CONFERENCE PROCEEDINGS, JANUARY 2025
Published by the Faculty of Science (FSC), FULafia
print ISSN: 2354-3388 DOI: https://doi.org/10.62050/fscp2024.413

A Review of Interpretation of Airborne Geophysical Data for Hydrocarbon, Geothermal Energy and Minerals Prospecting over Middle Benue Trough Nigeria

Sunday Ayigun[1]✉, Oladiran Johnson Abimbola[2], Shekwonyadu Iyakwari[3], Taiwo Adewumi[2] & Muhammed Mustapha Adejo[2]
[1]Department of Physics with Electronics, Federal Polytechnic Mubi, Adamawa State, Nigeria
[2]Department of Physics, Federal University of Lafia, Nasarawa State, Nigeria
[3]Department of Geology, Federal University of Lafia, Nasarawa State, Nigeria
✉ vicdan2016@gmail.com

Abstract: This paper focuses on the review of the interpretation of airborne geophysical data for hydrocarbon, geothermal energy, and minerals prospecting over the Middle Benue Trough of Nigeria by previous researchers in the field of geophysics and other geosciences. The objectives of the research include: to reveal the significance of aeromagnetic data interpretation for geothermal energy and mineral exploration, to determine the potency of spectral analysis techniques for geophysical data interpretation, and to determine the gap in geophysical techniques previously used in the area. Based on the reviewed papers, it was observed that Oasis Montaj software plays an imperative role in the area of aeromagnetic data, aero radiometric data, and aero gravity data interpretation using spectral analysis with different techniques for the identification of potential zones for hydrocarbon maturation sediment, geothermal energy, and minerals. There is possibility of hydrocarbon deposits occurrence, geothermal energy, and minerals at the Middle Benue Trough based on the research findings of the previous researchers. In order to achieve this, there is need to put more effort in the integration of geophysical techniques at the Middle Benue Trough to get detailed information about the hidden targets.
Keywords: Airborne data, geothermal energy, hydrocarbon, Middle Benue Trough

Introduction

Nigeria is endowed with an abundance of solid minerals, hydrocarbon reserves, and geothermal energy potential, to name a few [1, 2]. In order to explore and exploit these mineral deposits, which have the potential to be a conduit for Nigeria's industrial and economic development, geophysicists, geologists, and other geoscientist's application of geophysical techniques becomes crucial in this regard. Earth scientists employ the technique of airborne geophysical exploration to examine vast areas of uncharted territory, intricate topography, or inaccessible locations of significance. Fixed-wing aircraft, helicopters, and space satellites are used to carry out this technique. According to Ani *et al.* [3], the methods can be utilized to disclose the various characteristics of bed rock or soils, from the surface to many kilometers below it.

Researchers have achieved great success over the years in applying various techniques for interpreting aerial geophysical data. Aeromagnetic and Radiometric data are among the data that are interpreted [3, 4, 5, 6, 7, 8, 9, 10]. The Middle Benue Trough is situated in Nigeria, between latitudes 08 50^0N and 09 50^0N and longitudes 09 00^0E and 10 00^0E. Following the tectonic evolution of the Africa-South America split during the Aptian epoch and the emergence of the South Atlantic Ocean during the Cretaceous period, the Middle Benue Trough emerged as a linear rift system going NE-SW. Following this split, the South Atlantic Margin, the Gulf of Guinea, and the Benue Trough formed the triple junction [4].

This paper attempts to review various techniques for airborne geophysical data for hydrocarbon, geothermal energy and mineral exploration prospecting over Middle Benue Trough Nigeria.

The objectives of the review are as follows;

i) To reveals the significant of aeromagnetic data interpretation for geothermal and mineral exploration.
ii) To determine the potency of spectral analysis techniques for geophysical data interpretation.
iii) To determine the gap of geophysical techniques used for data interpretation at the Middle Benue Trough Nigeria

Search strategy

The primary sources of information for this peer-reviewed work were papers about Nigerian geothermal exploration. Research Gate, Google Scholar, Science Direct, Workshop, and Conferences were among the search engines from which these papers were retrieved. Articles and publications were located, vetted, and reviewed with the help of a preferred reporting item for systematic reviews and meta-analysis (PRISMA).

