Geological Interpretations Inferred From A High Resolution Aeromagnetic (Hram) Data Overs Parts Of Mmaku And Environs, South Eastern, Nigeria.

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ABSTRACT

Structural interpretations over parts of Mmaku, Ngwo, Ezeagu, Awka, Nanak Ekwulobia and Oji River settlement were inferred to delineate the basement morphology, determine the structural features and to the know the effect of those structures on the hydrocarbon potential of the area using a high resolution aeromagnetic data acquired from the Nigeria Geological survey agency in half degree sheet. Topographic map was generated using Sulphur 10 and Regional-residual separation applied on the Total magnetic intensity (TMI) data using the WingLink visualization and geophysical software. The results of the qualitative interpretation generated the Regional, residual, topographic and some gradient maps that depicted structural lineaments trending in the NE-SW, NW-SE, NNE-SSW and N-S directions but with the NE-SW trends being dominant. They NE-SW, NW-SE, NNE-SSW and the E-W, N-S trends are believed to be Pan African and Pre Pan African trends respectively. The NE-SW and the NW-SE tectonic trends also reveal a landward extension of the oceanic fracture zones that transverse through the study area. Finally, structurally low areas were delineated and these areas probably indicate zones of promising oil and gas fields.

Keywords: Pan African trends; Pre Pan African trends; geomagnetic correction model; economic potential.

INTRODUCTION

Aeromagnetic data has been one of the handy geophysical investigation tools used in delineating subsurface structures especially in mapping magnetic basement in sedimentary rocks. Although the method was used in mapping igneous and metamorphic rocks and structures related to them because these rocks have high magnetization compared to other rocks (Nettleton, 1971; Reynold *et.al.*, 1990), improved high resolution technology flown closer to the ground and with narrower spacing, has made aeromagnetic surveys presently designed to view subtle magnetization contrast than has been targeted (Graunch and Millegan, 1998). Large scale aeromagnetic surveys have been used to locate faults, shears zones and fractures (Anudu et al.,2012) and lineaments which could be possible host to varying earth resources such as minerals, oil and gas etc.

According to the department of petroleum resources (DPR), some oil chiefs through the joint venture operators, however, maintained that investments in the onshore area is not on their priority list as exploring in the hinterland yielded to non commercial discoveries. Nevertheless, the recent exploration for oil by Global energy company (GEC) through a joint venture with Afren Global Energy Resources (AGER) in Anambra basin coupled with a lot of unconfirmed reports on the availability of natural gas in some parts of Udi deemed it necessary to venture into this work.

LOCATION AND GEOLOGY OF THE STUDY AREA

The study area with Latitude 6^0 00’-6^0 30’N and Longitude $7^0$00’ 7^0 30’E and sheet number 301 is located in Enugu state and parts of Anambra state, south-east Nigeria. Fig.1 shows the study area with inserts maps of Enugu and Nigeria.

Geologically, study area lies between the Lower Benue Trough (Fig 2) and 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 Murat, 1972 reconstruction model, 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.

Four Cretaceous depositional cycles where recognized by Murat, 1972 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

