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GROUND PENETRATING RADAR METHOD TO DETECT ARCHAEOLOGICAL REMAINS AT BUKIT CHORAS, YAN, KEDAH: PRELIMINARY RESULTS

NORDIANA MOHD MUZTAZA[1,2], NASHA RODZIADI KHAW*[3], SURESH NARAYANEN[3], NURUL FITRIAH AHMAD ZAIDI[1], NUR ALISHA AKRAM[1], NINI HAVELA DISHONG[3], NAZRIN RAHMAN[1], NAJMIAH ROSLI[1], NUR AZWIN ISMAIL[1,2], ROSLI SAAD[1], ANDY ANDERSON BERY[1], SHYEH SAHIBUL KARAMAH MASNAN[3] SHAIFUL IDZWAN SHAHIDAN[3] AND MOHD MOKHTAR SAIDIN[3]

[1]School of Physics, 11800 Universiti Sains Malaysia (USM), Penang, Malaysia. [2]Centre of Tropical Geoengineering, Faculty of Civil Engineering, Universiti Teknologi Malaysia, 81310 UTM Johor Bahru, Johor, Malaysia. [3]Centre for Global Archaeological Research Malaysia, Universiti Sains Malaysia, 11800 Pulau Pinang, Malaysia..

**Corresponding author: rnasha@usm.my*

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Abstract: Ground penetrating radar (GPR) is a geophysical method that employs broad spectrum electromagnetic waves to detect buried features without physically altering the environment. A GPR survey was performed on a 7th Century C.E. archaeological site in Bukit Choras, Kota Sarang Semut, Kedah. The site contains cultural ruins of a stupa made of laterite blocks, as well as a few mounds and scattered bricks. The geostrategic position of this site opens the possibility for the discovery of more extensive building structures. Thus, a GPR survey was conducted to test the hypothesis on the presence of more buried structures around the stupas. A total of 13 survey lines with 250 MHz shielded antenna were set up at the site, covering an area of 2040 m^2. The results showed interesting anomalies, which raised the possibility for more buried structures within 1 m to 3 m below the surface. This is observed in the hyperbolic features on the radargram which showed variations of electrical properties on the subsoil. Aside from the stupa basement, which is clearly observable on the surface, the GPR results indicate the presence of buried archaeological features, such as laterite blocks.

Keywords: Geophysical survey**,** ground penetrating radar (GPR), radargram, Bukit Choras, archaeology.

Introduction

Ground penetrating radar (GPR) has been widely used as a non-invasive technique to identify buried remains. The GPR survey is often presented in radargrams, which are high resolution images that can provide reliable interpretation of what items laid beneath the ground. The method employs broad-spectrum electromagnetic technology, which functions as a detector of subsurface features that reflects energy without physically altering the environment (Daxin, 1994). In archaeology, this technique is the most practical as it does not require any excavation to detect archaeological remains that are not visible on the soil surface (Atya *et al.*, 2012; Novo *et al.*, 2014; Pettinelli *et al.*, 2012). GPR has been used in archaeological research of Sungai Batu in the state of Kedah in Peninsular Malaysia, which resulted in the discovery of several structural remains and iron smelting sites dating from the 6th Century B.C.E (Naizatul, 2012 & 2019; Naizatul & Mokhtar, 2019). Further application of this method at Lembah Bujang, an archaeologically-rich valley in the same state, could reveal more substantial evidence of historical remains, which can expand our knowledge and understanding about the history and culture of Ancient Kedah. One of the many well-preserved archaeological sites in Lembah Bujang is Bukit Choras, located in the district of Yan, Kedah (Figure 1).

The Bukit Choras archaeological site was first mentioned by Colonel James Low (Low, 1908; Wales, 1940) in the mid-19th century,

