The Organic-Rich and Siliceous Bahloul Formation: Environmental Evolution Using Facies Analysis and Sr/Ca and Mn Chemostratigraphy, Bargou Area, Tunisia

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1. Introduction

The Cenomanian-Turonian transition deposits in Tunisia (**Figure 1; Figure 2**) were initially described by Pervinquière (1903) who distinguished black shales "*marnes schisteuses*" and laminated limestone (*calcaire en plaquettes*) in Central Tunisia representing the Turonian onset. They were also described by Berthe (1949) and by Schijfsma (1955). Then, Burollet et al. (1952) and Burollet (1956) have attributed these deposits to the Bahloul Formation which is well developed in its type locality, Oued Bahloul, located southward Kessera village in central Tunisia.

These different lithostratigraphical units are geographically relayed and are controlled by the global relative sea level rise causing the major latest Cenomanian transgression which was interpreted as a combined phenomenon between a long-term sea level rise and basin subsidence (Haq et al., 1987; Hardenbol et al., 1993; Luning et al., 2004) generated by enhanced plate tectonic activity especially in the Atlantic area and by the change in the Milankovitch frequency band (Soua, 2010). The major rise in the Cenomanian sea level was interrupted by five third order relative sea-level falls (Haq et al., 1987). In the Bargou area (**Figure 1**), the Cenomanian-Turonian deposits are mainly composed of organic-rich black shales include special siliceous radiolarian-bearing laminated beds. No previous sequence stratigraphic framework has been taken yet on such siliceous deposition. In this work, we attempt to detail sequence stratigraphic framework using facies association and Sr/Ca and Mn variation.

2. Geological setting

The Bargou area (Figure 1), connected palaeogeographically to central Tunisia, is characterized by (1) emerged palaeohighs displaying gaps and discontinuities (Turki, 1985)

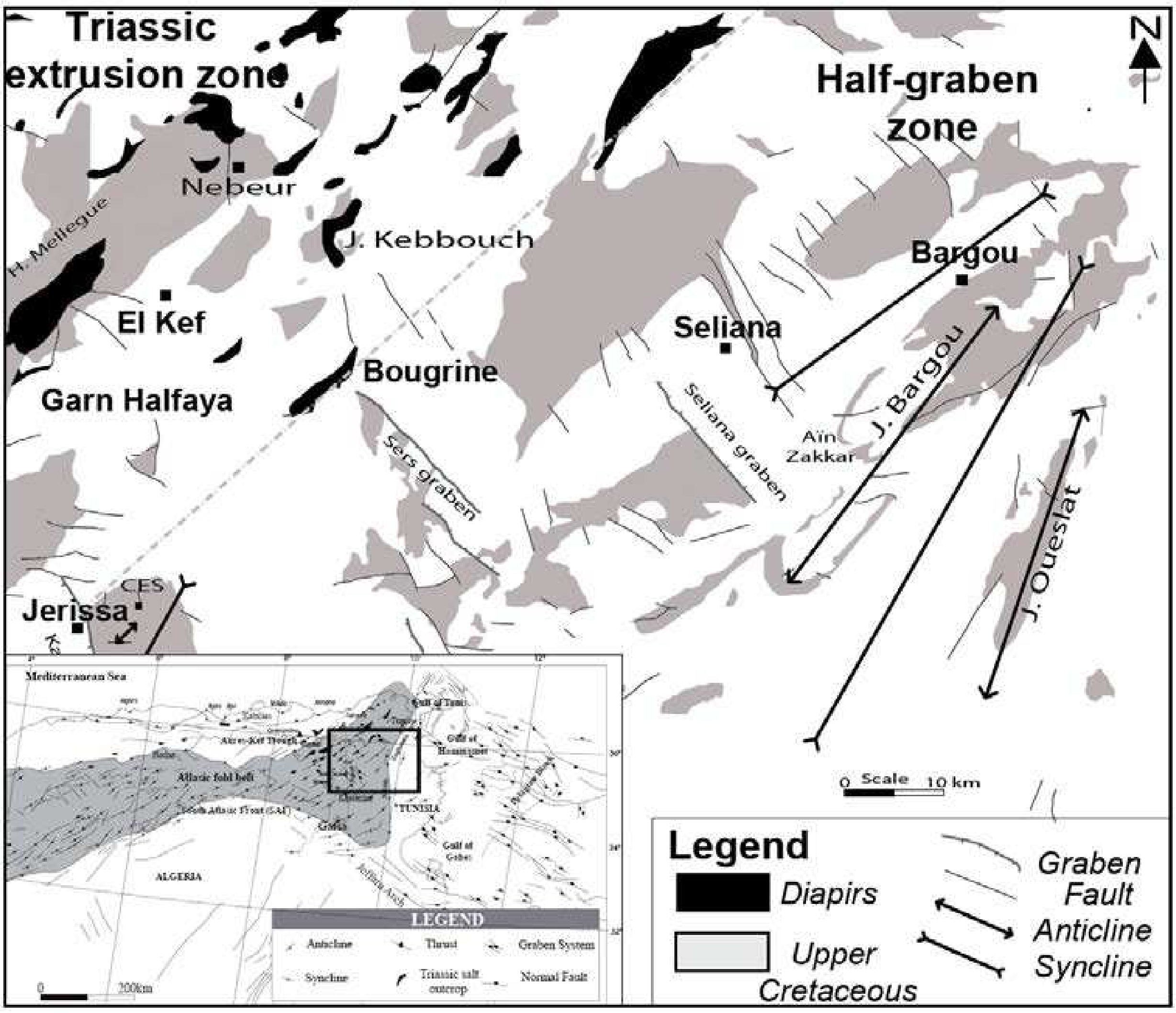

Fig. 1. Tectonic map of the central Tunisia Domain showing main upper cretaceous deposits and structures.

