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Tectono-sedimentologic and lithostratigraphic control in Aures Region: Case study Djebel Metlili, Batna, Algeria

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Summary

This research delves into the geological features of the western section of the Aures Basin, with a primary focus on Djebel Metlili. The geological characteristics span Mesozoic and Tertiary deposits, ranging from the Triassic to the Quaternary epochs. Notably, the higher Cretaceous period stands out for its substantial carbonate-rich sequence. The research relied on geological maps, field observations, core samples, and laboratory analyses, including lithostratigraphic examinations (cross-section) and thin section. Structural features show that is formed by large regular folds of ENE-WSW or E-W direction. Anticlines and synclines are often affected by transverse accidents at the axes of the folds. In its northern part is located immediately south of the Belezma-Batna mountains. Structural analysis highlights significant tectonic disturbances, oriented in a northwest-southeast direction. A detailed lithostratigraphic examination reveals marly formations interspersed with limestone-rich layers containing Inoceramus.

The southern part of Dj. Metlili, particularly the Santonian-Campanian series, unveils three distinct meso-transgressive sequences, linked to sea-level fluctuations associated with sedimentary basin subsidence. The studied area exhibits three distinct facies: one characterized by gray phosphate limestone with crisscrossed stratifications and agitated bioclastic sand, another featuring a mollusk-rich bioclastic limestone indicating a turbulent intertidal environment, and a third presenting a clay limestone bank with fine to medium grains and lumachels rich in oysters and gastropods. The associated grainstone texture in the microfacies suggests an internal platform

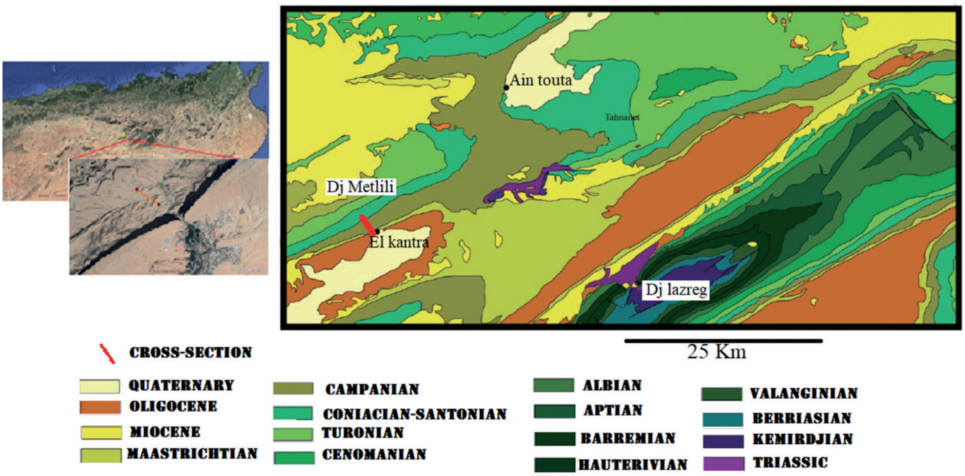
environment marked by dissolution, bioturbation, and ferruginization. This comprehensive exploration provides valuable insights into the geological history of the region, significantly contributing to our understanding of its evolution over time.

Keywords

Aures • Metlili • Santonian-Campanian • Inoceram • tectonics

1. Introduction

The Aurès massif constitutes the central feature of the Atlas domain, occupying a geographical area that extends from the Hodna Mountains in the west to the Nememcha-Ain Beda Mountains in the east [Villa 1980, Farah 1991, Frizon de Lamotte et al. 2000]. Its southern slope, towards Biskra, is limited by southern Atlas fault [Belkhodja and Bignot 2004, Benmansour et al. 2016]. The northern part includes Miocene marine detrital deposits occupying the Timgad Basin up to the northeast of Khenchla [Marred et al. 2022]. Dj. Metlili which is situated in the western part of the massif (Fig. 1), is characterized as a substantial folded geological structure, with a steeper southern flank in contrast to the northern flank. Its core comprises Albian deposits, while the northern and southern flanks prominently exhibit Upper Cretaceous terrains [Garah et al. 2023]. Overlying the Senonian formations [Ballais 2012], Miocene deposits are found in an unconformable relationship, indicating a geological gap or discontinuity in the record.



