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Ground Magnetic Survey for the Investigation of Iron Ore Deposit at Oke-Aro in Iseyin East, South-Western Nigeria

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Abstract

A ground magnetic survey was carried out to investigate the presence of iron ore at a location (Lat. 7.99883˚N to Lat. 7.99933˚N, Long. 3.57900˚E to Long. 3.57990˚E) in Iseyin, Oyo State, South-western Nigeria. Ten magnetic traverses each 100 m long at a separation of 5 m were run West-East. Magnetic intensity was taken at intervals of 10 m along each traverse line using the proton precession magnetometer (G-856 AX). The measured magnetic field data were corrected for drift and were presented as profiles. The profiles were interpreted by calculating the depth to the top of anomalies. The data obtained were used to construct magnetic anomaly maps in 2D and 3D. The magnetic survey results delineated this location into some high and low magnetic field intensity regions. The regions of high magnetic field anomaly indicated the presence of materials with high susceptibility which was suspected to be iron compounds. The quantitative and qualitative analyses on interpretations of field data collected were given, while these results provided values for the total component measurements of ground magnetic anomaly that widely ranged between a maximum positive peak result of 8 nT and to a minimum negative peak result of −6 nT. Using Peter's half slope technique, depth to the basement was assessed, which actually provided a maximum depth to basement of 6.25 m. From the knowledge of the geology of the area and also, the magnetic survey employed information, therefore, we can finally conclude that, the study area is under laid by geologic structures which favour the accumulation of iron-ore minerals deposit at Oke-Aro area in Iseyin.

Keywords

Magnetic Survey, Proton Precession Magnetometer, Ground Magnetic, Iron-Ore, 2-Dimensional, 3-Dimensional, GPS, Peter's Half Slope, Anomalies, Iseyin

1. Introduction

Magnetic prospecting entails measuring and interpreting local spatial variations in the earth's normal magnetic field. The immediate purpose of magnetic surveys is to detect rocks or minerals possessing unusual magnetic properties which reveal themselves by causing disturbances or anomalies in the intensity of the earth's magnetic field. Maps of magnetic anomalies are used to aid geological interpretations. They are usually containing large amount of complex details but sometimes individual magnetic anomaly is found, which stand out so clearly that they can be separated from neighbouring effects. In recent years, magnetic survey methods have been employed in various applications. These include environmental investigations for salt water intrusion environmental impact assessment and engineering applications such as assessment of road failure, pipe leakages, ground-water contamination, assessment of construction sites for dams and bridges [1] [2] [3] [4]. Groundwater explorations, delineation of depth to bedrock and subsurface mapping have also been areas of great geophysical advance. Because of the nature of the random test-putting method generally employed by archaeologists which in both tedious and inaccurate, the need has arisen for the introduction of better techniques, that is magnetic method, which could help in the location of these materials [5] [6] [7] [8]. Magnetic survey methods provide faster and more accurate results in archaeological investigation. For instance, the methods have been applied in the location of fired clay materials buried Kilus, furnaces and pottery; Ditches, pits, valleys and graves, buried stone walls, tombs and other artifacts have also been discovered using magnetic survey techniques [4] [9] [10]. The magnetic method has been used in the search for buried magnetic materials such as iron slag, buried ferrous material, iron ore, fire clay materials and limestone materials [11]. Magnetic surveys are used extensively in the search for metalliferous mineral deposits, a task accomplished [12]. Magnetic survey is capable of locating massive sulphide deposits, especially when used in conjunction with electromagnetic methods which had been reported on the location of prospective area for hydrocarbon deposits in Australia by the magnetic survey [5] [13] [14]. Although, it is possible that this application is only possible in quite specific-environments according to the author. In geotechnical and archaeological investigation, magnetic surveys were used to delineate zones of faulting in bed rock and to locate buried metallic, man-made features such as pipelines, old mine working and building [15] [16]. In this study, magnetic survey method has been used in the search for iron ore materials. It was aimed at locating the position and approximate depths of burial of these iron ore materials using the magnetic survey method.

