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RESEARCH ARTICLE

CLASSIFICATION OF THE BASEMENT COMPLEX USING AEROMAGNETIC AND REMOTE SENSING DATA ANALYSES: CASE STUDY OF EKITI STATE, SOUTH-WEST NIGERIA.

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ABSTRACT

This study investigates the basement rocks in Ekiti State for the purpose of geophysical classification so as to delineate prospective area of mineralization within the State. Aeromagnetic data and satellite imagery covering the entire state were analysed using appropriate software. Reduction to equator geophysical transformation was first carried out on the residual magnetic intensity data before the application of Fast Fourier Transform filters to generate some derivative maps such as the analytic signal and tilt derivative maps which amplified lineament and enhanced both weak and strong magnetic anomalies. The Shuttle Radar Topography Mission (SRTM) data were processed to produce lineament density map, which was analysed for various linear and curvilinear features. The study area was classified into magnetic-high anomalous zone (HMA), magnetic-intermediate anomalous zone (IMA) and magnetic-low anomalous zone (LMA) based on the analytical signal analysis. Analysis of the structures showed the dominance of northeast-southwest and northwest-southeast trends. Evaluation of Lineament density showed high value of 0.5203 km^{-2} around the centre and the western part of the study area, which are also HMA and IMA zones, an indication of concentration of more faults, joints and line of weaknesses which may serve as favourable tracts for mineralisation in the study area.

KEYWORDS

Aero-magnetic data, total magnetic intensity, Magnetic anomalous zone, lineament density.

1. Introduction

The area of study is situated within the basement complex part of Nigeria, where features such as faults, fractures (lineaments), arched, or domed structures are useful indicators in mineral exploration (Peterson et al., 1976). Few large ore bodies are found at the surface, so there is increase in search for covered and deep seated minerals (Dentith and Mudge, 2014). Airborne magnetic method is used extensively in the mineral exploration industry especially for the delineation of mineralization zones and metalliferous deposits in many parts of the world (Boadi et al., 2013). The study of the magnetic field of the earth is the oldest method in geophysics. It has been known for a long time that the earth behaves like a large magnet (Telford et al., 1990). Due to the advancement in instrumentation, the entire crustal section can now be mapped at different scales, from strongly magnetic basement at regional scale to weak magnetic sedimentary contacts at local scale (Nabighian et al., 2005).

The conventional ground magnetic method is relatively expensive and tedious when used as a reconnaissance tool in mineral exploration. It is also not reliable because of the difficulty in accessing most vital areas of interest. The recent development in satellite technology or remote sensing technology has greatly improved mineral exploration activity and make lineament systems easily accessible (Salawu, 2021). It has a wide range of application in groundwater exploration, geological mapping, mineral exploration, tectonic studies and climatic and weather studies (Ernst, 1975).

Aeromagnetic and remote sensing data have been utilized for structural analysis in part of Ekiti state but general classification of the entire state for mineral exploration purposes has not been carried out (Talabi and Tijani, 2011; Jayeoba and Odunmade, 2015; Ademila 2018 and Salawu et.al., 2021). This study provides information about the lineament system and various locations of explorable magnetic anomalies through analysis and interpretation of high resolution aeromagnetic and digital elevation model data. The classification of the state into various zones of anomalous magnetic body will serve as guide in selecting areas to focus on during decision on exploration activities.

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2. Location, Geomorphology and Geology of the Study Area

Ekiti State is located within the tropical zone. It falls between longitude 4°5' and 5°45' East and latitude 7°15' and 8°5' north. It covers a total area of 5,435 square kilometres and surrounded by four states - Ondo State, Kwara State, Kogi State and Osun State (Figure 1). The average elevation of the state above the mean sea level is about 250 meters. It has an undulating land surface that is made up of landscape with old plains divided by steep-sided out-cropping dome rocks which may occur alone or in groups or ridges. The state has tropical climate with two major seasons - wet season, which normally occurs from April to October and the dry season, which starts around November and ends around March. The south-westerly winds that emanate from the Gulf of Guinea control the wet season while the dry north-east wind from Sahara desert controls the dry season. The study area enjoys a moderate annual temperature ranging from 25°C to 30°C and an annual rainfall of about 1 500 mm (Talabi and Tijani, 2011).

