

## DEPTH ESTIMATION OF MINERAL DEPOSIT USING MAGNETIC METHOD IN ODUDUWA UNIVERSITY, IPETUMODU, SOUTHWESTERN NIGERIA

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### ABSTRACT

In this study we delineate the subsurface structures in an open field in Oduduwa University, Ipetumodu, Osun State covering 500m<sup>2</sup> using magnetic methods. The goal is to estimate depth to top and centre of mineral deposit of the study area. Ground magnetic survey was carried out along ten (10) profiles. The data set was processed and interpreted using a series of techniques and software (the slope methods, trend analysis and Golden software). The results indicate that profile 1 has the highest amplitude of 12.4 nT followed by profile 5 with 10.2 nT. The depth to basement top estimate ranges from 2.25 to 6.65 m while depth to center ranges from 8 to 25m. The magnetic anomaly obtained is between -8.8 nT and +5.8 nT. The ground magnetic contour, 3-D and vector maps showed that magnetic anomalies are as a result of rocks present in the region. The major rocks and minerals suspected to be found in this area and its environment are slate, gneiss and serpentinite. The high intensity values strongly suggest the presence of ferromagnetic minerals. The suspected points to have a high presence of minerals in the study area are between profiles 1 and 5.

**Keywords:** Magnetic field, Magnetic anomaly, Basement, Oduduwa University

### INTRODUCTION

The increasing importance given to environmental challenges has recently prompted the scientific society to improve on the geophysical techniques intended at the discovery of mineral ore deposit. The discovery and location of these mineral ores can be detected through several geophysical techniques (Foley, 1994; Gibson *et al.*, 1996; Marchetti, *et al.*, 1998). Efforts have been made by geological and mining engineers to find the meaning of the structure of the outermost formations of the Earth's crust. These have led to diverse comprehensive studies, which now stand as building-block to their efforts. Based on the aim and

objectives of investigation, there are many geophysical methods suitable to different situations. These methods include; magnetic, gravity, electrical, electromagnetic methods, to mention but few (Keary and Brooks, 2002; Musset and Khan, 2000) and this research makes use of these magnetic methods. The magnetic method of geophysical prospecting is a geophysical technique that measures variations in the earth's magnetic field to determine the location of subsurface features. This non destructive technique has numerous applications in engineering and environmental studies. These include; the location of voids, near-surface faults, igneous dikes, and buried ferromagnetic

objects like storage drums, pipes etc (Butler, 2005; Lowrie, 2001). In general, the technique that is aforementioned makes use of the magnetic survey which is constantly used for a quick detection of underground metallic refuse. This technique involves two different kinds of measurements viz the total intensity of the local magnetic field and its vertical gradient.

The discovery of metallic hidden objects using magnetometric survey accounts for the low cost of its non-persistent implementation, the quickness of data acquisition and processing. The analysis and localization of these hidden objects with only magnetic signature, depends solely on the depth of the object used and its makeup; since a nonmagnetic body is completely unable to detectable. This limitation can be dormant if other geophysical techniques (electromagnetic, GPR and electrical resistivity) which focused on different physical properties of the affected matter are used.

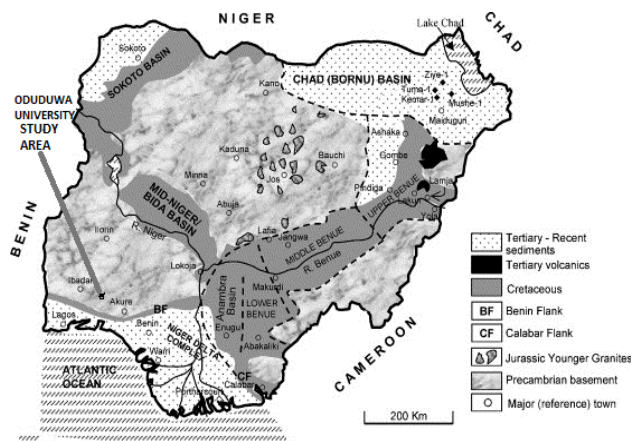
An application of ground magnetic surveys to the structural interpretation of an area is described in this study. Oduduwa University site (study area) is located within a tropical climate differentiated by irregular wet and dry seasons. The relationship existing between tectonic structures and mineralization makes this area an excellent prospecting target. This research work focuses on the data collected from the interpretations of the ground magnetic survey on a subsurface geological structure.

The primacy given to magnetic survey is such that deep insight into the depth of the top and center of magnetic sources in the area is delineated.

