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INVESTIGATION OF MINERAL DEPOSITION IN IJEDA, OSUN STATE SOUTHWESTERN NIGERIA USING GROUND MAGNETIC DATA

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ABSTRACT

A geophysical ground magnetic survey method was used to investigate the presence and depths of magnetic minerals at Ijeda, Oriade Local Government area of Osun-State Nigeria. A G856AX Proton precession magnetometer was used to acquire 122 magnetic data points partitioned into 11 profiles. The station intervals and spacing were 10 m and 5 m respectively between each profile. Regional gradient and the effect of a geomagnetic reference field were removed from the observed survey data, the residual anomalies obtained were plotted against distance using Microsoft excel. Analytic Signal Method (ASM) and Peter's Half Slope Method (PHSM) were utilized in estimating average Magnetic Source Depths. The Obtained magnetic data were plotted as 1-grid vector map, 2-D contour map and 3-D surface distribution map using surfer application to produce the qualitative analysis. The maximum and maximum magnetic intensity values obtained were 25.0 nT and -41.8 nT respectively, which suggested the area of magnetic mineral occurrences. The depths to the magnetic sources were calculated for 11 profiles and the average depth values ranged from 3.93 m ± 1.22 to 7.34 m ± 1.55 using both the ASM and the PHSM. The results showed that the study area holds a very good potential for magnetic mineral exploration.

Keywords: magnetic, qualitative, depth, profiles, anomalies

INTRODUCTION

Ground magnetic surveying is a geophysical survey technique that takes advantage of significant variances in material magnetic properties to characterize the Earth's subsurface. The magnetic field of the subsurface is generated from the core of the earth, and less than 90% of this field originated from the convection occurred between the inner core and upper mantle (Usman et al., 2023). The technique necessitates the collection of magnetic field amplitude measurements at distinct places along survey lines that are evenly spaced throughout the study region (Horsefall, 1997).

Securing sufficient mineral resources is critical to navigating a new age of industrial expansion as a result in most developing countries, Ground magnetic surveys have received little attention in the past, and aeromagnetic data cannot provide details of minor magnetic structures. As a result, using a ground magnetic survey method to look for minerals in tiny dimensional areas and delineate the underlying structure is critical.

In view of the fact that the aim of magnetic survey method is to map variations in magnetism which is in turn related to magnetic minerals distribution (Berkeley, 2001) and given that the total magnetic intensity which transverses over an area can aid the understanding of the underlying geology (Joshua *et al.*, 2013; Waswa *et al.*, 2015; Adegoke, and Layade, 2019). As a result, a magnetic survey is used to explore subsurface geology based on anomalies in the Earth due to the magnetic properties of the underlying rocks (Phillips *et al.* 1991; Edunjobi *et al.*, 2021). It's also utilized to map geological boundaries, such as faults, between magnetically different lithologies (Telford *et al.*, 2001). According to (Musset and Khan, 2000), Magnetic exploration can detect some iron deposits directly and is often beneficial for deducing subsurface structure that can help identify mineralized rock, effluent flow patterns, and the extent of permissive terranes for deposits beneath suficial cover. Magnetic survey can be used in engineering applications to analyze road failure, pipe leaks, ground-water contamination, and dam and bridge construction sites.

Literatures have shown various studies carried out in the region on magnetic survey such as; Determination of location and depth of mineral rocks at Olode Village in Ibadan (Akintayo *et al.,* 2014), where the locality and depth of mineral rocks were investigated using magnetic and resistivity methods in Olode Village, Oyo State, Nigeria. The magnetic method was also used as a means in ground water investigation in a basement complex terrain with a view to delineate the subsurface structure, estimate the overburden thickness and access groundwater in the locality (Oni *et al.*, 2020). Ground magnetic measurement was as well carried out with the aim of delineating the subsurface structures on Dala hill, Kano State in the studies carried out by (Shehu *et al.*, 2020). A Ground magnetic survey was equally done to investigate the presence of an iron ore deposit at Oke Aro in Iseyin East, Southwest Nigeria (Adebisi, 2018). Adegoke and Layade (2019) used ground magnetic data of Ajase and Gbede to investigate the magnetic mineral deposition. Also Interpretation of ground magnetic data of Ilesa, southwestern Nigeria for potential mineral targets (Kayode *et al.,* 2013) among others.