Selection criteria

Our choices were based on earlier, comparable studies that provided complete access to English language texts discussing the interpretation of high-resolution aeromagnetic, gravity, and radiometric data using Oasis Montaj software and various approaches for the exploration of geothermal energy.

Maduenyi *et al.* [4] conducted research on the interpretation and analysis of aeromagnetic data over Nigeria's Middle Benue Trough. For this analysis, high-resolution aeromagnetic data was used; the Middle Benue Trough includes parts of Gboko, Markurdi, Katsina-Ala, and Takum. Using source parameter imaging and spectral analysis methods, the depth to the basement and the assessment of hydrocarbon accumulation were established. Using the vertical derivative method and upward continuation, the area's structural features and basement morphology were identified. To get the outcome, MATLAB and Oasis Montaj 6.42 software were used. The results were obtained using Source Parameter Imaging (SPI). The qualitative analysis revealed lineaments with trend directions in the N-S, NE-SW, NWSE, and E-W directions, with the NE-SW being dominant. The depth to basement within the trough was found to be 3.72 to 0.85 *km*, the depth to magnetic basement was estimated to be at 3.42 *km*, and the average for the shallow depth was at 0.80 *km*.

According to Osinowo *et al.* [5], the assessment of the Middle Benue Basin's oil potential in East Central Nigeria was conducted utilizing high-resolution aeromagnetic data that was augmented, processed, and filtered to extract various derivatives and magnetic properties. Based on the study of aeromagnetic data, a shaped sedimentary mass confined to the north-west and south-east by the rocks of the Basement Complex spans 350 *km* in a NE-SE trend. Based on the results, the area under investigation may have hydrocarbon potential in a sedimentary basin with widespread deposits in the southern and western regions.

Ikumbur *et al.* [7] used radiometric and aeromagnetic methods to assess the geothermal energy potential of some areas of Middle Benue Trough Nigeria. The data on was digitized and compiled. The contoured maps that were created indicate the existence of radiometric elements (K, Th, and U) based on the data analysis. Geothermal gradient high and low locations are shown by the radiometric heat model. The quantitative interpretation indicates that there are variations in depth to anomalous magnetic sources between 0.76 and 4.46 *km*, depth to centroid between 7.29 and 19.6 *km*, Curie point variation between 12.70 and 37.22 *km*, geothermal gradient variation between 15.58 and 45.670 *C/km*, and geothermal heat flow variation between 38.9 and 114.17 mW/m^2.

Research on the existence of subsurface structures from the interpretation of crustal architectural structure near Ibi, Middle Benue, Nigeria, using aeromagnetic data was conducted by Salawu *et al.* [8]. The depth values to the local structural features were estimated using the 3D Euler deconvolution approach, while the depth to magnetic sources was measured using Source Parameter Imaging techniques. The second map displays two significant sub-basins with depths ranging from 2700 to 3300 *meters*. In addition to the significant results on sub-surface configuration, which is crucial for mineral and hydrocarbon exploration, the thickness of the sedimentary formation yielded may actually lead to hydrocarbon exploration in the area. The study's goals and purpose were achieved.

In order to improve high resolution aeromagnetic signal for structural depth research across the Middle Benue Trough in Nigeria, Ejiga *et al.* [9] worked on integrating digital edge enhancers. Two – source depth model is revealed by spectral analysis of the data set over the area in question. The origin of the deep depth, which has an average of 0.8 *km* and varies from 1.9 to 6.1 *km*, is determined by the magnetic signals of near-surface igneous intrusion from the post-Cretaceous period as well as other magnetized bodies trapped in the sediment. The region's pre-existing tectonic structure governs the spatial distribution of numerous hydrothermal minerals, including lead, zinc, and barite deposits, as well as mineralization. These minerals are related with the widespread Tertiary-recent magnetism.

