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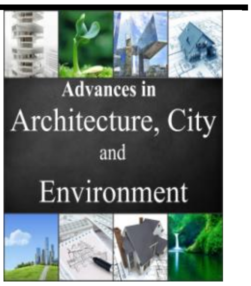

Geomagnetic Signature Pattern Of Industrial Layout Orile Igbon

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ABSTRACT

Ground magnetic data at Industrial Layout Orile Igbon was analyzed with a view to determining the areas that are competent for the construction of factories and other related buildings (e.g. high-rise administrative buildings). The study area falls within latitude $08^0\ 13^{'}\ 59.22^{''}$ to $08^0\ 15^{'}\ 0^{''}$ North and longitude $004^0\ 17^{'}\ 05.0^{''}$ to longitude $004^0\ 19^{'}\ 01.1^{''}$ East of Southwestern Nigeria. The ground magnetic survey was carried out, the acquired data was processed and analyzed. The qualitative interpretation revealed features like faults, contact between two rocks and fracture zones. However, the quantitative interpretation gave the overburden thickness to the top of the magnetic basement rock as varied between 6.0 and 33.5 m. Interpretation of ground magnetic data revealed that Industrial Layout Orile Igbon comprise of zones underlain with thin as well as thick overburden. It is therefore advisable that people should not ignorantly built factories making use of heavy machines where there is thick overburden as it might lead to subsidence or total collapse in the future. This could occur when the vibration of these heavy machines is transferred to the subsurface which might lead to ground motion which later has effect on the factory's foundation.

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INTRODUCTION

The earth subsurface has been of great concern to geoscientists, who seek to investigate it using diverse means, some for the purpose of having knowledge about the terrain they are, others do it for exploration of economic resources such as minerals and hydrocarbons which lie concealed beneath the earth surface, some for engineering investigation, while some for archaeological studies. The presence and magnitude of these anomalies in the subsurface can only be ascertained by geophysical investigations of the subsurface geologic structures in the study area.

Geophysical methods may be applied to a wide range of investigations from studies of the entire Earth to exploration of a localized region of the upper crust for engineering or other purposes (Kearey *et al.*, 2004). A wide range of geophysical methods exist, for each there is an operative physical property to which the method is sensitive. The type of physical property to which a method responds clearly determines its range of application. Thus, for instance, magnetic method very suitable for locating buried magnetic ore bodies, because of their magnetic susceptibility. Similarly, seismic and electrical methods are suitable for locating water table, because saturated rock may be distinguished from dry rock by its higher seismic velocity and higher electrical conductivity (Dobrin, 1976).

Geophysical methods are capable of detecting and delineating local features of potential interest. Geophysical methods for detecting discontinuities, faults, joints and other basement structures include the following: magnetics, seismic, electrical resistivity, potential field, well logging, gravity, radiometric, thermal and so on (Corell and Grauch, 1985). Some geophysical methods such as gamma-ray spectrometry and remote sensing measure surface attributes; others, such as thermal and some electrical methods are limited to detecting relatively shallow subsurface geological features. Geophysical modeling provides generalized and no-unique solution to questions concerning the geometry of the subsurface geologic structures (Reeves, 2005; Bonde *et al.*, 2014).

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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). Magnetic survey is employed here because of the following advantages over the other methods:

i. It has a broad spectrum of applications in engineering and environmental studies.
ii. It is relatively easy to perform and not too expensive as it requires little data processing.
iii. The method has good depth penetration when compared to other geophysical techniques.

Magnetic surveying investigates the subsurface geology of an area by detecting magnetic anomalies within the Earth's magnetic field, which are caused by the magnetic properties of the underlying rocks. Most rock-forming minerals are non magnetic but a few rock types contain sufficient amounts of magnetic minerals, which can impart magnetism to their host rocks and thus produce detectable magnetic anomalies (Okwueze, 2000). Rock magnetism has magnitude and direction, the latter being determined by the host rocks position relative to the past and present magnetic poles of the Earth (Okwueze, 2000).

In the present study, magnetic method has been used to delineate subsurface linear geologic structures which may be related to understanding the competent and weak zones in industrial layout Orile Igbon, Surulere Local Government Area, Oyo State, Nigeria. Though aeromagnetic survey is faster and is used for regional survey because it can cover large area in few hours, the ground magnetic survey is closer to the target than the airborne survey. Thus the magnetic anomaly measured on the ground will have a higher amplitude and shorter spatial wavelength than the anomaly at aircraft level.

It is imperative to carry out this research because dangers lie ahead if factories are built on buried fault or fractures. Generally, most of building failures happening today are people's ignorance about subsurface features. Some of these building collapses have been reported from the literatures and work of Akintorinwa *et al*., (2010), Fatoba *et al*., (2010), Akintorinwa and Abiola (2011), Egwuonwo (2012), Adagunodo *et al*., (2013a), Adagunodo *et al*., (2013b), and Adagunodo *et al* (2014). Therefore, it is necessary to carry out this pre-foundational geophysical survey which will reveal the geomagnetic basement pattern in the study area in order to give early warning about where to erect structures and what type of structures to erect at a particular place (either high-rise structures or bungalows).

