Geological Mapping of the Panafrican Mokong Gneisess and Granitoides (Far North Cameroon): Contribution of Semi-automatic Processing from Landsat 8 OLI/TIRS Images

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Abstract Field studies, Landsats 8 OLI/TIRS processing and the digital elevation model of SRTM images permit us to map the Mokong area, region situated in arid zone and located to the Northen part of the central African Orogenic belt in Cameroun. The use of Landsat's number 3 band of made it possible to highlight the lineaments. It has been noticed after analyses that the maximum number of lineaments are oriented N-S direction. The second major trends of lineaments in the study area are respectively, ENE-WSW, E-W and SSE-NNW. The landsat OLI/TIRS processing (colorful composition, band math, and principal component analysis) are permitted to discriminate four mains rocks types: gneisses-amphibolite; biotite granite, diorite-granodiorite and tonalite. All those facies are partially covered by alluvial deposits in the southern erea. The digital elevation model has permitted to identify some volcanic cover. The method used in this work offers promising prospects for geological mapping of arid regions where there is usually little map, because with this method, the time is reduced and the result is more precise.

Keywords: central African orogenic belt, geological mapping, image processing, Landsat 8 OLI/TIRS, arid zone, Mokong

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1. Introduction

The Brasiliano-Pan-African belt is the mega structure that extends to (1) Africa through Soudan, Nigeria, Chad, Cameroon and Central Africa; and (2) South America (Brasil) in the Borborema provinces. In Cameroon, this orogenic Belt has been subdivided into three lithotectonics domains on the basis of petrographical, structural, geochronological and isotopic features [1,2]: (1) the southern domain also called the Yaoundé domain, (2) the Central Cameroon domain or Adamawa-Yadé domain and (3) the Northern domain or North-West Cameroon domain (Figure 1).

The study area belongs to the northern domain, made up of more or less deformed granitoids and various rocks. The works [2-7] conducted in this area distinguish five units: (1) Poli group, (2) pre-syn-tectonic granitoids, (3) syn- to late-tectonic granitoids, (4) post-tectonic granitoids, and (5) molassic deposition basins. Each of these units is generally made up of the association of several types of rocks that can also be found on the same massif. It is therefore difficult to map them effectively using classical geological methods.

In recent years, remote sensing and satellite image processing (Landsat 8 OLI / TIRS images) have emerged as the fastest and most accurate geological mapping tools available to geologists, particularly when it is mapping in arid zones where outcrops are often difficult to access, thus complicating traditional mapping as is the case in our study area: Mokong located in the northern part of the North Cameroon domain. The processing of these multispectral data permits the production of distribution maps of the outcropping areas, classified according to the different lithologies and the lineament map. The combination of these two types of map gives a geological map.
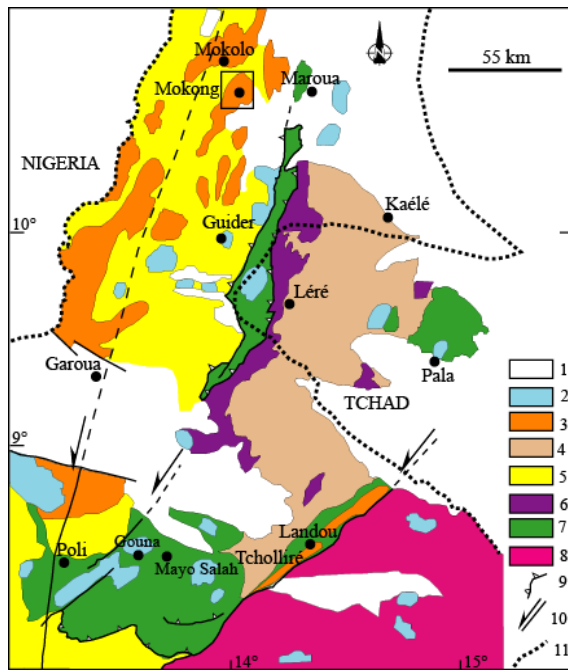
Figure 1. Geological map of North Cameroon (redrawn after [3]): 1) Post Panafrican sedimentary cover ; 2) Late-post tectonic granitoids; 3) syn-tectonic granitoids ; 4) batholith : tonalites, trondjémites and granodiorites of Mayo-Kebbi ; 5) medium and high grade metamorphism of NW Cameroon Domain ; 6) mafic to intermediate domain of Mayo-Kebbi domain (metadiorite and gabbro diorite) and amphibolitic; 7) the low-grade, high-grade Neoproterozoic metamorphic volcano-sedimentary sequences of the Poli-Léré group; 8) Paleoproterozoic remobilized from Adamawa-Yadé domains; 9) collision zone; 10) direction and sense of faults; TBSZ: Tcholliré-Banyo shear zone; GGSZ: Godé-Gormaya shear zone; 11) border between states

