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RESEARCH ARTICLE

EFFECT OF CONTINUATION AND DERIVATIVE FILTERS ON A HIGH RESOLUTION AEROMAGNETIC DATA COVERING PARTS OF LOWER BENUE TROUGH AND ANAMBRA BASIN.

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Abstract

This research presents the effect of various filters applied on the residual aeromagnetic map covering parts of lower Benue Trough and Anambra basin. The object of this study is to delineate the boundary of causative magnetic sources, delineate possible tectonic features and the structural controls with their corresponding trend pattern and then extrapolate the influence of those structures on the hydrocarbon and mineral potentials of the area. Using polynomial of different degrees, Regional-residual separation was carried out on the Total Magnetic Intensity (TMI) data and thereafter enhancement techniques like Upward continuation (at various kilometers), first vertical derivative (FVD), second vertical derivative (SVD), second vertical derivative (SVD) performed on the Residual data. The enhancement techniques were applied in order to establish the boundary between magnetic low and highs and also to discriminate the residuals (which are associated with the shallow bodies) from the regional which represents the deeply seated basement magnetic structures. Various contour configurations varying from been linear and elliptical to been irregular and circular, were revealed. These contours reveal possible tectonic trends and structures trending in the NE-SW, NW-SE, N-S and E-W directions. The linear and elliptical contours are possible fault zones and dyke like structures, respectively, existing within the study area while the irregular and circular contours are associated with high differentiation of the basement and possible magnetic aureole respectively. The NE-SW and NW-SE tectonic trends highlight possible oceanic fault and charcot fracture zones that transverse from the offshore Niger Delta region while the N-S and E-W trends are Pan African trends. This fault and fracture zones will, perhaps, serve as conduits for hydrocarbon and other mineralized fluids.

Introduction:-

Aeromagnetic technique is a geophysical technique in which a magnetometer is towed behind an aircraft. Aeromagnetic data has been, and will continue to be, handy in the geophysical and geological investigation of the earth's interior. Umeanoh (2015) asserted that aeromagnetic data can be used in mapping magnetic basement underlying sedimentary rocks and delineating igneous bodies within sedimentary sections as well as locating lineaments and structures which could be possible host to varying earth resources like groundwater, minerals and

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hydrocarbon. The measureable parameter in magnetic survey is the magnetic susceptibility. The total magnetic intensity (TMI) often shown on aeromagnetic maps is a measure of total magnetization of magnetic minerals in rocks. The two components of total magnetization are the induced and the remnant magnetizations, the vector sum of both gives total magnetization. The total magnetization of rocks is determined by not just the quantity and composition but also by the grain particles of the magnetic minerals and the processes that produced the remnant magnetization carried by the minerals (John and Emmanuel, 2014).

In Nigeria as well as most part of the world, aeromagnetic data gathering involving the use of aircraft in the survey has been accomplished by the government or in partnership with co-operate organizations to boast mineral exploration and perhaps hydrocarbon, groundwater and environmental studies. The datasets acquired by the government have been used extensively by individuals and perhaps corporate organizations in investigating the tectonic lineaments and structural implications of various features found. Goodhope and Mamah (2013) investigated the tectonic lineaments of the lower Benue trough and it was found that N-S, NE-SW, NW-SE and E-W directional trend exist within their study area. In 2013, Jatau and Nandom examined the morphology of the study area the using aeromagnetic data. Structures trending in the north-south, N-S, northeast-southwest, NE-SW, northwest-southeast, NW-SE, and east-west, E-W, directions were revealed. Opara *et.al.,* (2015) in their work established lineaments trending NE-SW, NW-SE, N-S and E-W using aeromagnetic data. Using aeromagnetic anomalies, Ofoha (2015) asserted that the NE-SW, NW-SE, NNE-SSW, E-W, N-S dominate within the Lower Benue Trough. Thus the major work for the researcher(s) is boiled down solely to interpretation. With this ease in data collection, more work has been down in research shifting attention from primary interpretation of basement structures to a more detailed and wider investigation of structures as well as lithologic variations within sedimentary sections (Onyewuchi, 2011).

Minerals have been established to prevail within the study area but recently researchers are of the opinion that the possibility of hydrocarbon accumulation is increasingly becoming feasible. Few of their arguments were based on the use of aeromagnetic data while majority were based on the use of seismic data for hydrocarbon exploration within their respective study areas. In addition to these studies, this study will delineate the tectonics, if any, and the structural controls that will encourage the migration and accumulation of hydrocarbon as well as minerals within the area. Therefore, this study will be of immense benefit to exploration companies, researchers and perhaps individual as it unveils the structural control of the area.

Location And Geology Of The Study Area:-

Enugu state and parts of Anambra state, south-east Nigeria, lies within the study area. The coordinates are Latitude 6^0 00'-6^0 30'N and Longitude $7^0$00' 7^0 30'E. The Benue Trough generally has been subdivided into three: the Upper Benue Trough at the NE Nigeria, the Middle Benue Trough and the Lower Benue Trough. The Lower Benue Trough has somewhat developed different tectonic history leading to the formation of Anambra Basin to the west and Abakaliki Anticlinorium to the east The Anambra Basin remained a stable platform supplying sediments to the Abakaliki depression during a period of spasmodic phase of platform subsidence (Ojoh, 1990) in the Turonian. Following the flextural inversion of the Abakaliki area during the Santonian uplift and folding, then the Anambra Basin was initiated (Umeanoh, 2015).

Four Cretaceous depositional cycles where recognized by Okiwelu *et.al.,* (2015) in the Lower Benue and each of these was associated with the transgression and regression of the sea. The opening of the Atlantic Ocean in the Middle Albian to Upper Albian gave rise to the transgression of the first sedimentary cycle. The Asu River group which consist predominantly sandstone and shale was deposited at this time. Between the Upper Cenomanian and Middle Turonian, the second sedimentary deposition of the Ezeaku Shale occurred. The third sedimentary circle occurred from Upper Turonian to the Lower Santonian leading to deposition of the Awgu Shale and Agbani Sandstone. The fourth and final depositional phase took place during the Campanian-Maastrichtian transgression. It was at this time that the Nkporo Shale, Owelli Sandstones, Afikpo Sandstone, Enugu Shale as well as the coal measures including the Mamu Formation, Ajali Sandstone and Nsukka Formation were deposited. The geological map (Fig 1) of the study was extracted from the regional geologic map and redigitized using the Arc GIS software for enhanced interpretation of the aeromagnetic map. Visually inspecting the map shows five main formations within the study area. These include: Nkporo Shale Formation, Mamu Formation, Ajali Formation, Nsukka Formation and Ameki Formation. The ages of the formations range from Maastrichtian to Campanian and to Eocene (Ameki formation).