2. Geological Setting of the Site

The study areas lie within the basement complex of Southwestern Nigeria which is characterized by migmatite gneiss. The local geological mapping of the study area revealed that the area is underlain mainly by a rock unite granite gneiss

[17]. The rocks are concealed in most areas and only six outcrops are exposed and visited within the study area. It is therefore suspected that the overburden is relatively thin within the study area [18]. The rocks are generally trending in northwest-southeast direction and dipping to the west. It is therefore suspected that the overburden is relatively thin within the study area. All the exposed outcrops observed have low fractures, indicating minor evidence of deformation. The megascopic minerals observed in this rock type include quartz, feldspar and biotite [19]. Granite gneiss rock with quartz vein intrusion in one of the locations within the study area. Therefore, **Figure 1(a)** shows general map of south western states of Nigeria, also **Figure 1(b)** and **Figure 1(c)** indicate map of Oyo state in Nigeria and map of Iseyin Township respectively, where the research was carried out.

3. Methodology Approach

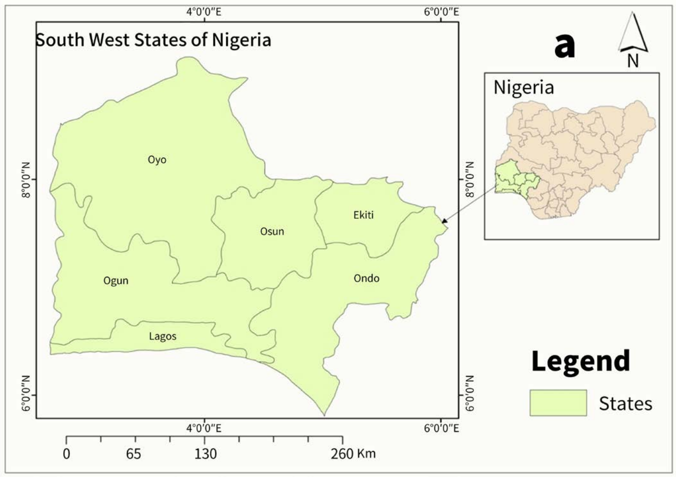
Through the interpretations of quantitative and qualitative analyses of the subsurface geological structures of the study area of the research and together with ground magnetic survey data obtained in the month of April, year 2010, were thoroughly examined. The research area was characterized by the magnetic survey method deep down into the depth to the magnetic sources basement of the study area. Determination of the structural and structure of the research area and the data collection techniques involves findings of the magnetics intensities at the district positions along the transverses that were evenly distributed within the research area of focus by obtaining segments which are enough to be used. The following steps were taken during ground magnetic survey of the study area. They are;

1) Acquisition of data,
2) Magnetic Data Interpretation,
3) Magnetic Data Analyses.

4. Results

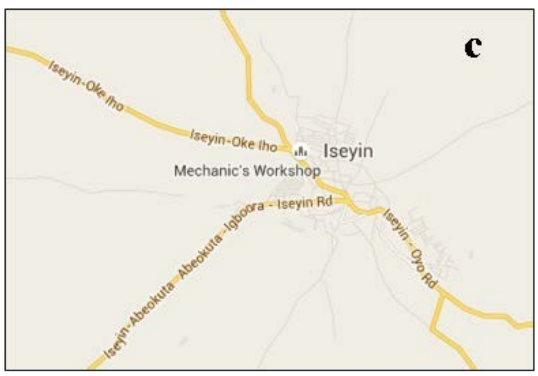
4.1. Acquisition of Data for the Area

As earlier mentioned a portable high-resolution proton precession geometric magnetometer was used for the investigation. The choice of this equipment was based on its eversible application in detailed survey for iron ore. The research took place in one location (Lat. 7.99883˚N to Lat. 7.99933˚N, Long. 3.57900˚E to Long. 3.59970˚E) at a particular site, which located at Iseyin near Anwar-Islahudeen Grammar School Iseyin in Oyo State, about 200m southeast of the school. The survey commenced with assessment of the area to locate suitable site for the magnetic survey. This involved cutting traverses through the fairly thick vegetation. This location was characterized predominantly by broken iron ore which was found scattered on the ground surface and it was also predominantly characterized by iron slag. At this location ten magnetic traverse lines were taken using a proton precession magnetometer (Model-Geometrics



(a)

(b)



(c)

Figure 1. Shows general map of (a) Southwestern states, (b) Oyo state, (c) Iseyin township in Oyo state of Nigeria respectively. (Courtesy from google 2016.)

G-856AX portable magnetometer) with 5 m spacing between each traverse and 10m station interval. All the traverses were 100 m long and were taken in the W-E direction. The traverses were numbered from 1 to 10. The data obtained were used to plot magnetic contour maps of 2D and 3D of each transverse obtained from the location.

