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GROUNDMAGNETIC INVESTIGATION INTO THE CAUSE OF THE SUBSIDENCE IN THE ABANDONED LOCAL GOVERNMENT SECRETARIAT, OGBOMOSO, NIGERIA

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ABSTRACT

Groundmagnetic was used to investigate the cause of the subsidence at an Abandoned Local Government Secretariat, Ogbomoso, Southwestern Nigeria with a view to determining whether the sinking and cracks in the plasterworks experienced at the Eastern side of the study area is due to subsurface features or insufficient use of building materials. The study took place at an Abandoned Local Government Secretariat Ogbomoso, Southwestern Nigeria which falls within latitude $08^0\ 09'\ 50.6''$ - $08^0\ 09'\ 55.9''$ and longitude $004^0\ 15'\ 36.1''$ - $004^0\ 15'\ 42.3''$. Proton Precision Magnetometer model GSM-19T was used to carry out the geophysical survey along four traverses in East-West and North-South directions. The traverses length ranges from 70m to 150m with inter station spacing of 10m. The results were presented as groundmagnetic profiles of varying magnetic intensities, groundmagnetic contoured map and groundmagnetic surface map. The basement topography was obtained from the profiles using half-width of the amplitude method. Areas with high magnetic values are the competent zones for construction while areas with low magnetic values are the weak zones. The quantitative interpretation gave the overburden thickness to the top of the magnetic basement rock as varied between 7.0m to 13.0m. Interpretation of groundmagnetic data revealed that the weak zones present at the Southeastern, Eastern and Northeastern part of the study area are the cause for the subsidence that occurred towards the Eastern side of the building. Contrary to the opinion of people that the building contractor used inferior building materials for the construction, we found out that half of the building is constructed on either collapse tunnel, fault or fracture which resulted into the sinking and new cracks in plasterworks experienced at the Eastern part of the abandoned Local Government secretariat.

Keywords: subsidence, magnetic intensities, competent zones, collapse tunnel, fault, fracture.

INTRODUCTION

Subsidence of a building structure results from the external factors which causes disruption, displacement, contraction or distortion of the ground under or around a building. It is also the downward movement of the ground supporting the building. Causes of subsidence include:

a) **Certain soils:** Clay soils are particularly vulnerable since the shrink and swell depends on their moisture content.
b) **Vegetation:** Trees and shrubs take moisture from clay soils particularly causing them to shrink especially during long periods of dry weather as root extends in search of water.
c) **Leaking drains:** These can wash away or erode the adjacent ground which then partially collapses or reducing the lateral strength of the ground. The support provided by this ground will then be reduced causing any building above to subside.
d) **Biodegradation:** Domestic refuse disposed of in the ground usually breaks down and consolidates at a steady rate. However, the apparent soundness of the ground can be misjudged and further decay or compaction occur resulting in the subsidence of the ground and any building above.
e) **Mining:** In most part of the subsurface, when shaft and tunnels are been left, it reduces its ability to support the ground above. The collapse of the tunnel causes the ground above to drop, hence causes damage to any building that is built on it.

Some of signs of subsidence include:

a) New or expanding cracks in plasterworks.
b) New or expanding cracks in outside bricks or rendering.
c) Sticking doors or windows.
d) Rippling wallpaper with no apparent cause e.g. damp.

In the case of abandoned local government secretariat that was investigated in this study, the Eastern part of this 2-storey building secretariat sank, new cracks in plasterworks were also discovered which made the user to abandon the place. Information recorded it that the secretariat was built about 3 decades ago in the old Oyo State regime. This misfortune was blamed on the building contractor to have used inferior building materials for the construction. We examined the study area and needed to be sure whether the subsidence in the building was truly due to the materials used during construction or some subsurface features like fault or fracture. That was when we decided to run the magnetic survey in the study area in order to start our investigation from subsurface features.

The magnetic method is one of the various techniques used in geophysical surveys. The magnetic survey method measures variations in the earth's magnetic field to determine the location of subsurface features. It also helps to delineate the displacement fractures, joints or in general the linear features for example competent areas deals with magnetic highs and areas of magnetic lows have weak zones like cracks, joints, and fractures etc. Other geophysical survey methods are the electromagnetic, electrical resistivity, seismic, radioactivity, well logging etc (Okwueze, 2000).

