The International Journal of Engineering and Science (IJES)
|| Volume || 10 || Issue || 5 || Series III || Pages || PP 45-50|| 2021 ||
ISSN (e): 2319-1813 ISSN (p): 20-24-1805

Interpretation of Aeromagnetic Data of Guzabure and Its Environs Chad Basin Northeastern Nigeria, Using Source Parameter Imaging

Nwobodo, A. .N. ,Ikeri, H. I. and Chikeleze, P. C
Department of Industrial Physics, Enugu State University of Science and Technology
Corresponding author: ifeanyihenry75@yahoo.com

---***ABSTRACT***---

The airborne magnetic data of Chad Basin areas have been interpreted qualitatively and quantitatively using source parameter imaging techniques. Six aeromagnetic data sheets covering an area bounded by latitudes 12° 00' to 13° 00' North and longitudes 12° 30' to 14° 00' East were used as basic data for determining the nature of the magnetic anomalies over the area. Regional anomaly was removed from the total magnetic intensity field to obtain the residual anomaly field using polynomial fitting method. The total magnetic intensity and residual intensity fields show range of magnetic anomalies which strongly revealed that the study area is magnetically heterogeneous. The horizontal derivatives maps show the occurrence of subsurface linear structures which suggests a significant presence of faults in the study area. Source Parameter Imaging (SPI) technique was employed in quantitative interpretation with the aim of determining depth/thickness of the sedimentary basin. The results from SPI estimated depth ranges from 345.0 m (shallow magnetic bodies) to 6880.6 m (deep lying magnetic bodies). The sedimentary thickness obtained in this work indicates the possibility of hydrocarbon accumulation in the study area.

***KEYWORDS**: Source parameter imaging, aeromagnetic data, Chad basin, Derivatives, Magnetic anomaly, Basement*

Date of Submission: 15-05-2021 Date of Acceptance: 31-05-2021

I. INTRODUCTION

Aeromagnetic survey is a modern geophysical method that has widely gained global attention both for fundamental research and as a reconnaissance tool for mineral exploration. It provides faster and cheaper mechanisms to investigate the sub-surface geology based on the anomalies in the earth's magnetic field that result from the underlying magnetic properties of the rocks. Researchers have consistently employed aeromagnetic method in search for oil and gas, mapping of magnetic basements at regional scale and also for exploration of weakly magnetic sedimentary contacts at local scales [1]. Airborne geophysical survey measures the local variation of different geochemical parameters of the earth such as distribution of magnetic minerals, density, electric conductivity and radioactive element concentration.

Aeromagnetic survey delineates the changes in the geomagnetic field, which manifest as a result of changes in the percentage of magnetite in the rock which further exposes the variations in the distribution and type of magnetic minerals beneath the earth surface [2]. In principle sedimentary formations are non-magnetic and thus have little effect while igneous and metamorphic rocks exhibit greater anomaly making it possible to identify geologic boundaries and exploration of bedrock geologic features concealed below and over formations [3]. A magnetic anomaly is a variation in the earth's magnetic field due to changes in the rocks magnetism. Mapping this anomaly over an area is the fundamental concept underlying the detection of structures obscured by overlying material. Magnetic anomalies are noted where vast accumulation of iron ore caused a local deviation in the earth's magnetic field which provides insight into the sub-surface structure and composition of the earth's crust. Interpretation of aeromagnetic data is useful for mapping of the surface and sub-surface regional geological features such as intrusive bodies, contacts, faults, basement rocks and mineralization [4]..

Interpretation of Aeromagnetic data could be done qualitatively and quantitatively. Qualitative interpretation is the interpretation of the survey results such as the major features revealed by a survey in terms of the likely geological formations and structures that give rise to the given anomalies [5], while quantitative interpretation on the other hand involves making numerical estimates of the depth and dimensions of the sources of anomalies mostly in the form of modeling of sources which could replicate the anomalies recorded in the field [6]. Quantitative interpretation methods of aeromagnetic data mostly employed are the Euler-3D methods, spectral analysis, analytical signal methods, source parameter imaging (SPI) methods, graphical interpretation methods and forward and inverse modeling [7]. In this research work .source parameter imaging was adopted for the interpretation of airborne magnetic data of Chad Basin.

