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Spectral Analysis of Aeromagnetic Anomalies from Parts of Mmaku and its Adjoining Areas in Southeastern, Nigeria

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Abstract- To estimate the depth to various magnetic sources within the study area, an aeromagnetic map with sheet number 301 published on a scale of 1:100000 was processed, analyzed and interpreted using spectral depth analytical technique with the aid of Arc GIS, Ms Excel and Origin Pro Software's. In this study, two layered source model, D1 and D2 were observed and proposed and also prospective areas were delineated using Surfer 10. The topographic map generated using Surfer 10 shows the undulating nature of the basement surface. Depths to the deeper magnetic sources, D1 vary from 3.472 km to 6.972 km but with an average depth value of 5.010 km while the depth to shallower magnetic sources, D2 vary from 1.177 km to 1.834 km but with an average depth of 1.047 km. D1 and D2 represents magnetic basement bodies and intrusions respectively. The estimated average depth to basement of 5.010 km suggest relative sedimentary thickness for hydrocarbon accumulation and the non uniform basement suggest lineaments resulting to possible conduits and traps for economic fluids. Hence, the possibility of the study area to add to the economic reserve of the country cannot be ruled out when seismic sections are run over the area.

Index Terms- Basement map, Economic deposition, Fast Fourier Transform (FFT), Geosoft file format, Spectral window.

I. Introduction

A classic use of the aeromagnetic method has been the estimation of the thickness to sediments (or depth to basement) within sedimentary basins and volcanic areas. The Benue Trough has been extensively studied by a lot of researchers with various aims including determination and reconstruction of the depositional, tectonic and evolutionary history, mapping of the geological and stratigraphic setting as well as the evaluation of the mineral potential of the basin. As such many geological tools and geophysical methods including, Seismic, Landsat, gravity, aeromagnetic, geochemistry etc as well as geological mapping have been employed in the various studies. On the origin, the Benue trough has been regarded as an intra-continental rift basin that resulted as a failed arm of the triple-junction during the separation of the South American plate from African (Burke *et. al.*, 1972, Olade, 1975). This aulacogen model explanation presumes the Benue Basin as being restricted to Nigeria only.

The main factors responsible for sedimentation within the study area during the Cretaceous are the progressive sea level rise from Albian Maastrichtian leading to worldwide transgression, regression and local tectonics (Petters, 1978). Spectral depth analytical technique which describes the frequency content of a signal based on a finite set of data (Igwesi and Umego, 2013) has proven to be apt for the determination of the depth to basement. Its advantage is that the spectral domain expressions of the anomalies are generally simple as compared to the expressions of the anomalies in the space domain (Igwesi and Umego, 2013). The method averages over an area so that, if noise is a factor, the results will give a more accurate result than other methods that are commonly used (Ofoha, 2015). Finally, features with given direction in space domain are transformed into a feature with only one direction in the spectral domain (Igwesi and Umego, 2013).

With the vision of ascertaining the basement morphology and hydrocarbon bearing potential of the study which could probably add to the economy of the nation thus reducing the dependence on the ever depleting Niger Delta basin, the present study was undertaken.

1.1 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 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