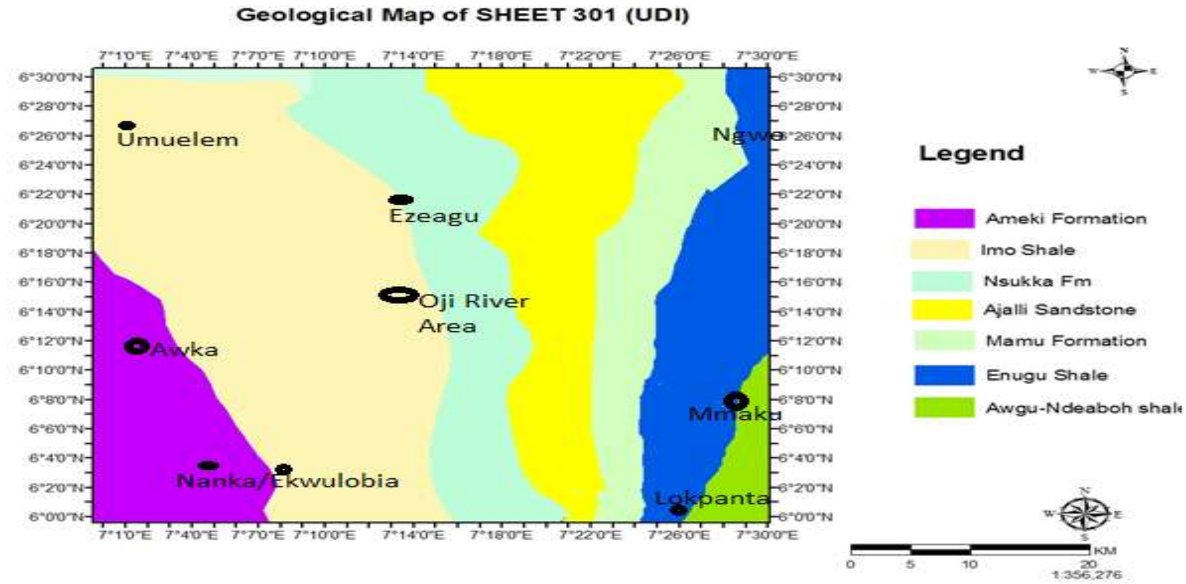

Fig 1:- Geological Map Of The Study Area

Materials and Methods:-

Digitized High Resolution Aeromagnetic (HRAM) data compiled by Fugro Airborn Service on behalf of the Nigerian Geological Survey Agency (NGSA) in 2009 was used for this study. The Total Magnetic Intensity (TMI) map with sheet number 301 was obtained in comma separated variable (CSV) format and in half degree sheet. The aeromagnetic data in CSV format was later produced into a raster format (Fig 3). The high resolution survey was carried out at flight line spacing of 500 meters and at a ground clearance of about 100 meters while the tie line spacing was 2 km at flight line direction of NE-SW.

For effective data analysis, processing and interpretation, the WingLink and ArcGIS softwares were used for the interpretation which was done qualitatively. The ArcGIS software was used to convert the data into a format that could be recognized by the WingLink software. After conversion, the data was imported into the WingLink environment for qualitative analysis which involves performing the regional-residual separation. This separation gave rise to the regional and residual maps. Upon the residual, further qualitative analysis like polynomial fitting of various degrees and upward continuation was applied. The regional-residual separation is governed by the expression shown below:

$T_f = R_d - Rg$ 1

Where

T_f= Total field

R_d= residual field

R_g= regional field

The polynomial fitting undertaken from the first degree to the kth degree is expressed by:

$$y = a_0 + a_1 x + \cdots + a_k x^k \quad 2$$

The residual is given by

$$R^2 = \sum_{i=1}^{n} \left[y_i - (a_0 + a_1 x_i + \cdots + a_k x_i^k) \right] \quad 3$$

Blakely (1996) showed the expression for upward continuation from Green's third identity of a potential field measured on a level $\boldsymbol{z = z_o}$ at point $\boldsymbol{P = (x, y, z_o - \Delta z)}$ as**;**

$$U(x,y,z_o-\Delta z)=\frac{\Delta z}{2\pi}\iint_{-\infty}^{\infty}\frac{U(x^I,y^I,z_o)}{[(x-x^I)^2+(y-y^I)^2+\Delta z]^{\frac{3}{2}}}dx^I dy^I, \quad 4$$

$$Where\ \Delta z>0$$

Applying the Fourier convolution to equation 4

$$\mathfrak{F}[U_u]=\mathfrak{F}[U]\mathfrak{F}[\psi_u] \quad 5$$

Where

$$\psi_u(x,y,\Delta z)=\frac{\Delta z}{2\pi(x^2+y^2+\Delta z^2)^{\frac{3}{2}}} \quad 6$$

Equation 5 is the analytical expression of $\mathfrak{F}[\psi_u]$ and $\mathfrak{F}[U_u]$ is the Fourier transform of the upward continued field

$$\mathfrak{F}[U_u]=e^{-\Delta z|k|}, \quad 5$$

$Where$

U_u = Upward continuation at the initial level

ψ_u = Upward continuation at a new level

and $\Delta z > 0$

Results:-

The data obtained in CSV format was produced into a raster form shown in Fig 2. This was in turn transformed into a contour format (Fig 3). Regional-residual separation using polynomial separation of degree 1 was undertaken and this gave rise to the residual map (Fig 3 a) and the regional map (Fig 3 b). Thereafter, higher polynomial fitting of degree 2 (Fig 4), degree 5 (Fig 5), degree 10 (Fig 6) and degree 20 (Fig 7) were applied on the residual (of degree one) so as evaluate the effect of each of the filters. Upon the residual map, upward continuation at 5 km (Fig 8), 10 km (Fig 9), 15 km (Fig 10) and 20 km (Fig 11) were also carried out. Similarly, first vertical derivative (Fig 12), second vertical derivative (Fig 13) and first horizontal derivative (Fig 14) were performed on the residual map so as to pronounce the effect of the shallow sources.

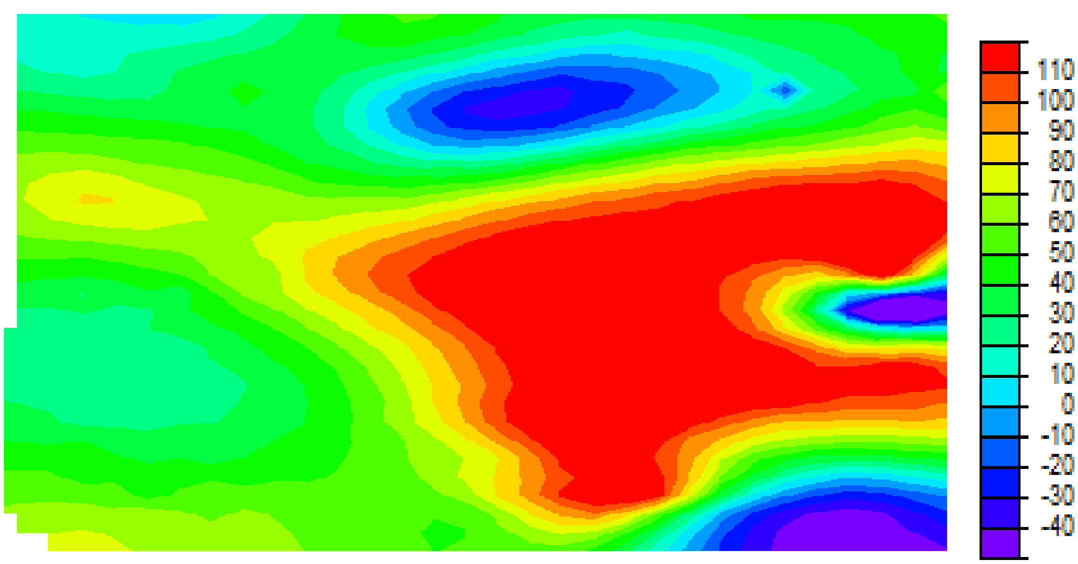

Fig 2:- Aeromagnetic Raster Map Of The Study Area (Nt)

