Investigation of Subsurface Linear Structure Controlling Mineral Entrapment using Potential Field Data of Ilesha

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Abstract:- The purpose of the research was to identify the locations and the depth of the lineaments in the study areausing aeromagnetic and gravity data, through the investigation of its geological boundary structures. This was achieved through the processing of potential field data of Ilesha and its environs as acquired from Nigeria Geological Survey Agency. Various edge detection techniques such as First Horizontal Derivative (FHD), First Vertical Derivative (FVD), Power Spectrumand Analytic Signalmethod (ASM) were used while Euler deconvolution (ED) and Source Parameter Imaging (SPI) were applied to determine the depth and location of the lineaments generating the magnetic structures. The results shows the concentration of lineaments entrapment in southwestern part of the study area and tilted towards the center of the study area.The gravity depth range recorded in the study area is between 62.11 m and 4002.68 m from E.D analysis; and between 512.65 m and 4957.56 m from SPI. Whereas the magnetic depth recorded ranges from 1096 m to 4168 m for E.D analysis.

Keywords:- *Lineament, Ilesha, Derivatives, Analytic Signal, Source Imaging Parameter.*

I. INTRODUCTION

Nigeria is believed to be blessed with different mineral resources (such as gold, bitumen, coal among others) deposited in different region in the country especially in southwest. These enormous solid mineral resources has made people clamoring for the diversification of economy of the nation away from crude oil, but government apathy has made illegal, informal mining of untapped solid minerals a lucrative business among some citizen which have resulted to huge land degradation posing environmental hazards in some of these areas. However, providing more geophysical information about the entrapment of the subsurface mineral structure of some of these area like Ilesha and its environs (in the southwest) to complement research of other geosciences may further attract interest if the individuals or government to diversify from oil exploration.

Ilesha and its environs are one of the area in southwest endowed with mineral resources such as gold deposit, this research is focused on the investigation of subsurface linear structures controlling the mineral entrapment using potential field data of Ilesha. The mineral deposit in Ilesha can be attributed to faults, fractures and dike generated from rock deformation due to forces arising from the internal movements within the earth's crust thereby making it possible for mineralizing fluids to be injected in the areas through conduits (Maltman, 1990).

There are numerous researchers who have carried out detailed work in different areas around Ilesha and its environs using geophysical applications for delineation of mineral productive zones, depth to subsurface determination geologic features, subsurface geologic layers, shear zones, faults, groundwater mapping among others. Some of these researchers among others are Layade et al., 2021; Okpoli and Akinbulejo, 2022; Ozebo et al. 2017; Bassey and Odong, 2017; Ayodele and Odeyemi, 2010; Ilugbo and Adebisi 2017; Akeredolu et al., 2022; Onyedim and Ogunkoya, 2002; Lattman 1958. Ojo 1992;Ilugbo and Adebiyi 2017, Akinlalu et al., 2016; Folami 1992. However this research is focused on investigating and comparing the linear structure believed to have entrapped the mineral resources using aeromagnetic data and gravity data of Ilesha and its environsand also obtained geological information from various reliable sources for interpretation of lineament extraction.

The term lineament was first used in the 19th century by a geologist named William Herbert Hobbs, he defined lineament in his publications in 1904 and 1912 as the landscape lines generated as a result of faults and joints to reveal the geological formation of the basement rocks. Other researchers later explained lineament as straight lines or nearly straight lines that can be seen as fractures, faults, joints and/or folds to display the underground geologic structures. The significance of structural geology especially lineaments (e.g. fractures, faults and joints) cannot be underestimated because they serve as reservoir not only for oil, gas and groundwater but also significant to mineral deposit. Meanwhile several geoscientists have studied the relation between mineral deposition and lineament density (O'Leary et al., 1976; Han et al., 2018; Manghany et al., 2009; Magowe and Carr, 1999; Hobbs 1912; Hung et al., 2005).

This research would further provide future guide for mineral exploration for miners because it would minimize indiscriminate mining activities in Ilesha area if make available. Hence it focusses on investigating the mineral potentials using extraction of lineaments from potential dataset (aeromagnetic and gravity dataset) of the study area thereby generating further geologic information about the depths, direction and trends of mineral ore (Ilugbo and Adebiyi, 2017; Bayowa et al., 2014; Bala et al., 2017).

II. GEOLOGY OF THE STUDY AREA

Ilesha is situated in Osun State, Southwest Nigeria. It has the coordinate of latitude is 7º 30ˡ N to 8º 00ˡ N and longitude from 4º 30ˡ E to 5º 00ˡ E.It lies within the tropical climate marked by wet and dry seasons with an average elevation of 391m above sea level. Temperature in Ilesha is moderately high during the day and may vary from season to season. The plate tectonic process of Pan African belt involving the collision of passive continental boundaries of the West African craton and the active continental boundaries (Pharusian belt) of the Tuareq shield is believed to have produced the internal region of the belt which generate the Nigerian basement complex (Black et.al., 1979; Caby et.al., 1981; Leblanc, 1981). The results of these collision generated the major and minor fracture/faults, joint that is predominantly located from northeastern to southwestern direction in the study area. The geology of study area-Ilesha has further been discussed by several authors emphasizing the fact that Ilesha area is underlain by Precambrian rocks which forms the crystalline basement complex in southwestern Nigeria (Ajayi and Egedegbe, 2003; Rahaman, 1976; Kayode et al., 2011; Kayode, 2006; 2009; 2010; Ajayi, 2003; 1981; Folami, 1992 and Akintorinwa et al., 2010).

Rocks in Ilesha are structurally partitioned into two zones (Ozebo et. al., 2014; Kayode, 2009; Folami, 1992; Elueze, 1986). The first zone is called major fractured zone otherwise known as Iwaraja fault zone. The rocks constituting these zone are amphibolites (the youngest rock type in Ilesha), granite-gneiss (which made up of biotite-hornblede gneiss and biotite-hornblende granite), quartz-schist, amphibolite-schist, quartzite and migmatite-gneiss complex (the oldest rock in the study area. Burke, et al., 1976). These rocks form part of the Proterozoic schist belt of Nigeria predominantly developed in southwestern Nigeria. The amphibolites in Ilesha constitute a massive larger percentage of mafic and intermediate rocks in southwestern Nigeria, however it is seen as low lying outcrops and mostly present in riverbeds. The second zone considered as minor zone is also known as Ifewara faults located in the western part of Ilesha (Ozebo et al., 2004; Kayode, 2009; Folami, 1992). The rocks in this zone are garnet, quartz, chlorite bodies and dolorites (Cyril and Blessing, 2021; Kayode, 2006; Folami, 1992; Rahaman, 1976).

