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Delineation of sub-surface structures using remote sensing and Aeromagnetic data: Case study of Federal University Oye-Ekiti campus

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Abstract
Remote sensing data comprising of Landsat 8 and aeromagnetic data have been used to delineate lineaments for structurally controlled groundwater prospect in the campus of Federal University Oye-Ekiti. Failed boreholes were observed in some places within the study area which had led to unavailability of municipal water supply. The Landsat 8 data was processed for edge sharpening enhancements and the aeromagnetic data was subdued to various data enhancement strategies such as the total magnetic intensity (TMI), reduction to equator (RTE), first vertical derivative, horizontal derivative and analytic signal were generated. Analysis and interpretation of the Landsat 8 were carried out in order to establish the lineament trends across the study area. The total magnetic intensity of the study area exhibited a magnetic signature ranging from 59.6 nT to 87.4 nT. Composite lineaments were generated from the Landsat 8 and Aeromagnetic lineaments and were recapitulated using rose diagrams. This revealed NE-SW as the major stretch with minor ones in NW-SE and E-W directions. Lineaments intercept were observed from the study area in between phase I and phase II and in phase III. The western part (phase III) of the region under study may be considered as the most probable zones for structurally controlled groundwater development.

Keywords: Analytic signal, Horizontal derivative, Magnetic intensity

1.0 Introduction

Federal University Oye-Ekiti is one of the fastest growing institutions in Nigeria (https://news.fuoye.edu.ng). The campus is underlain with basement rock which has shallow expression in some places that has led to either seasonal or failed boreholes within the region while other parts were overlaid by clayey overburden materials. Water is the most essential component of life (Olaseeni et al., 2020; Coker et al., 2021; Olaseeni et al., 2021) but it has become a scarce commodity in Oye and its environs due to the shallow basement and clayey nature of the overburden materials which did not have primary porosity (Ilugbo and Adebiyi 2017; Adebo et al., 2018; Ige et al., 2021; Ilugbo et al., 2023). This research work will address groundwater development plan that will meet the water needs of the university community by assessing subsurface structures that can reveal the degree of fracturing of the subsurface rocks and examine if the structures are structurally controlled. Subsurface structures can be delineated by using electrical, seismic, gravity and magnetic methods of geophysical prospecting (Bawallah et al., 2018; Akinluyi et al., 2021; Ilugbo et al., 2023). Structural arrangement of an area and zones of fracture assemblage can be best examining with lineament analysis (Ilugbo et al., 2023). However, different researchers have worked recently on structural mapping for groundwater development (Adeyeye et al., 2018; Akinluyi et al., 2018; Oyedele 2019; Banji et al., 2020; Akinluyi et al., 2021) using an integrated geophysical method. Remote sensing and aeromagnetic methods are the most commonly used methods for subsurface structural delineation because of their high resolutions (Ilugbo et al., 2023).

Remote sensing is good for both reconnaissance studies and delineation of subsurface structures (Rahaman 1988; Ogunmola et al., 2014; Akinlalu et al., 2018; Olaseeni et al., 2020). Geological, geomorphological, structural and mineral resources can be deciphered with Landsat 8 imagery (Akinlalu et al., 2018). Landsat imagery is also very relevant in terms of its high resolution. Contemporary advances in computer software and spatial-analysis techniques have led to the enhancement of geologic/subsurface structures (Ilugbo and Adebiyi 2017; Ilugbo et al., 2023). Subsurface structures can be delineated by using aeromagnetic data which represent a cogent element in identifying disparities of the geomagnetic field that results from the differences in the magnetic susceptibilities (Salawu et al., 2020; Faruwa et al., 2021). Integration of Landsat imagery and aeromagnetic data would unravel the subsurface structures that are useful for structurally controlled groundwater development in this region.

2.0 Experimental

2.1 Description and geology of the study area

The study area is the Federal University Oye-Ekiti (FUOYE), Ekiti State. The area lies within latitude 7º46'18"N to 7º46'58"N and longitude 5º18'35"E to 5º19'25" E (Figure 1). The study extent is reachable via two major and minor roads leading to different faculties within the region under study. The region is underlain by Basement Complex Rock of Southwestern Nigeria (Rahaman 1988, Bayode et al., 2014; Aroyehun and Akintorinwa, 2008). The main rock that underlain the study region is migmatite gneiss (Figure 2). Dendritic drainage pattern was noticed in the study area which could be related to the structures of the basement rock. Two streams (Atarin and Egburu) flow across the study area.

2.1 Materials and Method

The Landsat imagery was used and visual review of the individual bands was carried out. Band 5 was chose and it was elongated sequentially to output range. The imagery was processed with Arc GIS 10.3 software and filtered for visual lineaments' enhancement. The lineaments were digitized and geo-referenced to WGS 1984 in the UTM Zone 31N. The lineament extraction algorithm which consists of thresholding, curve extraction steps and edge detection was used to extract the lineament. The inclination of each lineament was calculated and the frequency of the lineament in a given inclination was explained by a rose diagram and plotted with Rockworks 16 software.

The aeromagnetic data was procured from the Nigerian Geological Survey Agency (NGSA). Total magnetic field intensity was obtained at a constant flight height of 80 m, flight line of 500 m (NW-SE) and tie line spacing of 2000 m (NE-SW). .

The magnetic data was analyzed and reduction to equator (RTE) filter was applied to the magnetic intensity map after upward continuation filter of 200 m height was carried out. The resultant residual magnetic intensity map of the area was effectuated by removing the regional field from the main RTE field. The residual magnetic anomaly (RMA) was subdued to different improvement techniques (analytic signal, first vertical derivative and total horizontal derivative) in order to enhance signal and delineate subsurface structures. The gridding techniques were achieved on the MAGMAP program of the Oasis montajTMSoftware. The relevant grids are entered and the fast Fourier transform was applied.

