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# Aeromagnetic Lineament Mapping and Structural Implications of The Wase Area, North-Central Nigeria

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**ABSTRACT**
Aeromagnetic interpretation is an effective approach for delineating subsurface geological structures that control mineralization within crystalline basement terrains. This study investigates the structural framework of the Wase area, north-central Nigeria, using high-resolution aeromagnetic data obtained from the Nigerian Geological Survey Agency (NGSA). The objective was to identify structural lineaments and evaluate their implications for mineral exploration. Total Magnetic Intensity (TMI) data were processed through regional–residual separation, First Vertical Derivative (FVD), Second Vertical Derivative (SVD), and Analytic Signal Amplitude (ASA) techniques to enhance shallow magnetic anomalies and structural discontinuities. The processed data revealed numerous faults, fractures, lithological contacts, and intrusive bodies. Rose diagram analysis indicated that NE–SW is the dominant structural trend, with subordinate NW–SE, N–S, and E–W orientations, reflecting the influence of the Pan-African orogeny and subsequent tectonic reactivation associated with the Benue Trough. Lineament density analysis identified the western and northwestern parts of the study area as zones of intense structural deformation that may have served as pathways for hydrothermal fluid migration and mineralization. The results demonstrate that integrated aeromagnetic derivative techniques provide a reliable, rapid, and cost-effective approach for structural mapping and reconnaissance mineral exploration within the Nigerian Basement Complex.

**Keywords:**
Aeromagnetic data,
Structural lineaments,
Analytic signal, First Vertical derivative,
Basement Complex,
Wase,
Mineral exploration.

## INTRODUCTION

The Nigerian Basement Complex forms part of the Pan-African Mobile Belt and comprises Precambrian crystalline rocks that have experienced multiple tectonic episodes involving deformation, metamorphism, magmatism, and faulting (Rahaman, 1988). These tectonic events produced numerous structural discontinuities, including faults, fractures, joints, and shear zones, which exert significant control on groundwater occurrence, engineering geology, and mineralization.

Aeromagnetic surveying has become one of the most effective geophysical techniques for regional geological mapping because variations in magnetic susceptibility enable the identification of lithological boundaries, basement configuration, faults, folds, intrusive bodies, and other subsurface geological structures (Kearey et al., 2002). Modern derivative-based processing techniques, including First Vertical Derivative (FVD), Second Vertical Derivative (SVD), and Analytic Signal Amplitude (ASA), significantly enhance shallow magnetic anomalies and improve the interpretation of geological structures, especially in low magnetic latitude regions such as Nigeria (Nabighian, 1972).

The Wase area occupies a strategic geological position between the Nigerian Basement Complex and the Benue Trough. The interaction between these tectonic provinces has produced a structurally complex environment with considerable mineral exploration potential. Previous aeromagnetic investigations within the Nigerian



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Basement Complex have successfully delineated regional structural trends; however, detailed structural characterization of the Wase area using integrated derivative techniques and lineament density analysis remains limited.

Research Gap

Although previous studies have interpreted aeromagnetic data within the Nigerian Basement Complex, comprehensive structural mapping integrating Total Magnetic Intensity, derivative filtering, analytic signal analysis, and lineament density evaluation for the Wase area remains scarce. Consequently, the structural controls on mineralization in this important transition zone are not yet fully understood.

Therefore, this study aims to:

I. Interpret aeromagnetic data over the Wase area.
II. Delineate subsurface structural lineaments.
III. Analyse structural orientations using rose diagram techniques.
IV. Evaluate the structural controls on mineralization.

The findings provide valuable geological information for future mineral exploration and regional tectonic investigations.

## MATERIALS AND METHODS

Research Design

This study adopted a quantitative geophysical interpretation approach involving digital processing and interpretation of aeromagnetic data to delineate subsurface geological structures and evaluate their significance for mineral exploration.

Study Area

**Geological Setting**

The study area lies in north-central Nigeria and consists predominantly of migmatite–gneiss complexes, older granites, younger granitic intrusions, and sedimentary formations associated with the Benue Trough (Rahaman, 1988).

The Pan-African Orogeny (~600 Ma) significantly influenced the structural framework of the Nigerian Basement Complex, producing dominant NE–SW structural trends (Ajibade & Wright, 1989). Subsequent tectonic reactivation associated with the opening of the Benue Trough further modified pre-existing structures (Ofoegbu, 1985).

These tectonic episodes produced fracture systems and shear zones that are potential conduits for mineralizing fluids.

