3-D Resistivity Imaging on Archaeology Characterization at Sungai Batu area in Kedah, Malaysia

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Abstract. Electrical Resistivity Imaging (ERI) was conducted at the archaeological site of Sungai Batu, Lembah Bujang in Kedah, Malaysia and it is located between Gunung Jerai in the North and Muda River in the South, Kuala Muda, Kedah. This paper presents the geophysical results that aimed to identify the characterization at Sungai Batu, Kedah. ERI survey was performed at plot SB2ZZ, Sungai Batu with total of 15 survey lines using pole-dipole array with electrode spacing of 0.75 m. The ERI results were then processed with Res2DInv and Res3Dinv softwares. Resistivity contrast shows good variation to correlate well with lithology of the earth materials. To enhance the results, data were visualized using isosurface resistivity surface. The ERI shows interesting anomaly with resistivity of 400 - 500 Ωm varies from 0.34 – 1.17 m and few spotted anomalies detected at deeper depth which varies from 2 m - 4 m. Based on-site calibration at partly exhumed sites, anomalies were interpreted as baked clay bricks. The results obtained in this study area gives reliable interpretation for archaeological interest.

1. Introduction

Archaeological prospection defined as non-destructive identification of features and relics buried at archaeological sites. It is also referring to discover of cultural assets from materials like bricks, furnace or stone that are already recovered from ground and analyzed using carbon dating. Geophysics prospection is fundamentally concerned with the identification of the contrast between materials in the subsurface of archaeological study area. The presence of underground features can be identified by electric resistance, electrical conductivity, magnetic susceptibility and as well as electromagnetic waves. There is a possibility of detecting buried features by implementation of these physical changes, there is a possibility of detecting buried features. The application of geophysical methods created a breakthrough of scientific approaches toward archaeological investigation in this modern century. Geophysical prospecting allows the physical changes of the subsurface to be mapped in archaeological area. It can also provide useful information and detect the anomaly of buried structures or individual artefacts before the excavation process started. One of the common geophysical method is electrical resistivity imaging (ERI) that provide the measurement of the specific electrical resistance of the soil. The use of resistivity in identification of buried features or anomaly has been a common practice [1]. In archaeological prospection, geophysical method especially 2D resistivity imaging method is non-destructive which applied in geo-subsurface study for meteorite impact [2]. Sungai Batu Archaeological Complex has a lot of buried artefact and monument, identified at least have 97

potential site for excavation [3]. From previous study, a geophysical investigation including magnetometer was carried out at an unexplored site in Sungai Batu, northwest Malaysia [4]. The magnetometer survey was performed using a G-856 proton precession magnetometer over 15 profiles. The magnetometer results displayed two main anomalies which had a high magnetic value, indicating buried structures. This paper presents the results of electrical resistivity imaging from plot SB2ZZ archaeological site in Sungai Batu, Lembah Bujang in Kedah Malaysia.

2. Methodology

The ERI investigation was carried out using a multi-electrode resistivity arrangement of pole-dipole array with a total of 15 survey lines (ZZ1-ZZ15). The pole-dipole array was chosen due to its sensitivity to horizontal changes in resistivity and it is suitable in mapping vertical structures [5]. To achieve detail results in the study area, the grid was design with minimum electrode spacing of 0.75 m and the parallel of each survey line with spacing of 2 m. SAS4000 (ABEM instrument) in multi-electrode configuration together with ES10-64 electrode selector was used to collect the apparent resistivity data. In the ERI method, the distribution of the electrical resistivity of the subsoil is obtained by injecting current into the ground at two current electrodes and measuring the potential difference at two potential electrodes at the surface. The ERI method worked by measure the resistivity distribution of the earth soil materials. Table 1 shows the resistivity value of the common rocks and soil materials [6]. Hence, the ERI results will be processed using Res2Dinv and Res3Dinv softwares. A least-squares inversion of the resistivity data was conducted using finite element mesh with surface topography to generate 2-D model of resistivity versus depth. The "smoothness-constrained robust inversion" method are also useful when the subsurface bodies have sharp boundaries [5]. After completing the inversion data in Res2Dinv and Res3Dinv, then Surfer 13 and Voxler 3 softwares were used to produce contour and isosurface map.

