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Geomagnetic Studies of Pegmatite Mineralization at Lema and Ndeji North-Central, Nigeria

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Abstract

The area under study lies in a transition environment of the Nupe Basin and the Southwestern Nigerian Basement Complex, its bounded by latitudes 008^0 30′ N to 009^0 00′ N and longitude 005^0 00′ E to 005^0 30′ E. Aeromagnetic data were acquired from Nigeria Geological Survey Agency (NGSA) and ground magnetic data of four profiles with two each 2.5 km and other two 1 km each were acquired using Proton-Precession Magnetometer and Earth Magnetometer Model EM2 with the aim of studying mineralization of pegmatite. Qualitative analysis revealed major and minor subsurface geologic structures significantly trending NE-SW direction, believed to have caused mineralization of pegmatite. The high magnetic anomalies in the basement region of the study area are attributed to relatively deep-seated low relief basement structures with possible rare metals of columbite and tantalite while region with low magnetic susceptibility are attributed to present of sandstone, quartz, graphite, and feldspar. Different values of gradient and anomalies indicates the presence of numerous and different amplitudes, shapes and orientations. Trend of most structures are in conformity with fault lines in geological map. Quantitative analysis revealed depth to top of magnetic bodies as 10 m to 95 m for ground survey and 0 m to 1.62 km for aeromagnetic survey hence, they are near-surface causative with high promising mineralization.

Keywords: *Pegmatite, Basement, Lema, Ndeji, Geologic, Structure, Mineralization, Causative, Amplitude, NE-SW.*

Introduction

An aeromagnetic geophysical technique has been widely used for geophysical and geological survey since its inception. The most distinguishing feature of this technique, compared with other geophysical techniques, is the rapid rate of coverage and low cost per unit area surveyed. The use of this technique makes it possible for geophysicists to acquire data regardless of ownership or accessibility of remote lands of interest. This inherent advantage has made it possible for large scale airborne magnetometer survey to be carried out around the globe.

However, the ground magnetic study is used for detailed mapping in order to study 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 unavoidable components are measured thus; 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 (Folame, 1992). Precambrian pegmatites of Nigeria are known to host a variety of rare metals, tantalum, niobium, tin, tungsten, columbite as well as lithium which is used in the production of microchips and microprocessors for computers and electronics, aircraft construction, casting, galvanizing, production of containers, metal wears. More importantly, the tantalum and niobium contained in these rare metals are used for heat and corrosion resistant steels and alloys applied in space ships and gas turbines Okunlola, (2005); (Adekoya *et al*., 2003); Garba (2003); Okunlola and Ogedengbe (2003); Okunlola and Jimba (2006); Okunlola and Somorin (2006); Okunlola and Ofonime (2006).

The study area covers Lafiagi (Sheet 203) in the Nigerian topographical map. A Sheet comprises of ½ degree by ½ degree contour map on a scale of 1:100,000. It is bounded by latitudes 008^0 30′ N to 009^0 00′ N and longitude 005^0 00′ E to 005^0 30′ E (Fig. 1). The study area has the mining sites between Lema and Ndeji town extended to Gbugbu.

Mining of tantalite from both pegmatites and the alluvial started around 2002 yet no geophysical research in this regard has been established in the area. The mining activity continues for the major periods of the year except during the very dry months when lack of water makes it difficult to mine and concentrate the minerals. Columbite and cassiterite are recovered as by-products of the tantalite mining, while other pegmatite minerals like quartz, feldspar, amblygonite-montebrasite, and mica are still being discarded in waste dumps.

