

Multiscale Integration of Gravity and Magnetic Methods for Hydrocarbon Exploration in Frontier Basins: A Methodological Framework and Case Study from the Lower Benue Trough, Nigeria

Sampson Chiehiura Igbokwe*, Magnus Uzoma Igboekwe, Chukwunenyeoke Amos-Uhegbu, Blessing Chikaodili Ejiogu, Somiebi Amakiri, and Gabriel Ezenwa Nneji

Received: : 13 August 2026/ Accepted: 24 September 2026/Published: 01 October 2026

DOI: [10.4314/cps.v13i11.5](https://doi.org/10.4314/cps.v13i11.5)

Abstract: Integrated gravity and aeromagnetic interpretation provides a valuable approach for investigating frontier sedimentary basins where seismic coverage is limited or insufficient to constrain regional basement architecture. This study develops and demonstrates a multiscale framework for integrating potential-field data from regional to local scales, emphasizing the complementary responses of gravity and magnetic methods to subsurface density and magnetization contrasts. The framework combines regional-residual separation, upward continuation, reduction to the magnetic equator, derivative-based edge detection, analytical signal analysis, Source Parameter Imaging (SPI), and spectral depth estimation. Interpretation is organized around geological correlation, comparative assessment of structural and depth indicators, and evaluation of the consistency and limitations of derived anomaly and depth estimates. The framework is demonstrated using legacy ground gravity observations, satellite-derived gravity information, and aeromagnetic data from the Nigerian Geological Survey Agency covering parts of the Lower Benue Trough, southeastern Nigeria. The interpreted results indicate shallow magnetic-source depths of approximately 0.3–3.7 km, magnetic centroid depths of 1.84–5.95 km, gravity-derived deep-source depths of 5.0–6.2 km, and gravity SPI depths of 2.4–2.9 km. The integrated interpretation reveals a structurally heterogeneous basin characterized by dominant NE–SW trends and subordinate NW–SE and N–S orientations. Differences among the depth estimates highlight the importance of distinguishing method-specific source parameters rather than treating them as equivalent measurements of basement depth. The framework provides a systematic basis for delineating potential structural

boundaries, assessing basin architecture, and generating testable geological hypotheses for subsequent petroleum-system investigations. The case study demonstrates the application of established processing techniques within an organized interpretive workflow rather than presenting newly acquired data or an independent inversion study.

Keywords: Gravity; aeromagnetic data; multiscale integration; source-depth estimation; structural interpretation; Lower Benue Trough; hydrocarbon exploration.

Sampson Chiehiura Igbokwe*

Department of Physics, Kingsley Ozumba Mbadiwe University, Ideato, Imo State, Nigeria.

Email: sampso2ng@gmail.com.

<https://orcid.org/0000-0002-5425-4626>

Magnus Uzoma Igboekwe

Department of Physics, Michael Okpara University of Agriculture, Umudike, Abia State, Nigeria.

Email: igboekwemu@yahoo.com

Chukwunenyeoke Amos-Uhegbu

Department of Geology, Michael Okpara University of Agriculture, Umudike, Abia State, Nigeria.

Email: [amos-](mailto:amos-uhgbu.chukwunenyeoke@mouau.edu.ng)

uhgbu.chukwunenyeoke@mouau.edu.ng

Blessing Chikaodili Ejiogu

Alvan Ikoku Federal University of Education, Owerri, Imo State, Nigeria.

Email:

blessing.ejiogu@alvanikoku.edu.ng

Somiebi Amakiri

School of Foundation Studies, Rivers State College of Health Science and Management Technology, Port Harcourt, Rivers State, Nigeria.

Email: mails4sommy@yahoo.com

Gabriel Ezenwa Nneji

Department of Physics, Michael Okpara
University of Agriculture, Umudike,
Abia State, Nigeria.

Email: nnejiprof695@gmail.com

1.0 Introduction

Hydrocarbon exploration in frontier sedimentary basins requires reliable information on basin geometry, sedimentary thickness, basement configuration, and structural discontinuities that may influence hydrocarbon generation, migration, and accumulation. However, these parameters are often inadequately constrained in areas where seismic surveys are limited by cost, accessibility, or incomplete spatial coverage. Gravity and magnetic methods provide valuable reconnaissance tools for investigating subsurface geological structures over regional and local scales. Gravity anomalies reflect lateral variations in subsurface density, whereas magnetic anomalies arise from contrasts in magnetic susceptibility and remanent magnetization. The complementary sensitivities of these methods make their integration useful for delineating basement relief, sedimentary depocentres, lithological boundaries, and major structural features that can guide subsequent geological and seismic investigations (Blakely, 1995; Hinze *et al.*, 2013; Lowrie & Fichtner, 2020). Although potential-field methods cannot independently establish the existence of a working petroleum system, they can provide important constraints for preliminary basin characterization and exploration targeting.

The geological interpretation of gravity and magnetic anomalies is complicated by their inherent non-uniqueness, whereby different combinations of source depth, geometry, density contrast, and magnetic properties may produce similar observed responses. Consequently, a

single anomaly map or processing technique may not adequately distinguish regional basement architecture from shallow geological features. Saltus & Blakely (2011) emphasized that non-uniqueness does not make potential-field interpretation ineffective; rather, geological constraints, complementary observations, and careful evaluation of uncertainty are necessary to develop meaningful interpretations. Several processing and interpretation techniques have therefore been developed to enhance particular characteristics of potential-field data. Regional-residual separation helps distinguish broad regional variations from shorter-wavelength anomalies, while upward continuation suppresses the relative influence of shallow sources and emphasizes longer-wavelength features. Derivative-based techniques, including horizontal-gradient and vertical-derivative analysis, enhance lateral changes in potential-field intensity and assist in identifying possible source boundaries (Blakely & Simpson, 1986; Phillips *et al.*, 2007). Analytical signal analysis provides additional information for locating magnetic sources, while spectral methods and source parameter imaging (SPI) can be used to estimate source depths under their respective assumptions (Jacobsen, 1987; Thurston & Smith, 1997). These methods provide complementary information, but their results remain sensitive to source geometry, data resolution, processing parameters, and the assumptions adopted during interpretation.

Previous investigations have established the importance of gravity and magnetic methods in understanding the geology and tectonic development of the Benue Trough. Cratchley and Jones (1965) examined the relationship between geological structures and gravity anomalies across the Benue Valley, providing an early geophysical basis for interpreting the subsurface configuration of the trough. Adighije (1979, 1981)



subsequently investigated the regional gravity field and the configuration of the basement beneath the Lower Benue Trough. His gravity interpretation identified alternating positive and negative Bouguer anomalies, which were attributed to variations in basement depth and sedimentary thickness. These investigations demonstrated the usefulness of gravity observations for reconstructing regional basin architecture, although their spatial sampling and interpretive approaches differ from those available through contemporary combinations of ground, satellite-derived, and airborne geophysical datasets.

Aeromagnetic investigations have further contributed to understanding basement structures, source depths, and potential exploration targets within the Lower Benue Trough. Osinowo and Taiwo (2020) applied high-resolution aeromagnetic data processing, including analytical signal analysis, tilt-derivative techniques, upward continuation, and Euler deconvolution, to investigate magnetic sources and structural features relevant to hydrocarbon exploration. Their results demonstrated the usefulness of magnetic attributes for differentiating geological domains and identifying structural lineaments at different scales. Subsequent investigations have employed source-depth estimation and modelling techniques to characterize magnetic sources and basement configuration in parts of the Lower Benue Trough and adjoining areas. Such studies show that magnetic data can provide important information on subsurface structure, but they also demonstrate that depth estimates depend on the selected method and the assumptions underlying the interpretation. More recent research in the Middle Benue Basin has similarly shown the value of enhanced aeromagnetic attributes for delineating structural trends and estimating sedimentary thickness in preliminary hydrocarbon assessment (Osinowo et al., 2023).

Despite these advances, integrating gravity and magnetic observations remains challenging because the methods

respond to different physical properties and may emphasize different geological sources. A structure that produces a distinct magnetic lineament may not generate a corresponding gravity anomaly of comparable spatial extent or amplitude. Similarly, source depths estimated using spectral analysis, SPI, and other techniques may represent different source populations or depth measures and should not automatically be treated as equivalent. Joint and integrated geophysical interpretation can reduce the range of plausible subsurface models when the relationships between datasets are geologically and physically justified (Moorkamp, 2017). However, the combination of multiple processing products does not, by itself, demonstrate that an inferred structure or depth estimate is correct. A defensible interpretation therefore requires a systematic workflow that organizes the analysis from regional to local scales, compares independent physical-property indicators, evaluates differences between depth estimates, and explicitly acknowledges uncertainties and limitations. The methodological issue addressed in this study is how such a workflow can be implemented consistently using heterogeneous potential-field datasets without overstating the certainty of the resulting geological interpretation.

