Imaging Subsurface Characterization at Bukit Bunuh Using 2D Resistivity Method: The Effectiveness of Enhancing Horizontal Resolution (EHR) Technique

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***Abstract*—2D resistivity method is an indirect method to the shallow subsurface survey for maintaining the geo-environment. It is used to measure the apparent resistivity of subsurface. This study was conducted at Bukit Bunuh, Perak (Malaysia), where EHR resistivity technique was developed in order to get detail and deeper penetration for shallow subsurface study. The survey line for EHR technique was executed in West-East direction while South-North direction was covered without EHR technique. The 2D resistivity results were compared between the survey line, with and without EHR technique. The survey used Pole-dipole array with 5 m minimum electrode spacing. The results show the first zone with resistivity value of 10-800 ohm-m and thickness 5-60 m as alluvium consisting of boulders (weathered granite) with resistivity value of >6000 ohm-m. The second zone with resistivity value >20 000 ohm-m was granitic bedrock. The penetration depth for 2D resistivity without EHR technique is 70m and with EHR techniques is 140m with 5m electrode spacing.**

***Index Terms*—Bukit bunuh, enhancing horizontal resolution (EHR), subsurface, 2D resistivity.**

I. Introduction

The shallow subsurface of the earth is an extremely important zone that supports our industrial and infrastructure. As safe and effective use of the near-surface environment is a major challenge facing our society, there is a great need to improve our understanding of the shallow subsurface. These challenging grounds are either hilly terrain or land with underlying materials of notorious mechanical characteristics, such as soft compressible deposits, loose granular deposits, brown fills, karstic limestone, waste dumps and peaty soil. The forms of structure proposed in this modern day demands taller and heavier structures, deeper depth of foundation and underground excavation [1]. Therefore, for projects involving subsurface or substructure works with foundation and underground space excavation; site formation with cut slope, fill, retaining structures and ground improvement works, geotechnical engineer and geophysicist are usually engaged in ground investigation and geotechnical and geophysical designs.

Geotechnical studies are usually used for subsurface, engineering and environmental works. Geophysical study provides supported data in order to save cost and time. Geophysical methods can be used to determine depth to bedrock, nature of overburden materials and near surface structures such as sinkholes, cavities, voids, faults and boulders [2].

This paper aims to show how 2D resistivity methods were successfully used for detection in shallow subsurface. An important part of this study is to improve the 2D resistivity horizontal resolution and prove a detail image of deep structure can be obtained using EHR technique.

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II. 2D Resistivity Method

A. Theory of 2D Resistivity

The 2D resistivity measurements are normally made by injecting current into the ground through two current electrodes, C_1 and C_2 and measuring the resulting voltage difference at two potential electrodes, P_1 and P_2 (Fig. 1). The resistivity of a soil or rock is dependent on several factors that include amount of interconnected pore water, porosity, amount of total dissolved solid such as salts and mineral composition (clays). The 2D DC resistivity method is described by [3], [4], [5] and [6].

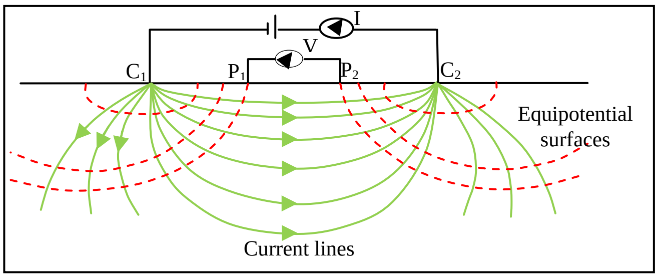

Fig. 1. Four-point electrode configuration in a two-layer model of resistivity, ρ_1 and ρ_2. I, current; U, voltage; C, current electrode; P, potential electrode [7].

B. Enhancing Horizontal Resolution (EHR) Technique

When two current electrodes are placed close to one another, current flows along arc-shaped paths connecting the two electrodes. About 50% of the current flows through rock at depths shallower than the current electrode spacing provided the earth has a constant resistivity. By increasing

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the electrode spacing, more of the injected current will flow to greater depths, as indicated in Fig. 2a. If the electrode spacing is much closer, current flows mostly near the earth surface and apparent resistivity will be dominated by resistivity structure of the near surface [8].

