Delineation of Linear Structures From Digitized Aeromagnetic Data of The Western Part of The Younger Granite Complex of North Central Nigeria

S. C. Alkali[1] and Gaiya S.[2]

Department of Geology, University of Maiduguri, Nigeria
e-mail: samailacrahalkali@yahoo.com
Department of Applied Science,Kaduna Polytechnic,Kaduna, Nigeria
e-mail: gaiyastephen@ymail.com

ABSTRACT: Residual magnetic anomaly field shows lower values resting upon intrusive younger granite rocks. Regions underlain by volcanic rocks and their associates are characterized by higher anomalies. Structurally the southwestern part is situated upon a relatively quite environment; the northeastern, north central and southeastern regions are characteristics of severed tectonic events. Linear structures are oriented in the N - S, NE – SW, NNE - SSW, NW – SE, E – W and ENE – SWS directions. Digital elevation model shows more than seventy five percent of the lineaments confining within the eastern side of the northwest corner to the southeast margin diagonal line. Individual lineaments exceeding 20 km long are deep-seated in origin and may represent regional subsurface faulting. Minor lineaments attained lateral dimensions shorter than 20 km. They are shallow structures and consist essentially of joints, veins and so on. Analyses of major and minor fracture lines on bidirectional rose diagrams organized into class intervals of 15^o recorded five classes for the major lineaments and four for the minor ones. The main structural units of the rose diagrams are oriented along the N – S, NE – SW, NNE – SSW, NW – SE and NNW – SSE directions. The NE - SW and NNE - SSW trending lineaments are interpreted as belonging to major fracture lines, which probably controlled the emplacement of the granite and the NE – SW trending joints. The NE - SW set is therefore interpreted as representing fractures associated with major movements attributable to past tectonics activities. Pegmatite zones and quartz veins are associated with the NNE – SSW linear structures.

[S. C. Alkali[1] and Gaiya S. **Delineation of Linear Structures From Digitized Aeromagnetic Data of The Western Part of The Younger Granite Complex of North Central Nigeria.** New York Science Journal 2011;4(9):56-62]. (ISSN: 1554-0200). http://www.sciencepub.net/newyork.

Keywords: magnetic anomaly; tectonic; lineaments; fractures; bidirectional rose

1. Introduction

Internal movements within the earth generate stresses that are capable of deforming rocks. The deformation occurs in brittle ways, where the rocks change shape by fracturing. Joints are the most common fractures (Maltman, 1990). Virtually every rock exposure has joints in it. Joints and other geological structures are linear structures or lineaments. The presence of these geological structures in rocks favours migration and trapping of fluids on the surface or within the subsurface. One of the main tasks in geology is the recognition of lineaments. The traditional approach involves the inspection of rock outcrops. However, because of their limited breath and continuity many segments of lineaments may be overlooked on the ground. The small and localized effects of such segments exposed discontinuity from one outcrop to another, and are often insufficient to reveal their rectilinear relationship. 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. The applications therefore require small-scale imagery to cover the extent of the element of interest.

The study is intended to delineate linear structures from the area using digitized aeromagnetic data so as to gain better understanding of the structural set-up of 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^{o}00’ N and 10^{o}00’ N and longitudes 8^{o}00’ E and 9^{o}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.

2. Literature review

The Younger Granite Province comprises of Precambrian to Lower Paleozoic basement rocks into which the Younger Granites suites are emplaced (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 and 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 were later used in the search for basalt covered alluvial cassiterite (Masson-Smith, 1965). Gravity surveys carried out by Ajakaiye (1968, 1974 and 1976) across the Younger Granite province show negative Bouguer anomalies 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 (Syke, 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 works of Ajala (1990) near Kaltungo and Ekanem (1992) around the Kerri-Kerri Formation offered evidences on extension of fracture zones into the northeast continental landmass of Nigeria.

