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Research paper

Investigation of Groundwater Potential Area Around Danbatta Using Ground Magnetic Data

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Abstract

Geophysical investigation was carried out around Dambatta with the aim of identifying groundwater potential zones using ground magnetic data. The acquired Total Magnetic Intensity (TMI) data was subjected to various filters such as non–linear filter, regional – residual and Reduce to Equator (RTE) using Oasis Montaj. The TMI, residual, and RTE grids obtained were processed in ArcGIS computer software, and the TMI, residual, and RTE maps of the study area were obtained. The RTE grid obtained was further subjected to lineament and Source Parameter Imaging (SPI). From the lineaments, regions of high fractures/weathering were noticed in the Northwestern, southwestern, and southeastern parts of the study area. The SPI grid was used to calculate the depth to the basement rock of the study area. Results of the interpretation and analysis of the data showed that the basement rocks is covered by an undulating topography with deep voids spreading across the area which good indication of groundwater accumulation. The area shows high magnetic anomalies in the NW, SW, SE and NE regions of the area. Regions with depth values 15.7m to 36.9m classified fractured regions and are inferred as areas of high groundwater potential regions. Three regions of the study area were isolated as regions of high groundwater potential area, these inference were drawn due to the appreciable depth and fracturing zone.

Keywords: *Aquifer; Groundwater; Ground Magnetic; Lineament; Source Parameter Imaging.*

1. Introduction

Geophysics is defined as a sub-discipline of earth science employing physical and mathematical principles to investigate the subsurface by examining variations in its physical properties. Geophysicists then use these variations to understand geological structures and subsurface conditions [1]. The choice of a geophysical technique such as magnetic, gravity, electric resistivity, electromagnetics, or seismic depends on the specific objectives of a given investigation.

Water serves as one of the most crucial natural resources for human existence, agriculture, and various industries. However, with increased population pressures and rapid urbanization rates globally, coupled with climate variability effects, availability and reliability of surface waters have become questionable, thus increasing reliance on groundwater sources [2].

This resource is primarily stored in aquifers contained within geological formations and is far more reliable than surface water in terms of both quality and quantity [3]. Despite significant investments made into borehole drilling ventures over recent years, there still exist many communities – particularly those located rural or semi-urban areas within Nigeria – without ready access to safe drinking water facilities [4]. One contributing factor responsible for this sad state of affairs can be attributed to the failure of many developers to conduct thorough prior geophysical investigations before initiating their work, often leading to dry holes drilled at great cost to local taxpayers'. In crystalline basement terrains where most northern Nigerian states lie, groundwater resides mainly in weathered zones amidst complex fracture systems necessitating detailed geophysical studies if proper exploration results are desired [5].

The magnetic method is one of the various geophysical techniques that have been recognized as an invaluable, non-invasive tool in groundwater exploration. It entails the measurement of the spatial variation of the Earth's magnetic field resulting from the subsurface geological characteristics of rocks that may indirectly indicate the existence of groundwater-bearing structures like faults, fractures, and lithological contacts [6]. It is both cost-effective and especially suited to hard rock terrains having aquifers related to their secondary porosity.

Against this backdrop, given the ever-increasing demands for water coupled with decreasing reliability of surface waters in Nigeria, there arises the need to seek affordable scientific methods of evaluating the groundwater potential. Therefore, this study employed the ground

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magnetic technique to assess the potential for groundwater in Kauyen Mai Unguwa Village, Dambatta L.G.A., Kano State. The objective was to identify sites conducive for sustainable exploitation of groundwater [7].

2. Methods

2.1. Location and hydrogeology of the study area

The study area comprises Dambatta Local Government Area in Kano State; it is bounded within the coordinates of 12°22′25″N to 8°29′09″E, 12°23′23″N to 8°29′51″E, respectively.

