International Journal of Earth, Energy and Environmental Sciences
ISSN: 2517-942X
Vol:7, No:9, 2013

Morphology of Parts of the Middle Benue Trough of Nigeria from Spectral Analysis of Aeromagnetic Data (Akiri Sheet 232 and Lafia Sheet 231)

B. S. Jatau and Nandom Abu

***Abstract*—**Structural interpretation of aeromagnetic data and Landsat imagery over the Middle Benue Trough was carried out to determine the depth to basement, delineate the basement morphology and relief, and the structural features within the basin. The aeromagnetic and Landsat data were subjected to various image and data enhancement and transformation routines. Results of the study revealed lineaments with trend directions in the N-S, NE-SW, NW-SE and E-W directions, with the NE-SW trends been dominant. The depths to basement within the trough were established to be at 1.8, 0.3 and 0.8km, as shown from the spectral analysis plot. The Source Parameter Imaging (SPI) plot generated showed the central-south/eastern portion of the study area as being deeper in contrast to the western-south-west portion. The basement morphology of the trough was interpreted as having parallel sets of micro-basins which could be considered as grabens and horsts in agreement with the general features interpreted by early workers.

***Keywords*—**Morphology, Middle Benue Trough, Spectral Analysis, Source Parameter Imaging.

I. Introduction

THE Benue Trough is a linear NE-SW trending rift system whose development is closely associated with the separation of Africa from South America and the opening of the South Atlantic Ocean during the Cretaceous period. The origin and evolution of the Benue Trough are fairly well documented [3], [4], [9], [13], as shown in Fig. 1.

The aeromagnetic data for this work is the Total Magnetic Intensity (TMI) data in grid format which was collected by Fugro Airborne Surveys at 200m flight line spacing and 80m terrain clearance for the Nigeria Geological Survey Agency in the year 2010.

The determination of sediment thickness above the basement and the delineation of major structures are very essential for better understanding of the geology of the Middle Benue Trough morphology. This work presents the results of the spectral analysis of aeromagnetic data over this area. The aims and objectives of this study is to determine the depth to the magnetic basement, delineate the basement morphology and relief, and to establish the structural features associated with the basin and infer the effects of such structures on the general tectonic history of the study area. Such structural lineaments (fractures, faults, shear zones and veins) usually serve as potential hosts and migration paths for groundwater, hydrocarbons, minerals, etc.

B. S. Jatau is with the Department of Geology and Mining, P.M.B.1022 Keffi, Nasarawa State University, Keffi- Nigeria (e-mail:bsjatau@yahoo.co.uk; +2348034529326)

Nandom Abu is with the Raw Materials Research & Development Council (RMRDC), 17 Aguyi-Ironsi Street, Maitama District, P.M.B 232, Garki-Abuja (e-mail:abunandom@yahoo.co.uk; +2348034536244).

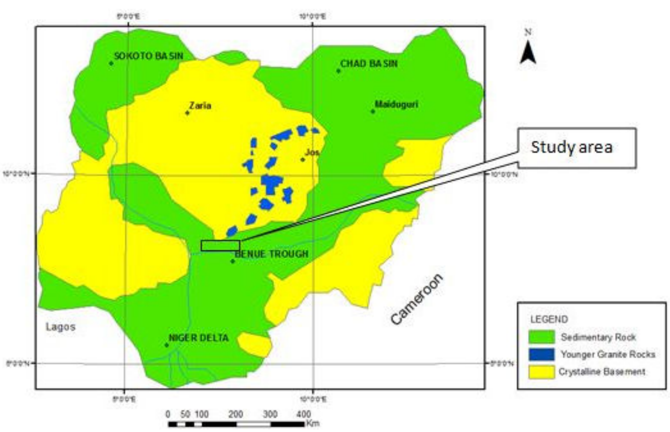

Fig. 1 Simplified geological map of Nigeria with study area, [7]