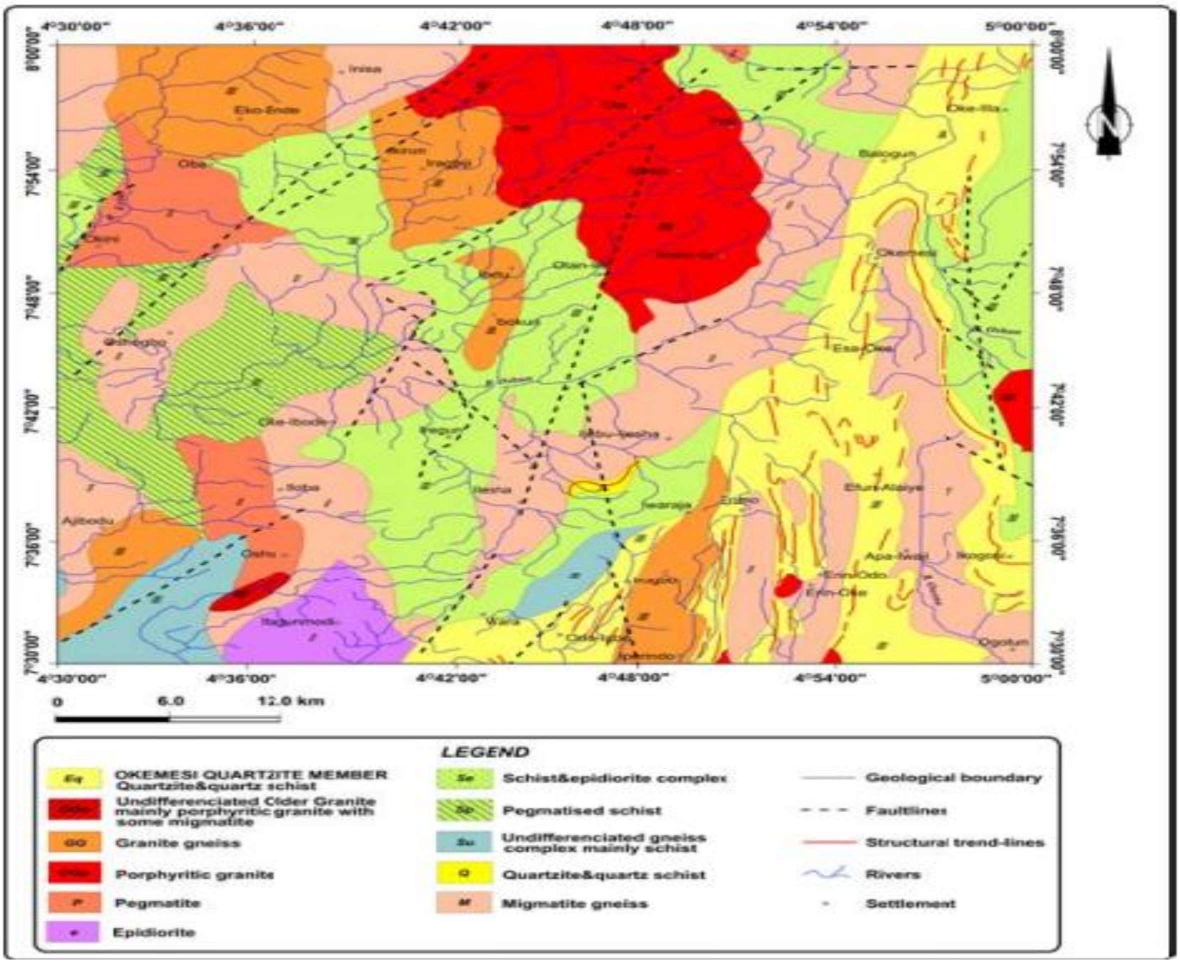

Fig. 1: Geological map of Ilesha and its environs (NGSA, 2009; Layade et al., 2021)

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III. METHODOLOGY

The materials employed in this study include a high resolution aeromagnetic dataset and corrected gravity dataset of Ilesha and its environs, both datasets correspond to sheet 243 on the sheet index map of Nigeria. The datasets were acquired from the Nigeria government through the Nigeria Geological Survey Agency (NGSA), as acquired for the agency by a Canadian outlet called Fugro Airborne Services. Other materials used in this research are potential field interpretation software like the QGIS, used in producing the geological map of the study area as well as Oasis Montaj v8.4 which helps to process, analyze and interpret the results of the research findings.

The aeromagnetic dataset obtained from NGSA (initially in gridded format) was converted to dataset to ease the processing. The figure 2 below shows the Total Magnetic Intensity (TMI) Map of Ilesha generated from the acquired data from NGSA. This map display the negative and lower intensity values because NGSA removed 33000nT values from all the data they acquired for easy computation. Therefore these values was returned to the dataset to generate the Real Total Magnetic Intensity (RTMI) of Ilesha and environs (figure 3).

In magnetic survey, the data acquired include the earth's magnetic field generated from the core (the center of the earth). This fields was generated due to the rotation of the earth and other unwanted cultural noises such as buried metals, moving vehicles etc. In other to remove these unwanted noise, the International Geomagnetic Reference Field (IGRF) values was removed using the Oasis Montaj which allows for the computation of IGRF values at every measured point in the study area.The generated IGRF values of each measured point were gridded to produce the IGRF map (figure 4).Total Magnetic Anomaly (TMA) map which represents the true condition of anomaly distribution in the area was produced (figure 5) after removing the IGRF values. The earth's magnetic field intensity decreases from the pole towards the equator thereby making magnetic anomaly interpretation difficult. This is because the peak of the anomaly is positioned wrongly over the magnetic sources. Hence the area of study which is located below the magnetic equator at low latitude is considered for reduction to magnetic equator (RTME) (figure 6) before any further analysis. The RTME would accurately reposition the magnetic anomalies directly over magnetic sources (Gilbert and Geldano 1985). Filtering techniques such as Analytic Signal (AS) and Derivatives were further carried out on the data to accentuate different magnetic signatures in the area.A power spectrum (P.S) and Euler deconvolution (E.D) maps was produced using a two dimensional Fast Fourier Transform technique, the map shows the noise level present in the data and depth to magnetic bodies.

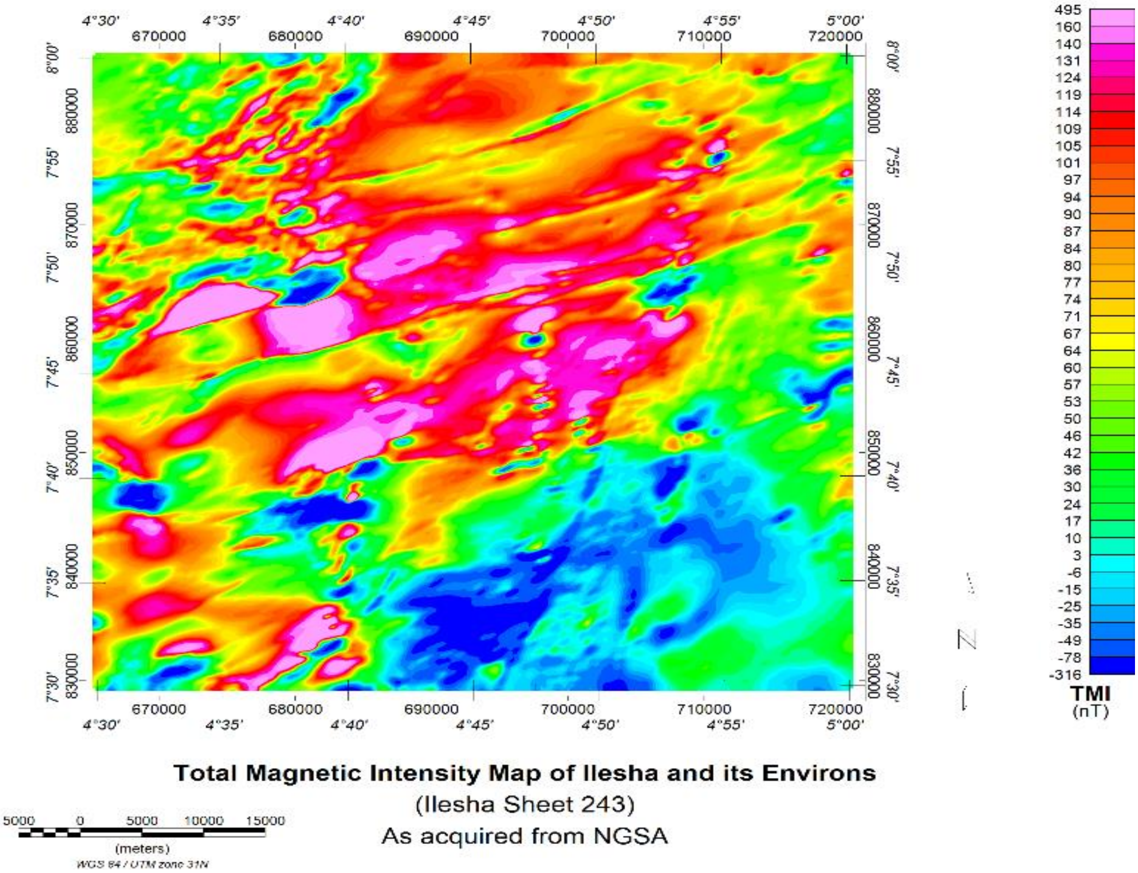

Fig. 2: Total Magnetic Intensity Map of Ilesha

The acquired gravity data from NGSA were in the format of a gridded data and then converted into dataset. The data were further gridded using minimum curvature algorithm to obtain Contour Bouguer Anomaly Map (figure 5).The regional residual separation of gravity anomaly was achieved through a high pass filter at 1000 m cut off wavelength using one dimensional Fast Fourier Transform for achieving the desired improvement in the quality of the gravity data. The result of these processes produced the residual anomaly map (figure 6).

IV. RESULT AND DISCUSSION

A. Aeromagnetic Interpretation

- *The Real Total Magnetic Intensity(RTMI) map*

The RTMI map (figure 3)was generated from TMI using Oasis montaj application to show the variation in locating the high and low magnetic anomaly susceptibility. The anomaly in magnetic bodies of the subsurface depicts information about delineation of subsurface magnetic structures through the variation in magnetic intensity values ranging from 32684 – 33495 nT. The high magnetic values (red to pink color) recorded majorly in the northwest is suspected to be due to the presence of youngest rock and amphibolites-schist in the area. However the low magnetic intensity (cyan to blue color) recorded majorly in the southwestern zone of the study area are as a result of the dominant of quartzite, quartz-schist, granite-gneiss and amphibolites.