2. Geological Setting

The study area is located in the Northern domain, a narrow and N-S elongate domain, less than 150 km in width, located to the east of the Eastern Nigerian domain and to the west of the Mayo-Kébbi domain (SW-Tchad). Many petrographical, geochemical and geochronological studies shows that this domain is younger comparatively to the others and made up of a neoproterozoic crust [3,8]. The paleoproterozoic crust is discontinuos or absent in this domain according to [1]. The tectonic evolution based on the structural studies is controversial, some author think that two principal phases of deformation control this domain, [3]. [2,7] showed three deformation phases and [6] based his tectonical evolution on four phases. This northen domain comprises the sinistral N-S Godé-gormaya and Mayo Nolti shear zone and the NE-SW Tcholliré-Banyo shear zone (Figure 1). The Godé-gormaya shear zone is a mayor trending shear zone which extend from the south of the Domain to the north of Benue trough [1]. According to [3] this shear zone extends toward the north beyond to the benue trough and pass at the north of Mokong locality.

3. Study Area

The study area (Figure 2) is located in the Far North region of Cameroon, the annual rainfall is 811mm with a short rainy season and a long dry season [9]. In dry season,

the soil is bare, the sky is not covered. The conditions are thus met to have satellite images without noise and little or no vegetation cover. That's why we chose landsats 8 images that date from the middle of the dry season. Their characteristics are as follows: path/row: 184/53; date: 21/03/2015; file type: GEOTIFF; projection: UTM, zone 33 north; ellipsoid: WGS-84.

4. Methodology

4.1. Lineament Mapping

A lineament is a mapable linear or curvilinear feature of a surface whose parts align in a straight or slightly curving relationship. They may be an expression of a fault or other line weakness [10,11,12]. There are three main methods for the extraction of lineaments from satellite images:

- Manual extraction: Here the user first starts by some image processing techniques to make edge enhancements, using the directional and non-directional filters, then the lineaments are digitized manually. Interpreter's personal skills and experience will condition the reproducibility of the final results
- Automatic extraction: various computer-aided methods for lineament extraction have been proposed. Use of such functions is easy and fast. They also offer a high degree of reproducibility in contrast to classic subjective manual processes [12,13]. But in this method, structures like roads, trees and aligned houses are often mistaken for lineaments.
- Semi-automatic extraction, which is an association of both previous methods, in fact, the lineaments are first extracted automatically, then superposed on the different geological, topographic and hydrographic network maps for validation. Validation is a process that consists to remove lineaments superposed on roads, aligned trees in forest reserves, and adding those extracted from hydrographic network that would have been forgotten.

For this work, we opted to use the Semi-automatic extraction. In our methodological approach (Figure 3) lineaments were automatically extracted from the panchromatic band with the LINE module of PCI Geomatica, and then exported (vector format) to QGIS for validation. However, the function includes several parameters that must be added simultaneously without possibility to visualize the impact of each of them separately.

The directional filters induce an optical effect of shadow focusing on the image like it was illuminated by oblique light. This type of filter was used in order to get a high accuracy in extraction [13,14]. Directional filters are applied to images using a convolution process by means of constructing a window normally with a (3×3) pixel box of Sobel- kernels filters (Table 1). The directional filter of Sobel kernel is a faster way to evaluate lineaments in four principal directions [15]. Four filtered images have been produced by Envi 5.0 software related to the directions N-S, E-W, NE-SW and NW-SE, which are used as input images for automatic extraction.
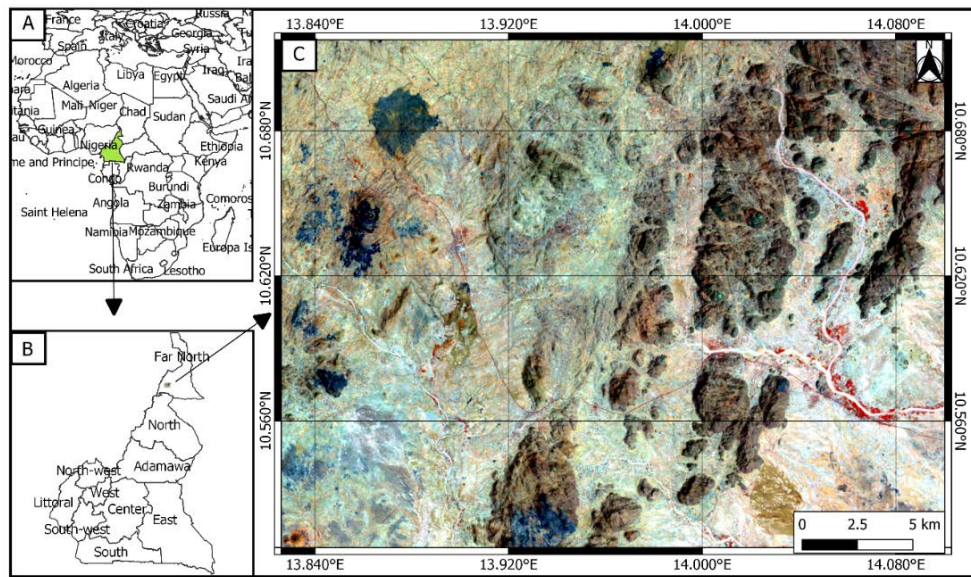
Figure 2. Location of the study area. A: Africa continent B: Administrative map of Cameroon showing the study area in the far north. C: .Map of the study area obtain from the 234 band as R: 4, G: 3 and B

