Ilorin Journal of Science
FAPSCON 2024 PROCEEDINGS, 2024, pp. 189 – 197 (Printed in Nigeria)
ISSN: 2408 – 4840 © 2024 Faculty of Physical Sciences, University of Ilorin
https://doi.org/10.54908/iljs.fapscon.2024.11.03.1025

ILORIN
JOURNAL OF SCEINCE

ILJS-24-075 (SPECIAL EDITION)

Integrating Aeromagnetic and Resistivity Data for Geologic Interpretation of Igbeti Schist Belt, Southwestern Nigeria: Implication for Mineral Exploration

Abubakar H. O.[1], Adebisi W. A.[2*], Folorunso I. O.[1] and Olatunji S.[1]
[1] Department of Geophysics, University of Ilorin, Ilorin, Nigeria.
[2] Department of Physical and Chemical Sciences, Federal University of Health Sciences, Ila-Orangun, Osun State, Nigeria

Abstract

To interpret the geologic features associated with the mineral occurrences in the Igbeti region of southwest Nigeria, which is confined by latitude $8^0 50'$ N to $8^0 55'$ N and longitude $4^0 15'$ E to $4^0 20'$ E, induced polarization techniques of electrical resistivity were integrated with high-resolution aeromagnetic data. Both datasets were processed and analyzed using various techniques to enhance interpretation. The resistivity data revealed anomalies whose resistivity values ranged from 0.05 to 284 Ωm and the chargeability values ranged from -3.89 to 5.77 mV/V indicating a great possibility of the presence of diamagnetic material associated with solid minerals. Depth to basement was established using source parameter imaging (SPI) and 3D Euler deconvolution methods. 3D Euler deconvolution produced depth results ranging from <10 m (shallow) to >30 m (deep). Additionally, shallow to deep magnetic sources with a range of 168.4 m to 679.1 m are seen according to the SPI depth estimate.
Keywords: Igbeti, induced polarization, chargeability, Euler deconvolution, source parameter imaging.

1.0 Introduction

Mineral exploration is the process of finding and mapping mineral ores on the earth's surface to facilitate their exploitation. It also quantifies available resources and aids in decision making including economic, safe, and appropriate exploitation. In many regions where there is suspicion of any mineral or due to inversion of available geology, trial-and-error with continual digging has been utilized as a search approach. However, this strategy makes it difficult to locate mineralized zones. The northern division of Oyo state has been found to contain metallic commercial mineral resources that are technically viable for exploration and exploitation (Olatunji & Adebisi, 2019). The extraction procedure in the area is trial-and-error, with excessive digging. Aside from being invasive, expensive, time-consuming, and often futile, the practice destroys vegetation and farmlands. It also has a significant impact on secondary health consequences such as morbidity, mortality, and discomfort.

To minimize or elude traditional drilling and sample procedures while limiting environmental effects and covering a wide/large area, proper geophysical survey approaches using innovative equipment are always advised (Uhlemann et al., 2018). Electrical geophysics can be employed as a reconnaissance tool to identify possible mineral resources or anomalies, particularly metallic objects (Egbelehulu et al., 2020). The

Corresponding Author: Adebisi W. A.
Email: warith.adebisi@fuhsi.edu.ng

aeromagnetic method is another geophysical method for mineral exploration. It is widely used for structural mapping, geological mapping, and calculating depth to magnetic sources (Olatunji & Adebisi, 2022). Thus, the major goal of this study is to use combined geophysical methods, electrical and aeromagnetic to analyze the geologic features of the Igbeti schist belt associated with mineralization.

Above all, a prior work by Coker et al. (2021) showed the viability of using two datasets (electrical and aeromagnetic) to delineate geological structures associated with probable mineral zones and depth estimation in Ago Iwoye, southwest Nigeria. Olatunji & Adebisi, (2019) also conducted a geomagnetic study of the Igbeti marble deposit using aeromagnetic data. The findings revealed magnetic highs and lows, indicating the presence of granitoids and large fault zones. The estimated depth of the basement ranged from 1.07 to 3.79 km. At the time of this research, detailed knowledge of the exact positions and depth of bodies containing the ore deposits is unknown in the area.