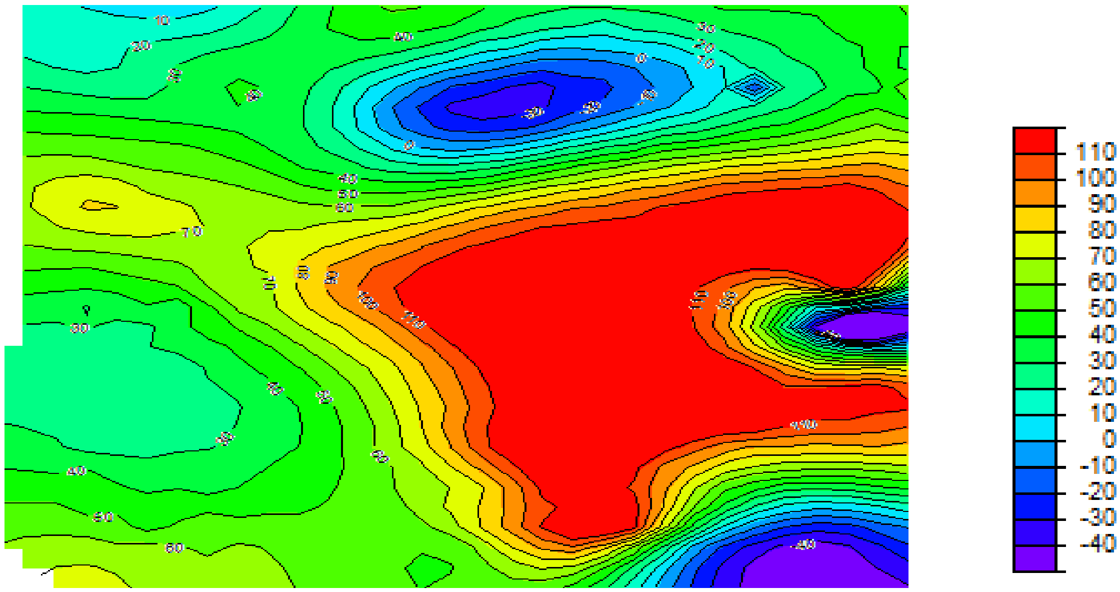

Fig 3:- Total Magnetic Intensity Contour Map (Nt)

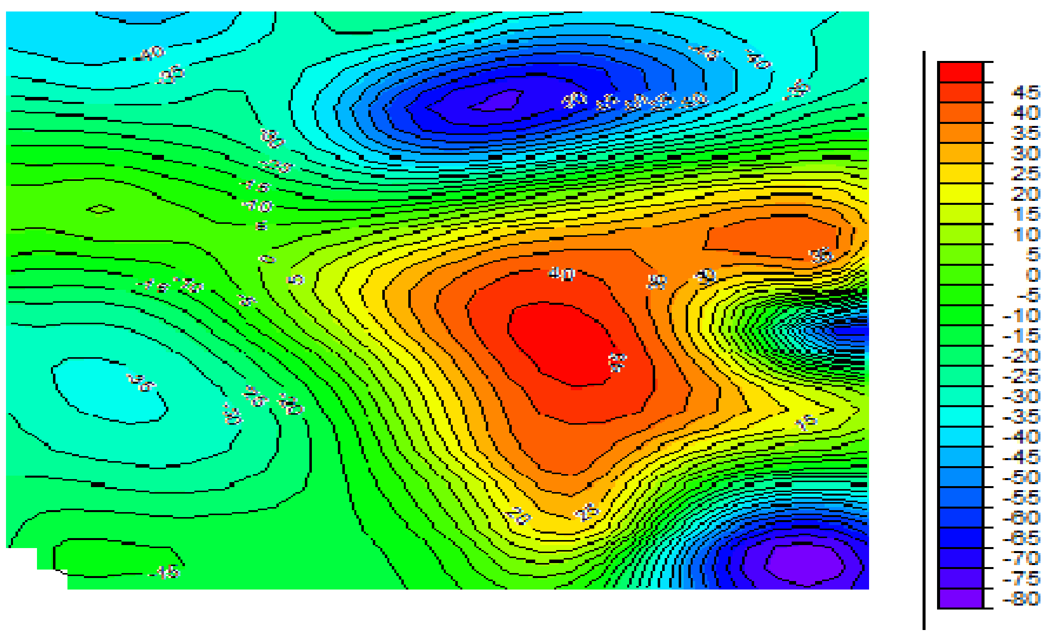

Fig 3 a:- The Residual Map Of Degree One (Nt)