II. GEOLOGY OF CHAD BASIN

The Chad Basin lies within a vast area of central and west Africa at an elevation of between 200 and 500m above sea level and covering approximately 230,000km^2 [8]. It is the largest area of inland drainage in Africa according to [9][10]. It extends into parts of the republic of Niger, Chad, Cameroon, Nigeria and Central Africa. The Nigerian Chad Basin as shown in Figure 1 is about one tenth of the Basin [11][12]. This Bornu-Chad Basin is a broad sediment-filled depression spanning northeastern Nigeria and adjoining parts of the Republic of Chad. The stratigraphy of Bornu-Chad Basin has been reported by several workers [13][14][15]. The stratigraphic sequence shows that Chad, Kerri-kerri and Gombe formations have an average thickness of 130 to 400 m. Below these formations are the Fika shale with a dark grey to black in color, with an average thickness of 430 m. Others are Gongila and Bima formations with an average thickness of 320 m and 3.5 km, respectively [16]

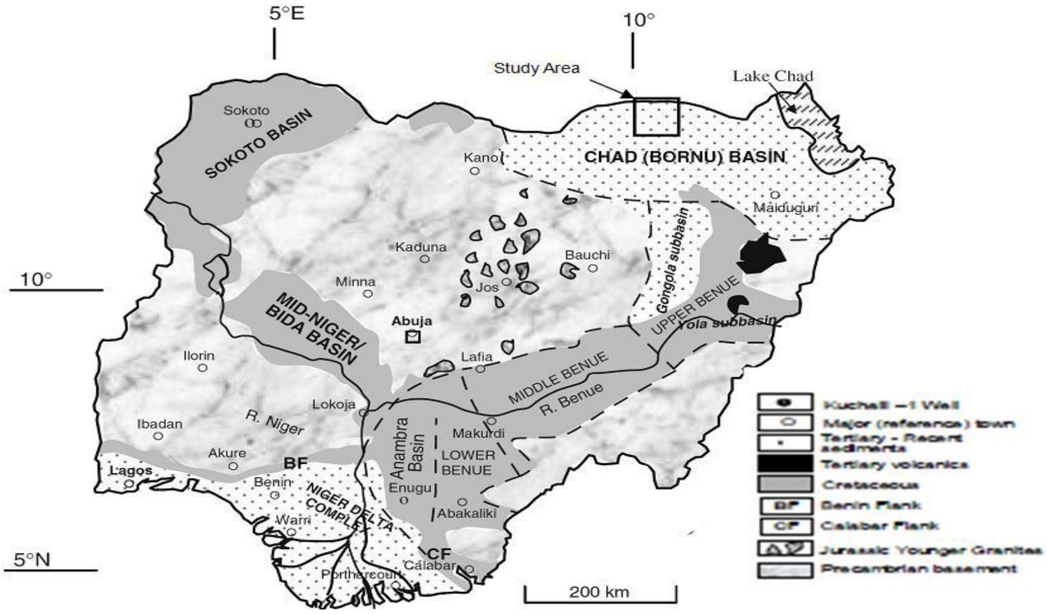

Fig 1: Map of Nigeria showing the study area

III. THEORETICAL FRAMEWORK

The Source parameter imaging (SPI) is a technique which uses an extension of the complex analytical signal to estimate magnetic depths [17]. This technique sometimes referred to as the local wave number method, 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 wave number (K) of the observed field, which can be calculated for any point within a grid of data via horizontal and vertical gradients [18]. The depth is displayed as an image. The SPI method requires first and second order derivatives and is thus susceptible to both noise in the data and to interference effects. The analytic signal $A_1(x,$ z) is defined by [19] as

$$A_1(x,z) = \frac{\partial M(x,z)}{\partial x} - j\frac{\partial M(x,z)}{\partial z} \qquad 1$$

where M(x, z) is the magnitude of the anomalous total magnetic field, j is the imaginary number, and z and x are Cartesian coordinates for the vertical direction and the horizontal direction perpendicular to strike, respectively. Nabighian (1972) showed that the horizontal and vertical derivatives comprising the real and imaginary parts of the 2D analytical signal are related by

$$\frac{\partial M(x,z)}{\partial x} \Leftrightarrow -j\frac{\partial M(x,z)}{\partial z} \qquad 2$$

where ⇔ denotes a Hilberts transform pair. The Local wavenumber K_1 is defined by [20] to be

$$K_1 = \frac{\partial}{\partial x}tan^{-1}\left[\frac{\partial M}{\partial z} / \frac{\partial M}{\partial x}\right] \qquad 3$$