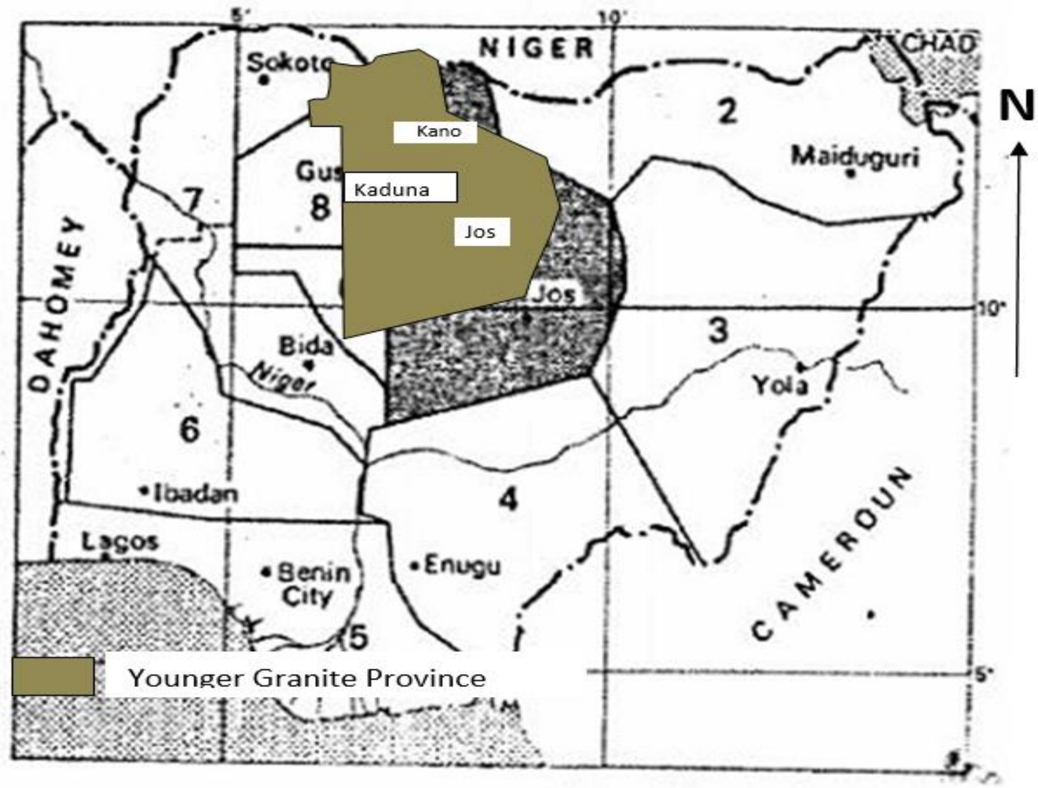


Figure 1. Map of Nigeria showing the Younger Granite Province (after Taofeeq, 2012)

