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# NEAR SURFACE CHARACTERIZATION USING ELECTRICAL RESISTIVITY IMAGING FOR ARCHAEOLOGICAL MONUMENT SITE AT BUKIT CHORAS, KEDAH, MALAYSIA

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**Abstract:** Bukit Choras is one of the temple sites of Ancient Kedah, a port-polity centred in the Bujang Valley which flourished between the 2nd to the 14th Century C.E. Being located in isolation, far to the north of the other sites of Ancient Kedah, the study area has rich cultural heritage value according to the recorded history. Previous surveys on the site had led to the discoveries of Buddhist structural remains as well as artefacts dated back to the 7th Century C.E. Aside from the ancient architectural features visible from the surface, there are potential for more structural remains being buried beneath the surface. This paper presents 2D electrical resistivity imaging to investigate the shallow subsurface characteristics at the archaeological site of Bukit Choras, Kedah, Malaysia. The study identified the subsurface was consisted of two main zones; low resistivity zone with a depth of 2 to 3 m and resistivity range value of 100 to 500 Ohm.m, surrounded by high resistivity zone with a range value of 500 to 3000 Ohm.m. This low resistivity zone is interpreted as a high conductivity zone and it is interpreted as laterite material which is derived from parent rock. This laterite material is made up of rich iron and aluminium contents. In addition, this low resistivity zone also interpreted as a potential zone in archaeology perspective. This is supported by the visible evidence on the Earth surface of the study area where laterite as local material is used for the Buddhists worship structure before the coming of Islam in Kedah, Malaysia.

Keywords: 2D resistivity imaging, cultural heritage;, conductivity;, archaeology.

## Introduction

The Geophysics is a subject of natural science that involves physical processes and properties of the Earth together with its surrounding space environment. The method's application for the subsurface study is quantitative methods for analysis in order to understand the characteristics of the subsurface condition. Modern geophysics include electrical, gravity and magnetic surveys have been used to locate the position of the archaeological structures (Sheriff, 1991). In exploration geophysics, geophysical surveys were used in various environmental studies which include analyse potential petroleum reservoirs, identify mineral deposits, locate groundwater, identify archaeological relics, determine the thickness of glaciers and soils, and assess sites for environmental remediation. In order to understand the shallow subsurface condition, a geophysical method such as electrical resistivity can be used to identify the subsurface characteristic which related to archaeological (Astin *et al*., 2007; Berge & Drahor, 2011). Geophysical imaging methods currently provide information about the subsurface based on different physical responses which propagated through the earth's inner. These physical responses represent the physical parameter of the subsurface as different material will have different characteristic. The 2D electrical resistivity imaging is one of the geophysical methods which works by injecting current at a pair of current electrodes and the potential difference is measured between a pair of potential electrodes (Nordiana *et al*., 2013; Bery *et al*., 2014).

Archaeological prospection is a non-destructive identification of features and relics buried at underground. The identification of the contrast between materials in the subsurface of the archaeological study area is conducted through geophysics prospection. By using electrical resistance, electrical conductivity, magnetic susceptibility and as well as electromagnetic waves, the presence of underground features can be identified. The 2D electrical resistivity imaging surveys are one of a geophysical method used in archaeological geophysics, as well as in site investigation of engineering Nordiana *et al*, 2013. The usage of resistivity parameters in the identification of buried features or anomaly has been regular practice (Karavul *et al*., 2010). A great number of geophysical methods are now available for specific archaeological demands. The characteristic of the site will determine whether to use a single method or combined geophysical methods (Günther *et al.*, 2006; Bery & Saad, 2013a). Recently, there is no doubt that the geophysical method such as 2D electrical resistivity imaging, provide essential tools to help archaeologists in excavation planning. In addition, geophysical surveys have been used widely by various researchers for archaeological study (Senos Matias & Almeida, 1992; Bevan, 2006; Astin *et al*., 2007; Bery & Saad, 2013b; Gaballah *et al*., 2018; Fischanger *et al*., 2019; Supriyadi *et al*., 2019). It shows that the geophysical method can be used to characterise the subsurface associated with archaeological perspective. This study was conducted at Bukit Choras, Kedah Malaysia, with the study objective, to characterise shallow ground subsurface for archaeological purpose using 2D electrical resistivity imaging.