Site Description:

The study area lies within latitude $08^0\ 13'\ 59.22''$ to $08^0\ 15'\ 0''$ North and longitude $004^0\ 17'\ 05.0''$ to longitude $004^0\ 19'\ 01.1''$ East. About four (4) factories have been built on this layout as at the time of this survey was carried out in which sawmill and sachet water factory was inclusive. The rate at which this study area develops necessitate this research in order to be able to elucidate the pattern of the subsurface with respect to construction purposes and possible zones to be explore for hydro-geologic prospects.

Geological settings:

The study area is underlain by Precambrian basement complex of Southwestern Nigeria which compose of 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.

Locally, Orile-Igbon is underlain by rocks of the Precambrian complex (figure 1) 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. The gneiss complex in the study area appears to be readily weathered and give rise to an undulating topography dipping in a N-S direction and cross cutting by numerous bands and lenses of pegmatites at several locations. They occur as granite gneisses and banded gneisses with coarse to medium grained texture but the main rock type in the study area is granite gneisses. This resembles the geological formation of Ogbomoso.

Theory Of Magnetic Methods:

The origin of the earth's magnetism is commonly believed to be the liquid outer core, which cools at the outside as a result of which the material becomes denser and sinks towards the inside of the outer core and new warm liquid matter rises to the outside, thus, convection currents are generated by liquid metallic matter which move through a weak cosmic magnetic field which subsequently generates induction currents (Nettleton, 1976). It is this induction current that generate the earth's magnetic field (Telford *et al*., 1976). Most rocks of the earth's crust contain crystals with magnetic minerals, thus most rocks have a certain amount of magnetism which usually has two components: induced by the magnetic field present while taken measurement, and remnant which formed during geologic history (Reijers, 1996).

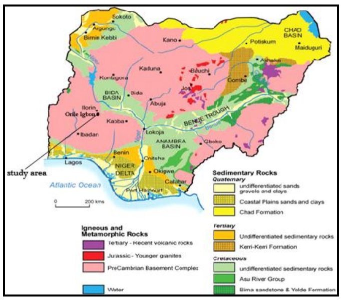

Fig. 1: Geological Map showing the study area (Macdonald *et al*, 2005).

The groundmagnetic study is used for detail mapping in order to understand the subsurface geology of an area. The technique requires measurements of the amplitude of magnetic components at discrete points along traverses distributed regularly throughout the survey area of interest. In groundmagnetic study, three components are measured which are horizontal, vertical and total components. The vertical components and the total components were mostly used in the past studies to delineate faults, fractures, depth to magnetic basement and other geological structures. In this study, total magnetic intensity is used to infer the possible geologic features in Orile Igbon, Oyo State, Nigeria.

The magnetic scalar potential due to continuous distribution of matters e.g. earth, may be calculated at an external point P (figure 2) (Telford *et al*, 1976; Parasnis, 1978). We may suppose that the material that fills a volume v has a continuous distribution of magnetic dipole moment per unit volume (m/v).

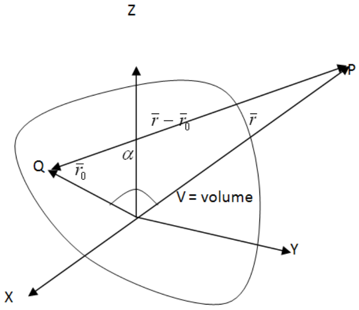

Fig. 2: Magnetic scalar potential.

Then: $\bar{J} = \bar{m}/v$ (1)

Where J = magnetic flux density

But the magnetic scalar potential A of a dipole at point P outside the volume V and whose moment is $\bar{m}$ given by;

$$A = \frac{m\cos\theta}{r^2} - \bar{m}.\bar{\nabla}\left(\frac{1}{r}\right) \tag{2}$$

Integrating Equation (2) gives,

$$A = -\int_V \bar{J}.\bar{\nabla}\frac{1}{|\bar{r}-\bar{r}_0|}dv \tag{3}$$

Note: dr_0 = distance

$$\therefore dr_0 \times dr_0 = area = d^3r_0$$

Volume = dv = d^3r_0

$$\therefore A = -\int_v \bar{J}.\bar{\nabla}\frac{1}{|\bar{r}-\bar{r}_0|}d^3r_0$$

$$where|\ \bar{r}-\bar{r}_0\ | = \sqrt{r^2 + r^{2_0} - 2rr_0\cos\theta} \tag{4}$$

The total magnetic filed intensity at point P outside the volume v is given as;

$$\bar{H} = -\bar{\nabla} A \tag{5}$$

Putting Equation (4) in (5) it gives:

$$\bar{H} = \bar{\nabla}\int_{v} \bar{J}.\bar{\nabla}\frac{1}{|\bar{r}-\bar{r}_0|}d^3 r_0 \tag{6}$$

Assuming the direction of magnetization is the same throughout the volume V and represented by r, then:

$$\bar{J}\cdot\nabla = J\frac{d}{dr} \tag{7}$$

Putting Equation (7) in (6), gives

$$\bar{H} = \bar{\nabla}\frac{d}{dr}\int_{v} J\frac{1}{|\bar{r}-\bar{r}_0|}d^3 r_0 \tag{8}$$

Gauss however, expresses the volume integral in terms of the surface integral given by;

$$\int_{V}\bar{\nabla}\cdot\bar{F}dv = \int_{S}\bar{F}.\hat{n}dA \tag{9}$$

Where A = surface area

$\hat{n}$ = unit outward normal vector on the surface S

F = a vector function which is analytic within and on a closed surface containing volume V.

