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Detection of subsurface archaeological features using the GPR method with a 250 MHz antenna in Borsippa site, Babylon, Iraq

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Abstract

The GPR method was used to determine the depth and extent of the subsurface archaeological features at the archaeological site of Borsippa. The extensions of the archaeological walls were identified through the creation of three-dimensional maps. The LMX200 device conducted the survey using a 250 MHZ antenna. sixty parallel profiles were collected and processed by GPR Slice software. Several reflections of possible archaeological walls buried at different depths and extensions of 2, 4, 6, 11, and 20 m were identified. The 250 MHz antenna gave clear reflections of the archaeological walls, with a penetration depth of up to 4 meters. The time slice map identified a buried archaeological structure at 1–1.1 m deep, consisting of many rooms with thick walls up to 2-3 m.

Keywords: Ground Penetrating Radar; archaeological structure; 250MHz antenna; Borsippa

تطبيق طريقة GPR لفحص السمات الأثرية الجوفية باستخدام هوائي 250 ميجاهرتز في موقع بورسيبا، بابل ، العراق

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الخلاصة:

تم استخدام طريقة GPR لتحديد عمق ومدى السمات الأثرية الجوفية في موقع بورسيبا الاثري. تم تحديد امتدادات الجدران الأثرية من خلال إنشاء خرائط ثلاثية الأبعاد. أجرى جهاز LMX200 المسح باستخدام هوائي 250 ميجا هرتز. تم جمع 60 ملف تعريف متوازي ومعالجتها بواسطة برنامج GPR Slice. تم تحديد العديد من الانعكاسات للجدران الأثرية المحتملة المدفونة على أعماق مختلفة بأمتدادات 2 و 4 و 6 و 11 و 20 مترًا. أعطى الهوائي 250 ميجاهرتز انعكاسات واضحة للجدران الأثرية بعمق اختراق يصل إلى 4 أمتار. حددت خريطة الشريحة الزمنية هيكلًا أثريًا مدفونًا على عمق يتراوح من 1 إلى 1.1 متر ، ويتألف من العديد من الغرف ذات الجدران السميكة (التي يصل سمكها إلى 2–3 متر).

1. Introduction

Ground penetrating radar is a more complex archaeological geophysical methods because data collection involves significant amounts of reflectance data from many cross-sections within grids, often producing massive 3D databases [1]. GPR can provide sufficient and accurate data regarding archaeological features and depth without destructive research, as

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excavation is generally expensive and often controversial [2]. A GPR survey is used to assess spatial changes in the travel times and intensities of pulsed electromagnetic radiation reflected off subsurface features (often geologic boundaries) of interest [3]. GPR transmits electromagnetic pulses from surface antennas into the ground and then measures the time between when the pulses are transmitted and when they return to the surface [4]. Multi-frequency antennas, 3-dimensional datasets, and computer programs were used in the new GPR data collection and processing methods to improve data collection and resolution over larger areas [5]. Using a lower frequency antenna is often the best solution, but the question of selecting the optimal frequency antenna remains. It is typically a balance between penetration depth and the desired level of detail. Generally, if the target features are between 1 and 3 meters below the ground surface, antennas between 200 and 500 megahertz will probably be optimal for transmitting energy to that depth and resolving most features and related stratigraphy [1]. A shield antenna with a frequency of 250 MHz gives the investigation accuracy and depth required to explore archaeological features [2]. The higher the amplitude of wave reflections through a medium, the more distinct the chemical and physical properties of the buried material [6]. Many studies have been conducted using the GPR method to investigate Babylon Governorate's archaeological features, for example, [7] mentioned that the high-amplitude reflections in the GPR profiles may represent archaeological walls.

2. Location of study area

Borsippa is an archaeological site located in the Babylon Governorate, Iraq. Borsippa was an ancient Sumerian city. It was built on both sides of a lake about 17.7 km southwest of Babylon on the eastern bank of the Euphrates (Figure1). According to [8], the research region is covered with Quaternary sediments from the floodplain and aeolian sediments.

