Miocene Formations Analysis within the North-Western Margin of Ma Labiod Basin (Algero-Tunisian Confines)

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Abstract: ***The study concerns miocene formations within the north-western marge of Ma Labiod basin at the southern region of Tebessa. These sediments are deposited in angular unconformity within the erosion surface of the earlier sediments folded during the tectonic atlasic phase. The results of the study, carried out on about 150 samples, have confirmed the sediments petrography and the different transport modes which are qualified of rolling, saltation and suspension). The petrographic study reveals detritus sediments basically quartz-bearing inter-bedded by some argillaceous intercalations. The sediments are known a far-off water transport supposed of a Saharan origin. The analysis of the sediments has also given the various sedimentological coefficients which confirm as a factor with the field work and all the data, the determination of the different environments, sequential analysis and the process of sedimentation. The deposits analysis has confirmed a development of downlap structures towards the western part of the basin. This analysis has also proved the presence of a detritus continental sedimentation of four sedimentary environments that are characterized by the river, delta, lake and marsh materials, manifested in several sedimentary cycles.***

Keywords: Miocene Sediments, Sedimentary Environments, Sequential analysis, Ma Labiod Bassin, Algero-Tunisian Confines.

1. Introduction

The area of research is located within the oriental Atlas Saharan at the southern region of Tebessa (Durozoy, 1956)1. It corresponds to the tortonian sediments within the north-western margin of Ma Labiod basin at the Algero-Tunisian borders (fig.1).

The aim of this work is contribute to the study of geological and sedimentary history of the Tortonian basin which is implemented during the distensive Alpine tectonic. The previous studies of the basin in question concerned only simple and brief observations of facies terrain. However, the purpose of this work is to expose further and varied study from erosion and transport modes to sedimentation and type of the sedimentary development process. The scientific value of this study is of great importance: First, for the recognition of such intra- mountainous Miocene basins, with monographs still unknown, and also for the importance of the retrieved data and their uses in the economic sector (in industry of glass, construction, foundry and other functions like abrasives of sanding and clothes industry of the sandpapers).

The work has been prepared on more than 200 samples distributed on four principal profiles where the sampling was carried out with respect to the vertical and lateral variations in order to define the sedimentary volume of the basin. The sediments appear to be of a detrital origin and are deposited in angular unconformity on the cretaceous substratum.

The exclusive previous works undertaken by Durozoy (1956)1 within the basin itself are limited to those of simple observations. In his work, he determined, without any palaeontological evidence, the lower and middle sandy Miocene (respectively named Burdigalian and Vindobonian), followed by an upper marly Miocene (Pontian).

The observations history established on the Miocene's sediments within the surroundings of the basin and the whole area were at the beginning of the twentieth century. However, all these works were done by simple macroscopic observations in the field without any detailed analyses. Brives (1919)2 has attributed to Miocene a tooth of *Dinotherium* encountered within the formations of El Kouif sandpit at the North-East of Tebessa. The same author (1920)3 has also found a Miocene *Mastodon* in this sandpit of El Kouif. Dubourdieu (1956)4 has described, in a geological investigation of the Ouenza area, the Miocene formations situated approximately at 8km in the North-East of the famous mine of iron layer. By macrofauna datation, this author summarized the miocene sediments of this region in three series of Burdigalian, Helvetian, and Tortonian. Dubourdieu and Hottinger (1959)5 announced the presence of Miocene *Neoaveolina* in the Miocene Mesloula at Djebel Bardo. Bles and Fleury (1970)6 have discovered, below the Miocene sand of El Kouif, a conglomerate composed of large rollers of the Eocene carbonated rocks (local material), which they regarded as lower Miocene. Kowalski and al. (1995a)7 and (1995b)8 have prearranged, instead of the macroscopic observations on the Miocene sediments, the first sedimentological work on the area, which contributed, in spite of their insufficiency, to the development comprehension of the Miocene deposits within certain localities of the area. Hamimed and Kowalski (2001)9 have worked on the Langhian-Serravalian sediments in some localities and have given a conclusion on Sedimentological process and paleogeography of these sediments within the studied localities. Hamimed and al. (2006)10a, b, c, (2008)11 and (2011)12 have given some works on the grabens of the Tebessa region and studied some Miocene sediments localities belonging essentially to its lower part.

2. Geological Background of the Region

The present appearance of the study area is certainly a result of a long process tectono-sedimentary; however, it is clear that regardless of the varied phenomena of local deformations, the sedimentation and morphological evolution are related to movements of the continent. In a summary overview, I will try to characterize the movement brought into play at different periods and types of content sedimentary filling the vast marine area created within the region in different geological epochs.

The history of the sedimentary series (Fig.2) outcropping is after the Paleozoic era and is about 7000m thick (Dubourdieu, 1956)4. It was noted that the entire Jurassic, Neocomian and the upper Paleogene are not known in the region, a lack to which is added the effects of the post-Lutetian-fold intense erosion and especially the intense uplift Quaternary.

