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Interpretation of Airborne Magnetic Data over Afikpo and Environs

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Abstract: *This research work presents an airborne magnetic based structural interpretation of Afikpo area. The objectives of this study are to produce a digitized airborne magnetic map of the study area, determine magnetic basement depth, delineate basement topography and to determine trends of deformation and this was done using several software which includes Oasis Montaj version 6.4HJ, sulfer10, and Mat lab 7.2 version. Thickness of the sediment present was determined, which can be used to access whether the sediment is enough to warrant accumulation of hydrocarbon. Providedgeological features of the Afikpo Area and inferred their relation with basin architecture, morphology and dynamics, thereby presenting a better understanding of the geology.The results of the spectral analysis of airborne magnetic data over the study area suggest the existence of two main source depths. The depth to basement or deeper source* D_2 *varies between 2.863km and 4.672km. The interpretation of mineralization potential of the study area was also gotten.*

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I. Introduction

The interpretation of airborne magnetic maps in the past decade has moved from the interpretation of basement structures to detailed examination of structures and lithologic variations in the sedimentary section. Magnetic basement is an assemblage of rocks that underlies sedimentary basins and may also outcrop in places. If the magnetic units in the basement occur at the basement surface, then depth determinations for these will map the basin floor morphology and its structure). In many sedimentary basins, magnetic anomalies arise from secondary mineralization along fault planes, which are often revealed on airborne magnetic maps as surface linear features. Most mineral deposits are related to some type of deformation of the lithosphere, and most theories of ore formation and concentration embody tectonic or deformational concepts. Some lineament patterns have been defined to be the most favorable structural conditions in control of various mineral deposits. They include the traces of major regional lineaments, the intersection of major lineaments or both major (regional) and local lineaments, lineaments of tensional nature, local highest concentration

Our world is magnetic thus because of this natural fact, various applications of magnetics have become explorable to earth scientists. Understanding the magnetic effects associated with Earth materials require the knowledge of the principles of magnetism (Dobrin and Savit, 1988). These basic principles are fundamental to the applications of magnetics for oil gas and mineral explorations. The inherent magnetism of rocks called magnetic susceptibility is caused by changes in the subsurface geologic structures. Magnetic susceptibility of rocks is the fundamental parameter in the applications of magnetics for oil and gas explorations. In every case, the susceptibility of rocks depends on the amount of magnetite (Fe_30_4) contained in the rock unit. The magnetic susceptibility (k) is the significant variable in magnetic playing the same role as density in gravity interpretation, although this property is represented as a range even for a particular rock and a wide overlap between rock types. The magnetic method is useful whenever the object of investigation has a contrast in the magnetic susceptibility or remanence that can be detected by the magnetometer and is measured in nanotesla (nT) or gamma (γ) units.Thus, the magnetic prospecting, the oldest of the geophysical exploration method is used for:Location and definition of Sedimentary Basin extent.

1.1 GEOLOGY OF THE STUDY AREA

The geology of Afikpo basin consists of two major lithostratigraphic units of limestone ridges and low-lying shale, each of which forms significant component of the Ikun beach and Aka Eze Formation. The major folds in the area have northeast southwest trend, south easterly dip and comprise both anticlines and synclines. In the study area limestone and shale are very important constituents of sedimentary processes and are therefore very crucial in the understanding of stratification history of their environments of deposition. Also the mineral and organic compositions, texture, and structure of the sedimentary sequences usually suggest their provenance characteristics. The stratigraphy of the study area consists of Ikun beach, Aka Eze, Okpu, Akanu, Ekeje, Uwana

.The Ikun beach, consisting of shale, sandstone, and limestone, is the older lithostratigraphic unit in the area. The study area lies between longitudes 7°51'E and 8°00'E and latitudes 5°53'N and 6°00'N within the Benue Trough. The Benue Trough of Nigeria formed as a result of series of tectonism and repetitive sedimentation in the Cretaceous time when South America separated from AfricaObaje, 2009. Afikpo is located in the southern Benue Trough, between the Abakiliki Anticlinorium running northeast and the Cameroon Line in the southeast.

