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Interpretation of ground magnetic data of Ilesa, Southwestern Nigeria for potential mineral targets

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ABSTRACT

A geophysical ground magnetic survey was carried out in eastern part of Ilesa town located in the southwestern part of Nigeria. Total field magnetic data was recorded using a proton precision geometric magnetometer along fifteen traverses. This research focused on delineation of subsurface geological structures that are suitable for mineral potential. The field data collected was qualitatively and quantitatively interpreted. The residual magnetic values were in the range of about 80nT to -330nT. The magnetic source depth was estimated using Peters half slope method which gave a maximum depth to basement of about 160m. The lateral extent of interpreted lithologies was estimated using the analytical signal. The results generated were used to delineate geological structures and to target areas with mineral potential.

Keywords: residual ground magnetic, source depth, geomagnetic section, mineral target, Ilesa east.

INTRODUCTION

The study area in located east of Ilesha town in Osun State, southwestern Nigeria. The topography is gentle at an elevation of approximately 1400m with some elevated rock outcrops in the northeastern and northwestern parts. This report has been necessitated by the need to get an insight into the structural signatures of the area which is very useful for the Ministry of Solid Minerals because of the rich metallic and non-metallic Ores such as Gold; Talc, Clay etc in this part of the country [1, 2].

A total of fifteen Traverses were covered during the survey work with high resolution of proton precision magnetometer in conjunction with Germin Global Positioning System (GPS). However, only the most significant areas covered by Traverses 11; 12, 14 and 15 will be consider in this write-up.

The aim of this study is to delineate subsurface structures that are useful for mineral exploration in the schist belt zone. The findings in this report are intended to compliment the previous reports published prior to this time and also contribute significantly to the development of solid mineral resources in the area. It is also expected that these results will enhance the knowledge of other scientists and miners for further work in the area.

1.2 Geological Setting

The geology consists of Precambrian rocks that are typical for the basement Complex of Nigeria [16]. The main rock types granite-gneiss, which occupies most part of the eastern part; amphibolite and schist occupy most of the study area; muscovite schist, quartzite and quartz-schist form part of the stratigraphy [1, 2, 4, 6, and 9].

The major rock associated with Ilesa area form part of the Proterozoic schist belts of Nigeria (Figure 1), which are predominantly, developed in the western half of the country. In terms of structural features, lithology and mineralization, the schist belts of Nigeria show considerable similarities to the Achaean Green Stone Belts. However, the latter usually contain much larger proportions of mafic and ultramafic bodies and assemblages of lower metamorphic grade [1, 7, 13, and 16].

Rocks in this area are structurally divided into two main segments by two major fracture zones often called the Iwaraja faults in the eastern part and the Ifewara faults in the western part [5, 6]. However; this study focuses on the northern part of the former faults zone. The area west of the fault comprises mostly amphibolites, amphibole schist, meta-ultramafites, and meta-pelites. Extensive psammitic units with minor meta-pelite constitute the eastern segment. These are found as quartzites and quartz schist. All these assemblages are associated with migmatitic gneisses and are cut by a variety of granitic bodies [13, 16].

The rocks of the Ilesa district may be broadly grouped into gneiss-migmatite complex, mafic-ultramafic suite (or amphibolite complex), meta-sedimentary assemblages and intrusive suite of granitic rocks. A variety of minor rock types are also related to these units. The gneiss-migmatite complex comprises migmatitic and granitic, calcereous and granulitic rocks. The mafic-ultramafic suite is composed mainly of amphibolites and amphibole schist and minor meta-ultramafites, made up of anthophillite-tremolite-chlorite and talc schist. The meta-sedimentary assemblages, chiefly meta-pelites and psammitic units are found as quartzites and quartz schist. The intrusive suite consists essentially of Pan African (c.600 Ma.) Granitic units. The minor rocks include garnet-quartz-chlorite bodies, biotite-garnet rock, syenitic bodies, and dolerites [6, 7, 9, and 16].

MAGNETIC METHODS

Most rocks of the earth's crust contain crystals with magnetic minerals; thus most rocks have a certain amount of magnetism which usually has two components; induced by the magnetic field present while taken measurement, and remanent which formed during geologic history [18, 20]. The origin of the earth's magnetism is commonly believed to be the liquid outer core, which cools at the outside as a result of which the material becomes denser and sinks towards the inside of the outer core, and new warm liquid matter rises to the outside; thus, convection currents are generated of liquid metallic matter which move through a weak cosmic magnetic field which subsequently generates induction currents [11]. It is this induction current that generate the earth's magnetic field [21].