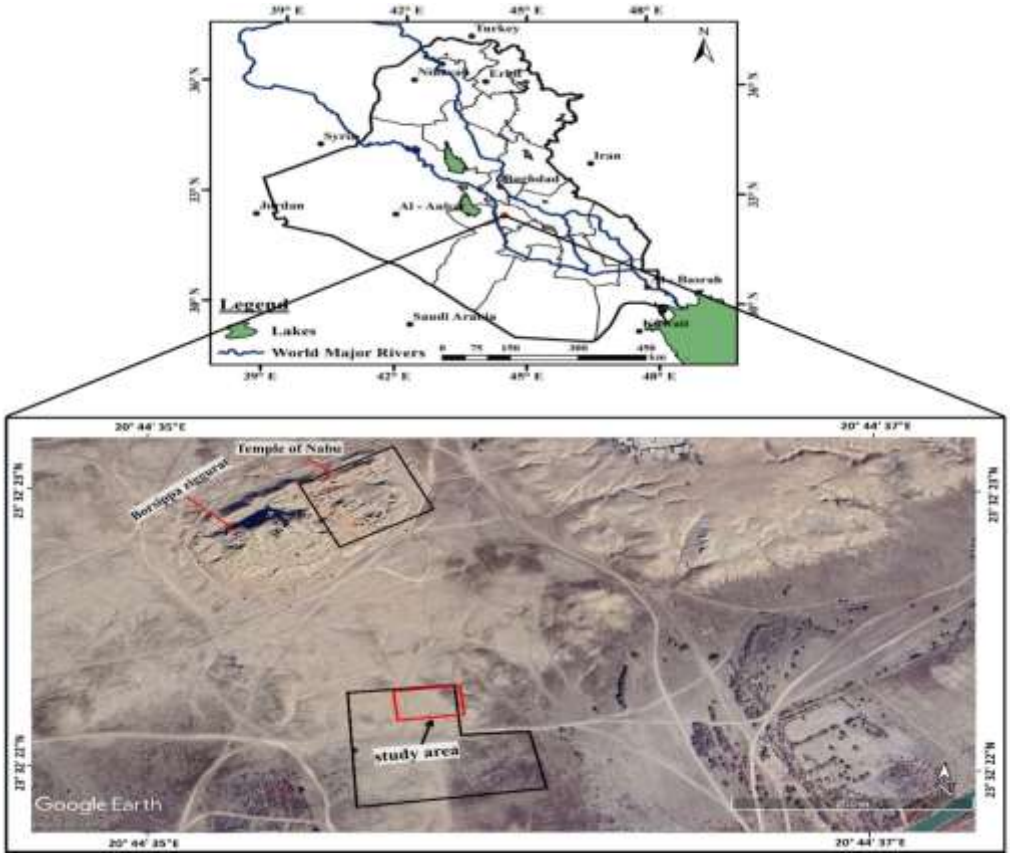

Figure 1: Location map of the study area.

2. Fieldwork

2.1 Data acquisition and processing:

Fieldwork was carried out in August 2022 by the LMX200 using a 250 MHz antenna. Sixty parallel profiles were collected to cover an area of about 48 m x 36 m with an inline spacing of 0.6 m as a profiled interval (Figure2). The survey parameters have the following default values: The point per trace is 500, the Time window is 200 ns, the velocity is 0.1 m/ns, the Time sampling interval is 0.4 ns, the Antenna separation is 0.25 m, and the step size is 0.05 m. This survey represents a detailed survey created based on an exploratory survey, as shown in Figure 2.