Besides the formation of lagoon deposits reported to the evaporitic Trias, there is a strong accumulation of marine Cretaceous formations, a marine Eocene, a Miocene (marine or continental) discordant on the older series, and then a continental Plio-Quaternary. In terms of sedimentation, the sedimentary series is characterized by the dominance of soft formations, clay or marl, highly developed on the indurate formations mainly represented by carbonates. With the exception of a few shallow at certain geological epochs, the seas experienced by this country were still epicontinental and did not have low funds in excess of several hundred meters deep (Dubourdieu, 1956)4. The geological history of the sedimentary series of the region can be summarized as follows:

A lagoon evaporitic Trias, whose Germanic facies type are widespread throughout North Africa. A calcareous and dolomitic Aptian testifying a shallow and warm sea where settled large reefs. A calcareous Albian and Vraconian, under a very thin thickness in places, so the existence of shoals, probably due to diapiric effects at these locations within a wide open sea on a subsiding background. A Cenomanian with powerful marly formations, rich in oyster coquinas and ammonites, as well as planktonic microfauna in a sea of high subsidence. A calcareous lower Turonian, corresponding to a slowing of subsidence and trending reef. Again, from the Upper Turonian, it settled a marly sedimentation identical to the Cenomanian and it is only temporarily interrupted by chalky limestone of the middle Campanian, heralding the more neritic limestones of the lower Maestrichtian.

The transition from Cretaceous to Tertiary is done without significant disruption within the gray marls, rich in planktonic microfauna, which track the passage from the Maestrichtian to Paleocene, with a low past of clay limestone and slightly chalky, which marks in part the Danian. From the Upper Paleocene (Thanetian) to Lutetian, it settles calcareous sediment with a very neritic character, emphasized by the large variations in thickness. A phosphatic horizon precedes the sedimentation as two sittings at the base of the Thanetian.

The lack of sedimentation from the Upper Lutetian to Miocene appears due to the influence of a compression phase development in the late Lutetian and since this time the region has experienced intense erosion until the Miocene times. During the Miocene, the marine or continental deposits, with variables facies (sandstone, clay, marl or carbonate) are deposited on a weathering surface of the Cretaceous or nummulitic folded formations, and sometimes even on the diapiric Trias.

3. Materials and Methods

The works in the field were realized on 216 samples, distributed on four profiles: Bouroumane profile (40 samples), Khorza profile (51 samples), Bordjtenoukla profile (70 samples) and Coltenoukla profile (50 samples). The study of these profiles reposes on field work as explained in (Comity of technicians, 1974)13 and in Ghoshal (2011)14 and laboratory analysis. The main points to see are resumed in:

- Bibliography, recognition and limitation of the study area.
- Field observations: in particular tectonic structures, sedimentary structures and limits between sequences.
- Granulometry analysis: sieving/settling tube) the detailed grain size analysis at the laboratory.
- Determination of the sedimentological coefficients and sedimentary environments.
- Petrographic and morphoscopic analyses of the sediments in using polarized microscope, binocular and Carbonatometry.
- Observation of macrofauna and the micropalaeontological analysis.
- Sequential analysis in using field and laboratory data.
- Interpretation of the results and correlation between the four profiles.

4. Laboratory Analyses

The movable sandy formations or with an argillaceous cement, non-cohesive strong on the grains, are particularly adapted to the technique of grain size analysis by sifting. However, it is necessary to give up applying this technique as soon as a perfect disintegration of the grains proves to be difficult. In this case it is obligatorily necessary to resort to the process of analysis by planimetric method on thin sections.
The morphoscopy of the quartz grains or other components of the sediment are studied under binocular or under the polarizing microscope. The collection of the results obtained from the various types of analyses contributes to detail the first observations carried out on the field.

To determine the mechanism of transport and the medium of deposit, two types of curves are to be carried out starting from the granulometric data:

4.1 Curve of the Refusal Cumulated Percentage

The interest of these curves is to deduce the transport mode of the sediments (rolling, saltation and suspension) and their depositional environments using the method of Vischer (1969)15, according to the table1 below:

Population of Sand transported by saltation (A)				
Environments	**%**	**Ranking**	**GPZ**	**DPZ**
River	65 – 98	Average	-1.5 - -1.0	2.75 - 3.50
Bed axis	0 – 50	Average	2.0 - 1.0	2.0 - -3.5
Bed flow	20 – 80	good	1.5 - 2.0	1.5 - 3.5
Channel flow	30 – 65	good	1.25 - 1.75	2.0 - 2.5
Beach	50 – 99	Very good	0.5 - 2.0	3.0 - 4.25
ZBW	20 – 90	good	1.5 - 2.5	3.0 - 4.25
ZTW	35 – 90	good– Very good	2.0 - 3.0	3.0 - >4.5
Dune	97 – 99	Very good	-	3.0 - 4.0
SC	0 - 70	Average /Bad	1.0 - 2.5	1.0 - 3.5
Population of Sand transported by suspension (B)				
Environments	**%**	**Ranking**	**RatioA/B**	**GPZ**
River	2 – 35	Bad	Small	>4.5
Bed axis	60 – 100	Bad	Big	>4.5
Bed flow	0 – 20	Bad – good	Big	3.5 – 4.5
Channel flow	2 – 5	Average – good	Average	3.5 – 4.0
Beach	0 – 10	Average –good	Small	3.5 – >4.5
ZBW	0 – 2	Good	Big	3.0 – >4.5
ZTW	50 – 70	good – bad	Big	3.75 – >4.5
Dune	1 – 3	Average	Average	4.0 – >4.5
SC	30 – 100	Bad	Big	>4.5
Population of Sand transported by rolling (C)				
Environments	**%**	**Ranking**	**RatioA/C**	**DPZ**
River	variable	Bad	Small	No limit
Bed axis	0 – 5	Bad	–	–
Bed flow	0 – 70	Average – Good	Average	-0.5 – -1.5
Channel flow	30 – 70	Average – Good	Average	<-0.5
Beach	0 – 50	Average	Average	<-1.0
ZBW	10 – 90	Average – Bad	Big	0.0 – 2.0
ZTW	0 – 10	Bad	Small	<0.0
Dune	0 – 2	Bad	Small	1.0 – 0.0
SC	0 – 40	Average – Bad	Big	No limit

