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Geophysical Survey of An Area Within Moshood Abiola Polytechnic, OJEERE Campus, Abeokuta, Southwest Nigeria

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Abstract - Geophysical surveys were carried out within Moshood Abiola Polytechnic, Ojeere Campus; situated within the southeastern part of Abeokuta, Southwest Nigeria. It covers about 960 hectares of land bounded by Ogun river to the south which covers the latitudes of 7°5'40" and 7°6'0"N and longitudes 3°19'30"E & 3°20'10" E respectively; it is within the basement complex area of Ogun state. Eight geophysical techniques such as EM method, Magnetic method, Gravity method, VLF method, SP method, Seismic method, CST and VES were employed along a traverse line with longitudes 7° 5.812 and 7° 5.726 and latitudes 3° 19.568 and 3° 19.525; of about 180m long. This was with the purpose of delineating zones of anomaly which were integrated for the proper delineation of subsurface strata, investigate the nature of the subsurface basement, fracture zones and the estimation of overburden thickness. The geophysical techniques such as CST, Seismic refraction, VLF and VES reveal three to four types of lithologies including topsoil, weathered layer, partially weathered layer, and fractured/fresh basement. The depth to basement was observed to be shallow with ranging from about 8-42m. The geophysical methods reveal some zones of anomaly which are areas of interest for groundwater exploitation, geotechnical foundation investigation, clay deposits investigation and for further research purposes.

Key words: Geophysical Survey; Field Mapping; Basement Complex, Subsurface. Moshood Abiola Polytechnic

I. INTRODUCTION

Geophysical field mapping exercise involved the imaging of the subsurface with eight geophysical methods; which were integrated together with the purpose of detecting anomalies.
Areas or spots of anomaly within the subsurface helps in detecting zones of interest for resources exploitation (in water, economic minerals, crude oil etc) for economic purpose or detecting incompetent subsurface layers (in road constructions, dams, embarkment, slopes, buildings etc) to ensure stability and durability of the structures and to avoid distress and failure of the structures which may result in loss of lives and properties.

The data obtained from the various geophysical methods were processed to give graphical and/or image representation of the acquired field data with a view of detecting areas of interest as anomalous zones, which helps in decision taking for economic resourses exploitations or detection of competent subsurface zones or otherwise for engineering construction purposes.

According to Soller, 2002, delieating zones of anomaly on a Geologic map helps in predicting zones of aquifers for water exploration and exploitation, ground water quality and contamination risks, earthquake predictions, zones of possible oil accumulations, landslide hazards, harnessing energy and mineral resources for economic growth, land-use planning and land management.
The geophysical mapping exercise in this report was carried within the campus of Moshood Abiola Polytechnic, Ojere Campus, southeastern Abeokuta, Southwestern Nigeria.

The mapping exercise was carried out between December 4-8, 2021 with the aim of delineating the subsurface lithologies, fracture zones, notable structural features etc
The area has a flat topography with gentle steeping slopes in some areas.that ranges from mountains, hills to flat lying outcrops.
The Ojeere campus is situated in the South-Eastern part of Abeokuta which covers about 960 hectares of rolling land bounded by Ogun river to the south which covers the latitude of 7°6′0″N and longitude of 3°20'10" E respectively.(Sodunke et al.,2019)

1.1 BACKGROUND OF STUDY

Geophysical methods are employed to provide information about the physical properties of the earth's; which are generally divided into the active and passive methods. The essence of using geophysical methods is to detect zones of anomaly which can give information about incompetent layers for foundation structures, area of crude oil accumulation in oil prospecting in the petroleum industry, detecting aquifers for underground water exploration or for mineral exploration

The information provided by these methods can be applied to sites with undesired or buried objects, to determine other geologic and hydrogeologic conditions, of the subsurface.

In the most generalized sense, geophysics is the application of physical principles to define geology and study geomaterials; for example, soil or rock (Greenhouse and Pehme, 2001)

It involves the study of those parts of the earth hidden from direct view by measuring their physical properties with appropriate instruments, usually on the surface. It also includes interpretation of the measurements to obtain useful information on the structure and composition of the concealed zones (Dobrin and King 1976). Whether active method or passive method geophysics affords the opportunity to cost effectively sample large volumes of the subsurface using such principles as seismic or electromagnetic (EM) wave transmission, electrical current flow, magnetic and gravity potential fields. The science is technical in its application, and is quantitative in its measurement, yet it provides only the qualitative information about geomaterial properties needed by engineers. For example, it does not directly measure density, moisture content, or stiffness, but provides a relationship between a measured value (e.g., seismic velocity) and the physical parameter that governs it (e.g., density).

The purpose of using geophysics, as defined for this study, is to identify and characterize physical properties of subsurface whose benefits include: reduced project costs, better and broader subsurface characterization, increased speed of acquisition, and utilizing a non-invasive approach to evaluate subsurface conditions.

Over the past 10 years the increased need to reduce risk for the design and construction of engineered structures has dictated better instrumentation and data processing software, as well as added educational opportunities, to effectively make geophysical technologies available.

The passive geophysical method also called non-contacting techniques such as ground conductivity, magnetometry, and gravity surveying are important in profiling, electrical resistivity traversing and sounding. Here the objective is to determine the boundaries between the different beds of soil or rock, in order either to correlate among boreholes or to infill between them. Techniques used for subsurface investigation include electrical resistivity, depth sounding methods and geophysical borehole logging. Sectioning is carried out to provide cross-sections of the ground, generally to give details of beds and layers. It is potentially useful when there are marked contrasts in the properties of the ground (as between the stiffness and strength of clay and rock), and the investigation is targeted at finding the position of a geometrically complex interface, or when there is a need to find hard inclusions or cavities. In addition, as with vertical profiling, these techniques can allow extrapolation of borehole data to areas of the site which have not been the subject of borehole investigation.

One of the major needs of any ground investigation is the classification of the subsoil into groups with similar geotechnical characteristics. Geophysical techniques are not generally of great use in this respect, except in limited circumstances. An example occurs where there is a need to distinguish between cohesive and non-cohesive soils. Provided that the salinity of the groundwater is low, it is normally possible to distinguish between these two groups of materials using either electrical resistivity or ground conductivity.

Finally, almost all geotechnical ground investigations aim to determine stiffness, strength, and other parameters in order to allow design calculations to be carried out.

This section provides an overview to some common geophysical methods that are used during investigation of subsurface investigations generally.

Geophysical methods such as the Electrical Resistivity (ER), Seismic Refraction, Electromagnetic (EM), Magnetic and Ground Penetrating Radar are used singly or in combinations for engineering site investigation, crude oil exploration, groundwater investigation and/or mineral exploration

1.2 GEOLOGY OF THE STUDY AREA

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The area of survey (MAP) is within the crystalline basement complex area of Ogun state (Figure 1.1) within the southwestern Nigeria basement complex; which lies between latitudes 7ºN and 10ºN and longtitudes 3ºE and 6ºE right in the equatorial rain forest region of Africa The main rock types within Abeokuta include the quartzite, migmatite gneisses, granites and gneiss with varying notable structural features such as fractures, faults, quartz veins, xenoliths etc.

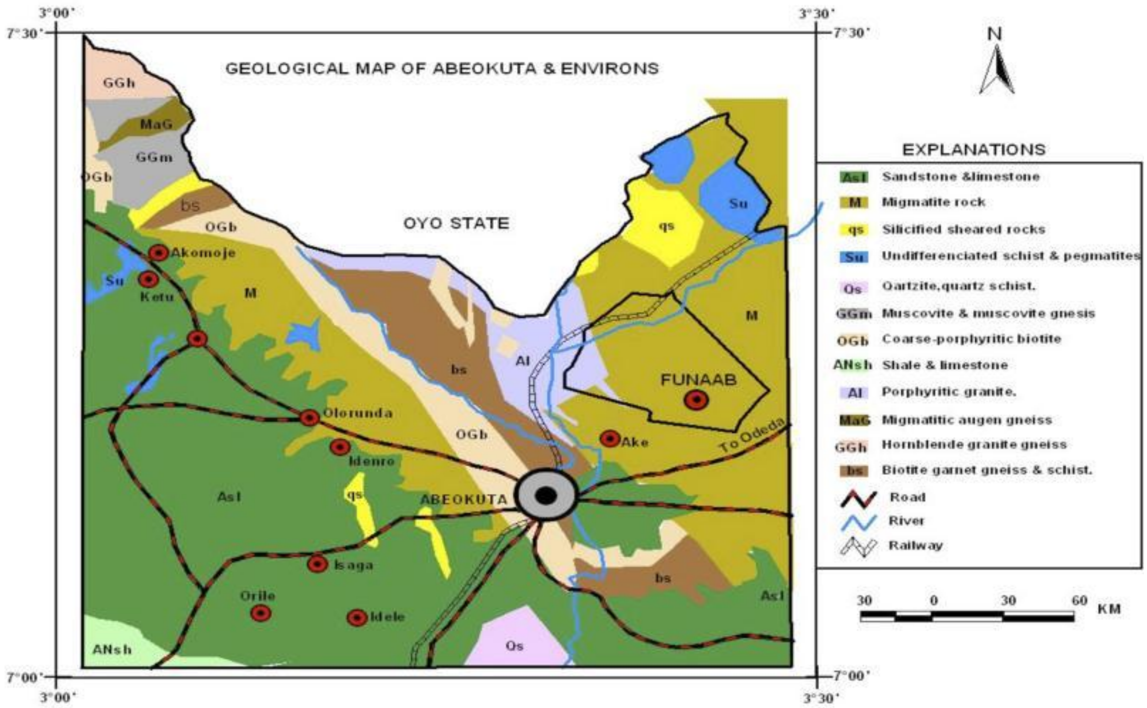

Fig. 1.1 Geological map of Abeokuta (After Olurin et al, 2016)

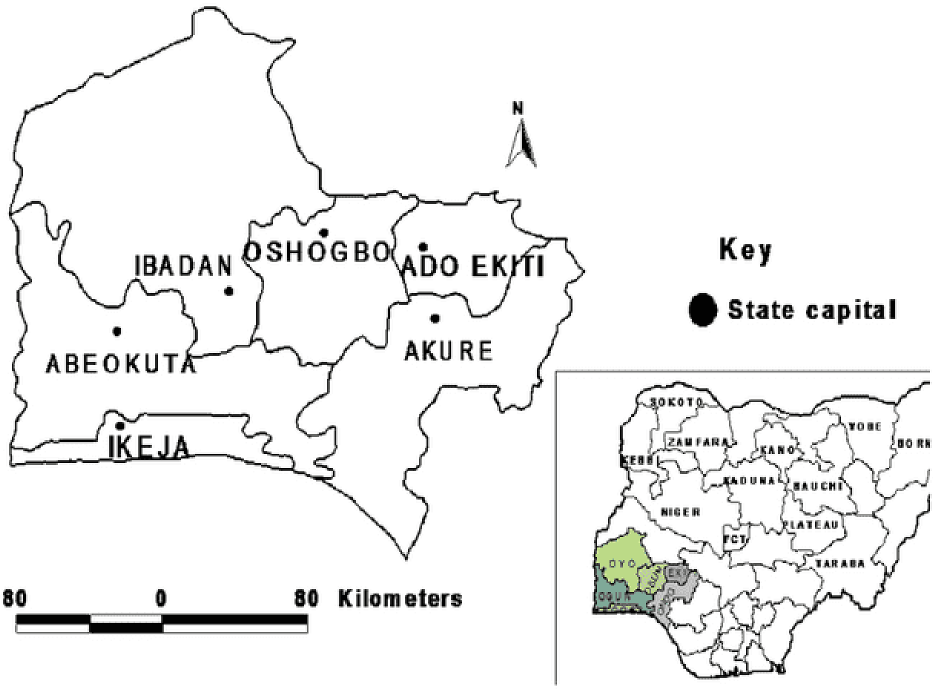

Fig..1.2: Map of Southwest, Nigeria showing the capital cities of Southwestern states.

1.3 DESCRIPTION OF THE STUDY AREA

The study area is within the Ojere campus of Moshood Abiola Polytechnic also known as MAPOLY, a tertiary institution of learning located in the South-Eastern part of Abeokuta, Ogun State, Southwest Nigera It covers about 960 hectares of land bounded by Ogun river to the south which covers the latitudes of 7°5′40″ and 7°6′0″N and

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longitudes of3°19'30"E 3°20'10" E respectively.(Sodunke et al., 2019)
Eight geophysical methods were employed along the traverse line (Fig. 1.3) to detect anomalous zones which were interpreted based on the variation of geologic properties within the subsurface

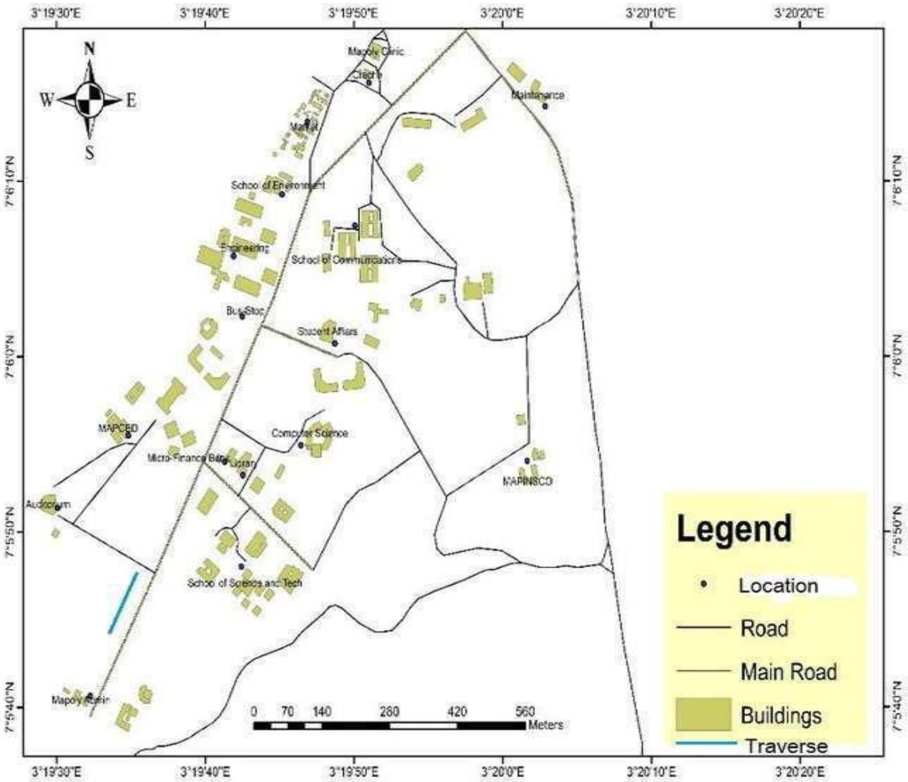

Fig.1.3 Base map of the study area showing the traverse line (About 180m) along which the eight geophysical methods were employed.

II. BASIC THEORY

2.1 Magnetic Method:

Magnetic surveying is an example of a passive method. The survey simply measures the strength of the local geomagnetic field and seeks anomalies in the field.
An anomaly arises when the local effect of a magnetic body is superimposed on the regional geomagnetic field.
Thus to recognise and interpret anomalies we have to understand both the structure and variability of the geomagnetic field and the magnetic character of buried objects, both natural and man-made.
It is non-axial, not centered on the earth and varies over a human lifetime.
Magnetic method measures the magnetic intensity of the earth whose values range between 25,000nT and 65,000nT .
This method is used to investigate the subsurface geology of an area by detecting anomalies within the Earth's magnetic field; which are caused by the magnetic nature of the underlying rocks.
Proton precision Magnetic meter(Scintrex) (Fig.3.01)is the instrument used in the acquisition of the data.

2.2 VLF (Very Low Frequency) Method

This method measures the electromagnetic variations which help in measuring the variations in conductivity of the subsurface.
The VLF receiver makes use of high-power military communications transmissions in the 15-25KHz band.
The VLF magnetic field induced eddy current which produces secondary magnetic fields with same frequency as the primary magnetic field but generally with a different phase.
The VLF instrument measures the tilt angles with real components (In phase and the imaginary component (Quadrative phase) at 150% and 40%(+ or -) respectively.

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It utilizes Very Low Frequency radio communication signals to determine electrical properties of near-surface soils and shallow bedrock (Mcneill and Labson, 1992). The technique is especially useful for mapping steeply dipping structures such as faults, fracture zones and areas of mineralization. In the reconnaissance mode, VLF profiles can be run quickly and inexpensively to identify anomalous areas which may require further investigation; either with more detailed geophysical measurements and/or drilling and sampling.

VLF can detect long conductors such as electric cables, pipelines, and certain bedrock fractures. The reception is best in the morning, but adequate all day. In order for the VLF method to be effective in detecting underground geologic structures, the structure must have:

1) The direction of its long axis within 30 degrees relative to a line tangent to the concentric rings that "ripple" from the transmitter (to initiate induction);
2) Minimum dimensions of approximately 50 meters in length, 10 meters in depth, and about one meter in thickness;
3) A dip angle not less than 30 degrees from horizontal; and
4) Higher electrical conductivity than the surrounding material.

