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Application of 2D Electrical Resistivity Method and Ground Penetration Rader for Detection of the Archaeological Remains in Kish Site, Babylon, Iraq

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Abstract

The 2D electrical resistivity imaging (ERI) is a non-destructive method with good efficiency to detect shallow subsurface features. The archeological subsurface features were investigated with this method in most cases with the assistance of other methods such as GPR method. Eleven 2D ERI profiles were carried out to investigate the subsurface archeological features in the Kish site in the Babylon area. The 2D electrical resistivity survey was achieved with ABEM Terrameter-LS2 Device and 30 electrodes with 1-meter spacing between the adjacent electrodes along each profile. The length of the profile is 29 meters and the spacing between the adjacent profiles is 3 meters. The software RES2DINV was used to obtain the final inverted models. The resistivity value of the study site is low, not exceeding 10 ohm.m. The variation in the resistivity anomalies values indicates many possible buried walls on the site. The clearest anomaly, which shows relatively high resistivity at the distance range of 8-11 m, appeared in all profiles nearly at the same position and extended in depth from 0.25-4 meters. This anomaly is interpreted as an ancient wall. Profiles 1, 5, and 10 to check the resistivity result. The GPR survey result generally confirms the resistivity result. The 2D ERI and GPR methods successfully detect the buried wall in the study site.

Keywords: Electrical Resistivity Imaging; Using Ground Penetrating Radar; archaeological features; Babylon, Iraq.

استخدام المسح الكهربائي ثنائي البعد والرادار الارضي للكشف عن المعالم الاثرية المدفونة في منطقة كيش، بابل، العراق

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الخلاصة

تعد طريقة التصوير الكهربائي ببعدين من الطرق الآمنة والفعالة للكشف عن الظواهر القريبة من سطح الارض. من الاهداف التي يمكن استكشافها بهذه الطريقة هي الاثار وغالبا ما تستخدم معها طريقة الرادار الارضي لزيادة الدقة. نفذ مسح كهربائي ببعدين للكشف الظواهر الاثارية في منطقة كيش في منطقة بابل. استخدم جهاز ABEM

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Tetrameter-LS2 مع 30 قطب كهربائي وبمسافة فاصلة بين قطب واخر 1 متر. طول كل مقطع 29 متر والمسافة الفاصلة بين مقطع واخر 3 متر. استخدم برنامج RES2DINV لتحويل المعطيات الى الموديل النهائي. القيم الكهربائية في موقع الدراسة كانت قليلة لا تتجاوز 10 اوم متر. التغير في قيم المقاومية الكهربائية دلت على وجود شواذ مقاومية عالية نسبيا أبرزها الشذوذ على مسافة 19-22 متر على جميع المقاطع قريب من جهة الجنوب الغربي من موقع الدراسة، وهذا الشذوذ 0.5 – 4 متر. تم تفسير هذا الشذوذ على انه جدار آثري. المقاطع 1 و5 و10 تم مسحها بطريقة الرادار الارضي لتأكيد نتائج المقاومية الكهربائية، توافقت النتائج بشكل عام من الطريقتين حيث اتضح وجود أكثر من جدار أثري بعضها واضحة وبعضها اقل وضوحا. تمكنت الطريقتين من تحديد الجدران في منطقة الدراسة بنجاح.

1. Introduction

Electrical resistivity imaging (ERI) and Ground Penetrating Radar (GPR) are useful geophysical methods for detecting underground archaeological features. The resistivity technique for archaeological features was used for the first time in 1964 [1]. The benefit of using the electrical imaging method because it is fast with low-cost compared with traditional excavation methods. The resistivity method is usually used in many applications such as water aquifers, engineering site evaluation, cavity, archeological sites studies, and structures investigation [2- 8], The geophysical methods (resistivity and GPR) characterize by the absence of any damage to the archaeological building. Using the resistivity and GPR methods the extension of the archaeological building and its depths can be detected [9]. Accordingly, many archaeological sites lack a geophysical survey to develop a clear picture of the existence and extent of the archaeological buildings. These archaeological sites can be investigated without direct excavation until the preparation is complete for excavation and maintenance.

