

Depth Estimation of Digitized Aeromagnetic Data of the Western Part of the Younger Granite Rocks of North Central Nigeria, West Africa

¹S.C. Alkali, ²S. Gaiya and ²B. Abba Musa

¹Department of Geology, University of Maiduguri, Nigeria

²Department of Applied Science, Kaduna Polytechnic, Kaduna, Nigeria

Abstract: The present study is aimed at estimating the depths extents of aeromagnetic anomalies over the younger granite rocks and their associates in the western part of North Central Nigeria. The Younger Granites rocks of North Central Nigeria are characterized by total magnetic intensity values ranging from 32670 to 33070 nanoTesla (nT). Most of the anomalous features trend in the northeast-southwest direction. Medium to higher magnetic intensity values occupy more than three quarter of the area. Third order polynomial trend surface fitting performed by least squares produced positive regional field without preferred direction. Higher regional field values are observed along the southern region and lower ones around the northeast. The surface residual anomaly has values between 32660 and 33061 nT. E-W, NE-SW and NNW-SSE are the main structural directions of the residual anomalies. Individual anomalies suggest discontinuity of the rock units. Residual anomalies of the total magnetic intensity fields fitted with third degree polynomial regional curves along four profiles produced both negative and positive values. Segments of the profiles with little variations are considered magnetic 'quiet' environments and those showing considerable variation are 'noisy' and indicate magnetic sources in the subsurface. Two and a half dimensional models of the subsurface structures suggest deep seated fault along the profiles that attained maximum depths of 12.0 km each along sections Mag1 and Mag2; 13.0 km along Mag3 and 26.6 km along Mag4. The steepness of the magnetic sources suggest possible relative displacement of the blocks of the rock bodies of these magnitudes. The fault correlate with Romanche fracture zone which, if extrapolated into Nigerian landmass will pass through the area diagonally in a NE-SW striking direction.

Keywords: Fault, magnetic intensity, polynomial, residual anomaly, rock units

INTRODUCTION

The topography of Nigeria is influenced by planar and linear structures resulting from ductile and brittle deformational events (Onugba and Eduvie, 2003). The structures generally have N-S, NE-SW, NW-SE and sometimes E-W trends (Wright, 1976; Oluyide, 1988; Udoh, 1988; Olasehinde and Awojobi, 2004). Regional strikes of foliations in basement rocks, lithologic boundaries, fold axes and axial planes maintain the N-S Pan-African imprint. Numerous fractures and faults formed river valleys all over the country.

Local lineaments are mostly fracture lines defined by joints that formed as a result of tensional stresses. These form a network cross cutting each other, which generally decrease in width and size with increase in depth, as they are commonly sealed up at depth by the lithostatic pressure and/or siliceous materials. Because geologic features are often large, structural analyses are conducted on regional scales, to provide a comprehensive look at the extent of faults, lineaments and other structural features. Thus the applications therefore require small-scale

imagery to cover the extent of the element of interest. This study is intended to obtain information about the depths to magnetic sources, their shapes and sizes. Accordingly it will help in gaining better understanding of the structural set-up in the area.

The study area constituting the western part of the Younger Granite complex of North Central Nigeria is shown in Fig. 1. It is bounded by latitudes 9°00' N and 10°00' N and longitudes 8°00' E and 9°00' E. and comprises the Federal Survey of Nigeria sheets 167 (Kafanchan), 168 (Naraguta), 188 (Jema'a) and 189 (Kurra) in Kaduna and Plateau States, Nigeria. The objective of the study is to determine the existence of prominent deep seated structure that may be correlated with the Romanche Fracture Zone in the intraplate landmass of Nigeria.

