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MEMOIRE

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Domaine : Sciences de la terre et de l'univers

Filière : Géologie

Spécialité : Géologie des bassins sédimentaires

Thème :

Upper miocene deposits from el malabiad (tebessa northeastern of algeria) : sedimentology, micropaliotology and paleoenviremantal implications

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Session 01


بسم الله الرحمن الرحيم

ملخص

يشتهر حوض الميوسين بتبسة (الشمال الشرقي الجزائري) بندرة محتواه الاحفوري, حيث أثمرت التحاليل التي تم إجراؤها على عينات من الحجرة الصفراء بيانات رسوبية وتكنولوجية وميكروباليونطولوجية تتمثل في هيمنة الرواسب الناعمة ذات الطبيعة الرملية والطمي الدي يحوي نسبة معتدلة من كربونات الكالسيوم المنحلة من الحجر الجيري في المناطق المحاذية (مسترشيي) بالإضافة الى التحليل المورفولوجي بالتنبؤ بتطورات ذات أهمية متفاوتة (النقل الطويل) بجزيئات مصقولة او اقل صقل والروابط المعدنية تتمثل في المعادن الطينية (سميكتيت، كاولينيت، ايليتلت وسبيوليت). حيث كشف الفحص الإيكنولوجي لقسم عين سيدي صلاح عن تجمع ثمانية أصناف:

Palaeophycus tubulis, Helminthopsis isp, Diplocterion isp, Archaeonassa isp, Arenicolites isp, Taenidium isp ،Skolithos cf. S. Linearis

تم العثور على هذه المطبوعات الأحفورية في سكوليثوس وكروزيانا، مما يشير إلى بيئة بحرية ضحلة (ساحلية غنية بالأكسجين) كشفت دراسات المستحاثات الدقيقة تجمعات الحيوانات الدقيقة من 20 نوعًا في 10 أجناس و13 عائلة. وهكذا، تم تحديد 4 افواج مورفولوجية منها 10 انواع و10 اجناس من الاستراكود، وتشير التحليلات الكمية والنوعية للمنخريات القاعية تدل على ان الرواسب الترتونية تقع في البيئات البحرية الضحلة (الساحلية الغنية بالاكسجين).

الكلمات المفتاحية: *الميوسين، تبسة، الحيوانات الدقيقة، ميكروباليونطولوجي، اكنولوجي، البيئة القديمة*

ABSTRACT

The Miocene basin of Tebessa in northern Algeria is known for its low paleontological content.

The analysis performed on trend samples at El Hajra Safra gave new sedimentological, ichnoological and micropaleontological data.

A fine fraction predominates in the sediment, followed by a sandy fraction, followed by a silty fraction with moderate $CaCO_3$ content from the limestone reliefs (Maastricht limestone).

Morphological analysis allows to predict more or less important evolutions (long transport) with blunt or less blunt particles. The mineral matrix corresponds to the clay minerals smectite, kaolinite, illite and sepiolite.

The ichnological examination of the Ain Sidi Salah section revealed assemblages of eight ichnotaxons:

Archaeonassa isp, Arenicolites isp, Diplocterion isp, Helminthopsis isp, Palaeophycus tubulis, Skolithos cf. S. Linearis, Taenidium isp. These fossil prints were found in Skolithos and Cruziana, indicating a shallow marine environment (oxygen-rich littoral).

Micropaleontological studies revealed microfaunal assemblages of 20 species in 10 genera, 13 families. covering 10 species of ostracods were identified.

Quantitative and qualitative analyses of benthic foraminifera indicate that the Trotonian deposits are located in shallow marine environments (littoral) and rich in oxygen.

Keywords *: Miocene; Tébessa; microfauna; micropaleontology; ichnology; paleoenvironment.*

RESUME

Le bassin miocène de Tébessa au nord de l'Algérie est connu pour son faible contenu paléontologique.

L'analyse effectuée sur des échantillons de tendances à El Hajra Safra a donné des nouvelles données sédimentologiques, ichnologiques et micropaléontologiques.

Une fraction fine prédomine dans le sédiment, suivie d'une fraction sableuse, suivie d'une fraction limoneuse à teneur modérée en CaCO3 provenant des reliefs calcareux (calcaire de Maastricht).

L'analyse morphologique permet de prévoir des évolutions plus ou moins importantes (transport long) avec des particules émoussées ou moins émoussées. La matrice minérale correspond aux minéraux argileux smectite, kaolinite, illite et sépiolite.

L'examen ichnologique de la section d'Ain Sidi Salah a révélé des assemblages de huit ichnotaxons :

Archaeonassa isp., Arenicolites isp., Diplocterion isp., Helminthopsis isp., Palaeophycus tubulis, Skolithos cf. S. Linearis, Taenidium isp. Ces empreintes fossiles ont été trouvées à *Skolithos* et Cruziana, indiquant un environnement marin peu profond (littorale riches en oxygène).

Des études micropaléontologiques ont révélé des assemblages de microfaune de 20 espèces dans 10 genres, 13 familles. Ainsi, 4 morpho-groupes et 10 espèces de foraminifères couvrant 10 espèces d'ostracodes ont été identifiés.

Les analyses quantitatives et qualitatives des foraminifères benthiques indiquent que les dépôts Trotonien sont situés dans des environnements marins peu profonds (littorale) et riches en oxygène.

***Mots Clé** : Miocène ; Tébessa ; Microfaune ; Micropaléontologie ; Ichnologie ; Paléoenvironnement.*

APPRECIATIONS

Above all, I thank God the most merciful who has given me the help and the will to be able to realize this work.

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*I address my sincere gratitude to all the teachers of the department of geology who helped and guided us throughout our course. My thanks also go to all the members of the jury **Ms: HDJAM RIAD** & **Mr: GOUAIDIA LAYACHI** who accepted to read this modest thesis to evaluate it.*

DEDICATIONS

With all of my pride, joy and love, I dedicate this thesis:

To my hero, my dearest father for all his endless love, trust and support I owe you all of my successes and achievements.

To my mother and my dear brothers Haithem & Saadou for their encouragement and support.

This path would never be the same if it wasn't for all of my friends: Hadil, Ines, Ikram and Fatima who made it full of new adventures, unexpected experiences and lots of walks & rocks.

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Rahabi Rofaida

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CHAPITRE I : GENERAL INTRODUCTION

I. ORIGINALITY AND OBJECTIVE OF THE STUDY

For several decades, the study of the Miocene geological history around the Mediterranean has been a very alluring topic. The multidisciplinary exploration of Miocene deposit sections and samples reveals valuable informations not only on paleoenvironmental evolution, but also on paleoclimatic climate and global or regional changes in the level of the Mediterranean Sea. Almost all studies on the Miocene series in Algeria have been concentrated in the northwestern region of the country (Chelif Bassin). Based on the distribution of foraminifera, these works offered chronological subdivisions and details on paleoenvironments.

The Miocene outcrops of the Tebessa region, situated on the Algerian-Tunisian border, are found in two basins, one southern and one northern, with distinct evolution and various facies. Lower and middle Miocene deposits consist of sandstones, sands, marls, and conglomerates resting on Cretaceous and even Triassic formations, whilst the Upper Miocene deposits consist of red marls with rare bariolated levels, sands, and sandstones.

The Miocene series covers three stratigraphic groups (Burdighalian, Langhian-Serravallian, and Tortonian) and has a thickness ranging from 50 to 200 m (Kowalski & al. 1995). The latter authors proposed that a ferruginous crust separates Langhian-Serravallian sediments from Tortonian strata.

With the exception of a few research (Kowalski & al. 1995 and Hamimed & al. 2001), it should be noted that micropalaeontological research studies in this region are quite rare.

The exploited areas (El Ma Labiod and Ouenza) are located in the Wilaya of Tebessa in Algeria's northeastern region. Our current work involves a sedimentological, ichnological, and micropalaeontological study to reconstruct the explored region's paleoenvironments.

Thick marine mixed siliciclastic-carbonate sediments with extensive ichnofauna have been deposited in the west Mediterranean Miocene peripheral basins (Naimi & al., 2020a). Several ichnological studies have been conducted on these deposits over the last decade, particularly in Spain and Italy (Uchman & Hanken, 2013; Monaco & Trecci, 2014; Belastegui & al., 2016). They feature diverse and remarkable trace-fossil assemblages in shallow marine habitats.

However, both bioturbation and bioerosion patterns have been documented infrequently (Doyle & al., 1998; Gibert & Robles, 2005).

Several studies on the Miocene marine series from Northern Algeria have recently been published [Benzina et al., 2019; Cherif et al., 2021; Naimi et al., 2020, 2021]. Miocene sediments from the Mediterranean Sea's southern frontier (Northeastern Algeria) are surfacing in the T'ebessa region. The Miocene series ranges in thickness from 50 to 200 m. The lower and middle Miocene are composed of sandstones, sands, marls, and conglomerates atop a transgressive surface (Cretaceous and even Triassic), but the upper Miocene is composed of red marls, sands, and sandstones.

Brives [1919, 1920] published the first paper on the Miocene of the T'ebessa region. Brives [1919, 1920] indicates the existence of Dinotherium teeth in the El Kouif sand quarry. Durozoy [1956] classified the lower and middle Miocene as sandstone and siliceous puddings, and the Vindobonian (upper Miocene) as clays and marls.

External bivalve moulds (Ostrea crassissima) were discovered by Morel [1957]. Furthermore, Dubourdieu et al., 1959] mentioned the presence of Neoaveolinea foraminiferous in Mesloula's Miocene. Vila [1977] cited and described an extensive list of foraminifera from the lower and middle Miocene in the Koudiat Mami and Rahia region. Previously, Hamimed and Kowalski [2001] classified the cropping deposit in the El Ma Labiod region as an azoic series and assigned it to the upper Miocene based on lithological association with similar dated Miocene sediments of Mechta Remila and Koudiat Naga in the north of T'ebessa [Kowalski et al., 1995a, 1995b].

The main objective of our work is to reconstruct the paleoenvironment of certain regions (Tebessa) during the Miocene by comparing it to the Mediterranean scale. This is the first record of foraminifera and ostracod material from the studied location upper Miocene. The Miocene deposits are more likely to be associated with a marginallittoral depositional environment, according to sedimentological, ichnological, and micropaleontological evidence.

* The work is based on a multi-proxy study including:

(1) a sedimentological and mineralogical study, (2) an ichnological study, (3)a micropalaeontological study of ostracods and foraminifera, with identification of this microfauna and calculation of the biocenotic parameters of the different association’s characteristic of the coastal paleoenvironments, (4) a comparative study between the paleoenvironments of chlef basin and tebessa basin from Miocene age.

The structure of the thesis is articulated on eight chapters:

Chapter 1: It presents a general introduction about the studied site.

Chapter 2: It includes the presentation of the regional and local geology.

Chapter 3: it presents a detailed description of study techniques used in this work.

Chapter 4: It is devoted to the presentation of the results of Sedimentological and ichnological study.

Chapter 5: It includes the presentation of the results of the systematic study of the microfauna (Micropaleontological study).

Chapter 6: It concerns the results of the descriptive and analytical micropalaeontological study of of ostracods and benthic foraminifera.

Chapter 7: It concerns the results of the study of the morphogroups of the benthic foraminifera and the reconstruction of the paleoenvironment

chapter 8: its devoted to Comparative study between the chlef basin and the el malabiad basin (miocene age).

The thesis will be finalized by a general conclusion including the main results and future perspectives.

II. GEOGRAPHIC SETTING

El Malabiod is an administrative district of Tebessa , It is one of the Daïrates that counts the wilaya According to the administrative division, its borders are:

- The Daïra of Oum Ali, in the South.
- The Algerian-Tunisian border, in the East.
- The city of Tébessa, in the North.
- The Daïra of Chéria, in the West.

The basin of El Malabiod, the region of our study is located 600 kilometers from Algiers in the south-east of Tebessa city region (near the Algerian-Tunisian border). This plain is located in the eastern section of the Atlas Sahara, Its natural limits are :

- In the North , a ridge line regrouping the Djebels, Doukkane, El Khenga,Bouremene
- In the South, the mountains of Boudjellal, El Guelia and Ed'Dalâa.
- In the West, Guebel Er'Rouiss and Draâ Douamiss.

➢ To the East, Djebel El Kechrid and Koudiet sidi Salah which materializes the confines of the Tunisian territory.

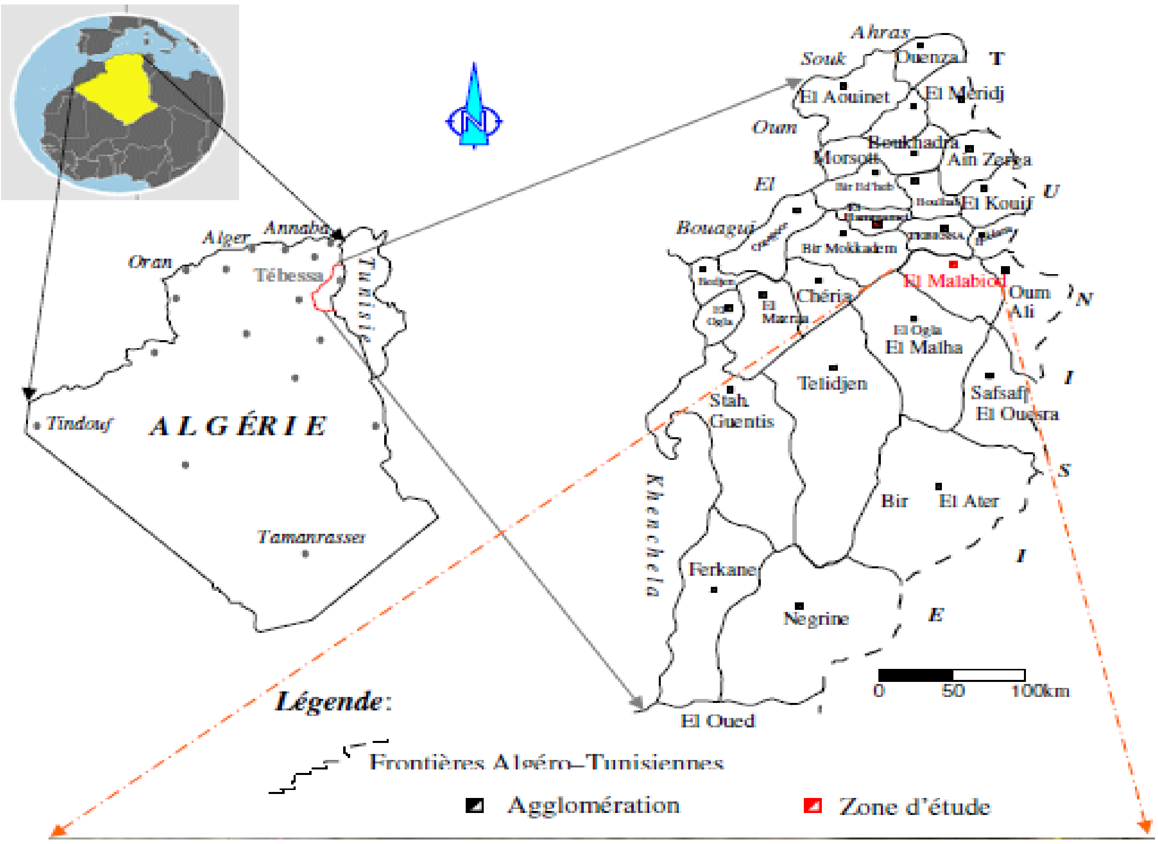


Figure 1. Geographic location and satellite view of El malabiad region (2023)

III. TOPOGRAPHY

The topography of the region is varied, with a series of steep mountains ranging in altitude from 1 432m (Djebel El Gautra) to 1 556m (Djebel Anoual).

Djebel Doukkane is the highest point at 1712m. This mountainous setting, which occupies the central part of the area, surrounds a plain with an average elevation of 1,020 to 1,200 m (Fig. 3). It appears to be a depression in the shape of a bowl. It has been reported that some remarkable hillsides with a relative height of about 10 to 20m above the plain have appeared. Their presence is attributed to the possible ascent of impermeable layers upstream of Wadi El Goussa, on the south side. on the axis parallel to the RN 16.

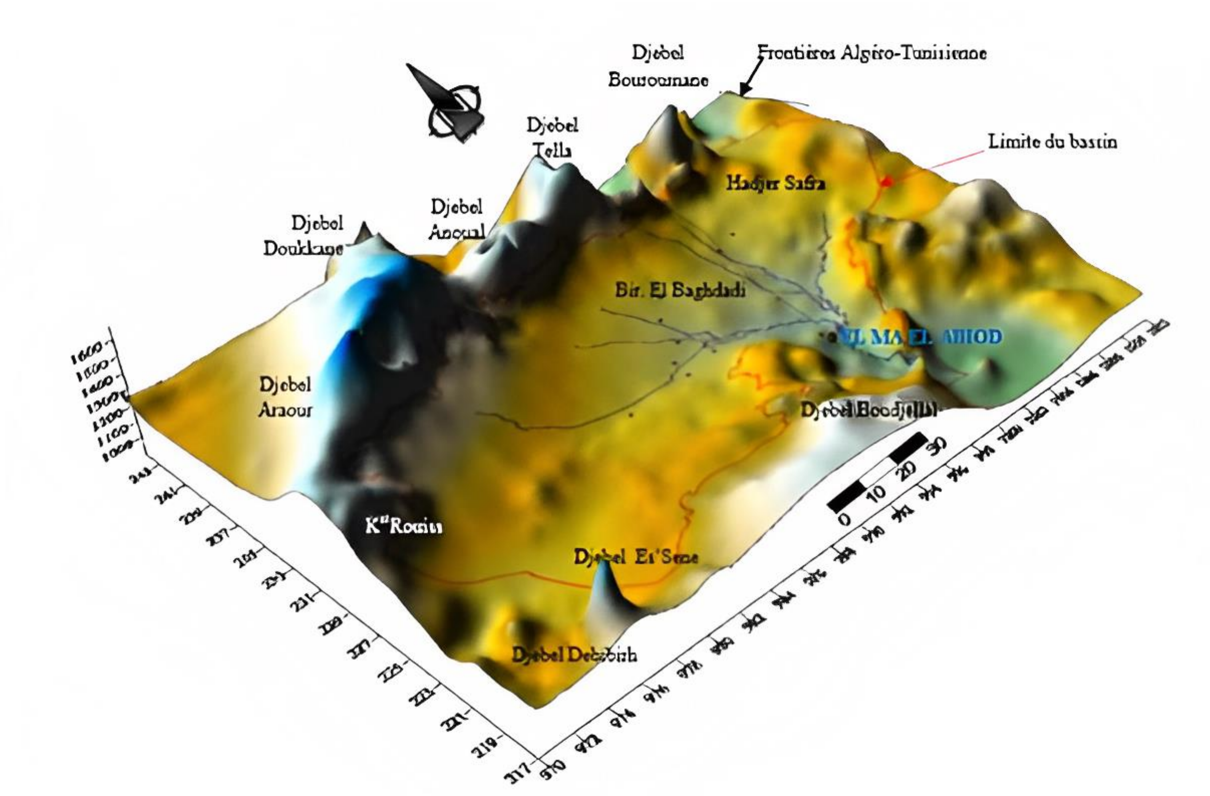


Figure 2Représentation in 3D of d' EL MALABIOD plaine (in ROUABHIA 2006)

IV. CLIMATE

Tebessa Wilaya is a meteorological transition zone which is characterized by four phases Bioclimatic phases:

- Subhumidity (400 to 500 mm/year), little extension, limited to peaks Some reliefs (Djebel Serdies and Djebel Bouroumane);
- Semi-desert (300 to 400 mm/year) covering the entire northern part of Vilaya;
- Semi-arid (200 to 300 mm/year) covered steppe plateau;
- Dry or temperate Sahara (less than 200 mm/year) extending beyond the Sahara Atlas.

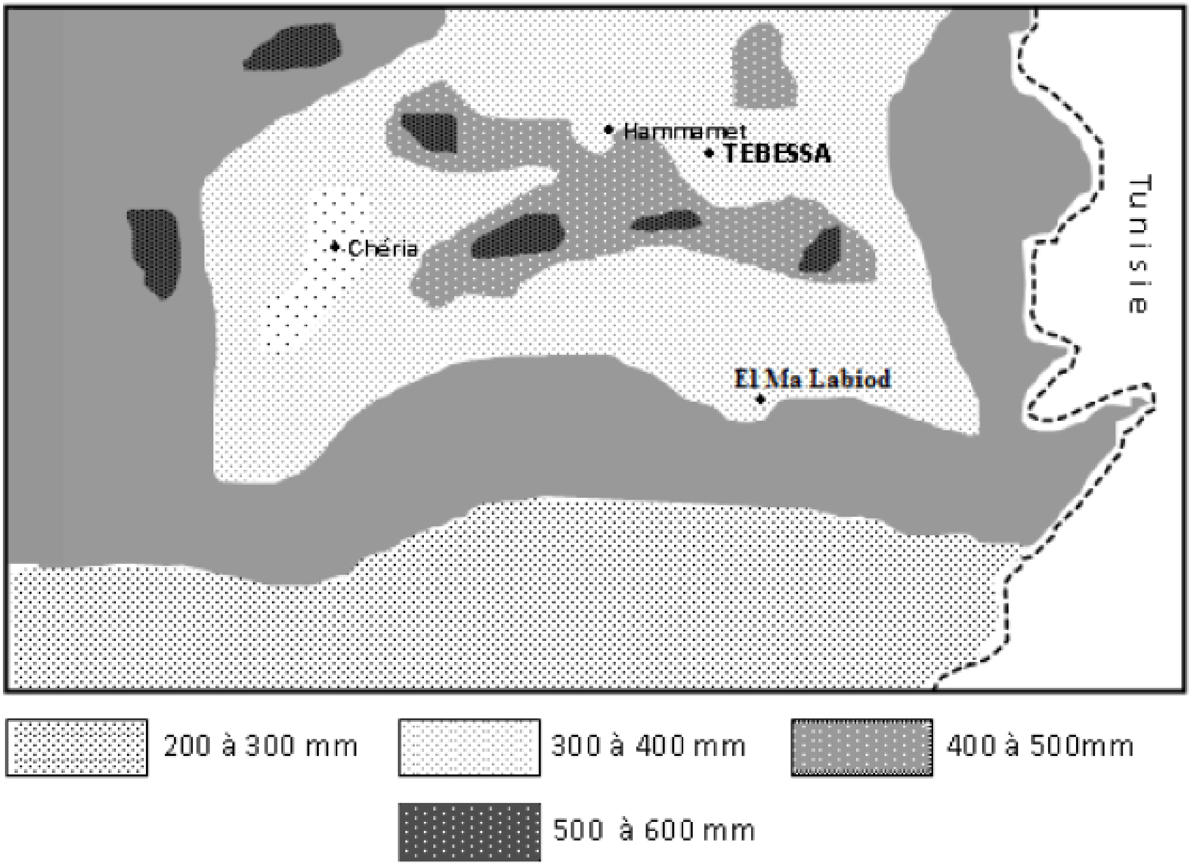


Figure 3. Rainfall map Chaumont – Paquin (average 1913 – 1963). In Guefaifia 2007

V. VEGETATION

Nobody can dispute the appeal of the carpet that constitutes any greenery in addition to its protective role against any sort of erosion that affects the legacy, has an incontrovertible impact in terms of precipitation. Indeed, the speed, duration, and consequences of a flood or runoff are inversely proportional to its degree of development, abundance, and rate of ground occupation.

In the El Malabiod region, there are agricultural lands (Domaniales, rch, and private), unproductive fields (surfaces in fallow lands), and forest...etc.

The forests in the region are characterized by tough natural conditions and are subject to overgrazing caused by an overpopulation of sheep and goats.

The type "Pinus halepensis"; Aleppo pine, is the main plant association. Except for attempts to reforest with the same species, it is in frightening condition. This tree stratum is associated with a relatively rich floristic procession, which includes holm oak, juniper oxycidae, rosemary, alfas, mugwort, and so on.

This distribution corresponds to an occupation rate of approximately 23.59% for the entire territory. The region's natural and botanical wealth is enhanced by the diversity of species.

A pastoral herbaceous steppe structure is introduced to this woodland canopy. the Alfa, which covers a significant portion of the land (12.69% El Malabiod)

CHAPITRE II: REGIONAL AND LOCAL GEOLOGY

I. INTRODUCTION

The Tebessa sedimentary formations recognized at the outcrop are primarily carbonate, Meso-Cenozoic in age, and have a thickness of more than 6000m. The Jurassic period is missing. These layers are covered by Quaternary-age superficial formations (Blès and Fleury, 1971).