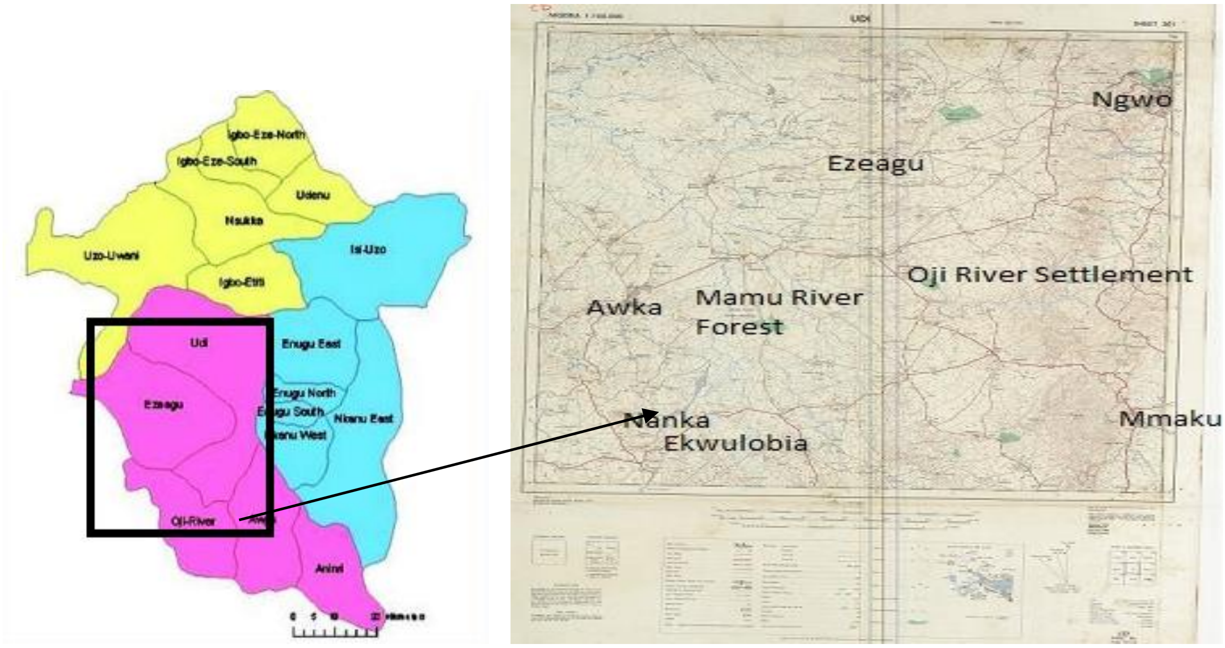

Fig 1: Location and Topographic Map of the study area (Courtesy: Survey Office, Enugu)

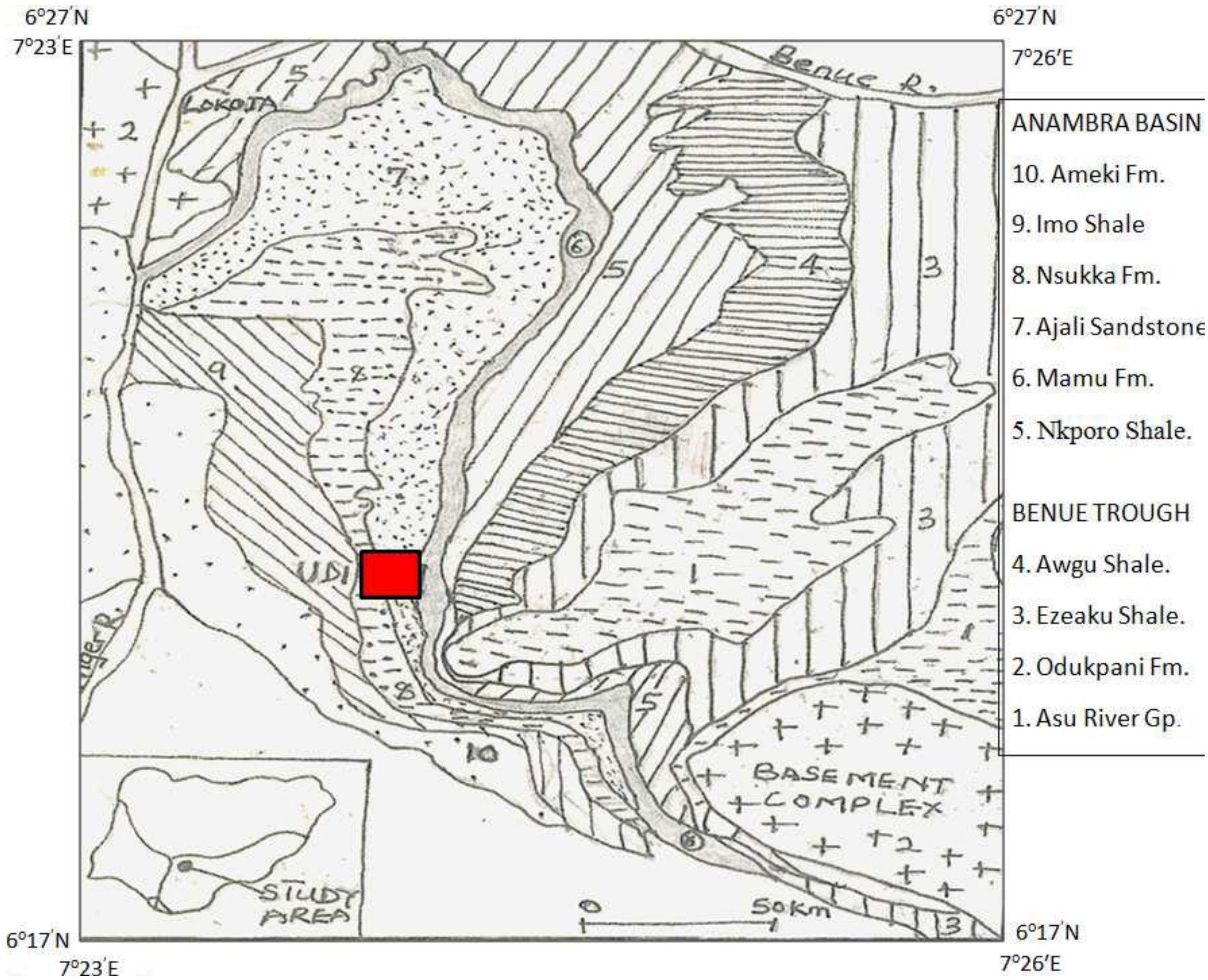

Fig 2: Regional Geology of the Lower Benue Trough showing the study area (adapted from Reyment, 1965 and Modified by Nwozor *et al*, 2012).