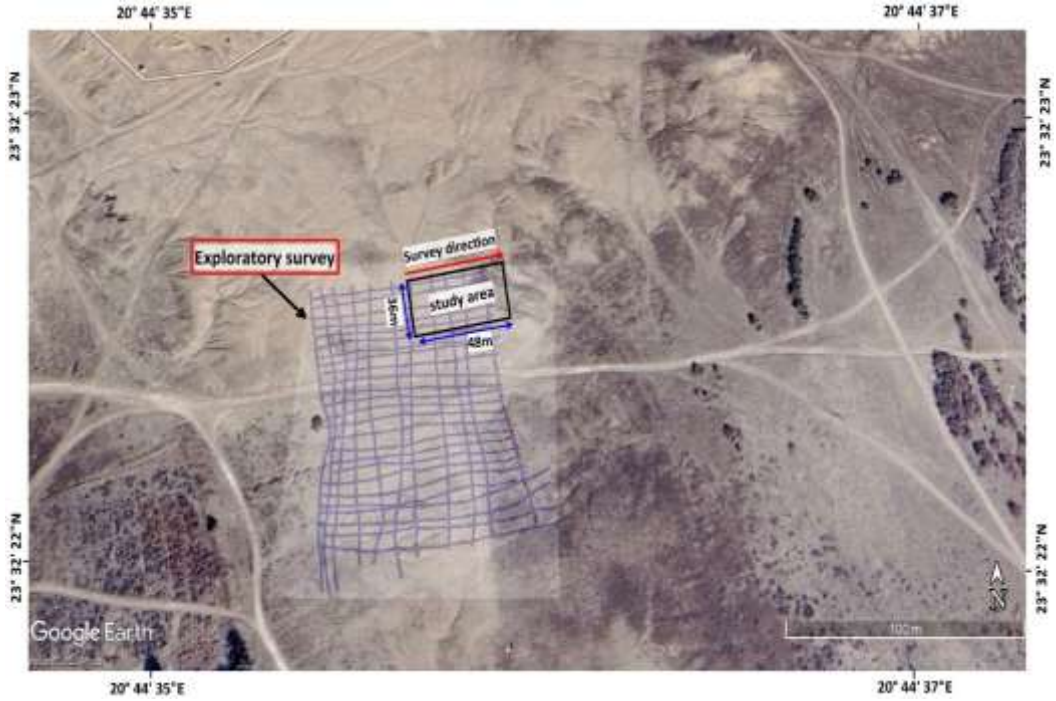

Figure 2: Google Earth Map displays the locations of 250 MHz antenna profiles.

The 250 MHz antenna data was processed by GPR slice software based on the following processing sequence:

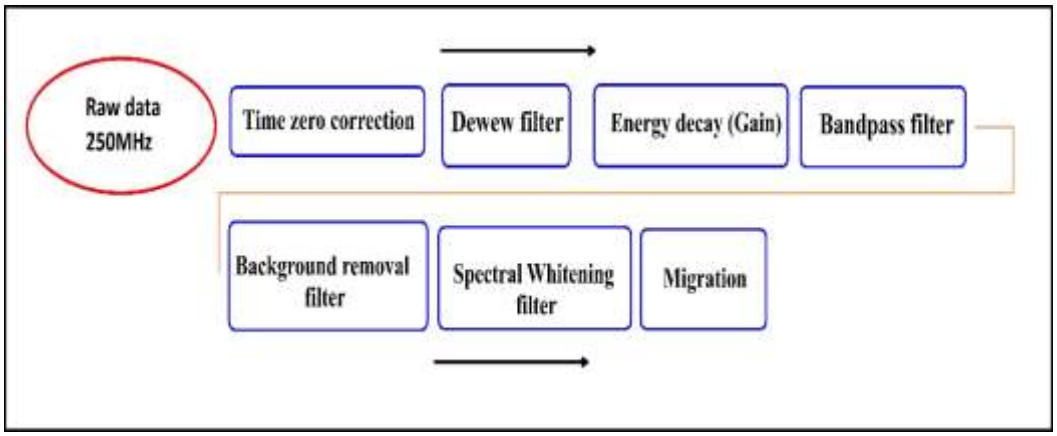

Figure 3: The processing sequence of the 250 MHz antenna.

