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Geological Mapping and Seismic Risk in the Eastern High Atlas: Case of Talsint Region (Morocco)

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Abstract: ***Talsint area is located in the Eastern High Atlas. It is known a seismic region. During the last decade (2005 to 2014) the seismic activity increased more than 160 earthquakes which disturbed the everyday life of the local population, it also causes damage on especially traditional constructions. Analyzing the geological structures and the faults is necessary for the comprehension of the geological built especially in the areas exposed to the seismic risks. The aim of this research is show the contribution of the remote sensing technique in the geological cartography. Various digital processing were applied out an image of high resolution space EMT of Landsat7 covering the Talsint region in order to extract geological lineament and faults. The application of supervised classification and directional filter (Moore) was carried out. A geological map and lineament density map are done. The highest densities obtained are oriented NE-SW and with of the same faults direction. These results correspond to the overall direction NE-SW of the structure resulting from the compression effect NW-SE. With the GIS, the faults F1 oriented NE-SW are mapped and to confirm the migration of the seismic activity towards the South-Est***

Keywords: Eastern High Atlas, Remote sensing, Geological mapping, seism

1. Introduction

The High Atlas is a 100 km wide showing E-W to NE- SW trending fold axes nearly orthogonal to the Atlantic coastline. The High Atlas resulted from the tectonic inversion of a Mesozoic extensional basin related to the opening of the Atlantic and Tethys ocean (Choubert and Faure-Muret. 1962, Mattauer et al. 1977, Schaer. 1987, Jacobshagen et al. 1988, Beauchamp et al. 1999, Laville and Pique. 1992, Pique et al. 2000). The compression related to convergence between Africa and Europe occurred from Cenozoic to present times (Laville et al. 1977, Dutour and Ferrandini. 1985, Gorler et al.1988, Fraissinet et al. 1988, Medina and Cherkaoui. 1991, El Harfi et al. 1996, Morel et al. 1993, 2000, etc.). The High Atlas of Morocco has been uplifted by two mechanisms: the first is thrusting with subsequent crustal thickening, and the second is lithospheric buoyancy induced by a thermal anomaly in the mantle (Teixell et al. 2005, Ayarza et al. 2005, Zeyen et al. 2005, and Missenard et al. 2006). The major compressional structures in the High Atlas consist of a large-scale folding system which affects Mesozoic and Cenozoic formations. The geological review in the literature show that the structure of the High Atlas is derived from NE-SW normal faults, and WNW-ESE and NNE-SSW strike-slip faults.

The objective of this study is to map the geological structure in the Talsint region. The analysis developed here is based on the numerical enhancement of a Landsat image and on the statistical processing of data generated through enhancement. The results are presented on surface geological structures, lineament maps, and polar diagram. The validity of the computer analysis was compared with previous studies.

2. The Study Area

The studied region is located in the eastern High Atlas (region of Talsint) (Fig1). It is located between the 32°27'36 and 33°12'36 north latitudes, and 2°38'24 and 3°40'48 longitude western. The area is limited to the East by the plain of Tamlelt with paleozoic substratum continued in the Algeria by the Saharian Atlas. In north it is bordered by the Estern Meseta and in the south by the Eastern Anti Atlas. Except for the buttonholes paleozoic, the mountains of Eastern High Atlas are primarily made up of tabular or folded cover Jurassic and Cretaceous (Du Dresnay R. 1979, and Caia J. 1969). In the bordering links, the Jurassic grounds level largely beside de Cretaceous grounds.

3. Data Selection and Methodology

3.1 Numerical enhancement of a Landsat

We use an ETM+ Landsat7 image, Orthorectified, with projection parameter WGS84 (Map projection UTM zone 30 N), the acquisition date is 2001, Mars 4. The landsat image is downloading from website of Maryland University (ftp.glcf.umd.edu). The mapping of geological unit is done from composite image (fig.1) by supervised classification procedure. A Spectral signature (training sites) is developed from specified locations in the image. These signatures are used to classify all pixels in the image (fig. 1).

Figure 1: Landsat ETM+ image covering the study region. Color Red Green and Blue represent Infra Red , Red and Green bands of the satellite.

The extraction of geological lineaments contained in the Landsat images may be made easier by various image enhancements processing such as the principal component analysis (Timoulali et al. 2012). The principal component reduces the correlation between the different spectral bands. The advantage of such technique is to manipulate visually a small number of spectral band containing much information and minimal noise. In our case, we have chosen the first principal component. Various methods exist to achieve enhancement and extraction of lineament (directional filters, edge enhancement algorithms, and the lines detection). The most objective are the lines detection algorithms especially the directional enhancement procedure, it is a five step procedure for detecting and enhancing the lineament (Moore, 1983) The detection of lineaments is automatic and we only retain the geological lineaments with length greater than 1.5 km. The GIS overlay technique is used to define the structural boundary and the faults.