Thus, the analytic signal could be defined based on second-order derivatives, $A_2(x, z)$, where

$$A_2(x, z) = \frac{\partial^2 M(x,z)}{\partial z\,\partial x} - j\frac{\partial^2 M(x,z)}{\partial^2 z} \qquad 4$$

This gives rise to a second-order local wave number K_2 expressed as

$$K_2 = \frac{\partial}{\partial x}\tan^{-1}\left[\frac{\partial^2 M}{\partial^2 z} \Big/ \frac{\partial^2 M}{\partial z\,\partial x}\right] \qquad 5$$

(Nabighian, 1972) derived the expressions for the first and second order local wave numbers as:

$$k_1 = \frac{(n_k + 1)h_k}{h_k^2 + x^2} \qquad 6$$

and

$$k_2 = \frac{(n_k + 2)h_k}{h_k^2 + x^2} \qquad 7$$

where n_k is the SPI structural index (subscript k = c, t or h), and nc=1 and nh = 2 for the contact, thin sheet and horizontal cylinder models and hk is the depth to the top of the contact, respectively. The algorithm in the Oasis Montaj software was used in computing the SPI depth of the magnetic data using the first vertical derivatives and horizontal gradient. The calculated SPI depth was gridded using the minimum curvature tool of the Oasis Montaj software which interpolated the data into an equally spaced cells in a specified co-ordinate system and displayed in a 2D map (figure.5).

IV. MATERIALS AND METHOD

Data Aquisition

Six aeromagnetic maps were acquired from National Geological Survey Agency (NGSA), Abuja. These sheets are sheets 44, 45, 46 ,66, 67 and 68. The aeromagnetic data were obtained as part of a nationwide aeromagnetic survey sponsored by geological survey of Nigeria. The data were acquired along a series of NW – SE flight lines with a spacing of 5km and an average flight elevation of about 80m while tie lines occur at about 2km interval. The geomagnetic gradient was removed from the data using the international geomagnetic reference field (IGRF). The six sheets were merged into a single composite sheet which formed the study area using Ms Excel software. Other data reduction techniques applied include: the regional – residual separation and the horizontal derivatives calculations.