The receiver for detecting VLF signals measures a tilt and quadrature component by means of two mutually perpendicular coils wound on ferrite cores. The coil whose axis is normally vertical is held in a horizontal position and rotated in azimuth to find a minimum.

This direction is in line with the transmitter station and is usually well defined (Telford et al., 1990). The same coil is first held vertically and tilted about a horizontal axis parallel to the direction of propagation. The second coil is rigidly mounted at right angles to the first. Its signal is shifted in phase by 900 and, connected in series with the vertical coil through which signal is fed into the receiver. The amplitude of this signal is adjustable on the quadrature dial, which reads percent plus or minus. A clinometer on the instrument allows tilt angle measurement. By tilt and quadrature adjustments, a good minimum is obtained. (Telford et al.,1990).

VLF instruments are "back pack" portable and operated by one person. Productivity depends on the terrain and vegetation, but generally several kilometers of line may be covered in a good day.

Precaution

- Take note of any signal pole(s) around and make necessary corrections when the data is being processed;
- Ensure that the military transmission station is always used as a reference for the direction of readings taking.

2.3 Gravity Method

This method adopts the principles of Newton's law of universal gravitation and Newton's second law of motion which are stated below:

-The gravitational force between two objects is directly proportional to their masses (m1, m2), and inversely proportional to the square of their distance (r).

-The mass (m1), times the acceleration (a) due to mass (m2), determines the gravitational force (F).

F=m1 a

-The acceleration due to gravity (a=g) of a body depends only the mass of attracting body (m2=M) and the distance to the center of that mass (r=R).

g=GM/R2

The variation of g across the earth's surface provides information about the distribution of density contrasts in the subsurface since m = □V (i.e. density x volume).

Like apparent conductivity and resistivity, the acceleration of gravity (g) is a basic physical property we measure, and from which, we infer the distribution of subsurface density contrast.

This method responds to the variation in the Earth's gravitational field due to density variations in the subsurface.

A variation in the density will result due to the presence of a body with varying density from those of the surrounding lithologies.

The instrument used was CG5 Autograv(Fig. 3.04) which measures the absolute value of gravity at discrete positions.

objective in exploration work is to associate variations with differences in the distribution of densities and hence rock types. Occasionally the whole gravitational field is measured or derivatives of the gravitational field, but usually the difference between the gravity field at two points is measured

2.4 Seismic Method

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The basic principle behind this method is the generation of elastic waves by a seismic source in order to 'image' the subsurface.
Seismic refraction method is applicable in the determination of rock competence for engineering application, depth to bedrock, groundwater exploration, crustal structure and tectonics. The seismic refraction method is based on the measurement of the travel time of seismic waves which are refracted at the interfaces between subsurface layers of different velocity (Ayolabi et al., 2009).

The seismic signal is introduced into the subsurface via a shot point using explosives, hammer blow, dropped weight or an elastic wave generator (Igboekwe and Ohaegbuchu, 2011). The energy generated either travels directly through the upper layer (direct arrivals), or travel down through the various layers before returning to the surface (refracted arrivals). The energy is then detected on surface at a series of receivers called geophones spaced at regular intervals (Anomohanran, 2012).

After a certain distance from the shot point, known as the cross over distance, the refracted signal is observed as a first arrival signal at the geophones (arriving before the direct arrival). Both compressional waves (P-waves) which provide depth information of interfaces and Shear waves (S-waves) which provide additional data about engineering properties of the subsurface media can be used in the seismic refraction method (Gabr et al., 2012). In seismic refraction method, the signal from the shot returns to the surface by refraction at subsurface interfaces and is recorded at distances much greater than the depth of investigation (Igboekwe and Ohaegbuchu, 2011). The method relies on the tendency of acoustic velocities to increase with depth, which sometimes makes it insensitive to low velocity layers in the subsurface. Based on the analysis of the field data, the seismic surveyor draws a profile showing the thickness of the subsurface and a good idea of what materials they consist of (Ayolabi et al., 2009).

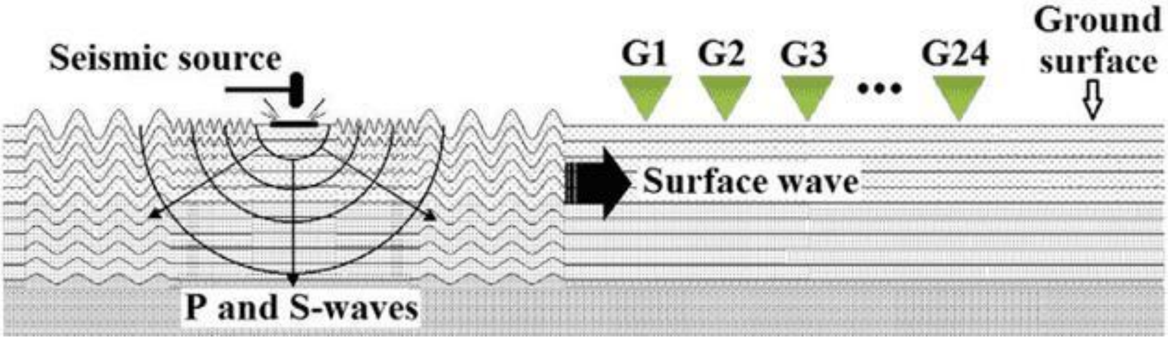

Fig. 2.1 : A model of seismic refraction method

2.5 Spontaneous Potential (SP) Method
The SP method is a passive method; which means no current is required to be injected into the ground. This method measures the natural potential of the subsurface which is due to;

i. Electrochemical interactions between minerals and subsurface fluid;
ii. Thermoelectric mechanism from temperature gradients;
iii. Electrokinetic process from the flow of fluid.

The self-potential method uses the principle of the surface measurement of natural potential differences resulting from electrochemical reactions in the subsurface.
This is possible by being able to calculate the potential distributions around polarized bodies, thus making assumptions about the distribution of charge over their surfaces. The anomalous body is assumed to occur directly over the anomaly minimum, although it may be displaced downhill in areas of steep topography. The depth of the anomaly can be estimated by the anomaly half width. The symmetry or asymmetry of the anomaly provides information on the attitude of the body, the steep slope and positive tail of the
anomaly lying on the down dip side. The type of overburden can have a pronounced effect on the presence or absence of SP anomalies. Sand has little effect but a Clay cover can mask the SP anomaly of an underlying body. The SP method is only of minor importance in exploration. This is because quantitative interpretation is difficult and the depth of penetration is limited to about 30m. It is, however, a rapid and cheap method requiring only simple field equipment.

Consequently, it can be useful in rapid ground reconnaissance.

2.6 Electromagnetic (EM-34) Method

EM survey is based on the response of the ground to the propagation of the EM field which is composed of an alternating electric intensity and magnetizing force.

A primary field is generated when an alternating current is passed through the coil placed over the ground surface.

The magnetic field flows into the earth surface which makes a conductive body within the subsurface to produce an eddy current .The eddy current in turn produces the secondary magnetic field; whose signal is received by the receiver.

The response of the receiver differs in phase and direction (Since the primary magnetic field above the earth surface did not undergo altering process unlike the secondary field)

Electromagnetic method is one of the geophysical methods commonly used in foundation investigation and environmental studies (Olorunfemi & Mesida, 1987; Sharma, 1997; Osinowo et al 2011).

Electromagnetic method makes use of a response of the ground to the propagation of electromagnetic fields which are composed of an alternating electric intensity and magnetizing force. There is a close analogy between the transmitter, receiver and buried conductor in the electromagnetic field situation, and a trio of electric circuits coupled by electromagnetic induction.

The electromagnetic ground method was developed in regions where the detection of conductive base metal deposits was facilitated by their large contrast with the resistive host rock and generally thin overburden. Practically, all electromagnetic equipment transmits and receives continuously, one frequency at a time. Such a continuous wave system is said to be operating in the frequency domain (Telford et al., 1990). Almost all electromagnetic fields equipments include a portable power source. However, limited use, have also been made of radio transmission stations in the frequency range of about 10 KHz to 100KHz and recently in the very low frequency range 5 to 25 KHz. One other field method that can be reasonably applied with electromagnetic method, is the AFMAG (audio-frequency magnetic fields), which makes use of atmospheric energy resulting from worldwide thunder storm.

An advantage of the inductive coupling is that it permits the use of electromagnetic systems in aircrafts. Airborne electromagnetic method, usually in combination with aeromagnetic equipments, has been widely used in mineral exploration reconnaissance and recent surveys.

2.7 Electrical Resistivity Survey

Electrical method employs direct currents or low frequency alternating currents to investigate differences in the electrical properties of materials in the subsurface. In the resistivity method, artificially-generated electric currents are introduced into the ground and the resulting potential differences are measured at the surface. Deviations from the pattern of potential differences expected for homogeneous ground provide information on the form and electrical properties of subsurface inhomogeneity.

The resistivity method is based on the principle of Ohm's law propounded by the German physicist; Georg Simon Ohm in 1827. The law establishes a relationship between the electric current I in a conducting wire, and the potential difference V across it. The linear relationship is expressed by the equation:

$$V = IR \qquad (2.1)$$

Where the R is the resistance of the conductor (Lowrie, 1997)

It was further shown that for a given material, the resistance R is proportional to the length L and inversely proportional to the cross-sectional area A of the conductor, expressed in the following equation

$$R = \rho \frac{L}{A} \qquad (2.2)$$

The proportionality constant ρ is the resistivity of the conductor measured in ohm-meter (Ωm). It is a physical property characteristic to the material of the conductor, which express its ability to oppose a flow of current as represented in figure 2.1. The inverse of ρ is the conductivity σ (Siemens per meter) of the material.

$$\sigma = \frac{1}{\rho} \qquad (2.3)$$

$$E = \frac{V}{L} \qquad (2.4)$$

$$J = \frac{I}{A} \qquad (2.5)$$

Where J=Current density,

Inserting equation (2.1) into equation (2.2), and rearranging the terms, we have

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$$\frac{V}{L} = \rho \frac{I}{A} \quad (2.6)$$

Thus, substituting for equation (2.4) and (2.5) in equation (2.6), Ohm's law can then be rewritten as

$$E = \rho J \quad (2.7)$$

This form is very useful in calculating the formulas used in resistivity methods of electrical methods of electrical surveying. However, the measured quantities are *V* and *I* (Lowrie, 1997).

Resistivity Method Principles
With an electrical current passed into the ground via two electrodes known as current electrodes, the two potential electrodes record the resultant potential difference betweenthem, depending on the arrangement or configuration of these pairs of electrodes, the current and potential measurements may be used to calculate resistivity. Therefore, a direct measure of electrical impedance of the subsurface material can be obtained. This method is based on the fact that there is a large contrast in the resistivity values of the different layers in the subsurface and is also used to characterize vertical and lateral changes in subsurface electrical properties. Figure 3.11 and 3.12 shows the basic concept of resistivity measurement.

2.7.1. Constant Separation Technique (CST) Method
The basic principle behind this method involves sending current into the ground via current electrodes; which generates a potential gradient within the subsurface.
The potential difference generated in the subsurface is measured by resistivity meter through the potential electrodes using Wenner array configuration.
It is the use of an electrical prospecting arrangement with fixed spacing of electrodes by moving the system progressively along profiles, detecting changes in resistivity of the earth as one move along the profile. Hence, it measures lateral variation of apparent resistivity. This method is employed in mineral prospecting to locate faults or shear zones and to detect localized bodies of anomalous conductivity. It is also used in geotechnical surveys to determine more importantly the presence of steep discontinuities. Results from a series of CST traverses with fixed electrode spacing can be employed in the production of resistivity pseudosections.

2.7.2 Vertical Electrical Sounding (VES) Method
VES is used to measure ground (Subsurface) resistivity by passing current through two current electrodes and deducing the voltage between a pair of potential electrode (Potential Difference) sing the relationship between voltage and current, the resistance is determined using Ohm's law:
R=V/I
Where
R=Resistance
V=Voltage
I= Current
Schlumberger array was used in conducting the VES. This consis four electrodes with two outer current electrodes and two inner potential electrodes(Fig.3.12) The difference between this array and the Wenner array is the distance between the potential electrodes with respect to the distance between the current electrodes.
The potential electrodes are connected to the ground with a distance of less than one-fifth of the distance between the current electrodes.

The advantages this array has over Wenner array are
- ✓ -fewer electrodes are required to be moved for each sounding;
- ✓ -cable length for potential electrodes is shorter;
- ✓ -better resolution; greater probing depth; And less time-consuming.

The Resistance values got from the Pasi terrameter were converted to their respective apparent resistivity values using the K-factor.
The apparent resistivity values were then plotted against the corresponding AB/2 (m) on a log-log graph with tracing paper. The curve-matching for each VES point was then made manually for the calculation of the real resistivity values of each lithologic unit and their corresponding thickness.
The curves were then filtered and the apparent resistivity values with their corresponding AB/2 values were imputed into a software known as WINRESIST (Version 1.0) to produce the curve-matched plots showing the real resistivity values of each lithologic unit and their corresponding thickness.

III. METHODOLOGY

3.1 DATA ACQUISITION

3.1.1. Magnetic Method

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This method is used to investigate the subsurface geology of an area by detecting anomalies within the Earth's magnetic field; which are caused by the magnetic nature of the underlying rocks.

Proton precision Magnetic meter(Scintrex)(Fig.3.01)is the instrument used in the acquisition of the data.

Data acquisition

The data was acquired by stop-and-go method with readings taken at 5m interval from each other on a traverse of 180m

Figure 3.01 Proton sensor that was connected to the magnetometer

Procedure

- Magnetometer (the Scintrex CS-3) was set up in readiness for the data acquisition . The proton magnetometer was connected to the sensor via the cable;

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- It was attached to the body of the person taking the reading; after which a base station was established;
- The geographic north was determined by a compass;
- The magnetometer was switched on with the sensor aligned to the direction of the geographic before taking the first readings at the base station;
- Subsequent readings were taken at each point of 5m interval along the traverse;
- Readings were taken at every 30minutes intervals at the base station;
- The coordinate of each point and that of the ase station were recorded

Precaution

- Avoid metallic materials around the area of survey to minimise errors in the readings; which must be corrected for incase the metallic materials are not avoidable
- Take note of any buried cables, metals or pipe

Table 3.01:Acquired data for the Magnetic method

S/N	Long (DD)	Lat (DD)	TIME (HH:MM:SS)	R1(nT)	R2(nT)	R3(nT)	Mean (nT)	E (m)
BS1	7.09637	3.32578	11:53:19	2744.3	3718.0	3898.0	3453.4	69
1	7.09687	3.32613	11:55:46	3632.5	3083.9	3028.4	3248.3	47
2	7.09670	3.32610	11:56:27	8904.3	7496.8	6786.9	7729.3	46
3	7.09677	3.32608	11:57:19	3136.6	4041.9	3792.1	3656.9	48
4	7.09672	3.32607	11:58:05	4037.2	3929.4	3495.3	3820.6	46
5	7.09667	3.32605	11:58:47	3970.0	4629.2	3187.4	3928.9	45
6	7.09662	3.32602	11:59:30	4141.2	3893.8	3345.5	3793.5	44
7	7.09660	3.32598	12:00:07	59313.2	66214.3	67987.1	64504.9	45
8	7.09657	3.32598	12:01:29	3836.4	4237.3	3214.5	3762.7	45
9	7.09653	3.32598	12:02:30	64391.2	56443.8	55662.1	58832.4	41
10	7.09645	3.32597	12:02:50	53730.5	79196.1	68519.5	67148.7	36
11	7.09642	3.32593	12:03:35	3760.5	3425.5	3333.6	3506.5	38
12	7.09638	3.32592	12:04:13	3755.7	3248.0	3128.1	3377.3	41
13	7.09635	3.32590	12:04:44	3954.7	3468.7	4428.4	3950.6	45
14	7.09618	3.32585	12:05:22	3495.7	3980.2	3757.6	3744.5	44
15	7.09628	3.32585	12:05:59	3518.8	3820.4	3449.3	3596.2	42
16	7.09623	3.32583	12:06:42	58594.1	59228.7	56128.3	57983.7	40
17	7.09620	3.32582	12:07:19	3933.4	3091.8	3557.2	3527.5	37
18	7.09617	3.32577	12:07:57	4623.3	3516.4	4664.5	4268.1	39
19	7.09612	3.32577	12:08:26	3503.1	3073.9	4291.6	3622.9	41
20	7.09607	3.32575	12:09:23	52620.5	55255.3	72391.9	60089.2	36
21	7.09605	3.32573	12:09:58	3698.7	2918.2	3220.7	3279.2	37
22	7.09600	3.32568	12:10:32	3191.4	3397.3	2971.5	3186.7	36
23	7.09597	3.32568	12:11:06	2974.2	3176.5	2820.2	2990.3	37
24	7.09590	3.32563	12:11:55	4606.4	3059.2	3656.4	3774.0	35
25	7.09587	3.32560	12:12:45	50912.4	57734.9	75553.4	61400.2	35
26	7.09583	3.32560	12:13:56	3927.5	2923.5	3169.5	3340.2	34
27	7.09578	3.32558	12:14:58	3887.5	3949.6	3960.4	3932.5	32
28	7.09575	3.32555	12:15:30	3254.1	3673.8	3670.5	3532.8	32
29	7.09570	3.32552	12:16:07	4077.4	4518.6	3541.5	4045.8	33
30	7.09567	3.32552	12:16:48	3730.1	3286.7	3113.4	3376.7	32
31	7.09562	3.32548	12:17:18	42138.5	65417.6	57726.3	55094.1	31

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32	7.09558	3.32548	12:18:58	3668.4	3393.0	3458.1	3506.5	29
33	7.09553	3.32547	12:20:04	2598.7	3333.9	2892.8	2941.8	30
BS2	7.09637	3.32578	12:22:04	95249.3	95750.0	88476.9	93158.7	69
34	7.09552	3.32545	12:24:08	21178.1	47456.3	44454.1	37696.2	31
35	7.09545	3.32542	12:24:59	71434.7	12758.1	20938.0	35043.6	30
36	7.09543	3.32542	12:25:00	12523.3	19538.1	17242.1	16434.5	28
BS3	7.09637	3.32578	12:28:58	3932.2	3233.4	3778.9	3648.2	69

BS: Base Station   Lat: Latitude   E: Elevation
Long: Lontitude   R: Magnetometer reading

3.1.2. VLF (Very Low Frequency) Method
This method measures the electromagnetic variations which helps in measuring the variations in conductivity of the subsurface.
The VLF receiver makes use of high power military communications transmissions in the 15-25KHz band.
Waves at VLF frequencies propagate very efficiently over long distances.
The user has no control over the amplitude and phase of the signal. The VLF magnetic field induced eddy current which produces secondary magnetic fields with same frequency as the primary magnetic field but generally with a different phase.
The VLF instrument measures the tilt angles with real components (In phase and the imaginary component (Quadrative phase) at 150% and 40%(+ or -) respectively.