3.2. Software Used

- The satellite images processing was performed by the Erdas Imagine 9.1.
- The detection and the mapping of lineaments was performed by the ArcMap.
- The density map of lineaments and was carried out under Rockworks16.

4. Results and Discussion

4.1. Supervised Classification

The objective of the supervised classification is to refine and mapping the geological structures in the study area. This classification is applied to a combination of 6 bands 1, 2, 3, 4, 5 and band 7. Indeed, the precision of supervised classification depends on the choice of training sites. The spectral signature must be homogeneous in the same training site and the training sites must have different spectral signatures. The result of the supervised classification (fig. 2) shows the geological structure in the area. Analysis of the geological map of the eastern High Atlas (from stratigraphy, palaeontology and sediment deposit) allows the mapping the Jurassic and cretaceous cover level. Indeed, these discrete stratigraphic are characterized by an alternation of grounds represented by: marly, yellow marly, reds gypseous, succession of Red Beds (Lower Bathonian), marly limestones and limestones and Continental Lower Member.

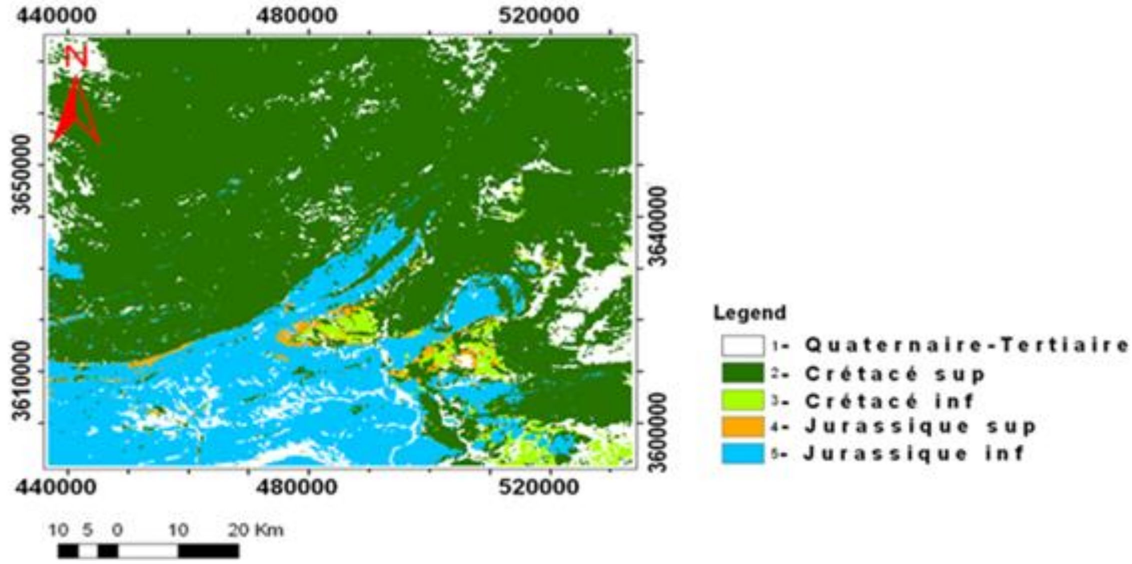

Figure 2: Geological map obtain from supervised multispectral classification of Landsat ETM+ image

From the tectonic study the Jurassic-Cretaceous around Anoual town formed the synclinal of Anoual and synclinal of Ksar Jilali are largely slack. This two synclinal are separated by the anticline from Foum Messaoud with lower lias deposit.

4.2. Application of the directional filters

For the detection and the enhancement of the linear structures related to the geological faults, we use the Moore directional filters (Moore G. K. 1983). A Haut pass filter window 3*3 is used for the enhancement of lineament in the direction NE-SW, WNW-ESE, NNW-SSE, ENE-WSW, NNE-SSW (Fig. 3). For the geological lineament, a length exceeds 1,5km were extracted (Fig. 4).