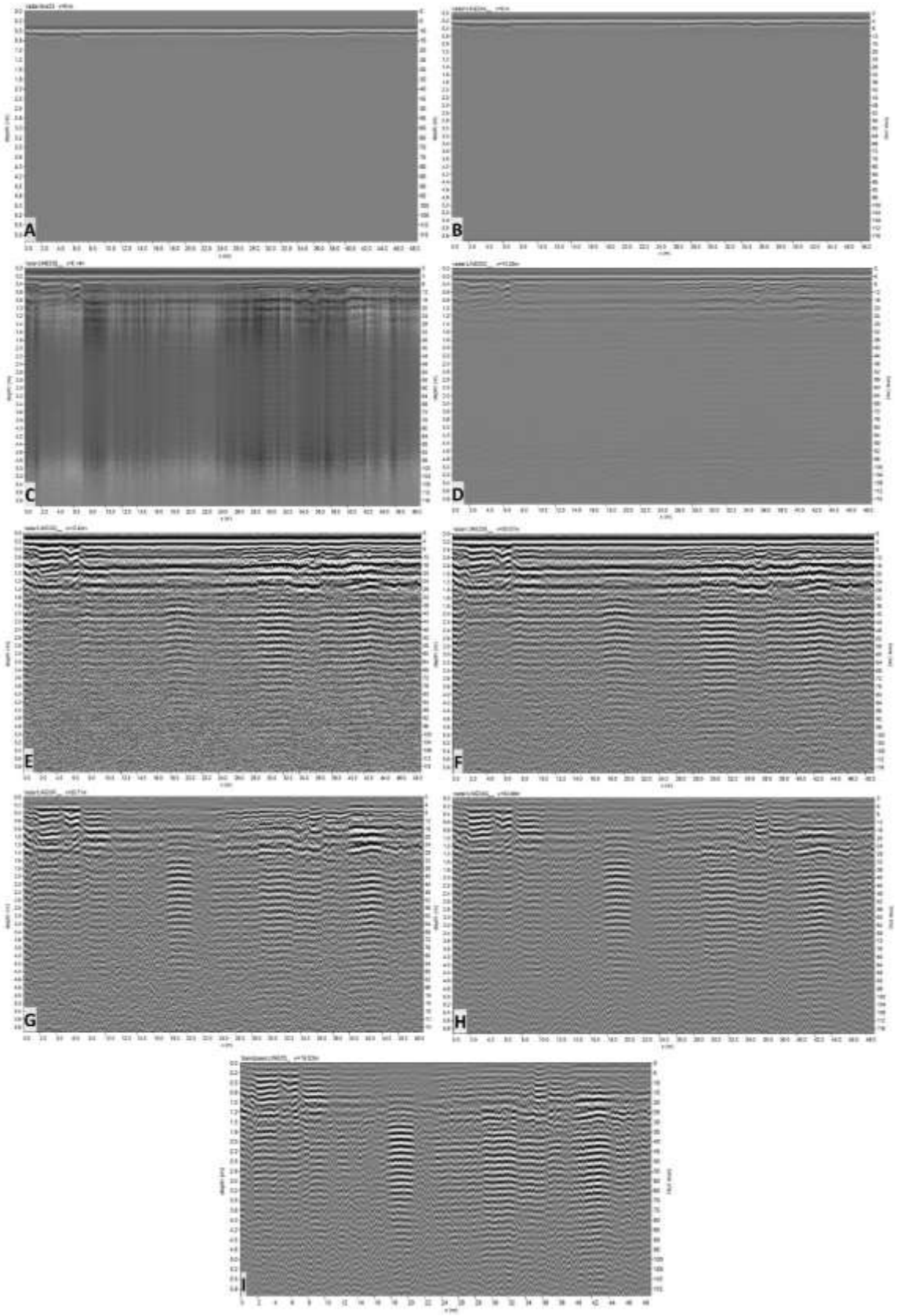

Figure 4: Processing sequence for the 250 MHz antenna profile 33.

Figure 4 Processing sequence for a 250MHz antenna data, A) Raw data before processing, B) Following zero correction (removing the distance between the antenna and ground level),

C) Before applying the dewow filter, D) After applying the dewow filter (removal of very low frequencies), E) After applying the gain filter (Enhancing the radar signal with depth to optimize reflections), F) After applying the bandpass filter (the low-frequency cutoff is 130 MHz, and the high-frequency cutoff is 500 MHz), G) After applying the background removal (removal the horizontal banding from the radar profile), H) After using the Spectral Whitening filter (removing the lower and higher frequencies with bandpass settings), I) After using the Migration filter (remove the distortions and attempts to correctly position subsurface reflection). All 250 MHz antenna profiles were processed using the same filter values. Using the same filter values on all GPR profiles gives a good resolution for profiles showing good reflections of the archaeal structure buried below the surface [9].

