GEOELECTRIC INVESTIGATION OF A SITE FOR A PROPOSED AIRPORT IN EBONYI STATE, SOUTHEAST NIGERIA.

Okiyi, I.M[1].; Olorunfemi, M.O[1].; Ojo, J.S[2].; Akintorinwa, O.J[2]. and Bayode, S[2].

[1]Dept. of Geology, Obafemi Awolowo University, Ile-Ife. Osun State
[2]Dept. of Applied Geophysics, Federal University of Technology, Akure. Ondo State.
(Corresponding Author: millijey@yahoo.com)
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ABSTRACT

A geoelectric investigation, involving 1-D Vertical Electrical Sounding (VES) with the Schlumberger array and 2-D Electrical Imaging with the dipole-dipole array, was carried out at a site proposed for an airport in Ebonyi State. This was with a view to generating near and subsurface images required for the assessment of the suitability of the site for civil engineering construction works. Fifty six (56) VES stations were occupied along eight (8) traverses while the dipole-dipole profiling was carried out along segments of three of the traverses. The VES curves were quantitatively interpreted and the results were used for the generation of geoelectric sections and isopach map of the lateritic layer. Four subsurface layers were delineated. These include the topsoil (lateritic in most places), lateritic shale, shale/clay and siltstone. The topsoil resistivity values varied from 24-5898 Ωm while the thicknesses ranged from 0.7 - 4.6 m. The lateritic shale second layer resistivities and thicknesses were 101-473 Ωm and 1.6 - 8.3 m respectively. The clay/shale third layer showed thicknesses and resistivity values of 3.6 – 108.3 m and 1 – 98 Ωm respectively. The fourth layer was siltstone with resistivity values ranging from 53 -3170 Ωm. The 2-D resistivity structures delineated two subsurface layers: a merged topsoil/lateritic shale top layer and the underlying clay/shale layer. No subsurface geologic structure was delineated. The high resistivity lateritic topsoil/lateritic shale and the basal siltstone constituted the two competent layers while the low resistivity shale/clay, the incompetent horizon. The upper competent lateritic layer could host light-medium weight civil engineering structures while heavy structures would need to be anchored on friction piles.

Keywords: Geoelectric Investigation, Subsurface Sequence, Subsoil Competence, Structure Foundation.

INTRODUCTION

Geophysical methods are applied in civil engineering construction related projects ranging from pre-construction feasibility studies to post construction integrity assessment (Klimis *et al*., 1999, Savvaidis *et al*., 1999, Luna and Jadi, 2000, Venkateswara *et al*., 2004, Othman, 2005 and Soupios *et al.,* 2005, 2006, 2007). Geophysical methods are used for the delineation of subsurface sequence, identification of geological structures and determination of physical parameters of rock formations. These information enhance rapid characterization of subsurface formations, identification of competent subsurface layers, determination of thickness and depth required for the design of civil engineering foundation.

Virtually all civil engineering structures (e.g roads, dams, runways, bridges e.t.c) are sited on earth materials (soils, regolith or rocks). Investigating the subsurface at a proposed site to ascertain fitness of the host earth materials is important prior to the design of such structures (Olorunfemi *et al*., 2004). Geotechnical and civil engineering structure failure could result from the nature of the subsoil, undetected near-surface/subsurface geological structures, features induced by anthropogenic activities or inhomogeneities in soils and geomaterials constituting the foundation (Olorunfemi *et al*., 2000a; Olorunfemi *et al*., 2000b, Oladapo *et al*., 2008; Akintorinwa *et al*., 2011 and Fatoba, 2012). Such anomalous features are amenable to geophysical delineation (Olorunfemi, 2008).

An airport is proposed for Nwezenyi/Amachi area of Ebonyi State, Nigeria. Such facility normally involves civil engineering foundation works that will require near and subsurface information. The pre-construction feasibility study, involving a geoelectrical survey of the proposed site, is reported in this paper.

Description of the Project Environment

The study area is situated in Abakaliki Local Government Area of Ebonyi State (Fig.1). The area is geographically located between Northings

695500 mN and 701500 mN and Eastings 418500 mE and 423500 mE, or between Latitudes 6° 17' 9" N and 6°21' 41.4" N and Longitudes 8°15' 48" E and 8° 17' 58.2" E. It has an areal extent of 26.40 km^2 and is accessible through Iboko-Ikwo road and Abakiliki-Cross River highway. The site is underlain by the shale formation of the ASU River Group (Fig. 2). The calcareous shale is dark grey in color but weathers into brownish material in the greater part of the formation. Although the ASU River Group is composed of predominantly shales, localized development of sandstone, siltstone, mudstone and limestone facies are common (Ofoegbu and Amajor, 1987) as well as extrusives and intrusives (Reyment, 1965; Tijani *et al.*, 1996). Small scale ironstone occurs interbedded within shale/clay as a result of oxidation which exists as surface deposits of laterites.

