Magnetic Rocks Distribution and Depth to Basement Analysis on an Old Quarry Site, Abeokuta, Southwestern, Nigeria

[1]Ojo, Akintayo O., [1]Adeloye, Mubor Y.; [1]Egbedele, Ismail A. & [2]Akinwande, Feyisayo A.
[1]Science Laboratory Technology Department, D.S. Adegbenro ICT Polytechnic, Itori-Ewekoro, Ogun State, Nigeria
[2]Mechanical Engineering Department, D.S. Adegbenro, ICT Polytechnic, Itori-Ewekoro, Ogun State, Nigeria
akintayoojo@yahoo.com, +2348033907885

ABSTRACT

Geomagnetic study was carried out to investigate the distribution and depth of formations of different magnetic rocks on an old quarry site, Abeokuta, Southwestern, Nigeria. Eight ground magnetic profiles were established with 10 m spacing intervals orientated in West-East and North-South directions, and ranged between 110 and 190 m. A total of 223 data points were acquired and corrected for all forms of magnetic variations. The resulting residual anomalies were plotted against distance using Microsoft Excel tool. Also, the residual anomalies were modeled into 2D and 3D contour sections using surfer 10. The depth to basement analysis was carried out using Peters' half slope graphical method. The resulting profiles and contour sections revealed variable anomalies which indicated contrast in the magnetic distributions of the subsurface. Mineral rocks with both high (150 to 300 nT) and low (0 to -150 nT) magnetic susceptibilities were observed across each of the profiles. Rocks with average susceptibilities (0 to 150 nT) dominated the profiles which indicated pegmatite vein that probably haboured rocks such as Tourmaline, Tantalite, Mica and Beryl in both massive and disseminated quantities. The mineral rocks with very thin bodies were observed at depths 3.48-17.42 m, intermediate bodies were buried at depths 2.61-13.06 m, while very thick bodies were located at depths between 2.09 and 10.45 m. The depth of these mineral rocks ranged between 2.09 and 17.42 m from the surface.

Keywords: Abeokuta, Old Quarry, Susceptibility, Mineral Rocks, Distribution, Depth

iSTEAMS Proceedings Reference Format
Ojo, Akintayo O., Adeloye, Mubor Y.; Egbedele, Ismail A. & Akinwande, Feyisayo A. (2019): Magnetic Rocks Distribution and Depth to Basement Analysis on an Old Quarry Site, Abeokuta, Southwestern, Nigeria. Proceedings of the 17th iSTEAMS Multidisciplinary Research Conference, D.S. Adegbenro ICT Polytechnic, Itori-Ewekoro, Ogun State, Nigeria, 21st – 23rd July, 2019. Pp 155-168. www.isteams.net - DOI Affix - https://doi.org/10.22624/AIMS/iSTEAMS-2019/V17N1P14

1. INTRODUCTION

Geomagnetic technique generally involves the measurement of magnetic anomalies in the subsurface as the earth's magnetic field intensities or vertical gradients of the earth's magnetic field. These anomalies are caused by the induction of magnetic rocks in the subsurface as a result of secondary magnetization induced in a ferrous body by the earth's magnetic field. The response of the induced anomaly depends on the geometry, orientation, size, depth and magnetic susceptibility of the ore body as well as the inclination and intensity of the subsurface earth's magnetic field. Ground magnetic method is very effective in delineation of both thin and large metallic ores (Ojo *et al.*, 2014; Kayode *et al.*, 2013); it responses to small changes in magnetic variations in the subsurface. A thin body can be detected to a depth of about 10 feet (Ojo *et al.*, 2014), while larger metallic objects can often be located to greater depths. According to Roger (2008), induced magnetic anomalies generally exhibits asymmetrical, south up or north down signatures, positive response to the south and negative response to the north of the object.

Magnetic prospecting, the oldest form of geophysical exploration, is used to explore for both oil and minerals (Telford *et al.*, 1990). Geophysicists use the measurements of earth's magnetic field intensities to reveal the subsurface magnetic susceptibility variations. The data obtained gives the sum of the earth's magnetic and induced magnetic body fields. The larger the magnetic body in size and quantity, the stronger the induced fields. If the data can be filtered in such a way that the natural fields can be removed, the results revealed varied regions of magnetic susceptibilities. Magnetic surveys are done from all conceivable platforms such as ground, vehicle, air, marine, satellite and in boreholes, and the results obtained are usually presented as profiles, maps and pseudo-sections. Raw data may be interpreted directly, significant processing may be applied, and inversion to estimate models of subsurface susceptibility distribution can also be carried out (Ojo and Popoola, 2014; Reynolds, 1997; Umego and Ojo, 1995). The application of magnetic method is so wide that it has become a culture to include magnetic survey in every comprehensive or integrated geophysical investigation (Nwosu *et al.*, 2015; Folami, 1980).

Magnetic susceptibility is probably the most easily measurable petro-physical parameter. The magnetic susceptibility of rocks is in principle controlled by the type and amount of magnetic minerals contained in the rocks (Frantisek *et al.*, 2009). This research is of high importance due to the recent advances in science and engineering which had led to increase in the demand of rare metals used in making electronic components, surgical implants, heat conductors, sutures, sculptures, bricks and so on. The increase in global demand of these mineral rocks had led to the renewed interest in the search for economically viable mineral deposits in Nigeria (Nwosu *et al.*, 2015; Ojo, 2013; Okunlola and Jimba, 2006; Okunlola and Ofonime, 2006; Okunlola, 2005).

2. THE STUDY AREA AND ITS GEOLOGICAL SETTING

The study area is located in Saje community, Abeokuta South Local Government Area of Ogun State, Southwestern Nigeria and covers an approximated area of 119,000 m^2. It is within an old quarry site abandoned by Aggregate Granite Industries (AGI) since 1999, and lies within latitude N07^{0}11.201'-N07^{0}11.480' and longitude E003^{0}21.001'-N003^{0}22.250'. Abeokuta is located on basement complex of igneous and metamorphic origin which overlain various sedimentary rocks (Fig. 1). The rugged rock-strewn relief is prominent towards the north, in the central and south-eastern parts of the city. The basement rocks comprised of folded schist, quartzite, gneiss, older granite and amphibolites/mica schist (Rahman, 1976; Jones and Hockey, 1964).

