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# Integrated Pseudo-Gravity, SPI, and 2D Magnetic Modelling for Hydrocarbon Prospectivity in the Upper Benue Trough, Nigeria

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## ABSTRACT

*Pseudo-gravity transformation of aeromagnetic data was applied to constrain basement architecture and sediment thickness in part of the Upper Benue Trough, northeastern Nigeria, with implications for hydrocarbon prospectivity. High-resolution aeromagnetic data were processed using Reduction to the Equator (RTE), pseudo-gravity filtering, and Source Parameter Imaging (SPI) to emphasize deep-seated structural features relevant to basin evolution. The pseudo-gravity field reveals long-wavelength anomalies ranging from approximately −0.34 to +0.22mGal, delineating a rift-segmented basement characterized by fault-bounded depressions and uplifted blocks trending NE–SW and NW–SE.SPI depth estimates derived from the pseudo-gravity field indicate basement depths varying from about 1.3 to >14km, reflecting pronounced lateral variations in crustal structure. Application of a 7 km depth cutoff isolates basin-scale features and highlights several structurally controlled depocenters with estimated sediment thicknesses of 5–7km, particularly along the Lomi–Kolmani–Gombe corridor. Two-dimensional magnetic models further confirm the presence of rift-related basement depressions reaching depths of 4.5–5. km, flanked by shallower basement highs, and show that basement relief dominates the long-wavelength magnetic response. These depocenters coincide with negative pseudo-gravity anomalies and are interpreted as long-lived subsidence zones favorable for hydrocarbon generation and preservation. Shallower depths (<3km) and positive pseudo-gravity anomalies mark uplifted basement blocks that likely influenced sediment dispersal and hydrocarbon migration pathways. The results demonstrate that pseudo-gravity analysis provides quantitative, exploration-relevant constraints on basement morphology and sediment distribution in data-limited frontier basins, offering a reliable framework for prioritizing seismic surveys and exploratory drilling in the Upper Benue Trough.*

**Keywords:** *Pseudo-gravity, SPI, 2D Modelling, Depocenters, Hydrocarbon prospectivity, and Upper Benue Trough*

## INTRODUCTION

Magnetic methods have long been recognized as one of the most efficient and cost-effective geophysical tools for regional subsurface investigations, particularly in areas where conventional datasets such as seismic reflection or gravity measurements are sparse, expensive, or spatially discontinuous (Robinson et al., 2008). Among these methods, aeromagnetic surveys provide continuous regional coverage, high spatial resolution, and strong sensitivity to subsurface structures that exert fundamental control on sedimentation patterns, tectonic evolution, and basin architecture. Consequently, aeromagnetic data have become indispensable in reconnaissance-level studies of sedimentary basins, especially in frontier regions targeted for hydrocarbon exploration (Elawadi et al., 2025; Kiani et al., 2023).

In sedimentary basins, understanding the configuration of the crystalline basement, the distribution of intrusive bodies, and the orientation of fault systems is critical for evaluating petroleum system elements such as source rock development, maturation history, migration pathways, and trap formation (Allen, 2013). Basement structures often influence sediment thickness variations and syn-depositional faulting, which in turn control accommodation space and depositional environments.

However, magnetic anomalies arise from contrasts in magnetic susceptibility and remanent magnetization rather than from density or acoustic impedance contrasts. This dependence on magnetization properties frequently complicates geological interpretation, particularly in areas characterized by heterogeneous basement lithologies, volcanic intrusions, or thermally altered rocks (Jackson, 1991; Rossi, 2017). As a result, magnetic anomaly maps may exhibit complex, high-frequency signatures that obscure deeper regional structures of petroleum significance.

To improve interpretability, magnetic data can be transformed into pseudo-gravity fields, a mathematical operation that converts magnetic anomalies into an equivalent gravity-like response (Foks & Li, 2016). The pseudo-gravity transformation assumes a proportional relationship between magnetization and density under specific geological conditions, thereby allowing the magnetic field to be viewed as if density contrasts generated it. This conversion produces anomaly maps that resemble gravity data, which are generally more intuitive for structural interpretation because gravity anomalies directly relate to mass distribution in the subsurface. As noted by Lösing et al., (2022), pseudo-gravity filtering enhances long-wavelength components of the magnetic field, emphasizing deeper crustal and basement structures while suppressing short-wavelength effects associated with shallow or highly magnetic sources.

The application of pseudo-gravity is particularly valuable in hydrocarbon exploration, where subsurface density variations commonly correspond to major geological features such as basement highs, fault-bounded grabens, intrusive complexes, sediment-filled depocenters, and structural ridges (Mashhadi & Safari, 2020). These features exert a strong influence on petroleum system evolution by affecting burial depth, geothermal gradients, fluid migration pathways, and structural trap development. In frontier basins where gravity data coverage is limited or nonexistent, pseudo-gravity serves as an effective substitute, enabling interpreters to delineate basin geometry and tectonic framework with greater confidence. By highlighting regional structural trends, pseudo-gravity maps facilitate the separation of shallow magnetic noise from deeper structural controls that are more relevant to hydrocarbon prospectivity (Azab, 2020).

Numerous studies have demonstrated the effectiveness of pseudo-gravity transformation in both geological and petroleum exploration contexts. Early applications focused on revealing deep crustal features masked by strong near-surface magnetic effects (Alao et al., 2024). Subsequent studies expanded its application to mapping rift structures, intrusive bodies, crustal thickness variations, and lithological boundaries, often in combination with derivative-based magnetic techniques such as tilt derivatives and analytic signal methods (Liu et al., 2023; Zhang et al., 2025). Pseudo-gravity anomalies have been shown to correlate strongly with major tectonic lineaments and basement structures that influence hydrocarbon accumulation (Adebiyi et al., 2023; Ugodulunwa et al., 2022).

