Journal of Geology & Geophysics
OPEN ACCESS Freely available online
Research Article

Application of Magnetic Method to Characterize Abaya Campus Building Site, Southern Ethiopia

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ABSTRACT

A geophysical survey involving magnetic method is conducted using ENVI-MAG proton precision magnetometer. The study is carried out with the aim of identifying the possible geological structures which may responsible for the failure of engineering structures. Three traverses having east-west orientation with a ten meters profile spacing and a readings station spacing and one traverse across the three traverses and randomly collected magnetic data were used. At each station three readings were taken and averaged out in order to increase the accuracy of data and diurnal and geomagnetic corrections were made. With the corrected data different anomalous maps were produced like total magnetic field anomaly map, residual magnetic anomaly map and analytical signal map using Oasis montaji 6.4 software for further interpretation. The result of this research has shown that the area is affected by different geological structures which may be the cause for the crack and the failure of the building in the area.

Keywords: Magnetic anomaly; Engineering structure; Magnetic method; Traverse

INTRODUCTION

Construction of sustainable civil engineering structures, whether simple or complex ones, requires profound knowledge about the characteristics of subsurface earth materials, particularly physical properties of the underlying rocks/soils, distribution of tectonic elements, contents of moisture/fluid within them, etc. Discontinuities in the form of bedding planes, joints, faults and folds highly determine the physical strength (deformation characteristic) of rocks. Similarly, properties of materials filling voids (openings), such as pure/mineralized water, air or both in unconsolidated soils or fractured rocks influence their physical characteristics. Therefore, the stability of civil engineering constructions depends on the correct assessment of the various physical and geotechnical properties of the underlying earth materials where the structures are intended to be erected [1].

However, constructions undertaken over formation with insufficient bearing capacities often result in unexpected failures, manifested by cracks, settlements, displacements or total collapses. Particularly, those structures erected over areas where expansive soils (such as clays) are widely distributed demand special attention as their shrinking and swelling characteristics can easily cause damages due to their property variations as a result of moisture/ fluid content fluctuations associated with seasonal changes [2].

Therefore, geotechnical investigation of any construction sites is essential to obtain reliable inputs that enable to develop economically and technically feasible structural designs incorporating mitigation measures to anticipated geo-hazard events [3]. Like elsewhere in the world, also in Ethiopia public officials require geotechnical investigation data acquired in accordance with the Ethiopian building construction code with accompanying recommendations prior to issuing a building permit in order to protect the safety of the public the surrounding environment [4].

Geophysical methods are extensively used in geotechnical investigations. These methods help in identifying local areas of concern which have no surface expression. Moreover, the methods help to delineate boundaries between residual soils, weathered rocks and fresh rock. It is also possible to locate anomalous foundation features like dykes, cavities, fault zones and buried river channels [5].

Unlike drilling, pitting and trenching, geophysical methods are environmentally safe and also do not cause any significant damages/concerns to the communities. Geophysical measurement responds to change in the physical, chemical, mechanical, elastic, radioactivity or thermal properties of the underlying earth materials. Because of such divers characteristics usually one or more of the properties correspond to certain features of earth materials, i.e., contact, discontinuity (fracture/fault zones). Unlike direct sampling, such as drilling or pitting and sending samples to laboratories for analyses, geophysical methods respond to different parameter in different ways and deliver information in a short time with minimum expenses [6].

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Received: 06-Jan-2022, Manuscript No. JGG-22-15412; **Editor assigned:** 07-Jan-2022, PreQC No. JGG-22-15412 (PQ); **Reviewed:** 21-Jan-2022, QC No. JGG-22-15412;**Revised:** 26-Jan-2022, Manuscript No. JGG-22-15412 (R); **Published:** 03-Feb-2022, DOI: 10.35248/2381-8719-22.11.1013.

Citation: Teshome AM (2022) Application of Magnetic Method to Characterize Abaya Campus Building Site, Southern Ethiopia. J Geol Geophys. 11:1013

For engineering applications seismic refraction, electrical resistivity and magnetic methods are widely used to map the subsurface structures. These methods depend on the acoustic impedance, ground resistivity and magnetic susceptibility contrast of the subsurface materials respectively. The unique tectonic setting of Ethiopia results in complex geological and geo-morphological setups where along with these and continuously deteriorating environmental conditions, the country is very vulnerable for such geo-hazard risks, as volcanic, seismic, land slide and alike. Every year Ethiopia allocates quite a substantial amount of budget to the expansion of infrastructures: Roads, bridges, dams and building complexes. Particularly, to expand access to education the construction of universities is taking place in different parts of the country [7].

