IOSR Journal of Applied Geology and Geophysics (IOSR-JAGG)
e-ISSN: 2321–0990, p-ISSN: 2321–0982.Volume 8, Issue 4 Ser. III (Jul. – Aug. 2020), PP 10-16
www.iosrjournals.org

Structural interpretation of Duhu and Adjoining Areas, Northeast Nigeria

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Abstract
Analysis of high resolution aeromagnetic data was carried out to evaluate the structural complexity of Duhu and adjoining areas, northeast Nigeria and its implication for mineral deposits. The total magnetic intensity data covering the areawas processed and filtered using Polynomial fitting method, Analytic signal and Pseudo-gravity. The polynomial fitting was used to carry out the regional residual separation to obtain the residual map. The analytic signalwas computed to enhance faults, fractures and folds. The lineament and corresponding rose plot show a dominate NE-SW trend with minor NW-SE and E-W structures within the study area. The northern and central parts of the area revealed high density of lineaments compared to the other parts of the study area,indicating areas that have been affected by high tectonic episodes. The lineaments are potential sites for mineral deposits. The pseudo-gravity map shows density variation of the study area and possible potential areas for non-magnetic/gravity controlled mineral deposits.

***Key Word**: Duhu and adjoining areas; Aeromagnetic data;Analytic signal; Lineaments; Pseudo-gravity*

Date of Submission: 16-08-2020 Date of Acceptance: 02-09-2020

I. Introduction

The study area according [1] lies between northings 10^{o}30'N to 11^{o}00'N and eastings 13^{o}00'E to 13^{o}30'E (Fig. 1). The area is characterized by hills to the southeastern and eastern parts, with other areas having low undulating topography. Drainage pattern is of the dendritic type, typical of a basement area. The aeromagnetic data over this area provide information about the structural patterns and hence the mineralization potentials of the area. Thus given an insight to the understanding of the structural geology of the area and its implication for mineral deposits.

The study was carried out,using the analytic signal and pseudo-gravity methods to delineate probable rock contacts, fractures, faults and possible folds and to identify deep seated magnetic anomalies which are imperative for the understanding of the tectonic episodes that affect the area and its associated mineralization.

According to [2] the geology of the study area (Fig.2) is made up of the Pan-African Older Granitoids which consists of three phases. The phases are distinguished as basic and intermediate plutonic rocks fine grain granites and syn-tectonic granites. These rocks vary considerably in structure, texture and mineralogy. The older granites are rich in potash which usually occur as microcline rocks phenocrysts. The basic and intermediate plutonic rocks include small irregular bodies of gabbro, quartz-diorite and granodiorite. The fine grained granites were intruded prior to the syn-tectonic granites, are a group of minor, discordant intrusions of small extent and alluvial [3].

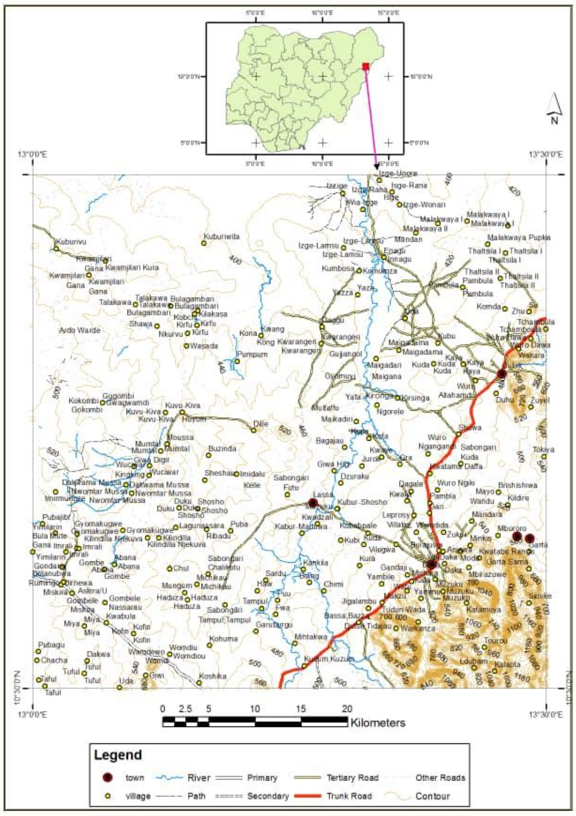

Figure 1: Topographic Map of The Study Area (After Digital Elevation Model 2006)