Furthermore, in other climes, similar research works carried out includes but not limited to, research work of Waswa *et al.*, (2015), used magnetic survey method to investigate the iron-ore deposits and share zone delineation at Mutomo Ikutha Area, South Eastern Kenya. Susceptibility and Ground Magnetic Surveying Soil creep and Pedoturbation were revealed by mapping across weathered Basalt Dikes as done by (Dobeneck *et al.*, 2021) and Low-altitude geophysical magnetic prospecting using a multirotor UAV as a viable alternative to traditional ground surveying (Parshin *et al.*, 2018).

In this study, the ground magnetic method was used to investigate magnetic deposited minerals. It aimed at locating its positions and depths through the approaches of the

Analytic Signal Method and the Peters half slope method (Peters, 1949) respectively.

Geology of the Study Area

The study area, Ijeda is located in Oriade Local Government area of Osun-State, southwestern Nigeria, between latitudes $N7^o37'28.3''$ to $N7^o37'25.3''$ and longitude $E4^o50'33.0''$ to $E4^o50'37.0''$. The area lies in rugged terrain, in which rocks such as granite gneiss and quartz outcrop. This location is underlain by Precambrian rocks typical of Nigeria's basement Complex, according to previous research (Rahaman, 1976). Granite and gneiss are two of the most common rock types found in this area, others are quartzite/quartz schist and undifferentiated schist including phyllite (Kayode, 2010; Ajayi, 1981; Elueze, 1986). The topographic relief of the area is gentle and is characterized with few local outcrops of granite.

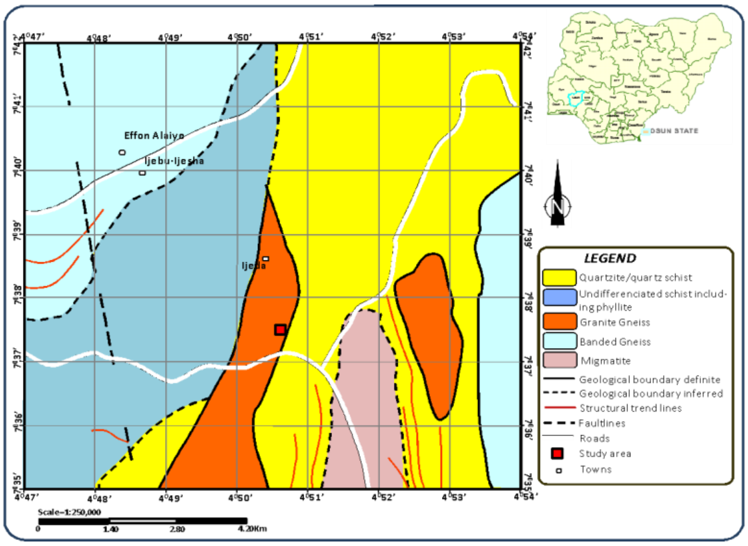

Figure 1: Geological map showing the study area

MATERIALS AND METHODS

The magnetic survey was created in such a way that it gave researchers a clear picture of the depth to magnetic sources in the study area. Measurements of magnetic intensities at discrete places along traverses that are regularly dispersed within the region of interest are required as part of the data gathering technique in order to cover enough sections to identify the structure and structural history of the research area (Adebisi, 2018). The research centered on subsurface geological features based on qualitative and quantitative interpretations of ground magnetic data acquired during fieldwork in Ijeda, Osun State, Nigeria.

