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Tectonic Deformations based on Lineaments Analysis of Mechtat Ain El Beida (Bou Arif Mountain) North East of Algeria

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ABSTRACT

The area of Mechtat Ain El Beida is a seat of complex tectonics. The aim of the study was to determine; the direction of different tectonic movements, their type and to establish deformations chronology which had the origin of the structuring of the area during the period between (Cretaceous to Miocene). To accomplish this work, a method of fracture's lineaments analysis was used, 51 satellite images, data measured and carried out from the field have been analyzed and the final results were gathered in one rose diagram. Four major directions were found combining in parallel with four major tectonic movements, related to the geologic times as followed, respectively: North-South direction (compression movement aged Miocene), North-South direction (distention movement aged Coniacian), North East-South West direction (compression movement aged Turonian) and finally, North West-South East direction (compression movement aged Cenomanian). The location of the study area in the mountain slope may have an economic importance due to its ability of capturing some mineral deposition, so a future sedimentological and mineralogical study is needed.

Key words: Tectonic, cretaceous, miocene, turonian, cenomanian, sedimentological, mineralogical

INTRODUCTION

The study area is situated in the Southeastern slope of Bou Arif massif between Amrane mountain and Chaabet El Besbes, in border of the flat shape of the Sahara, while it covers a paleogeographic and structural domain quite distinct which is the Atlasic (Mounts of Aures) (Vila, 1980). The area's history had known several geological studies. Among the first geologists: Laffitte (1939) had given the stratigraphic diagram of deposits with paleontological arguing and a description of the main tectonic elements. The research of Bureau (1986) covering the structural aspect, has interpreted the evolution of the Mounts of Bellezma by the model of the rock blocks, whereas, Guireaud (1973) and Kazi-Tani (1986) have treated the structural geology of sequential analysis and the paleogeography for the northern Algeria. Although, those studies have been done in the region, it is still needed to widen area's geological knowledge, especially for the structural domain because of its important value. The aim of this paper was to know the different deformations affecting the area and the main tectonic movements responsible for those deformations. This research was identified as being useful to sedimentologists in that it provides them with objective facts that can help them to draw the geological evolution of the area during the geological time (Cretaceous to Miocene) and helps mineralogists to find mineral depositions.

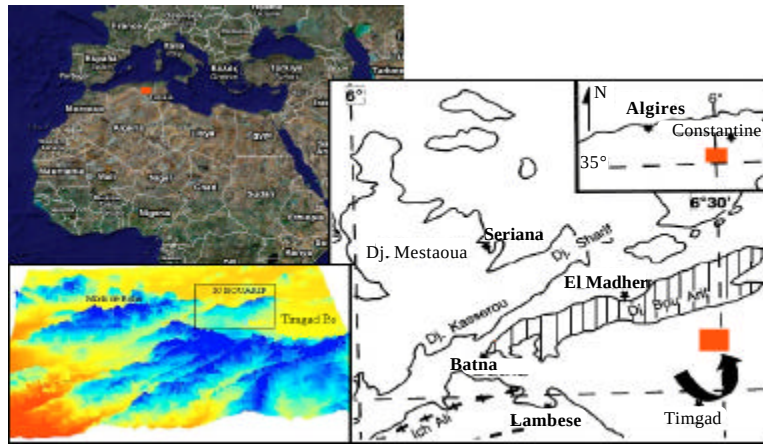


Fig. 1: Location map of the study area (Mechtat Ain el Beida)

GEOLOGICAL SETTING

The area that was the object of study (Mechtat Ain El Beida) is situated in the northeast of Algeria, in the northeastern bordure of Timgad Basin and the southeastern extremity of Bou Arif mountain (Mattaue, 1958) (Fig. 1). Its coordinates are the following: latitude $35^{\circ} 38' N$ - $35^{\circ} 35.5' S$; longitude $6^{\circ} 28' W$ - $6^{\circ} 31' E$ (Marmi, 1989). The massif of Bou Arif belongs to the Atlasic furrow (native front's country) (Yahyaoui, 1990). It is an anticline in bayonet shape of orientation NE-SW, with 40 km of length and 5 km of width, which is resulting from compressive tectonics related to the Atlasic movement of late Eocene and Alpine movement (Vila, 1980). It is a folded structure affected by many dextral and sinistral faults of direction NW-SE and NE-SW (Chadi, 2004), bordering the basin of Timgad in its northern part and truncated (1.5 km) in its central part (Fig. 1).

