

Geophysical Investigation of the Seismogenic Monitoring Center, Ile-Ife, Nigeria

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Abstract

2D electrical resistivity tomography was observed at Ile-Ife seismographic station, Osun state Nigeria with the aim of investigating the geological structures beneath the station in order to identify areas of anomalous resistivity that might be related to fractures or fault lines and also determine the lithology of the subsurface. This is to ensure that data observed by the seismic station are gotten with less noise. The data was carried out with Terrameter SAS 1000 and ES 464 electrode selector equipment. Dipole-dipole configuration at electrode spacing of 2 m was used to acquire the data. The result showed that the station is underlain by three layers; overburden composed of lateritic clay, clayey sand, the weathered and fresh basement. Fault lines and fractured zones were not observed in all profiles.

Keywords: Seismic station; ERT; Geology

Introduction

Seismological observatories are houses specifically built to house seismic hardware. The science of seismology depends critically on data collected at hundreds of observatories world-wide. These observatories are operated by variety of agencies, staffed by seismologists and technicians whose training and interest vary widely. While in industrialized countries, the observatory personnel normally have easy access to up-to-date technologies, spare-parts, infrastructure, know-how, consultancy and maintenance services, those in developing countries are often required to do a reliable job with very modest means. Recent seismic activities in Nigeria and some parts of the West-African sub-region has shown that the region is most probably seismically

unstable, that is, there exist fault lines that pass through the region. Therefore the need to continuously monitor the crust and the upper mantle for possible prediction of earthquake phenomena informed the establishment of the Center for Geodesy and Geodynamics, under the Federal Ministry of Science and Technology has been saddled with the responsibility of establishing and networking of Nigeria Network seismographic stations. Scientists and technicians at the centers have been working round the clock to ensure that the quality of data obtained from these stations is of international standard. Quality data are required with less noise to achieve this. The observance of noise on the seismic data affects the quality for precise earthquake locations. This noises which could be attributed to geological structures beneath the subsurface, could give false interpretation of

the subsurface. This research is to ensure that such data are gotten with less noise due to unknown geological structures beneath the subsurface. To ensure that such data are correct, a geophysical investigation is required to be carried out at the station to identify areas of anomalous resistivity that might be related to fractures or fault lines and to also determine the lithology of the subsurface. This to ensure that the data collected are of genuine quality and not just inferred by geological structures.

Geophysical investigations of the earth involve studying the physical properties of the earth to provide vital information on subsurface material conditions for numerous practical applications (Loke, 1999). These are done by taking measurements at or near the earth's surface that are influenced by the internal distribution of physical properties. Consequently, analysis of these measurements can reveal how the physical properties of the earth's interior vary vertically and laterally that reflect the subsurface geology. The methods employed include gravity, magnetics, seismic, resistivity, induced polarization, self-potential, radiometrics, ground penetrating radar, electromagnetic methods, etc. These methods are cost effective and capable of detecting and delineating local features of interest [1].

Recent developments in the electrical exploration methods have resulted in a lot of contributions in providing accurate subsurface information. One of the most important is the increasingly widespread use of two dimensional (2D) and three dimensional (3D) resistivity surveys [2-4]. The 2D surveys are the most practically economic compromise both in achieving accurate results and in limiting the survey cost [5].

Location and Geology of the Study Area

The Ile-Ife seismographic station is situated also on the basement complex in the equatorial rain forest of southern part of Nigeria with latitude $07^{\circ} 32' 49.06''\text{N}$ and longitude $04^{\circ} 32' 50.34''\text{E}$. The main lithologies include amphibolites, migmatite gneisses, granites and pegmatites. Other important rock units are schists, made up of biotite schist, quartzite schist, talc-tremolite schist, and the muscovite schist. The crystalline rocks intruded into these schistose rocks [6]. The amphibolite and the hornblende gneiss are the mafic and intermediate rocks in southwestern Nigeria. In Ilesha and Ile-Ife areas these amphibolites occur as low lying outcrops and most are seen in riverbeds while, the hornblende gneiss crops out at Igangan, Aiyetoro and Ifewara, along Ile-Ife road as low lying hills in southwestern Nigeria [6]. The hornblende gneiss is highly foliated, folded and faulted in places.