Table 1. Sobel - kernels in four principle directions

| N-S			NE-SW			E-W			NW-SE		
-1.0	0.0	1.0	-1.4	-0.7	0.0	-1.0	-1.0	-1.0	0.0	-0.7	-1.4
-1.0	0.0	1.0	-0.7	0.0	0.7	0.0	0.0	0.0	0.7	0.0	-0.7
-1.0	0.0	1.0	0.0	0.7	1.4	1.0	1.0	1.0	1.4	0.7	0.0
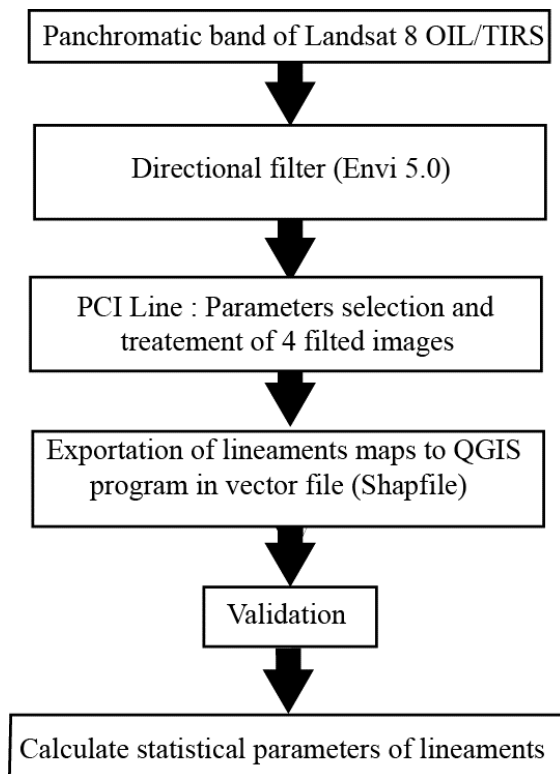
Figure 3. Flowchart shows steps lineaments extraction and analysis. Inspired after [12,16,17]

4.2. Lithological Mapping

It is imperative for best results to subject input images to the treatments for their improvement and optimization. It is mainly:

- geometric correction;
- atmospheric correction;
- thematic treatments (PCAs, Ratios);
- enhancement treatments (stretching);

The flowchart of the work done for lithological mapping is shown in Figure 4 below.
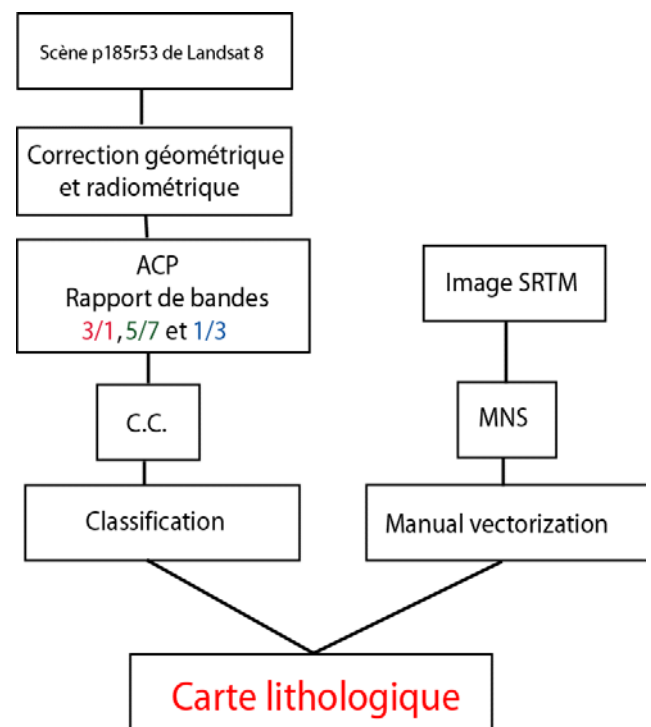
Figure 4. Organigram of the different treatments. PCA(principal component analysis); CC(colored composition); DEM (digital elevation model) Inspired after [18,19,20]

5. Results

5.1. Lineament Maps

In our study, enhancement of lineaments has been made from directional filters using Sobel operator. The convolution filter window of 3 by 3 was used in order to detect the lineament with the smallest length. A subset of directional filtering images is shown in Figure 5.In order to extract the discontinuities similar to the geological lineaments in the study area, the necessary and appropriate parameters for the Line Module PCI Geomatica were used.

