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Research Article

Qualitative interpretation of aeromagnetic data over parts of Middle Benue Trough Nigeria using HRAM

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Abstract

The new high resolution aeromagnetic data of parts of the Middle Benue Trough Nigeria have been qualitatively interpreted to assess some of it features. The regional-residual separation was performed with a first order polynomial using polifit program. The residual data obtained was contoured into 2-D and 3-D maps and this revealed two prominent magnetic anomaly source intensities; the low frequency anomaly and the high frequency anomaly sources. The low frequency anomalies emanates from deep seated bodies in areas with thicker sediments and may beviewed as the magnetic basement depth. The high frequency anomaly emanates from shallow seated geologic bodies in areas of shallower sediments and may be attributed to the volcanic rocks that intruded into the sedimentary formation and this could possibly be responsible for the mineralization found inthearea. Varying magnetic highs and lows have been found in the study area which might likely indicate undulating basement surface and likely traps. The general trend in the orientation of the magnetic contours and lineament was found to be predominantly in the NE-SW direction, an attribute of the Pan – African Orogeny trends. The regional field was found to dip gently and uniformly towards the North-eastern part of the study area from the South-western part with a regional gradient of 205gammas/km. Prominent closures and undulations are more in the basement surface around Gboko area than the Makurdi area. It's very likely that this study area with the oldest marine sedimentary layer of the Albian Age, Coniacian – Turonian Age, and Turonian – Senonianage possessing thesefavourable geologic features and traps mayhave the potential to generate hydrocarbon if other conditions are met.

Keywords: Middle Benue Trough, Magnetic anomaly, high resolution aeromagnetic data (HRAM), magnetic basement depth, magnetic highs and lows, high frequency and low frequency anomaly source.

INTRODUCTION

With the recently acquired high resolution aeromagnetic data covering the whole of Nigeria, the utilization of the data for mineral or hydrocarbon exploration is a topical issue. The location of the study area is also unique in having the earth's field inclination close to zero +/-2°, this makes intuitive interpretation of magnetic data difficult and reduction to the pole very unstable, thus making this an interesting case study.This work aims to visually inspect andinterpret the features of the plotted 2-D and 3-D surface contours and lineaments maps as regards to the basement topography andstructural trends.

The new high- resolution airborne survey carried out in Nigeria by Fugro airborne services in 2009 surveysfor the Nigerian Geological Survey Agency is of higher quality than that of 1970s. This survey was flown at 500m line spacing and 80m terrain clearance, hence of higher resolution, in digital form and of higher quality due to improvement in technology and powerful error correcting software. The old aeromagnetic data in Nigeria in the 1970s is of lower resolution being flown at a flight line spacing of 2km, average terrain clearance of 150m, and a nominal tie line spacing of 20kmand have become of limited use. A lot of previous studies have been carried out by many researchers using the old aeromagnetic data in Nigeria; these include Ofoegbu, (1984, 1985, 1986); Ahmed (1991); Nwachukwu (1985); Ofoegbu and Onuoha (1991); Onwuemesi (1996) etc, and have shown favourable geologic features to hydrocarbon accumulation. This study used the new data to re-evaluate the study area qualitatively.

The Location and Geology of the Study area

Geographically, the study area (shown in Figure 1) is located in the Middle Benue Trough Nigeriawithin Latitude 7^{0}00'N to 8^{0}00'N and Longitude 8^{0}50'E to 9^{0}50'E. In the aeromagnetic map it is represented by sheet numbers 251, 252, 271, 272.Geologically, the separation of the African Continent from the South American continent in the Aptian led to the tectonic evolution of the Benue trough (Grant, 1971). The Triple junction (RRF) characterized by South Atlantic Margin, the Gulf of Guinea and the Benue Trough consequently emerged. An aulacogen was said to have been formed (Olade, 1975) as the Benue trough failed to develop into rift. This Benue trough is part of the long stretch arm of the Central African rift system originating from the early Cretaceous rifting of the central West African basement uplift.Ithas been categorized into the Lower Benue Trough at the southern part, the Middle Benue Trough at the center while the Upper Benue Trough is at the Northern part (Samuel et al., 2011). Thick sedimentary cover of varied composition whose age ranges from Albian to Maastrichtian is said tocharacterize this trough (Obaje, 2004). Stratigraphically, the Asu-River Group of marine origin is the oldest deposited sediment in theMiddle Benue Trough followed by Ezeaku Formation, keana/Awe Formation, Awgu Formation and Lafia Sandstone as the youngest sediment (Obaje, 2004). The work of Cratchley and Jones (1965), Burke *et al.* (1970), Offodile (1976), Osazuwa *et al.* (1981) and Offoegbu (1985) have more on the geology of the Benue Trough.

