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# Preliminary geophysical investigation for road construction using integrated methods

## Predhodne geofizikalne raziskave tal pri gradnji cest z uporabo korelacijskih metod

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### Abstract

Integrated geophysical methods have been used to investigate the competency of the subsoil. The geophysical surveys conducted involve very low-frequency electromagnetic (VLF-EM) and electrical resistivity (ER) methods (dipole–dipole). ABEM Wadi and Ohmega resistivity meter were used to acquire VLF-EM and ER data, respectively, along two traverses. Station interval of 5 m was used for the VLF-EM survey, while inter-electrode spacing for dipole–dipole was 10 m; the inter-dipole expansion factor (*n*) ranged from 1 to 5. KHFFILT software was used to generate VLF-EM profiles and pseudosection, while DIPRO software was used for ER. Results from the ER method revealed the pattern of resistivity variations within the study area. The low resistivity values (11–25 Ohm-m) observed at the southern part of the study area could be attributed to changes in clay contents and degree of weathering in the subsurface. The results from the VLF-EM investigation revealed the presence of near-surface linear geologic structures of varying lengths, depths and attitudes, which suggest probable conductive zones that are inimical to the foundation of the road subgrade.

**Key words:** Electrical resistivity, roadway subgrade, subsoil competence, clay material, road failure

### Povzetek

Primernost globlje plasti tal za cestogradnjo smo preiskali s kombinacijo geofizikalnih metod. Uporabili smo zelo nizkofrekvenčne elektromagnetne (VLF-EM) in električne upornostne (dipolno-dipolne) postopke. Elektromagnetne in električne upornostne podatke smo izmerili po dveh profilih z opremo ABEM WADI in Ohmega merilcem upornosti. Preiskavo VLF-EM smo opravili ob 5-metrskem razmaku med postajama, medelektrodni dipolno-dipolni razmak je bil 10 m, znotraj dipolni ekspanzijski faktor (*n*) pa med 1 in 5. Za izdelavo elektromagnetnih profilov in psevdopresekov smo uporabili programsko opremo KHFFILT, za električno upornost pa opremo DIPRO. Rezultati so razkrili nekaj različnih vzorcev porazdelitve upornosti na proučevanem terenu. Nizke vrednosti upornosti (11-25 Ohm-m) v južnem delu preiskovanega ozemlja kaže pripisati spremembam vsebine gline in različni stopnji preperelosti tal. Rezultati elektromagnetne preiskave pričajo o navzočnosti blizupovršinskih linearnih geoloških struktur različne dolžine, globine in zaleganja, kar nakazuje verjetne prevodnostne cone, ki niso ugodne za izdelavo obstojne cestne podgradnje.

**Ključne besede:** električna upornost, cestna trasa, primernost tal, glinena zemljina, nezanesljivost podlage

## Introduction

Road failure constitutes a major problem in most part of the world. Most Nigerian roads fail immediately after construction and even before their design age. Some of the factors responsible for these road failures are poor construction materials, bad design, poor drainage network, geological factors, abandon river channels, high water table, water flooding and fallen tree trunks that were left and buried [1–5]. However, geological factors are rarely considered as one of the factors responsible for such failures even though these roads are built on the soil. This shows that road construction requires adequate knowledge of the conditions of subsurface [6]. The non-consideration of geologic factors has led to many road and highway failures in the country. Previous studies have shown that the integrity of roads can be undermined by the existence of geological features as well as the engineering characteristics of the underlying geologic sequences [7–14]. However, there is need to carryout pre-construction geophysical investigation prior to road construction. Therefore, this study aims to investigate the significance of geological factors in terms of the nature of the subsoil, near-surface structures and the bedrock structural disposition as possible causes of road failures at Aule along Ilesa Garage, Ondo State, Nigeria, using geophysical investigations.

## Description and geology of the study area

The study area is located in Aule in Akure South local government area of Ondo State, Nigeria. The study area falls within latitude 7°16′20″N–7°16′30″N and longitude 5°9′5″E–5°9′20″E (Figure 1). The study area lies within the Precambrian basement complex of Southwestern Nigeria. The Precambrian rocks of the region may be separated into three major petro-lithologic units, which are reactivated basement complex of gneisses and migmatites; the schist belt, which predominantly comprises supracrustal rocks occurring within northerly trending trough in the basement complex and the Pan African older granite series, a suite of granites and related rocks that intrude the above successions [15]. However, the main rock type found in the study area is migmatite–gneiss (Figure 2).

