AEROMAGNETIC AND AERORADIOMETRIC PROSPECTING FOR GOLD MINERALISATION POTENTIALS OVER ILESHA AND ITS ENVIRONS SOUTHWEST, NIGERIA

BY

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OCTOBER, 2021.

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A THESIS SUBMITTED TO THE POSTGRADUATE SCHOOL IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE AWARD OF THE DEGREE OF MASTER OF APPLIED GEO-PHYSICS

OCTOBER, 2021.

ABSTRACT

Gold mineralisation zones were mapped and investigated using airborne magnetic and radiometric data. The study is bounded with Latitudes 7°N to 8°N and longitude 4°E to 5°E. Analytical signal, first and second vertical derivative were applied to magnetic data so as to map the structural features in the study area. The result of the analytical signal reveals that the highest magnetic amplitude could be found at the North eastern part, central and western part of the study area. The low magnetic amplitude could be found around southeastern and northeastern part of the study area. The result of the 1VD and 2VD revealed both the major and minor magnetic lineament trends NE – SW directions. Similarly, the Ilesha –Ifewara fault line was also delineated which trends in the same direction with the fault line delineated. The result of the Source Parameter Imaging shows that the depth to magnetic mineralisation ranges 89.03 – 574.76 m. The hydrothermal alteration zone was determined from the radiometric data to have been located at northeastern, western and eastern part of the study area. These correspond to area delineated to be favourable features for host Gold mineralization.

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CHAPTER ONE

1.0 INTRODUCTION

1.1 Background to the Study

Nigeria's economy like other oil-dependent economy was severely affected by the global shock witnessed in the second half of 2014 and the present 2020 global economic meltdown resulted from Covid-19 pandemic that almost all the economic indices were negatively affected and growth plummeted. The country is in a downward spiral of economic damage like other oil-dependent countries, due to the plunge in the world oil prices (Fayemi, 2017). However, the diversification of the country's economy into the solid mineral resource sector will aid in curtailing the dwindling revenue. Nigeria is endowed with rich mineral resources which are widely distributed in almost all the thirty-six (36) states of the federation (Fayemi, 2016 and 2017).

Omoh (2015); Fayemi (2016); Jack *et al.* (2016) and Fayemi (2017) also reiterated that, beneath the soil cover there are numerous untapped mineral resources which can contribute immensely to the socio-economic development of the South-western part of Nigeria and Nigeria at large. Over the years, the Nigeria solid mineral resource sector has been left in the hands of untrained artisanal miners with limited financial backing. The present study area has been reported in several literatures to contain reasonable amount of gold deposits as reported by De Swardt (1947); Ajayi (2004). The principal objective of the research is to ascertain area with good potential for positive gold minerals which will serve as business opportunities and boasting the economy of the region and the rest of the country, thereby eradicating poverty in Nigeria and helping in the poverty alleviation, employment opportunities, economic empowerment and sustainability of the region and the entire Nigerian masses.

Therefore, the proper delineation of the potential gold mineralised zones will aid in the mitigation of the land degradation and also the release of the possible toxic waste to the populace around the study area. In order to achieve the goal of the present study, the search for the potential gold deposits is equivalent to the search for the subsurface geologic features such as; faults, folds, fractures, veins and shear zones and hydrothermally altered zones and lithology as all this will reflects the favourable gold mineralisation zones (Junner, 1940; Kerswill,1996).

According to (Ajeigbe *et al*., 2014), geologic structures (faults, folds, fractures, veins and shear zones and hydrothermally altered zones and lithology) have a very important role in emplacement of mineralisation. Under certain circumstances which occur fairly commonly, structural conditions are reflected significantly in the trends and intensities apparent on aeromagnetic maps.

Also, since mineralisation processes affect concentration of radioelement in rocks, radiometric method, therefore becomes a useful tool in identification of potential mineralised zone (Ogungbemi, 2018). Radiometric surveys are capable of directly detecting the presence of Uranium, Thorium and Potassium which also assists in locating some intrusive related mineral deposit.

Therefore, the integration of the airborne magnetic and radiometric dataset will aid in the mineralisation mapping. In particular, the measurement of earth's magnetic field intensity is referred to as magnetic method which involves the measurement of horizontal or vertical component (Mekonnen, 2004). Majority of the rock-forming minerals are relatively non-magnetic and thus magnetic minerals such as; magnetite and pyrrhotite yield significant magnetic anomalies (Akulga, 2013). In spite of the fact that, Gold deposits are non-magnetic, the magnetic method is used, because gold is closely related to pyrite which is also non-magnetic, since pyrite is metamorphosed into pyrrhotite at the upper green schist-lower amphibolite grades and also pyrrhotite is metamorphosed into magnetite (Keary *et al.,* 2002). As such, minerals that comprises of pyrrhotite and magnetite are easily delineated using the airborne magnetic survey (Salako *et al.,* 2019).

Additionally, the magnetic survey is also used to determine lithologic units such as; the presence of younger intrusive rocks, cross-cutting structures that are typically associated with shear hosted Archaeanorogenic gold deposits, as well as to differenciate between banded Iron formation (BIF), metasediments, metavolcanics and other rock types. On the other hand, the airborne radiometric method measures the surface distribution of Uranium, Thorium and Potassium activity concentrations. This makes the radiometric method excellent geophysical mapping tools which is capable of delineating subsurface geology in terms of its lithological units and the corresponding hydrothermal altered zones. The hydrothermal alteration zones are favourable zones hosting gold mineralisation.

1.2 Study Area

The study area (Figure 1.1) is bounded by geographic latitudes 7°00′N to 8°00′N and geographic longitude 4°00′E to 5°00′E within the precambrian of southwestern Nigeria. It covers a total land area of approximately 12100 km^2. The average rainfall of the area ranges from 1125 mm in derived savannah to 1475 mm in the rain forest belt. The mean annual temperature ranges from 27.2°C in the month of June to 39.0°C in December. The soil types are varied but mostly contain a high proportion of clay and sand, and are mainly dominated by laterite, these soils are mainly the well-drained Egbeda series known as alfisols which has been classified as one of the most fertile soils in the Nigeria cocoa belt (Smyth and Montgomery, 1962). The natural vegetation of the area is the Tropical Rain Forest which could only be found in patches all over the district but mainly on hills.

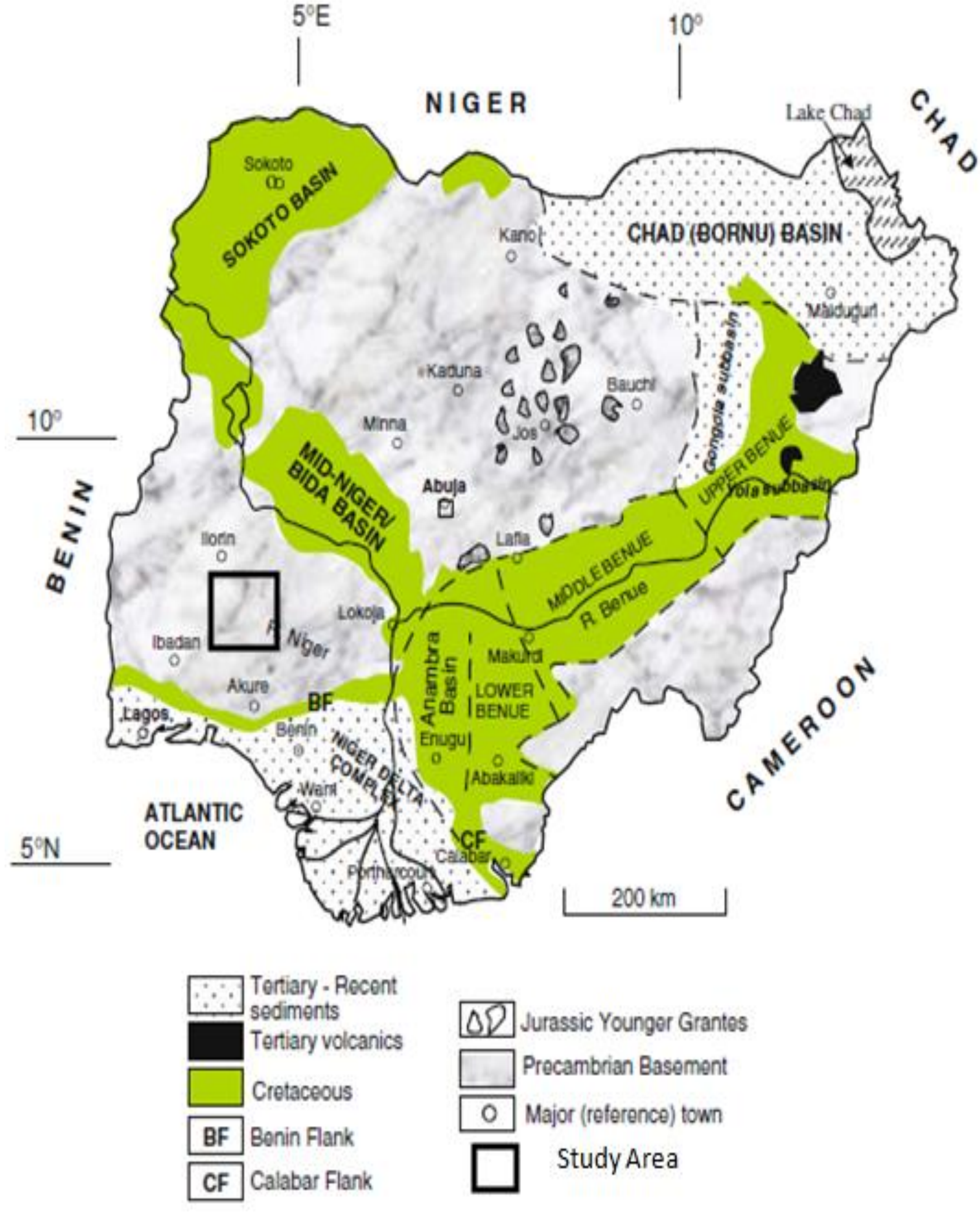


Figure 1.1: Geological Map of Nigeria showing the study area in black outline (Source: Obaje, 2009).

1.3 Statement of Research Problem

The current high rate of unemployment coupled with the over reliance of the country on the oil sector as the major source of revenue calls for diversification, to incorporate other sectors. Mineral exploration is capable of sustaining economic growth and industrial development of any nation. However, this had been left in the hand of artisanal miners that is sometime referred to as the informal sector, which is outside the legal and regulatory framework, because of its potential for environmental damage, social disruption and conflicts. Hence this research work on assessing of Gold mineralisation potentials in parts of Ilesha and its environ Southwest, Nigeria using magnetic and radiometric data

1.4 Justification of the Study

The study area is one of the regions that have the paleoproterozoic granite greenstone belts. The major rocks associated with Ilesha and other part of the study area form part of the proterozoic schist belts of Nigeria.

However, the airborne magnetic and radiometric methods have been used in the study area to map the geology, structures and hydrothermal altered zones. The mapped zones would then be used in the analysis and interpretations of areas with the potentials of gold mineralisation in the study area.

1.5 Significance of the Study

The research work seeks to map out lithological, geological, structural and hydrothermally altered zones associated with gold minerals using the enhanced radiometric and magnetic data in order to obtain the basic result on the abilities of the study area for future widening of gold exploration in the area and enhance standard of living.

1.6 Aim and Objectives

The aim this study is to use aero-magnetic and aero-radiometric for gold mineralization potential over Ilesha and its environ, southwestern Nigeria.

The objectives of the study are to:

i. Determine the subsurface geologic features such as; faults, fractures, lineaments and shear zones and approximate depth to the magnetic sources within the study area.

ii. Determine the concentration of radioactive elements and produce K/eTh, eTh/eU and eU/K and ternary map of radioactive elements (K, eTh and eU)

iii. Delineate and correlate areas of hydrothermal altered zones with identity magnetic structures that favours Gold mineralisation within the study area.

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 Regional Geology of the Study Area

The basement rocks of Nigeria is part of the extensive Pan-African Province of West Africa and are delimited in the west by the West African Craton and east by the Congo Craton. Nigeria basement comprises the Migmatite-gneiss complex, the Schist-belts and the older Granites. The Migmatite Gneiss complex is the oldest, most widespread and abundant rock type in the basement (Oyinloye, 1996). It is of Achean-Proterozoic age and a product of long, protracted and possibly polycyclic evolutionary histories. The older granites which is also known as Pan-African Granites include rocks of wide range of composition varying from tonalite, granodiorite, granite and syenite (Rahaman, 1976). The Ijero-pegmatite forms an intrusion into the biotite-schist that occupies the central part of the study area. The study area is an extension of the eastern end of Ife-Ijesha Schist-belt and falls within the basement complex of southwestern Nigeria.

The major rock associated with Ilesha and other part of the study area form part of the Proterozoic schist belts of Nigeria (Figure 2.1), which are predominantly developed in the western half of the country. In terms of structural features, lithology and mineralisation, the schist belts of Nigeria show considerable similarities to the Achaean Green Stone Belts. However, the later usually contain much larger proportions of mafic and ultramafic bodies and assemblages of lower metamorphic grade (Olusegun *et al*., 1995); Ajayi, (1981); Rahaman, (1976).