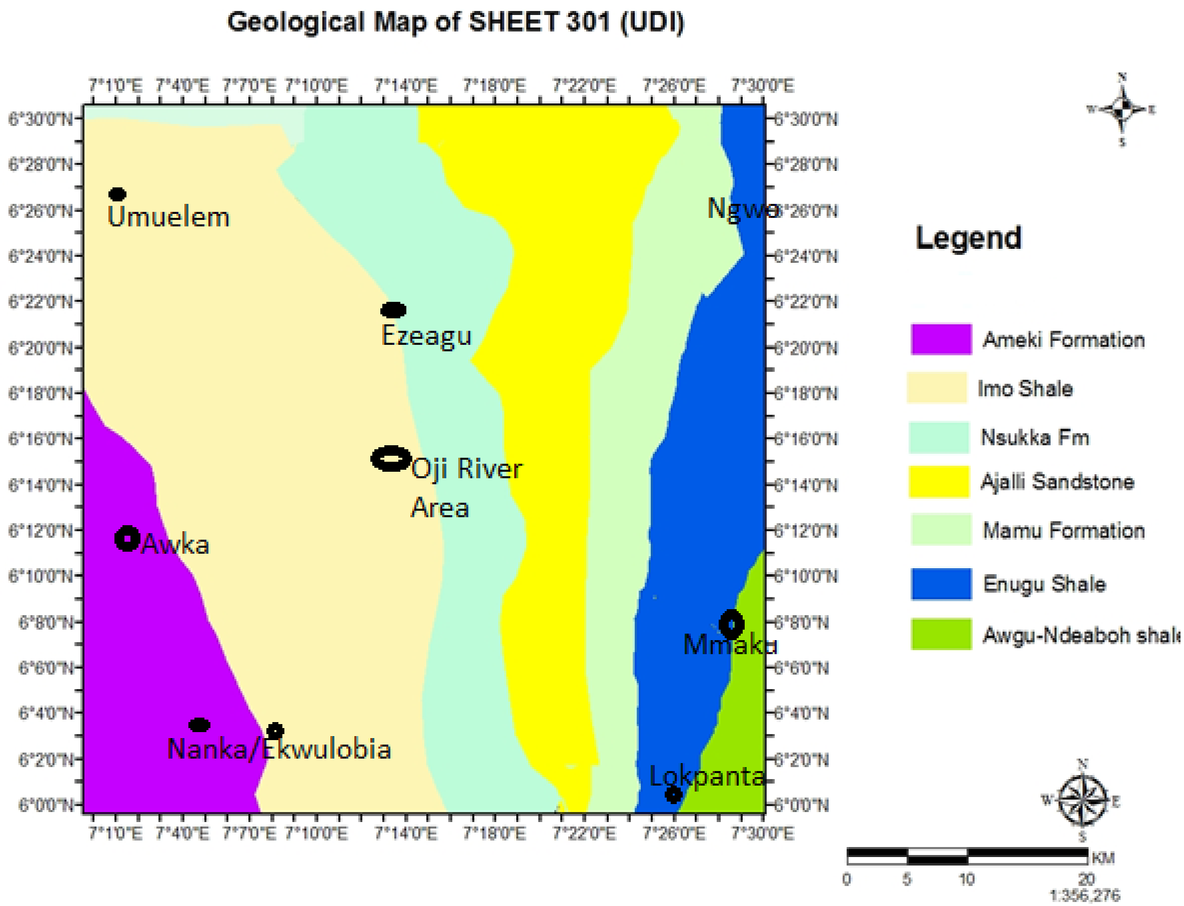

Fig 3: A Geologic Map of the Study Area (Courtsey:Nigeria geological agency)

MATERIALS AND METHOD

The aeromagnetic map (Fig 4) published on a scale of 1:100000 were acquired in a flight line direction, NE-SW by Fugro Air Servicers in 2009 on behalf of the Nigeria geological agency (NGSA). The high resolution data was acquired at a ground clearance and flight line spacing of about 100 m and 500 m respectively while the tie line spacing occur at 20 km. As part of the processing and pre-processing stages, diurnal variations were removed and the corrections for international geomagnetic reference field (IGRF) model, for the year 2010, applied by the NGSA using Oasis Montaj software. This was transmitted as IGFR corrected total magnetic intensity (TMI) data and was saved in Geosoft dataset as Geosoft grid file format. For onward processing and interpretation, the data in Geosoft file format was opened and converted to a format usable by the sulfer 10 and WingLink visualization software's using the Arc GIS software. The Sulfer 10 was, thereafter used to generate the topographic map while the WingLink was used to generate the Regional, residual and some gradient maps.