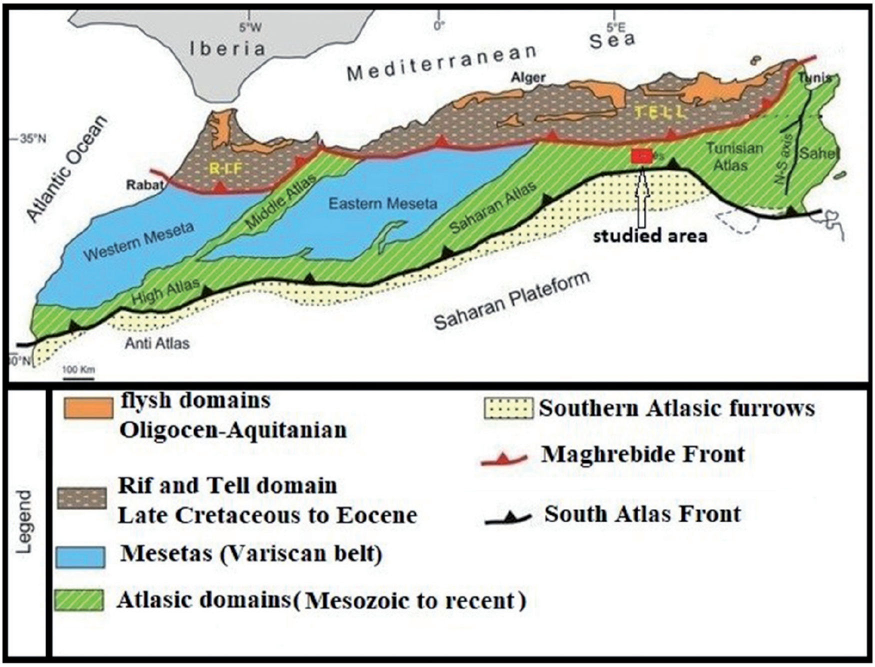
Source: extracted from Laffite [1939]

Fig. 1. Geographical location of the study area

In this section, our objective is to thoroughly examine the primary geological features that have influenced the sedimentation during the Upper Cretaceous period in the Aures region, drawing upon all the available data. The aims of this research encompass the characterization of distinct deposit facies, the detection of diverse discontinuities within the Santonian Campanian series, the reconstruction of sedimentation paleoenvironments, and the determination of the principal sedimentary sequences.

2. Geological frameworks

To gain a comprehensive understanding of the geological history within the El Kantara-Batna study area, it is imperative to contextualize it within its broader regional geological framework. The region lies within the North African coastal ranges, also known as the Maghrebides [Villa 1980, Wildi 1983, Benmansour 2023]. Geographically, the Metlili anticline is defined by Lambert coordinates, spanning from approximately 35° to 36° north in latitude and 5° to 6.5° east in longitude (Fig. 2).



Source: modified from Piqué et al. [1998] and Frizon de Lamotte et al. [2000]

Fig. 2. Geological sketch of the Maghreb

The core of this geological context is the Aures massif, it is characterized by a secondary fold system that developed in the Eocene period in alignment with the Atlas directions. Additionally, the region highlights diapiric Triassic formations dating back to the Aptian age. Structurally, the autochthonous atlasic domain, distinguished by various structures, is affected by tectonic deformation whose imprint, of the phases of the late Cretaceous and Eocene, is clearly expressed by Guiraud and Bosworth [1997]. However, after the deposition of the Neogene new important deformations appeared and which would be related to the phase of the basal Quaternary [Marmi and Abdellaoui 2010].

The Aures having a quite simple structure, it situated in the eastern extension of the Saharan Atlas Laffite [1939]. It is formed by large regular folds of ENE-WSW or E-W direction. Anticlines and synclines are often affected by transverse accidents at the axes of the folds [Marmi and Guiraud 2006]. The formations within the autochthonous Atlases domain exhibit distinctive features, marked by a carbonate composition extending from the Lower Jurassic to the Middle Jurassic [Marmi and Abdellaoui 2010]. Sedimentation beyond the Malm transitions to detrital sandstone, culminating in a regionally significant hard ground. The succeeding sedimentation, marked by a marl-carbonate shift, persists until the Lutetian period, punctuated by tectonic disruptions such as discontinuities, gaps, and hardened surfaces. The Mio-Plio-Quaternary, detrital, reflects recent tectonic activity and overlaps with earlier series, revealing the geological dynamics of the region across epochs [Herkat 2003].