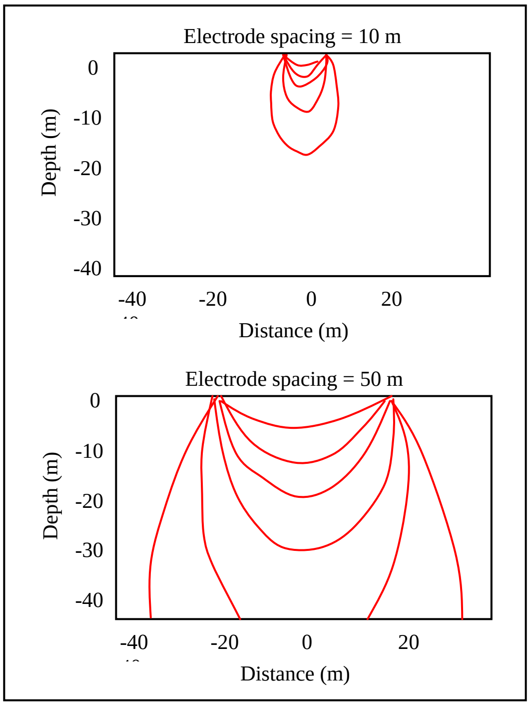

Fig. 2. Current flow through the earth with different electrode spacing.

III. MATH

Using EHR technique, the current will flow close to each other at a greater depth (Fig. 3).

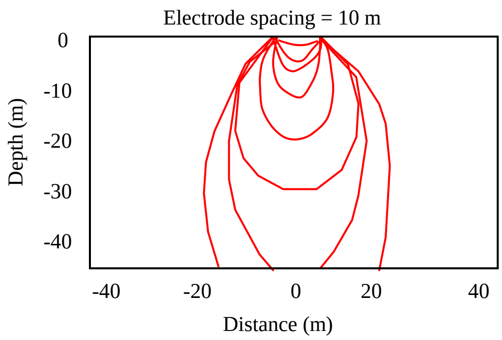

Fig. 3. Current flow through the earth with EHR technique

The important part of this study is to show that EHR technique can improve the 2D resistivity pseudo section and prove to get deeper penetration. 2D resistivity survey is to determine the subsurface resistivity distribution by taking measurements on the ground surface. The true resistivity of the subsurface can be estimated [9]. Fig. 4 shows the datum points for Pole-dipole arrays with and without EHR technique.

III. METHODOLOGY

The survey used ABEM SAS4000 system with Pole-dipole array. The survey lines were directed towards South-North and West-East direction with 5 m minimum electrode spacing. A total of 41 electrodes were used. The survey line of South-North direction used 2D resistivity method without EHR technique. The survey line of West-East direction was conducted using EHR technique where the first electrode was located at 0 m (beginning of the line) while the last electrode was located at 400 m (end of the line). The inter electrode spacing of 10 m was adopted for the study. After completion of data acquisition, the first electrode was shifted to the right by 5 m while the last electrode was located at 405 m and the process of data acquisition was repeated in the same line. The two sets of data acquired for each array was then combined during processing. The acquired data were processed using Res2Dinv software.

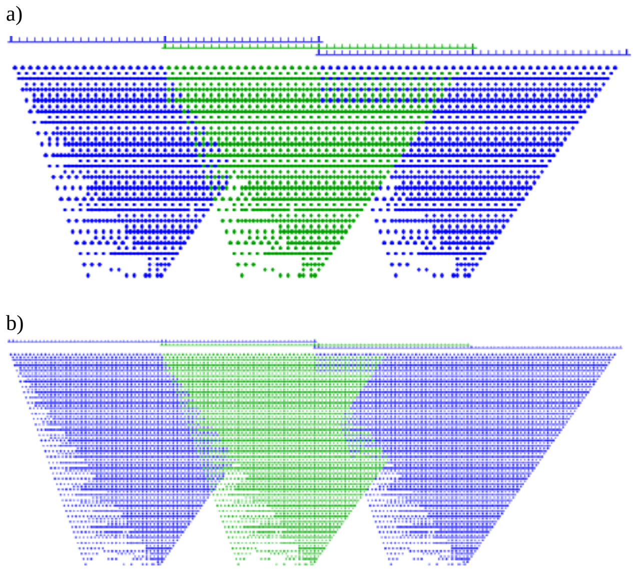

Fig. 4. 2D resistivity datum points to build up a pseudo section, a) common Pole-dipole array b) Pole-dipole array with EHR technique.