4.2. Magnetic Data Interpretation (MDI) of the Area

To prepare the data set for interpretations, data obtained through magnetic survey measurements in the study area were analysed. The following strategies were taken in data analyses:

1) The Global Positioning System (GPS) was used in taken longitude, latitude and elevation of study area as a mapping.

2) Trends analysis was performed on analysing of residual anomaly.

3) To obtained depths to basement, therefore the relative magnetic profiles were plotted.

4) Due to magnetic storms drift, corrections were performed on diurnal variations.

4.3. Magnetic Data Analyses (MDA) of the Area

Analyses of magnetic data collected involved various techniques according to some authors [20], but here we only considered these two techniques in our research. The two techniques were given below:

4.3.1. Contour Analyses

The presentation of the magnetic data of the study area was performed with the aid of contour maps used. The scaled maps were utilised to facilitate the interpretation of the techniques used because of it is superiority in imaging.

4.3.2. Profiles Analyses

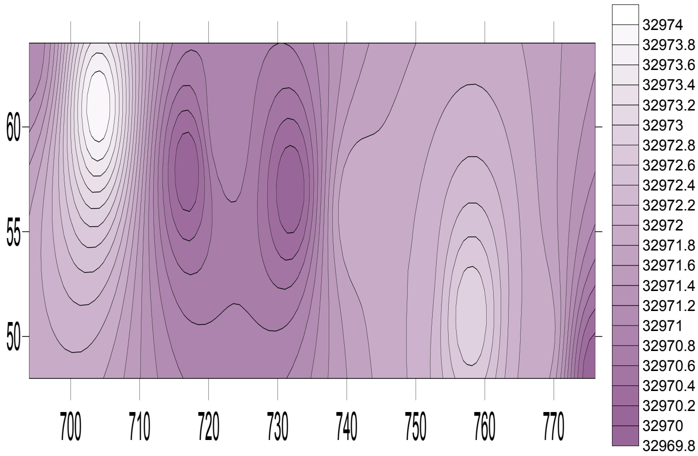
To reveal the detail that cannot be shown in grid-based presentations profile technique was employed for data presentation, whereas this has been found to be the earlier system form of data analyses but it is advantageous on its own side. Plotted ground magnetic profiles of each line of the research area were obtained to determine depths to basement of each profiles.

5. Discussions

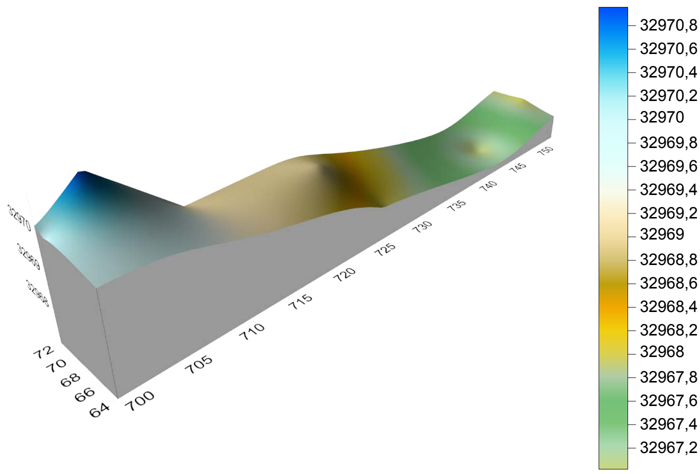
5.1. Line One: Traverse 1 in the Direction of SE-NW

In **Figure 2(a)** and **Figure 2(b)**, map of a visual inspection shows that the contour lines of the south western–south eastern part of the map are closely spaced signifying that the depth to the basement is thin in these areas. In the north eastern–north western location of the map the contour lines are widely spaced signifying that the depth to magnetic basement in those areas is relatively much. The possibility of faults zones was suggested from the Southwestern part of these areas.

