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Comparison of 2D Resistivity Imaging Survey Using Wenner, Wenner -Schlumberger and Dipole-dipole Electrode Arrays in Uruk Archaeological Site, Iraq

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Abstract

The survey compares the three common arrays using in 2D imaging surveys, Wenner, Wenner-Schlumberger and Dipole-dipole electrode arrays, and most suitable array is chosen in Uruk archaeological site. The Comparison consist of the resolution and efficiency of 2D resistivity imaging survey with these arrays. Three survey tests on a selected profile in Uruk archaeological site are done to examine the imaging capabilities of these arrays.The survey shows that the Dipole-dipole array has better horizontal data coverage than the Wenner. The horizontal data coverage for the Wenner-Schlumberger array is slightly wider than Wenner array but narrower than that obtained with the Dipole-dipole array. Also, the survey time for survey Dipole-dipole array longer than the others, then that for Wenner- Schlumberger, then at the later that for Wenner array. The survey shows that the Dipole-dipole array has a shallower depth of investigation compared to the Wenner and Wenner –Schlumberger arrays.Finally, it shows that Dipole-dipole array gives the highest resolution and best image for vertical anomalies. During the 2D resistivity imaging in Uruk, Dipole- dipole array is found to be the best array compared to Wenner and Wenner- Schlumberger arrays for detecting archaeological targets.

Introduction

It is known that each of the electrode configurations has its own advantages and limitations in fieldwork (Dahlin, and Zhou, 2004). The image created by means of 2D resistivity imaging, for the same structure will be different for each array.For these reasons, choosing the right array for the resistivity surveys is important(Loke, 2012). For 2D resistivity imaging, the electrode arrays might have different imaging abilities for a model, i.e. differences in spatial resolution, tendency for artifacts in the images, deviation from the true model resistivity and interpretable maximum depth. In order to obtain a high resolution and reliable image, the electrode array used should ideally give data with the maximum anomaly information and reasonable data coverage (Aizebeokhai ,2010). The choice of the best array for a field survey depends on the type of structure to be mapped, the sensitivity of the resistivity meter and the noise level background (Dahlin, and Loke, 1998).

Site description

The study area is located between the longitudes(45˚ 37′ 28″ E) to (45˚ 39′ 7.3″ E), and latitude (31˚ 18′ 34.5″ N) to (31˚ 20′ 14.5″ N), covering about (5.5 km^2). It situated about 30 Km east of Al-Samawah city, Al-Muthanna governorate, Iraq (Fig. 1). The maximum extent of this site is (3Km N-S) and (2.5Km E-W). The location type is ruins,(Fig. 2).

The area is located near the boundary between the Mesopotamia and the southern desert (Buday,1980) (AL-Mubarak, and Amin, 1983).It lies within the lower parts of Mesopotamian which is characterized by its approximately flat topography. On the other hand, the ruins existed inside the investigated site (hills of ancient civilization) represent the archeological buildings such as, houses and temples or ziggurats(Baker, 2002).

The study area is covered by the Quaternary alluvium deposits. It mainly consists of clay, silt and sand sediments (AL-Hashimi,1974).

Data acquisition

Wenner, Wenner Schlumberger and Dipole-dipole electrode arrays are applied in the site to chosethe most suitable array. The Comparison consist of the resolution and efficiency of (2D) resistivity imaging survey (Griffiths and Barker,1993).

To investigate the imaging capabilities of these electrode configurations, three test profiles, URUK-TEST-WEN, URUK-TEST-WEN-SCH, and URUK-TEST-DIPDIP which are located on the same line at the same location in Uruk are chosen (Fig 2). Resistivity survey is performed with an automated multi-electrode switching system. Theautomated multi-electrode switching system consist of Terrameter which is four channel resistivity instrument, electrode selector unit (ES10-64C) connects directly to the ABEM SAS (4000) Terrameter, the multi-function cable to operate the electrode selector with SAS (4000), (75) stainless steel electrodes to establish electric contact between an electronic conductor (the cable) to an ionic conductor (the earth), (75) cable jumpers which are cable-to electrode jumpers and cable set consisting of two durable plywood boxes for two electrode cables on two reel (Loke*et. al.* , 2007).

The acquisition included 2D resistivity imaging survey produced three(2D) resistivity imaging profiles each being sixty meters long ,comprising forty one electrodes with (1.5) meters electrode spacing for all the electrode configurations.The raw data files collected in the field are post processed.

Data processing

RES2DINV software is used in processing and interpretation.RES2DINV software is a computer program, that will automatically determine a (2D) resistivity model for the subsurface (Dahlin and Bernstone,1997);Geotomo software, 2006). The program has a set of predefined settings that generally give satisfactory results for most data sets (Barker,1992; Candansayar, and Basokur, 2001). However, in Uruk situation, better results are obtained by modifying some of the parameters that control the inversion process .

