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Geophysical Investigations of Groundwater Potential of Ara, Ilorin Kwara State.

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Abstract

Geophysical investigation of ground water potential of Ara in Ilorin, north central Nigeria has been conducted using ground magnetic method with the objective of delineating structures which are responsible for groundwater. Total field magnetic anomaly was obtained in 9 parallel profiles along the E-W direction to produce a magnetic map of the area. The total field was separated into residual and regional fields. Interpretation of the residual magnetic anomaly revealed regions of positive and negative anomalies with a peak value of 16 nT and -34 nT respectively. Quantitative interpretation using half-width method shows that the depth to magnetic basement ranges from 2.01 to 41.2m. The result also delineated geological features which are regarded as ground water signatures in the study area.

Keywords: *Magnetic anomaly, Ground water, Geological features.*

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 and analysis of these measurements can reveal how the physical properties of the Earth's interior vary vertically and laterally (Philip et al. 2002). There are series of available methods in geophysical investigation of groundwater, among which are seismic, electrical, electromagnetic and magnetic methods. These methods have been used extensively in the detection and mapping of subsurface boundaries, delineating of geological structures, and in the location of water tables and site investigation related to groundwater explorations (Telford et al. 1990).

The importance of water cannot be over emphasized; humanity can survive longer without food than without water (Reinhard 2006). There are mainly three sources of water, which include atmospheric water (mainly from precipitation as rainfall, snow, sleet, hails etc.), surface water (lakes, rivers, seas, oceans) and groundwater (Reinhard, 2006). Of the three, ground water is the most reliable. Rain water is considered insufficient because it is seasonal while surface water is mostly vulnerable to contamination, industrial pollution and other complications (Cristina, 2012). Therefore, a geophysical investigation of groundwater potential of Ara in Ilorin has been made in this work using magnetic method.

Studies have showed that groundwater could be explored using magnetic surveying method (Folami, 1992; Al-Garni et al., 2005; Hassanein et al., 2007; Al-Garni, 2009; Alagbe et al., 2010 Adelusi et al., 2013). Al-Garni (2009) carried out a magnetic investigation for groundwater in a complex subsurface terrain. The result of the magnetic survey delineated the basement structures which control the groundwater flow. He also showed that depth to the magnetic basement varies between 26 and 110m. Alagbe et al. (2010) studied the groundwater accumulation of Oke-Ogba area using magnetic methods. The interpretation of the magnetic intensity profiles revealed a network of geological features such as faults, fractures and joints which are prominent hydro-geologic indicators for groundwater development in the area. They also obtained a variation of overburdened thickness to the top of the magnetic basement ranging between 3.0 and 21.0m. Adelusi et al. (2013) interpreted aeromagnetic anomalies of Iwaraja and the result suggested varying magnetic intensities from different sources. Quantitative interpretation of the magnetic anomaly using half slope and automated Euler deconvolution techniques yielded information on depth to basement, ranging between 6 and 38 m. Lawal et al. (2012) also carried out a resistivity survey within Ara area and their result reveals three geo-electric layers which include the top lateritic region with resistivity ranging from 200-1000 Ω m and thickness of 4-8m. The weathered basement has a resistivity ranging from 20-400 Ω m with thickness of 10-50m while the fresh basement has a resistivity greater than 800 Ω m.

Location and Geology of the Study Area

Ara area lies within the latitude 08°44.1'N and 08°44.3'N and longitude 04°45.1'E and 04°45.4'E in Ilorin, North-central Nigeria. It is located in the Northern part of Ilorin with rugged troughs and crest which are due to erosions in the area. It has a distinct climate condition of wet and dry seasons: a dry season which usually lasts from October to February and a rainy season which lasts from March to September. Temperature variation is between 25°C around November/December and 35°C in February/March. Geologically, the area lies within the crystalline basement rocks of north central Nigeria. Fig 1 shows rocks