Since dv = d^3r_0, ds = d^2r0

Equation (9) becomes

$$\int_{V}\bar{\nabla}.\bar{F}d^3 r_0 = \int_{S}\bar{F}.\hat{n}d^2 r_0 \tag{10}$$

If the point P is outside the volume V, it implies that surface S encloses no attractive mass, and then the right hand side of equation (10) is zero. Hence;

$$\int_{V}\bar{\nabla}.\bar{F}d^3 r_0 = 0 \tag{11}$$

By differentiating Equation (11), we have

$$\bar{\nabla}.\bar{F} = 0 \tag{12}$$

Where F is any function

Taking $\bar{H}$ as the function, then Equation (12) becomes;

$$\bar{\nabla}.\bar{H} = 0 \tag{13}$$

By putting Equation (5) in (13), we have;

$$i.e.\bar{\nabla}.\bar{\nabla}\cdot A = 0$$

$$\therefore \bar{\nabla}^2\cdot A = 0$$

$$or$$

$$\frac{\partial^2 A}{\partial x^2}+\frac{\partial^2 A}{\partial y^2}+\frac{\partial^2 A}{\partial z^2} = 0 \tag{14}$$

If P is enclosed within the volume V, and considering equation (4), the magnetic potential A becomes:

$$A = -\int_{V-V^1}\bar{J}\cdot\bar{\nabla}\cdot\frac{1}{|r^1-\bar{r}_0^1|}d^3 r_0 - \int_{V^1}\bar{J}.\bar{\nabla}\cdot\frac{1}{|\bar{r}-\bar{r}_0|}d^3 r_0 \tag{15}$$

The first term is nonsingular, therefore it is harmonic everywhere. J may be made constant by making r^1 small enough in the second term. Hence;

$$\Rightarrow \bar{\nabla}^2.A = -\int_{V^1}\bar{\nabla}\cdot J\cdot\bar{\nabla}\cdot\bar{\nabla}\frac{1}{|\bar{r}-\bar{r}_0|}d^3 r_0 \tag{16}$$

From Gauss theorem, equation (16) becomes

$$\overline{\nabla}.A = -\int_S \overline{\nabla}.\overline{J}.\hat{n}.\overline{\nabla}\frac{1}{|\overline{r}-\overline{r_0}|}d^2r_0 \tag{17}$$

$$\overline{\nabla}.A = -\overline{\nabla}.\overline{J}\int_S \frac{\partial}{dr^1}.\frac{1}{r^1}d^2r_0$$

$$= -\overline{\nabla}.\overline{J}\left[-\left(\frac{1}{r^1}\right)^2\right]\int_s \; d^2r_0$$

$$= -\overline{\nabla}.\overline{J}\left[-\left(\frac{1}{r^1}\right)^2\right]4\pi(r^{11})^2$$

$$= \overline{\nabla}.\overline{J}\,\frac{4\pi(r^1)^2}{(r^1)^2}$$

$$\therefore \overline{\nabla}.A = 4\pi\overline{\nabla}.\overline{J} \tag{18}$$

Equation (18) is the required potential equation within regions occupied by magnetic bodies and it is also known as Poisson’s equation.

Amplitude of the Analytic Signal’s Derivation:

The complex analytic signal for 2-D structure is;

A(x, z) = |A|exp(iΘ) (19)

Where |A| is known as the analytic signal and i is the imaginary path. |A| can also be expressed as;

$$|A| = \sqrt{\left(\frac{\partial T}{\partial x}\right)^2 + \left(\frac{\partial T}{\partial z}\right)^2} \tag{20}$$

T is the magnitude of the Total Magnetic Intensity (TMI).

Analytic signal can also be defined mathematically as;

$$A(x, y, z) = \left(\frac{\partial T}{\partial x}\hat{x} + \frac{\partial T}{\partial y}\hat{y} + i\frac{\partial T}{\partial z}\hat{z}\right) \tag{21}$$

Where $\hat{x}, \hat{y}, \hat{z}$ are unit vectors in the x, y, and z direction.

i is the imaginary number which can also be expressed as $\sqrt{-1}$.

