

Structural Interpretation of Part of Anambra Basin Nigeria using Aeromagnetic and Landsat ETM data

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ABSTRACT

This paper presents the results of the structural interpretation over part of Anambra Basin carried out using Aeromagnetic and Landsat-ETM data. The study area is part of Anambra Basin, south Eastern Nigeria. Geographically, it is situated between Longitude 7000'E – 7030'E and Latitude 6000'N – 6030N. The study is aimed at giving a structural interpretation of the area by identifying the lineaments associated with the study area and to infer the effect of structures on the drainage system and its potential for hydrocarbon. The work demonstrates the advantages of using digitally processed Landsat-ETM data and Aeromagnetic data for geologic mapping. The data was processed and enhanced to give colour composites, geologic maps, drainage pattern, and fractures/lineaments. Trend analysis of the lineaments revealed on a rose diagram and from the regional plots showed structural trends of the study area to be in NW-SE, NE-SW, N-S, and E-W directions, but NW-SE was the most dominant. When the Landsat and aeromagnetic data were compared, it was observed that the areas with high lineament density are also the areas with high basement relief where as low lineament density areas are characteristic of low basement relief. The spectral analysis of the study area revealed a depth to basement ranging from 1.86km to 5.34km (Umuagu and Ugbene regions) with an average of 3.95km which is unsuitable for the production of hydrocarbons.

Keywords: Aeromagnetic data, allocyclic incursions, Landsat, Lineaments, polynomial fitting.

1. INTRODUCTION

Both magnetic and Landsat methods have a great deal in common and an interface for geological interpretation can be established between them [1]. They are both extensively used as reconnaissance tools in oil exploration, mineral exploration as well as deep crustal studies. For the past twenty years, there have been new revolution in the use of aeromagnetic surveys from the interpretation of solely basement structures to detailed examination of structure and lithologic variations in the sedimentary sections. In many sedimentary basins, magnetic anomalies result from secondary mineralization along fault planes, which are often revealed on aeromagnetic maps as surface linear features. Igneous and crystalline rocks commonly have high total magnetizations compared to other rock types, whereas sedimentary rocks and poorly consolidated sediments have much lower magnetizations [2].

[3] investigated the morphology of the basement beneath the pile of the sediment in the parts of the middle Benue trough, Nigeria. His work resulted in the delineation of the twelve major faults segments which divide the basement rocks into discrete blocks. Thus, he interpreted the boundaries between the segmented basement blocks, as high angle faults, some of which may be shear one. [4] used a preliminary interpretation of shallow regional structures deduced from ground magnetic data over the Eastern part of the Lower Benue Trough (confluence) area, Nigeria to investigate the anomalies found in the regions. He postulated that the NE-SW trending anomalies in the region are thought to be possibly associated with the basement ridges which occur within and parallel to the general trend of the Benue Trough.

Linear features are clearly discernible on landsat images and often indicate the form and position of individual folds, faults, joints, viens, lithologic contacts, and other geologic features that may lead to the location of individual mineral deposits. They often indicate the general geometry of subsurface structures of an area thereby providing a regional structural pattern.

1.01 Geology of Study Area

The study area is part of Anambra Basin, south Eastern Nigeria, which lies between Longitude 7°00'E – 7°30'E and Latitude 6°00'N – 6°30'N (fig. 1). The basin is 300km NE-SW trending syncline, located at the south western dip of the Benue trough in south eastern Nigeria. The trough is characteristically linear in shape and its sedimentary formations are continuous with the Nigerian Coastal Basin. It is characterized by Hills and Valleys. This hills and ridges were formed due to the resistance of sandstones to agent of denudation (like erosions etc). The plains and the valleys were formed as a result of the shales that were not resistant to agents of denudation. Therefore, the landform is as a result of the difference in the degree of resistance to agents of denudation and the bedrock varies from basement complex to shales, marls, and limestone, as well as sandstones and unconsolidated to semi-consolidated sands.