and (2) subsiding zones affected by deep water sedimentation. This area is dominated by N140° and N70° trend faults limiting several blocks. Cretaceous sedimentation varies on both sides. The Bargou mount is an anticlinarium structure NE-SW trending, with complex anticline folds separated by narrow synclines. This wide anticline structure is formed mostly by reefal upper Aptian to pelagic lower Albian strata. Its structural evolution may be summarized as follow: (1) during the late Jurassic to early Cretaceous, the area was subjected to a major extensional phase that delimited horst and graben systems (Martinez and Truillet, 1987) (2) In the uppermost Aptian, a regional compressional pulsation affecting the north-African platform had resulted from a transpressional scheme (Ben Ayed and Viguier, 1981) (3) New NNE-SSW trend anticline structures appeared attested by the Albian Fahdene Formation onlap features on the reefal aptian Serj deposits in subsurface (Messaoudi and Hammouda, 1994) or Albian-upper Aptian unconformity in outcrops (Ouahchi et al., 1998). (4) During the Albian, the geodynamic evolution is marked by the sealing of lower Cretaceous structures during an extensional phase that persisted to form graben systems promoting organic-rich and siliceous strata deposition throughout upper Cenomanian to Lower Turonian times. The major faults in this area are represented by

N140° and N70° trend features. The first trend borders the graben systems that extend across the Central Atlas, whereas the second one parallels the principal axe of the Bargou anticlinarium. Around the Bargou anticlinarium, the Bahloul thickness is significantly variable. It may vary from 10m to 40m in thickness. Uniquely, in this area, the top of the Bahloul represents many cenomanian olistolith levels (Soua et al., 2006) marking syndepositional tectonic activities (Turki, 1985). Elsewhere, these syn-sedimentary features are represented by local slumping. Generally speaking, in north-central Tunisia as well as on the Pelagian Province, Cretaceous diapiric movements of Triassic salt played locally an important role in controlling C/T deposition, (Patriat et al., 2003; Soua and Tribovillard, 2007; Soua et al., 2009). They are characterized by a marked thickness reduction and partly by development of detrital deposition (sandstones, conglomerates). The diapiric rise, starting from Aptian (and even before) to approximately middle Eocene was probably continuous, but it increased during periods of tectonic instability. Thus earlier diapiric movements and rise-up are super-imposed to the extensional features favouring depocenters individualisations in the central parts of rim-synclines (Soua et al., 2009).

3. Material and methods

In total 132 samples (Bahloul formation) are collected from Bargou area, Aïn Zakkar (AZ) and Dir ouled yahia section (OKS), throughout the C-T transition deposits including the Bahloul Formation (Figure 2). The high resolution sedimentological interest consists of sequence stratigraphic interpretation of the facies association inferred from classical sequence stratigraphy.
Major elements concentrations (Figure 3) were determined using Mass spectrometry (ICP-AES) process and trace elements were determined using Induced Coupled Plasma Mass Spectroscopy (ICP-MS) at ETAP. In this study Sr/Ca and Mn variation curves were determined to check relationships with sea level flucruation as described by Mabrouk et al. (2006). Thin sections were made in the hard limestone samples in order to analyze microfacies in the laboratory of sedimentology of the "Office National des Mines".

4. Facies association

Bargou area represents special organic-rich deposits showing mixed facies composed of both calcareous and siliceous material (Figure 4). In this case, at the Dir ouled Yahia (OKS) and Ain Zakkar (AZ) sections the C-T transition deposition became not conform to the typical Bahloul Formation as defined by its author (Burollet, 1956). Closer inspection of microfacies composing this mixed facies allows distinguishing diverse types (A-G) and differs from the typical Bahloul by the Facies E (see later, Figure 5).

4.1 Facies A: Calcisphaeres-rich massive limestone

It forms massive light grey limestones with nodular base. These calcisphaeres-rich are mainly packstone in texture and show bioturbations. They characterize the lower part of the studied C-T transition series equivalent to the typical Bahloul Formation. Among calcisphaeres, *Bonetocardiella sp., Calcisphaerula sp., and Pethonella sp.*, are associated with (1) diversified keeled planktonic foraminifera (*Rotalipora cushmani, Praeglobotruncana stephani, Dicarinella algeriana*) and globular forms like whiteinellids and hedbergellids (2) benthonic foraminifera (*Textularia, Lenticulina*) (3) echinoderms debris and (4) rounded phosphate and glauconite grains that may be evidence of reworking.