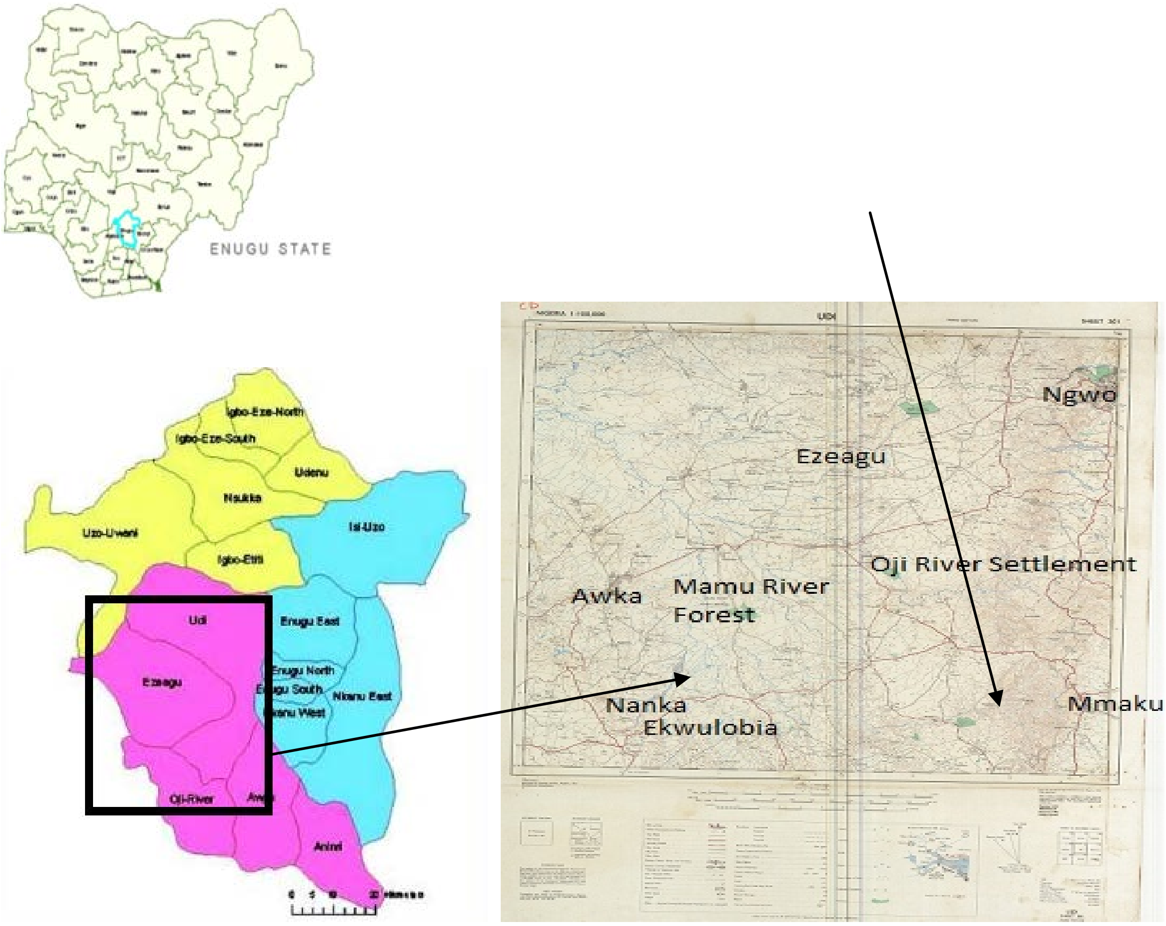

Fig 1: Location and Topographic Map of the study area (Courtesy: NGSA Office, Enugu)

II. MATERIALS AND METHODS

The aeromagnetic map (Fig 2) 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 Origin Pro 8 software's using the Arc GIS software. The Sulfer 10 was, thereafter used to generate the topographic map as D_1 was imported into Surfer 10 worksheet environment while the Origin Pro was used in determining the sedimentary thickness by partitioning or dividing the residual map into sixteen (16) equal spectral windows or grids using the filtering tool of the MS Excel sheet. This thereby makes easy the depth parameter to be determined by means of Fast Fourier Transform (FFT) which was performed on each window. Consequently, the radial average energy (power) spectrum was plotted in MS Excel using Excel chart wizard as Log of Energy (FFT magnitude) versus radial frequency in Rad/km. A straight line is then visually fit to the energy spectrum, both in the higher and lower frequency of the figure. The negative of slope of this line is equal to twice the depth to the center of mass of the bodies producing the magnetic anomaly. After the depth has been calculated over one window a new calculation is made over a new window. This continues over the spectral grid until all windows have had their radial spectra calculated and the depths picked. By calculating the depth value for each window or grid in a stepwise fashion, the average value of the whole cells thus gives the thickness to sediment. The

Depth values due to low frequency magnetic sources are then imported into surfer 10 for depth to magnetic basement map to be generated (Fig 3).

