Study of the paleoenvironemental changes using Calcareous Nanofossils in Lower Jurassic (Toarcian Stage)

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Abstract

Quantitative methods is used to reconstruct the paloenvironnemental conditions in Toarcian stage by using the ecological indicators of calcareous Nano fossils in three sections (Toka, Petousi, Chionistra). These sections are situated inThe Ionian Zone of northwestern Greece (Epirus region). A statistic program (PAST) is used to analysis the data of nanoplankton species.

Three Unitary Associations are determinate in the three sections.

The biostratigraphic correlation indicates the presence of a first Unitary Association (UA1) in all studied sections corresponding to the Lower Toarcian, but the second UA2 is noticed in Toka section and it’s absent in Petousi section. This absence is related to the presence of sedimentary lacuna in this section.

The curve of biodiversity increases from Chionistra to Petousi and becomes maximum in Toka.

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The high biodiversity of calcareous nanofossils correspond to the high nutriment fluctuation in pelagic section related to upwelling responsible to supply the nutriment from the profound marine zone.

Principal Component Analysis(PCA) was applied to calcareous nanofossils assemblages in order to interpret palaeoenvironmental changes. Two factors were extracted by PCA. The first factor PCA1 is interpreted by the increase of nutrient fluctuation and the domination of high trophic (meso- to eutrophic) conditions within the oceanic photic zone.

The second factor PCA2 present the increase in marine level corresponding to the domination of high temperature and eutrophic conditions in Toarcian stage.

Key words: Unitary Association, Principal Component Analysis, Toarcian, Calcareous Nannofossils, Biodiversity.

دراسة التغيرات البيئية القديمة باستخدام المستحاثات القزمة (النانوفوسيل) خلال الجوراسي الأسفل (طابق التوارسيان)

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الملخص

استخدمت طرائق كمية لإعادة بناء الشروط البيئية القديمة في طابق التوارسيان باستخدام مؤشرات بيئية من المستحاثات القزمة في ثلاث مقاطع (توكا، بيتوسي، كيونيسترانا)، واقعة في منطقة إيونيان في شمال غرب اليونان (إقليم إيبيروس)، كما استخدم برنامج إحصائي (PAST) لتحليل معطيات أنواع النانوبلانكتون حيث تم تحديد ثلاثة تجمعات وحدوية في المقاطع الثلاث. يشير الترابط البيوستراتيغرافي إلى وجود التجمع الوحدوي الأول في جميع المقاطع المدروسة متوافقا مع أسفل التوارسيان، في حين تم ملاحظة وجود التجمع الوحدوي الثاني في مقطع توكا واختفائه في مقطع بيتوسي . ويعود ذلك إلى وجود ثغرة استراتيغرافية في هذا المقطع. يزداد منحني التنوع الحيوي اعتبارا من مقطع كيونيسترانا إلى مقطع بيتوسي ليصبح أعظميا في مقطع توكا. إن التنوع الحيوي المرتفع للنانوفوسيل الكلسية يتوافق مع التدفق العالي للمواد المغذية في المقطع البيلاجي والذي يتوافق مع حركة التيارات

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البحرية العميقة المسؤولة عن نقل المواد المغذية القادمة من النطاق البحري العميق .تم تطبيق طريقة تحليل المكون الرئيسي لتجمعات المستحاثات القزمة الكلسية بغية معرفة تغيرات البيئات القديمة. واستنتج عاملان من استخدام الطريقة السابقة. فسّر العامل الأول (PCA1) نتيجة ازدياد تدفق المواد المغذية و المتوافق مع هيمنة شروط اغتذائية ضمن النطاق الضوئي المحيطي. يمثل العامل الثاني (PCA2) زيادة في المستوى البحري والمتوافق مع هيمنة درجة حرارة عالية مع شروط اغتذائية في طابق التوارسيان.

الكلمات المفتاحية: التجمع الوحدوي، تحاليل المكونات الأساسية، التوارسيان، المستحاثات القزمة، التنوع الحيوي.

