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INVESTIGATING THE BEHAVIOUR PATTERN OF ELECTRICAL POTENTIALS AROUND A CURRENT SOURCE

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ABSTRACT

An investigation into the behaviour pattern of electrical potentials due to current source on a horizontally stratified earth has been carried out using the principles of rotation of axis. The experiment was aimed at observing the behaviour of potential difference when placed around current source. The experiment was conducted at a field location beside Agbarho General Hospital along Ughelli express road, Agbarho.

The data was collected at various angles from a current source using a DC-inverter powered by a battery. The meter was set up at about 50m from the source of current with wire connecting the two. The sources were metallic pots hammered into the ground which is 100m way from the area. From these pots, holes of interval of 1m were dug in the north, south, east and west directions for 12m while distilled water was splashed within the hole to create a better connection with the electrodes.

Results from this experiment revealed that potential difference shows a trend of dropping with radius. As the radius increases, the voltage decreases through attenuation from the earth. This fits the expectations of an electric field through the earth. Further, the values on the polar plot become less symmetrical as the electrodes were moved further away from the current source suggesting that with less voltage, the more sensitive the instruments value becomes. We also observed that the measured data could have variations or anomalies that may not coincide with the general movement of the data due to more saturated soils or unconsolidated sands prevalent in the area.

Key words: Behaviour, Potential Difference, Current Source, Pole Dipole,

1.0 INTRODUCTION

Prospecting for mineral deposits around the world today is increasingly becoming difficult as most of the prospective areas are covered by superficial cover called the regolith which has the capability to distort the geophysical signals from minerals deposits. The SP anomalies are generated by flows of fluid, heat, ions in the earth, hence SP investigations can be used to locate and delineate sources associated with such flows (CORWIN, 1990). Such knowledge on the behaviour of electrical potential around a current source is very useful especially in the exploration for deep seated minerals deposits. The purpose of this investigation therefore is to use the self-potential method to obtain a set of measurements which may be interpreted to yield an equivalent model for the potential performance of the earth.

Generally, self-potential (SP) method of prospecting measures the potential difference between any two points on the ground that is produced by small, naturally currents that occur below the Earth's surface. The method is very simple, cost-effective, passive and non-intrusive and does not require the application of an electric current. Self-potential methods have long history of applications; some of which are documented by (Telford, 1990, Aubert & Atangana1996, Keary & Brooks 2002, Corwin & Hoover 1979, Stanley 2004, Wightman, W. E, Jalinoos, F., Sirles, P., and Hanna, K. 2003, Sheriff, R.E., 1991).

2.0 STUDY AREA

The study area, Agbarho, is a town in Ughelli North local government area of Delta state, Nigeria. It is located near the city of Warri and it lies within longitudes 5° 50' and 5° 59'E and latitudes 5° 30' and

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5° 35'N. The area which covers approximately 700 sq Km enjoys the Tropical Equatorial climate with an average annual temperature of 30°C and 3130 mm of rainfall, while relative humidity is 80% -90% (Efe, 2007). Three stratigraphic units underlay this area namely; top formation (Benin) with unconsolidated coastal plain sands, middle formation (Agbada) consisting of intervening unit of sandstone and shale and bottom unit shale known as the Akata formation, representing continental, paralic and marine depositional environments respectively (Short and Stauble, 1967). The area derives its water from the Sombreiro Warri Deltic Plain which overlies the coastal plain sand of the highly prolific Agbada formation. The area is considerably recharged by rainfall as such the water table is encountered at a minimum depth of 20 meters. Figure (1) is the map of Niger Delta region showing the location of study area.

