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FACULTY OF HYDROCARBON, RENEWABLE ENERGIES AND EARTH SCIENCES

DEPARTMENT OF EARTH SCIENCES (GEOLOGY)

Biostratigraphic Study based on feraminiferas in the Neogene Tafna Basin (NWAlgeria): cases study of Bled Aina and Guetna section

Dissertation submitted to the Department of Earth science as a partial fulfilment of the requirements for **the a Master's degree in Geology**

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Dedication

To the Almighty, Allah, the Light of my path and the Sustainer of my soul. All praise is due to Him, by whose grace all good things are accomplished. Thank You for granting me the strength to persevere when the journey felt long.

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Dedication

In the name of Allah, the Most Gracious, the Most Merciful; to Him belongs all praise for reaching the end of this journey." I dedicate this humble achievement first and foremost to Allah (SWT), the source of my strength and guidance.

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ABSTRACT

This biostratigraphic study aims to determine the relative age of the sedimentary deposits of the Tafna Basin (northwestern Algeria). through two geological sections located in the (Bled Aina and Guetna) areas. It is based on the study of planktonic foraminifera in order to determine the chronological framework of sediment deposition in both areas.

The results show that the two studied areas within the Tafna Basin belong to the Late Miocene, based on the presence of the species *Neogloboquadrina* .

This study contributes to a better geological understanding of the biostratigraphic evolution of the Tafna Basin, providing a fundamental basis for future research in these areas.

Résumé

Cette étude biostratigraphique vise à déterminer l’âge relatif des dépôts du bassin de la Tafna (Nord-Ouest de l’Algérie) à travers l’étude de deux coupes géologiques situées dans les régions de Bled Aïna et Guetna. Elle repose sur l’analyse des foraminifères planctoniques afin d’établir le cadre chronostratigraphique de la mise en place des sédiments dans ces deux localités.

Les résultats obtenus montrent que les deux sections appartenant au bassin de la Tafna sont attribuées au Miocène supérieur, sur la base de la présence de l’espèce index *Neogloboquadrina* .

Cette étude contribue à une meilleure compréhension de l’évolution biostratigraphique du bassin de la Tafna et constitue une base scientifique importante pour les futures recherches dans les zones étudiées.

الملخص

تهدف هذه الدراسة البيوستراتيغرافية إلى تحديد العمر النسبي لرواسب حوض التافنة (شمال غرب الجزائر) ، من خلال مقطعين جيولوجيين في منطقتي (بلاد عينة وغيطنة)، بالاعتماد على دراسة المنخربات العوالقية بهدف تحديد الإطار الزمني لتوضع الرسوبيات في المنطقتين.

وقد أظهرت النتائج أن المنطقتين التابعتين لحوض التافنة تعودان إلى العصر الميوسيني العلوي، استنادًا إلى وجود النوع *Neogloboquadrina* .

تساهم هذه الدراسة في تعميق الفهم الجيولوجي للتطور البيوستراتيغرافي لحوض التافنة، مما يضع ركيزة أساسية للأبحاث المستقبلية في المنطقتين.

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FIRST CHAPTER

I. Introduction

The Tafna Basin is considered one of the sublittoral basins in northwestern Algeria, located in the Tlemcen region. It takes its name from the Tafna River, which crosses the area. (Thomas ,1985) highlighted its significance as a major sublittoral basin and emphasized its geological complexity along the southern margin of the Mediterranean Sea, from both geodynamic and sedimentary perspectives. Where, the origin of the basin dates back to the Neogene period.

Biostratigraphy is a fundamental tool in sedimentary basin analysis, as it enables the relative dating and correlation of stratigraphic sequences based on fossil content. Among the various fossil groups, planktonic foraminifera are particularly valuable due to their rapid evolutionary rates, wide geographic distribution, and sensitivity to environmental changes. (Blow ,1969) established a detailed biostratigraphic zonation based on planktonic foraminifera, which has become a global reference for Neogene stratigraphy. His work demonstrated that these microfossils provide high-resolution age control and allow precise correlations between marine sedimentary sequences.

In this context, the Tafna Basin is characterized by a rich sedimentary and microfossil record, making it an ideal setting for biostratigraphic investigations. Therefore, the present study focuses on planktonic foraminifera as a reliable tool for determining the relaive age of Neogene sedimentary sequences within the basin.

II. Previous research

Since the nineteenth century numerous studies have been carried out in Tafna Basin, where they subjected its different geological aspects such as lithostratigraphy, paleontology….etc.,

II. 1. Ancient studies

The earliest studies in Tafna Basin date back to the colonial period, which were primarily exploratory< such works paved the way for more detailed research. Initial investigations were carried out by Bayle (1854) and Ville (1857), focusing on the Traras Massif and the surrounding coastal areas.

According to Pouyanne (1876), a study was published on the iron deposits of the Ouelhaca region (Lower Tafna), accompanied by a geological map at a scale of 1:100,000. The work of Gentil (1903) marked the first comprehensive research entirely devoted to the Tafna Basin. He established a fundamental lithostratigraphic and paleogeographic framework, proposing the existence of three Miocene sedimentary cycles: the Lower Miocene (Cartenian), the Middle Miocene (Helvetian–Tortonian), and the Upper Miocene (Sahelian).

Later, Dalloni (1917) reinterpreted the upper formations as Pliocene. However, Gentil, in his subsequent work (1918), maintained their attribution to the Sahelian (Upper Miocene).

From the mid-20th century onward, geological research expanded significantly. Perrodon (1957) investigated the limestone series and attributed them to the second Miocene sedimentary cycle, with part extending into the Late Miocene, based on micropaleontological evidence. Subsequently, Sadran (1958) contributed additional insights into reef formations through the study of Miocene volcanic activity.

Research intensified during the second half of the 20th century, marking the beginning of more modern and detailed investigations. Later works by Chaix (1982), Guernet et al. (1984), Freinex et al. (1987), and Saint Martin (1990) provided detailed descriptions of reef and pre-reef formations, along with their associated faunal assemblages during the Miocene.

Using planktonic foraminifera assemblages, Guardia et al. (1974), Guardia (1975), and Saint Martin et al. (1983) assigned the blue marls and limestone summits to the second Messinian post-nappe cycle. This interpretation was further clarified in the geological map produced by Guardia (1990), which accurately depicts the geology and outcrop distribution of the western Oran region.

II. 2. Recent studies

In his doctoral thesis, (Hamdane ,2004) focused on integrating bryozoan assemblages from various reef constructions within the basin. (Boucif ,2006) subsequently conducted a geodynamic study of the Neogene, demonstrating that the Tafna Basin experienced the same geodynamic regime as other Neogene basins along the northern Algerian margin.

Further applied and academic studies followed, including engineering works (Touati and Abdelli, 2005; Belkhouane, 2006; Benrezzak and Gourari, 2010; Mahboubi, 2012; Benzina, 2012) and several master's theses (Yebdri and Neghraoui, 2016; Habibes and Bedraoui, 2016; Bezzaoui, 2018; Guerfaf and Boulghit, 2019). More recently, Kechouche and Demai (2020) investigated various sedimentological, paleontological, and biostratigraphic aspects of the Upper Miocene deposits.

In the 1990s, Belkbir and Bessedik (1991) proposed a biostratigraphic synthesis, while Bessedik et al. (1997) attributed certain formations to the Vallesian based on marine continental correlations and micro-mammal remains.

Finally, recent academic research has focused on the sedimentological, paleontological, and biostratigraphic characteristics of Upper Miocene deposits, with contributions from Kechouche and Demai (2021). Subsequently, Benzina et al. (2023) reported that the Late Neogene turbidite deposits contain seismites and deformation structures generated by seismic activity related to tectonic movements in northwestern Algeria. Furthermore, Benzina et al. (2024) demonstrated that some of these structures were produced by tidal processes, reflecting strong hydrodynamic conditions in shallow marine environments during the Late Miocene.

In addition, Benzina et al. (2025) showed that several soft-sediment deformation structures from the Upper Miocene are associated with storm-induced sedimentary processes, indicating episodes of intense marine activity within the basin.

III. Geological setting

III. 1. Geodynamic framework

The Tafna Basin extends along a WSW–ENE direction and constitutes the westernmost limit of the Neogene coastal basins of Algeria (Neurdin, 1992). It belongs to the Tellian domain as defined by (Fenet, 1975). Structurally, the basin is part of the external zones of the Alpine chain, which are closely associated with the major (paroxysmal) phases of the Alpine orogeny (Guardia, 1975). The individualization of the basin began during the Early Miocene.(Fig 1).