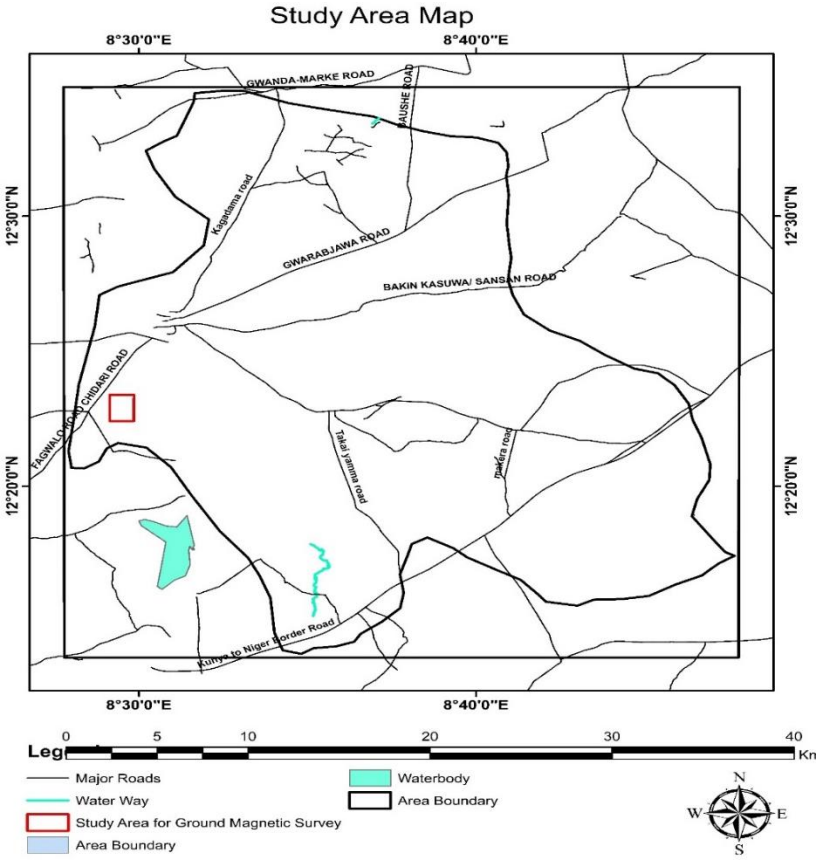


Fig. 1: Map of the Study Area (Designed by Dudutide Investment Nigeria Ltd).

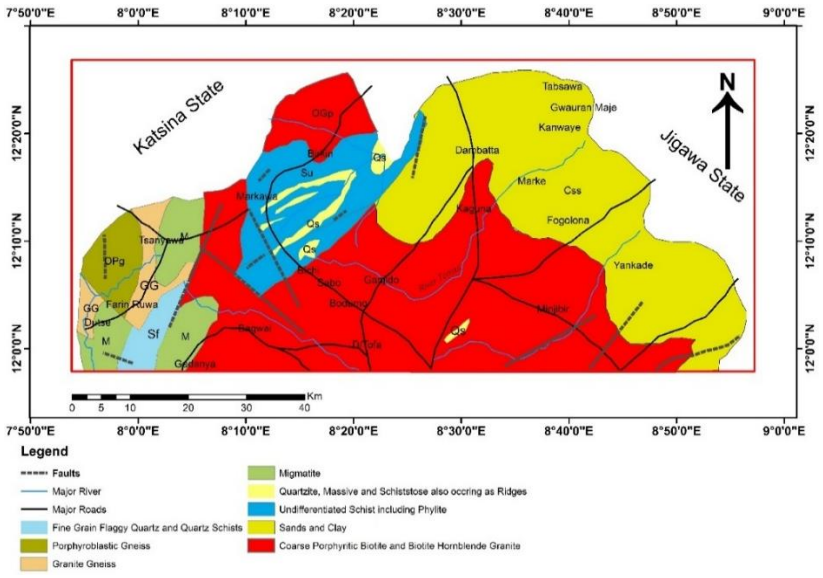


Fig. 2: Geological Map of the Study Area (Designed by Dudutide Investment Nigeria Ltd).

