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Lineament mapping of Ijebu-Ode basement terrain using aeromagnetic method

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Abstract

High-resolution aeromagnetic data from the Nigeria Geological Survey Agency (NGSA) were processed to produce the most spatially detailed lineament map of the Ijebu-Ode region in southwestern Nigeria to date. Reduction to the Equator (RTE), Analytic Signal Amplitude (ASA), and Euler deconvolution (structural index = 1) were applied to identify major and minor fault-related lineaments with high positional accuracy. The resulting structural map delineates numerous NW–SE and NE–SW trending lineaments consistent with regional tectonic fabrics, indicating continuity between surface and subsurface structures. The integrated analysis quantifies lineament orientations, densities, and patterns, providing a robust framework for geological mapping, groundwater exploration, and mineral prospecting. This work addresses a significant knowledge gap in basement complex mapping by applying modern aeromagnetic processing and offers a replicable workflow for similar terrains globally.

Keywords: Aeromagnetic Mapping; Structural Lineaments; Basement Geology; Fault Mapping; Geophysical Interpretation

1. Introduction

Lineaments are linear or curvilinear features on the Earth's surface that represent zones of structural weakness such as faults, fractures, or lithologic contacts [1]. These features often control groundwater flow, mineralization, and the localization of seismic events [2,3]. Aeromagnetic methods have proven effective in delineating lineaments in areas with limited bedrock exposure or dense vegetation [4,5].

The Ijebu-Ode region lies within the Nigerian Precambrian Basement Complex, characterized by crystalline rocks affected by multiple tectonic events. Despite its geological significance, detailed aeromagnetic-based structural mapping in this area has been scarce. High-resolution aeromagnetic data from NGSA were therefore processed in this study to produce a precise structural lineament map for Ijebu-Ode. This work contributes to regional geological understanding and provides baseline data for applied geoscience.

Remote sensing and geophysical methods for lineament mapping have evolved significantly over the past three decades [1]. Earlier studies in Nigeria used low-resolution aeromagnetic data to identify broad structural trends [6,7], but these often failed to resolve smaller-scale features crucial for local applications such as groundwater development [8]. Modern approaches integrate advanced filters—such as ASA, tilt derivatives, and Euler deconvolution—to highlight contacts, faults, and dike-like structures [9,5]. Applications in the West African Basement Complex have shown these methods reliably map both deep-seated and near-surface structures [10,11].

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However, there remains a gap in detailed aeromagnetic interpretation specifically for Ijebu-Ode. This study fills that gap by applying a suite of processing techniques to high-resolution data, generating a modern structural framework for the area.

2. Materials and Methods

2.1. Data Acquisition

Secondary high-resolution aeromagnetic data for Ijebu-Ode were obtained from the Nigeria Geological Survey Agency (NGSA). The data cover the study area with sufficient resolution to detect subtle structural anomalies.

2.2. Data Processing

Data processing was conducted using *Oasis Montaj* software (Geosoft). The following steps were applied to enhance and interpret the magnetic data:

Reduction to the Equator (RTE): Centers magnetic anomalies over their sources to facilitate interpretation at low latitudes [4]. Central magnetic inclination and declination values for the study area were used.

Analytic Signal Amplitude (ASA): Computes the three-dimensional analytic signal of the magnetic field, highlighting edges of magnetic sources. Peaks in the ASA map correspond to likely contacts, faults, and dike-like structures.

Euler Deconvolution (SI = 1): Uses a structural index (SI) of 1 to estimate the depth and location of dike-like and fault structures. Solutions indicate probable fault/dike trends and approximate depths.