## Methodology

Geophysical investigation involving the integration of very low-frequency electromagnetic (VLF-EM) and electrical resistivity (ER) methods was carried out along traverses in the area. Only survey for traverse 1 was carried out for both VLF-EM and ER, and detailed correlation between two methods is presented. However, due to inaccessibility to the road at the time of conducting measurements, only the ER method for traverse 2 was established. The ER method used dipole–dipole array using Ohmega resistivity meter. Basically, the ER method involves the passage of electric current using DC or low-frequency AC into the subsurface through two electrodes, that is, the current electrodes. The potential difference is measured between another pair of electrode, which may or not be within the current electrodes depending on the electrode array in use. The inter-electrode spacing used was 10 m, and the inter-dipole expansion factor ($n$) ranged from 1 to 5. ABEM Wadi was used for the VLF-EM acquisition. The VLF-EM method is an inductive exploration technique that is used in mapping shallow subsurface structural features in which the primary EM wave induces current flow. Although both the real and quadrature components of the VLF-EM were measured, the real component data, which are usually diagnostic of linear features, were processed for qualitative interpretation. VLF transmitter operating at a frequency of 18.9 kHz was used. The station-to-station interval of 5 m was adopted for the survey, and data were acquired along the established two traverses.

The resistivity data were processed using *DIPRO* software [17] to obtain 2-D pseudosections. The real and the filtered components of the VLF-EM data were plotted against station using the *KHFFILT* software [18] and were presented as profiles.

