Landmine Detection Using Magnetic Data and Pseudogravity Transforms: Case Study of Osi NE, Central Nigeria

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© 2025 جامعة العلوم والتكنولوجيا، المركز الرئيس عدن، اليمن. يمكن إعادة استخدام المادة المنشورة حسب رخصة مؤسسة المشاع الإبداعي شريطة الاستشهاد بالمؤلف والمجلة.

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Abstract— Landmines are a major problem in many areas of the world. Despite the development of numerous landmine sensors, the detection of non-metallic landmines continues to pose significant challenges. The aim of this contribution is to utilize structural indices to isolate gemstones and other objects, such as landmines, from the ground, based on their structures or geometry. In the mineral-rich zones of the Osi NE (Sheet 225) area of central Nigeria, I have employed the 3D Euler deconvolution of aeromagnetic and pseudogravity transforms to isolate landmines (military ordinances) and gemstones based on their structural identity. The approach relied on the analogy that both landmines and spherical host structures share the same structural index (SI), allowing for their isolation before differentiating them into ordinances or non-ordinances using Ground Penetrating Radar (GPR). Certain parts of the world have successfully used 3D structures like spheres and dipoles, commonly associated with certain gemstones, to locate or identify landmines such as tanks and drums. The gravity and magnetic techniques proved to be fast and effective tools for detecting landmines, especially at a regional scale; however, the differentiation and separation of the landmines from other non-ordnance involves the use of GPR techniques.

Keywords— Landmines, Isolation, Gemstones, 3-D Euler Deconvolution, Ordinances, Structures, Aeromagnetic and Pseudo-gravity.

I. INTRODUCTION

Landmines are a type of inexpensive weapon widely used in the pre-conflicted areas in many countries worldwide. The two main types are the metallic and non-metallic (mostly plastic) landmines. Magnetic, GPR, and metal detector (MD) techniques are the most commonly used methods for investigating them. Detecting low and non-metallic landmines using various geophysical techniques is a challenging task. GPR performance at different field sites shows excellent success in detecting metallic landmines. However, significant limitations are observed in the detection of low and non-metallic landmines. Researchers are testing the Electrical Resistivity Imaging (ERI) technique as an alternative or confirmation technique for detecting both metallic and non-metallic landmines in suspicious cleared areas. [1]. If an object below the ground is different from the surrounding material in terms of its conductivity (for metal targets), permittivity or dielectric constant (for plastic and non-conducting targets), or permeability (for ferrous metals), then GPR can find it [2].

Landmines are a major problem in many areas of the world. Despite the development of many different types of landmine sensors, it is still very difficult to detect non-metallic landmines. Soil properties such as water content affect most landmine detection sensors [3]. Reliable landmine detection is still an unresolved problem. Demining operations are complex activities because of the large variety of existing landmine types, many different possible soil and terrain conditions, and environmental circumstances. Due to its ability to detect both metallic and non-metallic objects, GPR is a promising method for detecting landmines that may allow faster and safer operations. The target signature primarily governs the performance of GPR, and the potential to discriminate targets based on the presence of internal reflections could be a valuable advantage for the identification and recognition process [4].

Geoscientists worldwide utilize gravity and magnetic (GM) techniques to search for oil and solid minerals buried in the earth's subsurface structures. Geoscientists have well-established the use of Euler Deconvolution as an interpretation tool to pinpoint the origin of potential field anomalies [5]. Other methods for structural study include 2D forward modeling and inversion [6], the estimation of the structural index [7], and other methods.

The use of the aeromagnetic and gravity method in this case is intended to focus additional exploration efforts in the demining of pre-conflicted and war-torn areas by isolating buried landmines from the ground. The identification of the potential structures with 3D shape-like landmines (Fig. 1) and gemstones, with the intent of isolating them from the ground, is the goal of this research. After the isolation with the 3D Euler Deconvolution, the 3D structures (gemstones and/or landmines) are then differentiated and separated using internal structure detection from GPR images.