Description and Geology of Study Area

The study area is Igbeti, a local town and the headquarters of Olorunsogo local government in Oyo state's Oyo North senatorial district. It shares borders with Kwara State, Ikoyi Ile, Igboho and Saki and the ancient Oyo National Park to the east, south, west and north respectively. The town is surrounded by steep outcrops, the most well-known of which is Iyamapo Hill. The mapped area spans sheet 201 of Nigeria's aeromagnetic map and is restricted by geographic latitude 8^0 50' N to 8^0 55' N and longitude 4^0 15' E to 4^0 20' E. The geology of the research area is predominantly related to the Precambrian age, as seen by the Basement Complex rocks that underlain a large chunk of Nigeria (Tijani, 2023). Various rock units in the area include the metamorphic gneisses, schist and igneous granitic and pegmatites rocks formed from slow-cooling magma often containing minerals. Granite and gneiss dominate the entire area.

2. Material and Methods

To fulfil the study's principal purpose, integrated electrical and aeromagnetic geophysical methods are used to gather a data set for investigating the subsurface of the mapped area. When indisputability is important, the integrated approach is often used to validate results (Arifin et al., 2019). The integration is deemed appropriate because both methods will complement each other in providing a clear understanding of the subsurface through the identification and characterization of various geological formations, lithological units, and structures present beneath the earth's surface, as well as the delineation of burial depths and precise mineral point of location (Edunjobi et al., 2023; Kayode et al., 2022). The electrical approach uses changes in resistivity/chargeability of geologic and lithological units, whereas the aeromagnetic method employs variations in magnetic characteristics and can determine the depth of the basement.

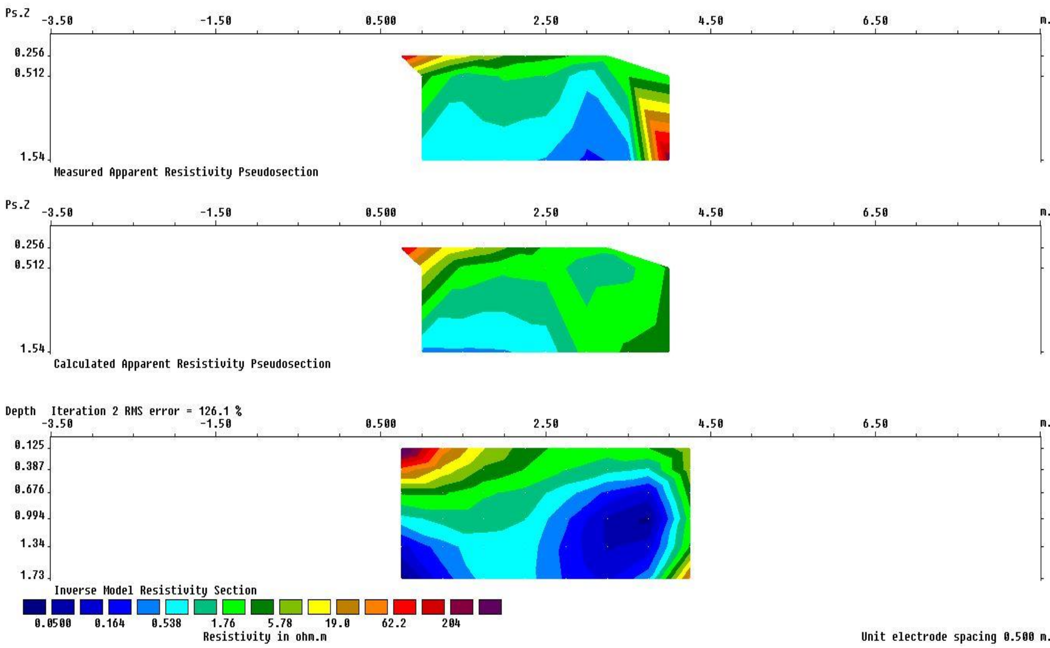
The induced polarization (IP) follows the same procedures as the electrical resistivity (ER) technology (Hasan Zaid et al., 2023) for investigating hidden materials (Yang et al., 2023). We applied this concept to the subsurface by injecting current into the ground, which operates as ions inside the geometry of the host rock bodies, and then measuring the potential variations that resulted (Spitzer & Chouteau, 2003). By changing the electrode configurations and monitoring the voltages at various distances from the current source, we collected a set of data points to evaluate and understand the subsurface. Following the fieldwork, data processing involved transferring the raw ER and IP data onto an appropriate platform, specifically an Excel sheet, as described by Aigner et al. (2024). Data adjustments for equipment drift and cultural disturbances are performed before the data is transformed into an appropriate time-domain format. We then estimated the apparent resistivity (Ωm) and chargeability values (mV/V) using the modified data. The next step involved generating 2D ER and IP pseudo-sections using the Res2Dinversion geophysical software suite.

