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INTEGRATED GEOLOGICAL AND AEROMAGNETIC INVESTIGATION OF BARITE MINERALIZATION IN DIDANGO AREA, MURI-LAU SUB-BASIN UPPER BENUE TROUGH NE NIGERIA

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ABSTRACT

Barite ($BaSO_4$) is a critical industrial mineral primarily used as a weighting agent in drilling fluids for oil and gas exploration due to its high specific gravity and chemical inertness. Despite the abundance of barite mineralization in Nigeria, many deposits in the Upper Benue Trough, particularly within the Muri-Lau Sub-Basin, remain poorly studied and their structural controls inadequately understood. This study integrates detailed geological mapping and high-resolution aeromagnetic analysis to investigate the mode of occurrence, structural controls, and economic potential of barite mineralization in the Didango area. Field observations revealed that barite occurs in hydrothermal veins associated with fault zones and fractures within sedimentary rocks. Aeromagnetic data, including Total Magnetic Intensity (TMI), Analytical Signal, Source Parameter Imaging (SPI), and Vertical Derivative maps, highlight E-W and N-S trending lineaments indicative of structurally controlled mineralization. High-intensity magnetic anomalies and shallow depth estimates correlate with known mineralized zones, suggesting potential for near-surface barite and base metal deposits. The results emphasize the role of tectonic structures in controlling fluid pathways and mineral deposition. This integrated approach enhances understanding of hydrothermal mineralization processes in the Muri-Lau Sub-Basin and fills an existing knowledge gap on the structural evolution of the area.

Keywords: Barite, Aeromagnetic, Lineament, Mineralization, Didango

INTRODUCTION

Barite ($BaSO_4$) is a dense, chemically inert sulfate mineral with widespread industrial applications. Its primary use is a weighting agent in drilling muds for oil and gas exploration, where it aids in controlling formation pressures, transporting drill cuttings, and cooling the drill bit (Abubakar and Hohl, 2020; Rabiu *et al.,* 2020). Additionally, barite is used in the manufacture of paints, paper, rubber, glass, and radiological applications due to its high specific gravity and low solubility in water (Afolayan *et al.,* 2023; Elkatatny *et al.,* 2023). Global demand for barite has increased significantly, driven by the expansion of petroleum exploration activities, particularly in developing economies. In Nigeria, barite is recognized as a strategic mineral for the oil and gas sector, yet local production remains insufficient to meet domestic demands, leading to heavy import dependence (Rabiu *et al.,* 2020). Several occurrences have been documented within the Benue Trough, but most exploration and characterization studies have focused on the Middle Benue (Azara and Lessel areas), while deposits in the Upper Benue Trough are comparatively underexplored and poorly constrained in terms of structural setting, genesis and economic potential (Kamale, 2025).

Nigeria hosts substantial barite deposits, primarily within the Lower and Middle Benue Trough, and more recently, in the Upper Benue Trough, including the Gongola and Lau Sub-Basins (Adeleye, 2019; Kamale *et al.,* 2019; Edet and Nyong, 2020, Kamale *et al.,* 2020). These occurrences span both sedimentary sequences and flanking basement complex rocks, though many remain underexplored and undocumented (Kamale and Haruna, 2023). The Didango area represents one such locality where barite mineralization has been observed by artisanal miners, yet without detailed geological or geophysical assessment. Understanding the geological controls in this region is therefore critical for developing scientific basis for exploration and sustainable resource development. The Lau Sub-Basin, a structurally complex segment of the Upper Benue Trough, offers promising barite mineralization linked to hydrothermal processes within faulted and fractured sedimentary and crystalline formations (Ikenna and Jerome, 2022). The Benue Trough, a linear intracontinental rift basin formed during the Cretaceous breakup of Gondwana, is a prolific metallogenic province containing significant deposits of barite, lead, zinc and fluorite (Benkhelil, 1989; Akande *et al.,* 2020). In the Didango area, barite mineralization is believed to be epigenetic, associated with hydrothermal fluids migrating along structurally controlled pathways such as faults, joints, and bedding planes in sandstones, shales, and limestones. These veins often occur as massive, stringer, or cavity-filling bodies of varying thickness, depending on the intensity of deformation and activity. A comprehensive understanding of the geological setting, structural architecture, and geophysical signatures of the Didango barite occurrences is necessary for resource evaluation and exploitation. Previous studies have highlighted the importance of integrating geological and geophysical methods in delineating mineralized zones (Nwosu *et al.*, 2021; Ekwueme and Akande, 2022).

This study presents the first integrated geological and aeromagnetic assessment of barite mineralization in the Didango area of Muri-Lau, Upper Benue Trough. While previous works have reported barite occurrences within the broader Benue Trough, the Didango deposits remain largely undocumented in academic literature. By combining field mapping with high-resolution aeromagnetic data, this research uniquely identifies structurally controlled mineralization pathways, revealing previously unmapped fault intersections and shallow magnetic anomalies directly correlated with barite occurrences. The study offers a novel geophysical-geological framework for evaluating epigenetic barite deposits in Nigeria's inland basins and contributes original insights into the structural evolution of the Muri-Lau Sub-Basin as it relates to mineral resource potential.

