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Full Length Research Paper

Ground magnetic study of Ilesa east, Southwestern Nigeria

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Ground magnetic survey of eastern part of Ilesa town in Osun State, Southwest Nigeria was performed. 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 160 m. 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.

Key words: Magnetic intensities, residual ground magnetic, geomagnetic sections, Ilesa east.

INTRODUCTION

The study area is located within tropical climate marked by the alternating wet and dry seasons. Temperature is moderately high during the day and also varies from season to season. Due to the passage of the sun on its way to and from the tropic of cancer, this resulted to two periods of high temperatures as recorded annually. The first period occur in March - April and the second period in November - December. The average daily temperature varies between about 20°C (for a very cold day) and about 35°C (for a very hot day). The coolest period is in the middle of the raining season (July - August) (Kayode, 2006).

Previous study has shown that this area is underlain by Precambrian rocks typical of the basement Complex of Nigeria (Rahaman, 1976). Some of the main rock types found in this area are granite-gneiss, which occupies most part of the eastern flank; amphibolites complex and schist occupies most part of the study area; muscovite schist and quartzite and quartz-schist form part of the rock units (Kayode, 2006; Ajayi et al., 2003; Folami, 1992; Ajayi, 1981, Elueze, 1986). The topography is gentle with few local outcrops in the northeastern and northwestern part. There has been conflicting reports on the nature and lateral shift of the major faults in this area which necessitated this research. However, this is a preliminary study; more comprehensive reports would be published on this zone in the nearest future.

Geological Setting

The geology of this area consists of Precambrian rocks that are typical for the basement Complex of Nigeria (Rahaman, 1976). 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 (Olusegun, et al., 1995; Ajayi, 1981; Rahaman, 1976)

Rocks in this area are structurally divided into two main segments by two major fracture zones often called the Iwaraja

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Figure 1. Location of the study area.

faults in the eastern part and the Ifewara faults in the western part (Folami, 1992; Elueze, 1986). 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 (Olusegun, et al., 1995; Rahaman, 1976).

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, 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 (Kayode, 2006, Folami, 1992, Rahaman, 1976).

Theory of magnetic methods

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 by liquid metallic matter which move through a weak cosmic magnetic field which subsequently generates induction currents (Nettleton, 1976). It is this induction current that generate the earth's magnetic field (Telford, et al., 1976). 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 remnant which formed during geologic history (Reijers, 1996).

However, the ground magnetic study is used for detail mapping in order to understand the subsurface geology of an area. 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,

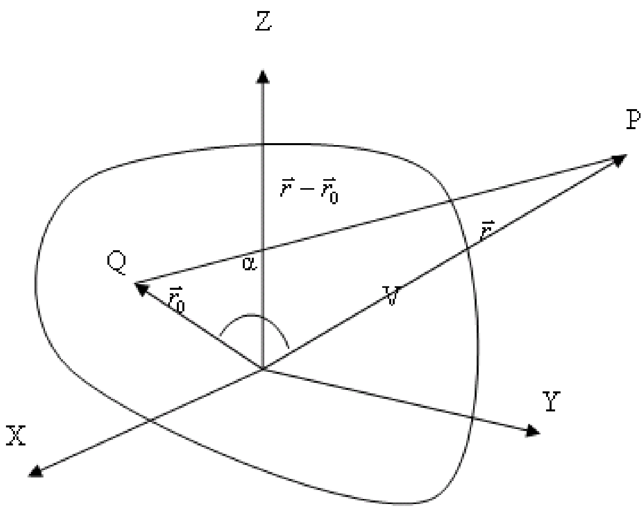

Figure 2. Magnetic scalar potential.

fractures, depth to magnetic basement and other geological structures (Folami, 1992).

The magnetic scalar potential due to a continuous distribution of matters e.g. earth, may be calculated at an external point P (Figure 2) (Telford, et al. 1976; Parasnis 1978). If the materials that fills the volume V has a continuous distribution of magnetic dipole moment per unit volume, then:

$$\vec{J} = \frac{\vec{m}}{V} \tag{1}$$

But the magnetic potential A of a dipole at point P outside the volume V and whose moment is $\vec{m}$ given by;

$$A = \frac{m\cos\theta}{r^2} - \vec{m}\cdot\vec{\nabla}\left(\frac{1}{r}\right) \tag{2}$$

