Nigerian Journal of Physics (NJP)
ISSN: 1595-0611
Volume 32(1), March 2023

Geophysical Investigation of Environmental and Engineering Features Using Aeromagnetic Data of Ogoja and Environs Southeastern Nigeria

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ABSTRACT
This study investigates the environmental and engineering implications of linear geologic features in Ogoja and its surroundings using interpreted aeromagnetic data. The regional and residual fields of the aeromagnetic data for the research region were separated using polynomials fitting techniques for first to fourth order. To trace and find the contact linear geologic structures within the study area, high resolution filters such as horizontal derivative (HD), first vertical derivative (FVD), and second vertical derivative (SVD) were used in Edge enhancement filtering for best fit residual anomaly. The depth to anomalous magnetic sources was estimated using the conventional Euler deconvolution approach. According to the findings, the research area is distinguished by near-surface lineaments that occur at maximum depths of 2000 m. Major trends could be seen in the NE-SW direction of the extracted lineaments from FVD and SVD, whereas minor trends aligned in the NW-SE direction. It is impossible to overstate the likelihood that some of the engineering and environmental issues in the research region, such as road failures, house cracks, and gully erosions, may be related to these near-surface geological phenomena.

Keywords:
Aeromagnetism,
Ogoja,
Euler Deconvolution,
Lineaments,
Edge Enhancement.

INTRODUCTION

From the reconnaissance survey carried out at the study sites, the unexplainable causes of failures of engineering structures which include roads, buildings and sometimes washing away of top soil led to this research. In order to understand subsurface and near-surface features which have environmental effect on the study area, geophysical investigation was carried out using aeromagnetic data. Subsurface structures which could contribute to the environmental and engineering challenges faced were also x-rayed. Thickness of different layers and their accompanying attributes were also examined. Since sedimentary surface of the study area is underlained by basement rock (Nganje et al, 2017), it is crucial to carry out this study to evaluate the possible effect the basement rock and associated activities can cause on the surface of the environment. The choice of the technique employed in this research was motivated because of its speedy and environmentally friendly nature as no direct contact is established with the earth in carrying out this investigation.

In this investigation, Aeromagnetism was used to measure the earth's magnetic field using flying devices within Ogoja and its surroundings. Prior to this study, Ground magnetic and gravitational surveys were used to identify the various geological features in the study area. However, some of these investigations lacked detailed information on the effect of geological features on the study environment because little effort has been made to establish the connection between these features observed and their effects (Ekwok, 2019).

In order to better comprehend the primary subsurface structures and establish their relationship with surface structural expressions within the study area, this research is focused on processing, analyzing, and interpreting aeromagnetic data from Ogoja. In this investigation, the presence of magnetic units, structures, and models of subsurface structures was noted. Aeromagnetic data collected over the region was used to carry out a complete geological interpretation of the features of Ogoja in relation to the surrounding environment and engineering structures.

Study Area

The Oban Massif and the southern segments of the Bamenda Massif, which envelop the locales of Ogoja and Obudu, are where the storm cellar complex in southeast Nigeria is concentrated. The presence of migmatitic gneisses, which are much of the time intruded by granitoid rocks, shows that the cellar complex in these locales is like those in different segments of the Nigerian cellar complex. Between the West African craton, the Congo craton, and south of the Tuareg safeguard is where the Nigerian cellar mind boggling, a part of the Skillet African versatile belt, is found. Different pre-Cambrian thermotectonic occasions that were joined by progressive provincial transformation made it be mutilated. The storm cellar rocks bear unmistakable engravings from each thermotectonic occasion. The Skillet African occasion, in any case, was broad to such an extent that it obliterated a large portion of the earlier occasions' structures, leaving just their remnants (McCurry, 1971a; Rahaman, 1976; Award, 1978; Ekwueme, 1987, 1994). Rather than the former occasions, for example, the early part of the broad Container African occasion pattern, which produced structures that were ENE-WSW, E-W, and NW-SE, this inescapable occasion pattern ordinarily made structures that were N-S to NE-SW (McCurry, 1971ab; Award, 1978; Ekwueme, 1987). Studies about Ogoja and its surroundings are scarce. In order to explain how the geology of Ogoja influences both the environment and engineering structures, this study will provide a full analysis of on it. Map of Ogoja's geology and surroundings is shown in Figure 1.

