# Geology, Structures and 2D Resistivity Imaging of the Main Observatory Station of the Center for Geodesy and Geodynamics, Toro, Bauchi State Nigeria

**Abba, M. J., Alhassan, Idris.**

**Center for Geodesy and Geodynamics, Toro, Bauchi State**

**DOI: https://doi.org/10.51244/IJRSI.2025.12010074**

**Received: 08 January 2025; Accepted: 17 January 2025; Published: 22 February 2025**

## ABSTRACT

Electrical resistivity method was used in carrying out geophysical investigations at the Centre for Geodesy and geodynamic Toro observatory station, Bauchi state with a view of determining the geology, structures and depth of the lithology of the basement. The Toro observatory station is undererlained by an Older Granite Rock of Migmatite-Gneise composition, the Lineaments observed at the field and satellite imagery are trending in the NE-SW direction. Vertical Electrical Sounding (VES) using Schlumberger array was carried out at forty (40) VES, ABEM terrameter (SAS 1000) was used for the data acquisition. The field data obtained have been analyzed using computer software (*IPI2win*) which gives an automatic interpretation of the apparent resistivity. Results from the interpretation suggest three layers in most parts of the study area. However, there is a case of two layers at the station. The resistivity value for the topsoil layer varies from 2 to 738**Ω**m with thickness ranging from 1 to 3.9meters, the weathered basement has resistivity values ranging from 32 to 1735**Ω**m and thickness of between 0.52 and 23 meters. The fresh basement(bedrock) has resistivity values ranging from 100 to 6,036**Ω**m which prove that the area is very stable for the establishment of the observatory station for carrying out earth observation research as well as monitor and predict geo-hazards using Space Geodetic and Geo-physical techniques for sustainable National Development.

**Keywords:** Electrical Resistivity, Vertical Electrical Sounding (VES), Migmatite-Gneise rock, Lineaments.

## INTRODUCTION

### Background

Geophysical investigations of the earth involve studying the physical properties of the earth to provide vital information on sub-surface material for numerous practical applications which cover an area of interest rapidly, the method is done by taking measurements at or near the earth's surface that are influenced by the internal distribution of physical properties. Geophysical surveys include magnetics, gravity, electromagnetic, induced polarization, ground penetration radar, electrical resistivity methods, etc. The observatories are operated by variety of agencies, staffed by geo-scientist and technicians whose training and interest vary widely (Obiadi *et al.*, 2012).

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 (Griffiths and Barker, 1993; Ritz *et al.*, 1999; White *et al.*, 2001; Dahlin, *et al.*, 2002). 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 (Keary and Brooks, 1988).

The 2D surveys offer a practical balance between cost-effectiveness and accuracy (Dahlin, 1996) in many geological conditions, the 2D electrical imaging surveys can produce results that are complimentary to the information obtained from other geophysical methods.

The Dipole-Dipole and Pole-Dipole arrays produce poorer vertical resolution and lower signal-to-noise ratios, but have better lateral resolution (Barker, 1979; Dahlin and Zhou, 2004). However, these conventional arrays may not be the most appropriate and effective options when the time or number of measurements given for the survey is limited, or when an object at a specific location in very complex structure becomes the target of the survey.

The use of 2D resistivity surveys has enabled mapping complex geological structures that were not previously possible with conventional 1D resistivity surveys (Loke, 1999). Two dimensional electrical imaging surveys model are more accurate than 1D resistivity sounding survey as it allows horizontal as well as vertical resistivity variations (Loke, 2004). Typical 1D resistivity sounding surveys usually involve approximately 10 to 20 readings, while the 2D imaging surveys contain 100 to 1000 measurements. The 2D electrical imaging method has many applications such as mapping freshwater aquifers, mapping of groundwater contamination, investigating landslides and mapping unconsolidated sediments (Acworth, 1987; Christenson and Sorensen, 1994; Barker, 1979; Dahlin and Owen, 1998; Ritz *et al.*, 1999). Over the past decade, there have been many developments in instrumentation and interpretation techniques so that 2D resistivity surveys can be carried out rapidly. In addition, some research studies have shown that a number of 2D data sections can be merged into a 3D data set for subsurface model (Bernstone *et al.*, 1997; Dahlin and Loke, 1997).

**History Behind Establishment of the Center for Geodesy and Geodynamics Toro**

The idea behind the establishment of the Centre for Geodesy and Geodynamics was conceived as far back as 1984 when a National Technical Committee on Earthquake Phenomena (NTCEP) was inaugurated by the Federal Ministry of Science and Technology following a reported Earth Tremor in Ijebu-Ode and Ibadan in the South - West Nigeria.

In 1989, Nigeria through the effort of the NTCEP indicated her interest in participating in global cooperative programme in Space Geodesy with the aim of providing new insight into African plate tectonics, global dynamics and the study of earthquake mechanism.

In 1990, a site for an Observatory to house the Very Long Baseline Interferometry (VLBI), Satellite Laser Ranging (SLR) and Global Positioning System (GPS) equipment was selected at Toro by some Nigerian Scientists Headed by Chief Professor Dagogo M. J. Fubara who was the first Geodesist in West Africa and National Aeronautics and Space Administration (NASA) officials.

The choice of the Toro station to host the observatory equipment for monitoring geo-hazards is based on its high resistivity of the solid geological bedrock ("the older granites") that can serve as immobile belt on which sensitive tracking system can be situated. The Toro site shall, in addition to satellite tracking, be responsible for:

1. Monumentation and footprint survey in accordance with the guidelines of the Space Geodetic Measurement Sites Sub-Committee of the International Coordination of Space Techniques for Geodesy and Geodynamics.
2. Global mean sea level monitoring network Centre at Bori, Rivers State, Nigeria.
3. Training of Observatory Personnel and Researchers in Nigeria and at NASA, NOAA, JPL in USA and other Space Research Centre's Worldwide.
4. Funding of small projects set up at designated local Universities and Institutes thereby developing a service scheme attractive to emerging physical Scientists and Mathematicians.
5. Organize symposia, seminar, lectures and workshops to propagate its works and programs.

In January, 2002, the Centre was established following the approval of the National Space Policy and Programs by the Federal Executive Council in May, 2001.

The eventual goals of the Centre for Geodesy and Geodynamics are to achieve Nigeria's capability, manpower and hardware development that can sufficiently address:

- Space Geodesy

ISSN No. 2321-2705 | DOI: 10.51244/IJRSI |Volume XII Issue I January 2025

- Crustal deformation Monitoring
- Subsidence and Global Mean Sea Level Monitoring

Electrical Resistivity Imaging (tomography) was carried out to create a 2D resistivity image of the study area. Electrical resistivity tomography consists of the application of constant direct currents imposing into the ground via two current electrodes and measuring the resulting voltage via two potentials electrodes at the surface. Any variation in subsurface resistivity (conductivity) alters the current flow patterns which in turns affect the distribution of electric potential. Any variations observed from the pattern of potential differences expected from uniform earth are deviations from the uniform earth. These deviations represent the geological target of resistivity exploration.