IV. STUDY AREA

The study was carried out in Bukit Bunuh, Perak, Malaysia (Fig. 5). The total length of the study line without EHR technique was 6 km from South to North, parallel to Sungai Perak. The length of study line using EHR technique 8 km, from West to East direction, perpendicular to Sungai Perak and two mountain ranges, Bintang and Titiwangsa Range.

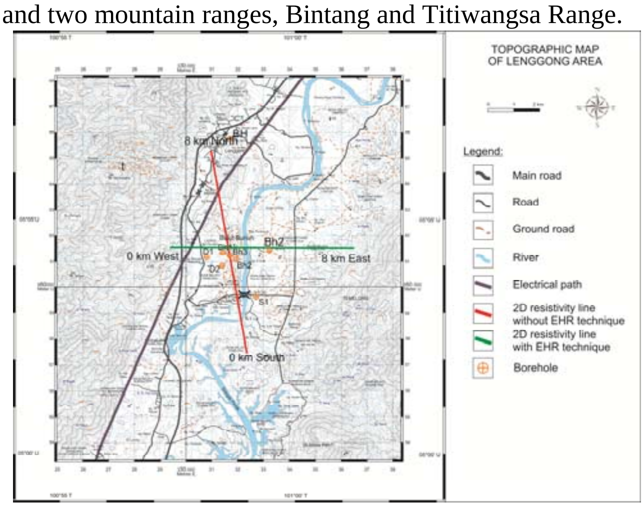

Fig. 5. 2D resistivity survey at Bukit Bunuh, Perak (Malaysia).

V. Results and Discussions

Resistivity section (Fig. 6-8) show the study area consists of two main zones. The first zone with resistivity value of 10-800 ohm-m and thickness 5-60 m was interpreted as alluvium. There were many boulders (weathered granite) with resistivity value of >6000 ohm-m embedded in the alluvium. The second zone with resistivity value >20 000 ohm-m was granitic bedrock. A lot of fractures (dashed line) were found along the survey line. The results of South-North direction, without EHR technique (Fig. 6) shows the deepest penetration is about 70 m, while East-West direction with EHR technique is 140m (Fig. 7 and Fig. 8) with 5 m minimum electrode spacing.