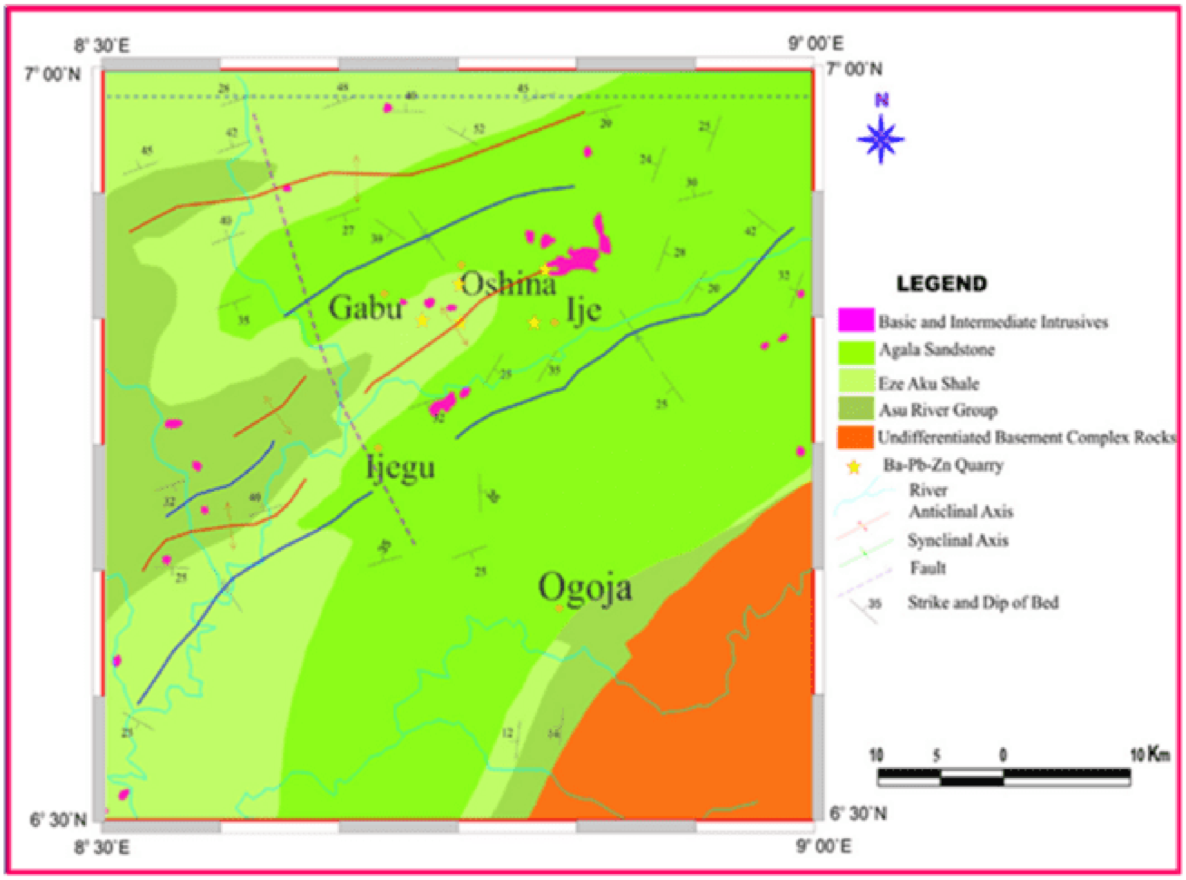

Figure 1: Geological Map of Ogoja town, in Cross River State Southern Nigeria (Ekwok, 2019).

MATERIALS AND METHODS

The data used for this research contains sixteen sheets of aeromagnetic dataset acquired by Fugro over Ogoja and environs. These data were recorded for magnetic measurements at an interval of 0.1. Having tie line separation of 200m, 80m territory clearance and 500m line of flight separation which is at 90^0 to the principal geologic leanings within the area lying in the NW – SE direction, the survey aircraft was therefore flown in the NE-SW direction.

The total magnetic intensity map (TMI) was created via the aid of Oasis Montaj software by combining the aeromagnetic data sheets that span the region into a single database. The flight route of the aircraft was also captured on video, which was later utilized to detect magnetic effects from man-made sources and to check navigation. Time-based disparities observed within the Earth's field during the survey were correctly assessed in order to create reliable magnetic anomaly maps. Magnetic surveys were avoided during strong magnetic storms, which seldom happen. Normal changes during a day commonly referred to as diurnal drift, are just few tens of the temporal changes, while changes in hundreds and thousands can take place within some of magnetic storms. Temporal changes observed while carrying out field measurements at the stations were corrected by presuming a change which is linear occurring between the field and repeated base station measurements. Diurnal drift correction was achieved by repeatedly measuring a base station. At fixed base sites, magnetometers with continuous recording were also utilized to keep track of the temporal variations. The field data were adjusted by subtracting the variances at the base site because time was precisely recorded at the field and base site. After all necessary modifications had been done; the contour maps or individual profiles from the magnetic survey data were shown. Field observations and maps of these traits were frequently used to identify anomalies brought on by cultural objects like bridges, pipelines, and railroads.

RESULTS AND DISCUSSION

Analysis of the Total magnetic Intensity of the study area

The research area's total magnetic intensity map is shown in Figure 2. The chart displays fluctuations in magnetic anomalies caused by sources with both short and long wavelengths. The range of the overall magnetic field intensity is -85.1 to 114.7nT. High magnetic anomalies (red to pink) predominate the study area's northern and southern regions, whereas low magnetic anomaly signals are present in the study area's center region (green to blue). The anomalies show the different susceptibilities of the sedimentary and foundation rocks beneath the studied area. Areas with high magnetic anomalies are typical of sedimentary rocks with high magnetite content underlain by crystalline basement rocks, while zones with low magnetic anomalies are indicative of sedimentary rocks with low magnetite content. Points of magnetic high are visible in the northern portion of the research region. Granitic rocks may have intruded into the sedimentary strata of the Agala Sandstone, leading to the high anomaly values up to 114.7nT and weakness of the sedimentary portion of the area due to intrusion. When compared to the geological map of the research area, the high magnetic signal to the southeast of the area correlates with the undifferentiated Basement Complex rocks.

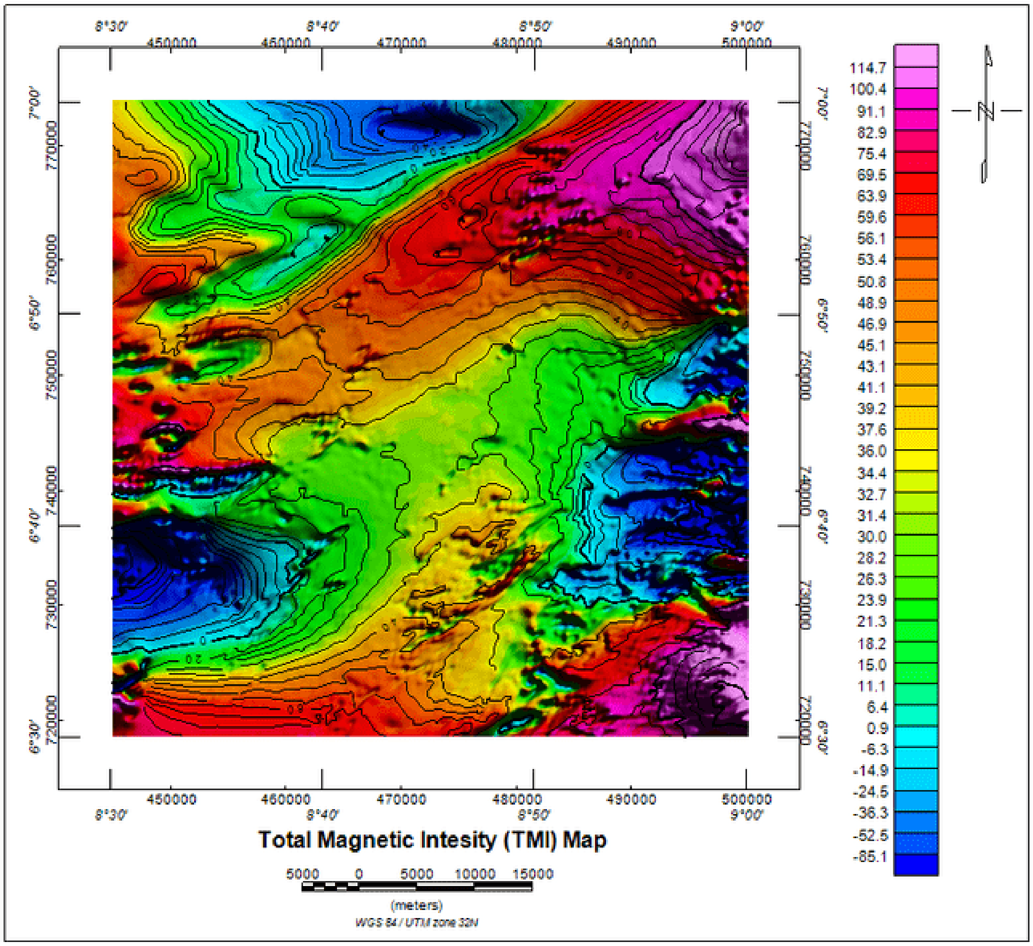

Figure 2: Total Magnetic Field Intensity as a colour shaded Contour Map of the Study area

