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# Source Depth Determination of the Ningi-Burra Younger Granite Complex North-Eastern Nigeria from Aeromagnetic Data

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## ABSTRACT

Source Parameter Imaging (SPI) of aeromagnetic data covering an area within Birnin-Kudu Sheet 105 SE, Gwaram Sheet 106 SW, Kalatu Sheet 127 NE and Kaffin Madaki sheet 128 NW, bounded between Latitudes 10° 55' N to 11° 10' N and Longitudes 9° 20' E to 9° 35' E. The application of Source Parameter Imaging (SPI) method revealed depth ranging from 64.704m to 538 to 777m, map of the depth estimates obtained from the SPI solution plot superimposed on the residual magnetic field intensity map of the area. The blue to cyan colours (64.704m to 111.520M) indicates the shallowest portions of the basement, the Green to Yellow colours (115.773m to 187.186m) represent the intermediate depth, while the Red to Pink coloured (201.698m to 538.77m) represent the highest peak of the area which are the deepest areas. The results from the SPI study indicate that deep seated bodies (dykes) dominated the area. Other Euler deconvolution solutions were also obtained by first selecting a magnetic structural index of zero (i.e., SI=0), followed by SI=0, SI=1, SI=2, and SI=3. This is based on the concept of Euler homogeneity, a description of scaling behavior in potential-field depth analysis. The magnetic structural index (SI=0) represents the depth of the contact with basement, which is as low as -131.093m and the highest is at 329.960m The best clustering solution was obtained by selecting a structural index of one (i.e., SI = 1) shows that the solution plotted as clustered in the region where the geological structures are located in the depth range of 8.707m to 1370.815m, which indicates that the deep magnetic bodies are concentrated at the peripheral side of the ring complex. The deeper magnetic sources are at the depth of -163.723m to the basement, while the highest depth to the shallower magnetic source in the area is 700.594m and represents the extrusive bodies in the area.

## INTRODUCTION

Aeromagnetic data analysis is an important tool in determining the magnetic basement depth beneath the strata which can be used for exploration of most economic minerals, oil, gas, and groundwater beneath the earth surface and the presence and magnitude of these resources can be ascertained by geophysical investigations of the subsurface structures in the area (Keary and Brooks, 1984).

The area of study is located within Birnin-Kudu Sheet 127 SE, Gwaram Sheet 128 SW, Kalatu Sheet 237 NE and Kaffin Madaki sheet 238 NW, is bounded between Latitudes 10° 55' N to 11° 10' N and Longitudes 9°20' E to 9° 35' E (Figure 1). The area falls within the Younger Granite province of Nigeria (Jacobson *et al.*, 1958), and form the Ningi-Burra Ring Complex that is situated about 150 km north of the Jos Plateau.

The geology of Nigeria is dominated by crystalline and sedimentary rocks both occurring approximately in equal proportions (Woakes *et al.,* 1987).

The Nigerian Younger Granites emplaced as an anorogenic rocks from high level magmatic activities and controlled by ring fracturing, faulting and cauldron subsidence (Turner, 1979) and hence their evolution as near ring (circular) complexes. They are however known to be associated with earlier acid volcanoes such as rhyolites and syenites (Elebe, 1990).

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The Ningi-Burra complex is exposed as a high structural level which means erosion has cut down to the roof zones of several granite plutons which has completely removed the flanks of the original volcanic structures, leaving only the circular or elliptical central volcanic masses which foundered during caldera formation.

These volcanic subsidence structures (cauldrons) as defined by Smith and Bailey (1968) provided nearly complete sections through the volcanic accumulations, from the basement floor almost to the products of the final eruptions.

Ningi-Burra Complex includes almost all of the rock types known in other parts of the province. In the early stages of each caldera-forming cycle, the ignimbrite eruptions were of small volume and the rocks had varies in crystal contents. Later, large high-level magma chambers must have developed from which the crystal-rich ignimbrites with volumes in the order of 100 $km^3$ were erupted, with accompanying caldera collapse (Jacobson and Jaques 1944).