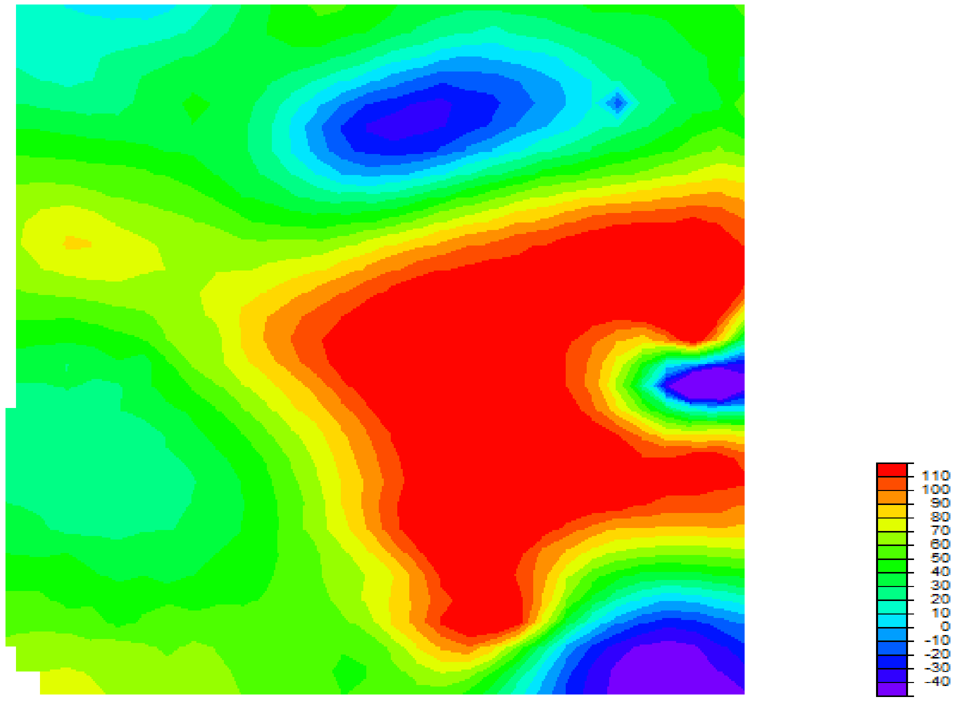

Fig. 4: A Raster Map of the Aeromagnetic Data (Udi Sheet 301)

RESULTS

To illuminate on the architectural frame work of the study area, the aeromagnetic raster map was transformed into its contoured TMI map (Fig 5) which reveals elliptical and irregular magnetic bodies with magnetic intensities ranging from -40 nT to 110 nT. The map is marked by high, intermediate and low magnetic signatures trending in the NE-SW and NW-SE. The high and low magnetic signatures could be attributed to either difference in lithology, variation in depth, susceptibility contrast or the degree of geological strike. Further processing on the contoured TMI map generated the residual (Fig 6), Regional (Fig 7) First vertical derivative (Fig 8), second vertical derivative (Fig 9), first horizontal derivative (Fig 10), upward continuation (Fig11), low pass (Fig 12), band pass(Fig 13) and high pass (Fig 14) filtered and the topographic maps (Fig 15).

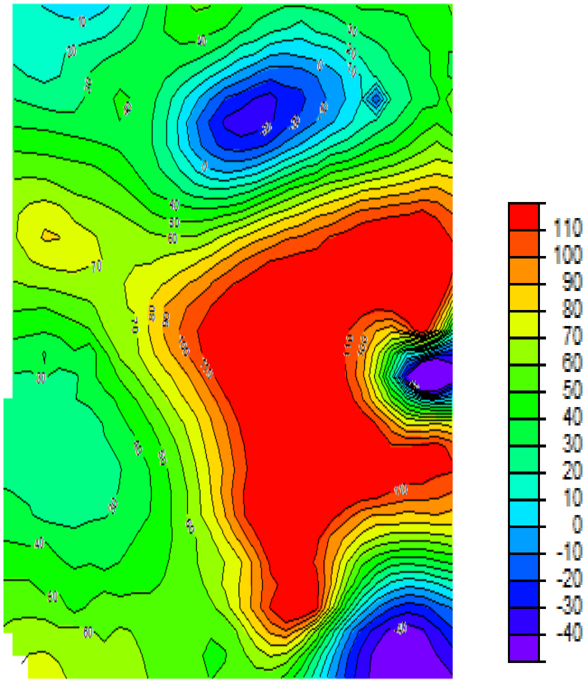

Fig. 5: Total Magnetic Intensity (TMI) Contour Map (nT)