3. 0 Results and discussion

3.1 Total Magnetic Intensity Map (TMI)

Figure 3 is the total magnetic intensity field across the study area presented as a colour-shaded map showing a magnetic signature ranging from 59.6 to 87.4 nT. The magnetic of the study area is heterogeneous. The magnetic high of magnitude 87.4 nT was noticed in the northwestern and southern part while magnetic low of magnitude 59.6 nT is perceived in the northeastern part. The colour patterns denote total magnetic intensity and can be used to interpret lithology and structure in the study area.

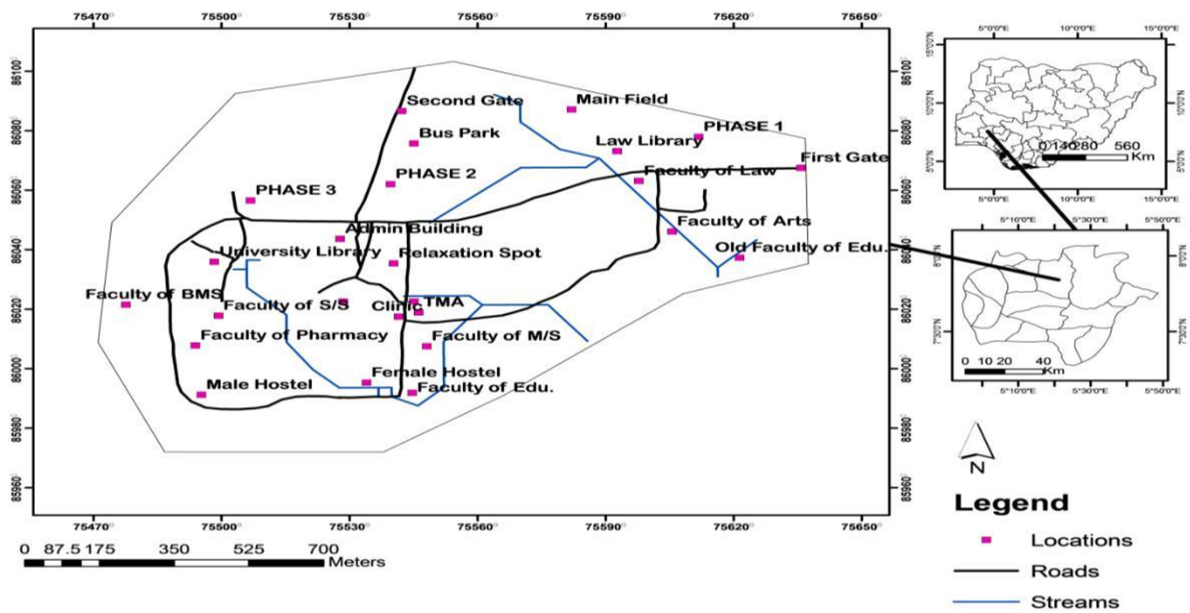
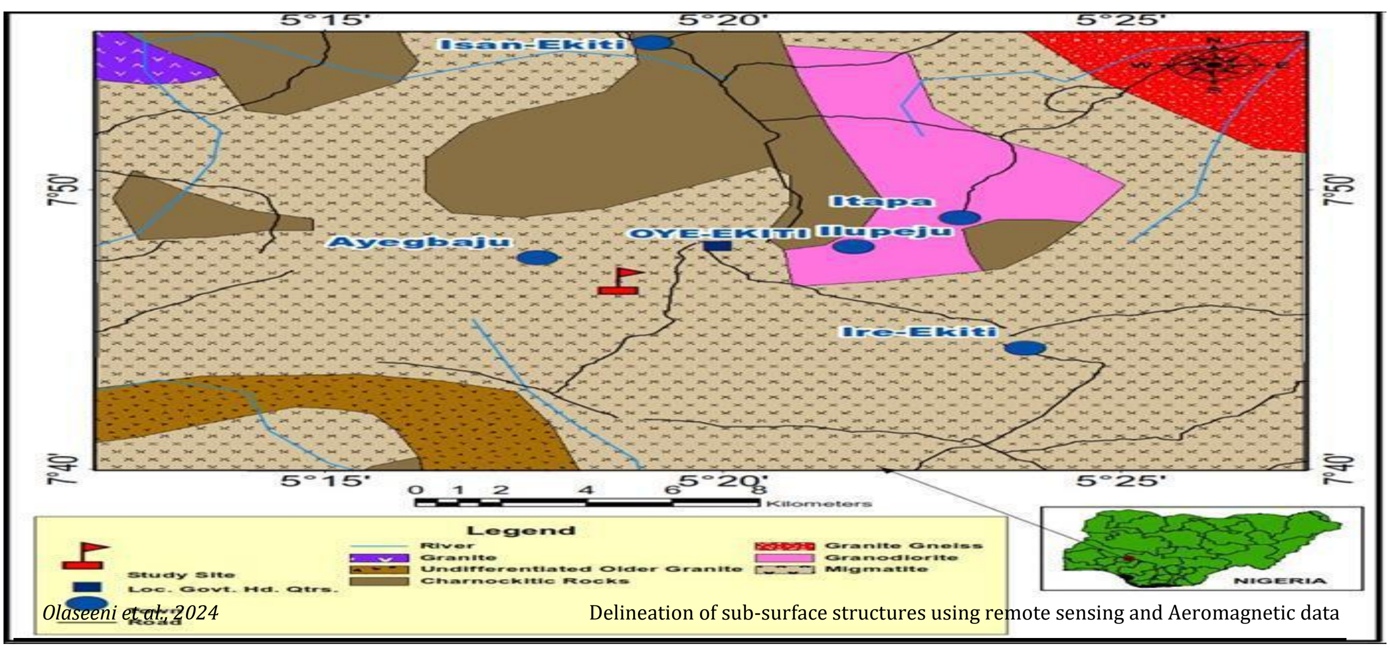