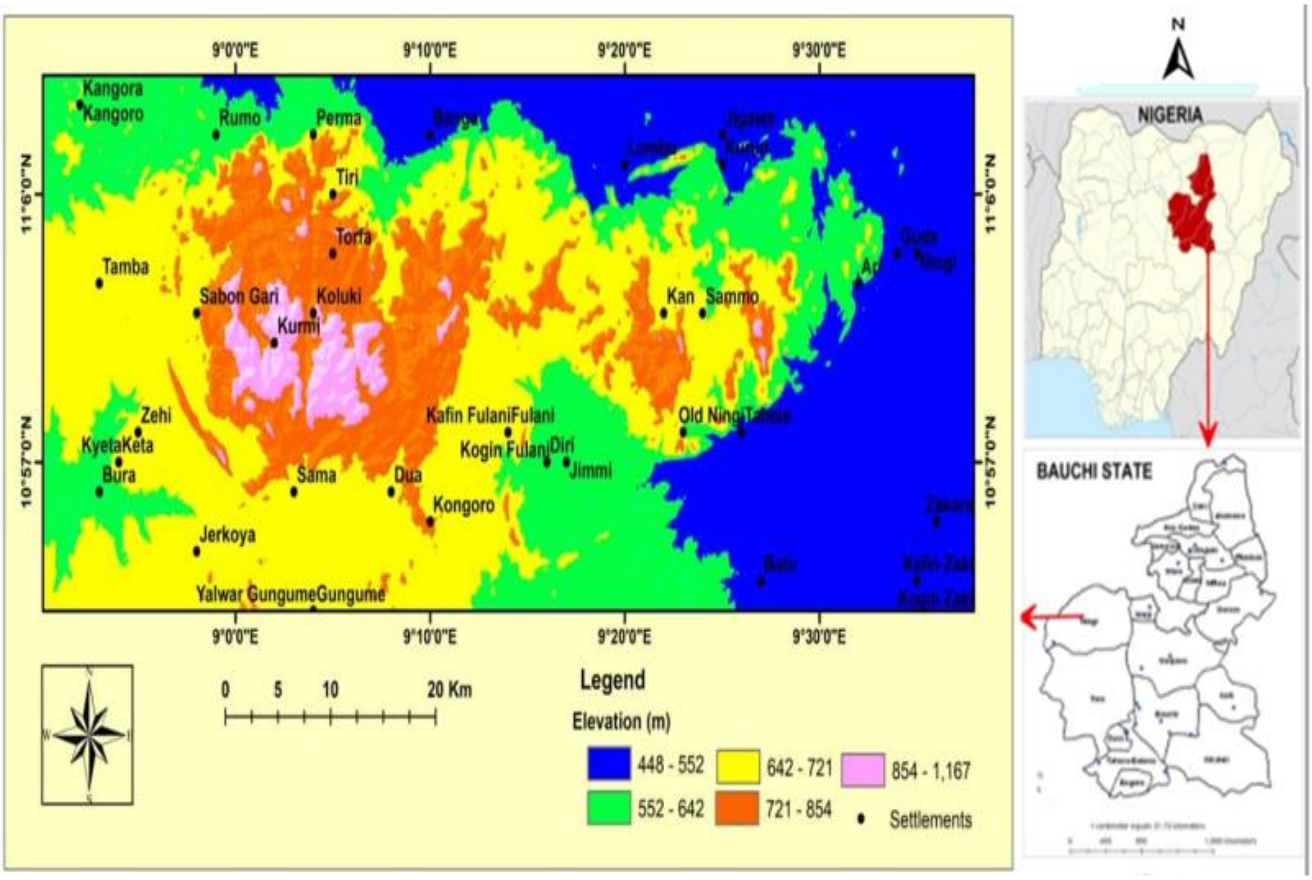


**Figure 1: Location and Elevation map of the study area**

## METHODOLOGY

Four quarter degree high resolutions aeromagnetic data provided both in grid and data-based format including DGRF-2005 removed, each on a scale of 1: 100,000 were purchased from the Nigerian Geological Survey Agency Abuja. The data sheets comprise of Birnin Kudu (Sheet 105), Gwaram (Sheet 106), Talaku (Sheet 127) and Kaffin Madaki (Sheet 128). The data was acquired using 3X Scintrex CS3 Cesium Vapour Magnetometer. The following flight parameters were utilised during the survey; flight line spacing was 500 meters, terrain clearance was 80 meters, flight direction was in the NW-SE, tie line spacing was 2 kilometres and tie line direction was in the NE-SW direction. Software used for data analysis is the Oasis Montaj version 8.4.

The extracted residual anomaly for qualitative interpretation is based on visual inspection of the data which begins with a visual inspection of the shapes and trends of the major anomalies, delineation of the structural trends, closer examination of the characteristic features of each individual anomaly. The total magnetic field

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intensity values presented in the maps were reduced by 33,000nT, therefore 33,000nT were added to the contour values to obtain the actual total magnetic field intensity values. The materials used in this work include both software and maps the software are; Oasis Montaj version 8.4 (2015), rockworks (2017), ILWIS 3.3 (2005), surfer11 (2012) and micro soft excels (2016). The maps include; aeromagnetic, Satellite image and their overlays with geological map. Euler Deconvolution method and Source Parameter Imagine (SPI) were applied on the Residual Magnetic Intensity grid using the Euler 3D extension module and SPI extension module of the Oasis Montaj software.

## RESULTS

### Total Magnetic Intensity (Tmi) Map

The acquired total magnetic intensity (TMI) map over Ningi-Burra Younger Granite Complex; figure 3.1 represent a TMI values from 33.176.315nT to 32,616.146nT with an average value of 32,990.9nT. The values are represented with a pink colour as high and blue colour as low. High TMI value is characterized by regions of relatively high magnetite content.

