

Integrating Aeromagnetic and Landsat ETM data in Structural Interpretation of upper Benue Trough Nigeria

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ABSTRACT

This study was aimed at investigating the Structural styles of the Upper Benue Trough as revealed in the Aeromagnetic and Landsat –ETM data. The Lineaments varied between 0 and 400m per 25km square in area and comprised faults, joints, ridges and folds – a majority of them trending in the NE – SW direction. The topography ranged from 272m to 900m in the North East region and from 200m to 915m in the North West region. An average sediment thickness of 3.98km was estimated which could favor hydrocarbon accumulation and maturation. Series of possible mineralization veins (especially those very close to faults) were interpreted which could house minerals like Lead, anhydrites and Tin. A semi-circular Horst was interpreted around Lafia which could possibly contain hydrocarbon beneath- within sediments draped over at high corners.

Keywords: Aeromagnetic data, hyperspectral Imagery, Landsat, Lineaments, Regionals

1. INTRODUCTION

In many parts of the world including West Africa and Nigeria, government agencies and private interests have employed aeromagnetic method to survey most of their countries in search for oil and gas and for mapping strongly magnetic basements at regional scale and for delineating weakly magnetic sedimentary contacts at local scale. With the use of aeromagnetic data, it has been possible to locate intrasedimentary faults and subtle lithological contacts. Airborne geophysical surveying is the process of measuring the variation of different physical or geochemical parameters of the earth such as distribution of magnetic minerals, density, electric conductivity and radioactive element concentration [1]. 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 therefore related to some type of deformation of the lithosphere, and most theories of ore formation and concentration embody tectonic or deformational concepts [2]; [3].

Lineaments are defined as any linear feature on the surface of the Earth or on potential fields or geochemical maps that may be evidence of geological processes such as fracturing or folding. Lineaments may indicate zones of increased porosity, the boundaries of uplifted blocks, fault traps, drape folds, fold hinges, petroleum reservoir boundaries, mineralized veins and shear zones, dikes, linear sinkholes, or springs aligned along a fault. Lineaments may represent dense fracturing along the zone of maximum curvature on a fold [4].

Remote sensing is one high tech answer to surface mapping. Through the acquisition and analysis of airphotos, multispectral and hyperspectral aircraft and satellite imagery, thermal, radar, gravity, magnetic, radiometrics, and sonar images the explorationist is able to preview large areas quickly and economically and start mapping in places that are remote or structurally complex. One can quickly and inexpensively evaluate the potential of a region and pinpoint targets where field work is necessary to answer questions. For example, true color imagery can provide information on the distribution of lineaments (whether echelon or those associated with circular features) and depth of surface water. Hyperspectral imagery can identify and show the distribution of argillic alteration associated with hydrothermal mineral deposits, clays associated with certain soil types, and hydrocarbon seeps.

The study is aimed at identifying and interpreting the structures associated with this area and to determine the potentials, economic or otherwise of this area using the aeromagnetic depth to magnetic basement (which by implication is the sedimentary thickness of the area) and Landsat Thematic Mapper Satellite imagery analysis. Both magnetic and Landsat imagery methods

have great deal in common and an interface for geological interpretation can be established between them. They are both extensively used as reconnaissance tools in oil exploration, mineral exploration as well as deep crustal studies.

2. GEOLOGY OF STUDY AREA

The Benue Trough is a NE-SW folded rift basin that runs diagonally across Nigeria. It formed simultaneously with the opening of the Gulf of Guinea and the Equatorial Atlantic in Aptian-Albian times, when the Equatorial part of Africa and South America began to separate[5]. The Trough is an elongate rifted depression in which the sediments reach well over 5000m thickness in places and have been strongly folded, probably by later adjustments along faults in the underlying basement. The Bida Basin is a shallow unfaulted arm of the Benue Trough. The Benue Trough probably provided the major link between the Mediterranean Ocean and Gulf of Guinea via the lullmedden and Chad Basins, during Upper Cretaceous times.

The basal lithic fill in the Benue trough (best exposed in the upper part) are the lower Cretaceous alluvial fan, braided river, Laustrine and deltaic Clastics of Bima Sandstone [6] which also extends into the central Benue Trough [7]. Volcanic and minor intrusive rocks are widespread and there are deposits of lead ores and coal. The trough bifurcates near its northeastern end, and the northern branch continues beneath the Chad Formation as an elongate depression that extends well beyond Lake Chad. The study area is part of the upper Benue Trough comprising of Yola and its adjoining area and lies within latitude 9° 00' and 10° 00' N and longitude 11° 30' and 12° 30' E (fig.1).