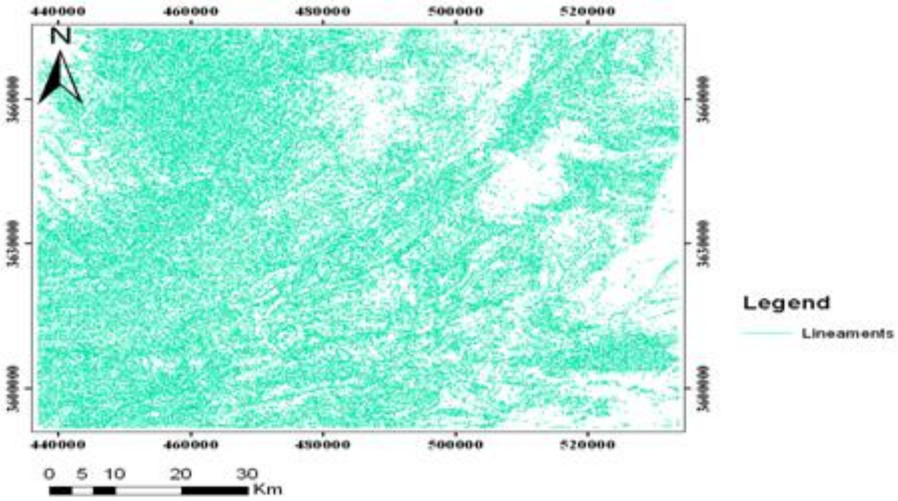

Figure 3: Enhancements and extraction of lineament by directional filters.

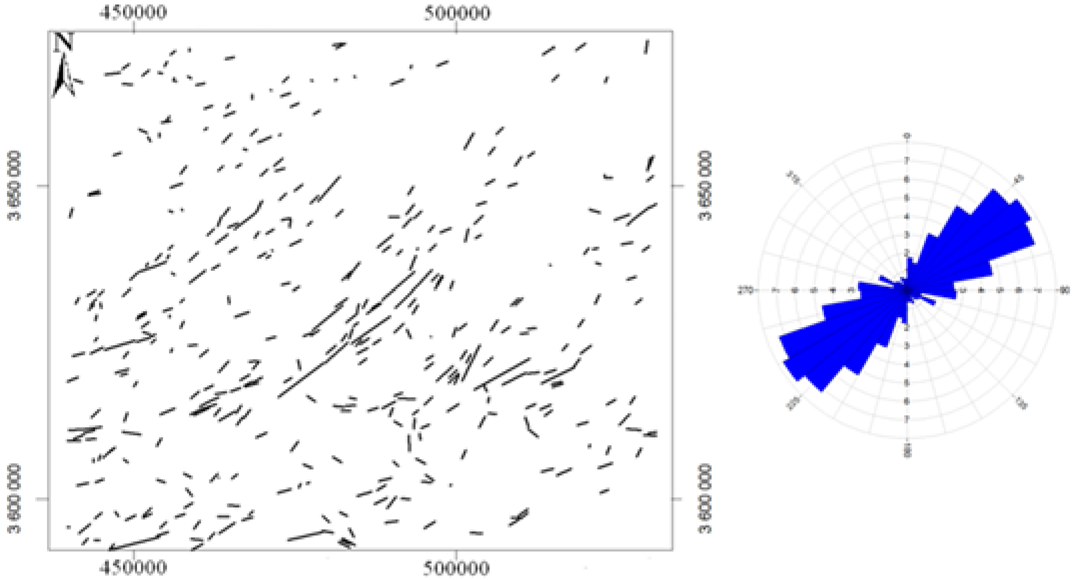

Figure 4: Extraction of the geological lineament map and preferential direction in the region by polar diagram.

In our study, the lineament statistical analysis by using the directional polar diagram was performed allows us to determine of the dominant orientation of feature extracted. This will determine the structural orientations and the fracture density. The dominant orientation of lineament is directed toward N 45 (fig. 4). The region of Talsint faults map shows that the Jurassic structures are affected of by two main families of faults (fig. 5)**,** The faults (F1’, F1’’, F1’’’, F1’’’’) are oriented SW-NE and the faults (F2’, F2’’) are oriented WNW-ESE to E-W (Fig. 5).