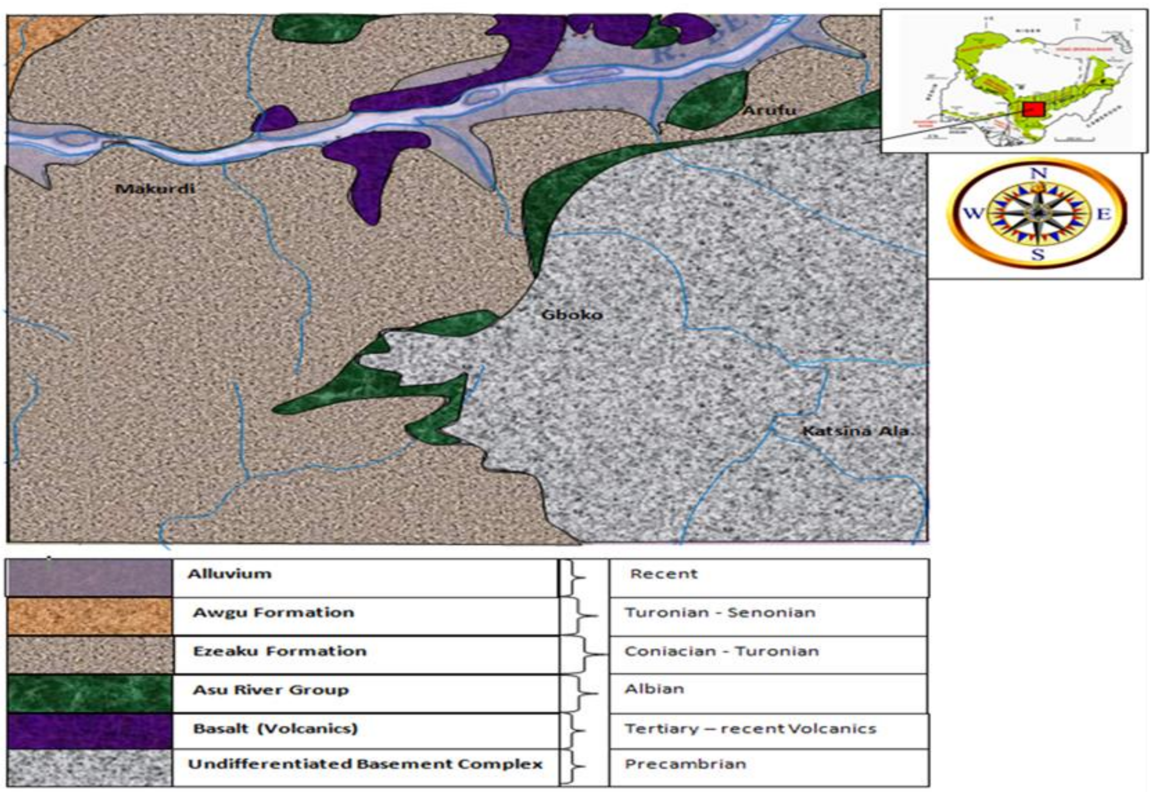

Figure 1. Geological map of part of the Middle Benue Trough (Modified from NGSA, 2003)

MATERIALS AND METHODS

A total area of about 12,100km^2 was studied. It is made up of four square sheets of number 251, 252,271 and 272,with each square block of 55 x 55 km^2 representing a map in the scale of 1:100,000. The new high-resolution airborne data of 2009 used for this work as shown in Figure 2 is in digital form and of higher resolution unlike the Map form of the 1970s. The geomagnetic gradient was removed from the data using the International Geomagnetic Reference Field (IGRF) formula.