4.2 Semi-Logarithmic Curve of the Sieved Cumulative Percentage

The interest of these curves is to determine some sedimentologic coefficients (median, percentile, medium grain, dispersion, skewness and kurtosis) usable in the interpretation of the various sedimentary environments. For this, we use the dimensions corresponding to the percentils (5, 16, 25, 50, 84, 95 and 99%) and their equivalents in unit (Ø) by the following formula of Krambein: Ø = - log d (mm), in order to determine the sedimentological coefficients according to the formulas of Gradzinski (1976)16:

- Median (Md): Dimension (in unit µm or Ø) corresponding to the percentile 50% on the cumulative grading curve.
- Percentile (C): Dimension (in unit µm or Ø) corresponding to the percentile 99% on the cumulative grading curve.
- Medium grain (Mz): $Mz = \frac{Ø16 + Ø50 + Ø84}{3}$
- Dispersion coefficient (δi) : $δi = \frac{Ø16 - Ø84}{4} + \frac{Ø5 - Ø95}{6.6}$

The application of the sedimentological coefficients: From the values of dispersion **δ**i (in unit Ø), one deduces the type of classification of each sample of the series according to the following table:

Dispersion (δi)	**Classification**
0.0 - 0.35	Very well classified
0.35 - 0.5	Well classified
0.5 - 0.71	Rather well classified
0.71 - 1.0	Fairly classified
1.0 - 2.0	Badly classified
2.0 - 4.0	Very badly classified
>4	Extremely badly classified

The diagram Mz/**δ**i (according to Miola and Weiser, 1968)17 is used to determine the mediums of beach compared to other mediums (see fig.5). The diagram Md/C (according to Passega, 1964)18 is used to confirm mediums of sedimentation, namely: Beach sediments, littoral sediments, neritic sediments and sediments of suspension currents of high and low speed (see fig.6).

4.3 Petrography

In order to lead a sedimentological analysis to good results, the recourse to a petrographic analysis is of an absolute necessity. Since the studied formations are sandy, or little cemented, they are adapted perfectly to the granulometric analysis. From this method of analysis, one obtains the sandy fractions and the corresponding powders of fraction lower than 40µ. The latter will undergo a chemical-weight analysis as in the case of the tender sediments, in order to deduct the proportions of the different cements of clays and calcite. The results obtained allow a classification of the sediments according to the physico-chemical and energy conditions of the deposit medium. The analysis of the sediments must be supplemented by objective evaluations (Ali, 2009)19 and Boulton (2007)20 relating to granulometry, classification, morphoscopy or others to say finally all that concerns the geological history of the particles.

The calcimetry analysis (Vatan, 1967)21 is employed to estimates the calcium carbonate percentage (%$CaCO_3$) present inside a specimen. This technique is based on a volumetric method for the evaluation of unsolved material present in a solution of hydrochloric acid (HCl). The carbonates present in the specimen are converted into CO_2 by adding HCl to the specimen according to the formulae ($CaCO_3 + 2HCl \longrightarrow CaCl_2 + H_2O + CO_2$). As a result of the pressure of the CO_2 released, the water in a burette that is de-aerated rises. The difference in level measured is an indication for the released quantity of CO_2, from which the carbonate content can be calculated. The carbonate content is expressed as equivalent calcium carbonate content.

5. Analyses Results

The results of observations and analyses of the work undertaken in the field and the laboratory are distributed in the following way:

- The observations and measurements in the field have proved that: the tortonian sediments rest in angular unconformity on older formations of Cretaceous (Turonian or Emscherian); these observations underlined the limits of sequences, especially represented by erosive contacts (see profiles) and various sedimentary structures.
- The granulometric analysis at the laboratory has given the various modes of transport; the sedimentological coefficients and determined the sedimentary environments.
- The petrographic analysis at the laboratory for the whole of the samples has given the essential or secondary components for sands or tender formations.
- The morphoscopic analysis of quartz was approved with a binocular study.
- The washing of the collected samples for a paleontological goal has proved a total absence of microfossils, therefore an azoic formation.

6. Discussion of the Results

6.1 Petrography Analysis

No classification of the sedimentary rocks allows expressing all the variability of the qualifying factors which characterize as exactly as possible the studied samples. However, a satisfactory lithological description can be carried out while emphasizing the principal criteria which are directly related to the genesis of the rocks. According to Vatan (1967)21, Chamley (1987)22 and Cojan (1999)23, these criteria are represented by the figurative elements, the cement, the structure and the color of the rock.