However, the ground magnetic study is used for detail mapping in order to understand the subsurface geology of an area [10]. The technique requires measurements of the amplitude of magnetic components at discrete points along traverses distributed regularly throughout the survey area of interest. In ground magnetic study, three components are measured which are Horizontal, Vertical and Total components. The vertical components and the total components are mostly used in the past studies to delineate faults, fractures, depth to magnetic basement and other geological structures [6, 10].

Susceptibility values are important for the quantitative interpretation of magnetic data and can be used for differentiating rock types. The magnetic susceptibility of rocks is controlled by the amount of magnetic minerals in them, grain size and mode of distribution. Ferrimagnetic substances give rise to higher magnetization and hence higher susceptibility [13].

MATERIALS AND METHODS

This study focused on the subsurface geological structures based on the qualitative and quantitative interpretations of the ground magnetic data collected during the fieldwork that was carried out in the months of April and May 2004 [9]. The magnetic survey was designed in such away that deep insight into the depth to magnetic sources in the area was delineated. The data acquisition technique requires measurements of the magnetic intensities at discrete points along traverses regularly distributed within the area of interest so as to cover enough segment used to determine the structure and the structural history of the study area.

The ground magnetic study of this area was undertaking which involves the following methods:-

3.1 Data Acquisition

Total field magnetic readings were recorded using a proton precession magnetometer. The survey direction and station locations were determined using Garmin GPS model GPS map 60CSx units. Coordinates were recorded using the WGS84 datum in the UTM zone 31N, [8]. In order to get the optimum information for preparation of magnetic anomaly maps a line separation of approximately 1000m a station spacing of 60m was chosen. The total length of the surveyed lines approximated 107 km. The line orientation was approximately perpendicular to the regional geological strike, [10].

3.2 Data Processing
The earth's geomagnetic field is not constant at any one point and time on the surface but undergoes diurnal variations mostly due to magnetic storms and diurnal variations, [14]. In order to measure the effect of spontaneous ionospheric magnetic readings a separate magnetometer was used as a base station.

3.3 Data Enhancement
The effect of the International Geo-reference Magnetic Field (IGRF) was assumed to be negligible on the survey grid which had dimensions that were roughly 3km by 5km. The diurnally corrected data was gridded with a cell size of 25m which is a quarter of the line separation using the Geosoft software [12].

The gridded Total Magnetic Intensity (TMI) data was presented on scaled maps to aid interpretation and geo-referencing of anomalies and infrastructure data. In order to improve the information content, short wave length noise that was introduced into the data by observed and recorded features such as fences, gates, power lines, telephone lines and cell phone towers was despiked and voids were interpolated using the Geosoft Software, [12].

3.4 Data Interpretation
In order to prepare the data for interpretation, the Total Magnetic Intensity (TMI) was further enhanced using filtering techniques such as Reduced to Pole (RTP), Vertical Derivative (VD) and Band Pass (BP). The qualitative approach to interpretation involves deducing useful information on structure and trends from the changes in intensity of contours on diurnally corrected magnetic maps [3].

The Reduction to Pole (RDP) is a theoretical solution which normalizes the effect of induced magnetization and the strike on the shape of the magnetic anomaly while preserving dip and textural information. The RTP anomaly over a vertically dipping dyke, having no remanence magnetization is always symmetrical is always a symmetrical magnetic high located directly over the dyke [10, 17 and 20].

Quantitative interpretation methods are used to estimate source depths and widths [3]. The Analytical Signal (ANSIG) is symmetrical as the dip varies. The source position of a magnetic body can be mapped from ANSIG data [10, 17]. The analytical signal shape can be used to derive the depth to the magnetic sources from the anomaly width at half the amplitude data. In order to estimate the depth to the source of magnetic anomalies ANSIG profiles were taken across two anomaly zones. The basic assumptions being field observations that include geology and magnetic susceptibility values [10, 20].

The Vertical Derivative (VD) enhances shortwave length anomalies. It suppresses the effect of deep seated geological bodies, which are normally not prospective mineral exploration targets. The Band Pass filter (BP) enhances the effect of features confined to specified wavelengths; this enables the identification of possible anomalies [10, 20].