The geology of Kano State comprised of sedimentary formation, which occupies small portion of the region and the basement complex covering the majority of the state also underlying the Chad formation sediments [8]. The Basement-sedimentary boundary is well defined, although in a few areas there is a transition zone in which the sediments are shallower [9]. In the basement complex, the rock types are predominantly migmatites, gneisses, schist, granites, and minor occurrences of quartzites, volcanic basalt and rhyolites. Majority of the

Chad Formation sediments now falls within Jigawa State (Auwalu, Saleh, Hotoro, & Adam, 2016; Chifu, Idi, Terhemba, Idowu, & Abdullahi, 2019).
Geologically, the area comprises gneiss-migmatite-granite complex rocks with an intrusion of schist rocks which lies between the Karau Karau and Kazaure Schist Belts, and quaternary sediments all belonging to the Northern Nigerian Basement Complex [10].

2.2. Theoretical background

2.2.1. Regional – residual separation

The TMI data were subjected to regional – residual separation using polynomial fitting. The residual magnetic intensity (RMI) data obtained was gridded using minimum curvature gridding. The RMI grid obtained was seen to have variation in magnetic strength as in Figure 4.

2.2.2. Reduce to equator (RTE)

The residual grid data was subjected to RTE using equation 1 in order to eliminate the effect of magnetic inclination in regions with low latitude by centering the peaks of the magnetic anomalies to their source body using the relation in equation 1. The RTE grid obtained was imported into the ArcGIS environment, and the RTE map was obtained.

$$L(\theta) = \frac{\sin(I) - i\cos(I).\cos(D-\theta)^2 x(-\cos^2(D-\theta)}{[\sin^2 I_a + \cos^2(I_a).\cos^2(D-\theta)]x[\sin^2(I) + \cos^2(I).\cos^2(D-\theta)]} \quad (1)$$

Where I is geomagnetic Inclination, D is Geomagnetic Declination, and I_a is Inclination for amplitude correction

2.2.3. Source parameter imaging

The RTE grid was used to calculate the depth to the basement rock using source parameter imaging (SPI) based on equation 2

$$\text{depth} = \frac{1}{K_{MAX}} \quad (2)$$

Where $K_{max} = \sqrt{\left(\frac{\partial T}{\partial x}\right)^2 + \left(\frac{\partial T}{\partial x}\right)^2}$ is the peak value of the local wave number K over step source [11]
To calculate the SPI, the first vertical derivative along z and horizontal derivative along x, and y axes were calculated, the helps detects magnetic source edges and geological boundaries. This also sharpens the edges of the anomalies and enhances shallow features [12]. The calculated SPI values were gridded using minimum curvature gridding function of Oasis Montaj. The grid was exported to the ArcGIS environment to obtain the SPI grid map.

2.2.4. Lineament detection

The RTE grid was also used to calculate the Tilt derivative (TDR) and the Horizontal gradient magnitude (HGM) using the relations in equations 3 and 4

$$HGM = \sqrt{\left(\frac{\partial T}{\partial x}\right)^2 + \left(\frac{\partial T}{\partial x}\right)^2} \quad (3)$$

$$TDR = \tan^{-1}\left[\frac{\frac{\partial T}{\partial z}}{\sqrt{\left(\frac{\partial T}{\partial x}\right)^2 + \left(\frac{\partial T}{\partial x}\right)^2}}\right] = \tan^{-1}\left[\frac{FVD}{HGM}\right] \quad (4)$$

HGM and TDR filters are used for edge and boundary detection between magnetic sources with almost the same susceptibility. Contour lines extracted from the TDR grid were superimposed on the HGM grid. The contour lines were observed to align with the peak edges of the HGM grid. The combined grids were imported into the ArcGIS environment, georeferenced, and digitized to generate lineaments; the lineaments were drawn at points of peak values of the HGM and zero contour lines aligned. Over 100 lineaments were extracted from the ground magnetic structure. The lineaments were processed and prepared into a lineament map.
The lineaments extracted were imported into the RockWorks 17 software environment and the rose diagram of the lineaments was drawn; the rose diagram shows the directional trend of the lineaments.