With the exception of certain slender clayey levels of delta plain and a swampy level on the base, lower Tortonian consists of sands or very tender sandstones with low clayey content, of whitish color or yellowish by weathering. Higher Tortonian is of the same composition in its lower part, however, towards its higher part the sedimentation becomes marshy with slender gypsies intercalations. We note the presence of silicified wood fragments, therefore a development of terrestrial plants in the highest zones of the basin environment. One notes also the presence of iron-bearing elements which are the product of deterioration of the ferruginous crust at the top of the sediments of Langhian-Serravalian.
According to the classification of Czerminski (1957)24, a systematic ternary diagram of sand, clays and carbonates), the petrographic analysis shows that the sediments are divided into two great sets of sandstone and tender formation. The sandstones are especially represented in two important fields of sandstone s.s. and argillaceous sandstone, and only of some marly sandstone samples with very small percentage of carbonates, which explains a purely detrital origin of the material. The tender sediments are much more argillaceous as are carbonated, and are represented by clays s.s., (marly, sandy and marno-sand spreaders) clays, marls s.s. and argillaceous marls.

6.2 Morphoscopy and Origin of Quartz

The morphoscopic analysis of quartz was carried out with a binocular microscope (see photos 9 to 15). The account of the grains was carried out on 300 grains approximately. The relative percentages of blunted glow (BG), the round mats (RM) and not-worn (NW) were calculated according to the scale of Powers (1953)25. A morphoscopic examination shows the omnipresence of the blunted glow grains (85%) what underlines the influence of transport by water. The RM grains are little and their percentage does not exceed the 15%. These quartz grains show traces of shock visible with the binocular microscope in the form of small cups, testifying to a wind resumption of the small particles. The presence of a ferruginous coating on some grains indicates the beginning of a pedogenesis. The NW grains are shown in very small percentage (< 3%). The presence of these grains would indicate a close source of contribution, with little reworked sediments. The quartz grains are then well blunted and sometimes even rounded and gleaming, which thus testifies a long river transport. The distant origin, probably Saharan, is also confirmed by the total absence of feldspars and the scarcity of the micas in the sediments.

6.3 Paleontology

The tortonian age, of these azoic sediments, was allotted by analogy of lithological position with the Miocene's sediments of Mechta Remila and Koudiat Naga located in the north of Tebessa. The micropaleontologic analysis in this area was determined by Van Ngoc in Kowalski & al. (1995a) 7. The authors have proved an age of Langhian-Serravalian to the sediments belonging to the lower part of the Miocene profile located under an iron-crust level and of Tortonian to those in its upper part.

6.4 Sedimentological and Sequential Analyses

The determination of the sedimentation and depositional environment studies (Henchiri, 2007)26, Moutaz and al. 2012)27 and the sequential analyses (Nichols, 2007)28 and (Sergio, 2007)29 are essentially based on the field works (sedimentary structures and textures, limits of the sequences…) and the laboratory analyses (granulometry, calculation of the different sedimentological coefficients, petrography…). All these studies, in particular the latter ones, are known under the name of sedimentological methods (Moiola and Weiser, 1968)18, Passega (1964)18, Visher (1969)15 and Folk (1966)30.

The granulometric, structural and sequential analyses of the four profiles sediments have given several sedimentary cycles. The sedimentary sequences with recurrence of several rhythms and with the hardened, perforated or gullied surfaces are primarily of order 3 or mesosequences (Mitchum and al., 1977) 31.

6.4.1- Lower Tortonian

6.4.1.1- Bouroumane Profile (fig.4A)

It lies on limestones of Turonian and is represented by four sedimentary cycles whose the first one makes 42m, the second 28m, the third 69.5m and the fourth 41.5m.

The first cycle is symmetrical and represented by a river simple megasequence 1 and a deltaic inverse megasequence1. The river megasequence is made up of two simple sequences with more coarse and scattered basic grains, surmounted by finer sediments with dishes structures. The deltaic megasequence is made up of four inverse sequences, with variable thickness, from which two of them begin with silty clays and the two others by clayey sands. The unit passes then to medium-coarse sands with tilted structure. These deltaic sediments represent in majority a delta forehead with sandy sediments surmounting an argillaceous base belonging rather to prodelta.

The second cycle is also symmetrical and represents a lake simple megasequence 2 and a deltaic inverse sequence. The lake sediments are fining-up passing from medium sand to argillaceous fine sand with parallel structure. The deltaic sequence makes the passage between argillaceous fine sand with horizontal structure and medium sand, passing to coarser one towards the top, with inclined structure; it represents the sediments of the delta forehead.

The third cycle is represented by the river simple sequence 3 and the deltaic inverse megasequence 3. The river sequence begins with disordered average sands which pass to fine sands with dishes structures and sometimes with current wrinkles. The inverse megasequence 3 of the delta forehead is represented by three inverse sequences where each one starts with fine-medium argillaceous sand, surmounted by coarsening-up grains of medium-coarse sand. In this megasequence, one observes strongly tilted structures of slip.

