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Integrated Geophysical Exploration for Mineralization of Parts of Mandara Mountains (Madagali Hills and Environs) Northeastern, Nigeria

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Abstract

The area lies within the basement terrain of northeastern Nigeria between longitudes 13° 30' -13° 41' E and latitudes 10° 47' - 11° 00' N. Ground magnetic and ground radiometric surveys were carried out to obtain information to some details on the geology of the area, and to link anomalous zones to mineralization. The data were acquired along twelve (12) traverses at a station interval of 1.85km (1') using geometric – 856 proton precision magnetometer and gamma scout tuned to Geiger Muller mode. Out of One Hundred and Sixty-Eight stations, only One Hundred and Twenty-one (121) stations were accessible and measured the raw field data were diurnally corrected and the international geomagnetic reference field (IGRF) computed online using 2010 – 2015 value for magnetic survey while the averaged surface data were contoured using a surface mapping system software surfer. The qualitative analysis of the magnetic data indicates that, the area consists of basic rocks, granites and metamorphic rocks while the field studies revealed that the dominant structural trends in the area are NE-SW NNE-SW, NW-SE, N-S, and E-W. The NE-SW and N-S trends are the most dominant and are attributed to pan African Agency. The qualitative interpretation of the radiometric data indicates that the radiometric anomalies are generally coincident with the mapped etiologies in the area: namely, metamorphic rocks (gneiss granite-gneiss, schist, etc), granites while lower radiometric anomalies are probably caused by basic extrusive (near-surface rocks) occurring as intrusion in the metamorphic basement. The intermediate radiometric anomalies ranging between 34-35cpm are attributed to metamorphic rocks. The results of the analysis also indicate no appreciates mineralization in the area and this could be attributed to unfavorable structural disposition, inadequate teaching and insufficient traps.

Keywords: *Structural trends, Geomagnetic, Structural disposition, Leaching.*

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Background to the Study

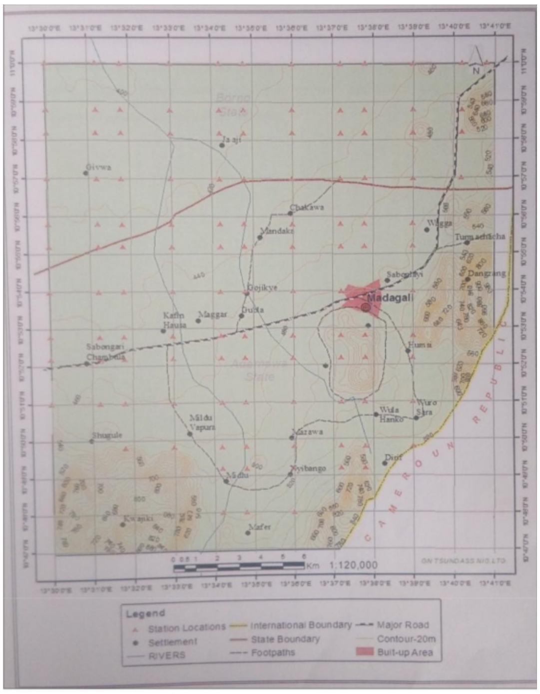
The main objectives of the study are to obtain information to some details on the geology of area, link anomalous zones to mineralization and to identify the structural trends in the area. The Mandara mountains are a volcanic range extending about 190km (about 120 mi) along the northern part of the Cameroon-Nigeria border, from the Benue River in the south (11.0˚N 13.9˚E). The highest evaluation is the summit of mount outplay, at 1,494km (4900 ft) above sea level (10˚ 53' 47'E). The region is densely populated, mainly by speakers of Chadic languages, including both the Mofu and the Kirdi ethnic groups.

The study area is located in the extreme eastern part of the geologically less explored Hawul basement complex of northeastern Nigeria. The area is covered by topographic map sheet 136 Madagali NW, produced on a scale of 1.120,000 by the United States geological survey (USGS) in 2006 (Fig.1) Madagali hills and environs is part of Mandara mountains which together with the adjacent Hawul and Adamawa mass its form the northeastern sector of the Nigerian basement complexes the madagali hills form prominent parallel and elongated topographic highs in the study area. The hills are dominated by granites rocks while the plans are underlain by metamorphic rocks.