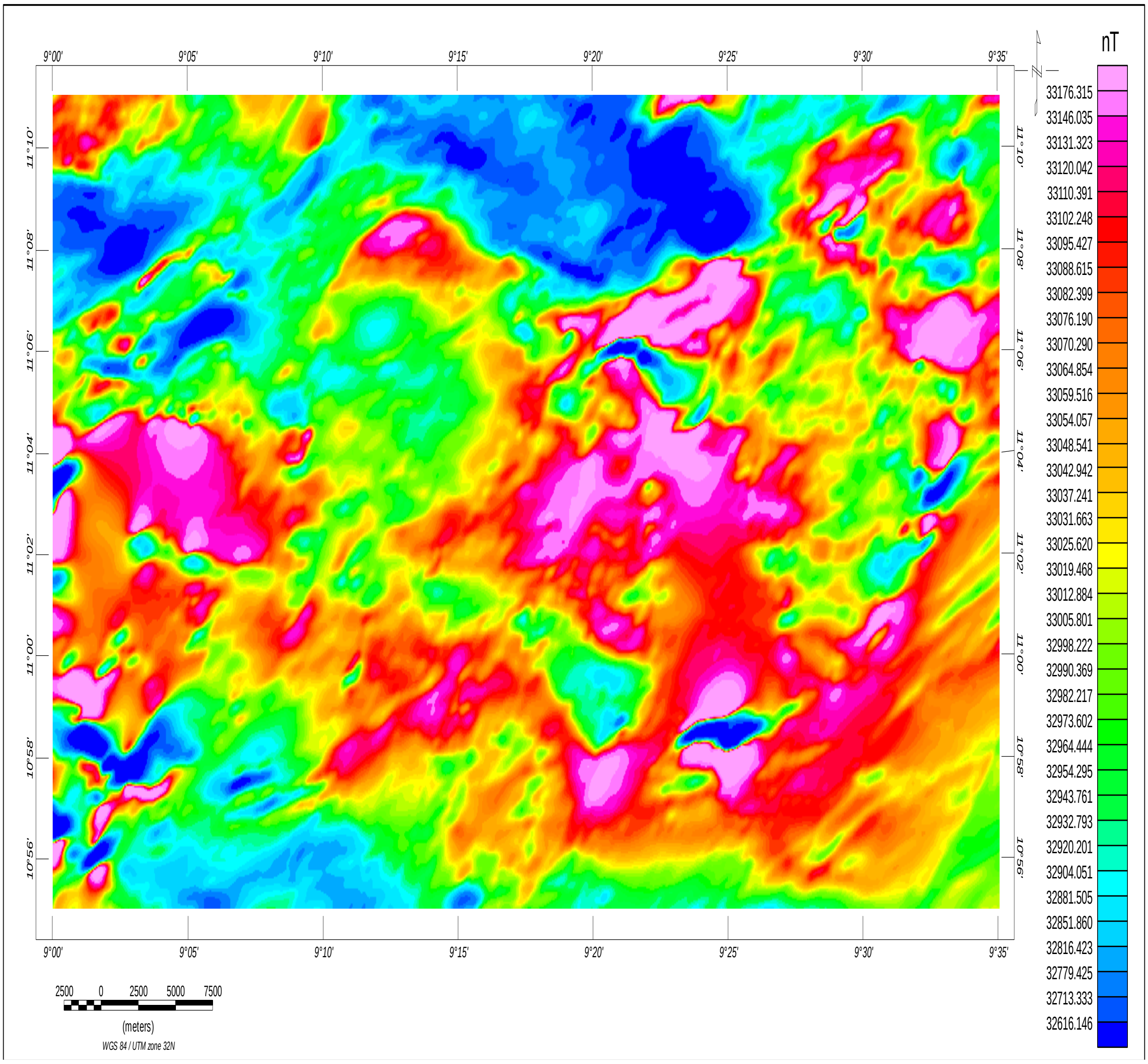


**Figure 3.1: TMI map of the study area.**

### Main Magnetic Field

The main magnetic field over Ningi-Burra Younger Granite Complex is generated using the DGRF model 2005 (epoch period of the survey), have values ranging from 33942.315nT to 33953.853nT with an average value of 33948.084nT (Fig. 3.2). This field represents the regional or dipole field of the study area, which was removed from the total magnetic intensity map to obtain the crustal field anomaly over the area.