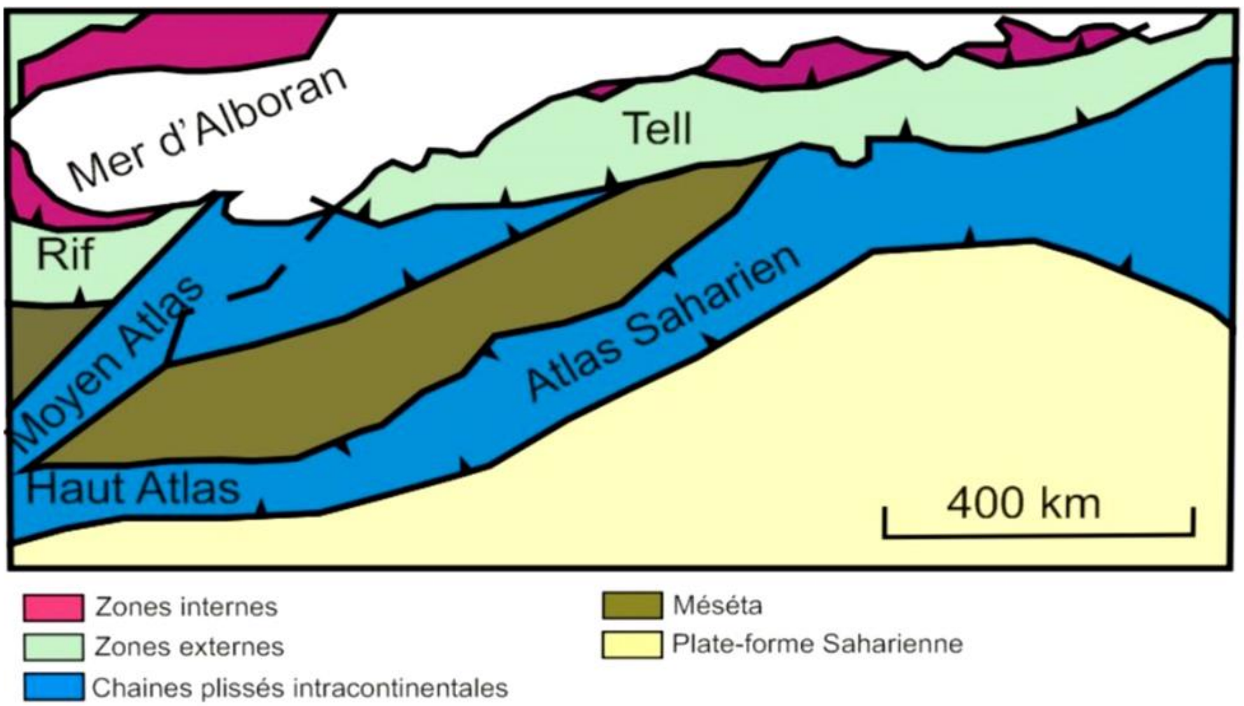

Fig.1- The main structural trends of NW Algeria (Benzina,2012)

III. 2. General Framework

The Tafna Basin belongs to the Tellian domain, and its structural evolution is related to the Alpine geodynamic regime. It is located in northwestern Algeria, along the southern margin of the Mediterranean Sea. This intramontaneous basin is traversed by the Tafna River, from which it derives its name.

The basin is bounded to the north by the Mediterranean Sea, while the Traras Mountains form its northwestern relief, partially separating it from the coastline. To the south, it is limited by the Tlemcen Mountains. Whilen, to the East, there is Sebâa Chioukh Mountains that extend toward the Tessala Mountains as northeastern boundary.

Overall, the Tafna Basin is situated within a complex mountainous framework, characteristic of the southern Mediterranean margin. (Fig 2).

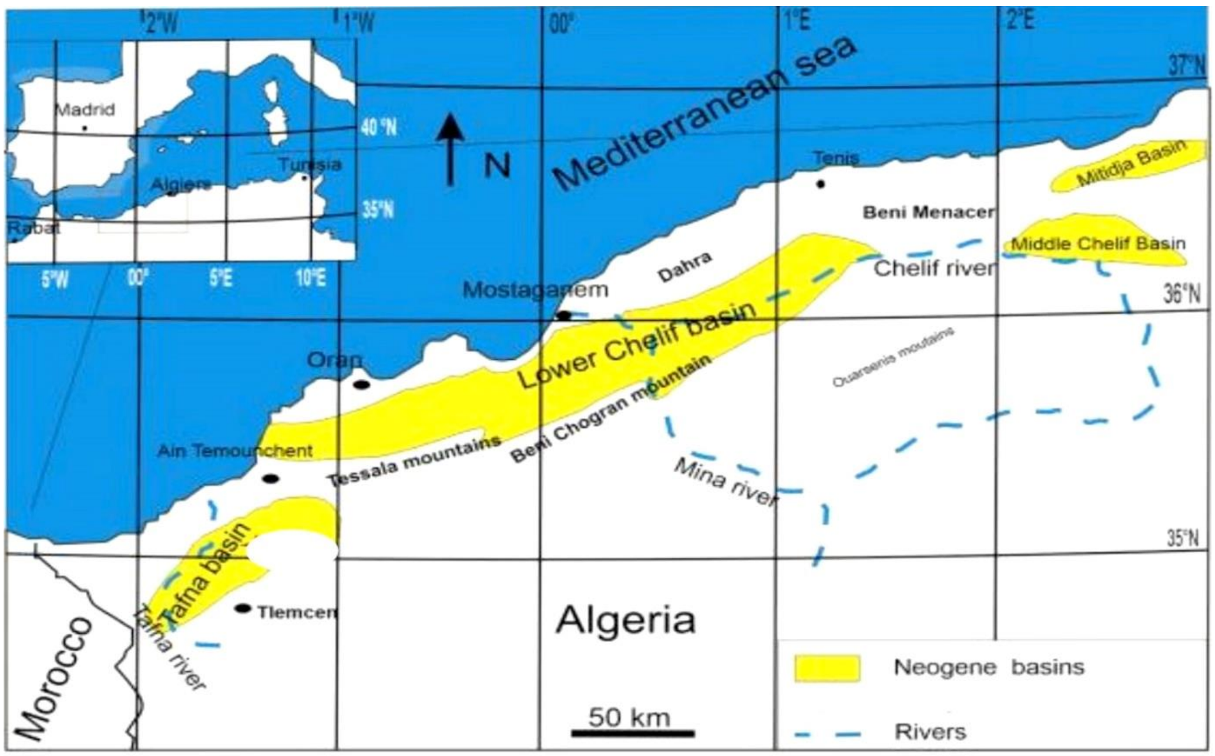

Fig.2-Neogene Basins in Western Algeria and position of the studied section. (Modified after Benzina et al, 2019).

III. 3. Area of study

III. 3.1 Bled Aina section

The Bled Aina section is located in the southern part of the Tafna Basin. It lies approximately 1 km from the town of Bensekrane and about 25 km North-East of the city of Tlemcen. The geological section extends over a length of about 65 m (Fig.3).

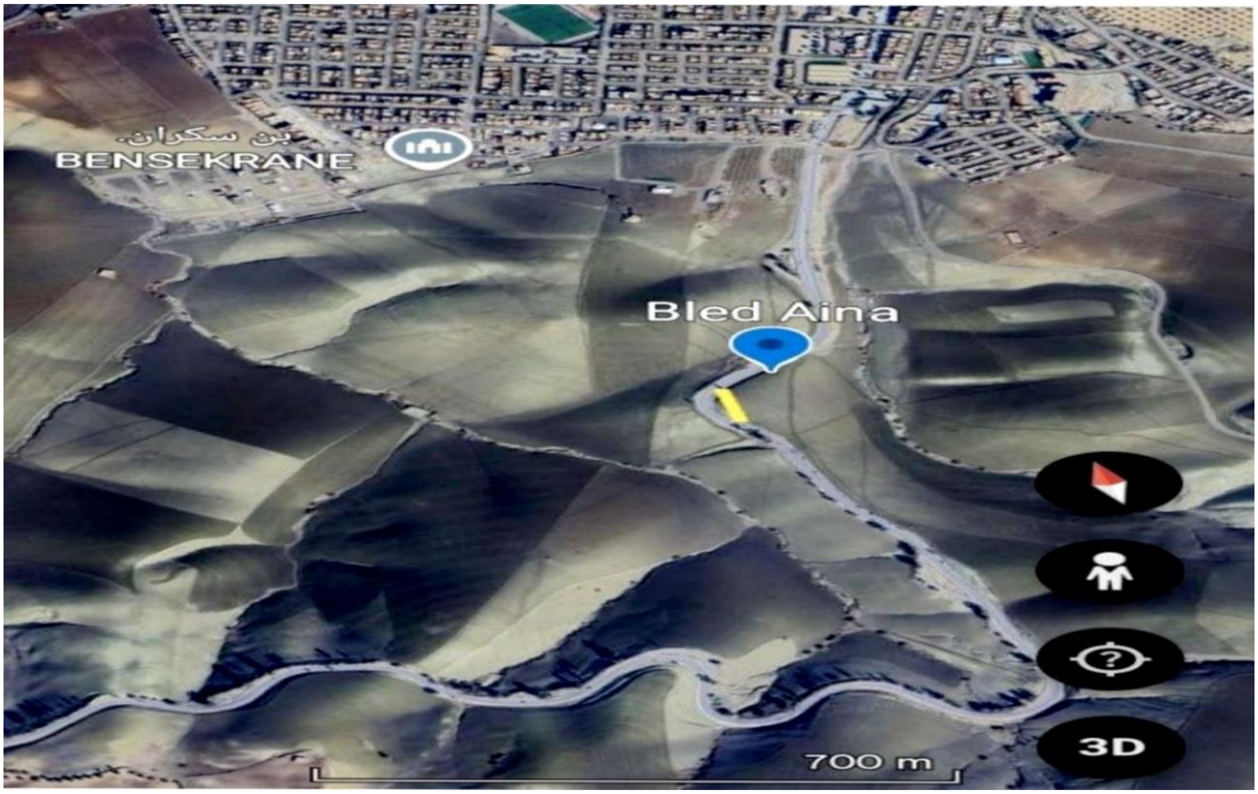

Fig.3- Satellite Image Showing the Location of Bled Aina Section.