Table 1. Resistivity value of common rocks and soil materials [6].

Material	Resistivity (Ωm)
Alluvium	10 - 800
Sand	60 - 1000
Clay	1 - 100(
Groundwater	10 - 100
Sandstone	8 - 4 x 1(
Shale	20 - 2 x 10
Limestone	50 - 4 x 10
Granite	5000 - 1000000

3. Geology and study area

The archaeological site is located at Sungai Batu in Lembah Bujang along the road from Sungai Petani to Merbok in Northwestern Malaysia. The study area is situated near Gunung Jerai and Sungai Merbok. The mid-south of Kedah was recorded as marine area in first and second century. Since the sea level was rise, the area changes to be landed area in years 1400 [7]. The soil types of the area are sandy clay covered with fine sand. The sediment was transported from the river and being settled around this area. The sea level rises, the settled area turn to be landed area [8]. Figure 1 shows geological map of peninsular Malaysia of the study area. It shows the lithology of the study area consist of schist, phyllite, slate and limestone. The study location was on Lot 1284, plot SB2ZZ with

coordinate of 5.694861° N, 100.450778° E and covers an area 30.6 m (W-E) and 29.0 (S-N). The ERI was conducted on the study area where each line was started from West to East and line ZZ15 located at 1 m longitude while line ZZ1 at 29 m longitude (Figure 2).

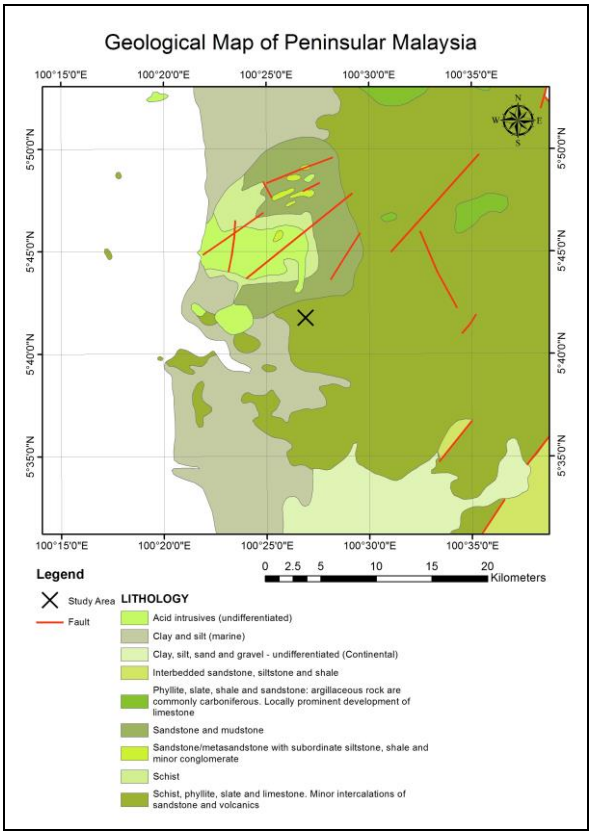

Figure 1. Geology map of Sungai Batu, Kedah [9].