The Lower Benue Trough in southeastern Nigeria provides an appropriate setting for demonstrating this approach because of its complex Cretaceous sedimentary architecture, basement-cover relationships, and tectonic history. The regional structure reflects the evolution of the Benue Trough in relation to the opening of the South Atlantic and subsequent tectonic deformation (Burke *et al.*, 1971; Grant, 1971; Benkhelil, 1989). The Abakaliki Fold Belt and associated structural trends contribute to the geological complexity of the region, where variations in basement



configuration and sedimentary thickness are important considerations for regional basin assessment. The study area covers parts of Udi, Nkalagu, Abakaliki, Okigwe, Afikpo, and Ugep, approximately between 5°30'N–6°30'N and 7°00'E–8°30'E. Earlier gravity and aeromagnetic investigations provide an established geological and geophysical context for the area; consequently, the contribution of the present study is not based on claiming that the region has never been investigated using integrated potential-field methods. Rather, it focuses on organizing established techniques into an explicit multiscale interpretive framework and demonstrating how the resulting products can be compared systematically.

The aim of this study is to develop and demonstrate a multiscale framework for integrating gravity and magnetic methods in the interpretation of frontier sedimentary basins, using a case study from the Lower Benue Trough, Nigeria. The specific objectives are to separate regional and residual anomaly components; apply continuation, derivative-based, analytical signal, and depth-estimation techniques to characterize potential-field sources; identify and compare structural trends inferred from gravity and magnetic observations; evaluate the consistency and limitations of the resulting depth estimates; and integrate the interpretations to develop a geological representation of the basin architecture. The case study draws on legacy ground gravity observations, satellite-derived gravity information, and aeromagnetic data obtained from the Nigerian Geological Survey Agency, using results from previous doctoral research. The study does not introduce a new inversion algorithm or constitute an independent inversion of newly acquired data. Its methodological contribution lies in the systematic organization of established processing and interpretation techniques,

the explicit comparison of complementary structural and depth indicators, and the recognition of uncertainties associated with heterogeneous potential-field datasets. The resulting workflow is intended to support preliminary basin screening, basement mapping, structural characterization, and the identification of geological targets for subsequent seismic and other subsurface investigations. In this way, the study provides a practical basis for generating testable geological hypotheses relevant to hydrocarbon exploration while recognizing that petroleum prospectivity ultimately requires additional evidence concerning source rocks, maturation, migration pathways, reservoir properties, seals, and trap integrity.

2.0 Geological and Geophysical Context

2.1 Lower Benue Trough

The Lower Benue Trough forms the southern sector of the larger Benue Trough system of Nigeria. It comprises Precambrian crystalline basement overlain by Cretaceous sedimentary successions whose thickness and structural configuration vary spatially. The basin developed through Cretaceous tectonism associated with the opening of the South Atlantic and was subsequently modified by deformation, folding, faulting and magmatic activity. The Abakaliki Fold Belt and associated structural elements form a major component of the regional architecture (Benkhelil 1989; Nwajide 2022).

For potential-field interpretation, the key geological contrast is between relatively dense and commonly magnetic crystalline basement rocks and lower-density, generally less magnetic sedimentary successions. Variations in basement relief, intrusions, faults and sediment thickness can therefore generate coupled but non-identical gravity and magnetic responses. A negative gravity



anomaly may indicate a sediment-filled depression, but it can also result from other low-density materials; similarly, a magnetic low may represent thick sedimentary cover, demagnetized

basement, or a change in basement lithology. Interpretation must consequently be constrained by geological context and by comparison of multiple products.

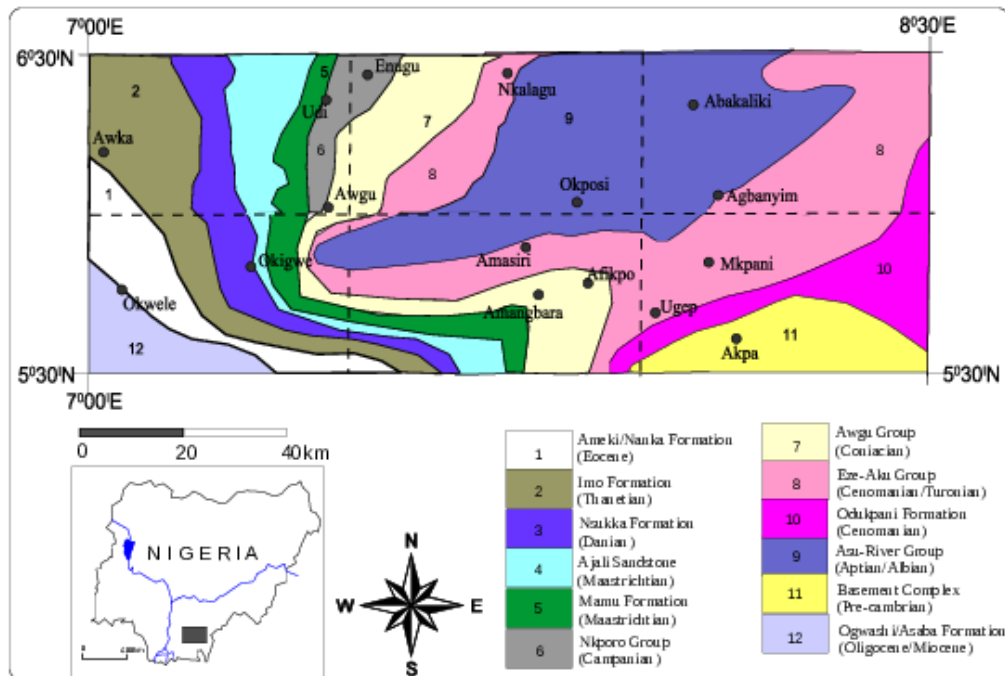


Fig. 1. Location of the study area within the Lower Benue Trough, southeastern Nigeria.

2.2 Physical Basis of Gravity and Magnetic Methods

Gravity and magnetic methods are potential-field techniques used to investigate subsurface geological structures through spatial variations in gravitational acceleration and the Earth's magnetic field. Their responses depend on contrasts in the physical properties of subsurface materials, particularly density for gravity and magnetization for magnetic measurements. Although both methods can provide information about sedimentary-basin geometry, basement relief, lithological boundaries, and structural discontinuities, they respond to different physical properties and should therefore be interpreted as complementary sources of geological information (Blakely, 1995; Hinze *et al.*, 2013). The gravitational potential generated by a subsurface distribution of density contrasts can be expressed as

$$Vg(r) = G \int V [\Delta\rho(r') / |r - r'|] dV'$$

and the observed gravity disturbance is obtained from the spatial derivative of the potential. In a Cartesian formulation, the vertical component can be written schematically as

$$\Delta g_z(r) = G \int V \Delta\rho(r') (z - z') / |r - r'|^3 dV'.$$

The exact reduction from observed gravity to a Bouguer anomaly also depends on elevation, terrain and reference-field corrections. In practical gravity surveys, observed measurements are corrected for relevant instrumental, tidal, latitude, elevation, and terrain effects, depending on the acquisition and reduction procedures. A gravity disturbance is defined as the difference between observed gravity and normal gravity evaluated at the corresponding point, whereas a Bouguer anomaly is obtained through a gravity-reduction procedure that accounts for elevation and the gravitational effects of the intervening



rock mass, with terrain and other applicable corrections. These quantities are related but are not interchangeable. Bouguer anomaly maps are commonly used to investigate lateral density variations associated with sedimentary thickness, basement relief, and geological structures. Because gravity anomalies represent the integrated effects of density contrasts over a subsurface volume, both shallow and deep sources may contribute to the observed signal. Regional-residual separation and continuation techniques can help distinguish anomaly components with different spatial wavelengths, although wavelength alone does not uniquely determine source depth (Blakely, 1995; Hinze *et al.*, 2013).

$$\Phi m(r) = (\mu_0/4\pi) \int V M(r') \cdot (r - r') / |r - r'|^3 dV'.$$

The measured total-field magnetic anomaly depends on the geometry, depth, magnetization strength, and direction of the causative source, as well as the direction of the Earth's main magnetic field. At low magnetic latitudes, anomaly maxima and minima may be displaced from their causative sources, complicating direct geological interpretation. Reduction to the magnetic equator is a mathematical transformation intended to reposition or normalize magnetic anomalies under an assumed inducing-field direction and an appropriate model of source magnetization. Its reliability depends on the magnetic inclination and declination used, the assumptions concerning remanent magnetization, and the stability of the transformation for the available data. Noise and poorly resolved short-wavelength features may be amplified or distorted under some transformation conditions. Reduction to the magnetic equator should therefore be interpreted alongside other products, such as analytical signal and derivative maps, rather than treated as a definitive correction for magnetic-anomaly non-uniqueness (Blakely, 1995).

In this study, the physical principles of gravity and magnetic methods provide the basis for integrating anomaly separation, continuation, derivative-based enhancement, analytical signal analysis, and source-depth estimation. Gravity interpretation is used to investigate density-related variations in basin architecture, while magnetic interpretation provides complementary constraints on basement lithology and structural configuration. Comparing the resulting products enables the assessment of spatial correspondence, structural orientations, and differences among estimated source depths. However, these comparisons are interpreted within the limitations of each technique and are not treated as independent validation unless supported by additional geological or geophysical evidence.

