MJPS….Vol.(2)….No(1)….December 2014

Investigation of Subsurface Archaeological Structures Using 2D Electrical Imaging in Babylonian Houses District ,Uruk Site, Iraq

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Abstract

Buried structures of Babylonian houses district are investigated using 2D resistivity imaging techniques . 2D resistivity imaging results show upper zone , near the surface with a high resistivity value which can often be found throughout the whole area and is characterized by dried clayed and sandy soil with broken and weathered different archaeological materials such as broken brick and slag mixed with core boulders. Underneath this upper zone, there is a prominent low resistive layer probably caused by the moisture in this region that reduces the resistivity with thickness which differs from parts of the site to the others . Also, 2D resistivity images illustrate zone with a high resistivity value indicating more intact zone of archaeological structures down to the bottom of the image . It indicates an archaeological structure extending vertically through the images which is typical for archaeological clay brick walls . 2D results show presence of several anomalies at different depths ranging from a very high to a low resistive

anomaly. The interpretation of these anomalies , ranged from core boulders, voids , air or clay –filled cavity or grave based on the geophysical and archaeological data of the site .

Introduction

Electrical resistivity surveys have been used in archaeology since 1946 . The development of new and fully 2D resistivity imaging systems, along with advanced and sophisticated processing and interpretation algorithms, have rendered this technique very attractive in archaeological sites (Loke , 2012) . 2D resistivity imaging is of high resolution at shallow depths , automated data acquisition for cost effectiveness , superior area coverage through at least two-dimensional information and output presented in easily interpretable form (Edwards, 1977) (Griffiths and Barker 1993) (Dahlin and Zhou, 2004) . The entire data handling process is automated as far as possible , including data acquisition , processing , interpretation and presentation . Such surveys are usually carried out using a large number of electrodes , 25 or more , connected to a multi-core cable . A laptop microcomputer together with an electronic switching unit is used to automatically select the relevant four electrodes for each measurement (Barker, 1992) . In this study, the target is to map the buried archaeological structures using 2D resistivity imaging technique .

Site description

The studied archaeological site of this research is located between the longitudes 45˚ 37′ 28″ E to 45˚ 39′ 7.3″ E , and latitudes 31˚ 18′ 34.5″ N to 31˚ 20′ 14.5″ N . It is situated about 30 Km east of Al-Samawah city, Al-Muthanna governorate (Fig. 1) .The maximum extent of this site is 3Km N-S and 2.5Km E-W covering an area of about 5.5 km^2 (Fig. 2). The location type is ruins . The area is located near the boundary between the Mesopotamia and the southern desert . It lies within the lower parts of Mesopotamia which is characterized by its approximately flat topography (Buday,1980) (AL-Mubarak, and Amin, 1983) . 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

The ABEM Lund system SAS 4000 is used in this study to acquire field data . SAS 4000 is an automatic electric imaging system . It consists of Terrameter which is four channel resistivity instrument with integrated PC for full control of data acquisition process and storage of data , 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 procedure of 2D resistivity imaging survey in this study is a 2D resistivity imaging technique to locate subsurface targets of the study area . The procedures consist of acquiring the apparent resistivity for the subsurface , calculating true resistivity by using RES2DINV software and finding the subsurface of the study area . Resistivity survey is performed with an automated multi-electrode switching system . The acquisition included 2D resistivity imaging survey produced (32) parallel 2D resistivity imaging profiles each being (100)m long , comprising (41) electrodes and collected over an area of (9300) square meters ,with (2.5) meters electrode spacing and ABEM SAS4000 multi-electrode system using Dipole- dipole array . The spacing between these profiles is (3) meters to give systematic information about the study area (Fig. 3).

Data processing

RES2DINV software is used in data processing and interpretation . RES2DINV ver. 3.57 was distributed by Geotomo software in August 2008 . RES2DINV software is a computer program , that will automatically determine a 2D resistivity subsurface model for the data obtained from 2D resistivity imaging survey (Dahlin and Bernstone,1997) .

The program has a set of predefined settings for the damping factors and other variables that generally give satisfactory results for most data sets (Dahlin and Loke, 1998) . However , in Uruk situation , better results are obtained by modifying some of the parameters that control the inversion process , as follow :

A low initial damping factor of (0.1) and low minimum damping factor of (0.01) are used , and no higher damping factor for the first layer is applied.The program is forced to produce models that are elongated vertically by selecting a higher value equal to 2.0 for the ratio of the vertical to horizontal flatness filter because the anomalies in the pseudosections are elongated vertically .

In forward modeling , the finite-element method is a choice because the data set contains topography . A finest mesh is used in this processing because a low resistivity layer lies below a high resistivity layer and the subsurface resistivity contrasts are large . A combination of Marquardt (or ridge regression) and Occam (or smoothness-constrained) inversion methods are used because such combination shows best results .

In this processing , severe reduction of the effect of the side blocks occurs due to the use of Dipole – dipole array measurement and the robust inversion option . Also, all blocks are made to have equal widths because of the severe reduction of the effect of the side blocks .

Best result shows with model refinement option .The actual unit electrode spacing for all profiles is (2.5)meters , and after model refinement becomes (1.25)meters . Edge detection is used in this processing to determine the boundary of the archaeological structures of Uruk.

Results and discussion

The interpreted inverse models of the whole lines , from line 1 to line 32(from profile URUK-ERI-1 to profile URUK-ERI-32)are illustrated in fig.(4). These images basically illustrate presence of three zones in Uruk archaeological site. The upper one has a high resistivity value . In the first zone , some anomalies with high resistivity can clearly be seen . The second zone shows a prominent low resistivity zone . Thickness of this layer is different from parts of the site to the others . In the second level , some anomalies of low and high resistivity values can clearly be seen. Underneath this intermediate zone is a more resistive zone indicating more intact zone of archaeological structures down to the bottom of the image .The images indicate an archaeological structure extending vertically . The inverse sections of these lines show several anomalies at different depths . The anomalies range from high to low resistive anomalies . 2D resistivity imaging profiles have maximum depth of investigation of (13.5) meters . A comparison of the results from adjacent profiles shows almost similar anomalies at similar depths .

On the basis of Uruk and the knowledge of the area, the integrated interpretation of the 2D resistivity imaging data, can help to eliminate some of the ambiguities in the interpretation results, also by showing the 2D inverse models of the lines , it is clear that ,these images basically illustrate the presence of three zones in Uruk. The upper one with a high resistivity value is interpreted as an alluvium soil consisted of sand and clay. In Uruk , weathering of archaeological structures produce clayed and sandy soil with core boulders and other partially weathered material because these structures are constructed mainly of clay . The high resistive areas near the surface are caused by the dried upper layers . In the first zone , some anomalies with high resistivity can clearly be seen, caused by boulders .The depth of these anomalies also indicates that they can be related to archaeological materials, because the normal depth of artifacts, which are found in Uruk , start in some locations at 0.5m. from the surface . The second zone shows a prominent low resistive zone below the first zone. This is probably caused by the moisture in this region that reduces the resistivity . Thickness of this layer differs from other parts of the site . In the second level ,some anomalies with high resistivity can clearly be seen , caused by archaeological structures which may be core boulders ,air cavities or graves because these structures are present at these depths in other locations of Uruk . Underneath this intermediate zone is a more resistive zone which indicates more intact zone of archaeological structures down to the bottom of the image . The images indicate an archaeological structure extended vertically through the images. This third level has a high resistivity value, which is most probably related to the buried remains and ruins of old buildings of archaeological structures .The inverse sections show presence of several anomalies at different depths ranging from a very high to low resistive anomaly. The interpretations of the high anomalies range from possible voids , to spanning the soil/archaeological structures interface , to core boulders . Also there are many anomalies of low resistivity values which are believed to be due to the presence of a deep clay –filled cavity or grave based on the archaeological data of the site .

Conclusions

One more advantage of the use of 2D resistivity imaging for this investigation is that an archaeological site is usually shallow, which facilitates the use of 2D resistivity imaging with an improvement in the resolution is attained . The final images are of high spatial resolution and clear anomalies which are attributed to buried archaeological structures . The results of 2D resistivity imaging method are shown the lateral and vertical variations of resistivity and thickness, because the measurements are very dense in the 2D resistivity imaging method . So , the 2D resistivity imaging survey is the best for shallow investigation . This study proves that 2D resistivity imaging method is very important tool in archaeology as it allows field archaeologists to readily discover and map buried archaeological features.