The oldest Formation identified in Dahomey basin is the Abeokuta Formation (Jones and Hockey, 1964); this was upgraded to a group status with three Formations by Omatsola and Adegoke (1981). Ise Formation has a conglomeratic and gritty base overlain by coarse to medium grained sandstone with inter-bedded kaolinite. Ise Formation is followed by a coarse to medium grained sandstone with inter-bedded shale, siltstone and clay stone, having a sandy fancies that is tar-bearing while the shale is organic-rich. The youngest is Araromi Formation, which is Cretaceous and made up of fine to medium grained sandstone at the base, overlain by shale and silt stone with inter-bedded limestone, marl and lignite. Abeokuta group is overlain by Ewekoro Formation, made of a limestone unit reported to be highly fossiliforous (Kogbe, 1989; Oyawoye, 1964).

3. METHODOLOGY

Ground magnetic study was used for detailed mapping in order to understand both the magnetic susceptibility distribution and mineral rock to basement (depths) analysis based on qualitative data interpretations. The field techniques involved the measurements of magnetic component amplitudes at discrete points along eight profiles. The geomagnetic survey was carried out using a proton precession magnetometer (model G-856AX) aligned across the study area as shown in Fig. 2. The length of each profile depends on the proximity of the quarry site to the neighboring community, and ranged between 110 and 190 m. A station interval of 5 m was adopted, and at each station, the total magnetic intensities were measured and the geo-coordinates were also recorded using Global Positioning System (GPS). A based station was set up about 800 meters away from the study area, and the ground magnetic readings were recorded at every thirty minutes interval; this is to correct the raw survey data for the diurnal variation effects. The data were also inspected for spikes, gaps, instrument noise and International Geomagnetic Reference Field corrections. A total of 223 data sets were obtained and the resulting residual anomalies were plotted against distance using Microsoft Excel tool. The 2D and 3D surface distributions of the residual anomalies were also generated using surfer 10.