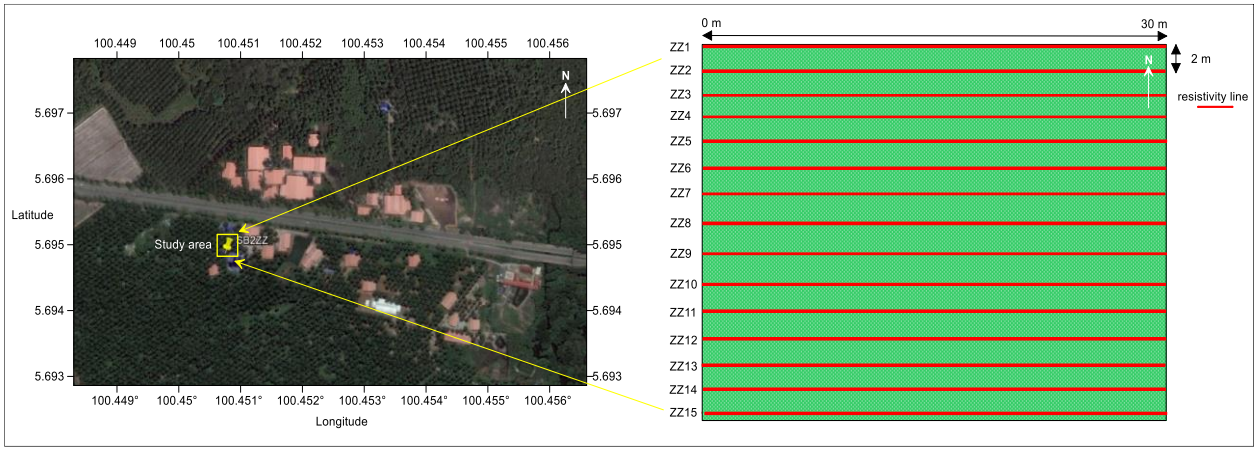

Figure 2. Survey line of ERI method at Sungai Batu, Kedah [10].

4. Results and discussion

Figure 3 display the pseudo-sections of ZZ1-ZZ15 respectively. To enhance the resistivity contrast, each pseudo-section has been assigned the same colour scale of resistivity value for each survey line. Generally, the study area is alluvium with resistivity of >40 Ωm and anomaly spotted with resistivity

value of >400 Ωm at depth varies from 0 m - 1.17 m. Few anomalies were spotted at deeper depth from 2 m - 4 m. Figure 4 shows the 3D resistivity value of horizontal section at depth 0.34 m - 0.73 m and 0.73 m - 1.17 m respectively. In this figure, it shows that the whole resistivity results of the study area at given depth. From the interpretation with different contrast of resistivity values, the possible anomaly interpreted as a buried structure of baked clay bricks. It appears that the anomaly with resistivity value range from 400 Ωm – 500 Ωm spotted at the study area. Figure 5 shows the isosurface resistivity value of 500 Ωm, the value not in the range will be excluded to focus on the location and pattern of the targeted anomaly. Hence, the suspected baked clay bricks were mapped using Voxler 3 to see the pattern of the anomaly.

