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Interpretation of High-Resolution Aeromagnetic Data over Ankpa and Its Environs, North-CentralNigeria Using Source Parameter Imaging and Euler Deconvolution Techniques

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ABSTRACT; This study presents the interpretation of high-resolution aeromagnetic data over Ankpa and its environs in north-central Nigeria, employing Source Parameter Imaging (SPI) and Euler Deconvolution techniques to characterize subsurface magnetic sources. The Total Magnetic Intensity (TMI) and Residual Magnetic Intensity (RMI) maps identify zones of shallow magnetic basement rocks and deep sedimentary covers. Depth estimates from SPI and Euler Deconvolution indicate a structurally complex basement with depths ranging from a few hundred meters to nearly 9 km. These results provide insights into fault-controlled troughs, basement uplifts, and intrusive bodies, which have implications for regional tectonics, mineral exploration, and geothermal potential. The integration of these advanced geophysical techniques enhances the understanding of the area's subsurface architecture, contributing valuable information for future geological and exploration activities.

Keywords: Aeromagnetic data, Source Parameter Imaging (SPI), Euler Deconvolution, Basement structure

I. INTRODUCTION

Aeromagnetic surveys are vital tools in regional geological and tectonic investigations, especially in sedimentary basins where direct subsurface information is limited (Salem et al., 2018). The Lower Benue Trough, a major sedimentary basin in Nigeria, hosts complex structural features resulting from multiple tectonic events, including folding, faulting, and magmatic intrusions. (Adebiyi, et al.,2023) Understanding the depth and geometry of basement rocks and related structures is essential for resource exploration High-resolution aeromagnetic data offer an improved spatial resolution that can delineate subtle magnetic anomalies related to geological features such as faults, fractures, and igneous intrusions. This study utilizes Source Parameter Imaging (SPI) and Euler Deconvolution techniques, widely recognized methods for estimating magnetic source depths, to analyze aeromagnetic data over Ankpa and its environs (Smith and Salem, 2005). The objective is to map subsurface structures, evaluate basement relief, and interpret the tectonic framework of the region, thereby providing insights relevant to mineral exploration, hydrocarbon potential, and geothermal resource assessment (Nwankwo and sunday, 2017 ; Nyabeze and Gwavava, 2018 ; Adewunmi et al., 2019).

II. LOCATION AND GEOLOGICAL SETTING OF THE STUDY AREA

The study area is located in Kogi State, Nigeria, between longitudes 7°30′E–8°00′E and latitudes 7°00′N–7°30′N (Figure 1). It lies within the Lower Benue Trough, a segment of the

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Nigerian sedimentary basin dominated by Cretaceous sedimentary rocks (Figure 2). The region's tectonic setting comprises Cretaceous to Recent sedimentary sequences overlying Neoproterozoic basement, with local influence from Jurassic Younger Granites (Akpan et al., 2016). A major mid-Santonian compressional event significantly deformed these units, resulting in folding, faulting, and uplift that shaped the present structural framework (Obaje, 2009).