Data Acquisition

A G-856AX proton precession magnetometer was used to record the magnetic readings. A station is the location where a discrete geophysical measurement is taken, and station intervals are the distance between subsequent measurements. The station interval on a profile line in this work was 10 meters while the interval between the profile lines was 5 meters, Readings in the form of observed magnetic values were therefore made along a series of profiles at equal spacing. A global positioning system (GPS) eTrex Garmin vista model was used for the location of position on the globe as well as the direction and elevation above the sea level. Measuring tape, pegs and lines were used to mark the position of base stations along every profile and also to measure the distance between one station to the other at equal intervals.

Data Correction

Magnetic data was reduced to remove all sources of magnetic variation considered noise from observations other than those coming from subsurface magnetic effects. For this research work, the process of trend analysis was used for the removal of regional gradients and the effect of a geomagnetic reference field from the observed survey data in order to obtain a smooth data.

Data Interpretation

The results obtained were interpreted qualitatively and quantitatively. The magnetic data are presented as profiles for the various components of the magnetic field. The profiles were obtained by plotting the various relative magnetic intensity values against their corresponding station position. The qualitative interpretation involved plotting and analysis of the contour map, wireframe map, 2D map and vector map of the data using the surfer software. It also involves the inspection of the ground magnetic profiles, maps and sections for trends that do not conform. The magnetic profiles were quantitatively interpreted and analyzed using the analytic signal methods and the half slope methods.

RESULTS AND DISCUSSION

The magnetic trends obtained from the anomaly graphs of profile 0 – profile 10 (Figures 2 – 12) indicate high magnetic anomalies with varying amplitudes and prominent slopes evenly distributed across the study area; this denotes a high distinction in magnetic susceptibility of the underlying rocks. P0, P1, P3, P6, P8 and P9 with high spikes of magnetic anomalies clearly signify regions of high magnetic intensities which are indications of metallic ores.