The resistivity method depends on the presence of a difference in resistivity contrast between the archaeological body and the surrounding materials. It is known that the rocks differ in the ability of electrical conductivity, which depends on several reasons, including the presence of water, voids and the quality of the minerals that make up them and the degree of compaction [10].

The other geophysical method is the GPR which was widely used in archeological studies in the later years [11, 12]. Many studies use both ERI and GPR methods to investigate archeological features. ERI and GPR were applied to study the buried geometrical feature in two historical sites in Napoli city. The joint interpretation of GPR and ERI confirms the initial knowledge of the subsoil archeological feature and plays an important role in safe the studied site [13].

This study attempts to investigate the extension and depth of the archeological features in the Kish site, which is called the Keshatu (This site is considered one main city of Sumerians civilians in Babylon City, Akkadian period), now it is known as Tel Al- Ahmar by using ERI method which is supported by the GPR method.

1.1 Location of Study Area

The Kish site, which is known as "Tel Al-Ahmar" and called in Akkadian civilization "Keshatu", is an archaeological area in Iraq and it is one of the main cities of the Sumerians. It is about 12 km east of Babylon and 80 km south of the capital, Baghdad. According to Sumerian mythology, Kish is the first city in which a king sits after the great flood that was mentioned in Sumerian myths and religions: Judaism, Christianity, and Islam. A French team of archaeologists led by Henri Dejognac first excavated Kish between 1912 and 1914. The location coordinates of the studied site are (32°32′52″-32°32′53″N) (44°36′18″44°36′19.5″E) (Figure 1).