$\sqrt{-1} \times \frac{\partial T}{\partial x}$ is the vertical component of analytic signal (22)

$\frac{\partial T}{\partial z} \times \frac{\partial T}{\partial y}$ is the horizontal component of analytic signal (23)

Recall that

$$\hat{x} = \frac{x}{\sqrt{x^2}} \tag{24}$$

$$\hat{x}^2 = \frac{x^2}{x^2} = 1 \tag{25}$$

$$\hat{y} = \frac{y}{\sqrt{y^2}} \tag{26}$$

$$\hat{y}^2 = \frac{y^2}{y^2} = 1 \tag{27}$$

$$\hat{z} = \frac{z}{\sqrt{z^2}} \tag{28}$$

$$\hat{z}^2 = \frac{z^2}{z^2} = 1 \tag{29}$$

Therefore, the modulus of A(x, y) can be written as;

$$|A(x, y, z)| = \sqrt{\left(\frac{\partial T}{\partial x}\hat{x}\right)^2 + \left(\frac{\partial T}{\partial y}\hat{y}\right)^2 + \left(\frac{\partial T}{\partial z}\hat{z}\right)^2} \tag{30}$$

By applying equation 25, 27 and 29, amplitude of the analytic signal can be written as;

$$|A(x, y, z)| = \sqrt{\left(\frac{\partial T}{\partial x}\right)^2 + \left(\frac{\partial T}{\partial y}\right)^2 + \left(\frac{\partial T}{\partial z}\right)^2} \tag{31}$$

The amplitude of the nth order derivative of Analytic signals is given as;

$$|A_n (x, y, z)| = \sqrt{\left(\frac{\partial Tn}{\partial x}\right)^2 + \left(\frac{\partial Tn}{\partial y}\right)^2 + \left(\frac{\partial Tn}{\partial z}\right)^2} \tag{32}$$

Amplitude of the analytic signal can be defined as square root of the sum of the vertical and two horizontal orthogonal derivatives of magnetic field.

The advantage of this method of magnetic data enhancement is that its amplitude function is always positive and does not need any assumption of the direction of body magnetization. The maxima of the analytic signal can be used to detect the structures responsible for the observed magnetic anomalies over the study area.

MATERIALS AND METHODS

Proton Precision Magnetometer model GSM-19T was used along eight (8) traverses in East-West and South-North directions to map the Industrial Layout Orile Igbon, Oyo State, Nigeria. The traverses length ranges from 80 m to 170 m with inter station spacing of 10 m. A base station was carefully selected at the beginning of a day's work and reoccupied after about every two hours. At this base station, the magnetic intensities are being measured at a stationary point in order to check for the 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).

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). Kriging Interpolation method has been adopted in this study. Kriging is a geostatistical gridding method that has proven useful and popular in many fields. Quantitative interpretation gave various depths to top of magnetic sources. The estimated magnetic depths to the basement along each traverse were presented in table 1.

RESULTS AND DISCUSSION

The analysis of ground magnetic survey was 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. the quantitative interpretation gave the overburden thickness to the top of the magnetic basement rock as varied between 6.0 and 33.5 m. Interpretation of ground magnetic data revealed that Industrial Layout Orile Igbon comprise of zones underlain with thin as well as thick overburden. It is therefore advisable that people should not ignorantly built factories making use of heavy machines where there is thick overburden as it might lead to subsidence or total collapse in the future. This could occur when the vibration of these heavy machines is transferred to the subsurface which might lead to ground motion which later has effect on the factory's foundation. The zones with magnetic lows (weak zones) could be explored for hydro-geologic prospects as water is also essential in industrial settings. However, the geomagnetic signature map (figure 5) revealed how competent and weak the subsurface are.

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

Magnetic Traverses:

Traverse 1:

The traverse covers a total length of 150 m (figure 3a) and trends in South to North direction. The traverse shows series of magnetic highs and lows with magnetic highs at A, B and C and magnetic lows at U, V and W. The magnetic highs at A, B and C are suspected to be due to near surface magnetic minerals such as crystalline rocks which could be igneous or metamorphic rocks. It may also due to intrusive igneous bodies concordantly intruding into the country rock (migmatite-gneiss). A, B and C are better for the construction of both high-rise building and low-rise building. However, the competent zones will be able to withstand any engineering activities in the study area. The magnetic lows at U, V and W are likely to be due to the presence of non-magnetic minerals such as fault, fracture, crack or contact between two rocks. These zones should not be totally condemned as regarding the engineering purposes. Administrative buildings (strictly bungalow) would be appropriate for constructions in these zones.

However, competent zones (area with magnetic highs) are the promising zones for engineering activities while weak zones (area with magnetic lows) are zones for constructing of low-rise buildings (e.g. administrative buildings) and region for hydro-geologic prospects.

Traverse 2:

The traverse covers a total length of 140 m (figure 3b) and trends in East to West direction. The traverse shows a magnetic high at A which is suspected to be an outcrop. The rocks beneath this traverse are suspected to be igneous or metamorphic rocks. This zone is regarded as the competent zone. Zone U shows a magnetic low which is suspected to be a contact between two rocks. Distance 68 m to 140 m from the starting point could be suspected to be an inflection point (contact between two rocks).

