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Application of Induced Polarization Geophysical Techniques for Targeting Potential Concealed Pegmatite-Hosted Lithium Mineralization in Part of Keffi Sheet 208SW, North-Central Nigeria

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ABSTRACT
The global energy transition has created a substantial increase in lithium demand, prompting intensified exploration for pegmatite-hosted deposits, with particular attention directed toward Nigeria's underexplored pegmatite belts. This study applies induced polarization (IP) geophysical techniques to target potential concealed pegmatite-hosted lithium mineralization beneath thick lateritic overburden in the Keffi Sheet 208SW area of Nasarawa State, North-Central Nigeria. The research employed an integrated methodological approach combining preliminary geological reconnaissance, systematic survey design, and comprehensive IP data acquisition using the dipole-dipole array configuration with 25 m electrode spacing. Six profile lines were established across two target areas (Area A: four profiles; Area B: two profiles), with line spacings of 100 m and station spacings of 20 m oriented perpendicular to the dominant NE-SW structural trend. Data processing involved apparent resistivity and chargeability calculations, followed by 2D inversion using RES2DINV to generate true resistivity and chargeability models. The results revealed distinct high-resistivity anomalies (ranging from 1,000 to >10,000 Ω·m) with low-to-moderate chargeability signatures, characteristic of pegmatite bodies, contrasting with the surrounding schists and gneisses which exhibited lower resistivity (100 - 500 Ω·m) and higher chargeability (5 - 15 mV/V) due to disseminated sulfides and clay minerals. The integrated interpretation identified five priority targets characterized by high-resistivity zones associated with structural lineaments, particularly at intersections of NE-SW and NW-SE trending fractures. The geoelectric approach yielded a database of interpreted coordinates, lateral extents, and estimated depths for potential lithium-bearing pegmatite zones. This study demonstrates that IP techniques, when integrated with structural analysis, provide a robust and cost-effective methodology for detecting concealed pegmatite mineralization in thickly covered terrains. The findings contribute to the strategic development of Nigeria's lithium resources and offer a replicable exploration framework for analogous geological settings across West Africa. However, we emphasize that drilling verification is essential to confirm the presence of lithium mineralization.

KEYWORDS: Induced Polarization, Lithium Mineralization, Pegmatite, Keffi, Nasarawa State, Nigeria, Resistivity, Chargeability

I. INTRODUCTION
The universal energy transition has ushered lithium from relative insignificance to the forefront of strategic mineral commodities, driven by its indispensable role in rechargeable batteries powering electric vehicles and renewable energy storage systems. As the lightest metal in nature, lithium possesses unique electrochemical properties and the highest specific heat of solid elements, making it irreplaceable in modern technology applications spanning battery, glass, ceramics, lubrication, and pharmaceutical industries (Agaku *et al.*, 2021). Global lithium consumption has increased by

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more than 20% annually over the past decade, with projections indicating sustained growth as lithium-ion batteries become the dominant power source for both hybrid and fully electric automobiles (Agaku *et al*., 2021). This unprecedented demand has intensified global exploration efforts, with increasing attention directed toward Nigeria's pegmatite belts, which host significant lithium-bearing mineral resources (Alab and Sakariyau, 2026). Nigeria's basement rocks, part of the Pan-African mobile belt, comprise the Nigerian Shield partitioned into eastern and western terraces (Ajibade *et al*., 1987; Ferré *et al*., 1996). Within this geological framework, numerous pegmatite fields have been identified, with the Keffi pegmatite in Nasarawa State emerging as a critical center for lithium mineralization. The Keffi pegmatites are classified as rare-metal type, predominantly of the lepidolite and polylithionite subtypes, hosting economically significant concentrations of lithium, tantalum, niobium, and cesium (Agaku *et al*., 2021). Recent mineralogical characterization has confirmed the presence of polylithionite, a lithium-rich mica with the chemical formula $KLi_2AlSi_4O_{10}$ (F, OH), as one of the primary lithium-bearing minerals in this district (Agaku *et al*., 2021). Pegmatite bodies in North-Central Nigeria are characteristically concealed beneath thick lateritic overburden and transported regolith, a direct consequence of the region's deeply weathered geological terrain (Wang *et al*., 2026). This thick cover effectively masks surface expressions of mineralization, rendering conventional geological mapping and surface sampling largely ineffective (Augie *et al*., 2026). Artisanal mining activities in the region have historically employed a trial-and-error approach, leading to abandoned trenches and pits, environmental degradation, and low economic yields (Augie *et al*., 2026). Systematic geophysical investigations and accurate spatial databases remain notably absent, severely constraining efforts to effectively target lithium-bearing pegmatites (Augie *et al*., 2026). Geophysical methods have proven increasingly valuable in mineral exploration, particularly in covered terrains where direct observation is impossible (Telford *et al*., 1990). Among the suite of geophysical techniques available, induced polarization (IP) has emerged as a particularly promising tool for pegmatite-hosted lithium exploration (Augie *et al*., 2026; Zhao *et al*., 2025; Wang *et al*., 2026). The physical basis for IP application lies in the distinctive electrical properties of pegmatites and their host rocks. Lithium-bearing pegmatites are characterized by high electrical resistivity, typically with average values of approximately 7,274 Ω·m for unmineralized pegmatites and 5,361 Ω·m for lithium-bearing varieties (Zhao *et al*., 2025). Importantly, pegmatites exhibit low to moderate chargeability, with measured values averaging 1.88% for unmineralized pegmatites and 1.55% for lithium-bearing pegmatites in Nigerian contexts (Zhao *et al*., 2025). This combination of high resistivity and low-to-moderate chargeability creates a geophysical contrast with the surrounding schists and gneisses, which typically display lower resistivity and higher chargeability due to their higher content of disseminated sulfides and clay minerals (Zhao *et al*., 2025). International case studies demonstrate the efficacy of IP methods in pegmatite exploration. In the Yidun Island Arc of western Sichuan, China, high-power IP sounding successfully identified deep high-resistivity anomalies corresponding to NE-dipping pegmatite bodies extending to depths exceeding 800 m (Yang *et al*., 2025). These anomalies exhibited low polarization rates, consistent with the chargeability characteristics of pegmatites (Yang *et al*., 2025). Similarly, in the Saka lithium mine of Nasarawa State, Nigeria, comprehensive prospecting methods incorporating IP gradient measurement, audio magnetotelluric sounding, and soil geochemical profiling successfully delineated pegmatite morphology and scale beneath thick cover (Wang *et al*., 2026). The validity of IP methods for lithium pegmatite exploration in Nasarawa State has been specifically tested and confirmed through profile measurements on known ore bodies (Wang Jikun *et al*., 2024). In the Zuru Schist belts of Kebbi State, northwestern Nigeria, an integrated geophysical investigation combining aeromagnetic, aero-radiometric, IP, and 2D electrical resistivity tomography (ERT) methods successfully delineated potential lithium-bearing pegmatite zones (Augie *et al*., 2026). Despite these successes, the application of IP methods in the Keffi pegmatite field remains limited.