of Nigeria mainly the migmatite-gneiss complex, which are the oldest basement rocks believed to have been of sedimentary origin but which have profoundly undergone many processes of metamorphism and magmatic intrusions. The rock types are mainly banded gneiss, gneisses, quartzite, calc silicates rocks, biotite hornblende schist and amphibolites rocks, Older granites; and Unmetamorphosed dolerite dykes, which comprises of pegmatite, quartz veins and dolerite dykes (Rahaman, 1973; Nwankwo, 2011), sheared gneiss and augen gneiss intruded by granodiorites and granites. It also contains both primary and secondary laterites. The study area falls within the category of hard rock terrain where aquifers possess distinct features from the porous to the permeability and are products of secondary processes. This type of rock deposits are weak and therefore readily yield to agents of erosion (Jimoh, 1997). The structural fabric is mainly a NW-SE trending fracture system dominated by a Southerly plunging (6° - 10°) anticlinorium with a gentle westerly dipping limb depicted (Olasehinde, 1999; Nwankwo, 2011). The topography of the area is relatively flat with little undulation and has values ranging between 270m to 420 m (Fig. 2)

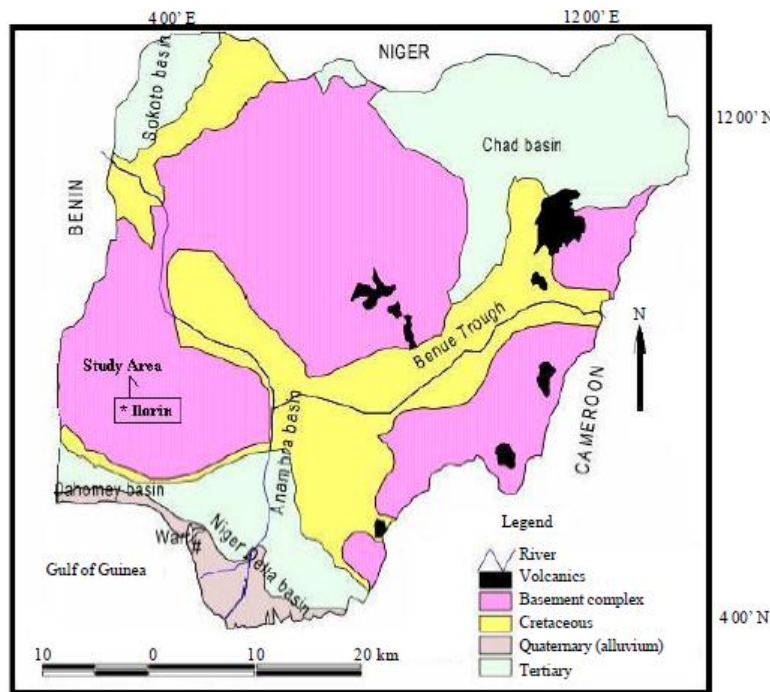


Fig. 1: Geologic Map of Nigeria showing the study area.

(m)