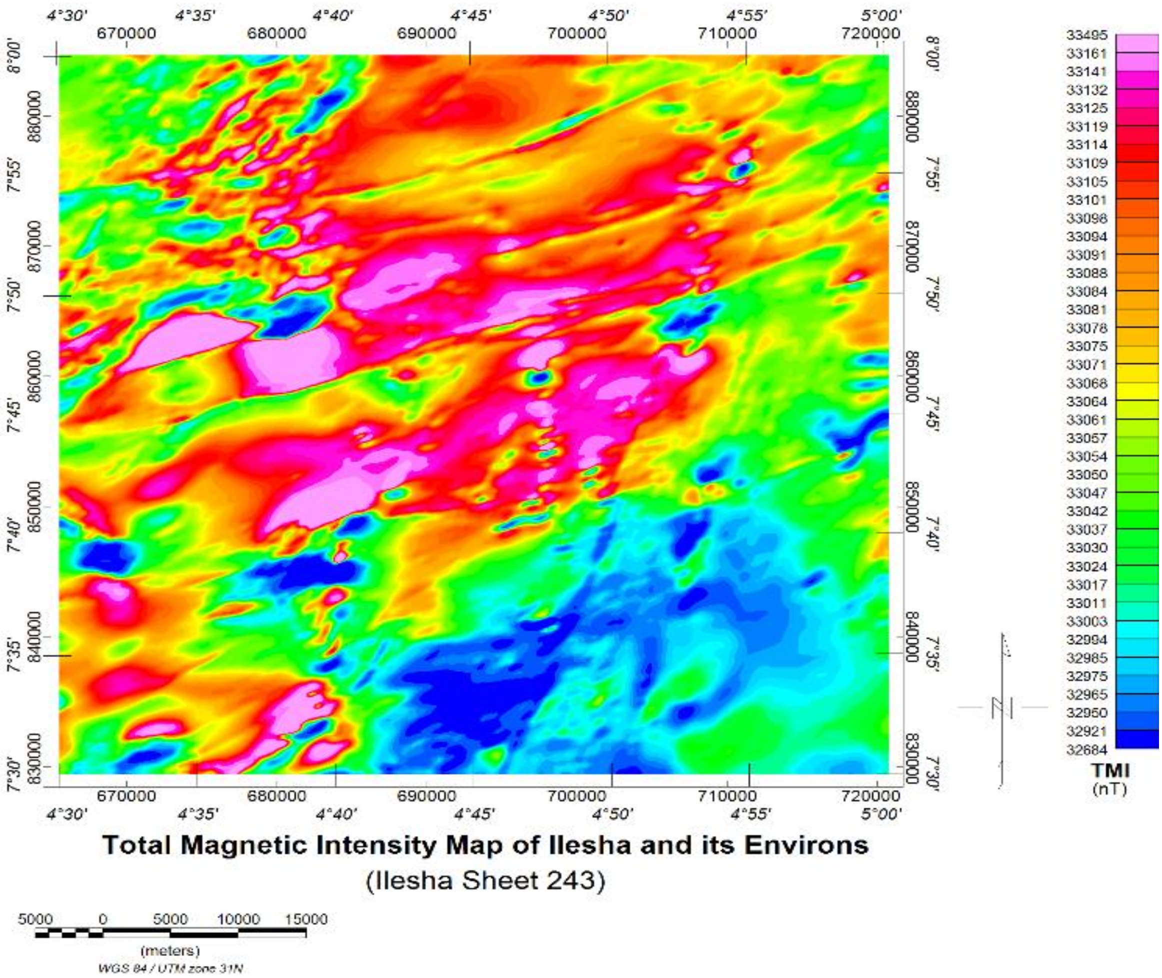

Fig. 3: Real TMI map of Ilesha and its Environs

- *The International Geomagnetic Reference Field (IGRF)*

Figure 4 below shows the International Geomagnetic Reference Field (IGRF) of the study area. The IGRF values display an increase from southwest to northeastern zone of the area.It can be said that northeastern zone contributes most to the magnetic field of the study area.

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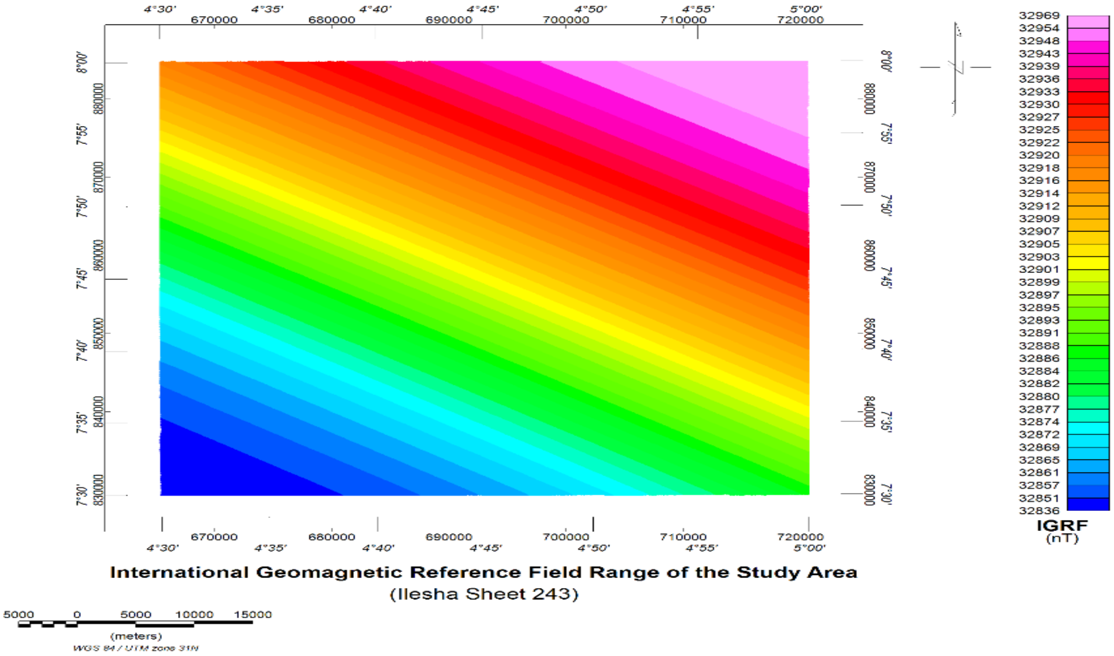

Fig. 4: IGRF map of the study area

- *Total Magnetic Anomaly (TMA) Map*

The total magnetic anomaly (TMA) of Ilesha presented in figure 5 recorded magnetic responses ranging between 610 nT and -193 nT. The region with reasonably high concentration of linear structures are located in southwestern part whereas the southeastern part is characterized by low concentration of lineaments. These linear structures may be related to tectonic activities such as faults and fractures in the study area. The south-east and north-east sections of the map are subdued magnetically to low magnetic responses. It has magnetic value ranging between 140 nT and -193 nT (from green color through cyan to blue color). The minimum magnetic anomalous value of -193 was discernible majorly at the south-east and some pocket of few places in south-west and north-west. The highest anomalous value of 610 nT labelled in south-west and part of north central could be attributed to the basement complex.

