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APPLICATION OF ELECTRICAL AND MAGNETIC GEOPHYSICAL METHODS IN DEPTH ESTIMATION OF POTENTIAL MINERAL DEPOSITAT OLABISI ONABANJO UNIVERSITY, AGO IWOYE, SOUTHWESTERN NIGERIA

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ABSTRACT

Geophysical techniques are powerful tools in depth estimation of minerals deposits. This survey was carried out to evaluate the nature and depth of mineral deposits near the Sports complex of Olabisi Onabanjo University (OOU), Ago-Iwoye.’. A total of five (5) Vertical Electrical Soundings (VES) points were investigated using Pasi Terrameter. The spread across the area using the Schlumberger configuration was with a maximum current electrode separation of 100m. The results obtained were interpreted quantitatively and qualitatively using partial curve matching and computer iteration programs known as WINRESIST and SURFER 11. Also, forty one (41) survey profiles were taken at a station interval of 5m using the GEM Magnetometer to acquire the Total Magnetic Intensity reading. The Guassian filter-Oasis Montaj was used for the computation of regional field from the observed TMI readings of the area. The geologic and structural map reveals a few visible fractured zones imbedded in the migmatite-gneiss deposits which spread from the northwest to the southern and eastern part of the study area and the granite gneiss was seen around the Southwestern and Northern parts. The delineated fractures could potentially serve as geologic traps for mineral localization. The 2D radial average power spectrum indicates that, the northeast part of the mapped area has a depth of 4.5mand a depth of 13m at the eastern part. It can be seen that the depth are shallow and there are visible outcrops at the study area.The approximate depth to the mineral deposit was determined using the standard Euler solution to be around 13 m and the elevation range obtained varies between 37 m – 50 m. The correlation of the electrical and magnetic techniques shows that both methods are able to give the estimated depth of shallow mineral deposit which range between 13 m – 18m.

Keywords: Euler solution, Geophysical Techniques, Lithology, Total Magnetic Intensity, Vertical Electrical Sounding.

INTRODUCTION

Geophysical techniques are a powerful tool that plays an important role in depth estimation of minerals deposits and delineation of aquifer configuration under varying hydrogeological conditions. Geophysical investigation involves the study of physical properties of the ground, thereby providing initial information on substance materials, condition numerous practical application by taking measurements at or near the earth surface that are influenced by the internal distribution of physical properties(Butler, 2005).

Consequently, analyses of these measurements are reviewed on how the physical properties of the earth interior vary in lithology and reflecting the subsurface geology. Therefore, the nature of the soil or rock supporting the substructure becomes extremely important issue for safety, structural integration and durability. The electrical resistivity imaging (ERI) using the Schlumberger configuration is always used to map the electrical properties as an aid to characterize the ground condition. Resistivity surveys measure variation in the electrical resistivity of the ground by applying small electric current across arrays of ground electrodes (Griffiths & Barker, 1993).The magnetic method of geophysical properties is a geophysical technique that measures variation in earth's magnetic field to determine the location of substance features. This non-destructive technique has numerous applications in the engineering and environmental studies which includes the location of visual near surface faults, igneous dikes and studied tomographic objects like storage drums, pipes, artifacts, and so on. Generally, this technique is used for quick detection of underground metallic deposits (Lowrie, 1007; Butler, 2005). A great number of researcheslike Abiola*et al.* (2009); Kayode*et al.* (2010); Ibrahim *et al.* (2015); Ismail*et al*. (2015); Majeed (2016); Sedera*et al.* (2016) and Ariyo*et al*., 2020 carried out studies to estimate the depth at which minerals are deposited as well as the nature and physical properties of the subsurface litholigic unit particularly in relation with mineral deposits using diverse geophysical methods.

The discovery of hidden metallic objects using magnetic survey accounts for the quickness of data acquisition and processing. The analysis and localization of hidden objects with only magnetic signature depends solely on the depth of the object and its makeup since a non-magnetic body is completely unable to be detectable. This limitation is dormant in this investigation since another geophysical method (electrical resistivity) which focused on different physical properties of the affected matter is used.The applications of electrical resistivity and magnetic surveys to estimate the depth at which minerals are deposited in the study area are employed.

Kayode *et al.* (2010) worked on Ground magnetic survey of eastern part of Ilesa town in Osun State, Southwest Nigeria. Total field magnetic data was recorded using high resolution proton precision geometric magnetometer which implores total components of the ground magnetic anomaly data running through fifteen traverses. This research focused on delineation of faults in this part of the highly mineralized Ilesa schist belt. The field data was qualitatively and quantitatively interpreted and the results gave values for the total component measurements of ground magnetic anomaly that varied between a minimum negative peak value of about -330 gammas and a maximum positive peak value of about 80 gammas. Depth to the basement rock was estimated using Peters half slope method which gave a maximum depth to basement of about 160m. Information on wide range of magnetic intensities over the different rock types in this area were obtained from the interpretations. The results generated were used to delineate rock boundaries, major and minor faults in this area.

Sedera *et al.* (2016) used magnetic method to delineate the depth estimation of mineral deposit. The study delineated the subsurface

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structure in an open field to estimate the depth to top and centre of mineral deposit in the study which is in an open field in Oduduwa University, Ipetumodu, and Osun State covering 500m^2 using magnetic methods. Ground magnetic survey was carried out along ten (10) profiles. The data set was processed and interpreted using a series of techniques and software (the slope methods, trend analysis and Golden software). The results indicate that profile 1 has the highest amplitude of 12.4 nT followed by profile 5 with 10.2 nT. The depth to basement top estimate ranges from 2.25 to 6.65 m while depth to centre ranges from 8 to 25 m. The magnetic anomaly obtained is between -8.8 nT and +5.8 nT. The ground magnetic contour showed that magnetic anomalies are as a result of rocks present in the region. The major rocks and minerals suspected to be found in this area and its environment are slate, gneiss and serpentenite.