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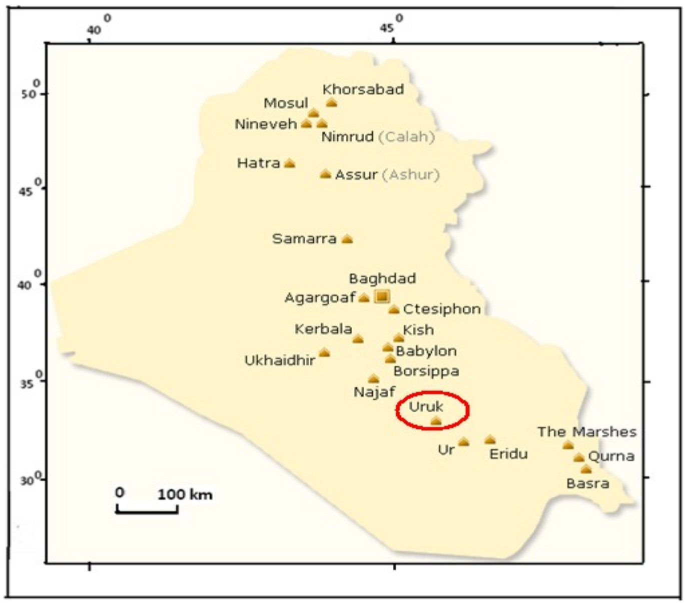
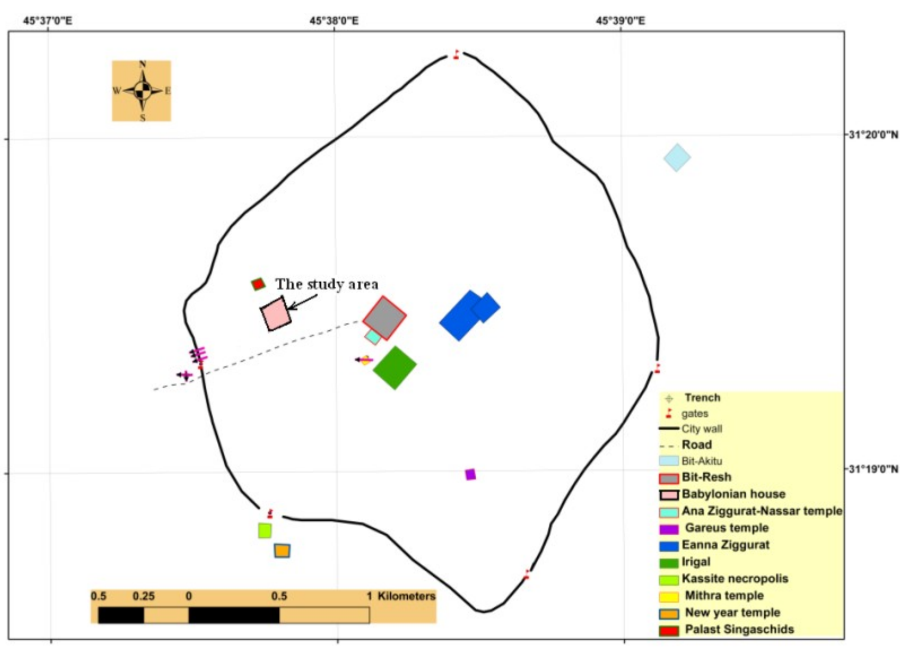
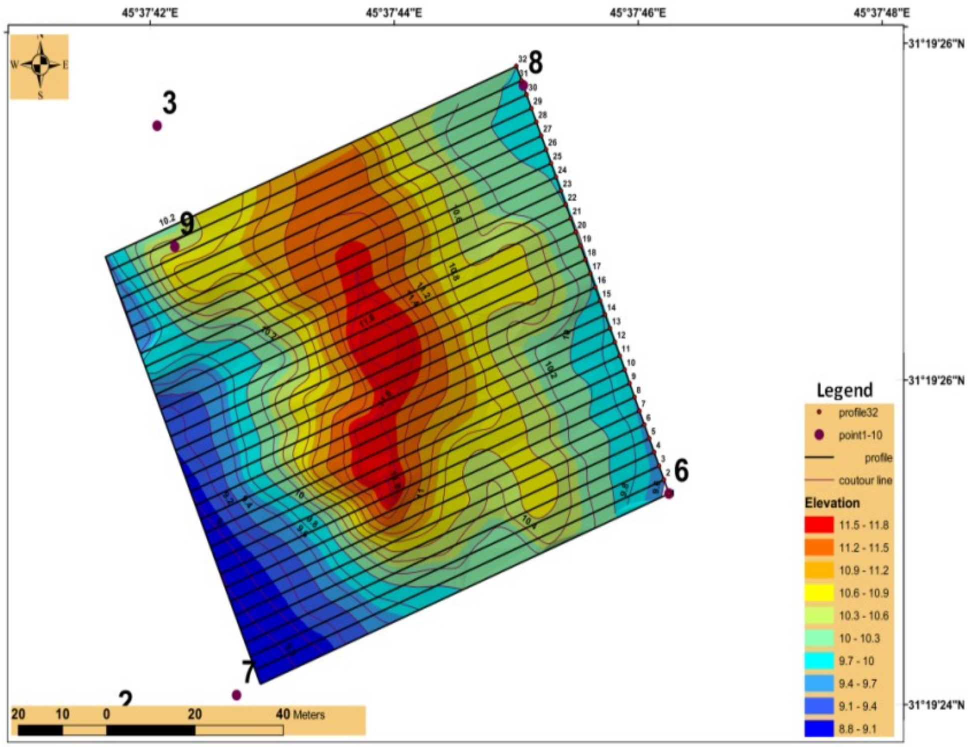


(Fig.1) Map of Iraq shows ancient Uruk city.



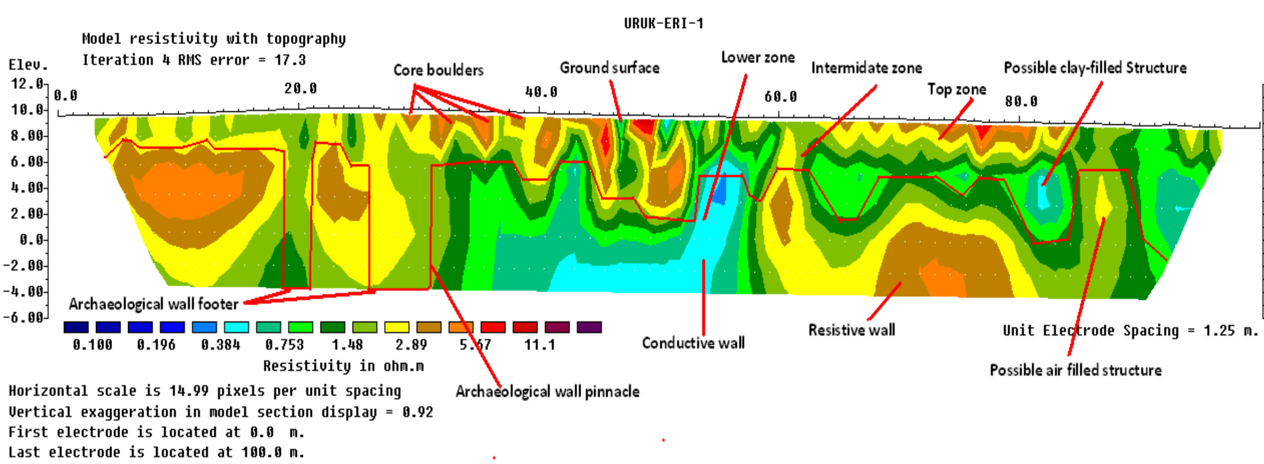
(Fig.2) Map of ancient Uruk city shows the study area

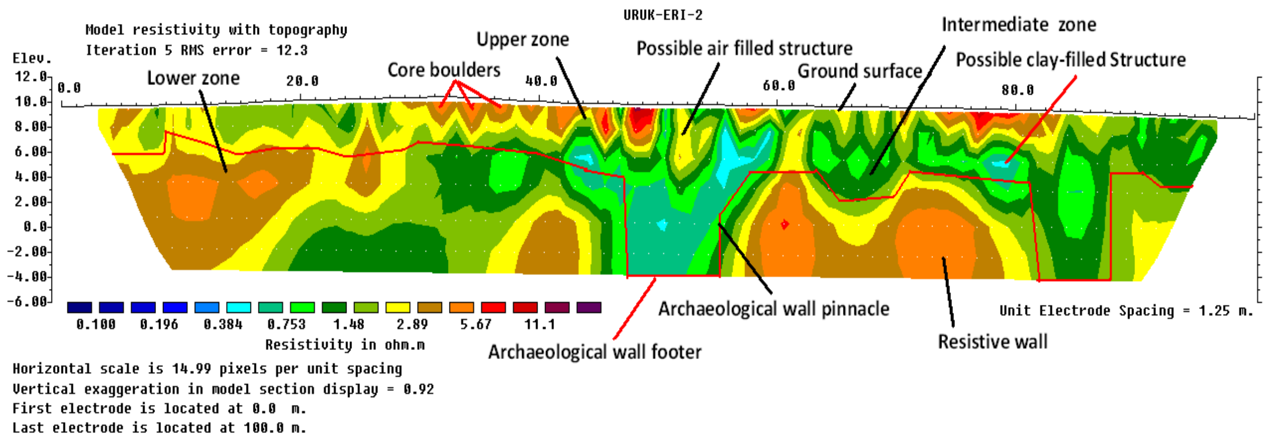
(Babylonian houses district).

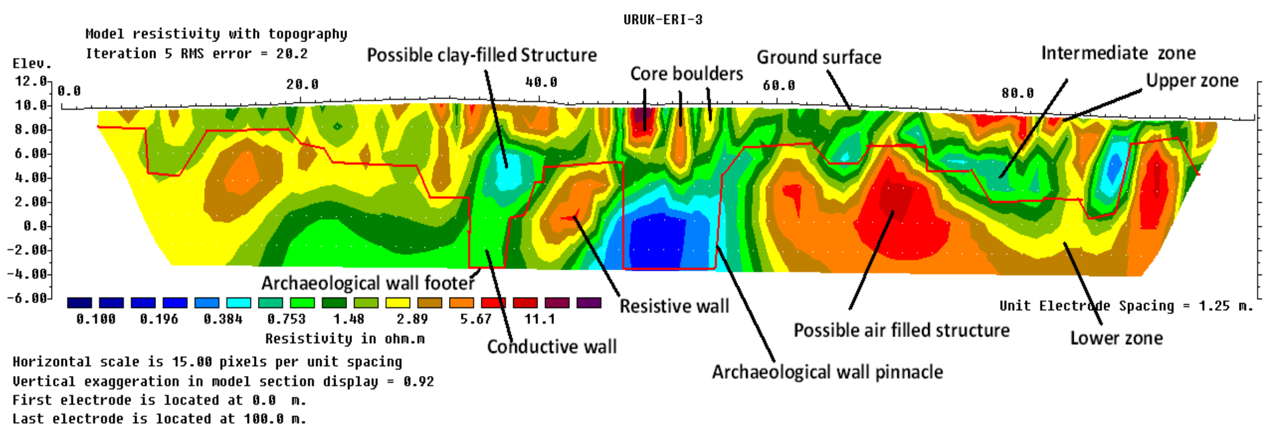


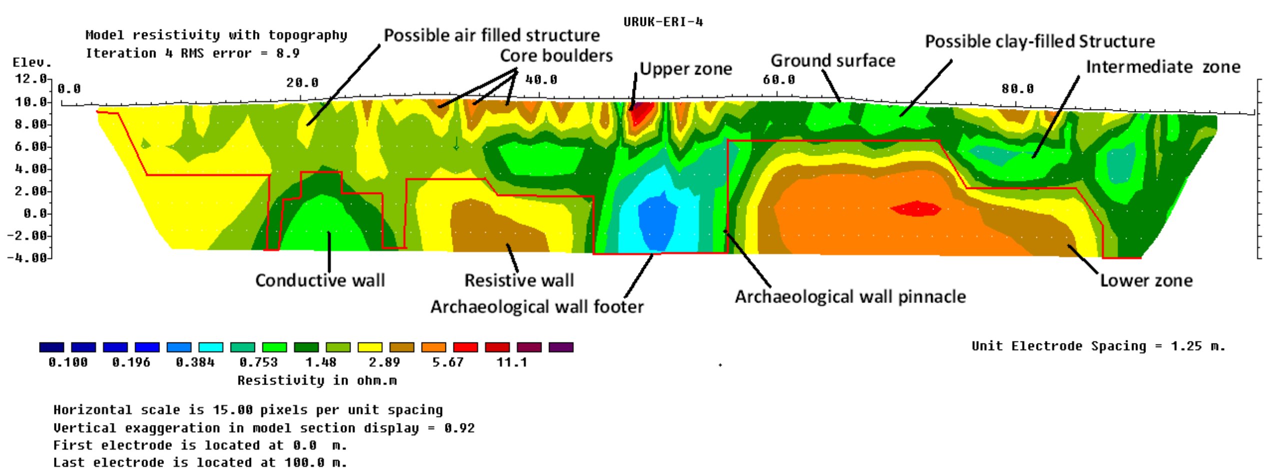
(Fig.3) Map of the Babylonian houses district with thirty two