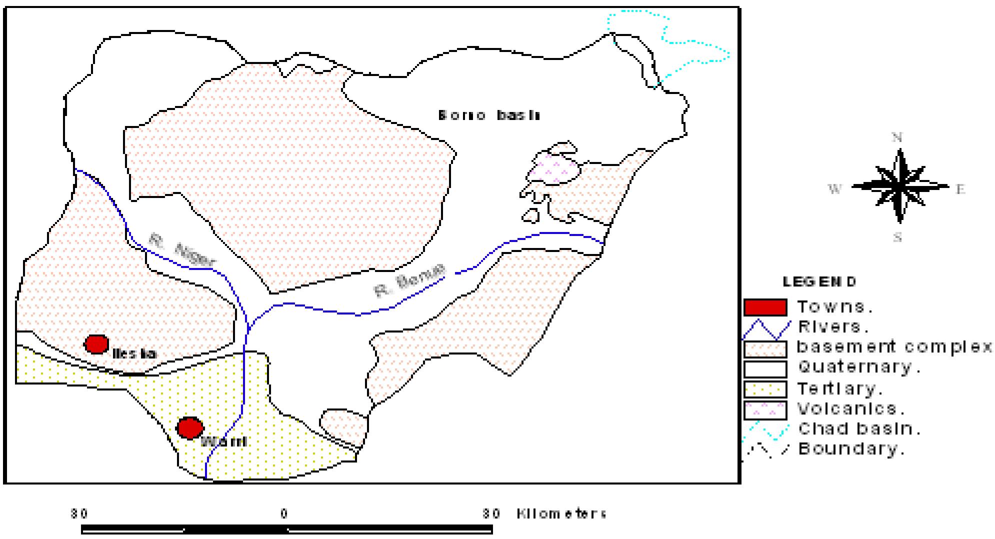

Figure 1: Map of Nigeria showing the study area (after Rahaman, 1976)

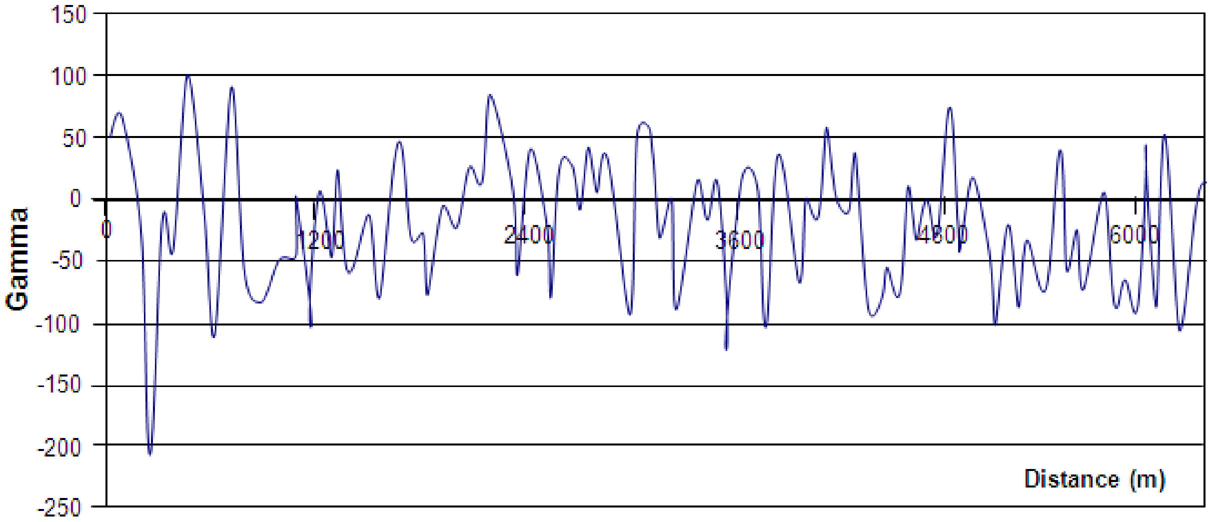

Figure 2a Total Relative Magnetic Intensity along Traverse 11 (SE - NW) of the study area