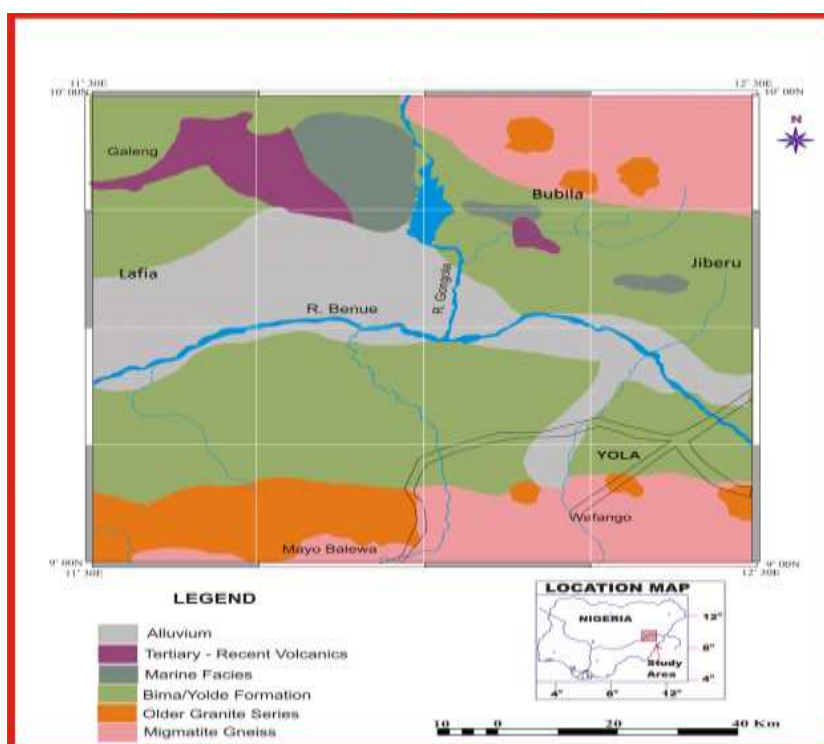


Fig.1. Geological map of study Area

The Upper Benue is largely referred to as failed rift valley [8]; [9], and so it is expected that the region should be a major depositional basin and therefore a good site for mineralisation. Upper Benue basin belongs to the genetically and physically related systems of faults and rifts termed the West and Central African Rift System (WCARS). The system's origin is attributed to the breakup of Gondwanaland and the opening of South Atlantic and Indian Ocean. The Upper Benue – Chad axial trough is believed to be the third and failed arm of a triple junction rift system that preceded the opening of the South Atlantic during the early Cretaceous and subsequent separation of African and South American continent [10].

The crystalline basement whose topography is believed to be irregular [11] is exposed in a number of locations in the region. Intruded into the basement is a series of basic, intermediate and acid plutonic rocks referred to as the older Granites. Notable outcrops of the older Granites include the small inliers of biotite granites which are found around Kaltungo, Gombe, Kokuwa, and in the Lafia area [12].

3. MATERIALS 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. The regional correction on the maps was based on I.G.R.F. (epoch date, 1st January 1974, using IGRF 1975 model). The maps were

digitized 2km along the flight line to produce the corresponding X,Y and the total magnetic field intensity Z as text files which are then analyzed using potential field software like USGS Potential field software version 2.0, Oasis Montaj 8.3. 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.

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 14th March 2006 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 etc. Also, ArcView 6.3 software was used to extract the lineaments and carry out statistical analysis of the interpreted lineaments in the area.

4. RESULTS AND INTERPRETATION

The total aeromagnetic map of study area is shown in fig.2, from which I could observe high magnetic anomalies in the range of 7800 to 7920 gammas. The 3D aeromagnetic map is shown in fig.3 from which one could conspicuously notice the low and high magnetic relief areas. The high areas are in red to pink colours while the low areas are in light-green to deep- blue colours. A diagonal line from the top of the 8.99707N latitude mark (as shown in fig.3) to the other end depicts the low relief areas as being predominantly on the right quadrant which makes this region likely to be of thick sedimentary origin (Yola, Jiberu and Mayo Balewa areas are part of this).