Integrating Equation (2) gives:

$$A = -\int_V \vec{J}\cdot\vec{\nabla}\frac{1}{|\vec{r}-\vec{r}_0|}dv \tag{3}$$

But $dv = d^3 r_0$

$$\therefore \quad A = -\int_V \vec{J}\cdot\vec{\nabla}\frac{1}{|\vec{r}-\vec{r}_0|}d^3 r_0 \tag{4}$$

The total magnetic field intensity at point P outside the volume V is given as:

$$\vec{H} = -\vec{\nabla}A \tag{5}$$

Putting Equation (4) in (5) it gives:

$$\vec{H} = \vec{\nabla}\int_V \vec{J}\cdot\vec{\nabla}\frac{1}{|\vec{r}-\vec{r}_0|}d^3 r_0 \tag{6}$$

Assuming the direction of magnetization is the same throughout the volume V and represented by r, then:

$$\vec{J}\cdot\vec{\nabla} = J\frac{d}{dr} \tag{7}$$

Putting Equation (7) in (6), gives;

$$\vec{H} = \vec{\nabla}\frac{d}{dr}\int_V J\frac{1}{|\vec{r}-\vec{r}_0|}d^3 r_0 \tag{8}$$

Gauss however, expresses the volume integral in terms of the surface integral given by;

$$\int_V \vec{\nabla}\cdot\vec{F}dv = \int_S \vec{F}\cdot\hat{n}\,dA \tag{9}$$

Where A ≡ surface area, $\hat{n}$ ≡ unit outward normal vector on the surface S and $\vec{F}$ ≡ is a vector function.

If the point P is outside the volume V, it implies that surface S encloses no attractive mass, and then the right hand side of Equation (9) is zero. Hence:

$$\int_V \vec{\nabla}\cdot\vec{F}d^3 r_0 = 0 \tag{10}$$

Differentiating Equation (10), we have:

$$\vec{\nabla}\cdot\vec{F} = 0 \tag{11}$$

Taking $\vec{H}$ as the function, then equation (11) becomes:

$$\vec{\nabla}\cdot\vec{H} = 0 \tag{12}$$

Putting Equation (5) in (12), we have:

$$\vec{\nabla}\cdot\vec{\nabla}\cdot A = 0$$

$$\Rightarrow \quad \vec{\nabla}^2\cdot A = 0$$

$$\therefore \quad \frac{\partial^2 A}{\partial x^2} + \frac{\partial^2 A}{\partial y^2} + \frac{\partial^2 A}{\partial z^2} = 0 \tag{13}$$

If P is enclosed within the volume V, the magnetic potential A becomes:

$$A = -\int_{V-V^1} \vec{J}\cdot\vec{\nabla}\cdot\frac{1}{|\vec{r}-\vec{r}_0|}d^3 r_0 - \int_{V^1} \vec{J}\cdot\vec{\nabla}\cdot\frac{1}{|\vec{r}-\vec{r}_0|}d^3 r_0 \tag{14}$$

The first term is nonsingular, therefore it is harmonic everywhere.
J may be made constant by making r' small enough in the second term.

$$\Rightarrow \quad \vec{\nabla}^2 \cdot A \;=\; -\int_{V1} \vec{\nabla} \cdot \vec{J} \cdot \vec{\nabla} \cdot \vec{\nabla} \cdot \frac{1}{|\vec{r} - \vec{r}_0|} d^3 r_0 \qquad (15)$$

From Gauss Theorem, Equation (15) becomes:

$$\vec{\nabla} \cdot A \;=\; -\int_S \vec{\nabla} \cdot \vec{J} \cdot \hat{n} \cdot \vec{\nabla} \frac{1}{|\vec{r} - \vec{r}_0|} d^2 r_0 \qquad (16)$$

$$= \; -\vec{\nabla} \cdot \vec{J} \int_S \frac{\partial}{\partial r'} \cdot \frac{1}{r'} d^2 r_0$$

$$= \; -\vec{\nabla} \cdot \vec{J} \left(-\left(\frac{1}{r'} \right)^2 \right) \int_S d^2 r_0$$

$$= \; -\vec{\nabla} \cdot \vec{J} \left(-\left(\frac{1}{r'} \right)^2 \right) 4\pi (r'')^2$$

$$= \; \vec{\nabla} \cdot \vec{J} \cdot \frac{4\pi (r')^2}{(r')^2}$$

$$\therefore \quad \nabla \cdot A \;=\; 4\pi \vec{\nabla} \cdot \vec{J} \qquad (17)$$

Equation (17) is the required potential equation within regions occupied by magnetic bodies.