Regional Anomaly Map Analysis

The regional and residual maps were created using the polynomial separation approach up to the fourth degree. This approach is based on the polynomial breakdown series and the analytical least squares method. The mathematical surface that best fits the magnetic field within a certain range is determined using the least-squares method (Gupta, 1983; Murthy and Krisshnamacharyulu, 1990; Nguimbous-Kouoh, et al., 2017). The surface is expressed to be the regional anomaly while residual anomaly was gotten by deducting the local magnetic field from the magnetic field that was actually observed, regional surface being normally a two-dimensional polynomial. The intricacy of the geology in the research area determined how these polynomials were ordered. Figures 3 and 4 show the first and fourth order polynomial surfaces of the regional anomaly discovered in this research. The impacts of long wavelength (low frequency) discontinuities are depicted in the regional anomaly maps. The current relationship between the mantle and the earth's crust or the shape of the base or the lithosphere when necessary can be defined to be noise or significant signal. The map displays broad regional trends that are relevant to the research area. These patterns are moving east to west. Depending on the direction of the contour variation, the various anomalies found can either be positive or negative. While high (positive) anomalies could be platform or consolidation zones of basement rocks, low (negative) anomalies might be areas of bedrock dilatation and magmatic upwelling. This is likely caused by either a successful isostatic readjustment or the region's unstable and complex geological environment.

