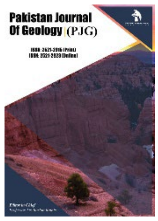
ZIBELINE INTERNATIONAL™ PUBLISHING

ISSN: 2521-2915 (Print)
ISSN: 2521-2923 (Online)
CODEN: PJGABN

Pakistan Journal of Geology (PJG)

DOI: http://doi.org/10.26480/pjg.02.2024.113.117



CrossMark

RESEARCH ARTICLE

THE MAPPING OF MINERAL POTENTIAL ZONES IN THE BAUCHI AREA, NORTHEAST NIGERIA, USING AEROMAGNETIC DATA.

A. Mamudu[a], E.S. Akanbi[a], and S.C. Odewumi[b]

[a]Department of Physics, University of Jos, Plateau State, Nigeria
[b]Department of Science Laboratory Technology, University of Jos, Plateau State, Nigeria3
Corresponding Author Email: mamuduafizu@yahoo.com

ARTICLE DETAILS

Article History:

Received 23 June 2024
Revised 09 July 2024
Accepted 23 August 2024
Available online 26 August 2024

ABSTRACT

The present study focuses on the Mapping of Mineral Potential Zones of the Bauchi area in Northeastern Nigeria from Aeromagnetic Data. The aeromagnetic data was enhanced using the first vertical derivative, horizontal derivative, analytic signal and centre for exploration targeting (CET) techniques. The software used to process the data are ArcGIS, Oasis montaj® andRockworks. The total magnetic anomalies ranged from -29822 to 508.9 nT. The high magnetic anomalies could be from underlying ferromagnesian rocks while the low magnetic anomalies could be from granitic intrusions in the Bauchi area. The first vertical derivative and horizontal gradient map revealed short wavelength anomalies with relatively high frequency caused by shallow seated features assigned to igneous intrusions. The analytic signal map revealed clusters or high amplitude of analytic signals which is an indication of shallow seated intrusions of different shapes that could be associated with mineralization. The lineament map shows linear structures that could be faults, joints and dyke that indicated the study area has undergone structural deformation and the corresponding rose plot reveals linear structures that trend in ENE–WSW, ESE–WNW, NE–SW, SE–NW, N-S and E-W directions. This shows that minerals in the study area are structurally controlled. The mineral potential map shows that Jimbin, Jangu, Kafi Madaki, Rauta, Nasarawa, Dabin-Kasa, Waya, Tsakani, Gidajo, Tafawa Balewa, Balowa, Bagoro, Dull, Bala and Kanam areas have mineral potential zones.

KEYWORDS

Aeromagnetic, data, Mapping, Mineral and potential.

1. INTRODUCTION

Minerals can be found along geological structures such as faults, joints and dykes that accommodate hydrothermal fluids which contain large amounts of dissolved minerals to the earth's surface and these minerals can be identified using geophysical tools and other geological processes (Olasunkanmi et al., 2018). Analytic signal technique was used to interpret the residual magnetic field of Naraguta area, and it was observed that a high analytic signal implied younger granite intrusion (Akanbi and Ugodulunwa, 2014).

Mineral potential zones was delineated from aeromagnetic data over part of Nasarawa state using first and second vertical derivatives, downward continuation, analytic signal and tilt derivative method (Adewumi and Salako, 2017). The lineament that could be a host to minerals trending NE-SW was observed. A study in 2017 interpreted aeromagnetic data of the Naraguta area to identify the subsurface structures and the mineralization zone using reduction–to–equator, upward continuation and first vertical derivatives (Ngama and Akanbi, 2017). Granitic intrusions, long narrow features (which could be dykes or long ore bodies) and dislocations (which could be due to subsurface fractures) were observed.

