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Magnetic Anomaly Investigation in Abia State and Environs for Mineral and Hydrocarbon Exploration

[1*]Azunna, Daniel E., [2]Chukwu, Godwill U., [2]Igboekwe, Magnus U. and [2]Ijeh, Boniface I.

[1]*Department of Physics, Clifford University, Owerrinta, Abia State, Nigeria.*
[2]*Department of Physics, Michael Okpara University of Agriculture, Umudike, Abia State, Nigeria.*
[*]*Corresponding Authour: azunnad@clifforduni.edu.ng*

Abstract:
Magnetic study was conducted in Abia State and parts of Imo, Enugu, Ebonyi and Benue states covering an area of about 48,400 km^2 and lies between latitude 5^0 0'N to $7^0$0'N and $7^0$0'E to $8^0$0'E. Eight data sheets of aeromagnetic survey with sheet numbers; 287 (Nsukka), 288 (Igumale), 301 (Udi), 302 (Nkalagu), 312 (Okigwe), 313 (Afikpo), 321 (Aba) and 322 (Ikot-Ekpene) were obtained from the Nigeria Geological Survey Agency and analysed to obtain the Total Magnetic Intensity (TMI) and the Source Parameter Imaging (SPI) of the study area. Results of the analyses show that the magnetic intensity in the study area ranges from -102.8 nT to 145.6 nT while the source parameter imaging reveals that the depth of the causative bodies range from -102.4 m to 7,618 m. Igneous intrusive deciphered from most parts of the study area as well as the shallow depth to magnetic basement suggest that the study area is mostly a zone for mineralogical exploration and are most unlikely to be viable for hydrocarbon exploration but Obolo-Eke and Ikem areas of Benue and Enugu states respectively have a likelihood of potential hydrocarbon deposit due to their low magnetic anomaly response and depth to magnetic response of up to 7km.

Keywords: *Magnetic Anomaly, Mineral, hydrocarbon, Total Magnetic Intensity, Source Parameter Imaging.*

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I. Introduction

Magnetic anomaly is a local variation in the earth's magnetic field due to the changes in the chemistry or magnetism of the rocks [1]. Magnetic anomalies arise either from remanent magnetization or from induced magnetization in the present geomagnetic field related to the magnetic susceptibilities [2]. Some materials in the earth are intrinsically magnetic while some become magnetized when in the neighborhood of a magnetic field and thereafter develop an induced magnetic field. Such fields interact with the earth's primary field giving rise to magnetic anomalies which is the magnetic responses noticed at the surface of the earth during magnetic survey. The magnetic field is measured in Tesla but it's conveniently measured in nanoTesla (nT) and the magnitude of the magnetic field of the earth is about 5×10^{-5} T [3].

Magnetic anomalies are a small fraction of the magnetic field ranging from 25,000 nT to 65,000 nT and it varies with latitude increasing from the equator to the magnetic poles [4]. Magnetic anomalies as small as 0.1 nT and large anomalies with amplitude of tens, hundreds and thousands of nT can be measured in a conventional aeromagnetic survey and this no doubt has various geological significances. The shape and amplitude of a magnetic anomaly depends on the location, shape, size, strike, burial depth, magnetic susceptibility, intrinsic magnetization of the causative body and the angle at which the survey lies relative to both the earth's magnetic field and to the causative body. [5].

Magnetic anomalies can either be negative or positive. While negative anomalies may form in troughs, sedimentary basins or where faults have dropped down the basement, positive magnetic anomalies can be created by irregularities in the buried basement rocks. Due to high magnetite content of basic igneous rocks, they are usually highly magnetic [6]. Acidic igneous rocks are less magnetic than basic igneous rocks although their magnetic behaviors change [7]. There is variability in the magnetic properties of metamorphic rocks while sedimentary rocks are usually non-magnetic and it is on this basis that magnetic surveying is done because the interpretation of survey data assumes that magnetic sources must be beneath the base of sedimentary sequence.

Many studies have been done in the different parts of Southern Benue Trough to determine the mineral and hydrocarbon viability using magnetic method. Some of them can be seen in the works of [8-18].