**Location and Climate of the Study Areas**

The Centre for Geodesy and Geodynamics, Toro observatory Station is about 5.5 kilometers north of Gayawa village; 6.0 kilometers north of the intersection of Toro- Magama village along the Toro-Bauchi highway, near Bargan-Tsamiya in Toro local government area of Bauchi state, figure 1.1; is the location of Toro Seismographic Station in Nigeria.

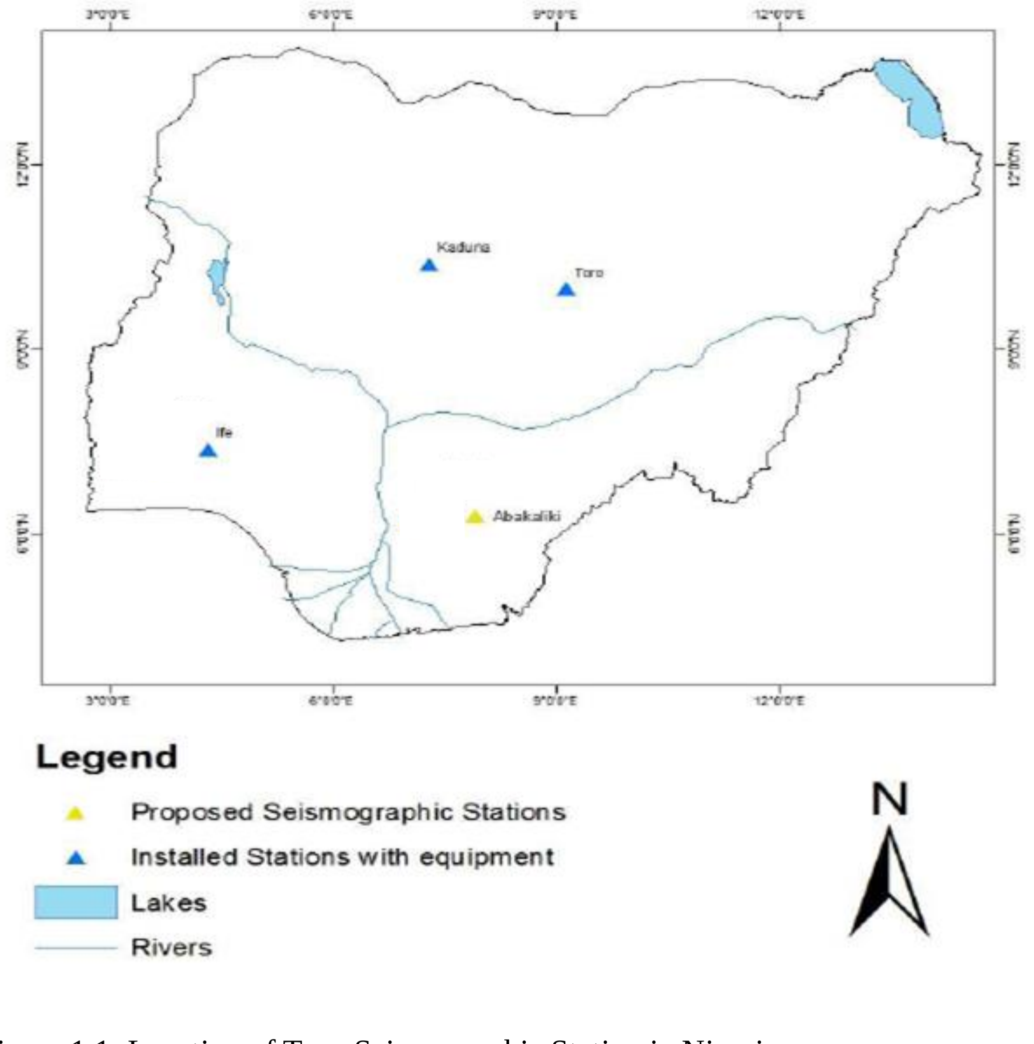



Figure 1.1: Location of Toro Seismographic Station in Nigeria.

The area is bounded on longitudes 10° 07' 309"E -1° 07' 340"E and latitudes 09° 07' 077"N - 09° 07' 155"N, within Toro sheet 148 SW map (Fig 1.2). The topographic map of Toro observatory station is represented in figure 1.3

Toro enjoys a tropical climate. The dry and hot weather peculiar to this region is interrupted only by less than five months of wet condition. November to February and early march are the hamattan months during which period cold and slightly dusty winds blow from the October. The area falls within the semi-arid zone of

Nigeria (Harold, 1970). It lies in the guinea savannah; the woodland vegetation is characterized by bushes generally less than 3 meters high.

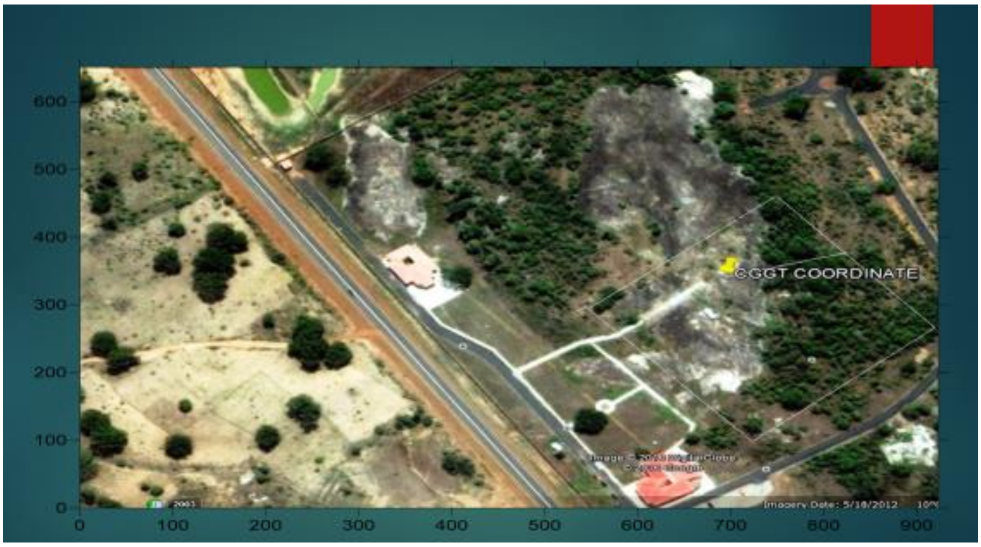



Figure 1.2: Aerial view of the Center for geodesy and geodynamics observatory station

