Tectonic Lineament Patterns from Geological and Ground Magnetic Study of Western Part of Adamawa Massif, North Eastern Nigeria

A. Yusuf, M.Sc.[1*]; Prof. N.E. Bassey[2]; J. Barka, M.Sc.[1]; and U.Y. Yaro, M.Sc.[3]

[1]Department of Geology, Gombe State University, PMB 0127, Gombe, Nigeria.
[2]Department of Geology, Akwa Ibom State University, Mkpat Enin, PMB 1167, Uoy, Nigeria.
[3]Department Geology, Abubakar Tafawa Balewa University, PMB 0248, Bauchi, Nigeria.

E-mail: abubakaryusuf1985@gmail.com*

ABSTRACT

Ground magnetic survey was conducted using G856-Memory-Mag™ Proton Precision Magnetometer and the Earth's magnetic field data acquired following a regular grid patterns. The aim of the survey is to delineate lineaments patterns and to relate them to the tectonic frame work of the Adamawa Massif of northeastern Nigeria.

The study area is composed of granite gneisses, biotite hornblende gneiss and porphyritic granites. Iron mineralized veins and non-mineralized fractures (joints and faults) were found to be predominantly oriented in a NE-SW and NW-SE trends. The magnetic anomalies observed after subjecting the potential field data to Horizontal Derivative filtration technique shows conformity with the direction of flows of rivers and stream channels found in the study area (this indicates structural control of the rivers and streams). These orientations are also concordant with the trends of structural features (foliation/fractural) mapped in the Adamawa Massif of northeastern Nigeria. The present research work has thrown more light on the geology and tectonics of the area.

(Keywords: Adamawa Massif, lineaments, magnetic anomalies, tectonic)

INTRODUCTION

The study area is located in the western part of the Adamawa massifs of northeastern Nigeria and lies between longitudes $11^0\ 50^/$ E and 12^0 00' E and latitudes $8^0\ 49^/$ N and $8^0 55$` N (Figure 1). It covers a total area of 205.35 km2. The area is drained by a number of rivers such as Rivers Tuwan, Kasale, Belwa, Vanmu, Yuwel and Darado. Climatic condition in the area is typical of northern part of Nigeria (i.e., characterized by both dry and wet seasons). The dry season begins from November and ends in March while, the wet season begins from April and ends in October. The area is characterized by a sparse vegetation with very few highly elevated terrains surrounded by settlements like; Wuro Gboki, Zabi, Sakla, Ganglamja, and towards the southeast of Mbambe Fulani settlement, and a generally flat plain covering about 95% of the study area.

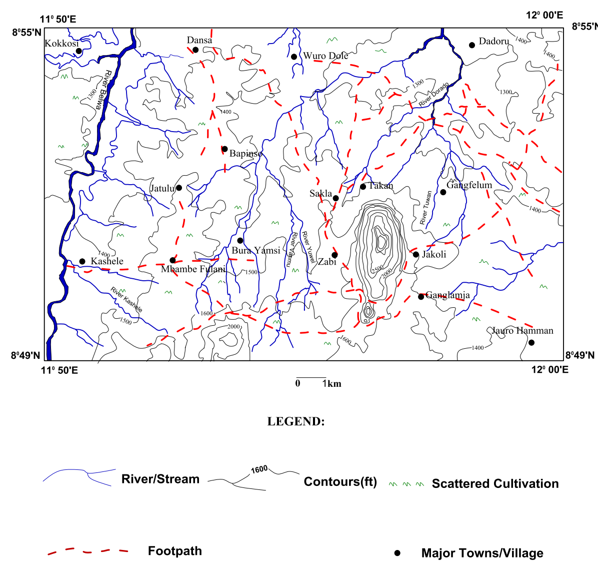

Figure1: Topographic Map of the Study Area (After Federal Surveys Agency of Nigeria, 1976).