Direct interpretation of magnetic anomalies alone may be insufficient due to the complexity of magnetic signatures in the Upper Benue Trough (Ekwok et al., 2021). Transforming magnetic data into pseudo-gravity fields enables the enhancement of deeper basement-related features while suppressing shallow magnetic effects, thereby allowing more reliable mapping of basin architecture, major fault systems, and intrusive bodies. Furthermore, pseudo-gravity transformation provides a robust framework for integrating magnetic data with geological mapping, gravity interpretation, and basin modeling studies, leading to a more comprehensive understanding of subsurface geometry (Adebiyi et al., 2023; A.K, 2025).

Given Nigeria's renewed focus on inland basin hydrocarbon exploration and energy diversification, there is a pressing need to revisit the structural framework of the Upper Benue Trough using advanced interpretation techniques such as pseudo-gravity transformation. While several aeromagnetic studies exist, many emphasize shallow source characterization or qualitative interpretation (Arogundade et al., 2020; Elawadi et al., 2024; Oha et al., 2016). Few have systematically applied pseudo-gravity analysis to resolve deeper structural patterns directly relevant to petroleum systems (Florio, 2018; Li et al., 2020).

The present study, therefore, applies pseudo-gravity transformation to high-resolution aeromagnetic data over part of the Upper Benue Trough, northeast Nigeria. The specific objectives are to generate pseudo-gravity fields from aeromagnetic data, delineate major basement structures, intrusive features, and evaluate the implications of these features for hydrocarbon prospectivity. By integrating pseudo-gravity results with qualitative and quantitative magnetic interpretation techniques, this study aims to develop an improved structural model that contributes meaningfully to ongoing assessments of the hydrocarbon potential of the Upper Benue Trough.

**Study Area and Geological Setting**

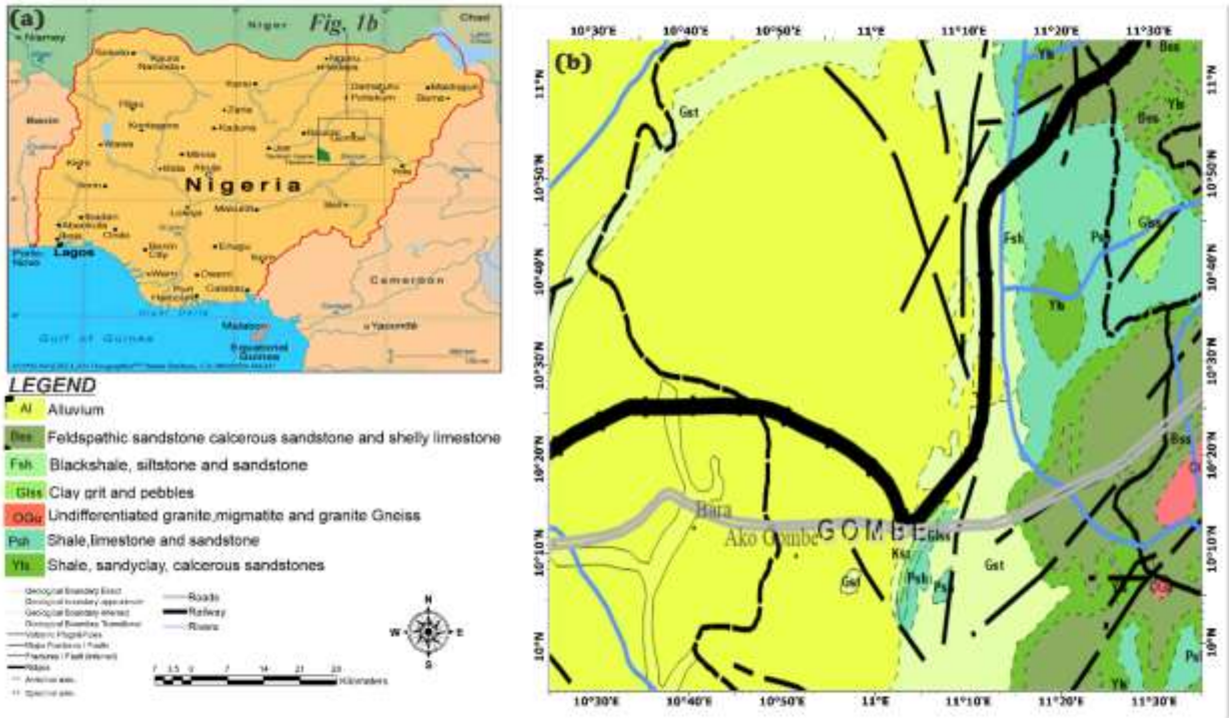


**Fig. 1:** (a) Administrative map of Nigeria showing the location of the study area (Fig. 1b) (Nationsonline.org), (b) geological and location map of the study area within the Upper Benue Trough, Gombe (NGSA).

The study area is located within the structurally complex Upper Benue Trough of northeastern Nigeria, around Gombe, Akko, Bara, and Pasham, and forms part of the Benue Rift System that developed during Early Cretaceous rifting associated with the separation of Africa and South America. The western part of the area is underlain by crystalline Basement Complex rocks, including granite, migmatite, and granite gneiss, which constitute the structural foundation for overlying Cretaceous sedimentary sequences comprising sandstones, limestones, shales, siltstones, and clay–grit–pebble deposits, reflecting transitions from continental to shallow marine depositional environments. Structurally, the region is characterized by dense fault and fracture networks trending mainly NE–SW, NW–SE, and N–S, which control basement morphology, sediment distribution, drainage patterns, and hydrocarbon prospectivity. The coexistence of basement highs, sediment-filled troughs, fault-bounded zones, and alluvial lowlands underscores the geological complexity of the area and highlights the suitability of aeromagnetic and gravity-based methods for delineating subsurface structures and assessing hydrocarbon potential in the Upper Benue Trough.

