DELINEATION OF STRUCTURES FOR SOLID MINERALS WITHIN KUBIL (SHEET 128) AND WAWA (SHEET 159) NORTH CENTRAL NIGERIA FROM AEROMAGNETIC DATA

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MTech/SPS/2017/6900

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SUBMITTED TO

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ABSTRACT

To resolve the problem of artisanal miners using trials and error method to locate solid minerals, a geophysical technique was employed to delineate structures that host mineral in the study area. The study focused on both (Qualitative and Quantitative) analyses of high resolution Aeromagnetic data to delineate the geological structures that could serve as host to mineral within Wawa (Sheet 128) and Kubil (Sheet 159) Niger State, Nigeria. The area is bounded by Latitude 4º00' and4º30E' to Longitude 9º30' and 10º30'N. The aeromagnetic data was subjected to various filtering method such as generating of Total Magnetic Intensity Map, Analytical Signal, First Vertical Derivatives and Center for Exploration Targeting (CET). The total magnetic intensity map comprises of both positive and negative anomalies with magnetic values within the study area ranges from -66.589 nT to 129.237 nT. Result of analytical signal depicts high amplitude response of magnetic anomalies ranges from 0.232 to 0.355 cycles in regions of shallow magnetic intrusive rocks and low amplitude response of magnetic anomalies ranges from 0.010 to 0.218 cycles in regions of relatively thick sedimentation. The first vertical derivative helped to place both low and high magnetic lineaments which are of interest that could serve as gold veins. These were located around latitude 9º50' to 10º10'N within Yangari, Lasun Sarabe, Wawa Malete town down to Doro across rivers Yakumosin. The major lineament are mapped as F1 to F7 on the first vertical derivatives. Similar structures were observed from the Centre for exploration targeting (CET) grid analysis only that they are more detailed. The mapped regions on the first vertical derivatives (FVD) hosting major lineaments are the potential minerised zone. Ground trothing should be conducted by relevant geological agency at zones of minerisation to confirm the mineral type and their relative abundance. Resistivity survey is recommended for the delineated regions of minerisation for a more detailed capturing of delineated structures since the current research is of a regional scale.

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CHAPTER ONE

1.0 INTRODUCTION

1.1 Background to the Study

Geophysics is a very potent and vital tool of exploration and consistently used in detail surveys. There are a lot of geophysical survey methods which include gravity, magnetic, radiometric, seismic, electrical resistivity etc. Each of the above survey method has a unique operative physical property like density, magnetic susceptibility, radioactivity, propagation or velocity of seismic waves, electrical conductivity etc. of the Earth (Kearey *et al*., 2002). These methods had been used to investigate the subsurface geology of an area of interest. Some of these methods can still be applied by flying the geophysical equipment namely magnetic, electromagnetic, radiometric and gravity. Airborne geophysics is an effective way for surveying a very large area quickly for regional exploration. (Kearey *et al*., 2002).

Aeromagnetic survey is the frequent type of airborne geophysical survey and has been recognised as a principal mapping tool for materials that are strongly magnetised (Murthy, 2007). Magnetic method seeks to probe the geology of the particular area due to the differences in the susceptibility of the field. These differences are as a result of the magnetic features of the rocks subsurface (Kearey *et al.,* 2002).The most vital magnetic minerals in soils are the iron oxides, such as magnetite. In soils the main source of magnetic minerals is the parent material through the soil formation processes. A general practice to identify the existence and concentration of magnetic minerals is the amount of the magnetic susceptibility in soils. Soil magnetic susceptibility can be related to different terrain topographic attributes such as the slope, elevation and concavity-convexity of the surface terrain to explain the distribution of magnetic minerals within soils (Rowland & Ahmed, 2018), Based on geomagnetism, the earth may be considered as made up of three parts: core, mantle and crust. Convection processes in the liquid part of the iron core give rise to a dipolar geomagnetic field that resembles that of a large bar-magnet aligned approximately along the earth's axis of rotation. The mantle has little effect on earth's magnetism, while interaction of the geomagnetic field with the rocks of the Earth's crust produces the magnetic anomalies recorded in detailed surveys carried out close to the earth's surface (Reeves, 2005). Thus an anomaly is created when the earth's magnetic field is disturbed by an object that can be magnetized. Survey data is interpreted based on the assumption that magnetic sources must lie below the base of the sedimentary sequence. This allows rapid identification of hidden sedimentary basins in mineral exploration. The thickness of the sedimentary sequence may be mapped by systematically determining the depths of the magnetic sources over the survey area. Depths to the magnetic basement are very useful in basin modeling such as determination of source rock volume and source rock burial depth. The identification and mapping of geometry, scale and nature of basement structures is critical in understanding the influence of basement during rift development, basin evolution and subsequent basin inversion. From regional aeromagnetic data sets, information such as tectonic frame of the upper crust can be obtained. The patterns and amplitude of anomalies reflect the depth and magnetic character of crystalline basement, the distribution and volume of intrusive and extrusive volcanic rocks and the nature of boundaries between magnetic terrains.

According to reports (2018) by the Nigeria Geological Survey Agency (NGSA), Nigeria as a nation has some 34 known major minerals resources distributed in 450 different locations across the country and given more invaluable attraction for investors. Minerals exploration for several solid minerals, e.g. tin, niobium, lead, zinc and gold, goes back for more than four decades but only tin and niobium production have rated on a world-wide scale (Rowland & Ahmed, 2018).

While the major international exploration groups have paid more than interest, there has been general exploration carried out by the tin mining groups and since the mid-1970s by several organisations and in particular the Nigerian Mining Corporation. Throughout its long history the Nigeria Geological Survey Agency had played an invaluable role in the exploration for mineral deposits many of which have been first presented by its officers. Presently, there is a great interest in the development of solid mineral resources whose production in the last three decades has been depreciating in every case. The privatisation, commercialisation and general reform exercises currently being undertaken by the Federal Republic of Nigeria are expected to lead to a positive change in the exploration, growth and development of Nigeria's solid mineral resources (Rowland & Ahmed, 2018).

1.1.1 Magnetism of the earth

The Earth may be divided into three parts *i.e* crust, mantle and core. The core of the Earth may also divide into two parts that is the molten outer core and the solid inner core. The core of the Earth is the main provider of heat energy in the Earth. Inglis (1955) pointed out that, it is impossible at present for determine the types of convectional motion in the molten core. Reeve (2010) indicated that the movement of the charged electric particles within the molten core produces a magnetic field around the Earth after several theoretical and experimental studies. This magnetic field enveloping the Earth give rise to the magnetic features of the various rocks found within or on the surface of the Earth. The flow of these electrical charges successfully creates a huge electromagnet (Clark and Emerson, 1991).

1.1.2 Nature of the geomagnetic field

The Earth's magnetic field within or at the surface of the Earth is produced from the molten outer core (Rivas, 2009). The Earth's magnetic field is made up of three parts (Telford *et al.*,1990) namely;

a. The major field, which differs comparatively gradually and originates within the Earth.
b. The minor field (compared to the major field), which differs rather quickly and of external origin.
c. The spatial variation of the major field which are usually lesser than the major field, are almost the same in time and place, and are brought by local magnetic anomalies within the Earth's crust. These are the areas of interest in magnetic surveying.

   The compass needle aligns itself in the direction of magnetic field of the Earth when hanged freely at any position on the surface of the Earth. This alignment creates an angle between the magnetic and geographic north (Kearey *et al.*, 2002).

   Almost 90% of the geomagnetic field can be characterized by the field of a theoretical magnetic dipole at the Earth's centre subtended at an angle of about 11.5° to the rotation axis (Kearey *et al.*, 2002)

1.1.3 The earth's magnetic field

If an unmagnetized steel needle could be hung at its centre of gravity, so that it is free to orient itself in any direction, and if other magnetic fields are absent, it would assume the course of the total geomagnetic field, a direction which is usually neither horizontal nor in line with the geographic meridian (Telford *et al.*, 1990).

The compass needle direction when hanged freely at any position of the Earth gives the direction of the geomagnetic field. The direction can be specified in terms of declination, the angle between the true north and the horizontal and the direction of the total field. The field magnitude is proportional to the maximum torque exerted on the compass needle by the field. The geomagnetic field to which the compass needle is reacting seems to be caused by complex interactions between the Earths hot, liquid, metal outer core as it rotates and convection with it, generating circular current at the core-mantle boundary. The Earth's magnetic field sources vary in nature and place. The dynamo action of the molten core produces the most extreme field recorded at the equator is in the range 30,000 nT whiles the poles record a range of 60,000 nT (Kono and Schubert, 2007).

Whitham, (1960) indicated that the magnetic elements are illustrated in (Figure 1.1.) below The declination 'D' is taken positive or negative depending on the deviation east or west of the geographic north. So declination can be defined as the angle the geographic north makes with the magnetic north of the Earth. The Fig. below in which the magnetic field is vertical plane, it is passing through the total magnetic force "T". Hence, the magnetic field of the Earth at every position on the surface of the Earth „V" and "H" are vertical and horizontal components of "F".

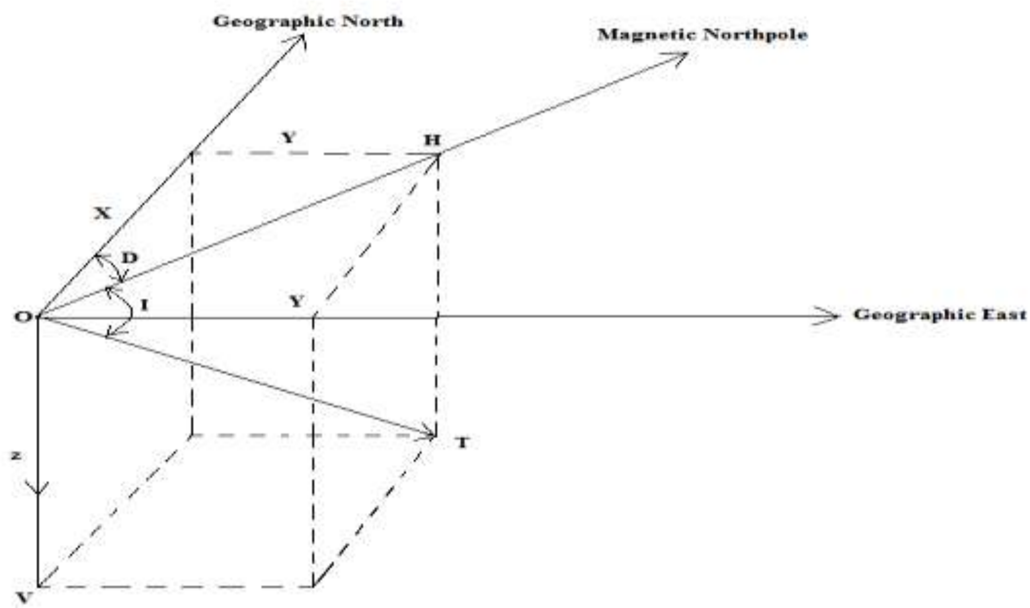

Figure 1.1: Vector representation of the geomagnetic field at any place on the Northern Hemisphere (Whitham, 1960).

These magnetic elements can be related as follows:

$$H = T \cos I \quad (1.1)$$

$$V = T \sin I \quad (1.2)$$

1.1.4 Maxwell's equations

The universe of classical electrodynamics begins with a vacuum containing matter solely in the form of electric charges, possibly in motion, and electric and magnetic fields. We can detect the presence of these fields by the forces they exert on a moving point charge q. Maxwell‟s equations provide the curl and divergence of the electric fields and magnetic fields in terms of other things. The universe we are operating in comprises an infinite vacuum containing electrical charges, represented by a local density **ρ**, which may be moving, and hence generating electric current, represented by a local current density **J**. The equations in vector form are: where is measured in (coulomb/m3), **J** is also measured in (ampere/m3), is permeability of vaccum (4π x 10-7 henries/m), is capacitivity of vaccum (107/ 4πc2 farads/m), **B** is in teslas and **E** is in volt/m

1.1.5 Magnetism of rocks and minerals

Most rock-forming minerals are non-magnetic. Only a few magnetic minerals, that include magnetite (Fe_3O_4), ilmenite ($FeTiO_3$) and pyrrhotite (FeS), significantly affect the magnetization field of the particular area. Magnetic rocks contain these minerals, usually in small quantities. Because subsurface temperatures increase with depth, substantial magnetization can occur only above certain depths. In areas with relatively high geothermal gradients, the maximum depth of magnetization is shallower than it is in areas with lower geothermal gradients. Most sedimentary rocks contain negligible quantities of magnetic minerals, and are therefore non-magnetic. Most basic igneous rocks, on the other hand, have high magnetic susceptibilities, while acid igneous rocks and metamorphic rocks can have susceptibilities ranging from negligible to extremely high (Reeves, 1989; Petersen, 1990; Reynolds, 1997).