The lithology and stratigraphic data are based on a synthesis of numerous authors' work (Dubourdieu 1956; 1959; David 1956; Fleury, 1969; Thiéberoz and Madre, 1976; Rouvier, 1977; Perthuisot, 1978; Chikhi 1980; Othmanine 1987; Perthuisot et al 1992; Bouzenoune, 1993...).

II. LITHOSTRATIGRAPHY

1. Triassic

According to Flandrin (1948), These formations go by the names of Djebel Djebissa, Ouenza, Boukhadra, Mesloula, and Hameimat South and North. regarded as the oldest in the area and takes the form of diapirs known as the "pays of the diapirs," are examples of an anticlinal that is a component of a group of extreme diapirs. According to A. Deghaichia (2014), the Trias is characterized by the presence of a red formation that is argilo-gypso-dolomitic. This formation includes dolomitic limestones and red and black colored dolomies, red and green argiles, and gray and rose gypses with bipyramidal quartz. and it emerges in chaotic crowds with no stratification. Its thickness is also unknown; however, it is estimated to be around 1000 meters (Rouvier et al., 1985; Pohl et al., 1986).

During the Triasic Period, a powerful series of evaporitic and argilo-gypsiferous deposits were formed in lagoons and lakes (Perthuisot 1978). The Trias would begin with a detritic series (growth and pelites) observed locally, followed by a powerful evaporitic ensemble with levels of argiles , fine psammitic growth, and irregular carbonate levels (Chevenine et al., 1989). Burollet (1973)

The oldest terrain in the study area outcrops in the southern part of the plain at Djebel Dalaa Er Rouail, in diapiric form.

It’s represented by typical facies of the region:

- Gypsum clay, limestone and cargneous. In the North-East and in Djebel Djebissa the Trias

appears in diapiric points.

- Red clays with gypsum.

- Limestones and dolomitic limestones in black platelets.

2. Cretaceous

- **The Barremian :**

According to (A.Deghaichia 2014) The outcrops of the Barremian are limited to some anticlinal structures (example: Jebel Bou Roumane, Jebel Mesloula and Jebel Boukhadra). Theya are characterized by deposits of 200 m of limestones, dolomites, sandstones, and marls. (Dubourdieu, 1956). Durozoy (1956)

- **The Aptian :**

The Aptian series is due to the development of reef facies. The sediments of the Aptian are found in the remarkable outcrops in the region of Mesloula, M'Khiriga., the Aptian deposits present two essential facies (Dubourdieu, 1956)

- Clastic facies, marl-sandstone with intercalations of calcareous-sandstone or calcareous-clay banks

clayey banks;

- Facies of organo-detrital reef limestones.

The lower Aptian is characterized by alternations of dark gray marls, compacted,

and dark grey, compact, cryptocrystalline limestones, sometimes clayey.The average thickness is 107m.

the Upper Aptian The outcrops dating from this stage, in the northern part, at Djebel Bouroumane,

are massive limestones, grey or reddish with intercalations of a few meters of marls

and limestone. The average thickness is 70m in the South. Drill hole BDJ2 encountered that

the upper Aptian is at 2316m depth, it consists of light grey oolitic limestones to dark grey bioclastic, sometimes cryptocrystalline, rarely silty and pyritic. Its thickness is of 215m.

- **The Albian :**

. Lower Albian

This stage occurs at Djebel Bouroumane, in the form of brown thick limestone banks,

and banks of rudists limestone. To the south of the study area the oil drilling BDJ2 gives from bottom to top the following succession:

- Light grey, whitish, brownish, compact oolitic limestones often chalky bioclastic or gravelly, with traces of foraminifera and intercalations of grey clay : 85m thick.

- Alternation of limestones, light grey, whitish, often bioclastic and rarely gravelly, clayey and of grey to dark grey clays, blackish laminated: 87m of thickness.

- White to brownish gray, compact microcrystalline dolomites: 40m thick.

- **Upper Albian**

The upper Albian is present in small outcrops, at the contact of the Triassic of Draa M'taa El Malabiod (Djebel Dalaa Er Rouail). It includes limestones and marlstones in platelets.

At Adeila, where the oil drilling BDJ2 was executed, the succession from bottom to top is following:

- Alternation of light grey, beige, clayey limestones, and grey to dark grey clay,more or less dolomitic: 116m thick.

- Alternation of grey, dark grey, clayey limestones and blackish grey marls, compact, hard, silty: 129m thick.

In the North, at Djebel Bouroumane, the layers at the bottom of its slopes which date from this stage They are constituted of a set of limestones and grey marly limestones in platelets and small benches. One notes the presence of many prints of Ammonites and Belemnites, the thickness of this formation is 150m.

3. Upper Cretaceous

It is represented in the region by the Cenomanian, Turonian, Coniacian, Santonian deposits, Campanian and Maastrichtian.

- **The Cenomanian:**

It outcrops quite widely in the south-eastern part in tectonic contact with the Triassic.

It is a series of yellow marls sometimes grey and lumellic limestone banks. The fauna is very abundant (Ostrea, Exogyra, Cardita). The thickness reaches 560m. At Adeila, according to the oil drilling BDJ2 where the Cenomanian series is the most complete, we note from bottom to top:

- Grey to dark grey clay, carbonate: 238m thick.

- Alternations of light grey limestones and grey to greenish laminated clay: 130m.

- Grey to light grey crystalline limestones with intercalation of grey to greenish clay: 76m.

- Alternation of dark grey clays and dark grey to light grey lumachellic limestone:

73m thick.

- Grey greenish clay with intercalations of white chalky limestone: 209.5m.

- Alternating white lithographic limestone and gray to greenish laminated clay:

204m thick.

- White to cream limestone sometimes grey cryptocrystalline to chalky: 39m thick.

- Fossiliferous greenish-gray clay, becoming marly in the last 16 meters with fine

whitish-gray limestone, lumachellic: 72m thick.

- **The Turonian :**

It outcrops widely in the North (Dj. Bouroumane, Dj. El-Koreiz, Tenoukla). At its base, one meets a constant series of grey marly limestone in small banks. The thickness does not does not exceed 60 to 70m. Below, it is a massive layer of beige limestones and dolomites or dolomitic limestones. Flint chips appear in the upper part.

Near Tnoukla, the upper Turonian, 150m thick, gives from top to bottom the following succession:

- Black gypsiferous marls.

- Grey marl and limestone in platelets.

- Black marls often lumachelliques and rogneuses. In the south at Djebel ED- DALAA, we note the presence of limestones, marls and limestone banks.

At 8 km west of these outcrops, the oil drilling BDJ2 gives from bottom to top the following succession:

- Brown limestones, chalky, slightly dolomitic, partially lumachellic:

109.5m thick.

- Light grey limestone, compact, with intercalation of grey to dark grey marly clay:

131.5m thick.

4. The Lower Campanian - Emscherian

These are marls and intercalations of lumellic limestones. These facies outcrop widely in Djebel Doukkane to the northwest and in Djebel Ed-Dalaa. Outcrops of rather small dimensions are to be reported near Tnoukla, M'Taguinaro and Adeila southwest of the town of El Ma El Abiod.

From the oil drilling BDJ2 where the series is the most complete, we note from bottom to top:

- Reddish brown clay and greenish grey marl: 47m thick.

- Grey clay with a few banks of light grey limestone: 83m thick.

- Grey clay with some banks of light grey fossiliferous limestone: 242m.

- Indurated grey marl, slightly dolomitic, intercalation of brown-red limestone

often marly: 88m thick.

5. Upper Campanian - Maestrichtian

It is located in the north west at Djebel Koreiz and in the center of the plain (M'Taguinaro), as well as in the vicinity of the town of El Ma El Abiod. It is characterized by white limestone and marlstone with inocerams. In Adeila, it outcrops largely in the form of white marlstone with inocerams. The oil drilling BDJ2 allowed the recognition, over a thickness of 67m, of the following facies: Limestone compact white limestone, clayey biomicrite with pelagic fauna.

6. Paleogene

It knows important variations of thickness of the deposits, towards the North (20-30m) and the South (60-120m). Their facies are formed by white micritic limestones intercalated with phosphate layers towards the upper level.

- **Paleocene:** Danian: Light grey clayey limestones, slightly chalky, alternating with grey marls. Montian: Homogeneous grey marls, with rare banks of clayey limestones and thin thin phosphate levels; surmounted by a lumachelle with oysters which develops towards the top. Thanetian: Marls and marly limestones with flint containing phosphate layers.
- **Eocene:** (Ypresian & Lutetian)
  Massive limestones with flint at the top, while at the base we have marly limestones with flinty marly limestones of low thickness dating from the Ypresian. In the proximity of the perimeters of the Mounts of Mellègue, their power is of 200 m. It also contains phosphate levels which are sometimes silicified at the top.

7. Neogene

- **Miocene:** The basin of El Malabiod is dominated in its quasi-totality by formations of age Miocene it was noted a wide outcrop of formations composed of conglomerate, sandstone, clay, marl and lacustrine limestone. The power of the Miocene varies from 50m to 200m. (M. Hamimed,2004) translate by three eustatic cycles with conglomerates, composed of sedimentary cycles of order 2 or 3 according to the dynamics of the sedimentary sheets. Two large Miocene sedimentary basins are identified: the El Ma Labiod basin El Ma Labiod basin in the South and the El Aouinet-Meskiana basin in the North (Hamimed, 2004).

8. Quaternary

formation largely covers the entire plain. The thickness is very small, not exceeding ten meters. The Quaternary is generally made up of of ancient facies (conglomerates, calcareous crust) and recent facies (silty scree).

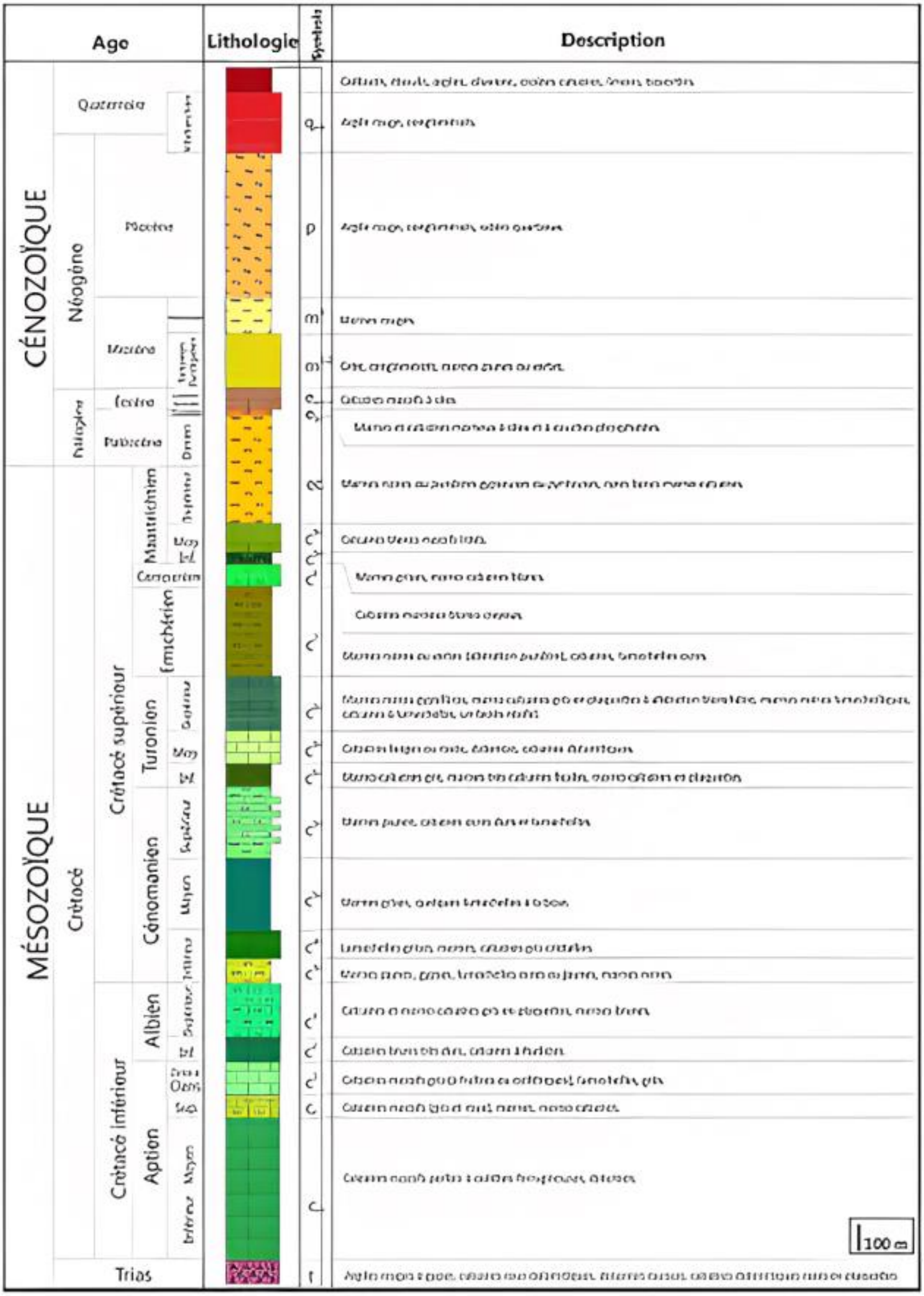


Figure 4 Complete lithostratigraphic column of the Tebessa region, with a summary lithological lithological description of the formations based on Durozoy (1956)

III. STRUCTURAL STUDY

1. Folding

The post-Pliocene fault system cuts anticlines and synclines in the SW-NE direction.

These folded structures are scattered throughout Tebessa, particularly in its eastern part, where some anticlines, such as Djebel Gouraya and Djebel Djebissa, outcrop. The folds change direction (E-W) a little to the south.

The two tectonic phases are ante-miocene, with the exception of the second, which occurred after the Miocene.

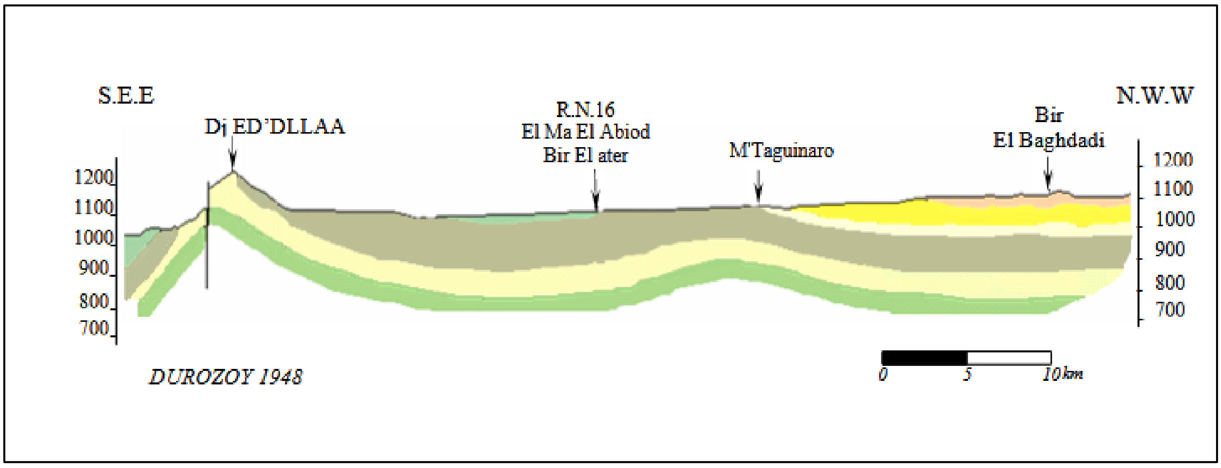


Figure 5 coupe géologique DUROZOY 1984

2. Diapirism

The Tebessa diapir at Djebel Djebissa is a triassic anticline formed by gypsum clays and some carbonate banks; the diapiric ascent occurred in the Plio-Quaternary and has an age similar to the subsidence of the collapse trough, which explains why the post-Pliocene tectonic phase was the most active. which explains that the post-Pliocene tectonic phase was the trigger for the diapiric ascent.

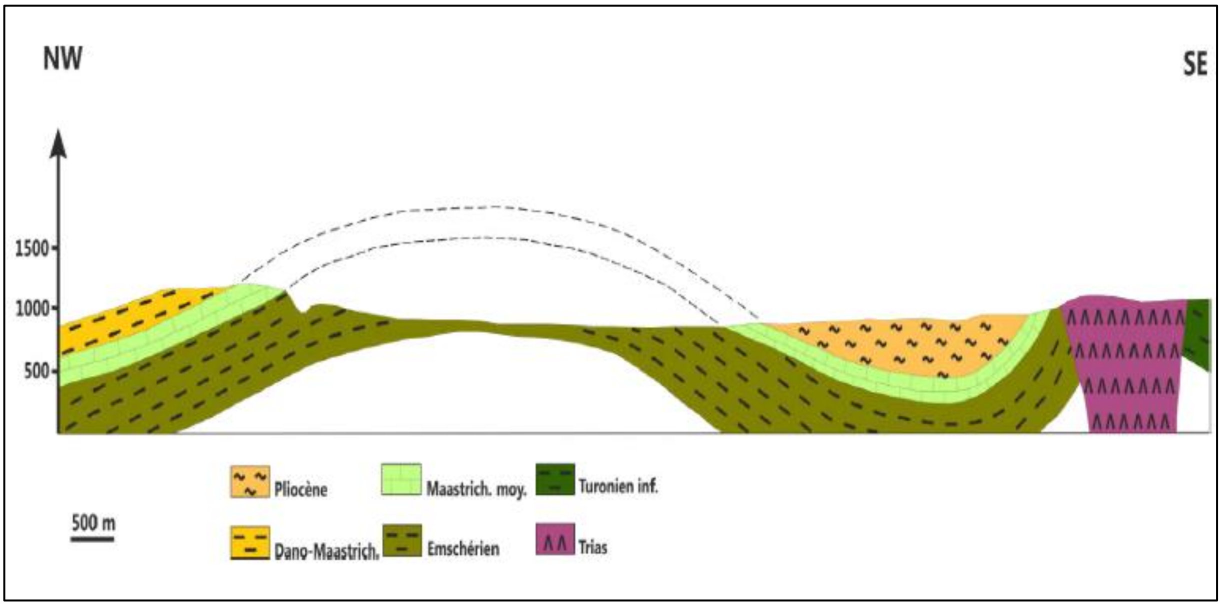


Figure 6 Geological section crossing the diapir which shows a folded structure in anticline (Emschian core) and a second one in syncline (Pliocene core), the cross-section is shown (the thickness of the formations is not respected).

3. Faults

The brittle tectonics is present in a remarkable way in Tebessa, a large system of faults system of faults-oriented NW-SE occupies about the four corners of the map of this region of these faults affect all the geological formations from the lower Cretaceous to the Pliocene, which proves that a large recent tectonic phase (which probably dates from the Quaternary -post post-Pliocene) has taken place in the region.

Other faults of SW-N direction indicate another ante-miocene tectonic phase, whose movements started already in the Campanian (Upper Cretaceous) and lasted for a long time the climax of the phase took place during the Lutetian (Eocene).

The first mentioned tectonic movements (post-Pliocene) played an important role for the the birth of a collapse trough (the Tebessa trough), following a series of NW-SE oriented troughs NW-SE oriented troughs located in the diapir zone at the Algerian-Tunisian confines. We can quote apart the ditch of Tébessa: the ditch of Morsott, that of Ouenza, Targuelt, and finally the ditch of Taoura.

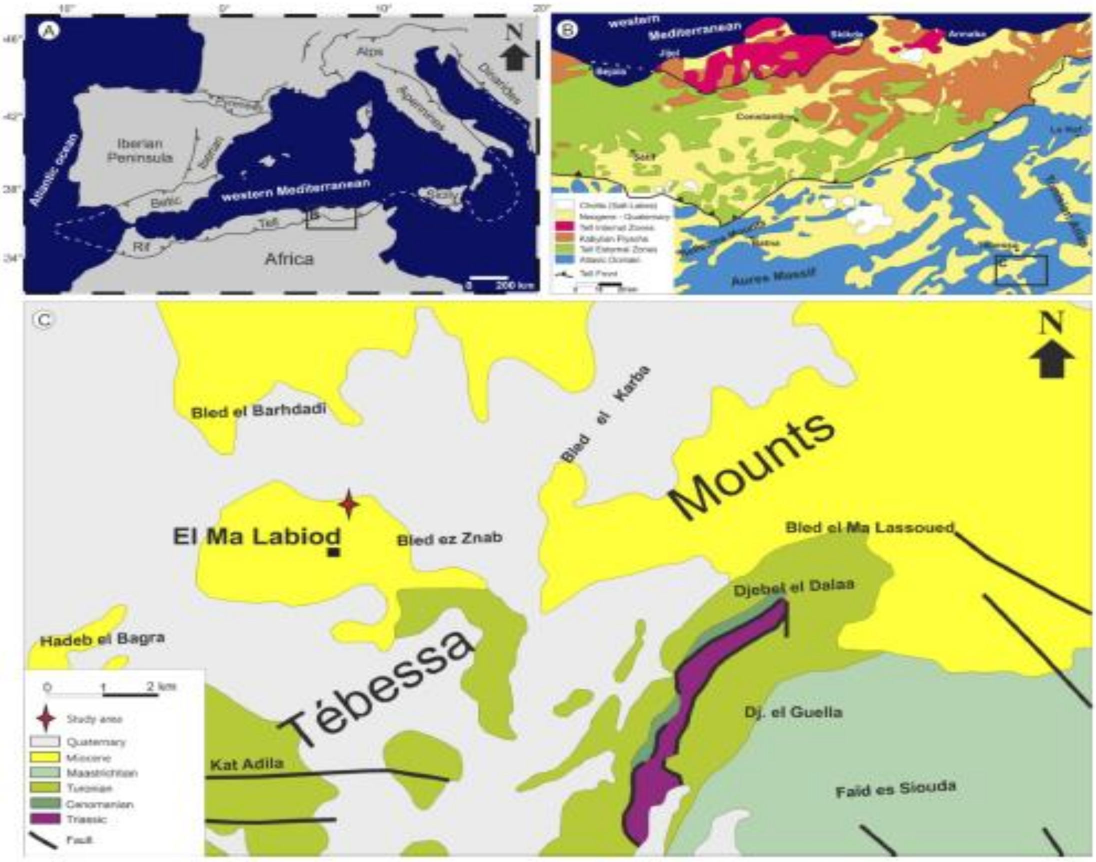


Figure 7. (A) Geographical location of the studied area (Modified after Soria et al.,2005); (B) Structural map of Eastern Algeria (modified after Benhenni et al., 2019);(C) Simplified geological map of the El Ma Labiod region, T/ebessa (extracted fromGeological Map of Algeria, after Algerian Geological Survey Agency "ASGA").

