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Interpretation of Aeromagnetic Survey and Satellite Imagery of Jos-Plateau, North-Central Nigeria

Nwankwoala, H.O; Ugwu, S.A and Agada, E.A

Department of Geology, Faculty of Science, University of Port Harcourt, Nigeria

ABSTRACT

The aim of this study is to demonstrate the geological application of the Nigeria Sat-1 image with respect to structural geology of the study area which involves image interpretation, lineaments extraction and analyses. This is very important because processed satellite data enhances structures that are probable host for mineralization and also for mapping sub-regional surface geology. This is crucial as comparing the geological map with interpreted aeromagnetic map and the satellite image creates detailed mineral potential map of the study area. Aeromagnetic interpretation study revealed that the major strike direction in the study area is NE – SW and characterized by magnetic anomalies ranging from 7630 to 7950nT. The predominant strike direction obtained from the satellite image of the study area is trending NW – SE direction while from the data measured in field (Rose plot) confirmed NE – SW, NW – SE trending. The aeromagnetic patterns and trend indicates three distinct geophysical zones (X, Y and Z). The aeromagnetic maps are characterized by belts of magnetic highs and lows which are non – continuous and with the magnetic trends which are sub-parallel to the trend of the geology of the study area. The geological mapping of the Jos – Plateau area, using aeromagnetic data and satellite image of the area based on structures, has proven useful in resolving that the Basement Complex in North Central Nigeria should not be regarded as a single tectonic province, but as a polycyclic structure with probable different episodes of orogenic activities. This study therefore highlighted the need for integration of Nig. Sat 1 Images alongside other geophysical data in the study area for mineral exploration as this will enhance the knowledge of surface structures (abundance and trend) and mining of shallow placer deposits in the area.

Keywords: *Aeromagnetic, Magnetic anomalies, Satellite Image, Lineaments, Jos-Plateau*

INTRODUCTION

Aeromagnetic method can be employed in locating fractures, faults and ring system of the basement rocks, which possibly control the mineralization. In line with the importance, the result of geophysical studies of the physical parameters of geologic bodies (e.g. dimension, body geometry, depth, density contrast, and susceptibility contrast) in comparison to information obtained from geology, offer complementary and better regional correlation than is possible from surface geological mapping alone.

Such geophysical approach enhances the understanding of the various structural characteristics observed on a regional scale. It also aids geological mapping to distinguish areas of development of sedimentary, metamorphic and intrusive rocks, while revealing zones of tectonic dislocation.

Geophysical studies of this nature have been of tremendous importance in unveiling a more precise and better understanding of the distribution and evolution of geologic provinces (Batterham *et al.*, 1983). These methods help to identify boundaries and areal extent of major structural units where it was difficult to precisely locate by geologic mapping (Donovan *et al.*, (1979), Stone *et al*., (2004), Ojo *et al*., 2009, 2012).

Tracing of structural provinces and boundaries beneath cover rocks, has been possible because of their general uniformity and flat lying state which makes them effectively transparent to magnetism, even in places where the basement geology is exposed, and the boundary can be mapped geologically. Geophysical studies can provide useful structural information that can be used to determine the altitude of the boundary at depth and provide evidence of thrusting or depositional overlap.

Nigeria Sat-1 image is indispensable for reconnaissance geological surveys, structural interpretations, image classification for lithology delineation, vegetation cover analyses and ground trotting. Demonstrating the geological application of the Nigeria Sat-1 image with respect to structural geology of the study area, involves image interpretation, lineaments extraction and analyses. Processed satellite data enhances structures that are probable host for mineralization and also map sub-regional surface geology. Comparing the geological map with interpreted aeromagnetic map and the satellite image creates detailed mineral potential map of the study area.

THE STUDY AREA

The study area covers 8600km^2 from latitudes 9^{o}36 to 9^{o}60^{l}N and Longitudes 8^{o}32 to 8^{o}56^{l}E and is bounded by 300-600meter escarpments around most of its circumference, with an average altitude of 1280metres and its highest point at 2010metres. It is the only region of temperate climate of Nigeria (Fig.1). Major towns are Jos, Bukuru, Rukuba, Barkin Ladi, Ganawuri, Vom, Kigom, which fall within Plateau State. The residents of the area are mainly farmers, miners and civil servants.