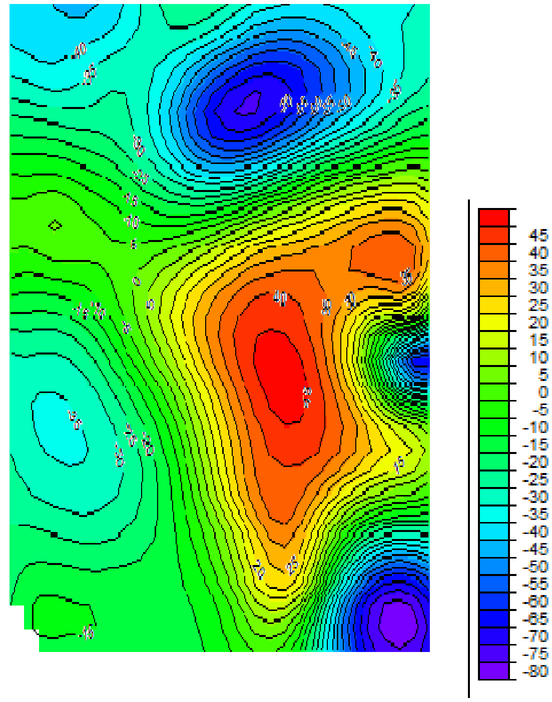

Fig 6: Residual Anomaly Map (nT)

