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MAGNETICS, 2-D RESISTIVITY AND GEOTECHNICAL STUDIES FOR SHALLOW SUBSURFACE SOIL CHARACTERIZATION IN LEMBAH BUJANG, KEDAH

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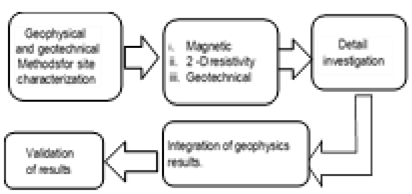
Graphical abstract



Abstract

Magnetic and 2-D resistivity surveys were conducted on the same line for soil characterizations. 2-D resistivity survey employed Pole-dipole array with 1 m electrode spacing while magnetic survey employed 2 m station spacing. Soil drilling was performed using hand auger at the 21st m on the line with 0.2 m sampling interval. All data were processed and overlaid for integration and validation. The magnetic results showed the distribution of magnetic residual as -4.55 to 1.61 nT, with the magnetic low (-4.55 to -0.058 nT) was identified at distances 10 to 26 m, 36 to 44 m, 74 to 82 m, 88 to105 m, 120 m and 150 m. Three zones were identified based on the 2-D resistivity results; low (16.9-35.2 Ω-m), moderate (73.3-152 Ω-m) and high (317-1373 Ω-m). The low resistivity values might be due to clay with high water content, and the low magnetic susceptibility distributions were due to soil of sedimentary origin. The samples obtained were sticky with variable sizes, greyish to brownish/reddish in color, and some of the samples exhibited the presence of shiny and black spots. The characteristics of the samples suggested that the soil was a product of completely weathered rock, classified as Grade V with high water contents and weak.

Keywords: magnetic susceptibility; 2-D resistivity survey; hand auger

1.0 INTRODUCTION

Geophysical application has been in the forefront of providing non – destructive, fast, low cost and efficient means of probing the earth subsurface. It uses contrast in physical properties of the earth in response to signals active or passive, to diagnose the subsurface distribution of earth materials. Good response to geophysical signal from some parameters in the subsurface, dictates the suitability of method to be used [1].

2-D resistivity method is one geophysical method uses multi – electrodes and exploits the flow of steady current in the ground. It tends to have advantage of providing a large property contrast [2] and has a wider application among other geophysical methods. It has been used extensively in different areas such as hydrogeology, mining and geotechnical investigations for many decades. More recently, its usage has been extended for environmental survey to address some natural and urban challenges [3].

Magnetic method on the other hand provides faster and cheap means of investigating subsurface of the earth on the basis of magnetic susceptibility distribution. Unless where there is magnetite present in soil or rock, magnetic response (susceptibility, k) for most earth materials is low (x 10^{-6}) [1]. This attribute makes it possible for magnetic method to discriminate between earth materials and any anomalous body, hence a good tool for characterizing the soil for shallow subsurface.

The integration of Magnetic and 2-D resistivity methods were used to investigate meteorite impact at Lenggong, Perak, Malaysia and discovered shallow granitic bedrock associated with effect of meteorite impact [4]. A similar approach was used to characterize and evaluate site competence for engineering purpose in Ethiopia [5].

This paper presents the Magnetic, 2-D resistivity and Geotechnical methods that have been used to characterize soil for shallow subsurface study. Analysis of soil samples taken at the site has revealed more information about the soil texture, color, strength and soil grade. The suitability of the site for foundation and other engineering purposes has also been inferred from the outcome of this study.

2.0 STUDY AREA

The study site is situated at Sungai Batu, Merbok; Kedah. The survey was conducted on a single line 160 m long along the north south direction. Magnetic and 2-D resistivity surveys were carried out on the same line. 2 m station interval was used for the magnetic survey while a minimum of 1 m electrode spacing was used for 2-D resistivity survey (Figure 1).