3. Material and methods

3.1. Tectonic markers and Lineament analysis

Deformation in the rock materials (comprising limestones and sandstones) within the study area is characterized by distinct tectonic markers. These markers manifest as discontinuous planar and linear structures, including stylolite joints, joint fractures, and echelon veins. These diverse manifestations are frequently accompanied by structures of varying sizes. Lineaments can be variously formed due to tectonic, faulting, fracturing, or other geological processes. The fundamental characteristics used for deciphering these structures are: photo tones which is the variations in tone or brightness in aerial photographs, a relief features, anomalies in the hydrographic network, abrupt termination of geological layers, discontinuities or abrupt endings of rock layers, and shearing and deformation of rock units. To analyze lineament maps, static methods are employed. This involves characterizing lineaments in a (x, y) plane by the angle they make with the north direction. The lineaments are sorted by increasing angle from 0° to 180°, and the data is divided into classes of 10°. For each class, the number of lineaments is counted, resulting in frequency rose diagrams representing the distribution of lineaments. The investigation into fracturing involved comprehensive fieldwork coupled with the examination of aerial photographs at a 1/20,000 scale. The primary objective was to comprehend fracture kinematics by scrutinizing associated deformations like compression, extension, shearing, and fault displacements proximate to fractures. Systematic analysis of aerial photographs, emphasizing relief, identified features such as riverbeds, ravines, slopes, terraces, talus slopes, escarpments, and geological elements like bedding orientations, fold axes, fault scarps, layer boundaries, faults, and joints. Following meticulous deciphering and analysis of the aerial photograph series, a synthesis operation was executed. This entailed transferring geological and morphological information from transparent sheets onto overlays superimposed on corresponding 1:50,000 scale topographic maps (El-Kantara Sheet No. 259 and Ain Touta Sheet No. 229).

Table 1. Frequency and cumulative length of joints fractures in study area

Classe	Length [m]	Frequency	Frequency [%]	Length [%]	Cumulative length	Cumulative frequency
10–20	0.109572	14	7.142	1.229	1.229	7.142
20–30	0.330736	14	7.142	3.709	4.939	14.285
30–40	0.532999	18	9.183	5.978	10.917	23.469
40–50	0.790696	7	3.571	8.869	19.787	27.040
50–60	0.493476	5	2.551	5.535	25.322	29.591
60–70	0.474052	4	2.040	5.317	30.640	31.632
80–90	0.949215	7	3.571	10.647	41.286	35.204
90–100	0.95876	12	6.122	10.754	52.041	41.326
100–110	0.858372	7	3.571	9.628	61.669	44.897
110–120	0.457315	6	3.061	5.129	66.799	47.959
120–130	0.50461	16	8.163	5.660	72.459	56.122
130–140	0.493353	36	18.367	5.533	77,993	74.489
140–150	0.50907	29	14.795	5.710	83.703	89.2857
150–160	0.485458	8	4.081	5.445	89.148	93.367
160–170	0.403105	8	4.081	4.521	93.670	97.448
170–180	0.564271	5	2.551	6.329	100	100
Total	8.91506	196				