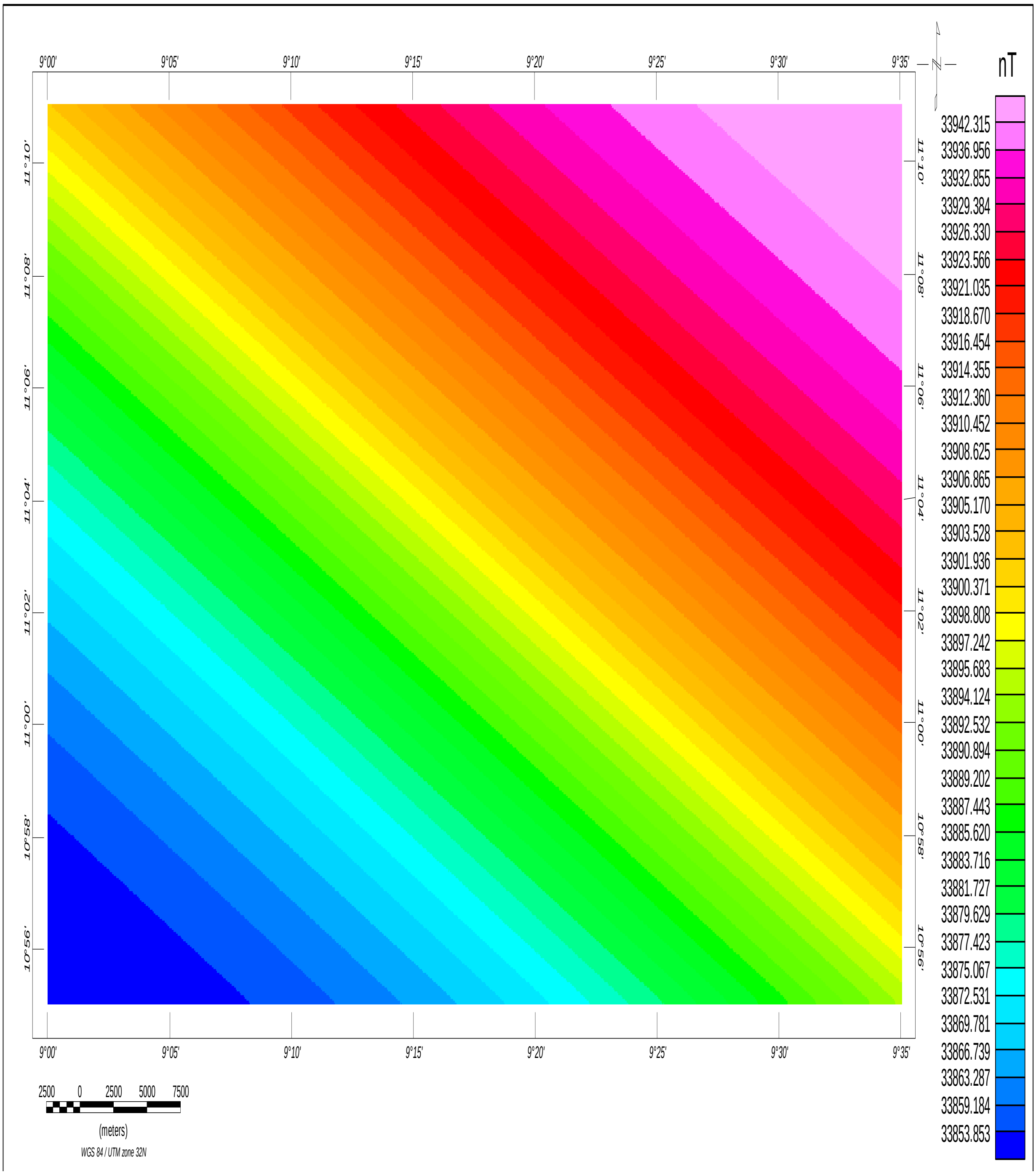


**Figure 3.2: Regional map of the study area**

## Crustal Magnetic Field

The crustal magnetic field of the Ningi-Burra Younger Granite Complex (Fig. 3.3) was obtained from the main field and shows values ranging from -1298.439nT to -723.281nT with an average value of -852.72nT. The variation in the crustal magnetic field within the study area is an indication that there are differences in geological, magnetic and chemical compositions of the rock's bodies. The crustal magnetic field map has low magnetic susceptibility in areas of high magnetic values pink colour (-764.020 to -723.261) and red colour (-822.169 to -764.020), while more magnetic susceptibility areas are depicted as low magnetic values blue colour (-1298.439 to -1082.708) and cyan colour (-1082.708 to -965.771). The intermediate colours are oranges (-841.183 to -822.169), yellow (-859.866 to -841.183) and green (-886.318 to -859.866).

