integrity Research Journals

**Applied Journal of Physical Science**
Volume 5(2), pages 32-43, April 2023
Article Number: 5183921D1
ISSN: 2756-6684
https://doi.org/10.31248/AJPS2023.087
https://integrityresjournals.org/journal/AJPS

*Full Length Research*

# Delineation of source magnetization and subsurface discontinuity of Ririwai Ring Complex along Kano, North Western Nigeria

**Mukhtar M.[1], Usman A.[2*], Jeba M.A.[2] and Lawan A.M.[3]**

[1]Department of Physics, Federal University of Agriculture, Zuru, Nigeria.
[2]Department of Physics, Kebbi State University of Science and Technology Aliero, Kebbi State Nigeria.
[3]Department of Geology, Skyline University, Nigeria.

*Corresponding author. Email: abuameer070@gmail.com



Received 12th January 2023; Accepted 14th February 2023

**ABSTRACT:** High Resolution Aeromagnetic (HRAM) data of Ririwai (sheet 126) which lies between latitude 10° 30' to 11° 00' N and longitude 8° 30' E to 9° 00' E, was used for this research. The study area, Ririwai is situated along Kano, in the Northwestern part of Nigeria, both qualitative and quantitative interpretation techniques were employed in this study. This procedure was carefully undertaken by employing enhancement filters; vertical derivative, upward continuation, analytical signal amplitude processing, and quantitative approaches such as Euler 3D deconvolution and an apparent susceptibility filter to help further give solutions for depth estimates and magnetization. The Euler deconvolution was able to show that the solution plotted clustered around the region where the geological structures are located with average depths range of <139.8 to >904.5 m, with very few solutions having depths less than 200 m, the most prominent structure particularly the Ririwai ring complex have a depth range of 182.9 to 301.5 m. The magnetic susceptibility reading obtained shows that the area is composed of rocks high in magnetic minerals such as magnetite along the western end of the area, it is also flanked by medium to high magnetic values around the central parts with only regions of low magnetic values predominantly along the Ririwai complex and its adjoining outcrops towards the eastern half of the area under study.

**Keywords:** Aeromagnetic, Euler deconvolution, magnetization, source, Ririwai, ring complex.

## INTRODUCTION

The Younger Granite petrographic province, exposed in Niger and Nigeria, consists of a north-south belt of igneous centers ranging in age from Ordovician (470 Ma) in northern Niger (Martin and Bowden, 1981) to Jurassic (l44 Ma) in the most southerly complex in Nigeria. The ring structures and cupolas represent roots of volcanoes. The Riruwai Complex provides one of the finest examples in the Nigerian province of the complete cycle of Younger Granite magmatic activity (Jacobson and Macleod, 1977). The Riruwai Complex with a distinctive topography is located l40 km south of Kano and occupies an area of about 129 Km$^2$. Prior knowledge shows that the analyses of magnetic measurements yield significant and reliable information about subsurface geologic structures, even though essentially concealed (Dobrin and Savit, 1988; Bozzo *et al*., 1999; Blakely *et al*., 2000 and Nur, 2000; Ashano and Olasehinde, 2010).

The Nigerian continental mass's magnetic lineation and places with distinctive magnetic character and field level are revealed by the analysis of aeromagnetic data, and these features are seen as representations of tectonic features connected to the igneous intrusion of various ages. The crystalline shield area with its distinctive Jurassic granitic ring complexes and neogenevolcanics, as well as the Benue Trough, which is thought to be a failed-rift arm, provide the data on the total field magnetic intensity (Ajakiaye *et al*., 1991). Based on the foregoing, this work uses the magnetic data collected over the Riruwai Younger Granite Ring Complex to determine the complex's tectonic makeup and how it affects the region's geodynamics, this is evident in the structural analysis performed in the works of Usman *et al. (*2020). The Nigerian Geological Survey obtained total-field aeromagnetic anomaly data from hunting Geology and Geophysics Limited undertook and completed the airborne Geophysical Survey (aeromagnetic), and the geological survey of Nigeria generated the map at a scale of 1:100,000 (Garba, 1988). However, because geologic features are frequently huge, structural assessments are done at the regional level to give a clear picture of how big faults, folds, lineaments, and other structural features are, therefore, to cover the extent of the interesting part, these need small-scale pictures. The goal of this study is to learn more about the location and orientation of magnetic sources. This makes it easier to understand the local structural layout.

## MATERIALS AND METHODS

### Location and general overview of the study area

The area of study has a geographical coordinate of latitude 10° 30' to 11° 00' N and longitude 8° 30' to 9° 00' E, and Ririwai's original name (with diacritics) is Riruwai, as shown in Figure 1. Ririwai is located in Kano in the northwestern part of Nigeria**.**

### Geology of the study area

The study area is in Kano State, Nigeria, and is part of the Western Younger Granite Complex, which extends from latitude 10°30' to 11°00'N and longitude 8°30' to 9°00'E. It also includes the Nigeria Geological Survey Sheet 126 (Ririwai). The rocks of the Precambrian to early Paleozoic Basement Complex contain the Ring Complex. It differs chemically from the sub-alkaline and calc-alkaline granitic basement suites that were intruded at the end of the Pan-African Orogenic event (Kinnaird, 1985), as illustrated in Figure 2.

### Structural trends

Particularly in the migmatite-gneisses, the regional north-south basement trend that denotes the final mark of the Pan-African Orogeny is visible. The photogeological trends and some measured north-south distances show some striking agreement (Olarewaju, 1976). The ages of the younger granite complexes decrease as they move southward, forming an N-S band (Alkali, 2013). According to Rahaman *et al*. (1984), the main regional magmatic activities were mostly concentrated in the ENE and WSW zones. According to the age pattern, the parent magma was likely locally produced from a number of concurrent high-level magma chambers linked to a shared deeper source. Fracture systems in the basement guided the location of these ring complexes (Alkali, 2013).

### Data acquisition

Ririwai (sheet 126) is located between latitude 10° 30' and 11° 00'N and longitude 8° 30' and 9° 00'E, according to High Resolution Aeromagnetic (HRAM) data. This information, which is on a scale of 1:100,000 and covers the whole study region, was purchased from the Nigerian Geological Survey Agency (NGSA). They were created using information gathered at a height of 80 meters along NE-SW flight lines that were roughly 500 meters apart. Given that the majority of the data was collected between 2005 and 2009, the main magnetic field of the earth was determined from the measurement results using the international geomagnetic reference field (IGRF) 2005 model.