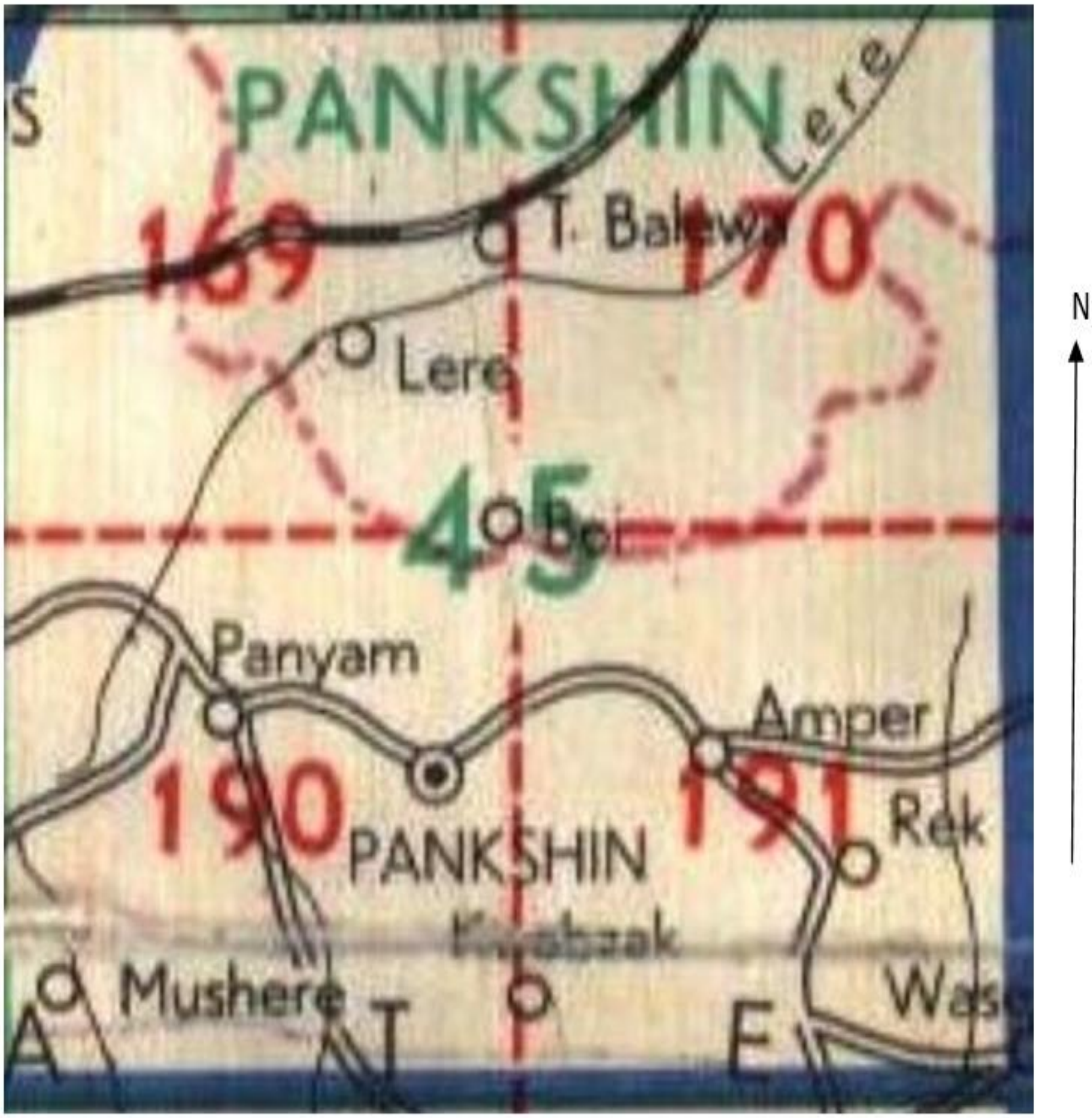


Fig. 2 **Sheet Map of the Study Area (Adopted from lineament map of Nigeria)**

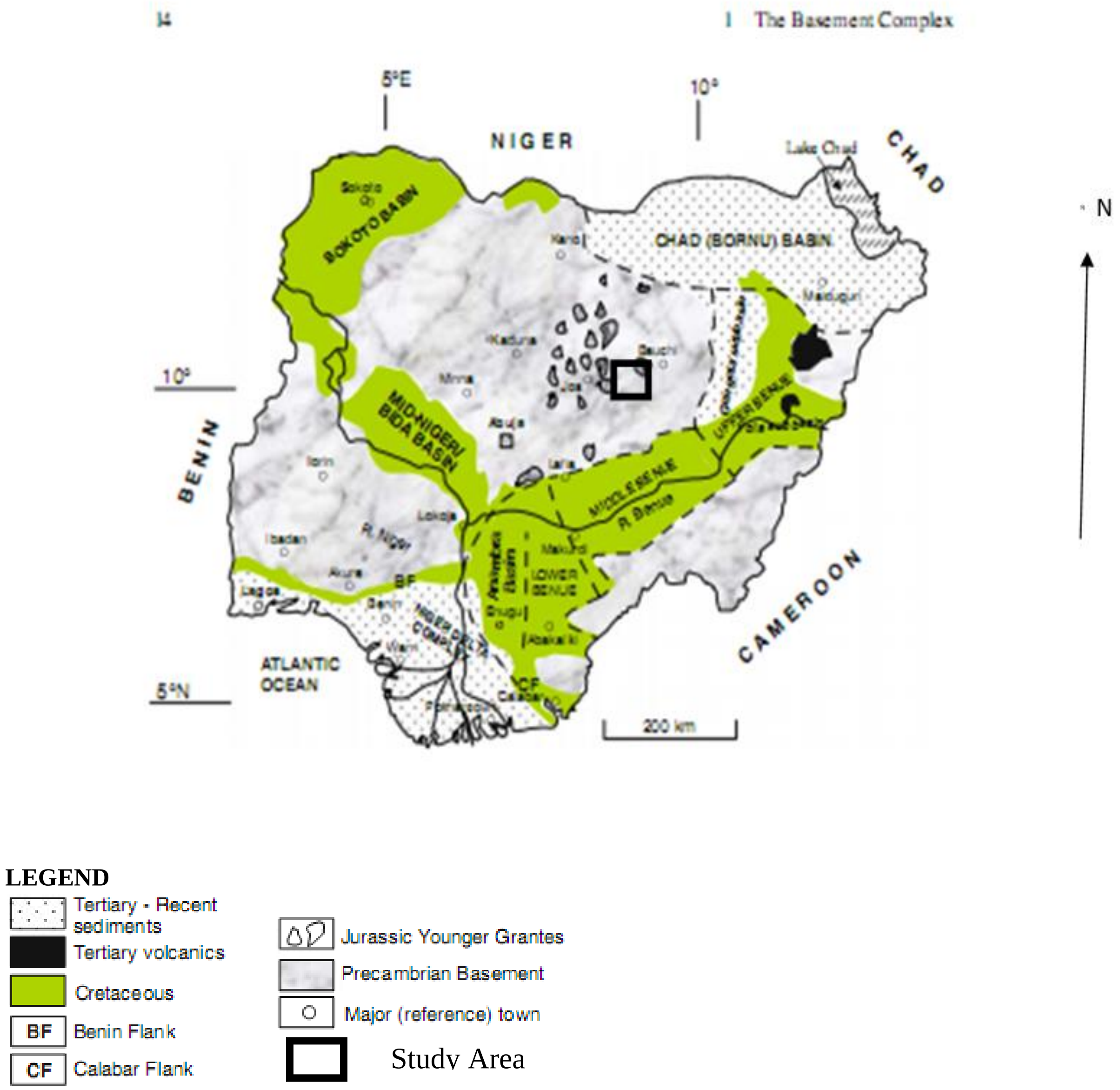


Fig.3. Location Map of the Study Area Modified After Geolog Map of Nigeria Showing the Major Geological Components

Data Source

The aeromagnetic data were obtained from the Nigerian Geological Survey Agency (NGSA). The survey was flown between 1974 and 1976 at an average terrain clearance of approximately 154 m with a flight-line spacing of 2 km, providing adequate resolution for regional structural interpretation.

Data Processing

The aeromagnetic dataset was processed sequentially using Oasis Montaj software. Initially, Total Magnetic Intensity (TMI) data were compiled and gridded using minimum-curvature interpolation. Regional magnetic effects were removed through regional–residual separation to isolate local magnetic anomalies associated with shallow geological sources.