2.3. Workflow

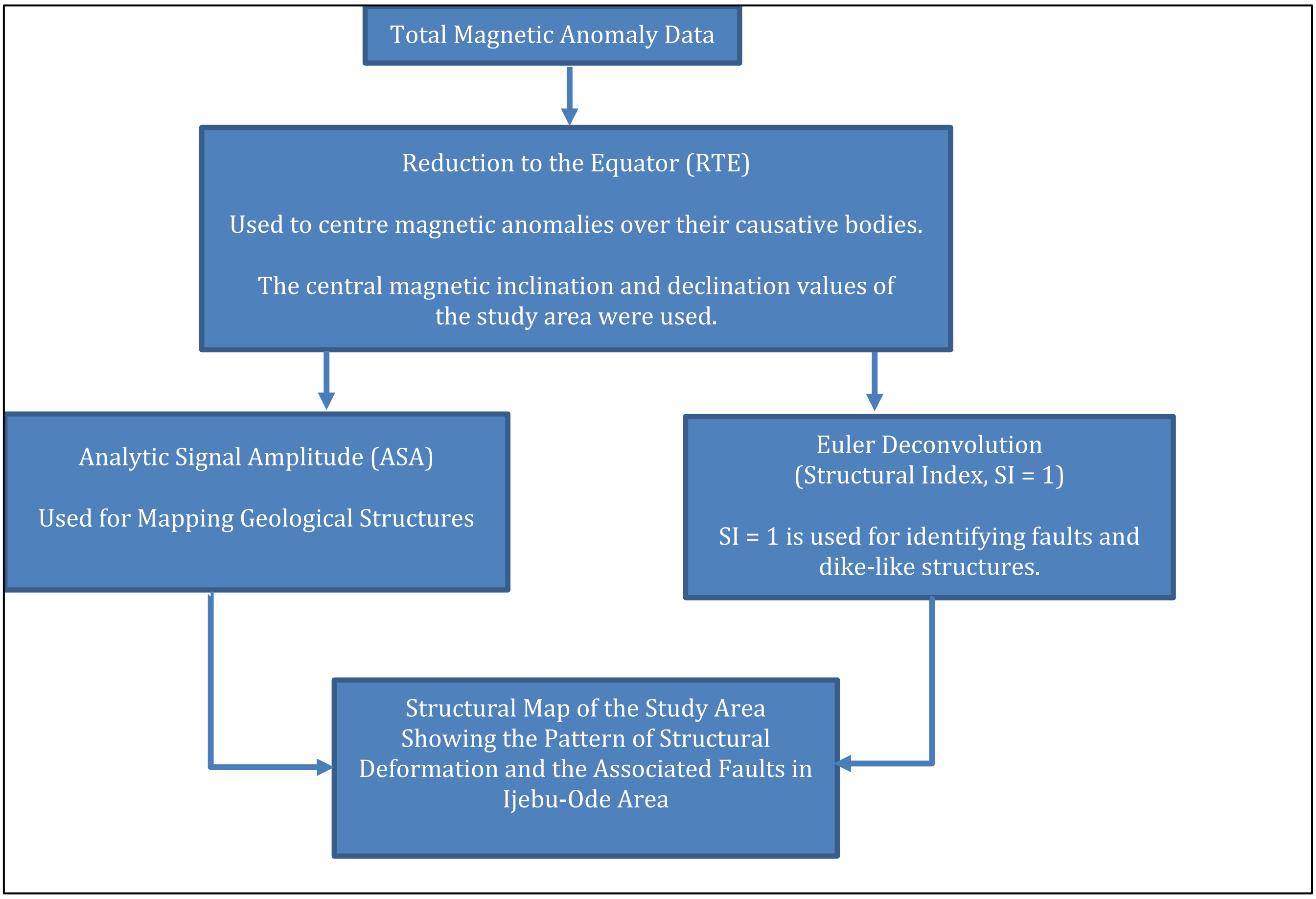

Figure 1 Workflow for aeromagnetic data processing and structural interpretation in the Ijebu-Ode study

Figure 1 shows the workflow for data processing and interpretation. Aeromagnetic data were first reduced to the equator and transformed into the analytic signal amplitude. Euler solutions were then extracted, all of which were integrated to generate the final structural lineament map of the study area. The figure outlines each step from raw Total Magnetic Anomaly to the interpreted structural map.

3. Results and Discussion

3.1. Total Magnetic Anomaly (TMA)

The Total Magnetic Anomaly map (Figure 2) reveals the raw magnetic intensity variations across Ijebu-Ode. Prominent high and low zones in the TMA suggest subsurface lithologic differences and potential structural features.

