SUBSURFACE IMAGING OF SOME PARTS OF AGO-IWOYE USING GEOPHYSICAL MAGNETIC METHOD.

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ABSTRACT

Near Surface characterization of some parts of Ago-Iwoye was carried out using magnetic method with the aim of evaluating the magnetic depth variation to basement rock and geologic structures and lineament. Magnetic data survey was carried using a Magnetometer on a lateral and horizontal spacing, starting at a base point and intervals of 10m. The coordinate of each point was obtained with the aid of a digital GPS. The acquired data was processed using OASIS Montaj with view to obtain the Total Magnetics Intensity (TMI), Reduction to Magnetic Equator (RTE), Source Parameter Imaging (SPI), Analytic Signal (AS) and Total Horizontal Derivative (THDR). The result shows that the amplitude of total magnetic strength obtained ranges from - 541.3 nT to 493.4 nT depicting low and high magnetic points respectively. The RTE Map corroborated that the amplitude of the magnetic intensity ranges from -353.2 nT to 488.3 nT describing the study area with varying magnetic intensity. This shows that geologic lineament and structures were delineated within the area which trends NW-SE, NE-SW and EW-NS. The imaging obtained from SPI showed clear variation to the magnetics basement within the area. These areas are associated with low magnetic and high magnetics basement. Different fault lines were unraveled in the study area which are capable to be groundwater recharge channel thereby producing high yield of groundwater. The study area is found to be rich in rock minerals for future exploitation. The study suggests further investigation in the area to obtain the bulk density of the rock minerals. Also this act will assist further elucidation of the geotechnical properties of the area for future engineering construction. However, the study has established the basic information about the area for the miners, building engineers and academic environment.

Keywords: Subsurface, Magnetic, Discontinuities, Groundwater, Imaging.

INTRODUCTION

The magnetic method is undoubtedly the most flexible of all the geophysical methods (Dobrin and Savit 1988; Winslow, *et al*., 2012) due to its fitness to both shallow and deep seated targets. It is perhaps the oldest of geophysical exploration techniques bloomed after the World War II. The magnetic method involves the measurement of variations in total magnetic field of the earth, caused by local differences in the magnetization of the subsurface rocks and soils (Adepelumi, et al. 2013). It has been proven to be relatively cheap for both local and regional studies such as hydrocarbon and mineral exploitation (Urban et al. 2012; Olorunfemi and Oni (2019). These techniques include delineation of geological structures, magnetic lineaments, igneous intrusions and estimation of the magnetic sources. The case of shallow subsurface investigations are focused towards the characterization of over-burden above the bedrock, defining the bedrock topography, determination of the presence of discontinuities and delineating buried metallic objects (Urban et al. 2012). These features can also help to determine the competence of the soil towards engineering structures. However, the main application of the magnetic method in groundwater investigation had been in defining large-scale basin structures and regional aquifers. Olorunfemi et al. (1986) and Olorunfemi and Oni (2019) used the method to map bedrock topography, basement faults/fractures and the location of crustal weakness that may represent preferential fluid flow paths. Its application in mapping unconsolidated sequence is limited as magnetic signatures for different sediment horizons are often weak. (Slater, 2007).

The study area (Ago – Iwoye) falls within the Basement Complex of South Western

Nigeria. It forms part of the Pan African mobile belt which lies to the East of West African Craton. The major rock types expected from the area according to the literatures include granite gneiss, granite, pegmatite and undifferentiated (Colombo, *et al.*, 2010). Bayewu et al 2017 affirmed that and these rocks have been intruded by quartz veins and pegmatite veins. Mineralogically, it consists of quartz, plagioclase, feldspar, biotite and hornblende which are metamorphic with varying degree of weathering. The degree of discontinuities within these rocks need to be evaluated so as to determine the possible mineral deposits. The study aimed in examining the subsurface characteristics of the basement rocks in Ago-Iwoye in order to delineate and characterize the discontinuities inform of faults line, fracture and dykes. The study tends to provide basic information about the near surface rocks in the area which will assist researchers, engineers and miners to plan or conduct further studies.