### Materials (software used)

High resolution aeromagnetic data of Ririwai, Numerous geophysical programs, including the Geosoft Oasis Montaj (8.4) module Software, Global Mapper 18.2.0, Grapher 8, and the Golden software, were used in the course of this study.

### Procedures

The following steps were meticulously used in this approach with the sole aim of getting the desired results. This involves processing analytical signal amplitude, upward continuation, and enhancement filter application in the form of vertical derivative. This is assisted by using quantitative methods like an apparent susceptibility calculation and Euler 3D deconvolution to further aid in providing solutions for depth estimation and magnetization.

### Data enhancement

The examination of structural features benefits greatly from the enhancement of magnetic data since it highlights the edges of anomalies. The first vertical derivative (FVD) is represented by:

$$FVD = \frac{\partial M}{\partial z}, \quad (1)$$

Where M is the potential field anomaly.


**Figure 1.** Google satellite Map of Riruwai ring complex. (Courtesy Google earth map, 2022).

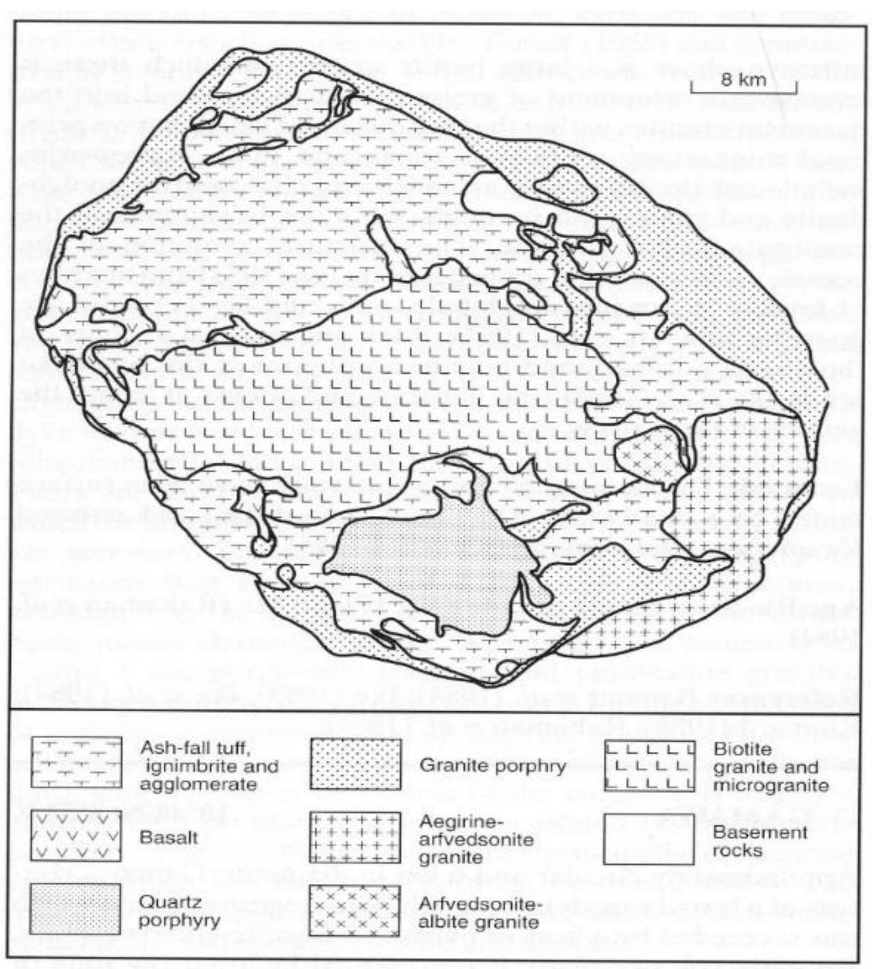


**Figure 2.** Geological Map of Ririwai (Modified after Kinnaird, 1985).

The vertical derivative was computed from the upward continuation map at 250 m. This is very important to this research as it enhances linear features and sharpens the response of the target structures of the magnetic anomaly Figure 4.

**Upward continuation of residual field**

Typically, this is a mathematical method for extrapolating data from one elevation to another. It is a filtering method that eliminates noise from high frequency shallow anomalies, which typically result from nearby cultural characteristics in the survey area. Usman *et al.* (2020) and Bourden and Turner, (1974), the upward continued ΔF (the total field magnetic anomaly) at a higher level (z = - h) is given by:

$$\Delta F\ (x, y, -h) = \frac{h}{2\pi} \iint \frac{\Delta F(x,y,0)dxdy}{((x-x^0)^2+(y-y^0)^2+h^2)} \qquad (2)$$

The empirical formula: Henderson (1960) gives the field at an elevation h, above the plane of the observed field (z = 0) in terms of the average value ΔF at the point (x, y, o).

**Technique for analytic signals**

The horizontal and vertical derivatives of the magnetic anomaly are combined to generate the complex function that represents the analytical signal (Figure 6). The analytical signal is known in three dimensions as:

$$A(x, y, z) = \frac{\partial T}{\partial x}\hat{x} + \frac{\partial T}{\partial y}\hat{y} + i\frac{\partial T}{\partial z}\hat{z} \qquad (3)$$

Where $\hat{x}$, $\hat{y}$ and $\hat{z}$ are unit vectors in the x, y and z directions, respectively $\frac{\partial T}{\partial z}$ is the vertical derivative of the magnetic anomaly field intensity, $\frac{\partial T}{\partial x}$ and $\frac{\partial T}{\partial y}$ are the horizontal derivatives of the magnetic anomaly field intensity (Garba, 1988).

The amplitude of the analytic signal in 3D is given by:

$$|A(x, y, z)| = \sqrt{\left(\frac{\partial T}{\partial x}\right)^2 + \left(\frac{\partial T}{\partial y}\right)^2 + \left(\frac{\partial T}{\partial z}\right)^2} \qquad (4)$$

**Depth estimation of magnetic source using Euler Deconvolution Method**

To obtain the approximate depth of the source of the anomalies (Figure 9), the Euler deconvolution method was applied to the residual field data. This technique provides automatic estimates of source location and depth. Therefore, Euler deconvolution is a boundary finder and depth estimation method. Euler deconvolution is commonly employed in magnetic interpretation because it requires only a little prior knowledge about the magnetic source geometry, and more importantly, it requires no information about the magnetization vector (Masson and smith, 1965; Burke, 1969). Euler deconvolution is based on Euler's homogeneity equation. Masson and smith (1965) showed that Euler's homogeneity relation could be written in the form:

$$(x - x_0)\frac{\partial T}{\partial x} + (y - y_0)\frac{\partial T}{\partial y} + (z - z_0)\frac{\partial T}{\partial z} = N(B - T), \qquad (5)$$

Where *B* is the regional value of the total magnetic field and $x_0$, $y_0$, and $z_0$ is the position of the magnetic source, which produces the total magnetic field *T* measured at x, y, z. *N* is called the structural index.