II. Basic Concept

2.1 PRINCIPLES OF AIRBORNE MAGNETIC SURVEY

An aeromagnetic survey method is a geophysical method performed using a magnetometer towed behind an aircraft. It is the oldest potential field method used for hydrocarbon and mineral exploration. In comparison with other geophysical methods, the aeromagnetic method plays a distinguished role in its rapid rate of coverage and low cost per unit area exploredAlagbe, 2015. The principle is same as a magnetic survey performed with a hand-held magnetometer, but allows much larger unexposed areas of the earth's surface to be covered quickly for regional reconnaissance. The aircraft typically flies in a grid-like pattern,the resolution of the data isdetermined by height, tie line and flight line spacing.

The magnetometer attached to the aircraft records tiny variations in the intensity of the ambient magnetic field due to the temporal effects of the constantly varying solar wind and spatial variations in the earth's magnetic field, the latter being due both to the regional magnetic field, and the local effect of magnetic minerals in the earth's crust. By subtracting the solar and regional effects, the resulting airborne magnetic map shows the spatial distribution and relative abundance of magnetic minerals in the upper levels of the crust. Different rock types differ in their magnetic minerals composition; hence, the magnetic map allows a visualization of the geological structure of the upper crust in the subsurface, explicitly the spatial geometry of body of rocks and the presence of faults and folds.

Airborne magnetic data was once presented as contour plots, but now is more commonly exposed as colored and shaded computer generated pseudo-topography images. The apparent hills, ridges and valleys are referred to as airborne magnetic anomalies, while the differences between actual measurements and theoretical values indicate anomalies in the magnetic field. These anomalies in turn represent changes in rock type or in thickness of rock units.

III. Methodology

3.1 DATA SOURCE

The airborne magnetic maps used for the study were obtained from the Geological Survey of Nigeria. The data were acquired and compiled by FAIREY SURVEYS LTD during an airborne geophysical survey between May to December, 1975. The nominal flying altitude above the terrain was 500 feet (approximately 152m) with flight line and tie-line spacing of 2km and 20km respectively. However, the flight and tie line direction is150˚/330˚ and 60˚/240˚ respectively. The regional correction of the magnetic data was based on International Geomagnetic Reference Field (IGRF).

The seven-band Landsat 5 TM image acquired on the 17th of December, 2000, belongs to a scene with Path number 188 and Row number 56. EROS EDC prepared and supplied the dataset in the new National Landsat Archive Production System (NLAPS), the National Data Format (NDF) to National Centre for Remote Sensing (NCRS), Jos. The image organization is in band sequential (BSQ) and the same data, in raster format, is presented in seven bands. Each scene was also radio metrically corrected. Four image scenes were mosaic, corrected for tonal variations before being subsisted to correspond to the coordinates of the study area.

3.2 PROCESSING OF AIRBORNE MAGNETIC DATA

The airborne magnetic maps used for the study were obtained from the Geological Survey of Nigeria. The data were acquired and compiled by FAIREY SURVEYS LTD during an airborne geophysical survey between May to December, 1975. The nominal flying altitude above the terrain was 500 feet (approximately 152m) with flight line and tie-line spacing of 2km and 20km respectively. However, the flight and tie line direction is150˚/330˚ 60˚/240˚ respectively. The regional correction of the magnetic data was based on IGRI.

Airborne magnetic data are mostly analyzed in these processes

- Airborne magnetic data filtration
- Regional- Residual Separation
- Depth estimation analysis

3.2.1 Filtering of Airborne magnetic Map

Filtering is separating signals of different wavelength, this is done to isolate and enhance anomalous features with a particular wavelength. The wavelength of an anomaly divided by three or four is approximately equal to the depth at which the body producing the anomaly is buried. Therefore, filtering can be useful in enhancing anomalies produced by features in a given depth range. Traditional filtering can be either band pass, low pass or high pass. Band pass filtering isolates wavelengths between user-defined upper and lower cut-off limits. In geophysical exploration, not every signal may of interest thus; there is always a need for filtration processes. Near surface or shallow anomalous sources usually produce relatively short wavelength disturbance. Practically, in digitization of aeromagnetic map manually, certain short-wavelengths are eliminated to allow a pass of longer wavelength disturbances of lower wave numbers. This is known as a low-pass filter. The irregularities in airborne magnetic maps are removed by low pass filtering, which thus produces a smoother map than the original. Alternatively, the filter in the Fourier domain can be designed to eliminate longer wavelengths and pass shorter ones. This is called a high pass filter. Wavelength filtering is a major consideration in selection of anomalies. In studying a large-scale crustal structure, a low pass filter is employed as small local bodies are of less interest. Similarly, in the investigation of anomalies due to shallow crustal sources, a high pass filtering is employed.