Geological Setting of Didango

The Didango area is located between latitudes 9º 00′N and 9º 30′N and longitudes11º 00′E and 11º 30′E, within the Muri-Lau arm of the Upper Benue Trough in northeastern Nigeria. It falls within the Federal Survey of Nigeria Sheet 194 (Lau SE), situated in the Karim Lamido Local Government Area of Taraba State (Fig. 1). The region forms part of a structurally complex zone known for base metal sulfide and barite mineralization. Geologically, the area comprises both Precambrian Basement Complex rocks and Cretaceous sedimentary sequences of the Benue Trough (NGSA, 2022). The basement rocks include migmatite-gneiss (occupying ~7% of the mapped area), granite-gneiss (~8%), and porphyritic granite (~35%). These lithologies dominate the southern and southwestern portions of the study area (NGSA, 2022). The sedimentary terrain, which includes sandstone, shale, and limestone, covers much of the northwestern axis and isolated portions of the eastern section (Nwajide, 2013; Bute, 2024). Recent unconsolidated alluvial sediments occur along the banks of major such as the Sibre and Lamurde, indicating ongoing fluvial processes.

The sedimentary units within the study area are part of the stratigraphic succession of the Upper Benue Trough, which includes formations such as the Bima Sandstone, Yolde Formation, Dukul, Jessu, Sekuliye, Numanha Formations, and Lamja Sandstones. These units reflect a transition from continental to marine depositional environments during the Cretaceous (Akande and Ojo, 2004; Nwajide, 2013; Finthan *et al*., 2023). The Bima Sandstone, the oldest Cretaceous formation in the trough, unconformably overlies the Basement Complex. It consists of coarse-grained fluvial deposits such as conglomerate, arkosic sandstones, and lenses of shale and mudstone (Braide, 1992; Nwajide, 2013). The Yolde Formation marks transitional facie, and comprises interbedded sandstone, siltstone, and mudstone, reflecting shallow marine to deltaic conditions. The Dukul Formation represents a fully marine sequence, composed of shales, marls, and limestones. The Jessu Formation is characterized by gypsiferous and non-gypsiferous shales interbedded with mudstones and sandstones, indicative of open marine settings (Finthan *et al.,* 2023). The Sekuliye Formation is characterized by gypsiferous shales with thin limestone bands, bearing Coniacian ammonite fossils (Nwajide, 2013; Ntekim and Adekeye, 2016). The Numanha Formation is dominated by gypsiferous black shales and interbedded laminated siltstones. The Lamja Sandstone comprises carbonaceous and non-carbonaceous siltstones, fine-grained sandstones, low-ranked coal layers (~24 cm thick), and fossiliferous bioclastic limestones. It is unconformably overlain by Tertiary basalts of the Longuda Plateau (Ntekim and Adekeye, 2016).

These formations collectively record the complex tectono-sedimentary evolution of the Upper Benue Trough, influenced by rifting, subsidence, and marine transgressions during the Cretaceous (Nwajide, 2013; Finthan *et al*., 2023). The tectonic framework plays a crucial role in controlling fluid migration and mineralization patterns, particularly in relation to faulting and fracturing of the sedimentary units and basement rocks (Kamale and Haruna, 2023).