Subsequently, the First Vertical Derivative (FVD) was applied to enhance shallow magnetic features and improve fault delineation. The Second Vertical Derivative (SVD) was then computed to emphasize lithological contacts, fractures, and subtle structural discontinuities.

Analytic Signal Amplitude (ASA) was calculated to accurately identify the edges of magnetic bodies independent of the direction of magnetization, making it particularly suitable for magnetic interpretation in low-latitude environments.

Structural lineaments were manually extracted from the derivative maps and statistically analysed using rose diagrams to determine the dominant structural orientations. Finally, lineament density mapping was carried out to identify structurally weak zones with enhanced mineralization potential.

## RESULTS AND DISCUSSION

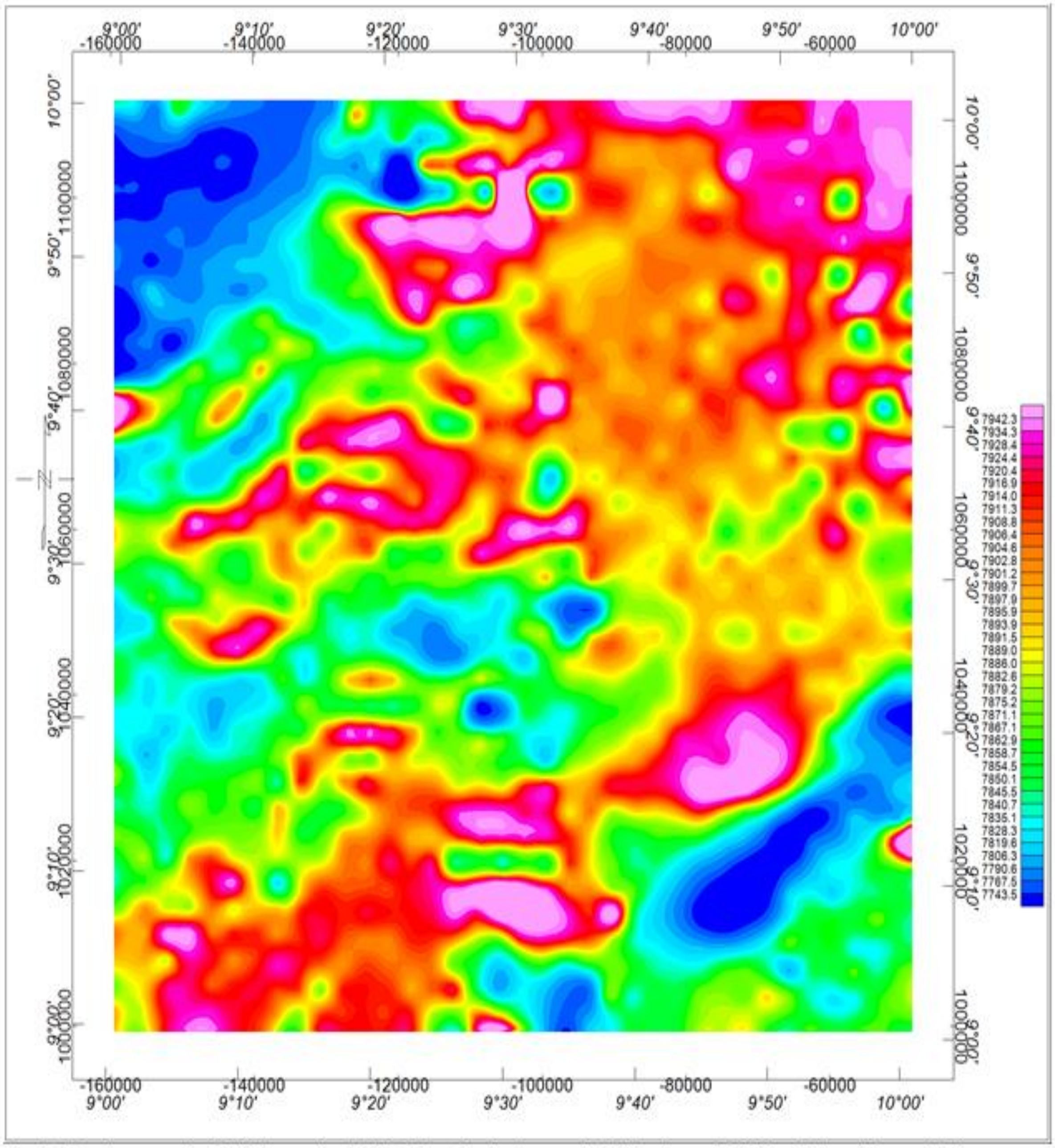

Fig 4: Total magnetic field intensity (TMI). To obtain the total TMI values, 25,000 nT should be added

