



Aeromagnetic Investigation of Structural Controls and Gold Mineralization Potential in the Zuru Schist Belt, Northwestern Nigeria

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Abstract

Gold mineralization within the Zuru Schist Belt of northwestern Nigeria is structurally controlled, but detailed delineation of subsurface structures and prospective mineralization zones in the Donko area remains limited. This study aimed to delineate geological structures and identify zones potentially favourable for gold mineralization using aeromagnetic data covering the Donko, Gwashi, Zuru and Wasagu map sheets. High-resolution aeromagnetic data obtained from the Nigerian Geological Survey Agency were processed using Oasis montaj. Total Magnetic Intensity, residual magnetic field, upward continuation, First Vertical Derivative, analytical signal, Source Parameter Imaging and Euler deconvolution techniques were applied to enhance magnetic anomalies, delineate structural features and estimate magnetic-source depths. The results revealed heterogeneous magnetic responses characterized by a dominant NE–SW structural trend, with subordinate NW–SE and N–S orientations. Source Parameter Imaging produced depth estimates ranging from approximately 94 to 554 m, while Euler deconvolution yielded depths of 177–509 m for structural index 1 and 356.6–803.8 m for structural index 2. Prominent magnetic lineaments and clustered magnetic-source solutions occur around the Donko mining area and extend toward the northeastern, central and southern parts of the study area. Areas characterized by intersecting lineaments, pronounced magnetic gradients and shallow-to-moderate magnetic sources were identified as prospective zones for gold mineralization. The study demonstrates that integrated aeromagnetic interpretation provides an effective approach for delineating structurally controlled mineralization targets and offers a basis for detailed exploration and field verification within the study area.

Keywords: Aeromagnetic data; Gold mineralization; Zuru Schist Belt; Structural lineaments; Source Parameter Imaging; Euler deconvolution.

Introduction

Gold mineralization in Precambrian terrains is commonly associated with faults, fractures, shear zones and other structures that control hydrothermal-fluid migration and ore deposition (Groves et al., 1998, 2000, 2018; Goldfarb et al., 2001; Bierlein et al., 2006). The Nigerian Basement Complex contains several gold-bearing schist belts, including the Zuru Schist Belt (ZSB), where gold occurs mainly within metasedimentary rocks and quartz- and quartz-tourmaline-bearing veins (Wright, 1985; Garba, 2000, 2003; Danbatta & Garba, 2007). The structural complexity of the ZSB, involving faults, folds and shear zones, has been linked to the distribution of gold occurrences (Garba, 2000, 2003; Fagbohun et al., 2024). Recent studies indicate that gold mineralization in the ZSB is preferentially associated with NNE–NE, E–W and NE–SW structures, with subsidiary NW-trending structures providing additional local controls (Salawu et al., 2023; Fagbohun et al., 2024). Aeromagnetic data are particularly useful for mapping concealed structures where weathering and limited exposure restrict surface observations. Techniques such as regional–residual separation, upward continuation, first vertical derivative and analytical signal enhance magnetic anomalies and structural boundaries (Blakely, 1995; Gunn et al., 1997; Reeves, 2005). Source Parameter Imaging and Euler deconvolution further provide estimates of magnetic-source depths and geometries (Thompson, 1982; Reid et al., 1990; Thurston & Smith, 1997). However, the detailed orientation, continuity and depth of magnetic structures within the Donko area remain poorly constrained. This study therefore uses high-resolution aeromagnetic data covering Donko, Gwashi, Zuru and Wasagu to investigate the subsurface structural framework. Regional–residual separation, upward continuation, first vertical derivative, analytical signal, SPI and Euler deconvolution are integrated to delineate structural features, estimate source depths and evaluate their significance for gold mineralization. The results provide a basis for identifying structurally favourable zones for subsequent geological, geochemical and ground-geophysical investigation.

