Electrical Resistivity as a Geophysical Mapping Tool; A Case Study Of The New Art Department, Knust- Ghana

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ABSTRACT
Continuous vertical electrical sounding (CVES) surveys were carried out on KNUST campus to ascertain the electrical properties of the formations in the area in order to determine its suitability for the construction of heavy structures. Eight 2D CVES profiles were conducted at the site in the study area with a wenner array using electrode separations of 1, 2.5 and 4 m. The apparent resistivity data were inverted using the least square inversion technique into subsurface electrical structures. The results on the profiles running N-S indicate a well defined boundary in the electrical resistivity structure between the wet granites at the base and the dry undifferentiated granites on top of it.

Keywords; *continuous vertical electrical sounding (CVES), KNUST, resistivity, Wenner array, inversion, imaging*

INTRODUCTION

Electrical resistivity surveys are based on the response of the earth to the flow of electrical current. Artificially generated electric currents are introduced into the ground and the resulting potential differences are measured at the surface (Telford et al., 1990; Lowrie 2007). All materials, including soil and rock, have an intrinsic property- resistivity that governs the relation between the current density and the gradient of the electrical potential. In general, the main principle in any geophysical explorations is to non-intrusively gather data on the area of interest (Scollar et al., 1990). Variations in the resistivity vertically or laterally produces variations in the relation between the applied current and the potential distribution as measured on the surface and thereby reveal something about their composition, extent, and physical properties of the material.Resistivity is therefore, one of the most variable physical properties (Keary et al., 2002)**ranging between 1.6×10^{-8} Ωm for native silver to about 10^{16}Ωm for pure sulphur.**

The resistivity method has varied applications in mining, groundwater detection, and subsurface geological structure among others. The use of geoelectrical method as an effective tool for gaining knowledge into the subsurface structure, in particular, for identifying anomalies and defining the complexity of the subsurface geology and is fast gaining grounds (Lapenna et al., 2005;Siddiqui and Osman, 2012). This may mainly be due to the fact that on electrical resistivity tomographies, faults lines and other geological formations such as fractures etc, easily stand out due to their low resistivity values compared to the surrounding (Aning et al., 2013). These features are normally identified as anomalies in the electrical resistivity tomographies as they differ from the host material.

Field studies by Ozegin et al., (2011) predicted that a geologic structure which was most probably a fracture was established and confirmed to be a potential source of building failure in a site, and this happens when building is constructed across the geologic structure. Garg (2007) found that if a building is constructed at a site, without properly considering the underground strata or its load-bearing capacity, it may settle excessively or differentially, causing development of cracks in the building which may ultimately lead to its failure and collapse. Subsurface geological features such as fractures, voids, and nearness of water table to the surface are among the inconveniences that pose constraint to constraint to building constructions especially to their foundations (Andrews et al., 2013).

The electrical resistivity method is very good tool for resolving geological problems ranging from the delineating of hidden underground structures (i.e. fractures, faults water accumulation etc.).It has also made the spatiotemporal evolution of groundwater flow relative to landslide occurrence to studies improve greatly (Aning et al., 2013).

In this work, the electrical resistivity distribution of the subsurface of the site would be measured by the application of the CVES method for imaging the subsurface of study area.

STUDY AREA

The survey site can be located behind the Engineering labs close to the new college of Arts building at the Kwame Nkrumah University of Science and Technology in Kumasi – Ghana. The project site falls within the wet sub-equitorial setting with mean minimum temperature of about 21.5 ^{o}C and maximum average temperature of 30.7 ^{o}C. The estimated area of the site is (160x100)

$m^2$with the land sloping gently in the South-North direction.

The area is underlain by Dahomeyan formation, mainly granitoid undifferentiated rocks as shown on fig. 1 and can be located on 6.6849083 °N and 1.5705194 °W. The Dahomeyan formation, consisting of mainly metamorphic rock such as gneiss and schist, occupies the south-southeastern corner of Ghana and occurs as four alternate belts of acid and basic gneisses, trending south-southwest to northeast direction (Griffis et al, 2002).