II. The Study Area

The area under study lies in the Southern Benue Trough (SBT) consisting of Abia state and parts of Enugu, Benue, Ebonyi, Imo and Benue states with a land mass of about of about 48,400km^2. They lie between latitude 5^0 0^I N to $7^0 0^I$ N and Longitude $7^0 0^I$ E to $8^0 0^I$ E. Figure 1 shows the map of the study area. It has a relatively even topography and a sloppy topography at the southern and northern parts respectively ranging from 100-600m above sea level.

The Southern Benue Trough (SBT) originated when the South American and African plate separated as a failed arm of an aulocogen at the time of the opening of the South Atlantic Oceans [19]. Geologically, the SBT contains rocks of cretaceous to tertiary ages with its stratigraphic history characterized by three sedimentary phases namely; the Abakili-Benue Phase, the Anambra-Benin Phase and the Niger-Delta Phase with their ages being Aptian-Satonian, Campanian-Mid Eocene and Late Eocene-Pliocene respectively [20]. The geology map of the study area is shown in figure 2.

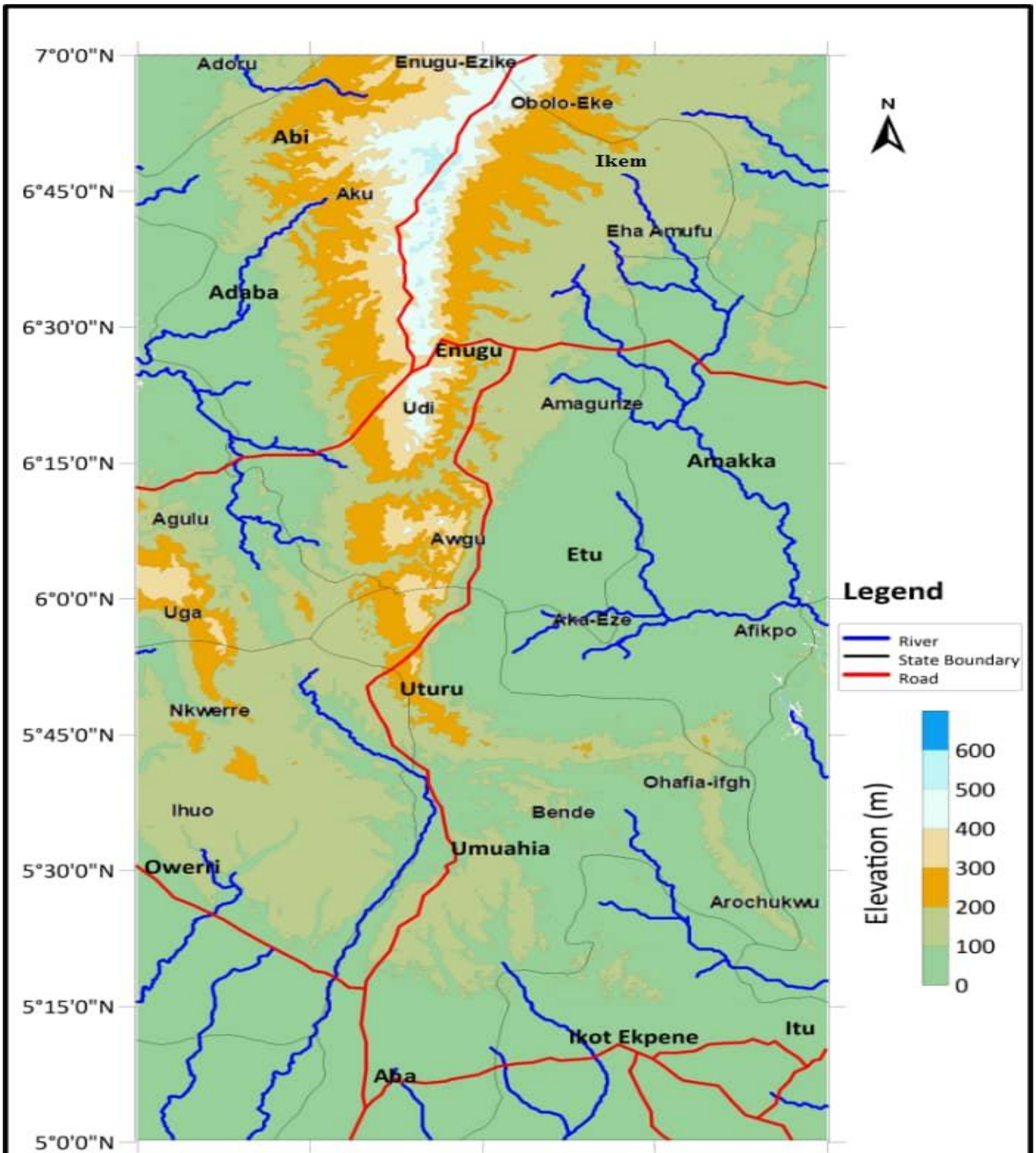

Figure 1: The Location Map of the Study Area showing Elevation

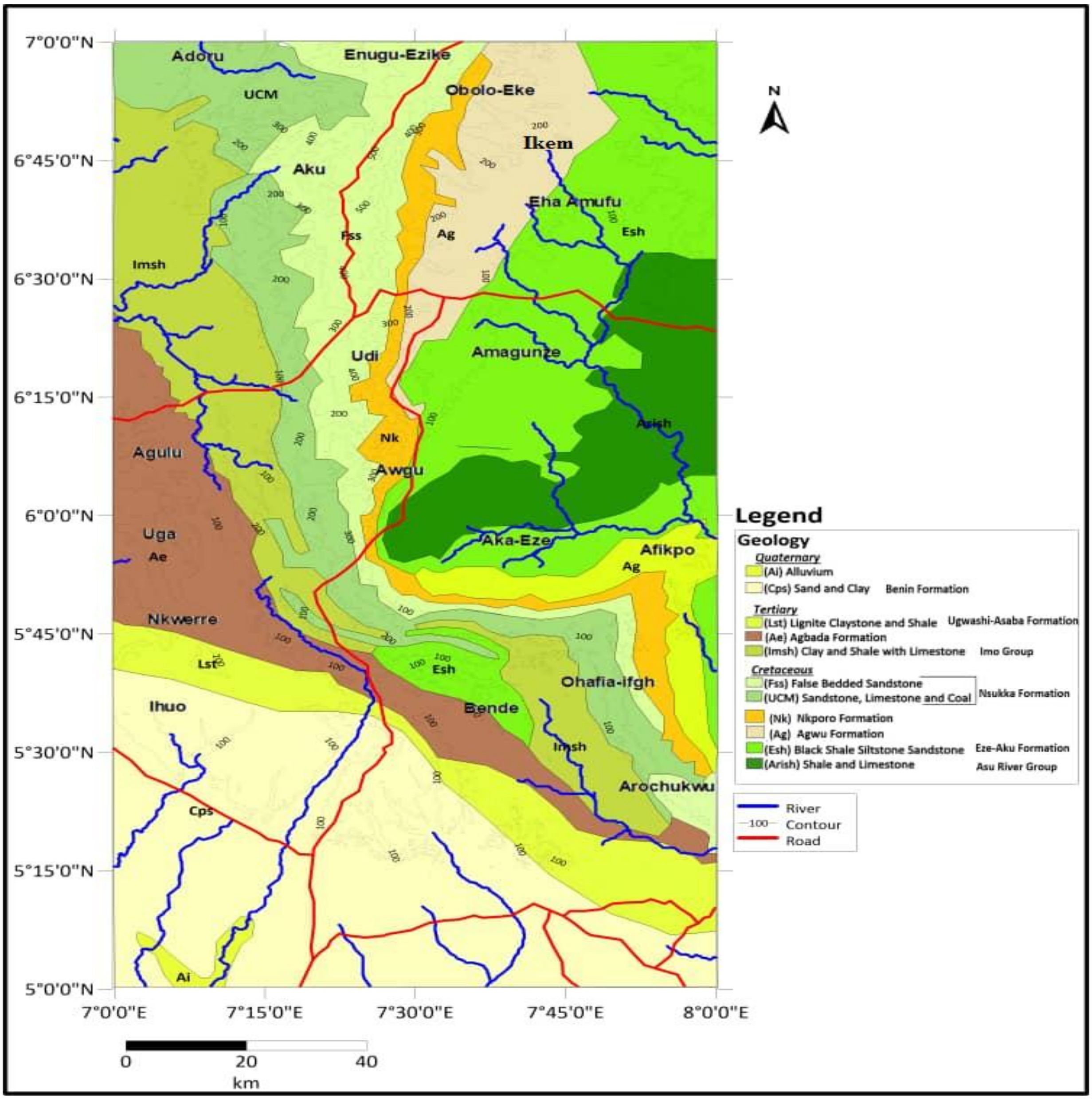

Figure 2: Geology Map of the Study Area [21].