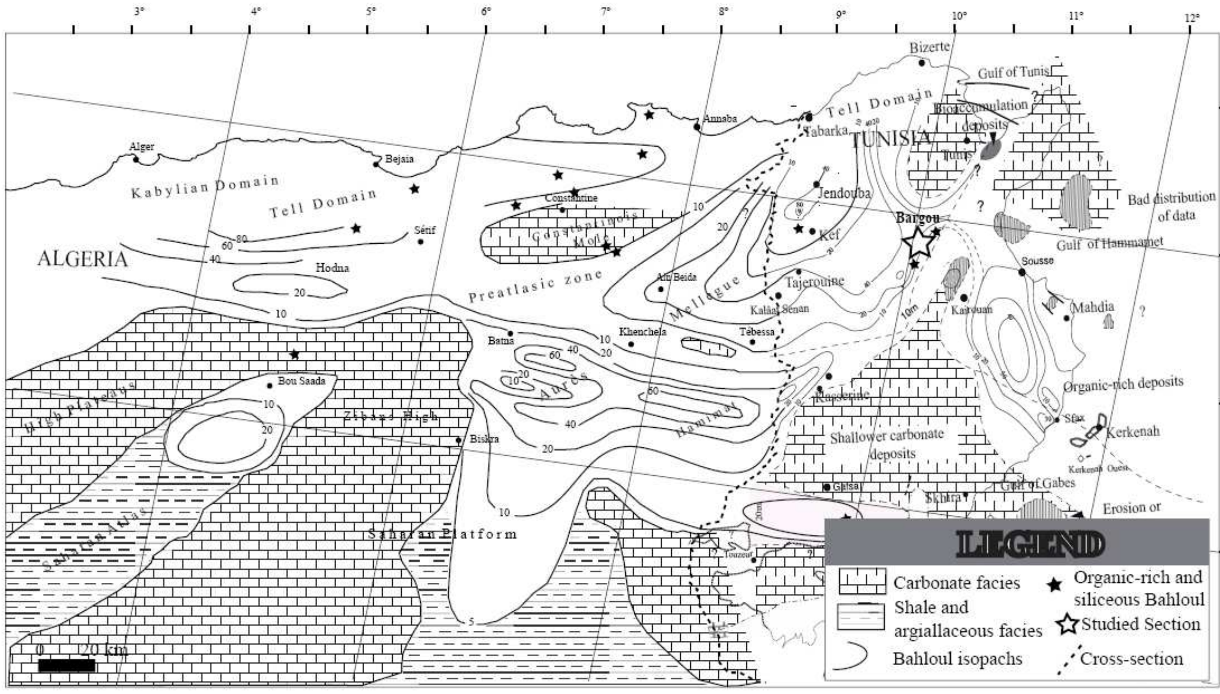

Fig. 2. Facies and thickness of the Organic-rich Late Cenomanian – Early Turonian and age equivalent units in Tunisia and Eastern Algeria superposed on the Structural setting of the eastern Maghrebian Domain during the C-T transition (inferred from the palaeogeographic map). Note the E-W trending structures are related to the Tethys rifting and the NW-SE trending structures are related to the Sirte rifting (Soua et al., 2009). Note that the isopach trends illustrated are simplified and short-distance thickness, and facies changes occur, related to the complex tectono-halokinetic palaeorelief at the time (see **Figure** 1). Organic-rich and carbonate or age equivalent units are not present on present palaeohigh.

4.2 Facies B: Pseudo-laminated limestone

They are of wackestone or mudstone texture (Figure 4). Those of wackestone texture are especially dark. In contrast those of mudstone texture are light-coloured and show frequent bioturbation marks and less varied microfauna. Similar facies are described by Layeb (1990). Within these pseudo-laminated limestones, the exclusive presence of globular planktonic foraminifera in organic-rich micritic matrix. This situation is sometimes interrupted by bioclastic material discharges (calcispheres, echinoderms debris) coming probably either from the platform or by the oxygenated episodes (supported also by ichnofossils presence).

4.3 Facies C: Laminated black shales

The Bahloul Formation is mainly composed of laminated black shales alternated with light marly levels. Microfacies analysis reveals that these black shales are constituted by tightened alternation composed of (1) light inframellimetric packstone and (2) dark mellimetric mudstone laminae.