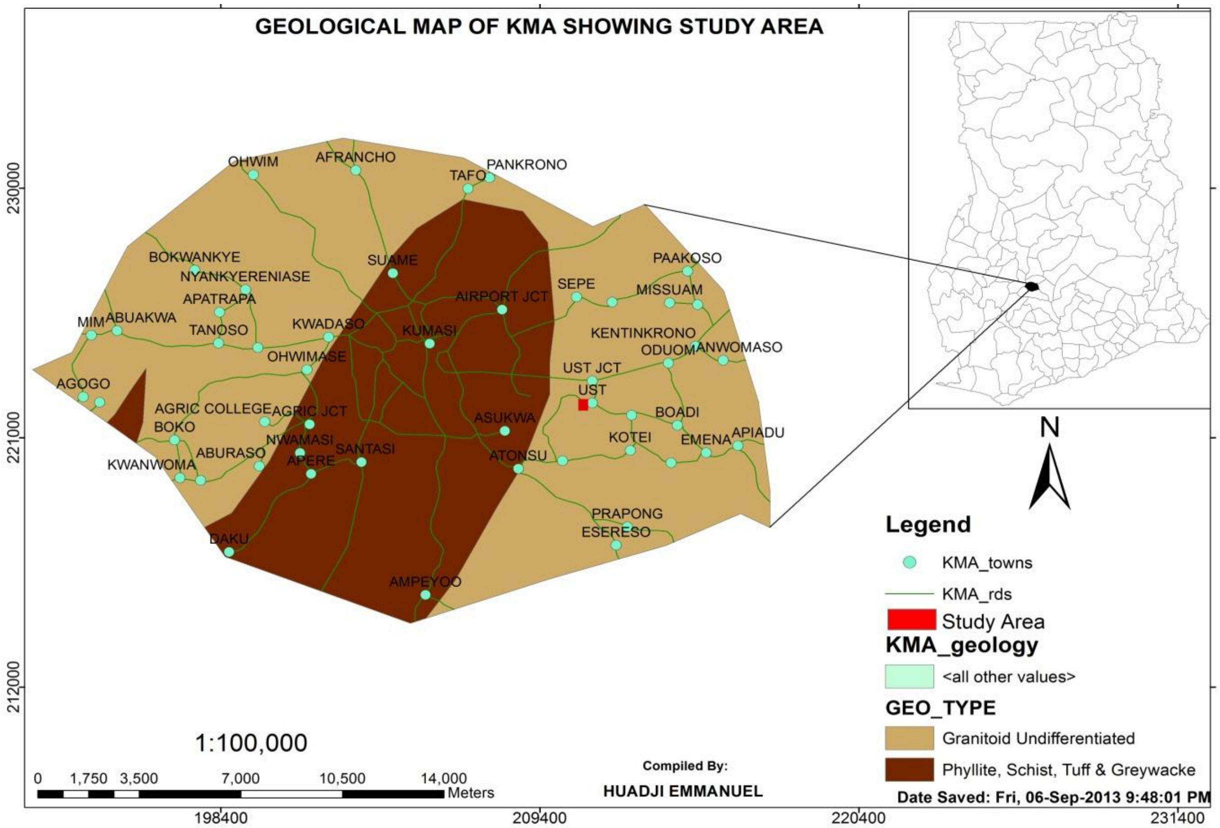

Fig.1: Geological map of Kumasi Metropolis showing the study area in red (Geological Survey Department,Ghana, 2009)

DATA ACQUISITION AND PROCESSING

The multi-electrode ABEM Lund Resistivity Imaging System was used to carry out the electrical resistivity measurements on 8 profiles (Fig.2). The system operates automatically once the geometrical parameters (array type, electrode separation and minimum current) are set. The Wenner array with 41 electrodes connected to four 40 m long multi-core cables was used to collect the data.This configuration (Wenner array) is able to give better resolution of the subsurface resistivity distribution(Hamzah et al., 2006).The Continuous Vertical Electrical Sounding (CVES) was used to acquire the data on the field. The equipment used for the survey includes the ABEM terrameter SAS 4000, power supply (car battery), electrodes and multi-conductor cables. For this survey, the electrode separations were as shown in Table 1.