**Magnetization/apparent (susceptibility) calculation**

Magnetic susceptibility is a measure of the magnetic properties of a material. The susceptibility indicates whether a material is attracted into or repelled out of a magnetic field, and is simply the degree of magnetization. Mathematically it is the ratio of magnetization I (magnetic moment per unit volume) to the applied magnetizing field intensity H. The susceptibility map filter includes a downward continuation to the source depth. Because a downward continuation filter magnitude increases with wavenumber, it tends to also amplify high-wavenumber noise in the data Usman *et al.* (2019). To prevent this noise from arising from the susceptibility map filter, an optimum depth filter was applied to help remove the high wave number that is considered noise in the data Figure 8.

**RESULTS**

The residual magnetic intensity map (Figure 3) displays the anomalous field values of relevance together with notable geological features that are primarily trending in the NW-SE directions and have magnetic field values between -90.4 and 146.5 nT. SURFER 13 and Oasis Montaj software were used for this.

The first order derivative map shows the response of the target structures with magnetic field values ranging from -0.099 to 0.179 nT/m is represented by the first vertical derivative map (Figure 4). As a result, deep-seated traits are sacrificed to improve linear structures.

The result (Figure 5) shows the upward continued field with magnetic field values ranging from 639.110 to 845.388 nT/m, the residual field was upward continued at

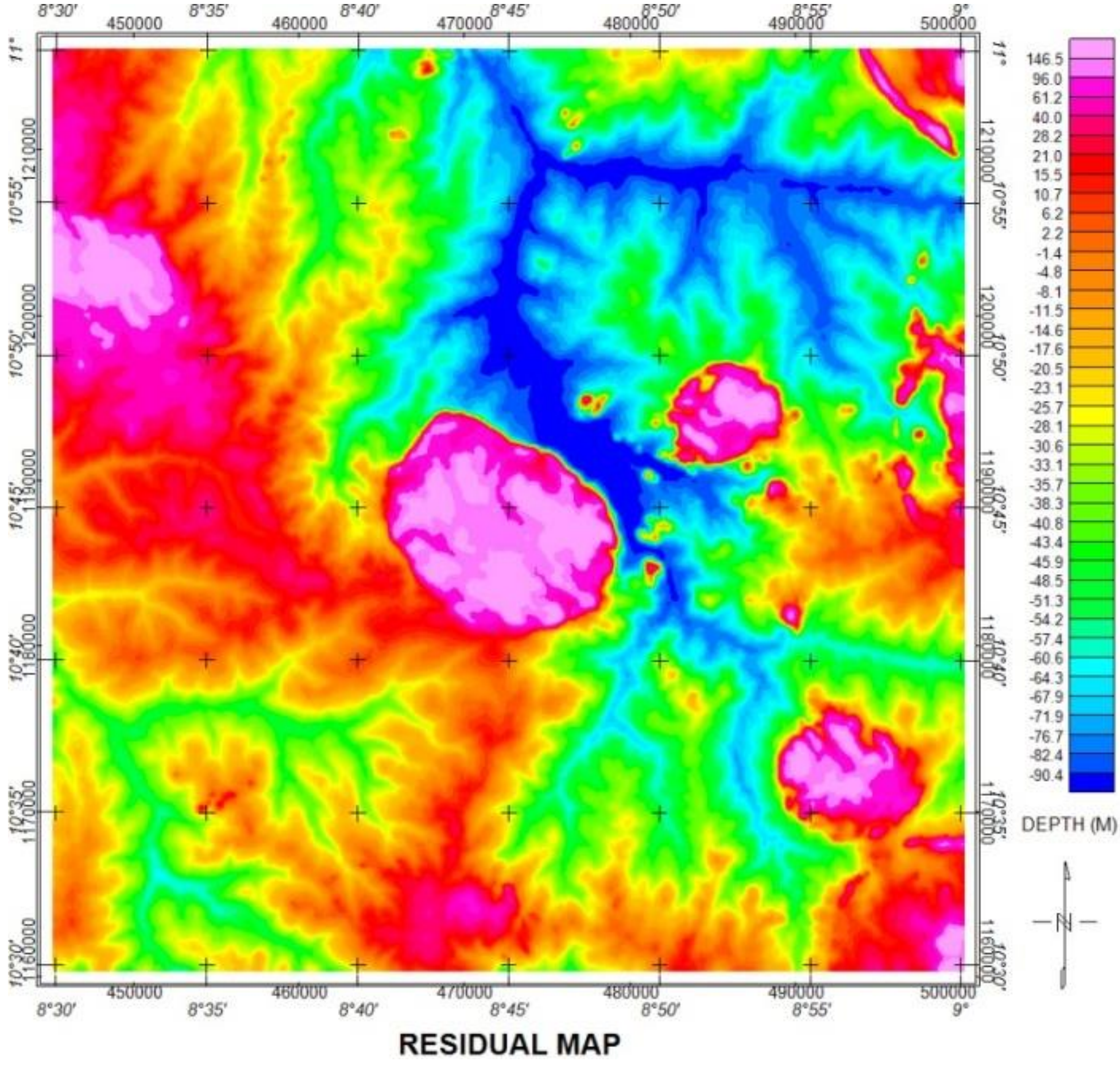


**Figure 3.** Residual magnetic intensity map.

40 km, revealing a shallow-seated regional influence (Figure 5). This helps to highlight the field's vast, NE-SW trending features. The combination of vertical and horizontal gradients is known as the analytical signal, or total gradient, as shown in Figure 6. The determination of source characteristics is based on the first derivative computation of magnetic anomalies, with magnetic field values ranging from 0.009 to 0.290 nT/m, this map is independent of magnetization direction and aids in the identification of notable features linked to anomalous discontinuities.

