Foraminifers of the Late Cretaceous- Early Eocene in central Tunisia: Biostratigraphy and paleoenvironment

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Abstract

Biostratigraphic and statistical studies were carried out on the Late Cretaceous- Early Eocene succession of Khanguet Zalga in Jebel Serj area, central Tunisia. Paleontological analysis shows the occurrence of about 300 species (200 benthic foraminifera and 48 planktonic foraminifera). The most significant foraminifera (relative abundance more than 5%) are indicated in the vertical charts of distribution. Based on the vertical stratigraphic distribution of the planktonic foraminiferal species, six zones and subzones are recognized: *Gansserina gansseri* zone of Late Cretaceous (lower Maastrichtian), *Igorina albeari* (P3b) zone of Middle Paleocene (Selandian), *Acarinina soldadoensis* (P4c) subzone of the upper Paleocene, *Morozovella velascoensis* (P5) zones of Late Palaeocene (Thanetian), *Morozovella edgari* (E3) and *Morozovella subbotinae* (E5) zones of Early Eocene (Lower Ypresian). Biotic parameters and benthic assemblages from Late Cretaceous- Early Eocene Serj section allow the reconstruction of paleoenvironment and paleoecological fluctuations. In fact, our records indicate that the environment evolved from an initially oligotrophic, middle bathyal depositional environment for *Gansserina gansseri*, and P4c zone to upper bathyal setting for P3b and P5 towards a more eutrophic inner neritic setting for E3 and E5. The high abundance and the low diversity in this section are related to the sedimentological, the minimum of dissolved oxygen and the paleodepth conditions. The ecosystem is unbalanced for middle bathyal environments (hyaline shell-groups), balanced for shallow environment and upper bathyal (agglutinated and calcareous shell-groups).

Keywords: Central Tunisia; Biostratigraphy; Paleo-diversity; Paleoenvironment; Foraminifera.

1- Introduction

The Paleocene -Early Eocene interval has been studied by several authors. It includes two spectacular events: the Cretaceous-Tertiary (K/T) boundary (characterized by a massive planktonic foraminifera extinction; Salaj, 1980; Keller, 1988; Coccioni and Galeotti, 1994; Keller *et al*., 1998 and Gearty, 2013) and Paleocene/Eocene boundary (Benthic Extinction Event (BEE); Tjalsma and Lohman, 1983; Thomas, 1990; Berggren and Aubry, 1996; Zili *et al*., 2009). The global warming event, recorded during the Paleocene and culminating in the Early Eocene, represents an important phase of biotic and environmental change (Zachos *et al*., 2001, 2003; Takeda *et al*., 2007).

In Tunisia, Paleocene marl-shale hemipelagic series, with a diversified paleobiodiversity deposited in open marine conditions, have been influenced by terrigenous input from Kasserine Island and Algerian promontory (Bishop, 1985; Zaier *et al*., 1998). Undoubted gaps in sedimentation, recorded in the Paleocene of eastern Tunisia, indicate the action of synsedimentary movements leading to some short-term shallowings or even local emergence which is confined to the areas where sedimentation was related to a so-called "hautfond" phenomenon. The Eocene corresponds to a prolific period for the development of Nummulite and planktonic foraminifera carbonate platforms along the continental margins of the Tethyan Ocean (Zaier *et al*., 1998; Jorry, 2003).

The main purpose of our research was to accurately correlate Late Cretaceous- Early Eocene of the central Tunisia with the Standard biostratigraphic scales. Moreover we discuss for the first time the relationship between paleodepth, morphology and shells groups of benthic foraminifera. Finally we observe if the global warming events have impact on the quantitative distribution of foraminifera.

In this paper we compile multiple sources of bio-magneto- astro-chronological time scale like Loeblich and Tappan, 1957; Berggren, 1960; Blow and Banner, 1962; Blow, 1979; Berggren 1995; Berggren and Pearson, 2005; Wade *et al*., 2011.

2- Geological Setting

The study area “Khanguet Zalga” is part of the southern edge of the Serj–Bargou massif from the Tunisian Central Atlas (Fig. 1). This anticlinal localizes 3 km from the city of Oueslatia. It is far 25 km South-East from the capital of Seliana. The main geological formations encountered in the section are the EI Haria bounded by the upper beds of the Abiod Formation (upper Maastrichtian) below and those of the Bou Dabbous (Eocene) above. Undoubted gaps in sedimentation, recorded in the Paleocene of Eastern Tunisia, indicate the action of synsedimentary movements. The section was chosen in view of its expanded and well exposed nature.

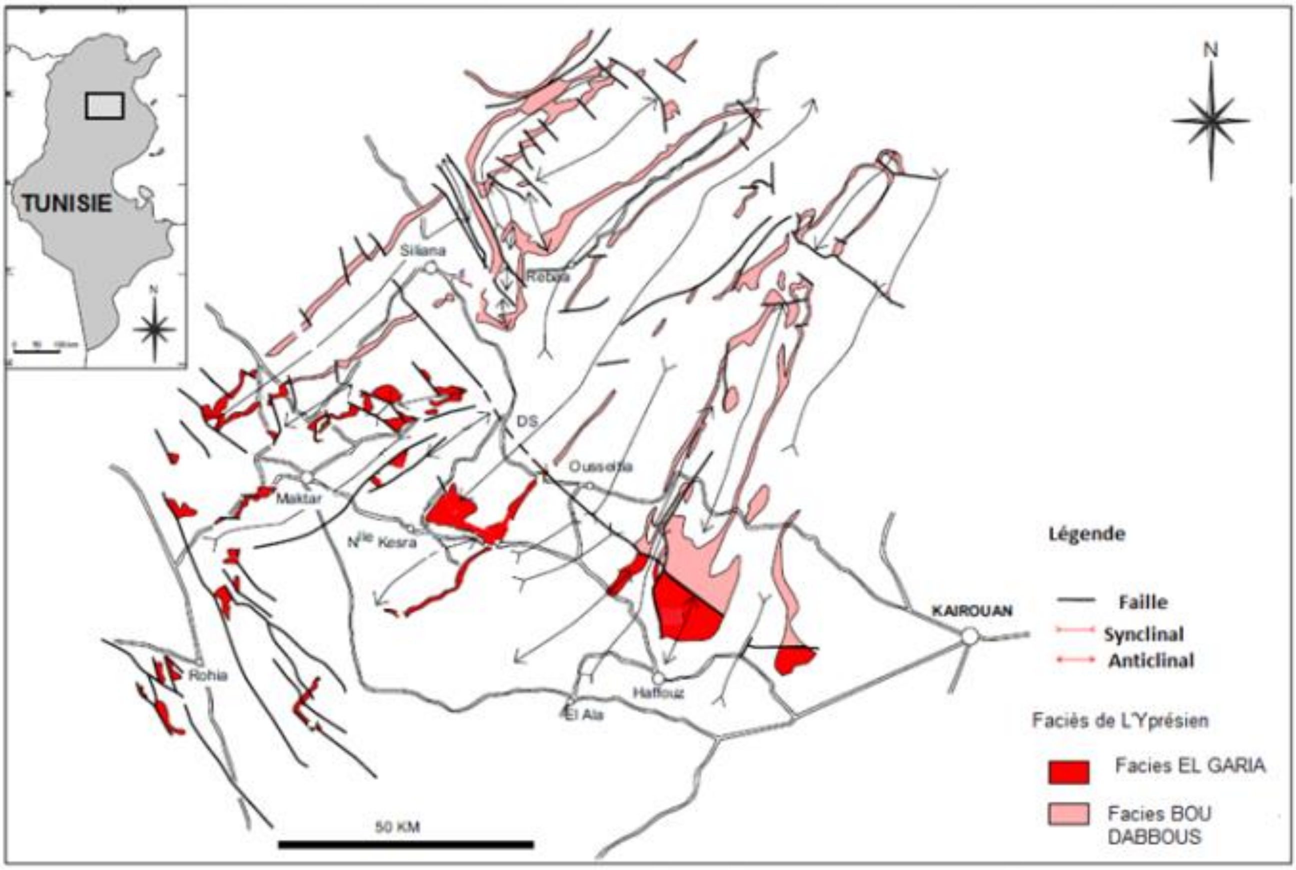

Figure 1) Structural framework and facies distribution of the Eocene in the region of Oueslatia (According Jorry et al. 2001, as amended).