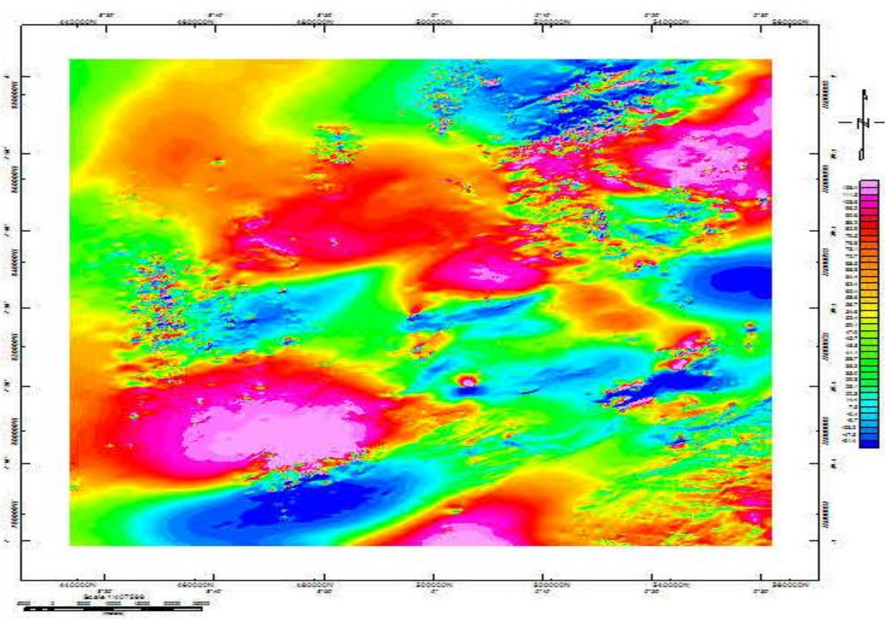

Figure 2. Magnetic anommaly map of Makurdi-Gboko Axis of the Middle Benue Trough Nigeria

The Qualitative interpretations

Qualitative interpretation of aeromagnetic data have been carried out by many researchers which includes Vacquier et al., 1951; Sharma, 1976 etc. The qualitative interpretation of a magnetic anomaly map begins with a visual inspection of the shapes and trends of the major anomalies, delineation of the structural trends, closer examination of the characteristic features of each individual anomaly etc. Thesefeatures majorly bothers on the relative locations and amplitudes of the positivecontour parts of the anomaly (magnetic highs) and negative contour parts of the anomaly (magnetic lows) Sharma, 1976.

The qualitative interpretation carried in this work bothers on the production and interpretation of the composite anomaly map of the area, the regional map, the residual map and the lineament map of the study area.

Production of composite aeromagnetic anomaly maps

The acquired digitized dataset were compiled, transported into sufer32software and used to generate the maps shown on figure 3a and b. This gave us the first picture and topography of the study area is 2-D contour and image map.

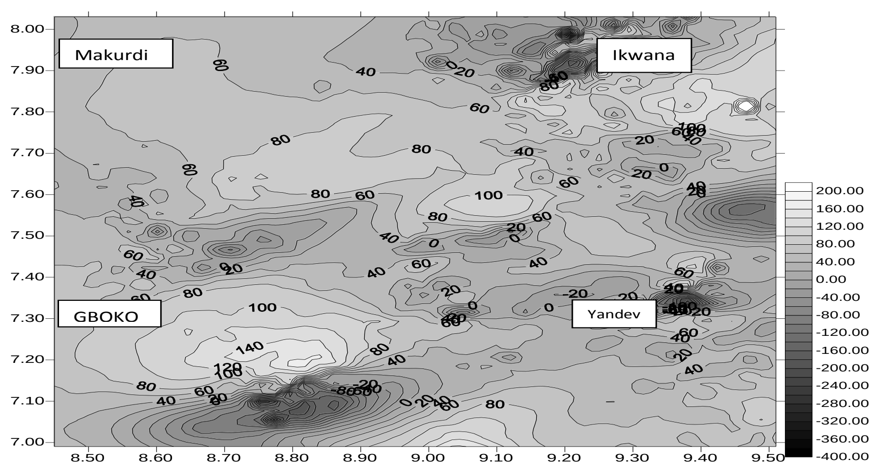

Figure 3a. 2-D Composite aeromagnetic anomaly contour map of the study area (add a background value of 32000nT to each value)

