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Application of Interpreted Aeromagnetic Data to Decipher Masked Structurally Controlled Pegmatite Mineralization in the Thickly Covered Terrain of Nasarawa State, Nigeria

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ABSTRACT

The increasing global demand for lithium, driven by the renewable energy transition and electric mobility, has positioned pegmatite-hosted lithium deposits as strategic mineral resources for the 21st century. The Nasarawa region of North Central Nigeria, situated within the Pan-African reworked mobile belt of the Nigerian Basement Complex, hosts significant pegmatite mineralization with documented rare metal potential. However, exploration efforts in this region face a fundamental challenge: extensive lateritic and sedimentary cover that masks surface expressions of mineralization, rendering conventional prospecting methods ineffective. This study employs an integrated aeromagnetic geophysical approach to detect concealed pegmatite mineralization in the thickly covered terrain of Nasarawa State. High-resolution aeromagnetic data obtained from the Nigerian Geological Survey Agency was processed and analyzed using advanced edge detection techniques including First Vertical Derivative (FVD), Analytical Signal Amplitude (ASA), Tilt Derivative (TDR), and Trend Analysis to identify structural lineaments and magnetic anomalies associated with mineralized zones. The results reveal that areas characterized by moderate magnetic anomalies with distinct horizontal and vertical gradient variations represent potential pegmatite-hosted mineralization zones. Lineaments and intersections of NE-SW trending structures, particularly where fault densities are high alongside magnetic sources at intermediate depths, are identified as possible zones of pegmatite mineralization. The findings demonstrate that integrated aeromagnetic interpretation, combined with structural analysis, provides an effective exploration strategy for identifying concealed pegmatite mineralization in covered terrains. This research contributes to the development of robust geophysical exploration protocols for lithium resources in the Nasarawa pegmatite belt and similar geological settings across Nigeria.

Keywords: Basement, Aeromagnetic, Lineament, Structures, Trend Analysis, 1VD,

1.0. INTRODUCTION

The global transition to renewable energy and electric mobility has dramatically increased demand for lithium, positioning it as a strategic mineral for the 21st century (Gunn, 2014). Pegmatitehosted lithium deposits, particularly those enriched in lithiumcesiumtantalum (LCT) mineralization, represent a primary source of this critical metal (London, 2018). The Nasarawa region of North Central Nigeria, situated within the PanAfrican reworked mobile belt of the Nigerian Basement Complex, hosts a significant pegmatite belt that has attracted considerable exploration interest due to its documented rare metal potential (Ogunleye *et al*., 2020). Recent geochronological studies have established that Nb-Ta-Be-Li mineralization in the Nassarawa Keffi pegmatite belt occurred during a prolonged post collisional extension period (ca. 572–548 Ma) associated with the Gondwanaforming orogeny, confirming the region's substantial rare metal endowment (Ajayi *et al*., 2023). The exploration of pegmatite type lithium deposits in Nasarawa State faces a fundamental challenge: the extensive lateritic and sedimentary cover that masks surface expressions of mineralization (Oyediran and Adeyemo, 2022). Conventional prospecting methods have demonstrated poor effectiveness in evaluating exploration targets within these covered terrains, necessitating the development of integrated geophysical approaches that can reliably detect concealed ore bodies (Zhdanov, 2015). Among geophysical techniques, the magnetic method is recognized as a sensitive and effective tool for prospecting mineralized zones, particularly when focused on areas of high structural complexity (Kearey *et al*., 2002). This sensitivity is crucial because pegmatites and associated mineralized structures are often characterized by linear features and lineaments that can serve as conduits facilitating the accumulation of mineral resources (Hobbs, 2018). However, the direct detection of pegmatite hosted bodies using magnetics is inherently indirect: highprecision magnetic surveys primarily detect intrusionrelated and metamorphic signatures associated with mineralization rather than the weakly magnetic ore bodies themselves (Fedi and Pilkington, 2012). Consequently, the integration of ground magnetic data with airborne magnetic surveys becomes essential for comprehensive subsurface characterization (Nabighian *et al*., 2005). The geological setting of Nasarawa State is dominated by migmatitic banded biotite gneiss, biotitemuscovite gneiss, and occasional amphibolite, intruded by biotite granites, leucogranites, and granitic pegmatites (Obiora, 2020). These pegmatites are associated with the extensive Nigerian pegmatite belt that trends NESW across the Basement Complex, with the Nasarawa field representing a critical segment of this metallogenic province (Kinnaird, 2013). The petrogenesis of these mineralized pegmatites remains a subject of investigation, with evidence suggesting derivation from the remelting of Paleoproterozoic basement rocks (Dada,