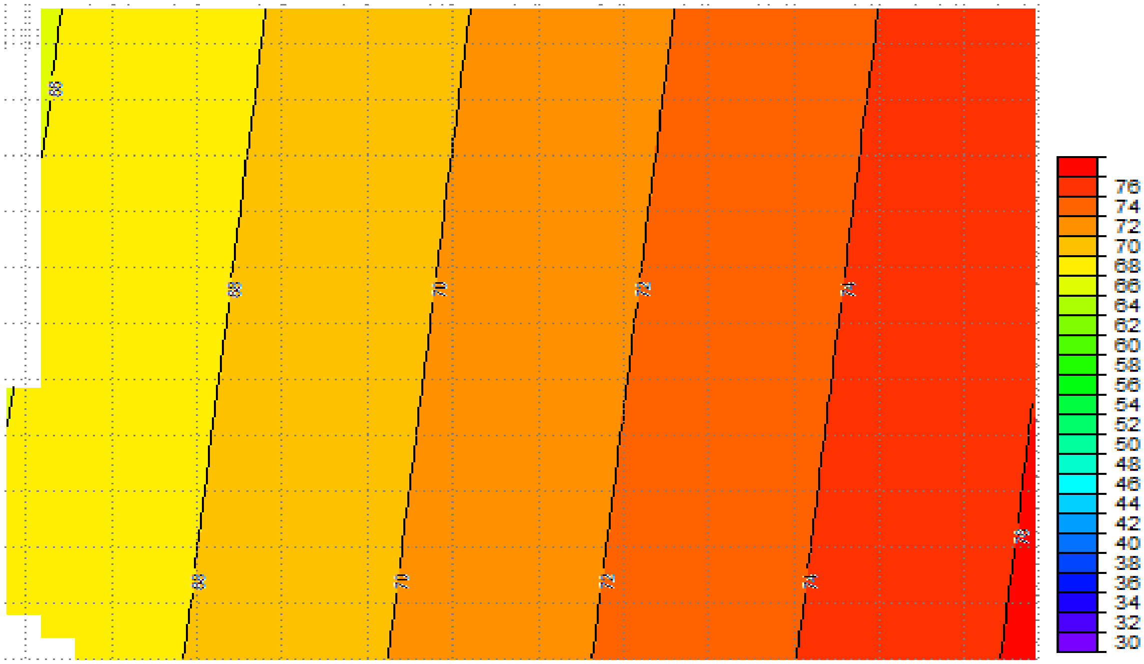

Fig 3 b:- The Regional Map

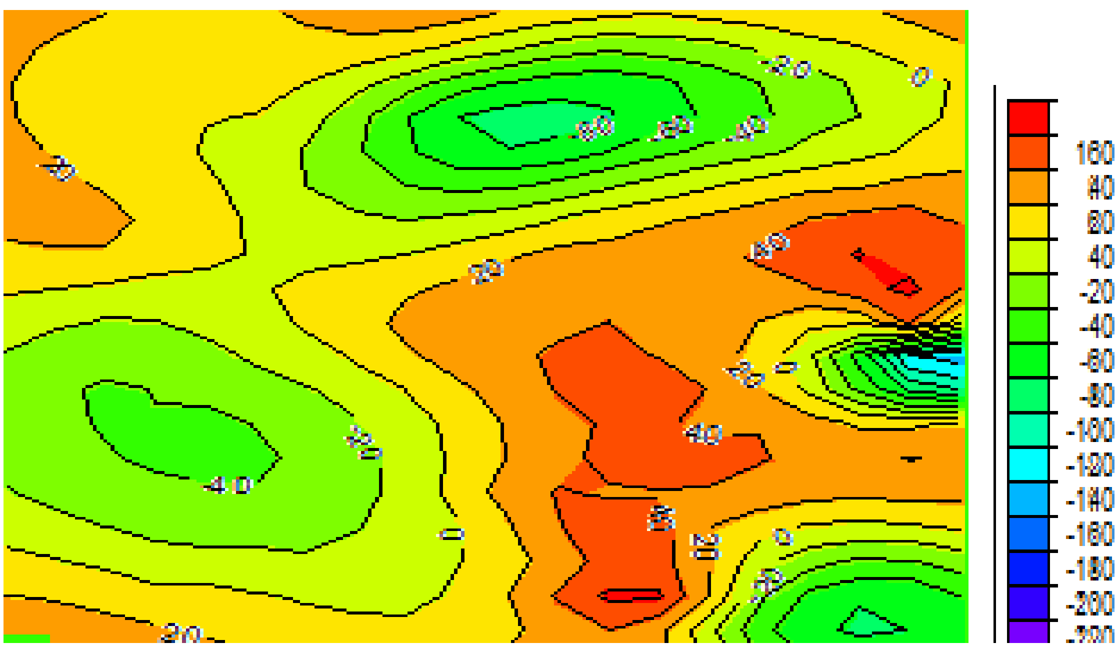

Fig 4:- The Residual Map Obtained By Applying Polynomial Fitting Of Degree Two (Nt)

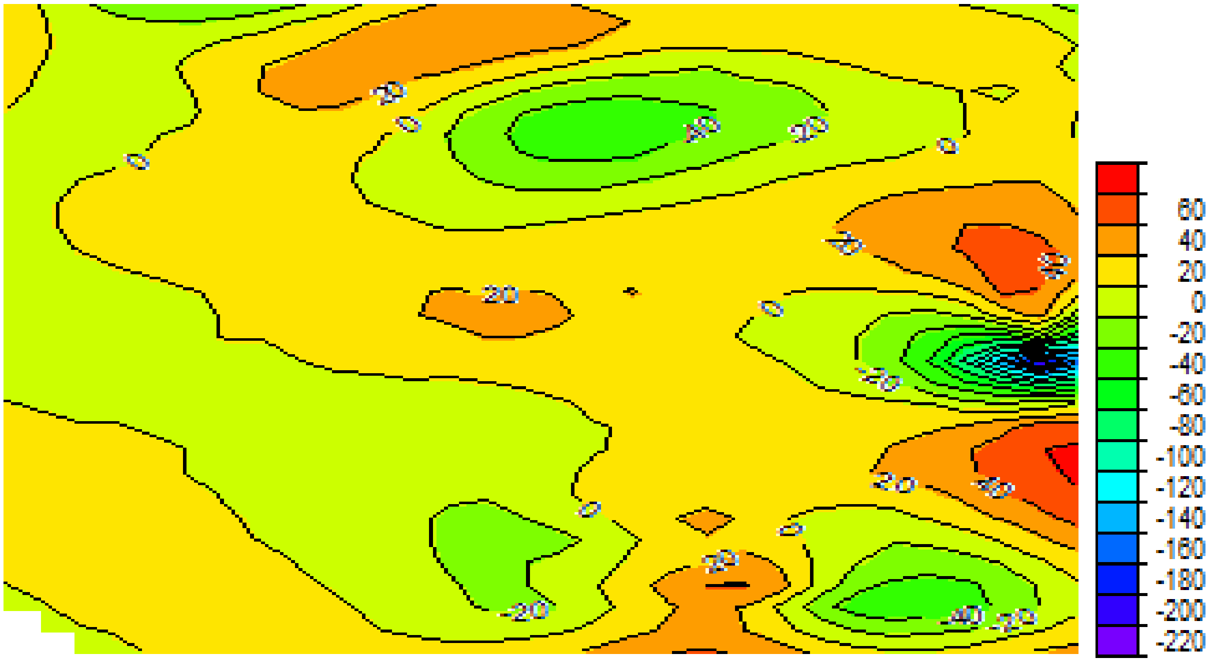

Fig 5:- The Residual Map Obtained By Applying Polynomial Fitting Of Degree Five (Nt)

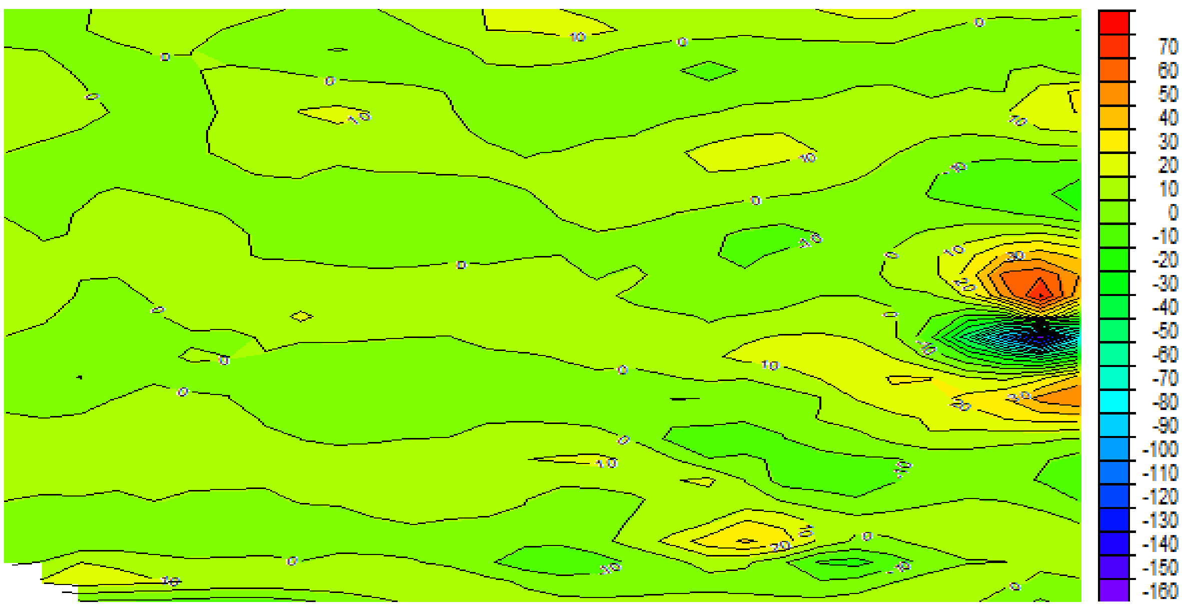

Fig 6:- The Residual Obtained By Applying Polynomial Fitting Of Degree Ten (Nt)