A. Geology of the Study Area

The Benue Trough of Nigeria is an intra cratonic rift system whose development is closely associated with the separation of Africa from South America and the opening of the South Atlantic Ocean during the Early Cretaceous [2], [5], [9], [13], [17]. The Trough consist of a long stretch of sedimentary basin running from about the northern tip of the Niger Delta Basin and terminates under the Chad Basin and sandwiched by the Basement Complex areas in the north and south of river Benue. It is filled by sediments that are Middle-Late Albian in age [10]. The oldest sediments belong to the Asu River Group and consist of shales and siltstones of marine origin, representing the first Middle Albian transgression into the Benue Trough. This formation is found at the crest of the Keana anticline to the east of Keana town [10]. The Asu River Formation is overlain by the transitional beds of the Awe Formation, which consist of flaggy, whitish, and medium to coarse-grained sandstones which are interbedded with carbonaceous shales or clays from which brine springs issue continuously. The Awe formation marks the beginning of the regressive phase of the Albian sea and is overlain by continental fluviatile sands of the Keana Formation, which is of late Cenomian to Early Turonian [10]. The Eze-aku, Agwu and Lafia Formations are also found within the study area, which are of Turonian to Early Maestriachian. The Eze-aku Formation consists essentially of calcareous shales, micaceeous fine to medium grained friable sandstones and occasional beds of limestones. The Agwu Formation, which is Coniacianin age, consists mainly of black shales, sandstones and some coal seams. The Lafia Formation is the youngest formation in the Benue Trough, Maestrichian in age, consists of coarse grained ferruginous sandstones, red loose sand, flaggy mudstones and clays [10], [11], [12].

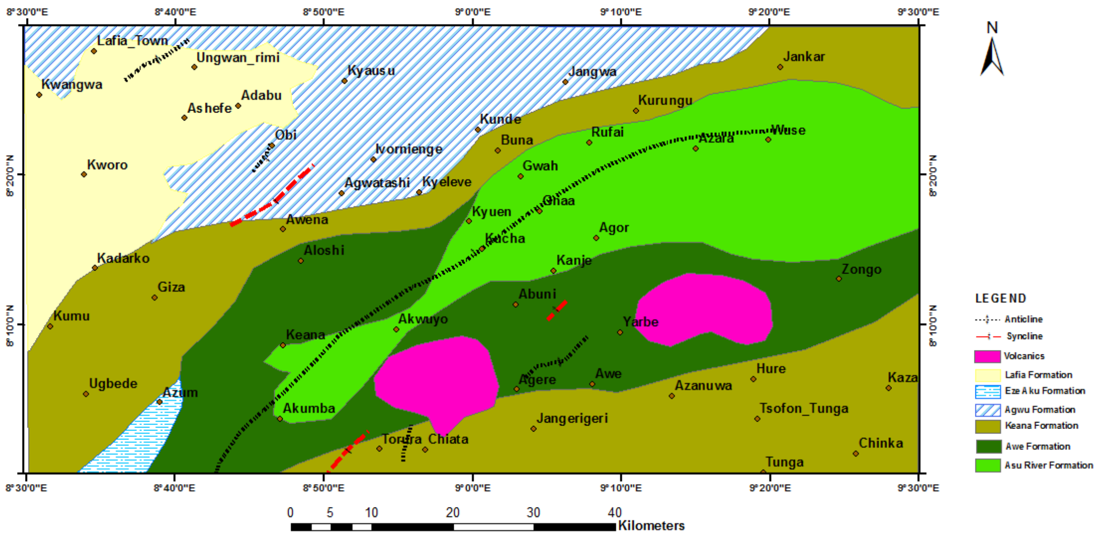

Fig. 2 Geology Map of Study Area and Towns [10]