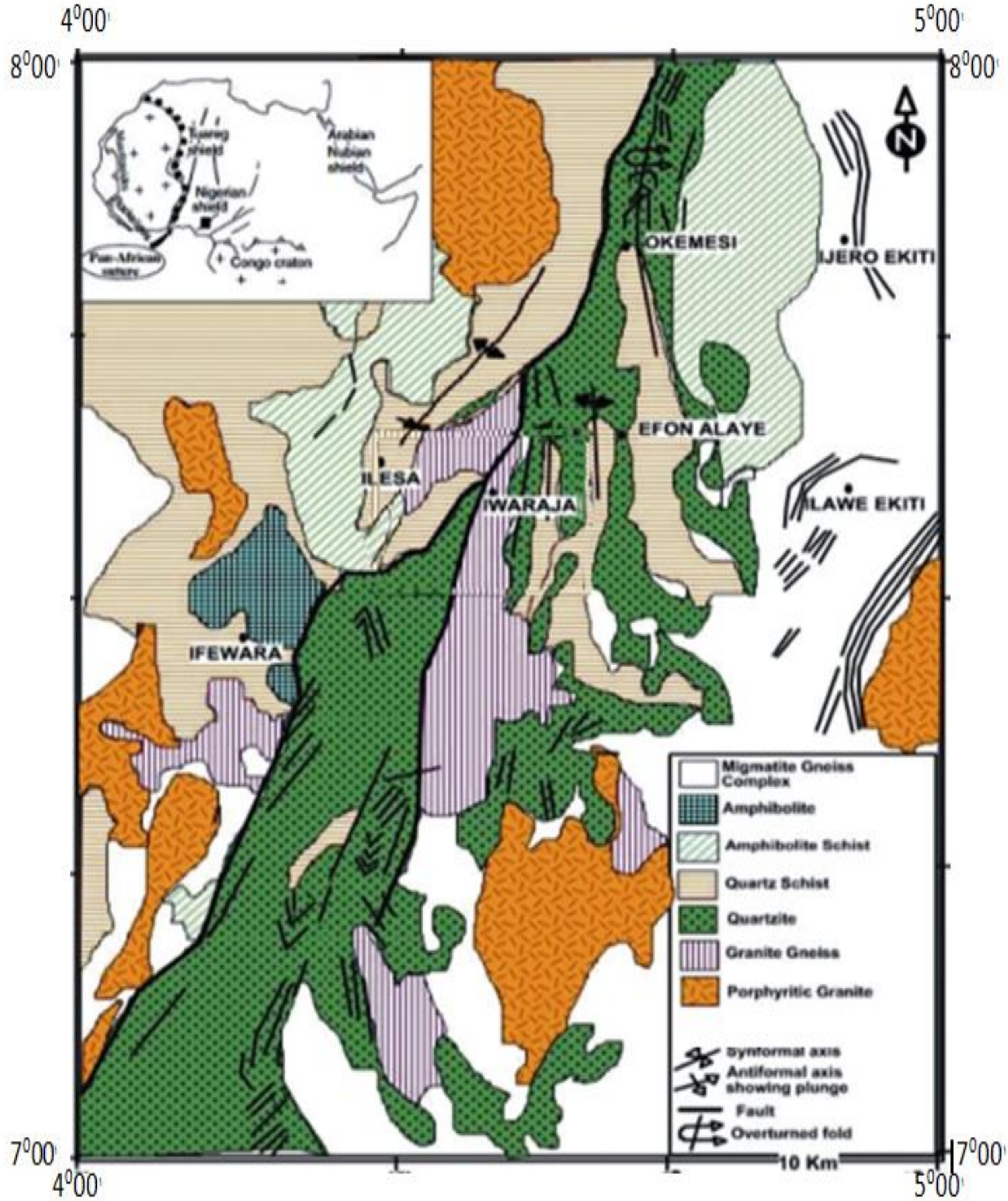


Figure 2.1: Geological map of the study area over Ilesha and its environment (NGSA)

Rock in Ilesha and other parts of this study area are structurally divided into two main segments by two major fracture zones often called the Iwaraja faults in the eastern part and the Ife-wara faults in the western part (Folami, 1992). The major rocks associated with the area form part of the Proterozoic schist belts in Nigeria as shown in Figure 2.1.
Migmatite – Gneiss complex; Quartz – Schist; Quartzite; Amphibolites;Granite – Gneiss; Amphibolites schist and porphyritic granite are the major rocks in the area as delineated in Figure 2.1, other minor rocks according to Folami, (1992) and Rahaman, (1976) are Garnet, Quartz Chlorite bodies and Dolorites.

2.2 Previous Geological Studies

In their quest to have adequate information on the locations, minimum reserves, and mineral resources that are of economic quantity in Osun State for investment purposes Ajeigbe, Adeniran and Babalola (2014) carried out a research on mineral prospecting potentials of Osun State the present study area. The study discovered that Osun State has a lot of minerals in which almost all are of economic quantity. The research suggested that the government should commission the preparation of a detailed mineral resources map of Osun State covering all the local government areas at a scale of 1:1 0000.
(De Swardt, 1953) noted that alluvial gold was first discovered in 1940, around Ilesha and Ife. Gold was first reported in September 1940 from the Owena River North of Ife-Ondo road. Later in December 1941, mining began south of Temogun. Between 1941 and 1952 over 50 ounces of gold were recovered from the stream sediments
Oyawoye (1964) and Rahaman (1976) noted that the rocks in Ilesha and it's environment show evidence of polyphase deformation with the plutonic episode of the Pan African event being the most pervasive.

Odeyemi (1981) suggested that almost all the foliation exhibited by rocks of southwestern Nigeria excluding the intrusive are tectonic in origin, because pre-existing primary structures have been obliterated by subsequent deformation.

Rahaman (1988) noted that the southwestern basement complex of Nigeria lies within the rest of the precambrian rocks in Nigeria, He grouped the rocks in this region as migmatite – gneiss – quartzite complex comprising largely of sedimentary series with associated minor igneous rock intrusions which have been altered by metamorphic, migmatitic and granitic processes.

Oluyide (1988) gave evidence that within the basement complex, tectonic deformation has completely obliterated primary structures except in a few places where they survived deformation.

Caby and Boesse (2002) reported that the southwestern basement complex of Nigeria has been affected by two phases of deformation namely D1, D2; the first phase (D1) produced tight to isoclinals folds while the second phase (D2) is characterized by more open folds of variable style and large vertical NNE-SSW trending fault.

Anifowose (2004) also noted that joints ranging from minor to major ones are found in all the rock types, some of which are filled with quartz, feldspars or a combination of both which lie generally in the NE-SW direction.

2.3 Previous Geophysical Studies

Taofeeq (2020) Integrated of aeromagnetic and aero-radiometric data for delineating lithology, structures and hydrothermal alteration zones in part of southwest Nigeria. The result obtained showed that the area is dominated by NE-SW, NW, NE, EW and NS structural directions though the structure trending NE-SW were found to be the most predominant and considered to be orientation of mineral deposit in the study area. Depth estimation in the shallow and deep seated magnetic source using analytical signal technique range 270 m to 2800 m, while power spectrum gave an average value of 2960 m.

Nwokeabia *et al*. (2018) Evaluated the economic potential of part of Ife-Ilesha Schist belt, western Nigeria, using airborne magnetic and radiometric dataset.The trend analysis was applied to the data to produce the residual field component of the data after which the first vertical derivative was computed to enhance folds, fractures and lithological contact. The main structural or early deformation event emplaced NNE-SSW structures and the second deformation event emplaced and reoriented the main structures to NE-SW and these are potential hydrothermal gold mineralisation zones within the area. The faults and contacts between schist metasediments and metavolcanic rocks noted to host gold mineralization in the Ife-Ilesha Belt were also delineated. The radiometric datasets retrieving geochemical information on Potassium (K), Thorium (Th) and Uranium (U) concentrations within their study area were used to delineate bedrock lithology of the Granite, schist, gneiss, as well as alteration and contact zones.

Vitalis *et al. (*2017) uses analytical signal method (ASM) and Local wavenumber (LWN) to process and analysed the magnetic data of Ilesha (Sheet 243) to generate the depth to magnetic sources as well as the source locations. The results obtained showed a shallower depth range limit for ASM between 0.348 km and 1.28 km, and a range of 0.478 km - 1.51 km for LWN of which they attribute to basic intrusive and/or magnetized bodies within the sedimentary cover. The deeper magnetic source which they attribute to depth to Precambrian basements varies between 1.46 km to 2.55 km for ASM and 1.81 km to 4.11 km for LWN. The overall results of the methods have revealed the prospect of the lithology of the area for magnetic mineral exploration in the field of applied geophysics.

Okeyode *et al. (*2017) used high resolution airborne radiometric data to study the nature of distribution of natural radioelements in the area with its geological structure and also subjected aeromagnetic data of the area to horizontal gradient method (HGM), analytic signal amplitude (ASA) and local wavenumber (LWN) automated gradient techniques to delineate the subsurface structure of the area. They obtained 0.1817 and 3.9296 msv/yr as environmental dose rate for the area. Although, there were extreme values, but the mean dose rate was 0.522 ± 0.310 msv/yr (within acceptable safe limit of 1.0 msv/yr). The total magnetic intensity values of the study obtained a ranged from -79.41 to 140.93 nT. The horizontal gradient method (HGM) and analytic signal amplitude (ASA) revealed that depth to magnetic sources ranged from 0.478 km to 4.112 km and 0.348 km to 2.551 km respectively, whereas local wavenumber (LWN) depth value ranged from 0.478 km to 5.48 km, which overestimated those compared using HGM and ASA functions. Apparent susceptibility of the study area ranged from -0.00325 to 0.00323 SI. They noted that the result of the study has shown that the apparent susceptibility within their study area is controlled mainly by ferromagnetic and diamagnetic minerals.

Olurin *et al. (*2016) applied power spectral method to interpret aeromagnetic data .The result of the interpretation shows that the magnetic sources are mainly distributed at two levels. The shallow sources (minimum depth) range in depth from 0.103 to 0.278 km below sea level and are inferred to be due to intrusions within the region. The deeper sources (maximum depth) range in depth from 2.739 to 3.325 km below sea level and are attributed to the underlying basement.

Akintayo *et al. (*2014) determined the location and depth of mineral rocks at Olode village in Ibadan using magnetic and resistivity geophysical methods. The magnetic signature obtained show considerable varying amplitude from a minimum value of 155.3 nT at a depth of 6.37m to a maximum value of 670.3 nT at a depth of 6.25 m.

Abraham *et al*. (2014) used spectal depth analysis of aeromagnetic data to estimate the heat flow of part of Ekiti State. They correlated their result with radiometric heat production (RHP) value obtained from the analysis of aero radiometric data. The study obtained an average value of 91.2 mWm^{-2} for the area heat flow and a value of 4.06 μWm^{-3} for (RHP). They noted that their RHP was relatively higher when compared to the average heat production of the precambrian shield, 0.77 ± 0.08 μWm^{-3}. They attributed this significant increase in RHP value to the high radioelement contents in the area.

Kayode (2010) interpreted the vertical magnetic components in Ijebu-Ilesha southwest Nigeria using ground magnetic survey and obtained depth to basement complex of 38 m – 244 m.

Kayode *et al. (*2010) estimated the depth to the basement rock of the eastern part of Ilesha. The basement depth was estimated using Peters half slope method which gave a maximum depth to basement of about 160 m. The study delineated Amphibolite, Quartz, and Quartz Schist as the major subsurface structures in the area. The results gave values for the total component measurements of ground magnetic anomaly as varied between -330gammas and 80gammas

Integration of surface electrical prospecting methods for fracture detection in Precambrian basement rocks of Iwaraja area, Southwest Nigeria, by (Adelusi *et al.*, 2009) showed a NE -SW trending of faults in that area and obtained depths of 10 – 55 m.

Anderson and Nash (1997) appraised the new high-resolution aeromagnetic, radiometric and remote sensing data over the rising mine area and lower Khan Gorge region of Namibia reported that the measurement of naturally occurring radioelements (K, Th, U) made through Gamma-ray spectrometry can be used to map and characterize the different lithological units' due to the variation in the concentration of these radioelement between different rocks. They also noted that in comparison with other airborne geophysical methods, gamma-ray spectrometric method show more success in mapping surface geology.

El-awady *et al*. (1984) used aeromagnetic data to study the complex crystalline basement structural pattern, shallower structures and local structures in four sedimentary formations at Faiyum in the western desert of Egypt. Additionally, the aeromagnetic data revealed the distribution of magnetic minerals in the bedrock without any influence by the non-magnetic regolith that overlay the bed rock.

Elkhateeb (1994) mentioned that data from airborne gamma-ray spectrometric surveys which include U, Th, K and their ratios (U/K, U/Th, and Th/K) beside the TC (total count) map frequently vary considerately; so they may be correlated with geological units.