III. 3.2. Lithostratigraphic study of Bled Aina Section

From a geological perspective, the Tafna Basin is characterized by deposits dating back to both the early Upper Miocene and Late Upper Miocene. The Former, is widely exposed in the basin and typically begins with a hard conglomeratic layer, overlain by marls and ferruginous sandstones. These formations are generally attributed to the Serravallian stage and are locally overlain by basaltic flows or discordant deposits.

The Upper Miocene is mainly developed in the northern part of the basin, extending from the Traras Massif to the Sabaa Chioukh. It is composed of gray marls, sands, and gypsum. This interval is characterized by two major sedimentary cycles. The first corresponds to a wine-red detrital formation attributed to the late Middle Miocene. The second includes red continental deposits and brackish to marine marls, which are overlain by algal- and coral-rich limestones of Messinian age (Gentil 1903; Fenet ,1975).

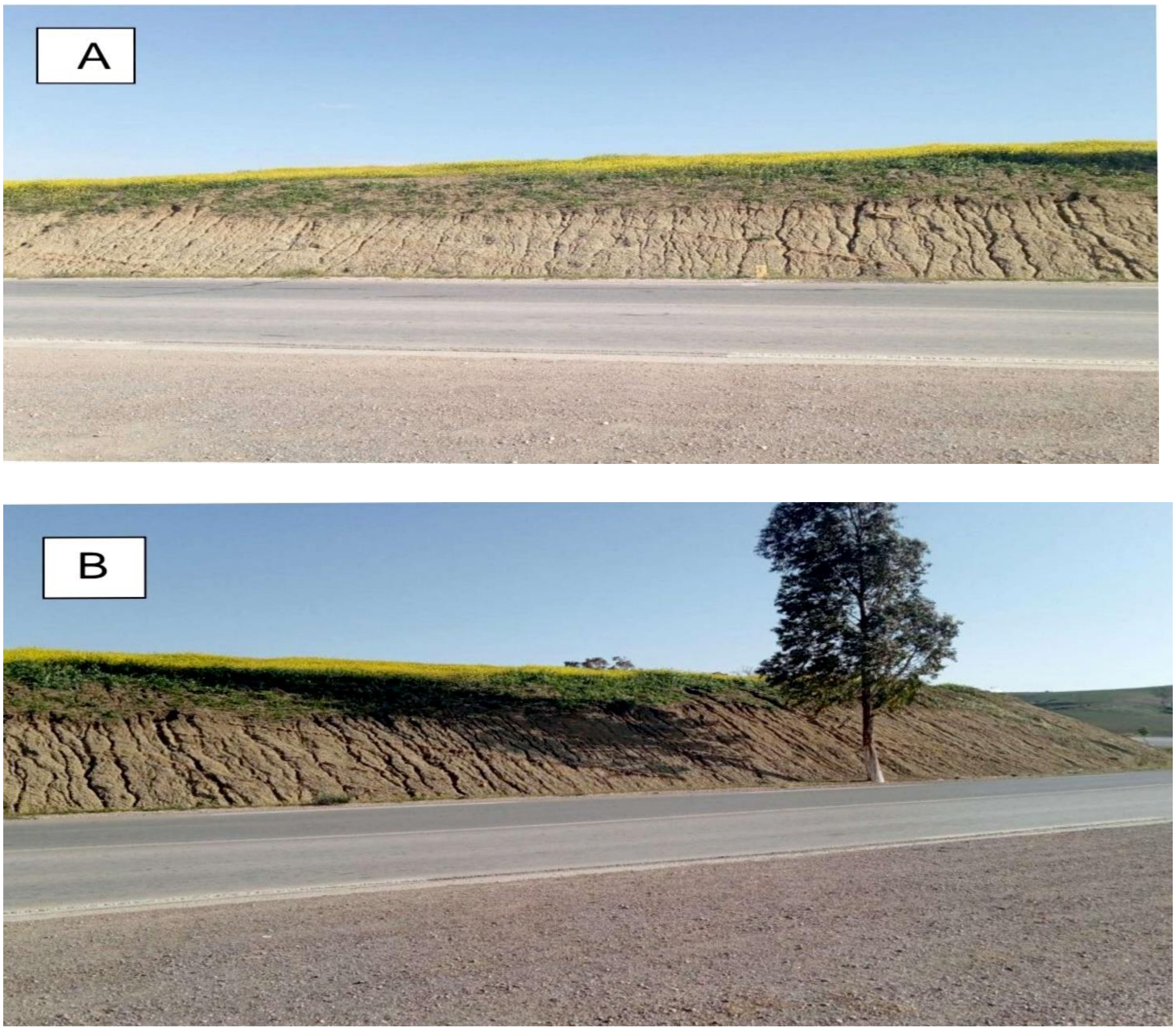

Fig.4- Bled Aina section: (A)The lower part.(B) The upper part.

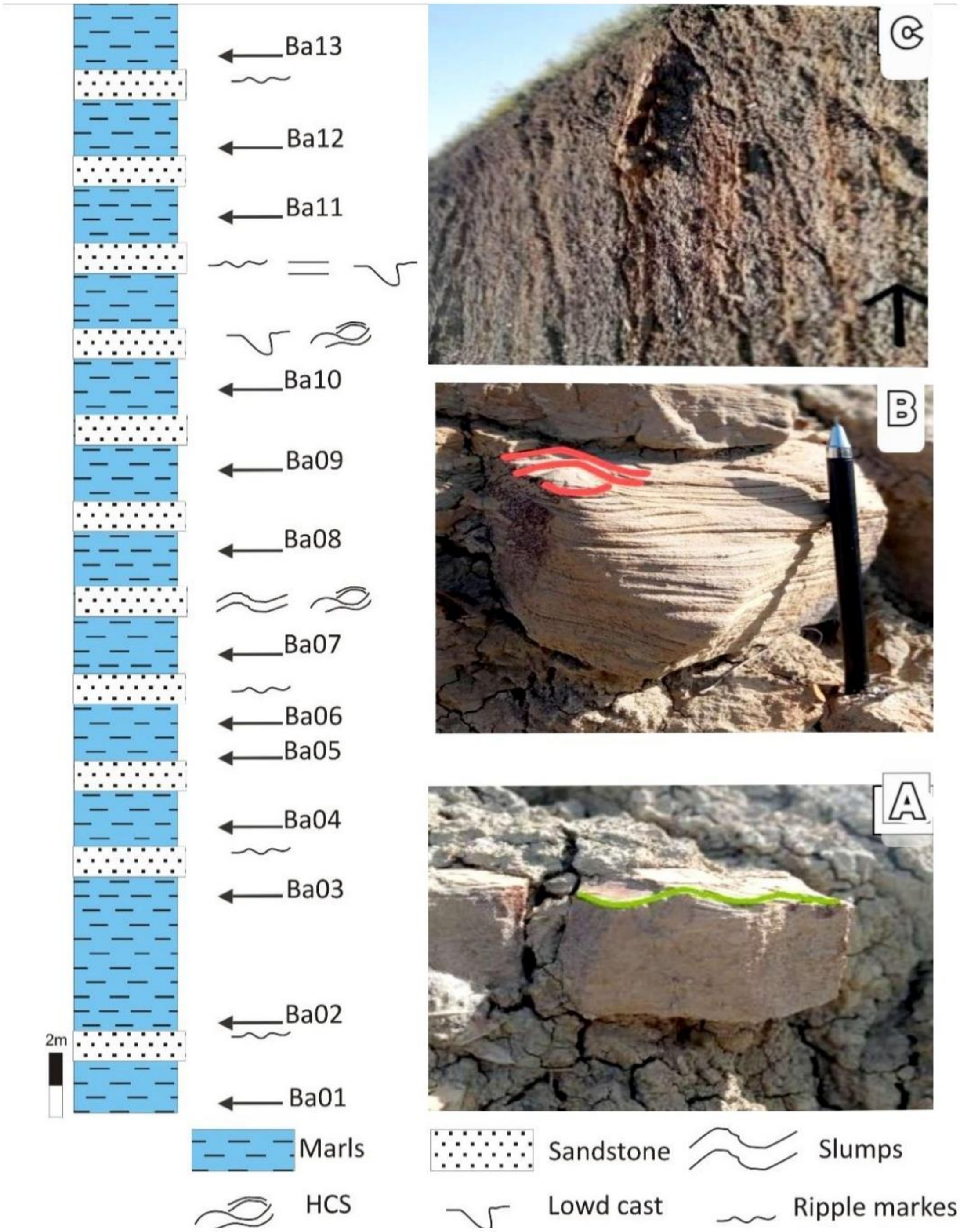

Fig.5- Lithological section of Bled Aina

The studied section consists of a rock succession with a total thickness of approximately 50 meters. From the base to the top, it is composed of an alternation of:

Marl layers (represented in blue color with black dashes), and intercalated sandstone beds (represented with dotted patterns), characterized by the presence of several sedimentary structures such as:

-Hummocky Cross

-Stratification (HCS).

-attached pseudonodules.

-Ripple marks.

-Slumps.

III. 3.3 Guetna section

The Guetna area from Tlemcen Province, is characterized by a diverse natural environment and smooth topography.