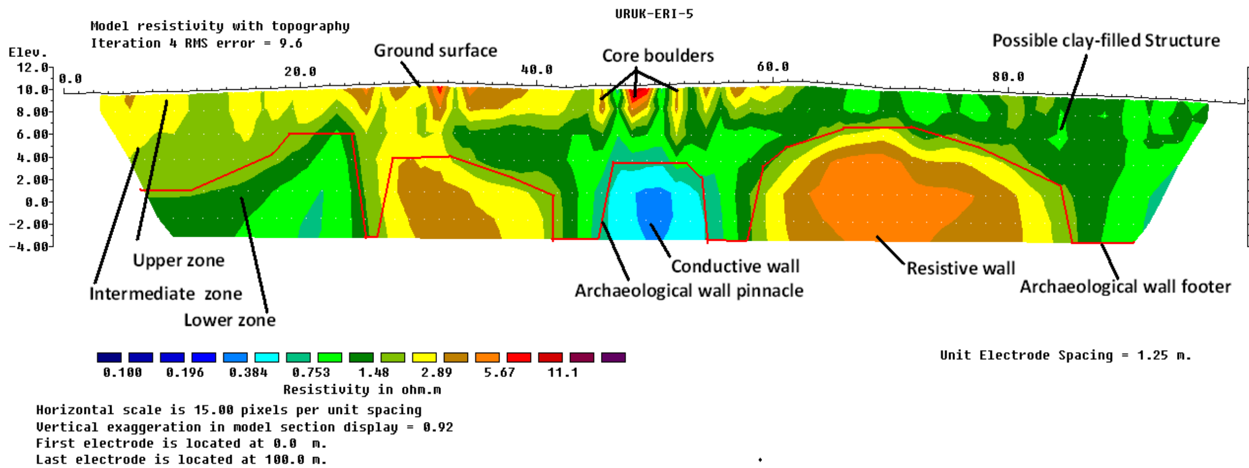
2D resistivity profiles.

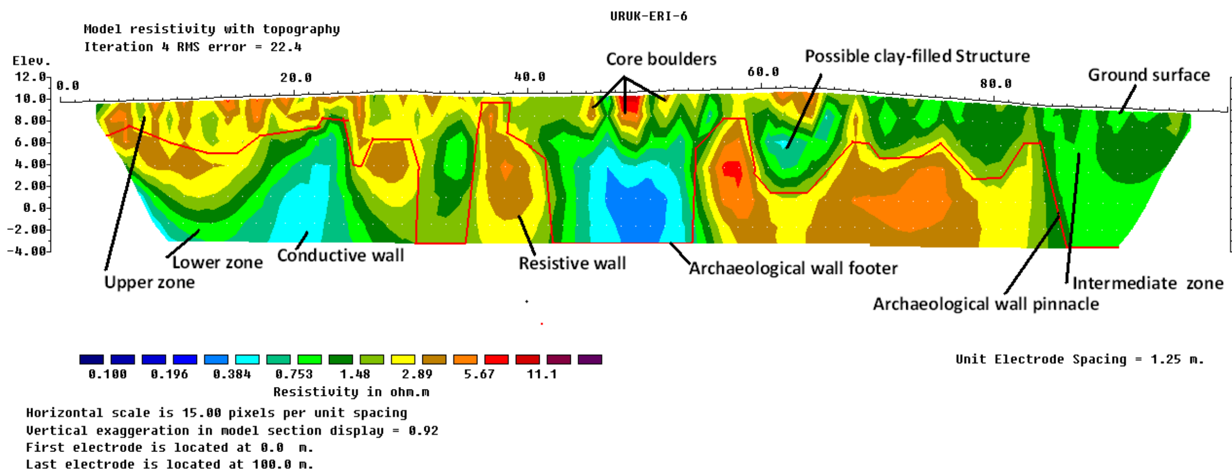


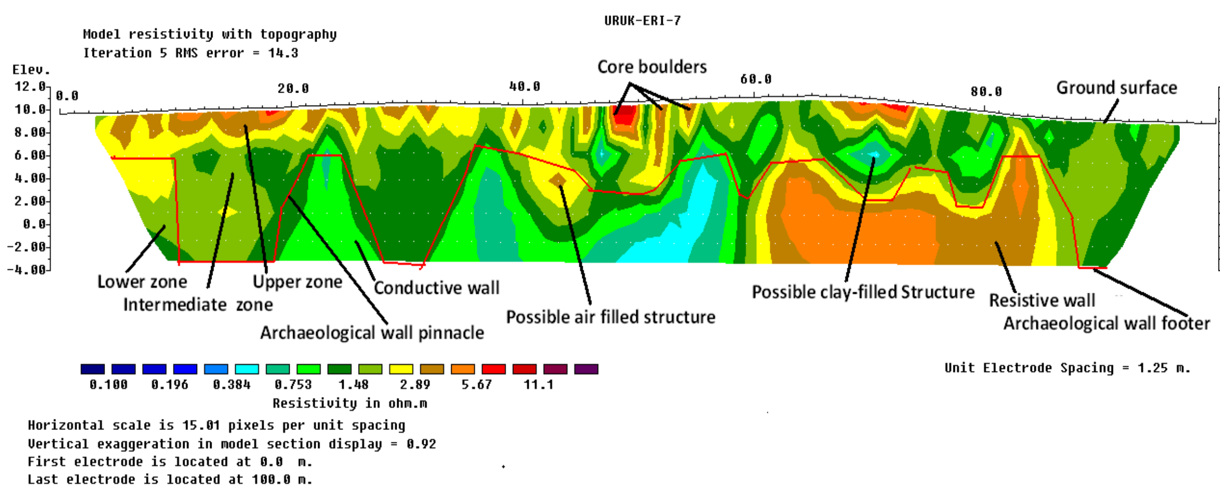

URUK-ERI-2
Model resistivity with topography
Iteration 5 RMS error = 12.3
Elev.
Lower zone
Core boulders
Upper zone
Possible air filled structure
Ground surface
Intermediate zone
Possible clay-filled Structure
Archaeological wall pinnacle
Archaeological wall footer
Resistive wall
0.100 0.196 0.384 0.753 1.48 2.89 5.67 11.1
Resistivity in ohm.m
Unit Electrode Spacing = 1.25 m.
Horizontal scale is 14.99 pixels per unit spacing
Vertical exaggeration in model section display = 0.92
First electrode is located at 0.0 m.
Last electrode is located at 100.0 m.

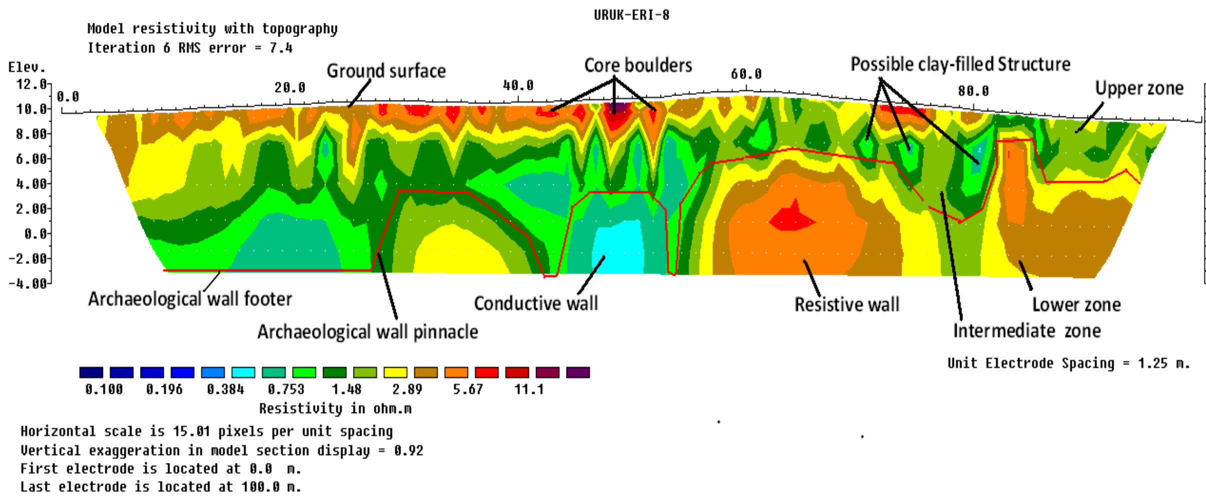

URUK-ERI-3
Model resistivity with topography
Iteration 5 RMS error = 20.2
Elev.
Possible clay-filled Structure
Core boulders
Ground surface
Intermediate zone
Upper zone
Archaeological wall footer
Resistive wall
Conductive wall
Possible air filled structure
Lower zone
Archaeological wall pinnacle
0.100 0.196 0.384 0.753 1.48 2.89 5.67 11.1
Resistivity in ohm.m
Unit Electrode Spacing = 1.25 m.
Horizontal scale is 15.00 pixels per unit spacing
Vertical exaggeration in model section display = 0.92
First electrode is located at 0.0 m.
Last electrode is located at 100.0 m.

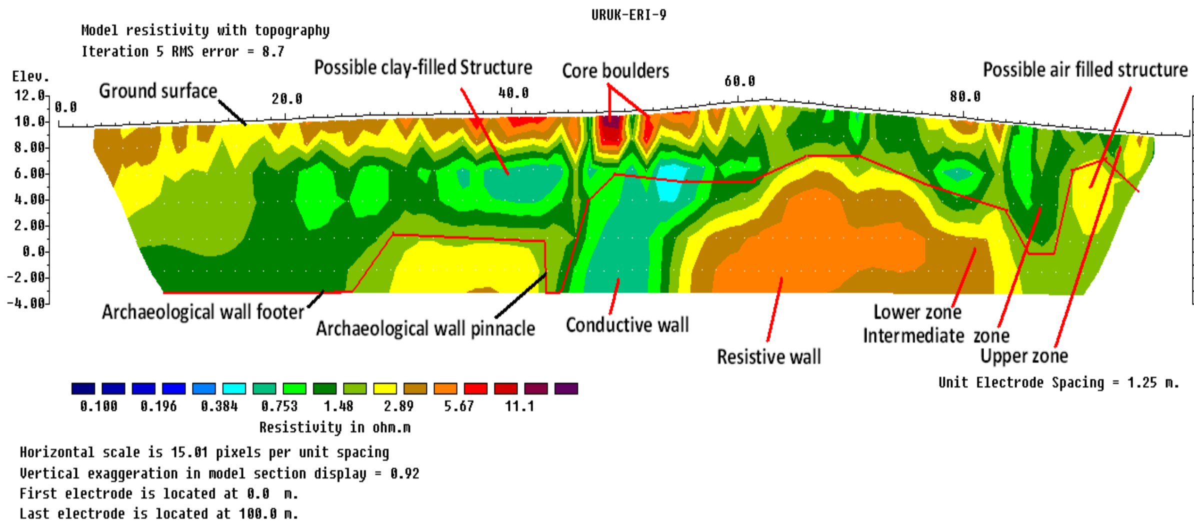

URUK-ERI-4
Model resistivity with topography
Iteration 4 RMS error = 8.9
Elev.
Possible air filled structure
Core boulders
Upper zone
Ground surface
Possible clay-filled Structure
Intermediate zone
Conductive wall
Resistive wall
Archaeological wall footer
Archaeological wall pinnacle
Lower zone
0.100 0.196 0.384 0.753 1.48 2.89 5.67 11.1
Resistivity in ohm.m
Unit Electrode Spacing = 1.25 m.
Horizontal scale is 15.00 pixels per unit spacing
Vertical exaggeration in model section display = 0.92
First electrode is located at 0.0 m.
Last electrode is located at 100.0 m.