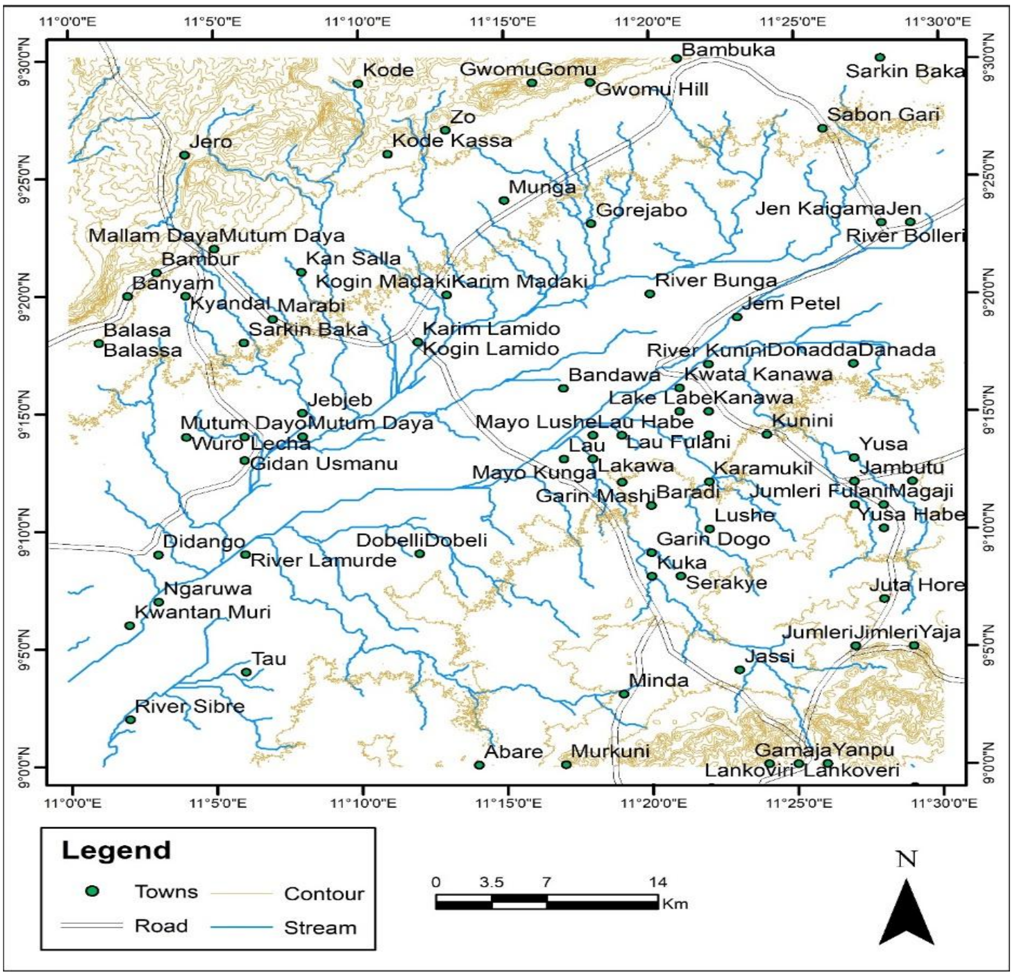

Figure 1: Topographic Map of Didango Area Showing the Location of the Study Area (NGSA, 2022)

MATERIALS AND METHODS

This study adopted an integrated approach combining geological fieldwork and aeromagnetic data interpretation to delineate the occurrence and structural control of barite mineralization in the Didango area, Muri-Lau Sub-Basin, Northern Benue Trough. The methodology involved the following stages:

Geological Field Mapping and Sample Collection

Detailed geological mapping was conducted at a scale 1:25,000 to identify lithological units, structural features, and mineralized veins. Structural data including joint orientations, fault planes, and vein trends were recorded using compass-clinometer. Representative rock and mineral samples were systematically collected from barite-bearing veins and host rocks for laboratory analysis.

Aeromagnetic Data Acquisition and Processing

High-resolution aeromagnetic data (sheet 194, Lau SE) was obtained from the Nigerian Geological Survey Agency (NGSA). The data was processed using Oasis Montaj and other geophysical software platforms. Filters applied include: Total Magnetic Intensity (TMI), First and Second Vertical Derivatives (FVD and SVD), Analytical Signal, Source Parameter Imaging (SPI), Tilt Derivative (TDR) and Horizontal Gradient Magnitude (HGM). These filters helped enhance subsurface features, delineate lineaments, and identify possible mineralized structures (Umaru *et al.*, 2023; Gajere *et al.*, 2024).

Structural and Lineament Analysis

Interpreted aeromagnetic maps were used to extract lineaments and fault patterns, employing edge detection algorithms and rose diagram generation. These were validated through correlation with field-based structural observations (Ahmadi *et al.*, 2023). The orientations and density of lineaments were analyzed to assess their control on mineralization.

Integration and Interpretation

The final stage involved synthesizing geological observations with aeromagnetic interpretations to delineate structurally controlled barite zones. Spatial correlation between magnetic anomalies, structural trends, and known mineral occurrences was used to infer prospective zones for further exploration (Umaru *et al.*, 2023; Gajere *et al.*, 2024).

RESULTS AND DISCUSSION

Aeromagnetic Interpretation and Structural Analysis

Aeromagnetic data interpretation of Lau Sheet 194 revealed several magnetic anomalies and structural trends that have direct implications for barite and associated base metal mineralization in Didango area. The data analysis utilized multiple derivative-enhancing filters to emphasize geological features and delineate structurally controlled mineralized zones.

Total Magnetic Intensity (TMI) Map

The TMI map highlights regional magnetic intensity variations, with high-intensity zones observed around coordinates (11º 10′E, 9º 25′N) and (11º 15′E, 9º10′E). These anomalies may correspond to magnetic -bearing lithologies or structurally emplaced mineralized zones. Magnetic lows, identified near (11º 08′E, 9º 12′N) and (11º 18′E, 9º 22′N), are interpreted as demagnetized zones likely due to hydrothermal alteration, a common feature in sulfide and barite-bearing systems (Ajayi, 1987; Akande and Mucke, 2020).