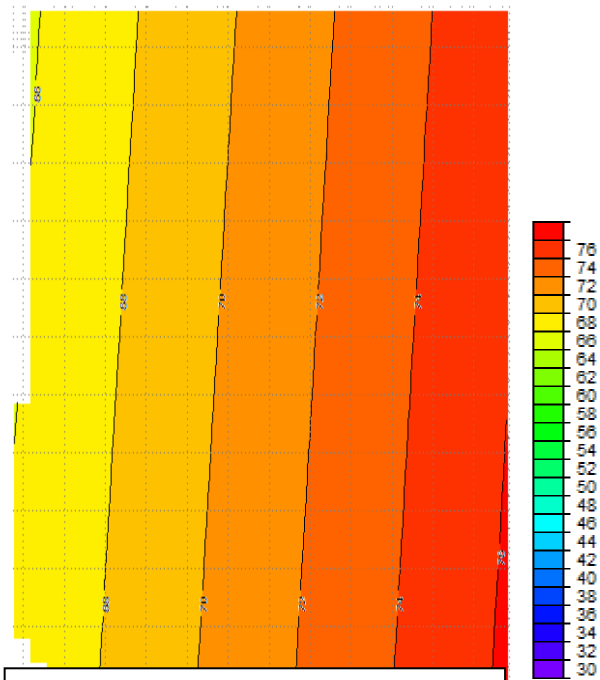

Fig 7: The Regional Map

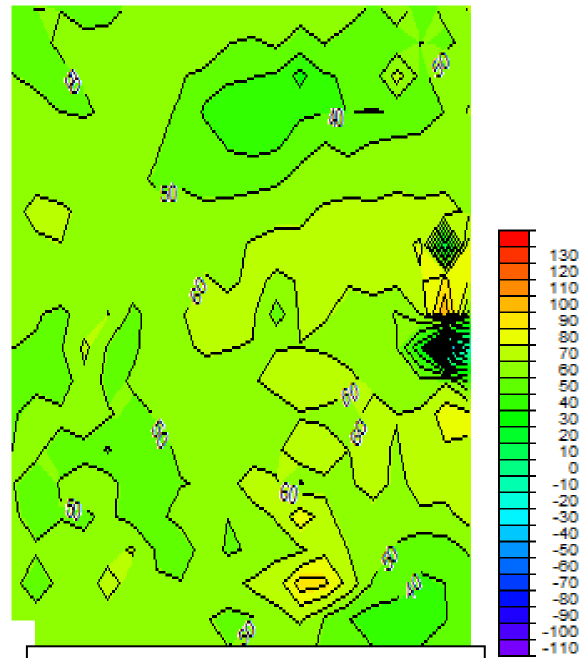

Fig 8: First vertical derivative

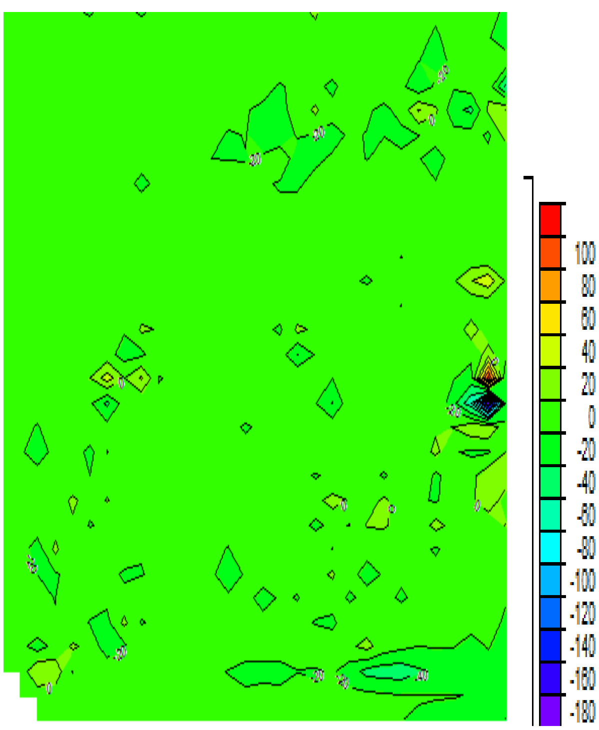

Fig 9: Second Vertical Derivative

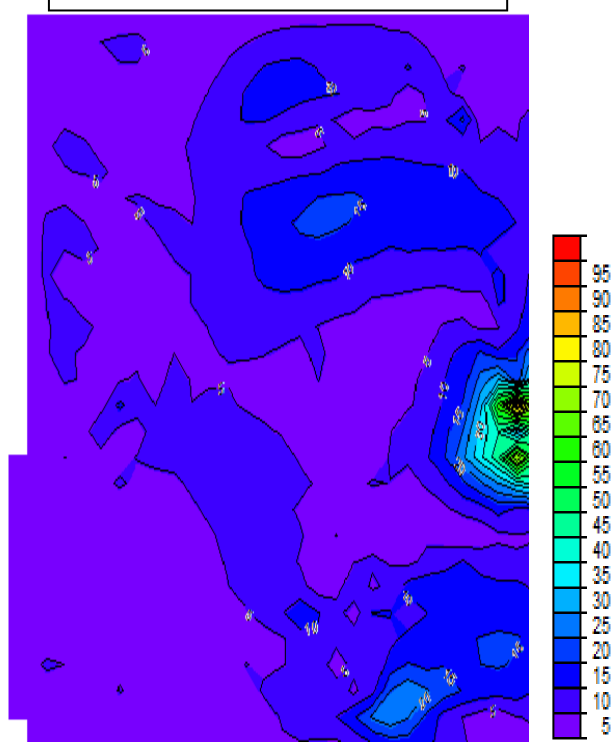

Fig 10: Horizontal Derivative Map

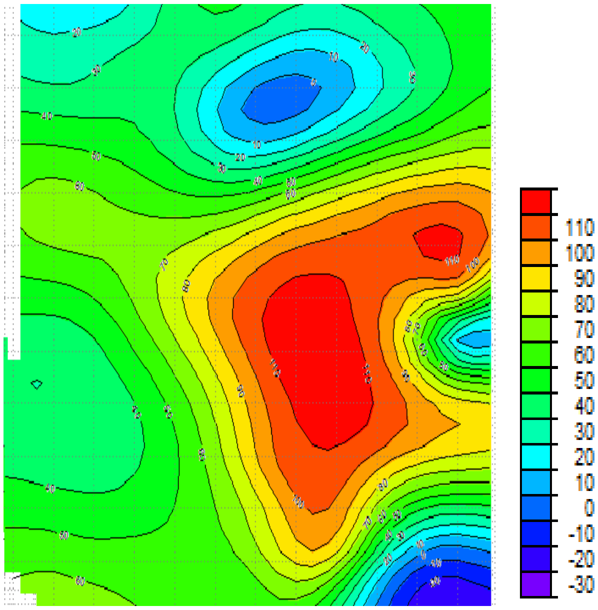

Fig 11: Upward Continuation Map

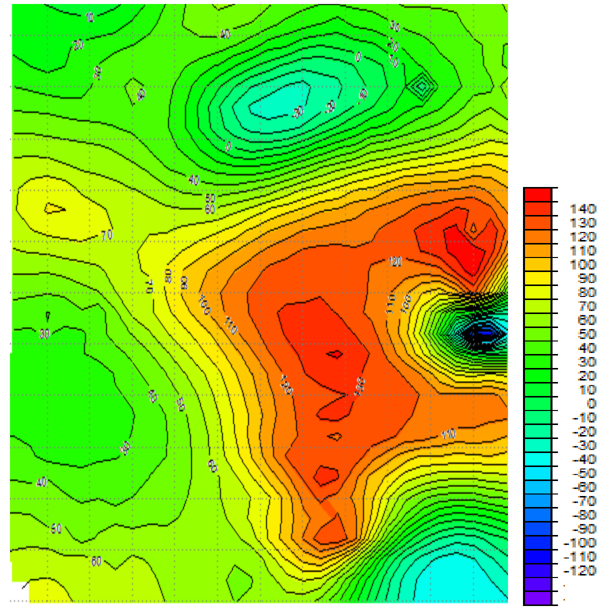

Fig 12: Low Pass Filtered Map

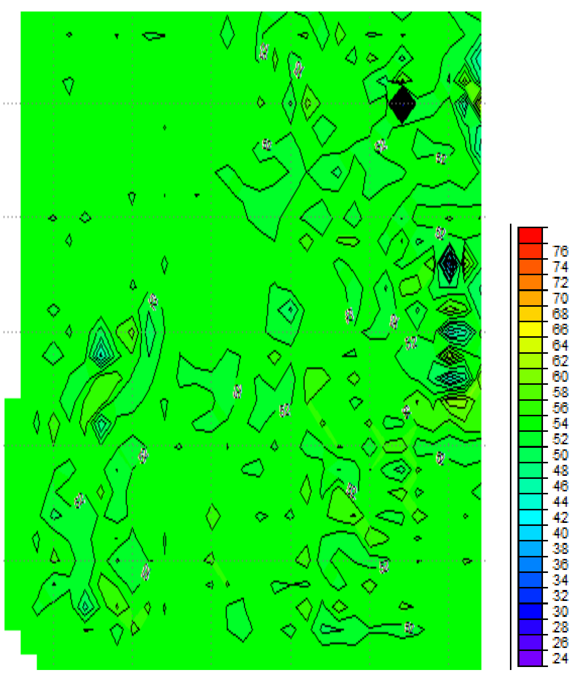

Fig 13: Band Pass Filtered Map

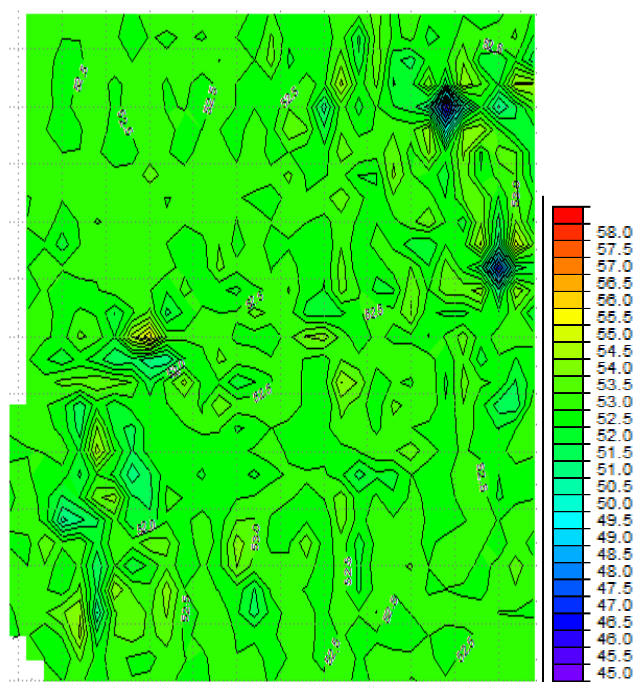

Fig 14: High Pass Filtered Map

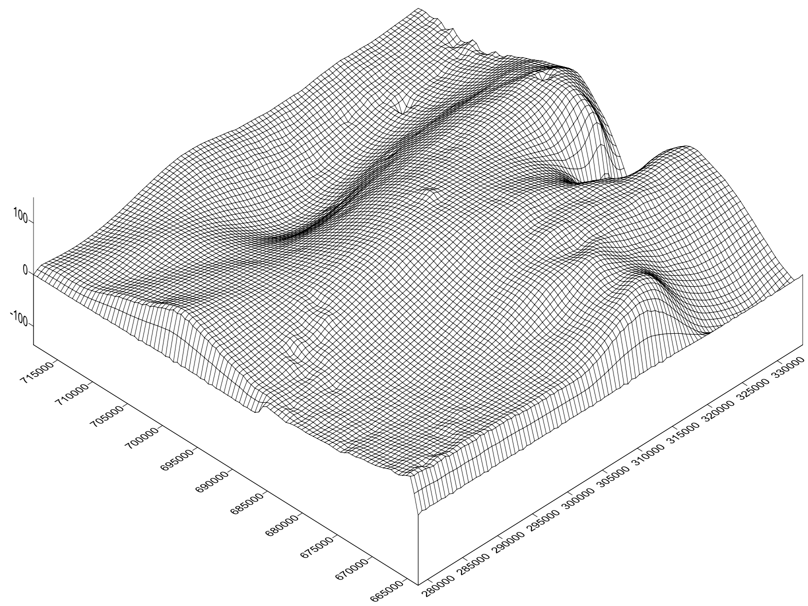

Fig 15: 3D TOPOGRAPHIC MAP OF THE STUDY AREA

DISCUSSION OF FINDINGS

Discernible on the raster map and its corresponding legend are total magnetic intensity (TMI) values that are small compared to the TMI values obtained by the agency between 1974 and 1980. This could be as a result of survey specifications which encompass the ground or terrain clearance, tie or flight line spacing and the geomagnetic correction model applied on the data. The raster map is made up of aggregate of colours which ranges from red, orange, yellow, light blue, blue, green and the magenta that is inscribed inside the blue colour. The inscribed magenta that have a lower magnetic intensity from its surrounding probably shows the superposition of magnetic units while the light blue and blue colours, according to Gunn *et.al.*, (1997) highlight zones made up of irregular weathering of magnetic units and assemblage of non magnetic units respectively. These colour variations believed to be a function of rock types reveal changes in the magnetic field intensity throughout the area of study. The colour map helps an analyst to partition the area into its various magnetic zones and also permits easy identification of causative magnetic bodies so that, perhaps at a glance, one identifies the magnetic highs and lows. The magnetic intensity however decreases with the red, orange, yellow, green, light blue, blue and magenta. Therefore, this map shows that the area is characterized into three zones comprising of high, intermediate and low magnetic amplitude anomalies. 