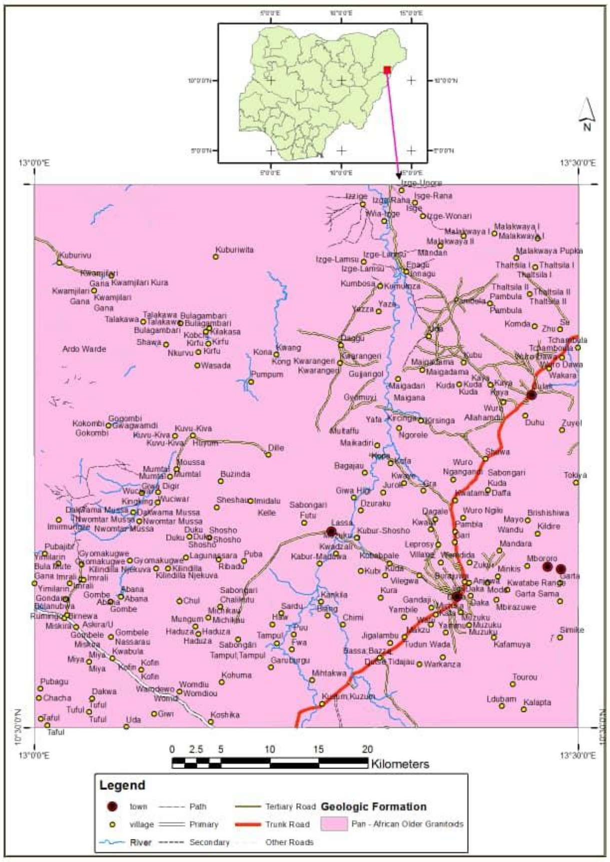

Figure 2: Geologic Mapof the Study Area (After Nigeria Geological Survey Agency 2006)

II. Material And Methods

Data Acquisition

The data that was used for the study, were procured from the Nigerian geological Survey Agency (NGSA), on a scale of 1:100000. The NGSA carried out a nationwide airborne aeromagnetic survey in 2009 with aim of diversifying the country's economy from mono product economy to other sector. Regional high resolution aeromagnetic data, were acquired in Nigeria by Fugro airborne survey limited for the NGSA between 204 and 2009. The acquisition, processing, compilation of the new data were jointly financed by the federal government of Nigeria and the World Bank as part of the sustainable management for mineral resource project. The aeromagnetic data was acquired using 3X Scintrex CS3 Cesium Vapour Magnetometer,were carried out by means of fixed-wing aircrafts flown at mean terrain clearance at 80m with 500m line spacing and nominal tie line spacing of 2km [4].

Data Processing

Polynomial fitting

The Polynomial fitting method was used in regional-residual separation to obtain the residual map. In polynomial fitting the regional is matched with mathematical Polynomial of low order to expose the residual features as random errors, and the treatment is based on statistical theory. The observed data are used to compute, usually by least square method, the mathematically described surface given 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 is the difference between the magnetic field value thus determined [5] [6] and [7]. The simplest approach is to fit a polynomial of first order to the magnetic data over a large area as possible around the zone of interest and to subtract the polynomial surface from the observed surface. If the regional field were a simple inclined plane it will be a first order surface. Thus

$$Z = Ax + By + C1 \qquad 1$$

The next stage of complexity is the representation of a second order polynomial where,

$$Z = Ax^2 + By^2 + CxyDx + Ey + F3. \qquad 2$$

The next stage of complexity is another representation of a third order polynomial, etc.

The residual magnetic field of the study area was produced by subtracting the regional field from the total magnetic field using the Polynomial fitting method. The computer program aero-super map was used to generate the coordinates of the total intensity field data values. This super data file, for all the magnetic values was used for production of composite aeromagnetic map of the study area using Oasis Montaj software version 7.0.1. The program was used to derive the residual magnetic values by subtracting values of regional field from the total magnetic field values to produce the residual magnetic map and the regional map.