Description and Geology of the study area

The area mapped is in OlabisiOnabanjo University (OOU) Permanent site in southwestern Nigeria. It lies within latitude 3^{o}52'' and 3^{o}53''E and on longitude 6^{0}54" and 6°56"N of the Greenwich meridian. It is found within the crystalline basement complex of southwestern Nigeria. The entire campus covers an area extent of approximately 43.5km^2, the study area is densely vegetated with major roads and foot path making the study area easily accessible as it is just behind the university Sport Centre.

Generally, in Nigeria about half of the total area is covered by igneous and metamorphic rocks while the other half is covered by sedimentary terrain (Figure 1). About 80% of these are Precambrian age and the remaining 20% are younger intrusive and volcanic lava. These crystalline rocks are collectively referred to as basement complex rocks. It is believe that the greater part of crustal growth took place by Archean which is greater than 2.65 billion years (Dada, 2006). Nigerian rockabilly can be grouped into the crystalline basement and sedimentary rocks. Half of the crystalline basement complex in Nigeria is underlain by the cretaceous and younger sediments. The crystalline rocks are divided by Dada (2006) into basement complex, younger granite, tertiary to recent volcanic. The study area falls within the basement complex rocks.

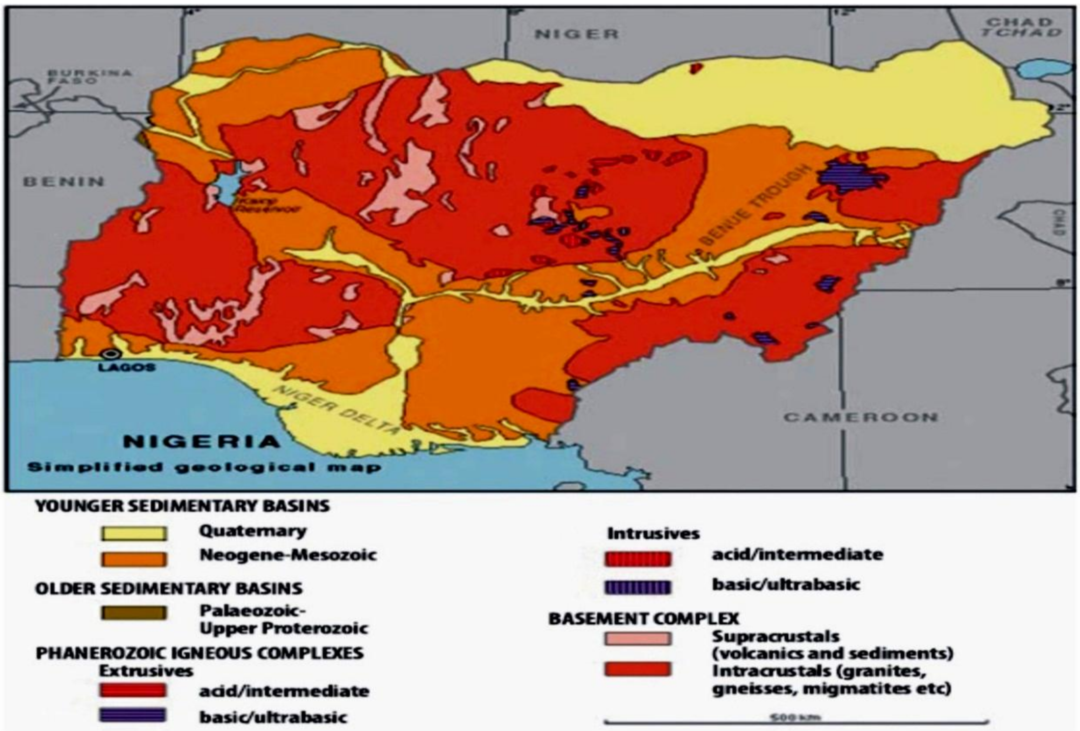

Figure 1: Geological map of Nigeria (after Oyawoye, 1972)

MATERIALS AND METHODS

Electrical resistivity method

A total of five (5) Vertical Electrical sounding stations were probed in the study area using Schlumberger electrode array (Figure 2). This method was used to delineate or reveal the vertical lithology and the number of the geoelectric layers. These stations were taken at different locations along each point.Current was passed into the ground through a pair of current electrode and the resultant potential generatedwasmeasured through a pair of potential electrode. Basically, a station was chosen and an iron rod was driven into the ground, this marks the Base station which was used as a mid-point from where MN/2 (potential electrode) and AB/2 (current electrode) spacing are measured in both directions using the marked midpoint and a measuring tape.

The current and potential electrodes were progressively set out to achieve a well-defined profile during which the current electrode was ensured to be five times of the potential electrode at the start. As the current electrode separation was been increase progressively the potential electrodes remain constant until potential reading become small to be measured. The potential electrode was increase in order to have meaningful readings and the maximum separation was 100m at depth and maximum potential electrode was 5m. The change in distance between the current electrodes increases the depth range at which the current penetrates.

