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Analysis of Aeromagnetic Data Over Middle Benue Trough And Its Adjourning Basement Terrain, North Central Nigeria

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Abstract: *The analysis of aeromagnetic data over Middle Benue Trough and its adjourning basement terrain using Source Parameter Imaging (SPI) in Oasis montaj version 8.2 indicates that, the depth to magnetic sources in adjourning basement varies between 0.2 km to1.7 km. The depth to magnetic source at the middle of the study area which made up of the Cretaceous sediments of middle Benue varies between 4 km to 6 km. The shallow depth at the adjourningbasement could be as a result of basic intrusive rocks of the basement terrain, while the deeper sources at the middle of the study area that made upof cretaceous sediments of middle Benue, could be due to rifting of the Benue Trough. From the results obtained the adjourning basement terrain could be a potential site for mineral exploration while, the sedimentary section belonging to the middle Benue Trough could be a potential site for petroleum exploration.*

Keywords: *Oasis Montaj, basement terrain, Source Parameter Imaging, Middle Benue and Magnetic source*

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I. Introduction

Magnetic field is a complex phenomenon arising from complex distributions of magnetization in the earth crust. Broadly speaking, there are two types of magnetization that contribute to the external magnetic fields caused by geologic features. The most common component arises from magnetic minerals immersed in the ambient field of earth (induced magnetization) (Likkason, 2007). A less common contribution but of equal or in same case the dominant effect, is a response left-over from ancient geological events (remnant magnetization). Many magnetic anomalies are combination of both types of magnetization, in most of these cases the remnant and induced field vectors point in different direction, the ratio of the remnant to induced magnetization is koennigsberger ratio and this expresses the relative contribution of each of these two vectors to the anomaly shapes and amplitude. Remnant magnetization is usually defined as magnetization embedded in the mineral composition of the rock due to direction of the earth’s field when the rock was formed. Remnant magnetization can also be caused either by chemical reaction in temperature above and below the Curie point, or long term exposure to an external field (Zietz and Andreasen 1967, Roest and Pilkington 1993). Considering the adjourning basement terrain, many authors have worked on the Jos plateau, especially in the younger granite complexes like the Riruwai younger granite ring complex, Ganawuri- Kigom complex, the Kagoro complex and the general environs of the plateau and also on the sediments, tectonic evolution and potentials of the Middle Benue Trough (Kasidi and Alkali, 2017)

In these study, various depth to magnetic source would be determined using a Source Parameter Imaging in both the Middle Benue and adjourning basement terrain.Very recently Kasidi and Nur (2013a, 2013b), utilized spectral analysis of a simplified mathematical formula for the interpretation of magnetic data over the Mutum Biyu and environs, Jalingo and environs Northeastern Nigeria, where depth to magnetic sources range between 0.5km to 3.0 km The study area is bounded by Latitude 8^o 00' - 9^o 00'E and longitude 9^o 00' - 9^o 30' N covering a total area of 6,050 km^2, (Fig. 1)