Analytic signal

The analytic signal for edge detection in magnetic anomaly was first used by [8] and is now widely used in magnetic interpretation as a means of positioning anomalies directly over their sources. The amplitude of the simple analytical signal peaks over magnetic contacts and can also be used to find horizontal locations and depths of magnetic contacts. This transformation is very useful at low magnetic latitude as it is independent of the inclination of the magnetic field. This very important application made it suitable to be used on magnetic data over Nigeria because magnetic inclination for the country varies from 7˚N to 13˚S and it is classified as a region with low magnetic latitude. Authors such as[9] and [10] used magnetic derivatives to determine the shape and edge in magnetic data. The analytical signal is given by

$$AS = \sqrt{\left(\frac{dA}{dx}\right)^2 + \left(\frac{dA}{dy}\right)^2 + \left(\frac{dA}{dz}\right)^2} \qquad 3$$

This filtering technique is considered the simplest approach to estimate contact locations (e.g. Faults), because the gradient is largest at the edges of tabular bodies. It requires a number of assumptions about the surface. Such assumptions are that the regional magnetic field, the source magnetization, the contacts are vertical, the contacts are isolated and the sources are thick [11]. In contrast the method is least susceptible to noise in the data because it only requires the two first order horizontal derivatives of the magnetic field. In the characterization of a site that may have potential for hosting minerals, hydrocarbons and ground water, it is essential to understand the existent framework of brittle deformation zones in the bedrock. These zones have effect on groundwater transport and the hydrochemistry in the bedrock, and the rock mechanical properties.

Lineament statistics are generally presented as Lineament density maps, Density of lineament intersections per defined cell area and Rose diagrams showing the orientation of lineaments. Lineament statistics can be used to check the structural homogeneity in the rock. Lineament intersections are of general interest regarding the groundwater flow in the bedrock as they indicate the location of potential channels (intersections between two or more deformation zones). Lineaments are generally shorter than the structures they reflect and a lineament is generally formed by a trace of fracture. For the purpose of this work the lineaments were manually drawn on the analytic signal map.

Pseudo-gravity

The pseudo-gravity transform has some special characteristics that reduce the dominance of the shallow magnetic sources and enhances the amplitude of magnetic anomalies from deeper magnetic source rocks. The theory behind the method can be found in texts such as [12] and involves an integration of the total field magnetic grid to derive a pseudo-gravity grid.The pseudo-gravity transform was applied to the total magnetic intensity grid of the study area using the FFT filter package available in Oasis montaj.

III. Result

Figure 3 showsthe total magnetic intensity (TMI) map of the study area. The map was subdivided into low magnetic intensity area having dark-blue-light-blue-green colour with values range of -193.775nT to 16.939nT. This covers most of the northern part of the area. Medium magnetic intensity with yellow-orange colour having values with the range of 29.719nT to 95.421nT occur mostly in the northwestern part and high magnetic intensity with red-pink colour having values range of 101.597nT to 240.799nT, occurs in the southeastern part of the study area.

Figure 4 shows the residual magnetic intensity (RMI) map of the study area. The map was also divided into low residual magnetic intensity values that vary from -166.740nT to 5.957nT with dark-blue-light-blue-green colour, medium with yellow-orange colour having values range of 9.244nT to 29.159nT and high residual magnetic intensity with red to pink colour having range of values from 32.521nT to 132.322nT. High magnetic intensity anomalies occur in the central and southern parts with pockets in the northern part; medium magnetic intensity covers most of the entire study area accompanied by the low magnetic intensity.

Figure 5 shows the analytic signal map of the study area with manually drawn lineaments. The lineaments are widely distributed throughout the study area, with high density in the northern and central parts. Major magnetic anomalies were observed orienting in the NE-SW direction, with others in the E-W and NW-SE direction.

Figure 6 shows rose diagram of the study area with orientation of lineaments that were measured and plotted from the analytic signal map. Major trends of the lineaments are oriented in the NE-SW direction with the E-W, NW-SE as minors.

Figure 7 shows the pseudo-gravity map of the study area with major anomalies in the extreme eastern part extending from the north to south and another in the extreme western part extending from the north to the south. The density vary from -0.204mGal to 0.177mGal.