To study the foundation conditions at site and evaluate its suitability for erecting a four story building to be used as dormitory for student, subsurface investigations were carried out employing electrical resistivity, magnetic and seismic refraction methods with an ultimate objective of generating inputs for civil applications [8].

MATERIALS AND METHODS

Description of the study area

Location: Abaya is one of the six campuses of Arba Minch University, which is one of the long-established Universities of Ethiopia. It is located in Secha Kifle Ketema of Arba Minch town, a town located 500 km south of Addis Ababa in the Southern Nations, Nationalities, and People's Region (SNNPR). It is located in the UTM zone of 37 N, and it is geographically bounded by 0664000 m to 0665000 m North and 0339200 m to 0340200 m East (Figure 1).

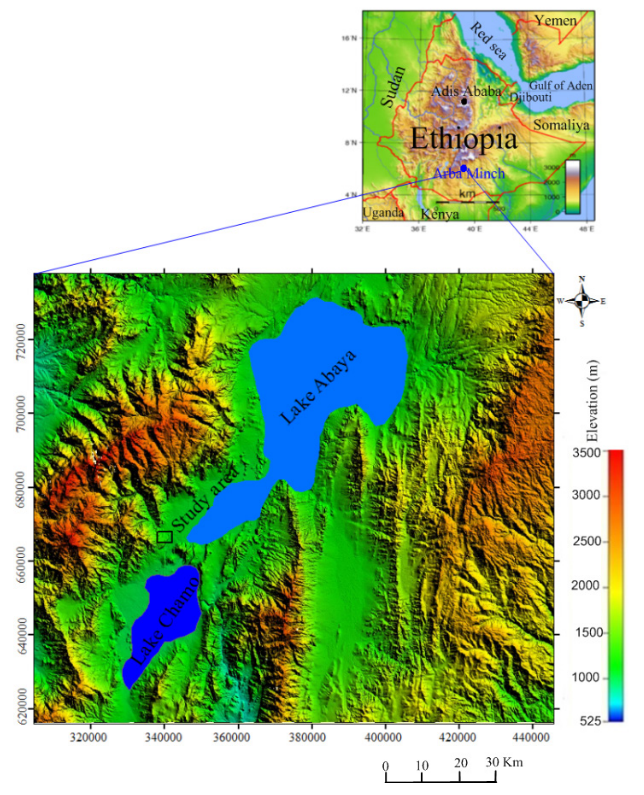

Figure 1: Location map of the study area.

Methodology

Four traverses magnetic data which is established approximately in the east west direction with a profile spacing of ten meter and one traverse perpendicular to the three traverses and randomly collected magnetic data were taken in the study area. Magnetic measurement where taken at ten meter interval using ENVI-MAG instrument (Scintrex) along the traverses. Three magnetic measurements were taken at each station and mean was adopted as the raw data for each observed station point for further processing. With these data the diurnal and geomagnetic corrections were carried out. Then with the corrected data oasis montaji software was used for magnetic interpretation by displaying magnetic anomaly map and magnetic profile [9].

Materials

The materials used during the field work are:

- Proton precision magnetometer (ENI-MAG)
- Geographic Positioning System (GPS)
- Topographic maps
- Geological hammer
- Burton compass
- Digital camera
- Satellite imagery and aerial photos

Data acquisition, processing and presentation

Instrumentation and data acquisition: A type of geophysical method employed is the magnetic method and the data are collected using INVI-MAG instrument along three east-west oriented traverses having ten meter profile and reading station spacing. Another one traverse is taken across the three traverses to determine if missing information is present and a randomly collected data also adopted as arrow data for further interpretation [10,11].

Magnetic data processing and presentation

Based on the above information diurnal and geomagnetic corrections are performed and the magnetic data's are presented as profile using Microsoft Excel. The regional and residual magnetic anomaly contribution to the total magnetic field anomaly is simply determined quantitatively using Microsoft excel. The magnetic anomaly map also displayed using oasis montaj and ArcGIS software for further interpretation.