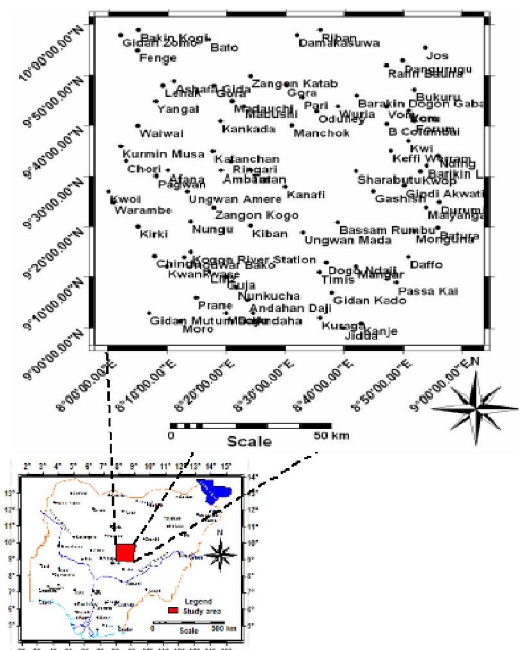


Fig. 1: Location map of the study area

3. 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.

The Volcanic rocks in most of the complexes have either been obliterated by later granite intrusions or eroded to the 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. Emplacement of 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^o are uncommon. Some of the ring dykes have lateral dimensions as much as two kilometres 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.

4. Methodology

The data for the research work consist of digitized aeromagnetic data of the western part of the Younger Granite complex. Main softwares used in the analyses of the digitized aeromagnetic data are Integrated Land and Watershed Information System3.3 (2005) (ILWIS 3.3), Surfer8 (2003), Grapher5 (2004) and OriginLab7 (2002). 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 extraction of the lineaments. Surfer8 and Grapher5 were used to plot some terrain models and constructions of rose diagrams.

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 respectivelty. 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 was used to measure distances on the maps.

5. The total magnetic intensity

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

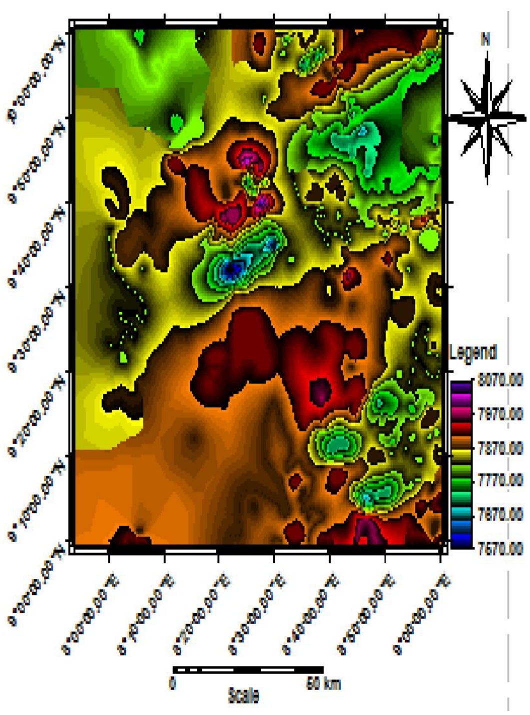


Fig. 2 Total magnetic intensity field

6. Regional anomaly

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

Third order polynomial trend surface fitting was performed on the total magnetic intensity map by least squares technique in an ILWIS environment to define the regional anomaly field given in Fig. 3.

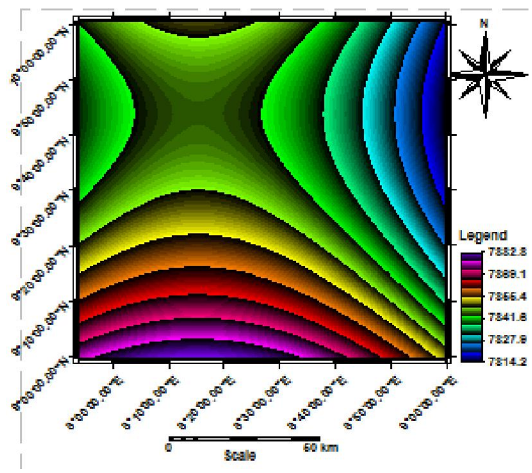
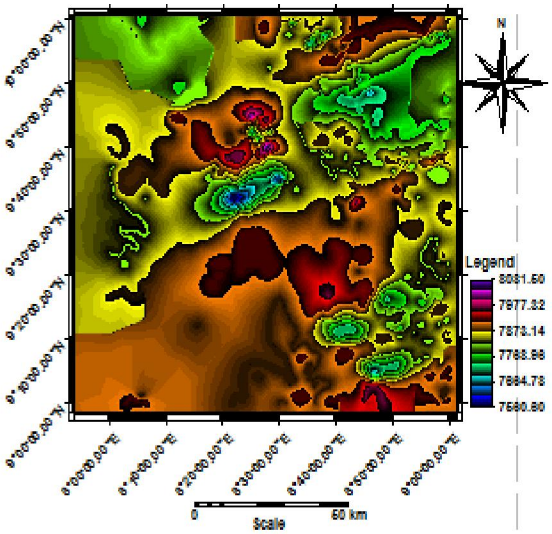


