



# Science Forum (Journal of Pure and Applied Sciences)



Journal Homepage: <https://atbuscienceforum.com.ng/index.php/jpas>

## Lineament Extraction and Structural Analysis Using TMI and SRTM Data in Rogo Area Northwestern Nigeria

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### Abstract

This study evaluates the application of Geographic Information Systems (GIS) and remote sensing techniques for lineament extraction using Total Magnetic Intensity (TMI) and Shuttle Radar Topographic Mission (SRTM) data. The methodology involves extracting lineament features, analyzing their spatial distribution, and examining their relationship with regional tectonic structures. Lineament extraction from SRTM and TMI data requires preprocessing to enhance linear features, followed by the application of specialized algorithms within ArcGIS 10.8.2 to identify and digitize these features. The extracted lineaments represent potential fault zones or structural trends influenced by variations in the magnetic field, indicative of underlying geological structures. To assess the effectiveness of different datasets in geological mapping, lineament analysis was conducted separately and simultaneously on TMI and SRTM-derived data. The extracted lineaments were compared to evaluate their spatial correlation and significance. Lineament density maps were generated to highlight areas of structural complexity, which are crucial for understanding subsurface geology. Findings indicate that a structurally complex zone identified from the SRTM data corresponds to quartzite ridges, likely reflecting surface faults. In contrast, a complex area detected in the northern part of the study area using TMI-derived lineaments may indicate subsurface faults, which could have implications for geological exploration. These results demonstrate the value of integrating remote sensing and geophysical data for structural analysis and potential resource exploration.

### Keywords

Fault,  
Lineaments,  
Magnetic,  
Structures,  
Tectonic.

## 1.0 Introduction

Lineament identification has become increasingly valuable to structural recognition (Yassaghi, 2006). Digital elevation models (DEM) derived from the Shuttle Radar Topography Mission (SRTM) data were used in this study to extract and map potential geological lineaments in the study area. The transmitters and receivers is able to manifest and detect features in spatial distribution. This study implemented several analysis and image processes to extract and map geological lineaments.

The magnetic data used for the study is a high resolution 100 m × 100 m grid of the total magnetic intensity (TMI) derived from aeroagnetic data collected along flight lines spaced 400 m apart. The magnetometer had a mean terrain clearance of 80 m and a recording interval of 0.1 s. The data was acquired for the Nigerian Geological Survey Agency between 2003 and 2010.

The lineaments were extracted from satellite images using manual lineament extraction techniques. Manual extraction criteria for the lineaments were based on photographic characteristics, such as (shape, size, pattern, shadow, tone and texture), geomorphologic features (fault-scarp, straight valley and drainage patterns). A series of landform interpretation experiments were conducted on the images by using different false color composites (FCC). A high-pass filter was implemented to explore the distribution of pixels of varying brightness and to detect and sharpen boundary discontinuities in the images. Shaded relief maps were constructed from the SRTM DEM by varying the azimuth and elevation of simulated sun illumination. To emphasize trends perpendicular and parallel to the sun azimuth (Soulakellis et al., 2006; Singh et al., 2007). The

extracted lineaments were statistically analyzed to create rose diagrams and to evaluate differences in lineaments' direction, count, density, and lengths. This study reveals that dominant lineaments tend to run NNW-SSE and NNE-SSW. Analysis and interpretation of extracted lineaments provided information about the tectonic evolution of the study area. The surface features making up a lineament may be geomorphological, i.e. caused by relief or tonal, i.e. caused by contrast differences. Straight stream valleys and aligned segments of a valley are typical geomorphological expressions of lineaments.

A tonal lineament may be a straight boundary between areas of contrasting tone. Differences in vegetation, moisture content, and soil or rock composition account for most tonal contrast. In general, linear features are formed by edges, which are marked by subtle brightness differences in the image and may be difficult to recognize. On the earth, lineaments could be (1) straight stream and valley, (2) aligned surface depressions, (3) soil tonal changes, (4) alignments in vegetation, (5) vegetation type and height changes, or (6) abrupt topographic changes. All of these phenomena might be the result of structural phenomena such as faults, joint sets, folds, cracks or fractures. A systematic study of these factors leads to better delineation of prospective zones in an area which is then followed up by ground trothing.