The study area is relatively flat with terrain elevation varying between 65 m and 75 m above mean sea level (Fig.1). Two main seasons exist in Abakaliki area: the dry season which spans from November to March and the rainy season which begins in April and ends in October with a hiatus in rainfall in the month of August commonly referred to as the "August break".

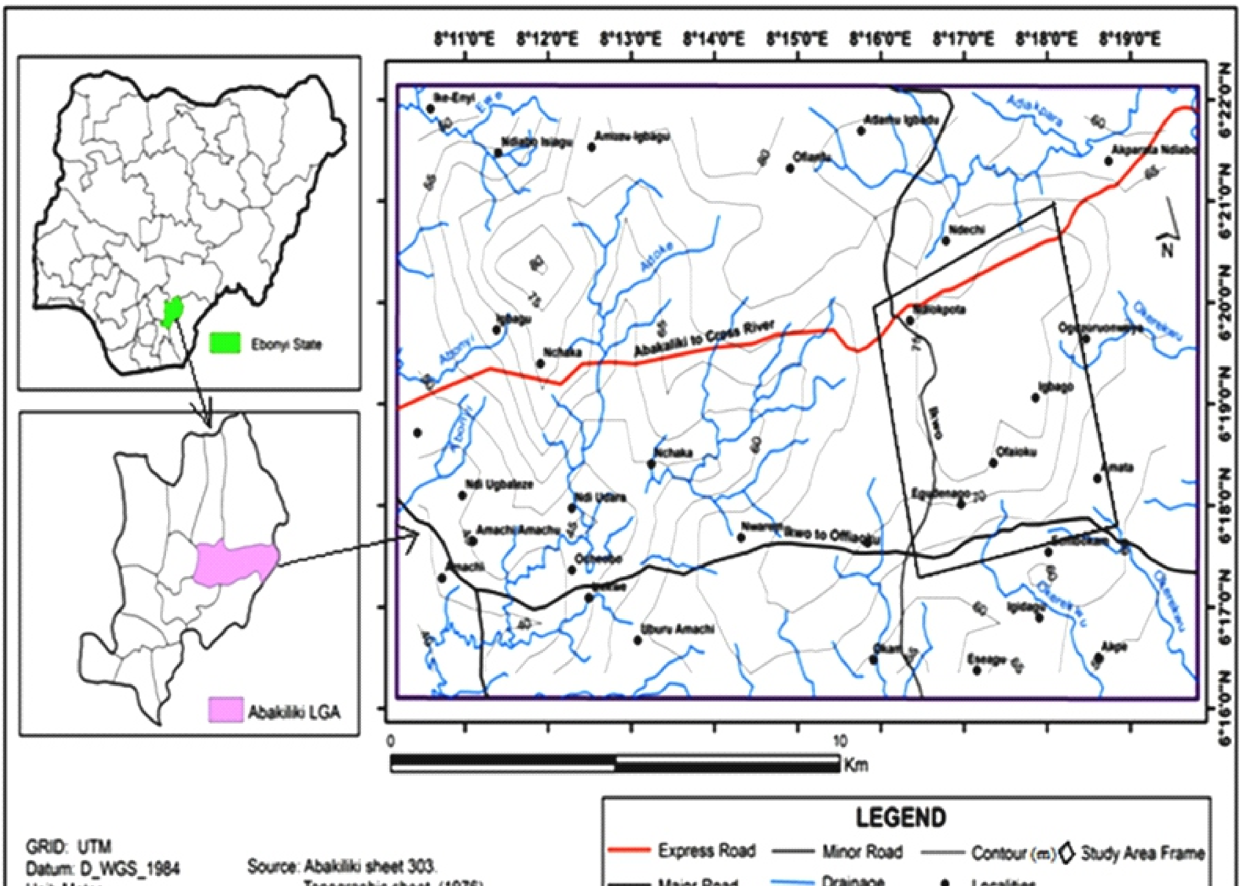

Figure 1: Topographic Map of the Study Area (Extracted from Abakiliki Sheet 303, Topographic Sheet, 1976)

Temperature in the dry season ranges from 20°C to 38°C,with generally lower evapotranspiration. Average annual rainfall varies from 1,500 to 1,650 mm. These climatic conditions are responsible for the development of thick lateritic soils in the Abakaliki area and its environs (Ezeh and Anike, 2009. The study area is mainly drained by numerous tributaries emanating from the Abonyi River (located outside the study area). The tributaries include rivers Okerekwu and Adiakpara. The drainage pattern is dendritic.