3. Results and discussion:

3.1 2D GPR profiles interpretation

Profile 16 (Figure 5) 250 MHz has a few high reflections that might be ancient walls with different lengths and depths of burial. The first wall is buried at a depth of 0.2 meters, starting from the beginning of the profile and extending to 8 meters. The second wall, at a distance of 20 meters, is buried at a depth of 0.6 meters and extends to 5 meters, the third wall, at a distance of 26 meters, is buried at a depth of 0.3 meters and extends to 8 meters. The fourth wall, at a distance of 39 meters, is buried at a depth of 0.5 meters and extends to 4 meters, and the fifth wall, at a distance of 46.5 meters, is buried at a depth of 0.6 meters and extends to 4.5 meters.

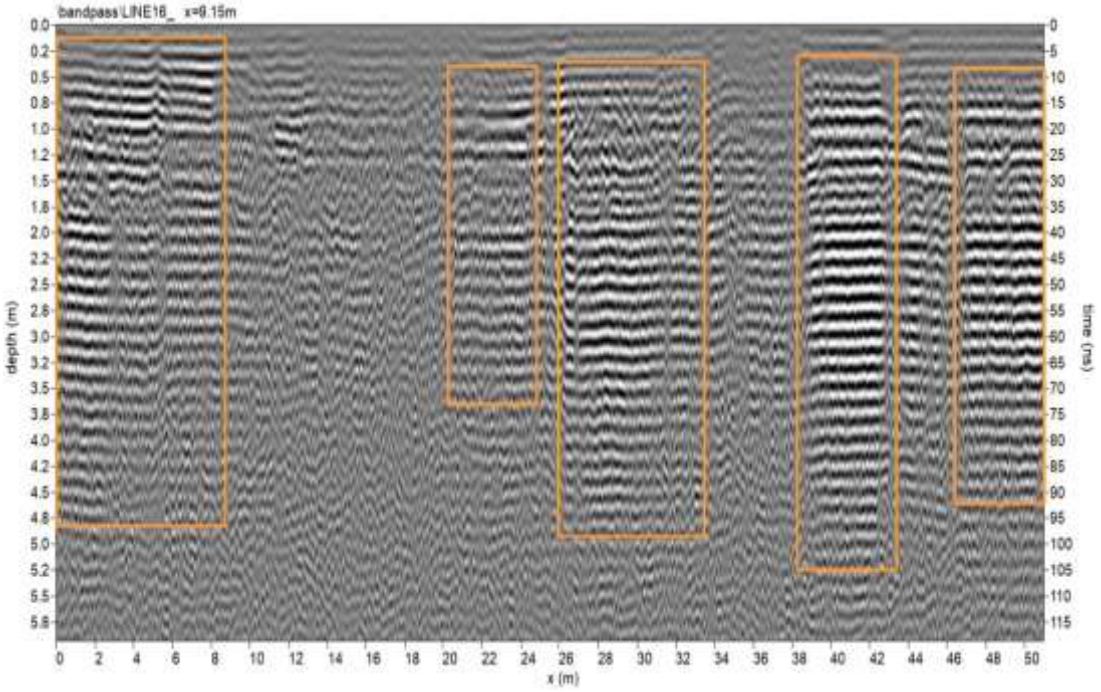

Figure 5: Profile 16 showing reflections of possible archaeological walls with varying extensions and burial depths.

Profile 26 (Figure 6) contains several possible reflections of ancient walls. The first wall is buried at a depth of 0.1 meters, starting from the beginning of the profile and extending to 7 meters. The second wall, at a distance of 9 meters, is buried at a depth of 0.2 meters and extends to 7 meters, the third wall, at a distance of 24 meters, is buried at a depth of 0.3 meters and extends to 6 meters. The fourth wall, at a distance of 33 meters, is buried at a depth of 0.5 meters and extends to 6 meters.