2.3 Complementarity and Non-Uniqueness

Gravity and magnetic data should not be interpreted as two maps that must show identical patterns. A basement block may produce a gravity high but only a weak magnetic response if it is weakly magnetized; conversely, a magnetic intrusive body may be prominent without producing a proportionate gravity anomaly if its density contrast is small. The objective of integration is therefore consistency rather than visual identity. Features that recur across independent physical-property products, particularly where their spatial positions and orientations agree, provide stronger structural evidence than features appearing in only one derivative map.

This distinction is central to a frontier-basin workflow. Potential-field integration can constrain the geometry of basin margins, basement highs and lows, fault corridors and source-depth distributions, but it cannot by itself establish the presence, maturity, migration history or commercial volume of hydrocarbons. Those conclusions



require geological, geochemical and, where available, seismic and well constraints.

3.0 Data and Multiscale Processing Framework

3.1 Case-Study Data

The case example uses the data architecture documented in the doctoral thesis. Legacy ground gravity data were compiled from earlier surveys, including Cratchley and Jones (1965), Adighije (1981) and Ofoegbu (1985). Satellite-

derived gravity information was incorporated to improve regional spatial continuity. The aeromagnetic component comprises Nigerian Geological Survey Agency (NGSA) data covering six sheets: 301–303 and 312–314. The thesis documents a nominal 500 m flight-line spacing, 2 km tie-line spacing, approximately 80 m terrain clearance and 100 m gridded cell size for the digital aeromagnetic products.

Table 1. Case-study datasets and their principal interpretive roles

Dataset	Principal source	Coverage specification	Primary interpretive role
Ground gravity	Cratchley & Jones (1965); Adighije (1981); Ofoegbu (1985)	Legacy observations; station spacing approximately 2–5 km	Regional density structure and basin configuration
Satellite-derived gravity	World Gravity Map and global marine/satellite gravity products	Regional continuous coverage	Long-wavelength gravity structure and basin-scale continuity
Aeromagnetic	Nigerian Geological Survey Agency	Sheets 301–303 and 312–314; 500 m line spacing; 2 km tie lines; 100 m grid	Basement architecture, magnetic contacts and structural trends

The case-study data specifications above summarize the specifications used in this analysis; they are not new acquisition parameters generated for this review.

3.2 Pre-processing and Regional-Residual Separation

Regional-residual separation is used to distinguish broad, long-wavelength components from shorter-wavelength anomalies. Polynomial surfaces may be tested at several orders, but the choice should be guided by both statistical behavior and geological plausibility. An arbitrarily selected polynomial order can remove genuine geological signal or retain regional curvature in the residual field. Upward continuation provides an alternative scale-dependent operation because it progressively attenuates short

wavelengths while preserving broad features (Jacobsen 1987).

For the case study, upward continuation was applied at multiple heights to both magnetic and gravity fields. The resulting sequence is interpreted as a scale ladder: low continuation heights retain shallow and intermediate features, whereas larger heights emphasize broad, deeper structures. This is more informative than selecting one 'regional' map because the transition of an anomaly through successive continuation levels contains qualitative information about source depth and lateral extent.

3.3 Reduction to the Magnetic Equator

Reduction to the magnetic equator (RTE) is appropriate for low magnetic latitudes



because it transforms the observed field toward an equivalent anomaly response at zero inclination. The transformation is performed in the wavenumber domain using the field inclination and declination. In the case-study workflow, the RTE product was used primarily to simplify spatial interpretation before derivative and edge-detection analysis. RTE should not be regarded as a depth filter; it changes anomaly geometry rather than independently estimating source depth.

3.4 Derivative and Edge-Detection Products

The total horizontal gradient is useful for emphasizing lateral changes in a potential field. For a field F , its magnitude can be written as

$$|THG| = \sqrt{[(\partial F/\partial x)^2 + (\partial F/\partial y)^2]}.$$

Maxima commonly occurs near contacts and steep lateral gradients, making the operator useful for mapping basement boundaries and major structural discontinuities (Cordell and Grauch 1985).

The tilt derivative is commonly expressed as the ratio of the vertical derivative to the total horizontal derivative:

$$TDR = \arctan[(\partial F/\partial z) / \sqrt{((\partial F/\partial x)^2 + (\partial F/\partial y)^2)}].$$

The zero contour can be useful for tracking source boundaries under appropriate source and data assumptions, while the normalized response helps visualize weak and strong anomalies within a common dynamic range (Miller and Singh 1994; Verduzco *et al.* 2004). It is nevertheless inappropriate to describe the TDR as depth-independent in a strict sense; its usefulness is that normalization can make boundaries of different amplitudes more conspicuous.

The analytical signal amplitude combines the three first derivatives of the field:

$$A(x,y) = \sqrt{[(\partial F/\partial x)^2 + (\partial F/\partial y)^2 + (\partial F/\partial z)^2]}.$$

For magnetic data, analytical signal maxima can locate magnetization contrasts with reduced sensitivity to the

direction of magnetization compared with the total-field anomaly itself (Nabighian 1972; Roest *et al.* 1992). The method is particularly useful for delineating source edges, although depth interpretation still depends on source geometry and amplitude behavior.

3.5 Source Parameter Imaging

Source Parameter Imaging (SPI) estimates source depth from the local wavenumber derived from the analytic signal. The method is based on idealized two-dimensional source models, including sloping contacts and dipping thin sheets (Thurston and Smith 1997). The principal strength of SPI is its ability to generate a spatially continuous depth product from gridded magnetic data. Its principal limitation is that the result is model-dependent; depth should therefore be interpreted as an estimate associated with the assumed source geometry, not as a direct observation of basement depth.

For this reason, SPI should be cross-checked against spectral centroid depth, gravity-derived depth estimates, known geology and structural boundaries. Agreement between independent estimates is more informative than a single depth map treated as ground truth.

3.6 Spectral Depth Estimation

Power-spectrum analysis provides a statistical route to estimating characteristic source depths. For an ensemble of magnetic sources, the logarithm of the radially averaged power spectrum commonly exhibits approximately linear segments whose slopes are related to source depth. The method originates in the statistical formulation of Spector and Grant (1970). In practice, the depth is obtained from the slope of the selected spectral segment under the assumptions of the adopted source ensemble and wavenumber convention; the relationship should therefore not be reduced to a universal expression of the form $\text{depth} = 1/k$.



The distinction between top depth and centroid depth is important. The shallow or top-depth component is more sensitive to the upper boundary of a source ensemble, whereas centroid depth represents a deeper characteristic level of the ensemble. Neither quantity is automatically equivalent to sediment thickness. In a sedimentary basin, they are best interpreted as proxies for basement or magnetic-source configuration and then compared with gravity-derived depths.

3.7 Multiscale Integration

The proposed framework organizes interpretation at three spatial scales. At the regional scale, long-wavelength gravity and magnetic products define basin geometry, major basement provinces and broad structural grain. At the intermediate scale, continuation products, regional-residual fields and spectral estimates constrain sub-basin configuration and depth variation. At the local scale, derivatives and analytical-

signal products delineate contacts, faults, intrusive margins and lineament intersections. This hierarchy follows the principle that geological features of different characteristic dimensions are preferentially expressed at different spatial wavelengths.

The operational relationships among these scales, their principal products and the corresponding integration tests are summarized in Table 2. At the regional scale, Bouguer gravity, regional gravity and magnetic fields, and high-level upward continuation are used to assess broad basin architecture and basement provinces. The principal integration test is whether the gravity and magnetic patterns support a consistent regional geological model. Because the two methods respond to different physical properties, their anomalies need not have identical shapes or signs; instead, their spatial relationships should be evaluated in the context of the expected density and magnetization contrasts.

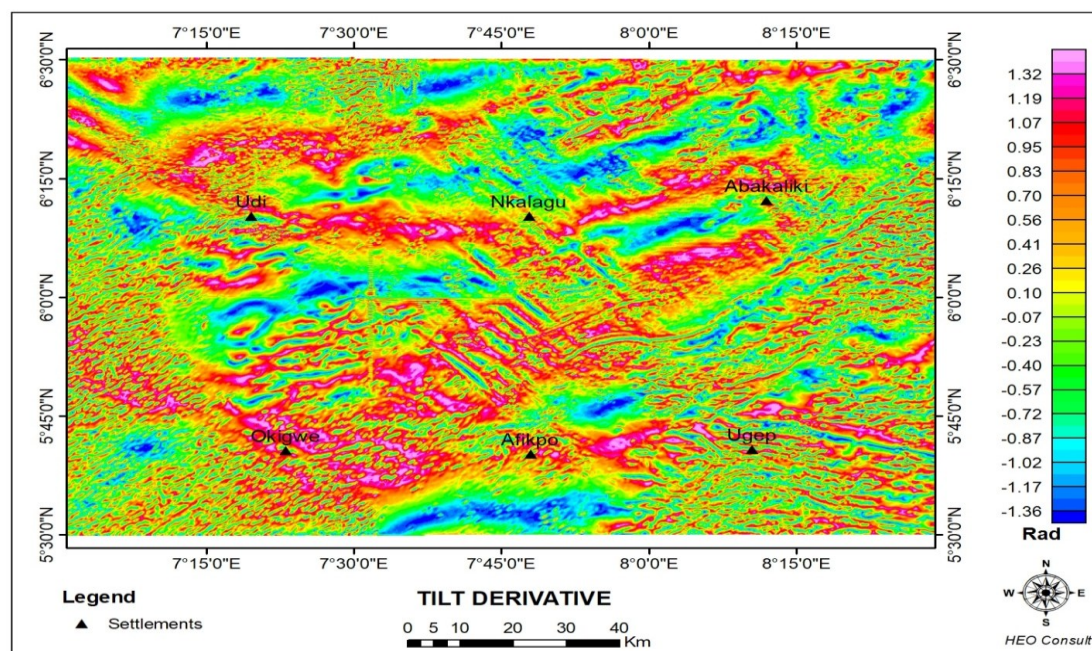


Fig. 2. Tilt derivative map of the aeromagnetic data.