The Guetna area is located in Tlemcen Province, northwestern Algeria, within the Tlemcen Mountains and the Tafna Basin. It is bounded by Sidi Bakhit to the east and Maghnia to the west, and extends northward toward the Mediterranean domain. Geologically, its position within the Tellian Atlas gives it regional significance, particularly in relation to basin evolution and sedimentary processes. The distance from the city of Tlemcen is approximately 15 to 20 km. Despite its importance, the area has not yet been the subject of detailed scientific investigations.

Despite its strategic position, the Guetna area has not yet been the subject of a scientific academic research regarding its biostratihraphy (Fig 6, 7).

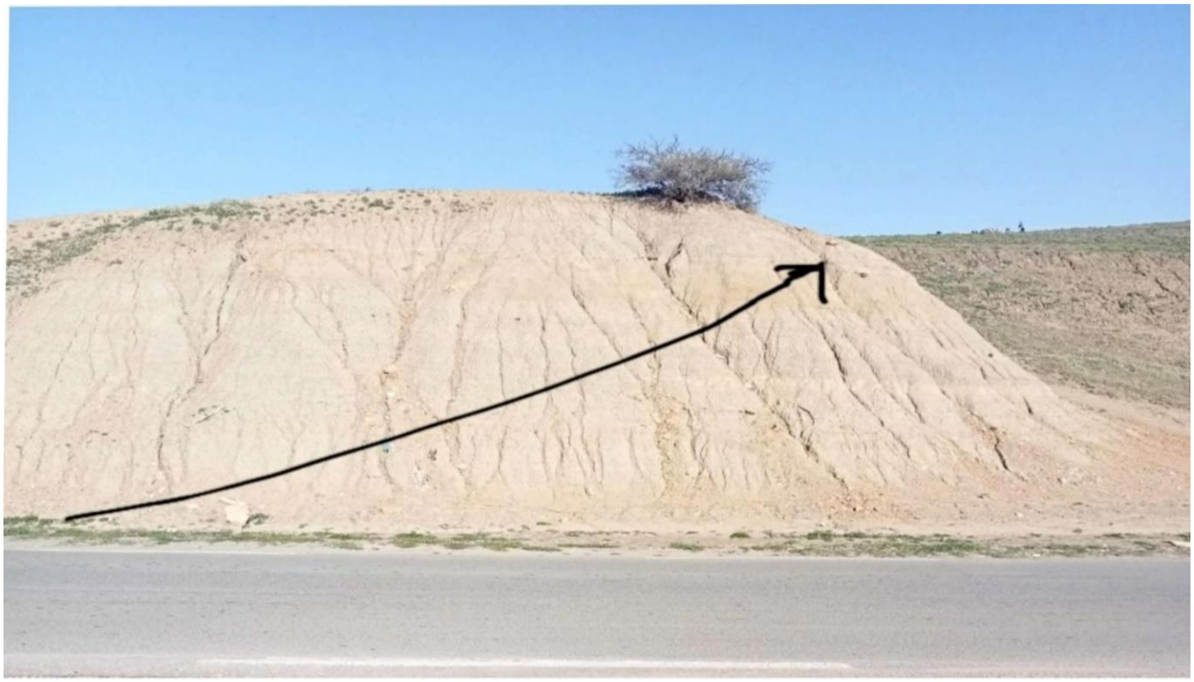

Fig.6- Field View of the Guetna Section

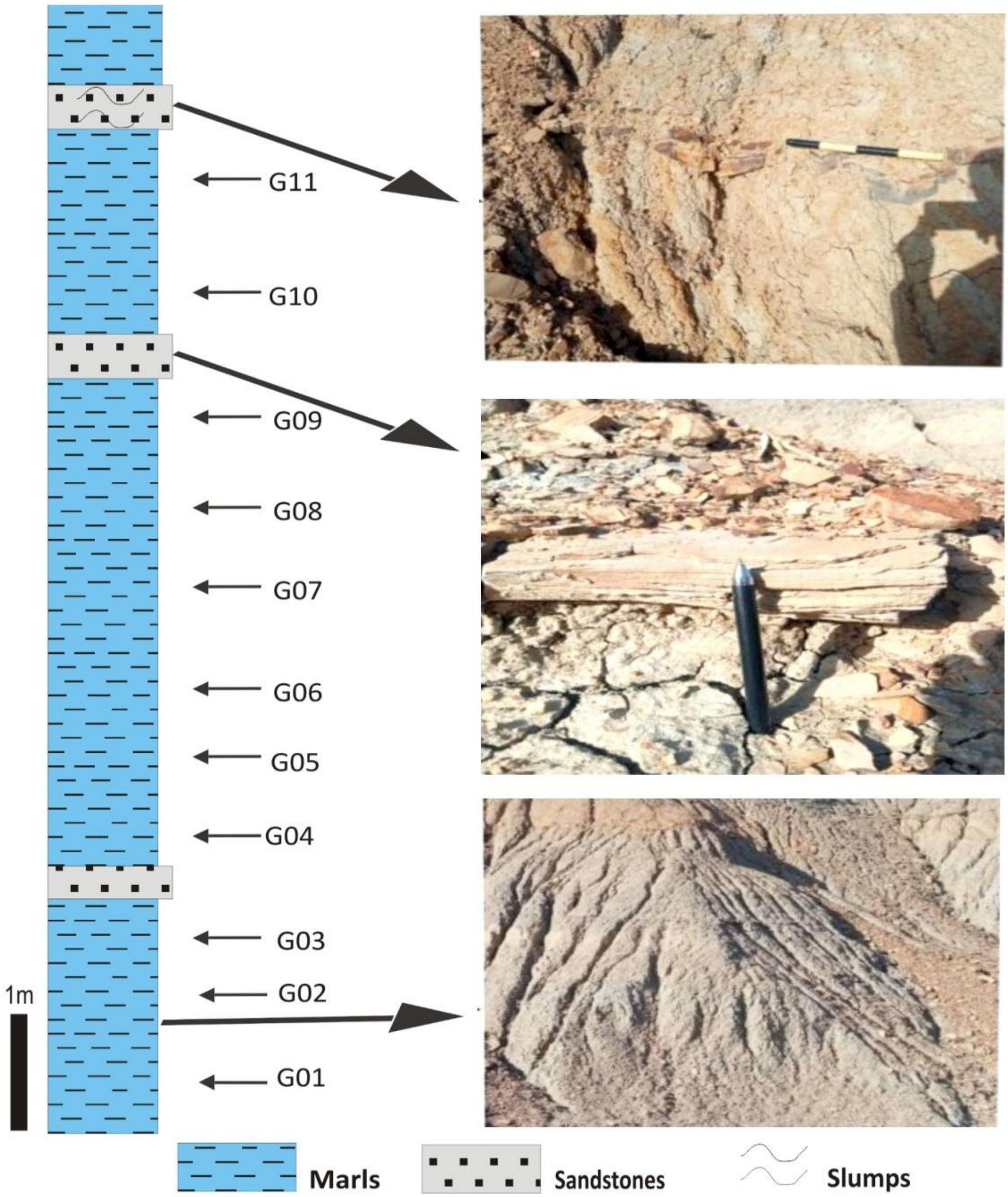

Fig.7- Lithological section of Guetna

III. 3.4 Lithostratigraphic description of Geutna section

The Geutna section exposes two main facies that are marls interbedded by thin sandstones beds.

- Sandstone's facies

The sandstones appear in scatter way along the section as thin yellowish beds interbedded the marl facies, they are fine-medium grained sandstone with horizontal and inclined laminations. The top of beds shows some ripples that are more likely got linguides forms, however the bottom part does show and specific sedimentological features except from a plane reactivation surface.

- Marls facies

Throughout the section the change of marls color is quite evident. Where, the bottom part of the section exhibits a thick grayish interval of marls, which is intercepted by decametric whitish marls. The latter on its own, from the middle part, is overlain by thick grayish marls succeeded by a metric yellowish interval. While, the upper part exposes the reappearance of a metric grayish interval.

IV. Problematic

The Tafna Basin is one among the Neogen basins that are stretched alongside Northern-west cost of Algeria. Within this basin, numerous studies have been carried out so far, involving geodynamic, volcanic, sedimentologic and palaeontologic studies. This latter, was subjected by set of scientific attempts that involve the study of coral reef, trace fossils, micro-mammals and foraminifera. However, the latter, have been widely used in the Neogene basins. Yet, their used is still limited regarding the basin in question (Tafna Basin).

In this sense, the current research looks for to endorse this aspect based on the study of Planktonic foraminifera in the meridional part of the basin, particulary Bled Aina and Guetna sections in order to get more insights about its Biostratigraphy period. Theus, how does biostratigraphy would play a pivotal role in determining the relative age of the sediments.

V. Objectives

This research is based on planktic foraminiferan subjectes the marls layers through detailed surveys, and involving sedimentological observations. Then, interpret the obtained data to determine the relative age of the sediments in both sections; Bled Aina and Guetna areas from Tafna Basin.