III. Materials and Methods

Eight sheets of aeromagnetic data were obtained from the Nigerian Geological Survey Agency (NGSA) over Aba, Ikot-Ekpene, Okigwe, Afikpo, Udi, Nkalagu, Nsukka and Igumale with sheet numbers; 321, 322, 312, 313, 301, 302, 207 and 208 respectively. The survey was carried out at a flying altitude of 80m above the terrain with a flight line spacing of 500 m and tie line spacing of 200 m along a series of NW-SE.

The flight line direction is 45^0 azimuth with an average magnetic inclination and magnetic declination of 9.75^0 and 1.30^0 respectively across the survey. The data is on a scale of 1:100,000 and the digital data consisting of the Total Magnetic Intensity (TMI) latitude and longitude of the area was windowed from the national grid data base delivered in American Standard Code for Information Interchange (ASCII) file in Geosoft format. The data was thereafter processed to obtain the depth to magnetic basement using the Source Parameter Imaging (SPI).

IV. Results and Discussions

The TMI and the SPI of the study area is as shown in figures 3 and 4 respectively. The TMI is a combination of the residual and regional field of the study area and it has positive magnetic intensities as well as negative magnetic intensities ranging from -102.8 nT to 145.6 nT. The northern part of the study area has predominantly negative magnetic anomalies of about -6.9 nT to -102.8 nT with the North-Eastern part having magnetic intensities of 75 nT to 112 nT. The central area has varying magnetic anomalies with an intermediate value of 15 nT to 44 nT, high anomalies of 92 nT and low anomalies of -31 nT. However, the Southern part of the study area has the highest magnetic responses from 92 nT to 145.6 nT.

Basic igneous rocks are more likely to be seen in the southern part of the study area due to its high magnetic susceptibility whereas sedimentary basins are more likely to be found in the Northern part of the study area. Furthermore, metamorphic rocks can as well be found more in the central area. From the Source Parameter Imaging (SPI) map, the depth of the magnetic anomalies ranges from -102.4 m to 7618 m. The deepest bodies spread across the study area except the Northwestern part of the study area which has shallower bodies. The minimum thickness of the sediment required for the commencement of hydrocarbon formation is 2 – 7 km while that of gas is 3 – 7 km [15]. However, the presence of igneous intrusions in an area indicates an exceedingly high temperature history capable of destroying any hydrocarbon that might have been formed in thermally over mature source rocks [13]. Therefore areas of high magnetic anomalies are unfavorable for hydrocarbon accumulation.

Therefore, Abia, Imo, Enugu and Ebony states have the highest magnetic anomaly which indicates igneous intrusions. However, Kogi and Benues states have low magnetic response and as such are made of sediments. Furthermore, due to the presence of igneous intrusive (high magnetic anomalies), areas like; Bende, Umuhia, Arochukwu, Ohafia (Abia State); Nkwere, Ihuo (Imo state); Afikpo, Amagunze, Eha-Amufu (Ebony state) are likely not to be viable for hydrocarbon prospects but they are zones of mineralogical prospects. On the other hand, Abi and Aku areas in Kogi state have low magnetic anomalies which is indicative of hydrocarbon potential but the depth of the sediments from the SPI (98-944m) is not sufficient for hydrocarbon accumulation. Nevertheless, Obolo-Eke and Ikem areas of Benue and Enugu states respectively may have potential for hydrocarbon due to its low magnetic anomaly response and depth to magnetic basement of up to 7km. This however is based on further confirmatory geophysical studies.

