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High Resolution Time-lapse Resistivity Tomography with Merging Data Levels by Two Different Optimized Resistivity Arrays for Slope Monitoring Study

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ABSTRACT

In this paper, we present high resolution time-lapse resistivity tomography study for slope monitoring using two optimized resistivity arrays of Wenner-Schlumberger and pole-dipole. These optimized resistivity arrays of Wenner-Schlumberger and pole-dipole give total of 2038 datum points for each data set. This slope monitoring study was conducted at Minden, Penang Island, 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. The overall results using these two different arrays were quite compromising and remarkably significant for good improvement in data quality and data acquisition technique.

KEYWORDS: Time-lapse resistivity; Optimized resistivity arrays; Merging data levels

INTRODUCTION

The term “landslide” includes very different types and processes of slope movements. A slope monitoring design must be adapted to the exact process or the chain of processes. The dynamic of a landslide is also a limiting factor in the use of some methods. The commonly accepted classification after Varnes (1978) respects these needs and defines five types of landslides: falls, topples, slides, spreads and flows.

Monitoring in general can be regarded as the regular observation and recording of activities taking place in a certain structure. It is a process of routinely gathering information on all aspects of the object. The term may be narrowed down with respect to deformation monitoring, whereas deformation monitoring is the systematic measurement and tracking of the alteration in the shape of an object as a result of external forces. However, especially in slope monitoring the inclusion of soil parameters like water content, vegetation, erosion and drainage as well as geomorphology and historical information is a major concern. Deformation monitoring and gathering measured values is a major component for further computation of soil and rock stability, deformation analysis, prediction and alarming (Moore, 1992). Since each monitoring project has specific requirements, the used measuring device for a deformation monitoring depends on the application, the chosen method and the required regularity and accuracy. Therefore, monitoring of slopes or landslide areas can only be defined, designed and realized in an interdisciplinary approach (Wunderlich, 2006). A close cooperation with experts from geophysics, geology and hydrology together with other experts from any measurement discipline such as geodesy and remote sensing is an indispensable requirement.

METHODOLOGY

Bery and Saad (2013a) have used geophysical methods of seismic refraction as well as engineering characterization for tropical environmental area. Bery and Saad (2013b) have used merging data levels using two different arrays for determine the dimension of bunkers. Slope monitoring using total station was proposed by Afeni and Cawood (2013). The purposes of their study are to provide a mine survey perspective on the typical problems that can be expected during slope monitoring using total station (also known as prism monitoring) and to suggest ways of monitoring such problems. Time-lapse direct-current (DC) resistivity tomography is shown to be a useful method for permafrost monitoring in high mountain areas conducted by Hauck and Vonder Mühll (2003). In their study, a combination of radiation, snow cover and resistivity measurements seem promising for long-term monitoring programmes of the permafrost evolution at low cost. Ng, Springman and Alonso (2008) have used back-analysis in saturated soil engineering which can help to refine and improve understanding, providing guidance for future designs, where the effects of soils suction and hydraulic hysteresis are still being explored.

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. 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.

Thus, environmental study at slope area using high resolution time-domain induced polarization with merging data levels by two different optimized arrays able to increase the understanding of the earth subsurface characterization proposed by Bery and Saad (2013c). In this study we are only discuss time-lapse resistivity method for slope monitoring study which is the continuation of the high resolution time-domain induced polarization as proposed by Bery and Saad (2013c). In studying the changes of the Earth's subsurface resistivity, we have used 2-D resistivity tomography method which is repeated over the same line at different times. The length of study line is 40 m with 1 m electrode spacing. In this study, we have chosen two optimized arrays which are Wenner-Schlumberger and pole-dipole 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 displayed in **Figure 1**, **Figure 2** and **Figure 3** in term of model blocks.

Our in-field investigation area is 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.

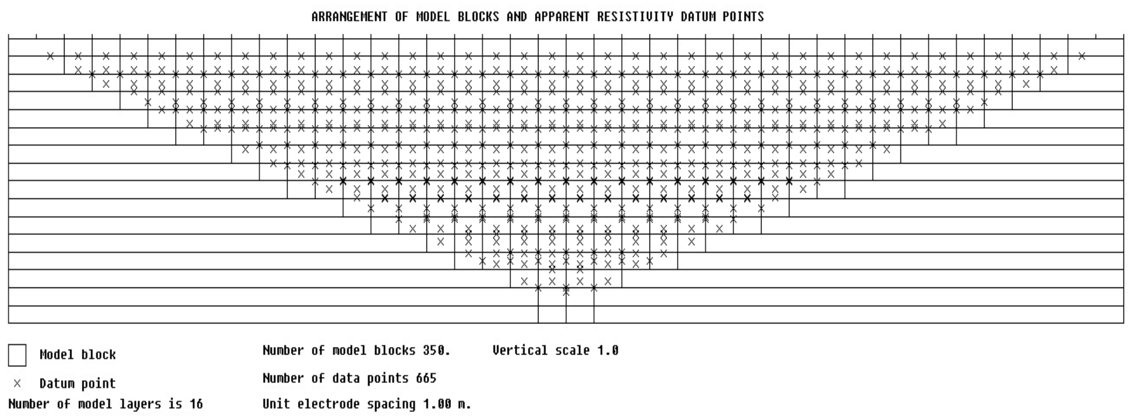

Figure 1: Arrangement of model block and apparent resistivity datum point for wenner-schlumberger array