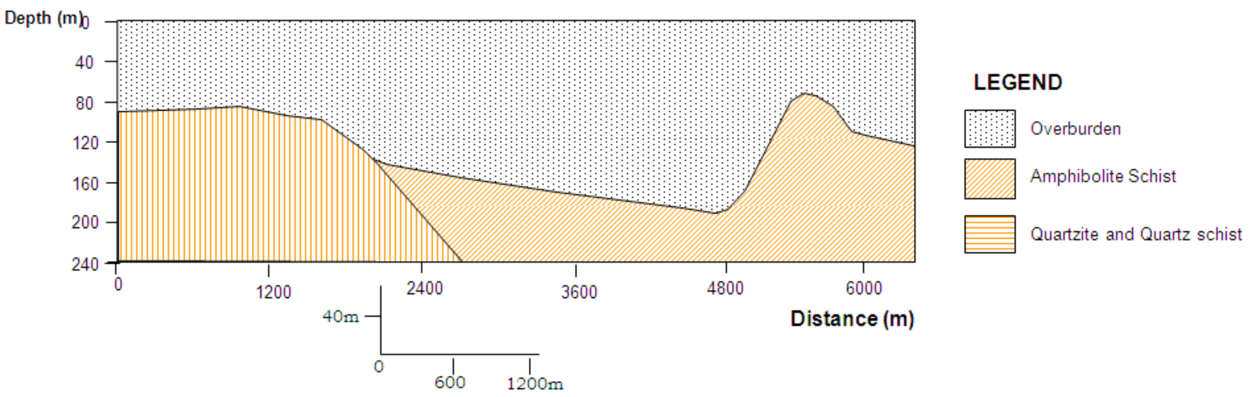

Figure 3a Geomagnetic Section along Traverse 11 (SE - NW) of the study area Area

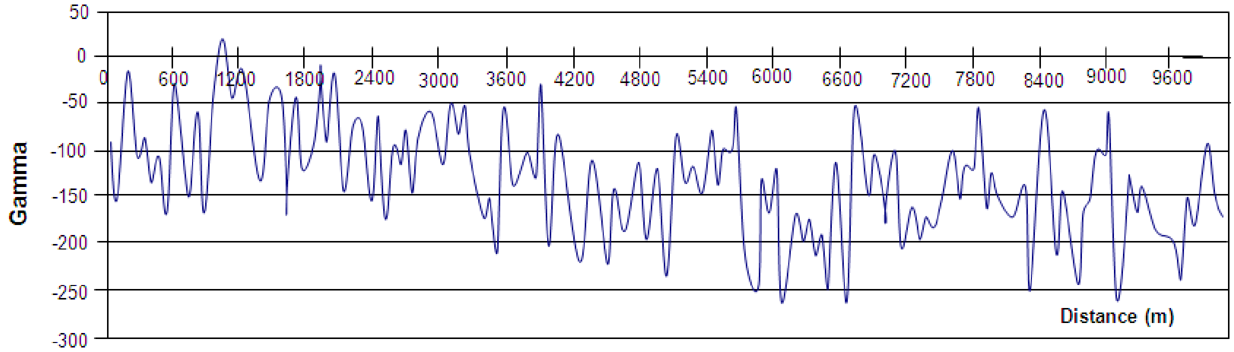

Figure 2b Total Relative Magnetic Intensity along Traverse 12 (NW - SE) of study area