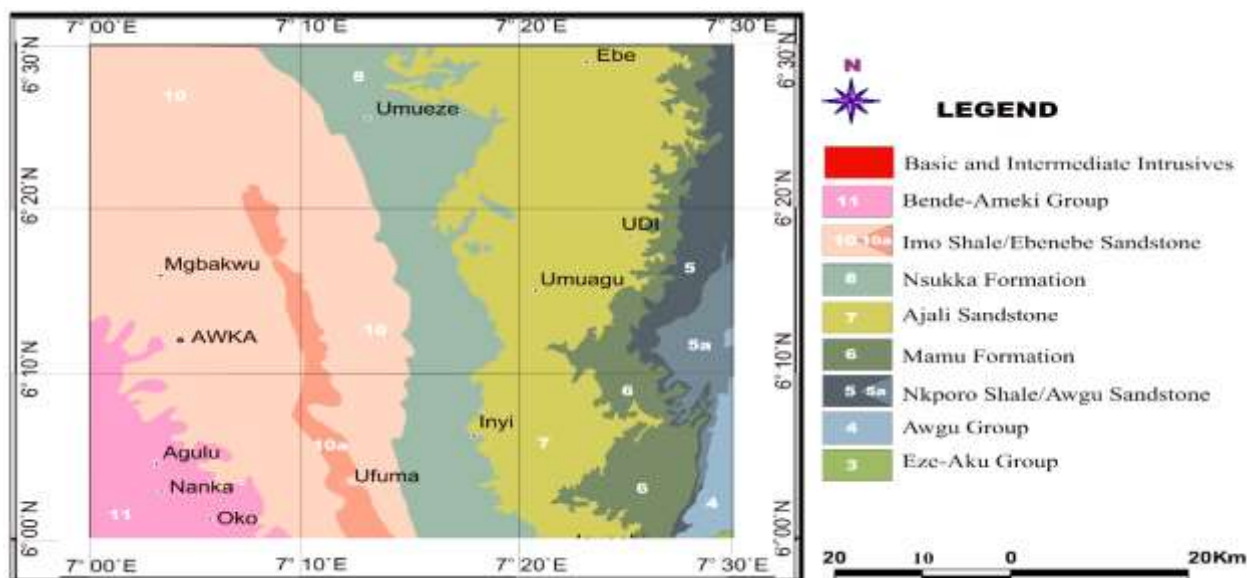


Fig.1. Geological map of study Area

[5] established the geology of north-east of Afikpo basin consisting of two major litho-stratigraphic units of sandstone ridges and low-laying shale each of which forms a significant component of the Middle AlbianAsu River Group and TuronianEzeaku formation. He aimed at examining the lithology and their stratigraphic relationships with a view to drawing inferences on the geology, provenance, depositional history and environment of the deposition of the sedimentary bodies in the area. Furthermore, the repeated allocyclic incursions of the sea resulted in characteristic basin-wide genetic sequences [6];[7], or parasequence sets [8]. Two allocyclic events have been recognized in the Anambra Basin that encompass large time intervals.

The numerous shallow intrusions in the Upper Benue basin occur substantially outside the basement surface in the region and show a gentle general southward increase with mean depth value ranging from 2km in the northern area to 2.62km in the south [9]; this is associated with the deposition of Awgu shale around Agbani. Turonian transgression, which marked the start of this cycle, is believed to have commenced from the Gulf of Guinea through the Anambra basin to the Benue Trough. Most of the deposits of this cycle have been eroded as a result of the upper Cretaceous tectonic activity. The fourth sedimentary cycle was marked by deposition of the Nkporo Shales, Owelli Sandstones, Afikpo Sandstones and Enugu shales during the Campanian-Maastrichtian ransgressive phase. This cycle also marked the deposition of the coal measures including: the Mamu Formation, Ajali Sandstones and Nsukka Formation. This frame work has been the basis for most subsequent stratigraphical analysis [10]. Similarly, [11] using spectral analysis of residual magnetic field over the middle Cross River Basin, determined the basement depths in the area. They discovered that the depth to the first layer varies from 0.258km to 1.424km with an average value of 0.698km while the second magnetic layer varies from 2.030km to 5.057km with an average value of 3.121km; he deduced that throughout the basin, depths to the basement surface vary from about 1km to about 4km.

2. THEORY AND METHOD

The aeromagnetic maps used for the study were obtained from the Geological Survey of Nigeria. The nominal flying altitude above the terrain was 500 feet (approximately 152m) with flight line and tile line spacing of 2km and 20km respectively. However, the flight and tie line direction is 150°/330° and 60°/240° respectively. The regional correction of the magnetic data was based on IGRI (Epoch data, 1 January, 1974). The first phase of digital processing of the contoured aeromagnetic total intensity field map on 1:100,000 (Plate 1) was digitization. The map was digitized manually with a 2cm by 2cm (equivalent to 2km by 2km) grid spacing. The method of interpolation adopted is the Kriging method. This method determines the most probable

value at each grid-node from the surrounding real data values. This was done by noting the coordinates (X and Y) and magnetic value (Z), forming a XYZ file. This is continuously done at every grid-node interval across the flight-lines. This produces XYZ as text files. These are run as 2XYZ program on the United States Geological Service (USGS) Potential Field software (Version 2.2) and Surfer Software to convert the binary numbers to post files called PST files. The Detour program, a Fortran 77 program is launched to view the data on screen to check errors. The Detour program produces the minimum and maximum values of X, Y, Z and shows the contour intervals. Geocon program, a screen viewing, shows the contouring interval. Then finally the contour program plots the Command (cmd) file to produce a total magnetic intensity map. Several potential field software with different analytical modules were used these include; Geosoft Oasis Montaj 8.3. HJ version, Surfer 10 and Matlab 8.1. Regional – residual separation was carried out using polynomial fitting – an analytical technique in which matching of the regionals by a polynomial surface of low order exposes the residual features as random errors. The Polynomial residue map was then subject to the Fast Fourier Transformation software (FFTIL) to perform further analysis.