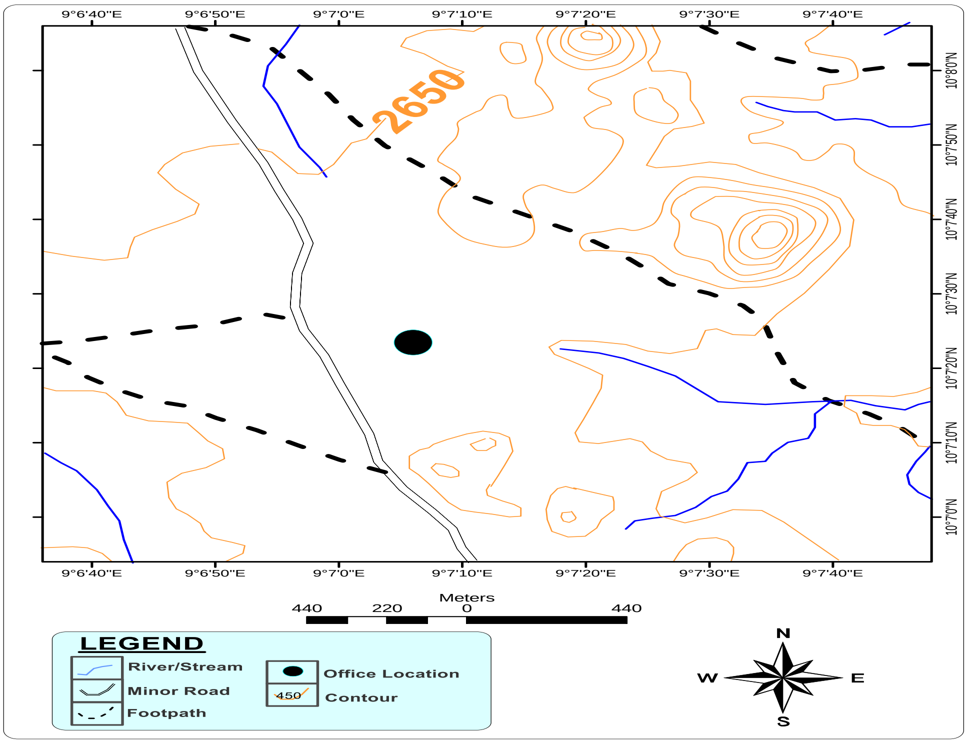



Figure 1.3: Topographic map of the Center for geodesy and geodynamics, Dot represents the observatory station

## Geology of the Toro Station

Toro station lies on the basement complex of Nigeria, which basically consist of older granitites and migmatite. It was because of the occurrence of these geological features in Bauchi state that necessitated the choice of this area for the Geodetic and Geodynamics Observatory site. The motion being that the surface expressions of the West African Craton – an ancient, is a stable core of the African continent that has not been deformed over geological time. This stable regions unit is representative of the most stable region of South Africa (corresponding to the Canadian Shield in North America). Many of the outcrops consist of smooth, spelled surfaces with no fractures and are ideal for an observatory site. These older granite formations of granulites, granites, and diorites date back to late Cambrian to Ordovician (500m.a.). (Teme, 1984).

ISSN No. 2321-2705 | DOI: 10.51244/IJRSI |Volume XII Issue I January 2025

### Statement of the problem

The subsurface knowledge of geological features of the stations need to be known so that it could not alter the quality of data being recorded at the station. This research work is therefore tailored towards the use of electrical resistivity method to create a 2D tomography of the subsurface to compliment previous techniques used in siting the observatory station, which will aid in revealing such geological features.

### Justification of the research

The most basic goal of observatory station is the determination of accurate measurements and locations. If noise at the sites is too high, many of the benefits of modern, high dynamic-range equipment will be lost. If a station is situated on soft ground, very broadband (VBB) or even broadband (BB) recording can be useless and short-period (SP) signals may be unrepresentative due to local ground effects. If the network layout is inappropriate, the locating data will be inaccurate or systematically biased. Quality data are required with less noise. This noise which could be attributed to geological structures beneath the subsurface which 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.

### Aim and Objectives of the Research

The aim of this research is to investigate the geological structures beneath main observatory station of the center for geodesy and geodynamics, Toro.

The objectives of the research work are as follows:

- To highlight the Geology and structures of the observatory station of the center for geodesy and geodynamics, Toro.
- To produce the resistivity models of the subsurface of the Toro observatory station.
- To determine the thickness and depth ranges of subsurface resistivity layers of the observatory station
- To determine any areas of anomalous resistivity in the various resistivity models that might be related to fractures and fault lines.

## RESEARCH METHODOLGY

### Instrumentation

In resistivity measurement nowadays, there are a range of instruments, from very simple to highly sophisticated equipment with the latter including the computer for infield data processing. The basic parts of any resistivity instrumentation are a portable power source which is either a D.C. or a low frequency A.C., Electrodes, preferably stainless-steel electrodes, and cable and reels, Global Positioning System (G.P.S), meters for measuring current and voltage both of which may be combined in a single meter reading resistance. The instrument used for this survey comprises the of GPS, stainless steel electrodes, hammers, measuring tapes and reels of cables.

The LUND Imaging System (Fig. 2.) consists of a basic unit, a standard resistivity meter (ABEM Terrameter SAS1000) and a multi-channel relay matrix switch unit, Electrode Selector ES 464. The system also has four multi-conductor electrode cables wound on reels each with 21 take-outs, stainless steel electrodes and cable jumpers and various connectors. The system is compatible with a portable PC-type computer or note book (laptop). Operating power comes from an internal 12 volts rechargeable NiCd battery pack. Data acquisition software featuring automatic measuring process, in-field quality control of measurements, automatic roll along, electrode cable geometry and switching sequence defined in address and protocol files which allow the user define survey strategies and arrays, onscreen echo of measurement progress, software for graphical and depth interpretation including pseudo section plotting in gray scale or color.

Signal Averaging System (SAS) results are more reliable than those obtained from single-short systems. The SAS 1000 can operate in different modes, e.g., resistivity, self-potential and induced polarization. In all its modes it is capable of measuring simultaneously in four channels thus making it suitable in all sorts of

ISSN No. 2321-2705 | DOI: 10.51244/IJRSI |Volume XII Issue I January 2025

resistivity surveys. The SAS 1000 is powered by a clip-on NiCd battery pack or by an external 12 volts' source, which clips conveniently onto the bottom of the instrument. The SAS-EBA external 12 volts' adapter allows the Terrameter to utilize an external 12 volts D.C. source, e.g., a car battery (ABEM LUND Instruction Manual, 2010). Stainless steel electrodes establish electric contact between electronic conductors, which are long cables, to an ionic conductor which is the ground. Electrodes generate noise, which is important only at the potential electrodes. Noise is the fluctuating voltage that appears between a pair of electrodes placed so close that no other natural voltages appear. But stainless steel electrodes create less noise. Current electrodes and potential electrodes make good contact with the ground to ensure low contact resistance and stability respectively (ABEM LUND Instruction Manual, 2010). The cables incorporate heavy gauge conductors with excellent insulation to ensure good survey results. The cables are expandable for deeper penetration by connecting them in series with a cable joint. The cables have taken-outs at 2m intervals along its length from which the cables are connected to the electrodes using cable jumpers having crocodile clips at both ends. The cables are wound on reels. Figure 3, shows the basic instrumentation of the ABEM LUND Imaging System and accessories.