A low initial damping factor of (0.1), low minimum damping factor of (0.01) and a finest mesh are used in this processingbecause a low resistivity layer lies below a high resistivity layer and the subsurface resistivity contrasts are large.

A combination of the Marquardt (or ridge regression) and Occam (or smoothness-constrained) inversion methods are used because such combination shows best results.

In Uruk, there is significant topographical relief along the survey line. For this cause , the program automatically selects the finite-element method that incorporates the topography into the used modeling mesh. In this case, the topographic modeling will be automatically carried out by the program when the data set are inverted.

Results and discussion

Figures (3,4 and 5) show the patterns of the data points in the pseudosections for Wenner, Wenner-Schlumberger and Dipole-dipole arrays respectively. These figures show that Dipole-dipole array has better horizontal data coverage than the Wenner.TheWenner-Schlumberger array has a slightly better horizontal coverage compared with the Wenner array. The horizontal data coverage for the Wenner-Schlumberger array is slightly wider than the Wenner array, but narrower than that obtained with the dipole-dipole array.

Table (1) gives data densities of Wenner, Wenner-Schlumberger and Dipole-dipole electrode arrays respectively. It shows that the Dipole-dipole survey has data density more than the others , then that for Wenner-Schlumberger, then at the later that for Wenner array Survey. This means that the survey time for survey of Dipole-dipole array is longer than the others, then that for Wenner- Schlumberger, then at the later that for Wenner array.

Figures (6, 7 and 8) show the investigation depths of Wenner, Wenner-Schlumberger and Dipole-dipole arrays respectively. The investigation depths of Wenner, Wenner- Schlumberger and Dipole-dipole arrays at this test survey are equal to (11, 8.68 and 6.13) meters respectively.

Figures (9,10 and 11) show the inversion results of Wenner, Wenner-Schlumberger and Dipole-dipole arrays respectively .These inverse models show that Dipole-dipole array gives the highest resolution and best image for vertical anomalies. Wenner and Wenner-Schlumberger arrays have similar behavior of imaging ability due to the resemblance of their electric field and measurements. The spatial resolution of Wenner array is poorer than the Dipole-dipole and Wenner-Schlumberger arrays .Accordingly, Dipole-dipole array is chosen for(2D) resistivity imaging.

Conclusions

Dipole-dipole array has better horizontal data coverage than the Wenner and Wenner- Schlumberger arrays. The Wenner-Schlumberger array has a slightly better horizontal coverage compared with the

Wenner array. The survey time for survey of Dipole-dipole array longer than the others, then that for Wenner- Schlumberger, then at the later that for Wenner array.Dipole-dipole array has a shallower depth of investigation compared to the Wenner and Wenner–Schlumberger arrays for (2D) survey. Dipole-dipole array measurement gives the highest resolution and best image for vertical anomalies. Accordingly, Dipole-dipole array is chosen for (2D) resistivity imaging.

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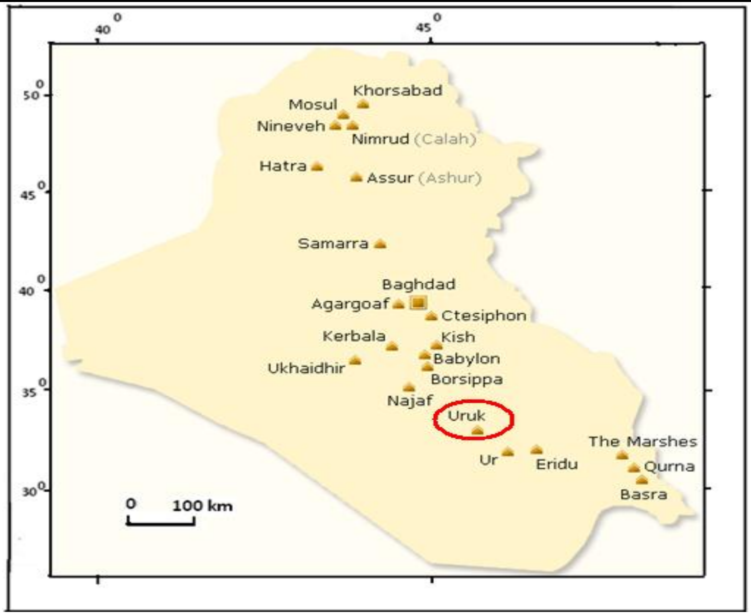
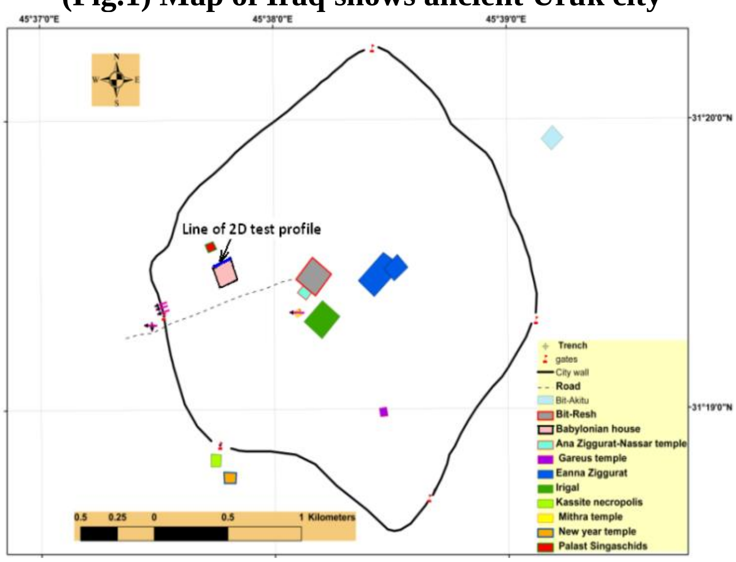


