



Estimation of Depth and Locations of Mineral Rocks using Magnetic Survey Method: Case of Sajiyan-Ero town, Ondo State, Southwest Nigeria

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Abstract

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A ground magnetic survey was carried out to determine the locations and approximate depth of suspecting mineral rocks at the surroundings of a site in Sajiyan-Ero town off Ogbese-Owo highway, Ondo State, Nigeria. This research was conceived as a result of suspicious presence of mineral rocks in the area and also to add to magnetic field database of southwestern Nigeria as no magnetic data have been acquired in the area. A total of 190 magnetic data points were acquired from twenty (20) profiles using a G-816 proton precession magnetometer with 10 m spacing intervals between each profiles and points. The magnetic data obtained were processed and analyzed after some corrections and presented into magnetic plots, contour, base and 3D maps. The slope method of depth interpretation was used to estimate the depth to the magnetic sources. The magnetic signature acquired show significant irregular amplitude from a positive peak with minimum value of 0.6 nT at an average depth to top of 5.5 m and center 17.6 m to a maximum value of 17.1 nT at an average depth of 7.92 m and 25.3 m to top and center of magnetic anomaly respectively. This corresponds to profiles 1 and 5. The negative peak values vary from -8.9 nT to -1.0 nT with an average depth to top of magnetic anomaly of 10.0 m and 4.58 m respectively. The average estimated depth to top of anomaly for the study area was 22.0 m with profile 2 having the maximum. The variations in depth determination from anomaly behavior have considerable environmental and geological significance. This depth at various points on the subsurface allows for mapping to infer thickness of mineral rocks deposits.

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INTRODUCTION

Magnetic geophysical techniques have found a wide range of applications in mineral exploration and geotechnical works (Ishola *et al.* 2010; Kayode and Adelusi 2010; Kayode *et al.* 2010; Adekoya *et al.* 2003). These techniques are known to be fast, high resolution, noninvasive, and cost-effective techniques. The magnetic method is very suitable for locating buried magnetite ore bodies because of their high magnetic susceptibility. The magnetic method of exploring the subsurface is used to either map or locate rock types that contain varying amounts of magnetic susceptible minerals or to locate man-made ferromagnetic (e.g., iron) substances (Philip *et al.* 2002; Lowrie 2011). Thus, the magnetic method has

found a broad spectrum of applications in exploration, engineering and environmental geophysics ranging from locating voids and metal containers containing contaminants to mapping dikes that act as barriers to groundwater flow. The technique requires measurements of the amplitude of magnetic components at discrete points along traverses distributed regularly throughout the survey area of interest.

The magnetic method is a geophysical technique that measures variations in the earth's magnetic field to determine the location of subsurface features. Magnetic field variations can be interpreted to determine an anomaly's depth, geometry and magnetic susceptibility. Three components are

measured which are horizontal, vertical, and total components. The vertical components and the total components are mostly used in the past studies to delineate faults, fractures, depth to magnetic basement and other geological structures (Folami 1992). The magnetic method is relatively easy to perform and inexpensive as it requires little data processing or manipulation. The technique has good depth penetration compared to other geophysical techniques such as ground penetrating radar, high frequency electromagnetic and DC-resistivity. The increase in global demand for these minerals especially the rare metals has led to the renewed interest in the search for economically viable mineral deposits in Nigeria (Ajayi and Ogedengbe 2003; Kayode 2006). A number of researchers have made research on the evaluation, exploitation and exploration of solid mineral deposit in the south western region of Nigeria (Okunola and Ogedengbe 2003; Okunola 2005).

Also some studies have shown that this area is characterized by Precambrian rocks typical of the basement Complex of Nigeria (Adekoya *et al.* 2003; Ajayi and Ogedengbe 2003; Obaje 2009). In this work, magnetic geophysical technique was used to identify the location and depth of formation of mineral rocks in the study area.

Geology and Location of Study Area

The town Sajiyan-Ero is located in Akure North Local Government Area of Ondo State in Southwestern Nigeria and about 25 km from Akure. It has predominantly rainforest with heavy presence of high undulating rocky and mountainous formations. These rocks are inherently characterized by low porosity and permeability. The study area lies on geographical Latitude 70 13' 24.96" to Latitude 70 13' 27.84" N and Longitude 50 27' 08.28" to 50 27' 10.44" E with elevation variation between 200-300 m and within the basement complex of South western Nigeria, which is characterized by migmatite gneiss (Kayode 2006). The local geological mapping of the study area revealed that the area is underlain mainly by a rock unit, granite gneiss. These rocks are concealed in most areas and some of the outcrops are exposed around the study area (Figure 1). It is therefore suspected that the overburden is relatively thin within the study area. The rocks are generally trending in Northwest-Southeast direction and dipping to the west. All the exposed outcrops observed have low fissures, indicating minor evidence of deformation. The prospective minerals observed in this rock type include granite, quartz, feldspar and biotite which can be exploited for

making tiles etc (Okunlola *et al.* 2009; Obaje 2009; Ojo *et al.* 2014).