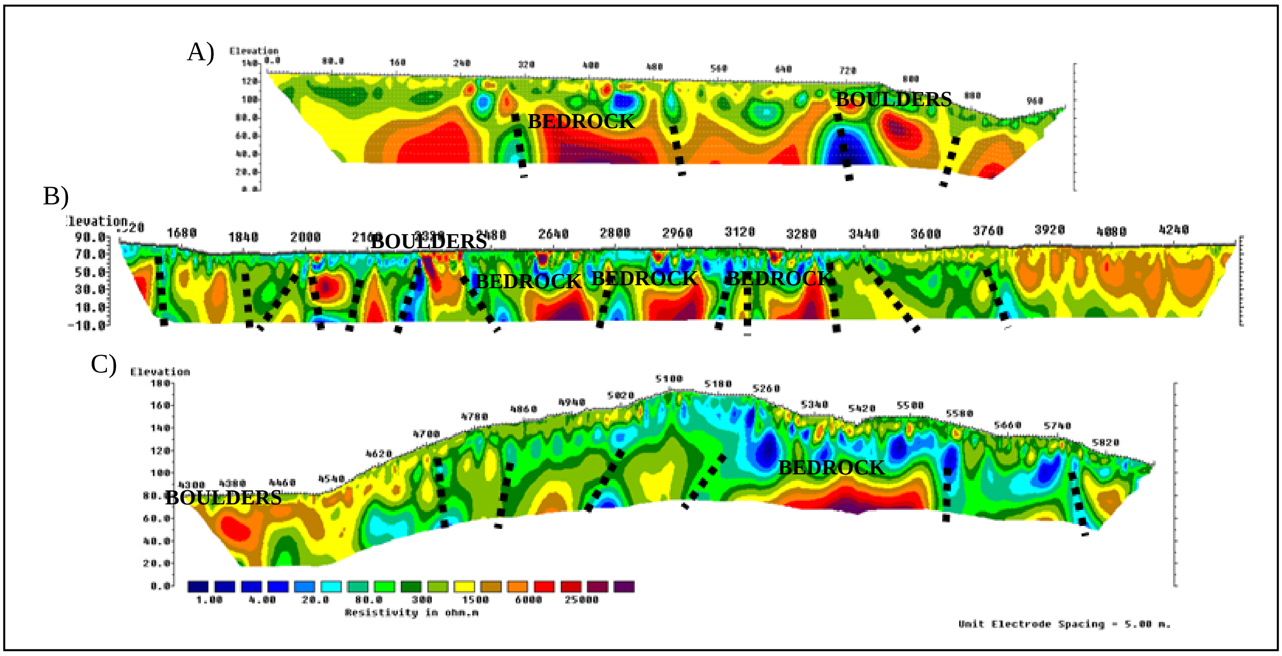

Fig. 6. Resistivity section of South-North line without EHR technique, 6 km length. A) Resistivity section 0-1000 m. B) Resistivity section 1520-4400 m. C) Resistivity section 4300-6000 m.