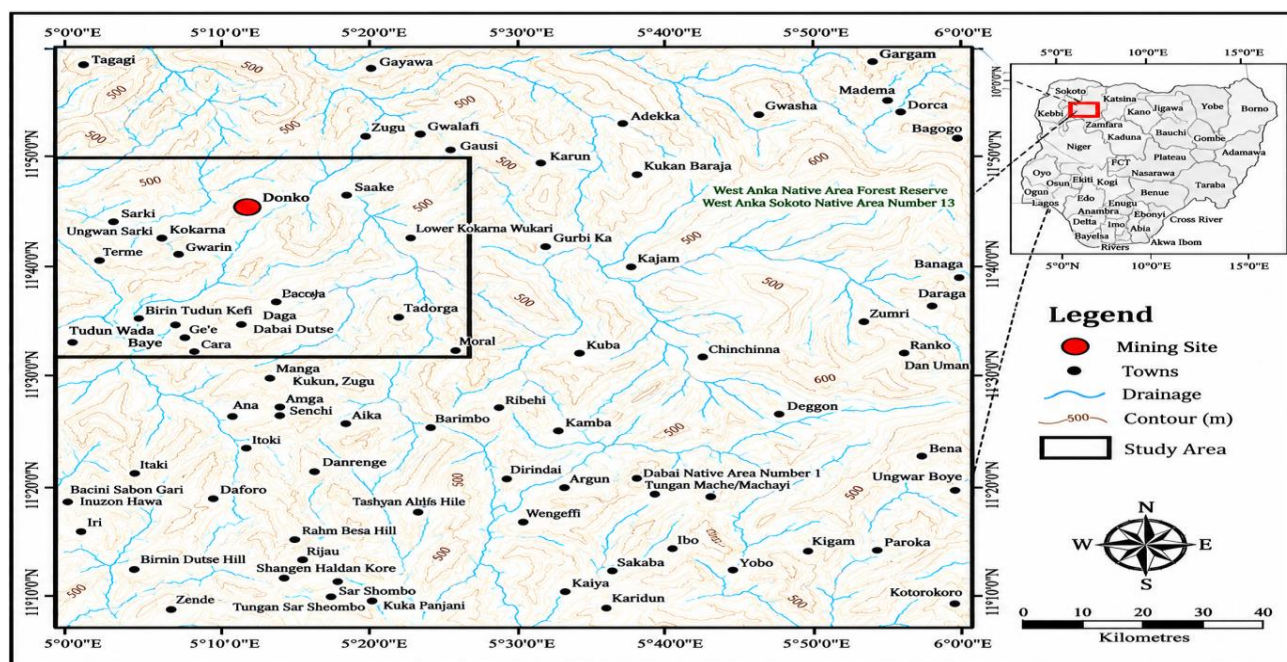
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Study Area Description

Location of the Study Area

The study area is located within the Donko (Sheet 74), Gwash (Sheet 75), Zuru (Sheet 97) and Wasagu (Sheet 98) map sheets in Kebbi State, northwestern Nigeria. It extends approximately from latitude 11°00'N to 12°00'N and longitude 5°00'E to 6°00'E, covering an area of about 12,100 km² (Fig. 1).

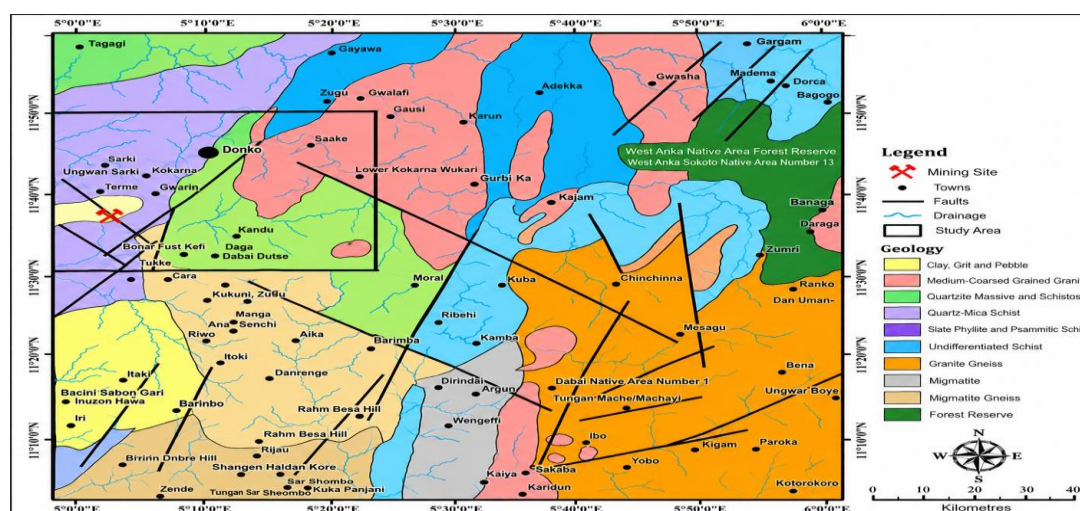
Fig. 1: Map of Nigeria showing location of the study (Adopted from WHO/UNEP, 1997)



Geology of the Study Area

The study area lies within the Zuru Schist Belt of the northern Nigerian Basement Complex and comprises medium-grained granite, quartzite, quartz–mica schist, schist–phyllite, psammitic schist, granite–gneiss, migmatite and migmatite–gneiss (Fig. 2). The basement rocks are Precambrian in age and consist mainly of migmatite–gneiss, Older Granite and schist, with associated quartz veins and pegmatites (Obaje, 2009).