STRATIGRAPHY

The sediments are primarily of age Cretaceous (Fig. 2). From the bottom to the top of the series, the stratigraphic sequence is as followed:

The Cenomanian age is characterized by 40 m of two limestone bars with Glauconite, separated by gray hard mudstones at the base and a thick layer (280 m) of gray- blue friable mudstones with *Heterohelix* (Fig. 2, left) at the top. Followed by 155 m of Turonian age facies; which is characterized by an alternation of gray mudstones and white muddy-limestones with Glauconite at the base; blue mudstones with fractured and broken fossils such as: *Rotalipora* and *Praeglobotruncana* (Fig. 2, left); followed by light brown hard mudstones at the top (Guireaud, 1973). Coniacian age is composed of 90 m of gray mudstones reach of *Textularia* (Fig. 2, left) with thin layers of nodulos limestones at the base and 30 m of alternation of light gray mudstones with thick layers of nodulos limestones at the top. From Coniacian to Oligocene time, the sediments has been totally eroded, whereas the Coniacian sediments were directly connected to Miocene once by a regional unconformity (Laffitte, 1939). The Miocene sediments thickness is about 78 m, mainly; polygenic red conglomerates with pebbles of variable size at the base and glauconitic red coarse sandstones.

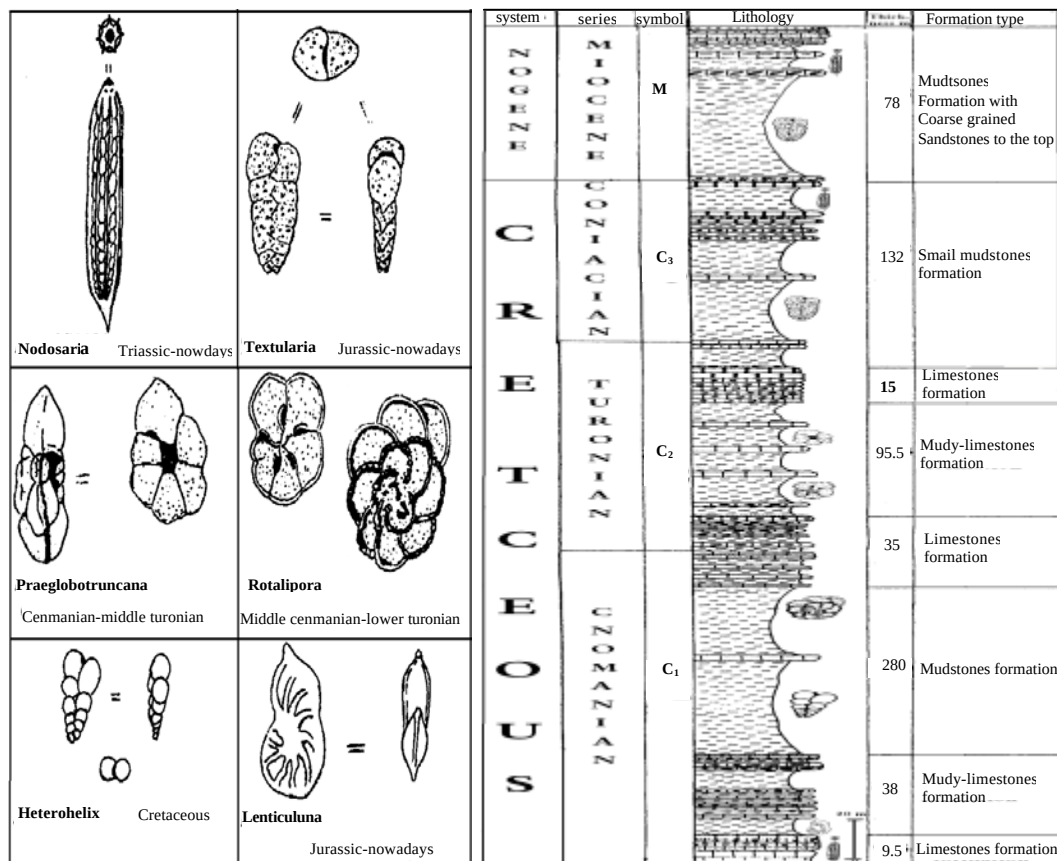


Fig. 2: Stratigraphic log of the study area (right) and main microfossils found in the washed mudstones, indicating specific ages of study area, Cretaceous and Miocene, respectively (left). These microfossils are mentioned on the stratigraphic column

METHODOLOGY

The study of structures and deformations influencing the study area required the uses of various methods of structural analysis: analyzing lineaments from satellite images and observations carried out on the field. The materials used were: Topographic and geological cards (Card of Ain EL Ksar N°173 with scale: 1/20000); satellite images (box N° 173, photos from 34 to 98) and tracing copy.