1. Introduction:

The upper Pliensbachien – Toarcianintervaleis characterised by many palaeclimatic variations (Mattioli and Erba., 1999).The Lower Toarcian is marked by anoxic events (Jenkyns, 1988) caused the perturbation in carbonate cycle (Gill *et al*., 2011; Newton *et al*., 2011). The curve of carbon indicates the presence of negative excursion of the stable isotope of carbon (Hesselbo *et al*., 2000; Hesselbo et al., 2007; Al-Suwaidi *et al.,* 2010). This negative excursion of carbon isotope correspond to an anoxic event (Suan *et al.,* 2010., 2011).

The anoxic event was associated with a warm period (Bailey et al., 2003; Jenkyns, 2003; Suan *et al.,* 2008), and mass biological extinction (Little and Benton, 1995; Wignall, 2001).

The domination of clay sedimentation during the anoxic events was related to the increase in acidification of water marine (Hermoso et al., 2012; Hönisch *et al.*, 2012; Trecalli *et al*., 2012).

Recently, the quantitative method of calcareous nanofossils was used to identify the paleo- geographic changes in the Lower Jurassic (Mailliot *et al*., 2006).Some index species of calcareous nanofossils are useful, like the climatic parameters, to identify the paleo environmental and climatic changes in the studied period (Suan et al., 2008; Mattioli *et al*., 2004)

The variation in the abundance of index species of calcareous nanofossils correspond to the changes in the conditions of environment (Mattioli *et al.,* 2004., 2009).

The date of Upper Pliensbachian – Lower Toarciany using the Stratigraphical range for the first occurrence (FADs) and the last occurrence (LADs) of index species of calcareous nanofossilsshowes a diachronism, between the different positions of sections in the same basin and between the different basins, related to long time needed to the horizental distribution.

The diachronism of bioevents of calcareous nanofossils observed in the biostratigraphicand correlation between different localities is strange. This problem showes the need to use new quantitative method (Unitary Association) to identify the presence or absence of sedimentary lacuna affected in the Stratigraphical distribution of calcareous nanofossils. These Unitary Associations are the stables biozones based on the assemblage of different species. The variation in this assemblage has indication for the change in climatic conditions. The aim of this work is to study the palaeoenvironments changes and to reconstruct more solid biostratigraphic schema by using the unitary associations of calcareous nanofossils for Toarcian stage in the studied sections.

2. Geological setting and stratigraphy

Three sections are selected for this study situated in The Ionian Zone of northwestern Greece (Epirus region) (Figure.1).

The evolution of this region is associated with Early Mesozoic opening and late Mesozoic–Early Cenozoic closure of the Tethys Ocean (Laubscher and Bernoulli, 1977; Karakitsios, 1992, 1995).

Ionian Zone presents various sediments composed from Triassic evaporates deposits traversing to series of Jurassic contains mixed carbonate– siliciclastic–siliceous sediments.

Early Jurassic sediments in the northwestern Greece was covered by a vast carbonate platform (Karakitsios, 1992, 1995) (Figure.1).

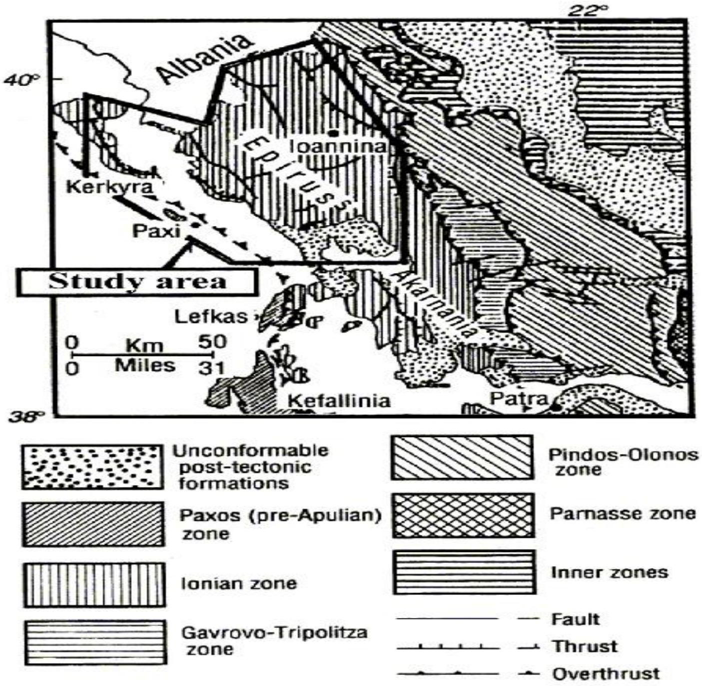

Figure.1. Geologic and Geographic position of (Epirus region) after Karakitsios, 1995

In the Pliensbachianstage ,the area of study was affected by extensional tectonics related to the opening of the Neotethys Ocean (Karakitsios, 1995).