At the intermediate scale, residual fields, moderate upward continuation, spectral depth estimates and Source Parameter

Imaging (SPI) are used to investigate sub-basin geometry, depth variations and structural corridors. Comparing



independent anomaly and depth products helps determine whether inferred depocentres and basement highs are supported by more than one interpretive method. However, the depth estimates must be interpreted according to their respective physical assumptions, since spectral centroid depths, SPI depths and gravity-derived depths may represent different source levels rather than the same geological interface.

At the local scale, the tilt derivative (TDR), horizontal-gradient analysis, analytical signal and lineament extraction are used to identify potential geological contacts, structural boundaries and intrusive margins. The recurrence of a boundary across independent derivative products increases confidence that it reflects a persistent geophysical feature rather than an artifact of a single transformation. Nevertheless, a mapped lineament cannot be classified

definitively as a fault solely because it appears on a derivative map; geological context and independent evidence are needed to establish its origin.

The integration matrix in Table 2 therefore provides a systematic means of evaluating geological interpretations across different spatial scales. Its main strength is the use of explicit integration tests rather than reliance on individual enhanced maps. Broad regional patterns establish the basin framework, intermediate-scale products constrain depth and sub-basin variations, and local-scale derivatives refine the position of potential boundaries. Interpretations that remain consistent across these scales provide a stronger basis for developing a geological model, although the final interpretation must still account for non-uniqueness, data resolution and the assumptions of each method.

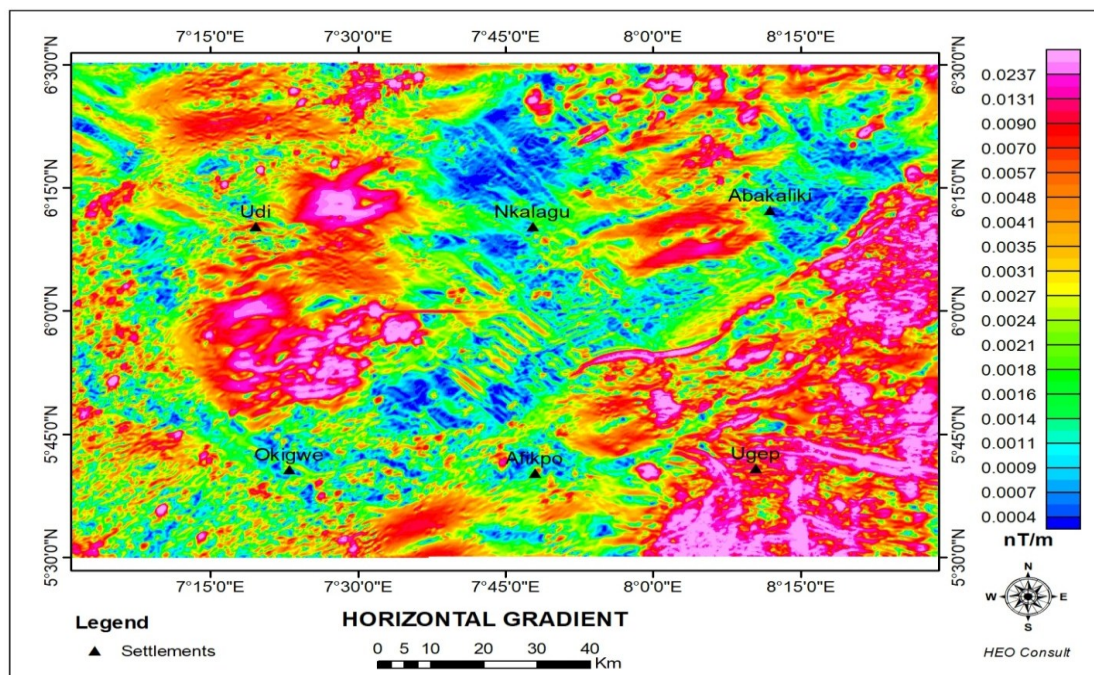


Fig. 3. Horizontal-gradient map of the aeromagnetic data.