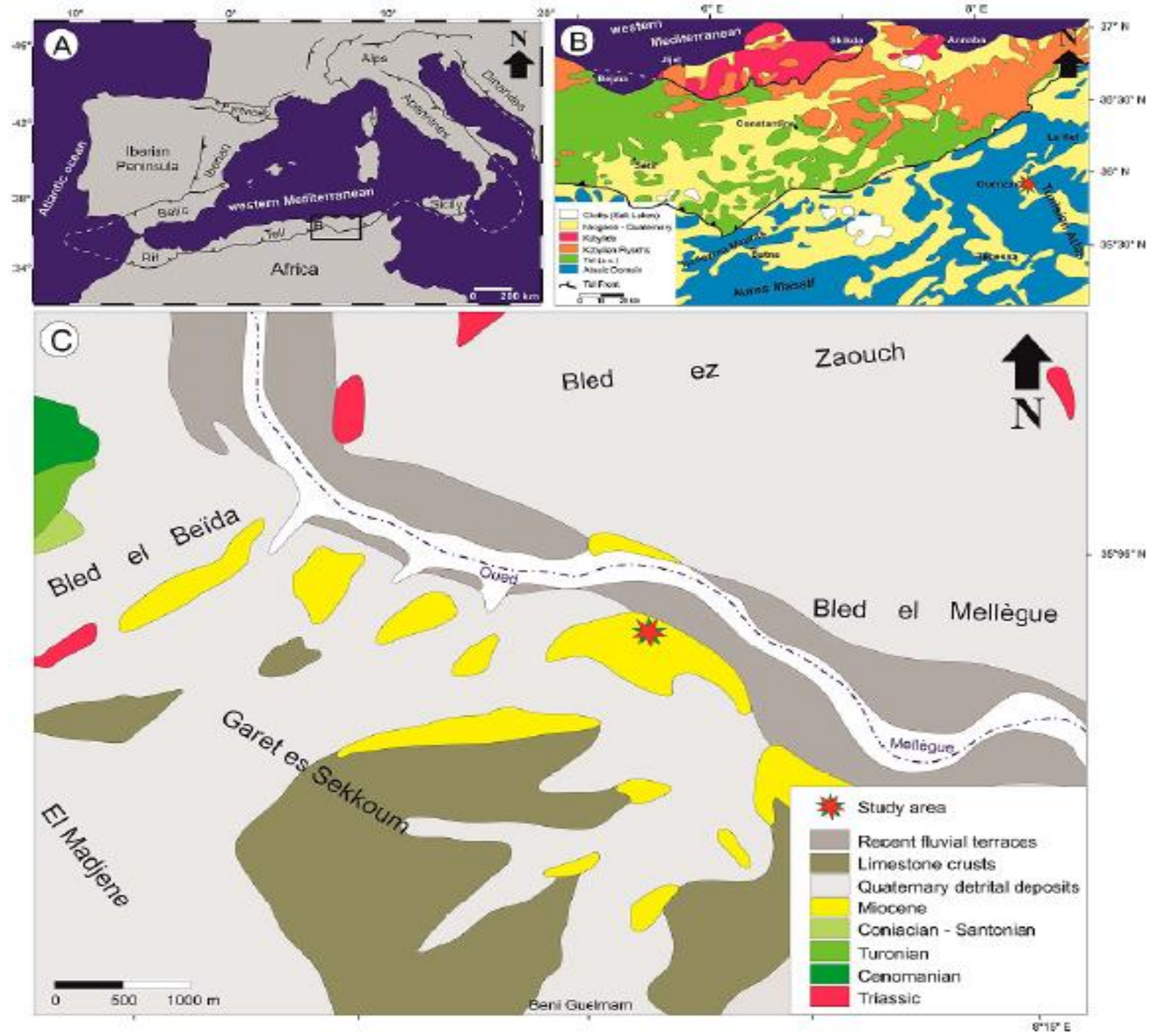


Figure 8 Location of the study area: A, location of northeastern Algeria in the western Mediterranean region and B, geological map of eastern Algeria; C, geological map of Aïn Sidi Salah locality.

CHAPITRE III: DESCRIPTION OF THE TECHNIQUES USED

I. INTRODUCTION

This chapter is devoted to the methods followed in the development of this work. We have proceeded to sedimentological, chemical/mineralogical and micropalaeontological analyses that allow to highlight the paleoenvironments of the sections studied.

Our work is divided into two main parts:

- Field work;

- Laboratory work.

Field work: On the field, we relied on a macroscopic description of the stratigraphic levels of the sections of EL MA, EL ABIOD. A detailed sampling on the various levels observed was carried out with the goal of establishing the paleoenvironmental evolution and microfaunal repetition in the studied areas.

Macroscopic explanation:

This operation seeks data on macrofacies (thickness, texture, color, shape and nature of boundaries, sedimentary structures, etc.).

Sampling:

The stratigraphic sections were sampled in a systematic manner, every 5 cm to 20 cm (500g for each sample).

II. LABORATORY WORK

Laboratory work is divided into three types of analysis. Sedimentological analysis It is the application of Several methodologies, including granulometric, morphoscopic, and petrographic methods, were combined to learn about the Miocene depositional circumstances in the research area, as well as its lateral and vertical and textural evolution

1. Sedimentological analysis

It is based on:

1.1. Granulometric analysis

Definition and purpose of the granulometric analysis Granulometric analysis is a sediment classification technique. It enables the separation of a set of particles into granulometric classes based on their size. Granulometric fractions are the particle classes that are obtained.

This analysis will reveal the substances associated with the granulometric fractions found in sediments. The particle size analysis is used to reconstruct transport conditions and modes of transport, with different sedimentological coefficients corresponding to different paleoenvironments. (Representation of the distribution of the mass of the particles in the dry state according to their dimension).

a-The coarse fraction with a diameter greater than 2 mm is recovered for sieving.

b- The fine fraction: For comparison, the raw sediment and the decarbonated sediment are subjected to granulometric analysis of the fine fraction.

Figure 8 MALVERN Mastersizer 2000 lase granulometer

Measurement principle:

Particle size analyses were traditionally performed by sieving with sieves of increasing mesh. These sieves were shaken manually or with the assistance of mechanical devices. Nowadays, more sophisticated devices (such as a laser granulometer) make analysis easier. Laser granulometry is a technique that uses the diffraction and diffusion of a laser beam when it strikes a particle. This method is founded on Fraunhofer and Mie's fundamental theories.

Fraunhofer's theory: the particles are opaque spherical with diameters greater than the wavelength used, and the particles diffract the light with the same efficiency when the rays are diffracted.

Mie's theory: Mie's theory is an extension of Fraunhofer's theory.

Light is not only diffracted by the particle, but it is also reflected and scattered when the media differs.

We measured grain size from 0.04 m to 2 mm using the MALVERNE 2000 laser granulometer (laboratory of the Institute of Paléontologie humaine de Paris - France).

The main benefit is thus having access to the distribution of all granulometric finer batches. However, it is important to note that the results obtained by the laser granulometer

give percentages in volume whereas those of the traditional sieving are in weight. Thus the indices allowing comparisons between sediments originally established from weighing data are difficult to apply to data calculated in volume, this is why we did not use them.

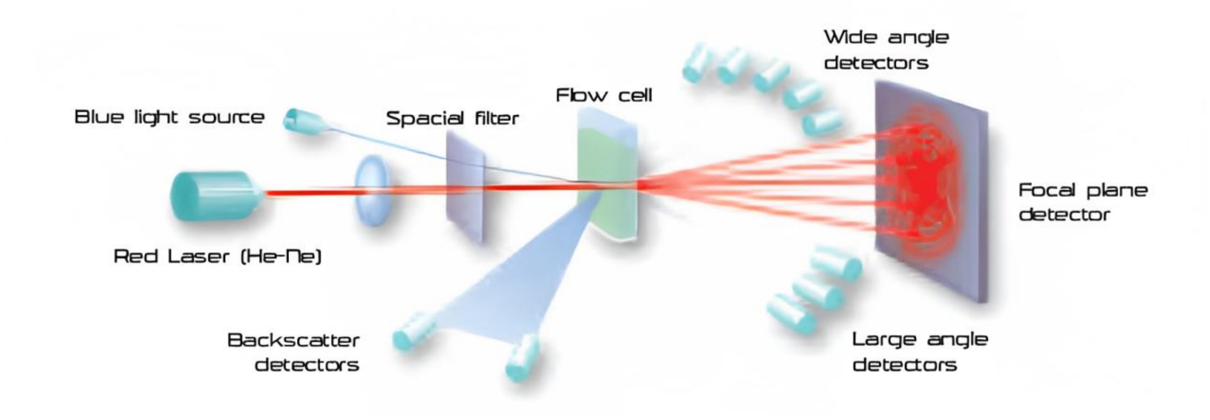


Figure 9 principle of granulometric measurements by the MALVERN 2000 analyzer

Steps and protocol:

- The samples are poured into the wet module, with water as the transport fluid

- The samples undergo an ultrasonic deflocculation for 30 seconds

- In the measurement cell, the laser beam meets the particles whose path is guided by a current

(The particles as deflectors)

- The particles re-emit the incident light with an intensity and an angle that depends on their size.

- The light diffracted by each particle will, with a certain angle, cross a Fourier lens.

- All particles of the same size diffract with the same angle and fall then on the same detector.

- A counting step then takes place.

The software converts the flux curves into particle volume curves, frequency curves and cumulative frequency curves and cumulative curves:

A. Frequency curve: the shape of the curve indicates the degree of classification (Miskovsky and Debard, 2002).

B. Cumulative curve: we can deduce the different quartiles and the various parameters of distribution. (Krumbein 2000) ($\Phi = -Log2(x)$,

x = diameter in mm.

1.1.1. The granulometric parameters

The mean: It is the logarithmic or arithmetic mean (depending on the nature of the scale of abscissa) of the values of the independent variable. This parameter gives the average dimension of the sample, the energy and the distance of the transport.

The Trask ranking index So:

So = (Q1/Q3) ½ in mm

According to Trask, the higher the So index, the worse the ranking.

The skewness coefficient (SK=Skewness)

It characterizes the degree of distortion of the symmetry of the distribution to reflect more the medium of deposition than the conditions of transport.

SK = (Q1.Q3/Md2)1/2 in mm

Kurtosis:

It is representative of the fineness of the peak (its width), it gives information on the distribution and transport.

1.2. Quartz grains Morphoscopy

Cailleux and Tricart (1963) proposed and applied this method on quartz grains to examine the shape and appearance of these grains. This method gives information on the mode of transport of the grains. These grains are examined under a binocular loupe.

1.2.1. Study method

The grains are previously washed with water or possibly with cold or hot hydrochloric acid.

They are then dried and observed with a binocular magnifying glass (isolated dry and on a black background).

We have noticed several forms; we mention the most used ones:

The transparent unworn: quartz with angular contours and a clear appearance. Their faces are flat, smooth and often present breaks

The opaque unworn: quartz of the same shape as before but with a dull appearance.

These two types of grains did not undergo transport, or underwent a fast transport which did not have time to leave its print (scree, torrents)

The transparent blunt: quartz with blunt angles, rounded. They are limpid;

Opaque blunts: quartz of the same shape as before but with a dull appearance.

The blunt quartz grains shining or opaque characterize a transport by water, of long duration. Those which are perfectly ovoid were worked in karstic environment.

The round-mats: quartz of circular form presenting traces of shocks which specify a transport by the wind.

Tableau 1. main types of quartz grain classification

Angularity	Description	Typical particles
Round	Smoothly curved sides and edges. Particles can be spherical or ellipsoidal.	
Subround	Similar to round but with some nearly plane sides and generally well-rounded corners and edges. However, some sharp edges might be present on broken particles.	
Subangular	Similar to angular but with slightly rounded edges and sides that are slightly curved.	
Angular	Sharp corners and edges and relatively plane sides with unpolished surfaces, such as freshly crushed rock.	

[a]Adapted from USBR (1990, page 208).

1.3. Determination of carbonates

The Calcimeter is an apparatus intended for the determination of the content of carbonates RCO3 of sediments. The analysis is based on the measurement of the volume of carbon dioxide released by a known quantity of sediment in contact with hydrochloric acid (HCl). At normal conditions of the experiment, it can be assimilated to a perfect gas. The gas released during the reaction exerts a pressure on the liquid contained in the graduated burette. The liquid goes from an initial volume V1 to a volume V2. The equation of the reaction produced in the burette is the following:

$RCO_3 + 2HCl$ <====> $RCl_2 + H_2O + CO_2$

$CaCO_3\% = [(\Delta V\ CO_2\ (ml)] / M\ (g)]$

ΔV: difference in initial volume (V1) and volume (V2) P: pressure T°: temperature M: mass in g of the sample.

We used Bernard's calcimeter whose principle is to determine the percentage of calcium carbonate on 0.5g of crushed and dried sediment with a mesh size lower than 2mm, and added the hydrochloric acid, the chemical reaction is the following:

$CaCO_3 + 2HCI$ $CaCL_2 + H_2O + CO_2$

$\%\ CaCO_3 = (V.0,25.100) / V0.0,5 = (V/V0).50$

V0 : volume of CO_2 Determined from 0.25 g of calcium carbonate.

V : volume of CO_2 Determined from 0.5 g of sediment.

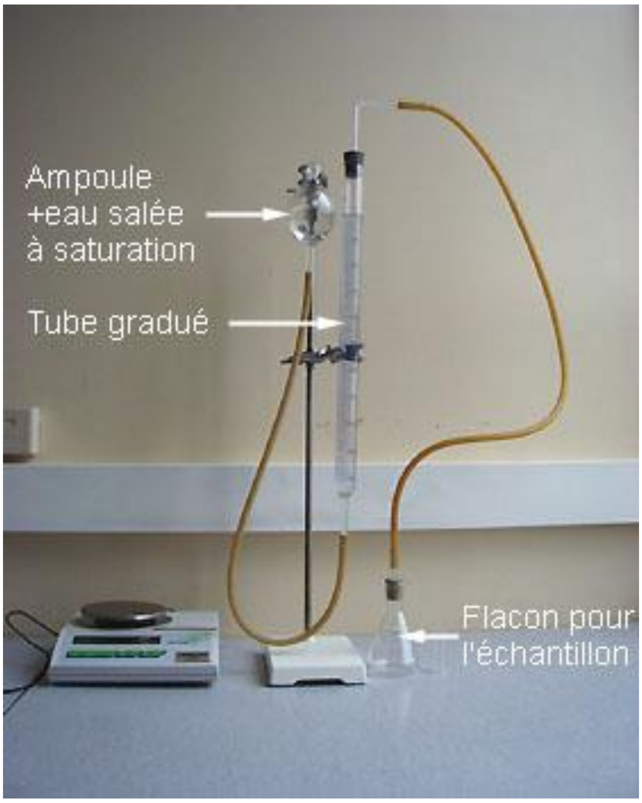


Figure 10 BERNARD calcimeter

1.3.1. Principle

This gasometric method carried out by the Bernad calcimeter consists in estimating the percentage of $CaCO_3$ contained in a rock according to the volume of CO_2 released in a manometric tube, after the attack of the rock with hydrochloric acid. It is recommended to fill the graduated burette with water saturated with NaCl which dissolves little carbonate dioxide.

1.3.2. Procedure

- Estimate the carbonate content by a preliminary effervescence test:
- If the release of CO_2 is strong, weigh 0.2- 0.5g of the sample;
- If the release of CO_2 is medium, 0.5-0.9g of the sample is weighed;
- If the release of CO_2 is low, we weigh 1g of the sample.

Prepare a saturated NaCl solution (about 3/4 of a liter) and pour it up to the and pour it up to half the height of the ampoule;

- Introduce the weight in the Erlenmeyer flask;
- Fill a small glass tube with 30% HCl;
- Insert the small tube into the Erlenmeyer flask with the forceps.
- Bring the liquid in the graduated tube and the ampoule to the same level by the ampoule, lowering it more or less
- Tilt the Erlenmeyer flask by the stopper to the hemolysis tube;
- Shake and then put the Erlenmeyer down and let the reaction continue:

$$CaCO_3 + 2\ HCl \longrightarrow CaCl_2 + H_2O + CO_2$$

During this time, the gas has pushed the water out of the tube into the the bulb.

2. Mineralogical analysis

2.1. Mineralogy of sands

The mineralogy of the sands is very important to recognize the paleogeographical conditions.

The raw sample should be washed between 2 mm and 40 µm sieves. The recovered fractions are treated with hydrochloric acid and then with hydrogen peroxide, to eliminate respectively carbonates and organic matter respectively. The recovered fraction is:

FS: between 1.60 mm and 0.630 mm

FI: 0.500 mm - 0.315 mm

FII: 0.250 mm - 0.160 mm

FIII: 0.125 mm - 0.040 mm

2.2.1. Light minerals*:*

This analysis concerns the FI fractions (from 315 to 500 µm) which have been densimetrically separated using bromoform ($CHBr_3$) with a density of 2.89. The mineralogical determination is performed under a polarizing microscope based on their optical criteria (Parfenoff et al, 1970) and the content of each mineral is related to the the whole fraction.

2.2.2. Heavy minerals*:*

after separation by bromoform ($CHBr_3$), 200 grains of the heavy fractions are mounted between slide and lamella by Canada balsam. The slides are observed by polarizing optical microscope at different magnifications. The identification of the minerals is ensured using the mineralogical description of Parfenoff et al. (1970) and Tourenq (2002).

2.2. The mineralogy of clays

2.2.1. Mineralogy by X-ray diffraction

X-ray diffraction constitutes the best adapted and most widespread technique to identify in a qualitative and semi-quantitative way the mineral clays of small size, often badly poorly crystallized and hydrated, of lamellar or fibrous form, and often present in a complex mixture of species.

2.2.2. Principle of X-ray diffraction (XRD)

This method is based on the fact that a beam of X-rays diffracts on specific planes according to the principle of Bragg's law:

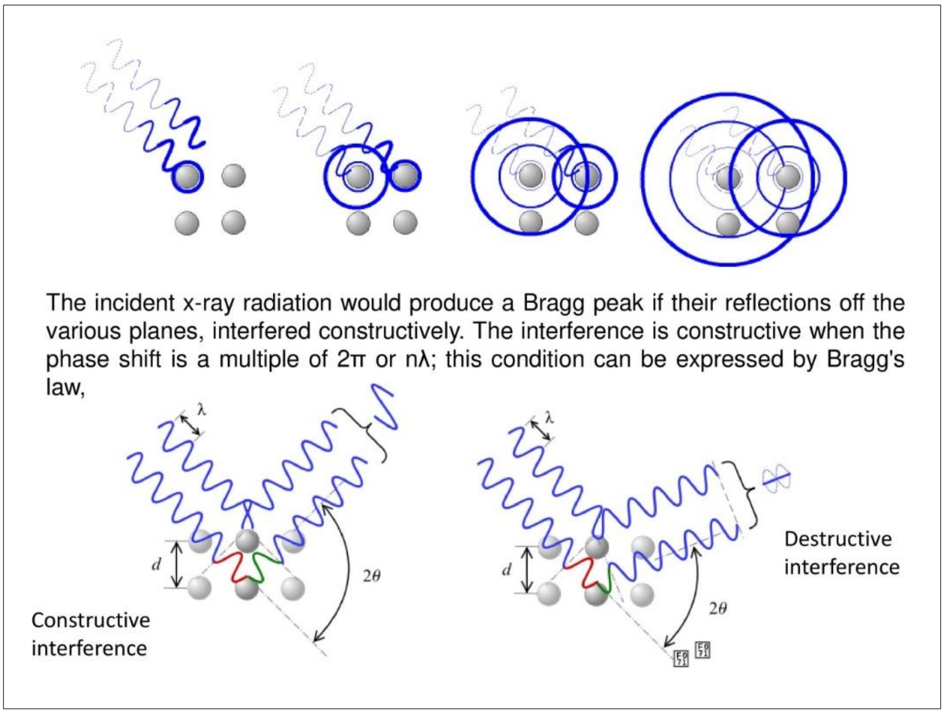


Figure 11 principle of diffraction and illustration of Bragg's Law (Eslinger&Peaver;1988)

Where:

n is the diffraction order (integer);

λ, the wavelength of the source;

d, the inter-reticular distance, i.e., the spacing between two successive parallel planes of the crystal lattice;

θ, the angle between the incident beam and the plane lattice.

Sample preparation was performed generally according to the procedure of Holtzapffel (1985)

3. Micropalaeontological analysis

3.1. Sample preparation

a. Washing and sorting: Washing and sorting are techniques used to extract microfossils from loose sediments (Pujos, 1976). The sediments are disaggregated and sieved under a water jet on two sieves (250 and 80 m) before being dried. Sorting has to be done after drying for the fractions greater than 250 and 125 m. The microfossils were then removed with a fine brush and placed in cells to be identified.

b. Determination and tally: The species of foraminifera and ostracods are determined after identifying the morphological characteristics of the various tests and using the available catalogs. The frequencies will be calculated by counting the individuals of each species, taking into account the paleo-ecological significance of each of them, will allow a paleo-environmental visualization of each of them.

3.2. The evolution of the work

from 1907 to 2017 is summarized in the descriptions below:

A. EARLY WORK (1907-1979)

- **Blayac (1907)** gave a preliminary synthesis on the mining research in the region of Tebessa region.

- It is to **Brives (1919-1920)** that we owe the first works on the Miocene of the Tébessa region, by pointing out the presence of Dinotherium teeth in the sand pit of El Kouif. After 10 years

- Laffitte (1936) reported that the facies of the eastern part of the Aurès are comparable to the facies of the Saharan Atlas with the existence of post-secondary folding.

- Castany (1948) showed the continuity of the collapse ditch from Tébessa to Kasserine in Tunisia.

- Durozoy and Dubourdieu (1958) attributed the post-Villafranchian age to the Tébessa trough thanks to the known deformations in the continental sediments of Villafranchian.

- Vincenne (1950) made a comparative mineralogical study in the lead deposit of Hameimat, he indicated that the mineralization is interbedded in the layers and that it is related to the breaks.

- Durozoy (1948-1956) showed in a map of the Tebessa region the stratigraphy of the Cretaceous based on an abundant macrofauna. In the region of EL Ma Labiod the Burdighalian is represented by sandstones under a weak alluvial cover and siliceous poudingues siliceous, the Vindobonian is represented by clays. The same author in (1956) considers that the lower and middle Miocene is represented by sands and the upper Miocene by marls.

- Dubourdieu (1956) pointed out that the deep movements play a preponderant role in the evolution of the region based on morphological and petrographic work in the region of El Ouenza.

- Morel (1957) realized a map of 1/20000 of the region of Dj Belkfif. He highlighted two folding directions of orientation N170° E and N135° E. He also pointed out that the Triassic is located in the South of this region and it is in tectonic contact with the Cretaceous series. He noted noted the existence of external mussels of bivalves (Ostera crassissima) in this region.

- Dubourdieu et al (1959) report the presence of Neoaveoline foraminifera in the Miocene of Mesloula.

- Voûte (1967) showed that this ditch was established after the Lower Miocene in the plain of Tébessa- Morsott.

- Blés (1969) did a work on the micro-fracturing of the Morsott area and its relation with the folds and faults. The same author in (1969) established the stratigraphy of the Cretaceous and Eocene Eocene stratigraphy of the Morsott sheet, and in (1970) an explanatory note of the Morsott map at 1/50000.

- Busson (1974) proposed data on the paleogeography and depositional conditions of the Triassic evaporitic of North Africa and Western Europe.

- Vila (1977) thanks to the microfauna, was able to attribute the deposits of the Koudiat Mami and Rahia to the lower and middle Miocene.

B. RECENT WORKS (1981-1998)

- Vila (1980) in a doctoral thesis, made a synthetic study concerning the stratigraphy, tectonics and paleogeography of many regions of northern Algeria, in the Algerian-Tunisian borders.

- Masse and Chikhi (1982) proposed an organization and a dynamic of the formation of the carbonate platform of Ouenza during the Upper Aptian.

- Othmanine (1987) in a thesis of Doctorate (3rd cycle), made a study on the albo-aptian paleogeography, diapirism, mineralization and structure of Dj Mzouzia, Dj.Bekfif, Hameimat North and Hameimat South, and he explained the absence of the Jurassic.

- **Zerdazi (1990)** reported that the positive and negative axes that characterize the anticlinal and synclinal structures oriented NESW become more complicated towards the East and especially towards the SE towards Tebessa after he established a gravity map of the surroundings of Tebessa.

- Kowalski et al (1995) made a study of the Miocene in the vicinity of Tebessa and considered the Upper Miocene of the El Ma Labiod area as an azoic series.

However, these same deposits were dated by lithological correlation with the sediments of the Miocene sediments of Mechta Remila and Koudiat north of Tébessa.

- Vila (1996) mentioned in a surface study of the Triassic masses in the Ben Gasseur area and the Kef Anticline. He applied the submarine "salt glacier" model in this region.

- Boufaâ et al (1996), made a study concerning the Neogene evolution of the atlasic structures in the surroundings of Tébessa. For them, these structures are the result of a tectonics with polyphase evolution.

- Perthuisot et al (1998) gave two hypotheses on the emplacement of the Triassic material material and they concluded that the "salt glacier" model is not applicable, while the diapir model remains valid in the North African region through a study of Triassic bodies in the the Mellègue region.

- Piqué et al (1998) made a study on the evolution of the Maghreb during the Meso Cenozoic Atlasic domains.

C. MODERN WORKS (1999-2010)

- Kowalski and Hamimed (2000) reported that the region is characterized by a and that the salt glacier model is not applicable in this region by comparative study of all the

region by comparative study of all the works done on the Triassic and its setting in

the Algerian-Tunisian confines region.

- Hamimed et al. (2001) reported that Miocene sediments are deposited in fluvial, deltaic deltaic, lacustrine and palustrine environments of the Miocene of El Ma Labiod despite the absence of biostratigraphic indicators, a Tortonian age has been attributed to these deposits.