### Location and Geology of the Study Area

The study area is situated at the Ipetumodu area of Osun State, Nigeria. It lies between latitudes 7.504268 and 7.504434°N and longitudes 4.452252 and 4.452925°E. The geology of this area is of Precambrian rocks that are characteristic for the basement Complex of Nigeria. The major rock found within the area form part of the Proterozoic schist belts of Nigeria (Figure 1). In terms of structural features, lithology and mineralization, the schist belts of Nigeria show considerable similarities to the Achaean Green Stone Belts.

Previous study has shown that the south western region of Nigeria is characterized by solid mineral deposit and more research work should be carried out to discover these minerals (Joshua *et al.*, 2010). 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). The topography of the area is gentle with few local outcrops in the northeastern and northwestern part. There have been contradictory reports on the nature and lateral shift of the major faults in this area hence the necessity for this work.



**Figure 1. Location and Geological Map of study Area**

### Theory of Magnetic Methods

The source of the earth's magnetism is assumed to be the liquid outer core. This cools outside and it leads to the material becoming denser and sinking towards the inside of the outer core and new warm liquid matter rising to the outside (Telford

*et al.*, 2001). Thus, liquid metallic matter generates convection currents which move through a weak cosmic magnetic field that subsequently produce induction currents. It is this induction current that generate the earth's magnetic field (Telford *et al.*, 2001; Lowrie, 2001). Crystals with magnetic minerals are the major content of most rocks of the earth's crust. Thus, most rocks contain some certain amount of magnetism which usually have two components; induction by the magnetic field present while taking measurement and remnant formed during geologic history (Reijers, 1996). Ground magnetic study however is used for detail mapping in order to understand the subsurface geology of an area. The technique requires measurements of the amplitude of magnetic components at discrete points along traverses distributed regularly throughout the survey area of interest. In ground magnetic study, three components are examined. These are horizontal, vertical and total components. The vertical components and the total components were mostly used in the past studies to delineate faults, fractures, depth to magnetic basement and other geological structures (Folami, 1992; Kayode, 2006, Akintayo, 2013).

$$\nabla \cdot \vec{A} = 4\pi \vec{\nabla} \cdot \vec{J} \quad (1)$$

Equation (1) above is the required potential equation within the regions occupied by magnetic bodies.

## MATERIALS AND METHODS

### Data Acquisition and Processing

Magnetic measurements were carried out using a proton magnetometer that involves three components. These components are; vertical, horizontal and total magnetic intensities. Ten (10) traverses of 150 points along East-west and West-east profiles were developed. The station interval was 10 m while the distance between lines was 5 m. The total area of the survey location was 500 employed in determining the depth to the top through trend analysis. The maximum slope

$m^2$ . The data acquisition technique requires measurements of the magnetic intensities at discrete points together with traverses regularly distributed within the study area. The magnetic data developed were processed so as to prepare the dataset for interpretations. The procedures for data processing include; drift correction, and plotting of the relative magnetic profiles. The peak points (positive or negative) on the magnetic profile plots are taken as reference points for the results of the depth estimation. For accuracy during measurement, the best method is to adjust the sensor in the same direction at each station wherever the measurement is being carried out. Figure 2 shows the grid points (profiles layout) in the study area. While preparing the data for interpretation, it was arranged traverse by traverse, and the line of best-fit was drawn in each profile to obtain the residual value of magnetic intensity, using Microsoft Excel. The value on the line was taken from the original (raw data) value to obtain either positive or negative values, which depicts anomaly in the data. On each profile, a tangent was drawn to the point of maximum slope, using a right-angled triangle construction and also a second line with half the same slope was drawn. The horizontal distance (S) between these two tangents is a measure of the depth to the magnetic body. The method of obtaining the above horizontal distance (S) is the half slope method. The estimate depth (d) to the top of the magnetized body can be calculated using equation 2, where (S) is the horizontal distance between half-slope tangents and (k) is constant ( $1.2 \leq k \leq 2$ ; usually  $k=1.6$ ). The vector map (Figure 13) and contour map (Figure 14) were constructed using the Surfer software.