Below the Curie temperature is when the magnetic features of rocks can exist. This temperature varies for different rock types but ranges from 550^0C to 600^oC. Present day geothermal studies have indicated that Curie point can be reached at depths 30 to 40 Km beneath the Earth. Based on these assumptions, it is estimated that all crustal rocks are very potent to carry magnetic features. Reeves (1989) suggested that the upper part of mantle has no magnetic properties hence the bottom of the Earth's crust may be effective depth where magnetic sources can be found. Magnetic materials can be grouped on the basis of their behavior when placed in an external field (Telford *et al.*, 1990). Many materials have equal numbers of electrons spinning and orbiting in opposite direction so that, in absence of some external magnetic field, their effects cancel out. If a magnetic field is applied, the electron orbits are very slightly disturbed electromagnetism induction. This very slightly weakens the field inside the material giving a minute magnetic effect called diamagnetism. Diamagnetism is independent of the temperature. Diamagnetic materials include quartz, feldspar, calcite, graphite, salt. The diamagnetic substances have negative magnetic susceptibilities (Reynolds, 1997).

The paramagnetic materials have unbalanced electrons so that the individual atoms or molecules act like very tiny magnets. In the absence of an external magnetic field these molecular magnets are arranged at random, giving no resultant magnetic effect to the material as a whole but if a magnetic field is applied the molecular magnetic becomes partially aligned with it thus increasing its strength. This is small effect is called paramagnetism. With paramagnetic materials which have positive values of magnetic susceptibilities. The total magnetic intensity will be bigger than the original magnetic field. Examples of such materials include pyroxene, olivine, pyrite, and biotite (Reynolds, 1997).

Strong paramagnetic materials such as iron, nickel and cobalt are said to be ferromagnetic. With ferromagnetic materials, there is almost a perfect arrangement of their domains. Ferromagnetic materials have all their magnetic dipoles aligned hence there is a magnetization of high effect being produced. With anti-ferromagnetic materials such as hematite its adjacent magnetic dipoles are opposite to the direction of magnetization hence produces zero magnetization effect. Materials such as magnetite, ilmenite show very strong magnetization effect and its domains align themselves in the direction of applied external field (Reynolds, 1997).

1.1.6 Magnetic susceptibility

The degree to which a material can be magnetized in an applied external field is a physical parameter known as magnetic susceptibility (Dalan, 2006). In geology, magnetic susceptibility is one characteristic of a mineral type. Its measurement gives us information about the type and quantity of minerals present in the sample. The measure of magnetization is solely characterized by the amount and composition (shape and size) of iron oxide in the rocks (Dearing, 1994;

Wemegah *et al.,* 2009).The magnetic susceptibility effectively is the magnetization effect divided by the applied magnetic field. If the magnetic field is **H** (A/m) and the magnetization is **M** (A/m), the

magnetic susceptibility is

$$\kappa = X_v = M/H \qquad (2.3)$$

Where X_v is volume of susceptibility

Although susceptibility has no units, to rationalize its numerical value to be compatible with the SI or rationalized system of units, the value in c.g.s. equivalent units should be multiplied by (Clark, 1997).

Reynolds (1997) indicates that most sedimentary rocks contain negligible quantities of magnetic minerals, and are therefore non-magnetic. Most basic igneous rocks, on the other hand, have high magnetic susceptibilities, while acid igneous rocks and metamorphic rocks can have susceptibilities ranging from negligible to extremely high. Magnetic susceptibility is a trace parameter of rocks, because the percentage of magnetic minerals is usually one percent or less, even in basic igneous rocks. Slight differences in iron oxide content of a mineral can cause large magnetic susceptibility variations. Remke *et al.* (2004) also pointed out that the amount of iron oxides in rocks are influenced by the parent rock, age of rock and weathering processes.

1.2 Statement of the Research Problem

Artisanal miners have engaged themselves by wildcat chase for gold, gemstones and other solid minerals digging and destroying places because they cannot really detect the exact locations where those solid minerals are, which have yielded low productivity. Hence there is a need for application of aeromagnetic data analysis (a geophysical method for revealing the subsurface) to determine accurate location of the potential minerals which would enhance better mining operation in the study area.

1.3 Aim and Objectives of the Study

The aim of this research work is to delineate geological structures that could host solid minerals such as gold and gemstone within the study area using the aeromagnetic data interpretation.

The Objectives of the Study are to:

i. generate the Total Magnetic Intensity (TMI) Map of the study area from gridded data;
ii. extract derivatives, Centre for exploration targeting (CET) and analytical signal maps;
iii. correlate delineated zone favorable to mineral accumulation in the study area.

1.4 Justification of the Study

Aeromagnetic methods are very effective in environmental monitoring and geological mapping. This work targets the structures that host solid minerals such as gold and gemstones that exist within the study area and delineate their precise location in terms of coordinate. With this database, knowledge of prospective investors in minerals exploration will greatly be enhanced and exploration activities be made easier.

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 Geology of the Study Area

Niger State lies between Latitudes 8º15' - 11º5'N and Longitudes 4º00' - 7º15'E. The State is bordered in the North by Kaduna and Kebbi States and in the South by Kogi State. It shares boundaries in the West with Kwara State and Benin republic and in the east with Federal Capital Territory(FCT) and Kaduna State. It divided into twenty five Local Government with landmass of about 80,000 square kilometers. The study area Kubil (Sheet 128) and Wawa (Sheet 159) under Borgu local Government Area of Niger State is located between Longitude 4º00'E – 4°30'E and Latitude 9°30'N – 10°30'N, it occupy the portion of the basement complex in Niger state. The Kubil and Wawa area comprises of meta sedimentary and meta-igneous rocks which have undergone polyphase deformation and metamorphism. These rocks have been intruded by granitic rocks of Pan-African age (Obaje *et al.,* 2004). Ten lithostratigraphic units have been recognized in Kubil and Wawa area (Figure. 2.1). The schist which occur as a flat laying narrow southwest-northeast belt at the central part of Borgu with small quartzite ridge parallel to it, the gneiss occur as a small suites at the northern and southern part of the area forming a contact with the granite. Feldspathic rich pegmatite is bounded to the east, the pegmatite host tourmaline. Granitic rocks dominate the rock types in the area and vary in texture and composition (Obaje *et al.,* 2004)

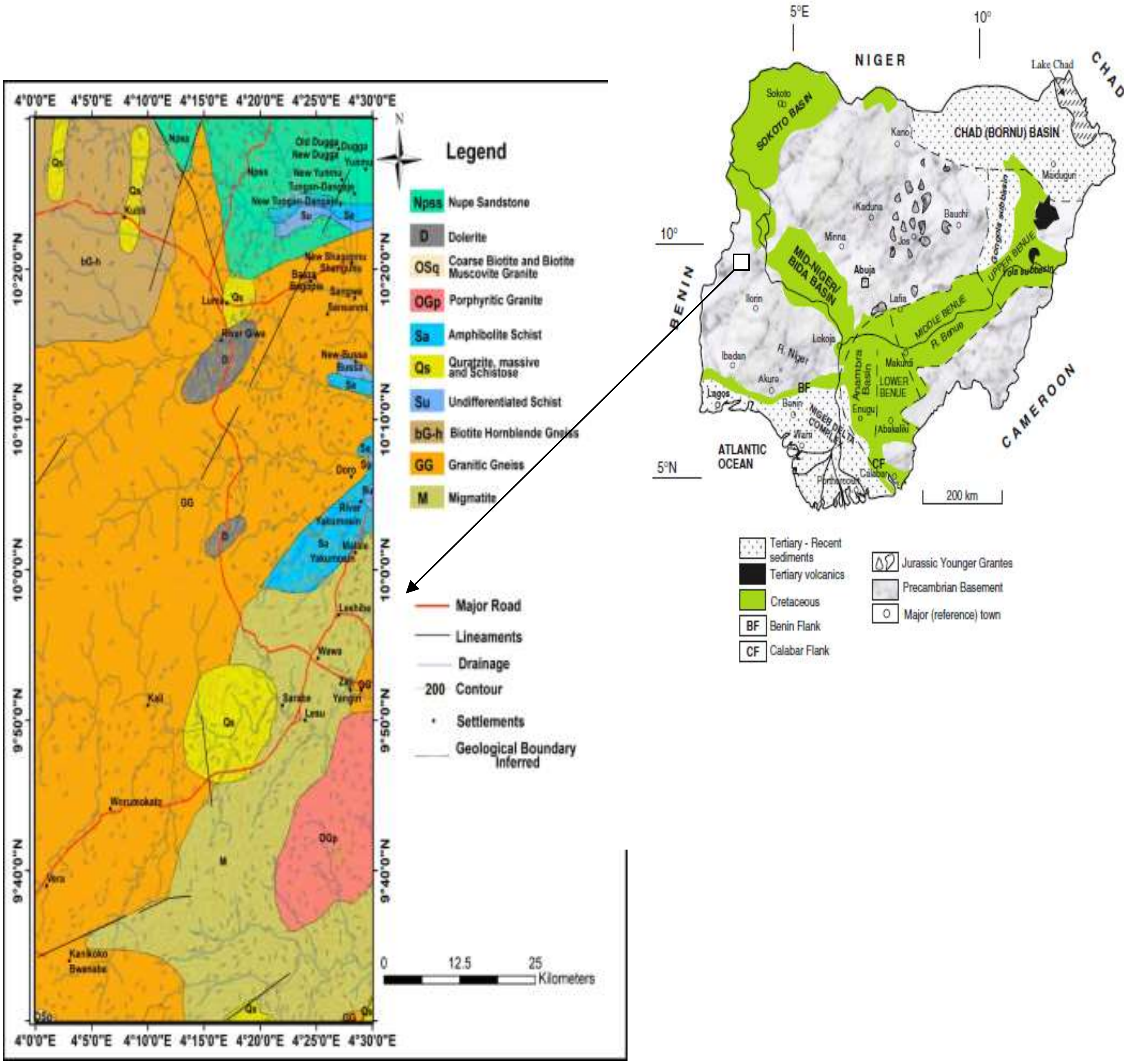

Figure 2.1: Geology Map of the study area (Modified from NGSA, 2009)

2.2 Geophysical Review of the Study

Rowland & Ahmed (2018), worked on analyses of high resolution aeromagnetic data and satellite imagery over parts of Nasarawa and environs. The airborne magnetic data and satellite imagery were interpreted to delineate structures and lineament pattern of the study area as potential for minerals occurrence, field work was undertaken in the study area to relate the effect of the structures in field to result obtained from the interpretation of the high resolution aeromagnetic data. The lineaments identified on both aeromagnetic map and Satellite imagery are in agreement with the main structural trend of the Benue Trough. Results from the interpretations indicate anomaly trends in the NE-SW, NW-SE, E-W, and NNE-SSW directions. The obtained depth to the magnetic source of the study area along the profiles ranges from 9.52 m to 443.11 m and the averaged depth obtained is 74.13 m for the entire region. The rose diagrams obtained from the magnetic residual map and the satellite imagery suggest predominantly NE-SW, NW-SE directions, the consistency in the alignment of lineaments suggests a possible genetic association of these anomalies. The occurrences of lineaments which include pegmatite's, fracture, faults joints veins and fold as revealed in the quantitative analysis of the magnetic residual contour map, satellite imagery and field work exercise show the interplay of tectonic activities due to multiple deformational episodes, this study highlight magnetic lineaments as key indicators to mineral occurrence.

Ishalu and Tsepav (2018), An interpretation of the ground magnetic data over suspected gold deposit using proton procession magnetometer and to determine the depth of gold deposits was carried out in Gwam area of Paiko LGA, Niger State. The Geotron Model G5 Proton Memory Magnetometer was used in interpreting the data of two hundred and nine (209) magnetic stations in twenty-six (26) profiles, while the Garmin(Oregon 550) GPS was used in measuring direction and orientation of profile lines. The survey area was 500 m and twenty six (26) profiles were created with a spacing of 20 m. On every profile line, a magnetic base station was established; total magnetic field reading and time were measured after every 1 minute 30 seconds on every station. Raw Magnetic data collected on the field sheet were transferred on the excel sheet for diurnal and IGRF corrections and the residual anomaly and the latitude and longitude was transferred into the origin software for the production of a colored contour map. The colored map aided the visibility of a wide range of anomalies in the magnetic map and the ranges of their intensities were also shown. The result shows that low magnetic intensities dominated the entire study area and it also correlates with properties of a diamagnetic material. Since gold is a diamagnetic material, it means that the probability of finding gold in the study area Gwam is high. The obtained depth to the magnetic source of the study area Gwam along the profiles ranges from 6.57 m to 543.33 m and the averaged depth obtained is 93.12 m for the entire region.