Surface and subsurface structural interpretation were carried out over the younger granite province from high aeromagnetic data using horizontal derivatives, analytical signal, Euler deconvolution and source parameter imaging (Sabinus et al., 2018). The result showed major lineaments that are mineral zones trending NE – SW was observed. A study used high-resolution aeromagnetic data to study the subsurface geology and structural framework of Potiskum and its environs (Yusuf et al., 2019). Analytic signal, source parameter imaging and extraction of linear structures were used on the residual data to reveal the sub-surface geology and structural framework of Potiskum and its environs. The results show both high and low magnetic anomalies trending in the major directions of E-W and NE-SW with the longest linear structure (fractures) stretching up to 38.6 km in length. Researchers mapped the presence of intrusive structures in the Chad Basin using derivatives of aeromagnetic data (Yusuf et al., 2022). The enhanced body and edges suggested a dyke-like structure intruding the Chad Basin.

This study aims to map mineral potential zones of the Bauchi area in northeastern Nigeria from aeromagnetic data. The study area is located predominantly in Bauchi State and the northern part of the plateau state on longitudes 9°30ꞌ to 10°30ꞌE and latitudes 9°30ꞌ to 11°00 N with a total area of 18150km2 as presented in Figure 1. The rock types present in the study area are Quartz porphyry, biotite granite, hornblende granite, coarse porphyritic hornblende granite, fine-grained biotite granite, medium-coarse-grained biotite granite, biotite granite, charnockitic rock, granite gneiss, migmatite gneiss, migmatite and sedimentary rock as shown in Figure 2.

2. MATERIALS AND METHOD

Data used for this research include a soft copy of six topographic maps of aeromagnetic data that were acquired from the Nigerian Geological Survey Agency (NGSA) on a map scale of 1:100,000 series. The data were obtained

Quick Response Code	Access this article online	
	Website: www.pakjgeology.com	**DOI:** 10.26480/pjg.02.2024.113.117

Cite The Article: A. Mamudu, E.S. Akanbi, and S.C. Odewumi (2024). The Mapping of Mineral Potential Zones in The Bauchi Area, Northeast Nigeria, Using Aeromagnetic Data. *Pakistan Journal of Geology, 8(2): 113-117.*

using a proton precession magnetometer with a resolution of 0.01nT. Each sheet has an area of 55km by 55km giving a total area of 18150km[2].

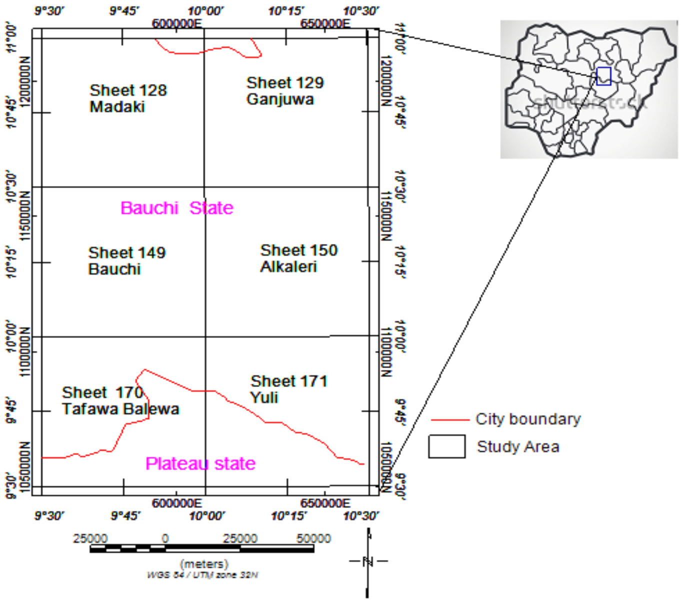


Figure 1: Location of the Study Area

The various map sheets obtained were processed and merged into a common dataset. The geomagnetic gradient (33000nT) was removed from the data using the International Geomagnetic Reference Field (IGRF 2010). A soft copy of the Geology map (Figure 2) published by NGSA at the same scale as the magnetic data was also acquired to actualise this study. Software such as Arc GIS, Oasis Montaj and Rockworks were acquired to process the data. To facilitate the interpretation of the data, reduction to the equator, first vertical derivative, horizontal derivative, analytic signal, and centre for exploration targeting (CET) techniques were used.