## Previous Studies

Previous studies have been done by using resistivity method in archaeology, and it has been widely used time by time. Alashloo *et al.* (2011) carried out an integrated geophysical investigation using both the electrical resistivity tomography (ERT) and magnetic methods at one of the unexcavated archaeological sites of Sungai Batu, Kedah, Malaysia. The primary purposes of this survey were to locate buried archaeological artefacts and to determine the shallow subsurface geology. The study area is part of Jerai formation in Kedah, and the elevation is about 12 m above sea level. This area consists of two facies. One of the facies is clay comprised of schist, semi-schist and mudstone. Another one is metamorphosed sand, including quartzite, granulite and grit (Bradford, 1972). The ERT survey was conducted over five (5) resistivity lines using a pole-dipole array with 2 m minimum electrode spacing along 20 m spaced parallel survey lines.

Leucci & Greco (2012) conducted a 3D resistivity survey at the archaeological site of Occhiolà (Sicily, Italy), a Middle Age village, which located on the northwestern part of a hill named "Terravecchia" at 491 m above sea level. The survey was conducted inside the ruins of "Spirito Santo" Church. This research aimed to explore the buried extension of the possible crypt and/or tombs inside the church. Epov & Chemyakina (2009) carried out several geophysical methods at different kinds of archaeological sites in Western Siberia and Altai. These methods include the resistivity method. Mathematics simulation of expected objects was performed due to geophysical technique adjustment based on the results of permafrost research inside the burial mounds on the Ukok plateau in Altai Mountains. Three Pazyryk burial mounds were chosen to test the results, the first one containing a permafrost target, the second free of ice and frozen ground.

Geoelectric surveys using electrical resistivity tomography (ERT) method by Reci *et al*. (2015) have been applied on two archaeological sites of Albania, which are Apollonia and Bylis. The purpose of this study was to detect the cultural layer and the underground archaeological buried features from the spatial distribution of true resistivity values. ERT is an active geoelectrical prospecting method used to obtain 2-D, 3-D and 4-D (with time) images of the subsurface electrical resistivity distribution.

Simyrdanis *et al.* (2016) conducted an extensive ERT survey in investigating part of the Hellenistic to Byzantine submerged archaeological site of Olous, located on the north-eastern coast of Crete, Greece. Two alternative survey modes were applied for ERT data collection, applying either a fixed cable position (static) or a moving (dynamic) array along a predefined survey line. The static mode used a 48-channel multicore cable, which was kept fixed and submerged along a specific line during data acquisition. Jinmin *et al.* (2017) used 2D electrical resistivity imaging at the archaeological site of Sungai Batu, Lembah Bujang in Kedah, Malaysia, to identify the soil's characterization at the study area. The 2D electrical resistivity imaging investigation was conducted using a multi-electrode resistivity arrangement of a Pole-Dipole array with a total of 15 survey lines. The Pole-Dipole array was chosen due to its sensitivity to horizontal changes in resistivity, and it is suitable in mapping vertical structures.

Ullrich *et al.* (2017) used 2D and 3D electrical resistivity measurements in archaeological prospecting on Tell Jenderes in Northern Syria. The interpreted resistivity structures are related to different settlement phases from the Bronze Age to the Hellenistic period. The survey was carried out in Spring 2005. Firstly, three 2D sections with lengths between 370–450 m was taken. The 2D resistivity models were based on measurements with an electrode distance of 1 m in Dipole-Dipole and Half-Wenner configurations. Approximately there were 10,000 individual measurements. The electrical resistivities are limited within a 10–80 Ωm range. The specific resistivities correspond to an extremely high electric conductivity between 12.5–100 mS/m.

Jinmin *et al*. (2018) have conducted 2-D electrical resistivity method to identify meteorite impact at Bukit Bunuh, Perak and buried archaeological features at Sungai Batu, Kedah. 2D electrical resistivity method is eco-friendly for environmental study and one of the most sensitive geophysical method for observing changes in electrical properties in the subsurface. In Bukit Bunuh, fourteen survey lines were set up with minimum electrode spacing of 5 m and Pole-Dipole array is used for all the survey lines. Meanwhile, in Sungai Batu, 15 survey lines were set up, and Pole-Dipole array was chosen with a minimum electrode spacing of 0.75 m.

