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On the Use of Linear Trend Analysis in Removing Regional Gradient from Ground Magnetic Data for Qualitative Interpretation

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ABSTRACT

Advances in technique development and data interpretation have greatly improved our ability to visualize the Earth subsurface. Total field magnetic data on the Olugere Area of Ijero Ekiti, Southwestern, Nigeria were acquired using the ground based magnetic technique with the aid of portable proton precession magnetometer G-856AX which implores total components of the ground magnetic anomaly data running through six profile lines. A total of six geophysical traverses, numbering aa to ff, were established in an E-W direction in the study area. The acquired total magnetic intensity (TMI) data were corrected for drift; the derived residual anomaly, which involves the removal of the regional gradient from the observed data from the field of linear trend analysis, was presented as profiles and maps. The residual magnetic values varied between a minimum negative peak value of about -223.1nT and a maximum positive peak value of about 536.7nT. Qualitative interpretation of the ground magnetic maps and profiles were adopted with an intention of determining the geologic structures that are suitable for mineral potential, ground water accumulation and establishing the competence of the survey area in hosting high rise structure and industrial site. Our results have demonstrated that careful analysis of magnetic data can delineate with fair to good precision the geological structures of the subsurface, which gives vital information about the mineral potential, ground water accumulation and the ability of the study area to hold high rise building.

Keywords: Geophysical, Physical, Magnetic field, Ground magnetic, Subsurface

INTRODUCTION

The science of geophysics applies the principles of physics to the study of the Earth. Geophysical investigations of the interior of the Earth involve taking measurements at or near the Earth's surface that are influenced by the internal distribution of physical properties. Analysis of these measurements can reveal how the physical properties of the Earth's interior vary vertically and laterally [1]. There is a broad division of geophysical surveying methods into those that make use of natural fields of the Earth and those that require the input into the ground of artificially generated energy. The natural methods utilize the gravitational, magnetic, electrical and electromagnetic fields of the Earth, searching for local perturbations in these naturally occurring fields that may be caused by concealing geological features of economic and other interest. Artificial source methods involve the generation of energy that may be used analogously to natural fields. In regards to this study, the magnetic geophysical survey method was adopted.

The magnetic method is a geophysical technique that investigates the subsurface geology on the basis of anomalies in the Earth's magnetic field resulting from the magnetic properties of the underlying rocks [2]. This non-destructive technique can be performed on land, sea and air, and has numerous applications in engineering and environmental studies including the location voids, near surface faults, igneous dikes and buried ferromagnetic objects like storage drums, pipe etc. [3].

The magnetic anomaly results from the contrast in magnetization when rocks with different magnetic properties are adjacent to each other, for example, when a strong magnetic basaltic dike intrudes a less magnetic host rock. The stray magnetic fields surrounding the dike disturb the geomagnetic field locally and can be measured with sensitive instrument called magnetometers. Magnetic investigations can therefore yield important data about geological structures. In relation to this, the qualitative interpretation of magnetic data is of particular interest to Earth's scientists.

location of study area

The study area (Olugere area of Ijero Ekiti, Southwestern, Nigeria) lies within the southwestern part of the Nigerian Precambrian basement complex [4,5] and is located within Latitude 7.77147°N to 7.77230°N and Longitude 5.00675°E to 5.00767°E. The local geological mapping of the study area (Figure 1) revealed that the area is underlain mainly by a rock unit, undifferentiated schist including phyllite. The rocks are concealed in most part and some outcrops are exposed around the study area. It is therefore suspected that the overburden is relatively thin within the study area.

METHODOLOGY

This study focused on the subsurface geological structures based on the qualitative interpretations of the ground magnetic data collected during the field work that was carried out at Olugere Area of Ijero Ekiti, Southwestern, Nigeria. The data acquisition technique requires measurements of the magnetic intensities at discrete points along profiles regularly distributed within the area of interest so as to cover enough segment used to determine the structure and the structural history of the study area.