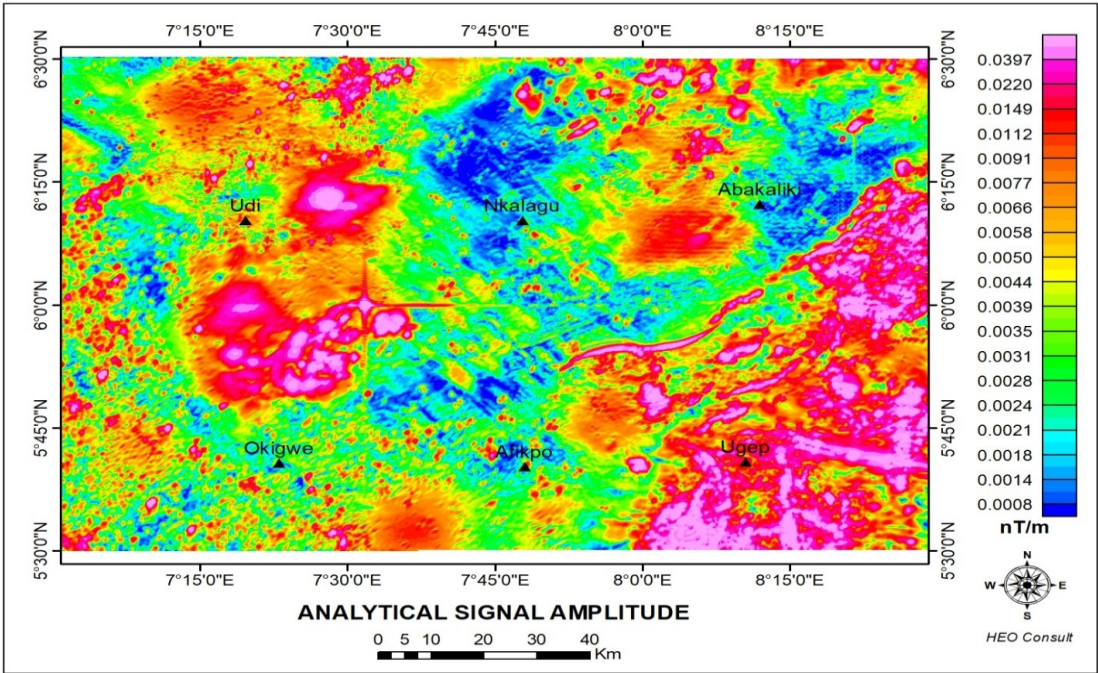


Fig. 4. Analytical-signal amplitude map of the aeromagnetic data



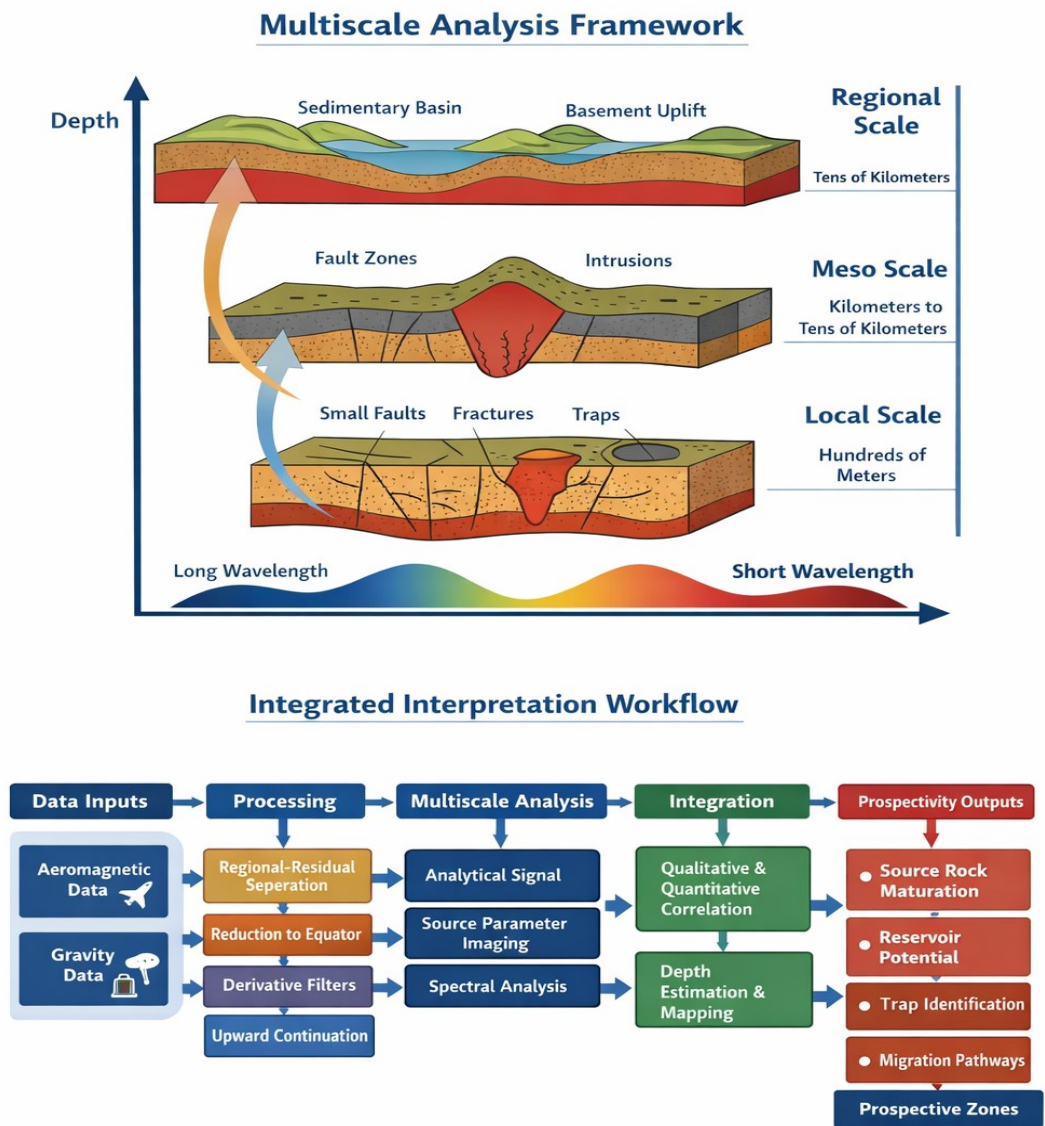


Fig. 5. Integrated interpretation workflow for multiscale gravity–magnetic analysis.

Table 2. Multiscale integration matrix used in the framework

Scale	Typical Products		Primary Information	Integration Test
Regional	Bouguer	gravity;	Basin geometry, broad basement provinces, regional structural grain	Do broad gravity and magnetic domains support a common basin architecture?
Intermediate	Residual	fields;	Sub-basin geometry, depth variation, structural corridors	Do independent depth and anomaly products locate comparable depocentres or basement highs?
	moderate continuation;	spectral depth; SPI		



Local	TDR; gradient; signal; extraction	horizontal analytical lineament	Contacts, faults, intrusive edges, fracture corridors	Do mapped boundaries recur across independent derivative products?
--------------	--	---------------------------------------	---	---

4.0 Geological Interpretation Framework for Frontier Basins

4.1 From Anomaly to Geological Boundary

Potential-field interpretation requires a clear distinction between the observed anomaly and the geological structure inferred from it. Gravity and magnetic maps represent variations in physical fields arising from subsurface density and magnetization contrasts, respectively; their geological significance must be established through systematic interpretation. The proposed framework therefore proceeds from anomaly geometry and derivative response to the persistence of features across spatial scales and, finally, assessment of their geological plausibility.

For instance, a linear gravity gradient that spatially aligns with a magnetic derivative lineament and persists across moderate upward-continuation levels may point to a major basement contact or basin-boundary structure. However, such interpretations remain provisional until alternative explanations, including lithological boundaries and overlapping sources, are thoroughly considered. Features that appear on only a single enhanced map demand extra scrutiny because they could simply reflect local sources, data noise, or processing effects. Therefore, reliable geological interpretations are achieved by evaluating the combined behavior of anomaly patterns, structural indicators, and available geological constraints rather than relying on a single data transformation.

4.2 Gravity-Magnetite Cross Validation

Gravity and magnetic observations are most useful when they are employed to investigate complementary geological properties. Gravity anomalies help constrain density variations associated with sedimentary-basin geometry, basement relief, and lithological changes,

whereas magnetic anomalies provide information on magnetized basement rocks, intrusive bodies, and magnetic contacts. Their combined interpretation can help distinguish plausible geological models, although the two fields are not expected to exhibit identical anomaly patterns.

Coincident gravity and magnetic lows may be consistent with thick sedimentary cover over a relatively deep basement surface, provided the sedimentary succession has a lower density and weaker magnetization than the underlying basement. However, this relationship is not unique because lithological changes, demagnetization, and source geometry can produce similar responses. Similarly, a gravity gradient that coincides with a magnetic lineament may indicate a basement contact or structural boundary even where the anomaly signs differ.

In this study, cross-validation is understood as the comparison of complementary evidence rather than a formal statistical validation procedure. The interpretation considers the spatial correspondence of anomaly boundaries, the orientations of structural lineaments, the consistency of depth estimates, and compatibility with the regional geological framework. Agreement between gravity and magnetic observations increases the plausibility of a proposed structure, but independent geological or geophysical evidence is required to establish its geological identity.

4.3 Structural Lineaments and Petroleum-System Relevance

Structural lineaments identified from potential-field data may represent faults, lithological contacts, intrusive margins, or other subsurface discontinuities. Their



interpretation requires consideration of spatial continuity, orientation, derivative response, relationships with adjacent anomalies, and consistency with the known geological setting. A linear feature visible on a single derivative map should not automatically be classified as a fault. In petroleum-system analysis, structural features may influence sediment accommodation, basin compartmentalization, migration pathways, and the development of structural traps. Nevertheless, the presence of a geophysical lineament does not establish that a fault is permeable, hydraulically connected, or capable of transmitting hydrocarbons. Faults may act as conduits or barriers depending on their geometry, displacement history, mineralization, and relationship with surrounding rocks.

Structural intersections and lineament corridors may therefore be prioritized for further investigation where they coincide with basin margins, significant depth transitions, or other geological indicators. Such features should be treated as exploration hypotheses requiring evaluation through geological mapping, seismic interpretation, well data, and, where appropriate, geochemical evidence. Potential-field interpretation provides a regional structural framework for exploration but does not independently establish hydrocarbon prospectivity.

4.4 Depth Integration

A major advantage of multiscale potential-field interpretation is the opportunity to compare depth estimates obtained using methods with different physical sensitivities and source assumptions. Source Parameter Imaging (SPI) can produce spatially detailed estimates of magnetic-source depth, spectral analysis provides characteristic depths for source populations, and gravity-derived methods constrain density-related interfaces and aspects of basin geometry. However, these

estimates may represent different physical boundaries and should not be averaged mechanically. The interpretation should distinguish between source-top depth, centroid depth, and other method-specific depth parameters. Magnetic centroid depth, for example, represents a characteristic depth of an ensemble of magnetic sources rather than a direct measurement of the sediment–basement interface. Likewise, a depth estimate derived from gravity data may correspond to a density interface or model-dependent source level rather than the actual top of crystalline basement.

The interpretation should distinguish between source-top depth, centroid depth, and other method-specific depth parameters. Magnetic centroid depth, for example, represents a characteristic depth of an ensemble of magnetic sources rather than a direct measurement of the sediment–basement interface. Likewise, a depth estimate derived from gravity data may correspond to a density interface or model-dependent source level rather than the actual top of crystalline basement.

Agreement between depth estimates is most informative when the methods address comparable geological interfaces and their assumptions are compatible. Systematic disagreement may reflect different source populations, lithological complexity, overlapping anomalies, or limitations of the adopted source models. Consequently, differences among depth estimates are retained as interpretive evidence and evaluated in relation to the geology and spatial patterns of the corresponding anomaly products.

4.5 Prospectivity Interpretation

For frontier hydrocarbon exploration, integrated gravity and magnetic interpretation can generate hypotheses about basin architecture, sedimentary depocentres, structural boundaries, and possible migration pathways. These observations may help prioritize areas for



subsequent investigation, particularly where the inferred structures are consistent with regional geology and independent exploration information. Nevertheless, potential-field methods cannot independently establish source-rock presence, organic richness, thermal maturity, hydrocarbon charge, reservoir quality, seal integrity, or commercial accumulation. Nor does a deep gravity or magnetic source necessarily correspond to a sufficiently thick or mature sedimentary succession. A defensible exploration workflow therefore uses potential-field interpretation to identify geological targets for further assessment using seismic, well, geological, and geochemical evidence. The integrated framework is intended to support preliminary basin characterization and exploration screening rather than provide a standalone ranking of commercial prospects.

5.0 Lower Benue Trough Case Example

5.1 Regional Magnetic Response

The results show substantial magnetic variability across the study area, consistent with heterogeneous basement composition, structural deformation and intrusive effects. The RTE and derivative products indicate a strong regional structural grain. NE–SW lineaments are prominent, with NW–SE and N–S trends occurring as subordinate orientations. The recurrence of these orientations across derivative products indicates that the observed structural fabric is not simply an artifact of one filter.

The TDR, horizontal-gradient and analytical-signal maps provide complementary views. The TDR map emphasizes linear and curvilinear boundaries and reveals dense structural zones around Udi, Nkalagu and Abakaliki. The horizontal-gradient product highlights sharp lateral changes, while the analytical signal emphasizes source boundaries and magnetic susceptibility contrasts. Taken together, these products indicate a basement

surface that is strongly segmented rather than a smooth regional interface.