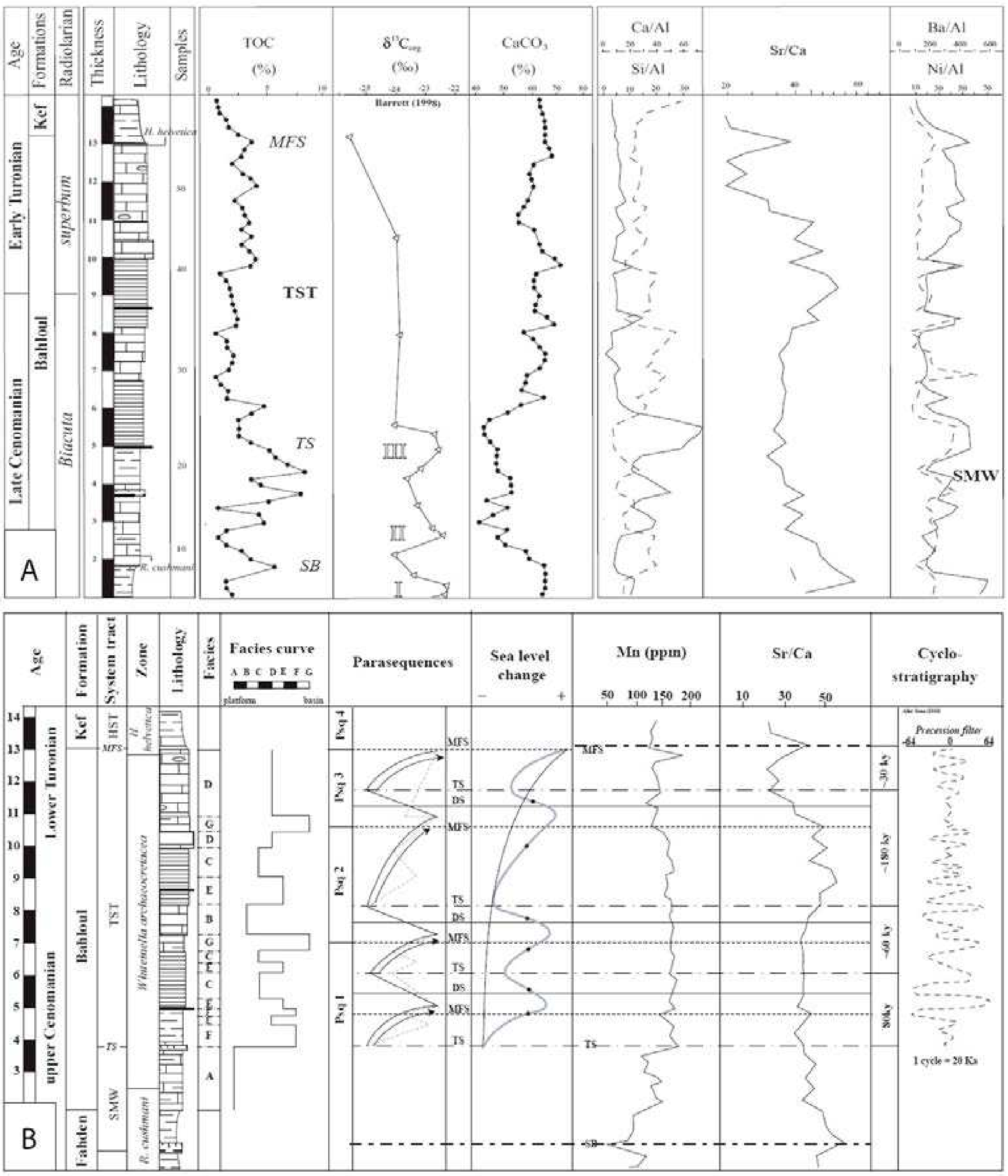

Fig. 3. **A** Lithology, Total Organic Carbon (TOC), calcimetry and chemostratigraphy data of the Ain Zakkar section combined with biostratigraphic framework. **B** Facies curve, parasequences sets, global trend and age of parasequences in Ain Zakkar section (Bargou area, central Tunisia).

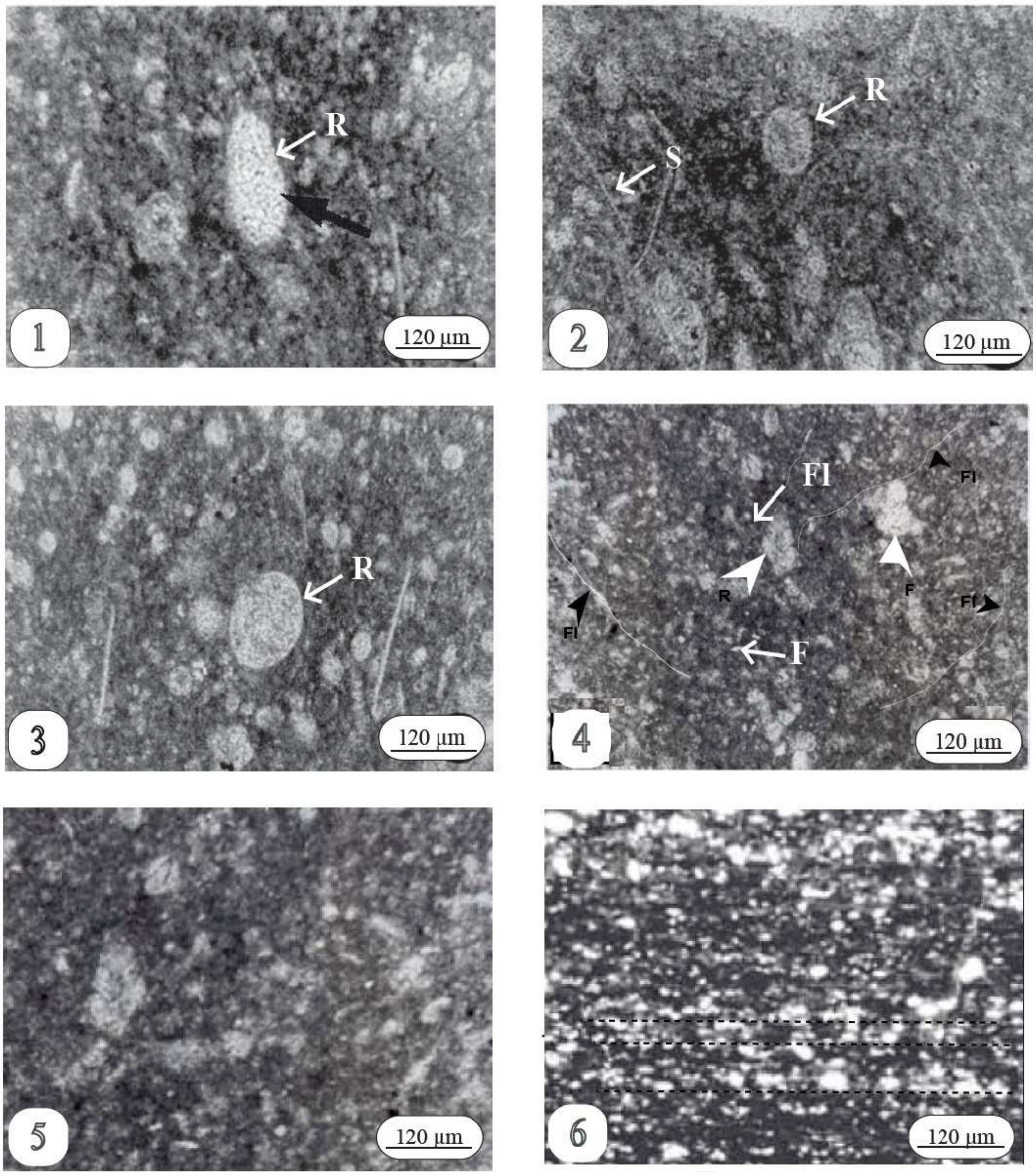

Fig. 4. (1-3) Micrographs of a radiolarian-rich layers from the Bahloul Formation at the AZ and OKS sections showing nassellarians and spumellarians, (4) micrograph across planktonic foraminiferal-rich and filaments beds; (5) microconglomeratic level at the base of the section showing broken skeltons of diverse fauna; (6) micrograph across laminated limestone beds. Note R: radiolarian, F: planktonic forminifer, Fl: filament, S: sponge spicule.