The aerial cover of only the study area is just 12 satellites images (from box n° 173); which is enough to extract the big structures and their related movements, that is why we integrate, surrounding area's aerial cover (39 images) which means that the total satellites images were use is 51 satellites images.

On two images we superimposed a square of tracing paper, on which we report the lineaments that appeared in the relief and corresponds with our definition. Furthermore, we carried other elements; these elements sometimes were of morphological origin (crest and peaks, rafters) and sometimes were of geological origin (geological layer, direction of the layer's movement, layer's strike).

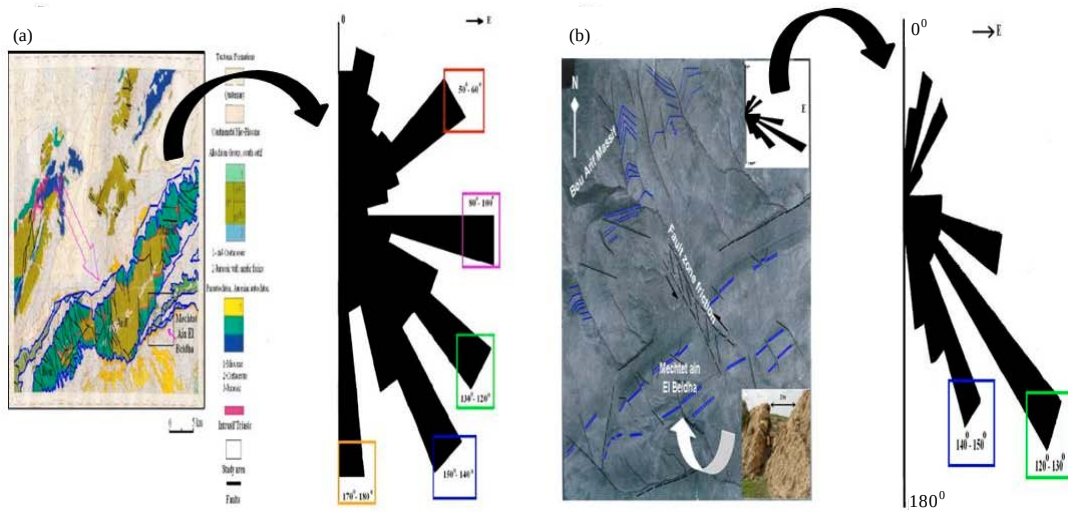


Fig. 3: A the rose diagram of different fracture lineaments analysis for the whole region showing five significant groups of lineaments: 50°-60° (red), 90°-100° (purple), 120°-130° (green), 140°-150° (blue) and 170°-180° (orange). B Satellite image of the study area indicating different fractures and faults (black lines) influencing the study area's geological formations (blue lines) with a Typical dextral strike-slip fault (right lower corner) with a movement of 2 m, deforming the massive limestones of the age Coniacian, the relative rose diagram which shows two significant lineaments group: 120°-130° and 140°-150°

For analyzing our lineaments card, we used the statistical methods. In fact, these methods characterized lineaments in a plan (X, Y); by an angle which is made by the lineament with the north and by its length (km). The lineaments were sorted out by an increasing angle of 0° to 180°, the file is divided in class of 10°; for every class we count the number of lineaments (frequencies) and we calculated the accumulated lengths of all lineaments of the class.

The statistical treatment was presented in the form of rosacea of frequencies. Observations and measurements carried out on the field from different structures (faults planes, diachases) have been also treated as the above lineaments and the results were shown in the rosacea diagram (Fig. 3: right upper corner).

RESULTS AND DISCUSSION

Figure 3 shows a satellite image of the study area, emphasizing the different fractures and faults (highlighted in black color) effecting the different sedimentary formations (highlighted in blue). The rose diagram of different fracture's lineaments analysis for the whole region which had been analyzed from 51 satellites images (Fig. 3: left) and the rose diagram of fracture lineaments analysis for only the study area (Fig. 3: right), presented the picks characterizing the predominant classes of lineaments. The combination of the results gathered from both rose diagrams of Fig. 3, had put in evidence five significant groups; they have been classed according to their order of importance as followed: the 1st group 140°-150° E; the 2nd group 170°-180° E; the 3rd group 90°-100° E; the 4th group 120°-130° E and the 5th group 50°-60° E.