The map image (Figure 7) demonstrates the three-dimensional Euler deconvolution intensity map of the residual magnetic intensity, with very low field values primarily located near the core central point, minimum to high field values along its southern end, and strong

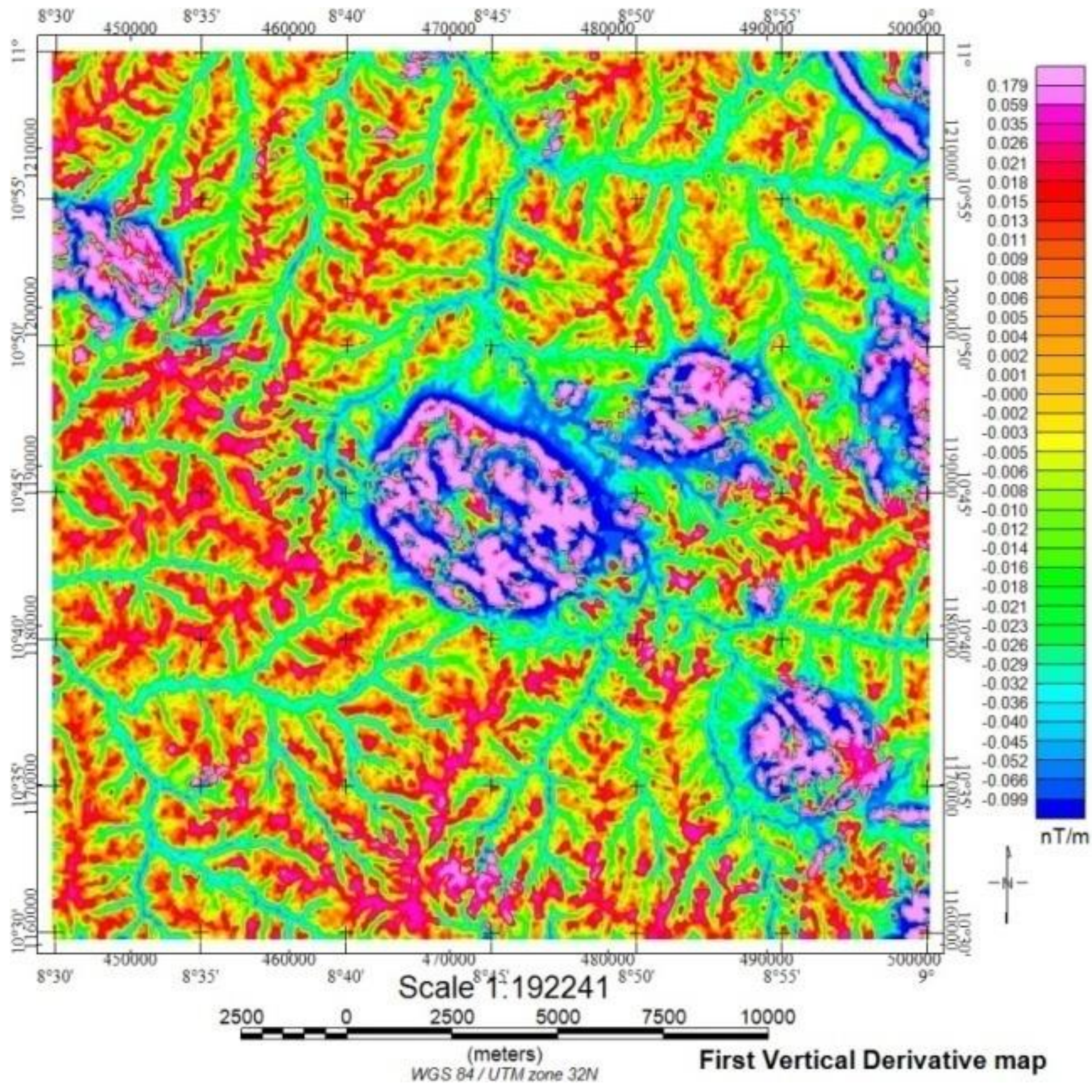


**Figure 4.** First vertical derivative.

magnetic signatures along the NE and SW side with an appreciable depth range indicating deep seated features, very low field values are primarily located in the central point of the Euler deconvolution map (Figure 7), with minimum to high field values along the southern end and strong magnetic signatures along the NE and SW flank. The source position is solved for, the source type is determined, and the depth of the causative bodies is shown at each point on the map, with depth values ranging from 139.8 to >904.5 m (Figure 9). The residual magnetic intensity map displays the anomalous field values of relevance together with notable geological features that