The purpose of magnetic surveying is to identify and describe regions of the earth's crust that have unusual (anomalous) magnetizations, ferromagnetic minerals are common and naturally occurring, these minerals (e.g., magnetite, pyrrhotite) have a net magnetic moment and thus relatively high susceptibility. Ground magnetic method is considered as being among the cheapest geophysical methods and from the operational point of view, also among the easiest and fastest and reveals much more details of the geological and structural information that are hidden from direct view of human beings. The present area of study is a sector of the geological province that is considered among the least explored of all geological provinces in Nigeria (Bassey and Peter, 2012). Hence, the need for more geo-scientific studies in the area, so that a better understanding of the geology and tectonic framework of the area will be unveil.

REGIONAL GEOLOGIC SETTING AND OTHER GEO-SCIENTIFIC STUDIES IN THE ADAMAWA BASEMENT COMPLEX

Adamawa Massif is a section of eastern Nigeria's Basement Complex, which is bounded by the Yola Trough to the north, Benue Rift to the West and Mamfe Embayment to the south (Figure 2). Among the rocks distributed in the area are; migmatite-gneisses, granite-gneiss, porphyritic granite, porphyroblastic gneiss, and biotite - hornblende granites (Rahaman, 1976, McCurry, 1971, Oyawoye, 1970). But, in a more recent work, Haruna *et al.* 2011 reported the occurrence of granodiorites, migmatites, porphyritic granites and fine grained granites with minor pegmatites in Monkin areas of the Adamawa Basement complex.

Moreover, employing petrological and mineralogical information, Haruna *et al.,* 2011 (op.cit.) shows that some granitiods (e.g the fine grained granites) that borders the Benue Trough constitutes the immediate source rocks of the uranium mineral enrichments in Bima Sandstone found within the Benue trough of Nigeria.

Several other geo-scientific studies were conducted in the Adamawa massif of northeastern Nigeria, among which includes; the work of Ofoegbu *et al.* (1985) who interpreted magnetic anomalies over Mutum-Biyu areas in terms of dyke-like body with an average width of 0.7 km and an average depth of 0.3 km.

A major tectonic element of the basement complex is an extensive occurrence of lineaments such as joints, faults, shear zones, straight channel streams, strike ridges and mylonites (Odeyemi *et al.,* 1999).

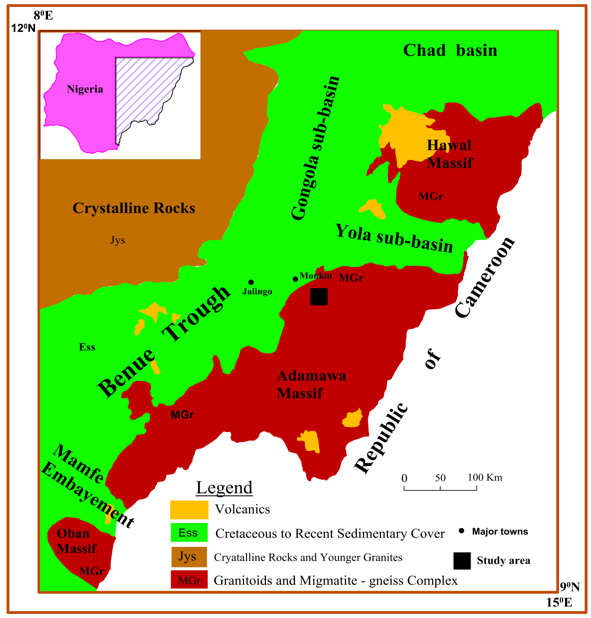

Figure 2: Regional Geological Setting of Adamawa Massif (Modified from Haruna *et al.,* 2011).

The major structural directions are N-S, NE-SW, NW-SE, and ESE-WNW (Benkhelil, 1982, Oluyide, 1988). Structures showing NE-SW, N-S trends are said to have been affected by the Pan-African orogeny whereas, those trending in the E-W, NW-SE are said to have been produced by events before the onset of the Pan-African Orogeny (Ekwueme, 1987)

Bappah (2009), carried out a geological interpretation of an aeromagnetic maps of Jalingo and Monkin areas of the Adamawa Massifs and reported the occurrence of lineaments oriented in a N-S, NE-SW, E-W, NW - SE direction, with NE-SW direction dominating the study area, which is in conformity with the dominant regional structural trends in the area.