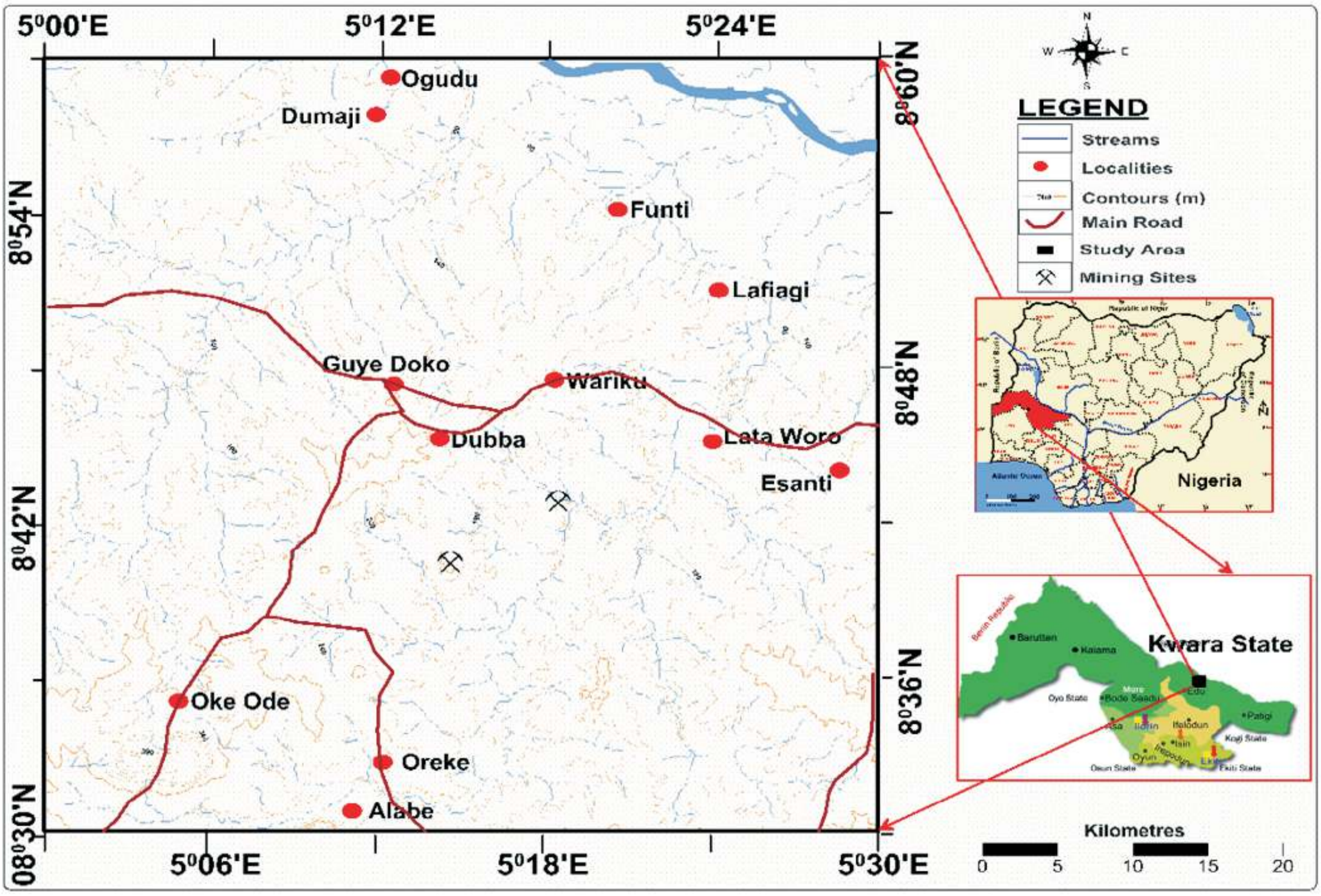

Fig. 1: Location map of the Study Area. (Extracted from Google Earth and DEM)

In lieu of this and the fact that pegmatite contains some rare metals that are magnetic in nature, magnetic method is used for this study with the aim of giving a better insight on lateral extend and approximate depth to the top of magnetic source in the area under study.

Geology of the Study Area

Central Nigeria is part of an Upper Proterozoic mobile belt extending from Algiers across the southern Sahara into Nigeria, Benin, and the Cameroun. This Pan-African belt continues into Northeast Brazil where analogous rare-metal mineralized pegmatites are also known (Schuiling, 1967). They host most of the economic minerals in the Basement Complex. Results of the rock ages also show that pegmatities' emplacement in the southwestern Nigeria occurred mainly after the peak of the Pan-African orogenic event in this area. The end of the Pan-African tectonic event is marked by a conjugate fracture system of the strike-slip faults (Ball, 1980). Fault directions have consistent trend and sense of displacement; i.e. a NE-SW (NNE-SSW) trending system having a dextral sense of movement and a NW-SE trending system a sinistral sense (McCurry, 1971; Wright, 1976; Holt *et al*., 1978; Ball, 1980). Both sets crosscut all the main Pan-African structures, including older N-S trending shear zones (mylonites) and late orogenic granites (Ball, 1980; Ajibade and Wright, 1989; Kuster, 1990; Garba, 1992). Gold and pegmatities' rare mineralization are closely associated with the fractures in the Pan-African belt (Kuster, 1990; Ekueme and Matheis, 1995; Garba, 2002, 2003).

The area under study lies in a transition environment between the Nupe Basin and the Southwestern Nigerian Basement Complex with the mining sites in Basement region of the study area (Fig. 2). The Basement Complex rocks include granites, biotite gneiss, amphibolite, quartz schist and mica schist with high percentage of pegmatite and the Sedimentary rocks consist of Nupe sandstone of Upper Cretaceous sediments (sandstone, ironstone and siltstone) which are believed to be between 300 m to 1000 m thick (Adeleye, 1973).