Analytical Signal Map

The Analytical Signal map delineates magnetic source edges, with prominent high-intensity anomalies (red-purple zones) between (11º 05′E, 9º 15′N) and (11º 20′E, 9º 25′N). These anomalies coincide with interpreted fault and fracture systems, supporting their role as mineralization conduits (Ajayi, 1987; Akande *et al*., 2020). The clustering of these features aligns with NE-SW and NW-SE trends, consistent with regional tectonic fabric (Kamale and Haruna, 2023).

Source Parameter Imaging (SPI) Map

The SPI map estimates depths to magnetic sources, revealing shallow magnetic bodies (<200 m depth) near (11º 15′E, 9º 15′N) and (11º 05′E, 9º 20′N). These anomalies are associated with known barite occurrences and are interpreted as structurally emplaced mineralized veins. Depth variability and high analytical intensity suggest tectonic reactivation and multiple phases of mineralizing fluid intrusion (Akande and Abimbola, 1989; Elkatatny *et al*., 2023).

First and Second Vertical Derivatives (FVD and SVD) Maps

FVD and SVD maps enhance high-frequency anomalies and shallow lithological contrasts. The results show linear features trending NE-SW and NW-SE, consistent with known mineralized fault zones. High-gradient anomalies were observed at (11º 10′E, 9º 20′N) and (11º 20′E, 9º 15′N), potentially marking ore-controlling structures (Chaanda *et al*., 2010, Ekwueme and Akande, 2022). The SVD map further identifies minor fault splays, fracture intersections, and shallow intrusions indicative of hydrothermal alteration zones.

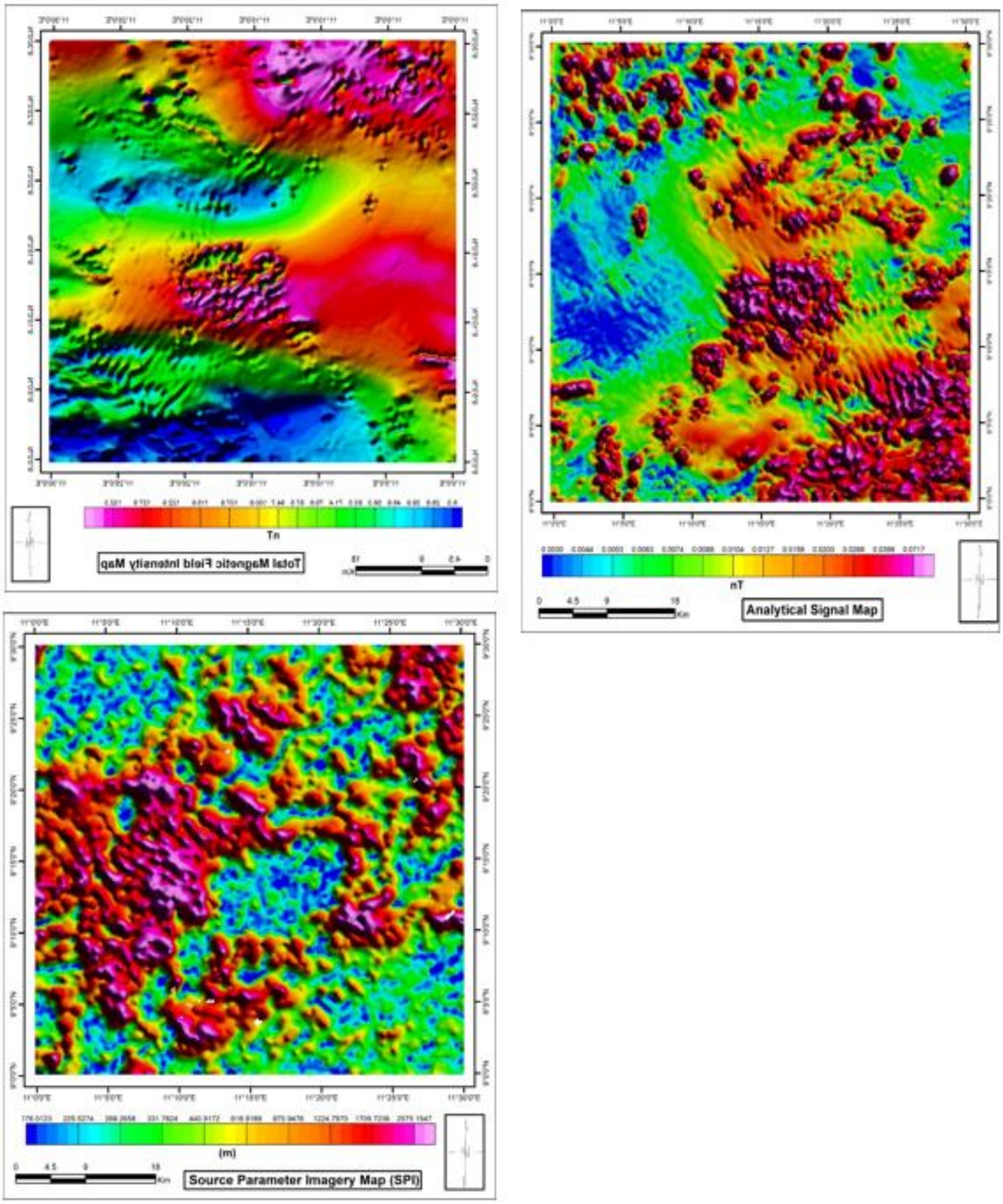

Figure 2: Total Magnetic Intensity Map, Analytical Signal Map and Source Parameter Imagery map of Lau Sheet 194