2.3. Magnetic data acquisition

A ground magnetic survey was carried out across all areas within the study area using a GEM GSM–19 Overhauser series magnetometer. Total field magnetic intensity (TMI) data were collected at station intervals of 80–100 m (but generally at 100 m). The non-uniformity in the station interval was due to the built-up nature of the community and varying degrees of accessibility and cultural interference. Before data acquisition, a base station was established within the study area where repeated readings were taken at intervals of about 60 min to monitor the trend of the time-varying component of the earth's total magnetic field (Diurnal variation), which were used to correct the field data for diurnal variation and offset by subtracting the base station magnetic measurement from a time-synchronized magnetic measurement along the occupied traverses. The TMI data were acquired along profiles of length 500m at an interval of approximately 100m between the profile lines. The diurnal error were corrected using GEM link 5.4. The corrected TMI data was gridded using Surfer 25.0, non linear filter was used to suppressed noise and reduce artifacts, therefore, increasing clarity and reliability of geophysical interpretation, the TMI grid was transferred to ArcGIS environment and the TMI map of the area was produced. Figure 3 shows the TMI map of the study area.

3. Results and Discussions

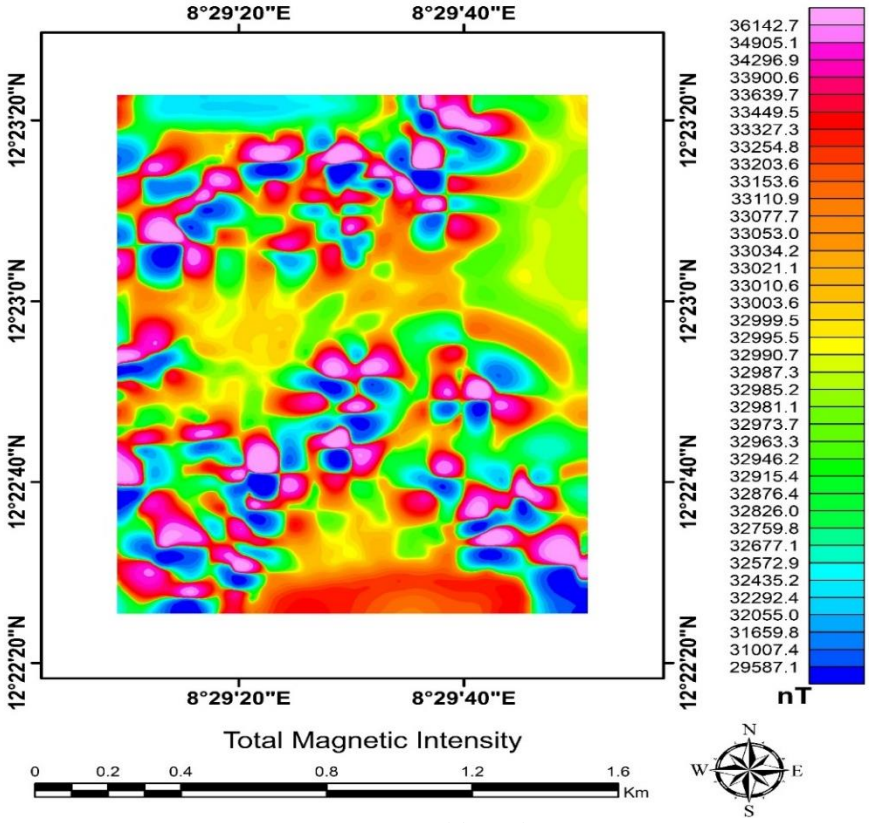


Fig. 3: TMI Map of the Study Area.