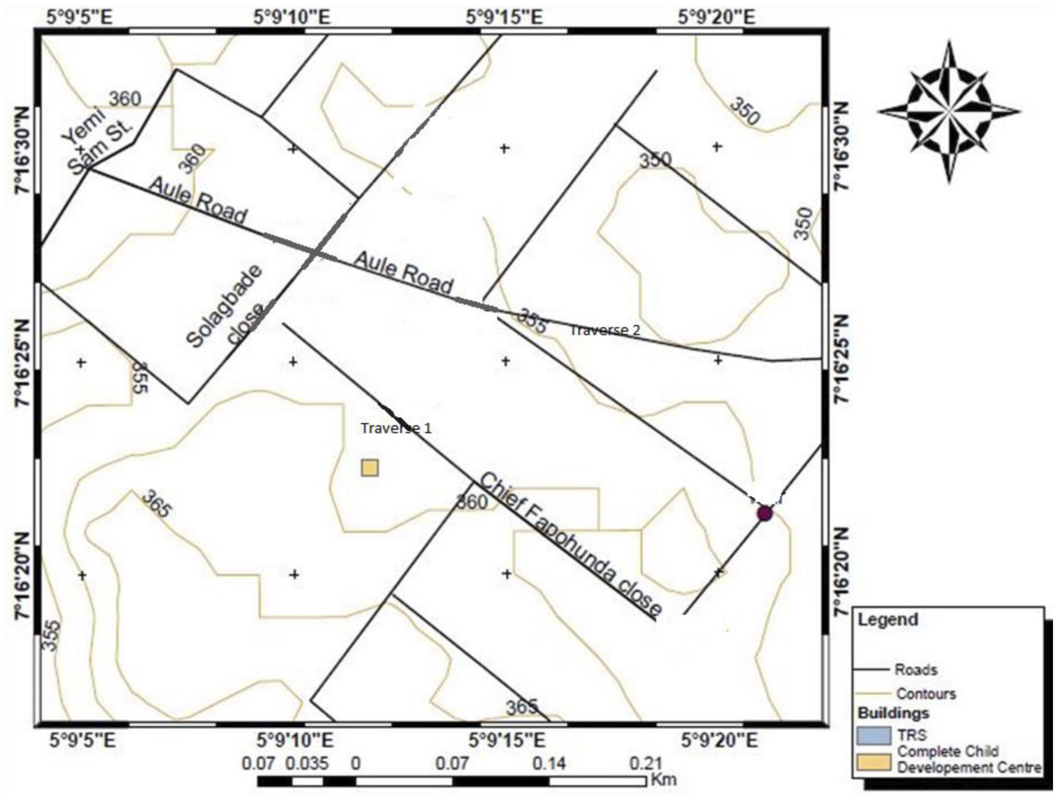


**Figure 1:** *Location map of the study area and its environs.*

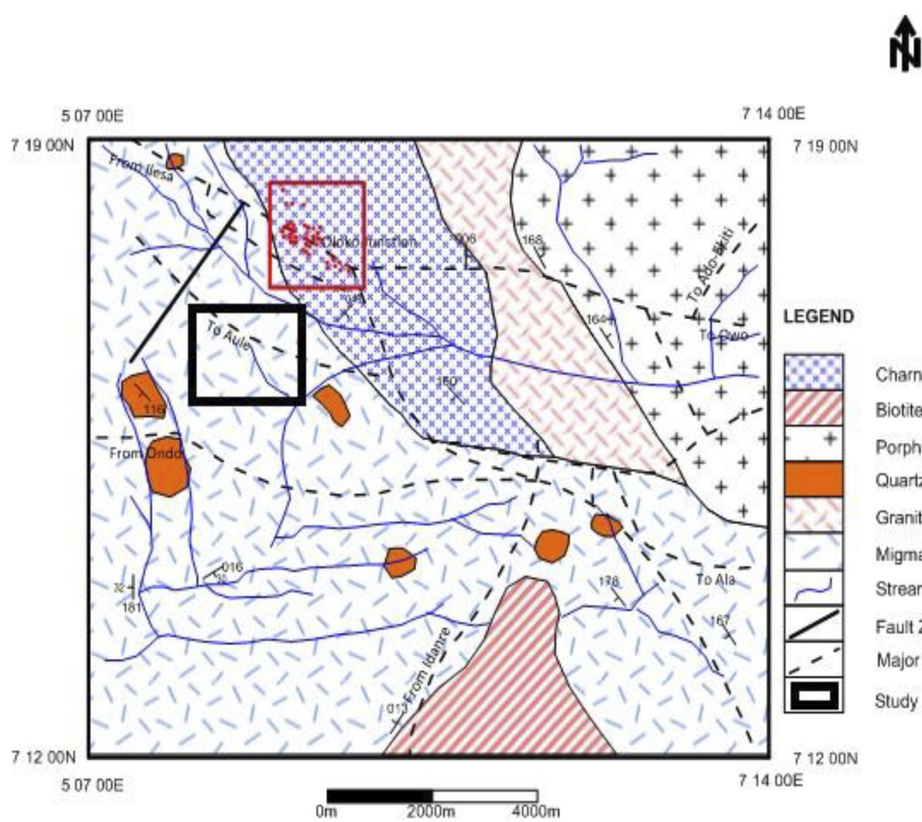


**Figure 2:** *Geological map of Akure (modified after [16]).*

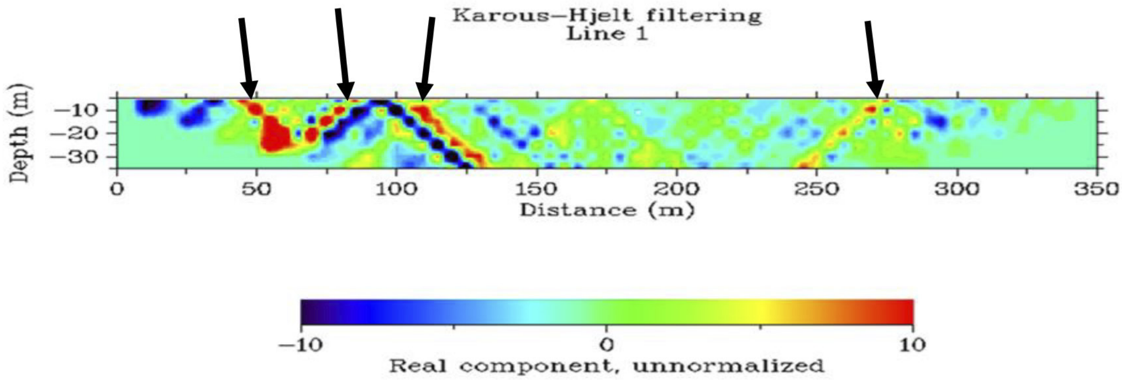


**Figure 3:** *2-D VLF-EM subsurface conductivity image for traverse 1.*

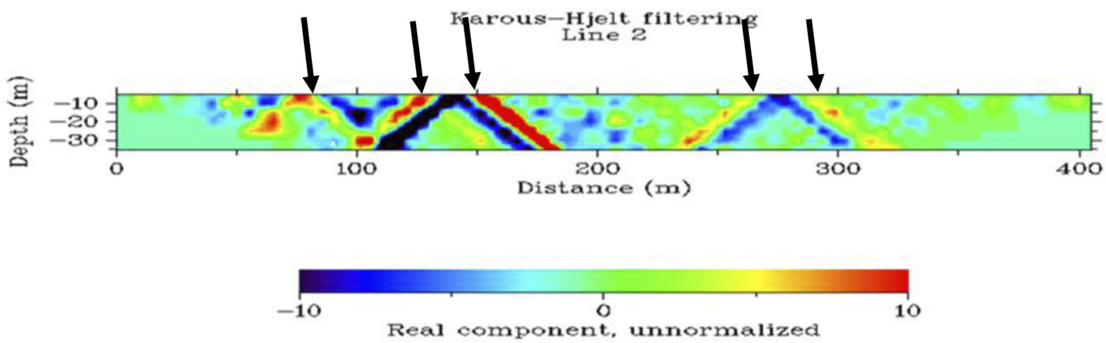


**Figure 4:** *2-D VLF-EM subsurface conductivity image for traverse 2.*

## Results and discussion

### *The VLF-EM Profiles*

Figure 3 shows suspected geologic features such as fault or fracture having varying degrees of conductivity as indicated by arrows on the section. Between distance 40 and 80 m, the resistivity is low, depicting a conductive body to a depth of about 10 m. Similarly, between distance 125–132 m and 180–200 m, a conductive body that orientate towards the northern part of the section at a depth exceeding 12 m is observed. In adddition, towards the northern part of the section is a conductive body at a distance between 240 and 250 m. However, two prominent high conductive zones were found at different points between 50–100 m and 250–275 m as shown in Figure 3.

Figure 4 shows similar structures such as fault or fracture along traverse 2. There are features of different degrees of conductivities on the section, while at distance between 150 and 200 m, a conductive zone is observed (low resistivity). At a distance between 5 and 35 m, a resistive body is observed, which may be as a result of an outcrop closer to the location. There is a presence of a highly conductive body between station distance 220 and 240 m, indicative of an incompetent layer across the road segment.

### *ER pseudosection*

The inverted section in Figure 5 shows that between stations 32 and 111, there is a layer of low resistivity (having values ranging from 11 to 35 Ohm-m) at depth of 1–10 m. The shape of the material suggests the presence of pocket of clay materials at these locations. There is also a resistive layer between stations 115 and 217, which is about 1–8 m thick. At stations 21–51 of the section, there is a layer of relatively thin resistive material as the topsoil, which may be an indication of the topsoil compaction along the road segment. At stations 301–321, the resistivity value is between 14 and 21 Ohm-m, indicating clayey materials. This region also shows high conductive layers between stations 111–121