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2022). The structural control on mineralization is paramount: fault structures trending in NE-SW directions have been identified as significant conduits for mineralization, with dip angles ranging from 65° to 82° and maximum depths reaching approximately 600 m (Odeyemi *et al*., 2021). Recent methodological advances have demonstrated the efficacy of integrated aeromagnetic and ground magnetic techniques in mineral exploration. Studies utilizing advanced edge detection methods such as analytic signal amplitude (ASA), total horizontal derivative (THD), tilt derivative, and first vertical derivative (FVD) have proven effective in locating geological contacts and edges of structures controlling mineralization (Verduzco *et al*., 2004; Cooper and Cowan, 2006). The present research addresses the critical need for an effective geophysical exploration strategy specifically tailored to the thickly covered terrain of Nasarawa State. By identifying structural lineament conciding with pegmatite trends, this study aims to establish a robust methodological framework for detecting masked pegmatite mineralization. The approach leverages the complementary strengths of regional aeromagnetic surveys for delineating largescale structural frameworks for preliminary characterization of prospective targets.

2.0 MATERIALS AND METHODS

2.1 Study Area and Geological Setting

The study area is located within the Nasarawa region of North Central Nigeria, which forms part of the PanAfrican reworked mobile belt of the Nigerian Basement Complex (Ogunleye *et al*., 2020). The area is underlain predominantly by migmatite, biotite gneiss, biotite muscovite gneiss, and rarely amphibolite, with intrusions of biotite granites, leucogranites, and granitic pegmatites occurring at various locations (Obiora, 2020). The pegmatite field is situated within the 400 km long Nigerian pegmatite belts that trends NE-SW across the Basement Complex (Kinnaird, 2013). The geological framework of the area is characterized by complex structural features, including faults and fractures trending in NE-SW and NWSE directions, which serve as significant conduits for mineralization, with dip angles ranging from 65° to 82° and maximum depths reaching approximately 600 m (Odeyemi *et al*., 2021).

2.2 Research Design

This study adopts a comprehensive aeromagnetic geophysical survey to detect masked pegmatite mineralization in the thickly covered terrain of Nasarawa State. The methodology is structured for regional reconnaissance using aeromagnetic data acquisition and preliminary processing to delineate mineralized structures and trends.

2.3 Aeromagnetic Data Acquisition and Processing

Highresolution aeromagnetic data was obtained from the Nigerian Geological Survey Agency (NGSA), which conducted a nationwide airborne geophysical survey. The aeromagnetic survey was executed using a nuclear precession magnetometer towed in a housing attached to the tail of an aircraft to remove the instrument from the magnetic effect of the aircraft (Nabighian *et al*., 2005). The survey parameters include flight lines spaced at intervals appropriate for detecting magnetic sources at target depths, with perpendicular tielines flown at right angles to the mean flight lines to provide quality control and correction for navigational and systematic errors (Kearey *et al*., 2002). Corrections procedures are in line with that of (Kearey *et al*., 2002; Nabighian *et al*., 2005; Langel, 1992; Baranov and Naudy, 1964).

3.0 RESULTS AND DISCUSSION

Based on established exploration models for the study area (Ogunleye and Adekola, 2023), areas characterized by moderate magnetic anomalies with distinct horizontal and vertical gradient variations, representing potential pegmatitehosted mineralization zones and were identified. Lineaments and intersections of NE-SW trending structures, particularly where fault densities are high alongside magnetic sources at intermediate depths are possible zone of pegmatite mineralization in the region from regional aeomagentic interpretations (Figures 1-7).