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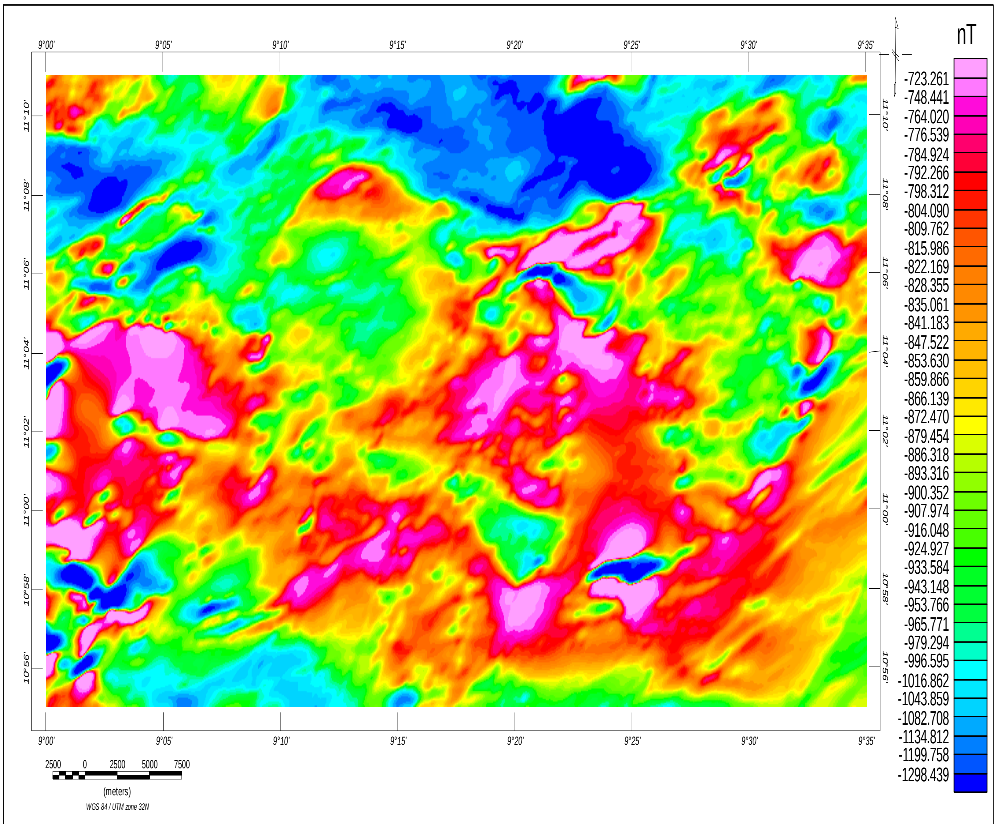


**Figure 3.3: Residual Magnetic map of the study area**

**Source Parameter Imaging (SPI)**

The results of the depth estimates from the application of Source Parameter Imaging (SPI) method in the study area revealed depth ranging from about 64.704m to 538.777m as shown in Figure 3.4, map of the depth estimates obtained from the SPI solution plot superimposed on the residual magnetic field intensity map of the study area. The blue to cyan areas (64.704m -111.520M) indicates the shallowest portions of the basement, the Green to Yellow colours (115.773m -174.965m) indicate intermediate depth, while the Red to Pink coloured (218.811m -538.777m) portion indicates the highest peak, which are the deepest areas.

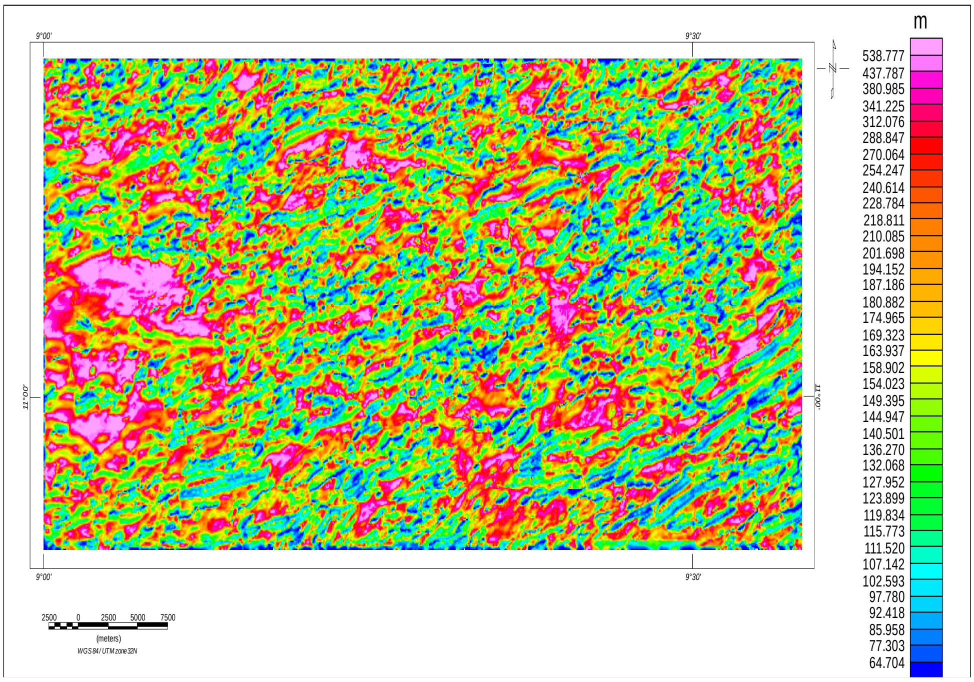


**Figure 3.4: Source Parameter Imaging (SPI) map superimposed on the Residual Magnetic Field Intensity map of the study area.**

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Other Euler deconvolution solutions were also obtained by first selecting a magnetic structural index of zero (i.e., SI=0), followed by SI=0, SI=1, SI=2, and SI=3. This is based on the concept of Euler homogeneity, a description of scaling behavior widely used in potential-field depth analysis, as shown in Table 1

**Table 1: Structural index of Geologic body with number of infinite dimensions**

| Geological Body | Number Of Infinite Dimensions | Magnetic Structural Index |
|---|---|---|
| Sphere | 0 | 3 |
| Pipe | 1(Z) | 2 |
| Horizontal Cylinder | 1(X-Y) | 2 |
| Dyke | 2(Z And X-Y) | 1 |
| Sill | 2(X And Y) | 1 |
| Contact | 3(X, Y, Z) | 0 |