Fig. 3 Regional anomaly field

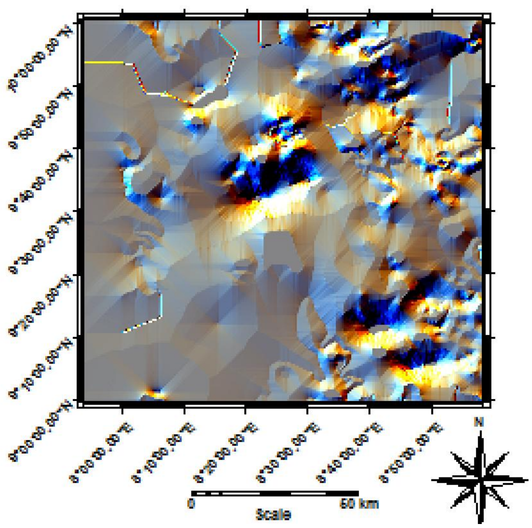
The trend surface regional anomaly field shows no preferred orientation direction. Higher regional values underlay the southern region and lower ones characterized the northeastern part. The central, northwestern, northern and parts of the southeast are underlain by regional anomaly fields of intermediate values.

7. Residual anomaly

Figs. 4a &b show raster and digital elevation model (DEM) images of the residual magnetic anomaly field after subtracting the regional anomaly field from the total magnetic intensity field. The field is characterized by values between 7660 and 8061 nT (Fig. 4a). The patterns and structural trends of the residual anomaly and the total magnetic intensity fields are similar, where lower values probably rest upon intrusive younger granite rocks and, areas underlain by volcanic rocks and their associates are the causative sources of the higher values. Major structural units and orientation directions are obvious from the DEM image in Fig. 4b. Here the southwestern part seems to be situated upon a relatively quite environment. Also from the figure, the northeastern, north central and southeastern regions responded to pronounced tectonic events. Linear structures are oriented in the N - S, NE – SW, NW – SE, NNE - SSW, E – W and ENE – SWS directions. The NE – SW structural trend lineaments are dominant in the area.



a.



b.

Fig. 4 Residual anomaly field (a). Raster and (b): Digital elevation model (DEM)

8. Lineaments

Lineaments extracted by the author from the DEM map of the residual anomaly in ILWIS 3.3 (2005) environment are shown in Fig. 5. Diagonally from the northwest corner to the southeast angle, more than seventy five percent of the lineaments are confined towards the right hand side of the figure. This further suggests major tectonic activities in the continent.