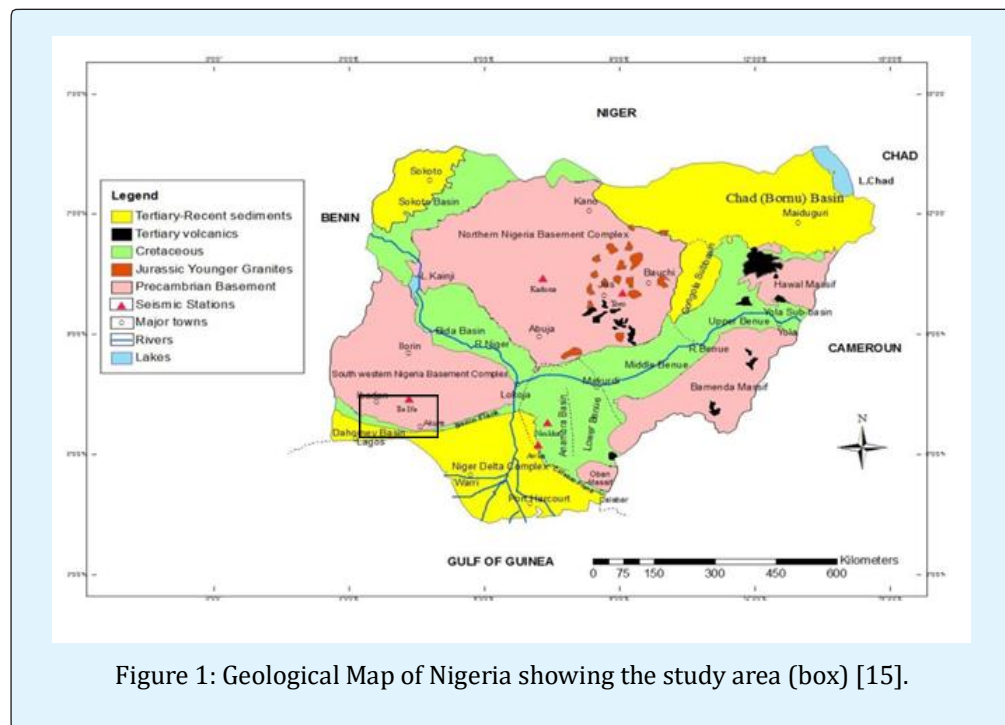


Figure 1: Geological Map of Nigeria showing the study area (box) [15].

The magmatite-gneissic complex which constitutes over 75% of the surface area of the southwestern Nigerian basement complex is said to have evolved through 3 major geotectonic events:

- (i) Initiation of crust forming process during the Early Proterozoic (2000 Ma) typified by the Ibadan (Southwestern Nigeria) grey gneisses considered by Woakes to have been derived directly from the mantle [7].
- (ii) Emplacement of granites in Early Proterozoic (2000 Ma) and
- (iii) The Pan African events (450-750 Ma). Rahaman and Ocan [8] on the basis of geological field mapping reported over ten evolutionary events within the basement complex with the emplacement of dolerite dykes as the youngest. On the basis of wide geochemical analyses and interpretation, tectonics studies, field mapping and plumb tectonics, Oyinloye [9-13] had suggested a modified sequence of evolutionary events in the Southwestern Nigeria basement complex as detailed in Figure 1 Burke [14]. The study area is underlain by regional gray gneiss and mica schist, and a sequence of lateritic clay (aquifers), clayey sand/sand, and weathered/fractured bedrock. The clayey sand/sand and weathered/fractured bedrock constitute the main aquifer, located within a bedrock depression that is the catchment area for the region. The relatively low-lying, gently undulating pediments are dissected by several river valleys.

Materials and Method

Data Acquisition and Processing

To achieve a 2D electrical resistivity tomography of the study area, the ABEM SAS 1000 Terameter was used, choosing the dipole-dipole array. The dipole-dipole array is very sensitive to horizontal changes in resistivity, but relatively insensitive to vertical changes in the resistivity [16]. Measurements were made along four profiles with each profile covering a total length of 164 m. The choice of direction of the profiles was so as to cover the study area which has a dimension of 164 by 82 m.