CHAPTER THREE

3.0 MATERIAL AND METHODS

3.1 Materials

The materials that would be used for this study includes:

i. Aeromagnetic data covering the study area.

ii. Radiometric data covering the study area .

iii. Microsoft Office (Word and Excel Packages).

iv. Laptop (work station).

3.2 Aeromagnetic andAeroradiometric data acquisition

For this research work, four (4) aeromagnetic data sheet and aero-radiometric data sheet needed were procured from the Nigerian Geological Survey Agency (NGSA) in Abuja. The aeromagnetic data was obtained using a proton magnetometer with resolution of 0.01 nT. The Aeromagnetic survey was conducted at 500 m line spacing and 80 m terrain clearance. The flight line direction was in the direction 135 azimuths; the tie line direction was at 45 azimuths. The flying line altitude was 80 m above the terrain. The average magnetic inclination and declination across the survey area were 9.75 and 1.30, respectively. The geomagnetic gradient was removed from the data using International Geomagnetic Reference Field (IGRF) formula. The Radiometric data acquired from the airborne survey were presented in a digital form as composite grid of 1:100000. The radiometric survey was conducted at flight height of 80m emphasise high resolution survey, with line spacing of 500m and tie line spacing of 5,000 m (Megwara *et al*., 2013). The four aeromagnetic and aero-radiometric data sheets used are 242 (Iwo), 243 (Ilesha), 262 (Apomu) and 263 (Ondo), which correspond to latitude 7^0N to $8\ ^0$N and longitude 4^0E to 5^0E. Each scaled 1:100,000 a superficial area of 12,100 km^2 (i.e. 55 km x 55 km).

3.3 Aeromagnetic Data Analysis

The first step in this work was to use the data sheets to produce Total magnetic intensity (TMI) map.

3.3.1 Production of total magnetic intensity (TMI) map

The four aeromagnetic data sheets were imported into Oasiss montaj 6.42v software, where they were assembled and merged, to produce the total magnetic intensity (TMI) map of the study area. The Oasis montaj software is primarily designed for potential data analyses, which uses Fourier domain techniques for data transformation.

3.3.2 Regional and residual separation

The Total Magnetic Intensity reflect the entire sources generating the magnetic anomalies. In geophysics, the issue is to dispose with or reduce to a minimum, the impacts of deep seated, non-profitable sources with minimum disturbance of the resultant anomaly as could reasonably be expected. A geophysical anomaly is normally made out of a wide range of frequencies, each frequency being defined by particular amplitude. The anomaly of importance might be defiled by "noise" comprising of regional patterns, uninteresting geologic variety, and instrument drift. In the event that both anomaly and noise content are known, and there is no overlapping between them, then a channel of concern would be created to wipe out the noise impacts.

Thus, this work (interpretation of the magnetic field) begins with the separation of the long-wavelength anomalies of the regional field component, which is attributed to deep and large scale sources from the shorter wavelength features constituting the residual field assumed to arise from shallow and small scale sources. The residual data is obtained as a derivative of the total intensity data.

3.3.3 Polynomial fitting

It is the most flexible of all the analytical methods for separating regional from residual it includes matching of the regional field with a low order polynomial surface in order to expose the residual elements as random errors. The techniques depend on statistical theory. The regional pattern is represented by a straight line or generally by a smooth polynomial curve. The observed data were used to process, usually by least square, the mathematical describable surface giving the closest fit to the magnetic field that can be obtained within a specified degree of detail. This surface is considered to be the regional field and the residual field is the difference between the total magnetic field value and the regional field value (Udensi, 2000). This was the method utilised in this work. The method is useful because of the limited spatial extent of the study area. It was assumed that the regional field is a first degree polynomial surface, regional were therefore calculated as two dimensional (2-D) first degree polynomial surface.

A Computer software (Oasis montaj) was used to derive the residual magnetic values by subtracting values of the regional field from the total magnetic values at the grid cross point as described above.

$$\text{Residual Field} = \text{Total Field} - \text{Regional Field} \tag{3.1}$$

3.4 Depth Analysis

The method employed in the analysis of depth are analytic signal.

3.4.1 Analytic signal

The application of analytic signals to magnetic interpretation was pioneered by Nabighian (1972), for 2D case, primarily as an apparatus for computing depth and position of sources.

The analytic signal method which is also known as total gradient method is a notable method for establishing the edges of magnetic anomalies. It is formed through the combination of the horizontal and vertical gradients of the magnetic anomaly. The analytic signal is not dependent of magnetization direction and Earth's magnetic field direction. This implies that all bodies with similar geometry have the same analytical signal It is based on the calculation of the first derivatives of magnetic anomalies to estimate source characteristics. The function used in the analytic signal technique is the analytic signal amplitude (absolute value) of the observed magnetic field at the location (*x*, *y*), described by three orthogonal gradients of the total magnetic field (Milligan and Gunn, 1997) via the expression:

$$|A(x,y)| = \sqrt{(\frac{\partial \mathrm{M}}{\partial \mathrm{x}})^2 + (\frac{\partial \mathrm{M}}{\partial \mathrm{y}})^2 + (\frac{\partial \mathrm{M}}{\partial \mathrm{z}})^2} \qquad (3.2)$$

where; $A\ (x, y)$ = amplitude of the analytic signal at (x, y),

M = observed magnetic field at (x, y).

3.4.2 First vertical derivatives

The first vertical derivative or vertical gradient can be thought of as component of the rate of change of the anomaly values as the potential field data are upward continued. First vertical derivative can be applied either in space or frequency domain. It is proposed by (Nabighian, 1984), using 3D Hilbert transforms in the x and y directions. It is used to enhance shallow features with their boundaries and associated lineaments. It amplifies short-wavelengths at the expense of longer anomalies related to deep sources.

It is formulated thus:

$$VDR = \frac{\partial \mathrm{M}}{\partial \mathrm{z}} \qquad (3.3)$$

The vertical gradient helps resolve closely-spaced short-wavelength anomalies. This filter is useful to emphasize shallow structures such as networks of faults, fractures and dykes as stated in objectives one and two.

3.4.3 Second vertical derivative

The second vertical derivative is the vertical gradient of the first vertical derivative. First vertical derivative data have become an important tool in magnetic interpretations. Second vertical derivative has even more resolving power than the first vertical derivative, but its application requires high quality data because of its greater enhancement of noise. It was shown by Hood and McClure (1965) that second vertical derivative is zero and rapidly changes sign at a point vertically over a contact. In magnetic data interpretation, second vertical derivatives are used to delineate the plain-view boundaries of intra-basement anomaly sources and are also found to be effective for enhancement of magnetic anomalies (Sharma, 2002). The zero-point (of the second vertical derivative) of the image map indicates the spatial locations of the magnetic source edges which in effect outline anomalous areas. Objectives one and two will be achieved through this method.

For this study, the first and second vertical derivatives were generated in Oasis Montaj using the MAGMAP GX.

3.4.4 Source Parameter Imaging (SPI^{TM})

The Source Parameter Imaging (SPI^{TM}) is a technique using an extension of the complex analytical signal to evaluate magnetic depths. The Source Parameter Imaging TM (SPI^{TM}) function is a fast, simple, and powerful method for calculating the depth of magnetic sources (objective three). Its accuracy has been shown to be +/- 20% in tests on real data sets with drill-hole control. This accuracy is analogous to that of Euler deconvolution, however SPI has the advantage of producing a more complete set of coherent solution points and it is easier to use (Salako, 2014). One merit of the SPI technique is that the depth can be visualized in a raster format and the true thickness determined for each anomaly.

This approach developed by (Thurston and Smith ,1997) and Thurston *et al*. (1999) sometimes referred to as the local wave number method uses the connection between source depth and the local wave number (k) of the observed field, which can be calculated for any point within a grid of data through vertical and horizontal gradients (Thurston and Smith, 1997). The depth is shown as an image. The basics are that for vertical contact, the peaks of the local wave number define the inverse of depth.

The SPI method (Thurston and Smith, 1997) estimates the depth parameter using the local wave number of the analytical signal (Salako, 2014). The analytical signal $A_1(x, z)$ is defined by Nabighian (1972) as

$$A_1(x,z) = \frac{\partial \mathrm{M(x,z)}}{\partial \mathrm{x}} - \mathrm{j}\frac{\partial \mathrm{M(x,z)}}{\partial \mathrm{z}} \quad (3.4)$$

where

$A_1(x,z)$ =Analytic signal

M(x,z) = magnitude of the anomalous total magnetic field,

j = imaginary number, z and x indicate the gradients in the vertical and horizontal direction respectively. Also, it was shown by Nabighian (1972) that the gradient changes constitutes the real and imaginary parts of the 2D analytical signal related as:

$$\frac{\partial \mathrm{M(x,z)}}{\partial \mathrm{x}} \Leftrightarrow -\mathrm{j}\frac{\partial \mathrm{M(x,z)}}{\partial \mathrm{z}} \quad (3.5)$$

where

$\Leftrightarrow$ implies a Hilbert transform.

Thurston and Smith (1972) defined the local wave number κ1 to be:

$$k_1 = \frac{\partial}{\partial \mathrm{x}} \tan^{-1}\left[\frac{\partial \mathrm{M}}{\partial \mathrm{z}} \Big/ \frac{\partial \mathrm{M}}{\partial \mathrm{x}}\right] \tag{3.6}$$

Salako (2014) stated that the signatures illustrated by Thurston and Smith (1972) utilized Hilbert transformation pair. The Hilbert transform and the vertical derivative operators are linear, so the vertical derivative will give the Hilbert transform pair as:

$$\frac{\partial^2 \mathrm{M(x,z)}}{\partial \mathrm{z}\, \partial \mathrm{x}} \Leftrightarrow -\frac{\partial^2 \mathrm{M(x,z)}}{\partial^2 \mathrm{z}} \tag{3.7}$$

Thus the analytic signal could be defined based on second-order derivatives, $A_2(x,z)$, where

$$A_2(x,z) = \frac{\partial^2 \mathrm{M(x,z)}}{\partial \mathrm{z}\, \partial \mathrm{x}} - \mathrm{j}\frac{\partial^2 \mathrm{M(x,z)}}{\partial^2 \mathrm{z}} \tag{3.8}$$

This gives rise to a second order local wave number κ_2, where

$$k_2 = \frac{\partial}{\partial \mathrm{x}} \tan^{-1}\left[\frac{\partial^2 \mathrm{M}}{\partial^2 \mathrm{z}} \Big/ \frac{\partial^2 \mathrm{M}}{\partial \mathrm{z}\, \partial \mathrm{x}}\right] \tag{3.9}$$

This first and second – order local wave numbers are used to determine the most appropriate model and depth estimate of any assumption about a model.

3.5 Airborne Radiometric Survey method

Geophysical survey is appreciated more when two or more geophysical methods are employed. Gamma-ray spectrometry has been widely used in geological mapping, generally as a complementary method to magnetism (Salako *et al.*, 2020*;* Anderson and Nash, 1997)

Geophysical radiometric survey also known as Gamma-Ray Spectrometry is a passive geophysical technique that is utilised to examine the subsurface of the Earth and it deals with the estimation of the spatial distribution of three radioactive elements (Potassium-K, Thorium-Th and Uranium-U) in the top 30 - 40 cm of the earth's crust by detecting and estimating the intensities of the gamma rays produced by these elements in a radioactive decay (IAEA, 2003). Despite the fact that there are numerous occurring radioactive elements that decay and radiate gamma rays, it is only the decay of Potassium, and the decay series of daughters of Thorium and Uranium as Uranium and Thorium cannot be measured directly. Daughter nuclides (Bi^{214} and Tl^{208}) generated during the decay of parent elements (Uranium and Thorium) are measured rather, and the abundance of parent elements is inferred. Therefore, Uranium and Thorium are expressed in equivalent parts per million (eU and eTh). Bi^{214} originates from the decay of U^{238} and is, consequently, an indicator of Uranium concentration in the earth materials that exist within the range of the detector, Tl^{208} originates from the decay of Th^{232} and is an indicator of Thorium content; and ^{40}K is one of the minor natural isotopes of Potassium and the main isotope of Potassium that is radioactive (Durrance, 1987; Gupta, 1991).

The airborne radiometric survey method is efficient in lithological discrimination and can reproduce geological contacts with high accuracy (depending on the spacing of the measurements) because the mapped information is provided by radiation that emanate only from a very shallow depth. In the present study, the method enables the location of geological boundaries and compositional zoning within geological units.

The radiometric method operates on the assumption that radioactive elements occur naturally in the crystals of particular minerals, the abundance of these minerals varies across the Earth's surface with changes in rock and soil type, and because the energy of gamma rays is characteristic of the radioactive element, it can be used to measure the abundance of these radioactive elements in an area. So by measuring the energies of gamma rays being emitted in an area, the particular mineral present in the Earth crust can be deduced (IAEA, 2003).