Adewumi and Salako (2017), worked on the determination qualitative analysis of aeromagnetic data of part of Nasarawa State had been carried out with the aim of delineating mineral potential zone. The study area is bounded by Longitude 8.0°E – 9.0°E and Latitude 8.0°N – 9.5°N with an estimated total area of 18,150 Km^2. Different filters were used to enhance the short wavelength anomalies which could give preliminary information about the magnetic minerals present in the study area. The total magnetic intensity map shows variation of both highs and lows magnetic signature ranges from −51.2 nT to 110.4 nT after the removal of IGRF value of 33,000 nT; the highs which is basement dominates the north-eastern and north-western part of the study area which corresponds to Akwanga, Wamba and Nasarawa Eggon; these are areas with promising solid minerals of economic potentials like, gold at Wamba; Tin, Columbite and Tantalite at Akwanga while Granite rocks with possible radioactive elements are in abundance at Nasarawa Eggon. The low magnetic values on the other hand, which is made up of sediment deposition also dominates the southern part of the study area, this area corresponds to Lafia, Doma and Keana; Lafia and Doma host some industrial minerals like Clay, glass Sands and the Salt Brines at Keana. The major high magnetic signature trends east-west. The greenish part of the study area indicates alluvium deposition. The filters used are vertical derivatives, downward continuation and analytic signal. The first and second vertical derivatives; shows structures like lineament that could be the host to minerals present in the study area and it trends NE-SW. The downward continued at the depth of 50 m and 100 m shows the veins where magnetic minerals most especially gold are known to settle along igneous and metamorphic rocks. The analytic signal map shows that magnetic amplitude highs could be found at the northern end with most lineaments delineated also conform to other filter used. The tilt derivative map enhances short wavelength anomalies which could be used to mapped shallow basement structures and mineral exploration targets. The results of these filters agreed largely and since most magnetic minerals are structural controls, it is expected that those lineaments identified, most especially at the northern part, could play host to those minerals aforementioned.

Dahuwa *et al.* (2018), work on aeromagnetic data analysis of Tafawa Balewa area using second vertical derivative and analytic signal over Wase and its adjoining areas were obtained and analysed for assessing the mineral potential of the area. This study is situated in northern Nigeria Basement Complex The area includes parts of Bauchi and Plateau states. These parts include: Maijuju, Tafawa Balwa ,Wase , and Pankshin covered by four . The study area covers an estimated area of about 18150 km^2 between latitudes 9º00' to 10º00'N and longitudes 9º00' to1º000'E the area has a balance of geographical features as well as climatic conditions. The entire western and northern parts are generally mountainous and rocky. This is as a result of the closeness to the Jos Plateau. The data were analyzed using the second vertical derivatives and analytic signal techniques. Result obtained showed the high density contours of the Second Vertical Derivative were found to correlate with exposed basement intrusion in the area. The analytic signal result highlighted areas of high magnetization contents which could be sites for possible mineralization.

Bala *et al*. (2016) worked on high resolution aeromagnetic data of Chibok and Damboa area (sheet 112 and 134 respectively), north eastern Nigeria, has been interpreted by applying spectral analysis technique in order to appraise the hydrocarbon accumulation potential of the area. The regional field was separated with a first order polynomial using Winglink software. The Total Magnetic Intensity Map (TMI) was subdivided into 18 spectral blocks allowing probe of 12.5 Km by 12.5 Km area for 15 minutes by 15 minutes windowing using Surfer 10 software. Two prominent magnetic depth source layers were identified. The deeper source depth values obtained ranges from 1.592 Km to 4.093 Km with an average depth of 2.390 Km as the magnetic basement depth while for the shallower source the depth values ranges from 0.403 Km to 0.795 Km with an average of 0.567 Km. The shallower depth source could attribute to the volcanic rocks that intruded the sedimentary formation and could possibly responsible for the mineralization found in parts of the study area. The significance of the magnetic depth values indicate that the sedimentary layer of the Albian age, Coniacian-Turonian age, and Turonian-Senonian age is thick enough to generate hydrocarbon. The temperatures at these depths range from 81.65°C to 169.16°C for the deeper sources and from 31.12°C to 32.82°C for the shallow sources. The temperature at the deep depth also satisfies a great condition for hydrocarbon generation/accumulation.

Bashar *et al.* (2016) worked on the total-field aeromagnetic data over Birnin – Kebbi and its adjoining areas, bounded between longitudes 4.0º00'E to 5.0º00'E and latitudes 11.5º00'N to 12.5º00'N were obtained and analyzed for subsurface lineament and depth analyses using first vertical derivative and local wave number methods. Orientation analysis of the lineaments inferred from the first vertical derivative map suggests that the major subsurface structural trends in the area were oriented along ENE-WSW, NE-SW and E-W directions while minor trends were along NW-SE, NNE-SSW, NNW-SSE and N-S directions. Result obtained from the depth analysis, as shown by the depth- to- basement map, suggested sedimentary thickness between 0.77 Km to 2.31 Km with the deepest areas, around Giru, associated with sedimentary thickness between 2.0 Km to 2.31 Km. The estimated sedimentary thickness and the temperature regime around the deepest areas were interpreted to be sufficient enough to warrant further hydrocarbon investigations.

Ofoha (2015) worked on Structural interpretations over parts of Mmaku, Ngwo, Ezeagu, Awka, Nanak Ekwulobia and Oji River settlement were inferred to delineate the basement morphology, determine the structural features and to the know the effect of those structures on the hydrocarbon potential of the area using a high resolution aeromagnetic data acquired from the Nigeria Geological survey agency in half degree sheet. Topographic map was generated using Sulphur 10 and Regional-residual separation applied on the Total magnetic intensity (TMI) data using the Wing Link visualization and geophysical software. The results of the qualitative interpretation generated the Regional, residual, topographic and some gradient maps that depicted structural lineaments trending in the NE-SW, NW-SE, NNE-SSW and N-S directions but with the NE-SW trends being dominant. They NE-SW, NW-SE, NNE-SSW and the E-W, N-S trends are believed to be Pan African and Pre Pan African trends respectively. The NE-SW and the NW-SE tectonic trends also reveal a landward extension of the oceanic fracture zones that transverse through the study area. Finally, structurally low areas were delineated and these areas probably indicate zones of promising oil and gas fields. The obtained depth to the magnetic source of the study area along the profiles ranges from 9.17 m to 332.33 m and the averaged depth obtained is 86.11 m for the entire region.

Adetona and Abu (2013), estimated the thickness of sedimentation within lower Benue Basin and Upper Anambra Basin, Nigeria, Using both spectral depth determination and source parameter imaging. Spectral depth analysis was run for forty-eight sections; the result shows that a maximum depth above 7 Km was obtained within the cretaceous sediments of Ida, Ankpa, and below Udegi at the middle of the study area. Minimum depth estimates between 188.0 and 452 meters were observed around the basement regions. Result from source parameter imaging shows a minimum depth of 76.983 meters and a maximum thickness of sedimentation of 9.847 km, which also occur within Idah, Ankpa, and Udegi axis.

Amigun *et al*. (2012), carried out the application of airborne magnetic method to exploration, evaluating the deposit geological characteristics and resource potential. Analyses involving the application of Upward / Downward Continuation filters, Second Vertical Derivative (SVD) filter and Apparent Susceptibility filter were performed to improve the quality of the magnetic data for better understanding of the subsurface geology of the deposit. From the downward continuation and SVD analyses, the small size mineralized bodies and shallow features in the study area were mapped. The faults delineated were grouped into two based on their trend i.e. NE – SW group and NW – SE group. On the upward continuation filtered map, a west – east linear feature with a trend similar to the principal orientation of the regional faults in Okene area was delineated. From the range of magnetic susceptibility values including other analyses, four rock types namely; migmatite gneiss, granite gneiss, brecciate ferruginous quartzite and iron ore mineralization were identified. Relative high magnetic susceptible zones (0.016 – 0.017) were inferred as area that magnetite type iron ore are concentrated in the deposit. The depths to the magnetic sources in the area were determined using spectral analysis. These depths ranged from 50 m to 300 m.

Okonkwo *et al*. (2012) worked on aeromagnetic data over a part of Maiduguri and Environs of the Southern Chad Basin, Nigeria was analyzed. The aeromagnetic anomaly map, its qualitative and quantitative interpretation helped in identifying the nature and depth of the magnetic sources in the study region. Depth to the basement of the basin structure ranges from about 0.5 Km in the southern part of the study area and gets deeper toward the northern part up to 3.0 Km. Lineament structural map and magnetic depth map values have been utilized to construct the interpretation of the main subsurface structures affecting the studied area, which correlate with the previous studies of the Chad Basin. The study area is characterized by predominant magnetic lineament trend in NE-SW (North East-South West) direction and subordinate E-W (East-West) direction. Results of the Spectral analysis method enabled delineation of the lithology and mapping the depths of subsurface geologic structures. The results also showed the most significant structural (NE-SW) trends affecting the distribution of these magnetic anomalies in the study area. The spectral analysis employed in depth calculations and temperature at depth calculations helped in revealing the possible subsurface structure of the area that assisted in delineation of promising area for hydrocarbon exploration.

Onuba *et al.* (2011) work on total field aeromagnetic anomalies over Okigwe area has been evaluated in order to map lineaments and estimate the depths to basement (sedimentary thicknesses). Aeromagnetic contour map of Okigwe (Sheet 312) was acquired, digitized and analyzed. Regional-residual separation and Slope methods were applied. The magnetic lineament map shows major geologic lineaments trending in NE-SW direction with minor ones trending in NW-SE direction. The major trend is in conformity with the trend of the Benue Tough. Visual study of the map shows presence of igneous intrusive in the northeastern part of the area. The results obtained using Slope methods indicate two depth sources in the area. On the average the deeper magnetic sources range from 2.0 to 4.99 Km, while the shallower magnetic sources range from 0.4 to 1.99 Km. Deeper magnetic sources probably depict depths to Precambrian Basement, whereas shallower sources probably depict depths to igneous intrusive and/or magnetized bodies within the sedimentary covers. Hydrocarbon exploration is not recommended since the area has low thickness of sediments on the average. All these deductions were reached at after due consideration to both qualitative and quantitative interpretations supported by geological information of the area.

CHAPTER THREE

3.0 MATERIALS AND METHOD

3.1 Materials

The total magnetic data of Kubil (sheet 128) and Wawa (sheet 159) of southern part of Niger State are acquired. The geomagnetic gradients are subtracted from the map using IGRF. The Study use of Oasis Montaj software in the processing of the total magnetic intensity (TIM) and ternary maps which were further subjected to different method.

The materials use for this research includes:

i. Aeromagnetic data covering the study area

ii. Geology map/Location map

iii. Geosoft (Oasis Montaj software package)

iv. ArcGIS software package

3.2 Method

i. generation of composite aeromagnetic map of the study area and application of reduction to equator and pole to remove dependence of the data on angle of inclination and declination.

ii. Obtaining the horizontal derivative in order to enhance near surface structures and produce input data for further analysis, evaluating the analytical signal so as to delineate region of out crop near surface intrusive bodies and equally to place the anomaly directly above the causative body, Correlating the structures from First Vertical Derivatives (FVD), Central Exploration Targeting (CET) and geology map.

3.3 Location of the Study Area

The area under investigation is Kubil (sheet 128) and Wawa (sheet 159) in Borgu local government area of Niger State, North Central Nigeria, it is bounded by Longitude 4°00"E – 4°300"E and Latitude 9°30'0"N - 10°30'0''N. The study area is located at the western part of Niger state which falls within basement complex and cretaceous sediment area is about 9 Km away from New Bussa. The region has an undulating topography and the elevation varies between 279 m above sea level. This area of study is accessible through a network of major and minor roads in addition to several foot paths.

The climate of the study area is that of a typical guinea savannah. There are two seasons associated with the climate; these include the rainy and dry seasons. The average total annual rainfall in this area is about 1300 mm and spreads over the months of April and October with the highest amount of rainfall being recorded between the months of August and September. (NIMET Seasonal Rainfall Prediction, 2020)**.** The maximum day time temperature is about 35ºC in the months of March and April, while a minimum temperature of about 24 ºC is recorded in the months of December and January. The mean annual temperatures are between 32 ºC to 33 ºC. The dry season is marked by influence of harmattan which is a result of north-east trade wind that blows across the Sahara Desert and that is often overloaded with red dust and last from the month of December to the month of January. During the dry season, much of these areas are reduced to bare land, resulting from the dryness of soil and from bush burning. The area has a gently undulating topography that is covered with vegetation, shrubs, trees and grasses. It has fine grain texture of sand; clayey-sand, laterite and pebbles of granites with few visible exposures. The study area is projected from administrative map of Nigeria (Figure 3.1.)