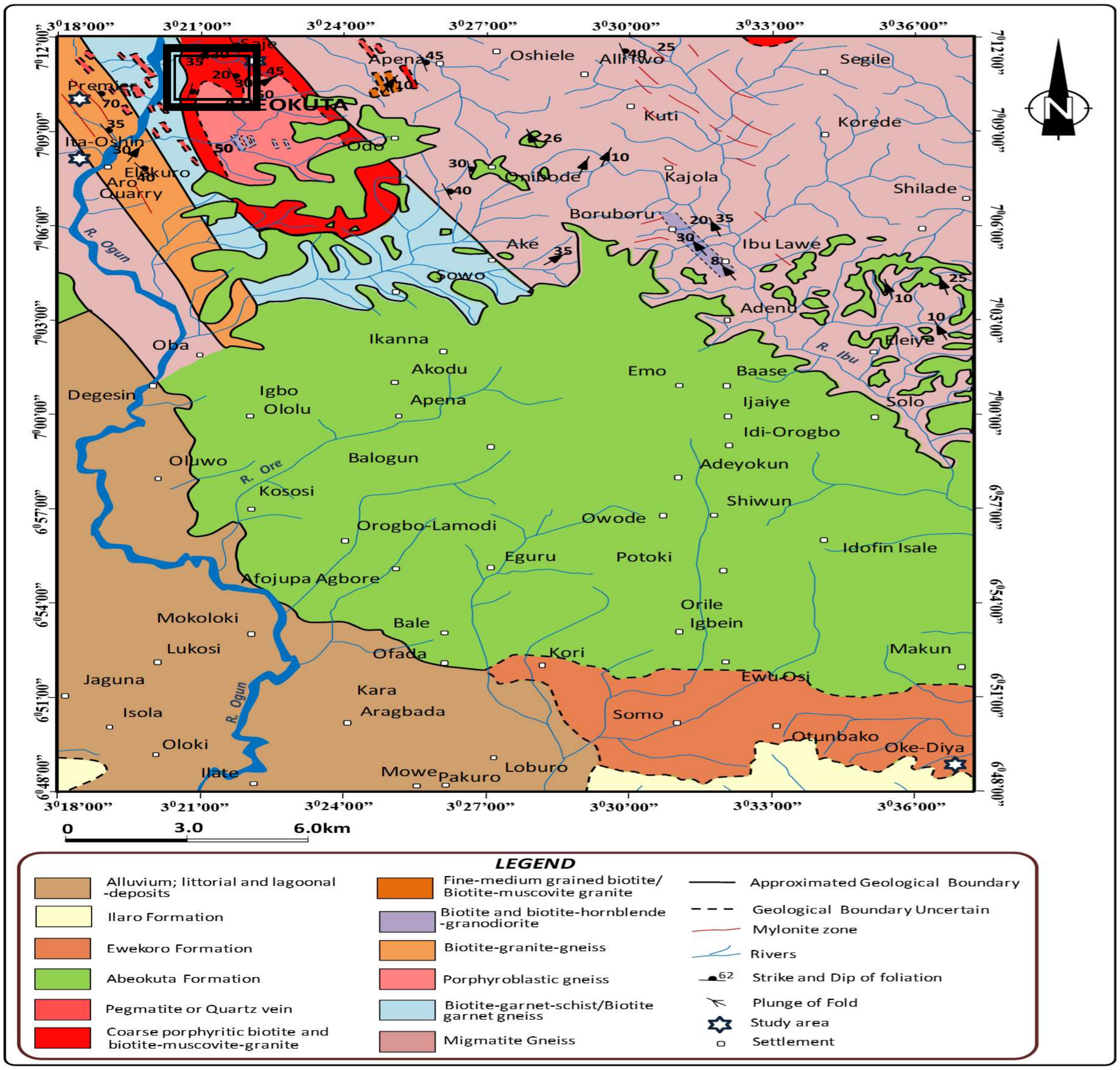

Figure 1: Geological map of Abeokuta showing the study area

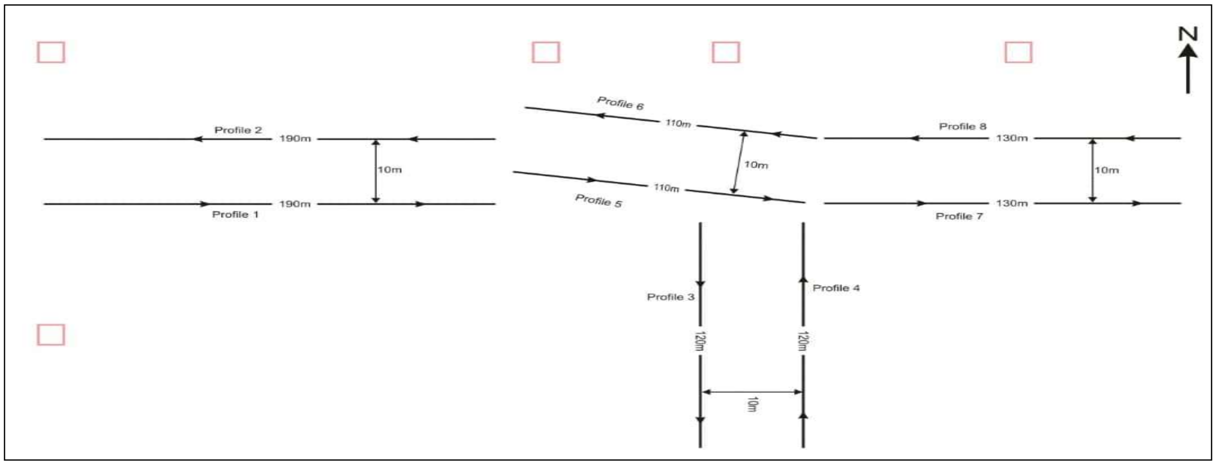

Fig. 2: Survey layout

In order to deduce the depths of the magnetic bodies in the subsurface, Peter's half slope method was adopted (Ojo *et al.*, 2014; Adegoke and Layade, 2014). This method is a theoretically based graphical method (Fig. 3) which is based on the mathematical expression for magnetic anomalies with vertical polarization over vertical dikes. Depending on the size of the magnetic object, the ore body is assigned with an index value ranging from 1.2-2.0. The product of an index value with the depth of magnetic source (h) is approximately equal to the horizontal distance (half maximum slope distance, d), that is, the horizontal distance is divided by the index value to obtain the depth of the metallic object. For bodies having very thin width-to-depth ratios, d=1.2h, and for bodies having very thick width-to-depth ratios, d=2.0h. For an average width-to-depth ratios, d=1.6h. The depth is determined in meters. In most cases, if the object's size is not ascertained, the distance is divided by both 1.2 and 2.0 to determine the depth in which the object is buried.

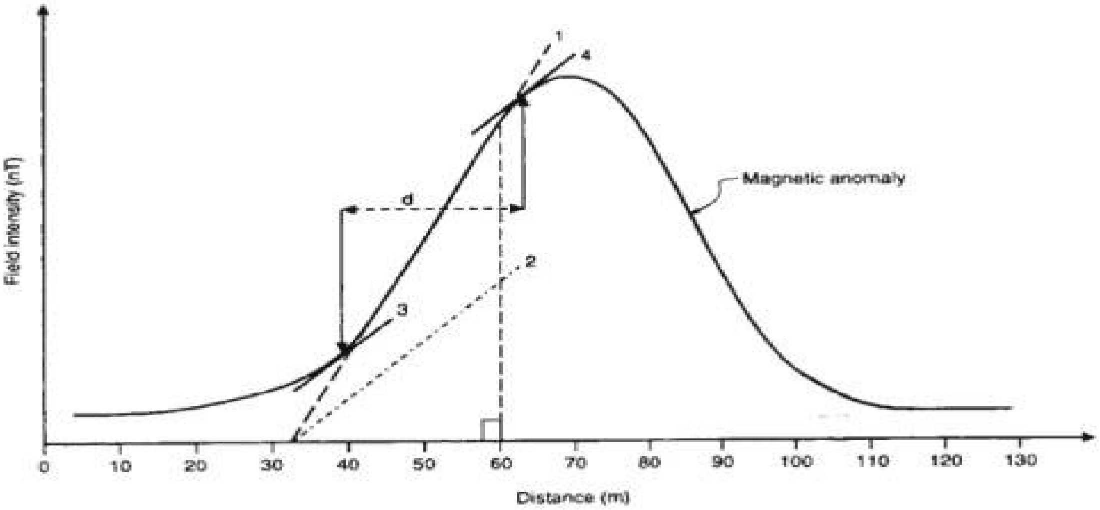

Fig. 3: Peter's half slope method of depth-to-basement analysis (Peter, 1949)

4. RESULTS AND DISCUSSION

Magnetic residual anomalies can be presented in several ways (Ojo *et al.*, 2014; Kayode and Adelusi, 2010). In this study, profiling and contour mapping were adopted.

4.1 Profiling

This is an old form of presenting magnetic data. The magnetic profiles were generated using Microsoft excel, and the method showed the magnetic responses (susceptibilities) in graphical forms (Figs. 4a-h).