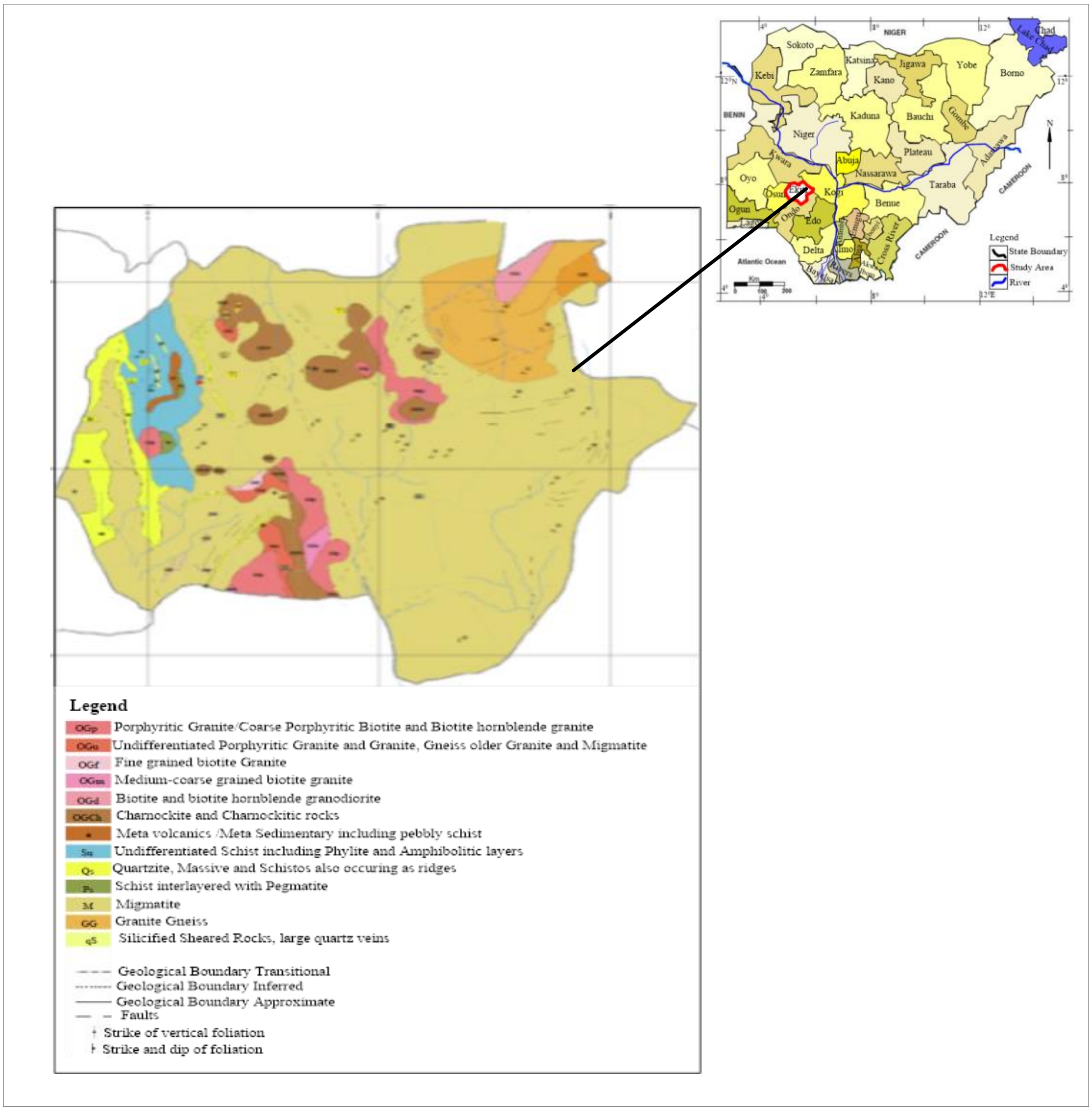

Figure 1: Geology and location map of the study area.

Ekiti State lies within the crystalline Basement Complex of Nigeria with major rock units as gneisses, schists, quartzite migmatite, charnockite, diorites, granites, granodiorites and pegmatites, all of which are of Precambrian – Cambrian age (Figure 1). The gneisses within the study area are of two types - the biotite gneiss (commonly fine grained and foliated) and the banded gneiss (which exhibits alternate light and dark colour banding).