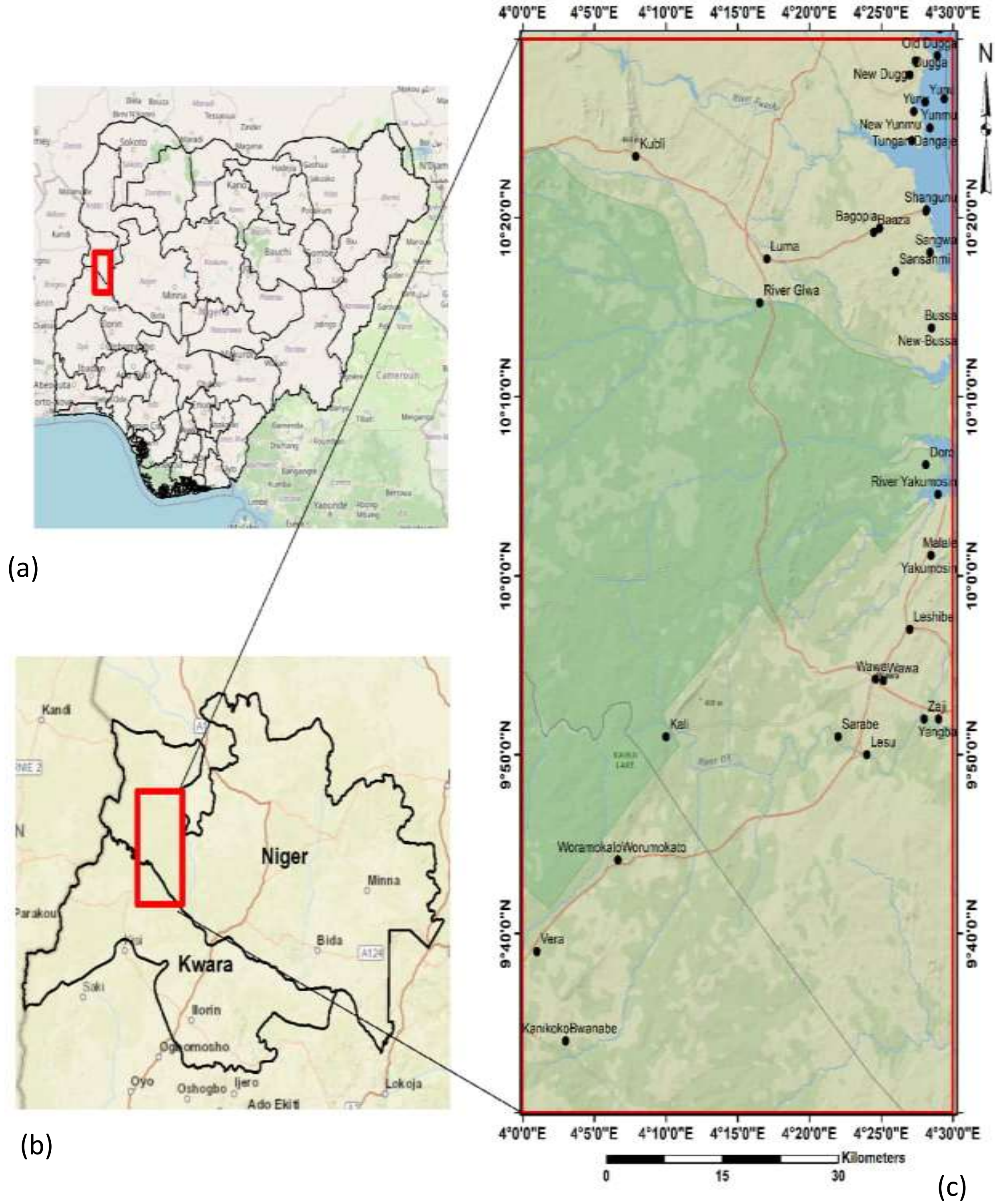

Figure 3.1 (a),(b) and (c): Location Map of the Study Area

3.4 Data Acquisition

Two sheets of aeromagnetic data were acquired from the Nigeria Geological Survey Agency (NGSA).The data acquisition, processing and compilation were done by Fugro airborne surveys which was completed in September 2007. It includes 826,000 line kilometers tie-line spacing. As part of a major project known as the sustainable management for minerals resources project by World Bank of Nigeria supported the phase II, survey blocks which were not covered in phase I completed August 2009. It included 1,104,000 line kilometers of magnetic and surveys flown at 500 m line spacing and 80 m terrain clearance. The adopted method to the aeromagnetic data are summarily given below.

3.5 Theories of Method

3.5.1 Total magnetic intensity

TMI map was produced using Oasis Mortaj. The software is an interactive computer program which places magnetic data according to their longitude and latitude bearing and gives a magnetic intensity map which is in colour aggregate.

3.5.2 Reduction to magnetic equator

Reduction to the equator is used in low magnetic latitudes to centre the peaks of magnetic anomalies over their sources. This will make the data easier to interpret without losing its geophysical meaning. Reducing the data to the equator (RTE) does much the same thing, but at low latitudes, a separate amplitude correction is usually required to prevent North-South signal in the data from dominating the results. To reduce magnetic data to equator, equation 3.1 is applicable.

$$L(\theta) = \frac{[\sin(I) - i.\cos(I).\cos(D-\theta)]^2 X \left(-\cos^2(D-\theta)\right)}{\left[\sin^2(I_a) + \cos^2(I_a).\cos^2(D-\theta)\right] X \left[\sin^2(I) + \cos^2(I).\cos^2(D-\theta)\right]}, if\ (|I_a|) < (|I|), I_a = I \quad \textbf{(3.1)}$$

Where

I = geomagnetic inclination

Ia = inclination for amplitude correction

D = geomagnetic declination

Sin (I) is the amplitude component while icos(I)cos(D-θ) is the phase component

This is a method of removing the dependence of magnetic data on the angle of magnetic inclination. This filter converts data which have been recorded in the inclined earth's magnetic field at the equator to what the data would look like if magnetic field had been vertical.

3.5.3 Reduction to pole

The vector nature of magnetic field, the superposition of multiple magnetic sources and presence of geological and cultural noises (such as noises due to pipe lines, power lines, railroads and etc) increases the complexity of anomalies from magnetic rocks, as a result, the interpretation of magnetic field data at low magnetic latitude is difficult. Furthermore an observed anomaly has asymmetric shape whenever magnetization occurs in anywhere rather than magnetic poles. To harness this problem, the best approach is to reduce the data to the magnetic pole where the presumably vertical magnetization vector will simplify observed anomalies. The aim of Reduction to the Pole is to take an observed total magnetic field map and reproduce a magnetic map that would have been observed if the survey had been conducted in the magnetic pole and changes the asymmetric form of observed anomalies to the symmetric form. This reduces the complexity of the observed anomalies. Data observed in low latitudes require some special treatment of North-South features due to high amplitude corrections needed for these features. Assuming induced magnetization of all magnetic sources, pole reduction can be calculated in the frequency domain using the following operator (Remke *et al.*, 2004).

$$L(\theta) = \frac{1}{[\sin(I) + i\cos(I)\cos(D-\theta)]^2} \qquad (3.2)$$

Where:

θ is the wave number direction

I is the magnetic inclination

D is the magnetic declination.

The amplitude component is represented by the *sin (I)* term while the phase component is given by the *icos (I) cos (D – 0)* term.

However, implementation of this method in the frequency domain causes some problems; It is unstable in low latitude, for body with unknown remanent magnetization it gives in correct results, induces synthetic noise to the data and lastly, frequency domain implementation of this technique, demands that the inclination and declination values should be fixed entirely on the survey area. It can be seen that as I approaches 0 (the magnetic equator) and (D-θ) approaches $\pi/2$ (a North – South feature), the operator approaches infinity (Remke *et al.*, 2004).This effect as illustrated by Figure 3.1, compares the magnetic anomalies over an East-West and North-South vertically dipping dyke-like body.

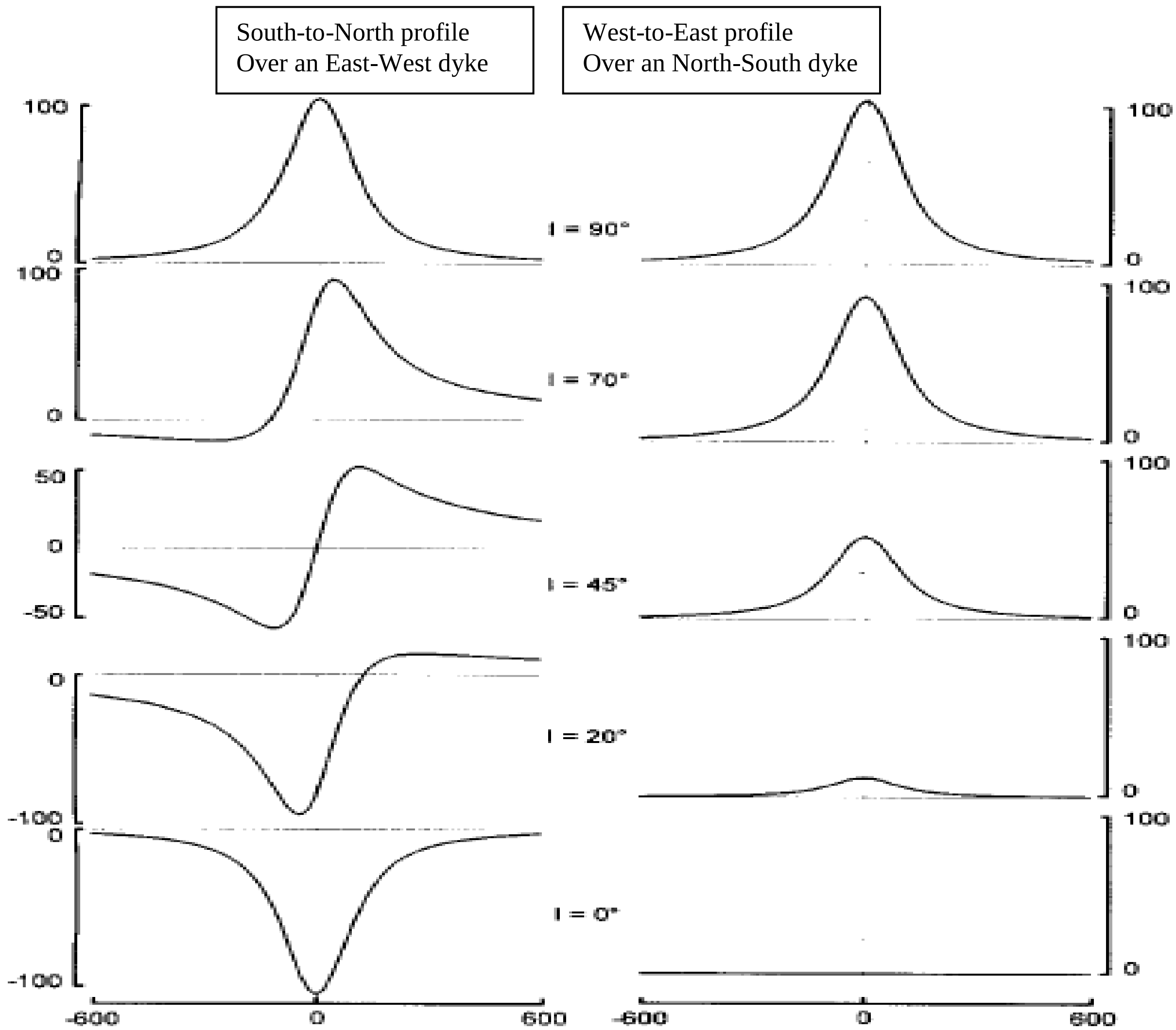

Figure 3.2: The shape of Total Magnetic Field Profiles over a Vertically Dipping dyke-like body (Remke *et al.*, 2004)

For the East-West striking dyke, the amplitude remains constant while the phase changes(shape). For the North-South striking dyke, the anomaly shape remains the same at all latitudes but the amplitude varies for different latitude. Reduction to pole involves correcting the shape of East-west features and correcting the amplitude of North-South features to produce the same profile as would be observed at an inclination of 90°.

At low attitude, the amplitude disappears, thus amplitude must be corrected. In the process of correcting the amplitude of this North-South feature, noise component and magnetic effects from bodies magnetized in the directions different from the induced field will be amplified. Many authors have addressed the noise problem of which the simplest and most effective technique is that developed by Fraser Grant and Jack Dodds.

Fraser and Jack (2002) addressed this problem by introducing a second inclination (I’) that is used to control the amplitude of the filter near the equator:

$$L(\theta) = \frac{1}{[\sin(I') + i\cos(I)\cos(D-\theta)]^2} \tag{3.3}$$

Where I′ is inclination for amplitude correction

In practice, (I’) is set to an inclination greater than the true inclination of the magnetic field. Anomaly shapes will be properly reduced to the pole by using the true inclination (I) in the complex term of equation (3.2). But by setting $I' > I$, unreasonably large amplitude corrections are avoided. Controlling the operator now becomes a matter of choosing the smallest I’ that will give the acceptable results.

Although the amplitude correction of the reduction to pole can be easily corrected using equation (3.2), it is only valid for induced magnetized bodies and remains invalid for remanently magnetized bodies. It would be preferable to produce a result that simply provides a measure of the amount of magnetization regardless of direction.

3.5.4 First vertical derivative (FVD)

Spatial resolution can also be achieved using the vertical derivative filter. The first vertical derivative filter computes the vertical rate change in the magnetic field. A first derivative tends to sharpen the edges of anomalies and enhance shallow features. The vertical derivative map is much more responsive to local influence than to broad or regional effect and therefore tends to give sharper picture than the map of the total field.

Vertical derivative

$$L(r) = r^n \tag{3.4}$$

Where n is the order of differentiation. And r is the wave number (radians/ground unit) Note: r = 2πk where k is cycles/ground unit. Ground unit is the survey ground units used in the grid (eg. meter, feet etc.).The vertical derivative is commonly applied to total magnetic field data to enhance the shallowest geologic sources in the data. As with other filters that enhance the high-wave number components of the spectrum, low-pass filters is apply to remove high-wave number noise.

3.5.5 Horizontal derivatives

The vertical derivative tends to sharpen the edge of anomalies and enhance shallow features. The resultant map is much more responsive to local influence than to bread or regional deep seated anomalies.