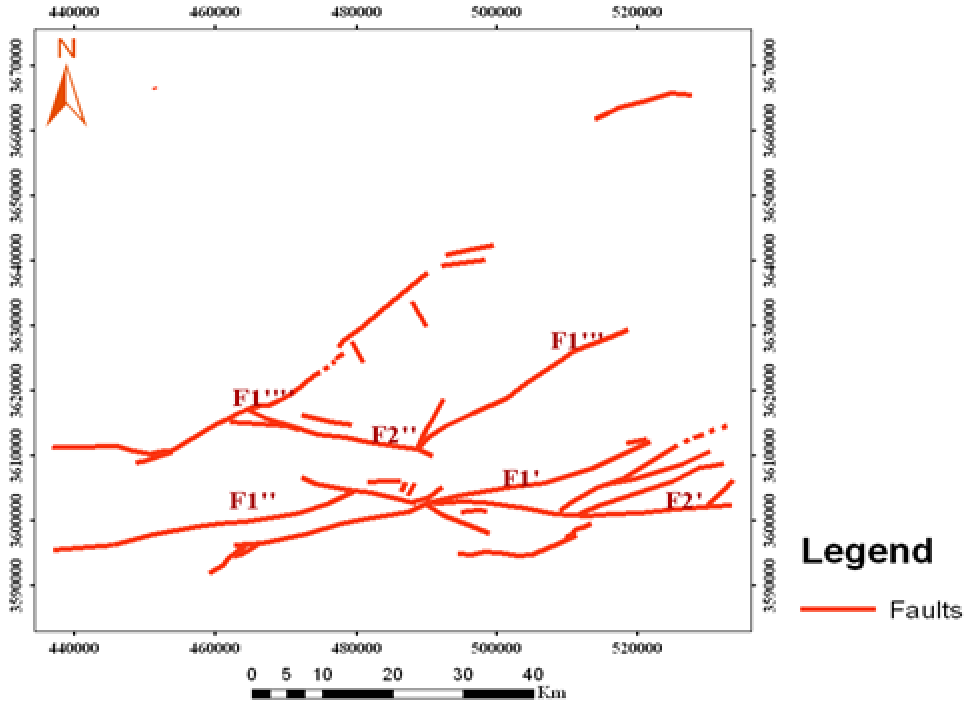

Figure 5: The Talsint region Faults map.

4.3. Integration of data in a GIS

The polar diagram shows that the lineament direction orientation is SW-NE to WSW-ENE and WNW-ESE to E-W. The comparison of maps fig.4 and fig.5, shows that the density of lineament is higher along the faults. The overlay of fault map on the geological map (Fig. 6) allows us to define the relationship between lineament and geological structure. Finally, we integrate the seismic data resulting from the seismic crisis on the final geological map (Fig. 7 and Fig 8).