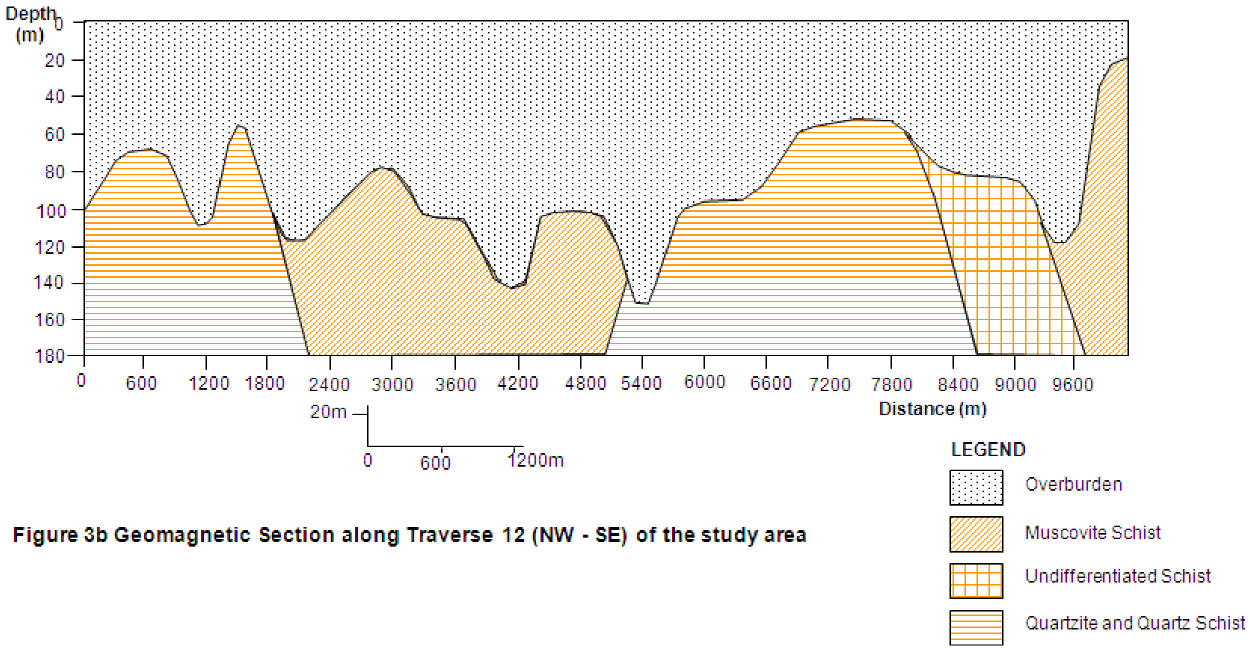

Figure 3b Geomagnetic Section along Traverse 12 (NW - SE) of the study area

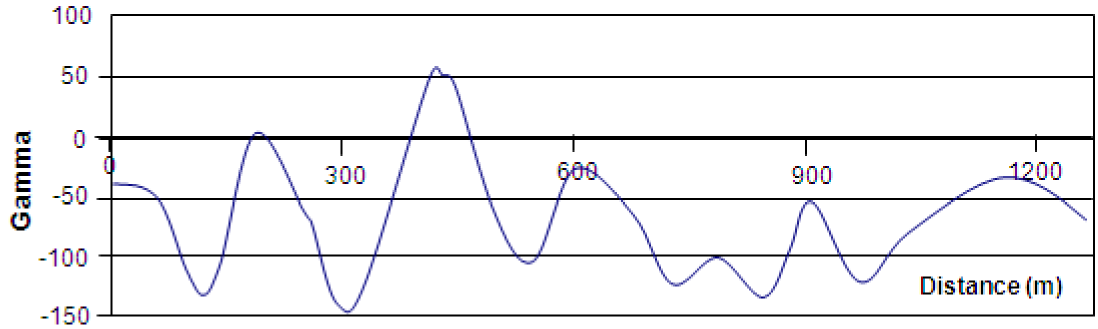

Figure 2c Total Relative Magnetic Intensity along Traverse 14 (SE - NW) of the study area

RESULTS AND DISCUSSION

4.1 Magnetic Data Interpretation

There are several methods of presenting magnetic data, but only two of these methods were adopted in this study. These methods are as summarized below: -

(a) Data Presentation

(i) **Profiles: -** Although this is the oldest form of data presentation but it has advantage of being able to show detail that cannot be shown in grid-based presentations. The ground magnetic profiles of the study area were generated and drawn as shown in Figures 2 (a-d).

(ii) **Contour: -** Contour maps were used in the presentation of the magnetic data of this area (Figure 4). The method was adopted because of its superior to images method.

(b) Data Interpretation

A qualitative and quantitative interpretation of the ground magnetic map, magnetic profiles and magnetic sections, which provides useful information on the estimates of the depth to the magnetic sources involves;
(iii) Separation of residual anomaly from the field anomaly using linear trend analysis.
(iv) Production of geomagnetic sections shown in Figures 3 (a-d).