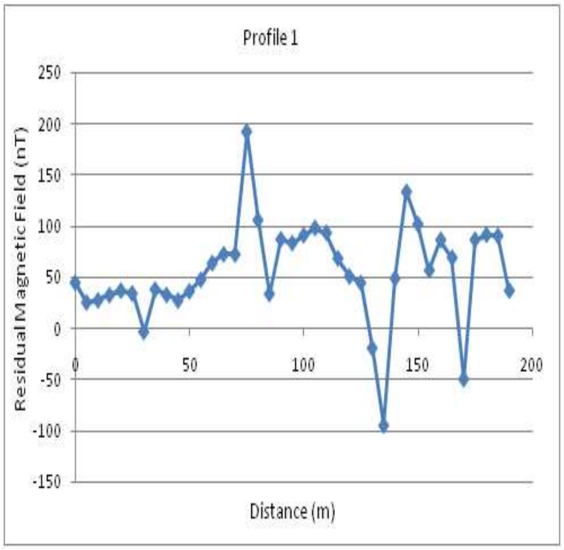

Fig. 4a: Profile 1 Magnetic Responses

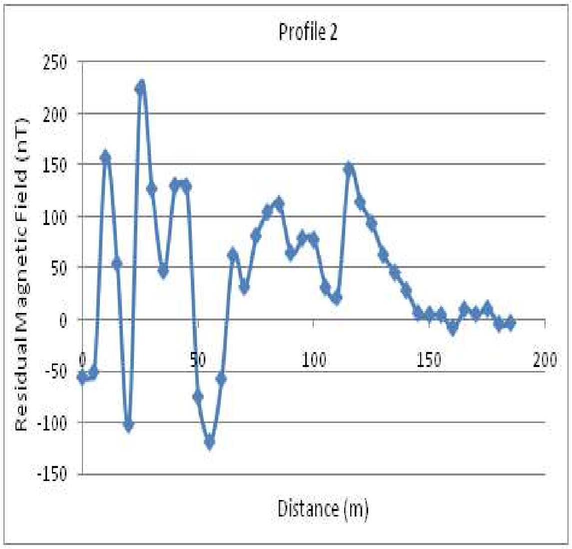

Fig. 4b: Profile 2 Magnetic Responses

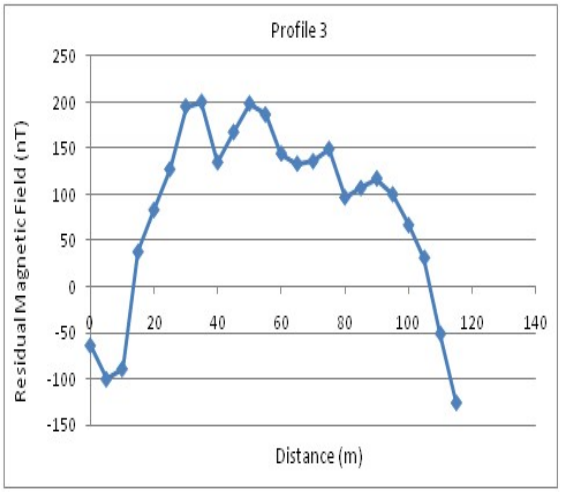

Fig. 4c: Profile 3 Magnetic Responses

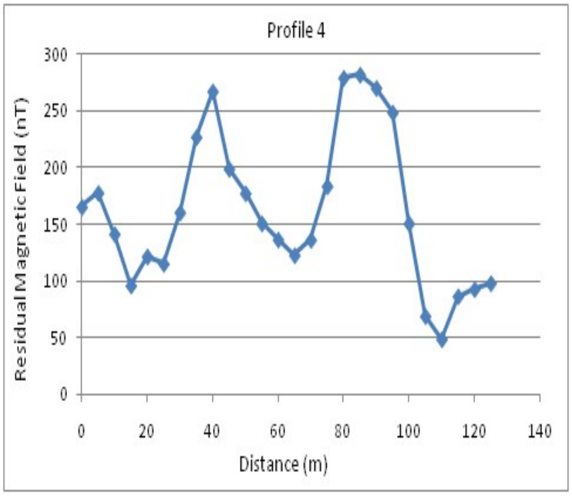

Fig. 4d: Profile 4 Magnetic Responses

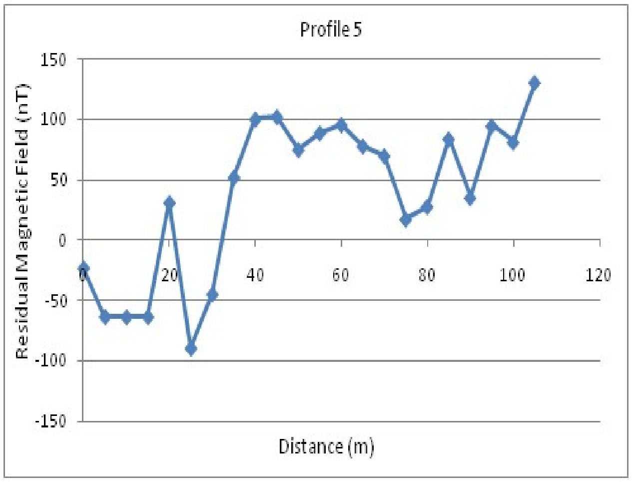

Fig. 4e: Profile 5 Magnetic Responses

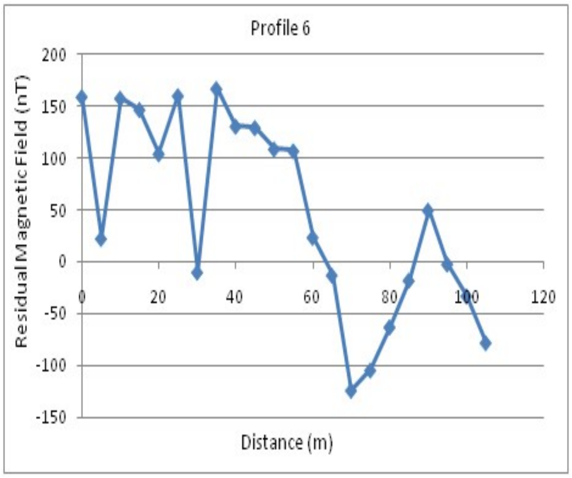

Fig. 4f: Profile 6 Magnetic Responses

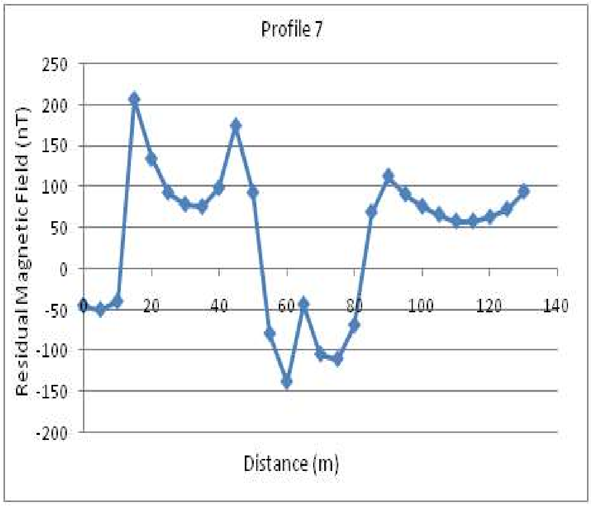

Fig. 4g: Profile 7 Magnetic Responses

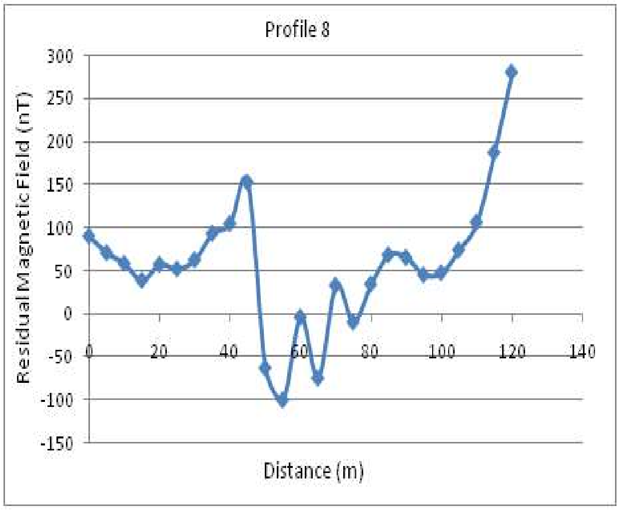

Fig. 4h: Profile 8 Magnetic Responses

These profiles were also used to estimate the depth to magnetic sources in the study area using Peters' half slope technique. Profiles have an advantage of being able to show details that cannot be revealed in the grid-based presentations, such as, contour mapping (Ojo *et al.*, 2014). The variations in the magnetic distributions in each profile were revealed in the profiles, and both the positive and negative residual magnetic fields were observed with more pronounced positive magnetic responses. In generally, this study revealed high magnetic distributions (susceptibilities) in profiles 4 and 8, relatively low magnetic susceptibilities in profiles 5 and 6, and average magnetic susceptibilities in profiles 1, 2, 3 and 7.

4.2 Contour mapping