Plate 2: ABEM LUND Imaging System together with Terrameter SAS 1000 and ES 464 used for Electrical Resistivity Tomography

**Dipole-Dipole Array**

Dipole-dipole array was used for the survey to achieve a 2-D resistivity tomography of the study areas. The dipole-dipole array is very sensitive to horizontal changes in resistivity, but relatively insensitive to vertical changes in the resistivity. That means that it is good in mapping vertical structures, such as dykes and cavities, but relatively poor in mapping horizontal structures such as sills or sedimentary layers. The dipole-dipole array is logically the most convenient array used in the field especially for large scale survey, figure 3.

In this type of array, all four electrodes are placed along the same line and the distance between the current electrodes A and B is equal to the distance between the potential electrodes M and N represented by 'a'.

The distance between the middle points of current and the passive electrode sets is an integer multiple of 'a' and the factor itself is assigned to be equal to 'n'. The geometric factor K can be found from the following expression:

$$K = \pi n\,(n+1)(n+2)a$$

Where: k = geometric factor

n = Multiple factor (1,2,3 etc.)

a = Distance between the electrodes

ISSN No. 2321-2705 | DOI: 10.51244/IJRSI |Volume XII Issue I January 2025

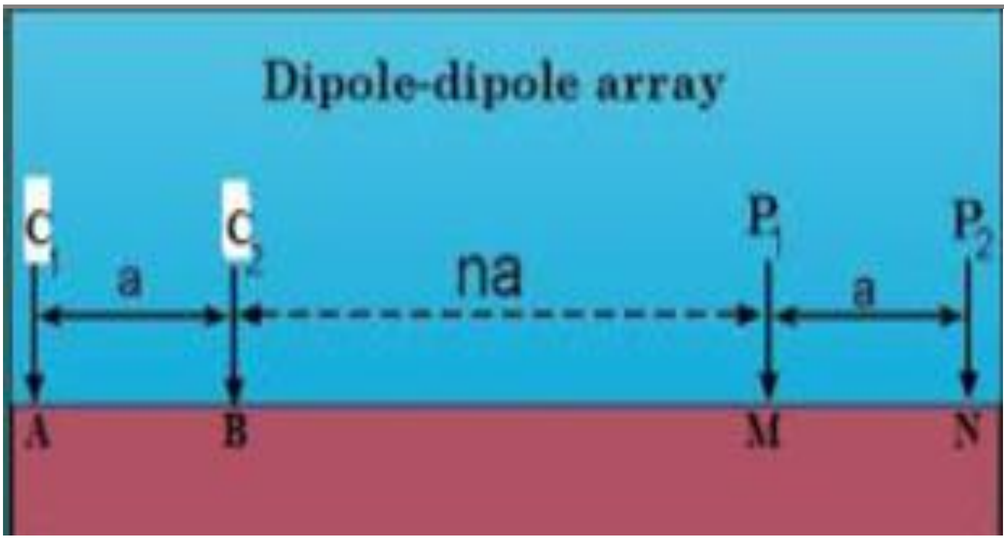



Figure 3: The Dipole-Dipole Array Configuration (Zhou *et al.*, 2000).

**The ABEM Lund Imaging System**

The LUND Imaging System is a multi-electrode system for cost effective and high resolution 2D and 3D resistivity surveys. It is an automatic electric imaging system suited for automatic resistivity profiling and drilling.

The LUND Resistivity Imaging System consists of a basic unit, a standard resistivity meter (ABEM Terrameter SAS1000) and a multi-channel relay matrix switch unit, Electrode Selector ES 464. The system also has four multi-conductor electrode cables wound on reels each with 21 take-outs, stainless steel electrodes and cable jumpers and various connectors

**Inversion of the 2D Data set**

The measured apparent resistivity data files for all the resistivity imaging survey lines were downloaded using dumping cable. The SAS4000 Utilities software was used to convert the original data file (in. s4k format) to the appropriate (DAT format) input file readable by the inversion software RES2DINV. The acquired data resistivity was first processed and inverted using the RES2DINV software

The standard least-square smoothness constrain inversion technique was used for the inversion. This technique divides the subsurface into rectangular blocks and the resistivity of the blocks are adjusted to reduce the difference between the measured and the calculated apparent resistivity values.

**Data Acquisition and Data Processing Procedure**

The dipole-dipole array was used to acquire electrical resistivity tomography data using computer-controlled measurements systems connected to multi-electrode arrays. The data acquisition process was completely controlled by the computer software which checked that all the electrodes are connected and properly grounded before measurement starts for proper data generation, also using stainless-steel electrodes minimize noise from the data, adding sodium chlorite (Table salt) enhance high data output.

The raw field data were processed using RES2DINV (Loke and Barker, 1996). This is a computer programme that automatically determines a two-dimensional (2D) resistivity model for the subsurface for the data obtained from electrical resistivity survey. It is a window based programme. This method is based on the following equation:

$(J^TJ + uF)\ d = J^Tg$ 4.1

Where $F = fxfx^T + fzfz^T$

ISSN No. 2321-2705 | DOI: 10.51244/IJRSI |Volume XII Issue I January 2025

fx= horizontal flatness filter

fz= vertical flatness filter

J = matrix of partial derivatives

u = damping factor

d = model perturbation factor

g = discrepancy vector

The forward problem is solved through a finite difference algorithm, whose main features area versatile user-defined discretization of the domain and a new approach to the solution of the inverse Fourier transform. The forward modelling subroutine is used to calculate the apparent resistivity values. The inverse procedure is based on an iterative smoothness-constrained least squares algorithm. This computer programme uses a smoothness constrained non-linear least squares optimization inversion technique to convert measured apparent resistivity values to true resistivity values and plot them in cross-sections. The inversion process removes geometrical effects from the pseudo section and produces an image of true depth and true formation resistivity. One advantage of this method is that the damping factor and flatness filter can be adjusted to suit different types of data. The programme creates a resistivity cross section, calculates the apparent resistivity for that cross-section, and compares the calculated apparent resistivity with the measured apparent resistivity. The iteration continues until a combined smoothness constrained objective function is minimized. The depth of investigation cannot be determined by simple calculations and it depends on the acquisition geometry, the conductivity structures and data errors (Oldenburg and Li, 1999). However, they have demonstrated through various modelling exercises that there is a loss of reliability in the inverted resistivity values at the bottom and ends of resistivity images where the resistivity values are least constrained by the data.