Derivative in the X direction is given by the algorithm,

$$L(\mu) = (\mu ii)^n \tag{3.5}$$

n is the order of differentiation, and μ represents the X component of the wave number and ii = $\sqrt{-1}$.

While the horizontal derivative in the Y direction is given by

$$L(V) = (Vi)^n \tag{3.6}$$

Where n is the order of differentiation V represents the Y component of the wave number and

$$i = \sqrt{-1}\frac{\partial f}{\partial x} \tag{3.7}$$

Total horizontal derivative is a good edge detector because it computes the maxima over the edges of the structures.

Total Horizontal derivative is given as;

$$THDR = \sqrt{[\frac{\partial T}{\partial x}]^2} + [\frac{\partial T}{\partial y}]^2 \tag{3.8}$$

The horizontal gradient method measures the rate of change in magnetic susceptibility in the ***x*** and ***y*** directions and produces a resultant grid. The gradients are all positive making this derivative easy to map.

3.5.6 Analytical signal

The analytical method gives the amplitude response of an anomaly. This filter applied to magnetic data is aimed at simplifying the fact that magnetic bodies usually have positive and negative peak associated with it, which may make it difficult to determine the exact location of causative body. For two dimensional bodies a bell shaped symmetrical function is derived and for a three dimensional bodies the function is amplified of analytical signal. This function and it derivatives are independent of strike, dip, magnetic declination, inclination and remanent magnetization Remke *et al.* (2004).

The analytic signal or total gradient is formed through the combination of the horizontal and vertical gradients of the magnetic anomaly. The analytic signal has a form over causative body that depends on the locations of the body (horizontal coordinate and depth) but not on its magnetization direction. This quantity is defined as a complex function that its real component is horizontal gradient and its imaginary component is vertical gradient. was able to prove that the imaginary component is Hilbert transform of real component.

Consider M(x, z) be 2-D Magnetic field that measured along x-axis, then the analytical signal, a(x,z) can be expressed in terms of vertical and horizontal gradient of M(x, z) with respect to x and z direction in Cartesian coordinate as followed Remke *et al.* (2004).

$$a(x,z) = \frac{\partial M}{\partial x} + i\frac{\partial M}{\partial z} \tag{3.9}$$

Where $\frac{\partial M}{\partial x}$ and $\frac{\partial M}{\partial z}$are Hilbert transform pair. The amplitude for the 2D signal is giving by

$$|A(x,z)| = \sqrt{\left(\frac{\partial M}{\partial x}\right)^2 + \left(\frac{\partial M}{\partial z}\right)^2} \tag{3.10}$$

For the 3-D case, the analytic signal is given by

$$a(x,z) = \frac{\partial M}{\partial x} + \frac{\partial M}{\partial y} + i\frac{\partial M}{\partial z} \tag{3.11}$$

The amplitude of the analytic signal in the 3-D case given by:

$$|A(x,z)| = \sqrt{\left(\frac{\partial M}{\partial x}\right)^2 + \left(\frac{\partial M}{\partial y}\right)^2 + \left(\frac{\partial M}{\partial z}\right)^2} \tag{3.12}$$

Where M = magnetic field

The analytical signal can be calculated with commonly available computer software. The x and y derivatives can be calculated directly from total magnetic field grid using a simple 3×3 filter, and the vertical gradient is routinely calculated using FFT techniques.

Some of the properties of the analytic signal are

i. Its absolute value is symmetric it is independent to body magnetization direction and ambient geomagnetic field and only is relevant to body location.
ii. This quantity can be employed to causative body depth estimation.
iii. Its maximum value lies over body directly

3.5.7 The centre for exploration targeting (CET) grid analysis plug-In for structures

Centre for exploration targeting a grid analysis plug on for structural analysis automatically delineate peak linear structure within extensive potential data. It consists of five separate stages which are.

By employing standard deviation σ of a cell values x_i given by

$$\sigma = \sqrt{\tfrac{1}{N}\sum_{i=1}^{N}\left(x_{i\,-\,\mu}\right)^2} \qquad (3.13)$$

When interpreting the output, values which approach zero indicate very little variation, whereas large values indicate high variation. Kovesi (1991).The next stage is to apply Phase Symmetry; this property is useful in detecting line-like features through identifying axes of symmetry. It is also known that the symmetry of a signal is closely related to the periodicity of its spatial frequency. Consequently, it is natural to utilize a frequency-based approach to detect axes of symmetry. This plug-in implements the phase symmetry algorithm developed by Kovesi (1991).

In the one-dimensional case (ID), a point of symmetry in the spatial domain corresponds with a point where local frequency components are at either a minimum or a maximum. To identify points of symmetry in two-dimensional (2D) data we first break the data into 1D profile and analyze these over multiple orientations at varying scales. For example, a line-like feature will produce strong symmetry responses from the D profiles sampled from all orientations except for those parallel to the line. The result from phase symmetry is passed through Amplitude Thresholding, in conduction with non-maximal suppression (NMS). The NMS is useful for finding ridges since low values are suppressed whilst points of local maxima are preserved, it also take into account the local features orientation so that the continuity of features is maximized and can be used to remove noise and highlight linear features. A description of the NMS algorithm is given below.

For each cell in the grid, it examines the value at a distance, r, in the directions perpendicular to the local feature orientation- the local feature orientation is typically the direction in which a ridge or valley is running. If the cell has a value greater than those on either side of it, the cell is kept since it is a local maximum; otherwise it is set to zero.

The Amplitude Threshold plug-in applies the algorithm followed by a threshold step. Threshold marks cells in grid as either ‘foreground’ or ‘background’ cells depending on whether the cell value is greater or less than a pecified threshold value respectively. Thus threshold will reduce a grid to a binary of only two distint cells values: 1 for regions of interest and a dummy value for background. In this suite of tools, Amplitude Threshold is useful for reducing phase symmetry or phase congruency output to a grid depicting only trend lines.

Finally, Skeleton to Vector is applied. The skeleton to vector plug-in is for vectorising the sletonised structurs from the skeletonisation plug-in via a line fitting method described below. This vectorised data can then be used as input to the structural complexity map plug-ins. for each structure in the grid, a line is formed between its start and end points. If the structure deviates from this line by more than a specified tolerance the structure is divided into two at the point of maximum deviation and the line fitting process is repeated on those two new structure segments. This process is continued recursively until no structure segment deviates from its corresponding line segment by more than the specified tolerance. These line segments from the vectorised representation of the structures within the grid. Lam *et al.* (1992).

CHAPTER FOUR

4.0 RESULTS AND DISCUSSION

4.1 The Total Magnetic Intensity Map (TMI) production of the Study Area

The gridded aeromagnetic data obtained from NGSA whose parameter were stated chapter three (3) above were gridded using minimum curvature mode on the Oasis Montaj and display in color aggregate map (Figure 4.1). The map exhibits the various magnetic susceptibility that constitutes the lithology within the study area. Being an area that is close to the equator the effect of Earth's field plays a significant role in variation of susceptibility. The areas with high positive magnetic susceptibility are showing high magnetic values ranging from 85.776 nT to 129.237 nT while region with low magnetic susceptibility shows magnetic values ranging from -66.589 nT to 53.871 nT. The total magnetic intensity map (Figure 4.1) comprises of both positive and negative anomalies with magnetic values within the study area ranges from -66.589 nT to 129.237 nT. The mid-portion region of the study area show a relatively low susceptibility this region pronounced activities due to the close variation in field, this can be remove as a result of thick sediment that present in between Wawa and Kubil. The low magnetic susceptibility was also observed in between high magnetic susceptibility at the southern end of the study area.

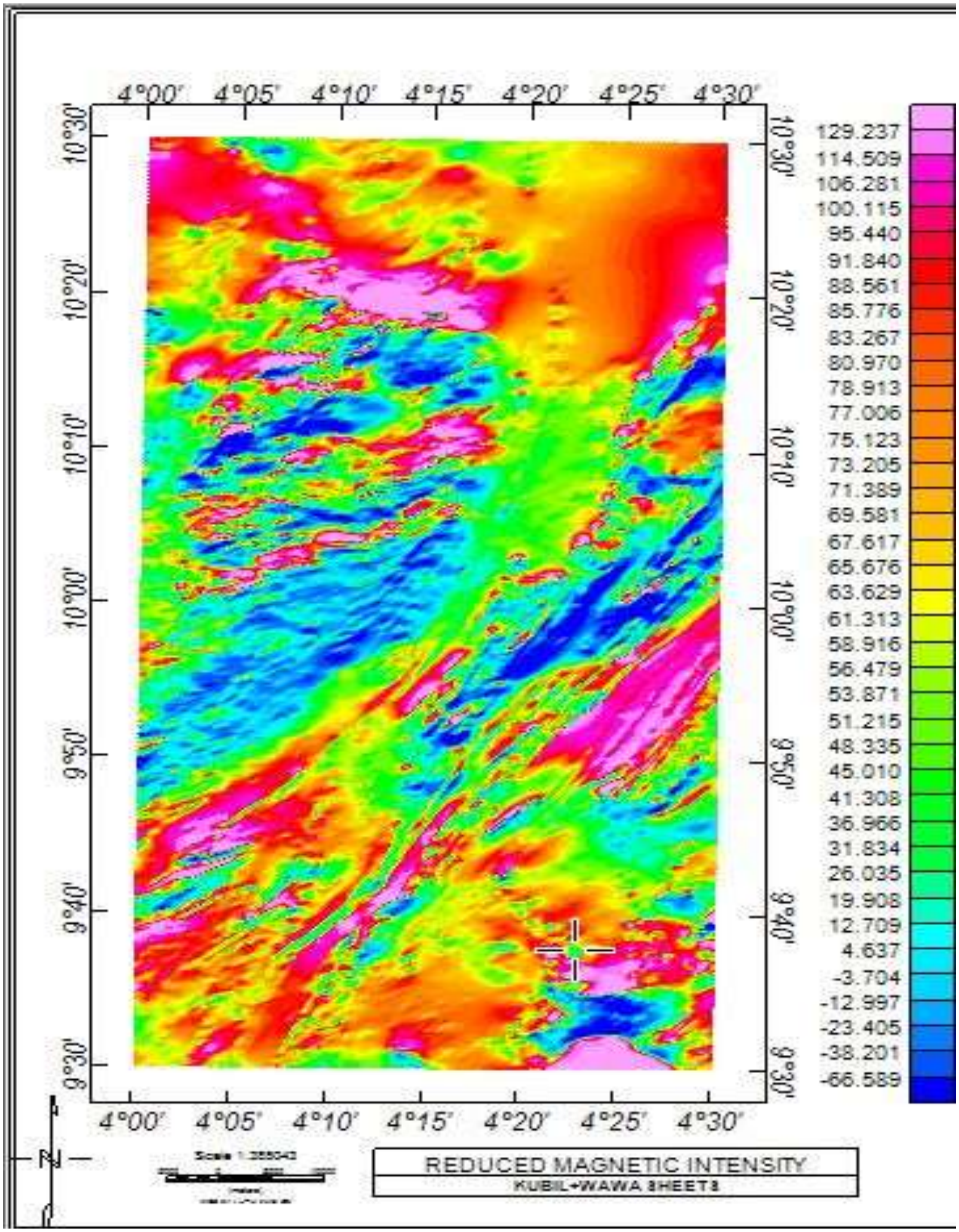

Figure (4.1) Total Magnetic Intensity Map (TMI) of the Study Area

4.2 Total Magnetic Intensity Reduce to Equator Map (TMI-RTE)

The TMI map was reduced to Equator (Figure 4.2) for the purpose of removing the dependency of the magnetic field on the angle of inclination and as a result, the position and shape of the anomaly was altered. The anomalies were observed to have been mixed with low and high anomalies. The areas with high magnetic susceptibility are showing high magnetic values ranges from 85.776 nT to 129.237 nT while region with low magnetic susceptibility shows magnetic values ranges from -66.589 nT to 53.871 nT.