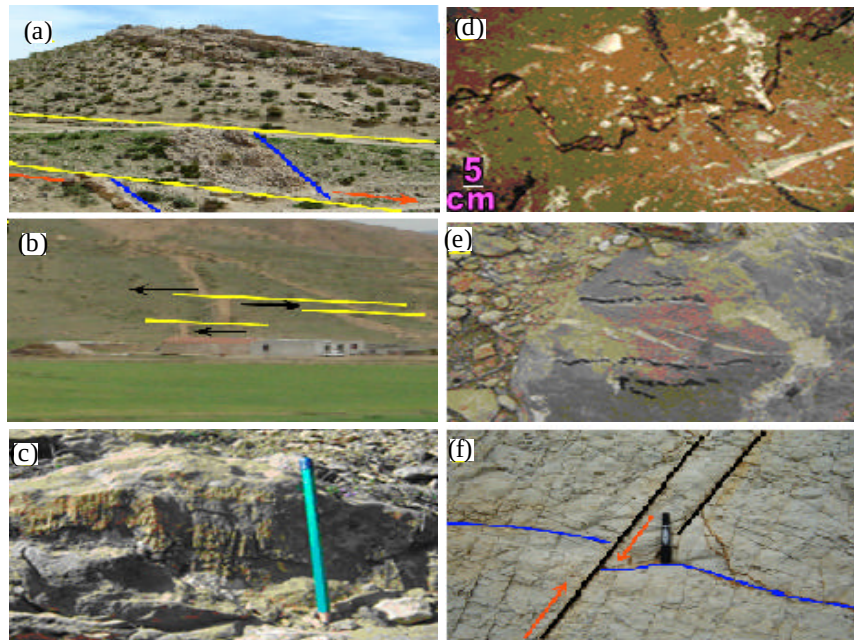


Fig. 4(a-f): Some structures carried out from the field. (a): Dextral sliding fault in muddy-limestone of Turonian. (b): Sinistral sliding fault. (c): Vertical normal fault plan with stylolitic joints in limestone of Coniacian. (d): Stylolitic joints in thin section scale found in Turonian carbonates resulted from a compressive movement of NE-SW direction. (e): Slits of tension indicates a dextral sliding movement to the East in the muddy-limestone of Cenomanian age. (f): Reverse fault affecting the Cenomanian limy-mudstones

Group 140°-150°: This class is presented especially in the southwestern part of Bou Arif massif and with a significant extent (Fig. 3). The main lineaments belonging to this class were followed by dextral sliding movement, which has deformed some horizon levels (mountain peaks) of Turonian age and also has deformed faults of NE-SW direction (Fig. 4a); this implies that faults of NW-SE direction are posterior in age with faults of NE-SW direction. On the geological map, these faults also affected the Quaternary age sediments and presented vast alluvial fans (Owoyemi and Willis, 2006). Thus, we can interpret that it is extremely possible that, these faults are active until nowadays. Generally, on geologic terrestrial sphere, a structural movement with an unspecified direction generates several types of fractures (Morley, 2002), where (normal fault, reverse fault and sliding strike-slip faults) are the main. According to Table 1, the group 140°-150° is a dextral sliding fault of NW-SE direction, thus, it was generated by the tectonic movement of N-S direction. This movement named Alpine movement and aged post Tortonian has been cited by many geologists and it is well known in the Saharan Atlas of Algeria (Vila, 1980; Kazi-Tani, 1986).

Group 170°-180°: This group is presented in the central part of the Fig. 3; in both north-northeastern part (with a noticed concentration) and central deviated part (little concentration), of Bou Arif massif. These faults affected the sedimentary formations of anterior Cenomanian (Aptian and Albian). Generally, a fault is composed of two blocks named, respectively: the hanging

Table 1: Orientation of the principal directions of deformation (Fran and George, 1961)