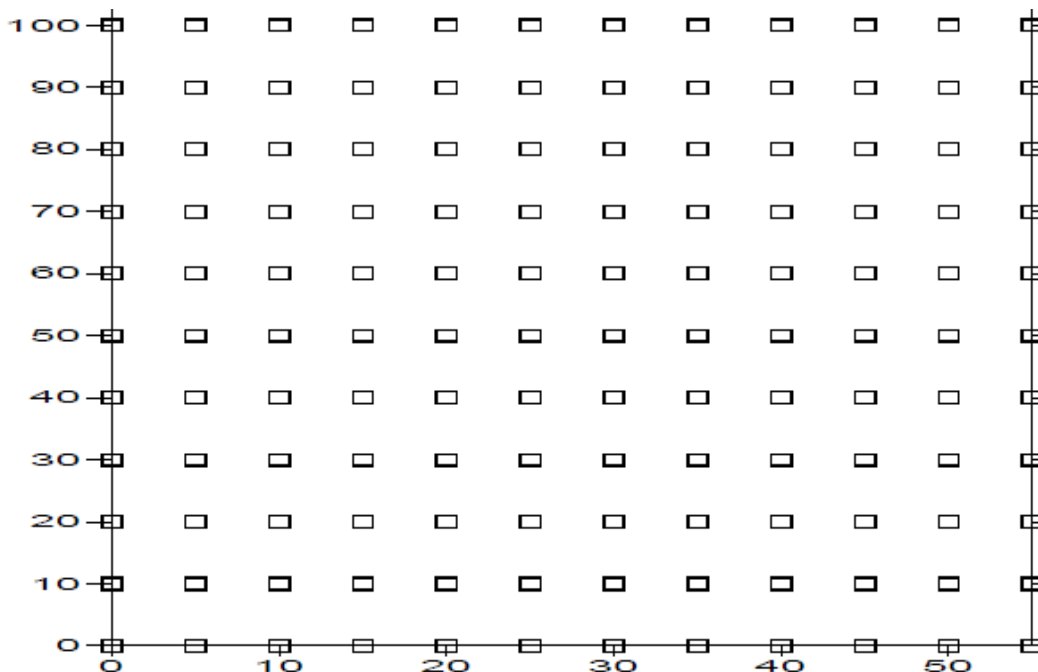
$$d = kS \quad (2)$$

The half-slope technique calculates the depth estimation of buried magnetic body to the top of the basement rocks. After data correction, the following steps were of the anomaly for each profile was determined using a right-angled triangle

construction. Two lines constructed with a slope, which was equal to half the maximum slope and tangential to the curve, were measured. The horizontal separation between the two points of tangent is an approximate evaluation of the depth to the magnetic body. The slope of the curve created by the anomaly in a profile data determines the estimation of the depth of magnetic anomaly. The depth of an anomaly is related to the horizontal extent of tangent to the maximum slope.

Another basic concept of estimating the slope method is to approximate the anomaly curve using a straight line, whose slope is the

maximum slope of the anomaly. The approach is to determine two points; points at which lines with half the maximum slope are tangent to the magnetic profile, and divide the horizontal distance by an “index value” of 1.2 to 2.0. This index value increases with the width to the depth ratios for the causative body. It is assumed in general, that the depth of investigation is a function of the target size and shape for near surface investigations, and this depth of investigation varies from 0 to 55 m depending on the quantity (i.e. size) of the hidden source (Philip *et al.*, 2002; Butler, 2005).



**Figure 2. Schematic Layout of profiles of Study area**

## RESULTS

The vector map (Figure 13) suggests appreciable magnetic minerals that cause special changes in the direction of magnetic field. It clearly highlights different changes in the direction of the magnetic field, which suggests that the target location where the magnetic mineral is more significant appears within that region of the map, and such area indicates the likely presence of minerals such as slate, gneiss mentioned earlier.

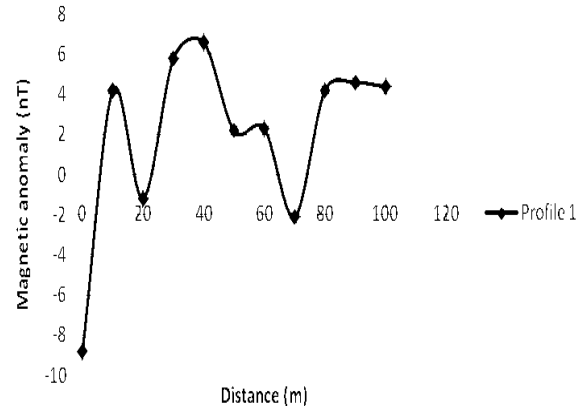
The contour lines displayed in Figure 14 characterizes sharp gradient which are areas with higher magnetic susceptibility. Contour lines that are widely spaced imply shallow slope, which is an area with lower magnetic susceptibility. The prominence of sudden change in the contour over an appreciable distance, with frequent trend in the south-west direction of the study area, implies discontinuity in depth, possibly due to subsurface major faults. The 3D plot (Figure 15) has shown the location and signatures of the magnetic minerals in the study area. The area of the map is also good for engineering purpose and other part of the map, where the directions point towards the east, shows low magnetic signature and that area is good for hydro-geologic purpose. Six out of the ten magnetic plots clearly have distinct magnetic signatures. Tables 1 and 2 presents and determines the estimated basement depths to top and center of anomaly.