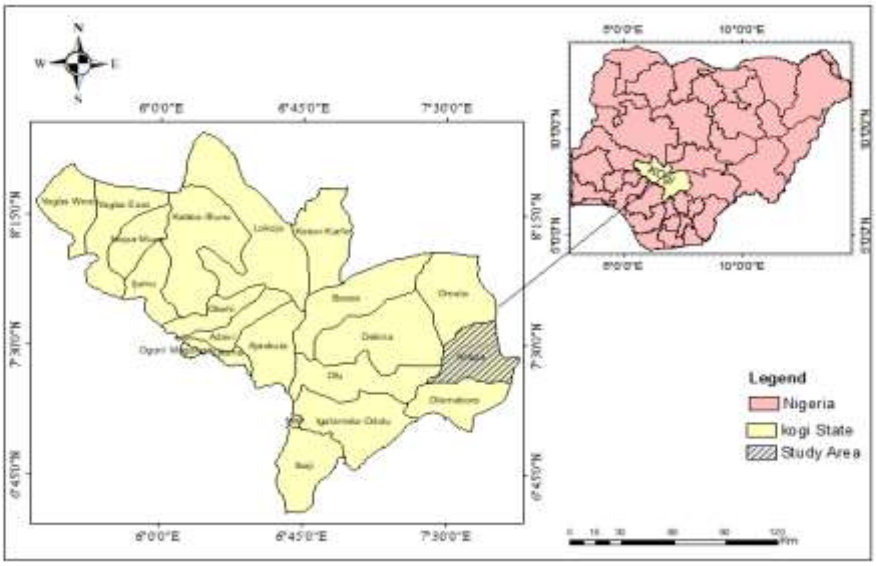

Figure 1: Map of Kogi State showing the Study Area

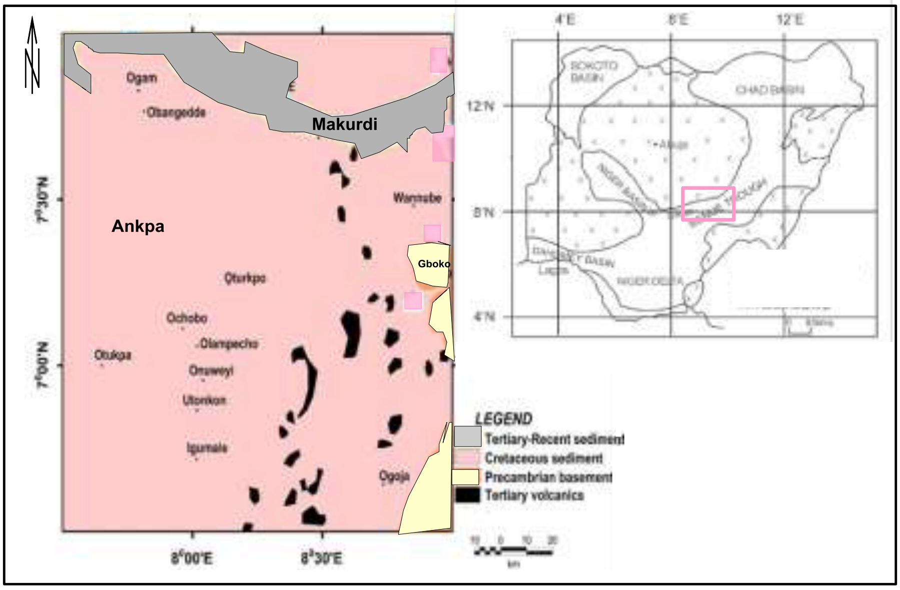

Figure 2: Geological map of the study area (Modified after Mukaila et al., 2018)

III. MATERIAL AND METHODS

3.1 MAGNETIC DATA ACQUISITION

The high-resolution aeromagnetic data used in this study, covering Ankpa and its environs (Sheet 269), were obtained from the Nigerian Geological Survey Agency (NGSA). Acquired between 2021 and 2023 by Xcalibur Airborne Geophysics under NGSA's geoscientific data upgrade initiative, the survey employed 150 m flight line spacing, 1,500 m tie-line spacing, and a flight altitude of 50 m. These specifications provide enhanced spatial resolution compared to earlier datasets. Pre-processing included corrections for instrumental noise, diurnal variations, and removal

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of the International Geomagnetic Reference Field (IGRF), ensuring data quality for detailed structural analysis.

3.2 AEROMAGNETIC DATA ANALYSIS

The aeromagnetic data, supplied in GEOSOFT grid format and projected to the WGS84/UTM Zone 32N coordinate system, were extracted and processed using GEOSOFT Oasis Montaj 8.4. Various filtering and enhancement techniques embedded in the software were applied to improve anomaly resolution and facilitate accurate structural interpretation. The Total Magnetic Intensity (TMI) data were reduced to the magnetic equator to correct for equatorial distortions and to center anomalies symmetrically over their causative sources, appropriate for the study area's low-latitude location. Depth estimation was carried out using both Euler Deconvolution and Source Parameter Imaging (SPI), which utilize the horizontal and vertical gradients of the magnetic field to determine the depth and configuration of magnetic sources. These methods provided valuable insights into subsurface structures, including faults, contacts, and intrusions, which are important for geological and geophysical interpretation