The residual magnetic anomalies were presented in scaled 2D and 3D contour sections (Figs. 5-8). These sections were grid-based and visualized the subsurface magnetic field variations; they revealed varying degree of magnetic distributions across the profiles. The contour lines were widely spaced on the profiles which indicated that the depths to magnetic basements were relatively large. Also, closely spaced and linear sub-parallel oriented sections were observed across the profiles, and this suggested shallow magnetic anomalies which could also indicate faults or fractured zones. The contour maps generally revealed spikes which indicated massive presence of magnetic rocks in the subsurface.

The magnetic intensity distributions in the scaled 2D and 3D contour plots across the study area revealed high magnetic susceptibilities in profiles 3 and 4 (Fig. 6) and 7 and 8 (Fig. 8), low magnetic susceptibilities in profiles 5 and 6 (Fig. 7), and average magnetic susceptibilities in profiles 1 and 2 (Fig. 5). These results were actually in agreement with results observed in the profiling (Fig. 4). Generally, the contour sections revealed that the regions with average susceptibility values ranging from 0-150 nT dominated the pseudo-sections. This is an indication that the study area is on quartz or pegmatite vein which haboured some economical viable mineral deposits such as Beryl, Tourmaline and Mica in both high and low quantities. Regions with low (0 to -150 nT) and high (150 to 300 nT) magnetic susceptibility values were also pronounced across the sections.

The regions that revealed high and low magnetic susceptibilities such as Mica, Feldspar, Beryl, Tantalite, Tourmaline and Columbite were in agreement with some previous studies on pegmatite and quartz vein (Ojo *et al*., 2014; Okunlola *et al*., 2009; Ajayi and Ogedengbe, 2003).