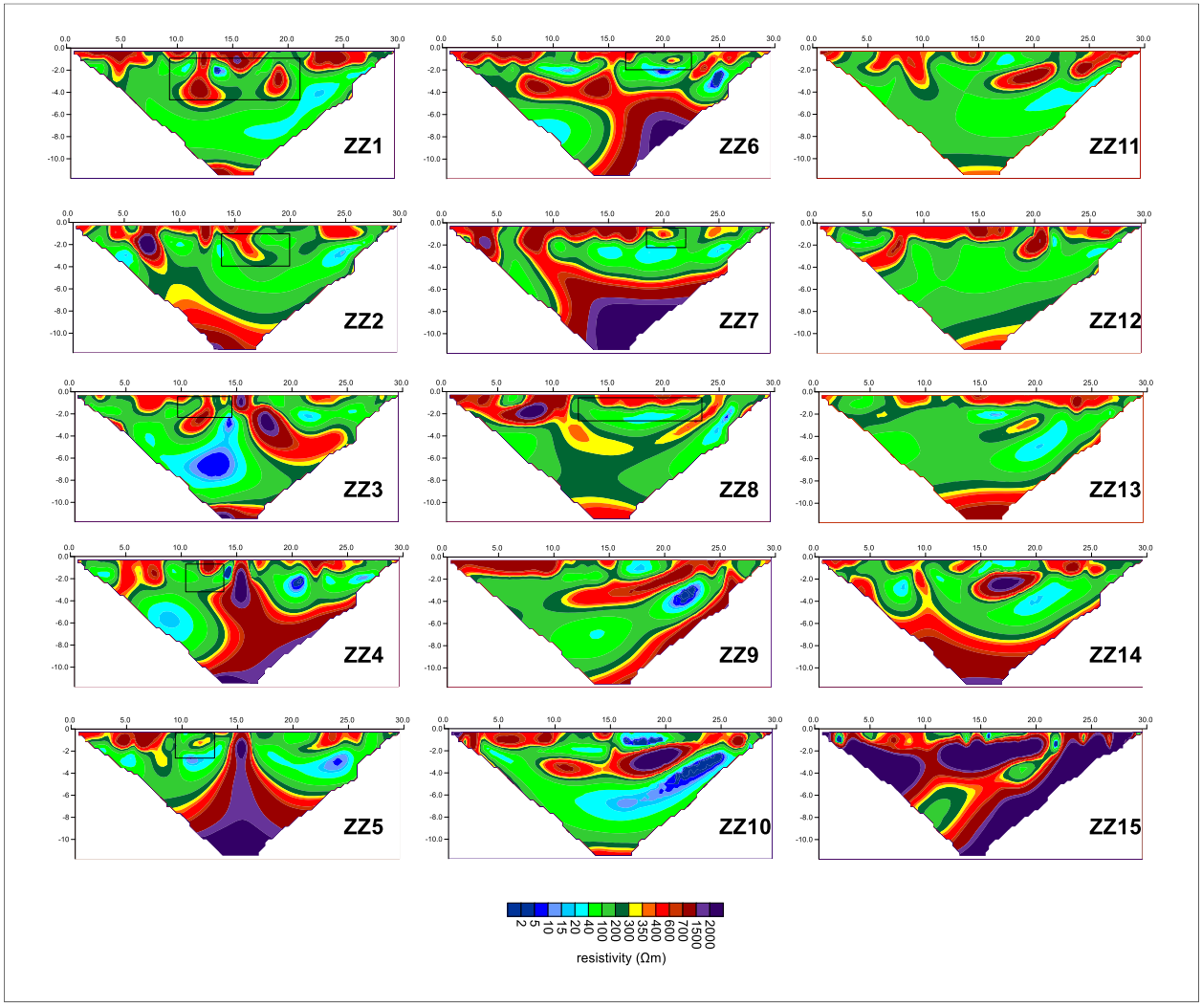

Figure 3. 2D electrical resistivity imaging results of ZZ1-ZZ15, Plot SB2ZZ.