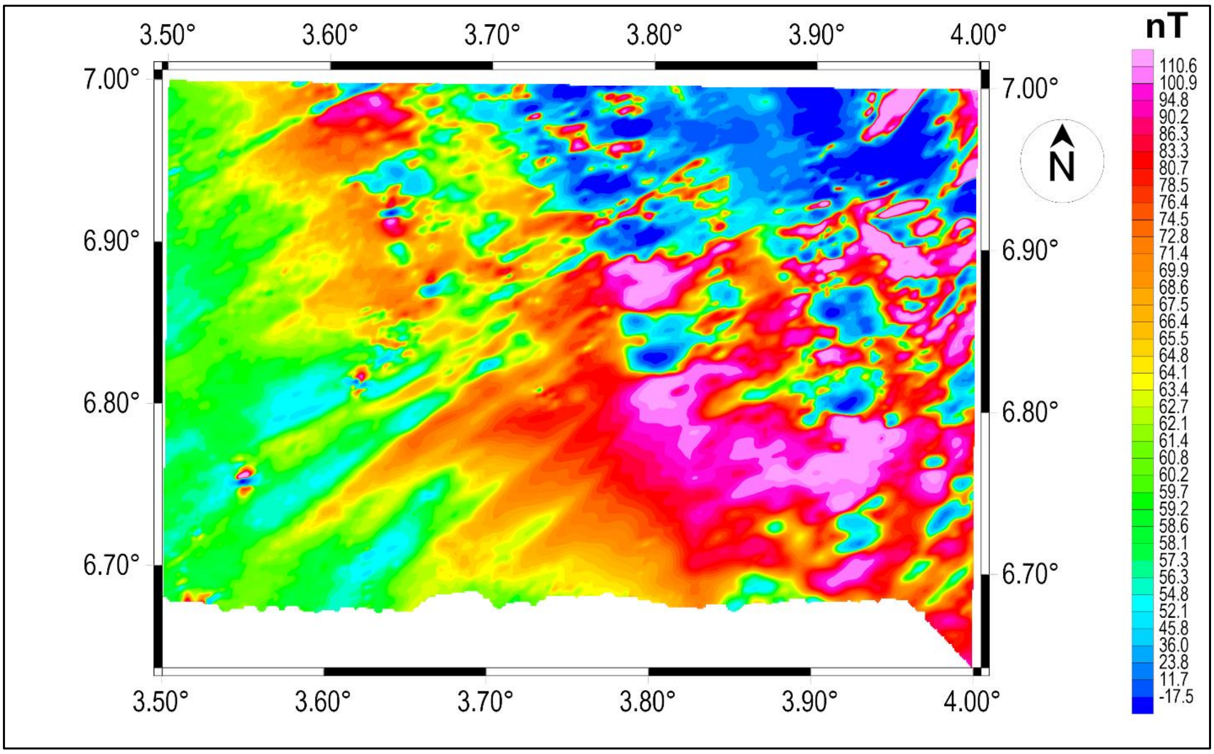

Figure 2 Total Magnetic Anomaly map of the Ijebu-Ode area

3.2. Reduction to the Equator (RTE)

The RTE map (Figure 3) repositions anomalies directly over their sources, improving alignment of anomalies with causative bodies. This transformation enhances the interpretability of fault trends by correcting for the geomagnetic inclination.