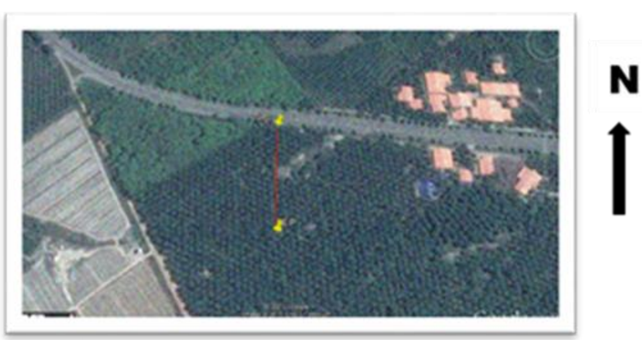


Figure 1 Study area [6]

3.0 GEOLOGY OF THE STUDY AREA

Sungai Batu is located along the road between Sungai Petani and Merbok in Lembah Bujang Malaysia (Figure 2). It has been documented in the past, between first and second century that mid-southern part of Kedah was known to be a marine area. The sea level receded about 1400 years [7] leaving behind some sediments transported by river. The receded area has been transformed to land [8]. The soil types in the area are mainly sandy clay soil covered with fine sand. The geomorphology of the area is flat. There are planted palm and rubber trees dominating the landscape alongside small rivers and swamps to the south and west of the survey line.

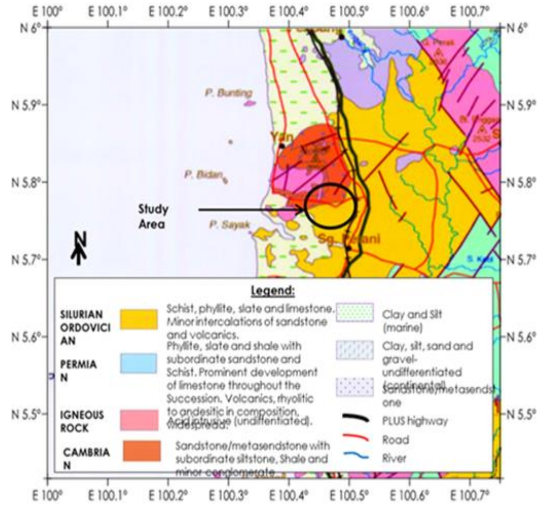


Figure 2 Geology map of Sungai Batu, Kedah [9]

4.0 METHODOLOGY

4.1 Magnetic Method

Ground magnetic data was acquired with 2 m station spacing using GEM GST-T magnetometer trending N-S. The conventional procedures for ground magnetic survey were adopted in this study. The data acquired was corrected and then processed using software [10] and [11].

4.2 2-D Resistivity Method

The resistivity method in essence measures the resistivity distribution of the subsurface materials [12]. The survey using Pole-dipole array conducted on the same line of magnetic line with eight spreads; each 20 m long using 1 m minimum electrode spacing. Arrangement of electrodes for a 2-D resistivity survey and the sequence of measurements used to build up a pseudosection are as shown in Figure 3. The data was acquired using SAS 4000 ABEM terrameter and processed using resist 2Dinv software with standard constrain algorithm.

4.3 Hand Auger Drill

A borehole was drilled using hand auger and soil samples were taken from the surface at 0.2 m depth interval to penetrate a depth of 5 m at position 21 m on the survey line. The samples collected were analyzed in the laboratory to determine their magnetic susceptibility, soil texture, and color.

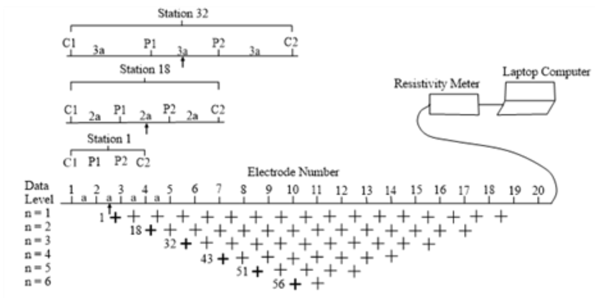


Figure 3 Arrangement of electrodes for a 2-D resistivity survey and the sequence of measurements used to build up a pseudosection [13].