The collected data resistivity was processed and inverted using the RES2DINV software developed by Loke and Barker [17]. The inversion technique used was the standard least-square smoothness constrain. Generally, the programme automatically creates 2D model by dividing the subsurface into rectangular blocks [17] and the resistivity of the blocks was iteratively adjusted to reduce the difference between the measured and the calculated apparent resistivity values. The apparent resistivity values were calculated by the finite-difference method. The program calculates the apparent resistivity values and compares these to the measured data. During

iteration, the modelled resistivity values will be adjusted until the calculated apparent resistivity values of the model agree with the actual measurements. The iteration is stopped when the inversion process converges (i.e., when the RMS error either falls to acceptable limits, usually less than 5% or when the change between RMS errors for consecutive iterations becomes infinitesimally small). Prior to data inversion, the apparent resistivity data set were inspected in accordance with the suggestion of Loke [18] for bad datum point and such points were deleted.

Interpretation of Results

The results of the standard constrain inversion technique for the dipole-dipole array configuration for each profile is presented in Figures 2-5. R.M.S. errors of 3.7%, 4.1%, 5.0% and 5.4% were obtained. Profile one runs west-east of the study area, covering a distance of 82 m. The resistivity model revealed high resistivity values (900 Ω m-1400 Ω m) of depth 2.5 -5.0 m, with lateral distance of 2 – 70 m. Lower resistivity values (280 Ω m - 430 Ω m) are found at depth of 0 -2.4 m with a lateral distance of 2 – 80 m.

Profile 2 runs north-south of the study area, covering a distance of 82 m. The resistivity model showed low resistivity values (100 Ω m-305 Ω m) at a depth of 0 – 2.9 m, with a lateral length of 5– 55 m. Higher resistivity values (1000 Ω m-2500 Ω m) were observed at depth range of 3.0 m- 4.0 m, with lateral distance of 10 – 58 m. At a depth of 7.90 – 11.5 m. Lower resistivity range (200 Ω m- 305 Ω m) is observed, with a lateral length of 18 – 55 m.

Profile 3 runs north –south of the study area, at an inter-profile spacing of 20 m from profile 2. The resistivity model showed low resistivity values (200 Ω m-285 Ω m) at a depth of 0 – 2.5 m, with a lateral distance of 5 -68 m. Higher resistivity values (1000 Ω m-2000 Ω m) are found at a depth range of 3.0 – 7.90 m, covering a lateral distance of 5 – 60 m. Lower resistivity range (200 Ω m-250 Ω m) is observed at depth of 8.0 – 11.5 m, with a lateral distance of 20 -55 m.

Profile 4 runs west-east of the study area, with an inter-profile spacing of 20 m from profile 1. Low resistivity values (100 Ω m-300 Ω m) were observed at a depth range of 0 – 2.55 m, with a lateral distance of 5- 70 m. Higher resistivity values (1000 Ω m-2500 Ω m) were observed at a depth range of 3.0 – 7.90 m, covering a lateral distance of 5 -65 m. Lower resistivity range (130

Ωm -230 Ωm) was observed at a depth of 8.0 – 11.5 m, covering a lateral distance of 20 – 50 m.

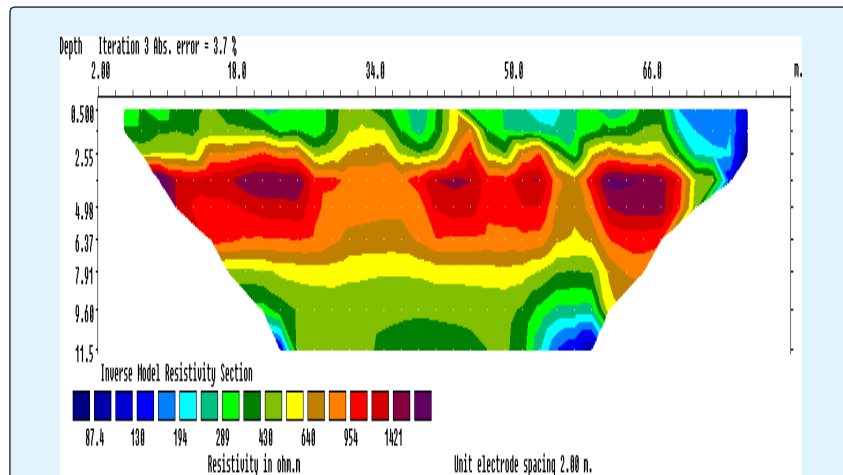


Figure 2: 2D inversion of the dipole-dipole array data along profile 1.