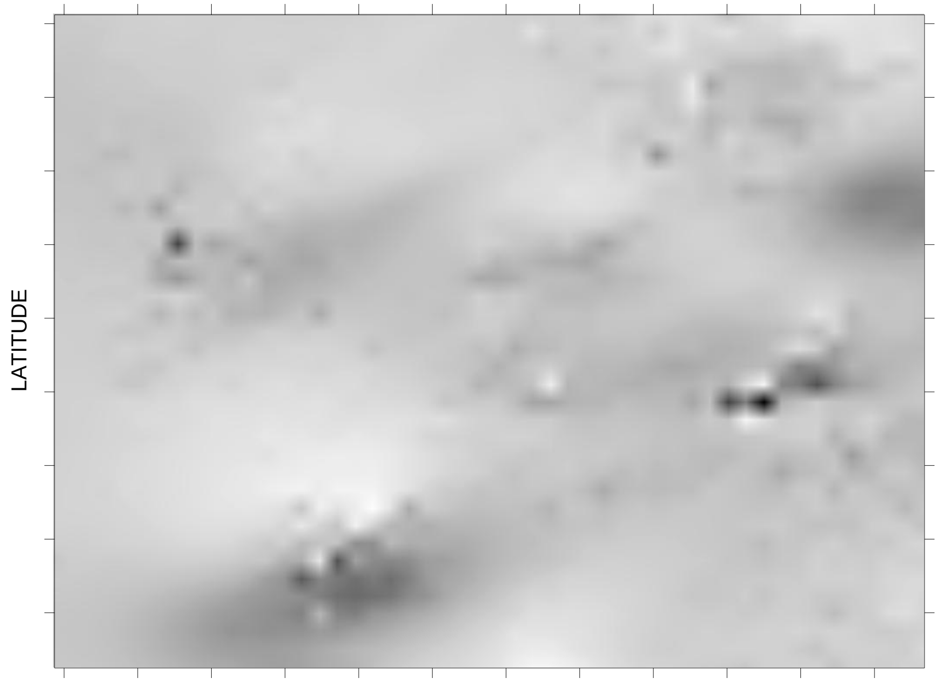

Figure 3b. 2-D total field image map

Regional and Residual anomaly Maps

The acquired dataset usually comprise of the superposition of the effects of all underground magnetic sources. Usually the targets in this aeromagnetic exploration are the anomalies of the basement rock, and their magnetic field is superimposed in the regional field that comes from larger or deeper sources, and must be separated to get the residual data.The regional field was removed from the total magnetic field intensity data (observed data) through the first order polynomial using polifit program. The regional and the residual maps have been presented in figure 4 and 5.