In order to ascertain the sedimentary thickness for hydrocarbon maturation and accumulation, Nwogwugwu *et al.* [11] used high resolution aeromagnetic data to measure the depth to basement rocks over portions of the Middle Benue Trough, North Central Nigeria. Order one polynomial fitting was used to perform the regional/residual separation on the data. During the data analysis, Source Parameter Imaging was also utilized. The largest sedimentary thickness of 2.21 *km* is shown by the Source Parameter Imaging results in the farthest southern region of the region, which includes Kwolla and Shendam. Pankshim is at a minimum depth of 0.05 *km*. The results of the spectral analysis indicate that the greatest depth is 0.25 *km*, which is the same as the SPI, and the minimum depth is 0.51 *km*. Since the sedimentary thickness is less than 3.0 *km*, the result is not a viable zone for hydrocarbon development. The research's goal and objectives were accomplished.

Using high resolution aeromagnetic data and maximum slope techniques, Nwosu *et al.* [12] estimated the average depth of 3.66 *km* for the deep magnetic basement and 0.80 *km* for the shallow magnetic basement over a portion of the Middle Benue Trough in Nigeria. This was done using an empirical depth rule based on slope techniques. The deep magnetic source was calculated to have an average depth of 3.74 *km* using the half slope method and an empirical constant of 0.63. The findings showed that, under the right circumstances, the oldest geological formation–marine sediment dating back to the Albian era – and its average basement depth of 3.70 kilometers would be favorable for the storage of hydrocarbons. The study's goal was accomplished.

In order to identify possible zones for hydrocarbon exploitation and to determine the depth to magnetic sources in the region under investigation, Ayuba and Nur worked on the interpretation of high-resolution aeromagnetic data for hydrocarbon potentials over portions of Nasarawa and surroundings in North-Central Nigeria [13]. The results showed that the shallow anomaly, which may be the result of magnetic intrusions into the sediment, was assessed to be at 0.21 *km*, while the average depth to magnetic basement sources was 3.05 *km*. The findings indicate the likelihood of hydrocarbon potentials in the area, as the 3.05 *km* magnetic basement depth at the southern section of the area is equivalent to the depth of cretaceous sediment. The purpose and goals of the study were accomplished

Ndubuisi and Obinwa examined the potential for geothermal energy in Nigeria's central Benue Trough: Learning from aerial potential field data [14]. To find the Curie point depth, geothermal gradient, and heat flow within the study area, spectral analysis techniques were applied to the aeromagnetic data set. Geological and heat flow contour maps illustrating the locations of geothermal energy hot spots in the southern, western, and eastern regions of the regions were produced after the data underwent both qualitative and quantitative data analysis. Good geothermal energy exploration and exploitation is located in the hot spot. The study's goals were accomplished through research.

In order to estimate the Curie point depth isotherm of portions of the Middle Benue Trough, North East, and Nigeria, Aliyu *et al.* [15] evaluated high resolution aeromagnetic data. Using polynomial fitting, regional/residual separation on the total magnetic intensity was applied to the magnetic data. The result showed that the curie isotherm depth ranged from 17.04 *km* to 27.40 *km*, with an average value of 22.5 *km*. The study's findings suggested that there may be some possibility for geothermal energy exploration in the region. The study's goal and purpose were accomplished.

Using the Power Spectrum and Source Parameter Imaging Technique, Okwesili *et al.* [16] conducted a geophysical study of aero gravity anomalies over the Lafia and Akiri regions of the Middle Benue Trough, Nigeria. The greatest predicted value of the basement depth, according to Power Spectrum study, is 5.6 kilometers. The initial vertical derivatives and horizontal gradient were applied to the data using Oasis Montaj Software in order to calculate the SPI depth of the gravity data. Both shallow and deep lying gravity anomalous entities had depth values ranging from -983.2 to -5572.6 meters, according to the source Parameter Imaging. According to the results, the accumulation of petroleum and hydrocarbons is influenced by the depth to the basement and the density contrast. The study's goal and purpose were accomplished.