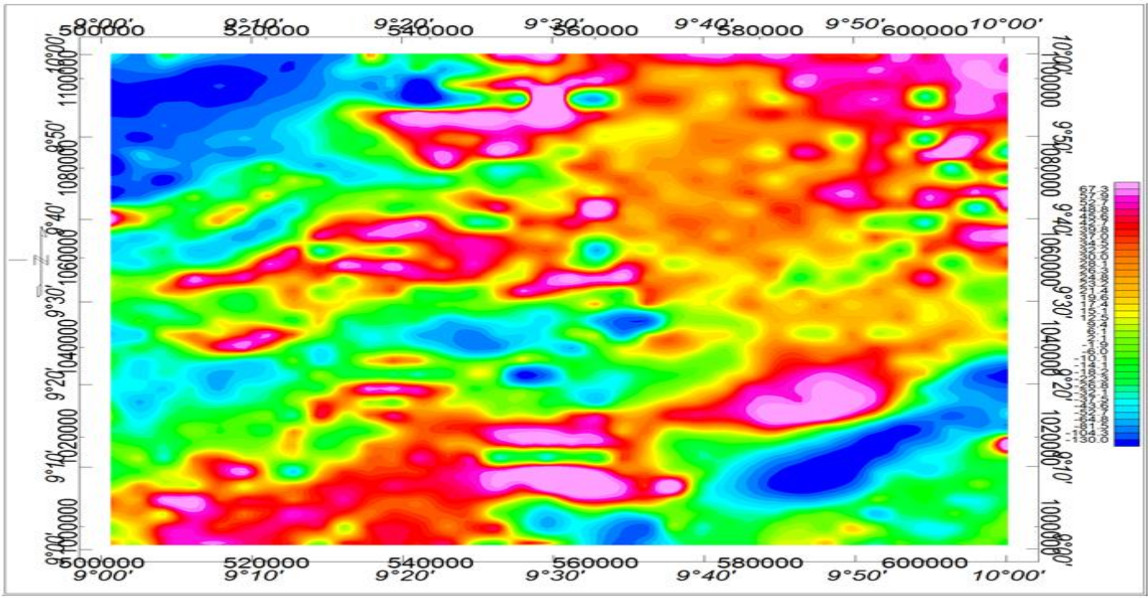


Fig.5 Residual Map of the Study Area

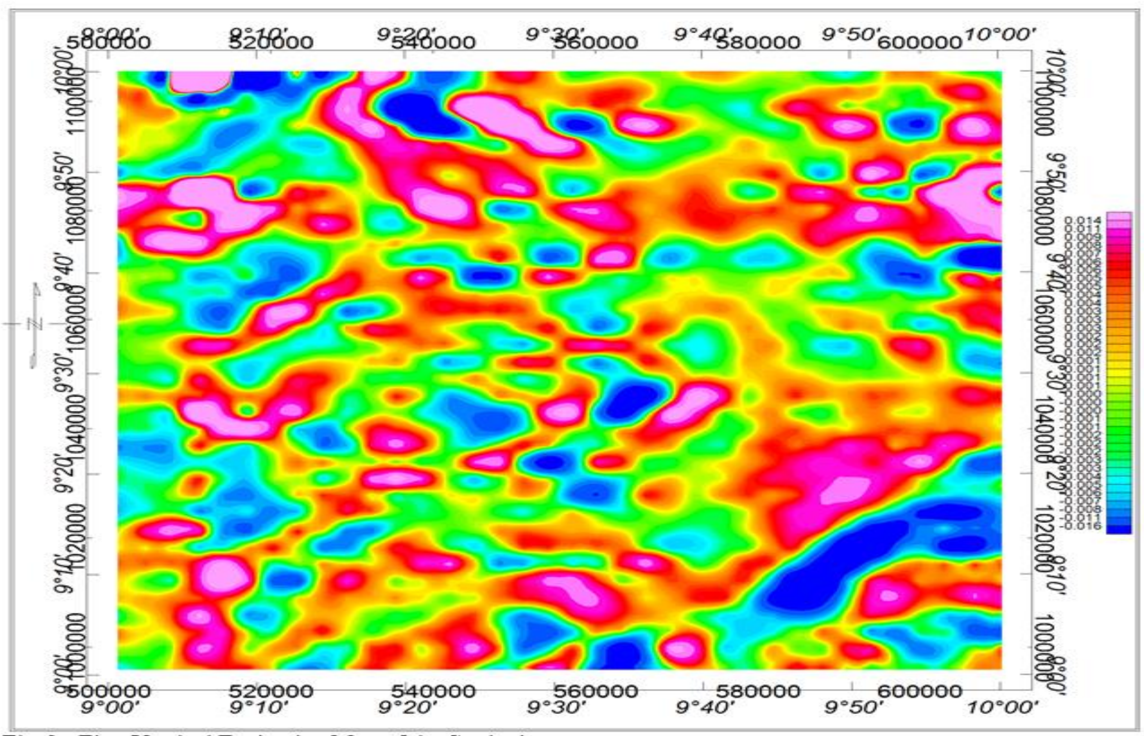


Fig.6 a First Vertical Derivative Map of the Study Area.