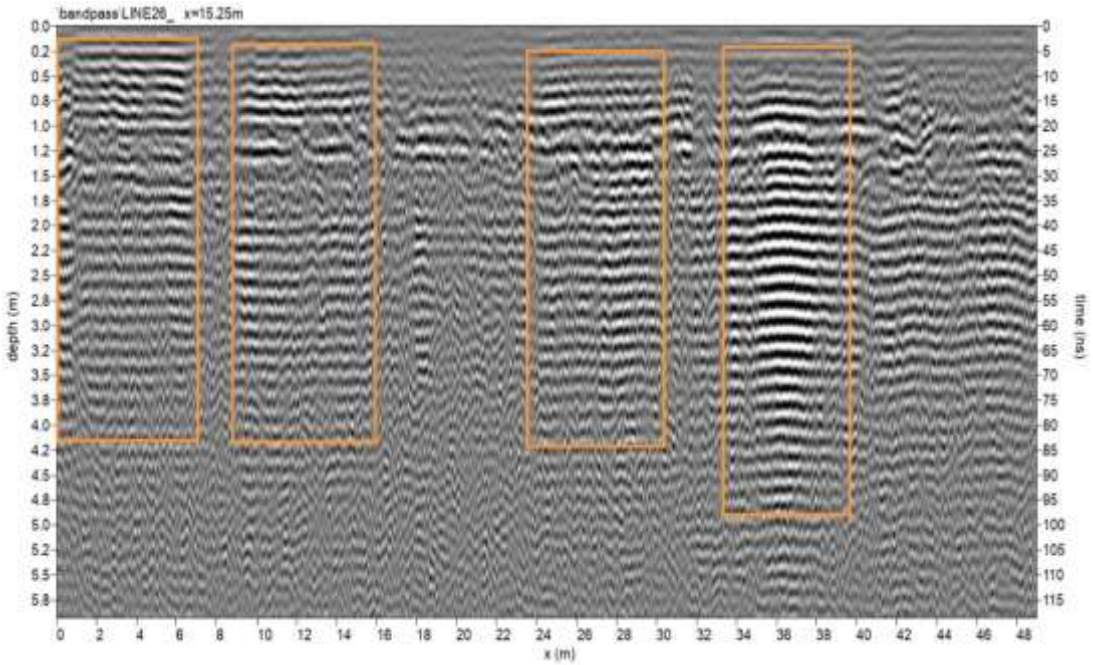

Figure 6: Profile 26 showing reflections of possible archaeological walls with varying extensions and burial depths.

3.2 Time slice maps (3D)

For a precise interpretation of the data and the locating anomalies of relevance, the horizontal radar maps (slices) are crucial [10] . The GPR slice software was used to construct a time slice map to identify the lengths of the ancient walls, whose reflections are visible in the GPR profiles. (Figure 7) A time slice at a depth of 1–1.1 meters contains reflections of five potential archaeological rooms buried at a depth of 1 meter. Room (A) is 7 meters long and 8 meters wide; room (B) is 12 meters long and 8 meters wide. Room (C) is 19 meters long and 15 meters wide; room (D) is 5 meters long and 7 meters wide; and room (E) is 25 meters long and 21 meters wide. The walls separating rooms are of two types: the first type is 3 meters thick and separates rooms (A-B), (B-C), and (B-E), and the second type is 2 m thick and separates rooms (C-E) and (D-E).

