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High Resolution Time-domain Induced Polarization Tomography with Merging Data Levels by Two Different Optimized Arrays for Slope Monitoring Study

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ABSTRACT

In this paper, we present the results of electrical resistivity and induced polarization real in-field data collected using wenner-schlumberger and pole-dipole arrays. The study was conducted at Minden site in Penang, Malaysia. Inversion results from computer suggested that optimized wenner-schlumberger and pole-dipole arrays would be equally effective but the merge data levels technique for both arrays would able to provide high resolution at imaging slope area. Our in-field data results showed that the two arrays imaged the subsurface for slope monitoring equally well. When in-field data levels from these two different arrays were merged and analyzed using 2-D inversion, however, the merging data levels using two different arrays was able to resolve the subsurface characterizations. Because the merging data levels using two different arrays requires roughly two times as measurement per line, we conclude that this technique is preferable for environmental geophysics than single array only when the high improvement in resolution at sensitivity, horizontal coverage, signal strength and investigation depth is more important than rapid data acquisition.

KEYWORDS: Induced polarization; Slope; High resolution; Merging data levels.

INTRODUCTION

The enhancement of resolution is crucial in geophysical imaging and characterization of buried structure targets. The identification of buried structure, based on amplitude and geometry indicators obtained using geophysical methods, requires details understanding that imaging targets and in focusing on actual objectives of potential interest.

The geophysical method of induced polarization utilized the electrical polarizability of subsurface soils and rocks for exploration purposes. While originally developed for the prospection and characterization of mineral deposit, which represent well polarisable targets, in recent years the value of the induced polarization method has been increasingly recognized also for near surface investigations in relatively low polarisable, sedimentary environments. Ponziani et al. (2012) study the influence of physical and chemical properties on the spectral induced polarization (SIP) response of peat samples. The degree of humification of the peat samples shows an inverse correlation with polarizability in term of the measured induced polarization phase angle. Dahlin and Leroux (2012) show how data quality in time-domain induced polarization acquisition using multi-electrode systems can be improved by separating current and potential cables, which they attribute to reduced capacitive coupling effects in the data.

Geophysical method such as electrical resistivity has been use for long time in investigation of subsurface (Bery 2012). Application of resistivity is usually used to determine depth to bedrock, nature of overburden materials and near surface structures such as sinkholes, cavities, voids, faults and boulders. Resistivity method is predominantly used in shallow subsurface investigation and it is non-destructive and non-invasive (Nordiana et al. 2011). Saad et al. (2011) studied meteorite impact at Bukit Bunuh using 2-D resistivity imaging method. Thus, environmental study helps for the estimation and prediction the properties of the subsurface material especially in reducing the cost of investigation and increase the understanding of the earth subsurface characterization proposed by Bery and Saad (2013a). 2D resistivity method is used to measure the apparent resistivity of ground subsurface. The study conducted by Kiu et al. (2012), Jinmin et al. (2013) and Nordiana et al. (2013) at Bukit Bunuh, Perak, Malaysia successful in fractures and faults within granitic bedrock and other potential areas of poor rock quality. The highly fractured bedrock could be one of the possible causes of meteorite impact. Bery and Saad (2013b) show the application of merged data levels using two different arrays for high resolution resistivity tomography for bunkers study. They successfully show that merged data levels using two different arrays able to map the dimension of the buried bunkers.

METHODOLOGY

Our field investigation areas are located at south of Penang Island, Malaysia. The major portion of Penang Island is underlain by igneous rocks. All igneous rocks are granites in terms of Streckeisen classification (Ong, 1993). These granites can be classified on the basis of proportions of alkali feldspar to total feldspars. On this basis granites of Penang Island are further divided into two main groups: the North Penang Pluton approximately north of latitude 5° 23' and the South Penang Pluton. In the northern part of the island, the alkali feldspars that generally do not exhibit distinct cross-hatched twining are orthoclase to intermediate microcline in composition. In the southern region, they generally exhibit well-developed cross-hatched twining and are believed to be microcline. The North Penang Pluton has been divided into Feringgi Granite, Tanjung Bungah Granite and Muka Head micro granite. The South Penang Pluton has been divided into Batu Maung Granite and Sungai Ara Granite (Ong, 1993).

This time-domain induced polarization study was conducted at the same line but at different time. This is due to monitoring study of the slope. The total study line is 40 m with 1 m electrode spacing. Various type of electrode combination (array) can be use in electrical resistivity method. In this study, we have chose two type only that is pole-dipole and wenner-schlumberger arrays. RES2DINV software was used for inverting the apparent resistivity data to a resistivity model section. For this technique, the merging data levels for wenner-schlumberger and pole-dipole arrays are display in **Figure 1, Figure 2** and **Figure 3** in term of model blocks.