3.2.2 Regional – Residual Separation

Regional-Residual separation involves a careful analysis of the potential field profile in the area within and beyond the area of immediate concern on the map. In most cases such analysis is subjective because limited knowledge is known about the geology of the area under investigation.

Several methods can be used for the separation of the regional trends from regional data. These include:

- Visual or graphical methods
- Polynomial fitting
- Filtering method
- Vertical derivative methods

Graphical Depth determination

Application of aeromagnetic to the detection and mapping of sediment thickness in the sedimentary basins in the pre-computer times were based on the range of graphical techniques which rely on the fact that deeper magnetic sources have broader anomalies than shallower sources. Various parameters defining this broadness were measured and related to the depth through simple empirical relationship or by the use of graph. These methods and indeed virtually all qualitative interpretation method are based on the concept that the magnetic source in the majority cases be approximated by simple geometric sources. Curves for dipping dyke model applicable to magnetic bodies with elongated plate-like geometry such as dyke, lava flows, magnetic sediments basement uplifts and certain ore bodies are a well-known of such curves.

3.2.3 Estimating Magnetic Depth—Overview

The depths to magnetic source routines are a very useful product of any magnetic interpretation. Reliable depths can help to plan drill holes to test both magnetic and non-magnetic targets. If one can reliably estimate the thickness of non-mineralized cover rocks, you can greatly improve the accurate budgeting and planning of any exploration program. In oil exploration, reliable estimates of depth to magnetic basement are essential.The increasing size and resolution of aeromagnetic surveys methods indicates that automated processes of estimating depths are essential for cost effective interpretation.

Traditional depth estimation techniques involve the use of contours, stretched histogram pseudo-color compositions and first vertical derivative data. But recently there are exciting suite of new-generation depth estimation tools and products. These tools include

- Improved Naudy Automatic Model,
- Matched filter depth separation and slicing,
- Traditional and Extended Euler Deconvolution,
- Phillips method,
- Complex amplitude and instantaneous phase,
- Analytic signal,
- Magnetic coherence map,
- Vertical derivative, pass, continuation and directional filters,
- Powerful visualization and hard copy composition language and tools.

All the methods are based on the transform of the potential field anomalies into special functions that form gradient peaks and ridges over the sources. These maxima peak values are located directly above the magnetic contacts, depending on an assumed geometric model. All the methods can use the same function to locate the contacts and estimate the source depths Jeffrey D Philips, 2016.

3.3 REPRESENTATION OF AIRBORNE MAGNETIC DATA

Once a reliable grid has been created, several types of visual presentation of aeromagnetic data are available, of which contouring is only perhaps the most traditional - and once familiar. Most of the alternative methods rely on using the grid or raster directly by displaying each grid value as a picture element or pixel, either on a screen display or on a paper copy (Reeves, 2005). The following visual presentation of aeromagnetic exists. They are: Contour map, Grey-Scale image, shaded relief image, color raster and combined shaded relief.

The digitized airborne magnetic map is the first in series of maps generated from the digitations of old maps. The other maps or images are by-products of digitized contour maps.

3.4 PROCESSES OF INTERPRETATION OF AIRBORNE MAGNETIC DATA

The interpretation of aeromagnetic data involves both qualitative and quantitative approach. Qualitative interpretation encompasses: delineation of magnetic zones of the contour map based on its magnetic texture, character and intensity of the anomalies; analyzing the magnetic zones by studying the shape and amplitude of the magnetic profiles over the bodies, and making meaning from those shapes.

Quantitative interpretation involves taking measurements and drawing inferences from those calculations. To achieve this, depth to magnetic anomalous bodies were calculated using the following slope methods: Peters', Hannel's and Tiburg's, as well as 2-D spectral analysis.

IV. Map Presentation And Analysis

4.1 Total Magnetic Field Intensity Map

The total magnetic field intensity map gotten after digitization of the contour map is presented as: total field intensity map, image map, basement surface map and relief map Figures 1,2,3,4,5,6. Figures 7 and 8 show the first regional and residual trends from polynomial regression respectively.