The tectonic evolution of the Ionian basin gives a complex faults with half-graben geometry (Walzebuck, 1982; Baudin et al., 1990; Karakitsios, 1995).This complex palaeogeography resulted in abrupt changes in thickness of the syn-rift formations, which takes the shape of syn-sedimentary wedges (Karakitsios, 1992, 1995).

Toarcian–Tithonian successions presents the dipper sediments founds in the middle zone of the graben of Ionian basin. The sedimentary system structure indicates depositions controlled by extension related to the opening of the Neotethys Ocean (Karakitsios, 1992, 1995).

2.1. Toka section

The lower part of this section(39°23′N, 20°50′E) begins by nodular limestones marked by green nodules with thickness down to 3 meters. Next, the sedimentary series composed of 3 meters of grey marl change to black shales and 5 meters of laminated marls situated above the shale.

The uppermost of Toka finish by Limestone, comprising grey limestones with intercalations of green-grey marls (Figure.2).

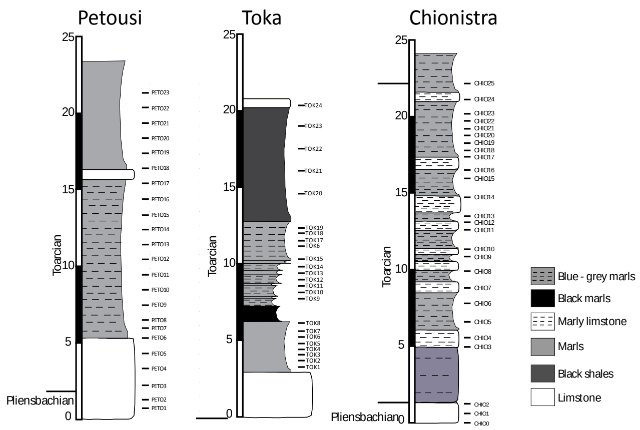

Figure.2. Sedimentary series in the three studied sections (Toka,Petousi, Chionistra)

2.2. Petousi section

The Petousi section (39°30′N, 20°35′E), is located around 2 km W-SW from Petousi village.

This section begins by a thick layer of limestone about 4 meters thick (Figure.2), and

about 10 meters of marly clay located above the last layer. The uppermost meters of this section changes to marl layer of about 5 meters thick. A thin layer of Limestone separates the two layers (Marly clay in the bottom and marl in upper) (Figure.2).

2.3. Chionistra section

The section of Chionistra (39°32′N, 20°30′E), is located around 1 km SW ofElataria village.

The outcrtop is characterized by the alternance of limestone- marly clay – marlylimston from the lower part of this section(Figure.2). The thickness of marly clay layers decrease from lower part to the middle part at 10 meters hight. The system of sedimentation increases the thickness of marly clay layers in going to the uppermost part of this section(Figure.2).

3. Methodology

73 samples (24 from Toka, 23 from Petousi, 26 from Chionistra) were analyzed using the statistic program to create the Unitary associations and the curve of biodiversity.

Slides were prepared from the powdered rock according to the technique described in Bown and Young (1998), and then analyzed in an optical polarizing Leitz microscope at ×1250.

Calcareous Nanofossils were counted for each sample in a surface area of the slide and all species are identified (300 individual).

Then, the quantitative analysis is used to identifiy the paleo- climatic variations in the Upper Pliensbachian Lower Toarcian period by using some index species which there assemblages has an environmental importance.

PAlaeontologicalSTatistics"PAST", is a statistical program used in the quantitative studies of fossils. This program analyzes the data in a quantitative method to constructs representative biozones based on the maximum assembly of biomarkers.