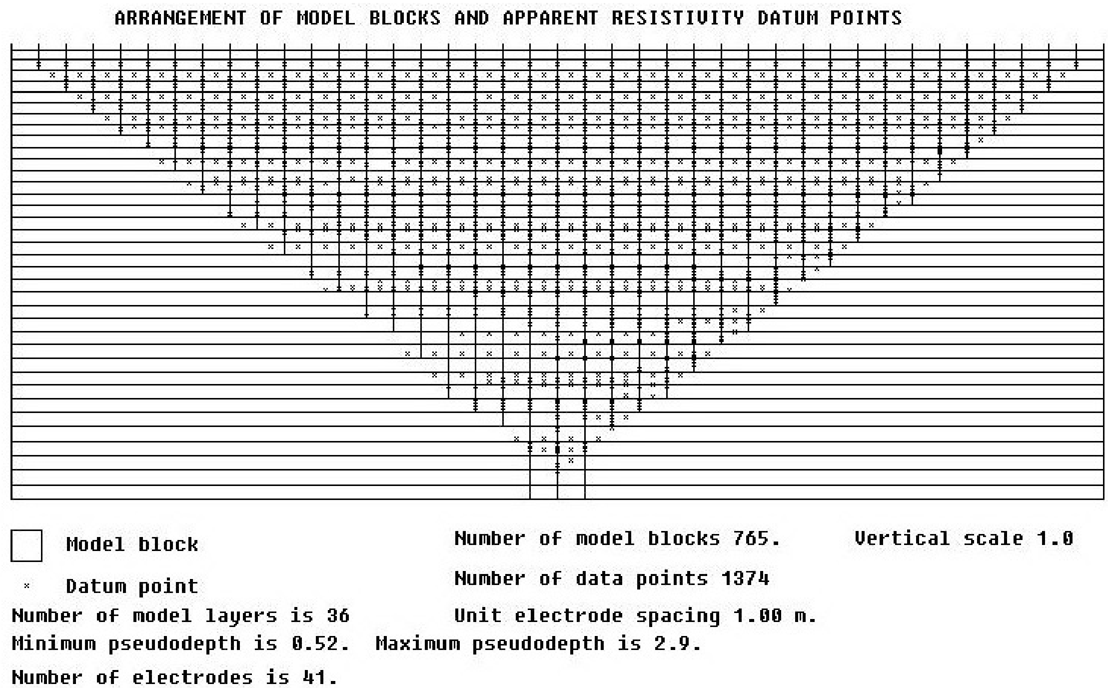

Figure 1: The data levels used in this study with 1374 datum points for pole-dipole array