IV. RESULT AND DISCUSSION

4.1 TOTAL MAGNETIC FIELD INTENSITY

The total magnetic intensity (TMI) map of the study areashows the magnetic intensity distribution over the area characterized by low and high magnetic anomalies ranging from -179.1 nTto 75.7 nT (Figure 3).The high magnetic intensity zones, denoted by red to pink colorations, are predominantly located in the northwestern, central, and northeastern portions of the map, around regions such as Ikebe, Eheche, Ameji, Ogeni, and Okpto, which may likely correspond to shallow magnetic basement rocks or mafic intrusions, which are characteristic of the Lower Benue Trough's magmatic and tectonic history.Conversely, lower TMI values, marked by green to deep blue colurs, dominate the southern portion of the study area, particularly around Aidogodo, Okpoga, and Ojapo. These areas may indicate the presence of thicker sedimentary cover or deeply buried non-magnetic basement complexes.

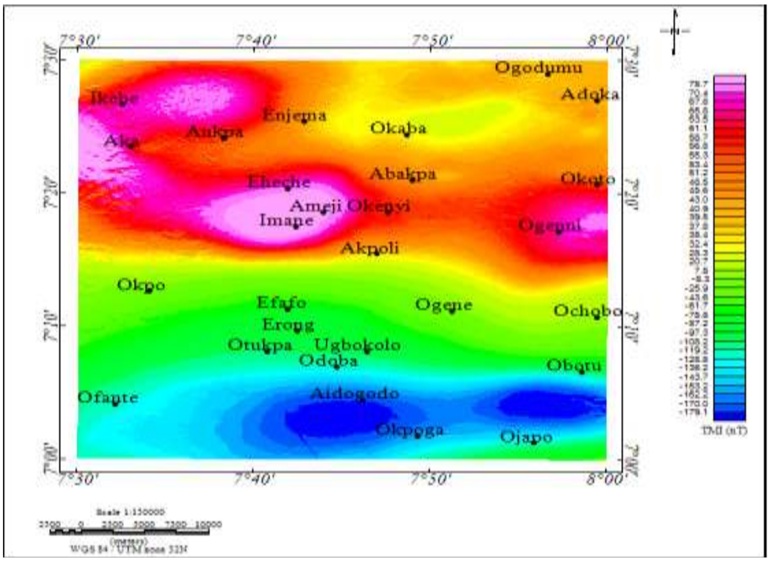

Figure 3: Total magnetic field intensity map of the Study Area

4.2 RESIDUAL MAGNETIC FIELD INTENSITY

Figure 4 shows the Residual Magnetic Intensity (RMI) map of the study area within the Lower Benue Trough, with field values ranging from -89.5 nT to 79.0 nT, as indicated by the colour legend bar. This map presents refined magnetic signatures that highlight near-surface geological features after the removal of the regional magnetic field. High residual magnetic anomalies are observed around Imane, Akpoli, Ogenni, and Okoto, which are zones associated with shallow-seated, magnetically susceptible bodies. Low residual magnetic values are concentrated in the southern and southeastern parts of the area, particularly near Aidogodo, Okpoga, and Ojapo.

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These zones likely correspond to deeper basement surfaces or thicker sedimentary cover, potentially indicating basin structures or depressions.