The magnetic properties within a rock type can be quite variable (Carmichael, 1989) depending on chemical in homogeneity depositional and or crystallization and post-deformational conditions. The mineral contribution to the magnetic susceptibility of a rock has been widely given in literature (Thompson and old field 1986, Lowrie, 1990, schon, 1996). The values of magnetic susceptibility depend on the grain size, the presence of minute crystal lattice such as dislocations, lattice valences, impurities etc and the amount of iron are in a sample.

Radiometric survey came into limelight with the demand for uranium in nuclear technology. But the technique is not limited to the search for uranium ores or associated minerals it can be used in geological and structural mapping (Parasnis, 1986). In nature certain nuclear of atoms disintegrate Spartan easily emitting alpha and beta (ά and ß) particles. The phenomenon is thrown as radio activity. In some rare instances, emission of X particles is followed by gamma rays (γ -rays) or particles. The γ-particle is purely electromagnetic radiation which does not alter the nuclear charge. The ά and ß particles loses their energy when passing through matter. Thus, radiometric surveying is ultimately the search for places with abnormally high gamma (γ) radiations.

Fig. 1: Topographic Map of the Study Area



Source: After US Geological Survey, 2006

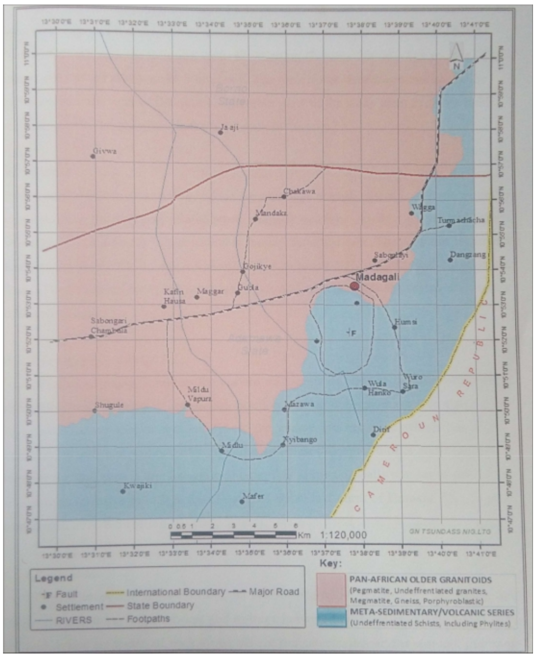
Geology of the Area

The Mandara Mountains were formed millions of years ago when a continental pace of basement rock deep beneath the Africa continent rose up, fragmenting and splitting as it was pushed to the surface. The diameter was significantly wetter in those times, so enormous amount of precipitation formed numerous rivers that rushed through these factures, carving them deeper and wider, resulting in the ranges notably rugged terrain.

Volcanic activity also played a role in the formation of the range. Eruptions level formed volcanic cones whose vents were eventually plugged with hardening magma. These hardened cores are called volcanic plugs. In case of the Mandara Mountains, the plugs were much more erosion-resistant than the exterior of the cones which wore away over time. Eventually, only the plugs remained, forming the stark, needle like sprees such as Kapsikipeak that the range is known for (Scheffel et.al, 1980).

Madagali hills are part of Hawul basement which is one of the three massifs in the northeastern Nigeria that share a long border with the Republic of Cameroon. The area is under lain mainly by migmatite-gneiss intruded by large volume of pan-African granitoids, schist and minor taconites. Outcrops are restricted to the eastern and southern part of the study area as the northern and western sides are characterized by ponds and flood plans (Fig. 11). The pan-Africa granitoids of the extreme northeastern tip of Nigeria, north of the Benue trough was described by Islam and Baba (1997) as alkaline and mixed origin Baba et. al, (1996) described the Liga hills granites (north of the study area) as being products of anorexics of crystal material. Bassey, (2006) studied the structures of Madagali hills NE Nigeria from airborne magnetic and satellite data and stated that the lithological units in the area are gneiss, schist and granites. He concluded that the magnetic satellite and field studies have thrown some light on the geology and structure of this parts of Nigeria's basement complex that has been datively under studied. The major lineament observed have been accounted for in terms of faults foliations, joints, shear zones, dykes and veins. The lineaments have regional extensions into Niger, Chad and Cameroon. The chad basin evolution involved interplay of NW-SE, NE-SW, N-S and possibly E-W tectonics. Major drainage channels in the area are structurally controlled. The study has revealed E-W structures as the youngest which is different from observations elsewhere in Nigerian basement (Bassey, 2006a).