Fig. 2: Geological map of the study area showing Donkoarea (adopted from NGSA 2009).



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Aeromagnetic Data Acquisition and Processing

The study used secondary airborne magnetic data from the Nigerian Geological Survey Agency (NGSA) covering the Donko (74), Gwashi (75), Zuru (97) and Wasagu (98) map sheets. The data were acquired by Fugro-Airborne Surveys (FAS) at a mean terrain clearance of approximately 0.08 km, with 0.5 km flight-line spacing and 5 km tie-line spacing, and were processed in Geosoft Oasis montaj. Regional-residual separation, upward continuation, first vertical derivative (FVD), analytical signal (AS), Source Parameter Imaging (SPI) and Euler deconvolution were applied to enhance magnetic structures and estimate source depths. The resulting products were integrated to delineate the subsurface structural framework and identify zones potentially favourable for gold mineralization (Figs. 3 and 4).

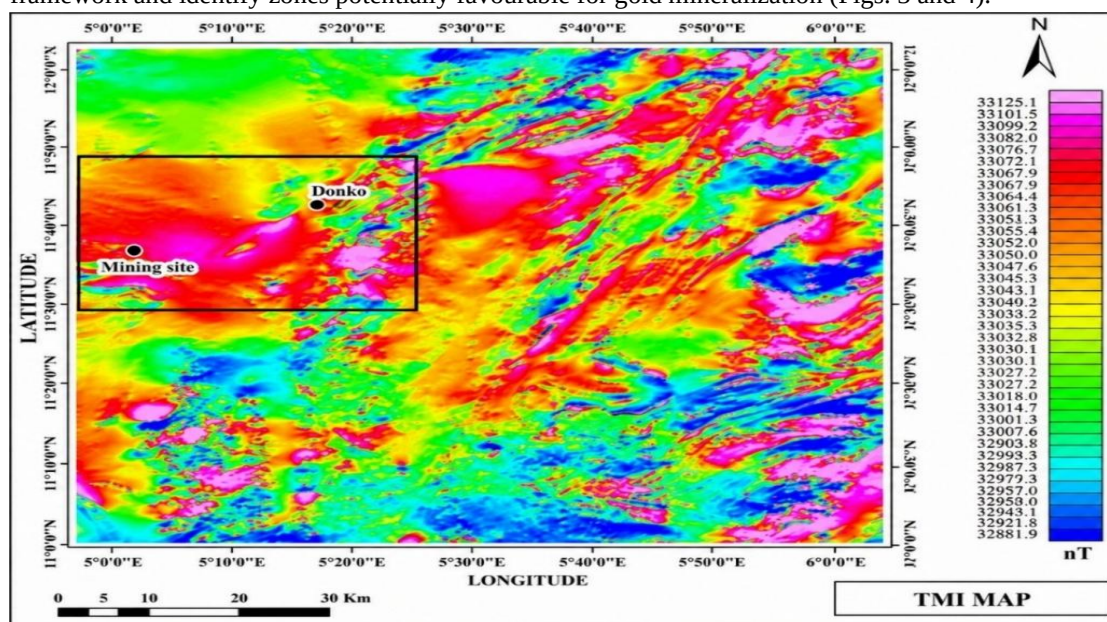


Fig. 3: Total Magnetic Intensity Map of the study area.