Also Kasidi and Nur (2012), analyzed aeromagnetic data over Mutum - Biyu and environs in the Adamawa Massif by employing spectral analysis and Hilbert transformation of the data in the area, they found two magnetic source depth, which account for deeper and shallower sources. The deeper source, which they interpreted as originating from basement, varies from 661 m to 2722 m, while the shallower magnetic sources interpreted as near surface intrusions with depth from 137 to 590 m.

MATERIALS AND METHODS

Magnetic Field Data Acquisition and Processing

The magnetic data over the study area was acquired using *G-856-Mag*^{TM} proton precision magnetometer (Plate I) along profiles using the loop system, and along intersecting grid lines (Figure 3). The distance between stations were 1.852 km, which is equivalent to one minute ($1^{/}$) interval on the topographical map of the area. The stations interval was selected in order to have a moderate number of stations, and make the data acquisition exercise completed within the available time. There was a base station, which was located at a chosen geomagnetic reference point close to the study area, and this was used in monitoring diurnal variations.

Plate I: Shows the G-856-Mag^{TM} Proton Precision Magnetometer used for the Magnetic Data Acquisition.

Measurements were taken at the base station at the beginning of the survey and it was reoccupied in less than two hours (2 hours) and another reading taken again. During magnetic field data acquisition, measurement points were selected carefully to avoid the impact of cultural magnetic sources such as metallic objects, roofing zinc etc. In a situation where, it became impossible to avoid the cultural sources of magnetic field influence, measurements taken at that point was eliminated. Time for every measurement was also recorded in a field note book.

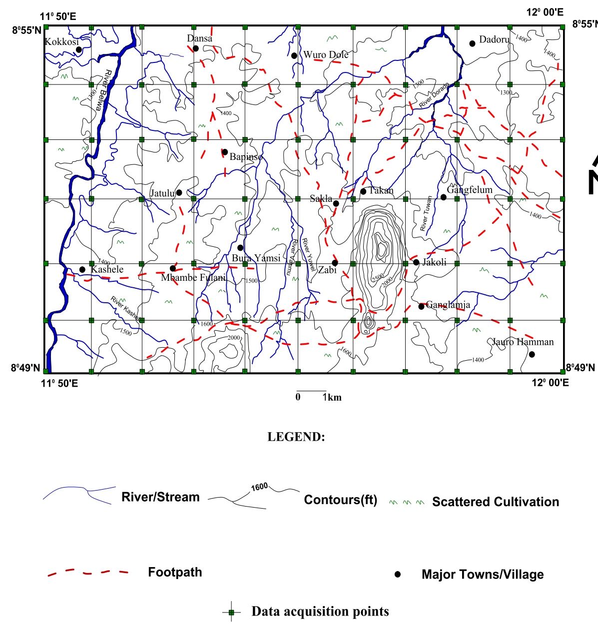

Figure 3: Gridded Topographic Map of the Study Area used in Magnetic Data Acquisition.

Magnetic Field Data Reduction

The reading obtained at every station was subjected to:

Diurnal Correction: this correction is done in order to remove the effect of diurnal variation on the magnetic data. This effect was removed by finding the differences observed in the base station and then distribute it among the readings at stations occupied during the day according to the time of observations, where the change is positive, the correcting factor is then subtracted from the field data acquired across all the stations found within that loop, and where the change is negative, it is then added from the field data acquired across all the stations found within that loop.

Data Enhancement Technique

The reduced potential field data were used to plot the total magnetic intensity (TMI) map of the study area. After this, the potential field's data filtered using horizontal derivatives filter. The description is as shown below.

Horizontal Derivatives

The TMI data when subjected to horizontal derivatives processing, produces residuals with higher resolution and suppresses the regional field effects, it emphasizes the expressions of local features, and removes the effects of large anomalies or regional influences. The horizontal derivative method evaluates the rate of change of magnetic values with distance (laterally). This enhancement is also designed to look at fault and contact features. Maxima in the enhanced data indicate source edges. It is complementary to the filtered and first vertical derivative enhancements. It usually produces a more exact location for faults than the first vertical derivative.