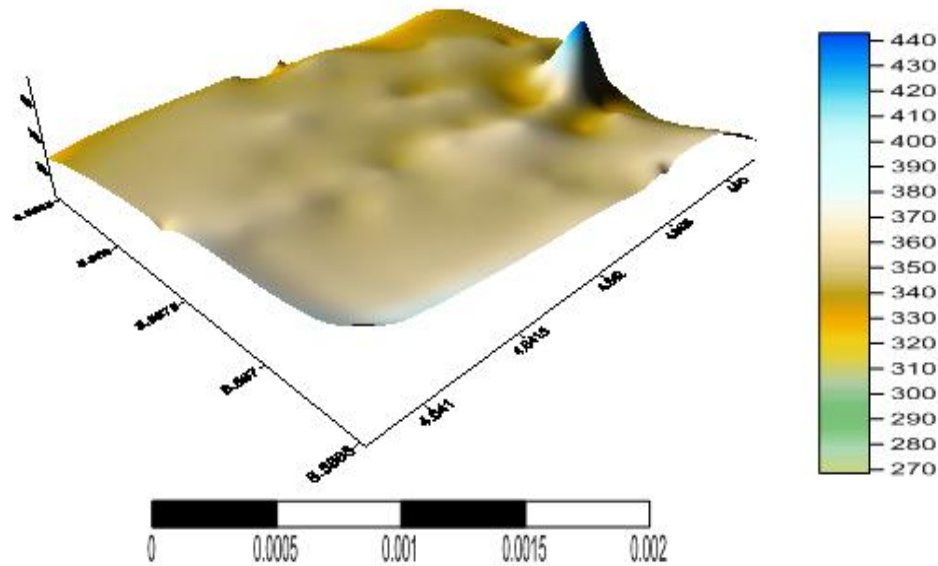


Fig. 2: Topography map of the study area in 3D

Basic Equations

Analytic signal method developed by (Nabighian, 1972, 1984) shows that the amplitude (absolute value) of the 3-D analytic signal at location (x,y) can be easily derived from the three orthogonal gradients of the total magnetic field using the expression:

$$|A(x, y)| = \sqrt{\left[\frac{dT}{dx}\right]^2 + \left[\frac{dT}{dy}\right]^2 + \left[\frac{dT}{dz}\right]^2} \quad 1$$

$[A(x, y)]$ = the amplitude of the analytic signal at (x,y)

T = is the observed magnetic field at (x,y).

The amplitude of the analytic signal is affected by the vector components of the model and the shape of the analytic signal is dependent only on depth. Roest et al. (1992) calculated the shape of the analytic signal over several simple bodies as:

$$[A(x, y)] = \alpha \frac{1}{x^2 + h^2} \quad 2$$

h = depth to the top the contact

x = width of the magnetic source

α = Amplitude factor

The depth to the magnetic basement can be calculated from various model shapes on the magnetic profiles.

Materials and Methods

Ground magnetic measurements were taken using a high resolution proton precision geometric magnetometer, model G-856. The magnetometer produces an absolute and relatively high resolution of the field and displays measurement in digital lighted readout. The data acquisition technique requires measurements of the amplitude of the Total magnetic intensities at discrete points along traverses distributed at equal intervals throughout the study area. Nine parallel magnetic profiles with a spacing interval of 10m and inter profile spacing of about 10 to 90m were conducted along the E-W direction. A base station was carefully selected and established near the study area where the magnetometer was continuously returned at every profile reading to correct for diurnal variations of earth magnetic field and other sources of external interferences. The magnetic readings were also corrected for non-mean, near surface effect, and drift correction. No magnetic storm was recorded during the period of the field work. The noises were removed by filtering the data using three-point moving average filter (Breiner, 1973). The magnetic field data was eventually presented as profiles by plotting the relative total magnetic field data against station separations for each profile (Fig.3) which was later contoured into total magnetic field map shown in Fig (4). This total magnetic field value was separated into residual and regional fields using least square polynomial method (Nwankwo 2006), and the residual field was interpreted quantitatively and qualitatively.

Results and Discussions

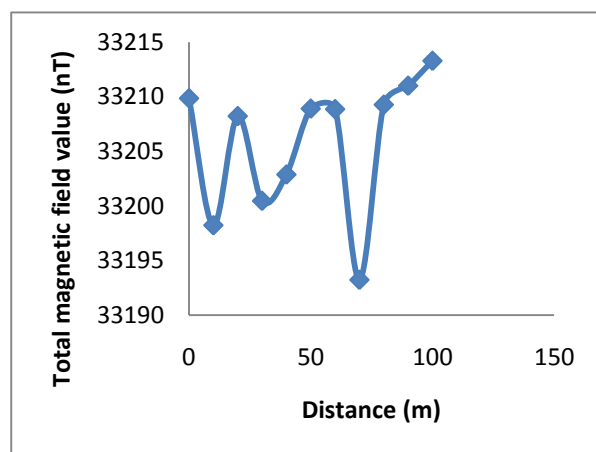
Ara area has been investigated and results obtained were discussed quantitatively and qualitatively. The quantitative interpretation involves estimation of the depth to the top of the magnetic basement. The result obtained from the analysis of residual anomaly using analytic signal method reveals maximum amplitude along the profiles and depth to the top of the magnetic basement were estimated with values ranging between 2.06 and 41.2m. This is shown in Table (1).