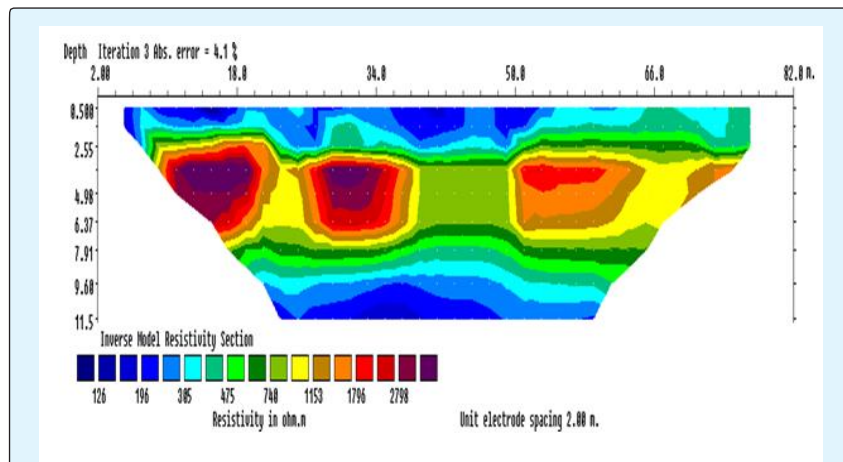


Figure 3: 2D inversion of the dipole-dipole array data along profile 2.

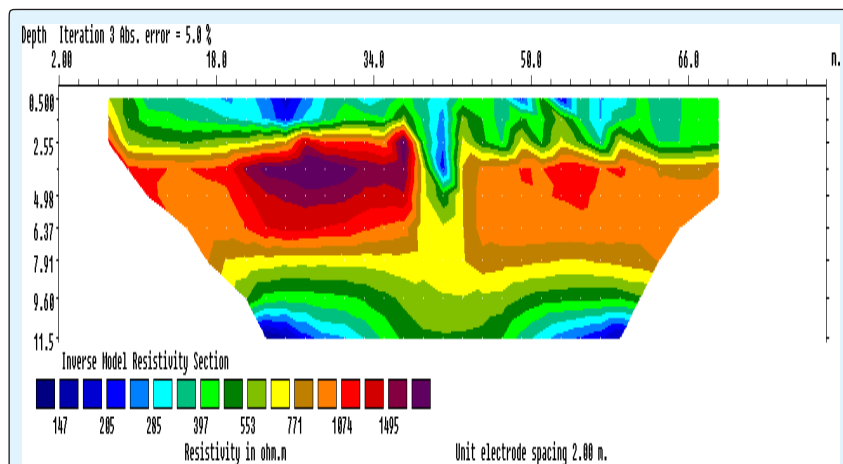


Figure 4: 2D inversion of the dipole-dipole array data along profile 3.

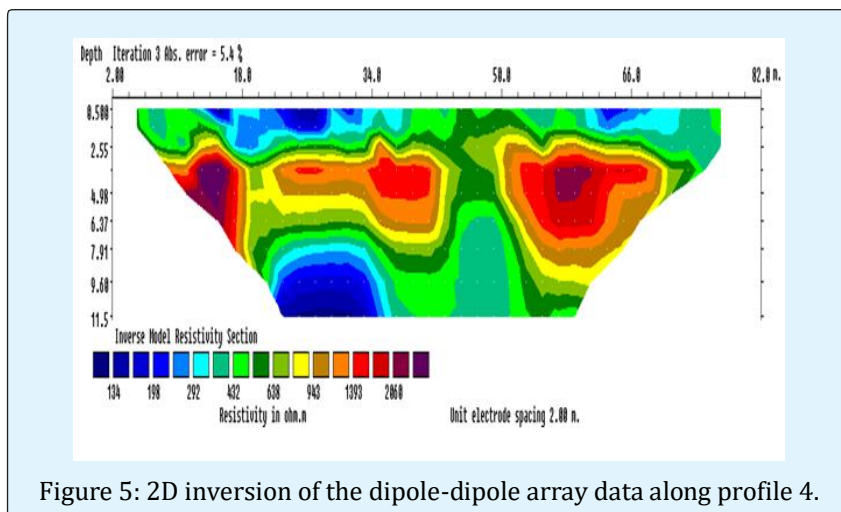


Figure 5: 2D inversion of the dipole-dipole array data along profile 4.