LOCATION AND GEOLOGICAL SETTINGS OF THE AREA

Ago-Iwoye being the study area lies between longitude 3° 54' E to 4° 00' E and latitude 6° 55'N to 7° 00' N. The town is well accessible by networks of major and minor roads by the neighboring cities such as Ijebu Igbo, Ibadan, Ijebu Ode, Isara and Illishan. Many untarred roads and foot paths linking to this town as reported by Akintola, *et al.,* 2012. The town is situated within the tropical rain forest region of West Africa with the climate characterized by alternating dry and wet seasons with heavy rainfall, high temperature and humidity in the year. According to Onakomaiya *et al*., 1992, the wet season spans from March to October and peaks in June/July while the dry season spans from November to February. The mean annual rainfall ranges from 100 to 1500 mm with average rainfall of about 100 mm. There are lots of vegetation covers such as trees, shrubs and grasses. The temperature of the area ranges from 18 to 34 °C. (Bayewu *et al.*, 2017). Geologically, the study area is made up of primarily metamorphic rock belonging to Migmatite Gneiss Complex. The major rock types found in this area are; pegmatite, granite gneiss, and banded gneiss manifesting along the NNW to SSE trend. The minerals obtainable in the banded gneiss are mainly felsic and mafic minerals which are distinctly segregated into alternating bands of light and dark coloured minerals. The gneisses comprise of biotite-hornblende granite and quartzite schist. The quartzite schists are composed mostly of quartz with some mica and/or tourmaline. (Stephen, *et al*., 2018).

However, the entire Ago - Iwoye Township is underlain by pink pegmatite which range texturally, from medium to coarse grained materials. Mineralogical, feldspar and quartz are the most abundant minerals while muscovite and tourmaline occurs as accessory mineral.

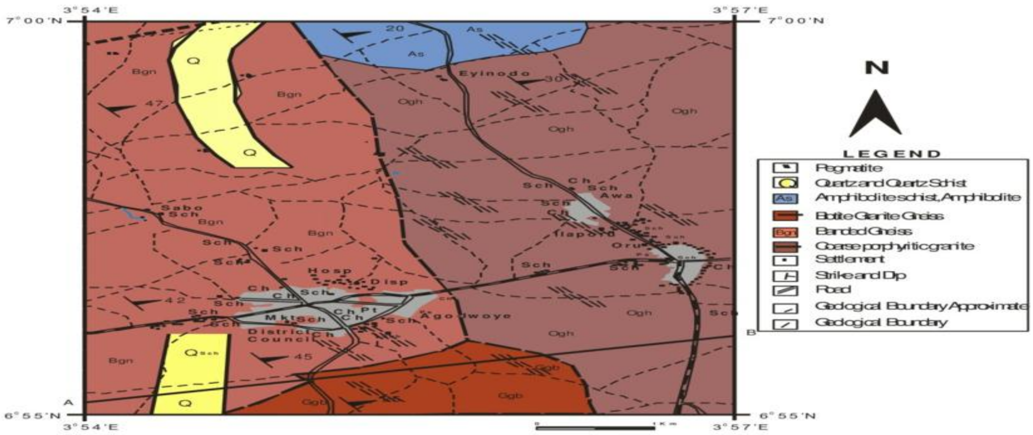

Figure 1: Geological Map of Ago-Iwoye area (Akintola, *et al.*, 2012)

MATERIALS AND METHODS Data Acquisition

The magnetic data used for this study was acquired using a Scintrex Magnetometer with other accessories on a lateral and horizontal spacing. The acquisition was designed to commence from a chosen base point and readings were taken at horizontal spacing interval of 10m. The magnetometer has an inbuilt compass which enable the easy identification of North pole/direction at each instant reading. The magnetic sensor was made to be accurately placed during the data acquisition procedure. Metallic objects and magnetic conducting substance were kept away from the data acquisition area in order to minimize the error in the data. Other components of data acquisition device include sensors, signal conditioning circuitry, analog to signal converters, etc. The coordinate of each point was obtained with the aid of a digital GPS. The acquired magnetic data are obtained using both absolute and relative measurements. Absolute measurements give the total value of the earth's magnetic field at a fixed point while relative measurements provide the change in the magnetic field at a location compared to a base station.

Data Processing

The processing of the acquired magnetic data is a crucial phase in the search and understanding the deposits and anomaly within the subsurface. The process includes the transforming of acquired data obtained during the data acquisition into digitalized mode inform of plots or maps. The maps and plots can be interpreted as anomaly inform of lithologic contacts, mapping salt domes in weakly magnetic sediments. The magnetic processing in this study was done using the Geosoft software, Oasis Montaj™ v.6.4.2 for the qualitative analysis in order to obtain the total magnetic intensity, residual magnetic anomalies, regional magnetic intensity, detection of rock contact and geometries on the analytical signal map with their tilt derivatives. The quantitative interpretation which involves 2D magnetic modeling of the profiles in the study area, was also carried out for the estimation of depths to magnetic sources.