The Unitary Association (AU) is a zone identified by the maximum coexistence of the biomarkers species that characterizes the studied interval. It is used to identify the presence or absence of a sedimentary lacuna when the interval biozones are unable to identify it.

4. Resulats

4.1. Unitary Associations in the three sections (UAs)

PAST program translate the vertical distribution of the species in form absence/ presence.

Three UAs are identified in the studied sections. The first UA is characterized by the coexistence of 25 species index. It is identified by the late occurrence of four species *L. barozii, C. poulnabronei, P. liasicusdistinctus, c. cantaluppii, B. prinsii*(Figure.3).

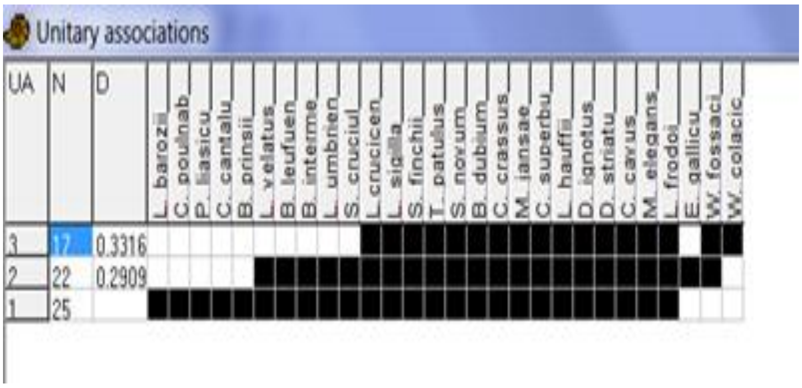

Figure. 3. Unitary Associations in the studied sections

The second UA (UA2) is defined by the coexistence of 22 index taxa; and it is marked by the last occurrence of *L. velatus, B. leufuensis, B. intermedium,L. umbriensis, S. cruciulum*, and the first occurrence of *E. gallicus, W. fossacinta*(Figure.3).

UA3 presents the coexistence of 17 species. This UA is determinate by the first Occurrence of *W. colacicchii*, and the delete (absence) of *E. gallicus* (Figure.3).

4.2. Diversity curve

The treatment of results gives the change in the biodiversity of different taxa of calcareous nanofossils. The blue curve explain that the diversity is low in Petousi section corresponding to the samples between 0-23. The green curve presents the maximum number of bioevents (First Occurrence of index species) in Petousi section (Figure.4).One bioevents of Late Occurrence is observed in this section presented by the peak of red curve in the sample 20 (Figure.4).

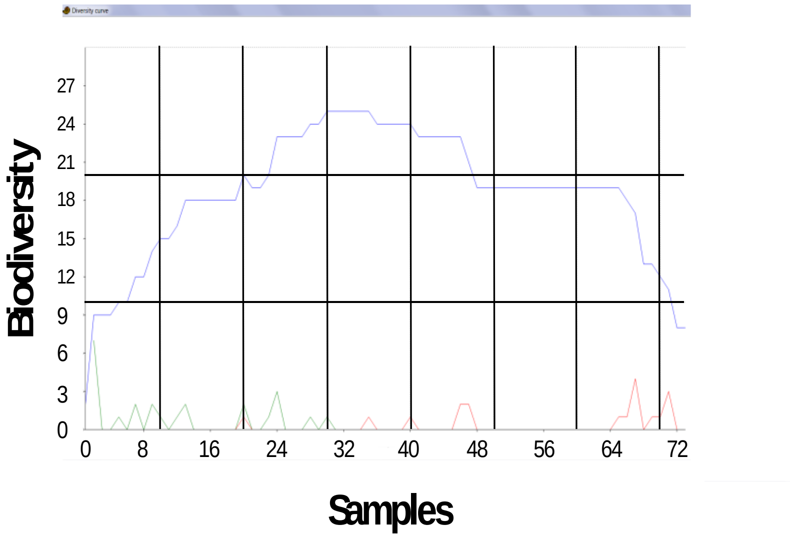

Figure. 4. Curve of Biodiversity in the studied sections

The Toka section is characterized by many bioevents of FO in the upper part of this section and some bioevents of LO of index species in the lower part of this section. The value of Diversity decreases from the upper to the lower part of Toka section (Figure.4).