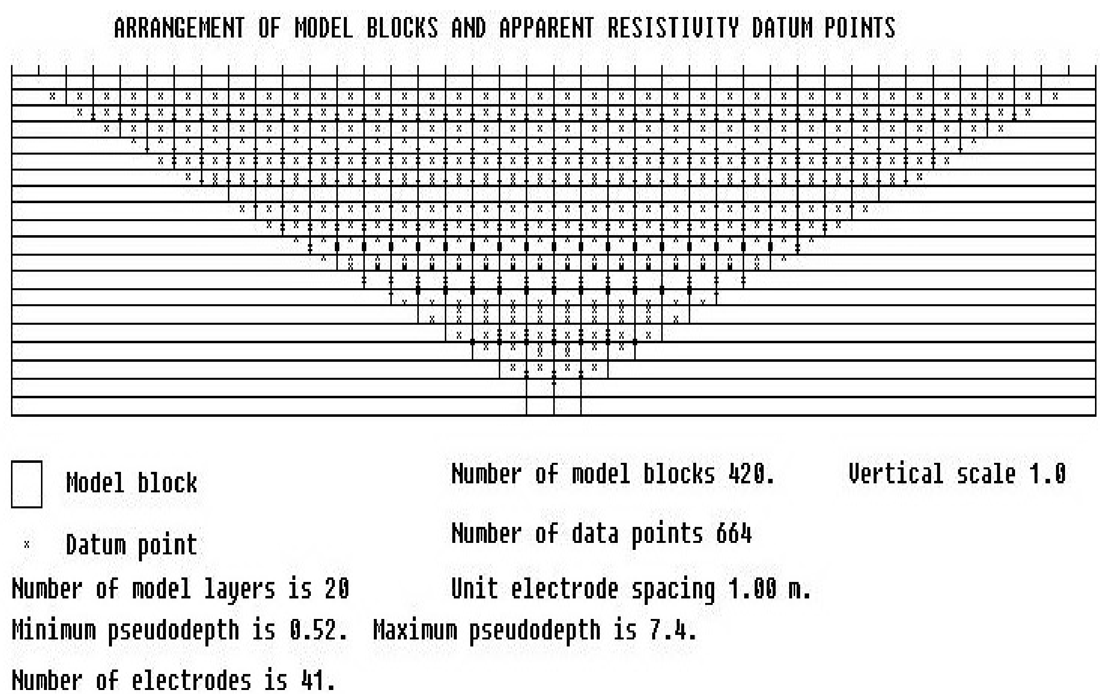

Figure 2: The data levels used in this study with 664 datum points for wenner-schlumberger array

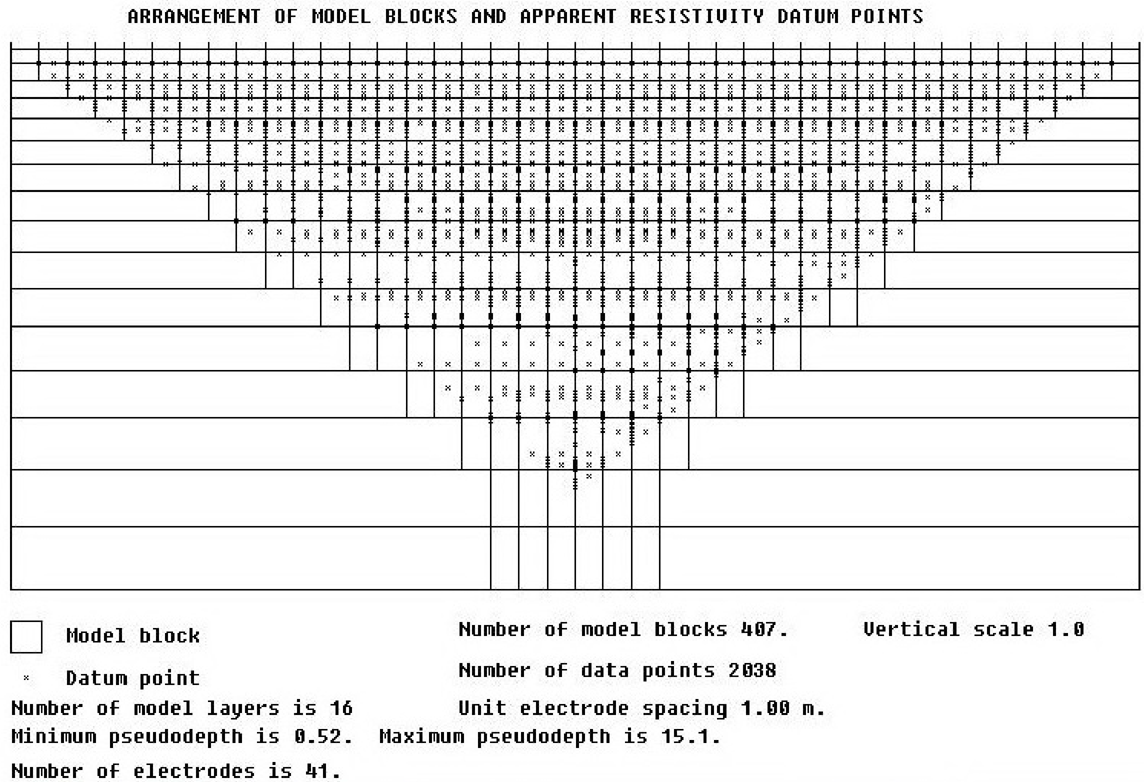

Figure 3: The merging data levels used in this study with 664 datum points for wenner-schlumberger and 1374 datum points for pole-dipole arrays (total of 2038 datum points)

RESULTS AND DISCUSSION

In this study, the combination of two different data levels of electrical methods is able to give reasonable and reliable results. The slope monitoring by subsurface characterization was shown in electrical resistivity and induced polarization results. Thus, this combining data levels technique can be applied for other near surface study such as cavities detection, hydro-geophysics etc. Each of arrays in electrical methods has their limitation. Thus, this technique can be used to improve the data and signals quality for resistivity and induced polarization surveys, particularly in noisy areas.

