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Lineaments Extraction from Remote Sensing Data for Detection of Hydrothermal Alteration zones in Northern Nigeria.

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Abstract: *Nigeria is a country blessed with abundant mineral resources of which only a small percentage has been harnessed; this is due to its focus on crude oil as the primary source of income. However, since prices of crude oil have drastically fallen, the nation has woken up and wants to explore the mineral resources sector to reduce dependence on oil and improve her gross domestic income (GDP).*
This research explores remote sensing and GIS techniques to efficiently extract lineaments of the study area from band 4 of Landsat 7 ETM+ in PCI Geomatica with the help of its LINE extraction algorithm. Nonetheless, false colour composite of bands 4:7:3 in RGB respectively showed locations of possible hydrothermal alteration zones in purple hue. Comparing the lineaments image with the bands 4:7:3 composite image showed that there is a correlation between locations with prevalence of lineaments and locations with purple hues. Overlaying existing/known minerals locations (obtain from Nigeria Geological Survey Agency (NGS)) on the lineaments density map corroborate the existence of hydrothermal alteration zones as obtained from the image processing.
Keywords: *Mineral mapping, Remote Sensing, Nigeria, Lineaments, Hydrothermal Alteration.*

I. Introduction

The global fall in oil prices is a wakeup call for countries such as Nigeria, a nation where crude oil forms about 90% of its export commodity. The fall in global oil prices has adversely affected the Nigerian economy because of its dependence on imported goods. This has resulted in budget deficit thereby making the government to borrow in order to fund the budget [1][2][3]. As a measure to address the economic doldrums, the current government is bent on reviving the economy by introducing or re-introducing former industries such as farming and solid minerals exploration [4][5]. Geospatial technology a less expensive, reliable and less cumbersome strategy for mineral detection and exploration should be implemented [6].

Thus, exploring new technology such as spatial technology for mineral prospecting in Nigeria will be of great help in terms of time and cost saving while covering large area of land [7]. Using remote sensing and GIS for mineral exploration has been in existence for a long time and there have been quite a number of publications on its application in lineaments extraction but not quite as many in mineral mapping in Nigeria. For instance, [8] carried out a research on the use of spatial analysis in Bwari Area Council to detect hydrothermal alteration zones. The result of the research was compared with existing mineral deposits maps and it was determined that the use of remote sensing agree with the existing maps and did better because the spatial technique was able to detect alteration zones that were previously unknowns or not appearing on the existing maps. Other researchers that used satellite images for lineament extraction are [9] [10][11].

Majority of the Nigerian states are not taking full advantage of the natural resources available in their domain, either due to negligence or lack of adequate information on the extent of mineral deposits and its effect on their economy. It is in light of the above, that this research aim to use Landsat 7ETM+ data to detect hydrothermal alteration zones in Northern Nigeria by extracting structural lineaments and creating bands combination. Lineaments are linear or curvilinear features on the earth surface which may be created during a structural phenomenon such as fault, fracture and joint [6]. The prevalence of lineaments is an indication of high tectonic activity or a result of human induced activities which in turn may indicate a possibility of deposition.

II. Study Area

The study area is situated in the northern part of Nigeria covering some part of Kano, Jigawa, Kaduna, Bauchi state lying between coordinates of 7° to 10°E and 10° to 12°N. The Northern Nigerian Basement Complex comprises three groups of rocks namely, migmatites and (high grade) gneisses derived from Birrimian sedimentary rocks through high grade metamorphism and granitization; the Younger Metasediments of Upper Proterozoic age which are low grade metamorphic rocks that were folded along with the migmatite and gneisses during the Pan-African orogeny; and the Older Granite series which were intruded during the Pan-African orogeny [12]. In the study area, [13] also reports the occurrence of rocks of the Younger Granites series [14] so termed because they are Jurassic in age, as well as volcanics, and occasional younger dykes and flows.

The crystalline Basement complex rocks are the oldest in the area, and they include both igneous and metamorphic types. The three divisions of the Basement rocks generally recognized in the area are the migmatites-gneiss complex, the meta-sedimentary rocks and the Older (or Pan African) granites.

The various rock units and formations include; Granite-gneiss, Biotite granites/fine grained, biotite-granite, Charnokitic rocks, Migmatite-Gneiss, and Granite porphyry.

