ELECTRICAL RESISTIVITY AND GROUND MAGNETIC SURVEY FOR THE INVESTIGATION OF POTENTIAL MINERAL TARGETS AT AKO-MATOLE, SOUTHWESTERN, NIGERIA

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ABSTRACT

A geophysical electrical resistivity and ground magnetic survey was carried out at Ako- Matole, Ago-Iwoye, Ogun State, Southwestern part of Nigeria. The survey area lies between the latitude *6.936342*°to 6.936965°N and longitude 3.861218° to 3.862697°E. The study aimed at investigation of the nature of the potential mineral deposits of the location using both electrical resistivity and ground magnetic methods. Schlumberger array was employed for the electrical resistivity data acquisition using ABEM SAS 1000 Terrameter to delineate the resistivity values and depth to the basement rocks. The electrical resistivity technique involves the measurement of apparent resistivity distribution of the subsurface, and from which the true resistivity values of the various earth materials can be computed. WinResist was used for electrical resistivity data processing. *Magnetic method involves* the measurement the measurement of the earth's magnetic field intensity The basic task of magnetic methods in prospection is to differentiate subsurface according to its magnetic properties. A proton precession magnetometer was used to acquire the magnetic data The Cartesian technique was used for the magnetic data acquisition; Gaussian filter approach which filters the regional from residual was applied on the field. The acquired data were subjected to Oasis montaj software. The field data collected was qualitatively and quantitatively interpreted. The electrical resistivity results inferred topsoil, clay and sandy clay/clayey sand with resistivity values ranging from 160.5-289.9Ωm, 34.4-69.6Ωm, and 146.6-437.5Ωm respectively with total depth to basement rocks ranging from 11.9m and 19,2m.TheTotal Magnetic Intensity (TMI) value of the area ranges between 32856.2 to 33323.2 nT *while the residual magnetic values were in the range of about* -4.3 and 1.7 nT. From the interpretations of the magnetic maps, it reveals the presence of magnetic anomaly at some parts of the study area which indicates the presence of potential magnetic mineral which can be very useful for exploration. This is trending at the Northeastern - Southeastern (NE – SE) part of the study area, the Southwestern (SW) part of the study area possesses lowest magnetic intensity; this implies that more mineral target is available in the Eastern region. The subsurface geological structural traps for mineralized localization include the presence of shallowly buried magnetic sources at the eastern part inferred as granite gneisses.

Keywords: Electrical resistivity, Magnetic field intensity, Magnetic method, Magnetic mineral, Residual anomaly.

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INTRODUCTION

Geophysical methods involving electrical resistivity and ground magnetic techniques is widely used in investigating potential mineral targets of an area due to its effectiveness and quick detection of underground metallic deposits (Lowie, 2001; Butler, 2005). Basement structures are essentially significant for several well-known exploration and environmental motives. Structural fabric of basement rocks when interpreted may deduce the deformative patterns and the magnitude of causative stress impact responsible for deformation (Ariyo *et al.,* 2020).Rocks do not differ only by their macroscopic or microscopic properties. They also differ by their chemical and physical properties. Significant concentration of

magnetic mineral occurs in several mineral deposit associated with magnetic rock units. Hence the rocks differ according to their origin, structure, texture, etc. they also differ by density, magnetization, resistivity, etc. A magnetic high anomaly is where the measured field strength is higher than the value predicted by global model.
Anomalies in the earth's magnetic field are caused by induced or remanent magnetism. Induced magnetic anomalies are the result of secondary magnetization induced in a ferrous body by the earth's magnetic field. Magnetic prospecting looks for variations in the magnetic field of the earth that are caused by changes in the subsurface geologic structure or by differences in the magnetic properties of near-surface rocks. The inherent magnetism of rocks is called the magnetic susceptibility (Valenta, 2015). In general, the magnetic content (susceptibility) of rocks is extremely variable depending on the type of rock and the environment it is in. Common causes of magnetic anomalies include dykes, faults and lava flows. In a geothermal environment, due to high temperatures, the susceptibility decreases. It is not usually possible to identify with certainty the causative lithology of any anomaly from magnetic information alone (Roest *et al.,* 1992). Magnetic gradient anomalies gives better definitions of shallow buried features such as buried tanks and drums, but are less useful for investigating large geological features. Magnetic is otherwise useful in exploring iron ore deposit and deducing subsurface lithology and structure that may indirectly aid identification of mineralized rocks, pattern of effluent flow((Mariita, 2007; Kayode and Adelusi, 2010). Kayode *et al.* (2013) applied magnetics method to delineate subsurface geological structure for suitable mineral potential using a proton precession magnetometer. The lateral extent of interpreted lithology was estimated using analytical signal and the results were used to obtain the geological structures and potential mineral targets. The field magnetic intensity of the ground magnetic data obtained in this study has been used to delineate potential mineral and the depth. The electrical resistivity also adopted for characterization of the subsurface materials.