METHODOLOGY

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. The magnetic survey was designed in such a way 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 involving the following methods:

Data acquisition

The magnetic measurements were recorded using a proton magnetometer that involves three components which are vertical, horizontal and total magnetic intensities. Observations were made along series of traverses at equal spacing with a base station carefully selected, where the magnetic intensities are being measured at a stationary point.

Data processing

The magnetic data collected in the study area were processed so as to prepare the dataset for interpretations. These steps to data processing are:

1. Drift correction due to diurnal variations mostly which was as a result of magnetic storms.
2. Plotting of the relative magnetic profiles.
3. Residual anomaly processing (trends analysis).

Data presentation

There are several methods of presenting magnetic data (Obot, and Wolfe, 1981), but only two of these methods were adopted in this study. These methods are as summarized below:

1. 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 3a - d.
2. Contour: Contour maps were used in the presentation of the magnetic data of this area (Figure 5). The method was produced on scaled maps to aid interpretation because of it is superior to images method.

DISCUSSION OF RESULTS

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), Parasnis (1978). 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:

1. Separation of residual anomaly from the field anomaly using linear trend analysis.
2. Production of geomagnetic sections shown in Figures 3a – d (Obot and Wolfe, 1981).

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 (Peters 1949). 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 3a - d.

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 differ. The plot was characterized by complete varying mostly negative amplitudes from a minimum peak value of about -210 gammas at a distance of about 240 m from the initial station position and a maximum positive peak value of about 100 gammas at a distance of about 420 m (Figure 3a) were recorded. Two rock units were delineated from

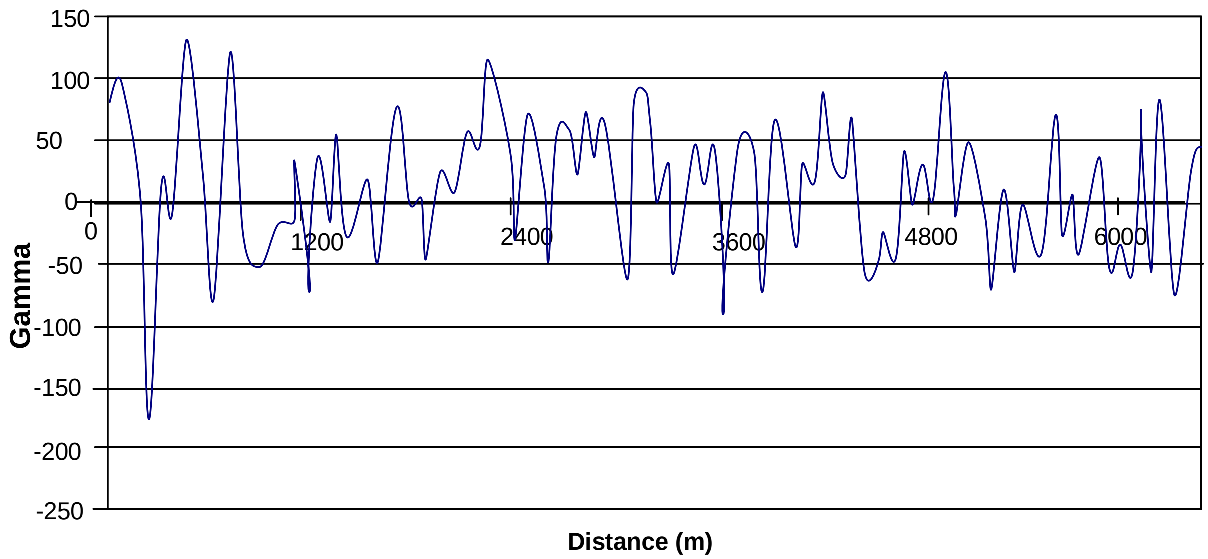

Figure 3a. Total relative magnetic intensity along traverse 11 (SE - NW) of the study area.