The magnetic structural index (SI=0) represents the depth of the contact with basement, which is as low as -131.093m and the highest is at 329.960m as represented on Figure 3.5

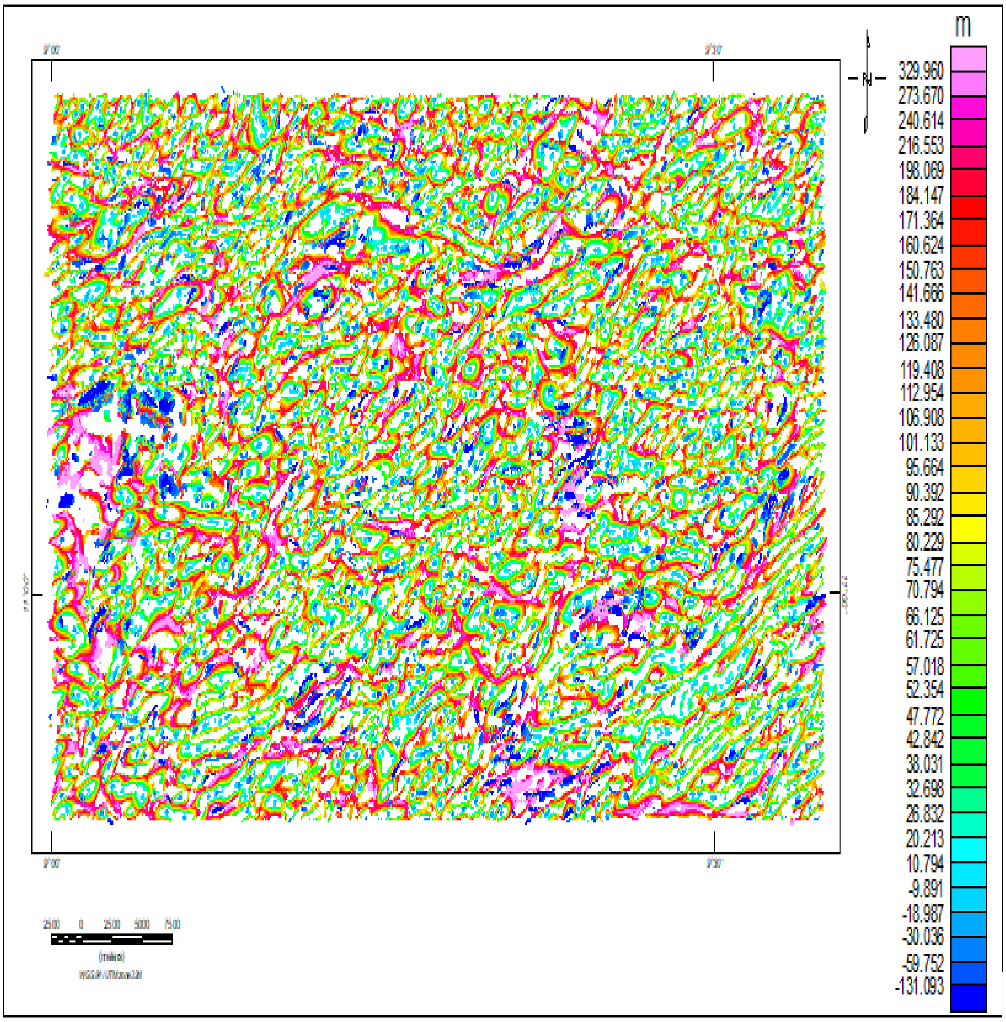


**Figure 3.5: Source Parameter Imaging (SPI) map obtained by selecting a magnetic structural index of zero (i.e., SI=0 representing the depth of the contact with basement, with 3 dimensions, X, Y&Z).**

The best clustering solution was obtained by selecting a structural index of one (i.e., SI = 1), shows that the solution plotted as clustered in the region where the geological structures are located in the depth range of 8.707m to 1370.815m (Figure 3.6), which indicates that the deep magnetic bodies are concentrated at the peripheral side of the ring complex.