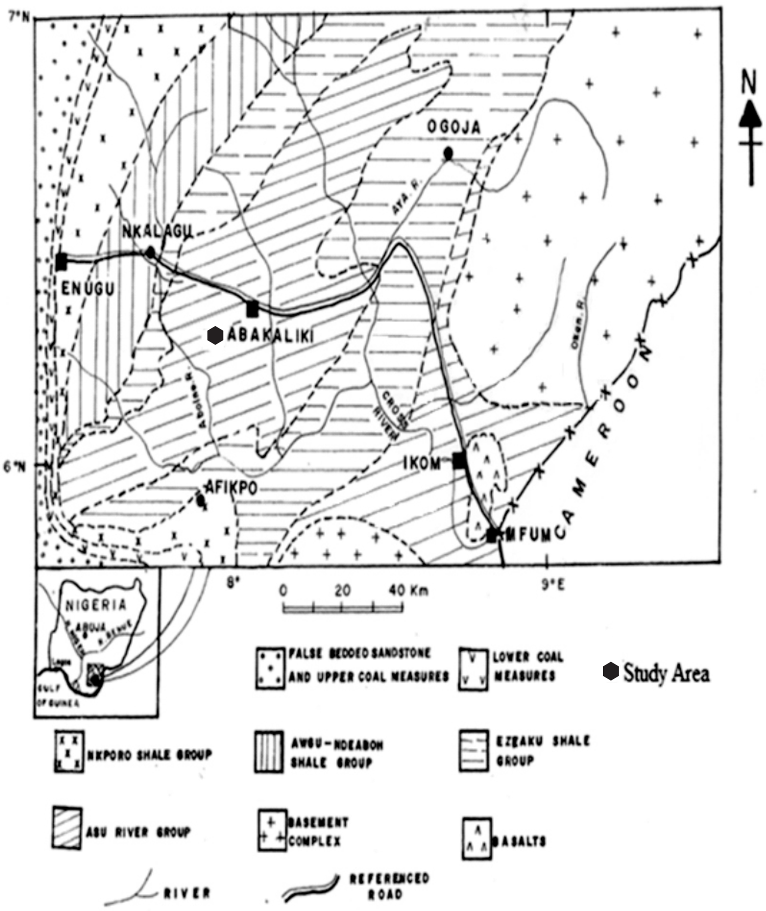

Fig. 2: Generalized Geological Map of the Project Area
(Adapted from Geological Map of Nigeria Published by G.S.D., 1974)

METHOD OF STUDY

Eight (8) parallel traverses trending approximately in the WSW-ENE direction were established in the study area (Fig.3). The traverses varied in length from 2.75 – 3.05 km. Fifty six (56) Vertical Electrical Sounding (VES) stations were occupied along these traverses using the Schlumberger electrode array. The distance between the VES points ranged between 325 m and 625 m while the electrode spacing (AB/2) was varried between 1 to 125 m. The PASI Digital Resistivity Meter was used for the geophysical data acquisition while the Global Positioning System (GPS) was used to record the geographic coordinates of the VES stations. The quantitative interpretation of the VES curves involved partial curve matching and computer assisted 1-D forward modelling with the WinRESIST software (Vander Velper, 2004).