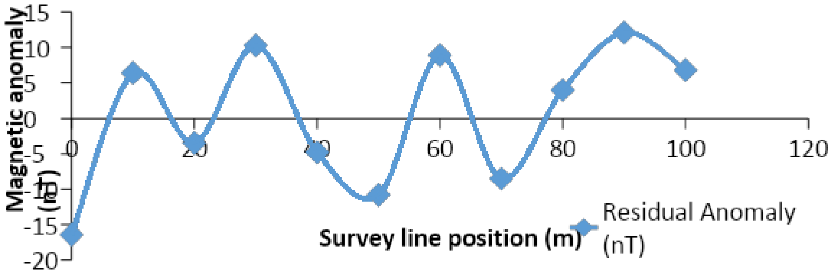

Figure 2: Magnetic anomaly plot of Profile 0

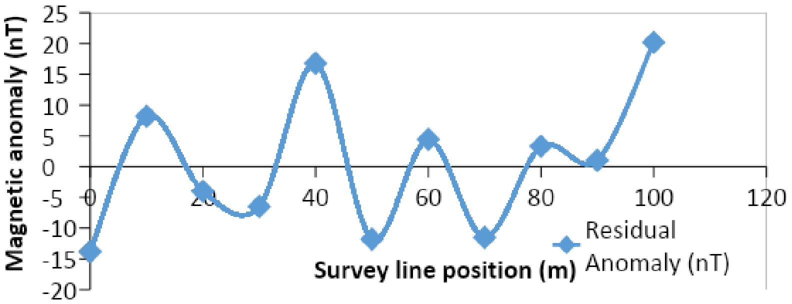

Figure 3: Magnetic anomaly plot of Profile 1

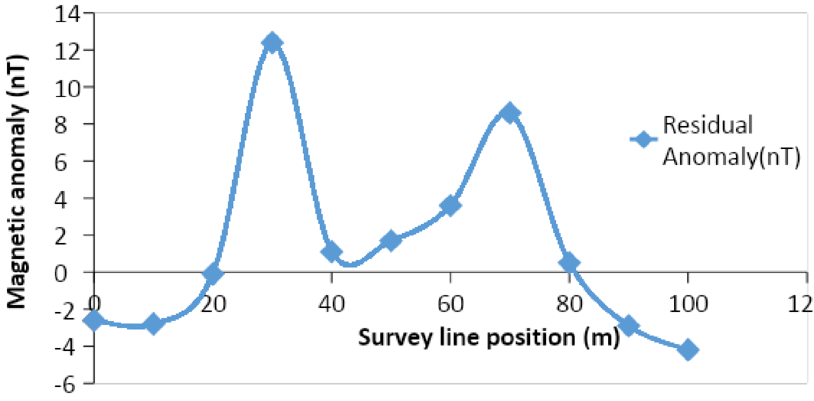

Figure 4: Magnetic anomaly plot of Profile 2

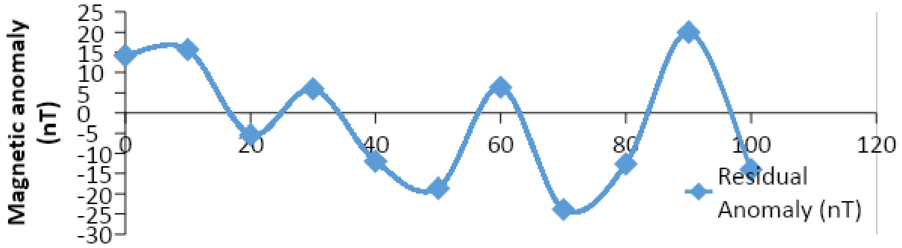

Figure 5: Magnetic anomaly plot of Profile 3

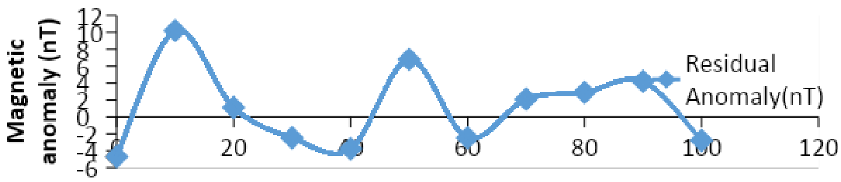

Figure 6: Magnetic anomaly plot of Profile 4

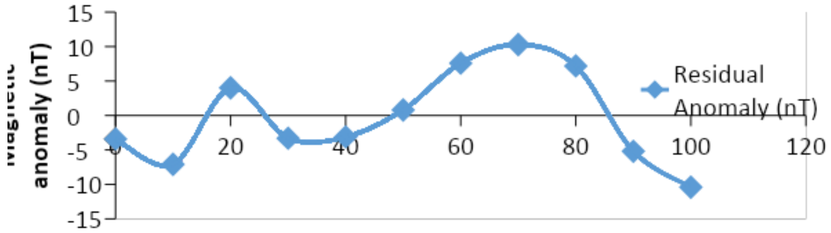

Figure 7: Magnetic anomaly plot of Profile 5

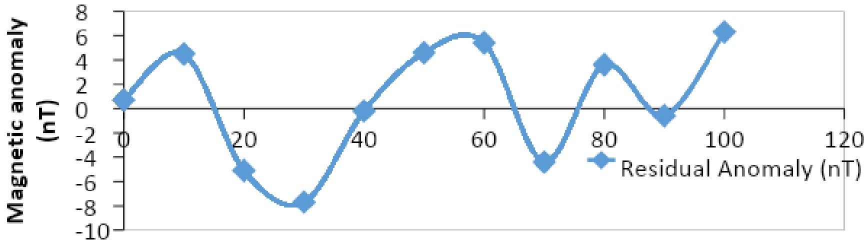

Figure 8: Magnetic anomaly plot of Profile 6

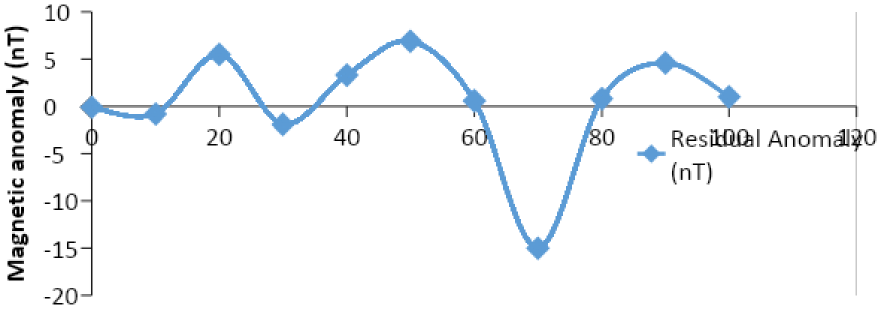

Figure 9: Magnetic anomaly plot of Profile 7