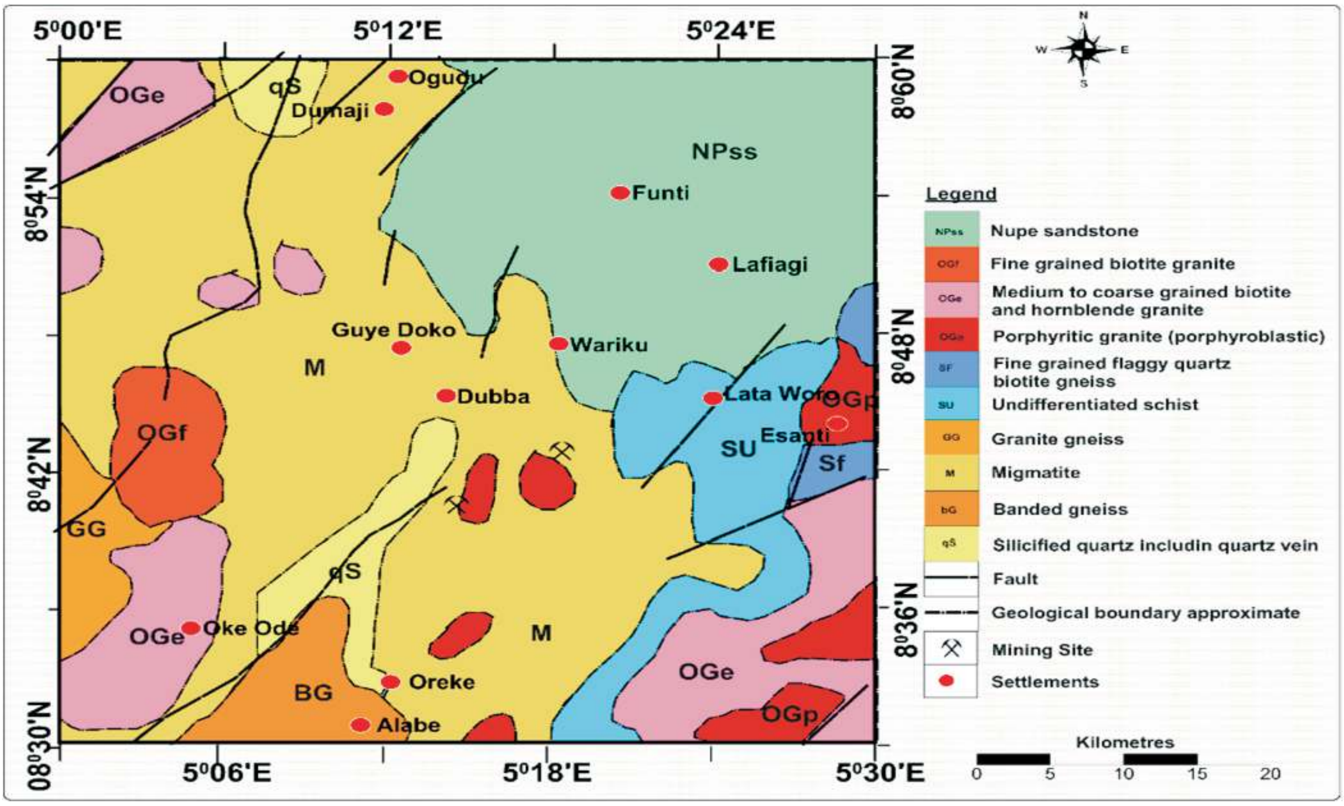

Fig. 2: Geological Map of the Study Area (After NGSA 2006).

Materials and Data Acquisition

The materials employed for this study include software (Oasis Montaj^{TM}, Surfer 13, Grapher 9, etc) used in the analysis and computation of both aeromagnetic and ground magnetic data. Two magnetometers (Proton-Precession Magnetometer and Earth Magnetometer Model EM2) and a GPS, Laptop, Wrist Watch etc.

The high-resolution aeromagnetic data were acquired as part of a nationwide aeromagnetic survey sponsored by the Nigeria Geological Survey Agency (NGSA). The survey was conducted in two phases and lasted from 2005 to 2009. The data was acquired along a series of NW – SE flight lines with a line spacing of 500 m and an average of 80 m terrain clearance. Since most of the data was acquired between 2005 and 2009, international geomagnetic reference field (IGRF) 2005 model was used in obtaining the main magnetic field of the earth from the measured values. However, total magnetic field comprises the effects of all magnetic sources hence, total magnetic intensity map produced (Fig. 3) characterised with high magnetic anomalies of NE-SW trending direction in the basement region of the study area could be attributed to relatively deep-seated low relief basement structures.

The ground magnetic survey data were acquired using two magnetometers. One magnetometer was stationed at a point within the survey area to take base station readings at equal time interval (10 minutes) while the other measured total magnetic field intensity along four traverses in NW-SE direction in which two were 2.4 km long each (8.68354^{0}N to 5.23249^{0}E and 8.66433^{0}N to 5.25648^{0}E) and other two were 1 km long each (8.71719^{0}N to 5.30397^{0}E and 8.71011^{0}N to 5.31308^{0}E) all are perpendicular to exposed and identified faults from aeromagnetic map, suspected to have caused mineralization of pegmatite in the area. The traverse inter-station spacing was 20 m while inter-traverse spacing was 500 m. The stations' coordinates and time of acquiring data were recorded during the survey for effective daily or diurnal variation corrections of earth's magnetic field. This was done to remove all temporal variation due to flow of charged particles in the Earth's such as magnetic storm in the observed magnetic data.