4.3.1 Light laminae

The light laminae contain abundant calcisphaeres and globular scarce biserial/triserial and trochospiral planktonic foraminiferal which may agglomerated in aggregates. The dominant biserial and triserial, *Heterohelix moremani*, *H. reussi* and *Guembelitria cenomana* are associated to scarce trochospiral forms belonging to whiteinellids and hedbergellids. These laminae may also contain either exclusively calcisphaeres like as within the lower and upper part of the studied section or associated whiteinellids heterohelicids or hedbergellids. Some laminae display thus, monospecific association.

4.3.2 Dark laminae

These wackestone texture laminae display significant pellets concentration and scarce globular planktonic foraminifera. The ovoid pelletoids represent no internal structure and they correspond probably to small organic-rich pellets (Purser, 1980). Their origin is discussed but probably they come from gelatinous planktonic forms analogue to the present salps. Currently, in Mediterranean Sea, salps and notably *Salpa fusiformis* can be absent during several years from the water mass, then it forms suddenly large scale population that may influence the whole pelagic community. Their diatoms-rich pellets become abundant and generate organic-rich flux involving a considerable organic matter input through the lower water mass (Morand and Dallot, 1985).

4.4 Facies D: Filament-rich laminated limestone

These filaments-rich laminated limestones occur in the upper part of the studied series at the OKS section. They display wackestone to packstone texture (figure 4). The filaments are present as elongated and thin with imbricated and tangled arrangement enveloping sparitic elements. We don't believe that these filaments are larval-planktonic stage bivalves as reported by Robaszynski et al., (1994) because in our material they display several features such as tangling and overlapping. Moreover, they display heterogeneous sizes. Sometimes these light-coloured, thin filaments are present as elongated or arched. Their abundance is related to that of planktonic foraminifera and defines pelagic facies (Soua, 2011). All these figured elements are slightly oriented with the stratification trend. Analogous facies was documented also in Juassic series. Within these series, similar filaments are attributed to debris of pelagic bivalves like as Picnodonta.

4.5 Facies E: Radiolarian-rich laminated black shales

In Bargou area, radiolarian-rich laminated black shales were reported from the Oued OKS section (Soua, 2005; Soua et al. 2006). They occur as decimetric laminated silicified limestone. They were labelled "Silexites" by Layeb and Belayouni (1989). The same facies occurs in Guern Halfaya, from Tajerouine area (Soua et al., 2008) and it is associated with diapir. The radiolarian-bearing laminated black shales in Bargou area are formed by millimetric light wackestone and dark mudstone laminae. The light laminae display a significant siliceous radiolarian concentration, however, the dark one display a dense organic rich small dark coloured pellets concentration.

4.6 Facies F: Dark marls with tiny planktonic globular foraminifera

Dark marls which don't exceed 1 m in thickness are present in AZ section in the lower part of the Bahloul Formation, just above the surface of condensation. They are dark and contain dissociated tiny globular chambers of whiteinellids, hedbergellids and *Heterohelicacea* (*Heterohelix* and *Guembelitria*) species within mud matrix. This facies suggests deep marine non agitated depositional pattern. In these marls, the eutrophic surface dweller *Guembelitria* scarcity, the benthonic foraminiferal absence and the surface dwellers whiteinellids and heterohelicids proliferation may indicate concurrent eutrophic condition at the surface sea water and anoxic condition at the sea floor (Soua, 2005). The same facies (dark marls with tiny globular chambers of planktonic foraminifera) is reported from the Hammem Mellegue section, Kef area (Nederbragt and Fiorentino, 1999; Soua et al., 2008; Soua, 2010).

4.7 Facies G: Light clayey limestones

They are of mudstone texture with scarce entire planktonic foraminifera having globular and keeled chambers. They are associated with rare pyritous ostracods and scarce benthic foraminifera (*Lenticulina* sp., *Bulimina* sp.).

5. Sr/Ca & Mn chemostratigraphy

5.1 Relationship between Sr/Ca and sea level change

In Bargou area, the Sr/Ca ratio curve (Figure 3) displays more than one short-term cycle that generally match with the depositional sequences. Generally speaking, higher Sr/Ca values broadly span the upper parts of LST's and HST's (respectively ~58 and ~56, Figure 3), with peak values (~58) very close to sequence boundaries (SB). The Sr/Ca ratio values generally fall through TST (mean value ~40) and remain relatively constant through the lower part of the Bahloul Formation, then show a significant decrease to much lower Sr/Ca values for reaching minimum values in the upper part of it (~20) close to the MFS at the top of the formation (Figure 3; Figure 5). This feature is conforming to that described by Mabrouk et al. (2006) in Bahloul Formation from Tunisian onshore and elsewhere.

5.2 Relationships between manganese (Mn) and sealevel changes

In Bargou area the Mn fluctuations (Figure 3) across each depositional sequence systems tract do not correlate well with either silicate or carbonate contents (Figure 5). This is may be due to the Mn supply that was coupled with the biogenic flux (e.g. organic carbon), which must have decreased during the SMW (Murphy, 1998; Stoll and Schrag, 2001; Mabrouk et al. 2006; Soua, 2010b).

Mn profile increased with rising sea-level, reaching a maximum around each MFS (Figure 3b), before decreasing again through the overlying HST, representing a period of relative constant carbonate supply.