3.5.1 Basic principles of radiometric survey

Some rocks and soils are radioactive naturally, comprising different degrees of variety of elements showing natural decay and releasing different variety of radiations (alpha α, beta β, gamma γ) within particular energy levels. At present only the gamma (γ) ray radiation has adequate energy usable in geophysical mapping or exploration as it is the only one that is emitted as an electromagnetic wave (Livia *et al.*, 2017), enabling it to be more penetrable compared with alpha and beta, being able to cross bodies and buildings. A gamma spectrum measured in nature therefore yields information about exact concentration of radioactive nuclides in the material detected by the detector system.

3.5.2 Natural radioactivity of rocks

As all rocks and other earth material are radioactive, the radiometry studies the distribution of radioactive material in the earth, taking into consideration the electromagnetic radiation gamma emitted by nuclear decay. Therefore, the radiometry comprises of detecting nuclear emissions from rocks containing radioactive minerals (Livia, 2017).

The Uranium and Thorium in igneous rocks are concentrated much in a few accessory minerals such as zircon, sphene and apitite (Slagstad, 2008). Other notably radioactive minerals, such as pyrochlore, thorite, monazite, uraninite, and allanite, are prevalent in nature but are negligible constituents of rocks, and are spread unevenly. The minerals that transmit Thorium and Uranium are commonly associated with felsic intrusions - specifically with younger intrusions; they can be found substantially less in mafic rocks or in volcanics. The Uranium and Thorium content of rocks usually increases with acidity, with the maximum concentrations located in pegmatites, (Slagstad, 2008). The highest concentrations of Uranium and Thorium in sedimentary rocks are generally found in shales.

Potassium is predominantly concentrated in feldspars and micas; rocks with none of these minerals have very low Potassium. Therefore, mafic and ultramafic rocks have very low Potassium content. The Potassium substance of sedimentary rocks is highly variable however it tends to be higher in shale than in carbonates or sandstones.

3.5.3 Radioactive Minerals

Radioactive elements occur naturally in the crystals of many minerals and by virtue of the presence of the radioactive element in these minerals, the minerals become radioactive in nature. There is variation in the quantity of these minerals across the Earth's surface with variations in rock and soil type. Common radioactive minerals with their respective radioactive elements in their crystal lattice and the corresponding environment in which these radioactive minerals occur are shown in Table 3.1.

Table 3.1 Radioactive Elements and the Minerals in which they occur and their Depositional environment *(Telford et al., 1990)*

Radioactive elements	Radioactive mineral	Environment of deposition
Uranium	1.Uraninite (Oxide of U, Pb, Re + Th, Rare Earth)	1.Granites, pegmatites and with vein deposits of Ag, Pb, Cu e.t.c
	2.Carbonite ($K_2O.2UO_3.V_2O_5.2H_2O$)	2.Sandstones
	3.Gummite (Uraninite alteration)	3.Associated with uraninite
Thorium	1.Monazite (ThO_2+Rare earth phosphate)	1.Granite, pegmatites, gneiss
	2. Thorianite[$(Th, U)O_2$]	2. Granite, pegmatites, placers
	3.Thorite, Uranothorite [$ThSiO_4$+U]	3. Granite, pegmatites, placers
Potassium	1.Orthoclase and microcline feldspars ($KAlSi_3O_8$)	1.Main constituent in acid igneous rocks and pegmatite
	2.Muscovite [$H_2KAl(SiO_4)_3$]	2. Main constituent in acid igneous rocks and pegmatite
	3. Alunite [$K_2Al_6(OH)_{12}SiO$]	3. Alteration in acid volcanic
	4.Sylvite,Carnallite[$KCl,MgCl_2,6H_2O$]	4. Saline deposits in sediments

3.5.4 Gridded Channels of K, U, Th, Ratio Maps and Ternary Map

The airborne radiometric data will be gridded with the minimum least curvature gridding procedure. The minimum curvature gridding techniques (Briggs, 1974) uses two dimensional spines to estimate the value of the corrected data onto a mesh with regular spaced interval values, utilizing the minimum curvature iterative algorithm that adapts weights such that the curved nature of the surface is reduced according to Briggs conditions.

The gridded images will then be used to interpret and map the geology of the whole study area by making inferences from literature what high or low radioactive material implies relating to geology of a specific region of the area. Ratio and ternary image will be produced to help in the identification and mapping of zones that are hydrothermally altered. A decrease in Th and an increase in K is indicative of alteration environment in an ore deposit (Ostrovskiy, 1975). A low Uranium concentration with a high Potassium concentration would lead to a low values U/K ratio which is indicative of granitite rocks. The depletion of Uranium leaves negative aureoles which is the results of pervasive hydrothermal alteration (Boyle, 1979). Even though, Thorium is generally immobile, an enrichment of Thorium and Potassium is indicative of hydrothermal alteration in some gold deposits (Silva *et al*., 2003). A ternary map was created with the grid display in Geosoft by assigning Potassium with red, Thorium with green and Uranium with blue. The ternary map showed the concentration of the elements relative to each other. The ternary map showed the concentration of the elements relative to each other airborne gamma-ray spectrometry data are the measurements of the surface concentrations of radioelements which are usually presented as colour images or contours of the spatial distribution of either single radioelement, or composite images (Salako *et al*., 2019). Specialised gridding techniques provided in the Geosoft software (Oasis montaj^{TM}) will be used to enhance observed radioactive distribution of the primary radioelements (Potassium, Uranium and Thorium), and generate images and maps for easy identification and characterisation of radiometric signatures associated with mineralization, trends of structures and pattern of geologic units.

CHAPTER FOUR

4.0 RESULTS AND DISCUSSION

4.1 Aeromagnetic Data Interpretation

4.1.1 Total magnetic Intensity

The total magnetic intensity map of the study area bounded by 7.0^0 to 8.0^0 N latitude and 4.0^0 to 5.0^0 E longitude is produced into map (Figure 4.1) in colour aggregate. The total magnetic intensity map revealed the positive and negative magnetic anomalies ranging from -73nT to 137 nT with an average value of 46.302 nT. Almost all part of the study area revealed low and high magnetic anomalies. Geologically, the high anomalies signature are seen to occur in area underlain Okemisi by Quartzite, Quartz- schist and Amphibolite, while the negative magnetic anomalies which are the low magnetic signature ranging from -19nT to - 75nT were situated at southeastern part of the study area. Geologically, the low anomalies are seen to occur in Ilawe underlain by migmatite Gnesis complex, Porphyritic Granite and Granite Gneiss. Equally worth mentioning are set of lineaments trend from NE to NW and NE to SW.

4.1.2 Reduction to Equator (RTE)

It can be seen on the reduction to equator map (Figure 4.2a) that high magnetic signature coloured pink are observed at the northeastern, southern edge and western edge of the study area. Low magnetic signature was situated at southeastern part of the study area. Hence, the reduction to equator and total magnetic intensity activities with both low and high magnetic anomalies are set of lineament trend NE to SW directions.

4.1.3 Reduction to pole (RTP)

The reduction to pole map (Figure 4.2b) reveals the magnetic structure with high magnetic intensity on TMI map which was changed to low magnetic and those with low magnetic anomalies on the TMI map were changed to high magnetic as a result of removing the angle of delineation. The filtering method helped in correcting latitude effect within the study area.

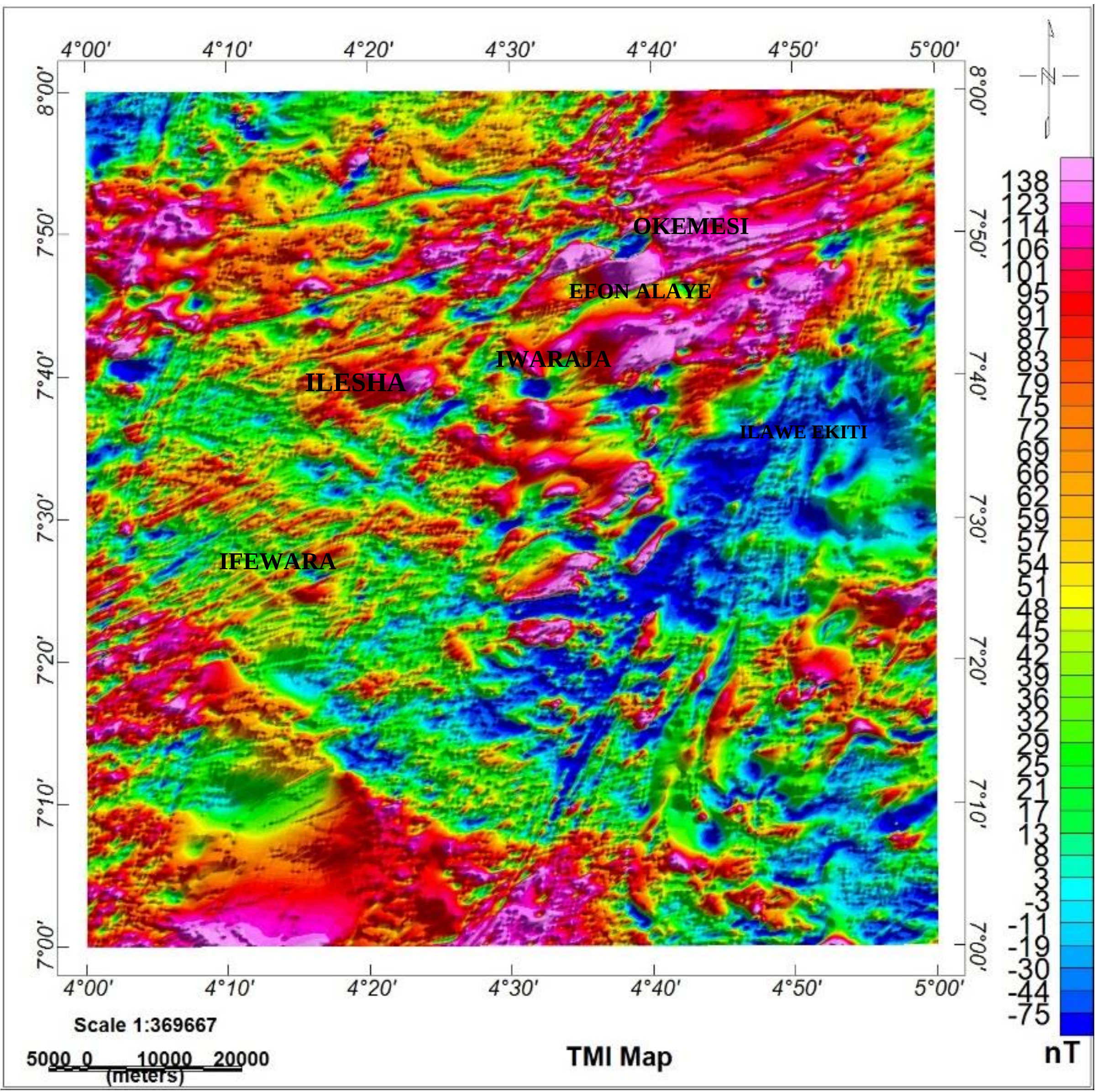


Figure 4.1: Total Magnetic Intensity Map of the study area (33000nT was removed)