Methods

Regional Residual Separation

Primarily aeromagnetic data are used in geophysical survey as a reconnaissance studies for detail ground investigation(s). However, regional-residual separation

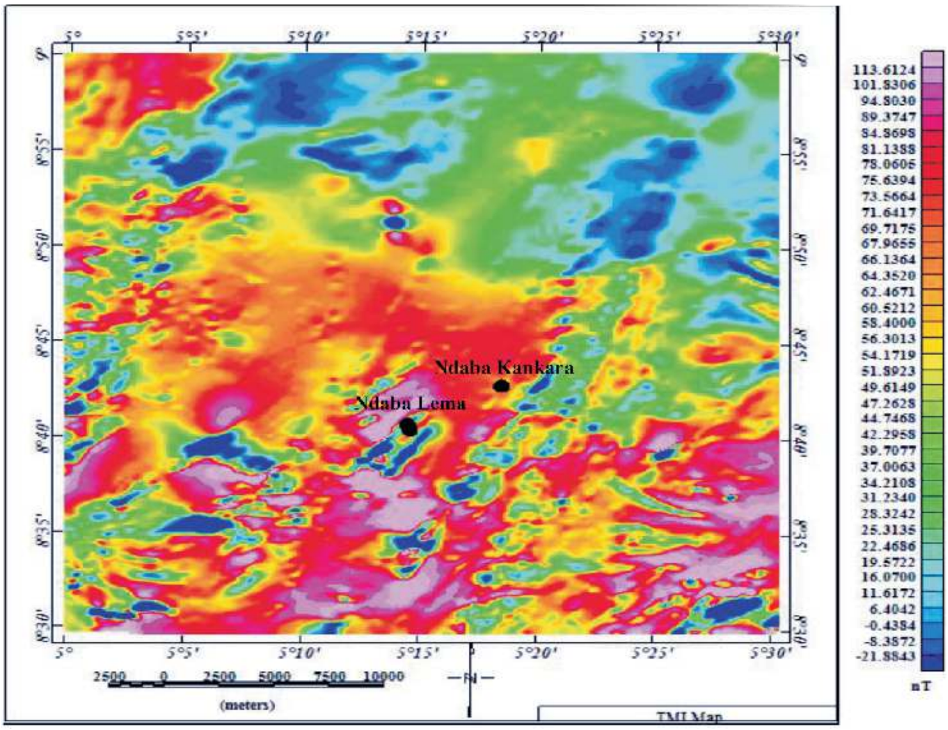

Fig. 3: Total Magnetic Intensity (TMI) Map of the Study Area

techniques were applied by fitting a two-dimensional, first order polynomial (trend surface) to the digitized total magnetic field intensity data by method of Least-squares (Davis, 1973). They possess different values of gradient indicating the presence of anomalous bodies. Shaded relief map (Fig.5) was produced to show approximate shape and trend of subsurface geologic structures while red crosses are the mining sites. Most structures trend almost the same direction (NE-SW) with fault line on figure 2.