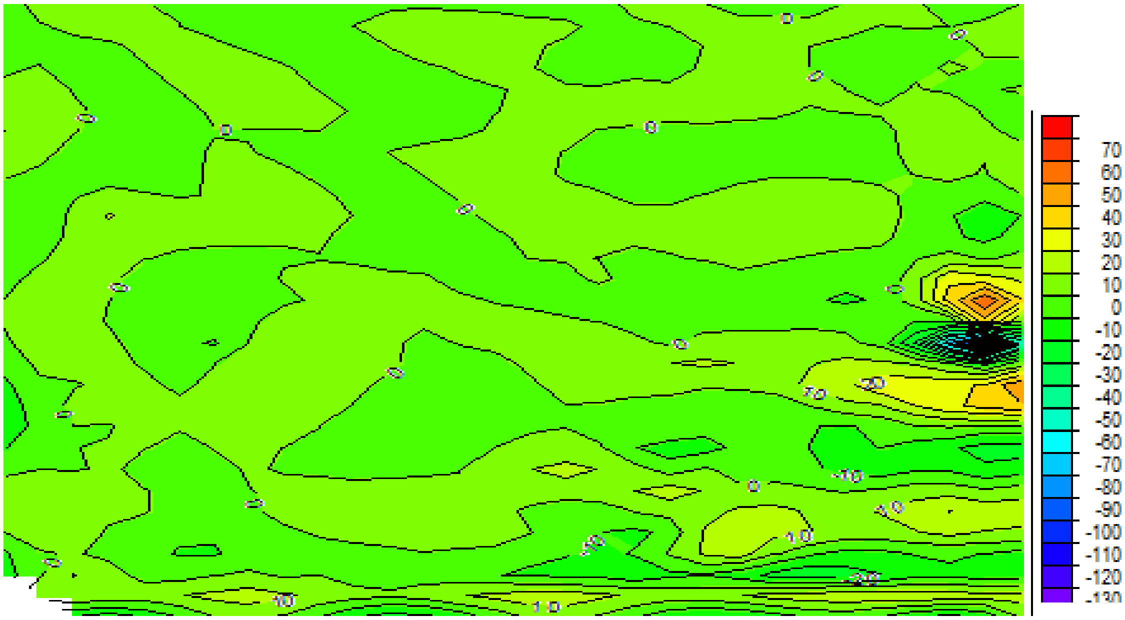

Fig 7:- The Residual Obtained By Applying Polynomial Fitting Of Degree 2o (Nt)