## RESEARCH METHOD

**Aeromagnetic Data Acquisition and Preprocessing**

High-resolution aeromagnetic data used in this study were obtained from the Nigerian Geological Survey Agency (NGSA) and cover part of the Upper Benue Trough around Gombe and its environs in northeastern Nigeria. The data were acquired using a fixed-wing aircraft equipped with a high-sensitivity proton precession magnetometer. Survey parameters consisted of NW–SE–oriented flight lines spaced at 500 m, with tie-lines at 2km intervals and an average terrain clearance of approximately 80 m. This acquisition geometry ensures adequate spatial resolution for resolving both regional basement architecture and intermediate-scale structural features relevant to sedimentary basin analysis and hydrocarbon prospectivity.

Standard preprocessing procedures were applied to the raw Total Magnetic Intensity (TMI) data to improve data quality and remove non-geological effects. These procedures included diurnal correction using base-station magnetometer records, lag and heading corrections to compensate for aircraft motion, tie-line leveling to reduce line-to-line discrepancies, and micro-leveling to suppress residual noise and striping effects. The International Geomagnetic Reference Field (IGRF), with a regional intensity of approximately 33,000 nT, was removed to isolate crustal magnetic anomalies associated with subsurface geological sources (Abbass & Mallam, 2013). All preprocessing and subsequent potential-field transformations were carried out using Oasis Montaj, which provides robust tools for magnetic data processing and interpretation in low-latitude environments.

Because the study area lies within a low magnetic latitude region, the observed magnetic anomalies are inherently asymmetric and laterally displaced from their causative sources. To correct for this effect, Reduction to the Equator (RTE) was applied to the residual TMI data (Machina et al., 2025). RTE transforms the observed magnetic field into an equivalent response as if measured at the magnetic equator by accounting for the regional inclination and declination of the Earth's magnetic field (Bem et al., 2025). This process improves anomaly symmetry and repositions magnetic responses directly over their sources, thereby producing a more reliable dataset for depth estimation and pseudo-gravity transformation.

**Pseudo-Gravity Transformation**

Pseudo-gravity transformation was applied to the RTE-corrected magnetic data to enhance long-wavelength anomalies associated with deep basement structures and suppress short-wavelength effects caused by shallow magnetic bodies (Thilakarathna et al., 2025). The method exploits the mathematical equivalence between magnetic and gravity potential fields by converting magnetic anomalies into gravity-like responses that are more sensitive to deeper density-related sources. This transformation facilitates more intuitive structural interpretation, particularly in complex rift settings where magnetic signatures are often dominated by near-surface effects.

In the frequency domain, pseudo-gravity is obtained by integrating the magnetic field and applying a wavenumber-dependent filter. The pseudo-gravity field can be expressed as (Yang et al., 2025):

$$P(x,y) = \mathcal{F}^{-1}\left[\frac{1}{|K|}M(k_x,k_y)\right] \qquad 1$$

where $P(x,y)$ is the pseudo-gravity field, $M(k_x,k_y)$ is the Fourier transform of the magnetic field, |k| is the radial wavenumber, and $\mathcal{F}^{-1}$ denotes the inverse Fourier transform.

The resulting pseudo-gravity anomaly map provides an improved representation of basement relief, regional fault systems, intrusive bodies, and sediment-filled depocentres. Broad, smooth pseudo-gravity anomalies are indicative of deep-seated structures, whereas sharper responses are typically associated with relatively shallow features (Wang et al., 2024). Pseudo-gravity interpretation was conducted within Oasis Montaj, allowing seamless integration with other magnetic derivatives and filtering operations.

**Source Parameter Imaging (SPI) Depth Estimation**

Source Parameter Imaging (SPI) was applied to estimate depths to the top of magnetic sources and constrain basement relief (Ndikum et al., 2024). SPI computes the local wavenumber (k) from the vertical and horizontal derivatives of the magnetic field as (Dai et al., 2022):

$$k = \frac{\partial T/\partial z}{\sqrt{\left(\frac{\partial T}{\partial x^2}\right) + \left(\frac{\partial T}{\partial y^2}\right)}} \qquad 2$$

Depth to magnetic sources (Z) is then estimated as:

$$Z = \frac{1}{\mathrm{k}} \qquad 3$$

SPI provides rapid, stable, and spatially continuous depth estimates that are particularly useful for mapping basement highs, fault-controlled structural lows, and sedimentary depocentres (Villani et al., 2019). In this study, a cut-off depth of 7km was applied during SPI processing to emphasize deeper basement-related features and minimize the influence of shallow magnetic sources. SPI depth maps were processed and visualized using ArcGIS 10 Pro, which enabled spatial integration with structural trends, lineament patterns, and pseudo-gravity anomalies.

To aid visualization of the subsurface structural framework, the pseudo-gravity anomaly field was displayed as a three-dimensional (3D) surface plot using Surfer 16. The 3D representation provides a qualitative view of spatial variations in pseudo-gravity intensity, highlighting relative basement highs and lows across the study area. Elevated pseudo-gravity responses correspond to uplifted basement blocks or dense intrusive features, whereas depressed surfaces indicate sediment-filled depocentres and structurally controlled lows. This visualization was used solely for interpretational support, enabling clearer identification of regional structural trends and basin architecture, and does not represent 3D forward or inverse modeling. The 3D pseudo-gravity plot complements the SPI depth estimates, enhancing interpretation of basement relief and tectonic segmentation within the Upper Benue Trough (Garba et al., 2024).