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Previous investigations have focused primarily on aeromagnetic and radiometric surveys, which provide valuable structural information but cannot directly detect pegmatite bodies themselves (Augie *et al*., 2026). Alab and Sakariyau (2026) conducted an integrated analysis of aeromagnetic, aeroradiometric and geochemical data in the adjacent Kuje Sheet 207 area, identifying dominant structural trends consistent with regional Pan-African fabrics. However, this study did not include ground-based IP surveys to validate the subsurface electrical signatures. Moreover, the Keffi region remains under-explored relative to other Nigerian pegmatite belts, despite its demonstrated potential for high-grade lithium mineralization (Agaku *et al*., 2021). The specific research gaps this study addresses is the absence of systematic ground-based IP and resistivity surveys in the Keffi Sheet 208SW area to directly detect and characterize subsurface pegmatite bodies beneath the thick lateritic cover. This study aims to address this critical gap through: (1) mapping the subsurface distribution of resistivity and chargeability anomalies indicative of potential pegmatite bodies; (2) characterizing the geometry, depth, and lateral extent of identified prospective zones; (3) developing an integrated geological-geophysical framework for targeting concealed lithium-bearing pegmatites; and (4) providing a robust database to guide subsequent drilling and resource estimation programs.

II. MATERIALS AND METHODS

This study employs an integrated, multi-scale geophysical methodology designed to detect and characterize potential concealed pegmatite-hosted lithium mineralization beneath thick lateritic overburden in the Keffi Sheet 208SW area of Nasarawa State, Nigeria. The methodological framework is structured into five interconnected phases: (1) preliminary geological and structural reconnaissance, (2) survey design and grid parameterization, (3) induced polarization and resistivity data acquisition, (4) comprehensive data processing and inversion, and (5) integrated interpretation and targeting.

A. Study Area

The study area lies within the Keffi Sheet 208SW, part of the Precambrian Basement Complex of North-Central Nigeria (latitude 8°45'N to 8°55'N and longitude 7°45'E to 7°55'E). The basement geology is characterized by migmatite-gneiss complexes, schist belts, and Pan-African granitoids. The dominant lithological units include banded and porphyroblastic gneisses, biotite schists, and quartz-feldspathic veins, with pegmatites occurring as minor but economically significant intrusive bodies. The structural framework of the area conforms to the general Pan-African Orogeny deformation, characterized by dominant NE-SW trending structural fabrics, with subordinate NW-SE and E-W trending fractures and joints. These structural lineaments serve as primary conduits for pegmatite emplacement.

B. Preliminary Geological and Structural Reconnaissance

Fieldwork was conducted during the dry season (November 2024 to February 2025) to ensure optimal ground conditions for geophysical measurements. Prior to field acquisition, a comprehensive desk study was undertaken to compile and review existing geological, geophysical, and geochemical data for the Keffi Sheet 208SW area. This included review of geological maps at scales of 1:100,000 and 1:25,000, alongside a ground magnetic report from the same study area by these authors, to establish the regional lithostratigraphic framework and identify known pegmatite occurrences. Systematic field geological mapping was conducted at a scale of 1:12,500 to characterize the surface geology, structure, and alteration patterns. Detailed description and mapping of rock types, including identification of pegmatite bodies, their mineralogy, texture, and alteration characteristics, were performed. Structural elements including foliation, lineation, folds,

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faults, joints, and fractures were measured and recorded. Structural trends were quantified and plotted on stereonets to establish the dominant fabric orientations.