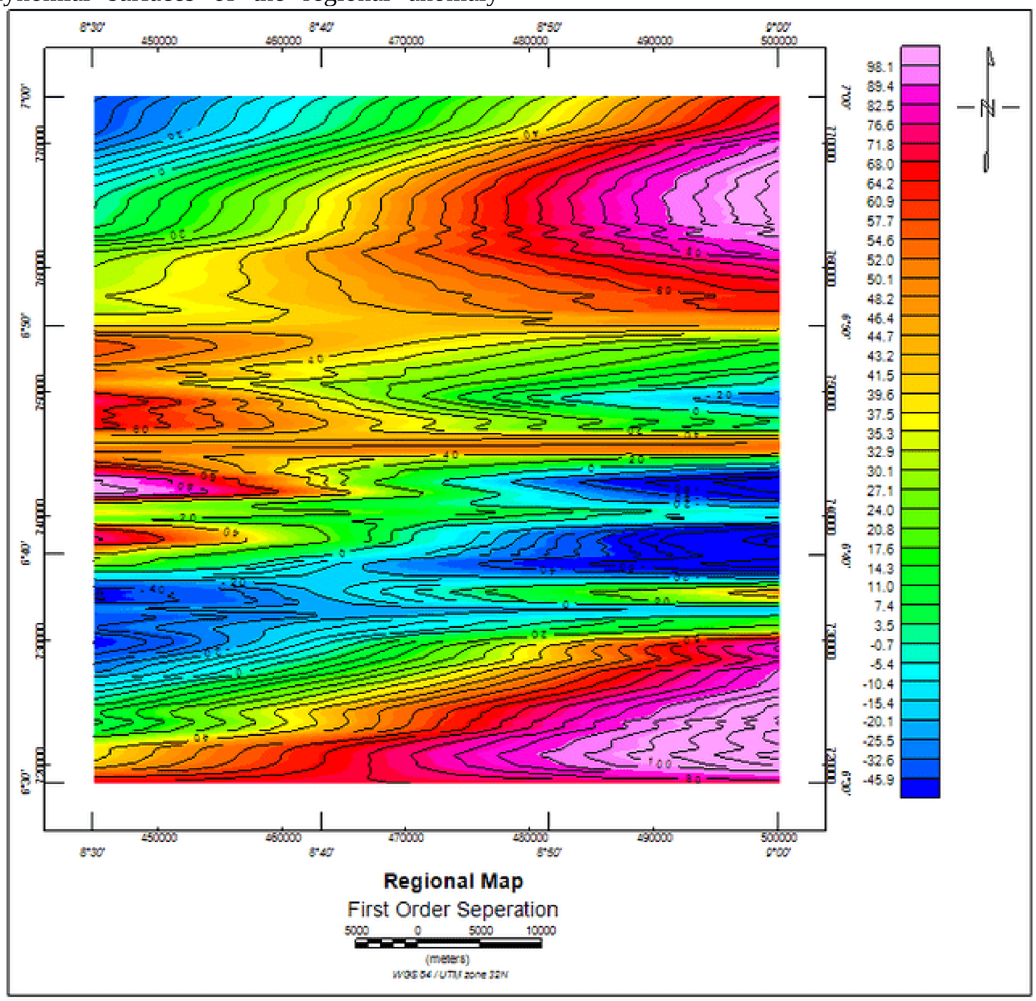

Figure 3: First Order Regional Map of the Study area

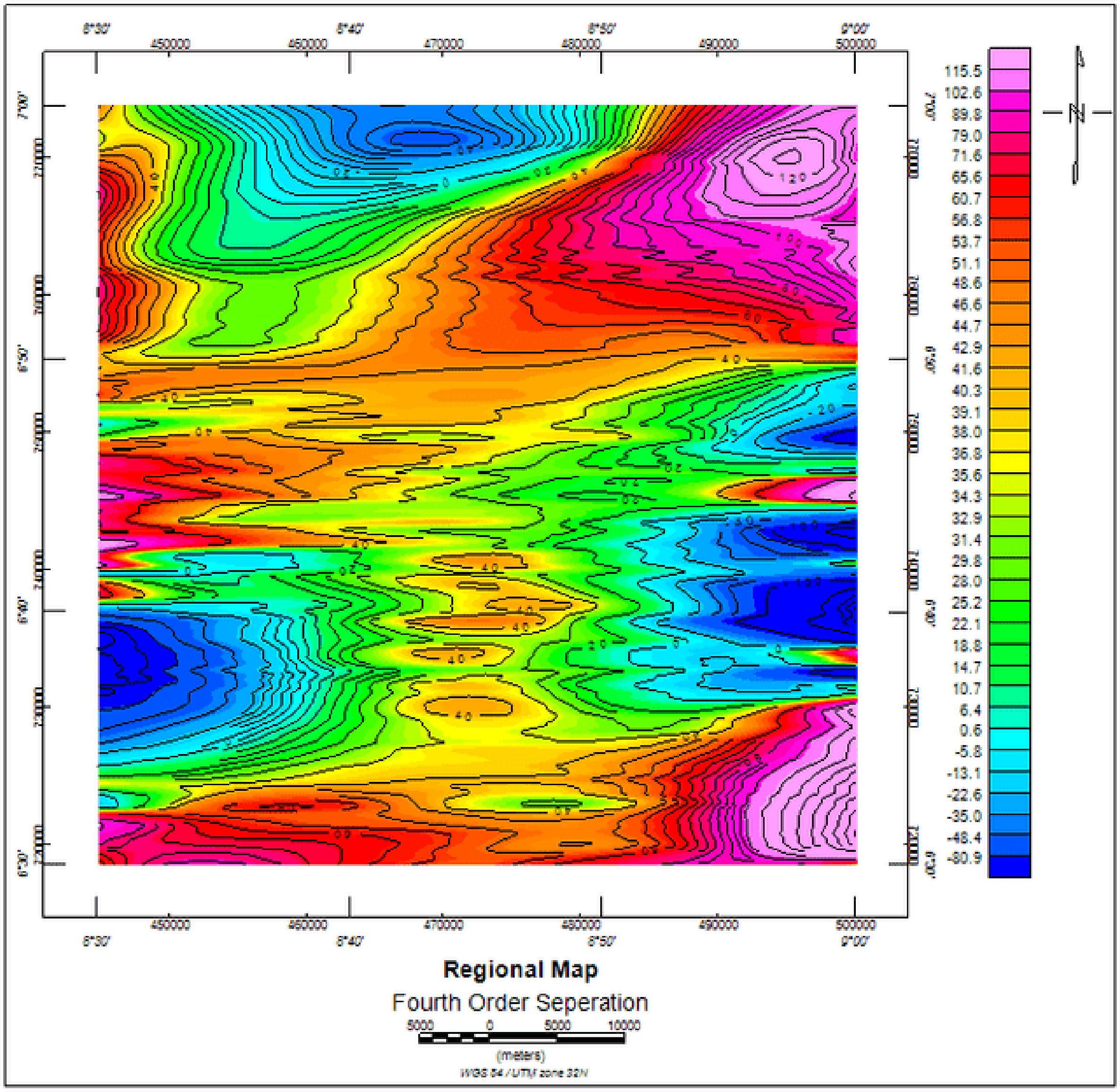

Figure 4: Fourth Order Regional Map of the Study area

The Residual Anomaly Maps Analysis

In figures 5 and 6, maps of the residual anomaly's first and fourth-order polynomial surfaces are displayed. Heterogeneities in the upper crust are mostly responsible for residual anomalies. Usually, mineralization or oil fields produce these. After removing the regional magnetic field trend, data from the residual fields were calculated. The residual maps typically exhibit both positive and negative anomalies, with the majority of these anomalies moving NE-SW and E-W. The subsurface and near surface geological characteristics in the research sites have an impact, which is represented by the residual anomaly maps. Due to magmatic intrusions into the sediments, the raising of the basement caused the high and low magnetic signals shown in the maps, which are represented as undulations (Cratchley et al., 1984; Schull, 1988; Schuster et al., 2003; Schuster et al., 2005; Nguimbous-Kouoh, 2010). The regional residual anomalies are accompanied by a sharp gradient that dips downward; this gradient can be connected to structural geological boundaries which has direct effect on the surface and surface structures.