The fourth cycle is only represented by a fluvial simple sequence 4 in the lower part, becoming marshy in the upper part. The sand river sediments are medium and bit disordered grains at the base passing higher in finer grains with dishes and slightly tilted structure. At the top, the grains are very fine with unidirectional and tilted structures. In the highest part of the sequence, silty clays with horizontal stratifications are observed.

6.4.1.2- Djebel Khorza Profile (fig.4B)

This profile makes a vertical continuation with Bouroumane profile (fig.3A). Therefore an offlap sedimentary structure is developed towards the west of the basin. It is composed of four other sedimentary cycles whose thicknesses from the base are respectively: 37.5m, 16m, 46.5m and 58m.

The fourth cycle rests on the lower Turonian limestones and it is represented only by the inverse sequence 4 which makes approximately 30m of marshy silty clay similar to that which is at the top of the Bouroumane profile. This marshy clay is surmounted by deltaic sandstones with medium-coarse grains and strongly tilted structure.

The fifth cycle is composed of a fluvial simple megasequence 5 and a deltaic inverse sequence5. The fluvial megasequence is composed of sandstone with medium-fine grains, scattered at the base and with tilted dishes structure at higher part. The deltaic inverse sequence begins with silty clays passing to fine-medium sandstones with tilted structure.

The sixth cycle represents a lake simple megasequence 6 and a deltaic inverse megasequence 6. The lake sediments are with parallel structure and vertical graded bedding with mainly fine grains at the base passing at the top of each sequence in more argillaceous sediments. The deltaic megasequence is mainly with medium grains conversely graded and a tilted structure. One of the sequences begins by a slightly silty argillaceous passage.

The seventh cycle is composed of a fluvial simple megasequence 7 and a deltaic inverse megasequence 7. The river sediments are of medium graded grains, with disordered structure at the base, but more ordered and inclined presenting dishes figures higher. The deltaic sediments are conversely graded and generally with fine-medium grains containing thin levels of coarse grains. At the base of certain sequences, one observes slight silty clay in intercalations. At the base of the sequences, the structure is rather horizontal that in top where it is quite tilted marking the direction of the currents.

6.4.2 Upper Tortonian (fig.5)

The sedimentological analyses, carried out on two profiles of upper Tortonian of El Ma Labiod basin, confirmed a downlap structures mode deposits towards the west of the basin. This higher part of the tortonian basin includes four types of sedimentary environments formed of detritus continental material which develops in river-washes, deltaic, lake and marshy deposits.

The sequential analysis of the two profiles made it possible to define five elementary cycles. The lower part the profile reveals passages between river and delta sediments, which pass in higher part to those of lake and finally in marshy sediments. The sedimentary sequences with recurrence of several rhythms and with hardened, perforated or gullied surfaces are primarily of order 3 or mesosequences (Mitchum and al., 1977)31.

A sequential correlation (fig.5), between profiles, made it possible to prove the dynamism and the mode of the basin development, and also giving its lateral variation in sedimentary volume from the eastern to the western zones. This sequential correlation, inside the same basin, is of a paramount importance for the recognition of its geological history and consequently of its comparison to other basins of the same or different age in order to give the various developments and sedimentological aspects of the study area.

The first two cycles, alternate in river and delta sediments (approximately 150 m of thickness), are entirely developed in the Tenoukla Bordj profile, being located within the eastern part of the study area. At the base of the profile, appears a deltaic segment connecting with the summit part of the lower Tortonian sediments, therefore, there is always a downlap structures development towards the western direction of the basin.

The third cycle (50m) begins with a fining-up sequence of river sediments, only expressed in the Tenoukla Bordj profile, and then surmounted by a coarsening-up sequence of deltaic sediments, which make the base of the second profile located in the Tenoukla Col towards the west. Within this latter profile the deltaic sediments rest in angular discordance on the marly emscherian sediments, therefore one note a development of downlap structures towards the west.

The forth cycle (40m), which appears in lake sediments at the base and deltaic ones at the top, is presented at the same time within the two profiles (Tenoukla Bordj and Tenoukla Col). However, it is with more important lake sediments in the first profile and with those of deltaic sediments relatively developed in the second profile. Therefore, it is clear that the old sediments are always developed in the east than in the west where the recent sediments discover the old ones and exceed them.

The fifth cycle begins by the lake sediments and passes gradually to those of marsh. It is expressed in the two cited profiles above, however, it is much more developed in that located in the west where the lake sequences of the base are more important and the marshy deposit covers and exceeds greatly the eastern sediments of the Tenoukla Bordj profile, therefore a downlap development is repeated even in the upper part of the formation.

The petrographic analyses show silici-clastic sediments with rare argillaceous intercalations. At the upper part the formation they pass to a marshy facies with the mean intercalations of crystalline gypsum. One notes the sporadic presence of silicified wood, the rare spangles of muscovite, but, a total absence of feldspars. According to Tucker (1995)32, one presumes a far-off river transport of an origin probably Saharan.