3. Materials and Methods

Eight aeromagnetic sheets - sheet 224, 225, 243, 244, 245, 263, 264 and 265 in grid format, were combined to form a composite magnetic map of Ekiti state. The magnetic data were acquired by Fugro Airborne Survey using 3x Scintrex CS3 Cesium Vapour magnetometer for the Nigeria Geological Survey Agency (NGSA) during aeromagnetic survey programme in Nigeria between 2004 and 2009 (Salawu et al., 2021). Diurnal and secular corrections were carried out on the data by the survey company during on-board data processing. The re-projection of the data from WGS84 (universal transverse mercator of zone 32N) to WGS84 (universal transverse mercator of zone 31N) was carried out with GEOSOFT Oasis Montaj software because of the location of the study area on the map of the UTM grid zones of the world. This became necessary for proper alignment of the data coordinates with the exact locations in the study area. The Shuttle Radar Topography Mission Digital Elevation Model (SRTM DEM) of longitude 1.70°E – 20.50°E and latitude 3.50°N – 14.10°N was obtained from http://earthexplorer.usgs.gov/ and clipped to the extent of the study area which falls within longitude 4°5'E and 5°45'E; latitude 7°15'N and 8°5'N. Shuttle Radar Topography Mission (SRTM) makes use of Synthetic Aperture Radar (SAR) and Radar Interferometry systems to collect high resolution digital elevation models (DEM) of the earth. Shuttle Radar Topography Mission Digital Elevation Model is a useful set of data when no survey Digital Elevation Model data are available or when available survey DEM data are affected by large missing data or gaps where interpolation or extrapolation may not be appropriate (Wendi et al., 2016). It gives complete and high resolution digital elevation model of the earth (Rabus et al., 2003; Zhang et al., 2011).

4. Data Processing and Result

4.1 Magnetic data

The magnetic field intensity map of the study area was generated from the total magnetic field intensity grid data produced by the Nigerian Geological Survey Agency from the aeromagnetic data acquired by Fugro Airborne Survey Limited. It shows the differentiation in the magnetic field intensity over the entire Ekiti state, marked by low or negative and high or positive magnetic anomalies that vary from -126.78nT to 168.34nT (Figure 2a). This total field is composed of the short-wavelength spatial variations caused by the rock magnetism in the upper crust and the long-wavelength variations originating from the core, which needs to be separated from the observed field so as to obtain the residual effects, which are short-wavelength components and the anomalies of geological interest.

4.1.1 Regional – Residual Separation Of Total Magnetic Intensity

Least-square polynomial fitting of first order was utilized in the removal of the regional field from the total field to obtain residual field which is the magnetic field of the interest. Polynomial fitting methods assume that a polynomial surface adequately models the regional field whose smoothness is controlled by the polynomial order (Agocs, 1951; Simpson, 1954**)**. The values of the residual magnetic field intensity ranges from -162.0 to 126.1 nT (Figure 2b). This residual image shows clearer near-surface anomalies which could not be easily mapped out in the total magnetic intensity image. The variation of about 295 nT observed in the study area is due to wide variation in magnetic susceptibility values of various litho-units in the area.