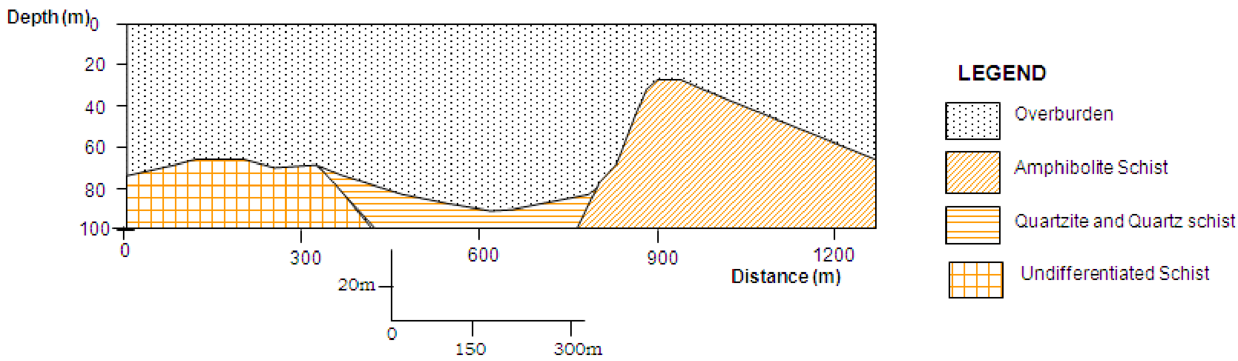

Figure 3c Geomagnetic Section along Traverse 14 (SE - NW) of the study area

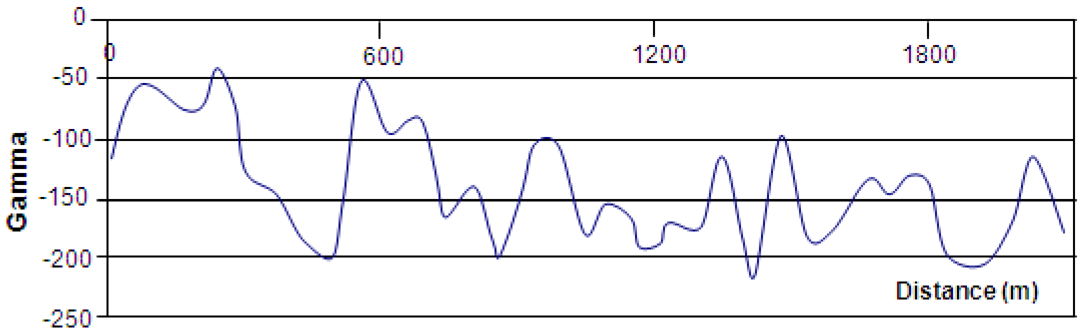

Figure 2d Total Relative Magnetic Intensity along Traverse 15 (NW - SE) of the study area

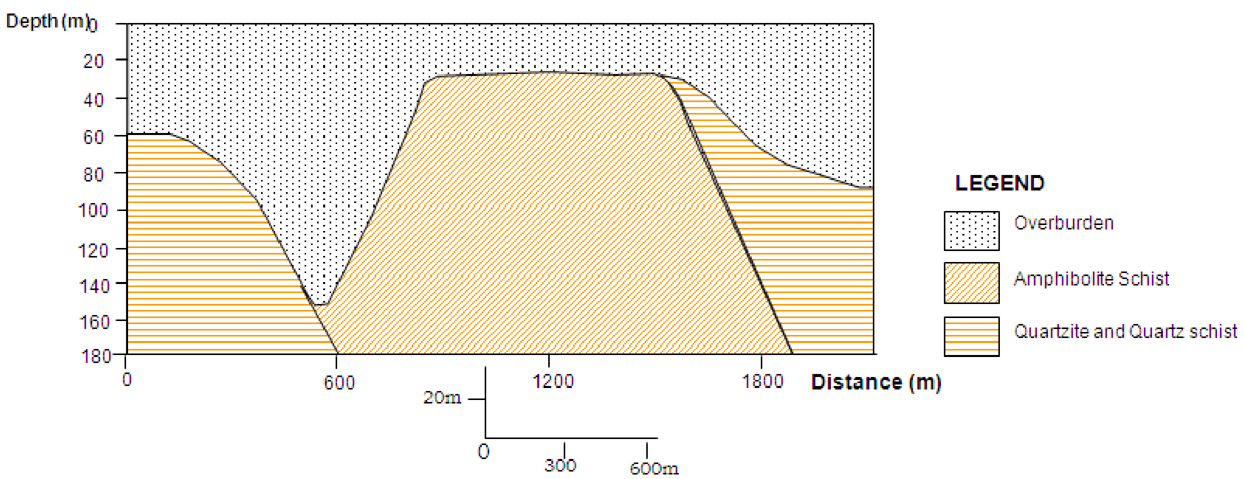

Figure 3d Geomagnetic Section along Traverse 15 (NW - SE) of the study area

4.2 Depth to Basement Calculations

The depth estimation of the basement in the area and identification of the rock boundaries was carried out using Peter's half slope method for depth estimate [15]. The Table 1 shows the depth estimate from the ground magnetic data. The location of inflection points which is an indicative of rock contacts couple with the pre-knowledge of the geology of the study area during the fieldwork, enables the geomagnetic sections of the area to be drawn Figures 3 (a-d).