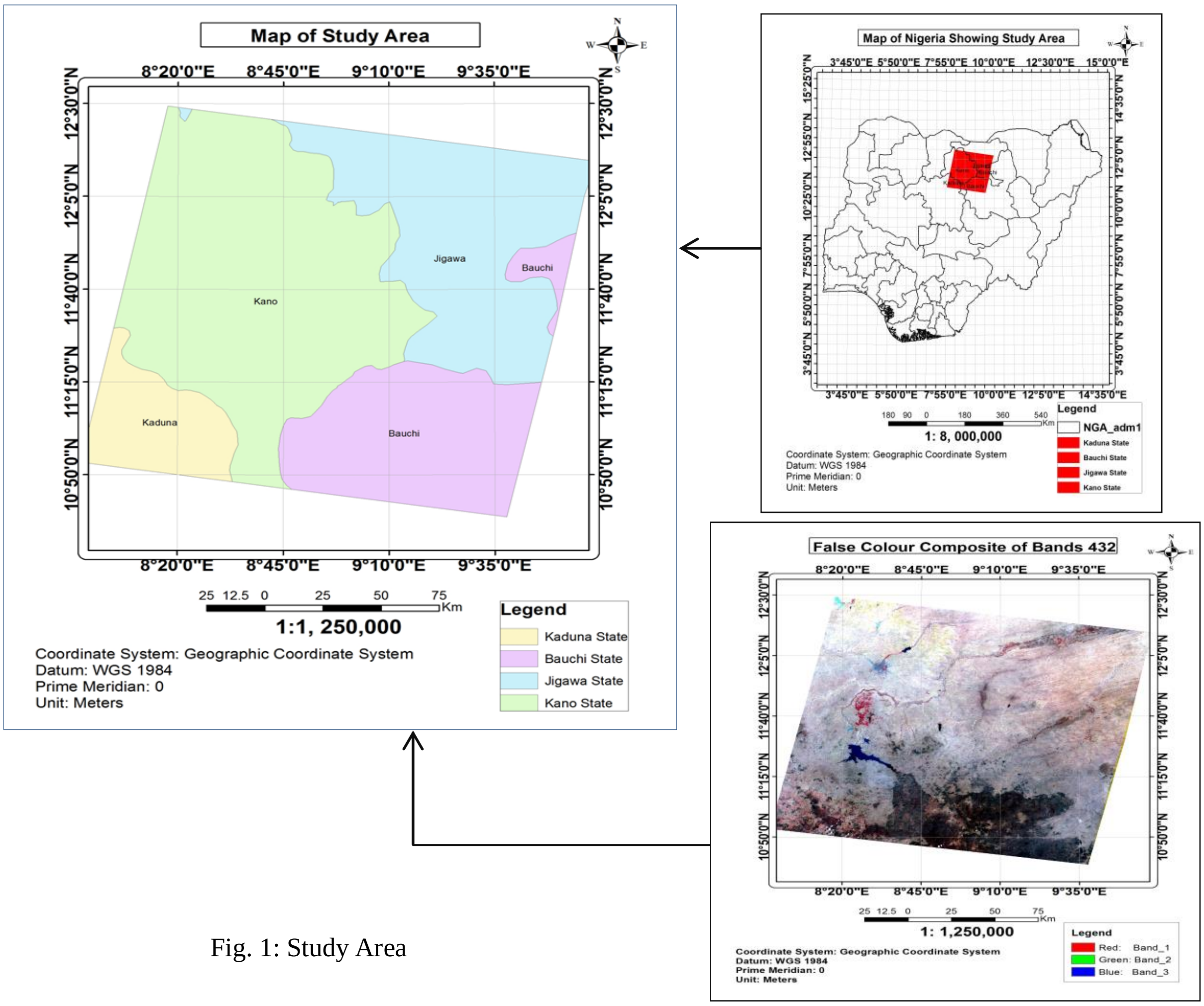


Fig. 1: Study Area

Data and Pre-processing

The methodology used in this study is shown in the flowchart below, which provide a step-by-step breakdown of the stages taken to arrive at the required result:

Landsat 7 ETM+ containing 6 bands acquired on 2009-06-08 and digital elevation model (90m DEM) was obtained from U.S. Geological Survey. The image was geometrically project to UTM Zone 32 N and WGS-84 in order to avoid distortion, and then converted to radiance from digital value (DN). Shapefiles of the study area were obtained from National Space Research and Development Agency in Nigeria. In addition, existing mineral deposit locations were obtained from geological survey of Nigeria.