2.1 First vertical derivative

This technique enhances short wavelength and is relatively insensitive to noise. It is used for delineating near-surface lineaments and contacts (Ahmed et al., 2018). The first vertical derivative is a useful technique in processing magnetic data by enhancing shallow sources and suppressing deeper sources (Reeve et al., 2009). The transform is a useful interpretation tool in the determination of shallow seated fractures and faults by making the edges of shallow seated anomalies sharper or clearer.

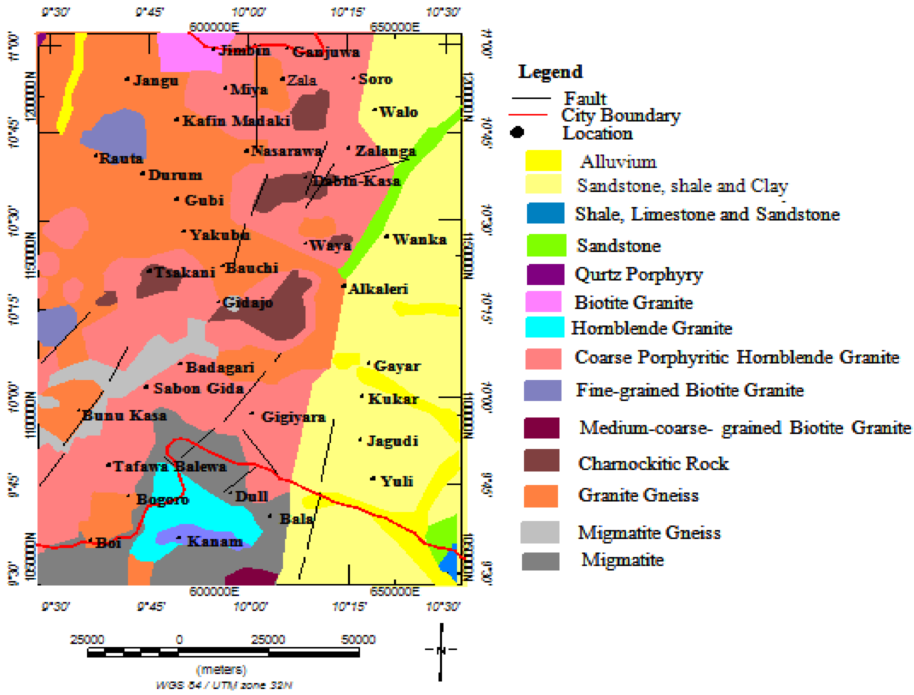


Figure 2: Geology Map of the Study Area (NGSA 2019)

The first vertical derivative is obtained from the Laplace equation (Ibraheem et al., 2019);

$$\frac{\partial T}{\partial z} = -\left(\frac{\partial T}{\partial x} + \frac{\partial T}{\partial y}\right) \quad (1)$$

Where T is total magnetic field vector, $\frac{\partial T}{\partial z}$, $\frac{\partial T}{\partial x}$ and $\frac{\partial T}{\partial y}$ are first vertical derivatives in x, y and z directions respectively.

2.2 Horizontal Gradient

This technique was applied to the study to calculate the horizontal derivatives in the x and y directions. This process involves the enhancement of high-frequency anomalies and the sharpening of the edges of geological bodies. It is used to map the outline of geological structures such as faults, joints, dykes and igneous intrusions. According to Milligan and Gunn in 1997, the Horizontal gradient is given as;

$$\text{Horizontal gradient } (HG_{X,Y}) = \left[\left(\frac{\partial T}{\partial x}\right)^2 + \left(\frac{\partial T}{\partial y}\right)^2\right]^{\frac{1}{2}} \quad (2)$$

Where $\frac{\partial T}{\partial x}$ and $\frac{\partial T}{\partial y}$ are horizontal derivative in x and y direction respectively (Milligan and Gunn, 1997)