LITERATURE REVIEW

The Younger Granite Province comprises of Precambrian to Lower Paleozoic basement rocks into which the Younger Granites suites are emplaced

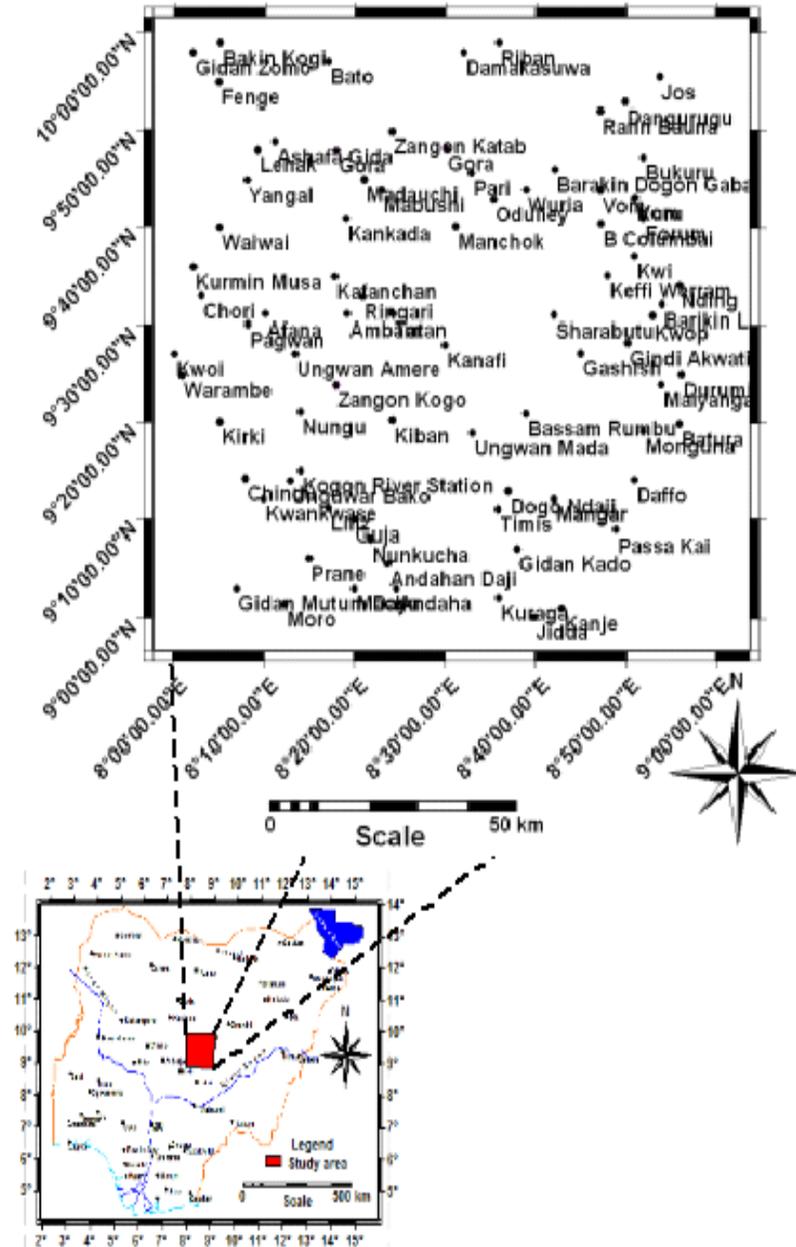


Fig. 1: Location map of the study area

(MacLeod *et al.*, 1965). The basement rocks cover about three quarters of the province and consist of ancient sediments (MacLeod *et al.*, 1965; Oyawoye, 1964, 1972).

Electrical resistivity and magnetic methods were first used in the northern part of the study area along buried channels that contained cassiterite, columbite and other accessory resistant minerals (Shaw, 1951). Magnetic, seismic, resistivity and gravity methods covered alluvial cassiterite (Masson-Smith, 1965). Gravity surveys carried out by Ajakaiye (1968, 1974, 1976) across the Younger

Granite province show negative Bouguer anomalies ranging from -94 to -25 mGals

Four major oceanic fracture zones cut the Atlantic coast to the northeast on approaching the coast of Guinea at the north and terminated at a relatively short distance inland (Burke, 1969; Grant, 1971; Le Pichon and Hayes, 1974). They seem to have developed near pre-existing zones of weakness inherited from previous orogenic activities in the continents (Sykes, 1978). Aeromagnetic anomalies and tectonic trends in and around the Benue

Trough of Nigeria show that the Nigerian continental landmass contains lineaments with definite magnetic signatures (Ajakaiye *et al.*, 1986) which, are enhanced by the presence of anorogenic ring complexes. The studies of Ajala (1990) near Kaltungo and Ekanem (1992) around the Kerri-Kerri Formation offered evidences on extrapolation of fracture zones into the northeast continental landmass.