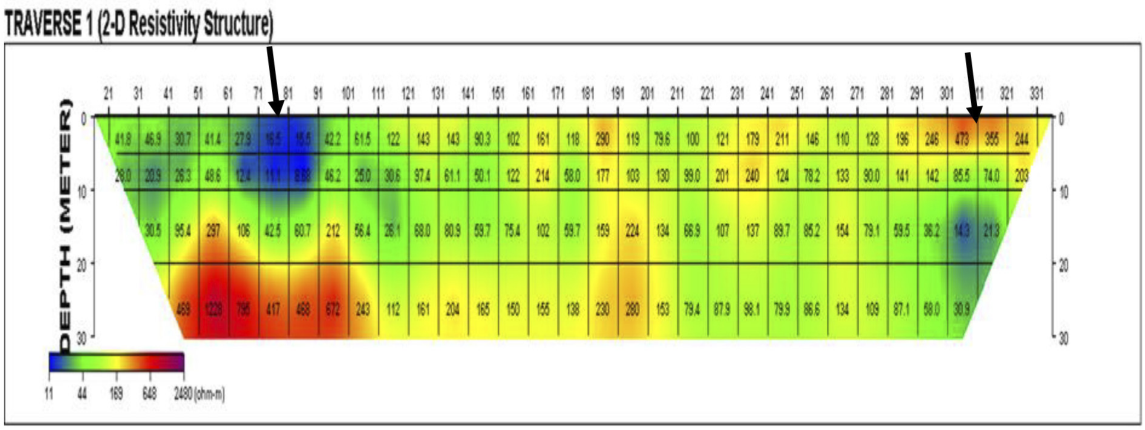


**Figure 5:** *The inverse model resistivity section for traverse 1.*

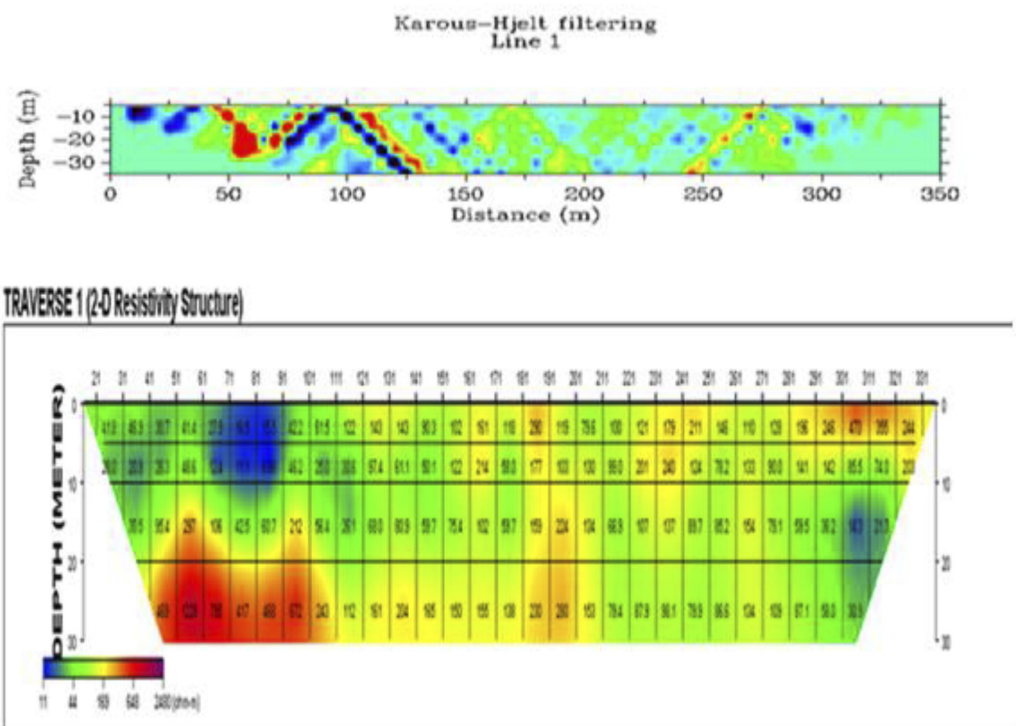


**Figure 6:** *Correlation between conductive VLF-EM and dipole–dipole resistivity survey for traverse 1.*

and 301–321 along the profile due to their relative low resistivity, indicating high saturation in the region [19]. The relatively high-resistivity anomalies observed at the depth of about 4 m at the southern part of the section between stations 41 and 105 show that the subsurface materials in this region are highly resistive. The topsoil is conductive between stations 1 and 91, depicting clayey material, although there is decrease in clay material between stations 101 and 331 with thick overburden. The correlation between VLF profile and pseudosection resistivity for traverse 1 (Figure 6) shows that the principal geologic features that could pose a threat to the road construction in the study area is found at distance between 40 and 80 m in traverse 1 and stations 60 and 91 in the inverse model resistivity section, which could be a pocket of clay material.

## Conclusions

Integrated geophysical methods have been used to investigate the subsoil competency along Aule–Akure road, Ondo State, Southwestern Nigeria. The results show that there is a pattern of resistivity variations within the study area. The low resistivity anomalies observed along the traverses could be due to changes in moisture contents or the point being a water collection centre, which could cause the topsoil to be incompetent.

The results also indicate the clayey nature of the topsoil/subgrade soil on which the road pavement could be established. Clay, although highly porous but less permeable owing to poor connectivity of its pores, retains water without releasing it, thus making it swell and this subsequently will lead to road failure. The presence of near-surface linear features such as faults, fractured zones, fissures and joints in the subsoil beneath the road pavement could cause pavement failure.

Therefore, proper drainage pattern should be constructed between traverses 1 and 2 in order to discourage the accumulation of runoff and thereby expose the subsurface material to erosion and lead to incompetency of the investigated area, and the excavation of the clay material established should be carried out at a depth of about 4 m and be replaced by more competent geologic material before the construction of road.

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