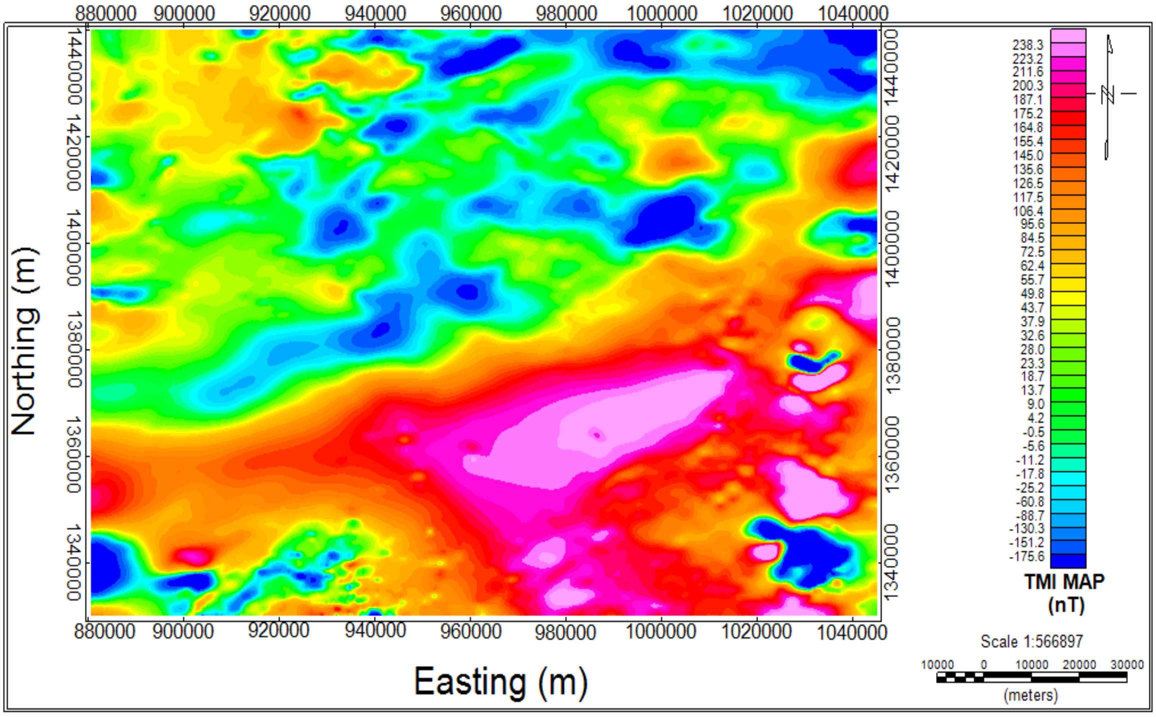

Fig 2: Total magnetic intensity (TMI) map of the study area.

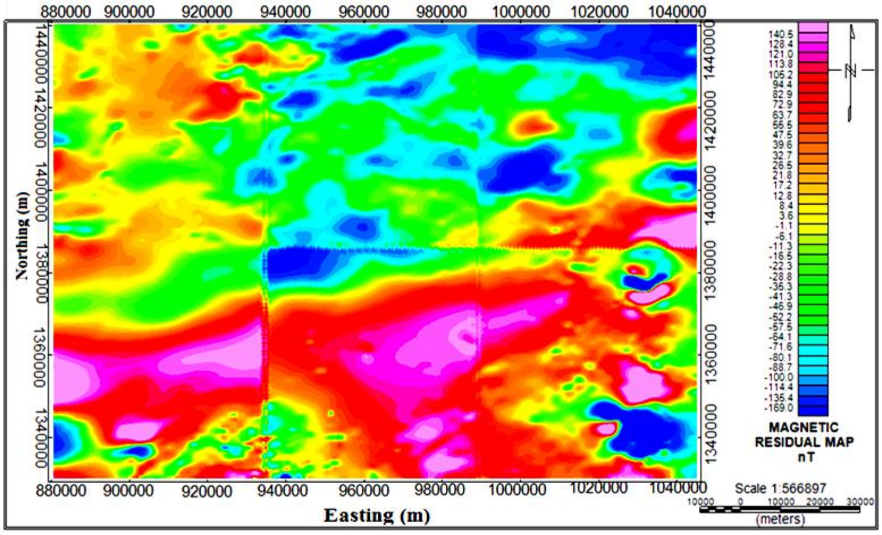

Fig: 3 Residual anomaly map of the study area.

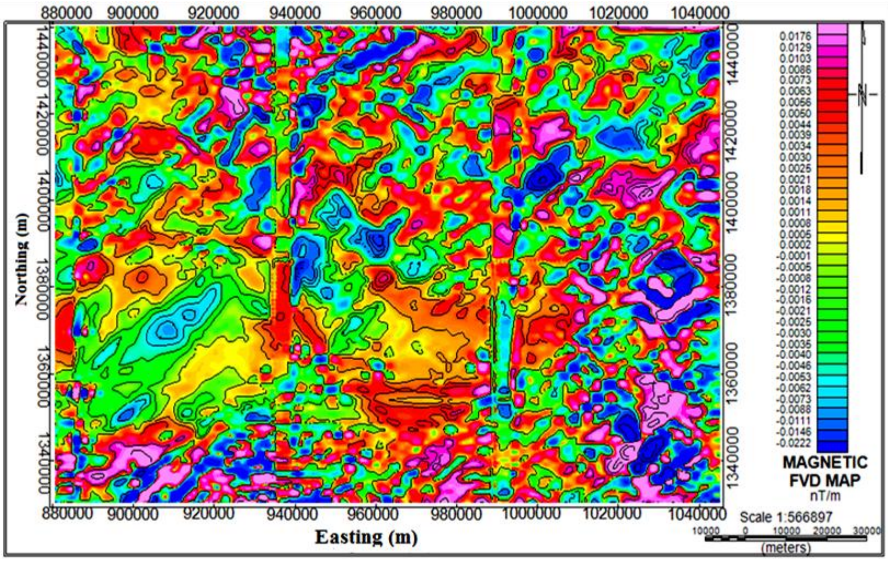

Fig 4a: First vertical derivative map of the study area.