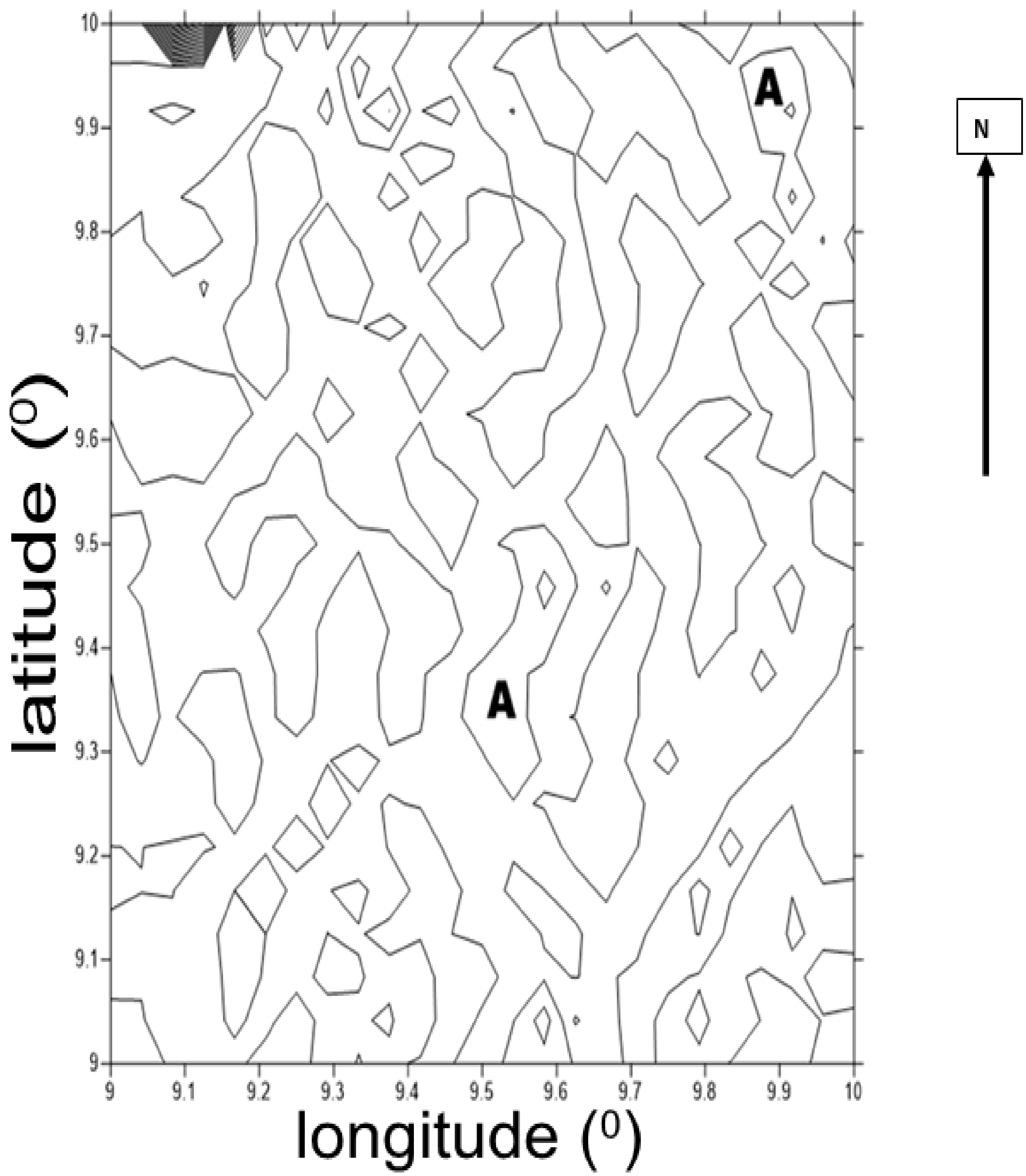


Fig. 6b Second vertical derivative (SVD) contour map indicating the curvature of the anomaly