Geological Mapping

The geological mapping of the area was carried out using the following equipment; global positioning system (GPS), compass clinometer, measurement tape, geological hammer and a digital camera. During the mapping exercise, traverses were taken across the study area purely on foot, outcrops were examined and the observation made were plotted on the base map, and recorded in a field note book. The lithologic boundaries between different rocks types were delineated. Strike and dip of structures encountered on the rocks such as joints, veins, and foliations were measured using compass clinometers and are recorded in the field note book.

RESULTS AND DISCUSSION

The results obtained from the geological mapping exercise in the area revealed that the area is underlain by three major rock types which include porphyritic granites, biotite-hornblende gneiss and granite gneiss (Figure 4). Iron occurs as mineralized veins in the granite gneiss. The porphyritic granite dominates the northwestern part of the study area (Figure 4.), and constitutes about 40% of the total area.

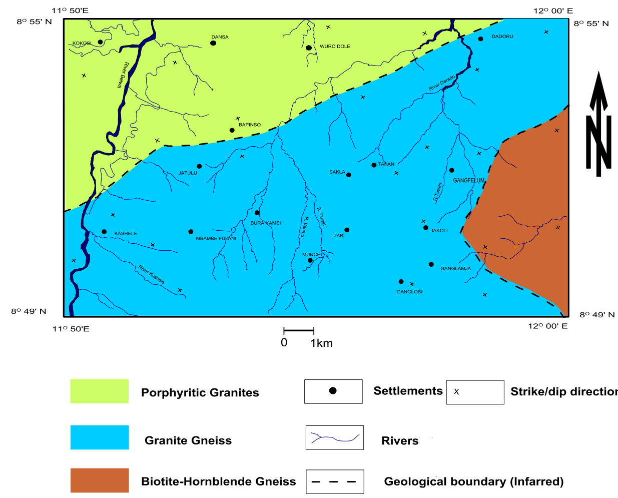

Figure 4: Geology of the Study Area (part of Adamawa Massifs) Northeastern Nigeria (from the present Study).

The porphyritic granite has large pinkish to whitish prismatic feldspar crystals as phenocrysts. It has numerous mineralized veins and Joints whose dominant trends (Figure 5) is given as NNE – SSW. The central, northeastern, southwestern, and southern parts of the mapped area are underlain by a granite-gneiss rock (Figure 4). This rock type is metamorphosed and is considered to have been affected by more than one thermo-tectonic event (Kogbe, 1989).

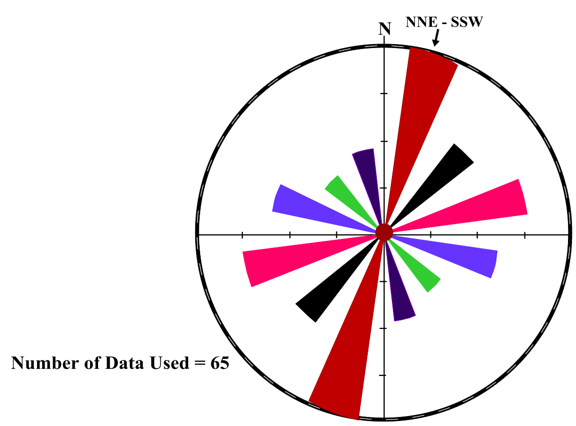

Figure 5: Rose Diagram Plot for Joints and Veins Pattern in Porphyritic Granite.

The granite gneisses constitute about 50% of the lithologies of the area and consist of minerals like biotite and feldspars. It has foliation whose major trend is mainly NNE – SSW (Figure 6). Another metamorphic rock found in the eastern part of the area of study is the biotite-hornblende gneiss, which constitutes about 5% of the total area of study (Figure 4). This is a highly foliated rock (Plate II) it is well exposed along stream channels in the study area. The foliation trends mainly in the (Figure 7) are ENE – WSW direction.