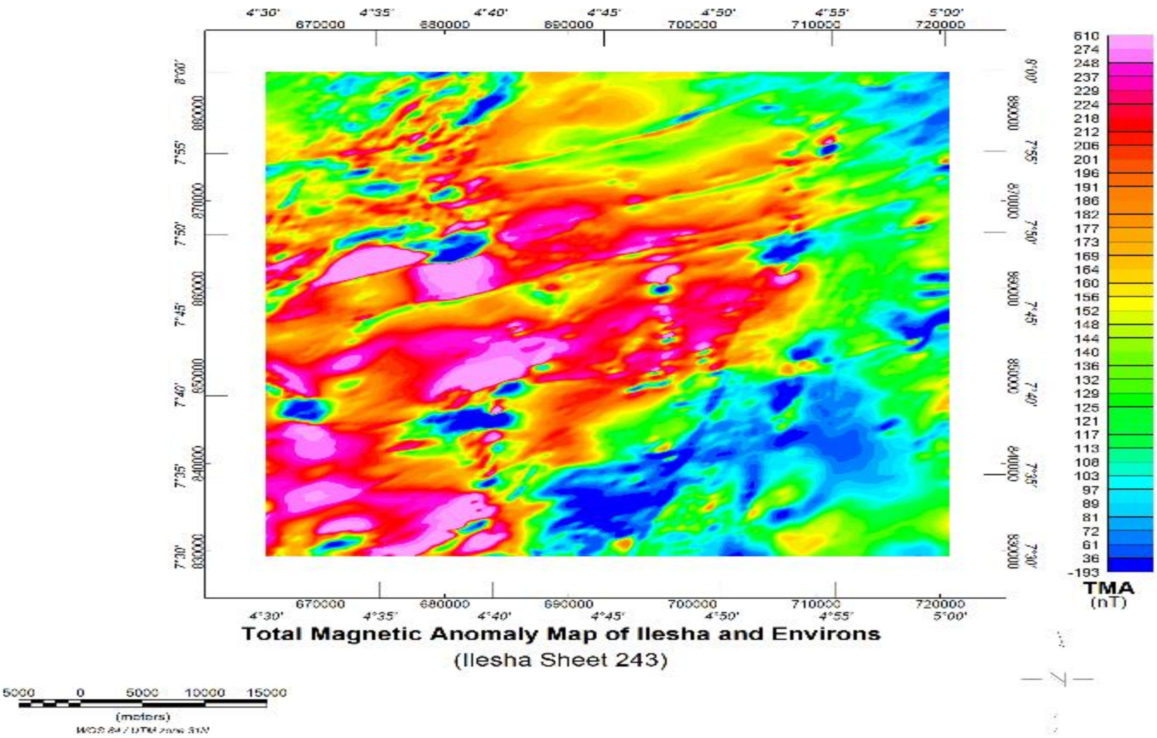

Fig. 5: The TMA map of Ilesha and its environs

➢ *Reduction to Magnetic Equator (RTME)*

The Reduction to Magnetic Equator (RTME) anomaly map of Ilesha and its environs as shown in figure 6 were to filter the anomaly to align the peak of the identified signals on the geologic bodies for better interpretation. The map is sectioned into three (3) major zones. The first zone is dominated with high concentration of linear structures with red to pink color originating from central part of the study area to southwestern part, it has a relatively high magnetic values between 184-360 nT and can be suspected to be lineament with high magnetic contents such as amphibolites schist, quartz and schist (Olomo et al., 2022). The second zone (blue to cyan color) is identified majorly in southeastern part of the study area with low magnetic intensity value ranging from -43 to 116nT. This zone is dominated with granite-gneiss, quartzite and migmatite-gneiss. While the greenish-yelowish area of the study area (intermediate zone) shows its amplitude magnetic intensity ranged between 116 nT and 184 nT.

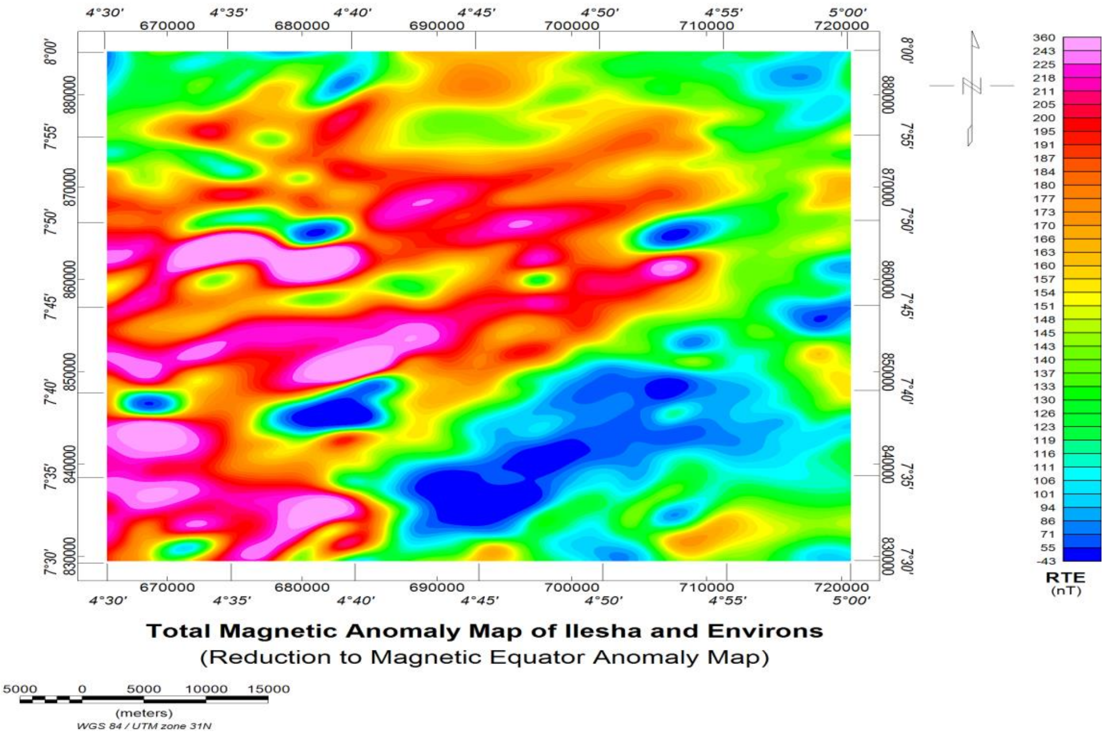

Fig. 6: The reduction to magnetic equator anomaly map of Ilesha and its environs

➢ *The radially Average Power Spectrum*

The radially Average Power Spectrum (figure 7) was produced using Reduction to Magnetic Equator (RTME) grid to show the level of noise and also generate the deep and final shallow magnetic sources which is less than 5 km. The noise level revealed on the spectrum are minimal. Smoothening filters were further required to accentuate the magnetic signature.

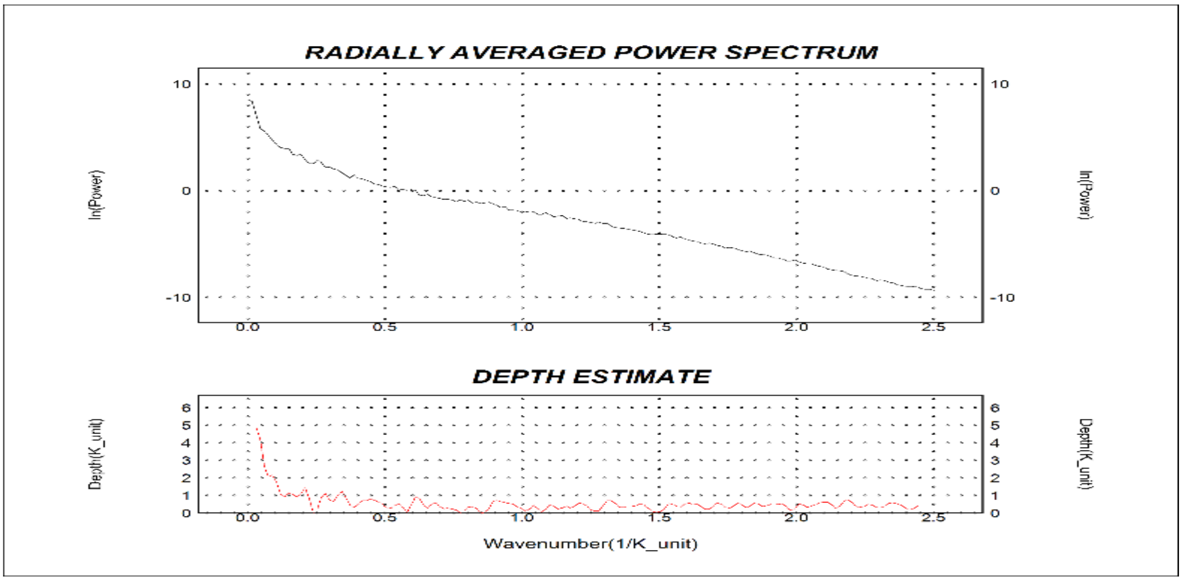

Fig. 7: The radially Average Power Spectrum

➢ *First Vertical Derivatives (FVD)*

Figure 8 represents the First Vertical Derivative (FVD) of the study area showing the values of magnetic anomaly ranges between -0.101 nT/m and 0.188 nT/m. The map displayed a pronounced and enhanced structural features (like faults, dykes and fractures)that serves as a major pathway for mineralization activities in the study area. The first segment (blue, cyan and green color) areas observed on the map corresponds to low magnetic response zones while the second segment (violet and magenta colors) trending from the north to south of the map is ascribed to high magnetic response zones (i.e. areas with high magnetic bodies). Observation also shows the presence of structural features that generates lineaments in the direction from northern to southern part. These identified lineaments may have contributed to transportation of mineralizing fluid through the Earth’s conduits which results in various mineral activities taken place in the area.