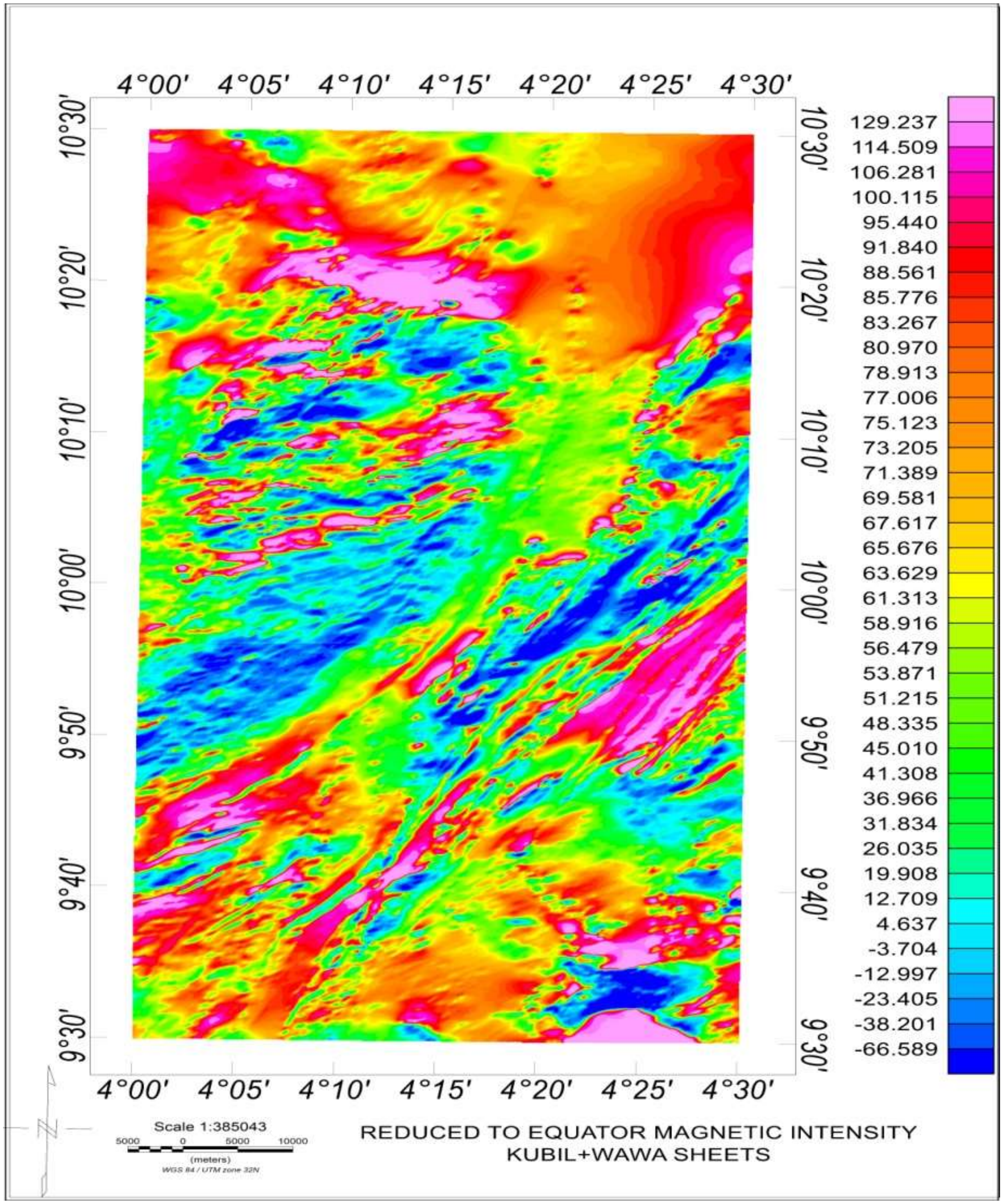

Figure 4.2: Total Magnetic Intensity Reduce to Equator Map of the Study Area

4.3 Total magnetic Intensity Reduce to Pole (TMI-RTP) Map

A major effect observe of total magnetic intensity reduce to pole compare to the total magnetic intensity reduce to equator is that the anomalis exhibit high magnetic susceptibility is observed within low magnetic intensity rocks while those with low magnetic values actually are within the high magnetic intensity rocks with the field and better symmetry of anomalis were achieved. A major (relatively) high magnetic intensity anomaly dominate the entire central portion of the study area, which may be due to the effect of Granite gneiss susceptibility, compare to other lithologies within the study area. Regional trend of major anomalis within the area is NE-SW except for E-W trending with low susceptibility at the Northern end, within the Biotite gneiss. The areas with high magnetic susceptibility are showing high magnetic values ranging from 85.776 nT to 129.237 nT while region with low magnetic susceptibility shows magnetic values ranging from -66.589 nT to 53.871 nT. (Figure 4.3)

4.4 Derivative

The Nupe sand stone that constitute part of the sedimentary formation within the study area is situated at North-eastern corner and is intruded by Amphibolite shirts strata (Figure 2.1 Geology Map) this is very evident on the derivative maps. The contact between this sedimentary formation and the basement which forms more than 80% of the entire areas is define by a set of fold and a fracture line that is evident as a horizontal line around latitude $10^{o}20^{'}$ on the First Vertical Derivative (FVD).

4.4.1 Horizontal derivatives map (Dx, Dy and Dz)

Three derivatives were computed as in xyz directions and mapped, they observed the turning points to the magnetic data at a shallow depth. These directional derivatives helps illustrate any sharp changes in regular pattern to the magnetic values that can be interpreted as lineament and their relative directions. Generally the structures deduced from these derivatives trends in NS-EW direction agree with the regional structural trend within the field. These structures are shown vividly on the (Figure 4.4.1- 4.4.3) Dx and Dz derivatives.

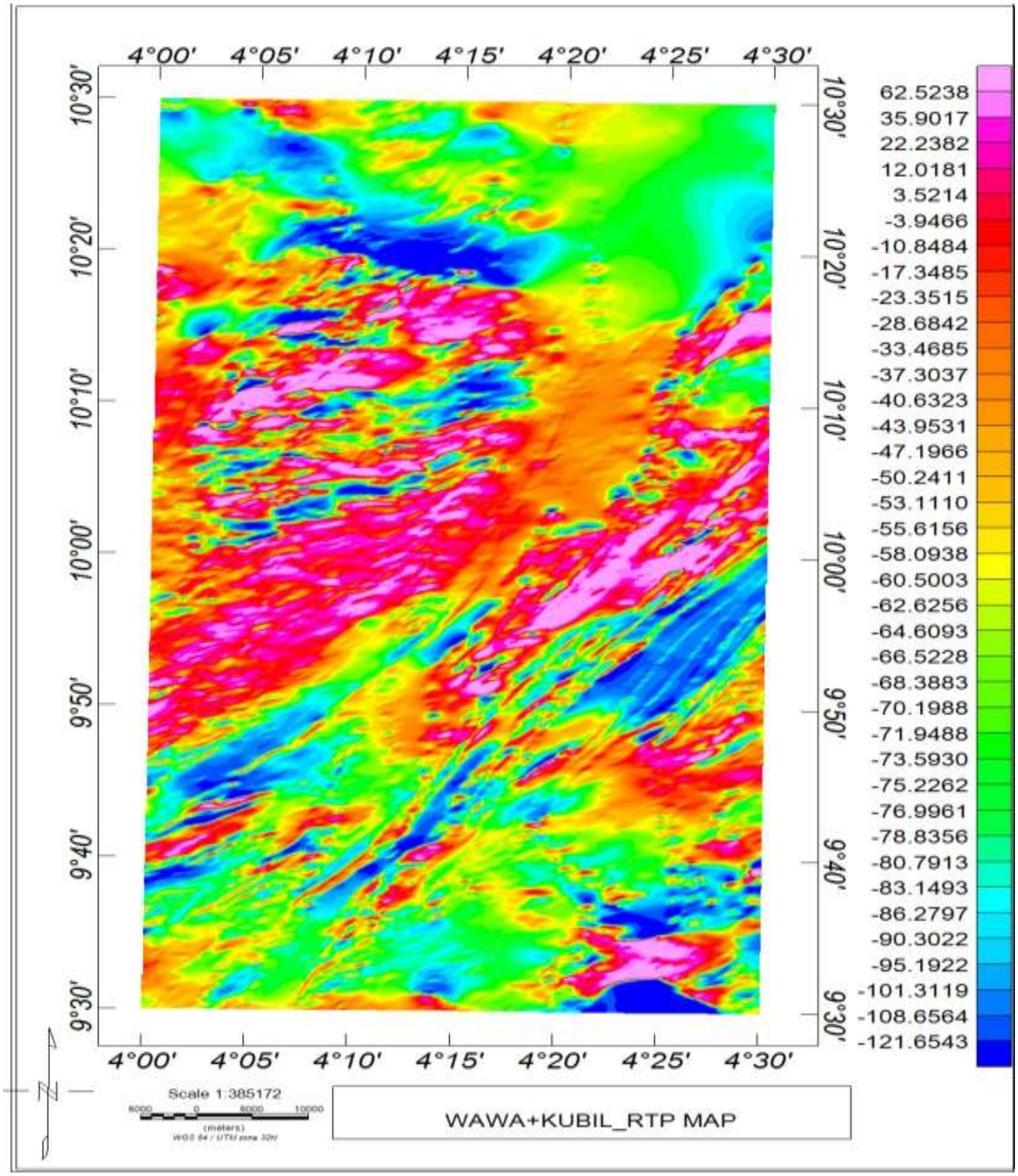

Figure 4.3: Total Magnetic Intensity Map (TMI) Reduced to Pole Map of the Study Area