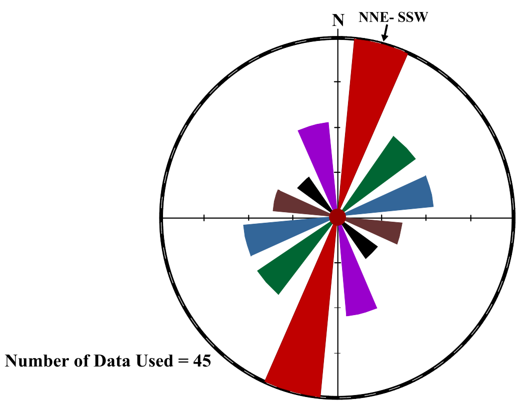

Figure 6: Rose Diagram Plot for Foliation Pattern in Granite-Gneiss.

Plate II: Shows Foliations in Biotite Hornblende Gneiss in the Study Area.

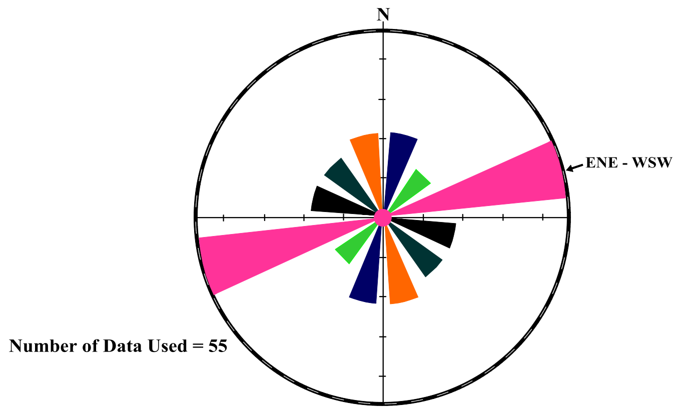

Figure 7: Rose Diagram Plot for Foliation Pattern in Biotite - Hornblende Gneiss.

The total magnetic field intensity (TMI) map of the study area (Figure 8) shows that, the area is composed of high amplitude, high gradient, and short wavelength anomalies, especially in the areas around Gangfelum, Ganglamja, Sakla, and Takan settlements.

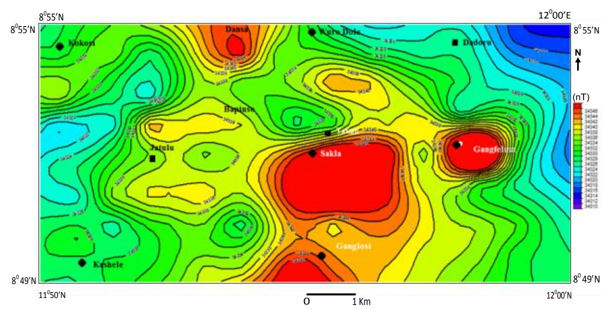

Figure 8: Total Magnetic Field Intensity (TMI) Map of the Study Area (contour interval: 2 nT).

The above mentioned areas are characterized by amplitude that ranges from 42 nT – 48 nT, and are attributed to shallow geological bodies (sources). Another area also of high amplitude is situated around “Dansa” settlement in the north - northwestern part of the study area which is attributed to shallow sources of magnetic geologic material which is evidenced by the presence of mine out iron mineralized veins found within the rocks around that area (Plate III.).

Plate III: Iron Mineralization Mine – Out Veins (oriented in NE-SW) in the Granite Gneiss in the Study Area.

Visual observation of the total field magnetic intensity map shows that some areas are characterized by high, low, and intermediate amplitude anomalies. These values range from 10 - 48 nT, on the TMI map. Areas with medium amplitude magnetic anomalies on the TMI map are interpreted as the background magnetic field in the area, whereas areas characterized by low amplitude, broad wavelength, and low gradient especially in the northwest – northwestern part, northeast – eastern part of the area are considered to be generated from deeper sources and are further interpreted as the structurally controlled stream channel that might be controlled from deeper part of the Earth in the study area.