2.3 Analytic signal method

The analytic signal method is very useful for delineating magnetic source location and the magnitude of analytic signal peaks over magnetic contacts (Oladunjoye et al., 2014). An analytic signal filter was applied to the study because it will help to identify the location of sub-surface igneous intrusions and map the edges and contact of sub-surface bodies. Since Nigeria is located at a low magnetic latitude, an analytic signal was suitable to delineate and locate geologic boundaries of geomagnetic bodies (Phillips, 2000). The amplitude of the analytic signal in the 3-D case is given by:

$$[a(x,y,z)]=\sqrt{\left(\frac{\partial\varphi}{\partial x}\right)^2+\left(\frac{\partial\varphi}{\partial y}\right)^2+\left(\frac{\partial\varphi}{\partial z}\right)^2} \quad (3)$$

Where, $\frac{\partial\varphi}{\partial x}$, $\frac{\partial\varphi}{\partial y}$, and $\frac{\partial\varphi}{\partial z}$ are analytic signal amplitude in x, y and z direction.

3. RESULT AND DISCUSSION

3.1 First Vertical Derivative (FVD) maps

First vertical derivative (FVD) map improves and sharpens anomalies over causative bodies. The FVD map presented in Figure 3 shows inferred faults, fractures, folds, contacts and to some extent the shape of some lithologic contacts which indicate structural features. The map shows relatively short wavelength (relatively high frequency) anomalies caused by shallow seated features assumed to be geological structures. The map was observed to consist of local anomalies trending in ENE – WSW ESE – WNW, NE – SW, SE – NW, N - S and E –W directions which could result from near-surface structures such as fractures and igneous intrusions like dykes cross-cutting the country rocks within the study area.

The study area is underlain by relatively high-frequency anomalies which suggest the presence of near-surface causative bodies except in the southeastern part of the study area which indicates the presence of deep-seated geological structures and sedimentary cover. High-frequency anomalies were observed at Jimbin, Jangu, Kafi Madaki, Rauta, Nasarawa, Dabin- kasa, Waya, Tsakani, Gidajo, Tafawa Balewa, Balowa, Bagoro, dull, Bala and Kanam is structurally controlled. The lineaments distinguish the edges of the magnetic source bodies which may signify the locations of the faults, fractures, folds or contacts. The regions with high linear deformations are suggested potential sites for mineralization. Similar observations were made by researchers in their various geophysical works that involve mapping of geological structures associated with mineralization (Yusuf et al., 2019; Oladunjoye et al., 2014; Phillips, 2000)

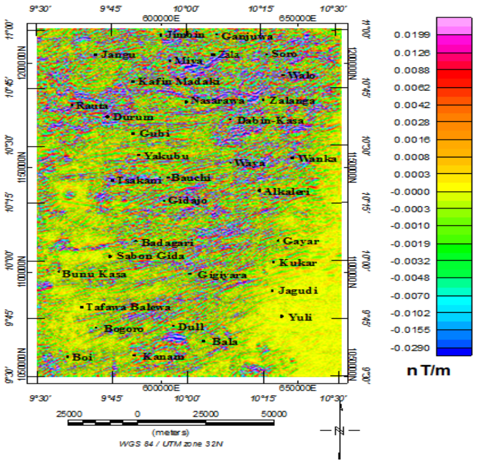


Figure 3: First Vertical Derivative Map of the Study Area

3.2 Horizontal Gradient map of the study area

The horizontal gradient map as shown in Figure 4 is used to estimate the linear structures such as contacts and faults. This filter was also used by researchers in a study for structural interpretation of the Northern Sokoto Basin (Stephen and Iduma, 2018). In this map, more accurate positions of faults, fractures and joints were observed in the study area compared to the results of first vertical derivative. The filter makes the geological structures (faults, fractures and joints) within the study area clearer, hence making it more visible for interpretation.