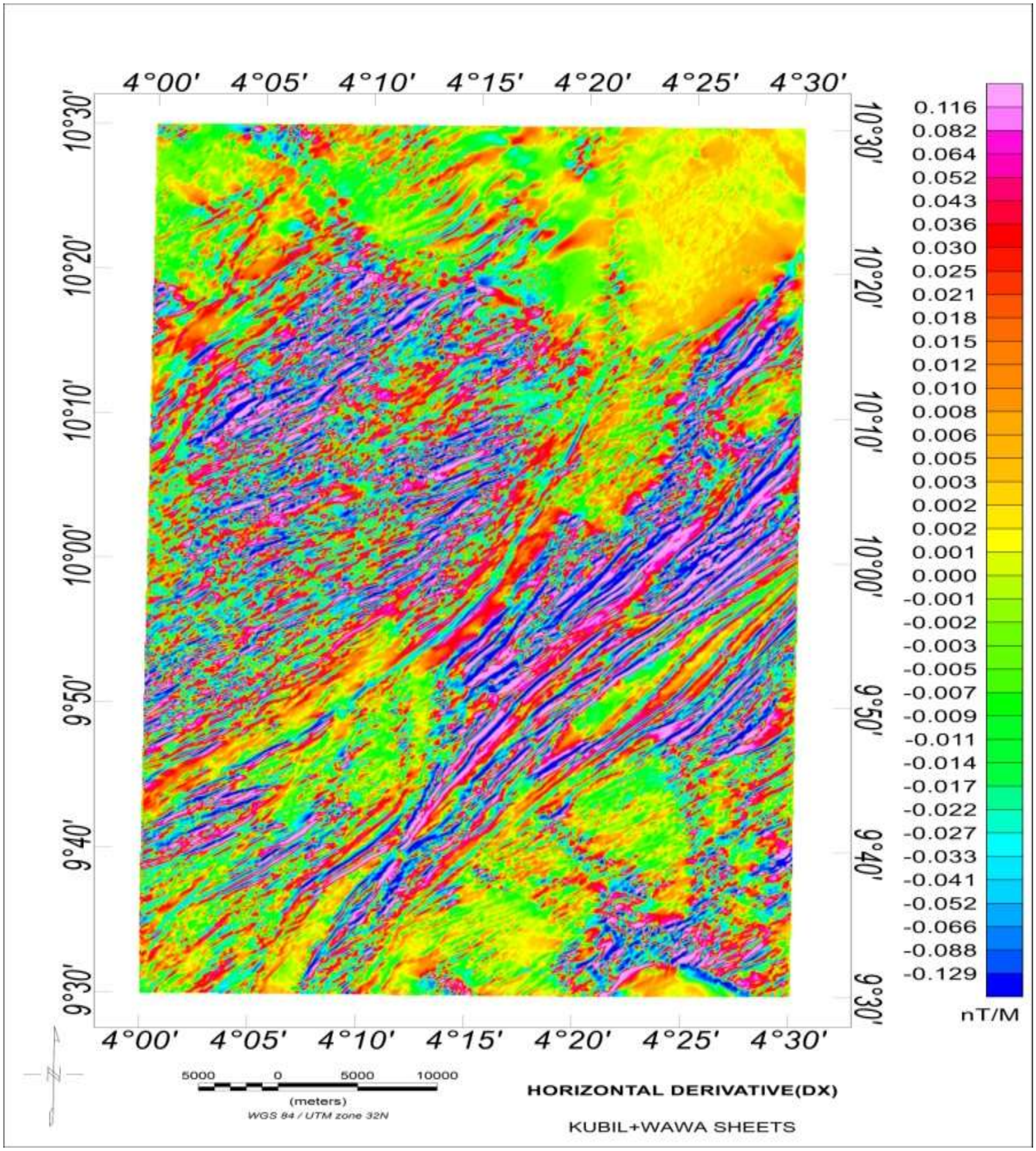

Figure 4.4.1: Horizontal Derivatives Map (Dx) of the Study Area

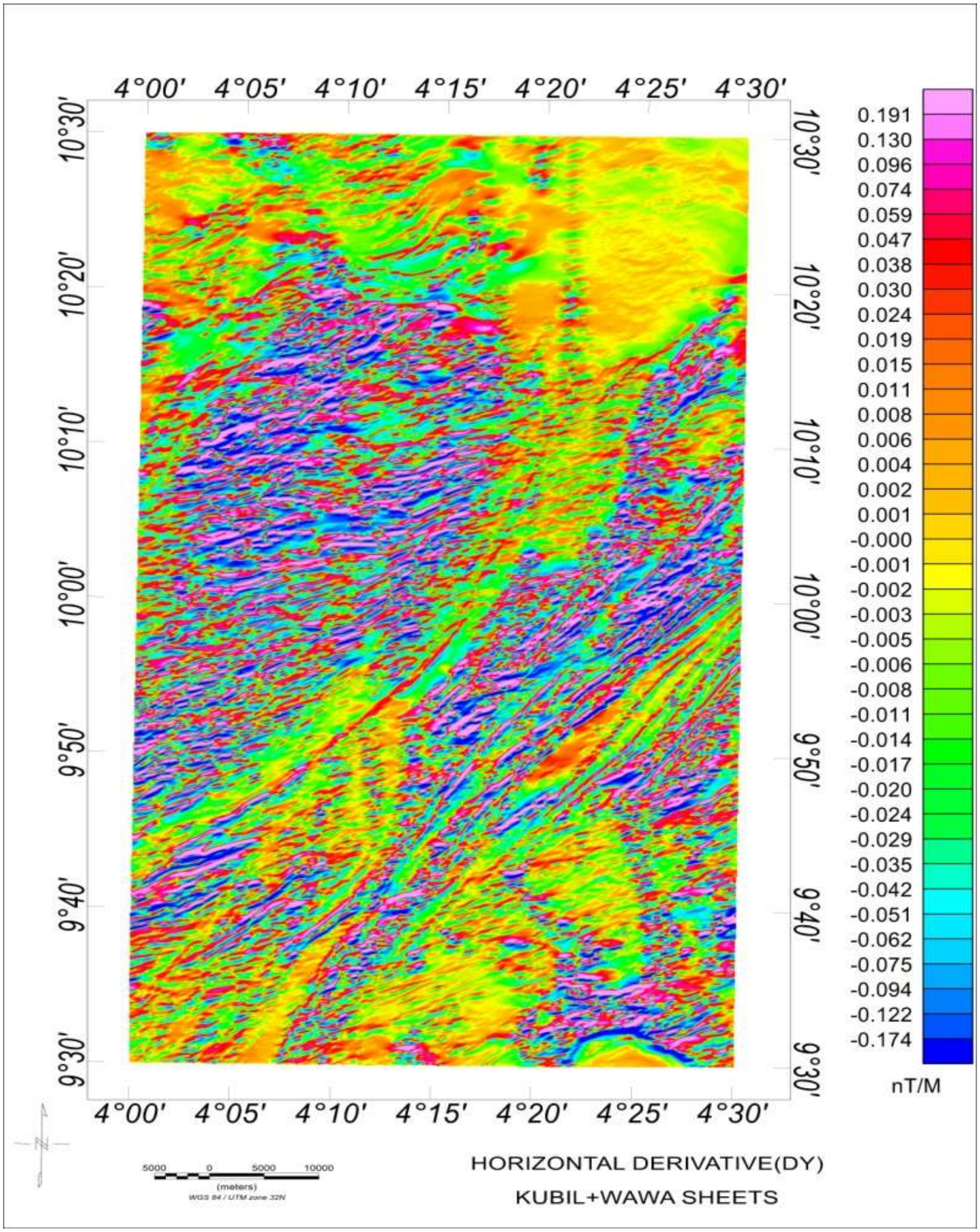

Figure 4.4.2: Horizontal Derivatives Map (Dy) of the Study Area

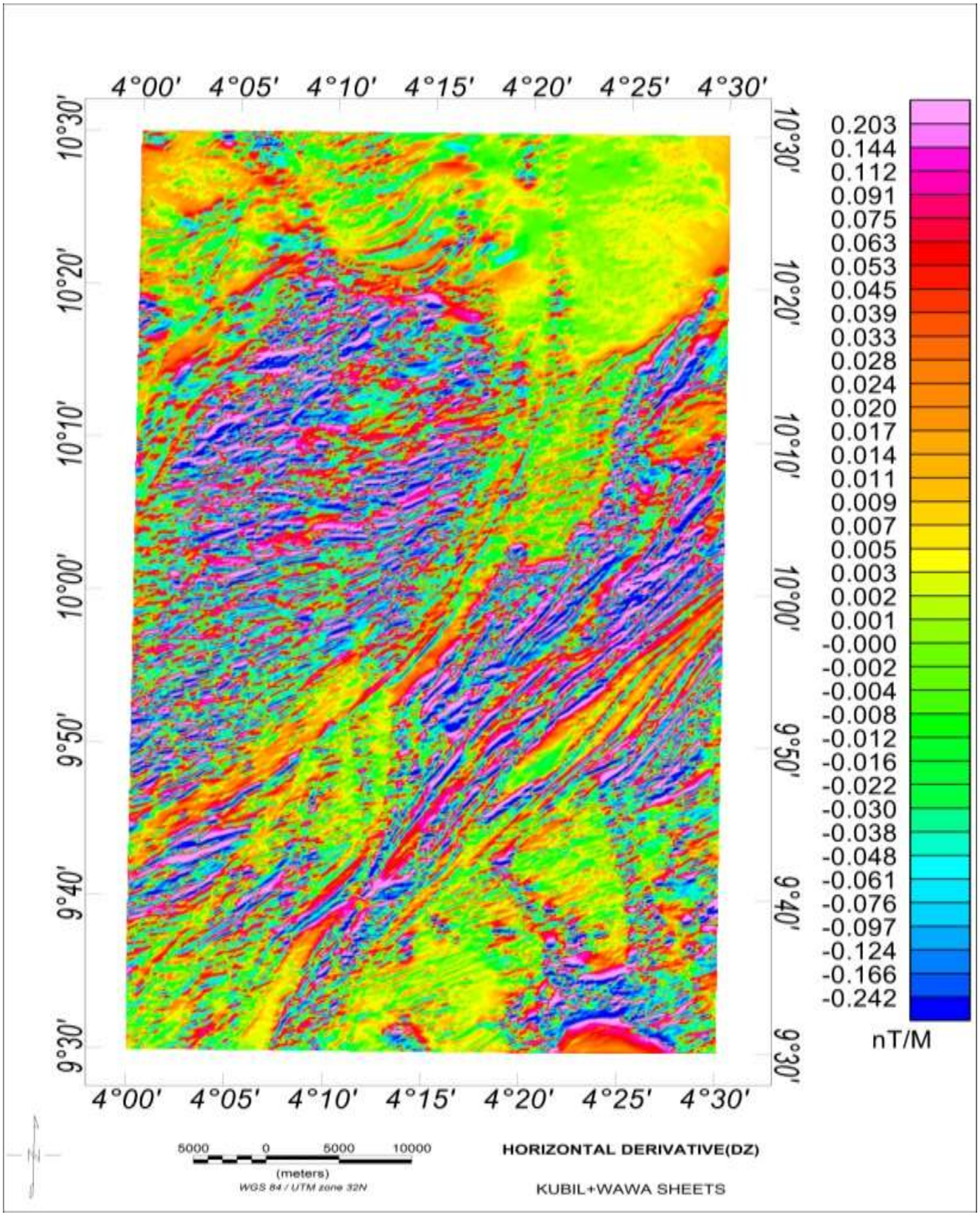

Figure 4.4.3: Horizontal Derivatives Map (Dz) of the Study Area

4.5 Analytical Signal Map

The 3D analytical signal map computed from horizontal derivatives in x, y and z but the z component was achieved in frequency domain after Fourier transform. It depicts the amplitude responses of the magnetic susceptibility ranges from 0.232 m to 0.355 m represent region of magnetic rocks specify the major anomalies were cleared observed and delineated above the causative bodies. While the amplitude response of the magnetic susceptibility ranges from 0.010 m to 0.218 m represent high sedimentation. It is observed that regions with very low amplitude are where the maximum depth to magnetic rocks were obtained while regions with high amplitude are the minimum depth to magnetic rocks. (Figure 4.5)

4.6 First Vertical Derivative Map (FVD)

On the first vertical derivative map (FVD) (Figure 4.6), regions with relatively high overburden are shown in a yellowish green coloration while area of basement and low overburden comes in blue to pink colour. Regions of lineaments are marked with deep blue and deep red colour depending on the susceptibility of the anomaly. These lineaments are mapped on the grey scale of first vertical derivative (FVD) map (Figure 4.7). Area of interest where mineralized lineament are mapped and denoted as a swamp of linear diagonally structures starting from the North East and trending in South Western direction, around latitude 9º50'N to 10º10'N, situated within Yangari Village to Lasun, Sarabe, Wawa, Malete down to Doro across rivers Yakumosin. This regions exhibit mineralize zones.