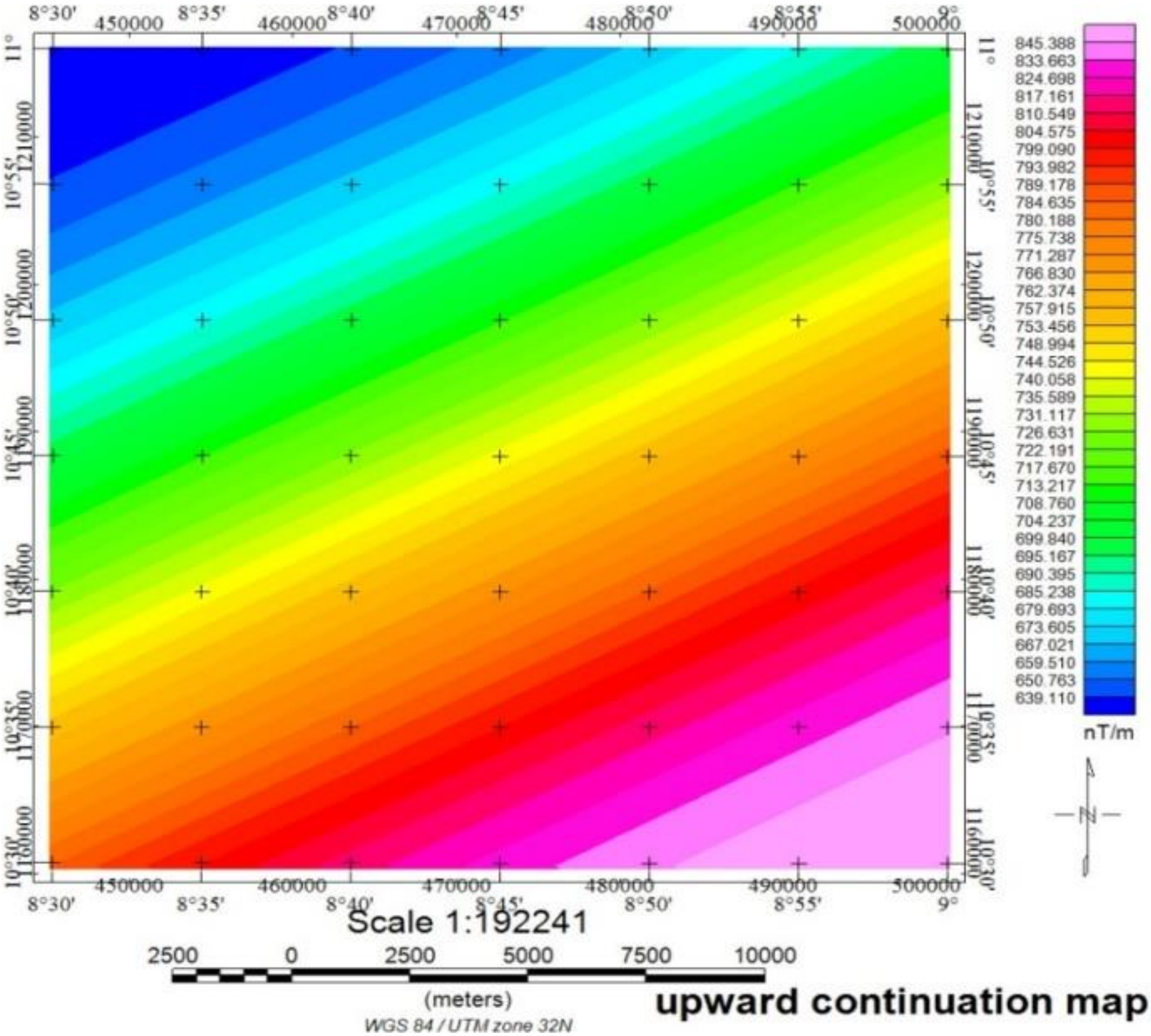


**Figure 5.** Upward continuation map.

are primarily trending in the NW-SE directions and have magnetic field values between -90.4 and 146.5 nT (Figure 3). SURFER 13 and Oasis Montaj software were used for this. From the result, very low field values are primarily located in the central point of the Euler deconvolution map (Figure 9), with minimum to high field values along the southern end and strong magnetic signatures along the NE and SW flank. The source position and the source type is determined, and also the indicated depth of the causative bodies is shown in Figure 9. The research area's magnetization map is shown in Figure 8, with values for magnetic susceptibility ranging from 0.001 to 0.006 SI. These magnetic susceptibility readings reveal that the westernmost portion of the area under study is made up of rocks rich in magnetic minerals like magnetite and that it is also bordered by medium to high-magnetic susceptibility values on all sides. The eastern half of the research area also indicates high intensity with an appreciable deeper depth range. The Ririwai complex and its surrounding outcrops are the only areas with low magnetic values in the centre.

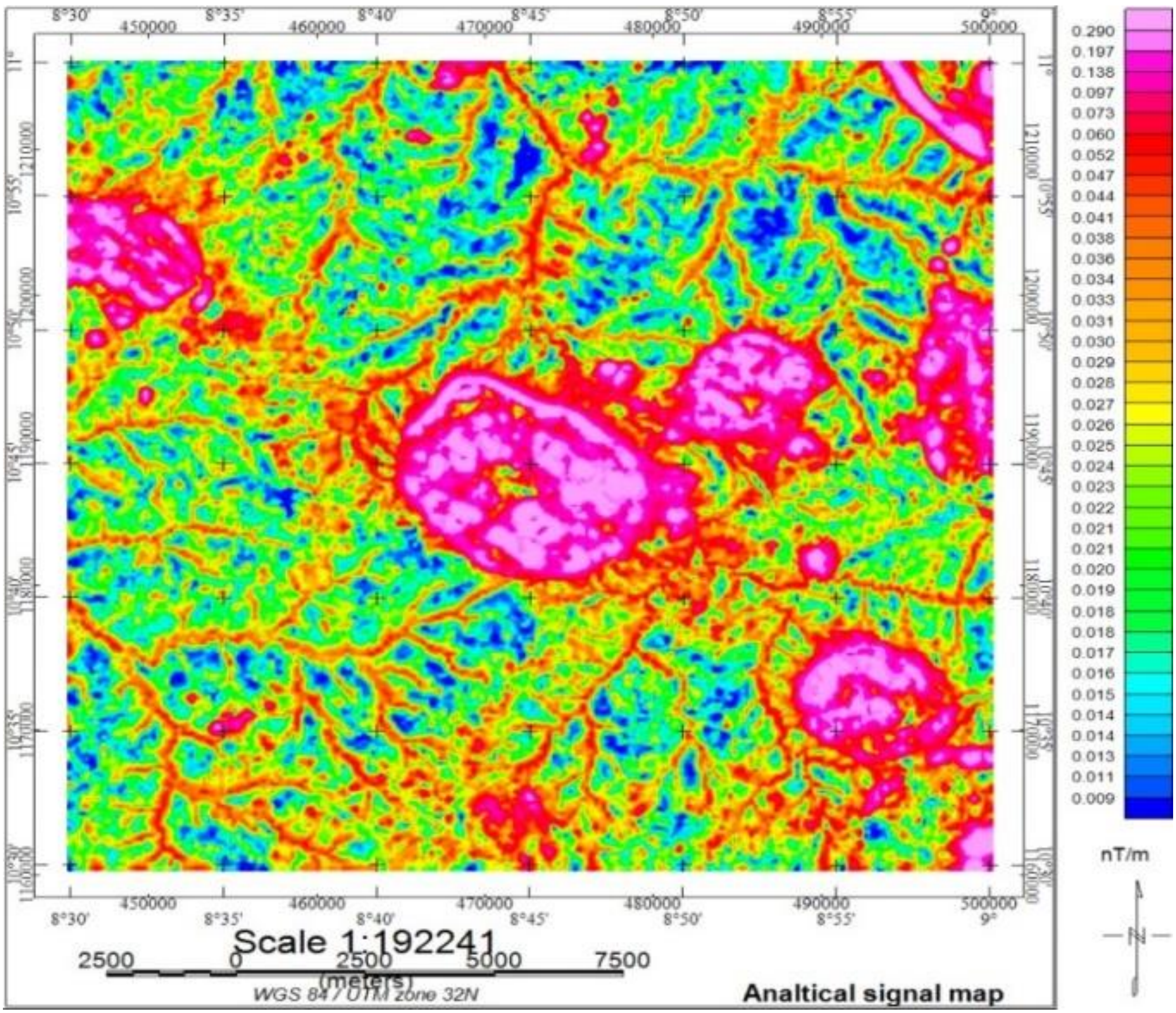


**Figure 6.** Analytic signal map of the area.

## DISCUSSION

In this study, aeromagnetic data is used in order to achieve the primary aim of the study which is to investigate the subsurface structures of Ririwai Ring Complexes using the magnetics method to verify the probable internal behaviour of rock magnetization across the area of study.