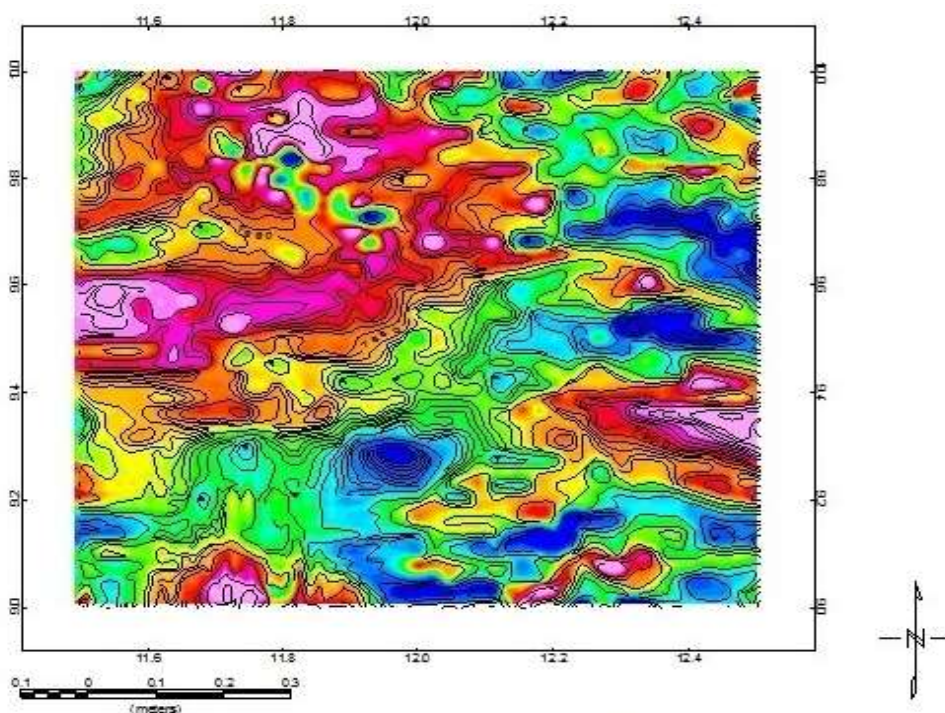


Fig.2. Total Magnetic Field Map of study Area

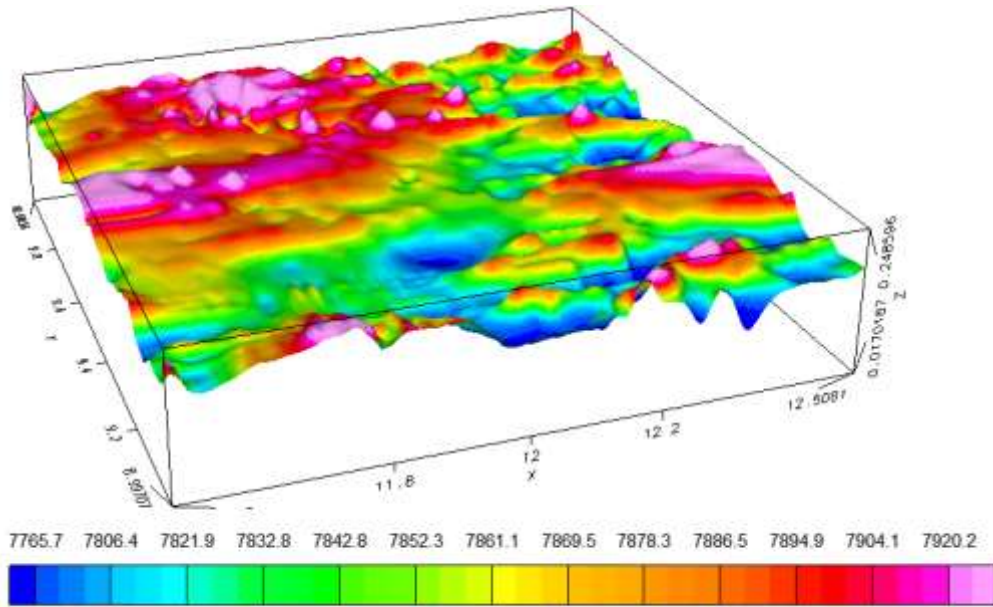


Fig.3. 3-D aeromagnetic surface map of the study area

Figures 4 and 5 represent the first degree residual field 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 entire North West region is magnetically high while about 32% of the South East region is correspondingly high.