General geology: The Younger Granite rocks are discordant, high-level intrusions, which transgressed all units of the basement complex. They were preceded by acid volcanism and emplaced by ring faulting and block subsidence. Granites and rhyolites underlay major parts of the province. Intermediate and basic rocks occur. Emplacement of the Younger Granites is associated with epeirogenic uplift (Turner, 1989). Their age is Jurassic. The Older Granites and accompanying metamorphism of the basement are Pan African age (Jacobson *et al.*, 1958; van Breeman and Bowden, 1973). A great variety and number of the Younger Granite complexes exhibit different degrees of erosion. The large complexes involved greater volumes of magma.

Volcanic rocks in most of the complexes have either been obliterated by later granite intrusions or eroded to an extent that their original pattern of distribution is conjectural. Where the lavas are preserved, they are confined within the major peripheral ring faults. The early groups are products of vent intrusion from group of vents aligned along ring-fractures. The fractures extended to the surface and provided zones of weakness that facilitated the upward passage of the magma. These same ring-fractures often served as the loci of intrusion of the large ring-dykes. Pyroclastic rocks are abundant and there are thick interactions of tuffs and coarse agglomerates within the lava succession.

Emplacement of ring-dykes within circular and polygonal features initiated many of the intrusive cycles. The emplacement of the ring-dykes directly succeeded the volcanic cycle and many of the initial ring-fractures, which control the distribution of the volcanic eruptions, also served as the loci of the ring-dykes. The ring dykes are generally steep structures and contact dipping outwards at angles less than 80° are uncommon. Some of the ring dykes are as much as 2 km in widths. In the Younger Granite province there is a practically continuous sequence of intrusives formed from the narrow ring dykes to large irregular granite plutons. Many of the smaller granite intrusions represent the upper, flat-lying roof sections of the ring intrusions and, some of these are remarkably shallow in comparison with their lateral dimensions. Others are stock and bosses with steeply dipping contacts, which probably continued to a considerable depth.

METHODOLOGY

The data for this study consist of digitized aeromagnetic data of the western part of the Younger Granite complex. The study conducted in April, 2011 forms part of the Younger Granite Complex of North Central Nigeria.

Main softwares used in the analyses of the digitized aeromagnetic data are Integrated Land and Watershed Information System 3.3 (2005) (ILWIS 3.3 Academic, 2005), Surfer8 (2003), Grapher5 (2004), OriginLab7 (2002) and Cooper (2003). ILWIS was applied in digitizing, extracting and proper positioning of prominent features using the Universal Transverse Mercator (UTM) system. Third order regional polynomial trend surface was fitted to the total magnetic intensity field in the same environment to obtain a general surface view of the residual anomaly. Also third order polynomial fitting along four profiles was used to remove the regional anomaly field from the total magnetic intensity field in an OriginLab7 environment to obtain the residual anomaly field used for depth estimation of the anomalies. Surfer8 and Grapher5 were used to plot some terrain models.

The coordinate system projection parameter adopted for the study comprises the Universal Transverse Mercator system with Nigeria and Minna as the datum area and datum respectively. Since the area is located south of 5°N latitude and south of the equator, the Clarke 1880 ellipsoid was used and the central meridian scale factor of 0.9996 used to measure distances on the maps.

Anomaly fields: Figure 2 shows a raster map of total magnetic intensity field. The field range from 7670 to 8070 nanoTesla (nT) which the value of 25000 nT is to be added to every contour level. Lower values occupy the extreme northwest, the northeast, the central and the southeast regions. A smaller part of the same values is observed from the extreme north northeast region. Most of the anomalous features trend in the northeast-southwest direction. Northwest-southeast structural trend is secondary in occurrence. Medium to higher magnetic intensity values occupy more than three quarter of the area, mainly along the southwest, the west and parts of the north and northeast.