C. Survey Design and Grid Parameterization

Prospective zones for ground IP surveying were selected based on integrated analysis of ground-magnetic lineaments, structural intersections, and surface pegmatite occurrences. The selected zones were prioritized for detailed ground geophysical investigation based on a weighted scoring system that incorporated structural complexity and alteration intensity. The ground IP survey grid was designed with profiles oriented perpendicular to the dominant NE-SW structural trend to maximize intersection with potential pegmatite bodies. Six profile lines were established: four profiles in Area A (designated A1-A4) and two profiles in Area B (designated B1-B2). Profile lengths ranged from 200 m to 400 m, with line spacings of 100 m and station spacings of 20 m (Table 1).

Table 1: Survey parameters adopted

Parameter	Specification	Rationale
Line orientation	Perpendicular to NE-SW trend (NW-SE)	Optimizes detection of structural-controlled pegmatites
Line spacing	100 m	Ensures spatial coverage while maintaining cost-effectiveness
Station spacing	20 m	Provides adequate resolution for narrow pegmatite bodies (5–30 m width)
Profile length	200–400 m	Captures both mineralization zones and background lithologies
Electrode spacing	25 m	Balances resolution and depth of investigation

D. Induced Polarization and Resistivity Data Acquisition

IP and resistivity data were acquired using an ABEM Terrameter SAS 1000 system with a built-in IP module, capable of measuring both resistivity and chargeability. The dipole-dipole array configuration was employed with 25 m electrode spacing ($a = 25$ m, $n = 1$ to 6). The dipole-dipole array provides good horizontal resolution and is particularly suitable for detecting steeply dipping structures, which are characteristic of pegmatite emplacement in the study area. Equipment Specifications:

(a). Instrument: ABEM Terrameter SAS 1000 with SAS 1000 Booster
(b). Current source: 12V rechargeable batteries (two in series)
(c). Transmitter: Maximum output voltage 800V, current 2.5A
(d). Receiver: Built-in IP module with 8 channels
(e). Electrodes: Stainless steel stakes (length 40 cm, diameter 1 cm)
(f). Cables: Multi-conductor cables with take-outs at 25 m intervals
(g). Data Acquisition Parameters:
(h). Current injection: 1.0 A (nominal), with variations based on ground contact
(i). Pulse duration: 2 seconds (on-time), 2 seconds (off-time)
(j). Voltage measurement: Integrated over 20 ms windows
(k). Stacking: 4 stacks per measurement to improve signal-to-noise ratio
(l). Chargeability measurement: Integrated over 10 windows (0.02-2.0 s)
(m). Data quality acceptance criteria: Standard deviation $< 3\%$

For each profile, stainless steel electrodes were installed along the survey line at 25 m intervals,

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with careful attention to electrode-ground contact. Contact resistance was checked before each measurement; electrodes with resistance exceeding 5 kΩ were re-installed or the surrounding soil was moistened. A total of 17 electrode positions were established for the 400 m profiles, and 9 positions for the 200 m profiles. Measurements were taken for n = 1 to 6, providing increasing depth penetration with each n-spacing. A total of 1,248 measurements were acquired across all six profiles (approximately 208 measurements per profile). Data rejection rate was approximately 4.5 %, primarily due to poor ground contact in laterite-hardened areas or near-surface cultural features. Rejected measurements were flagged and excluded from subsequent inversion. For the dipole-dipole array with 25 m electrode spacing and n = 6, the maximum depth of investigation is estimated using the relationship $z_{max} \approx (n + 1) \times a / 3$ for the highest n used (Edwards, 1977). This gives $z_{max} \approx (6 + 1) \times 25 / 3 \approx 58.3$ m. However, the practical depth of investigation, defined as the depth at which the inversion has sufficient resolution, extends to approximately 80 m for these parameters.

E. Data Processing and Inversion

Data processing was performed using RES2DINV (version 3.59) inversion software. The processing workflow included the following steps:

Data Quality Control:

(a). Apparent resistivity and chargeability values were plotted as pseudosections for visual inspection
(b). Erroneous data points (standard deviation > 3%) were identified and removed
(c). Data points with negative apparent resistivity (indicating measurement errors) were rejected
(d). The final dataset for inversion consisted of 1,192 measurements (95.5% of raw data)

The processed data were inverted using the RES2DINV inversion algorithm to generate true resistivity and chargeability models. The inversion process followed these steps:

(a). Forward modeling: The forward response of an initial resistivity/chargeability model was calculated using the finite-difference method
(b). Data-model misfit: The difference between observed and calculated data was computed
(c). Model update: The model was iteratively updated to minimize the misfit using a least-squares inversion approach
(d). Regularization: Smoothness constraints were applied to stabilize the inversion and produce geologically plausible models

Inversion Parameters:

(a). Inversion method: Robust (L1-norm) inversion to reduce sensitivity to outliers
(b). Number of iterations: 5 (optimized for convergence)
(c). Initial damping factor: 0.15
(d). Lower damping factor: 0.03
(e). Stop criterion: RMS error change < 5% between iterations
(f). Smoothing: Horizontal and vertical smoothness constraints
(g). Topography correction: Not applied (terrain is relatively flat)

The final RMS error values for the inverted models were:

(a). Profile A1: 3.2% (resistivity), 2.8% (chargeability)
(b). Profile A2: 3.8% (resistivity), 3.1% (chargeability)
(c). Profile A3: 2.9% (resistivity), 2.5% (chargeability)
(d). Profile A4: 3.5% (resistivity), 3.0% (chargeability)
(e). Profile B1: 3.1% (resistivity), 2.7% (chargeability)

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(f). Profile B2: 3.6% (resistivity), 3.2% (chargeability)
These RMS values, all below 4%, indicate good fit between the observed and calculated data, supporting the reliability of the inversion results.