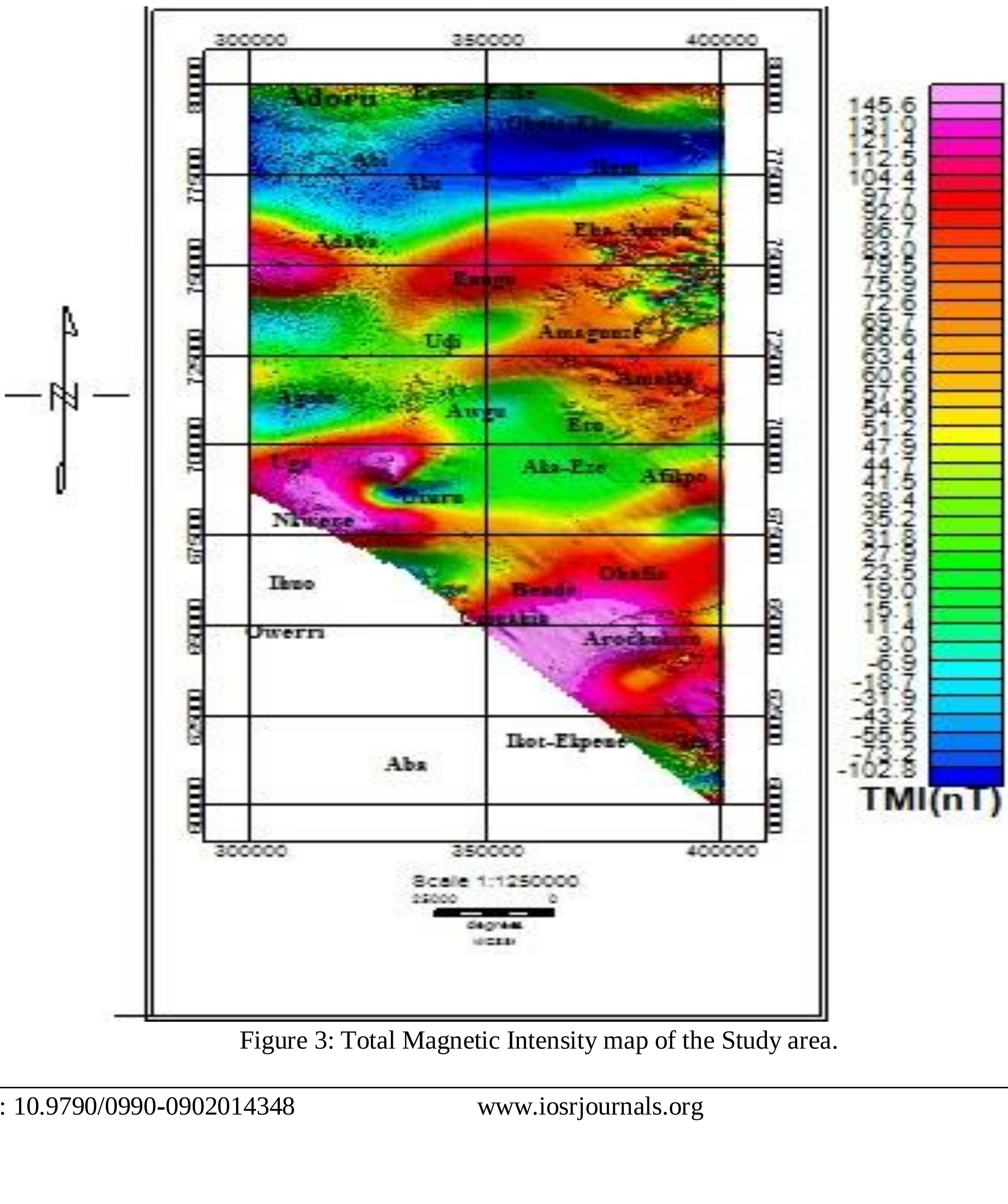

Figure 3: Total Magnetic Intensity map of the Study area.