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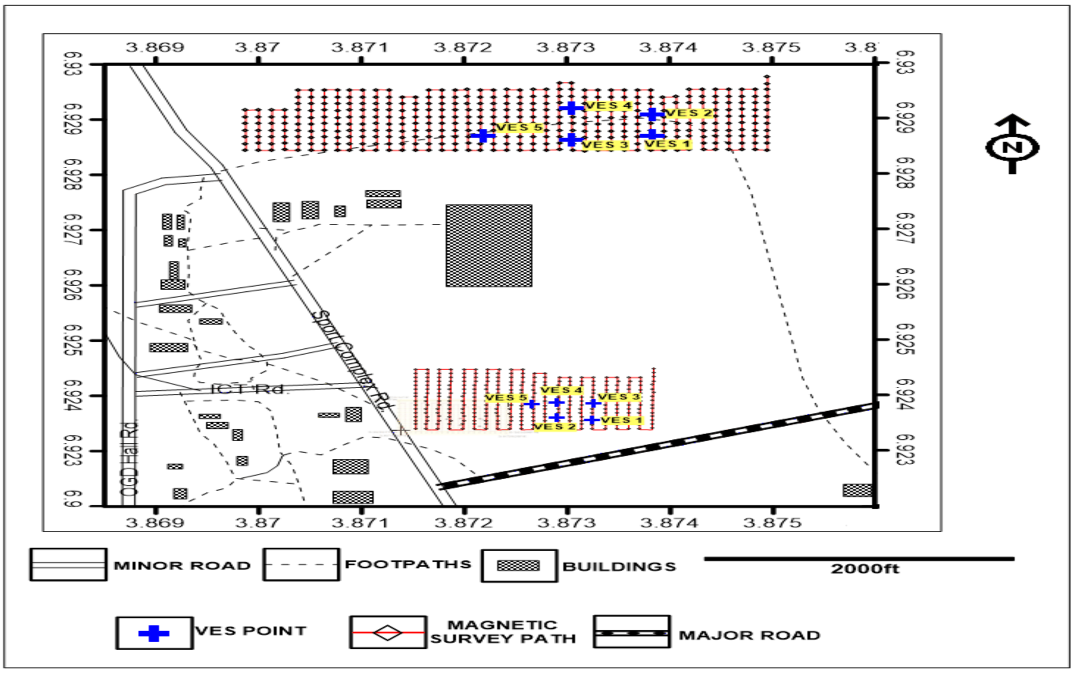

Figure 2: Location Map Showing Survey Path Extract

The purpose of electrical survey is to determine the subsurface resistivity distribution by making measurements, on the ground surface. From these measurements the true resistivity of the subsurface was estimated. The ground resistivity is related to various geological parameters such as the mineral and fluid contact, density, porosity and degree of water saturation in the rock.

Processing of Electrical Resistivity Surveying Data

The processing of electrical resistivity data is achieved using the WINRESIST program designed to operate in an automated and robust manner with minimal input from the user. It has a set of difficult parameters which guides the inversion process. In most cases the default parameters give reasonable results. The problem of non-uniqueness is well known in the inversion of resistivity sounding and other geophysical data. For the same measured data set, there is a wide range of models giving rise to the same calculated apparent resistivity value. To narrow down the range of possible models, normally some assumptions are made concerning the nature of the subsurface that can be incorporated into inversion subroutine.

The partial curve matching technique is fairly accurate and is a dependable one for interpretation. It involves the comparison of field obtained curves with characteristics standard curves. The construction of series of standard curves is based on the relationship between the hypothetical curves of resistivity against depth/thickness. Before interpretation is made with the master set of horizontal layer, it must be satisfied that the form of the sounding curve is sufficiently smooth and not distorted by sharp curves or discontinuities. Two different sets of curve are normally employed for this technique (Keller and Frischneckt, 1996), and they are theoretical 2-layer master curves.

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:

$$\left(J_i = \frac{M}{LA}\right) \mathbf{(1)}$$

Where 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:

$$(\mathrm{Ji} = \mathrm{kH}) \mathbf{(2)}$$

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,

The field procedure for ground magnetic surveying fundamentally requires the inspection of the area to enable the removal and/or avoidance of metallic objects or structures that might distort the local magnetic field in the study area. Base station establishment immediately superseded the inspection exercise. This is followed by the gridding of the area, which was done at a station interval of 5m using the Cartesian coordinate system. The first (base) reading was then taken at the established base station noting the starting time of the survey. Magnetometer was then moved to the next point for the acquisition of its Total Magnetic Intensity reading. This process was progressively advanced accordingly to all points until the last point in the grid was covered but however repeated measurements at the base station to keep track of diurnal changes. Forty one (41) survey profiles were conducted at the study area. Figure 3 shows the survey path extract.

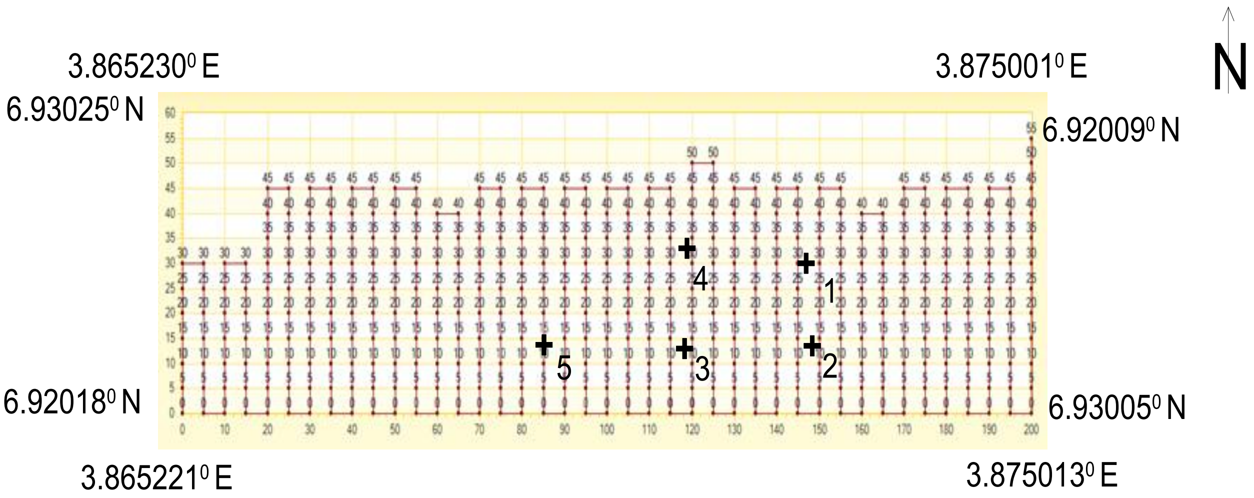

Figure 3: Survey Path Extract.