Potential field data are the sum of the effect of all sources causing the anomaly. Residual mapping eliminates or reduces to minima the effects of deep-seated, non-commercial sources with little distortion of the resultant anomaly.

Third order polynomial trend surface fitting performed by least squares in an ILWIS environment defined the regional field in Fig. 3.

The regional field has no preferred direction, however, higher regional field values are observed along the southern region and lower ones around the northeast. Intermediate regional field values are recorded around the central, northwest, north and parts of the southeast regions.

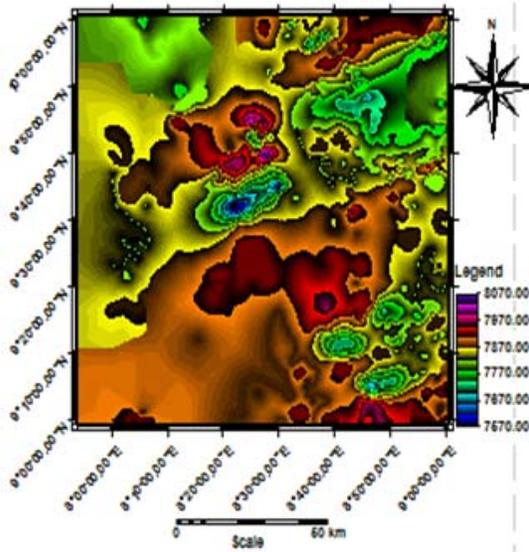


Fig. 2: Total magnetic intensity map

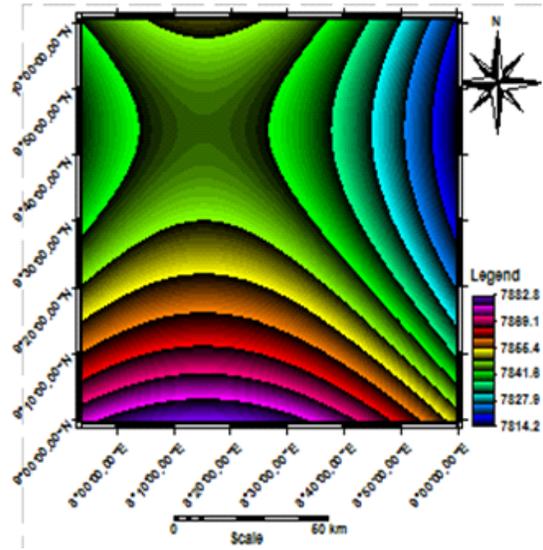


Fig. 3: Regional anomaly field

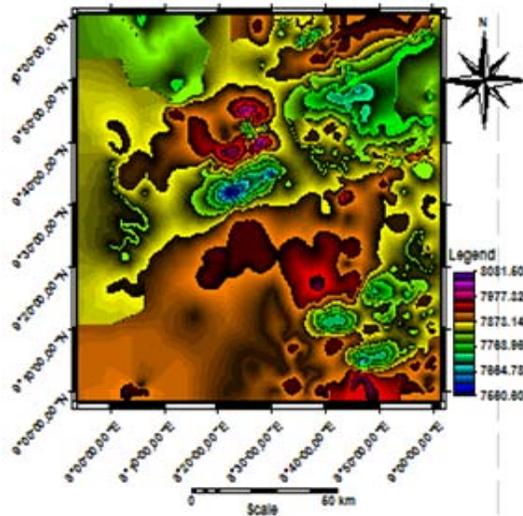


Fig. 4: Residual anomaly field

Figure 4 is a raster map of the residual magnetic anomaly field after subtracting the regional anomaly field from the total magnetic intensity field. The field is characterized by positive values between 7660 and 8061 nT. The patterns and structural trends of the residual anomaly and the total magnetic intensity fields are similar, where lower values probably rest upon the intrusive younger granite rocks while areas underlain by basic and intermediate rocks are causative anomalies of higher residual anomaly values.