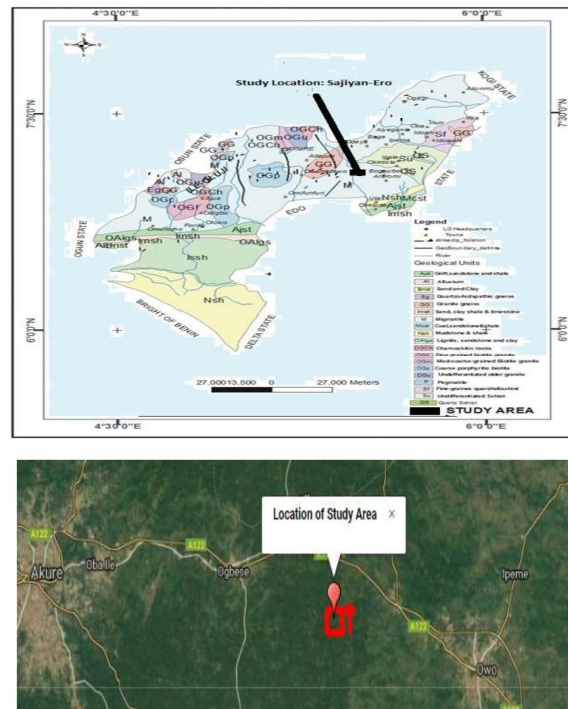


Figure 1: Geological and Location Map of Study area (NGSA and GMAPGIS)

MATERIALS AND METHODS

The Magnetic field intensity measurements were carried out using a portable proton precession magnetometer and a total of 191 magnetic data points from twenty magnetic profiles were taken across the study area in N-S direction. A Global Positioning System was used to measure the longitude, latitude and elevation along the profiles. An evaluation of the study area was done and electrical transmission lines, grounded metallic structures and other sources that could generate noise to the data were avoided. The magnetic data obtained were corrected for the effect of diurnal variations and removal of regional magnetic field. Removal of the regional magnetic field was done by subtracting the International Geomagnetic Reference Field (IGRF) (model 2010 in Geosoft Oasis Montaj software) value from the obtained data after drift correction to obtain the needed magnetic anomaly. The corrected magnetic data were plotted as 2D and 3D magnetic contour maps of the whole survey area using Surfer 10. Also, the residual anomalies obtained were plotted against distance using Microsoft Excel. The profiles were interpreted using the slope methods (Peter's half slope and the half width rule methods) to determine the approximate depth to the top and center of the buried magnetic body.

Peter's Half-Slope Method

A theoretically based graphical method was devised by (Peters 1949) and is known as Peter's half-slope method (Figure 2). In his classical paper on magnetic interpretation, he presented a rule of thumb to find the depth to the magnetic source. Peter's rule is based on the mathematical expression for magnetic anomalies over vertical dikes with vertical polarization.

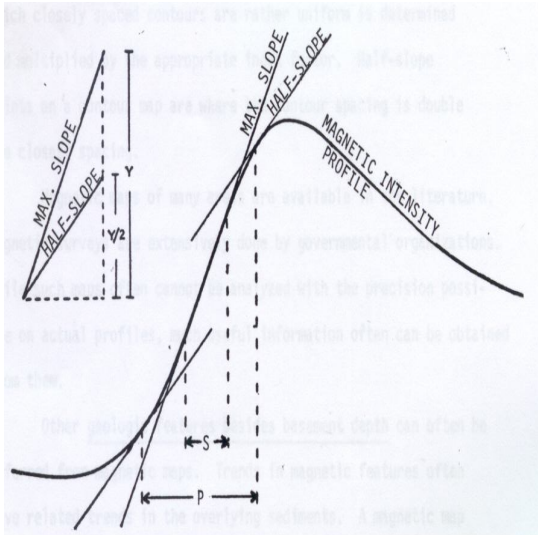


Figure 2: Slope method of depth-to-basement estimation (after Peters 1949)

In Figure 2, a tangent line 1 is drawn to the point of maximum slope and, using a right-angled triangle construction, a line (line 2) with half the slope of the original tangent is then constructed. Two further lines with the same shape as line 2 are then drawn where they form tangents to the anomaly (lines 3 and 4). The horizontal distance, S between these two tangents is a measure of the depth to the magnetic body. According to Peter, the half-maximum slope distance (S) is equal (approximately) to $1.6h$, where h is the depth to the magnetic source (Figure 2). The magnetic body was given an index value or "proportionality factor," ranging from 1.2 to 2, depending on the object's size. For example, large objects would have a value approaching 2, while a smaller item, such as a handgun, would be around 1.2. There is no formula to ascribe specific index values to objects of certain sizes; therefore, the value depends on your perception of the object's size, with the typical index value at 1.6. Then the distance is divided by index value to find the depth of the object. If the object's size is not definite, divide the distance by both 1.2 and 2 to determine the depths between which the object is buried. For bodies having very

small width-to-depth ratios (i.e., thin sheets), $S=1.2h$ and for bodies having very large width-to-depth ratios, $S=2.0h$. Therefore, for a 2D body with vertical sides, uniform and nearly vertical magnetization, the following holds: $S= 1.2h$ (very thin body), $S = 1.6h$ (intermediate thickness), and $S= 2.0h$ (very thick body), where S is the horizontal distance corresponding to half the maximum slope, which is tangent to the curve, and is depth to the basement of the body.

RESULTS AND DISCUSSIONS

An assessment of the contour, base and 3D maps (Figures 3, 4 and 5) shows that the contour lines and peaks of the western part of the contour map are widely spaced indicating that the depth to magnetic basement in these areas is relatively large or that is no presence of pegmatite whereas, at the eastern part of the contour map, the contour lines are closely spaced indicating that the depth to the basement is shallow in these areas. The closely spaced, linear sub-parallel orientation of contours at the eastern part suggests shallow subsurface geologic structures and the possibility of faults or local fractured zones passing through these areas. Also, there are spikes at the eastern part indicating that there is presence of magnetic mineral rocks, whereas the western part is plain and there are no spikes at all indicating that there is a little or no presence of magnetic mineral rocks.