These previous studies showed that the non-destructive geophysical method of electrical resistivity is a suitable method for a preliminary study to characterise the subsurface of the Earth. The survey design such as electrode separation, survey length and array type parameters must be taken into consideration to obtain a good quality result that can help to achieve the study objective.

## Geology, history and geomorphology of the study area

The study area for this study is located at Bukit Choras Kedah, Malaysia. This area is located at Kota Sarang Semut, the northern part of Kedah state. Over much of north Kedah, south Kedah and the Semanggol area of north Perak, marine Triassic arenaceous and argillaceous rocks with chert bands occur, where the rocks have turbidite characteristics (Khoo & Tan, 1983). Isolated occurrences of Triassic limestones are also known in north Kedah. Bukit Choras composed primarily of shale and mudstone (Allen, 1985).

According to Zakaria (1989), the peak of Bukit Choras contains the material remains of an ancient Buddhist community, based on the presence of a *stupa* (Buddhist sacred structure), laterite brick mounds, as well as the remains of what appear to be ancient water ponds, believed to have been dated from the 7$^{th}$ Century C.E. Previous observations showed that the site had probably functioned as a complex for Buddhist worship. Thus, this site has a great potential for a geophysical survey, especially in order to locate other possible buried human-made structures, aside from those already visible on the surface. Figure 1 shows the candi structure which made of laterite. This laterite could be obtained from the nearby area and it is used to build the structure of Buddhist worship.

Figure 1: Candi structure made of laterite bricks is used as candi structure at Bukit Choras (Zakaria, 1989)

The survey area is located at the peak of Bukit Choras, Kedah. The site is covered by secondary jungle and bushes, while the areas around the hill are covered by rubber plantation. Before conducting the geophysical survey, the study area has been cleared from the bushes to expose the soil surface (Figure 2 – Figure 4).

Laterite is soil and rock type which is commonly high content of aluminium and iron. It also considered having formed in a wet and dry tropical region. Almost all laterites are rusty-red in colour because of this material content of high iron oxide. In addition, laterites also formed from prolonged weathering process of underlying laterite rock as parent rock.

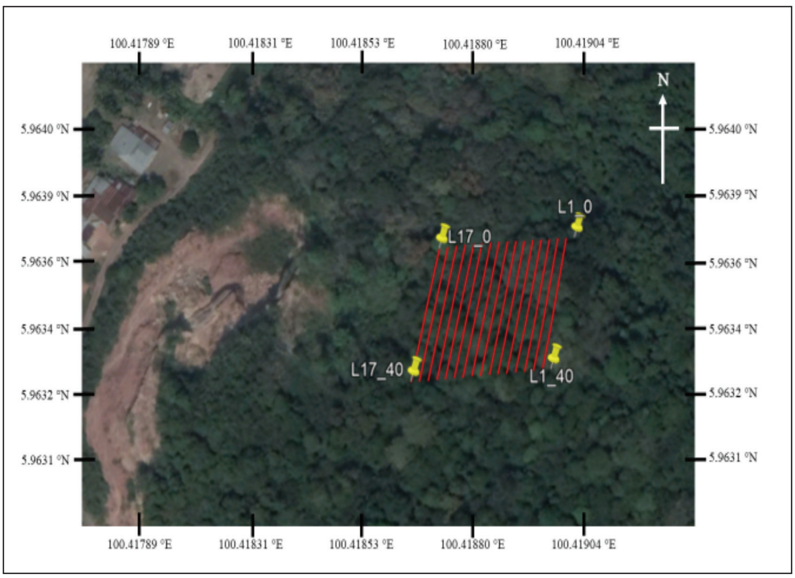


Figure 2: Location of the study area

Figure 3: The site views of the archaeological site at Bukit Choras, Kedah, Malaysia