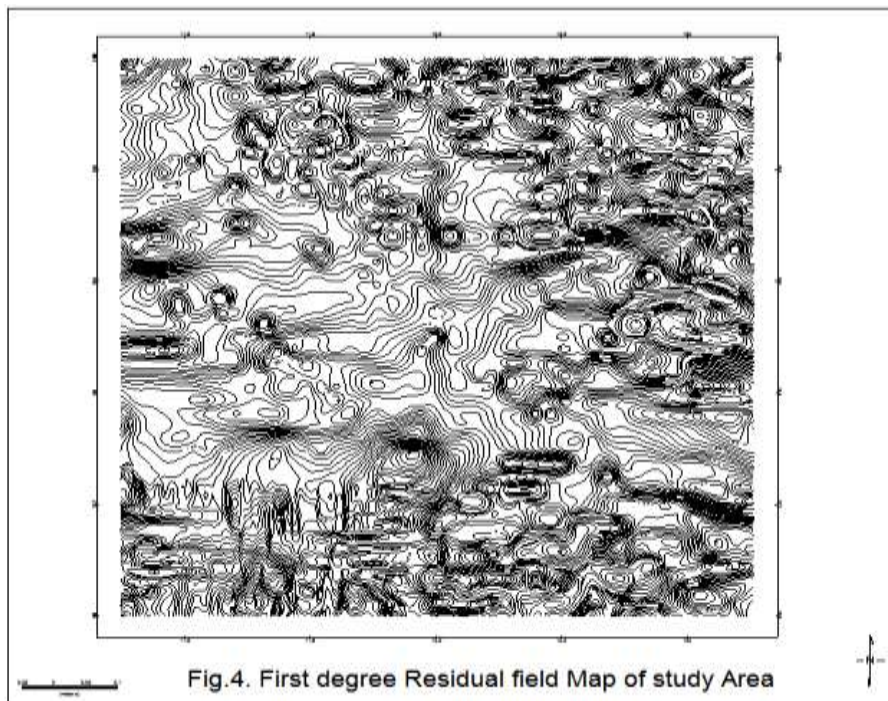
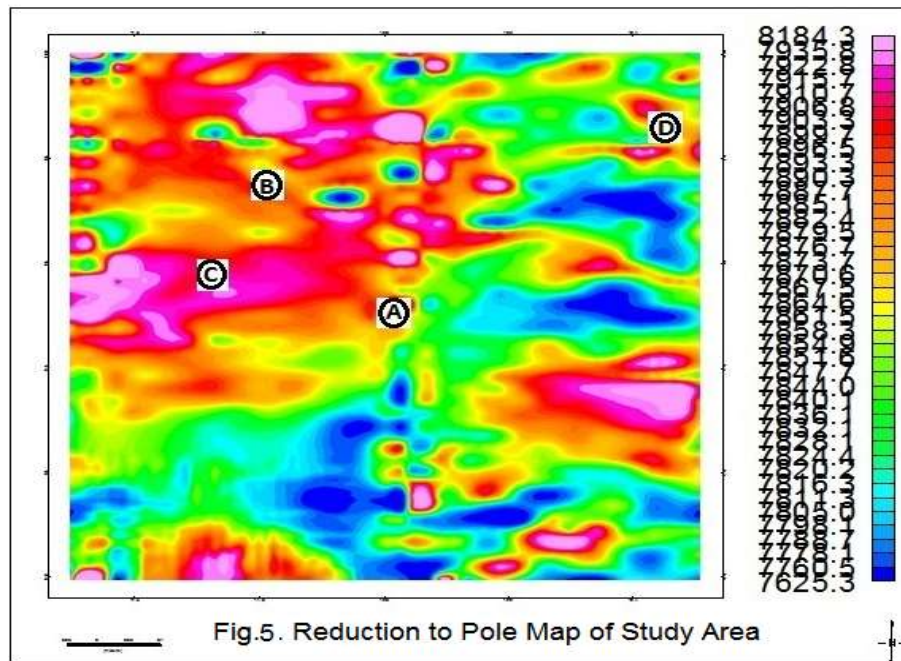


Fig.4. First degree Residual field Map of study Area



For the Spectral determination of depth to magnetization, the study area was divided into four blocks containing 4 x 4 (A₁ to D₄ as shown in fig.5.) data points. The estimated depths to magnetic basements are shown as D₁ and D₂ (table 1). The first layer depth (D₁) is from the shallower sources and varies from 0.1km to 1.3km with an average of 0.64km while the second layer depth (D₂) varies from 2.2km to 5.5km with an average of 3.98km.