Fig. 3.02 VLF receiver

Procedure of VLF method
- The VLF receiver was turned on after which it was moved elliptically to determine the point with the lowest sound to locate the direction of the military transmission station;
- Readings were taken at directions perpendicular to the direction of the military transmission station starting from the first point along the traverse line with 5m interval;
- Readings were taken at the caliberation of 0-150% for the in-phase while the curvature measurements was taken between 40% at each sampling location

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VLF method was used to detect possible fracture zones at distance of 20 m along the traverse from a depth of about 15m and at 50m from the depth 10m and below. These possible fractures zones beneath these traverses suggest good locations for presence of groundwater. They are also areas to investigate subsurface layer competence for building foundation

Table 3.02: Acquired data for VLF method

S/N	Station (m)	Long (DD)	Lat (DD)	InPhase	QuadPhase	FRASER_IN	FRASER_QUAD	ELEVATION (m)
1	0	7.09687	3.32613	105	14	45	1.4	47
2	5	7.09670	3.32610	110	13	-40	3.3	46
3	10	7.09677	3.32608	140	14.2	10	8	48
4	15	7.09672	3.32607	120	14.2	95	9.6	46
5	20	7.09667	3.32605	90	16.3	-10	5.9	45
6	25	7.09662	3.32602	180	20.1	-65	4.3	44
7	30	7.09660	3.32598	125	20	-20	2.1	45
8	35	7.09657	3.32598	135	22.3	5	0.1	45
9	40	7.09653	3.32598	105	22.1	30	0	41
10	45	7.09645	3.32597	135	22.3	32	-0.1	36
11	50	7.09642	3.32593	110	22.2	-58	-10.2	38
12	55	7.09638	3.32592	160	22.2	-100	-20.4	41
13	60	7.09635	3.32590	117	22.2	-50	-9.2	45
14	65	7.09618	3.32585	95	12	-21	2	44
15	70	7.09628	3.32585	82	12	-12	3	42
16	75	7.09623	3.32583	80	13	-12	1	40
17	80	7.09620	3.32582	76	13	-14	-3	37
18	85	7.09617	3.32577	74	15	-13	-2	39
19	90	7.09612	3.32577	70	12	-8	1	41
20	95	7.09607	3.32575	66	13	-8	5	36
21	100	7.09605	3.32573	65	12	-12	6	37
22	105	7.09600	3.32568	63	14	-13	3	36
23	110	7.09597	3.32568	60	16	-12	2	37
24	115	7.09590	3.32563	56	16	-14	1	35
25	120	7.09587	3.32560	54	17	-16	0	35
26	125	7.09583	3.32560	50	17	-14	1	34
27	130	7.09578	3.32558	46	17	-13	4	32
28	135	7.09575	3.32555	42	17	-13	3	32
29	140	7.09570	3.32552	40	18	-11	-2	33
30	145	7.09567	3.32552	35	20	-11	-1	32
31	150	7.09562	3.32548	34	18	-12	2	31
32	155	7.09558	3.32548	30	18	-14	1	29
33	160	7.09553	3.32547	28	19	-17	1	30
34	165	7.09552	3.32545	24	19	-29	-18	31
35	170	7.09545	3.32542	20	19	-35	-39	30
36	175	7.09543	3.32542	15	20	-15	-20	28

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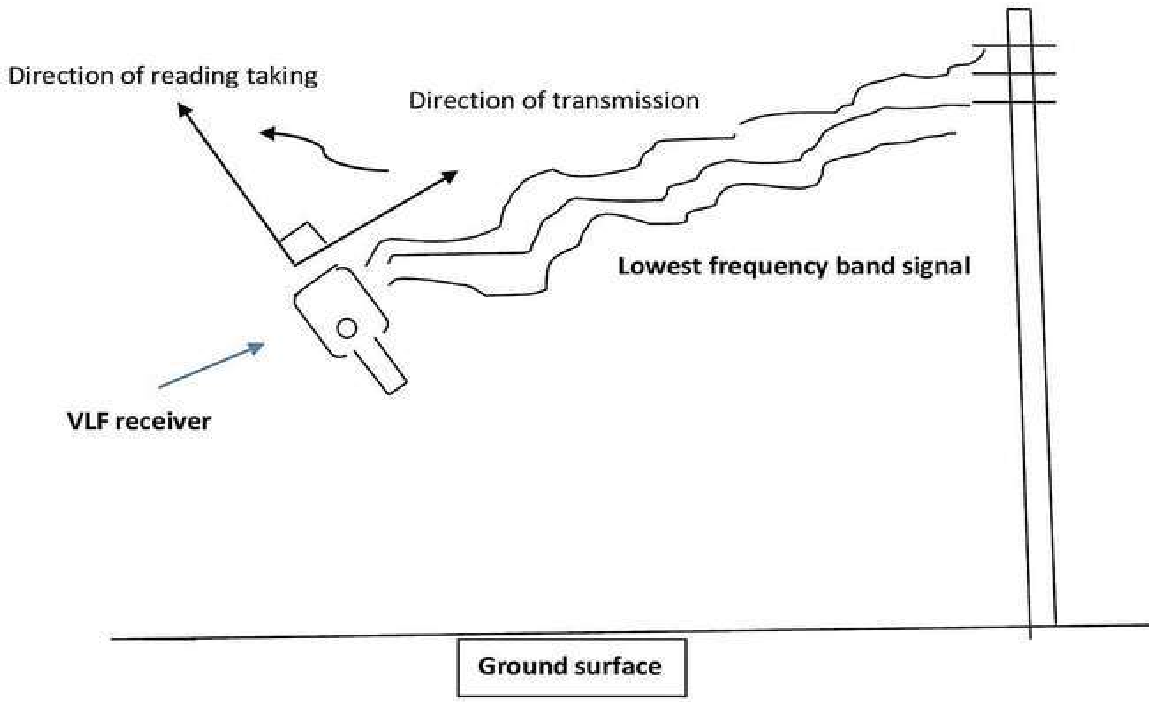

Figure 3.03:The princinple of VLF data acquisition

3.1.3. Gravity Method

This method responds to the variation in the Earth's gravitational field due to density variations in the subsurface. A variation in the density will result due to the presence of a body with varying density from those of the surrounding lithologies.

The instrument used was CG5 Autograv which measures the absolute value of gravity at discrete positions.

Figure 3.04. CG5 Autograv gravimeter used for the gravity data acquisition

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Procedure of data acquisition

- Set up a base station to for the correction of errors due to instrument drift;
- At each station of readings taking;
- Level the tripod stand;
- Balance the gravimeter on the tripod stand;
- Turn on the gravity meter and adjust the tripod until vertical and horizontal lines appear on the screen with a cross over point at the centre with the appearance of a smiley face on the screen;
- Start measurements by taking records of readings displayed on the instrument's screen;
- The readings were recorded in a table format with the time of measurement, the geographic coordinates, elevation, tripod height to base of gravimeter from the ground surface and the station number;
- The base station was visited at every hour interval with the first and last reading taken at the base station

Precaution

- First and last readings must be taken at the base station;
- Readings must be taken at the base station at specified time intervals;
- Tripod height and the elevation readings must always be taken

Table 3.03:Data acquired for the gravity method

S/N	Long (DD)	Lat (DD)	TIME (HH:MM:SS)	R1(mGal)	R2(mGal)	R3(mGal)	Mean (mGal)	TH (cm)	E (m)
BS1	7.0963667	3.3257833	16:05:17	2833.452	2833.438	2833.417	2833.436	15.5	69
1	7.0968667	3.3261333	16:14:33	2833.51	2832.484	2832.448	2832.814	15.2	47
2	7.0967000	3.3261000	16:23:35	2832.106	2831.88	2831.63	2831.872	16	46
3	7.0967667	3.3260833	16:28:52	2832.145	2832.062	2831.997	2832.068	14	48
4	7.0967167	3.3260667	16:36:34	2832.242	2832.25	2832.253	2832.248	13.5	46
5	7.0966667	3.3260500	16:41:00	2832.274	2832.279	2832.294	2832.282	14	45
6	7.0966167	3.3260167	16:44:56	2832.135	2832.282	2832.269	2832.229	15	44
7	7.0966000	3.3259833	16:48:30	2831.863	2832.146	2832.156	2832.055	15	45
8	7.0965667	3.3259833	16:54:08	2831.863	2831.732	2831.631	2831.742	14	45
9	7.0965333	3.3259833	16:59:25	2832.172	2832.153	2832.122	2832.149	13.5	41
10	7.0964500	3.3259667	17:03:54	2831.093	2830.633	2830.217	2830.648	14	36
11	7.0964167	3.3259333	17:08:02	2832.357	2832.329	2832.305	2832.330	16	38
12	7.0963833	3.3259167	17:12:21	2832.063	2832.038	2832.011	2832.037	15.2	41
BS2	7.0963667	3.3257833	17:17:45	2831.935	2831.936	2831.926	2831.932	13.6	69
13	7.0963500	3.3259000	17:21:13	2831.751	2831.695	2831.64	2831.695	15	45
14	7.0961833	3.3258500	17:25:00	2832.194	2832.295	2832.38	2832.290	15.8	44
15	7.0962833	3.3258500	17:28:43	2832.185	2832.151	2832.125	2832.154	15.2	42
16	7.0962333	3.3258333	17:32:52	2830.949	2830.922	2830.901	2830.924	14.8	40
BS3	7.0963667	3.3257833	17:37:34	2831.644	2831.611	2831.587	2831.614	16	69
BS4	7.0963667	3.3257833	08:29:52	2823.385	2823.367	2823.361	2823.371	16	69
17	7.0962000	3.3258167	08:34:12	2823.348	2823.364	2823.363	2823.358	14	37
18	7.0961667	3.3257667	08:37:55	2823.455	2823.406	2823.378	2823.413	14.2	39
19	7.0961167	3.3257667	08:42:00	2823.445	2823.439	2823.433	2823.436	14	41
20	7.0960667	3.3257500	08:46:29	2823.583	2823.55	2823.535	2823.556	15	36
21	7.0960500	3.3257333	08:51:10	2823.821	2823.853	2823.882	2823.852	15	37
22	7.0960000	3.3256833	08:56:59	2824.105	2824.163	2824.212	2824.160	14.6	36
23	7.0959667	3.3256833	09:01:54	2823.817	2823.812	2823.812	2823.814	15	37
24	7.0959000	3.3256333	09:05:48	2824.349	2824.493	2824.613	2824.485	15.4	35
25	7.0958667	3.3256000	09:11:45	2823.807	2823.818	2823.894	2823.840	13	35
26	7.0958333	3.3256000	09:01:51	2823.984	2824.001	2824.011	2823.999	15	34

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27	7.0957833	3.3255833	09:20:17	2823.778	2823.75	2823.72	2823.749	13.2	32
28	7.0957500	3.3255500	09:30:20	2823.852	2823.813	2823.783	2823.816	13.4	32
BS5	7.0963667	3.3257833	09:37:13	2824	2822.769	2822.764	2823.178	16.4	69
29	7.0957000	3.3255167	09:44:34	2824	2823.921	2823.935	2823.952	15	33
30	7.0956667	3.3255167	09:50:02	2824	2824.968	2824.982	2824.650	14.2	32
31	7.0956167	3.3254833	09:54:24	2824	2823.769	2823.891	2823.887	16	31
32	7.0955833	3.3254833	10:01:02	2824	2824.12	2824.085	2824.068	14.6	29
33	7.0955333	3.3254667	10:05:47	2824	2824.043	2824.107	2824.050	15	30
34	7.0955167	3.3254500	10:09:37	2824	2824.515	2824.346	2824.287	15	31
35	7.0954500	3.3254167	10:14:47	2824	2824.08	2824.135	2824.072	14	30
36	7.0954333	3.3254167	10:19:03	2824	2824.75	2824.7	2824.483	14.4	28
BS6	7.0963667	3.3257833	10:24:47	2824	2822.489	2824.505	2823.665	16.2	69

Gravity method reveal zones of higher gravity value of 2832mGal within a lateral distance of 0-70m and lower gravity value of 2824mGal extending from 80m; thus depicting area of more dense rock (less weathered) and less dense (more weathered) rocks respectively.

3.1.4. Seismic Method

The basic principle behind this method is the generation of elastic waves by a seismic source in order to 'image' the subsurface.

A sledge hammer was hit on a plate to generate elastic waves whose responses were picked at each geophone. The signals from the geophones were displayed on the screen of the seismogram which were then used for interpretation

Procedure

Instruments' components:

i. Geophones (25 units)
ii. Battery
iii. Seismometer
iv. Cables
v. Sledge hammer
vi. Metal plate

Figure 3.05 Seismogram for seismic readings taking

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Figure 3.06: Set up cables, geophones, hammer and plate

Procedural steps:

- The points of the geophones were first determined to know the total length of the first spread;
- The seismometer is located at the mid-point of the spread;
- Each geophone was implanted on the ground surface to make proper contact o each point at 2.5m intervals;
- Each of the geophone was connected to the signal cable connected to the seismometer;
- The sensor geophone (25th geophone) was also connected to the seismometer;
- The sensor geophone was inserted to the ground for a firm contact with the ground at the first offset of the spread for readings taking;
- Subsequent readings were taken at each sensor geophone point of between 1st &2nd geophones , 6&7, 12th & 13th geophones, 18th & 19th geophones and 23rd & 24th geophones respectively;
- Each reading was taken at each shot point (where the hammer was used to hit the metal plate for the generation of elastic waves in the subsurface)

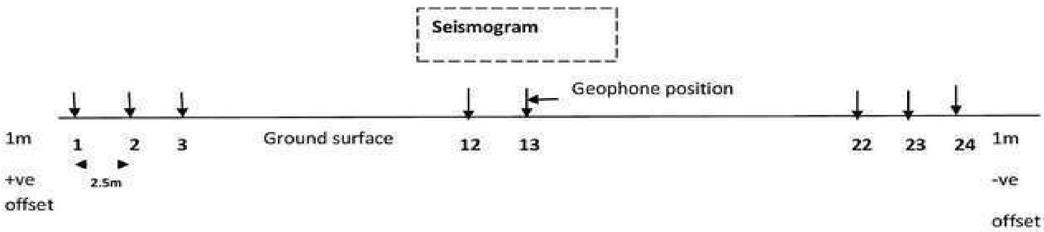

Figure 3.07:Configuration set up for seismic data acquisition

How readings were taken:

- Negative one meter offset was taken after stacking thrice ad then saved the file;
- Other shots with 3 stacks at points between the 6th & 7th geophones, 12th & 13th geophones, 18th and 19th geophones and 23rd & 24th geophones respectively were taken;
- The positive offset of 1m was the taken after the last (24th) geophone. This was the first spread;
- The same process was followed for the second and third spreads of 60m each.