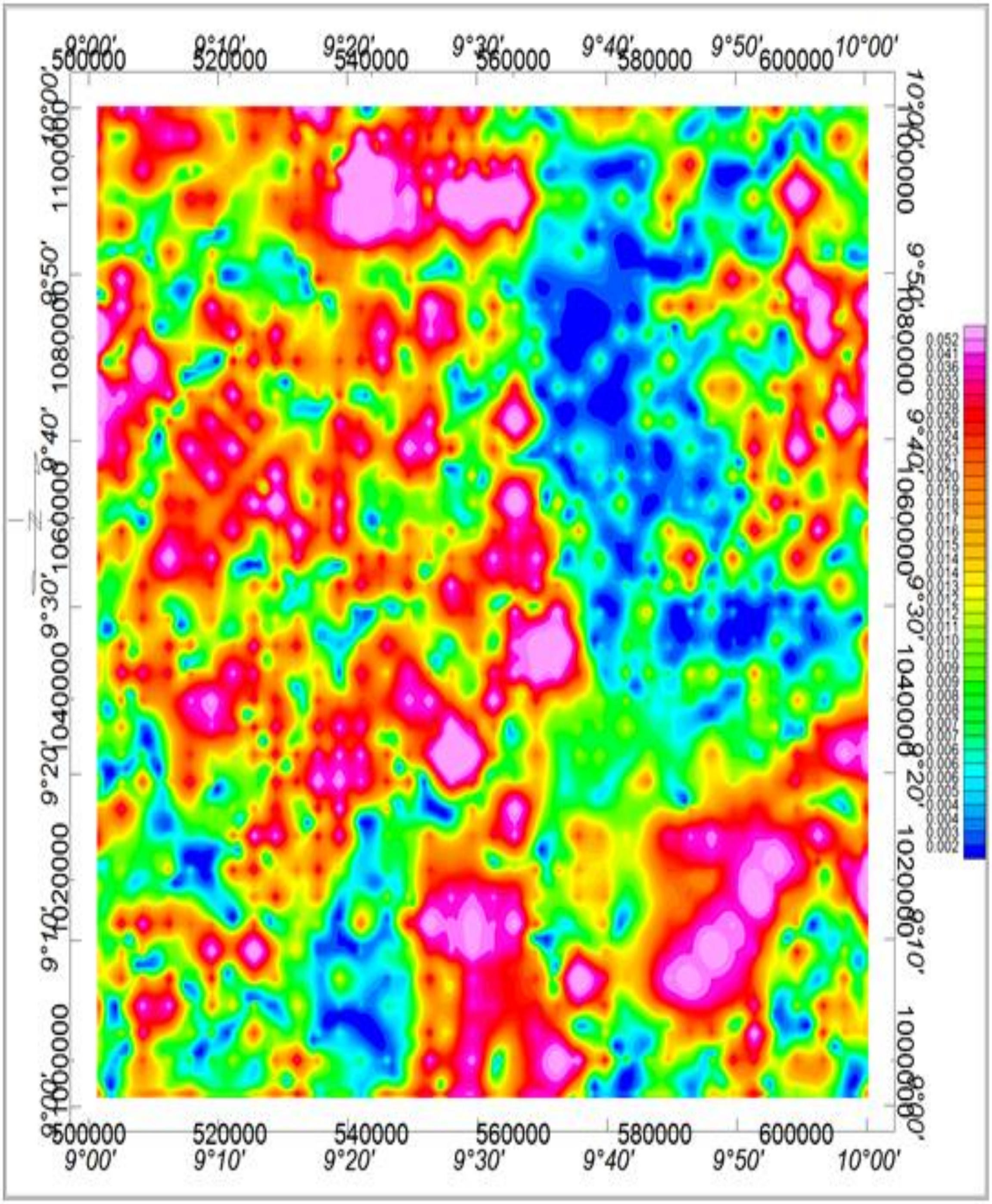

Figure 7 Analytic Signal Amplitude Map of the Study Area.

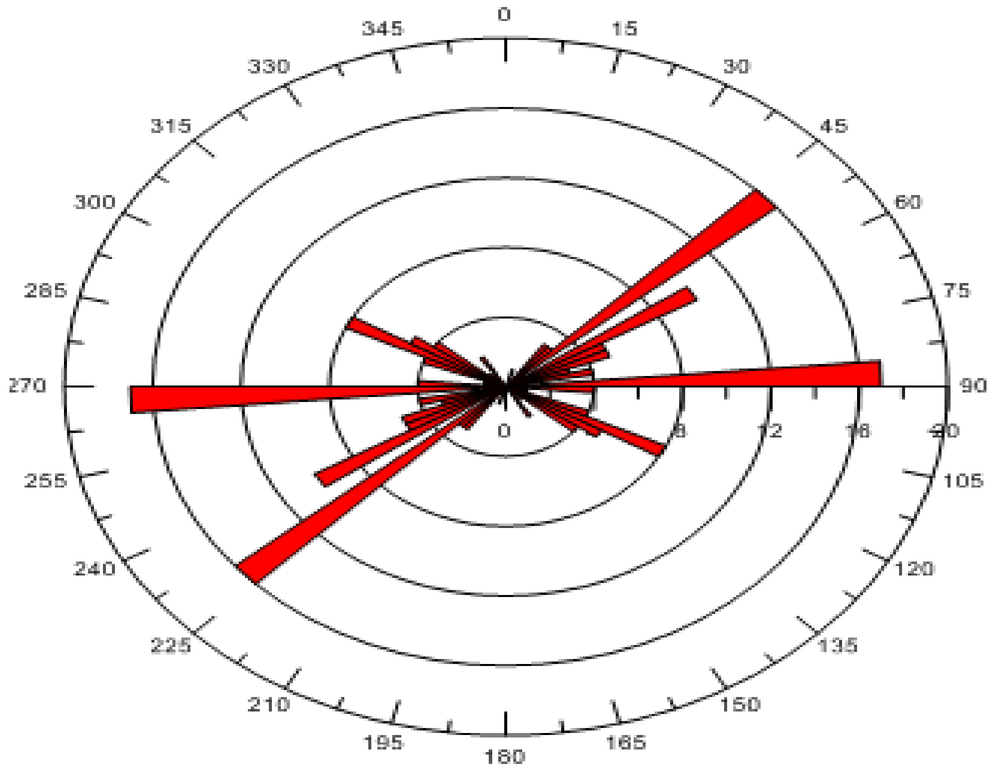


Fig.8 Rose diagram for lineaments Produced from Aeromagnetic Data of the study Area