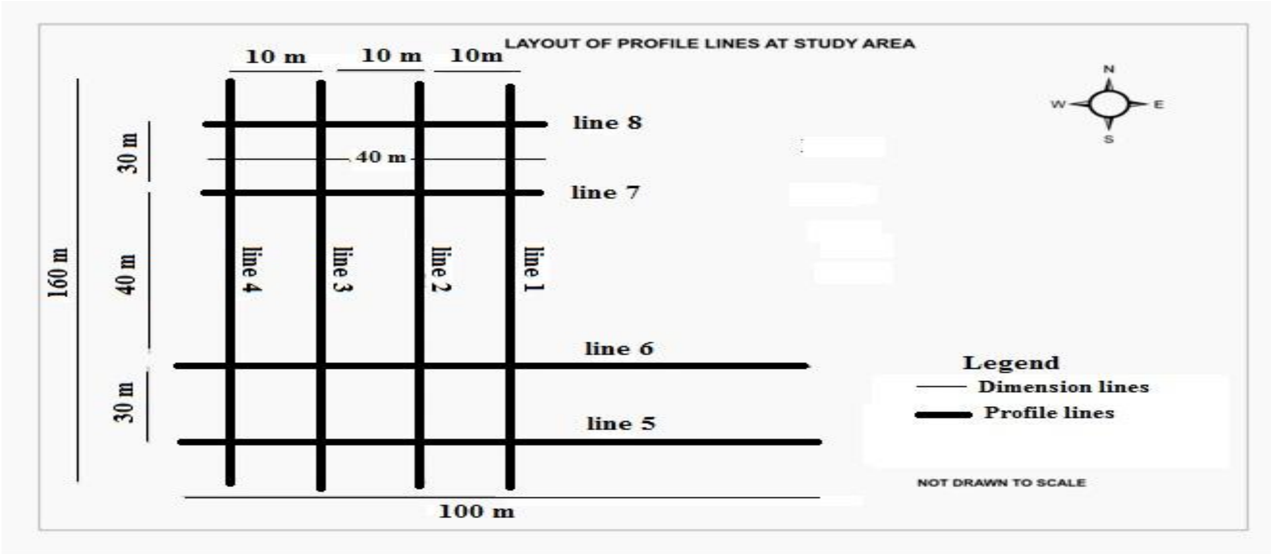

Figure 2 Profile layout

Table 1: Table showing electrode spacing and length of profile lines

Lines	**Electrode separation /m**	**Length of line /m**
1,2,3 and 4	4	160
5 and 6	2.5	100
7 and 8	1	40

The electrode separation was chosen in other to get a better resolution of the near surface structures so as to properly interpret the resistivity tomograph and advice the authorities on where to put up structures in future.

The resistivity measurements was taken along the profile lines as shown in Fig. 2, with 4 automatically selected electrodes according to the configuration protocols set on the ABEM terrameter. Each electrode position is uniquely identified at a takeout on the cable. This helps in identifying the required current and potential pairs during the measurement at various data levels as **'a'**(electrode separation) is increased by a factor.

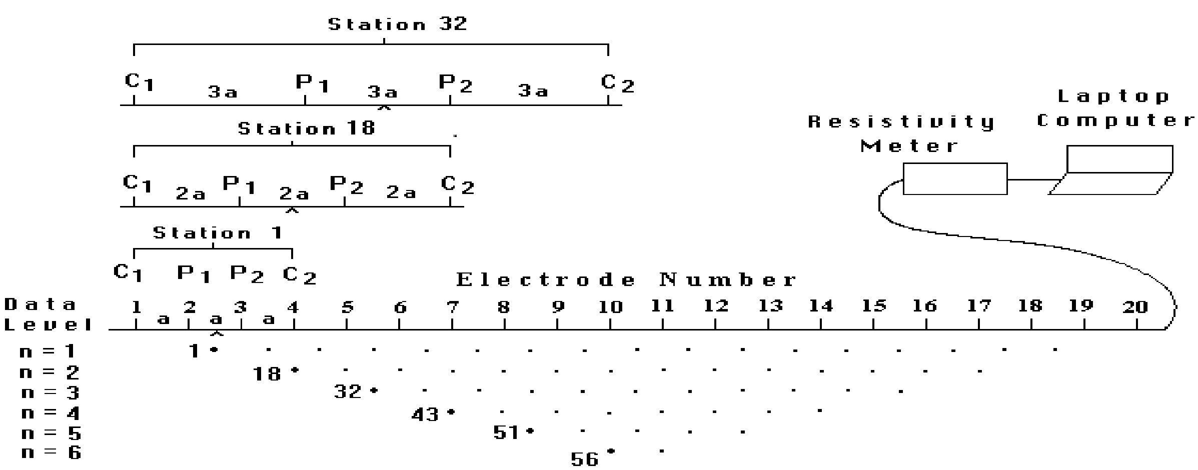

Fig. 3: Sketch of the electrodes for 2D geoelectrical resistivity survey and the sequence of measurement for building the pseudosection (Loke, 2011)