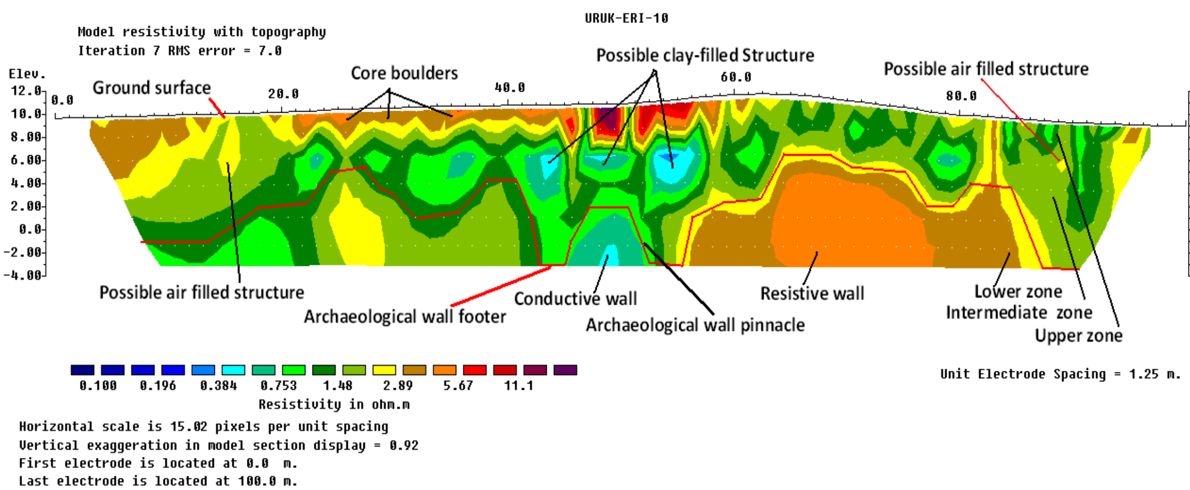

URUK-ERI-5
Model resistivity with topography
Iteration 4 RMS error = 9.6
Elev.
Ground surface
Core boulders
Possible clay-filled Structure
Upper zone
Intermediate zone
Lower zone
Conductive wall
Archaeological wall pinnacle
Resistive wall
Archaeological wall footer
0.100 0.196 0.384 0.753 1.48 2.89 5.67 11.1
Resistivity in ohm.m
Unit Electrode Spacing = 1.25 m.
Horizontal scale is 15.00 pixels per unit spacing
Vertical exaggeration in model section display = 0.92
First electrode is located at 0.0 m.
Last electrode is located at 100.0 m.

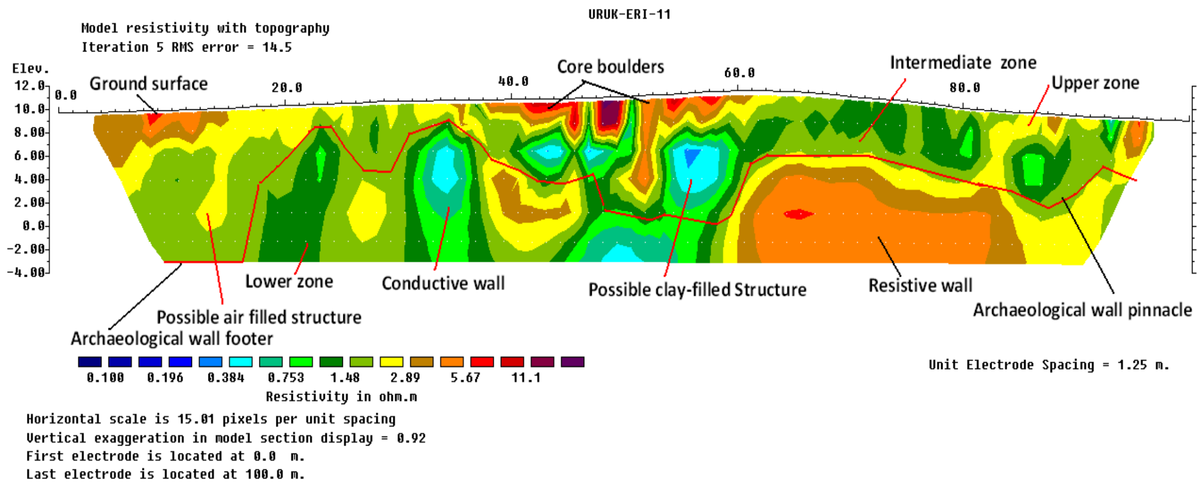

URUK-ERI-6
Model resistivity with topography
Iteration 4 RMS error = 22.4
Elev.
Core boulders
Possible clay-filled Structure
Ground surface
Lower zone
Conductive wall
Upper zone
Resistive wall
Archaeological wall footer
Intermediate zone
Archaeological wall pinnacle
0.100 0.196 0.384 0.753 1.48 2.89 5.67 11.1
Resistivity in ohm.m
Unit Electrode Spacing = 1.25 m.
Horizontal scale is 15.00 pixels per unit spacing
Vertical exaggeration in model section display = 0.92
First electrode is located at 0.0 m.
Last electrode is located at 100.0 m.

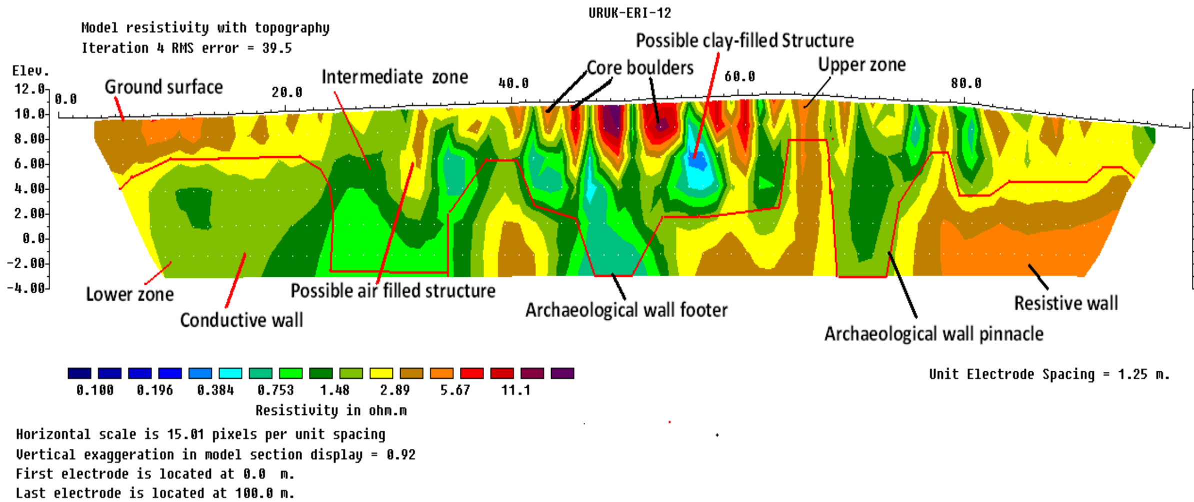

URUK-ERI-7
Model resistivity with topography
Iteration 5 RMS error = 14.3
Elev.
Core boulders
Ground surface
Lower zone
Intermediate zone
Upper zone
Archaeological wall pinnacle
Conductive wall
Possible air filled structure
Possible clay-filled Structure
Resistive wall
Archaeological wall footer
0.100 0.196 0.384 0.753 1.48 2.89 5.67 11.1
Resistivity in ohm.m
Unit Electrode Spacing = 1.25 m.
Horizontal scale is 15.01 pixels per unit spacing
Vertical exaggeration in model section display = 0.92
First electrode is located at 0.0 m.
Last electrode is located at 100.0 m.

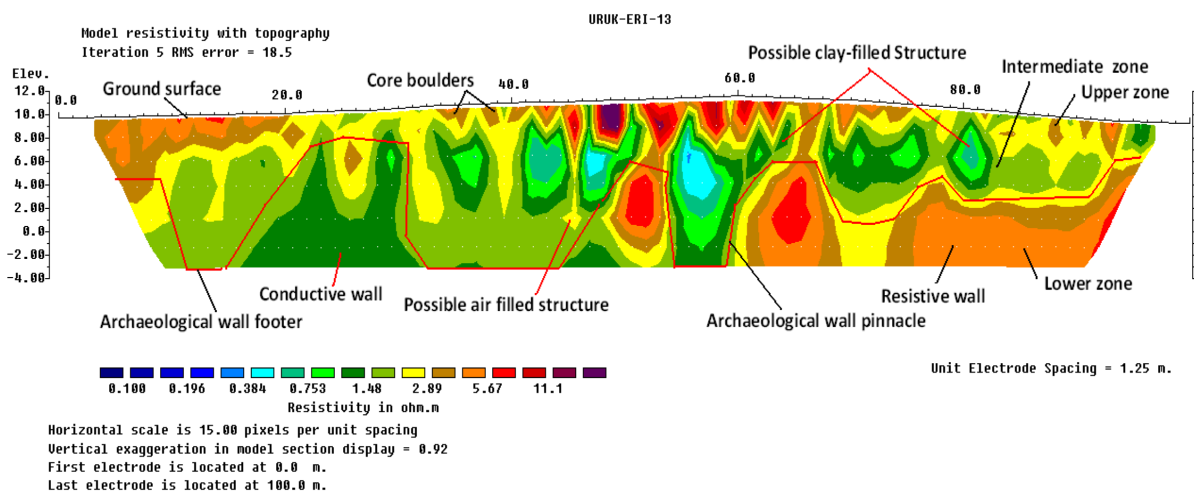

URUK-ERI-8
Model resistivity with topography
Iteration 6 RMS error = 7.4
Elev.
Ground surface
Core boulders
Possible clay-filled Structure
Upper zone
Archaeological wall footer
Archaeological wall pinnacle
Conductive wall
Resistive wall
Lower zone
Intermediate zone
Unit Electrode Spacing = 1.25 m.
0.100 0.196 0.384 0.753 1.48 2.89 5.67 11.1
Resistivity in ohm.m
Horizontal scale is 15.01 pixels per unit spacing
Vertical exaggeration in model section display = 0.92
First electrode is located at 0.0 m.
Last electrode is located at 100.0 m.

