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Qualitative evaluation of aeromagnetic data of Mmaku area, Nigeria, by means of upward continuation, band pass, highs pass and low pass filtering actions

Daniel C. Umeanoh[1], S. A. Ugwu[1], Chimezie C. Ofoha[2,*]

[1]Department of Geology, University of Port Harcourt, Rivers State, Nigeria

[2]Department of Physics, University of Port Harcourt, Rivers State, Nigeria

*E-mail address: williamscharles333@yahoo.com

ABSTRACT

The focus of this research is to delineate subsurface structures as well as their edges by interpreting a high resolution aeromagnetic data via qualitative approach. The study area lies between Latitude 6°00’- 6°30’N and Longitude 7°00’ - 7°30’E in Enugu state, south-east Nigeria. Regional-residual separation algorithm was applied on the total magnetic intensity aeromagnetic map in order to generate the residual and regional maps. On the resulting residual data, further enhancement techniques like the upward continuation at 5 km, 10 km and 20 km, band pass, high pass and low pass enhancement technique/filtering actions were undertaken. Result of the qualitative analysis shows that the study area is characterized by numerous faults and fractures expressed as NNE-SSW, E-W, N-S, NE-SW, NW-SE, and ENE-WSW tectonic trends. The NE-SW and NW-SE tectonic trends indicate that the area is affected by the charcot and oceanic fractures that existed within offshore Niger Delta, Nigeria while the ENE-WSW. NNE-SSW, E-W and N-S tectonic trends exemplify that the separation of Africa from South America affected the area.

***Keywords*:** Gneisses, filtered maps, structural trends, faults, qualitative

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1. INTRODUCTION

The magnetic method can objectively be used to search for earth resources like mineral, oil and gas and perhaps, water. The search for the earth resources is based on the detection of unusual magnetic properties which reveal themselves by causing anomalies in the intensity of the earth's magnetic field [1]. [2] stated that this technique is frequently used in the search for buried magnetic materials. When the magnetic method is performed in the air, it plays an important and distinguished role when compared with other geophysical methods in that it covers large part of the survey area in the shortest period of time. The aeromagnetic technique is also advantageous as it requires low cost per unit area explored. During acquisition, aeromagnetic survey maps spatial variations in the magnetic field of the earth which occurs due to changes in lithology, susceptibility contrast, depth variation and/or inclination and declination of the geomagnetic field. In their opinion, [3] associated the variations in the earth's magnetic field to the percentage of magnetite in the rock. The data obtained is usually used to produce geological interpretation of an area [4].

The aeromagnetic data of the study area and with sheet number 301 covers Latitude 6°00' - 6°30'N and Longitude 7°00' - 7°30'E in Enugu state, south-east Nigeria.

Potential field data like the aeromagnetic data can be processed and interpreted at ease through the application of various filters on the data in order to accentuate certain hidden and chosen features. Thus, this research adopted the application of upward continuation, band pass, high pass and low pass filtering actions to exhume subsurface structural features associated with the area.

1. 1. Geology of the study area

Geologically, study area lies between the Lower Benue Trough and partly in Anambra basin. 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 resulting in the formation of the Anambra Basin to the west and Abakaliki Anticlinorium to the east. According to [5] reconstruction model, the Anambra Basin remained a stable platform supplying sediments to the Abakaliki depression during a period of spasmodic phase of platform subsidence [6] in the Turonian. Following the flextural inversion of the Abakaliki area during the Santonian uplift and folding, then the Anambra Basin was initiated.

Four Cretaceous depositional cycles where recognized by [5] 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 geology of the map (Fig 1) sheet 301 was extracted from the regional geologic map and redigitized for enhanced interpretation of the aeromagnetic map. The five main formations within the study map area are 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). From the re-digitized map in fig. 1.3, the formations become younger towards the SW.