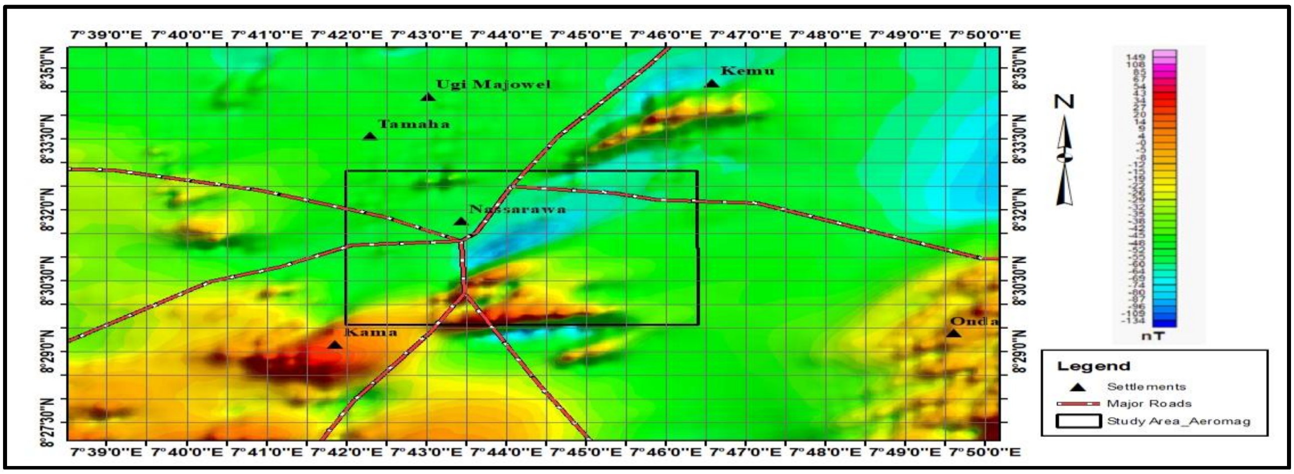

Figure 1: Aeromagnetic, Total Magnetic Intensity (TMI) map of the study area