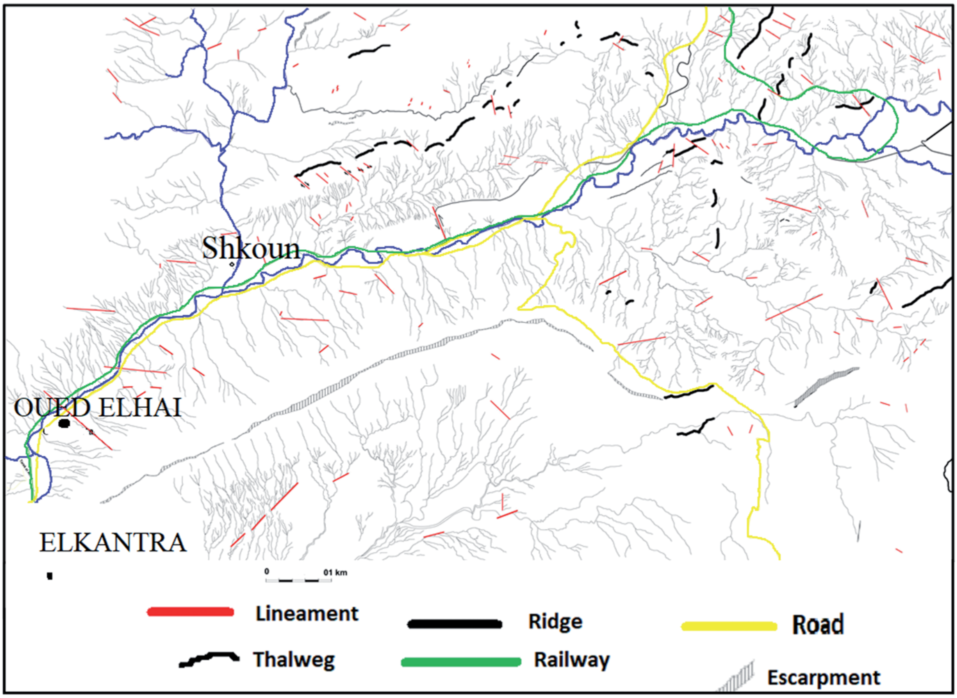
3.2. Construct geological cross sections

A comprehensive geological cross-section of Dj. Metlili has been meticulously created, adhering to rigorous scientific methodology. This process entailed the use of a variety of materials and equipment, such as a geological hammer, a compass, GPS technology, a measuring tap for estimating thicknesses and distances, a clinometer for measuring dip angles, a magnifying glass for close examination of rock and intricate details, and a camera for capturing photographs. Within the cross-section four distinct lithological units have been identified, each possessing its unique characteristics: laminated limestone, finely bioclastic silicified limestone, green marl rich in echinoids, and gypsum. Facies and facies models define the precise palaeogeographical, paleotectonic framework, within which the many discontinuities of the Santonian series of El Kantara are set up. This involves the characterization of the different sedimentary facies, their interpretation in terms of deposition media and their integration into a facies model.

4. Result and discussion

4.1. Structural analysis

A morpho-structural map is created using more than two hundred linear features (Fig. 3). Based on their orientations, these linear features are grouped into eight families, which are as follows: NW-SE, NE-SW, NNE-SSW, NNW-SSE, E-W, N-S, ENE-WSW, and WNW-ESE.



Source: Authors' own study

Fig. 3. Structural analysis of the study area

The most important family from a frequency perspective is the NW-SE direction. According to the linear map, the spatial distribution of these features, in general, is homogeneous across the entire area. However, there is a stronger concentration in the western half of the region. When comparing these linear features with the geological map, it appears that in most cases, they are related to tectonic features (fractures, faults), this family is also present, but with a higher density, often marked by shearing features, primarily dextral (throughout the map). These are well expressed in competent rocks such as carbonates, which tend to fracture under stress. However, in detrital terrains (especially clays and marls), the rock deforms intensely, but fractures are rarely visible.

The most significant (large linear feature, GL), with a regional NW-SE orientation, appears to be more recent in comparison to the others; it consists of relay segments. It corresponds to a tectonic feature affecting geological formations, both ancient and recent, sometimes displacing them. It is characterized by dextral movement kinetics. Therefore, from a dynamic perspective, it would be active and would characterize active tectonics in the region.

A significant NW-SE-oriented linear feature crosses Dj. Metlili, but its trace is absent in recent Douar Seggana plain deposits, suggesting either an earlier manifestation or low-intensity dynamics. Shorter linear features flanking these exhibit predominant WNW-ESE and E-W directions, indicating diverse geological influences. On the scale of the Aures, these N-S features are sometimes also encountered [Guiraud 1997]. In the study area, N-S-oriented features are distributed in the western part of the morpho-structural map. These features have a dextral displacement, marked by probable shearing. This has generated various structures such as folds, thrusts, and conjugate NW-SE and NE-SW faults [Aissaoui 1985, Marmi and Guiraud 2006].

The stereographic projection of joint sets has provided the following stress directions: 1) Family N-S and E-W, which are related to the NW-SE Atlasic phase. 2) Family NW-SE and NE-SW related to the N-S Alpine phase.