Two-dimensional (2D) forward modeling was conducted directly on the Total Magnetic Intensity (TMI) data using 2D GM-SYS magnetic models, rather than the pseudo-gravity field, due to the inherent sensitivity of the pseudo-gravity transformation to deep-seated, regional magnetic sources. While pseudo-gravity is effective for imaging basin-scale basement architecture, its transformation enhances long-wavelength components and suppresses shorter-wavelength anomalies associated with shallow to intermediate-depth basement relief (Salem et al., 2012). This results in depth estimates that locally exceed 10 km, which, although valuable for understanding crustal-scale deformation, are less suitable for constraining sediment basement interfaces relevant to hydrocarbon exploration. In contrast, TMI data preserve both regional and residual magnetic components, allowing more realistic modeling of basement undulations within the upper crust (Beamish et al., 2016). Forward modelling of the TMI profiles therefore provides better control on basement geometry, susceptibility contrasts, and sediment thickness within exploration-relevant depth ranges (Adewumi et al., 2022).

## RESULT AND DISCUSSION

The TMI map (Figure 2a) displays significant magnetic amplitude variations ranging from approximately –74nT to +195nT, reflecting contrasts between magnetic basement rocks and overlying sedimentary units. Prominent positive anomalies dominate the central and southeastern parts of the area, particularly around Lomi, Gombe, and Tongo, and are interpreted as shallow magnetic basement or magnetized intrusive bodies. In contrast, broad negative anomalies occur in the northwestern (Dukku) and southwestern (Kolmani) sectors, indicating deeper basement surfaces or thicker sedimentary cover. Sharp magnetic gradients separating these anomalies delineate major structural boundaries, likely associated with basement faults and lithological contacts (Salawu et al., 2019).

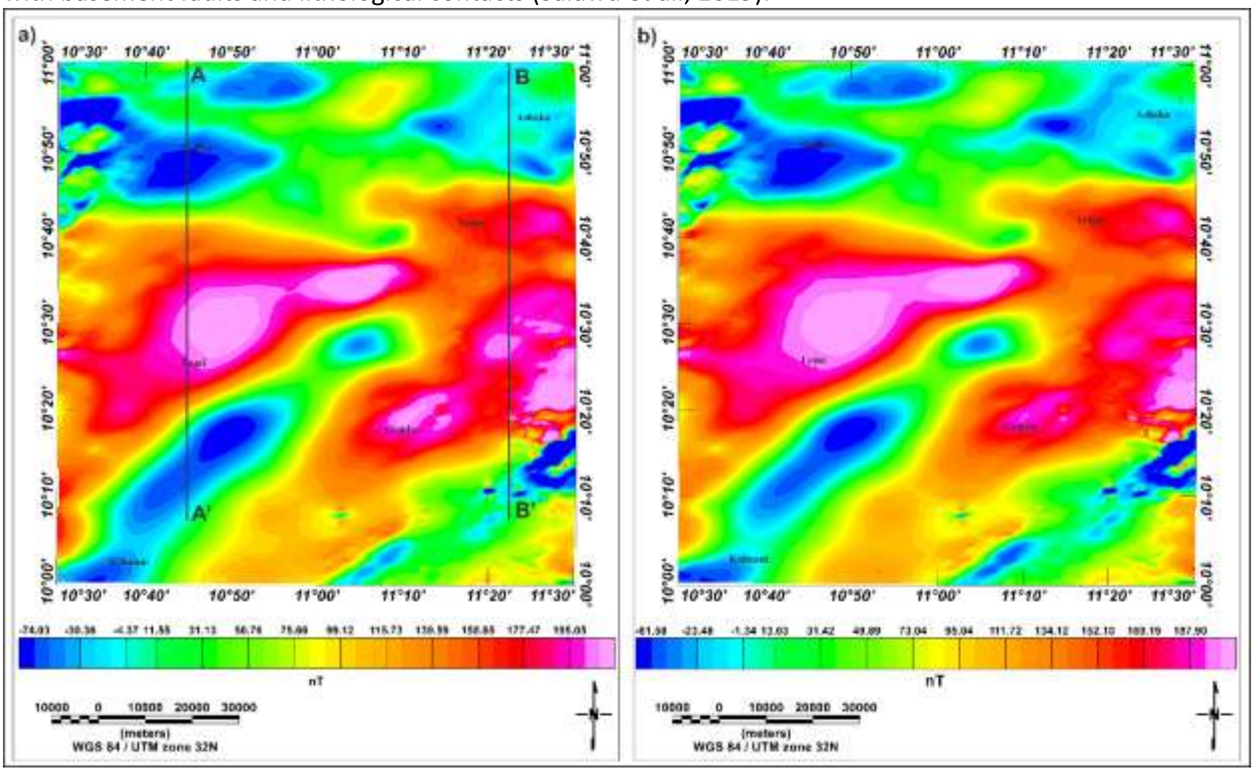

**Figure 2:** (a) Total Magnetic Intensity (TMI) map of the study area, corrected for the International Geomagnetic Reference Field (IGRF) and contoured in nanotesla (nT), showing the locations of 2D profiles

A–A′ and B–B′. (b) Reduction to the Equator (RTE) magnetic anomaly map showing repositioned magnetic sources at low magnetic latitude.

The RTE-transformed magnetic map (Figure 2b) enhances anomaly symmetry and positions magnetic highs more directly over their causative sources, consistent with the low magnetic latitude of the Upper Benue Trough (Ejiga et al., 2021). The map exhibits anomaly amplitudes ranging from approximately –62nT to +188nT, with pronounced magnetic highs concentrated around Lomi, Tongo, and Gombe, suggesting shallow or magnetized basement features. Broad magnetic lows dominate the northwestern (Dukku) and southwestern (Kolmani) areas, indicative of deeper basement surfaces and thicker sedimentary sequences. Linear gradients separating these domains highlight structurally controlled boundaries, likely associated with major basement faults (Strugale et al., 2021).

