DOI: 10.24996/ijs.2019.60.1.12

ISSN: 0067-2904

Using of Ground Penetrating Radar (GPR) for investigate the subsurface archaeological features of Babylon, the ancient city (Mound zoona)

Mohammed S.Nehaba[1*], Jassim M. Thabit[1],Ammar J. Mohammed[2]
[1]Department of Geology, College of Science, University of Baghdad, Baghdad, Iraq
[2]College of Science, University of Karbala, Karbala, Iraq

Abstract

Ground Penetrating Radar (GPR) method has been used in the province of Babylon, the ancient city (constituted mound zoona) archeological site The study area is located South of the city of Hilla by 40 km between longitudes 44° 24′ 40″ E to 44° 27′ 00″ E, and latitudes 32° 31′ 10 ″ N to 32° 33′ 00″ N,

The type of GPR that used in the survey fieldwork was of Malå Geoscience / Sweden type (RAMAC /GPR). The constituted mounts zoona district are surveyed using Seventy – four parallel profiles trending S-N ,N-S , E-W and W-E using the available antenna 160 MHz and 450 MHz, with Five meter spacing between each other are acquired the round-trip survey was conducted for ease and speed of fieldwork for both antenna 160 MHz and 450 MHz taking this into consideration in the interpretation and take special area with dimensions 20*20 meter according to the first shape anomalies individual profiles with one meter between the old the profiles that spacing Five meter also direction longitudinal and transverse also the round-trip survey was conducted for ease and speed of fieldwork was surveyed depending on the result of the regional survey.

It is found that the upper zone of the constituted mounts Zoona characterized by dried clay and sandy soil with brocken archaeological materials, The second zone shows a prominent low resistivity zone probably caused by the moisture in this region that reduces the resistivity. The thickness of this layer is different from parts of the site to the others. The third deeper zone is typical for archaeological walls. Some of the main anomalies, may refer to buried archaeological remains of clay brick walls

The 2D and 3D view of the constituted mounts zoona show that the archaeological anomalies are concentrated mainly in the SE part of the district with higher values of the height of the archaeological walls that range between (6-8) meters and reach to more than (10) meters. At the parts of the study area some walls are with low height that range 4-6 meters.

Keywords: GPR, Archeaological city, Mound Zoona, Babylon, Iraq

*Email: abohomam1986@gmail.com

استخدام الطريقة الجيورادارية للتحري عن الظواهر الأثرية المدفونة في مدينة بابل القديمة (تل زونة)

محمد صالح نهابة[1*]، جاسم محمد ثابت[1]، عمار جاسم محمد[2]

[1]قسم علم الارض، كلية العلوم، جامعة بغداد، بغداد، العراق

[2]كلية العلوم، جامعة كربلاء، كربلاء، العراق

الخلاصة

تم استخدام طريقة الجيورادار الارضي (GPR) في محافظة بابل – اثار مدينة بابل القديمة – موقع (تل زونة) ضمن المواقع الاثرية تقع منطقة الدراسة جنوب مدينة الحلة ب 40 كم بين خطي طول ′24 °44 40″ E و″00 ′27 °44 E وخطي عرض ″10 ′31 °32 N و ″00 ′33 °32 N .

تم عمل مسح لمنطقة الدراسة بأستخدام جهاز الجيورادارنوع رامكو سويدي الصنع حيث تم تسجيل 74 مسار تقريبا على شكل مسارات طولية بأجاه جنوب – شمال , شمال – جنوب ومسارات عرضية بأتجاه شرق – غرب , غرب – شرق ذهاب وأياب وبأستخدام الانتنة المتوفرة حيث كانت الانتنة المتوفرة هي 160 , 450 ميكاهيرتز وتم اجراء مسح عام للمنطقة الدراسة (تل زونة) وبمسافه بين مسار واخر 5 متر وبأستخدام الانتنه المذكورة حيث تم استخدام الانتنة 160 , 450 ميكاهيرتز لجميع المسارات حيث يتم تسجيل المسار بواسطة الانتنة 160 ميكاهيرتز ومن ثم يتم تسجيل المسار نفسه بواسطة الانتنة 450 ميكاهيرتز وهكذا تم تسجيل جميع المسارات وبعد ذلك تم اختيار منطقة معينة حسب الشكل الاولي للشذوذ بأبعاد 20*20 متر وتحديدها من ثم تم اخذ مسارات بينية بين المسارات المأخوذة سابقا لتكثيف القراءات في المنطقة المختارة وكذلك تم استخدام الانتنة 160 و 450 ميكاهيرتز لجميع المسارات البينية

كان من الواضح تقسيم المنطقة إلي عدة انطقه , النطاق الأول الأعلى المتواجد خلال كل منطقة الدراسة 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. تحت هذا النطاق يتواجد نطاق وسطي ذو مقاومة منخفضة نسبيا و هذه المنطقة من المحتمل سببها الرطوبة في هذه المنطقة والتي أدت لخفض المقاومة النوعية , وان سمك هذا النطاق الوسطي مختلف من مكان لأخر في الموقع الأثاري. أما النطاق الثالث فهو الأعمق و مثل الحيطان و الأسس الأثارية المدفونة المصنوعة من الطين المفخور .

بينت خارطة توزيع الشواذ الأثارية تحت السطحية والشكل المجسم للشواذ الأثارية تحت السطحية لمنطقة الدراسة أن الشواذ الأثارية تحت السطحية تتركز بصورة رئيسية في الجزء الجنوبي من منطقة الدراسة مع قيم عالية لارتفاعات الجدران الأثارية تتراوح بين (6–10) متر .من جانب آخر هناك حيطان أثارية اقل مع ارتفاعات أدنى لها في بقية الجهات من المنطقة تتراوح بين(4–6) متر.

1. Introduction

Geophysical surveying provides a relatively fast, non-invasive, and low cost tool that succeeds in getting different kinds of information about the subsurface features.