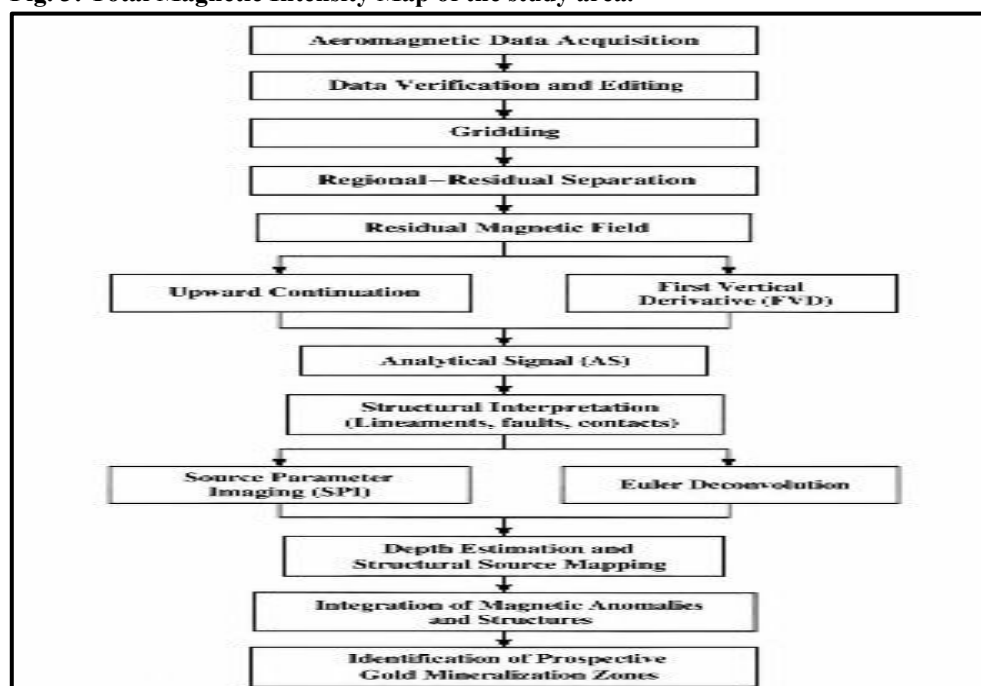


Fig. 4 Methodological Workflow

Presentation of Results and Discussion

The TMI and residual magnetic maps reveal heterogeneous magnetic responses dominated by elongated NE–SW anomalies, with stronger responses mainly in the central, northern and northeastern sectors (Figures 3 and 4). The residual values range from -140.3 to 102.1 nT, while the 200-m upward continuation preserves the major NE–SW trends, suggesting that some structures extend to depth (Figure 5). The FVD further enhances shallow contacts and structural discontinuities, revealing prominent linear and curvilinear features whose intersections indicate structurally complex zones (Figure 6). Such magnetic patterns are consistent with the use of derivative transformations for mapping basement structures and lithological contacts (Blakely, 1995; Gunn et al., 1997; Reeves, 2005).

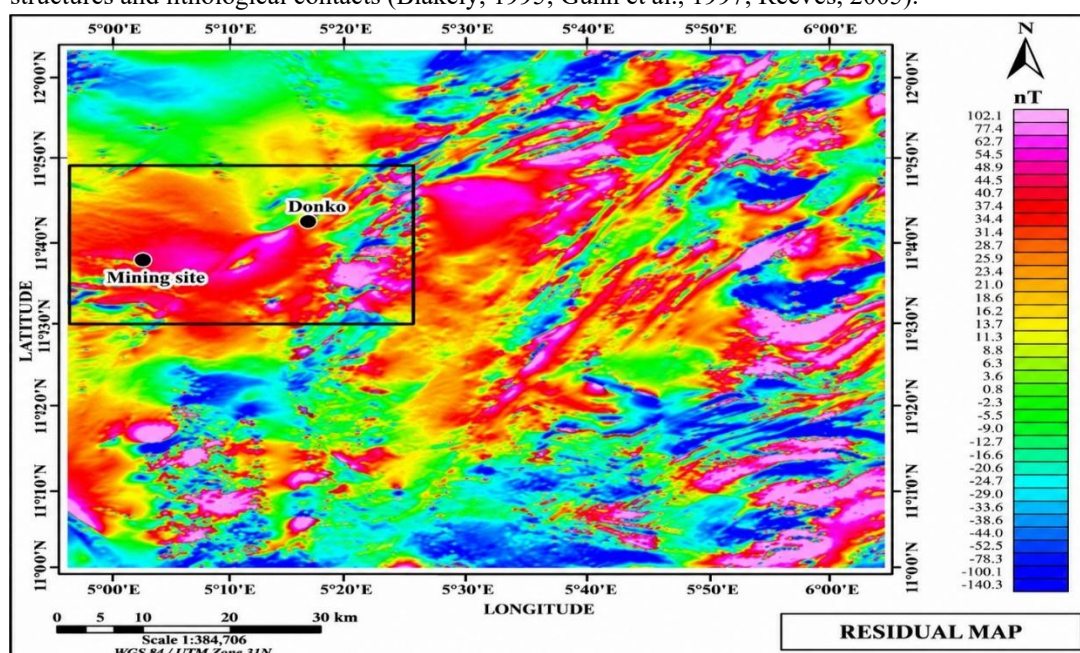


Fig. 4. Residual magnetic field map of the study area.