The low gradient, low amplitude anomaly that ranges from 22 nT – 24 nT and oriented in the NE – SW direction was interpreted as major Lineament that runs in the similar direction in the Western part of the geologic map of the study area (Figure 4).

Areas characterized by the predominance of short wavelength, high gradient, high amplitude anomalies from both total field magnetic intensity map (Figure 8), and the residual horizontal derivatives map (Figure 9) of the study area) includes: Gangfelum, Sakla, Takan, Jatulu, and Dansa settlements of the study area. Whereas those with long wavelength, low gradient, low amplitude anomalies (34338nT - 34320nT) interpreted as being from the deeper sources follow the northeast – southwest direction and located in between Jatulu and Kokkosi settlement in the western part of the *TMI* map of the study area.

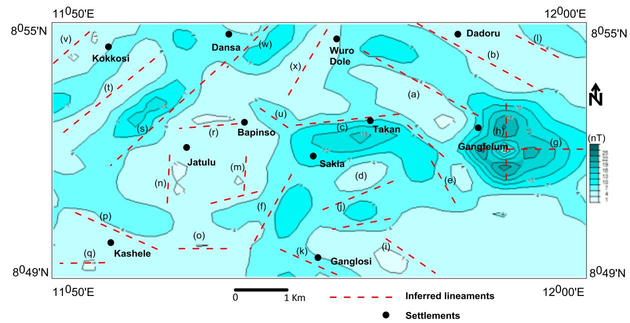

Figure 9. Horizontal Derivatives Map of the Study Area with Inferred Lineaments (Cont. int. 3nT).

Horizontal Derivatives Map

Considering Figure 9, linear features oriented in a NNE – SSW, E – W, N – S, NW – SE direction and represented by letters; a, to x are interpreted as being caused by orientation of major rivers and streams (Figure 10) which are structurally controlled in the study area.

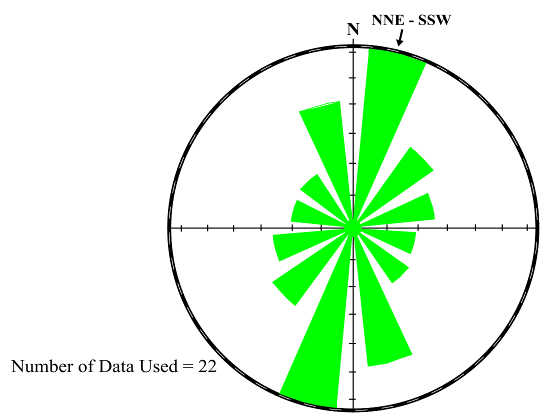

Figure 10: Rose Diagram Plot for Lineation Pattern from Stream Direction of Dadoru and Environs.

The major and very high gradient/ high amplitude anomaly labeled (D, C, and H) observed in the northern and eastern part of Figure 8 shows a northward and eastward broadening of the width of the anomaly, with magnetic values that ranges from 9 nT to 21 nT. This is interpreted as major point of occurrence of iron mineralization as evidenced by the exposure of a mine out pit found to be trending in NE-SW direction and along stream channel near Gangfelum in the eastern part of the Map. The inferred lineaments deduced from the Horizontal derivative map (Figure 11) of the study area were plotted on a rose diagram, and majority of them shows agreements with the trends of most rivers and Streams channels found in the study area.

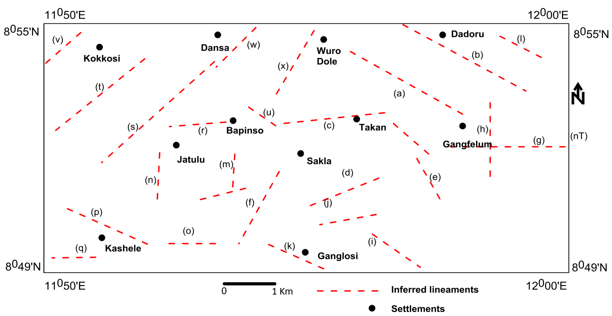

Figure 11: Lineament Map of the Study area inferred from the Horizontal derivative map.