A local high-resolution aeromagnetic investigation of Nkalagu and its environs likewise identified multiple lineament orientations and estimated shallow and deep magnetic-source depths (Igbokwe *et al.*, 2023). This provides a regional comparison for the structural trends described here; however, differences in survey coverage and processing mean that the correspondence should not be treated as proof that individual lineaments or source bodies are identical.

5.2 Magnetic Depth Results

The spectral analysis gives shallow magnetic-source depths of approximately 0.3–3.7 km and centroid depths of approximately 1.84–5.95 km. These are characteristic magnetic-source depths and should not be equated directly with sediment thickness. Nevertheless, their spatial distribution provides a useful proxy for variations in basement configuration when interpreted together with gravity and structural information.

The centroid-depth distribution indicates relatively shallow magnetic-source conditions around Udi, with deeper source ensembles toward Nkalagu and parts of the southern study area. The study identifies particularly deep magnetic-source conditions around Nkalagu and deeper portions of the basin toward the southern sectors. The spatial variation is consistent with differential subsidence and a highly uneven basement surface.

The SPI results provide a complementary depth image. The study reports shallow magnetic-source depths extending from very shallow zones in parts of Ugep to deeper localized zones around the major depocentres. The key methodological lesson is that SPI and spectral products should be read together: SPI supplies detailed spatial variation, whereas spectral centroid depth provides a broader statistical depth measure.

5.3 Gravity Response and Structural Boundaries

The total Bouguer gravity field in the study area ranges approximately from –23.03 to +15.85 mGal. Broad negative anomalies



occur particularly around the southern-central basin, including the Okigwe–Afikpo sector, and are interpreted in the study as expressions of lower-density sedimentary accumulations and basin depressions. Positive anomalies around Udi, Abakaliki and parts of Ugep are associated with denser or shallower basement and/or intrusive components. The interpretation is consistent with the expected density contrast between crystalline basement and sedimentary fill, but alternative lithological explanations remain possible.

The gravity horizontal-gradient and analytical-signal products sharpen the boundaries between these density domains. Strong responses around Udi and along transitions toward Okigwe and Afikpo indicate major density discontinuities. Lower-amplitude zones around Nkalagu are compatible with thicker sedimentary cover, while transition zones around the basin margins define structural slopes and potential fault-controlled boundaries.

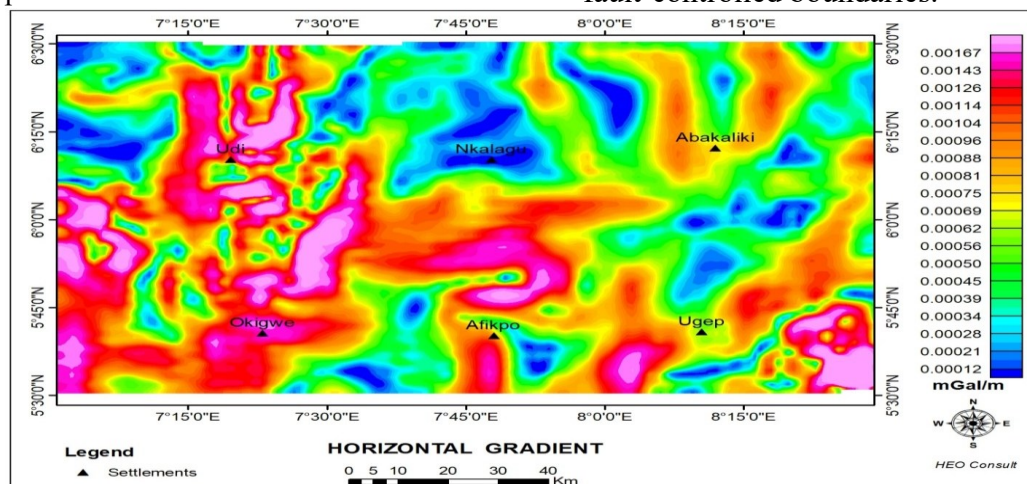


Fig. 6. Horizontal-gradient map of the gravity data

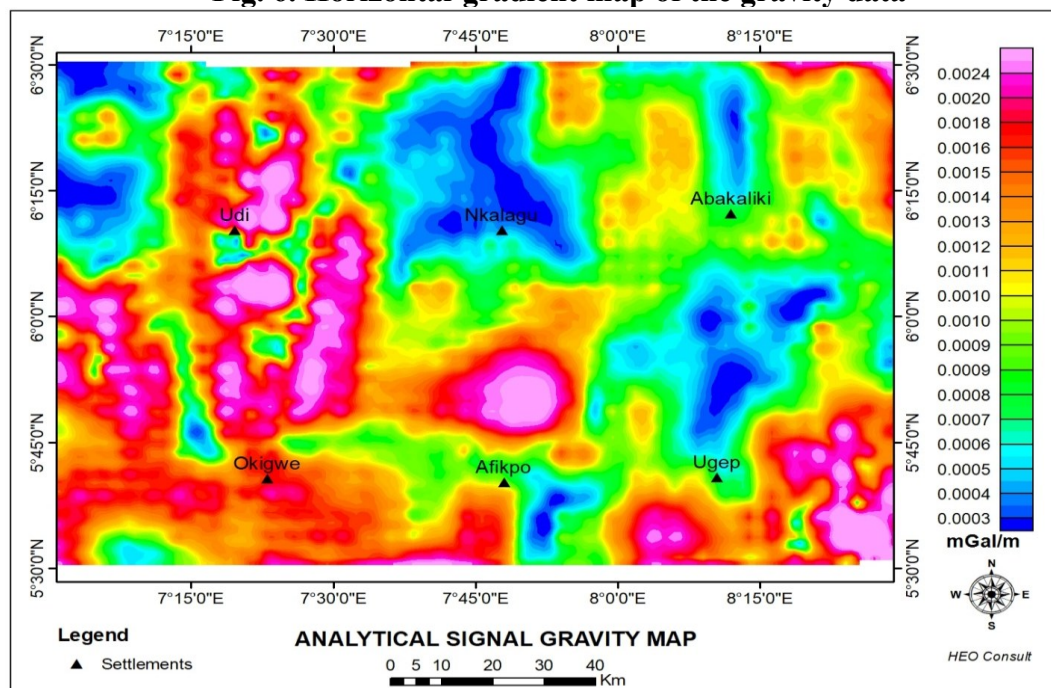


Fig. 7. Analytical-signal map of the gravity data.

5.4 Deep Gravity Sources and Basin Architecture

The gravity-derived deep-source map provides one of the clearest basin-scale

indicators in the study. Deep-source estimates range from approximately 5.0 to 6.2 km. The northern Udi–Nkalagu–Abakaliki sector generally shows shallower



deep-source conditions of about 5.0–5.4 km, whereas deeper conditions occur toward Okigwe, Afikpo and Ugep. The deepest part of the mapped gravity source surface is concentrated around Afikpo and extends toward Ugep, locally exceeding 6 km and approaching approximately 6.2 km.

The Okigwe sector is also associated with a substantial deep-source response, approximately 5.6–5.8 km in the study interpretation. These spatial changes define a basement configuration characterized by broad depressions separated by shallower basement highs. Such geometry is important for petroleum-system analysis because sediment thickness, burial history and structural compartmentalization can vary substantially over relatively short lateral distances.

The gravity Source Parameter Imaging results provide a shallower characteristic source-depth range of approximately 2.4–2.9 km. The difference between these values and the 5.0–6.2 km deep-source estimates is not necessarily contradictory: the methods respond to different source ensembles and physical interfaces. This difference is precisely why a multiscale, multiproduct approach is preferable to treating one depth map as the unique basement surface.

The case study therefore supports a descriptive interpretation in which the deepest sedimentary/basement depressions occur toward Afikpo and Ugep, with substantial depth also indicated around Okigwe and Nkalagu, while Udi and Abakaliki contain relatively shallower basement-related responses. These results define areas for further petroleum-system investigation; they do not constitute a standalone ranking of commercial prospects.

6.0 Discussion

6.1 Why Multiscale Integration Improves Interpretation

6.1 Why Multiscale Integration Improves Interpretation

The case study demonstrates three complementary benefits of multiscale integration. First, scale separation

reduces the tendency to interpret shallow anomalies as basin-scale structures. Second, derivative products transform broad anomaly fields into boundary-oriented representations that facilitate comparison with mapped geology. Third, depth estimates obtained using different methods provide a means of evaluating the consistency of the interpretation. The most reliable geological model is therefore not derived from a single map but from the integration of multiple geophysical products that can be explained by a coherent structural framework.

The principal results and their interpretive significance are summarized in Table 3. The results demonstrate that gravity and magnetic methods provide complementary information about the subsurface architecture of the Lower Benue Trough. The reduction-to-the-equator (RTE) magnetic anomaly ranges from approximately –26 to +151 nT, illustrating the spatial variation in magnetic response after accounting for low-latitude magnetic geometry. However, the anomaly range alone cannot establish source depth or uniquely identify the geological bodies responsible for the observed variations.