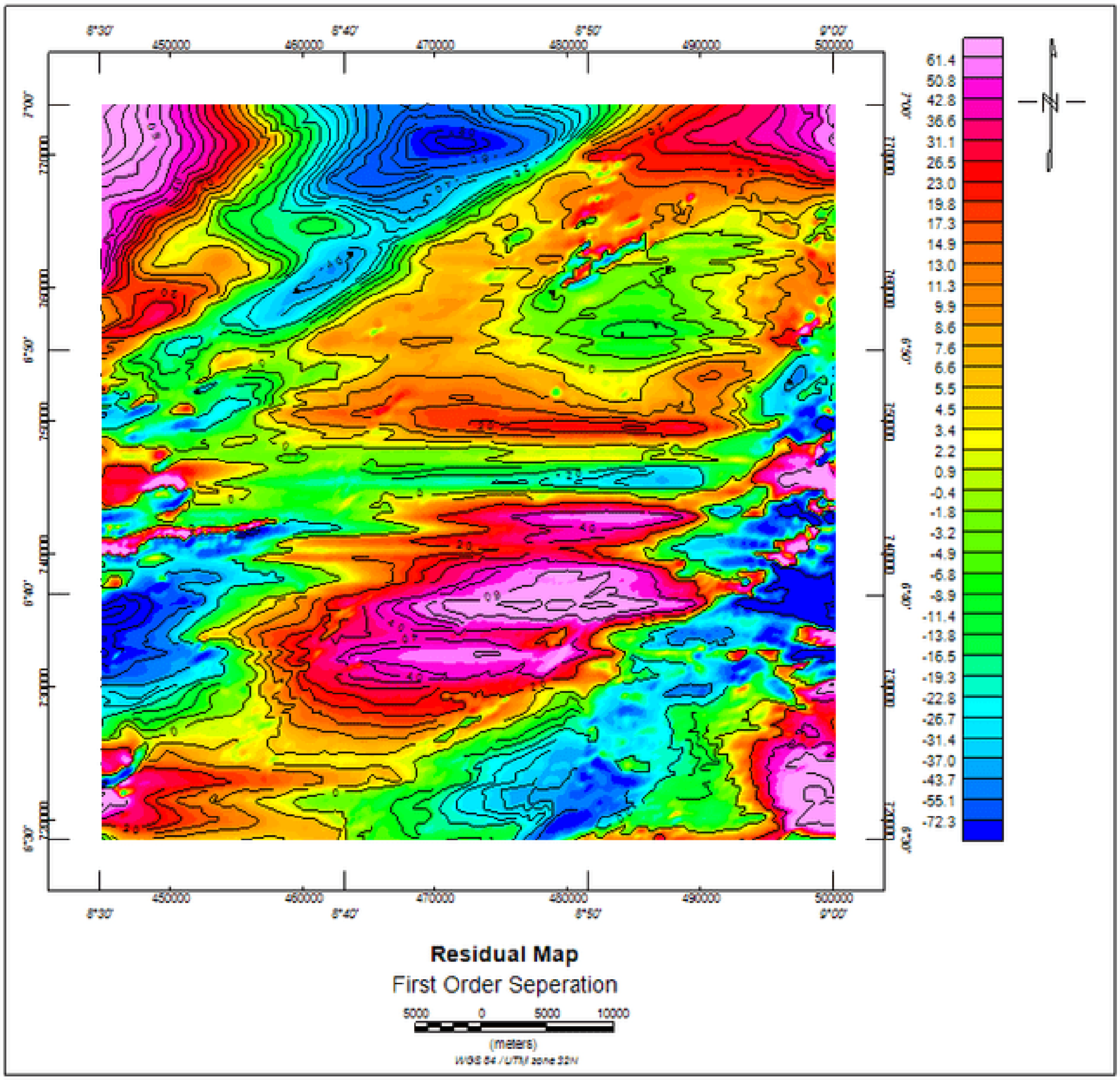

Figure 5**:** First Order Residual Map of the Study area

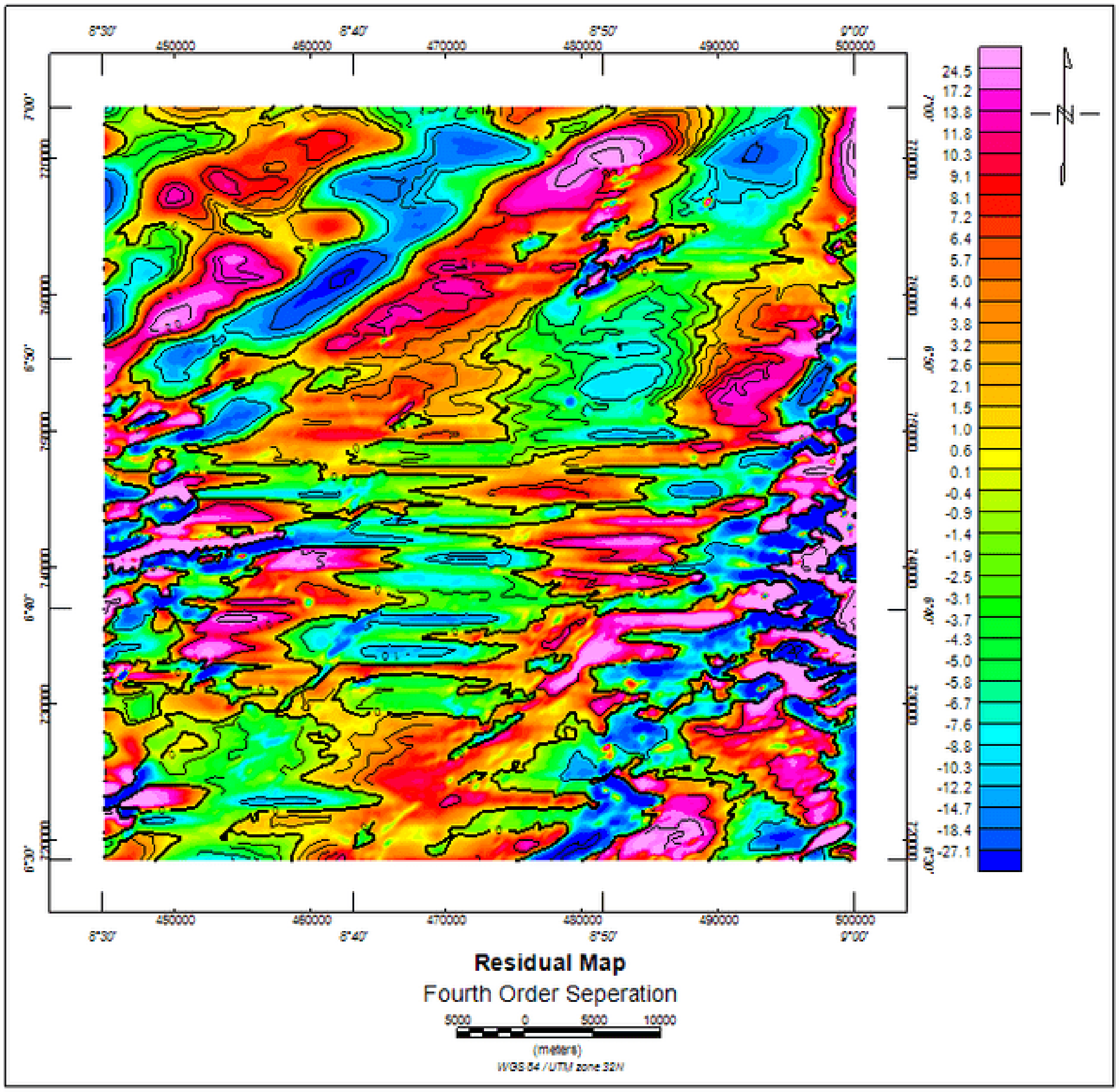

Figure 6: Fourth Order Residual Map of the Study area

Linear geological features

Horizontal derivative map

The horizontal derivative filter can be used to distinguish the contacts between different basement lithologies, which may be faults, fault boundaries, or other linear structures. The horizontal derivative (HD) map shown in Figure 7 depicts the research area's contacts for near-surface linear geologic structures. Major anomalies going NE-SW direction are shown on the map.