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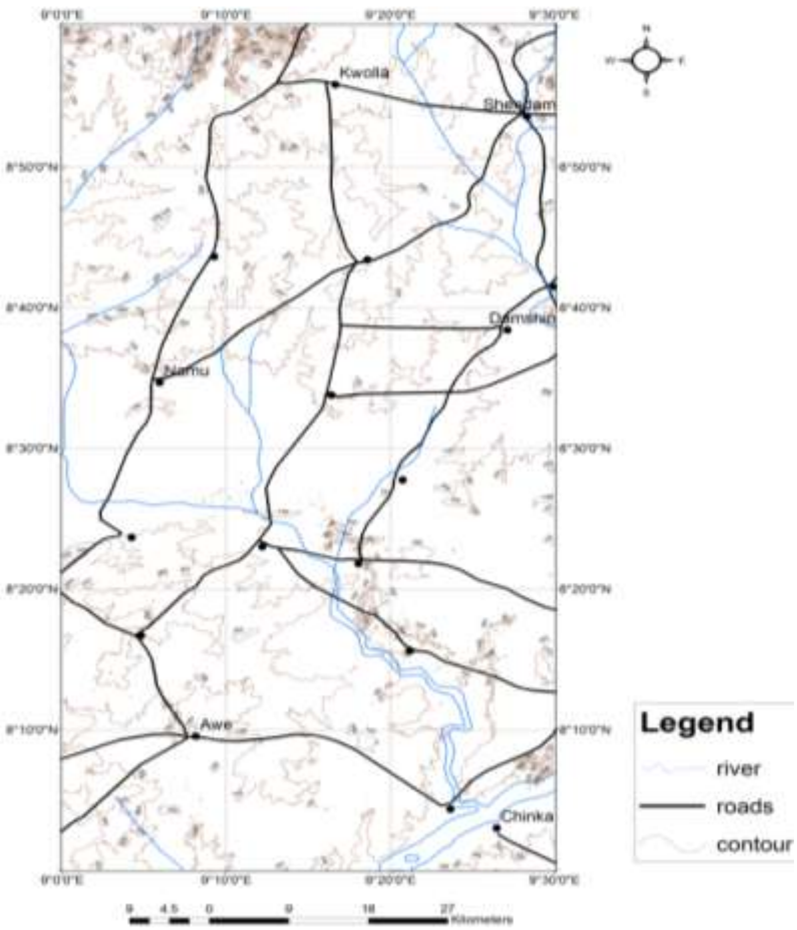


Figure.1 Location map of the study area (modified from USGS 2014)

II. Geology Of The Study Area

The geology of the study area consist of basement complex dominated by three rock types, the older granites, the younger granites and volcanoes and sheets of basalts. The older granites date to the late Cambrian and Ordovician, the younger granites were emplaced dating to the Jurassic. The Cretaceous Sediments of the Benue Trough. The Middle Benue Trough extends Northeast ward approximately as far as line joining Bashar and Mutum Biyu. This boundary marks the Southern limit of the Gombe and Keri-Keri Formation, while the older sediments of the Upper Benue Trough undergo lateral facies change in this area. The earliest work done in the Middle Benue Trough of Nigeria was reported by Falconer (1911) who reported the Asu River Group to be the oldest marine sedimentary formation which he then referred to it as the "Lower Shale", Tattam (1944) described the lithological unit as the "Cross River Series" and the name "Asu River Group" was obtained. The Keana Formation is thought to be equivalent to the "Muri Sandstone" in the north. Cratchley and Jones (1965) subsequently used the "Keana Sandstone" to describe the formation in Lafia-Awe area. Simpson (1954) first mentioned the "Ezeaku Formation" in the literature where he described a sequence of hard dark grey to black flaggy calcareous shale, siltstone and sandstone in the stream south of the Okigwe-Afikpo road.

The six formations include the Asu River Group, Awe Formation, Keana Formation, Ezeaku Formation, Awgu Formation and finally the youngest which is the Lafia Formation, while the two formations exposed in the studied area are the Awe Formation and Keana Formation which are essentially sandstones with intercalations of calcareous shale and claystone which are covered by laterite resulting from the weathering of volcanic rocks which were emplaced during the widespread volcanic activities that took over in the Tertiary Period. Basalt flows occur around Awe and dolerite sills, of presumed Cenozoic age, have been encountered within the Lafia Formation (Offodile, 1976; Obaje, 1994). Offodile (1976) reported that intrusives in the Lafia-Awe area are restricted to anticlinal structures. In the Middle Benue Trough, the volcanics are mostly confined to the Keana, Awe, Kanje and Jangerigeri areas (Fig.2)