The purpose of magnetic survey is to locate rocks or minerals having unusual magnetic properties which reveal themselves as anomalies in the intensity of the earth's magnetic field (Abdelrahaman and Essa, 2005). It has been used extensively in basement mapping and subsurface geological structures such as rock contacts, rock boundaries, fractures and faulted zones (Ofoegbu and Hein, 1991; Folami, 1992; Alagbe *et al*., 2010; Kayode, 2010; Kayode *et al*., 2010; Bayode and Akpoarebe, 2011; Kayode *et al*., 2011; Adagunodo and Sunmonu, 2012; Lawal *et al*., 2012; Sunmonu *et al*., 2012). In the present study, magnetic method was used to investigate the cause of the subsidence that occurred in the abandoned local government secretariat Ogbomoso in order to determine whether the subsidence is from the subsurface features (e.g. fault, fracture, or contact between two rocks) or it was due to use of inferior building materials during construction of the building.

SITE DESCRIPTION

The studied area lies within the crystalline Basement Complex of Nigeria (MacDonald and Davies, 2000). It lies within latitude $08^0\ 09'\ 50.6''$ - $08^0\ 09'\ 55.9''$ and longitude $004^0\ 15'\ 36.1''$ - $004^0\ 15'\ 42.3''$. The study area is located at Ogbomoso North Local Government Area. It is located between Ogbomoso North Local Government Secretariat and Ladoke Akintola University of Technology, Ogbomoso. The study area is accessible with network of roads that surrounds it.

HYDROGEOLOGICAL SETTING

According to MacDonald and Davies (2000) who classified the hydrogeology of Sub-Saharan Africa into four provinces, these are: Precambrian basement rocks, volcanic rocks, unconsolidated sediments and consolidated sedimentary rocks (Figure-1(a)). These four provinces are well represented in Nigeria (Figure-1(b)). The study area is located on the Precambrian basement rocks of Southwestern Nigeria which comprise of crystalline and metamorphic rocks over 550 million years old (MacDonald and Davies, 2000).

Unweathered basement rock contains negligible groundwater. However, significant aquifers develop within the weathered overburden and fractured bedrock (MacDonald and Davies, 2000; Alagbe, 2005). In the soil zone (top soil) of Precambrian basement, permeability is usually high, but groundwater does not exist throughout the year and dries out soon after the rains end. Beneath the soil zone, the rock is often highly weathered and clay rich, therefore permeability is low. Towards the base of the weathered zone, near the fresh rock interface, the proportion of clay significantly reduces. This horizon, which consists of fractured rock, is often permeable, allowing water to move freely. Wells or boreholes that penetrate this horizon can usually provide sufficient water for consumption (MacDonald and Davies, 2000).

Deeper fractures within the basement rocks are also an important source of groundwater, particularly where the weathered zone is thin or absent. These deep fractures are tectonically controlled and can sometimes provide supplies of up to one or even five litre/s. The groundwater resources within the regolith and deeper fracture zones depend on the thickness of the water-bearing zone and the relative depth of the water table. The deeper the weathering, the more sustainable the groundwater (MacDonald and Davies, 2000).

GEOLOGICAL SETTING

Regionally, the study area lies within the South Western parts of the Basement rocks, which is part of the much larger Pan-Africa mobile belt that lies in between the West Africa Craton and Congo Craton, suspected to have been subjected only to a thermotectonic event (Alagbe, 2005). In general, the southwestern Nigeria crystalline Basement (Figure-2) can be grouped into three:

(i) **The Migmatite-gneiss complex:** It composes of Migmatite and gneiss of various compositions. Relics of sedimentary rocks such as quartzitic rocks occurring within the group with ages ranging from Pan-Africa (600Ma) to Leonian (Russ, 1957). They have been metamorphosed in the middle to upper amphibolite facies (Ajibade *et al*., 1988).

(ii) **Metasedimentary and metavolcanic rocks:** (This is also known as Low grade sediment dominated schist belt) trending N-S which are considered to be Upper Proterozoic (Birimian) in age. The Northwestern basement has well developed schist belts (Green Schist facies) comprising mainly of phyllite, Schist, quartzitic and banded iron formation (BIF). The rocks are considered to be Upper Proterozoic that has been infolded into Migmatite-gneiss complex (Trusswell and Cope, 1963).

(iii) **The Pan-African older granite series:** This intrude both into the Migmatite-gneiss-quartzite complex and the Low grade schist belts. They range widely in age and composition from true granite to granodiorite, adamalite and tonalities. Other rocks associated with it are highly hypersthenes bearing rocks called charnokites.

Their Rb/Sr ages range between 750 and 450Ma (Ajibade *et al*., 1988), which are considered to be ages of emplacement, classify these rocks as strictly belonging to Pan Africa. Notably among the granite series are Kusheriki granites (Trusswell and Cope, 1963). The above three division is largely based on lithology and does not in

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anyway reflect the range of Complex field relationship and structures displayed on the rocks.