Ground penetrating radar (GPR) is a non-destructive, high resolution geophysical method of archaeological investigation, and it is a valuable addition to modern archaeological investigations. The first application in an archaeological survey was conducted by Vickers and Dolphin [1]. GPR has become a very important geophysical method for archaeological exploration where buried cultural resources are rare, contested, or simply off-limits [2-5]. Also, the application of GPR in engineering, mining, and environmental geology studies is well documented and highly effective [6-9]

New developments in GPR acquisition, processing equipment and methods include multi frequency antennae, complex 3D datasets, 3D isoamplitude displays, and computer programs to increase data collection and resolution over larger areas [10-13]. In addition, if 3D data are collected using multi-channel GPR arrays, including animations of large, complex data sets, they can generate realistic and accurate 3D images [11-14].

Iraq is dominated by semi-arid environments and an enormous quantity and diversity of archaeological sites. Yet, these cultural properties occur in different environments and various geological formations. Still, buried archaeological features are disturbed by the effects of semi-arid conditions, which complicate interpretation of subsurface geophysical anomalies. The aim of this research is to investigate and outline the locations of buried archaeological features in an un excavated area in Babylon, the ancient city (constituted mounts zoona), and to evaluate the utility of the GPR technique for detecting the dimensions and depths of these archaeological features in semi-arid areas.

2.Geology of the study area

The Babylon archeological city is located about 90 km to the south of the capital Baghdad and about 40 km to the north of Hilla city. in the Mesopotamian zone, in the stable shelf according to the physiographic subdivision of Iraq [15]. It is bounded from the west by Shatt Al-Hilla river, (a branch of the Euphrates River), and from the east of Babylon Canal, whereas from north and south by two artificial lakes

The study area is covered by flood plain and Aeolian sediments of Quaternary age. Lithologically, the sediments are represented by gravels, sands, and prevalently silt. The thickness of Quaternary sediments reaches about 20-25m. The first meter of these sediments generally shows homogeneity and consists mainly of silty clay and sand of local channels. The western part of the area consists mainly of flood plain sediments of Shatt Al-Hilla River.

The second meter of sediments below ground surface proved some differences between the deposition outside the outer wall and inside it. The area outside the wall composed of sandy deposits up to 1.5 m while the area within the wall composed mainly of silty clay. This means that the outer wall had acted as an embankment and protected the inner area from the floods [17]..

Mineralogically,the sand and silt fraction consists of quartz, feldspar, carbonate minerals (calcite, dolomite), chert and a variety of heavy minerals. The clay fraction is characterized by a suite of clay minerals, including montmorillonite, chlorite, kaolinite and illite. Both the carbonate fraction and the clay minerals seem to be of detrital origin [16]. Pre-Quaternary sediments had been found at a depth 25.0 m. below the ground surface, these sediments are mainly formed of sands and silty clays. (Figure-1)

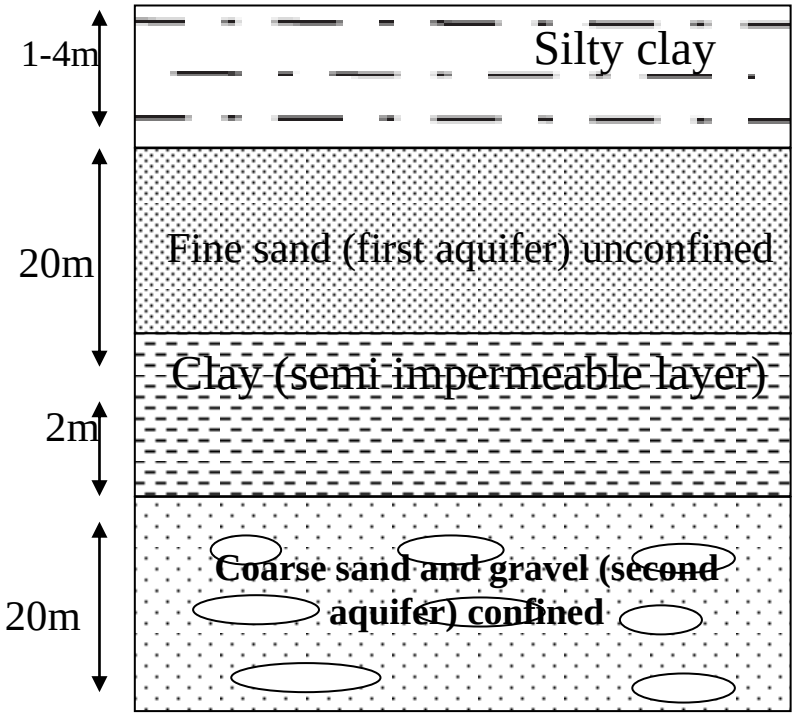

Figure 1-Lithologic section of the sediment in study area.

3. The Exploratory field visit:

The field exploration is carried out to detect all the phenomena and information to help design the site survey. Extent, location, and impact of any surface features such as archaeological structure, sources of noise that prevent measurements and the equipments of possible fairly high are studied
The reconnaissance survey of the studied site clears many facts concerning the area.The first fact the area represented a site of ancient city, including many civilian tools. Some of remains of clay sun-backed things were found on the surface of the earth; secondly, there are many brick walls It is believed to have been used in the construction of the walls and the room as well as there are many phenomena of tools used in ancient cities (Figure-2).

Figure 2-brick wall and tools used in ancient cities.

The elevation of the studied area varied between (0 – 25 cm), the average elevation of the area is about 9.5 meters above natural Earth. The topographic survey carried out by the researcher using (Auto level: AL-24). The topographic survey took a period of two days. This survey included the established of profiles and points of measurements and the study area nearly flat no need to a topographic correction.