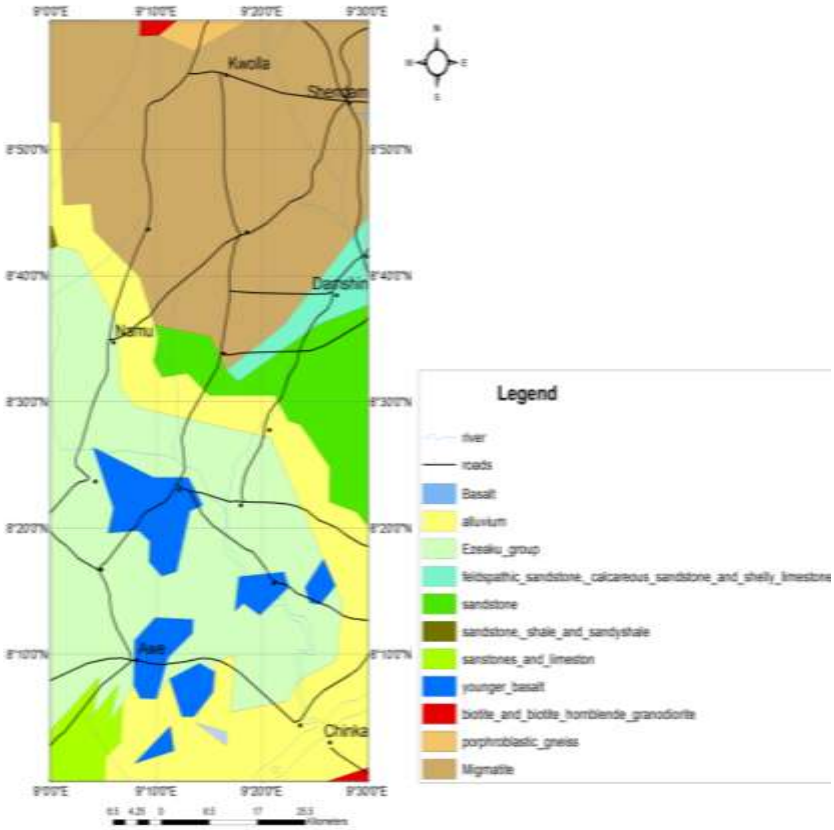


Figure.2 Geological map of the study area. (modified from NGSA 2006)

III. Methodology

For this study, the data was obtained digitally from The Nigerian Geological Survey Agency (NGSA), Abuja. Geosoft Oasis Montaj software was used to get both the Regional-Residual Map and the Source Parameter Imaging (SPI) of the study area from the TMI map (Total Magnetic Intensity map). Analytic signal was derived from the TMI map. Polynomial fitting method of the first order was used in separation of the regional and residual data.

IV. Analytic Signal

Analytic Signal method was applied directly to the residual data. The analytic signal method generally produces good horizontal locations for contacts and layer edges independent of dip and inclination. It improves or generates more energy to the data. The analytic signal depends on the first derivative of the vertical component of the magnetic field as well as the horizontal derivatives so is thus more susceptible to noise than the horizontal gradient method. It basically enhances the intensity over an intrusive body.

The analytic signal of potential field data in 2- D could be written as,

$A(x) = \varphi_x + i\varphi_z \quad 1$

Where φ_x and φ_z is a horizontal and horizontal derivatives.

The 2-D analytic signal amplitude (ASA) of potential field is

$/A(x)/ = \sqrt{\varphi_x^2 + i\varphi_z^2} \quad 2$

Roest et al. (1992) write the analytic signal in 3D as a vector encompassing the horizontal derivatives and their Hilbert transform and the 3D analytical amplitude of the potential field measured on a horizontal plane as Ø (x, y):

$/A(x,y)/ = \sqrt{\varphi_x^2 + \varphi_y^2 + \varphi_z^2} \quad 3$

V. Source Parameter Imaging (SPI)

The Source Parameter Imaging (SPI) is a technique using on extension of the complex analytical signal to estimate magnetic depths. This technique developed by Thurston and Smith (1997) and Thurston et al (1999) sometimes referred to as the local wave number method is a profile or grid-based method for estimating magnetic source depths, and for some source geometries the dip and susceptibility contrast.