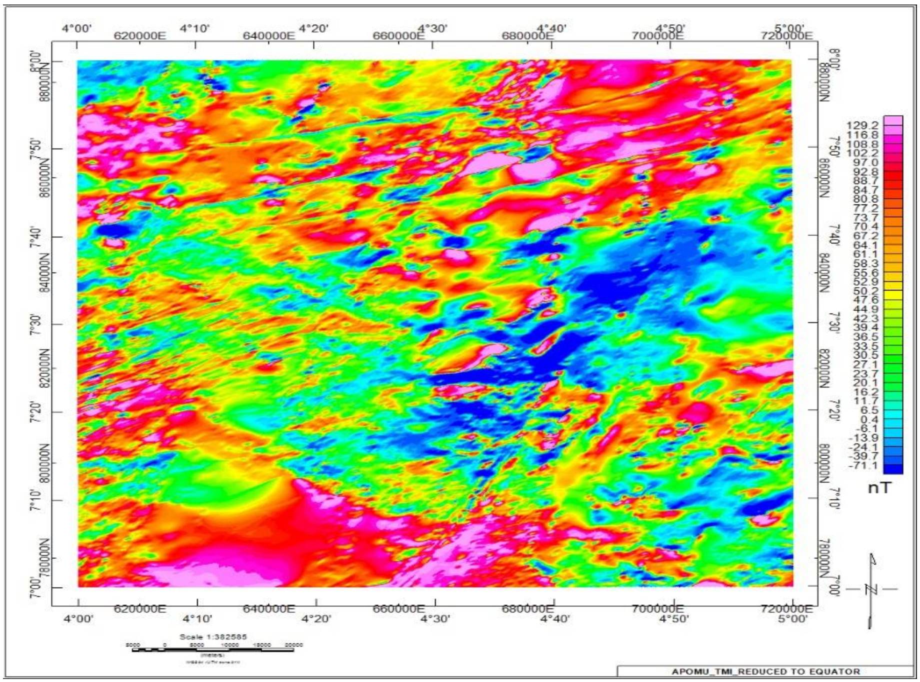


Figure 4.2a: Total Magnetic Intensity Map Reduction to Equator Map

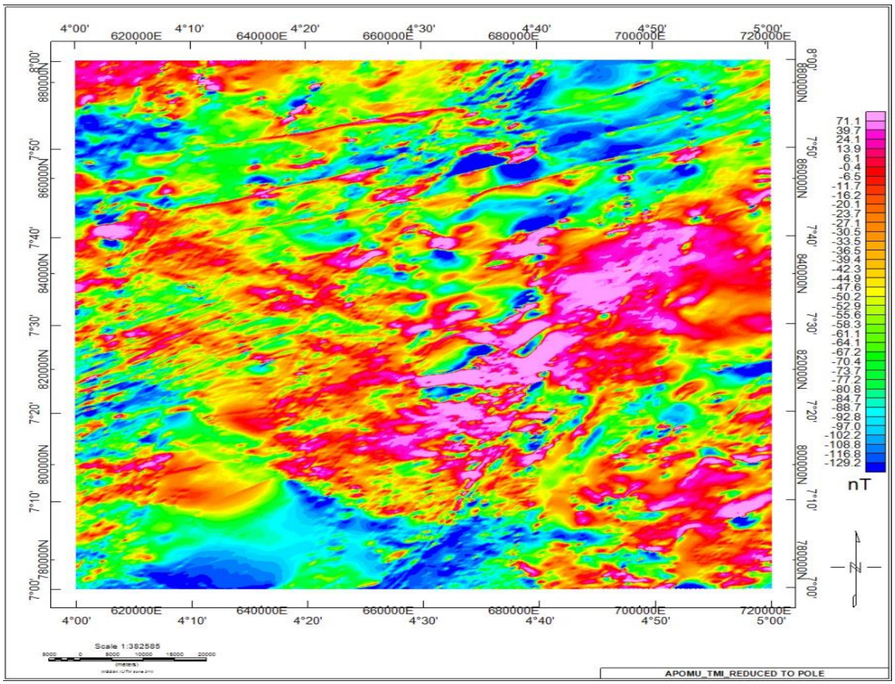


Figure 4.2b: Total Magnetic Intensity Map Reduction to Pole Map

4.1.4 Horizontal Derivatives Map (H_x, H_y, H_z)

The regional structures that are of deeper source have generally disappear leaving behind the surface structures that are of short wavelength with high frequency occurrence with mixture of high and low magnetic susceptibility. The mixture of high and low magnetic susceptibilities occurs at the lower mid portion, North edge, Western edge of the study area and this lies approximately in y-direction. While horizontal derivative H_y showed that the mixture of high and low magnetic susceptibility lies in x - direction and horizontal derivatives H_z showed magnetic structures revealed both in x and y direction, delineate and interpreted as major fault lines Ife-wara and Iwaraja and minor fracture or fault line at Ijero Ekiti and Ilawe Ekiti.. These might signify the fracture and deformation of basement rocks as shown in Figure 4.3b, 4.3c and 4.3a.

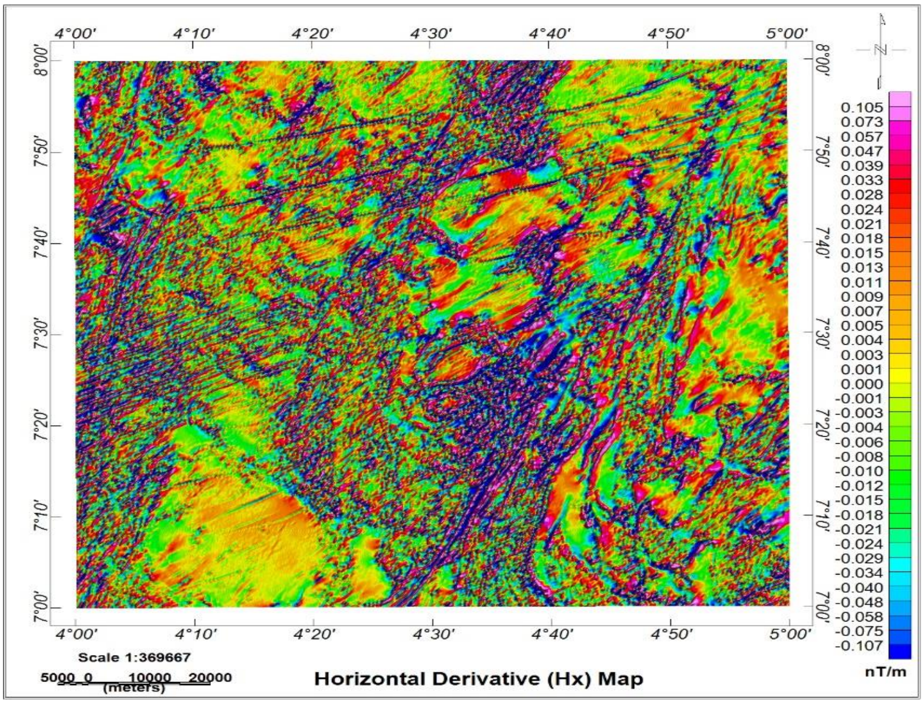


Figure 4.3a: Horizontal Derivative (H_x) Map

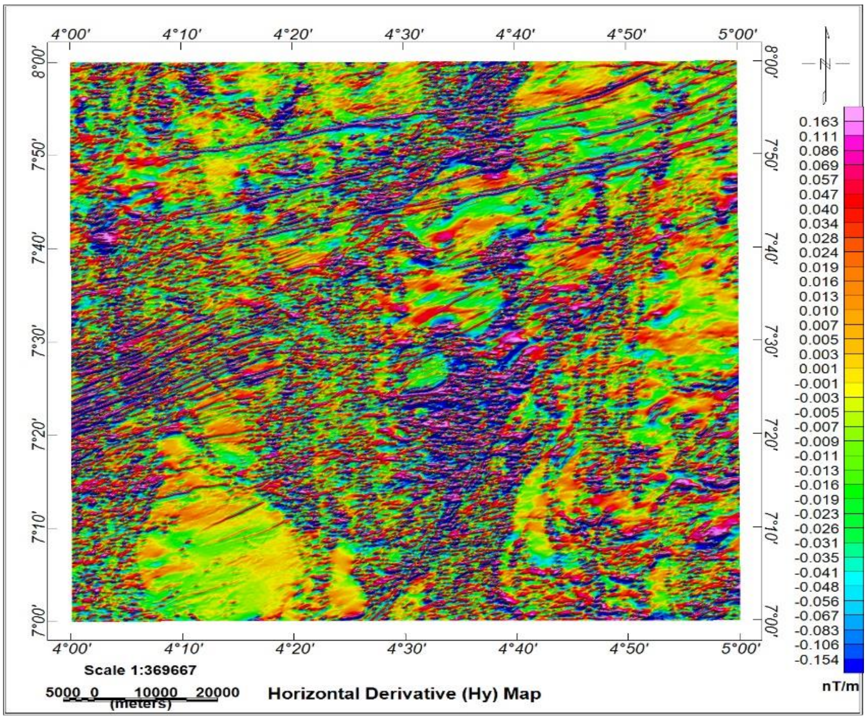


Figure 4.3b: Horizontal Derivative (H_y) Map

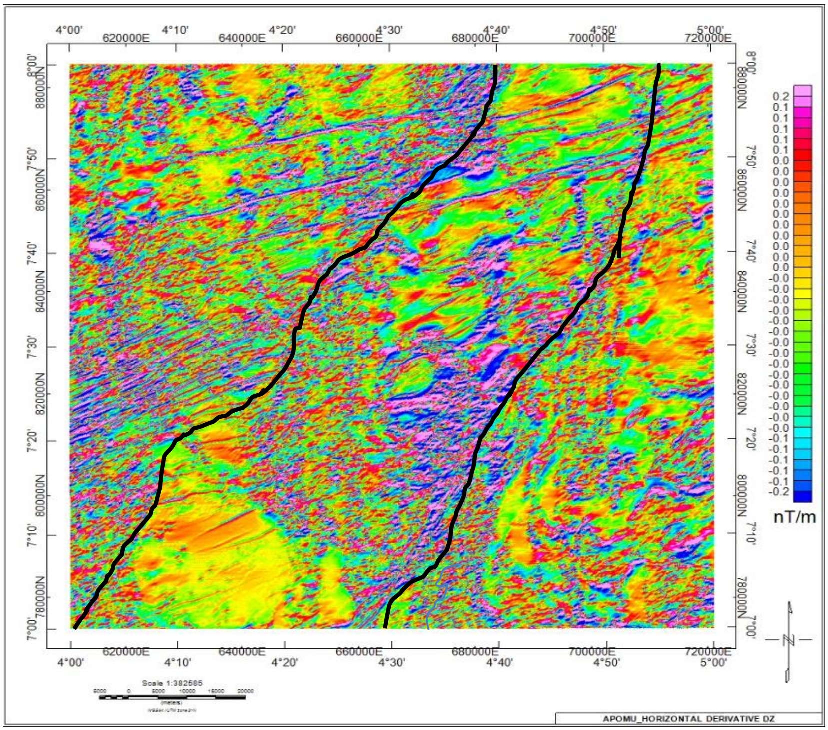


Figure 4.3c: Horizontal Derivative (H_z) Map

4.1.5 First Vertical Derivative

The first vertical derivative map (Figure 4.4a) depicts the near surface structure with the mixture of both high and low frequency magnetic anomalies. The first vertical derivatives map reveals that high frequency (HF) with short wavelength and low frequency with long wavelength only appear at the lower southwestern edge and eastern edge of the study area. Equally worth mentioning is set of lineament in pink trending NE - SW directions as shown in grey scale map (Figure 4.4b) which can serve as the host for solid minerals. Almost the study area is occupied by these high frequency magnetic anomalies, revealing shallow depth to causative sources when correlated with some other parts such as Northeastern edge and Southwestern with deeper sources which have the presence of thick sedimentary covers. The sets of lineaments features trend in NE to NW and NE to SW directions, represent lithological boundaries and could be also delineate and interpreted as major fault lines Ife-wara and Iwaraja and fracture or fault line at Ijero Ekiti and Ilawe Ekiti. While the set of short linear (blue) features located at western edge of the study area trend mostly toward the NE - SW directions. They are located within the lithological boundaries of magnetic source bodies of Quartz schist, Amphibolite schist and Granite Gneiss.