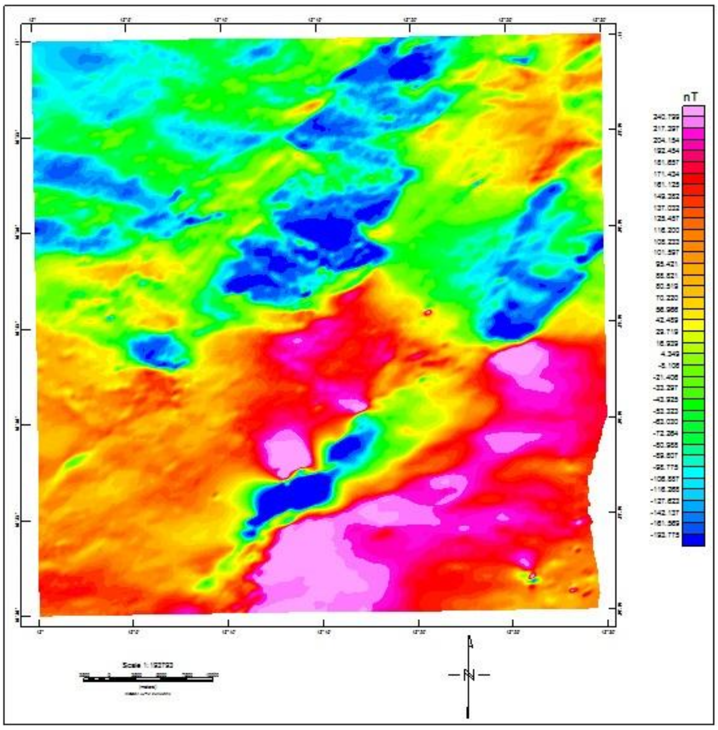

Figure 3: Total Magnetic Intensity (TMI) Map of the Study Area.

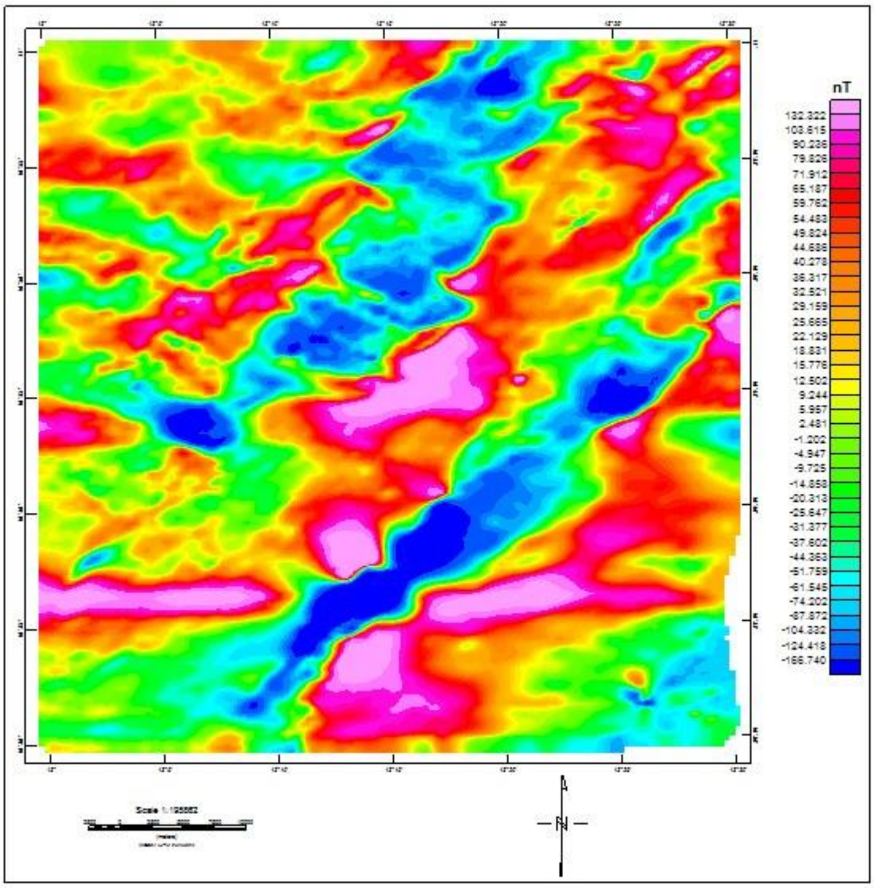

Figure 4: Residual Magnetic Intensity (RMI) Map of the Study Area.

