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Using Landsat 7 ETM+ for geological mapping of Precambrian AREAS: Example of Aleksod (Hoggar, Algeria)

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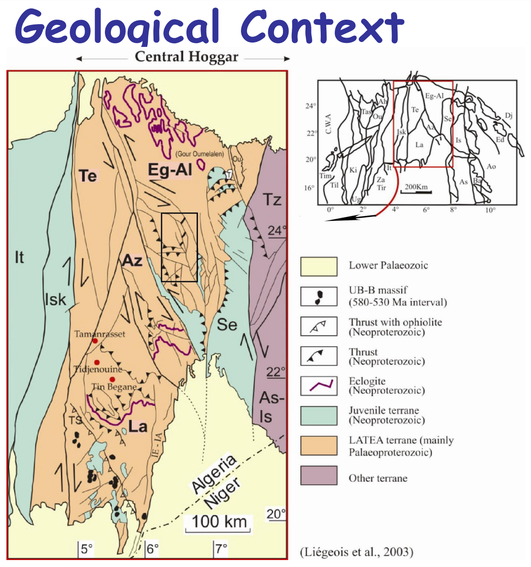
Introduction

The aim of this study is to test the use of image processing satellite Landsat 7 ETM + for mapping desertic arid precambrian areas on scales of the 1/100.000 to the 1/200.000. We have chosen the area of Aleksod located in central Hoggar (Southern of Algeria), which corresponds to outcrops allotted essentially to Palaeoproterozoïc (2000 My) and Panafrican (600 My). It is one of the best mapped areas of Hoggar. Indeed, Jean-Michel Bertrand, in his thesis (Bertrand, 1973), published a geological map at 1:100,000. This work provided the basis for our study. The objective is to compare, through integration in a GIS, the results we obtained in several image processing Landsta7 ETM + (color composites, directional filters, principal component analysis, ratios of bands, etc ...) with the geological map of Bertrand (1974) to determine the most efficient and estimate the interest that could be achieved using these techniques in the development of geological maps in the Hoggar..

This contribution is also a tribute to the outstanding work, including the Hoggar, made by Prof. JM. Bertrand (deceased in 2011).

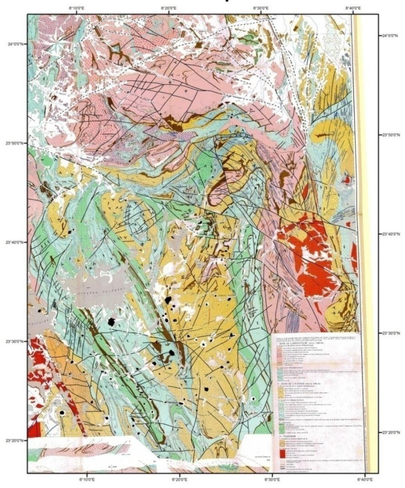
Geological Context



(Liégeois et al., 2003)

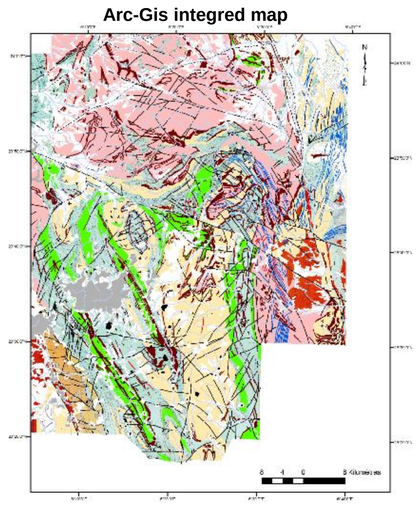
The study area is located in the central Hoggar, which is limited by two major accidents, the 4°50 megaschear zone, at West, and 8°30 megaschear zone, at East. Its polycyclic evolution is linked to two major tectono-metamorphic events : the Eburnean (2000 ± 100 Ma) and the Pan-African (650 ± 100 Ma

Scanned map



The first stage of this work was to digitize and integrate the map produced by Bertrand (1984) in a GIS using the software Arc-Gis. This allows us to directly compare the results obtained by processing the satellite images Landsat 7 ETM + with the work of Bertrand (1973)