In remote sensing images, geological lineaments show up as lines or linear structures that are significantly brighter or darker than the background pixels. Such lineaments include: faults and fractures that have obvious displacement, ruptures that have no significant fracture displacement (e.g, joint zones, cleavage belts, structural fissures, and tectonic crush

zones), large crustal fractures, deep faults, buried faults, linear micro-geomorphological features, and linear traces can manifest abnormal hues (Vassilas et al., 2002). Conventional detection of geological lineaments on the field is costly and time-consuming, and sometimes, it is even impossible due to physical and geographical challenges. Therefore, during the last decade, geological lineament detection via remote sensing has been widespread, leading to effective results for many applications. The routine procedure for geological lineament extraction from digital remote sensing data usually involves initial digital image enhancement followed by manual interpretation. There have been significant approaches for the evaluation and automatic detection of lineaments and curvilinear features from satellite images (Karnieli et al., 1996), but the human expert is still an asset for lineament

detection and interpretation with its subjective perception (Suzen and Toprak, 1998).

Digital enhancement of TMI and SRTM data results in extraction of maximum information and an increased interpretability. GIS techniques facilitate integration and analysis of large volumes of data. Whereas ground truthing help to validate results further and offer a better understanding of features in hard rock.

## 2.0 Study Area

The study area lies within Rogo Local Government Area of Kano State Nigeria. It is situated within latitude  $11^{\circ} 30' 00''$  N and  $11^{\circ} 37' 30''$  N and longitude  $07^{\circ} 45' 00''$  E and  $7^{\circ} 52' 30''$  E (fig 1). The area is accessible through a major road, such as that linking Karaye to Rogo and a minor road from Kudan to Rogo. There are also footpaths, dry rivers and stream channels also used in accessing the remote parts of the area.