Using a variety of methods, including Polynomial Fitting Order, Analytical Signal, Source Parameter Imaging, and Spectral Analysis, Salako *et al.* [17] analyzed aeromagnetic data to quantify sedimentary thickness over portions of the Middle Benue Trough, North East Nigeria. A sedimentary thickness ranging from 101.8 to 2550.0 *m* is indicated by the SPI result. An estimate of the research area's depth with sedimentary thickness ranging from 1.20 *km* to 3.20 *km* was obtained using spectral analysis. In line with the hydrocarbon (gas) buildup in the southern and central regions of the study area was the research's conclusion. The research's goal and purpose were fulfilled.

The Benue Trough in Nigeria is the source of gravity anomalies that [18] studied. The examination of the gravity data indicates that the anomalies are the center positive gravity of the order of approximately +40 *mGal* surrounding the Otukpo area, which is explained by the contribution of an igneous intrusive (2.76 *g/cc*) somewhat syenite intrusion. The Anambra Basin, where a thicker sediment fill of 8.4 *km* is estimated, is consistent with the negative gravity anomaly of -33 *mGal*. According to the analysis of the gravity anomalies beneath the Nigerian Peninsula's Benue Trough, intrusions are firmly isolated from the anticlinal folded axis. Maps showing the locations of the volcanic extrusive bodies surrounding the Gboko and Oban massif basements, north of Calabar, were created.

The goal of Alfaifi *et al.* [19] exploratory assessment of geothermal resources in a portion of Nigeria's Middle Benue Trough was to identify the geothermal potential region within the study area by interpreting airborne potential field data using spectral analysis techniques. The findings showed that the Curie depth point is located between 6.0 and 16 *kilometers*. Thin CPD (6.0–8.0 *km*) is a defining feature of Abakaliki anticlinorium santonian intrusions, which are connected to Gboko Anticlines (GA). The high values of heat flow (HF) (>155 mW/m^2) and geothermal gradient (GG) (>740 *c*/*km*) dominate the mapped geothermal anomalies within the GA with shallow CPD (< 8.0 *km*). The study's goals and purpose were fulfilled.

In order to ascertain the type of mineralization and the depth to basement of the studied area, Emeka *et al.* [20] conducted forward and inverse modeling of aeromagnetic anomalies across portions of the Middle Benue Trough, Nigeria. The data was interpreted using Potent Q and Oasis Montaj software. The outcome indicates that the bodies' magnetic susceptibility at depths of 4650, 1160, 2420, 980, and 3420 *meters* was, following forward and inverse modeling of profiles 1–5, 0.0400, 0.0003, 0.0002, 0.0001, and 0.0250, respectively. The highest magnetic susceptibilities were found near Akiri in the northeastern section of the study area; the region has a higher likelihood of hydrocarbon accumulation. The magnetic susceptibilities are correlated with the presence of minerals like pyrites and graphite as well as rock types like granite, limestone, Schist, guesis, and marble.

In order to identify mineral reserves, Adonu *et al.* [21] analyzed aircraft radiometric data of Nigeria's Middle Benue Trough. To develop an enhanced observed radiometric distribution of the radioactive element (Potassium, Thorium, and Uranium), the data was interpreted using the minimal curvature approach utilizing Oasis Montaj 8.4 software. The count rates for uranium, thorium, and potassium were 1.67–6.21 *ppm*, 6.79–27.71 *ppm*, and 0.11–3.75%, respectively, according to the ternary image of the primary radiometric. In the studied area, radioactive elements are highly concentrated.