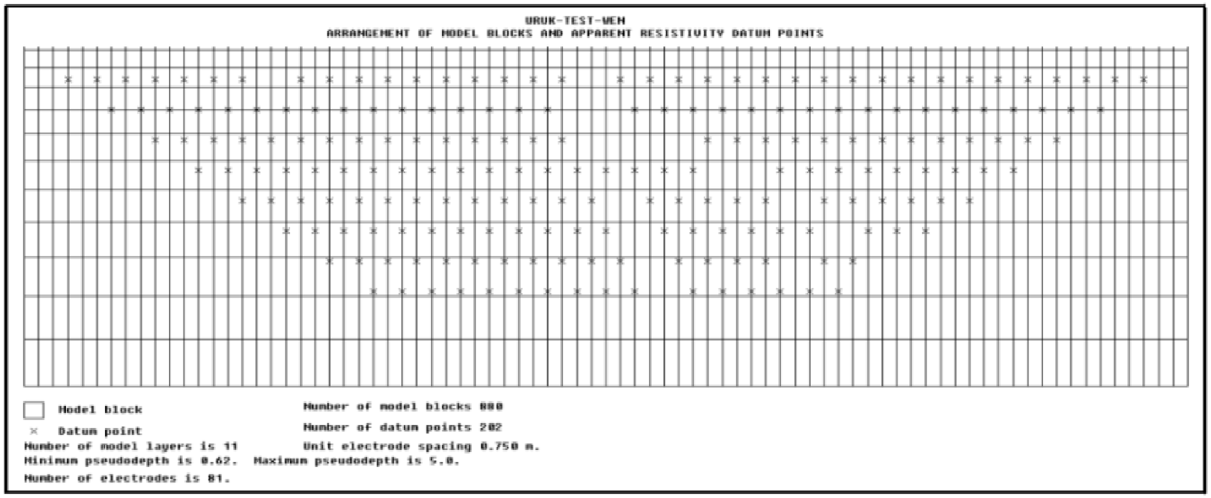
(Fig.1) Map of Iraq shows ancient Uruk city



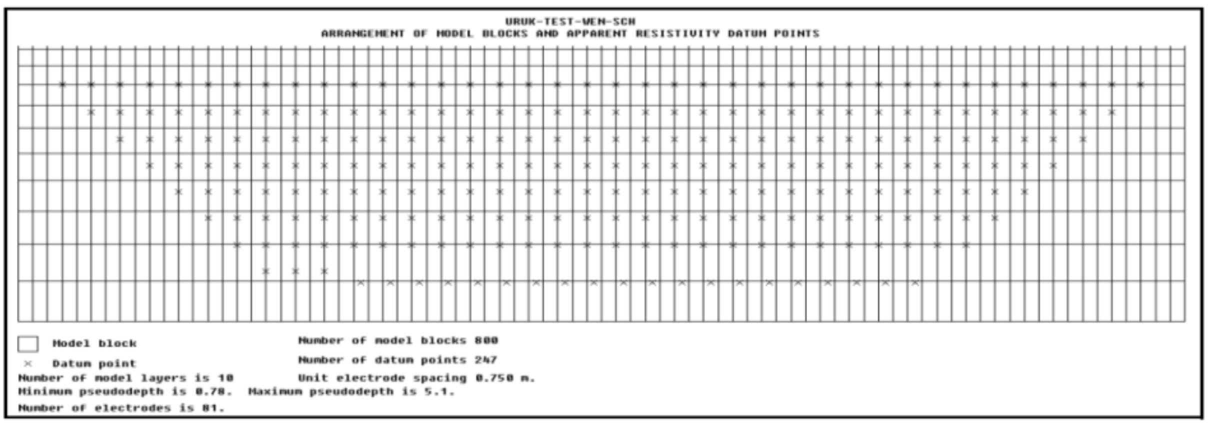
(Fig. 2) Map of ancientUruk cityshowsline of 2D test profile