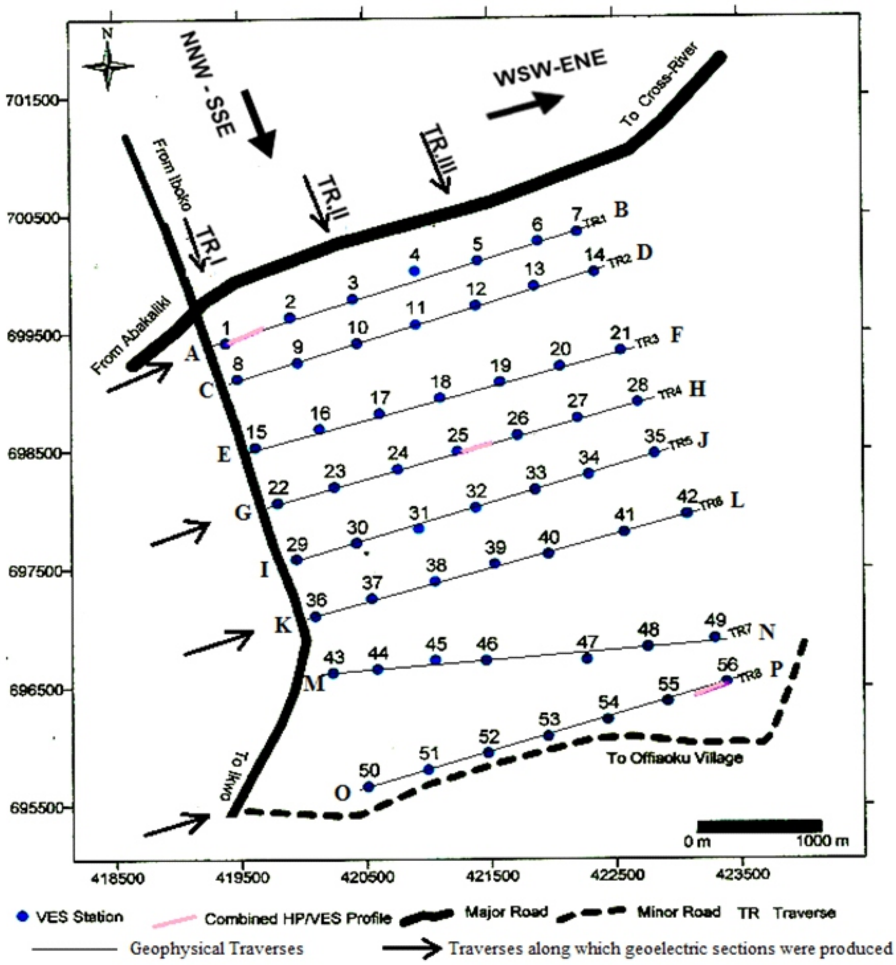

Figure 3: Layout of the Geophysical Traverses and Vertical Electrical Sounding (VES) Points and 2-D Imaging Traverses.

The VES interpretation results were used to generate geoelectric sections. Figure 4 shows the typical VES curves and the interpretation models. In the 2-D Imaging technique, the Dipole Dipole array was employed. The Dipole Dipole profiling was carried out along segments of three traverses (Fig.3). The dipole length was 10 m while the expansion factor, n, was varied from 1 to 5. The quantitative interpretation of the Dipole Dipole data involved 2-D inversion of the apparent resistivity data using the Dipro for Windows (2001) software. The number of layers obtained from the VES interpretation was used to constrain the 2-D inversion.

RESULTS AND DISCUSSION

The observed VES type curves include the H, Q, HA, HK, QH, QQ, HKH, HKQ, HQQ, QHA, QHK, QQH, HKQH, QHKH, and QQHK types. The QH type curve predominates with 34% of occurrence followed by the QQH type with 14% occurrence.

Figures 5 and 6 show the typical geoelectric section for the study area. The geoelectric sections identify four subsurface layers which include the lateritic topsoil (with outcropping shale/clay in few places) with layer resistivity values of 24-5898 ohm-m and thicknesses of 0.7-4.6 m; lateritic shale with layer resistivities of 101-473 ohm-m and thicknesses of 1.6-8.3 m; shale/clay layer with layer resistivity values of 1-98 ohm-m and thicknesses of 3.6-108.3 m and the siltstone bedrock with layer resistivity values of 56-1929 ohm-m and depth to rock head varying from 15-114.0 m.