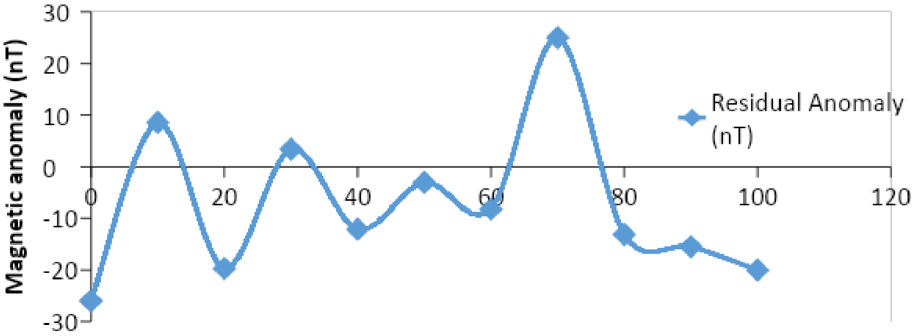

Figure 10: Magnetic anomaly plot of Profile 8

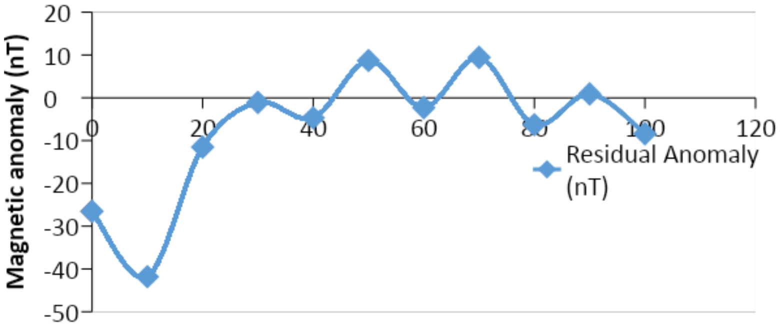

Figure 11: Magnetic anomaly plot of Profile 9

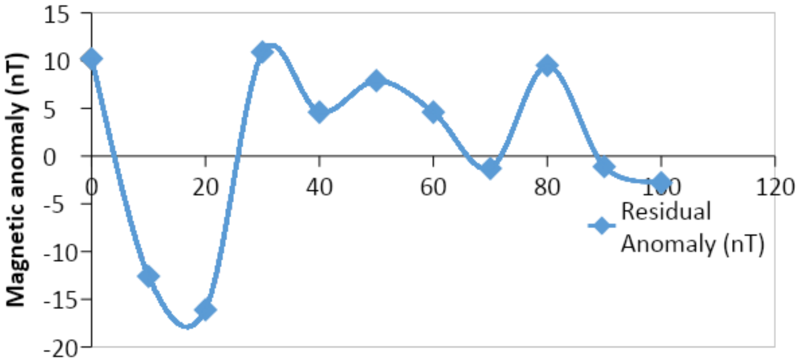

Figure 12: Magnetic anomaly plot of Profile 10

The study area has a maximum and minimum magnetic intensity values of 25.0 nT and -41.8 nT respectively on P8 and P9 as evident on Figures 10 and 11. The depth to source variation of the 10 profiles was calculated using both the Analytic Signal Method and the Peters Half Slope Method for a contact, a thin sheet (dyke), a horizontal cylinder, and for a thin body, an intermediate body and a thick body.