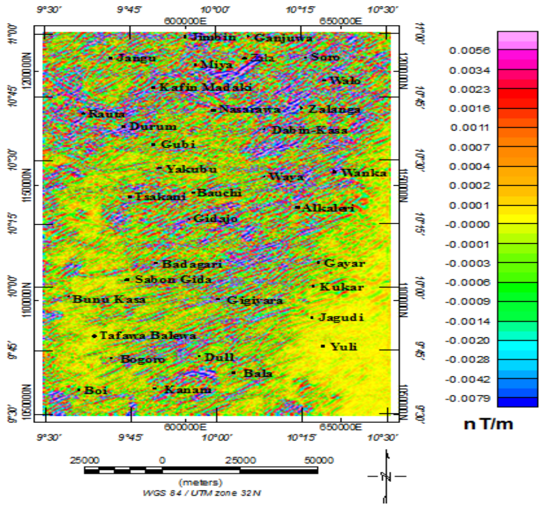


Figure 4: Horizontal Gradient Map of the Study Area

3.3 Analytic Signal (AS) map

The analytic signal map (Figure 5) of the study area shows linear structures which suggest geologic features which can serve as channels for mineralizing fluids. The analytic signal map showed variations in the magnetic properties of the magnetic sources and highlighted discontinuities and anomaly texture in the study area. The amplitude of the analytic signal is suggested to describe the shape of the causative bodies in the study area. The mapped maxima (ridges and peaks) in the calculated analytic signal map were observed to locate the anomalous body edges and corners. The strength of magnetisation of the underlain rocks in the study area suggests the amplitude of the analytic signal. On the analytical signal map of the study area (Figure 5), clusters of analytical signals identified in the area could be associated with older granites and migmatites which have been affected by four thermotectonic events namely Liberian, Eburnean, Kibaran and Pan-African. Thermotectonic events were accompanied by folding, faulting, granitization and metamorphism.

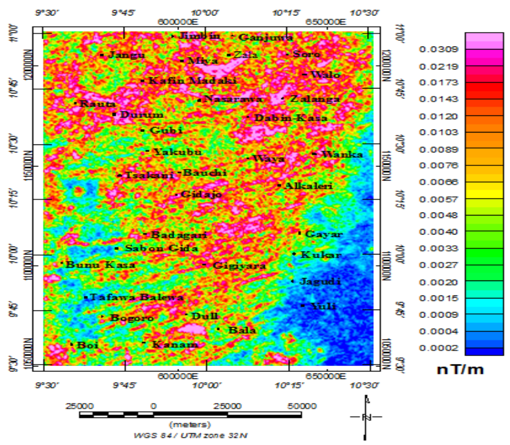


Figure 5: Analytical Signal Map of the Study Area

On the analytical signal map of the study area (Figure 5), clusters of analytical signals identified in the area could be associated with older granites and migmatites which have been affected by four thermotectonic events namely Liberian, Eburnean, Kibaran and Pan-African. Thermotectonic events were accompanied by folding, faulting, granitization and metamorphism hydrothermal alteration; therefore, hydrothermal deposits could be responsible for the peak signals. High analytic signal clusters were also observed at Jimbin, Jangu, Kafi Madaki, Rauta, Nasarawa, Dabin- kasa, Waya, Tsakani, Gidajo, Tafawa Balewa, Balowa, Bagoro, dull, Bala and Kanam. The production of an analytic signal map makes it easy to identify the contact of geological bodies and rocks of different degrees of magnetization

3.4 Lineament map of the study area

Lineaments which are features in a landscape that are expressions of the underlain geological structures such as faults, fracture zones, shear zones and igneous intrusions like dykes and veins were observed in Figure 6. Similar features were observed by researchers when they interpreted aeromagnetic data of the Naraguta area to identify the subsurface structures and the mineralization zone (Ngama and Akanbi, 2017)