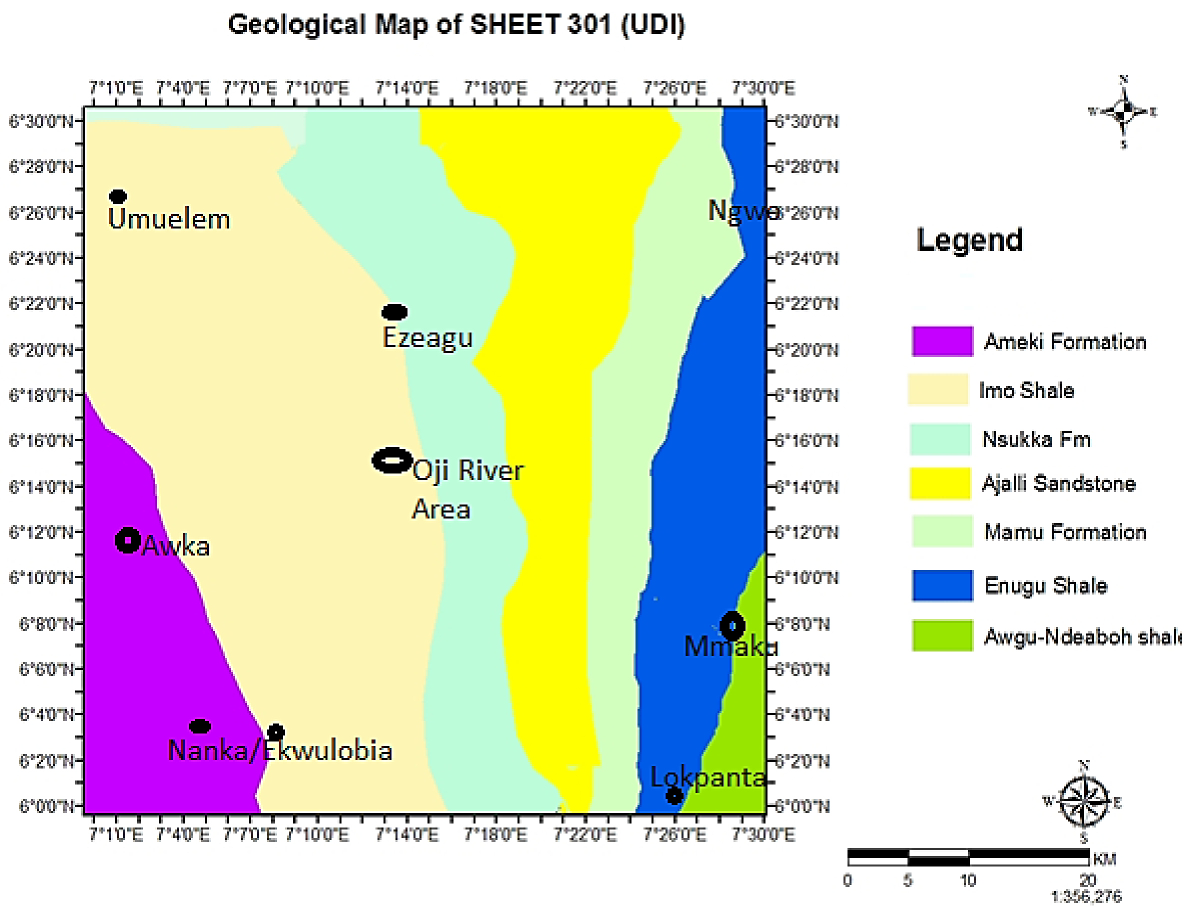

Fig. 1. A Geologic Map of the Study Area (Modified Sheet 301and Re-digitized NGSA geologic map of Nigeria)

2. MATERIALS AND METHOD

The aeromagnetic data of the study area was obtained by Fugro Airborne servicers as part of a nationwide aeromagnetic survey sponsored by the Nigeria Geological Survey Agency (NGSA). The data were acquired along a series of NW-SE flight lines with a spacing of 500m and average flight lines, while tie lines occur at about 2km in a direction of NE-SW. The geomagnetic gradient was removed from the data using the International Geomagnetic Reference Field. The data was made available in X, Y, Z format, where X values represent the distance of a point from the origin pointing to the east direction; Y values represent the distance of a point from the origin in the ordinate direction while the Z values represent the values of the total magnetic intensity at a point. The total area covered was about 3025 km^2.

For the purpose of this study, the acquired data in geosoft format was was opened and digitized in ESRI ArcGIS software for onward processing and interpretation. Digitization was done in grid of 1km x 1km spacing and values of TMI, X (latitude) and Y (longitude) were picked at the intersection of the grid nodes. This 1 km × 1 km grid points generated over 6000 sample points. The x and y show the coordinates while the z represents the TMI value at the point. The coordinates have been automatically converted and recognized in meter scale. This was implemented in ArcGIS 9.3 software and the xyz data was saved as MS Excel file format.

2. 1. Corrections/enhancement techniques applied on the aeromagnetic data

On the acquired aeomagnetic geomagnetic correction was applied by the Nigerian Geological Survey Agency, NGSA, by estimating the geomagnetic gradient from the raw data using International Geomagnetic Reference Field (IGRF) of 2010. Also, the data was corrected for tem-poral variations recorded by the base station magnetometer and referenced to an arbitrary station by the agency. Thereafter the data was saved in geosoft file format by the agency

2. 1. 1. Regional-residual separation

Several regional-residual separations exist and some of them were applied on the data as explained below. A crucial step was undertaken in order to obtain the regional and the residual fields. This step was the application of polynomial fitting of degree one on the aeromagnetic or total magnetic intensity map of the study area. The actual regional and residual field maps were generated. To further accentuate the hidden features of the area, other types of regional-residual technique were applied on the residual data. These techniques were applied on the residual field because the residual data contains our anomalies of interest.

2. 1. 2. Upward continuation enhancement technique

Upward continuation enhancement technique was carried out at 5 km, 10 km and 20 km using the residual data. The essence is to project the observed data to a higher level. This filtering action attenuates the short wavelength component thereby making the long wavelength component or the deeply seated more apparent to the interpreter's eye.
[7] believed that the upward continuation analytical action is governed by

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

where:

$\Delta z > 0$

Applying Fourier convolution to equation 3.2, we obtained

$$\mathcal{F}[U_u]=\mathcal{F}[U]\mathcal{F}[\psi_u]$$

where:

U_u = Upward continuation at the initial level

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

ψ_u = Upward continuation at a new level and can be expressed as

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

2. 1. 3. Band pass enhancement technique

On the residual data, a band pass enhancement technique was applied through the use of the band pass filter algorithm emplaced on the menu bar of the WingLink Software. The band pass filter applied was made to allow signals between 2 km - 10 km of wavelength. Signals outside this wavelength were discriminated.