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Table 3.04:Readings of acquired data for seismic method

SPREAD 1 (0-57.5m)			
SHOT POINT INTERVAL	SHOT POINT (m)	FILE NUMBER	STACKINGS
Negative Offset	-1	026005	3
G1 & G2	1.25	026006	3
G6 & G7	13.75	026007	4
G12 & G13	28.75	026008	4
G18 & G19	43.75	026009	3
G23 & G24	53.75	026010	3
Positive Offset	58.5	026011	3
SPREAD 2 (57.5 - 115m)			
SHOT POINT INTERVAL	SHOT POINT (m)	FILE NUMBER	STACKINGS
Negative Offset	56.5	026012	3
G1 & G2	58.75	026013	3
G6 & G7	71.25	026014	3
G12 & G13	86.25	026015	3
G18 & G19	101.25	026016	3
G23 & G24	111.25	026017	3
Positive Offset	116	026018	3
SPREAD 3 (115 - 172.5m)			
SHOT POINT INTERVAL	SHOT POINT (m)	FILE NUMBER	STACKINGS
Negative Offset	114	026019	3
G1 & G2	116.25	026020	7
G6 & G7	128.75	026021	3
G12 & G13	143.75	026022	3
G18 & G19	158.75	026023	4
G23 & G24	168.75	026024	4
Positive Offset	173.5	026025	7

Precautions

- Each geophone must be confirmed to be properly connected before taking of readings;
- The right offset distance must be determined for optimum signal strength;
- Each shot point must be accurately determined before taking readings. For example, between geophones 1 & 2, 6 & 7, 12 & 13, 18 & 19 and 23 & 24 respectively for each spread.

The seismic processed data acquired within the lateral distance of 0-60m show the travel-time of the seismic wave of the top layer, second and third layers in the subsurface to be 300m/s, 1000 m/s and 2000m/s respectively. Layer one with velocity of 436 m/s and thickness ranging from 1-5 m is the topsoil while, the second layer with velocity of 1000m/s thickness ranging from 2-4m possibly represents the weathered layer. The third layer with velocity of 2000m/s suggests the partly weathered layer.

3.1.5. Spontaneous Potential (SP) Method

The SP method is a passive method; which means no current is required to be injected into the ground.
This method measures the natural potential of the subsurface which is due to;

- Electrochemical interactions between minerals and subsurface flid;
- Thermoelectric mechanism from temperature gradients;
- Electrokinetic process from the flow of fluid.

Procedure

The equipments used are:

i. Two non-conducting electrodes as trailing and leading electrodes;
ii. Multimeter for reading taking;
iii. Cables

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Procedural steps

Two methods were carried out for the survey viz;

(a) Potential gradient method

(b) Total field method

Potential gradient method

5m spacing was used for the traverse of about 180m with the following steps:

- The trailing and leading electrodes were connected to the multimeter;
- The trailing electrode was implanted to the ground at the zero point of the traverse with the leading electrode at point 5m after which reading was taking from the screen of the multimeter;
- Positions of the trailing and leading electrodes were shifted by 5m forward with a constant spacing (Separation) of 5m between them;
- The readings were taken for all the 36 points of the traverse.

Total field method

In this method, the trailing electrode was made constant at the 0 point whilie the leading electrode was moved from 5m with 5m interval till the last point on the traverse.

Readings were taken when the mltimeter was set at 200mV.

Precaution

- The cables must be well connected to the multimeter;
- The trailing and the leading electrode must be rightly connected to the multimeter;
- The point of electrode insertion to the ground should be slightly moisturized with water to maintain a good contact to the ground and easy electrons movements

Table 3.05:SP readings

S/N	TE(m)	RE(m)	SD	MIDPOINT	SP1(mV)	SP2(mV)	SP2(mV)	SP AVERAGE
1	0	5	0-5	2.5	-3.8	-3.5	-3.4	-3.57
2	5	10	5-10	7.5	-5.3	-4.9	-5.2	-5.13
3	10	15	10-15	12.5	-4.1	-3.9	-3.7	-3.90
4	15	20	15-20	17.5	-4.5	-4.3	-4.0	-4.27
5	20	25	20-25	22.5	-6.1	-5.9	-4.8	-5.60
6	25	30	25-30	27.5	-5.2	-5.0	-5.2	-5.13
7	30	35	30-35	32.5	-5.0	-4.5	-4.3	-4.60
8	35	40	35-40	37.5	-4.6	-4.4	-4.3	-4.43
9	40	45	40-45	42.5	-4.7	-4.6	-4.4	-4.57
10	45	50	45-50	47.5	-4.8	-4.5	-4.2	-4.50
11	50	55	50-55	52.5	-5.1	-5.0	-4.9	-5.00
12	55	60	55-60	57.5	-4.4	-4.3	-3.9	-4.20
13	60	65	60-65	62.5	-5.9	-5.6	-5.3	-5.60
14	65	70	65-70	67.5	-4.1	-4.0	-3.9	-4.00
15	70	75	70-75	72.5	-5.4	-5.3	-5.1	-5.27
16	75	80	75-80	77.5	-5.2	-5.4	-5.5	-5.37
17	80	85	80-85	82.5	-4.7	-4.5	-4.4	-4.53
18	85	90	85-90	87.5	-5.8	-5.9	-6.0	-5.90
19	90	95	90-95	92.5	-5.8	-5.7	-5.3	-5.60
20	95	100	95-100	97.5	-4.0	-3.8	-3.8	-3.87
21	100	105	100-105	102.5	-6.0	-5.9	-5.5	-5.80
22	105	110	105-110	107.5	-6.5	-5.0	-4.1	-5.20
23	110	115	110-115	112.5	-4.6	-4.9	-5.0	-4.83
24	115	120	115-120	117.5	-5.5	-5.0	-4.6	-5.03
25	120	125	120-125	122.5	-5.5	-5.2	-5.1	-5.27
26	125	130	125-130	127.5	-5.5	-5.4	-5.1	-5.33
27	130	135	130-135	132.5	-5.4	-4.8	-5.9	-5.37

28	135	140	135-140	137.5	-5.2	-5.0	-4.7	-4.97
29	140	145	140-145	142.5	-4.0	-3.8	-3.6	-3.80
30	145	150	145-150	147.5	-3.8	-3.5	-3.3	-3.53
31	150	155	150-155	152.5	-3.4	-3.0	-2.6	-3.00
32	155	160	155-160	157.5	-2.7	-3.0	-3.5	-3.07
33	160	165	160-165	162.5	-2.9	-2.8	-2.7	-2.80
34	165	170	165-170	167.5	-2.8	-2.7	-2.5	-2.67
35	170	175	170-175	172.5	-2.5	-2.3	-2.2	-2.33

TE: Trailing Electrode SP: Spontaneous Potential reading
RE: Roving Electrode SD: Separation Distance

3.1.6. Electromagnetic (EM-34) Method

EM survey is based on the response of the ground to the propagation of the EM field which is composed of an alternating electric intensity and magnetizing force.

A primary field is generated when an alternating current is passed through the coil placed over the ground surface.

The magnetic field flows into the earth surface which makes a conductive body within the subsurface to produce an eddy current .The eddy current in turn produces the secondary magnetic field; whose signal is received by the receiver.

The response of the receiver differs in phase and direction (Since the primary magnetic field above the earth surface did not undergo altering process unlike the secondary field)

Procedure

- The points along the traverse were determined from the zero point to the last point with 5m spacing interval;
- The transmitter coil and the receiver coil were connected to the transmitter and receiver by cables;
- The transmitter coil was placed on zero point of the traverse line while the receiver coil was was placed at 10m position with 5m spacing and moved with same 5m spacing along the traverse till the last point on the traverse;
- The transmitter and the receiver were switched on for readings taking on each point;
- Two different readings were taken on each point for the Horizontal Dipole Mode(HDM) and Vertical Dipole Mode (VDM). These were taken when the coils were standing aligned to each other and lying down respectively;
- The separation distance of 10m was maintained with 5m spacing along the traverse;
- The values were taken when the countdown were 10s, 20s, and 40s for 10m, 20m and 40m respectively;
- The readings for 20m and 40m were taking following the third step above;

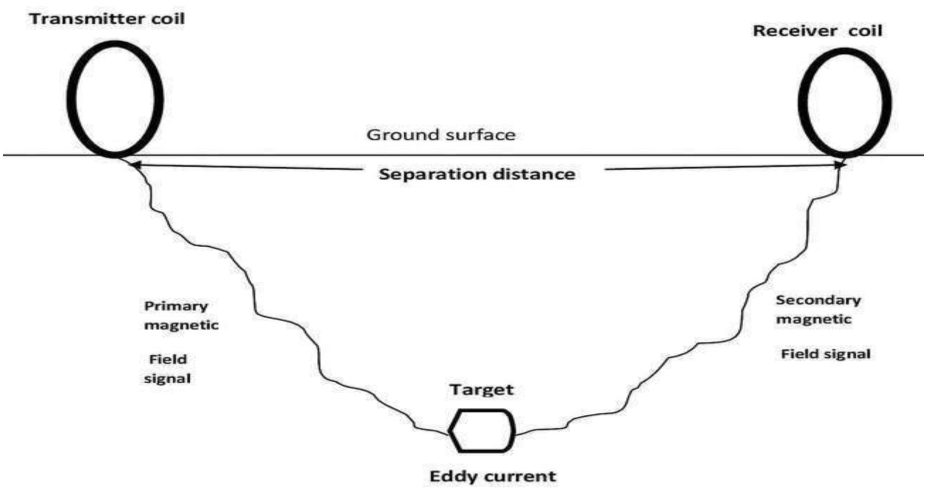

Figure 3.08: Horizontal Dipole Mode (HDM)

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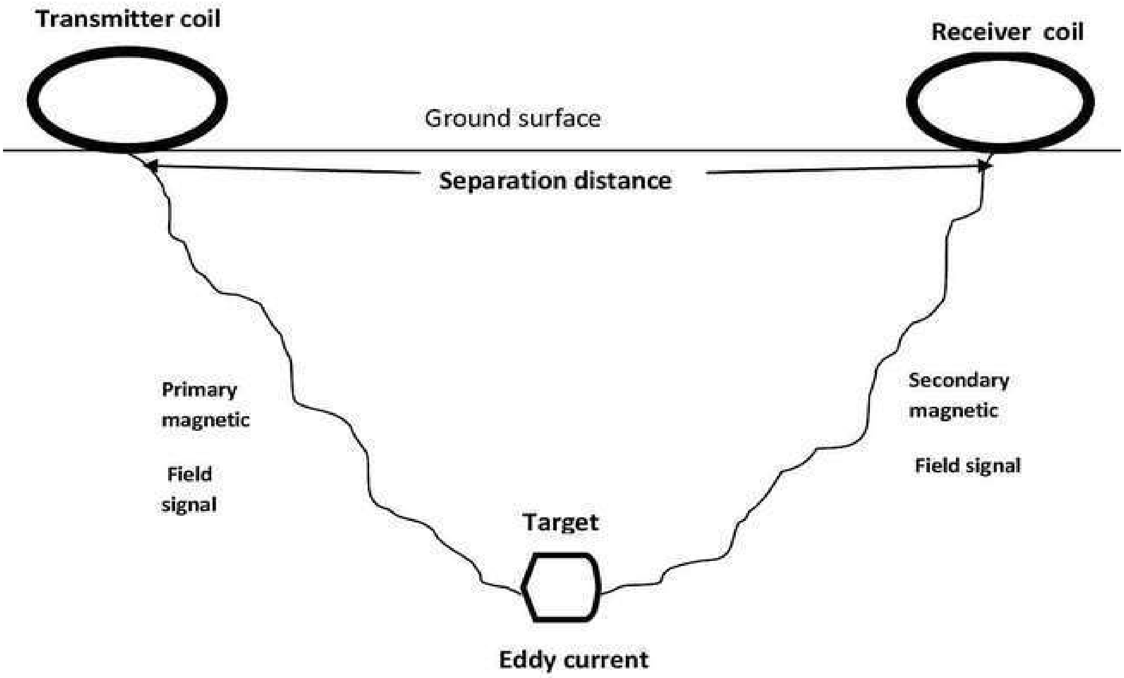

Figure 3.09: Vertical Dipole Mode (VDM)

Precautions

- The cables must be properly fixed and connected to the coils from the transmitter and receiver respectively;
- The coils must align to each other for both HDM and VDM readings;
- The counts must be accurately checked for reading taking per separation distance

Table 3.06: Acquired data for EM method

S/N	T(m)	R(m)	SD	MIDPOINT(m)	HDM(mS/m)	VDM(mS/m)
1	0	10	0-10	5	59.0	165.0
2	5	15	5-15	10	59.0	83.0
3	10	20	10-20	15	51.0	74.0
4	15	25	15-25	20	46.0	62.0
5	20	30	20-30	25	46.0	58.0
6	25	35	25-35	30	47.0	60.0
7	30	40	30-40	35	38.0	50.0
8	35	45	35-45	40	42.0	66.0
9	40	50	40-50	45	40.0	65.0
10	45	55	45-55	50	45.0	65.0
11	50	60	50-60	55	50.0	53.0
12	55	65	55-65	60	45.0	58.0
13	60	70	60-70	65	44.0	59.0
14	65	75	65-75	70	45.0	61.0
15	70	80	70-80	75	45.0	55.0
16	75	85	75-85	80	39.0	53.0
17	80	90	80-90	85	38.0	50.0
18	85	95	85-95	90	36.0	48.0
19	90	100	90-100	95	42.0	51.0

20	95	105	95-105	100	39.0	50.0
21	100	110	100-110	105	43.0	60.0
22	105	115	105-115	110	44.0	54.0
23	110	120	110-120	115	36.0	50.0
24	115	125	115-125	120	42.0	53.0
25	120	130	120-130	125	38.0	54.0
26	125	135	125-135	130	40.0	54.0
27	130	140	130-140	135	39.0	51.0
28	135	145	135-145	140	45.0	56.0
29	140	150	140-150	145	44.0	55.0
30	145	155	145-155	150	39.0	52.0
31	150	160	150-160	155	39.0	54.0
32	155	165	155-165	160	44.0	52.0
33	160	170	160-170	165	51.0	61.0
34	165	175	165-175	170	47.0	60.0

By integrating the three spacing arrays in EM method (10m, 20m and 40m spacing) the likely areas of interests are within 20-30m,85-110m and 135m along the traverse which are cross-over/ necking points; which can give inference for aquifer or incompetent subsurface zones along the traverse.

3.1.7. Constant Separation Technique (CST) Method

The basic principle behind this method involves sending current into the ground via current electrodes; which generates a potential gradient within the subsurface.

The potential difference generated in the subsurface is measured by resistivity meter through the potential electrodes using Wenner array configuration.

The resistivity meter used is Pasi terrameter with readings in resistance (Ohm). These values were converted to their respective apparent resistivity values (Ohm-m) with a K-factor($2\pi a$) where a is the electrode spacing.

Figure 3.10:Resistivity meter, Battery and Cables (Current &potential)

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Procedure

i. The terrameter was connected to the pairs of current and potential cables;
ii. The cables were connected to the pairs of current and potential electrodes respectively;
iii. Readings were taken from the zero point on the traverse with C1 and C2 on zero and 15m points respectively. The potential electrodes were implanted at points 5m and 10m respectively with a spacing of 5m interval;
iv. Readings were taken along the traverse with 5m spacing;
v. The same process was followed for electrode spaciong 10m, 15m and 20m respectively.