VI. Material and Methods

IV. 1. Material

Here are below the main material used in the laboratory for our procedure:

- Sieve 125um
- Binocular
- Magnetic needle (for species selection)
- boxes (for sample preservation)
- Cells (for species preservation)
- Absorbent paper

IV. 2. Methode in the Field

Fieldwork required the use of a set of equipment, including a hammer, colored pencils and an eraser, a 10% HCl bottle, a ruler and meter stick, a compass, a field notebook, a topographic map, and a GPS device. The orientation of some microfractures was measured in the field. For faults and strike-slip structures, observations focused on lithology, facies, sedimentary structures, and discontinuities.

The fieldwork concluded with the collection and proper packaging of samples in labeled plastic bags, each indicating its exact location within the section. A systematic and detailed sampling strategy was applied, involving approximately 300 g of loose sediment collected at a depth of 15 cm.

The field data of the studied sections, Bled Aïna and Guetna, were based on previous works carried out by Abi Miloud and Bechrair (2025) for the Bled Aïna section and by Chegoua and difallah (2025) for the Guetna section.

IV. 3. Methode in the laboratory

Thirteen (13) samples were brought from the field to be carefully prepared for paleontological and biostratigraphic analysis. Each sample was washed and sieved using a 125 µm mesh. Where we must mark 300 members from every individual sample to classify them in terms of their species/genus level. The doubtful species would be marked by Sp (as suffix) after every genus name ,it is called (Cf) after every species name species. The sample collection process was complemented by a detailed description of the various geological formations observed along the Bled Aina sections.

In the same way, eleven (11) samples were collected from the Gutena area and the sampling process was completed with a detailed documentation of the geological formations, including lithological and sedimentary characteristics along the Guetna section. Before conducting statistical analysis, several adjustments were made to enhance the graphical representation and avoiding ambiguities in interpretations.

Taxa with very low percentages were excluded to improve data representation species. Identification was carried out by placing the dried specimens under an electron microscope and comparing them with documented fossil records described in the relevant literature.

Fig.8- The main materials used in the laboratory for our procedures.

SECOND CHAPTER

I. Introduction

Foraminifera are single-celled organisms belonging to a group of protists. They are characterized by a streaming granular ectoplasm used for feeding and other functions, and they commonly possess an external shell, known as a “test,” which varies widely in form and composition.

Foraminifera are of major importance in geology because of their small size, high abundance, and well-preserved diagnostic tests. These characteristics make them excellent tools for biostratigraphy, age determination, sediment correlation, and paleoenvironmental reconstruction. They are widely used both as living organisms that provide ecological information and as fossilized tests that preserve geochemical signals related to paleotemperature, glaciation, and other paleogeographic conditions.

Foraminifera occur in all marine environments and may be either planktonic or benthic in lifestyle. The most widely accepted classification of foraminifera is based on the system proposed by Loeblich and Tappan (1964).

I. 1. Definition of systematic

Systematic classification is the study of the diversity of living organisms and their evolutionary relationships, with the aim of organizing them into natural groups that reflect their shared ancestry. It uses different types of evidence, including genetic, anatomical, and behavioral data, to determine relationships between species and classify them according to their evolutionary lineages.

Systematics forms the basis for understanding the evolution of life on Earth. It includes taxonomy, which deals with the naming of organisms and their hierarchical classification into ranked categories.

I. 2. Definition of taxonomy

Taxonomy is the scientific discipline concerned with the classification of living organisms through their identification, naming, and arrangement based on shared characteristics. It organizes organisms into a hierarchical system of ranks, ranging from species and genus to family and order, and extending up to kingdom.

This classification system facilitates the study of biodiversity and enhances our understanding of evolutionary relationships among organisms. Taxonomy is based on the binomial nomenclature system developed by Carl Linnaeus(1758), in which each organism is assigned a two-part scientific name consisting of a genus and a species, such as *Homo sapiens* for humans.

II. Systymatic of the identified taxa

Kingdom: Protista

Subkingdom: Harosa

Infrakingdom: Rhizaria

Phylum: Foraminifera

Class: Globothalamea

Subclass: Rotaliana

Order :Rotaliida

Foraminifera planktons

Globothalamea (Class)

Rotaliana (Subclass)

Rotaliida (Order)

Globigerinina (Suborder)

Globigerinoidea (Superfamily)

Globigerinidae (Family)

Globigerininae (Subfamily)

Subclass: Globigerina

Order: Globigerinida

Genus: Globigerina

Globigerina Sp

Description

The species has 4 chambers on the umbilical side in the last whorl, while the spiral side is more or less convex. The aperture is semicircular, without a well-defined lip.

Globigerina Foliata BOLLI 1957

Synonymy

1957- *Globigerina foliata* BOLLI: p.111.pl.24, fig.1.

1959- *Globigerina foliata* : BLOW. pl. 10, figs.42.

1962- *Globigerina foliata*: TAKAYANAGI & SAITO, pl.25, fig. 1.

Description

Globigerina foliata is characterized by its four globular chambers that increase rapidly in size in the last whorl. They are well hidden from one another and separated by incised margins, giving a very lobed outline in umbilical view. The shells are variable in size and can reach 400 µm. The opening is semi-circular, very small, and well-centered on the umbilical cord (Wernli,1988).

Globigerina falconensis Blow 1959

Synonymy

1959- *Globigerina falconensis BLOW*: p.177.Pl.9, fig.40-41.

1962- *Globigerina falconensis* : TAKAYANAGI & SAITO.pl.24,fig.13.

1971- *Globigerina (Globigerina) falconensis*: JENKINS.pl.16, fig.463-465.

Description

This small *Globigerina* has a remarkably stable morphology and a consistent size (280-300 µm) in our fauna. Its most striking feature is a low, arched aperture, sometimes taut and almost straight, with a prominent, often sharp, lip. It has four chambers in ambical view, the last two being of equal size. The spiral face is very slightly curved, almost curved, as is the umbilical face, giving it an oval profile with a parallel face in lateral view (Wernli,1988).

Globogerina bulloides bulloides Orbigny 1826

Synonymy

1826-*Globogerina bulloides* D'Orbigny: BANNER &BLOW.p.277, p.3, pl.1, fig.1-4.

1971- *Globogerina (Globogerina) bulloides*: JENKINS.fig.408-410.

1972- *Globogerina bulloides*: BIZON &BIZON.p.156,fig.1-3.

Description

The shells, generally, quite large, can reach 480 of large diameter. In umbilical view they are often as wide as: high with a growth of the size of lodges, which are subglobilates with very incised sutures. Diagnostic characters are the low trochospire, overlooking almost flat spiral face and a wide open umbilicus, leaving easily seeing the openings of the N-1 and N-2 boxes. On the last lodge, the opening itself is in arc relative: low (in relation *G. opertura*) and sometimes clearly larger than high, in basket handle. The last lodge is hardly greater than the penultimate and are sometimes found individuals with the last abortive lodge giving a last turn to 5 boxes,(Wernli,1988).

***Globogerina bulloides opertura* CUSHMAN 1918**

Synonymy

1918- *Globogerina opertur*a: CUSHMAN.p.67.pl.12,fig8.

1969- *Globogerina bulloides opertura*: BLOW.pl.12,fig8.

1971- *Globogerina riveroae*: POSTUMA.p.271.

Description

Globigerina Bulloides apertura differs from *G. Bullcides* S.S., by its higher trochospire, Don-Nani a curved spiral face and by its umbilical view higher than wide. The opening is quite large, in an arc of a circle and not sub-quadrangular as is often the case in *G. Builoides* S.S. It is larger than in *G. decoraperta* and if its border has a different structure from that of the rest of the test it does not carry a real bead (Wernli,1988).

Suborder: Globigerinina

Superfamily: Globigerinoidea

Family: Globigerinoidae

Genus : Globigerinoides

Globigerinoïdes trilobus WERNLI 1979

Synonymy

1970- *Globigerinoïdes trilobus trilobus*: CIFELLI&SMITH.pl.6, fig1.

1974-*Globigerinoïdes triloba* : CITA &al.pl7,fig.2.

1979- *Globigerinoïdes trilobus*: WERNLI.pl.2, fig.12.

Description

The shell is generally rectangular in shape with three locules in the last whorl, tightly packed together. The trochospire is low, and the logs increase in size rapidly, so that the last one occupies half the shell volume. In oral view, the shell is divided into two subequal parts by the last sulcus. The aperture is very low, a wide slit with a lip, positioned rather extraumbilically above locule n-2. The secondary spiral aperture is also low, a taut arc, and often inconspicuous. *G. trilobus* is very common in our faunas. It appears in the basal part of the Miccene, just after *G. primordia*. *G. Trilobus*, (Wernli,1988).

Suborder: Globigerinina

Superfamily: Globortalioidea

Family: Globortalioidae

Genus : Globortalia

Neogloboquardina BLOW 1959

Synonymy

1959-*Globortalia* BLOW: p.208.pl.17,fig.100.

1967-*Globortalia* : BIZON.p.41.pl.1,fig.6.

1969-*Globortalia (T)* : BLOW.pl.33,fig.3.

Description

Neogloboquadrina has a low trochospire with 4 to 5 locules in the last whorl, arranged relatively compactly, and slowly increasing in size at the end of ontogeny. The locules are subglobular, separated by moderately incised sutures, but primarily straight and radial on both faces of the test. The last locule is often slightly aborted (as in the holocytype) and also, more rarely, distinctly reduced. The essential characteristic of this species is that the aperture is low and wide, distinctly extra-omphalic, and poorly developed, almost closed. The umbilicus is also poorly developed and almost closed. The lateral view is crucial for differentiating this species from *G. dutertrei:* the spiral face is slightly convex, almost flat. It seems clear, based on our fauna, that *G.* gives rise to 2 branches during, (Wernli,1988).