II. Methodology and Materials

A magnetic basement is an assemblage of rocks that underlies sedimentary basins and may also outcrop in places. If the magnetic units in the basement occur at the basement surface, then depth determinations for these will map the basin floor morphology and its structure [1], [15]. In many sedimentary basins, magnetic anomalies arise from secondary mineralization along fault planes, which are often revealed on aeromagnetic maps as surface linear features. Most mineral deposits are related to some type of deformation of the lithosphere, and most theories of ore formation and concentration embody tectonic or deformational concepts [16]. Some lineament patterns have been defined to be the most favorable structural conditions in control of various mineral deposits [1], [8], [14], [15], [16]. They include the traces of major regional lineaments, intersection of major lineaments or both major (regional) and local lineaments, lineaments of tensional nature, local highest concentration (or density) of lineament, between echelon lineaments and lineaments associated with circular features. Linear features are clearly discernible on aeromagnetic maps and often indicate the form and position of individual folds, faults, joints, veins, lithological contacts, and other geologic features that may lead to the location of individual mineral deposits [8]. The raw aeromagnetic data and Satellite Imageries for the study were obtained from the Nigerian Geological Survey Agency, Abuja and National Centre for Remote Sensing, Jos, respectively. The data available for interpretation in this study is the Total Magnetic Intensity (TMI) data in grid format which was collected by Fugro Airborne surveys at 200m flight line spacing and 80m terrain clearance.

III. Result Presentation

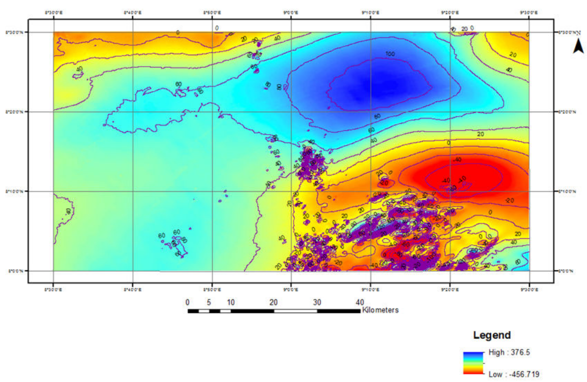

Fig. 3 TMI contour draped on grid

Several potential field software with different analytical modules were used in the interpretation of the aeromagnetic data. These include Geosoft's Oasis Montaj, and ILWIS.

Similarly, ArcView 9.3 software was used to extract the lineaments and carry out statistical analysis of the interpreted lineaments in the area. Presented, below are the result, Figs.3, 4, & 5. Fig. 6 was generated from the source parameter imagery.

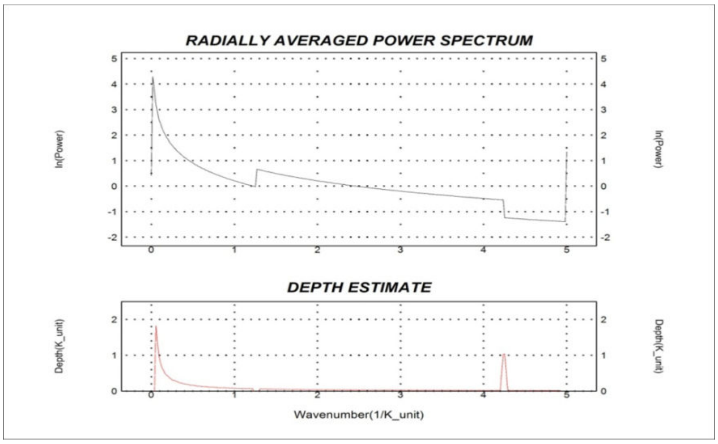

Fig. 4 The energy spectrum in the wave number domain and spectral analysis for regional-residual separation

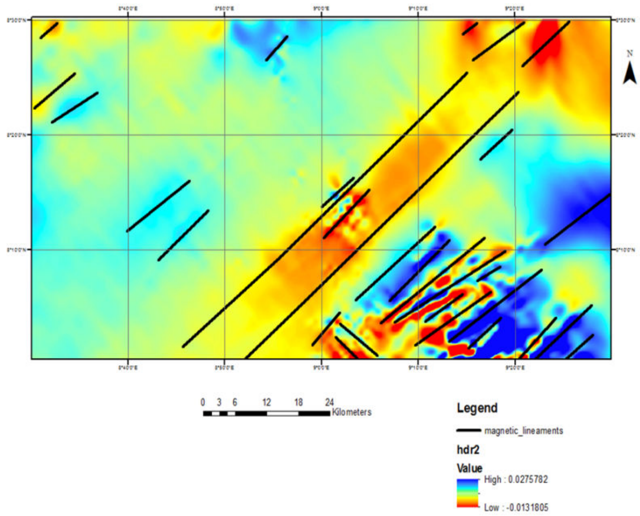

Fig. 5 Total Horizontal Derivative of the RTE data and Basement Lineament

International Journal of Earth, Energy and Environmental Sciences
ISSN: 2517-942X
Vol:7, No:9, 2013