Reduction to the equator (RTE) is part of the enhancement techniques done to the acquired magnetic data so as to differentiate between low and high magnetic latitudes. This is because magnetic anomalies are usually displaced from their causative sources, therefore, reduction to the equator is employed in low magnetic latitudes ($I = -10.2°$) (Hogg 2004).

This is because it makes the magnetic field of the earth and magnetization of the magnetic sources to appear horizontal (as in the magnetic equator), likewise centers the peaks of the magnetic anomalies over their sources thereby removing the asymmetry of the magnetic anomaly due to non-zero magnetic inclination ((Dobrin and Savit, 1988).

$$g' = -\mu T(0) - \frac{1}{2\pi}\iint T(\rho,\omega)\Omega_3(\omega)\frac{d\rho}{\rho}d\omega \quad (1)$$

Provided that the polar coordinate satisfy equation 2

$$\Omega_3(\omega) = 2\sum_{i=1}^{\infty}(-\eta)^l\, k(k+\mu)coskω \quad (2)$$

This procedure helps us in making the data easier when locating the target location or point of magnetic source (Christensen and Dranfield, 2002). Likewise, Total Horizontal Derivative (THD) were obtained from the acquired data. The derivatives (being a magnetic vector data) give further information as regards the variation direction of the total magnetic field (Phillips 2002). It is the derivative products which unravel the pattern of discontinuities and texture of anomaly. Therefore, it is useful in mapping linear features such as fault zones or dykes (Christensen and Dranfield, 2002). If $F(x, y)$ is the magnetic field, then the horizontal gradient magnitude THD(x, y) is represented as the Pythagorean sum of the gradients in orthogonal directions (Phillips, 2000).

$$THD(x,y) = \sqrt{\left(\frac{dF}{dx}\right)^2 + \left(\frac{dF}{dy}\right)^2} \quad (3)$$

The data processing involves the ability to infer and deduce significant interpretations and analysis from the acquired data. However, for the purpose of this study, the acquired data was filtered using the fast Fourier transform (equations 4 – 8), conversion of data from one form to another by reducing the data to magnetic equator (RTE) and producing residual magnetic intensity map. The reduction process is necessary because we are dealing with shallow source depths and the rock types available in the area has a relatively large contrasts in magnetization as obtained in the literature. The asymmetric and lateral shift of measured magnetic total field was corrected by applying RTE procedures via equations 1 and 2. The rate of change of magnetic field spatially in vertical and horizontal directions is quantified with their derivatives by enhancing local anomalies obscured by broader regional trends. THDR is related to vertical derivative (VDR) by mathematical expression in equation (3) and its map delineated the presence of contacts, faults and other lateral structures (Christensen and Dranfield, 2002; Bayewu et al., 2017).

$$Re(k) = \sum_{x=0}^{N-1} f(x)\cos\left(\frac{2\pi xk}{N}\right) \quad (4)$$

$$lm(k) = \sum_{x=0}^{N-1} f(x)\sin\left(\frac{2\pi xk}{N}\right) \quad (5)$$

In general,

$$Re(k) = \sum_{x=0}^{N-1} f(x)\exp\left(\frac{2\pi xk}{N}\right); 0 \leq \frac{N}{2} \quad (6)$$

$Re(k)$ and $lm(k)$ are real and imaginary coefficients of the data set that are evenly spaced and acquired in orderly manner. f(x) is the measured values as a function of distance along the profile line (Phillips, 2002; Christensen and Dranfield, 2002)

$$|F(k)| = \sqrt{(Re\,F(k))^2 + (ilm\,F(k)^2)} \quad (7)$$

$$|F(k)|^2 = (Re\,F(k))^2 + (ilmF(k))^2 \quad (8)$$

RESULTS AND DISCUSSION

The results of the processed acquired magnetics data obtained in the study area are presented as maps and imaging representation as depicted in Figures 2 - 4. The maps obtained from the processed data are; Total Magnetics Intensity (TMI), Reduction to Magnetic Equator (RTE), Source Parameter Imaging (SPI), Analytic Signal (AS) and Total Horizontal Derivative (THDR).