Given a residual magnetic anomaly map of dimensions l x l, digitized at equal intervals, the residual total intensity anomaly values can be expressed in terms of a double Fourier series expression given as expressed in (1):

$$T(x, y) = \sum_{n=1}^N \sum_{m=1}^M P_m^n \cos \left\{ \left(\frac{2\pi}{l} \right) (nx + my) \right\} + Q_m^n \sin \left\{ \left(\frac{2\pi}{l} \right) (nx - my) \right\} \dots \dots \dots \quad (1)$$

where, l = dimensions of the block, P_m^n and Q_m^n are the Fourier amplitudes, and N and M are the number of grid points along the x and y directions respectively. Using the complex form, the two dimensional Fourier transform pair may be written in the forms of (2) and (3):

$$G(u, v) = \int_{-\infty}^{\infty} \int_{-\infty}^{\infty} g(x, y) e^{-j(u_x + v_y)} dx dy \dots \dots \dots \quad (2)$$

and

$$g(x, y) = \int_{-\infty}^{\infty} \int_{-\infty}^{\infty} G(u, v) e^{j(u_x + v_y)} du dv \dots \dots \dots \quad (3)$$

where, u and v are the angular frequencies in the x and y directions respectively. This method involves some practical problems which include the problem of aliasing, truncation effect or Gibb’s phenomenon and the problems associated with even and odd symmetries of the real and imaginary parts of the Fourier transform [12]. However, in this research, these problems were taken care of by the software used in the analysis.

Reduction to the Pole (RTP) which removes the effects of geomagnetic latitude by applying a mathematical filter to the gridded data to produce an anomaly map that would have resulted had the area of interest been surveyed at the magnetic pole [13] was performed. Similarly, the first and second Vertical Derivatives which are equivalent to observing the vertical gradients directly with a magnetic gradiometer and have the same advantages, namely enhancing shallow sources, suppressing deeper ones, and giving a better resolution of closely-spaced sources [14] were also performed. Upward and Downward Continuation filters which transform the data to what it would have been if the measurements had been made at different heights above the source [15] were as well carried out.

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 method allows an estimate of the depth of an ensemble of magnetized blocks of varying depth, width, thickness and magnetization.

Landsat Thematic Mapper (Landsat 7 ETM) imagery acquired on 17th April 2009 from NASRDA, Nigeria was used to map linear structures in the study area. The raw data was georeferenced using the coordinates of the topographic sheets in the study area. The geo-reference projection was carried out using the Universal Transverse Mercator (UTM). Image processing, enhancement and analysis were carried out using ILWIS 3.1 Academic software. Image enhancement operations carried out on the imagery include contrast stretching, spatial filtering, edge enhancement and colour composite generation. Also, ArcView 6.3 software was used to extract the lineaments and carry out statistical analysis of the interpreted lineaments in the area.

3. RESULTS AND INTERPRETATION

The colour coded total magnetic field intensity map showed in Fig. 4.2 has the areas with high magnetic intensity around the area colour coded light pink and pink (with magnetic strengths between 7890 and 7970 gammas), followed by respectively in the order of decreasing intensity. The clustering of magnetic anomalies around the South Eastern part of the study area indicates a high

basement relief. The basement in the area can be said to be close to the surface. Such areas have very low ability to produce hydrocarbons as there is not enough depth for deep burial and subsequently thermal maturation. However, because of the igneous and metamorphic nature of the basement, it has a high mineralisation potential.

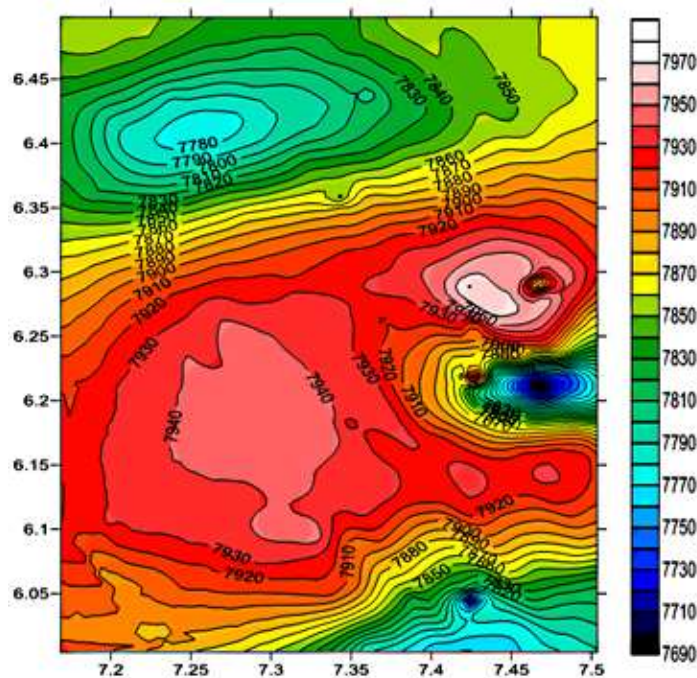


Fig. 2 Total Magnetic field map of study area

The area colour coded yellow and green can be said to be of intermediate intensity of the study area with those coloured dark blue and subsequently light blue with the lowest intensity. This blue coded area is low basement relief. The 3D surface map generated clearly indicates areas of high magnetic intensity. The areas with high magnetic intensity is indicated as an uplifted area with the highest point being the blue shaded area, this blue coloured area has the highest basement relief of the study area (e.g.s are Awka, Obudu and Udi).