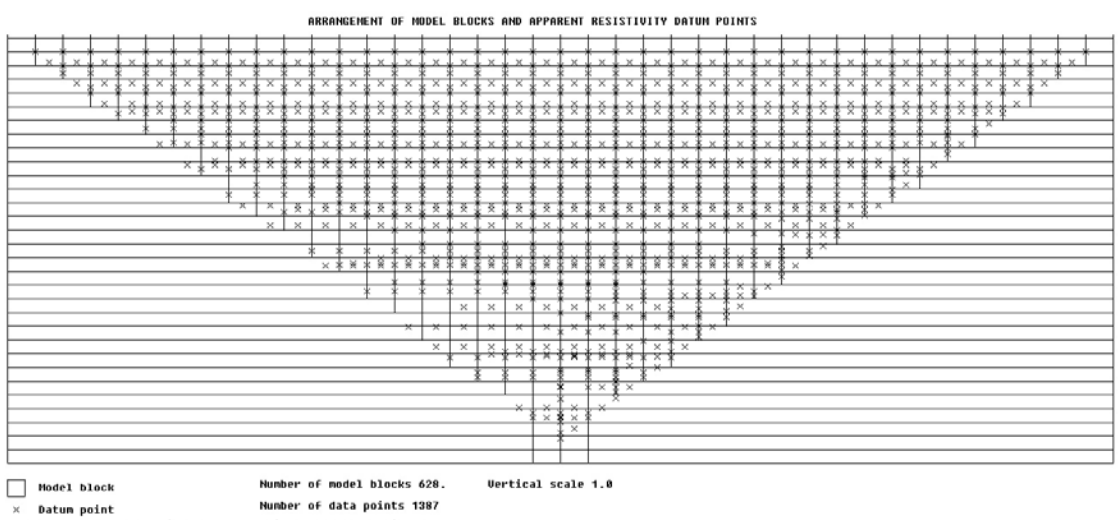

Figure 2: Arrangement of model block and apparent resistivity datum point for pole-dipole array

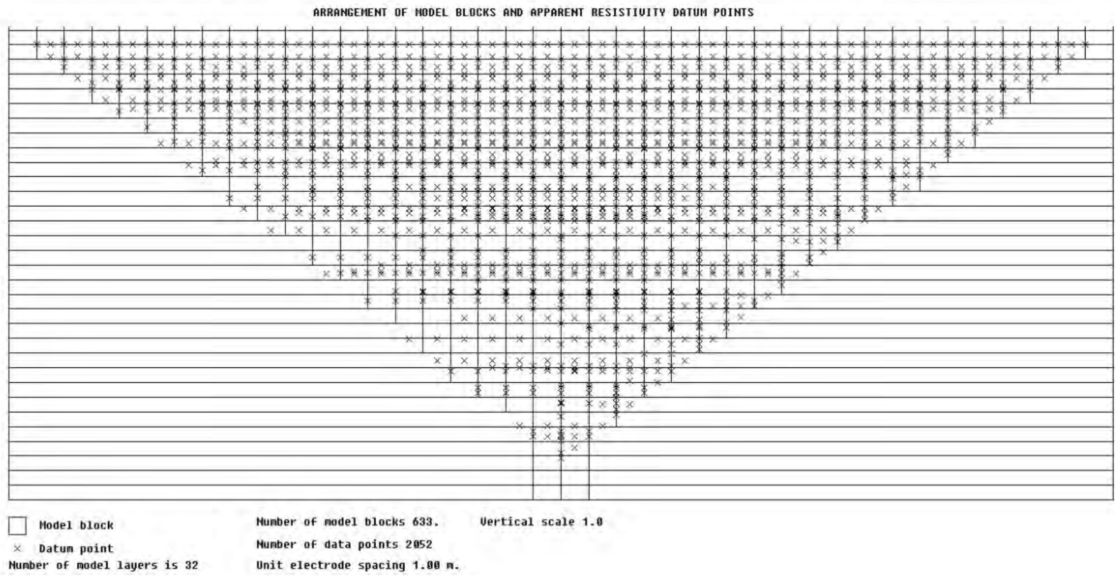

Figure 3: Arrangement of model block and apparent resistivity datum point for merging data levels using optimized Wenner-Schlumberger and pole-dipole arrays

RESULTS AND DISCUSSION

In this study, the merging data levels by two different optimized arrays of time-lapse resistivity for slope monitoring is able to give reasonable and reliable results. The slope monitoring by subsurface characterization was shown in electrical resistivity and percentage change in resistivity results. Each of arrays in electrical methods has their limitation. Thus we prove in this study, this technique can be used to improve the data and signals quality for time-lapse resistivity study, particularly in noise areas. The percentage change in model resistivity for November 2013 and December 2013 are displayed **Figure 4** and **Figure 5**. From the time-lapse resistivity results, it shows that the water is present in the subsurface especially during rainy season. It shows that the higher percentage change of model resistivity, the weaker the subsurface zone. This is cause by the rapid changes of subsurface due to change in water content. Meanwhile, zones with less or no percentage change in model resistivity indicate that the subsurface is compacted or unsaturated zones.