2. 1. 4. High pass enhancement technique

High pass filtering action was applied on the residual aeromagnetic data so as to cut off any signal with wavelength higher than 2 km. The filter enhanced features at depths characterised by short wavelength anomalies.

2. 1. 5. Low pass enhancement technique

A cut off of 2 km was adopted while applying low pass filter on the residual data. When it was applied, signals whose wavelengths were less than 2 km were pronounced. Wavelength signals higher than 2 km were attenuated.

3. RESULTS AND DISCUSSION

Present on the aeromagnetic map (Fig. 2) are colour differences signifying magnetic field changes within the area. These changes could be as a result of changes in lithology, depth of causative sources, susceptibility contrast and/or inclination and declination of the earths magnetic field. Two magnetic zones of high and low were revealed on the map. The magnetic high is associated with red and yellow colours and they have anomalous values ranging from 30 nT to 110 nT. Prominent feature as a broadened, circular and elongated anomalous shapes are apparent on the map. The central-eastern portion of the map with broadened red, orange and yellow colours exhibits high magnetic intensity that cut across the study area. This 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. On the other hand, the magnetic low is linked with the blue, green and the magnetic colours. The magnetic low is expressed as negative and positive anomalies ranging from – 40 nT to 30 nT.

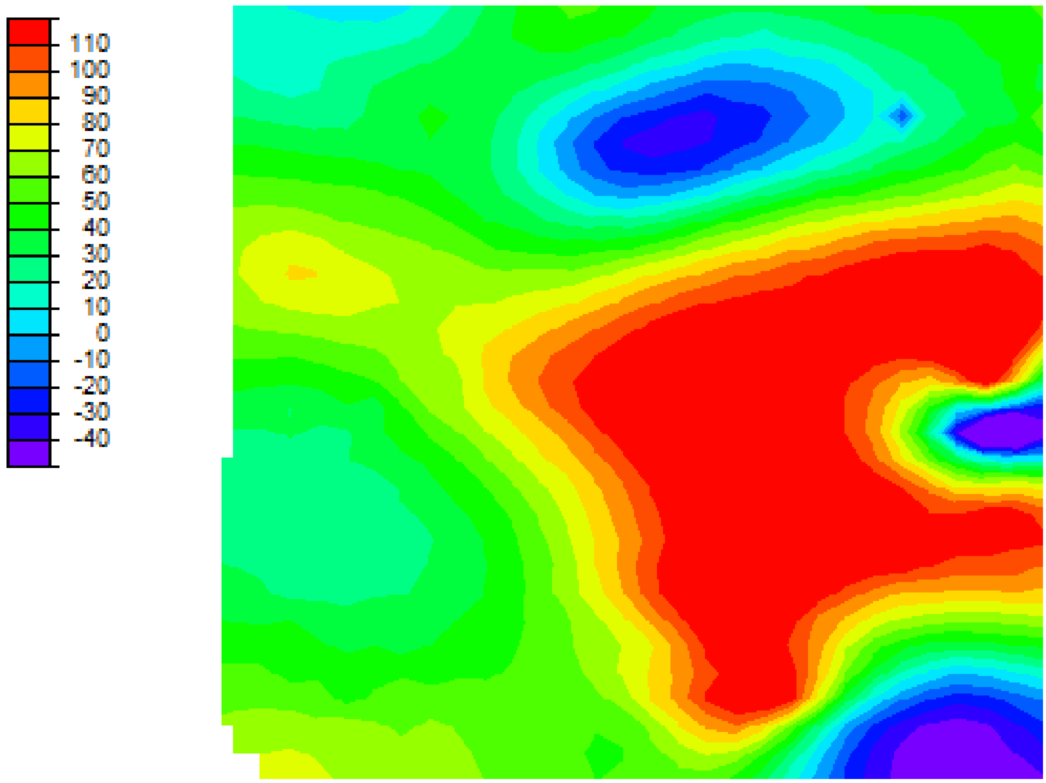

Fig. 2. Aeromagnetic raster map of the study area (nT)

On transforming the raster aeromagnetic map to contour aeromagnetic map (Fig. 3), signatures of various sizes and shapes became obvious on the aeromagnetic map. The signatures range from being irrgular, localized, circular, broadened, parallel and elliptical. The total magnetic intensity aeromagnetic map consists of long wavelength regional anomalies. Superimposed on the regional are the short wavelengths residual which are of primary in importance as they may provide evidence of the existence of mineral ore bodies or reservoir type sedimentary structures. To further highlight subtle or concealed features as well as hidden tectonics and reduce ambiguity that accompany magnetic data interpretations the need for regional-residual separation.

The residual map (Fig 4) reveals series of magnetic contours that are more or less circular, parallel, broadened or localized. The northern, eastern, south eastern and south western portion of the map is characterized with magnetic low contours or weak anomalies which, perhaps reflect the presence of a local relief on the basement surface [7] that is to be analyzed quantitatively and whose intensity ranges between -80 nT and -50 nT. At the eastern and south eastern portions of the map are smaller magnetic contours which according to [8] is indicative of a distinct lithology from the surrounding or possibly a lava flow as evidenced by the inhomogeneity of the magnetic units.