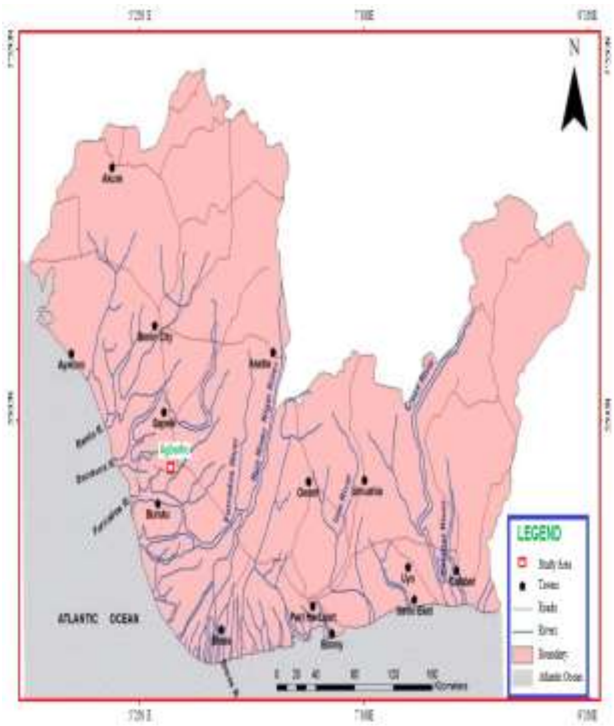


Figure 2.1: Map of Niger Delta Region, showing the location of study area (modified after Olonaniyi and Owoyemi 2006)

3.0 BASIC THEORY

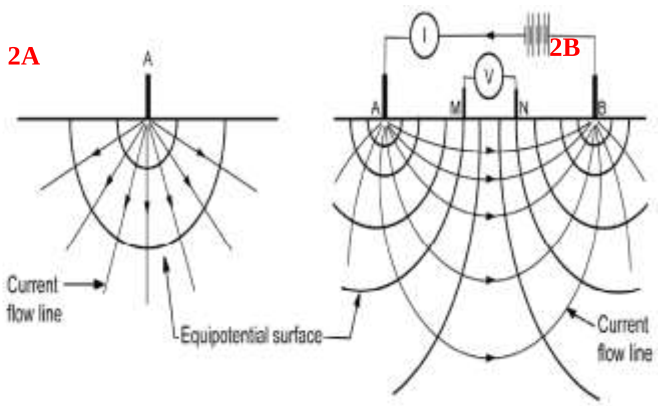
If we consider the case of single electrode at the surface of a homogenous medium of resistivity (ρ), in which a current I flows away radially. We could describe the voltage drop between any two points on the surface by a potential gradient in the form $\frac{dv}{dx^1}$, which would be negative because the potential decreases in the direction of the flow. Equipotential lines intersect the lines of equal current at right angles. The current density (J) is the current (I) divided by the area over which the current is distributed i.e. for a hemisphere this is $2\pi r^2$, and so the current density decreases with increasing distance from the current source. The potential difference across a hemispherical shell of incremental thickness (dr) is given by:

$$\frac{dv}{dr} = -\rho\left(\frac{1}{2\pi r^2}\right) \quad (1)$$

Thus, the voltage (V) at a point r from the current point source is express as

$$V_r = -\rho\int\left(\frac{1}{2\pi r^2}\right)dr = \left(\frac{\rho 1}{2\pi r}\right).\frac{1}{r} \quad (2)$$

In a homogeneous ground (half space) the current flow radially out from the current source and the arising equipotential surfaces run perpendicular to the current flow lines and form half spheres (Figure 2a). In the common situation with both current source and current sink, the current flow lines and the equipotential surfaces become more complex (Figure 2b). However, in reality the current flow lines and the equipotential lines will form an even more complex pattern as the current flow lines will bend at boundaries, where the resistivities change.



Simplified current flow lines and equipotential surfaces arising from (a) a single current source and from (b) a set of current electrodes (a current source and sink).

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The theory and field methods used for resistivity surveys are usually based on the use of direct current, because it allows greater depth of investigation than alternating current. Also, it helps to avoid the complexities caused by effects of ground inductance and capacitance and resulting frequency dependence of resistivity (Wightman, Jalinoos, Sirles, and Hanna, 2003**)**. Figure 3 is the pole dipole configuration used to collect data.