On the basis of the variation in magnetic intensity across the study area, there was a high magnetic intensity at the eastern region and low magnetic intensity at the western region of the contour maps. The magnetic signature obtained for the total component relative magnetic intensity plot along the traverses showed considerable varying amplitude from a minimum peak value of about 0.6 nT at a depth to top of about 5.5 m and center of 17.6m to a maximum peak value of about 17.1 nT at a depth to top of about 7.92 m and center of 25.3m. The depth of the magnetic basement reveals the major and minor rock contacts in the area separated with different colors (Figure 5). This contouring method is the oldest form of data presentation and it has the advantage of being able to show details that cannot be shown in grid-based presentations. The ground magnetic profiles of the study area were generated using Microsoft Excel as shown in Figures 6 to 15. From these figures, the depth estimation of the basement in the area and identification of the rock boundaries was carried out using Peter's half-slope method (Peters, 1949). The estimated depth calculations for selected profiles are shown in Figures 6 to 15 and are computed in Tables 1 and 2.

Table 1: Result showing estimated values of depth to center of anomaly body or source

Profiles	Sampled Peak Points and depth (m)						N	SD	SE	Average depth (m)
	1	2	3	4	5	6				
1	16.00	20.00	40.00	-	-	-	3	12.86	7.42	25.30
2	16.00	40.00	40.00	-	-	-	3	13.86	8.00	32.00
3	12.00	12.00	12.00	20.00	16.00	16.00	6	4.43	1.81	14.60
4	12.00	16.00	8.00	-	20.00	-	4	5.16	2.58	14.40
5	12.00	8.00	24.00	28.00	16.00	-	5	8.33	3.72	17.60
6	12.00	16.00	20.00	12.00	8.00	-	5	4.56	2.04	13.60
7	8.00	20.00	10.00	20.00	-	-	4	6.43	3.21	14.50
8	16.00	20.00	20.00	-	-	-	3	2.31	1.33	18.70
9	16.00	16.00	12.00	-	-	-	3	2.31	1.33	14.70
10	12.00	20.00	8.00	16.00	20.00	-	5	5.22	2.33	15.20
11	18.00	8.00	16.00	24.00	-	-	4	6.61	3.30	16.50
12	12.00	16.00	12.00	20.00	-	-	4	3.83	1.91	15.00
13	8.00	20.00	12.00	8.00	-	-	4	5.66	2.83	12.00
14	21.00	12.00	12.00	8.00	20.00	-	5	5.64	2.52	14.60
15	8.00	16.00	20.00	8.00	20.00	-	5	6.07	2.71	14.40
16	12.00	12.00	24.00	20.00	16.00	-	5	5.22	2.33	16.80
17	8.00	16.00	12.00	16.00	12.00	-	5	3.35	1.50	12.80
18	12.00	16.00	12.00	16.00	-	-	4	2.31	1.15	14.00
19	12.00	20.00	20.00	20.00	12.00	-	5	4.38	1.96	16.80
20	20.00	20.00	16.00	12.00	-	-	4	3.83	1.91	17.00

NB: N = No. of selected peak Points; Standard Error (SE) = Standard Deviation (SD)/√N

Table 2: Result showing estimated values of depth to top of anomaly body or source

Profiles	Sampled Peak Points and depth (m)						N	SD	SE	Average depth (m)
	1	2	3	4	5	6				
1	5.00	6.25	12.50	-	-	-	3	4.02	2.32	7.90
2	5.00	12.50	12.50	-	-	-	3	4.33	2.50	10.00
3	3.75	3.75	3.75	6.25	5.00	5.00	6	1.02	0.42	4.60
4	3.75	5.00	2.50	5.00	6.25	-	5	1.43	0.64	4.50
5	3.75	2.50	7.50	8.75	5.00	-	5	2.59	1.16	5.50
6	3.75	5.00	6.25	3.75	2.50	-	5	1.43	0.64	4.30
7	2.50	6.25	3.13	6.25	-	-	4	2.00	1.00	4.50
8	5.00	6.25	6.25	-	-	-	3	0.72	0.42	5.80
9	5.00	5.00	3.75	-	-	-	3	0.72	0.42	4.60
10	3.75	6.25	2.50	5.00	6.25	-	5	1.63	0.73	4.80
11	5.63	2.50	5.00	7.50	-	-	4	2.07	1.03	5.20
12	3.75	5.00	3.75	6.25	-	-	4	1.20	0.60	4.70
13	2.50	6.25	3.75	2.50	-	-	4	1.77	0.88	3.80
14	3.75	3.75	3.75	2.50	6.25	-	5	1.37	0.61	4.00
15	2.50	5.00	6.25	2.50	6.25	-	5	1.90	0.85	4.50
16	3.75	3.75	7.50	6.25	5.00	-	5	1.63	0.73	5.30
17	2.50	5.00	3.75	5.00	3.75	-	5	1.05	0.47	4.00
18	3.75	5.00	3.75	5.00	-	-	4	0.72	0.36	4.40
19	3.75	6.25	6.25	6.25	3.75	-	5	1.37	0.61	5.30
20	6.25	6.25	6.25	5.00	3.75	-	5	1.12	0.50	5.50

NB: N = No. of selected peak Points; Standard Error (SE) = Standard Deviation (SD)/√N