3- Material and methods

The studied material is extracted from 116 samples collected from the Khanguet Zalga section. Samples are spaced from 10 cm to 1 m within for shaley and marly sediments and 30 cm to 10 m in massive calcareous beds. About 100 grammes of each sample were treated with a 10% hydrogen peroxide solution during a day. After disintegration, samples were washed through a sieve column metallic background with mesh sizes decreasing from top to bottom (2 mm to 0.63 µm) in order to remove the organic and clay fractions. The dry residues were sieved into three fractions (>63 µm, >250 µm, and >500 µm). Each fraction was examined under binocular microscope. All the foraminifera observed were picked, identified, counted, MEB-photographed and placed in foraminifer's slides and covered for safety and future reference. Most of species are illustrated on Plates 1 through 4. The slides were properly labelled with well name and sample reference. The foraminiferal species was determined on the base of several publishing like Ellis and Messina (1940) and Loeblich Tappan's (1988).

In the discussion below we differentiate between lowest (LO) and highest (HO) occurrences of marker species used to define biozone boundaries. Reference sources for the zonal datum's that have been paleomagnetically calibrated and their ages are presented in Figure 2. We adopt the naming convention for five categories of interval zones as described by Berggren and Pearson 2005 and Wade *et al*. 2011.

In order to define paleoenvironmental conditions, 24 samples were selected for this study. The multivariable statistical analyses based on a wide range of diversity indexes (specific richness RS, Shannon-Weaver index HS (Murray 1991), dominance index D (den Dulk 2000), Fisher α index (Williams 1964) and equitability E (Murray 1991) are so useful for paleoenvironmental interpretations.

4- Results

4.1- Lithology and micropaleontology analysis

From the base to the top we have four lithological units in the Late Cretaceous- Early Eocene interval of Khanguet Zalga section.

- The upper beds of the Abiod Formation (4 m thick): This formation is the oldest exposed rock unit in the study area. It consists of whitish grey fossiliferous limestone packstones with same quartz and dolomite crystal and few beds marly limestones intercalations; the washed marls contains many forms such as the *Globotruncanidae* with, *Kuglerina rotundata, Rugoglobigerina reicheli, Planomalina prairichillensis, Laeviheterohelix glabrans, Laeviheterohelix sp., Planomalina alvarez* and *Hedbergella monmouthensis* for planktonic species. Benthic foraminifera are present throughout the set and delivered the following forms: *Lenticulina rotulata, Dentalina reussi and Bolivina incrassata giganta*. This set is attributed to lower Maastrichtian, *Ganserina ganseri* Zone. The top of this unit is topped by a hard ground area.
- El Haria Formation (73 m thick): the base of this unit comprises dark-grey shales and marls with a gypseous vein intercalations and celestibarite nodule. Succeeded by green-grey shales and marls with nine thin beds of limestones. This unit shows many forms (Fig. 2 and 3) such as: *Subbotina*, *Morozovella*, *Globanomalina* and *Acarinina* for planktonic genus and *Lenticulina, Nodosaria, Anomalinoides, Cibicidoides, Spiroplectammina, Bathysiphon, Hyperammina, Bulimina* and *Bolivina* for benthic genus. The use of planktonic foraminiferal zonation in regional biostratigraphic studies has allowed for dividing this set on three Zones. After the remaniement, appears the first index species *Morozovella angulata* concomitant with *Igorina albeari*, 2 m above the index species *Globanomalina pseudomenardii* have been

occurred. This part of the Formation corresponds to the subzone P3b of the Zone *Morozovella angulata* P3. It is interpreted as an equivalent of the Selandian. In this biostratigraphic interval P3b, the enrichment by agglutinated benthic foraminifers assemblage with same calcareous forms (Fig. 2 and 3), indicate that the climate became cooler compared to the same during the Late Cretaceous period (Sliter and Backer, 1972; Thomas, 1990a; Galeotti and Coccioni, 2002; Guasti *et al*., 2007). The Midway assemblage of *Nodosaria-Dentalina* (Fig. 3) indicates a water depth of about 400 to 500 m.

From the first occurrence of *Acarinina soldadoensis* (Fig. 2), simultaneously with two planktonic species datum *Globanomalina pseudomenardii* and *Morozovella velascoensis,* to the highest occurrences of *Globanomalina pseudomenardii,* 34 m thick is attributed to the subzone P4c of the Zone P4. Planktonic foraminifers generally predominate (Fig. 4), being represented by genera and species typical of open warm-water marine basin. Benthic foraminiferal assemblages are dominated by *Bolivina, Nuttallides truempyi, Osangularia, Oridorsalis, Lenticulina, Anomalinoides* and *Cibicidoides* (Fig. 3). The species present in this assemblage are characterized by moderated geographic distribution as they are known almost exclusively from deep sea sediments (Tjalsma and Lohmann, 1983; Hulsbos,1986; Nomura, 1991; Thomas, 2003) penetrated by DSDP in Indian and Pacific oceans and known on land from the Transcaspian area, Italy and southern France. Summarizing analysis obtained on foraminiferal distribution in the subzone P4c *Acarinina soldadoensis*/*Globanomalina pseudomenardii* show a middle bathyal depositional environment, with a paleodepth included between 500-600 m.

The top of this Formation is attributed to the later zone of Paleocene *Morozovella velascoensis* (P5) (Fig. 2). It is characterized by the partial range of the nominate taxon between the highst occurrences of *Globanomalina pseudomenardii* and the first occurrence of *Morozovella edgari*. In this zone, two depositional environments were identified: the first is similar to the P4c, so middle bathyal depositional environment. The second is characterized by a decreasing contribution of the elements of the ‘Velasco type’ with mass occurrence of Midway Benthic foraminiferal assemblages (Fig.3), dominated by the *Anomalinoides welleri - cibicidoides dayi* assemblage indicating a water depth of about 400m.

- Chouabine Formation (1m thick): intervals marked by phosphatized marl clay containing shark and fish teeth and coprolites, but macro-vertebrate remains have not been observed. The Eocene period still with this unit, we have the first occurrences of index species *Morozovella edgari* and *Morozovella marginodendata* which are attributed to the Partial-range zone of the *Morozovella marginodentata* (E3) of the Early Ypresian. The most benthic species are *Anomalinoides acuta, Planularia crosswicksona, Lenticulina coegaensis, Anomalinoides midwayensis* and *Lenticulina* sp. and many large *Frondicularia phosphatica* (Fig. 3) associated to numerous fragments of brachiopod and gastropod shells, indicating periods of shallowing marine basin.
- Bou Dabbous Formation (23m thick): The base consists of black massive limestones with some marly intercalations which consist of diverse fauna planktonic forms indicate a foraminiferal Zones *Morozovella subbotinae* (E5) (Fig.2), this carbonate member is topped by a speckled grey hard massive limestone with *Globigerine* and few *Nummulite*. From the *Morozovella marginodentata* (E3) to the *Morozovella subbotinae* (E5) Benthic and planktonic foraminifers are relatively moderate (Fig. 4).