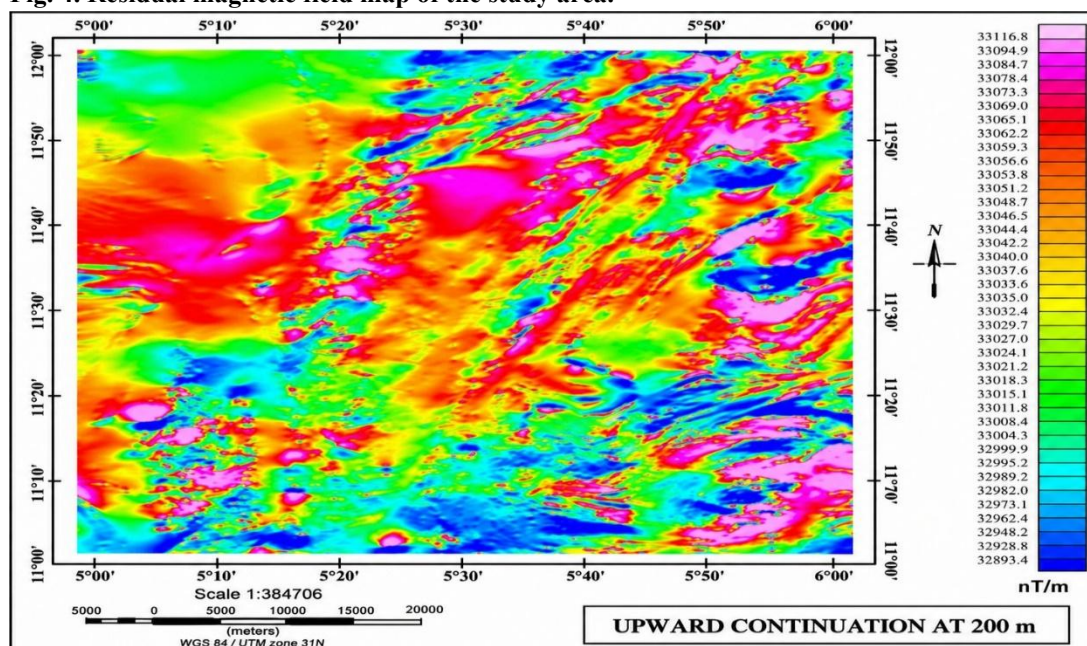


Fig. 5. Upward continuation map of the study area at 200 m.

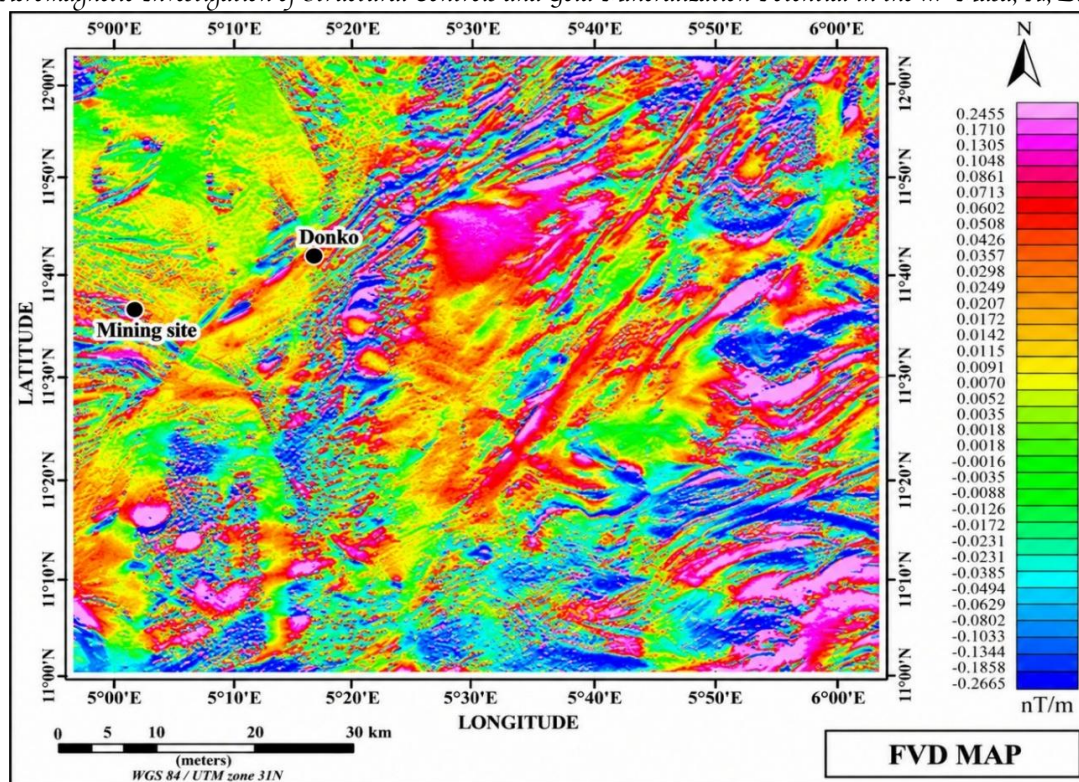


Fig. 6. First Vertical Derivative (FVD) map of the study area.