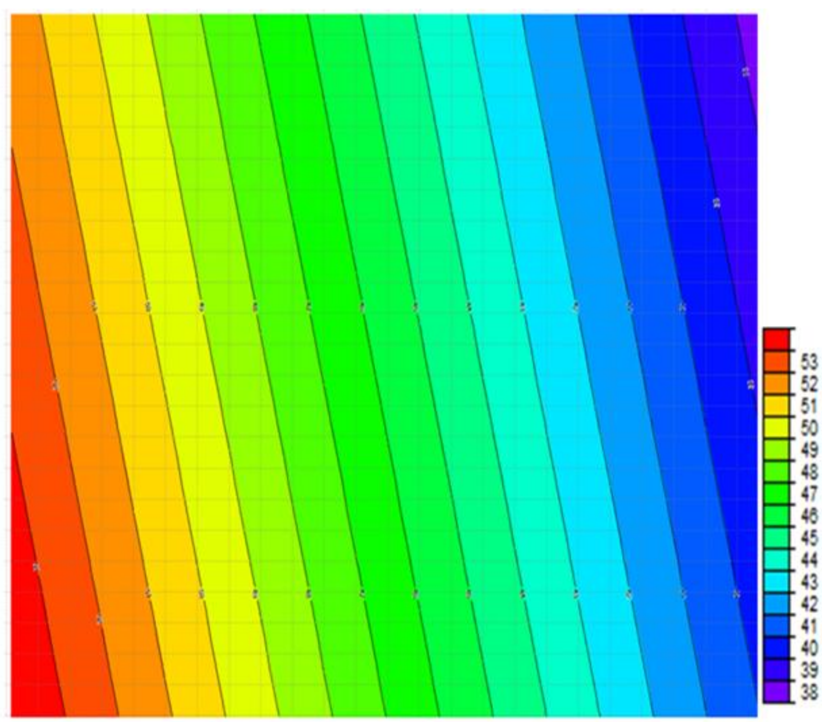

Figure 4. The Regional magnetic field anomaly map of the study area (add 32000nT to every value

The trends in this regional map (Figure 4) appearing in uniform variations represented by parallel evenly spaced contours can be observed to run in the NW-SE direction. This has been attributed to deeper heterogeneity of the earth crust during the sequence of events at possible opening up of South American and African plate. The regional field dips gently and uniformly towards the North-eastern part of the study area from the South-western part with a regional gradient of 205gammas/km. The 2-D residual map on of the study area has been shown on Figures 5a and the anomalies numbered.

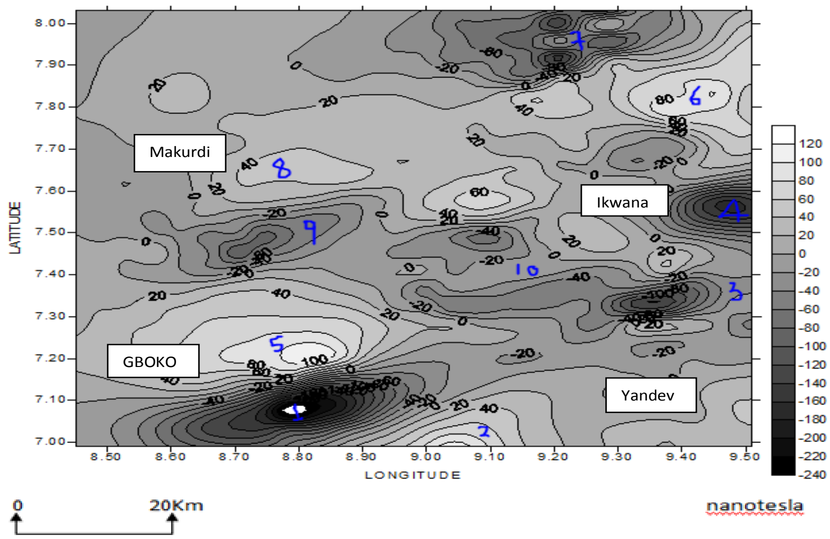

Figure 5a. The 2-D residual anomaly contour map of the project area

A look at the residual map of the study area on Figure 5a shows that the area is made up of magnetic highs and lows (high frequency and low frequency magnetic anomaly source).The most prominent anomalies on the residual map have been labelled (anomalies 1-9) which represents the magnetic signatures of the subsurface structures. Itcould be seen that the magnetic anomalies in the study area is separated into magnetics lows(1,3,4,7,9) which are related to deep-seated bodies which are areas of thickersediment; and magnetic highs(2,5,6,8) related to near-surface bodies which are areas of shallower sediment. About one third of the map can be seen to be featureless which may correspond to undifferentiated basement in the south-eastern part of the study area.The varying amplitude of these magnetic anomalies is an indication of varying topography and different sedimentary thickness in the study area.These variations in the anomaly amplitude may also indicate possibly the occurrences of basement complex rocks containing varying amounts of magnetic minerals. The general trends in the orientation of these magnetic contour closures could be observed to be in the NE-SW directionwith subordinate E-W orientation. Prominent closures and undulations are more noticeable in the basement surface of Gboko environs than others. Makurdi area is observed on Ezeaku Formation and Awgu Formation and nearly featureless. The clearer picture of the study area as discussed above has been revealed by figure 5b which is a 3-D view of figure 5a.