Structural Analysis

The area is dominated by the rocks of the late Precambrian aged orogenic phase-Pan African Orogenic, thus, the geological structures were assumed to have link with the tectonic regimes and other interplayed activities associated with it. However, the most prevailing structures encountered on the field are foliations, joints and minor faults and iron mineralized fractures.

Measurements of strike and dips of the structure surfaces were taken on the field during the mapping, and the data were plotted on rose diagram of GEOrient package for structural features associated with each litho-unit, the result shows that granite gneiss has dominant NE – SW trending faults and joints systems with 3 major clusters corresponding to NE-SW, NNE-SSW and marginal WNW-ESE directions and the foliations show one major NNE-SSW cluster with two other minor clusters trending NE - SW, and ENE-WSW trends on the biotite hornblende gneiss, there are three structural clusters with one major trend and two minor others.

The major cluster trends ENE – WSW while the others trend in the NE-SW and NW-SE direction. A combination of the orientation of both major lineaments such as; rivers/ stream channels and small scale structures such as; joints, veins (both iron mineralized and quartzo-feldspathic), (Figures 5, 6 and 7) shows that, the study area have been affected by orogenic events such as; Pan-African, which accounts for the NNE – SSW, NE – SW oriented features (lineaments), and the Pre-Pan-African orogenic events that accounts for the remaining NWW–SEE, NNW-SSE, structures in the study area (Ekwueme, 1994).

CONCLUSION

Magnetic and geological field studies of Western Part of Adamawa Massif has provided more in-sight on the geology, structure and their relationship to the regional tectonic frame work of the basement complex that has earlier been considered as being relatively the least in terms of geo-scientific research.

The geological field mapping of this area reveals that the area is underlain by these rock types; porphyritic granites, granite gneiss, and biotite hornblende gneiss. Field structural studies also revealed the occurrence of joints, faults, iron mineralized veins, and quartzo- feldspathic veins that were oriented in either N–S, NE–SW, E–W or NW–SE direction but with NE–SW orientation showing better preponderance.

The magnetic anomalies observed on the magnetic maps produced after filtration shows the dominancy of NE-SW trends that coincides with the trends of major rivers and streams found in the study area, this suggest structural control of the rivers and streams found in the area under consideration.

REFERENCES

1. Benkhelil, J. 1982. “Structural Map of the Upper Benue Valley”. *Journal of Mining and Geology*. 18:140-151.

2. Bappah, A.A.. 2009. “Geological Interpretation of Aeromagnetic Maps of Jalingo and Monkin Areas of the Adamawa Massifs, Northeastern Nigeria”. Unpublished M.Sc. Thesis, Federal University of Technology Yola: Adamawa State, Nigeria.

3. Bassey, N.E. and A. Peter. 2012. “Pattern and Significance of Geosciences and Mining Research Works in Nigeria from 2008 – 2012”. *International Research Journal of Geology and Mining (IRJGM)* 4(2):57 – 63.

4. Ekwueme, B.N. 1987. “Structural Orientations and Precambrian Episodes of Uwet Area Oban Massif, S.E”. *Precambrian Resources*. 34:269-289.

5. Ekwueme, B.N. 1994. “Structural Features of Southern Obudu Plateau, Bamenda Massif, S.E Nigeria: Preliminary Interpretation”. *Journal of Mining and Geology*. 30(1):45 – 59.

6. Federal Surveys Agency of Nigeria. 1976. “Topographic Sheet 216. Monkin NE, Nigeria. Scale: 1: 100,000”.

7. Haruna, I.V., D.M. Orazulike, and A.B. Ofulume. 2011. “Some Petrological and Mineralogical Constraints on the Source and Processes for Uranium Mineralization on the Granitoids of Zing – Monkin Areas”. *Global Journal of Geological Sciences*. 9(2).

8. Kasidi, S. and A. Nur. 2012. “Analysis of Aeromagnetic Data Over Mutum-Biyu and Environs, Northeastern Nigeria”. *Research Journal of Engineering and Applied Science*. 1:142 – 148.