The estimated magnetic shallow-source depths range from approximately 0.3 to 3.7 km, whereas magnetic centroid depths range from approximately 1.84 to 5.95 km. These estimates indicate variation in the depth distribution of magnetic sources, with the centroid results providing characteristic depths for deeper source ensembles rather than the depths of a single, continuous basement surface. The difference between the two ranges reinforces the importance of distinguishing shallow magnetic sources from deeper magnetic-source distributions during geological interpretation.

The gravity results provide an independent perspective on basin architecture. Bouguer anomalies range



from approximately -23.03 to $+15.85$ mGal, reflecting lateral variations in subsurface density. Gravity source parameter imaging (SPI) yields depths of approximately 2.4–2.9 km, while the estimated deep-source depths range from approximately 5.0 to 6.2 km. These results represent different characteristic source levels and should not be interpreted as interchangeable measurements of sediment thickness or basement depth. In particular, the deeper gravity estimates may help constrain broad density interfaces and basement configuration, but their geological

significance requires corroboration from independent information.

The dominant interpreted structural orientation is NE–SW, with subordinate NW–SE and N–S trends. This pattern provides a regional structural framework for comparing gravity and magnetic lineaments and identifying areas that warrant further geological investigation. Nevertheless, interpreted lineaments should not automatically be classified as faults because potential-field gradients can also reflect lithological boundaries, intrusive bodies, and variations in physical properties.

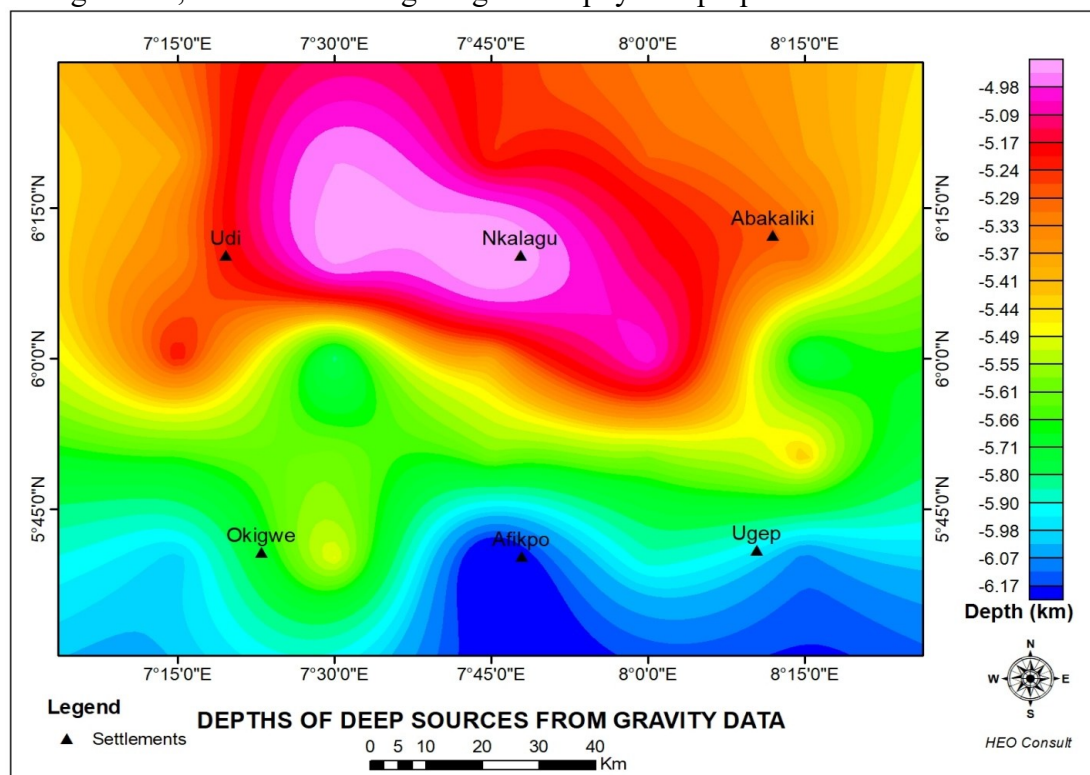


Fig. 8. Deep-source depth map derived from the gravity data.

Taken together, the results in Table 3 show why multiscale integration is more informative than relying on an individual transformation or depth-estimation technique. The combination of anomaly geometry, source-depth estimates and structural orientations enables the development of a more internally consistent interpretation. However, the differences among the estimated depths also demonstrate that each method responds to particular source

characteristics and assumptions. Consequently, confidence in the interpretation should be based on the convergence of independent observations rather than the apparent precision of any single estimate.

This principle is consistent with the broader literature on potential-field filtering and integrated geophysical interpretation. Filter operators are not merely image-enhancement devices; each embodies assumptions about spatial



frequency, source geometry or derivative behaviour. Consequently, the interpreter should document the geological

information each operator is intended to reveal and the information it may suppress (Núñez-Demarco et al., 2022).

Table 3. Summary of principal case-study results and interpretive constraints

Parameter	Range	Interpretive significance	Principal caution
RTE magnetic anomaly	Approximately -26 to +151 nT	Normalizes low-latitude magnetic geometry	Not a depth estimate; anomaly geometry remains non-unique
Magnetic shallow-source depth	Approximately 0.3–3.7 km	Spatial variation in shallow magnetic sources	Not equivalent automatically to sediment thickness
Magnetic centroid depth	Approximately 1.84–5.95 km	Characteristic depth of deeper magnetic-source ensembles	Represents an ensemble depth, not a unique basement surface
Gravity Bouguer anomaly	Approximately -23.03 to +15.85 mGal	Density variations and basin-scale architecture	Anomaly sign is not uniquely diagnostic of lithology
Gravity SPI depth	Approximately 2.4–2.9 km	Shallower characteristic density-source depth	Model-dependent; different source level from deep-source estimate
Gravity deep-source depth	Approximately 5.0–6.2 km	Broad basin/deep density interface and basement configuration	Should be validated with independent constraints
Dominant structural orientations	NE–SW; subordinate NW–SE and N–S	Regional structural grain and lineament organization	Lineaments require geological validation before being called faults

6.2 Uncertainty and Non-Uniqueness

Potential-field interpretation is intrinsically non-unique. Depth estimates are affected by source geometry, spectral-window selection, grid resolution, continuation height, noise and remanent magnetization. Gravity estimates are additionally affected by regional-field choice, Bouguer reduction assumptions and the density model. Magnetic interpretation can be affected by remanent magnetization and by the validity of reduction-to-equator assumptions. These uncertainties should

be carried through to the geological interpretation rather than hidden by a single deterministic map. An important implication is that agreement among methods should be evaluated qualitatively and quantitatively. For example, if a deep gravity source coincides with a magnetic centroid-depth maximum and a broad gravity low, the three observations provide mutually reinforcing evidence for a deep basin domain. If the products disagree, the discrepancy is itself informative and may indicate multiple source levels, intrusive



bodies, magnetization contrasts or methodological limitations.

6.3 Implications for Petroleum-System Analysis

Potential-field methods are most effective when used to establish the structural and basin-scale framework within which petroleum-system elements are evaluated. Deep depocentres can identify areas where substantial sedimentary burial may have occurred; structural gradients and lineament intersections can guide investigation of possible migration pathways and traps; basement highs can define structural compartments and basin margins. However, source-rock richness and maturity require geochemical and thermal evidence, reservoir quality requires lithological and petrophysical evidence, and seal effectiveness requires stratigraphic and structural analysis. Potential-field data should therefore guide—not replace—integrated petroleum-system evaluation.

6.4 Practical Workflow for Frontier Basins

A defensible workflow can be summarized as follows: (1) establish the geological and tectonic framework; (2) compile and quality-control gravity and magnetic data; (3) produce base anomaly fields; (4) examine multiple regional–residual and continuation scales; (5) apply RTE where appropriate for low-latitude magnetic data; (6) generate TDR, horizontal-gradient and analytical-signal products; (7) estimate characteristic depths using SPI and spectral methods; (8) compare gravity and magnetic boundaries; (9) construct an integrated structural and depth model; and (10) validate the model against geology, wells, seismic information, geochemistry or independent geophysical datasets. The sequence is deliberately iterative rather than strictly linear.

7.0 Limitations and Recommendations

The principal limitation of the case study is the absence of a fully constrained three-

dimensional inversion tied to independent seismic and well data. The study results provide multiple potential-field indicators, but these remain subject to the non-uniqueness of gravity and magnetic interpretation. A second limitation is that the depth products correspond to different source assumptions and therefore cannot be merged into one numerical basement surface without additional constraints. A third limitation is that potential-field evidence alone cannot determine petroleum charge, reservoir quality or seal integrity.

Future work should therefore incorporate constrained 2-D or 3-D inversion where independent density and susceptibility information are available, uncertainty analysis for depth estimates, and integration with seismic reflection/refraction, well logs, geochemistry and thermal data. Where appropriate, cross-gradient or other structurally coupled inversion methods can be considered, but only when the physical assumptions underlying the coupling are justified. Modern joint-inversion reviews emphasize that integration can reduce model ambiguity but can also introduce bias when inappropriate coupling assumptions are imposed (Moorkamp 2017).