Discussion of Results

According to previous literatures (Olayinka AI, Akpan EJ and Magbagbeola OA) [19], the main lithology of the south-western Nigeria basement complex include the amphibolites, migmatite, gneisses, granites and pegmatites. Other important rock units are the schists, made up of biotite schist, quartzite schist talk-tremolite schist and the muscovite schist. Also, the typical geological sequence in a basement complex terrain consist of top layer, highly weathered layer (which is mostly clay/clayey sand) and fractured/ fresh basement rock. In basement complex terrain, the geological structure normally encountered is characterized by the existence of hard rock basement overlain by a weathered overburden of variable thickness [20]. This was used as guide in determining the lithology of the study area. The interpretation of data resulting from the 2D ERT provided information on lateral variations of the formations,

resistivity of the weathered/fractured basement and presence or absence of fracture zones.

It can be seen that all four profiles (Figure 2-5) consist of three layers; overburden layer, weathered basement rock and the fresh basement layer. The overburden includes the topsoil, clayey sand/sand or sandy clay/clay, and the weathered/ fractured basement, whose thickness ranges from 3.1–35 m, as partially confirmed by the dug pits. Generally, the distribution of the surface soil resistivity in the inversion models show a wide variation in the soil resistivity and at different depth along the profiles. The resistivity of the three-layer case reveals the top layer is characterized by its relatively low resistivity across the study site with the resistivity values ranging between 100 Ω m- 400 Ω m. with thickness varying from <1.2 m-2.9 m. The variation in the resistivity values depict the inhomogeneity nature of the layer. The subsurface heterogeneity comes from the presence of clayey sand/sand clay with lateritic clay and sometimes outcrop (Figure 6).

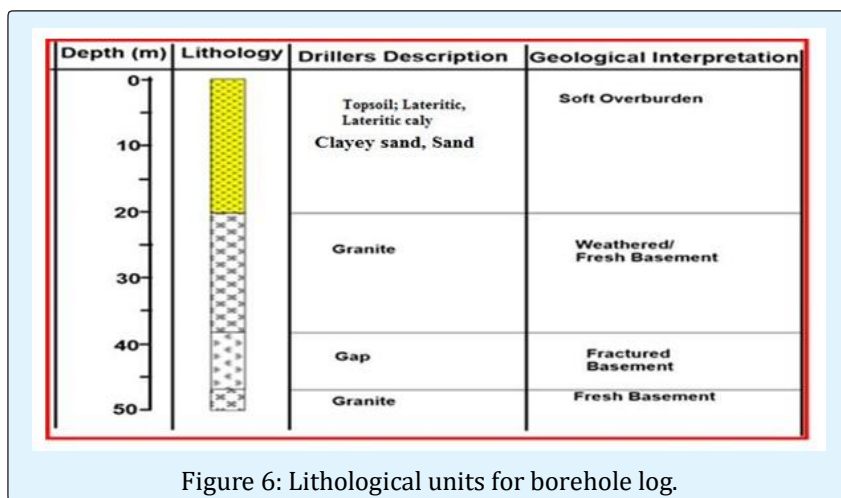


Figure 6: Lithological units for borehole log.

The fresh/fractured basement underlies the aquiferous zone, with resistivity ranging from 200 Ωm -305 Ωm with varying depth > 35 m. Geophysical studies in south-western basement complex of Nigeria have identified thick overburden as zones of high ground water potentials [21-23].

Conclusion

2D electrical resistivity tomography has provided a clear view of the lithological units and geo- electrical structure underlying the study area. The area is underlain by three layers of different lithological units. Also, no fault lines or fractured zones were observed in all profiles and as a result no geological structure was found to infer false results to the seismic station.

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