Chionistra section is characterized by a stable value of diversity about 19 species from the top to the lower part of this section. This part do not present any bioevents. The red curve indicate the presence of many bioevents corresponding to the LO of some index taxon in the lower part of CHO section. The diversity values decrease to about eight species in the basal part of Chionistra section (Figure.4).

4.3. PCA (Principal Component Analysis) of Calcareous Nanofossils:

Two factors were extracted from Principal Component Analysis for the studied sections.

The first factor (PCA1) is characterized by high values for the species of genus *Biscutum* like *B. intermedium*, *B. leufuensis*, *B. dubium* between (0,4- 1,2) and negative values for the species of *Watznuaria* like *W. fossacinta*, *W. colacicchii* entre (-2,5, -3,5) (Figure.5).
The second factor (PCA2) corresponds to a positive values (0,8 – 1,2) for *M. jansae*, *M. elegans* but the species *B. intermedium*, *B. leufuensis* correspond to a negatives values about -1,2 (Figure.5).

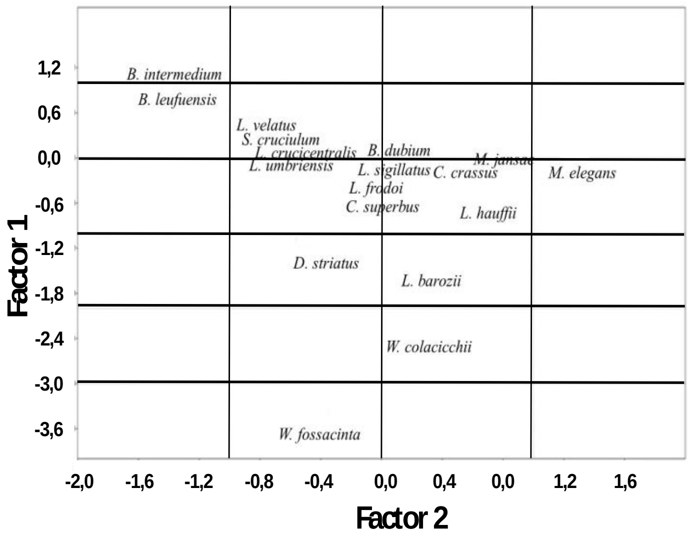

Figure. 5. Principal Component Analysis of Calcareous Nanofossils

The species *L. sigillatus*, *L. frodoi*, *L. hauffii*, *L. umbriensis*, *L. crucicentralis*, *C. superbus*, *C. crassus* are found around the value (0) between (-0,4 to 0,4) and have the mid values for the two factors (Figure.5).

5. Discussion

5.1. Distribution of Bioevents in the sections

The treatment of results indicates that the number of bioevents of calcareous nanofossils is different between the three sections. The events decrease from Petousi section from values of 17events in the lower part to 10 events in the top of this section (Figure.6).

Toka section is characterized by light diminution from 11events to 7 events. The middle part of this section presents a stable value of events 9. The top part correspond a decrease of events from 8 to 7 (Figure.6).

The decrease in the number of events continues in Chionistra section from 7 events in the lower part and finish in the top by 2 events (Figure.6).

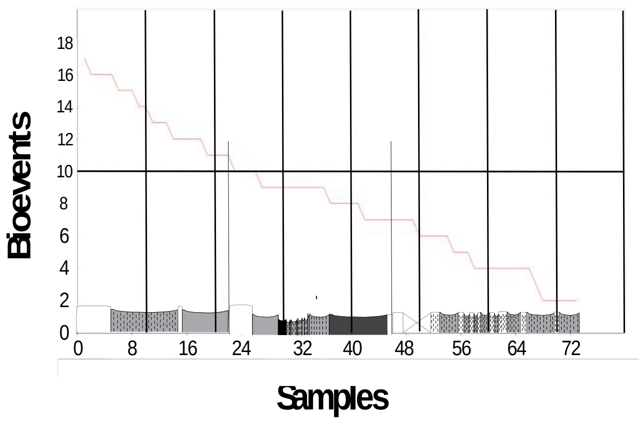

Figure. 6. Curve of the number of bioevents of Calcareous Nanofossils taxa.