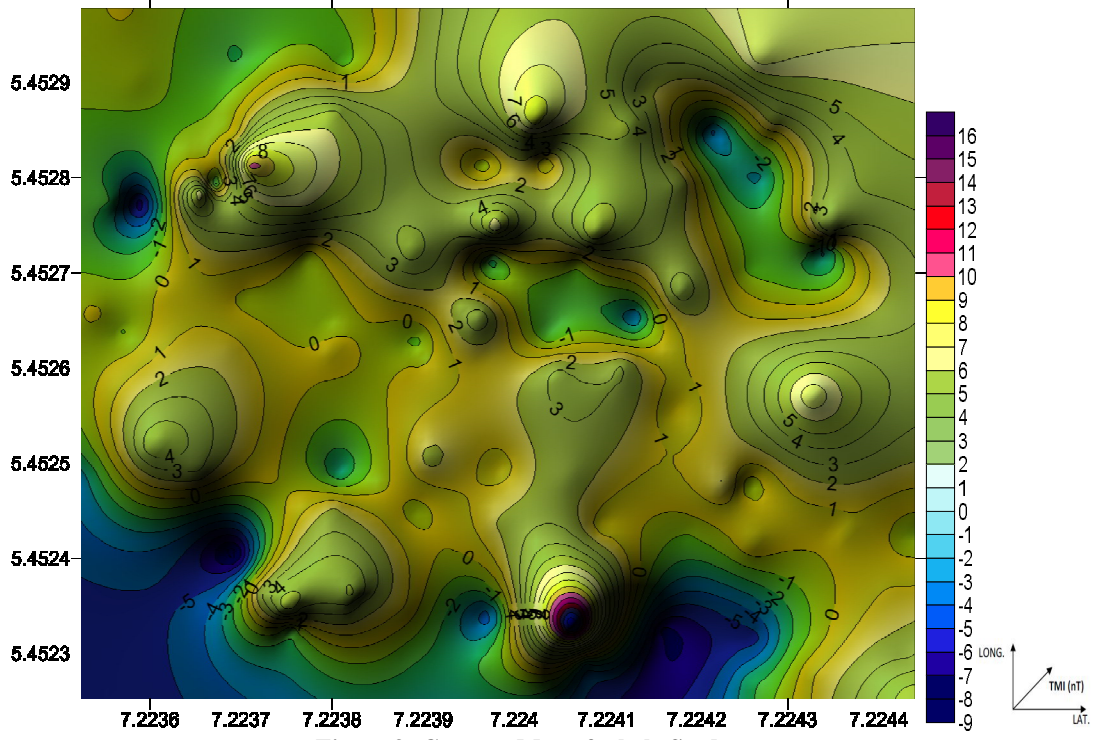


Figure 3: Contour Map of whole Study area

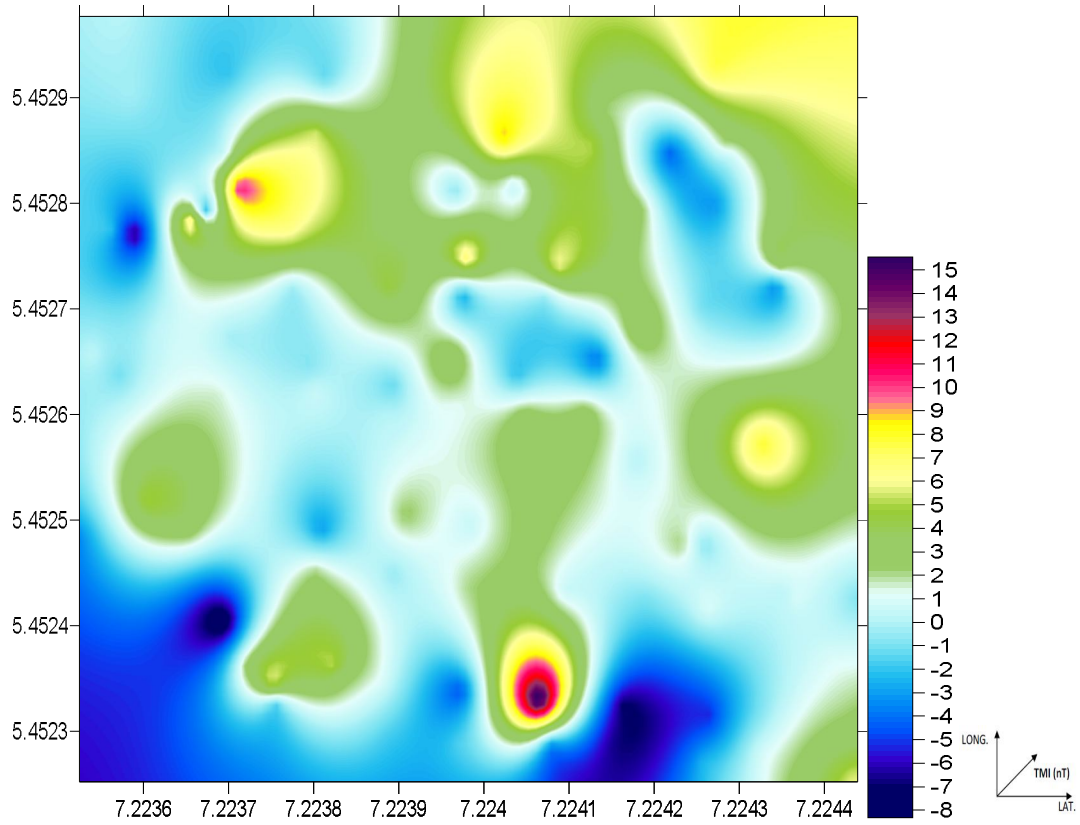


Figure 4: Base Map of whole Study area

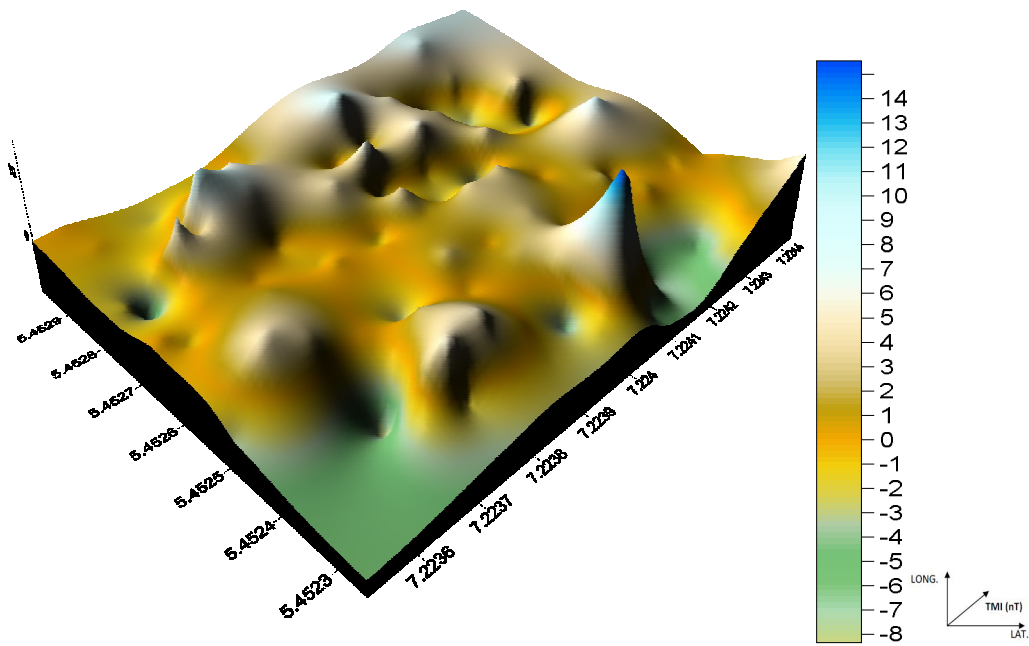


Figure 5: 3D Surface contour Map of whole Study area

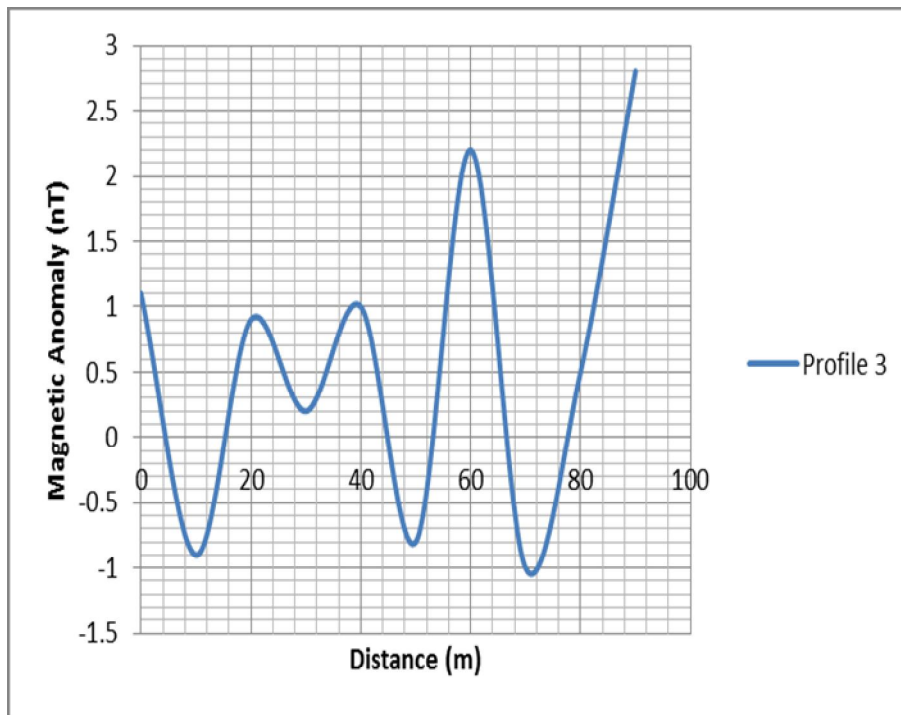


Figure 6: Corrected magnetic Field Plot for Profile 3

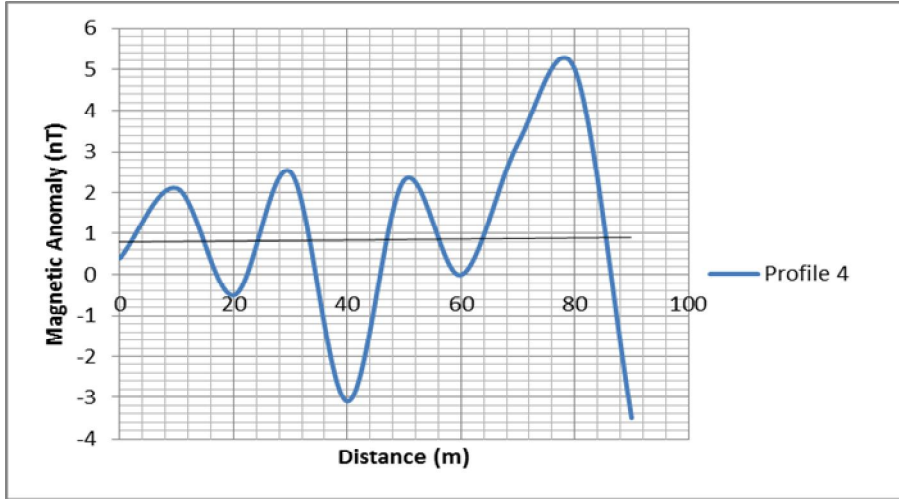


Figure 7: Corrected magnetic Field Plot for Profile 4

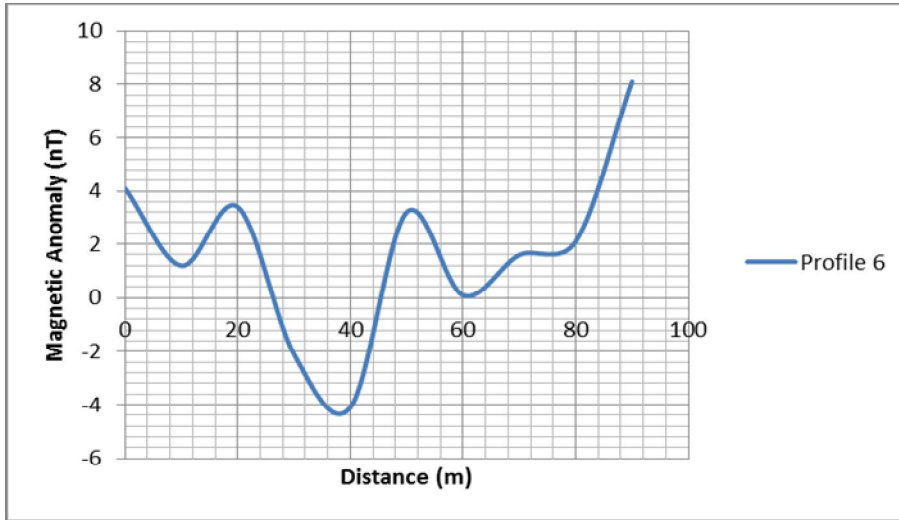


Figure 8: Corrected magnetic Field Plot for Profile 6

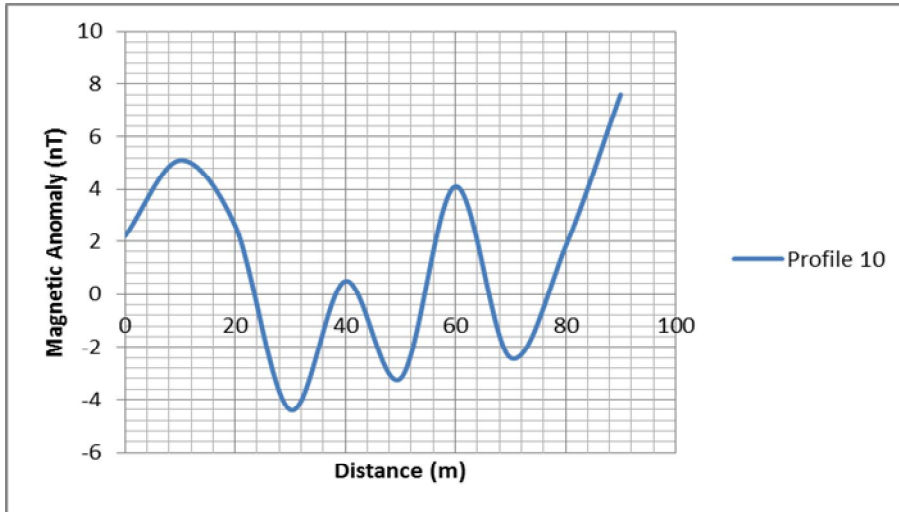


Figure 9: Corrected magnetic Field Plot for Profile 10

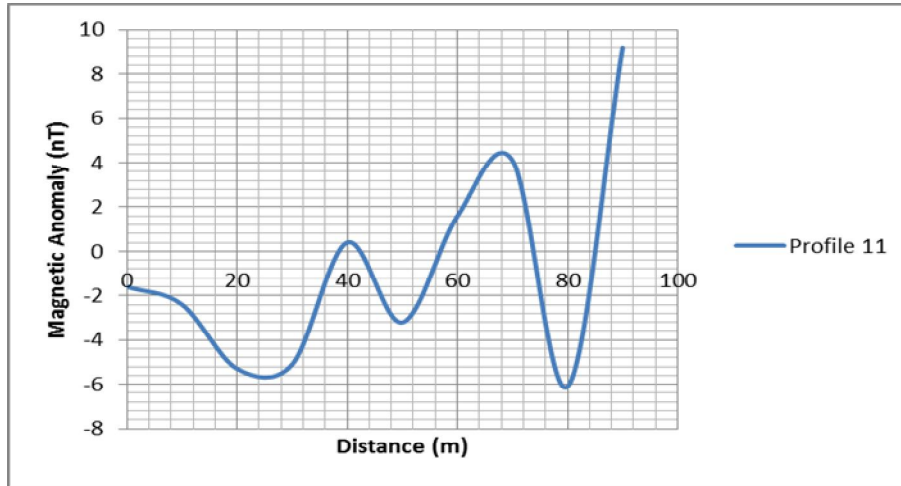


Figure 10: Corrected magnetic Field Plot for Profile 11

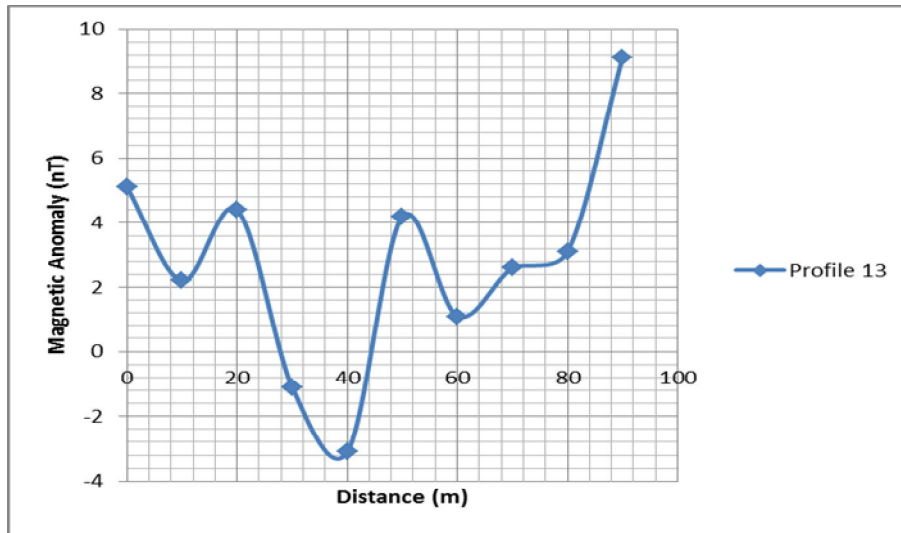


Figure 11: Corrected magnetic Field Plot for Profile 13

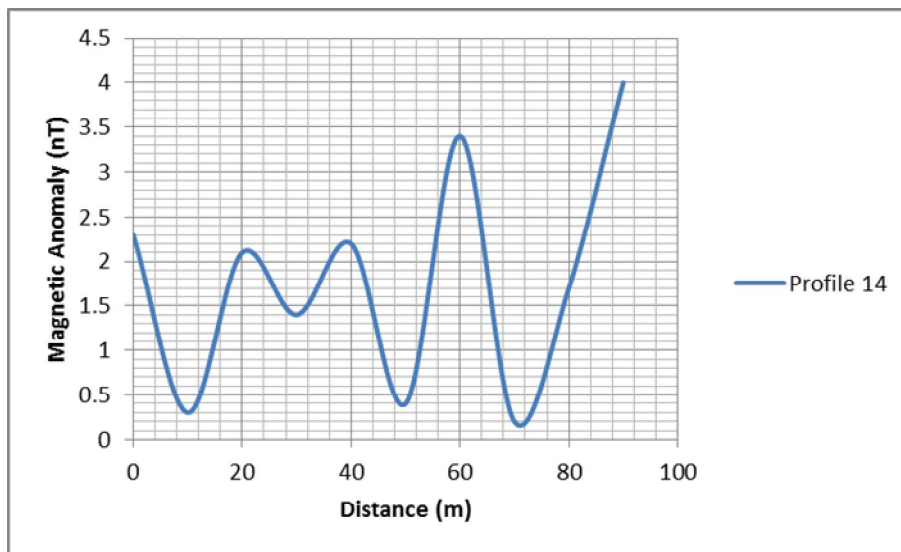


Figure 12: Corrected magnetic Field Plot for Profile 14

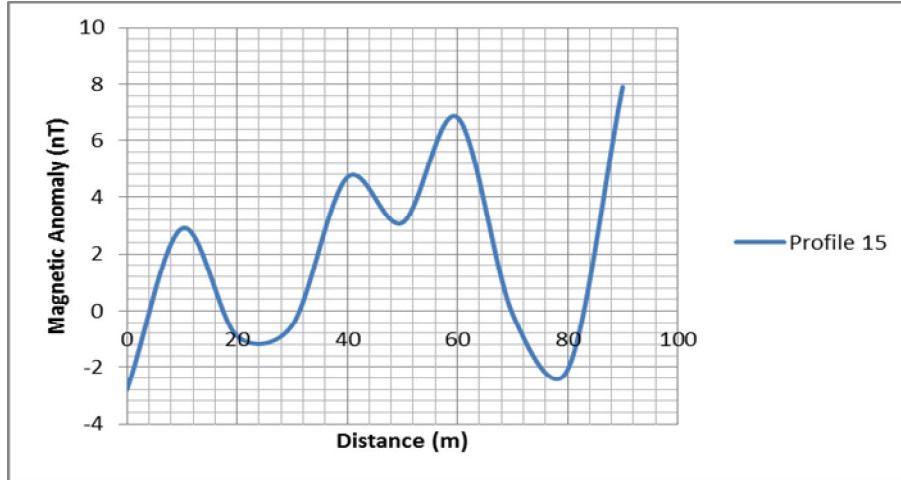


Figure 13: Corrected magnetic Field Plot for Profile 15

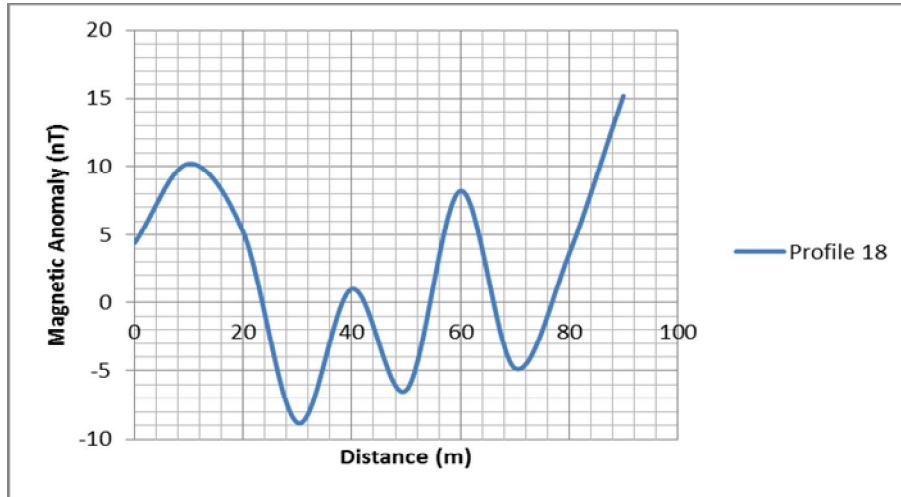


Figure 14: Corrected magnetic Field Plot for Profile 18

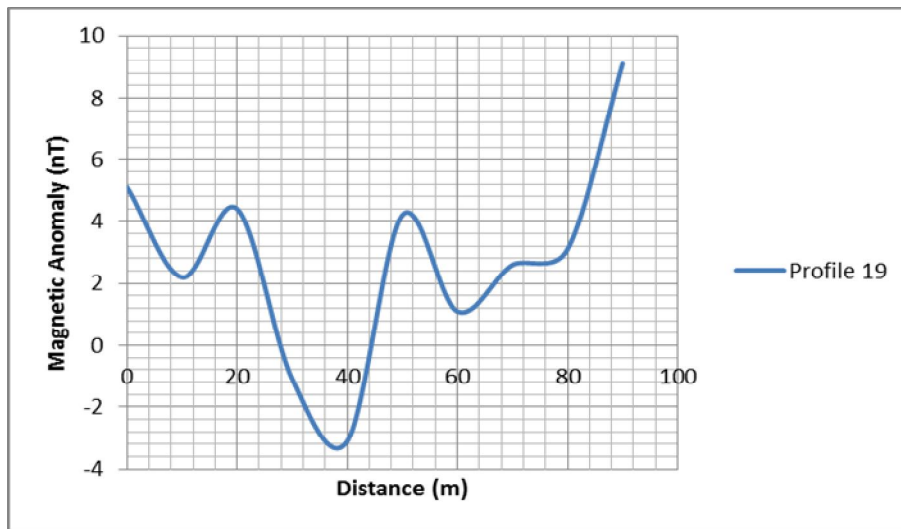


Figure 15: Corrected magnetic Field Plot for Profile 19