7. Diagrams Interpretation of the Profiles

The analysis of the diagrams Mz/δi (according to Friedman,1962)33, and (1978)34, (Moiola and Weiser,1968)17, and C/Md (according to Passega, 1964)18 confirm the results obtained by the sequential analysis and those obtained by the method of (Visher,1969)15 concerning the different mediums and sedimentary environments of each profile. By treating separately the studied profiles, the values of the sedimentological coefficients always check the sequences and sedimentary cycles; however, it is preferable to consider the whole of the profiles in the same diagram in order to deduce the different mediums which testify the variable energies of transport and sedimentation.

7.1 Diagram Mz/δi (fig.6)

The analysis of the relations between the sedimentological coefficients of the average grain Mz and the dispersion δi (Mz/δi) shows variable values, according to the different environments (deltaic, fluvial or lake) which knew the basin during the Tortonian. The values of the two sedimentological coefficients are between (0.2 - 3.1) for Mz and between (0.50 - 2.3) for δi. At first sight, one notes that the diagram (fig.4) shows a distribution of the samples in three distinct fields. The field (A), with low values of Mz (Ø) and variables of δi, represents, in particular, the deltaic sediments and those of the bed river basic where the energy of the environment is higher. The field (B), with average values of Mz (Ø) and little dispersed of δi, represents the sediments of an average energy of river (shallow mediums) and those of delta having a modest energy too. The field (C), with the highest values of Mz (Ø), and weak and little dispersed of δi, indicates a weak energy which represents the lake sediments and those of alluvial and delta plains.

7.2 Diagram C/Md (fig.7)

The analysis of the relations between the sedimentological indices represented by the median (Md) and the percentile (C: fractile correspondent to 99%), shows a large differentiation of the values of the median (110 - 910µm) and of coefficient C (310 - 6000µm). These variations of values are in connection with the change of the medium (river, delta and lake) of sedimentation, which is clearly shown by three quite distinct fields with variable energy.

The restrict field (A) characterizes in particular the lake sediments whose the values of the medians are generally lower than those of the fluvial medium, and the values of the coefficient C are also low and little variables. These characteristics represent the sediments of the suspension currents (homogeneous suspension). To these lake sediments, one joints the fine sediments of the alluvial plains and those of the river environments in deep hollows characterizing a very weak energy.

The field (B) characterizes the river sediments of an average energy (especially of split suspension) with values of the coefficients (C and Md) generally average and little dispersed, but in majority of the cases lower than those of the delta and the high currents of suspension.

The field (C) is the broadest one, it characterizes the deltaic sediments which show a great diversity of the values (C and Md), which correctly translate the variation of energy which is related to the displacement of the delta face.
The sedimentological coefficients (C and Md) of the whole sediments of the basin confirm then the presence of sedimentary environments of very variable energy of delta, river and lake.

8. Conclusion

The depression of the Western part of the basin was done after emergence of the Eastern part of the basin where settled the older sediments which are finished by an iron-siliceous crust of continental weathering.

The field works have shown that the miocene sediments of the Western part of the basin, like that of Eastern ones, were deposited in angular unconformity within the erosion surface above the former sediments folded during the finished-lutetian atlasic phase.

The detritus sediments are deposited in four continental environments (river, delta, lake and marsh) and the sedimentation process has known an offlap structures development towards the western zones of the basin. The sequential analysis has confirmed the presence of seven sedimentary cycles in the lower Tortonian sediments and five others in its upper part.

The petrographic and morphological analysis proved a far-off water transport of an origin most likely Saharan. The existence of the silicified pieces of wood indicates a development of the plants in the highest zones of the environment.

The paleontological analysis proved an azoic area; therefore the conditions within the basin were not favorable for the development of the life.

According to the recorded thicknesses and without including the erosion phenomenon of this higher part of the basin, one notes that a continuous subsidence, becoming weaker towards the summit (marshy sedimentation), that knew this tortonian basin exceeds largely that of the langhian-serravalian basin located towards the eastern part at the algero-tunisian borders.

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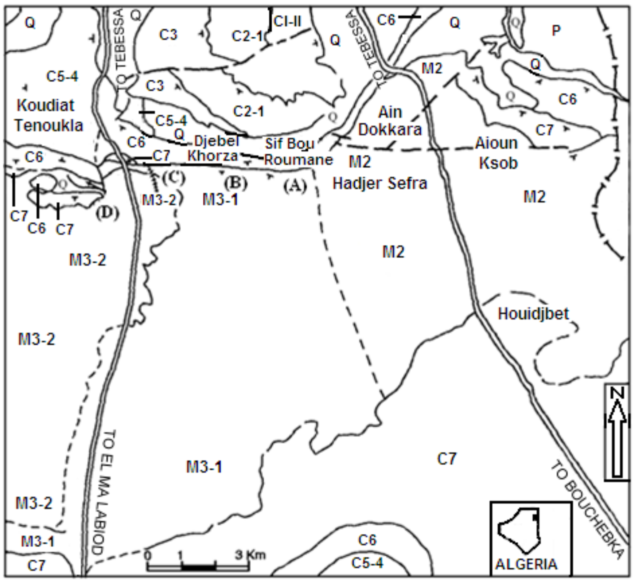
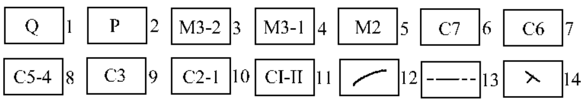


Figure 1: Geological draft of the area of El Ma Labiod (Durozoy, 1949 and 1956), reinterpreted by the authors, and the position of the four profiles A, B, C and D.