The results are presented in Tables 1 and 3 with depth range of 3.13 m – 5.75 m estimated for a contact, 1.80 m – 3.32 m for a thin sheet while a depth range of 4.06 m – 7.50 m was estimated for a horizontal cylinder respectively. Also, for the structural indices of the Peters Half slope, a depth range of 7.28m - 13.33m was estimated for a thin structural body, a range of 5.45m - 10.00m for an intermediate structural body while a depth range of 4.38m – 8.00m was estimated for a very thick structural body respectively.

Table 1: Estimated Magnetic Depths (m) of different Geological Model for Magnetic Mineral Deposits using the Analytic Signal Method (ASM)

	CONTACT	**THIN SHEET**	**HORIZONTAL CYLINDER**	**AVERAGE DEPTH**	**STANDARD DEVIATION(±0.00)**
Profile 1	3.56	2.06	4.65	3.42	1.06
Profile 2	4.50	2.31	5.87	4.23	1.46
Profile 3	4.00	2.31	5.21	3.84	1.19
Profile 4	3.25	1.88	4.24	3.12	0.97
Profile 5	5.75	3.32	7.50	5.52	1.71
Profile 6	4.67	2.69	6.08	4.48	1.39
Profile 7	5.00	2.82	6.52	4.78	1.52
Profile 8	3.50	2.02	4.56	3.36	1.04
Profile 9	3.33	1.92	4.34	3.20	0.99
Profile 10	3.75	2.17	4.89	3.60	1.12
Average depth of structural index	**4.04**	**2.30**	**5.26**	**3.93**	
Standard deviation	**±0.80**	**±0.45**	**±1.04**	**±0.77**	

Table 2: Range of Depths for Geological Bodies associated with the Analytic Signal Approach

STRUCTURAL INDEX	**RANGE (m)**
CONTACT	3.13 - 5.75
DYKE	1.80 - 3.32
HORIZONTAL CYLINDER	4.06 - 7.50

Table 3: Estimated Magnetic Depths (m) of different Geological Model for Magnetic Mineral Deposits using the Peters Half Slope Method (PHSM)

	THIN BODY	**INTERMEDIATE BODY**	**THICK BODY**	**AVERAGE DEPTH**	**STANDARD DEVIATION (±0.00)**
Profile 0	8.96	6.72	5.38	7.02	1.48
Profile 1	8.33	6.25	5.00	6.53	1.37
Profile 2	11.65	8.75	7.00	9.13	1.92
Profile 3	9.16	6.87	5.50	7.18	1.51
Profile 4	7.49	5.63	4.50	5.87	1.23
Profile 5	13.33	10.00	8.00	10.44	2.20
Profile 6	11.11	8.33	6.67	8.70	1.83

Profile 7	10.00	7.45	6.00	7.82	1.65
Profile 8	7.28	5.45	4.38	5.70	1.20
Profile 9	8.33	6.25	5.00	6.53	1.37
Profile 10	7.50	5.60	4.50	5.87	1.24
Average Depth Of Structural Index	9.38	7.03	5.63	7.34	
Standard Deviation	±1.86	±1.40	±1.12	±1.46	

Table 4: Range of Depths for Geological Bodies associated with the Peters Half Slope Approach

STRUCTURAL INDEX	RANGE (m)
THIN BODY	7.28 – 13.33
INTERMEDIATE BODY	5.45 – 10.00
THICK BODY	4.38 – 8.00

Figure 13 gives the 2D graphical representation of the average depth across the 10 traverses with reference to both methods and clearly, the Analytic Signal method was revealed to be of lower depths. Irrespective of the magnetic structure and shape of the deposit, an average depth range of 3.93 m ± 1.22 m to 7.34 m ± 1.55 was estimated for this magnetic study and this generally suggested that the metallic body beneath this study area is of a shallow depth.