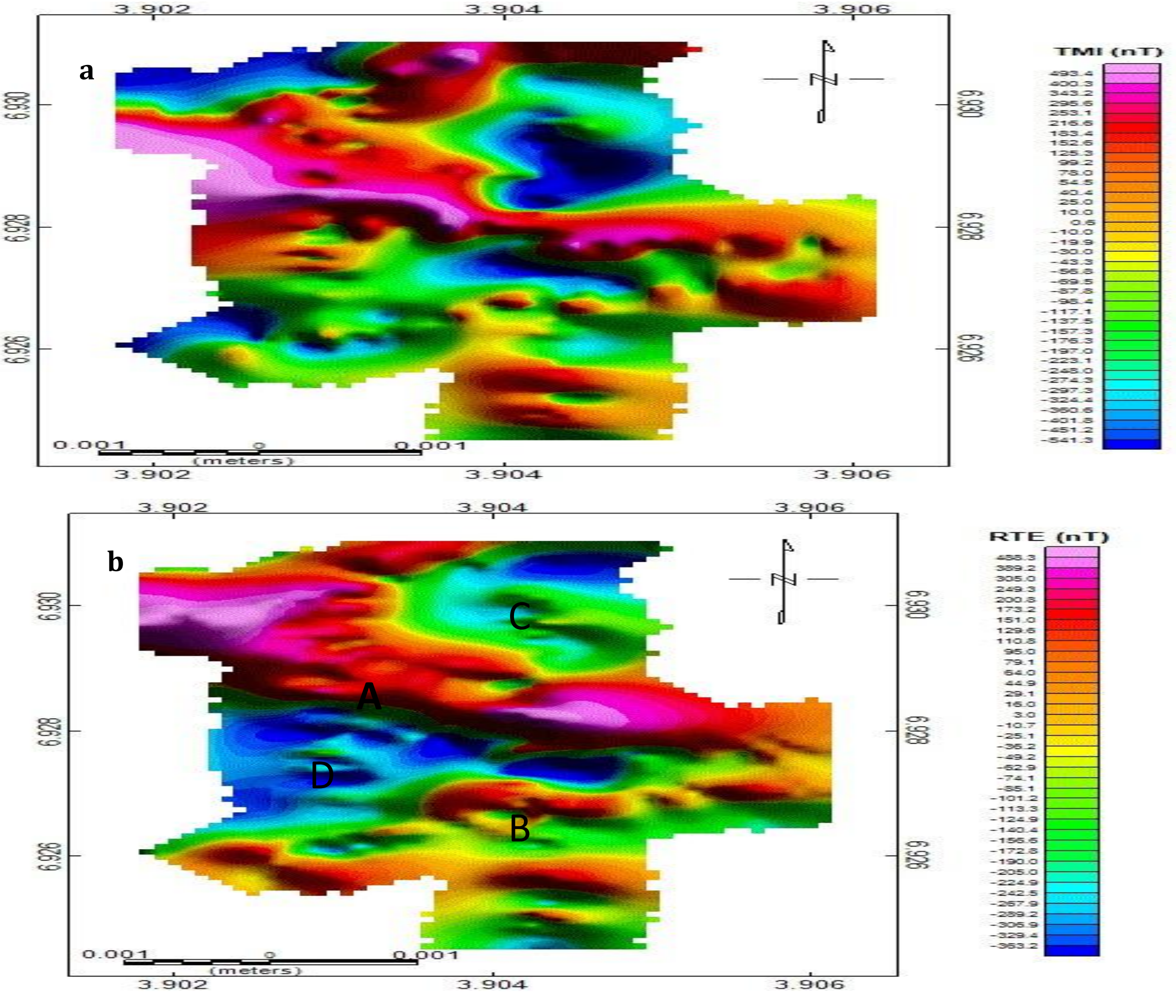

Figure 2: Representative of magnetic maps showing (a) Total Magnetic Intensity (TMI) (b) Reduction to Magnetic Equator (RTE)

The total magnetic strength map generated for the area as represented in Figure 2 presents the overall magnetic response, regional magnetic field and magnetic anomaly due to the magnetic induction of magnetic minerals present in shallow subterranean geology. Its amplitude ranges from - 541.3 nT to 493.4 nT. However, this map has been overshadowed by the effects of the regional magnetic field and the non-zero magnetic tilt (I = 10.20), which usually leads to distortion and target mis-alignment of the anomaly of interest. Therefore, the data was reduced to the magnetic equator in order to overcome magnetic inclination due to non-zero and the position of the anomaly was rightly located using the reduced to the Magnetic Equator (RTE) map.