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Processing of Magnetic Surveying Data

Diurnal Correction: Sequel to acquisition, the observed Total Magnetic Intensity (TMI) were manually corrected by distributing the differences observed in the TMI of the base station among the rover stations in accordance to the time of observation. The diurnal changes ranges between 0.5 to 27.4nT on Day 1 and between 0.2 to 20nT on Day 2. The magnitude of diurnal variation is subtle in the morning and evening, but peaks in the afternoon when the solar intensity is very high.

Geomagnetic Correction: The Guassian filter (Oasis Montaj) was used for the computation of regional field from the observed TMI readings of the area. It is a smooth filter often used for low-pass or high-pass applications.

Reduction to the Equator: Residual anomaly calculation was generated via the subtraction of the regional (field) grid from the total magnetic intensity, and re-centered using an inclination of -12° and declination of -1.98° back to the correct position.

Filtering: Analytical signal filter, tilt derivative filter and first vertical derivative filter were used for the enhancement of magnetic features in the study location.

Geomagnetic Data Interpretation: Direct method of interpretation was adopted. Spector & Grant (1970) demonstrated the use of power spectrum for depth determination by graphically proving that the log-power spectrum has a linear gradient whose magnitude is dependent upon the source depth, thereby providing a rapid depth estimates from regularly spaced field data. A great advantage of this spectral analysis technique is that it does not dispense with the need for geomagnetic or diurnal correction since it removes only low wave number component. A more rigorous but more complex technique adopted for depth estimation of magnetic source is Euler deconvolution (Reid *et al.*, 1990) using a structural index of 1.0.

RESULTS AND DISCUSSION

Electrical resistivity survey

The representation of the iterated curve plotted for the study area (Figure 4) shows the various numbers of layers, their resistivity’s with varying depth and thickness. The interpretation of five (5) Vertical Electrical Soundings (VES) acquired in the area reveals the presence of three to four geoelectric layers. The summary of the computer interpretation is presented in Table 1.

Table 1: Geoelectric Parameters

VES NO	NO OF LAYERS	RESISTIVITY (Ohm –m)	THICKNESS (m)	DEPTH (m)	LITHOLOGY	CURVE TYPES
1	1	632.7	1.0	1.0	Topsoil	HA
	2	17.8	3.0	4.0	Clay	
	3	101.0	18.6	22.6	Sandy clay	
	4	2389.0	-	-	Fresh basement	
2	1	687.7	1.4	1.4	Topsoil	H
	2	15.2	4.7	6.1	Clay	
	3	2150.7	-	-	Fresh basement	

3	1	226.3	3.2	3.2	Topsoil	H
	2	24.6	6.0	9.2	Clay	
	3	3702.2	-	-	Fresh basement	
4	1	463.8	2.1	2.1	Topsoil	HA
	2	24.1	3.4	5.5	Clay	
	3	248.1	4.2	9.7	Clayey sand	
	4	1913.2	-	-	Fresh basement	
5	1	375.0	0.8	0.8	Topsoil	HA
	2	116.1	5.6	6.4	Sandy clay	
	3	312.0	3.0	9.3	Clayey sand	
	4	2300.9	-	-	Fresh basement	

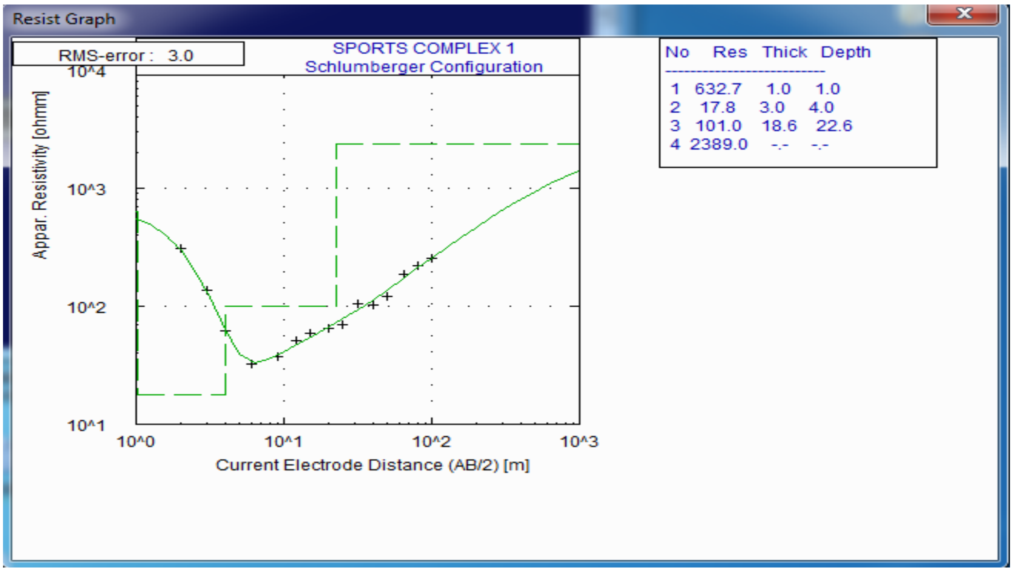

Figure 4: Iterated curve of VES 1

The number of layers inferred from the five (5) VES points, near the sports complex, ranges from 3 to 4 as shown in Table1. The layers are described as topsoil, clay, sandy clay, clayey sand and fresh bedrock based on the values of their corresponding resistivity.