The area under study is located near the central part of Nigeria. It covers 8600km^2 with average altitude of 1280 to 2010metres. It is within the Nigerian basement complex and the Younger granite complex, covering Jos-Bukuru complex, Ganawuri, Rukuba, Kagoro, Miango, Forum and Kigom complex. The rock types of the basement complex comprise a group of older granulite gneisses succeeded by a series of migmatite, granite-gneisses and granites, forming a single petrogenetic unit.

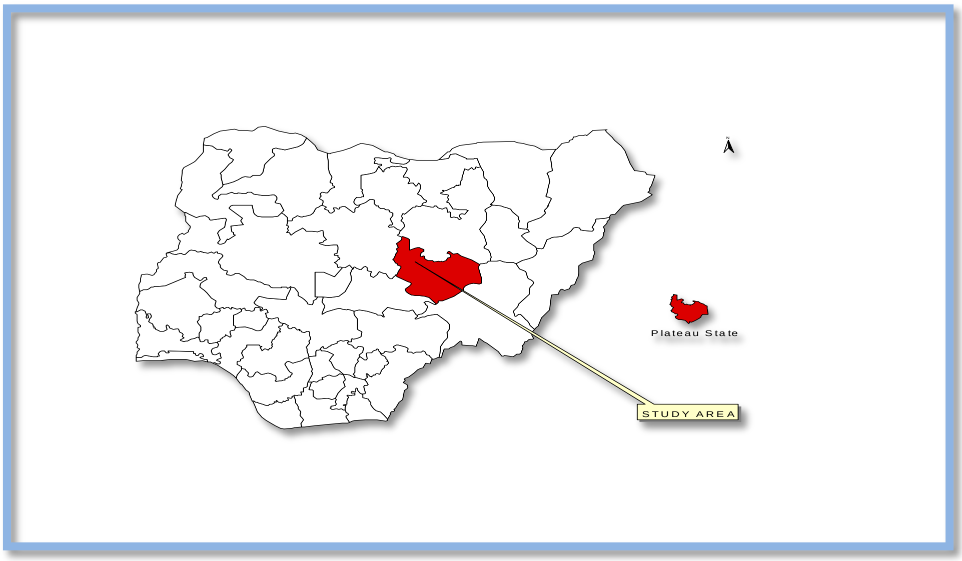

Fig1. *Map of Nigeria showing the study area*

METHODOLOGY

Data Acquisition

Magnetic Data

The air-borne magnetic survey was flown and compiled by Hunting Geology and Geophysics limited. Flying completed July 1974, and the final maps completed January 1975, at the scale of 1:100,000. Points were plotted from 35mm film. The fiducially point used for the survey was 42091. The flight line direction was 150^o/330^o, while the tie line was 60^o/240^o. Normal flight line spacing was 2km, while the nominal tie spacing was 20km. The normal flying altitude above the terrain was 152.4metre and a total field value of 2500nT was subtracted from the acquired data as the background value according to the 1994 International Geomagnetic Reference Field (IGRE) Formula.

The methodology employed in this study can be summarized as follows:

I. Digitization and modification of the geological map of the study area. (Geological map, extracted from bulletin 32 Vol. 1, of Geological Survey of Nigeria).
II. Digitization, qualitative and quantitative (Horizontal slope distance method) Interpretation of the aeromagnetic data of the study area. (Aeromagnetic data obtained from the Geological survey Agency of Nigeria, Kaduna. (Sheet 168).
III. Extraction of Lineaments from the satellite image covering the study area. (Sat-image acquired from National Centre for Remote sensing Jos, Plateau State.).
IV. Overlaying I, II, and III to give a better interpretation of the geology of the study area.