4.2. Lithostratigraphy

The series of the Santonian-Campanian exposed to the outcrop is in the periclinal NE of the structure of the anticline of Djebel Metlili, near the locality of Tamarins. It is marl and has limestone intercalations towards the summit, marked morphologically by a succession of bars, drawing a ridge along the road from Biskra to El Kantara (Fig. 4).

Sequence IA: The sequence has a total thickness of about 100 m, it is characterized by large banks of bioclastic limestone at the base and marl-limestone intercalations to the summit.

Sequence IB: It is an marly sequence rich in echinoids, bivalves and gastropods intercalated by beds of calcareous kidneys with a total thickness reached about 270 m, is characterized at the top by the appearance of ammonite (*Tissotia tissoti*, Fig 5).

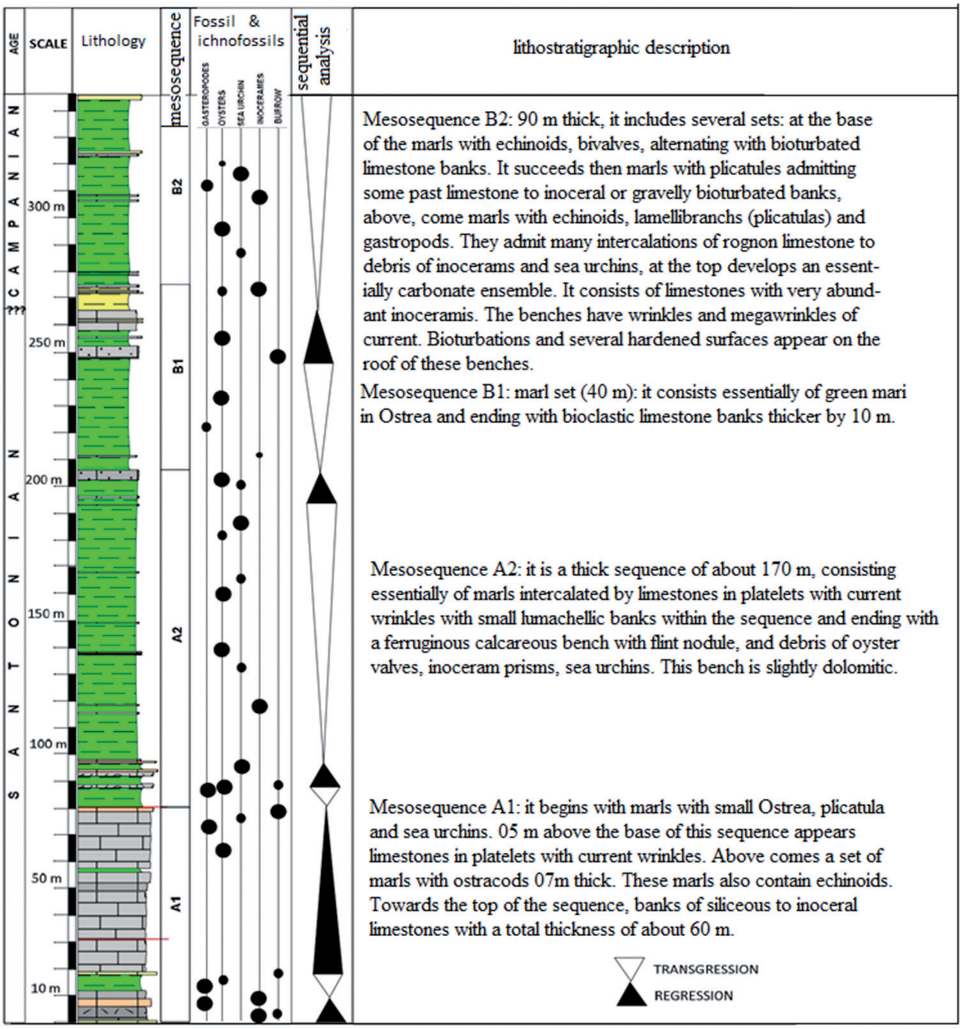


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Fig. 4. Synthetic sections representing the Santonian-Campanian