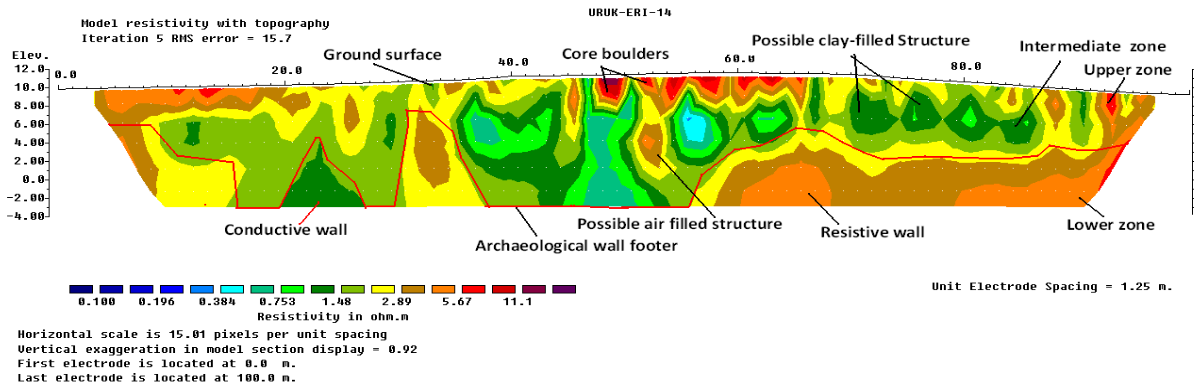

URUK-ERI-9
Model resistivity with topography
Iteration 5 RMS error = 8.7
Elev.
Ground surface
Possible clay-filled Structure
Core boulders
Possible air filled structure
Archaeological wall footer
Archaeological wall pinnacle
Conductive wall
Resistive wall
Lower zone
Intermediate zone
Upper zone
Unit Electrode Spacing = 1.25 m.
0.100 0.196 0.384 0.753 1.48 2.89 5.67 11.1
Resistivity in ohm.m
Horizontal scale is 15.01 pixels per unit spacing
Vertical exaggeration in model section display = 0.92
First electrode is located at 0.0 m.
Last electrode is located at 100.0 m.

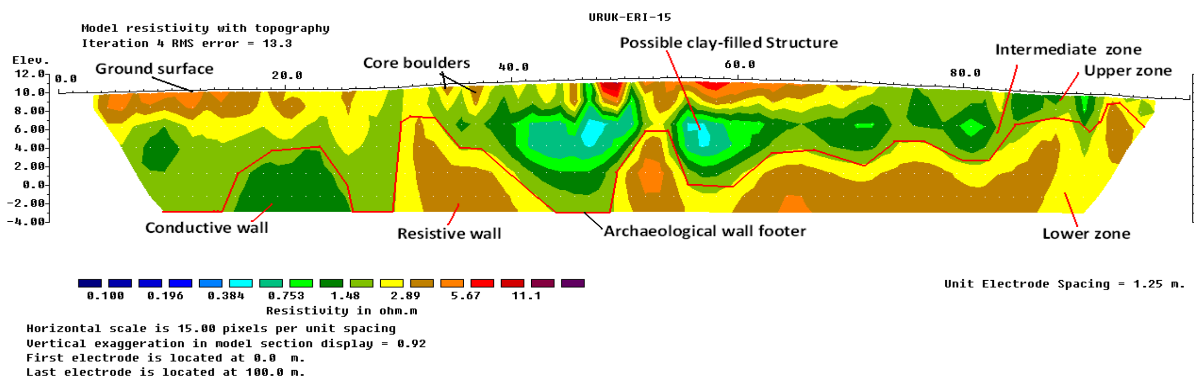

URUK-ERI-10
Model resistivity with topography
Iteration 7 RMS error = 7.0
Elev.
Ground surface
Core boulders
Possible clay-filled Structure
Possible air filled structure
Possible air filled structure
Archaeological wall footer
Conductive wall
Archaeological wall pinnacle
Resistive wall
Lower zone
Intermediate zone
Upper zone
Unit Electrode Spacing = 1.25 m.
0.100 0.196 0.384 0.753 1.48 2.89 5.67 11.1
Resistivity in ohm.m
Horizontal scale is 15.02 pixels per unit spacing
Vertical exaggeration in model section display = 0.92
First electrode is located at 0.0 m.
Last electrode is located at 100.0 m.

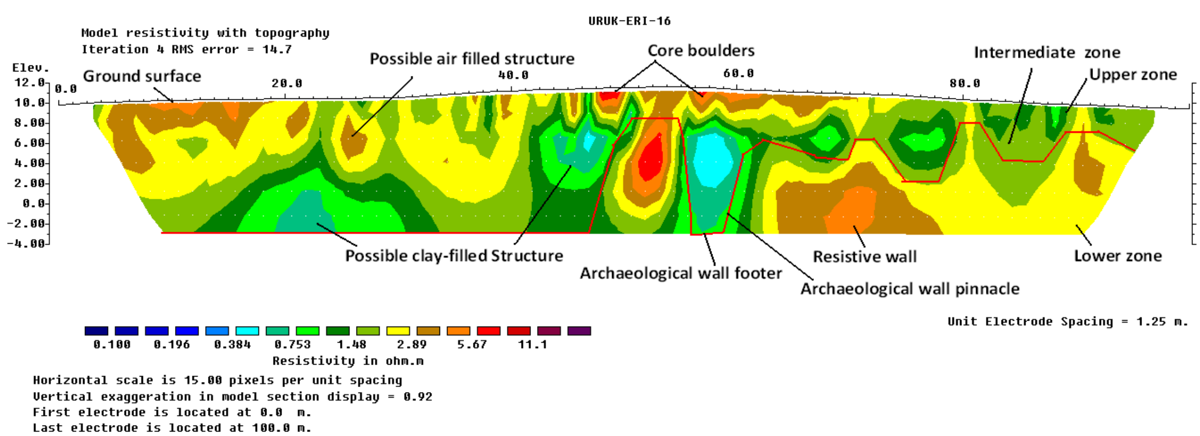

URUK-ERI-11
Model resistivity with topography
Iteration 5 RMS error = 14.5
Elev.
Ground surface
Core boulders
Intermediate zone
Upper zone
Lower zone
Conductive wall
Possible clay-filled Structure
Resistive wall
Archaeological wall pinnacle
Possible air filled structure
Archaeological wall footer
0.100 0.196 0.384 0.753 1.48 2.89 5.67 11.1
Resistivity in ohm.m
Unit Electrode Spacing = 1.25 m.
Horizontal scale is 15.01 pixels per unit spacing
Vertical exaggeration in model section display = 0.92
First electrode is located at 0.0 m.
Last electrode is located at 100.0 m.

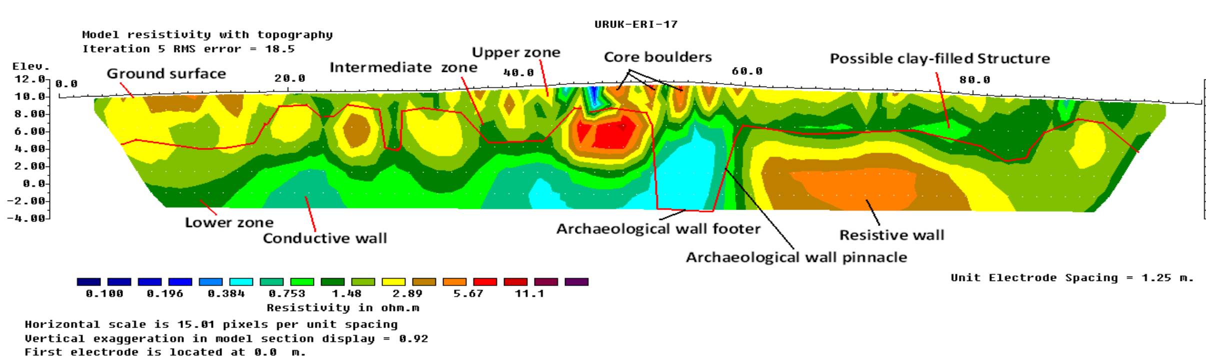

URUK-ERI-12
Model resistivity with topography
Iteration 4 RMS error = 39.5
Elev.
Possible clay-filled Structure
Core boulders
Upper zone
Ground surface
Intermediate zone
Lower zone
Conductive wall
Possible air filled structure
Archaeological wall footer
Resistive wall
Archaeological wall pinnacle
0.100 0.196 0.384 0.753 1.48 2.89 5.67 11.1
Resistivity in ohm.m
Unit Electrode Spacing = 1.25 m.
Horizontal scale is 15.01 pixels per unit spacing
Vertical exaggeration in model section display = 0.92
First electrode is located at 0.0 m.
Last electrode is located at 100.0 m.

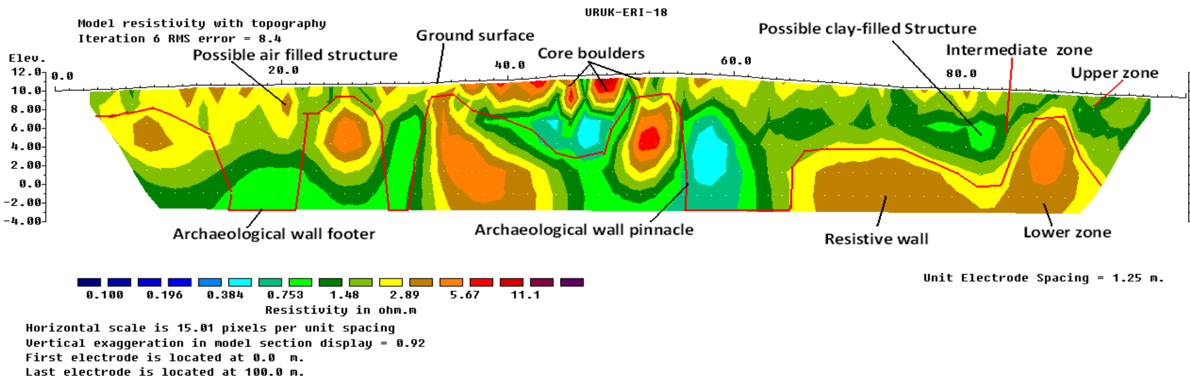

URUK-ERI-13
Model resistivity with topography
Iteration 5 RMS error = 18.5
Elev.
Possible clay-filled Structure
Intermediate zone
Upper zone
Ground surface
Core boulders
Conductive wall
Possible air filled structure
Archaeological wall footer
Resistive wall
Lower zone
Archaeological wall pinnacle
0.100 0.196 0.384 0.753 1.48 2.89 5.67 11.1
Resistivity in ohm.m
Unit Electrode Spacing = 1.25 m.
Horizontal scale is 15.00 pixels per unit spacing
Vertical exaggeration in model section display = 0.92
First electrode is located at 0.0 m.
Last electrode is located at 100.0 m.