The reduction to the Magnetic Equator (RTE) Map as showed in Figure 2b depicted that the amplitude of the magnetic intensity ranges from -353.2 nT to 488.3 nT describing varying magnetic intensity within the study area. The region labelled **A** and **B** show positive magnetic intensity (corresponding to low magnetic susceptibility in low magnetic latitude). This is likely to represent low magnetic rock unit such as quartzite or porphyritic granite gneiss while the negative intensities are found at the Southwestern (SW) and Northeastern (NE) part of the area (**C and D**). These corresponds to rock units with high magnetic mineral content such as the amphibolite and Biotite-granite gneiss. This submission described the degree of the weathering process on the rock body in the study area.

The Source Parameter Imaging (SPI) map (figure 3a) showed that the depth to the magnetic basement in the study area has varying depth. The SPI map described shallow magnetic lows at the centre depicting the better yield of groundwater with surrounding magnetic ridges. Likewise, these magnetic lows could depict the fractures through which the groundwater will be recharged. However, erecting of engineering structures has to be avoided along the magnetic lows without detailed subsurface information to unravel the nature and extent of the faults line.

The Analytic Signal (AS) and the Total Horizontal Derivative (THDR) map as presented in figure 3 b – c showed the location map of geologic contacts in the study area. The peak anomaly points represent the location of the contact AS and THDR maps. These contact locations (anomaly maxima) are highlighted on the map using white and purple lines respectively. The identified structures within the study area are showing N-S, NW-SE and NE-SW orientations. The linear nature of the structures coupled with the geologic information suggests that the contacts are likely to be fractures, faults or joints but not geologic contacts.

In addition to the above, the AS and THDR results were synthesized and used to evolve a structure map as presented in Figure 4a. The consistent structures on the two maps were digitized to obtain the magnetics lineament as showed in Figure 4b. The map revealed that there are fractures within the study area. These structures have NW-SE, NE-SW, E-W and N-S and orientations. It also shows that the structures are concentrated in the southern part of the study area. These intersections are possible target areas for groundwater exploitation.