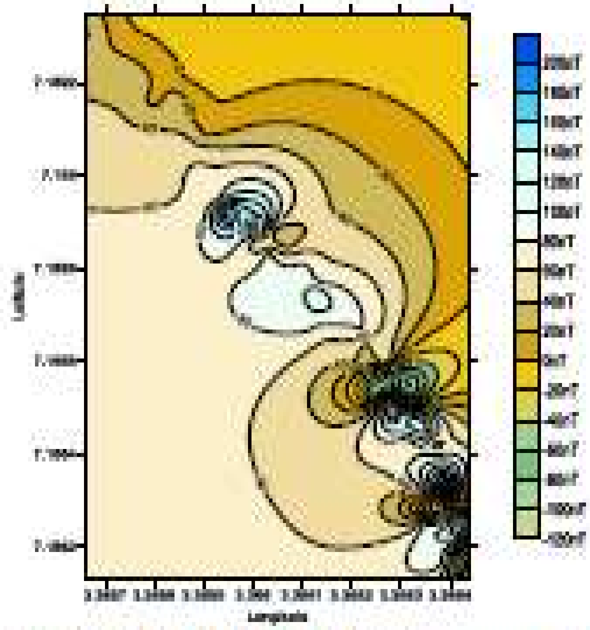

Fig. 5a: 2D TMI of profiles 1 and 2

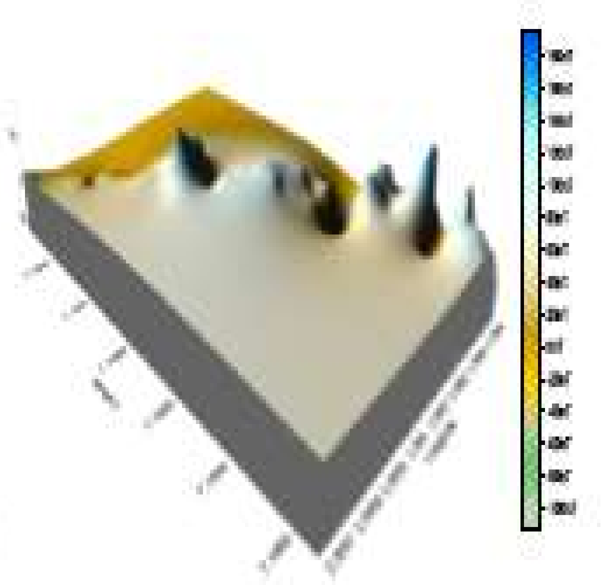

Fig. 5b: 3D TMI of profiles 1 and 2

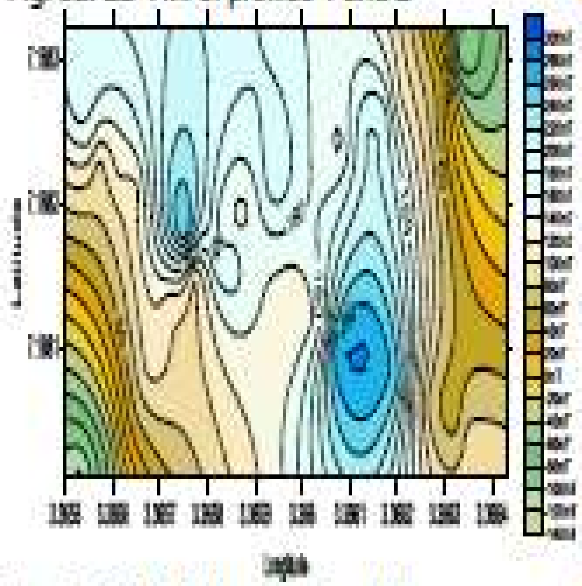

Fig. 6a: 2D TMI of profiles 3 and 4

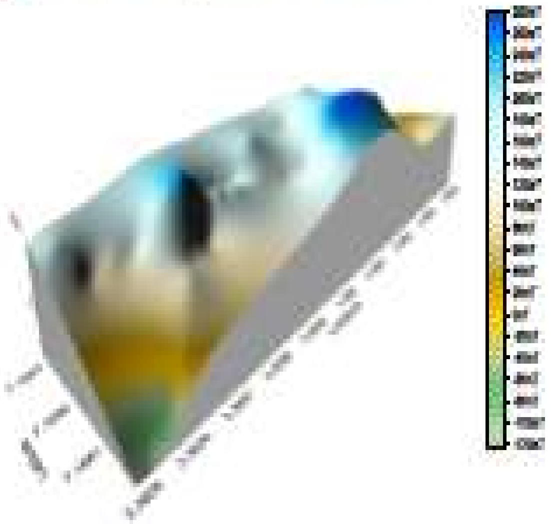

Fig. 6b: 3D TMI of profiles 3 and 4

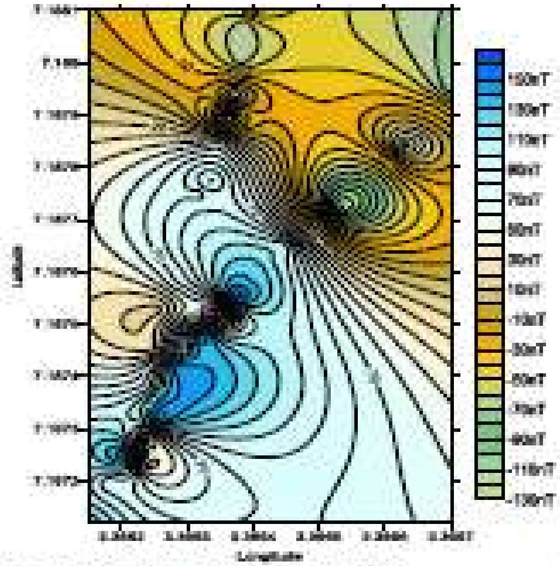

Fig. 7a: 2D TMI of profiles 5 and 6

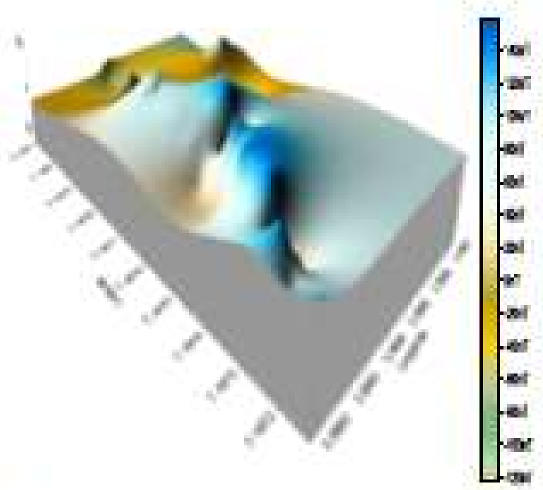

Fig. 7b: 3D TMI of profiles 5 and 6

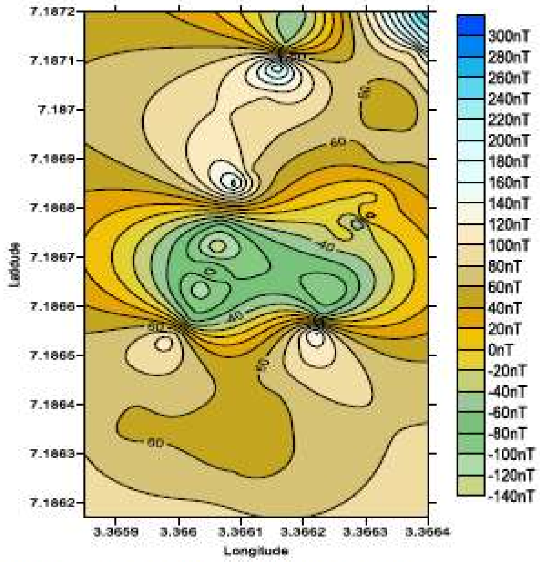

Fig. 8a: 2D TMI of Profiles 7 and 8

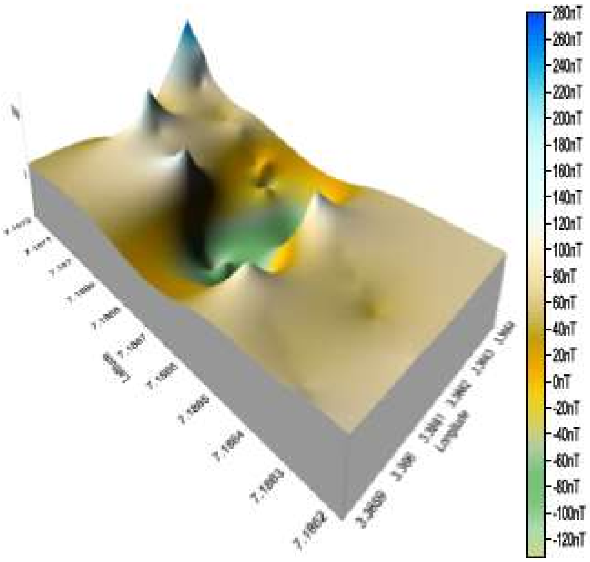

Fig. 8b: 3D TMI of profiles 7 and 8

4.3 Peter's Half Slope Method

This method estimated depth to basement analysis of mineral rocks in the study area. Table 1 summarizes the depth estimations from the ground magnetic data. The depths of magnetic sources were deduced from profiles (Figs. 4a-h) adopting Peter's half slope method.

Table 1: Summary of depth estimates from the ground magnetic data

Profiles	Very Thin Body (m)	Average Thickness (m)	Very Thick Body (m)	Mean (m)
1	6.40	4.81	3.85	5.02
	3.84	2.88	2.31	3.01
	5.13	3.84	3.08	4.02
2	5.05	3.79	3.03	3.96
	8.84	6.63	5.31	6.93
	12.63	9.47	7.58	9.89
3	14.80	11.11	8.89	11.60
	8.71	6.53	5.23	6.82
	7.84	5.88	4.71	6.14
4	12.03	9.03	7.22	9.43
	15.74	11.81	9.45	12.33
5	4.36	3.27	2.62	3.42
	5.88	4.41	3.53	4.61
	8.82	6.61	5.29	6.91
6	4.54	3.41	2.73	3.56
	12.12	9.09	7.27	9.49
	8.33	6.25	5.00	6.53
7	5.23	3.92	3.14	4.09
	8.71	6.53	5.23	6.82
	3.48	2.61	2.09	2.73
8	4.36	3.27	2.62	3.42
	9.58	7.19	5.75	7.51
	17.42	13.06	10.45	13.64
Mean	10.24	6.32	5.06	6.60

In profile 1 (Fig. 4a), 1 cm represents 50 units on the “residual magnetic field” axis while 3 cm represents 50 units on the “distance” axis. On the graph (profile 1), using a centimeter (cm) rule to measure the length on the “distance” axis, then, $13cm = 200m$