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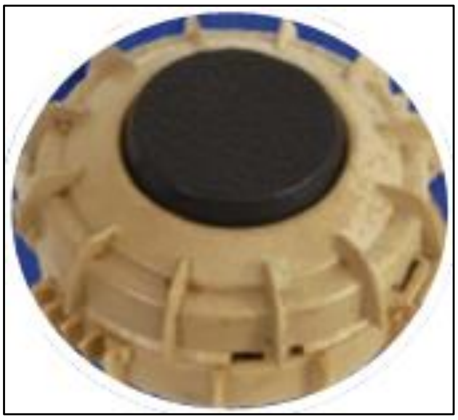

Fig. 1. A typical VS-50 landmine (After [4])

A. Location, Geomorphology and Regional Geology

The study area covers Osi NE (Sheet 225) in the transition environment of the Bida Basin and the Southwestern Nigerian Basement Complex (Fig. 2). A sheet comprises a ½ degree by ½ degree contour map on a scale of 1:100,000. The study area is bounded by latitudes 8° 15’ and 8° 30’ N and longitudes 5° 45’ and 6° 00’ E (Osi NE, Sheet 225) with an area extent of approx. 729 km² in the Bida basin area of central Nigeria. The vegetation is of the Guinea savannah type with two distinct seasons (rainy and dry) [8] with a tropical Guinea-type climate [9].

The Bida Basin is a NW-SE trending embayment perpendicular to the main axis of the Benue Trough and the Niger Delta Basin of Nigeria. The thin sedimentary cover overlying the basement rock in this transition environment is said to be responsible for the low depth to sources along magnetic profiles [10].