The aeromagnetic data (sheet 201) was collected on the contract agreement between the national administration of the Nigeria government through the Nigerian Geological Survey Agency (NGSA) and Fugro Airborne Surveys by flying a magnetometer-equipped aircraft at flight line and tie line trend of 135 and 45^0 respectively, recording interval of 0.1 s or less, 80 m mean flying height, flight line of 500 m and tie line forms the second dataset. The aeromagnetic data was processed using the Geosoft Oasis Montaj software. Upward continuation to a plane height of 200 m to remove cultural anomalies with high frequencies was initially done. It thereby reduces the impact of near-surface features while emphasizing deeper structures across the research area (Tazi et al., 2022). After attenuation, the research area's magnetic field accentuates inherent, long-wavelength magnetic entities. The residual field map of interest data was then generated using the robust polynomial fitting approach (Gabtni & Jallouli, 2017). The improvement methods applied to the residual magnetic intensity data for structural mapping and relative depth to the basement of the study area include Euler deconvolution (Daniel O. B. & Kingsley K., 2020) and source parameter imaging (Al-Badani & Al-Wathaf, 2018).

3. Results and Discussion

3.1 Responses from 2D pseudo-section of resistivity and chargeability data

Figure 1 presents a 2D pseudo-section illustrating the resistivity model obtained along the selected profile. This pseudo section shows three resistivity zones and employs a colour scheme where purple represents high values, green represents intermediate values and blue represents low values. Notably, the profile reveals multiple areas exhibiting anomalous resistivity responses, depicted in shades ranging from light blue to blue and light green, with resistivity values ranging between 0.0500 and 284 Ωm. This could suggest the presence of near-surface marble deposits or it is a likely representative of a discrete geological unit. These anomalies are located at depths of approximately 0.125 m and 1.73 m extending towards the southwestern of the profile.



Figures 1: 2D Pseudo section of the resistivity data

Figure 2 shows the corresponding 2D pseudo-section of the chargeability model obtained along the selected profile. The induced polarization pseudo section shows relatively high chargeability compared to the first layer which corresponded to low resistivity values of Figure 2. In this case, there is a reasonable observation of total agreement with both resistivity and chargeability models. The depth of this highly conductive zone is estimated at 1.73 m. This major conductive unit may be interpreted as a highly favourable zone to test for mineralization in a detailed exploration campaign.