Figure 3 shows the TMI map of the study area, which ranges from 29587.1nT to 36142.7nT, this indicates structural variation of magnetic strength of the rock types around the area. High magnetic values were observed in the NE, NW, SE, and SW regions, with a value range of 33153.6nT to 36142.7nT. Intermediate to low magnetic strength is observed in the NE, NW, SE, and SW regions of the study area with value range of 31106.0nT to 34594.3nT.

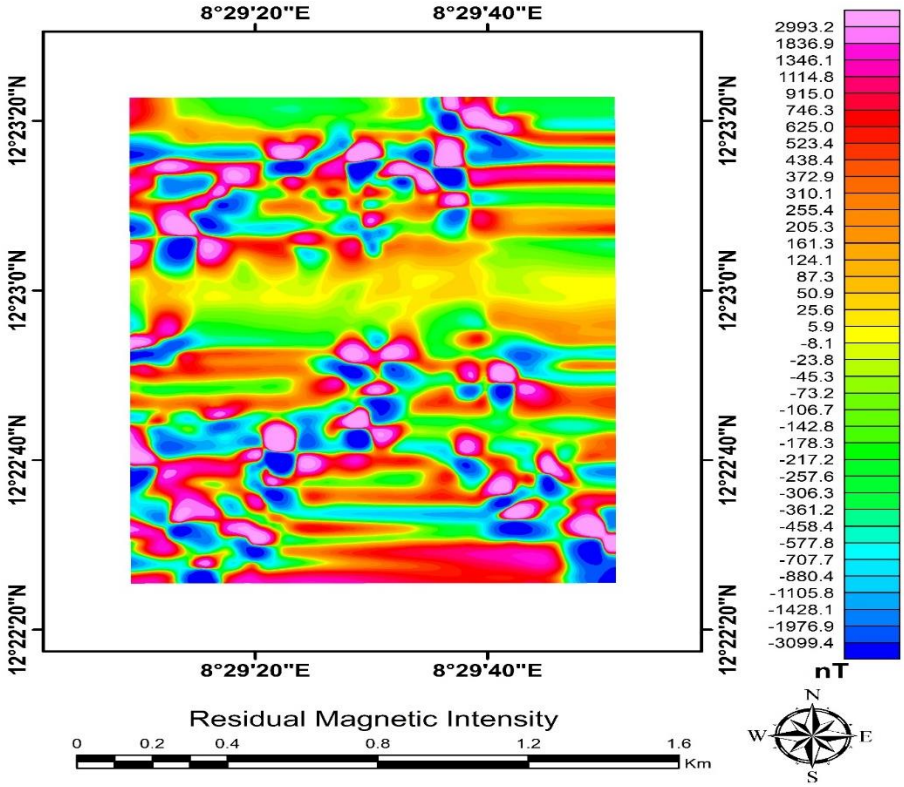


Fig. 4: Residual Map of the Study Area.

Figure 4 shows the residual map of the area. The map show the variation in the magnetic susceptibility across the area. High magnetic intensity was observed in the NW, SW, SE, and NEE regions of the area, with a value range of -2689.9 nT to 1494.6nT.