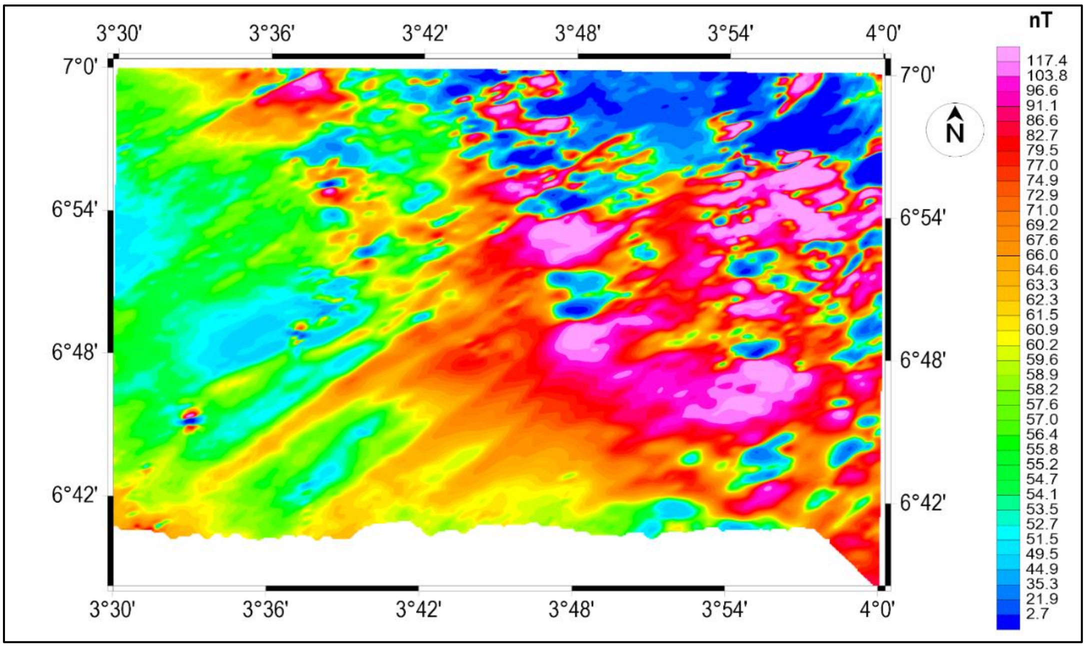

Figure 3 RTE map of the Ijebu-Ode area

3.3. Analytic Signal Amplitude (ASA)

The ASA map (Figure 4) highlights sharp magnetic gradients as peaks. These peaks correspond to likely fault contacts and edges of magnetic bodies. Overlaid black lines indicate the lineaments interpreted from the ASA peaks.

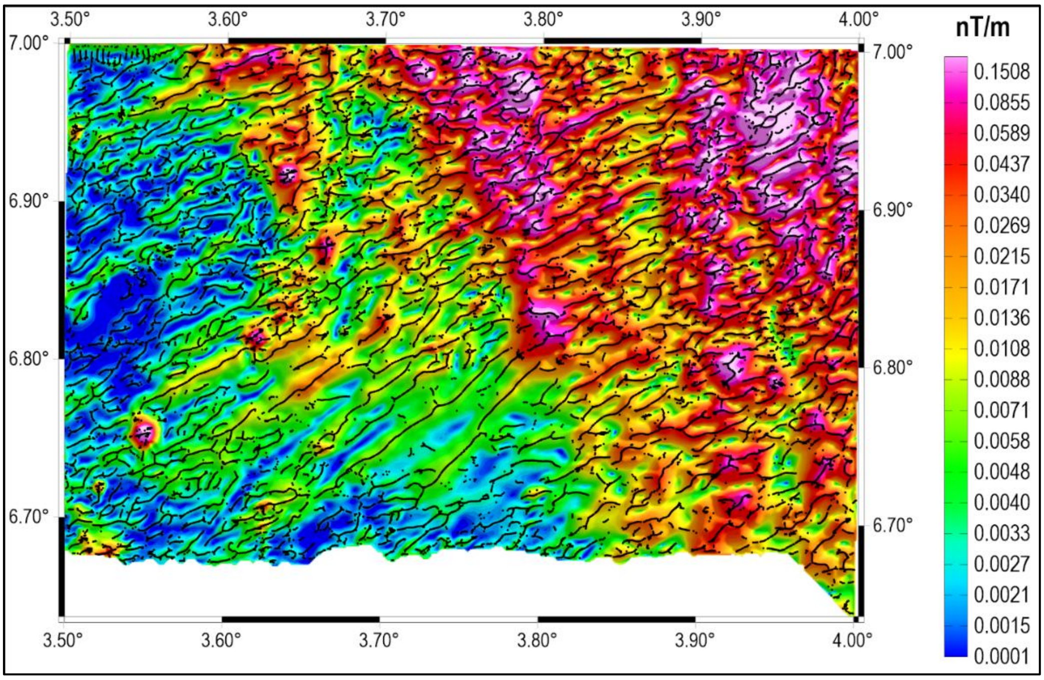

Figure 4 ASA map showing sharp magnetic gradients and interpreted structural edges

3.4. Euler Deconvolution

Euler solutions with structural index SI = 1 delineate probable fault and dike structures (Figure 5). The Euler map, interpreted in conjunction with ASA, aids in confirming the location and approximate depth of fault-related features.