- **Sihem Selmi-Laouar (2004)** in a doctoral thesis, made a geochemical study using of stable isotopes on the polymetallic mineralization of the diapirs zone of North of Tebessa. She mentioned that the albo-aptian formations with reef character in contact with the Triassic are the most mineralized in Pb, Zn, Ba, F. The different morphological types of the deposits are affected by two generations of mineralization (early and late).

- **Hamimed (2004)** in a doctoral thesis; made a sedimentological and paleogeographical paleogeographic study of the Miocene deposits in the Northeastern Saharan Atlas country of the confines Algerian-Tunisian. He concluded that the Miocene basin of Tebessa is subdivided into two parts, southern basin south of Tebessa and northern basin in the north. The two basins are widely outcropped, under various facies, the deposits of the lower and middle Miocene sandstones, sands, marls and conglomerates and rest by a transgressive surface on the on the anti-Miocene formations (Albian, Senonian and even Triassic), whereas the terminal Miocene is characterized by red marls with rare bariolated levels, marking the levels, marking the installation of a phase of regression, the thickness of the Miocene series varies between 50 m and 200 m, it is represented by four stratigraphic units (Burdiglian, Langhian - Serravallian and Tortonian)

D. CURRENT STATUS OF WORK (2010-2017)

- **Ruault-Djerrab et al. (2011, 2012, 2014)** studied the Cretaceous deposits and considered that these considered that these sediments are deposited in a deep outer shelf in an upper slope environment under low oxygenation conditions, planktonic microfauna and geochemical analysis have identified OAE-2 in this region. During the Late Cretaceous, sedimentation is predominantly marly.

- **Defaflia (2014)** in a PhD thesis, made a stratigraphic and paleoenvironmental study of the Quaternary formations of the El Ma El Abiod region (Tébessa, Algeria). He concluded that the sedimentary deposits were deposited during the Quaternary under climatic conditions more clement than the present and an alternation of a calm environment favoring pedogenesis with a dynamic regime characterized by the dominance of the coarse fraction.

- **Degaichia (2014)** in a doctoral thesis in science made sedimentological and paleoenvironmental studies on the Pliocene sediments of the collapse ditch of Tebessa.

- **Boulamia (2015)** in a doctoral thesis, made sedimentological and petromineralogical studies on the phosphates of marine origin. He concluded that the phosphate material is represented by pellets, coprolites, enameloid and dentin of marine fish teeth and is cemented by a Marine and is cemented by a clay or carbonate matrix.

- Defaflia et al. (2015) studied the Mio-Plio-Quaternary grabens in the Algerian-Tunisian confines and concluded that all collapse ditches in the Algerian Tunisians cut the Atlasic structures fini-lutetian older than them. The distensive Miocene distensive phase is manifested by the creation of collapse ditches. There are two phases of post-Miocene folding in the surroundings of Tebessa: the folding of the lower Pliocene, whose distensive the distensive phase of which caused the collapse of the Morsott ditch, and the folds of the of the Upper Pliocene (Lower Villafranchian).

- Kechiched (2017, 2018, 2020) made a geochemical and sedimentological study on the phosphates in the region of Tebessa, he found that the formations of the Paleocene and Eocene of this region are essentially constituted of marls, shell limestones, limestones rich in teeth of shark and Nummulites, showing nodules of flint and layers of phosphorite. The phosphate material is represented by pellets, coprolites, enameloid and enameloid and dentine of marine fish teeth and is cemented by a clay or carbonate matrix and show an enrichment in glauconite which can indicate processes of reworking of processes of reworking of the phosphate particles before their deposition and their final burial in a suboxic to sub-reduced environment could be recorded in the Phosphorites of Tebessa.

CHAPITRE IV: SEDIMENTOLOGICAL AND ICHNOLOGICAL STUDY

I. SEDIMENTOLOGICAL STUDY:

1. Introduction

This chapter is based on a sedimentological analysis of Tebessa's Miocene deposits based on the examination of one section at the study site. The sedimentological approach used to determine the paleoenvironment through lithological, granulometric, and mineralogical studies.

2. Sectional organization

A cut was made in the El Hajdra Safra sand quarries. The samples are distributed in a systematic manner. The sections are divided into several successive levels, each characterized by distinct lithological and faunistic criteria, and this from top to bottom.
El Hadjra Safra stratigraphic section I: Thirty-five (35) samples were collected in a systematic manner from the top to the bottom of the stratigraphic section.

3. Lithological level descriptions

The EL hajra Safra section is taken in the sand quarry of El Ma Labiod and is 250 cm deep. This geological section is divided into three (03) levels, from top to bottom:
Level 1 (from 0 to 115 cm): This level is characterized by the absence of fauna at the base and is dominated by a silty matrix and very fine silty sand subordinating layers of fine to coarse sand.
Level 2 (between 115 and 210 cm): This level has heterogeneous granulometry, with silty sands with intercalations of fine to coarse sand beds of beige and light yellow with clayey cement, accompanied by a bed of small gravels with carbonate concretions containing shell debris.
Level 3 (between 210 and 250 cm): This level consists of very fine silty sands, whitish sands that are slightly carbonated, and rare passages of coarse sands with the presence of some gravel and small pebbles. It is abundant in shell fragments.

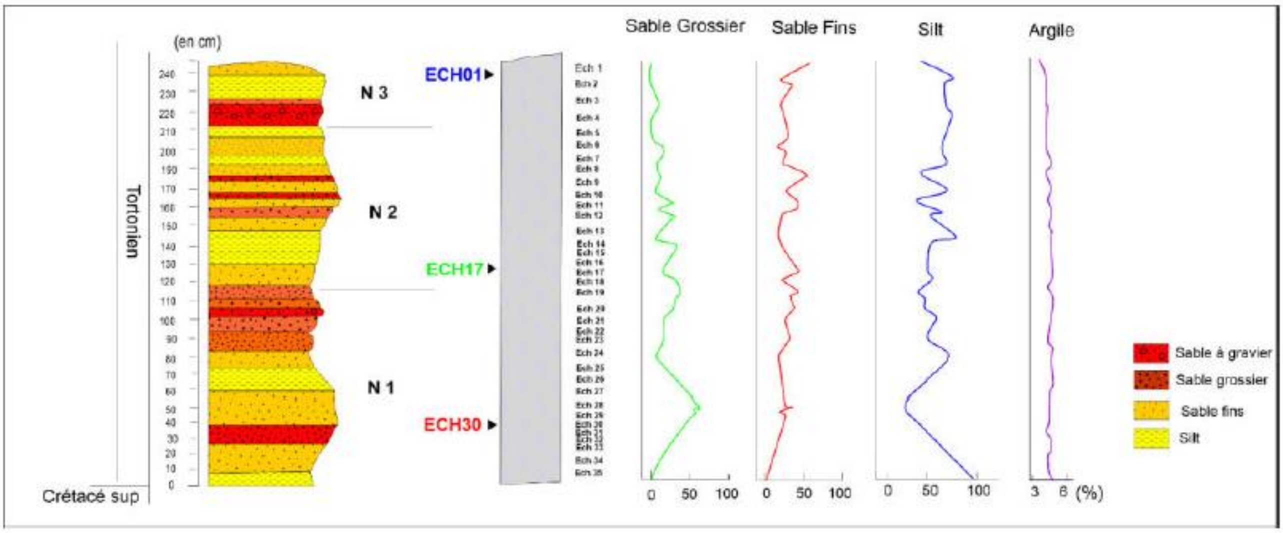


Figure 12 section of El Hadjra Safra & the evolution of the granometric fractions

3. Granulometric analysis

The granulometric parameters of the sedimentary facies of the El Hadjra Safra section are represented in the figure.

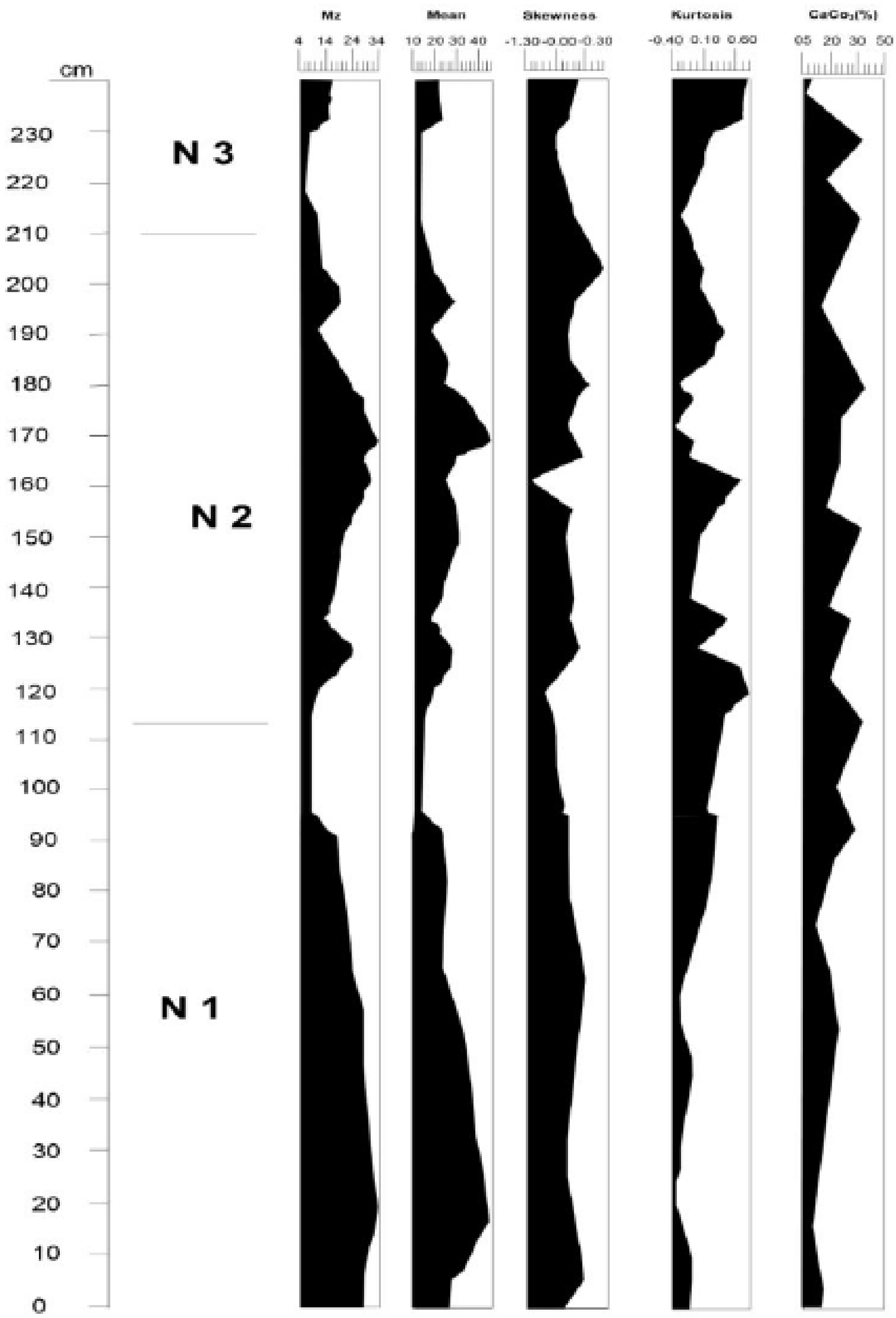


Figure 13 evolution of the granulometric parameters of El Hadjra Safra

have been selected to present the meaning and characteristics of the sediment grain size indices (Tables 1,2,3). The evolution of the particle size parameters and the frequency and cumulative particle size curves of the El Hadjra Safra section gives us the following information:

Level 1: This level is characterized by an alternation between sediments with a fine to coarse polymodal granularity with a symmetrical distribution (-0.1<Sk<0.1). The grain-size facies is sublogarithmic (N≈0). and logarithmic, they characterize more or less muddy deposits.

Level 2: This level is characterized by fine fractions with a medium to large grains 3.32<Mz<4, l. The frequency curves are generally trimodal with an almost asymmetric distribution almost asymmetric (Sk<1) and a leptokurtic (K>0) appearance. The particle size distribution is sublogarithmic (N≈0) corresponding to more or less muddy deposits of relatively calm littoral zones (Rivière 1977).

Level 3: This is a very poorly classified sediment (σ < 4), bimodal at the base and unimodal at the top, with an asymmetric distribution toward coarse (-Sk<1) and a leptokurtic appearance (K>0). The cumulative curve gives logarithmic to sub-logarithmic values (N≈0), parabolic (N>0) and hyperbolic(N<0).

After decarbonation, the curves of the majority of samples do not change their gaits and indicate a poorly classified sand, except for sample n° 1 which shows a hyperbolic curve (Well classified sand). The median and other particle size parameters of this sample decrease, which is due to the enrichment of the material in carbonate material.

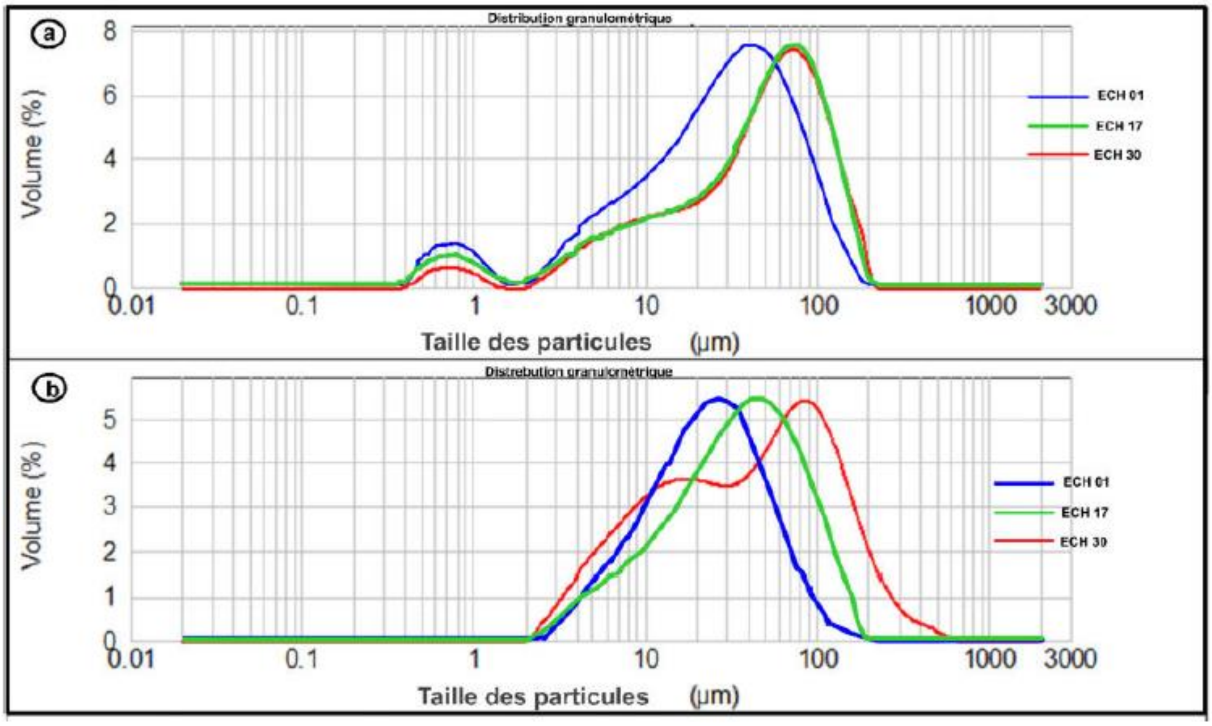


Figure 14 (a) frequency curves of the samples: (blue): ech.01, (green): ech.17, (red): ech.30; (b) Frequency curves of samples: (Blue): ech.01, (Green): ech.17, (Red): ech.30 (decarbonated).

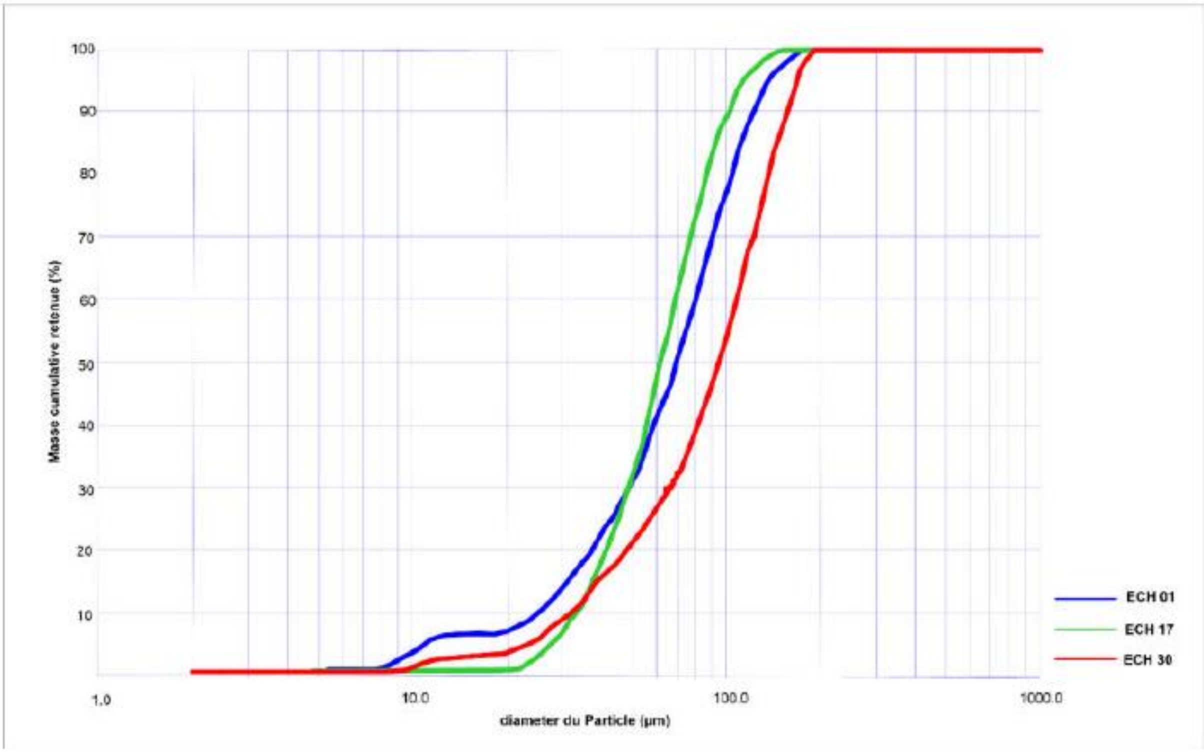


Figure 15 cumulative curves: (Blue): ech.01, (Green): ech.17, (Red): ech.30.

4. Morphology of quartz grains:

Morphology of quartz grains reveals the presence of blunt or sub-blunt and shiny grains in all samples (82%), indicating a fluvial transport transport into the littoral, given the presence of marine microfauna (foraminifera and ostracodes). The transport must have originated from the surrounding landforms, specifically Cretaceous limestone outcrops (presence of limestone grains). The grains rondmats (RM) are reported at the top (they account for 12% of the sediment), and they are highlighted by a ferruginous coating, indicating the start of pedogenesis. Finally, unworn grains (NU) account for a small percentage (6%), indicating a nearby food source with little evolved sediments.

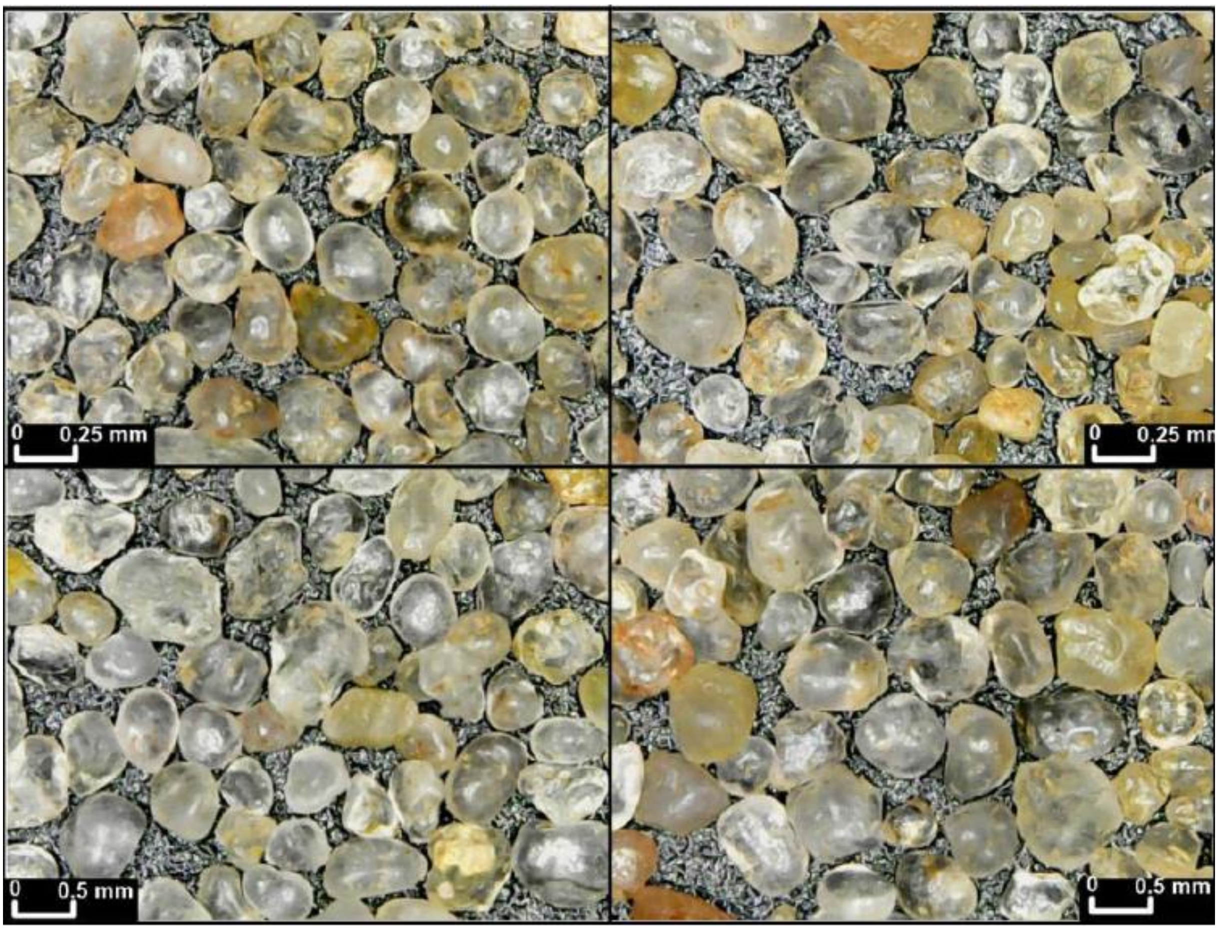


Figure 16 Observation with the magnifying glass of the grains of quartz for the morphoscopic study of the El Hadjra Safra section (Ech: 03; 17; 33).

5. Mineralogical study

Mineralogy of sands

Study of light minerals

Light minerals are more abundant than heavy minerals. This study shows the quasi dominance of quartz.

Study of heavy minerals

Heavy minerals are totally absent.