Quantitative interpretation of the residual anomaly:

The essence of quantitative interpretation is to obtain information about the depth to the magnetic source, its

Table 1: Latitudes of residual anomaly cross sections

Profile name	Latitude
Mag1	9°54'34.22" N
Mag2	9°46'35.23" N
Mag3	9°34'57.26" N
Mag4	9°15'25.76" N

shape and size and detail about its susceptibility. The mathematical problem of the interpretation is that of finding the mass distribution of the anomaly fields on plane surfaces which is often confronted by non unique solution.

To minimize errors in interpreting the data, four horizontal sections cutting across prominent anomalous

features were chosen from top to bottom. Approximate latitudes along which the residual anomaly sections were derived are given by Table 1.

The total magnetic intensity field along the profiles were then fitted with third order polynomial regional curves using OriginLab7 (2002) software. The residual anomaly curves obtained by subtracting the regional background curves from the total magnetic intensity curves are given in Fig. 5a to d together with the total magnetic intensity and regional anomaly field curves.

The interpretation technique consists of identifying zones with different magnetic characteristics. Segments of the profile with little variations are considered magnetic 'quiet' and are associated with rocks with low susceptibility. Segments showing considerable variation are 'noisy' and indicate magnetic sources in the subsurface. Unlike the trend surface map where the residual anomaly values are all positive, these profile sections produced both negative and positive values which suggest that the curves are well fitted.

Prior to modeling the residual anomaly curves were filter with a three band low filter. The models assumed rock units with different susceptibilities, shapes and sizes. The accepted models along the smoothed curves are presented in Fig 6a to d.

RESULTS AND DISCUSSION

Profile section Mag1 has ten anomalous bodies (Fig. 6a) with susceptibility values from 0.00012 to 0.0039 SI units obtained from anomaly numbers 10 and 9, respectively. Minimum widths of 0.72 km and maximum of 22.29 km were recorded from anomaly numbers 6 and 8 respectively. The structural thicknesses vary from 6.0 km for anomaly number 9 to 12.0 km for anomaly number 8.

Profile section Mag2 shown in Fig. 6b also has 10 anomalous rock units. The minimum susceptibility value of 0.0014 SI units is obtained from anomaly number 3, while anomaly body number 1 has maximum susceptibility value of 0.0036 SI units. Anomaly number 10 extends a distance of 1.60 km while that of number 4