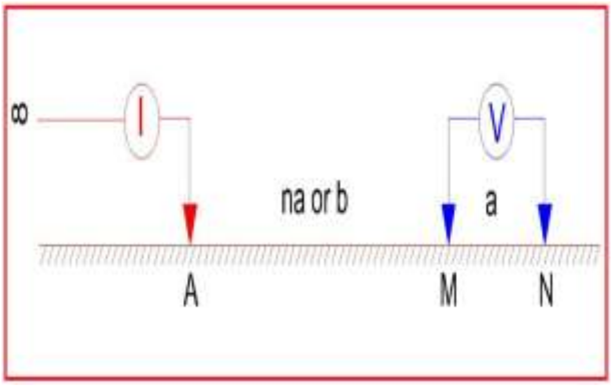

Figure 3: Pole-dipole configuration used to collect the data

4.0 MATERIALS AND METHOD

Materials used for this investigation includes tape, DC-inverter, battery, milliammetres,high-impendance voltmeters, current cables, clips, porous pots, electrolytes, conductor rod, hand corer, clinometers, water. The inverter is powered by a battery and once it is switches the meter from AC to DC a steading current reading would be recorded for the data. This meter was set up about 50m from the source of current with wire connecting the two. The source was a metallic pot hammered into the ground with another hammered that is 100m way from the area.

In the first set of experiment (Figure 4), readings were taken 12 meters in the North, South, East and West directions from the source current electrode with a current of 0.185A DC being supplied to the earth surface. The second set of readings was taken by rotating the axes NE45^0 from true North from the source current electrode with a current of 0.19A DC being supplied to the earth surface. Final analysis and plotting of voltage readings along various radii and angle (polar plot) were obtained and comparison of the results was drawn.

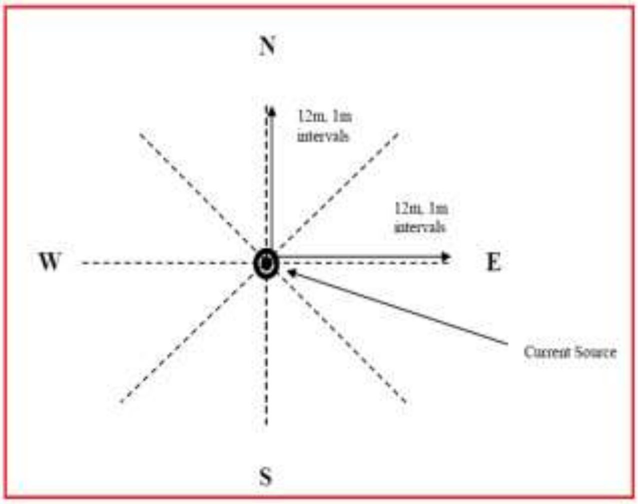

Figure 4: Diagram of the data collection around the current source

During the survey, it was essential to pay attention to detail in survey planning. To improve the quality and reliability some safety precautions were taken, the survey was conducted away from trees to avoid any osmotic potential due to tree roots. The voltmeters used were measuring to 3 decimals and had very high impedances to ensure very little current was drawn out of the circuit. The pots themselves were checked to ensure that saturation of the copper sulphate solution was sufficient i.e. super saturation was occurring with some crystals then forming in the bottom of the pot. This is done to stop any chemical reactions that may affect the data. The current was measured (and was equal) for both sets of lines to eliminate the need for any corrections between the two sets of line measurements.

5.0 RESULTS

Results of the potential field data collected around current electrode at various radii and angles with respect to North plus when the axes was rotated NE45^0 (table 1 and 2) and angle versus voltage (table 3) were used for interpretation. From the interpretation of the data various graph was plotted to investigate the radial electric field.