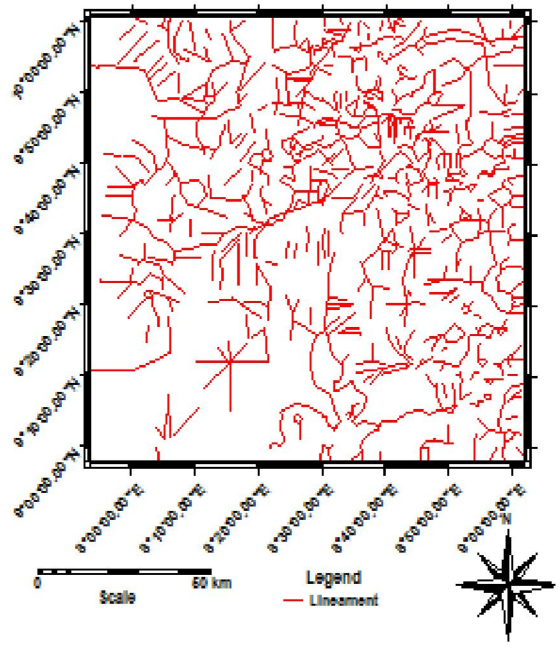


Fig. 5 Lineaments map

9. Lineament direction histogram

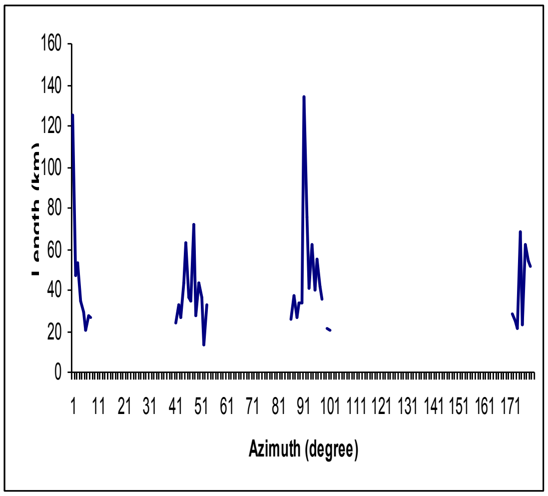
Figs. 6a & b show the magnitudes of individual lineament orientation.. The lengths of the lineaments are plotted against their respective azimuths. The magnitudes of the individual lineament that exceeded 20 km long in Fig. 6a are assumed to be deep-seated in origin and may represent regional subsurface faulting. Linear structures that are less than 20 km long shown in Fig. 6b are shallow in origin and may include joints, veins etc that occur locally.

10. Rose diagram

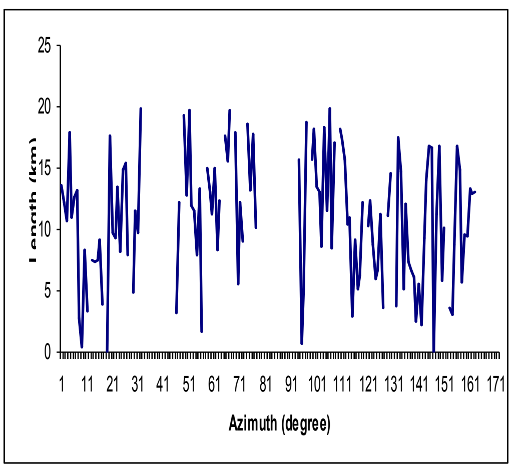
Directional analyses of major and minor fracture lines are presented on bidirectional rose diagrams in Figs. 7a & b. The trend and/or strike direction of the rose diagrams data are organized in class intervals of 15^o. Each class represents the number of occurrences of the events that fall within the specified angular region. A family of concentric circles provides scaled control for the number of fracture-orientation observations that occupy each class interval. The number of points from the selected data column controlled the bar length within each class. Five class intervals are recorded in Fig. 7a and four in Fig. 7b.

Directional rose diagram in Fig. 7a revealed sixty three data points within the class interval 000^o - 0015^o. Eighteen fracture orientation observations occupy class interval 015^o - 030^o. Angular regions 030^o - 045^o and 330^o - 345^o revealed ten data points each. Striking lineaments observed within the angular regions of 045^o – 060^o and 315^o - 330^o have the lowest numbers of five data points each.

Structural lines within class interval 345^o – 000^o in Fig. 7b have seventy data points. Those within 330^o - 345^o revealed ten data points. Fifty fracture orientation events are contained in the 315^o - 330^o class and the 300^o – 315^o class interval contains only fifteen observational events.