(Table 1)Densities data points of the three test survey profiles

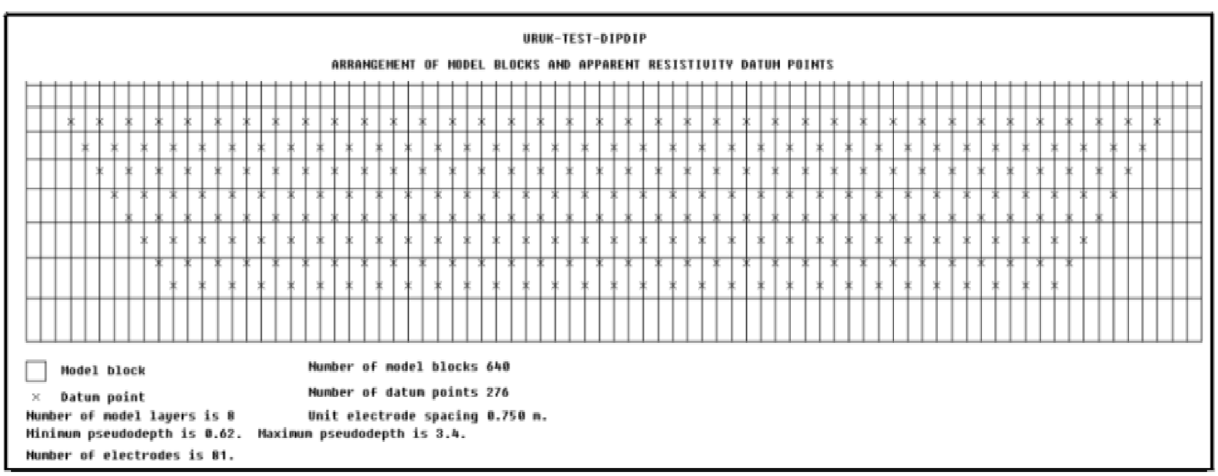
Configuration	Densities of data points
Wenner	202
Wenner-Schlumberger	247
Dipole-dipole	276



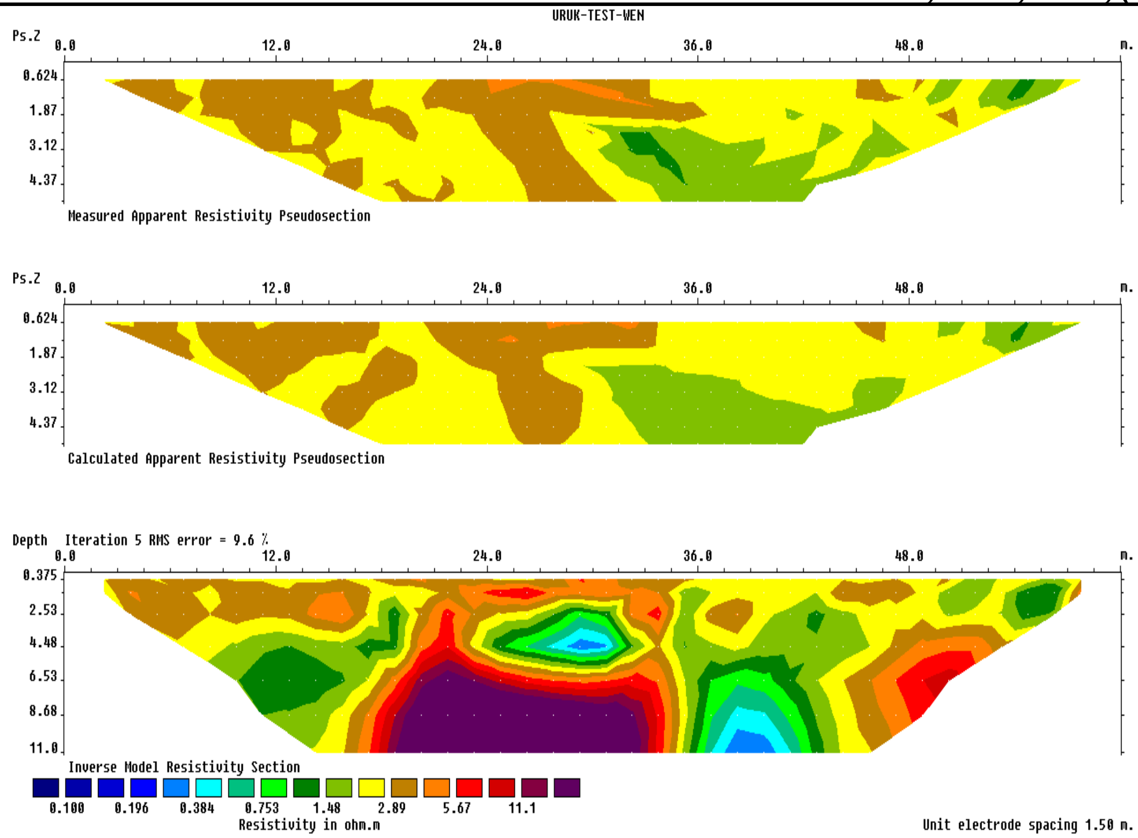
(Fig. 3) The pattern of model block arrangement and apparentresistivity datum points in thepseudosections of the testsurvey Profile URUK-TEST-WEN for Wenner array