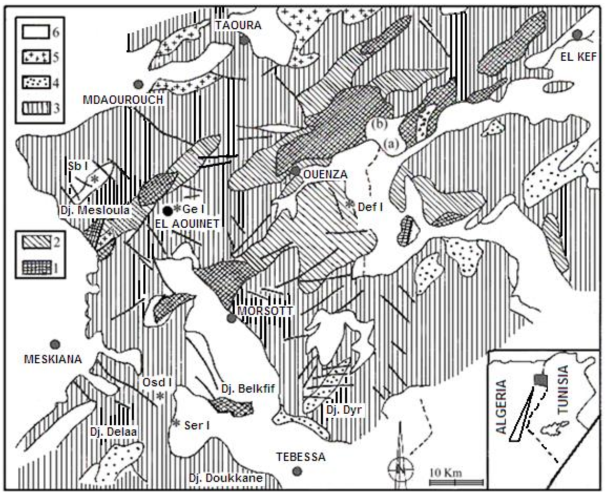


Figure 2: Geological map of the Eastern Saharan Atlas at the Algerian-Tunisian borders (Wildi, 1983), simplified by the authors

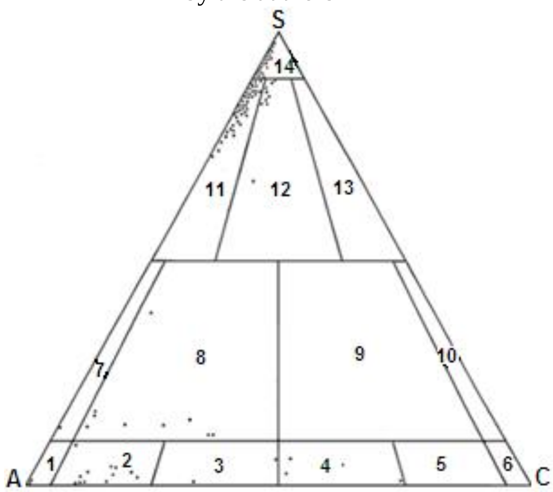


Figure 3: Classification of tortonian sediments (according to Czerminski, 1955)

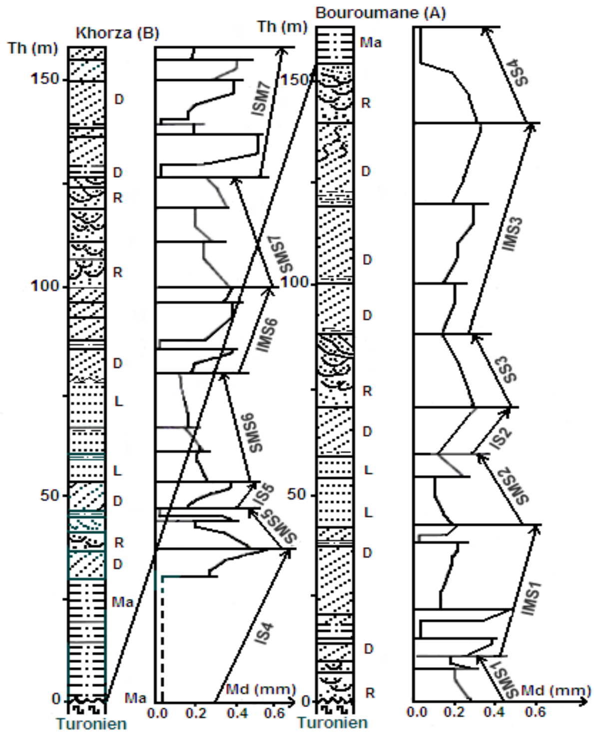


Figure 4: Lower Tortonian: geological profiles (A) and (B)

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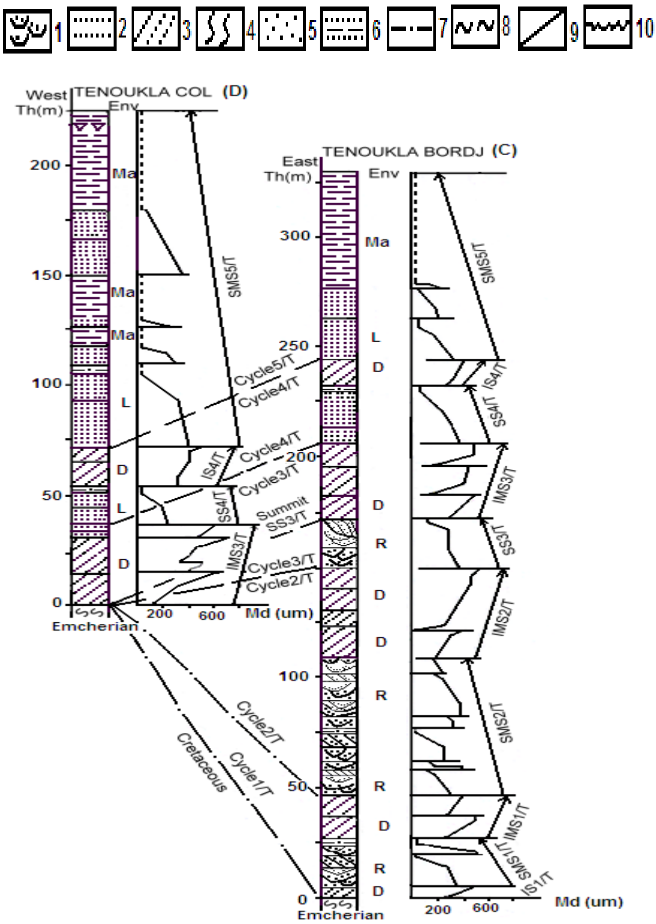
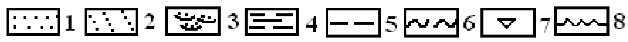