6. Third order sequences

6.1 Vertical evolution of systems tract

6.1.1 Shelf margin wedge (SMW)

In the Aïn Zakkar location, the SMW is represented by the uppermost part of the late Cenomanian Fahdene Formation and the overlying calcisphaeres-rich argillaceous wackestone-packstone bioturbated limestones arranged by the authors in the Bahloul Formation or pre-Bahloul deposits (Accarie et al., 1999; Caron et al., 2006). The erosive base and the lenticular shape of this deposition interval suggest a channel sedimentary body. It is characterized by its highest abundance in calcisphaeres compared to planktonic, benthic foraminifera, bioclasts as well as fauna mixture.

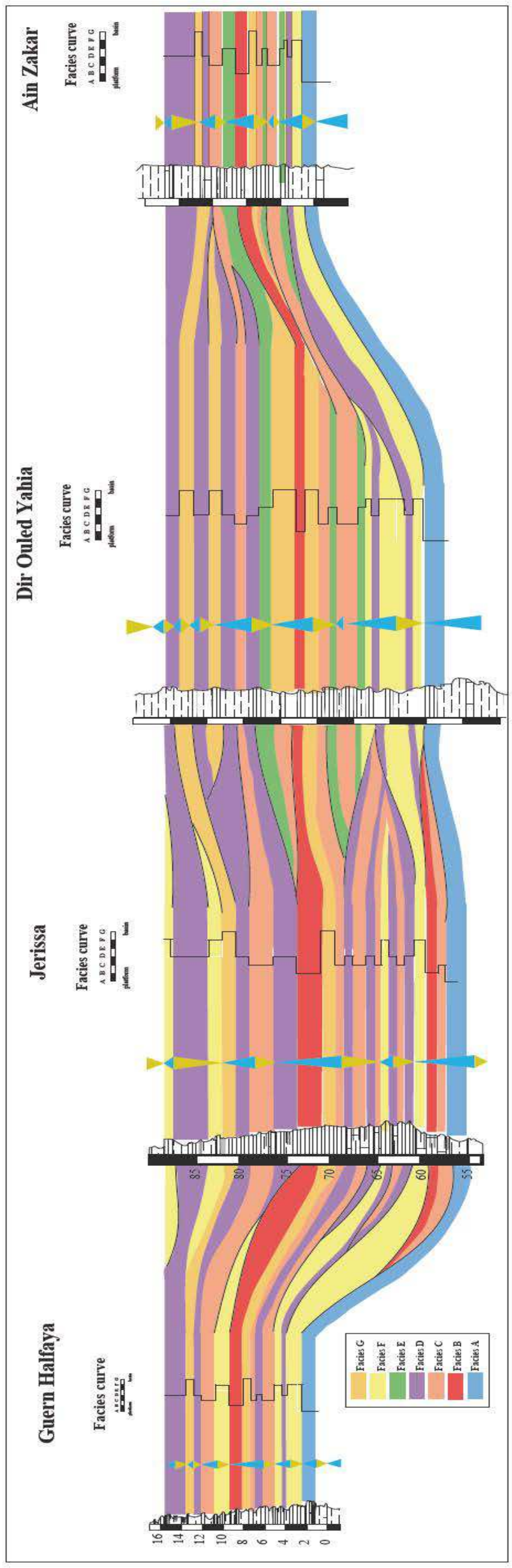

Fig. 5. Sequence stratigraphic correlation between Bargou area (OKS and AZ sections) and central Tunisia (Jerissa and Guern Halfaya, after soua, 2011)

This systems tract includes a microconglomeratic surface of condensation, rich in phosphate and glauconite grains. Internally, the microconglomeratic bed has discontinuous, wavy, parallel seams of glauconite-rich shale. Close inspection may also reveal clasts concentrations, ichnofossills (*Zoophycos* and *Thalassinoides*) and bioclasts. This surface is sharp and overlain by a (transgressive) lag of reworked bioclasts (mainly echinoderms) from the neighbor platform as well as glauconite and phosphatic grains. These data were not described by Zagrarni et al. (2008) although they are expressed in many Bahloul sections. It marks the limit between the SMW and the TST (Figure 5 Figure 6) and represents a fast shore line migration into the continent.