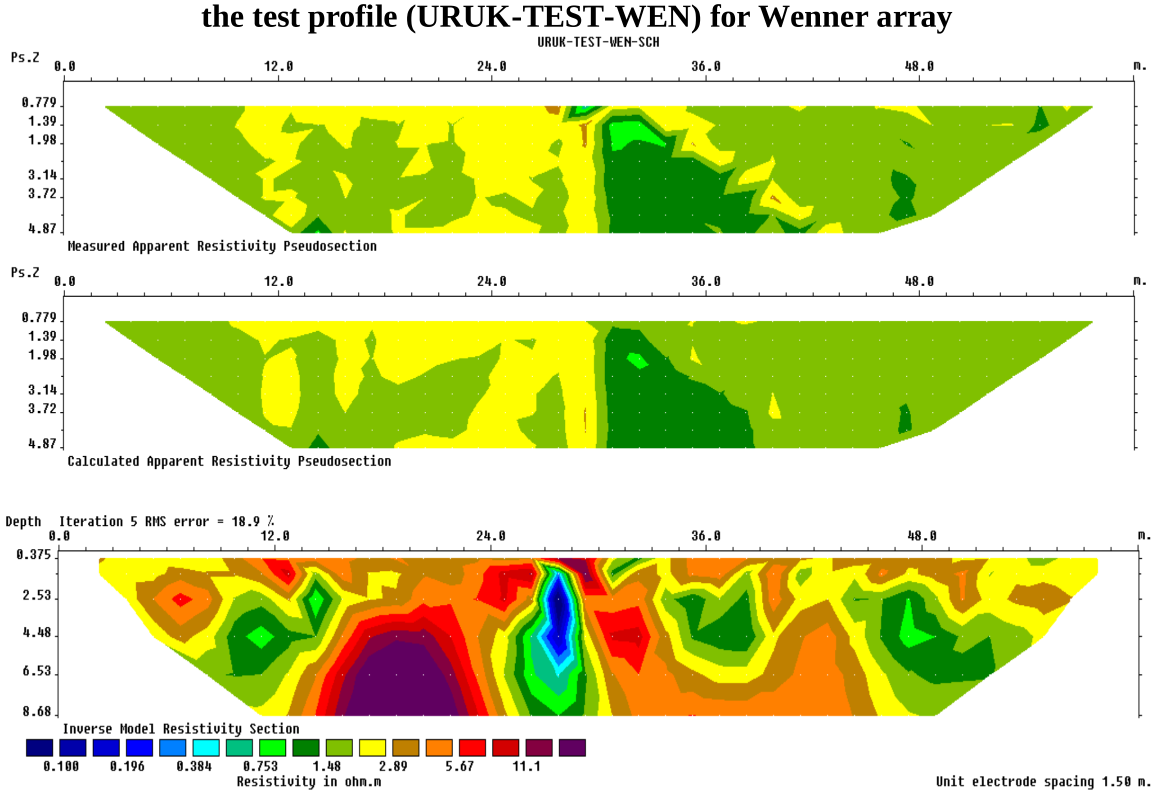
(Fig. 4)The pattern of model block arrangement and apparent resistivity datum points in thepseudosections of the test survey Profile URUK-TEST-WEN-SCH for Wenner -Schlumberger array