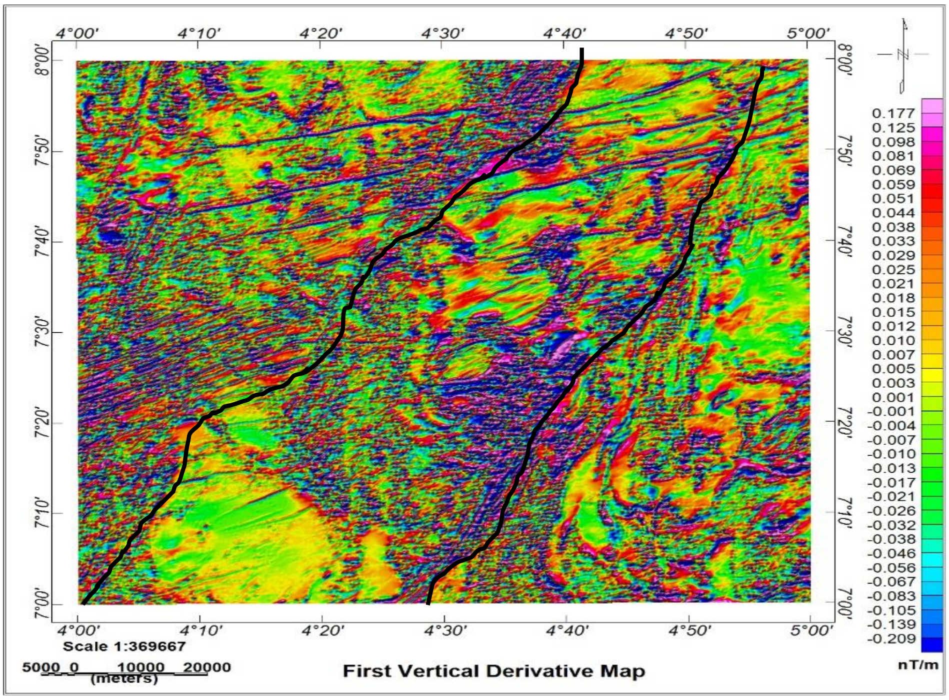


Figure 4.4a: First Vertical Derivative of The Study Area

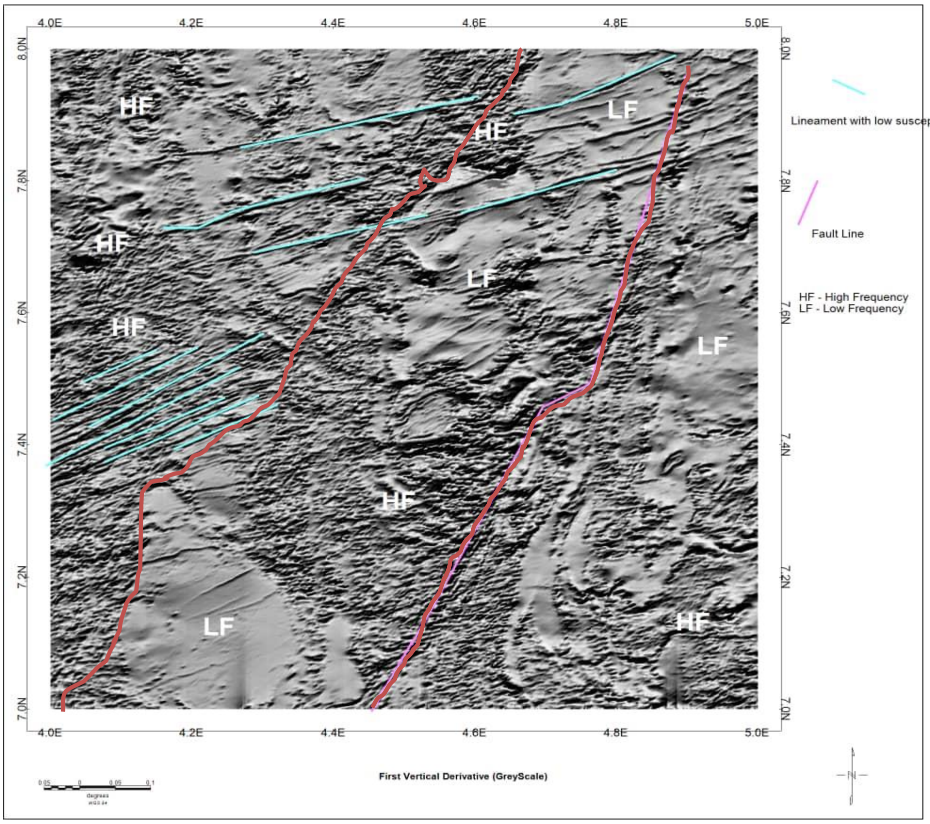


Figure 4.4b: First Vertical Derivative Map of the Study Area in Grey Scale

4.1.6 Second Vertical Derivative

The map depicts the near surface structure with the mixture of both high and low frequency magnetic anomalies. The second vertical derivatives map (Figure 4.4c) reveals that almost all the entire study area was occupied by high frequency (HF) with short wavelength and low frequency with long wavelength only appear at the lower southwestern edge and eastern edge of the study area. Equally worth mention is set lineament in red coloration trending NE - SW directions as shown in grey scale map (Figure 4.4b) serve as the host for solid minerals. This set of lineaments can also represent lithological boundary and could be delineate and interpreted as a major fault lines.

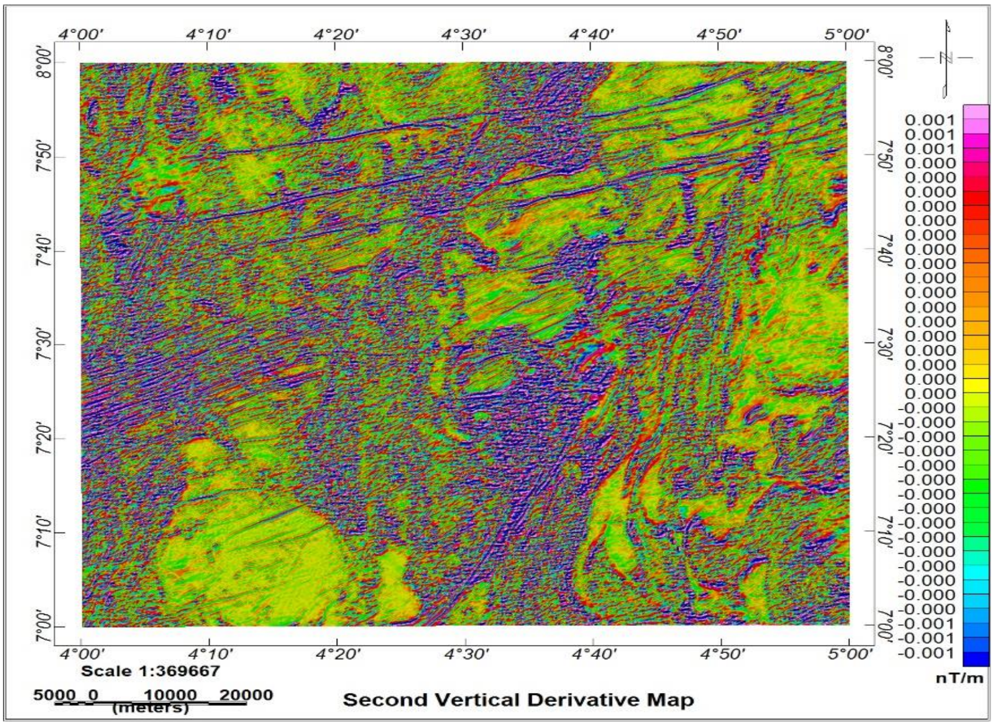
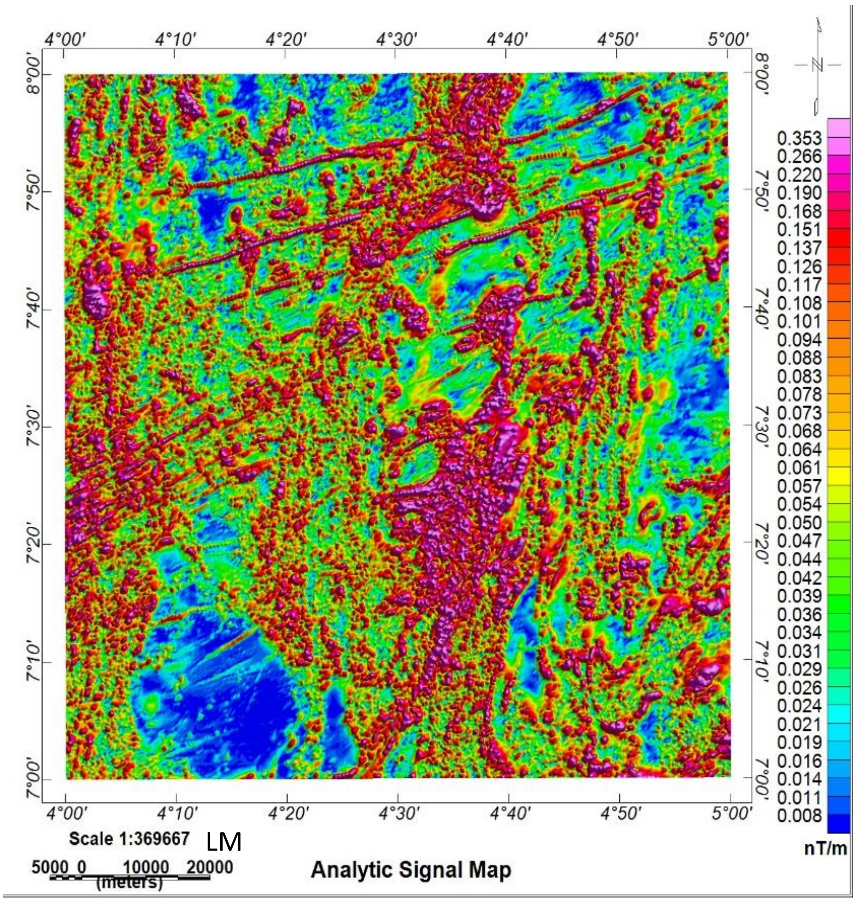


Figure 4.4c: Second Vertical Derivative Map of the study

4.1.7 Analytic Signal (AS)

The analytic signal map is good in locating contacts and sheet like structures by forming maxima northeastern and southeastern of magnetic sources. The analytic signal map (Fig. 4.5) has figured out the variation in the magnetization of the magnetic sources in the study area and highlights discontinuities and anomaly texture. These structures are observed around northeastern and southeastern of the area and also span towards the western end of the map. This is used to estimate depth and width of infinite dike automatically. The AS map show clearly the major anomalies trending in the NE-SW, NW-SE, and E-W direction as previously seen on both the residual magnetic intensity (RMI) map and the horizontal gradient map. Analytic signal magnitude ranges from 0.008T/m to 0.357nT/m. Analytic signal high magnitude ranging between 0.190nT/m-0.353nT/m represented with pink and red colour Okemesi, Iwaraja, ifewara underlain by Ampholite schist and Quartz schist. These magnitudes appear to surround those of lower magnitude ranging from 0.008nT/m to 0.026nT/m represented with blue colour occurring all over the map.



LM: Low Magnitude HM: High Magnitude

Figure 4.5: Analytical signal (AS) Map of the study area

4.1.8 Source Parameter Imaging (SPI)

The SPI method of depth estimation was used to appropriately reveal the depth to the top of magnetic sources in the study area. The filter was helpful in mapping the depth to buried magnetic bodies which may be deep seated basement rocks or near surface intrusive rocks. The distribution of depth to causative bodies of magnetic anomalies across the study area (Figure 4.6) ranges from 89.038 m to 574.763 m. The shallowest depth occurrence was recorded at the western edge, parts of north and southern regions while the southwestern, southeastern and northeastern regions recorded intercalation of shallow and deep depths ranges coincide with analytical signal map.

The western region, parts of north and southern regions which are occupied by shallow intrusive magnetic bodies also corresponds to regions delineated to host major magnetic lineaments trending NE-SW and NE-NW direction of study area.

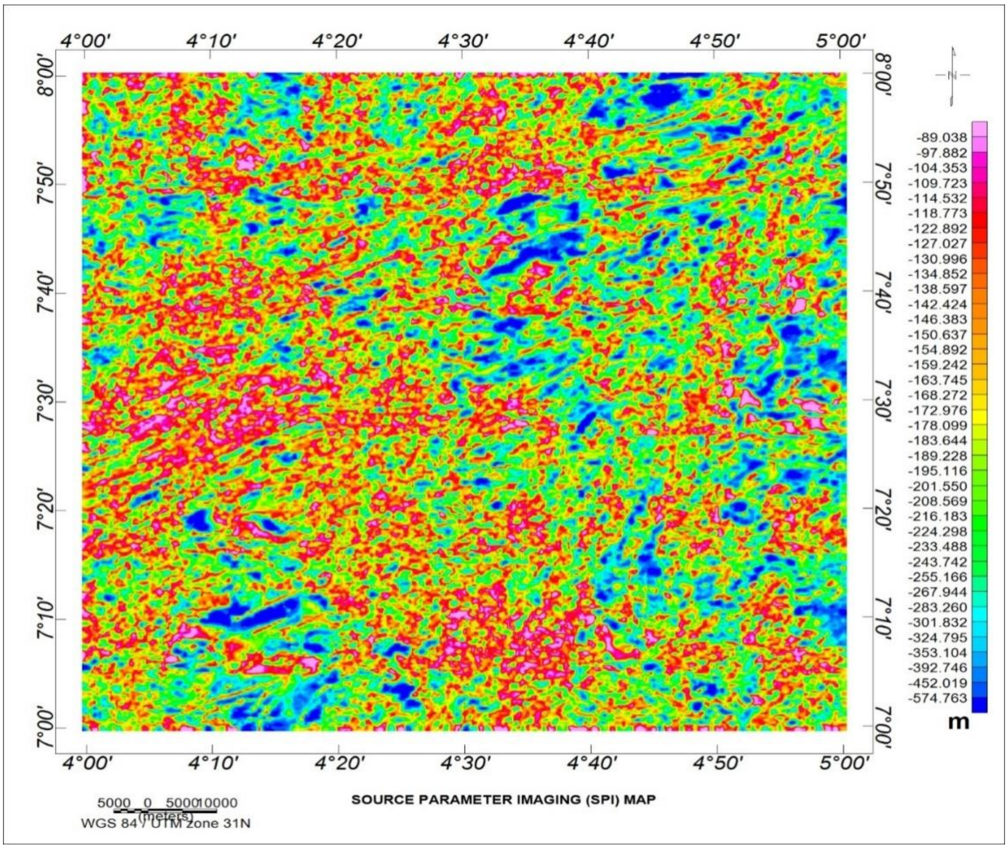


Figure 4.6: Source Parameter Imaging Map of the study area

4.2 RADIOMETRIC DATA INTERPRETATIONS

4.2.1 RADIOELEMENS MAPS

4.2.1.1 *Potassium Map*

The Potassium map (Figure 4.6a) depicts Potassium contents ranging from 0.16 to 3.25 % that reflects different lithological units and alteration within the study area. Potassium always increases during alterations signatures as a result of K enrichment rocks present within the study area. But decrease in their content as a result of weathering because of its mobility. This map depicts both high and low content of Potassium. The high region accomplished by pink colouration ranging from 2.08 % to 3.25 % at the upper part of the North, Northwestern, Southwestern and Southeastern edge at Okemesi underlain by Quartzite and Amphibolite of the study area. Low region ranges from 0.16 % - 0.33 % accomplished by blue coloration revealed that Potassium was observed to occur in small bit all over the map.