The diurnal base station values were corrected for secular variation by removing the International Geomagnetic Reference Field (IGRF) field value at the base station location, computed at the time of measurement. The Residual Magnetic Anomaly (RMA) is calculated from the Total Magnetic Anomaly (TMFA) using excel software. TMFA is determined by removing the Diurnally Corrected value (DC) and the Regional Magnetic Field (IGRF) from the average of magnetic field intensity reading at each station. The regional magnetic field is calculated from the International Geomagnetic Reference Field (IGRF). The regional magnetic field, calculated for the specific survey location and time using the IGRF model, is removed from the resultant TMA to obtain the RMA. Regional effects of the earth's magnetic field were removed by subtracting from each reading the value computed from the IGRF 2010 model. IGRF was computed at each survey data point using the actual time that point was surveyed.

Magnetic data distribution

Figure 2 shows the magnetic data distribution which is made by using the location of the data when they are collected at the field through arc GIS software. This involves three traverses with an approximate orientation of east-west and one traverse which are made across to the other three to visualize and predict the missed geological structures or weak zones and geology beyond the above three. Beside to this the point on the map shows the random data taken in the investigation site.

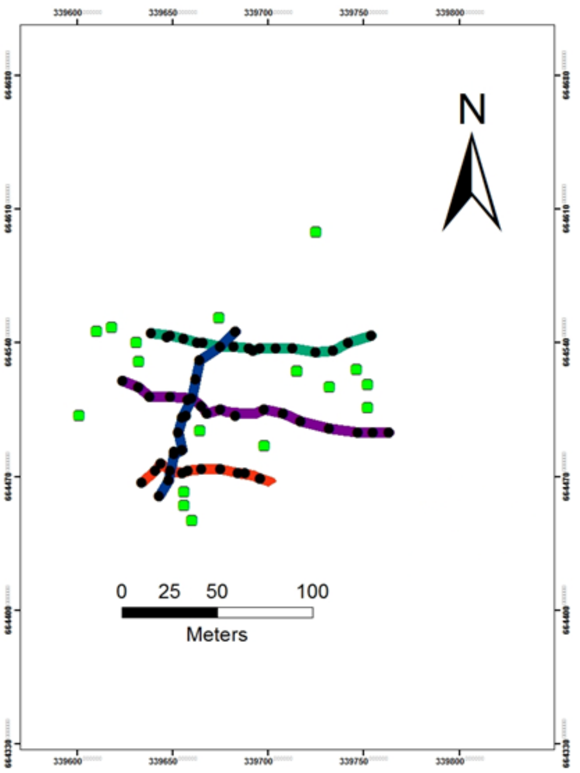

Figure 2: Graphical representation of chemical analysis of Okra. **Note:** ( ) Random data; ( ) profile-4; ( ) profile-3; ( ) profile-2;( )profile-1.

RESULTS AND DISCUSSION

This chapter includes interpretation of the magnetic data collected on the field and their profile picture and their representative maps. Data is processed in a way so localized anomalies caused by shallow magnetic objects (residual magnetic anomaly) would be more obvious. Total magnetic profile show larger scale geologic features, such as basin shape or anomalous rock types deep within the basement. Based on this information the residual magnetic anomaly profile profiles are presented correspondingly with the total magnetic field anomaly profile as shown below.

Magnetic profiles

The magnetic profiles are linear representative of the magnetic anomaly of the subsurface condition of the study area; and they are processed by excel 2007.

Profile 1: The Figure 3 below which contains 17 data points shows the profile line one that is oriented east-west direction of the study area. This profile line shows the subsurface image of one part of the study area. It indicates that in the first profile from 10-60 m, 80-100 m and 130-160 m distance is not suitable to construct any building due to the presence of either weak zones or materials with shallow magnetic anomaly values like clay; unless corrective measure is taken. Starting from 100 m to 130 m and it is advisable to construct the building due to the presence of competent (weathering resistant) rocks (Figure 4).

