profiles using the Bristow's method (Figure6, and 8).

Figure (5) shows the apparent resistivity pseudosection of the data interpretation of the Pole-dipole measurements (Bristow's method) along traverse W-E, with a-spacing of (5m). It appears increasing in apparent resistivity values near the position of the cave reaching approximately (750 Ω.m); this may reflect the presence of the fracture of the cavity near the middle-distance of the traverse line. While many anomalies which elongated along the traverse may represent another unknown parts of the cavity. The upper part of Figure (6) shows the Maximum residual resistivity anomalies ranging between (550-800 Ω.m). Therefore, they delineate several high apparent resistivity anomalies (H_1, $H2_{...}$), which may be due to the cavity. Graphical interpretation of the Pole-dipole data acquired along the traverse W-E at the lower part of Figure (6), shows the circular arcs are drawn around each current station at radii corresponding to higher resistance perturbations, than the average apparent resistivity of the host medium, which are represented a shallow dry carbonate rocks and room of K-3 cavity which is opened at midpoint of the traverse. Data

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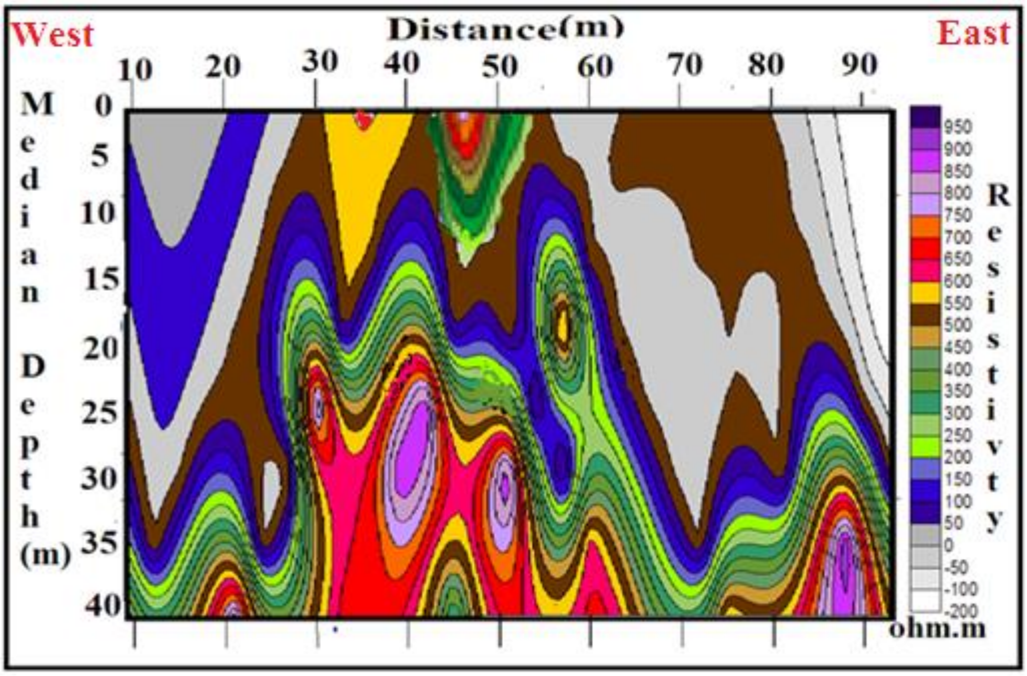

Figure (5): Apparent resistivity pseudosection along traverse W-E with a=5m.

