

An application of the 2–D D.C. Resistivity method in Building Site Investigation – a case study: Southsouth Nigeria.

K.O. Ozegin[1*], A.O. Oseghale[2], Audu A.L[2], E.J. Ofotokun [3]

1. Department of Physics, Ambrose Alli University, Ekpoma, Edo State, Nigeria.
2. Department of Applied Geophysics, Federal University of Technology, Akure, Ondo State.
3. Department of Science Laboratory Technology, Delta State Polytechnic, Oghara, Delta State.

* E-mail of the corresponding author: *ozeginkess@yahoo.com*

Abstract
A 2-D D.C resistivity method was employed in the investigation of a building site in south- south Nigeria using the double-dipole technique. The aim was to establish the existence of a subsurface geologic structure in the study area. Two profiles were occupied and the resulting pseudosections delineated four distinct geologic layers. The first layer indicates the presence of clay; the second layer indicates the presence of highly weathered rock materials, the third layer indicate the presence of partly weathered/ fractured basement materials and the fourth layer constitute the fresh bedrock material. The presence of a geologic structure which is most probably a fracture was established and it was concluded to be a potential source of building failure in the site especially if the building is constructed across the geologic structure.
Key words: Resistivity, Geologic structure, Building site, Failure.

1. Introduction

Geophysical investigation of the earth's subsurface at sites designated for civil engineering works should be of paramount interest because, near-surface structures – cavities, sink holes, voids, fractures, faults among others – and or inhomogeneities in the foundation geomaterials are major origins of hazards in civil engineering structures. 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 develpoment of cracks in the building which may ultimately lead to its failure and collapse (Garg 2007). Hence building foundations should be examined to acertain their load-bearing capacity, their uniform load transmitting capacity to the subsoil zone and then laying of the building foundations on stable, hard bedrock or hard soil to control shrinkage of of the subsoil zone. Preliminary studies are capable of delineating anomalous structures such as unconsolidated soil formations with varying resistivities and expansivities, naturally occuring underground channels which may expedite weathering and surface deformation (Ozegin et al. 2011a). Geoelectric methods are efficient, cost-effective and usaually employed in a broad range of geotechnical applications from building site investigations, land reclamation, dam site investigation and bridge construction; with the aim of investigating subsurface geologic structures, characterisation of the existing subsurface rocks and evaluating the depth to competent bedrocks that are stable and suitable for the development of civil engineering foundations since they combine high speed and appreciable accuracy in providing subsurface information over large areas (Kurtenacker 1934; More 1952; Olorunfemi and Mesida 1987; Oladapo 1987; Adepelumi and Olorunfemi 2000; Soupios et al. 2006). The electrical resistivity of a formation is directly related to the nature, quantity, quality and distribution of the formation water (Adewumi and Olorunfemi 2005). The objectives of this study are to delineate subsurface geoeletric sequence/ materials and establish the existence of potentially hazardous geologic structure(s). The sharp contrast in geoelectric characteristics of subsurface geologic materials displayed by the 2-D resistivity (double–dipole) technique, makes it an ideal tool for near-surface geophysical investigations, thus necessitating its use in this study.

Theory

In this technique, the potential electrodes are closely separated and at varying distances from the current electrodes which are also closely separated (Figure 1).

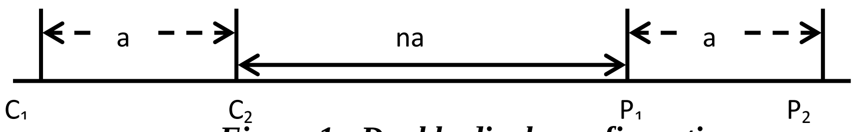


Figure 1.: Double-dipole configuration.

$$\rho_a = \pi R a n \left(n+1\right)\left(n+2\right)$$

Where

ρ_a the apparent resistivity (ohm – m)

R is the resistance (ohms)

a is the potential – potential and current – current electrode spacing (m)

n is the number of increment (n = 1, 2, 3, ...) in metres.