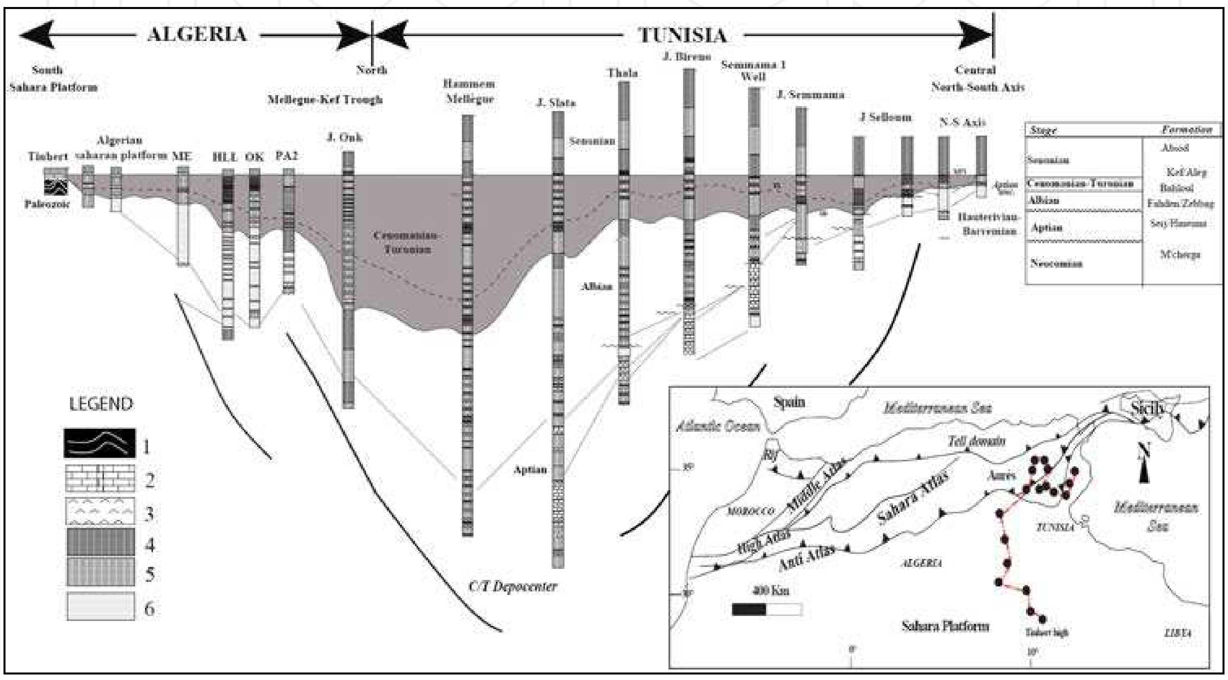

Fig. 6. Tentative correlation between several Bahloul sections in Tunisia and Algeria. Datum used is MFS (Top of Bahloul formation). 1.magmatic rocks, 2. Carbonate, 3.evaporites, 4.black shales, 5.marls/clays, 6. Sandstone.

6.1.2 Transgressive systems tract (TST)

The remainder Bahloul Formation part is considered as belonging to a transgressive systems tract (TST). Its lower boundary is represented by a transgressive surface (TS) overlying by calcareous and marly retrogradation parasequences succession (a parasequence is shallowing-upward and is bounded by a flooding surface). Indeed, following the eustatic rise, this retrogradational pattern indicates that, accommodation space creation exceeded sediment flux and the basin was underfilled. Within these parasequences, limestones are laminated plated organic-rich black shales encompassing, sometimes, pyrite nodules or iron oxides. These black shales contain tiny globular chambers of planktonic foraminifera (whiteinellids, herbedgellids, *Heterohelicacea*), and radiolarian (nassallarian), and ammonites indicating a depositional environment deepening when compared to the underlying systems tract and also an enhanced primary productivity, proved by the nassellarian prolifiration. The top of this calcareous unit, characterized by phosphate and glauconite grains abundance, suggests a maximum flooding surface (MFS). In contrast, the fissile marly levels are bioturbated. They contain a rather poor fauna of small agglutinated benthic foraminifera (e.g., neobulliminids) and weakly keeled planktonic foraminifera (e.g., dicarinellids), testifying however that oxygen-rich bottom waters influx may induced a well-oxygenated water column when compared to dark laminated limestones. The MFS is situated at the top of filaments-rich limestones. It is represented by a surface of condensation, rich in grains of glauconite and phosphorite.

6.1.3 "Early" highstand systems tract (lowermost Kef formation)

The early highstand systems tract always corresponds to retrogradational then progradational facies. In the Bargou area like in the entire megabasin spanning the central Tunisia (Figure 6), this systems tract is represented by the lowermost Kef formation marls/limestones alternations.

7. Discussion

7.1 Lateral evolution of systems tract

7.1.1 Shelf margin wedge (SMW)

This systems tract including a microconglomeratic surface of condensation, rich in phosphate and glauconite grains. Internally, the microconglomeratic bed has discontinuous, wavy, parallel seams of glauconite-rich shale. This surface is sharp and overlain by a (transgressive) lag of reworked bioclasts (mainly echinoderms) from the neighbor platform as well as glauconite and phosphatic grains. It marks the limit between the SMW and the TST (Figure 5) and represents a fast shore line migration into the continent. This systems tract is represented generally by the Facies A. Elsewhere, in the platform sequence (Razgallah et al., 1994; Abdallah et al., 2000), the SMW does not have an equivalent (Figure 6). Towards the south, the emerged Zebbag platform is subjected to sharp erosion following the fast fall relative sea level. This erosion is represented by the unconformity which overlies the limestones containing *Neolobites vibrayeanus* and *Calycoceras sp.* (Abdallah et al., 2000). In the studied area, the upper part of the SMW is related to the calcareous Bahloul Formation genesis because the Fahdene Formation was originally defined as an argillaceous unit (Burollet, 1956). Therefore, the Bahloul Formation starts by a lithoclastic calcareous unit. Elswhere, in Kalâat Senan area (Accarie et al., 1999) and in the type locality of the Bahloul Formation (Caron et al., 2006), the same facies was assigned to the "pré-Bahloul" deposits. It is generally composed by the alternation of Facies F and D. in the neighboring section these latter facies are much developed (Figure 5) while in NW Tunisia, we note the alternation of Facies B and C (in Jerissa section).

7.1.2 Transgressive systems tract (TST)

The remainder Bahloul Formation part is considered as belonging to a transgressive systems tract (TST). The top of this calcareous unit, characterized by phosphate and glauconite grains abundance, suggests a maximum flooding surface (MFS). It is represented by a surface of condensation, rich in grains of glauconite and phosphorite. Towards the south, in the adjacent platform (Gafsa basin), as well as in the Oued Bahloul location (Maamouri et al., 1994), this surface is recorded by abundant lowermost Turonian ammonites (e.g. *Fagesia sp*. and *Watinoceras sp*.). Nevertheless, this surface occurs when the accommodation space creation is faster than before. In this case there would be no progradation as mentioned by

Zagrarni et al. (2008). On the platform setting, the transgressive interval corresponds to the pelagic fauna limestones unit (Razgallah et al., 1994). Indeed, following eustatic rise, the accomodation space creation rate is much stronger than the sedimentary input, making consequently a gradual inundation of the Zebbag platform and the pelagic facies deposition. In the studied sections, we note the development of a special Facies E (siliceous and radiolarian-rich). It is worthy to mention the presence of such organic rich facies in the Algerian Tinhert belonging to the saharian platform (Figure 6).