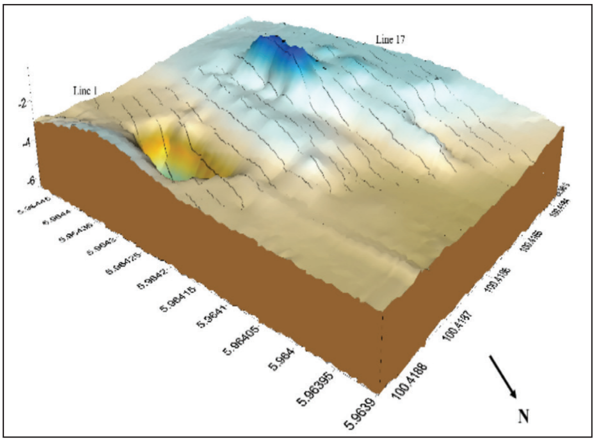


Figure. 4: Topography model of the study area at Bukit Choras, Kedah, Malaysia

**Materials and Methods**

Electrical resistivity method is one of the non-destructive geophysical methods. This method works by measuring potential difference at a pair of potential electrodes while injecting current at a pair of current electrodes (Bery *et al*., 2014). An electrode array with constant spacing is used to investigate lateral changes in apparent resistivity at the subsurface. In an electrical resistivity survey, the increase in electrode spacing will result in greater depths. Therefore, suitable electrode spacing is required in order to cover the shallow interest in archaeological study.

Total of 17 resistivity survey lines with 3 m of line interval was mapped at Bukit Choras, Kedah, Malaysia. ABEM Terrameter SAS4000 unit and 10-64 Electrode Selector unit were used in the data acquisition. Total of 41 stainless steel electrodes was planted on the ground with a minimum of 1 m spacing between each electrode. The length of each survey line was 40 m, which is in a north-south direction (Figure 5). All electrodes were connected through two resistivity cables that were connected by jumper cables. In this survey, Wenner-Schlumberger array was used. This array type is used because it has better signal strength compared to Pole-Dipole array (Loke, 2004; Bery, 2018a). A total

Figure 5: The site views of the archaeological site at Bukit Choras, Kedah, Malaysia

of three days required to cover all the 17 survey lines. On the first day, the survey has covered Line 1 until Line 5 of the study area. On the second day, Line 6 to Line 13 was covered and the lastly finished Line 17 on the last day.

The data obtained from the survey were transferred and converted using SAS4000 Utilities software to get the apparent resistivity values, thus presenting the geometry of the electrical resistivity survey. RES2DINV software was used to process and analyse the data, and to produce an inverse model resistivity with topography. The data sets were filtered using RMS error statistics scheme. This data filtering is required for the raw resistivity data in order to remove bad data points that can lead to misinterpretation in the resistivity models. Next, the final resistivity model with topography is saved into a specific format for visualization and contouring purposes using Surfer 8 software.

## Results and Discussion

The total of 14 survey lines was conducted and interpretation was made with the interest of suspected anomaly. The 2D resistivity data were processed and inverted into resistivity models with topography for interpretation. Based on the results of the 2D resistivity model with topography on this study area, the results are interpreted from Line 1 until Line 6 due to the suspected interesting signature from the geophysical data (Figure 6 and Figure 7). 2D resistivity model from Line 7 until Line 14 did not show significant geophysical signature that can be related to archaeological as they have a similar pattern as Line 6. The results of 2D