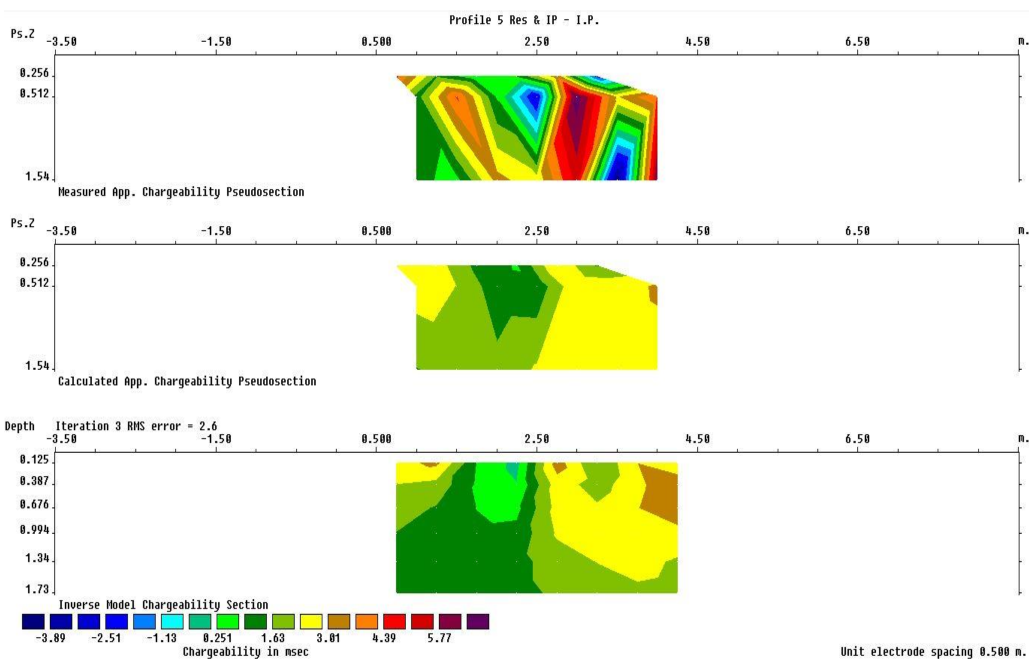


Figure 2: 2D pseudo-section of the chargeability data

3.2 Total magnetic intensity (TMI) map

The TMI map (Figure 3) of the geographic boundaries shows a pictorial representation of buried magnetic structures assumed to be geological attributes displayed in different colours. In totality, the Earth's magnetic field and the field produced by magnetic bodies that are beneath the Earth's surface exhibit both positive high and low magnetic anomalies ranging from 7.5 nT to 54 nT. The variations may be due to variance in lithology, the measure of how much a material becomes magnetized (susceptibility), and variation in the amount of strike and depth to magnetic basement. Also, the trend observed on the map corresponds to the litho-tectonic domains of the area. The minimum values of 7.5 nT to 29.7 nT, may indicate an occurrence of magnetized bodies at lower feet observed mainly in the southwestern part of the map and scattered around the northeastern and southwestern part of the study area while the maximum value of 35.1 nT to 54.0 nT which are in pink colour is major observed in the centre, and scattered around the northern and southern part of the study area and they are a result of the underlying Precambrian basement.