9. McCurry, P. 1971. “Pan African Orogeny in Northern Nigeria”. In: Ekwueme, B.N. 1987 Structural features of Southern Obudu Plateau, Bamenda Massif, S.E.Nigeria. *Journal of Mining and Geology*. 30(1):45-59.

10. Oyawoye, M.O. 1970. “The Basement Complex of Nigeria”. In: Dessauvagie. T.F.J. and Whiteman, A.J.W. (eds.). *African Geology*. University of Ibadan Press: Ibadan, Nigeria. 67-99.

11. Ofoegbu, C.O. 1985. “Interpretation of a Linear Magnetic Features near Mutum – Biyu, Northeast, Ngeria”. *Revista Brazilleira de Geofisica*. 3:91 – 97.

12. Oluyide, P.O. 1988. “Structural Trends in the Nigerian Complex”. In: *Precambrian Geology of Nigeria*, P.O. Oluyide (coordinator). Geological Survey of Nigeria Publication: Lagos, Nigeria. 93-98.

13. Odeyemi, I.B, Y.B. Anifowose, and Y.A. Asiwaju Bello. 1999. “Multi-Techniques Graphical Analyses of Fractures from Remote Sensing Images of Basement Region of Nigeria”. *J. Min. Geol*. 35(1):9-21

14. Rahaman, M.A. 1976. “Review of Basement Geology of Southwestern Nigeria”. In: C.A. Kogbe, (ed.). *Geology of Nigeria*. Elizabethan Publishing Company: Lagos, Nigeria. 41-58.

ABOUT THE AUTHORS

Professor N.E. Bassey, is a Professor of Applied Geophysics at the Department of Geology, Akwa-Ibom State University, Mkpat Enin, Uyo, Akwa-Ibom State, Nigeria. He is a registered and active member of the Nigerian Minining and Geosciences Society (NMGS), Nigerian Association of Petroleum Explorationists (NAPE), and Council of Mining Engineers and Geoscientists (COMEG). He holds a Bachelor of Science (B.Sc.), Master of Science (M.Sc.) and Doctor of Philosophy (Ph.D.) degree in Applied Geophysics from the University of Jos, University of Calabar, and Abubakar Tafawa Balewa University, Bauchi, respectively. His research interests are in geophysics and tectonics.

Mr. A. Yusuf, is a Lecturer in the Department of Geology, Gombe State, University Gombe, Nigeria. He holds a B.Sc. and M.Sc. degree in Geology and Applied Geophysics from Gombe State, University Gombe, Nigeria, Modibbo Adama University of Technology, Yola, Nigeria respectively. His research interests are in the areas of applied and exploration geophysics.

Mr. J. Barka, is a Lecturer in the Department of Geology, Gombe State, University Gombe, Nigeria. He holds a B.Sc. and M.Sc. degree in Geology and Applied Geophysics from, Abubakar Tafawa Balewa University, Bauchi, Nigeria, Modibbo Adama University of Technology, Yola, Nigeria, respectively. He is currently pursuing his Ph.D. degree in Applied Geophysics from Modibbo Adama University of Technology, Yola, Nigeria. His research interests are in the areas of applied geology and geophysics.

Mr. U.Y Yaro, is currently pursuing a Ph.D. Applied Geophysics at University of Liecester, United Kingdom. He holds a B.Sc. and M.Sc. degree in Applied Geology and Applied Geophysics from, Abubakar Tafawa Balewa University, Bauchi, Nigeria, Modibbo Adama University of Technology, Yola, Nigeria respectively. He is also a Lecturer at Department of Geology, Abubakar Tafawa Balewa University, Bauchi, Nigeria. His research interests are in the areas of applied geology and geophysics.

SUGGESTED CITATION

Yusuf, A., N.E. Bassey; J. Barka, and U.Y. Yaro. 2018. "Tectonic Lineament Patterns from Geological and Ground Magnetic Study of Western Part of Adamawa Massif, North Eastern Nigeria". *Pacific Journal of Science and Technology.* 19(1):342-350.

Pacific Journal of Science and Technology