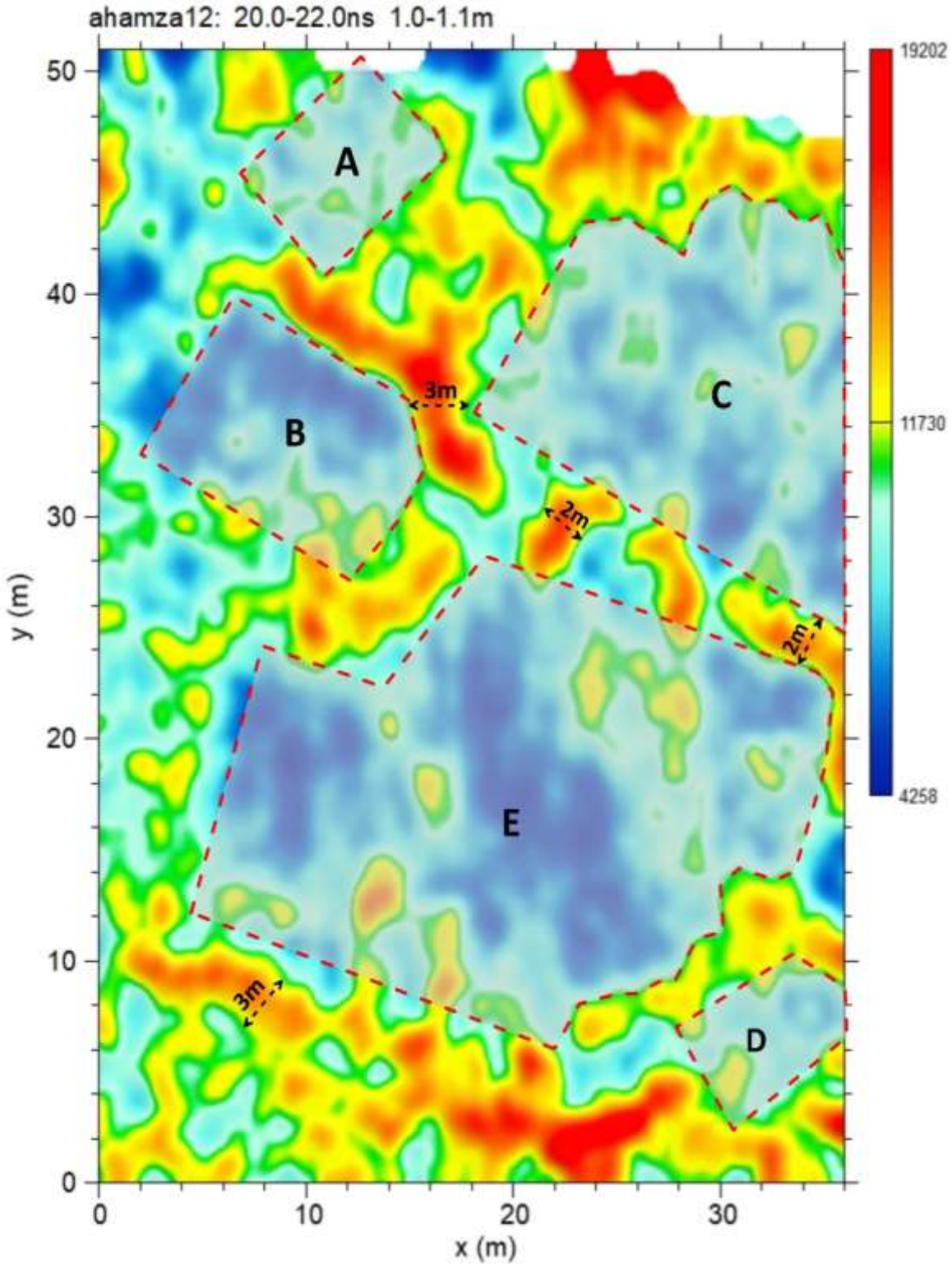

Figure 7: A time slice at 1-1.1 m depth shows five possible archaeological rooms: A, B, C, D, and E.

4. Conclusions:

The GPR survey using a 250 MHz antenna revealed a possible archaeological structure buried at 1–1.1 meters. It extends along the survey area, 48 m by 36 m, comprising five rooms: A, B, C, D, and E. The walls of these rooms have a thickness of 2–3 meters. With a penetration depth of 4 meters, the 250 MHz antenna gave clear reflections of the archaeological walls in

GPR profiles. This helped make clear time slice maps of the rooms of the archaeological structure.

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