The first layer has resistivity values ranging from 226.3Ωm to 687.7 Ωm, hence an average resistivity value of 477.3Ωm. The thickness value corresponding to the topsoil range from 0.8m to 3.2m and having an average layer thickness of 1.7 m. Layer 1 is interpreted as topsoil. The second layer has resistivity values ranging from 15.2Ωm to 116.1 Ωm, with an average of 65.6Ωm while thickness range from 3.0m to6.0m, with an average value of 4.5m and isinterpreted as clay and sandy clay. Layer 3 is the terminating layer for three geoelectric layers recorded for VES 2 and 3 with resistivity values of 2150.7 Ωmand 3702.2 Ωmrespectively and interpreted as fresh basement. The third layer has resistivity values ranging from 101.0Ωm to 312.0Ωmfor VES 1, 4 and 5 with four geoelectric layers; while corresponding

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thickness ranging from 3.0m to 18.6m.This is interpreted as clayey sand and sandy clay. Thefourth layer, which is the terminating layer, has resistivity values ranging from 1913.2 Ωmto 2300.9 Ωm, and it is interpreted as the fresh basement.

Magneticsurvey

The Total Magnetic Intensity (TMI) value of the area ranges between 32567nT to 33163nT (Figure5). Regional field value range is 32880nT to 33005nT in magnitude trending from the southwest to the northeastern part of the study area. Subtraction of the regional field from the residual generated the residual anomalies whose range -151nT to 70nT indicative of heterogeneous susceptibility of basement rocks constituting the area. Subtraction of the regional field from the residual generated the residual anomalies whose value range is -151nT to 70nT indicative of heterogeneous susceptibility of basement rocks constituting the area

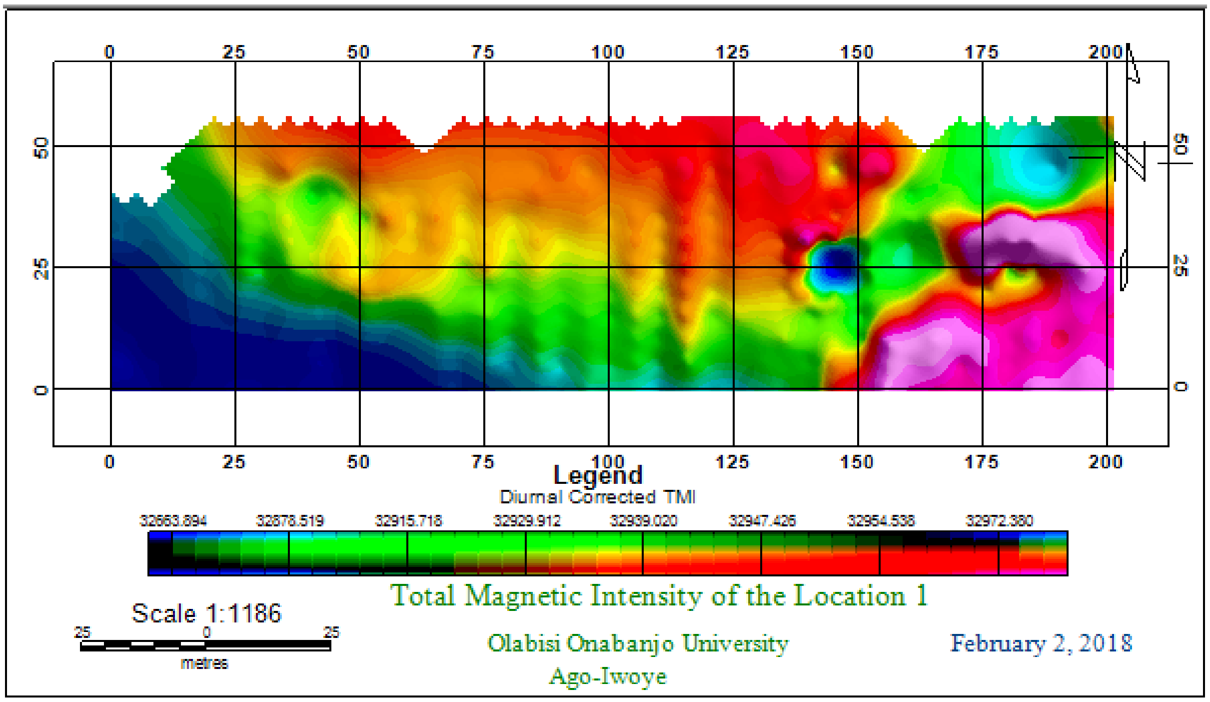

Figure5: Total Magnetic Intensity (Diurnal Correction Applied)

The regional magnetic intensity (Figure 6) depicts that the magnetic intensity is high at the Northeast with a value of 32972nT while at the southwest it is considered low with a value of 32563nTand intermediate at the northwest with a value of 32929nT.