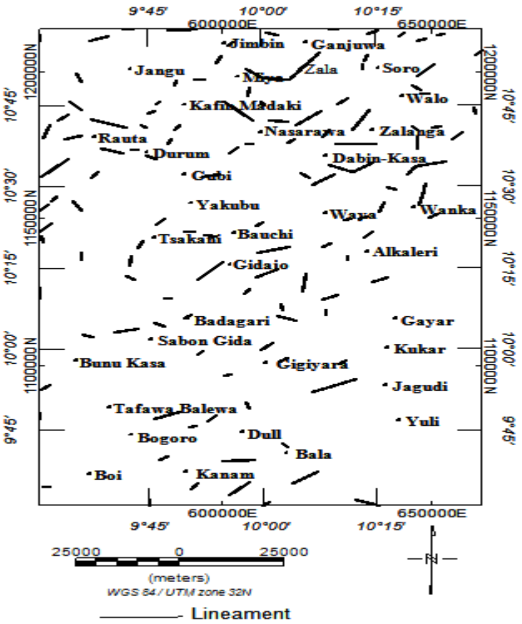


Figure 6: Lineament Map of the Study Area

The vectorisation map of the study area presented in Figure 5 was extracted from the residual map using the centre for exploration targeting techniques (CET) which reveals \the Bauchi area to be highly fractured with linear structures (faults). The map shows an uneven scheme of geological lineament, lithologic deformation and sub-surface lineaments with discontinuities (fractures) which might appear as joints, faults, share zones, pegmatitic veins, dykes, aplitic veins, quartz veins, rock contacts, intrusives and lineation which reveal the extent of tectonic deformation in the study area.

Linear structures trending in ENE-WSW, ESE-WNW, NE-SW, SE-SW, N-S and E-W direction were also observed. The orientation of the lineament shows the results of heterogeneity of the study area which reveals geologic features affecting Basement Complex. The lineaments show that the minerals in the study area are suggested to be located in fractures. The orientation of the lineaments was plotted on a rosette diagram and the result is shown in Figure 7. The same pattern of orientation was deduced from Figures 3, 4, 5 and 6. This result corresponds to what was obtained by (Anudu et al., 2014). The ENE – WSW structural trend corresponds with the structural trend of the Basement complex of Nigeria and it was believed to be tectonically induced while the E-W trends were assumed to be the oldest probably caused by Pre- Pan African events (Mullan, 1978; Yusuf, 2019). The study area constitutes part of the northeast Basement Complex of Nigeria which has experienced tectonic–metamorphic deformation whose resultant effect produced varied brittle and ductile structures (faults, folds, mineral stretching and foliation). These structures may serve as paths for emplacement of minerals within the study area.

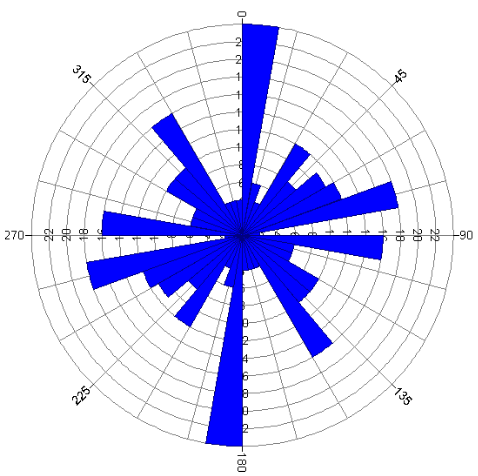


Figure 7: Rose plot of the study area

3.5 Mineral potential map

Mineral potential map as shown in Figure 8 was produced using Arc GIS software. The mineral potential zones were classified into high, moderate and low. The high and moderate mineral zones were observed around Jimbin, Miya, Ganguwa, Zala, Soro, Kafin Madaki, Zalanga, Wailo, Rauta, Nasarawa, Dabin- Kasa, Gubi, Tsakani, Waya, Gidajor, Gigiyara, Bogoro and Kanam areas. Minerals found in Bauchi State according to the Ministry of Foreign Affairs in 2023 are Gold, Cassiterite, Columbite, Wolframite, Iron, Gypsum and Clay. These minerals are suggested as the potential minerals that could be found in the study area.