Table 1. Summary of spectral estimation of basement depths in the study area

SPECTRAL BLOCK	LONGITUDE		LATITUDE		DEPTH (KM)	
	X ₁	X ₂	Y ₁	Y ₂	D ₁	D ₂
D1	11.50	11.75	9.00	9.25	1.2	3.6
D2	11.50	11.75	9.25	9.50	0.6	4.1
D3	11.75	12.00	9.00	9.25	0.9	4.3
D4	11.75	12.00	9.25	9.50	0.5	4.2
B1	11.50	11.75	9.50	9.75	0.9	3.7
B2	11.50	11.75	9.75	10.00	0.8	2.2
B3	11.75	12.00	9.50	9.75	0.2	3.2
B4	11.75	12.00	9.75	10.00	1.1	4.2
A1	12.00	12.25	9.00	9.25	0.7	5.2
A2	12.00	12.25	9.25	9.50	0.9	2.2
A3	12.25	12.50	9.00	9.25	0.7	3.2
A4	12.25	12.50	9.25	9.50	0.5	4.4
C1	12.00	12.25	9.50	9.75	0.4	5.2
C2	12.00	12.25	9.75	10.00	1.3	5.5
C3	12.25	12.50	9.50	9.75	0.1	3.4
C4	12.25	12.50	9.75	10.00	0.5	5.0

The D₂basement depth (sedimentary thickness) contour map of the study area is shown in fig. 6. This is in conformity with the predicted area of sedimentary deposits from Fig. 3 and also in tandem with the stated diagonal depositional sequence that formed the trough (as depicted in the NE-SW increase in sedimentary thickness seen in fig. 6)

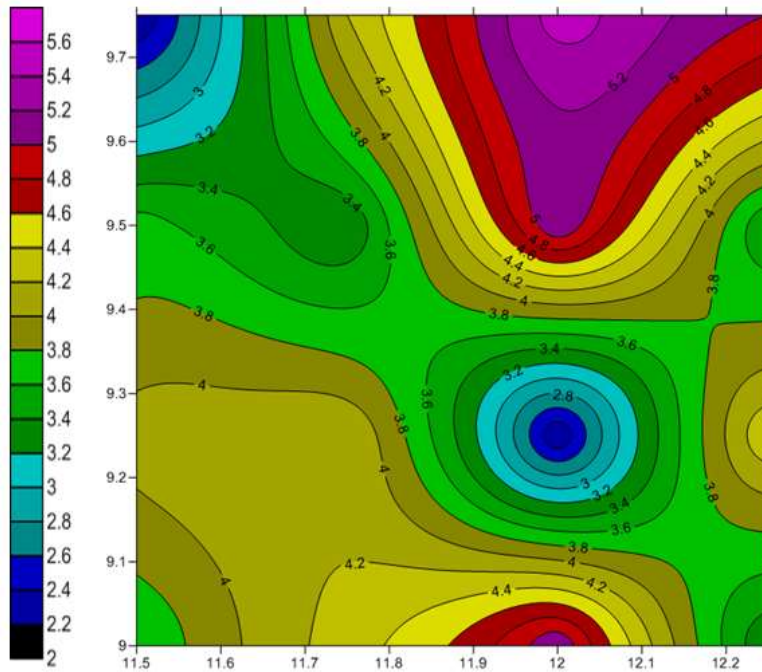


Fig. 6. Sediment thickness contour map of Study area

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 area marked “E” (which is elongated – high magnetic region) represents near surface magnetic feature possibly made of elongated intrusion with strike in the NE –SW direction, the area marked “M” (which is broad – high magnetic region) represents deep seethed magnetic feature possibly made of intrusive rock, while “U” being close to a possible joint “R₁” with a distinct higher magnetic anomaly compared to its surrounding is further investigated with the Landsat ETM data. F₁, F₂, and F₃ are interpreted as faults based on the pattern of magnetic contours around them while V₁, V₂, V₃, and V₄ are probable mineralization veins considering their closeness to faults.