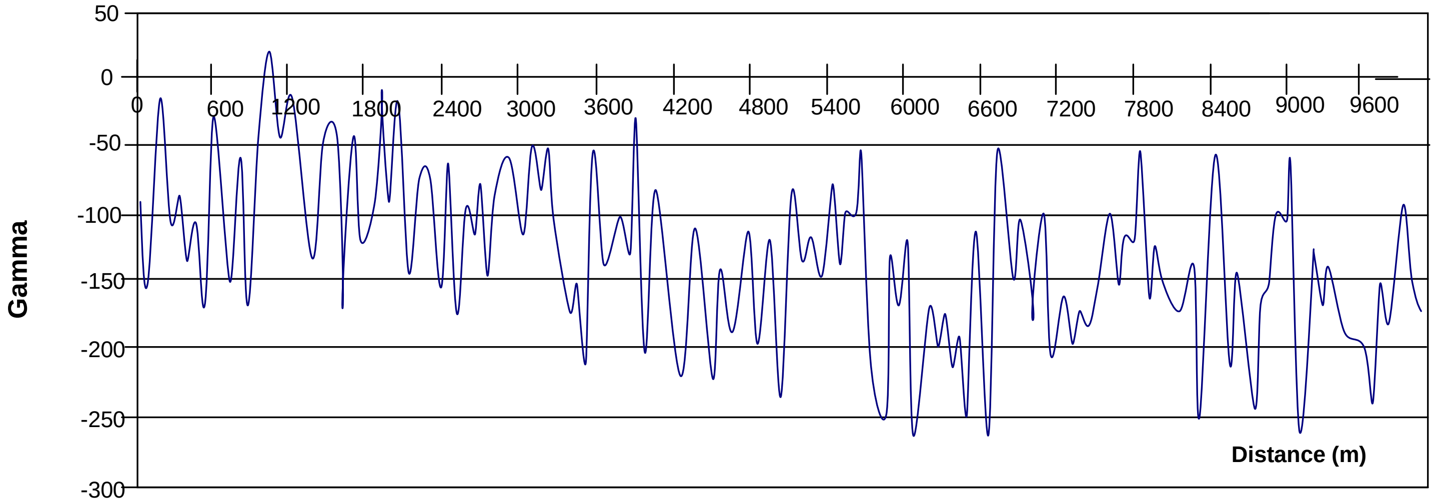

Figure 3b. Total relative magnetic intensity along traverse 12 (NW - SE) of study area.

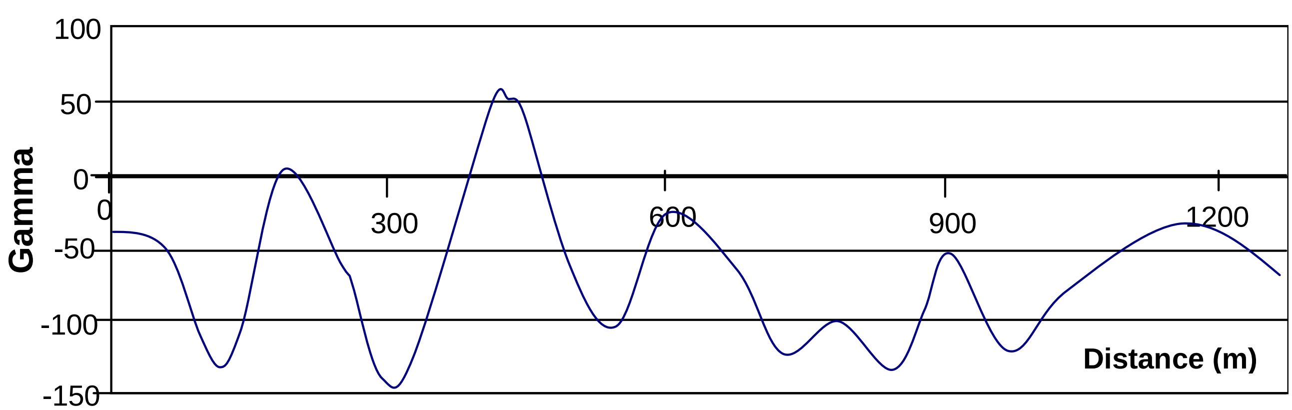

Figure 3c. Total relative magnetic intensity along traverse 14 (SE - NW) of the study area.