The total relative magnetic intensity plotted along this traverse has magnetic capturing that are same to those acquired in vertical and horizontal components, only that the amplitude of magnetic intensity displays with positive and negative values. Characteristics of the profile was completely varying through negative amplitudes form a very low peak value of about −1.5 nT from a distance of about 90 m in the preliminary place of location and a maximum positive peak value of



(a)



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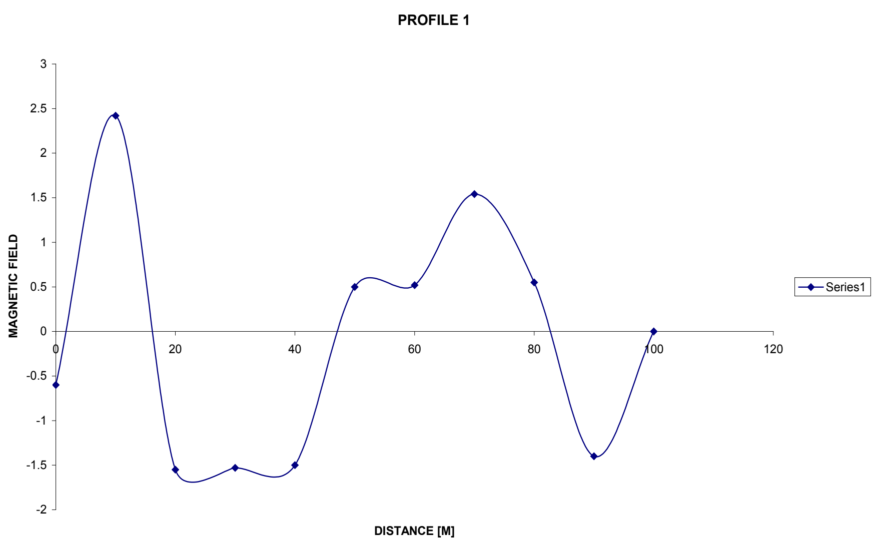


(c)

Figure 2. Shows Line one of Magnetic-field in (a) 2-Dimensional; (b) 3-Dimensional contour map of the study area respectively; (c) Traverse one (SE-NW) indicate the total relative magnetic intensity along profile one of the research area.

about 2.5 nT from a distance of 10m as it can see in Figure 2(c) under the interpretation of profile data.

Base on the variation in magnetic intensity across the study area, it then appeared generally that magnetic intensity increment in western towards the east–north east, totally suggested the possibility of the presence of the iron ore slags and also a slight decrease in magnetic intensity towards the south east and south-eastern part of the magnetic map suggested fault locations. In northwest-southeast direction and dipping to the west within the survey area, the iron ore compounds are generally trending.

5.2. Line Ten: Traverse 10 in the Direction of NW-SE

The variation in magnetic field intensity across the study area, based on the appearance of a generally increment in magnetic field intensity from the upper eastern part and south western towards the east–south east and a slight decrease in magnetic field intensity towards the north east and north-eastern part of the magnetic map suggested iron ore deposition.

In Figure 3(a) and Figure 3(b), map of a visual assessment showing that the contour lines of the north western–north eastern part of the map are widely spaced revealed that the depth to magnetic basement in these areas are relatively higher. The contour lines are closely spaced at the south eastern–south western portion of the map, indicating that the depth to the basement is shallow in these areas.

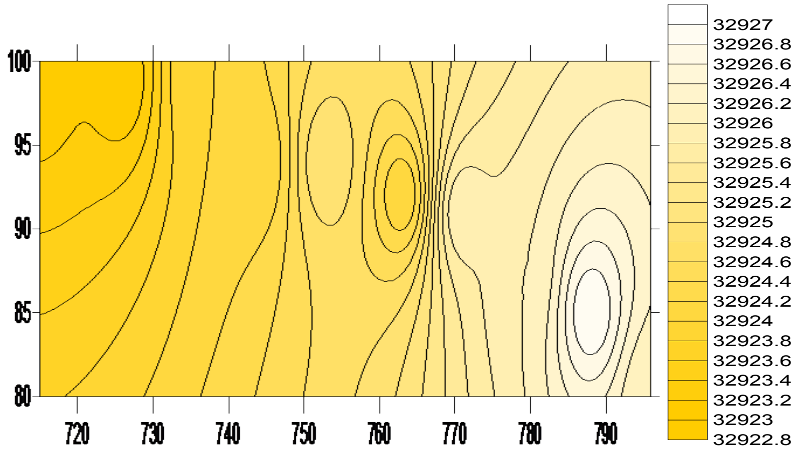
The total relative magnetic intensity plotted along this traverse is very related to those obtained in vertical and horizontal components except that the magnetic intensity displays identical positive and negative amplitudes of magnetic signature.