Fig. 2: Geological Map of the Study Area



Source: Modified after Nigerian Geological Survey (NGS), 2006

Methodology

The topographic map of the study area was gridded to produced one hundred and Sixty-eight (168) grids. Out of which only one hundred and Twenty-One (121) stations were occupied and measured. The grid size chosen was one minute (1') interval appropriately 1.85 km for both techniques. This interval was chosen as it made stations to be moderate in number and field work completed within available time frame.

Traverse was established perpendicular to the strike directions (i.e. N-S). All the traverses were taken in straight lines either along the roads, footpaths or through bush. The lines were marked at convenient intervals (stations) with red permanent marker for easy identification of stations.

Data Acquisition

For the magnetic survey, the data were acquired along twelve (12) traverses in the N-S direction at station interval of 1.85km using the geometric-856 proton precision magnetometer, which measures the total intensity of the earth's magnetic field. Readings were not taken within the vicinity of metallic objects such as motorcycles, cars, tarred roads, fencings, houses which might perturb the local magnetic field. For similar reason, operators of the magnetometer should not carry any metallic object.

The magnetic instrument has a resolution of one (1) nanotesla (InT). A base station was set no about a few meters away from the survey area where the magnetometer records the magnetic readings at a time interval of two (2) hours (2hrs) using a looping technique. Reoccupation of the base station was done to check for diurnal variation of the earth's magnetic field. Each of the 24km long traverses have a station interval of 1.85km determined using a global positioning system (GPS). Three different magnetometer readings were taken at each station and the average taken. The time (period) at which reading were taken were recorded for each station. The coordinate of each station of each traverse line were recorded by the GPS. On the whole, one hundred and twenty-one (121) measurements were recorded.

For the radiometric survey, the data were measured or obtained using gamma scout tuned to Geiger Muller counter mode for gamma ray detection. The instrument measures the radiations and present the reading electrically (digitally) as number of pulses received. The number of pulses is proportional to the level of radioactivity in the environment over which measurement is taken.

The instrument is also equipped with an electronic timer, this pulse rate can be determined in second, minute or hour. Radiation intensity may strongly fluctuate on a short-term basis; hence instrument manufacturer recommends measuring of average pulse rate Bassey, et, al. (2013). This takes care of atmosphere and cosmic ray backgrounds on obtained results. For this work, pulse rate was measured over an internal of three (3) minutes at each station and the average pulse was recorded for each station. The three (3) minutes timing was considered satisfactory for this work as the average pulse per minutes or counts per minute (cpm) over similar environment should a good level of constituency. Measurements were made directly over outcrops (exposure) except where such were absent. The averaged radiometric data was countered using surfer, version computer software to produce the radiometric counter maps.

Data Processing

The magnetic data obtained were corrected for diurnal variation (i.e. for positive drift; it was subtracted from the field data while for negative drift; it was added to the field data). The earth's normal (true) magnetic field of the study area was calculated using the International Geomagnetic Reference Field (IGRF), of 2010-2015 and subtracted from the diurnal corrected values to produce the total magnetic field intensity (TMI), map (Fig. 3). The TMI map was then processed by subjecting it to regional- residual separation (polynomial fitting), low-pass filtering, first horizontal order first virtual derivative polynomial fitting and downward continuation.

For the radiometric data, the averaged radiometric data was contoured using surface mapping system software called surfer II version computer software.