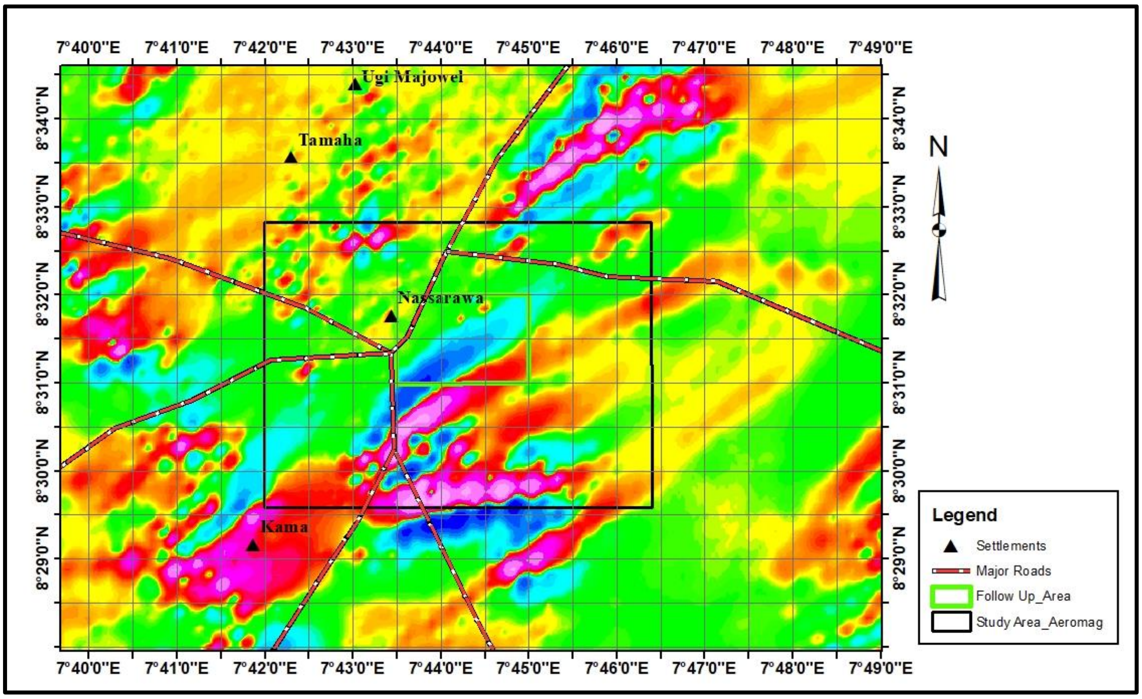

Figure 2: First Vertical Derivative (1VD) map of the study area

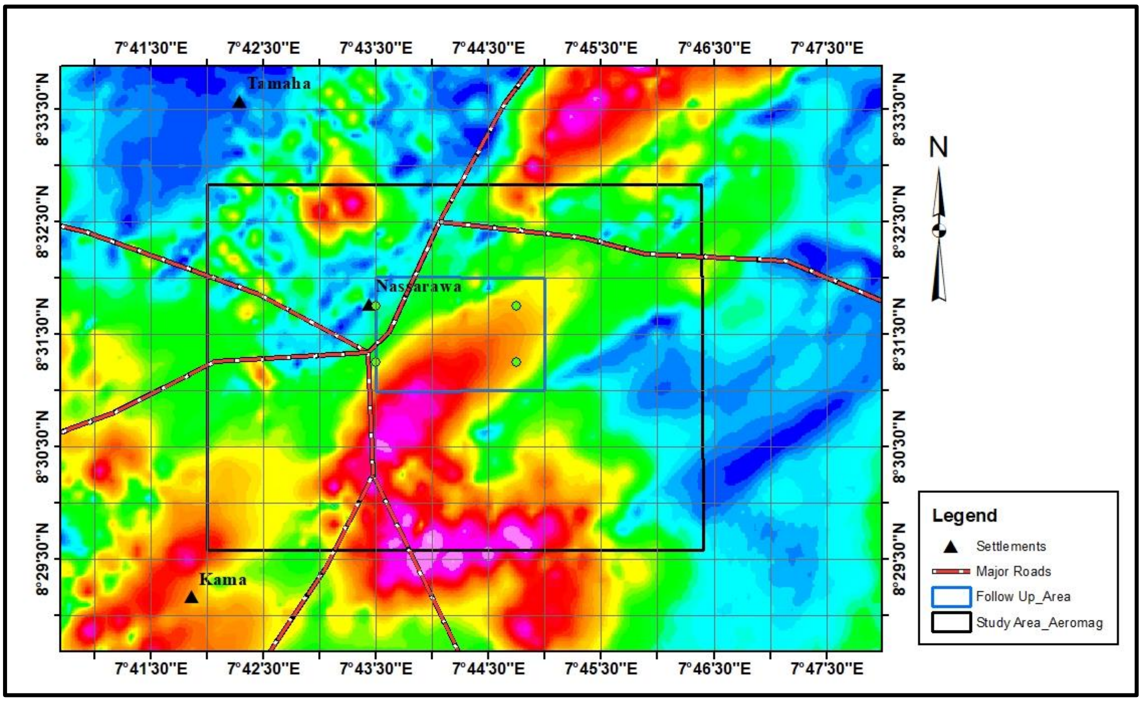