Figure 5: Upper Tortonian: geological profiles (C) and (D)



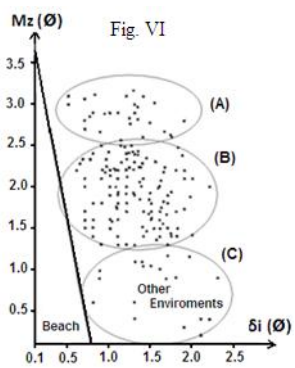


Figure 6: Diagramme Mz/δi of the tortonian sediments (according to Moiola and Weiser, 1968)

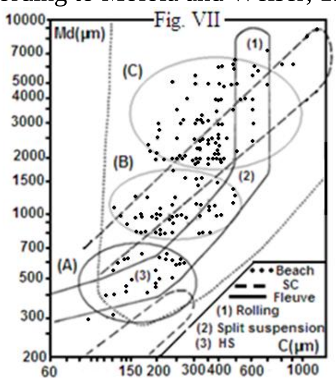


Figure 7: Diagramme C/Md of the tortonian sediments (according to Passega, 1964).

Captions:

Captions (tab.1) : A/B: Degree of mixing of two populations of grains A (saltation) and B (suspension); A/C: Degree of mixing of two populations of grains A (saltation) and C (Rolling); DPZ: Breaking point of the diagram in limit of medium grains; GPZ : Breaking point of the diagram in limit of large grains; SC: Suspension current; ZBW: Zone of breaking waves; ZTW: Zone of translative waves.

Captions (fig.1) :A- Profile of the Tenoukla Bordj ; B- Profile of the Tenoukla col ; 1- Quaternary (Q) ; 2- Pliocene (P) ; 3- Upper Tortonian : multi-coloured clays (M3-2) ; 4- Lower Tortonian (M3-1) : sandstone with argillaceous intercalations; 5- Langhian-Serravalian (M2) : sandstone ; 6- Emscherian (C7) : lumachella marls ; 7- Turonian (C6) : limestone (base) and marls (summit) ; 8- Cenomanian (C5-4) : lumachella marls ; 9- Vraconian (C3) : black and marly limestone ; 10- Albian (C2-1) : grey limestone ; 11- Aptian (CI-II) : limestone (summit) and dolomitic limestone (base) ; 12- Geological contours ; 13- Faults ; 14- Dips.

Captions (fig.2) : 1- Trias, 2- Crétacé inférieur, 3- Crétacé supérieur, 4- Paléogène, 5- Miocène, 6- Quaternaire, (a)- Hammeimat, (b)- Djebel Harraba et Sidi Embarka, (*)- Forages.

Captions (fig.3): 1- Clay; 2- Marly clay; 3- The argillaceous marle; 4- The marle; 5- Marly Limestone; Limestone; 7- Sandy clay; 8- Marlo-**sandy** Clay; 9- marlo-sandy Limestone; 10- sandy Limestone; 11- Argillaceous sandstones; 12- Marly sandstones; 13- Carbonated sandstone; 14- Sandstone. A- Argiles; C- Carbonates; S- Sands.

Captions (fig.4): D- Delta ; Md- Median; IMS- Inverse megasequence; IS- Inverse sequence; L- Lake; M a – Marsh; R- River; SMS- Simple megasequence; SS- Simple sequence; Th- Thickness in meters. 1- Dishes structure sandstone; 2- Parallel structure sandstone; 3- Tilted structure sandstone; 4- Flow structure sandstone; 5- disordered structure sandstone; 6- Argillaceous sandstone; 7- Silted clays; 8- Marls; 9- Limits of facies; 10- Angular unconformity.

Captions (fig.5): Cr- Cretaceous; D- Delta; Env- Environment; IMS- Inverse Megasequence; IS- Inverse Sequence; L- Lake; M a - Marsh; Md- Median in micron meters; Mi- Miocene; N°- Sample Number; R- River; SMS- Simple Megasequence; SS- Simple Sequence; T- Tortonian; Th- Thickness in meters. 1- Sandstone with horizontale structure,; 2- Sandstone with tilted structure ; 3- Sandstone with dished structure; 4- Clays; 5- Clays with sandstone; 6- Marls; 7- Inserted gyps; 8- Angular unconformity (Cr/Mi) and disconformity.

Captions (fig.6 and 7): HS- Homogeneous suspension, SC- Suspension currents.