Arc-Gis integred map



Bertrand (1973) described :

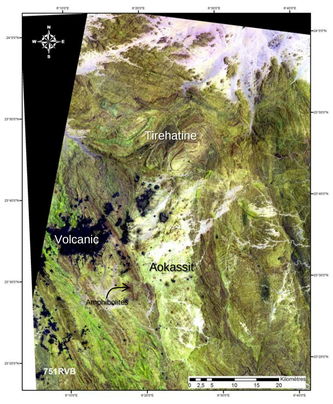
- a northern part dominated by the Arechchoum serie, which also extends along the East edge of map. This serie is essentialy made up by gray tonalitic gneisses and orthogneisses (pink on the map); and rarer metasedimentary formations (in blue on the chart).

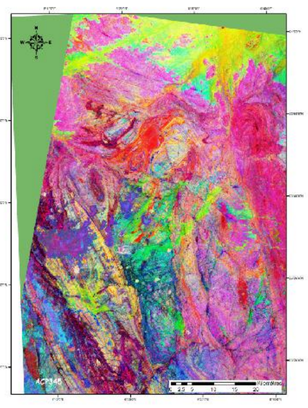
- a south-western part dominated by Aleksod serie. This serie consists of metasediments - quarzites, marbles and metapelites (in blue on the map), associated with a large volume of amphibolitic basic rocks (in green and brown on the map).

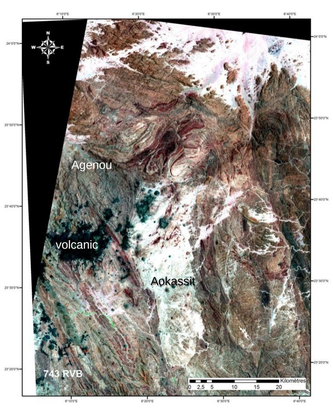
These two series (Arechchoum serie and Aleksod serie), are metamorphized in the amphibolite facies or granulite facies, and considered as paleoproterozoïc.

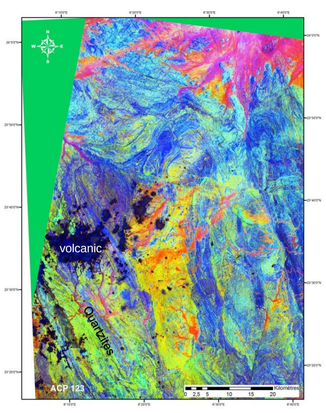
With that are added Panafrican formations, represented by volcanogenic formations metamorphized in the green schists facies (orange on the map) and intrusive acid plutonic rocks - granitoid (in red); and of Cenozoic-Quaternary volcanic rocks. It corresponds to basalts (in gray on the map) and trachytic and phonolitic protusions (in black).

The treatments used



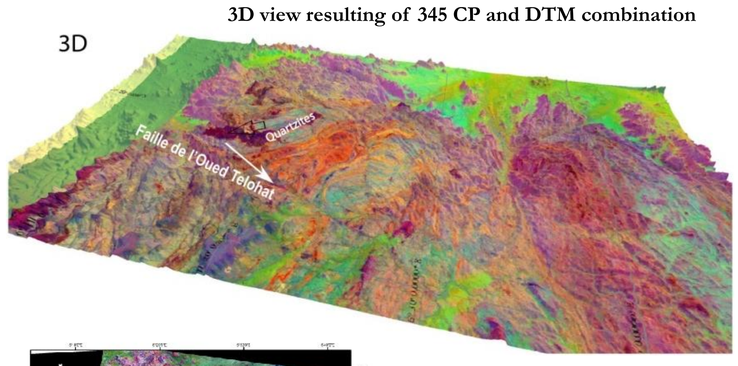


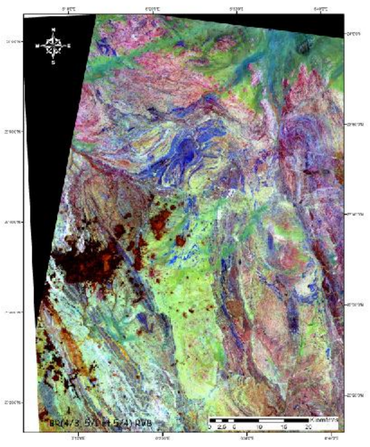




1- The *color composites* (called false color RGB): The three primary colors (red, green and blue) are associated with three channels of the satellite image. By coding the six channels of same resolution (30 m, Bands 1, 2, 3, 4, 5 and 7) of a Landsat image with the three primary colors, you can develop 216 color compositions.