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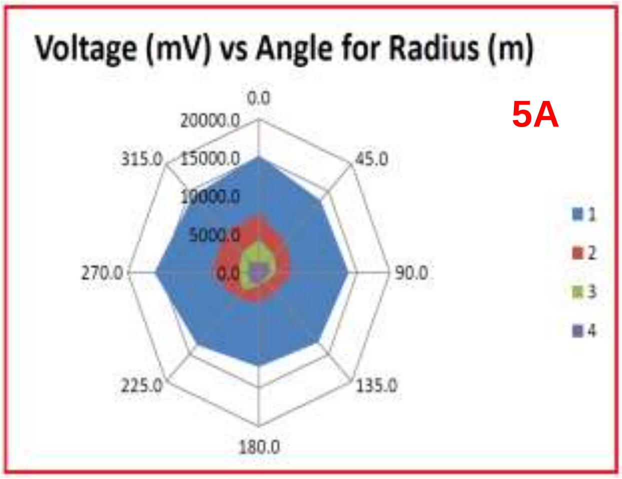
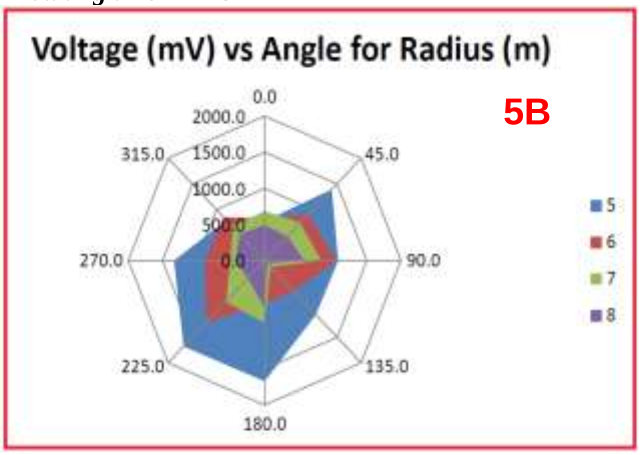
North Direction		South Direction		East Direction		West Direction	
Radius (m)	Voltage (V)	Radius (m)	Voltage (V)	Radius (m)	Voltage (V)	Radius (m)	Voltage (V)
1	15.4	1	12.26	1	13.72	1	15.45
2	7.67	2	3.953	2	5.1	2	7.25
3	4.3	3	1.59	3	2.656	3	3.135
4	1.3	4	1.52	4	1.68	4	1.615
5	0.5464	5	1.67	5	1.078	5	1.33
6	0.5882	6	0.5882	6	1.056	6	0.875
7	0.687	7	0.687	7	0.826	7	0.502
8	0.4901	8	0.4901	8	0.584	8	0.48
9	0.405	9	0.405	9	0.371	9	0.338
10	0.3578	10	0.3578	10	0.261	10	0.248
11	0.2801	11	0.2801	11	0.168	11	0.2

Table 1: Voltage vs Radius values for different angles obtained from NSEW direction

NW		NE		SE		SW	
Radius (m)	Voltage (V)	Radius (m)	Voltage (V)	Radius (m)	Voltage (V)	Radius (m)	Voltage (V)
1	14.18	1	13.29	1	12.8	1	13.3
2	7.33	2	5.715	2	3.4	2	4.71
3	3.65	3	3.208	3	1.6	3	3.23
4	2.08	4	1.938	4	1.12	4	1.81
5	0.7949	5	1.392	5	1.062	5	1.21
6	0.8406	6	0.906	6	0.568	6	0.803
7	0.6638	7	0.7265	7	0.121	7	0.4
8	0.5174	8	0.4732	8	0.0562	8	0.367
9	0.3653	9	0.3935	9	0.101	9	0.367
10	0.267	10	0.235	10	0.0401	10	0.21
11	0.1554	11	0.1673	11	0.0258	11	0.035

Table 2: Voltage vs Radius values for different angles obtained on rotating axis NE 45^0





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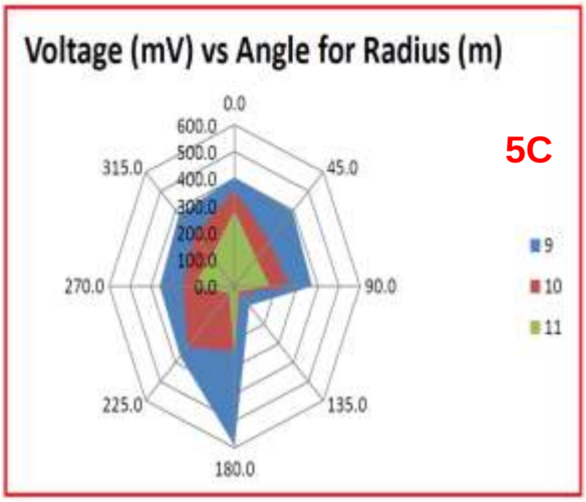