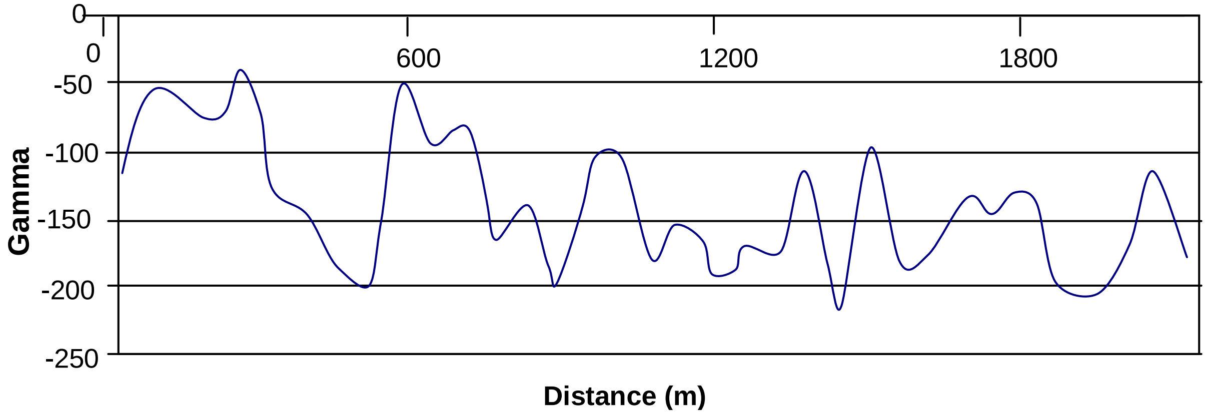

Figure 3d. Total relative magnetic intensity along Traverse 15 (NW - SE) of the study area.

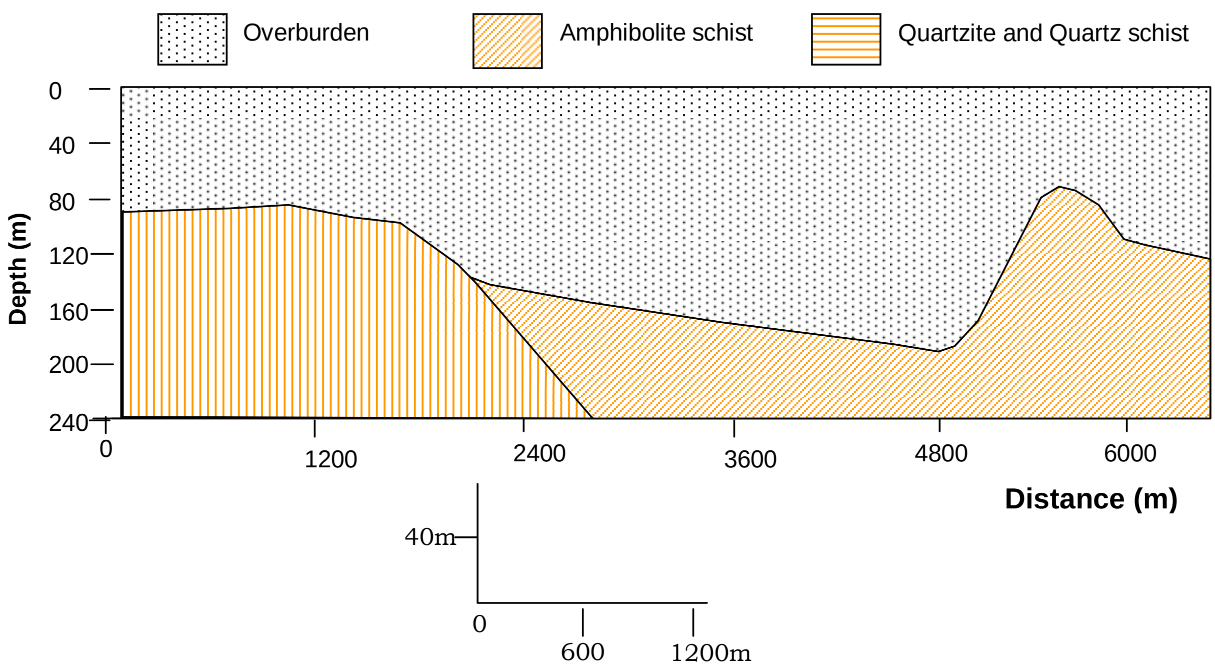

Figure 4a. Geomagnetic section along traverse 11 (SE - NW) of the study area.

the corresponding geomagnetic section as shown in Figure 4a.