The lineament extraction algorithm of PCI Geomatica software consists of edge detection, thresholding and curve extraction steps. Suggested settings values was selected from several settings tests. The threshold values are shown in Table 2.

Table 2. Suggested parameters values

Parameters	Values
RADI	5
FTHR	50
LTHR	30
FTHR	3
ATHR	30
DTHR	20

The superposition of the four lineament maps obtained (Figure 6a) from the filtered images led to the creation of a synthethic lineament map. Lineaments which were repeated more than once are eliminated to avoid repeating segments in the synthesis map. [12] noted that the automatic methods generate many insignificant lineaments. Thus, the lineaments derived from human activities (road, forestry reserve…), and meaningless lineaments were manually eliminated using GIS tools. The lineament map obtained by automatic extraction and manual elimination is shown in Figure 6 (a) and (b).

The extracted lineaments are analyzed in order to get informations related to length, density and orientation analysis. Generally, the frequency of automatic extracted lineaments is greater than the number of lineaments in the fault map of the study area.

The most important factor for this is that the lineaments in the automated one are shorter in length compared with the length of fault lines. This technique identifies the highest number of lineaments and the highest total length of lineaments compared with the number and the total length of faults in the study area.

Lineaments orientations are usually analyzed by rose diagram in all researches dealing with these structures. A line direction program (QGIS extension) was used to obtain lineament directions. The conventional method consists in producing directional rosettes lineaments classes by 20° orientation.
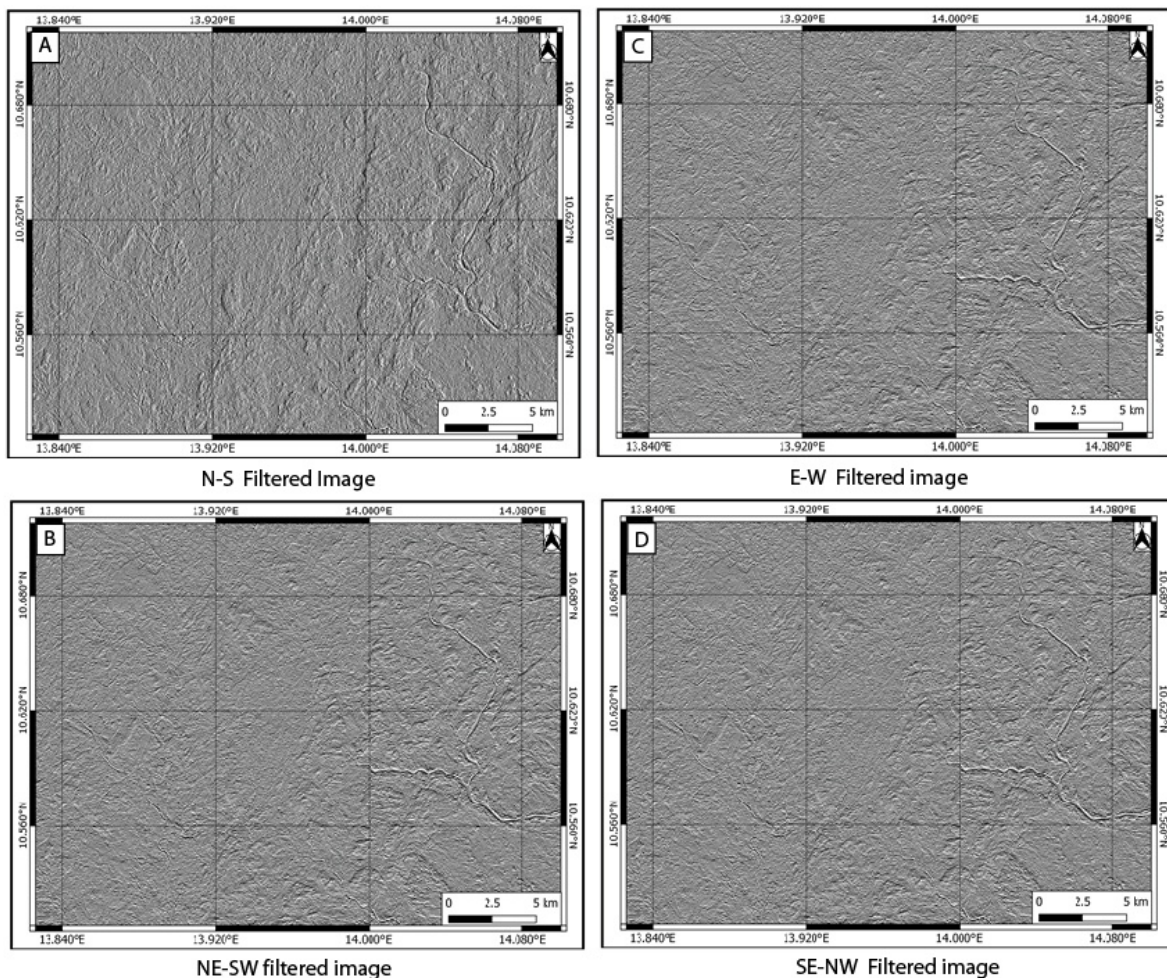