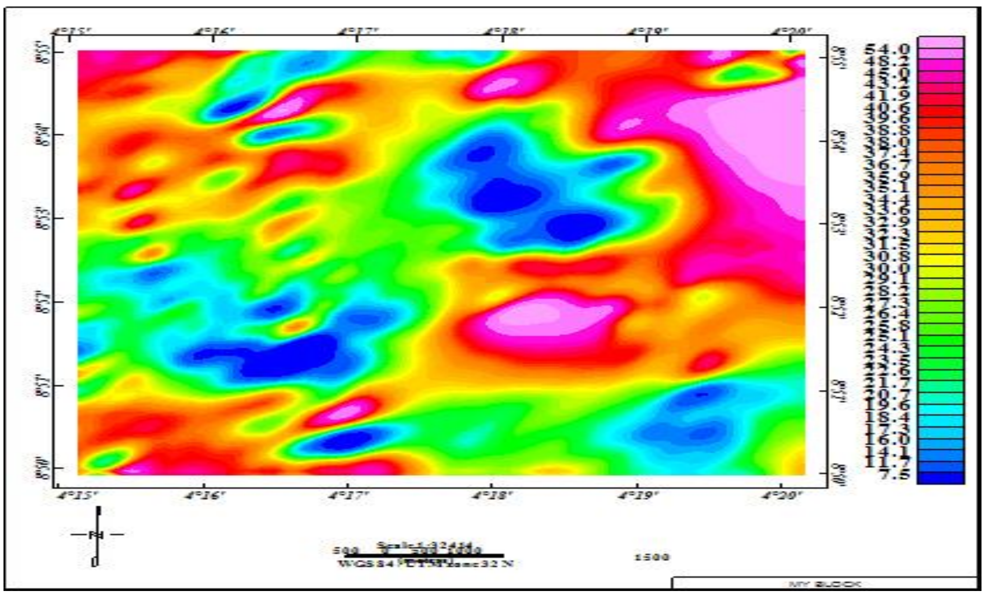


Figure 3: Total Magnetic Intensity (TMI) map of the study area

3.3 Upward continuation

The residual grid after the upward continuation to an elevation of 200 m, highlights and broadens the shallow magnetic source depth to a deeper magnetic source depth thus enhancing the positions of the inherent structural structures linked with the basement. The magnetic intensity values (Figure 4) range from the smallest value of -10.2 nT to a concentrated value of 11.1 nT.

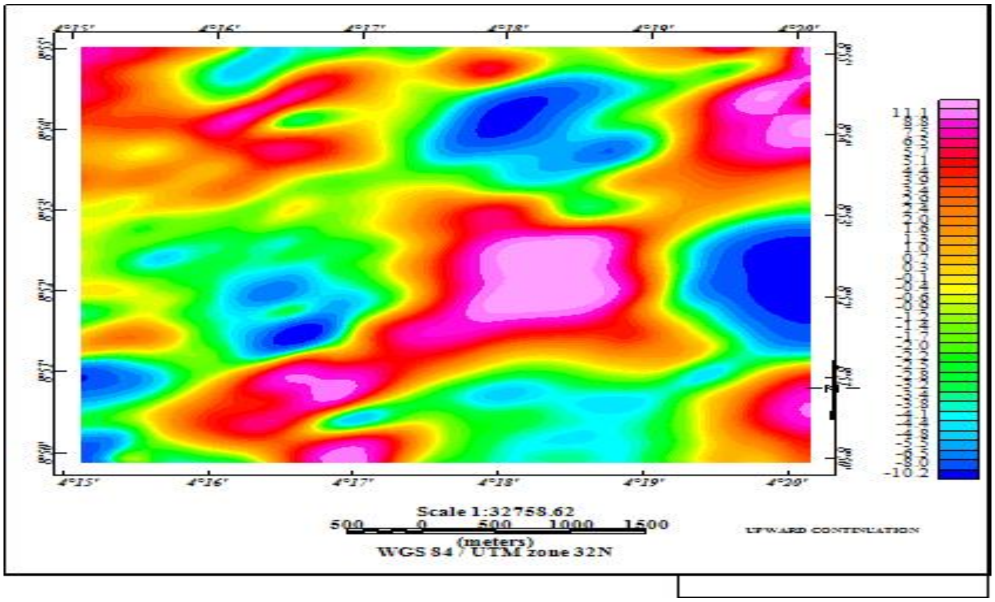


Figure 4: Upward continuation map of the study area

High magnetic intensity ranges from 7.2 nT to 11.1 nT corresponds to magnetic bodies trending in the NE-SW direction and the low magnetic intensities with intensities ranging from -10.2 nT to -3.4 nT which could be attributed to sedimentary terrain. The general trending fabric of the upward continuation map trends in the NE- SW direction and few trending in the NW- SE direction of the study area.