In general, the curve of the distribution of events presents a diminution in the number of event from the Petousi section to Toka and Chionistra section.

The number of events decreases in every section from the lower part toward the top of this section (Figure.6).

The change in the number of events could berelatedto the different reaction with the change in the environmental conditions (Variations in the temperature of marine water, change in the level of water column, change in preservation, variation in the sedimentary system). The diminution of bioevents curve of Calcareous Nanofossilsgoes with the increase in the deep of marine environment from the section of Petousito Chiostrata.

5.2. Vertical distribution

The results of the PAST program gives the difference in the vertical distribution along the studied sections (Figure.7).

The number of species coexisttogother founds in Toka section is more than in Petousi section (Figure.7).Petousi section is characterized by the existence of 20 taxa, but Chionistrasection contains 19 species. Some species are found in Toaka section like *B. intermedium*, *B. grande*, but they are absent in Petousi and Chionistra (Figure.7). *W. fossacinta* disparate in Chionistra section but it is present in the other two sections. In contrast *W. fossacinta* is observed in just one section (Petousi) and absent in Toka and Chionistra sections (Figure.7). Toka is composed 23 species in coexistence. Some species like *M. jansae*, *C. cavus* are absent interpreted as the bad preservation in this section.

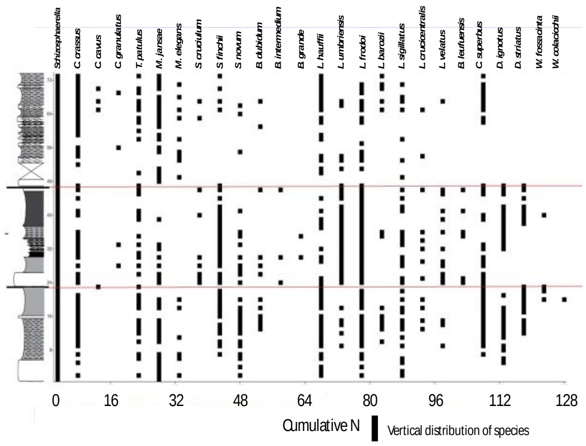

Figure. 7. Calcareous Nannofossils species Stratigraphical range

Toka section presents a period of sedimentation dominated by paleoenvironmental conditions favorite to the deposition of mudstone. These conditions correspond to high temperature of marine water with the increase in the thickness of column water. The high diversity of calcareous nanofossils corresponds to the high nutriment fluctuation in pelagic section due to upwelling responsible of the supply of the nutriment from in the profound marine zone.

5. 3. Biostratigraphic correlation

The analysis of results indicates that the first Unitary Association is found in the three sections. One UA is observed in the Chionistra section. The UA1 extend from the base of this section and finishes in the last sample in the top CHIO25 (Figure.8).

In Toka section the UA1 correspond to the sedimentary interval between the samples TOK1 and TOK13, in addition, the second UA (UA2) date the sedimentary alternation between TOK14- TOK17. The program presents a sedimentary alternation unidentified by the Unitary Associations zones for the upper part in this section. Two UAs (UA1 or UA2) identifies this last zone (Figure.8).

UA1 corresponds to the sedimentary series in Petousi section between the samples PETO1 and PETO19 followed by UA3 correspondingtothe sample PETO20 (Figure.8).

The upper part of this section extends between the two samples PETO21 and PETO23 is dating by two UAS (UA2 or UA3).