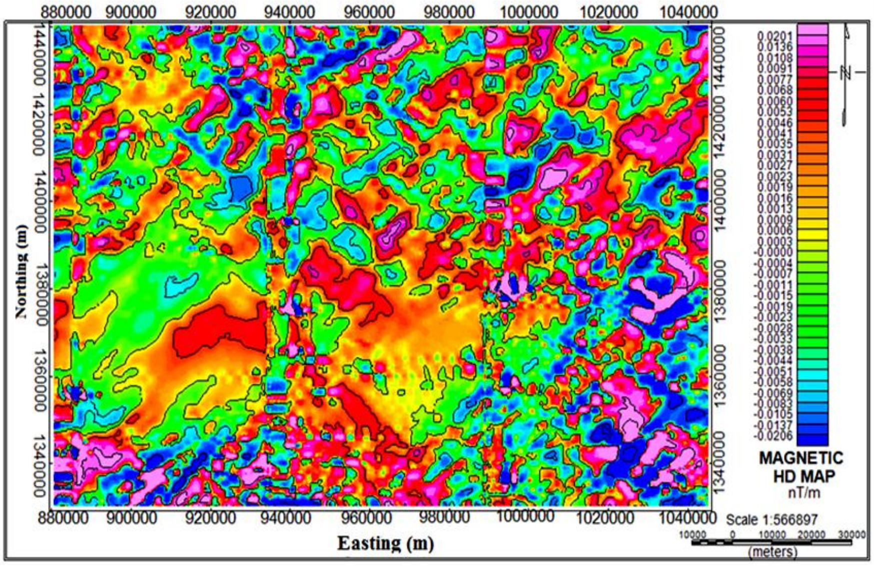

Fig 4b: Horizontal derivative map of the study area.

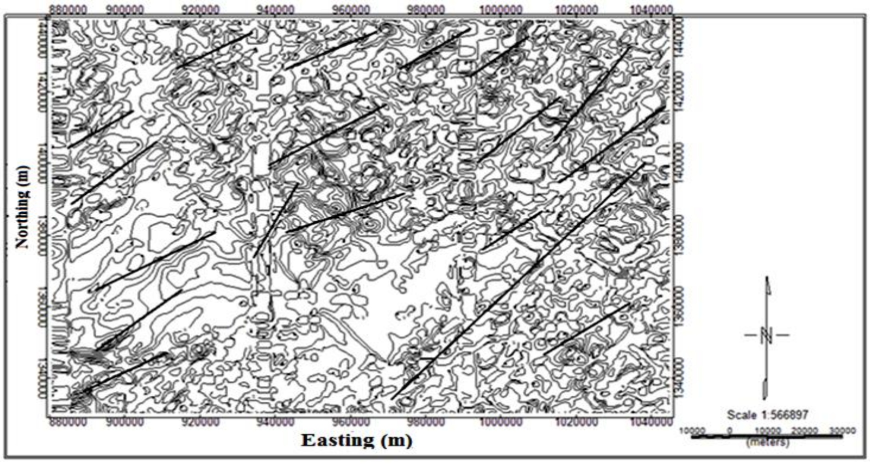

Fig 4c: Magnetic lineament map showing the lines of the faults in the study area (derived from horizontal derivative)