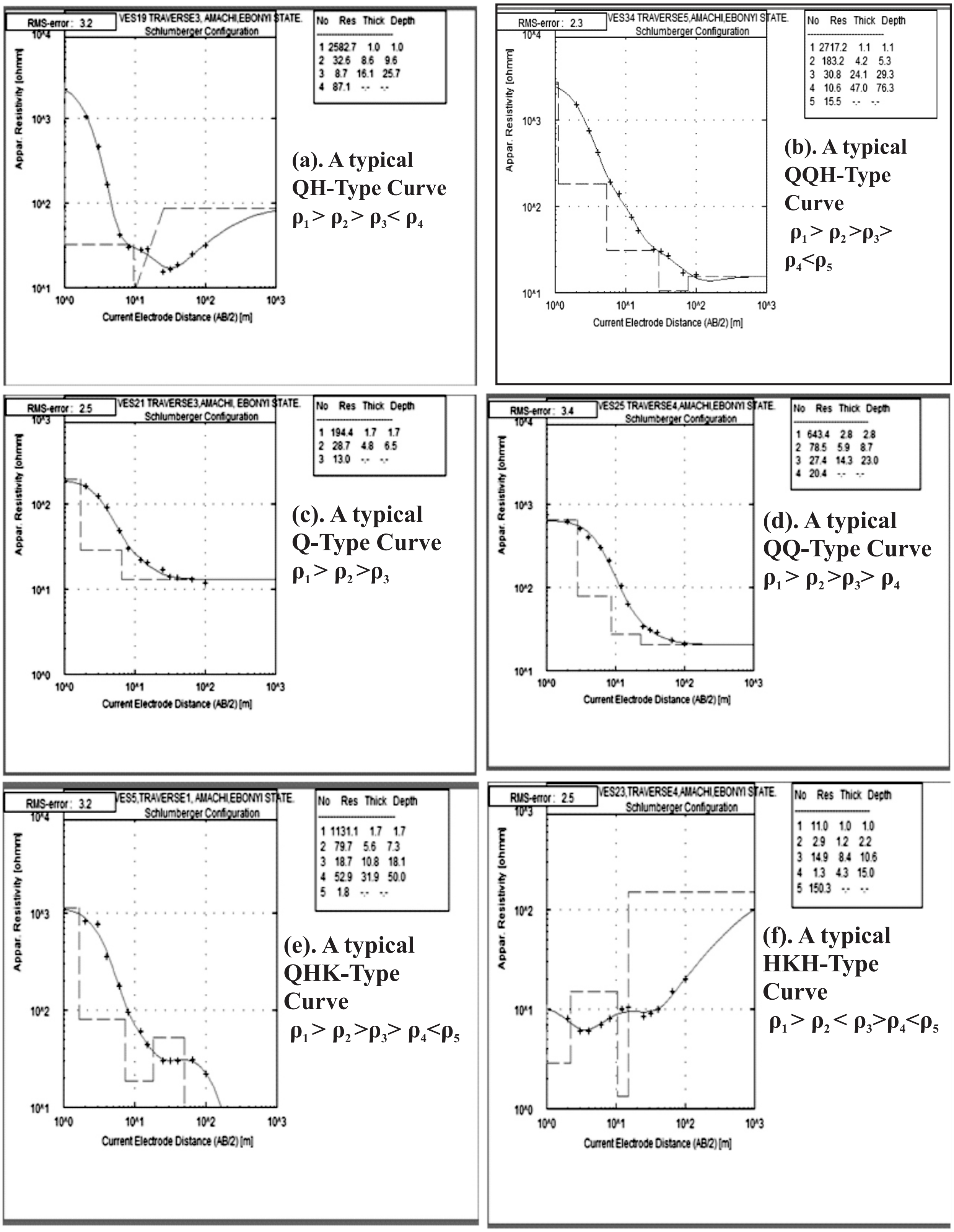

Figure 4: Typical VES Type Curves from the Study Area

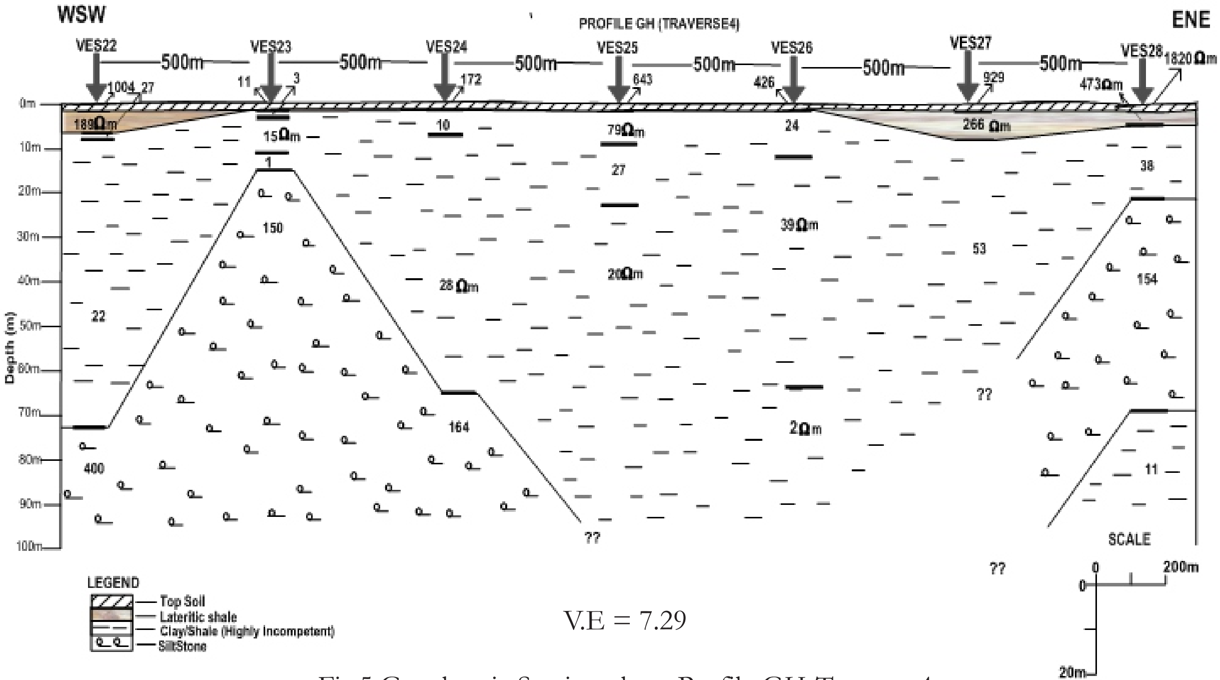

Fig.5:Geoelectric Section along Profile GH-Traverse 4

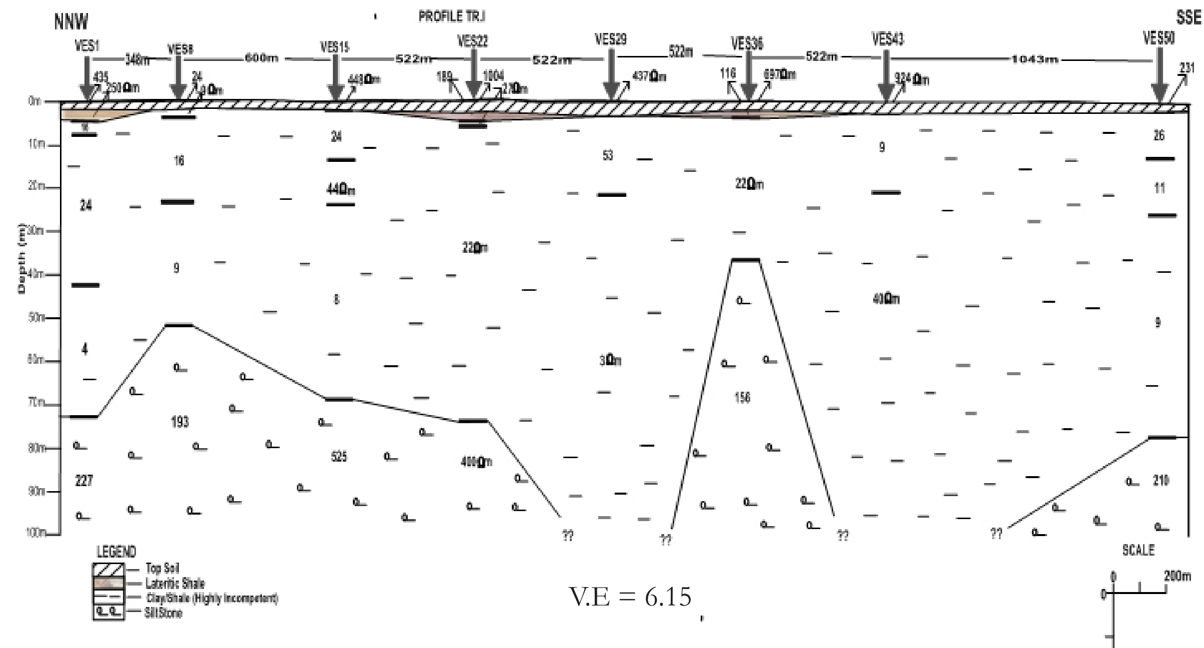

Fig.6: Geoelectric Section along Traverse I

A competent subsoil is usually characterized by low porosity, low fluid content and consequently high resistivity. Such subsoil can be assessed through layer resistivity measurements as the degree of competence is directly related to resistivity (Idornigie *et al.*, 2006; Fadugba and Olorunfemi, 2011; Fatoba, 2012).