$13cm = 200m$

$1cm = x(m)$

Then, $x = 1cm = 15.38m$

Three peaks were considered on this profile. The first peak revealed the half maximum slope distance (d) between the two tangents to be 0.50 cm, and in meters, $d = 0.50 \times 15.38 = 7.69m$. The depths can then be calculated as follows;

For very thin body, $h = \frac{7.69}{1.20} = 6.40m$;

For average thickness, $h = \frac{7.69}{1.60} = 4.81m$; and

For very thick body, $h = \frac{7.69}{2.00} = 3.85m$.

Considering the second peak, the d between the two tangents is 0.30 cm. Therefore, $d = 0.30 \times 15.38 = 4.61m$. Depths for the second peak were calculated as;

For very thin body, $h = \frac{4.61}{1.20} = 3.84m$;

For intermediate thickness, $h = \frac{4.61}{1.60} = 2.88m$; and

For very thick body, $h = \frac{4.61}{2.00} = 2.31m$.

The half maximum slope distance (d) between the two tangents of the third peak is 0.40 cm. The distance in meter, $d = 0.40 \times 15.38 = 6.15m$. Thus, the third peak depths were calculated as; For very thin body, $h = \frac{6.15}{1.20} = 5.13m$;

For intermediate thickness, $h = \frac{6.15}{1.60} = 3.84m$; and

For very thick body, $h = \frac{6.15}{2.00} = 3.08m$.

These calculations revealed that the depth of magnetic rocks having very thin, average and very thick bodies ranged from 3.48-17.42, 2.61-13.06 and 2.09-10.45 m respectively. The shapes of these buried mineral rocks were not specified by this method, it assumes that weathering and some other factors could leads to the deformation of these rocks. Notwithstanding, this method gives the possible geometry of the buried mineral rocks. Peter (1949) proposed that the shallower the depth, the thicker the body of the mineral rocks and the higher the magnetic anomaly susceptibility. Also, he explains that the deeper the depth, the thinner the magnetic body and the lower the magnetic anomaly susceptibility.