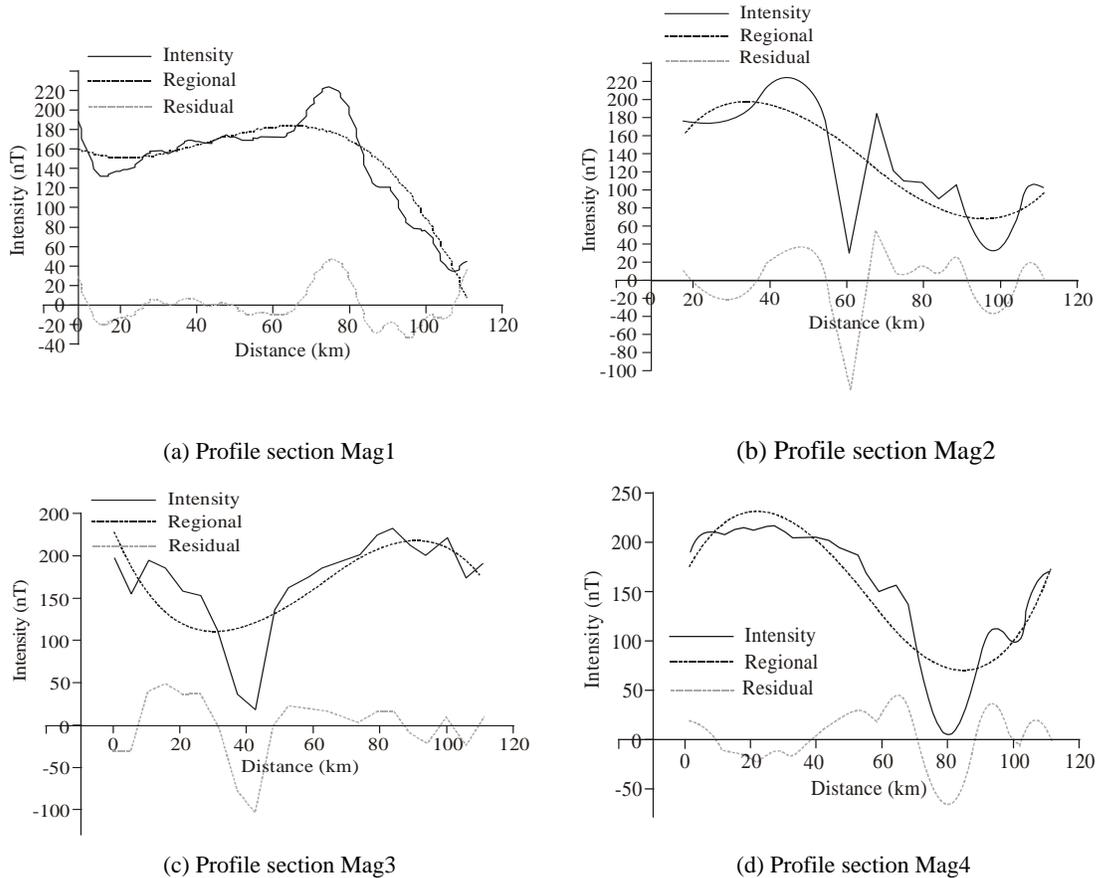
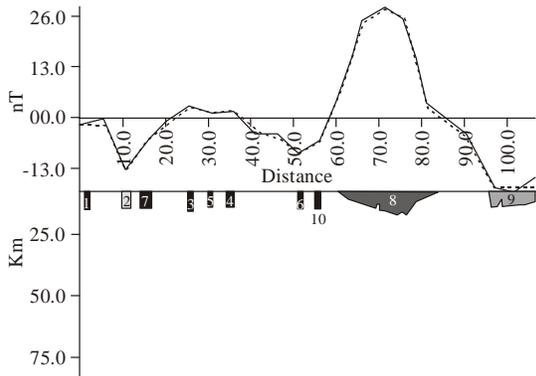
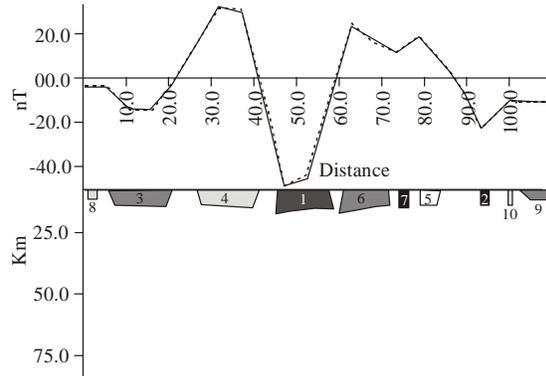


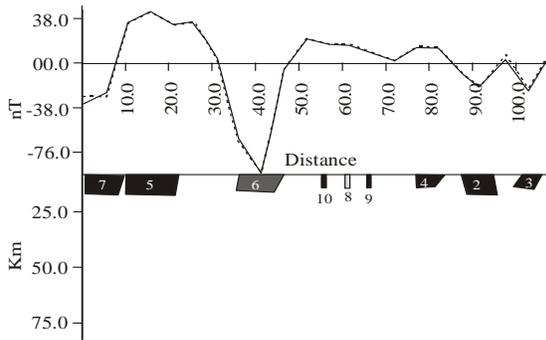
Fig. 5: Total magnetic intensity, regional anomaly and residual anomaly curves along profile sections