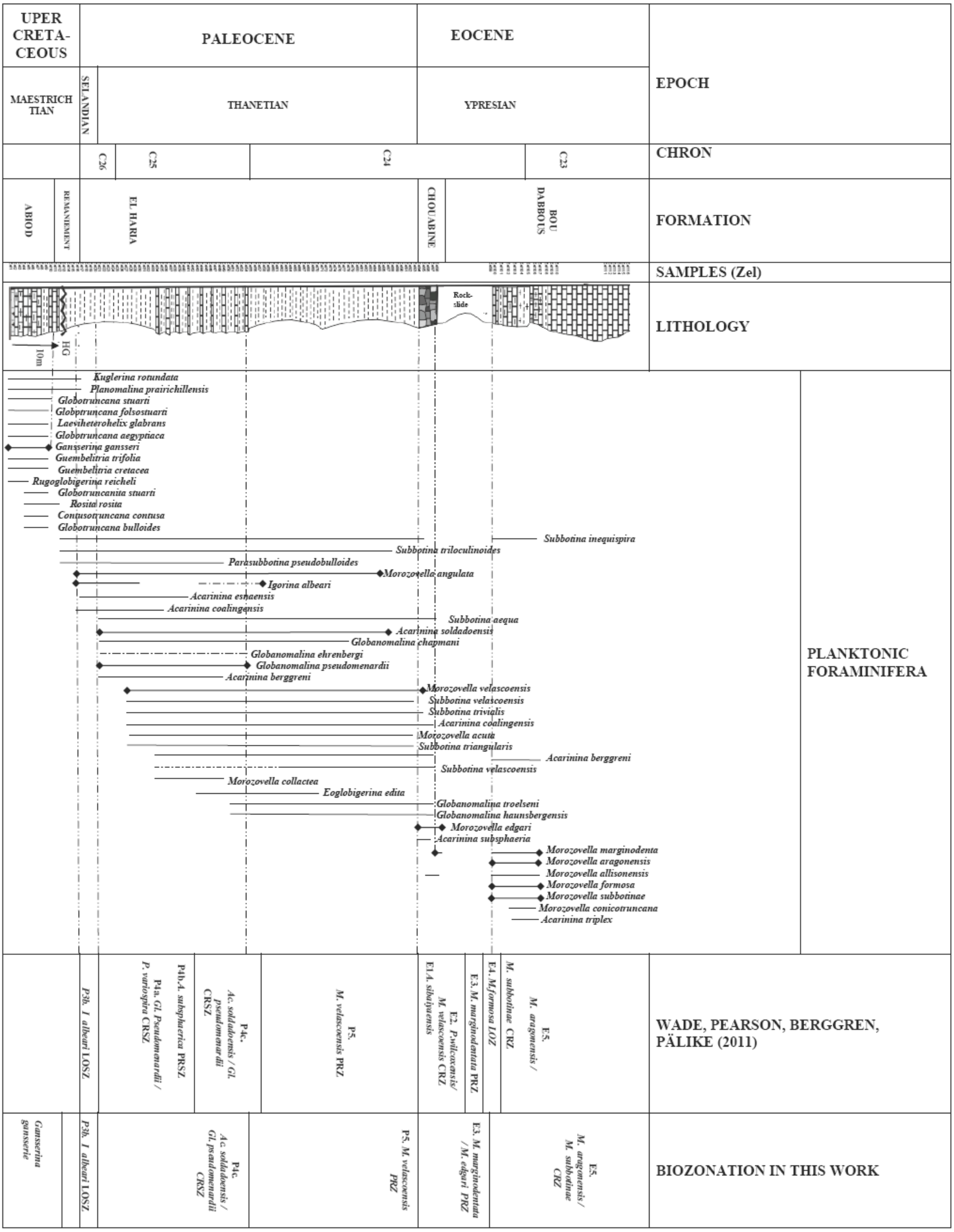

Figure 2) Planktonic species distribution of the Serj section.

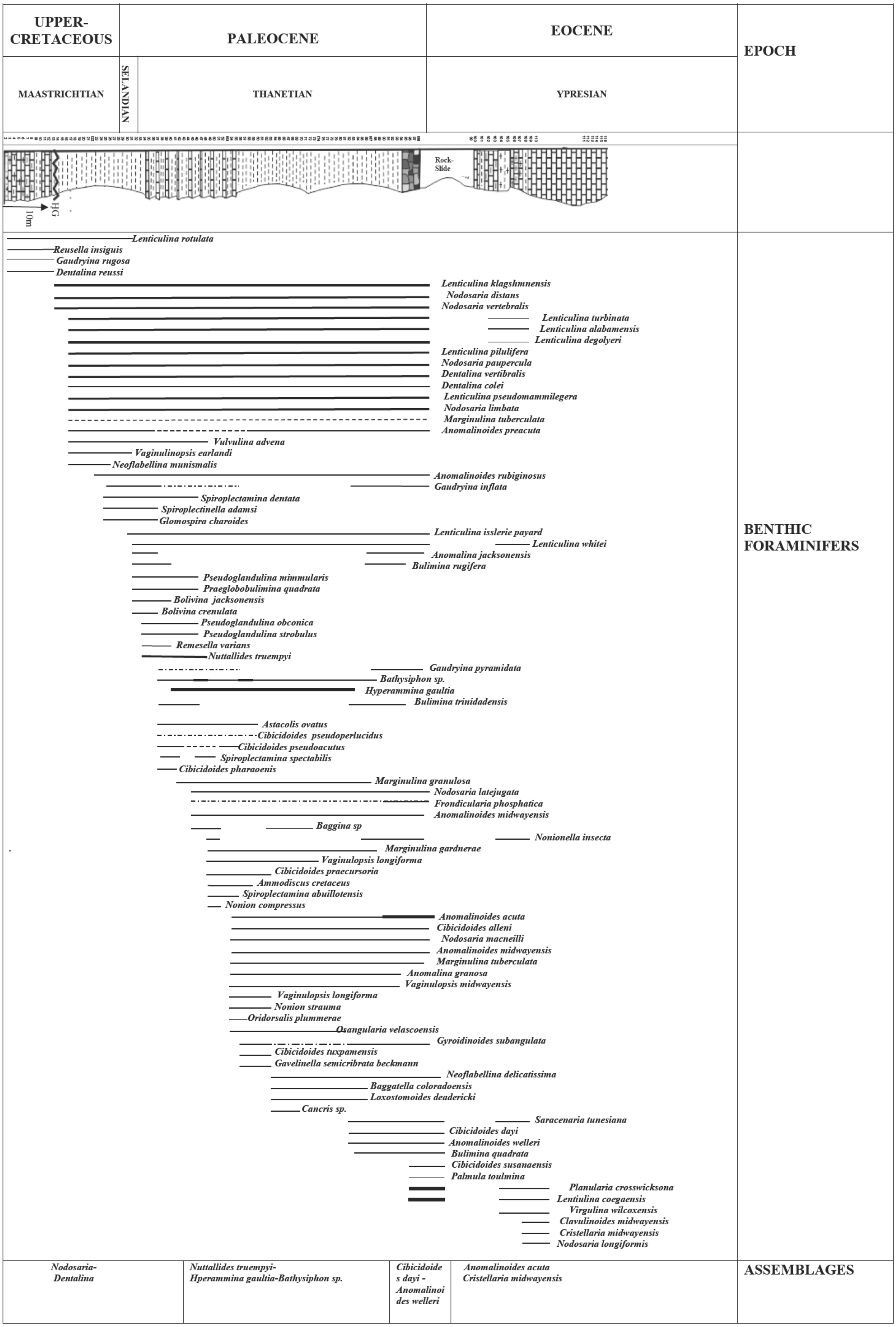

Figure 3) Benthic species distribution of the Serj section.

4.2- Relationship between paleo-diversity and paleo-depth

4.2.1- Total microfauna

During the Paleocene-Early Eocene there was a general increase in foraminiferal densitie for all size fractions (Fig. 4). For the Early Cretaceous (Abiod Formation) we have the lowest numbers of microfauna compared to Paleocene - Early Eocene, there was a general decrease foraminifers presented a minimum density of ~120 specimens in Zel 15. The Paleocene (El Haria Formation) is characterized by the highest densities of microfauna individuals; they were recorded in Zel 53 and Zel 55 (more than 450 fossiliferous individuals). Figure 5 show a progressive dominance of benthic forms from the Early to Late Thanetian. During the Ypresian (Chouabine and Bou Dabbous formations) we have a clear decrease of the total microfauna with the equitability between benthic and planktonic forms. Based on the relative numbers of different shells types of benthic foraminifera we can divide the section in to three shells-zones.