Figure 3: Analytical Signal (ANSIG) map of the study area

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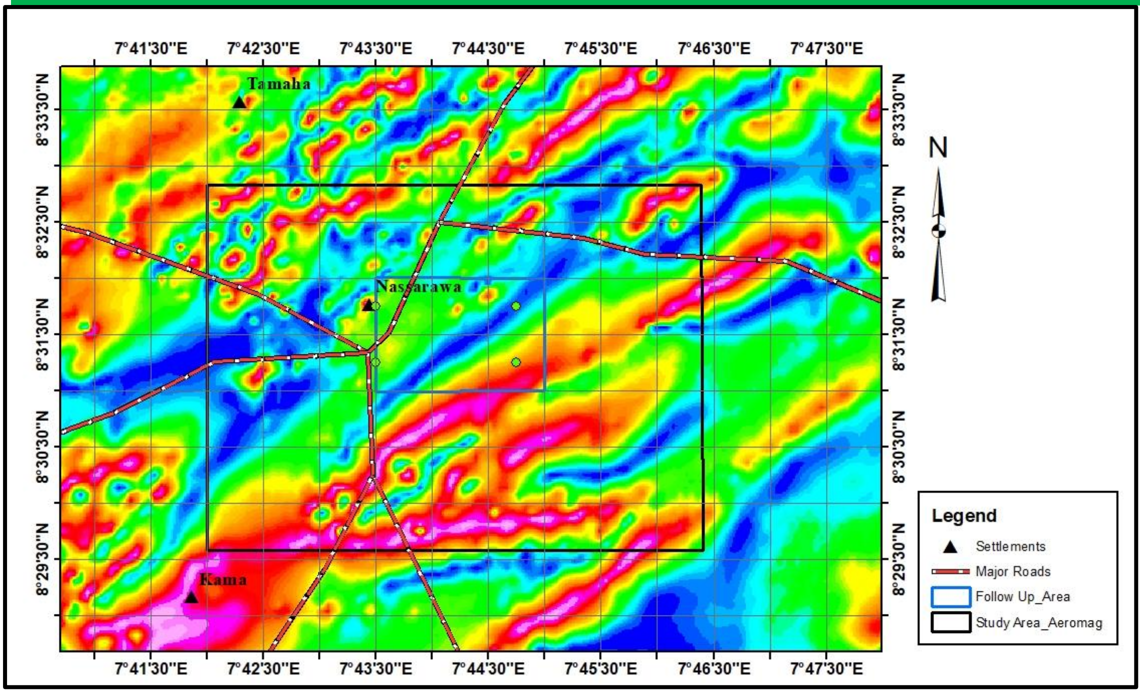