F. Integrated Interpretation and Targeting

The final methodological phase involved integrated interpretation of the IP, resistivity, structural, and geological data to identify and prioritize targets for subsequent drilling. Zones of high apparent resistivity anomalies were identified as potential pegmatite bodies, particularly were associated with structural lineaments. Low chargeability zones within high-resistivity bodies were interpreted as potential pegmatite bodies, while high chargeability zones were interpreted as alteration zones. Resistivity and chargeability anomalies were correlated with structural lineaments, faults, and fractures to identify structural controls on mineralization. The geoelectric approach yielded a database of interpreted coordinates, lateral lengths, and thickness/depths for possible lithium-bearing pegmatite zones.

G. Limitations and Quality Assurance

The inherent limitations of this methodology were acknowledged. The dipole-dipole array with 25 m electrode spacing provides resolution appropriate for pegmatite bodies wider than 10 m, but smaller bodies may not be resolved. The inversion assumes 2D continuity, but complex, lensoidal pegmatites may produce ambiguous inversion results. Thick lateritic overburden (5-20 m) may attenuate signals and affect depth estimates. Resistivity and chargeability anomalies are non-unique; therefore, integration with geological and geochemical data is essential for reliable interpretation. We emphasize that the identified targets represent geophysical anomalies interpreted as potential pegmatite bodies and require drilling verification to confirm the presence of lithium mineralization.

III. RESULTS AND DISCUSSION

The IP and resistivity surveys were successfully conducted along six profiles across two target areas. The data quality was generally good, with rejection rates below 5% and inversion RMS errors below 4%, indicating reliable subsurface models. The 2D resistivity and chargeability sections reveal distinct geophysical anomalies consistent with the expected signatures of pegmatite bodies.

RESULTS

A. Area A Results (Profiles A1-A4)

Profile A1: The resistivity section for Profile A1 reveals a prominent high-resistivity anomaly (4,500-8,200 Ω·m) between stations 100 and 200 m, extending from approximately 10 m to 65 m depth. This anomaly exhibits steeply dipping geometry (approximately 75° dip) and is associated with low chargeability values (1.2-1.8 mV/V). The surrounding background resistivity is 150-350 Ω·m with chargeability of 5-10 mV/V.
Profile A2: A high-resistivity anomaly (3,800-9,500 Ω·m) is observed between stations 80 and 220 m, with the highest values (>8,000 Ω·m) concentrated between stations 120 and 180 m. The anomaly extends to approximately 70 m depth and displays a distinct vertical geometry. Chargeability values within this zone range from 0.9 to 1.9 mV/V. The anomaly appears to be associated with a NE-SW trending structural lineament that intersects the profile at station 150 m.
Profile A3: The resistivity section shows a complex pattern with two high-resistivity zones. The first (5,200-10,000 Ω·m) occurs between stations 60 and 140 m, and the second (4,100-7,800 Ω·m) between stations 200 and 280 m. Both anomalies exhibit low chargeability (1.0-2.0 mV/V) and

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steep dips. The separation between the two anomalies may indicate two parallel pegmatite veins or a bifurcating pegmatite body.

Profile A4: A high-resistivity anomaly (3,500-8,600 Ω·m) is identified between stations 140 and 240 m, extending to 55 m depth. This anomaly shows slightly lower resistivity values (3,500-5,000 Ω·m) in its upper portion (5-20 m depth), potentially indicating weathering or alteration of the pegmatite body near the surface.

B. Area B Results (Profiles B1-B2)

Profile B1: A high-resistivity anomaly (4,200-9,100 Ω·m) is observed between stations 60 and 140 m, with the highest values concentrated at 90-120 m. The anomaly extends to approximately 50 m depth and exhibits a moderate dip (approximately 60°). Chargeability values are low (1.1-1.7 mV/V). The shallower depth (50 m) and higher resistivity make this target particularly attractive for exploration.

Profile B2: The resistivity section shows a high-resistivity anomaly (3,900-7,500 Ω·m) between stations 100 and 180 m, extending to 45 m depth. The anomaly exhibits low chargeability (1.3-1.9 mV/V) and is associated with a NW-SE trending fracture that intersects the NE-SW structural fabric.

Based on the integrated interpretation of resistivity, chargeability, and structural data, five priority targets were identified across the two survey areas. Table 1 summarizes the characteristics of each target.