## DISCUSSION

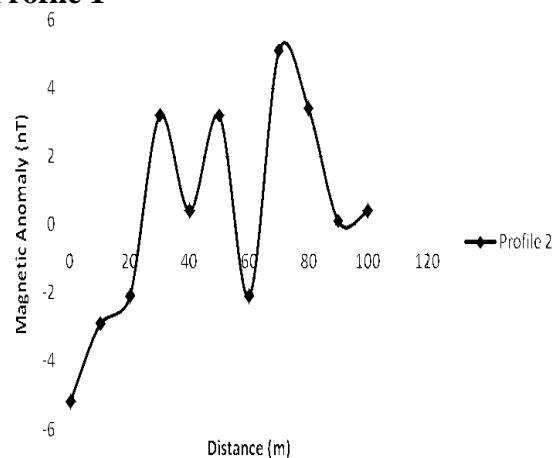
Profile 1 has the highest amplitude of 12.4 nT followed by profile 4 and profile 8 with amplitude 3.5 and 3.4 nT, respectively. It was also observed that the minimum depth is 2.25 m which indicates near-surface feature and maximum depth of 6.65m. The major rocks and minerals suspected to be found in this studied area and its environs are slate, gneiss,

serpentinite, rhyolite, pegmatite, gabbro, basalts, oceanic basalts and hematite.

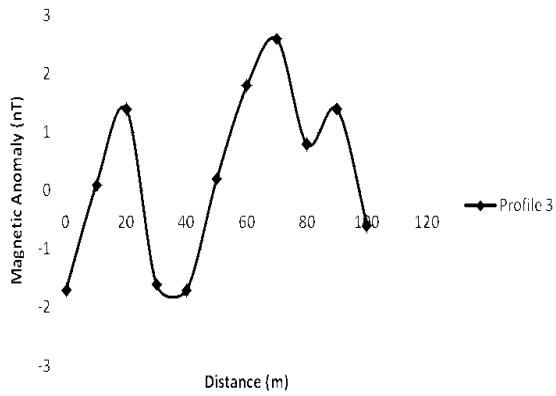
This was achieved using susceptibility data by (Reynolds, 1997). High residual points (maximum and minimum peaks on magnetic plots) observed (Figures 3-12) are suspected areas with near surface rocks with appreciable magnetite content. The peak points on profile 3 (Figure 5) are suspected to be fractured because of the wide gap between the two peak points. Low residual points on Figures 8 and 9 are suspected area with non-magnetic minerals or contact between rocks which are good points for hydro-geologic purposes.



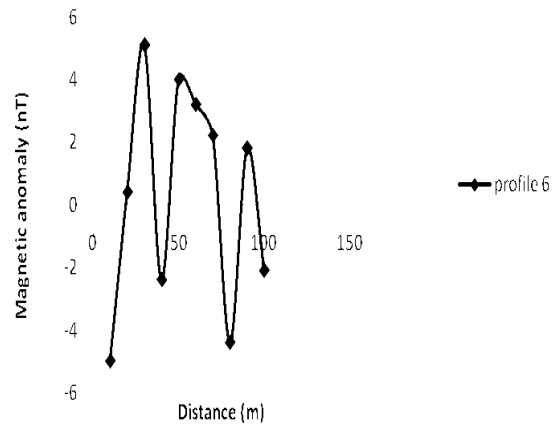
**Figure 3. Corrected Magnetic Field Plot for Profile 1**



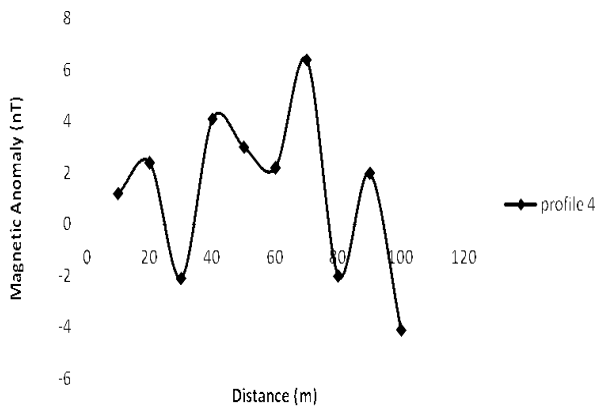
**Figure 4. Corrected Magnetic Field Plot for Profile 2**