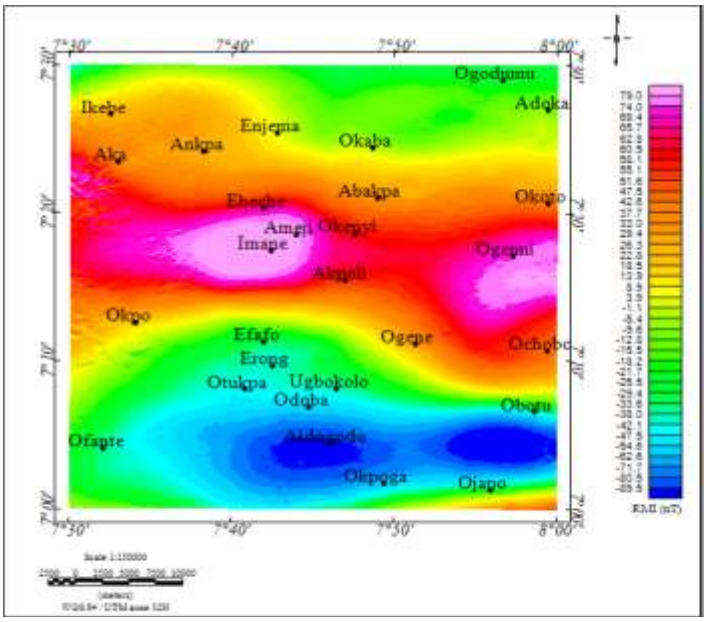

Figure 4: Residual magnetic field intensity map of the Study Area

4.3 REDUCTION TO EQUATOR

The residual magnetic intensity data was reduced to magnetic equator (RTE) to correct for the effect of latitude and realign the anomalies in order to have their peaks symmetrically centered over their corresponding sources(Ojo and Osazuwa, 2021). The RTE map (figure 5) reveals prominent high magnetic anomalies around Imane, Akpoli, Abakpa, Ogenni, and Okoto, suggesting the presence of magnetically susceptible, shallow-seated intrusions or structural features such as faults and fractures that may serve as conduits for geothermal fluids. These zones represent favorable targets for geothermal exploration, as they may correspond to heat sources or fluid pathways.The low valuesobserved in the southern parts of the area, notably around Aidogodo, Okpoga, and Ojapomay indicate deeper basement structures or thicker sedimentary cover, potentially marking geothermal reservoir zones or basin-like features that could support heat accumulation in the area.

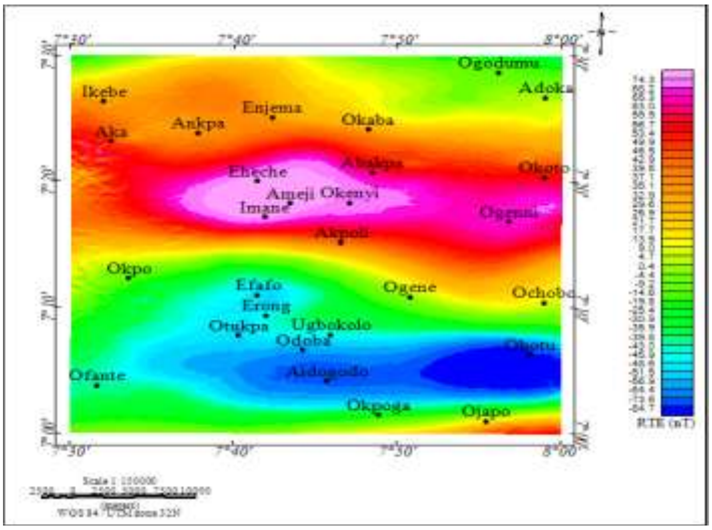

Figure 5: Reduction to magnetic equator map of the Study Area

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4.4 UPWARD CONTINUATION

The upward continuation of the aeromagnetic data at 500 m elevation was employed to suppress near-surface anomalies and enhance the response of deeper magnetic sources. The filter was applied on the RTE data to accentuate the response from the basement rocks (Ayodeji and Dare, 2015). The resulting map (Figure 6) delineates broad magnetic anomalies that reflect deep-seated features. High magnetic intensity zones, observed around Ankpa, Abakpa, Okaba, and Ogenni, are interpreted as regions underlain by magnetically responsive basement highs or possibly deep-seated igneous intrusions**.** These features likely represent uplifted basement blocks or intracrustal bodies associated with the extensional tectonics that shaped the Lower Benue Trough. However**,** low magnetic intensity zones, particularly around Aidogodo, Okpoga, Ojapo, and Ofante, suggest areas ofthicker sedimentary cover or magnetically less responsive basement, potentially indicating basement depressions or graben-like structures