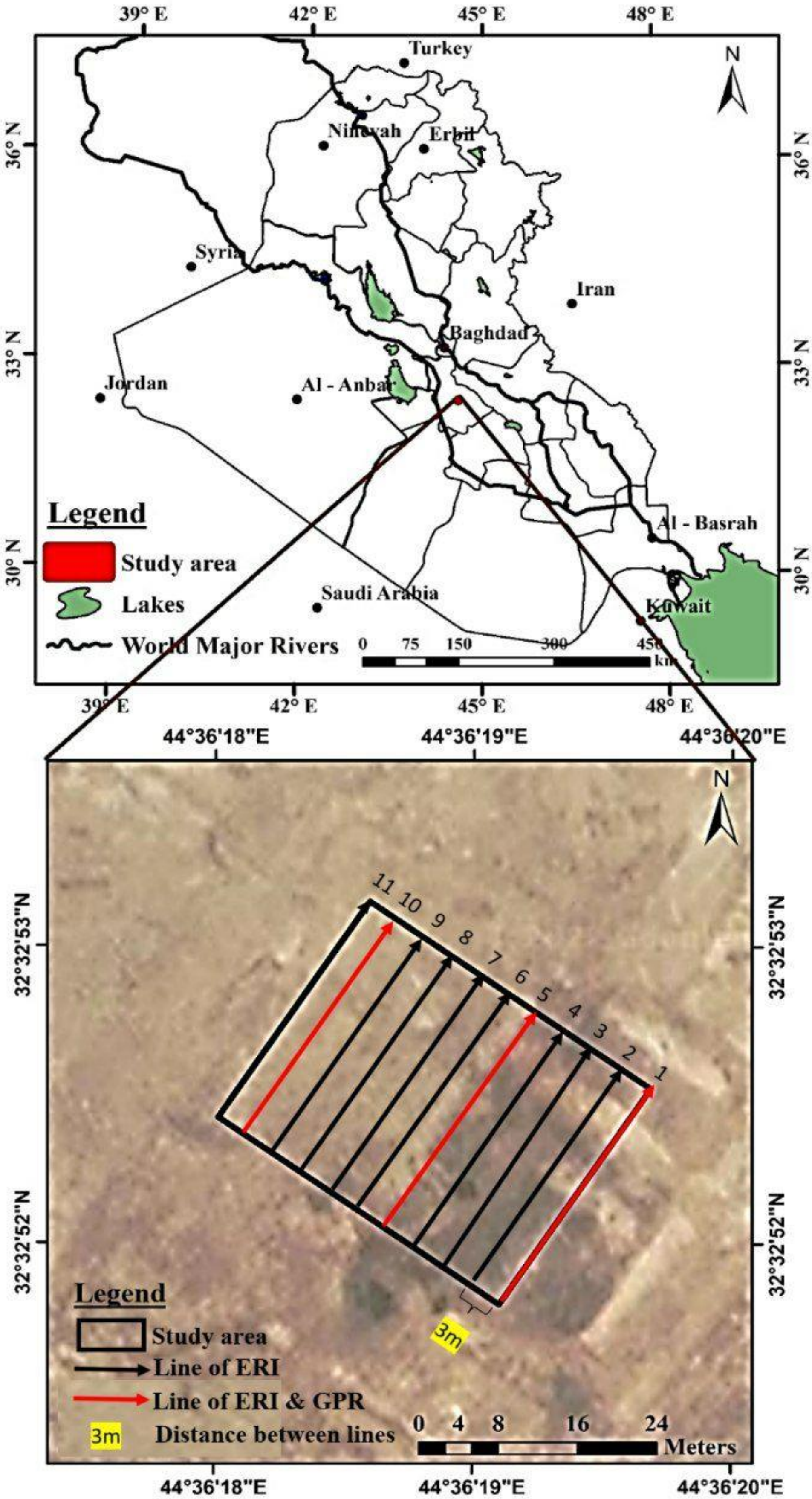

Figure 1: Location map of the study area showing the measurement profiles with a length of 29m and a distance between each to the profile of 3m.

2- Materials and Methods

2.1 The theory of resistivity investigation

The idea of resistivity method involves sending electric current to the ground through a pair of metal electrodes placed at two points in the ground and measuring the electric potential difference mediated by two other electrodes. According to Ohm's law, the relationship between the current, electricity, voltage, and resistance facing the passage of the current can be measured. Taking into account the geometric factor of the electrode configuration and the distance between them. [14], (Figure 2).

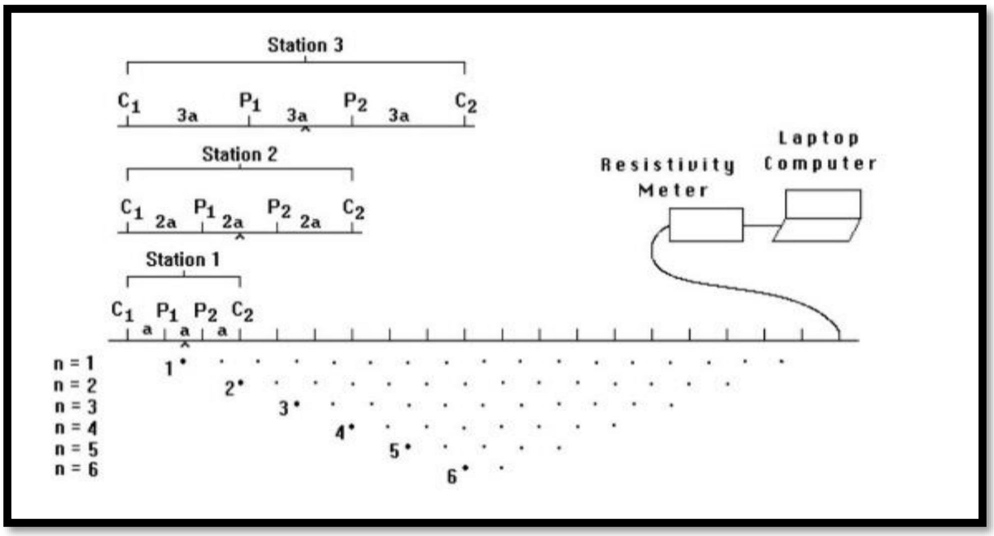

Figure 2: Arrangement of electrodes and distribution of measurement points in imaging Two-dimensional technique [14].