5. CONCLUSION

The magnetic signatures obtained from this study showed varying magnetic amplitudes with minimum susceptibility value of approximately -150 nT to a maximum susceptibility value of approximately 280 nT. Rocks with high magnetic susceptibilities (Tantalite and Columbite), and low magnetic susceptibilities (Graphite, Sandstone and Quartz) were observed along the profiles in disseminated quantities. The 2D and 3D sections revealed higher percentage of regions with average magnetic susceptibilities which also indicated that the study area is predominantly quartz or pegmatite vein, and possibly haboured rocks such as Beryl, Quartz and Tourmaline in massive quantities. The depth of the magnetic sources revealed that the major and minor mineral rock contacts in the study area. The average depths of the buried mineral rocks ranged between 2.09 and 17.42 m.

REFERENCES

1. Adegoke, J.A. and Layade, G.O. (2014): Variation of Structural Index of Peters Half Slope in Determining Magnetic Source-Depth. *Archives of Physics Research* 5(2): 23-31.
2. Ajayi T.R. and Ogedengbe, O. (2003): Opportunities for the exploitation of precious and rare metals in Nigeria. Prospects for investment in mineral resources of Southwestern Nigeria, A. A. Elueze (ed), *Nigerian Mining and Geosciences Society (NMGS)*, 15-56 pp.
3. Folami, S.L., (1980): Interpretation of aeromagnetic anomalies in Iwaraja area, South Western Nigeria. *J Mm, Geol.* 28(2): 393-397.
4. Frantisek Hrouda, Marta Chlupacora and Martin Chadinia (2009): The use of magnetic Susceptibility of Rocks in Geological Exploration. Published by Terraplus Geophysical Equipment Supplier, First Edition.
5. Jones H.A. and Hockey R.D. (1964): The geology of South Western Nigeria, *Bulletin, Geological Survey, Nigerian* No 31; 101.
6. Kayode J.S., Adelusi A.O. and Nyabeze P.K. (2013): Interpretation of ground magnetic data of Ilesa, Southwestern Nigeria for potential mineral targets. *Advances in Applied Science Research* 4(1):163-172
7. Kayode J.S. and Adelusi A.O. (2010): Ground Magnetic Data Interpretation of Ijebu-Jesa Area, Southwestern Nigeria, Using Total Component. *Research Journal of Applied Sciences, Engineering and Technology* 2(8): 703-709.
8. Kogbe, C. A. (1989): *Geology of Nigeria*. Second Edition, Elizabethan Publishing & Co., Lagos pp. 41-58.
9. Nwosu O.B., Umego M.N., Onuba L.N. (2015): Comparison of Magnetic Basement Depth Values from Spectral Technique, SPITH and Slope Techniques using HRAM. *J. Geol. Geophys* 4: 232. doi:10.4172/2381-8719.1000232.
10. Ojo, A.O. and Popoola, O.I. (2014): Geomagnetic of mineral rocks at Awo, Osun State, Southwest Nigeria. *International Journal of Advanced Geosciences* 2(1): 20-30.
11. Ojo, Akintayo O. (2013): Geomagnetic and geoelectric investigation of mineral rocks at Awo, Osun State, southwest Nigeria. *International Journal of Physical Research* 1(2): 60-74.
12. Ojo, Akintayo O., Omotoso, Toyin O. and Adekanle, Olorunyomi J. (2014): Determination of Location and Depth of Mineral Rocks at Olode Village in Ibadan, Oyo State, Nigeria Using Geophysical Methods. *International Journal of Geophysics*, vol. 2014, Article ID 306862, 13 pages. doi:10.1155/2014/306862.
13. Okunlola, O.A. and Jimba, S. (2006): Compositional trends in relation to Ta-Nb mineralization in Precambrian pegmatite of Aramoko-Ara-Ijero area, south western Nigeria. *Journal of Mining and Geology* 42(2): 113-126.
14. Okunlola, O.A. and Ofonime, B.E. (2006): Geological setting, petrographical features and age of rare metal (Ta-Nb) mineralization of pegmatite of Komu area, Southwestern Nigeria. *African Journal of Science and Tech. (AJST)*; *Science and Engineering Series* 7(1): 96-110.
15. Okunlola, O.A. (2005): Metallogeny of Tantalum-niobium mineralization of Precambrian pegmatite of Nigeria. *Mineral Wealth* 104(2): 38-50.
16. Okunlola, O.A., Adeigbe, O.C. and Oluwatoke, O.O. (2009): Compositional and petrogenetic features of schistose rocks of Ibadan area, southwestern Nigeria. *Earth Sciences Research Journals* 13(2): 29-43.
17. Omatsola M.E. and Adegoke O.S. (1981): Tectonic Evolution and Cretaceous Stratigraphy of the Dahomey Basin. *Journal of mining Geology* 8: 130-137.
18. Oyawoye, M. O. (1964): The geology of the basement complex. *Journal of Nigeria Mining, Geology and Metallurgy* 1: 87-102.
19. Peters L.J (1949): The direct approach to magnetic interpretation and its practical application. *Geophysics* 14: 290-320.

20. Rahaman, M.A., (1976): Review of the basement geology of southwestern Nigeria In Kogbe, C.A. (Ed); Geology of Nigeria. Elizabethan publishing co, Lagos 41-58 pp.
21. Reynolds, John M. (1997): An introduction to Applied and Environmental Geophysics. Reynold Geo-Sciences Limited. Second Edition.
22. Roger, S. (2008): Magnetic Susceptibility as a Tool for Investigating Igneous Rocks experience from IODP Expedition 304.
23. Telford W.M., Geldart L.P. and Sheriff R.A. (1990): Applied geophysics. Cambridge University Press.
24. Umego, M.N. and Ojo, S.B. (1995): A magnetic depth to basement analysis in the Sokoto basin, North Western Nigeria. *Journal of mining and geology* 31(2): 161-167.