The analytical signal map highlights magnetic-source boundaries, with amplitudes of approximately 0.0044–0.5096 nT/m and prominent NE–SW-oriented anomalies around the Donko mining area (Figure 9). These responses are consistent with the capability of analytical signal techniques to enhance magnetic contacts and structural boundaries (Nabighian, 1972; Roest et al., 1992). SPI estimates indicate source depths of about 94–554 m (Figure 10), while Euler deconvolution gives depths of 177–509 m for SI = 1 and 356.6–803.8 m for SI = 2 (Figures 11 and 12). The correspondence between SPI and Euler SI = 1 supports the identification of the principal magnetic-source zones, while the deeper SI = 2 solutions reflect different assumed source geometries (Thurston & Smith, 1997; Thompson, 1982; Reid et al., 1990; Hsu, 2002).

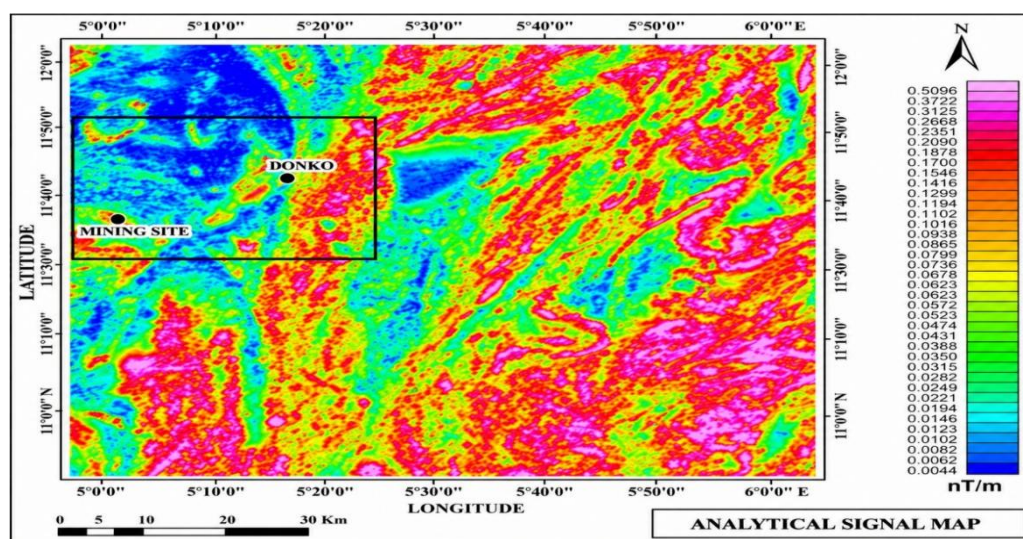


Fig. 9. Analytical Signal (AS) map of the study area.