The advantage of this technique is the reduction of inductive coupling between potential and current electrodes (Telford et. al., 1990). The current- current and potential-potential electrode pairs have a common mid-point. The separation between the pairs is usually varied depending on the aim of the investigation.

2. Study Area

2.1 Location and Accessibility

The study area is located on $7^{0}17^{I}0^{II}$ North and $6^{0}6^{I}0^{II}$ East, on the south flank of Lampese, South- south Nigeria. The climate is predominantly the rainforest characterised by two seasons-the wet season (between April-October) and the dry season (between October-March); the mean annual rainfall is approximately 1250mm with a temperature range of 18^{0}C-33^{0}C. The topography is generally undulating with the highlands of granitic origin located East of the area. The area is accessible by roads like the Auchi-Abuja high way. The location of the study area can be seen from figure 2.

2.2 Geological Setting

Regionally, the area is underlain by rocks of the Precambrian Basement Complex (Figure 2). According to Odeyemi (1976) “Three major groups of rocks underlie the Basement Complex in this area with the sequence as follows:

III. Syn-to-late tectonic porphyritic biotite and biotite-hornblende, grandiorites and adamelites, charnokites and gabbros; unmetamorphorsed dolerite, pegmatite, aplite and cyenite dykes.

II. Low-grade metasediments (Schists, Calc-silicate gneisses, marbles, polymicts, metaconglomerates and quarzites).

I. Migmatites, biotites and biotite-hornblende and gneisses".

Locally, the study area consists of quartzite and conglomerates and igneous intrusions with the quartzites occurring around and overlying the other rock types. The vein quartz occurs as igneous intrusions in almost all outcrops and emplaced along fractures and veins through the conglomerates.

3. Materials and Methods

The 2-D D.C (2-Dimensional Direct Current) electrical resistivity investigations were executed along two profiles spaced 100m apart as a combined sounding-profiling survey using the double-dipole technique. The Ohmega resistance meter was employed in the data acquisition process. The lengths of the profiles were 200m. The data set were inverted for true subsurface resistivity using DIPROfWIN version 4.0 inversion software and the resulting estimated models presented and interpreted accordingly.