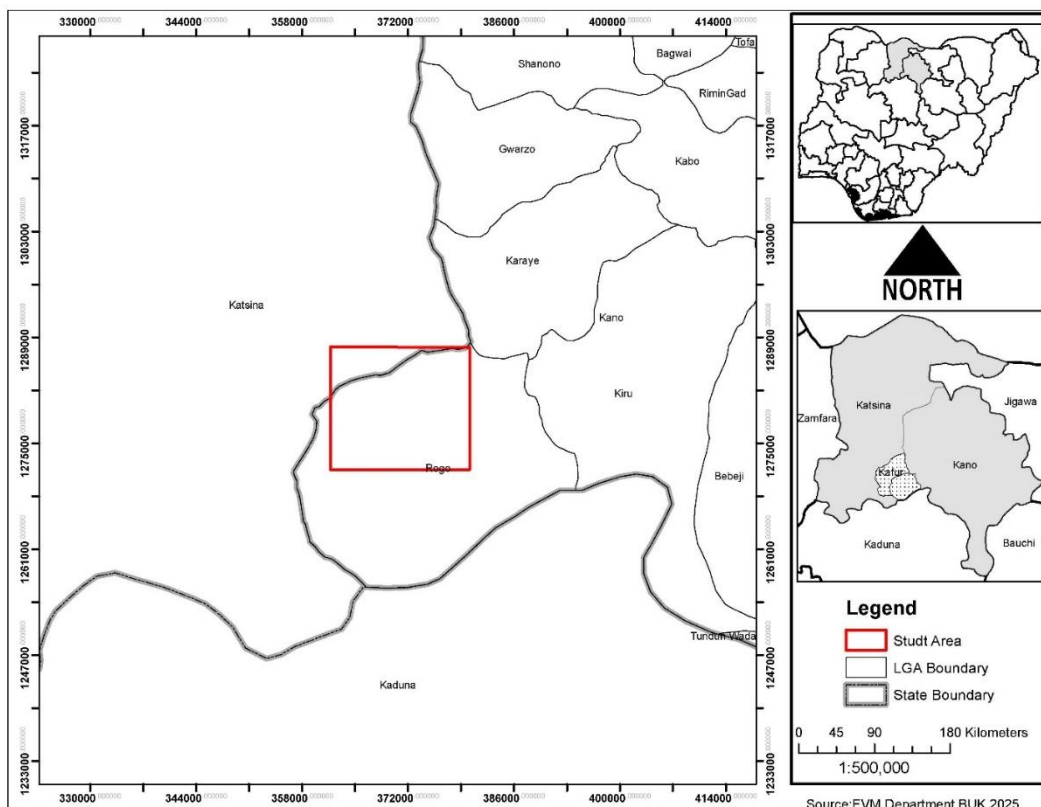


Figure 1. Map of the study area

Geologically, it is situated on the Precambrian to Lower Paleozoic crystalline basement complex of northern Nigeria comprised mainly of granitic gneisses, quartzite/schistose rock, medium to coarse grained biotite granite and porphyritic biotite granite. The granitic gneisses are grouped under the Precambrian migmatite-gneiss complex rocks; quartzite/schistose rocks are Precambrian metasedimentary rocks, whereas the medium to coarse grained biotite granite and porphyritic biotite granite belong to the Lower Palaeozoic and

are referred to as the Older Granites or Pan-African granitoids (NGSA, 2009).

### 3.0 Materials and Methods

The aim of this paper is to create a methodology for digital extraction and lineament analysis. The processing is developed based on the map scale of 1:50 000. (Fig 2) shows the major steps which are applied for the lineament analysis.

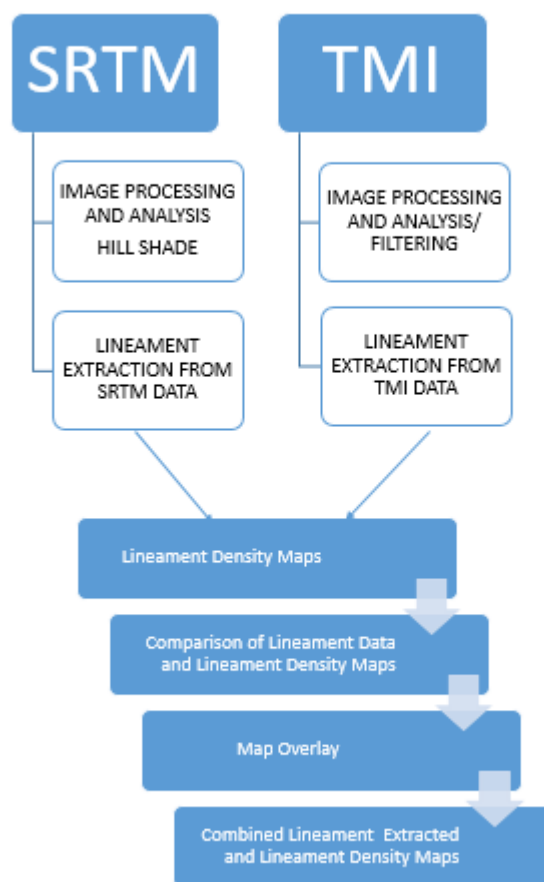


Figure 2. Methodology used to identify and analyze lineaments

Digital lineament extraction is performed by visual interpretation by human operators are well suited for spatial assessment; the identification is facilitated using an image enhancement process e.g., directional filtering, band ratio. Once

appropriate features are interpreted they are manually to demarcate the geological features. This 100 m spaced grid is lower resolution than the SRTM data, but has the advantage of showing subsurface geological features with a magnetic

susceptibility contrast that may have no topographic manifestation. Key steps in lineament extraction from TMI data, involves ensuring that the lineaments occur in the correct location. Characteristic points on a magnetic anomaly (peaks and locations of greatest slope) can shift depending on the magnetic inclination of the Earth's field (Dentith and Mudge, 2014). At the magnetic equator and magnetic pole, the locations of maximum gradient correspond most closely to changes in magnetic susceptibility, so the most accurate location of geological lineaments requires the data be transformed mathematically as if the data were collected at the pole of equator.

Close to the equator, the pole transformation is unstable, so these data are usually transformed or reduced to the equator (RTE) This transformation assumes that there is no remanent magnetization, and if some is present then there can still be a shift in the characteristic points and an error in the location of the lineaments (Dentith and Mudge, 2014). The regional field was removed and the resulting residual field analyzed. Filtering of TMI by applying spatial filters like high-pass filters can accentuate linear features and remove unwanted signal or noise. The first vertical derivative (FVD) of the data is an example of a high-pass filter commonly used to highlight sharp magnetic gradients associated with faults.