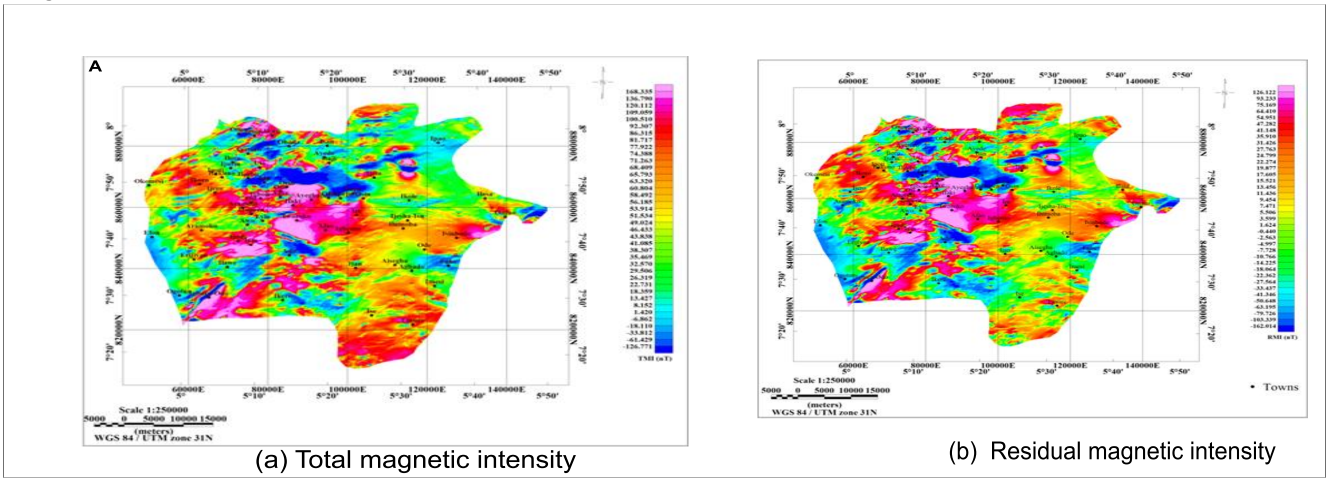

Figure 2: Total magnetic field intensity and Residual magnetic field intensity maps

4.1.2 Reduction to Magnetic Equator

The residual magnetic field intensity data were reduced to magnetic equator (RTE) and upward continued to 100 m before subjecting it other processing to correct for latitudinal effect and increase the signal-to-noise ratio of the data. The reduction to magnetic equator transformation was performed through the application of geophysical transformation filter with GEOSOFT Oasis Montaj software. The required values of inclination and declination for the process were taken to be -10.484^0 and -1.443^0 respectively. These values of the geomagnetic elements were for the centre of the study area.

4.1.3 Analytic Signal

Analytic Signal method is an interpretation technique of potential field data that depends on the calculation of the first derivatives of magnetic anomalies to determine the source properties and to locate position of geologic boundaries such as contacts and faults. The amplitude of the analytic signal produces maxima over magnetic sources regardless of the direction of the magnetization (Macleod et al., 1993).

The differentiation in the magnetization of the magnetic sources in the study area are accentuated by the analytic signal. It also highlights discontinuities and anomaly texture of the entire area. The analytical signal map displays high values, ranging from 0.0575nT/m to 0.323nT/m (pink) from north to south and towards the west while regions with low values from 0.0048nT/m to 0.0188nT/m (blue) can be seen in the southeastern part (Figure 3)

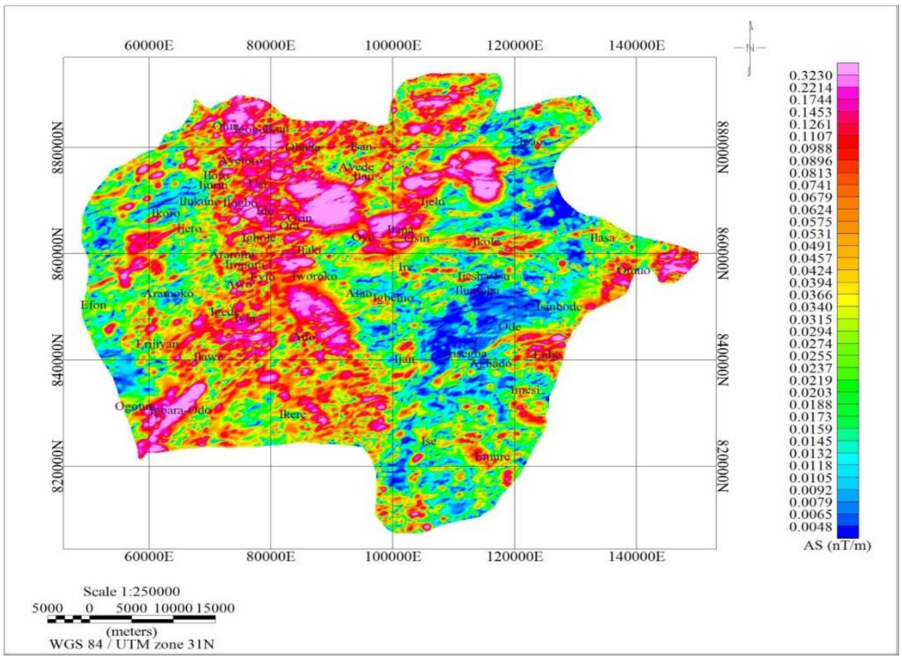

Figure 3: Analytic signal map of Ekiti State

4.2 Lineament Analysis

Lineaments can be defined as the mappable and simple linear features of a surface, whose parts are aligned in rectilinear or slightly curvilinear relationship that differ clearly from the patterns of adjacent features and presumably reveal subsurface phenomenal (O'leary et al., 1976). They are expressions of old, deep-crustal or trans-lithospheric structure which are periodically reactivated as planes of weakness during subsequent tectonic activities.