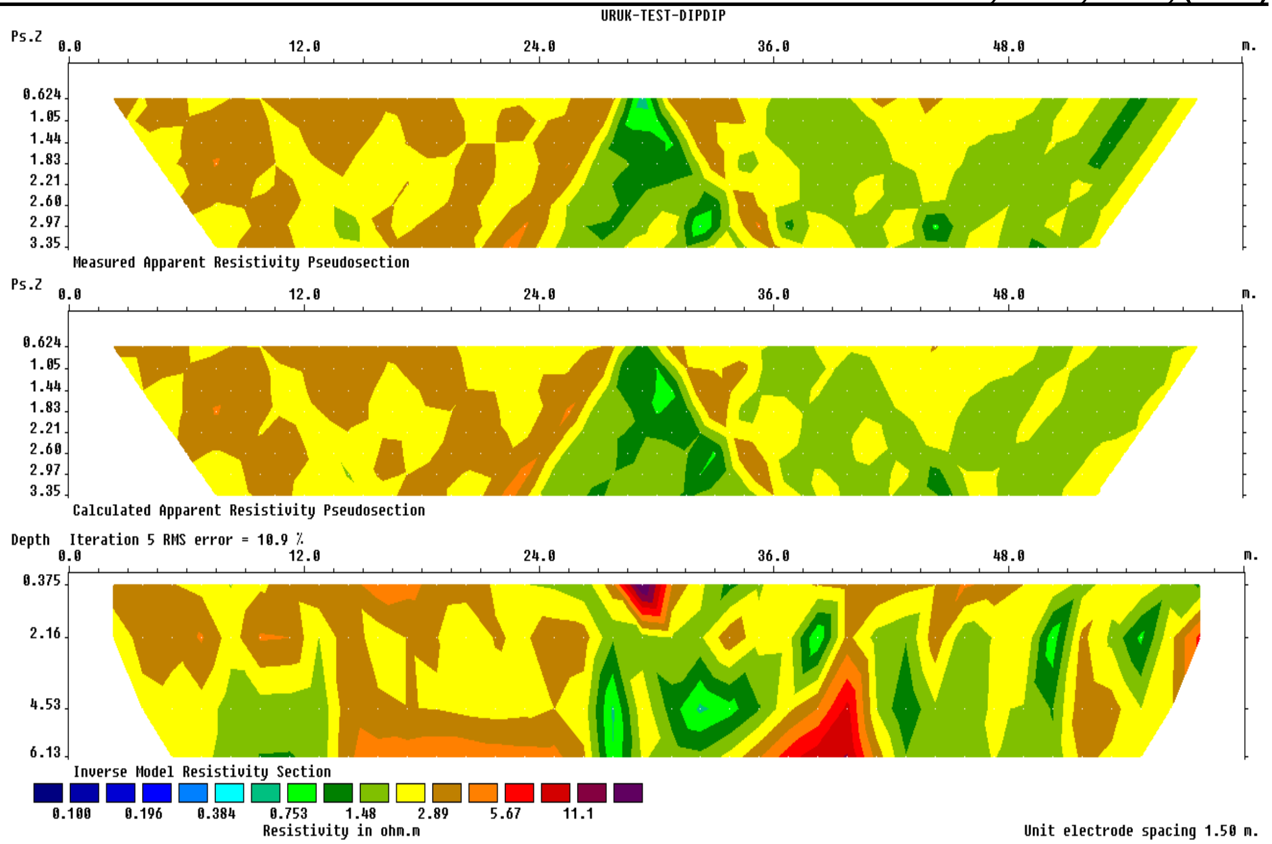
(Fig.5) The pattern of model block arrangement and apparentresistivitydatum points in thepseudosections of the testsurvey ProfileURUK-TEST-DIPDIP for dipole- dipole array



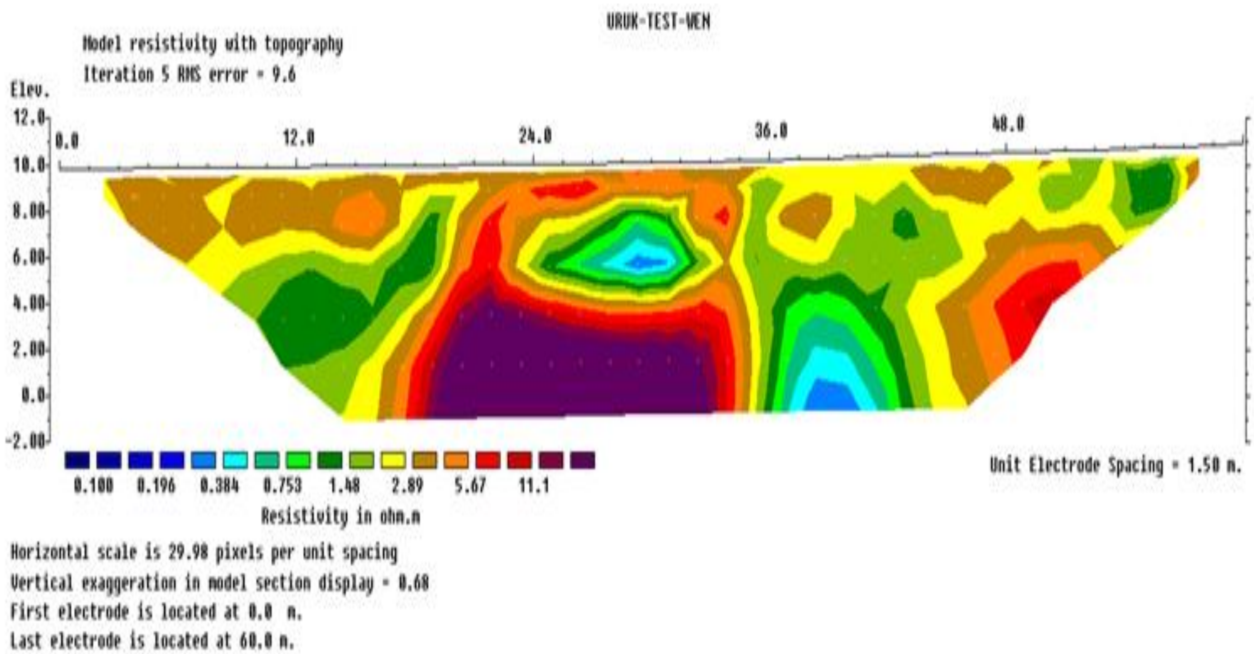
(Fig.6)The observed and calculated psedosections with inverse model of the test profile (URUK-TEST-WEN) for Wenner array