Lineaments are identified on these maps through digitization within a GIS platform. Automatic lineament extraction uses specialized software algorithms like "LINE" in GIS to automatically identify and extract linear features based on predefined parameters like edge detection, thresholding, and curve fitting. Images can also be enhanced using principal component analysis (PCA): A statistical technique to reduce data dimensionality that can isolate the most significant linear features.

### 3.1 Lineament Analysis and Interpretation

The spatial character of might be lineaments that are subtly evident in the image are first enhanced by applying non-directional edge filtering technique. For each non-directional filters enhance linear features having almost any orientation in an image. Directional filters were applied to the image for detailed identification of linear features in a specific direction, but the direction must be chosen carefully, as features oriented perpendicular to the specific orientation are not enhanced (Haralick et al., 1987), An example of a directional filter is a first derivative edge enhancement filter that selectively enhances image features having specific direction components (gradients). The east direction that can be used to highlight faults and lineaments oriented approximately north-south.

Several false color composite (FCC) images have been created and visually interpreted to improve the possibility of lineament extraction. Directional filters were used to enhance specific linear trends in the image (fig 3). The detected lineaments were later analyze to calculate the lineament density. (Fig 4) which shows the concentration of lineaments in specific areas to identify zones of high structural complexity.

## 4.0 Results

### 4.1 Data Presentation and Analysis

Computer based manipulation in digital data processing is done to enhance the data for accurate and appealing imagery that can provide better information about the raw data. Data extraction algorithms are used to extract geological features.

In (fig 2) SRTM and TMI data set were used to produce shaded relief maps at intervals of sun angle in ArcGIS environment using "Hillshade tool". After generation of the shaded relief maps, lineaments were manually digitized on map scale, to ensure all lineaments are geological features

the extracted lineaments of SRTM and TMI were compared and non-geological features were eliminated from the lineament output to produce Lineament density map using "Line density" tool in ArcGIS. The extracted lineaments and lineament density data were then compared before computing statistical analysis. Map overlay of SRTM and TMI data done and the final output result is combined lineament extracted and density map. Rockworks software was then employed to prepare the rose diagram to understand the orientation of the lineaments.

#### 4.2 Lineament extraction from TMI Data

TMI map of the area, shown in (fig 3), shows that the TMI values range between 32743 to 32942 nT and were characterized by short wavelength (high wavenumber), medium wavelength (moderate wavenumber) and long wavelength (low wavenumber) anomalies. Figure 5a shows that the northeastern (NE) and northwestern (NW) parts were predominantly occupied by anomalies associated with high TMI values while the remaining portions of the area were occupied by anomalies associated with low TMI values. Furthermore, the map showed that the trends of the TMI anomalies were mostly oriented along NW-SE directions