Data acquisition

Geometric proton precession magnetometer G-856AX, was used for this study. The operation is simple and the magnetometer has built in digital memories that can store over 5000 single sensor measurements. All operations are controlled from the keys embedded in a weather-proof membrane that comprises that magnetometer console's front panel [6]. The survey was carried out at a site of 100 m by 50 m with a total number of 6 profiles established in West-East direction. The profile length ranges from 0-100m with station separation 10m, while the interval between the profile lines is 10 meters.

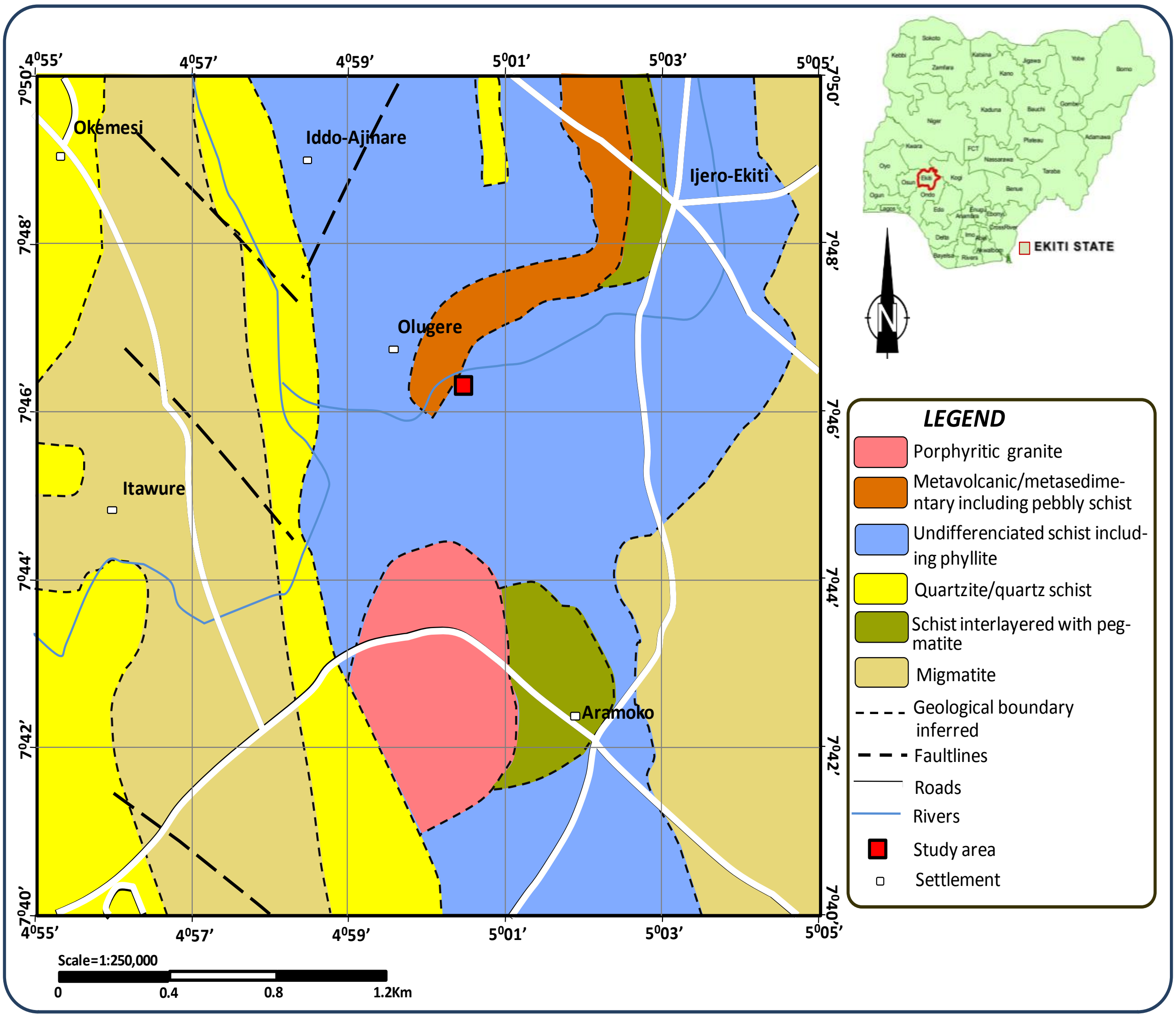


Figure 1 Geological map of the study area (Modified from Nigerian Geological Survey Agency 2009)

Data correction and presentation

In preparing the observed (field) data for presentation and interpretation, a procedure known as Linear Trend Analysis was adopted to remove the regional gradient from the observed (field) data. The procedure involves fitting a trend line to the observations using the least squares criterion and subsequently subtracted from the observed data to leave the local anomalies as positive and negative residuals. The trend line equations ($i - vi$) used for the profiles *a-f* in this work are stated below respectively;

$$y = -0.551x + 33110 \qquad (i)$$

$$y = -0.793x + 33017 \qquad (ii)$$

$$y = -0.301x + 3310 \qquad (iii)$$

$$y = 3.055x + 3303 \qquad (iv)$$

$$y = -0.499x + 33165 \qquad (v)$$

$$y = -0.177x + 33168 \qquad (vi)$$

There are several methods of presenting magnetic data [7] but only two of these methods were adopted in this study. These methods are as summarized below;

Profiles