3.4 Euler deconvolution (ED) map

The depths of geologic bodies where probable mineral deposits are concentrated along or aligned within the study area are shown in Figure 5. The depth estimate obtained from the result of the Euler deconvolution shows depth estimates from shallow to deep magnetic sources ranging from <10 m to >30 m. Many portions of geographic coordinates show a deep depth of >30 m while the shallow depth is also seen scattered at 10 m to 20 m. The non-uniformity of the depths of the lineaments suggests that all the outlines do not have the same source, and the orientation of the solutions trends towards the NE- SW direction and few trends in the NW- SE directions.

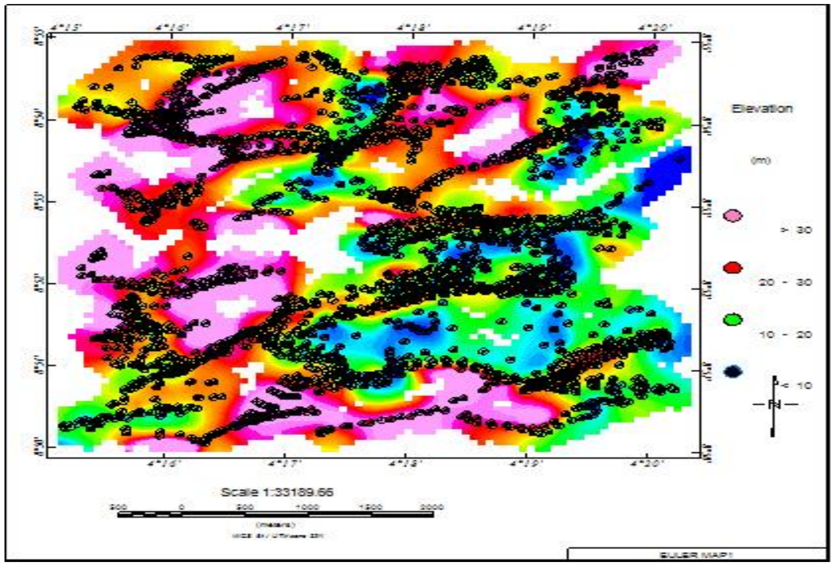


Figure 5: Euler deconvolution map of the study area

3.5 Source parameter imaging (SPI) map

Figure 6 (SPI map) exemplified and highlighted magnetic anomalies alleged to be the spatial location of different lineaments (geologic structures) at different depths within the study area. The map exposes the depth estimate of lineaments in connection with ore mineral deposits in the study area. The depth assessment obtained from the SPI map shows shallow to deep magnetic sources ranging from 168.4 m to 679.1 m. Some parts of the study area show a deep depth of > 330.4 m while the shallow depth is < 304.8 m.