Globortalia obesa BOLLI 1957

Synonymy

1957b-*Globortalia obesa* BOLLI: p.149.pl.29, fig.2-3.

1975- *Globortalia obesa*: STAINFORTH, al, fig.130.

1972- *Globortalia obesa*: BIZON & BIZON (atlas).p.100,fig.1-5.

Description

Globortalia obesa is particularly distinctive due to its very low trochospire and a rapid increase in the size of the locules in the last whorl. The distal half of the last locule forms a broad overhang above the rest of the tegmentum. The locules are distinctly globular with incised sutures that form a neat orthogonal cross in both umbilical and spiral views. The spiral face is flat, even concave. The umbilicus is distinct, narrow, and deep. The arc-shaped aperture is rather restricted and extraumbilical (Wernli,1988).

Globorotalia Catalano & Sprovieri 1971

Synonymy

1971-*Globorotalia :* Catalano & Sprovieri p. 241, pl. 1, fig .1-2.

1976-*Globorotalia* ROMEO: D'ONOFRIO &al .pl.2, fig.3.

1980-*Globorotalia* : WERNLI.pl.3,fig.1-4-5.

Description:

The test is plano-convex; its spiral side is strongly flattened to slightly curved, while the umbilical side is strongly convex with a conical shape. There are 4½ to 5 globular chambers in the last whorl, separated by well-incised sutures. According to the first description by Catalano & Sprovieri (1971), the species consists of 5 chambers in the last whorl. The umbilicus is large, well developed, and deep, with a very open and high aperture that bears a median lip. The test is smooth (Wernli,1988).

Globortalia puncticulata DONDI & PAPETTI 1968

Synonymy

1968- *Globortalia puncticulata* padna : DONDI & PAPETTI.pl.3,fig.1-4.

1970- *Globortalia puncticulata*: CIFELLI & SMITH.pl.6,fig3.

1972- *Globortalia puncticulata*: BIZON & BIZON.P116,fig.1-3.

Description

As Stainforti et al. (1975, p. 403) Frequent confusion still reigns in the literature for this species wrongly determined as *G. crassaformis* and vice versa. The test is well lobed in lateral view with a sub-plane or slightly convex spiral face and a strongly convex rounded umbilical face. The lodges, 4 in number in the last lap, are well inflated but with a tendency to turbination. The growth of the lodges in the back tower is slow and the sutures often form an orthogonal cross in umbilical view. The opening, very characteristic of the species, is ample, in a hemicular are (Wernli,1988).

Globorotalia scitula ventriosa

Description

is characterized by a lenticular to biconvex test, with a relatively flat spiral side and a more convex umbilical side. The test is composed of several chambers arranged in a trochospiral pattern, increasing progressively in size in the last whorl. The surface is finely perforate and may appear slightly rough. The aperture is interiomarginal and arched, extending along the inner margin of the last chamber, often bordered by a thin lip. This subspecies is typically associated with relatively deep marine environments and cool to temperate conditions, (Wernli,1988).

THIRD CHAPTER

I. Introduction

Biostratigraphy is a fundamental tool in geological studies that enables the relative dating and correlation of sedimentary rock layers based on their fossil content. Among the most important microfossils used in this discipline, planktonic foraminifera that are particularly significant due to their rapid evolutionary rates, wide geographic distribution, and high sensitivity to environmental changes, making them reliable indicators for reconstructing paleoenvironmental and paleoclimatic conditions. However, The Tafna Basin that is located in northwestern Algeria, represents one of the Neogene sedimentary basins, preserving a geological record of marine environmental evolution. It is characterized by diverse lithological facies such as marls, limestones, and sandstones, which contain abundant and well-preserved microfossils.

The Neogene period itself was marked by important climatic and oceanographic changes that strongly influenced marine sedimentation and the distribution of marine organisms, and these variations are well recorded within the fossil assemblages of the basin.

In this sense, previous biostratigraphic studies in the Tafna Basin, including the work of Ghada Sabrina and Asma sayah, have contributed to establish a preliminary stratigraphic framework, henceforth, improving the understanding of its paleoenvironmental evolution. Based on these studies, the present work aims to further investigate the biostratigraphy of the Neogene deposits in the Tafna Basin by analyzing planktonic foraminiferal assemblages in order to refine and update the stratigraphic frame and provide a more detailed reconstruction of the geological evolution of the basin.

The study of foraminifera distribution along with their classification in sedimentary records is a fundamental tool for establish Biostratigraphic scale. This chapter attempt to identify planktonic foraminifera found in samples that were brought from the field . The classification will be made according to their structure and morphology.

II. Biostratigraphy Based on Planktonic Foraminifera

Biostratigraphy based on planktonic foraminifera represents one of the most refined and high-resolution methods for dating and correlating marine sedimentary sequences. Planktonic foraminifera are microscopic, unicellular protists that live suspended in the upper layers of the ocean and produce calcareous shells, which are readily preserved in marine sediments after their death. Their evolutionary rates are relatively rapid, leading to frequent morphological changes that can be identified in the fossil record and used to establish detailed biostratigraphic zonations.

In addition, these organisms have a broad geographic distribution, often extending across entire ocean basins, which makes them particularly suitable for long-distance stratigraphic correlations. The identification of successive species and assemblages allows geologists to define biozones with high temporal resolution, especially within the Cenozoic era, including the Neogene period.

Planktonic foraminifera are also highly sensitive to environmental parameters such as sea surface temperature, salinity, nutrient availability, and ocean circulation patterns. This ecological sensitivity enables their assemblages to serve not only as chronological markers but also as valuable indicators of paleoenvironmental and paleoclimatic conditions. Variations in species composition can reflect major climatic events, such as global cooling or warming phases, as well as regional oceanographic changes. Standardized zonation schemes based on planktonic foraminifera have been developed and widely adopted, facilitating consistent correlations between different marine basins around the world (e.g.; Blow 1969; Belkebir et al., 1996 ; Lirer et al., 2019).

These zonations are continuously refined as new data and improved taxonomic frameworks. In applied geology, planktonic foraminiferal biostratigraphy is extensively used in the exploration of oil and gas, where it assists in identifying stratigraphic horizons, correlating wells, and improving subsurface models .When combined with other stratigraphic approaches, such as isotopic analysis and magnetostratigraphy, it provides a robust and integrated framework for interpreting sedimentary records (e.g., Hilgen et al., 2000; 2003). .

Consequently, planktonic foraminifera play a central role in modern biostratigraphic studies and remain indispensable tools for both academic research and industrial applications.

III. Definition of planktonic foraminifera association

Planktonic foraminifera association is defined as the assemblage of planktonic foraminiferal species that live suspended in the water column of marine environments. Their distribution is mainly controlled by environmental parameters such as water temperature, salinity, depth, nutrient availability, and oceanic circulation. These associations are widely used as bioindicators for reconstructing paleoceanographic conditions, including climatic variations, sea-surface temperature changes, and water mass distribution. Different species of planktonic foraminiferal associations are related to specific marine settings, such as shallow or deep environments. The study of their distribution and composition provides valuable information about past and present oceanographic and climatic processes.

The terminology used in the current study for the taxonomic quantification of associations is as follows:

Dominant taxon: when the taxon exceeds 50%.

Abundant taxon: when the taxon is between 25% and 50%.

Frequent taxon: when the taxon is between 10% and 25%.

Present taxon: when the taxon is below 10%.

A total of 300 individuals from each single sample are counted to identify the species. These species are then classified in a tables including the identified taxa, either at the species or genus level.

Based on the criterion of species dominance or non-dominance, the relative age of sedimentary units can be found out.

Table 01: Percentage of Taxa in Bled Aina

Samples	*Globogerina Sp*	*Globogerina Cf foliata*	*Globogerinoides trilobus*	*Neogloboquadrina*	*Globorotalia obesa*	*Globorotalia*	**Number of species**
13							**0**
12			P	P	P	P	**4**
11							**0**
10							**0**
09							**0**
08		P					**1**
07	P						**1**
06							**0**
05				P			**1**
04							**0**
03							**0**
02							**0**
01							**0**

D. Dominant, **A**. Abundant , **F**. Freauent , **P**. Present

III. 1. Bled Aina section

III. 1.1. Index Species in Bled Aina section

The planktonic foraminifera in the Bled Aina section are in different rate throughout the stratigraphic levels.

The number of species ranges from 0 to 4 species at most. So that, The maximum species is recorded at level 12 (4 species), with (*Globigerinoides trilobus, Neogloboquadrina* , *Globorotalia obesa*, and *Globorotalia*) occurring together.

The other samples (13, 11, 10, 09, 06, 04, 03, 02, 01) show no planktic species, indicating either unfavorable environmental conditions (shallowest marine environement) or poor fossil preservation.

A few levels (08, 07, 05) show a very low species number (one single species only), reflecting sporadic occurrence of taxa such as (*Globigerina sp*, *Globogerina Cf foliata* and *Globorotalia)*.

Overall, the planktonic foraminifera assemlage reflects a poor discontinuous fossil distribution, with a single (relatively) diversed interval. This suggests unstable environmental conditions that affects the distribution.