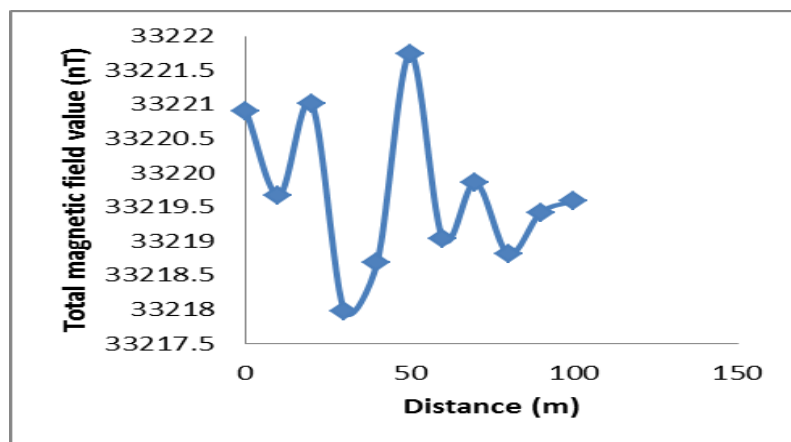
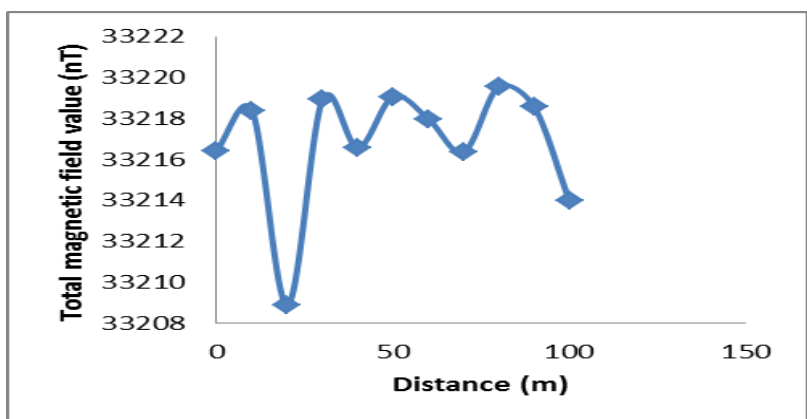
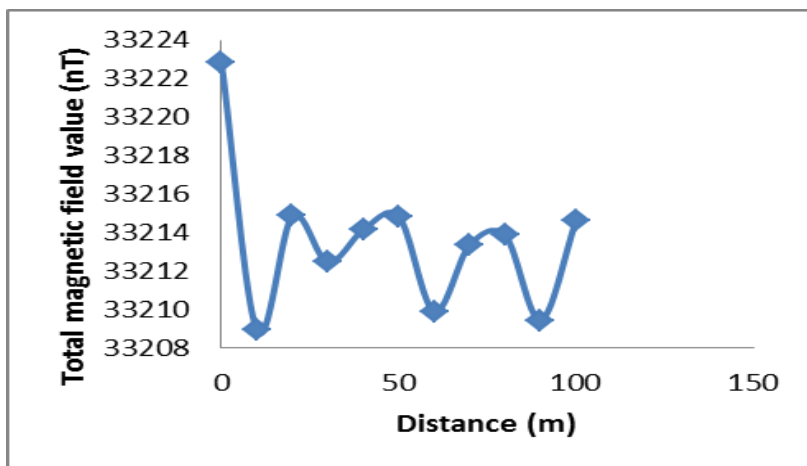
From the result of the qualitative interpretation, the residual map (Fig. 5), shows a great similarity to the Total Magnetic Field Map (Fig. 4). Magnetic anomalies in the residual map appear as elongated, circular or semi-circular in shapes. These shapes suggest that most of the basement rocks in the study area are either outcropping or extend to shallow depths. Magnetic anomalies discontinuities observed connecting zones of gradient characterized by changes in the amplitude are also noticeable in the study area. These discontinuities are a suggestion of fault and joint affecting the basement. Positive and Negative anomalies also dominate the study area. The negative anomalies which trend linearly in the NW-SE direction cut across the study area with a maximum value of (-34 nT) due to