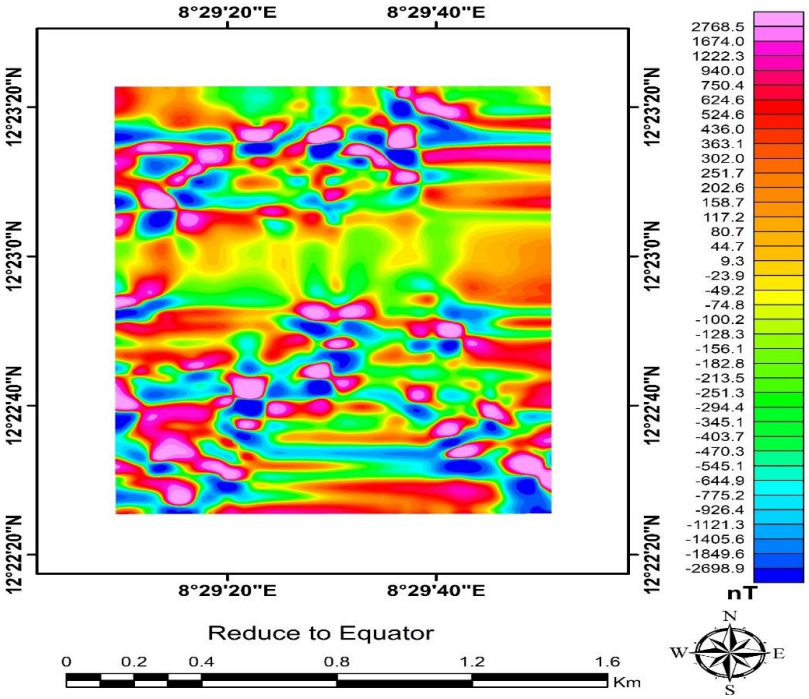


Fig. 5: RTE Map of the Study Area.

Figure 5 shows the RTE map of the area. The RTE map shows a striking resemblance to the residual map of the area. The map shows a value range of -1981.7 nT to 1460.6 nT; high intensity was observed in the NW, SW, SE, and NEE regions of the area, with a value range of 375.0nT to 1460.6nT and intermediate to low magnetic intensity of -1981.7 nT to 327. nT.

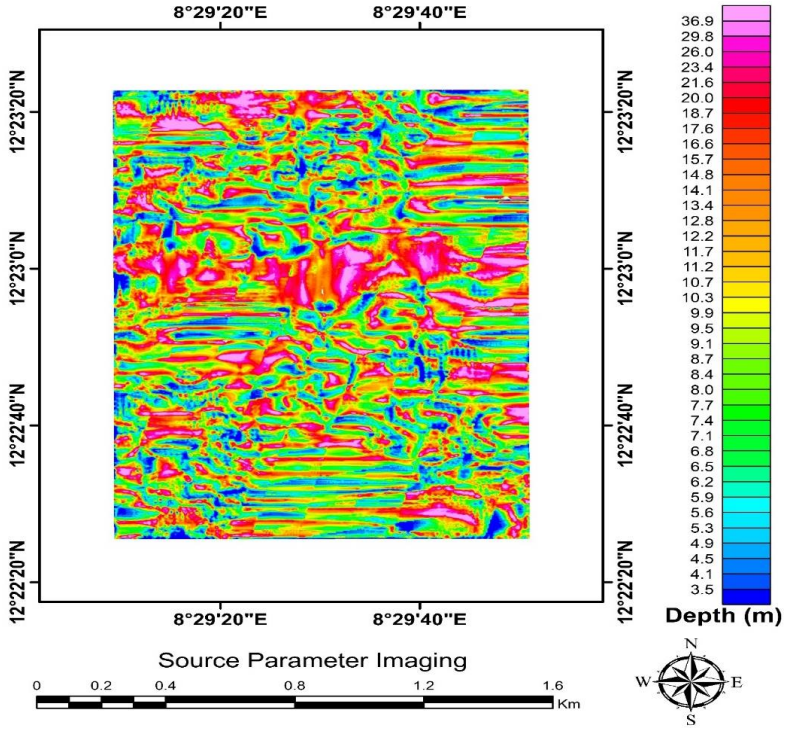


Fig. 6: SPI Map of the Study Area.