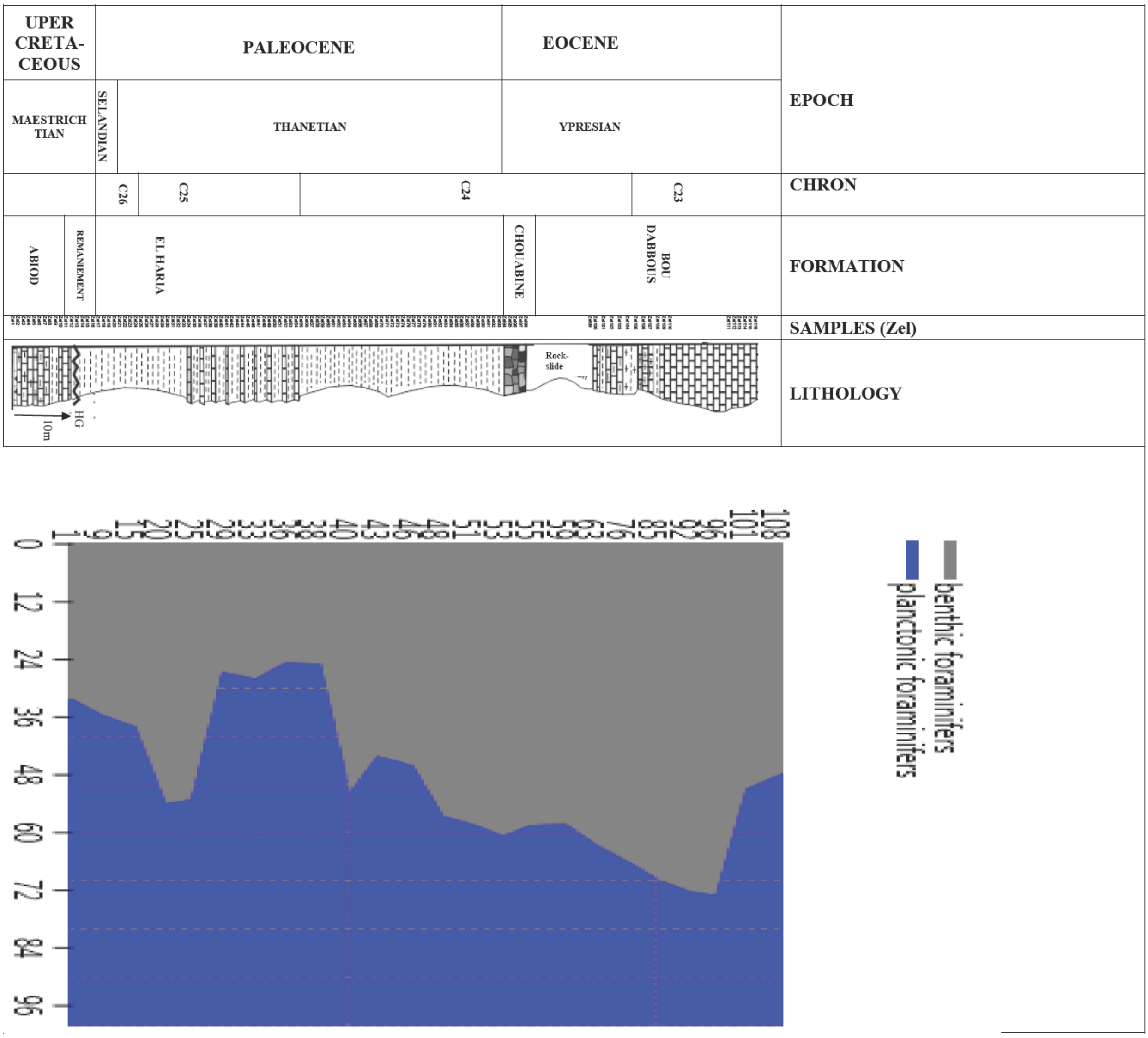

Figure 4) Percentage of foraminiferal faunas.

From Zel9 to Zel35 (top of the Abiod and the base of El Haria Formation) we have the dominance of hyaline with same calcite shells (planktonic forms with Nodosaria and Lenticulina), between Zel 36 and Zel 72 (middle of El Haria Formation) we have the predominance of agglutinated shells (*Hyprerammina* and *bathysiphon*) the end (top of El Haria, Chouabine, and Bou Dabbous Formations) of the section is particularly rich in calcareous species (*Anomalinoides*, *cibicidoides* and lenticulina).

The ratio between planktonic and benthic foraminifera P/B has been calculated in order to estimate paleodepth and productivity fluctuations. The results in figure 5 indicate that the environment evolved from an initially oligotrophic, deep sea, middle bathyal, to upper bathyal setting towards eutrophic outer neritic setting.

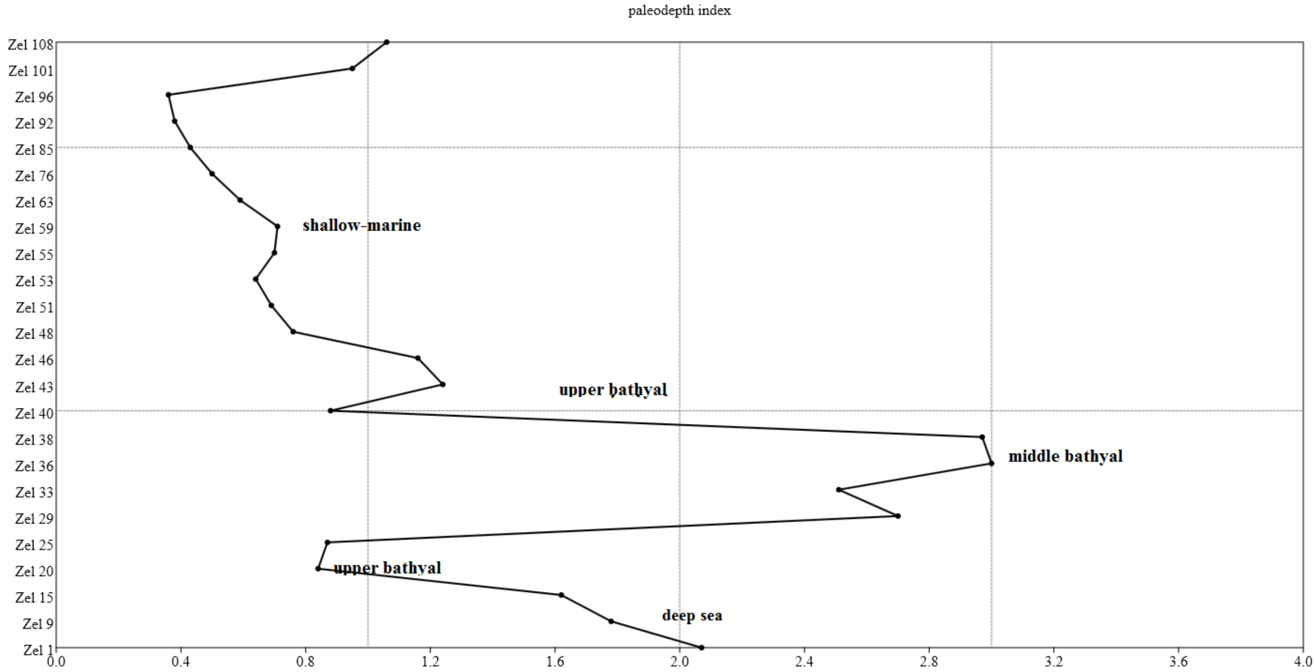

Figure 5) The paleodepth index.

4.2.2- Generic diversity of benthic foraminifera

Benthic foraminifera are an important component of meiofaunal communities in many benthic environments, making them particularly useful for ecological as well as paleoecological studies. Table 1 presents the number of all genus that are >5% of all size fractions (500, 250 and 63µm); it suggests the presence of three main faunal boundaries. Between Zel 9 and Zel 51 we have a phase of increase in number genus. Between Zel 53 and Zel 92 we have the maximum of diversity. Between Zel96 and Zel 108 there is a clearly decreasing of diversity.