III. Methodology

The Canny edge detection algorithm of Geomatica V9 is applied to the pre-processed band 5 image where the image is filtered by Gaussian functions whose radius is given by the RADI parameter. In addition, Gradient computation is applied followed by suppression of non-local maximum gradient producing an edge strength image. The edge strength image is then subjected to further thresholding in order to obtain a binary image. Having executed the thresholding and the filtering processes, structural lineaments were then extracted from the binary edge image by subjecting it to LINE algorithm of Geomatica V9 [15] Afterwards the extracted structural lineaments were exported to ArcGIS v10.1 and corrected by removing and filtering irrelevant structures using the expertise/professional knowledge of the study area. The resultant structural lineaments were subjected to geometric calculation to obtain polyline angles which is integrated in RockWorks 16 software to create Rose diagram. The rose diagram shows lineament trend or direction. A structural lineament density map was produced.

The final processing was done by combining bands 4:7:3 to corroborate the result found in the lineament extraction by delineating possible hydrothermal alteration zones.

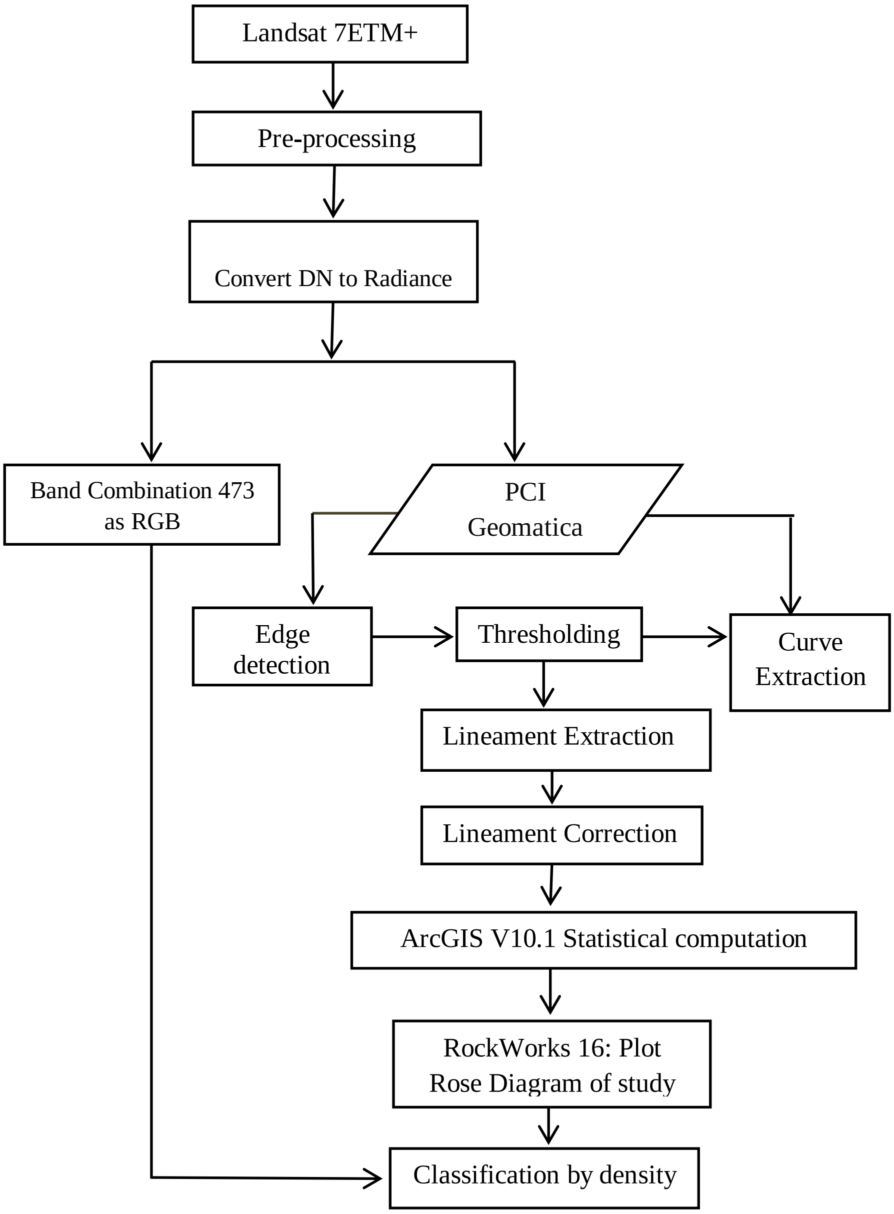


Fig.2: Flow chart of lineament and bands combination analysis.