Fig. 1: Base Map of the study area



3.2 Near Surface Noise Removal

Fig. 2: Geological Map of Part of Ekiti State Showing the Study Area (After Geological Survey of Nigeria Akure sheet 61, 2006)

The resulting enhance TMI field over the study is shown in Figure 4. The de-noised TMI map clearly shows improvement in the positioning and trends of the observed various local anomalies. The map is significantly similar to the TMI, except that the anomaly signature is more enhanced with the removal of the near surface noise. The magnetic intensity values ranges from 60.749 to 85.104 nT.

3.3 Reduction to Equator Field Map (RTE)

The RTE magnetic field map is presented in Figure 5 and the magnetic values varies from -23.3 nT to 40.1 nT. The highest

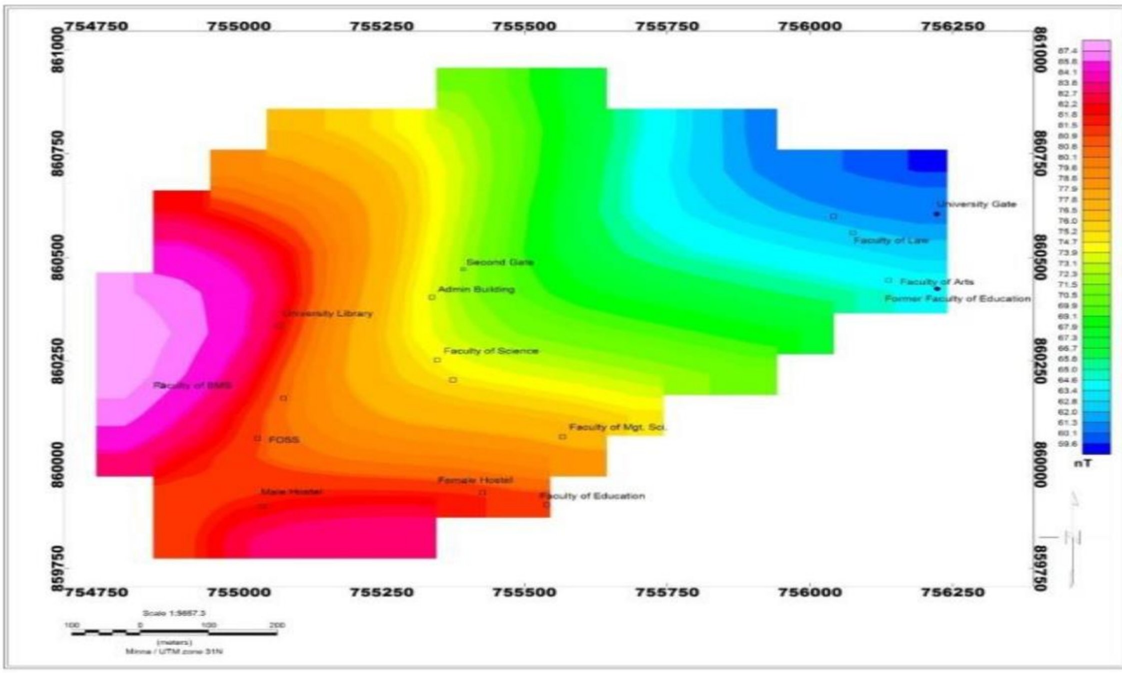


Fig. 3: Total Magnetic Intensity Map of the Study Area.

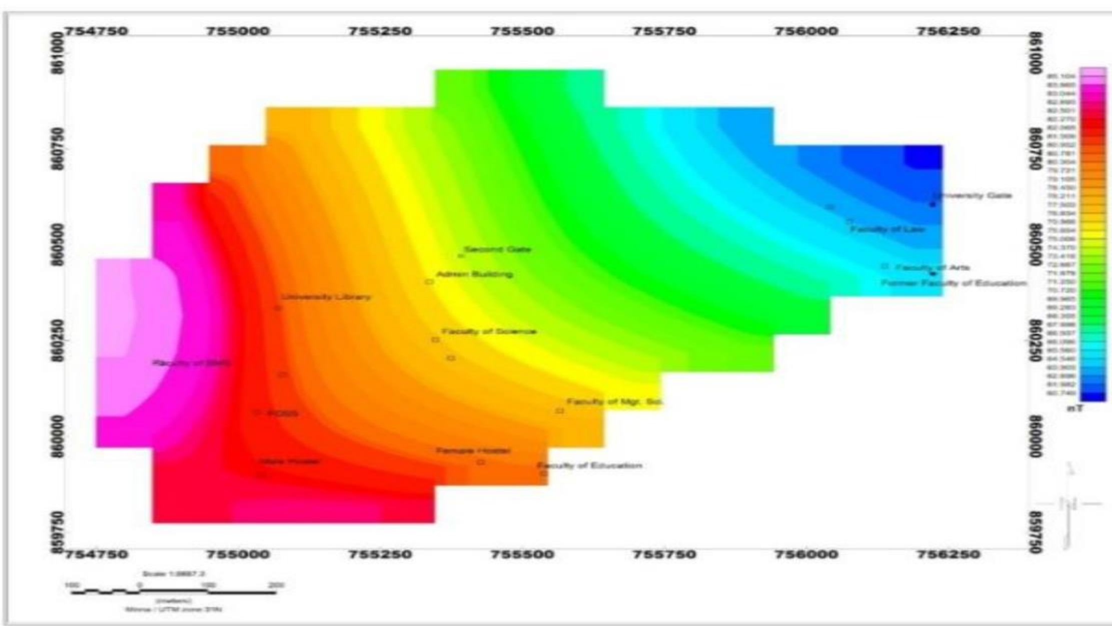


Fig. 4: Near Surface Noise Removal Map Upward Continued to 200 m of the Study Are

magnetic anomalies amplitudes are located in the northeastern part of the study area. Low amplitudes are noticed in the southwestern part of the study area.