As a precaution for the acquisition of reliable and accurate resistivity data, the cables are checked for cuts and on every line, the electrodes are checked for contact resistance. Where the ground contact resistance is bad, salt water is sprinkled around the electrodes and lowered deeply into the ground.

The processing of the electrical resistivity measurements was done using the Res2DINV software, after the data was topographically corrected. The data was first read in and bad datum point (which usually shows as spikes) were then exterminated to enhance the data. Inversion was then carried out to estimate the true resistivity structure of the subsurface. The L_1 norm (robust inversion technique) of the least square inversion technique was used to allow the modeling of relatively sharp changes in resistivity because the inversion algorithm aims to minimize the absolute value of data misfit (Loke et al. 2003).

Model refinement option of the “Inversion” menu was used to take care of the large resistivity variations near the ground surface. With this option, the program automatically reduces the unit electrode spacing it uses by half of that given in the data. The user defined logarithmic contour intervals option was used for easier comparison of the images.

RESULTS AND DISCUSSION

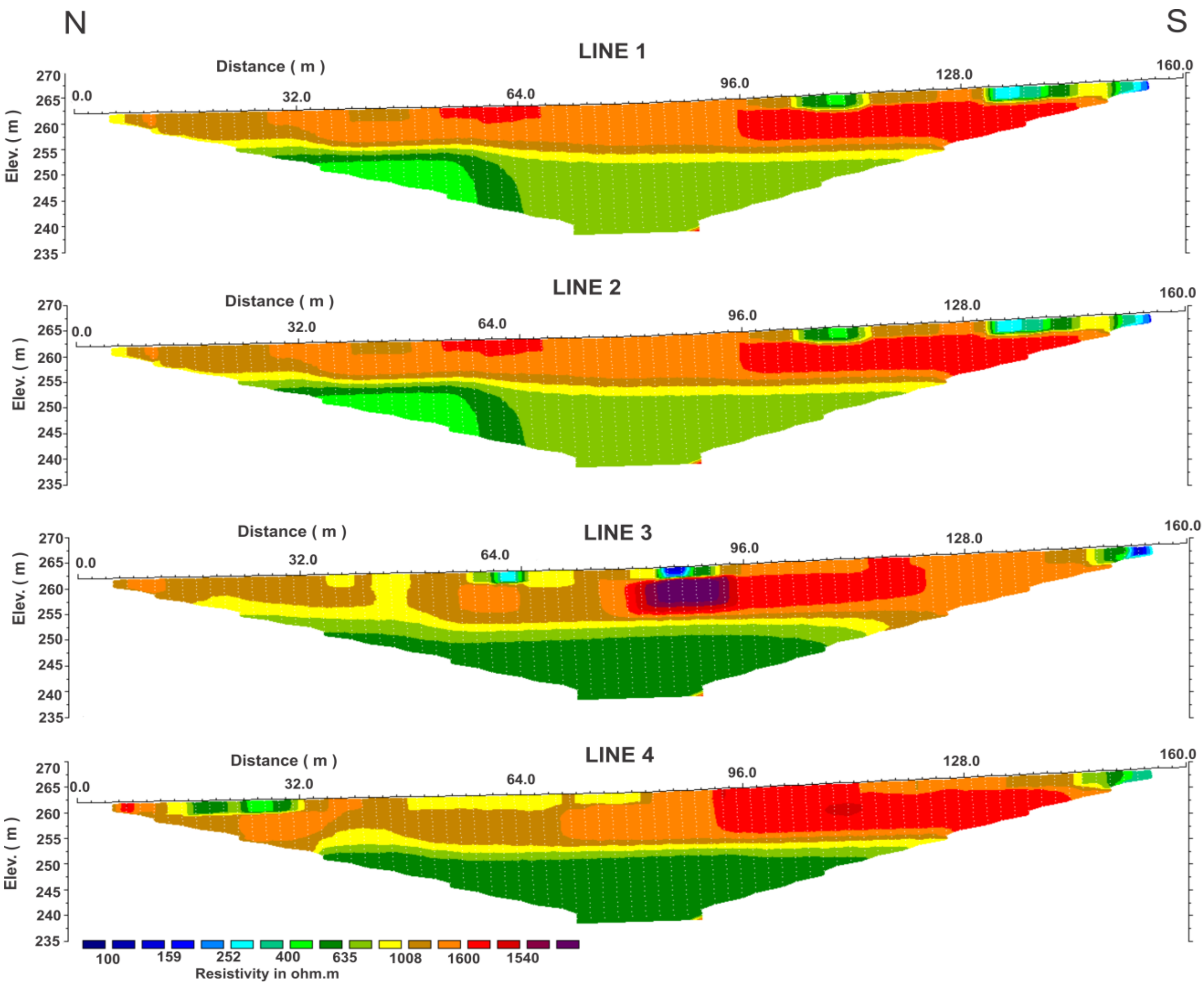

Fig. 4: Models for lines running North-South

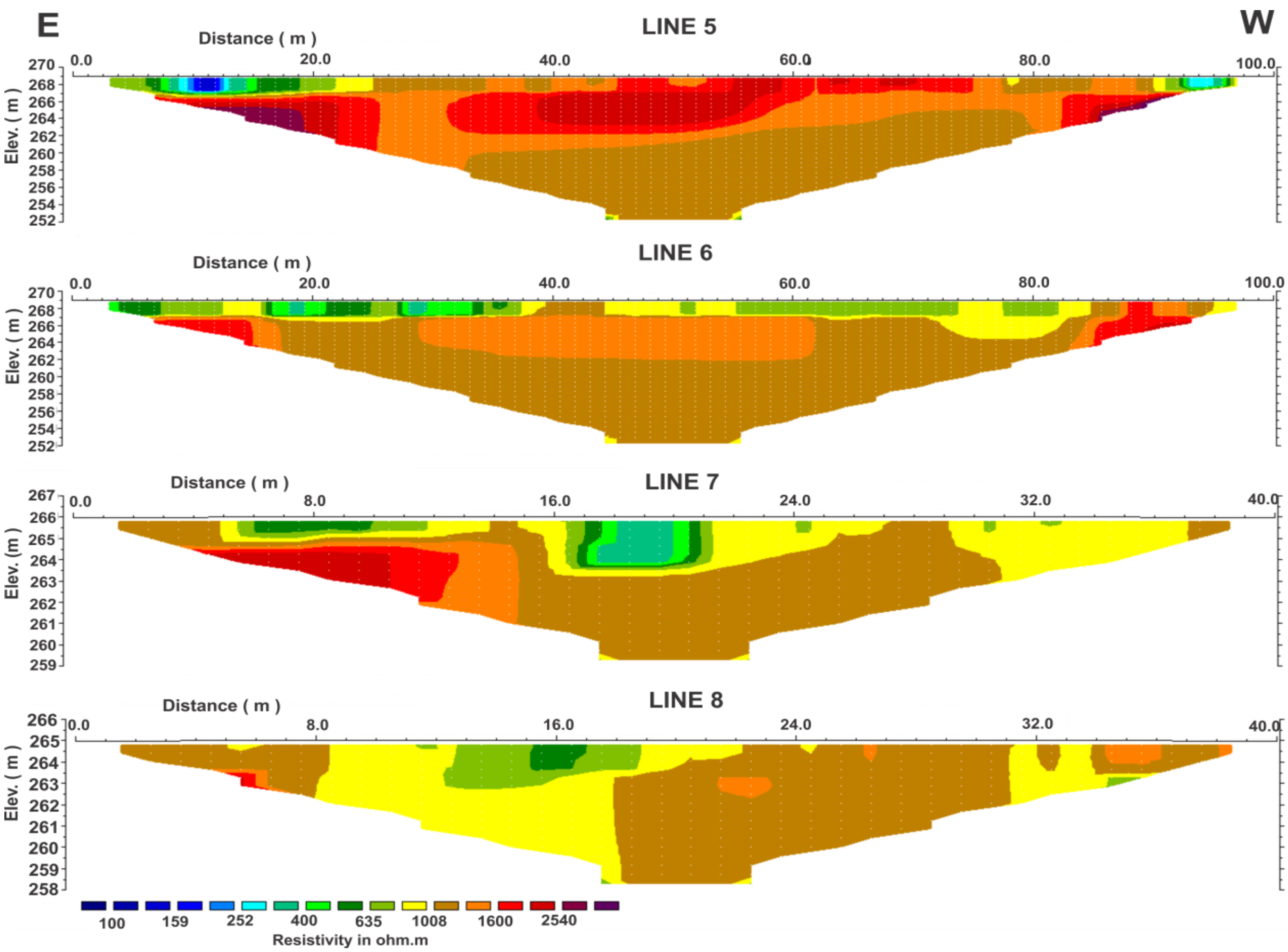

Fig. 5: Models for lines running East-West

On lines 1and 2, apparent resistivity generally decreases with depth. High resistive materials are found at the top with patches of low resistivity materials on the surface to an elevation of about 260 m. The high resistive materials in the subsurface can be found to depths of about 10 m. A slab-like material of a very high resistivity situated beneath the 96 m and 128 m marks occurs at an elevation of about 262 m to 255 m above sea level.