Field data is analyzed for electrical resistivity values using the inversion resistivity method. The data were smoothed depending on the least squares method. The values represent a large number of rectangles distributed over a Pseudo-section and the sizes of these rectangles depend based on the values of the apparent resistivity. The resistivity field data were prosed using RES2DINV software to process field data to obtain the inversion profiles. Data were analyzed and plotted in pseudo-section and eleven sections were obtained. In order to achieve accurate results and a low error rate, the data was processed using the iteration method; the iteration fixed number is seven, and the RMS error rate is between 1% and 3%.

It is the distinguishing electrical property of soil in nature, the electrical conductivity, which is of two types: the first type, known as metallic conduction, results from the movement of ions through the metal; the second type, known as electrolytic conduction, results from the movement of ions through the solutions that fill the pores of the soil. [15]. Because the mineral grains that makeup, they are insulating as they are interconnected with each other to different degrees, leaving each other with different pores in size and completely or partially filled with water. Therefore, the connection is through water confined between the spaces [16]. The specific resistance of the soil depends on the specific resistance of the electrolyte that fills the voids [17]. The specific resistance of sedimentary rocks depends on several factors, including porosity, degree of saturation, salinity, and the nature of the solution in the voids. On this basis, the specific resistance of the soil changes to a large degree, not only from one formation to another but during the sediments of the same formation, meaning that there is no specific relationship between the rock and the specific resistance.

2.2 Fieldwork

The fieldwork was done in February 2022 after obtaining fundamental approval from the General Authority for Antiquities and Heritage. Kish is one of the archaeological sites confirmed by the Authority, from which the Chinese carried out an excavation in 1989, but it was not completed due to the war in 1991 so the site is closed. Geologically, the site is covered with silty clay deposits.

The field measurements in the archaeological site of Kish were carried out on eleven parallel profiles, each one 29 m long, and with an interval of 3 m between any two adjacent profiles. The Wenner array was used with 30 electrodes at a spacing distance of 1 m between any two adjacent electrodes.

2.2.1 The electrical resistivity method

The most recent Terrameter LS2 model, made by ABEM, is used. These instruments include many accessories (Figure 3), including 2 units of multipurpose cable, 30 units of jumper cable, 30 units of stainless-steel electrode, 1 unit of a 12-volt battery, and 1 unit of remote cable.

Figure 3 : The used ABEM TERRAMETER – LS2 Electrostatic Scanning Device.

2.2.2 The GPR method

A useful complement to contemporary archaeological investigations is Ground Penetrating Radar (GPR), which is a non-destructive, high-resolution geophysical technology of archaeological inquiry. GPR has grown to be a good geophysical tool for archaeological excavation in areas where access to buried cultural artefacts is limited [8].

In this investigation, the studied site was surveyed using the MAL RAMAC/GPR system with a 450 MHz shielded antenna, that because this antenna is more suited to finding archaeological sites at depths between 1 and 5 meters. The common filters used in GPRSlicV.7 to analyze the GPR raw data were 1-subtract mean (dewow),2- static correction, 3-background removal, 4-manual gain (y), 5- band base filter [17]. To get rid of direct current (DC) bias, the subtract mean (dewow) filter was utilized. The static correction was used to adjust the zero time, and background removal was employed to remove horizontal or nearly horizontal characteristics from the GPR data so that the processed section could see fainter, more delicate signals; the radar signals were completely equalized, and undesirable frequencies were removed from the traces using a band base filter. This pattern could be used as the best standard for GPR data. The 2D GPR data were exported in SEG-Y format after these filters were applied.