The method utilizes the relationship between source and the local wave number (k) of the observed field, which can be calculated for any point within a grid of data via horizontal and vertical gradients (Thurston and Smith, (1997). The original SPI method (Thurston and Smith, 1997) works for two models: a dipping thin dike and a sloping contact. The local wave number has maxima located over isolated contacts, and depths can be estimated without assumptions about the thickness of the source bodies (Smith, et. al., 1998). Solution grids using the SPI technique show the edge locations, depths, dips and susceptibility contrasts.

The local wave number, map more closely, resembles geology than either the magnetic map or its derivatives. The SPI method requires first and second order derivatives and is thus susceptible to both noise in the data and to interference effects. The SPI method (Thurston and Smith, 1997) estimated the depth from the local wave number of the analytic signal. The analytic signal $A_1(x, z)$ is defined by Nabighian (1972) as

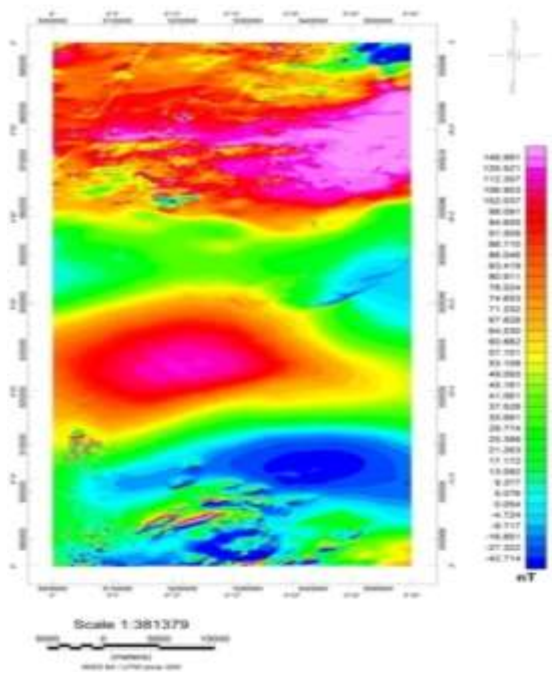
$$A_1(x, z) = \frac{\partial M(x,z)}{\partial x} - j\frac{\partial M(x,z)}{\partial z} \quad 4$$

Where $M(x, z)$ is the magnitude of the anomalous total magnetic field, j is the imaginary number and z and x are Cartesian coordinate for the vertical direction and the horizontal direction perpendicular to strike, respectively.

The local wave number k1 is defined by Thurston and Smith (1997) to be

$$K1 = \frac{\partial}{\partial x}\tan^{-1}\frac{\partial M/\partial z}{\partial M/\partial x} \quad 5$$

VI. Results



From the analysis of aeromagnetic data, the following results were obtained and Presented in figures which were discussed below in detailed,