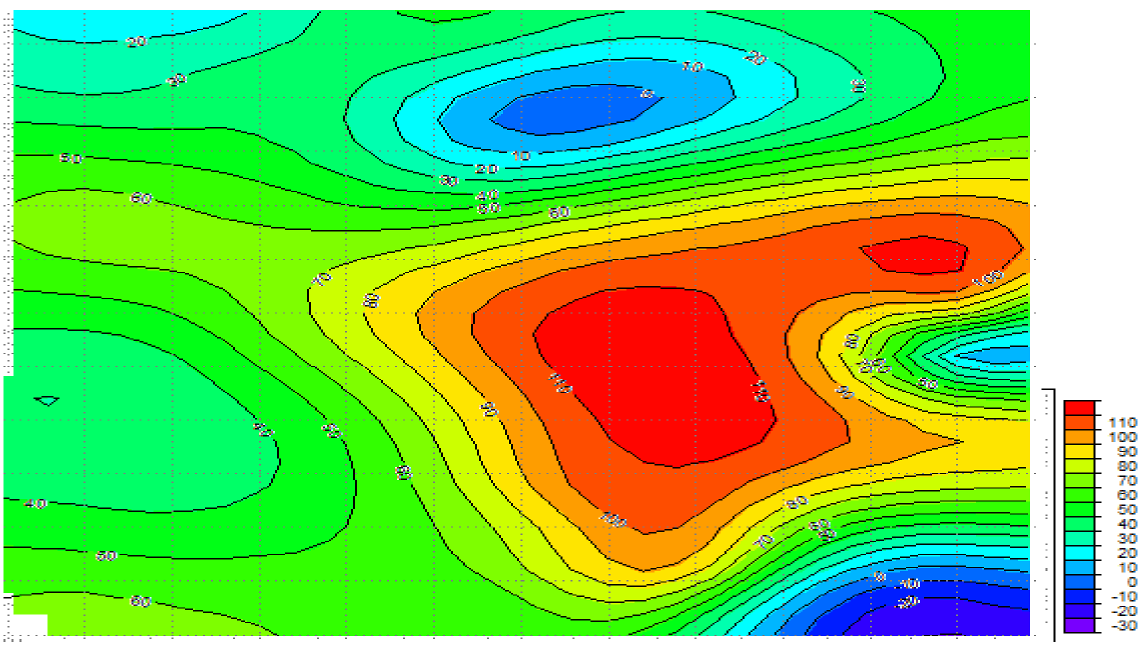

Fig 8:- Upward Continuation At 5 Km

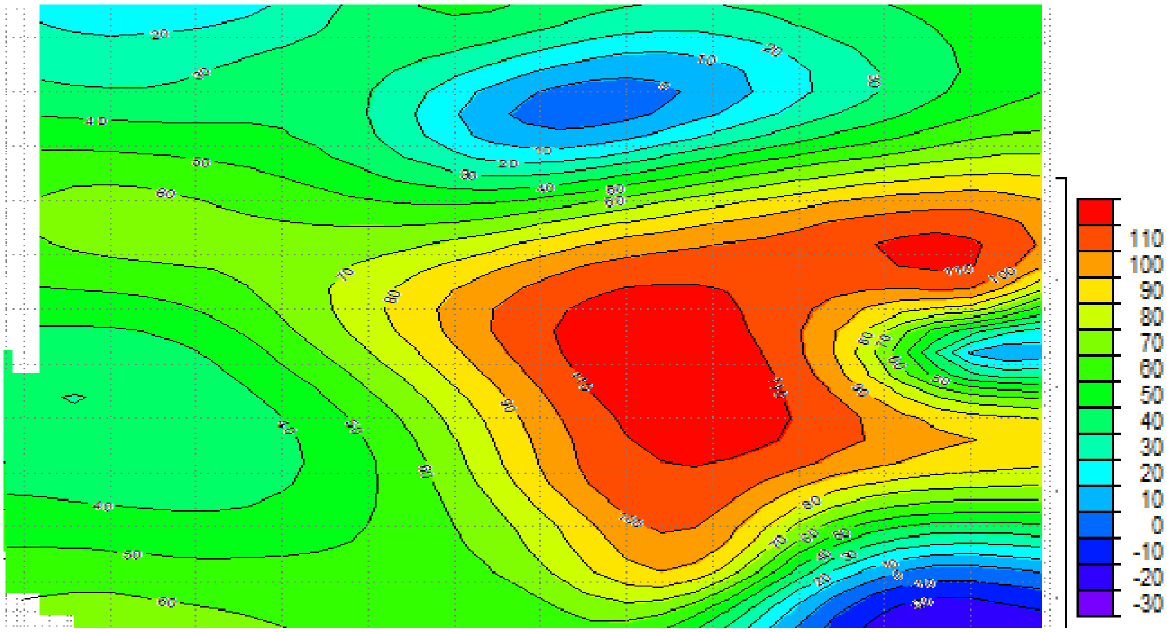

Fig 9:- Upward Continuation At 10 Km

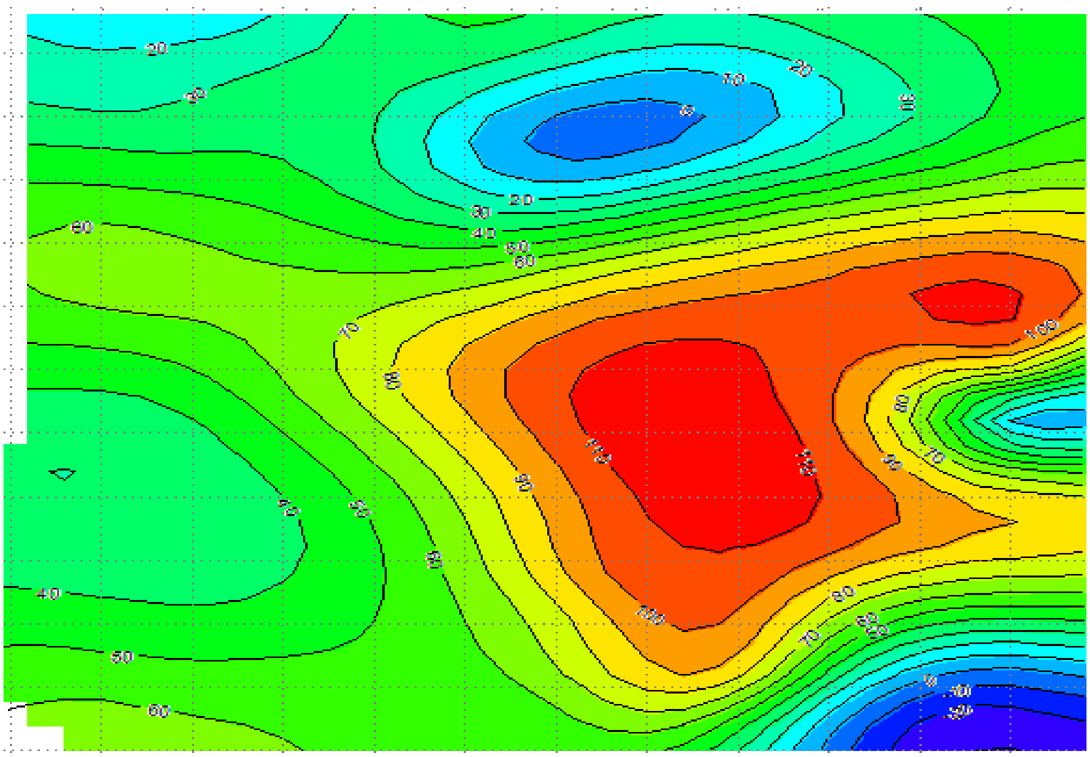
Fig 10:- Upward Continuation At 15 Km

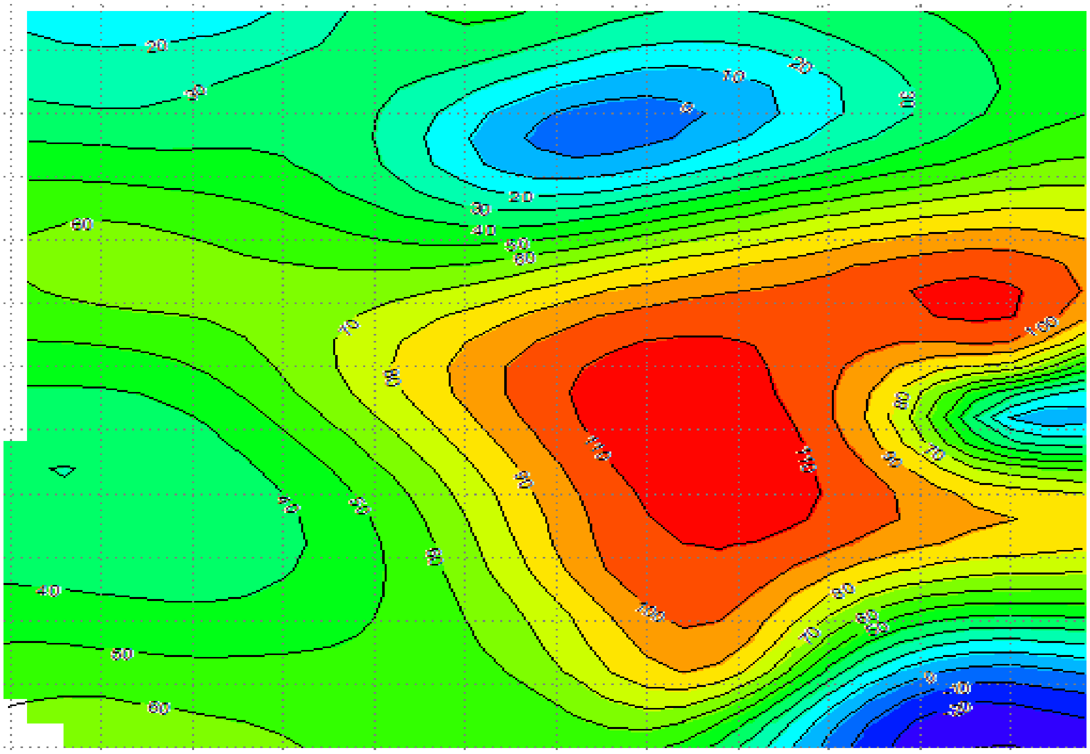

Fig 11:- Upward Continuation At 20 Km

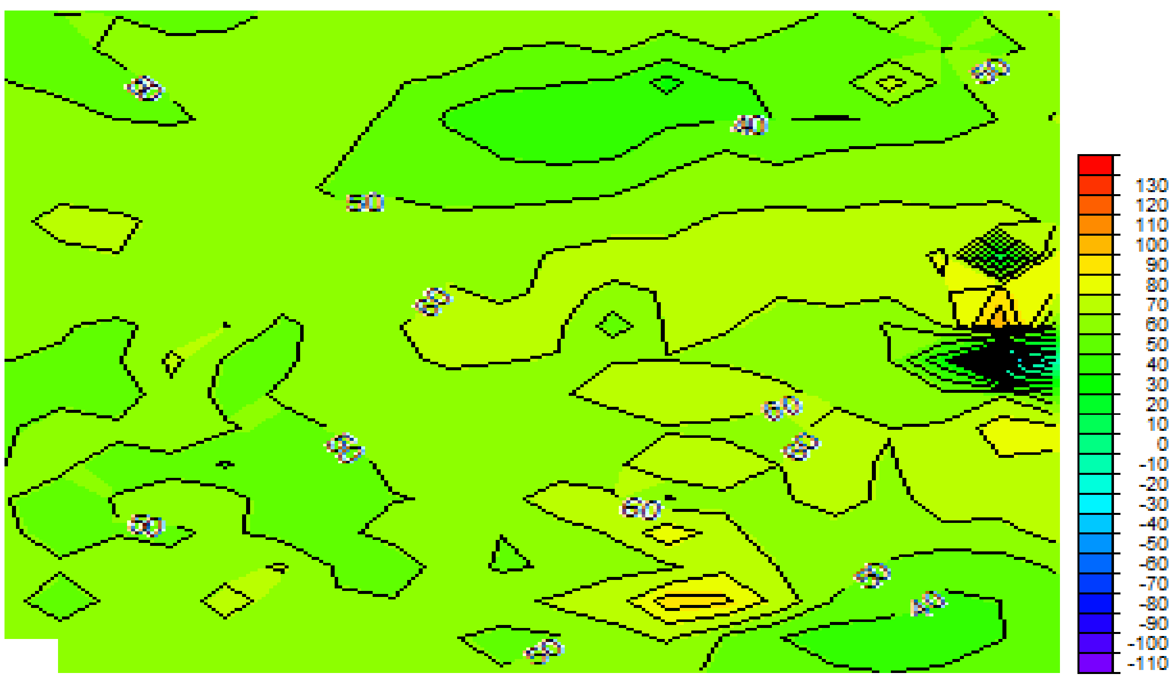

Fig 13:-First Vertical Derivative

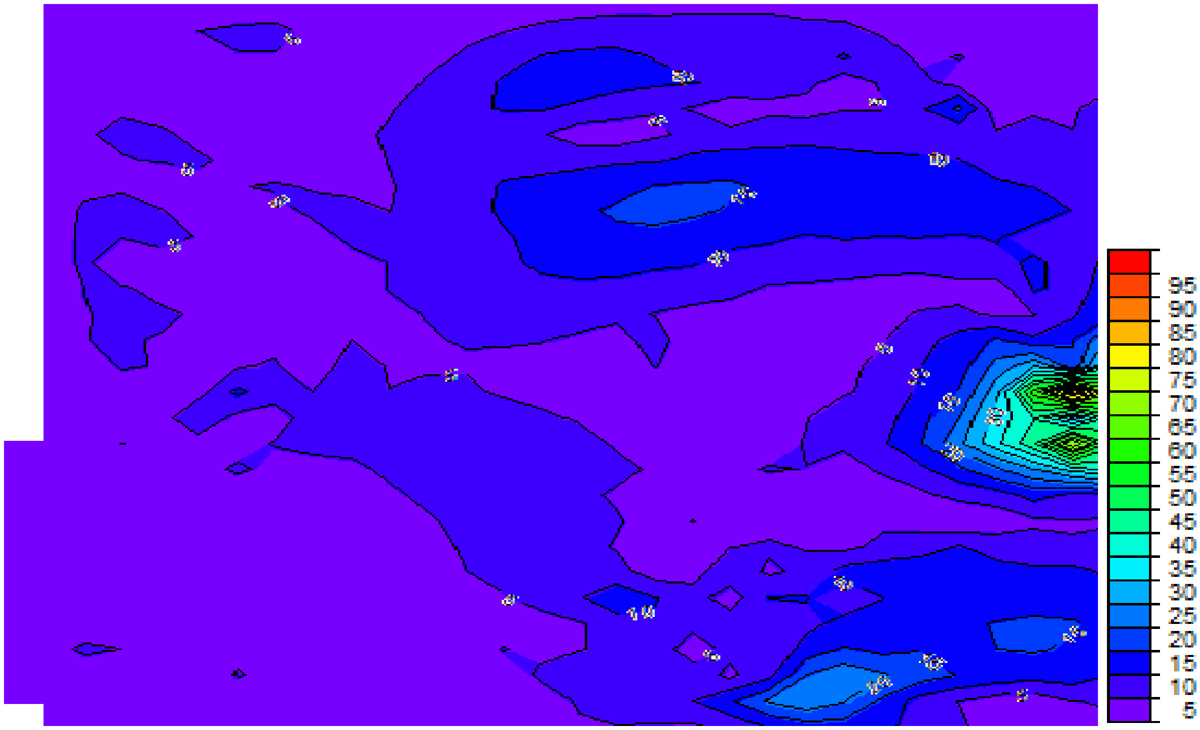

Fig 14:- Horizontal Derivative Map

Discussion of Findings:-

The qualitative and the total magnetic intensity maps show colour variations ranging from red, yellow, light blue, blue, green and the magenta, although with the magenta inscribed inside the blue colour. These colour contrast reflects magnetic field changes within the area of study and it aids an interpreter to partition the study area in question into various magnetic units. According to Kiani (2016), these acute variations in terms of colour differences could be due to the variations in geologic boundaries, lithology and/or basement topography. The TMI map reveals zones of high, intermediate and low existing within the area. The yellow and red colours, represent magnetic high and this was found to dominate the central and eastern portion of the map. This magnetic zone is also discernible slightly within the western and northern part of the map while the intermediate magnetic unit is nearly distributed evenly within the TMI map and this is depicted with the green colour. The magnetic low is, nevertheless, designated with the magenta, light blue and blue colours and this is distributed within northern and south eastern portion of the map. Beside the TMI map is a legend showing the anomalous values for each of the magnetic zones. The anomalous values for the magnetic high ranges from 70 nT to 110 nT and these values cut across majorly the central and the eastern portion of the map. Values ranging from 20 nT to 60 nT and 10 nT to -40 nT are associated with the intermediate and low zones respectively. The intermediate