Discussion

Findings from the literature review, spectral analysis of aeromagnetic, aero-radiometric, and aero- gravity data is essential for mineral discovery in the fields of geophysics and geoscience. This reviewed work demonstrated the importance of interpreting aeromagnetic data in the context of geothermal and hydrocarbon exploration, depending on the depth to magnetic sources and the concentration of hydrocarbon deposits,

respectively. Because of the high concentration of radioactive elements, radiogenic heat formation, Curie point depth, and geothermal gradient in the study area of some research work, the interpretation of radiometric data with Oasis Montaj led to the identification of geothermal energy potential zones. Additionally, the interpretation of gravity data at the Middle Benue Trough reveals gravity anomalies of some of the buried minerals beneath the earth surface.

Conclusion

This reviewed paper includes a review of the literature on earlier studies conducted in Nigeria's Middle Benue Trough. The researchers used Oasis Montaj Software to conduct their study in the Middle Benue Trough of Nigeria using the Spectral Analysis method of data interpretation. They employed a variety of techniques, including quantifiable and qualitative techniques, Source Parameter Imaging (SPI), regional and residual separation, forward and inverse modeling, analytic signal, and polynomial fitting order. Some research work identified potential zones for minerals exploration, hydrocarbon maturation sediment, and geothermal energy exploration; however, some areas did not yield positive results based on the aim and objectives of the research. These techniques produced some positive results at the Middle Benue Trough.

Recommendations

The analyzed study led to the following recommendations being made:

1. Integration of geophysical techniques at the Middle Benue Trough in Nigeria requires further effort.
2. In addition to the previous approach utilized in the area, other methods such as remote sensing, radiometric method, and satellite imaging are needed to obtain more detailed information about the possible zones for mineral exploration.

References

[1] Nur, A. M., Onuha, M. K. & Ofoegbu, O. C. (1994). Spectral analysis of aeromagnetic data over the Middle Banue Trough, Nigeria. *Journal of Mining and Geology*, 30(1), 211-217.

[2] Bamidele, F.F. (2018). Geology and mineral resources of Kogi State, Nigeria. *International Journal of Multidisciplinary Science and Engineering*, 9(7), 7-12.

[3] Ani, E. P., Ugwu, G. Z. & Nwobodo, A. N. (2023). Geophysical Interpretation of Airborne Radiometric Data over parts of Middle Benue Trough Nigeria for Mineral Deposit. *International Journal of Research in Engineering and Science*, 11(2), 335-343.

[4] Manduenyi, A. C., Haruna, O. E., Okehie, B. M., Abdulsalam, N. N. & Olna, R.I. (2022). An aeromagnetic data analysis and interpretation over Middle Benue Trough Nigeria. *International Journal of Advanced Research in Physical Science*, 9(4), 1-18.

[5] Osinowo, O. O., Akanji, O. A., Sanuade, A. O. & Esho, O. O. (2023). Hydrocarbon potential evaluation of Middle Benue Besin, East Central Nigeria using high resolution aeromagnetic data. *Result in Geophysical Science*, 14. https://doi.org/10.1016/j.ringps2023.100058.

[6] Abdulsalam, N. N., Ogoh, K. E. & Ologe, O. (2022). Evaluation of structural frame work and depth estimate using high resolution airborne magnetic data over some parts of Middle Benue Trough Nigeria. *International Journal of Geosciences*, 13, 557-575. https://doi.org/10.4236/ijg.2022.137030

[7] Ikumbur, E. B., Onwuemesi, A. G., Anakwuba, E. K., Chiwuko, A. I. & Usman, A. O. (2023). Evaluation of geothermal energy potential of parts of the Middle Benue Trough Nigeria: aeromagnetic and aeroradiometric approach. *Iranian Journal of Geophysics*, 16(4), 37-52.

[8] Salawu, B. N., Orosun, M. M., Adebiyi, S. L., Abdulraheem, Y. T. & Dada, S. S. (2020). Existence of subsurface structure from aeromagnetic data interpretation of crustal architecture around Ibi, Middle Benue Nigeria. *Spring Nature Journal*, 2(427). https://doi.org/10.10007/s42452-020-2230-5

[9] Ejiga, E. G., Ismail, N. E. H. & Yusuff, I. (2021). Implementation digital edge on improve high resolution aeromagnetic signals for structural – Depth analysis around the Middle Benue Trough, Nigeria. *Minerals*, 11, 1247. https://doi.org/10.3390/min11111247.