8.0 Conclusions

A multiscale gravity–magnetic framework provides a practical means of investigating frontier sedimentary basins where direct subsurface control is limited. The framework is based on the complementary physical sensitivity of gravity and magnetic data and uses regional–residual separation, upward continuation, RTE, derivative filters, analytical signal, SPI and spectral analysis as mutually constraining tools rather than as isolated processing steps.

Application to the Lower Benue Trough case study demonstrates substantial spatial variability in basement-related source depths and structural expression. Results indicate shallow magnetic-source depths of approximately 0.3–3.7 km, magnetic centroid depths of approximately 1.84–5.95 km,



gravity SPI depths of approximately 2.4–2.9 km and gravity-derived deep-source depths of approximately 5.0–6.2 km. The structural interpretation is dominated by NE–SW trends with subordinate NW–SE and N–S orientations. The deepest gravity-derived source domains occur toward Afikpo and Ugep, with substantial deep-source conditions also around Okigwe and Nkalagu, whereas Udi and Abakaliki are characterized more strongly by shallower basement-related responses.

The principal methodological conclusion is that no individual potential-field transformation should be treated as a unique geological solution. Confidence is increased when anomaly geometry, derivative boundaries, spectral/depth information and independent gravity–magnetic responses converge on the same subsurface architecture. In frontier-basin exploration, such an integrated model is best used to define and prioritize hypotheses for subsequent geological, seismic, geochemical and drilling investigations rather than to claim hydrocarbon accumulation from potential-field evidence alone.

9.0 References

- Adighije, C. I. (1979). Gravity field of Benue Trough, Nigeria. *Nature*, 282, pp. 199–201. <https://doi.org/10.1038/282199a0>
- Adighije, C. I. (1981). A gravity interpretation of the Benue Trough, Nigeria. *Tectonophysics*, 79, pp. 109–128. [https://doi.org/10.1016/0040-1951\(81\)90235-3](https://doi.org/10.1016/0040-1951(81)90235-3)
- Adighije, C. I. (1981). Gravity study of Lower Benue Trough, Nigeria. *Geological Magazine*, 118, 1, pp. 59–67. <https://doi.org/10.1017/S0016756800024808>
- Benkheilil, J. (1989). The origin and evolution of the Cretaceous Benue Trough (Nigeria). *Journal of African Earth Sciences*, 8, pp. 251–282. [https://doi.org/10.1016/S0899-5362\(89\)80028-4](https://doi.org/10.1016/S0899-5362(89)80028-4)
- Blakely, R. J. (1995). *Potential Theory in Gravity and Magnetic Applications*. Cambridge University Press.
- Blakely, R. J., & Simpson, R. W. (1986). Approximating edges of source bodies from magnetic or gravity anomalies. *Geophysics*, 51, 7, pp. 1494–1498. <https://doi.org/10.1190/1.1442197>
- Burke, K., Dessauvagie, T. F. J., & Whiteman, A. J. (1971). Opening of the Gulf of Guinea and geological history of the Benue Depression and Niger Delta. *Nature*, 233, pp. 51–55.
- Cordell, L., & Grauch, V. J. S. (1985). Mapping basement magnetization zones from aeromagnetic data in the San Juan Basin, New Mexico. In W. J. Hinze (Ed.), *The Utility of Regional Gravity and Magnetic Anomaly Maps*, pp. 181–197. Society of Exploration Geophysicists.
- Cratchley, C. R., & Jones, G. P. (1965). An Interpretation of the Geology and Gravity Anomalies of the Benue Valley, Nigeria. *Geophysical Paper No. 1*. Overseas Geological Surveys.
- Grant, N. K. (1971). South Atlantic, Benue Trough, and Gulf of Guinea triple junction. *Geological Society of America Bulletin*, 82, pp. 2295–2298.
- Hinze, W. J., von Frese, R. R. B., & Saad, A. H. (2013). *Gravity and Magnetic Exploration: Principles, Practices, and Applications*. Cambridge University Press.
- Igbokwe, S. C., Agbodike, I. C., & Ejiogu, B. C. (2023). Structural and tectonic interpretation of Nkalagu and environs using high-resolution aeromagnetic data. *Austin Journal of Earth Science*, 6, 1, p. 1028. <https://doi.org/10.26420/austin.jearthsci.2023.1028>
- Jacobsen, B. H. (1987). A case for upward continuation as a standard separation filter for potential-field maps. *Geophysics*, 52, 8, pp. 1138–1148. <https://doi.org/10.1190/1.1442378>

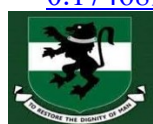


- Lowrie, W., & Fichtner, A. (2020). Fundamentals of Geophysics (3rd ed.). Cambridge University Press. <https://doi.org/10.1017/9781108685917>
- Miller, H. G., & Singh, V. (1994). Potential field tilt—a new concept for location of potential field sources. *Journal of Applied Geophysics*, 32, pp. 213–217. [https://doi.org/10.1016/0926-9851\(94\)90022-1](https://doi.org/10.1016/0926-9851(94)90022-1)
- Moorkamp, M. (2017). Integrating electromagnetic data with other geophysical observations for enhanced imaging of the Earth: A tutorial and review. *Surveys in Geophysics*, 38, pp. 935–962. <https://doi.org/10.1007/s10712-017-9413-7>
- Nabighian, M. N. (1972). The analytic signal of two-dimensional magnetic bodies with polygonal cross-section: Its properties and use for automated anomaly interpretation. *Geophysics*, 37, 3, pp. 507–517. <https://doi.org/10.1190/1.1440276>
- Núñez-Demarco, P., Bonilla, A., Sánchez-Bettucci, L., & Prezzi, C. (2022). Potential-field filters for gravity and magnetic interpretation: A review. *Surveys in Geophysics*, 43, pp. 603–664. <https://doi.org/10.1007/s10712-022-09752-x>
- Nwajide, C. S. (2022). *Geology of Nigeria's Sedimentary Basins* (2nd ed.). Albishara Educational Publications.
- Ofoegbu, C. O. (1985). A review of the geology of the Benue Trough, Nigeria. *Journal of African Earth Sciences*, 3, pp. 283–291. [https://doi.org/10.1016/0899-5362\(85\)90001-6](https://doi.org/10.1016/0899-5362(85)90001-6)
- Osinowo, O. O., & Taiwo, T. O. (2020). Analysis of high-resolution aeromagnetic (HRAM) data of Lower Benue Trough, Southeastern Nigeria, for hydrocarbon potential evaluation. *NRIAG Journal of Astronomy & Geophysics*, 9, 1, pp. 350–361. <https://doi.org/10.1080/20909977.2020.1746890>
- Osinowo, O. O., Akanji, A. O., Sanuade, O. A., & Esho, O. O. (2023). Hydrocarbon potential evaluation of Middle Benue Basin, East Central Nigeria using high-resolution aeromagnetic data. *Results in Geophysical Sciences*, 14, Article 100058. <https://doi.org/10.1016/j.ringps.2023.100058>
- Phillips, J. D., Hansen, R. O., & Blakely, R. J. (2007). The use of curvature in potential-field interpretation. *Exploration Geophysics*, 38, 2, pp. 111–119. <https://doi.org/10.1071/EG07014>
- Roest, W. R., Verhoef, J., & Pilkington, M. (1992). Magnetic interpretation using the 3-D analytic signal. *Geophysics*, 57, 1, pp. 116–125. <https://doi.org/10.1190/1.1443174>
- Saltus, R. W., & Blakely, R. J. (2011). Unique geologic insights from “non-unique” gravity and magnetic interpretation. *GSA Today*, 21, 12, pp. 4–11. <https://doi.org/10.1130/GSATG136A.1>
- Spector, A., & Grant, F. S. (1970). Statistical models for interpreting aeromagnetic data. *Geophysics*, 35, 2, pp. 293–302. <https://doi.org/10.1190/1.1440092>
- Thurston, J. B., & Smith, R. S. (1997). Automatic conversion of magnetic data to depth, dip, and susceptibility contrast using the SPI method. *Geophysics*, 62, 3, pp. 807–813. <https://doi.org/10.1190/1.1444190>
- Verduzco, B., Fairhead, J. D., Green, C. M., & MacKenzie, C. (2004). New insights into magnetic derivatives for structural mapping. *The Leading Edge*, 23, 2, pp. 116–119. <https://doi.org/10.1190/1.1651454>

Declarations

Funding

No external funding statement is asserted in this manuscript; the funding declaration should be completed in the publisher's submission system according



to the actual funding status of the research.

Conflict of interest

The author declares no conflict of interest related to the preparation of this manuscript.

Data availability

The case-study interpretation is based on datasets and processed products documented for this case study. Underlying NGSA and legacy/satellite gravity datasets may be subject to the access conditions of their respective custodians. The manuscript does not claim to release a new independent dataset.

Ethics approval

Not applicable.

Consent to participate

Not applicable.

Consent for publication

Not applicable.

Author contributions

Sampson Chiehiura Igbokwe: conceptualization, methodology, data interpretation, case-study synthesis, writing and revision.

AI Use Disclosure

AI-assisted tools were used for language editing and manuscript formatting. The authors are responsible for the research, data, scientific analysis, interpretations, and conclusions presented in the manuscript, and for checking the accuracy and integrity of the final submission.