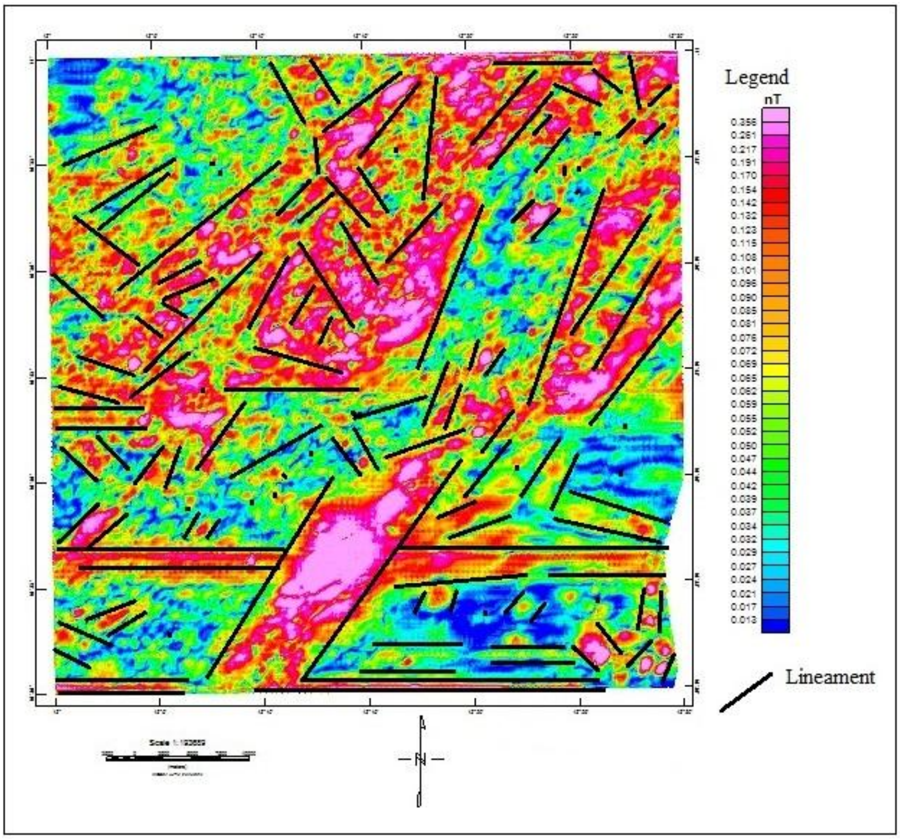

Figure 5: Analytic SignalMap of the Study Area showing Lineaments.