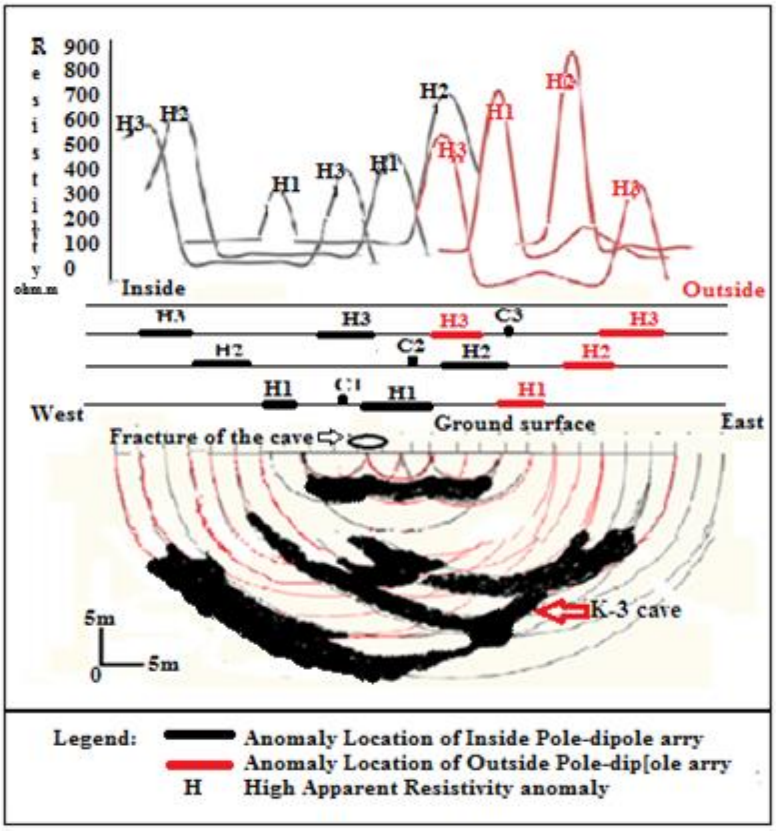

Figure (6): Intersecting arcs and interpreted anomaly location for the Bristow' s method along the W-E traverse with a=5