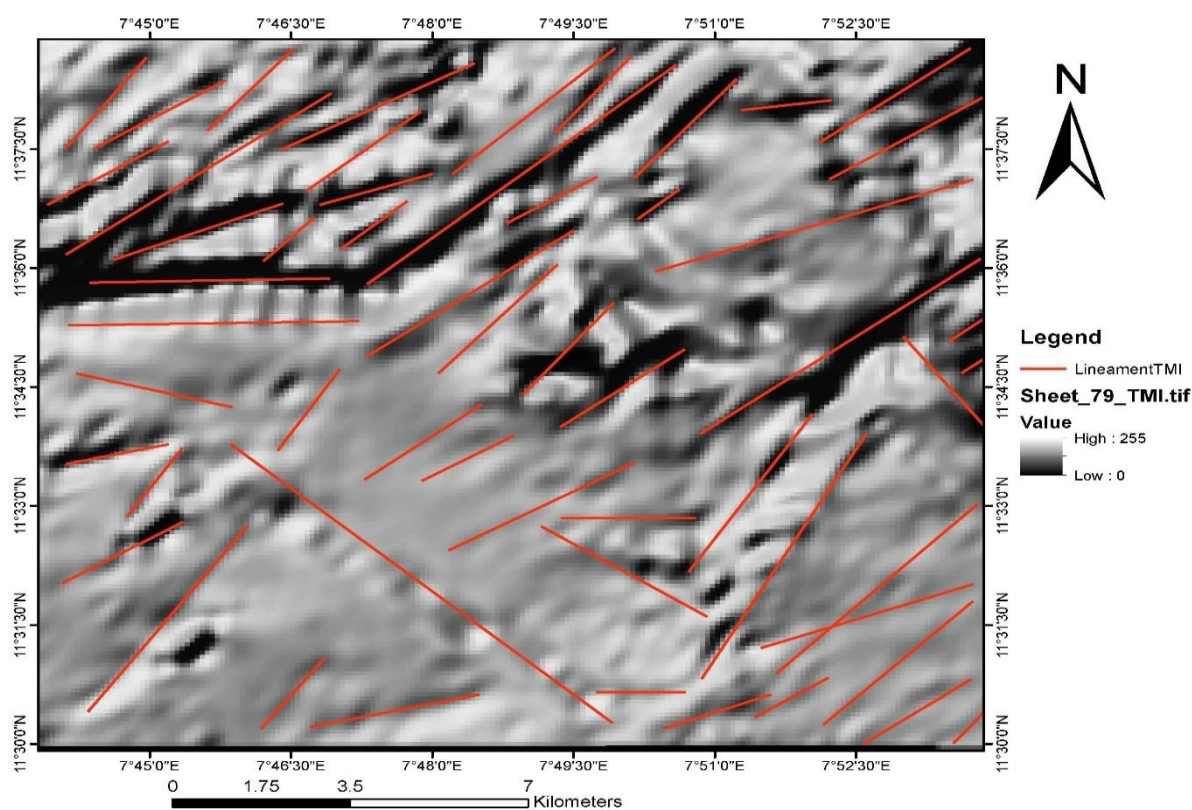


Figure 3. TMI Image of the study area

#### 4.3 Lineament extraction from SRTM Data

The Shuttle Radar Topography Mission (SRTM) data is shown on (fig 4) enhanced with a sun angle of 180°. SRTM images were used to extract the lineaments at this and other sun angles in this

study. The number of extracted lineaments changes with the use of different sun angles, so a number of these angles can be used to identify more with the SRTM data.

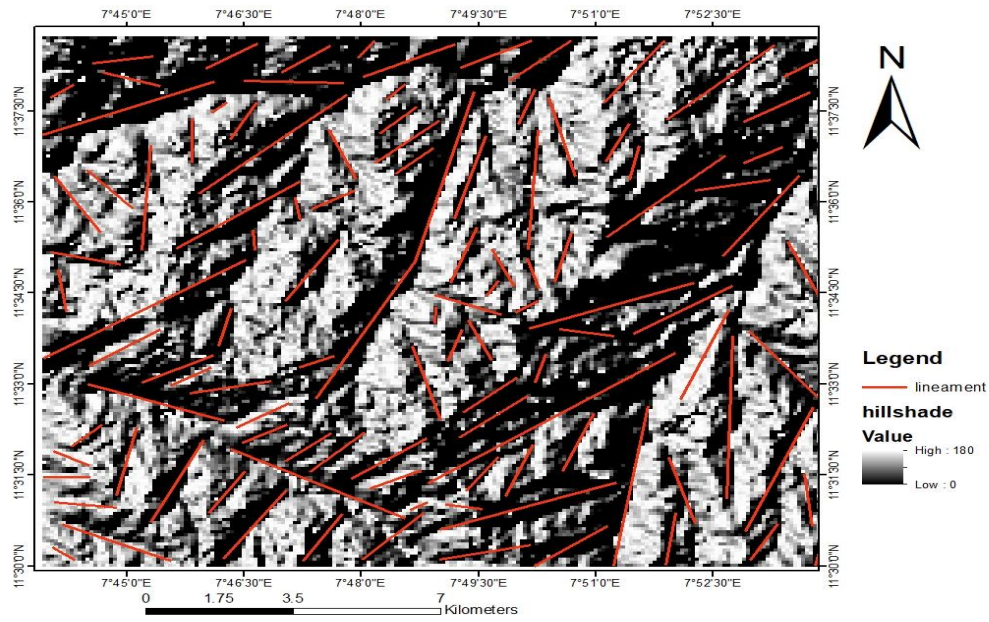


Figure 4. Shuttle Radar Topography Mission (SRTM) data showing the hill shade sun angle at 180° with lineament lines.