(a) Major fractures

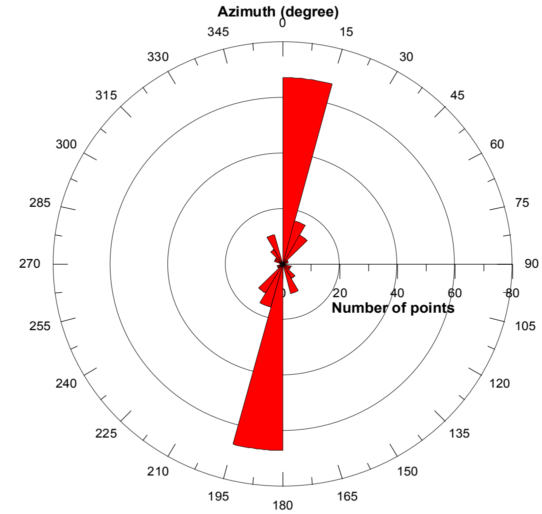


(b) Minor fractures

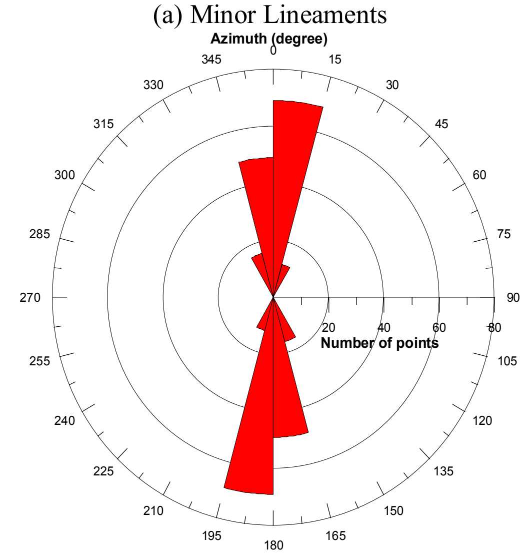
Fig. 6 Individual fracture orientations

11. Discussion

The lineaments in Fig. 5 are classified into major and minor features. The major lineaments in this context comprise structural features longer than 20 km (see Figs. 6a & 7a). Such structures are interpreted as being deep seated and tectonic in origin. The minor lineaments attained lateral dimensions that are shorter than 20 km (Figs 6b & 7b). They are shallow structures and consist essentially of joints, veins etc. The individual joints could be metres or tens of metres in length; however, they may form in sets that could have regional continuity.



(a) Minor Lineaments



(b) Minor lineament

Fig. 7 Directional rose diagram

The longer peaks in the sector of Fig. 6a indicate higher density of linear structures. The long narrow peaks depict well defined sets of directions. The shorter lineaments in Fig. 6b have greater tendencies of being shallower structures.

Structural units within class interval 000^o – 030^o are oriented in the NNE – SSW direction. NE – SW linear features lie within the class interval 030^o – 060^o. Linear features within the 330^o – 000^o class has NNW – SSE trend and, the 300^o – 330^o family strike in the NE – SW direction. Thus lineaments in the area are oriented along four main directions which are NE – SW, NNE – SSW, NW – SE and NNW.

The N – S linear direction may be added among these four fractures.

The NE - SW and NNE - SSW trending lineaments is interpreted as belonging to a major fracture system, which probably controlled the emplacement of the granite and NE – SW trending joints. The NE - SW set is therefore interpreted as belonging to fractures associated with major movements. The origin of the causative mechanism is attributed to tectonics activities (Alkali and Yusuf, 2010). The lineaments striking in the NNE - SSW direction probably represent zones of pegmatite and quartz veins (De Swart, 1953), which are frequently seen in the study area.

On regional scale the NNE - SSW lineaments probably represent the same trending fractures of the Nigerian Basement rocks described by Chukwu-Ike and Norman (1977); Oluyide (1988); Udoh (1988); Onyedim and Ocan (2001). According to the authors the trending fractures are major strike – slip faults, which controlled major drainage patterns, emplacement of the Older and Younger Granites and location of Cretaceous to Recent volcanic activity in Nigeria.

12. Conclusion

The Younger Granite complex of North Central Nigeria is characterized by five main directional lineaments. The NE – SW linear structures belong to fractures associated with major movement produced by previous tectonic forces. Pegmatite and quartz zones are associated with the NNE – SSW linear structures. NNW – SSE and NW – SE structural lines are probably produced by ductile and brittle deformational events that affected the Nigerian basement rocks.

Corresponding Author
Gaiya Stephen
Department of Applied Science,Kaduna Polytechnic,Kaduna, Nigeria
E-mail: gaiyastephen@ymail.com