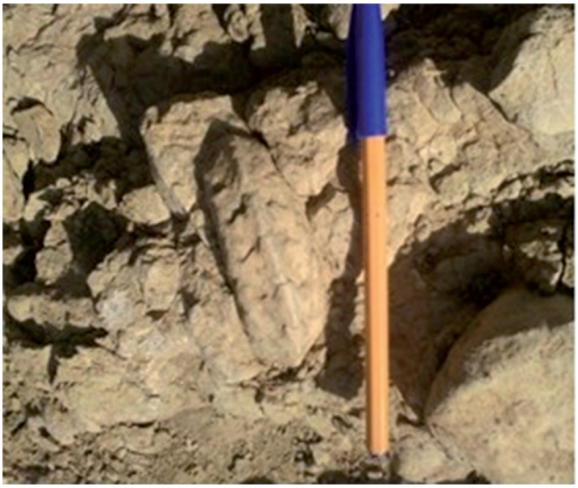

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Fig. 5. Ammonite (*Tissotia tissoti*)

4.3. Facies analysis

Facies 1

Macrofacies of phosphate limestone with medium grain of gray color with flint vein (Fig. 6 photo a), 1.8 to 2 m, with crisscrossed stratifications, and an accumulation of organisms that are parallel to the stratification characterize the roof of the bank.

Microfacies with bioclastic packstone (Fig. 6). It is a bioclastic sand microfacies with microparticle cement, packstone texture.

The figurative elements are represented by echinoderms (Fig. 6 photo b), gastropods (Fig. 6 photo e), lamellibranch and some benthic foraminifera (Fig. 6 photo c), we notice the presence of quartz (Fig. 6 photo b). These elements are presented in a rounded to sub-rounded form, half of which are broken and cracked. The packstone texture and microsparitic cement indicate that the environment is agitated.

Facies 2

Macrofacies with 1 m, bioclastic limestone with medium and gray grains (Fig. 7 photo a) rich in molluscs (gastropods, inocerams). It is marked by the presence of accumulation of lumachels. Microfacies with 2 m: bioclastic grainstone (Fig. 7), the texture is grainstone with syntactic sparite cement, bioclasts are essentially echinoderms, gastropods, inocerams debris, algae (Fig. 7 photo b) and benthic foraminifera (benthic twisted: Glomospira, Fig. 7 photo c, Dentalina Fig. 7 photo d). The size of the elements is usually average to a rounded and elongated shape. Micritization and compaction are the most answered phenomena in these facies. At the outcrop level, the roof has a rich burrowing surface. The grainstone character and the sparitic cement testify to a turbulent environment. Internal platform medium (intertidal), the latter is confirmed

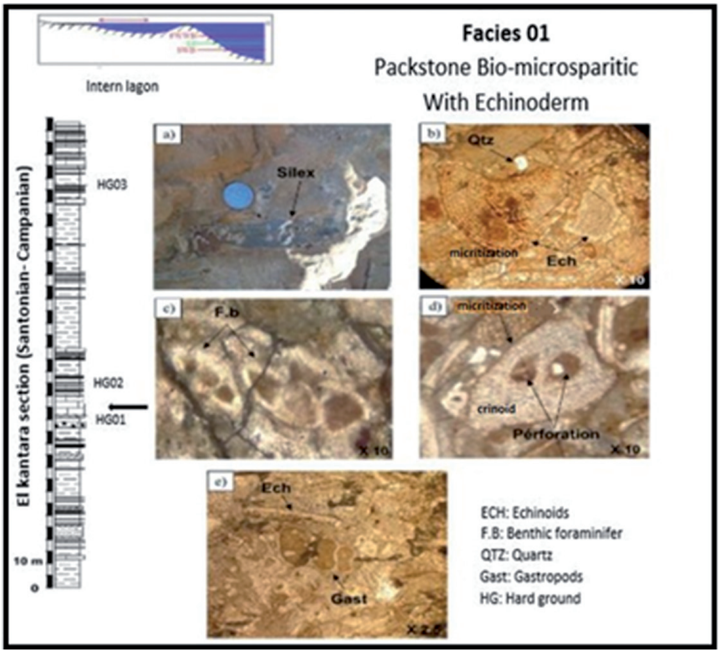

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Fig. 6. Facies 1. Packstone microspartic with echinoderm