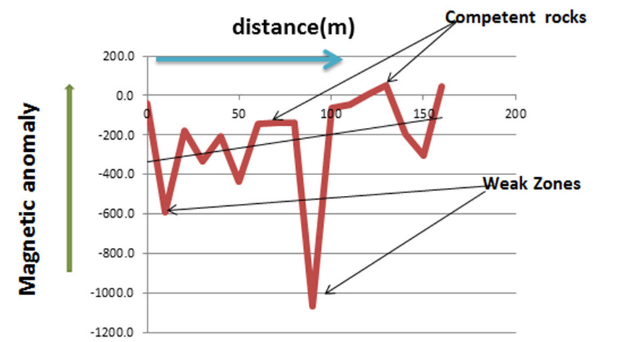

Figure 3: Total magnetic anomaly profile 1.

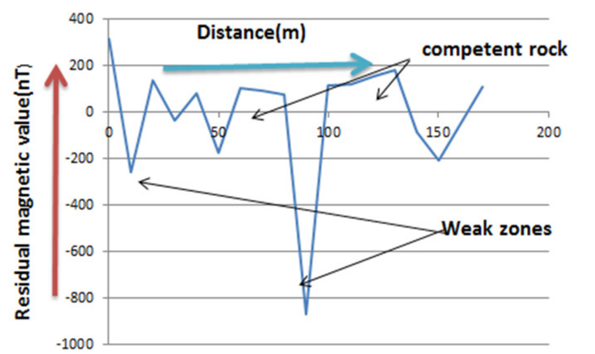

Figure 4: Residual magnetic anomaly profile 1.

Profile 2: This profile is constructed from 17 data point's shows variable magnetic anomaly values within small intervals that the area totally needs a special design or it is not possible to put any engineering structures because either may be due to the presence of many weak zones or the low magnetic value of the overlying thick clay soil. But with the absence of alternatives it is better to do corrective measures like; use pillars as a building foundation by allowing it up to the competent rock, remove the weak material till to the competent layer is encountered or blend and mix the overlying clay soil with appropriate material like sand to increase the suitability for building foundation (Figures 5 and 6).

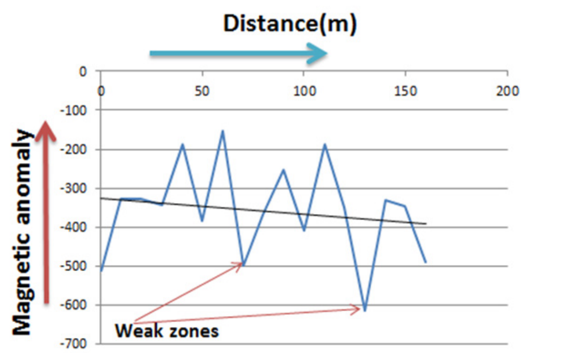

Figure 5: Total magnetic anomaly profile 2.

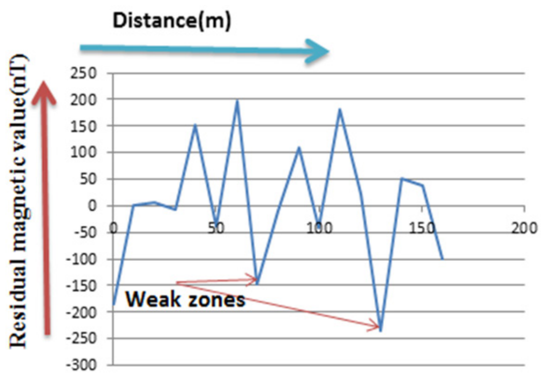

Figure 6: Residual magnetic anomaly profile 2.

Profile 3: This profile which contains 10 data points with fractured rock which extends from 20 m up to 70 m. This indicates that the fractured rock which exists from 20-70 m is not suitable to erect building. But beyond the distance of 70 m it is recommendable to put any engineering structure due to the presence of competent rock (Figures 7 and 8).

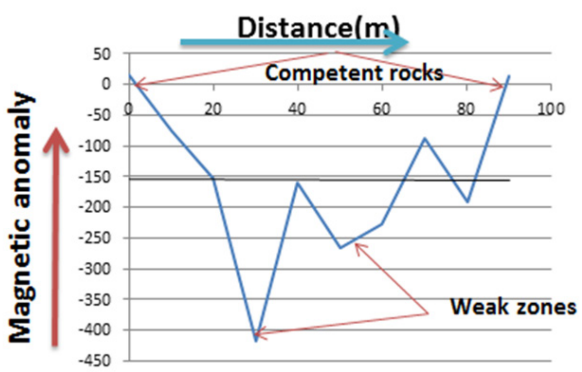

Figure 7: Total magnetic anomaly profile 3.