3.5. First Vertical Derivative (FVD)

First vertical derivative (Figure 6) intensifies shallow features. It is probably less vulnerable to noise in the data compared to other higher order derivatives. The FVD Map below depicts that the low to moderate anomalies with values ranging from -0.023 nT/m to -0.014 nT/m and -0.011 nT/m to -0.003 nT/m respectively are more concentrated at the central part of the study area while high anomalies with value ranging from 0.005 nT/m to 0.027 nT/m dominate southern and northwestern part of the area. Lineament was observed on first vertical derivative map which is of shallow

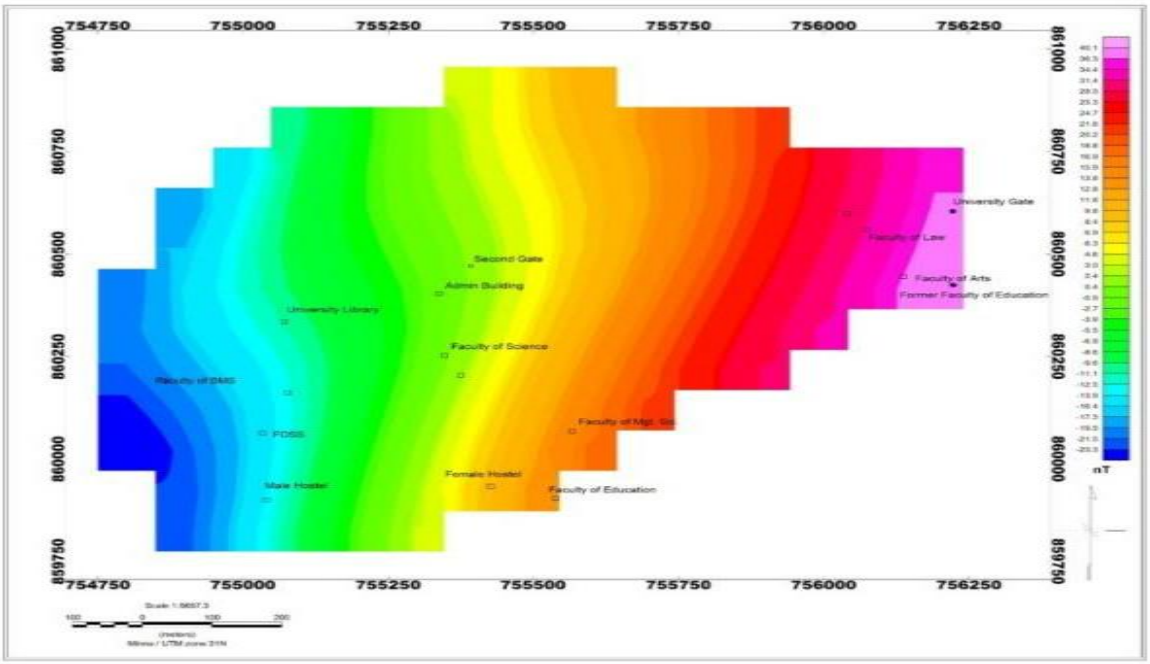
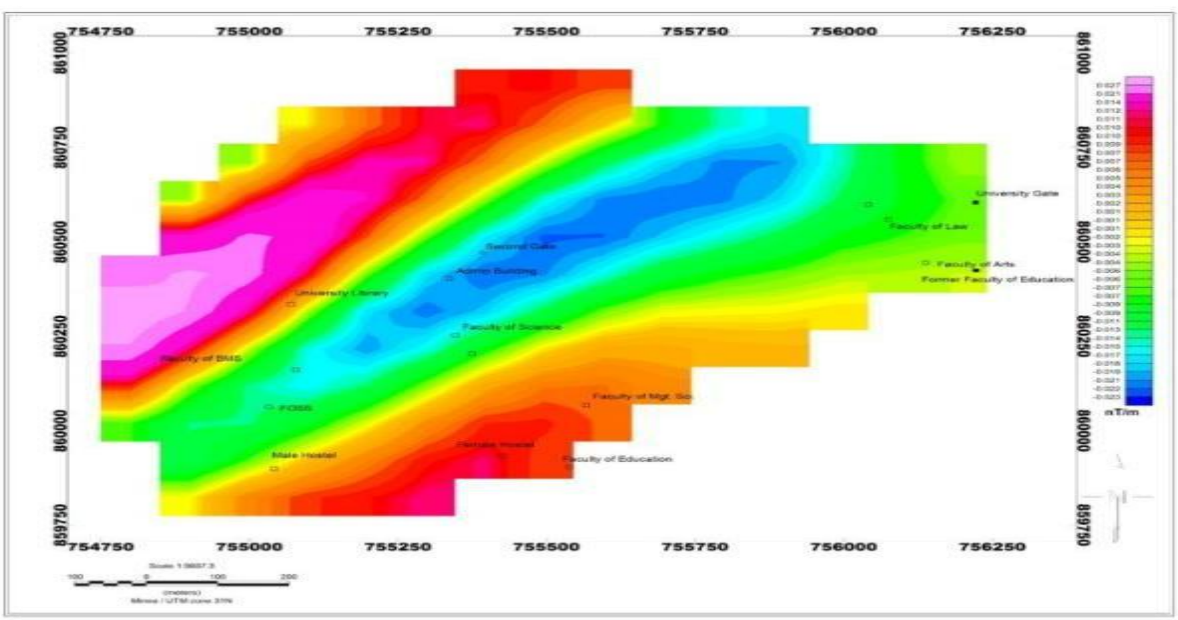


Fig. 5: Reduction to Equator (RTE) Map of the Study Area.