4.The planning of the study area:

The dimensions and the size of studying area were selected by the researcher and in cooperation with the supervisor the length of the study area is 60 meters and 30 m is the width, (Figure-3), The Seventy- two straight profiles were used to achived the GPR survey direction longitudinal and transverse the round-trip survey was conducted for ease and speed of fieldwork in the area nearly flat

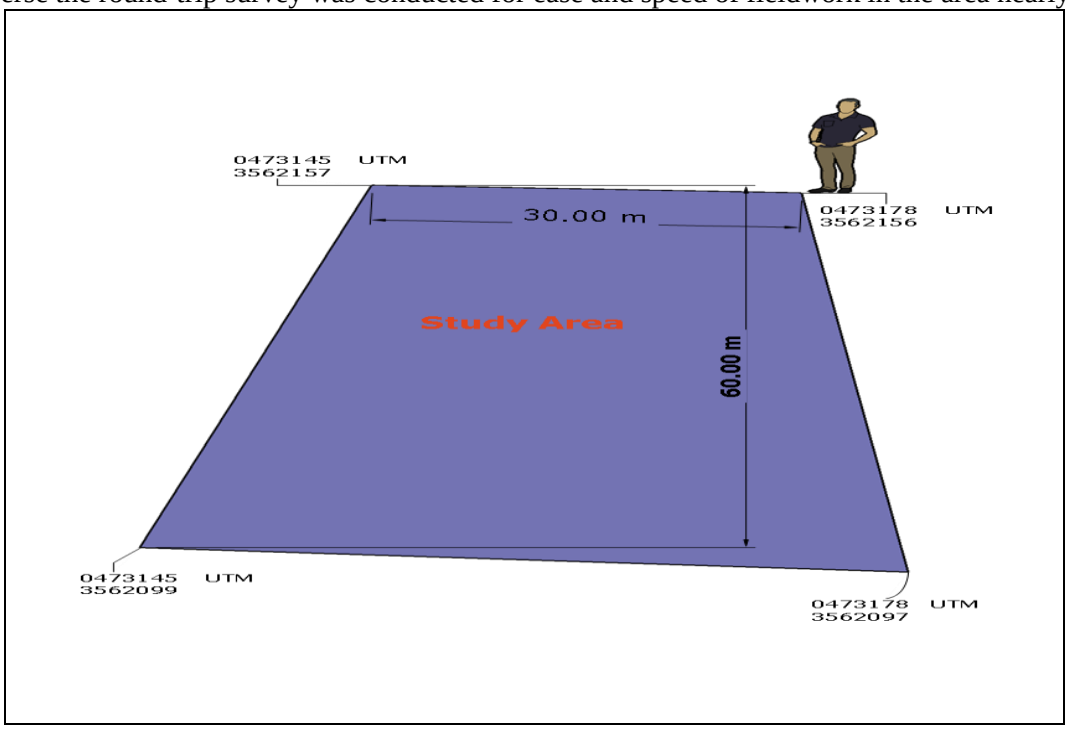

Figure 3-the study area

5.GPR data acquisition

a- General survey

The survey is carried out in Babylon, the ancient city (constituted mounts zoona) area. The topographic variation is surveyed precisely so that the GPR profiles can display with topography. Survey strings are used to guide the passage of an instrument for accurate positioning in a survey of the Babylon, the ancient city (constituted mounts zoona) area of GPR profiles. The used velocity is 0.1 m/ns. A grid pattern parallels the GPR survey system is carried out in the zoona district and 40 individual profiles with Five meters spacing between each other are acquired in the direction longitudinal 26 profiles and transverse 14 profiles the round-trip survey was conducted for ease and speed of fieldwork for both antennas 160 MHz and 450 MHz Figures-4 and 5.

b- Detail survey

Take a special area with dimensions 20*20 meter according to the first shape anomalies, The used velocity is 0.1 m/ns. A grid pattern parallels the GPR survey system is carried out in the zoona district and 32 individual profiles with one meter interval in between the old profiles that spacing Five meters also direction longitudinal 16 profiles and transverse 16 profiles the round-trip survey was conducted for ease and speed of fieldwork for both antennas 160 MHz and 450 MHz, (Figures- 6 and 7). These GPR data acquisition steps are carried out in March 2018. Four field works are carried out during this duration

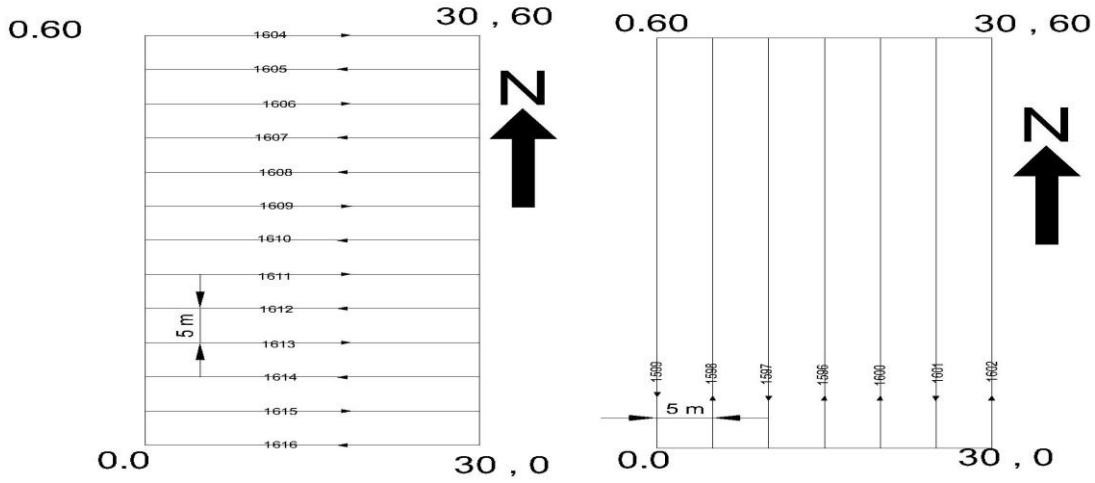

Figure 4-Sketch shows the GPR profiles of general survey and antenna 160 MHz.