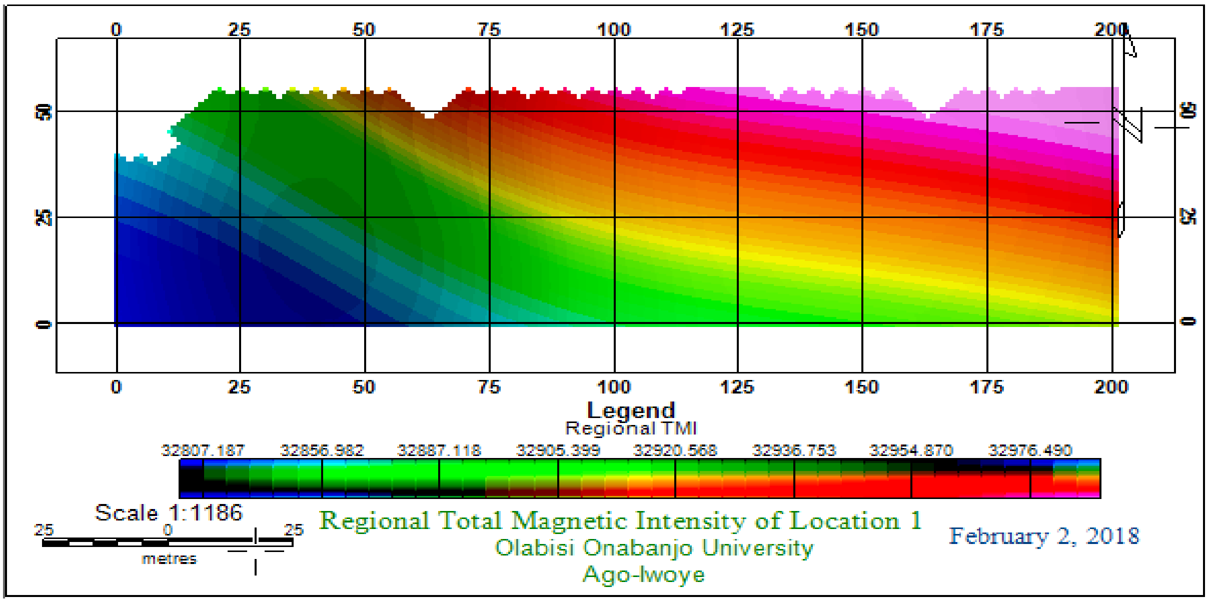

Figure 6: Regional Magnetic Intensity

The residual anomaly map (Figure 7) depicts the conductivity of the study area showing that at the northwestern part has a high conductivity with a value ranging from 31nT to 64nT while at the southwest the conductivity is reasonably low with a value ranging from -1.6nT to -151nT and intermediate conductivity of 14nTat the north.

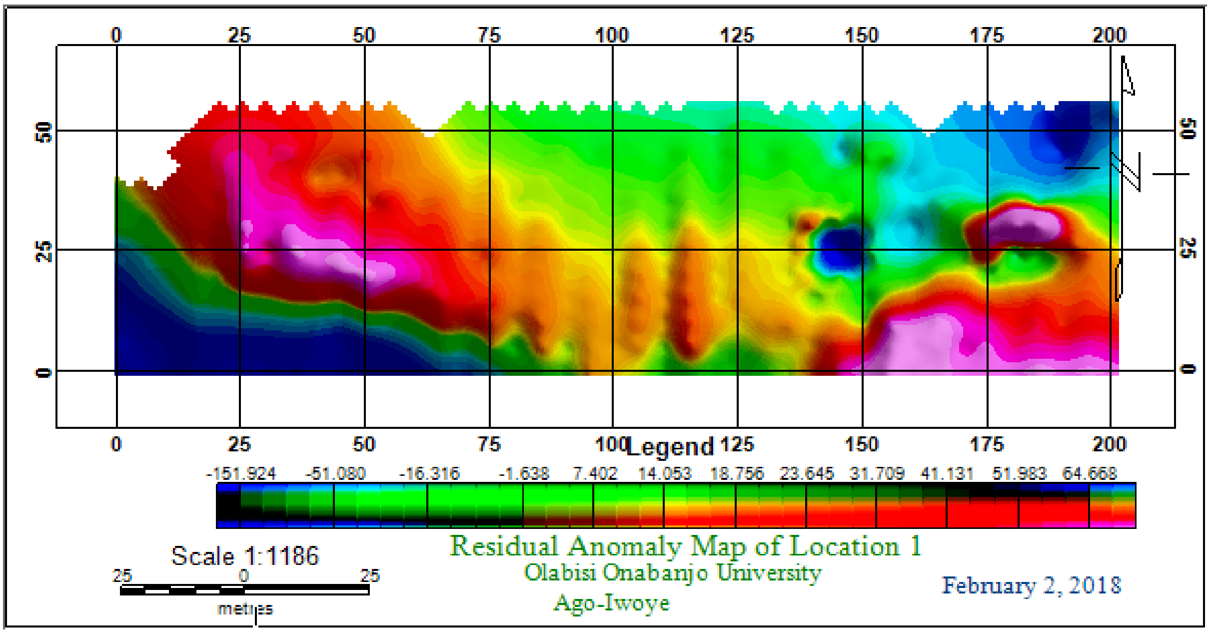

Figure 7: Residual Anomaly Map

The analytic signal map was produced with the effect of filtering which helped in enhancing the magnetic features in the study area (Figure 8). The analytic signal tends to be high within the Southwest with a value ranging between -15.3 - 11.5, 0.8 - 26 and 0 - 1.7. The results generated were used to delineate geological structures and to target area with mineral potential.

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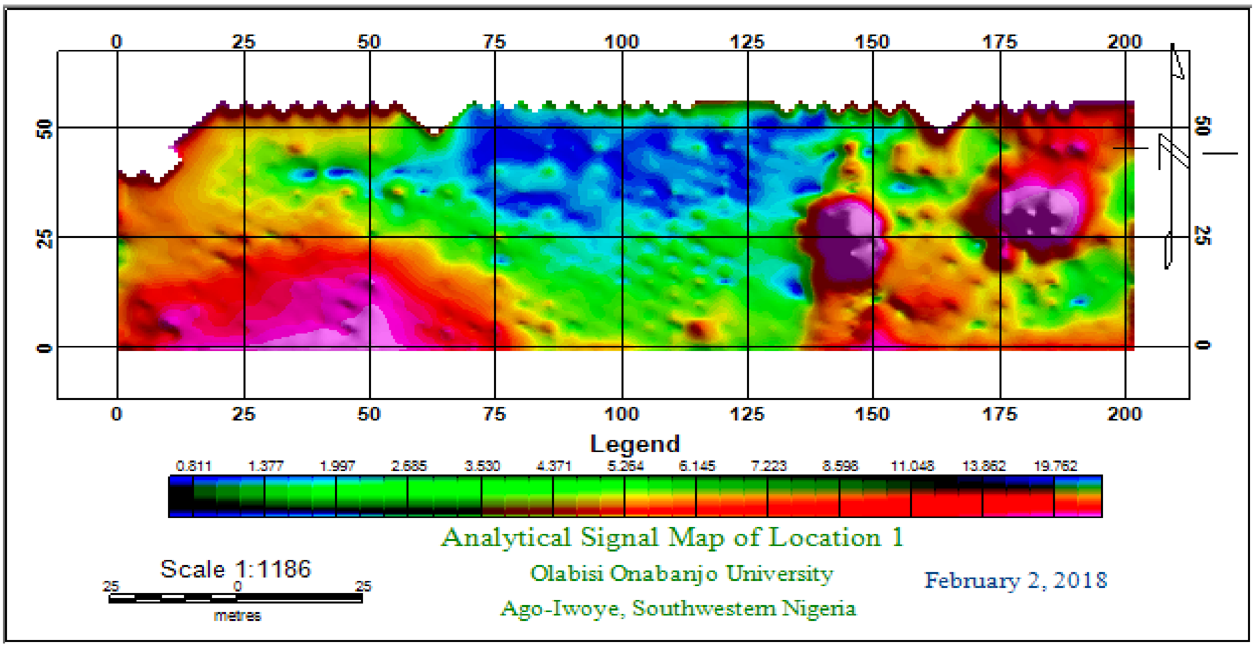

