Research Journal of Earth Sciences 4 (2): 44-48, 2012
ISSN 1995-9044

DOI: 10.5829/idosi.rjes.2012.4.2.1110

Extraction of Structural Lineaments from Satellite Images Landsat 7 ETM+ of Tighza Mining District (Central Morocco)

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Abstract: Lineament analysis constitutes an interesting approach in the geological mapping and mineral exploration. In our study, various types of techniques to extract lineaments were applied to a Landsat 7 ETM + image covering the Tighza mining district. The techniques include various enhancements on the image; application of directional filters (sobel) and non-directional (gradient). Before starting the extraction, various treatments are applied to the satellite image: the spatial and radiometric improving, the colored composition analysis, the principal component analysis (PCA) and the reporting of the spectral bands, etc.). *Among* the extraction approaches used, we quote the application of the directional filters on CP1, CP2 and CP1/ETM7 images. These filters allowed mapping a larger number of lineaments. The highest densities obtained are oriented NE-SW, E-W and N-S, with the predominance of the first direction. These results correspond to the overall direction NE-SW of the Central Massif structures resulting from the compression effect NW-SE of the Namuro-westphalian major tectonic phase.

Key words: Tighza · Central Morocco · Satellite images · Geological mapping · Structural lineaments · Directional filters

INTRODUCTION

The mapping of lineaments (fracturing) is an essential component for the mineral exploration research. The lineaments are linear or curvilinear discontinuities in direct connection with the faults and the composite fractures; and are associated with geomorphological features and/or a various tectonic structures [1] such as faults, fractures, folds axes and lithological contacts. They result the topographic depressions, the water system and the vegetation anomalies.

The Mapping by conventional methods (monitoring of the faults in the field) doesn't allow the identification of all existing lineaments. The experience has shown the value of remote sensing data for the lineaments mapping and the geological structures identification [2]. Also, the synoptic view provided by satellite images, with a high spatial resolution, makes the lineament analysis easier. However, all the lineaments don't automatically geological structures. Indeed, roads, tracks and water system are also considered as lineaments.

The objective of this study is to map the Tighza structural lineaments by using filtering techniques applied to different processed images. The resulting map will be used for geodynamic analysis of the area and will be an aid to mineral exploration.

General Context: The Tighza mining district is located in the north east of Central Morocco, near the western edge of the Middle-Atlas Causse, about thirty kilometers in the northwest of the Khenifra city and 7 km in the west of the M'rirt city. It is accessible via the main road N° 24 joining Azrou to Khénifra, also via the Secondary Highway N° 209 which connects M'rirt to Meknes (Fig. 1a).

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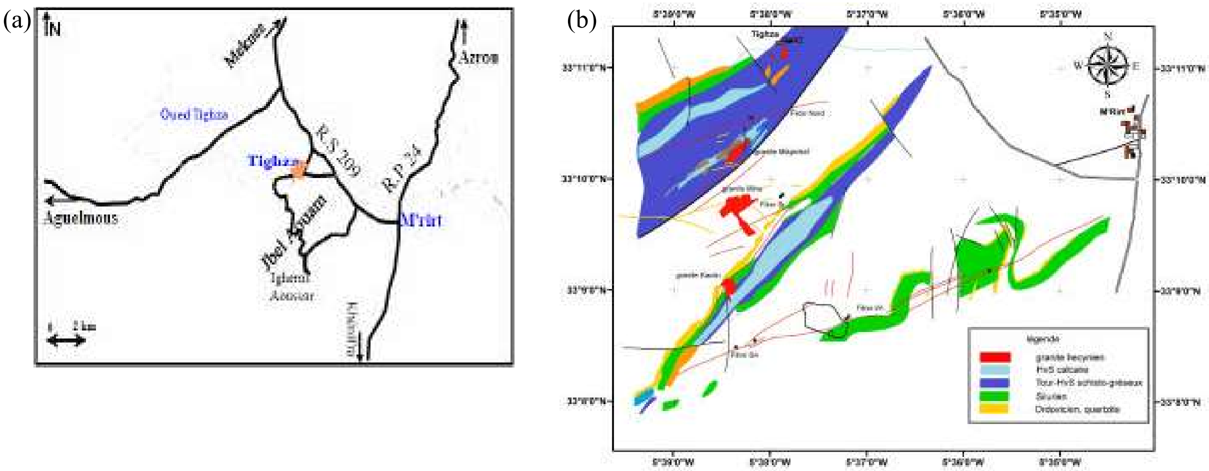