The profile characteristic was completely varied through negative amplitudes from a very low minimum peak value of about −3 nT from a distance of about 90 m at the first place of location and a maximum positive peak value of about 3 nT from a distance of about 60 m and this can be seen from Figure 3(c), which actually revealed the occurrence of the materials with high susceptibility that were suspected to be iron ore or iron compounds. The possibility of faults locations or local fractured zones of the study area on the map towards the west suggested the closely spaced, linear sub parallel orientation of contours from the south-eastern part of the map.

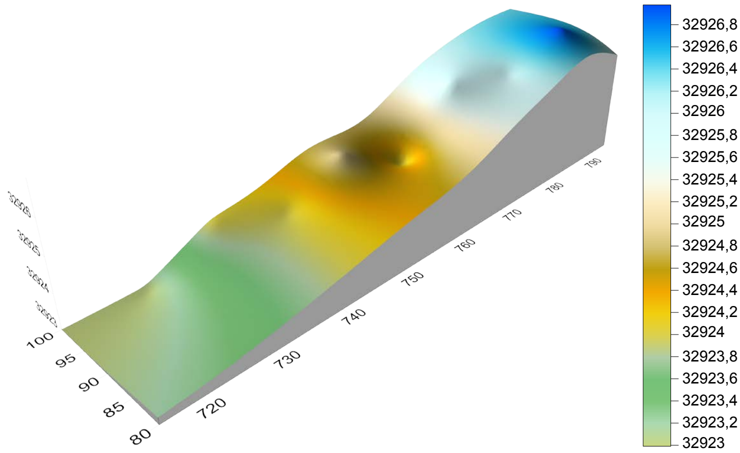
5.3. Interpretation of Profiles Data

The data for interpretation was prepared by treating the Total Magnetic Intensity (TMI) further using filtering techniques (FTs). The ground magnetic map (GMM) and magnetic profiles (GP), involve a qualitative and quantitative analyses which provides useful information on the estimate of the depth to the magnetic sources basement:

1) By utilizing linear trend analysis (LTA), residual anomaly was detached



(a)



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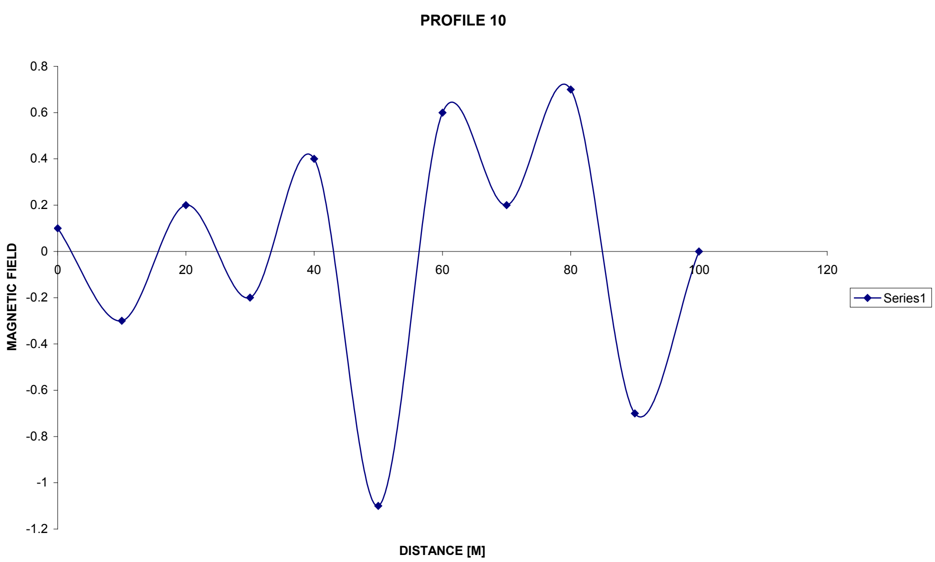


(c)

Figure 3. Indicate Line Ten of Magnetic-field in (a) 2-Dimensional, (b) 3-Dimensional contour map of the study area respectively; (c) Traverse Ten (NW-SE) revealed the total relative magnetic intensity along profile ten of the research area.

from the field anomaly which enable the better results to be obtained and use it for interpretation.

2) The data obtained through the linear trend analyses was used to plot residual ground magnetic intensity anomalies which were further utilized for total relative magnetic intensity interpretation, that was revealed in Figure 2(c) and Figure 3(c).

5.4. Determination of Depth to Basement (DDB)

Calculations

By utilizing Peter's Half Slope (PHS) technique for estimating the depths [21]. The iron ore boundaries and depth approximation of basement iron ore in the research area was find out. Table 1 (a) and Table 1(b) below, revealed the depth approximation from the data acquired through ground magnetic survey in the site.