5.0 RESULT AND DISCUSSION

5.1 Magnetic

Figure 4 shows relatively low magnetic responses at points 10-26 m, 36-44 m, 74-82 m, 88-105 m, 120 m and 150 m. These could be interpreted as materials that are degraded by weathering, such as sandy soil. Physical examination on the samples show some decay organic materials. The susceptibility of the soil is generally low and is typical of a product of sediments and weathered rocks.

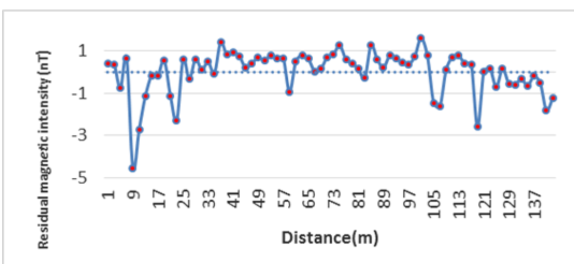


Figure 4 Magnetic residual plot

5.2 2-D Resistivity

Figure 5 vertical and horizontal variations in subsurface resistivity. The 2-D resistivity identifies three resistivity zones, low (16.9-35.2 Ω-m); moderate (73.3-152 Ω-m) and high (317-1373 Ω-m). The top soil is made up materials of low resistivity values;16.9-35.2 Ω-m which could be attributed to soil with high water content and suggested as clay (wet or dry) [14]. This low resistivity extends down to a depth of 2-3m at various locations beneath the survey line. Between the depths of 2-5m, beneath the locations of 10-28 m, 36-44 m, 74-82 m, 88-105 m and 123-132 m, values are 660-1373 Ω-m have been observed. This may probably be due to highly weathered granite. Below the depth of 9-16.2 m, the entire survey line is characterized by moderately low resistivity. This also suggests the presence of weathered rock.

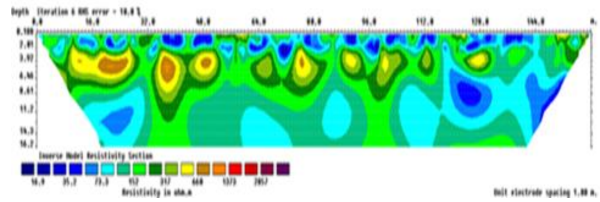


Figure 5 Inversion section of resistivity result

5.3 Soil Samples

Figure 6 shows magnetic susceptibility values plotted against depth indicated a generally low susceptibility value, which is typical of sedimentary materials of the order of 10^{-6} SI unit [15]. However, there are outliers observed at depth 0.6-0.8 m, 2.4-2.8 m and 4.6-4.8 m with susceptibility values of 160 x 10^{-6}, 16 x10^{-6} and 1.29 x10^{-6} SI units respectively. The true magnetic susceptibility values were converted from the apparent susceptibility (Table 1).

The soil samples have been found to be sticky, with varying colors at different depths. The texture is made of grains of different sizes; clay at the top-most and coarse at depths from 4.2- 5.0 m. Table 2 shows the interpretation of the Hand Auger borehole.

6.0 CONCLUSION

Three geophysical methods were used for the site investigation and soil characterization in Lembah Bujang. The site was investigated based on geophysical responses of some parameters in the subsurface and was complimented by samples from borehole. The top soil was found to be of low resistivity value to the depth of 2-3 m at various points and identified as clay. Between the depths of 2 to 5 m, the resistivity values were in the range of 660-1373 Ω-m and the material was suspected to be sandy clay. Correlation between magnetic responses and resistivity values indicated that low magnetic response corresponded to moderately high resistivity along the entire length of the survey line.

Samples obtained from different depths in the drilled hole were sticky soil of different grain sizes ranging from clay sized to coarse grain soil with mixed colors from grey to red / brown. Shiny and black spots were observed on some of the soil samples. This is suggestive of muscovite mica, biotite and indicative of a product of heavily weathered granite. The material was classified as Grade V weak soil, and the high water content indicated the site was waterlogged.