References

1. Maltman, A., 1990: Geological Maps – An Introduction. John Wiley & Sons Ltd, Baffins Lane, Chichester, West Sussex, England, 184 p.
2. MacLeod, W, N., Turner, D. C. and Wright, E. P., 1965: The Geology of the Jos Plateau. Vol. 1; General Geology. Geolgical Survey of Nigeria. Bull. No. 32, 118 p.
3. Oyawoye, M. O., 1964: The Geology of the Nigerian Basement Complex. Journal of Nigeria Mining, Geology and Metallurgical Society, Vol. 1, No.2, pp 87 – 103.
4. Oyawoye, M. O., 1972: The Basement Complex of Nigeria. In: Dessauwagie T. F. J. and Whiteman A. J. eds. Africa Geology, University of Ibadan, pp 67 – 99.
5. Shaw, S. H.; 1951: Report on Magnetic and Resistivity Work in the Plateau Tinfield. Oversea Geological Survey Report, London.
6. Masson-Smith, D. 1965: Geophysical Prospecting for Basalt Covered Cassiterite on the Jos Plateau, Northern Nigeria. Oversea Geological Survey, London, Geophysical Report, No. 27.
7. Ajakaiye, D. E. 1968: A Gravity Interpretation of the Lurei Younger Granite Ring Complex of Northern Nigeria. Geol. Mag. 105, pp 256 – 263.
8. Ajakaiye, D. E. 1974: Gavity Profile across the Banke Ring Complex, Nigeria. Geoexploration 12, pp 59 - .66
9. Ajakaiye, D. E. 1976: Density of Rocks in the Nigerian Younger Granite Province. In Geology of Nigeria by Kogbe, C. A. (ed). Elizabethan Publishing Company. Lagos, Nigeria, pp 225 - 233.
10. Burke, K. 1969. Seismic Areas of the Guinea Coast where Atlantic Fracture Zones Reach Africa. Nature. 222 pp 655-657.
11. Grant, N. K. 1971: South Atlantic, Benue Trough and Gulf of Guinea Cretaceous Triple Junction. Geol. Soc. Amer., Bull 82, pp 2295 – 2298.
12. Le Pichon, X and Hayes, D. E. 1974: Marginal Offset Fractures Zones and the Early Opening of the South Atlantic. Journal of Geophysical Research, 76, pp 6283 – 6293.
13. Sykes, L. R.; 1978: Intraplate Seismicity, reactivation of Preexisting Zones of Weakness, Alkaline Magmatism and other Tectonism Posdating Continental Fragmentation. Reviews of Geophysics and Space Physics, 16(4
14. Ajakaiye, D. E.; Hall, D. H.; Miller, T. W., Verheijen P. J. T.; Award, M. B. and Ojo S. B. 1986 Aeromagnetic Anomalies and Tectonic Trends in and around the Benue Trough, Nigeria, Nature, 319 pp 582 - 584.
15. 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.
16. 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.
17. Turner, D. C.; 1989: Structure and Petrology of the Younger Granite Ring Complexes. In

Geology of Nigeria, Kogbe, C. A (ed), Rock View International, France, pp 175 – 190.

18. Jacobson, R. R. E., MacLeod, W. N. and Black, R. 1958: Ring Complexes in the Younger Granite Province of Northern Nigeria. Geological Society of London, Mem. 1, 72 p.
19. van Breeman, O. and Bowden, P., 1973: Sequential Age Trend for some Nigerian Mesozoic Granites, Nature Physical Sciences, 242, pp 9 – 11.
20. ILWIS 3.3 Academic, 2005: ITC, RSG/GSD. Holland.
21. Surfer8 (2003): Surface Mapping System. Thematic Mapping System. Golden Software Inc. Golden, Colorado. www.goldensoftware.com
22. Grapher5 (2004): Graphing System. Golden Software Inc. Golden, Colorado. www.goldensoftware.com.
23. Origin7 2002: Scientific Graphing and Analysis Software. OriginLab Corporation. Northampton, U. S. A. http://www.OriginLab.com.
24. Alkali, S. C. and Yusuf, S. N. (2010): Gravity Study over Jos – Bukuru Younger Granite Complex, North Central Nigeria. Scholars Research Library, Archives of Physics Research, 1(4), (http://scholarsresearchlibrary.com/archive.html), pp 178 – 191.
25. De Swart, A. M. J.; 1953: The Geology of the Country around Ilesha. Geological Survey of Nigeria, Bulletin 23, 154 p.
26. Chukwu-Ike, I. M. and Norman, J. W., 1977: Mineralized Crustal Failures shown on Satellite Imagery of Nigeria. Trans. Inst. Min. & Metall., 86, pp 55 – 57.
27. .Oluyide, P. O., 1988: Structural Trends in the Nigerian Basement Complex. Precambrian Geology of Nigeria. Geological Survey of Nigeria Publication, pp 93 – 98.
28. Udoh, A. N., 1988: An Interpretation of Satellite Imageries of Nigeria 7^{o}40'N. Precambrian Geology of Nigeria. Geological Survey of Nigeria Publication, pp 99 – 102.
29. Onyedim, G. C. and Ocan, O. O., 2001: Correlation of Spot Imagery Lineaments with Geological Fractures in part of Ilesha area, Southwestern Nigeria. Journal of Mining and Geology, Vol 37(1), pp 15 – 22.

8/23/2011