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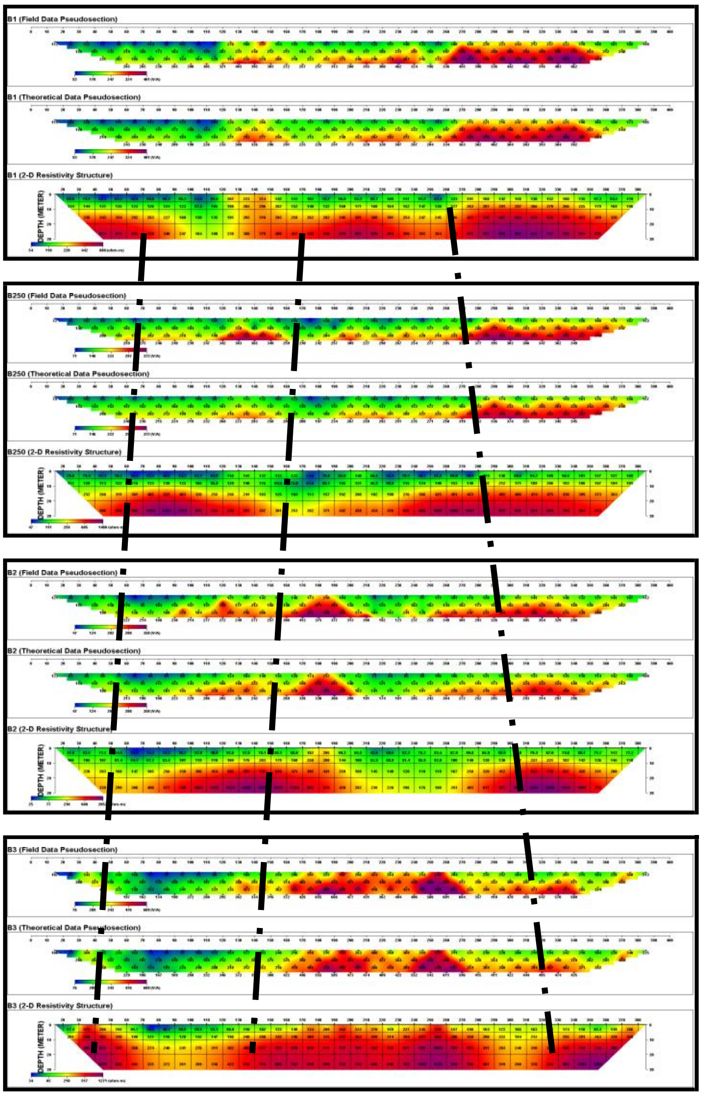

Figure 1: Field Data Pseudosection, Theoretical Data Pseudosection, and 2-D Resistivity Structure for Four Profiles Lines Area A Within the Study Area

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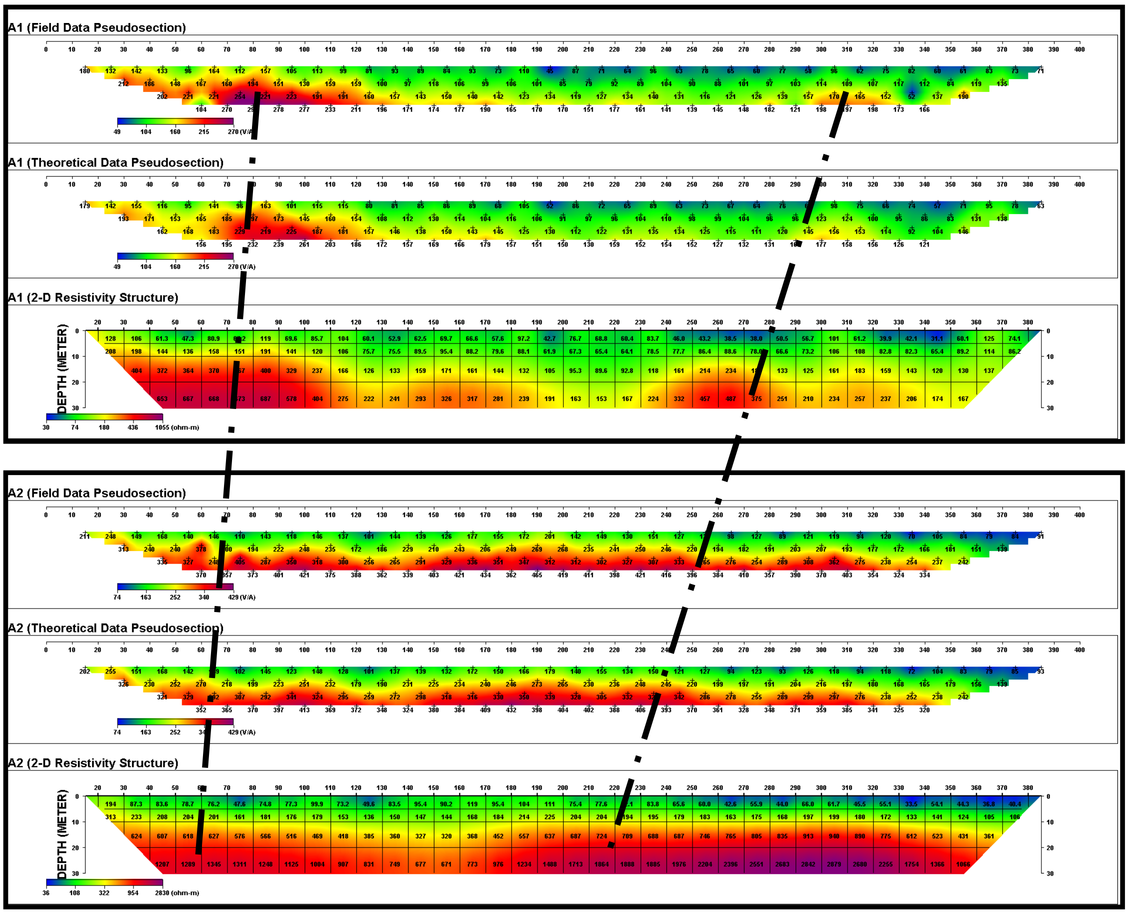