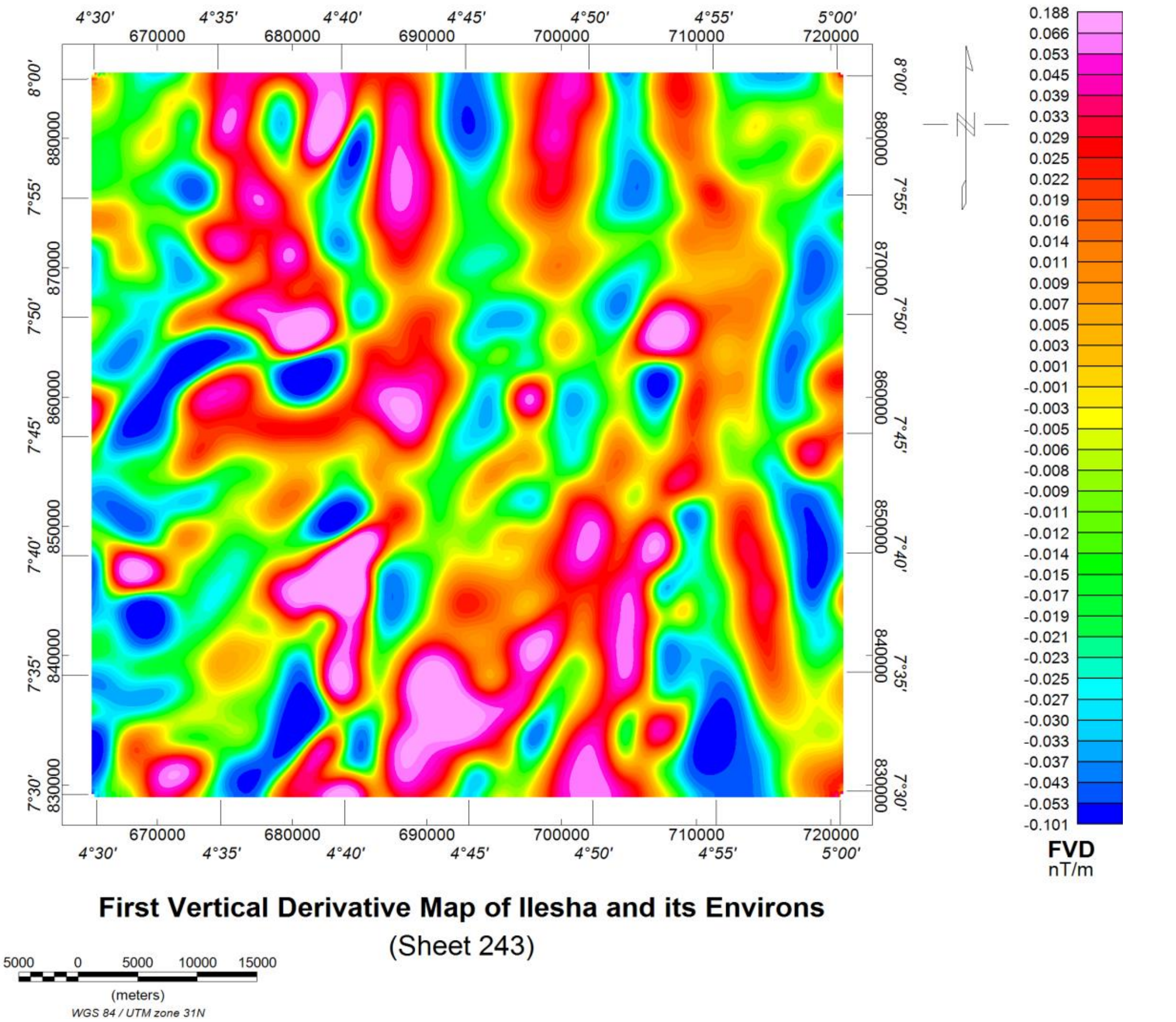

Fig. 8: First Vertical Derivative map

➢ *First Horizontal Derivatives (FHD)*

Figure 9 shows the First Horizontal Derivative (FHD) generated from aeromagnetic data processed using Oasis Montaj software. The filter is used in detecting the edges of magnetic anomalies dueto the enhancement of small and near surface magnetized structures related to the geology of the structures of the study area (Gupta and Ramani 1982). The map is identified with relatively highline aments (magnetic signature) with magnetic variation ranging from 0.001 to -.110 nT/m and an elliptical magnetic low responses (blue-yellow color) ranged between -0.001 to 0.159 nT/m.

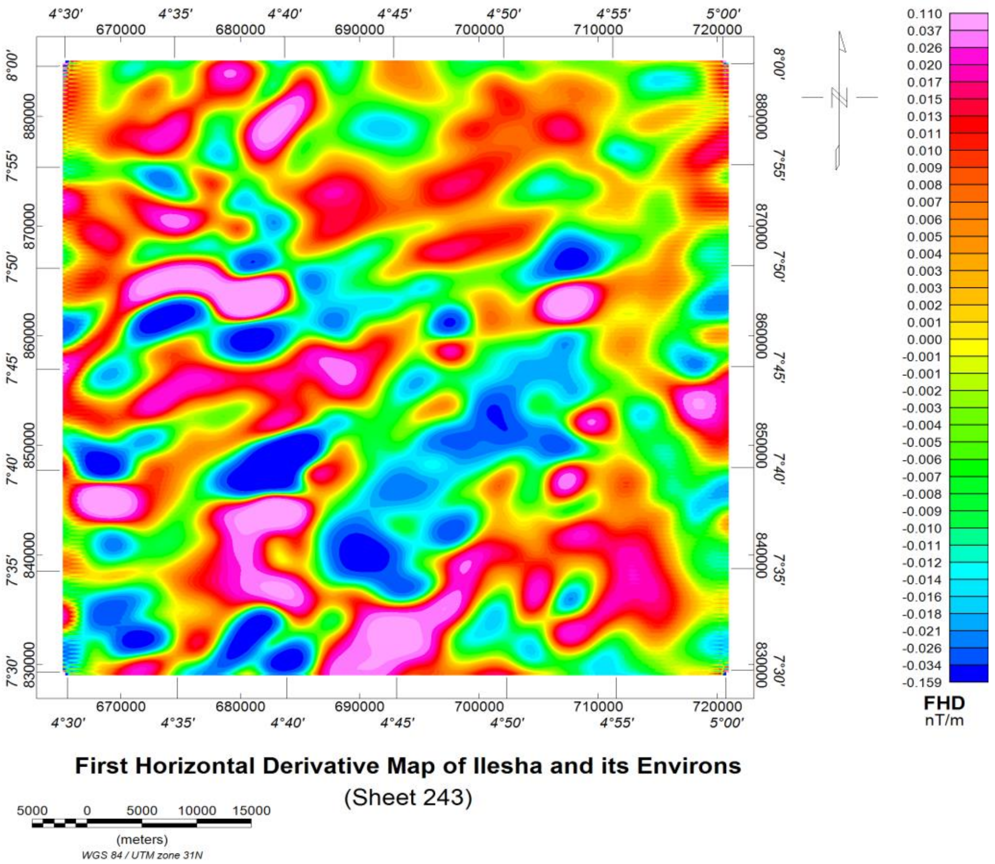

Fig. 9: First Horizontal Derivative map

➤ *Analytical Signal Map (ASM)*

The magnetic anomaly of analytical signal (figure 10) generated from aeromagnetic data shows clearly the boundary and location of the lineaments such as faults and fractures in the form of magnetic source bodies. The anomaly ranges between 0.001 nT/m and 0.189 nT/m. The map is discernible with high magnetic response trending majorly in south-west and north-western section of the study area as characterized by violet, magenta, pink and red colors.