The basement complex in Nigeria is underlain by gneiss, migmatites and metasediments of Precambrian age, which have been intruded by a series of granitic rocks of late Precambrian to lower Palaeozoic. The plutonic rocks are known as Older Granite and have been dated to about 500 to 600 million years, representing the Pan-African orogeny in Nigeria (Szentes, 2009). The Older Granite suites in Nigeria were so named by Falconer (1911) to differentiate them from the Mesozoic tin-bearing Younger Granite suites, which are volcanic/granitic ring complexes in the Jos Plateau area (Ephraim, 2012). The contacts with the gneisses are gradational passing from granite into metasomatic gneiss with marginal migmatites. The contacts between granites and metasediments are sharp with no marginal migmatites (Oyawoye, 1964).

The granitic rocks are all compositionally similar, containing quartz, microcline, plagioclase and biotite with accessory apatite and zircon. The porphyritic granite is the most typical type of the Older Granite. It is coarse to very coarse grained with large white or pink prismatic phenocrystals of microcline. The granites are variably foliated becoming almost gneissose in places. Occasionally, medium to fine grained granodiorite, quartz syenite and microgranite also appear (Szentes, 2009).

The youngest rock of the basement formation is a series of rhyolites and rhyodacites that were intruded into the Older Granite bodies during the lower Palaeozoic uplift following the Pan-African orogeny. The ring tectonic complexes of the Jurassic age-Younger Granites-intruded into the late Precambrian basement rocks in a N-S trending zone (Szentes, 2009; Akintola *et al*., 2012). The Younger Granite is 160 to 170 million years old (Szentes, 2009). Its emplacement was associated with epirogenetic uplift. The ring structure and the petrology follow a general pattern. Their evolution can be summarized in three stages as the early volcanic stage, the caldera and ring dyke stage and the intrusive stage. The earliest rocks are volcanic, composed of rhyolite with minor associated basalts and trachytes. They are closely associated with the outer ring dykes of granite porphyry. Within the ring dykes there are stoc-like intrusions of biotite granite. The centre of the complexes is composed mainly of massive biotite granite with smaller intrusions of porphyry (Kobke, 1976).

The granites are composed of alkali feldspar, quartz with a small proportion of mafic minerals and are classed as alkali feldspar granites. They are unfoliated. The Younger Granite is the source of the tin mineralization in the Jos Plateau region of Nigeria (Szentes, 2009).

Locally, the study area lies within Ogbomoso and is underlain by rocks of the Precambrian complex with Quartzite and Quartz-Schist and Undifferentiated Gneiss and Migmatite (Ajibade *et al*., 1988). The rock groups in the area include quartzites and gneisses (Ajibade *et al*., 1988). Schistose quartzites with micaceous minerals alternating with quartzo-feldsparthic ones are also experienced in the area. The gneisses are the most dominant rock type. They occur as granite gneisses and banded gneisses with coarse to medium grained texture but the main rock types especially in the study area is granite gneisses (Figure-3).

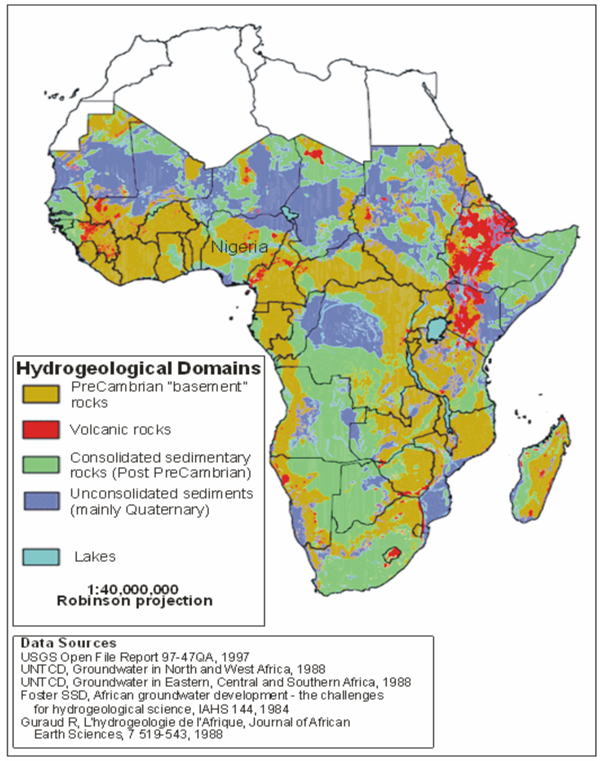

Figure-1(a). The hydrogeological domains of Sub-Saharan Africa (after MacDonald and Davies, 2000).