The pseudo-gravity map (Figure 3a) reveals long-wavelength anomalies ranging from approximately –0.34 to +0.22mGal, reflecting variations in basement density and magnetization beneath the study area. Prominent negative pseudo-gravity anomalies are observed around Lomi and Dukku, forming broad depressions interpreted as basement lows or depocentres. In contrast, positive anomalies dominate the Kolmani, Ashaka, and southeastern margins, indicating relatively dense or uplifted basement blocks. The smooth, laterally continuous nature of the anomalies suggests that the pseudo-gravity transformation has effectively suppressed near-surface magnetic effects, thereby emphasizing deeper crustal structures (Salawu et al., 2019).

The pseudo-gravity derived SPI depth map (Figure 3b) indicates basement depths ranging from approximately 1.3km to >14.4km, revealing pronounced lateral variations in crustal structure across the study area. The deepest SPI solutions (>10km) form extensive, coherent zones around Lomi and parts of Tongo, defining major basement depressions. Moderate depths (5–9km) dominate the Gombe–central corridor, while relatively shallow depths (<4km) are restricted to the northern and southeastern margins, including parts of Dukku and Ashaka. The smooth, long-wavelength character of the depth distribution reflects the emphasis of the pseudo-gravity transformation on deep-seated magnetic sources (Ganguli et al., 2021).

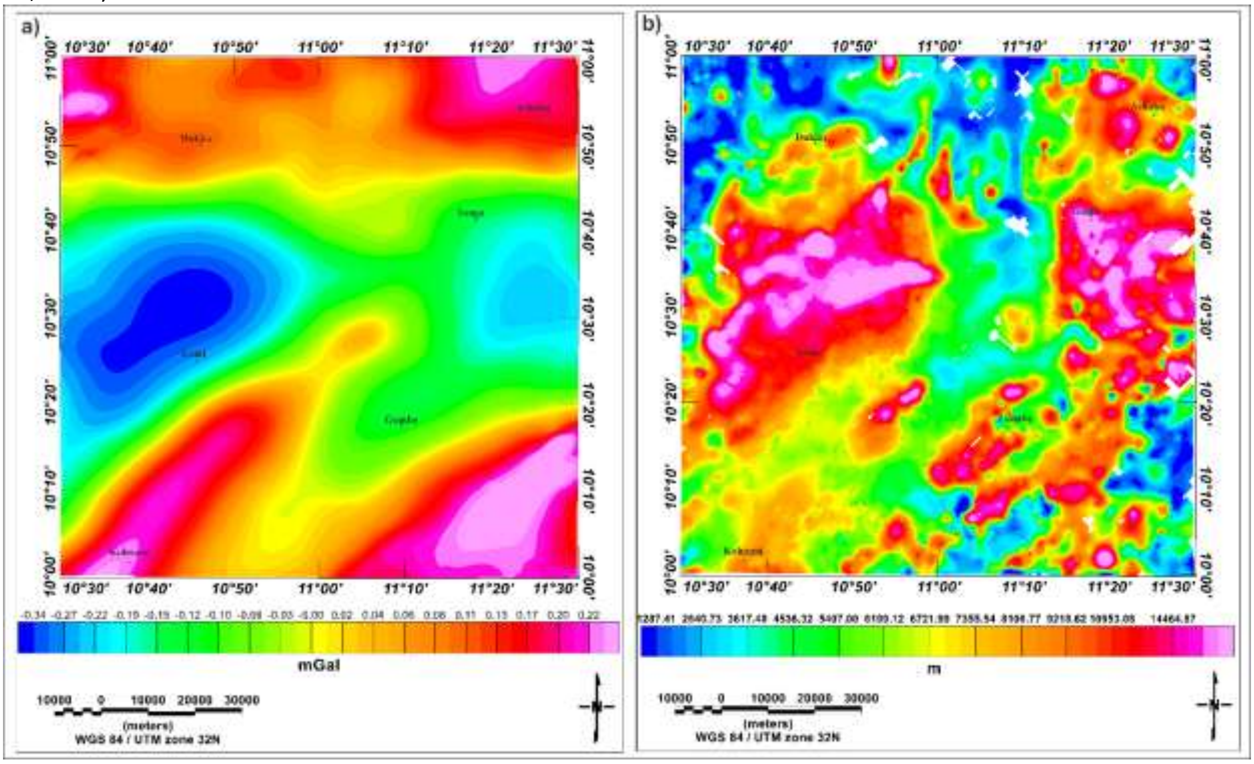


**Figure 3:** (a) Pseudo-gravity anomaly map generated from the RTE magnetic data, emphasizing deep-seated basement density contrasts, (b) Total Source Parameter Imaging (SPI) depth map derived from the pseudo-gravity field, showing full basement depth distribution across the study area.

The SPI depth map derived from the pseudo-gravity field with a cutoff depth of 7km (Figure 4a) reveals a heterogeneous basement morphology across the study area. Shallow source depths (0.177–2.8km) occur as scattered clusters, mainly around the northeastern and southeastern margins, suggesting near-surface magnetic sources likely related to basement highs or shallow intrusions. Intermediate depths (2.8–5.0km) dominate the central parts, forming linear to curvilinear trends that align with mapped structural lineaments. The deepest sources (5.0–7.0km) define elongated zones extending predominantly NE–SW, especially around the Lomi–Kolmani–Gombe axis, indicating significant basement depressions and thick sedimentary accumulations.

The superimposed SPI depth solutions (cutoff at 7km) on the pseudo-gravity anomaly map (Figure 4b) show a strong spatial correlation between deep source estimates and negative pseudo-gravity anomalies. The deepest SPI solutions (5–7km) form continuous NE–SW trending belts, particularly along the Lomi–Kolmani–Gombe corridor, coinciding with broad pseudo-gravity lows interpreted as basement depressions. Intermediate depths (2.8–5.0km) cluster along the flanks of these lows, while shallow solutions (2.8km) are mainly associated with pseudo-gravity highs, indicating uplifted or shallow basement blocks.