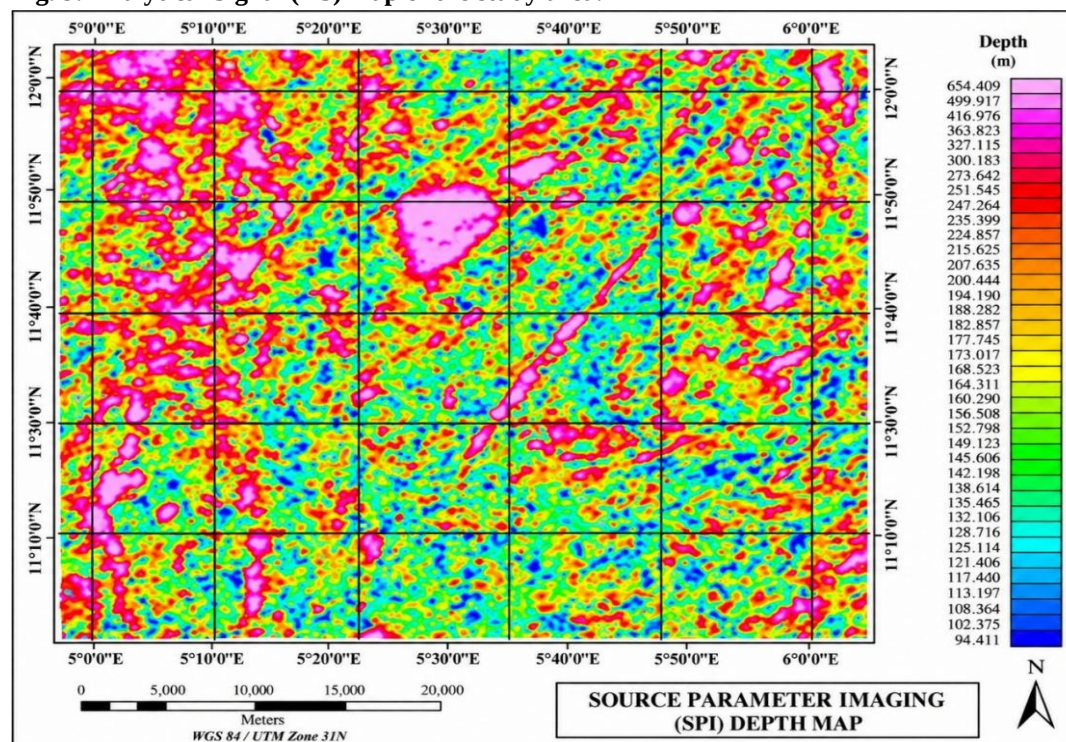


Fig. 10. Source Parameter Imaging Map showing mining site and Donko area

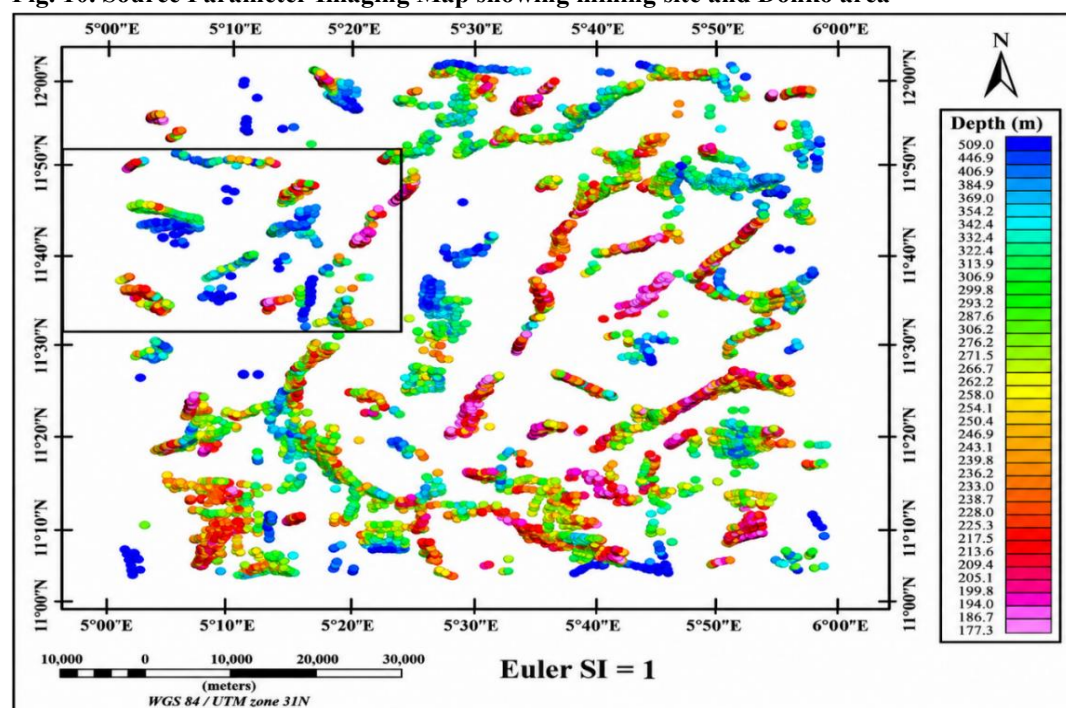


Fig. 11. Standard Euler Solutions Obtained from Aeromagnetic Data (SI=1)