Traverse 3:

The traverse covers a total length of 150 m (figure 3c) and trends in South to North direction. The traverse shows series of magnetic highs and lows with magnetic highs at A, B, C and D and magnetic lows at U, V and W. The sharp amplitude at B is suspected to be an outcrop. The magnetic highs at A, B, C and D are suspected to be due to near surface magnetic minerals such as crystalline rocks (igneous or metamorphic). It may also be due to intrusive igneous bodies concordantly intruding into the country rock (migmatite-gneiss). These areas are competent zones where weak zones are marked with U, V, and W.

Traverse 4:

The traverse covers a total length of 170 m (figure 3d) and trends in East to West direction. The traverse shows series of magnetic highs and lows with magnetic highs at A, B and C and magnetic lows at U, V and W. The magnetic highs at A and B are suspected to be due to near surface magnetic minerals such as crystalline rocks (igneous or metamorphic) with a suspected outcrop at C. The presence of near-surface at A and B and an outcrop at C suspected the rocks present there to be igneous or metamorphic rocks. These zones are considered as competent zones where weak zones are point U, V, W. However, a vivid bow shape at point V is interpreted as fractured zone.

Traverse 5:

The traverse covers a total length of 80 m (figure 3e) and trends in South to North direction. The traverse shows a magnetic high at A which is suspected to be the presence of near surface magnetic minerals such as crystalline rocks (igneous or metamorphic rocks). This zone could be considered as fair for engineering purposes. Also, distance 32 m to 60 m from the starting point could be suspected to be an inflection point (contact between two rocks). When artificial basement is created beneath this region, it could be useful for engineering purpose. Magnetic low is present at U, this region should be considered as bad for engineering purposes because of the bow shape present there and a very low magnetization level at this region. However, point U could be considered as good for hydrogeologic purposes as groundwater is also essential at any standard industrial settings.

Traverse 6:

The traverse covers a total length of 80 m (figure 3f) and trends in South to North direction. The traverse shows series of magnetic highs and lows with magnetic highs at A and B and magnetic lows at U, V and W. The magnetic highs at A and B are suspected to be due to near surface magnetic minerals such as crystalline rocks which could be igneous or metamorphic rocks. These zones are competent for engineering purposes. Distance 0 m to 42 m from the starting point including the magnetic lows at U and V are suspected to be inflection points. This could be suspected to be contacts between rocks. The magnetic low present at W are suspected to be due to presence of non-magnetic minerals such as fault or contact between two rocks. These weak zones will be suitable for construction of administrative building (strictly bungalow).

Traverse 7:

The traverse covers a total length of 80 m (figure 3g) and trends in South to North direction. The traverse shows series of magnetic highs and lows with magnetic highs at A, B and C and magnetic lows at U and V. The magnetic highs at A and C are suspected to be an outcrop with the magnetic high at B which is suspected to be due to near surface magnetic minerals such as crystalline rocks. The rock types present beneath this traverse are suspected to be igneous or metamorphic rocks. These zones (A, B and C) are regarded as the competent zones. However, weak zones are present at U and V which are indicative of features like joints or rock contact.

Traverse 8:

The traverse covers a total length of 80 m (figure 3h) and trends in South to North direction. The traverse shows series of magnetic highs and lows with magnetic highs at A, B and C and magnetic lows at U and V. The magnetic highs at A and B are suspected to be due to near surface magnetic minerals such as crystalline rocks (igneous or metamorphic) with an outcrop at C; distance 44 m to 80 m along the traverse. These zones (A, B and C) are the competent zones while point U and V are considered as weak zones.

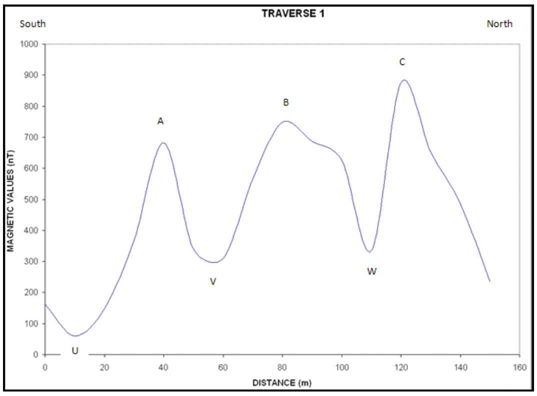

Fig. 3a: Magnetic profile along traverse 1.

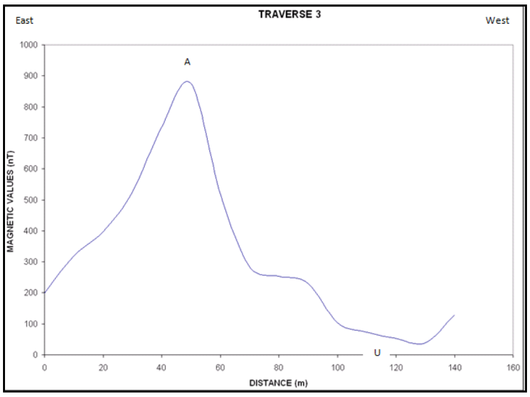

Fig. 3b: Magnetic profile along traverse 2.