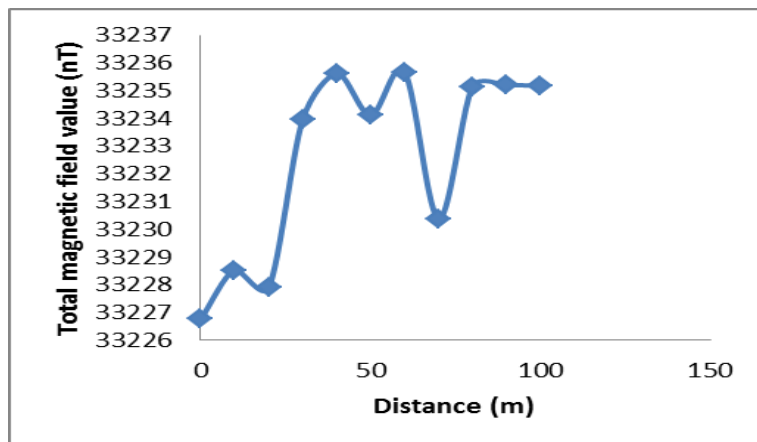
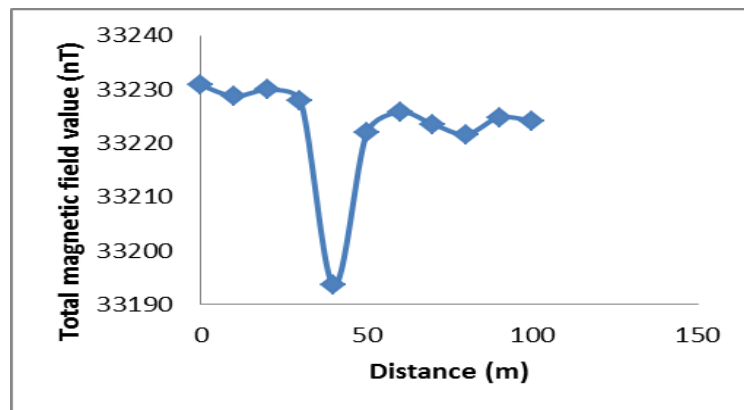
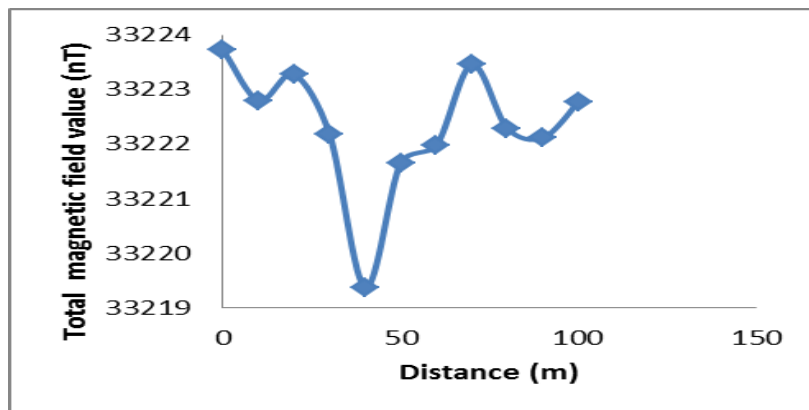
their low magnetic content. These anomalies reflect the down-faulted blocks of the basement complex that may possibly represent fractures which control ground water potential of the area. Also, positive anomalies can be observed in northern and central parts of the area with maximum amplitude of (16 nT). These anomalies are highly magnetic due to their high magnetite content and these are indications of hidden ores and undifferentiated basement rock. These geological structures delineated serve as potential hosts for groundwater in the area.