From the electrical resistivity tomography results in **Figure 2** and **Figure 3**, they showed that the moisture zone (mixture of water and alluvium) is detected and represented by low resistivity range from 1-100 Ω.m and high chargeability range value of 5 – 8 mV/V. The surrounding area is weathered surface material classified as clayey sand with resistivity values range from 300 Ω.m to 1500 Ω.m. The resistivity tomography results are supported by the time-domain induced polarization tomography results. The clayey sand soil can be classified as a composite matrix of coarse and fine grains (laboratory tests). The changes of the moisture zone are detected spread to other area at the slope subsurface. This is shown by low resistivity zone getting large compared to the earlier study. This could be caused by the entering rain water or seepage from the top of the slope.

The robust inversion constrain for 2D inversion resistivity models was selected in this study because this scheme is less sensitive to very noisy data points but give a higher apparent resistivity root mean squares (RMS). Moreover, the robust inversion constrain is suitable if there are boundaries present. This paper also presents the summary of the applied array (wenner-schlumberger, pole-dipole and combined arrays). This is shown in **Table 1**. The datum of is increases to 2038 datum points when merging data levels for two different arrays. Horizontal coverage, vertical resolution, signals strength, investigation depth is improved better compared to single wenner-schlumberger and pole-dipole arrays. The investigation depth for combined arrays is 15.10 m deeper compared to wenner-schlumberger array with 7.40 m and pole-dipole array with 14.30 m. Number of data level for combined array was also improved with value of 115.

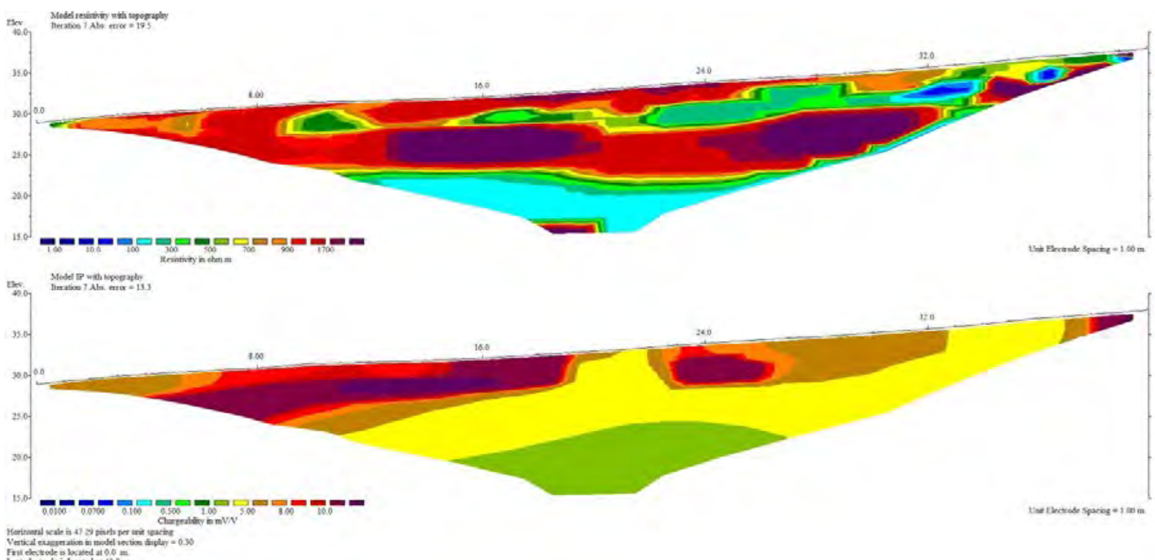

Figure 3: Resistivity (above) and induced polarization (below) inverted models for merging data levels using wenner-schlumberger and pole-dipole arrays (Stage 1)