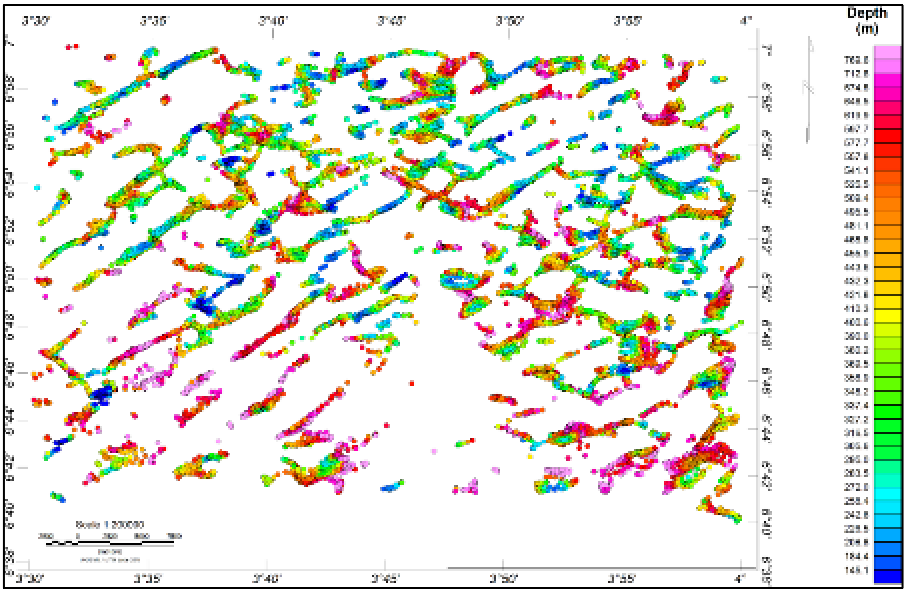

Figure 5 Euler deconvolution map (SI = 1) showing inferred fault/dike trends

3.5. Structural Map

Integration of RTE, ASA, and Euler results yields the final structural lineament map (Figure 6). This map shows major NW–SE and NE–SW trending faults, with subordinate E–W and N–S lineament sets. These orientations are quantitatively summarized in a rose diagram (not shown) with prominent peaks near 45° (NE–SW) and 130° (NW–SE).