Profile	DEPTH TO MAGNETIC BASEMENT			
	A (m)	B (m)	C (m)	D (m)
1	20.6	16.8	24.7	-
2	20.6	4.12	24.7	-
3	41.2	28.8	2.06	-
4	32.9	20.6	20.6	-
5	12.4	16.5	16.5	12.4
6	2.06	41.2	2.06	-
7	12.4	24.7	-	-
8	28.8	16.5	24.7	-
9	20.6	16.5	24.7	-

Table 1: Depth Estimate of the anomaly profile using half width Depth Interpretation method.







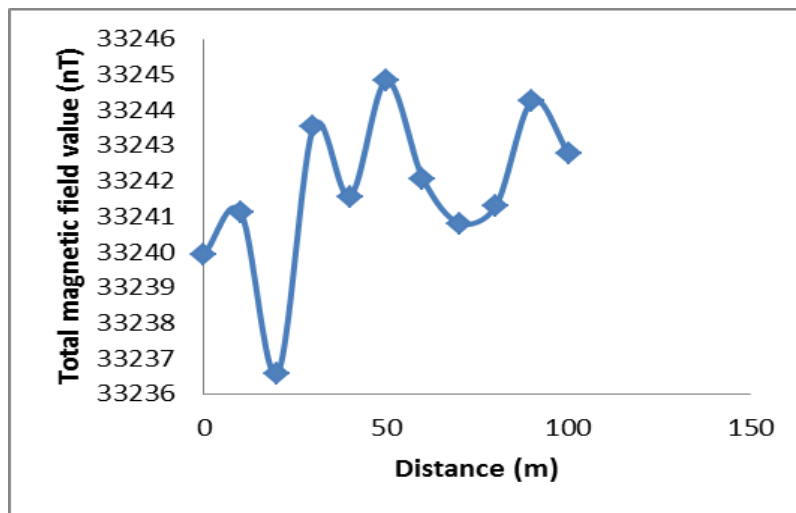
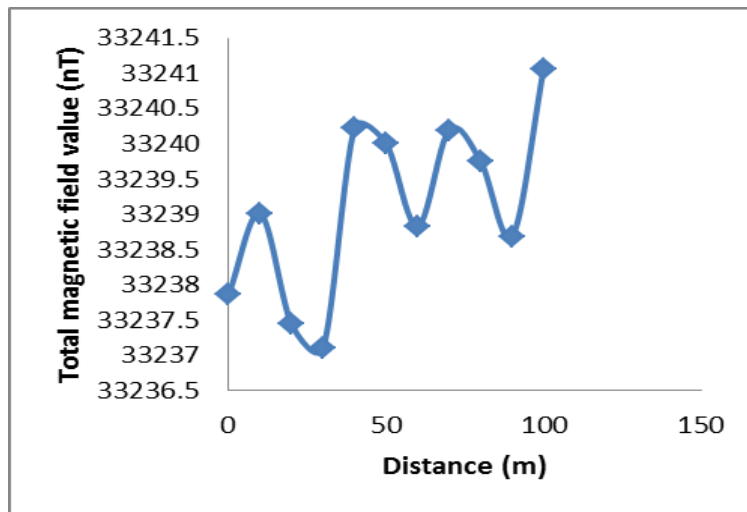


Fig. 3: Relative total magnetic field values against station separations of all the profiles.