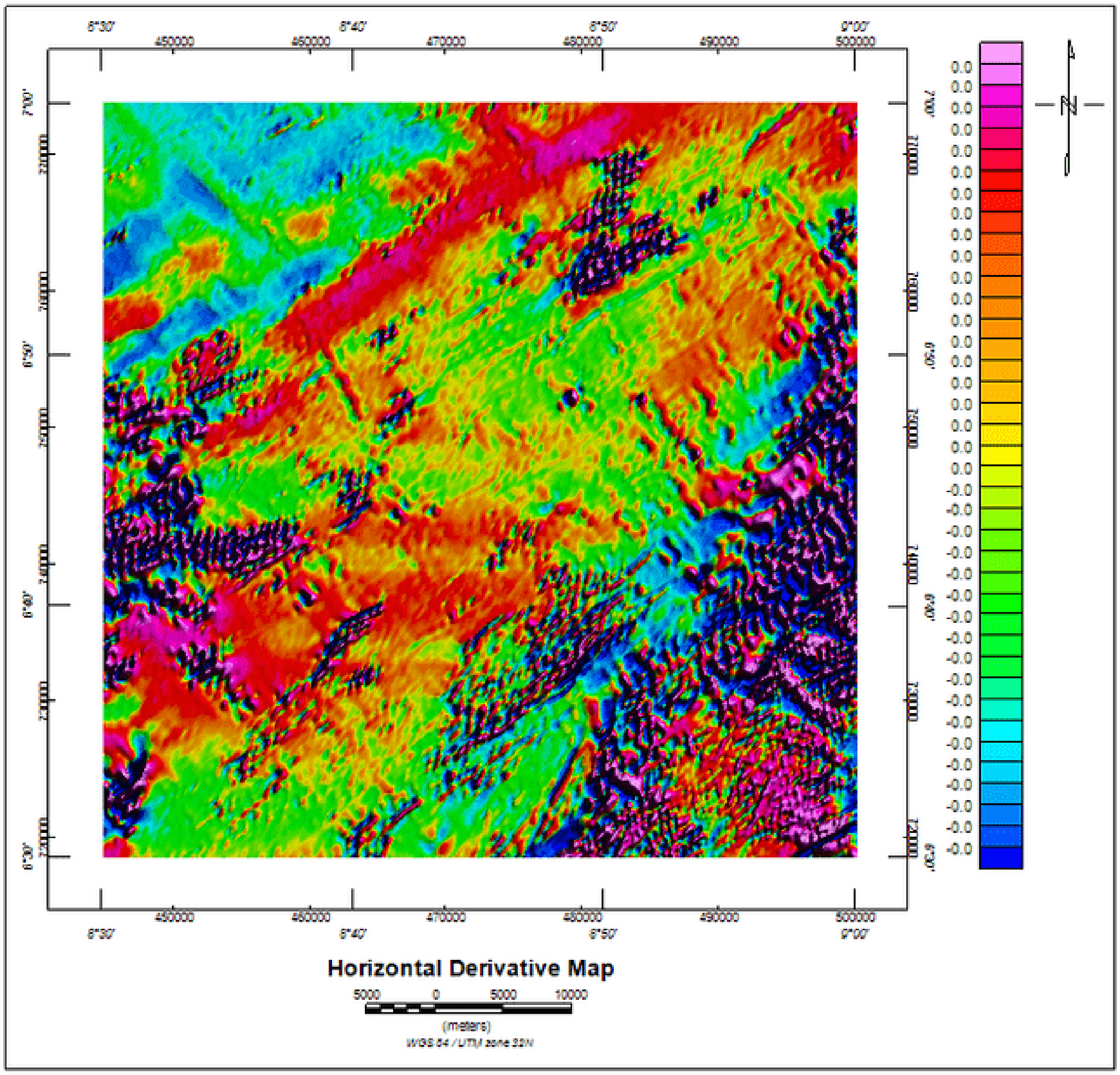

Figure 7: Horizontal Derivative Map of the Study area

One way to understand the HD maxima is to relate it to the margin of intrusive rocks or to the fault structure (Setyawan et. al, 2015). In this study, intrusive rocks and crystalline basement rocks are inferred from the maximum of the HD anomaly map. The sedimentary rocks are thought to connect with the minima. In general, large faults that strike in the NE-SW and NW-SE orientations have the potential to cut across the study region. Additionally, the horizontal gradient technique does not confirm geological faults, which means that it only discovers faults with vertical expansion (Grauch, 1987).

Vertical Derivatives

The shallow features are enhanced and anomalous edges are sharpened by the vertical derivatives. The derivative filter tends to provide a sharper image than the map of the total field intensity because it is significantly more responsive to local impacts than to wide or regional effects. Smaller anomalies were easily spotted in regions with significant regional instability. In reality, where high frequency characteristics are obscured by large amplitude, low frequency anomalies, the first vertical derivative (FVD) was employed to better define these features.

The first vertical derivative calculation in this research provided the same benefits as directly monitoring the vertical gradient with a magnetic gradiometer, including boosting near-surface magnetic sources and improving the resolution of closely spaced sources just as stated by Reeves et al., (1997) and Pal & Majumdar (2015). To increase this impact even further, second, third and higher order vertical derivatives were calculated; however, above the second vertical derivative, the signal in the data became more pronounced than the noise. Figures 8 and 9 show maps of the first vertical derivative enhancement filters as well as the extracted lineament and associated rose diagram. These maps made it easy to see that the region is made up of near-surface linear geological structures that primarily trend in the NE-SW, NW-SE and E-W directions. The maps help to clarify the position, direction, and pattern of geologic features in the Ogoja region of southeast Nigeria.