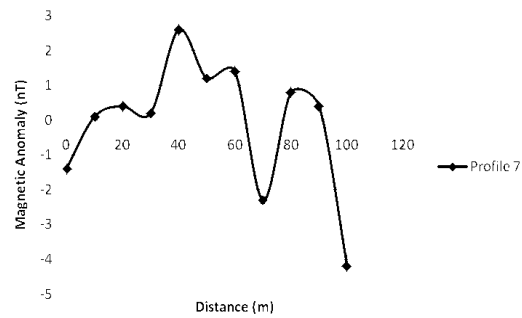
**Figure 5. Corrected Magnetic Field Plot for Profile 3**



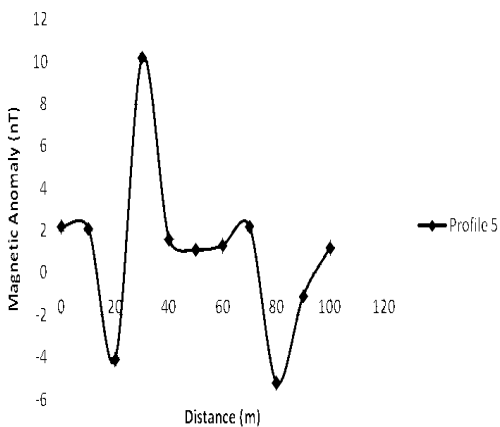
**Figure 8. Corrected Magnetic Field Plot for Profile 6**



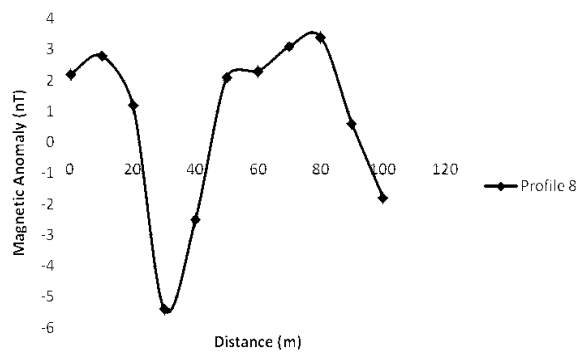
**Figure 6. Corrected Magnetic Field Plot for Profile 4**



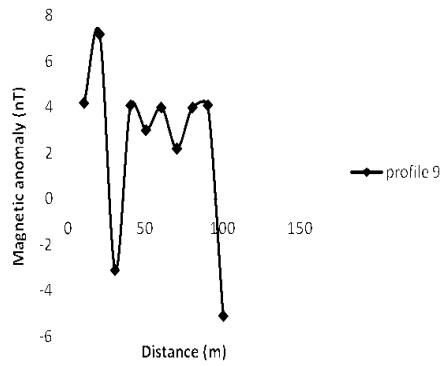
**Figure 9. Corrected Magnetic Field Plot for Profile 7**



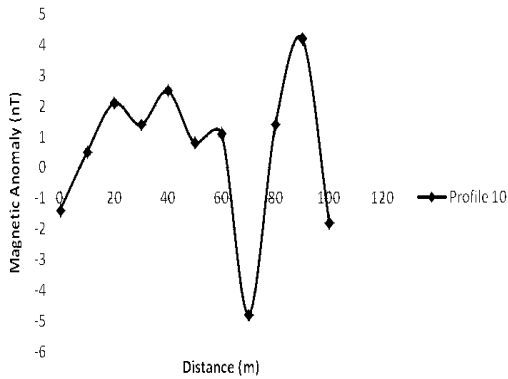
**Figure 7. Corrected Magnetic Field Plot for Profile 5**



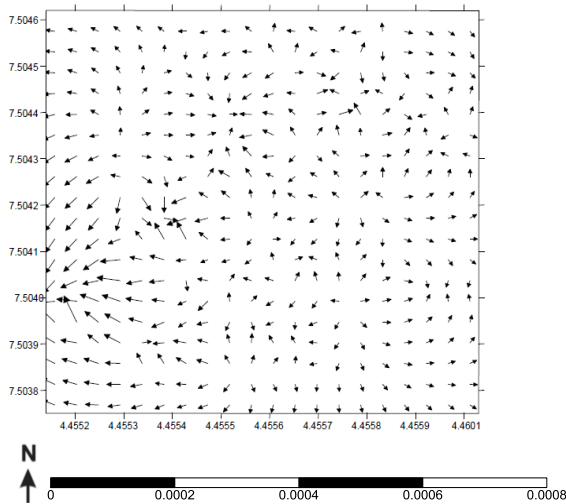
**Figure 10. Corrected Magnetic Field Plot for Profile 8**