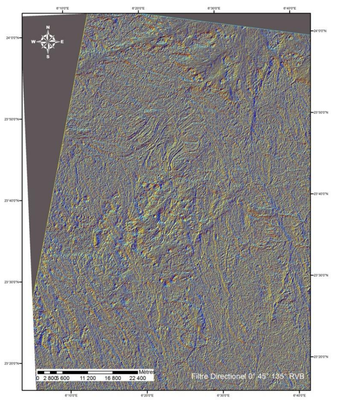
3D view resulting of 345 CP and DTM combination

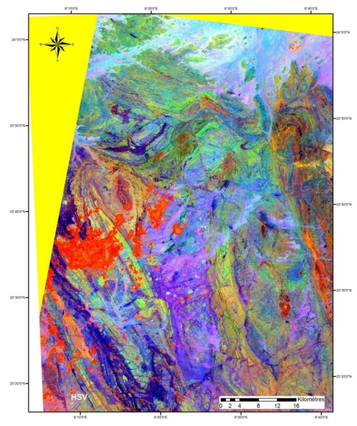




2-The Principal Component Analysis (PCA) of image transformations based on complex statistical treatments are used to reduce data redundancy between bands, the "neo" bands that result are called components. Often, the three principal components contain over 90% of the information contained in the six initial bands.

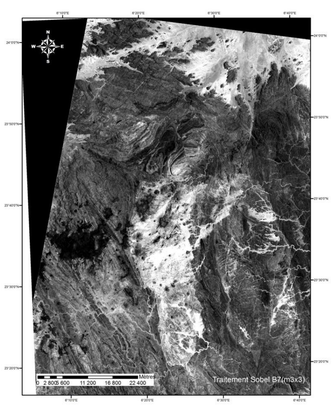
3- The band ratios: This analysis is based on the notion of reflectance, it represents a multi-spectral method widely used to highlight the differences between channels. It consists in dividing the DN (digital number) in a band by the DN of another band for a given pixel (we recall that a pixel corresponds to a value between 0 and 255, corresponding to the intensity of gray , with 0 = black and 255 = white). In practice, three band ratios are used to obtain an image in RGB. In the case of Aleksod, we used the ratios between other bands: 5/7, 1/3 and 3/4 (used here after fusion with the band 8 with the method HSV) and 7/5, 3 / 4 and 3/2.

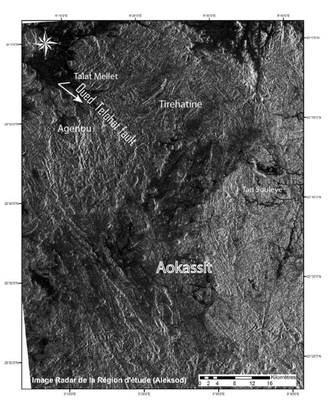




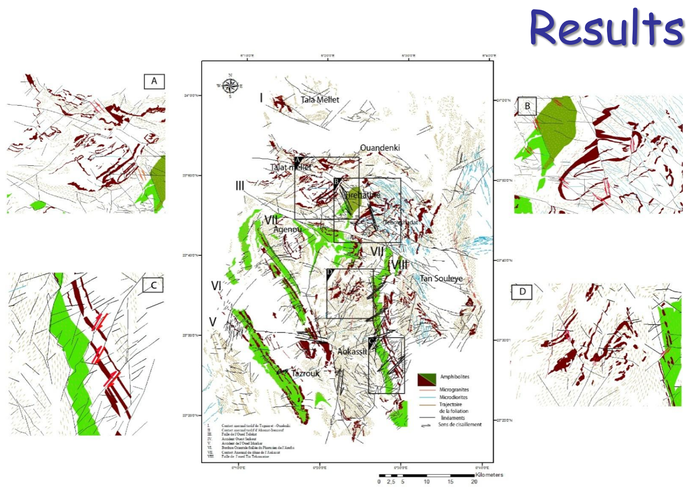
4-The directional filters: They improve the perception of lineaments causing an optical effect of shadow on the image. The enhancement was made in the directions 0 °, 45 ° and 135 ° due to the strong contrast in the images obtained. These filters were applied to different bands and the results of PCA. 6