N-S Filtered Image

E-W Filtered image

NE-SW filtered image

SE-NW Filtered image

Figure 5. Four subset filtered images derived from panchromatic band of Landsat 8 OLI/TIR

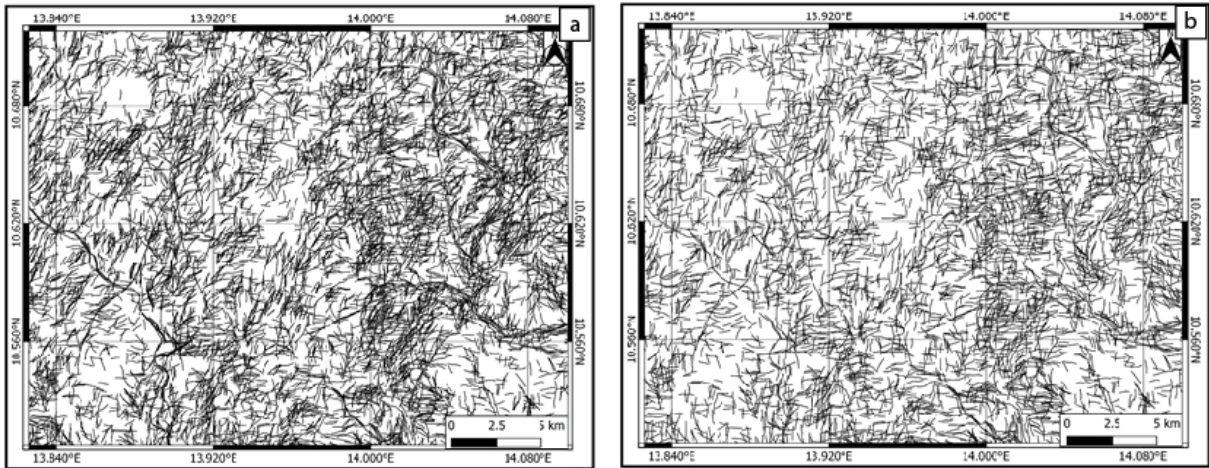**Figure 6. (a)** Automatic extraction lineament map, result to the superposition of the four. **(b)** lineaments map obtain after validation process
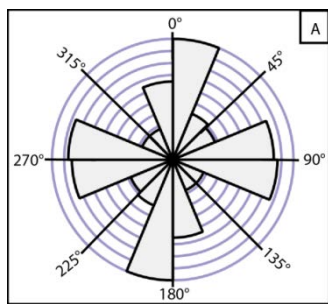

Figure 7. Rose diagram for extracted lineament

As shown in Figure 7, it has been noticed that the maximum number of lineaments is oriented N-S direction. The second major trends of lineaments in the study area are respectively, ENE-WSW, and E-W and SSE-NNW.

5.2. Lithological Map

The two green spots in Figure 8, Figure 9 and Figure 10 represent two forest reserves in the study area and are considered at the end of image processing as alluvial deposits.

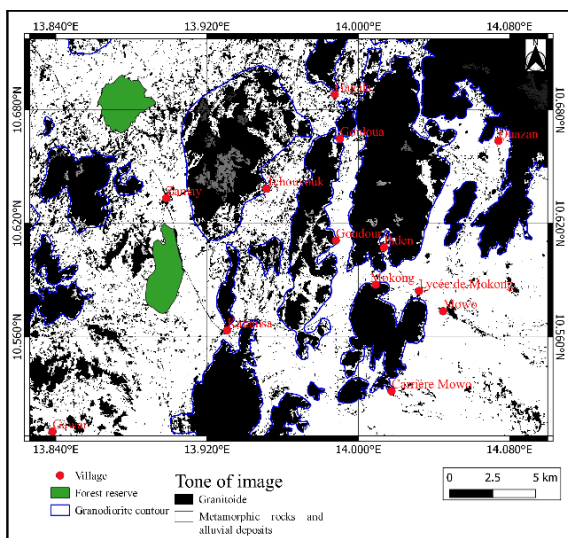### 5.2.1. Discrimination of Granitoid Domain

Figure 8. Segmentation carried out on the 3 OLI band discriminating the crystalline rocks of alluvium and crystallophyllian rocks.