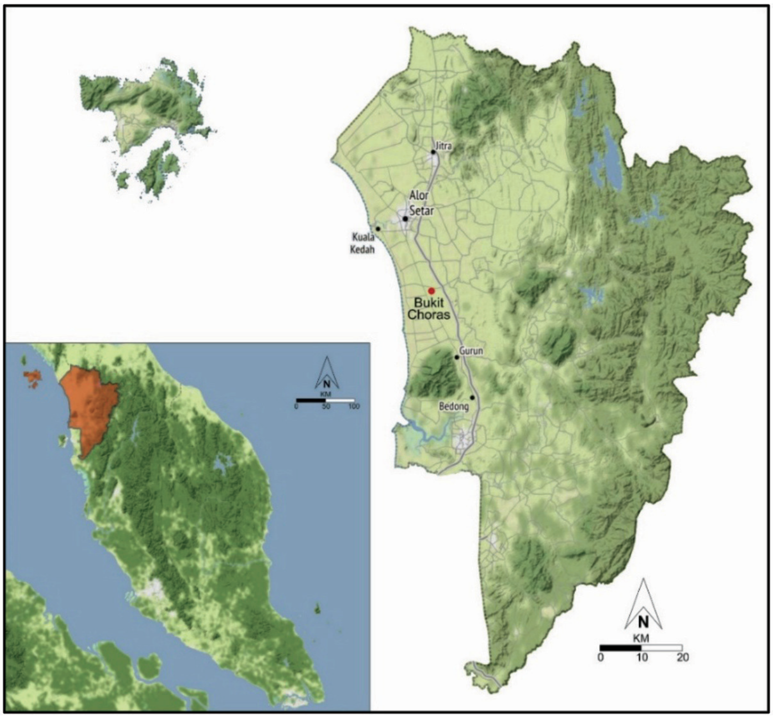


Figure 1: Location of Bukit Choras in Kedah, Peninsular Malaysia (Stamen, 2020)

where temple remains were first discovered. In 1937, British archaeologist H.G. Quaritch Wales partially excavated the structural remains made of laterite blocks, believed to be a stupa basement with a stairway leading up from the south (Wales, 1940). To the south of the stairway, Wales found another platform made of laterite blocks, which he suggested to be the base for a wooden structure. Buried underneath this platform were many artefacts, such as ceramics, inscriptions and iron objects. Unfortunately, Wales did not provide any illustrations or photographs on the ground plan, and orientation of the buildings. The site was revisited by Kamaruddin Zakaria of the Muzium Department in 1984, who mapped two water tanks to the east of the main structure reported earlier by Low and Wales (Kamaruddin, 1987).

Between 2017 and 2019, an archaeological mapping was carried out in Bukit Choras by a research team from the Centre for Global Archaeological Research, Universiti Sains Malaysia (CGAR, USM), Penang. Aside from the structural remains already reported by Low (1908), Wales (1940) and Kamaruddin (1987), several other mounds and scattered laterite blocks have been discovered after the soil surface was cleared of dried leaves and undergrowth. This suggested the presence of more subsurface remains beneath the mounds and scattered bricks. Therefore, suitable geophysical methods need to be conducted in the study area without damaging the mounds and exposed laterite blocks. The objective of this research is to identify the possible archaeological anomalies in the Bukit Choras site using GPR to confirm the presence of possible buried structures before more excavation is decided in the study area.

Study Area

Bukit Choras is located 8 km east from current shoreline and 20 km north from Gunung Jerai. It is largely surrounded by flat terrains of less than 7 m from mean sea level. The highest elevation point of Bukit Choras, which is where the archaeological remains were found, is 50 m above the sea level (Figure 2). There are also smaller hills in the vicinity, with similar

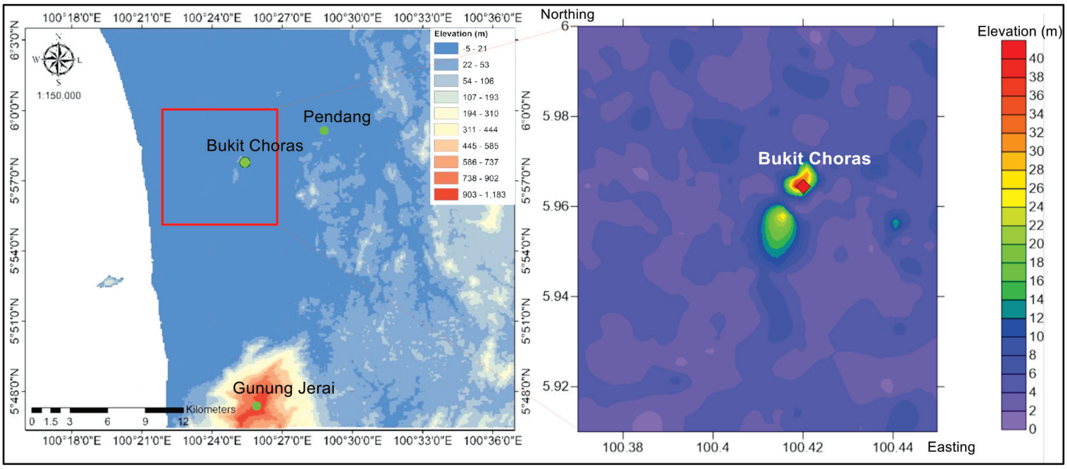


Figure 2: Topography of Bukit Choras' surroundings relative to Gunung Jerai (left) and the magnified topography of the site (right) (modified from geological map of Peninsular Malaysia, JMG, 1985)

elevations and geological settings. Similar to other sacred sites in Southeast Asia and the Indo-Pakistan Subcontinent, ancient societies in Lembah Bujang tended to construct their temples on higher ground, as hills and mountains were perceived to be dwellings of deities. Aside from having a high elevation, Bukit Choras was also the site of a Buddhist shrine as it is located relatively near the coastline and easily accessible.