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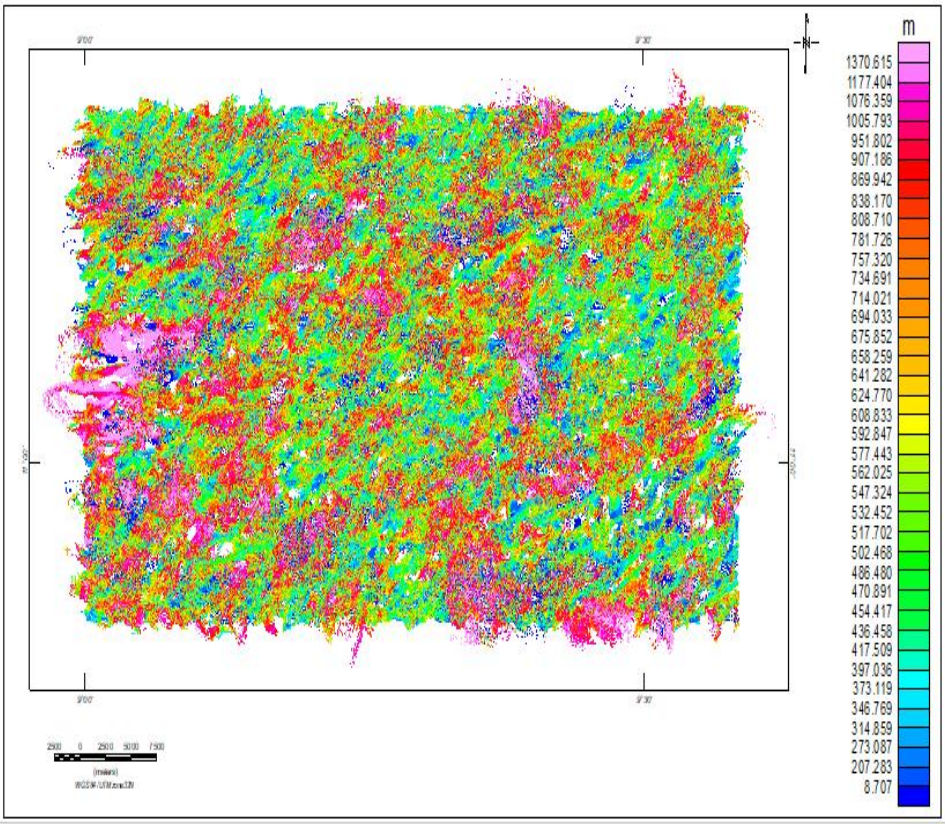


**Figure 3.6: Source Parameter Imaging (SPI) map obtained by selecting a magnetic structural index of one (i.e., SI=1, representing the depth of sills with 2 dimensions (X&Y) and dykes with 2 dimensions (Z&X-Y).**

The deeper magnetic sources are at depth of up to -163.723m to the basement, while the highest depth to the shallower magnetic source in the study area is 700.594m and represents the extrusive bodies (Figure 3.7).

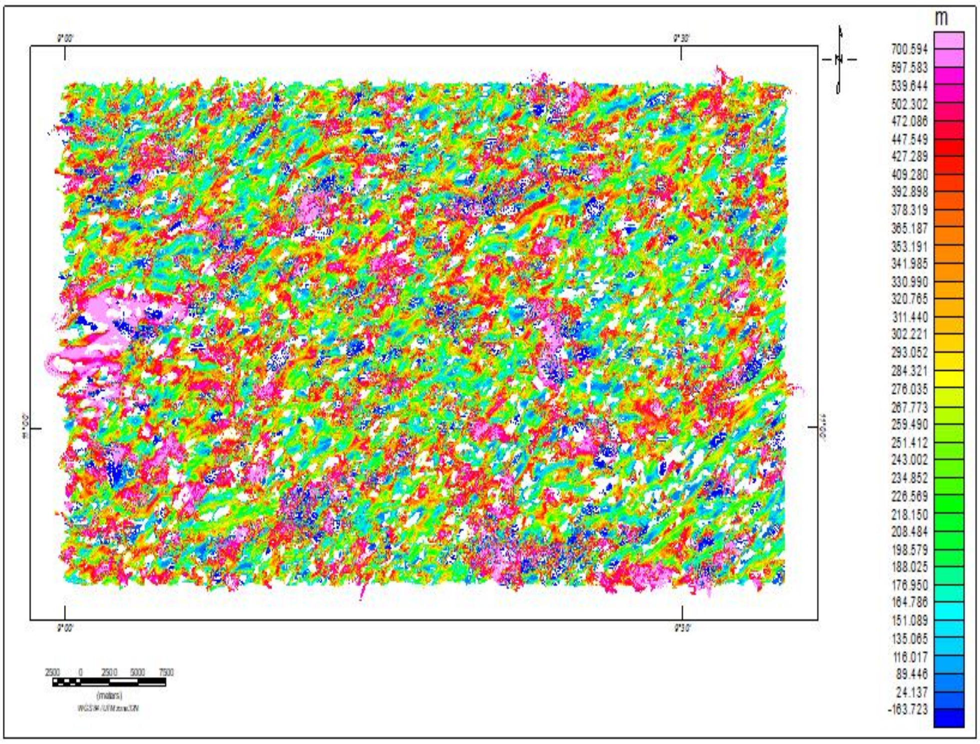


**Figure 3.7: Source Parameter Imaging (SPI) map obtained by selecting a magnetic structural index of 2 (i.e., SI=2 representing the depth of horizontal cylinders with 1 dimension (X-Y) and pipes with 2 dimension (Z).**

For dipping contacts with number of infinite dimensions X, Y, Z, the maximum values are located directly over the isolated contact edges and are independent of the magnetic inclination, declination, dip, strike, and any remnant magnetization. The depth is estimated at the source edge from the reciprocal of the local wave number (Figure 3.8).