The image segmentation technic generated a two-tone binary image: black and white (Figure 8). The black tone, represents the crystalline rocks as a whole, while the alluvial deposit is represented by the white tone. The blue lines on the image (Figure 8) represent the geological contours of the granitoids. It can also be seen that granitoids are not well represented on the south-east and south-west slide.

5.2.2. Discrimination of Alluvial Deposits

The colorful composition (CC) of the bands resulting from the PCAs has allowed to distinguish the domain of the metamorphic rocks from the alluvial deposits domain. Thus, the Figure 9 (colorful composition Red: PCA256, Green: PCA157, Blue: PCA156) confirms the preceding observations:

- The metamorphic rocks represented by the hue red tone, is found in the northern part;
- The alluvial deposits in dark gray are located in the southern part.

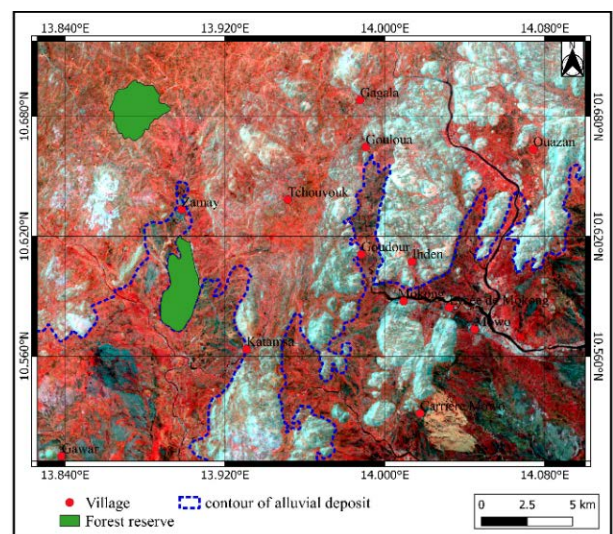The boundary between the two sets is marked by the blue dashed line.

Figure 9. 256PCA, 157PCA, 156 PCA

In white on the same Figure 9, we can identify the field of granitoids. But here, it is difficult to make a difference between the types of granitoids on one hand and between

the granitoids and the volcanic cover on the other. Other colorful compositions are therefore necessary.

5.2.3. Discrimination of Different Types of Granitoids

Figure 10 below distinguishes between (1) the metamorphic rocks domain, (2) the sedimentary rocks domain, (3) the volcanic rocks domain and (4) the different types of granitoids.

Metamorphic rocks appear in blue tone.

Sedimentary rocks appear with a green to olive green color.

Volcanic rocks in the extreme south-east (Gawar domes), show a bright red tone in a plain (green hue).

The granitoids are differentiated from each other by:

- A pink hue, which represents the biotite granites;

- A much whiter shade that is usually found inside the pink hues of the granites. This hue represents, diorites, and granodiorites.

- A pink hue dotted with white in the North-East which represents tonalites.

The syenites outcrop on the field in the form of modest dykes and sills (vein thickness <30 meters), indeed, it will be very difficult or impossible to map them efficiently since the Landsats 8 OLI / TIRS images. Therefore any object whose size is less than 30m cannot be represented on the image.
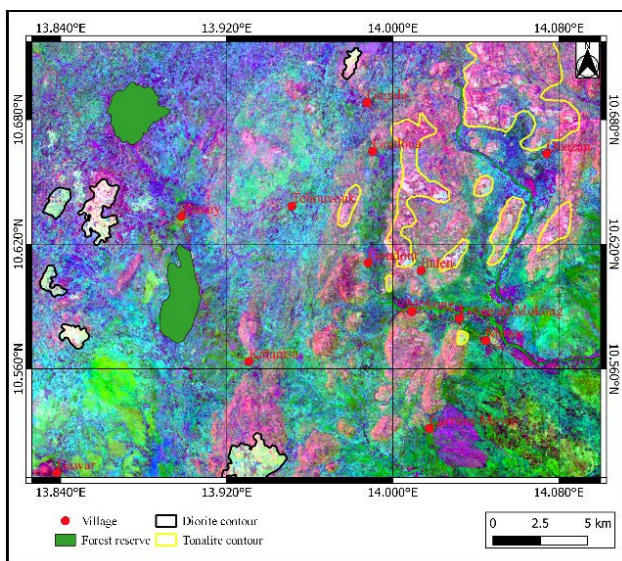