Tilt Derivative (TDR) Map

The DTR map emphasizes structural boundaries and deep-seated anomalies. High-gradient anomalies around (11° 12′E, 9° 18′E) and (11° 25′E, 9° 22′N) reflect zones of significant magnetic contrast, interpreted as deep-seated shear zones or basement-rooted faults. These zones may represent favorable pathways for hydrothermal fluids responsible for barite precipitation (Nwosu and Onyekuru, 2021; Mohammed and Yaro, 2023).

Horizontal Gradient Map (HGM)

The HGM map reveals strong lateral contrasts and potential ore-hosting lineaments. High-gradient anomalies are concentrated around (11° 15′E, 9° 56′N) to (11° 25′E, 9° 58′N), delineating NE-SW trending structures that coincide with areas of known mineralization. These structures are interpreted as conduits for mineralizing fluids, consistent with vein-type barite deposition models (Michael, 2012; Fatoye *et al*., 2023).

Lineament and Contour-Anomaly Maps

Lineament interpretation reveals dominant NE-SW and NW-SE structural trends, which reflect the regional tectonic framework of the Benue Trough (Carter *et al.*, 1963; Offodile, 1980). Intersections of lineaments, especially near (11° 05′E, 9° 57′N) and (11° 15′E, 9° 58′N), correspond with high anomaly clusters and key exploration targets due to increased permeability and fluid flow potential (Adeleye, 2019; Kamale and Haruna, 2023).

Regional Magnetic Field

The regional Magnetic Field map illustrates a systematic NW-SE gradient in magnetic intensity, indicating deep basement features and regional tectonic alignment. This gradient may reflect lithological transitions and crustal block boundaries that exert secondary control on barite distribution (Kamale and Haruna, 2023).