Muscovite schist

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

Amphibolites schist

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

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 1020 m from the initial station position. The depth of probing for this method differs from the other two methods. The

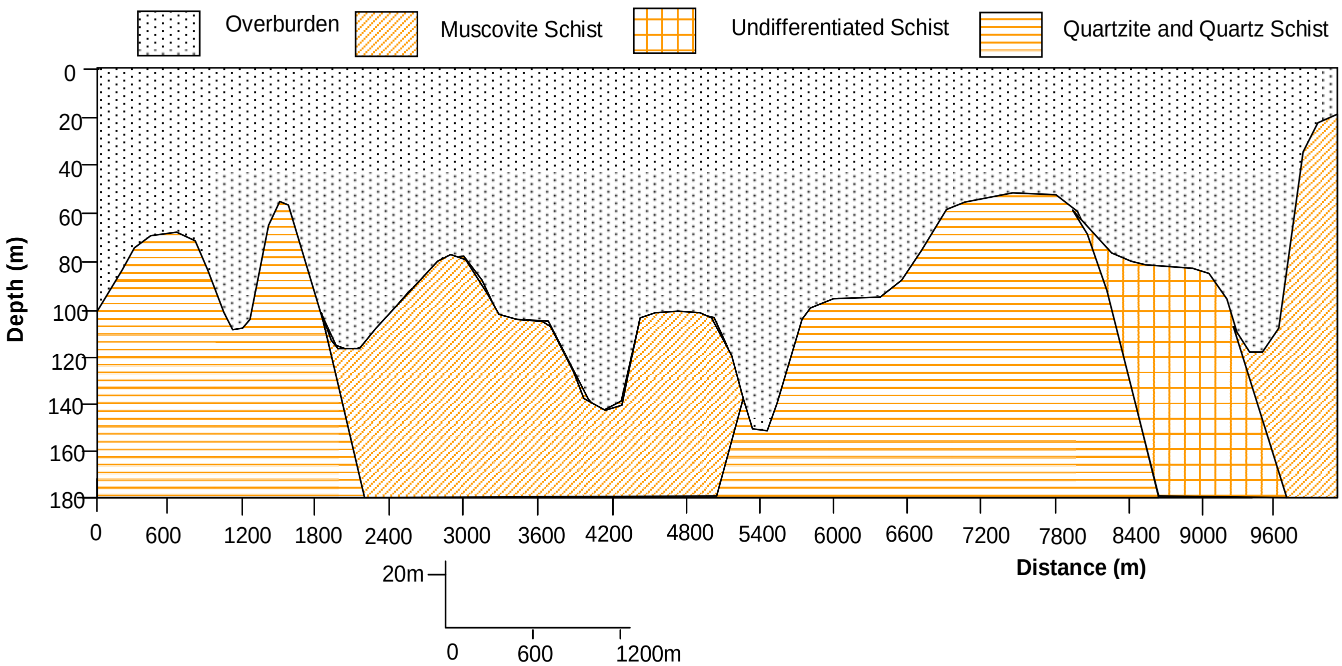

Figure 4b. Geomagnetic section along traverse 12 (NW - SE) of the study area.

traverse was characterized by complete varying negative amplitudes from a very low minimum negative peak value of about -260 gammas at distances of about 6000, 6600 and 9000 m respectively from the initial station position and a maximum positive peak value of about 20 gammas at a distance of about 1020 m (Figure 3b) were recorded. Three rock units were delineated from the corresponding geomagnetic section as shown in Figure 4b.

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 2 km for the first part and from about 5 to 8.5 km for the second segment. The depth to the magnetic basement varies between about 50 m and about 110 m at the first and second segments respectively.

Amphibolites schist

Amphibolites schist that spread across a total distance of about 5 km underlay the second and the last segments of this profile. The depth to the magnetic basement within this rock unit varies between 20 m and about 120 m.

Undifferentiated schist

This rock type was delineated at about 8.2 km from the starting point and ends at about 9.4 km towards the end of the profile. The depth to the magnetic basement for this rock unit varies within 80 to 100 m.

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 420 m 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 300 m from the initial station position and a maximum positive peak value of about 50 gammas at a distance of about 420 m (Figure 3c) were recorded. Three rock units were delineated from the corresponding geomagnetic section as shown in Figure 4c.

Quartz schist and quartzite

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

Amphibolites schist

Amphibolites schist was delineated at a distance of about 800 m towards the end of this profile. The depth to