Bukit Choras is a crescent-shaped ridge located in Kota Sarang Semut, Kedah, which extended over 646 m from northeast to the southwest. The GPR survey was done at the southernmost point of the ridge's summit, where the structural remains, mounds and exposed laterite blocks were located. The study area, which is around 2040 m^2, is shown in the yellow border of Figure 3. The smaller red box indicate the location of the main stupa

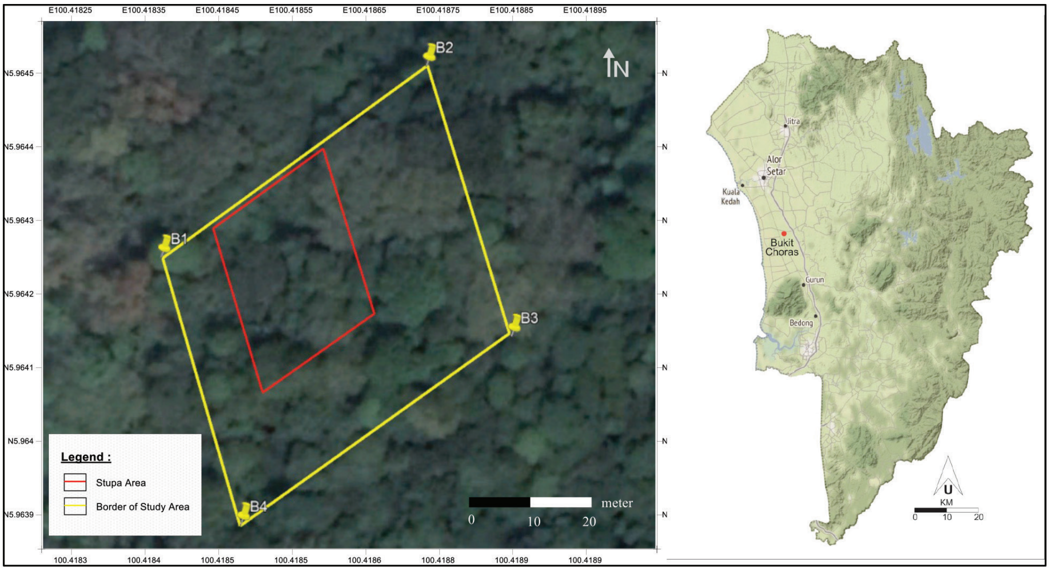


Figure 3: The locations of study area and stupa (Google Earth, 2018; Steman, 2020)

basement observable on the surface, while the area between the red and yellow lines indicates where other mounds and scattered bricks are located. The coordinates of each rhombus points are shown in Table 1.

Figure 4 shows the 3-D image of the stupa basement of Bukit Choras constructed using the Surfer® 8.0 software (Golden software, LLC. Colorado, USA), where a deep pit may be observed in the east, which was first reported by Kamarudin (1987), and thought to be an ancient water pond. The stupa basement, which was the highest point of the study area, is located in the west as indicated by the darker blue color.

Bukit Choras is part of the sedimentary "Kubang Pasu Formation", which consists of mainly shallow-marine shelf sediment that deepened eastwards to the Mahang and Sungai Petani Formations (Lee, 2009). Kubang Pasu Formation is mainly composed of phyllite, slate, shale and sandstone, where the grey argillaceous rock are commonly found during the Carboniferous period (Jones, 1973). The thick-bedded quartz and feldspathic grey, red and purple sandstones are interbedded with subordinate varicoloured mudstone. The formation's outcrops may be found in central Perlis, eastern Perlis and northwest Kedah, where the stones are distinguished by their lighter colour and sandy texture compared to the outcrops of the Singa Formation (Burton, 1967). Wales (1940) mentioned that the inscription tablets found in Bukit Choras were made from locally found slatestone. However, Bradford (1972) characterized Bukit Choras' composition as primarily shale and mudstone, thus bringing light to a new theory by Allen (1986) that the tablets might have actually been shale instead of slate. Another research contradicted Allen's theory as it claimed to have discovered slate in isolated outcrops at several localities, including Kota Sarang Semut (Jasin *et al.,* 2010). However, all these opinions were formed under

Table 1: Coordinates of the four angles of the study area with WGS84 system.