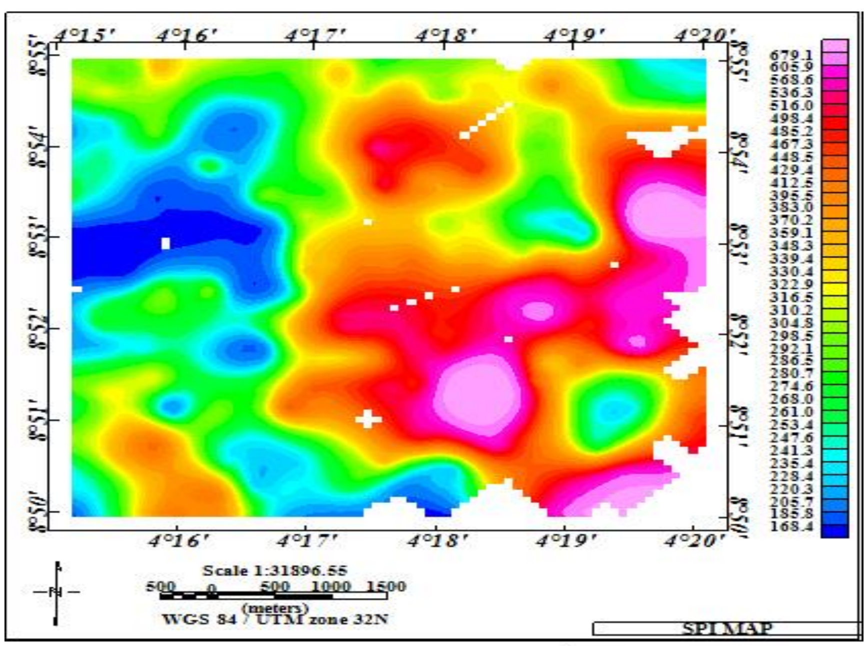


Figure 6: Source parameter imaging (SPI) of the study area

4. Conclusion

Integrated induced polarization and high-resolution aeromagnetic data were processed to investigate geologic structures associated with mineral exploration in the Igbeti area of Oyo state. The inverted IP models enabled the identification of various lithological units establishing possibly mineralized regions. The resistivity models successfully identified several bodies with low resistivity and corresponding high chargeability at relatively shallow depths. Notably, the profile reveals resistivity values ranging between 0.0500 and 1.76 Ωm suggesting the presence of near-surface marble deposits or it is a likely representative of a discrete geological unit. These anomalies are located at depths of approximately 0.676 m and 1.73 m extending towards the southwestern of the profile. The interpretation of filtered magnetic anomalies indicated the presence of mineralogy within the area. The depth estimate obtained from the result of the SPI map shows shallow to deep magnetic sources ranging from 168.4 m to 679.1 m. Some parts of the study area show a deep depth of > 330.4 m while the shallow depth is < 304.8 m.

References

Aigner, L., Werthmüller, D., & Flores Orozco, A. (2024). Sensitivity analysis of inverted model parameters from transient electromagnetic measurements affected by induced polarization effects. *Journal of Applied Geophysics*, *223*, 105334. https://doi.org/10.1016/j.jappgeo.2024.105334

Al-Badani, M. A., & Al-Wathaf, Y. M. (2018). Using the aeromagnetic data for mapping the basement depth and contact locations, in the southern part of Tihamah region, western Yemen. *Egyptian Journal of Petroleum*, *27*(4), 485–495. https://doi.org/10.1016/j.ejpe.2017.07.015

Arifin, M. H., Kayode, J. S., Izwan, M. K., Zaid, H. A. H., & Hussin, H. (2019). Data for the potential gold mineralization mapping with the applications of Electrical Resistivity Imaging and Induced Polarization geophysical surveys. *Data in Brief*, *22*, 830–835. https://doi.org/10.1016/j.dib.2018.12.086

Coker, J. O., Akinmoladun, A. E., Agbelemoge, A. J., Ariyo, S. O., Bayewu, O. O., Mosuro, G. O., & Alaka, A. O. (2021). Application of electrical and magnetic geophysical methods in-depth estimation of potential mineral depositat Olabisi Onabanjo University, Ago Iwoye, Southwestern Nigeria. *Scientia Africana*, *19*(3), 1–14. https://doi.org/10.4314/sa.v19i3.2

Daniel O. B., N., & Kingsley K., T. (2020). Application of 3D Euler Deconvolution and 2D inverse modelling to basin depth estimation, the case of the Keta basin, Ghana. *NRIAG Journal of Astronomy and Geophysics*, *9*(1), 393–401. https://doi.org/10.1080/20909977.2020.1743019

Edunjobi, H. O., Layade, O. G., Makinde, V., Bada, B. S., Ogunbayo, A. F., & Atunrase, K. A. (2023). Qualitative interpretation of high-resolution aeromagnetic data of Abeokuta metropolis for geological characterisation. *Results in Geophysical Sciences*, *15*, 100062. https://doi.org/10.1016/j.ringps.2023.100062