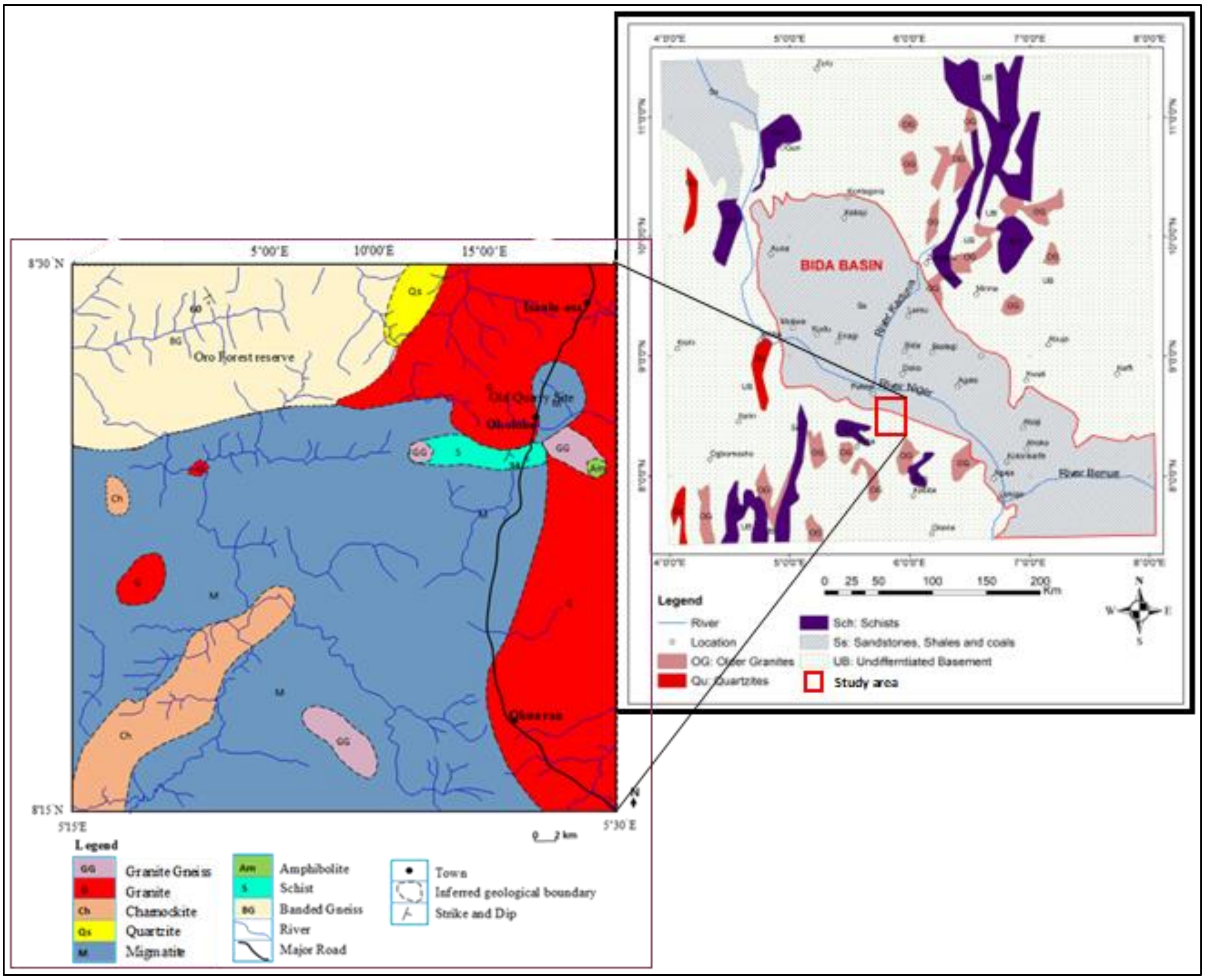

Fig. 2. Geological Map of the Osi NE Study Area as obtained from fieldwork. (Inset is the Geological Map of Bida basin; Adapted from [11]

II. MATERIALS AND METHODS

A. *Data Source and Analysis*

The aeromagnetic data of Osi NE (Sheet 225) was procured from the Nigeria Geological Survey Agency (NGSA), Abuja, Nigeria, while the pseudogravity map was generated from the aeromagnetic map that was reduced to the equator using Oasis MontajTM software. The survey, which was aimed at mineral and groundwater development, was collected at a flight height of 80 m, a flight line spacing of 500 m, and a tie line spacing of 2000 m. The flight line direction was NW-SE, whereas the tie lines were NE-SW. For ease of processing, the data was stripped of a common value of 32,000 nT. Data collection for this area was done in 2006, so a 2005 epoch International Geomagnetic Reference Field (IGRF) was used to calculate Inclination and Declination as follows:

Field Strength = 33129.9632 nT; Inclination = -6.87339275; Declination = -2.51357917.

Figures 3a and b are the Total Magnetic Intensity (TMI) reduced to the equator and pseudogravity transform maps of the study area, respectively.