Mineralogy of clays

According to the mineralogical analysis of the samples of the El Hadjra safra section (10 samples) to the RX diffractometer, it turns out that the clayey procession of the deposits is composed by illite, sepiolite, kaolinite, smectite and chlorite. Their distribution allowed us to distinguish:

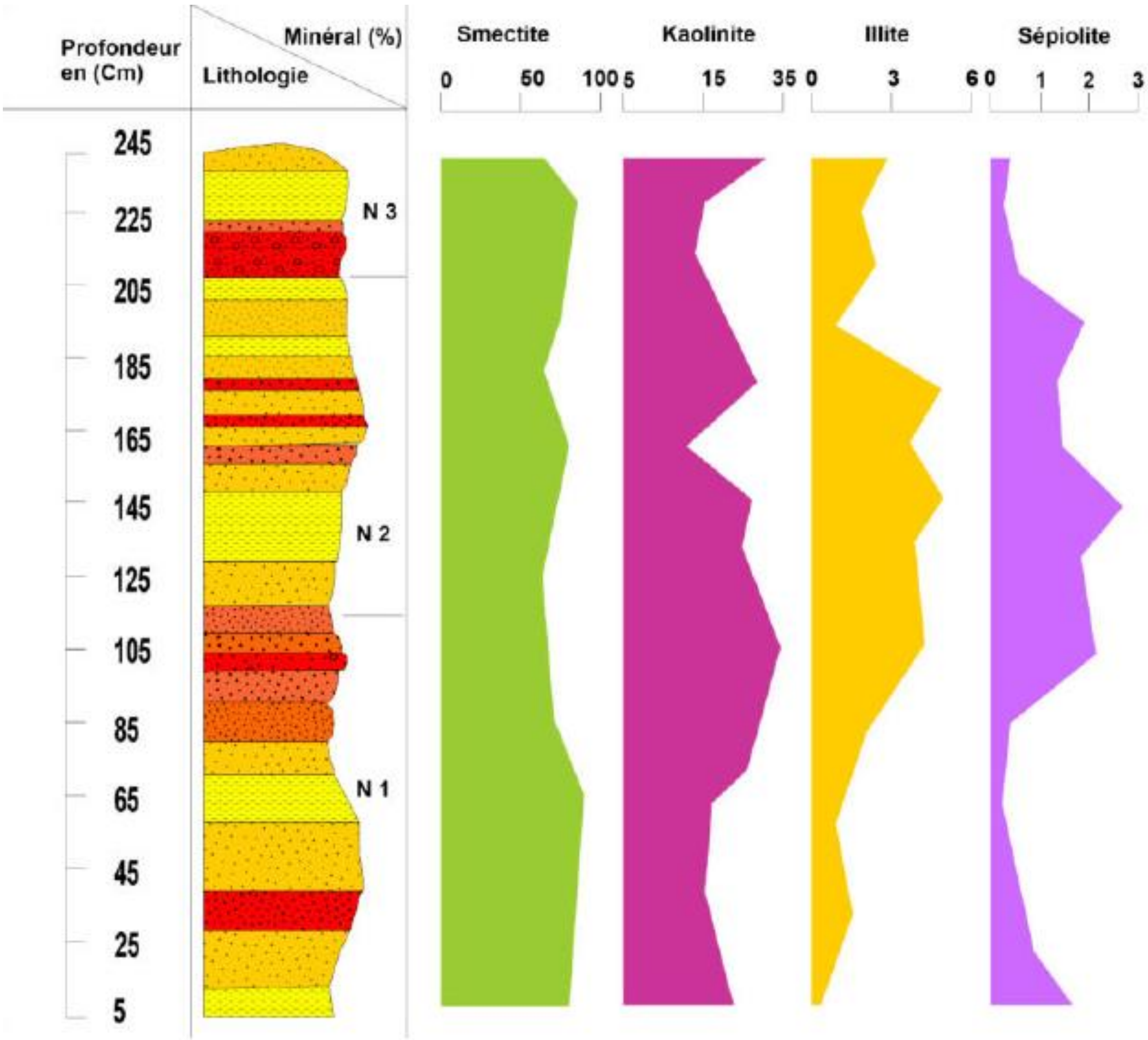


Figure 17 Evolution of clay minerals along the El Hadjra Safra section.

Level 3: The clayey procession is composed of smectite (64% to 84%), kaolinite (15% to 30%), illite (1 to 3%), and sepiolite (0.2 to 2%) in decreasing order

Level 2: It has the same distribution of clay minerals as level 3, but what distinguishes it is the relative increase in the percentages of kaolinite, illite, and sepiolite.

Level 1: (from 80 cm to the bottom of the section): It has the same clay mineral distribution as level 2.

6. Discussion

Clay minerals can be useful tracers for the evolution of the origin of sedimentary material over time (Sabatier, 2008). In the case of El Hadjra Safra, smectite, along with kaolinite, constitute the most abundant clay minerals, with to a lesser extent of illite, while sepiolite is almost absent (does not exceed 1%).

The evolution of the clay minerals in the El Hadjra Safra section reveals that: smectite is formed in large quantities as a result of a hot climate with alternating wet and dry phases (Chameley, 1971).

This points to a terrigenous detrital origin. When compared to kaolinite, the illite contents evolve in the opposite direction.

Indeed, it is found in sediments with a detritic character (Trauth, 1977), as well as in confined environments rich in organic matter. Smectite neoformation is common in this type of environment (Millot, 1970).

Illite forms in cold and/or dry climates (Millot, 1964; Chamley, 1989), its distribution through the sedimentary process is almost homogeneous, and the coincidence with quartz-rich facies suggests a terrigenous detrital origin. When compared to kaolinite, the illite contents evolve in the opposite direction.

7. Conclusion:

The representation of the characteristics and grain size fractions with carbonate levels reveals a fine particle size (less than 50 µm) sediment. These silts and fine sands that are frequently misclassified based on the values of the cumulative curve indices and the shapes of the frequency curves. The formation of these deposit is linked to a regime abnormality. Also, some samples are monogenic with unimodal curves (> 60% silts), while others are bimodal, indicating a mixing of sand and silt that cannot be explained by the same hydro-sedimentary processes. The morphoscopic observations indicate a proximity of aquatic transport of littoral appearance.

II. ICHNOLOGICAL STUDY:

1. Introduction:

Thick marine mixed siliciclastic-carbonate sediments with extensive ichnofauna have been deposited in the west Mediterranean Miocene peripheral basins (Naimi et al., 2020a).

Several ichnological studies have been conducted on these deposits over the last decade, particularly in Spain and Italy (Uchman & Hanken, 2013; Monaco & Trecci, 2014; Belastegui et al., 2016). They feature diverse and remarkable trace-fossil assemblages in shallow marine settings. However, both bioturbation and bioerosion patterns have been documented infrequently (Doyle et al., 1998; de Gibert & Robles, 2005).

Sidi Saleh is a tectonized region defined by the presence of Miocene formations consisting of alternating sandstone and marl at the Miocene lower-middle (Burdigalian-Langhian) level and conglomerates at the Miocene (Serravallian-Tortonian) level.

Except for some foraminifera, these tectonic processes have resulted in the difficulty to achieve acceptable micropalaeontological data.

As a result, we utilised all available data to characterize the paleoenvironment of the Ain Sidi Salah area as accurately as feasible.

2. Location and geological background:

The study area belongs to Tebessa Mounts, which constitute the easternmost part of the Algerian Atlasic domain, consisting of the southern part of an Algerian alpine chain (Durand-Delga, 1969; Halamski & Cherif, 2017) Tebessan Mounts are characterized by Triassic strata, cropping out as diapirs and composed of gyrpsum, clays, anhydrite and dolomite (Dubourdieu, 1956) The overlying Cretaceous deposits (late Albian–Turonian), where two anoxic events were identified at the end of the Albian and the Cenomanian (OAE-2).

The studied outcrop is located at Aïn Sidi Salah locality, to the east of Ouenza city, in the southeastern part of the Algerian-Tunisian border. It consists of a succession of yellowish, 2 to 11 m-thick quartz-dominated fine- to coarsegrained sandstones, with sharp erosive bases. The sandstone beds are intercalated with greenish to grayish clayey marls, 0.5–39 m thick, represented essentially by smectite, chlorite, kaolinite and illite clay minerals (Mazouz, 2009).

Tableau 2. Distribution of the main facies, ichnogenera and depositional settings (N.DEFAFLIA & Benkhedda 2021)

Facies	General description	Trace fossils	Sedimentary structures	Sedimentary processes	Environment
Facies F1: Marlstones	2.5 – 8.3 m thick, massive, grey to green in color, containing benthic foraminifera and ostracods, with intercalation s Sandstone beds (0.15 m mean)	/	/	Decantation processes mainly poststorm or tide current	Storm dominated siliciclastic platform
Facies F2: Claystones	0.8 – 5.5 m thick, massive, reddish sandy claystones, intercalated by thin sandstone	cf. *Taenidium* isp.	/	Decantation processes and possibly related to pedogenic processes	

	levels				
Facies F3: Rippled fine sandstones	Yellow to grey fine sandstones, 0.6 – 1.3 m thick, intercalated within marlstone facies, channelized, and showing ripple marks	*Thalassinoides* isp. cf. *Archaeonassa* isp. *Diplocraterion* isp. *Helminthopsis* isp. *Skolithos* cf. *S. linearis*	Wavy crosslaminated, wavy/ripplemarks	Weather wave or tide current in littoral zone	
Facies F4: Laminated sandstones	Brown to yellow, fine to mediumgrained, 0.05 – 0.4 m thick, highly channelized, with sharp erosive bases	*Arenicolites* isp. *Palaeophycus tubularis* *Skolithos* cf. *S. linearis*	Horizontal and planar stratification	Deposition under high and rapid energy related to storm event	
Facies F5: Stormdominated sandstones	Brown in color, fine to medium grained sandstone beds, 0.2 – 0.45 m in thickness, channelized, showing sometimes calcareous debris	*Skolithos* cf. *S. linearis* *Thalassinoides* isp.	Hummocky crossstratification (HCS), horizontal lamination	Middle term of the tempest sequence from stormdominated platform (middle offshore)	

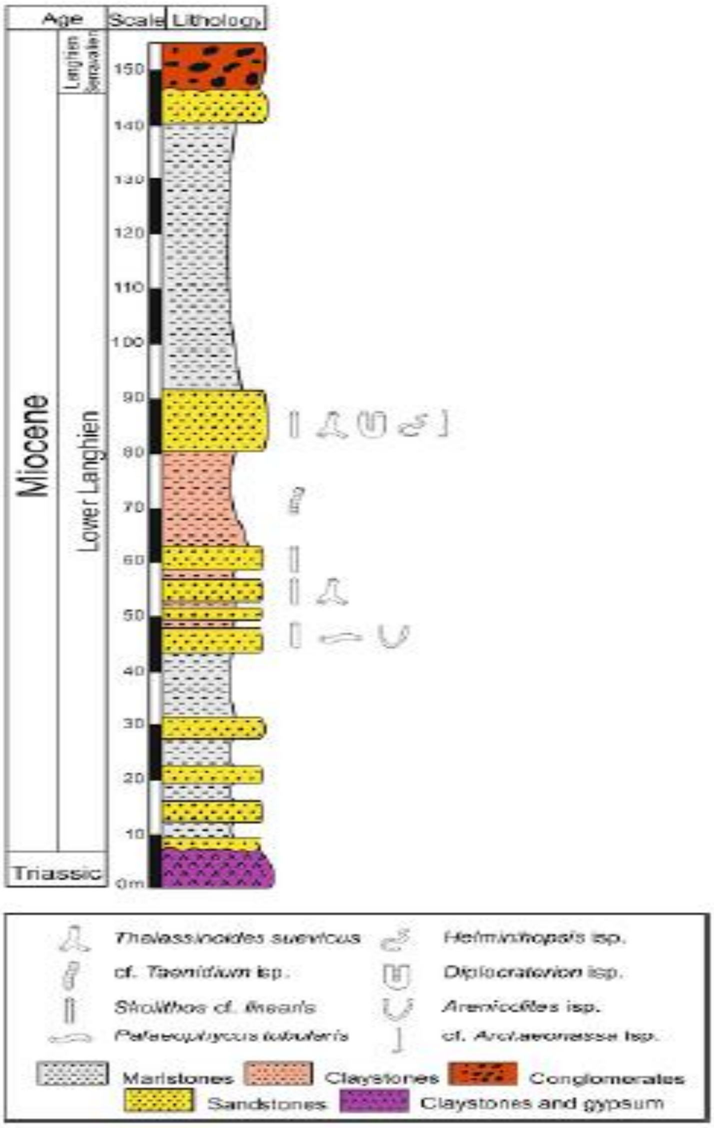


Figure 18 Stratigraphic column and trace fossils distribution of the Aïn Sidi Salah section (Tébessa, northeastern Algeria). (N. DEFAFLIA & Benkhedda2021)

3. Systematic ichnology:

The trace fossil assemblage is poorly diverse, consisting of eight ichnotaxa, the majority of which have been identified at the ichnogenus level. Skolithos cf. S. linearis is numerous, Diplocraterion isp., and Thalassinoides isp. are common, and cf. Archaeonassa isp., Arenicolites isp., Helminthopsis isp., Palaeophycus tubularis, and cf. Taenidium isp. are rare, according to this study.

Furthermore, the majority of specimens are preserved as epichnia and endichnia.

Tableau 3. Main characteristics & description of the studied ichnoassemblage (N. DEFAFLIA & Benkhadda 2021 modified)

Ichnotaxa	Toponomy	Description	Abundance	Ethology	Main producers
cf. *Archaeonassa* isp.	Epichnia	Subhorizontal, unbranched, cylindrical and rarely meandering trail, preserved as convex hyporelief, composed of concave central zone bounded by two convex parallel lateral ridges. It is found in the top of fine-grained sandstone with ripple marks.	Rare	Repichnia, praedichnia	Gastropods, crustaceans
Arenicolites isp.	Endichnia	Incomplete unbranched U-shaped burrows, at least 125 mm long, having a pair of closely spaced circles with subvertical orientation, and preserved as endichnia. Tube diameter is 36 mm.	Rare	Domichnia	Worms
*Diplocraterion*isp.	Epichnia	U-shaped, vertical burrow, preserved as epichnia at the top of fine-grained sandstone beds, and no specific characteristics are shown. The burrow diameter	Common	Domichnia	Crustaceans, polychaetes

		varies from 1. 5 to 6 mm and distance the between the two limbs of the U-shaped burrow is 1213 mm.			
Helminthopsis isp.	Epichnia	Horizontal simple, smooth and meandering string, 3 mm in diameter and 160 mm in length, preserved as a concave epichnial ridge in fine-grained sandstone.	Rare	Pascichnia, repichnia	Polychaetes
Palaeophycus tubularis	Epichnia	Epichnial convex, simple, straight, unbranched, cylindrical to subcylindrical burrow, horizontal to bedding. Diameter is 15 mm and the maximum length is 104 mm.	Rare	Domichnia	Worms
Skolithos cf. *S. linearis*	Endichnia	Preserved as endichnia straight, simple, elongated, vertical to subvertical, cylindrical and unbranching tube, with lined walls and passive filling.	Abundant	Domichnia	Worms, crustaceans
cf. *Taenidium* isp.	Endichnia	cf. Taenidium isp. is winding, unbranched,	Rare	Pascichnia	Arthropods

		and thinly-lined burrow, vertical to the bedding plane, preserved as endichnial in sandy-claystone facies, up to 100 mm long and about 5 mm in diameter.			
Thalassinoides isp.	Endichnia	Straight or slightly curved, oblique, large, mostly with Y- to T-shaped branched burrowing network, 1030 mm wide and 50 to 150 mm long.	Common	Domichnia	Decapod crustaceans

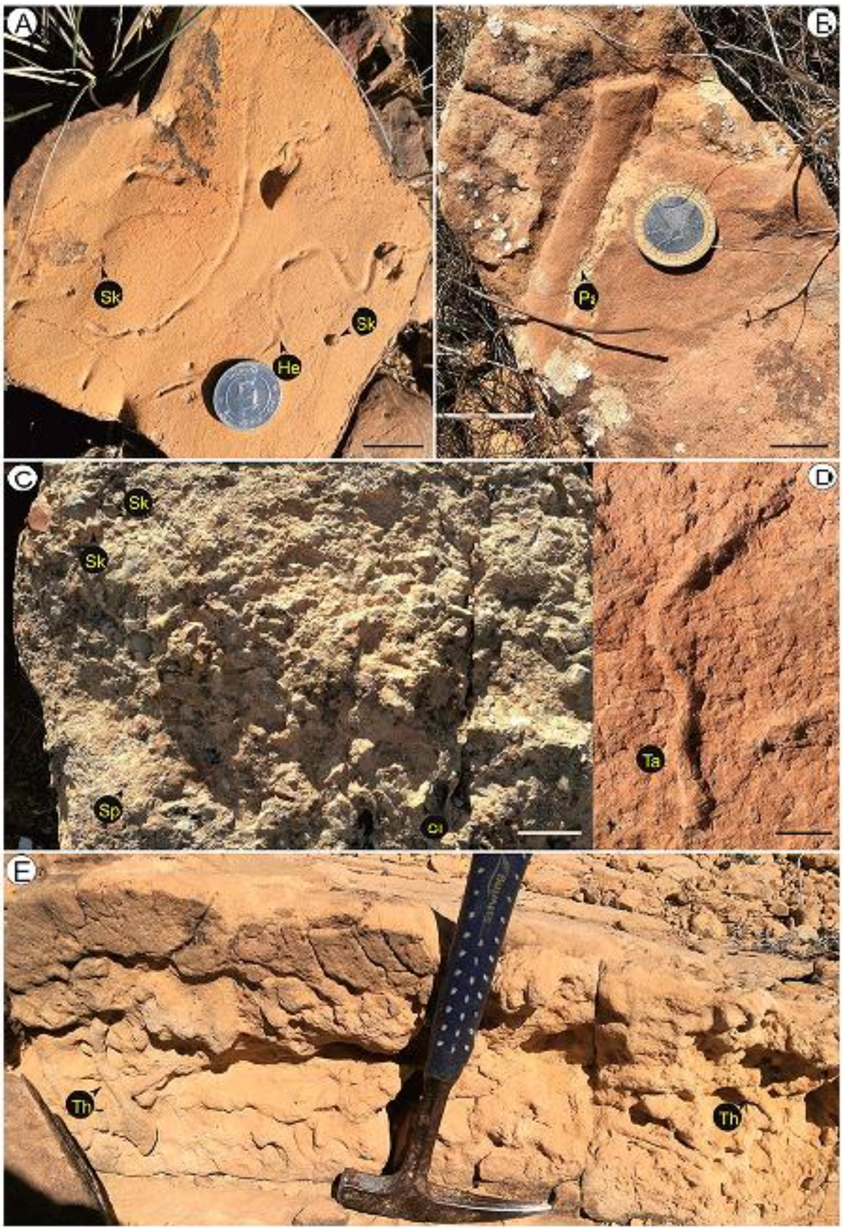


Figure 19 : Trace-fossils from the lower Langhian of Aïn Sidi Salah: A, *Helminthopsis* isp. (He) associated with *Skolithos* cf. *S. linearis* (Sk); B, *Palaeophycus tubularis* (Pa); C, sandstone bed rich in *Skolithos* cf. *S. linearis* burrows (Sk), with probably pipe structures of *S.* cf. *S. linearis* burrows (Sp), and its lost traces (Sl) ; D, cf. *Taenidium* isp. (Ta) (the possible meniscate fill is indicated by white arrow); E, sandstone bed showing abundant *Thalassinoides suevicus* (Th). Scale bars: A–B = 2 cm; C = 5 cm; D = 1 cm.

4. Ichnological analysis

The traces were found in claystones, rippling fine sandstones, laminated sandstones, and storm-dominated sandstones with tightly packed bioclast-supported shell layers. Sub-horizontal to sub-vertical burrows of cf. Archaeonassa isp., Arenicolites isp., Diplocraterion isp., Helminthopsis isp., Palaeophycus tubularis, Skolithos cf. S. linearis, Taenidium isp., and Thalassinoides isp. characterize the trace-fossil assemblage. S. cf. linearis is the most abundant trace-fossil. The observed low ichnodiversity could be due to stress factors such as excessive energy (Buatois & Mángano, 2013).

The ichnoassemblage in the subject is dominated by post-depositional living (domichnia) traces, which are primarily attributable to suspension- or deposit-feeding organisms (e.g. Thalassinoides isp.). The fundamental feature of shallow marine trace-fossils is that they exhibit more ethological variety than those seen in other habitats (Joseph et al., 2020). Pemberton et al. (2001) discovered proximal and archetypical Cruziana ichnofacies in an upper offshore-lower shoreface habitat. Based on a sedimentological approach, Mazouz (2009) proposed a shallow marine habitat with moderate to high energy conditions for the Tebessa Basin. Vertical structures imply opportunistic colonization of storm-dominated sandstones (post-event community), whereas horizontal structures (laminated sandstones) indicate favorable weather circumstances (Pervesler & Uchman, 2004). The presence of post-depositional trace-fossil Arenicolites and Skolithos in sandstone strata may imply a storm-related highenergy environment on the lower to middle shoreface (MacEachern et al., 2012). Furthermore, bivalve shell debris may be linked to storm occurrences (tempestitedeposits) and represent a shoreface depositional environment. Thalassinoides is a softground character (Myrow, 1995), and its co-occurrence with wide and open burrows, as well as Palaeophycus, implies a shallow marine environment with well-oxygenated water above the sea bottom (Naimi et al., 2020a; Naimi & Cherif, 2021). Worms (polychaetes and phoronids) are the most prevalent producers of the investigated trace-fossils, but crustaceans and arthropods are also possible tracemakers. Under normal salinity circumstances, the examined ichnoassemblage, coupled with paleontological evidence and recorded bivalves, suggest adequate food resources in both the substrate and the water column (Fürsich, 1973; Wilson & Rigby, 2000; Mángano et al., 1999; 2005; Gurav et al., 2014).

Suspension feeders thrive in water with moderately strong currents, uneven sedimentation rates, and a high flux of food particles (Buatois & Mángano, 2011). Gingras et al. (2011) also considered the abundance of persistent U-shaped burrows and vertical tubes to be suggestive of shallow-marine environments with shifting sandy substrates, moderate-to-high-energy conditions, and suspended food.

From an ichnological standpoint, the series demonstrates a change in environmental circumstances from the nearshore to the offshore zone. The colonization took place in properly oxygenated shallow-marine waters in a high-energy environment.

An Sidi Salah's trace-fossil assemblage is directly tied to shallow marine ichnofacies and typically demonstrates Skolithos development, which is the diagnostic of Skolithos ichnofacies type conditions.

5. Paleogeography

A large marine incursion began across the expanse of epicontinental Algeria during the Early-Middle Miocene (Bessedik et al., 2002). A patch reef suggesting maximum flooding has been discovered in the Lower Chelif Basin's Langhian-Serravalian transgression detrital strata (Belkebir et al., 1994). As a result of the opening of the Algero-Provençal Basin, which occupies the western section of the Mediterranean Sea, this transgression has been recorded from the entire western Mediterranean Basin (de Gibert & Robles, 2005). These transgression deposits are overlain by Serravalian reddish detrital sediments from the continental crust. 2002; Bessedik et al. Late Miocene (Tortonian-Messinian) marine transgression deposits complete the Miocene series (Benzina et al., 2019; Naimi et al., 2020a).

The attribution of the examined deposits to the lower Langhian based on planktonic foraminifera allows the Tebessa basin to be linked to the other peripheral basins of the southern Mediterranean as well as the Lower Chelif Basin. The bioturbated sandstones (Facies F3-F5) were deposited in a transgressive setting associated with a large transgression observed in other peri-Mediterranean basins.

They are also overlain by reddish conglomerates comparable to those found in Algeria's Lower Chelif Basin, a reference Miocene sequence.

6. Conclusion

Ichnological investigation of the lower Langhian sequence at An Sidi Salah indicated minimal ichnodiversity represented by subhorizontally to subvertically oriented burrows belonging to eight Skolithos and proximal Cruziana Ichnofacies. Thus, Archaeonassa isp., Arenicolites isp., Diplocraterion isp., Helminthopsis isp., Palaeophycus tubularis, Skolithos cf. linearis, Taenidium isp., and Thalassinoides isp. are among the trace-fossils. The Skolithos ichnofacies indicates a high hydrodynamic energy condition of the foreshoreshoreface environment with infrequent storm events, whereas the proximal Cruziana ichnofacies indicates a moderate energy condition of the shoreface. Despite the lack of body fossils, this ichnoassemblage shows that suspension- or deposit-feeding animals, primarily worms (polychaetes and phoronids), crustaceans, and arthropods, existed inside these deposits.

CHAPITRE V: SEDIMENTOLOGICAL AND ICHNOLOGICAL STUDY

I. INTRODUCTION

Several specialized books and theses (Loeblich and Tappan 1988, 1989; De Marcelle K. Boudagher-Fadel 2017; Lennart Bornmalm 1995...) have been used to determine microfossils. The proposed classification wMill therefore be as comprehensive as possible (with genus name and species), but due to a lack of data on some holotypes, we have preferred to leave it in open nomenclature in some instances (genus name only, or even family name).

II. AVAILABLE MICROFOSSILS

Microfauna research, specifically the study of foraminifera and ostracods, is crucial for stratigraphic dating and the reconstruction of paleoenvironments.