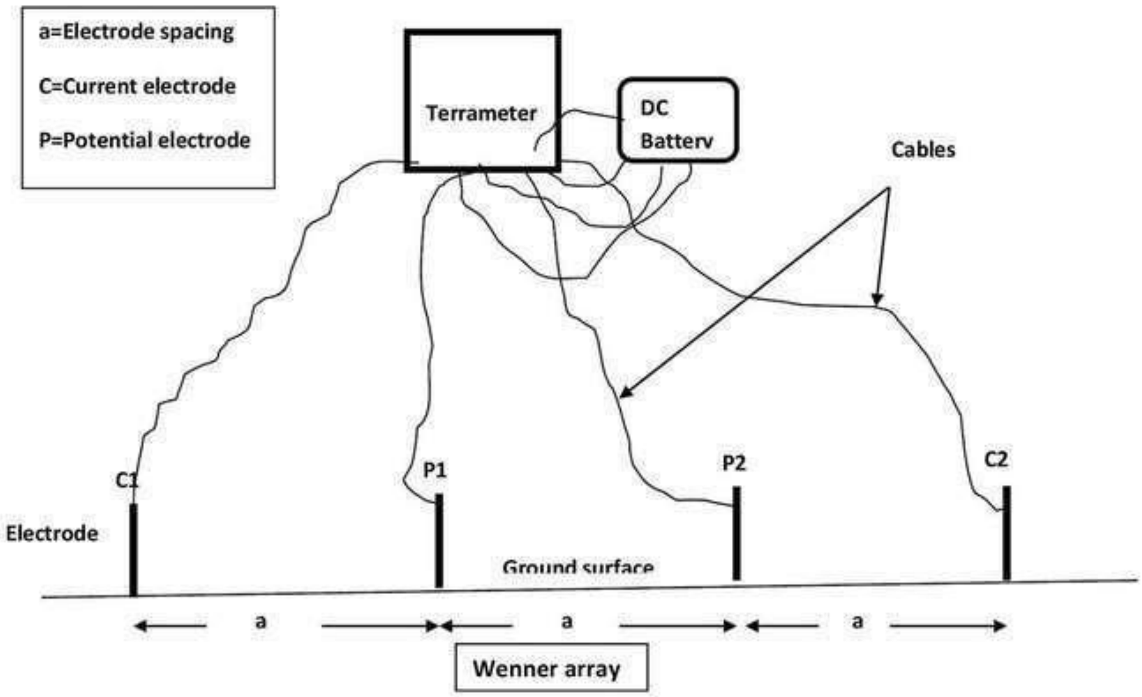

Figure 3.11: Field set up of Wenner array configuration

Precations

- Current and potential cables must be well connected to the current and potential electrodes respectively and rightly connected to the resistivity meter;
- The electrodes must make proper contact with the ground to avoid error;

Table 3.07:Data acquired for CST method (Wenner array with a=5m)

S/N	C1	P1	P2	C2	E.S (m)	M.P(m)	K-Factor	R (Ohms)	A.R (Ohm-m)
1	0	5	10	15	5	7.5	31.42	5.4	169.65
2	5	10	15	20	5	12.5	31.42	7.2	226.19
3	10	15	20	25	5	17.5	31.42	10.4	326.73
4	15	20	25	30	5	22.5	31.42	9.7	304.73
5	20	25	30	35	5	27.5	31.42	11.1	348.72
6	25	30	35	40	5	32.5	31.42	11.0	345.58
7	30	35	40	45	5	37.5	31.42	10.1	317.30
8	35	40	45	50	5	42.5	31.42	7.9	248.19
9	40	45	50	55	5	47.5	31.42	5.9	185.35
10	45	50	55	60	5	52.5	31.42	5.6	175.93
11	50	55	60	65	5	57.5	31.42	5.9	185.35
12	55	60	65	70	5	62.5	31.42	6.8	213.63

13	60	65	70	75	5	67.5	31.42	6.0	188.50
14	65	70	75	80	5	72.5	31.42	7.5	235.62
15	70	75	80	85	5	77.5	31.42	9.2	289.03
16	75	80	85	90	5	82.5	31.42	12.1	380.13
17	80	85	90	95	5	87.5	31.42	11.1	348.72
18	85	90	95	100	5	92.5	31.42	11.5	361.28
19	90	95	100	105	5	97.5	31.42	13.0	408.41
20	95	100	105	110	5	102.5	31.42	14.2	446.11
21	100	105	110	115	5	107.5	31.42	14.9	468.10
22	105	110	115	120	5	112.5	31.42	14.6	458.67
23	110	115	120	125	5	117.5	31.42	16.2	508.94
24	115	120	125	130	5	122.5	31.42	13.5	424.12
25	120	125	130	135	5	127.5	31.42	16.0	502.65
26	125	130	135	140	5	132.5	31.42	12.5	392.70
27	130	135	140	145	5	137.5	31.42	13.0	408.41
28	135	140	145	150	5	142.5	31.42	11.2	351.86
29	140	145	150	155	5	147.5	31.42	10.6	333.01
30	145	150	155	160	5	152.5	31.42	8.8	276.46
31	150	155	160	165	5	157.5	31.42	8.4	263.89
32	155	160	165	170	5	162.5	31.42	8.3	260.75
33	160	165	170	175	5	167.5	31.42	7.5	235.62

Table 3.08:Data acquired for CST method (Wenner array with a=10m)

S/N	C1	P1	P2	C2	SD(m)	M.P(m)	K-Factor	R (Ohms)	A.R(Ohm-m)
1	0	10	20	30	10	15	62.83	2.1	131.95
2	5	15	25	35	10	20	62.83	2.6	163.36
3	10	20	30	40	10	25	62.83	2.9	182.21
4	15	25	35	45	10	30	62.83	2.4	150.80
5	20	30	40	50	10	35	62.83	1.1	69.12
6	25	35	45	55	10	40	62.83	1.4	87.96
7	30	40	50	60	10	45	62.83	2.5	157.08
8	35	45	55	65	10	50	62.83	2	125.66
9	40	50	60	70	10	55	62.83	1.8	113.10
10	45	55	65	75	10	60	62.83	2.9	182.21
11	50	60	70	80	10	65	62.83	2.3	144.51
12	55	65	75	85	10	70	62.83	2.3	144.51
13	60	70	80	90	10	75	62.83	2.1	131.95
14	65	75	85	95	10	80	62.83	2.3	144.51
15	70	80	90	100	10	85	62.83	2.6	163.36
16	75	85	95	105	10	90	62.83	2.2	138.23
17	80	90	100	110	10	95	62.83	1.7	106.81
18	85	95	105	115	10	100	62.83	2.6	163.36
19	90	100	110	120	10	105	62.83	3.2	201.06
20	95	105	115	125	10	110	62.83	2.4	150.80
21	100	110	120	130	10	115	62.83	2	125.66

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22	105	115	125	135	10	120	62.83	2.8	175.93
23	110	120	130	140	10	125	62.83	2.5	157.08
24	115	125	135	145	10	130	62.83	2.5	157.08
25	120	130	140	150	10	135	62.83	2.8	175.93
26	125	135	145	155	10	140	62.83	2.6	163.36
27	130	140	150	160	10	145	62.83	2.4	150.80
28	135	145	155	165	10	150	62.83	2.7	169.65
29	140	150	160	170	10	155	62.83	2.2	138.23
30	145	155	165	175	10	160	62.83	2.3	144.51

Table 3.09:Data acquired for CST method (Wenner array with a=15m)

S/N	C1	P1	P2	C2	S.D(m)	M.P	K-Factor	R (Ohms)	A.R (Ohm-m)
1	0	15	30	45	15	22.5	94.25	1.30	122.52
2	5	20	35	50	15	27.5	94.25	0.97	91.17
3	10	25	40	55	15	32.5	94.25	1.10	103.67
4	15	30	45	60	15	37.5	94.25	2.80	263.89
5	20	35	50	65	15	42.5	94.25	1.20	113.10
6	25	40	55	70	15	47.5	94.25	0.84	79.52
7	30	45	60	75	15	52.5	94.25	1.10	103.67
8	35	50	65	80	15	57.5	94.25	0.98	92.22
9	40	55	70	85	15	62.5	94.25	1.30	122.52
10	45	60	75	90	15	67.5	94.25	0.91	86.19
11	50	65	80	95	15	72.5	94.25	1.20	113.10
12	55	70	85	100	15	77.5	94.25	1.40	131.95
13	60	75	90	105	15	82.5	94.25	1.60	150.80
14	65	80	95	110	15	87.5	94.25	1.30	122.52
15	70	85	100	115	15	92.5	94.25	2.60	245.04
16	75	90	105	120	15	97.5	94.25	0.98	92.24
17	80	95	110	125	15	102.5	94.25	1.30	122.52
18	85	100	115	130	15	107.5	94.25	0.70	66.20
19	90	105	120	135	15	112.5	94.25	1.30	122.52
20	95	110	125	140	15	117.5	94.25	1.20	113.10
21	100	115	130	145	15	122.5	94.25	0.76	71.97
22	105	120	135	150	15	127.5	94.25	0.69	64.61
23	110	125	140	155	15	132.5	94.25	0.70	66.16
24	115	130	145	160	15	137.5	94.25	1.10	103.67
25	120	135	150	165	15	142.5	94.25	0.95	89.84
26	125	140	155	170	15	147.5	94.25	0.96	90.52
27	130	145	160	175	15	152.5	94.25	0.72	67.41

Table 3.10:Data acquired for CST method (Wenner array with a=20m)

S/N	C1	P1	P2	C2	S.D	M.P	K-Factor	R(Ohms)	A.R(Ohm-m)
1	0	20	40	60	20	30	125.66	0.69	86.49
2	5	25	45	65	20	35	125.66	0.30	37.88

3	10	30	50	70	20	40	125.66	0.39	49.34
4	15	35	55	75	20	45	125.66	0.40	50.67
5	20	40	60	80	20	50	125.66	0.59	74.05
6	25	45	65	85	20	55	125.66	0.80	100.62
7	30	50	70	90	20	60	125.66	0.81	101.45
8	35	55	75	95	20	65	125.66	0.59	74.22
9	40	60	80	100	20	70	125.66	1.10	138.23
10	45	65	85	105	20	75	125.66	0.96	120.21
11	50	70	90	110	20	80	125.66	0.83	104.62
12	55	75	95	115	20	85	125.66	0.90	113.17
13	60	80	100	120	20	90	125.66	1.50	188.50
14	65	85	105	125	20	95	125.66	0.94	118.31
15	70	90	110	130	20	100	125.66	0.53	66.35
16	75	95	115	135	20	105	125.66	0.70	87.84
17	80	100	120	140	20	110	125.66	1.00	125.66
18	85	105	125	145	20	115	125.66	0.66	83.50
19	90	110	130	150	20	120	125.66	0.97	122.23
20	95	115	135	155	20	125	125.66	0.53	66.30
21	100	120	140	160	20	130	125.66	0.91	114.22
22	105	125	145	165	20	135	125.66	0.79	99.20
23	110	130	150	170	20	140	125.66	0.53	66.60
24	115	135	155	175	20	145	125.66	0.43	54.58

C: Current electrode — R: Resistance reading(Ohm)
P: Potential electrode — A.R: Apparent resistivity reading (Ohm-m)
E.S: Electrode Spacing — M.P: Mid-point

3.1.8. Vertical Electrical Sounding (VES) Method

VES is used to measure ground (Subsurface) resistivity by passing current through two current electrodes and deducing the voltage between a pair of potential electrode (Potential Difference) sing the relationship between voltage and current, the resistance is determined using Ohm's law:

R=V/I

Where
R=Resistance
V=Voltage
I= Current

The set up of the equipment is same as the one of CST except for the difference in the electrode configuration (which is Shlumberger array)

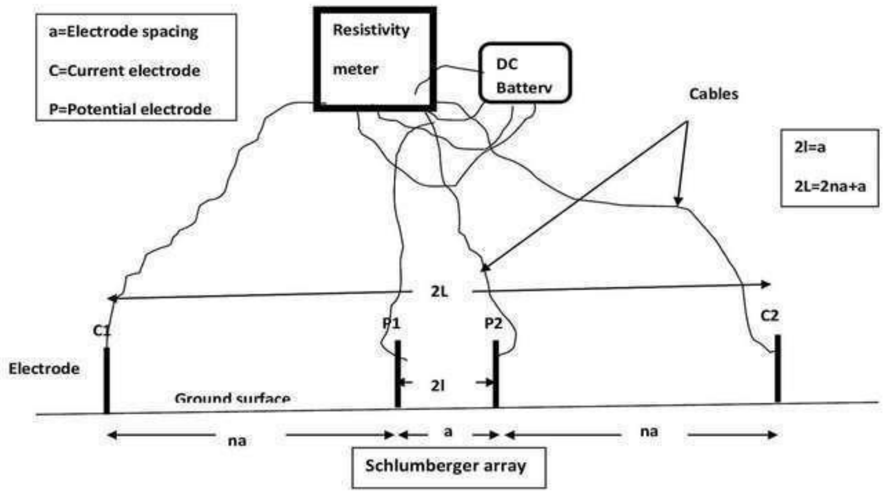

Figure 3.12: Field set up of Schlumberger array configuration

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Table 3.11:The VES data at 30m

S/N	AB/2 (m)	MN/2 (m)	k-FACTOR	R(ohms)	A.R(Ohm-m)
1	1	0.25	5.89	78.50	462.40
2	2	0.25	24.74	16.40	405.74
3	3	0.25	56.16	7.00	393.09
4	4	0.25	100.14	3.60	360.50
5	6	0.25	225.80	1.40	316.12
6	6	0.5	112.31	3.20	359.40
7	9	0.5	253.68	1.20	304.42
8	12	0.5	451.60	0.62	278.01
9	15	0.5	706.07	0.30	210.34
10	15	1	351.86	0.56	197.18
11	20	1	626.75	0.17	104.85
12	25	1	980.18	0.11	103.41
13	32	1	1606.92	0.70	1119.22
14	40	1	2511.70	0.15	389.06
15	40	2.5	1001.38	0.29	288.00
16	50	2.5	1566.87	0.09	144.62
17	65	2.5	2650.72	0.06	147.38
18	80	2.5	4017.31	0.05	188.81
19	100	2.5	6279.26	0.03	188.38
20	100	5	3133.74	0.06	174.24
21	120	5	4516.04	0.04	198.71
22	160	5	8034.62	0.06	513.41

Table 3.12:The VES data at 50m

S/N	AB/2 (m)	MN/2 (m)	k-FACTOR	R(ohms)	A.R(Ohm-m)
1	1	0.25	5.89	135.80	799.93
2	2	0.25	24.74	17.30	428.00
3	3	0.25	56.16	5.70	320.09
4	4	0.25	100.14	2.70	270.37
5	6	0.25	225.80	0.96	216.77
6	6	0.5	112.31	2.00	224.62
7	9	0.5	253.68	0.63	159.57
8	12	0.5	451.60	0.27	122.43
9	15	0.5	706.07	0.17	116.50
10	15	1	351.86	0.83	292.75
11	20	1	626.75	0.20	122.40
12	25	1	980.18	0.09	92.43
13	32	1	1606.92	0.05	78.58
14	40	1	2511.70	0.05	117.80
15	40	2.5	1001.38	0.19	187.36
16	50	2.5	1566.87	0.05	77.09
17	65	2.5	2650.72	0.03	84.03
18	80	2.5	4017.31	0.04	161.50
19	100	2.5	6279.26	0.02	147.56

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20	100	5	3133.74	0.05	152.61
21	120	5	4516.04	0.02	101.61
22	160	5	8034.62	0.03	205.69

AB: Current electrodes R: Resistance reading(Ohm)
MN: Potential electrodes A.R: Apparent Resistivity

From the 2-D pseudosection produced using Wenner array, the traverse surveyed indicates four geoelectric layers with the first layer (top soil) having resistivity values ranging between 212Ωm and 508Ωm with an average thickness of 2.0m.The second layer has resistivity values ranging between 66Ωm and 212Ωm typifying a partly weathered basement with varying thickness along the traverse from the depth of about 3m.The partly weathered layer has a thickness of more than 20m within the horizontal distances of 55-75m and 100-125m from the depth of about 3m.
The third layer of the pseudosection along the traverse has resistivity values that vary between 37Ωm and 66Ωm from the depth of about 8m within the horizontal distances of 32m-55m and 123-160m; thus typifying a highly weathered basement layer(Clay).

The fourth layer's resistivity values are between 123Ωm and 160Ωm from depth of 8m with the horizontal distance of 75m-98m which represents a fractured basement.

The resistivity values of VES at 30m and 50m along the traverse range between 79.4Ωm-456.3Ωm and 67.5Ωm-824.1 Ωm respectively.

The curve type generated for the two VES points as generated by Winresist software is QH, typifying the top soil being underlain by layer with lower resistivity value to the third layer with an increasing resistivity value of the fourth layer. This suggests that the second and third layer have higher weathering rates compared to the fourth layer which is fractured basement as illustrated in the geoelectric section.

3.2 DATA PROCESSING

3.2.1. Magnetic Method

The field magnetic data were subjected to the diurnal and drift correction. The regional was removed from the corrected data so as to emphasize the residual. The residual data represents, presumably effects of the intermediate zone of interest after near surface noise and the regional have been removed. This correction removes the background effect.

3.2.2. Very Low Frequency (VLF) Method

The VLF-EM data were processed by applying Fraser and Karous-Hjert filter after which the filtered data were loaded into Oasis Montaj software. The Fraser filtering on the in-phase component was carried to removes complex patterns before interpretation. This filter provides an apparent depth profile from the current density which is derived from the magnitude of the vertical component of the magnetic field at a specific location.

3.2.3. Gravity Method

The gravity data was processed using Bouguer anomaly data by means of Oasis Montaj software. Bouguer correction was done and gridding was carried out using bi-directional gridding method before which map was produced.

3.2.4. Seismic Method

The software used for processing the seismic refraction data was Pickwin and Plotfera. The seismic records were loaded into the Pickwin software and first arrivals were picked. This was followed by the estimation of velocity from the time-distance graph (Figure 4.07) after which velocity inversion was carried out to generate a 2D velocity tomography.(Figure 4.08)

3.2.5. Spontaneous Potential (SP) Method

Preparing the data in excel worksheet

Excel and Surfer software were used to process the SP data. The field data collected was presented in graphs as a function of the distance.
The field data collected were prepared in Excel worksheet and the files were saved in .dat, .txt
The SP data were corrected for the reference and the closure correction was also done.

Creating a grid

Data-files contain data collected in the field were converted into an evenly spaced grid. The grid files are produced and open in Surfer.

Extracting a Profile

Two successive griddings of the data were done because the repartition of SP measurements in the field is often irregular. The resulting grid is then added to the original dataset to create your SP maps. A section of a grid file is extracted to extract part of a DEM. Topographic profiles from a DEM and SP profiles are created.

3.2.6. Electromagnetic (EM-34) Method

The readings of the EM acquired on the field with 10m, 20m and 40m spacing were plotted on excel respectively by plotting the distance(m) on the X-axis and the EM readings(mS/m) for both HDM and VDM readings on the Y-axis; for the purpose of identifying necking and cross-overs.

3.2.7. Constant Separation Technique (CST) Method

The resistivity (CST) data collected were processed by means of RES2D (Geotomo) modeling software in order to perform 2D geo-electrical data inversion. The CST data were first prepared in Excel and the resulting plots were observed to filter some errors before loading the data into the software.