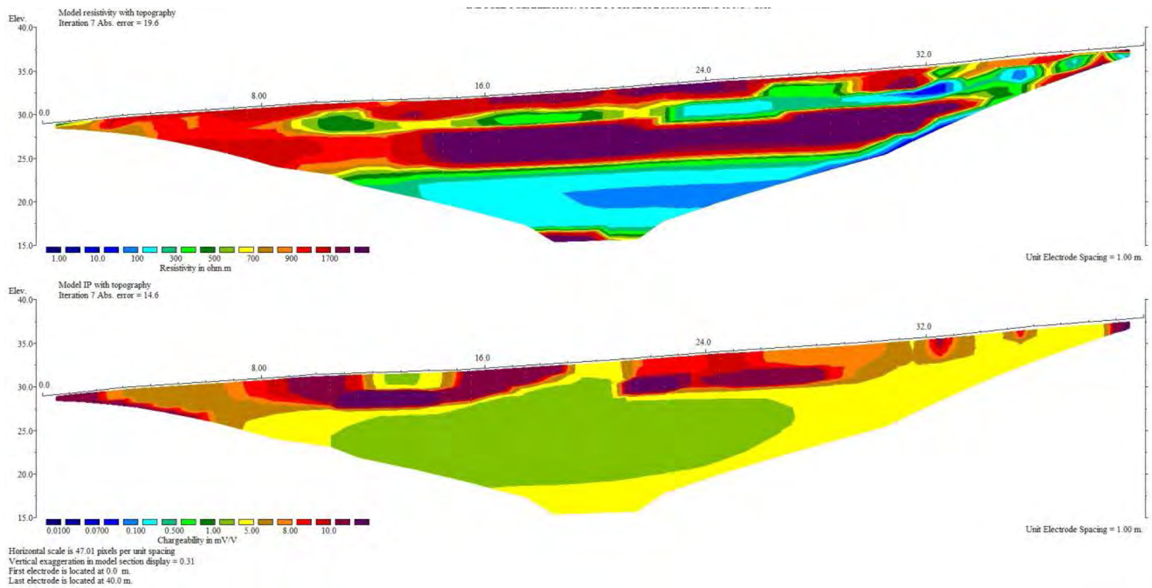

Figure 4: Resistivity (above) and induced polarization (below) inverted models for merging data levels using wenner-schlumberger and pole-dipole arrays (Stage 2)

In this study, we are also show the RMS error for all three (Stage 2 only) 2-D inverted model resistivity and time-domain induced polarization sections. The final iteration (Iteration 6) shows that all three resistivity inverse models have different value. 2-D inverted model resistivity section for wenner-schlumberger array gives 13.62 %, pole-dipole array gives 12.46 % and merged both arrays give 14.6 %. **Figure 4** shows the graph of RMS error against iteration number for all three 2-D inverted model resistivity and induced polarization results.

Table 1: The summary of wenner-schlumberger, dipole-dipole and merged arrays (last study)

Arrays		Wenner-Schlumberger	Pole-Dipole	Merged arrays
Main criteria	Datum points	664	1374	2038 (664+1374)
	Horizontal coverage	Medium	Good	Good
	Vertical resolution	Good	Medium	Good
	Signals strength	Good	Good	Good
	Investigation depth	7.40 m	14.30 m	15.10 m
Model parameters	Number of data level	36	79	115 (36+79)
	Number of layers	11	16	16
	Number of blocks	286	401	401

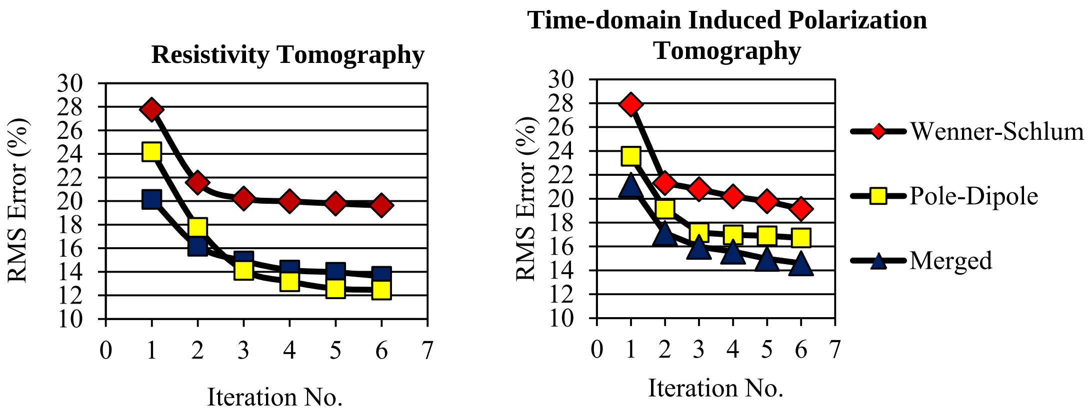

Figure 5: Graphs of RMS percentage error versus iteration number for all the 2-D inverted resistivity and induced polarization models for Stage 2 only.

CONCLUSION

Although data collected using wenner-schlumberger and pole-dipole arrays did helped us to characterize the slope subsurface until depth of 15.1 m from the Earth surface, the overall results for the two different arrays were quite compromising and remarkably significant. We conclude that despite the location, for most applications, the merging data levels using both wenner-schlumberger and pole-dipole arrays is successful in locate and give the actual changes of the slope subsurface condition at different period of monitoring study. We speculate that the merged arrays data levels reason is only better is that the resolution of the resistivity and time-domain induced polarization methods is inherently poor for large electrode spacing. The additional time and expense associated with merging data levels using two or three different arrays might be justified under exceptional circumstances where the target of interest is at the limit of the investigation depth or where limited access precludes using only one array.

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