The anomalous field values of interest are shown on the residual magnetic intensity map in Figure 3 which represents the results obtained after subtracting the smooth presumable deep seated regional effects from the observed field. The first vertical derivative map, which corresponds to the response of the target structures, is displayed in Figure 4 and is utilized to improve the upward continuing field data. From the result of Figure 4, the responses associated with high frequency shallow anomalies were very obvious with prominent lineation indicating near surface linear features of interest which might serve as the probable host to mineralogical fluid along the vicinity of the area under consideration. Figure 5 displays the upward continuing field map, from the result obtained, the map (Figure 5) was upward continued to a

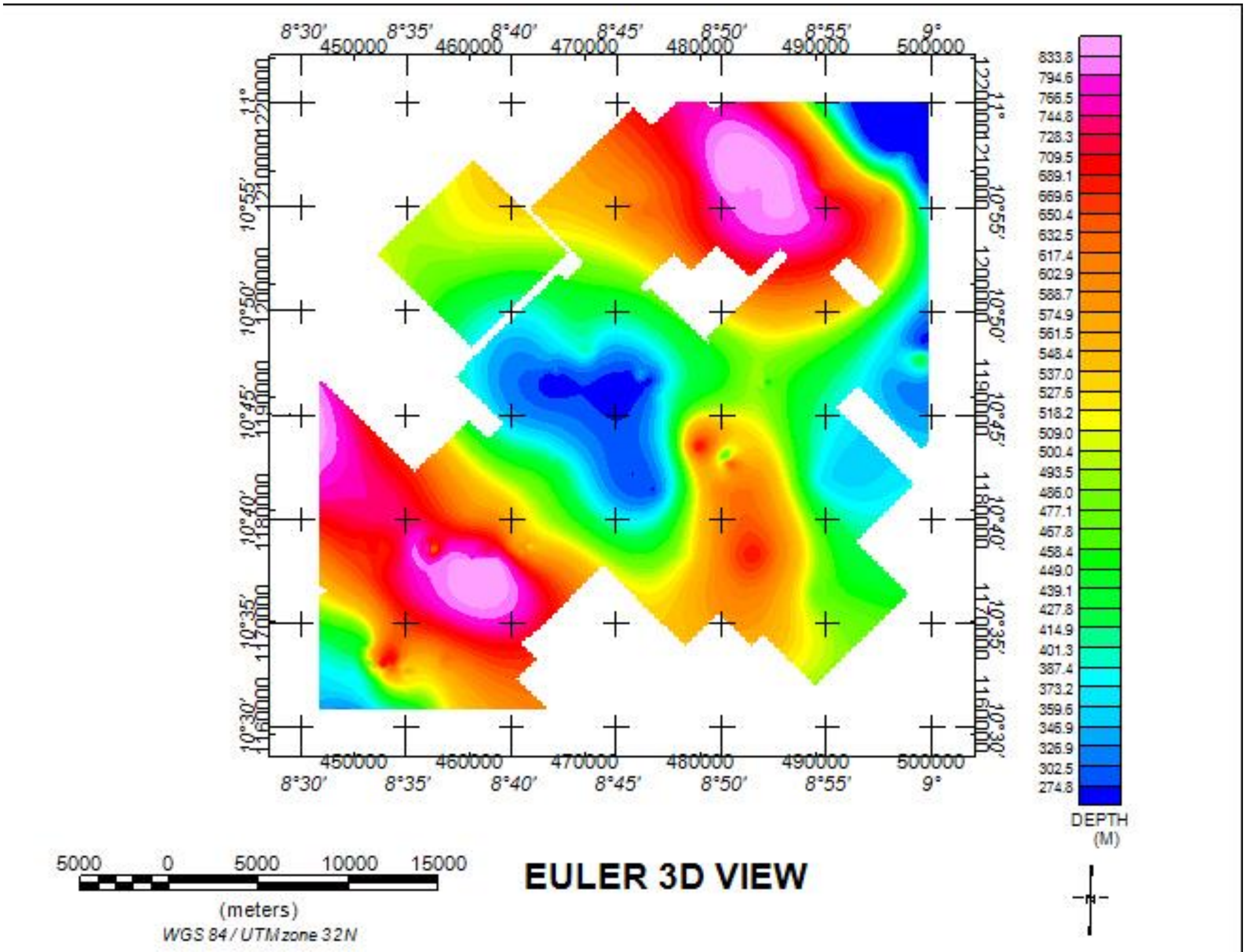


**Figure 7.** Euler 3D view map.

height of 40 km and the major interest was to obtain the regional field map which generally shows up as a trend caused by deeper homogeneity of the earth crust, and from the result obtained (Figure 5), the orientation of the trend of the anomaly was also confirmed to be aligned in the NE/SW direction. To determine the source positions of the magnetic anomaly regardless of direction and remnant magnetization in the sources, the analytical signal filter was applied to the Residual Magnetic Intensity (RMI) grid. This computation is known as the analytical signal map. The generated analytical signal map of the research region is displayed in Figure 6. This signal aids in revealing the local structural and magnetic characteristics in a clear pattern. The outcome demonstrates the orientation of the Ririwai Ring Complex, with a medium to low analytic signal in the south-western portion of the region and a high analytic signal amplitude most noticeably at the east-west flank indicating the boundary of anomalous sources across the region which also is in the range of the values obtained for the boundary in the works of Alkali *(*2013).

However, we used the Euler method to determine the relevant depth to the magnetic bodies' source (Figure 9). This demonstrates that the solutions plotted clustered around the area where the geological structures are located, with average depths ranging from 139.8 to >904.5 m, and very few solutions having depths less than 200 m. The Ririwai Ring Complex is the most notable structure, with a depth range of 182.9 to 301.5 m, which also agrees with the works of Usman *et al. (*2020). The sum of the vertical and horizontal gradients is known as the analytical signal (or total gradient) and is used to determine source characteristics, it is based on the first derivative computation