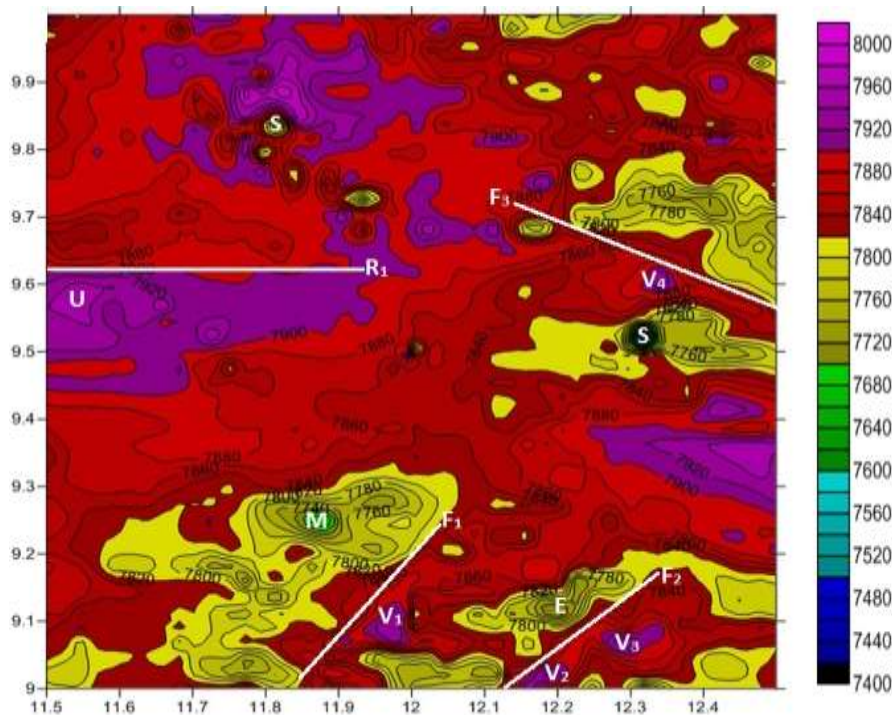


Fig. 7. Interpretation Map of study Area

Landsat ETM data which are usually employed for structural and tectonic interpretations such as locating faults, drainage patterns, geomorphology, plate position slope, lineaments and the boundary between geologic units are greatly applied in this study. Fig.8 shows the Digital Elevation Model of the Study Area, the highest peaks represented by the dark green colour are seen as small patches following a topographically high feature with maximum topographic height of 915m. Light green, yellow and red colours are closely packed together representing an abrupt change in topography from 767m to 371m. A look at the Lineament Density

map (fig.9) revealed a number of lineaments (over 13km in size) trending in the NE – SW, N - S, NW – SE and E – W directions. The trend surface analysis of the structural features of the area in relation to the interpreted Lineaments from the rose diagram (fig. 10) 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 correspond to the major lineament trend of the study area.