7.1.3 Highstand systems tract (lowermost Kef Formation)

In the Bargou area like in the entire megabasin spanning the central Tunisia (Figure 5; Figure 6), this systems tract is represented by the lowermost Kef formation marls/limestones alternations. Towards the south (i.e., Gafsa basin) within the platform, this systems tract is represented by the subreefal carbonates of the Gattar member that recorded the filling of the space made available and making a progradational pattern. In this case the Gattar member is the exclusive equivalent of the Kef Formation.

7.2 Sr/Ca & Mn variation

Considering the Cenomanian-Turonian changes record related to sea-level seeing that, the Sr/Ca values change recorded in marine carbonates of pelagic environments have been considered recently as reflecting past fluctuations of the oceanic Sr and Ca budgets (Ando et al., 2006). Large and rapid increases in seawater Sr/Ca ratios and Mn profiles matches with many large Cretaceous sea level rises/falls (Stoll and Shrag, 1996). It has been suggested that sources of Sr variations in Cretaceous carbonates can be related to changes in seawater Sr/Ca or Mn.

It was reported that the Sr/Ca ratios rose progressively through the mid- to late Cretaceous, a period of generally rising eustatic sea-level (Renard, 1985; Stoll and Schrag, 2001; Hancock, 1989; Haq et al., 1988; Hancock, 1993).

In our material (Figure 3), the observed relationships between the Sr/Ca profile and the sequence stratigraphy systems tract are consistent with sea-level change forcing the short-term Sr/Ca record. Falling sea-levels during late high-stands and low stands led to exposure of carbonate shelves and pulses of aragonite-derived Sr to the oceans. Rising sea-levels during transgression promoted renewed aragonite deposition and falling seawater Sr/Ca (Stoll and Schrag, 2001). This was reversed by the development of mature carbonate platform systems with lower aragonite accumulation rates during the high stand.

Our results confirm the relationship occurrence between stratigraphic sequence sytems tract and Sr/Ca evolution as described at Culver (Murphy, 1998; Mabrouk et al., 2006) and elsewhere in Gubbio (Stoll and Schrag, 2001). The Culver Sr/Ca profile was may be compared with that of Gubbio (Italy) and Bargou (Tunisia) inspite that these three sections cannot be easily correlated biostratigraphically in detail since the biomarker among macrofossils and foraminifera are rare even absent at both Italian (Gubbio) and Tunisian (Bargou) sections seeing their siliceous facies frequency. In fact using Sr/Ca profiles, ratios maxima identified within this interval transition at Culver (England) and at Gubbio (Italy) are also identifiable at Bargou (Tunisia). Mabrouk et al. (2006) mentioned that breaks within the Sr/Ca curves may indicate sedimentological or diagenetic effect. At the Bargou section these breaks may correspond to intervals of silica-rich black shales comparable to the Livello Bonarelli.

Increasing Mn in the TST (Bahloul Formation, Figure 3) might be related to increased productivity during sea-level rise promoting an increased organic matter-associated particulate Mn flux to the seafloor. Therefore, high Mn contents might be caused by lower rates of sedimentation, with increased efficiency of Mn redox cycling leading to elevated Mn contents in the sediment (Renard, 1985).

8. Conclusion

The Late Cenomanian – Early Turonian organic-rich and Siliceous Bahloul Formation exposed in Bargou area containing planktonic foraminifera and radiolarians occurs. Seven different facies association were recognized with a special Facies E, a siliceous and radiolarian-bearing one that differs from the other Bahloul sections. Indeed, these facies and lithologic units are genetically linked and integrated in a part of third order global sequence. Therefore, important relationships exist also between Sr/Ca ratios profile and eustatic sea-level change. Within the Cenomanian-Turonian transition, Sr/Ca maxima span the upper parts of high-stand (HST) and the overlying shelf margin wedge (SMW) of the Fahdene Formation and the lower part of the siliceous Bahloul Formation, with maximum values around sequence boundaries. Sr/Ca values fall through the transgressive systems tract (TST) and attain minimum values in the upper part of it. Furthermore, manganese exhibits important relationships to sequences but differently from Sr/Ca, with minima around sequence boundaries and through SMW, rising values from the TS through TST, maxima around maximum flooding surfaces, and normally decreasing through HST.

From this high-resolution sequence sstratigraphic analysis, using facies association and Sr/Ca & Mn variations we note (1) the development of some laminated organic-rich facies in the basal part of the TST, (2) the coincidence of sudden negative shift of the Mn profile with the SB and sudden positive shifts with the TS and near to MFS respectively, (3) development of a special siliceous and radiolarian-rich facies (Facies E) in Bargou area, (4) a good correlation of Sr/Ca & Mn with eustatic sea level variarion.

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We are increasingly faced with environmental problems and required to make important decisions. In many cases an understanding of one or more geologic processes is essential to finding the appropriate solution. Earth and Environmental Sciences are by their very nature a dynamic field in which new issues continue to arise and old ones often evolve. The principal aim of this book is to present the reader with a broad overview of Earth and Environmental Sciences. Hopefully, this recent research will provide the reader with a useful foundation for discussing and evaluating specific environmental issues, as well as for developing ideas for problem solving. The book has been divided into nine sections; Geology, Geochemistry, Seismology, Hydrology, Hydrogeology, Mineralogy, Soil, Remote Sensing and Environmental Sciences.

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