RESULTS AND INTERPRETATION

An isomagnetic map made from aeromagnetic map, sheet 168, covering the study area is shown in (Fig. 2). The sheet was subjected to qualitative and quantitative interpretation and the corresponding magnetic interpretation map is shown in (Fig.3)

About 46% of the total survey showing up as composite assemblages, comprising closely spaced irregular contours were aligned in a NW-SE direction (Fig 2.1a) this patterns occur around Vom, Ukuru, Ganawuri, Kagoro, e.t.c. The magnetic field value ranged from 7670 to 7985nT, while the major trend of anomalies is NE-SW. These anomalies were underlain by rock units made up of newer basalts, older granite and undifferentiated migmatite. The irregular patterns and short amplitude of the contours was suggestive of the complex nature and near surface origin of underlying rock types. In the SW and NE part of the study area, around Damakasuwa, Miango, Kurmin Rizgo, the anomalies were composed of broadly spaced contours (Fig. 2.1a). These anomalies were characterized by magnetic intensity values of between 7704 to 7970nT. The anomalies were underlain mainly by migmatite banded granite, undifferentiated basement complex and older granite.

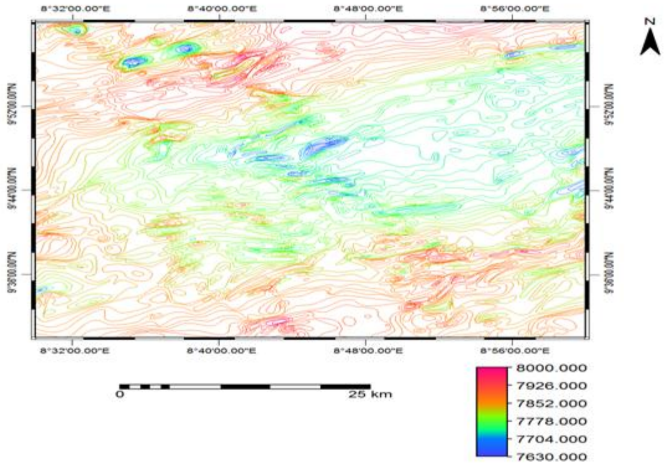

Fig2. *Digitized Aeromagnetic Map of Study*

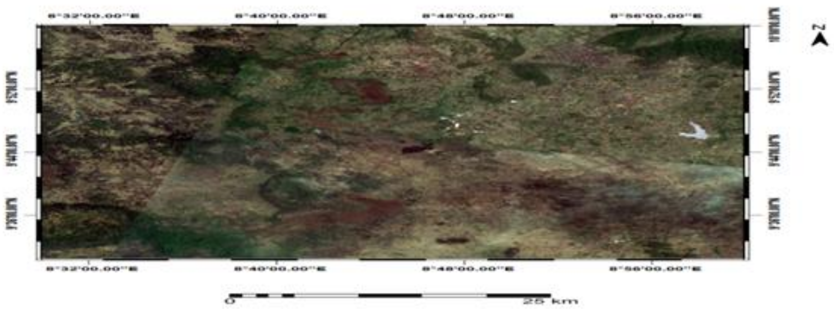

Fig3. Spot Image of the Study Area

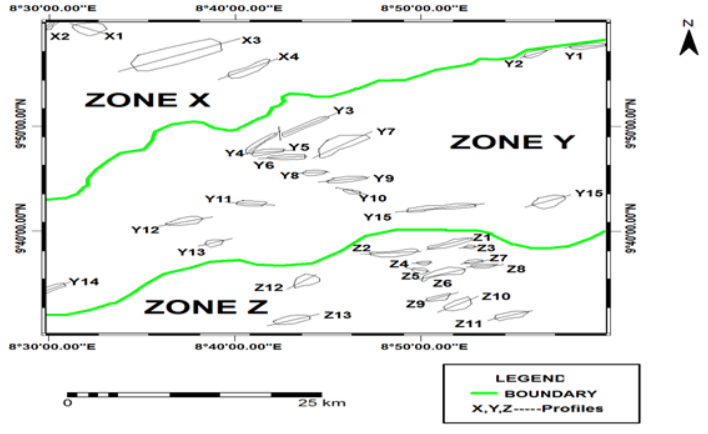

Fig4a. *Magnetic Interpretation Map showing Magnetic Anomalies, Boundaries/Profiles.*