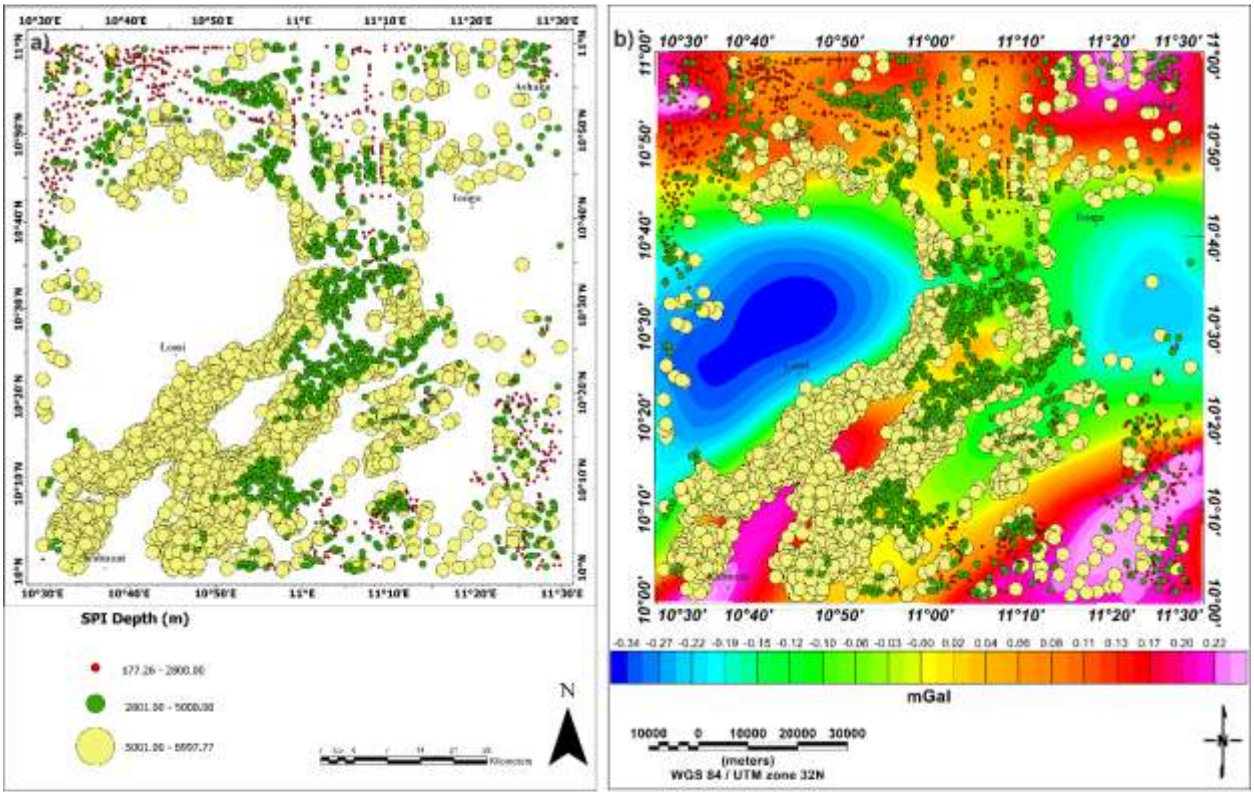


**Figure 4:** (a) Source Parameter Imaging (SPI) depth map derived from the pseudo-gravity field with a cutoff depth of 7km, highlighting shallow to intermediate basement structures, (b) Superimposed SPI depth solutions (cutoff at 7km) on the pseudo-gravity anomaly map illustrating structurally controlled depocenters.

The 3D pseudo-gravity surface (Figure 5) reveals pronounced long-wavelength undulations that define the regional basement morphology beneath the Upper Benue Trough. Prominent depressions (green–ash lows) indicate structurally controlled basement lows, while elevated ridges (brown–green highs) correspond to uplifted basement blocks or intrusive bodies (Ekpo et al., 2024). The surface geometry highlights a dominant NE–SW–oriented trough flanked by basement highs, consistent with rift-related segmentation of the basin. Steep gradients along the flanks of the depressions suggest major fault boundaries separating basement highs from deep depocenters.