From figures 1,2,5 magnetic anomalies both short and long wavelengths are seen within the study area. These are represented by magnetic highs and lows. Areas with high magnetic intensity anomalies are seen on the northern flank and around Afikpo on the study area. These high intensity anomalies are interpreted as lineaments due to the tectonic events on the basin. The presence of intrusions may be suspected. Intrusions are described on the airborne magnetic maps by elliptical or circular contours (Akanbi and Udensi, 2006).

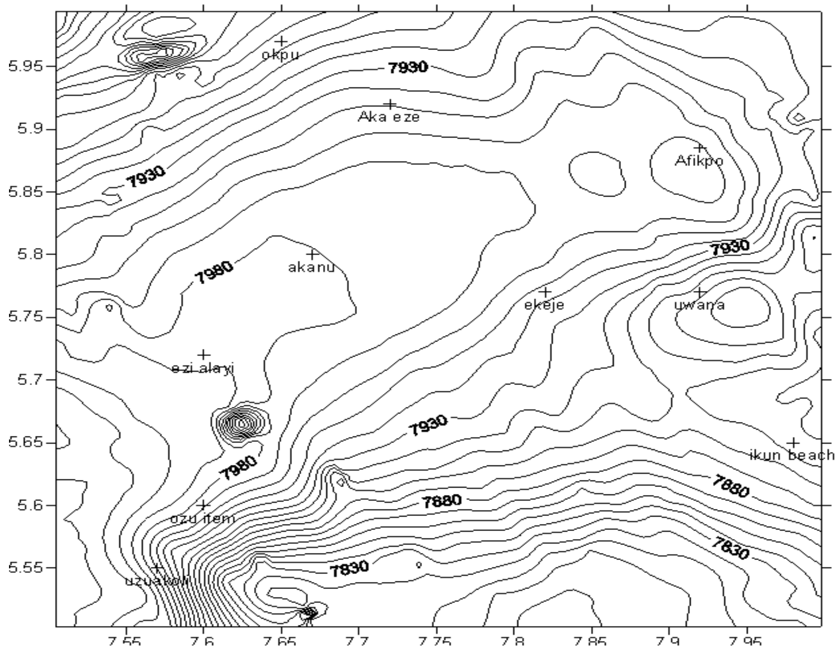

Figure1: total magnetic field intensity map of the study area

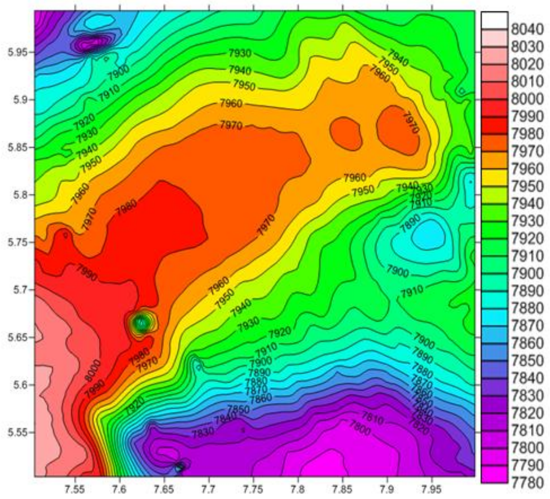

Figure 2: Color Raster map of the study area

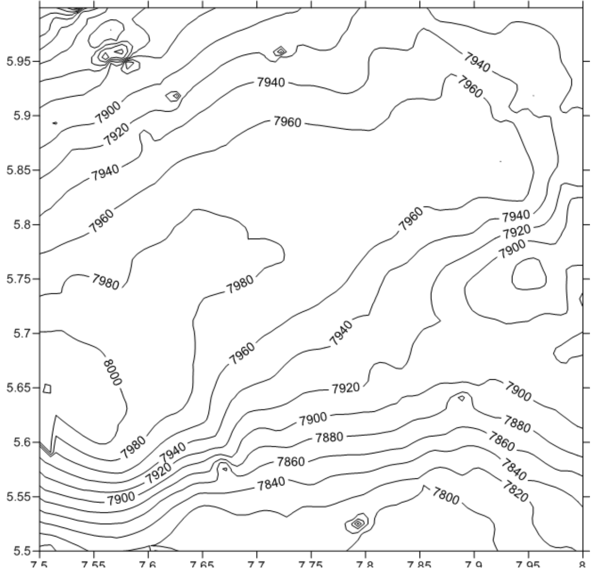

Figure3: Band pass filtered(BPF)map of the study area

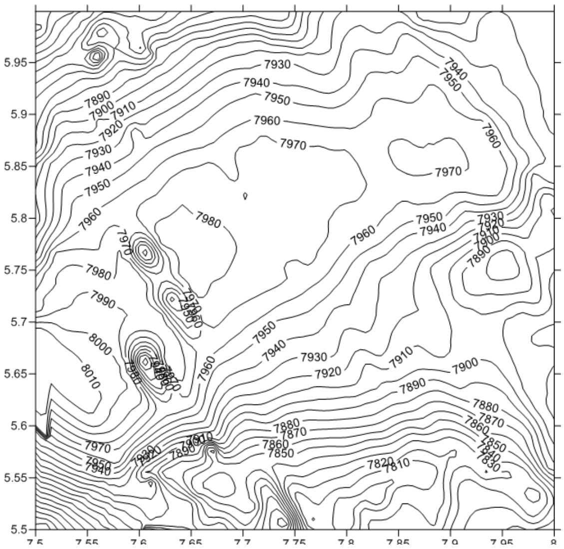

Figure4: Nonlinear filtered (NLF) map of the study area

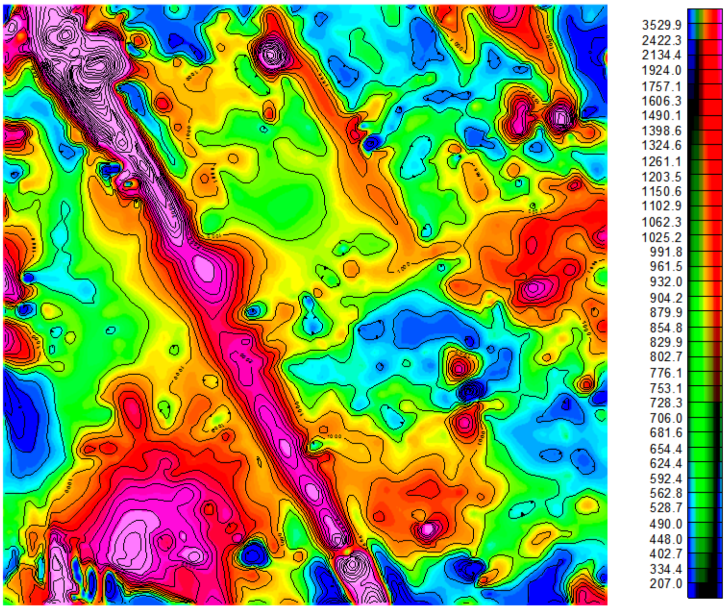

Figure 5. Output analytical signal contour map of the study area

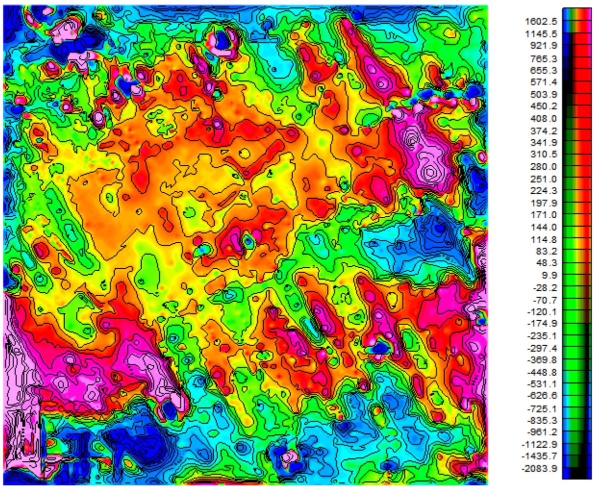