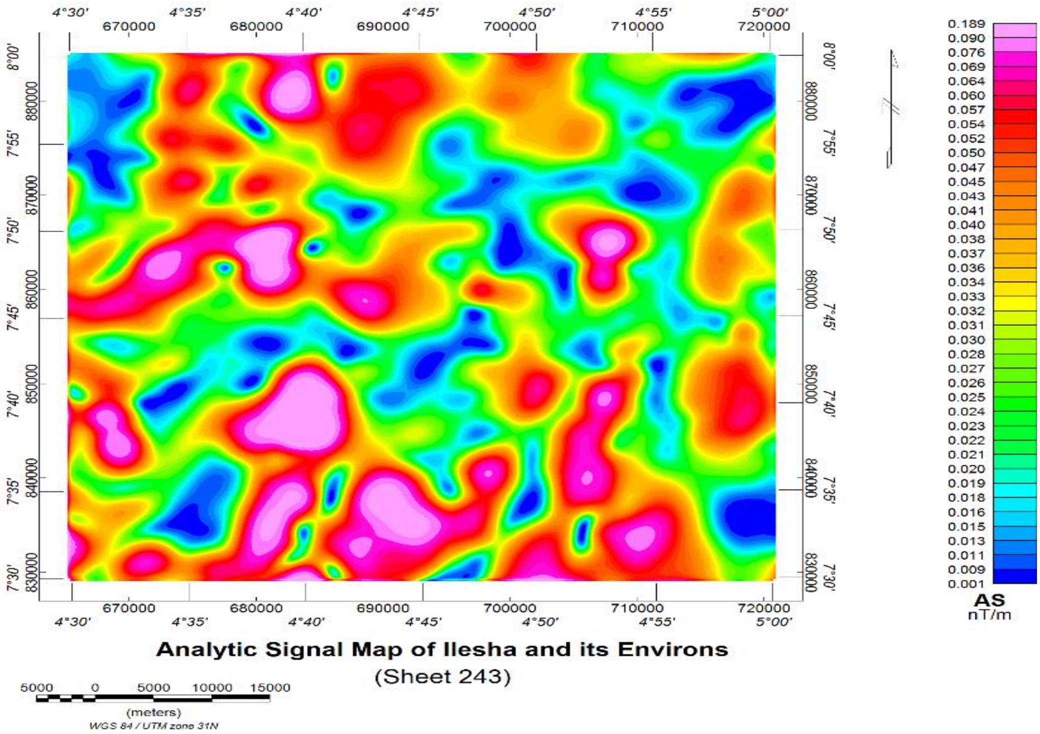

Fig. 10: Analytical Signal Map

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➢ *Euler Deconvolution (E.D) Map*

The result of E.D process on the airborne data of the study area with the structural index 1 is presented in figure 11. The minimum and maximum depths of magnetic bodies recorded are 1096 m and 3168 m respectively. The highest Euler depths recorded corresponds to region of deep magnetic sources while the shallow magnetic sources is located at the minimum depth range. The extracted location of the lineaments indicate the positions of faults, dykes and geological contact.

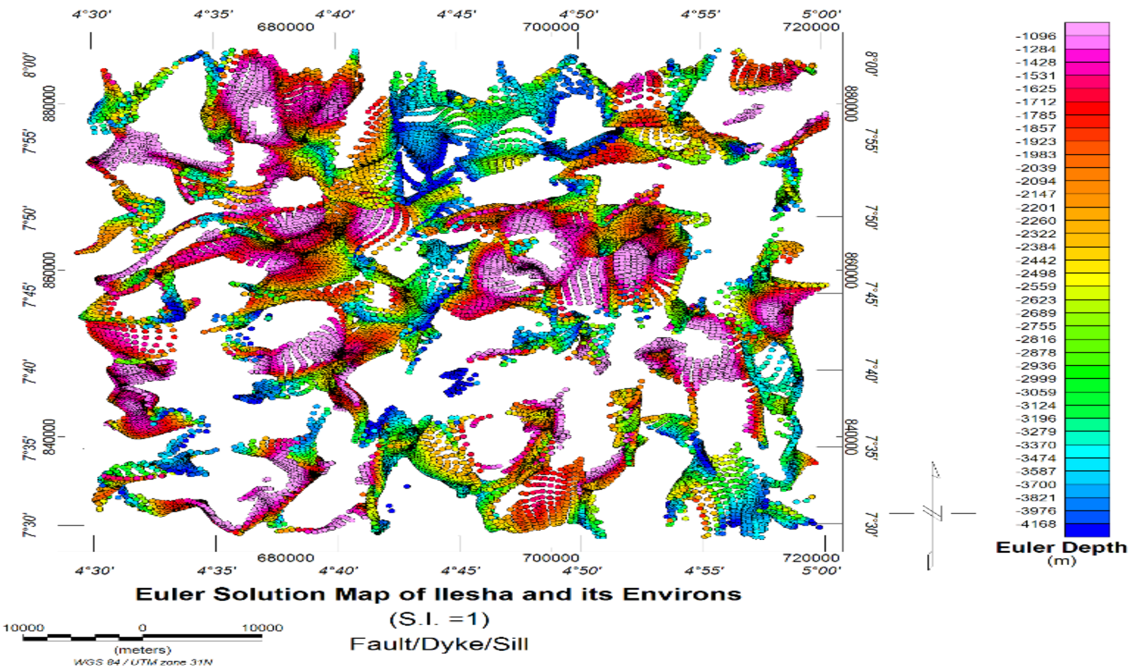

Fig. 11: Euler Deconvolution map of the study area

B. GRAVITY INTERPRETATION

➢ *Residual Gravity Anomaly Map (RAM)*

The Bouguer Gravity Anomaly (BGA) observed in fields are categorized into two (2): the regional anomalous field and the residual gravity anomalous field which is the anomalous of interest (Mickus et al., 1991; Linsser, 1967). A separation method was applied to gravity anomalous data to separate the anomalous of interest from the regional anomaly thereby produced a map called the residual gravity anomaly map (figure 12).

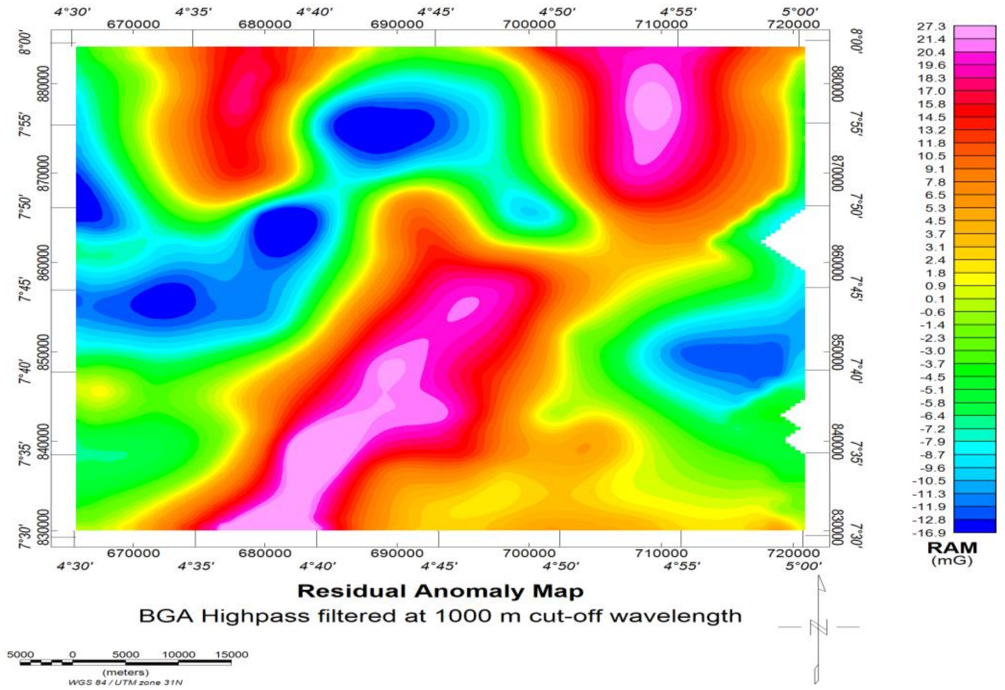

Fig. 12: Residual Anomaly Map

➢ *Contoured Gravity Anomaly (CGA)*

Figure 13 is the representation of Contoured Bouguer Anomaly (CBA) map which was achieved through a high pass filter at 1000 m cut off wavelength using a one dimension Fast Fourier Transform (FFT). The figure illustrates the lateral changes in gravity field of the earth, with the gravity anomaly ranges from 10.0 mG to 15.6 mG. It shows the maximum range of high gravity anomaly recorded in the study area and it's dominant in part of northeast tilting towards the center and southwestern part of the map. Generally, thisdominant high gravity anomaly may depict lineaments like faults and dike for the concentration of magnetic bodies.