Figure 4: Tilt Derivative (TDR) map of the study area

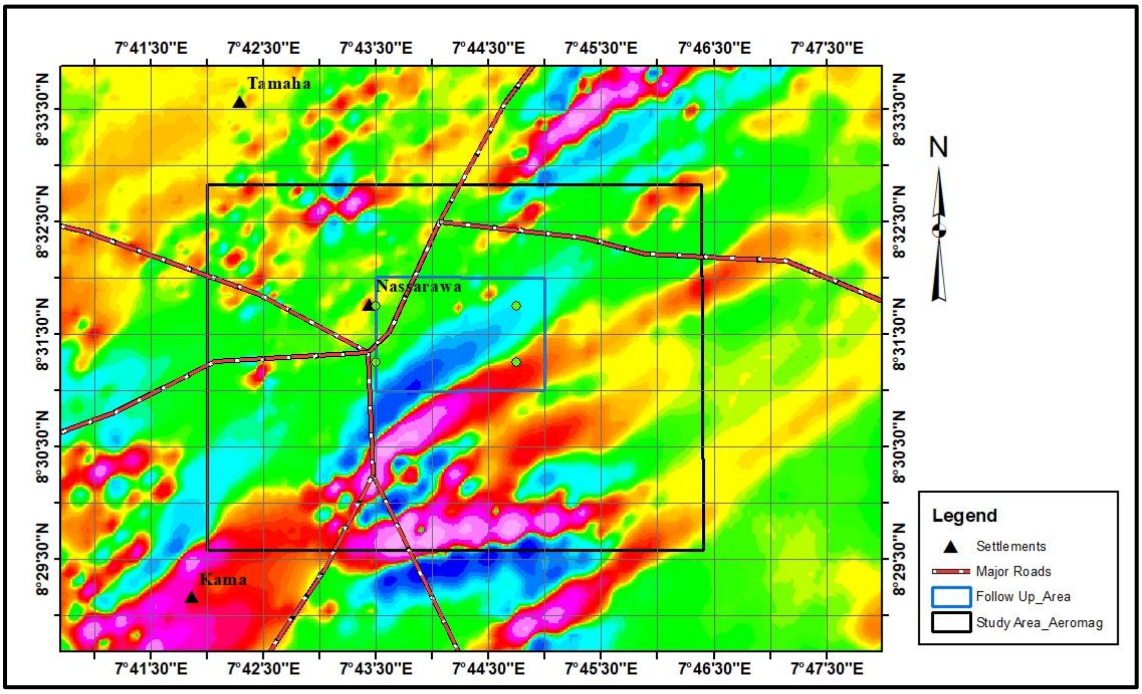

Figure 5: Trend Analysis map of the study area

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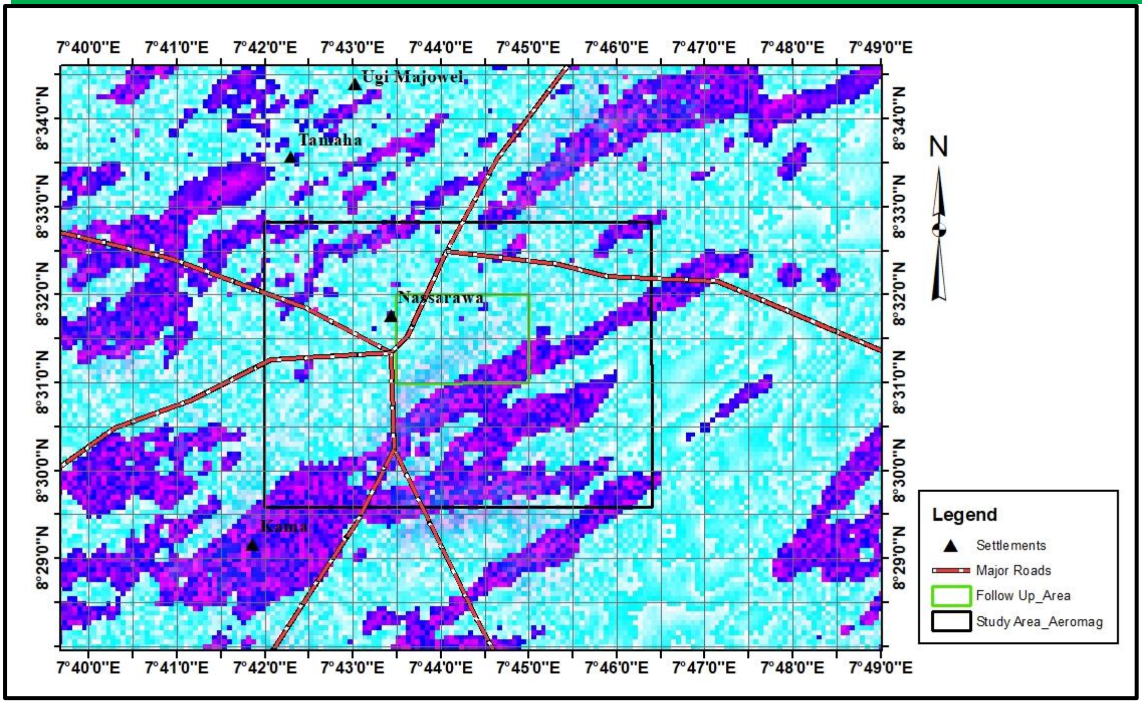