## RESULTS

### Geological Section from Borehole Data

Meaningful geological interpretations of all profiles were carried out using borehole data which served as a control as represented in figure 4. The borehole log helped to understand the vertical geological section of the study area by harmonizing the different units of the log with the 2D electrical resistivity sections. The soil types in the boreholes are clearly distinguished but in the case of the electrical imaging sections it is difficult to distinguish the soil types, because the different soil types in the borehole are combined into a layer in the electrical imaging. In the following sections the results of the individual profile lines and their interpretations are presented.

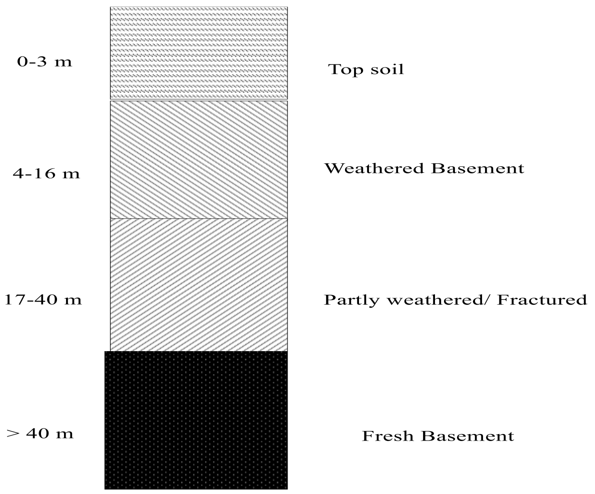



Figure 4: Borehole log 10 m from the Toro Station

ISSN No. 2321-2705 | DOI: 10.51244/IJRSI |Volume XII Issue I January 2025

### Field Results from Toro Station

The electrical resistivity images of the earth subsurface obtained in the study areas are presented and displayed as a resistivity model obtained by the optimization technique of RES2DINV, which minimizes the difference between the calculated and measured pseudo-sections of the apparent resistivity data sets. The 2D electrical resistivity images of the earth's subsurface along the profiles obtained at the Toro station are presented in profile 1- 4.

### Profile 1 at Toro Station

The resistivity inversion result of profile 1 from Toro station is represented in figure 5. The inverted resistivity section revealed three distinct layers. The layers were interpreted as the overburden, weathered basement and fresh basement, using the borehole log and standard resistivity values as guide in the interpretation. The overburden mainly consists of laterite and lateritic clay with resistivity range from 26 Ωm to 160 Ωm. The overburden layer at a horizontal profile length of 2 to 38 m was found to intrude the subsurface up to the depth of 11.5 m and the same was observed at profile length 66 to 80 m. The depth of the weathered basement ranges from 7 to 11 m between 10 and 165 m along the profile, with a resistivity range of 280 Ωm – 600 Ωm. The depth of the fresh basement layer extends beyond 11 m.

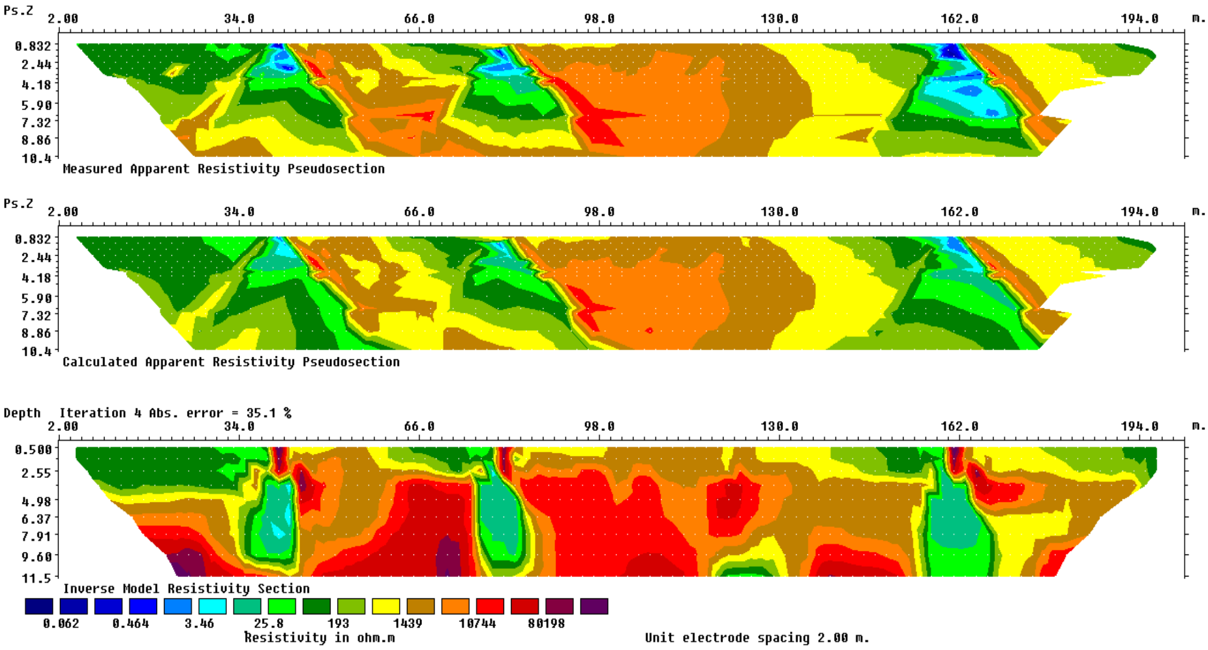



Figure 5: Result of 2D inversion of profile 1 at Toro station.

### Profile 2 at Toro Station

Inverse resistivity sections of this profile also reveal three separate layers a represented in figure 6. The first is the overburden (lateritic and lateritic clay). The lateritic clay of the overburden layer reveals low apparent resistivity ranging from less than 65 to 129 Ωm. It occurs along the horizontal distances of 2 to 30 m, 50 to 85 m from the beginning of the profile, and occurs at depths ranging from 0 to 3 m. The laterite is exposed at a lateral distance of 30 to 85 m along the profile having an apparent resistivity ranging from 129 to 377 Ωm. Depth range of occurrence of layer is from 0 to 3 m.

The second layer is the weathered basement with apparent resistivity range 377 to 745 of Ωm. It underlies the lateritic layer having a depth range of about 4 m (at a lateral distance of 110 m) to 8 m (at a lateral distance of 50 m along the profile).

The third layer along this profile is fresh basement which underlies the weathered basement. Apparent resistivity values obtained for this layer ranges from 745 -1405 Ωm at depths of about 10 – 11 m and beyond.