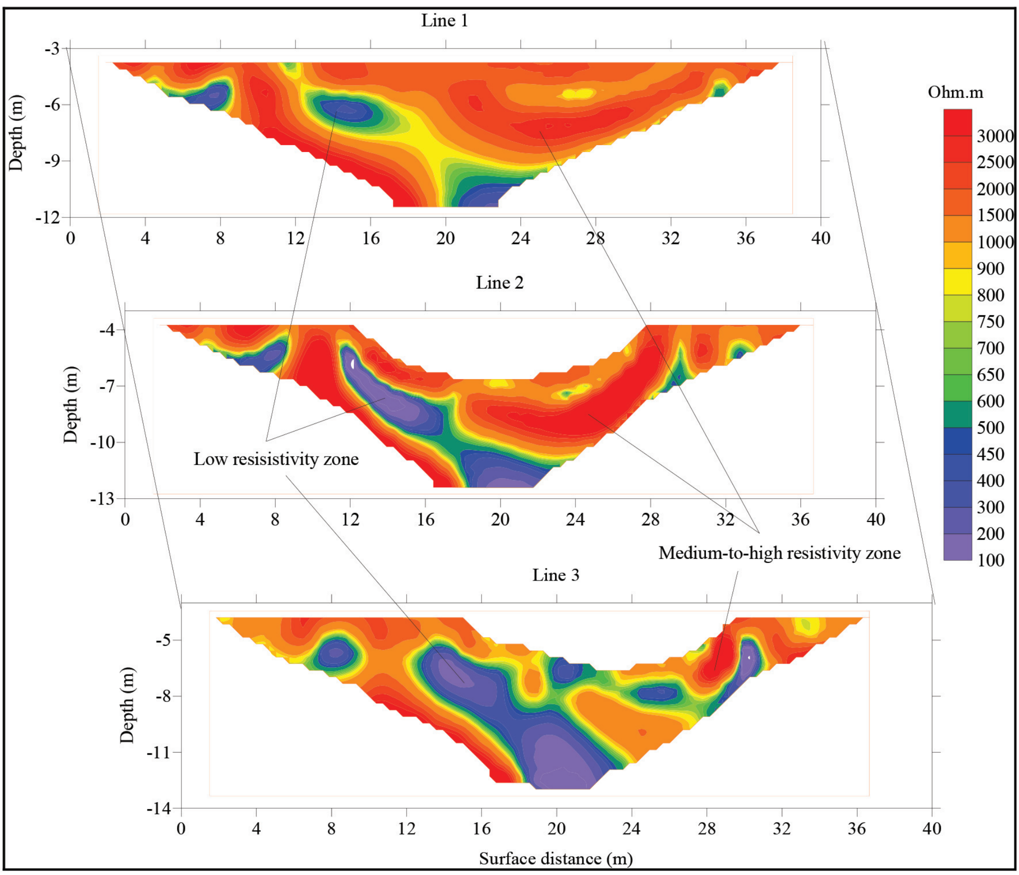


Figure 6: 2D resistivity models with topography for Line 1 to Line 3

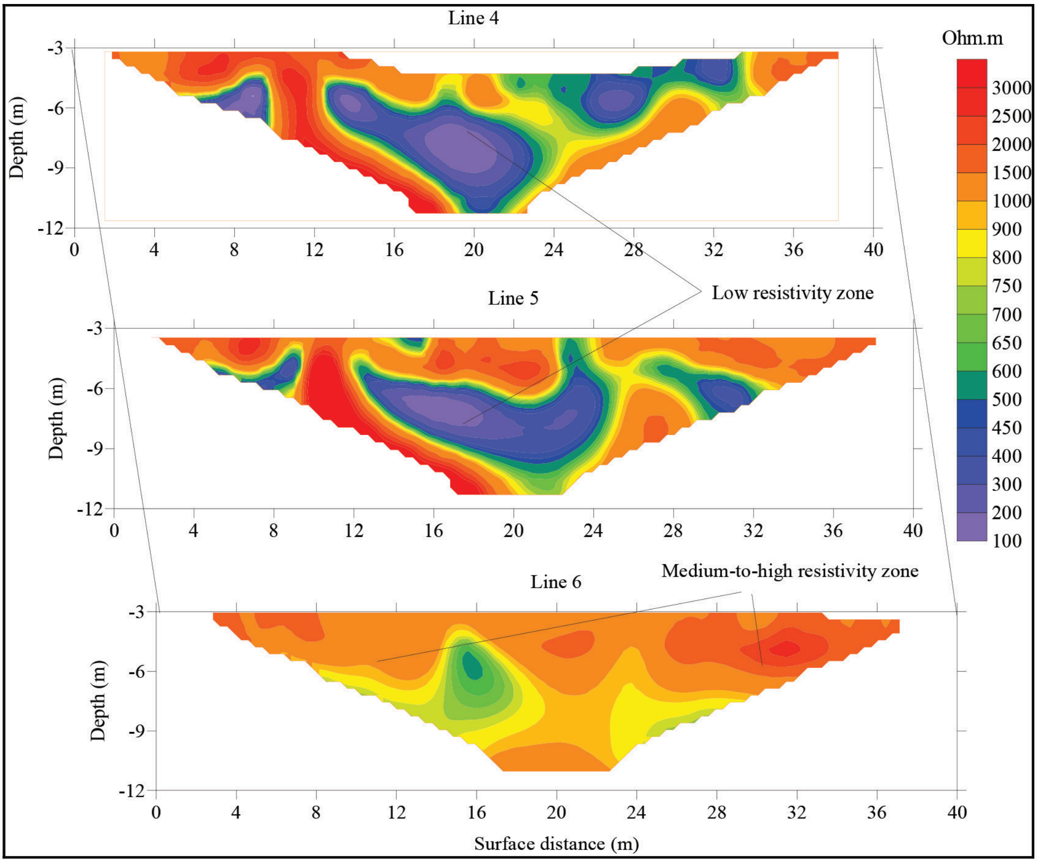


Figure 7: 2D resistivity models with topography for Line 4 to Line 6

resistivity model show the maximum depth of investigation of the resistivity model with topography is about 9 m. The interpretation of the obtained results is intercorrelated with the archaeological point-of-view since the study site has visible evidence of an abundance of archaeological structure.

Generally, the subsurface of the study area at Bukit Choras, Kedah is made-up of laterite soil type (Telford *et al*., 1990) which consist of two main zones; low resistivity zone with value of 100 to 500 Ohm.m, and medium-to-high zone with value of 500 to 3000 Ohm.m (Telford *et al*., 1990; Vincent *et al*., 2017). From Line 1 until Line 5, the low resistivity zone is located about 2 to 3 m from the earth's surface (depth of 5 m) and surface distance of 13 to 23 m, respectively (Figure 6 & 7). This low resistivity zone also interpreted as high conductivity zone of laterite soil, which is due to this laterite soil rich in iron and aluminium (Eyles, 1970; Oyelami & Van Rooy, 2016; Bery, 2018b). This laterite soil commonly considered to have formed in wet and hot tropical areas, with a rusty-red colour, due to high iron oxide content. However, low resistivity zone of laterite soil is unidentified at Line 6 and most of the section is covered with medium-to-high resistivity zone. It shows that the subsurface characteristic at Line 6 is made up of low content of iron oxide. Therefore, based on these resistivity model results, it shows that Line 1 until Line 5 has an interesting feature that can be related to archaeology perspective.