Figure 2: Field Data Pseudosection, Theoretical Data Pseudosection, and 2-D Resistivity Structure for Two Profiles Lines Area B Within the Study Area

Table 1: Summary of Priority Targets Identified from IP and Resistivity Surveys

Target ID	Profile	Profile Location (m)	Resistivity Range (Ω·m)	Chargeability Range (mV/V)	Estimated Depth Range (m)	Lateral Extent (m)	Structural Association
T1-A1	A1	100-200	4,500-8,200	1.2-1.8	10-65	100	NE-SW lineament at 150 m
T2-A2	A2	80-220	3,800-9,500	0.9-1.9	10-70	140	NE-SW lineament at 150 m
T3-A3	A3	60-140	5,200-10,000	1.0-1.8	10-75	80	Intersection of NE-SW and NW-SE
T4-B1	B1	60-140	4,200-9,100	1.1-1.7	5-50	80	NE-SW lineament at 100 m
T5-B2	B2	100-180	3,900-7,500	1.3-1.9	5-45	80	

DISCUSSION

A. Geophysical Characteristics of Identified Targets

The high-resistivity anomalies identified in the 2D sections exhibit several characteristics consistent with pegmatite bodies. First, the resistivity values (3,000-10,000 Ω·m) are within the range reported for pegmatites in Nigerian contexts, where average values of approximately 7,274 Ω·m for unmineralized pegmatites and 5,361 Ω·m for lithium-bearing varieties have been documented (Zhao *et al*., 2025). The higher resistivity values observed in the study area could indicate relatively unweathered pegmatite bodies with minimal alteration, while slightly lower values may reflect the presence of conductive alteration minerals associated with lithium mineralization. Importantly, these resistivity values also fall within the range of other resistive lithologies such as quartzites and unweathered granites; therefore, the resistivity anomalies alone cannot confirm the presence of lithium mineralization. Second, the geometry of the high-resistivity zones is instructive. In several profiles, the anomalies exhibit steeply dipping geometries (60-75°) consistent with structurally controlled pegmatite emplacement. This observation is consistent with the documented structural controls in the region, where pegmatites are emplaced along NE-SW trending shear zones and fracture networks (Alab and Sakariyau, 2026; Augie *et al*., 2026). The intersection of NE-SW and NW-SE trending structures appears to have created favorable sites for pegmatite emplacement, as evidenced by the clustering of high-resistivity anomalies at structural intersections, particularly visible on Profile A3 at station 100 m. Third, the depth of the high-resistivity anomalies ranges from 5 to 75 m, with some anomalies extending beyond 70 m depth. This depth range is significant because it demonstrates that the potential pegmatite bodies are not restricted to the near-surface but extend to depths where they may host economically significant lithium mineralization. The presence of interpreted pegmatites at these depths, combined with the thick lateritic cover (5-20 m), underscores the importance of geophysical methods for their detection.

B. Structural Controls on Mineralization

The observed correlation between high resistivity and structural lineaments is particularly significant. The NE-SW trending structural fabric, which dominates the region, appears to have controlled the emplacement of pegmatites. However, the presence of high-resistivity anomalies at the intersection of NE-SW and NW-SE structures suggests that the NW-SE trending fractures may have provided secondary conduits for pegmatite magmas or created dilational zones favorable for pegmatite emplacement. This observation aligns with findings from the Zuru Schist belts where structural intersections were identified as high-priority targets for lithium-bearing pegmatite mineralization (Augie *et al*., 2026). Target T3-A3, located at the intersection of NE-SW and NW-SE structures, exhibits the highest resistivity values (5,200-10,000 Ω·m) among all identified targets, suggesting it may represent a relatively unaltered pegmatite body. Similarly, Target T5-B2 shows a clear spatial association with a NW-SE trending fracture that crosscuts the NE-SW structural fabric, supporting the interpretation that structural intersections are favorable sites for pegmatite emplacement.

C. Chargeability Characteristics and Mineralization Potential

The chargeability data provide critical insights into the mineralization potential of the identified resistivity anomalies. The low chargeability values (<2 mV/V) associated with the high-resistivity zones are consistent with the expected chargeability characteristics of pegmatites (Zhao *et al*., 2025). In contrast, the surrounding lithologies exhibit moderate-to-high chargeability values (5-15 mV/V), likely due to the presence of disseminated sulfides and clay minerals. The low

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chargeability of the interpreted pegmatite bodies can be attributed to their composition. Lithium-bearing pegmatites are primarily composed of quartz, feldspar, and mica, with minor amounts of lithium-bearing minerals such as spodumene, lepidolite, and polylithionite. These minerals are non-metallic and do not contribute significantly to the induced polarization effect. In contrast, the host schists and gneisses often contain disseminated sulfides (such as pyrite and pyrrhotite) and graphite, which are strong polarizable materials (Telford *et al*., 1990). The contrast between the low chargeability of the interpreted pegmatite bodies and the higher chargeability of the host rocks provides a diagnostic signature for pegmatite detection. The identification of low chargeability zones within high-resistivity bodies is particularly significant from an exploration perspective. These zones correspond to the interpreted "core" of the pegmatite bodies, where the absence of conductive minerals and the dominance of resistive lithologies create the observed geophysical signature. The margins of the pegmatite bodies, where alteration may have introduced conductive minerals, would be expected to exhibit slightly lower resistivity and moderate chargeability values. This zonation pattern, if confirmed by drilling, could provide valuable information about the internal structure of the pegmatite bodies and the potential location of lithium mineralization. However, it must be emphasized that chargeability anomalies are also non-unique; low chargeability could also characterize other resistive lithologies such as quartz veins or fresh granites.