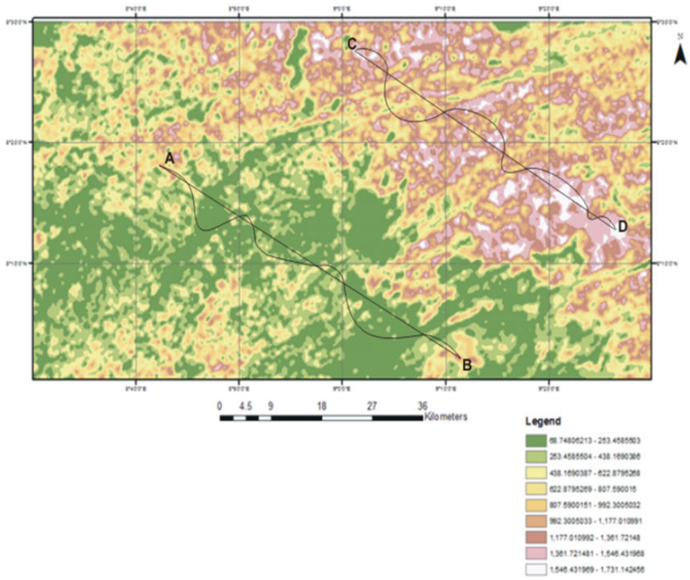

Fig. 6 Depth to basement map derived from Source Parameter Imaging (SPI), and Profile Lines A-B, C-D