Genus richness varies between the samples, the highest genus numbers were found at the thanetian samples (Zel 51 to Zel 96). Genus richness is also comparatively low in Zel 9. Generally, the genus number shows the same trends as the total density of biomass.

The profile of Shannon index (Fig. 6) increases from the base to the top of the section. Values are less than 3 which indicate a minimum of dissolved oxygen concentration. The low values of fisher index reflect a low diversity and high dominance of same genus.

The evenness J (Fig. 6) has two different phases. The first consists of simples with values less than 0,8 (Zel 20, 25, 33, 40, 43, 46 and 48). It characterizes unbalanced assemblages with the biotope. When the evenness is upper to 0,8 the assemblages are stable and the environment is balanced. The dominance index D values (Fig. 6) are more than 0,1 indicate low diversity.

Throughout the section, the dissolved oxygen and the diversity are minimal from the bottom to the top, whereas the dominance is higher. The ecosystem is unbalanced for the deep and middle bathyal environments (hyaline shell-groups), balanced for shallow environment and upperbathyal (agglutinated and calcareous shell-groups).

Table 1) Abundance of Genus of benthic foraminifera (more than 5% of the total).

	Hyperammina	*Bathysiphon*	*Ammodiscus*	*Dentalina*	*Nodosaria*	*Neoflabellina*	*Lenticulina*	*Saracenaria*	*Marginulopsis*	*Valvulina*	*Marginulina*	*Bolivina*	*Bulimina*	*Anomalinoide*	*Gavelinella*	*cibicidoides*	*Gaudryina*	*Spiroplectamina*	*Nuttallides*	*Planularia*	*Cristellaria*	*Virgulina*
Zel 9	0	0	0	32,20	28,81	38,98	0	0	0		0	23		0	0	0	0	0	0	0	0	0
Zel 15	0	0	0	8,19	13,11	22,95	6,55	8,19	11,47	18,03	11,47	0	5	7	0	0	11	7	0	0	0	0
Zel 20	0	0	0	5,08	15,25	10,16	32,54	1,69	15,25	0				9	0	0	0	0	0	0	0	0
Zel 25	0	0	0	5,67	30,49	41,13	2,12	7,80	5,67	7,09	0	11	8	10	0	0	0	0	0	0	0	0
Zel 29	0	0	0	5,88	30,39	51,96	3,92	4,90	2,94	0	0	4	5	3	0	0	0	0	0	0	0	0
Zel 33	0	0	0	6,03	25	49,13	0,86	5,17	6,89	6,89	0	6	8	8	0	0	0	0	0	0	0	0
Zel 36	15,33	8,66	2,66	8	9,33	11,33	14	8,66	12,66	9,33	0	17	21	0	0	0	13	19	14	0	0	0
Zel 38	13,23	8,08	0,73	15,44	5,14	9,55	11,76	18,38	12,5	5,14	0	16	25	0	0	0	0	17	7	0	0	0
Zel 40	26,48	28,97	0,62	5,29	11,83	2,18	6,54	1,86	1,55	1,55	1,86	7,78	2,80	0,62	0	0	0	9	2	0	0	0
Zel 43	34,43	31,78	2,31	1,32	3,64	1,98	4,63	0,99	1,98	0,66	2,64	4,30	5,62	3,64	0	17	0	11	0	0	0	0
Zel 46	7,352	2,45	0,49	1,47	27,94	2,45	31,37	3,43	3,43	0,49	4,41	8,33	6,37	0		13	0	0	0	0	0	0
Zel 48	25,70	29,09	1,97	1,69	3,38	1,97	5,93	0,56	1,41	0,84	3,10	7,06	6,21	7,90	1,41	1,69	0	6	0	0	0	0
Zel 51	20,95	6,287	2,69	4,79	12,57	1,49	16,16	2,39	5,08	1,19	4,49	6,28	4,79	6,58	4,19	0	14	0	0	0	0	0
Zel 53	20,09	22,14	1,36	2,73	11,64	1,82	14,38	2,73	1,82	0,22	2,28	5,02	5,93	2,51	3,19	2,05	0	0	0	0	0	0
Zel 55	20,98	23,83	2,07	2,33	8,54	2,59	12,69	1,81	2,33	0,77	2,33	6,21	5,18	2,33	4,14	1,81	0	0	0	0	0	0
Zel 59	17,66	13,33	2,33	7,66	5,66	13,66	1,66	3,33	4,33	8,66	5,66	5	6,33	4,66	0	19	14	0	0	0	0	0
Zel 63	10,65	13,01	4,73	12,42	5,32	13,90	3,84	2,07	3,25	9,46	2,07	5,32	4,73	5,62	3,55	0	12	0	0	0	0	0
Zel 76	3,53	10,28	7,39	14,46	7,07	17,04	5,46	2,57	4,50	8,36	2,89	3,53	4,18	5,46	3,21	0	10	0	0	0	0	0
Zel 85	0	0	0	7,19	9,93	6,50	10,61	5,13	2,39	6,16	10,61	4,79	12,67	6,50	11,64	5,82	0	0	0	0	0	0
Zel 92	0	0	0	6,57	12,45	7,95	14,53	6,22	4,15	5,53	11,76	4,15	9,68	4,15	9,68	3,11	0	0	0	0	0	0
Zel 96	0	0	0	5,98	8,09	5,63	15,49	5,28	3,52	6,33	5,63	4,92	16,19	2,11	7,39	2,46	10,91	0	0	31	0	0
Zel 101	0	0	0	0	23,71	37,11	16,49	22,68	0		0			0	0	0	0	0	0	22	0	0
Zel 108	0	0	0	0	14,93	25	12,98	17,78	13,46	15,86	0			0	0	0	0	0	0	37	28	33

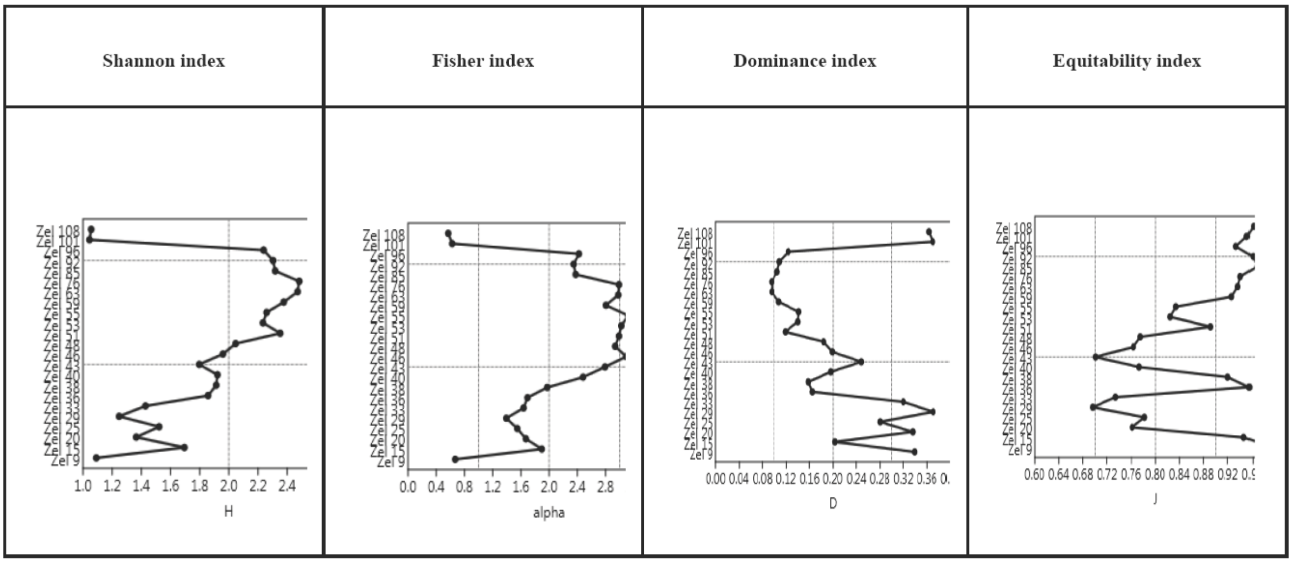

Figure 6) Biodiversity index fluctuations.