IV. Result and Discussion

False Colour Composite

The contrast stretched bands 4:7:3 false colour composite was examined for areas of potential mineralization. It was found that converting the original image form digital number (DN) radiance during the pre-processing further enhanced the detection of the hydrothermal alteration zones identified as purple hues, while built-up areas appeared as cyan, water as deep blue, vegetation as red and bare-surface as white colours respectively (Fig 3). Since structural lineaments are essential for mineral mapping as their presence may indicate potential for the presence of deposit [16]; band 4 of the Landsat7 ETM+ was used to extract lineament in the study area (Fig. 4). The lineaments in Fig 4 appeared as straight or curvilinear features representing man-made structures such as transportation networks e.g. roads, canals, etc. or natural structures such as faults/fractures, lithological boundaries, unconformities or drainage networks such as rivers. The longest lineament is identified as part of a river originating from Jigawa state and running in a South-West direction. Displaying the two maps side by side (i.e. 4:7:3 band composite in RGB and the extracted lineaments); hydrothermal alteration zones indicated in purple (Fig. 3) coincided with the locations of lineament (blue linear/curve-linear features in Fig. 4) which are in a NE-SW direction as shown by the rose diagram (Fig. 5).

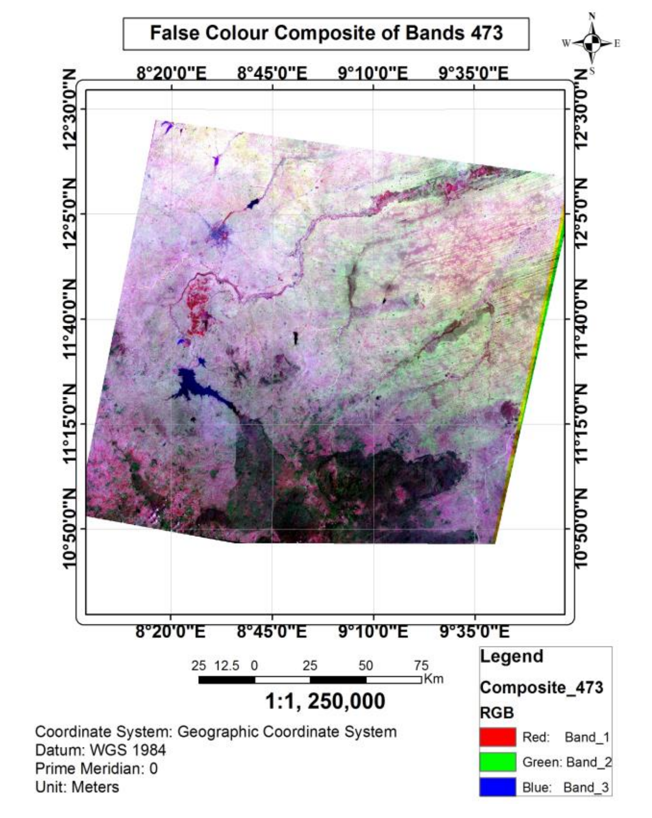


Fig. 3: False Colour Composite Of Bands 4:7:3 In RGB

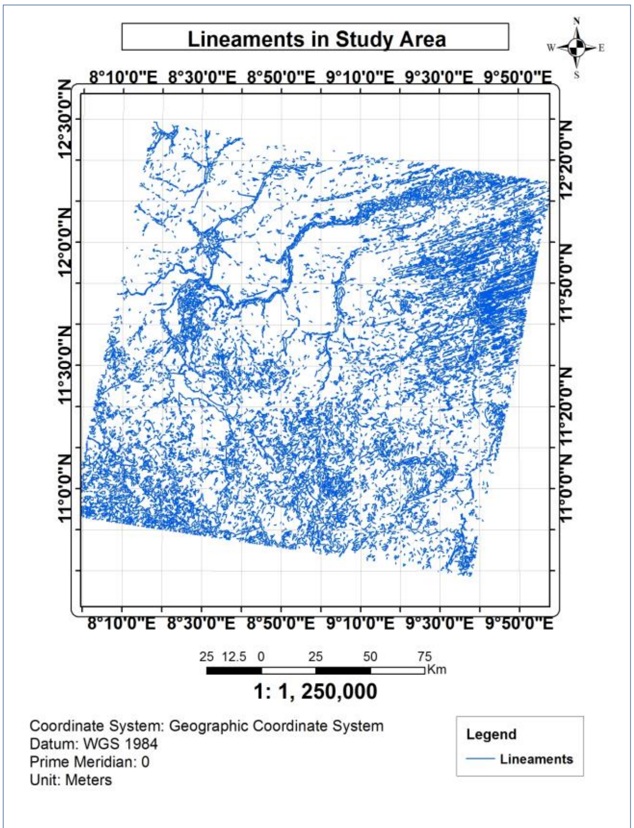
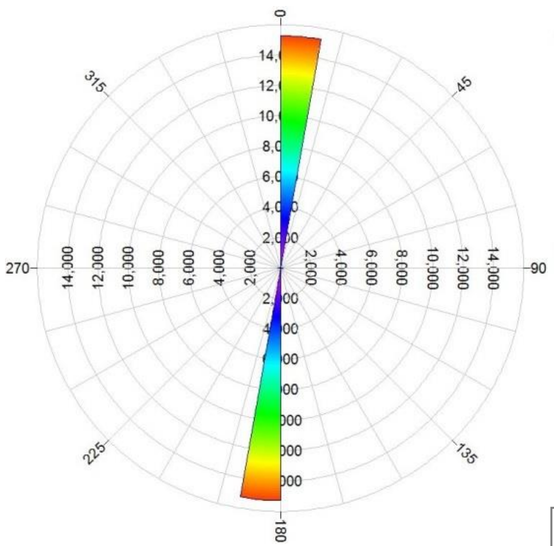


Fig. 4: Extracted Lineaments Overlaid on Band4

The structural lineament density map was generated in order to highlight areas with high prevalence of the structures from the statistics generated; the shortest lineament is 0.007883km while the longest lineament is 17.2473km trending majorly in a NE-SW direction formed during the Pan African crustal [17].