In Table 1 lineament extracted from SRTM and TMI were calculated and the mean length was determined. Lineaments from TMI were less with 54 only compared to SRTM with 109 while the mean average distance of the data, seem on (fig 5a and 5b) is 3.49 km for TMI and 2.05 km for SRTM.

Table 1. Statistics of extracted lineament from SRTM and TMI

Data	Number of lineaments	Total Distance (KM) length	Mean (Length)
TMI	54	188.28	3.49
SRTM	109	223.16	2.05

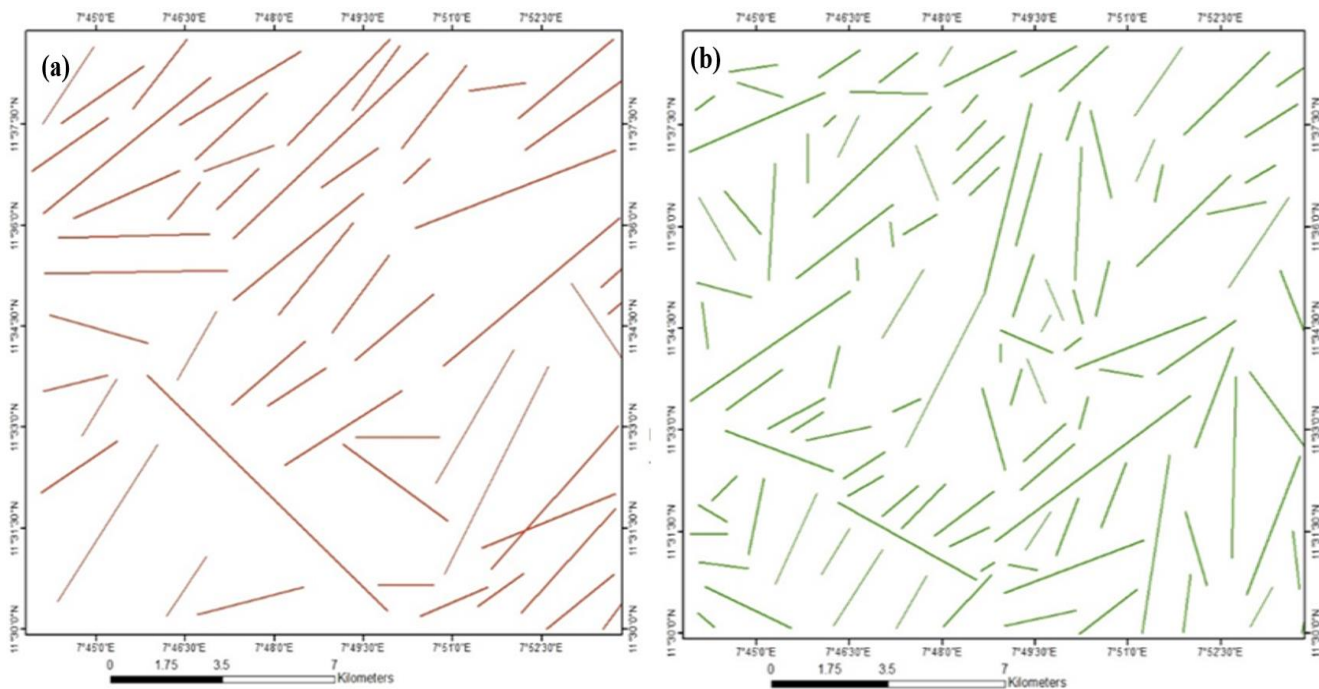


Figure 5. Lineament extracted from a) TMI and b) SRTM Image

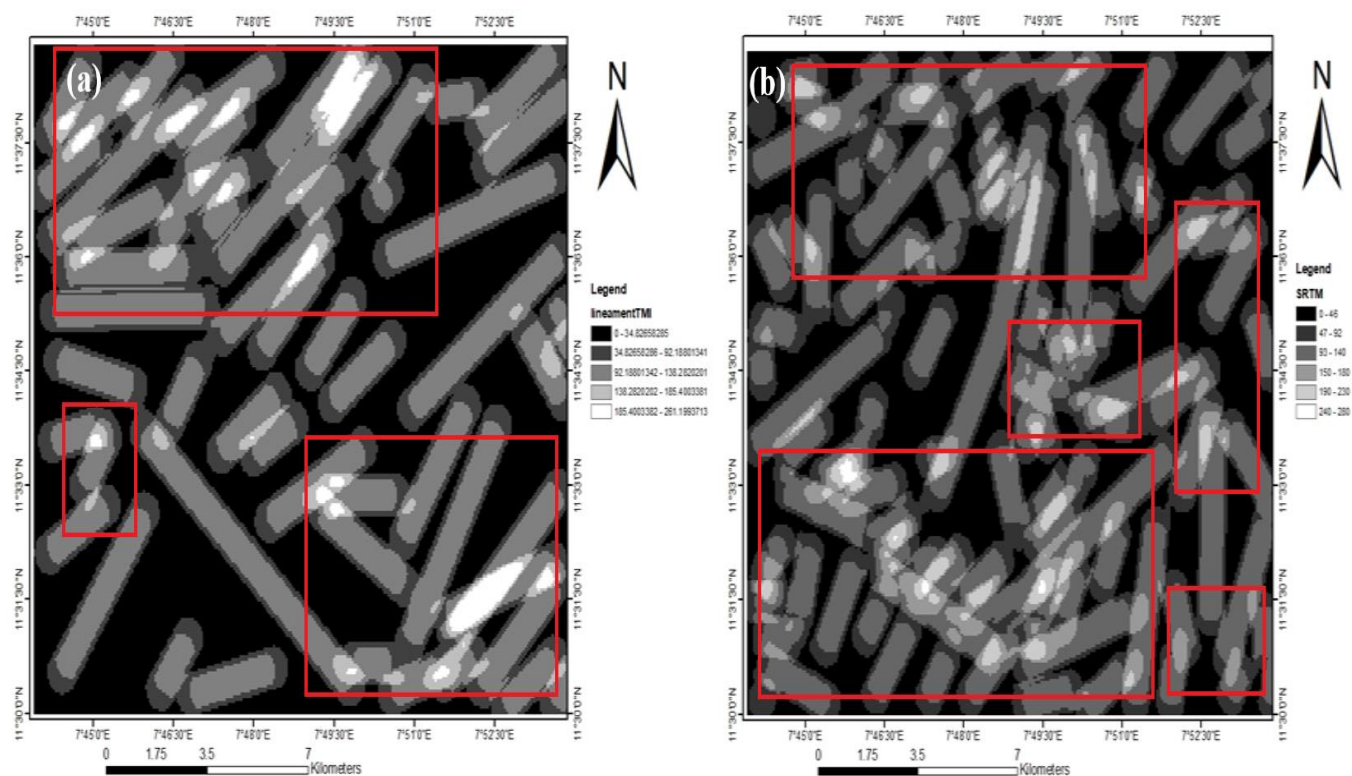


Figure 6. Lineament density map from a) TMI and b) SRTM image derived from a sun angle of  $180^\circ$

The lower southern part of the map in (fig 6b) has a higher density of lineaments indicating an area that is structurally controlled and this corresponds to an area in the field where there are quartzite ridges which are good markers of regional faulting. The area with the higher lineament density for the TMI (fig 6a) is observed to be at the upper left side and lower right section with the longest lineament trending