In all the profiles, the estimated depth to center and top of anomaly source was deduced using slope method (Peter's half-slope and half width rule method) and the results are presented in tables 1 and 2. On the average, the depths of these mineral rocks from the surface are in the interval of 5.16 m to 16.53 m. Considering this method; Peter's method does not specify the shape of the buried body. In the method, it is assumed that there can be a deformation of these mineral rocks due to factors such as weathering. The possible geometry of the mineral rocks are given through the index values or proportionality factor. The shallower the depth, the thicker the body of the mineral rocks and the anomaly will be more pronounced. Also, the deeper the depth, the thinner the body of the mineral rocks and the anomaly will be less pronounced.

CONCLUSION

A ground magnetic survey was carried out on Sajiyan-Ero town, Ondo State, Southwest and the results of the investigation revealed that the area is under laid by magnetic rocks with minerals at low depths, and defined lineament and target zones depicted by the point of the peak of the anomalies in each of the profile collected. The study also revealed the lithological units in basement structure such as bedrocks, topography, bedrock depression, rock boundaries, contact zones which can serve as deposit centers for mineral resources and also to meet the demands of searching deposits in this area. Thus the usefulness of magnetic survey is invaluable in depicting the subsurface geology of the mineral deposit. The estimated depth (i.e. top and center) to the magnetic basement in each profile were obtained using slope method and half width method which gives values between 8 m to 24 m to center and 2.5 m to 8.75m to top of anomalies respectively. These values are not real depths but approximate ones.

The linear nature of the anomalies in this area support the report that rocks are bounded and offset by cracks and fissures which can serve as deposit center for mineral resources. The interpretation provided by ground magnetic survey helps to have a picture of subsurface characteristics. The magnetic data acquired will also add to and improve the database of magnetic data of the region.

REFERENCES

Adekoya J.A., Kehinde-Phillips O.O. and Odukoya A.M. (2003) Geological distribution of mineral resources in Southwestern Nigeria," in *Prospects for Investment in Mineral Resources of Southwestern Nigeria*, A. A.

- Elueze, Ed., pp. 1–13, Nigerian Mining and Geosciences (NMGS)