Figure 5: Voltage vs Angle for radius A) 1-4, B) 5-8, C) 9-11. The three polar plots above show the voltage drop as we progressively move further away from the electrode at the centre. It is expected that the potential difference should decrease as we move outwards as the voltage is indirectly proportional to distance. Using a logarithmic scale to produce interpretable plots, it is clear that the South East line has considerable drop from 7-11m. Another large voltage drop can be seen on the South Western line at 11m. On the whole it is clear that the voltage decreases largely with increasing radius, a consequence of the inverse relationship between the two components

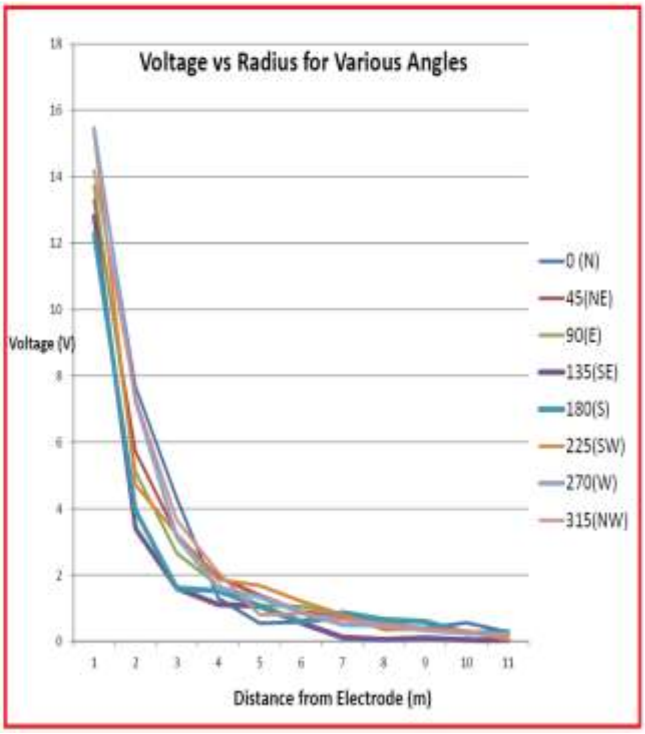

Figure 6: Voltage vs radius drops for various angles. Despite the similarity in voltages with angles, there are some variations that stand out in this dataset. The South Eastern line after 6 meters takes a sudden plunge to very low voltages whilst the Southern and Eastern lines maintain similar to the other lines. As expected, the voltage as a whole decreases at further distances. The current spreads uniformly away from the source while the potential varies inversely with distance from the current source

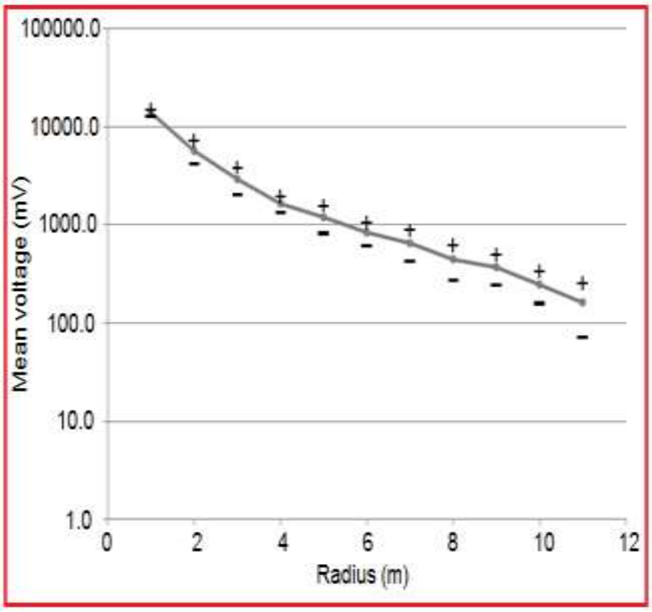

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Figure 7: The mean voltage, with error bars as the standard deviation, on a log plot. We think the log plot is suggesting that the relative error is increasing with increasing radius (and consequently decreasing voltage). The multimeters will be more inaccurate when measuring smaller voltages. Given a constant value of "noise", lower voltage values will have consequently higher relative error values.