cut across almost the study area while the magnetic low occurs around the northern, eastern and south western portion. Generally the magnetic values attached to the legend are little compared to those values obtained between by the Nigerian Geological Survey Agency (NGSA) between 1974 and 1980. This is due to the IGRF values that have been subtracted from the TMI values but Kiani (2016) opined that this could be attributed to survey specifications encompassing the ground clearance, flight line and tie line spacing. The magenta and the red colours inscribed inside the blue and yellow colours respectively are believed to be superposition of magnetic units. As earlier stated, the red and yellow zone denotes magnetic high units. The magnetic high regions could be attributable to Pre-Cambrian basement rocks (Migmatites, gneisses and older granites) and is believed to be associated with some tectonic activities which occurred during the Pan African Orogeny while the area with the magenta, blue and light blue colours are part of the magnetic low and are believed to be associated with structures housing sediments. According to Gunn *et. al.,* (1997), the light blue and blue colour highlight zones made up of irregular weathering of magnetic units and assemblage of non magnetic units. The green colour that is spatially distributed however represents intermediate magnetic intensity and this is probably indicative of granitic rocks. From the legend behind the TMI map, it is evident that the magnetic values decreases with the red, yellow, green, light blue, blue, magenta.

Visual inspection of the contoured TMI map reveals contours of varying configurations. The contours revealed vary from being closely parked, elliptical, broadened, irregular, parallel and localized. The contours trend in the NE-SW and NW-SE direction. The TMI data consist of high frequency components superimposed on the low frequency components, thus the need for regional-residual separation which aided in unraveling some hidden features.