5- Discussion

In the Serj section, the lack area which extends from *Gansserina gansseri* to *M. angulata* zone (*Igorina albeari* P3b subzone) covers 10 MA; this section appears to be the most completely log in the region. Since other surrounding sections (plateau of Kesra, Oued Bahloul and Touijine) have sedimentary gaps between 12 to 14MA (Lajnef *et al*., 2005; Jorry, 2004).

The hiatus show a break in the sedimentation accompanied by previous erosion filed marls El Haria Formation. It may be explained by the presence gypseous vein intercalations and celestibarite nodule which indicate an uprising in the region during periods of Maastrichtian – Paleocene.

The benthic faunal assemblages in the studied section may reflect different depositional environments. From deep sea for the *Ganserina ganseri* zone and the *Igorina albeari* subzone P3b with a water depth of about 400–500 m, a middle bathyal depositional for the subzone P4c *Acarinina soldadoensis*/ *Globanomalina pseudomenardii* with a paleobathymetry included between 500-600 m, to a phase of shallowing from upper bathyal to outer neritic setting for the end of the section. The paleoecological indexes of benthic foraminifera illustrate three gradual shell groups (hyaline, agglutinated and calcareous groups) with decreasing paleodepth and age. The high abundance and the low diversity in this section are related to the sedimentological, the minimum of dissolved oxygen and the paleodepth conditions. A positive relationship was observed between shell-groups, paleodepth and lithology. The paleodepth fluctuations in this region are related to the subsidence phenomena.

The minimum of dissolved oxygen have a negative impact, by limiting the diversity of individuals. Currents with a minimum of oxygen can explain this situation. Therefore, only species that tolerate oxygen deficiency persist. This is deduced from the low diversity and the high abundances of some epifaunal species.

We don’t have clear relationship between the distributions of foraminifers and the Global events (K/T) and the Paleocene–Eocene thermal maximum (PETM). During the late Paleocene, both shallowing of the marine basin and sedimentary gap in Central Tunisia is common with the sections of The Boreal (Gradstein *et al*., 1988, 1992, 1994; Nagy, 2005) and the Meridional provinces in Europe (Szczechura and Pozaryska 1971; Gradstein and Bäckström, 1996). Several regions of province were recorded by sedimentary gaps and occupied by hyposaline or even fresh-water, usually occupying shallow basins with restricted marine microfauna (Akhmetiev *et al*., 2010; Oreshkina, 2012). Planktonic microfauna so important for accurate dating of deposits are rare or absent. All the European stratotypes of the Paleocene–Early Eocene were epicontinental, bounded by deposits representing transgressional or regressional phases. These sections are bounded by hard ground surfaces. The group of benthic forms primarily comprises elements of the Velasco type (*Nuttallides truempyi, Osangularia velascoensis, Bulimina trinitatensis*…) typical of deep sea sediments of the Tethys. Their occurrence indicates the proximity of a deep marine basin. Therefore it may be concluded that this assemblage lived on deeper shelf close to the continental slope. A similar situation was found in the case of the Paleocene microfauna of Babica clays from the Polish Carpathians (Szczechura and Pozaryska, 1974) and elsewhere in Europe. There are, however, elements of the Midway type (*Cibicidoides*, *Anomalinoides* and *Lenticulina*), typical of an epicontinental shelf marine basin, of a rather pandemic type. They are known from the North America and southern and central Europe, and Australia (Liu and Olsson, 1992; Berggren and Norris, 1997; Hollis *et al*., 2003; Alegret and Thomas, 2005; Bown, 2005; Alegret, 2007; Alegretand Thomas, 2009; Hulland Norris, 2011 and Alegret*et al*., 2012). The Paleocene yields also some benthic elements unknown from the Boreal provinces, which are characteristic of the Tethyan province and the North African province (*Frondicu nlaria phosphatica* and *Palmula sp*.) caracterise the shallow deposit of the end Paleocene.

6- Conclusions

Micropaleontological study of planktonic foraminifera retrieved from Khanguet Zalga sections spanning the Late Cretaceous- Early Eocene interval yielded six planktonic foraminiferal zones: *Gansserina gansseri* zone of Late Cretaceous (lower Maastrichtian), *Igorina albeari* (P3b) zone of Middle Paleocene (Selandian), *Acarinina soldadoensis* (P4c) subzone of the upper Paleocene, *Morozovella velascoensis* (P5) zones of Late Palaeocene (Thanetian), *Morozovella edgari* (E3) and *Morozovella subbotinae* (E5) zones of Early Eocene (lower Ypresian).

Biostratigraphic and quantitative distribution of benthic and planktonic foraminifera allow the reconstruction of sea-level and paleoenvironmental conditions. Our records indicate that the environment evolved from an initially deep sea sediments relatively poor especially in benthic forms; planktonic foraminifera are rich and diverse. After the sedimentary gap, Selandian marl clay is composed especially of midway warm-water forms, indicate an upper bathyal deposition. During the Thanetian we have two changements in paleodepth, from the middle bathyal for the base of planktonic foraminifera Zone P4c to upper bathyal for the Late of P4c to P5, these fluctuations are reflected by the extinctions of numerous species Velasco type like *Nuttallides truempyi* and *Hyperammina gaultia*. The lack of any clearly cold-water elements and the occurrence of other warm-water forms such as *Buliminids* suggest some increase in the temperature of the water. The Early Eocene period still with phosphatized marl clay with faunas dominated by shallow-marine taxa (*Anomalinoides, Buliminids, Haplophragmoides*). The top of the section is interpreted as indicating an outer shelf setting.

These micropaleontological analyses show that the section maybe one of the most completely section in the region.

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Appendices:

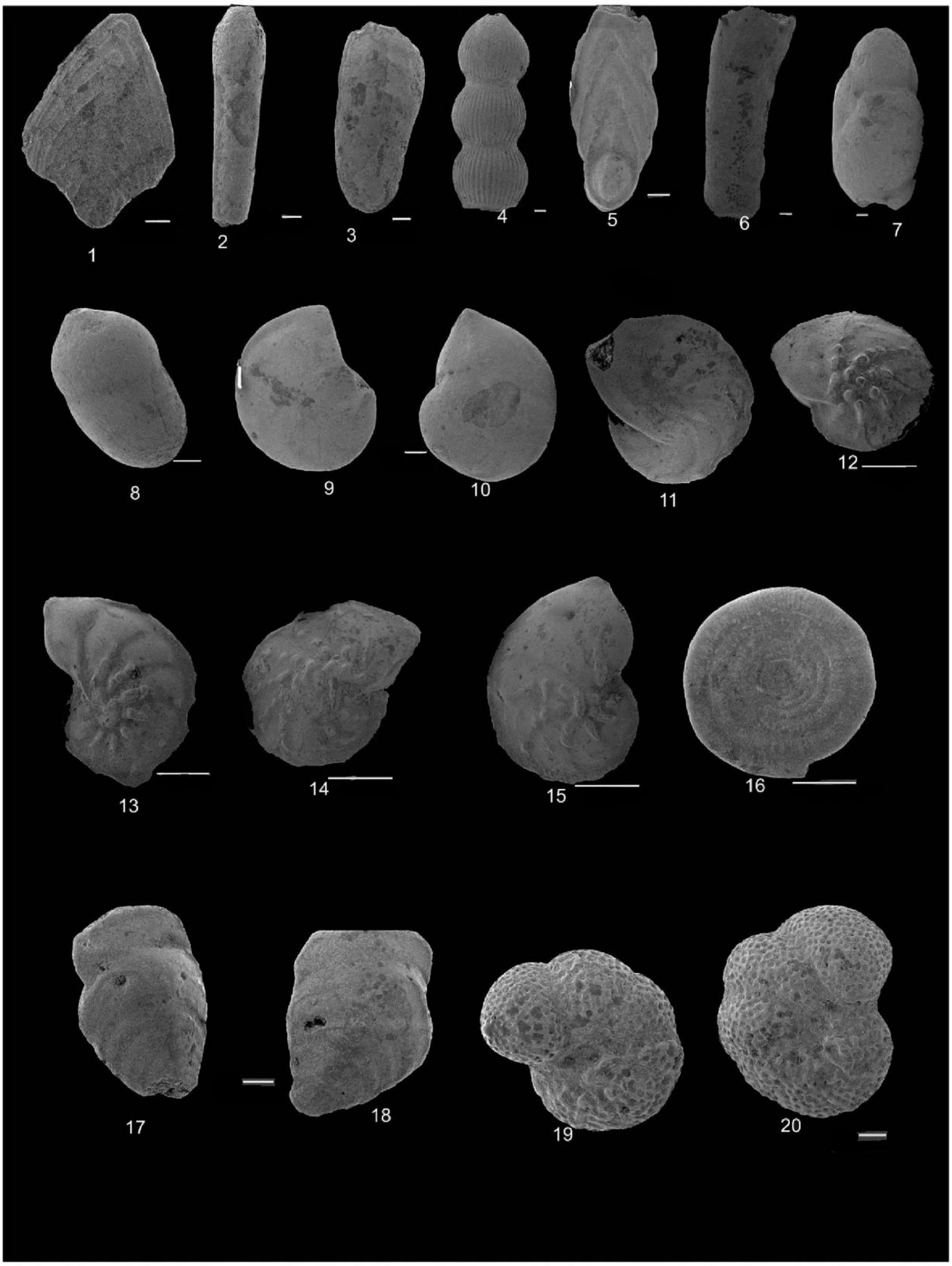

Plate 1) *1: Neoflabellina munismalis (WEDEKIND) (Zel.2); 2: Dentalina reussi NEUGEBOREN (Zel.2); 3: Vaginulinopsis longiforma (PLUMMER) (Zel.2); 4: Nodosaria limbata d'ORBIGNY (Zel.10); 5: Frondicularia sp. (Zel.24); 6: Marginulina sp. (Zel.15); 7: Bulimina quadrata PLUMMER (Zel.16); 8: Marginulina sbbullata Hantk. (Zel.16); 9-10: Lenticulina rosetta (Zel.6); 11: Lenticulina degolyeri (PLUMMER) (Zel.16); 12-13: Lenticulina pilulifera (CUSHMAN) (Zel.15); 14: Lenticulina klagshmnensis (BORTZEN) (Zel.16); 15: Lenticulina sp. (Zel.16); 16: Ammodiscus cretaceous CUSHMAN et HAN (Zel.15); 17-18 : Vulvulina pennatula (Zel.15); 19-20: Anomalina granosa (Zel.33).*

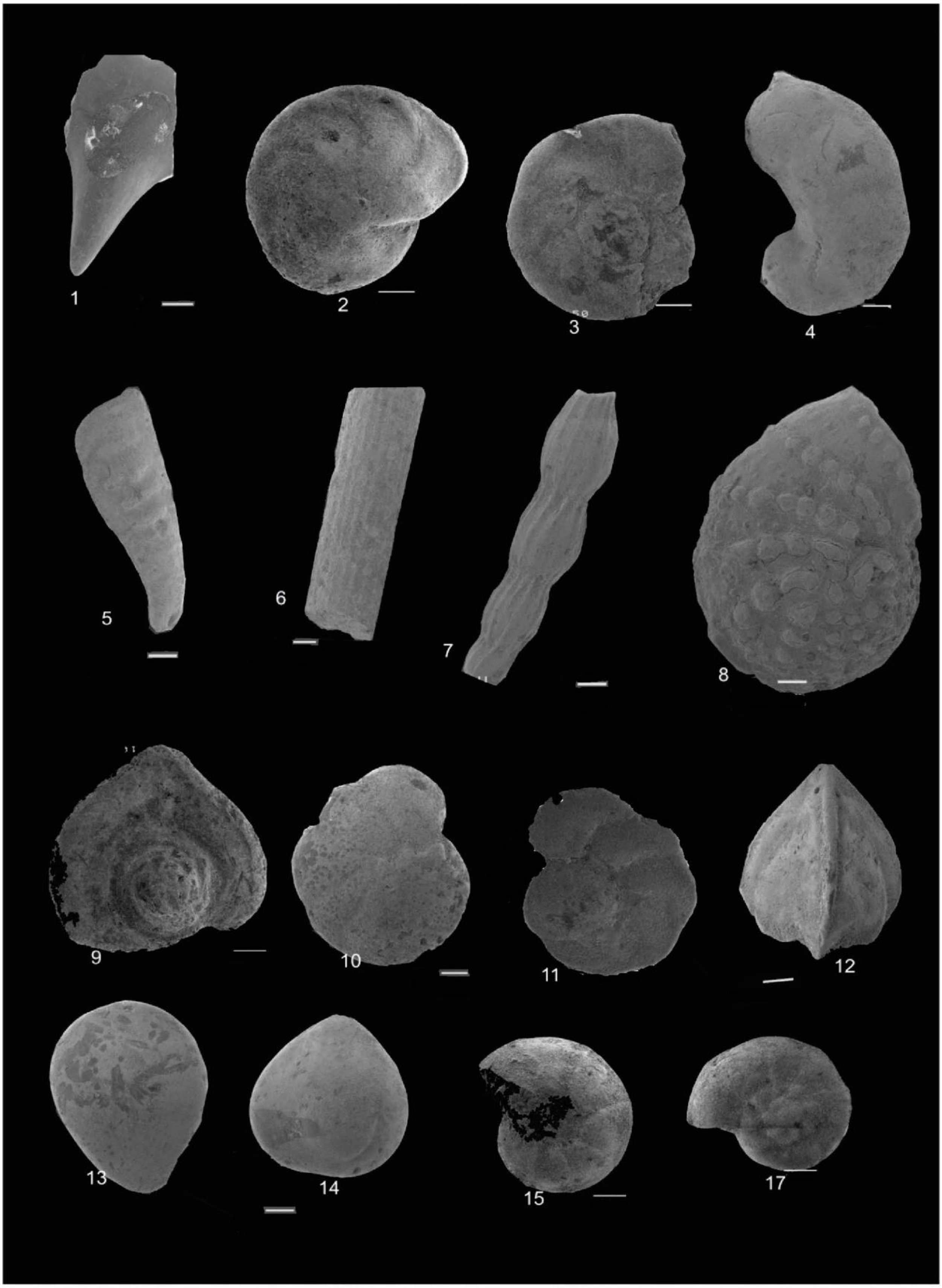

Plate 2) *1: (Zel.38); 2-3: Lenticulina turbinata (Zel.35); 4: Sarasenaria tunesiana TEN DAM et SIGAL. (Zel.35); 5: Vaginulopsis midwayena (Zel.35); 6: Spicule d'échinoderme (Zel.38); 7: Nodosaria macneili CUSHMAN (Zel.38); 8: Marginulina tuberculata (PLUMMER) (Zel.38); 9: palmula toulmini (Zel.23); 10-11 : Cibicidoides praecursoria (SCHWAGER) (Zel.46); 12: Frondicularia phosphatica (Zel.63); 13-14: globulina gibba d'ORBIGNY (Zel.63); 15-16: Gyroidinoides subangulata (PLUMMER) (Zel.63).*