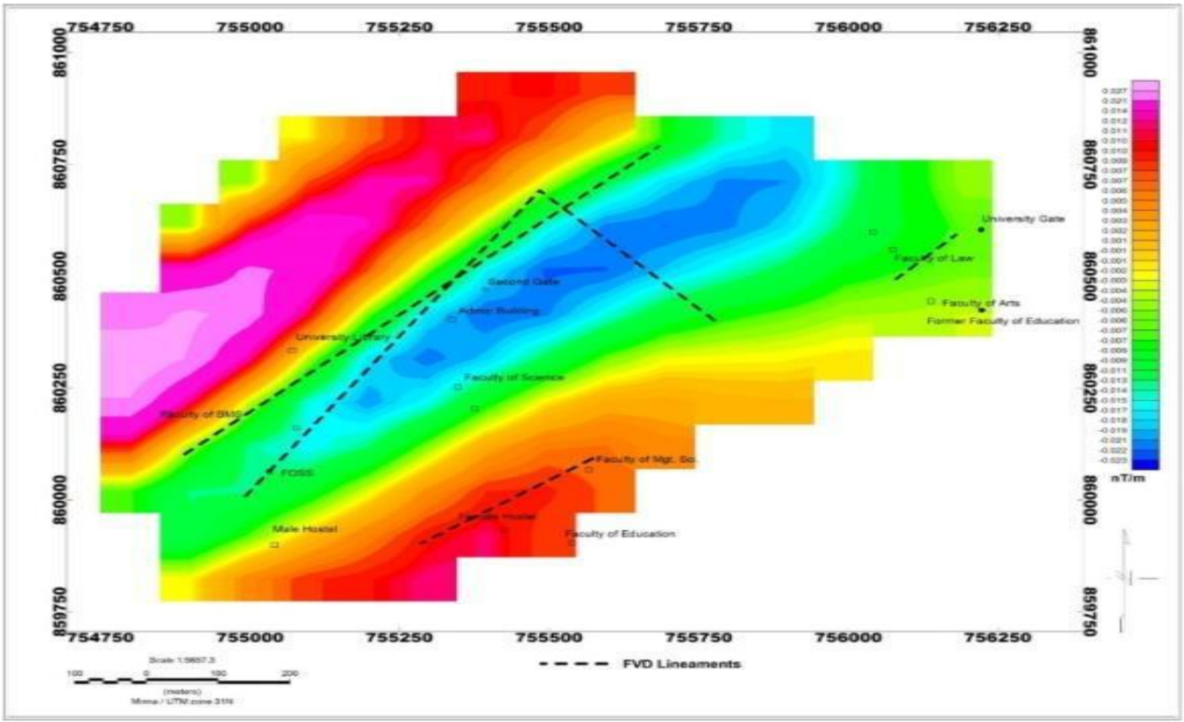


Fig. 7: Lineament on the First Vertical Derivative Map of the Study Area.