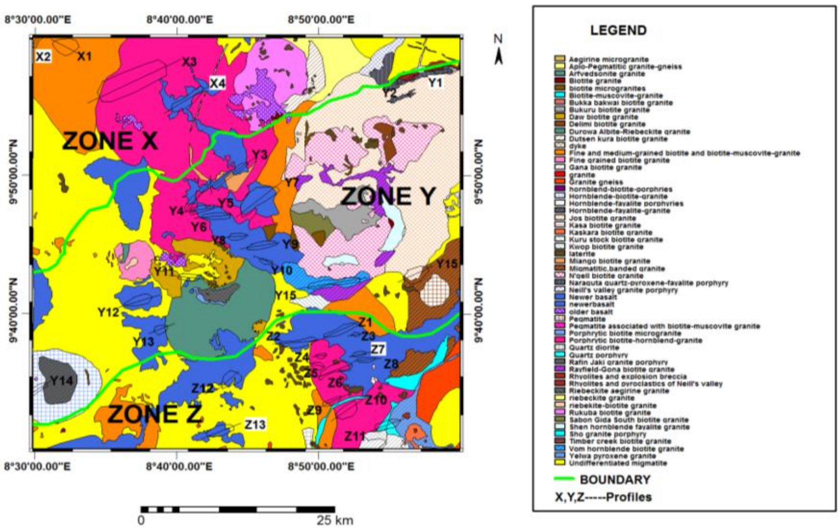

Fig4b. *Magnetic Interpretation Map Showing the Magnetic Anomalies/Boundary Overlain on Geological Map of the Study Area. (Modified, GSN*

Qualitative Interpretation

Three major magnetically identifiable zones (zone X, Y and Z) (Fig. 4a) were established based on the dominant magnetic signatures, which were composed of the amplitude, strike and patterns of the anomalies. These were further related to the underlying geology map. (Fig. 4b)

Description of Zones

Zone X

This zone covers the Northwestern part of the study area (Fig. 4a), within which lies the Miango, Yelwa and Fadan Chawai town and characterized by magnetic anomalies ranging from 7680 to 7965nT. The amplitude of these anomalies ranged from 31nT (x_2) to 327nT (x_4) (Table 1). The anomalies fall into two major trends of NE-SW and NW-SE directions and the magnetic texture is irregular. The long axis of the anomalies is about 3.8kilometres while the length of the short axis is about 0.41kilometres. The zone is underlain by deep undifferentiated basement complex consisting of older basalt (Fig. 4b).

Zone Y

This zone occupies the central part of the study area. (Fig. 4a) and encompasses about 49% of the entire study area, within which lies the Vom, Ganawuri, parts of Jos-Bukuru and Kagoro town. It is characterized by magnetic anomalies ranging from 7675 to 7850nT and amplitude from 21.80nT (y_{11}) to 175.20nT (y_7). The long axis of the anomalies is about 3.5km while the length of the short axis is about 0.9km. The irregular magnetic texture, according to (Wright, 1971), cannot be satisfactorily explained solely in terms of the underlying crystalline basement, but also the contributions of sizeable intrusive bodies whose composition are of basic to intermediate intrusive. The underlying basement rock is composed of undifferentiated migmatite banded granite, newer basalt and older basalt (Fig. 4b). The magnetic anomalies observed here directly reflect, the underlying basement structure and the younger granite complex.

Zone Z

This zone covers the south eastern part of the study area and is magnetically complex similar to that of zone X. the anomalies are generally linear to each other. The magnetic lineaments common in this zone are identified as long and narrow belts of magnetic closure. They range from 1.1 kilometres to 3.2 kilometres in length and amplitude from 18nT (z_{12}) to 150nT (z_{13}).

The concentration of magnetic linear anomalies appears connected with the occurrence of dykes along fractured basement and contact metamorphism. The basement rock which outcropped within the zone is located at the centre and southwest of the geologic map. (Fig 4b). It composed of an assemblage of older basalt. Other rocks include biotite granite, quartz-pyroxene-fayalite porphyry, granite porphyry, migmatite, banded granite, quartz diorite and laterite.