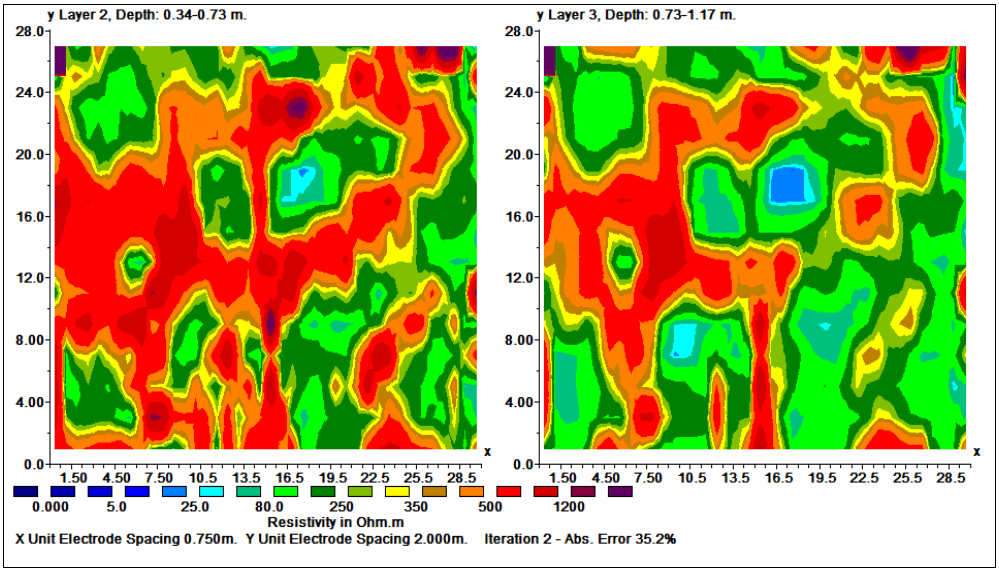

Figure 4. 3D electrical resistivity imaging results at the study area with given depth.

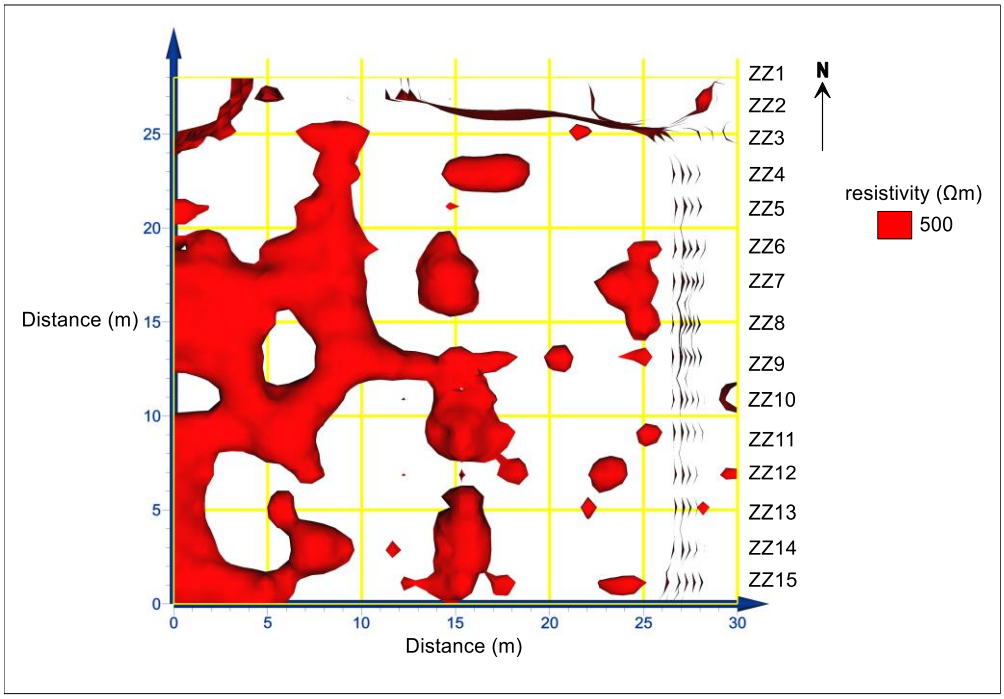

Figure 5. Isosurface resistivity anomaly at Plot SB2ZZ.

5. Conclusion

The archaeological area at Sungai Batu, Lembah Bujang (Kedah, Malaysia) shows promising results that the area has the anomaly of suspected baked clay bricks. This paper has demonstrated that the application of geophysical method particularly using ERI was applicable in archaeological point of view. The 3D ERI is useful to delineate the location and pattern of the underground anomaly with large data coverage. The isosurface resistivity shows effective ways to visualized the suspected targeted anomaly of resistivity value specifically at the studied area. More surveys using different geophysical methods are recommended to support the appearance of the anomaly at the study area.

Acknowledgments
The authors would like to thank laboratory assistant, postgraduate students of Geophysics Program, School of Physics and including Centre for Global Archaeological Research (CGAR), Universiti Sains Malaysia for sponsoring the project.

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