Fig. 1: Geographic location (a) & geological context of Tighza mining district (b)

Geologically, the Tighza mining district, part of the Kasbat-Tadla-Azrou anticlinorium, rightly illustrates the Hercynian geology of the greater unity of the Moroccan western Meseta. It consists of the Paleozoic sedimentary rocks of Ordovician to Carboniferous (Fig. 1b). These lands are affected by a low regional metamorphism (anchi to epizonal) which have been distorted by the different phases of the Hercynian orogeny wich structured the entire region of Central Morocco into an ensemble of the anticlinoria and synclinoria oriented NE-SW resulting from the major phase of the Hercynian orogeny called Namuro-westphalian phase and the strike-slip shearing zones with a repeated games allowed the establishment of a polymetallic mineralization economically important [3-10]. The vein-type mineralizations, which hosted in the Paleozoic formations, are represented by the Pb, Zn, Ag, W and Au. They are currently being exploited by the Touissit Mining Company (TMC). It provides 52% of the Pb national production, 26% Ag and 3.2% Zn. The annual production is 350000 ttv, 30000 t Pb and 4000 t Zn. The estimated reserves are more than 5 million ttv [11].

MATERIALS AND METHODS

In this work, we used an optical image Landsat ETM + data that have 9 channels:

- 3 in the visible: ETM1 (blue), ETM2 (green) and ETM3 (red)
- A channel in the NIR: ETM4
- 2 channels in the MIR: ETM5 and ETM7,
- 2 channels in the thermal infrared: ETM61 and ETM62,
- A panchromatic channel ETM8.

The spatial resolution is about 30m for bands ETM1, ETM2, ETM3, ETM4, ETM5 and ETM7, 15m for band ETM8, while it is about 60 m for band ETM6.

The major advantage of Landsat ETM + data is the combination of the high spectral (6 bands) and spatial (15m in panchromatic mode) resolution with the large surface swath (185km * 185km).

The satellite images processing was performed by means of the *Erdas Imagine 9.1* software.

In order to map the structural lineaments, the methodology used in this work is to apply directional filters on CP1, CP1/ETM7 and CP2 images.

The principal component analysis (PCA), the images combinations and the directional spatial filtering have been applied for the enhancement images. The PCA is to develop the image signal on the basis of mutually orthogonal functions [12]. This technique is used to find the axes of greatest variance in the space of a radiometric image.

In order to map the majority of the fractures affecting the geological formations of the study area, we conducted the principal components analysis involves firstly to achieve a first PCA (CP1) by using the visible bands ETM1, ETM2 and ETM3, then the second PCA (CP2). Some details in the image could be enhanced through the application of the images combination technique whose the principle is based on the mathematical operation to generate the reports of bands (CP1/ETM7). Among the filters used in our study, we quote:

- The sobel directional filters 5x5 and 7x7;
- The gradient filter [13].

RESULTS AND DISCUSSION

Satellite Image Pretreatment

Spatial Enhancement: The spatial enhancement is a treatment based on the values of individual pixels and neighboring pixels. It aims to improve the spatial resolution of the image. So, for our image, we performed a spatial enhancement treatment by fusion of the multispectral image with 6 channels (1, 2, 3, 4, 5 and 7) and the panchromatic channel (channel 8). This treatment allowed us to reduce the size of our image pixels from 30 to 15 m.

Radiometric Enhancement: The radiometric enhancements include applying a transformation, linear or non-linear versus the signal amplitude for each of the image pixels so that all amplitudes occupies more effectively the available gray scale (usually from 0 to 255. in our study, we used a radiometric processing of the histograms of raw channels, thus the contrast improving to facilitate the visual interpretation of the image.