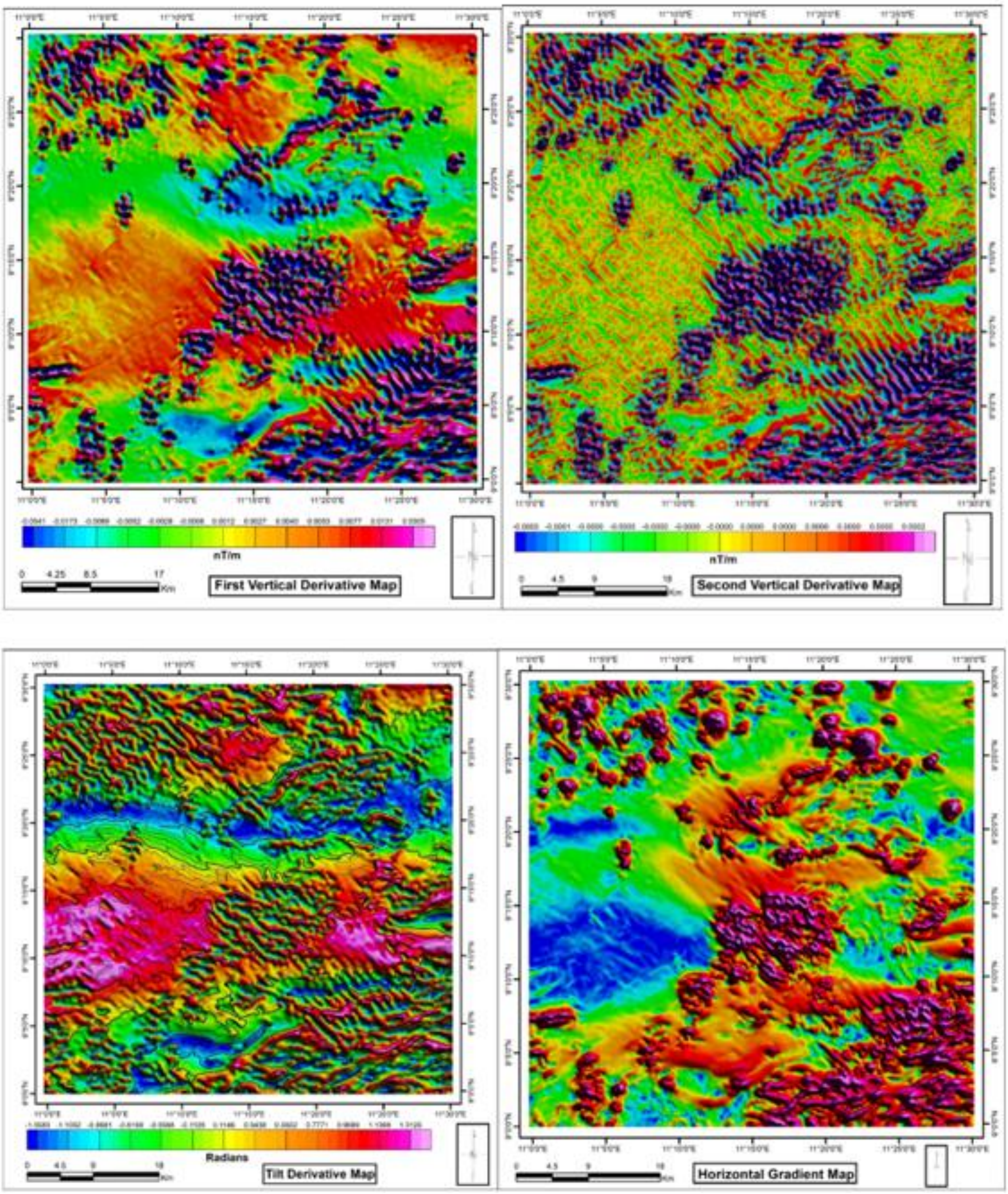

Figure 3: Second Vertical Derivative (FVD) map, Second Vertical Derivative map, Tilt Derivative (TDR) map and Horizontal Gradient (HGM) map of Lau Sheet 194

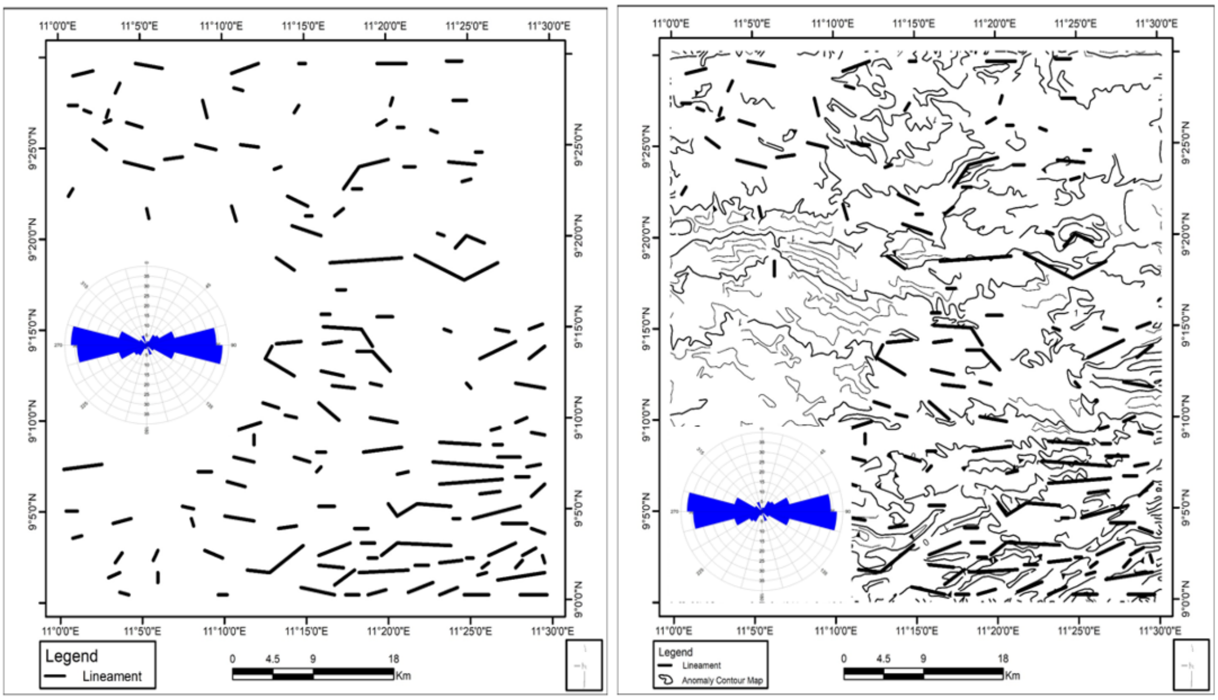

Figure 4: Interpreted Structural Map Around the Area of Interest, Anomaly Contour Map Superimposed on a Lineament Around the Area of Interest and Rose Plot for the Lineaments of Lau sheet 194