TABLE 1: Depth Estimate of Total Component Relative Magnetic Intensity

Profile	Anomaly Number				
	1	2	3	4	5
1	-	74m	118m	-	74m
2	88m	-	72m	-	120m
3	46m	-	-	46m	-
4	123m	235m	-	162m	-
5	41m	142m	-	-	-
6	112m	213m	-	-	-
7	121m	194m	-	-	-
8	100m	100m	75m	-	-
9	165m	150m	-	-	60m
10	52m	61m	-	-	-
11	-	194m	194m	-	-
12	57m	105m	-	-	80m
13	-	75m	-	-	-
14	89m	52m	-	-	75m
15	153m	38m	-	-	-

4.3 Ground Magnetic Interpretations

4.3.1 TRAVERSE 11 (SE – NW)

The magnetic signature obtained for the total relative magnetic intensity plot along this traverse is very similar to those obtained in Horizontal and Vertical components except for the depth of probing which differs. The plot was characterized by complete varying mostly negative amplitudes from a minimum peak value of about –210 gammas at a distance of about 240m from the initial station position and a maximum positive peak value of about 100 gammas at a distance of about 420m (Figure 2a) were recorded.

Two rock units were delineated from the corresponding geomagnetic section as shown in Figure 3a.

Muscovite schist: - Muscovite schist forms the first segment of the profile. The unit starts from the first station and extended to about 3000m along the profile with depth to the magnetic basement, which varies between about 90m and about 120m.

Amphibolites schist: - The second rock unit delineated along the profile covers most part of the traverse starting from about 3000m and spread to the end of the profile with depth to the magnetic basement ranging from about 70m to about 130m.

4.3.2 TRAVERSE 12 (E – W)

The magnetic signature obtained for the total relative magnetic intensity plot along this traverse is very similar to those obtained in Horizontal and Vertical components except that the magnetic intensity exhibit mostly negative amplitudes with the exception of point 17 about 1020m from the initial station position. The depth of probing for this method differs from the other two methods. The traverse was characterized by complete varying negative amplitudes from a very low minimum negative peak value of about –260 gammas at distances of about 6000m, 6600m and 9000m respectively from the initial station position and a maximum positive peak value of about 20 gammas at a distance of about 1020m (Figure 2b) were recorded.

Three rock units were delineated from the corresponding geomagnetic section as shown in Figure 3b.

Quartz schist and Quartzite: - The first and third segments were delineated as quartz schist starting from the initial point at Ijebu-jesa town covering about 2km for the first part and from about 5km to about 8.5km for the second segment. The depth to the magnetic basement varies between about 50m and about 110m at the first and second segments respectively.

Amphibolites Schist: - Amphibolites schist that spread across a total distance of about 5km underlay the second and the last segments of this profile. The depth to the magnetic basement within this rock unit varies between about 20m and about 120m. **Undifferentiated Schist: -** This rock type was delineated at about 8.2km from the starting point and ends at about 9.4km towards the end of the profile. The depth to the magnetic basement for this rock unit varies within about 80m to about 100m.

4.3.3 TRAVERSE 14 (SE – NW)

The magnetic signature obtained for the total relative magnetic intensity plot along this traverse is very similar to those obtained in Horizontal and Vertical components except that the magnetic intensity exhibit mostly negative amplitudes with the exception of point 7 about 420m from the initial station position. The depth of probing for this method differs from the other two methods.

The profile was characterized by complete varying negative amplitudes from a very low minimum peak value of about –149 gammas at a distance of about 300m from the initial station position and a maximum positive peak value of about 50 gammas at a distance of about 420m (Figure 2c) were recorded.

Three rock units were delineated from the corresponding geomagnetic section as shown in Figure 3c.

Quartz schist and Quartzite: - This rock unit was delineated at about 420m to about 800m from the initial station position. The depth to the magnetic basement varies between about 70m and about 90m.

Amphibolites Schist: - Amphibolites schist was delineated at a distance of about 800m towards the end of this profile. The depth to basement within this rock unit varies from about 40m to about 60m.

Undifferentiated Schist: - This rock type was delineated at the starting point covering a distance of about 420m from the starting point. The depth to the magnetic basement within this rock unit is fairly constant at about 70m.

4.3.4 TRAVERSE 15 (NW - SE)

The magnetic signature obtained for the total relative magnetic intensity plot along this traverse is very similar to those obtained in Horizontal and Vertical components except that the magnetic intensity exhibit mostly negative amplitudes. The depth of probing for this method differs from the other two methods.

The profile was characterized by complete varying negative amplitudes from a very low peak value of about –210 gammas at a distance of about 1500m from the initial station position and a maximum negative peak value of about -45 gammas at a distance of about 420m (Figure 2d) were recorded.