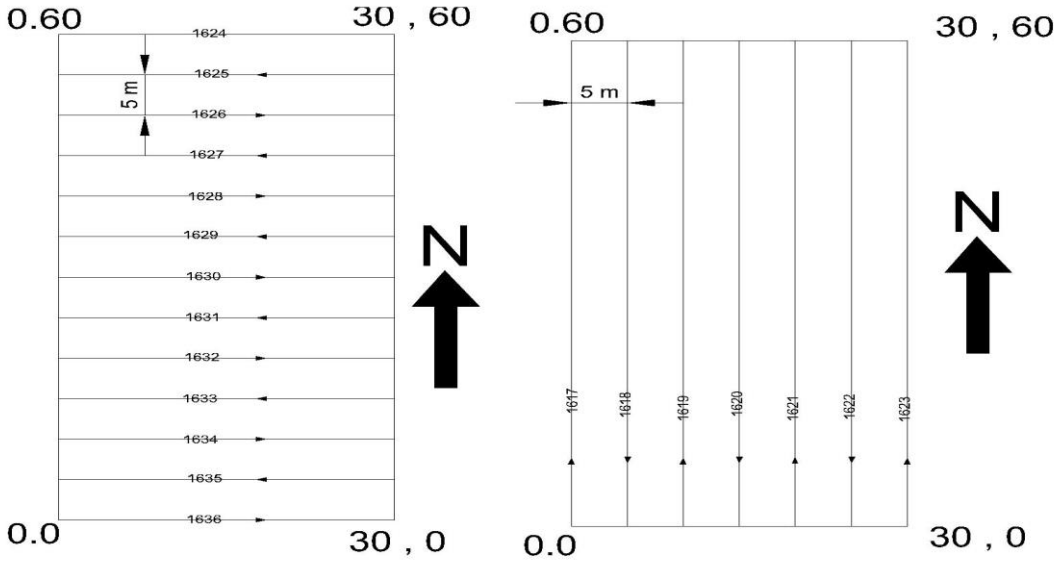

Figure 5- Sketch shows the GPR profiles of general survey and antenna 450 MHz

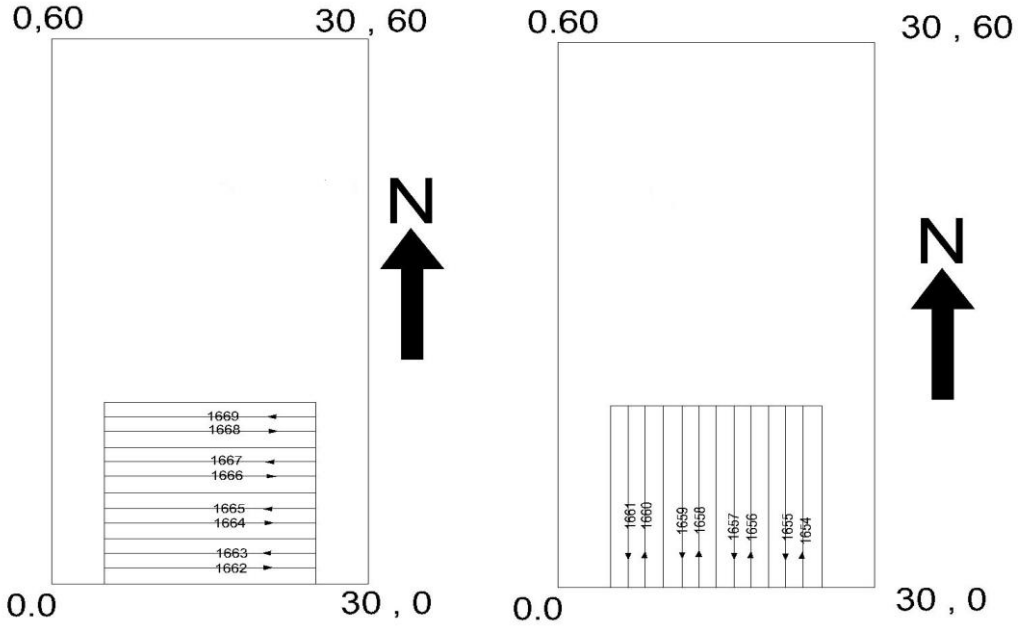

Figure 6- Sketch shows the GPR profiles of detail survey and antenna 160 MHz

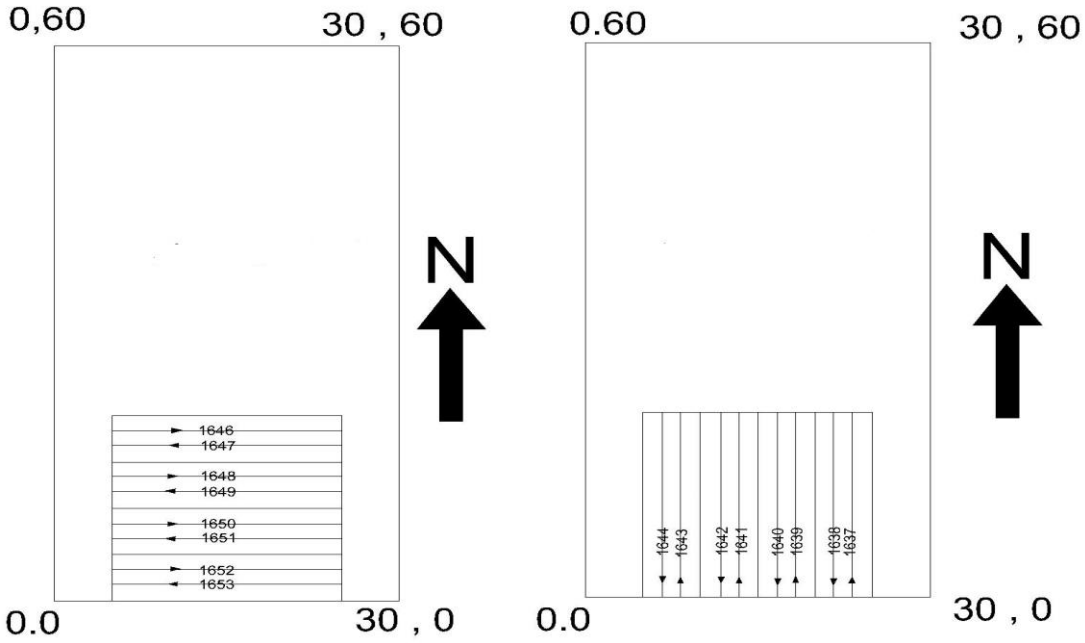

Figure 7- Sketch shows the GPR profiles of detail survey and antenna 450 MHz

6.Data processing

A number of filters and gains may be applied to enhance the reflections of buried objects in GPR records, and to mitigate unwanted noise [18,19]. Also, when the reflections or radar waves have low amplitude, the analysis of these amplitudes cannot give an accurate and an important picture of the subsurface [20].