Figure 6: Enhnced Trend Analysis (ETA) map of the study area

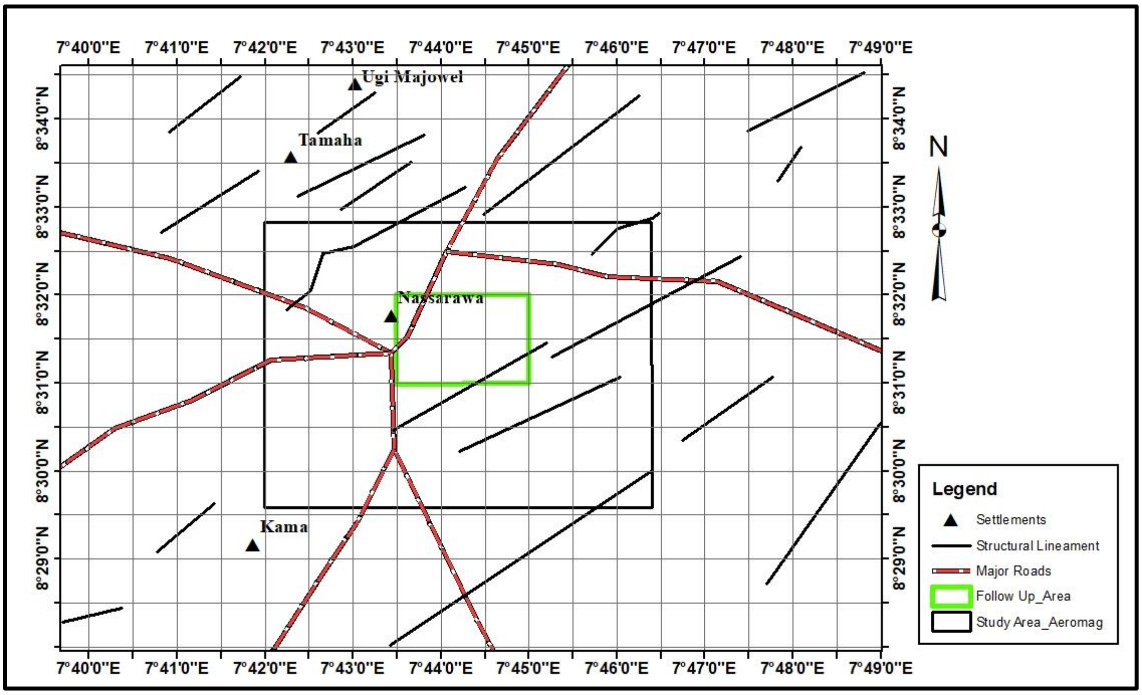

Figure 7: Supervised Digitised Structural Lineament map of the study area

4.0 CONCLUSION

This study has successfully demonstrated the efficacy of integrated aeromagnetic geophysical techniques in detecting concealed pegmatite-hosted lithium mineralization within the thickly lateritic and sedimentary covered terrain of Nasarawa State, North Central Nigeria. The application of high-resolution aeromagnetic data, processed through advanced edge detection methods including First Vertical Derivative (FVD), Analytical Signal Amplitude (ASA), Tilt Derivative (TDR), and Trend Analysis, has proven effective in identifying structural lineaments and magnetic anomalies that serve as proxies for mineralized zones.The interpretation of aeromagnetic maps reveals that moderate magnetic anomalies exhibiting distinct horizontal and vertical gradient variations are indicative of potential pegmatite-hosted mineralization zones. Furthermore, the identification of lineaments and intersections of NE-SW trending structures, particularly in

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areas characterized by high fault densities and magnetic sources at intermediate depths, provides reliable targets for pegmatite mineralization. These findings align with established exploration models for the region and confirm the structural control on mineralization, with fault trends in NE-SW directions serving as significant conduits for mineralizing fluids. The methodological framework developed in this study offers a cost-effective and time-efficient approach for regional reconnaissance in covered terrains, addressing the critical challenge of surface expression masking that has historically hampered exploration efforts in the Nasarawa pegmatite belt. The integration of aeromagnetic data with structural analysis provides a robust foundation for subsequent ground-based geophysical surveys and targeted drilling programs. Given the strategic importance of lithium for global energy transition and Nigeria's potential to contribute to the lithium supply chain, this research provides a valuable exploration template that can be extended to other pegmatite fields within the Nigerian Basement Complex. Future work should focus on ground magnetic surveys to validate the identified targets, integration with geochemical and petrological studies, and three-dimensional modeling of subsurface structures to refine exploration targets and estimate resource potential.