Line 3 however, shows the high resistive material exposed at the surface at depths of about 0.3 m at the 92 m mark through to the 140 m mark in the south. The most resistive material on the site is recorded on this line at 88 m and found at depths of 3 m to 7 m. However, low resistivity is recorded directly above this material. The fourth line records high resistivity at the center of the profile line and stretches to the end of the line to depths of about 10 m.

The profile lines 5, 6, 7 and 8 in Fig. 5, run from the East to the West at varied depths due to the profile lengths. Line 5 probes to a maximum depth of 15.5 m. It therefore does not provide any information on the low resistivity layers encountered in the first four lines. However, the high resistive materials are exposed at the surface on this line. The most resistive material in the area is found at the 15 m mark.
At about 30 m from line 5 in the north direction, profile line 6 shows relatively low resistivity materials on the surface at an average depth of about 3 m with the high resistive material directly below it. This line also provides information to depths of about 15.5 m.
The seventh line which is 40 m from the sixth shows similar resistivity distribution as line 6. Low resistivity materials encountered at the center and the depth of probe is about 6.7 m from the surface.The final line, line 8 at the north shows low resistivity distribution in the region.

In general, the resistivity values of the subsurface materials at the site are in the range of resistivity of granitic materials. The upper layer is made of highly resistive materials to a depth of about 10 m and it can be infer to be disseminated granitic material.From careful observation, the yellowish feature that stretches from north to south at a depth of approximately 10 m is likely to be the water table. Beneath this feature is fresh granitic material. The top part of the fresh granite just below the water table is saturated with water giving it a low resistivity as compared to the whole fresh granite.

The models that stretch from east to west could not provide information on the water table and the fresh granite owing to their short lengths,in other words the depth of investigation of these profiles were shallow (<16m). Resistivity values of materials from these models correspond with that of the upper part of the models that runs from north to south which are in the range of the resistivity of granites.
It is very evident, especially, from the profiles at the south that the area is made up of high resistive materials and towards the north, resistivity decreases.

CONCLUSION

The following conclusions can be drawn from this study conducted at the site in front of the new college of Art Building, KNUST.

- The relatively low resistivity data recorded below 10m depths at these areas were generally due to a highly conductive material likely water saturated granitic rocks**.**
- The highly resistive materials area could be the undifferentiated granitoids (resistivity of 100Ωm to 1×10^6Ωm).
- Possible weathering of the granitoid could have resulted in formation of lateritic soils especially at the south of the site forming a hardpan in which the soil grains become cemented by iron-oxides.
- The cemented soils contain few pores hence are resistive to the flow of current and can be said to be the most compacted areas on the site.
- At an elevation of 255 m can be inferred to be a water table and it runs across the four lines (1, 2, 3, and 4).
- The southern section of the site can be said to mechanical stable to hold a heavy surface structure compared to the north and is highly recommended for construction.

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