Although this is the oldest form of data presentation, but it has the advantage of being able to show detail that cannot be shown in the grid based presentations. The linear trend analysis was applied to the observed (field) data, which enabled the separation of the residual anomaly from the observed (field) anomaly. The magnetic profiles were plotted using Microsoft Excel, in which the residual anomaly is plotted against distance (station spacing) as shown in Figures 2a-2f.

Contour

Contour maps were used in the presentation of the magnetic data of the study area. The method was produced on scaled maps to aid interpretation because of it is superior to images method. In order to prepare the data for qualitative interpretation, the 2D and 3D contour maps (Figures 3 and 4) were generated on Surfer representing the subsurface structure of the study area at the Olugere of Ijero Ekiti, Southwest, Nigeria.

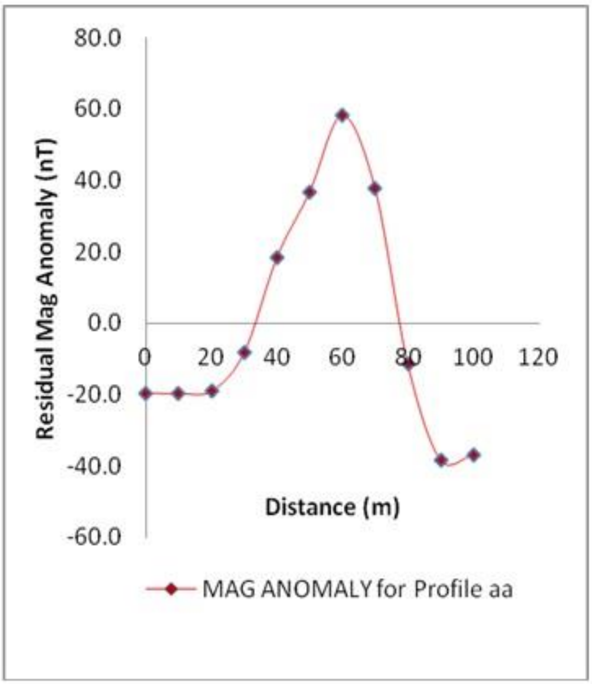
RESULT AND DISCUSSION

The individual profile interpretation shows variable anomalies which is an indication of susceptibility contrast of the rock types. The anomaly signature is not evenly distributed along the respective profile. In magnetic profile *a* (Figure 2a), the magnetic anomaly is visible at a horizontal distance 34 m to 78 m, which indicates the presence of magnetic source body, suspected to be a magnetic mineral around that area. The magnetic profile *b* (Figure 2b) depicts an area with high magnetic intensity values (at a and b) and areas with low magnetic intensity values (at c and d). Folami [8] had ascertained that the portion with low magnetic intensity value depicts areas in the subsurface that are potentially good for ground water accumulation and transmission. Thus, the areas (c and d) could be further investigated for water supply.