After completing the resistivity survey of the selected area, three parallel GPR profiles were scanned to confirm the resistivity survey. The first, fifth, and tenth profiles were chosen to be scanned. Malå Geoscience Instrument, Swedish Model (RAMAC/GPR) was used, and the survey used a frequency antenna, 450 MHz (Figure 4).

3. Results and discussion

3.1 2D electrical resistivity imaging (ERI)

The analysis of the inversion sections showed a similarity in the distribution of the electrical resistance values of the soil layers. The recurrence of the high resistance in all sections at the distance of 8–11 m despite the distance between these paths of three meters indicates the extension of the effects as if they were a wall. The depth of the wall is approximately 3 m (Figures 4-a and 4-b). In order to confirm the ERI results, three GPR profiles were carried out on profiles, 1, 5 and 10, (Figures 5-a, 5-b, and 5-c). When compare the ERI and the GPR profiles indicate the presence of the main ancient wall.

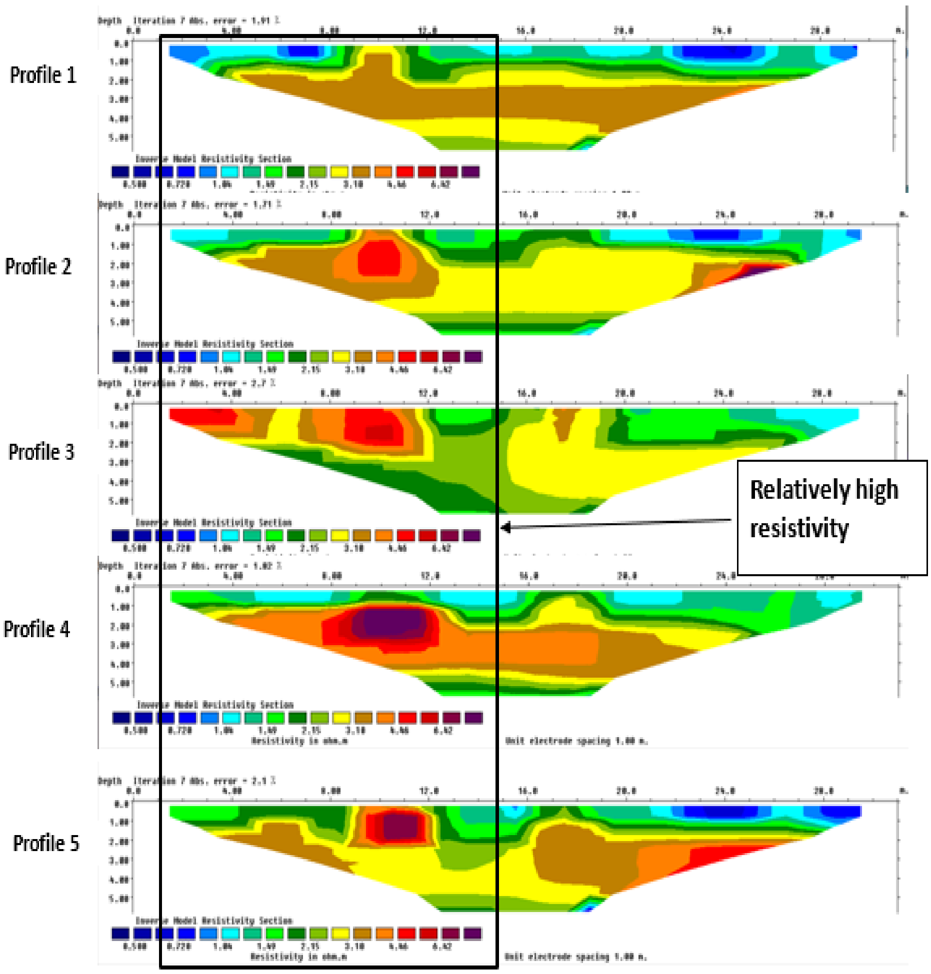

Figure 4 a: The inverse model of the 5 ERI profiles. The extension of the ancient wall is shown in all profiles at a distance of 10-12 m along the surveyed profiles.