3.2.8. Vertical Electrical Sounding (VES) Method

Manual (curve matching) and analytical method (computer iteration) were employed for processing the VES data using IPI2Win software. The apparent resistivity data obtained from the VES survey were presented as depth sounding curves. These data were processed using a partial curve matching, the results of the curve matching were fed into the computer as a stating model in an iterative forward modeling technique, upon which Subsurface geoelectric model were generated and presented as layer resistivity and thickness.

IV. RESULTS AND DISCUSSIONS

4.1 . Magnetic Method

The plot of the magnetic data is shown in figure 4.01below with region ‘A’ and ‘B^A’ having negative anomaly within the horizontal distances of 28-48m and 72-100m respectively; while region ‘C^A’ has a positive anomaly within the horizontal distance of 145-165m. Since the terrain is a basement complex area, the variation in the magnetic values in the area (as also revealed in the 2-D magnetic section in figure 4.02 could be an indication of basement relief or discontinuities(such as faults, fractures or joints)(Opara et el., 2015) or difference in the rate of basement weathering.

Integration of other geophysical methods will give a better inference of the area of survey for a better understanding of the subsurface layers for the type of anomalous zones and overburden thickness.

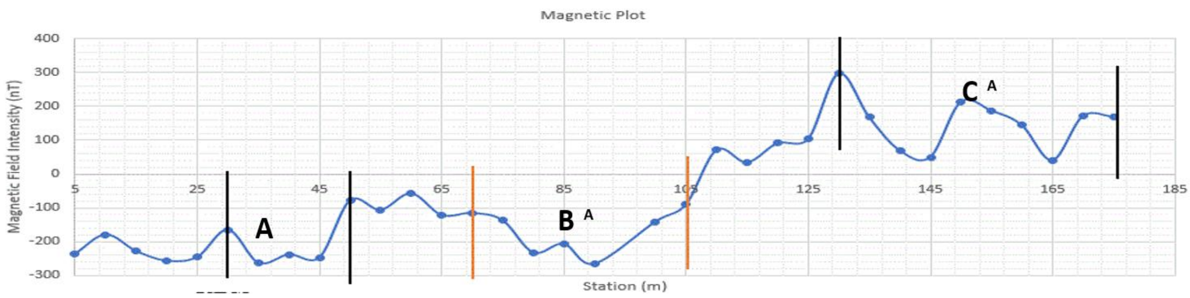

Figure 4.01: Magnetic data plot

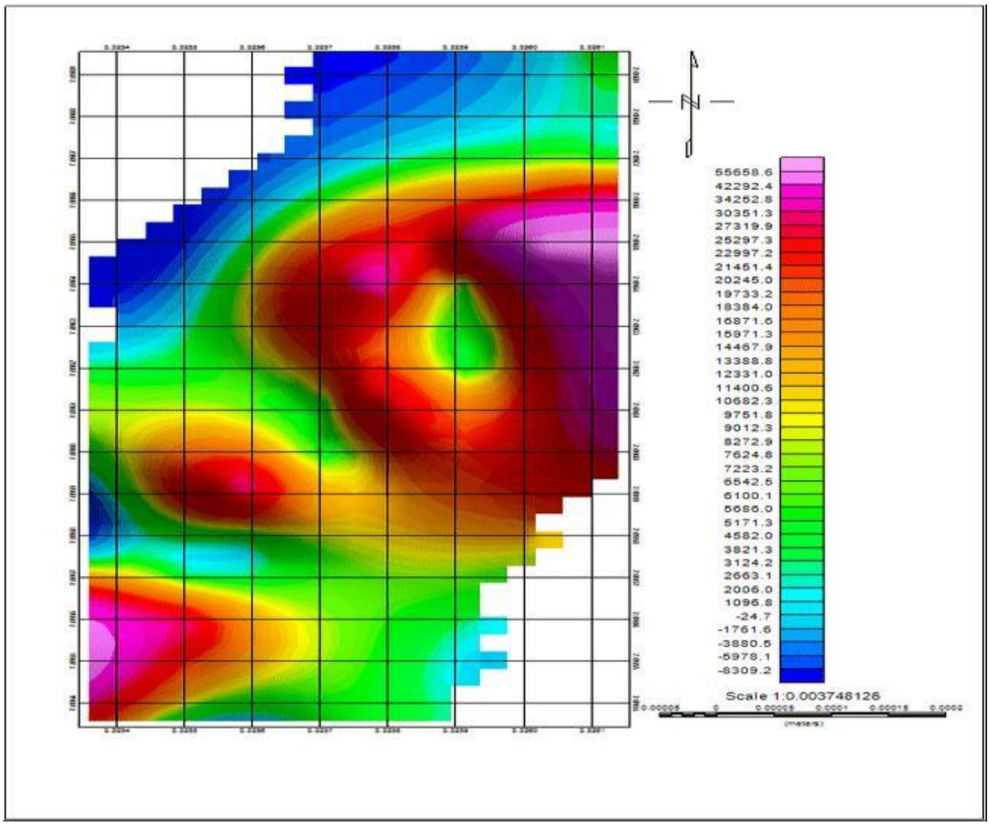

Figure 4.02: 2-D image of the magnetic variation

4.2. VLF (Very Low Frequency) Method

The plots of the Frazer filtered real component along along the profile and the VLF 2-D Model are presented in Figures 4.02 and 4.03 respectively. Fraser filtered real maximum peaks (Figure 4.02) and the inverted real component 2D image (Figure 4.03) all suggests possible fractures or conductive zones at 0 m, 20 m,50m and between 120 -180m respectively along traverse. The possible fractured zone at distance of 20 m along the traverse is from a depth of about 15 m and at 50m is from 10m and below. These possible fractures zones beneath these traverses suggest good locations for presence of groundwater. They are also areas to investigate for mineral deposits.

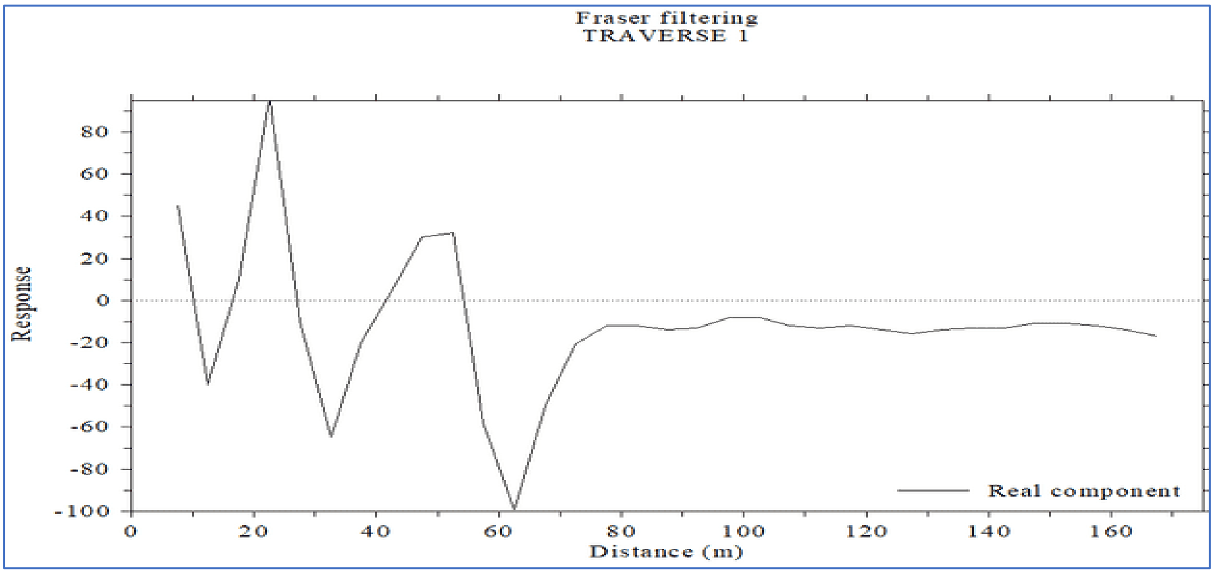

Figure 4.02: Frazer filtered real component plot along the Traverse .

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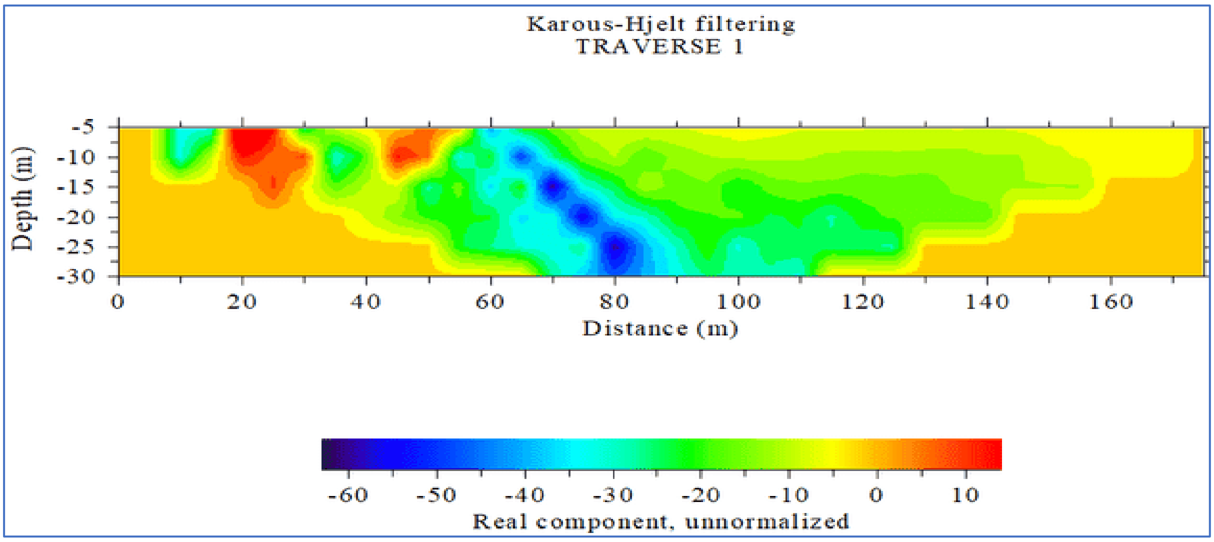

Figure 4.03: VLF 2-D Model along the Traverse .

4.3. Gravity Method
The plot of the gravity data is shown below in figure 4.04 With region 'A' having higher average gravity value of 2832mGal within the horizontal distance of 0-70m while the region 'B' with lower gavity values with an average value of 2824mGal extending from the horizontal distance of 80m. Region 'A' depicts area of more dense rock with respect to the region 'B' with less dense rock. This depicts region 'B' to be of more weathered basement compared to region 'B'.

Detailed subsurface lithology layers could be inferred with other geophysical methods; which is the essence of applying different geophysical methods for this report.
The processed results of all the geophysical methods are later integrated for a better resolution of the subsurface survey.
Fig.4.05 and fig.4.06 show the 2-D Bouger anomaly and regional anomaly respectively.

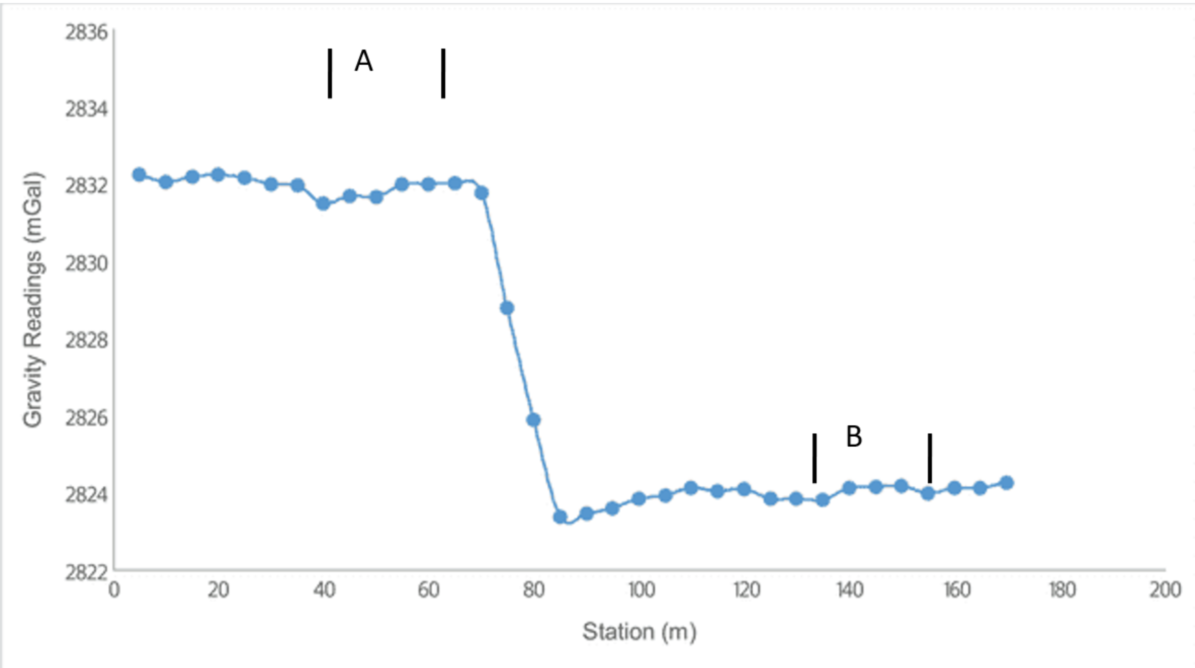

Figure 4.04: Gravity data plot

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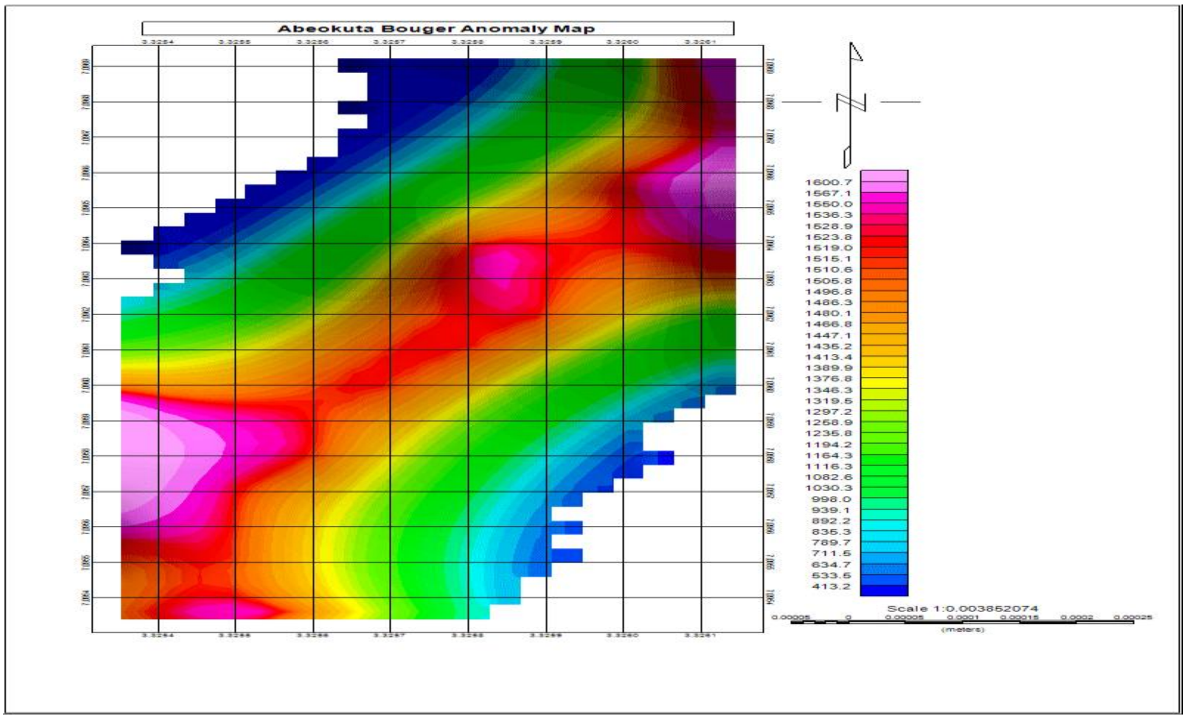

Figure 4.05: 2-D Bouger anomaly

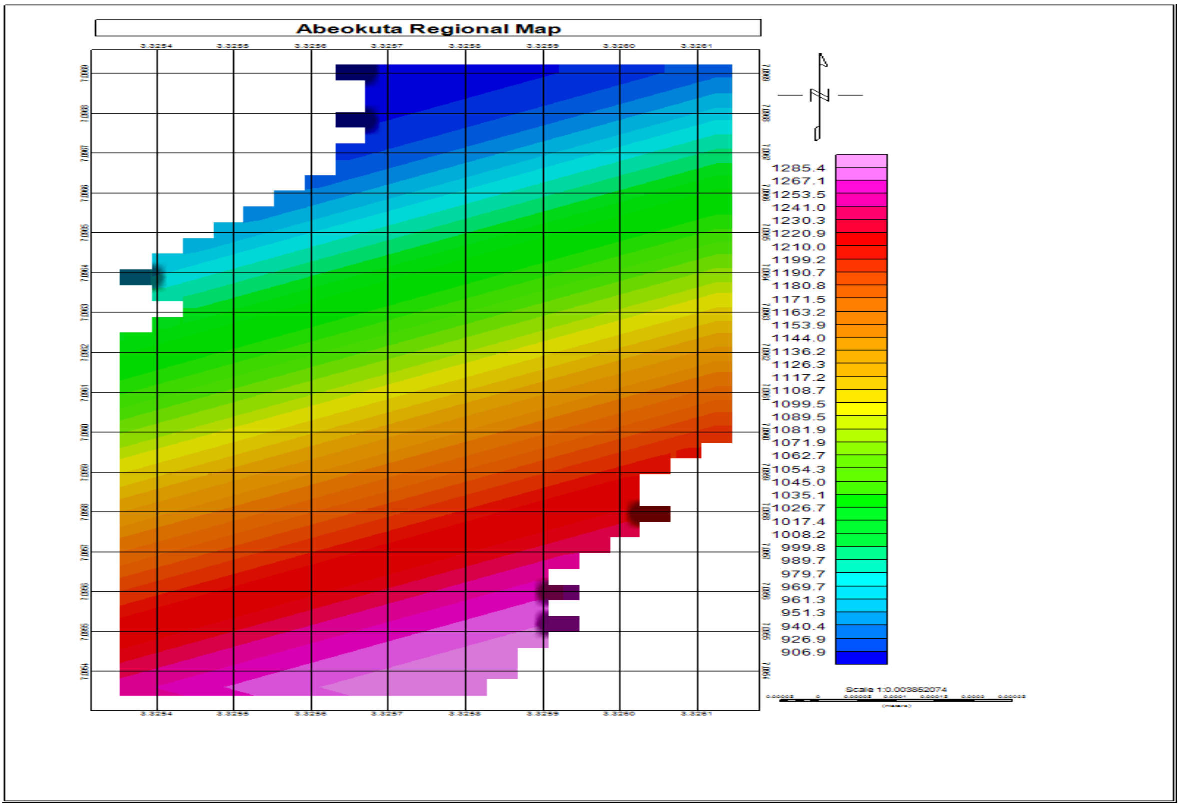

Figure 4.06: Regional anomaly

4.4. Seismic Method

The velocity tomography beneath the traverse (Fig.4.07) shows vertical primary velocity distribution and expected increase of primary velocity with depth. It also reveals the different layers have varying thicknesses and the depth to top of each layer vary giving indication of subsurface heterogeneity. The velocity variation suggests different lithologies/rock formations beneath the traverse.