NW-SE at the lower left side. The frequency and length of this lineament indicate a probable reactivation of faults. The result of this study indicate that, the study area is most likely related to dextral (fig 8a) wrench fault system with displacements which appear in the order of the tens of kilometers. The lineaments are also, associated with locally developed conjugate sinistral faults

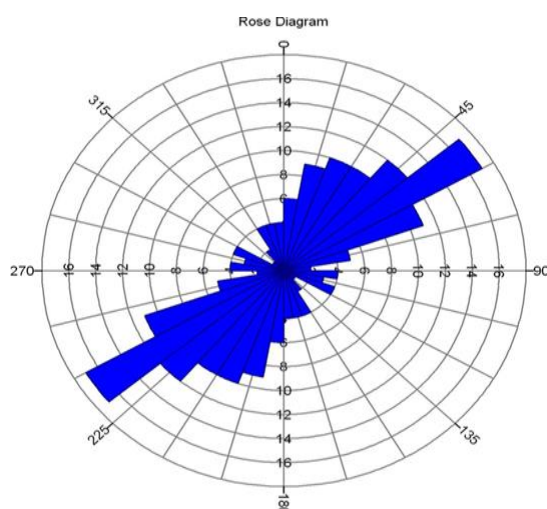


Figure 7. Rose diagram: Plotting the azimuths of extracted lineaments to identify dominant structural trends in the study area

## 5. Conclusion

We have used images of total magnetic intensity TMI and Shuttle Radar Topographic Mission (SRTM) data to identify what could be geological lineaments. The segregation of TMI data for

lineaments extraction based on angles of the geological formations allowed us to obtain information about the tectonic evolution of the investigated area.