Point	Northing	Easting
B1	5.964249°	100.418364°
B2	5.964510°	100.418733°
B3	5.964140°	100.418852°
B4	5.963883°	100.418474°

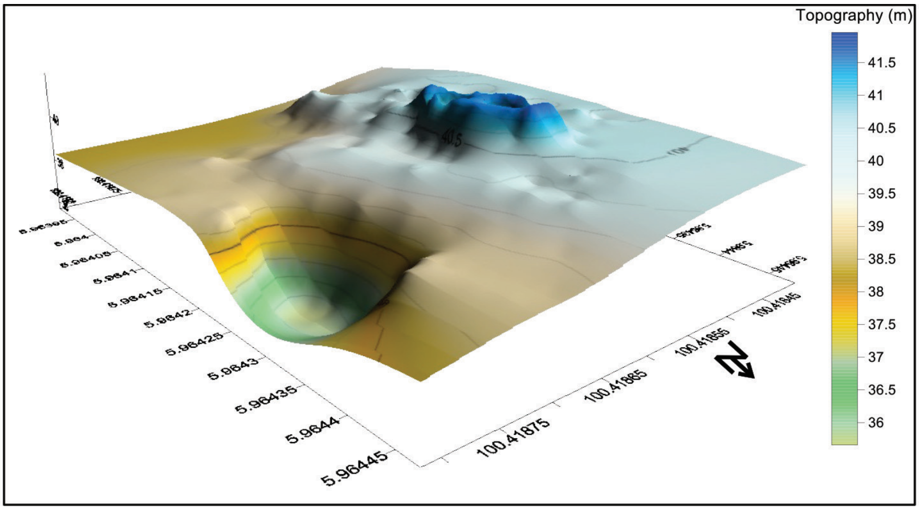


Figure 4: 3-D image of Bukit Choras according to the elevation constructed using Surfer® 8.0

the presumption that the tablets were locally made.

Encircling Bukit Choras is the flat-terrained, unconsolidated Quaternary marine and continental deposits consisting of clay, silt, sand and peat with minor gravel (Figure 5). The marine clay layer thickened towards the coast (up to 20 m thick) and overlaid a sandy-clay layer. The Quaternary deposits overlay mainly the Carboniferous sedimentary rocks (inclusive of the Kubang Pasu Formation), which dipped generally in south-southwest direction (Jones, 1981).

Methodology

GPR is a technique that applied high frequency radio waves through the ground, yielding data with very high resolution in a short time. These waves travel at a specific velocity based on the permittivity of the soil material. The velocity varied according to the type of soil material. This was because of the difference in electrical properties of the material that would, thus, reflect the radiowaves at different response times. GPR beams energy in the form of electromagnetic waves into the probed material (Dong & Ansari, 2011). A portion of this energy that was transmitted earlier would be reflected back to the antenna at any boundary in the subsurface, across which there existed an electrical contrast. The radar recorder would record an image of the reflected energy continuously as the antenna traversed across the ground surface. The electromagnetic waves travelled at their own unique velocity due to the material properties of the ground.