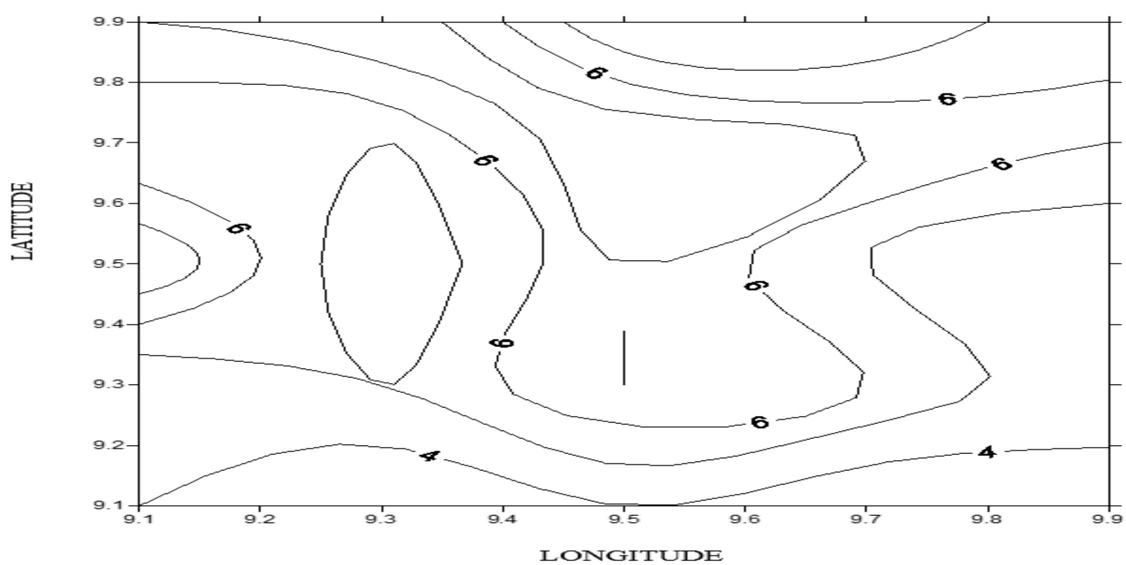


Fig.9 Lineament density map of the study area (Contour interval is 1) for magnetic lineaments

The TMI map reveals heterogeneous magnetic distribution, characterized by alternating high and low intensity zones. These variations reflect differences in lithological composition and magnetic susceptibility contrast. Figure 4

The derivative maps significantly enhanced shallow geological structures by sharpening magnetic gradients associated with faults, fractures, and lithological boundaries. Similar observations have been reported by Anakwuba and Chinwuko (2015), who demonstrated the effectiveness of derivative filtering for structural mapping within the Lower Benue Trough.

The FVD and SVD maps enhanced linear magnetic discontinuities corresponding to faults, fractures, and lithological boundaries. The derivative maps provided improved clarity of shallow subsurface structures. Figure 6a &b

The Analytic Signal Amplitude map effectively delineated the boundaries of magnetic sources irrespective of magnetization direction. This finding agrees with Nabighian (1972), who established the superiority of analytic signal processing for interpreting magnetic data in low magnetic latitude environments.

High ASA values delineate the edges of magnetized bodies and structural contacts. The analytic signal proved effective in locating source boundaries independent of magnetization direction, particularly in low magnetic latitude conditions (Nabighian, 1972). figure 7

**Structural Analysis**

Lineament extraction revealed four dominant orientations figure 8:

NE–SW (major trend)

NW–SE

N–S

E–W

The NE–SW trend corresponds to the regional Pan-African structural grain (Ajibade & Wright, 1989). The NW–SE and N–S trends may reflect later tectonic reactivation associated with Benue Trough development (Ofoegbu, 1985).

Lineament density analysi indicates zones of intense fracturing in the western and northwestern sectors of the study area, suggesting structural weakness andpossible hydrothermal fluid pathways. Figure 9

Rose diagram analysis shows that the dominant NE–SW structural orientation corresponds closely with the regional Pan-African tectonic grain reported by Rahaman (1988) and Ajibade and Wright (1989). The subordinate NW–SE and N–S orientations are interpreted as products of later tectonic reactivation associated with the evolution of the Benue Trough (Ofoegbu, 1985).

The concentration of lineaments within the western and northwestern sectors indicates zones of intense deformation. Such structurally weak regions commonly facilitate hydrothermal fluid migration and are widely recognised as favourable targets for mineral exploration. Similar relationships between structural density and mineralization have been reported in recent aeromagnetic investigations of the Nigerian Basement Complex.

Although aeromagnetic interpretation effectively identifies structural controls, it cannot independently confirm the occurrence of economic mineral deposits. Therefore, the identified target zones should be validated through geological mapping, geochemical investigations, electrical resistivity surveys, induced polarization, or drilling programmes.

**Mineralization Implications**

Mineral deposits in basement terrains are often structurally controlled (Kearey et al., 2002). The following zones are considered prospective:

i. Structural intersections
ii. High lineament density areas
iii. Regions exhibiting strong magnetic contrast

These features may represent favorable environments for hydrothermal mineralization. However, magnetic data alone cannot confirm mineral occurrence, and integrated geophysical and geochemical investigations are recommended.

## CONCLUSION

Aeromagnetic interpretation has successfully delineated the principal structural framework of the Wase area, north-central Nigeria. The integration of Total Magnetic Intensity, derivative filtering, Analytic Signal Amplitude, and lineament density analysis enabled the identification of faults, fractures, lithological contacts, and intrusive bodies controlling the regional structural architecture.

The dominant NE–SW structural trend confirms the influence of the Pan-African tectonic event, while subordinate NW–SE, N–S, and E–W trends indicate later tectonic reactivation related to the Benue Trough. High lineament-density zones identified within the western and northwestern sectors represent structurally favorable regions for hydrothermal fluid migration and possible mineralization.

This study demonstrates that integrated aeromagnetic interpretation provides a reliable and cost-effective tool for structural mapping and reconnaissance mineral exploration within the Nigerian Basement Complex. Nevertheless, aeromagnetic data alone cannot establish the presence of economic mineral deposits. Future studies should integrate geological field mapping, geochemical sampling, ground geophysical surveys, and drilling to validate the identified exploration targets.

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