Figure 8: Analytical Signal Map

Figure 9 shows the parameters for depth estimation using the radially average power spectrum with a linear gradient whose magnitude is dependent upon the source depth; it shows a rapid depth estimate from regularly spaced field data at the study area.It can be seen that the depth are shallow and there are visible outcrops at the study area.

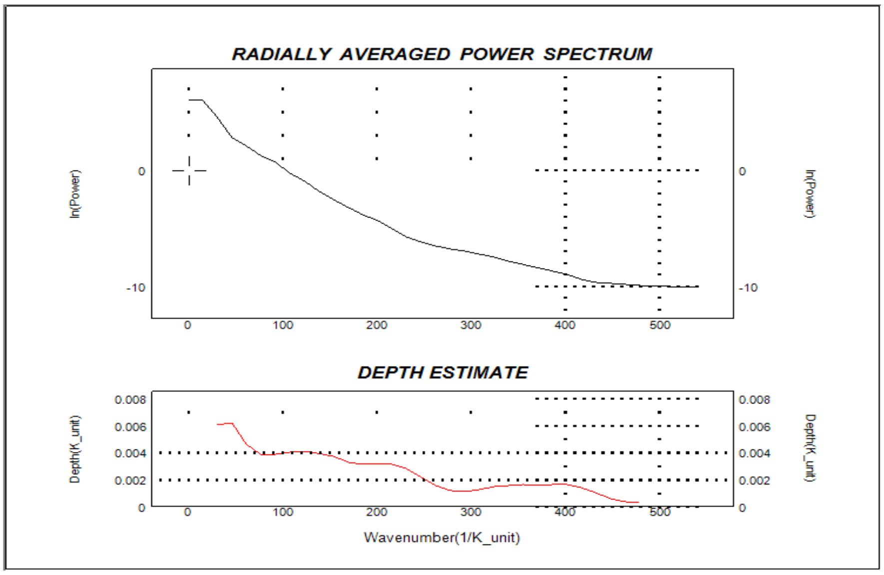

Figure 9: Radially Averaged Power Spectrum depicting the depth estimation parameters

Figure 10 shows the 2Dradial average power spectrum indicates that, at the northeast part of the mapped area it has a depth of 4.5mand at the eastern part with a depth of 13m.

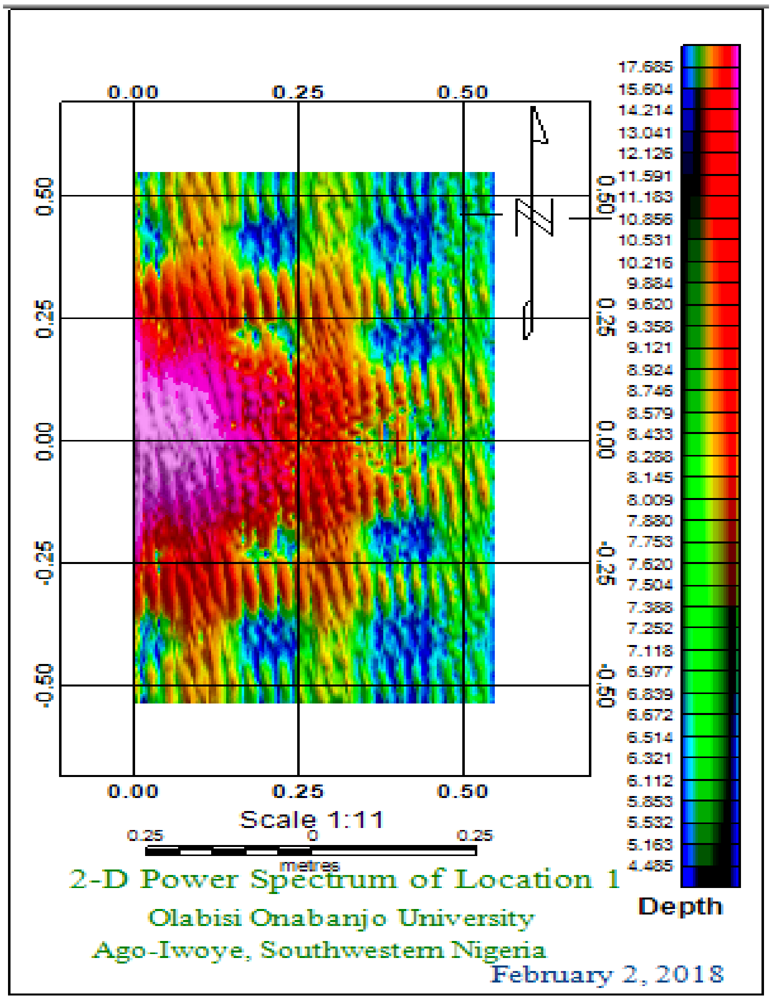

Figure 10: 2D Radial Average Power Spectrum

The standard Euler solution (figure 11) shows a more rigorous but more complex technique adopted for depth estimation of magnetic sources gives a maximum depth to the basement of about 13m (50m-37m) at the southwest with minimum depth of 2m at the northern part of the mapped area.