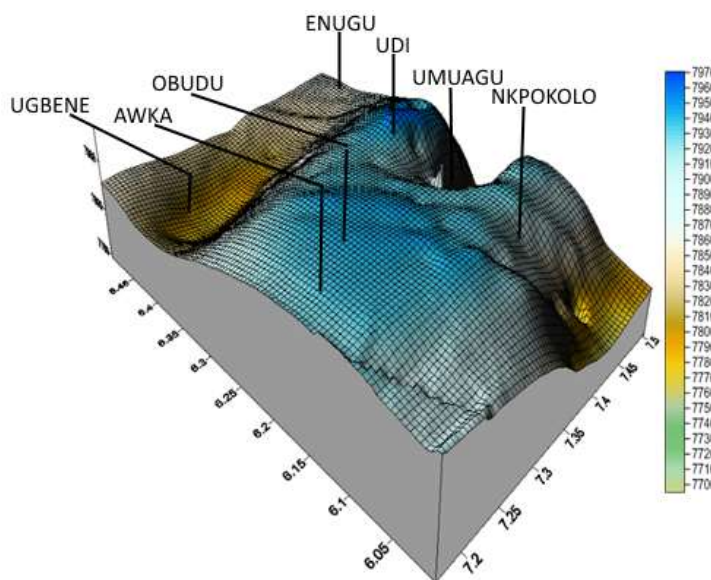
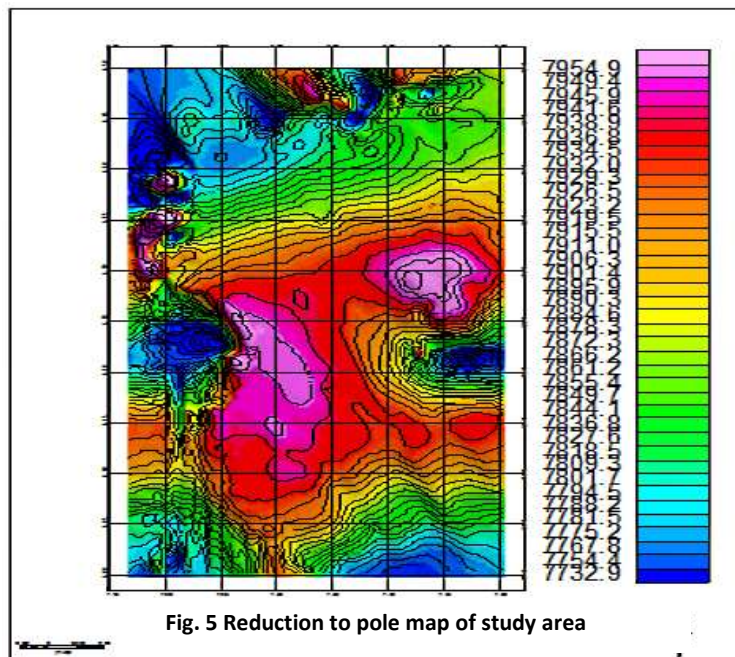
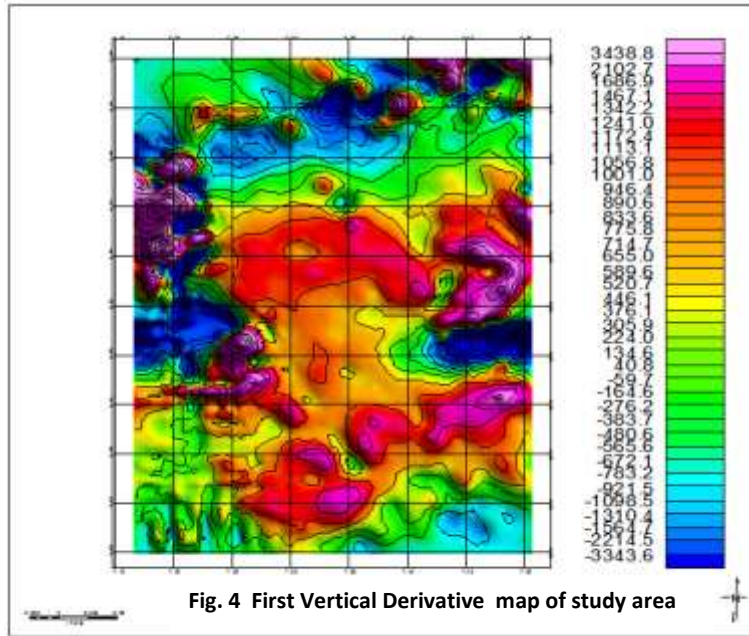


Fig. 3 3D Total (surface) Magnetic field map of study area

The 3D surface map of the area effectively shows the shape and features of the basement underlying the deposited sediments. It is the basement that produces the magnetic field recorded by the magnetometer for this study. The areas coloured green has the lowest basement relief and these areas would definitely contain more sedimentary deposits than the areas with high basement relief. Figures 4 and 5 represent the first vertical derivative map and the Reduction to Pole (RTP) aeromagnetic maps respectively. The two are in conformity with the distribution of magnetic highs and lows in the study area. It could be deduced that the far Northern region is magnetically low while the central portion is very high.