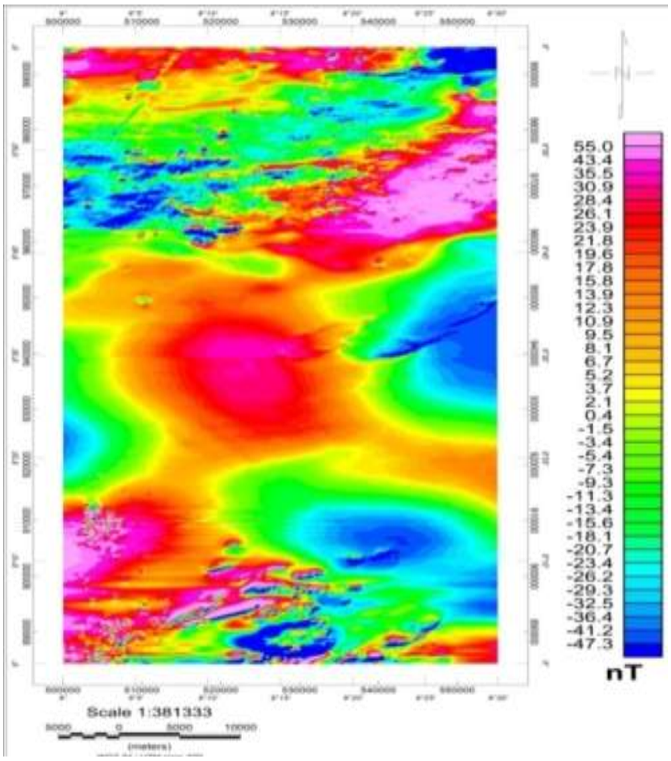


Figure.4: Residual Map of the Study area

Figure.3: TMI map of the study area

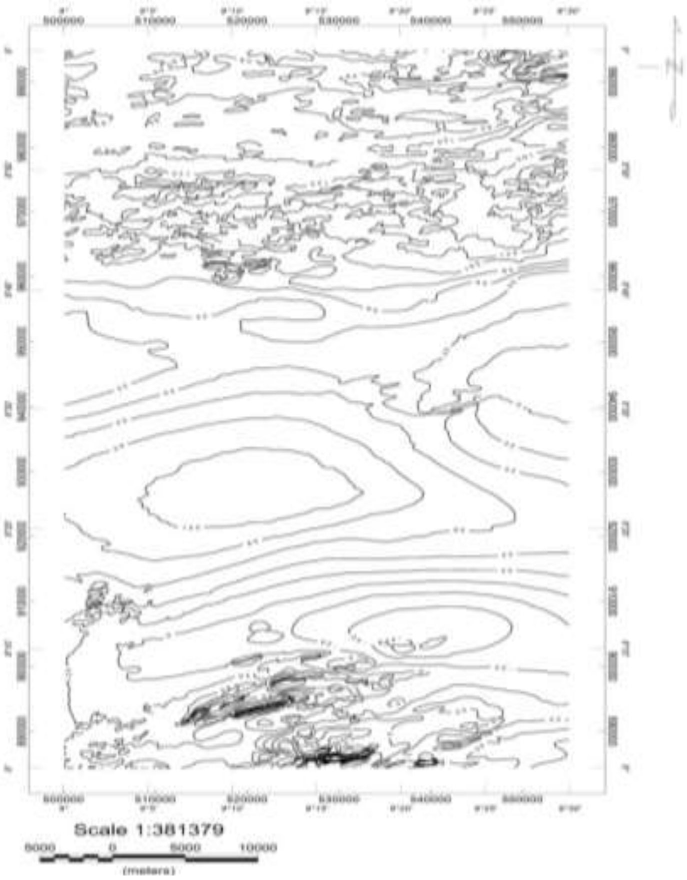


Figure.5: TMI Contour of the study area

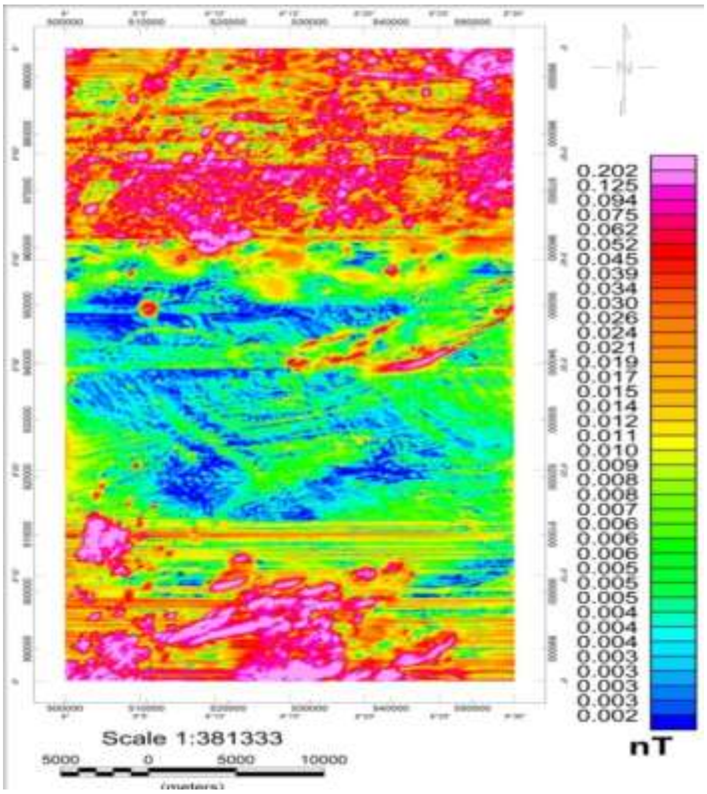


Figure.6: Analytical Signal Map over the study area