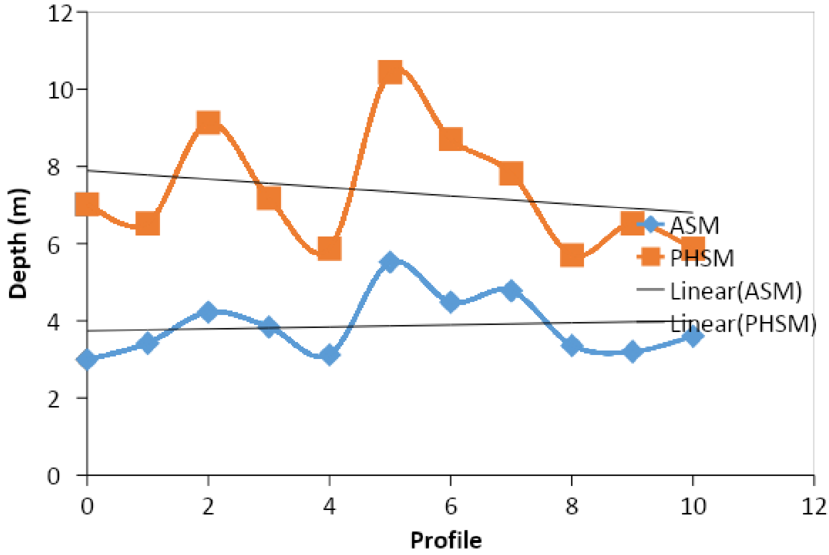

Figure 13: 2-D Graphical Representation of Depths across the study area with reference to both methods

The generated contour map and 3D surface distribution map of the study area were further analyzed using the surfer 14 golden software and are presented in Figures 14 and 15.

A visual inspection of the contour plots in Figure 14 clearly shows the alignment of contour lines closely spaced at different intervals, Also, a prominent accumulation of the contour lines was noticed at the center of the map which is an apparent indication of the presence of mineral deposits at virtually low depths with major concentration at the center of the study area. The contour map is in conformity with the 3D surface distribution map with evidence of spike and peak variations aligned across the center of the distribution map of figure 15.

The closely spaced, sub-parallel orientation of contours relatively distributed in the contour plot of the entire study area reveals the distribution of mineral deposits at shallow depths across the study area.