The Rad Explorer Ver. 1.4 software products by Mala GeoScience Inc. include the following filters:

1. DC removal filters
2. Background filters
3. Time zero adjustment

4. Amplitude correction

The GPR profiles have been processed using standard filters to enhance the desired reflections, and correct the positions of reflectors on the radar record. The steps of applying the filter processing depend on the accuracy of collected profiles and the aim of survey. All the profiles were processed with the same range of filter values, because the subsurface features have approximately the same original characteristics of clay bricks.

Combined use of these filters provides acceptable resolution of profiles containing good and undistorted images of archaeological anomalies below the surface. No topographic corrections were used because the area is flat.

The estimated velocity (using reflected wave method) is used for converting the two ways time (vertical scale of time in radar profile) into actual depth of subsurface archaeology in all GPR profiles, This parameter is equal to 0.1 m/ns.

7. Analysis of GPR profiles and archaeological results

a- Antenna 160 MHz results

36 GPR profiles have been conducted using antenna 160MHz direction (x, y) standard measuring setting used for this GPR survey

1. Antenna center frequency: 160 MHz
2. Time windows: 113 ns
3. Velocity: 0.1 m/ns (with reflected wave method)
4. Point interval: 0.049 m
5. Sampling frequency: 2240 MHz
6. Antenna separation: 0.330 m
7. Number of samples: 700

Primarily the GPR data were visualized with 2D profiles, these profiles were interpreted with by (RadExplorer software) adding different filters in order to enhance the profiles section and reduce the noise. Parts of the filters were excluded because they increase the lack of clarity of the signal. Most of the important filters that were used in this group are Time-zero, Dc removal, Background removal, and Amplitude correction. In below shown the anomalies in study area Figures-8,9 and 10.

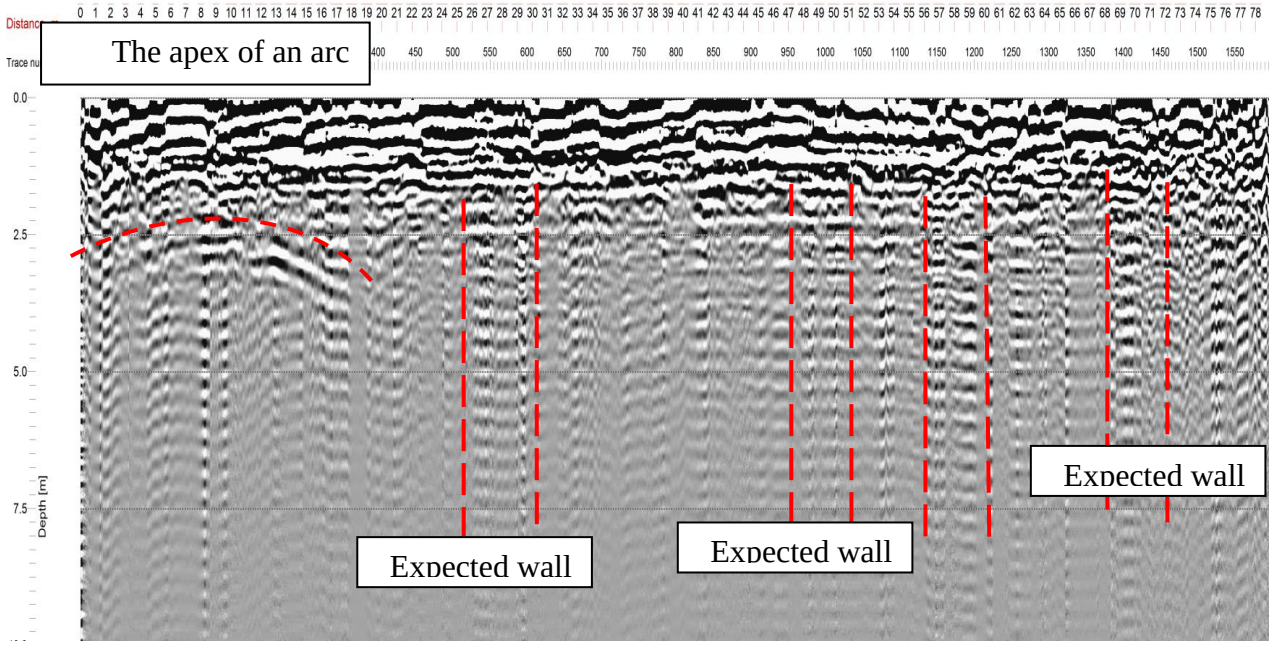

Figure 8- Archaeological anomalies along GPR profile (1596).

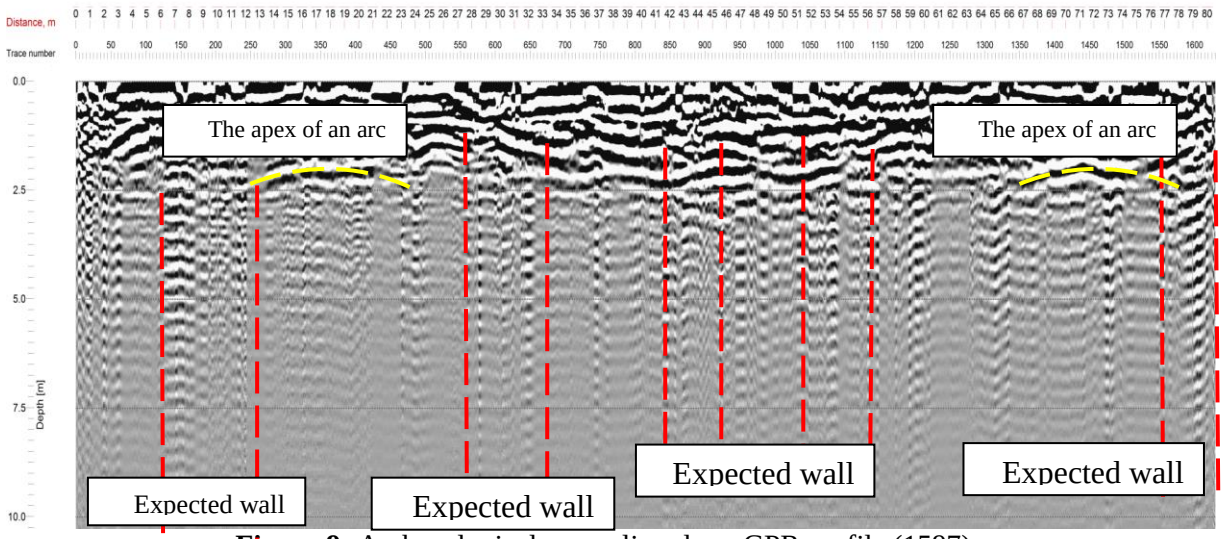

Figure 9- Archaeological anomalies along GPR profile (1597).