- Ajayi T.R and Ogedengbe O. (2003) Opportunities for the exploitation of precious and rare metals in Nigeria," in *Prospects for Investment in Mineral Resources of Southwestern Nigeria*, A. A. Elueze, Ed., pp. 15–56, Nigerian Mining and Geosciences Society (NMGS)
- Folami S.L. (1992) Interpretation of aeromagnetic anomalies in Iwaraja area, South Western Nigeria," *Journal of Mining and Geology*, vol. 28, no. 2, pp. 393–397
- Ishola K.S., Adeoti L and Obianeri A (2010) Interpretation of the historic site, Agorin in Badagry, Southwestern Nigeria using geophysical methods," *Ozean Journal of applied Sciences*, vol. 5, no. 1, pp. 85–99
- Kayode J.S. (2006) Ground magnetic study of Jeda-Iloko area, South-Western Nigeria and its geological implications [*M.S. thesis*], *Federal University of Technology, Akure, Nigeria*
- 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*, vol. 2, no. 8, pp. 703–709
- Kayode J.S, Nyabese P and Adelusi A.O. (2010) Ground magnetic study of Ilesa east, Southwestern Nigeria," *African Journal of Environmental Science and Technology*, vol. 4, no. 3, pp. 122–131
- Lowrie W. (2011) *Fundamentals of Geophysics*, Cambridge University Press, Cambridge, UK, 2nd edition