Figure 6 shows the SPI map of the area. The map shows the depth around the area, which is categorized into three classes: deeper depth, intermediate depth and shallow depth. The deeper depth region was observed to have value range of 24.0m to 54.3m, intermediate depth was observed to have value range of 13.8m 22.8m, and value range of 4m to 13.2m are observed in the shallow regions of the study area. Deeper depth regions in the area have high tendency to accumulate groundwater, as fluid tends to move from regions of high pressure to regions of low pressure, as indicated by [9]; [13]

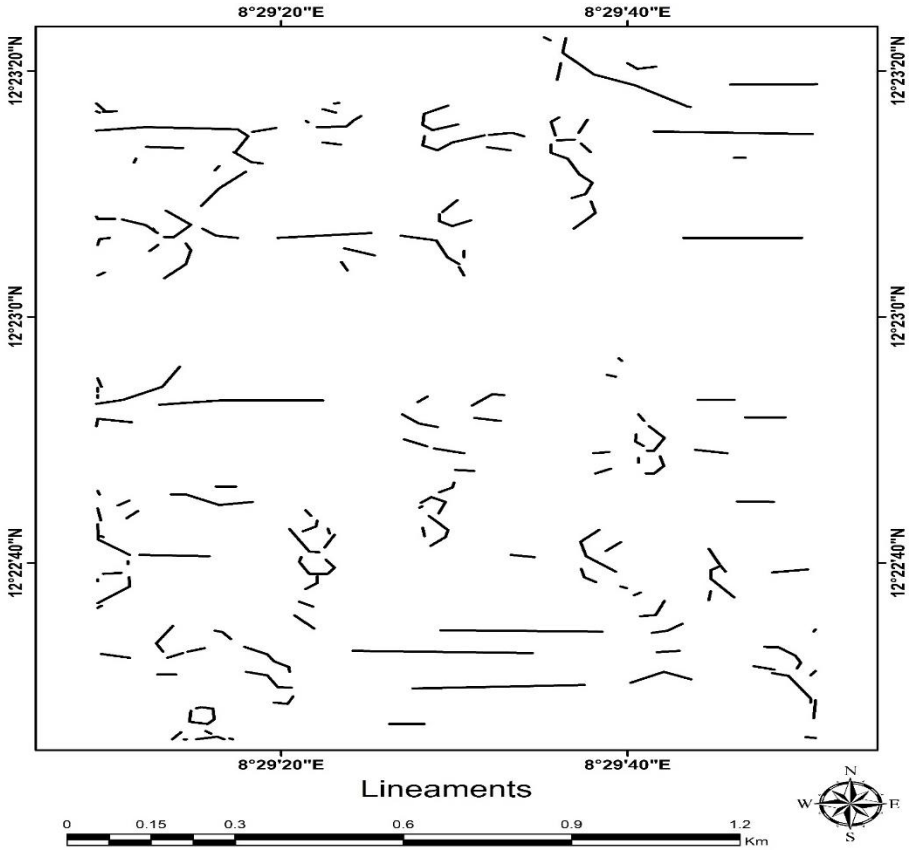


Fig. 7: Lineaments Map of the Study Area.

Figure 7 show the lineaments around the study area. The lineaments indicate faults and fractures around the study area. High number of fractures were observed in the NE, NW, and SW parts of the area. These fractures were observed to have a high tendency to store ground-water, hence serving as an aquifer zone.