Figure 10. PCA 157 CC

5.2.4. Discrimination of Volcanic Rocks

Volcanic rocks are represented by basalts, dolerite dykes and rhyolites that outcrop as domes and veins. The basalt domes (Figure 11) are easily identifiable. Basalt outcrops in the form of small thickness veins and domes, their coordinates were projected on the digital surface model (Figure 11). Some veins have been ables to be recognized and vectorized manually. Due to the fact that the field campaigns could not cover all the square meters of the entire field, and in order to map all facies, we have superposed the map data from this work to the existing geological map (Figure 11). On the latter, we also vectorized the volcanic rocks (represented in black).
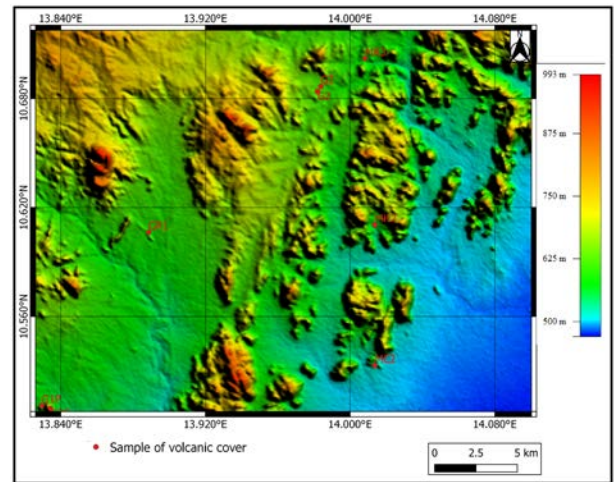

Figure 11. Digital elevation model of the study area

5.2.5. Examples of Type's Rocks

To verify our methodological approach, 5 rock samples on the various facies identified were selected and then cut into thin sections to make petrographic studies. There are: gneiss, biotite granite, diorite, epidote bearing granite and basalt (Figure 12).
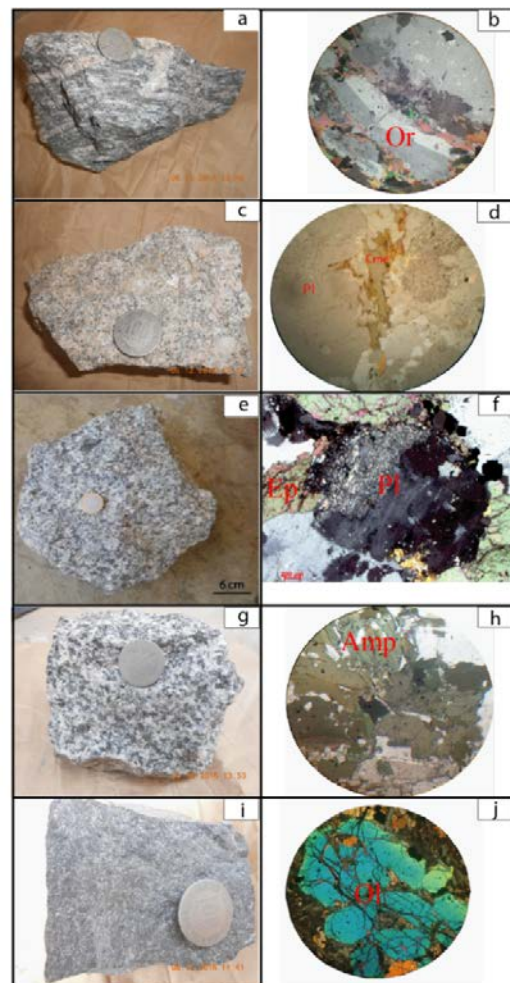