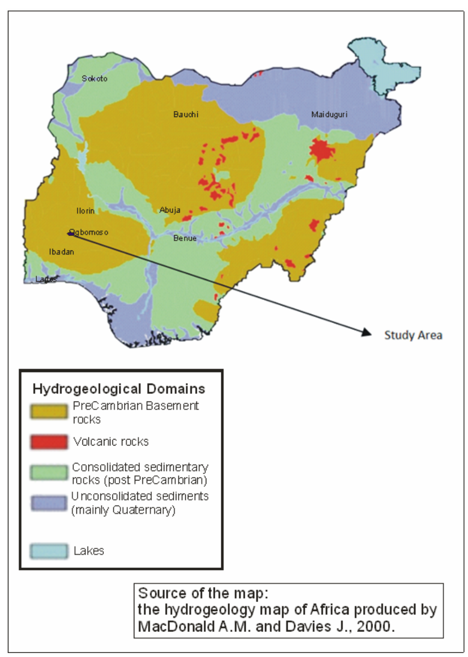

Figure-1(b). The hydrogeological domains of Nigeria.

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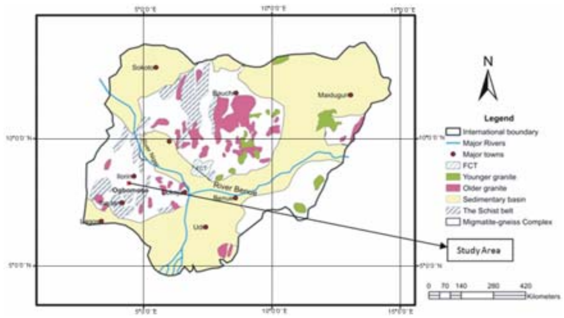

Figure-2. Geological map of Nigeria showing the study area. (Modified after Ajibade *et al*, 1988).

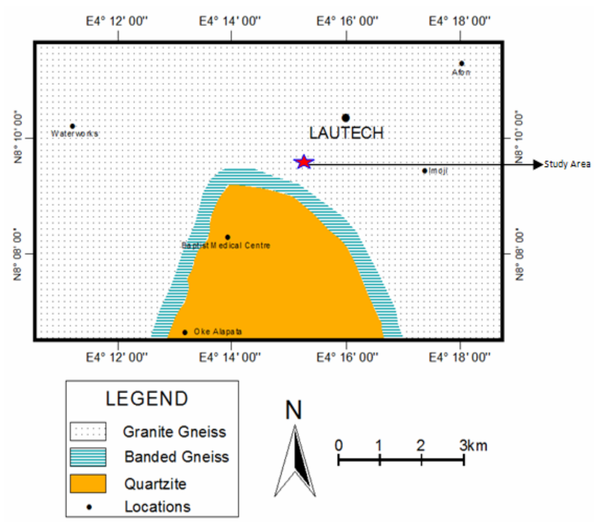

Figure-3. Geological Map of Ogbomosho North Local Government Area (modified after Adeleke, 2009).

MATERIALS AND METHODS

Proton Precision Magnetometer model GSM-19T was used to carry out the geophysical survey along four traverses (Figure-4) in East-West and North-South directions. The traverses length ranges from 70m to 150m with inter station spacing of 10m. A base station was carefully selected before the survey started which was reoccupied frequently to check for diurnal variations. The raw data was input into a personal computer (PC) to remove regional field from the Total Magnetic Intensities (TMI) recorded for each traverses using Signproc software (Cooper, 2000). In order to prepare the data for interpretation, the residual anomaly that has been separated from the regional field was further enhanced using analytic signal filtering technique (Nabighian, 1972). Analytic signal is used here because it reflects the shallow anomalies and suppresses the deep anomalies. It also has these properties:

a) Its real and imaginary components satisfy Cauchy-Riemann conditions.
b) Its absolute value is symmetric rather than x-axis which is dependent to body magnetization direction and ambient geomagnetic field and only is relevant to body location.
c) This quantity can be employed to causative body depth estimate.
d) Its maximum value lies over anomalous body directly.

The eventual magnetic data were presented as magnetic profiles by plotting the magnetic values against station separations for each traverse. Magnetic contour map (2D plot) and surface map (3D plot) were also constructed for a more qualitative interpretation using Surfer 8 software (Surfer 8, 2002). The quantitative interpretation involved the use of half-width of the amplitude method for the estimation of overburden thickness (Folami, 1992). The estimated magnetic depths to the basement along each traverse were determine and presented in Table-1.