Table1. *Estimated Depth, Width, Amplitude, and Susceptibility of Magnetic Anomaly with Existing Geology*

S/NO	MAG ZONE & ANOM. NO (FIG. X)	LATITUDE FIG. X	LONGITUDE FIG. X	DEPTH (Z) (1.3 X HSD) (KM)	ANOMALOUS WIDTH Z/3 (KM)	AMPLITUDE OF ANOMALY (DT) NT	SUSCEPTIBILITY (K) S.I. UNIT	CORRESPONDING EXISTING GEOLOGY
1.	X X_1	$9^{O} 58^{I}$ N	$8^{O} 30^{I}$E	0.65	0.22	75.00	0.004351	Fine to medium – grained biotite (Muscorite) Granite.
2.	X X_2	$9^{O} 57^{I}$ N	$8^{O} 32^{I}$E	0.91	0.30	31.00	0.018463	Fine to medium – grained biotite (Muscorite) Granite.
3.	X X_3	$9^{O} 54^{I}$ N	$8^{O} 38^{I}$E	1.17	0.39	60.50	0.035637	Hornblende – biotite porphyries
4.	X X_4	$9^{O} 53^{I}$ N	$8^{O} 41^{I}$E	0.91	0.30	327.00	0.194759	Newer Basalt
5.	Y Y_1	$9^{O} 55^{I}$ N	$8^{O} 58^{I}$E	0.91	0.30	25.70	0.015307	Newer Basalt
6.	Y Y_2	$9^{O} 54^{I}$ N	$8^{O} 56^{I}$E	1.30	0.43	61.00	0.036211	Newer Basalt
7.	Y Y_3	$9^{O} 50^{I}$ N	$8^{O} 45^{I}$E	0.52	0.17	92.00	0.055255	Newer Basalt
8.	Y Y_4	$9^{O} 48^{I}$ N	$8^{O} 43^{I}$E	0.91	0.30	37.00	0.022037	Newer Basalt
9.	Y Y_5	$9^{O} 47^{I}$ N	$8^{O} 43^{I}$E	1.04	0.35	54.90	0.032030	Newer Basalt
10.	Y Y_6	$9^{O} 46^{I}$ N	$8^{O} 44^{I}$E	0.78	0.26	80.50	0.050364	Newer Basalt
11.	Y Y_7	$9^{O} 48^{I}$ N	$8^{O} 47^{I}$E	0.78	0.26	175.20	0.103201	Newer Basalt
12.	Y Y_8	$9^{O} 45^{I}$ N	$8^{O} 45^{I}$E	0.65	0.22	48.70	0.028252	Newer Basalt
13.	Y Y_9	$9^{O} 43^{I}$ N	$8^{O} 47^{I}$E	1.17	0.39	65.50	0.038583	Newer Basalt
14.	Y Y_{10}	$9^{O} 42^{I}$ N	$8^{O} 46^{I}$E	2.21	0.74	93.50	0.054828	Newer Basalt
15.	Y Y_{11}	$9^{O} 41^{I}$ N	$8^{O} 39^{I}$E	1.04	0.35	21.80	0.012719	Undifferentiated Migmatite
16.	Y Y_{12}	$9^{O} 40^{I}$ N	$8^{O} 37^{I}$E	1.82	0.61	37.00	0.021676	Newer Basalt
17.	Y Y_{13}	$9^{O} 37^{I}$ N	$8^{O} 38^{I}$E	2.99	1.00	56.00	0.032877	Newer Basalt/Alfred Smith
18.	Y Y_{14}	$9^{O} 34^{I}$ N	$8^{O} 31^{I}$E	0.78	0.26	65.00	0.038288	Shen hornblende fayalite granite
19.	Y Y_{15}	$9^{O} 38^{I}$ N	$8^{O} 50^{I}$E	0.91	0.30	86.00	0.051221	Vom hornblende biotite granite
20.	Y Y_{16}	$9^{O} 43^{I}$ N	$8^{O} 56^{I}$E	2.08	0.70	92.50	0.053968	Jos biotite/Migmatite band granite
21.	Z Z_1	$9^{O} 38^{I}$ N	$8^{O} 51^{I}$E	0.65	0.22	60.00	0.034807	Newer Basalt
22.	Z Z_2	$9^{O} 36^{I}$ N	$8^{O} 48^{I}$E	0.91	0.30	57.50	0.034247	Newer Basalt
23.	Z Z_3	$9^{O} 36^{I}$ N	$8^{O} 51^{I}$E	1.82	0.61	31.50	0.018454	Newer Basalt
24.	Z Z_4	$9^{O} 34^{I}$ N	$8^{O} 50^{I}$E	0.78	0.26	83.00	0.048691	Hornblende biotite porphyries
25.	Z Z_5	$9^{O} 33^{I}$ N	$8^{O} 49^{I}$E	1.43	0.48	31.50	0.018426	Hornblende biotite porphyries
26.	Z Z_6	$9^{O} 33^{I}$ N	$8^{O} 50^{I}$E	2.60	0.87	86.00	0.050464	Hornblende biotite porphyries
27.	Z Z_7	$9^{O} 34^{I}$ N	$8^{O} 52^{I}$E	1.04	0.35	54.90	0.032031	Newer Basalt
28.	Z Z_8	$9^{O} 33^{I}$ N	$8^{O} 53^{I}$E	0.78	0.26	40.30	0.023739	Newer Basalt
29.	Z Z_9	$9^{O} 32^{I}$ N	$8^{O} 51^{I}$E	0.91	0.30	94.50	0.056284	Hornblende biotite porphyries/Aegirine micro granite.
30.	Z Z_{10}	$9^{O} 32^{I}$ N	$8^{O} 50^{I}$E	0.65	0.22	73.00	0.042349	Hornblende biotite granite
31.	Z Z_{11}	$9^{O} 31^{I}$ N	$8^{O} 52^{I}$E	1.82	0.61	26.30	0.015407	Sho granite porphyry/Yelwa pyroxene granite
32.	Z Z_{12}	$9^{O} 33^{I}$ N	$8^{O} 44^{I}$E	2.34	0.78	18.00	0.010603	Newer basalt
33.	Z Z_{13}	$9^{O} 31^{I}$ N	$8^{O} 45^{I}$E	0.91	0.30	150.00	0.089339	Newer basalt (Undifferentiated Migmatite)