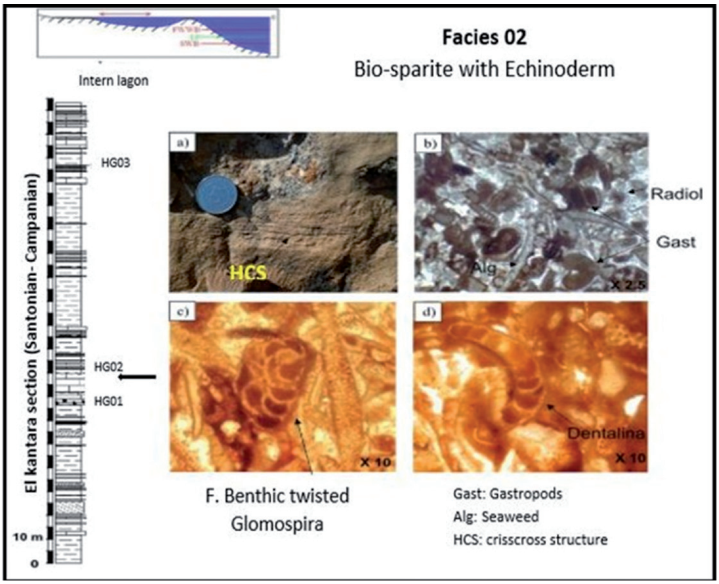

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Fig. 7. Facies 2. Biosparite with microsparite with echinoderm

by the variety of bioclasts. It is characterized by burrowing organisms (burrows) that are indicators of sedimentation stoppage.

Facies 3

Macrofacies with 0.5 m, fine-grained brown bioclastic limestone bank with wavy surface, rich in molluscs (oysters, gastropods).

Microfacies (Fig. 8), the texture is algal packstone, poorly classified, with microsparitic cement. The figurative elements are echinoderms, lamellibranches (Fig. 8 photo b), ostracodes (Fig. 8 photo c), and rhodophytes (Fig. 8 photo d). Note the presence of quartz with a sub-rounded shape and phosphate. Diagenetic phenomena are dissolution, micritization, silicification, oxidation and bioturbation. The packstone texture is related to an agitated environment and the diagenetic phenomena in these microfacies indicate a cessation of sedimentation. The variety of bioclasts and diagenetic phenomena signified an intertidal to subtidal medium.

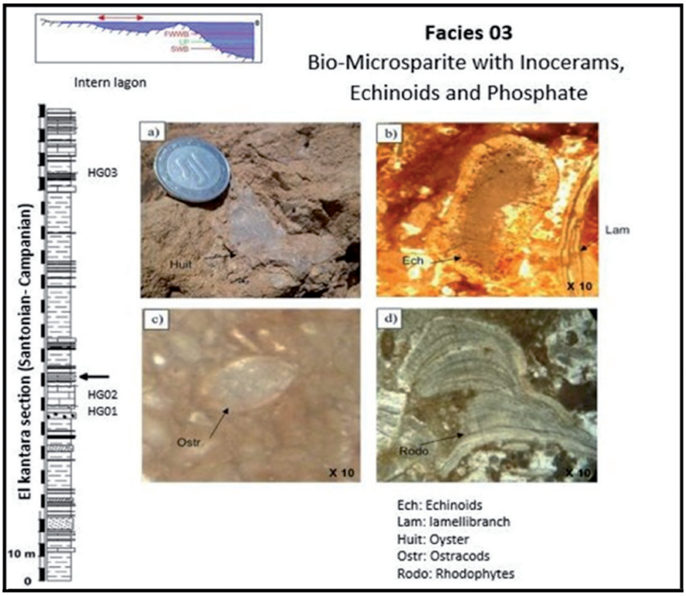

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Fig. 8. Facies 3. Biomicrosparite with Inocerams, echinoids and phosphate

Facies 4

Macrofacies with 0.3 m, bioclastic limestone with medium brown grains with bioturbated surface characterized by flint nodules (Fig. 9 photo a), with traces of burrows at the top. Microfacies (Fig. 9) it is a phosphate grainstone bioclastic sand, the figured elements are misclassified to a rounded shape, medium size. These elements are joined by a sparitic cement.