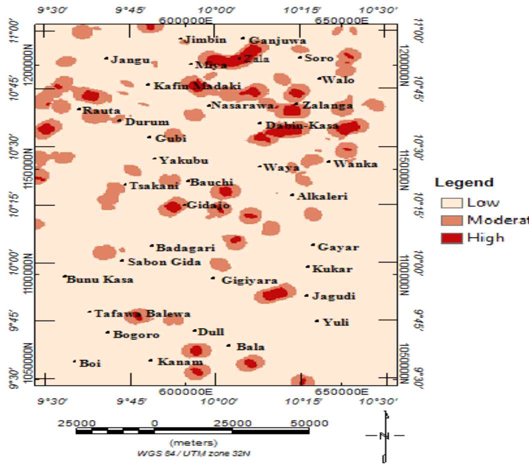


Figure 8: Mineral Potential Map of the Study Area

4. Conclusion

Aeromagnetic data of the Bauchi area was processed and enhanced using first vertical derivatives, horizontal gradient, analytic signal and centre for exploration targeting techniques. The first vertical derivative and horizontal gradient map show shallow, sharp and high-frequency anomalies which suggest underlain causative bodies in the study area. The analytic signal map shows a cluster of an analytic signal which indicates, fractures, discontinuity, faults and the shape of shallow causative bodies. The lineament map shows that the Bauchi area has undergone tectonic deformations. The rose plot shows that the linear structures in the study area trend NEN-WSW, ESE-WNW, NE-SW, SE-NW and E-W directions. The structural complexity of the study area indicates that mineralization of Jimbin, Jangu, Kafi Madaki, Rauta, Nasarawa, Dabin- kasa, Waya, Tsakani, Gidajo, Tafawa Balewa, Balowa, Bagoro, dull, Bala and Kanam is structurally controlled.

Acknowledgments

We thank the referees for the reasonable suggestions and recommendations to making this research a success.

References

Adewumi, T. and Salako, K. A., 2017. Delineation of Mineral Potential Zone Using High Resolution Aeromagnetic Data over Part of Nasarawa State, North Central, Nigeria. Egyptian Journal of Petroleum 27. Pp. 759-767,https://www.sciencedirect.com/science/article/pii/S1110062117302295

Ahmed, Z., Lawal, K. M. and Ahmed, A. I., 2018. Interpretation of High-resolution Aeromagnetic Data of Part of Southwestern Nigeria for Subsurface Mapping", Dutse Journal of Pure and Applied Science 4, Pp. 221 -235, https://www.researchgate.net/publication/382258874

Akanbi, E. S. and Ugodulunwa, F. X. O., 2014. Using Analytic Signal Technique in the Interpretation of the Residual Magnetic Field of Naraguta area, North-Central Nigeria". Nigerian Journal of Physics, 21, Pp. 29 – 35, https://www.researchgate.net/publication/343888987

Anudu G. K., Stephenson R. A. and Macdonald, D. M., 2014. Using High Resolution Aeromagnetic Data to Recognize and Map Intrasedimentary Volcanic Rocks and Geological Structures Across the Cretaceous Middle Benue Trough, Nigeria", Elsevier Journal of African Earth Science 99, Pp. 625–636, https://www.academia.edu/43783176/

Ibraheem, I. M., Haggag, M., and Tezkan, B., 2019. Edge detectors as structural imaging tools using aeromagnetic data: a case study of Sohag Area, Egypt", Geosciences. Multidisciplinary Digital Publishing Institute 9, Pp. 211, https://www.academia.edu/en/547777 67/

Milligan, P. R. and Gunn, P. J., 1997. Enhancements and Presentation of Airborne Geophysical Data, AGSO Journal of Australian Geology and Geophysics 17, Pp. 2 – this Issue, https://www.researchgate.net/publication/348413024

Mullan H. S., 1978. Structural Distinction between a Metasedimentary Cover and an Underlying Basement in the 600my old Pan- African Domain of Northwestern Nigeria, West Africa, Discussion. Geological Society of America Bulletin 89, Pp. 983- 984, https://www.ajol.info/index.php/swj/article/view/212379/200286