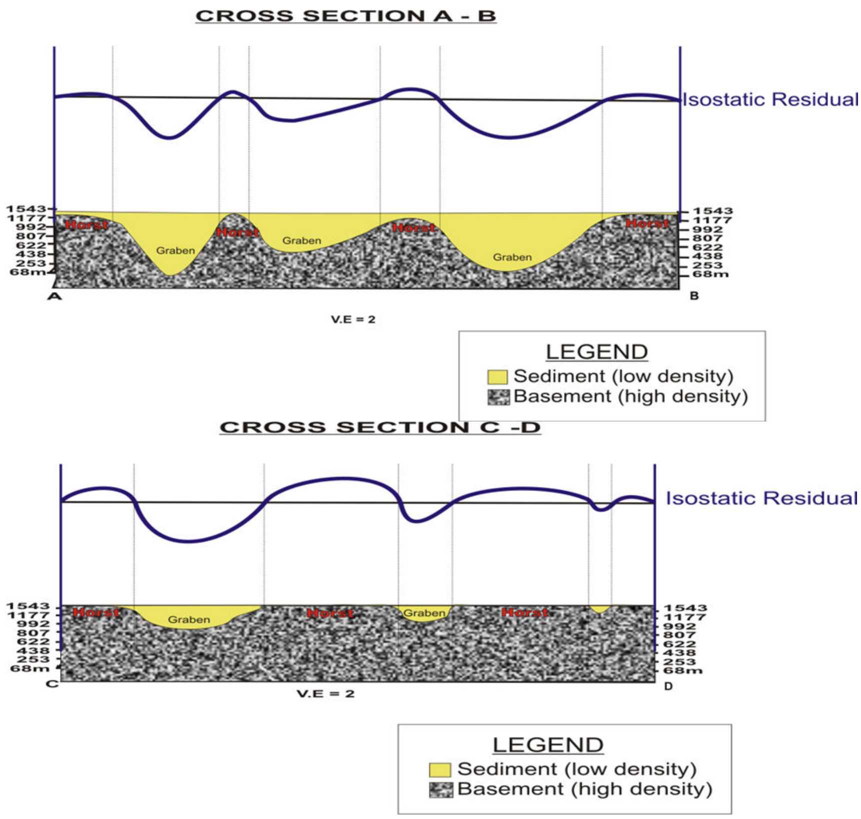

Fig. 7 Cross-section over Profiles A-B, C-D

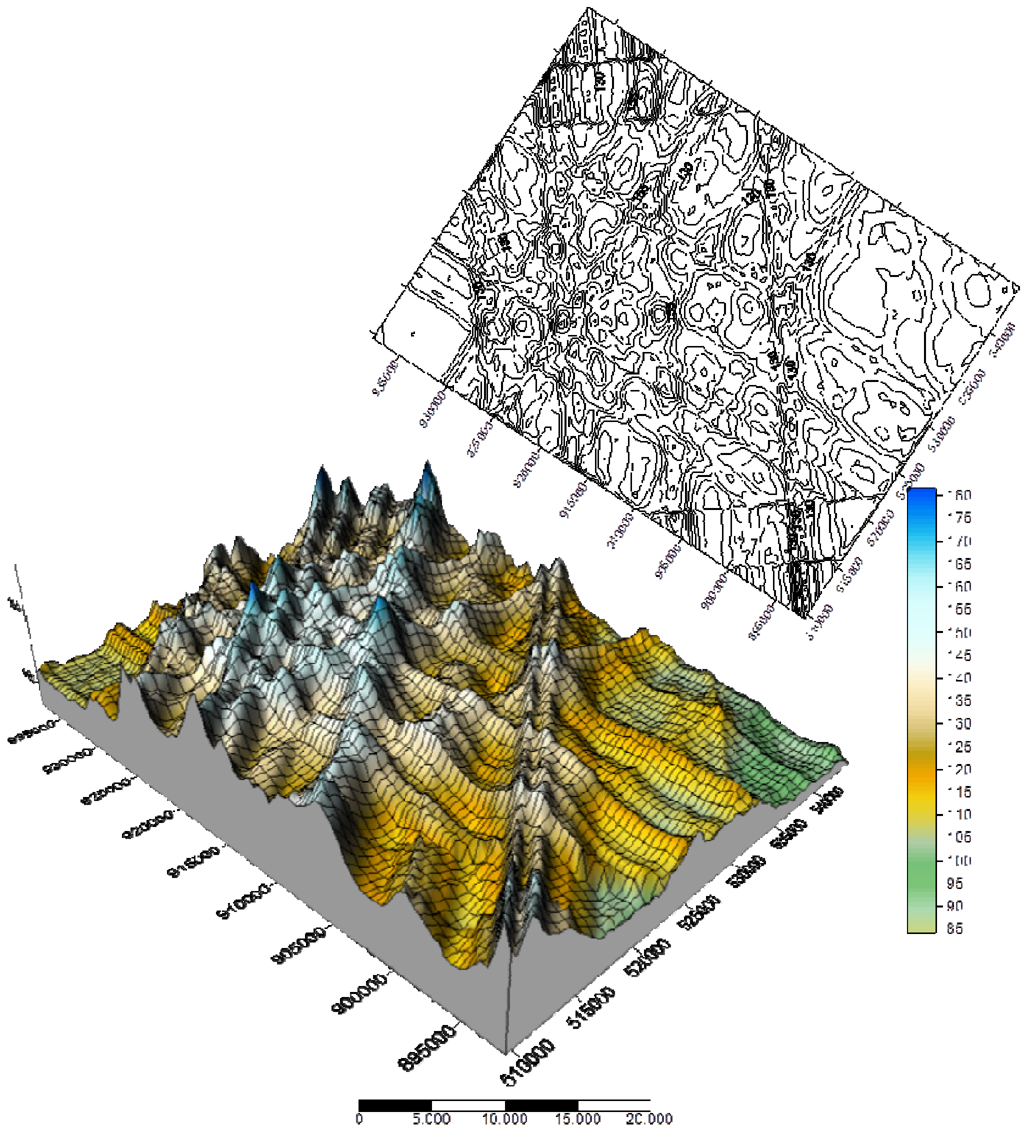

Fig. 8 Basement Morphology of the Sudy Area

IV. Discussion

Several interpretation methods were applied with the final goal of enhancing the signature of hidden structures. Differences in layer thickness, depth to the magnetic layer(s) and magnetic susceptibility of the layers govern the variability of the anomaly shapes. Further investigations of these variables using simple models provide graphical and conceptual guides for understanding the aeromagnetic expression of faults, how to locate and trace them from aeromagnetic anomalies.