1. Foraminifera

1.1. Generalizations

Protozoa are foraminifera (Sen Gupta, 1999). Foraminifera tests can be organic, agglutinated, carbonate, or even siliceous (infrequently). These tests involve one or more orifices and one or more chambers (lodges). They range in size from 38 micrometers to 1 millimeter. Foraminifera are given the ability to fossilize by their shells, which is largely dependent on their own nature and the physicochemical conditions of the sedimentary environment.

1.2. sedimentary setting

The primary foraminifera classification criteria are based on the test's morphology and chemical composition (Loeblich and Tappan, 1988; Sen Gupta, 1999).

1.3. Microhabitat

Due to the physico-chemical, ecological and activity conditions of the sediment (Corliss, 1985), the distribution of benthic foraminifera in the sediment constitutes the microhabitat It Is generally studied to a depth of ten centimeters There Are two types of species; one type living on the surface of the sediment (epipelic) and another type living in the sediment (endopelic). The TROX model (TRophic and OXygen), explains this distribution according to these parameters The presence and distribution of oxygen at depth controls the life and distribution of organisms. It is determined by the availability of food.

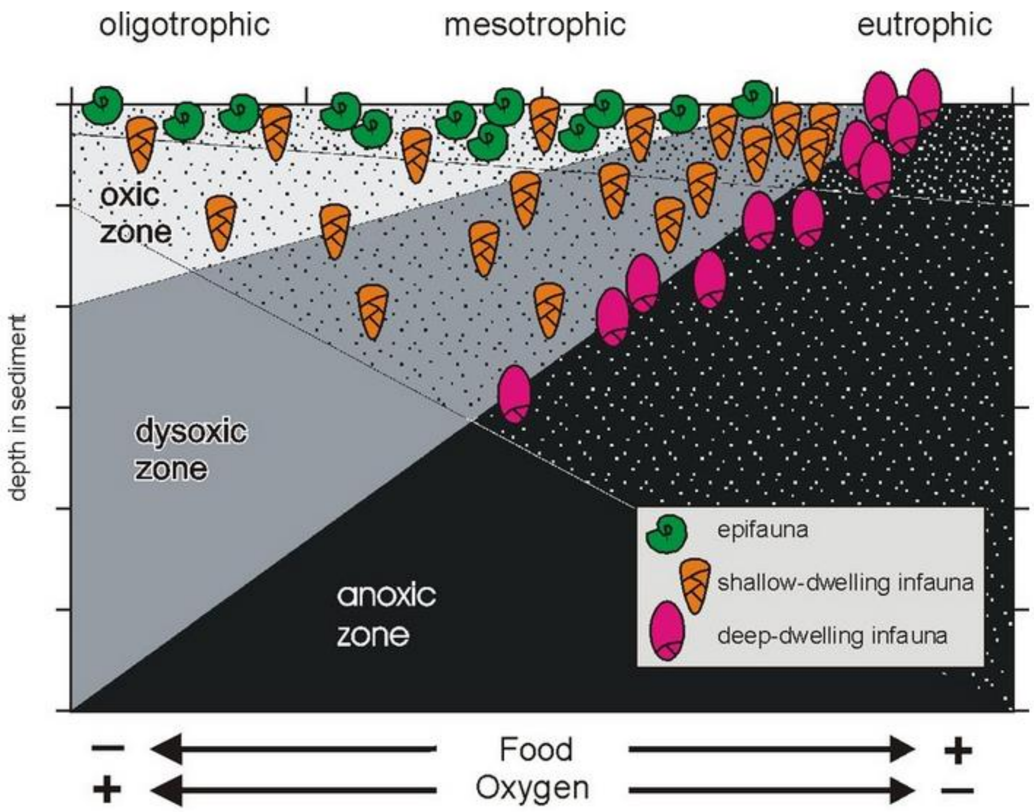


Figure 19 Microhabitat model as a function of depth of the oxic zone and organic matter abundance (Jorissen et al., 1995; De Stigter, 1996).

The abundance and distribution of foraminifera are largely determined by the following parameters:

- **Oxidation**

Oxygen is an essential element controlling the life and biodiversity of benthic foraminifera, according to Sen Gupta and Machain-Castillo, 1993; Gooday, 1994; Jorissen et al. al. 2000. The specific richness of species decreases in closed basins such as ponds, lagoons, or salt marshes.

- **Organic matter**

The quality of organic matter exported to the sediment influences the composition, density, and microhabitats of benthic foraminifera communities (Altenbach and Sarnthein, 1989; Corliss and Emerson, 1990; Corliss, 1991; Jorissen et al, 1995, Jorissen et al, 1998; De Rijk et al, 2000; Licari et al, 2003).

- **The pH of the water**

This parameter is used in the creation of the tests. Murray (1991) found that agglutinated tests are more resistant to acidic pH. Boltovskoy and Wright (1976) discovered that calcareous test dissolution began at a pH of 7.8.

- **Salinity**

The types and distribution of foraminifera are influenced by the salinity of the environment. They are euhaline in hyposaline environments, stenohaline in normal salinity, and euryhaline in hypersaline environments, with environments decreasing in diversity and number of species as salinity increases (Murray, 2006).

- **Temperature and hydrodynamics**

Temperature changes and environmental energy influence oxygen supply (Murray, 2006)

1.4. Planktonic foraminifera

- **Sub-order:** GLOBIGERINA Blow, 1979
- **Super-family:** GLOBIGERINACEA Carpenter, Parker & Jones, 1862
- **Family:** GLOBIGERINIDAE Carpenter, Parker & Jones, 1862
- **Subfamily:** GLOBIGERININAE Carpenter, Parker & Jones, 1862
- **Genus :** Globigerina d'ORBIGNY, 1826

It is characterized by a trochospiral test with spherical or ovoid lodges and a main umbilical opening.

umbilical main opening.

- **Globigerina decoraperta TAKAYANAGI et SAITO, 1962**

1962- Globigerina druryi decoraperta Takayanagi et Saito, Tohoku univ., Sc. Rept.,

Sendaivser. 2 (Geol.), soec. bp. 28.

1971- Globigerina woodi decoraperta: Jenkins, pl. 16.

1985- Globigerina decoraperta Takayanagi et Saito: Iaccarino, p. 302, pl. 301.

1986- Globigerina decoraperta Takayanagi et Saito: Belkebir, p. 114, pl. I, 3. 7.

- **Genus: Globigerinoides CUSHMAN, 1927.**

Its form is distinguished by the presence of several secondary openings on the spiral face.

- **Globigerinoides obliquus BOLLI, 1957**

1 969- Globigerinoïdes obliquus extremus Bolli et Bermudez : Boll. Infor. Asoc. Venez.

Geol. Miner. Petr., 8, n° 5, p. l39, pl. 1.

1969- Globigerinoïdes obliquus extremus : BLOW, p.324, pl.21.

1973- Globigerinoïdes obliquus extremus Bolli & Burmudz : Cita & Gartner, Riv. Ital.

Paleont. 79, pl. 52.

1975- Globigerinoïdes obliquus extremus : Sat- Ntforth et al.

1983- Globigerinïdes extremus Bolli: Kennett & Srinivasan, Hutch. Ross. Pub. Comp.,

p. 58, pl. 12.

1985- Globigerinoïdes obliquus extremus Bolli : Bolli & Saunders, Cambridges. Univ.

Press, p. 194.

1987- Globigerinoïdes extremus Bolli & Burmudz : Sierro, Paleont. Neog. Huelva, pl.

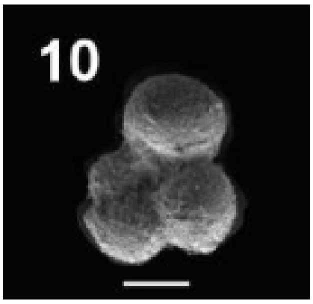


Figure 20 Globigerinoides obliquus (MEB photo, Scale bar: 200 µm)

- **Subfamily:** Orbulininae SCHULTZE, 1854
- **Genus:** Orbulina d'Orbigny, 1839.

The species of this genus are built of one lodge in the first place which multiplies afterwards in the adult stage in several lodges with a spherical to subspherical form according to the genus, the enveloping entirely or partially the rest of the test. From their juvenile stage the

species have small holes well visible at the base.

- **Orbulina bilobata D'ORBIGNY, 1946**

1846 Globigerina bilobata D'ORBIGNY. D'ORBIGNY: p. 164 pl. 9.

1941 Orbulina bilobata D'ORBIGNY. PALMER: p. 286 pl. 28,

1949 Orbulina bilobata D'ORBIGNY. BERMUDEZ : p. 282 pl. 22,

1956 Biorbulina bilobata D'ORBIGNY. BLOW : pp. 69-70.

1957 Orbulina bilobata D'ORBIGNY. BOLLI : pl. 27.

1975 Orbulina bilobata D'ORBIGNY. SRINIVASAN: p.149 pl. 4.

- **Family: Globorotaliidae CUSHMAN, 1927.**
- **Subfamily:** Globorotaliinae CHAPMAN & PARR, 1862
- **Genus: Globigerinella**

Test with low trochospire rate in early stage, later almost planispiral and evolves, globular to oval chambers rapidly enlarging, about four to six in the final turn, radial radial sutures, depressed, rounded periphery and calcareous wall, densely perforated with with an interior-marginal opening.

- **Globigerinella obesa Boli, 1957**

1957 *Globorotalia obesa* Bolli : U. S. Nat. Mus. Bull., 215, p. 119, pl. 29.

1972 *Globorotalia obesa Bolli :* Bizon & Bizon, *Edit. Technip,* Paris, *p. 100.*

1983 Globorotalia obesa Bolli : Kennet et Srinivasan, *Hutch. Ross. Pub*. Comp., p. 134, pl. 59.

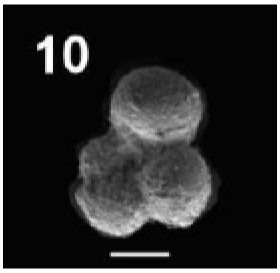


Figure 21 : *Globigerinella obesa* (MEB photo , Scale bar: 200 µm)

1.4.1. Stratigraphic attribution

Kowalski et al (1974) and Hamimed et al (2001,2004) have performed an initiation on the stratigraphic study in this series. In this study, the micropalaeontological analysis of planktonic foraminifera was carried out on different samples taken from the different sections. In the middle and upper part of the successions in two sections, we have identified the first common occurrence of Neogloboquadrina acostaensis (10.57 Ma, Zone N16, Blow, 1969; interval zone, MMi 11, Lirer et al., 2019). In the Mediterranean Basin, the first occurrence of this species corresponds to the Middle Tortonian (Hilgen et al., 2000, 2003, 2005, 2012; Lourens et al., 2005; Iaccarino et al., 2007; Wade et al., 2011); Capella et al., 2018; Lirer et al., 2019). The first appearance of Globigerinoides obliquus (8.37 Ma, MMi 12 interval zone, Lirer et al., 2019) indicating the Late Tortonian (Iaccarino et al, 2007; Lirer et al., 2019). The presence of these species indicates that the El Hadjra Safra Formation was deposited during the Middle-Upper Tortonian. In the different samples taken in the lower parts of the El Hadjra Safra formations, planktonic foraminifera were absent or rare and poorly preserved. However, Wiman (1974) described in the middle interval N. acostaensis, N. humerosa, G. obliquus, Globigerinoides trilobus and Globorotalia saheliana, G. obesa. This assemblage confirms the Tortonian age.

1.5. Benthic foraminifera

- **Suborder: LAGENINA Delage & Herouard, 1896**
- **Super-family: NODOSARIACEA Ehrenberg, 1838**
- **Family: NODOSARIIDAE Ehrenberg, 1838**
- **Subfamily: NODOSARIINAE Ehrenberg, 1838**
- **Genus Laevidentalina Loeblich & Tappan, 1986**

Test uniseriate elongate, arcuate, prolocle rounded to fusiform, may be apiculate, wall calcareous, optically radial, hyaline, very finely perforated, surface smooth and unadorned and round of opening.

- **Genus: Dentalina Risso, 1826**

Test uniseriate, elongated and arched. The opening is terminal radiate, submarginal with oblique sutures.

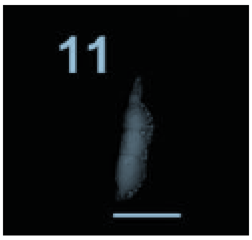


Figure 22 : Dentalina Risso (MEB photo, Scale bar: 200 µm)

- Dentalina elegans D'Orbigny, 1846

1846 - *Dentalina elegans* D'Orbigny, p.45, plate 1.

1895 - *Nodosaria communis* Egger, Jahrsber, Naturhist. Ver. Pessau, Vol. 16, p. 20, pl. ii.

1969 - *Dentalina communis* (D'Orbigny): Martinez, Vol2, pp.147-180, pl. VII.

1985 - *Dentalina elegans* D'Orbigny: Papp and Schmid, p.28, pl.10.

1986 - *Dentalina communis (*D'Orbigny) : Bartebstein et Bolli, p. 956, pl. 2.

Figure 23 : *Dentalina elegans* (MEB photo, Scale bar: 200 µm)

- Subfamily PLECTOFRONDICULARIINAE Cushman, 1927

- Genre: Amphimorphina Neugeboren, 1850

Elongated, microspherical to megalospherical uniserial test with six chambers arranged in two parts in the early stage, calcareous wall, perforated, smooth surface at the beginning, opening radiating in the early stage, with three to eight openings.

- **Amphimorphina haueriana** Neugeboren, 1850

Amphimorphina haueriana Neugeboren, 1850, p. 127, pl. 4.

Nodosaria compressiuscula Neugeboren, 1852, p. 59, pl. 1.

Plectofrondicularia trinitatensis Cushman & Jarvis, 1929, p. 11, pl. 2.

Amphimorphina miocenica Cushman, 1948, p. 220, pl. 15n.

Amphimorphinella butonensis Keyzer var. *compressa* Keyzer, 1953, p. 276, pl.

Figure 24 : ***Amphimorphina (MEB photo, Scale bar: 200 µm)***

- Family: VAGINULINIDAE Reuss, 1860

- Subfamily: LENTICULININAE Chapman, 1934

- Genus: Lenticulina Lamarck, 1804

Test planispiral involute, free with a lenticular shape. The margins are angular or keeled and the sutures well marked. The round opening is located at the base of the last lodge. At the base of each lodge, the wall shows digitations. This last character seems to distinguish this genus of Brizalina. Sometimes, the final lodge can have a central position. The calcareous wall, hyaline, finely perforated, can be decorated with ribs.

- Lenticulina calar (Linné, 1758)

Nautilus calcar Linné, 1758, p. 709 (fide Ellis & Messina).

Nautilus calcar Linné, 1758 var. *α* Fichtel & Moll, 1798, p. 71, pl. 11.

Robulina calcar (Linné) - d'Orbigny, 1846, p. 99, pl. 4.

Cristellaria calcar (Linné) - Parker & Jones, 1860, tab. p. 100, p. 111.

Nodosarina calcar (Linné) - Goës, 1882, pl.3.

Robulus calcar (Linné) - Dieci, 1959, p. 28, pl. 2.

Lenticulina calcar (Linné) - Rögl, 1968, p. 75, pl. 5.

2. Ostracods

Ostracods are small crustaceans (0.5 to 2 mm) that belong to the Arthropod phylum. A bivalve carapace protects the body, which is calcified and articulated dorsally by a hinge. They have adapted to all aquatic environments, from stagnant pools in poorly drained fields on the continent to the depths of the ocean. In 98% of cases, they live a benthic lifestyle. When an individual dies, the soft parts vanish quickly, leaving only the carapace to fossilize.

Ostracods are one of the largest groups of crustaceans, with a rich and continuous fossil record dating back to the Upper Cambrian (more than 65 000 fossil and living species have already been described (Horne).

2.1. Ecology and Lifestyle

The majority of ostracods are benthic. The classification of fossil ostracods is based on Salinity, temperature, the nature of the substrate, bathymetry, and the amount of nutrients are natural conditions that control the distribution of ostracods (Whatley, 1988).

- **Saltiness**

Ostracods live in a wide range of environments depending on their tolerance to salinity and its fluctuations (De Deckker et al., 2011; Remane and Schlipper, 1958). Species numbers in freshwater assemblages are decreasing. Cyprideistorosa characterizes brackish water assemblages as euryhaline and eurythermal.

Marine ostracods: the most numerous and diverse. In the littoral, some genera support minor variations in salinity (euryhalins).

- **The temperature**

The majority of ostracods are eurythermic. The psychrospheric ostracods live in a well-oxygenated psychrosphere, and some species are eurythermic.

- **The foundation**

Ostracodes are found in very small numbers in coarse sediments (sands, oolites, etc.). The fauna in the mixed sandy and clayey sediments is far more diverse.

- **Water depth and oxygenation**

Depth influences the distribution of dissolved oxygen in water, which influences the spatial and temporal distribution of ostracods.

2.2. The following parameters are established, analyzed, and compared in this study:

Animal density: This is the total number of ostracods and foraminifera found per unit of raw sediment weight. It provides information on the trophic richness, good ventilation, and the energy level of the environment.

The specific richness: the large number of species attests to the living environment's physicochemical stability.

The affiliations: According to the composition of each association and by comparing it to the current environments, it will be possible to assign it to one of the marine, coastal, lagoon, or brackish environments.

The pelagic index: it is the ratio between planktonic foraminifera on the total weight of foraminifera.

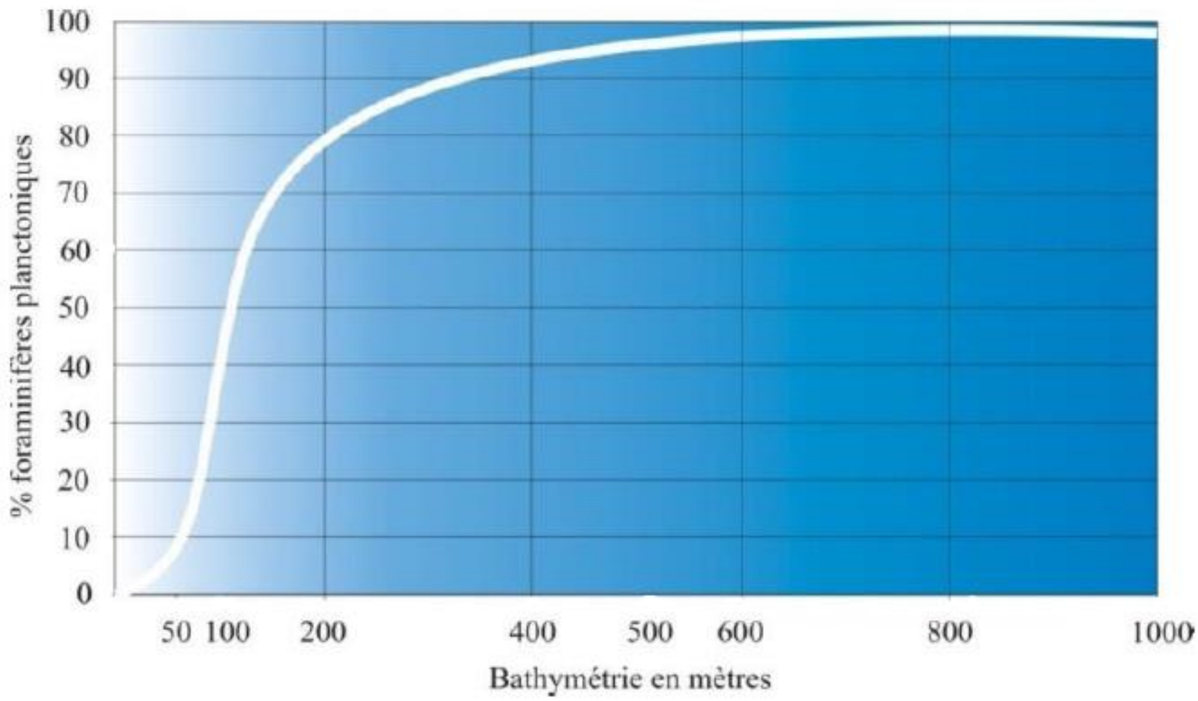


Figure 25 index of pleagisme

Diversity indices: The diversity indices are frequently used in ecology because they are parameters of characterization of a They are parameters of characterization of a settlement.

The Shannon (H) and Equitability (E) diversity indices (Shannon, 1948; Hayek and Buzas,1997) were also calculated to assess the biodiversity of each sample.

The Shannon index (H): It is the most frequently used in benthic ecology studies.

benthic ecology studies. The Shannon index (H) is calculated with the following formula:

With Pi: relative abundance = Ni / N for i varying from 1 to n Ni: number of individuals of the species € in the sample

N: total number of individuals in the sample.

The Shannon index (H) is minimal (=0) if all individuals in the stand belong to the same species.

H is also minimal if, in a stand, each species is represented by a single individual, except for one species which is

except for one species which is represented by all the other individuals of the stand. H

is maximal when all individuals are equally distributed over all species

(Frontier, 1983).

The equitability index (E) (Piélou, 1966) represents the ratio between the theoretical maximum species diversity and the logarithm of the species diversity. and the logarithm in base 2 of the species richness of the sample, and which varies between [0 and 1].

This index (E) is maximal when the species have identical abundances in the stand

and it is minimal when a single species dominates the whole stand.

2.3. The found ostracods

Using the classification system developed by Morkhoven, 1963, Hartman and Puri, 1974, as well as modern scientific sites, 10 species and 10 genera were determined in the

sections studied.

Class: Ostracoda latreille, 1806.

Order: podocopida Muller, 1896.

super family: Cytheracea Baird, 1850.

- **Family:** Xestoleberidae Sars, 1920.

Genus: Uroleberis Triebel, 1958.

Type species: Uroleberis ssp.

Super Family: Cypridoidea Baird, 1845

- **Family:** Candonidae Kaufmann, 1900

Subfamily: Paracypridinae Sars, 1923

Genus : Paracypris Sars, 1866

Type species : Paracypris ssp.

- **Family:** Candonidae Stchepinsky, 1963

Genus : Phlyctenophora Stchepinsky, 1963

Type species: Phlyctenophora ssp.

Super Family: Cytherelloidea G.O. Sars, 1866

- **Family:** Cytherellidae Sars, 1866

Genus: Cytherella Jones, 1849

Type species: Cytherella ssp.

Super Family: Cytheruroidae Mueller, 1894)

- **Family:** Cytheruridae Mueller, 1894)

Genus : Kangarina Mueller, 1894)

Type species: Kangarina ssp.

Super Family: Hemicytheridae Puri, 1953

Genus: Hemicytheridea Kingma, 1948

Type species: Hemicytheridea ssp.

Genus: Heterocythereis Elofson, 1941

Type species: Heterocythereis ssp.

Genus: Grinioneis (Reuss, 1850) Malz & Jellinek, 1984

Type species: Grinioneis ssp.

Type species: Pseudomutilus.

Class Ostracoda LATREILLE, 1806

Order Podocopida SARS, 1866

Suborder Cytherocopina GRÜNDEL, 1967

Superfamily Cytheroidea BAIRD, 1850

- **Family** Trachyleberididae SYLVESTER-BRADLEY, 1948

Subfamily Trachyleberidinae SYLVESTER-BRADLEY, 1948

Genus Quasiagrenocythere n.gen.

Etymology: Similar to Agrenocythere BENSON,1972.

Type-species: Quasiagrenocythere tevestaensis n.gen. n.sp.

Diagnosis: Genus, currently monospecific, considered to be a member of the Subfamily Trachyleberidinae SYLVESTER-BRADLEY, 1948, distinguished by a strong, large carapace, symmetric in dorsal view, reticulated, distinguishable from the Genus Agrenocythere BENSON, 1972, with which it shares some affinity, by the presence of an eye tubercle and the absence of the ventral carina.

Quasiagrenocythere tevestaensis n.gen. n.sp.

Etymology: From "Tevesta" the roman name of the city of Tebessa near the type locality.

Holotype: One complete carapace (PMC.O89 h 06.03.2021).

Paratypes: One complete carapace and four valves (PMC.O195 p 06.03.2021).

Other materials: Some immature specimens.

Type locality: El Hadjra Safra (south side of P. Romain Mount, GPS 35°19'42"N 8°11' 31.8"E), along N16 southbound, in very fine-grained, whitish silty sands.

Stratigraphic range: Tortonian, identified by the first common occurrence (FCO) of Neogloboquadrina

acostaensis (BLOW, 1959) (samples 8 to 10).

Diagnosis: A large, reticulated species with a notable eye tubercle and acute tail processes hooked upwards.