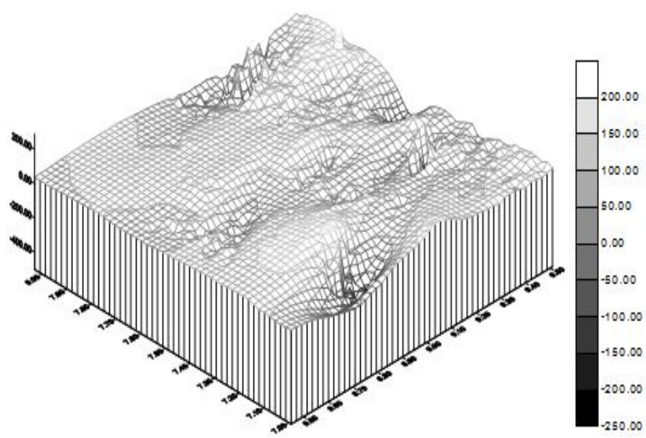

Figure 5b. The 3-D view of themap showing the undulating topography of the basement

Magnetic lineament map

The positions of geologic features appearing as thin elliptical closures and nosing on the aeromagnetic map are usually indicated by lines drawn parallel to the elongation and through the centre of the anomalies. Shown of Figure 6 is the structural trend map showing the direction of lines of the major faults within the study area.

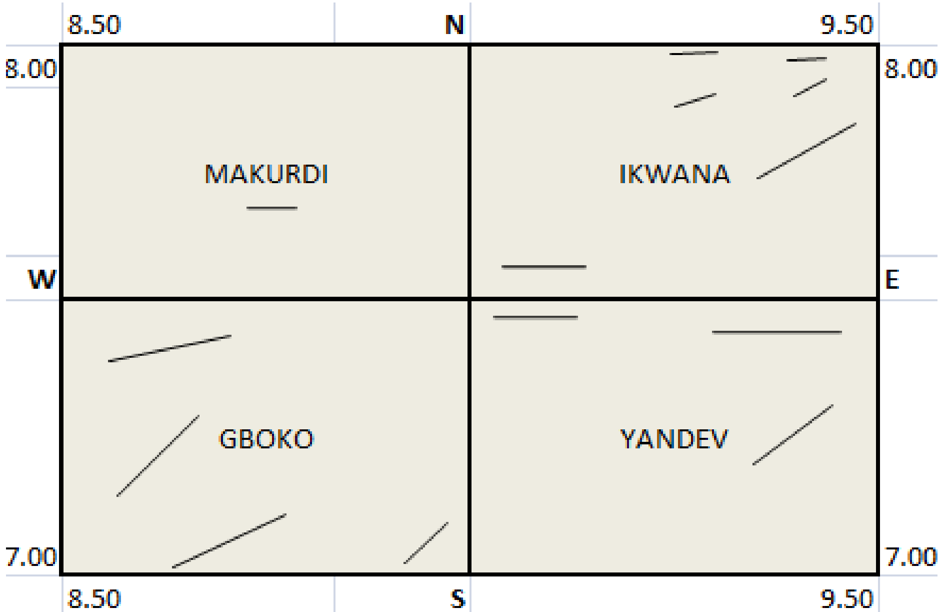

Figure 6. Magnetic lineament map showing the directions of faults in the study area (derived from residual map)

The main trends of the magnetic lineaments in the study area are in NE-SW with subordinate E-W trend. These magnetic lineament lines could be indicative of directions of migration of hydrocarbons in the area if present and could also indicate the trend of structural fractures in the study area.