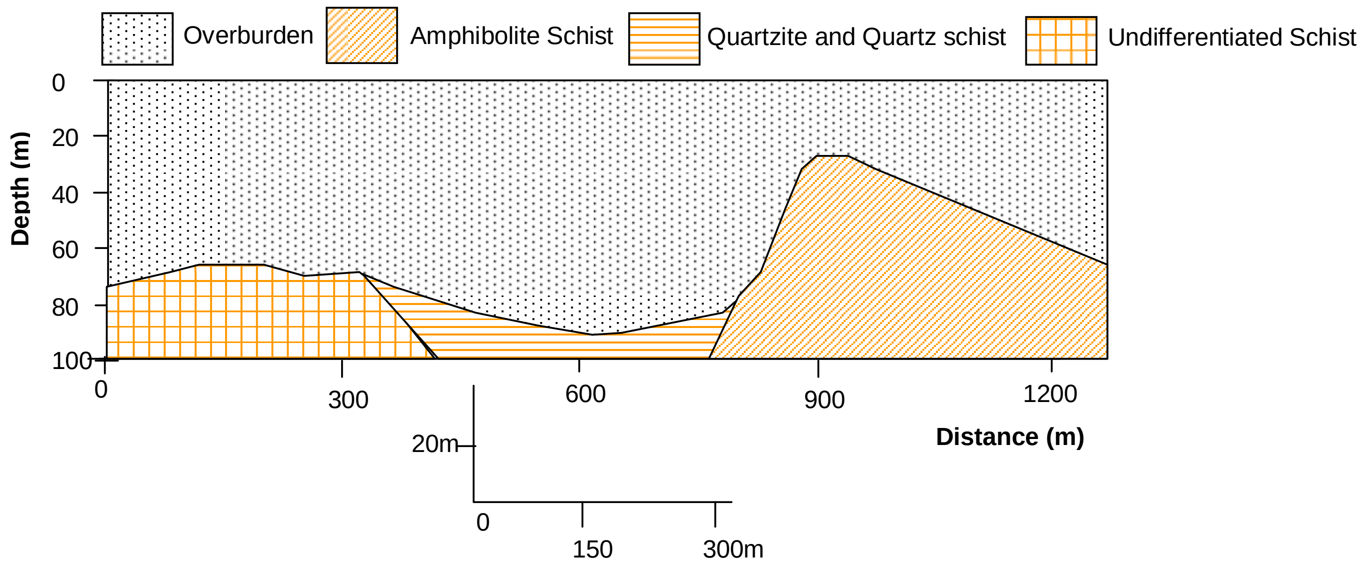

Figure 4c. Geomagnetic section along traverse 14 (SE - NW) of the study area.

basement within this rock unit varies from about 40 to 60 m.

Undifferentiated schist

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

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 1500 m from the initial station position and a maximum negative peak value of about -45 gammas at a distance of about 420 m (Figure 3d) were recorded. Two rock units were delineated from the corresponding geomagnetic section as shown in Figure 4d.

Quartz schist and quartzite

This rock unit was delineated at the first and the last segments about 540 m with the base extending to about 600 m. The last segment starts from about 1720 m from constant at about 40 m at the first segment and about 60 m in the last segments.

Amphibolites schist

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

Residual ground magnetic map of Ilesa Eastern part

The residual ground magnetic map of the study area using total relative magnetic components gives moderately low magnetic values which vary from about -250 nT to about 60 nT as shown in Figure 5. Two regions of (Positive and Negative) magnetic anomaly with highest value of about 60 nT was recorded in the Southeastern part of the area and negative anomaly region with the lowest value of about -250 nT was recorded at around the Western and Eastern parts of the area. The map the initial station position and extend towards the end of the profile. The depth to the magnetic basement is fairly further reveals the major and minor rock contacts in the area separated with different colours. The highest magnetic value of about 60 nT 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 geological structures in this part of the Ilesa schist belt.