The Shuttle Radar Topography Mission digital elevation model of the study area was enhanced in ArcMap to generate hill-shaded DEM which

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evinced the linear features in the area. The hill-shaded image produced was saved in Tagged Image File Format (TIFF) and imported into PCI Geomatical for lineament extraction. Evaluation of the lineament density map revealed high concentration of lineaments in the western and central parts of the study area with high value of 0.5203 km^{-2} (Figure 4). This is an indication of concentration of more geological features like faults, joints and line of weaknesses, which could serve as conduits or trapped zones for mineralizing fluids in the areas.

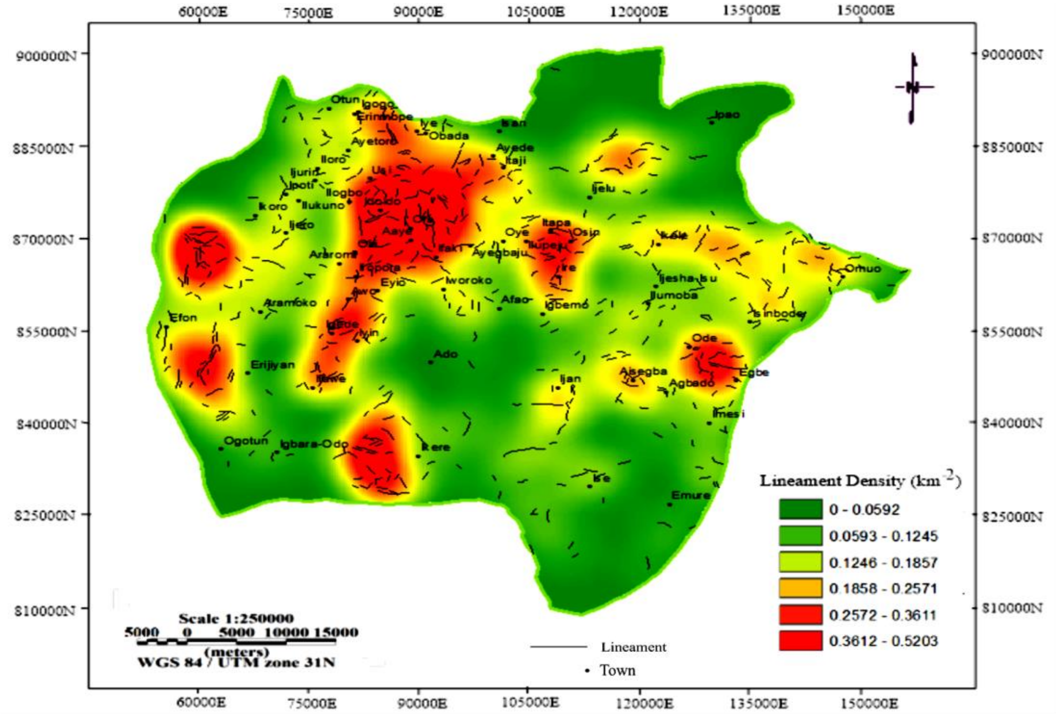

Figure 4: Lineament density map of Ekiti State

4.3 Integrated Analytic Signal And Lineament Map

Magnetic minerals are normally concentrated along some geological structures which can be seen as magnetic lineaments. The dominant linear features which trend along northeast to southwest and northwest to southeast directions are found majorly around the northwestern part of the study area. A few numbers of magnetic lineaments trending E - W were also noticed in some parts of the study area

Based on the analytic signal analysis of the aeromagnetic data of the study area, Ekiti State can be classified into three magnetic zones – magnetic-high anomalous zone (HMA), magnetic-intermediate anomalous zone (IMA) and magnetic-low anomalous zone (LMA) (Figure 5). The magnetic-high anomalous zone, which span from the south between Igbara-Odo and Ikere, through the centre, around Ado, Eyio, Ifaki and Iworoko, to the north, between Ijelu and Otun, is characterized by magnetic anomalies trending NW – SE and NE – SW directions. The integrated analytic signal and lineament map (figure 5) reveals clearly concentration of more lineaments that trend along NW – SE and NE – SW directions in this zone. Due to these features, this region is believed to have more mineral potential than the two other zones. However, similar trends and some minor magnetic anomalies are observed at the two other zones especially around Ijero in the IMA zone and Egbe area in the LMA zone. These are also mineral potential areas