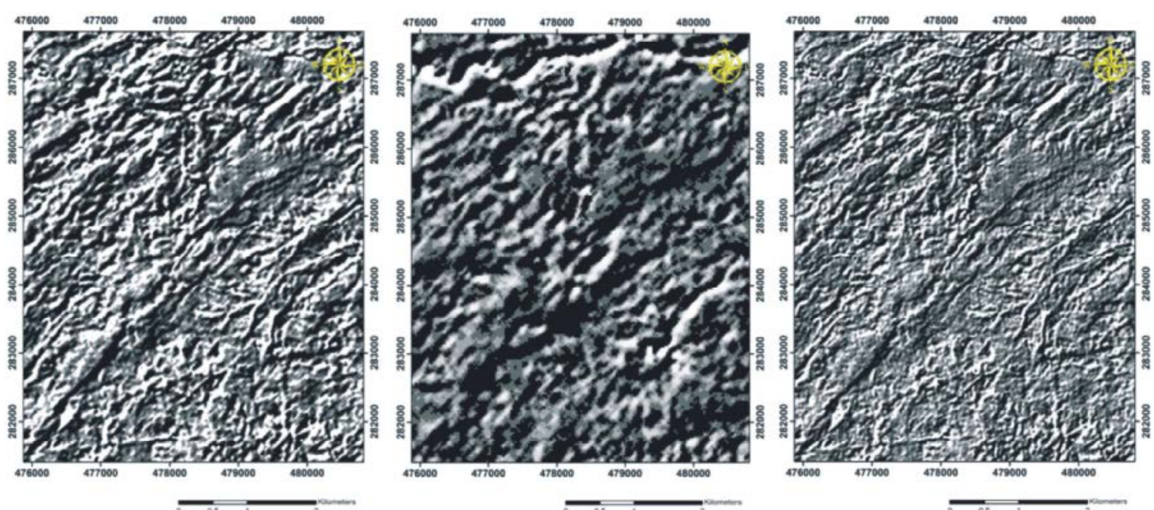
Color Compositions: In the remote sensing, the colored composition is a significant representation of an image obtained by one or more channel combinations. In general, each channel is assigned to a primary color corresponding to an image band. The advantage of the high spectral resolution is to have several possible choices of the three bands combinations in addition to the true color combination. In the geological mapping, the best choice is to select bands in terms of the spectral characteristics attributed to the presence of different minerals in rocks [14, 15].

Lineaments Mapping: The application of the sobel directional filters 5x5 and 7x7 in the directions N-S, E-W, NE-SW and NW-SE and finally the gradient filter [13] to the CP1, CP1/ETM7 and CP2 images can enhance the images-discontinuities corresponding to the lineaments.

The lineaments enhancement has thus been performed in the first step from the directional filters by using sobel operator.

Given the angular range ± 45° of the directional filters around the raising main direction, four derived images were generated from four sobel directional filters. This allows to highlight the structural lineaments in all possible directions (N-S, NE-SW, E-W and NW-SE). The filters size depends on the needs. In this study, we chose the directional filtering made from the matrices with the 7*7 and 5*5 sizes. In the second step, we performed the lineaments extraction by using the gradient filter 7x7 [13]. This will allow us to draw and perform the lineaments map of the study area.

The lineaments mapping, mainly based on the visual interpretation of the images is performed by plotting the linear structures located on the various filtered images CP1, CP1/ETM7 and CP2 (Fig. 2). Only the structural lineaments have an interest in this study. Indeed, the traced lineaments are systematically checked on the other images before being selected. This is to eliminate the artefacts corresponding to the infrastructure (roads, tracks, water system,...).



(CP1, sobel 7x7) (CP1/ETM7, sobel 7x7) (CP2, sobel 5x5)

Fig. 2: Sobel directional filters NW-SE to enhance the discontinuities-images in the NE-SW