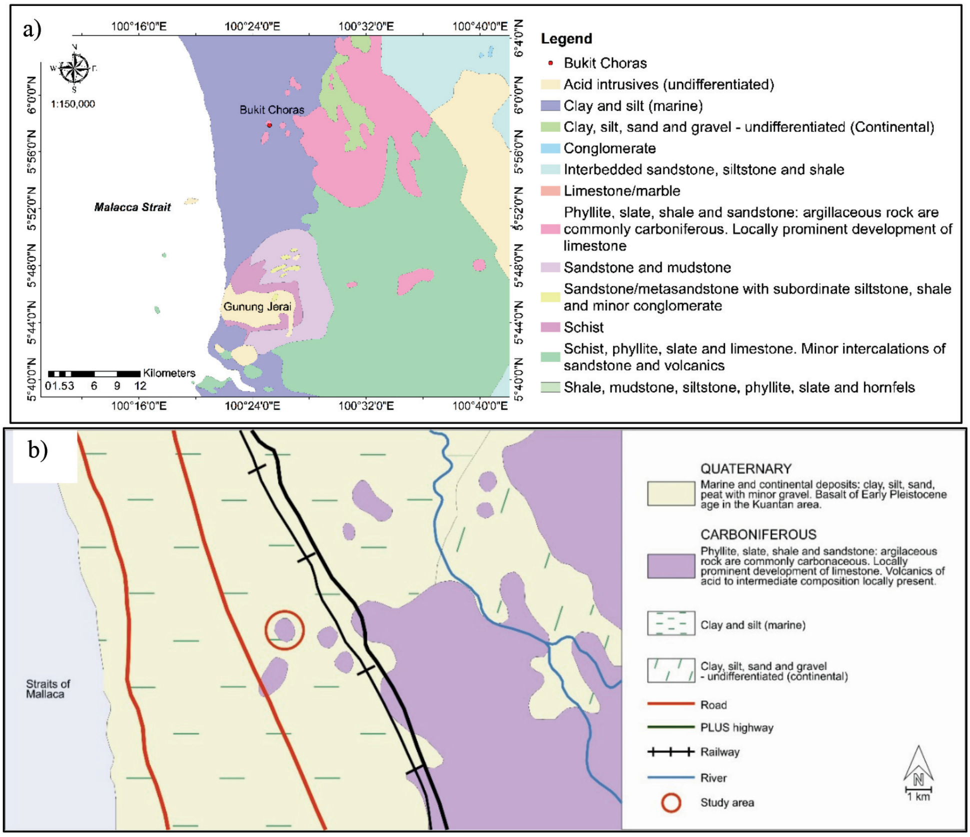


Figure 5: Geological distribution of a) Kedah and b) focus area of Bukit Choras [modified from geology and mineral resources of Perlis, north Kedah and the Langkawi Islands (1981)]

Hence, once these velocities were distinguished or closely estimated from ground conductivity values and other information, these two-way travel times could be converted to depth measurements. Penetration into the ground and resolution of the image produced by the radar were crucially based on ground electric conductivity and dielectric constant. A total of thirteen GPR survey lines with the length of 40 m each using 250 MHz antenna were set up in the study to identify anomalies in a single profile that might represent features of interest (Figure 6). The sequences of the survey lines were labelled as G1 to G13, with 5 m interval spacing between them. The GPR data were then filtered and processed using RAMAC GROUND VISION and REFLEXW software. Table 2 shows the GPR setting parameter during data acquisition.

Table 2: GPR setting parameter

Parameter	Setting
Point Interval	0.025m
Sample Frequency	26000

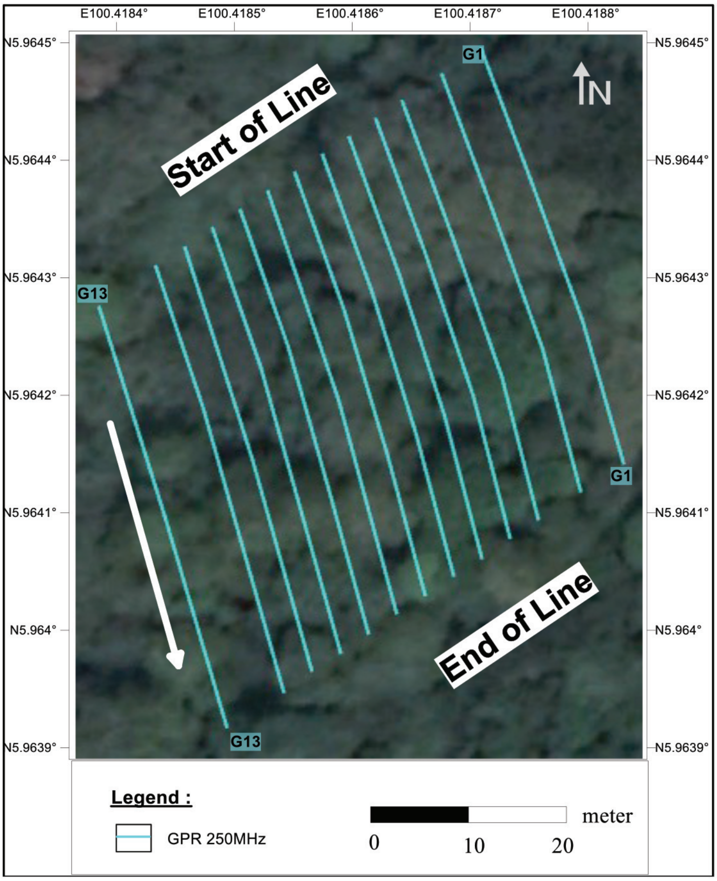


Figure 6: GPR 250 MHz survey lines

Results and Discussion

Figure 6 shows a radargram representing the result of the first survey line, G1, at the study area. Few suspected anomalies were detected at all the survey lines between a depth of 1 m to 3 m from the surface (Figure 7 and 8). In addition, there was also a large land depression in the middle of the survey line between G1 and G2. The interpretation of GPR data at Bukit Choras was made based on the spatial distribution and depth of the high-amplitude reflections shown (Conyers, 2013). Anomalies labeled as "?" in Figures 7, 8 and 9 were suspected to be buried archaeological structures, although they were not clearly recognizable in the radargrams.