Natural Resources - Ministry of Foreign Affairs, Nigeria. 2024. Nigeria State and their Natural Resources". Retrieved January 26, 2024. https://foreignaffairs.gov.ng/nigeria/natural-resources. https://foreignaffairs.gov.ng/nigeria/natural-resources/

Ngama E. J. and Akanbi, E.S., 2017. Qualitative Interpretation of Recently Acquired Aeromagnetic Data of Naraguta Area, North Central Nigeria. Journal of Geography, Environment and Earth Science International 11, Pp. 1 – 14, https://www.researchgate.net/publication /319283686

Ngama E. J., and Akanbi E. S., 2017. Qualitative Interpretation of Recently Acquired Aeromagnetic Data of Naraguta Area, North Central Nigeria, Journal of Geography, Environment and Earth Science International 11, Pp. 1 – 14, https://www.researchgate.net/publication/319283686

Oladunjoye, H. T., Olasunkanmi, N. K. and Olaleye, A. O., 2014. Geophysical Evaluation of Magnetic Data of Okenugbo Area,Ago-Iwoye, Southwestern, Nigeria",Academic Journal of Interdisciplinary Studies. 3, Pp. 105 – 112, https://studylib.net/doc/11979652/

Olasunkanmi, N., Bamigboye O., Saminu, O., Salawu, N., and Bamidele T., 2018. Interpretation of High Resolution Aeromagnetic Data of Kaoje and its Environs, Western Part of the Zuru Schist Belt, Nigeria: Implication for Fe–Mn Occurrence, Heliyon, 6, Pp. 1-10, https://www.mdpi.com/2075-163X/12/10/1250

Phillips, J. D., 2000. Locating Magnetic Contacts: a Comparison of the Horizontal Gradient, Analytic Signal and Local Wavenumber Methods. In SEG Technical Program Expanded Abstracts, Society of Exploration Geophysicists, Pp. 402–405, https://www.mdpi.com/2076-3417/12/18/9078

Reeve, C., 2005. Aeromagnetic Survey: Principles, Practice and Interpretation, Geosoft, (2005). https://www.iosrjournals.org/iosr-jagg/papers/Vol.%206%20Issue%203/Version- 1/E0603015160.pdf

Sabinus, I. I., Ifeanyi O. A, Nasir, N. A., and Mosto, K. O., 2018. Improved Mapping of the Structural Disposition of some Younger Granite Ring Complexes of Nigeria using High Resolution Aaeromagnetic Data". Journal of Geology & Geophysics 7, Pp. 2 -13, https://www.researchgate.net/publication/327115535

Stephen O. I., and Iduma, U., 2018. Structural Interpretation of Northern Sokoto Basin, Using Airborne Magnetic Data, International Journal of Innovative Research in Science, Engineering and Technology, 7, Pp. 8041 – 8048, https://www.researchgate.net/publication/370376656

Yusuf, S. N., Imagbe, L. O., Yohanna, O. M., Ibrahim, Y., and Kuku, A. Y., 2022. Imaging Magmatic Intrusions Using Derivatives of High-resolution Aeromagnetic Data Over the Nigerian Sector the Chad Basin, Scientific African 16, Pp. 1-12, https://www.researchgate.net/publication/360376524

Yusuf, S. N., Kasidi, S., Kuku, A. Y., Ibrahim, Y. and Peter, G. M., 2019. Interpretation of High-Resolution Aeromagnetic Data over Potiskum and Environs, Northeastern, Nigeria, Journal of Mining and Geology 55, Pp. 139 – 146, https://www.researchgate.net/publication/354633490

Yusuf, S. N., Kasidi, S., Kuku, A. Y., Ibrahim, Y., and Peter, G. M., 2019. "Interpretation of High-Resolution Aeromagnetic Data over Potiskum and Environs, Northeastern, Nigeria", Journal of Mining and Geology 55, Pp. 139 – 146, https://www.researchgate.net/publication/354633490