Figure6: Vertical derivativemap of the study area

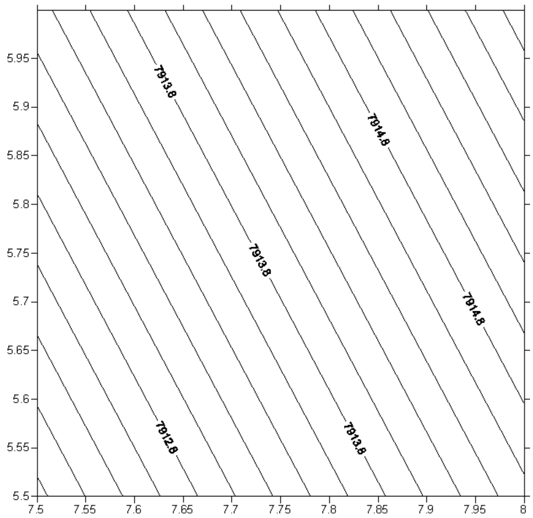

Figure 7. First degree regionaltrends from polynomial regression

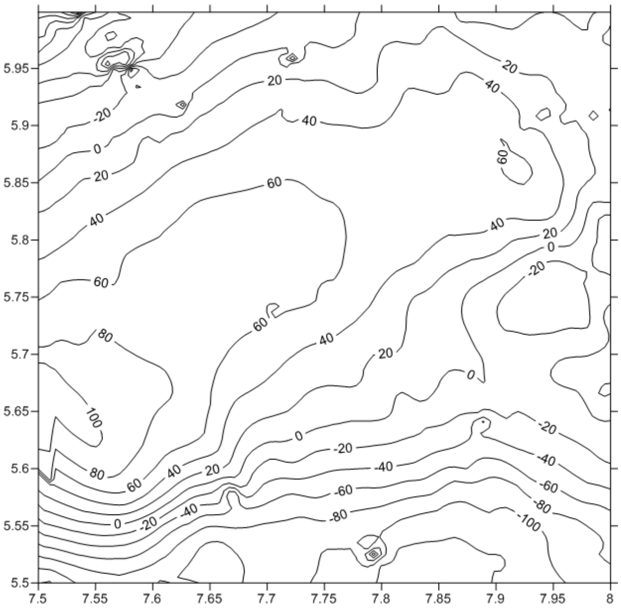

Figure 8. First degree residual field from polynomial regression

Table 1: The computed spectral depths in km of the study area.

SPECTRAL SHEETS	LONGITUDE	LONGITUDE	LATITUDE	LATITUDE	ESTIMATED DEPTHS(KM)	
	X1	X2	Y1	Y2	D1	D2
SP1	7.50	7.75	5.50	5.75	1.723	4.136
SP2	7.50	7.75	5.75	6.00	0.973	1.849
SP3	7.75	8.00	5.50	5.75	0.235	0.518
SP4	7.75	8.00	5.75	6.00	1.848	4.136