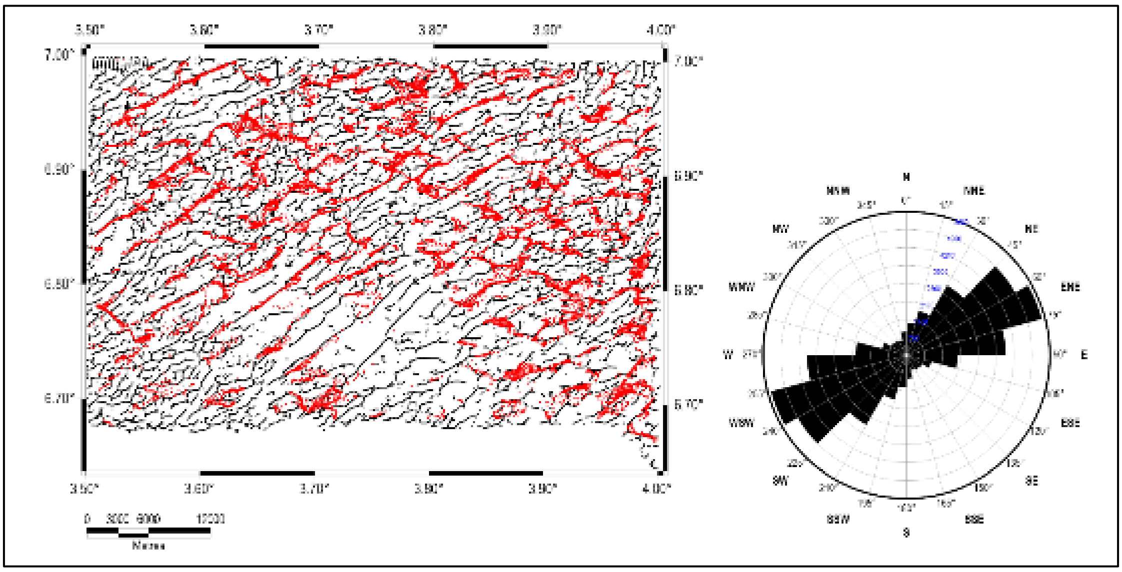

Figure 6 Structural map of Ijebu-Ode showing mapped lineaments and dominant fault orientations

The combined results reveal a dense network of lineaments across the study area. The dominant NW–SE and NE–SW orientations, with secondary E–W and N–S trends, suggest a regionally consistent structural fabric. Many extracted lineaments align with known faults and dike traces, confirming the geological significance of the mapped features. For example, several NW–SE lineaments coincide with the trace of a regional Pan-African shear zone, and E–W lineaments align with known Proterozoic dikes. The rose diagram peaks at ~45° and 130° azimuth indicate that long fractures are uncommon, implying local to intermediate scale structures. Multi-angle hillshading analysis uniquely highlighted short lineaments that single-direction shading missed, and terrain roughness is elevated in zones of intersecting lineaments. Notably, areas with high fracturing (intersecting NE–SW lineaments) exhibit high topographic roughness, supporting the structural interpretations.

The pervasive NW–SE and NE–SW orientations reflect the tectonic history of the basement. These directions are consistent with Pan-African-age structures common in West Africa, often attributed to Gondwana amalgamation forces. The minor E–W lineaments likely represent older or reactivated fabrics (possibly older Proterozoic shear zones) that were differentially oriented during later events. The alignment of mapped lineaments with known faults indicates the features are true structural elements rather than artifacts of processing, corroborating prior studies that combined remote sensing and geophysics [1].

Compared to earlier work, our study provides improved spatial coverage and resolution of lineaments. Ramli et al. [2] demonstrated that remote sensing can reveal inaccessible fractures in tropical forests; here we extend this concept to a basement terrain using newer data and methods. Unlike some past studies that relied on a single image (e.g. Landsat) or coarse digital elevation models (DEMs), we combined multi-sensor imagery and high-resolution DEMs to maximize feature detection. As noted by Gabrielsen and Olesen [1], lineament analysis is most effective when merged with geophysical data. Although our approach was remote sensing–centric, the consistency of our lineaments with aeromagnetic-inferred faults in the literature [12] suggests robustness. For example, Eze et al. [12] reported similar NW–SE and NE–SW trends in adjacent basins based on aeromagnetic data, matching our surface mapping.

Our contributions are twofold: (1) demonstrating that freely available imagery and Google Earth digital surface models (DSM) can yield high-quality reconnaissance lineament maps, and (2) identifying previously unmapped lineaments in this region. The resulting structural map fills a knowledge gap, aiding resource exploration and hazard assessment. Future work could incorporate these lineaments into 3D geological models or test them with field surveys and targeted geophysical surveys for further validation. This refined structural picture is critical for detailed geological mapping and applied geoscience in Ijebu-Ode.

4. Conclusion

High-resolution aeromagnetic processing successfully mapped fault-related lineaments in the Ijebu-Ode basement. The integrated structural map provides a robust framework for future geological, hydrogeological, and mineral exploration. This research produces the most spatially detailed lineament map of the Ijebu-Ode region to date, detecting both major and minor faults with high positional accuracy. By demonstrating continuity between surface and subsurface structures and quantifying their orientations and densities, the study overcomes limitations of previous surface-only mapping. The methodology highlights structural controls on groundwater pathways and potential mineralization zones and provides a replicable aeromagnetic workflow for structural lineament mapping in tropical basement complexes.

Compliance with ethical standards

Acknowledgments

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Disclosure of conflict of interest

The authors declare no conflicts of interest.

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