The Spectral determination of depth to magnetization for the study area was performed using Udi as reference the spectral points are highlighted on table 1. The estimated depths to magnetic basements are shown as D_1 and D_2 . The first layer depth (D_1) is from the shallower sources and varies from 0.79km to 3.29km with an average of 1.93km while the second layer depth (D_2) varies from 1.86km to 5.34km with an average of 3.95km.

Table 1 Spectral computed depth to magnetic basement of the study area

TOWN	X1	X2	Y1	Y2	ESTIMATED DEPTHS(KM)	
UDI					D1	D2
A	7.00	7.25	6.00	6.25	3.285	4.941
B	7.00	7.25	6.25	6.50	2.285	5.342
C	7.25	7.50	6.00	6.25	0.785	1.858
D	7.25	7.50	6.25	6.50	1.348	3.667

The basement depth (sedimentary thickness) contour map - D₂ of part of the study area (Udi reference) is shown in fig. 6. This revealed thick deposits in the range of 3km to 5km in the NW – SW flanks affecting towns like Umuagu and Umuabut areas such as Ugbene and Nkpokolo should also bear thick deposits as inferred in fig. 3.

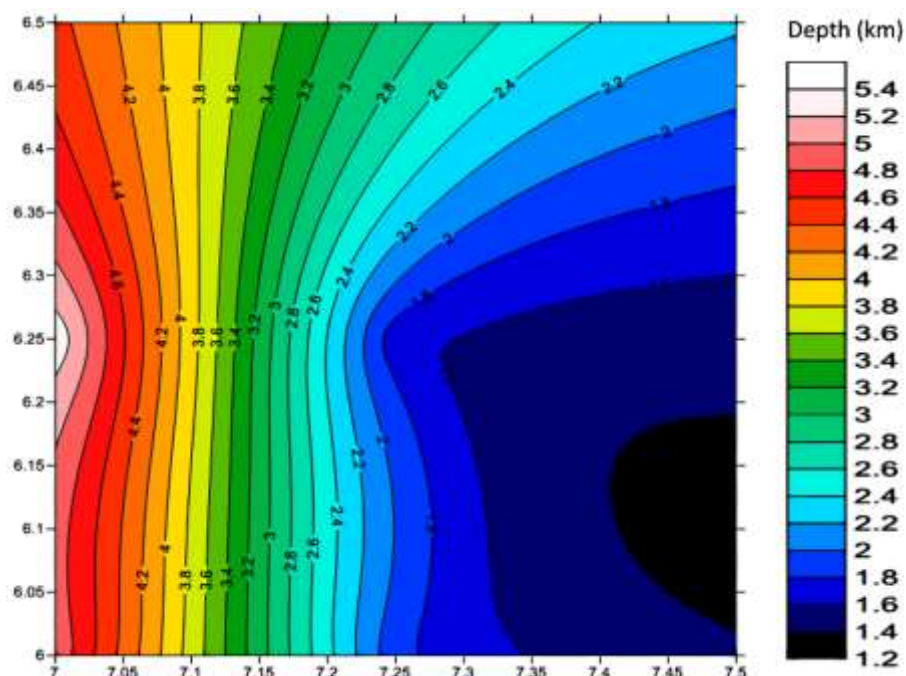


Fig. 6 Sedimentary thickness contour map of part of study

A narrow down on structural interpretation of the Study Area using fig. 7 highlights that; the areas marked “S” (which are short – high magnetic regions) represent near surface magnetic features possibly made of intrusive rocks, the areas marked “E” (which depict elongated – high magnetic region) represent near surface magnetic features possibly made of elongated intrusion with strike in the NE – SW direction, the areas marked “M” (which are broad – high magnetic regions) represent deep seethed magnetic

features possibly made of intrusive rocks, while “J” bears shape reminiscent of joint though requiring further investigation with the Landsat ETM data. F₁, F₂, and F₃ are interpreted as faults based on the pattern of magnetic contours around them.