Description: In lateral exterior view, the carapace is large, elongated, and subrectangular. The front margin is regularly arched and marked by numerous composite spines, the dorsal margin is straight and curved upwards at the eye tubercle, the posterior margin has a caudal process that is slightly sharp and hooked upwards, and the ventral margin is straight with a shallow oral concavity. Symmetrical valves in dorsal view, with thick and flattened anterior and posterior ends, and a swelling middle section of the carapace with a little central groove. A polygonal grid with big fossae and robust muri decorates the carapace's outer surface. Except in the anterior area, where they are uniformly oriented parallel to the anterior margin, and in the posterior area, fossae are randomly placed across the surface of the carapace. and in the antero-central area, where the fossae are practically concentrically aligned to form what resembles BENSON's (1972) "castrum". The muri in the center and along the carapace's center line are heavily pitted There are composite spines along the anterior and posterior margins, as well as two "intramural pore conuli," the first in the center of the dorsal border and the second at the end of the upper side of the caudal process. There are a few typical pore canals and tubercles in the dorsal area. Eye tubercles are clearly visible.

1 – Globotruncana sp.

2 - cf Neogloboquadrina humerosa

3- Globorotalia sp.

4 - cf Globorotalia saheliana

5 - cf Lenticulina calar

6 – Lenticulina sp.

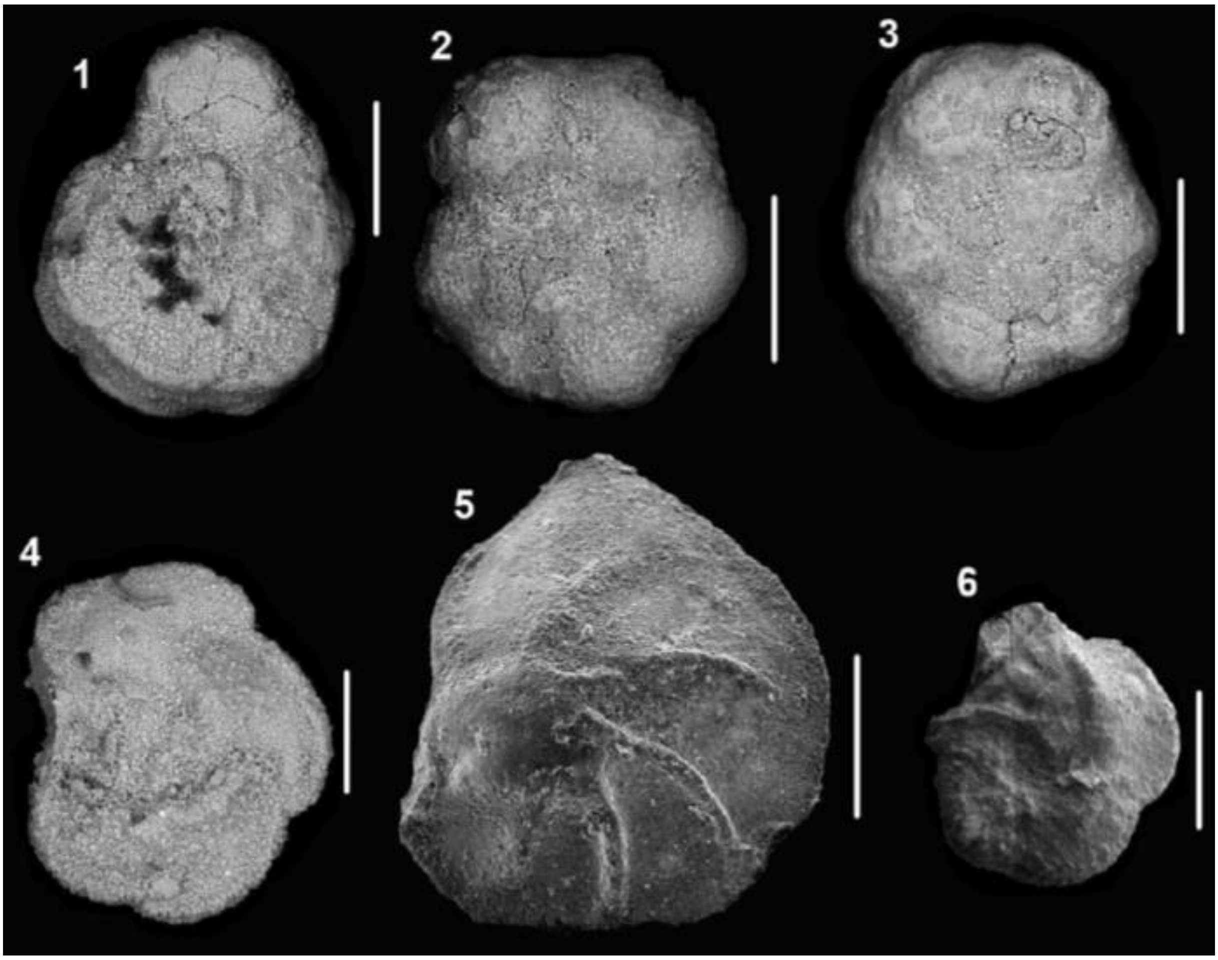


Figure 26 plache 1 (MEB photo , scal bar : 200 µm)

III. CONCLUSION

The description of this new taxa adds to our understanding of the Algerian Miocene ostracofauna. At the moment, the presented taxa is monospecific, only discovered in the fossil record, and connected with an exceedingly limited microfauna; thus, no hypothesis on their autoecology and/or synecology can be developed. The analogies of Quasiagrenocythere n.gen. with the diverse genera could confirm, in the first case, a preference for deep or somewhat deep-water settings, and, in the second case, a preference for shallower environments.

Additional research may yield fresh data that will allow for a more detailed paleoecological result.From the samples in the section of El Hadjra Safra (35 samples) and Ain Sidi Salah (53 samples) 06 families, 08 genera and 07 species of foraminifera were determined, as well as 07 families, 07 genera and 07 species of ostracods.

CHAPITRE VI: THE STUDY OF THE MICROFAUNA, PALEOENVIRONMENTAL IMPLICATIONS AND MORPHOGROUPS OF BENTHIC FORAMINIFERA

I. THE STUDY OF THE MICROFAUNA AND PALEOENVIRONMENTAL IMPLICATIONS

1. introduction

The main goal of this chapter is to attempt to reconstruct the paleoenvironments of the regions studied throughout the Miocene. This chapter is divided into two sections: (1) computation and estimation of quantitative and statistical analyses (the indices) to determine the sedimentary, and (2) an attempt to interpret the collected data (qualitative and quantitative study of the distribution of microfaunal assemblages, as well as a global interpretation in terms of paleoenvironment.

2. Quantitative and statistical analysis

Quantitative and statistical methods based on microfossil counts enable accurate paleobathymetry information to be obtained. These are the diversity index, the Shannon index (H), the equitability (E), and the substrate characterisation.

According to Tronchetti (1984), there are two types of substrates: muddy types characterized by a matrix largely argillaceous binding a figured phase with dominating biological, and clayey and detritic sedimentation binding components, principally minerals with a reduced percentage of foraminifera.

3. Analysis and interpretation of data

The quantitative analysis of the microfauna is based for each sample on counts

performed within the fraction ≥ 125 µm (nearly 300 individuals of benthic foraminifera,

planktonic with ostracods were collected at each time).

4. Foraminifers

4.1. Region of El Hadjra Safra

- Level 3

This level is constituted by various coarse sands, and poor in microfauna. The observation of the quantitative parameters, recorded and presented in figures .6.1 allowed to note that:

- The specific diversity reaches 5 to 20 individuals in the samples,The ratio P/P+B reaches the value of 1 in the first sample then decreases to 0.0 à 0,01.

- The Shannon index (H) decreases to 0.0 to 0.5 indicating a marginal environment.

- The equitability (E) reaches 0.8, generally suggesting a balanced environment.

The values of paleobathymetry calculated according to the formula of Van der Zwaan are 0 m and 50 m respectively (Figure .6.1). Therefore, the C-level deposits are considered infralittoral. considered as infralittoral. The existence of certain types of benthic foraminifera (eg : Lenticulina, Brizalina, Gyroidinoides...) testifies to episodes of under oxygenation at the time of deposition.

- Level 2

It is a sandy level, and sandy silt. The quantitative parameters recorded revealed that:

- The species diversity reaches 20-50 species in each sample.

- The P/P+B ratio reaches the value of 1 in the first sample then decreases to 0.1 à 0.15.

- The Shannon index (H) has a value (≥ 2), indicating proximity to the shallow marine platform.

- Equitability (E) is 0.2 to 0.8 suggesting a low equilibrium environment.

This level is marked by the abundance of benthic foraminifera, reflecting infralittoral environments. In the upper part of this level, we find forms characteristic of sediments of infralittoral (proximal) origin (eg: Ammonia). It is probable that these forms have been reworked within a zone with bathymetry between 0 and 100 meters.

- Level 1:

This level is siltier compared to levels 2 and 3. The quantitative parameters recorded are the following:

- The specific diversity reaches more than 60 species in the first sample.

- The P/P+B reaches the value of 1 in the first sample then decreases to 0.2 to 0.4.

- The Shannon index (H) goes from 2 to 3 indicating the proximity of the marine platform (proximal platform).

- The equitability (E) is characterized by values between 0.2 to 0.4 not very equitable In the upper part of level 2, the percentage of planktonic foraminifera remains high.

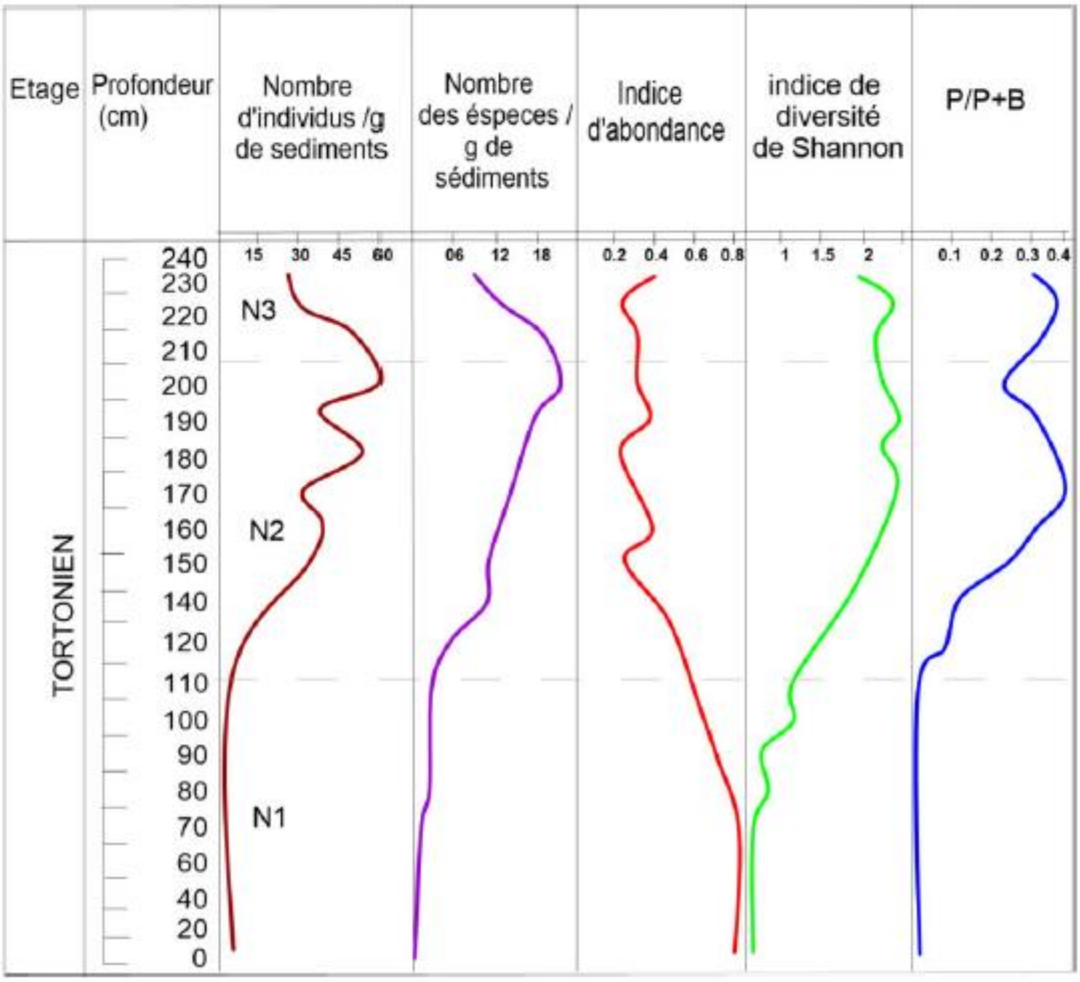


Figure 27 Paleoecological evidence of El Hadjra Safra.

4.2. Interpretation

Based on the evidence presented above, we can deduce that the Upper Miocene deposits of El Hadjra Safra related to a coastal environment. The paleo-depth is estimated to be between 30-100 m. The facies homogeneity (clay + sand) and lack of limestone appear to translate a muddy-sandy substratum.

5. Conclusion

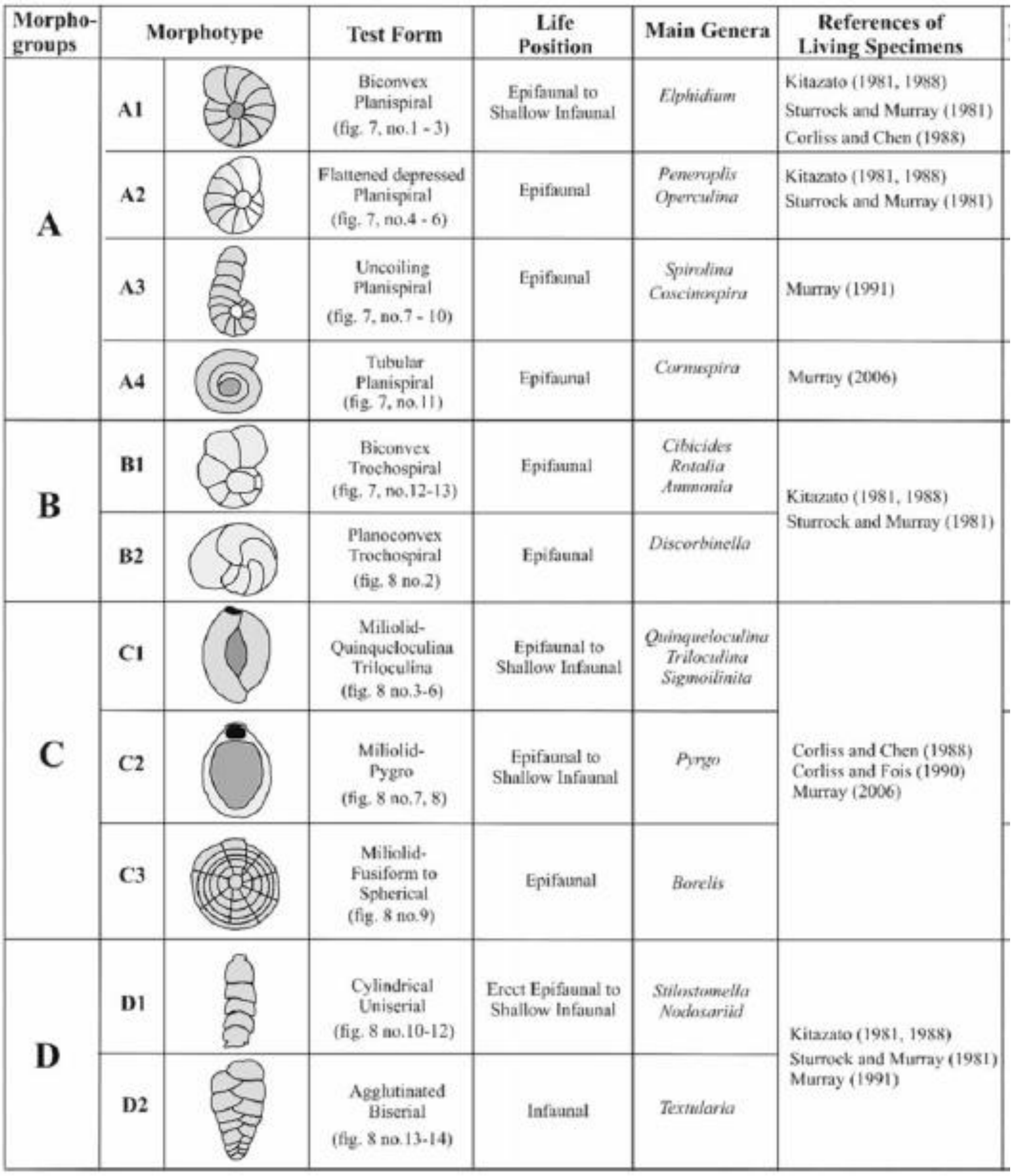
This current morpho-statistical study of ostracods from the El Kouif region has yielded crucial results in terms of the parameters governing the varied paleoecological conditions that existed during the Miocene epoch. These factors include salinity, the composition of the sediments, the energy of the environment, and oxygen saturation. The majority of these metrics were at high levels, indicating a low-energy nearshore environment.

II. STUDY OF THE MORPHOGROUPS OF BENTHIC FORAMINIFERA

1. Introduction

Morphogroup analysis is essentially based on the morphology of microfaunal test morphology. It is a hypothesis that believes that variations in environmental circumstances and feeding environmental conditions and feeding methods have governed the varied test forms of foraminifera and lifestyles regardless of taxonomy.

Morphogroups/morphotypes are described as a set of forms that have comparable test morphologies but differ in taxonomic status (Murray, 2006). Corliss and Chen (1988) established morphotypes as groups of foraminiferal species based on test shape. The concept of morphotyping foraminiferal taxa based on their morphology is based on the existence of a relationship between "shape" and "function" of the foraminifera test.



Morpho-groups	Morphotype	Test Form	Life Position	Main Genera	References of Living Specimens
A	A1	Biconvex Planispiral (fig. 7, no.1 - 3)	Epifaunal to Shallow Infaunal	*Elphidium*	Kitazato (1981, 1988) Sturrock and Murray (1981) Corliss and Chen (1988)
	A2	Flattened depressed Planispiral (fig. 7, no.4 - 6)	Epifaunal	*Peneroplis* *Operculina*	Kitazato (1981, 1988) Sturrock and Murray (1981)
	A3	Uncoiling Planispiral (fig. 7, no.7 - 10)	Epifaunal	*Spirolina* *Coscinospira*	Murray (1991)
	A4	Tubular Planispiral (fig. 7, no.11)	Epifaunal	*Cornuspira*	Murray (2006)
B	B1	Biconvex Trochospiral (fig. 7, no.12-13)	Epifaunal	*Cibicides* *Rotalia* *Ammonia*	Kitazato (1981, 1988) Sturrock and Murray (1981)
	B2	Planoconvex Trochospiral (fig. 8 no.2)	Epifaunal	*Discorbinella*	
C	C1	Miliolid-Quinqueloculina Triloculina (fig. 8 no.3-6)	Epifaunal to Shallow Infaunal	*Quinqueloculina* *Triloculina* *Sigmoilinita*	Corliss and Chen (1988) Corliss and Fois (1990) Murray (2006)
	C2	Miliolid-Pygro (fig. 8 no.7, 8)	Epifaunal to Shallow Infaunal	*Pyrgo*	
	C3	Miliolid-Fusiform to Spherical (fig. 8 no.9)	Epifaunal	*Borelis*	
D	D1	Cylindrical Uniserial (fig. 8 no.10-12)	Erect Epifaunal to Shallow Infaunal	*Stilostomella* *Nodosariid*	Kitazato (1981, 1988) Sturrock and Murray (1981) Murray (1991)
	D2	Agglutinated Biserial (fig. 8 no.13-14)	Infaunal	*Textularia*	

Figure 28 Morphotype and morphogroups of benthic foraminifera (after Setoyama, 2012).

Charnock and Jones' (1985) morphogroup scheme for agglutinated foraminifera was updated and expanded as follows:

1) Rounded trochospiral (RT) morphogroup. Valvulineria bradyana (Fornasini, 1900) is one example of a species with a and a broadly rounded perimeter.

2) Plano-convex trochospiral (PT) morphogroup. It is represented by trochospiral tests with a flat spiral side and a narrowly rounded to sharp periphery, such as Hanzawaia boueana (D'Orbigny, 1846).

3) Biconvex trochospiral (BT) morphogroup. It includes species with trochospiral tests in coiled mode and biconvex morphology, with a strongly inclined to narrowly inclined to narrowly rounded margin, such as Heterolepa dutemplei (D'Orbigny, 1846).

4) Miliolin (M) morphology. It includes species with flattened tests, an elliptical form, and a milioline chamber arrangement, such as Quinqueloculina sp. 5) Rounded planispiral morphogroup (RP). It contains compact tests with planispiral chambers and a roughly rounded periphery, such as Melonisbarleeanus (Williamson, 1858): Melonisbarleeanus (Williamson, 1858): Melonisbarleeanus (Williamson, 1858): Melonisbarleeanus (Williamson, 1858): Melonis

6) Lenticular (L) morphogroup. Lenticulina arcuatostriata (Hantken, 1868) has a biconvex shape with a sharply inclined or keeled perimeter.

7) The morphogroups conical and cylindrical (T / C). It is represented by round, oval, or triangular cross sections, as well as parallel or subparallel sides.

This morphogroup includes rectilinear and straight uniseriate, biseriate, and triseriate tests.

Laevidentalina communis (d'Orbigny, 1826), for example, and Bulimina aculeata (d'Orbigny, 1826).

8) Spherical morphogroup (S) contains unilocular, planispiral, and multilocular trochospiral tests, such as Pullenia quinqueloba (Reuss, 1851)

9) Flattened conical (FT) morphogroup. Uniseriate, biseriate, and palmate tests palmate, with oval to compressed and parallel sections at subparallel sides, for example, Brizalina dilatata (Reuss, 1850).

10) Morphogroup T (tube-shaped). Ammobaculites sp., for example, has a basic morphology with straight or curved tubes with a flattened or rounded cross section and clumped wall.

11) The flattened ovoid (FO) morphogroup consists of single chambered hyaline forms with an oval contour and a carinated perimeter. Palliolatellacrebra

12) A streptospiral and heteromorphic morphogroup that consists primarily of irregularly coiled agglutinated forms with irregular coiling or at least two or more types of chamber layout.

Benthic foraminifera morphotypes are found in the Miocene deposits of El Ma Labiod and EL Kouif. A total of 36 genera and 54 species have previously been recorded and described. Because of the tremendous taxonomic richness, we were able to produce the first paleoecological assessment of the foraminiferal assemblages. The type of the test roll-up (i.e. the addition of chamber) (ii) and the shape of the test (i) are used to define groups.

(ii) In this investigation, we employed a morphogroup approach for agglutinated foraminifera developed by Murray et al. (2011). The latter defined morphogroups/morphotypes as a set of forms that had similar test morphologies but not taxonomic similarities. This distinction is labeled alphabetically from A to D . Each of these groupings, A, B, C, and D, is further classified into four, two, and three morphotypes, respectively.