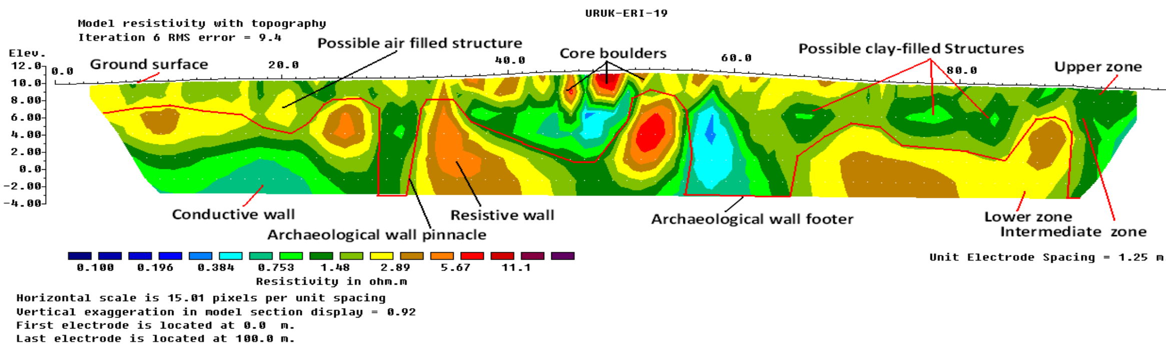

URUK-ERI-14
Model resistivity with topography
Iteration 5 RMS error = 15.7
Elev.
Ground surface
Core boulders
Possible clay-filled Structure
Intermediate zone
Upper zone
Conductive wall
Possible air filled structure
Resistive wall
Lower zone
Archaeological wall footer
Unit Electrode Spacing = 1.25 m.
0.100 0.196 0.384 0.753 1.48 2.89 5.67 11.1
Resistivity in ohm.m
Horizontal scale is 15.01 pixels per unit spacing
Vertical exaggeration in model section display = 0.92
First electrode is located at 0.0 m.
Last electrode is located at 100.0 m.

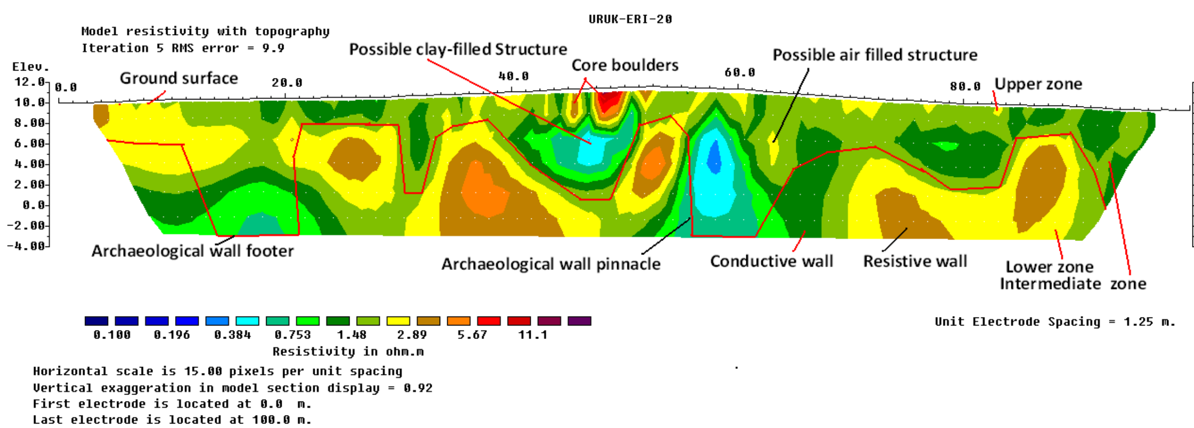

URUK-ERI-15
Model resistivity with topography
Iteration 4 RMS error = 13.3
Elev.
Ground surface
Core boulders
Possible clay-filled Structure
Intermediate zone
Upper zone
Conductive wall
Resistive wall
Archaeological wall footer
Lower zone
Unit Electrode Spacing = 1.25 m.
0.100 0.196 0.384 0.753 1.48 2.89 5.67 11.1
Resistivity in ohm.m
Horizontal scale is 15.00 pixels per unit spacing
Vertical exaggeration in model section display = 0.92
First electrode is located at 0.0 m.
Last electrode is located at 100.0 m.

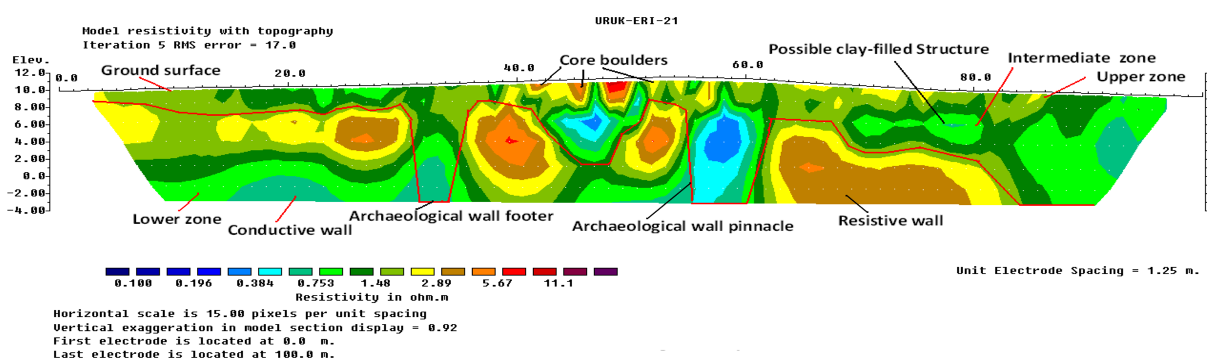

URUK-ERI-16
Model resistivity with topography
Iteration 4 RMS error = 14.7
Elev.
Possible air filled structure
Core boulders
Intermediate zone
Ground surface
Upper zone
Possible clay-filled Structure
Resistive wall
Lower zone
Archaeological wall footer
Archaeological wall pinnacle
Unit Electrode Spacing = 1.25 m.
0.100 0.196 0.384 0.753 1.48 2.89 5.67 11.1
Resistivity in ohm.m
Horizontal scale is 15.00 pixels per unit spacing
Vertical exaggeration in model section display = 0.92
First electrode is located at 0.0 m.
Last electrode is located at 100.0 m.

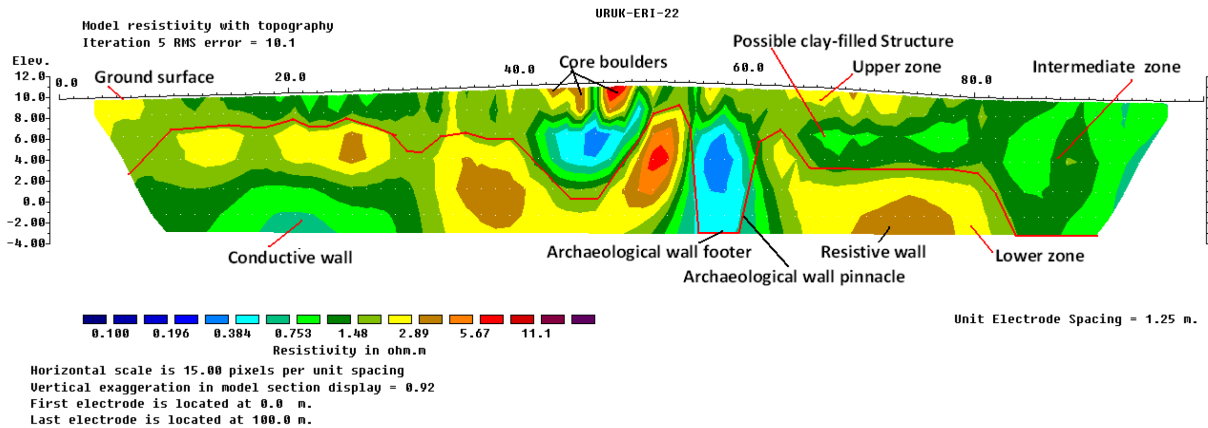

URUK-ERI-17
Model resistivity with topography
Iteration 5 RMS error = 18.5
Elev.
Upper zone
Core boulders
Possible clay-filled Structure
Ground surface
Intermediate zone
Lower zone
Conductive wall
Archaeological wall footer
Resistive wall
Archaeological wall pinnacle
Unit Electrode Spacing = 1.25 m.
0.100 0.196 0.384 0.753 1.48 2.89 5.67 11.1
Resistivity in ohm.m
Horizontal scale is 15.01 pixels per unit spacing
Vertical exaggeration in model section display = 0.92
First electrode is located at 0.0 m.
Last electrode is located at 100.0 m.

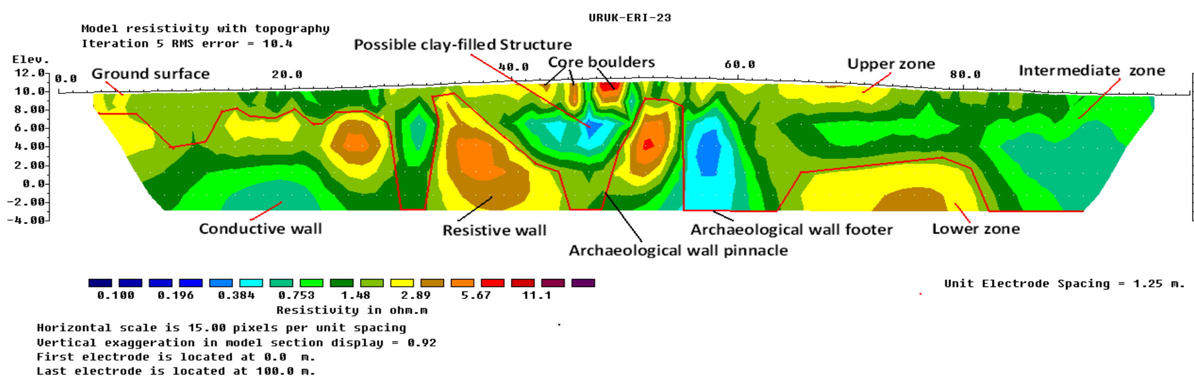

URUK-ERI-18
Model resistivity with topography
Iteration 6 RMS error = 8.4
Ground surface
Possible air filled structure
Core boulders
Possible clay-filled Structure
Intermediate zone
Upper zone
Elev.
Archaeological wall footer
Archaeological wall pinnacle
Resistive wall
Lower zone
Unit Electrode Spacing = 1.25 m.
0.100 0.196 0.384 0.753 1.48 2.89 5.67 11.1
Resistivity in ohm.m
Horizontal scale is 15.01 pixels per unit spacing
Vertical exaggeration in model section display = 0.92
First electrode is located at 0.0 m.
Last electrode is located at 100.0 m.