[10] Ademola, O., Akingboye. A. S. & Ojamomi. A. I. (2018). Radiometric survey in geological mapping of parts of basement complex area of Nigeria. *Vietriam Journal of Earth Science*, 40(3), 288-298. https://doi.org/10.15625/0866-7187/40/3/12619

[11] Nwogwugwu, E. O., Salako, K. A., Adewumi, T. & Okwokwo, I. O. (2017). Determination of depth to basement over parts of Middle Benue Trough, North Central Nigeria, using high resolution aeromagnetic data. *Journal of Geology and Mining Research*, 9(3), 18-27. https://doi.org/10.5897/JGMR2017.0276

[12] Nwosu, O. B. & Onuba, L. N. (2023). Evaluation of the magnetic depth over parts of Middle Benue Trough Nigeria by empirical depth rule base on the slope techniques using the HRAM. *Interpretation Journal of Scientific & Technology Research*, 2(11), 19-22.

[13] Ayuba. A. R. & Nur, A. (2019). Interpretation of high resolution aeromagnetic data for hydrocarbon potentials over parts of Nasarawa and Environs North Central Nigeria. *World Journal of Applied Physics* 4(1), 1-11.

[14] Ndubuisi, G. E. & Obinwa, O. (2023). Investigating the geothermal energy potentials within the central Benue Trough Nigeria: Insight from airborne potential field data. *International Journal of Innovative Science and Research Technology*, 8(3), 2420-2429.

[15] Aliyu, A., Salako, A. K., Adewumi, T. & Mohammed, A. (2018). Interpretation of high-resolution aeromagnetic data to estimate the Curie point depth isothern of parts of Middle Benue Trough, North East, Nigeria. *Physical Science International Journal*, 7(3), 1-9. https://doi.org/10.9734/PSIJ/2018/38651

[16] Okwesili, N. A., Nneka, F. O. & Orji, P. O. (2020). Geophysical survey of aerogravity anomalies over Lafia and Akiri regions of Middle Benue Trough Nigeria, employing Power Spectrum and Source Parameter Imaging Technique. *IOSR Journal of Applied Physics*, 58-68.

[17] Salako, K. A., Adetona, A. A., Rafiu, A. A., Alhassan, U. D. & Alkali, A. (2019). Determination of sedimentary thickness over parts of Middle Benue Trough, North–East, Nigeria using aeromagnetic data. *2nd School of Physical Science Biennial, International Conference FUT Minna*, 2019.

[18] Abdullahi, M. & Singh, U. K. (2018). Basement geology derived from gravity anomalies beneath the Benue Trough of Nigeria. *Arab Journal Geoscience*, 11, 694. https://doi.org/10.1007/s12517-018-4065-6

[19] Alfaifi, J. H., Ekwok, E. S., Ulem, A. C., Eldosouky, M. A., Oyaysi, S., Abdelrahman, K., Andras, P. & Akpan, E. A. (2022). Exploratory assessment of geothermal resources in some parts of Middle Benue Trough Nigeria using airborne potential field data. *Journal of King Saud University-Science*, 35, 102521. http://doi.org/10.1016/jjksus.

[20] Emeka, G. O., Zeruwa, G. U. & Austin, O. (2019). Forward and inverse modelling of aeromagnetic anomalies over parts of Middle Benue Trough Nigeria. *American Journal of Geophysics, Geochemistry and Geosystem*, 5(1), 16-23.

[21] Adonu, I. I, Ugwu, G. Z. & Onyisbi, G. E. (2022). Interpretation of Airborne Radiometric Data of part of Middle Benue Trough of Nigeria for mineral exploration deposit. *I0SR Journal of Applied Geology and Geophysics*, 10(1), 58-62. https://doi.org/10.9790/0990-10010z5862