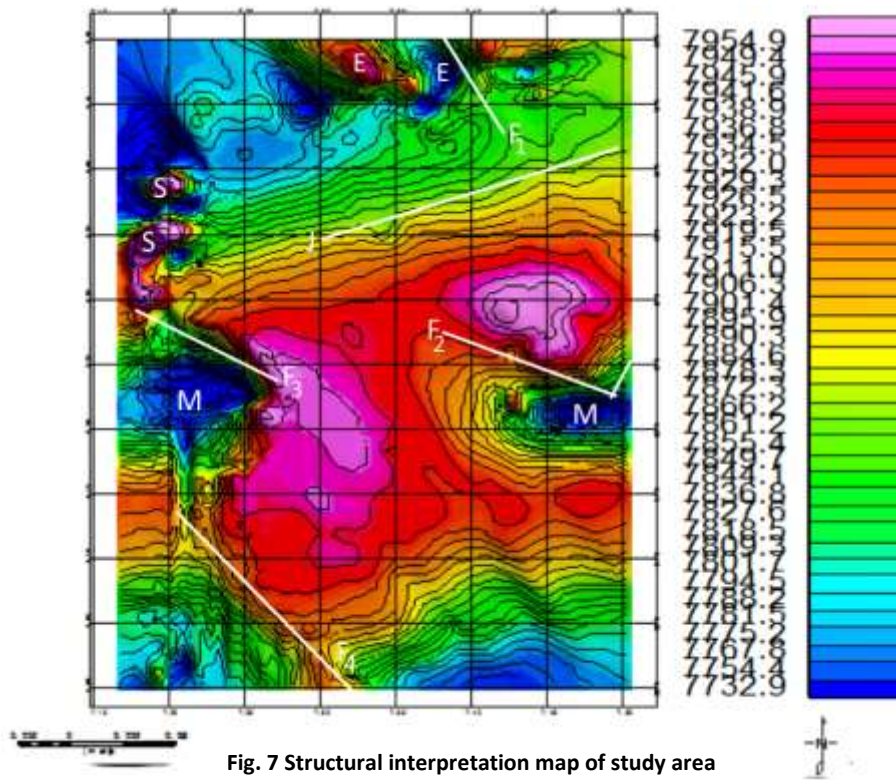


Fig. 7 Structural interpretation map of study area

The Digital Elevation map is employed for structural, geologic and tectonic interpretations such as locating faults, drainage pattern, geomorphology, plate position, slope, lineaments and the boundary between geologic units. Such map (as in fig. 8) has a high elevation ranging from 344m – 540m which is the highest peak in the area; the central part in red has an average elevation of 148m – 343m above sea level. The northern part has a low elevation of 17m – 146 m above sea level.

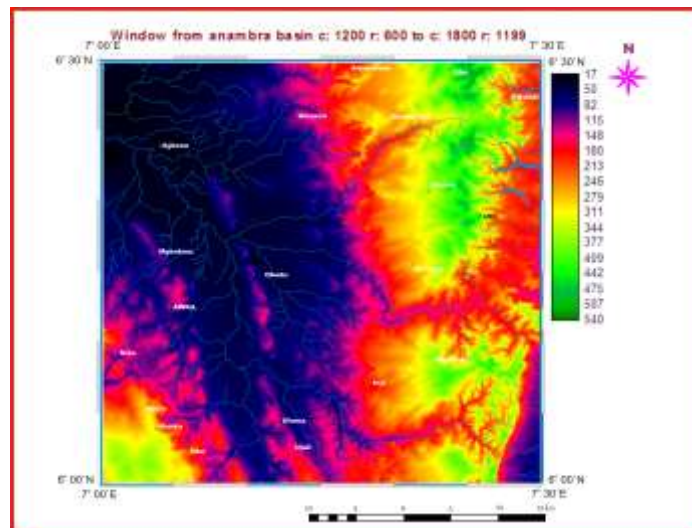


Fig. 8 Digital Elevation map of study area

The elevation of the area is on the increase as you move from the north eastern part to the south western part of the area. The highest peaks represented by the dark green color are seen as small patches following a topographically high feature with a maximum topographic height of 540m running N-W. Light green, yellow and red colors are closely packed together representing an abrupt change in topography from 442m to 148m.

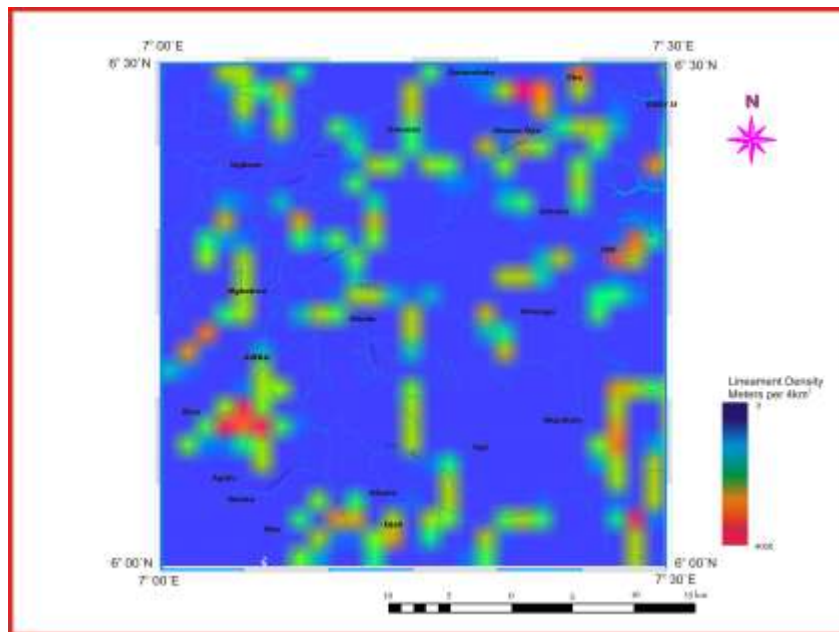


Fig. 9 Lineament density map of study area

The interpretation of Lineament density map (fig. 9) revealed a number of lineaments and mega lineaments over 15 km in size trending in the NE – SW, N- S, NW – SE and E – W directions. The trend surface analysis of the tectonic and structural features of the area in relation to the interpreted Lineaments from the rose diagram revealed surface trend of NE – SW, N- S, NW – SE, and E – W directions with the dominant structural trends being in the NE – SW and the N – S which corresponds to the major lineament trend of the study area. This shows that the area has a rugged topography and it is partly deformed by tectonic activities. The lineament trends are in line with the results of previous works which suggested that the southeastern part of Nigeria has a complex network of fractures.