Geology and location of the study Area

Basement complex rocks are subdivided into migmatite-gneiss complexes; the older meta-sediments; the younger meta-sediments; the older granites; and the younger granite alkaline ring complexes and volcanic rocks. The migmatite - gneiss complex is the commonest rock type in the Nigerian Basement complex. It comprises two main types of gneisses: the biotite gneiss and the banded gneiss (figure 1). Very common, the biotitic gneisses are normally fine-grained with strong foliation caused by the parallel arrangement of alternating dark and light minerals (Oyawoye, 1972; Holt, 1982).The banded gneisses show alternating light-coloured and dark bands and exhibit complex folding of their bands. The migmatite gneiss complex is the oldest basement rock, and is believed to be of sedimentary origin but was later profoundly altered into metamorphic and granite conditions. The older meta-sediments were also among the earliest rocks to form on the Nigerian Basement Complex.

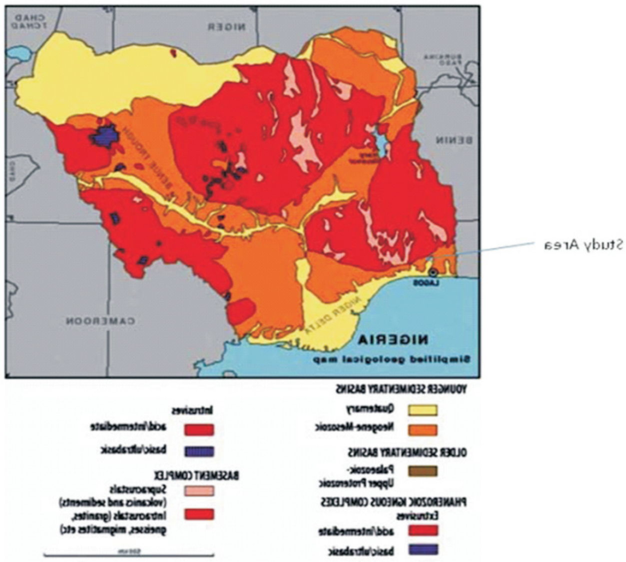


Figure 1: Regional map of Nigeria showing the study area (Modified after Ajibade *et al.,* 1979)

The study area is located at Ago-Iwoye northern part of Ogun state, Southwestern Nigeria. The survey was carried out at Ako-matole, Ago-Iwoye, Ogun State (figure 2). It lies at the basement complex of Nigeria between latitude 6.936342° to 6.936965°N and longitude 3.861218° to 3.862697°E. It has a population of about 120,000.It is located 79km by road north- east of Lagos; it is within 100km of the Atlantic Ocean in the northern part of Ogun state and possesses a worn tropical climate. The major source of livelihood in the area is farming and trading.

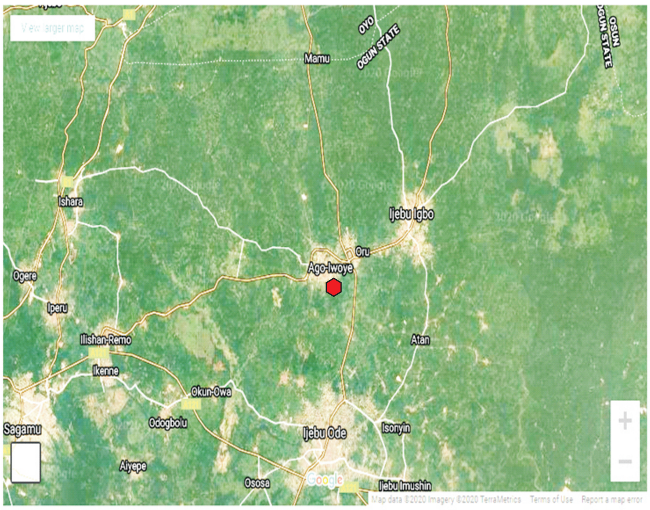


Figure 2: Location map showing the study area
⬢(Google Map, 2020)