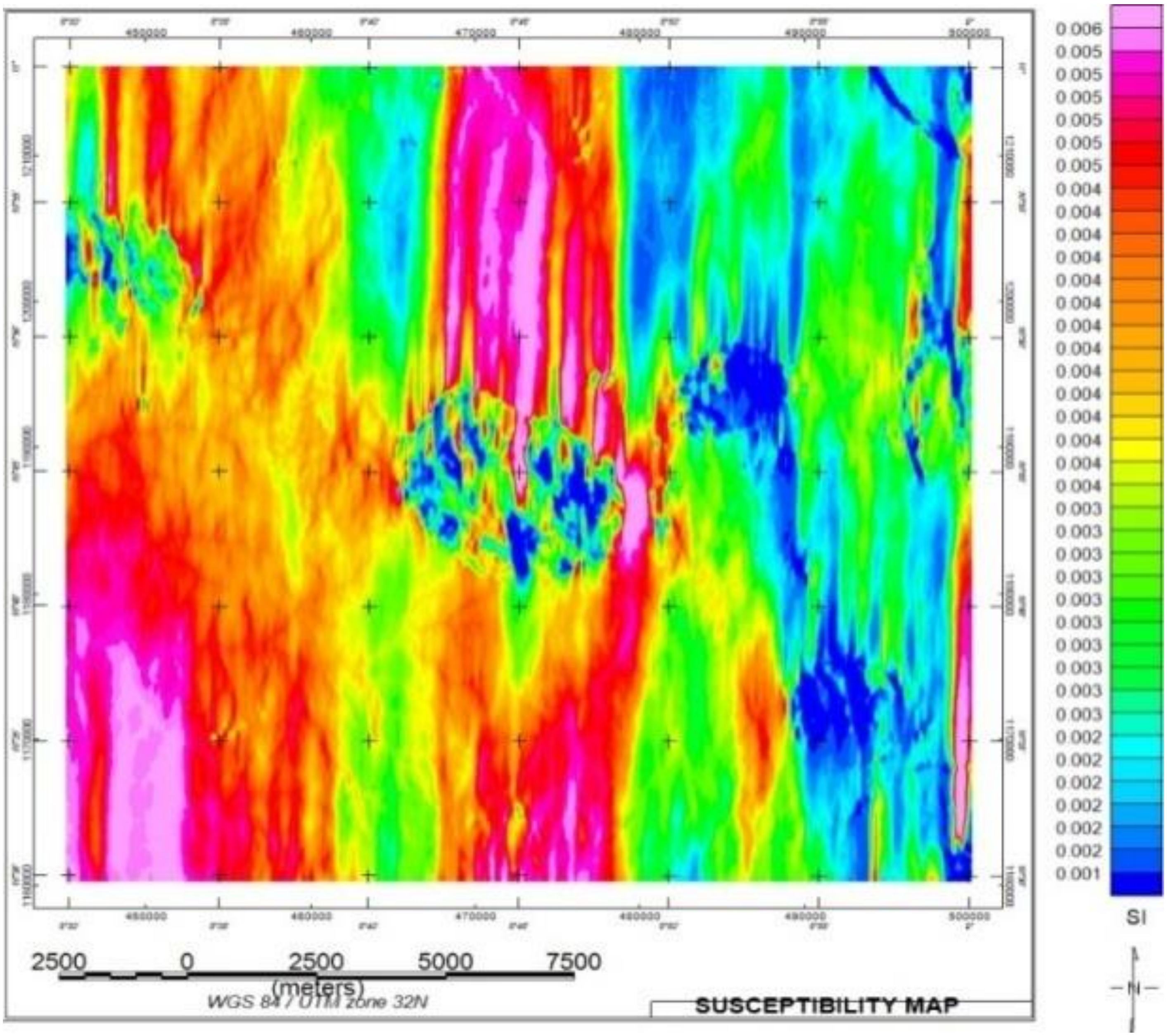


**Figure 8.** Euler depth solution.

of magnetic anomalies. This result (Figure 6) provides the magnetic field values ranging from 0.009 to 0.290 nT/m, this map is independent of magnetization direction and aids in the identification of notable features linked to anomalous discontinuities. The result also indicates the presence of magnetic rich minerals in the form of magnetite as also seen in the susceptibility mapobtained. The map (Figure 8) portraying magnetic susceptibility readings reveals that the westernmost portion of the area under study is made up of rocks rich in magnetic minerals like magnetite and that it is also bordered by medium to high-magnetic susceptibility values on all sides. The eastern half of the research area also indicates high intensity with an appreciable deeper depth range. The Ririwai Complex and its surrounding outcrops are the only areas with low magnetic values in the centre.

The map figure 9. Demonstrates the three-dimensional Euler deconvolution image of the residual magnetic intensity, with very low field values primarily located near the core central point, minimum to high field values along its southern end, and strong magnetic signatures along the NE and SW side. (Figure 9). This is in agreement with the