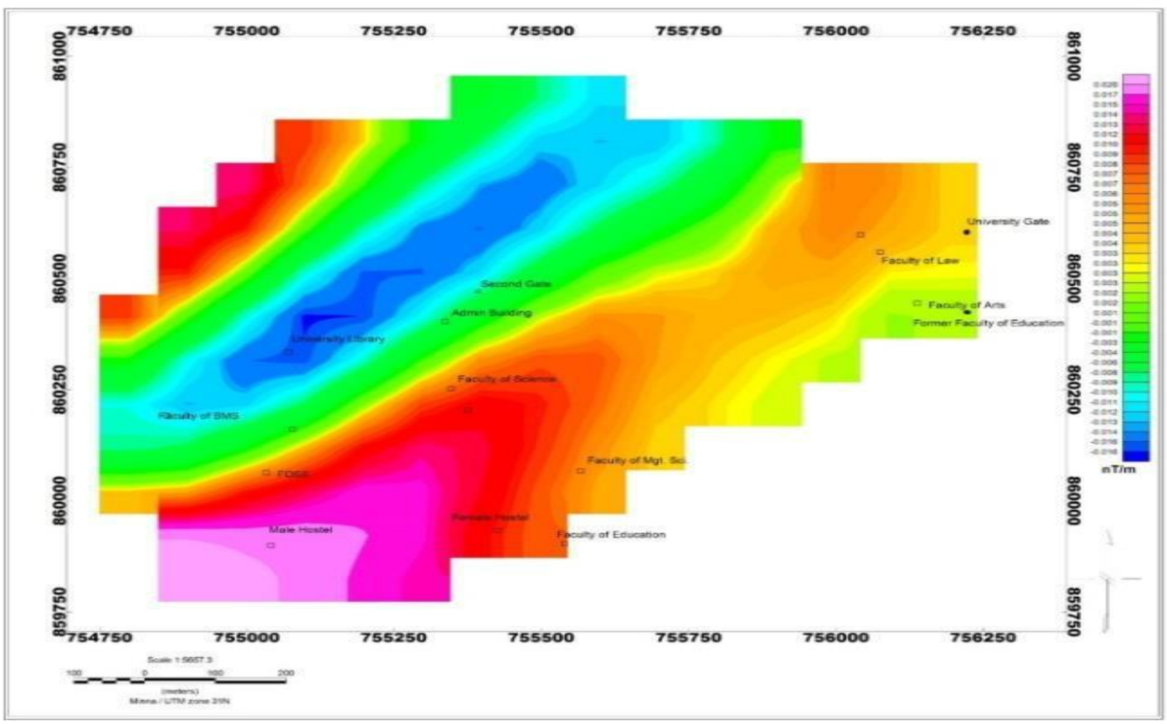


Fig. 8: Horizontal Derivative Map of the Study Area.

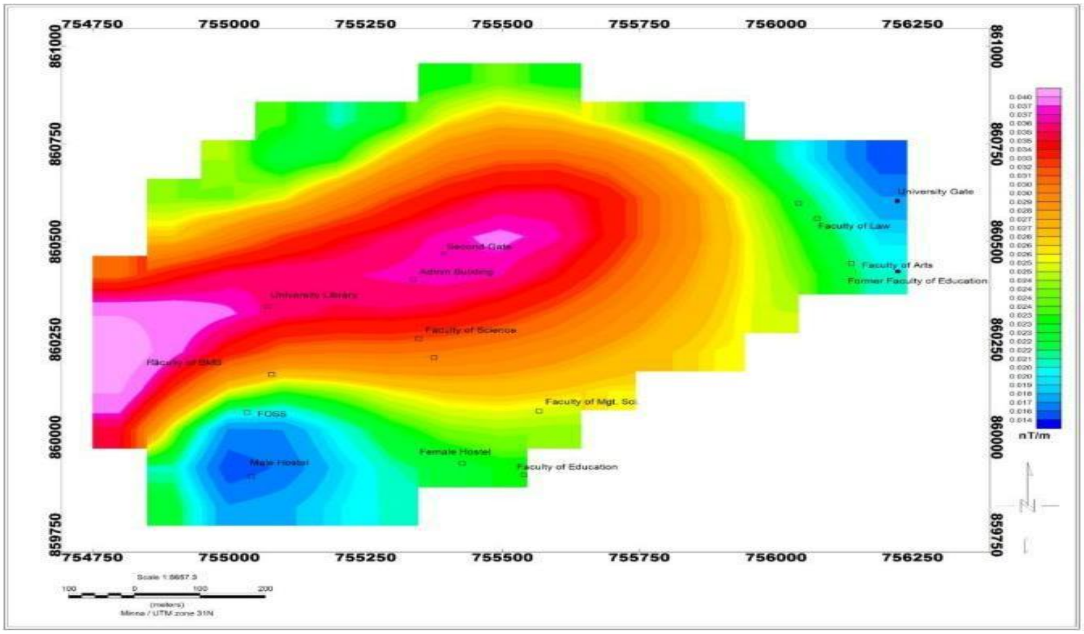


Fig. 9: Analytic Signal Map of the Study Area.

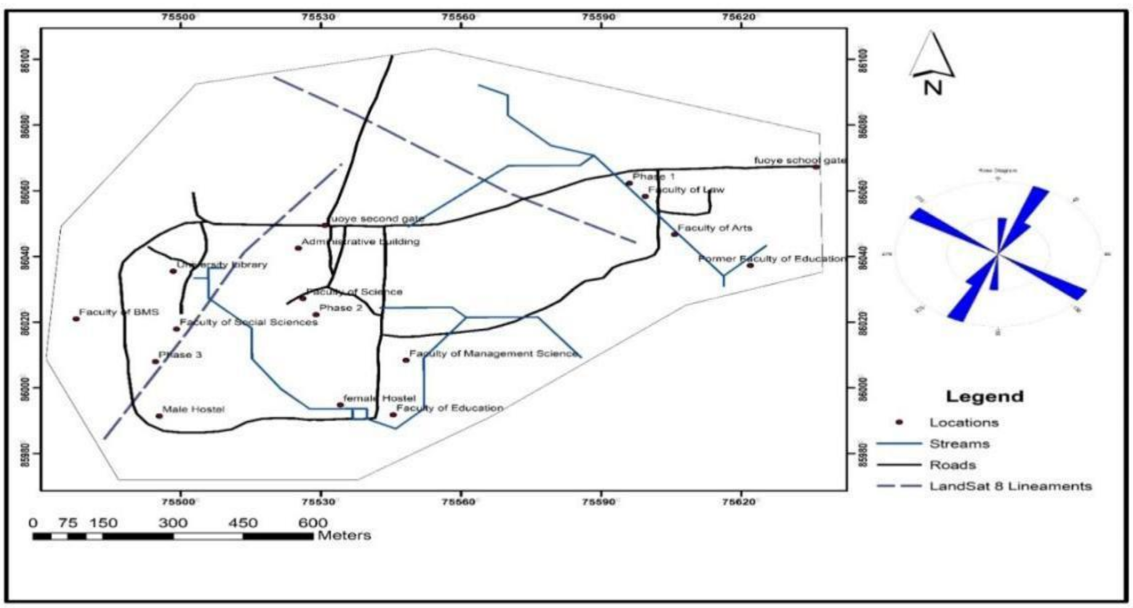


Fig. 10: Lineaments Map from Landsat 8 and Rose Diagram showing the Orientation of Lineaments of the Study Area.

depth anomaly trending from the northeastern part to the southwestern part of the study area (Figure 7).