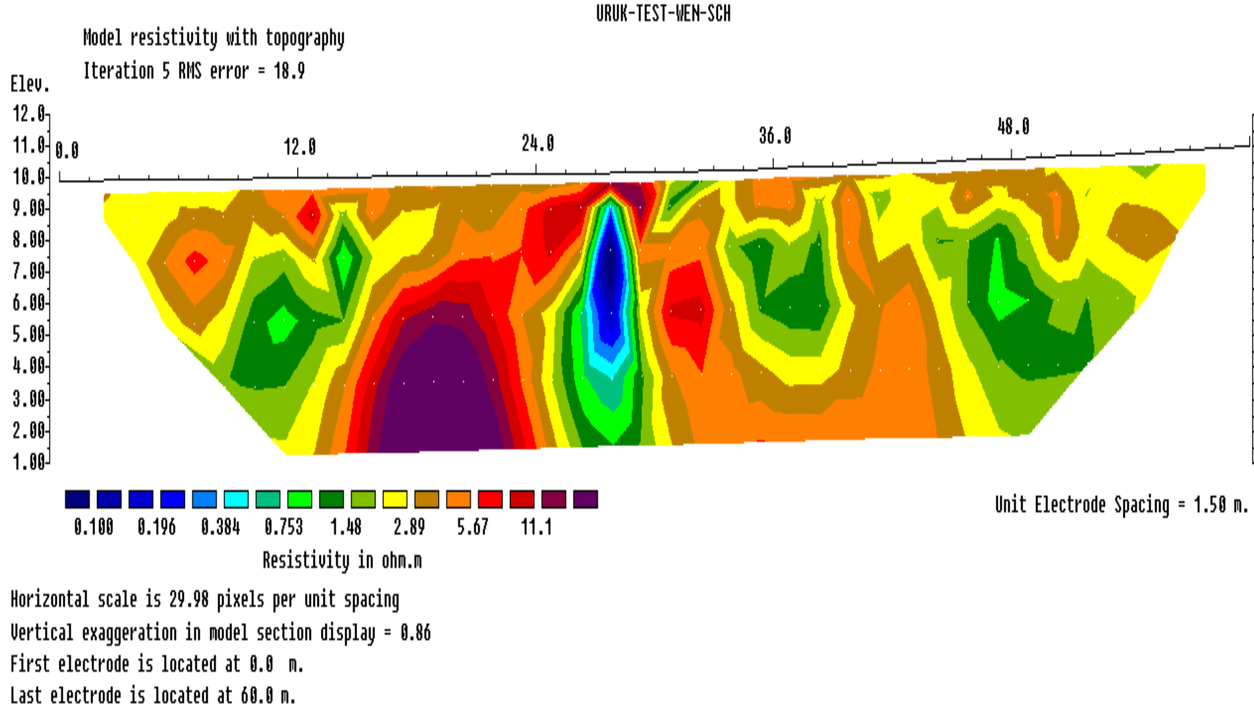
(Fig. 7) The observed and calculated psedosections with inverse model of the test profile (URUK-TEST-WEN-SCH) for Wenner- Schlumberger array.