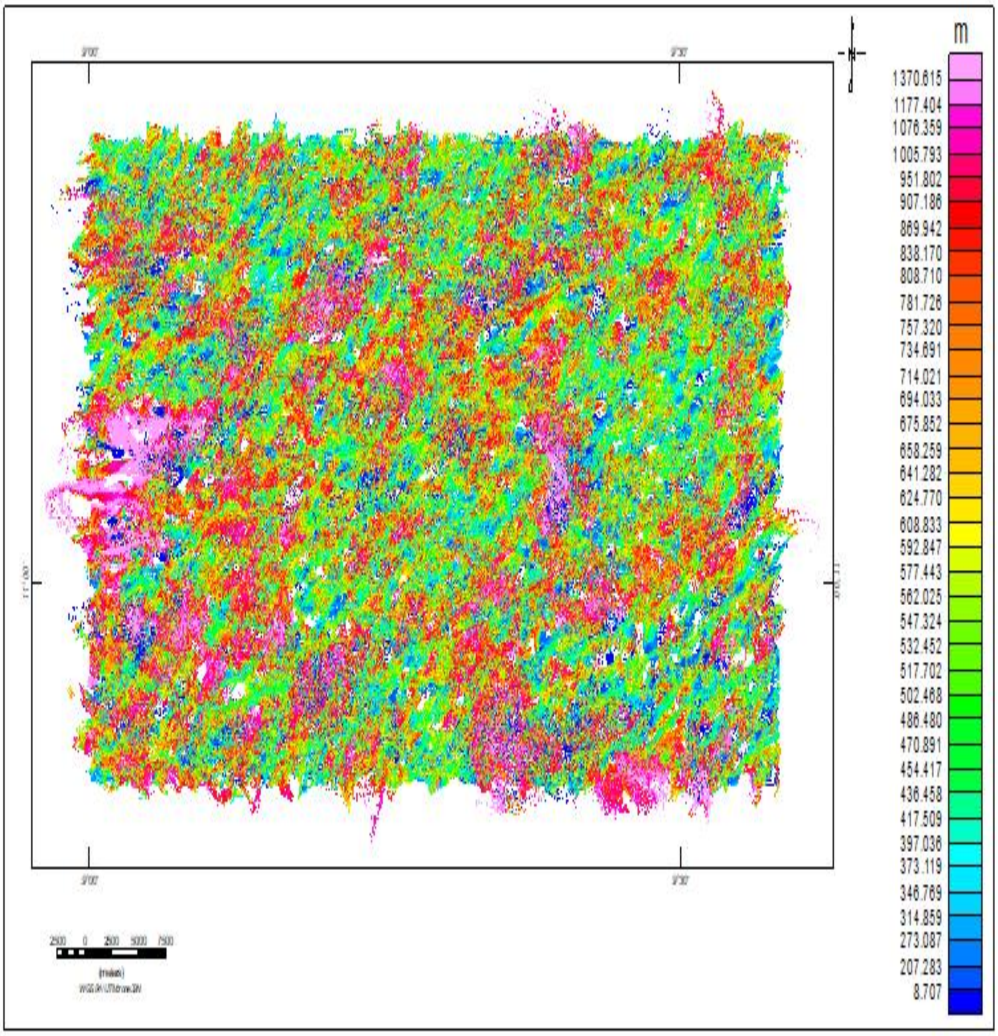


**Figure 3.8: Source Parameter Imaging (SPI) map obtained by selecting a magnetic structural index of 3 (i.e., SI=3 representing the depth of spheres with 0 dimensions).**

## DISCUSSION

Euler deconvolution and source parameter imaging technique confirms favorably with results of other researchers such as Kamba and Ahmad (2017). The source parameter map corresponds greatly with the residual magnetic field intensity and geologic map. The highest depth can be found at the east-western part of the study area. However, relatively higher depth is found around northern and southwestern parts of the study area. The result from SPI agrees to some extent with the result from spectral depth determination of Salako, (2014), Udensi and Osazuwa, (2004).

## CONCLUSION

The total Magnetic Intensity (TMI) map over Ningi-Burra Younger Granite Complex shows values ranging from 31677.9nT to 33555.2nT, with Main Magnetic Field values ranging from 33841.2 nT to 33955.1 nT and the crustal magnetic field values ranges from -2177.7nT to -320.5nT. The crustal magnetic field map shows low magnetic susceptibility in areas of high magnetic values of -764.020 to -723.261 and -822.169 to -764.020 while more magnetic susceptibility areas are depicted as low magnetic values -1298.439 to -1082.708 and -1082.708 to -965.771.

The maps produced revealed the nature and distribution of deep-seated structures, with the depth obtained by SPI values ranges from 158.3 to 569.7m, indicating deep seated bodies dominated the area. The deeper magnetic sources are at the depth of -163.723m to the basement, while the highest depth to the shallower magnetic source (which represents the extrusive bodies), is at 700.594m.

Euler solution was obtained by selecting a structural index of 1, 2 and 3 giving a depth values ranging from 8.787-1370.615, -163.723-700.594, 8.787-1370.615 meters respectively.

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