ISSN No. 2321-2705 | DOI: 10.51244/IJRSI |Volume XII Issue I January 2025

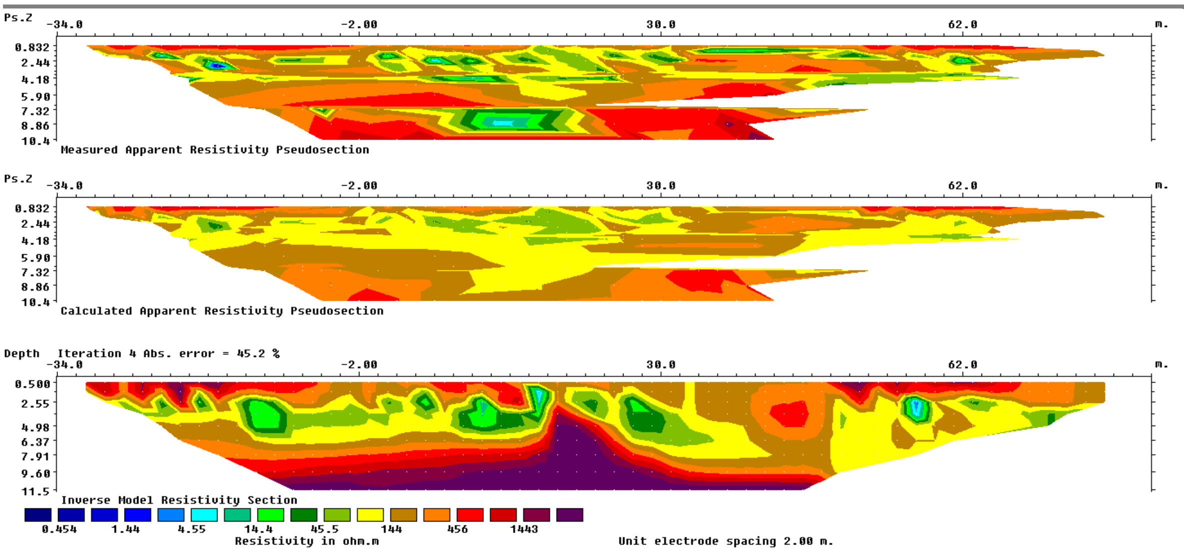



Figure 6: Result of 2D inversion of profile 2 from Toro station.

## Profile 3 at Toro Station

This profile also reveals four distinct layers as represented in figure 7. These are: overburden (lateritic clay, lateritic layer) weathered basement, fractured basement and fresh basement respectively. The overburden forms the first layer, with the lateritic clay revealing apparent resistivity range of 55 to 107 Ωm. Its occurrence is at a lateral distance of about 2 to 34 m and 80 to 160 m to the end of the profile. Maximum depth reached by this layer is about 6 m. Lateritic layer has apparent resistivity ranging from 107 to 393 Ωm. The layer is exposed at the surface at lateral distances of 0 to 35 m and 55 to 105 m respectively. Depth bound of this layer is from 0 to 10 m (maximum depth occurring at a lateral distance of 30 m from profile start).

The second layer along this profile is the weathered basement with apparent resistivity values ranging from 393 to 735 Ωm. This layer is partly exposed a lateral distance of 2 to 160 m along the profile and reaches depths of about 7 to 11 m. The third layer is the fractured basement which occurs beneath the weathered basement at a distance of 85 m along the profile and a depth of 10 m. The apparent resistivity ranges of this layer obtained from the inverse resistivity model ranges from 201 to 735 Ωm.

The fresh basement forms the fourth and final layer and has apparent resistivity ranges of 735 to 1132 Ωm. It also outcrops at the surface at a horizontal distance of between 50 to 55 m along the profile. It reaches depths greater than 11 m, as represented in figure 9.

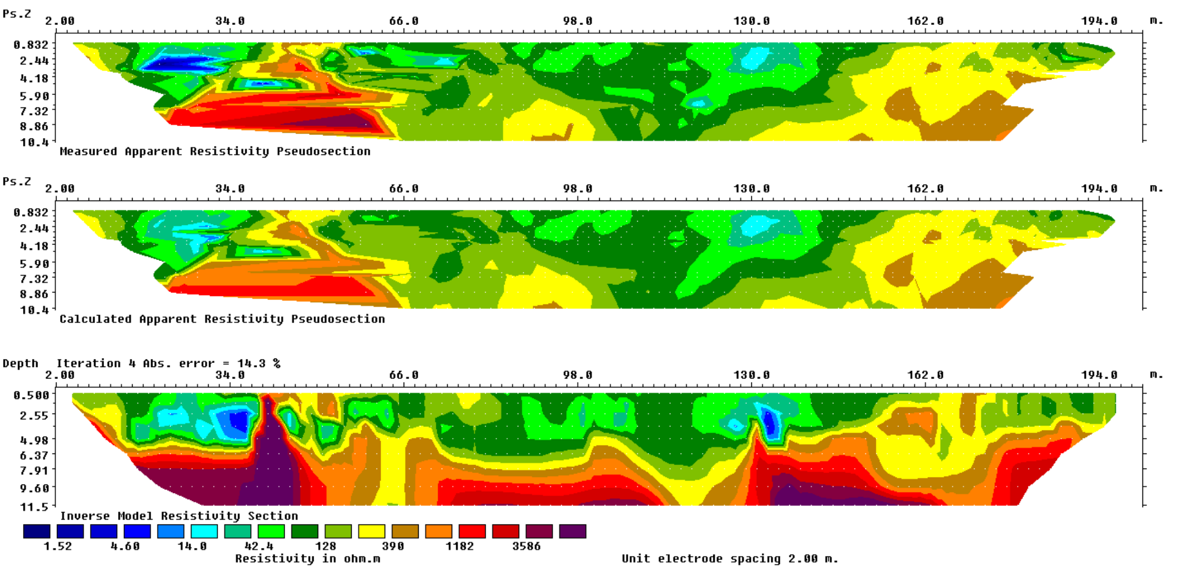



Figure 7: Result of 2D inversion of profile 3 at Toro station.

ISSN No. 2321-2705 | DOI: 10.51244/IJRSI |Volume XII Issue I January 2025

**Profile 4 at Toro Station**

The overburden consists of laterite and lateritic clay which forms the first layer in the inverse resistivity model with apparent resistivity value that ranges from 53 to 100 Ωm. It occurs laterally at distances of 10 to 55 m, 132 to 150 m and 180 to 185 m from the beginning of the profile as in figure 8.

The weathered basement which has apparent resistivity values ranging from 341 to 923 Ωm, underlies the overburden. It occurred at depths of between 4 to 7 m. The final layer along this traverse is the fresh basement with apparent resistivity greater than 923 Ωm. The layer is shallowest at depths of about 11 m at a lateral distance of about 130 m from the beginning of the profile. The fresh basement extends to depths beyond 11m.