Figure 10 is the lineament on density map which is used to correlate the trends of drainage and structural orientation in the whole area and from statistical analysis and visual observation; it reveals that the drainage pattern in the study area is structurally controlled since both the lineaments and drainage system correspond with each other. The composite images revealed a dendritic pattern which trends in the NE-SW, NW-SE and N-S directions. This pattern reveals a lithological, structural and topographical homogeneity of the study area. This occurs on homogeneous, gentle, uniformly sloping sedimentary surface whose main collector drains may indicate a fault or fracture.

The rose diagram which is a plot of the lineaments showing their trends in different directions, and displays the lineaments in their subtle trends and their dominant trends is shown in fig. 11. The dominant trend is always recognized as the longest plotted lineament. In fig. 4.27, the NE-SW trend controlled the deposition of sediments in the Trough, the cretaceous Magmatism and orientation of folds belts, drainage and mineralization in the area [16];[17]. In contrast NW-SE trend influenced distribution of facies and discontinuities along which occurred synsedimentary faults. The course of major rivers and their tributaries appears to be determined and controlled by these structural features.

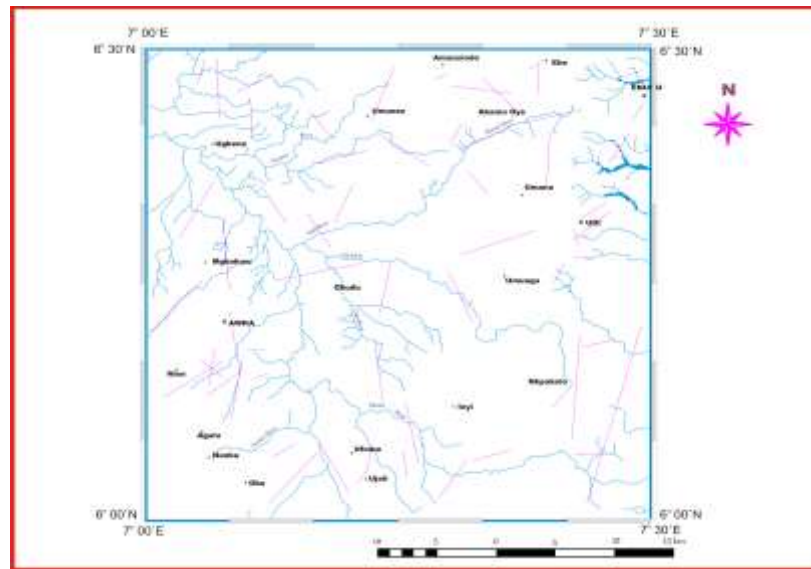
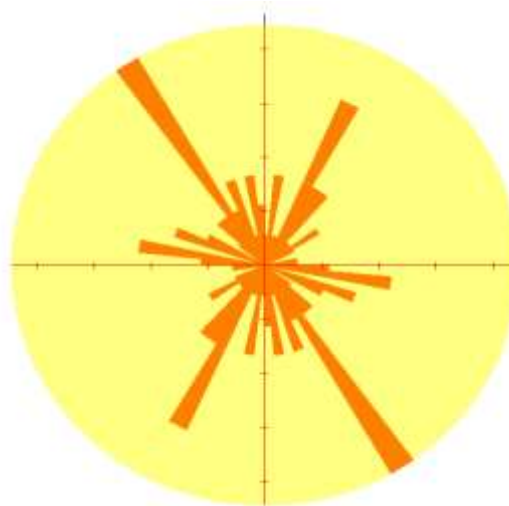


Fig. 10 Lineament on drainage map of study area



Number of data plotted = 60 Scale spacing = 3% [2 data] Mean Resultant dir'n = 169°
 Sector Interval Angle = 6° Maximum = 13.3% [8 data] Circular Mean Dev. = 79°

Fig. 11 Rose diagram of the Linear features in the study area

4.0 CONCLUSION

Since the primary objective of this study is to identify structures expressed as lineaments and classify them according to their spatial and directional attributes, it was necessary to process the aeromagnetic and Landsat -ETM data in a manner that would both enhance trends and facilitate the computation of locations and depths to magnetic sources. Drainage pattern, termination of potential field (gravity or magnetic) map anomalies on a linear trend, termination of drainage line on linear trends and straight stream segments were the basic hypothetical models used to map fractures/faults. [18]believes that lineaments can also be revealed on aeromagnetic maps by breaks in anomaly trends (lengthwise) and prominently narrow magnetic lows (broadwise) and sharp gradients of anomaly. The aeromagnetic analysis and interpretation as well as digitally processed satellite remotely sensed data have revealed that the prominent structural patterns in the study area are trending in the NW-SE, NE-SW, N-S and E-W directions respectively. Also, the rock type distribution within the vicinity in terms of igneous/metamorphic or sedimentary rocks has been revealed.