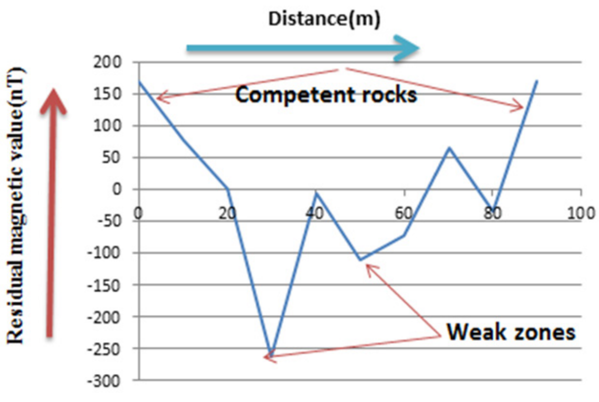

Figure 8: Residual magnetic anomaly profile 3.

Profile 4: This profile is the across profile to the above three horizontal profiles which is approximately done in the E-W direction and is used to visualize the missed geological structures or weak zones and lithological stratification across the three profiles seen above Figure 9. The surveyed profile has a length of about 130 m and according to the profile beyond 10 m distance the area is recommendable to construct the building (Figure 10).

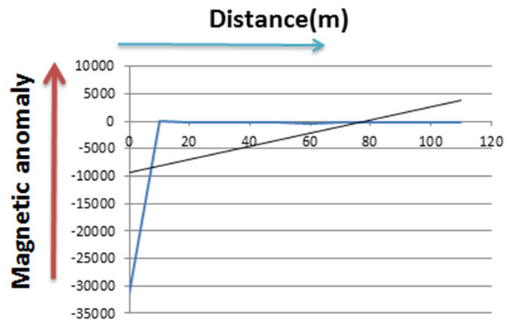

Figure 9: Total magnetic anomaly profile 4.

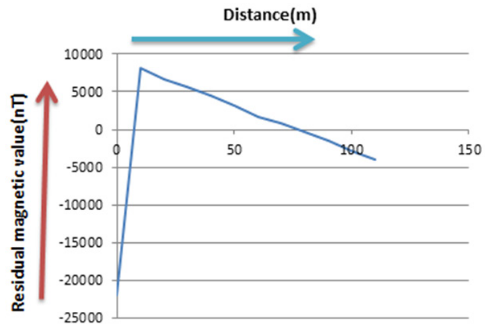

Figure 10: Residual magnetic anomaly profile 4.

Magnetic anomaly map

Magnetic variation or susceptibility may be analyzed using either total magnetic anomaly or residual maps. Magnetic residual maps reveal much more detailed geologic features in particular, the geometry and configuration of individual basement blocks. They bring out the subtle magnetic anomalies that result from the changes in rock type across basement block boundaries. Total magnetic anomaly maps show larger scale geologic features, such as basin shape or anomalous rock types deep within the basement. Keeping this information in mind both the total magnetic field anomaly and residual magnetic anomaly are displayed for comparison purpose side by side as shown in in the Figures 11 and 12 below.

One of the most applications of magnetic method in building foundation study is to locate boundaries between different litho logic units and geological structures that display magnetic contrasts such as faults or dykes. To interpret the magnetic data in terms of such subsurface indications, the magnetic data are presented in different forms. After applying all the necessary reductions, the magnetic anomaly map is prepared as shown in Figure 11. According to this map the study area is classified in to three zones.

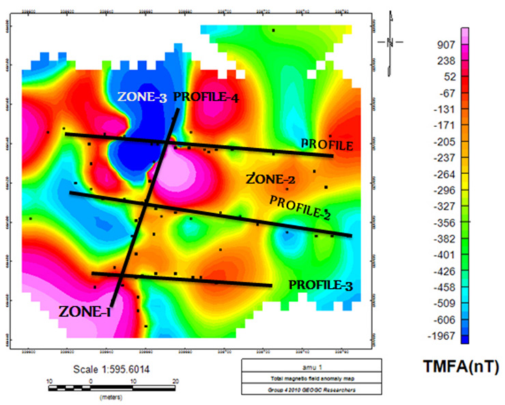

Figure 11: Magnetic anomaly map.