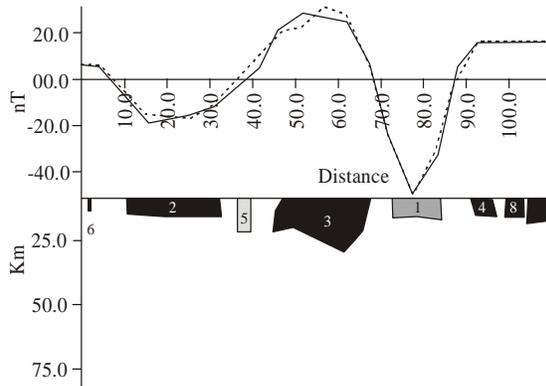
(a) Profile section Mag1



(b) Profile section Mag2



(c) Profile section Mag3



(d) Profile section Mag4

Fig. 6: Interpreted models along the profiles

has lateral dimension of 14.56 km. The lowest thickness value of 4.3 km was obtained from anomaly number 8 and the highest thickness of 12.0 km was observed from body number 1.

Minimum and maximum susceptibility values (0.0014 and 0.0105 SI units) occur over anomalies 4 and 1 respectively Fig. 6c. Estimated widths of 0.57 and 12.56 km are the lowest and highest values observed from anomaly numbers 8 and 5, respectively. Minimum thicknesses of 6.6 km were each calculated for the anomalies 9 and 10. Anomaly number 2 possesses maximum thickness of 12.5 km.

The bottom profile section Mag4 is shown by the interpreted model in Fig. 6d. The section has minimum and maximum susceptibility values of 0.0012 and 0.0042 SI units over anomalies 4 and 1, respectively. Lateral extensions of 0.23 km (minimum) and 22.28 km (maximum) were recorded from anomalies 6 and 3 respectively. Thicknesses of 8.2 and 26.6 km are the minimum and maximum values determined over anomaly bodies 6 and 3, respectively.

CONCLUSION

The Younger Granites rocks of North Central Nigeria are characterized by total magnetic intensity values ranging 32670 to 33070 nT. The residual anomaly values fall between 32660 to 33681 nT. Three degree trend surface regional fitting of the total magnetic intensity field also produced positive values surface map of the residual anomaly field. Cross section of the residual anomaly values are both negative and positive. E-W, NE-SW and NNW-SSE are the main structural trends of the residual anomalies. Individual anomalies suggest discontinuities of the rock units. Two and a half dimensional modeling of the subsurface structures suggest existence of a prominent deep seated fault along the profiles. The fault attained depth maxima of 12.0 km along sections Mag1 and Mag2, 13.0 km along Mag3 and 26.6 km along Mag4. The steepness of some of the residual anomaly rock units suggests possible relative displacement of the blocks of the rock bodies of these magnitudes. The fault correlate with Romanche fracture zone which, if extrapolated into the Nigerian landmass will cut across the study area.