Materials and Methods

The electrical resistivity method involves the determination of subsurface resistivity distribution by taking ground surface measurements (Amigun *et al.,* 2012). The true resistivity of the subsurface is estimated from these measurements. This requires passing electrical current (I) into the ground by means of two electrodes and the potential difference (ΔV) is measured between another pair of electrodes. Its apparent resistivity is represented by equation (1)(Telford and Sherif, 1990):

$$\rho_\alpha = \frac{\Delta v}{I} G$$

Where ρ_a is apparent resistivity and G is the geometric factor which value depends on the electrode array's geometric spread. The mode of measurement adopted is the vertical electrical sounding (VES). For vertical electrical sounding technique involving the Schlumberger array with a four electrode configuration, the mid-point of the array is kept fixed while the distance between the current electrodes is progressively increased (figure 3).

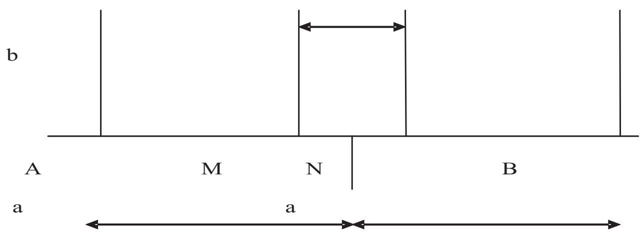


Figure 3: Schlumberger Electrode Configuration

Hence, the apparent resistivity value is calculated using the equation (2) according to (Amigun *et al.,* 2012).

$$\rho_a = \frac{\pi R(AB/2)^2}{MN} \qquad (2)$$

Where AB is current electrode spacing, MN is potential electrode spacing, R is electrical resistance and π is a constant equal to 3.142; from the expression in equation (2) that is for Schlumberger array, the distance between the potential electrodes is small compared to the distance (Amigun *et al.,* 2012). ABEM SAS 1000 Terrameter with its accessories was used to acquire the data using Schlumberger array. Five vertical electrical soundings were carried out at the study area.

The field data of the Vertical Electrical Sounding (VES) was processed with the WinResist software. The resistivity value and distance (AB/2) for each point at every station was entered into the software, after which the software plots the curve. The software then performs iteration to smoothen the curve until it gives a curve of best fit.

Data acquisition using ground magnetic method: The principle of magnetic surveying is based on the measurement of spatial variation in the intensity of the magnetic field of the earth; influenced by the subsurface changes in magnetic susceptibility or remanence of the underlying rocks.

The intensity of induced magnetization *J*i of a material is defined as the dipole moment per unit volume of material:

$$\left(J_i = \frac{M}{LA}\right) \qquad (3$$

Here *M* is the magnetic moment; a parameter proportional to both the length *L* and cross-sectional area *A of the material* and *J*i is consequently expressed in Am^{-1}.

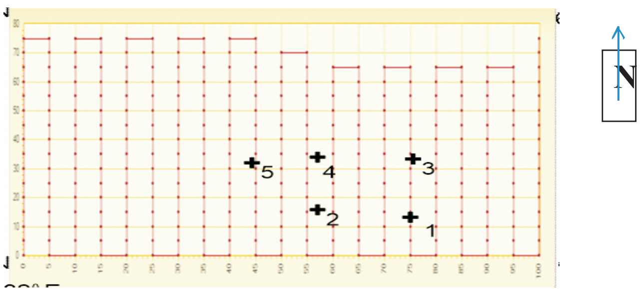
Another useful relationship is the proportionality between induced intensity of magnetization and the magnetizing force *H* of the inducing field:

(Ji = kH) (4)

Where: '***k'*** is a proportionality constant known as *magnetic susceptibility of the material*. Since *J*i and *H* are both measured in Am^{-1}, susceptibility is a dimensionless quantity in an unperturbed geomagnetic field. Proton precession magnetometer with its accessories was used to acquire the ground magnetic data which gave the magnetic field strength. It measures the variations in the earth's magnetic field presents as Total magnetic intensity of the study area. Magnetic survey readings are acquired in the northern direction, with the Northern region moving in an x-axis form while the Eastern region moves in a y-axis form (figure 4).The Cartesian procedure was used in this case. All data collected was programmed on the magnetometer. The magnetometer must be programmed and it is also important for taking the total magnetic intensity which has to do with signal noise and it is operated by a single person. Magnetometers are sensitive to metallic minerals like beltbuckles, wristwatches etc. must be removed when operating the unit.