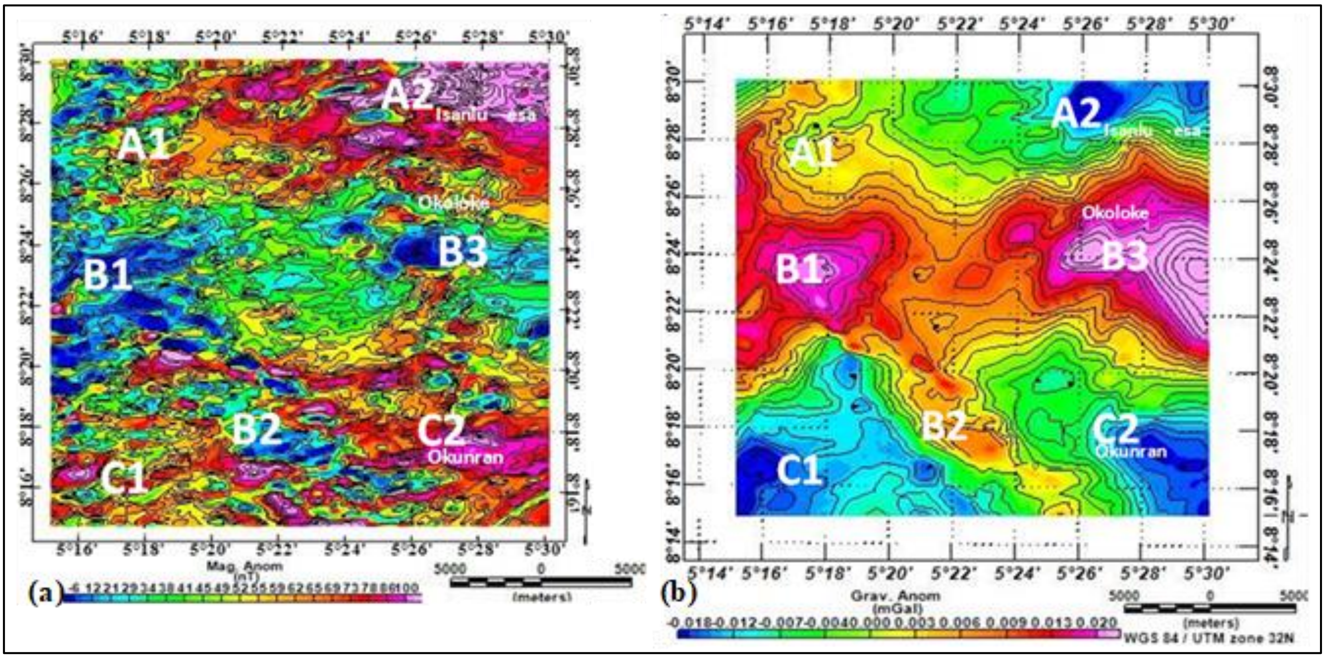

Fig. 3. (a) Total magnetic intensity map of the study area (REDE and its Contour) (After [18]). (b) Pseudogravity transforms an**d** its Contour map

B. *The 3D Euler Deconvolution Method*

According to [12], Euler deconvolution ([13], [14]) is a popularly used automatic interpretational method of potential field data, which uses the original anomaly, its derivatives, and the given structural index to estimate the source location parameters, and the precision of the estimated locations depends on the similarity between the given structural index and the real shape ([7], [15], [16]). The structural index (SI) is a measure of the rate of change with distance of the field [17]. The SI of 0.0, 2.0, and 3.0 (magnetic) and 0.0, 1.0, and 2.0 (gravity) represent step, pipe, and sphere, respectively. The correct SI for a given feature is that which gives the tightest clustering of solutions.

The 3-D Euler Deconvolution processing routine of the Oasis MontajTM is an automatic location and depth determination software package for gridded magnetic and gravity data.

Theory of Euler Deconvolution Method:

Any three-dimensional function *f (x,y,z)* is said to be *homogeneous* of degree *n* if the function obeys the expression [17]:

$$f(tx,ty,tz) = t^n f(x,y,z) \tag{1}$$

From this it can be shown that the following (known as *Euler's equation*) is also satisfied [17]:

$$x\frac{\partial f}{\partial x} + y\frac{\partial f}{\partial y} + z\frac{\partial f}{\partial z} = nf \tag{2}$$

[14] has shown that simple magnetic and gravity models conform to Euler's equation. The degree of homogeneity, *n*, can be interpreted as a *structural index* (SI). [13] have shown that a magnetic contact will yield an index of 0.5 provided that an offset A is introduced to incorporate an anomaly amplitude, strike and dip factors [17]:

$$A = (x\ \ x_0)\frac{\partial T}{\partial x} + (y\ \ y_0)\frac{\partial T}{\partial y} + (z\ \ z_0)\frac{\partial T}{\partial z} \tag{3}$$

Given a set of observed total field data, we can determine an optimum source location$^{(x_0,y_0,z_0)}$ by solving Euler's equations for a given index n by least-squares inversion of the data.

III. RESULTS AND DISCUSSION

A. Pattern Interpretation of the Aeromagnetic and Gravity Data

The REDE submenu of Oasis montajTM software reduces the Total Magnetic Intensity map and its contour to the equator in Figure 3 (a), while Figure 3 (b) displays the Pseudogravity map and its contour. Based on their patterns, I have divided the aeromagnetic and pseudogravity anomalies maps into three distinct zones and subzones, each with various magnetic and gravimetric characteristics, for qualitative analysis. These include:

- Zone A, located in the northern part of the study area, is characterized by anomalies with moderately high to very high magnetic reliefs (A1 and A2; Figure 3a) and corresponding low to very low density reliefs (A1 and A2; Figure 3b). The amplitudes here vary mostly from < 52 to > 100 nT and from < -0.018 mGal to approx. 0.003 mGal for magnetic data and pseudogravity transforms, respectively.
- Zone B, located in the central part of the study area, is characterized by low to intermediate magnetic reliefs (subzones B1 to B3; Figure 3a) and corresponding high-density reliefs (subzones B1 to B3; Figure 3b). The amplitudes of the anomalies in this zone typically range from approximately -6 nT to 52 nT, while for magnetic data and pseudogravity transforms, they range from 0.003 to approximately 0.025 mGal.
- Zone C is characterized by a mixture of high and moderately low magnetic reliefs (i.e., subzones C1 and C2; Figure 3a) and corresponding moderate and low pseudogravity reliefs (i.e., subzones C1 and C2; Figure 3b). These anomalies have amplitudes of approx. 29 to > 100 nT and -0.018 to approx. 0.001 mGal for the magnetic and gravity data, respectively.