Statistical Summary	
Calculation method:	Length
Class Interval:	10.0 Degrees
Azimuth Filtering:	Activated
Minimum Azimuth #1:	0.0 Degrees
Maximum Azimuth #1:	360.0 Degrees
Data Type:	Bidirectional
Population:	15.432
Total length of all Lineation:	462.83
Maximum Bin Population:	15,273.0
Mean Bin Population:	5,144.0
Standard Deviation Bin Population:	7,846.2
Maximum Bin Population (%):	49.48
Mean Bin Population (%):	16.67
Standard Deviation Bin Population (%):	25.42

Fig. 5: Rose Diagram showing direction for which the lineament trending

A lineaments density map was generated in order to highlight locations with high prevalence of the structures (Fig. 7). Thus, Red colour represents areas with the highest prevalence while ash colour represents areas with the least prevalence. Overlaying the lineaments on digital elevation model (DEM, Fig. 6) and contours on the lineaments density image (Fig. 7) showed that the largest patch with the highest number of fractures appears in the North-East (jigawa) part of the image and on an elevation of at most 500m (i.e. orange circle). The second largest area with a predominant number of faults line (i.e. green circle) appears on an elevation of 700m. Meanwhile, the highest elevation in the image is 1097m and it contains the third largest prevalence of fault lines (i.e. purple circle); this shows that area with the lowest elevation experienced significant impact of tectonic activity in the study area. It should be noted that from ground-truth the locations in black circle represent water body and built-up areas.

However, because of the large spectral width between Landsat ETM^+ bands, detection using this band combination (i.e. 4:7:3) is more of a general way of mapping the hydrothermal alteration zones [18]. Therefore, a more precise way of pinpointing and mapping mineral deposits is the use of images with narrow spectral bands such as Aster and Hyperion.