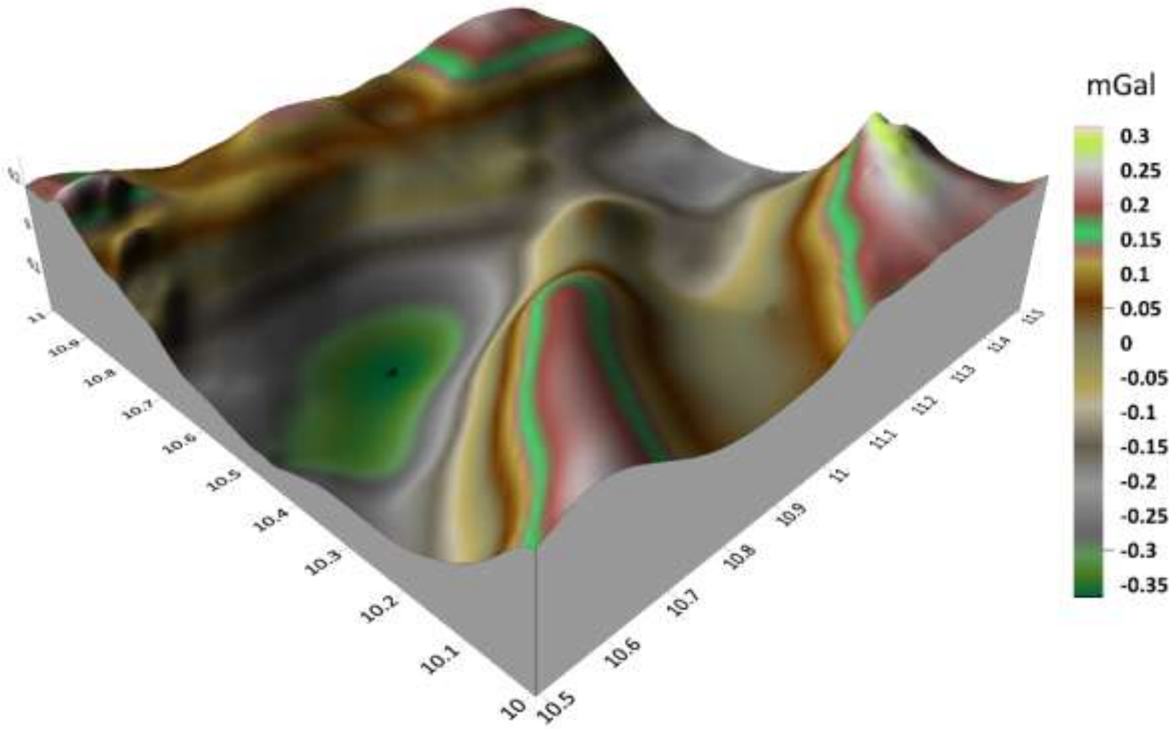


**Figure 5:** Three-dimensional surface representation of the pseudo-gravity field revealing basement relief and regional basin architecture.

The 2D GM-SYS magnetic models (Figure 6) along profiles A–A′ and B–B′ reveal a fault-controlled basement architecture with alternating basement highs and deep structural depressions beneath a non-magnetic sedimentary cover. Magnetic susceptibilities range from 0.001 to 0.004 SI, with higher values marking uplifted or magnetized basement highs and lower values defining rift-related grabens or half-grabens that reach depths of 4–5 km. A broad central basement depression is evident along profile B–B′, flanked by shallower basement blocks. The close match between observed and calculated magnetic responses (misfits of 4.3–12.3 nT) confirms that the models adequately represent the dominant basement relief and structural framework.

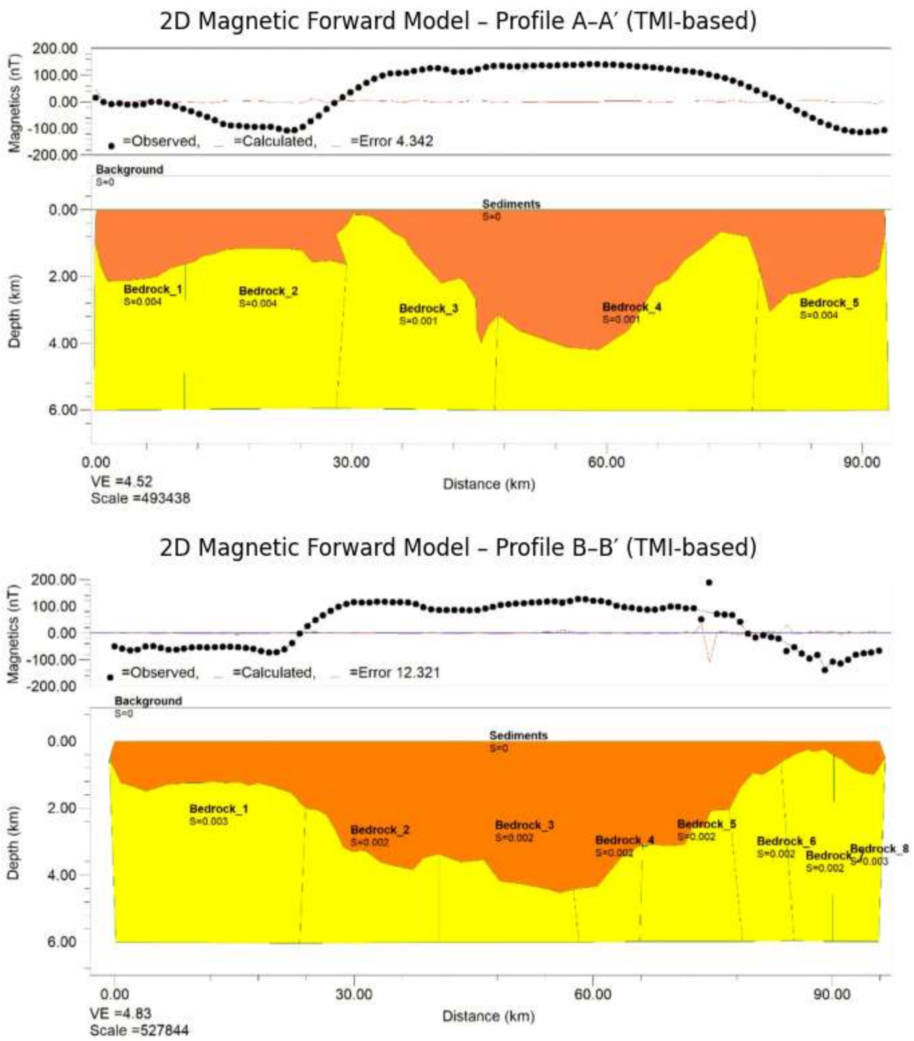


**Figure 6:** 2D Magnetic Forward Modelling along the two TMI Profiles

**Discussion**

The integrated aeromagnetic, pseudo-gravity, and depth-to-basement analyses reveal a rift-controlled structural framework that exerts first-order control on hydrocarbon prospectivity within the Upper Benue Trough. The aeromagnetic anomaly pattern is characterized by extensive magnetic lows separated by intervening highs, reflecting basement segmentation associated with Early Cretaceous rifting and later tectonic reactivation. Okhovatzadeh et al. (2025) showed that such contrasting magnetic signatures in rift basins commonly mark fault-bounded depocentres and uplifted basement blocks, which play a critical role in basin compartmentalization. In the present study, magnetic highs are interpreted as uplifted or intruded basement blocks that locally form structural closures along their flanks, while broad magnetic lows delineate depocentres that acted as primary accommodation zones for sediment accumulation. These depocentres are favourable for hydrocarbon generation due to increased burial depth, enhanced thermal maturation, and prolonged subsidence.