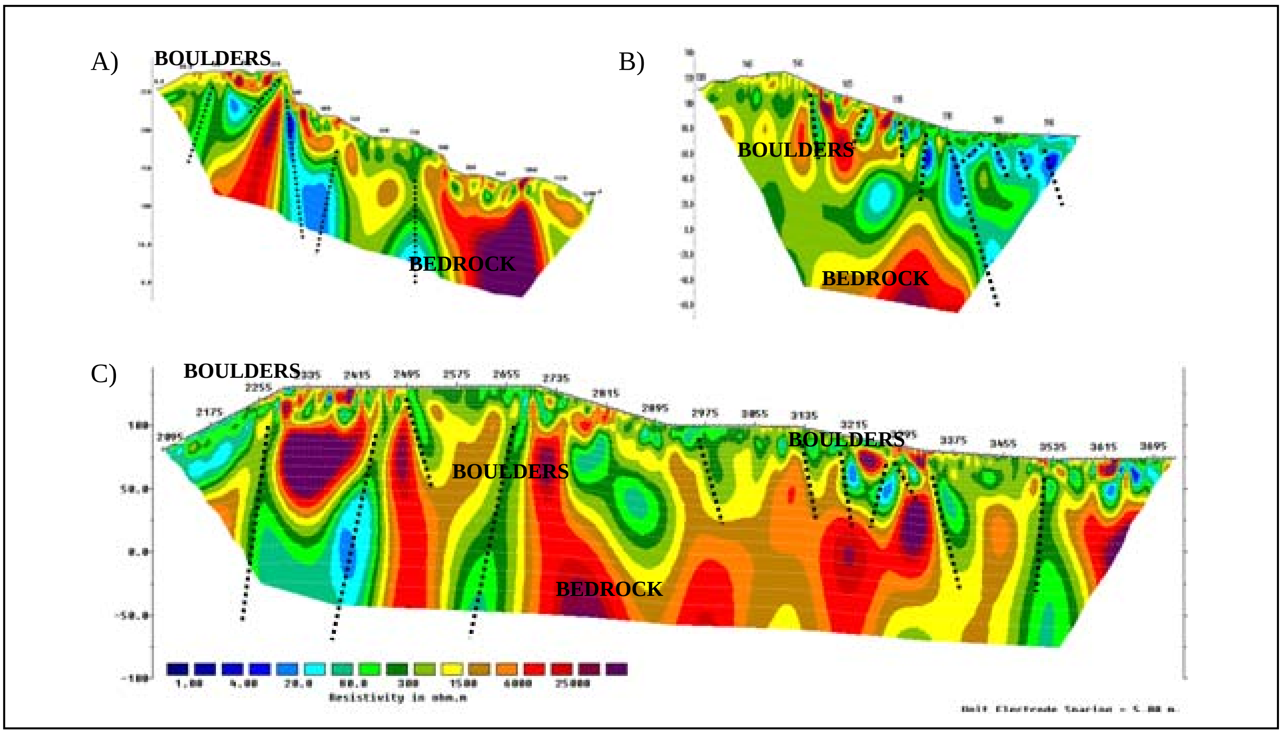

Fig. 7. Resistivity section of West-East line, with EHR technique. A) Resistivity section of 0-1200 m, B) Resistivity section of 1385-1995 m and C) Resistivity section of 2095-3730 m.

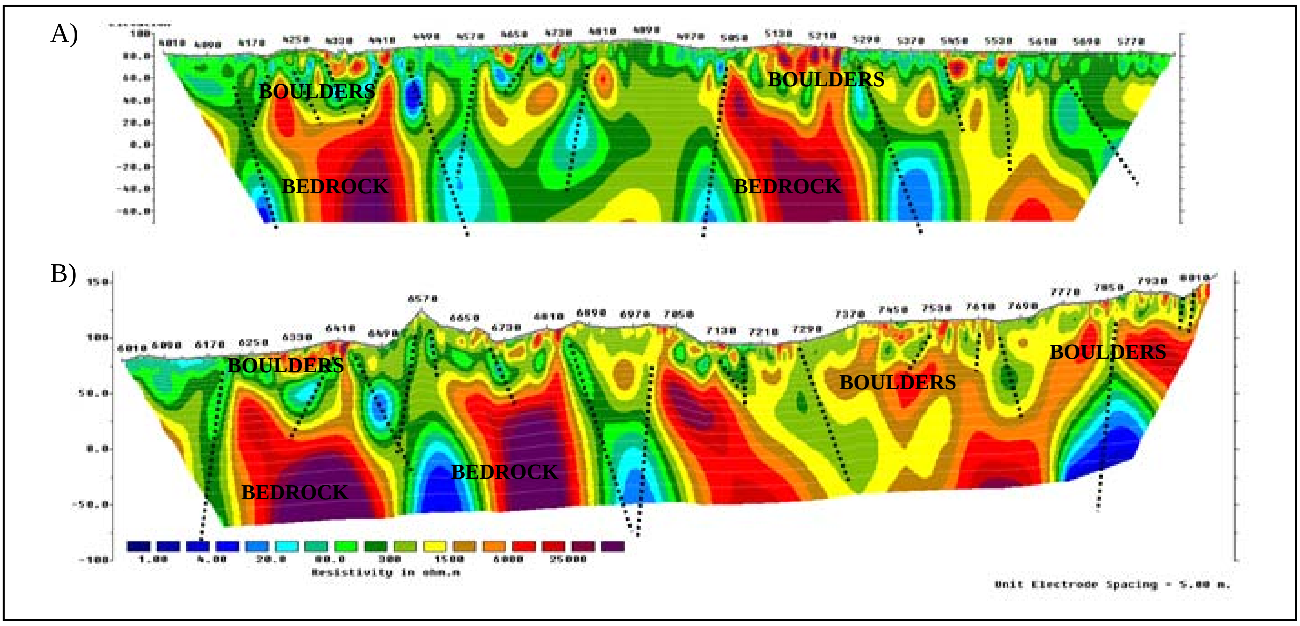

Fig. 8. Resistivity section of West-East line, with EHR technique, A) Resistivity section of 4010-5850 m and B) Resistivity section of 6010-8020 m

VI. Conclusion

The South-North and West-East direction result shows variation in resistivity values and depth of penetration. However, result from the EHR technique produced better image mapping in term of resolutions and penetration depth. This technique improves the horizontal resolution of subsurface resistivity. Application of combining data in resistivity surveys may be a useful strategy for improved resistivity mapping in shallow subsurface.

Acknowledgments

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