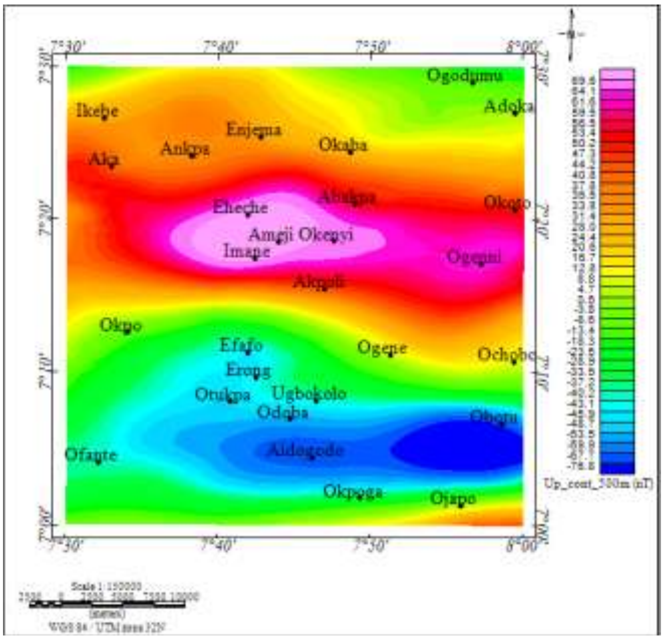

Figure 6: Upward continuation (500m) map of the Study Area

4.5 Source parameter imaging

Depth estimations of magnetic sources were obtained by applying the Source Parameter Imaging (SPI) technique to the upward-continued RTE magnetic data of the study area, using GEOSOFT Oasis Montaj software (Ojo et al., 2025). The estimated depths range from approximately 755.7 m to 7976.4 m (Figure 7), indicating significant basement relief beneath the sedimentary cover. Shallow depths (≤ 2000 m), represented by blue to green shades, are observed around Okpo, Ojapo, Ofante, and Aidogodo, suggesting zones of basement uplift or shallow magnetic sources. In contrast, deeper sources (> 5000 m), indicated by pink to red hues, dominate the central and northern sectors near Akpoli, Abakpa, Ameji, and Okenyi, implying deep-seated basement depressions or fault-controlled troughs. These depth values were used to generate a basement topography map of the study area using Surfer 9 software, which reveals the undulating nature of the basement surface. The surface plot of the SPI depths (Figure 8) illustrates variations in the depth to magnetic source rocks, with valleys indicating zones where the sedimentary cover is significantly thicker than in surrounding areas.

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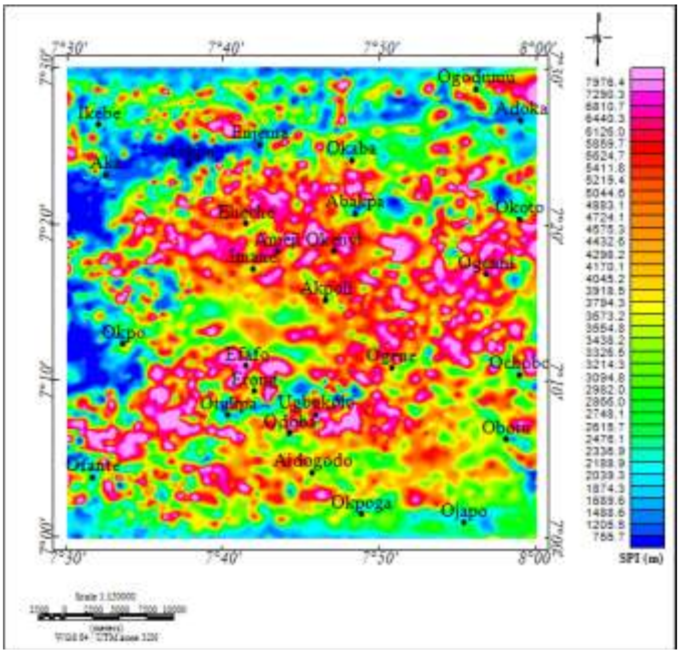