The dominant NE–SW and NW–SE orientations of magnetic anomalies and gradients correspond to regional fault systems that governed basin architecture and sediment dispersal. Elawadi et al. (2025) demonstrated that such orthogonal fault trends are typical of syn-rift graben and half-graben systems, where thick sedimentary successions accumulate and petroleum systems evolve. In the Upper Benue Trough, these structural trends define fault-controlled depocentres and basement highs that likely influenced sediment routing, compartmentalization, and trap development. Although aeromagnetic data do not directly detect hydrocarbons, Okoro et al. (2021) indicated that structurally consistent magnetic lows, when integrated with pseudo-gravity and depth estimation techniques, provide a reliable regional framework for identifying prospective zones in frontier basins.

Reduction to the Equator (RTE) processing significantly enhances the structural clarity of the magnetic data by correcting inclination-related distortion. The RTE map resolves elongated magnetic highs and lows aligned with the principal tectonic trends of the Upper Benue Trough, allowing improved delineation of basement faults and depocentres. Ndikilar et al. (2019) noted that such corrected magnetic signatures in the Benue Trough region commonly reflect variations in sediment thickness and basement relief. In this study, magnetic lows identified on the RTE map particularly within the Kolmani–Dukku sector are interpreted as zones of increased sediment thickness that may favour hydrocarbon generation and preservation, whereas magnetic highs represent uplifted basement blocks that acted as structural barriers and influenced sediment distribution.

The pseudo-gravity transformation provides a gravity-equivalent representation of the magnetic data, enabling clearer interpretation of deep basement configuration relevant to basin-scale hydrocarbon assessment. Olawuyi (2020) showed that pseudo-gravity effectively suppresses shallow magnetic effects while enhancing long-wavelength anomalies associated with deep-seated basement structures. In the present study, negative pseudo-gravity anomalies closely correspond with magnetic lows and delineate major sediment-filled depocentres, especially along the Lomi–Dukku corridor, interpreted as long-lived centres of rift-related subsidence. Positive pseudo-gravity anomalies delineate basement highs that likely influenced basin compartmentalization and may have served as migration pathways or structural trapping elements, consistent with interpretations of Florio et al. (2021) in comparable rift basins.

Source Parameter Imaging (SPI) applied to the pseudo-gravity field yields depth estimates that emphasize regional, deep-seated crustal sources. Lacombe and Bellahsen (2016) demonstrated that deeply buried basement structures in rift basins provide valuable insight into crustal thinning, subsidence history, and tectonic evolution. In this study, SPI depths locally exceeding 10 km coincide with negative pseudo-gravity anomalies and magnetic lows along the central basin axis, confirming the presence of major depocentres with significant sediment thickness. Applying a 7 km SPI depth cutoff, following the approach of Okoro et al. (2021), isolates depths more relevant to sedimentary basin architecture and hydrocarbon prospectivity. The filtered SPI solutions define fault-controlled grabens and half-grabens aligned predominantly along NE–SW trends, consistent with the tectonic grain of the Upper Benue Trough described by Strugale and Cartwright (2022).

The 2D magnetic models indicate a fault-controlled horst–graben basement architecture beneath the Upper Benue Trough, with broad rift-related basement depressions reaching depths of about 4.5–5.0 km and flanked by shallower basement highs. These depressions coincide with magnetic and pseudo-gravity lows as well as deeper SPI solutions, confirming their interpretation as major sedimentary depocentres formed during basin subsidence. Variations in basement magnetic susceptibility (0.002–0.004 SI) reflect lateral heterogeneity within the crystalline basement, likely related to tectonic deformation or magmatic intrusions. The depocentres represent the most favorable zones for enhanced sediment burial and hydrocarbon maturation, while adjacent basement highs likely influenced sediment distribution and hydrocarbon migration pathways.

**Conclusion**

This study demonstrates that pseudo-gravity transformation and 2D magnetic modelling of aeromagnetic data provide robust quantitative constraints on basement architecture, sediment thickness, and hydrocarbon prospectivity in the Upper Benue Trough. Depth estimation from pseudo-gravity–based Source Parameter Imaging (SPI) indicates basement depths ranging from approximately 1.3km to >14km, defining a strongly segmented rift basin characterized by fault-controlled horst–graben architecture with broad basement depressions flanked by shallower basement highs. The 2D magnetic models consistently image rift-related depocentres reaching depths of about 4.5–5.0km, which spatially coincide with negative pseudo-gravity anomalies (−0.34 to −0.18mGal), reduced magnetic amplitudes, and deeper SPI solutions along the Lomi–Kolmani–Gombe corridor, confirming their interpretation as major sedimentary depocentres formed during basin subsidence. Application of a 7km depth cutoff isolates basin-scale structures relevant to sedimentary processes and reveals NE–SW trending depocentres with estimated sediment thicknesses of 5–7km, sufficient for hydrocarbon generation under favorable thermal conditions. Variations in basement magnetic susceptibility (0.002–0.004 SI) reflect lateral heterogeneity within the crystalline basement, likely related to tectonic deformation or magmatic intrusions, while positive pseudo-gravity anomalies (>0.10mGal) and shallow SPI depths (<3km) delineate uplifted basement blocks that likely influenced sediment routing, structural compartmentalization, and hydrocarbon migration pathways. The integrated pseudo-gravity, SPI, and 2D magnetic modelling results provide measurable constraints on basin geometry in a data-limited region and demonstrate the effectiveness of pseudo-gravity analysis as a reconnaissance tool for prioritizing high-value exploration targets for subsequent seismic imaging, thermal modelling, and exploratory drilling in the Upper Benue Trough.

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