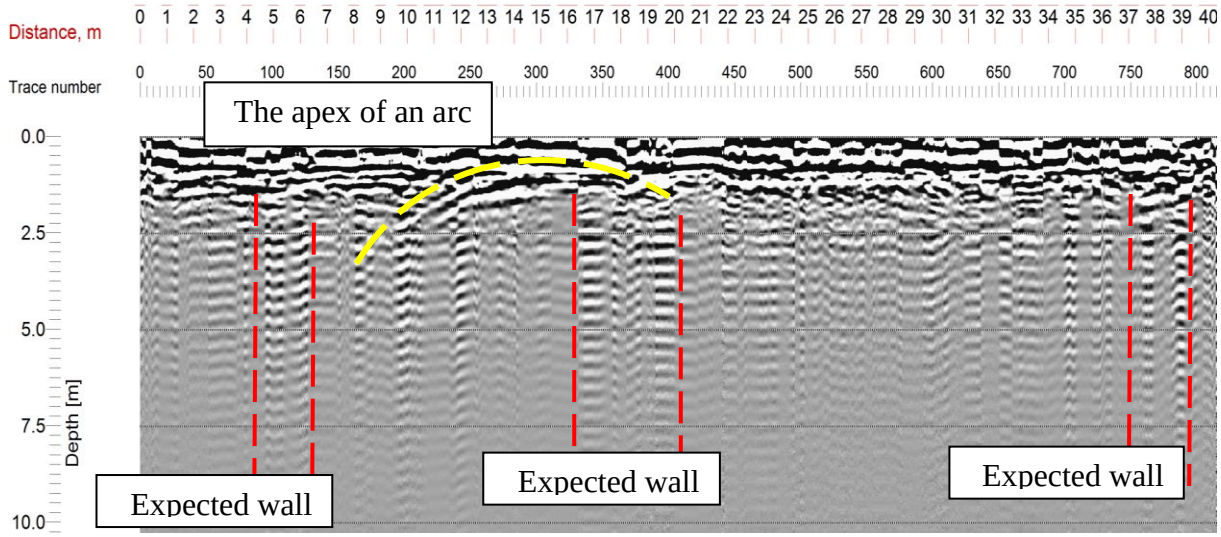

Figure 10-Archaeological anomalies along GPR profile (1615).

b- Antenna 450 MHz results

36 GPR profiles have been conducted using antenna 450 MHz direction (x, y) above profiles when using antenna 160 MHz . A standard measuring setting was used for this GPR survey

1. Antenna center frequency: 450 MHz
2. Time windows: 144 ns
3. Velocity: 0.1 m/ns (with reflected wave method)
4. Point interval: 0.034 m
5. Sampling frequency: 5120 MHz
6. Antenna separation: 0.180 m
7. Number of samples: 733

Primarily the GPR data were visualized with 2D profiles, These profiles were interpreted with by (RadExplorer software) adding different filters in order to enhancement the profiles section and reduce the noise. Parts of the filters were excluded because they increase the lack of clarity of the signal. Most of the important filters that were used in this group are Time-zero, Dc removal, Background removal, and Amplitude correction. In below shown the anomalies in study area Figures-(11 and12).

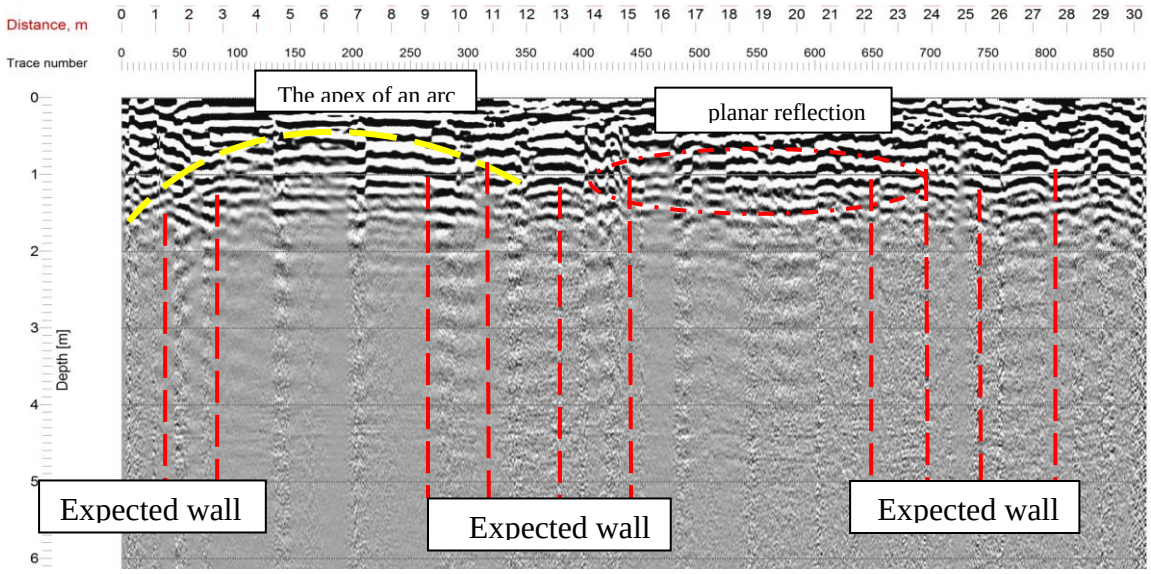

Figure 11- Archaeological anomalies along GPR profile (1637).