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. Gunn et. al., (1997) speculated that the orange and yellow colours can be regarded as magnetic aureoles. The northern, south-western, south-eastern and eastern with light blue, blue and magenta colours exhibit low magnetic intensity which probably is indicative of structures housing sediments while the green colour that is spatially distributed however represents intermediate magnetic intensity and this indicate probable granitic rocks.

Visual studies of the contoured TMI map shows relatively closed, closed, smooth, parallel, elliptical, broadened, irregular and localized magnetic contours. The TMI map however 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 elucidate on the economic potential of the study area and to highlight some subtle or concealed features as well as to highlight hidden tectonics and reduce ambiguity that accompany magnetic data interpretations the need for Regional-residual separation and generation of topographic and some gradient maps from the contoured TMI map became paramount.

The residual map reveals series of relatively closed magnetic signatures 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 that is to be analyzed quantitatively (Ofoha, 2015) 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 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 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. It could therefore be inferred that the low and high magnetic anomalies may be associated with the presence of shale gas found within the reservoir structured sandstone 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.

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. The second vertical derivative map in contrast depicts irregular shallow magnetic bodies with shorter and weaker wavelengths trending in the E-W, and N-S directions while the horizontal derivative map points out zones with magnetic low which trends in the E-W direction.

Unlike the TMI and residual maps, the upward continuation map highlights smoothened magnetic signatures and it accentuates the regional effect relative to the short wavelengths. Similarly, the low pass filtered map accentuates clearly the deep seated regional with little or no trace of the dyke like structures which are possible oil and gas play. Short wavelength contours representing shallow magnetic sources can obviously be seen on the band pass and high pass filtered maps. 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 3D topographic map replicates the architectural framework of the basement. It shows structural highs and lows. The structural highs corresponding to the location of the magnetic highs are noticeable at the central portion while the structural lows coinciding with the location of the magnetic lows are conspicuous at the northern, eastern and south western portion of the map. The structural lows having a dyke like body thus represents potential oil and gas prospect.

CONCLUSION

The study area is characterized with relatively low magnetic intrusions that will not be detrimental to hydrocarbon exploration and also with basement highs and lows flanked possibly by dykes, faults, lineaments and fracture zones that aid the migration and entrapment of hydrocarbon. These structural features – low magnetic intrusions, structural highs and lows, faults, dykes, lineaments and fracture zones - hugely affect the basement morphology postively such that they enhance the migration, accumulution, maturation and exploration of hydrocarbon.

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