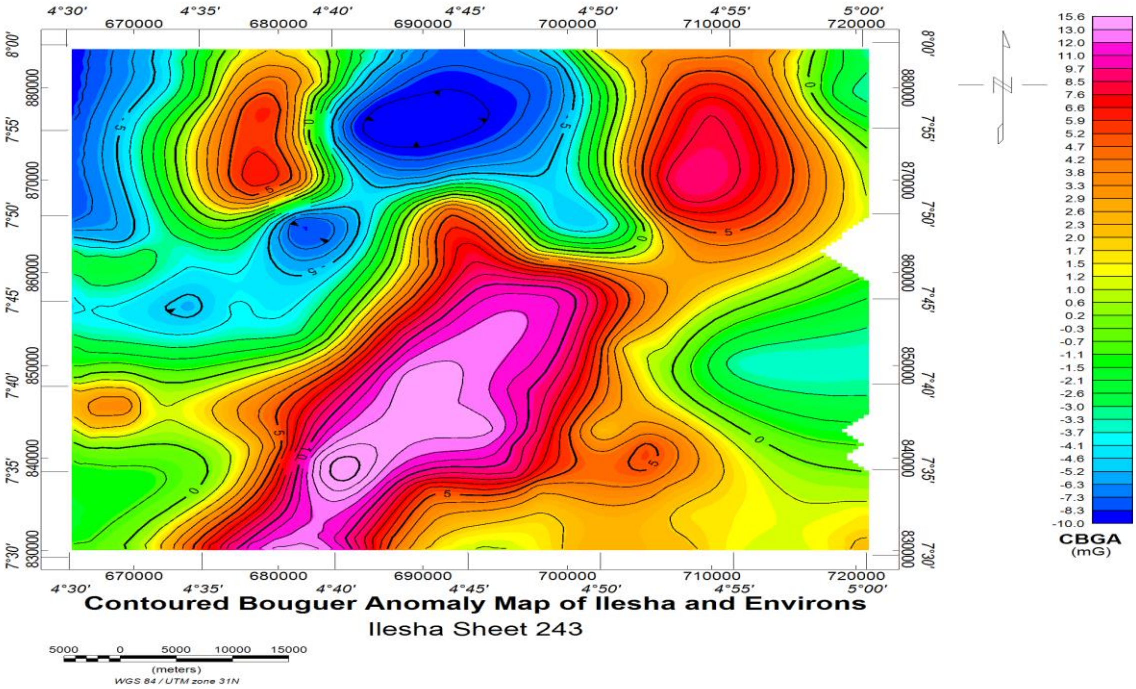

Fig. 13: Contoured Gravity Anomaly Map

➢ *Analytic SignalMap(ASM)*

The processing of analytical signal map reposition the anomalies directly above their respective magnetic (causative) structures. Figure 14 displayed the presence of lineament entrapement in the areas of high analytical amplitude which forms 'Y'-shape in the study area. The top end of the legend (from magenta to pink color) shows locations of the linear structures suspected to be mineral deposit of higher densities and it may coincide with the possible location of deeply seated anomalies such as the presence of amphibolite-schist, Quartz and some of the oldest rock type in the areas.

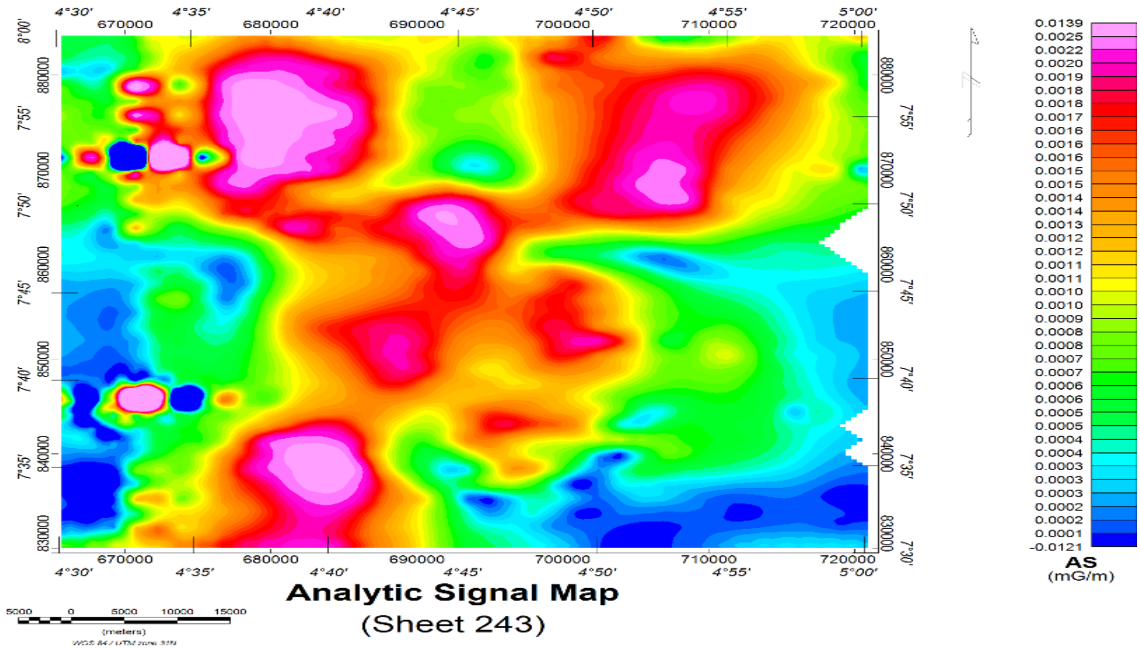

Fig. 14: Analytic signal map of the study area

➢ *First Order Vertical Derivative (FOVD)*

The First Order Vertical Derivative (FOVD) map presented in figure 15 displayed the sharpness in the edges of the gravity anomalies. It also revealed the direction of linear structures trending from the northern to southern part with even distribution of their positive and negative anomalies. The FOVD shows gravity values ranging from negative 0.0367 mG/m to positive 0.0231 mG/m. The maxima of FOVD(pink, magenta and red color areas) on the map can be interpreted as the locations of the magnetic structures (lineament) or any lithological contacts. The edges of the deeper bodies represents the zero values on the legend (Alhassan 2021 et.al.).

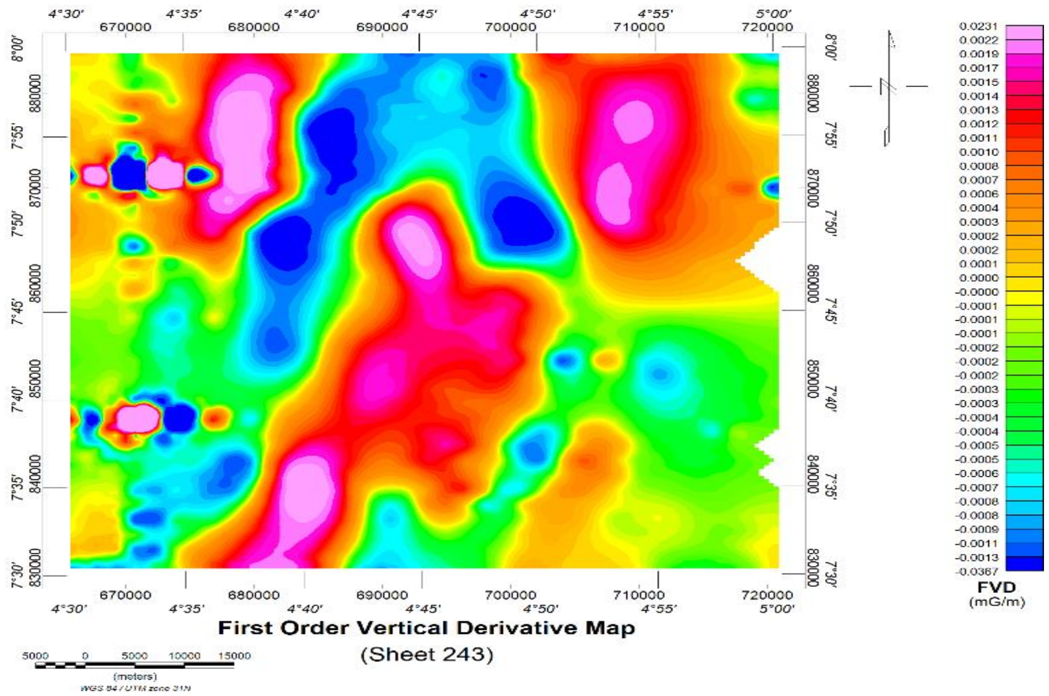

Fig. 15: First Order Vertical Derivative

➢ *First Horizontal Derivative (FOHD)*

The First Order Horizontal Derivative (FOHD) map of the study area (figure 16) was generated using Oasis Montaj, it revealed the exact position of the linear structures of mineral resources entrapped in the geologic dense structures with variation in their depth, and width in meters. The FOHD map generated the depth values ranging from -0.0154mG/km to 0.0306mG/km with the maximum depth (0.0306 mG/m) revealed at north-east and south west part of the study area.