The anomalous body along profile *c* is observed at a distance of 14 m to 36 m and also at a distance of about 40 m to 84 m, although the latter is more pronounced. This suggests that the causative body, suspected to be a magnetic mineral at the distance of 40 m to 84 m is of higher magnetic susceptibility compared to the causative body present at a distance of 14 m to 36 m. This profile is characterized by complete varying negative amplitudes from the very low peak value of about -30.4NT at a distance of 100 m from the initial station point and a maximum positive peak value of about 28.3NT at a distance of 70 m.

Profile *d* was mainly characterized by area with magnetic lows, as the anomaly amplitude was seen to decrease from 100.5nT at the initial start point (0 m) to -223.1nT at a distance of about 88 m along that profile line. This indicates a discontinuity (fault) in the magnetic basement of the study area along this profile line. The significantly low magnetic intensity values also suggest a fracture or fault zone along this profile, hence this region cannot host high rise buildings and heavy machines that could set the region into vibration must not be installed because it might lead to building collapse in the future.

Profiles *e* and *f* depict varying anomaly amplitudes from the very low peak value of about -8.2nT to a maximum positive peak of about 10.8nT. The profiles are magnetically quiet in the first few meters of the profile lines, as the anomaly signatures was observed at the centre of the profile lines. The causative body is suggested to be a magnetic mineral and such region (of magnetic mineral) is not feasible for ground water accumulation.



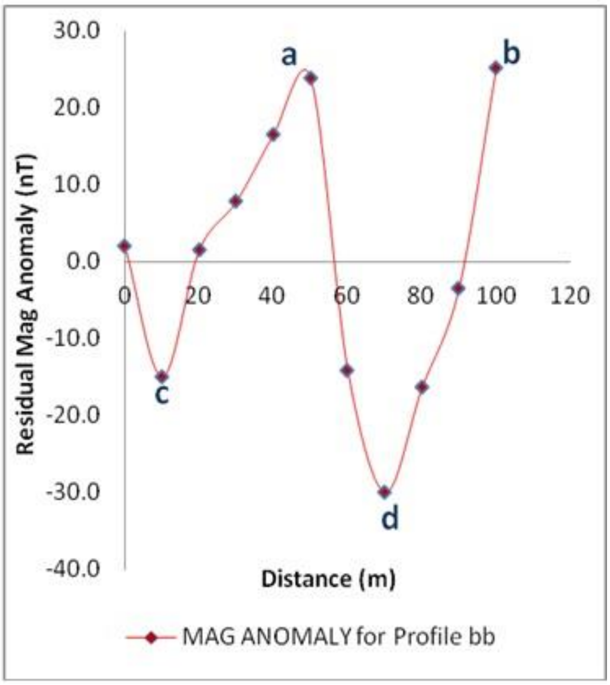
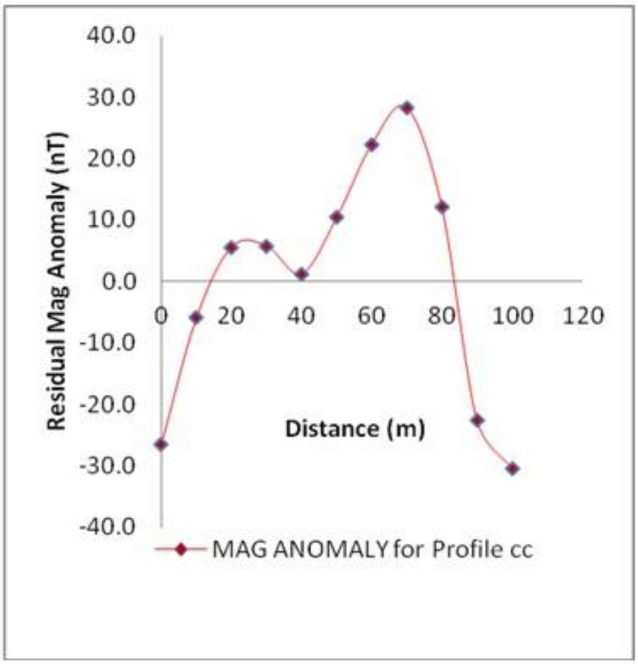