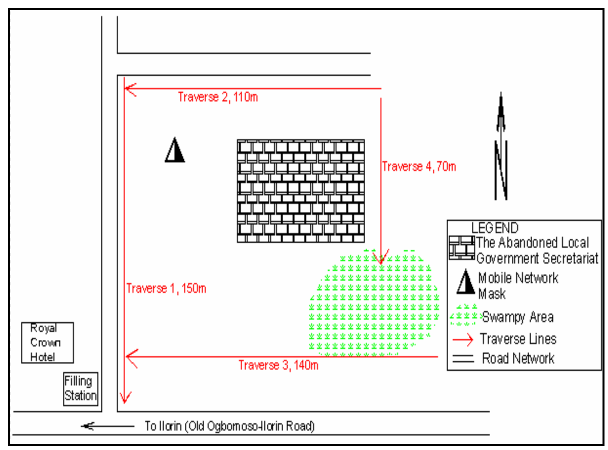

Figure-4. Layout map of groundmagnetic survey.

RESULTS AND DISCUSSIONS

The results of the investigation into the cause of the subsidence in the abandoned local government secretariat using groundmagnetic survey were discussed in terms of quantitative and qualitative interpretations. The quantitative interpretation involves the estimation of the overburden thickness to the top of the magnetic basement, and is as shown in Table-1. It indicated varied basement topography with depth ranging from 7.0 to 13.0 m. Traverse 3 and 4 showed depths to basement of 13.0 and 12.0m respectively. This shows there is suspect of averagely thick overburden towards the Eastern side of the study area (overburden thickness >10m).

The qualitative interpretation involves interpretation of the magnetic traverses, magnetic contoured map (2D plot) and magnetic surface map (3D plot).

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Table-1. Depth estimates of groundmagnetic traverses relative to the ground surface from Abandoned Local Government Secretariat, Ogbomoso using Half-Width of the amplitude method.

Traverses	Depth to the magnetic sources (m)	
	A	B
Traverse 1	7.0	9.0
Traverse 2	8.0	7.5
Traverse 3	13.0	-
Traverse 4	12.0	-

Magnetic traverses

Traverse-1

The traverse covers a total length of 150m (Figure-5(a)) and trends in North to South direction. This traverse falls into the Western side of the abandoned Local Government Secretariat. The traverse shows two magnetic highs as indicated by A and B and a magnetic low as indicated by U. Magnetic highs at A and B are suspected to be due to near surface magnetic minerals such as crystalline rocks (igneous or metamorphic rocks). These magnetic highs zones at distance 20m to 48m and 100m to 132m from the starting point might be considered as competent zones for construction of building. Magnetic low at U are suspected to be due to presence of non-magnetic minerals such as fault, fracture, crack or contact between two rocks. This zone will not be able to withstand high-rise building. Distances 60m to 100m from the starting point are suspected to be an inflection point (contact between two rocks). Generally on this traverse, if artificial basement is created at distance 0m to 20m, 48m to 100m and 132m to 150m from the starting point, the traverse might have been competent for the construction of low-rise building or maximum of a storey building (Barry, 1999).