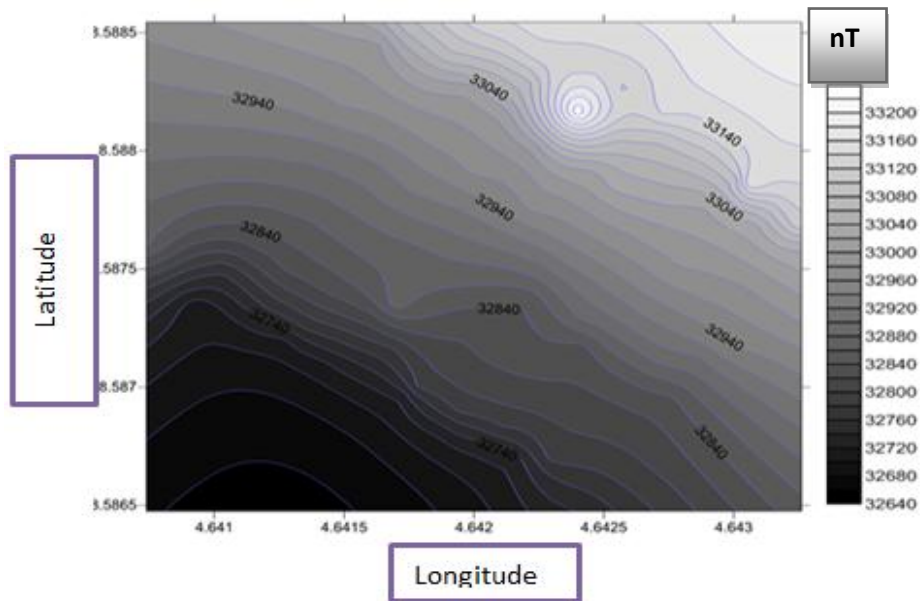


Fig. 4: Contoured of Total magnetic field map.

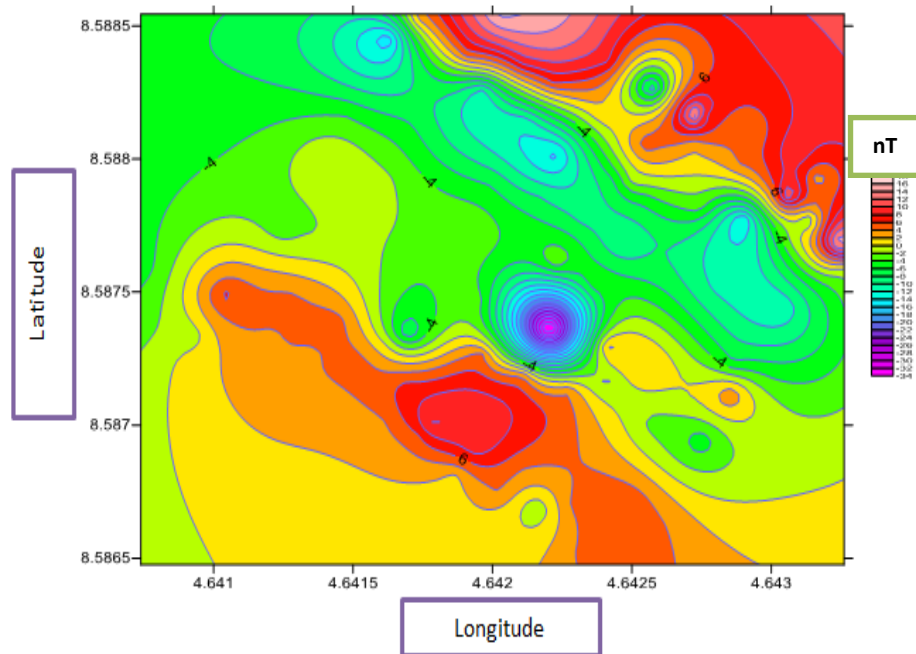


Fig. 5: Contour of Residual anomaly map of study area.

Conclusions

The geophysical investigation on ground water potential of Ara area in Ilorin, basement complex revealed a network of geologic features which serve as potential host for groundwater on the residual anomaly map and undifferentiated basement rock at some other locations. The estimated depth to top of magnetic basement which ranges between 2.06m and 41.2m agrees with the value previously established in the area using electrical resistivity method. The study has shown that geological features rather than overburdened thickness have more dominant hydrogeological indicators for delineation of groundwater potential in the area.

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