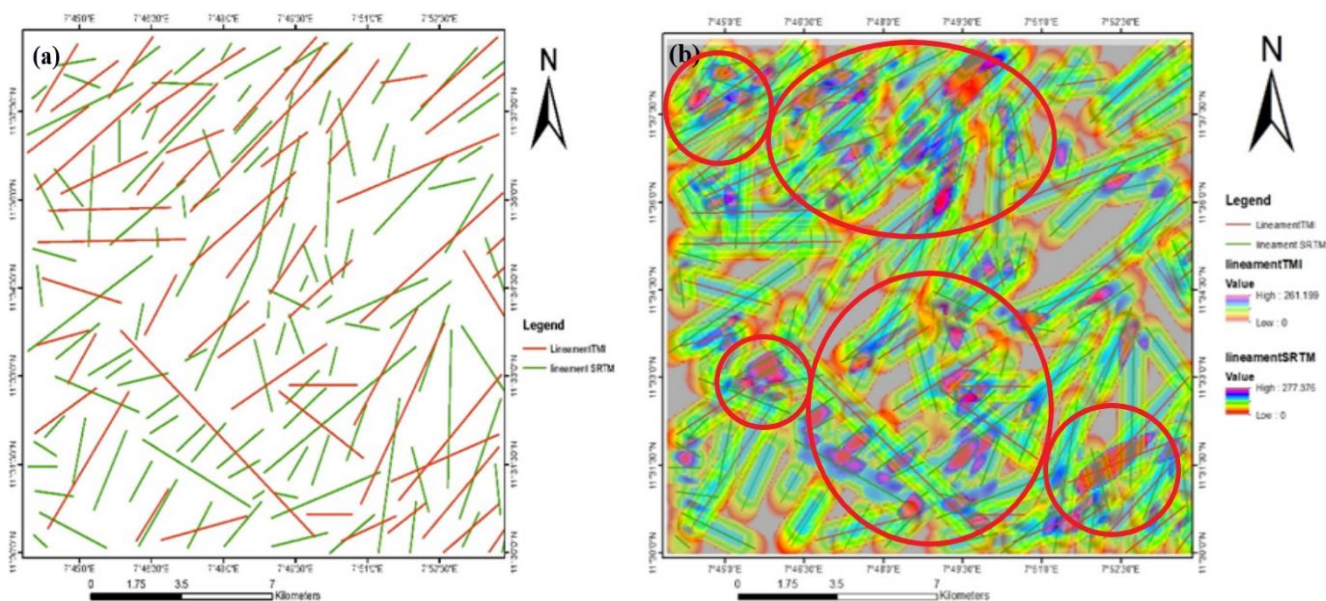


Figure 8. a) Combined lineament extraction and b) density map for TMI and SRTM circled areas reflecting high structural complexity.

The SRTM data are images of the topographic surface and field studies confirm that there are quartzite ridges in the ore complex areas. These quartzite ridges may reflect faults, which are often associated with mineral deposits, particularly gold. The areas of high structural complexity in the magnetic data are reflecting complexity in the subsurface geology and these could be prospective for mineral deposits as well. These structurally complex areas are worthy of further ground trothing at surface, further geophysics and if these are encouraging, further investigations at depth, such as trenching or drilling. The results also show that, lineaments extracted from TMI data are longer and few (54) in number compared with SRTM which are many (109) and shorter density and distribution of the lineaments, and topographic and geologic factors.

## 6. Acknowledgments

This work is part of my PhD thesis and wish to specially thank Prof A I Haruna Chairman Supervisory Committee and Prof. Richard Smith my supervisor as a visiting scholar in Laurentian University Canada for his time to improve the manuscript, with constructive criticisms, and suggestions. I alone remain responsible for any mistake that escapes scrutiny.

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