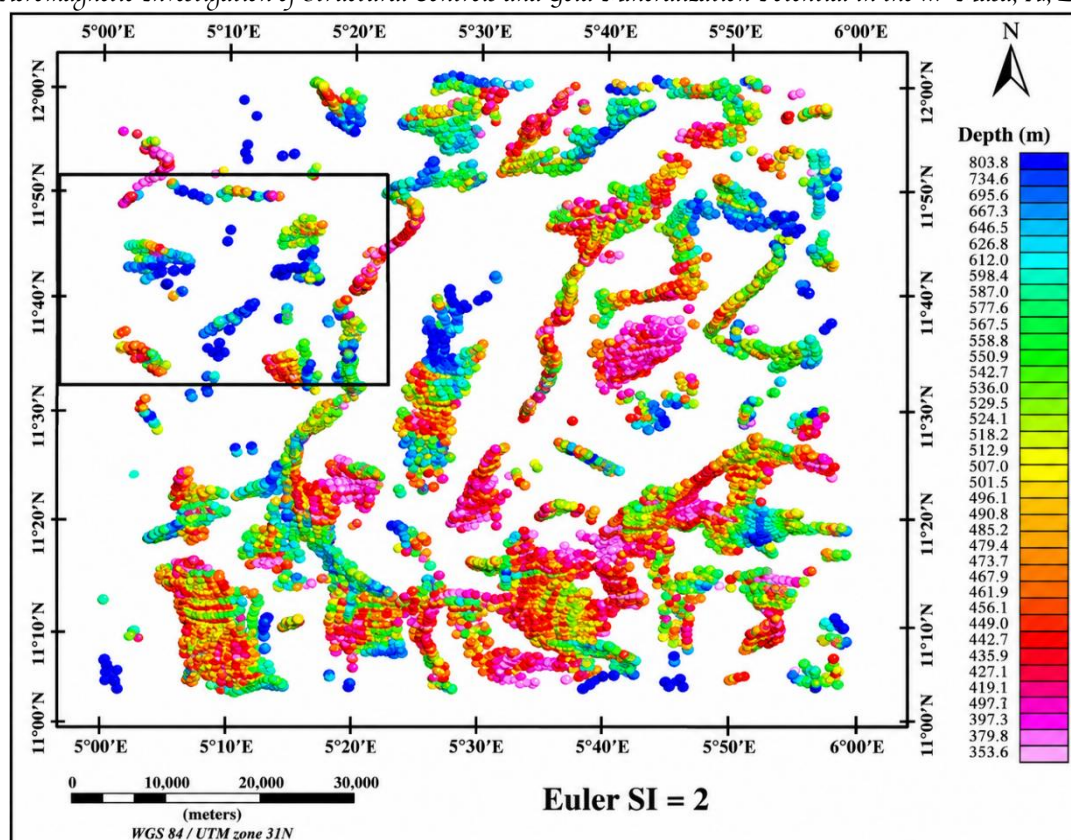


Fig. 12. Standard Euler Solutions Obtained from Aeromagnetic Data (SI=2)

Integration of the magnetic derivatives, analytical signal and source-depth estimates indicates a dominant NE–SW structural framework with subordinate NW–SE and N–S trends (Figures 6–12). Structurally complex zones around the Donko mining area and extending toward the northeastern, central and southern sectors are characterized by intersecting lineaments and shallow-to-moderate magnetic sources. These features are considered favourable for structurally controlled gold mineralization because faults and fractures may provide pathways for mineralizing fluids, consistent with previous interpretations of structural control within the Zuru Schist Belt (Olasunkanmi et al., 2020; Salawu et al., 2023; Fagbohun et al., 2024). Nevertheless, the identified zones represent exploration targets rather than direct confirmation of mineralization and require geological and geochemical validation.

Conclusion

The study successfully applied aeromagnetic data processing and interpretation techniques to investigate the structural framework and delineate prospective gold mineralization zones within the Donko area of the Zuru Schist Belt, northwestern Nigeria. The TMI, residual magnetic field, upward continuation, FVD and analytical signal maps revealed pronounced magnetic variations and a dominant NE–SW structural trend, with subordinate NW–SE and N–S orientations. The SPI results indicated magnetic-source depths of approximately 94–554 m, while Euler deconvolution produced source depths of 177–509 m for SI = 1 and 356.6–803.8 m for SI = 2. The close correspondence between the major magnetic lineaments, source-depth distributions and the Donko mining area indicates that the mineralization is likely associated with structurally complex zones. The most prospective areas occur around the mining site and extend toward the northeastern, central and southern parts of the study area, particularly where prominent structures intersect and coincide with shallow-to-moderate magnetic sources. These results demonstrate the effectiveness of integrated aeromagnetic interpretation for defining structural targets and provide useful targets for detailed ground-based exploration and future verification of gold mineralization in the study area.



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