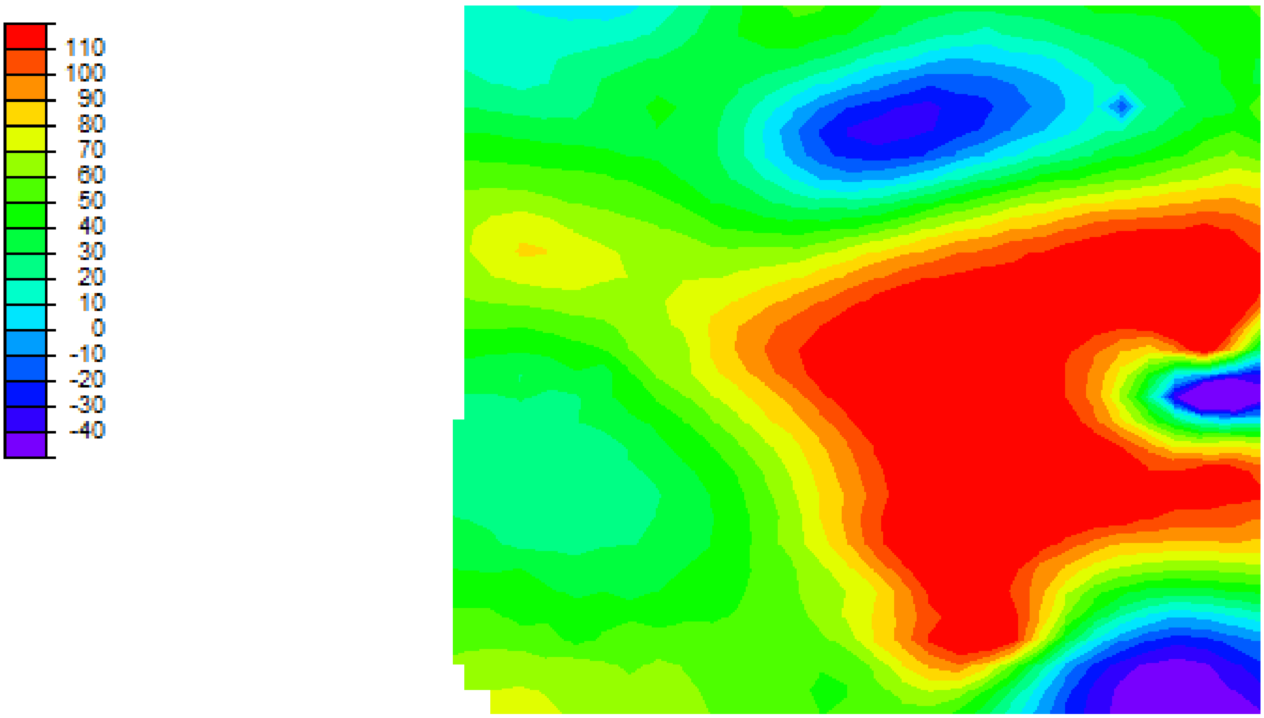

Fig. 2: Raster Map of the Aeromagnetic Data (Udi Sheet 301)

III. RESULTS AND DISCUSSION

Table 1 summarizes the depth to various magnetic bodies. The table shows the maximum and minimum slopes, M_1 and M_2, and two magnetic source models,

TABLE 1: Established Depth to Basement (Sediment thickness) through the study area using spectral analysis.

CELL PLOTS	SLOPE		DEPTH (m)	
	M_1	M_2	D_1	D_2
Cell 1	-7187	-3385	-3594.	-1692
Cell 2	-6944		-3472	
Cell 3	-10000.0	-3461	-5000	-1731
Cell 4	-12500.0	-2857	-6250	-1429
Cell 5	-9259	-2500.0	-4630	-1250

Cell 6	-10344	-3125.0	-5173	-1563
Cell 7	-11000		-5500	
Cell 8	-10344	-3125.0	-5172	-1563
Cell 9	-11857		-5929	
Cell 10	-7105	-3125.0	-3553	-1563
Cell 11	-12500	-3162	-6250	-1581
Cell 12	-13944	-3667	-6972	-1834
Cell 13	-8333	-2353	-4167	-1177
Cell 14	-10000		-5000	
Cell 15	-9000	-2750	-4500	-1375
Cell 16	-10000		-5000	