MORPHOGROUP	A	B				C		D
SUBGROUP		B1	B2	B3	B4	C1	C2	
Chambers	Unilocular/ multilocular	Unilocular	Unilocular/ ?multilocular	Multilocular	Unilocular/ multilocular	Multilocular	Multilocular	Multilocular
Test form	Tubular or branching	Globular	Coiled, flattened	Planispiral/ trochospiral	Irregular, conical, concavo-convex	Elongate, mixed growth	Elongate, quinqueloculine	Trochospiral
Examples	Komokiaceans Astrorhizids	Saccamminids	Ammodiscids ?Rzehakinids	Most Lituolids Trochamminids*	Attached forms Trochamminids*	Varied	some Rzehakinids *Miliammina*	Trochamminids*

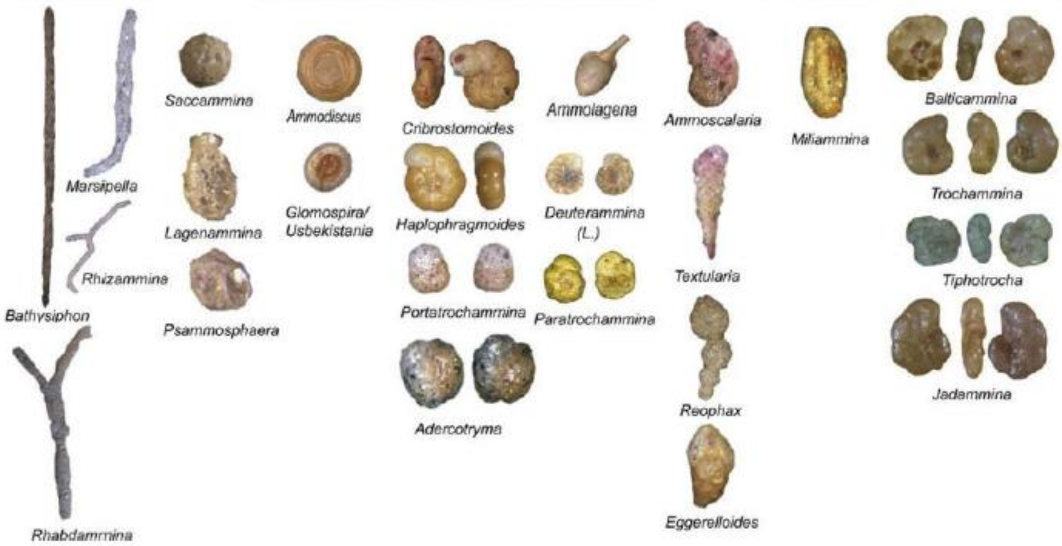


Figure 29 Modified morphogroup diagram from Jones and Charnock (1985) with illustrations of representative taxa. * Trochamminids: globular or biconvex forms B3, permanently attached, watch glass B4 permanently attached, watch-glass shaped, concavo-convex forms, and lenticular or plano-convex forms D. For groups A and B2, multilocular refers to forms having a proloculus and a deuteroconch (Murray 2011).

2. Analysis of the assemblages

The dominance of the principal genera and morphotypes at each level that shift vertically are used to determine the assemblages. The evolution of foraminiferal assemblages is linked to changes in the environment during sedimentation.

Three foraminiferal assemblages were characterized at the section A level, while four assemblages were identified in section B.

3. Section of El Hadjra Safra

1st assemblage

This assemblage is found in the top part of the El Hadjra Sahra section (7.1), and it contains seven genera. Cibicides (44%), Bolivina (29%) and Hanzawaia (16%) dominate the assemblage, with

Heterolepa, Melonis, Textularia and Pullenia, Uvigerina and Marginulina accounting for the remaining 1 to 5%.

2nd assemblage

The assemblage, which includes 11 taxa and is dominated by the A2 and C1 morphotypes, is found in the middle of the El Hadjra Safra section (Figure 7.2).

The A2 and C1 morphotypes dominated the taxa (Figure 7.2). Bulimina (30%), Cibicides (20%), and Bolivina (12%) are the most prevalent genera. The remaining genera, which account for 33% of the total, are nodosariids, Ammonia, Gyroidinoides, Heterolepa, and Valvulineria (Figure 7.2), Spiroline (4%), Sigmoilinita (3%), Ammonia, and Cibicidoides (1%). Bivalves and gastropods are among the macrofossils discovered.

3rd Assemblage

In general, there is little faunal variety in this assemblage, with absolute abundances ranging from present to rare. This assemblage was discovered in the lower area of El Hadjra Safra. A total of 120 specimens were counted covering four genera: Bolivina,Bulimina, Cibicides and Textularia.

4. Interpretation and paleoenvironment

The vertical history of benthic foraminifera has allowed us to identify three distinct assemblages, each of which suggests a different paleoenvironmental situation.

In the bottom parts of both sections, we notice a limited faunal diversity with absolute abundances ranging from present to rare, represented only by Bolivina, Bulimina, Textularia, Gyroidinoides, and Rectuvigerina, indicating a shallow and more or less reductive marine habitat near a vegetative cover. This observation is consistent with the low values obtained from the indexes of pelagism, variety, and equitability. Benthic foraminiferal paleo-populations dominate other microorganisms in the median region. dominance over other microfauna, as well as limited diversity ($H > 2$). They are dominated by species from the Bolivinidae and Buliminidae families. This shows that the environment has been enriched in nutrients as a result of low oxygen levels.

oxygen. Their elongated and flattened form is thought to be an adaptation to lower oxygen levels (Bernhard in Drinia et al., 2008). However, the low values of the pelagic index (20 to 40%) preclude the functioning of upwellings. Upwelling zones, according to Berger and Diester-Haass (1988), are frequently associated with large quantities of planktonic foraminifera. The habitat is deepening in the upper section, as evidenced by the proliferation of Bolivinidae and Buliminidae alongside Cibicides spp. and Hanzawaia boueana.

The rise in the pelagic index values validates this conclusion. The presence of these taxa within the same assemblage demonstrates a definite vertical succession of microhabitats. This means that the sand surface has high oxygen concentrations (Jorissen et al., 1995). As a result, this area of the section shows a mixed, oxygenated, and nutrient-rich environment.

Moving up in our section, the assemblage suggests a deeperening of the environment with more stable circumstances (littoral), well oxygenated, and muddy substratum.

5. Conclusion

The benthic foraminifera of the El Ma Labiod section were studied, and 20 species, 14 genera and 10 families, were discovered. The quantitative, qualitative, and qualitative studies enabled the identification of four morphogroups and three assemblages of benthic foraminifera from the seafloor.

Except for morphotypes B2 and D1, the assemblage 3 outlined at the bottom of the sections displays a low to very rare diversity. Assemblage 2 is defined in the middle of the sections and demonstrates an increase in the pelagic index as well as the growth of benthic foraminifera (morphogroup A and B).Benthic foraminifera (morphogroups A, B, D), in an eutrophic and moderately oxygenated environment.The microfauna gets richer and more diverse again in the top section (Assemblage 1). This shift in benthic foraminifera microfaunal composition signals the transition from a shallow and hypoxic reductive environment to an aerial and oxygenated oxygenated habitat with a vaso-sandy substrate and significant hydrodynamism (littoral).

CHAPITRE VII: OTHER EXAMPLES OF MIOCENE IMPLICATIONS IN THE WESTERN PART OF ALGERIA

I. INTRODUCTION

This paleogeography altered across time and space as a result of tectonic, eustatism, and climate changes. The significant facies differences are intimately associated to distinct types of supplies:

-to the north, direct supplies from the elevating coastal block.

-to the south, distant source in the area of Medea and Bou Hanifia.

and to the east, the existence of longshore currents carrying detrital supplies from the Krouminie.

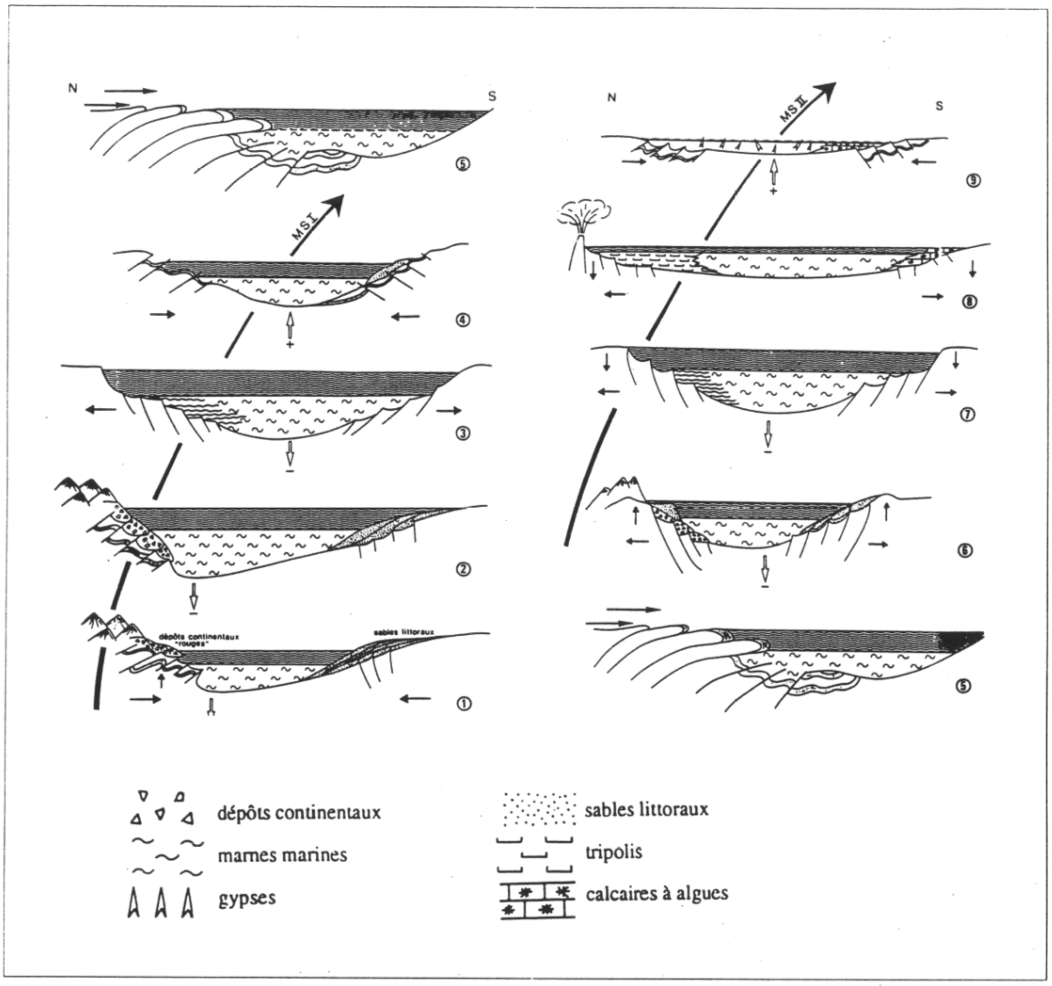


Figure 30 Evolution of Chélif basin during Miocene. Interaction tectonique-sedimentation. MSI

II. PALEOGEOGRAPHY

The Miocene paleogeography of the Cheif Basin is characterized by large fluctuations in facies, which are conditioned by internal parameters (transtension or transpression) and external characteristics (intertropical intertropical climate with increasing aridity in the Messinian epoch). The various types of input have revealed the presence of: - EW "longshore" currents draining material; SN arrives at: - Bou-Hanifia: a fluvial network that drains the High plates

- Médéa: delta - de la Tafna: fluvial inputs from the Monts de Tlemcen and the high plates; -direct" punctual regional inputs from erosion of neighboring massifs such as the Tessalas, Beni Chougran and Ouarsenis for the basin; The novelty of these conclusions may be found in the detection of these significant "longshore" currents, which are influenced by tides and swell and transverse the basin from east to west. With few reservations, the Neogene researched fauna can be compared to present fauna, as if almost all species are extinct now; genus (save Gigantopecten) is present today, in the Atlanto-Mediterranean mild temperate zone or in the subtropical and tropical regions (Satour et al. 2011).

Meanwhile, the collected material (85%) is dominated by epibenthic suspensivore forms (mobile or sessile), whereas only three genera are classified as detritivore feeders.

However, multiple extinctions occurred during the Miocene-Pliocene transition, followed by fauna replenishment, affecting tropical and subtropical macrofauna (Lauriat- Rage et al. 1992). In fact, over 30% of new bivalve species, including numerous genera, arose during the Pliocene (Georgiades-Dikeoulia 1995), and species from this period are still present in the Mediterranean deep fauna today. This is possible. During the Messinian salinity crisis (Rouchy 1986; Clauzon et al. 1996; White 2000; Taviani 2002), certain deep-sea species maintained or survived (Ben Moussa et al. 1988; Barrier et al. 1989; Di Geronimo 1990; Laubier and Emig 1993), which might most likely be explained by the persistence hypothesis.

Furthermore, Peres and Picard (1964) defined two bio cenosis of infra littoral and circa littoral floors: the biota of the Posidonia meadow (HP), which is constituted of the superposition of two biotope photophile settlements of shallow infra littoral and sciaphilous deep settlement of circa littoral; and the soft unstable bottom biocenosis (MI).

detrital levels of the "Sidi Ali blue marl formation formation" (Sidi Moussa section). the above-mentioned biozone, indicative of the extreme base Upper Langhian to Serravallian interval. of praeorbulines) and non-basal Lower Tortonian in contrast to the other sections, the continental conglomerates between two well-dated marine sediments: - at the base, samples taken from the marine level's marine levels, preceding the continental terms, give an upper Langhian age, given the presence unconformity by Tortonian marls with Neoglobo- quadrina acostaensis s. s. indicating biozone N16. have only a Serravallian age, at the oldest Upper Langhian compared with those at nearby Sidi Rahlem.

76 Ma base of the Tortonian marls. postnappe" Miocene deposits are mapped by Devaux continental sediments (= Devaux`s laguno continental cycle of Devaux 16) are preceded by marine marine levels of Upper Serravallian date (N14) unconformity by marine sedimentation characteristic of the marine sedimentation (N16). The Serravallian-Tortonian boundary in western Algeria would therefore be the oldest Upper Serravallian and the youngest Basal Tortonian (N15 >).

and the cinerite level they contain, these deposits All sections reveal the absence of deposits deposits equivalent to the upper N15 biozone interval would most certainly be materialized by continental deposits Meïda and Sidi Rahlem. the Serravallo-Tortonian boundary would also be Bouhanifia" formation (Neurdin-Trescartes 17) at Sidi These data suggest that the marine trans- marine trans-gression observed on the margins ravallo-tortonian boundary predates it. The basal Tortonian basal (upper Globorotalia menardii biozone, or upper N15 plus base of N16) is absent from all (nappes), Lower Langhian (Sidi Moussa), Lower Marine marine Serravallian (Djebel Meni) or continental continental Serravallian (Oued Tangroutah) and probably even the continental Tortonian

III. CONCLUSION

a boundary is located at the base of the conglomerate- level preceding the two sandstone bars B(not at the top of the same unit) (= "red sandstone" of Belkebir et al. 2003) nor at the base of the "yellowish sandstone This boundary is marked by a major discontinuity of the Tortonian transgression, whose age is thought to be on the margins of the Chélif basin, considering the Serravallo-tortonian boundary , Upper Langhian and Serravallian (Sidi Moussa) deposits seems to be the margins of the Chélif basin, an erosion that continued erosion period was followed by a vast Tortonian transgression transgression, more commonly known as the "Upper Miocene characterized by a highly detrital facies, with microfauna conglomerate (Sidi Moussa) or sandstone (Oued Tangroutah). (Oued Tangroutah) accompanied by an abrupt change change in microfauna, slightly preceding the.

GENERAL CONCLUSION

The obtained results point to a littoral environment closer to the continent (marginolittoral environment).

For the first time, an ichnological research was conducted on Miocene strata in northeastern Algeria. Algeria has improved understanding of the paleoenvironment in the studied area during the Miocene.

- Section El Hadjra Safra

Except for Diplocaterion isp, this section is devoid of fossil remains.

- An Sidi Salah Section

The Lower Langhian (middle Miocene) ichnological investigation of the An Sidi Salah section revealed a poor ichnodiversity represented by sub-horizontal to sub-vertical burrows, covering eight ichnotaxa, indicating the ichnofacies with Skolithos à Cruziana proximate. These traces are represented by :cf. Archaeonassa.isp ; Arenicolite ;Diplocraterion isp., Helminthopsis isp., Palaeophycus tubularis, Skolithos isp., S. cf. linearis, Taenidium isp., and Thalassinoides isp. This ichnoassemblage shows that the biotope was inhabited by suspensivorous or detritivorous creatures, primarily worms (polychaetes and phoronids), crustaceans, and arthropods. These fossil traces are from the ichnofacies Skolithos à Cruziana, which lived in a shallow marine habitat (littoral). The Thalassinoids' great size suggests well-oxygenated marine waters with moderate to high energy conditions, vulnerable to storms on occasion. These traces are represented by:cf. Archaeonassa. isp Arenicolite.

The micropalaeontological examination, particularly the systematics of the Miocene deposits, reveals the existence of foraminifera with 07 orders, 25 families, 42 genera, and 78 species grouped into 04 morphogroups, as well as ostracods with 01 order, 05 families, 10 genera, and 10 species.

The planktonic foraminifera markers allowed the Tortonian to be identified with the Neogloboquadrina biozone of Belkebir & Bessedik (1991), and the Lower Langhian with the Globorotalia mayeri biozone of Belkebir (1986). Furthermore, quantitative and qualitative examination of benthic foraminifera has allowed the definition of many assemblages of benthic foraminifera. These assemblages share microfaunistic and paleoecological similarities in both sections. These traces are represented by :cf. Archaeonassa.isp Arenicolite.

In the lower regions of both sections, we notice a low faunal variety represented only by morphotypes B2 and D1, indicating a shallow marine habitat with good oxygenation.

The benthic foraminiferal paleopopulations in the median parts exhibit a high abundance and limited diversity, an increase in the pelagic index and considerable pelagism, and an important development of microfauna evolution. They are dominated by benthic foraminifera of the morphogroups A, B, and D, which live in an eutrophic and moderately oxygenated environment.

The habitat is deepening in the higher parts, as evidenced by the proliferation of Bolivinidae and Buliminidae alongside Cibicides spp. and Hanzawaia boueana.

The rise in pelagic index values supports this observation. These traces are represented by: cf. Archaeonassa.isp Arenicolite

The presence of these taxa within the same assemblage obviously implies a vertical succession of microhabitats. This shift in benthic foraminifera microfaunal composition reflects a transition from a shallow and hypoxic reducing environment to an aerated and oxygenated environment with a vaso-sandy substrate and significant hydrodynamism (littoral).

BIBLIOGRAPHY

1) ***Ameur, R. (1984).*** *Découverte de nouveaux rongeurs dans la formation Miocène de Bou Hanifia (Algérie occidentale). Geobios, 17(2), 167-175.*
2) **Baucon, A., & Neto de Carvalho, C. (2008).** From the river to the sea: Pramollo, a new ichnolagerstätte from the Carnic Alps (Carboniferous, Italy-Austria). *Studi Trent. Sci. Nat. Acta Geol*, *83*, 87-114.
3) **Baucon, A., Felletti, F. (2013),** Neoichnology of a barrier-island system: the Mula di Muggia
4) **Baucon, A; Ronchi, A., Felletti F., (2014),** Evolution of crustaceans at the edge of the end-
5) ***Benkhedda, A. B. D. E. L. H. A. K. I. M., Defaflia, N., Cherif, A. M. I. N. E., Naimi, M. N., Mazouz, E., & Palma-Ramírez, A. R. T. U. R. O. (2021).*** *Shallow marine trace fossils from the middle Miocene of the Tebessa Basin (NE Algeria) and their palaeoenvironmental implications. Revista Brasileira de Paleontologia, 24(4), 323-335.*
6) ***Bignot. G., (1988),*** *Micropaléontologie. Edition Dunod. pp. 193.201.*
7) ***Biostratigraphique et géodynamique****. Mémoires du Service Géologique de l'Algérie, 11:167 186.*
8) ***Bizon, G. (1977).*** *REMARKS ON SOME BIOSTRATIGRAPHIC PROBLEMS IN THE MEDITERRANEAN NEOGENE.*
9) ***Bizon, G., (1967),*** *Contribution à la connaissance des foraminifères planctoniques d'Epire et*
10) ***Bizon, G., Bizon J. J., (1972),*** *Atlas des principaux foraminifères planctoniques du bassin*
11) ***Defaflia, N., Abdessadok, S., Djerrab, A., & Chouabbi, A. (2013).*** *ETUDE SEDIMENTOLOGIQUE ET PALEOENVIRONNEMENTALE DES FORMATIONS QUATERNAIRES ALLUVIONNAIRES DE L'OUED BIRZGUEL, EL MA EL ABIOD, WILAYA DE TEBESSA. ALGERIE.*
12) ***DEGAICHIA, A. (2014).*** *DOCTORAT EN SCIENCES (Doctoral dissertation, Université des Sciences et de la Technologie Houari-Boumediene).*
13) ***Des Iles Ioniennes (Grèce occidentale).*** *Publ. Inst. Franc. Pétrole, Edit. Technip, pp. 1-142.*
14) ***Djerrab, A., Zedam, R., Camps, P., Defaflia, N., Abdessadok, S., Triki, D., ... & Bahra, N. (2012).*** *Étude sédimentologique et magnétique d'une séquence alluviale du Pléistocène supérieur-Holocène de l'oued Adaila (El Ma Labiod, Tébessa, Algérie) et indications*

paléoenvironnementales. Quaternaire. Revue de l'Association française pour l'étude du Quaternaire, 23(3), 227-240.

15) **Gaaloul, N., Ghazzay, W., & Razgallah, S. (2019).** *Lower to Middle Miocene Deposits of North-East Tunisia: Implied Facies Evolution and Tectonic-Sedimentary Control. In Paleobiodiversity and Tectono-Sedimentary Records in the Mediterranean Tethys and Related Eastern Areas: Proceedings of the 1st Springer Conference of the Arabian Journal of Geosciences (CAJG-1), Tunisia 2018 (pp. 275-278). Springer International Publishing.*
16) **Hamida, D. (2015).** *The Reconstruction of Paleo-Environment Albo-Aptian Sediments of the Massive El Hmaima North Tébessa North-Eastern Algeria. J Geol Geosci, 4(188), 2.*
17) **Hamimed, M., Boulamia, S., & Defaflia, N. (2015).** *Miocene formations analysis within the north-western margin of Ma Labiod Basin (Algero-Tunisian Confines). International Journal of Science and Research, 129, 380-394.*
18) **Kowalski, W. M., Hamimed, M., & Pharisat, A. (2002).** *Les étapes d'effondrement des grabens dans les confins algéro-tunisiens. Bulletin du Service géologique de l'Algérie, 13(2), 131-152.*
19) **Kowalski, W. M., Van Ngoc, N., Baghiani, B., & Pharisat, A. (1992).** *Paléogéographie du Miocène des environs d'El Aouinet (nord de Tebessa), NE de l'Algérie*
20) **KOWALSKI, W. M., VAN NGOC, N., BAGHIANI, B., & PHARISAT**, *A. PALÉOGÉOGRAPHIE DU MIocÈNE DEs ENνιHoNs D'EL AoUINET (NORD DE TEBESSA), NE DE L'ALGÉRIE.*
21) **KOWALSKY, W., PHARISAT, M., & HAMMIMED, M. (1995).** *Analyses sédémentologiques de sables de miocène des environs de Tébessa. Ann. Sci., Université de Besançon.*
22) **Mazrou, S., & Mahboubi, M. (2021).** *Tidally dominated Miocene deltaic deposits and pipe rocks in the Tebessa Basin, eastern Algeria: sedimentological and ichnological characteristics. Geologos, 27(1), 15-34.*
23) **Méditerranéen** *: Oligocène à Quaternaire. Techniq. (Edit.), Paris, 316 p.*
24) **Mosbahi, M., Benabdallah, S., & Boussema, M. R. (2013).** *Assessment of soil erosion risk using SWAT model. Arabian Journal of Geosciences, 6(10), 4011-4019.*
25) **Neogene. Intern. Symp. Struct. Hist. Med. Bas., Split. Ed. Technip. Paris**, *p. 381-390.*
26) **Neurdin-Trescartes, J. (1995).** *Paléogéographie du Bassin du Chélif (Algérie) au Miocène. Causes et conséquences. Géologie Méditerranéenne, 22(2), 61-71.*
27) ***Palaeogeography, Palaeoclimatology, Palaeoecology***, 375:112–124. *doi: 10.1016/j.palaeo.2013.02.011*

28) **Permian crisis:** ichnonet work analysis of the fluvial succession of Nurra (Permian–Triassic,

29) ***Saint Martin, J. P. (1987).*** *Les Formations récifales coralliennes du Miocène supérieur d'Algérie et du Maroc : Aspects paléoécologiques et paléogéographiques (Doctoral dissertation, Aix-Marseille 1).*

30) **Sardinia, Italy. *Palaeogeography, Palaeoclimatology, Palaeoecology*,** 410:74–103.*doi: 10.1016/j.palaeo.2014.05.034*

31) ***Somaya, S. (2021).*** *Actualisation des données hydrogéologiques et hydrochimique de la nappe des sables du miocène d'EL MALBIOD, Tébessa NE Algérien (Doctoral dissertation).*

32) ***Thomas, H., & Petter, G. (1986).*** *Révision de la faune de mammifères du Miocène supérieurde Menacer (ex-Marceau), Algérie : Discussion sur l'âge du gisement. Geobios, 19(3), 357-373.*