Table 1 Apparent and true susceptibility values of soil samples

x(m)	y(m)	Description	Apparent Susceptibility Value (x10-6) cgs Unit	Apparent Susceptibility Value (x10-6) SI Unit	True susceptibility (x10-6) SI unit
21	0-0.2	brownish clay	12	150.816	96.52224
21	0.2-0.4	brownish clay	12	150.816	96.52224
21	0.4-0.6	brownish clay	12	150.816	96.52224
21	0.6-0.8	brownish clay	20	251.36	160.8704
21	0.8-1.0	mixture of brown and grey clay	20	251.36	160.8704
21	1.0-1.2	mixture of brown and grey clay	10	125.68	80.4352
21	1.2-1.4	mixture of brown and grey clay	6	75.408	48.26112
21	1.4-1.6	mixture of brown and grey clay	6	75.408	48.26112
21	1.6-1.8	mixture of brown and grey clay	6	75.408	48.26112
21	1.8-2.0	mixture of brown and grey clay	6	75.408	48.26112
21	2.0-2-2	mixture of brown and grey clay	6	75.408	48.26112
21	2.2-2.4	mixture of brown and grey clay with decayed leafs	9	113.112	72.39168
21	2.4-2.6	gray clay	2	25.136	16.08704
21	2.6-2.8	gray clay	2	25.136	16.08704
21	2.8-3.0	gray clay	6	75.408	48.26112
21	3.0-3.2	gray clay	6	75.408	48.26112
21	3.2-3.4	gray clay	6	75.408	48.26112
21	3.4-3.6	gray clay	6	75.408	48.26112
21	3.6-3.8	gray clay	6	75.408	48.26112
21	3.8-4.0	gray clay	6	75.408	48.26112
21	4.0-4.2	gray sand	6	75.408	48.26112
21	4.2-4.4	gray sand	8	100.544	64.34816
21	4.4-4.6	gray sand with leafs	10	125.68	80.4352
21	4.6-4.8	gray sand	16	201.088	128.69632
21	4.8-5.0	gray sand	10	125.68	80.4352

True susceptibility Value = Apparent Susceptibility * square of the ratio of standard sample diameter to true sample diameter.

Table 2 Interpretation of Hand Auger borehole log

Depth(m)	Description of Soil	Inference
0-1.6	Consist of fine grain minerals, sticky and reddish in colour owing to oxidation of iron.	Clay
1.6-3.6	Consist of less reddish and more gray fine grain, with some shiny alongside dark colour particles. These particles are suspected to be mica and biotite.	Clay material from weathered granite
3.6-4.2	Traces of sand and silt. Increase in particle size and gray in colour. The presence of mica, biotite and quartz becomes visibly clear.	Sandy clay
4.2-5.0	Highly weathered granite with coarser grain size and gray in colour.	Sandy clay

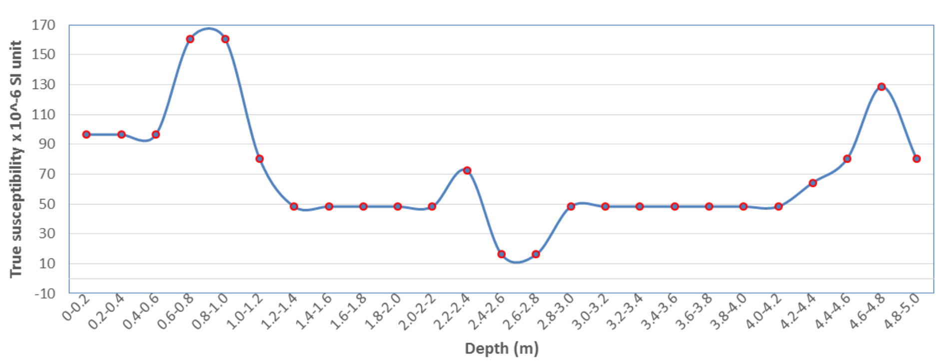


Figure 6 True magnetic susceptibility of samples plot with depth

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