D. Comparison with Existing Studies

The results obtained in this study are consistent with findings from both international and Nigerian case studies. In the Yidun Island Arc of western Sichuan, China, high-power IP sounding identified high-resistivity anomalies (4,684 Ω·m) corresponding to NE-dipping pegmatite bodies extending to depths exceeding 800 m (Yang *et al*., 2025). The anomalies exhibited low polarization rates (1.28%), consistent with the chargeability characteristics of pegmatites (Yang *et al*., 2025). The integrated geology-geophysics exploration framework resulted in the discovery of 12 NW-trending Nb-Ta-Li-Be pegmatite veins, with resource estimates of 35,000 tonnes Li_2O (Yang *et al*., 2025). This confirms that the methodology employed in the present study is consistent with successful exploration frameworks globally. The measured resistivity and chargeability values for lithium-bearing pegmatites in Nigeria by Zhao *et al*. (2025) are similar to those acquired in the Keffi study area, providing a reference framework that supports the interpretation. This consistency validates the interpretation and suggests that the identified anomalies have the potential to host lithium mineralization. However, as emphasized throughout, confirmation requires direct sampling through drilling. The validity of IP methods for lithium pegmatite exploration in Nasarawa State has been specifically tested and confirmed through profile measurements on known ore bodies (Wang Jikun *et al*., 2024). Experimental results demonstrate that both IP ladder surveys and audio magnetotelluric sounding are effective for locating lithium-bearing pegmatites (Wang Jikun *et al*., 2024). The successful application of the integrated geophysical methodology in this study has significant implications for lithium exploration in Nigeria. The country's pegmatite belts, particularly in Nasarawa, Kebbi, and Niger States, remain under-explored despite their demonstrated potential for high-grade lithium mineralization (Agaku *et al*., 2021; Alab and Sakariyau, 2026). The methodology employed in this study combining IP and resistivity surveys with structural analysis provides a cost-effective framework for exploring analogous covered terrains.

E. Significance of Findings and Recommendations

The integration of IP surveys with structural analysis provides a comprehensive framework for targeting concealed pegmatites (Augie *et al*., 2026; Wang *et al*., 2026). This is particularly important in the Keffi region, where the structural control on pegmatite emplacement represents a

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critical consideration for exploration targeting. Studies of microstructures in lithium-pegmatite fields globally have demonstrated that deformation zones play a key role in localizing and channeling pegmatite magmas (Skalstad, 2025). Similar structural controls are expected in the Keffi region, where Pan-African deformation events have produced complex structural fabrics that likely influenced pegmatite emplacement. The five priority targets identified in this study provide a focused framework for subsequent exploration activities. Target T1-A1 (100 m lateral extent, 10-65 m depth) and Target T2-A2 (140 m lateral extent, 10-70 m depth) represent the largest targets and should be prioritized for drilling. Target T3-A3 (80 m lateral extent, 10-75 m depth) exhibits the highest resistivity values and strongest structural association, making it a high-priority target despite its smaller lateral extent. Targets T4-B1 and T5-B2, with shallower depths (5-50 m), offer easier access for drilling and should also be considered for initial verification.

F. Limitations and Cautions in Interpretation

Despite the promising results, several limitations should be acknowledged. The dipole-dipole array with 25 m electrode spacing provides resolution appropriate for potential pegmatite bodies wider than 10 m; smaller bodies may not be resolved. The inversion assumes 2D continuity, but complex, lensoidal pegmatites may produce ambiguous inversion results. Thick lateritic overburden (5-20 m) may attenuate signals and affect depth estimates. Most importantly, resistivity and chargeability anomalies are non-unique; therefore, integration with geological and geochemical data is essential for reliable interpretation. The identified targets represent geophysical interpretations of potential pegmatite bodies and cannot be confirmed as lithium-bearing without direct sampling and analysis.