V. RESULT AND DISCUSSION

The total magnetic intensity of the study area shows range of magnetic anomalies which vary from -88.400 nT to 238.003 nT while the residual values are from -169.000 nT to 140.500 nT. The residual magnetic field was used to bring into focus local features which tend to be obscured by the broad features of the regional field. The areas of strong positive anomalies likely indicate a higher concentration of magnetically susceptible minerals while areas with broad magnetic lows are likely areas of lower susceptibility minerals. Horizontal derivative enhancement technique was applied on the Total magnetic intensity field to reveal subtle geophysical features. The horizontal derivative map (Figure 4b) shows the occurrence of subsurface linear structures which could be the presence of faults in the area; the fault lines are visible on the lineament map (Figure 4c). The lineament could be a favourable structure for the control of mineral deposits in the area. This agrees with [21] who investigated the basement fault propagation into the overlying sedimentary cover in parts of the Nigerian sector of Chad Basin. They asserted that faults constitute potential structural traps for oil accumulation or conduit for oil migration. In Figure 5, the negative depth values shown on the SPI legend depicts the depths of buried magnetic bodies, which may be deep seated basement rocks or near surface intrusive. The pink colour generally indicates areas occupied by shallow magnetic bodies, while the blue colour showed areas of deep lying magnetic bodies. The SPI depth result ranged from 345.0 m (shallow magnetic bodies) to 6880.6 m (deep lying magnetic bodies). These depths were also in line with the range of depths predicted by earlier researchers that worked in Chad Basin [22] obtained a maximum sedimentary thickness of 5.0 km from Source Parameter Imaging of aeromagnetic data of Upper Benue Trough and Borno Basin, Northeast, Nigeria.

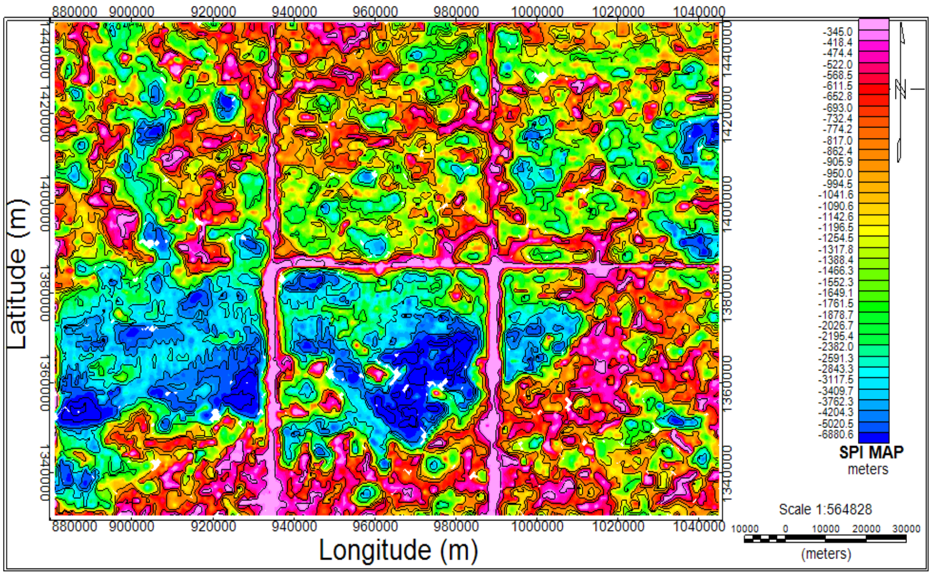

Fig.5: Source parameter image (SPI) map of the study area.

VI. CONCLUSION

The maximum depth obtained in this work shows thick sediment that could be feasible for hydrocarbon accumulation which strongly agrees with the work of [23] that the minimum thickness of the sediment required for the commencement of oil formation from marine organic remains would be 2.3 km.

ACKNOWLEDGEMEMT

The authors wish to appreciate the Nigerian Geological Survey agency for providing the airborne radiometric data used for this study.