Beneath traverse (0-60m), the processed section (Fig. 4.08) reveals three subsurface layers with velocities of 300m/s, 1000 m/s and 2000m/s respectively. Layer one with velocity of 436 m/s and thickness ranging from 1-5 m is the topsoil while, the second layer with velocity of 1000m/s thickness ranging from 2-4 m possibly represents the weathered layer. The third layer with velocity of 2000m/s suggests the partly weathered layer.

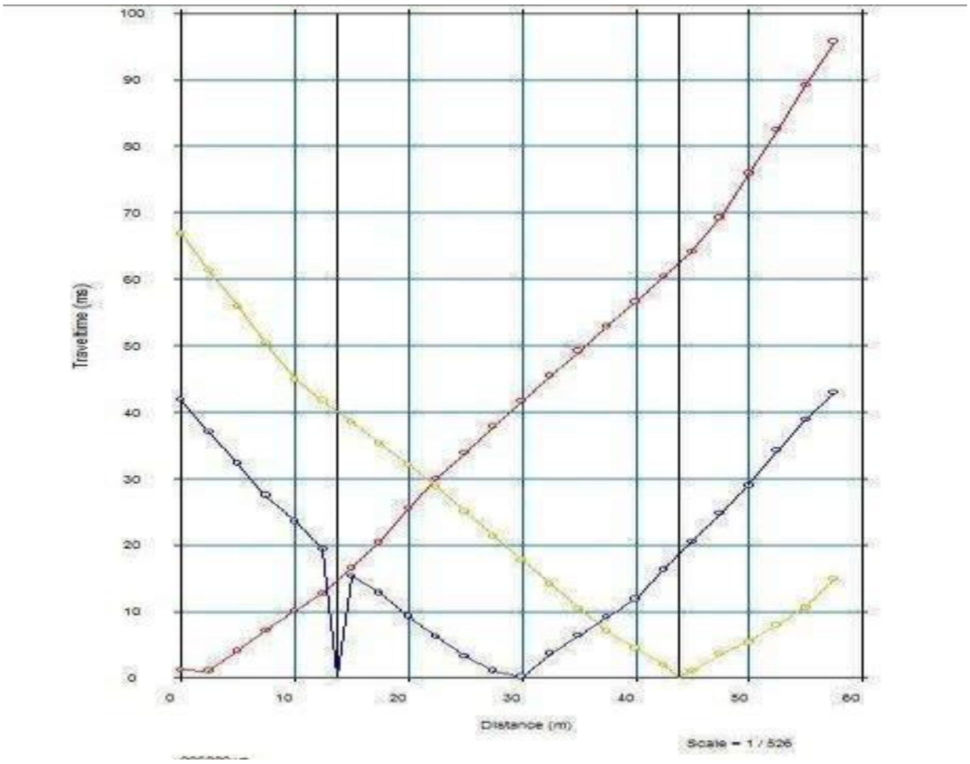

Figure 4.07:Image of the time-distance graphs from which layer velocities were estimated

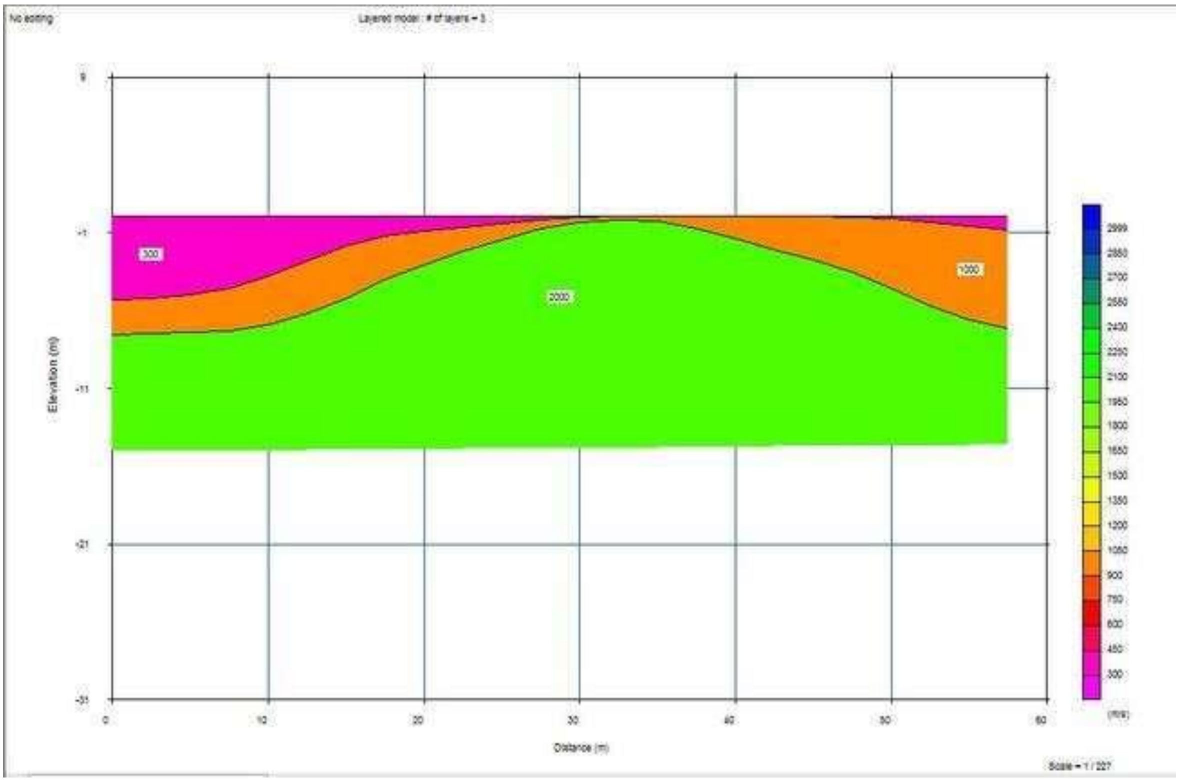

Figure 4.08: 2D velocity tomography showing primary velocity variation with depth beneath the traverse

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4.5. Spontaneous Potential (SP) Method

From the SP reading plots for 5m, 10m and 20m as depicted in figure 4.09, figure 4.10 and figure 4.11 respectively, points of interest with lower SP values for 5m, 10m and 20m spacing show common anomaly zones at 20m, 60m and 110m along the traverse. This also partly correlates with the processed data for the magnetic method, VLF method, EM method and CST methods.

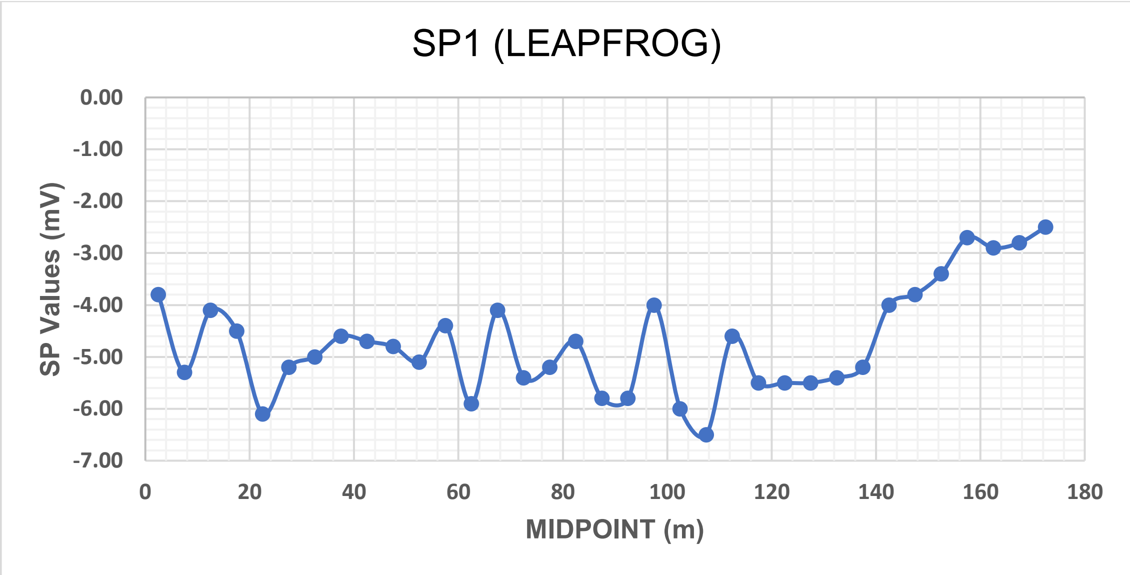

Figure 4.09: SP plot for 5m spacing

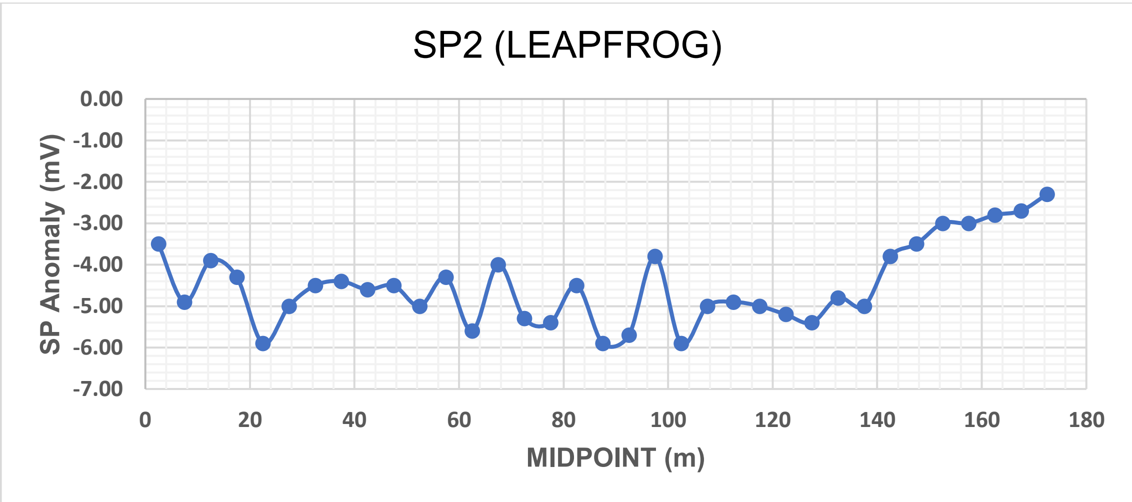

Figure 4.10:SP plot for 10m spacing

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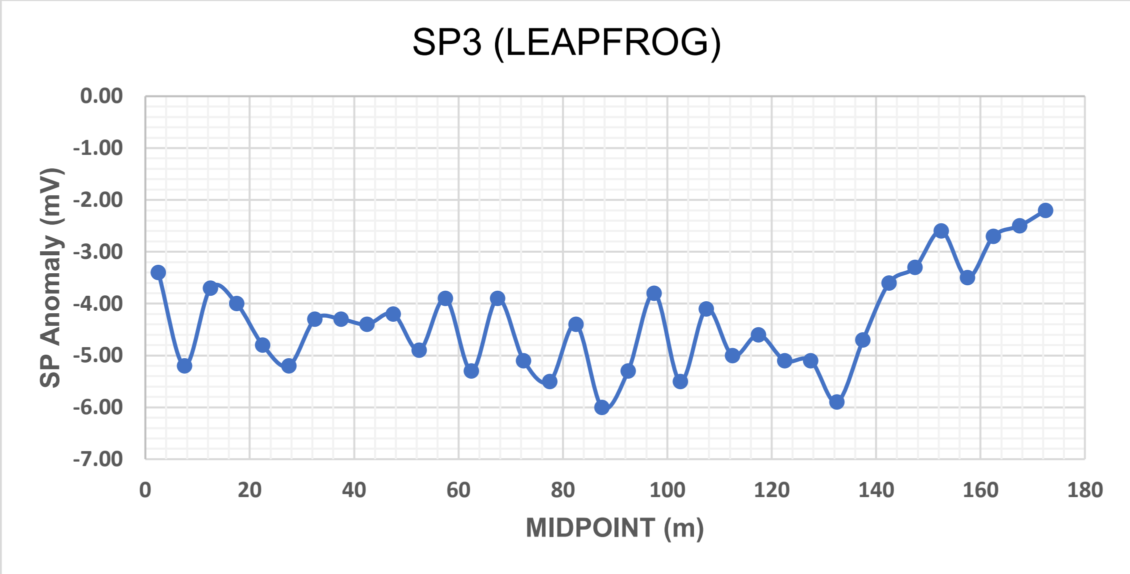

Figure 4.11: SP plot for 20m spacing

4.6. Electromagnetic (EM-34) Method

The plot of the EM data taken along the data is shown in the figure 4.12 below. The points at which the HD and VD curves cross for 10m spacing are at 25m, 110m and 155m. For 20m spacing the cross-over points are 10m, 20m, 64m, 85m and 135m.(Figure 4.13)

While for 40m spacing (Figure 4.13), the cross-over points are at 30m, 38m,66m, 92m, 110m, and 135m. These cross-over points are areas of interest for fracture zones, aquifers, weak zones for foundation or likely zones of mineralization.

By integrating the 3 spacing data plots, the likely areas of interests area within 20-30m,85-110m and 135m.