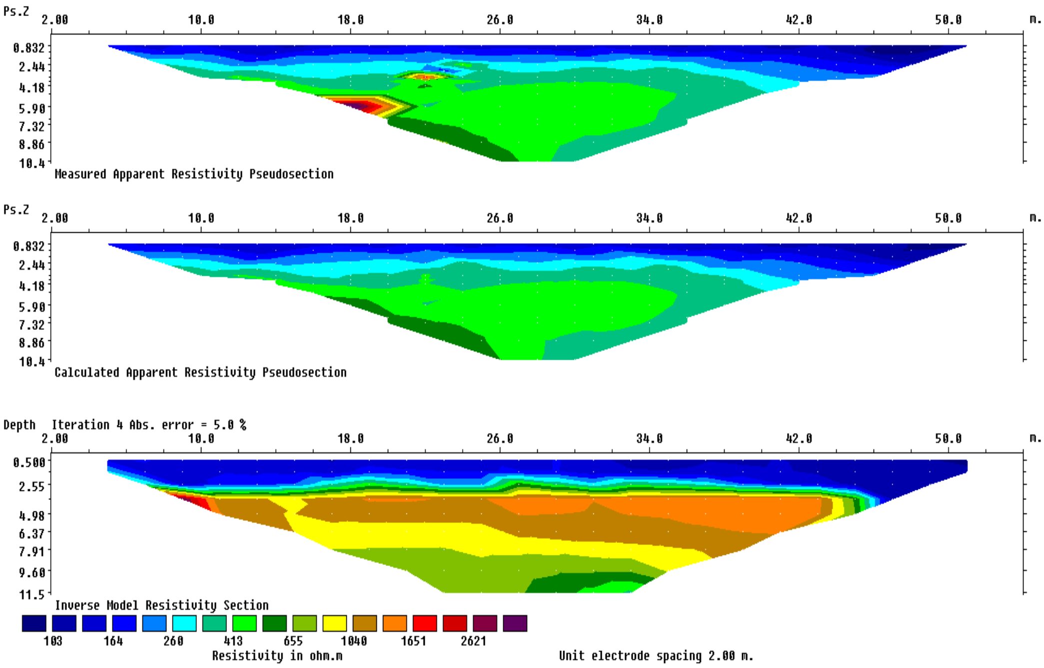



Figure 8: Result of 2D inversion of profile 4 at Toro station.

**Stacked resistivity pseudo-section of all profiles at Toro station**

The stacked resistivity pseudo-section of all profiles in Toro station, showing the continuity of the distinct layers of each study area is represented in Horizontal stacking of all profiles in figure 9.

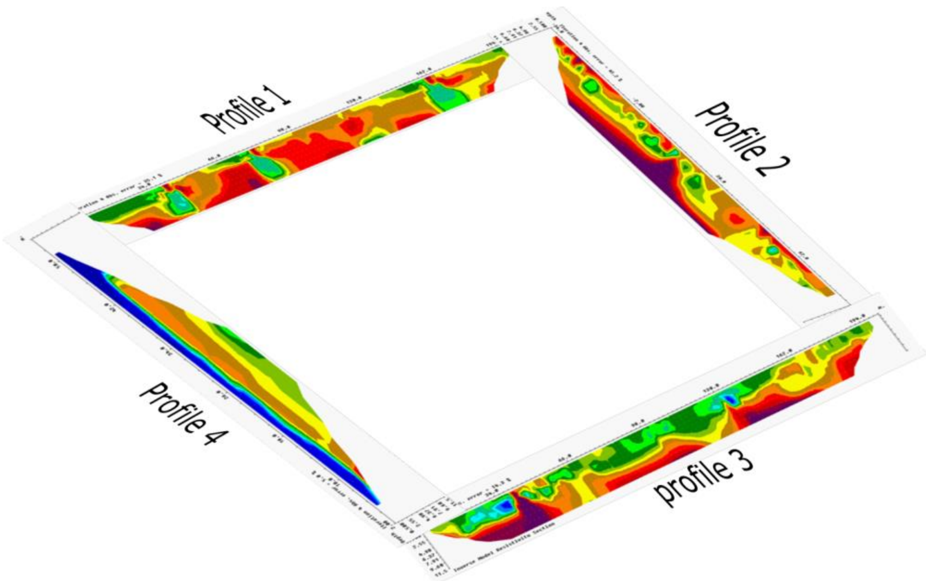
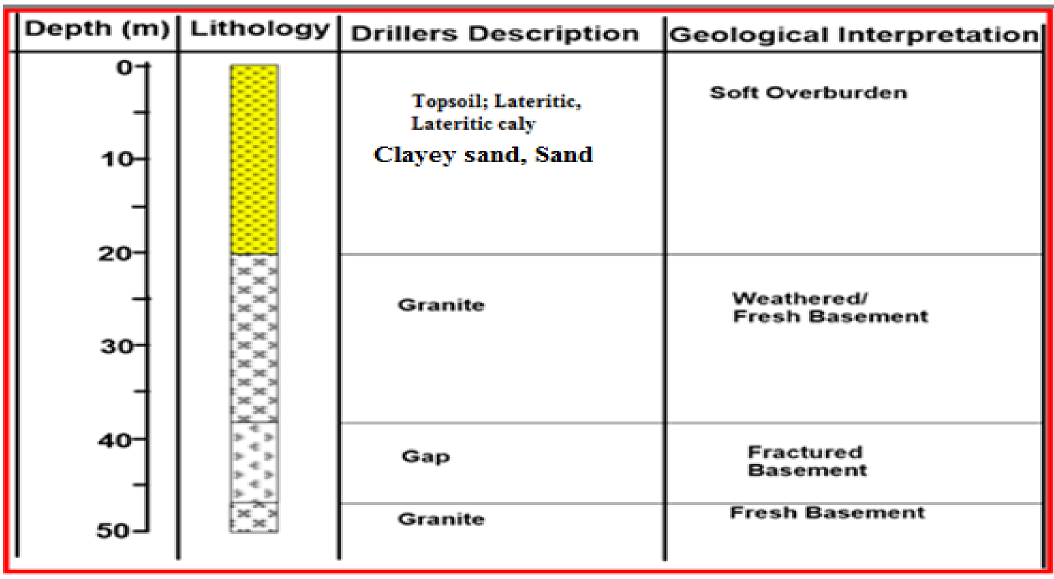



Figure 9: Horizontal stacking of all profiles at Toro station

INTERNATIONAL JOURNAL OF RESEARCH AND SCIENTIFIC INNOVATION (IJRSI)
ISSN No. 2321-2705 | DOI: 10.51244/IJRSI |Volume XII Issue I January 2025




## DISCUSSION

Specific knowledge of geology of an observatory station is extremely useful in order to accomplish the major goal of such station, which is recording quality data with less noise. The resistivity value for the topsoil layer found to be from 2 to 738**Ω**m which the thickness value ranges of 1 to 3.9meters, the weathered basement has resistivity values ranging from 32 to 1735**Ω**m and thickness value of between 0.52 and 23 meters, the fresh basement has resistivity values ranging from 100 to 6,036**Ω**m hence the underground conditions at the station influence both the seismic signal and the noise conditions and thus have a significant bearing on the potential sensitivity of an observatory station.