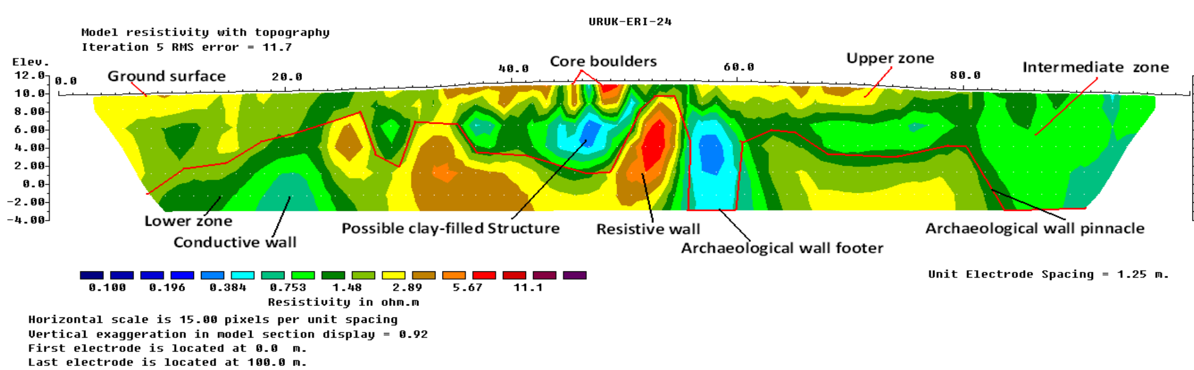

URUK-ERI-19
Model resistivity with topography
Iteration 6 RMS error = 9.4
Possible air filled structure
Core boulders
Possible clay-filled Structures
Ground surface
Upper zone
Elev.
Conductive wall
Resistive wall
Archaeological wall pinnacle
Archaeological wall footer
Lower zone
Intermediate zone
Unit Electrode Spacing = 1.25 m.
0.100 0.196 0.384 0.753 1.48 2.89 5.67 11.1
Resistivity in ohm.m
Horizontal scale is 15.01 pixels per unit spacing
Vertical exaggeration in model section display = 0.92
First electrode is located at 0.0 m.
Last electrode is located at 100.0 m.

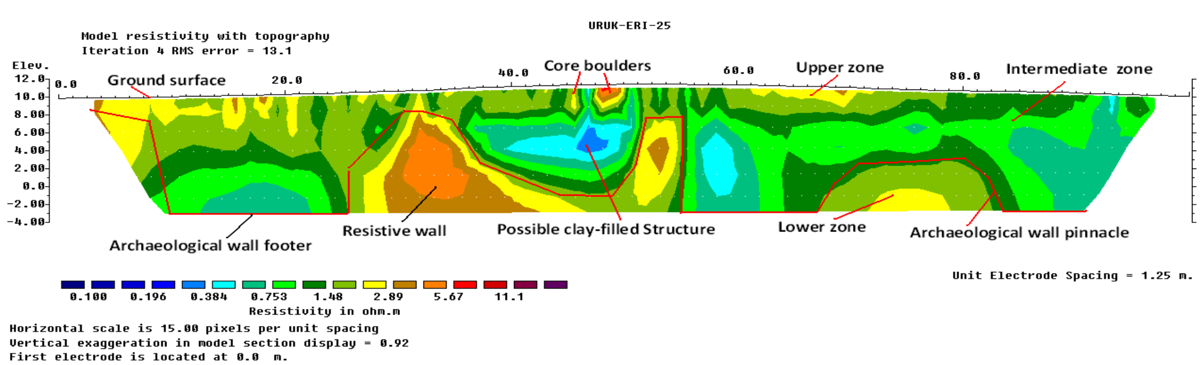

URUK-ERI-20
Model resistivity with topography
Iteration 5 RMS error = 9.9
Possible clay-filled Structure
Core boulders
Possible air filled structure
Ground surface
Upper zone
Elev.
Archaeological wall footer
Archaeological wall pinnacle
Conductive wall
Resistive wall
Lower zone
Intermediate zone
Unit Electrode Spacing = 1.25 m.
0.100 0.196 0.384 0.753 1.48 2.89 5.67 11.1
Resistivity in ohm.m
Horizontal scale is 15.00 pixels per unit spacing
Vertical exaggeration in model section display = 0.92
First electrode is located at 0.0 m.
Last electrode is located at 100.0 m.

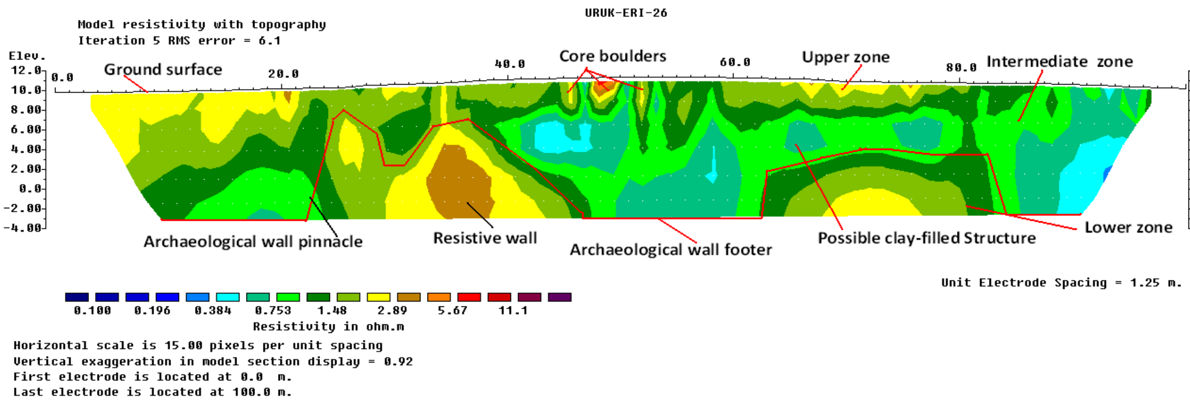

URUK-ERI-21
Model resistivity with topography
Iteration 5 RMS error = 17.0
Possible clay-filled Structure
Core boulders
Intermediate zone
Ground surface
Upper zone
Elev.
Lower zone
Conductive wall
Archaeological wall footer
Archaeological wall pinnacle
Resistive wall
Unit Electrode Spacing = 1.25 m.
0.100 0.196 0.384 0.753 1.48 2.89 5.67 11.1
Resistivity in ohm.m
Horizontal scale is 15.00 pixels per unit spacing
Vertical exaggeration in model section display = 0.92
First electrode is located at 0.0 m.
Last electrode is located at 100.0 m.

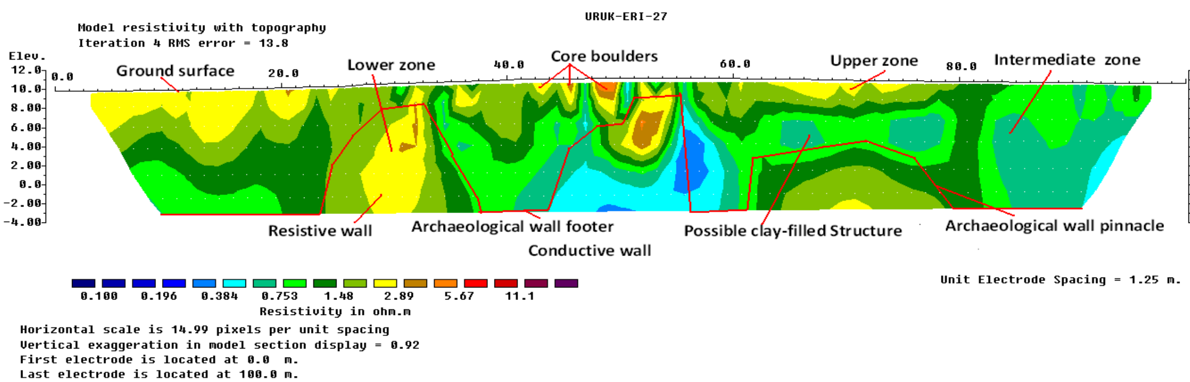

URUK-ERI-22
Model resistivity with topography
Iteration 5 RMS error = 10.1
Ground surface
Core boulders
Possible clay-filled Structure
Upper zone
Intermediate zone
Conductive wall
Archaeological wall footer
Resistive wall
Lower zone
Archaeological wall pinnacle
0.100 0.196 0.384 0.753 1.48 2.89 5.67 11.1
Resistivity in ohm.m
Unit Electrode Spacing = 1.25 m.
Horizontal scale is 15.00 pixels per unit spacing
Vertical exaggeration in model section display = 0.92
First electrode is located at 0.0 m.
Last electrode is located at 100.0 m.

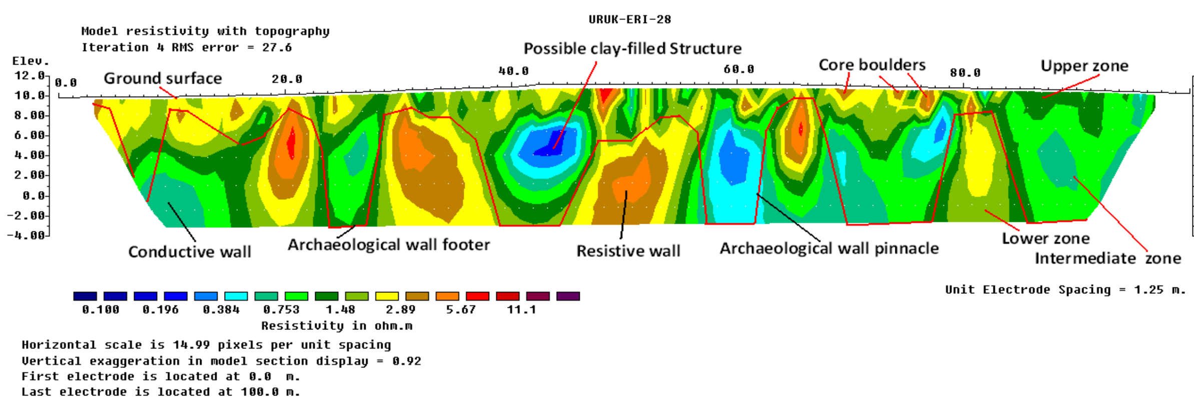

URUK-ERI-23
Model resistivity with topography
Iteration 5 RMS error = 10.4
Possible clay-filled Structure
Ground surface
Core boulders
Upper zone
Intermediate zone
Conductive wall
Resistive wall
Archaeological wall footer
Lower zone
Archaeological wall pinnacle
0.100 0.196 0.384 0.753 1.48 2.89 5.67 11.1
Resistivity in ohm.m
Unit Electrode Spacing = 1.25 m.
Horizontal scale is 15.00 pixels per unit spacing
Vertical exaggeration in model section display = 0.92
First electrode is located at 0.0 m.
Last electrode is located at 100.0 m.