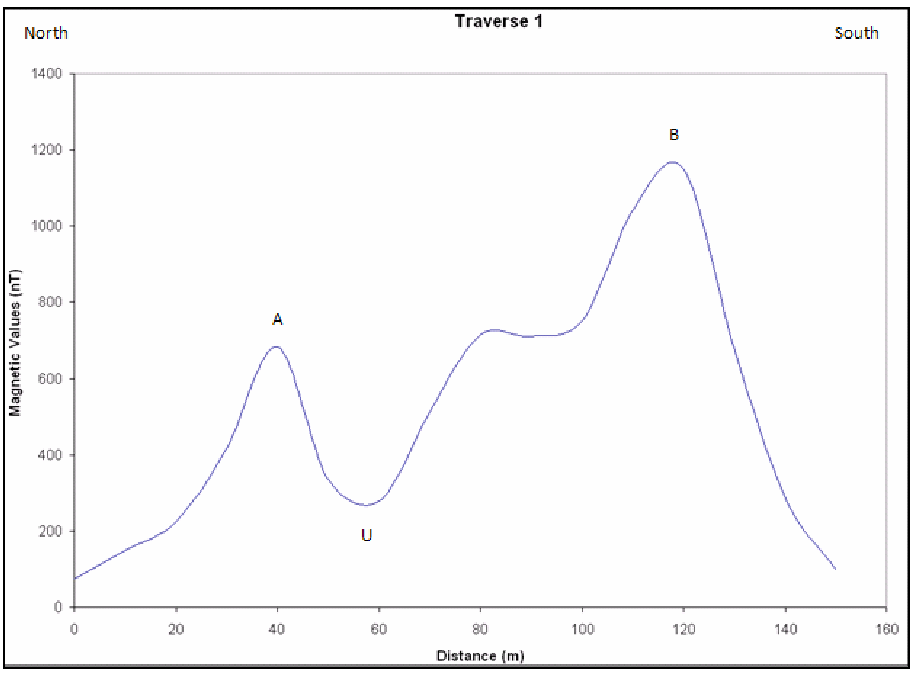

Figure-5(a). Magnetic profile along traverse-1.

Traverse-2

The traverse covers a total length of 110m (Figure-5(b)) and trends in East to West direction. It falls on the Northern side of the study area. The traverse shows two magnetic highs as indicated by A and B and a magnetic low as indicated by U. Magnetic highs at A and B are suspected to be due to near surface magnetic minerals such as crystalline rocks (igneous or metamorphic rocks). These magnetic highs zones are regarded as competent zones for construction of building. Magnetic low at U are suspected to be due to presence of non-magnetic minerals such as fault, fracture, crack or contact between two rocks. This zone will be dangerous for the construction of high-rise building. Generally, because of deep nature of zone U, traverse-2 could not be suitable for the construction of 2-storey building.

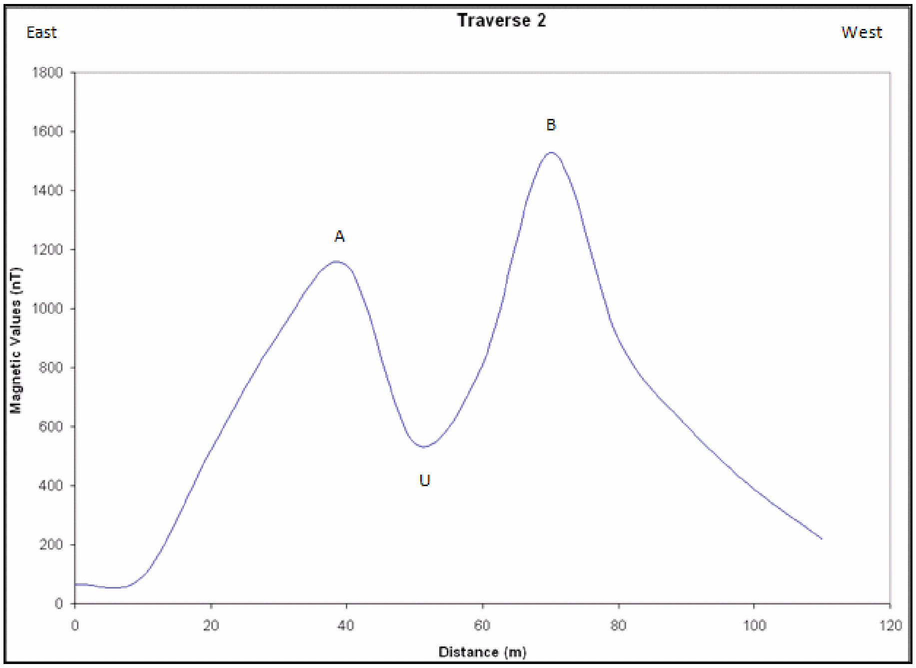

Figure-5(b). Magnetic profile along traverse-2.

Traverse-3

The traverse covers a total length of 140m (Figure-5(c)) and trends in East to West direction. It falls on the Southern part of the study area. The magnetic high along this traverse is marked as A; distance 72m to 140m. This zone is competent for the construction of high-rise building. However, distance 0m to 72m is suspected to be due to presence of non-magnetic minerals like fault, fracture, crack or contact between two rocks. This zone should be avoided for construction of building. Even if it could not be avoided totally, it must be low-rise building that should be present there.