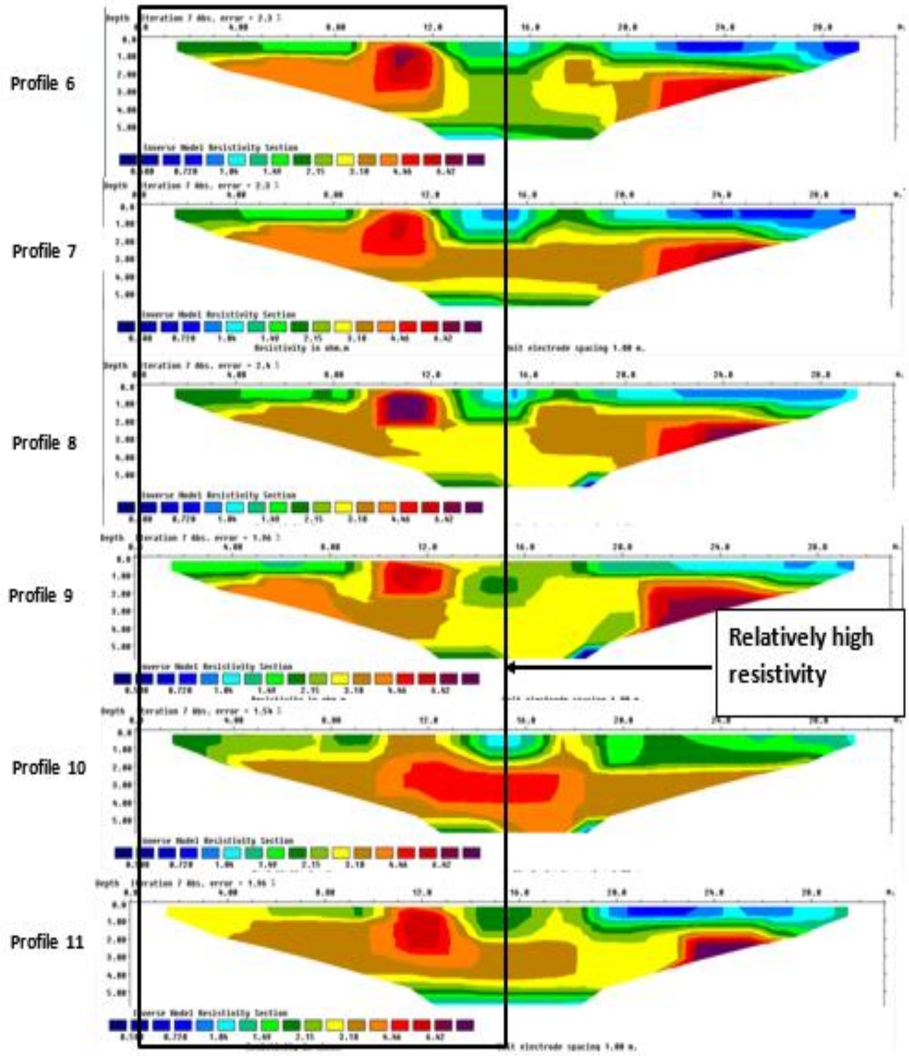

Figure 4 b: The inverse model of the 6 ERI profiles. The extension of the ancient wall is shown in all profiles at the distance 10-12 m and 21-28m along the surveyed profiles.

3.2 Data acquire from GPR

Three parallel profiles were measured in the same direction as the ERT profile, with a gap of 12 m between each profile, the location of these profiles fit ERI profiles 1, 5, and 10. The length of each profile is 29 meters.