REFERENCES

- Ajakaiye, D.E., 1968. A gravity interpretation of the lurei younger granite ring complex of northern Nigeria. *Geol. Mag.*, 105: 256-263.
- Ajakaiye, D.E., 1974. Gravity Profile across the banke ring complex, Nigeria. *Geoexploration*, 12: 59-66.
- Ajakaiye, D.E., 1976. Density of Rocks in the Nigerian Younger Granite Province. In: Kogbe, C.A., (Ed.), *Geology of Nigeria* Elizabethan Publishing Co., Lagos, Nigeria, pp: 225-233.
- Ajakaiye, D.E., D.H. Hall, T.W. Miller, P.J.T. Verheijen, M.B. Award and S.B. Ojo, 1986. Aeromagnetic anomalies and tectonic trends in and around the benue trough Nigeria. *Nature*, 319: 582-584.
- Ajala, S.W., 1990. Gravity anomaly and tectonic trend in gombe area inferred correlation with the chain fracture zone. M.Sc. Thesis, University of Jos, Nigeria.
- Burke, K., 1969. Seismic areas of the guinea coast where atlantic fracture zones reach Africa. *Nature*, 222: 655-657.
- Cooper, G.R.J., 2003. *Geomodel for Windows*. School of Geosciences, University of the Witwatersrand Johannesburg, South Africa. Retrieved from: www.wits.ac.za/science/geophysics/gc.htm.
- Ekanem, K.E., 1992. Gravity anomaly trend in and around the kerri-kerri basin: Inferred correlation with the romanche fracture zone. M.Sc. Thesis, University of Jos, Nigeria.
- Grant, N.K., 1971. South atlantic, benue trough and gulf of guinea cretaceous triple junction. *Geol. Soc. Amer. Bull.*, 82: 2295-2298.
- Grapher5, 2004. *Graphing System*. Golden Software Inc. Golden, Colorado. Retrieved from: www.goldensoftware.com.
- ILWIS 3.3 Academic, 2005. ITC, RSG/GSD.
- Jacobson, R.R.E., W.N. MacLeod and R. Black, 1958. Ring Complexes in the Younger Granite Province of Northern Nigeria. *Geological Society of London, Mem.*, 1: 72.
- Le Pichon, X. and D.E. Hayes, 1974. Marginal offset fractures zones and the early opening of the South Atlantic. *J. Geophys. Res.*, 76: 6283-6293.
- MacLeod, W.N., D.C. Turner and E.P. Wright, 1965. The geology of the jos plateau. *General Geol. Survey Niger. Bull.*, 1(32): 118.
- Masson-Smith, D., 1965. *Geophysical Prospecting for Basalt Covered Cassiterite on the Jos Plateau, Northern Nigeria*. Oversea Geological Survey, Geophysical Report, London, No. 27.
- Olasehinde, P.I. and M.O. Awojobi, 2004. Geological and geophysical evidences of a north-south fracture system east and west of the upper gurara river in central Nigeria. *Water Resour. J. Niger. Associ. Hydrogeol.*, 15: 33-37.
- Oluyide, P.O., 1988. *Structural Trends in the Nigerian Basement Complex*. Precambrian Geology of Nigeria. Geological Survey of Nigeria Publication, Nigeria, pp: 93-98.
- Onugba, A. and O.M. Eduvie, 2003. *Hydrogeology of Nigeria*. Paper on Groundwater Workshop, Organized by UNICEP, Jos., pp: 20.
- OriginLab7, 2002. *Scientific Graphing and Analysis Software*. OriginLab Corporation. Northampton, U.S.A. Retrieved from: <http://www.OriginLab.com>.
- Oyawaye, M.O., 1964. The geology of the nigerian basement complex. *J. Niger. Min. Geol. Metall. Soc.*, 1(2): 87-103.
- Oyawaye, M.O., 1972. The Basement Complex of Nigeria. In: Dessauwagie, T.F.J. and A.J. Whiteman, (Eds.), *Africa Geology*, University of Ibadan, pp: 67-99.
- Shaw, S.H., 1951. *Report on Magnetic and Resistivity Work in the Plateau Tinfield*. Oversea Geological Survey Report, London.
- Surfer8, 2003. *Surface Mapping System*. Thematic Mapping System. Golden Software Inc., Golden, Colorado. Retrieved from: www.goldensoftware.com.
- Sykes, L.R., 1978. Intraplate seismicity, reactivation of preexisting zones of weakness, alkaline magmatism and other tectonism postdating continental fragmentation. *Rev. Geophys. Space Ge.*, 16(4).
- Turner, D.C., 1989. Structure and Petrology of the Younger Granite Ring Complexes. In: Kogbe, C.A., (Ed.), *Geology of Nigeria*. Rock View International, France, pp: 175-190.
- Udoh, A.N., 1988. An Interpretation of Satellite Imageries of Nigeria 7°40'N. *Precambrian Geology of Nigeria*. Geological Survey of Nigeria Publication, Nigeria, pp: 99-102.
- Van Breeman, O. and P. Bowden, 1973. Sequential age trend for some nigerian mesozoic granites. *Nature Phys. Sci.*, 242: 9-11.
- Wright, J.B., 1976. Fracture system in nigeria and initiation of fracture zones in the south Atlantic. *Tectonophysics*, 34: 43-47.