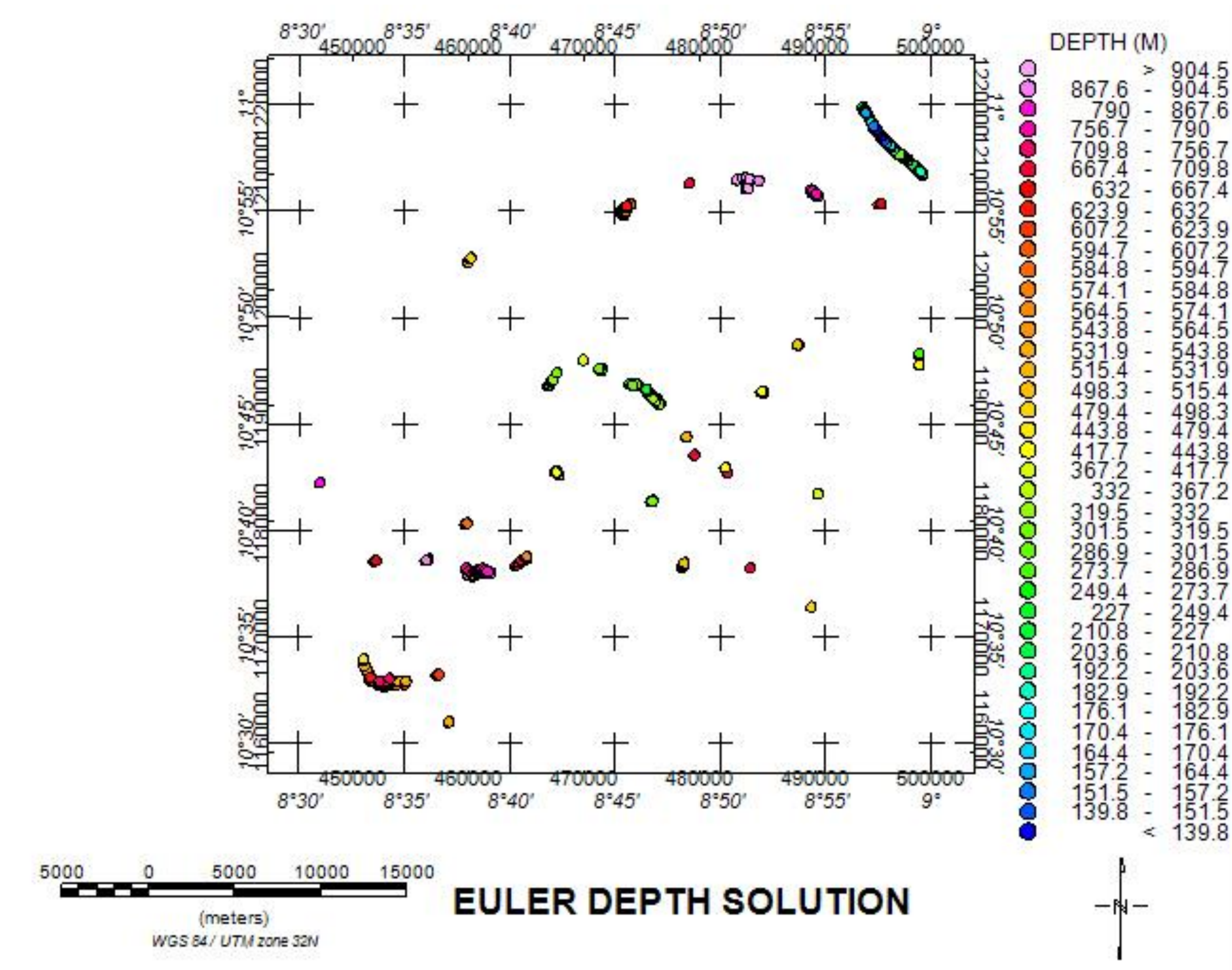


**Figure 9.** Magnetization map.

result obtained in the work of Usman *et al.* (2020). The source position is solved for and the source type is determined, the depth of the causative body is shown at each point on the map, with depth values ranging from (139.8 to> 904.5 m).

## Conclusion

The Ririwai Ring Complex, which is the most notable structure, shows a shallow depth range, with almost the same depth range for all magnetic signatures in the area. This, however, prompts the need for a futuristic approach to the exploration of magnetic minerals such as magnetite and other ferrous materials around Riruwai in Nigeria. The Euler deconvolution was able to demonstrate that the solution plotted clustered around the region where the geological structures are located, with an average depth range of 139.8 to >904.5 m.

## CONFLICT OF INTEREST

The authors declare that they have no conflict of interest.

## ACKNOWLEDGEMENT

The authors will like to acknowledge Usman Ahmed (PhD) of the Department of Physics, Kebbi State University of Science and Technology, Aleiro for his technical and constructive contribution to this work. Also, we will like to thank the Nigerian Geological Survey Agency (NGSA) for making available the aeromagnetic data used for the work.

## REFERENCES

Ajakiaye, D. E., Hall, D. H., Ashiekaa, J. A., & Udensi, E. E. (1991). Magnetic anomalies in the Nigerian continental mass based on aeromagnetic surveys. *Tectonophysics*, *192*(1-2), 211-230.

Alkali, S. C. (2013). Mapping and analysis of the density of lineaments around Kagoro Younger Granite rocks in northcentral Nigeria. *Global Advanced Research Journal of Engineering, Technology and Innovation*, *2*(10), 295-303.

Ashano, E. C., & Olasehinde, A. (2010). An integrated study of the economic mineral potential of the Ropp Complex, Northcentral Nigeria. *Global Journal of Geological Sciences*, *8*(1), 1-15.

Blakely, R. J., Langenheim, V. E., Ponce, D. A., & Dixon, G. L. (2000). Aeromagnetic survey of the Amargosa Desert, Nevada and California: A tool for understanding near-surface geology and hydrology. *Open-file Report. U. S. Geological Survey*, (188), 32.

Bourden, P., & Turner, D. C. (1974).*Alkaline and Associated, Ring-Complexes in the Nigerian Nije Provincing West Africa in Alkaline Rocks. International Journal of Scientific Research.*

Bozzo, E., Ferraccioli, F., Gambetta, M., Caneva, G., Spano, M., Chiappini, M., & Damaske, D. (1999). Recent progress in magnetic anomaly mapping over Victoria Land (Antarctica) and the GITARA 5 survey. *Antarctic Science*, *11*(2), 209-216.

Burke, K. (1969). *Seismic area of the guinea coast where Atlantic fracture zones reach.* Africa nature Pp. 655-657.

Dobrin, M. B., & Savit, C. H., (1988): *Introduction to geophysical prospecting* (4th edition). McGraw Hill book company, NY. 688p.

Garba, I. (1988). The variety and possible origin of the Nigerian gold mineralization. Okolom-Dogonadji and Waya veins as case studies. *Journal of African Earth Sciences (and the Middle East)*, *7*(7-8), 981-986.

Google earth map (2022).

Henderson R.G (1960). Models of Interpreting Aeromagnetic Data*. Geophysics 26,* 132-143.

Jacobson, R. R. E. & Macleod, W. N. (1977) Geology of the Liruei, Banke and adjacent younger granite ring complexes. *Bulletin of Geological Survey of Nigeria*, *33*, 1-117.

Kinnaird, J. A. (1985). Hydrothermal alteration and mineralization of the alkaline anorogenic ring complexes of Nigeria. *Journal of African Earth Sciences (1983)*, *3*(1-2), 229-251.

Masson– smith, D. (1965*). Geophysical prospecting for basalt covered cassiterite on the jos plateau, northern Nigeria over sea geological survey, geophysical report,* London, No. 27.

Martin, R. F., & Bowden, P. (1981). Peraluminous granites produced by rock-fluid interaction in the Ririwai nonorogenic ring-complex, Nigeria; mineralogical evidence. *The Canadian Mineralogist*, *19*(1), 65-82.

Nur, A. (2000). Analysis of aeromagnetic data over the Yola arm of the Upper Benue Trough, Nigeria. *Journal of Mining and Geology*, *36*, 77-84.

Olarewaju, V. O. (1976). *The basement complex geology of 1:100,000 sheet 126, Ririwai, Northcentral Nigeri*a. M.Sc. thesis (Unpublished) Department of Physics ABU, Zaria, Nigeria.

Rahaman, M. A., Van Breemen, O., Bowden, P., & Bennett, J. N. (1984). Age migrations of anorogenic ring complexes in Northern Nigeria. *The Journal of Geology*, *92*(2), 173-184.

Usman, A., Lawan, A. M., Lawal, M. M., Jonathan, L. A., Sununu, S. T. (2021). Structural analysis of selected ring complexes in some parts of the Nigerian Younger Granite Provinces. *Saudi Journal of Engineering Technology*, *6*(12), 467-475.

Usman, A., Sani, M. A., Lawal, K. M., & Magaji, S. S. (2019). Aeromagnetic investigation of geologic structures associated with gold mineralization along danja, northwestern Nigeria. *Bima Journal of Science and Technology*, *3*(01), 184-195.