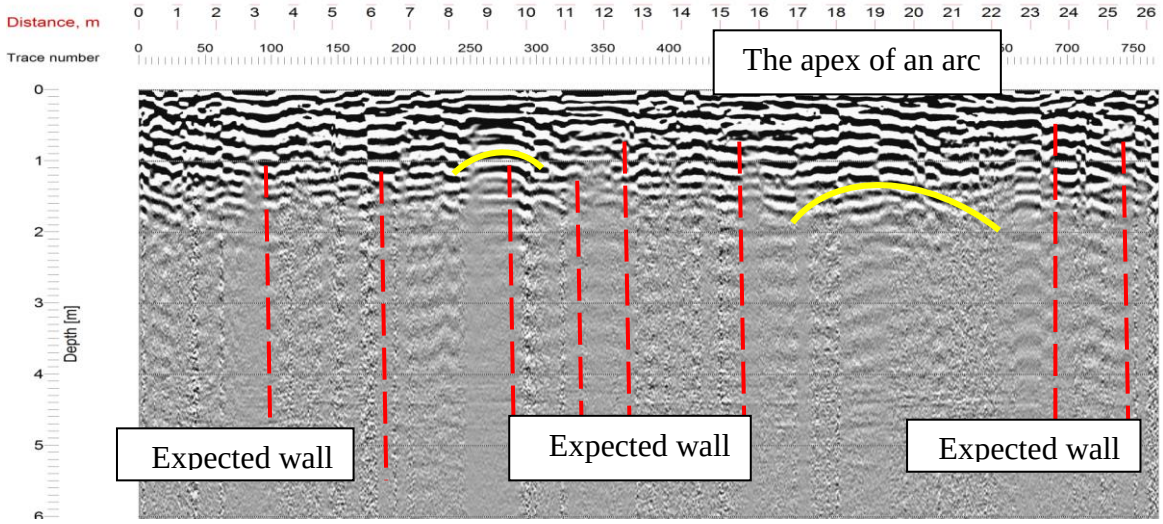

Figure 12-Archaeological anomalies along GPR profile (1651).

8.3D views of the archaeological anomalies

Map and 3D view of the archaeological anomalies foundations in the study area are formed by using data of the GPR profile (from GPR line 1596 to GPR line 1669). (Figure-14) show this map structures represented in the 3D models. These data represent the location anomalies in the study area. The almost subsurface features in the final 3D map show that these shapes of the wall and this means the wall can be used for any civil building such as temples or big palace. In general, the results of the GPR survey are important for understanding the nature and distribution of subsurface features, and this may help to guide archaeologists and geophysicists in future excavations here and elsewhere.

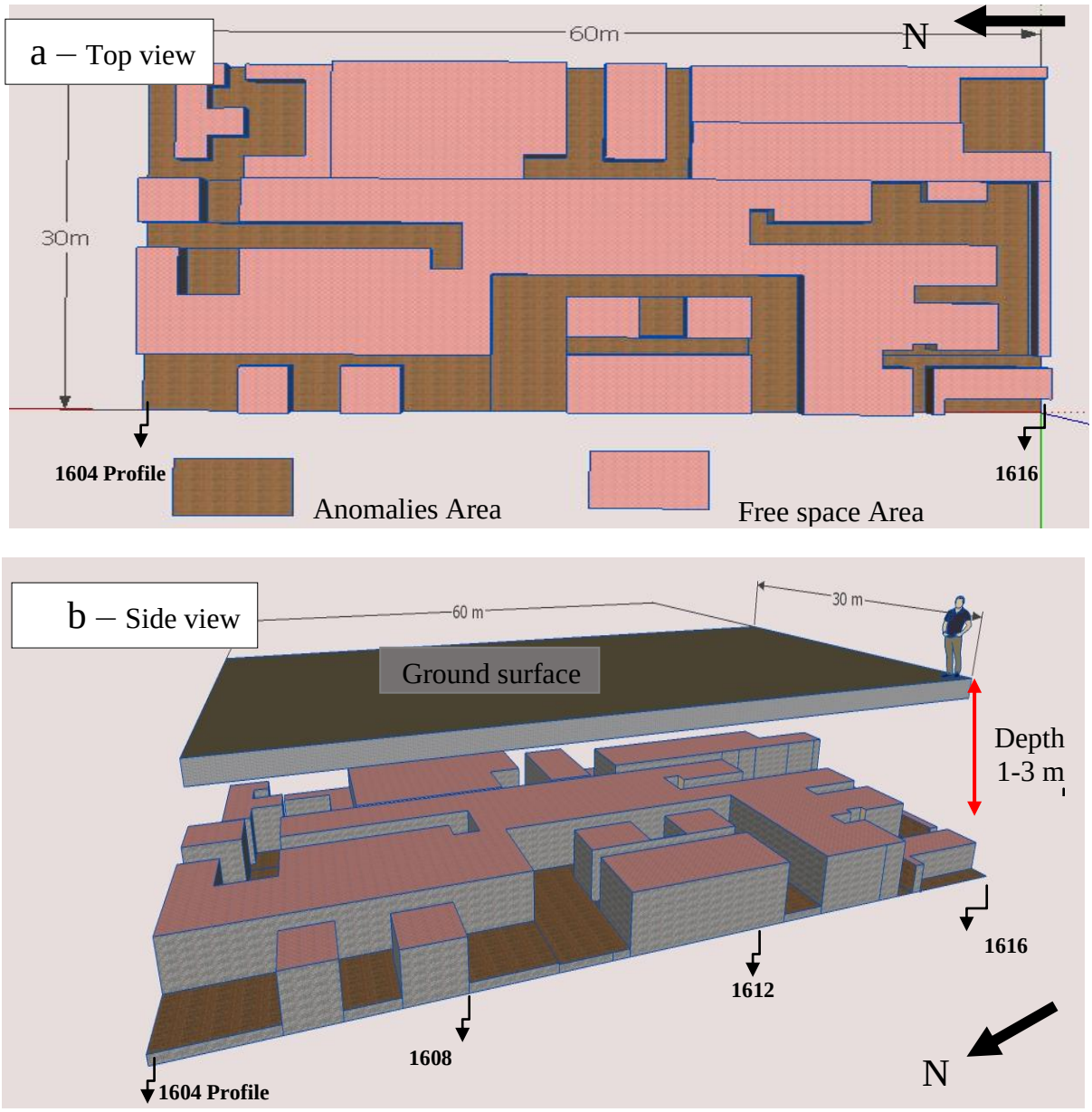

Figure 13- Stages **a** and **b** of structures represented in the 3D models

9.Conclusions

Based on the findings of the present study, the following conclusions are made:

1. Characterized the GPR images illustrate anomalies by reflections continuous with different widths. The GPR images indicate archaeological structures vertically extending through the images..
2. The antenna 160 MHz frequency is good and give results best than antenna 450 MHZ in this study because given image more resolution and anomalies of a clearer .
3. The most types of Iraq soils are composed from clay & silt, and this type of soil is affected the penetration depth of the GPR method. Whenever the soil is dry, the results were better; the more moisture in the soil will be as noise and this will be a significant impact on the investigation of objects near the surface may distort the picture section.
4. The high frequency means high resolution however, the depth of investigate target is so important to estimated the suitable antenna frequency. The 160 and 450 MHz frequency is good but the survey needs to support by another method from geophysical methods.
5. GPR images are characterized by point reflection anomalies like dense or reflective buried items, planar reflections ,buried trenches and pits, or object which is located at the apex of the arc. These

point reflection anomalies are concentrated mainly near the surface. Corresponding to these GPR images.

6. According to the interpretation of GPR images models of the study area the top zone found to be including dried clayed and sandy soil with broken and weathered different archaeological materials such as broken brick and slag mixed with core boulders. The second zone shows low resistivity. This second zone is probably caused by the moisture in this region that reduces the resistivity. The thickness of this layer is different from parts of the site to the others. The third deeper zone is typical for archaeological walls. Most of the main anomalies perhaps refer to buried archaeological remains of clay brick walls..
7. The GPR results show a good agreement and integrated interpretation. One more advantage of the use GPR for this investigation is that an archaeological site is usually shallow, which facilitates the GPR with an improvement in the resolution is attained. The results show good agreement.
8. The final images are of high spatial resolution and clear anomalies which are attributed to buried archaeological structures.

References

1. Vickers, R.L., Dolphin, L. and Johnson, D**. 1976**. Archaeological investigations at Chaco Canyon using subsurface radar, in remote sensing experiments in cultural resource studies: Non-destructive methods of archaeological exploration, survey, and analysis. Reports of the Chaco center. National Park Service and University of New Mexico, Albuquerque, New Mexico, **1**: 81-101.
2. Goodman, D. and Nishimura, Y. **1993**. Ground radar view of Japanese burial mounds. *Antiquity* ,**67**(255): 349-354.
3. Gracia, V.P., Canas, J.A., Pujades, L.G., Clapes, J., Caselles, O., Garcia, F. and Osorio R. **2000.** GPR survey to confirm the location of ancient structures under the Valencian Cathedral (Spain). *Journal of Applied Geophysics*, **43**: 167-174.
4. Ernenwein, E.G. **2006**. Imaging in the ground penetrating radar near-field zone: A case study from New Mexico. USA, Archaeological Prospection, **13**: 154-156.
5. Conyers, L.B. and Lucius, J.E. **1996**.Velocity analysis in archaeological ground penetrating radar studies. *Archaeological Prospection*, **3**: 25-38.
6. Ulricksen, C.P. **1982**. Application of impulse radar to civil engineering. Unpublished Ph.D. Thesis, Lund University of Technology, Lund, Sweden.
7. Pilon, J.A. **1992.** Ground penetrating radar, Geological Survey of Canada, Minister of Supply and Services, Paper 90-4, 241.
8. Grandjean, G., Gourry, J.C. **1996**. GPR data processing for 3d fracture mapping in a marble quarry (Thassos, Greece). *Journal of Applied Geophysics*, **36**: 19–30.
9. Arcone, S.A., Lawson, D.E., Delaney, A.J., Strasser, J.C. and Strasser, J.D. **1998.** Ground penetrating radar reflection profiling of groundwater and bedrock in an area of discontinuous permafrost. *Geophysics*, 63: 1573-1584.
10. Leckebusch, J. **2009.** Test and data processing of a stepped frequency GPR array, 8th International Conference on Archaeological Prospection, Paris, 305-307.
11. Novo, A., Grasmueck, M., Viggiano, D.A. and Lorenzo, H. **2008.** 3D GPR in archaeology: what can be gained from dense data acquisition and processing. In: Proceedings of the 12th International Conference on Ground Penetrating Radar (GPR 2008), Birmingham, 16-19.
12. Sala, J. and Linford, N. **2012**. Processing stepped frequency continuous wave GPR systems to obtain maximum value from archaeological data sets. *Near Surface Geophysics*, **10**: 3-10.
13. Trinks, I., Johansson, B., Gustafsson, J., Emilsson, J., Friborg, J., Gustafsson, C., Nissen, J. and Hinterleitner, A. **2010**. Efficient, large-scale archaeological prospection using a true three-dimensional ground penetrating radar array system. *Archaeological Prospection,* **17**: 175-186.
14. Conyers, L.B. and Leckebusch, J. **2010.** Geophysical archaeology research agendas for the future: Some ground penetrating radar examples. *Archaeological Prospection*, **17**: 117-123.

15. Grealy, M. **2006.** Resolution of ground penetrating radar reflections at differing frequencies, *Archaeological Prospection*, **13**: 142-146.
16. Jassim, S.Z. and Goff, J C. **2006.** Geology of Iraq, Czech Republic, 341P.
17. Boniger, U., Tronicke, J. **2010**. Improving the interpretability of 3D GPR data using target–specific attributes: application to tomb detection.. *Journal of Archaeological Science*, **37**: 360-367.
18. Karim, Ibtisam, **2005.** Lowering Groundwater Levels in the Ancient City of Babylon, Unpub.Msc., University of Technolog, 130p
19. Annan, A.P. **1999**. Practical processing of GPR data. Sensors and Software Inc., Ontario, 16.
20. Grealy, M. **2006.** Resolution of ground-penetrating radar reflections at differing frequencies, *Archaeological Prospection*, **13**, 5p.
21. Weaver, W. **2006.** Ground-penetrating radar mapping in clay: Success from South Carolina, USA. *Archaeological Prospection*, **13**: 147-150.