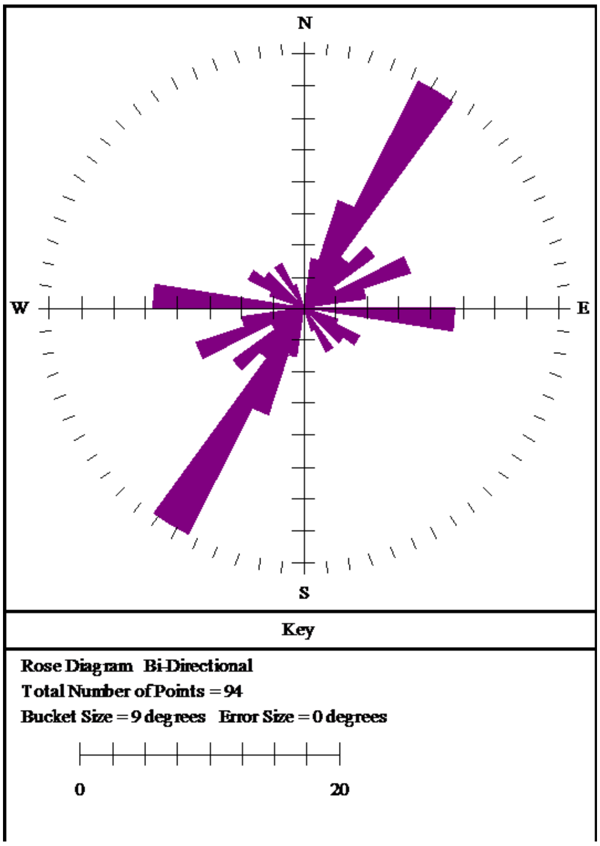

Figure 6: Rose diagram showing orientation of lineaments of the study area

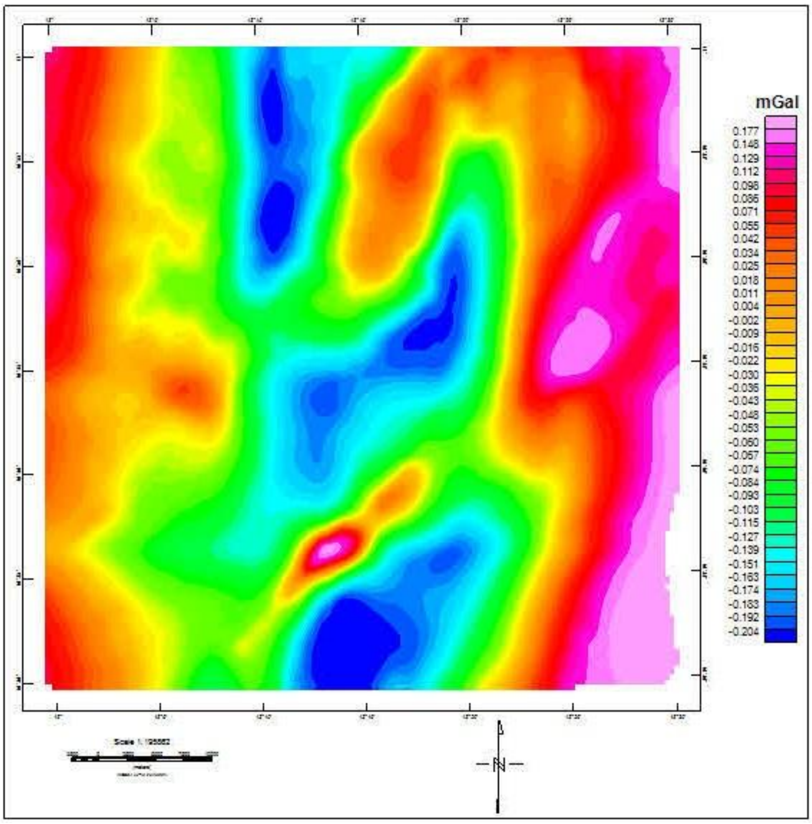

Figure 7: Pseudo-gravity Map of the Study Area.

IV. Discussion

The mineralization of rocks depends on the chemical composition of the rocks during their formation and the various tectonic episodes that has affected the rocks. Considering this fact, the total magnetic intensity (Fig.3) showed magnetic signature ranging from 101.597nT to 240.799nT. The magnetic highs observed could be as the result of the presence of basic rocks of dark coloured ferromagnetic minerals that contain minerals such as iron in form of magnetite; while the magnetic lows are associated with granitic and allied rocks.

There would always be a magnetic susceptibility contrast across fracture zones due to oxidation of magnetite to hematite and or infilling of fracture planes by dyke like bodies, whose magnetic susceptibilities are different from those of their host rocks. Such geological features appeared as thin elliptical closures or nosing on the aeromagnetic maps which is observed as magnetic lineaments on the residual magnetic map of the study area [13].

The result of the lineaments from the analytic signal map (Fig. 5) revealed lineaments with dominant trends in the NE-SW direction with minors in the E-W and NW-SE direction. The northern and central parts of the area indicate high density of lineaments compared to the other parts of the study area, indicating high deformational activities compared to other areas with low density as a result of low deformational activities.The azimuth diagram (Fig.6) further illustrated the magnitude and the trend of the fractures. Thesefractures are in line with the Pan-African and pre-pan-African deformational episode in the area. The fractures could be related to thosedeveloped in the pre-existing zones of weakness, which are in alignment to the major lineaments through Africa [14] and [15].Most high magnitude lineament could be attributed to deep seated fractures, while the low magnitude ones could be attributed to shallow weathered zones in the study area.Lineaments are sties for localized concentration of pegmatite dykes that could host various types of mineralization in major granitic intrusions.

The pseudo-gravity map (Fig. 7) shows density range of -0.204mGal to 0.177mGal. High density areas with pink colour could be possible areas for non-magnetic or high density minerals and therefore possible areas for exploration of gravity controlled minerals. The study therefore gives an insight to detailed geophysical, geological and geochemical investigation for mineral exploration of the area.

V. Conclusion

The structural complexity of Duhu and adjoining areas that was analyzed using high resolution aeromagnetic data, revealed different structural patterns of NE-SW as dominant trend of the area, while NW-SE and E-W are the minor structural trends. These structural trends are associated with Pre-Pan-African and Pan-African deformational episodes that affected the study area. These structures are potential mineralization zones and hence potential sites for mineral deposits. The findings of the pseudo-gravity revealed density variations of the area with high density occurring in areas with pink colour, which could be areas that host non-magnetic/gravity controlled mineral deposits.

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