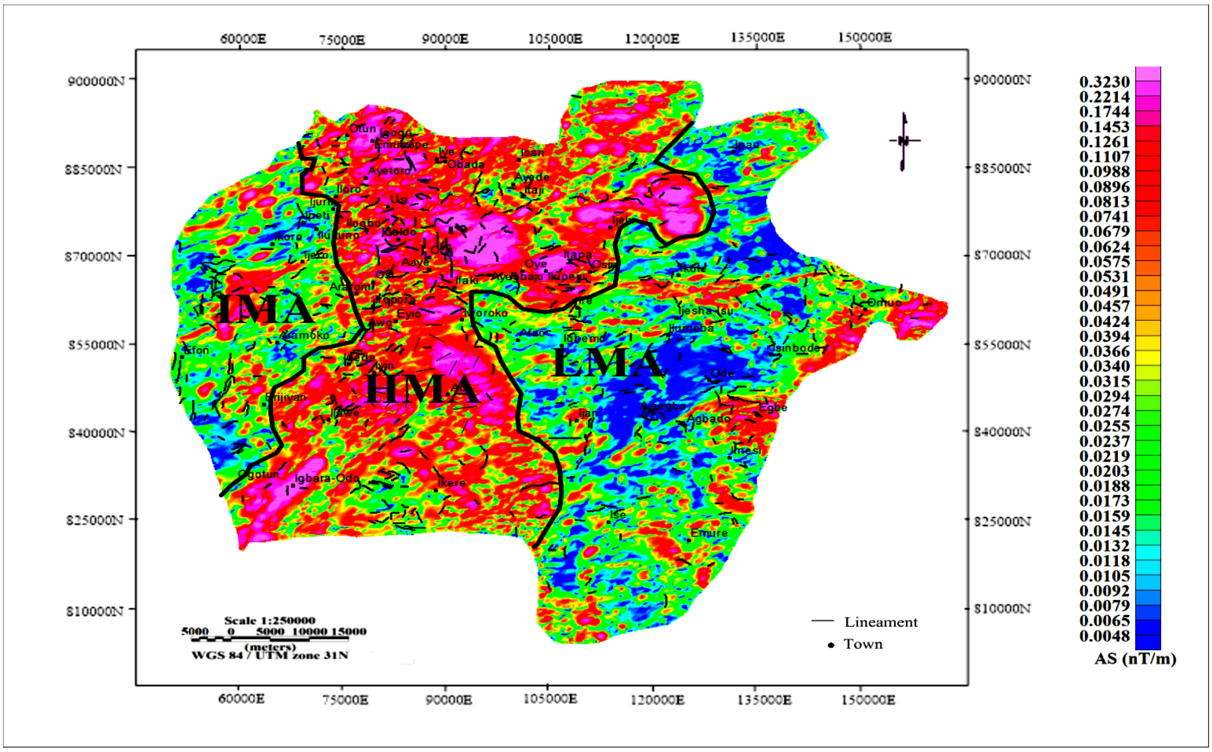

Figure 5: Integrated analytic signal and lineament map

5. Conclusion

Integration method has been used to classify the basement complex of Ekiti State, majorly, for the purpose of mineral exploration. Careful analysis of the aeromagnetic data of the state indicated that the state could be classified into three magnetic anomalous zones, which are: high magnetic anomalous zone (HMA); intermediate magnetic anomalous zone (IMA) and low magnetic anomalous zone (LMA). The high magnetic anomalous zone which extends from the south through the centre to the north is considered to be the most mineralized region with many lineament features which can serve as mineral conduits.

Negative magnetic anomalies were observed majorly around the western part of the study area over biotite granite and granodiorite, charnockitic and pegmatitic rocks and migmatite. The prominent ones are seen around Osin/Itapa and Ido axis to the north, Egbe to the east, Ado at the centre, Ikere area in the south and Aramoko in the west. Some of these areas with prominent anomalies have surface expression of mineralized rocks. Other areas in the region where the anomalies are not accompanied by any surface expression may likely have granitic intrusion buried at relatively shallow depth.

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