DISCUSSIONS

Qualitative analysis of aeromagnetic data of the study area in the middle Benue trough have revealed that the area is made up of magnetic lowsor low frequency anomalies corresponding to deep lying bodieswhere thicker sedimentsare found and this may possibly be the magnetic basement depth. It have equally revealed that the study areas is also made up of high frequency anomalies corresponding to near surface lying bodies where the sediments are shallower and this may be regarded as the magnetic intrusions into the sediment probably through the magmatic activities and could be responsible for the lead-Zinc mineralization found in the area. Active magmatisms have been reported in the Benue Trough with Ofoegbu and Odigi (1989) confirming the close associations between magmatisms, mineralization and fractures in the area. The varying magnetic highs and lows correspond to undulating topography and likely favourable traps for hydrocarbon accumulations. Geological and geophysical studies carried out by Ofoegbu (1984, 1985, and 1986) in the Benue trough have shown that the area possessed qualities like thick sedimentary sequence, marine source bed, block faulting and suitable traps notable with oil producing regions of the country. This study has equally revealed the general trend in the orientation of the magnetic contour closures and the magnetic lineament structuresto be predominantly in the NE-SWdirection, an attribute of the Pan – African Orogeny trends. Wright (1968) and Ajakaiye et al. (1980) had earlier identified a conjugate pair of NE-SW and NW-SE fracture in the Benue trough which is attributed to deeper heterogeneity of the earth crust during the sequence of events at possible opening up of South American and African plate.

Previous studies showed the geology of the area to be associated with the marine Albian Asu River Group which commenced sedimentation in the middle Benue Trough. If this study area is quantitatively interpreted using spectral analysis or any other method to determine the thickness of this magnetic basement,it is very likely that this thickness may be greater than 2.3km deep hence the area may be favourable for hydrocarbon accumulation if other conditions are made. Wright et al. (1985) reported that when all other conditions for hydrocarbon accumulation are favourable, and the average temperature gradient of 1^{o}C for 30m obtainable in oil rich Niger Delta is applicable, then the minimum thickness of the sediment required to achieve the threshold temperature of 115^{o}C for the commencement of oil formation from marine organic remains would be 2.3km deep. More attention should be paid to the Gboko area because it has more favourable geologic features/sediments.

Previous studies have confirmed that the geology of the Benue Trough offers promises to prospective investors and researchers in general. The quantitative calculations done in this trough using the old data by researchers like Nwachukwu (1985), Ahmed (1991), Osazuwa et al. (1981) and Onyewuchi et al. (2012) have all revealed two magnetic source layers and have shown the thickness of the magnetic basement of this area to be more 2.3km deep.

CONCLUSIONS

These qualitative results obtained from the use of this new high resolution data have shown some similarities with those done by previous researchers using the old data. However, works using this data is more dependable and exacts owing to the high resolution nature of the 2009 data over the 1970s data in terms of terrain clearance and line spacing. Also the stressful work of digitizing the map and the likely error that could be introduced during the process have all been eliminated because the 2009 data is in a digitized format. These features like thick sedimentary thickness and likely traps obtained through qualitative interpretation of contour maps of the study is an indication that quantitative interpretation is likely to yield good result and that hydrocarbon prospecting should be intensified over Asu-River Group of Albian age, Ezeaku Coniacian – Turonian age, and Awgu Turonian – Senonian age since the sediment over the area are sufficient to generate hydrocarbon and therefore may likely be a good source rocks.

References

Ahmed NM(1991). Spectral Analysis of Aeromagnetic Data Over the Middle Benue Trough, Nigeria; research publication; M.Sc. thesis University of Nigeria Nsukka.

Bath M(1974). Spectral analysis in Geophysics Elsevier Amsterdam.

Bhattacharrya BK(1966). Continuous Spectrum of t he total magnetic field anomaly due to rectangular prismatic body, Geophysics. 31: 97 - 121.

Burke K, Dessauvagie TFJ, Whiteman A(l 970). Geological history of the Benue Valley and Adjacent areas: In T.F. J. Dessauvagie and AJ. Whiteman (eds), African Geology. University of Ibadan Press, Nigeria. Pp. 187-205.