Table 1. Shows computed approximate (a) depth (h) of the iron ore (b) depth (h) of the iron ore to the top of the basement rock.

(a)

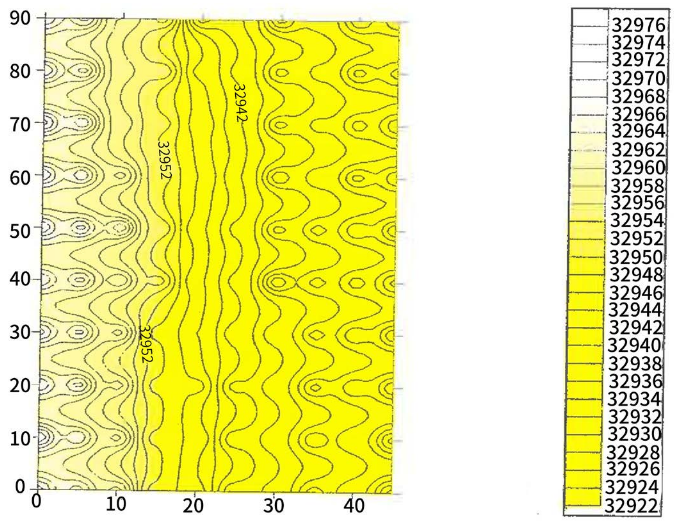
Profile Line	Anomaly Number			
	1	2	3	4
1	5.00 m	-	-	-
2	1.88 m	1.88 m	-	-
3	5.00 m	3.13c m	-	-
4	5.00 m	0.63 m	-	-
5	0.63 m	0.31 m	5.63 m	-
6	2.50 m	1.25 m	-	-
7	5.00 m	4.38 m	-	-
8	6.25 m	5.00 m	-	-
9	1.88 m	4.38 m	-	-
10	0.50 m	5.29 m	3.50 m	4.71 m

(b)

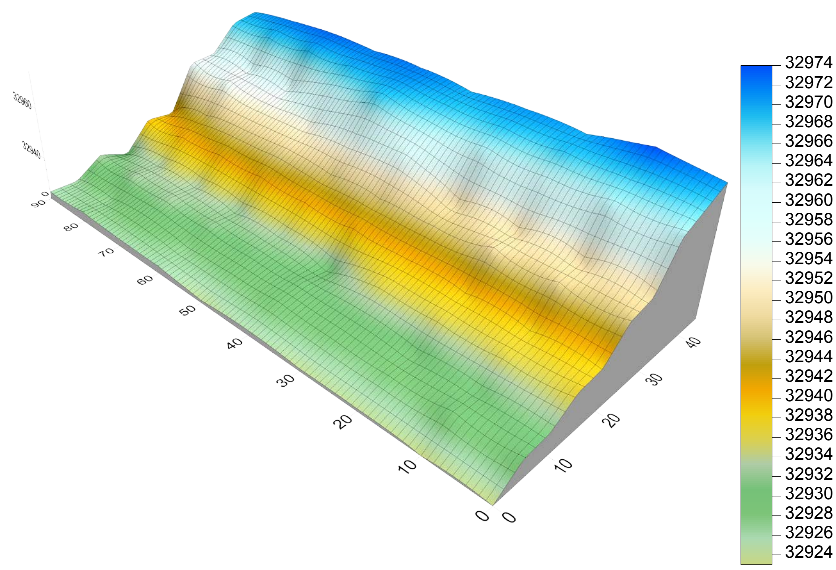
Profile Line	Anomaly Number			
	1	2	3	4
1	5.88 m	3.53 m	-	-
2	3.53 m	5.88 m	-	-
3	5.88 m	-	-	-
4	9.41 m	1.18 m	-	-
5	1.18 m	0.59 m	10.59 m	-
6	4.71 m	2.35 m	-	-
7	5.88 m	8.24 m	-	-
8	11.76 m	9.41 m	-	-
9	3.53 m	8.24 m	-	-
10	10.31 m	2.81 m	1.88 m	2.50 m

Through the previous information acquire about the geological area of the research study and the indication of iron ore slags found during the field exercises, together with the General map of mineral deposits in southwestern state of Nigeria (courtesy from Google 2016), enables the residual ground magnetic profiles to be plotted. This was later used to plot total relative magnetic intensity of each transverses as it appears in Figure 2(c) and Figure 3(c).