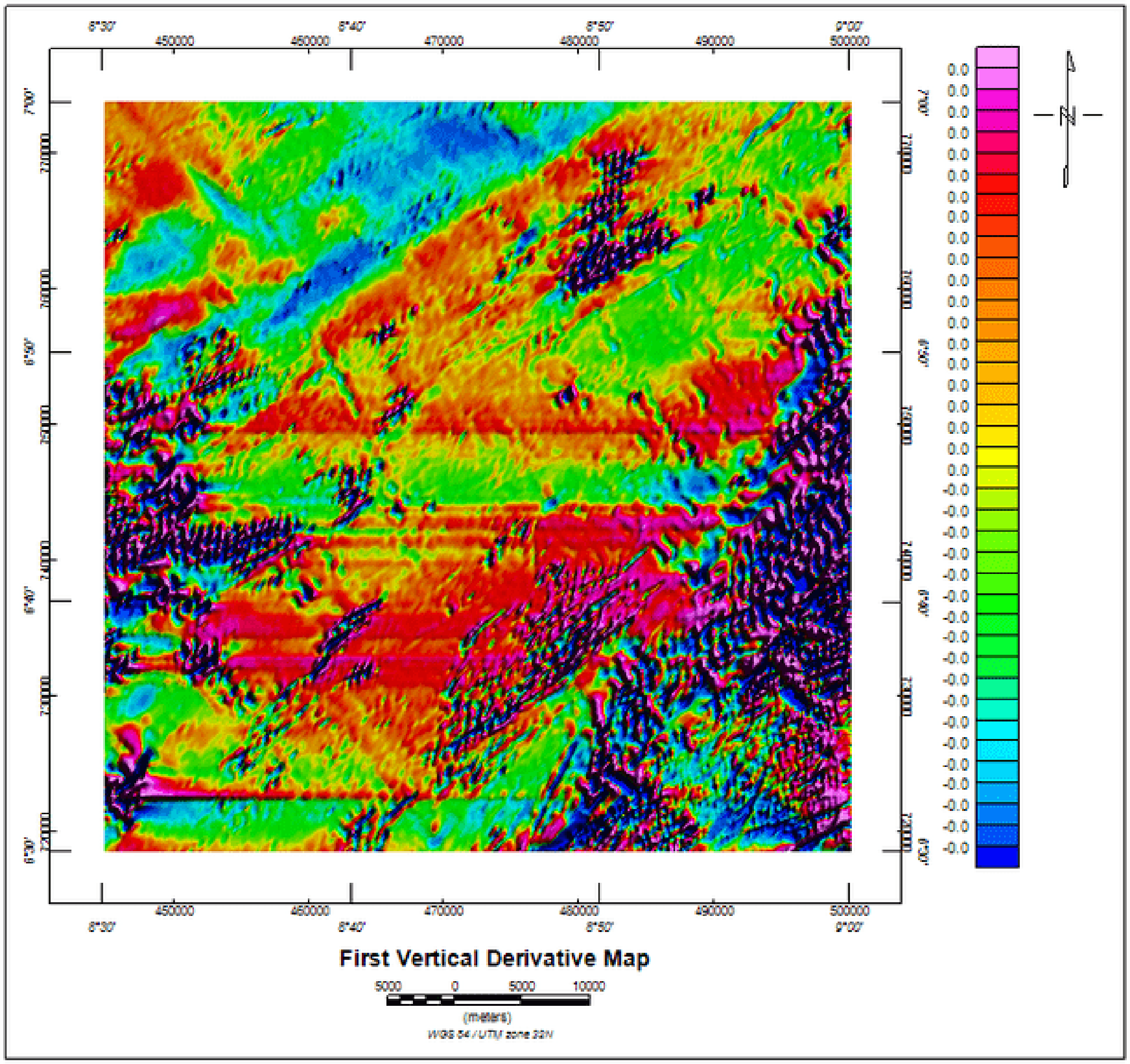

Figure 8: First Vertical Derivative Map of the Study area

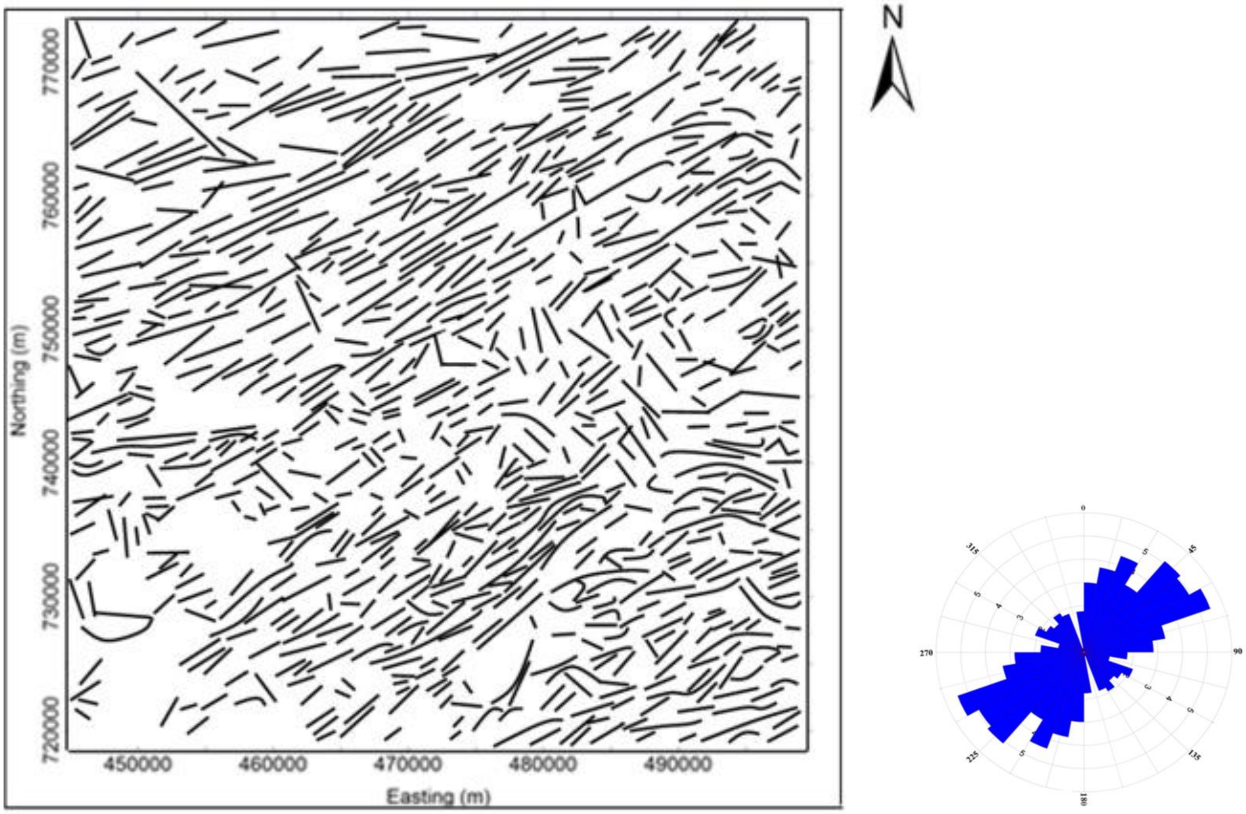

Figure 9: Lineaments extracted from first vertical derivative map and rose diagram showing the main structural trend in the study area.

Furthermore, the first and second vertical derivative filters' ability to precisely map the margins of shallow seated geologic features that might have negative environmental and engineering implications in the study area was demonstrated by high-resolution lineament maps of the investigated area.

Magnetic Basement Depth Estimation

The conventional Euler deconvolution method was used on the aeromagnetic data to determine the depths of these lineaments in the area under investigation. The main advantage of the traditional Euler deconvolution techniques is that they are a depth weighting method that reveals the configuration and geometry of basement rocks as well as the depth to basement rocks at various solution locations. In order to establish the depth to the linear structural characteristics that may be the cause of the environmental and engineering issues observed in the research region, the thickness of the underlying sediments was also measured using the depth weighting study.

The conventional Euler solution for structural indices of 0, 1, 2, and 3 were obtained from the research and Figure 10 shows the Euler depth solution plot of the study area (Structural Index 3.0). The maps' 0–2000 m depth scale reveals that the mapped geologic features were not buried more than 2 km below the surface. The Benue Trough's broad conveyance of near-surface Santonian middle-mafic Igneous, calc-antacid magmas, and tuffs interruptions, as well as the presence of exceptionally prepared shales in the study region, are believed to be the reasons for thin sedimentation and high convergence of lineaments. (Benkhelil, 1997; Ekwok et al., 2020).