One may then infer a related map in terms of bedrock quality grades with respect to their suitability for the installation of an observatory equipment for recording Geo-hazards. Table 1; shows the classification of bedrock "quality" grades. This was used as guide to infer the best sites for carrying out earth observation research as well as monitor and predict geo-hazards.

Table. 1: Classification of Bedrock "quality" and Grades

| Grade | **Type of sediments/rocks** | **Seismic waves (S-wave) velocity** |
|---|---|---|
| 1 | Unconsolidated (Alluvial) sediments (clays, sands, mud) | < 100 – 600 m/s |
| 2 | Consolidated clastic sediments (shale, sandstone); schist | 500 – 2100 m/s |
| 3 | Less compact carbonatic rocks (limestone, dolomite) and less compact metamorphic rocks | 1800 – 3800 m |
| 4 | Compact metamorphic rocks (granite gneiss rocks) | 2100 – 3800 m/s |
| 5 | Magmatic rocks (granites, basalts); marble, quartzite | 2500 - > 4000 m/ |

This investigation reveals a minimum of three and a maximum of four geo-electric sections. The corresponding lithological layers were obtained with borehole log and standard resistivity values used as control. From all four stations, distinct layers were observed and varied in both depth and resistivity.

## CONCLUSSION

Considering the Toro observatory station, it was found to consist of three distinct layers; overburden (laterite and lateritic clay, with average depth of 0- 5 m), weathered (granite, with an average depth of 6-11 m) and fractured basement (with depth > 15 m). According to the quality category, this lithology falls within the grade 5, which indicates best rock for seismic recordings.

By definition, an anomaly is characterized by values markedly different from those that surround it. In depth-to-bedrock investigations, it is the top of the bedrock that is of primary interest. Defining this target as an anomaly, it is straight forward to see that it should be characterized by a large change in physical properties. Data from the resistivity profiles of Toro station shows that the bedrock is at a depth of 11- 15m.

2D electrical resistivity tomography has provided a clear view of the lithological units and geo-electrical structure underlying the study area. Each of the study area is underlain by three layers of different lithological units and how they affect seismic station data recording based on the quality grade category for best rock or soil for seismic recording. 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.

The eventual goals of the Centre for Geodesy and Geodynamics are to achieve Nigeria's capability, manpower and hardware development that can sufficiently address: Space Geodesy, Crustal deformation Monitoring, Subsidence and Global Mean Sea Level Monitoring.

## RECOMMENDATIONS

A 2D seismic refraction survey and aeromagnetic data survey should be conducted in the study area to further compliment the results for the selection of an observatory station.

It is recommended for carrying out resistivity survey to;

1. The electrode spacing should be 25cm apart if possible or 50cm apart if necessary
2. Set up the electrodes in straight line across the ground and centered above the area of interest
3. Record the measured resistivity as some instruments display the data directly while others require calculation
4. Correlate the resistivity survey with borehole data to connect resistivity signatures with specific rock or soil layers

## REFFERENCES

1. Acworth, R. I. (1987). The development of crystalline basement aquifers in a tropical environment. Quarterly Journal of Engineering Geology, 20, 265-272.
2. Barker R D. (1979). Signal contribution sections and their use in resistivity studies. Geophysics J R Astron Soc.; 59:123–129. doi: 10.1111/j.1365-246X.1979.tb02555.
3. Bernstone C., Dahlin T., and Johnson P. (1997). 3D visualization of a resistivity data set- an example from a sludge disposal site: Symp. Appl Geophys. Eng. Environ.Probl., procs., 917-925.
4. Christensen, N. B. and Sorensen, K.I. (1994). Integrated use of electromagnetic methods for hydro geological investigations. Processing of the symposium on the Application of Geophysics to Engineering and Environmental problems, March 1994, Boston Massachusetts, pp. 163 – 176
5. Dahlin T., and Loke M.H. (1997). Quasi-3D resistivity imaging mapping of 3D structures using two-dimensionaldc resistivity techniques, 3rd Mtg. Environ. Eng. Geophys. Assn., Expanded Abstract, 143-146.
6. Dahlin, T and Owen, R. (1998). Geophysical investigations of alluvial aquifers in Zimbabwe. Proceeding of the IV Meeting of the Environmental and Engineering Geophysical Society (European Section), September 1998, Barcelona Spain, pp 151 – 154.
7. Dahlin, T. (1996): 2D Resistivity Surveying for Environmental and Engineering Applications. FIRST BREAK.Vol. 14 (7): P. 275 – 283.
8. Dahlin, T., Bernstone, C., Loke, M.H., 2002. A 3D resistivity investigation of a contaminated site at Lernacken in Sweden. Geophysics 60 (6), 1682-1690.
9. Dahlin, T., Zhou, B., 2004. A numerical comparison of 2D resistivity imaging with tenelectrode arrays. Geophysical Prospecting 52 (5), 379–398.
10. Griffiths, D.H. and Barker, R.D. (1993). Two – dimensional resistivity imaging and modeling in areas of complex geology. Journal of Applied Geophysics, 29: pp. 211 – 2
11. Kearey, P., and Brooks, M. (1988). An introductory to geophysical exploration oxford, London Blackwell scientific publications,171-199ppC.A.

12. Loke, M.H. and R.D. Barker, (1996). Rapid least-squares inversion of apparent resistivity pseudo sections by a quasi-Newton method. Geophysical Prospect. 44: 131-152. DOI:10.1111/j.1365-2478. 1996.tb00142. x.
13. Loke, M.H. (2004): Tutorial: 2D and 3D Electrical Imagine Surveys (From the Internet pp. 1-136).
14. Obiadi, I.I., Onwuemesi, A.G., Anike, O.L., Obiadi, C.M., Ajaegwu, N.E., Anakwuba, E.K., Akpunonu, E.O. and Ezim, E.O. (2012). Imaging subsurface fracture characteristics using 2D electrical resistivity tomography. International Research Journal of Engineering Science, Technology and Innovation (IRJESTI) Vol. 1(4) pp. 103-110.
15. Oldenburg, D. W., Li, Y. (1999). Estimating depth of investigation in DC resistivity and IP survey Volume 64 Issue 2 Mar 1999 Pages: 323-649ISSN (print):0016-8033ISSN (online):1942-2156
16. Ritz, M., Parisot, J. C., Diouf, S., Beauvais, A and Dione, F. (1999). Electrical imaging of lateritic weathering mantle over grain and metamorphic basement of eastern Senegal, West Africa. Journal of Applied Geophysics, 41, pp. 335 344.
17. Teme, S. C. (1984). “The main observatory Monument at the Toro Center for Geodesy and Geodynamics. Initial field investigations, paper delivered at the NASRDA Technical Advisory Committee Meeting, Abuja, sept.21.35pp.
18. White, R.M.S., Collins, S., Denne, R., Hee, R., Brown, P., 2001. A new survey design for 3D IP modelling at Copper hill. Exploration Geophysics 32 (4), 152–155.