Figure 2a Magnetic field plot for profile **Figure 2b Magnetic field plot for profile**



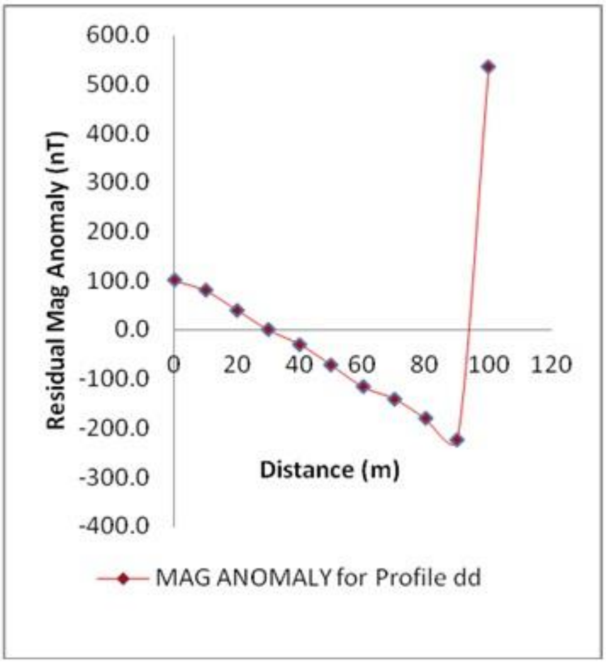
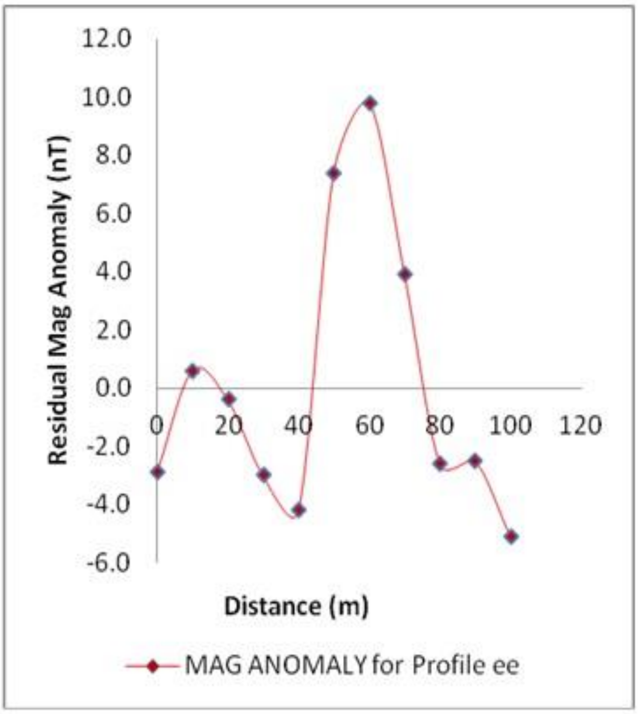


Figure 2c Magnetic field plot for Profile **Figure 2d Magnetic field plot for Profile**