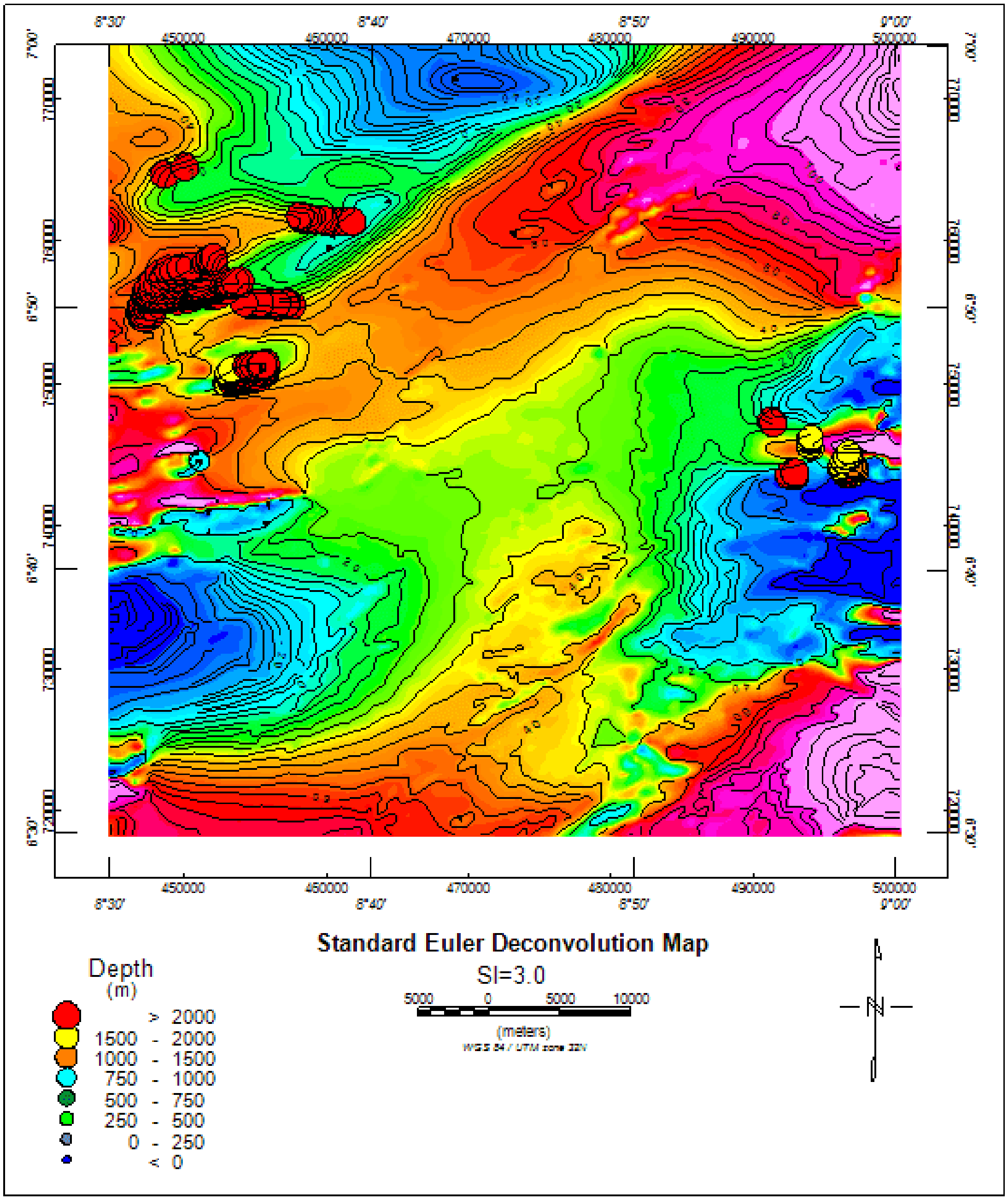

Figure 10: Euler depth solution plot of the study area (Structural Index 3.0).

CONCLUSION

The basement geometry, dominating structural trends, and sedimentation of the lineaments documented in the research region were all under the influence of the Benue Trough's structural framework. From the aerial magnetic data, enhanced structural maps which defined the boundaries of shallow seated geologic features that contribute to soil failures were produced using the HD, FVD, and SVD filters (Eldosouky, 2022). The spatial distributions and variations in the magnetic susceptibility of the research area were revealed by the regional and residual anomaly maps obtained. Statistical calculation was also made to determine the trend of the identified geologic features, which was then displayed as a rose diagram. According to the structural map's interpretation, the primary structural trend is NE-SW, with the secondary orientation being NW-SE indicating lines of possible weakness. In the structural map produced by the FVD and SVD, this tendency was found to be both very regular and dominant. The Lower Benue Trough (LBT) has previously shown similar structural tendencies (Ekwok et al., 2021a, b & c). The extensive intrusions, as well as metamorphosed Albian shales connected to the Santonian orogeny (Benkhelil, 1987; Ofoegbu and Onuoha, 1991; Ekwok et al., 2021c; Ekwok et al., 2022a), were the causes of these near-surface geologic features (Ekwok et al., 2019). The high concentration of lineaments in the Ogoja region was the result of the associated tectonic perturbations, which also acted as conduits for brine migration and entrapment.

Moreover, an undeniable consistency was seen from the lineament patterns as far as the pattern of examination of the geologic features gathered from the HD, FVD, and SVD maps exist. The all-out results exhibited that the utilization of these channels related to surface geologic mapping can be helpful for imaging lineaments in a muddled geologic region, for example, the locale explored in this research, which is portrayed by different periods of distortion. The areas of the Precambrian storm cellar regions from the high recurrence TMI maps and the spatial conveyance of the super short wavelength inconsistencies match each other very well. These guides explain the vitally attractive zones and add fundamentally to how we might interpret how short-wavelength peculiarities in the LBT are conveyed spatially. They significantly validate with different revelations in the locale (e.g., Oha et al., 2016; Ekwok et al., 2022). The Euler solutions' maximum depth of about 2000 m emphasizes the shallow character of the geologic structures, with linear characteristics located at depths near the surface.

In this work, a geophysical analysis of the environmental and engineering consequences of linear geologic features in Ogoja and its surroundings has been made. Aeromagnetic data was upgraded using high precision filters like HD, FVD, and SVD to provide better lineament maps of the Ogoja region in southeast Nigeria. The regional and residual fields of the magnetic data were separated using the polynomials fitting approach for first to fourth order prior to the application of the upgraded filters. The best suited residual anomaly map was then processed via the structural enhancement filters to provide a set of relatively well-correlated geologic features. Furthermore, the study area's shallow seated geologic features' boundaries were accurately delineated by the HD, FVD, and SVD filters. The Ogoja region's structural maps were created using the lineaments that were taken from the FVD and SVD. The maps that were produced showed structural tendencies like NE-SW and NW-SE which points to lines of weakness. In general, the majority of the geologic formations trended NE-SW and followed the structural orientation of the Benue Trough. By using the conventional Euler deconvolution found for structural indices of 0 to 3, it was possible to determine the depths of these lineaments. The Euler solution maps' maximum depth of 2km revealed that geologic features were shallow-seated fundamentals that give rise to most of the engineering and environmental issues in the study area, such as road failures, home cracking, and gully erosion.

RECOMMENDATIONS

To prevent structural failures seen in the study area, it is advisable that areas with pronounced lines of weakness should be avoided in setting up engineering structures. In a situation where these areas cannot be avoided, adequate reinforcement is advised before any structure can be set up. These areas of weakness should also be shielded from activities that will encourage erosion, like excavation and other forms of environmentally unhealthy human activities. Frequent environmental monitoring is advised within the study area to put every situation in check. Deforestation should heavily be discouraged and the growing of flora should be encouraged.

CONFLICT OF INTEREST

There is none declared.

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