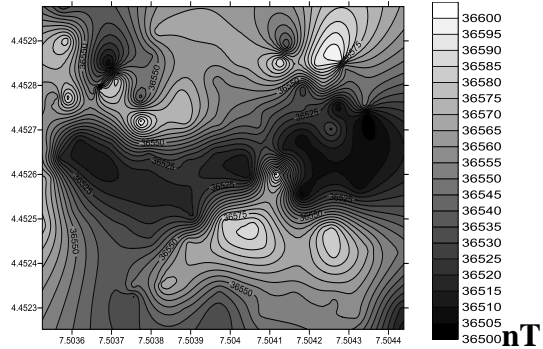
**Figure 11. Corrected Magnetic Field Plot for Profile 9**



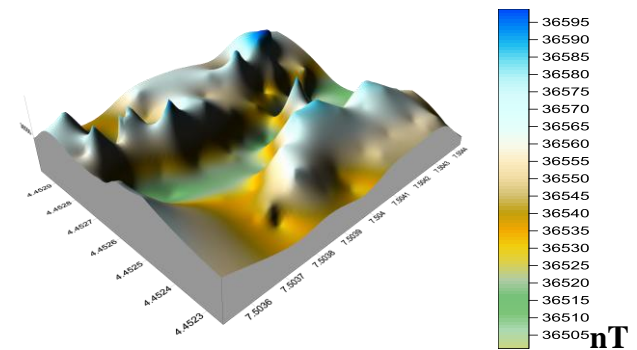
**Figure 12. Corrected Magnetic Field Plot for Profile 10**



**Figure 13. Changes in Magnetic field direction of Study area**



**Figure 14. Contour Map of Study area**



**Figure 15. 3D Surface Map of study area**

**Table 1. Showing depth to centre of anomaly body or source**

	Point 1	Point 2	Point 3	Point 4	Point 5
<b>Profile 1</b>	8m	16m	15m	-	-
<b>Profile 2</b>	11m	6.5m	6.5m	10m	-
<b>Profile 3</b>	12m	12m	15m	12m	-
<b>Profile 4</b>	18m	20m	-	-	-
<b>Profile 5</b>	12m	16m	12m	12m	-
<b>Profile 6</b>	10m	22m	-	-	-
<b>Profile 7</b>	10m	10m	8m	-	-
<b>Profile 8</b>	10m	16m	-	-	-
<b>Profile 9</b>	8m	10m	16m	-	-
<b>Profile 10</b>	6m	12.5m	6.5m	-	-

**Table 2. Showing depth to top of anomaly body or source**

	Point 1	Point 2	Point 3	Point 4
<b>Profile 1</b>	5m	2.25m	3.125m	-
<b>Profile 2</b>	2.875m	2.5m	2.5m	2.5m
<b>Profile 3</b>	6.5m	2.5m	3.125m	2.5m
<b>Profile 4</b>	4.375m	3.75m	-	-
<b>Profile 5</b>	2.25m	2.5m	2.5m	2.25m
<b>Profile 6</b>	3.75m	2.5m	-	-
<b>Profile 7</b>	2.5m	1.75m	2.5m	-
<b>Profile 8</b>	5.625m	3.5m	-	-
<b>Profile 9</b>	2.875m	3.125m	-	-
<b>Profile 10</b>	2.25m	2.25m	2.15m	-

## CONCLUSION

The ground magnetic study of the area has helped to delineate the geophysical characteristics of the area. The profiles (Figures 3-15) obtained from the data have helped to determine approximate depth to the magnetic basement of the studied area. Also it has helped in producing contour map, 3D Surface map for the study area which will serve as a reference for further studies in the region. Profile 1 has the highest amplitude of 12.4 nT and profile 5 having 10.2 nT. The depth to the top of basement rocks ranges between 2.25 to 6.65 m. The highly mineralized region of the study area is between profiles 1 to 5. Hence, there is a need for further study using more advanced approach so that ground magnetic study can equally expose lithological units in basement structures to meet the demands of searching for mineral deposits in the area.

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