Data Interpretation

The total magnetic field intensity (TMI) map of the area (Fig. 3) showed that the area is characterized by both high amplitude and short wavelength, and low amplitude and long wavelength anomalies. The high amplitude to near-surface (shallow) features while the low amplitude and long wavelength the anomalies are attributed to deep seated features. Form the total magnetic field intensity map and residual magnetic map (Fig. 4) it can be seen that; the area is characterized by both high and low frequency anomalies.

On the residual magnetic map, it is that, the magnetic anomalies amplitude ranges from a minimum of -160nT to a maximum of 320nT.

The areas of positive anomalies occur in the southern, eastern, extreme north, northwest and part of the central part of the study area. These areas can be interpreted in terms of occurrences of basics rocks. This can be explained in the light of the available regional geological reports on the mandara hills, and the adjoining basement regions (Adamawa Massif in Nigeria and the northern Cameroon basement). According the reports, these regions have wide spread occurrence of basalts, trachyte and trachyte basalts (Avborbo et. al., 1986; Fitton, 1987; moraeu et. al, 1987; Toteu, 1990; Bassey et. al; 1999 Bassey, 2005). The positive residual anomalies in the study area are interpreted in terms of the presence of granitoids and metamorphic rocks in the area. They may also be due to susceptibility variations in lithologies or a combination of both.

Whereas the radiometric contour maps (Fig. 5 and 6) shows that the gamma(γ) radiations vary between 16cpm and 66cpm. The radiometric anomalies are generally coincident with the mapped lithologies in the area, namely; granites, metamorphic rocks (gneiss, schist and granite-gneiss) and sub-cropping basic rocks. Higher radiometric anomalies occur over granites as found in the central part of Madagali town (>64cpm). The lowest radiometric anomalies occur over inferred sub-cropping basic rocks (such as basalt, trachyte etc) in the extreme north, east and northwest part of the study area. The anomaly values range between 16-30 cpm. The low anomalies are probably caused by sub-cropping basic (near-surface or soil or overburden covered) rocks occurring as intrusions in the metamorphic basement. The high radioactivity of granites is due to the presence of orthoclase feldspar minerals, namely, orthoclase and microcline which contain potassium (40K), a radioactive element;

Orthoclase feldspar has the chemical formula $KALS1_{2}08$. The presence of intermediate radioactivity of metamorphic rocks is due to the presence of orthoclase feldspar also but lesser amount (Telford et. al, 1954), part of the radioactivity of the rocks may however be due to the presence of minute quantities of uranium end thorium.

Fig. 3: Total Magnetic Field Intensity (TMI) Map
(Cont. int. 40nT)

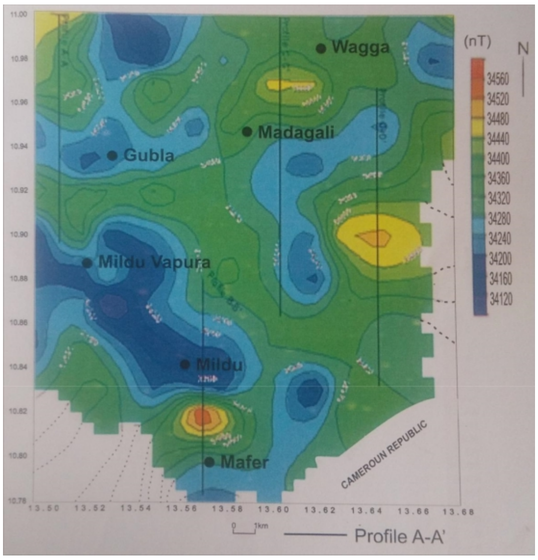
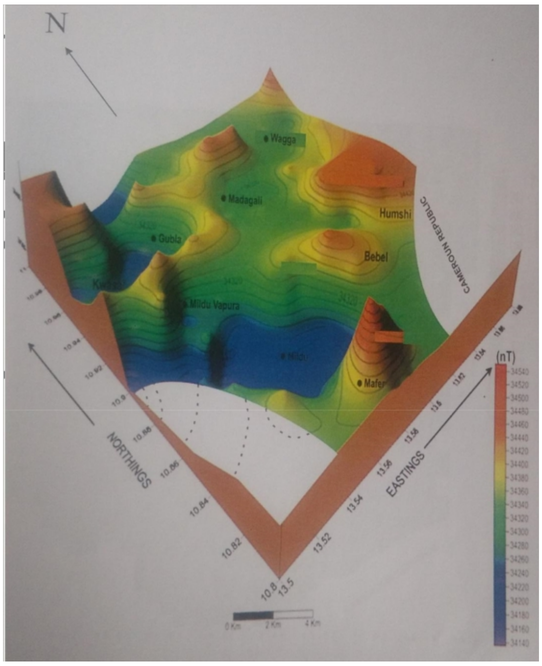