Figure 12. Samples and thins sections of gneiss (a and b); biotite granite (c and d), epidote bearing tonalite (e and f), diorite (g and h) and basalt (i and j)
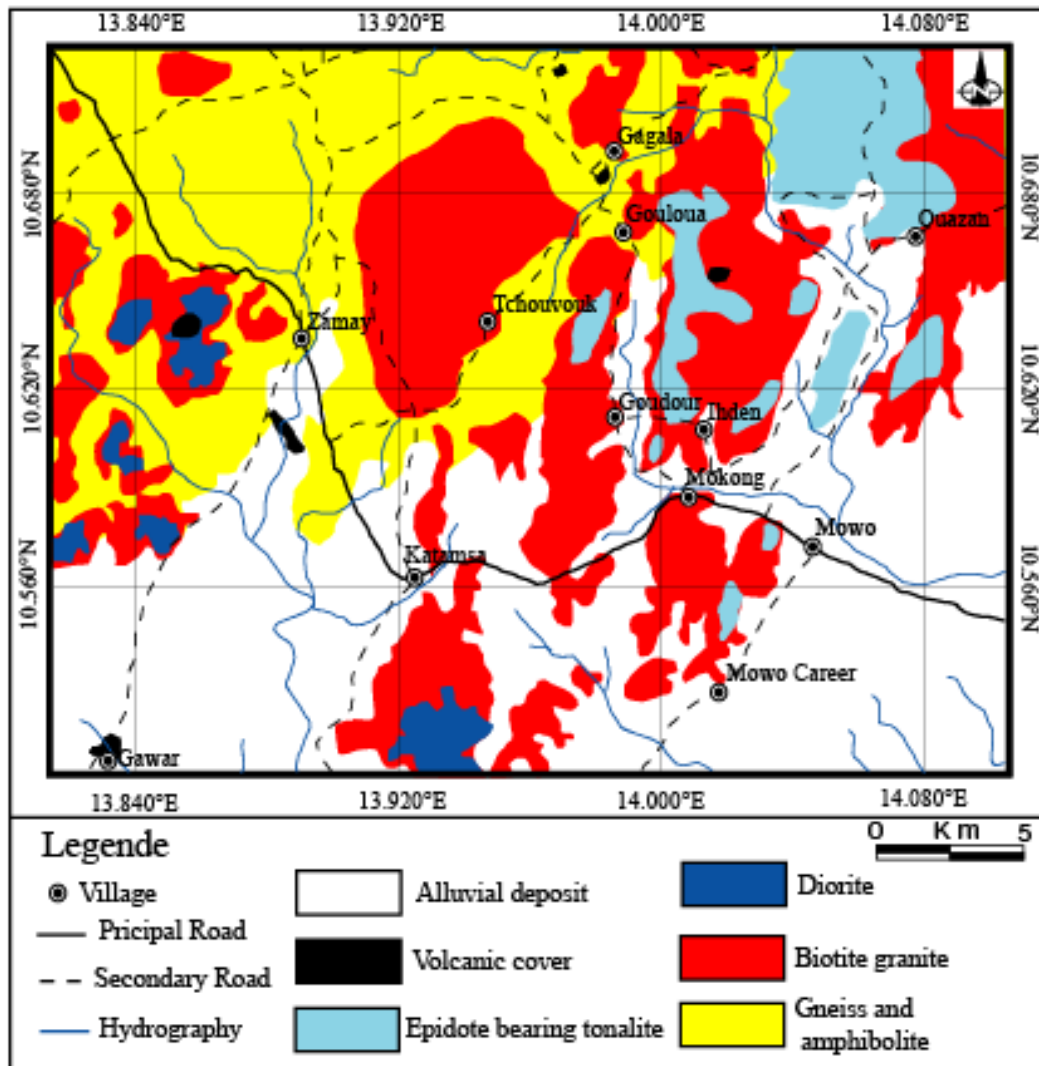
Figure 13. Lithological Map of the study area

We immediately noticed that these rocks differ from each other in mineralogical composition, color, structure and texture. These differences are therefore at the origin of the different spectral signatures recorded in the different treatments.

The gneiss sample shows alternating light and dark bands; while the thin section shows a granoblastic texture with minerals such as: feldspar, quartz, and biotite.

The light gray granite is a granular texture with a mineral assemblage dominated by feldspars, quartz and biotite such as gneiss. But the difference with gneiss is that granite is less rich in biotite. The tonalite is dark gray and has a grainy texture with minerals such as: feldspars, quartz, biotite, amphibole and epidote. The epidote, which is generally known as an accessory mineral in the granitoids, has a larger proportion in this sample (more than 3%).

Diorite, dark gray, but darker than tonalite. A grainy texture, has a mineral assemblage consisting of feldspar, quartz biotite and amphibole. It is also richer in amphibole than epidote tonalite.

The basalt black color has a porphyro-blastic texture, with olivine phenocrystals embedded in a matrix.

The results of all study permit us to have the Lithological Map of the study area that is shown in Figure 13.

6. Discussion and Conclusion

In geology, two main methods of cartography are generally used: the field works that are nowadays the most used method, is a long and tedious work. The second method is the use and processing of Landsat 8 OLI / TIRS images. It is this second method we used for mapping the Mokong region, which corresponds to pan-African outcrops in arid zones. In this work we show that the use and processing of Landsats 8 OLI / TIRS satellite images coupled with bibliographic work, fieldwork used as verification and validation tools is useful in mapping. The results clearly show that: (1) directional filters and semi-automatic extraction of lineaments allowed a good mapping of lineaments with N-S major direction; ENE-WSW, E-W and SSE-NNW directions are considered minor directions. These results are consistent with data from [2,3,7,8], who think that the North domain is stretched North-South. (2) the techniques of segmentation, of the 256-157-156 colorful composition (bands math), 157 of the PCA highlight some lithologic features such as: zonations of granites different lithological types that would otherwise have been difficult to detect in the field. These results have modified the geological map of [21].

In conclusion, we can say that the method used in this work offers two main advantages: (1) faster and more efficient lineament and lithologic structures localisation; (2) a much more precise outcome than the use of conventional cartography. This offers very promising prospects for geological mapping that is more efficient both in terms of quality and preparation time for the arid zones of the country (North and Far North) where only one map has been published at a scale of 1: 500,000 by [22].

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