3.6. Horizontal Derivative Map

Figure 8 is the horizontal derivative map. It is used to estimate contact (e.g. faults). It unveils comprehensive information about the contacts and the tectonic setting of the study area

3.7. Analytic Signal Map

The analytic signal is susceptive to the noises in the data, refine regional structure and improve edges of the anomalies. Analytic signal (Figure 9) was calculated by combining both vertical and horizontal derivatives. It locates the anomaly at the middle of the creative body. The analytic signal maps range in amplitude from 0.014 to 0.040 nT/m. Low magnetic anomalies trend in the study

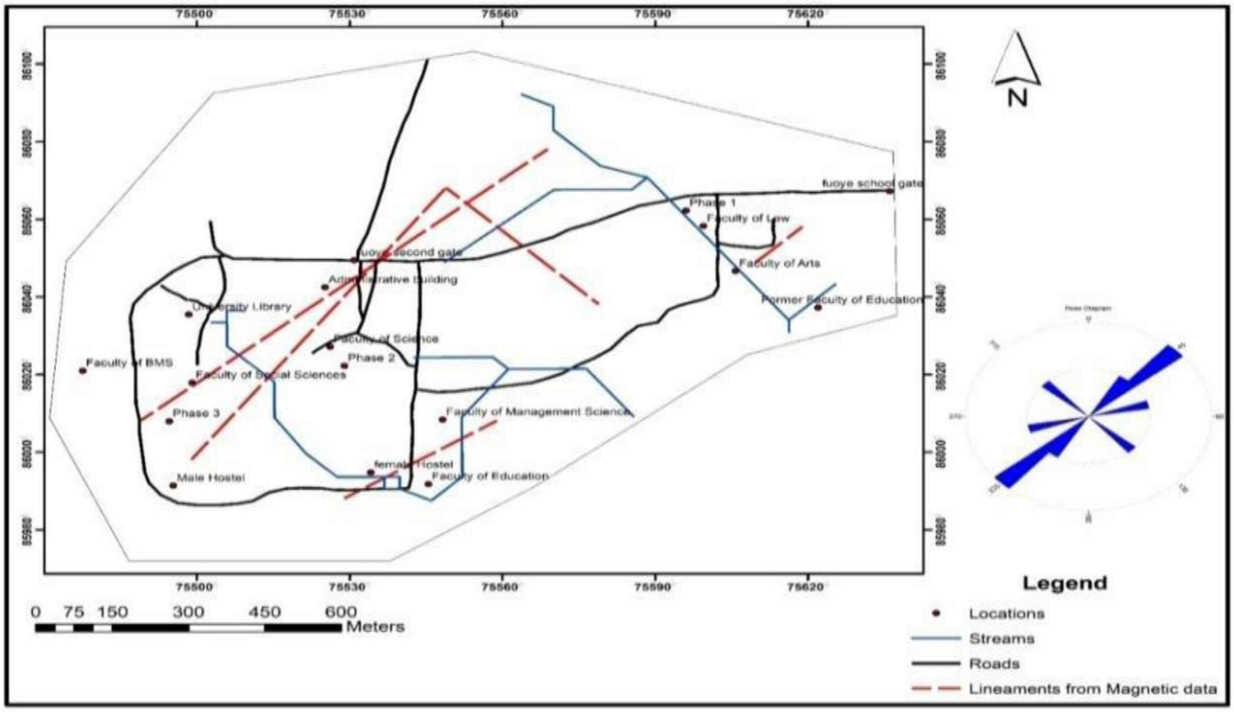


Fig. 11: Lineaments Map from Aeromagnetic Data and Rose Diagram showing the Orientation of Lineaments of the Study Area

area are predominantly in the northeastern and southern part with values ranging from 0.014 to 0.020 nT/m. Magnetic high values ranging from 0.030 to 0.040 nT/m was observed at the western and the central part of the study area.

3.8. Landsat 8 lineament

The Prewitt Gradient filter was introduced using five different directions such as North filter, South filter, West filter, East filter and Non-directional filter. The filtered images were used for the extraction of lineaments and orientation of each lineament was calculated. A rose diagram which explains the frequency of lineation in a given orientation was plotted (Figure 10). The major trend of lineaments was noticed in northeast and southwestern (NE-SW) while the minor trend is in NW-SE direction.

3.9. Aeromagnetic lineament

The aeromagnetic lineament map shows several lineaments concentrations in northeast-southwest directions (areas with high lineaments density) while on the northwestern and southeastern part are less concentrated. Aeromagnetic lineament map displays the usefulness of aeromagnetic interpretation in lineament mapping and analysis for groundwater exploration in the study area. The rose diagram prepared from the extracted aeromagnetic lineaments (Figure 11) shows that major lineaments observed at NE-SW directions are probably identify with tectonic activities such as fractures, faults and joints. The major lineament directions are associated with groundwater development of the region. Minor lineament inclinations were also observed at eastern and western part.

3.10. Composite lineament and lineament density

The composite lineament of the Landsat and aeromagnetic lineaments (Figure 12) and their lineament densities (Figure 13) reveal lineament intercept at the southwestern (phase III) and at the northeastern (in between phase I and phase II) part. The sub-surface structures in the study area will favour structurally controlled groundwater development especially at the southwestern part (phase III).