3.3 Comparing GPR and ERI Profiles

a. The anomaly in the GPR section from a distance of 8 to 11 meters, as well as from a distance of 24 to 26 meters, and the presence of a high resistance at the same distance in the electrical section, confirmed the existence of an installation-like wall (Figure 5-a). It is noticed that the GPR signal weakens slightly at a depth of 2.5 m due to the depth of the water underground according to the electrical section.

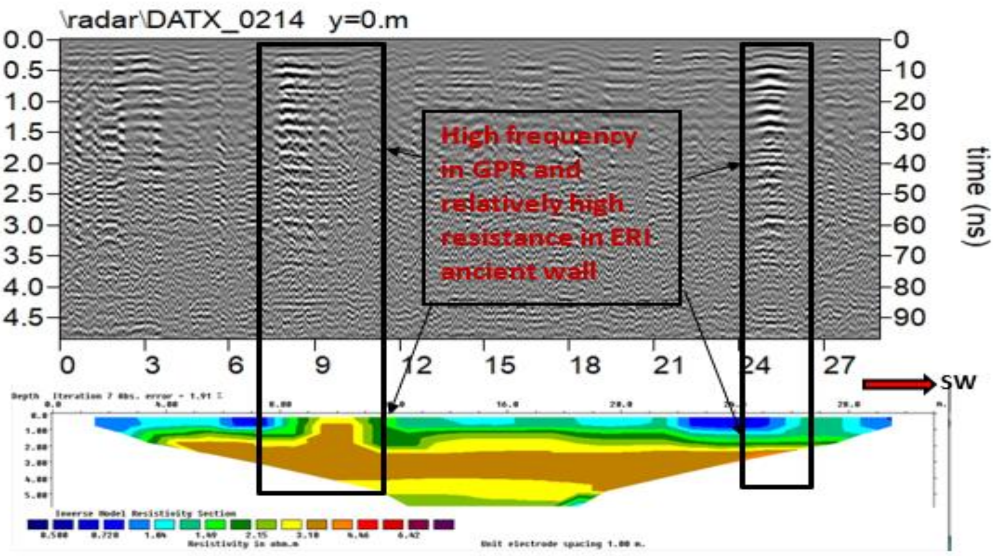

Figure 5 a: Comparing the GPR profile (1) and the ERI Profile (1).

b. The anomaly in the GPR section from a distance of 8.5 to 11 meters, as well as from a distance of 24 to 26 meters, and the presence of a high resistance at the same distance in the electrical section, suggest the presence of an installation-like wall, according to a comparison between GPR Profile No. 2 and ERI Profile No. 5 (Figure 5-b).

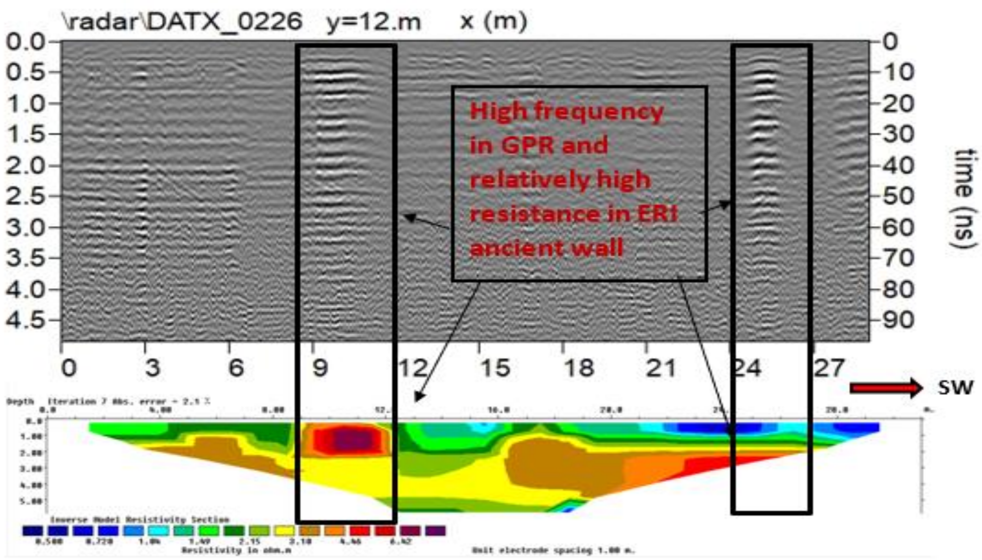

Figure 5 b: Comparing the GPR profile (2) and the ERI Profile (5).