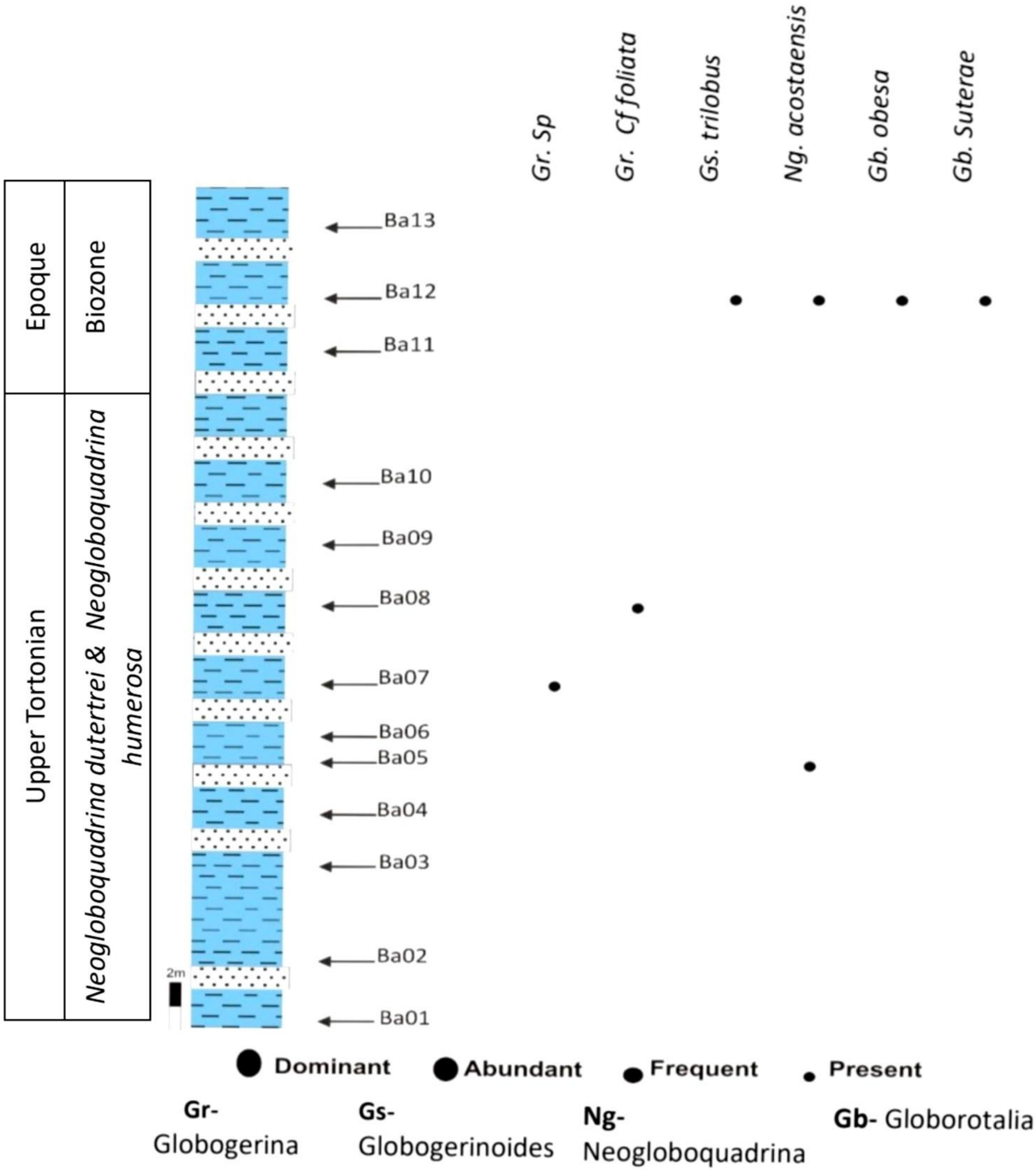

Fig.09- Evolution of planktonic foraminifera taxa along Bled Aina section.

III. 1.2. Biostratigraphic association in Bled Aina

From table of taxa percentage in Bled Aina section, the assemblage shows that the presence of planktonic foraminifera is somehow in good preservation.

The biostratigraphic association in this area is characterized by a low-diversity of planktonic foraminifera species. The fauna is mainly consists of three genera: *Globigerina* represented by *Globigerina sp*. and *Globigerina (cf) foliate, Globigerinoides* notably involves *Globigerinoides trilobus* and *Neogloboquadrina .* Finally, *Globorotalia* that includes *Globorotalia obesa*, and *Globorotalia)*

The distribution shows that: The highest diversity occurs at sample 12, where 4 species are present simultaneously.

Some other levels show very low diversity (0–1 species), indicating discontinuous or poor fossil content. The assemblage is somehow dominated by *Globorotalia* and *Globigerinoides*, may indicate harsh marine conditions.

Overall, this association reflects a poor to moderate planktonic foraminiferal assemblage, with a peak of diversity at a single stratigraphic level 12.

This association suggests a planktonic foraminiferal assemblage typical of relatively shallow, restricted marine conditions. Thus the presence of *Neogloboquadrina* refers to Tortonian stage. However the presence of *G.* corresponding the Upper Miocene period, in particular the Biozone *Neogloboquadrina.*

Table 02: The percentage of mineral presence in the samples from the Bled Aina area.

Sample	Quartz	Fer	Gypsum
1	71%	27%	2%
2	8%	91%	1%
3	2%	53%	45%
4	23%	1%	76%
5	1%	81%	8%
6	3%	85%	12%
7	7%	92%	1%
8	2%	97%	1%
9	14%	7%	79%
10	6%	82%	12%
11	3%	77%	21%
12	1%	91%	7%
13	4%	84%	12%

III. 1.3. Mineral analysis table of the Bled Aina area

Bled Aina samples show the presence of a set minerals in different percentage (Quartz, Iron and Gypsum).

The minerals in this section shows may come from continental detrital clasts (Quartz), oxidizing process, and evaporitic sedimentation, reflecting significant geological and climatic variations in the region.

The high iron content indicates strong oxidizing conditions that promoted iron re-precipitation within the restricted environment, while the presence of gypsum reflects evaporitic phases associated with increased salinity in partially restricted settings in shallow marine environment. While, the generally quartz content suggests continental clastic input.

These environmental changes had a direct impact on planktonic foraminifera, as high salinity or strongly oxidizing conditions reduced their diversity and altered their distribution, whereas less stressful intervals allowed their recovery and diversification. Overall, these results indicate a complex environmental evolution of the area possibly controlled by sea-level fluctuations and detrital clastic input from the continent.

Table 03 : Percentage of Taxa in Guetna

Samples	*Globogerina Cf falconensis*	*Globogerina bulloides bulloides*	*Globogerina bulloides opertura*	*Globogerinoides trilobus*	*Neogloboquadrina*	*Globorotalia puncticulata*	*Globorotalia scitula ventriosa*	**Number of species**
11	P			P				**2**
10								**0**
09								**0**
08			P	P	P	P		**4**
07		P	P	A	F		P	**5**
06								**0**
05				P	P			**2**
04								**0**
03								**0**
02		P		P	P			**3**
01								**0**

D. Dominant, **A**. Abundant , **F**. Freauent , **P**. Present

III. 2. Guetna section

III. 2.1. Species Index in Guetna Section

The planktonic foraminifera in the Guetna section shows a moderate to relatively high diversity of planktonic foraminifera, with values ranging from 0 to 5 species per level.

The highest species index is recorded at level 07 (5 species), representing the peak of planktic diversity.

This level is also characterized by the presence of abundant (A) and frequent (F) taxa such as (*Globigerinoides trilobus* and *Neogloboquadrina*), indicating suitable environmental conditions for these species.

A relatively high diversity is also observed at level 08 (4 species) and level 02 (3 species), reflecting intervals of -developed assemblages.

Some levels (11 and 05) show a low index species (2 species), suggesting limited but persistent faunal presence.

Several levels (10, 09, 06, 04, 03, 01) are devoid of species (index = 0).

Overall, the Planktonic species in Guetna is somehow richer assemblage compared to Bled Aina, with clear intervals of increased diversity. This suggests more stable open marine conditions, allowing better development of planktonic foraminifera.

The co-occurrence of *Neogloboquadrina* , *Globorotalia puncticulata*, and *Globigerinoides trilobus* indicates:

Neogloboquadrina along with the assemblage species refers to Late Miocene (Tortonian).