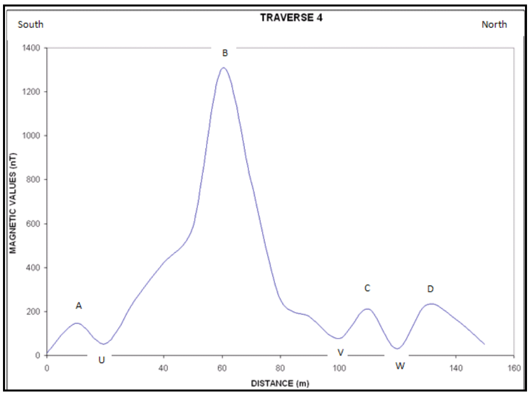

Fig. 3c: Magnetic profile along traverse 3.

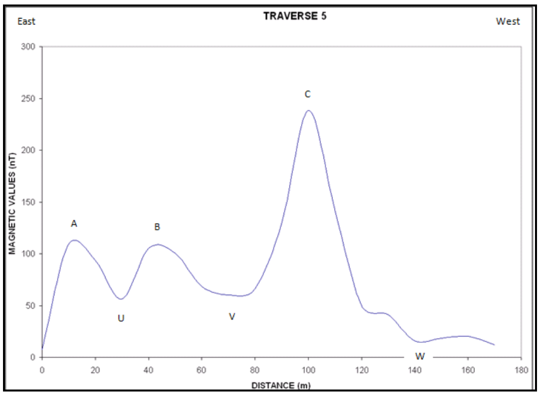

Fig. 3d: Magnetic profile along traverse 4.

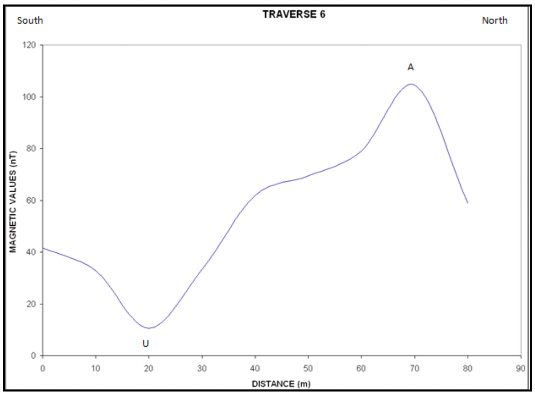

Fig. 3e: Magnetic profile along traverse 5.

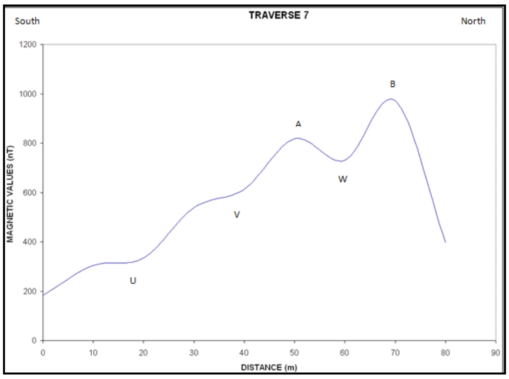

Fig. 3f: Magnetic profile along traverse 6.

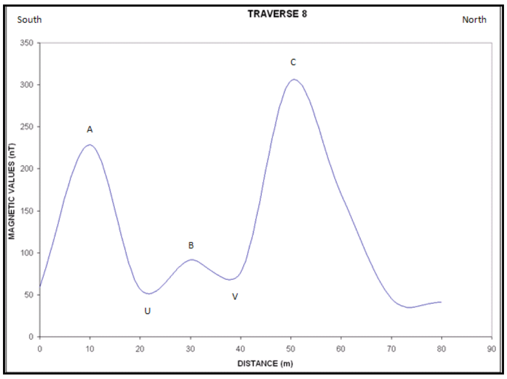

Fig. 3g: Magnetic profile along traverse 7.

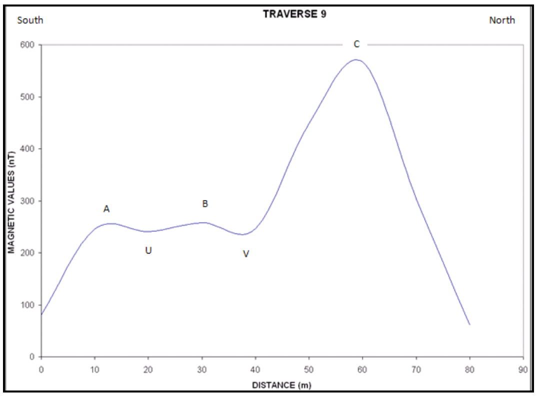

Fig. 3h: Magnetic profile along traverse 8.

Table 1: Depth estimates of ground magnetic traverses relative to the ground surface in Orile-Igbon.