c. GPR Profile No. 3 and ERI Profile No. 10 comparison results in an installation-like wall being there since there is a high resistance at the same distance in the electrical part and a low anomaly in the GPR section at a distance of 10–12 meters, respectively. Nonetheless, the electrical profile shows a 13–19 m range of high resistance while the GPR profile shows no frequency (Figure 5-c).

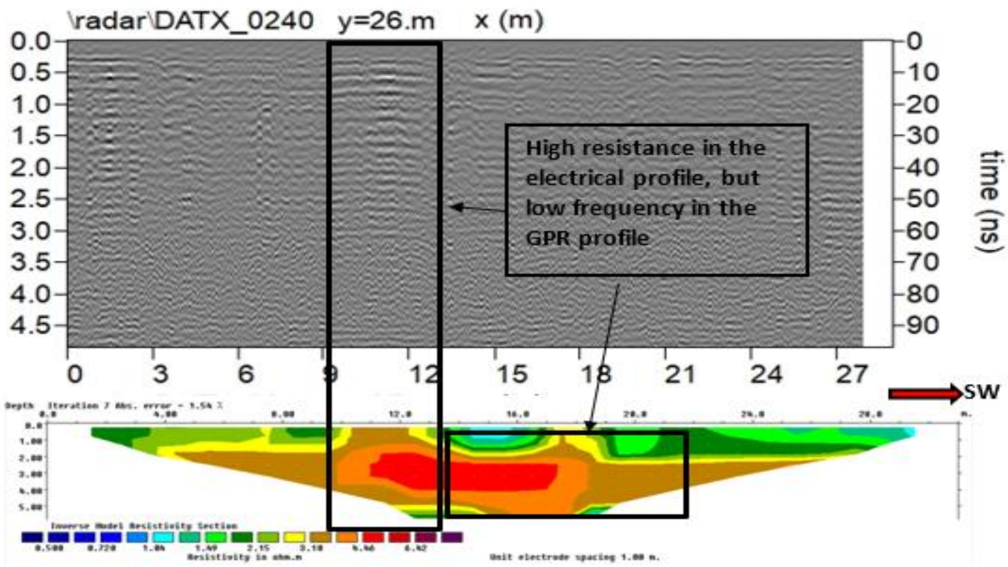

Figure 5 c: Comparing the GPR profile (3) and the ERI Profile (10).

4. Conclusions

-In this investigation, subsurface artefacts and the remains of buried walls in the archaeological site of Babylon were found using the GPR and electrical resistivity.

-The study demonstrates that the electrical resistivity method can accurately measure the extent and depth of the walls made of relics in the study's archaeological area.

-From the application of the electrical resistivity method, it was able to detect the expected walls from the appearance of the anomaly clearly at a distance (8-11-24-26 m).

- The electrical resistivity values were found to be low, this may be due to building the ancient walls of clay from the same materials in the study area. However, many relatively high resistivity anomalies were detected in ERI profiles.

- The ability of GPR to image quickly is a powerful aspect and gives flexible, easy, and rapid, work.

- The eleventh ERI profile and the integrated GPR profiles with the selected ERI profiles 1, 5, and 10 is supporting the idea of the presence of a wall.

-The depth of the wall may be extended from 1 to 3.5m.

-The ERI method gives very good results and the GPR method can confirm the ERI result.

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