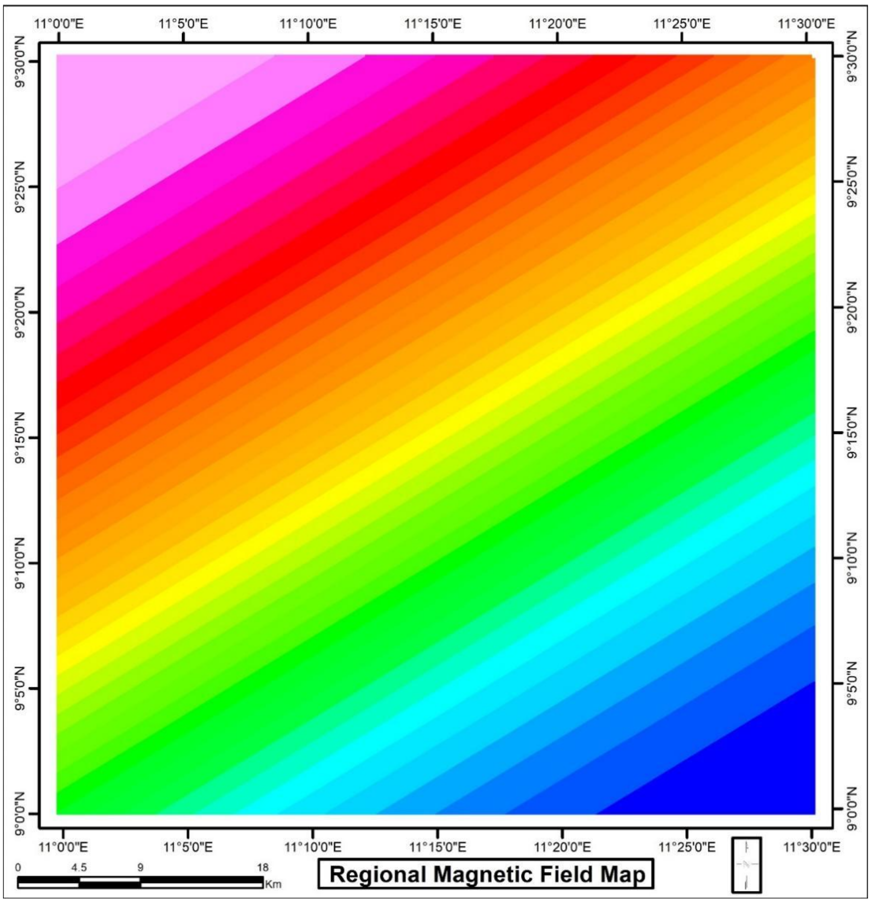

Figure 5: Regional Magnetic Field map of Lau Sheet 194

Barite Mineralization

Field investigations reveal that barite mineralization in the Didango area is hosted predominantly within Cretaceous sandstone units of the Bima and Yolde Formations (Fig. 6). The ore occurs as hydrothermal veins emplaced along a network of pre-existing fractures, fault planes and bedding-parallel partings clear evidence of a post-depositional, epigenetic origin (Kamale *et al.,* 2020;

Auwalu, 2024). Veins are preferentially localized where sandstone competency contrasts with shale interbeds, suggesting mechanical stratigraphy played a key role in focusing fluid flow. The veins display three principal morphologies, massive, granular and fibrous with individual lodes extending > 47 m along strike and attaining widths of 0.87 – 3.60 m. Barite is dominantly creamy-white but exhibits local brown, green and black tints caused by inclusions of iron oxides, clay minerals and minor sulfides (e.g., galena, pyrite). Colloform banding, vug-filling textures and brecciated wall-rock fragments record multiple hydrothermal pulses under low- to medium-temperature conditions (~180 – 250 °C), consistent with other vein-type deposits in the Benue Trough (Kontak *et al.*, 2021). Wall-rock alteration halos up to 1.5 m thick are characterized by silicification, ferruginisation and chloritisation, confirming reactive interaction between meteoric–basinal fluids and host lithologies. Geochemical analyses from previous studies (Akande and Mucke, 2020; Nwosu and Onyekuru, 2021) demonstrate elevated Ba, Sr and trace Pb–Zn contents, supporting a mixed basinal-brine and basement-derived fluid signature. Structurally, veining aligns with E–W and N–S fault systems mapped in both field and aeromagnetic datasets. These steeply dipping, strike-slip faults were reactivated during post-Santonian compression, providing high-permeability pathways for ascending Ba-rich fluids. Rose-plot statistics indicate that vein density peaks where these two fault sets intersect, underlining the importance of structural linkage and dilation in ore emplacement. Comparatively, Didango mineralization mirrors the vein-type barite districts at Azara (Middle Benue Trough) and Liji (Upper Benue Trough), where tectonically driven fluid flow precipitated barite ± Pb–Zn within rift-related fault corridors (El-Nafaty, 2015; Kamale *et al.*, 2020). This regional analogy strengthens the exploration model that structurally controlled hydrothermal systems dominate barite endowment in the Benue Trough. Genetically, the deposit is interpreted as an epigenetic, structurally controlled hydrothermal vein system formed by the mixing of Ba-rich basinal brines with meteoric waters under declining temperature–pressure regimes. The spatial coincidence of shallow magnetic lows, mapped fractures and surface veins suggests that integrated magnetic–structural analysis is an effective predictor of undiscovered lodes (Kamale *et al.*, 2020; Auwalu, 2024). Consequently, fault intersections and dilatational jogs identified in aeromagnetic interpretations constitute high-priority targets for follow-up geochemical sampling and exploratory drilling.