Egbelehulu, P., Mallam, A., Abdulsalam, N., & Adewumi, T. (2020). A Review of Electrical Methods as A Worthy Tool for Mineral Exploration. *Pakistan Journal of Geology*, *4*(2), 97–100. https://doi.org/10.2478/pjg-2020-0011

Gabtni, H., & Jallouli, C. (2017). Regional-residual separation of potential field: An example from Tunisia. *Journal of Applied Geophysics*, *137*, 8–24. https://doi.org/10.1016/j.jappgeo.2016.12.011

Hasan Zaid, H. A., Arifin, M. H., Kayode, J. S., Basori, M. B. I., Umor, M. R., & Hilmi Hazim, S. (2023). Application of 2-D Electrical Resistivity Imaging, and Induced Polarization Methods for

Delineating Gold Mineralisation at Felda Chiku 3, Kelantan, Malaysia. *Sains Malaysiana*, *52*(1), 305–320. https://doi.org/10.17576/jsm-2023-5201-25

Kayode, J. S., Arifin, M. H., Basori, M. B. I., & Nawawi, M. N. M. (2022). Gold Prospecting Mapping in the Peninsular Malaysia Gold Belts. *Pure and Applied Geophysics*, *179*(9), 3295–3328. https://doi.org/10.1007/s00024-022-03121-w

Leuenberger, A., Winkler, M. S., Cambaco, O., Cossa, H., Kihwele, F., Lyatuu, I., Zabré, H. R., Farnham, A., Macete, E., & Munguambe, K. (2021). Health impacts of industrial mining on surrounding communities: Local perspectives from three sub-Saharan African countries. *PLOS ONE*, *16*(6), e0252433. https://doi.org/10.1371/journal.pone.0252433

Olatunji, S., & Adebisi, W. (2019). Geomagnetic Assessment of the Igbeti Marble Deposit (Nigeria). In D. M. Doronzo, E. Schingaro, J. S. Armstrong-Altrin, & B. Zoheir (Eds.), *Petrogenesis and Exploration of the Earth's Interior* (pp. 273–276). Springer International Publishing. https://doi.org/10.1007/978-3-030-01575-6_66

Olatunji, S., & Adebisi, W. A. (2022). Werner Deconvolution Technique for the Interpretation of Residual Aeromagnetic Anomalies of Igbeti Schist Belt; Implication for Marble Exploration. *Indonesian Journal on Geoscience*, *9*(2), 209–217. https://doi.org/10.17014/ijog.9.2.209-217

Spitzer, K., & Chouteau, M. (2003). A DC resistivity and IP borehole survey at the Casa Berardi gold mine in northwestern Quebec. *GEOPHYSICS*, *68*(2), 453–463. https://doi.org/10.1190/1.1567221

Tazi, M. J., Azzab, D. E., Charroud, M., Jabrane, O., Ouahzizi, Y., Zahour, R., & Amadou, A. H. (2022). Identification of potential mineral exploration targets from the interpretation of aeromagnetic data covering the Sirwa region (Central Anti-Atlas, Morocco). *Scientific African*, *17*, e01351. https://doi.org/10.1016/j.sciaf.2022.e01351

Tijani, M. N. (2023). Geology of Nigeria. In A. Faniran, L. K. Jeje, O. A. Fashae, & A. O. Olusola (Eds.), *Landscapes and Landforms of Nigeria* (pp. 3–32). Springer Nature Switzerland. https://doi.org/10.1007/978-3-031-17972-3_1

Uhlemann, S., Chambers, J., Falck, W., Tirado Alonso, A., Fernández González, J., & Espín De Gea, A. (2018). Applying Electrical Resistivity Tomography in Ornamental Stone Mining: Challenges and Solutions. *Minerals*, *8*(11), 491. https://doi.org/10.3390/min8110491

Yang, Y., Zhang, G., Yao, C., Deng, Z., Ren, Z., & Li, C. (2023). Application of Induced Polarization Method in Mineral Resource Exploration. *Sustainability*, *15*(4), 3840. https://doi.org/10.3390/su15043840