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 2052 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.

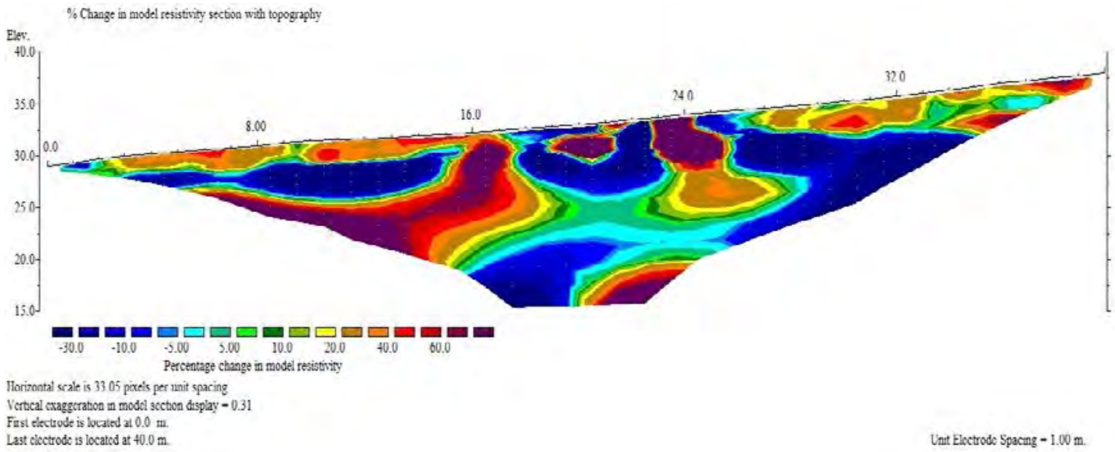

Figure 4: Time-lapse resistivity result with merging data levels by two different optimized arrays for November infield 2013 infield survey.

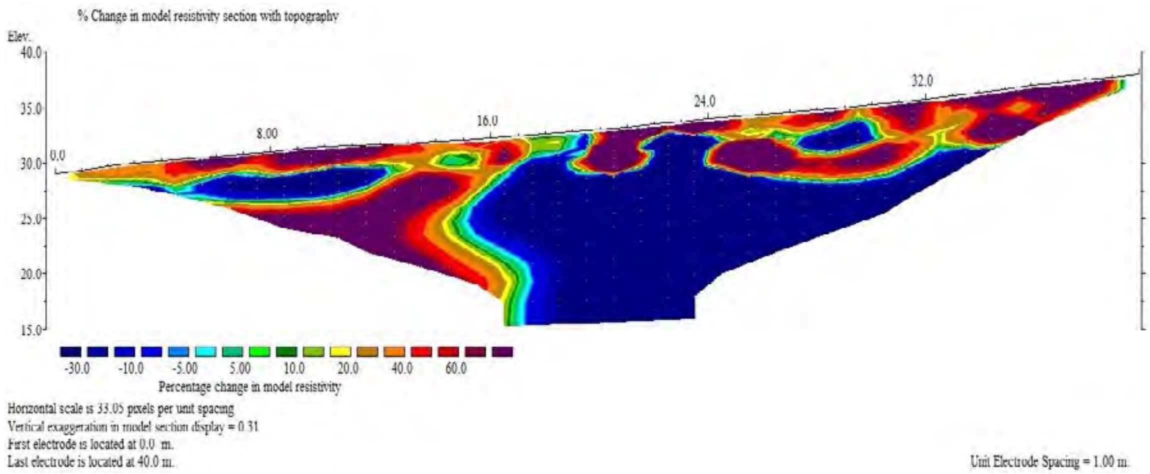

Figure 5: Time-lapse resistivity result with merging data levels by two different optimized arrays for December 2013 infield survey.

Table 1: The summary of Wenner-Schlumberger, dipole-dipole and merged arrays parameters

Optimized arrays		Wenner-Schlumberger	Pole-Dipole	Merged arrays
Main criteria	Datum points	665	1387	2052 (665+13787)
	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	16	31	32
	Number of blocks	350	628	663

CONCLUSION

Although data collected using optimized arrays of Wenner-Schlumberger and pole-dipole did helped us to characterize the slope subsurface, the overall results using these two different arrays were quite compromising and remarkably significant for improve data acquisition technique. 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 time-lapse resistivity method is inherently poor for large electrode spacing. The additional time and expense associated with merging data levels using these two different optimized 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. Moreover, this study is successful because this study is conducted at a low cost and provides reliable and acceptable slope subsurface information.

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