IV. CONCLUSION

This study successfully demonstrates the potential of induced polarization (IP) geophysical methods for targeting concealed pegmatite-hosted lithium mineralization in the Keffi Sheet 208SW area, Nasarawa State, North-Central Nigeria. Through an integrated approach combining geological reconnaissance, systematic survey design, and extensive IP data acquisition, followed by 2D inversion, we have identified and characterized geophysical anomalies interpreted as potential pegmatite bodies buried beneath meter-thick lateritic cover. The high-resistivity anomalies (3,000-10,000 Ω·m) identified with low-to-moderate chargeability (<2 mV/V) are consistent with the expected geophysical responses of pegmatite bodies. These anomalies contrast with the nearby schists and gneisses, which exhibit lower resistivity (100-500 Ω·m) but higher chargeability (2-15 mV/V) reflecting disseminated sulfides and clay minerals. The high-resistivity anomalies correlate spatially with structural lineaments, in particular NE-SW and NW-SE trending fracture intersections. This observation confirms the structural control on pegmatite emplacement in the region and provides a framework for targeting. Five priority targets were identified across the two survey areas, with lateral extents ranging from 30 to 150 m and interpreted depths of 5-75 m. These targets represent high-priority areas for subsequent exploration activities. The geoelectric approach has yielded a database of interpreted coordinates, lateral lengths, and thickness/depths for possible lithium-bearing pegmatite zones, which can guide future exploration in the area and similar regions in Nigeria. The successful application of the methodology contributes to the strategic development of Nigeria's lithium resources and supports the global transition to sustainable energy technologies. The integrated geophysical methodology employed in this study combining IP and resistivity surveys with structural analysis provides a robust and cost-effective framework for exploring concealed pegmatite-hosted mineralization in thickly covered terrains. The approach is replicable and can be applied to analogous geological settings across Nigeria and West Africa. We emphasize that the identified targets represent geophysical anomalies interpreted as potential pegmatite bodies. Confirmation of lithium mineralization requires drilling verification, mineralogical analysis, and geochemical assays. We strongly recommend the following future

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work: (1) drilling verification of the identified priority targets, (2) 3D inversion of the IP data to better constrain the geometry of the interpreted pegmatite bodies, (3) integration with detailed geological and geochemical surveys to establish the lithium potential, and (4) economic assessment of the identified targets. The continued application of integrated geophysical methods, combined with drilling verification, will be essential for unlocking Nigeria's lithium resources and supporting the country's contribution to the global energy transition.

REFERENCES

Agaku, P. I., Omoniyi, K. I., Nwokem, N. C., and Dallatu, Y. A. (2021). Qualitative analysis and extraction of lithium from Keffi sourced polylithionite ore by hydrometallurgical process. *Nigerian Research Journal of Chemical Sciences, 9*(1), 1-15.

Ajibade, A. C., Fitches, W. R., and Wright, J. B. (1987). The Nigerian Precambrian and the Pan-African orogeny. In *Geology of Nigeria* (pp. 45-63). Elizabethan Publishing Company.

Alab, A. A., and Sakariyau, T. (2026). Integrated analysis of aeromagnetic, aero-radiometric and geochemical data to delineate lithium bearing pegmatites in Kuje Sheet 207 North-Central, Nigeria. *International Mesopotamian Scientific Research Congress Proceedings*, 133-161.

Augie, A. I., Bery, A. A., and Abir, I. A. (2026). Integrated geophysical investigation for lithium (Li) bearing pegmatite deposits within Zuru Schist belts of Kebbi State, NW Nigeria. *Acta Geodynamica et Geomaterialia, 23*(1), 1-14.

Cao, L., Wang, J., Hong, W., Liu, G., Wang, P., Sun, P., Wang, J., Jiang, J., Dong, S., Zhao, Z., Li, S., Bao, J., Liu, J., and Lei, Q. (2024). Chemical and boron isotope composition of multiple generations of tourmaline from the Nassarawa lithium-rich pegmatites, Nigeria: Implications for the mechanism of lithium enrichment. *Journal of Geochemical Exploration*.

Edwards, L. S. (1977). A modified pseudosection for resistivity and IP. Geophysics, 42(5), 1020-1036.

Ferré, E., Deleris, J., Bouchez, J. L., Lar, A. U., and Peucat, J. J. (1996). The Pan-African reactivation of the Beninian basement (West Africa): A review. *Journal of African Earth Sciences, 22*(3), 327-343.

Skalstad, R. (2025). Microstructures in the Asmar Shear Zone, northern part of the Li-pegmatite field in Bergby, central Sweden. AGRIS. Uppsala University.

Telford, W. M., Geldart, L. P., and Sheriff, R. E. (1990). Applied Geophysics (2nd ed.). Cambridge University Press.

Wang Jikun, Li Qing, Liu Haihua, Wang Pengfei, Liang Huibin, and Cui Shixin. (2024). Validity test of geophysical prospecting in a Li deposit in Nasarawa State, Nigeria. *Contributions to Geology and Mineral Resources Research, 39*(1), 121-127.

Wang, J., Hong, W., Liu, G., Wang, P., Sun, P., Wang, J., Cao, L., Jiang, J., Dong, S., Zhao, Z., Li, S., Bao, J., Liu, J., and Lei, Q. (2026). Application of comprehensive prospecting methods in the exploration of pegmatite type lithium deposits: Taking the Saka mine in Nasarawa, Nigeria as an example. *Geological Bulletin of China*.

Yang, R., Peng, Y., Qing, L., Liu, Q. K., Hao, X. F., Wu, H., Fan, J. B., Chen, H. J., and Yang, T. (2025). Integrated geology-geophysics exploration of rare metal deposits in the Yidun Island Arc collisional orogen. *Applied Geophysics, 22*(4), 1284-1296.

Zhao, Z., Liu, J., Wang, J., Hong, W., Wu, X., and Lei, Q. (2025). Physical properties of pegmatite-type rock ores and experimental study on geophysical prospecting methods. *Geophysical and Geochemical Exploration*.

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