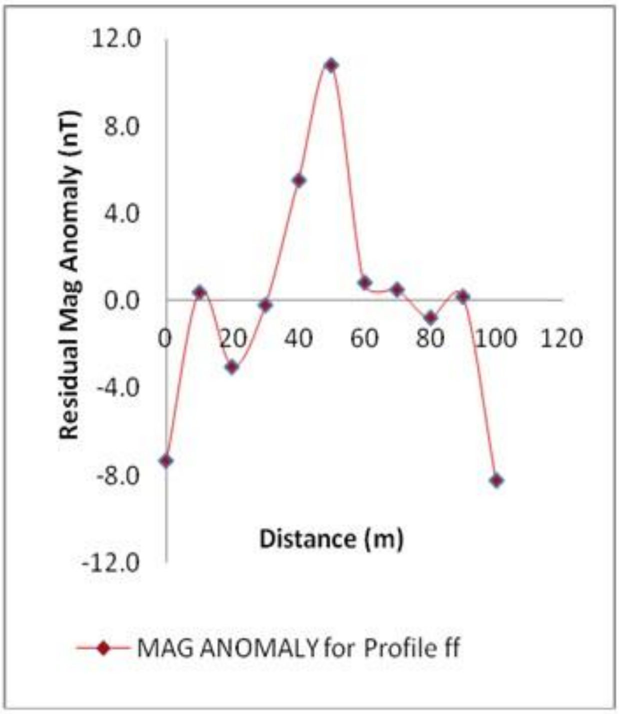


Figure 2e Magnetic field plot for Profile **Figure 2f Magnetic field plot for Profile**