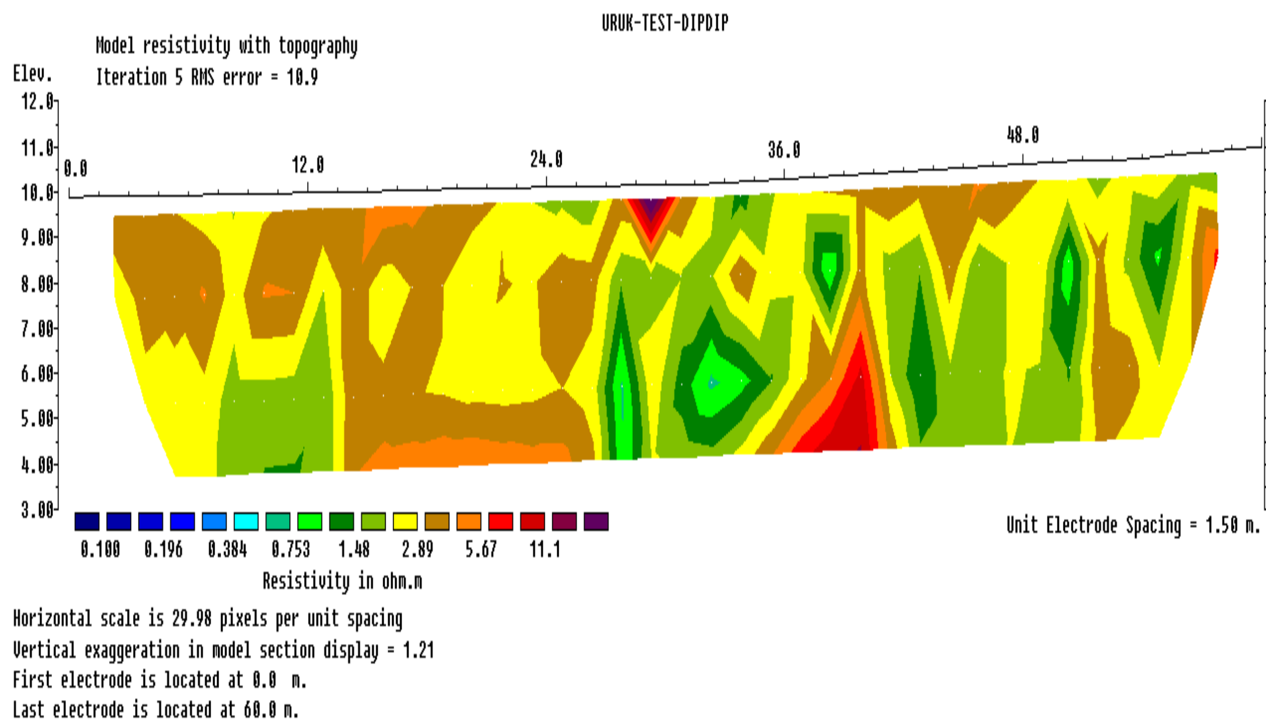
(Fig. 8)The observed and calculated psedosections with inverse model of the test profile (URUK-TEST-DIPDIP) for Dipole-dipole array



(Fig. 9)Inverse model with topography correction of profile (URUK-TEST-WEN)for Wenner array



(Fig.10)Inverse model with topography correction of profile (URUK-TEST-WEN-SCH) for Wenner-Schlumberger array



(Fig. 11)Inverse model with topography correction of profile (URUK-TEST-DIPDIP) for Dipole-dipole array

الخلاصة:

تم مقارنة ترتيبات الأقطاب الكهربائية المشهورة الاستخدام واختيار الأفضل لغرض استخدامه في إجراء المسح الكهربائي التصويري الثنائي البعد في منطقة الوركاء الاثارية.المقارنة شملت الكفاءة والوضوح في المسح الكهربائي التصويري الثنائي البعد لترتيبات فنر وفنر-شلمبرجر وثنائي القطب- ثنائي القطب. نفذ المسح بثلاث مسارات تصويرية ثنائية البعد تقع على نفس الخط و بطول يبلغ (60) متر.بين المسح أن ترتيب الأقطاب نوع ثنائي القطب-ثنائي القطب كان الأفضل في تغطية المعلومات الجانبية من ترتيب فنر ولكن تغطية المعلومات الجانبية لترتيب فنر-شلمبرجر أضيق من تغطية المعلومات الجانبية لترتيب فنر. كذلك فان وقت المسح لترتيب الأقطاب نوع ثنائي القطب– ثنائي القطب أطول من الترتيبين الآخرين.بين المسح أن ترتيب ثنائي القطب– ثنائي القطب اقل عمقا بالاستكشاف من النوعين الآخرين وأن الأكثر عمقا كان ترتيب فنر.أن صور ترتيب ثنائي القطب– ثنائي القطب كانت الأحسن والأوضح للشواذ العمودية. بين المسح أن ترتيب الأقطاب نوع ثنائي القطب- ثنائي القطب كان الأفضل للاستخدام بمنطقة الدراسة بالمقارنة مع ترتيبي الأقطاب الكهربائية نوع فنر وفنر– شلمبرجر.