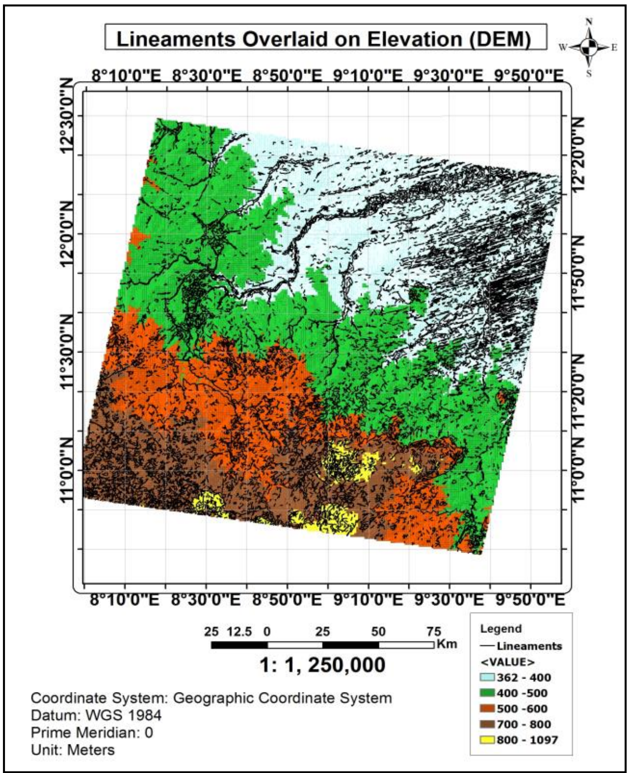


Fig.6: Elevation in meters of the Study Area showing lineaments

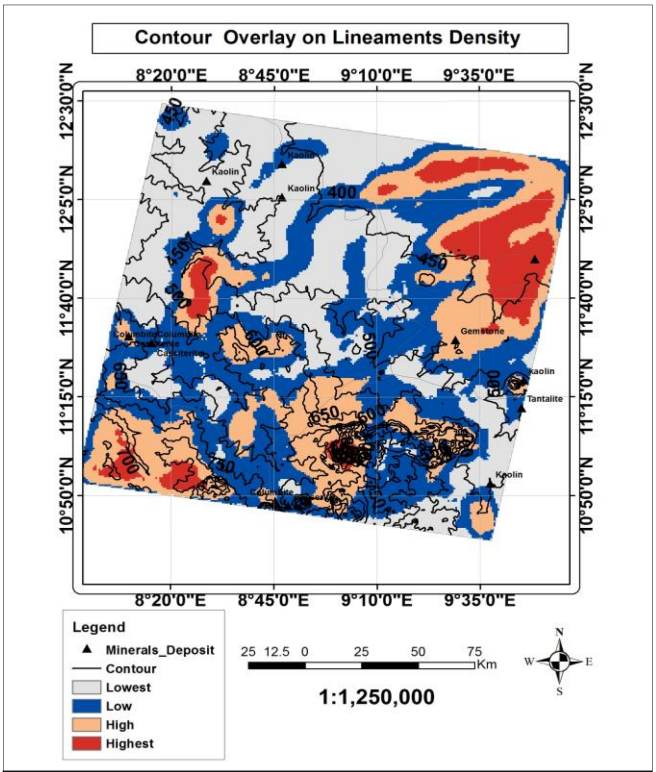


Fig.7: Lineaments Density showing Elevations

V. Conclusion

The high prevalence of fault lines in the orange, green and purple circles can be attributed to the effect of high rate of tectonic activities in those regions which is more pronounced in the orange circle than the other two. Whereas, the mineral deposit represented by black triangles in fig. 7 are some of the existing and known locations of minerals deposit which include but are not limited to kaolin, cassiterite and columbite etc in kano and Bauchi state while Jigawa state contains gemstone, kaolin etc as provided by the Nigeria Geological Survey.

Since band combination 4:7:3, lineament extraction and existing geological/mineral maps are in agreement with the locations of potential mineralization, it goes without saying that spatial technology can be applied in Nigeria for mineral prospecting. Remote sensing data such as satellite imagery make lineaments extraction easier, time saving and cheaper than the traditional method. However, limitations encountered with using remote sensing data (especially satellite images) in mineral prospecting is that, man-made features such as built-up areas, and impervious surfaces appear as hydrothermal zones due to their high reflectance properties and the building method/materials used in creating them. For instance, in this research, man-made features such as built-up areas and roads were also represented as lineaments; this can interfere with the accuracy of the result.

Therefore, the use of images with high spectral resolution (i.e. very narrow bands) processed in software that can perform spectral un-mixing will provide a solution for the above limitation.

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