6.0 DISCUSSION OF RESULTS

The image displayed by electric field as the lines increase outwards from the current source at the centre is shown in Figure 5A-C. With increasing radius the voltage decreases through attenuation through the earth. This fits the expectations of an electric field through the earth. As the voltage is recorded further away from the current source the electric energy supplied by the source decreases over the distance thus decreasing the voltage. However, there are some jumps in the data after 6m creating an asymmetrical display on the polar plot. The values on the polar plot become less symmetrical as the electrodes were moved further away from the current source. This could infer that with less voltage, the more sensitive the instruments value becomes. Also a channel of water or even more plausible a tree root, due to fact that the measurements were taken 50m from a large tree. Also there is irrigation throughout the field that could create disturbances in the measurements.

The resistivity versus radius plot Figure (6) follows the expected behaviour line. Given our experimental procedures it is unreasonable to expect it to closely follow it but it is encouraging to see that the data is centred on it with the variations being roughly equal on either side.

Experimental error is significant in this experiment due to, low number of readings/trials and the tendency of the voltage reading not to settle on a stable number. Nevertheless, the data does show a significantly lower resistivity in the south east direction. This could possibly have been caused by a particularly conductive body, such as a metal pipe, orientated in this direction. For the same reasons, the resistivity vs. radius data is not constant.

7.0 CONCLUSIONS:

The outcome of this lab demonstrated that various techniques used to collect the data can have a major effect on the results and interpretation. Also that the data can have variations or anomalies that do not coincide with the general movement of the data that is due to more saturated soils or unconsolidated sands. We believe that the irrigation system that was observed would provide point sources that interrupted the data. These points sources were tangent to one another and could provide explanation of a pipe or channel of saturated sand. Overall these attributes influenced the behaviour of the potentials and thus influenced the interpretation.

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Appendix 1

Angle (N)	0	0	0	0	0	0	0	0	0	0	0
Voltage	15.4	7.67	4.3	1.3	0.546	0.687	0.687	0.490	0.405	0.357	0.280
Angle (NE)	45	45	45	45	45	45	45	45	45	45	45
Voltage	13.29	5.715	3.208	1.938	1.392	0.906	0.726	0.473	0.393	0.235	0.167
Angle E	90	90	90	90	90	90	90	90	90	90	90
Voltage	13.72	5.1	2.656	1.68	1.078	1.056	0.826	0.584	0.371	0.261	0.168
Angle (SE)	135	135	135	135	135	135	135	135	135	135	135
Voltage	12.8	3.4	1.6	1.12	1.062	0.568	0.121	0.056	0.101	0.040	0.026
Angle (S)	180	180	180	180	180	180	180	180	180	180	180
Voltage	12.26	3.953	1.59	1.52	1.67	0.588	0.687	0.490	0.405	0.357	0.280
Angle (SW)	225	225	225	225	225	225	225	225	225	225	225
Voltage	13.3	4.71	3.23	1.81	1.21	0.803	0.4	0.367	0.318	0.21	0.04
Angle W	270	270	270	270	270	270	270	270	270	270	270
Voltage	15.45	7.25	3.135	1.615	1.33	0.875	0.502	0.48	0.338	0.248	0.2

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Angle (NW)	315	315	315	315	315	315	315	315	315	315	315
Voltage	14.18	7.33	3.65	20.8	0.795	0.841	0.664	0.517	0.365	0.267	0.155

Table 3: Voltage vs Angle reading from the data set