B. Zone Coloured Euler Solutions for 3-D Structures

Figure 4a shows the results obtained for structural index 3.0 (i.e. sphere or dipole model; magnetic). The zones where there are good number of clusters are labelled A to F for spheres or dipoles. In Oasis montajTM, window size determination is either by default (i.e. 20 x 20) or through iterations, as the correct SI for a given feature will give the tightest clustering of solutions or sharpest focus of results. Tanks and drums have been detected or explored worldwide with structural index 3.0 (magnetic) of 3D Euler Deconvolution [19]. Figure 4b shows the result obtained for structural index 2.0 (i.e. sphere or dipole model; pseudogravity). The areas where there are good number of clusters are labelled G to J for sphere. Tanks and drums have been detected or explored worldwide with structural index 2.0 (gravity) of 3D Euler Deconvolution[19]. After the isolation with the 3D Euler Deconvolution, the 3D structures (gemstones and/or landmines) are then differentiated and separated using internal structure detection from GPR images.

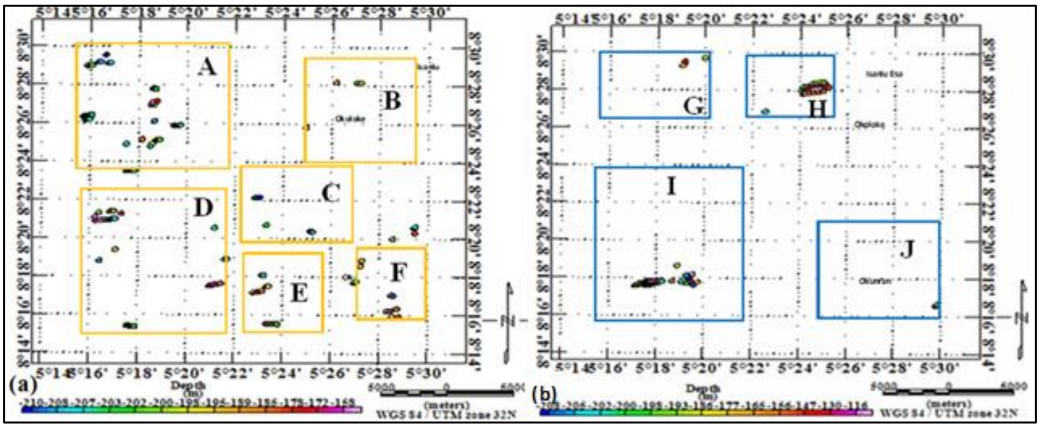

Fig. 4. (a) A Typical Aeromagnetic Euler Solutions Map for Sphere (S.I =3.0) (b) A Typical Pseudogravity Euler Solutions Map for Sphere (S.I =2.0) showing the Zones of Clustering

IV. CONCLUSION

The aeromagnetic data from Osi NE study area was processed for structural mapping and mining study. The different structures were delineated and especially the 3D structures which are represented by Euler structural indices 3.0 (i.e. sphere or dipole model; magnetic) and 2.0 (i.e. sphere or dipole model; pseudogravity) respectively were first isolated with 3D Euler deconvolution method in the study area. These 3D structures are then differentiated and separated into gemstones and/or landmines using internal structure detection technique from GPR images. The abundance of spherical features in the study area confirms the usefulness of the 3D Euler in isolating spheres /dipoles or landmines and prospective zone for mineral exploration. The structural indices of 3.0 and 2.0 (i.e. sphere or dipole model) in magnetic and gravity respectively have been used worldwide to detect tanks and drums (or metalliferous bodies and landmines).

ETHICAL AND COMPETING INTEREST

I declare that I have no known competing financial interests or personal relationships which have or could be perceived to have influenced the work reported on this article.

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REFERENCES

[1] M. Metwaly, "Detection of metallic and plastic landmines using the GPR and 2-D resistivity techniques," *Nat. Hazards Earth Syst. Sci.*, vol. 7, pp. 755–763, 2007, doi: 10.5194/nhess-7-755-2007.