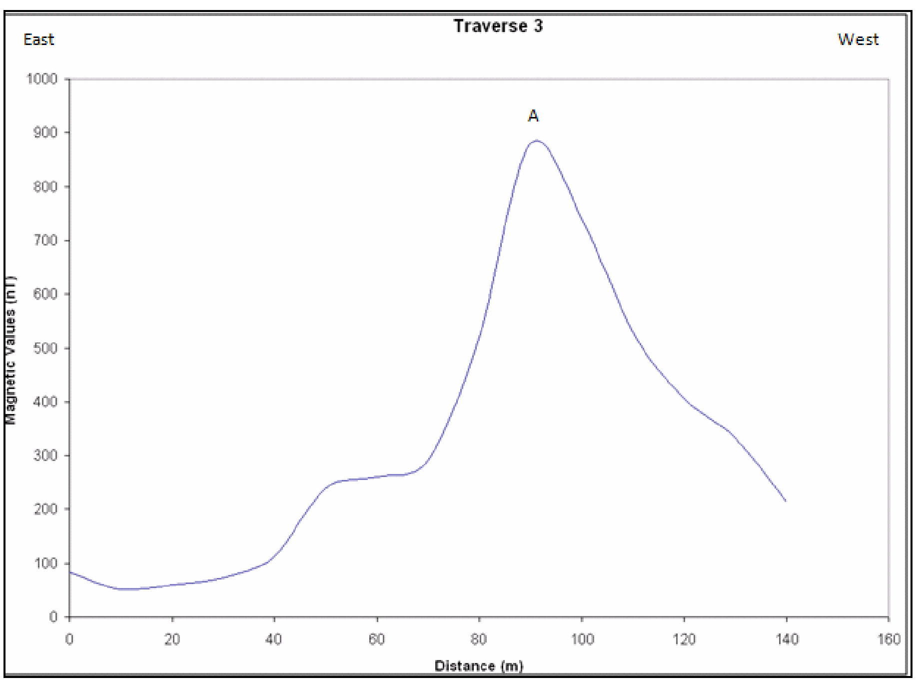

Figure-5(c). Magnetic profile along traverse-3.

Traverse-4

The traverse covers a total length of 70m (Figure-5(d)) and trends in North to South direction. It falls towards the Eastern side of the study area. The magnetic high along this traverse is marked as A; distance 10m to 50m. This zone is competent for the construction of building but it is not evenly distributed throughout the traverse. However, distance 0m to 10m and 50m to 70m are suspected to be an inflection point (contact between two rocks or discontinuity from other basement rocks). This zone should be avoided for construction of high-rise building.

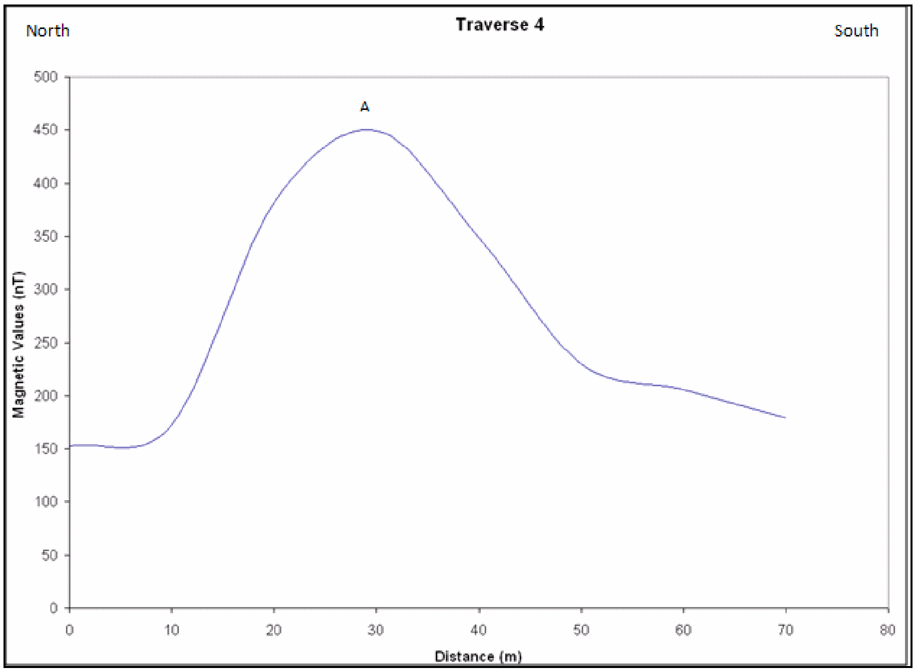

Figure-5(d). Magnetic profile along traverse-4.

Magnetic contour map

The magnetic 2-D contour map constructed using the magnetic values are as shown in Figure-6. The contour map reveals the basement structure and shows the structural trend of the study area. High magnetic susceptibility values with closely packed contour lines are present towards the peak of the Northern and Southern side of the study area, and some regions towards the Western zone of the study area. This shows the presence of near-surface magnetic minerals in these zones.