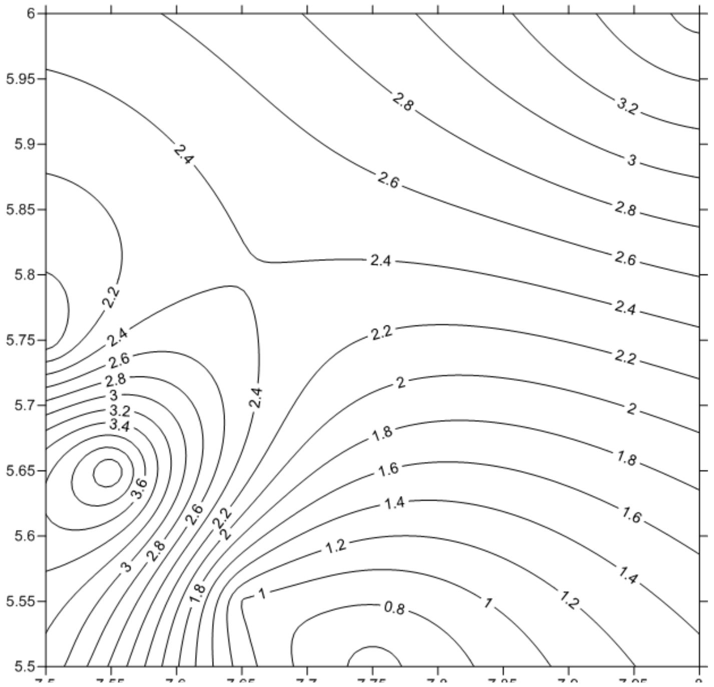

Figure 9: Depth to basement map estimated from spectral inversion**.**

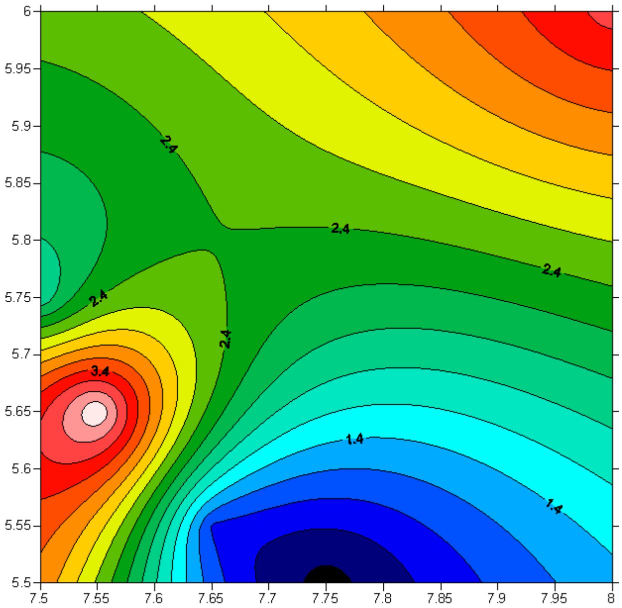

Fig 10. Depth to basementmap estimated from spectral inversion**.**

The first layer depth (D_1), is the depth to the shallower source represented by the second segment of the spectrum (Fig.9). This layer (D_1) varies from 0.235km to 1.723km, with an average of 1.194km.

The second layer depth (D_2) varies from 0.518km to 4.136km, with an average of 2.659km. This layer may be attributed to magnetic rocks intruded onto the basement surface. Another probable origin of the magnetic anomalies contributing to this layer is the lateral variations in basement susceptibilities, and intra-basement features like faults and fractures (Kangkolo et al., 1997). It can be deduced that the D_2 values obtained from the spectral plots represent the average depths to the basement complex in the blocks considered. Depth to basement map estimated from spectral inversion of the area was generated (fig 10). The maps reveal the sedimentary thickness, as thinning towards the NE direction. This direction coincides with areas were the basement outcrops such as the Akanu. The sedimentary thickness of this area ranges from 1.4km to 3.4km. The color codes show the depth in km.

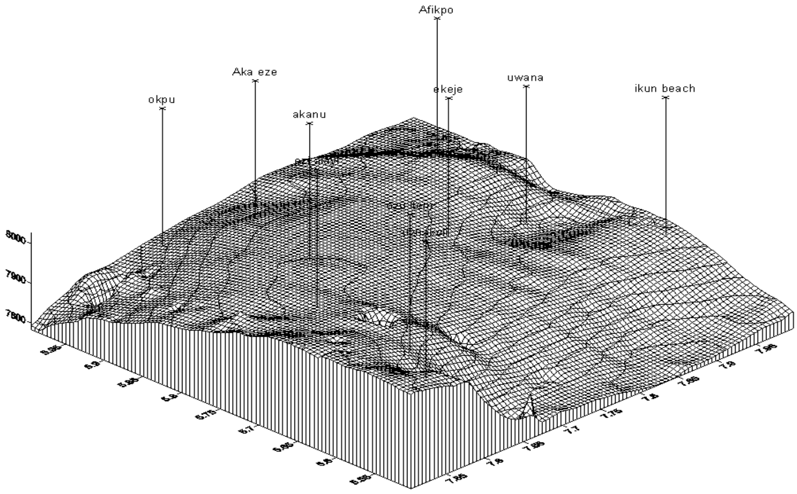

Figure 11:3-D wireframe map of the magnetic basement showing a quite relief

The 3-D representation of the topography of the magnetic basement surface of the study area is shown by Figure 11. The study area is displayed as having crest and trough. The basement topography is also folded. This fold may be interpreted as part of the Okpu folded belt. In terms of folding, the area could be described as moderately tectonic active. The smooth surface of the trough zone makes the area to be interpreted as tectonically inactive zone.

On the basis of the high elevation, Afikpo could be described as a tectonic active zone.