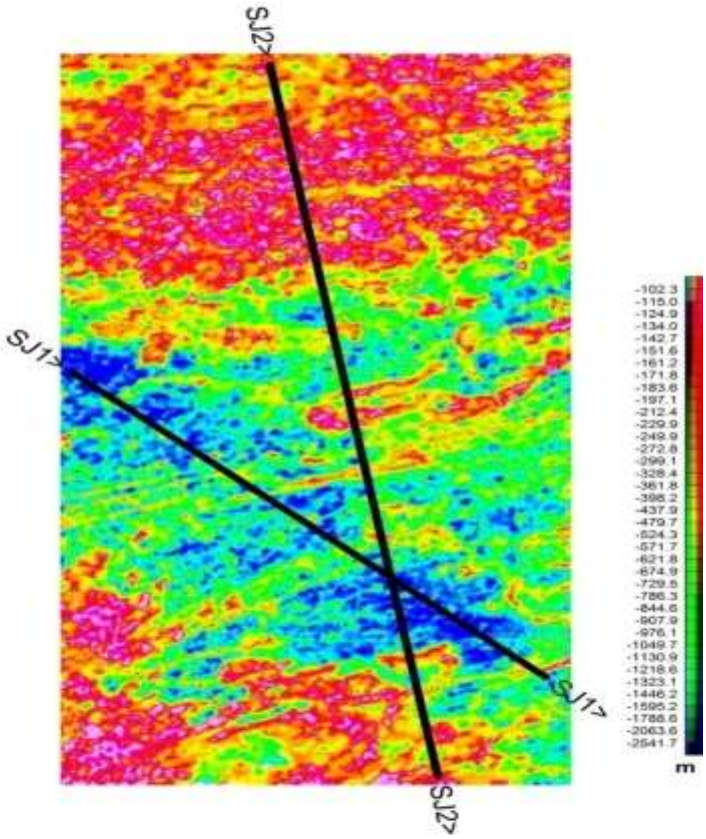


Figure.7: SPI Map with profiles over the Study area

Figure 8 and 9 below shows the variation in depth to magnetic source along profile SJ1 and SJ2 respectively. High peaks on the analytic signal profile indicate basic intrusion over the crystalline basement.