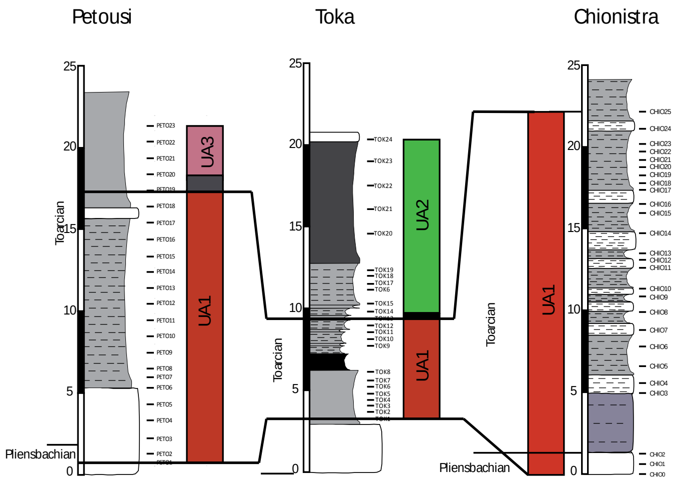

Figure. 8. Unitary Associations in the studied sections

The unidentified zone in the upper part of Toka section (UA1/2) is situated above the UA2 zone and it must be the complement of UA2 so it is named UA2 in the top of this section (Figure.8).

The same result is noticed in Petousi section. The unidentified top alternation of this section is found Stratigraphical range above the UA3 so it must correspond to the last Unitary Association (Figure.8).

The biostratigraphic correlations using the Unitary Associations between the three sections indicate the presence of the first Unitary Association (UA1) in all studied sections.

The absence of UA2 between the UA1 and UA3 in Petousi section compared with Toka section is interpreted by the presence of sedimentary lacuna in Petousi, which gives the change in the assemblage of species and disappearance of the assemblage identified UA2 in Petousi.

The global sedimentary alternation in Chionistra coincides with the first Unitary Association (UA1), corresponding t Lower Toarcian.

5.4. Palaeoenvironmental changes across Lower Toarcian

Principal Component Analysis performed on calcareous nanofossils indicates major changes acrossToarcian stage. The first factor (PCA1) received a positive loading from some species like *B. intermedium, B. leufuensis*. The abundance of species of *Biscutum* genus goes with the increase of nutrient fluctuation, and the recent studies indicate to high abundance of *Biscutum* genus in the layers rich in organic materials (Borneman and Mutterlose, 2008; Duchamp-Alphonse et al., 2007; Mattioli *et al.*, 2004). In addition,Lotharingius species were adapted to high nutrient supply and shallow environemnt (Pittet and Mattioli, 2002; Mattioli and Pittet, 2004; Olivier *et al*., 2004; Tremolada *et al.*,2005) and the positive values for the last genus goes with the

PCA1 indicate to the domination of high trophic (meso- to eutrophic) conditions within the ocean photic zone.

The second factor (PCA2) coincide with the positive value for the species of *Mitrolithusjansae, Mitrolithuselegans*, and negative loading for *B. intermedium, B. leufuensis.*

The abundance of *Mitrolithus* species corresponds to the lower part of photic zone (Mattioli and Pittet, 2004; Mattioli *et al*., 2004), in addition, the negative loading for Biscutumspecies explains the diminution in the nutrient fluctuation interpreted with increase of the distance of the section from the continent.

The precedent results indicate that the PCA2 represent the increase in marine level corresponding to the domination of high temperature and eutrophic conditions in Toarcian stage.

6. Conclusion:

The quantitative method of calcareous nanofossils is used to reconstruct the paloenvironnemental conditions in Toarcian stage by using the ecological indicators species in three sections (Toka, Petousi, Chionistra) in northwestern Greece (Epirus region).

Three Unitary Associations are recorded in the studied sections. The biostratigraphic correlation between the sections indicate the presence of first Unitary Association (UA1) in all sections corresponding to the Lower Toarcian, but the UA2 is noticed in Toka section only and it is absente in Petousi section. This absence is interpreted with the presence of sedimentary lacuna in this section.

The analysis of (PCA) indicates the domination of two factors. The first factor PCA1 has the positive loading for the Biscutum species and negative values for Lotharingius species. This factors interpreted by the increase of nutrient fluctuation and the domination of high trophic (meso- to eutrophic) conditions within the ocean photic zone.

The second factor is characterized by the positive values of Mitrolithus species and negative values for Biscutum species. This PCA2 presents the increase in marine level corresponding to the domination of high temperature and eutrophic conditions in Toarcian stage.

This work needs further reconstruction of the unitary associations of foraminifera and compare it with the unitary association of nanofossils to have very solid biostratigraphic schema and using quantitative analyzesin more detail for the two groups of fossils (foraminifera and Nannofossils).

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