Faults type	Movement directions			
	Normal fault (°)	Reverse fault (°)	Dextral sliding (°)	Sinistral sliding (°)
N-S	NS	EW	NW-SE	NE-SW
E-W	EW	NS	NE-SW	NW-SE
NE-SW	NE-SW	NW-SE	NS	EW
NW-SE	NW-SE	NE-SW	EW	NS

wall and the foot wall, separated by a fault plan (Ocamb, 1961). The kinematic of these faults was not totally clear, neither in satellites images, nor in the field. In the field, it was found that these faults: (1) sometimes did not show the foot wall and (2) sometimes did not show the hanging wall. It can be interpreted that; (1) faults without any foot wall existence is due to the nature (friable or hard) of crossed sediments (Nigro and Renda, 2004), in this case, faults had crossed mudstones formations, which explains why a fault movement could not be seen and (2) faults without hanging wall is probably due to the erosion phenomena (Song and Cawood, 2001) (sediments were totally eroded by a strong erosion). Thus, it can be considered that the main lineaments belonging to this class are reverse faults, for example (Fig. 4f). According to Table 1 and what was preceded above, the group 170°-180°, is a reverse fault of N-S direction, which was generated by the tectonic movement of E-W direction.

Group 90°-100°: The concentration of these lineaments was marked on a line of E-W direction, while the extent was not very significant. The majority of these features were located in the northeastern part of Bou Arif massif (Fig. 1). These faults affected the limestone formations of Aptian age. Based on the topographic map, this group presented an interchangeable kinematic between: normal faults (little concentration) and sinistral sliding faults (Fig. 4b) with a considerable concentration, while this kinematic was not so clear in the satellite images. It can be considered that, normal fault with E-W direction is due to a distension tectonic movement directed N-S during the Coniacian age. Although, the rare distribution of these faults, they can not be neglected because, they were presenting special characteristics of a very important movement of distension (Fran and George, 1961). This movement is responsible for the creation of collapse basins of N-S direction, limited by a normal faults of E-W direction (Bracene and de Lamotte, 2002). Sinistral strike-slip faults are widely distributed and the main faults for this group. It can be inferred that, these faults were the result of a compressive tectonic movement of NE-SW direction (Kazi-Tani, 1986). Although this movement is not well known in the literature, but also it can not be neglected due to its structural importance. It was also responsible for the formation of reverse faults directed 145° and normal faults of 50° direction (southeastern part of Bou Arif massif) (Fig. 1).

Group 120°-130°: This group is concentrated in the southern part of Bou Arif massif and totally absent in both north and south, where the extent is rather significant (Fig. 1-3). These faults affected all sedimentary formations (Aptian carbonates, Cenomanian muddy-limestone and Miocene sandstones). Generally, they presented a specific kinematic of reverse faults with direction NW-SE. This kinematic sometimes, can not be seen clearly on the satellite images because of the tight and closed fault plan, but it is much clearer on the field. As it mentioned above (for preceding group), this faults have been also generated from a compressive tectonic movement with NE-SW direction (Fig. 4d).

Group 50°-60°: This class of lineaments presents a maximum concentration in the southeastern part of Fig. 2, with an invaluable extent. This group of faults is characterized by its specific location surrounding and limiting basins (Timgad basin) (Kazi-Tani, 1986). Some of these faults could make an abnormal contact between the sandstones formations of Miocene age and Turonian muddy-limestone (Vila, 1980). It can be referred that, this kind of contacts can only be a result of a reverse fault, thus, this class is mainly characterized by reverse faulting. Based on Table 1 and the topographic map, a reverse fault of NE-SW direction is the result of a compressive tectonic movement of NW-SE direction. This movement is well known in the literature (Laffitte, 1939) and named Atlasic movement. It was responsible for the formation of big NE-SW elongated structures such as: Bou Arif anticline, normal faults of NW-SE direction and important sinistral sliding faults directed N-S (Guireaud, 1973).

CONCLUSIONS

During the period between Cretaceous and Miocene, the study area was affected by different kinds of deformations (normal faults, reverse faults, disconnecting) which created, structured and gave the recent area's shape. Based on lineaments analysis of different cartographic data, the area knew four types of tectonic movements; cited in their chronological order as followed:

- Turonian compressive movement of NE-SW direction ; responsible of the formation of the reverse faults with direction 140°-150° and normal faults of direction 50°
- Distension movement aged Coniacian with N-S direction; had given birth to the normal faults of 80°-100° direction and the reverse faults of 170°
- Another compression movement directed NW-SE and aged upper Eocene, known in the literature by the Atlasic movement, plays a significant role in the structuring of the anticline of Bou Arif by folding it according to a NW-SE direction, resulting from a major overlapping movement with southern vergency and also formed a reverse faults with direction of 60°
- Finally the compression phase of direction (N-S) affect the sedimentary layers of the Miocene (post Tortonian) and formed the normal faults with direction of 170°, the reverse fault E-W and the disconnecting fault with direction of 140°

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