LINEAMENT EXTRACTION AND ANALYSIS

A lineament is a mappable simple or complex (composite) linear feature of a surface whose parts are aligned in a rectilinear or slightly curvilinear relationship which differs distinctly from the parts of adjacent feature and presumably reflects as a subsurface phenomenon. They are expressions of ancient deep – crystal structures, which periodically, have been reactivated as tectonic events.

These planes of weakness and particularly their intersections may provide high permeability channels for ascent of deeply derived mineralization. These lineaments are therefore extracted from the aeromagnetic map and satellite image of the study area. (Figs.6a & 6b). The major structures plotted from the lineaments generated, shows that NE – SW and NW-SE structures are more abundant in the study area. Relicts of E – S and N – S were also observed. These structures agree with the trends of

Pan African fractures and faults found in the basement complex of Nigeria and with the measured trends of foliations and fractures. Lineament analysis applied to mineral exploration attempts to define the most favourable location for mineral concentrations and in hydrological exploration for accommodation of water in fractures. Fig 7 shows the Geological Map of Study Area overlain with Magnetic Lineaments and Lineaments Extracted from Spot Image.

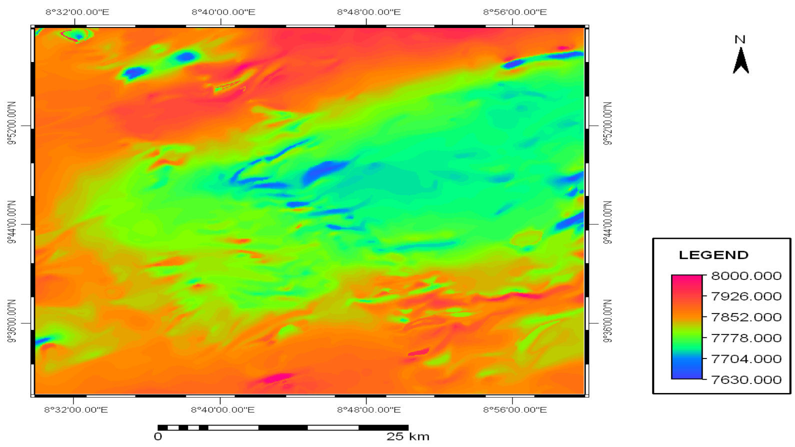

Fig5. *Interpolated Aeromagnetic Map of the Study Area*

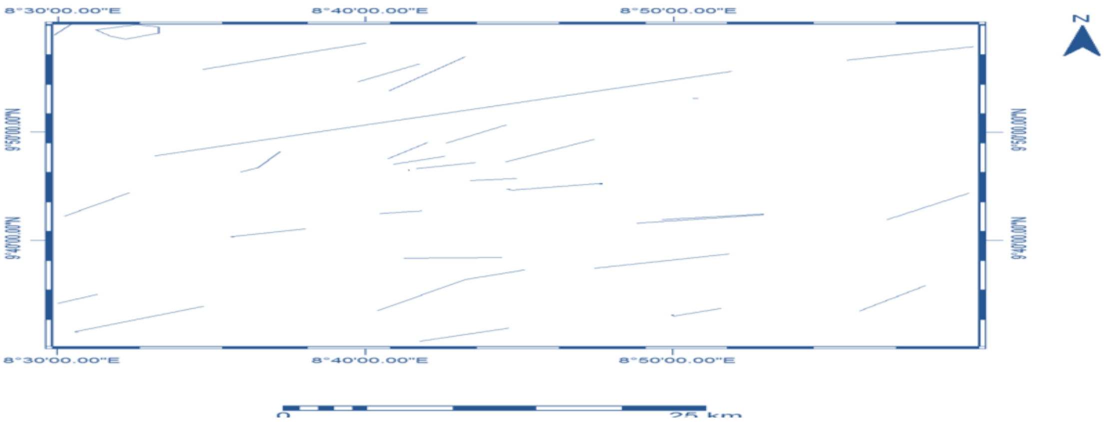

Fig6a. *Map of Lineaments Extracted from Aeromagnetic map of the study area*