The whole data collected in the location were utilized to plot magnetic contour maps of 2D and 3D of the general area where the research was carried out as it was revealed in Figure 4(a) and Figure 4(b) respectively which clearly shows how the iron ore trending in both two–dimensional and three–dimensional in whole area.



(a)



(b)

Figure 4. Revealed the magnetic-field in (a) 2-Dimensional, (b) 3-Dimensional contour map plotted for the whole survey area.

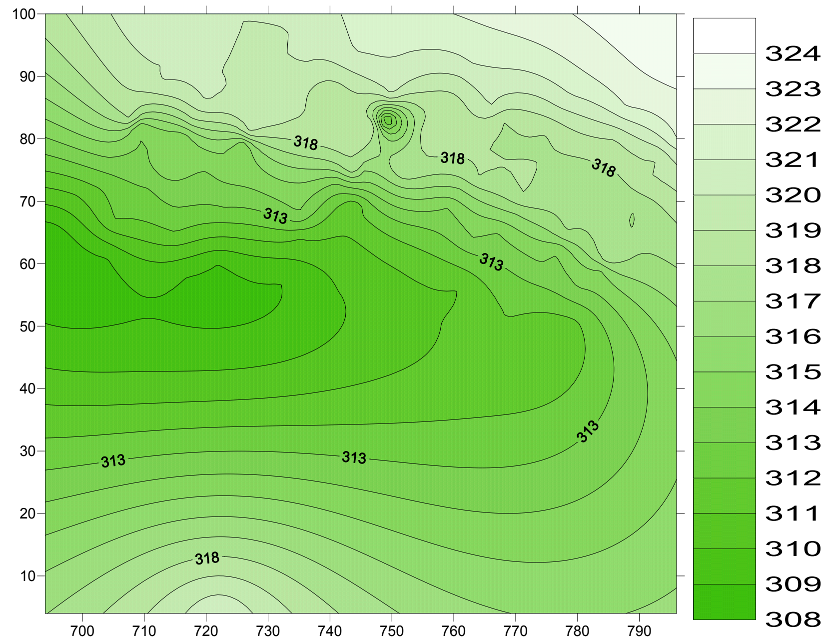


Figure 5. Revealed the elevation contour map in 2D of the whole study area.

The Global Positioning of System (GPS) was used to take the longitude, latitudes and elevation of the study area at each four points on the base station. The data obtained were used to plot elevation contour map of 2D as it was shown in Figure 5 and the numbers at each contour points virtually revealed the elevation of each area at different locations along whole area where the research was carried out.

In summary, from all the observations, where there is/are increase in magnetic field intensity or high magnetic field anomaly along the traverse, indicated the presence of materials with high susceptibility which were suspected to be the iron ore compounds, which were also noted from Figure 4(a) and Figure 4(b).

6. Conclusions

The iron ore deposit across the location (Lat. 7.99880˚N to Lat. 7.99933˚N, Long. 3.57900˚E to Long. 3.57990˚E) had been investigated by using high resolution proton precession geometric magnetometer to acquire magnetic data of the regions of study.

The following conclusions are deduced from the results obtained.

The local geological mapping of the study area revealed that the area was underlaid mainly by iron compounds. It is therefore suspected that the overburden is relatively thin within the location.

A visual inspection of the map shows that the contour lines of the south western-south-eastern part of the map are widely spaced. This implies that the depths of the magnetic basement of these areas are relatively high. At the north eastern-north-western portion of the map, the contour lines are closely spaced. This implies that the depth of the basement is shallow in these areas. The closely spaced linear sub parallel orientation of contours from the north-eastern part of the map toward the west suggested the possibility of faults, low fractures and minor evidence of deformation.

Based on the variation in magnetic intensity across the study area, there is a slight decrease towards the south-eastern part of the magnetic map. This indicated that the regions of low magnetic field anomaly suggested the presence of iron compounds with low susceptibility and there appeared a general increase in magnetic intensity from the upper western and north-western part towards the east north-east. This corresponding to the regions of high magnetic field anomaly indicated the presence of iron compounds with high susceptibility. The profile was characterized by complete varying negative amplitude from a very low minimum to a positive maximum peak value. This implies that the maximum positive peak value which corresponded to the region of high magnetic field anomaly indicated the presence of materials which were suspected to be iron compounds.

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