[2] N. Milisavljevic, I. Bloch, S. Broek, and M. Acheroy, "Improving mine recognition through processing and Dempster–Shafer fusion of ground-penetrating radar data," *Pattern Recognition*, vol. 36, no. 5, pp. 1233–1250, 2003, doi: 10.1016/S0031-3203(02)00251-0.

[3] S. H. Hong, T. W. Miller, H. Tobin, B. Borchers, J. M. H. Hendrickx, H. A. Lensen, and P. B. W. Schwering, "Impact of soil water content on landmine detection using radar and thermal infrared sensors," *Proc. SPIE*, vol. 4394, 2001, doi: 10.1117/12.445492.

[4] F. Lombardi, H. D. Griffiths, and A. Balleri, "Landmine internal structure detection from ground-penetrating radar images," in *Proc. IEEE Radar Conf.*, Oklahoma City, OK, 2018, pp. 23–27.

[5] M. F. Mushayandebvu, V. Lesur, A. B. Reid, and J. D. Fairhead, "Grid Euler deconvolution with constraints for 2D structures," *Geophysics*, vol. 69, pp. 489–496, 2004, doi: 10.1190/1.1707069.

[6] M. Talwani and J. R. Heirtzler, "Computation of magnetic anomalies caused by two-dimensional structures of arbitrary shape," in *Computers in the Mineral Industries*, G. A. Parks, Ed., Stanford, CA: Stanford University, 1964, pp. 464–480.

[7] V. C. F. Barbosa, J. B. C. Silva, and W. E. Medeiros, "Stability analysis and improvement of structural index estimation in Euler deconvolution," *Geophysics*, vol. 64, pp. 48–60, 1999.

[8] P. O. Udo, *Physical Geography of Nigeria*, Ibadan, Nigeria: Heinemann Education Publishers, 1982, pp. 3–8.

[9] M. O. Kehinde and E. P. Leaohnert, "Groundwater resources studies in the Bida Basin, Central Nigeria," *Water Resour. J. Niger. Assoc. Hydro-Geol.*, vol. 2, pp. 117–124, 1989.

[10] I. U. Megwara and E. E. Udensi, "Structural analysis using aeromagnetic data: Case study of parts of Southern Bida Basin, Nigeria and the surrounding basement rocks," *Earth Sci. Res.*, vol. 3, no. 2, pp. 27–42, 2014.

[11] N. G. Obaje, A. Moumouni, N. G. Goki, and M. S. Chaanda, "Stratigraphy, paleogeography and hydrocarbon resource potentials of the Bida Basin in North-Central Nigeria," *J. Mining Geol.*, vol. 47, no. 2, pp. 97–114, 2011.

[12] G. Ma, "The application of extended Euler deconvolution method in the interpretation of potential field data," *J. Appl. Geophys.*, vol. 107, pp. 188–194, 2014.

[13] A. B. Reid, J. M. Alisop, H. Granser, A. J. Millett, and I. W. Somerton, "Magnetic interpretations in three dimensions using Euler deconvolution," *Geophysics*, vol. 55, pp. 80–91, 1990.

[14] D. T. Thompson, "A new technique for making computer-assisted depth estimates from magnetic data," *Geophysics*, vol. 47, pp. 31–37, 1982.

[15] D. Ravat, "Use of fractal dimension to determine the applicability of Euler's homogeneity equation for finding source locations of gravity and magnetic anomalies," *Symp. Appl. Geophys. Eng. Environ. Probl.*, pp. 1082, 1994, doi: 10.4133/1.2922078.

[16] P. Y. Stavrev, "Euler deconvolution using differential similarity transmissions of gravity or magnetic anomalies," *Geophys. Prospect.*, vol. 45, pp. 207–246, 1997.

[17] N. Whitehead and C. Musselman, *Montaj Grav/Mag Interpretation: Processing, Analysis and Visualization System for 3D Inversion of Potential Field Data for Oasis MontajTM*, Tutorial and User Guide, Version 6.1, Toronto, ON, Canada: Geosoft Inc., 2005.

[18] NGSA, *TMI Map of Osi NE (Sheet 225)*, Nigeria Geological Survey Agency, 2009.

[19] M. Marchetti and A. Settimi, "Integrated geophysical measurements on a test site for detection of buried steel drums," *Ann. Geophys.*, vol. 54, no. 1, pp. 105–114, 2011.

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https://doi.org/10.20428/jst.v30i2.2449