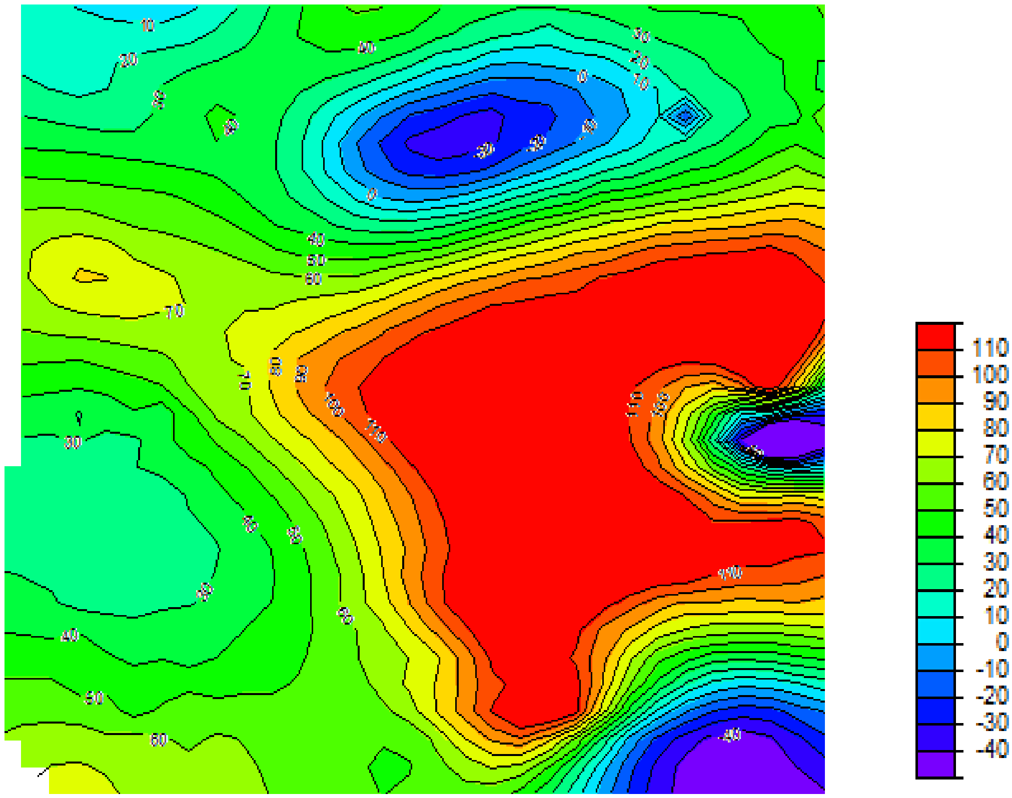

Fig. 3. Aeromagnetic map in contour format (nT)

Emplaced centrally are attenuated magnetic signatures which run towards the southern and eastern portion of the map. The central portion of the map lies within the Oji Rivers settlement underlained by Nsukka Formation, Ajali Formation, Mamu Formation, Imo shale, and the Enugu shale. The magnetic low contours however occuring at the northern, eastern, south eastern and western portion falls within the Umuelem, Ngwo, Mmaku, Lokpanta, Nanak Ekwulobia and Awka province.

These magnetically low regions are underlain by the Ajali sandstone, Nsukka Formation, Enugu shale and the Ameki Formation. Nevertheless, attenuation of the low magnetic unit from blue to light blue colouration can be observed at the north and south eastern portion of the residual map.

This is attributed to the weathering of magnetic unit involved. Subsurface tectonic trends in the ENE-SWS, E-W, NW-SE and N-S directions are apparent on the map but with the ENE-SWS becoming more dominating. Visual inspection of the regional aeromagnetic map (Fig 5) indicates regional NNE-SSW tectonic trends. These trends however show possible faults and fractures zones within the area.

Dissimilar to the TMI and residual maps, the upward continuation maps at various levels (Fig 6, Fig 7 and Fig 8) highlight similar and smoothened magnetic signatures. The upward continuation maps highlight regional effect relative to the short wavelengths. This is indicated by the long wavelength signatures pre-dominating the maps.