Fig. 4: Magnetic 3-D Surface Map of the Study Area
(Cont. Int. 20nT)



Discussion

The earth's magnetic field is a composite of anomalies of varying frequencies. The highest frequency event of interest are those created by geological conditions in the shallow subsurface and the lowest frequency events are caused by magnetic property contracts at or beneath the basement surface while intermediate frequency events are created within a sedimentary section map by map interpretation showed different anomaly signatures which is indicate of the susceptibility contact of the rock types and to certain extent, the effects of instructions, fissures and rock contracts (Kayode et, al; 2010).

In this area of study, the magnetic field intensity varies between 34120-34580 nanotesla (nT), which is a measure of the magnetic mineral continent present in the underlying rock units and on conditions near /or far beneath the surface, from the two maps (total magnetic field intensity, TMI and the residual magnetic map), four (4) areas of significant positive anomalies were observed. These areas are; South of Mildu town, east of Madagali town, South of Wagga and North West of the study area. The highest positive anomaly occurs at Mildu town. This area shows a magnetic high of 34480-34580 nT. These areas of high magnetic susceptibility values are most likely to be regions of basic igneous rocks.

The lowest magnetic anomalies occur in areas north of Mildu town, east of Wagga, north of Gubla and around Milduvapura villages. These are most likely to be regions of acidic igneous rocks such as granites. The positive residual anomalies can be explained in the light of available regional geological reports on Mandara hills and the adjoining basement regions (Adamawa Massif in Nigeria and northern Cameroon basement). These regions have wide spread occurrences of basalts, trachyte, and trachyte basalts (Avborbov et. al, 1986, fitton 1987, Moraeu et. al 1987, Toteu, 1990; Bassey, et. al; 1986; Bassey, 2006). The positive residual anomalies are attributed to these basic and intermediate rocks.

Areas of occurrences of zero or negative residual anomalies in the area are interpreted in terms of the presence of granites, gneiss and schist. They may also be due to susceptibility variations in lithologies or a combination of both (Bassey, 2006). The magnetic and field studies showed that the area has experienced polyphase thermos tectonic events involving magmatism, metamorphism and structural deformations.

From the field structural data, the oldest deformational features trend NW-SE. These features are foliations, shear zones, and joints. These NW-SE lineaments are among the longest and invariably are of deep crustal origin (Odeyemi et. al, 1999). Other geophysical evidences (gravity and seismic) exist to show these lineaments continue beneath the chad basin into Niger Republic where they have surface expression as the Tenere Rift (Lake Chad Basin Commission, 1973; Cratchley et. al, 1984 Nur, 2001).

Whereas, the radiometric contour map and its 3-D surface map (Fig. 5 and 6) revealed two areas of high radiometry, namely; central part of Madagali and around Humbuli village in the extreme southwestern part of the study area. The radioactivity in counts per minutes (cpm) in these areas ranges between 38-66cpm. Most part of the study area have low radioactivity. The radiometric values in these areas ranges between 16-22 cpm. This shows that most part of the area is underlain by metamorphic rocks and sub-cropping basic igneous rocks as suggested by their low radio activities. This means that, the radiometric anomalies generally coincident with the main lithiologies in the area, namely; metamorphic tocks (gneiss, granite-gneiss, schist), granites (fine grained, medium gained and coarse grained) and basic rocks such as basalt, trachyte etc). Higher radiometric anomalies occur over granites as are seen in the central part of Madagali town (> 64cpm) and around Humbuli village in the extreme southwestern part of the area. The low radioactivity is probably caused by or due to basic extrusive (near-surface) rocks occurring as intrusive in the metamorphic basement.