Two rock units were delineated from the corresponding geomagnetic section as shown in Figure 3d.

Quartz schist and Quartzite: - This rock unit was delineated at the first and the last segments about 540m with the base extending to about 600m. The last segment starts from about 1720m from the initial station position and extend towards the end of the profile. The depth to the magnetic basement is fairly constant at about 40m at the first segment and about 60m last segments.

Amphibolites Schist: - The amphibolites complex was delineated at the central part of the traverse starting from about 600m and extended to about 1900m from the starting point. The depth to the magnetic basement within this segment is fairly constant at about 30m.

Residual Ground Magnetic Map of Ilesa eastern part

The residual ground magnetic map of the study area using Total relative magnetic components was produced. It gives moderately low magnetic values which vary from about -250nT to about 60nT as shown in Figure 4. Two regions of (Positive and Negative) magnetic anomaly with highest value of about 60nT was recorded in the southeastern part of the area and negative anomaly region with the lowest value of about -250nT was recorded at around the western and eastern parts of the area. The map further reveals the major and minor rock contacts in the area separated with different colours. The highest magnetic value of about 60nT recorded in the southeastern part further confirms the earlier submissions by Kayode, 2006. This is an indicative of shallow subsurface geologic structures. The northeastern part through the eastern area towards the southern part of the area supports the previous reports on the existence of major geological subsurface structures in this part of the schist belt.

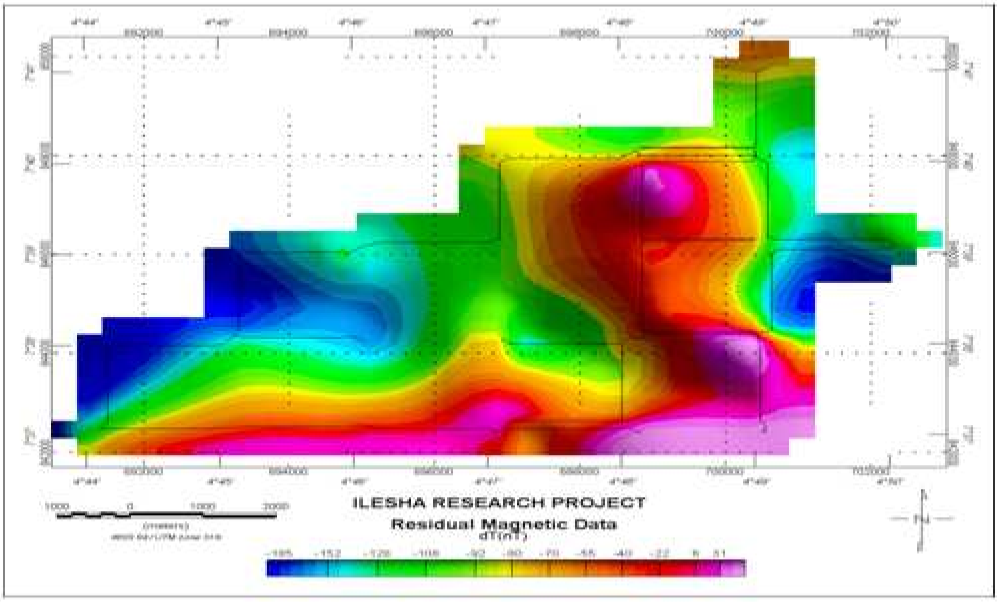

Figure 4: Residual magnetic map of the study area using Total Relative Magnetic Intensity.

CONCLUSION

Based on qualitative and quantitative analysis of the magnetic data, lineaments and target zones were interpreted as shown in Figure 4.

The ground magnetic study of this area has helped in many ways to delineate the geologic structures which are of great benefits for the solid minerals sector of Nigeria economic. The geomagnetic sections (Figures 3) of the study area helped in delineation of the different rock contacts and geological boundaries that are very useful in mapping the basement structures of the area and this has help to reveal the solid mineral potential of the schist belt. The major subsurface structures delineated i.e. the Amphibolites, Quartz and Quartz Schist etc this will aid the mineral exploration work in the area. The linear nature of the anomalies in this part of the schist belt suggests that the rocks may be bounded and offset by faults. The results further support the delineation of faults in this part of the schist belt. Therefore, this study needs to be aided by latest technology so that ground magnetic study can equally reveal lithologic units in basement structures to meet the demands of searching for mineral deposits in the area.

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