5-The Sobel filter: it is used to detect edges of objects in an image, making two scans one horizontal and one vertical, the matrix used is [-1 0 1; -2 0 2 - 1 0 1]. He often gives good results for detection of lineaments.

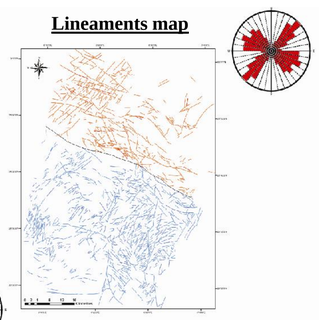


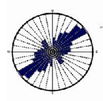


Results

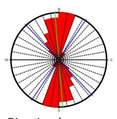


Lineaments map

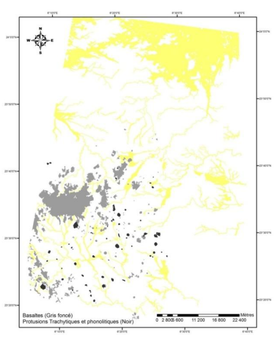


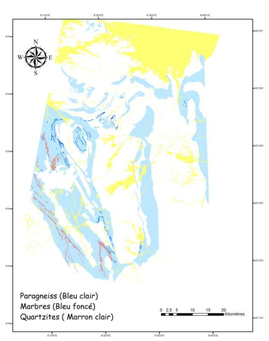


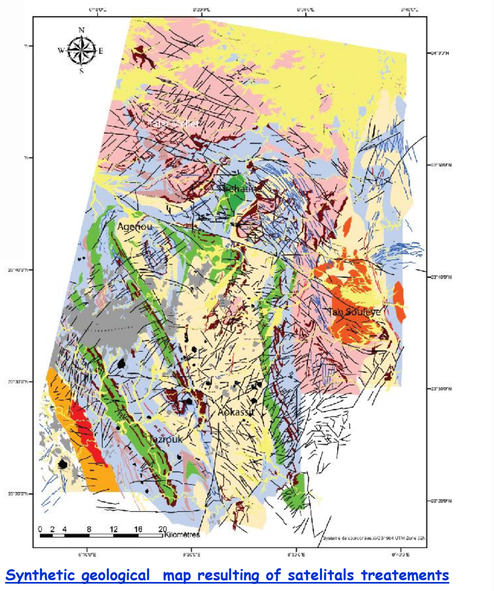
Directionel rosace of the microdiorites



Directionel rosace of the microgranites







Synthetic geological map resulting of satelitals treatements

Microdolerite and microgranites dykes swarm

Thanks to the treatments used, a very fine discrimination between different lithologies could be obtained. The results show a concordance which usually varies between 75% (series of Aleksod) and 95% (volcanism and amphibolites) with the map of Bertrand (1973), which can be considered remarkable.

Conclusion

This work shows that geological mapping using satellite image processing can be extremely effective when it is associated with a parallel bibliographic and field work (replaced here by the geological map of Bertrand, 1973) as a tool for reference, verification and validation.

These results show clearly that the nature of Aleksod lithologies can come out from an extremely reliable way, particularly by using as a preliminary a thorough statistical study of the correlation and covariance between bands and of the treatments such as principal components analysis and bands ratios. The directional and sobel filtering, as well as some colored compositions allow an accurate mapping of lineaments.

This gives us, for Hoggar, where only two geological maps at 1:200,000 were published (in the central Hoggar), very promising methodology for geological mapping more efficient both in quality and in time making .