REFERENCES

[1]. Folami, S.L: Interpretation of Aeromagnetic Anomalies in Iwaraja Area, southwestern Nigeria. Journal of Mining and Geology 28 (2), 1992, 391 – 396.
[2]. Kasidi, S. and NdatuwongL.G : Spectral Analysis of Aeromagnetic data over Longuda plateau and Environs, North-Eastern Nigeria Continental J. Earth sciences (3), 2008, 28 – 32.
[3]. Alberto,G. and Politecnico, T. : Integrated data processing for archeological magnetic surveys. The Leading Edge 23, (11), 2005,1138-1144.
[4]. Roest, W.R.; Verhoef, J. and Pilkington: Magnetic interpretation using the 3D analytic signal.Geophysics 57, 1992, 116-125.
[5]. Reid, A. B., Allsop, J. M., Granser, H., Millet, A. J., and Somerton, I. W. (1990). Magnetic interpretation in threedimensions using Euler deconvolution: Geophysics, 55: 80-9.
[6]. Macleod, I.N; Jones, K and Dai T.F : 3D analytic signal in the Interpretation of total magnetic field data at low magnetic latitudes.Exploration Geophysics, 24, 1993, 679 – 687.
[7]. Reid, A. B., Allsop, J. M., Granser, H., Millet, A. J., andSomerton, I. W. (1990). Magnetic interpretation in threedimensions using Euler deconvolution: Geophysics, 55: 80-9.
[8]. Ajana, O., Udensi, E.E., Momoh, M., Rai, J. K. and Muhammad, S. B. (2014). Spectral Depths Estimate of Subsurface Structures in Parts of Borno Basin, Northeastern Nigeria, using Aeromagnetic Data. *Journal of Applied Geology and Geophysics,* 2(2): 55-60.
[9]. Barber, W. (1965). Pressure water in the Chad formation of Bornu and Dikwa Emirates, NE Nigeria. *Bulletin Geological Survey of Nigeria,* (35): 138.
[10]. Matheis, G. (1976). Short review of the geology of chad basin in Nigeria, in C.A., Kogbe (2), Geology of Nigeria, (Elizabethan Publication Company, Lagos, Nigeria), 289-294.
[11]. Wright, J. B., Hastings, D., Jones, W.B. and Williams, H.R. (1985). Geology and Mineral resources of West Africa. George Allen and Urwin, London. 90- 120
[12]. Falconer, J. D. (1911). The geology and geography of northern Nigeria (MacMillan London, UK).
[13]. Avbovbo, A. A., Ayoola, E. O. and Osahon, G. A. (1986). Depositional and structural styles in Chad Basin of Northeastern Nigeria. *Bulletin American Association Petroleum Geologists,* 70(121): 1787 – 1798.
[14]. Roest, W.R.; Verhoef, J. and Pilkington: Magnetic interpretation using the 3D analytic signal.Geophysics 57, 1992, 116-125.
[15]. Obaje, N. G. (2009). Geology and mineral resources of Nigeria. *Berlin: Springer Publishers*, 1–203
[16]. Nwankwo, C. N. and Ekine, A. S. (2009). Geothermal gradients in the Chad Basin, Nigeria, from bottom hole temperature logs. *International Journal of Physical Sciences*, 4(12): 777-783.
[17]. Thurston, J. B. and Smith, R. S. (1997). Automatic conversion of magnetic data to depth, dip, and susceptibility contrast using the SPI™ method. *Geophysics*, 62(3): 807-813.
[18]. Salako, K. A. (2014). Depth to Basement Determination Using Source Parameter Imaging (SPI) of Aeromagnetic Data: An Application to Upper Benue Trough and Borno Basin, Northeast, Nigeria. *Academic Research International,* 5(3): 74-86.
[19]. Nabighian, M. N. (1972). The analytic signal of two dimensional bodies with polygonal cross section: Its properties and use for automated anomaly interpretation. Geophysics, 37, 507–517.
[20]. Smith, R. S., Thurston, J. B. Dai, T.-F.and.MacLeod, I. N. (1998) the improved source parameter imaging method: Geophysical Prospecting, 46, 141–151.
[21]. Nwosu, O. B. (2014). Determination of Magnetic Basement Depth over Parts of Middle Benue Trough by Source Parameter Imaging (SPI) Technique Using HRAM. *International journal of scientific & technology research,* 3(1): 262.
[22]. Folami, S.L: Interpretation of Aeromagnetic Anomalies in Iwaraja Area, southwestern Nigeria. Journal of Mining and Geology 28 (2), 1992, 391 – 396
[23]. Wright, J. B. (1976). Origin of the Benue trough- a critical review, in C.A., Kogbe (2), Geology of Nigeria, (Lagos, Nigeria: Elizabethan Publication Company), 309-317.
.