References

Ajayi, O. A., Ogunleye, P. O., and Adebayo, A. O. (2023). Geochronological constraints on Nb-Ta-Be-Li mineralization in the Nassarawa-Keffi pegmatite belt, Nigeria: Implications for post-collisional extension during the Gondwana-forming orogeny. *Journal of African Earth Sciences*, *198*, 104812.

Baranov, V., and Naudy, H. (1964). Numerical calculation of the formula of reduction to the magnetic pole. *Geophysics*, 29(1), 67-79.

Cooper, G. R. J., and Cowan, D. R. (2006). Enhancing potential field data using filters based on the local phase. *Computers and Geosciences*, 32(10), 1585-1591.

Dada, S. S. (2022). Petrogenesis of mineralized pegmatites in the Nigerian Basement Complex: Evidence for remelting of Paleoproterozoic basement rocks. *Precambrian Research*, 368, 106478.

Fedi, M., and Pilkington, M. (2012). Understanding magnetic sources and their significance in mineral exploration. *Geophysical Prospecting*, 60(5), 807-820.

Gunn, G. (2014). *Critical metals handbook*. John Wiley and Sons.

Hobbs, B. A. (2018). Structural controls on mineralization: The role of lineaments and fault systems. *Ore Geology Reviews*, 98, 1-15.

Kearey, P., Brooks, M., and Hill, I. (2002). *An introduction to geophysical exploration* (3rd ed.). Blackwell Science.

Kinnaird, J. A. (2013). The Nigerian pegmatite belt: A metallogenic province. *Journal of African Earth Sciences*, 81, 1-12.

Langel, R. A. (1992). The magnetic field of the Earth's lithosphere: The satellite perspective. *Reviews of Geophysics*, 30(2), 117-148.

London, D. (2018). Ore-forming processes within granitic pegmatites. *Ore Geology Reviews*, 101, 349-383.

Nabighian, M. N., Grauch, V. J. S., Hansen, R. O., LaFehr, T. R., Li, Y., Peirce, J. W., Phillips, J. D., and Ruder, M. E. (2005). The historical development of the magnetic method in exploration. *Geophysics*, 70(6), 33ND-61ND.

Obiora, D. N. (2020). Petrology and geochemistry of the basement rocks of Nasarawa area, North Central Nigeria. *Journal of African Earth Sciences*, 162, 103729.

Odeyemi, I. B., Ogunleye, P. O., and Adekola, S. A. (2021). Structural control of mineralization in the Nasarawa pegmatite field: Fault architecture and depth constraints. *Ore Geology Reviews*, 132, 103998.

Ogunleye, P. O., and Adekola, S. A. (2023). Exploration models for pegmatite-hosted mineralization in the Nasarawa region, Nigeria. *Journal of Geochemical Exploration*, 245, 107136.

Ogunleye, P. O., Obiora, D. N., and Adebayo, O. F. (2020). Rare metal potential of the Nasarawa pegmatite belt, North Central Nigeria: A review. *Journal of African Earth Sciences*, 167, 103855.

Oyediran, I. A., and Adeyemo, T. O. (2022). Challenges of mineral exploration in lateritic and sedimentary terrains of Nigeria: The case of Nasarawa State. *Exploration Geophysics*, 53(3), 285-298.

Verduzco, B., Fairhead, J. D., Green, C. M., and MacKenzie, C. (2004). New insights into magnetic derivatives for structural mapping. *The Leading Edge*, 23(2), 116-119.

Zhdanov, M. S. (2015). *Inverse theory and applications in geophysics* (2nd ed.). Elsevier.