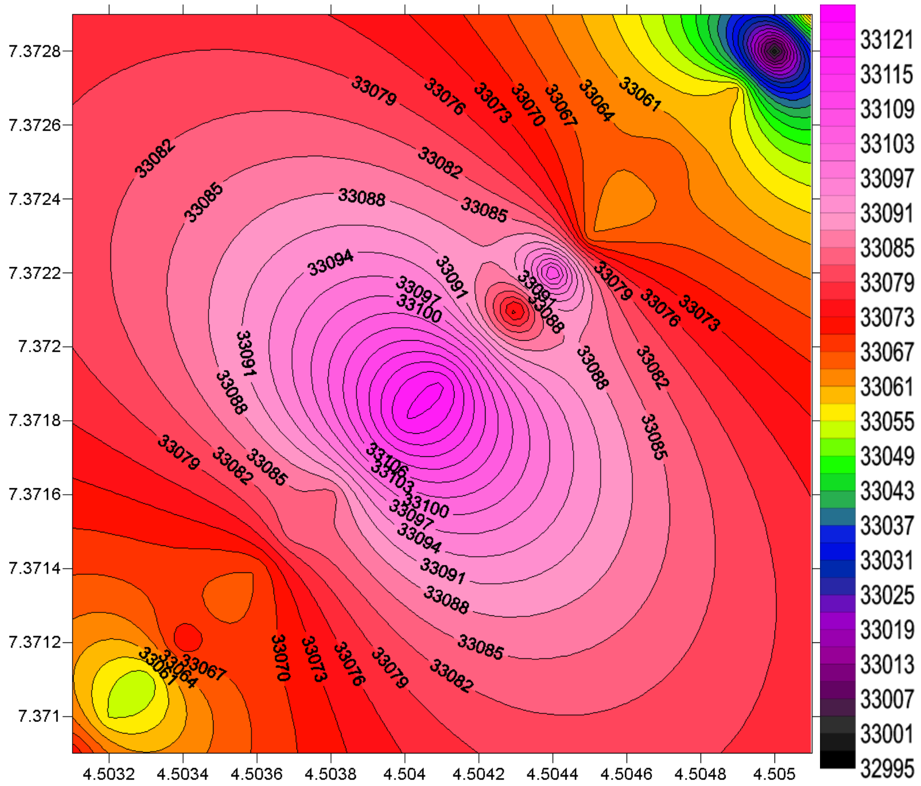

Figure 14: 2-D Contour Map of the Study Area

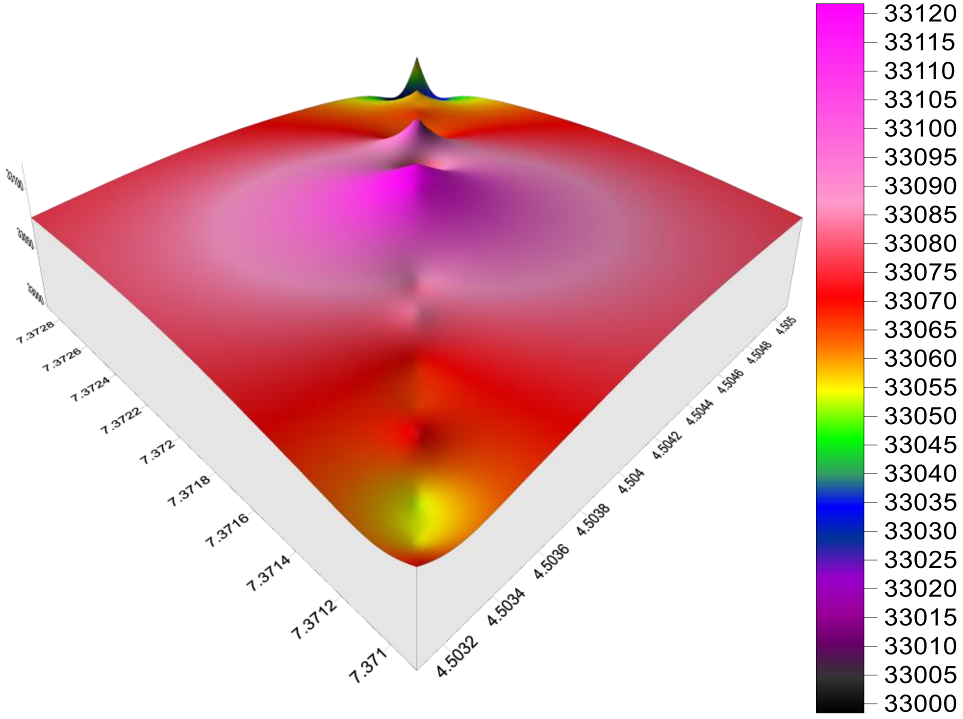

Figure 15: 3-D Surface Distribution Map of the Study Area

CONCLUSION

The magnetic survey of this area has helped to establish the presence of magnetic mineral deposits in the study area and to estimate its depths with varying structural index using distinctive geological depth estimation models. An average depth range of 3.93 m ± 1.22 m to 7.34 m ± 1.55 was estimated for this magnetic study irrespective of the shape or structure of the deposit; this depicts a shallow depth to magnetic source and a near surface feature. The research area is primarily underlain by migmatite/migmatite gneiss, according to local geological mapping these are confirmed host rocks to magnetic minerals.

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Competing Interests:

Authors affirmed that there is no competing interest as regarding this research work and the write up.

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Authors were responsible for the finance of the project and documentation.

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