Forty-six (46) VES curves (out of fifty six (56) VES curves) constituting about 82% of the investigated points, display initial Q type curve characteristics indicating decreasing layer resistivity and hence subsoil competence (from the upper layer) with depth. About 82% of these curves also display subsequently an H or K type characteristics or commenced with H type curve indicating a relatively high resistivity and hence competent layer at depth. The geoelectric sections developed from the interpretation results of these VES curves (e.g. Figs. 5&6) identify two distinctly relatively high resistivity (up to 5898 Ωm) horizons composed of lateritic topsoil/lateritic shale (layers 1 and 2) and the basal siltstone (layer 4). In between these presumably competent layers is the very low resistivity (1 to 98 Ωm) and highly incompetent clay/shale. The geoelectric sections therefore display two competent horizons, identified as upper and lower competent subsoils. The upper competent layer comprises the lateritic topsoil and the underlying lateritic shale second layer. This upper competent layer is within the reach of road and runway pavement and light to medium weight civil engineering foundation structures. The lower competent siltstone has its rock head at depths varying from 15 to 114 m. This horizon is not within the reach of shallow foundation and in most places very deep for pile foundation. This study therefore, focuses on the upper competent layer which is hereby referred to as the lateritic layer.

The isopach map of the lateritic layer is displayed in Figure 7. The map shows that the lateritic layer thickness ranges from 0.7 – 9.1. The highest thicknesses (> 4 m) were observed on the eastern flank, extreme north and north central part and extreme western flank. Most parts (up to 80%) of the survey area has lateritic topsoil/lateritic shale thicknesses of greater than 2.0 m. Fatoba (2012) established that road pavement founded on lateritic soil thickness of up to 2.0 m is not likely to fail.

The 2-D Resistivity Structures imaged the subsurface stratigraphic sequence to a depth of about 30 m as typically displayed in Figure 8. The figure shows modelled resistivity values of between 11 and 264 Ωm within the upper 30 m. The resistivity structure identifies two subsurface layers – a merged topsoil/lateritic shale top layer and the underlying clay/shale layer. The merged topsoil/lateritic shale is displayed in purple/reddish brown/yellow colour, with modeled resistivity values in the 70 – 264 Ωm range. The thickness of this topsoil/lateritic shale layer varies from 6-9 m. The underlying low resistivity (11 – 50 Ωm) layer in blue/green colour constitutes the clay/shale layer. The patches of very low resistivity (in blue colour) are diagnostic of plastic clay/shale. The 2-D resistivity structure correlated very well with the VES interpretation model along this traverse (see Fig. 8).

Within the upper 30 m, the 2 –D resistivity structures, like the 2-D geoelectric sections display a subsurface sequence with a decreasing resistivity and by implication, a decreasing competence with depth. The resistivity structures identify the lateritic topsoil/lateritic shale as the most competent layer within and on which civil engineering foundations of roads, runways and buildings can be founded. None of the 2-D resistivity structures show evidence of inclined geological structures such as faults and dykes that could be inimical to civil engineering foundation stability. There are however, indications of pockets of very low resistivity, very incompetent suspected plastic shale/clay that could precipitate structure settlement.