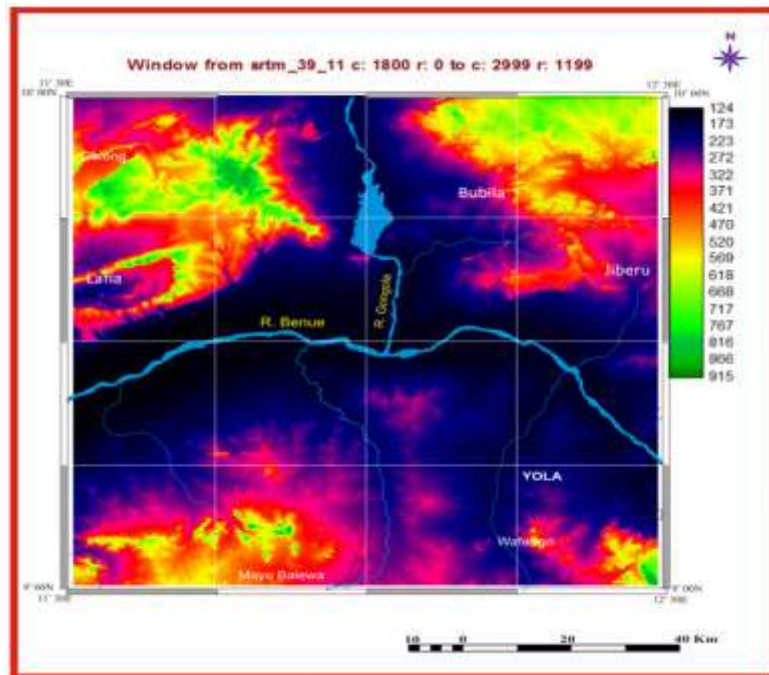


Fig. 8. Digital Elevation Model of Study Area

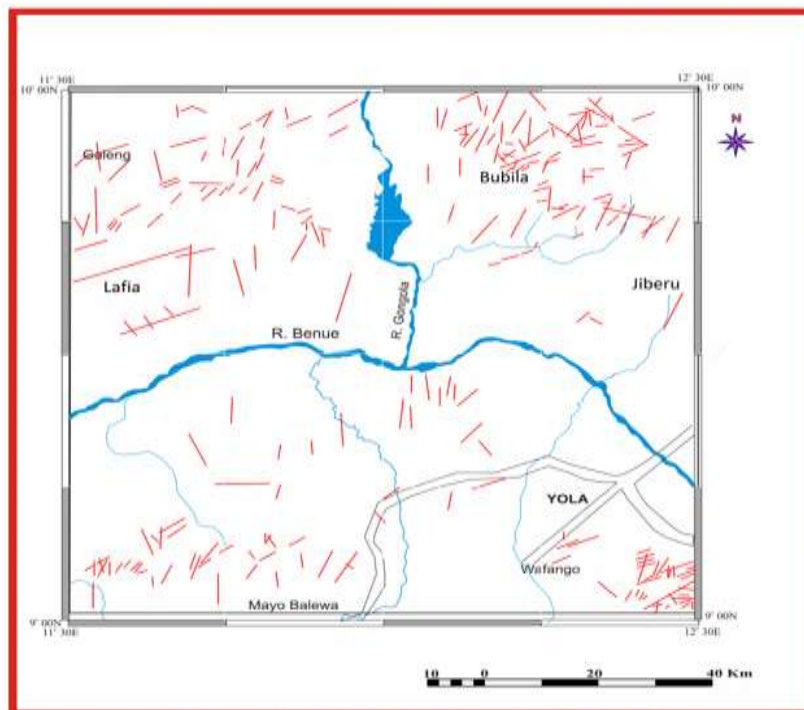
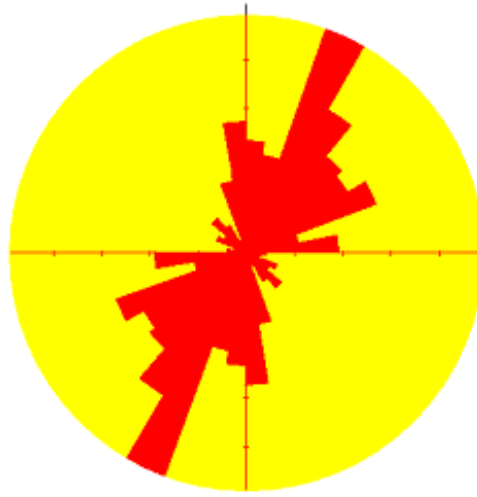


Fig.9. Lineament Density Map of Study Area

These dominant trends controlled the deposition of sediments in the trough, the cretaceous magmatism and orientation of fold belts, and the mineralization in the area. Fig. 11 is the RGB 532 Colour Composite map of the Study area from which we affirm that “U” is a Semi – circular Horst while R_1 is a folded joint (that is referring to fig. 7).



Number of data plotted = 245, Sector Interval Angle = 10°, scale spacing = 3% [7 data]
Maximum = 14.8% [36 data], Mean Resultant dir'n = 030, Circular Mean Dev. = 42°