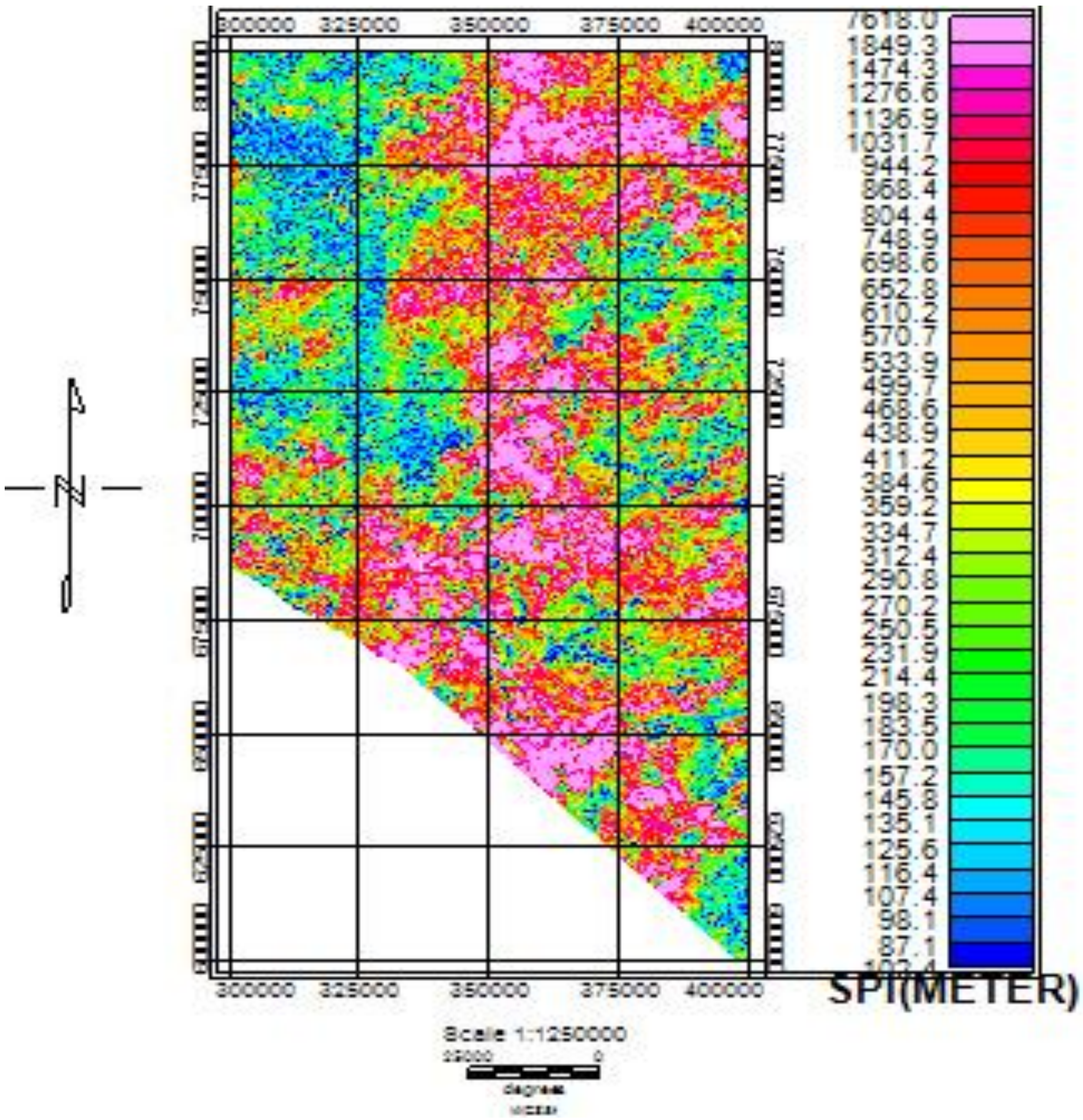

Figure 4: Source Parameter Imaging of the Study Area

V. Conclusion

Magnetic anomaly is a diagnostic property to decipher the nature of rocks and minerals in the subsurface. It is also used to determine the depth of basement rocks which is a parameter in deciphering the mineralogical and hydrocarbon potential of an area. For the study area, the eight aeromagnetic data sheets were analyzed and it reveals that the study area is mainly viable for mineralogical exploration and this agrees with the findings of other researchers like [11, 22] who have also succeeded in identifying some of the minerals in the area to include but not limited to: lead, zinc, fluorites, calcites, graphite, sulphide and kaolinitic minerals.

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