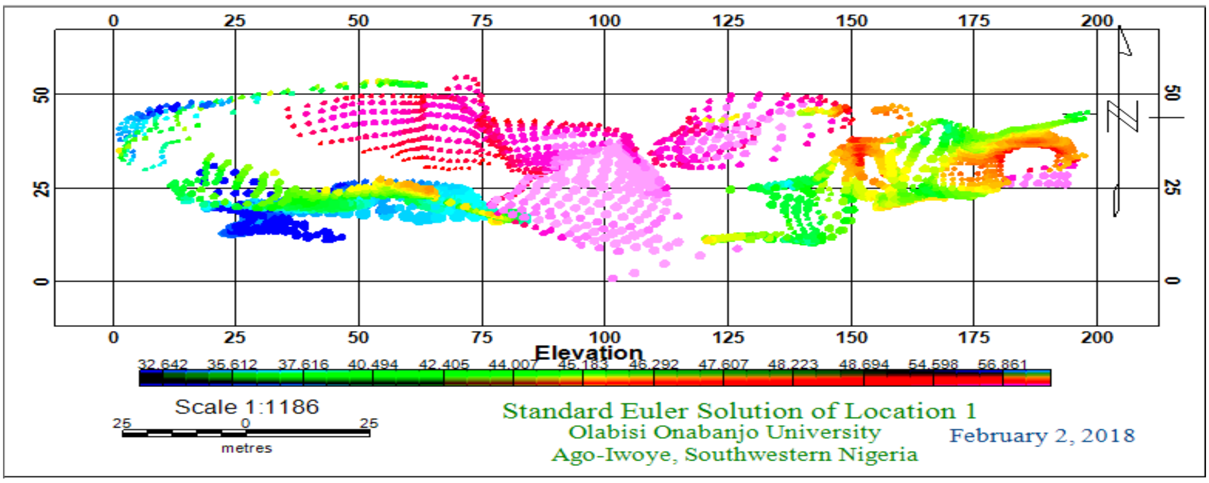

Figure 11: Standard Euler Solution map

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Figure 12 shows the geologic and structural map of the study area. There are few visible fractured zones imbedded in the migmatite-gneiss deposits which spread from the northwest to the southern and eastern part of the study area. The granite gneiss can be seen around the South Western and Northern part.

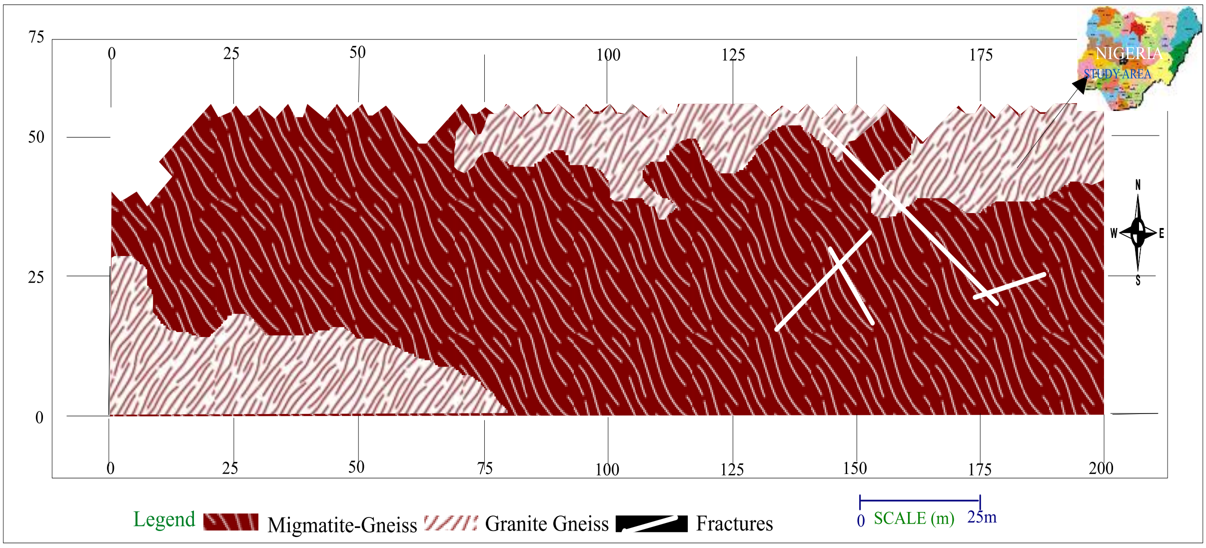

Figure 12: Geologic and Structural Map

However, anomalous low susceptibility within the migmatite body is clear indications of fractures, which at this location trends bi-directionally in the northwest – southeast and northeast-southwest. In terms of mineral potential of the area, the eastern part is apparently the most prolific part of the investigated area; characteristically constituted by appreciable magnetic minerals (magnetite) which are naturally found in association with ferromagnesian. More importantly, the delineated fractures in the area can potentially serve as geologic traps for mineral localization.

CONCLUSION

The ground electrical resistivity and magnetic study of the area has helped to delineate the geophysical characteristics of the study area. The results obtained from the data have helped to determine approximate depth to the mineral deposit of the study area using the standard Euler solution and other parameters.The elevation range obtained from standard Euler solution varies between 37 m – 50 m. The correlation of the electrical and magnetic methods shows that both methods are able to give the estimated depth of mineral deposit which range between 13 m – 18 m.

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