3.862697^{0}E **3.863520^0 E**

6.936965^{0}N **6.937210^{0}N**



6.936342^{0}N **6.936369^{0}N**

3.861218^{0}E **3.862406^{0}E**

Figure 4: Survey Path Extract for Magnetic Survey.

The acquired data was subjected to Oasis montaj software to make accurate magnetic anomaly maps, a temporal change in the earth's magnetic field during the period of the survey was considered. The Gaussian filter which filters the region from the residual was applied. The processed magnetic data were presented as total magnetic intensity pseudo section, residual magnetic intensity map and analytical signal map.

Results and Discussion

Results and discussion using electrical method

The summary of the processed vertical electrical sounding is presented in table 1. This shows the layering parameters of the five iterated vertical electrical sounding curves based on the resistivity value, the thickness and depth.

Table 1: Summary of Layering Parameters

VES	NO OF LAYERS	RESISTIVITY (Unit)	THICKNESS (Unit)	DEPTH (Unit)	LITHOLOGY
		179.4	1.5	1.5	Topsoil
1	3	39.6	10.4	11.9	Clay
		246.6			Sandy Clay
		289.9	1.2	1.2	Topsoil
2	3	69.6	12.7	13.9	Clay
		201.2			Sandy Clay
		199.1	1.3	1.3	Topsoil
3	3	48.5	11.6	12.9	Clay
		437.5			Clayey Sand
		160.5	1.4	1.4	Topsoil
4	3	34.4	14.5	15.8	Clay
		275.1			Sandy Clay
		169.5	1.2	1.2	Topsoil
5	3	45.4	18.0	19.2	Clay
		164.6			Sandy Clay

Key : VES =

Three geoelectric layers were delineated to show topsoil, clay ,sandy clay /clayey sand with different resistivity values and corresponding thicknesses.

The first layer has low resistivity values ranging from 160.5Ωm to 289.9Ωm, with an average resistivity value of 199.7Ωm interpreted as topsoil The thickness value corresponding to the topsoil range from 1.2m to 1.5m and having an average layer thickness of 1.3mThe second layer has resistivity values ranging from 34.4 to 69.6 interpreted as clay, with an average of 47.5Ωm and thickness ranging from 10.4m to 18.0m, having an average layer thickness of 13.4m. The third layer, which is the terminating layer, has resistivity values ranging from 146.6 to 437.5 and it is interpreted as sandy clay/clayey sand. The total depth to basement rock ranging from 11.9m to 19.2m with an average value of 14.7m

Results and discussion using magnetic method

The Total Magnetic Intensity of the study area ranged between 32856.2-33323.2 nT (figure 5). Upward continuation of the deep seated magnetic sources shows high intensity at the Southeastern part (violet)and with the most striking intensity at the top most Northwestern part while the lowest magnetic intensity is revealed at the northern (green) andwith an obvious less intensityat the corner of the Southwestern part of the map (blue).

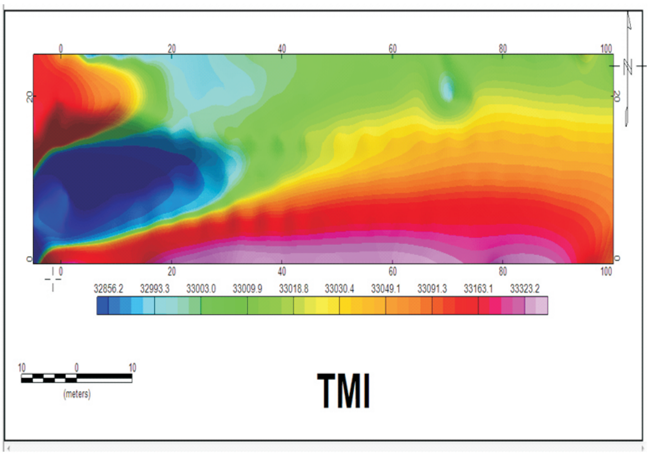


Figure 5: Total Magnetic Intensity of the Study Area. It shows the resultant susceptibility reaction contributed by near and deep seated geologic bodies.

The residual magnetic anomalies: Subtraction of the regional field from the total magnetic field generated the residual magnetic anomalies whose range is -4.3 and 1.7Nt (figure6) indicating a heterogeneous susceptibility of basement rocks constituting the area. The Magnetic anomalies depicted in the magnetic map of the area are essentially of the splashes low intensity magnetic closures (blue) found at base of the Southern part to the extreme side of the western part and wellpronounced high intensity magnetic closures (violet) found Northeastern and Southeastern parts.The violet coloured zones on the map shows the areas with high magnetic residuals and blue coloured zones shows low magnetic residual which may be an indication of variation in depth of occurrences of the geological bodies. The green coloured zones on the map depict fractures within the granite gneisses of the basement complex.