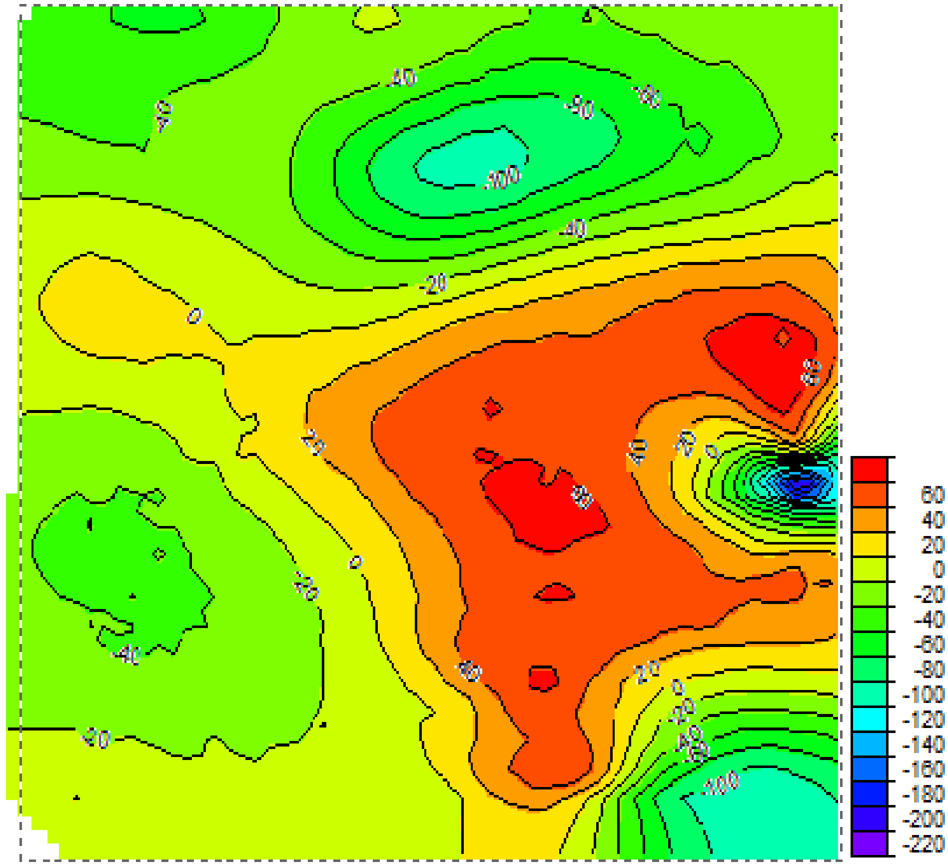

Fig. 4. Residual map of the study area (nT)

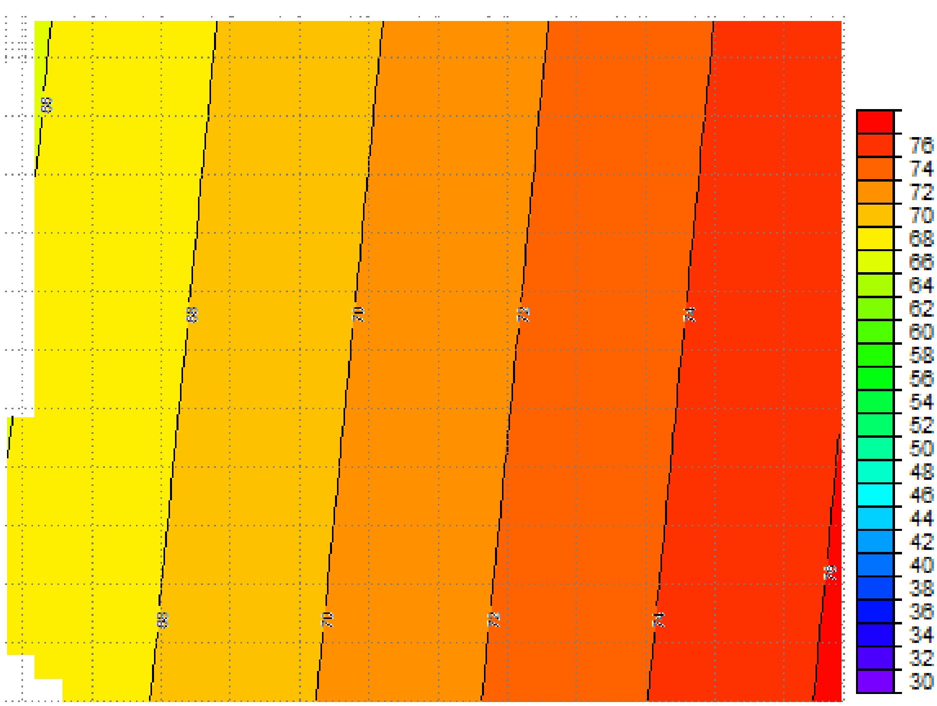

Fig. 5. Regional map of the study area (nT)