Dispatched contour lines are experienced towards the Eastern and Central region of the study area. This suspect the presence of collapse tunnel or fracture in the region which might have been responsible for the outlook of the 2-D map. Therefore, it seems that the abandoned L.G. secretariat is built on collapse tunnel or fracture.

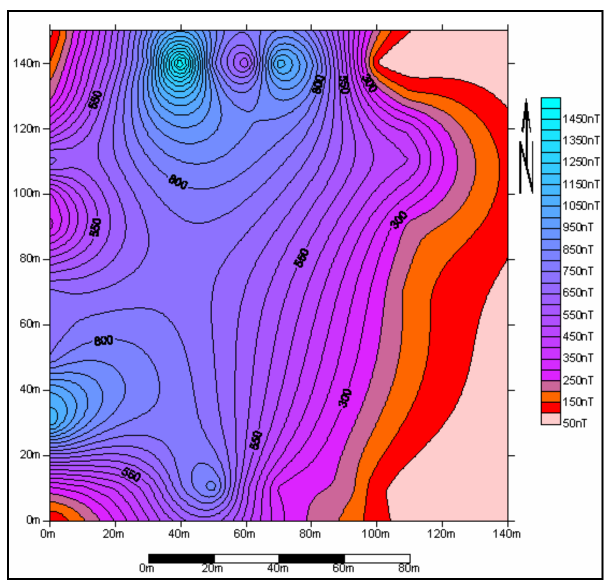

Figure-6. The contoured map (2D plot).

Magnetic surface map

The magnetic 3-D surface map indicates the levels or magnitude of the magnetic contrast as shown through the colour and the colour code bar (Figure-7). The colour difference shows the same trend as that of the 2-D contour

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map and the magnetic values shows a significant magnetic contrast which defines the level of magnetization in the study area. 3-D plot showed vividly that half of the study area has high magnetic susceptibility while its remaining half has low magnetic susceptibility. The presence of low magnetic susceptibility at Eastern, Southeastern and towards the peak of Northeastern region of the study area suspects the area to be underlain with collapse tunnel, fault or fracture which constitutes part of where the abandoned local L.G. secretariat is built.

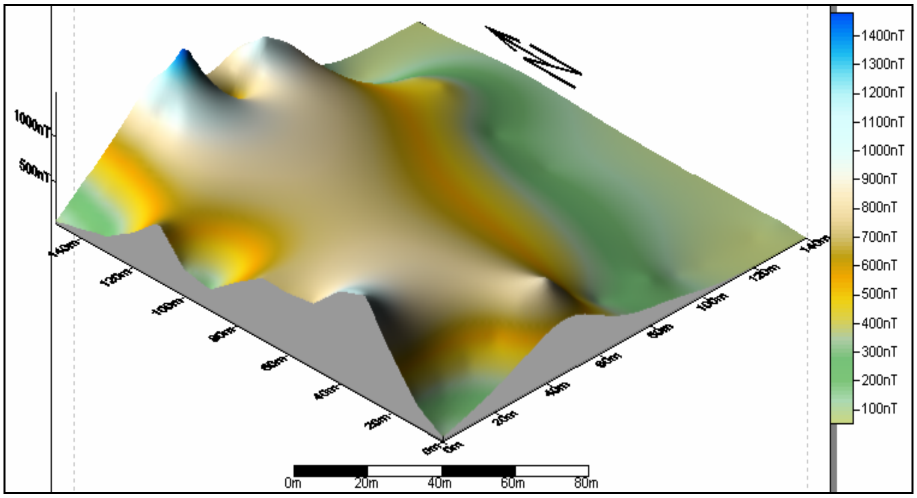

Figure-7. The surface map (3D plot).

CONCLUSIONS

The magnetic method has been used to investigate into the cause of the subsidence that occurred in an Abandoned Local Government Secretariat, Ogbomoso, Southwestern Nigeria and found out that half of the building is constructed on either collapse tunnel, fault or fracture which resulted into the sinking and new cracks in plasterworks experienced at the Eastern part of the abandoned Local Government secretariat. A multidimensional approach to the studies (that is the magnetic profiles, magnetic contoured map, magnetic surface map and depth to the basement estimation) has made the study both very qualitative and quantitative as information missed by any of the approach is revealed by the other and thereby necessitating justifiable conclusions. Relevant geophysical techniques like Electrical Resistivity, Seismic Refraction, Ground Penetrating Radar or Gravimetric method can be used as a reconnaissance tool in the study area to confirm the predictions in this study.

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