There were many hyperbolic features noted on the radargrams, but the features were not distinct due to the variations in electrical properties of the subsoil (G3-G6). This might be a point source reflector, which might be denoted as any buried structure or anomalies (Conyers, 1995).

GPR signals showed vague hyperbolic features that could be seen on the radargrams interpreted as laterite bricks due to the drastic change in dielectric constant and conductivity (Reynolds, 2011) (Figures 8 and 9). As the distance passed through the exposed laterite bricks, the GPR signals showed stronger signal representing different features underground due to low signal attenuation, which indicated low conductivity of the materials (Barnes & Trottier, 2004). Following the anomalous flow patterns from G7 to G10, the anomaly at 10-20 m was believed to occur due to the diffraction from the base of the expected stupa (Muztaza et. al., 2012). The most interesting anomalies were found along G5 to G12, and these provided very good reflection from the top of the exposed laterite. Besides that, other characteristics of the buried archaeological remains were indicated as a mound area and there were exposed remains found on top of the surface (Ismail *et al.*, 2018). On the radargram sections, G13 appeared as hyperbola or asymmetric hyperbola indicated as "?" in Figure 9.

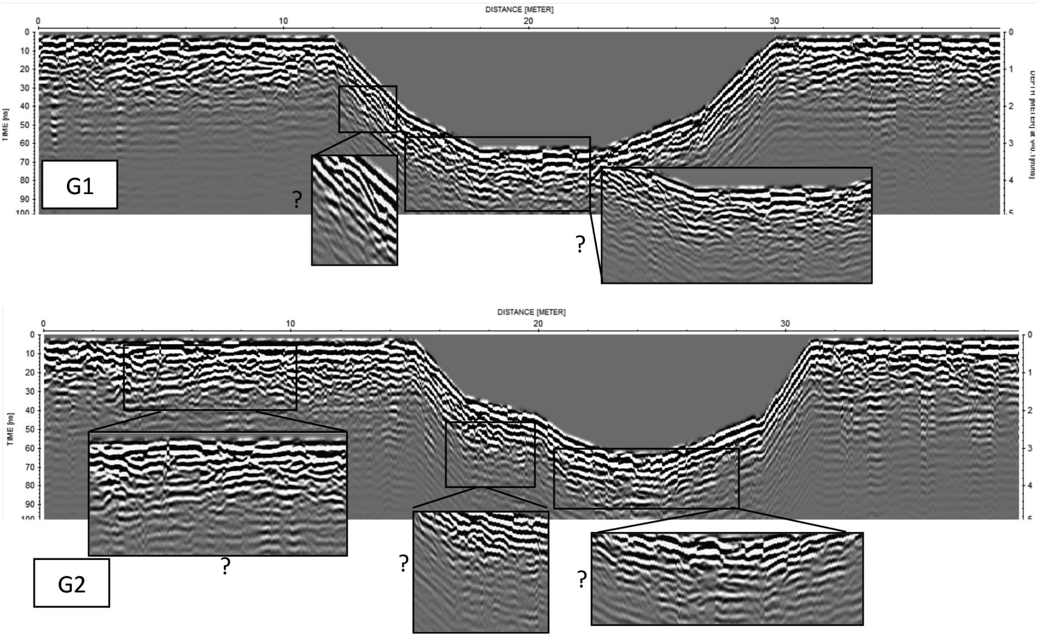


Figure 7: The radargram images of G1 and G2

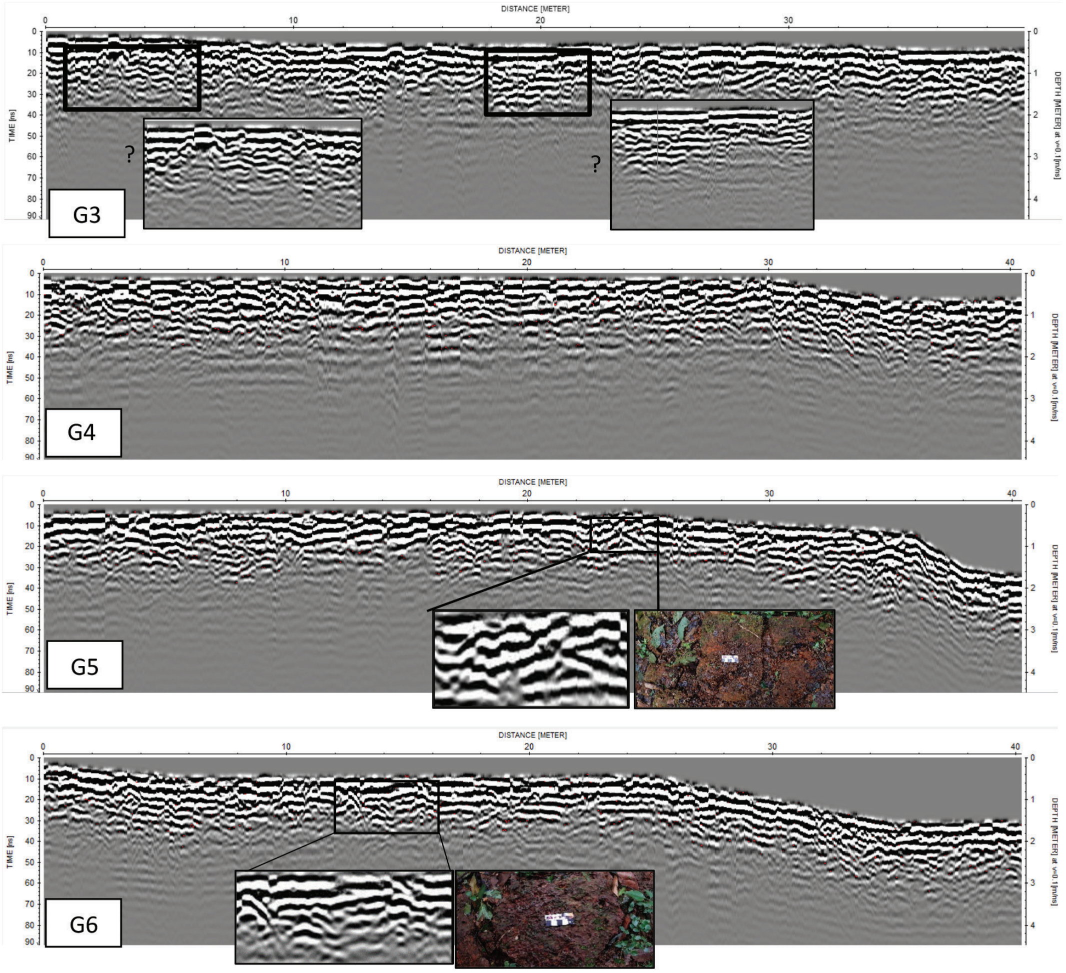
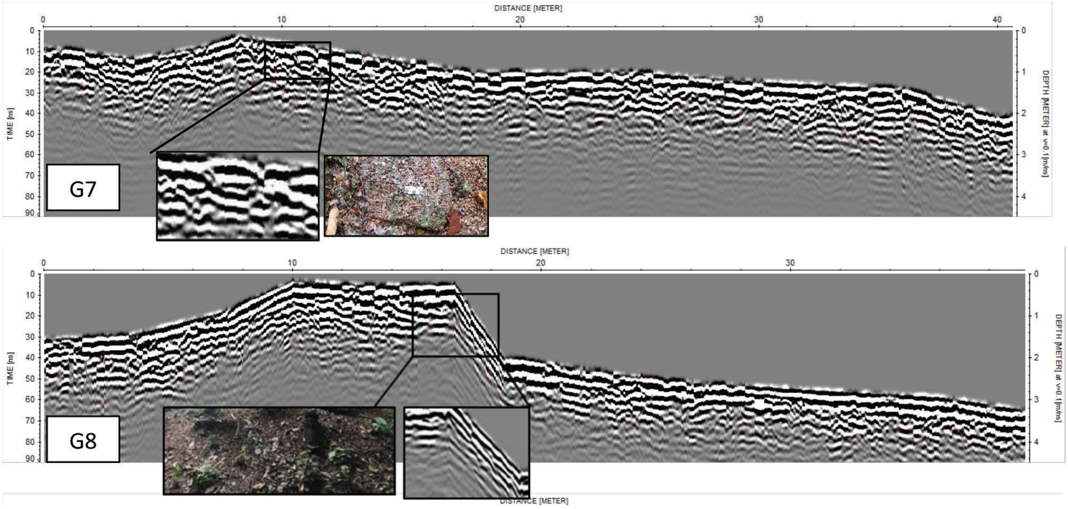


Figure 8: The radargram images of G3-G6 with label '?' and exposed laterite bricks