- Oasis Montaj (Geosoft Program), 2010. Geosoft Mapping and Application System, Inc, Suite 500, Richmond St. West Toronto, ON Canada N5S1V6
- Obaje N.G. (2009) *Geology and Mineral Resources of Nigeria*, vol. 120 of *Lecture Notes in Earth Sciences*, Springer, New York, NY, USA
- Ojo A.O., Omotoso T.O. and Adekanle O.J. (2014) Determination of Location and Depth of Mineral Rocks at Olode Village in Ibadan, Oyo State, Nigeria, Using Geophysical Methods *Hindawi International Journal of Geophysics Volume 2014:1-13*
- Okunlola O.A. (2005) Metallogeny of Tantalum-niobium mineralization of Precambrian pegmatite of Nigeria," *Mineral Wealth*, vol. 104, no. 2, pp. 38–50
- Okunlola O.A. and Ogedengbe O. (2003) Investment potential of gemstone occurrences in Southwestern Nigeria," in *Prospects for Investment in Mineral Resources of Southwestern Nigeria*, A. A. Elueze, Ed., pp. 41–45, Nigerian Mining and Geosciences Society (NMGS)

- 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 Journal*, vol. 13, no. 2, pp. 119–133
- Peters L.J. (1949) The direct approach to magnetic interpretation and its practical application,” *Geophysics*, vol. 14, pp. 290–320
- Philip K., Brooks M. and Hill L. (2002) *An Introduction to Geophysical Exploration*, Blackwell Science, London, UK, 3rd edition