Polynomial fitting of various degrees was applied so as to pronounce shallow related anomalies at various levels. Unlike the TMI map, the residual map of degree one enhanced the accentuation of closely parked magnetic anomalies indicating shallow anomalous features. These features are subdued which is typical of a sedimentary terrain. These residual map signatures trend in the NE-SW and NW-SE but with the former occurring most. In the map, the magnetic lows are more pronounced than that which is observed on the TMI map. These magnetic low zones are conspicuous at the northern, eastern, south eastern portion but less apparent at the western portion of the map. At the eastern and south eastern portions of the map are smaller magnetic contours which according to Gunn *et al.,(1997)* is indicative of a distinct lithology from the surrounding or possibly a lava flow as evidenced by the inhomogeneity of the magnetic units. Emplaced centrally are attenuated magnetic signatures which run towards the southern and eastern portion of the map. The central portion of the map with high magnetic values lies within the Oji Rivers settlement and is cut by Nsukka Formation, Ajali Formation, Mamu Formation, Imo shale, and the Enugu shale. The magnetic low contours however occurring at the northern, eastern, south eastern and western portion falls within the Umuelem, Ngwo, Mmaku, Lokpanta, Nanak Ekwulobia and Awka province. Comparatively with the geologic map, these magnetically low regions are cut by the Ajali sandstone, Nsukka Formation, Enugu shale and the Ameki Formation. It could therefore be inferred that the low and high magnetic anomalies may be associated with the presence of shale gas found within the structures and magnetic intrusions respectively. Hence, the relatively closed, smooth, elliptical and localized anomaly contours designated with the blue and magenta colours are possibly established hydrocarbon target within the area of study. Revealed on the non commercial regional map are planar NNE-SSW tectonic trend. The NNE-SSW trend in conjunction with the NE-SW, NW-SE trends are conceived to be Pan African trends by Anudu *et.al.,* (2012). The NE-SW and NW-SE tectonic trends serve as migratory part for hydrocarbon and hydrothermal fluids and also depicts an onward extension of the Atlantic fracture zones. Some of these tectonic trends representing fracture and fault zones were still observed in the result of Umeanoh (2015) whose work falls within parts of the study area. He obtained the NE-SW and NW-SE tectonic trends.

The residual of degree two typically exemplifies shallow sources as evidenced with the short wavelength anomalies. Unlike the residual of first degree, the contours of the second degree residual are relatively spaced. This therefore indicates that the magnetic sources discernible at the second degree residual are deeper in depth. On the map of the second degree residual polynomial, the igneous intrusive appear more and are irregular at the eastern portion of the map. Elliptical and near elliptical contours are obvious at the northern and south-western portion of the map. These contours are appeared on the residual of degree one and on the TMI map but were more pronounced on the residual map of degree two. Critical look at the residual of degree one and two as well as the TMI map finds out that the contours with near elliptical and elliptical structures are emplaced at the same locality. Hence the more probability of locating a dyke like structure which is associated with the elliptical shape. At the eastern portion of the TMI and the residual map of degree one are closely parked contours which disappeared gradually on the residual of degree two. They contours, however, trend in the NE-SW, E-W, N-S and NW-SE but with the NE-SW tectonic trends dominating.

When polynomial fitting of degree five was applied, the contours were more spaced and the intrusive spread spatially more on the map. The number of contours that appeared on the residual of degree one were lesser in number. The near elliptical shaped contour disappeared and the numbers of contours that make up the elliptical contour lessen. But the isolated and closely spaced contours were intact. NW-SE, few E-W and N-S trends are obvious on the map.

The residual maps obtained by applying polynomial fittings of degree ten and twenty were synonymous in terms of contour configurations. They contours trending majorly in the E-W direction are equally spaced and irregular. Few NW-SE structures can also be seen. At the eastern portion of the maps are closely parked contours but with the contours been more broadened in the residual map of degree ten than that of degree twenty.

Unlike the TMI and residual maps, the upward continuation maps (at 5 km, 10 km, 15 km and 20 km) highlight similar and smoothened magnetic signatures. The upward continuation maps accentuate regional effect relative to the residual. The regionals are the deeply seated or the long wavelength magnetic bodies while the residuals are the shallow seated or short wavelength sources. When the residual of degree one was upward continued at 5 km, 10 km, 15 km and 20 km, similar contour characteristics were apparent. It can therefore be inferred that the same magnetic sources can be located at different measurement points. However, the contours trend in the E-W and NW-SE directions. These directional contours or signatures trending NE-SW, NW-SE, N-S, and E-W suggest lineaments, faults and local fracture zones within the study area.

The first vertical derivative map shows shallow seated magnetic bodies as evidenced with the irregular and short wavelength magnetic contours trending NE-SW and NW-SE while the horizontal derivative map points out zones with magnetic low which trends in the E-W and N-S directions but with the E-W trend being dominant.

Conclusion:-

From the result of the data reduction, each of the filters gives different responses from the next except for the upward continuation filter where similar responses were observed. It could therefore be concluded that numerous filters give a different output from the next filter. However, there are remarkable correlations in terms of the tectonic trends depicted in the study area. More also, the presence of structural trends suggest the influence of structures on the accumulation and migration of hydrocarbon and hydrothermal fluids within the study area.

Acknowledgement:-

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References:-

1. Anudu, G.K., Onuba, L.N., Onwuemesi, A.G., and Ikpokonte, A.E. (2012): Analysis of aeromagnetic data over Wamba and its adjourning areas in north central Nigeria, 16(1), 25-33.
2. Goodhope, A. and Luke, M. (2013): Structural interpretation of Abakiliki- Ugep, Using Airborne and Landsat Thematic Mapper (TM) Data. Journal of natural science research, 3(13), 137-148.
3. Gunn, P.J., Maidment, D. and Milligan, P.R. (1997): Interpreting aeromagnetic data in areas of limited outcrop. Journal of Austrian Geology and Geophysics, 17(2), 175-185.
4. Jatau, B. S. and Nandom, A. (2013): Morphology of Parts of the Middle Benue Trough of Nigeria from Spectral Analysis of Aeromagnetic Data. International Journal of Environmental, Chemical, Ecological, Geological and Geophysical Engineering. 7(9), 622-627.
5. John, U. M and Emmanuel, E.U. (2014): Structural Analysis Using Aeromagnetic Data: Case Study of Parts of Southern Bida Basin, Nigeria and the Surrounding Basement Rocks. Earth Science Research, 3(2), 24-42.
6. Kiani, I. (2016): Interpretation of aeromagnetic data over parts of Sokoto basin, northwestern Nigeria. Msc thesis, University of PortHarcourt, Choba, Rivers State, (Unpubl).
7. Ofoha, C.C. (2015): Geological interpretations inferred from a high resolution aeromagnetic (HRAM) data over parts of mmaku and environs, south eastern, Nigeria. International Journal of Applied Science and Mathematical Theory, Vol. 1 No.4 , 1-15.
8. Ojoh, k. (1990): Cretaceous geodynamic evolution of the equatorial domain South Atlantic; stratigraphy, basin analysis and paelogeography. Bulletin, Centre Research, exploration and production ELF-Aquitaine, 14, 419-442.
9. Okiwelu, A.A., Obianwu, V.I., Eze,O., and Ude, I.A. (2012): Magnetic anomaly patterns, fault block tectonism and hydrocarbon related structural features in the Niger Delta basin. Journal of applied geology and geophysics, Vol 2, Issue1 Ver.1, 31-46.
10. Onyewuchi, A.R. (2011): Interpretation of Aeromagnetic and Landsat Imageries of Okposi, Ebonyi State, SE Nigeria, Msc thesis, University of Port Harcourt, Choba, Rivers State, (Unpubl).
11. Opara, A.I., Onyekuru. S. O., Essien, A. G., Onyewuchi, R. A., Okonkwo, A. C., Emberga, T. T. and Nosiri, O. P. (2015): Lineament and Tectonic Interpretation Over Abakiliki Area: Evidences from Airborne Magnetic and Landsat ETM Data. International Journal of Research and Innovations in Earth Science, 2(4), 111-121
12. Umeanoh, D.C. (2015): Structural interpretation of aeromagnetic data over parts of lower benue trough, Nigeria, Msc thesis, University of PortHarcourt, Choba, Nigeria, (Unpubl).