From the ongoing discussion, this part of Mandara Mountains (Madagali NW) appeared to have low or no mineralization potential. Ordinarily, the area is expected to have some appreciable mineralization because of its proximity to and similarities in geological and structural settings with Gumchi area known for its uranium mineralization. This study however, revealed that certain fundamental factors favorable for the mineralization in Gumchi area are either lacking or minimal the area.

Fig. 5: Radiometric Contour Map of the Study Area
(Cont. Int. 4 cpm)

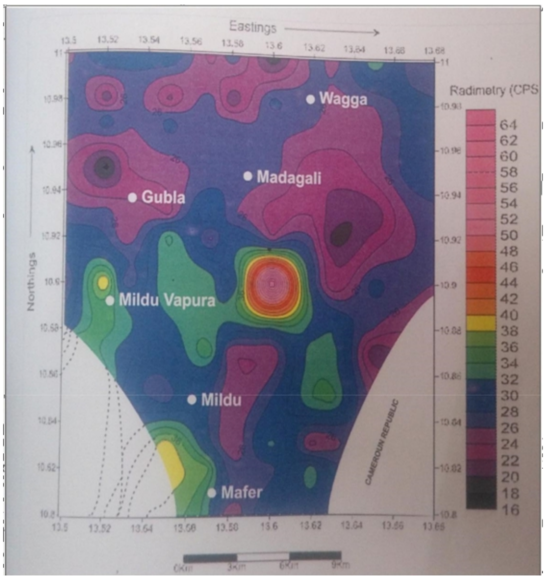
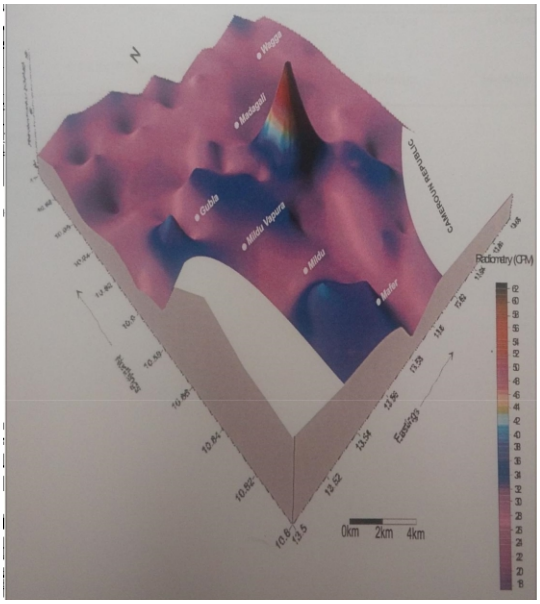


Fig. 6: Radiometric 3-D Surface Map
(Cont. Int. 2cpm)



Conclusion

The integrated geophysical exploration study of this parts of Mandara Mountains (Madagali hills and environs), revealed that the area is dominantly underlain by metamorphic rocks (Migmatite-gneiss, schist etc) intruded by large volumes of granites (granites of variable textures).

Although the study area is adjacent to a uranium-mineralized Gumchiarea with very similar geological settings, this part of Mandara mountains (Madagali hills and environs), have not proved to be significantly mineralized. The poor mineralization in this area despite its proximity to and similarities in geological settings and lithology with the uraniferous Gumchi area could be attributed to;

1. Absence of the structural intersection between the N-S and NW-SE fractures which are known to control the mineralization in Gumchi.
2. Insufficient volcanic dykes in the mylonite zones which serve as traps for the mineralizing fluids and;
3. Inadequate leaching of the host rocks as evident in the low iron (fe) content of the mylonite relative of the granite.

Reference

Avbovbo, A. A. Ayoola, E. O. & Osahon, G. A. (1986). Depositional and structural styles in chad basin of NE Nigeria, *A. A.P.G Bulletin* 70 (12) 1787-1798.

Baba, S. (2008). Geology of Madagali area, northwestern Nigeria, Doctoral thesis, Madibbo Adama University of Technology, Yola, Adamawa State Nigeria.