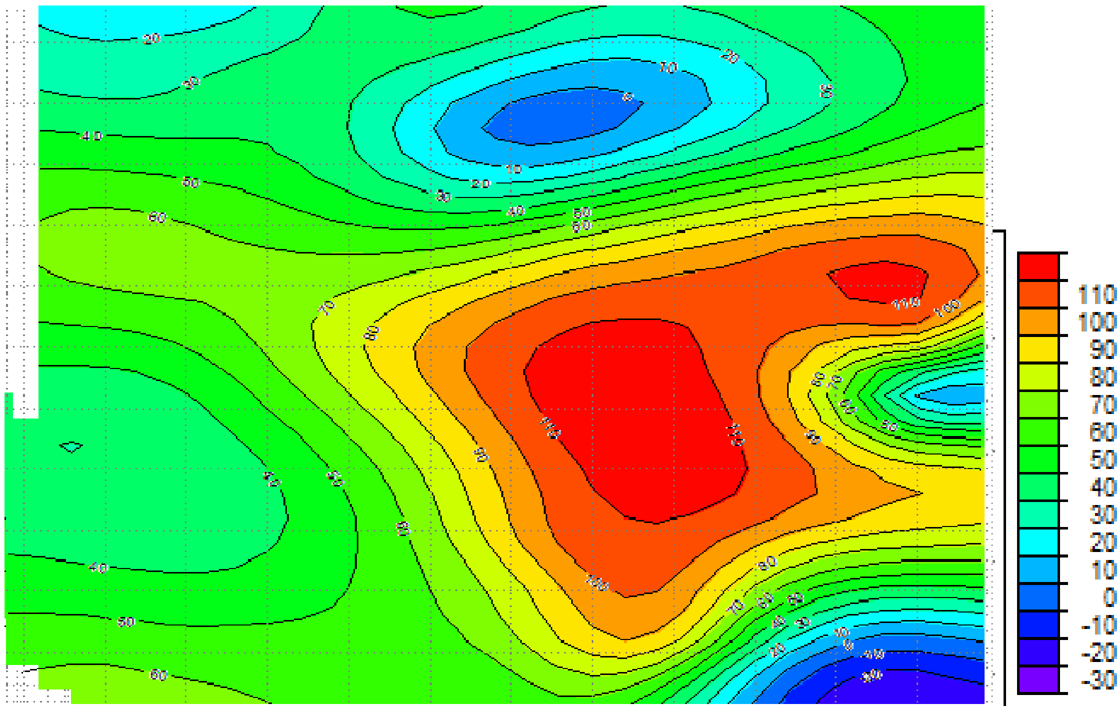

Fig. 6. Upward continuation map at 5 km

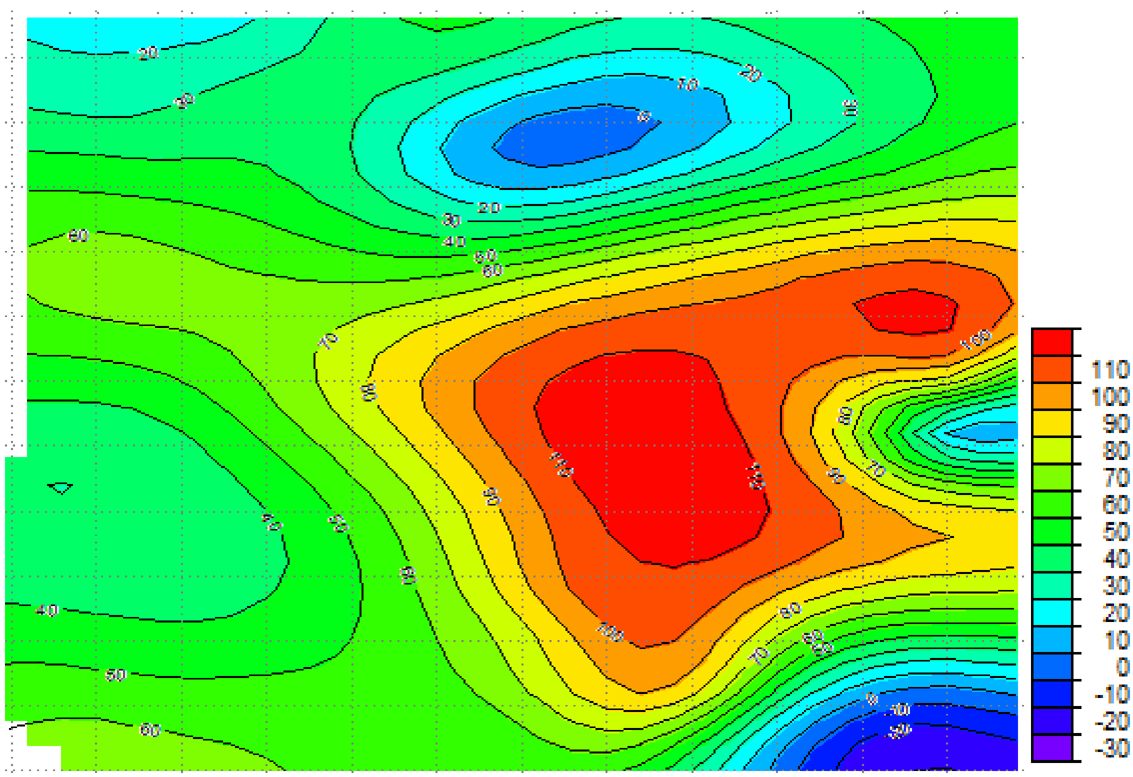

Fig. 7. Upward continuation map at 10 km

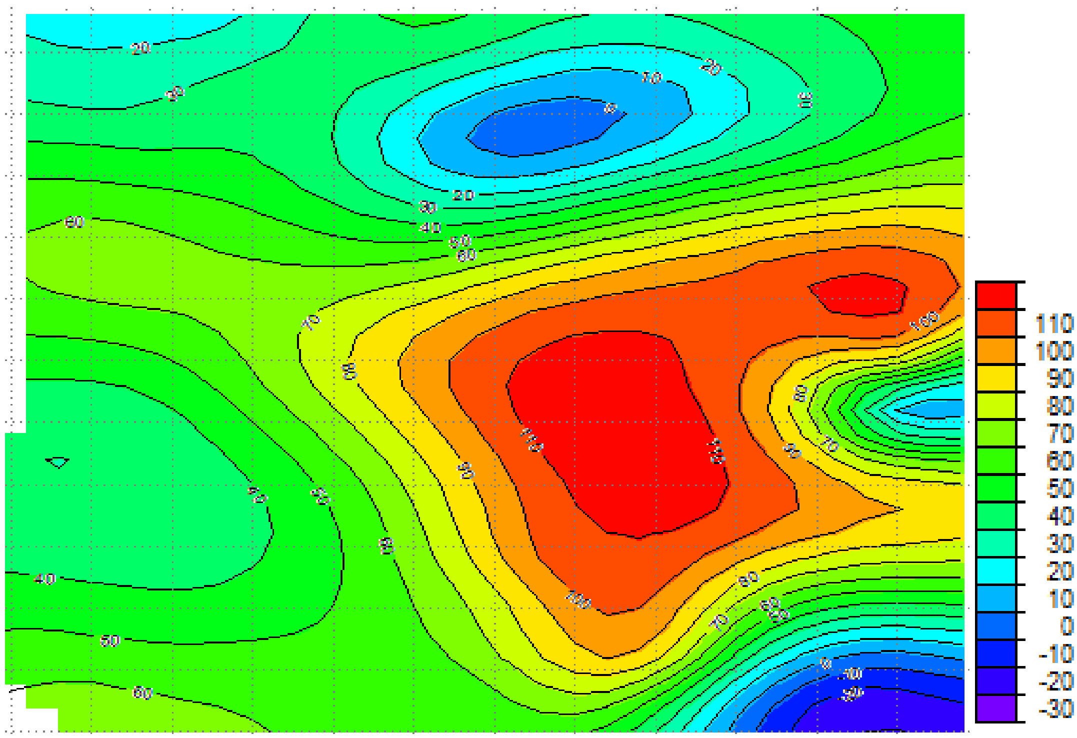

Fig. 8. Upward continuation map at 20 km

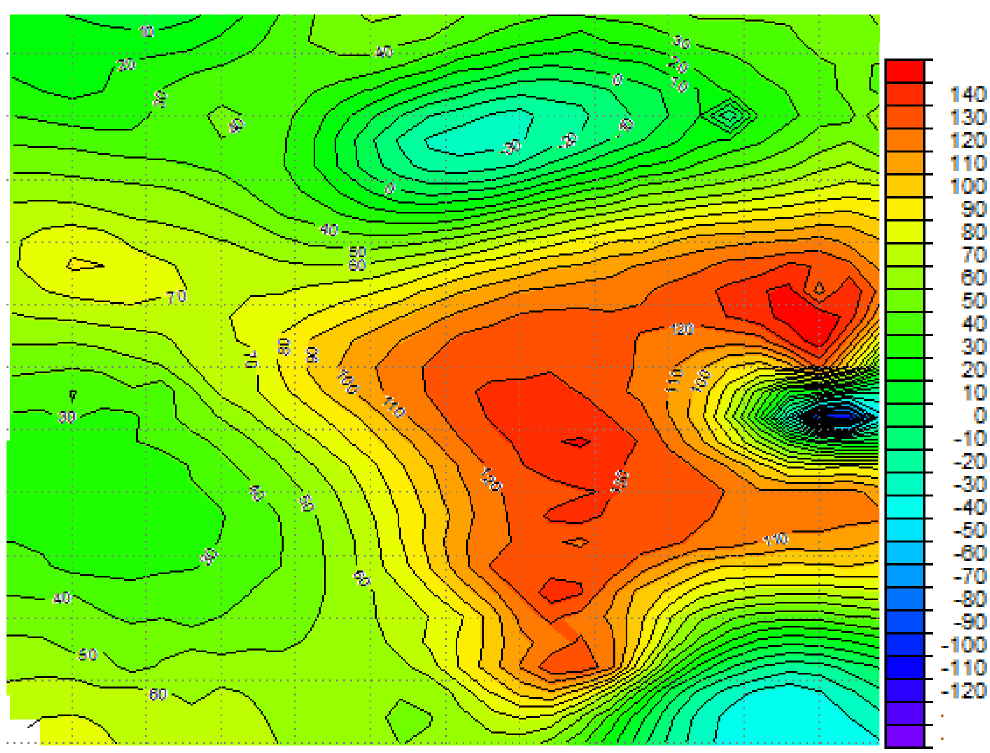

Fig. 9. Low pass filtered map at cut off of 2 km

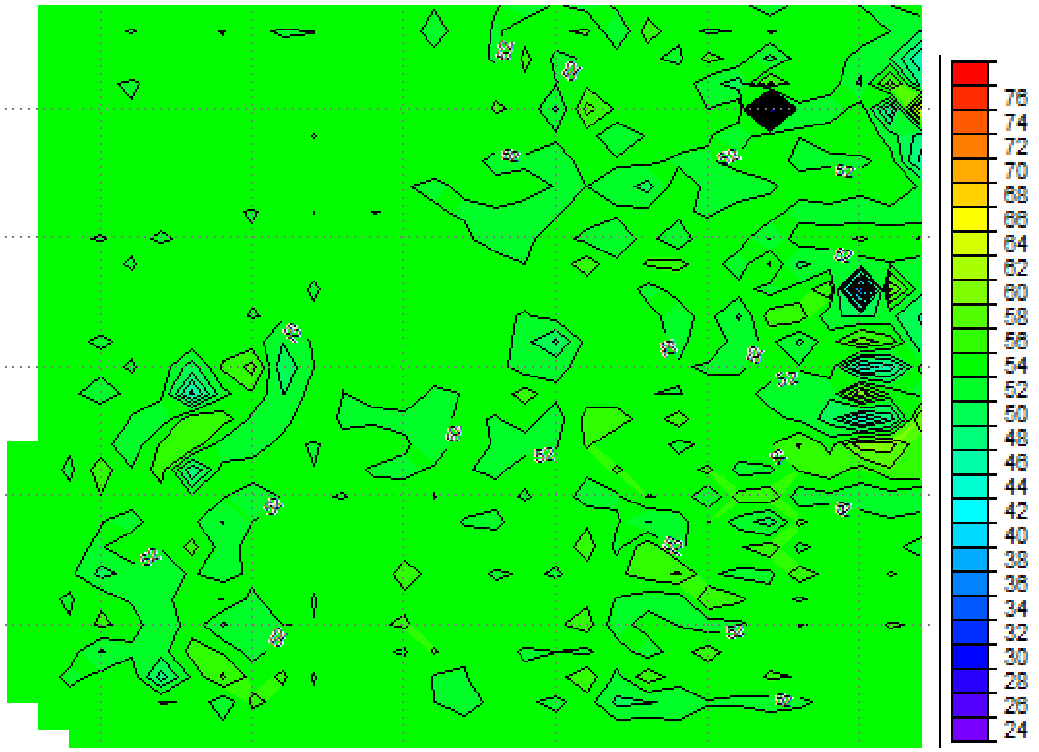

Fig. 10. Band pass filtered map at 2-10 km

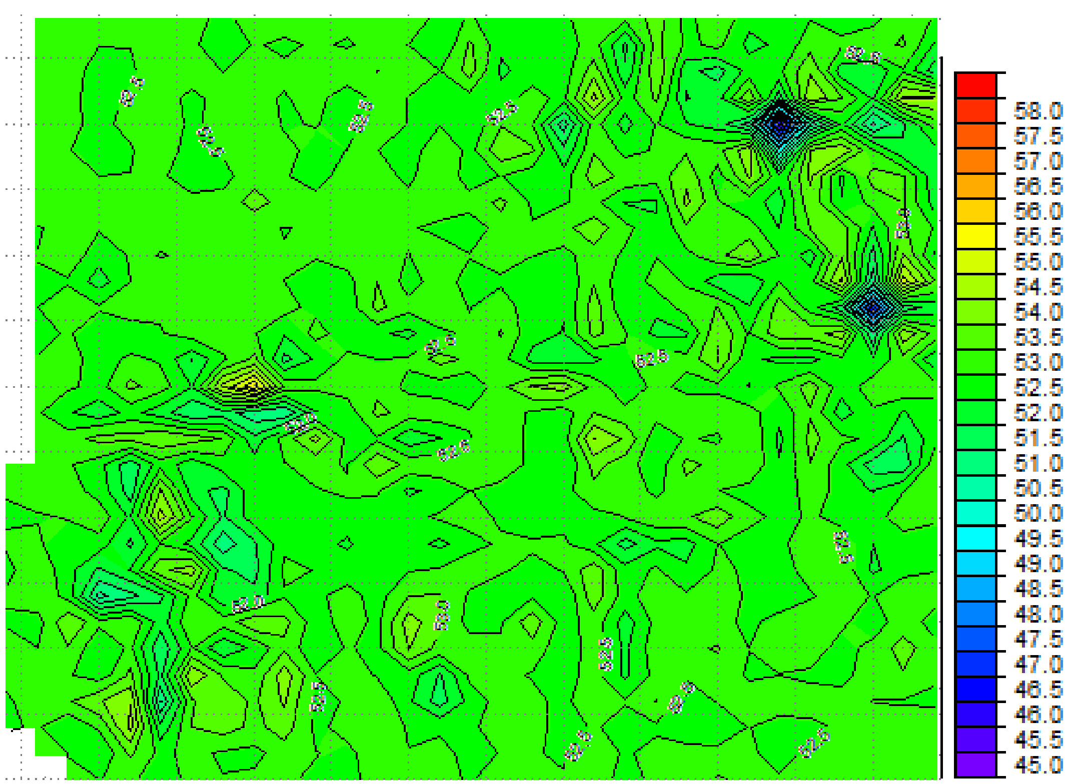

Fig. 11. High pass filtered map at cut off of 2 km

These upward continuation maps show anomalies with magnetic intensity values ranging from -30 nT to 110 nT. It can therefore be deduced that similar causative sources exist at different datum/levels. Similarly, the low pass