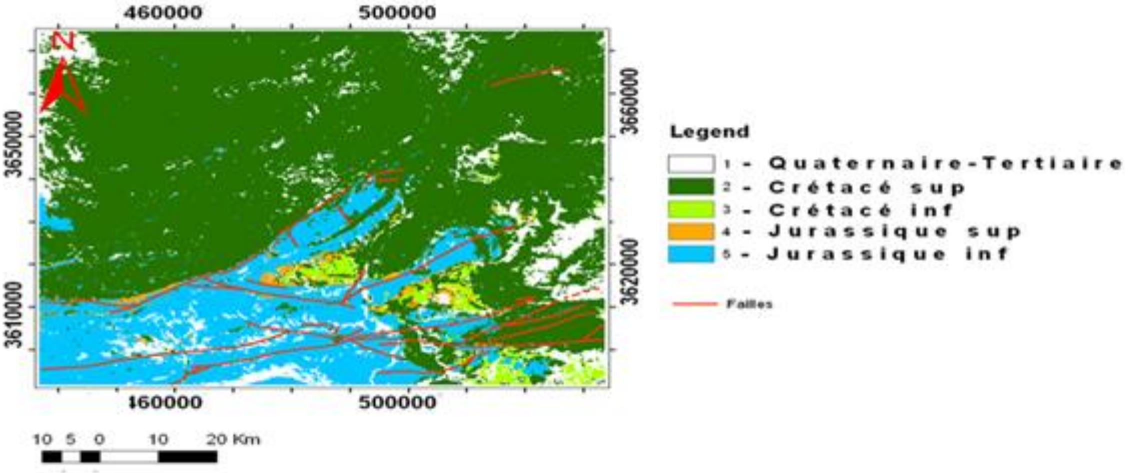

Figure 6: Position of faults on the geological structure**.**

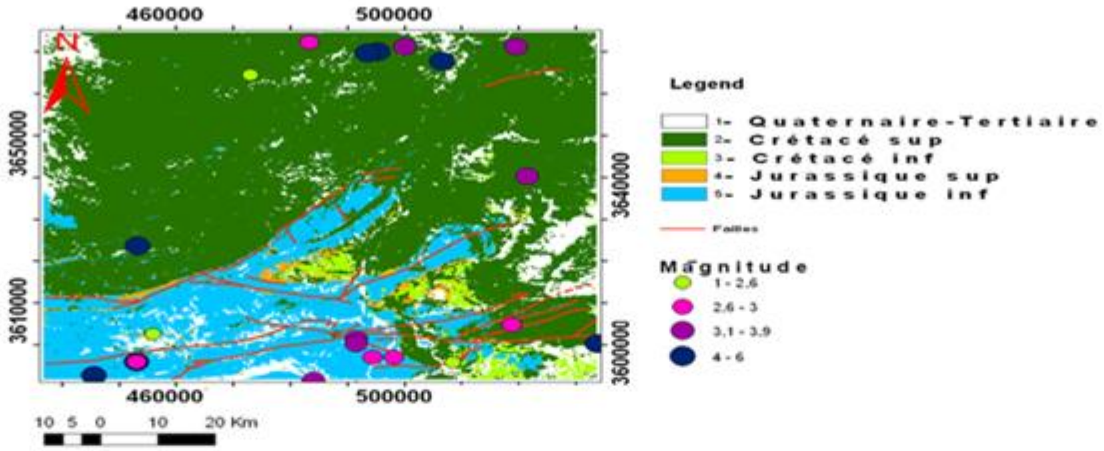

Figure 7: Integration of the seismic data from the seismic crisis (1901 to 2004) on the geological map.

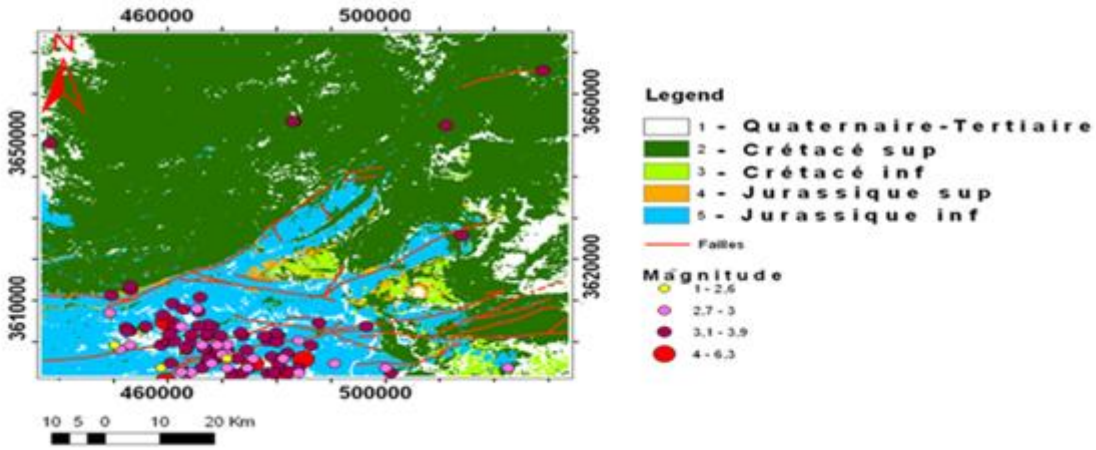

Figure 8: Integration of the seismic data resulting from the seismic crisis (2005-2014) on the geological map.

5. Interpretation and Discussion

This study allowed conclude that the faults in the study area were part of the southern atlas groove which separate High Atlas from the Anti Atlas (Fig 6). The seismic analysis from 1901 to 2005 shows a weak seismic activity in this region (fig. 7). From 2006 a strong seismic activity is recorded in the region (Fig. 8). The first strong earthquake (M=5 on the Richter scale) was recorded the 31january 2007, and it is localised in the SW of the study area on a fault close the Talsint region. Therefore, the seismic activity shows a migration towards the SW of the Talsint region (fig. 8). Geologically, the compression oriented NW-SE between African and Eurasian plate is causing faults and the current seismic activity. Indeed, the seismic activity is founded along the faults (F1' and F1'') oriented to NE-SW.

6. Conclusion

The digital processing applied out an image allowed obtaining a geological map and the geologic lineament map. The highest densities of lineament obtained are oriented NE-SW and with of the same faults F1' oriented NE-SW. The current seismic activity confirms the migration of the seismic activity towards the South-Est. The compression oriented NW-SE between African and Eurasian plate is causing faults and the current seismic activity. The simultaneous use of the techniques of digital processing of satellite images and a GIS made it possible to locate the active faults responsible for the seismic activity. This localization of the faults reduced the cost of investigation and allowed a better monitoring of the seismic activity.

7. Acknowledgements

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