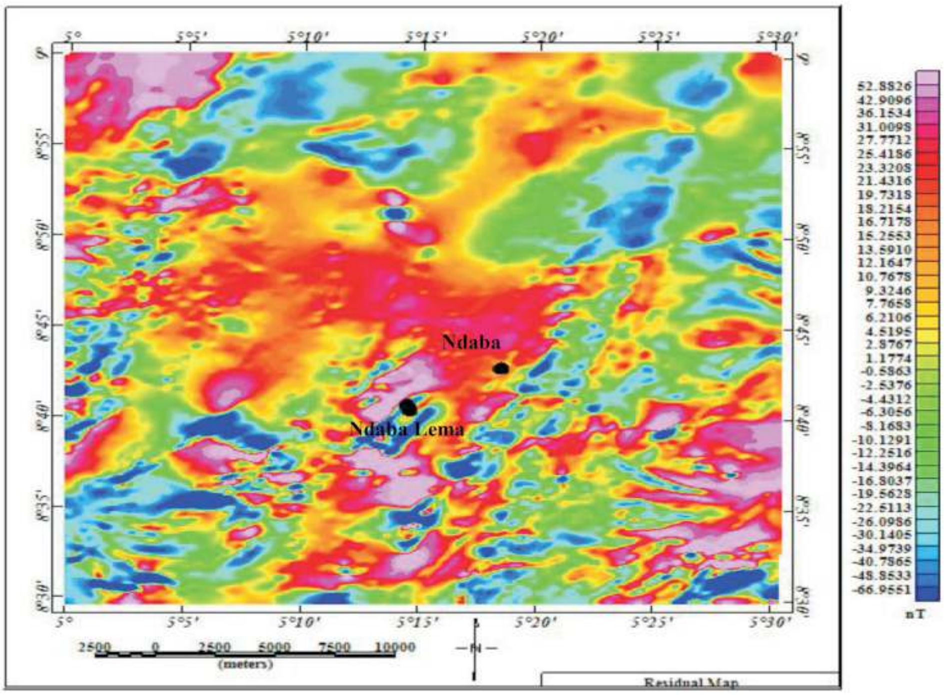

Fig. 4: Residual Intensity of the Study Area

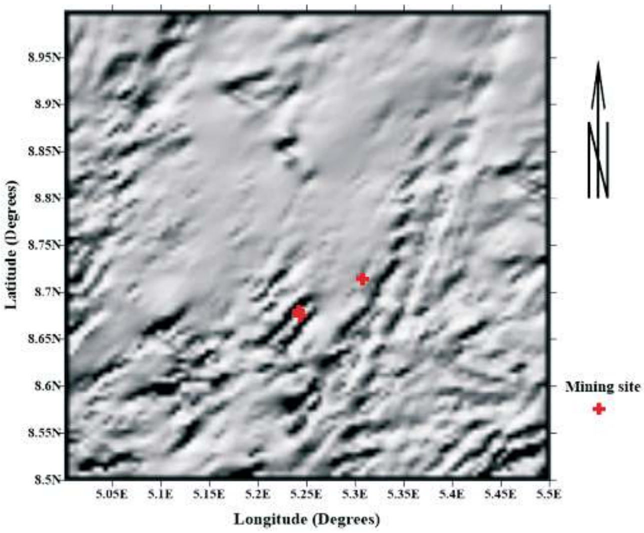

Fig. 5: Shaded Relief Map of the Study Area

Theory of Werner Deconvolution

After all necessary inspections and corrections, Werner quantitative analysis was performed on both aeromagnetic and ground magnetic data to obtain approximate depth to magnetic source body of deep and shallow seated low frequency and high frequency body respectively as the case may be. Traverses were taken such that they cut across sediment and basement region to generate both contact and dike solution to source body at various depth. Werner deconvolution uses horizontal and vertical derivatives to calculate depth to the magnetic anomalies. The Werner deconvolution function assumes the source bodies to be either dikes or contacts with infinite depth extent and uses a least-squares approach to solve for the source body parameters in a series of moving windows that moves along the profile and continually solves for the four unknown parameters (xo, z, A and B) (Ku & Sharp, 1983), however the equation of Ku and Sharp, (1983) below was used to determine depth to top of magnetic source.

$$F(X) = \frac{A(x - x_0) + BZ}{(x - x_0)^2 + Z^2} \quad \text{..(1)}$$

Where x_o is the surface point directly above the centre of the top of the dike, x is the measurement point and x-axis is normal to the strike, and z is the depth to the top. A and B (to be determined) are functions of the dike's geometry and mineralization (Telford, et al., 1990).

Solutions derived from the total field gradient are designated "Dike" solutions and solutions derived from the horizontal gradient are designated "Contact" solutions.

Figure 8 shown four aeromagnetic traverses laid across the entire area under study, black spots are mining sites.

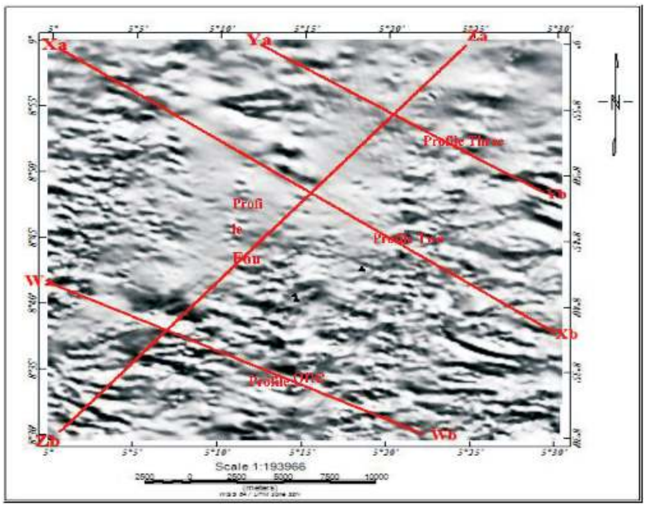

Fig. 6: Relief Map Showing line path of Werner Deconvolution Traverses (1-4)

Results and Discussions

The summary results are provided in table 1. Traverses three and four have longest depth attributed to overburden sediments in the NNE of the study area. There's distinct depth variation along traverse four as we go from sedimentary to basement region which also confirmed differences in geological setting of the study area hence, aeromagnetic survey can be used to delineate between sedimentary terrain and basement complex (Fig. 7). Figures 7-10 are werner depth plot of the four aeromagnetic traverses that revealed minor and major faults and geologic structures causing mineralization of pegmatite having concentrated solutions in depth range between 0 – 600 m. This depth is in conformity with work of (Adeleye, 1973).