4.2.1.2 *Thorium Map*

The Thorium map (Figure 4.6b) depicts Thorium contents ranging from 0.80 to 33.27 ppm. High Th concentrations are closely related to felsic minerals and low Th concentrations are related to mafic minerals (Shives *et al.*, 2000). The granitoids at the western and central parts of the area registered moderate to low Th concentration while those at the eastern corner is characterised with high Th content. Thorium is generally considered very immobile (Silva *et al*., 2003), thus, the regions with low Thorium concentration suggest that Th was mobilised in hydrothermally altered systems. The low Th patterns shows alteration patterns in the different rocks and along lithologic boundaries and within these zones are faults and shears which host hydrothermal fluid which leach Th concentration.

4.2.1.3 *Uranium Map*

The eU map (Figures 4.9) shows high level of Uranium concentration ranging from 4.62 ppm to 7.24ppm. High eU is observed to be trending northwestern and southeastern from the northern and southern part of the map, while the low and intermediate levels ranging from 0.13 ppm to 1.26ppm are not clearly defined in the study area.

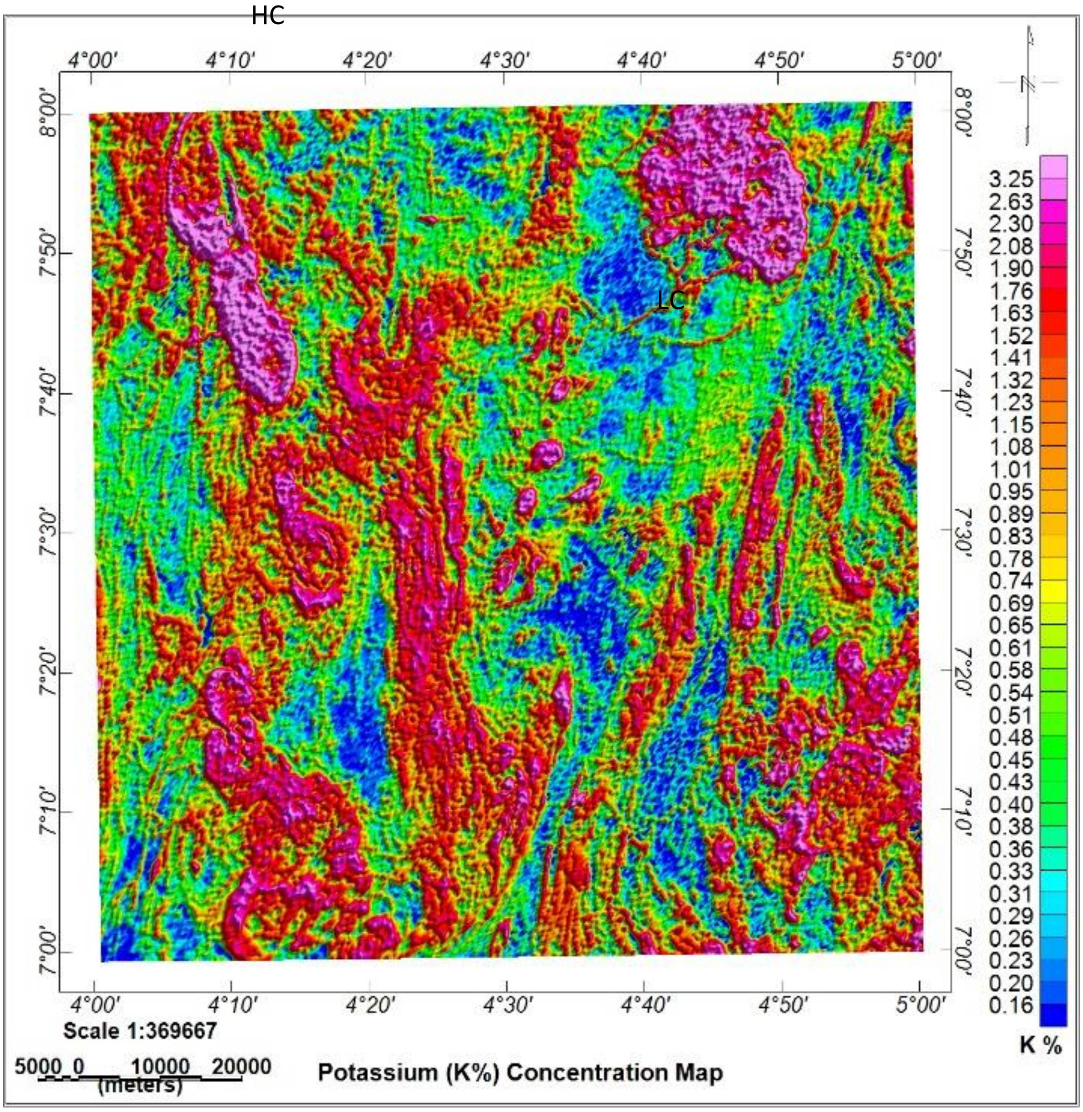


Figure 4.7a: Potassium concentration (K%) map

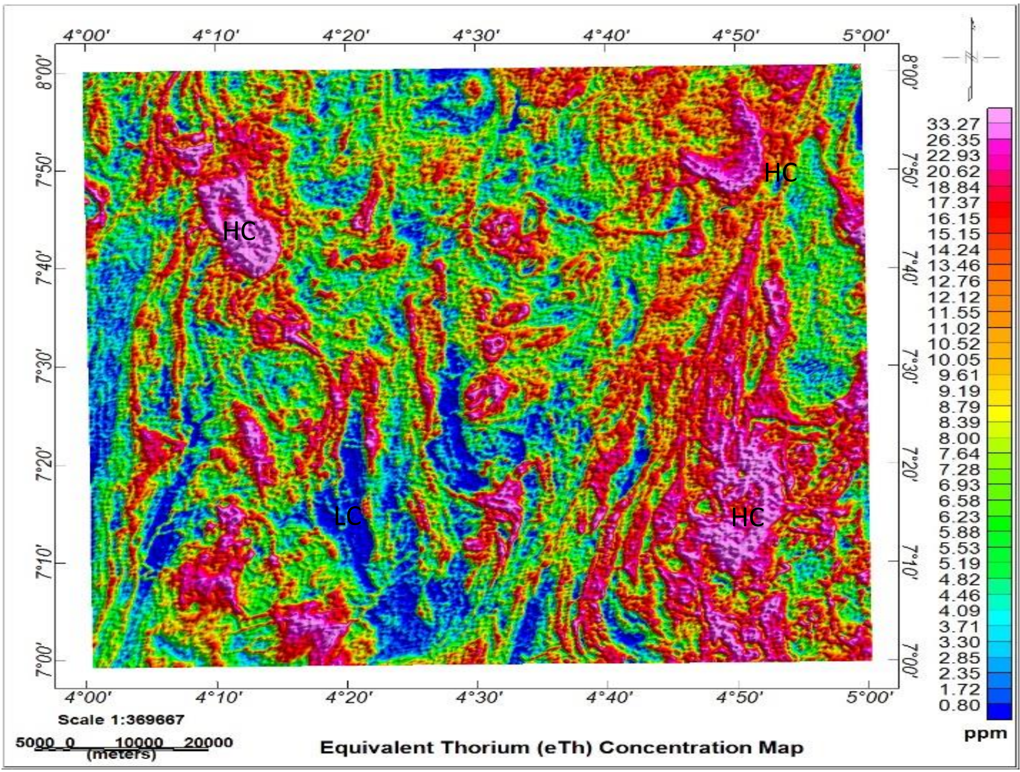


Figure 4.7b: Thorium concentration (eTh) map

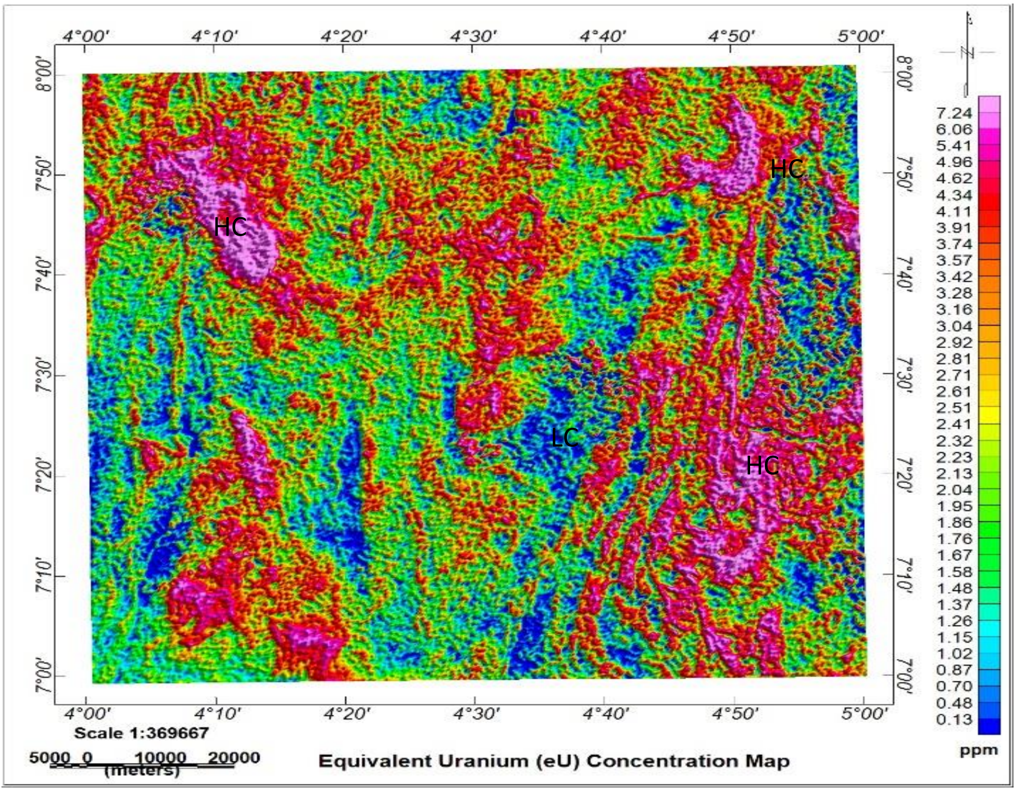


Figure 4.7c: Uranium concentration (eU) map

4.2.1.4 *Ratio Map K/eTh, eU/eTh and eTh/eU*

The degree to which the source materials of regolith are weathered or leached were obtained with the application of Th channel and ratio channel (K/Th U/Th). Potassium K response is associated with easily weathered minerals because of it mobilities features. Thorium and Uranium are usually related to residual clay, oxides and accessory minerals. The K/Th concentration map (Figure 4.8a) depicts some lithology contact and enhance alterations signatures. The increase in Potassium content in K/Th ratio map accompanied by Quartzite region is indicative of hydrothermal alterations. High K and low concentration of eTh are associated with alterations in many ore deposits (Ostrovskiy, 1975). These occur as a result of the K enrichment rock which is not accompanied by the Th during hydrothermal alteration process (Dickson and Scott, 1997). This assertion makes the K/eTh ratio map important when searching for signatures associated with hydrothermal alteration zones. Peak values of K/Th in pink colouration, registered at the western, central and Northeastern parts of the study area are clear indications of K enrichments due to alterations and thus potent host for gold mineralisation.

The Uranium and Potassium ratio map in (Figure 4.8b) show strong content of Potassium in red colouration and it implies weak content of Uranium and vice versa. Ostrovsky (1975) discovered that the weak content in Thorium with the strong content of Potassium occur at the shear contact zone between two geological formations. However, this was observed at the Northeastern and southeastern part of the study area. The number of mineralisation of Gold distinct demonstrates a rise in Thorium and Potassium within the Quartzite rock in the northeastern direction. The Th/U map in (Figure 4.8c) reveal the Thorium alteration zone reflecting coincidentally in increase in Thorium Th and Potassium K. The Southeastern and Northeastern of the study area are seen to record high

Thorium content and fairly high at mid-point of western and a trace of Thorium at Southern part of the study.