Baba, S., Emofurieta, W. O. & EL-Nafaty J. M. (1996). Petro chemistry of Loga Hills Granites, NE Nigeria, *Borno Jour. Geol.* 1, 35-58.

Bassey, N. E. (2005). Selective structural geological mapping and interpretation of landsat and aeromagnetic data over Hawul Basement complex, N.E Nigeria Ph.D Thesis, Abubakar Tafawa Balewa University. Bauchi, Bauchi State, Nigeria.

Bassey, N. E. (2006). Structure of Madagali hills, N.E Nigeria from Airbone magnetic and satellite data, *Global Journal of Georgical Science, 4* (I), 47-57.

Bassey, N. E, Ezeigbo, H. I. M. & Kwache, J. B. (1999). Hydrogeological study of Duhu area (sheet 135) N.E Nigeria on the basis of Aeromagnetic data, *Water Resources, 10,* 560-577.

Bassey, N. E, Kaigama, U. & Oluwasegun, A. (2013). Radiometric mapping of song area and Environs, Hawul Basement complex NE Nigeria, *International Journal of Science and Technology, 2*(9).

Carmchael, R. S. (1989). Practical handbook of physical properties of rocks and minerals, CRC press, Boca Raton Ann Arbor, Boston.

Cratchley, C. R., Louis P. & Ajakaiye, D. E. (1984). Geophysical and geological evidence for the Benue-Chad Basin cretaceous Rift valley system and its tectonic implications, Jour. Afr. Earth Sci. 2 (2) 141-150.

Fitton, J. G. (1983). Active versus passive continental rifting evidence from the West African rift system, *Tectono-Physics 94*, 473-481.

Geosystem, SRL (2003). Wing link (version 2-03-01) Electronic software.

Golden Software Inc. (2012). *Surface mapping system (surfer version 11.0.642),* (Electronic software).

Islam, M. R. & Baba, S. (1997). The geology of the basement complex of Northern parts of Mandara Hills, viilviii, 99-105.

Lake Chad Commission Report (1913). *Survey for water resources of the Chad Basin for development purpose,* F.A.O Rome.

Lowries, W. (1990). Fundamentals of geophysics, Cambridge University Press, low price paper Back Edition, 229-306.

Moreau, C., Regnault, J. M, Deruelle, B. & Robineau, B. (1987). A new tectonic model for the Cameroon line, Central Africa, *Tectono-Physics 139*, 317-334.

Nigeria Geological Survey Agency (NGASA), (2006). Geological map of Nigeria, Abuja.

Nur, A. (2001) Spectral analysis and Hilbert transformation of gravity data over Southwest of the Chad Basin, Nigeria, *Jour. Min. Geol. 37*(2) 153-161.

Odeyemi, I. B, Anifowose, Y. B. & Asiwaju-Bello, Y. A. (1999). Multi technique graphical analysis of fractures from remote sensing images of basement regions of Nigeria, *Jour. Min. Geol. 35*(1) 9-21.

Parasnis, D. S. (1986). Principles of applied geophysics chapman and hills, Cambridge, 58-65.

Scheffel, R. L. & Wernet, S. J., eds. (1980). *Natural wanders of world: United State of America: Reader's digest association,* Inc. 226-227 ISBN 0-89577- 087-3

Schon, J. H. (1986). Physical properties of rocks: Fundamentals and principle of petrophysics, in: Klaus, H. and Sven, T. (Eds): Handbook of Geophysical Exploration, 18, 583. Pergamon press, London.

Telford, W. M, Geldart, L. P, Sherrif, R. E. & keys, D. A. (1984). *Applied geophysics*, Cambridge University Press. 860P.

Thompson, R. & Old-field, F. (1986). *Environmental magnetism, 227 Alen and Unwin*, London.

Toteu, S. F. (1990). Geochemical characterization of the main petro graphical and structured units of Northern Cameroon: Implications for pan African evolution, *Journal of African Earth Science 1*0 (4) 615-621.

US Geological Survey (2006). *Topographic map sheet 136 Madagali NW*, Nigeria, Scale: 1, 120,000.