filtered map (Fig 9) accentuates clearly the deep seated regional with little or no trace of the dyke like structures which are possible oil and gas play. The deep seated or regional anomalies found on the low filtered map vary from -120 nT to 140 nT. Short wavelength contours representing shallow magnetic sources can obviously be seen on the band pass and high pass filtered maps (Fig 10 and 11) but with the high pass filtered map depicting longer wavelength anomalies. Anomalies having intensity values between 24 nT-70 nT and 45 nT-58 nT, respectively, for the band pass and high pass filtered maps. Conspicuous on the filtered maps are N-S, E-W, NE-SW, WSW-ENE and NW-SE tectonic structural trends.

4. CONCLUSION

In this research work, qualitative method of data analysis and interpretation was adopted in order to delineate subsurface structures as well as their edges. The results revealed more prominent lineaments expressed as N-S, E-W, NE-SW, WSW-ENE, NNE and SSW and NW-SE tectonic trends. These tectonic trends emanating from deep and shallow sources show that the study area is characterized by faults and fractures. The NE-SW, NNE-SSW and NW-SE trends represents the dominant tectonic trends and are also believed to have occurred during the separation of Africa and South America. Finally, the NE-SW and NW-SE tectonic trends conform with the oceanic and charcot fracture zone existing within the Niger Delta region, Nigeria.

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