Table 1: Numerical values of werner analysis (aeromagnetic)

Traverse number	Traverse Trend (direction)	Traverse Length (km)	No of contact solutions	No of dike solutions	Depth range (km)
1	NW-SE	54	15	20	0 - 1.4
2	NW-SE	70	22	15	0 - 1.1
3	NW-SE	40	13	18	0 - 1.62
4	NE-SW	75	26	32	0 - 1.62

Magnetic field intensity (nT) against distance (m) (Figure 11 and 12) gives a considerable high magnetic intensity along ground magnetic traverses. Around 1.3 km of traverse one revealed very low intensity while traverses three and four indicates high mineralization potential. Depth to the surface of the magnetic

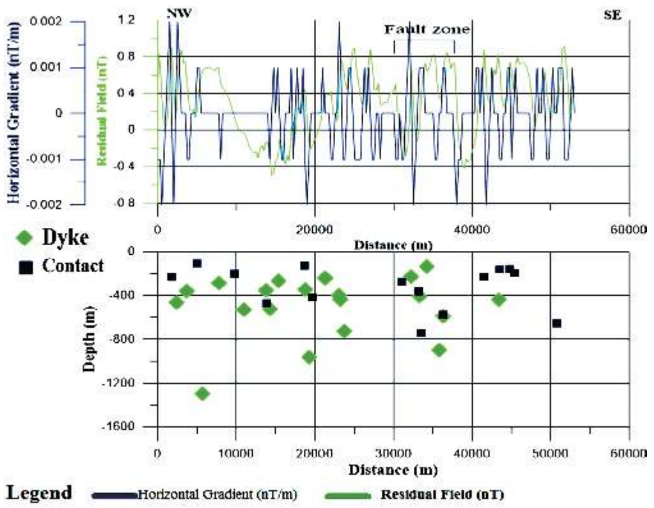

Fig. 7: Werner Depth Solution plot for Traverse one

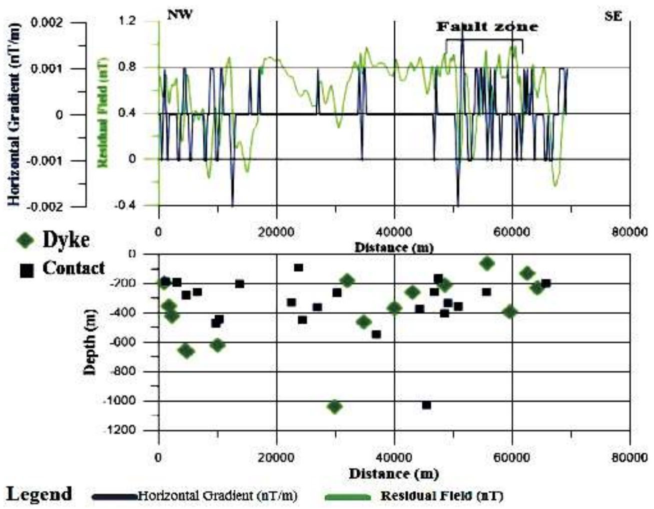

Fig. 8: Werner Depth Solution plot for Traverse Two

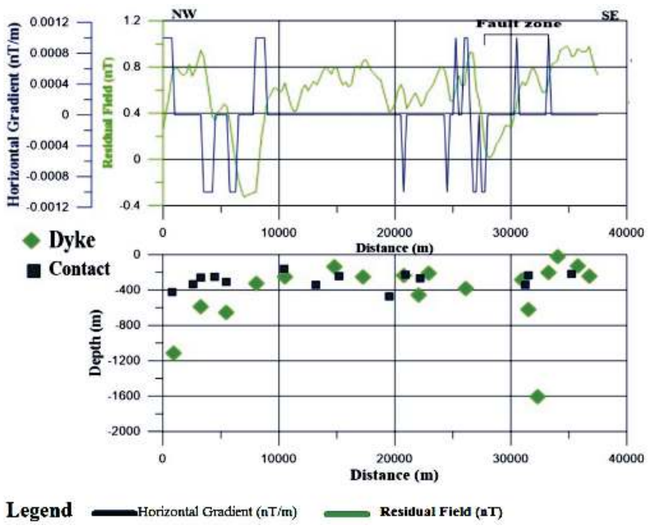

Fig. 9: Werner Depth Solution plot for Traverse Three

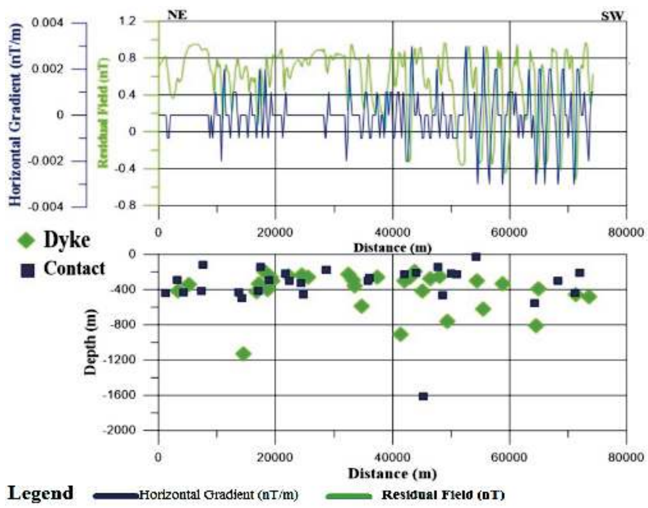

Fig. 10: Werner Depth Solution plot for Traverse Four

anomalous sources is shown by werner solution plots in Figures 13 and 14, un-continuous fault trending NE-SW was confirmed around Ndaba and Lema mining sites during ground survey, inferred pegmatite mineralization Figure 14. Recorded depth ranging from 10 m to 95 m indicates shallowness of causative body. Depths are within the depth range of mining pits measured with tape rule on the field and similar results were obtained by Ojo et al. (2014) using magnetic and resistivity to locate and determine the depth of pegmatite vein at Olode Village as 5.80 m to 6.72 m.