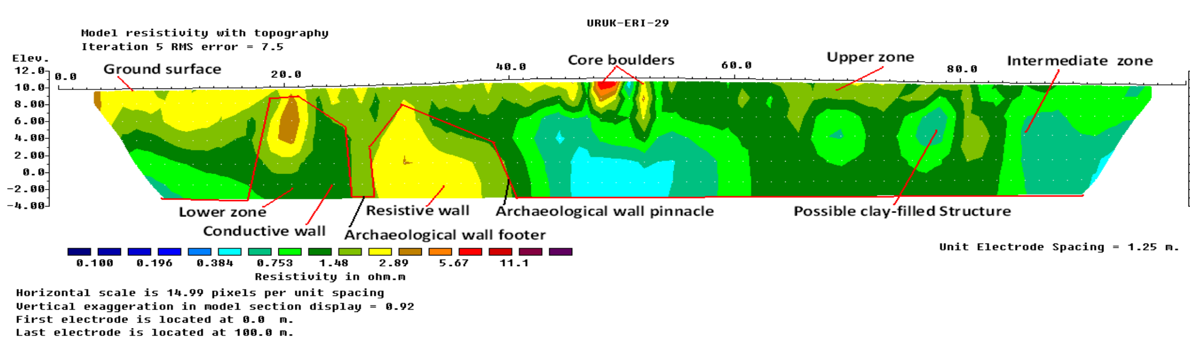

URUK-ERI-24
Model resistivity with topography
Iteration 5 RMS error = 11.7
Core boulders
Upper zone
Intermediate zone
Ground surface
Lower zone
Conductive wall
Possible clay-filled Structure
Resistive wall
Archaeological wall footer
Archaeological wall pinnacle
0.100 0.196 0.384 0.753 1.48 2.89 5.67 11.1
Resistivity in ohm.m
Unit Electrode Spacing = 1.25 m.
Horizontal scale is 15.00 pixels per unit spacing
Vertical exaggeration in model section display = 0.92
First electrode is located at 0.0 m.
Last electrode is located at 100.0 m.

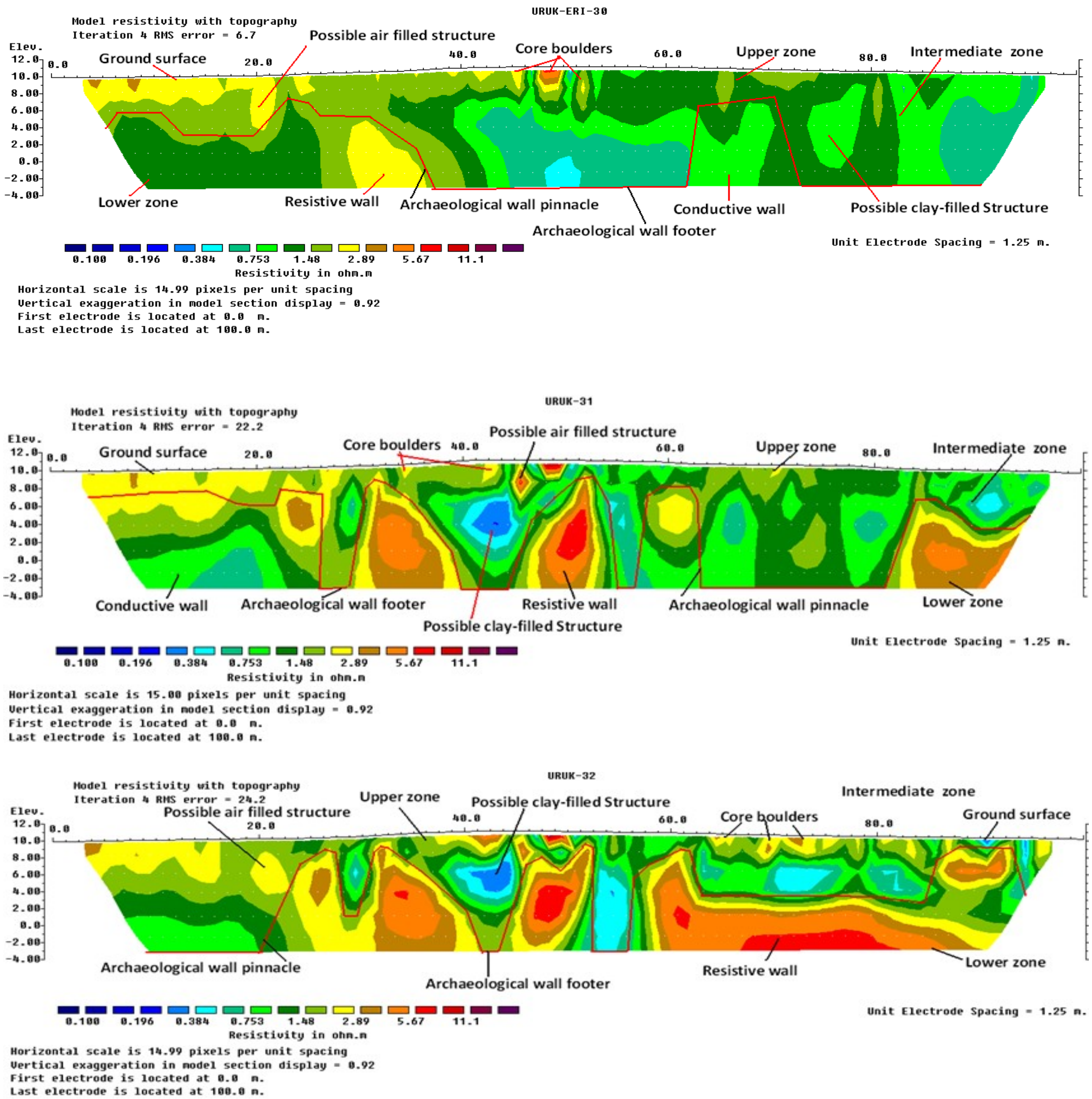

URUK-ERI-25
Model resistivity with topography
Iteration 4 RMS error = 13.1
Core boulders
Upper zone
Intermediate zone
Ground surface
Archaeological wall footer
Resistive wall
Possible clay-filled Structure
Lower zone
Archaeological wall pinnacle
Unit Electrode Spacing = 1.25 m.
0.100 0.196 0.384 0.753 1.48 2.89 5.67 11.1
Resistivity in ohm.m
Horizontal scale is 15.00 pixels per unit spacing
Vertical exaggeration in model section display = 0.92
First electrode is located at 0.0 m.
Last electrode is located at 100.0 m.


URUK-ERI-26
Model resistivity with topography
Iteration 5 RMS error = 6.1
Elev.
12.0
10.0
8.00
6.00
4.00
2.00
0.0
-2.00
-4.00
0.0
20.0
40.0
60.0
80.0
Ground surface
Core boulders
Upper zone
Intermediate zone
Archaeological wall pinnacle
Resistive wall
Archaeological wall footer
Possible clay-filled Structure
Lower zone
Unit Electrode Spacing = 1.25 m.
0.100
0.196
0.384
0.753
1.48
2.89
5.67
11.1
Resistivity in ohm.m
Horizontal scale is 15.00 pixels per unit spacing
Vertical exaggeration in model section display = 0.92
First electrode is located at 0.0 m.
Last electrode is located at 100.0 m.


URUK-ERI-27
Model resistivity with topography
Iteration 4 RMS error = 13.8
Elev.
12.0
10.0
8.00
6.00
4.00
2.00
0.0
-2.00
-4.00
0.0
20.0
40.0
60.0
80.0
Ground surface
Lower zone
Core boulders
Upper zone
Intermediate zone
Resistive wall
Archaeological wall footer
Conductive wall
Possible clay-filled Structure
Archaeological wall pinnacle
Unit Electrode Spacing = 1.25 m.
0.100
0.196
0.384
0.753
1.48
2.89
5.67
11.1
Resistivity in ohm.m
Horizontal scale is 14.99 pixels per unit spacing
Vertical exaggeration in model section display = 0.92
First electrode is located at 0.0 m.
Last electrode is located at 100.0 m.


URUK-ERI-28
Model resistivity with topography
Iteration 4 RMS error = 27.6
Elev.
12.0
10.0
8.00
6.00
4.00
2.00
0.0
-2.00
-4.00
0.0
20.0
40.0
60.0
80.0
Possible clay-filled Structure
Ground surface
Core boulders
Upper zone
Conductive wall
Archaeological wall footer
Resistive wall
Archaeological wall pinnacle
Lower zone
Intermediate zone
Unit Electrode Spacing = 1.25 m.
0.100
0.196
0.384
0.753
1.48
2.89
5.67
11.1
Resistivity in ohm.m
Horizontal scale is 14.99 pixels per unit spacing
Vertical exaggeration in model section display = 0.92
First electrode is located at 0.0 m.
Last electrode is located at 100.0 m.


URUK-ERI-29
Model resistivity with topography
Iteration 5 RMS error = 7.5
Elev.
12.0
10.0
8.00
6.00
4.00
2.00
0.0
-2.00
-4.00
0.0
20.0
40.0
60.0
80.0
Ground surface
Core boulders
Upper zone
Intermediate zone
Lower zone
Conductive wall
Resistive wall
Archaeological wall footer
Archaeological wall pinnacle
Possible clay-filled Structure
Unit Electrode Spacing = 1.25 m.
0.100
0.196
0.384
0.753
1.48
2.89
5.67
11.1
Resistivity in ohm.m
Horizontal scale is 14.99 pixels per unit spacing
Vertical exaggeration in model section display = 0.92
First electrode is located at 0.0 m.
Last electrode is located at 100.0 m.



(Fig.4)The interpreted inverse models of the whole lines , from line 1 to line 32(from profile URUK-ERI-1 to profile URUK-ERI-32).

الملخص

تم التحري الجيوفيزيائي عن التراكيب الأثارية تحت السطحية بمنطقة البيوت البابلية باستخدام طريقة التصوير الكهربائي الثنائي البعد . بينت موديلات التصوير الكهربائي الثنائية البعد شواذ

عميقة و متميزة ذات قيم عالية المقاومة مشيرة إلى النطاق الأكثر سلامة من التراكيب الأثرية التحت السطحية و الممتدة حتى نهاية عمق الاستكشاف , وفي هذا النطاق العميق من منطقة الدراسة كانت موديلات التصوير الكهربائي الثنائية البعد تشير إلى تركيب أثري تحت سطحي يمتد بشكل عمودي خلال الصور و مثل الحيطان و الأسس الأثرية المدفونة المصنوعة من الطين المفخور . كذلك بينت هذه الموديلات شواذ ضحلة العمق في أنحاء منطقة الدراسة مثلت النطاق الأعلى لمنطقة البيوت البابلية ذات قيم عالية المقاومة مثل تربة رملية و طينية جافة مع بعض المواد الأثارية المحطمة مثل الطابوق المكسر و الخراب المخلوط باللباب الصخري و الناتج عن تحطم الحيطان الأثارية بفعل التجوية و التعرية, وهي تعلو نطاق آخر ذو قيم واطئة المقاومة و سمك متغير من مكان لآخر بمنطقة الدراسة و هذه المنطقة من المحتمل سببها الرطوبة في هذه المنطقة والتي أدت لخفض المقاومة النوعية . كما امتازت الموديلات بشواذ متباينة القيم للمقاومة و بأعماق مختلفة و خصوصا قرب سطح الأرض حيث تتركز الشواذ ذات قيم المقاومة العالية والتفسير لهذه الشواذ تراوح بين لباب صخرية و فراغات أو تجاويف أو قبور مملوءة بالهواء أو مملوءة بالطين الرطب اعتمادا على المعطيات الجيوفيزيائية و الأثارية.