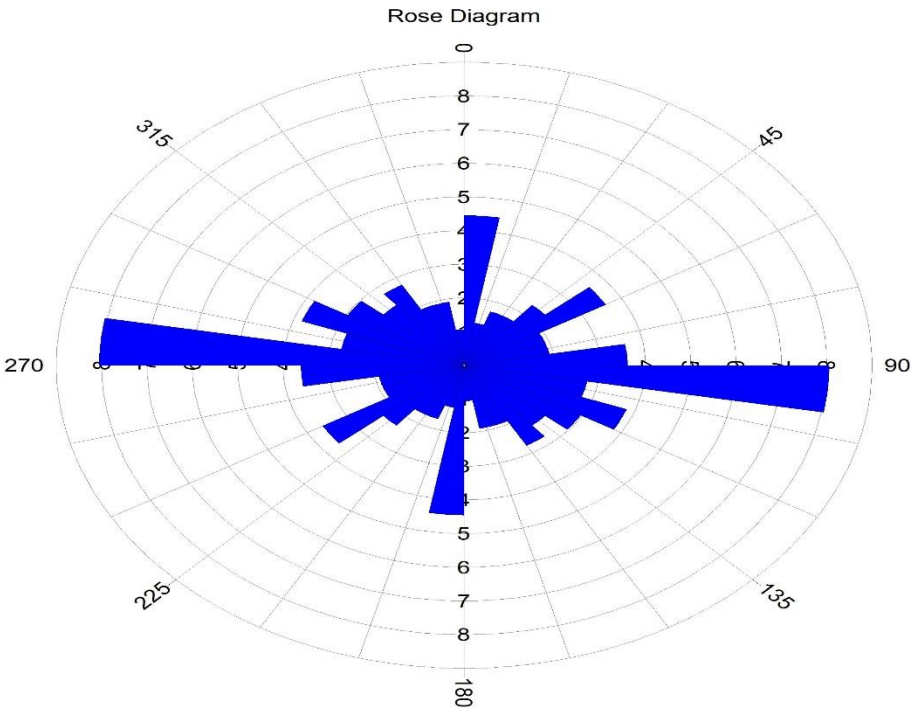


Fig. 8: Rose Diagram of the Study Area.

The rose diagram in Figure 8 shows that the general trend of the lineament is from NW to SE.
Figures 3 – 8 show the interpreted results of the magnetic data with regard to groundwater potential regions. The results shown in Table 1 indicate region locations and their respective average depth.

Regions	Longitude (^{0}N)	Latitude (^{0}E)	Average Depth (m)
A	7.876360° 7.876360° 8.485060°	12.370943° 12.997143° 12.997143°	16.2 – 54.3

B	8.485060° 7.875872° 7.875872° 8.480327°	12.370943° 12.370604° 12.993913° 12.993913°	15. 6 – 30.8
C	8.480327° 7.886149° 7.886149° 8.481839° 8. 481839°	12.370604° 12.380630° 12.996394° 12.996394° 12.380630°	13.8 – 42.8

4. Discussion

Analysis of the interpreted results of the TMI shows variation in magnetic susceptibility with intermediate intensity surrounding the high magnetic intensity regions. These variations or changes in the magnetic anomalies give rise to regions with peaks and depressions in the NW, SW, SE, and NE parts. The residual and RTE maps show close resemblance to the TMI map. These regions of depressions indicate regions that could accumulate groundwater. The SPI map show regions of deeper depth of value range 42.8m to 54.3m. These deeper regions serve as groundwater potential regions due to factors such as fractures observed from area lineaments and appreciable depth; this is in agreement with hydrogeological depth inferred by [13]. The regions with shallow depth are inferred as the sedimentary layer serving as overburden with varying lithology. Three regions were isolated and marked A, B and C as shown in Table 1. These isolated areas are inferred as region of high groundwater potential due to their appreciable depth, serving as low-pressure regions and fractures that aid fluid movement.

5. Conclusions

The magnetic method, as a geophysical technique, serves as a valuable tool for groundwater investigation. In this study, magnetic data were acquired, processed, and interpreted using Oasis Montaj 8.4 and ArcGIS 10.8. The processed grids were subsequently analyzed to identify groundwater potential zones. Various filters, including residualization through polynomial fitting and reduction to the equator (RTE), were applied to the magnetic data. Regions with depth values ranging from 13.8 m to 54.3 m, classified as fractured zones, are inferred to represent areas of high groundwater potential. High magnetic anomalies were observed in the northwest, southwest, southeast, and northeast regions of the study area. The source parameter imaging (SPI) results were categorized into three depth regions: deeper, intermediate, and shallow. Three regions were identified as having high groundwater potential based on their appreciable depth and degree of fracturing.

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