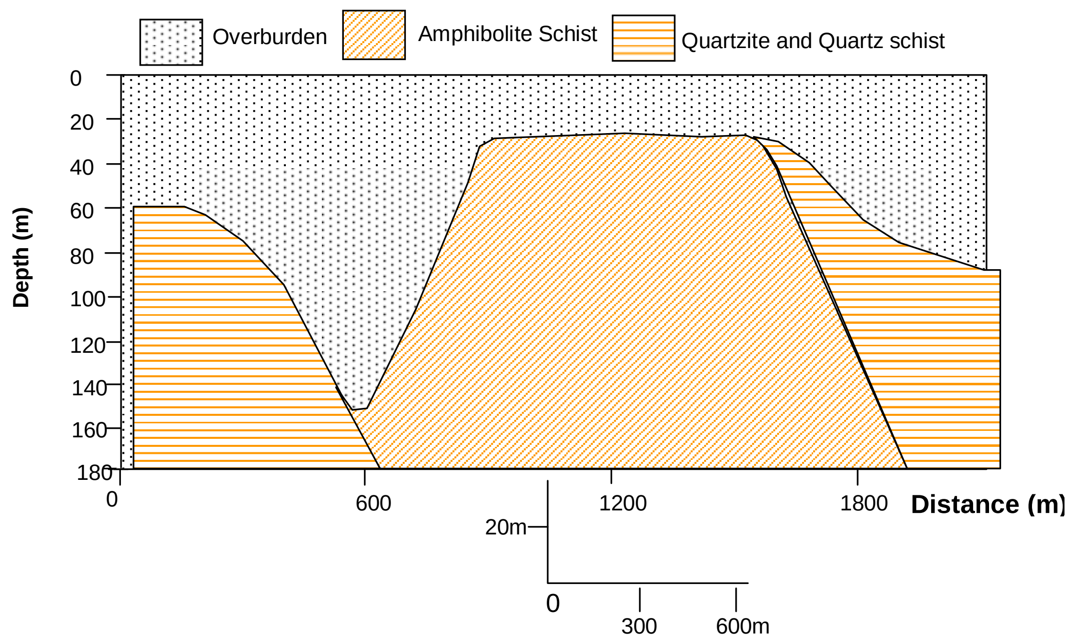

Figure 4d. Geomagnetic section along Traverse 15 (NW - SE) of the study area.

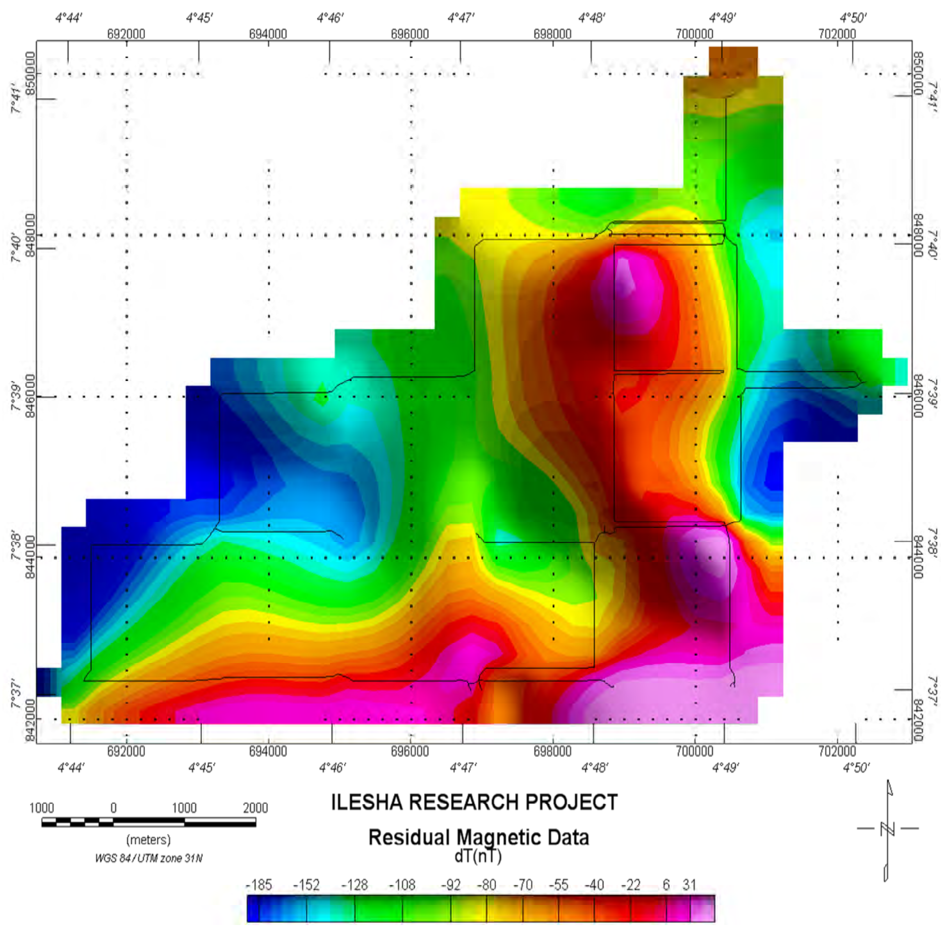

Figure 5. Residual magnetic map of the study area using total relative magnetic intensity.

Conclusion

The ground magnetic study of this area has helped in many ways to delineate lineaments and target zones which are of great benefits to the solid minerals sector of Nigeria economy. First, the geomagnetic sections 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. Secondly, the major subsurface structures delineated (the Amphibolites, Quartz, Quartz Schist etc) will aid the mineral exploration work in the area. Lastly, 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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