Fig.10. Azimuth Frequency (Rose) diagram of the Study area

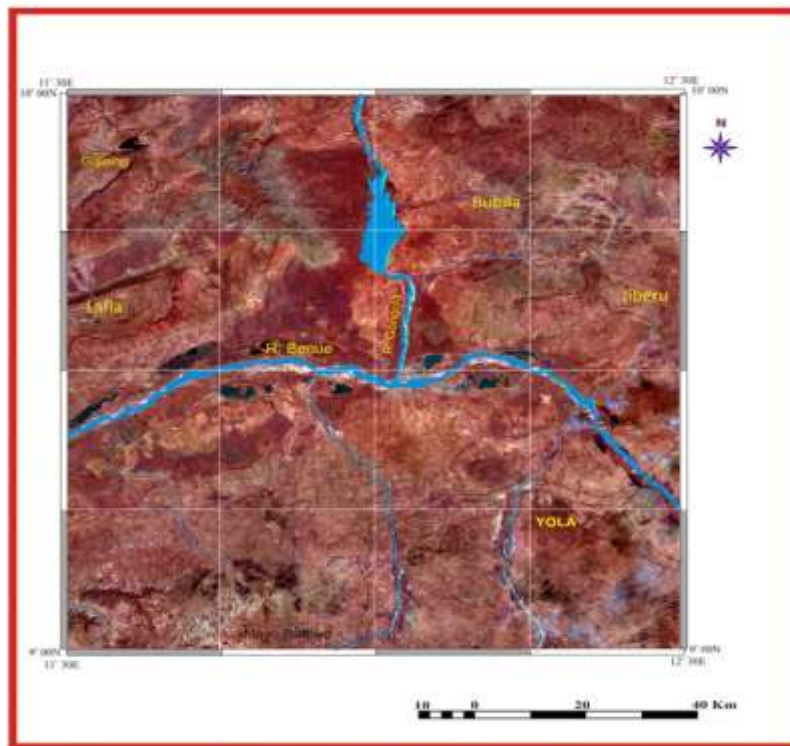


Fig.11. The RGB 532 Coloured Composite of the Study Area

5. CONCLUSION

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 25kilometr square in the area.

From the economic point of view, it can be concluded that the average sediment thickness of 3.975km obtained in this study is good enough for accumulation and entrapment of hydrocarbons especially in the Yola, Jiberu and Wafango regions. This average basement depth is in agreement with previous works done in and around the area. As such one canpostulate theexistence of petroleum accumulation at such depth in this part of the Upper Benue Trough. It is also possible to observe the existence of other mineral traps such as for lead, anhydrides, Tin etc. Furthermore, the structures found in the study area are more magnetic which

agrees to the cretaceous geology of the Upper Benue trough. The semi-circular Horst around Lafia should be thoroughly explored for underground minerals

This study thus confirms that the synergy between Aeromagnetic and Landsat ETM data cannot be discountenanced; both therefore have a lot of research potentials for geologic applications.

REFERENCES

- [1] Kasidi, S., and Ndatuwong, L.G., (2008). Spectral Analysis of Aeromagnetic data over Longuda plateau and Environs, North-Eastern Nigeria Continental. *Jour. of Earth sciences* (3), 28 – 32.
- [2] Opara, A.I., Onyewuchi, R.A., Onyekuru, S.O., Okonkwo, A.C., Nwosu, I.E., Emberga, T.T., and 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.
- [3] Ananaba, S.E., and Ajakaiye, D.E., (1987). Evidence of tectonic control of mineralization of Nigeria from lineament density analysis: A Landsat study; *Int. Journal. Rem. Sensing*; vol.1, no.10; pp. 1445-1453.
- [4] Prost, G.L., (2014). *Remote Sensing for Geoscientists*. CRC Press Boca Raton.
- [5] Benkhelil, J., (1987). The origin and evolution of the Cretaceous Benue Trough (Nigeria). *Jour. Afr. Earth Sci.* 8:251-282.
- [6] Allix, P., and Popoff, M., (1983). The Lower Cretaceous of the northeastern part of the Benue Trough (Nigeria): An example showing the close relationship between tectonics and sedimentation. *Bull. Cent.Rech.Explor. Prod. Elf-Aquitaine*, 7: 349 - 359.
- [7] Nwajide, C.S., (1990). *Cretaceous sedimentation and paleogeography of the Central Benue Trough*. In: C.O. Ofoegbu (Editor), *The Benue Trough Structure and Evolution*. Friedr. Vieweg and Sohn, Braunschweig/Wiesbaden, pp 19-38.
- [8] Cratchley, C.R., Lonis, P., and Ajakaiye, D.E., (1984). Geophysical and geological evidence for the Benue-chad basin Cretaceous rift valley system and its Tectonic Implications. *Journal of African Earth Sciences* 2 (2), 141 – 150.
- [9] Nwogbo, P.O., Ojo, S.B., and 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] Adegoke, A. K., (2012). Biostratigraph and Depositional Environment of the sediments in Borno Basin, Northeastern Nigeria. *Indian Journal of Science and Technology*, 5 (6), 2800-2809.
- [11] Carter, J.D., Barber, W., Tait, E.A., and Jones, G.P., (1963). The Geology of parts of Adamawa, Bauch and Bornu Provinces in North-eastern Nigeria. *Bull. Geol. Surv. Nigeria*, 30.
- [12] Alagbe, O.A., and Sunmonu, L.A., (2014). Interpretation of Aeromagnetic Data from Upper Benue Basin, Nigeria Using Automated Techniques. *IOSR Journal of Applied Geology and Geophysics* Vol. 2, 5, pp 22 – 40.
- [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.