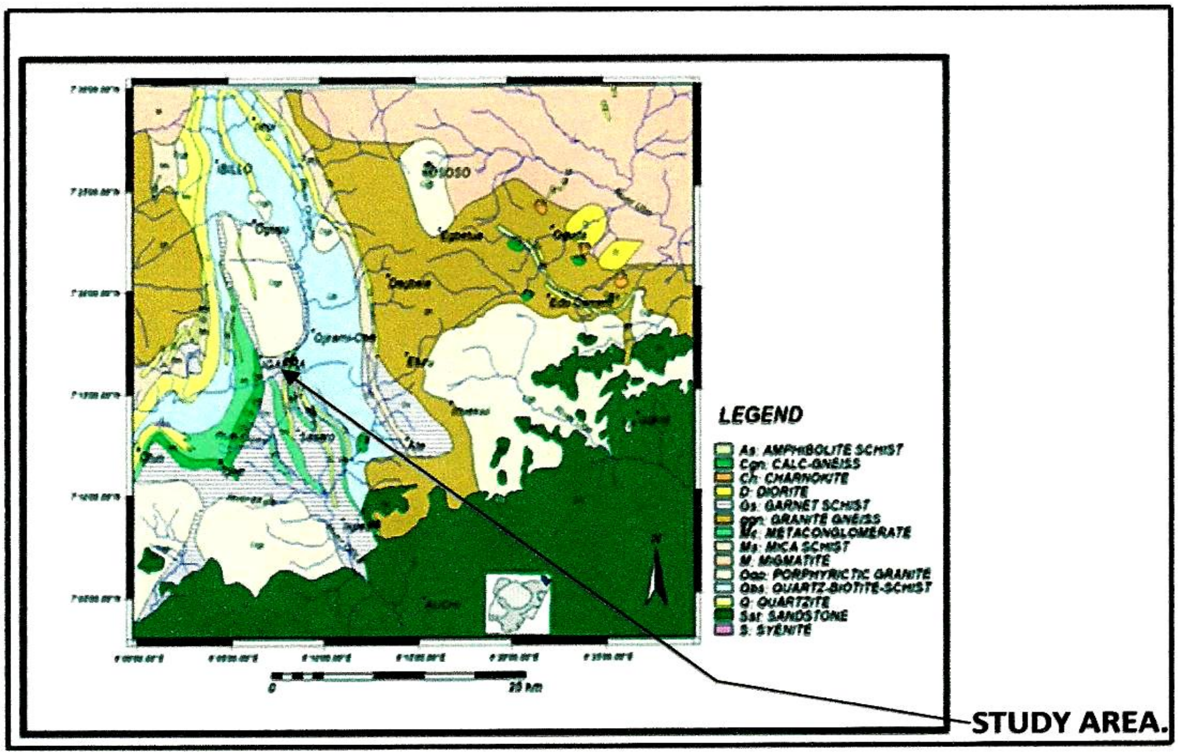
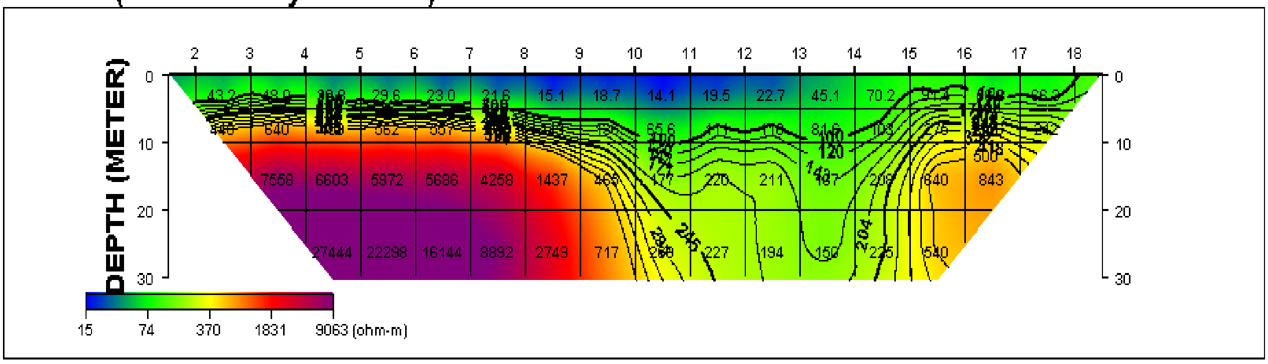


Figure 2: The geological map of Lampese and its surroundings Showing the study area.