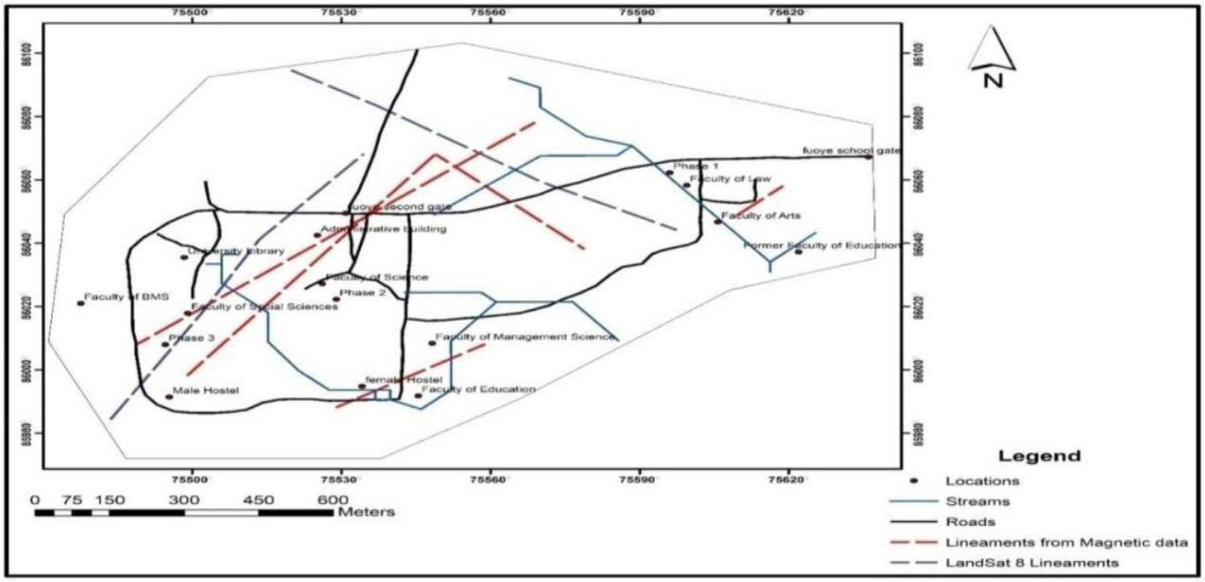


Fig. 12: Composite Lineament Map from Aeromagnetic and Landsat 8 of the Study Area

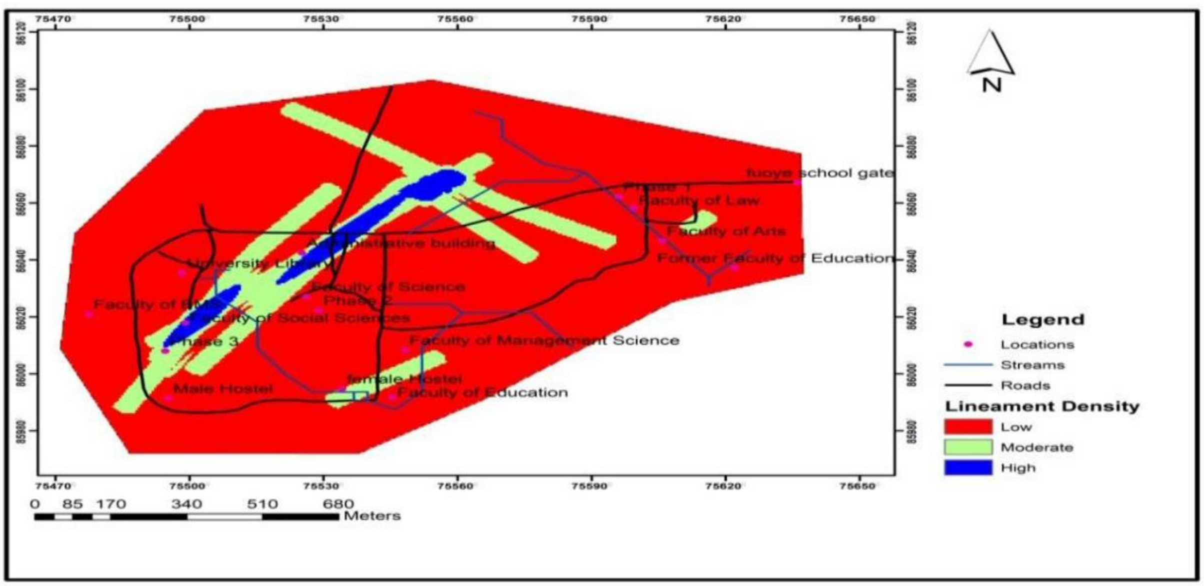


Fig. 13: Lineament Density Map of the Study Area.

Conclusion

Landsat and aeromagnetic data covering the study area were subdued to various images and data enhancements. The total magnetic intensity over the study area after digitization showed a magnetic signature ranging from 59.6 nT to 87.4 nT.

The aeromagnetic and Landsat lineament maps of the study area have been encapsulated using rose diagrams, divulging NE-SW as the major trend with some secondary trends NW-SE and E-W directions. The study area is underlain by a major rock type (migmatite gneiss) which has shallow manifestations in areas of low lineament densities (Bala, 2021). The groundwater development in the area is highly reliable in places where the lineaments intercept each other (areas of high lineament density coupled with deep basement) as showed on the composite lineament and lineament density (Ilugbo and Adebiyi, 2017, Aroyehun, 2022). The groundwater systems within the lineament intercept zones of the study area are structurally controlled and this will provide solution to the water scarcity arising from seasonal and failed boreholes problem within the campus.

Declaration of Conflict of Interests

The authors declare no conflict of interests.

Authors' Contributions

Conception: [OO]
Design: [OO, MA, OB,]
Execution: [OO, MA, OA, OO, SG]
Interpretation: [OO, MA, OO]
Writing the paper: [OO, MA, OA, OO]

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