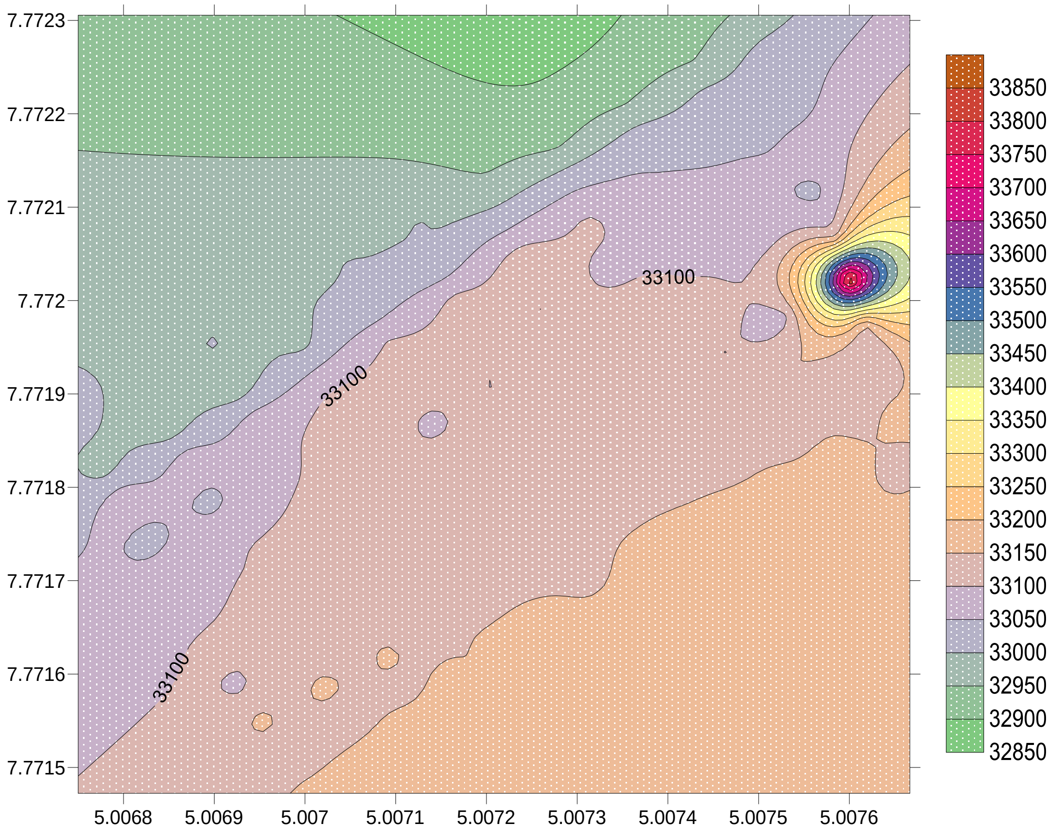


Figure 3 2D Contour Map for the study area

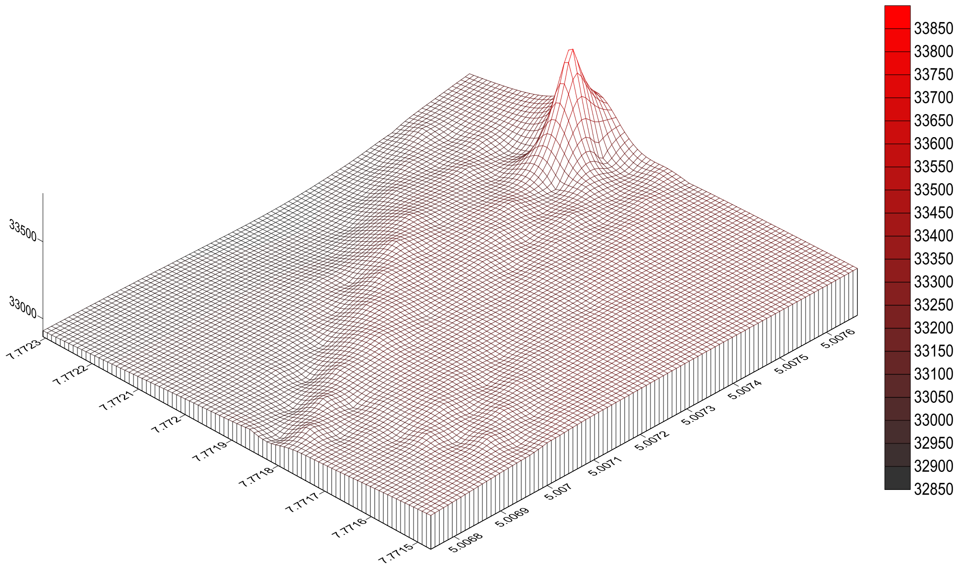


Figure 4 3D Surface Map for the study area

A visual inspection of the 2D contour map (Figure 3) of the study area shows the areas of magnetic lows and magnetic highs analyzed with color variations. The low magnetic intensity distribution is observable at the North-eastern part of the study area map, which is an indication of a deep fracture or fault zone. Thus, this region of the study area is not competent for high rise structures to avoid subsidence of the structures in the future, which may lead to loss of valuable lives and properties but it's a better site for hydro-geological purpose. The centre of the study area map towards the Southern part of the map is of moderately high magnetic intensity values. This is a region of magnetic rock intrusions competent for high rise structure and heavy machine.

CONCLUSION

Qualitative interpretation of the magnetic data reveals the varying amplitudes of the anomaly signature and the points of low magnetic intensity on the magnetic profiles suggest possible discontinuity or faults or fracture zones, which also implies that the magnetic body source is not evenly distributed along the respective profile in the entire study area. It also helps characterize the lithology and the configuration of the anomalous zone, hence the source of the mineralization. Considering the factors governing the accumulation of minerals, that is discontinuity or fractures or faults, a conclusion can be made that the information provided by the geophysical (ground magnetic survey) method employed in the study area is underlain by accumulation of minerals in disseminating quantities.

The results have demonstrated that careful analysis of magnetic data can delineate with fair to good precision the geologic structures that give vital information, like the zone of mineralization, ground water accumulation and geophysical evaluation of the study area.

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