4. Results and Discussion

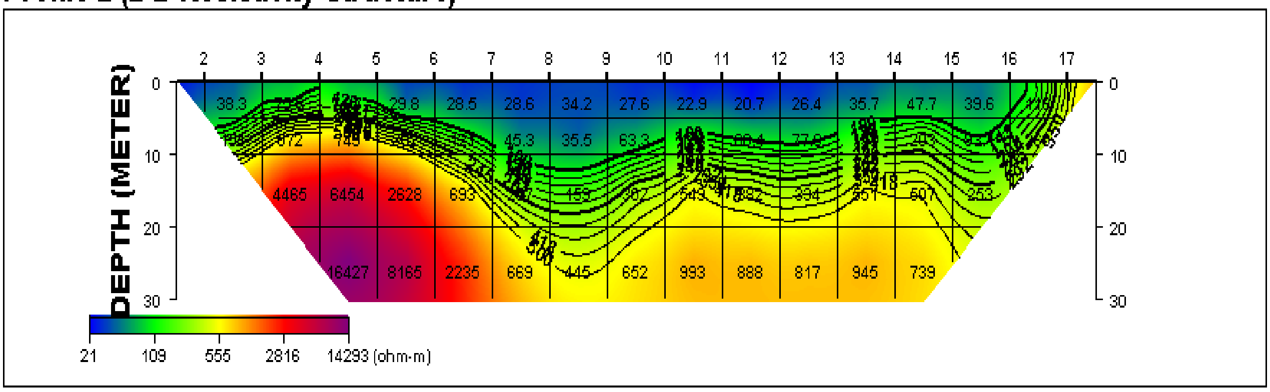
Profile 1 shows four distinct geologic layers. The first layer is a very low resistivity layer of less than 38.7 ohm-m as can be observed at depths between 0 – 3 m on the south and depths of between 0 – 17 m (between 27 – 80 m) across the traverse. This layer indicates the presence of high water retaining material (e.g. clay) due to its very low resistivity value range. The second layer which is a relatively more resistive having resistivity values in the range of 38.7 – 318 ohm-m, can be observed across the section. The depth of this layer ranges between 5 – 10 m to the south, 10 – 20 m at the centre and 5 – 17 m to the north. This area indicates the presence of clayey sand/ highly weathered rock materials as indicated in Momoh et. al., 2008. The third layer with resistivity values in the range of 318 – 757 ohm-m, stretches across the section. It ranges in depth of between 5 – 10 m in the south and 12 m – infinity (between 47.5 – 75 m) and 20 m – infinity (between 37.5 – 47.5 m). This layer indicates the presence of a weathered/ fractured basement material. However, a medium of very high resistivity values in the range of 962 – 9076 ohm-m can be observed on the southern part of the traverse (between 10 – 35 m) at depths of 7 m – infinity, indicating the presence of a fresh basement rock.

Profile 1 (2-D Resistivity Structure)



(a)

Profile 2 (2-D Resistivity Structure)



(b)

Figure 3(a & b).: 2 – D subsurface Resistivity Images along profiles 1 and 2 in the study site.

Profile 2 also shows four distinct geologic layers. A low resistivity (of less than 32.6 ohm-m) material with depth of 0 – 5 m can be observed between 15 – 65 m along the traverse, indicating the presence of clay/ alluvium. The second layer has resistivity values in the range of 32.6 – 232 ohm-m and can be observed reaching the surface at between 0 – 30 m to the south, and 68 – 90 m to the north of the traverse with depth values in the range of 0 – 7 m in the southern flank and 0 – 10 m on the northern flank. The material can also be seen to be lying between two highly resistive media (between 47.5 – 75 m) with depths in the range of 10 m – infinity. This material indicates the presence of clayey sand/ highly weathered rock materials. The third medium which is the weathered/ fractured medium has resistivity values in the range of 232 – 421 ohm-m .It can be seen between 0 – 60 m from the south and between 72 m – infinity to the north, surrounding the highly resistive media (located south and north). The resistive media have resistivity values in the range of 421 – 15870 ohm-m and 435 – 985 ohm-m respectively with depths in the range of 7 m – infinity and 11 m – infinity respectively. The high resistivity media indicates the presence of fresh basement in the study location (Momoh et. al., 2008). Garg (2007) indicates that geological discontinuities and structural dislocations of the underground strata are some of the geological causes of differential settlement in buildings. Such geologic discontinuities can be clearly observed across the study area most especially beneath profile 1 (Figure 3a) and the hard bedrock can be observed to be lying below the weathered zone.

5. Conclusion

From the results discussed above, (Figure 3(a & b)), the competent bedrock can be seen at depths in the range of 5m – infinity across the site. A weak zone that indicates the presence of a geologic structure can be observed between 35 – 55 m (Profile 1) and between 50 – 75 m (Profile 2) which is most probably a fracture as can be observed from its trend in an E – W direction. The location of this feature correspond to the depression and linear feature observed on study area. This geologic structure could become a source of building failure and collapse on the site in the future most especially if the building is constructed across the structure in an S – N orientation. Since the bedrock lies below the weathered zone, piles should be taken up to the sound or competent bedrock for very major and heavy buildings; while raft foundations should be used for shallow foundations in the case of small buildings.

The integration of lithologic logs with surface geoelectric studies of the foundation systems in the area would enhance the accuracy of the results. This study is envisaged to constitute background information for more elaborate building development programme in the study area.

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