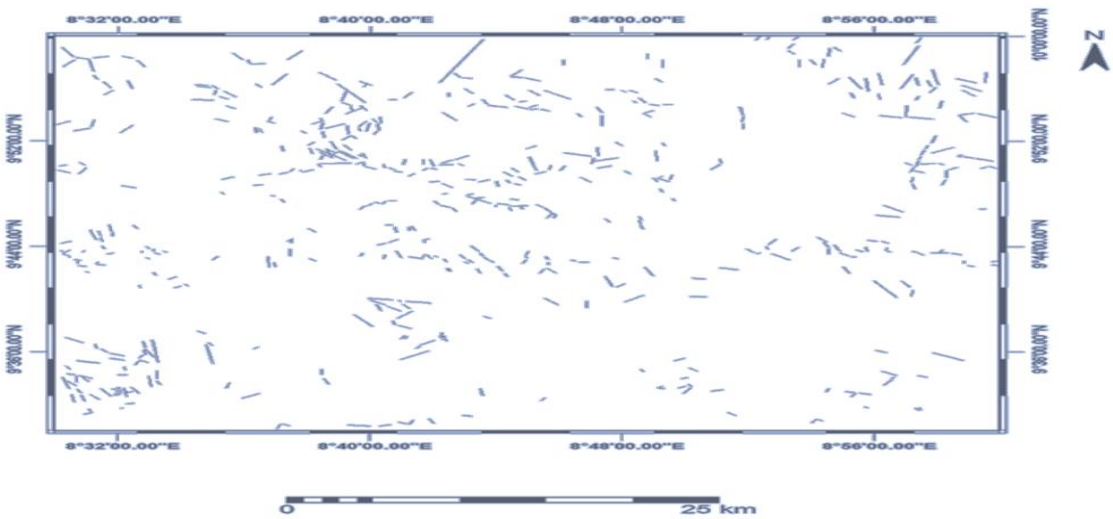

Fig6b. *Map of Lineaments Extracted from Spot Image of the Study Area*

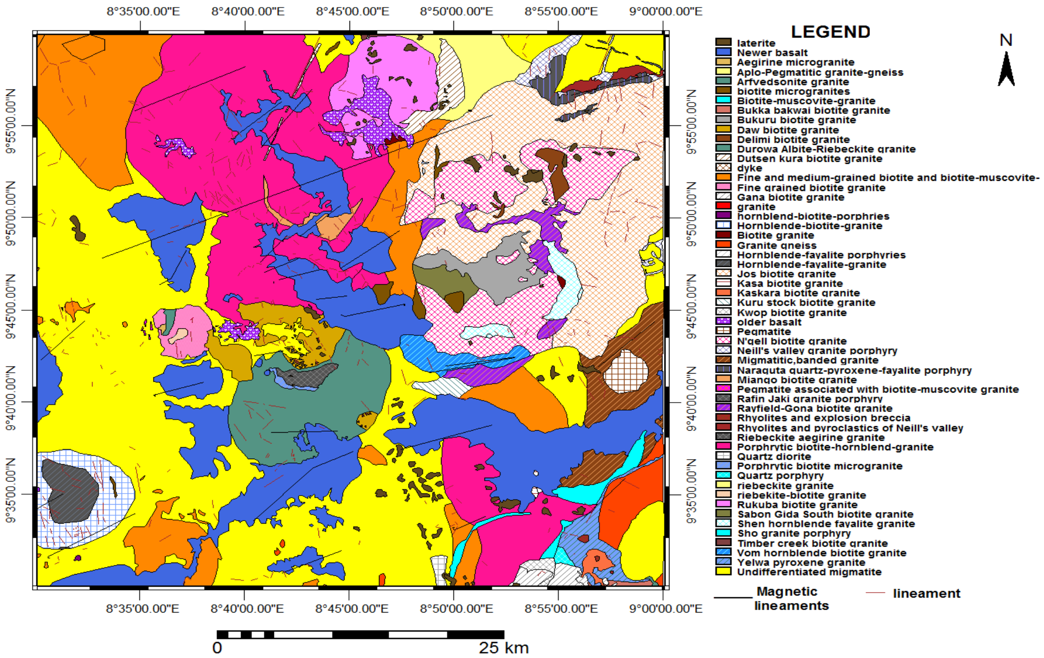

Fig7. *Geological Map of Study Area overlain with Magnetic Lineaments and Lineaments Extracted from Spot Image. (Modified GSN)*

Quantitative Interpetation

Quantitative estimates were carried out using the Horizontal Slope Distance (HSD) method. This was used to obtain the values for parameters of depth, magnetic susceptibility, width and amplitude of individual anomalies in the study area, (Table 1).

In zone X, profiles x_1-x_4 were used to estimate these parameters of depth, magnetic susceptibility, width and amplitude of individual anomalies in the study area. (Table 1) supposed to be caused by the underlying basement rocks and undifferentiated magnetic basement complex rocks in the area. These groups of anomalous bodies have high magnetic susceptibilities (0.194759) S.I. units (x_4) and amplitude between 31nT (x_2) and 327nT (x_4). (Table 1)

Zone Y, sixteen different profiles were taken within the region to evaluate these parameters, the anomalies were presumed to be due to the supposedly deep-seated basement rocks underlying the central regions around Jos and Bukuru areas. The average depth estimated from Horizontal Slope Distance (H.S.D.), to the top of bodies underlying the younger granite rocks cover in the NW of

Zone Y is 2.00 kilometre (y_{13}) while an average of 1.11 kilometre obtains in the other parts of the zone (Table 1). Zone Z has thirteen major profile having a depth range of 0.65 kilometres (z_1) to 2.34 kilometre (z_{12}) (Table 1). The table also gives values for the other parameters of width, susceptibility and amplitude of the anomalies of causative bodies in the zone.

CONCLUSIONS

From the aeromagnetic interpretation, the major strike direction is NE – SW, and it is characterized by magnetic anomalies ranging from 7630 to 7950nT. The predominant strike direction obtained from the satellite image of the study area is trending NW – SE direction, while from the data measured in field (Rose plot) confirmed NE – SW, NW – SE trending.

The aeromagnetic patterns and trend in the study area indicate three distinct geophysical zones (X, Y and Z). The aeromagnetic maps are characterized by belts of magnetic highs and lows which are non – continuous and with the magnetic trends which are sub-parallel to the trend of the geology of the study area.

This geological mapping of the Jos – Plateau area, using aeromagnetic data and satellite image of the area based on structures, has proven useful in resolving to what is regarded as over generalization by Rahaman (1981), conclusion that "The Basement complex in North Central Nigeria should not be regarded as a single tectonic province, but as a polycyclic structure with probable different episodes of orogenic activities". The result of magnetic interpretation is expected to be less unique and accurate than when integrated with gravity or/and seismic method. Therefore, an integration of one or more of these data sets will offer explorationists the opportunity of combining the advantages of these methods.

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