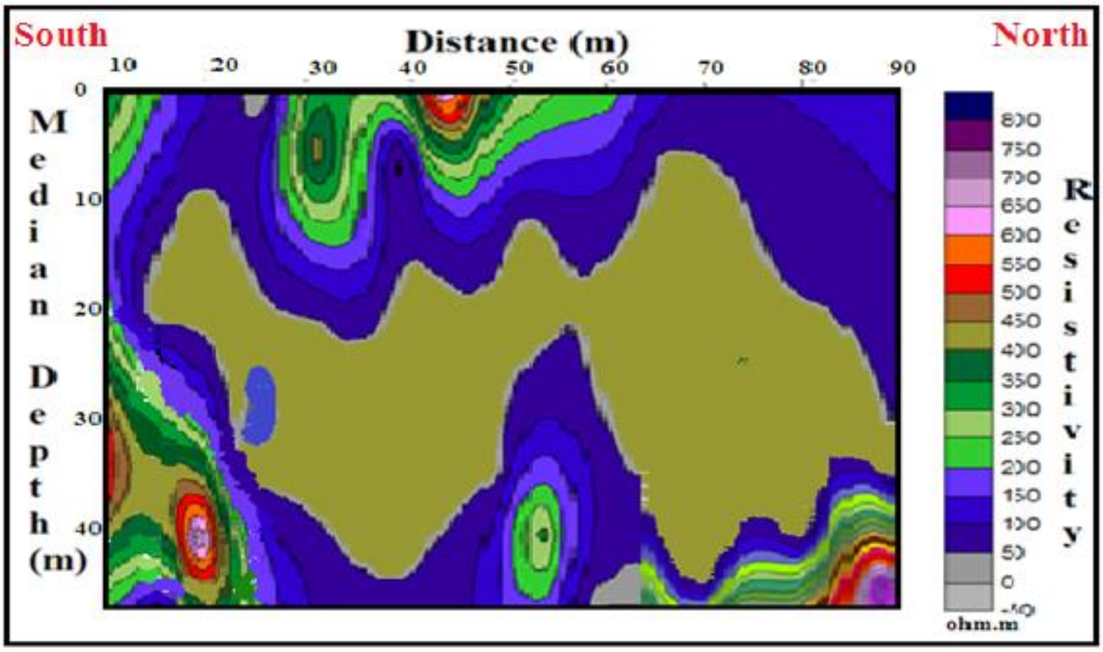

Figure (7): Apparent resistivity pseudosection along traverse S-N with a=5m

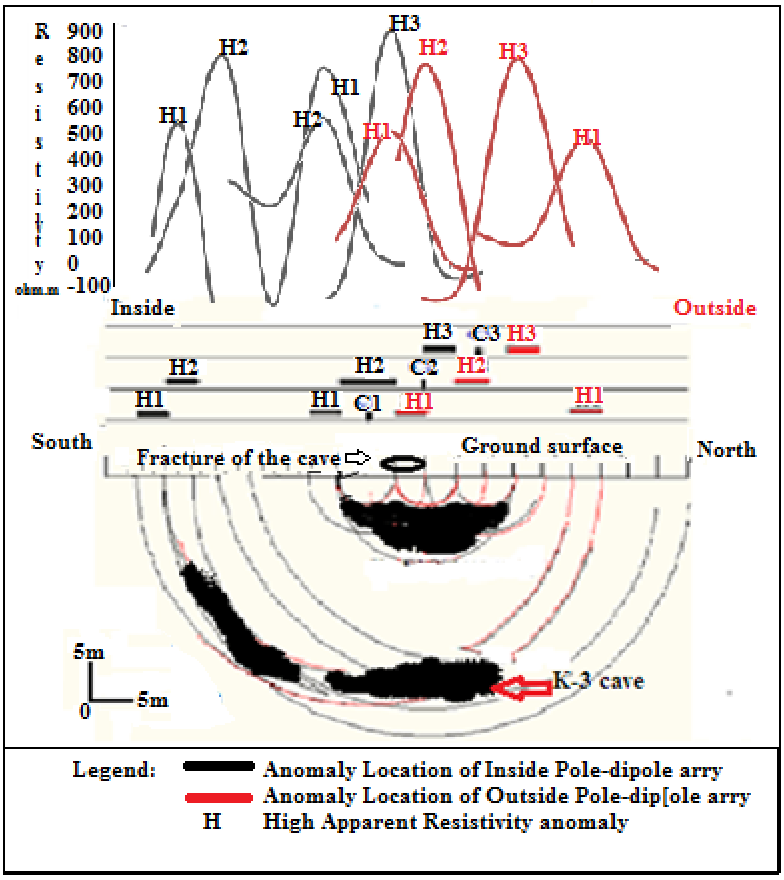

Figure (8): Intersecting arcs and interpreted anomaly location for the Bristow' s method along the S-N traverse with a=5m.

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interpretation of the traverse trending W-E, with a-spacing equal to (5m) identified the anomaly of the cavity at (35.5m) depth, (29.0m) height, and(58.6m) width, while the actual dimensions of depth and height near the cavity fracture were (35.80m), (29.5m), respectively.

Figure (7) shows the apparent resistivity pseudosection of the data interpretation for an overlapping the Pole-dipole survey along S-N line, with (a=5m) of potential electrode spacing. High anomalous results of apparent resistivity appear in the section, which is surrounded by lower background resistivity; this anomaly is located near the middle-distance of the survey line, and may be reflecting the location of K-3.

Figure (8) Shows the interpretation of the apparent resistivity data for S-N Pole-dipole survey with (a=5m) of potential electrode spacing (a). Maximum residual resistivity anomalies range between (650-750 Ω.m), which may indicate the presence of the K-3cavity, as shown in the upper part of Figure (7). Meanwhile, the lower part shows the circular arcs intersecting; this determined the location of the cavity**.** Therefore, the survey along the traverse S-N is also performed with (a=5m). The data interpretation indicated that the cavity of depth, height, and width are (34.7m), (28.8m), and(58.6m) respectively, which are approximately the same as the actual dimensions of the cavity with small variations of about (1.1m) depth and (0.7m) height respectively at midpoint of the traverse.

6.CONCLUSIONS

The conclusions of this study can be briefed as follow

1- Data interpretation of graphical Bristow's method analyses the anomalies in the apparent resistivity, which caused by K-3 cavity (Haditha area), along the traverse trending W-E line. It is based upon direct interpretation techniques with potential electrode spacing (a- spacing) of (5m). The anomaly indicated a cavity at (35.5m) depth, (29.0m) height, and(58.6m) width, while the actual dimensions of depth and height near the cavity fracture were (35.80m), (29.5m), respectively.

2- Bristow's method with an overlapping along the traverse S-N above K-3 cavity, with (a=5m) potential electrode spacing (a) is performed. Data interpretation indicated small differences of about (1.1m) depth and (0.7m) height respectively at midpoint of the traverse.

3- The results of application Bristow's method and the interpretation indicate an error not exceeded 3% in depth and 2% in height values. It is concluded that this method is very useful to be able to detect subsurface cavities and voids.

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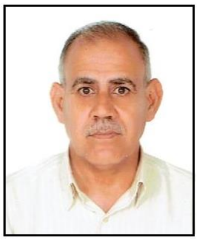

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