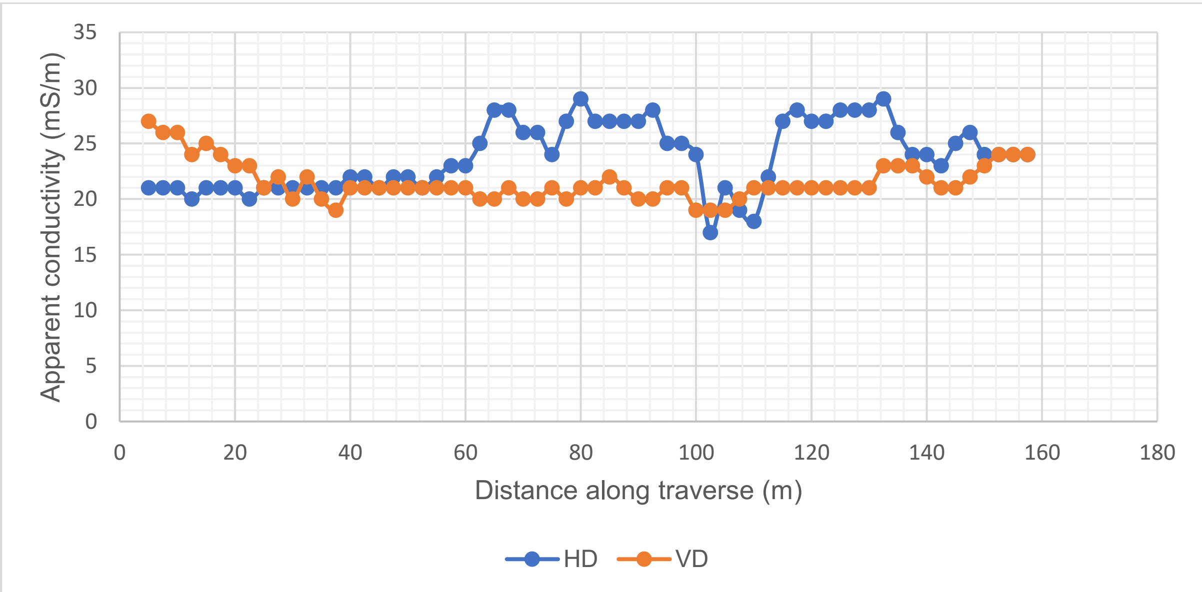

Figure 4.12: Electromagnetic Profile on Traverse 1 (10 m Horizontal and Vertical Dipole)

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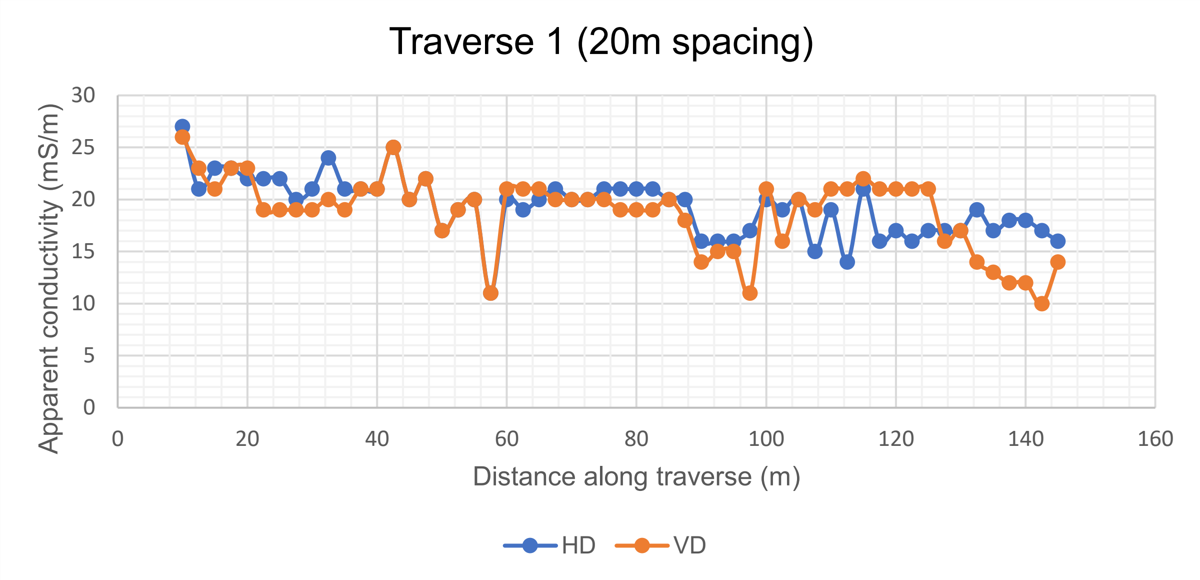

Figure 4.13: Electromagnetic Profile on Traverse 1 (20 m Horizontal and Vertical Dipole)

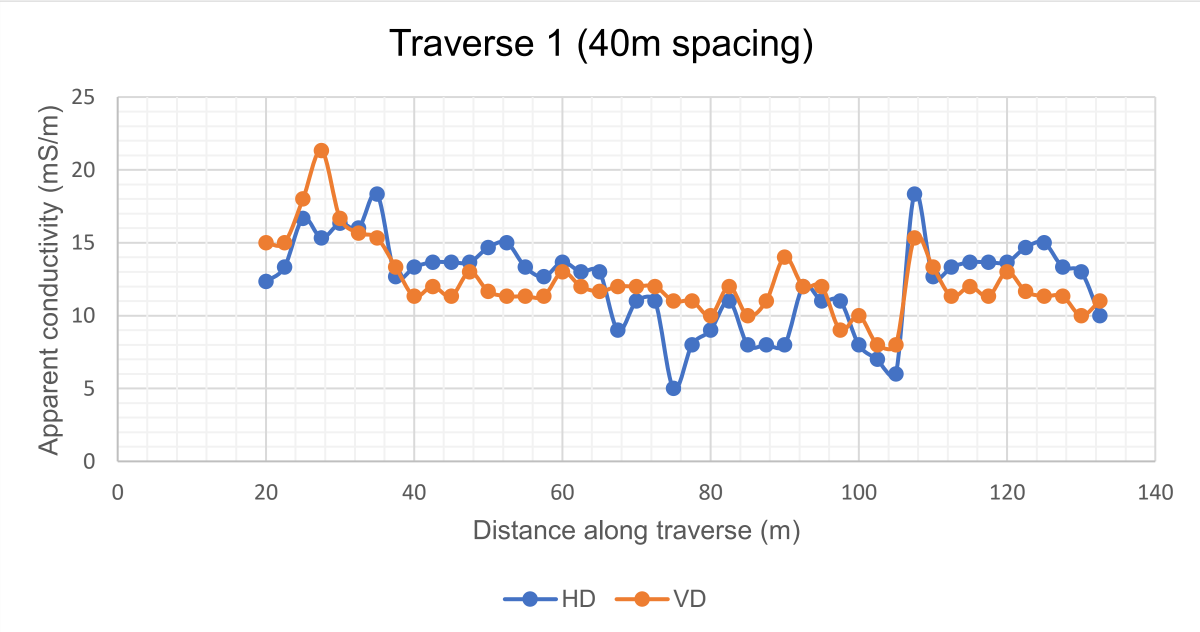

Figure 4.14: Electromagnetic Profile on Traverse 1 (40 m Horizontal and Vertical Dipole)

4.7. Constant Separation Technique (CST) Method

The 2-D pseudosection(Resistivity image) beneath the traverse surveyed indicate four geoelectric layers (Figure 4.15) with the first layer which is the top soil having resistivity values ranging between 212Ωm and 508Ωm with an average thickness of 2.0m.The second layer has resistivity values ranging between 66Ωm and 212Ωm typifying a partly weathered basement with varying thickness along the traverse from the depth of about 3m.The partly weathered layer has a thickess of more than 20m within the horizontal distances of 55-75m and 100-125m from the depth of about 3m.

The third layer of the pseudosection along the traverse has resistivity values that vary between 37Ωm and 66Ωm from the depth of about 8m within the horizontal distances of 32m-55m and 123-160m; thus typifying a highly weathered basement layer.

The fourth layer's resistivity values is between 123Ωm and 160Ωm from depth of 8m with the horizontal distance of 75m-98m which represents a fractured basement.

The 2-D image reveal the terrain within the horizontal distance of 75m and 98m to be of a fair to good aquifer for groundwater exploitation. Although, the resistivity values of the area surveyed with the electrical resistivity imaging reveal the terrain to be fair to good for erecting structures that require shallow foundations; other geophysical/geotechnical investigations are however recommended for high-rise buildings.

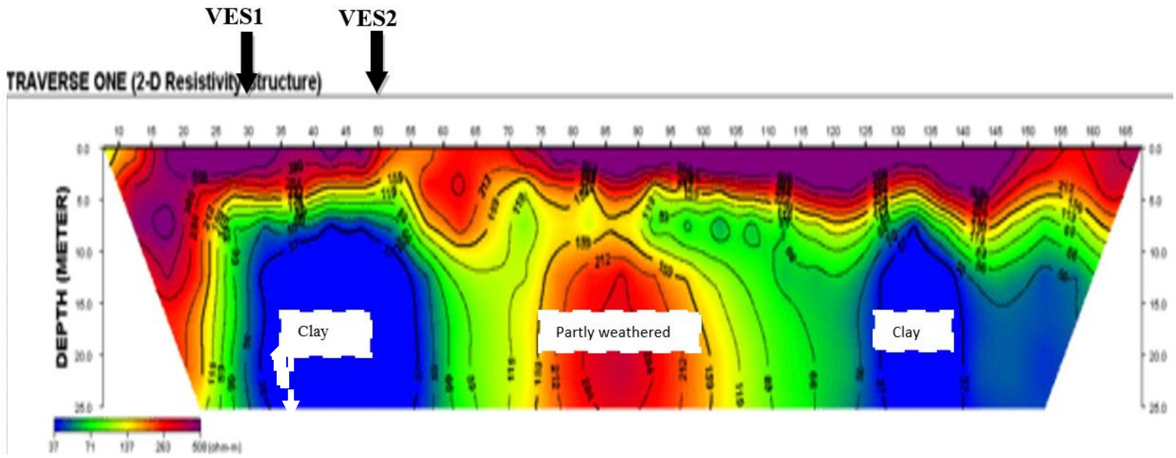

Figure 4.15: 2-D Resistivity Section along the traverse

4.8. Vertical Electrical Sounding (VES) Method

The two VES carried out at point 30m and 50m along the traverse delineated 4 geoelectric sections as shown in Figure 4.18; which also show same correlation with the 2-D pseudosection.(Figure 4.15)

The curve type generated for the two VES points as generated by Winresist software is QH(Figure 4.16 & 4.17)

Four layers were delineated beneath VES 1(@30m) which include: T. Clay h the resistivity value of 456.3Ωm to the depth of 0.8m, the second and third layers' resistivity values are 376.5Ωm and 79.4Ωm and thickness 4.9m and 16.0m respectively; typifying weathered basement layers.

The fourth layer is of the resistivity value of 288.3Ωm from the depth of 21.7m which is a fractured basement and pose a good aquifer area for groundwater exploitation.

Four layers were also delineated beneath VES 2 (@50m) which include: Top soil with the resistivity value of 824.1Ωm to the depth of 0.9m, the second and third layers' resistivity values are 214.1Ωm and 67.5Ωm and thickness 5.0m and 36.7m respectively; typifying weathered basement layers.

The fourth layer is of the resistivity value of 224.7Ωm from the depth of 42.6m Clay a fractured basement which makes a better aquifer zone for groundwater exploitation than the second layer(with resistivity value of 214.1 Ωm) because the latter may not yield sufficient water and could easily get contaminated due to its proximity to the surface.

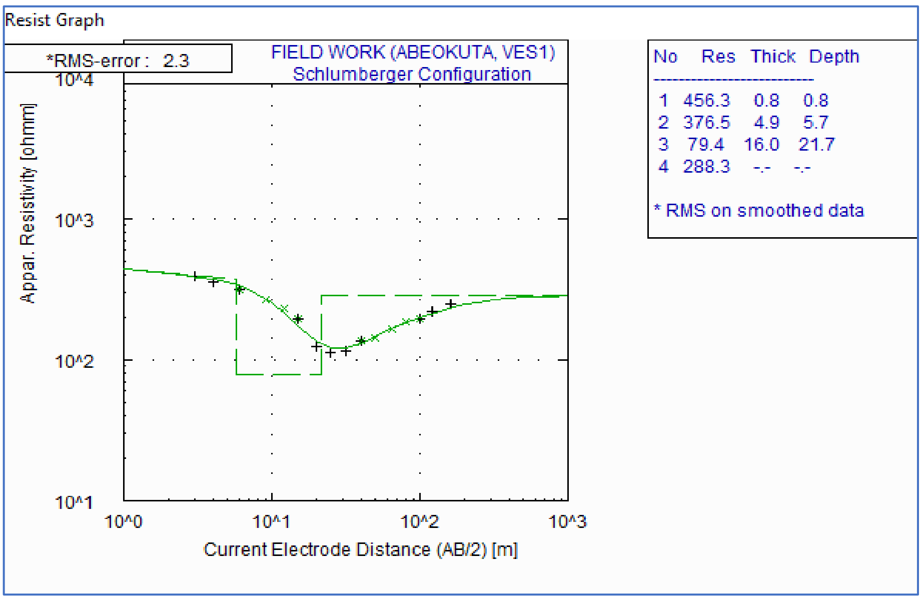

Figure 4.16:QH curve generated for VES at 30m

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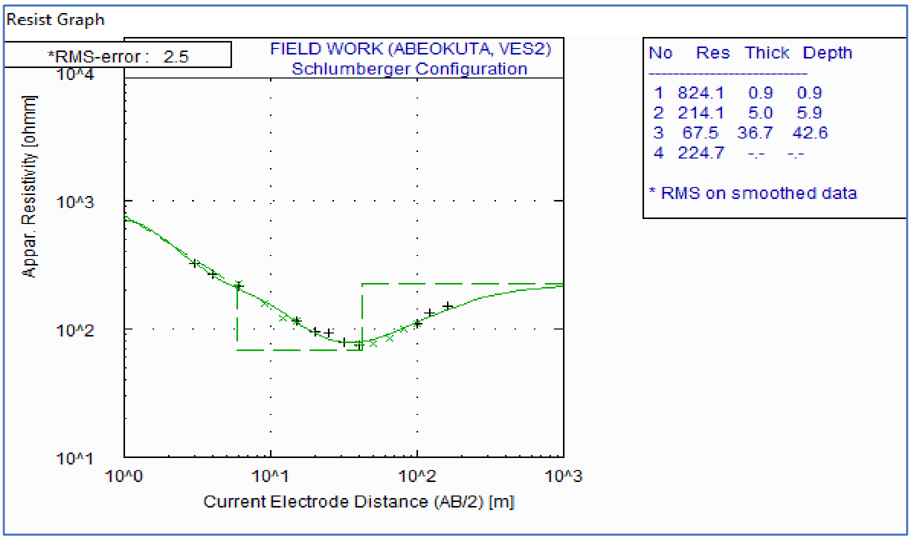

Figure 4.17:QH curve generated for VES at 50m

Table 4.1 showing the interpreted VES results for each of the VES points

VES Station	Layer	Resistivity (Ωm)	Thickness (m)	Depth (m)	Curve Type	Lithology
1	1	456.3	0.8	0.8	QH	Topsoil
	2	376.5	4.9	5.7		Weathered Layer
	3	79.4	16.0	21.7		Weathered Layer
	4	288.3	---	---		Fractured Basement
2	1	824.1	0.9	0.9	QH	Topsoil
	2	214.1	5.0	5.9		Weathered Layer
	3	67.5	36.7	42.6		Weathered Layer
	4	224.7	---	---		Fractured Basement

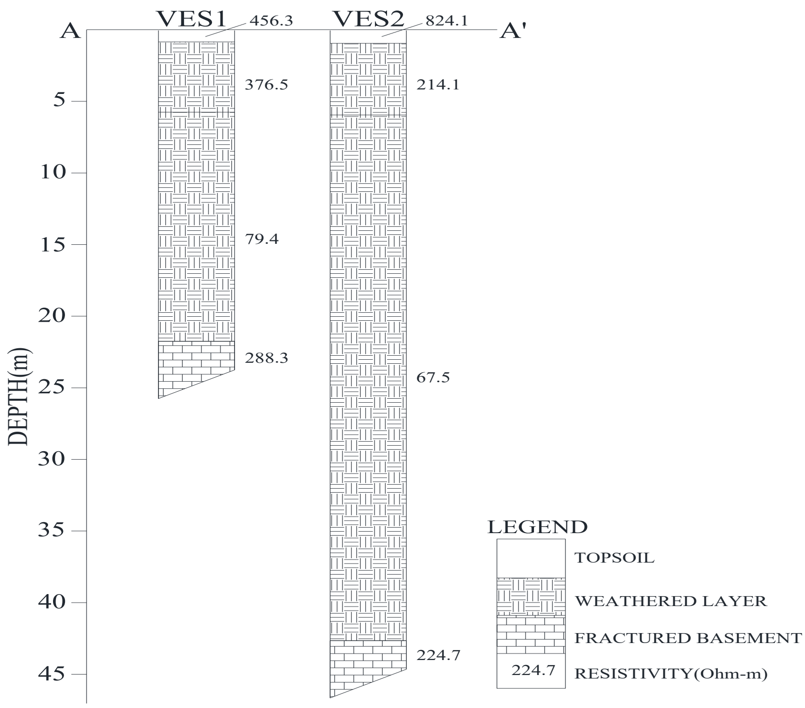

Figure 4.18. Geoelectric section from VES 6, 7 and 8 showing the delineated lithologies

V. CONCLUSION AND RECOMMENDATION

5.1 Conclusion

The eight geophysical techniques such as EM method, Magnetic method,Gravity method, VLF method, SP method, Seismic method, CST and VES employed along the traverse reveal some zones of anomaly which are areas of interest for groundwater exploration, building foundation/geotechnical investigations, clay mineral deposit assessment and possibly underground buried objects' investigation.

The geophysical techniques deployed such as CST, Seismic refraction, VLF and VES to image the subsurface in the study are reveals that there are three to four types of lithologies including topsoil, weathered layer, partially weathered layer, and fractured/fresh basement.

The depth to basement was observed to be shallow with ranging from about 8-42m.

5.2 Recommendation

1. Further geotechnical investigations should be carried to know the type of foumdation to be done for the construction of bulding (Especially for high-rise buildings;
2. Boreholes may be sunk at the deeper parts of the weathered layer and at the suspected fractured basements delineated for groundwater exploitation;
3. Further investigations maybe carried out at areas of very resistivity values (<100ohm-m) to ascertain if it is due to clay materials deposits(from the weathered basement) or as a result of other reason(s)

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