Traverses	Depth to the magnetic sources (m)			
	A	B	C	D
Traverse 1	12.0	33.5	18.0	-
Traverse 2	28.0	-	-	-
Traverse 3	10.0	17.0	10.0	16.0
Traverse 4	17.0	20.0	17.0	-
Traverse 5	15.0	-	-	-
Traverse 6	8.0	9.0	-	-
Traverse 7	11.0	7.0	14.0	-
Traverse 8	6.0	8.0	22.5	-

Magnetic Contour Map:

The magnetic contour map is shown in figure 4. The contour map revealed the basement structure and shows the structural trend of the study area. Magnetic susceptibility ≥ 100 nT with closely packed contour lines are present towards the Eastern, Central, Northern, some parts of Northwestern, Western, some parts of Southwestern, some parts of Southeastern and Southern region of the study area. This is likely to be near surface materials such as crystalline rocks. These zones are competent zones for engineering activities.

Areas with low magnetic values below 100 nT which are marked with arrows characterized some part of the Northeastern, towards the extreme of the Northwestern, region between the Southwestern and Southern part and towards the extreme of the Southeastern part of the study area. These zones are weak zones. These zones should be use for construction of administrative buildings, warehouse buildings etc and perhaps explore for groundwater prospects especially for the industries that uses water for the production of their products.

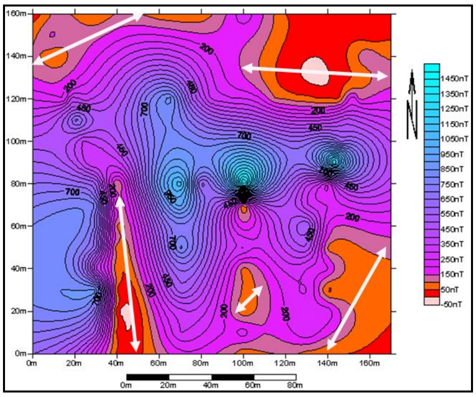

Fig. 4: The contoured map (2D plot).

The geomagnetic signature pattern:

The geomagnetic 3-D map indicates the levels or magnitude of the magnetic contrast as shown through the colour and the colour code bar (figure 5). The colour difference shows the same trend as that of the contour map and the magnetic values shows a significant magnetic contrast which defines the level of magnetization in the study area. The areas with high and higher magnetic values like the Eastern, Central, Northern, some parts of Northwestern, Western, some parts of Southwestern, some parts of Southeastern and Southern region of the study area are suspected to be the areas with near surface magnetic minerals such as crystalline rocks (igneous or metamorphic). These areas with high and higher magnetic values are competent zones. However, the areas with low magnetic values below 100 nT (some part of the Northeastern, towards the extreme of the Northwestern, region between the Southwestern and Southern part and towards the extreme of the Southeastern part of the study area) could be regarded as the areas underlain with non-magnetic minerals or areas with thick overburden. Generally, the overburden thickness in this study area ranges from 6.0 m to 33.5 m (table 1). This indicates that the subsurface ranges from zones of thin overburden (overburden ≤ 15 m) to thick overburden (overburden > 15 m) as reported by Adagunodo *et al*. (2014).

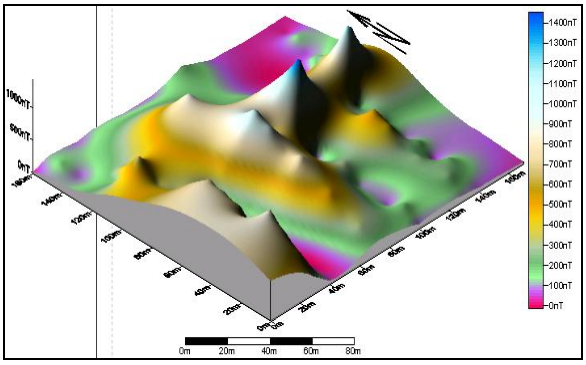

Fig. 5: The geomagnetic signature map.

Conclusion:

Ground magnetic geophysical survey that was done at industrial layout Orile Igbon was analyzed qualitatively and quantitatively. The study revealed materials with magnetic minerals like metamorphic and igneous rocks while in another areas revealed materials with non-magnetic minerals like faults, fractures, rock contacts and joints between two rocks along the traverses been investigated in the area. The subsurface has proved its inhomogeneity with series of high magnetic values which will serve as areas for engineering purposes and low magnetic values which will serve as areas for construction of low-rise buildings (administrative building and warehouses) or areas for hydrogeologic purposes. A multidimensional approach to the studies (that is the magnetic profiles, magnetic contoured map, geomagnetic pattern 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.

Interpretation of ground magnetic data revealed that Industrial Layout Orile Igbon comprise of zones underlain with thin as well as thick overburden. It is therefore advisable that people should not ignorantly built factories making use of heavy machines where there is thick overburden as it might lead to subsidence or total collapse in the future. However, weak zones could be explored further for hydrogeologic prospects apart from construction of administrative buildings and warehouses there.