Figure 7: Source Parameter Imaging map of the Study Area

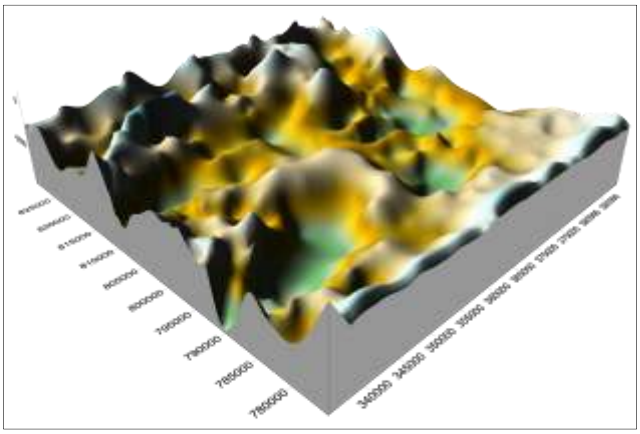

Figure 8: Surface plot of SPI depth

4.6 Euler Deconvolution

Euler deconvolution is a widely used method for estimating source depth and geometry from magnetic data, particularly effective in automated interpretation due to its minimal dependence on prior geological assumptions (Reid et al., 1990; Marwan &Yahia, 2017). In this study, it was applied to high-resolution aeromagnetic data from the Ankpa area, Lower Benue Trough, to map the depth and distribution of magnetic sources using spatial derivatives of the magnetic field. Depth estimates range from 0 to 8968 m (figure 9). Shallow sources (0–913.91 m) are mainly in the west and south, likely linked to intrusions or uplifted basement. Moderate depths (913.92–2997.76 m) dominate the central region, while deeper sources (2997.77–8968.24 m) occur in the east and central parts, particularly around Okaba, Akpoli, Ameji, Okenyi, and Adoka, suggesting deep-seated intrusions or fault-bounded troughs. The results indicate a structurally complex basement, consistent with the tectonic setting and relevant to sedimentation, mineralization, and hydrocarbon potential.

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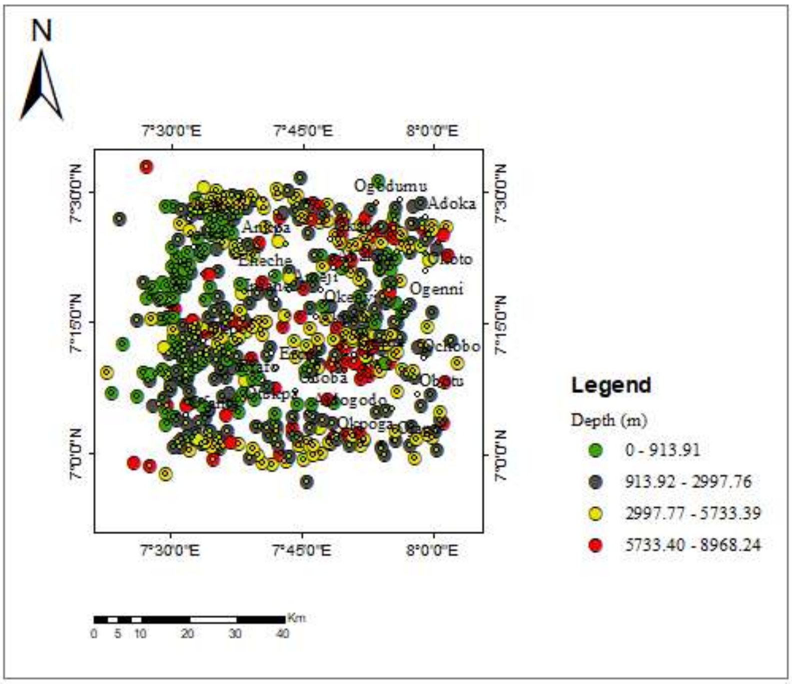

Figure 9. Euler Deconvolution Depth Plot of the Study Area

V. CONCLUSION

The interpretation of high-resolution aeromagnetic data using Source Parameter Imaging and Euler Deconvolution techniques has successfully delineated the subsurface magnetic sources within the Ankpa area of the Lower Benue Trough. The results reveal a structurally complex basement characterized by varying depths and structural relief, ranging from shallow intrusions and basement uplifts to deep fault-controlled troughs. The identified high magnetic anomaly zones correspond to shallow basement rocks and potential mafic intrusions, while low anomaly areas indicate thick sedimentary cover or basement depressions. These structural features reflect the tectonic history of the region and have significant implications for mineralization, hydrocarbon exploration, and geothermal energy prospects. The integration of these depth estimation techniques demonstrates their effectiveness in enhancing the understanding of basement morphology and structural framework, thereby providing a reliable geophysical basis for future exploration and geological studies in the Lower Benue Trough.

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