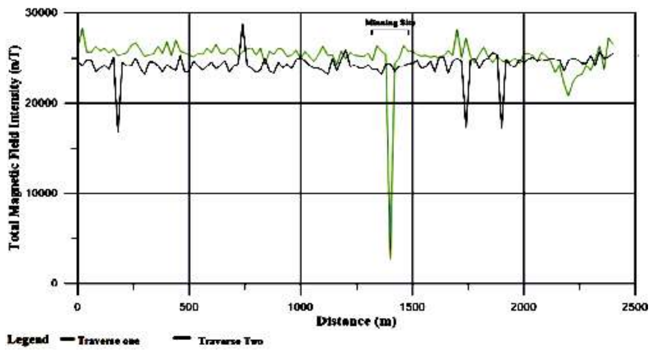

Fig. 11: Two Ground Magnetic Survey Traverses Acquired at Ndaba-Lema

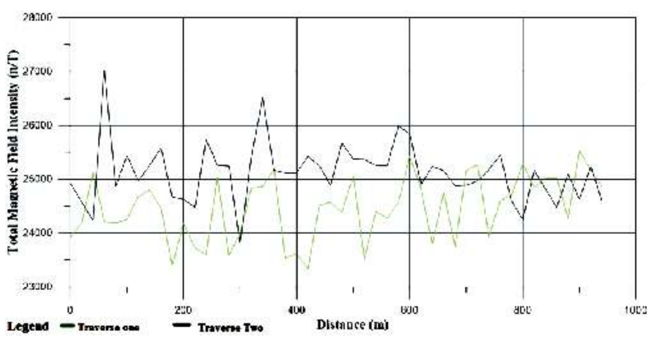

Fig. 12: Two Ground Magnetic Survey Traverses Acquired at Ndaba-Kankara

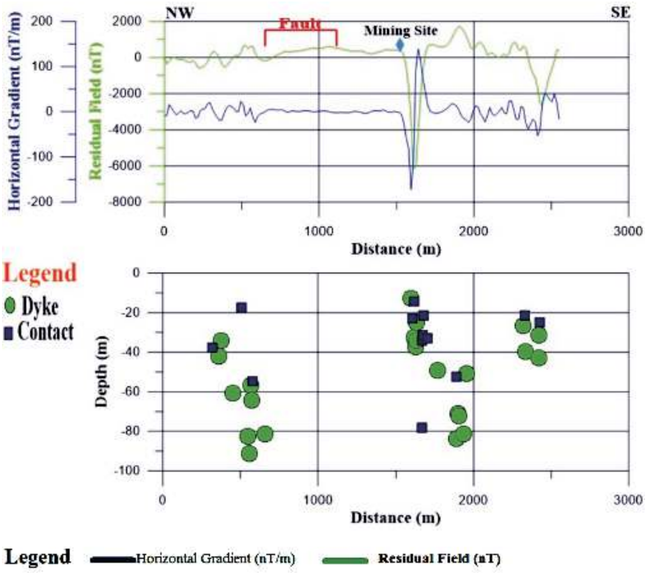

Fig. 13: Werner Solution Plots of Digitized Traverses at Ndaba-Lema

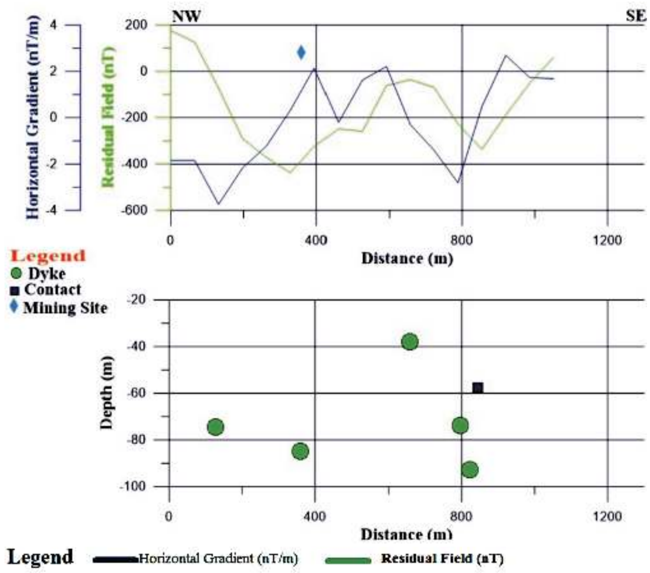

Fig. 14: Werner Solution Plots of Digitized Traverses at Ndaba-Kankara

A major fault line cutting the area around longitude 5° 15' and coming out around longitude 5° 30' is an extension of the Romanche trench line (Udensi *et al*., 2003), the draped map (Figure 15) of shaded relief of residual and geologic map clearly shows the points of mineralization coinciding with lineament suspected to be a fault within the study area, it has shown also that the mining sites are in migmatitic area and at contact between migmatite and granite.

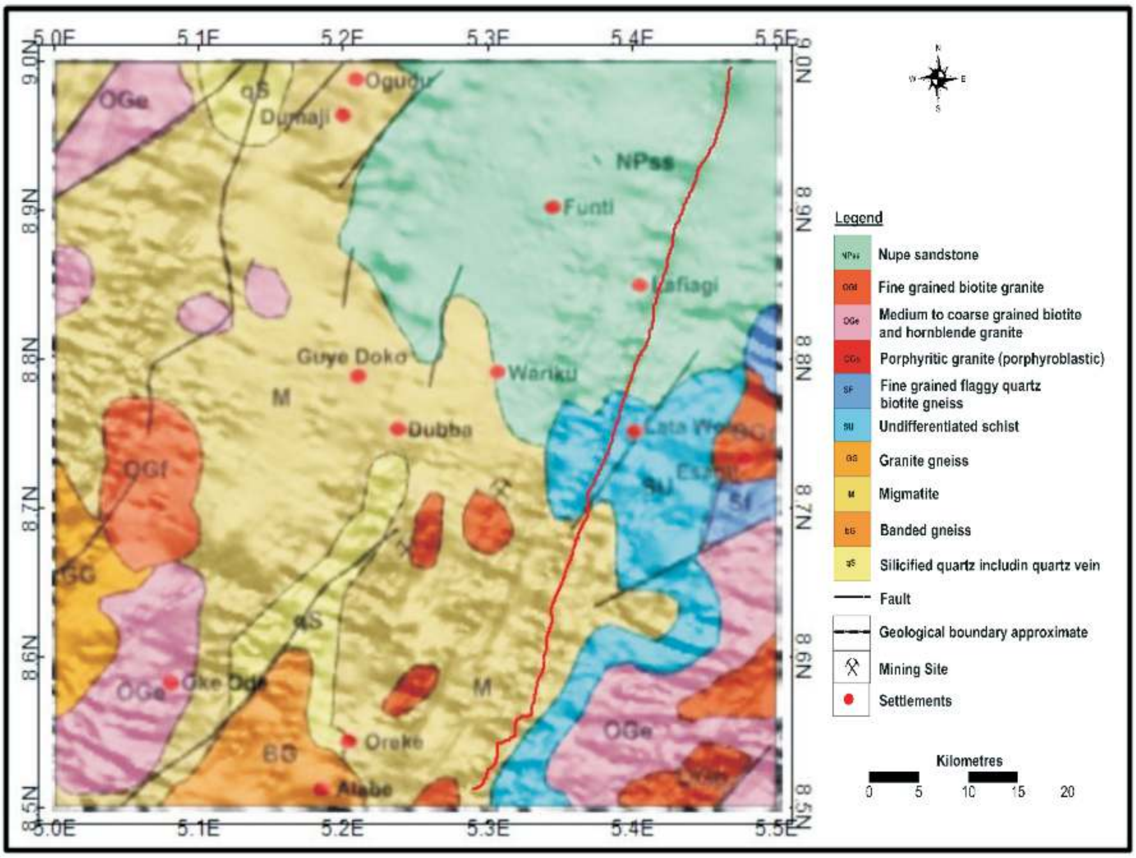

Fig. 17: Shaded Relief of Residual draped with Geological Map.

Conclusion

Qualitative analysis revealed considerable magnetic susceptibility in the entire area under study having higher susceptibility at basement region, minerals within region of high magnetic susceptibility are columbite and tantalite while regions with low susceptibility are sandstone, quartz, graphite, and feldspar. Quantitative analysis revealed depth of causative bodies in interval of 10 m to 95 m for ground magnetic survey and 0 m to 1.62 km for aeromagnetic survey. The main structural features within the area are in the form of high and low structures as well as faulting. The highs and lows are mainly attributed to uplifted and downfaulted blocks within the basement. The main trends are in NE-SW direction. Depth range of aeromagnetic is much higher than ground magnetic in that, first is longer in traverse length, inter traverse and inter station spacing than the later, hence aeromagnetic survey is a tool for delineating between sedimentary and basement region. Ground magnetic depth range obtained are more relative than aero-magnetic for near-surface exploration and exploitation.

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