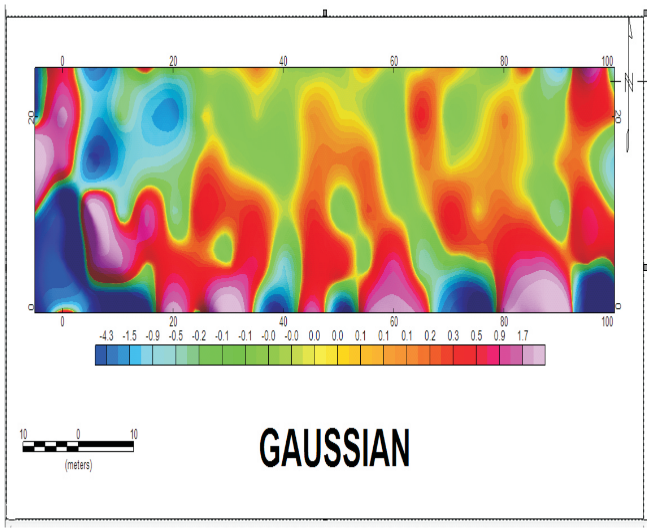


Figure 6: Residual Anomaly Map of the study area.

Analytical signal map were used for the enhancement of magnetic features in the study area. The zones with the violet closures signifies zones with high analytical signal amplitude which indicate presence of anomalies and presence of induced magnetized body irrespective of the direction of magnetization. It can be used to locate the edges of remanent magnetized bodies, reveal anomalies textures and highlight discontinuities. It can also sharpen and enhance regional structures and the edges of anomalies in a grid.

The analytical signal range of the upward continuation map ranges between 0.0nT and 2.2nT (figure7). High magnetic intensity areas are illustrated on the generated magnetic map using violet, while areas observed to be inherently characterized by low magnetic intensity are shaded blue, the background signal amplitude (green) of the gneiss covers some portion of this study area.

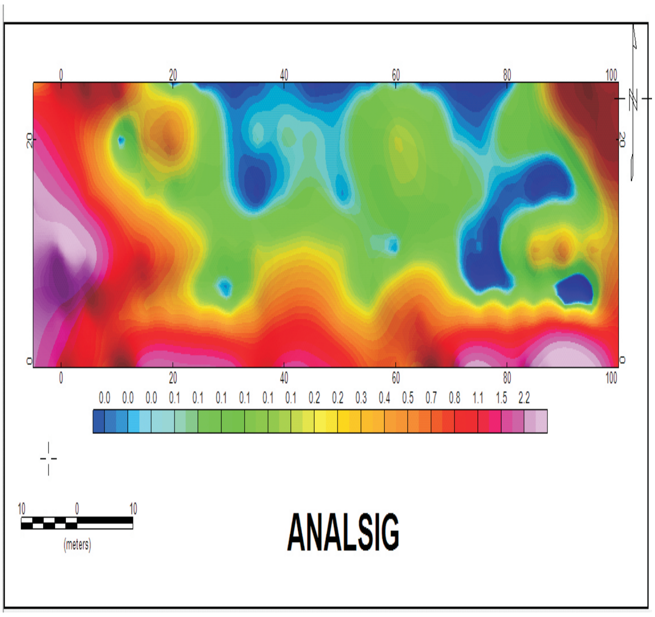


Figure 7: The Analytical Signal Map of the study area.

Conclusion and Recommendation

The combined method of geophysical survey has thrown more light to the investigation of potential mineral targets of the study area. The electrical resistivity results revealed the range of values of total depth to the basement rock between 11.9m and 19.2m. From the study, the magnetic maps interpretation shows the presence of magnetic anomaly at some parts of the study area which indicates the presence of potential magnetic mineral which can be very useful for exploration. This is trending at the Northeastern - Southeastern (NE – SE) part of the study area, the Southwestern (SW) part of the study area possesses lowest magnetic intensity; this implies that more mineral target is available in the Eastern region. The subsurface geological structural traps for mineralized localization include the presence of shallowly buried magnetic sources at the eastern part inferred as granite gneisses.

It is recommended that integrated geophysical studies including 2-D resistivity and aeromagnetic methods should be considered to ascertain the actual presence of magnetic mineral deposits since; there are features from the results showing the presence of geological fractures formed though not well pronounced...

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