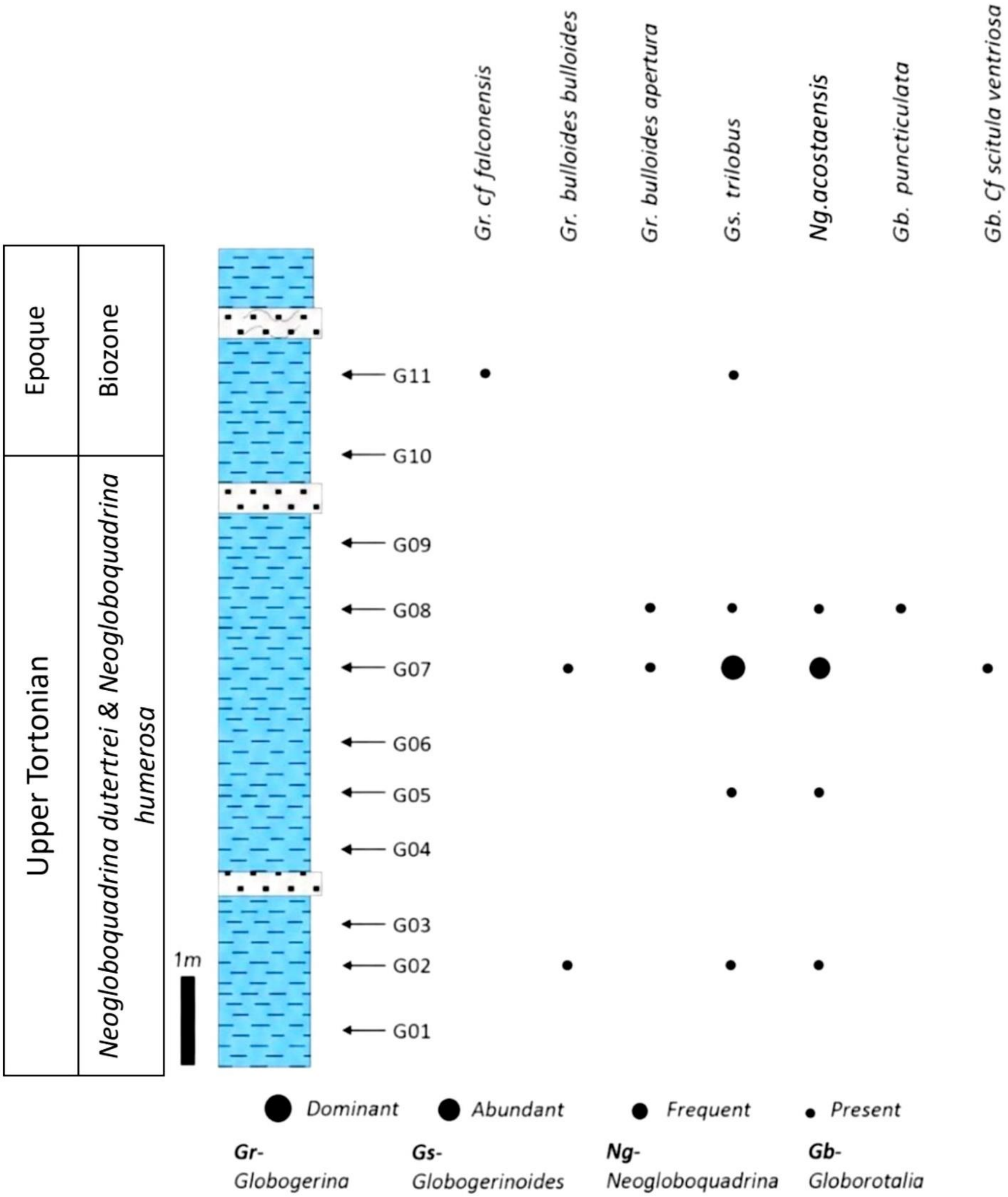

Fig.10- Evolution of planktonic taxa along the Geutna.

III. 2.2. Biostratigraphic association in Geutna

The Planktonic forminifera association in the Guetna section is composed of a moderately diverse assemblage, where it is dominated by species: *Globigerina* (*Globigerina cf falconensis, Globigerina bulloides bulloides, Globigerina bulloides apertura*) ,*Globigerinoides (Globigerinoides trilobus). Neogloboquadrina* , *Globorotalia* (including *Globorotalia puncticulata*, and *Globorotalia scitula ventriosa*).

The distribution shows that: The highest diversity is recorded at level 07 (5 species), indicating as a developed assemblage.

A relatively high diversity is also observed at level 08 (4 species) and level 02 (3 species). Several levels show absence of species, suggesting interruptions in sedimentation or moderate environmental conditions.

The presence of abundant (A) and frequent (F) species at level 07 reflects balanced ecological conditions for planktonic foraminifera.

Several levels (10, 09, 06, 04, 03, 01) are devoid of species (index = 0), indicating either restricted ecological environment or poor fossil preservation.

According to Sierro et al. (1993), the coiling change from sinistral to dextral in *Globorotalia* and *Globorotalia ventriosa* represents an important biostratigraphic event. This transition occurs at a high frequency (>90%) and is dated at approximately 7.28 Ma. The event nearly coincides with the frequent occurrence of *Globorotalia miotumida* and is widely used as a marker for the Tortonian interval (Hilgen et al., 2000; Morigi et al., 2007).

Overall, the Guetna assemblage is more diversified and better distributed than in Bled Aina, indicating more stable open marine conditions with intervals of favorable paleoenvironmental settings

Table 04: The percentage of mineral presence in the samples from the Guetna area per sample.

Sample	Quartz	Fer	Gypsum
1	5%	60%	45%
2	3%	16%	81%
3	13%	73%	14%
4	19%	62%	19%
5	13%	10%	77%
6	5%	90%	5%
7	66%	22%	12%
8	46%	46%	8%
9	33%	34%	33%
10	1%	97%	2%
11	60%	38%	2%

III. 2.3. Mineral analysis table of the Geutna area

As mentioned above, Guetna section shows the same minerals presence in different percentage (Quartz ,Iron and Gypsum).

The mineral assemblage from the Guetna area shows a clear variability mainly composed of quartz, iron, and gypsum, with a marked dominance of iron in most samples. This high iron content reflects strong oxidizing conditions and active diagenetic processes that led to significant ferruginization within the depositional environment as part of continental detrital clasts. Gypsum is also recorded in high proportions in some samples, indicating episodes of evaporitic conditions associated with restricted or lagoonal settings where sulfate precipitation was favored. In contrast, quartz shows variable proportions ranging from low to moderate values, with higher peaks in certain samples, *reflecting fluctuations in detrital input derived from continental sources and changes in transport energy*. Overall, this mineralogical variability indicates alternating depositional conditions characterized by evaporitic phases, ferruginous enrichment, and varying continental supply. *It also suggests that chemical processes were more dominant than mechanical deposition*. Collectively, these features reflect a dynamic evolution of the Tafna Basin controlled by changes in sea level, *detrital input,* and depositional environments ranging from shallow marine to partially restricted settings.

IV. Context biostratigraphic of study area (Bled Aina and Guetna)

The comparative analysis of the planktonic foraminiferal assemblages from Bled Aina and Guetna sections reveals a slight difference in both species diversity and biostratigraphic significance.

Bled Aina is characterized by a very low species, ranging from 0 to 4 species per level, with most levels being barren and only one level (12) showing relatively higher diversity. This indicates a restricted unbalanced environment.

In contrast, Guetna exhibits a moderate species, ranging from 0 to 7 species per level. the considerable presence is levels (02, 07, 08), while the peak diversity at level 07 reflects the highest value. This comparison clearly shows that Guetna has a richer and more continuous faunal distribution than Bled Aina.

To sum up, both sections Bled Aina and Geutna exposed the presence of *Neogloboquadrina* and *Globorotalia* , that indicate the Upper miocebe more particalary *Neogloboquadrina* Biozone.

V. Conclusion

The current study is about a micropaleontological investigation in the Late Neogene Tafna Basin northwestern Algeria, particulary, in two stratigraphic sections located that are Bled Aïna and Guetna section.

On the basis of the evolution of planktonic foraminifera study this research aims at to determine the relative period of sediments deposition. This process considers a set of key foraminifera species (index species).

The finding show that in Bled Aïna section, three species belonging to six genera were identified, whereas in the Guetna section, three species distributed among seven genera were recorded. Most of these taxa are characterized by calcareous tests.

The results show a little distinction planktic foraminiferal distribution between the two areas;

In Bled Aïna, planktonic foraminifera are relatively scarce, with benthic foraminifera, particularly with the over-dominance of the genus (Ammonia).

In contrast, the Guetna section shows a more abundance of planktonic foraminifera compared to the former one, indicating more favorable paleoenvironmental conditions for their development. This distinction has something to do with sediment composition and depositional conditions, which directly affected the distribution of planktonic foraminifera within the Tafna Basin.

In the Bled Aïna section, oxidized clasts are strongly dominates (often exceeding %80), while quartz and gypsum contents remain low. This indicates oxidizing environment, which are unfavorable for foraminifera. As a result, planktonic forms are rare, whereas benthic foraminifera, such as the genus Ammonia, dominate due to their ability to tolerate harsh environmental conditions (as restricted evnvironment).

In contrast, the Guetna section shows a variable mineralogical composition, with alternating dominance of gypsum, quartz, and oxidized clasts. The presence of gypsum reflects shall marine environment conditions. These fluctuating conditions are relatively more favorable for planktonic foraminifera, leading to their more abundance and diversity, although their populations may decrease during periods of intense evaporation.

Both sections show the presence of two well-represented index planktonic foraminiferal taxa (Bled Aïna and Guetna sections), namely *Globigerinoides* and *Globorotalia .*

The occurrence of *Globigerinoides* allowed to know the relative age, that indicating the Tortonian stage of the Late Miocene.

However, when integrating the overall assemblage taxa mainly *Globorotalia* the studied succession is ultimately attributed to a Tortonian stage more precisely (Upper Toronian), more particularly, *Neogloboquadrina* Biozone. Subseauently, this interpretation reflects a Late Miocene depositional framework with significant biostratigraphic constraints provided by the identified planktonic foraminiferal assemblages.

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