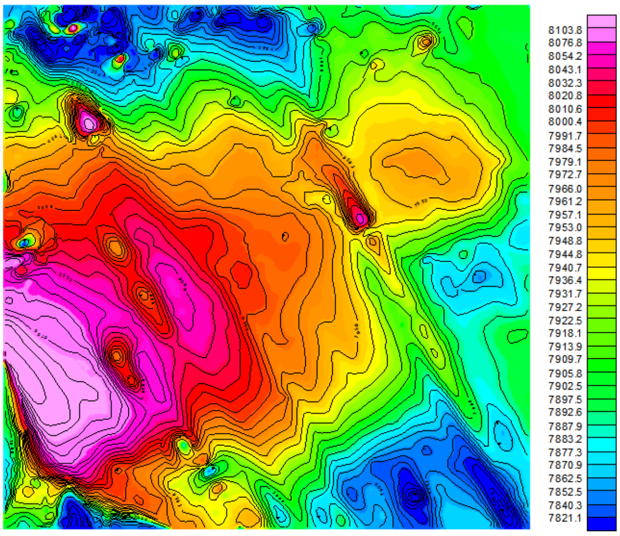

Figure 12: Reduction to pole(RTP) contour mapof the study area

4.2 REDUCTION TO POLE

The effects of reduction to pole are manifested as shift of the main anomaly from the Centre of the magnetic source and are due to vector nature of the measured magnetic field. It removes the effect of earth's magnetic field. The shape of any anomaly depends on the inclination and declination of the main magnetic field of the earth. The reduction to pole filter reconstructs the magnetic field of a data set as if it were at the pole.The reduction to pole of the total magnetic field intensity map of the study area reveal that there is a negligible shift or no change in the anomalies on reduction to the pole (Fig. 12). This is apparent because the study area is a low latitude zone. The reduction to pole filter reconstructs the magnetic field of a data set as if it were at the pole.

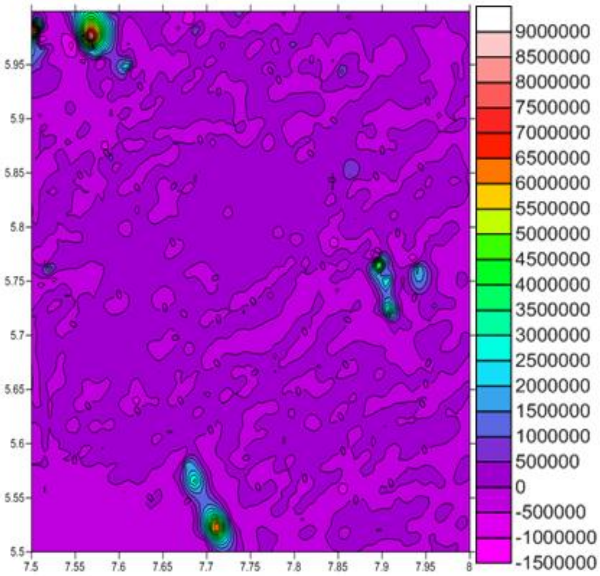

Figure 13. Second vertical derivative of zero contour s of the study area

4.3 THE SECOND VERTICAL DERIVATIVE

The closures seen on the zero contour derivative (Fig. 13) similar to the residual anomalies reflect area with similar lithology and shallow to near surface magnetized source bodies. Similar to the total magnetic intensity, it reveals lineaments with NE-SW trend.

V. Discussion

Through processed airborne magnetic data the study area has been described as a moderately active zone.The study area located within the lower Benue Trough has a distinctive basin orientation trend. The first polynomial regional surface has been discovered to indicate the basin orientation. To this effect, it was discovered from the first order polynomial regional surface a NE-SW orientation. The total field of the airborne magnetic data presented as a 3-D surface map shows a basement surface that is folded.The results of the spectral analysis of airborne magnetic data over the study area suggest the existence of two main source depths. The depth to basement or deeper source D_2 varies between 2.863km and 4.672km. The deeper sources, represented by the first segment of the spectrum reflect the Precambrian basement. This layer may be attributed to magnetic rocks intruded on the basement. The inhomogeneity in the basement composition is due to the structural and topographic relief of the basement surface, lateral variations in basement susceptibilities, and intra-basement features like faults and fractures. Logically, D_2 represents theaverage depth to the basement complex of the study area. In terms of petroleum prospecting the study area seems profitable.

VI. Conclusion

The interpretation of airborne magnetic data of study reveals that Afikpomap has a dominant NE-SW trend which reflects that of the basin. The low magnetic intensity and intrusive around Afikpo suggest the existence of deeply penetrating fractures within the area. This means that the area is prolific for petroleum exploration.

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