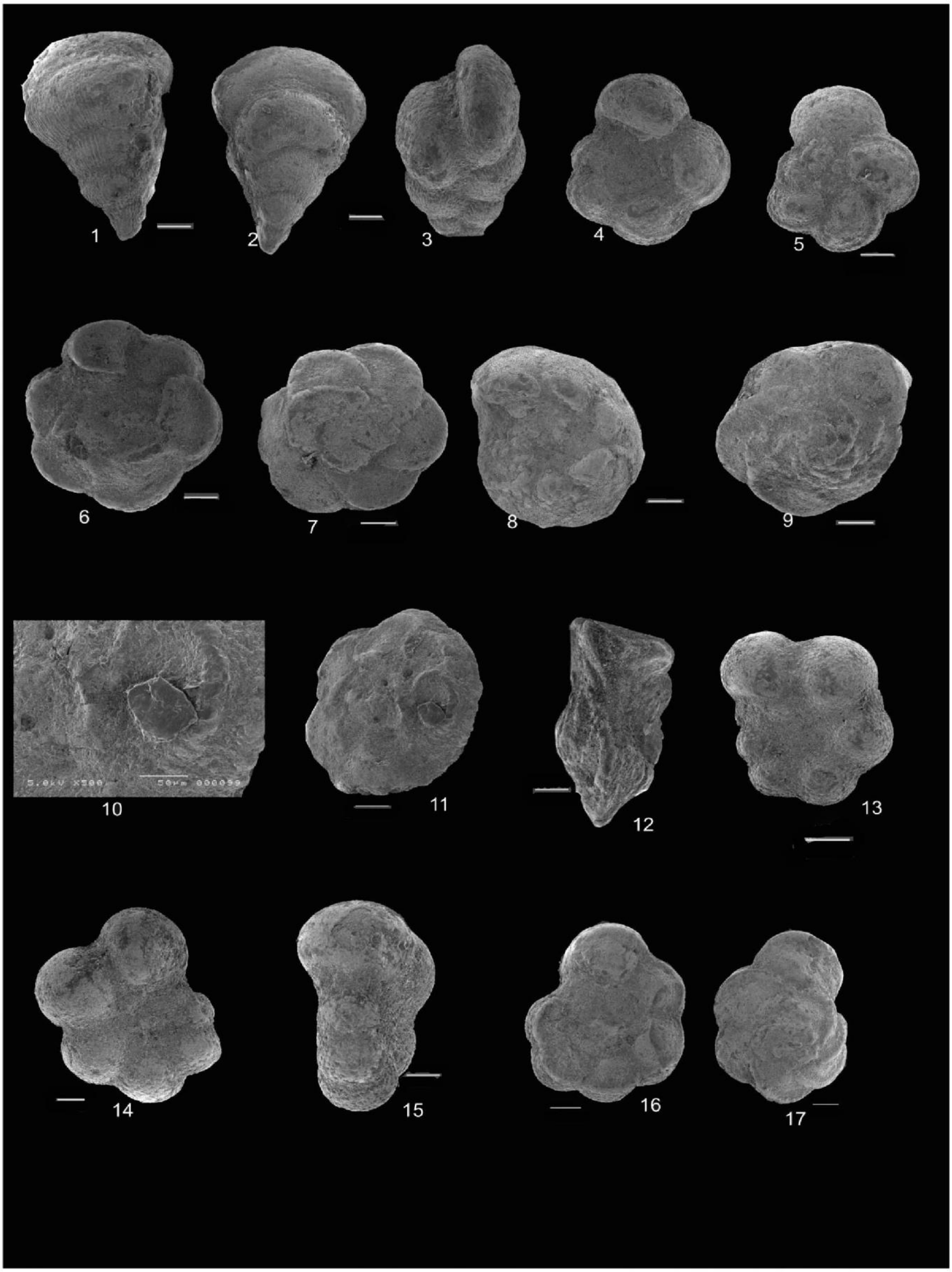

Plate 3) *1-2-3: Pseudotextularia nuttalli (Zel.1); 4-5: Globotruncana bulloides (Zel.1); 6-7: Globotruncana falsostuarti (Zel.2); 8- 9-10-11-12: Globotruncana stuartiformis (Zel.4); 13-14-15: Planomalina alvarez Zel.4); 15-16: Globotruncana linneiana (Zel.4).*

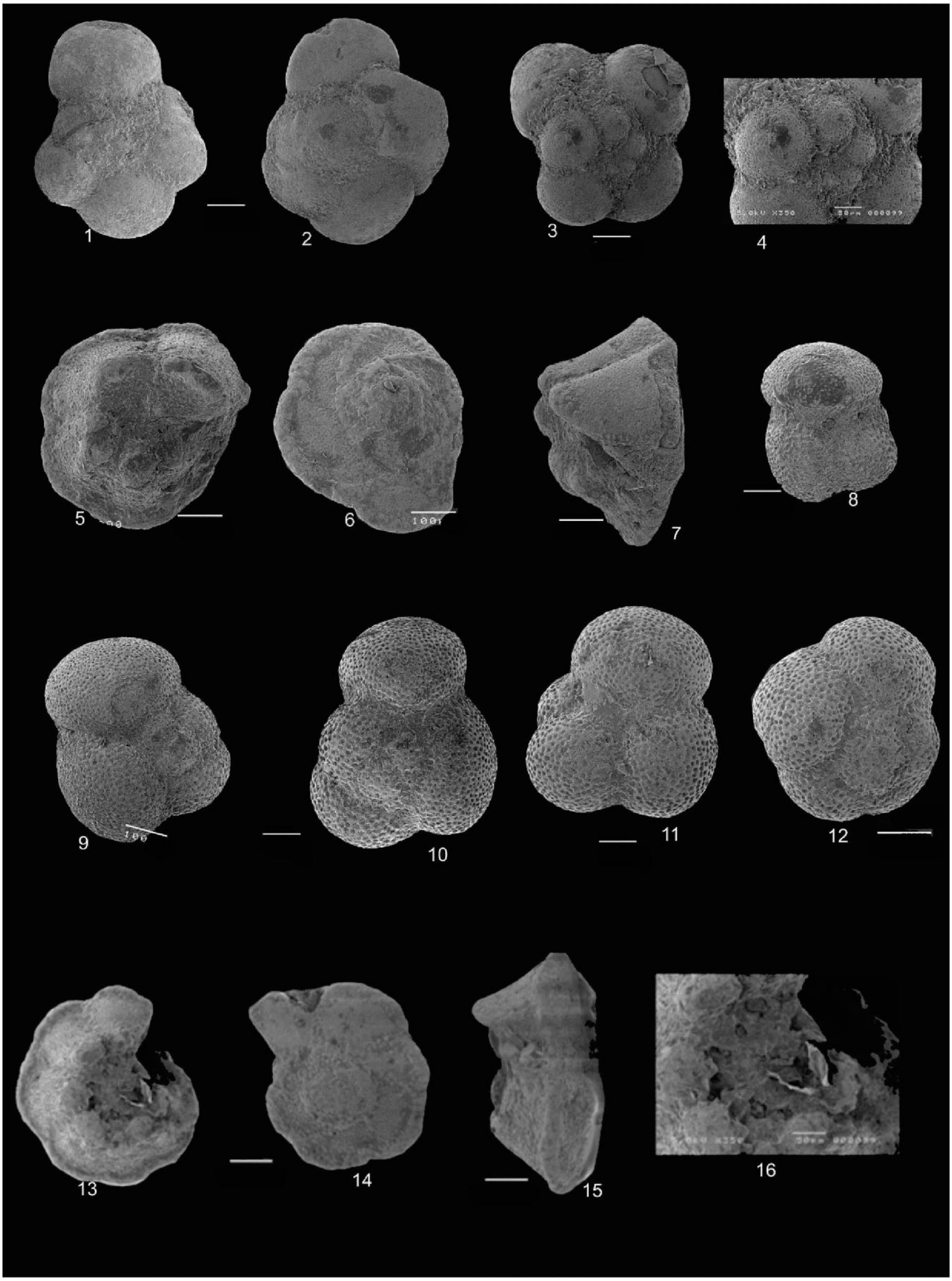

Plate 4) *1-2: Globanomalina pseudomenardii (Zel.48); 3-4: Eogobigerina edita (Zel.35); 5-6-7: Morozovella acuta (Zel.41); 8-9: Subbotina velascoensis CUSHMAN (Zel.47); 10-11: Subbotina sp.1 CUSHMAN (Zel.50); 12: Subbotina sp.2 (BECKMANN) (Zel.50); 13-14-15-16: Morozovella velascoensis (CUSHMAN) (Zel.56).*