The regional field in the case of the Lafia-Akiri area is the Basement Complex, mainly gneisses and migmatic gneisses that underlies the sediments [4], [13]. The residual fields are made up of high frequency components that could be intrusive or volcanic and noise, mainly cultural noise from settlements. This implies that the total magnetic intensity (TMI) grid data is composed of a wide range of wavelengths [14], [16]. One of the objectives of this research is to derive depth to the basement, so the high frequency components of the data were removed. A power spectrum was computed from depth slicing of the data using Geosoft's Oasis Montaj and resultant map, Fig. 4. The slices show variations coming from different depths mainly 1800m, 500m and 330m.

When gravity or magnetic sources occur in cluster at a certain depth, the sources will be shown as a straight line that has a gradient of -4π in a power spectrum which is the plot of the logarithm of the amplitude of the source against the wave number [8], [14]. Therefore, different straight-line branches in a power spectrum show the existence of clusters of gravity or magnetic sources at the different depths. From the power spectrum, Fig. 4, the signals coming from a depth of 1.8 km are thought to be from the basement, that from a depth of 500m and 300m are from the residual field which are made up of intrusive or volcanic and cultural noise.

To separate the regional field, a low pass filter was applied to the data where low wavenumbers (long wavelengths from the regional field) are passed and high wavenumbers (short wavelengths) rejected. From the spectral analysis, the deepest sources are at a depth of 1.8 km so a cut-off wavelength of 1.5km was selected with a Gaussian roll-off to minimize ringing.

Total horizontal derivative is a good edge detector because it computes the maxima over the edges of the structures. Full (or Total) Horizontal derivative

$$\text{THDR} = \sqrt{\left[\frac{\partial T}{\partial x}\right]^2 + \left[\frac{\partial T}{\partial y}\right]^2} \qquad (1)$$

The horizontal gradient method measures the rate of change in magnetic susceptibility in the $\boldsymbol{x}$ and $\boldsymbol{y}$ directions and produces a resultant grid. The gradients are all positive making this derivative easy to map. This method shows contacts that are linear and very continuous because it requires only horizontal derivatives. This derivative was applied to the RTE data of the Study area using Geosoft's Oasis Montaj and the output is shown in Fig. 5.

Average depth values to buried magnetic rocks using the power spectrum of total intensity field were achieved using spectral analysis. These depths were established from the slope of the log-power spectrum at the lower end of the total wave number or spatial frequency band. The application of spectral analysis to the interpretation of potential field data is sufficiently well established [1], [8], [14]. The method allows an estimate of the depth of an ensemble of magnetized blocks of varying depth, width, thickness and magnetization. This approach involves the Fourier Transformation of the aeromagnetic data to compute the energy (or amplitude) spectrum. This is plotted on a logarithmic scale against frequency. The slopes of the segments yield estimates of average depths to magnetic sources of anomalies.

Source Parameter Imaging or SPI was also applied to the magnetic data. This is a profile or grid-based method for estimating magnetic source depths, and for some source geometries the dip and susceptibility contrast. The method utilizes the relationship between source depth and the local wavenumber (k) of the observed field, which were calculated for any point within a grid of data via horizontal and vertical gradients. At peaks in the local wavenumber grid, the source depth is equal to n/k, where n depends on the assumed source geometry.

The plot generated, Fig. 6, showed the central-south/eastern portion of the study area as being deeper in contrast to the western-south west portion which is shallowest.