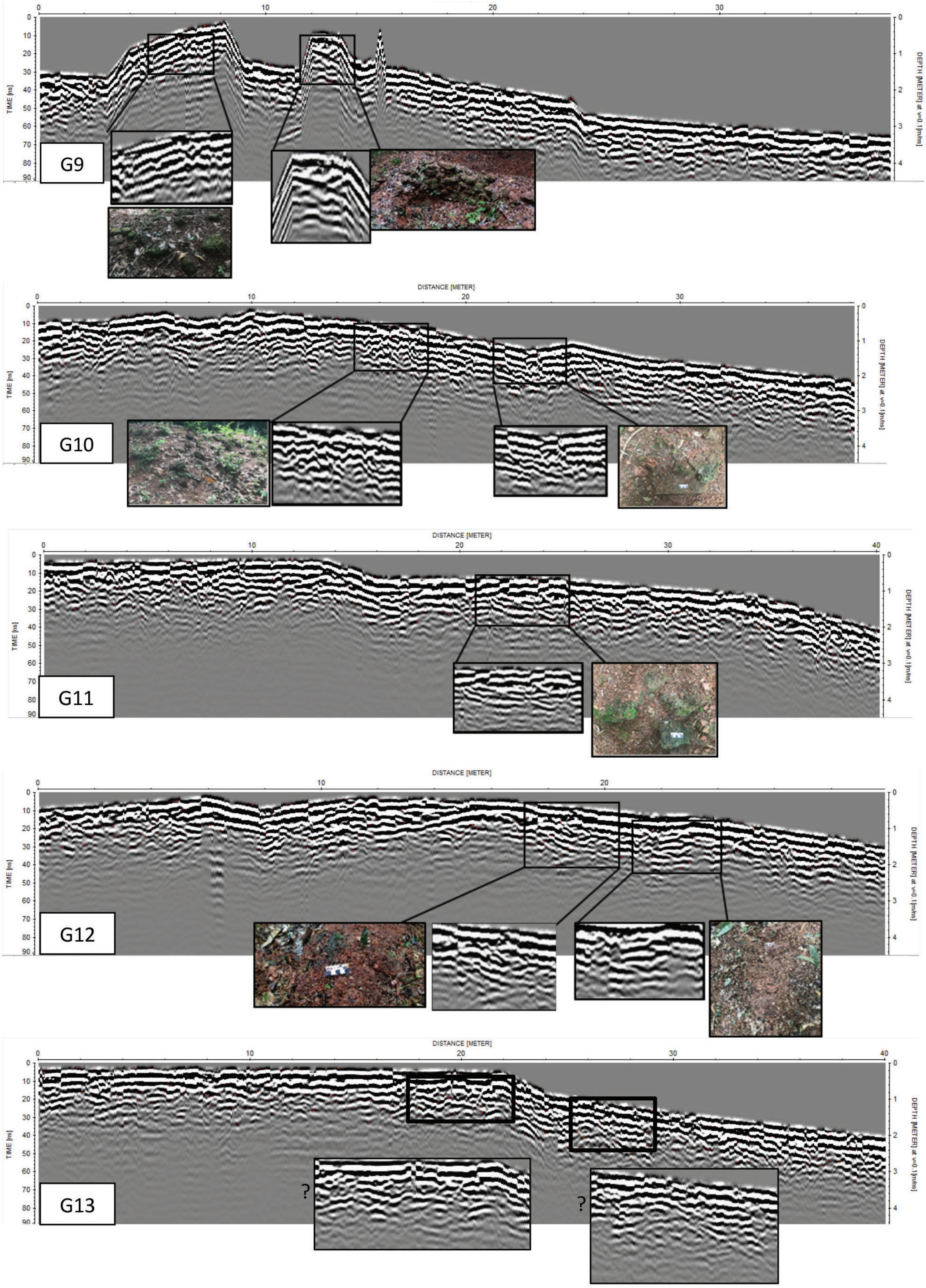


Figure 9: The radargram images of G7 to G13 with exposed laterite bricks

Conclusion

Radargram images of GPR showed that the high amplitude or hyperbolic signal might be a possible archaeological anomaly. Comparing the shape of the exposed laterite in the radargrams, it could be possible that the structure responsible for that anomaly had scattered all over the study area.

This finding was consistent with the general layout of a Buddhist religious complex in the Indian Subcontinent and Southeast Asia, where the main stupa was usually surrounded by other subsidiary buildings comprising shrines and living quarters for monks. The GPR survey had shown the possibility for similar architectural layout in the Bukit Choras site, where the main stupa was surrounded by other structural remains, which were still buried underground. This study had positioned Bukit Choras as one of the most potential sites for excavation to uncover the structural remains, which might shed more light into the history and culture of Ancient Kedah.

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