Zone-1 is characterized by very higher magnetic anomaly and it covers the northern, southern western, north western, and also at the central parts of the area. Zone-2, which have intermediate magnetic anomaly covers most of the eastern and southern part of the study area. The area designated by Zone-3, show very low magnetic anomaly and it covers the northwestern and some portion of the western part of the area. The low magnetic anomaly is interpreted as weak zone on the on the above profile lines Figure 12.

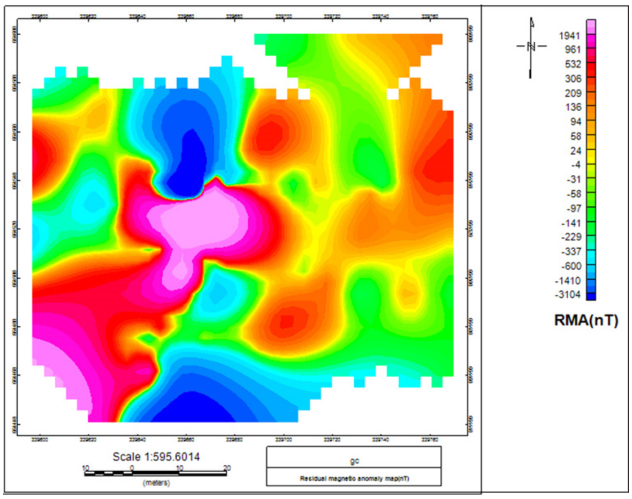

Figure 12: Residual magnetic anomaly map.

Analytical signal map

The analytical signal map shown in Figure 13 below was developed from the residual magnetic anomaly map. Over the causative bodies, the analytic signal has a form that depends on the locations of the bodies but not their directions of magnetization. Therefore, this method is very useful at low magnetic latitudes. The map specifically resolves near surface (shallow) anomaly sources very well and is good at locating the edges of shallow bodies, for the reason that the amplitude of the simple analytical signal peaks (attains maxima) over magnetic contacts. Distinct areas associated with geological contacts that need special design consideration for heavy structures are clearly identified and outlined on the map.

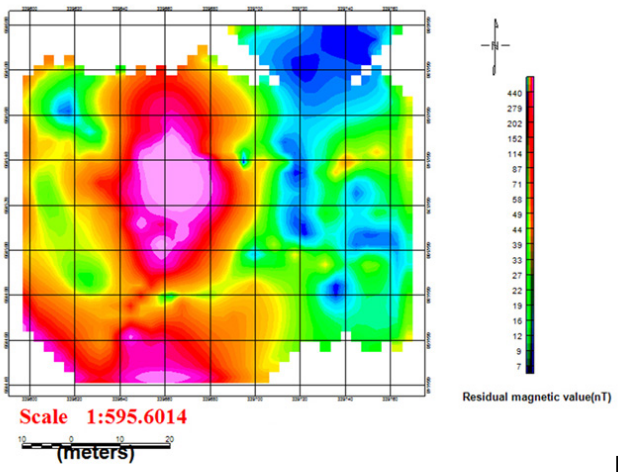

Figure 13: Analytical signal map.

CONCLUSION

The magnetic method for building foundation study has been conducted in south nations, nationalities, people's regional state (SNNPRS) Arba Minch University in the parts of Abaya Campus. The main purpose of this study was to identify the subsurface conditions including the geology and the geological structures in the study area based on the results from the magnetic method investigation. Hence magnetic anomaly map and magnetic anomaly profile plots were developed using Oasis montaji and Microsoft excel respectively.

Accordingly, the study area is interpreted to comprise of three zones in which the first zone exhibit high magnetic anomaly. This zone is located in the northern, southwestern, northwestern, and also at the central part of the study area. The second zone comprises of the eastern and southern part of the study area that exhibit intermediate magnetic anomaly. The third zone is the one which covers the northwestern and some portion of the western part of the study area and described by very low magnetic anomaly. Using analytical signal map the distinct areas associated with geological contacts that need special design consideration for heavy structures are clearly identified and outlined on the map. Based on the interpretations made in this study, the areas described under zone one best fit for building foundation. While zone two is useful to put the foundation of building with some enhancements in design to prevent problems associated with the weak zones and zone three is not suitable for erecting building due to the presence of either incompetent rock or weak zones.

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