From the results of the Regional-Residual separation, the resultant magnetic grid was modeled for the basin morphology, Figs. 7-8. This presented the basement within the study area as having sets of micro-basins, in agreement with earlier workers in this area. This revelation became eminent, probably because of the enhanced aeromagnetic data and the soft ware used in the study.

V. Conclusion

Basement depths and sediment thickness over parts of the Middle Benue Trough were established through spectral analysis of the enhanced aeromagnetic data recently acquired by the Nigeria Geological Survey Agency, Abuja. The results of this study have confirmed the irregular nature of the trough, which is made up of horst-graben-like structures or micro-basins.

References

[1] Anderson-Mayes, A.(1997). Harnessing Spatial Analysis with GIS to Improve Interpretation Airborne Geophysical Data. Paper Presented at GeoComputation, 26th-29th August 1997.
[2] Ajakaiye, D.E. & Ajayi, C.O.(1986). Structures deducted from gravity data in the Middle Benue, Nigeria. Journal of African Earth Sciences, Vol. 5, No. 4, pp 359 – 369.
[3] Benkhelil,J.(1987). The evolution of the cretaceous Benue Trough, Nigeria. Journal of African Earth Sciences, Vol.8,251-282.3
[4] Burke,K.C.,Dessaurage, T.F.J.and Whitman, A.J.(,1971).Geological History of the Benue Valley and Adjacent Areas. African Geology,University of Ibadan press, Ibadan.
[5] Cratchley, C.B. and Jones, G.P. (1965) .An interpretation of the geology and gravity anomalies of the Benue Valley, Nigeria. Overseas Geological Survey.Geophysics. Paper, No. 1, pp 1 – 26.
[6] Geosoft Oasis Montaj, Arc GIS,Suffer8.0; Ilwis, Arcview 9.3.
[7] Nigerian Geological Survey Agency (NGSA), 2010.
[8] Nur, M.A, Onuoha, K.M, Ofoegbu, C.O (1994). Spectral Analysis of Aeromagnetic Data over the Benue Trough. Journal Mining and Geology, Vol. 30,. 2, pp 211-217.
[9] Nwachukwu, S.O.(1972). The Tectonic Evolution of the Southern portion of the Benue, Nigeria.Geological Magazine, NO.pp411-419.
[10] Offodile, M.E. (1976). The Geology of the Middle Benue, Nigeria. Ph.D. Thesis. University of Uppsala, Sweden. 166p.
[11] Offodile, M.E. (1984). The Geology and Tectonics of Awe Brine Field.Journal of Earth Sciences.Vol. 2, No 3 pp 189 – 203.
[12] Offodile, M.E. (2012). Searching for Petroleum within the Middle Benue Trough of Nigeria. Paper Presented at PDTF Chair at University of Jos, Nigeria, on the 14th of April, 2012.
[13] Olade, M.A.(1975). Evolution of Nigeria's Benue Trough (Aulocogen); Atectonic model/ Geol.Mag. 112, pp575-578
[14] Okereke, C.N., Onu, N.N., Ibe, K.K., Selemo, A.O.I., Opara,A.I., Ikoro, D.O., Ibeneme, S.I. &Oha, I.A (2012).Analysis Of Landsat and Aeromagnetic Data For Mapping Of Linear Structures: A Case Study Of Yola Area, Upper Benue Trough, Nigeria.International Journal of Engineering Research Applications, Vol. 2, Issue 3, May-Jun 2012, pp.1968-1977.
[15] Onyedim, G.C, Alagoa, K.D, Adedokun, I.O, Aderogba, A.A, Ovuru, C, (2009).Mapping High- Basement Faults in the Middle Benue Trough, Nigeria from Gravity Inversion Surface.Earth Sciences Research Journal, vol.13 no.2 Bogotá July/Dec. 2009.
[16] Onyewuchi, R. A, Opara, A.I, Ahiarakwem, C.A, Oko, F.U. (2012).Geological Interpretations Inferred from Airborne Magnetic and Landsat Data: Case Study Nkalagu Area, South eastern Nigeria. International Journal of Science and Technology. Volume 2 No.4, April 2012..