Cratchley CR, Jones GP(1965). An interpretation of Geology and Gravity anomalies of the Benue Valley Nigeia Geophy.Pap.Overseas Geol. Surv. London, No, 1

Grant NK(1971). South Atlantic, Benue Trough and Gulf of Guinea Cretaceous triple Junction; Geological Society of American Bulletin. 82: 2295 – 2298.

Mishra DC, Naidu PS(1974). Two-dimentional Power spectral analysis of aeromagnetic fields, Geophysics Prop. 22: 345 – 534.

Nwachukwu JI(1985). Petroleum Prospects of Benue Trough, Nigeria. Am Assoc. Pet. Geol. Bull. 69 (4): 601-609.

Obaje NG(2004). Geology and Mineral resources of Nigeria. Springer Dordrecht Heidelbug London New York.

Offodile ME(1976). The geology of the middle Benue Nigeria. Disertation, Univ. of Uppsala Sweden.

Ofoegbu CO (1985a). A review of the geology of the Benue Trough of the Nigeria. J. Afr. Sci. 3: 285-291.

Ofoegbu CO (1985c). Long Wavelength anomalies and the crustal structure underneath the Benue Trough and surrounding regions, Nig. J. Min. Geol. 22: 45 - 50.

Ofoegbu CO(1984a). Aeromagnetic anomalies over the lower and middle Benue Trough Nigeria; Nig. J. Min. Geol. 21: 103- 108.

Ofoegbu CO(1984b). A model for the tectonic evolution of the Benue Trough of Nigeria.*Geologische Rundschau*. 73: 1007-1018.

Ofoegbu CO(1986). A preliminary result of a pseudogravity study of the Benue Trough, Nigeria. J. Afr. Earth Sci. 5: 187- 192

Ofoegbu CO(1988). An aeromagnetic study of the part of the upper Benue Trough. Nig. J. Afr. Earth Sci. 7: 77-90.

Ofoegbu CO, Odigi M1(1989). Basement structures and ore mineralization in the Benue Trough, In the Benue Trough: Structure and Evolution (ed. Ofoegbu, C.0,) Earth Evol. Sci. 239-248.

Ofoegbu CO, Onuoha KM(1991). Analysis o f magnetic data over the Abakaliki Anticlinorium of the Lower Benue Trough, Nigeria. Marine and Petr. Geol. 8:174-183.

Olade MA (1975). Evolution of Nigerian Benue trough (Aulocogen): A tectonic model. Geol. Mag. 112: 575 -583.

Onwuemesi AG (1997). One-dimensional spectral analysis of aeromagnetic anomalies and curie depth isotherm in the Anambra basin of Nigeria. J. Geodynamics. 23(2): 95-107.

Onyewuchi RA, Opara AI, Ahiarakwem CA, Oko FU(2012). Geological Interpretations Inferred From Airborne Magnetic and Landsat Data: Case Study of Nkalagu Area, SoutheasternNigeria Int. J. Sci. Technol. 2: 4.

Osazuwa IB, Ajakaiye DE, Verheijen PJT(1981). Analysis of the structure of parts of Upper Benue rift valley on the basis of new geophysical data. Earth evolution Sci. 2.

Samuel OA, Olusola JO, Olabisi AA (2011). Stratigraphic Evolution and Petroleum Potential of Middle Cretaceous Sediments in theLower and Middle BenueTrough, Nigeria: Insightsfrom New Source Rock Facies Evaluation. Petrol. Technol. Devel. J. 1.

Sharma PV(1976). Geophysical Methods in Geology, Elsevier Scientific Publishing Company,Amsterdam-Oxford-New York. Pp. 428.

Spector A, Grant FS(1970). Statistical models for interpreting aeromagnetic Data; Geophy. 25: 293-302.

Vacquier V, Steenland NC, Henderson RG, Zeitz I(1951). Interpretation of aeromagnetic maps, Geol. Soc. Am., Memoir. Pp. 47.

Wright JB, Hastings D, Jones WB, Williams HR (1985). Geology and Mineral resources of West Africa. George Allen and Urwin, London. Pp. 90-120.