It is recommended that the approach used in this work can also be adopted by other geophysicists researching especially into the subsurface features of a particular area. Other relevant geophysical techniques such as electrical resistivity technique (especially Vertical Electrical Sounding, Electrical Resistivity Tomography, and Dipole-dipole configuration) and seismic refraction technique could be employed in the study area in order to confirm the predictions.

REFERENCES

Adagunodo T.A., L.A. Sunmonu, O.P. Oladejo and I.A. Ojoawo, 2013a. Vertical Electrical Sounding to Determine Fracture Distribution at Adumasun Area, Oniye, Southwestern Nigeria. *IOSR Journal of Applied Geology and Geophysics*. 1(3): 10–22.

Adagunodo T.A., L.A. Sunmonu, O.P. Oladejo and E.R. Olafisoye 2013b. Groundmagnetic Investigation into Cause of the Subsidence in the Abandoned Local Government Secretariat, Ogbomoso, Nigeria. *ARPN Journal of Earth Sciences*. 2(3), 101–109.

Adagunodo T.A., L.A. Sunmonu and O.P. Oladejo 2014. Effect of Constructing High-Rise Buildings without a Geophysical Survey. *Nigerian Journal of Physics*. Special Edition, 91–100.

Ajibade A.C., M.A. Rahaman and A.E.O. Ogezi 1988. The Precambrian of Nigeria, a Geochronological Survey. *Publication of the Geological Survey of Nigeria*.

Akintorinwa, O.J. and O. Abiola, 2011. Subsoil evaluation for pre-foundation study using geophysical and geotechnical approach. *Journal of emerging trends I engineering and applied sciences*, 2(5): 858-863.

Akintorinwa, O.J., J.S. Ojo and M.O. Olorunfemi, 2010. Geophysical investigation of pavement failure in a basement complex terrain of southwestern Nigeria. *The Pacific Journal of Science and Technology,* 11(2): 649-663.

Barry S., 1999. The construction of buildings. Blackwell Science Ltd. Seventh edition, 1: 1-40.

Bonde, D.S., E.E. Udensi and M. Momoh, 2014. Modeling of magnetic anomaly zones in Sokoto Basin, Nigeria. *IOSR Journal of Applied Geology and Geophysics,* 2(1): 19-25.

Cooper, G.R.J., 2000. Signproc version 1.56. Processing and Interpretation Software for Magnetic data. School of Geosciences, University of the Witwatersrand, Johannesburg, South Africa.

Corell, L. and V.J.S. Grouch, 1985. Mapping basement zones from magnetic data in the san juan basin; New Mexico: presented at the 52nd Annual International Meeting, *Society for exploration geophysicists,* Dallas U.S.A.

Dobrin, M.B., 1976. Introduction to Geophysical Prospecting. Mc-Graw Hill Books Co (3rd Ed.) N.Y. Pp. 630.

Egwuonwo, G.N., 2012. Application of geophysical imaging in investigation of structural failure of buildings; Case study of three building sites in Zaria area, Northwestern Nigeria. *The Pacific Journal of Science and Technology,* 13(1): 580-589.

Falconer, B.E., 1911. The Geology and Geography of Northern Nigeria. *Macmillan Publishers, London*.

Fatoba, J.O., J.O. Alo and A.A. Fakeye, 2010. Geoelectric imaging for foundation failure investigation at Olabisi Onabanjo University mini campus, Ago Iwoye, Southwestern Nigeria. *Journal of Applied Sciences Research,* 6(12): 2192-2198.

Kearey, P., M. Brooks and I. Hill, 2004. An Introduction to Geophysical Exploration. Third Edition, *Blackwell Pub*.

McDonald A., J. Davies, R. Calow and J. Chilton, 2005. Developing Groundwater Resources. A guide to rural water supply. IIDG Publishing.

Nabighian, M.N., 1972. The analytic signal of two-dimensional magnetic bodies with polygonal cross section: its properties and use for automated anomaly interpretation. *Geophysics*, 37: 507-517.

Nettleton L.L., 1976. Gravity and Magnetics in oil prospecting. *McGraw-Hill*, New York, 394-413.

Okwueze, E., 2000. Shell Intensive Training Program, *Geophysics Lectures*.

Parasnis, D.S., 1978. Principle of Applied Geophysics, 3rd Ed. *Chapman and Hall*, New York, USA.

Reeves, C., 2005. Aeromagnetic Surveys; Principles, Practice and Interpretation, Training Programme, *NGSA, Nigeria*.

Reijers, T.J.A., 1996. Selected chapters in geology. *Shell Petrol. Dev. Company, Warri, Nigeria*. 87-90.

Surfer 8, 2002. Version 8.01. Surface mapping system. Golden Software Inc, Colorado.

Telford W.M., L.P. Geldart, R.E. Sheriff and D.A. Keys, 1976. Applied Geophysics, Cambridge Univ. Press, 770.

Trusswell, J.F. and R.N. Cope, 1963. The Geology of Part of Nigeria and Zaria province. *Northern Nigeria Bull. Geological Surv Nigeria*, 29-42.