The lineament patterns observed on the Landsat-ETM image have been summarized using Rose diagram and further analyzed using geo-statistical techniques. The lineament density in the study area varies from 0-4000m per 25km square in the area. From the economic point of view, it can be concluded that the average sediment thickness of 3.95km obtained in this study is fairly significant for accumulation and entrapment of hydrocarbons. This average basement depth is in agreement with previous works done in and around the area. As such one can postulate the existence of petroleum accumulation at such depth in this part of the Lower Benue Trough. It is as well possible to observe the existence of other mineral traps such as for lead, and anhydrides etc.

Furthermore, the structures found in the study area are more magnetic which agrees to the cretaceous geology of the lower Benue trough. In conclusion, this study has shown beyond doubt that both Landsat ETM and aeromagnetics have a lot of research potentials for geologic applications.

REFERENCES

- [1] Opara, A.I. (2011). Estimation of the Depth to Magnetic Basement in Parts of the Dahomey Basin, Southwestern Nigeria: *Australian Journal of Basic and Applied Sciences*, vol. 5(9): 335-343.
- [2] Reynolds, R. L., Rosenbaum, J. G., Hudson, M. R. & Fishman, N. S. (1990). Rock Magnetism, the distribution of Magnetic Minerals in the Earth's Crust and Aeromagnetic Anomalies: *U. S. Geological Survey Bulletin*, 19 (24), 24-45 p.
- [3] Onyedim, G. C. & Awoyemi, A. E. (2006). Aeromagnetic Imaging of the Basement Morphology in the part of the Middle Benue Trough. *Journal of Mining and Geology*. Vol. 42 (2), pp. 157-163.
- [4] Ikpokonte, A. E. & Ajayi, C. O. (2003). A Preliminary Interpretation of the Shallow Regional Structures deduced from Ground Magnetic Data over the Eastern Part of the Lower Venue Through (confluence) Area, Nigeria. *Nig. Journal of Earth Sciences*, Vol. 2, 2003. Pg. 57-69.
- [5] Ukaegbu, V. U. & Akpabio, I. O. (2009). Geology and Stratigraphy of the Middle Cretaceous Sequences Northeast of Afikpo Basin, Lower Benue Trough, Nigeria. *The Pacific Journal of Science and Technology*. Vol. (10). No. 1, pp. 518-527.
- [6] Bush, D.A. (1971). Genetic units in delta prospecting. *AAPG Bull.*, 55:1137-1154.
- [7] Galloway, W.E. (1989). Genetic stratigraphic sequences in basin analysis 1: Architecture and genesis of flooding-surface bounded depositional units. *AAPG Bull.* 73: 125-142.
- [8] Van Wagoner, J.C., Posamentier, H.W., Mitchum, R.M., Vail, P.R., Sarg, J.E, Loutit, T.S. & Hardenbol, J. (1988). An overview of the fundamentals of sequence stratigraphy and key definitions. In: C.K. Wilgus, B.S. Hastings, H. Posamentier, C.A. Ross & C.G. St. C. Kendall (Editors), *Sea-Level Changes: An Integrated Approach*. *SEPM, Spec. Publ.* 42: 39-46.
- [9] Nwogbo, P.O., Ojo, S.B., & Osazuwa, I.B. (1991). Spectral Analysis and Interpretation of Aeromagnetic data over the Upper Benue Trough of Nigeria. *Nigeria Journal of Physics*, (3), 128 – 141.
- [10] Zaborski, P. M. (1998). A Review of the Cretaceous System in Nigeria. *African Geoscience Review*, Vol. 5, No. 4 , pp. 385-400.
- [11] Kangoko, R., Ojo, S.B. & Umego, M.N. (1997). Estimation of Basement depths in the Middle Cross River basin by Spectral analysis of the Aeromagnetic field. *Nig. Journ. Of Phys.* Vol. 9, pp.30-36.
- [12] Opara, A.I., Onyewuchi, R.A., Onyekuru, S.O., Okonkwo, A.C., Nwosu, I.E., Emberga, T.T., & Nosiri, O.P. (2014). Structural interpretation of the Afikpo sub-basin: evidences from airborne magnetic and Landsat ETM data. *Elixir Earth Science*. 71, 24546 – 24552.
- [13] Reynolds, J.M. (2011). *An introduction to Applied and Environmental Geophysics*. John Wiley and sons UK.
- [14] Reeves, C. (2005). *Aeromagnetic Surveys Principles, Practice and Interpretation*. Published by Geosoft.
- [15] Dentith, M., and Mudge, S. T. (2014). *Geophysics for the mineral exploration Geoscientist*. University Printing House, Cambridge CB2 8BS, UK.
- [16] Burke, K.C. (1972). Longshore drift, submarine canyon and submarine fans in development of Niger delta. *AAPG. Bull.*, 56: 1975-1983.
- [17] Agagu, O.K., Fayose, E.A. & Petters, S.W. (1985). Stratigraphy and sedimentation in the Senonian Anambra Basin of eastern Nigeria. *Nigerian J. Min. Geol.*, 22: 25-36

- [18] Ajayi, C.O., Ikpokonte, A. E. & Ike, E. C. (1991). Structural pattern in the Lower BenueTrough,Nigeria: Deductions from ground magnetic data; *Journal of Mining and Geology* ,Vol.27, No.2;pp.33- 40.