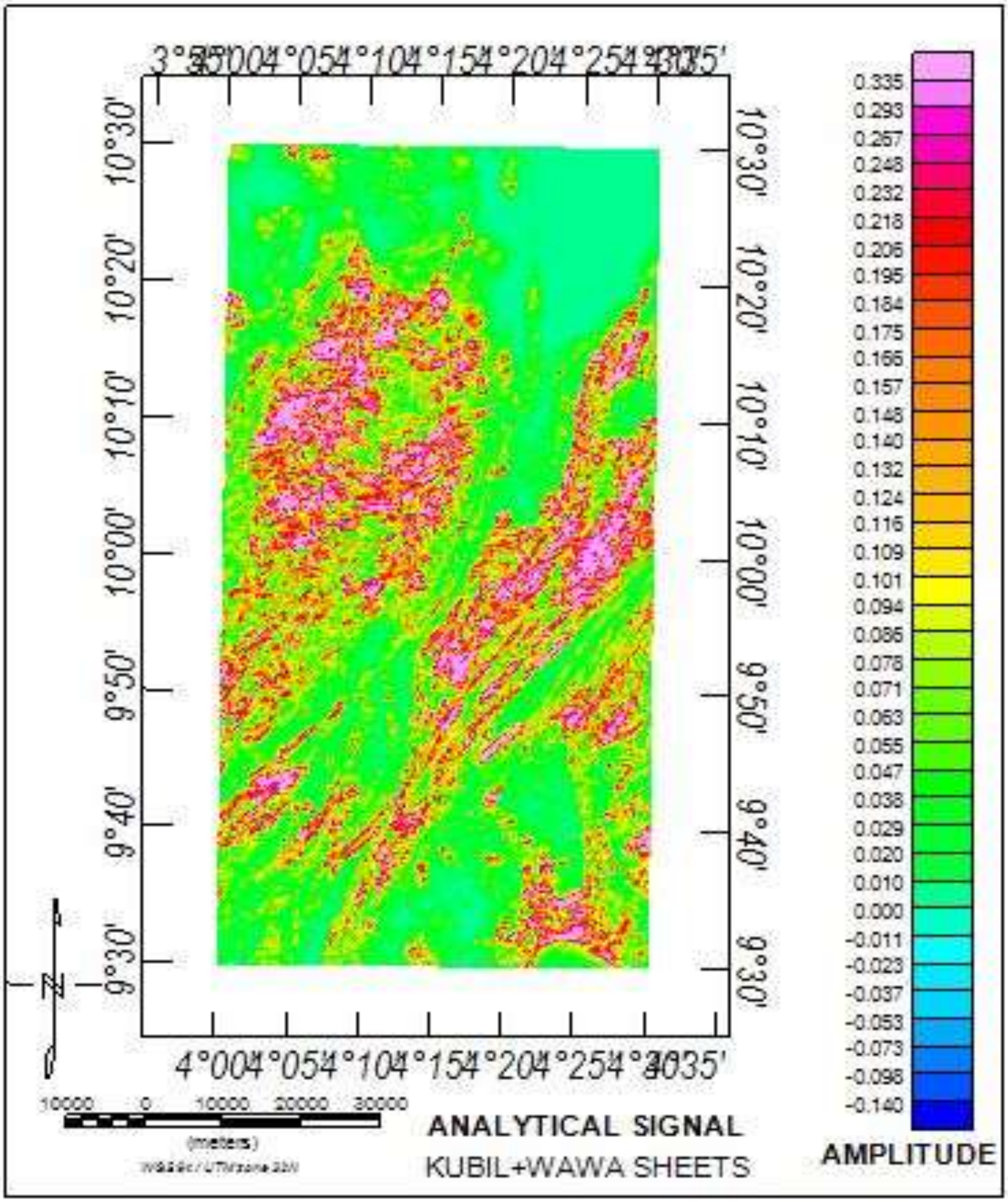

Figure 4.5: Analytical Signal Map of the Study Area

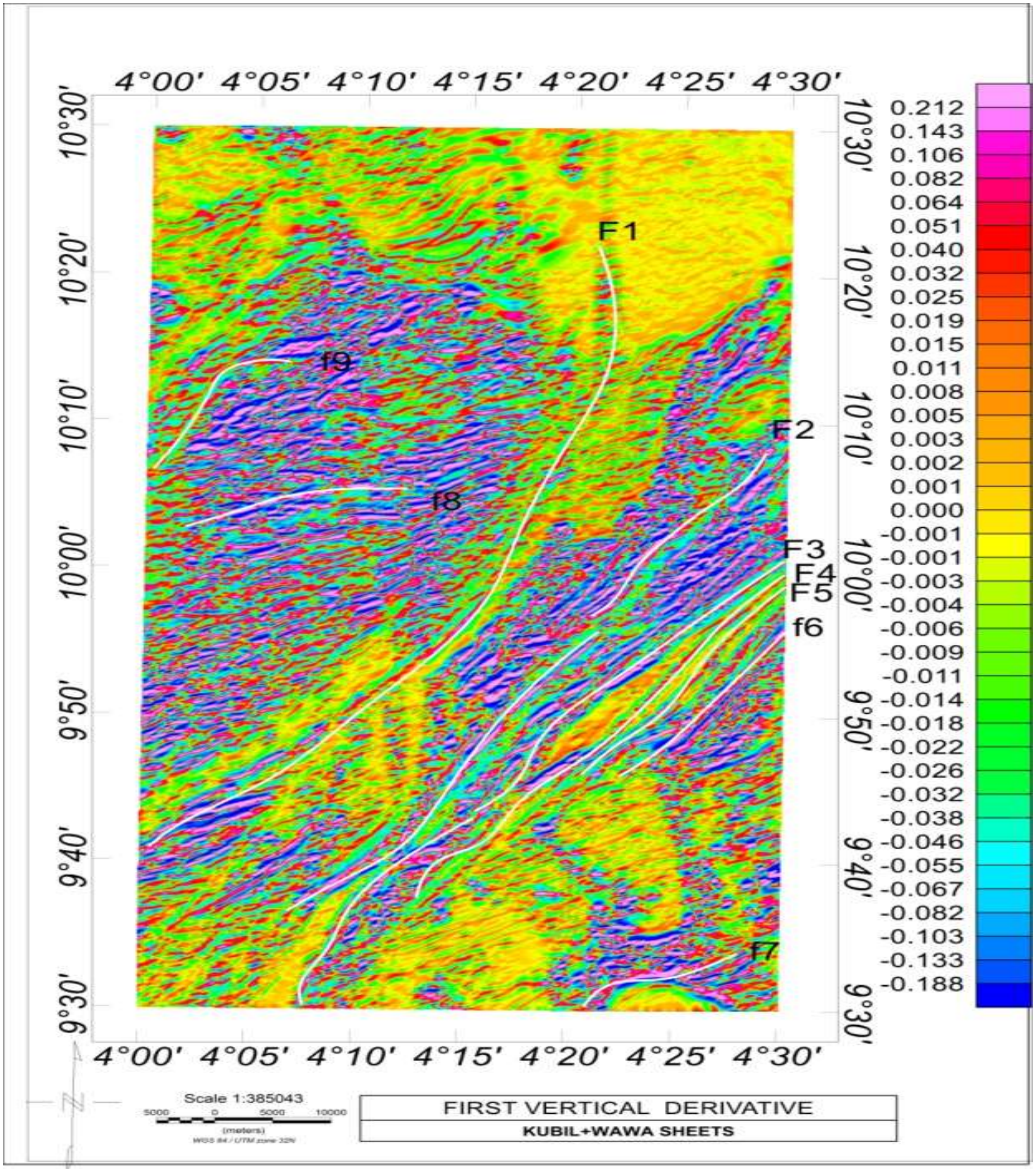

Figure 4.6: First Vertical Derivatives Map (FVD) of the Study Area

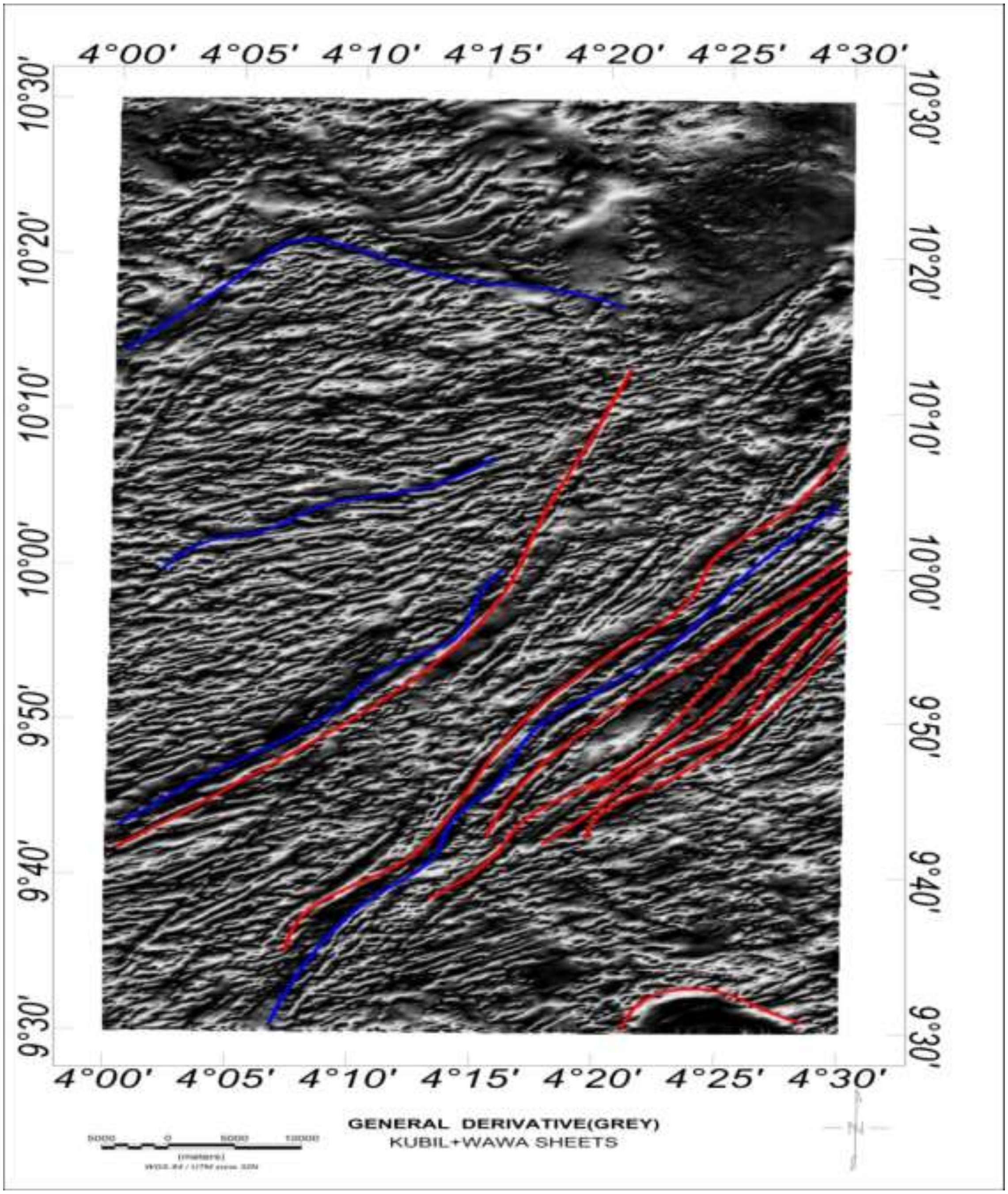

Figure 4.7: First Vertical Derivatives Map (Grey Scale) of the Study Area

4.7 Centre for Exploration Targeting (CET) Map

Centre for exploration targeting is a method of delineating and mapped lineaments automatically. The results from CET map (Figure 4.8) interestingly correlate with the lineaments mapped on the first vertical derivative. Though more detail that was observed on the 1VD (figure 4.7). An added advantage is that the centre for exploration targeting (CET) over 1VD was able to extract the coordinates where lineaments were observed. The coordinate (9º50' to 10º10') shows where major structures and lineament with varying degree of mineralisation were mapped.

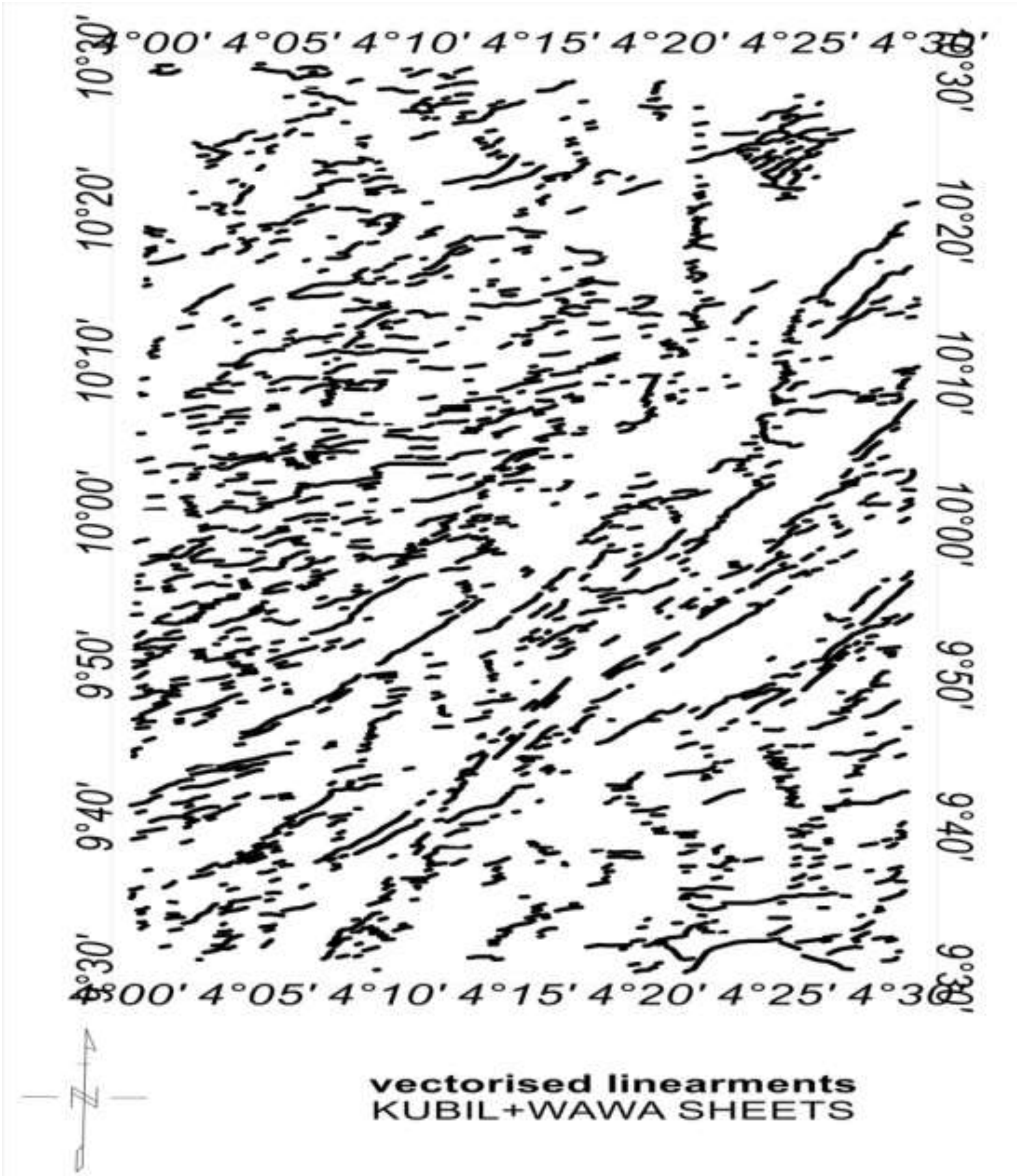

Figure 4.8: Center for Exploration Targeting Map (CET) of the study area

CHAPTER FIVE

5.0 CONCLUSION AND RECOMMENDATIONS

5.1 CONCLUSION

The Aeromagnetic data of Kubil and Wawa areas were interpreted to delineate the structure that can serve as host for gold mineralization and other associated minerals. An area of 55 X 110 km square was subjected to filtering method such as vertical derivatives, horizontal derivative, analytical signal and Centre for exploration targeting (CET). The following result was obtained:

The total magnetic intensity map (Figure 4.1) comprises of both positive and negative anomalies. The negatives anomalies are mostly at the mid portion of the study area with some isolated anomalies showing high magnetic susceptibility. The magnetic susceptibility of the study area ranges from -66.589 nT to 129.237 nT. The variations in susceptibility occur as a result of lateral variation in rock.

The analytical signal map depicts the amplitude responses of the magnetic susceptibility ranges from 0.232 m to 0.355 m represent region of magnetic rocks specify the major anomalies were clearly observed and delineated above the causative bodies. While the amplitude response of the magnetic susceptibility ranges from 0.010 m to 0.218 m represent high sedimentation.

The first vertical derivative (FVD) map helped us to delineate the region of high overburden with yellowish green colouration and area of basement are low overburden with blue and pink colour. The area of interest where mineralization lineaments are mapped and denoted as a swamp of lineal diagonally structures starting from south western end and trendy in a east southern and south western direction around latitude 9º50'N to 10º00'N to Lasun Sarabe, Wawa malete down to Divo across rivers Yakumosin. These regions exhibit Mineralization zones. The center for exploration targeting (CET) method mapped lineament and structures automatically. These lineaments and structures correspond with what was observed in first vertical derivatives maps. The major lineament are mapped as F1 to F7 on the first vertical derivatives. Similar structures were observed from the Centre for exploration targeting (CET) grid analysis only that they are more detailed. The mapped regions on the first vertical derivatives (FVD) hosting major lineaments are the potential minerised zone.

5.2 RECOMMENDATIONS

1. Ground trothing should be conducted by relevant geological agency at zones of minerisation to confirm the mineral type and their relative abundance.
2. A ground geophysical method such as resistivity survey is recommended for the delineated regions of minerisation for a more detailed capturing of delineated structures since the current research is of a regional scaled.

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