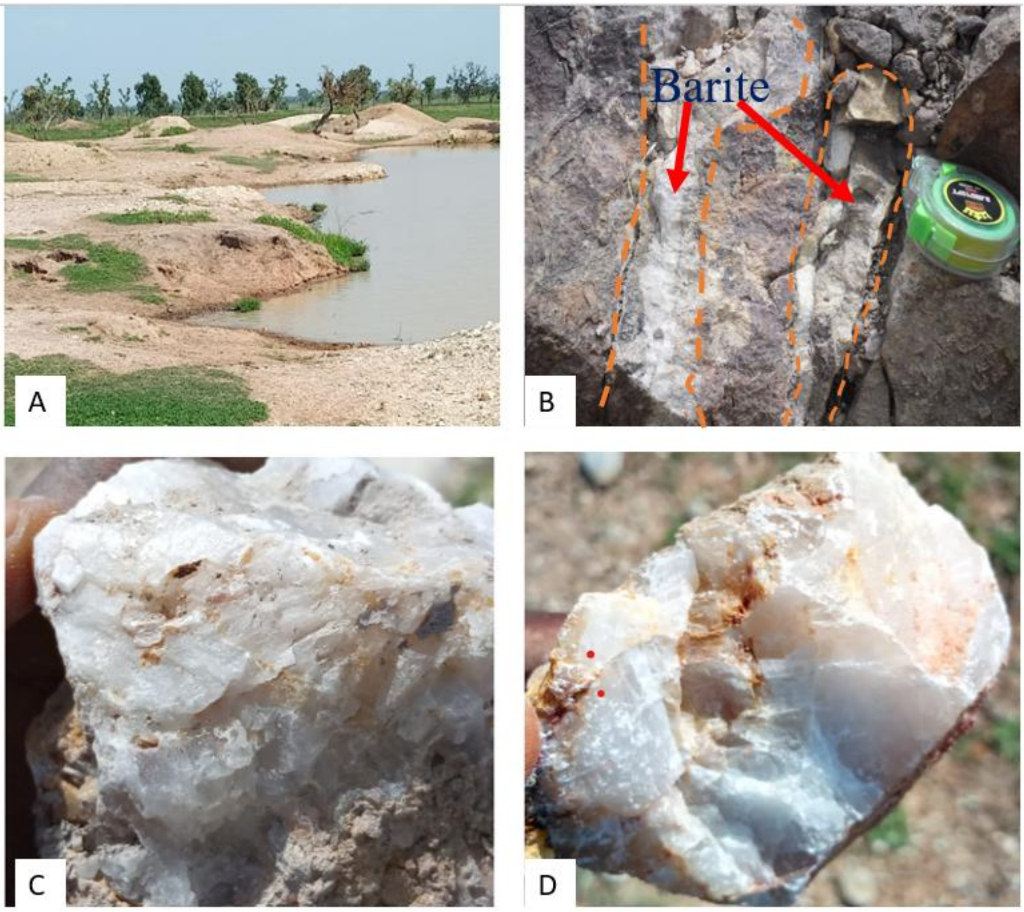

Figure 6: Field Photograph of Didango Barite field (A) Barite mining Pit Filled with Water, (B) Barite Veins in Altered Sandstones, (C and D) Massive Barite with Tints of Ferrous Material

CONCLUSION

This study employed an integrated geological and aeromagnetic approach to delineate barite mineralization in the Didango area of the Muri-Lau Sub-Basin, Northern Benue Trough. Field investigations revealed structurally controlled barite veins occurring within sedimentary and basement lithologies, consistent with epigenetic mineralization models. Aeromagnetic data, including TMI, SPI, vertical derivatives, and structural lineament maps, identified several NE-SW and NW-SE trending fault systems associated with mineralized zones.

The alignment of high-intensity magnetic anomalies with shallow SPI depth estimates and field-observed veins underscores the role of tectonic structures in controlling fluid flow and mineral deposition. The analytical signal and derivative maps highlighted high-potential areas for further exploration, particularly around fault intersections and zones of hydrothermal alteration.
These findings contribute to the geoscientific understanding of barite mineralization in the Upper Benue Trough and offer a predictive framework for identifying prospective barite and base metal deposits in structurally complex terrains. Specifically, this study demonstrates that integrating high-resolution aeromagnetic data with detailed field mapping can effectively reveal subsurface structural controls that are not observable from the surface geology alone. The correlation of shallow SPI depth estimate with mapped hydrothermal veins confirms that barite emplacement in Didango area is governed by intersecting NE-SW and NW-SE fault systems, a relationship not previously documented for this sub-basin. The outcomes are significant for guiding future exploration programs, resource development, and sustainable mineral exploitation in northeastern Nigeria.

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