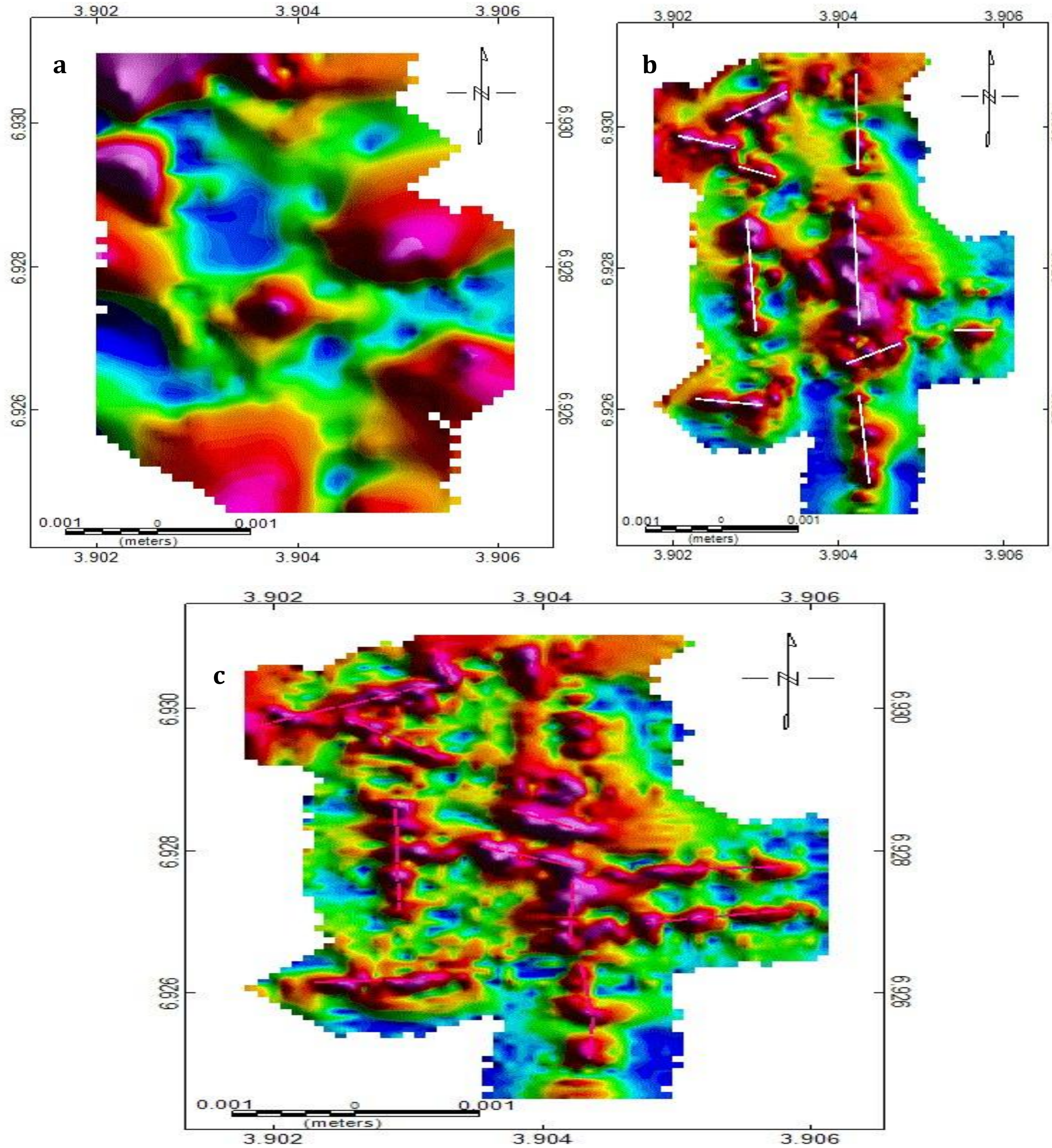

Figure 3: Representative of Magnetic Maps showing (a) Source Parameter Imaging (SPI) (b) Analytic Signal (AS) with Superimposed Lineament (c) Total Horizontal Derivative (THDR) with Superimposed Lineaments.

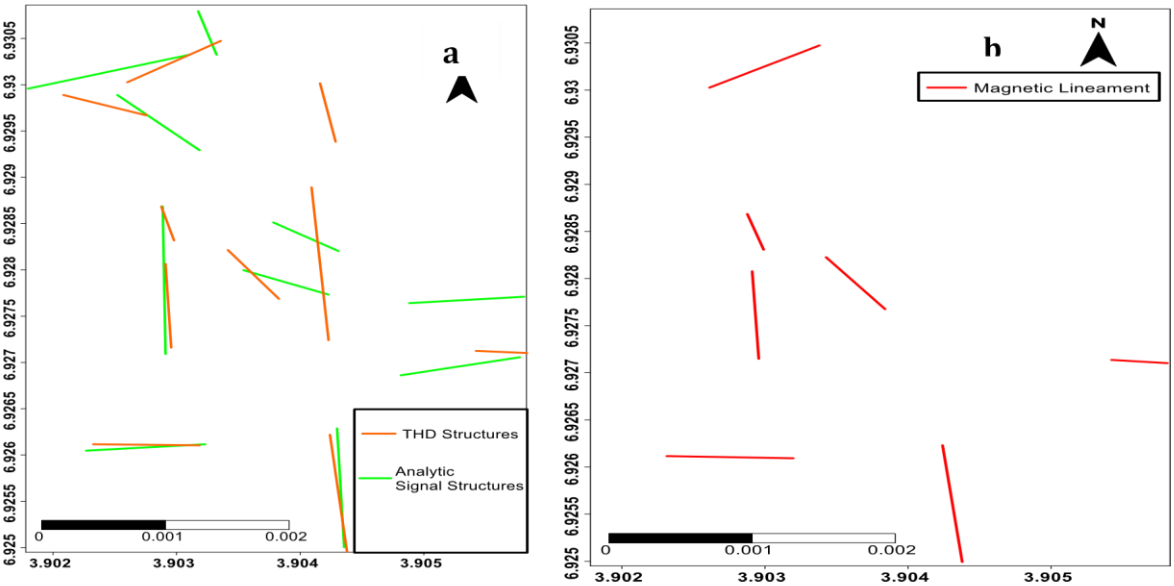

Figure 4: Representative of Magnetic Maps showing (a) Superimposed Lineament from Total Horizontal Derivatives (THDR) (b) Derived Magnetic Lineament from THDR and AS.

CONCLUSION

In conclusion, geologic lineament informs of fractures, fault lines with traces of weathering has been delineated with their orientation from the study. The variation of the estimated magnetic intensities aids the description of the formation that are likely to be in abundant in the area. The presence of the frequent fault lines illustrates the presence of high groundwater yield in the area. However, these signatures are inimical to founding layer of any engineering structures without additional study of subsurface information via geotechnical and other related methods. Moreover, further studies with the usage of gravity method is recommended in the study area in order to obtain the bulk density of the possible mineral accumulation. Likewise, detailed search thru geotechnical investigation in the study area will unravel the bearing capacity of the subsurface in response to engineering structures.

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