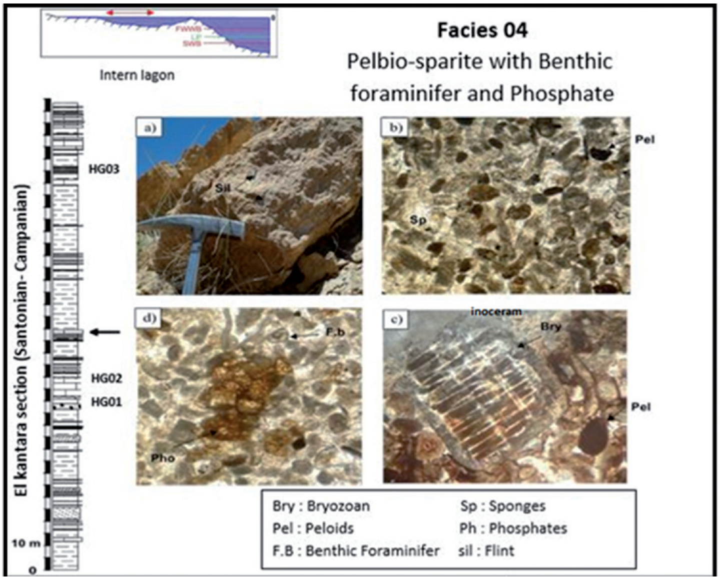

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Fig. 9. Facies 4. Pelbio-sparite with benthic foraminfera and phosphate

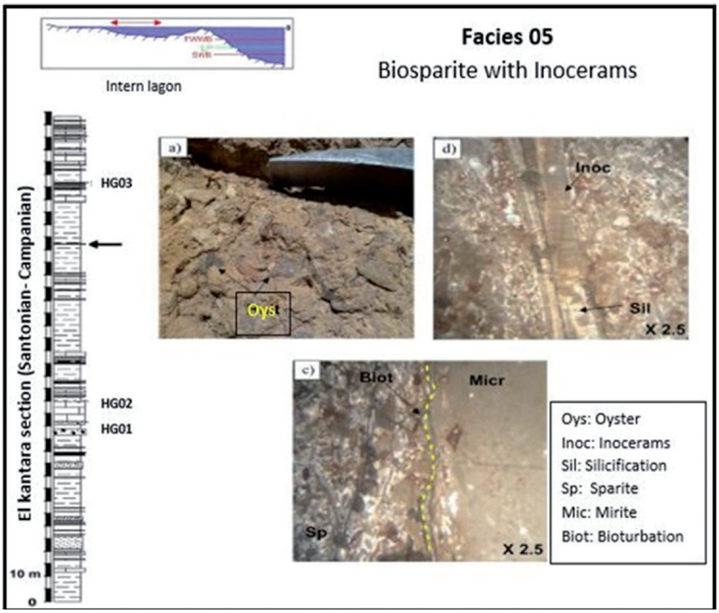

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Fig. 10. Facies 5. Biosparite with Inocerams

They are represented by pellets (Fig. 9 photo b, d), benthic foraminifera (Gvelinellidae, Fig. 9 photo c), inocerams debris, lamellibranches, algae, bryozoans with the presence of quartz with a sub-rounded shape. Diagenetic phenomena marked by compaction, ferruginization, and dissolution. Sparitic cement, Pillet, phosphate, and grainstone texture, indicate a restless environment. Generally, bioclastic sands are beach sands presented in internal platforms intertidal.

Facies 5

Macrofacies clay limestone bank with fine to medium grains (Fig. 10 photo a), characterized by lumachels at the roof of the bench rich in oysters, bivalves and gastropods, the base is clayey, and the top is little dolomitized.

Microfacies (Fig. 10) it is a microfacies with grainstone texture (bioclastic sand), represented by inocerams (Fig. 10 photo b), lamellibranches and echinoids, with poor ranking. Elements are usually rounded to sub-rounded and medium in size, characterized by dissolution, bioturbation and ferruginization (Fig. 10 photo c).

The abundance of inocerams and lamellibranchs indicates that the environment is internal platform (intertidal).

5. Conclusion

The study carried out on the Santonian-Campanian series of the El-Kantara region allowed us to specify certain lithostratigraphic characters relating to the series of the atlases domain: In the Santonian: The series is characterized by an evolution of facies from West to East, along the southern flank, towards a more marl succession with the appearance of a level of limestone in general rich in inocerams towards the top of the interval, announces the radical change in sedimentation. Four hard grounds highlighted in the Santonian interval and could be indications of tectonic or eustatic by tectonic control of sedimentation induced by the set of E-W accidents passing through this study area.

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