The presence of low resistivity zone is interpreted as a potential zone where the area has a high content of iron and aluminium in laterite as local material for laterite brick structure as described by Vincent *et al*. (2017). These minerals are commonly used as a human-made structure such as candi. A candi is a Hindu-Buddhist temple which is mostly built during the Hindu-Buddhist period. According to Sedyawati (2013), candi is described as sacred structures of Buddhist and Hindu heritage, and it is used for ceremonies and religious rituals. The previous study also supported that candi structure was constructed with laterite rock as reported by Zakaria (1989).

## Conclusion

2D Electrical resistivity survey is one of the geophysical methods that are widely used in archaeological geophysics. It is used to investigate the ground subsurface characteristics. This method utilizes differences in electrical potential to identify subsurface materials. The basic setup for a resistivity survey involves using a resistivity meter and four electrodes. The type of array used in a survey depends on the target itself. During this electrical resistivity survey, Wenner-Schlumberger array was used with a minimum electrode spacing of 1 m and a total length of 40 m.

From the results of 2D resistivity models obtained, the survey area can be classified into two main zones, namely low resistivity (100 to 500 Ohm.m) and high resistivity (500 to 3000 Ohm.m). The presence of low resistivity zone interpreted as a potential zone of the archaeological target where the area has a high content of iron and aluminium, which are commonly used as a man-made structure. These results of 2D resistivity models were interpreted with archaeological point-of-view and previous study. The visible evidence such as remaining Buddhist worship structure help in the interpretation of 2D resistivity models. This preliminary work can be used to support the previous study by Zakaria (1989) where non-geophysical method has been used in their work. In order to obtain more information about the subsurface characterization at Bukit Choras in the future, other geophysical methods such as GPR and magnetic surveys can be carried out at this area to validate the 2D resistivity model results.

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