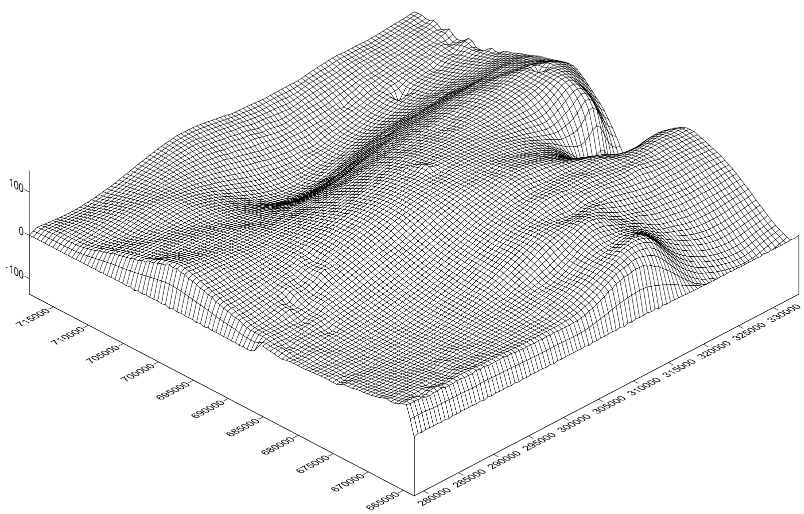

FIG 3: 3D depth to basement map

D_1 and D_2 was observed and then proposed across the study area. D_1 was then used to generate the 3D depth to basement map depicting the undulating nature of the magnetic basement. The slope is a negative slope; hence the corresponding depth values are all negative values. D_1 and D_2 consequently represent the deep and shallow seated magnetic sources respectively. The deeper magnetic sources regarded as the low frequency component is represented by the steep gradient of the spectral energy curve while the shallow magnetic bodies seen as the high frequency component is represented by the less steep gradient of the energy curve. The deeper magnetic sources are attributable to magnetic bodies on the basement surface and the shallow sources probably regarded as magnetic intrusions. These deeper sources lie at depth that varies between 3.472 km and 6.972 km but with an average or true depth value of 5.010 km. Conversely, the shallower magnetic bodies lie between 1.177 km and 1.834 km but with an average depth of 1.047 km. Maximum sedimentary thickness of 6.972 km found in block 12 is located in the eastern portion of the map whereas the minimum sediment of 1.177 km found in block 13 is located in the north western portion of study area. The depth to shallow sources for window two, seven, nine and fourteen were not computed nevertheless, due to the absolute noise effect within the region as evidenced by the non linearity of the energy curve. The established true sedimentary thickness is in disparity with the results obtained by most previous researchers that had worked within the area of study. Igwesi and Umego (2013), obtained basement depth for deeper magnetic sources to vary between 1.16 km and 6.13 km but with an average depth of 3.03 km while the depth for the shallower source bodies was evaluated to vary from 0.06 km to 0.37 km but with average of 0.22 km. Igwesi and Umego (2013) also reported that Owuemesi (1997) and Madufor (1984), opined the sedimentary thickness to range from 0.9 km to 5.6 km ,1.95 km to 5.09 km respectively while Kogbe (1989) determined the average sedimentary thickness to be 3.03 km. Similarly, Ofoegbo and Onuoha (1991) showed that the basement depth vary from 1.2 km to 2.5 km These differences in true sedimentary thickness value is owed to rapid progressive sea level rise leading to high transgressive and less regressive patterns with tectonic activities as at when the data was obtained within the study area. The basement map nevertheless presents successive patterns of structural (basement) highs and lows which are, perhaps, attractive site for economic deposition.

IV. CONCLUSION

The results of the quantitative analysis shows that the study area holds a promise for hydrocarbon accumulation and exploration provided other conditions are met. The 3D basement topographic map presents irregular nature of the basement which are possibly associated with faults and fractures that aids the migration and entrapment of hydrocarbon and other mineralized deposits.

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