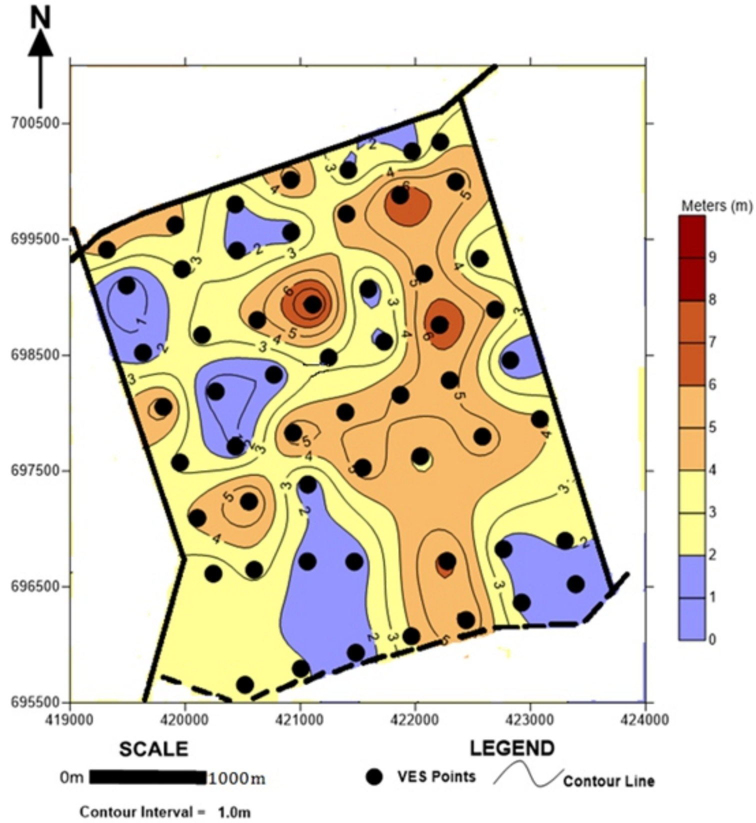

Figure 7: Isopach Map of the Lateritic Layer

Both the geoelectric sections developed from the results of the 1-D VES curves and the 2-D resistivity structures identify relatively high resistivity topsoil and an underlying lateritic shale that are considered competent. The delineated total thickness of both units are respectively 0.7 – 9.1 m and < 1.0 – 10 m from the geoelectric sections and 2-D resistivity structures respectively. The generally high resistivity topsoil/lateritic layer is considered competent and in most places thick enough (> 2.0 m) to host pavement of an airport runway, roads and the foundation of light to medium weight civil engineering structures directly. The unit can provide satisfactory bearing stratum for spread footing for low to medium load while the footings are not placed close to the underlying soft shale stratum.

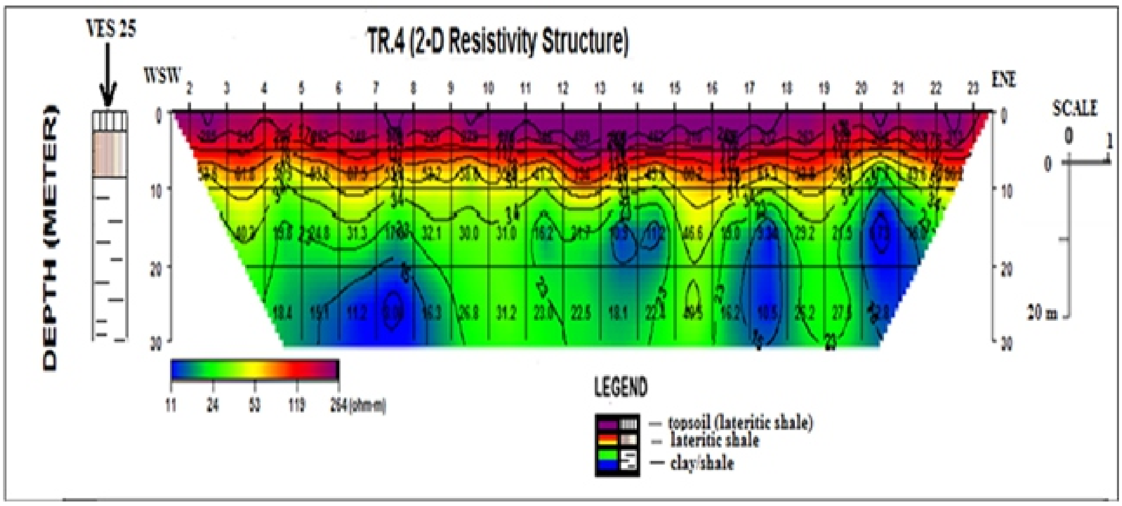

Figure 8: The 2-D Resistivity Structure Beneath a Segment of Traverse (TR.4) with Correlated VES Interpretation Model

However, this upper competent unit is underlain directly by low resistivity incompetent clay/shale which outcrops directly at some locations, as observed from isolated VES stations.

This site may therefore not be able to accommodate excessive overburden cut, as this will place pavement/civil engineering foundation on settlement prone incompetent shale formation. Heavy civil engineering structure foundation may need to be anchored on friction piles, in view of the very thick column (3.6 – 108.3 m) of the incompetent shale layer.

CONCLUSION

Both the geoelectric sections and the 2-D resistivity structures identify relatively high resistivity topsoil and an underlying lateritic shale. The topsoil/lateritic layer, based on high resistivity values, is considered competent and in most places thick enough (> 2.0 m) to host pavement of an airport runway, roads and the foundation of light to medium weight civil engineering structures directly. The unit can provide satisfactory bearing stratum for spread footing for low to medium load while the footings are not placed close to the underlying soft shale stratum. Heavy civil engineering structure foundation may, however, need to be anchored on friction piles in view of the very thick column (3.6 – 108.3 m) of the incompetent shale/clay layer.

An airport can be constructed within the proposed site provided the location and design of its facilities which include the runway, roads and buildings took cognizance of the site geologic and geoelectric characteristics.

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