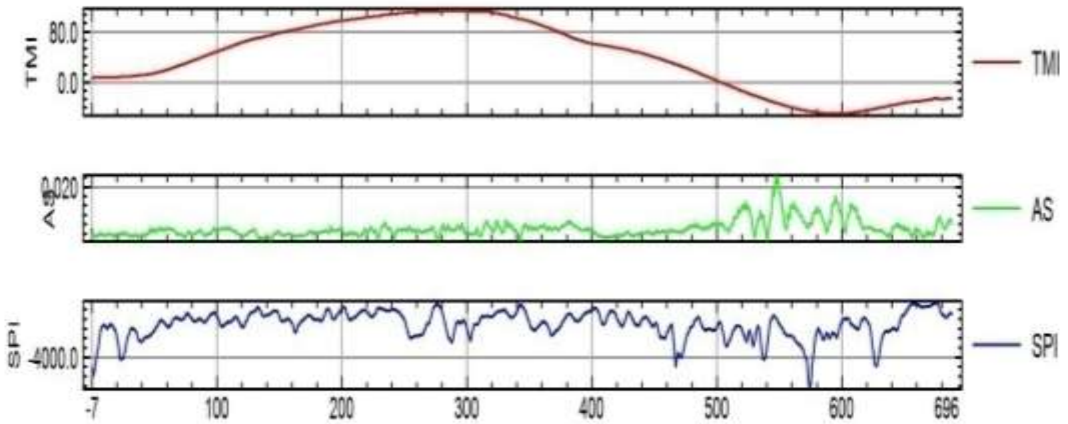


Figure.8: Profile along SJ1

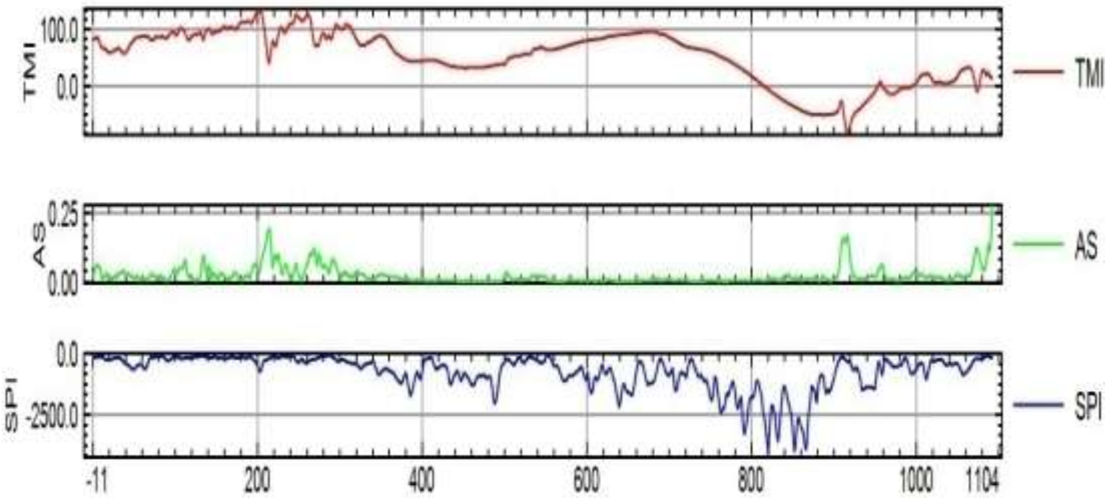


Figure.9: Profile along SJ2

VII. Discussion

In Fig. 3 the total magnetic intensity over the study area which shows range of colours from red, indicates highest values and the blue colour indicate lowest values. The range of values is from to 42.714nT - 146.991nT, the lowest values being associated with sediments at the central part of the study area. The higher values reflect the adjourning basement terrain.The general trend of the magnetic contourare predominantly NE-SW direction, an attribute of the Pan – African Orogeny.The residual map on Fig. 4 shows deep seated magnetic anomaly and having high frequency ranging from 35.5 to 55.0 nT represented by pink color. The blue areas are related to shallow seated low frequency anomaly with intensity ranging from -29.3 to 47.3nT.The depth estimate obtained from Source Parameter Imaging (SPI) indicated by profiles on the profile map of the study area (Fig. 7)are deduced from the two profile drawn, profiles SJ1 and SJ2 (Fig. 8 and 9) respectively. Across the study area there is variation in depth to magnetic sources (with 6km at the eastern and western end of the profile). The depth to shallow sources range from 0.2 km to 1.7 km, while the deeper sources lie between 4 km to 6 km. The shallow sources correspond to the adjourning basement terrain while the deeper sources correspond to the cretaceous sediment of middle Benue Trough. These depths to magnetic sources in the Middle Benue Trough make it a potential site for hydrocarbon exploration

VIII. Conclusion

The analysis of aeromagnetic data over Middle Benue Trough and adjourning basement terrain using source parameter Imaging practically showed that the upwelling of magma due to volcanic activities in the adjourning basement terrain lead to shallow depth to magnetic source, a such it can be utilized for mineral exploration. While the rifting of Benue Trough led to thick deposition of Cretaceous sedimentary rock which gave rise to deeper magnetic source which could be a guide for oil exploration in the Middle Benue.

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