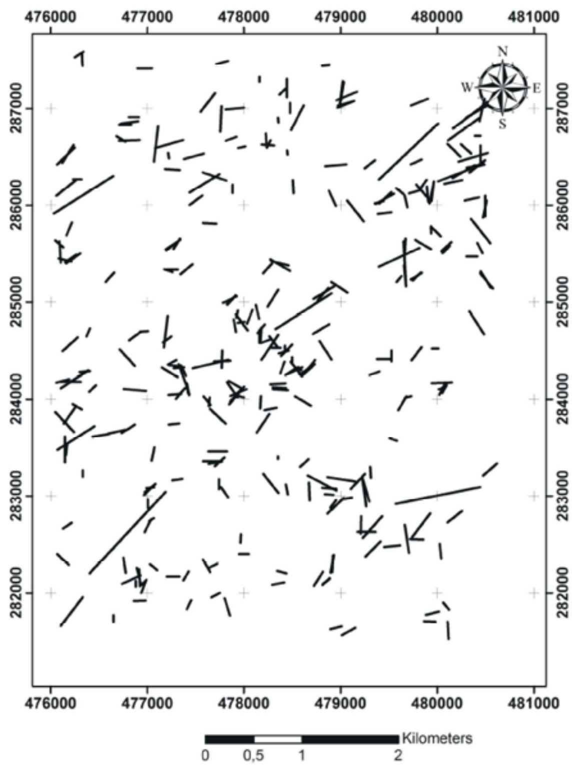


Fig. 3: Synthetic map of the lineaments obtained from the images of the sobel directional and gradient filters

The next step is the superposition of the lineaments maps obtained in different directions to create a synthesis lineaments map. To avoid the segments repetition on the map synthesis, we proceed to the elimination of all the lineaments that are repeated more than once. The synthesis map is, in turn, given in the figure (Fig. 3).

Statistical Analysis of Lineaments: The statistical analysis of the lineaments has been explored by several authors to study the lineaments network geometry and to identify the dominant directions at the regional level [16, 17]. The conventional method is to produce the directional rosettes proportional to the lineaments cumulative length by classes of 10° orientation.

In our study, the identified lineaments from the satellite images are subject to frequency analysis in order to highlight the main directions can then be compared to the direction of the reported accidents on the field. Therefore, the lineaments statistical analysis by using the directional rosettes was performed by means of the *Rockworks15* software. This will determine the structural orientations and the fracture density.

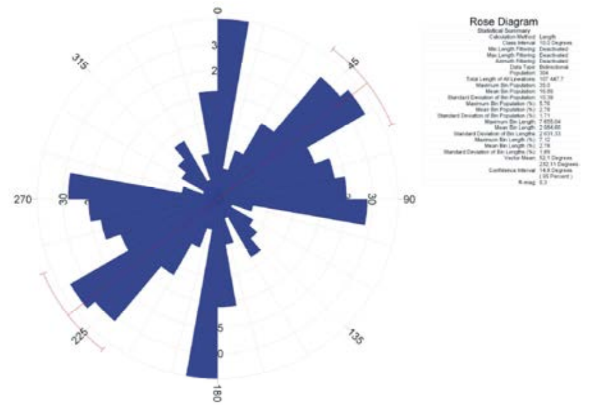


Fig. 4: Directional rosette of the Map, after the sobel directional and gradient filters

To better understand the lineaments distribution, we conducted an analysis of the lineaments, firstly for each filter, then to the same direction and finally we performed the synthesis map rosette collecting all the lineaments from the set of treatments.

The digital processing of the satellite images from the filters used provides more detailed complementary structural information. Indeed, from the extracted lineaments synthesis of different filtered images, the general map of the major lineaments representing all the unique segments reveals three important families of the lineaments orientation (Fig. 4): NE-SW, E-W et N-S, with the predominance of the first direction. We also note that the overall direction of the Central Massif structures is NE-SW. This is consistent with the compression effect NW-SE of the Namuro-westphalian major tectonic phase.

CONCLUSION

The remote sensing offers a synoptic view to study the large geographical areas. Indeed, the lineaments mapping is an essential component for understanding the regional tectonics. The remote sensing image; satellite so that air; is surely the most accurate visual model, the richest of the geographic space. In our study, the different treatments applied to the Landsat7 ETM+ images which we quote: geometric correction, spatial and radiometric enhancement, color composition, classification, PCA, sobel directional and gradient filters and creating the new channels. These treatments provide information on the geological formations lithology and more detailed additional tectonics data. Indeed, we were able to map at the regional level the major lineaments network in order to give an idea about the distribution of different structural lineaments families in the study area. We then distinguish three important families of the lineaments orientation: NE-SW, E-W and N-S, with the predominance of the first direction. This result agrees well with the compression effect NW-SE of the Namuro-westphalian major tectonic phase responsible for the implementation of the faults NE-SW.

ACKNOWLEDGEMENTS

This work was performed under the Protars III D15/31 Project and with the support of the fellowship N° b11/006 granted by the National Center for Scientific and Technical Research and the Touissit Mining Company. We thank all who contributed, in one way or another, to make this work.

Particular thanks to the TMC geologists and Directorate, which we like to express our gratitude.

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