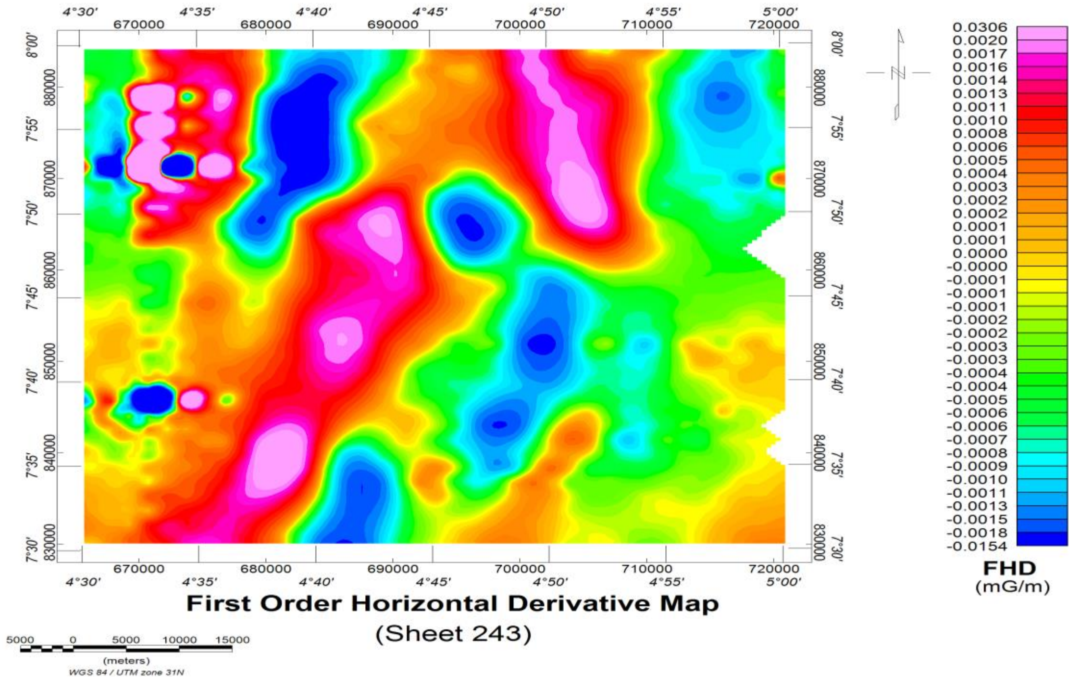

Fig. 16: First Order Horizontal Derivative Map

C. Depth interpretation

➢ *Source Parameter Imaging (SPI)*

Figure 17 is gravitySource parameter imaging (SPI) map used in generating the distribution of depth to anomalous variation in the study area through the application of Oasis Montaj. The depth recorded varies from -4957.96 m (deep gravity anomalous structures) to -512.65 m (shallow gravity anomalous structures). The negative values indicates the depths of buried gravity structures which may either be near surface or deep seated basement rocks.Generally, from red color upward (-1842.80 m) depicts areas of near surface intrusive while from cyan color of depth -3838.05 m to blue color of depth -4957.96 m are areas of deepest lying anomalous gravity sources. However, the intermediate depth range between magenta color and cyan color (i.e -1218.30 m to -3838.05 m) connotes less deep to shallow deep lying anomalous sources.

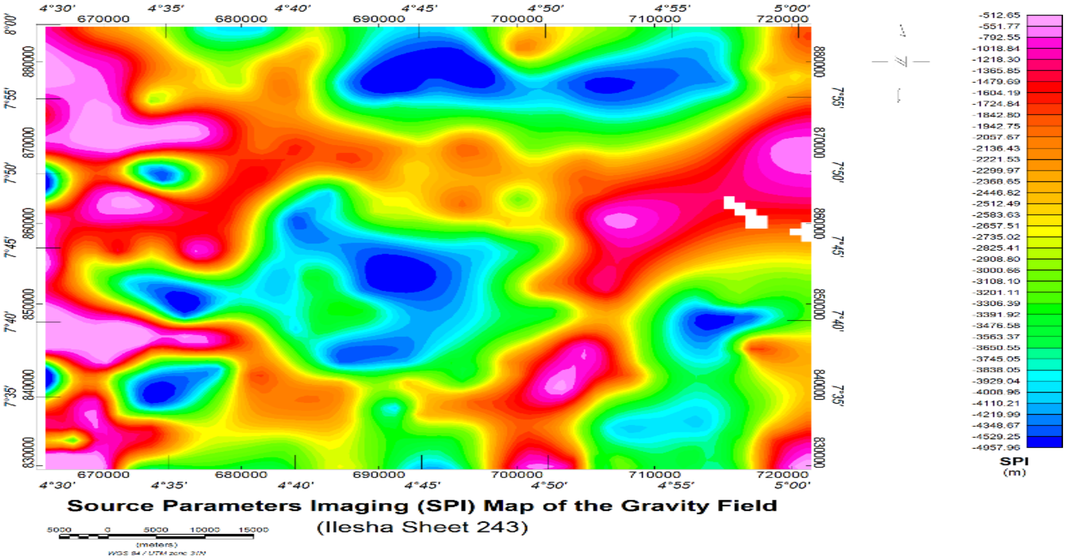

Fig. 17: Source Parameter Imaging of the study area

➢ *Euler Deconvolution (E.D)*

Figure 18 illustrate the Euler deconvolution result generated from Oasis Montaj application. The depth range from magenta color (-608.87 m) to the top end of the legend signifies shallowest depth areas of gravity anomalous structures, whereas the depth range from cyan color (-2854.91 m) to the bottom blue color is identified with deepest areas of the gravity anomaly. The depth range in between the cyan color and magenta color portrays areas of less deep to shallow depth of gravity anomalous structures (i.e. between -608.87 m and -2854.91 m deep). The negative depth values attached to the legend shows that determined depth is the depth below the subsurface.

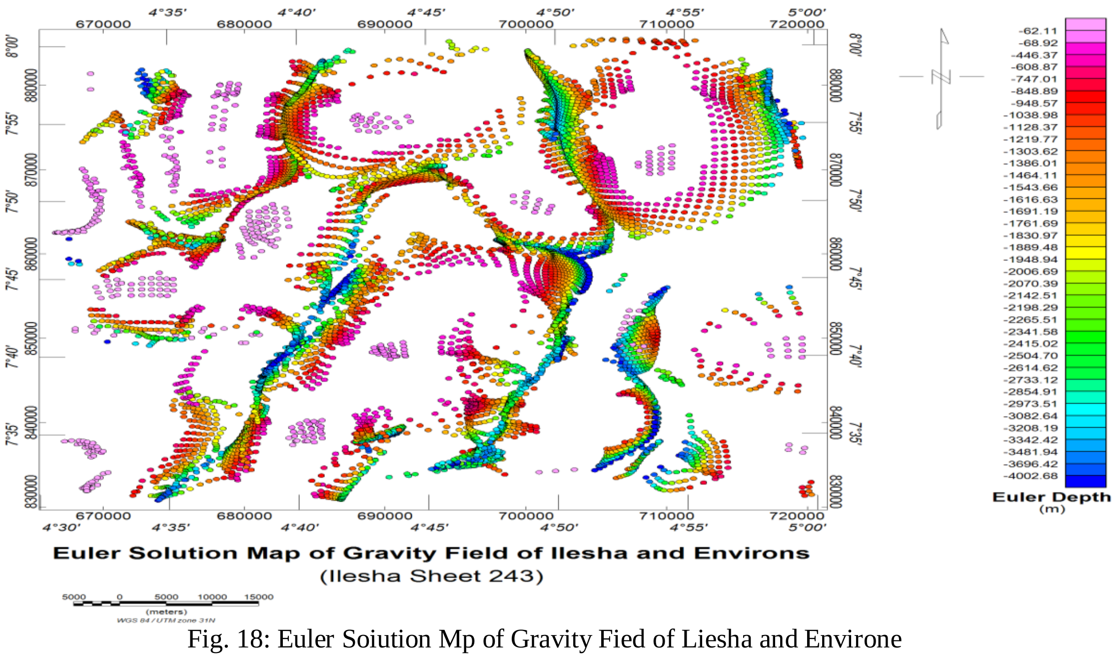

Fig. 18: Euler Soiution Mp of Gravity Fied of Liesha and Environe

V. CONCLUSION

This research have been able to investigate the patterns and trends of geological boundary structures of the study area to determine its lineament entrapment. Both qualitative and quantitative interpretation of the potential field data produced an insight on the trends and magnetic signatures of the fractures and faults of the study area. The edge detection techniques like analytic signal, derivatives and power spectrum were applied to the potential field data in other to identify the hidden geological features while SPI and ED were utilized to determine the depth. The results of the qualitative analysis shows high presence of mineral entrapment in the southwestern part and extends to the central part from both magnetic and gravity imagery of the study area, whereas the quantitative interpretation reveals similarities between the magnetic and gravity depth recorded for the mineral entrapment at the deep sources. The average deep depth recorded from gravity is 4480.32 m and 4168 m was recorded from magnetic interpretation. However the average shallow depth recorded from gravity is 287.38 m and 1096 from magnetic.

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