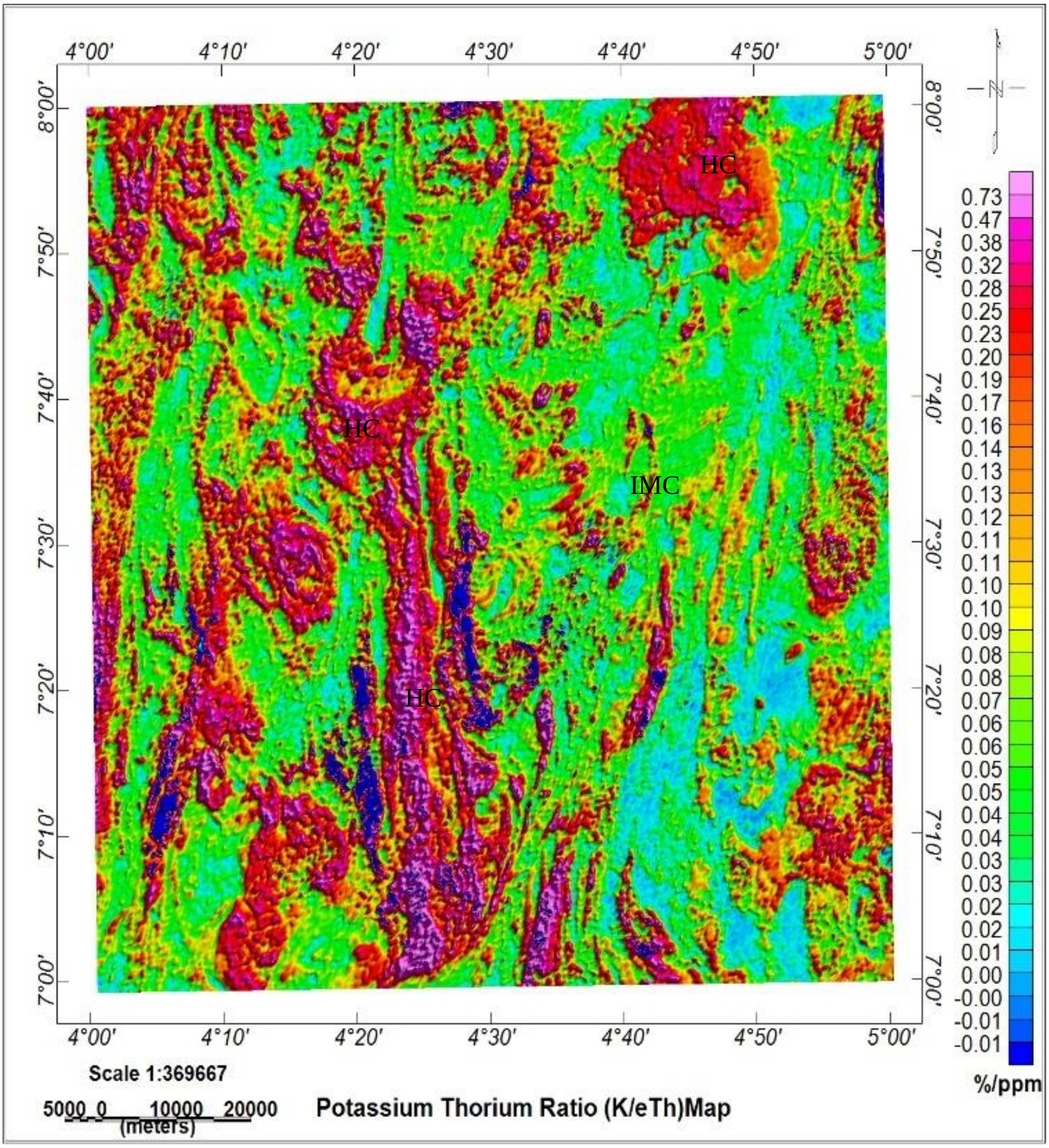


Figure 4.8a: Potassium and Thorium Ratio (K / eTh) map

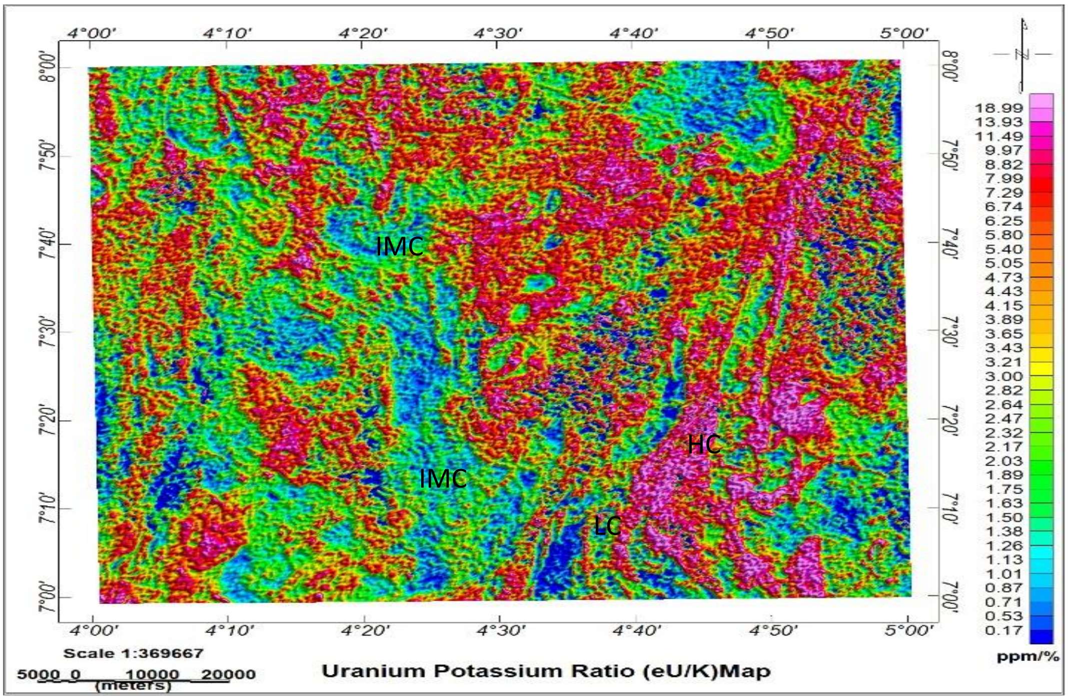


Figure 4.8b: Uranium and Potassium Ratio (eU / k) map

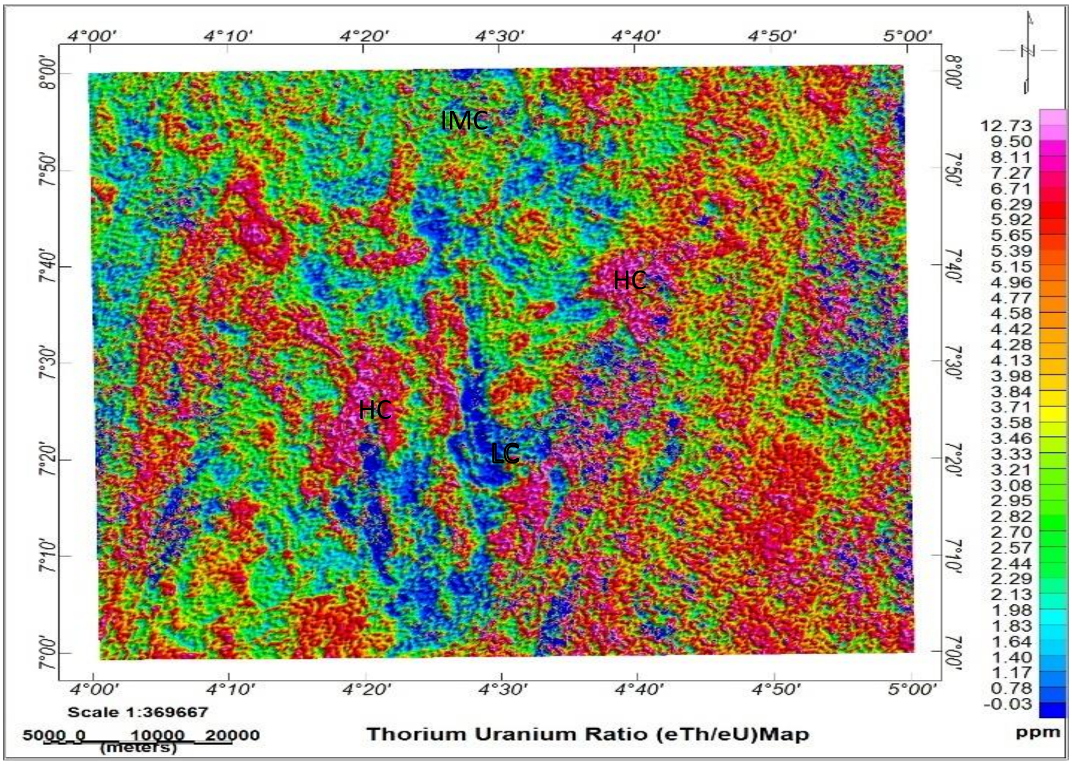
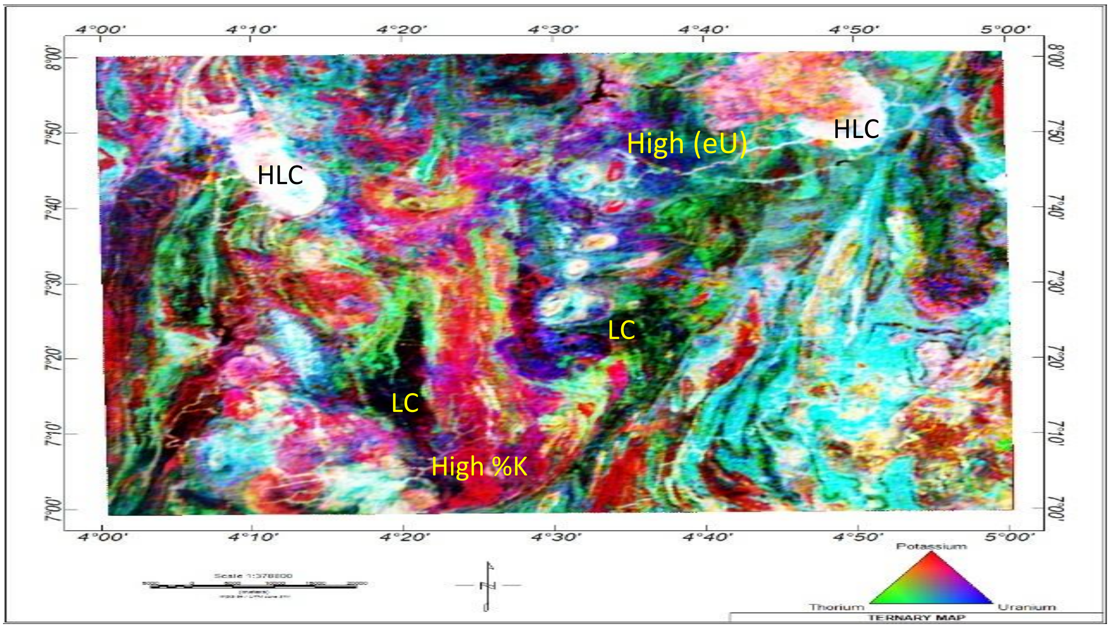


Figure 4.8c: Thorium and Uranium (eTh/eU) map

4.2.2 Ternary Map

Different rock types display different concentration characteristics of the three main radioactive elements (K, eTh and eU). Therefore, results gotten from this data are used to identify zones of consistent lithology and contacts between different lithologies. The Ternary map (Figure 4.8) of the study area showed the variations of the three radioelements. The map was produced by using different colours to represent the K (in percent), eU (in ppm) and eTh (in ppm). The colour index at each corner of the triangular legend (K in red, eU in blue and eTh in green) shows 100% concentration of the indicated radioelements. Relatively high concentrations of all radioelements appear as white while those with relatively low concentration appear as black. High K, eTh, and eU are observed to occur Northeastern at Okemesi underlain by Amphibolite and Northwestern at Ilesha Area underlain by Quartz schist and high concentration of Potassium observed at southwestern, northeastern and northwestern underlain by Amphibolite schist and Quartz schist.



HLC- High Level

LC- low Concentration

Figure 4.9: Ternary Map (RGB=K, eTh, eU) of the Study area

CHAPTER FIVE

5.0 CONCLUSION AND RECOMMENDATIONS

5.1 Conclusion

The analysis of aero-radiometric and aeromagnetic data for gold mineralisation over Ilesha and its environs, southwestern Nigeria was achieved by delineating mineralisation potential zones via mapping lithology, structural elements, and hydrothermal alteration areas.

The structural features were observed to have trended more in the NE-SW direction which may be associated with the orientation of the mineral deposits, as most magnetic minerals are structurally controlled. The direction of major lineaments also corresponds to the direction of the Ife-Wara and Iwaraja fault line, Ijero Ekiti and Ilawe Ekiti fault line that runs through the southwestern basement complex and the depth to occurrence of Gold mineralisation was found to not be more than 89 m.

The Ratios of the radioelements (K/eTh) determined the region of hydrothermally affected zones. These zones serve as pathways for the movement of fluids which could react with the granitic rocks. Significant traces of hydrothermally altered zones were mapped at the northeastern and central to southern part of the study area.

The affected regions of alteration coincided with regions of major magnetic lineaments observed on the first vertical derivative map and thus represent the regions of potential gold mineralisation.

5.2 Recommendations

The study thereby recommended thatnorth-eastern, central and southern parts of the study area are the regions of gold mineralisation and should be areas to be exploit for gold mining. Those areas are the zones delineated from both the magnetic and radiometric data sets. The delineated Gold mineralization zones should be signed to 2D electrical resistivity and Induced Polarisation methods so as to ascertain the level of conductivity layers.

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