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Planktonic foraminiferal ecozones: response of the pelagic environment to palaeoclimatic changes in the eastern Mediterranean Sea

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Abstract

A detailed study of the planktonic environment of the eastern Mediterranean Sea has permitted the reconstruction of the climatic history of this part of the basin during the time span from 9.7 to 6.6 Ma. The eastern Mediterranean Sea is confirmed as having a strong sensitivity to the climatic changes that occurred during that timespan. One of the very few complete hemipelagic successions of the Upper Miocene in Mediterranean is found in Gavdos island (SW Crete). Quantitative and qualitative modifications of the planktonic foraminiferal communities observed in Metochia section exhibit a sequence of biological events summarized in 11 successive main time intervals. The bioevents are defined by frequency peaks and/or local (re)-occurrences or (temporary) disappearances of some of the taxa, in association with more or less important fluctuations of the more common species. The planktonic foraminifera show a strong correlation with sea surface temperature variations and with changes in the physical and chemical properties of the upper water column caused by the climatic instability. Two prominent shifts in faunal parameters divide the period recorded in Metochia section into three major time slices that are discussed in chronological order: a cooling trend from 9,7 to 7,6 Ma, a warmer period from 7,6 to 7,2 Ma and then a cooling trend which finishes at the Messinian.

Keywords: Ecostratigraphy, Planktonic foraminifera, Late Miocene, Gavdos island.

Introduction

Our understanding of paleoclimatic variability has been considerably increased by the many recent studies of global climatic changes (IMBRIE *et al.*, 1984; CHAPPELL & SHACKLETTON 1986; BARNOLA *et al.*, 1987; EDWARDS *et al.*, 1987; BOND *et al.*, 1993; WINOGRAD *et al.*, 1997; DANSGAARD *et al.*, 1993; JOUZEL *et al.*, 1993; ROSSIGNOL-STRICK, 1995; BAR-MATTHEWS *et al.*, 1997). It is well appreciated that the climate system is complex and is affected by forcing factors and feedback related to polar ice bodies and to oceanic and atmospheric circulation.

The signals registered by changes in abundance and distribution of fossil micro-organisms represent one of the most powerful tools in many environmental reconstructions, and in the Mediterranean region they provide a reliable and well-documented record at both global and local scales.

But the paleoclimate of the eastern Mediterranean region (BAR-MATTHEWS *et al.*, 1997; BAR-MATTHEWS *et al.*, 1996; HOROWITZ, 1979; GOODFRIEND, 1991) has received little attention despite its unique position, being a transition zone between a humid climate in the north and an arid climate in the south, and despite the fact that this area is densely populated and was so in the past. The climate of this region is influenced by the inter-relationship between the climatic pattern of Europe and those of the adjacent countries of North Africa and Asia.

In the geological past, during the Middle-Late Miocene the convergence of the African and Eurasian plates resulted first in narrowing and finally closure of the seaways that existed between the Mediterranean Sea and the Atlantic- and Indian Oceans, resulting in the so-called Salinity Crisis. The present paper aims at a detailed reconstruction of paleoenvironmental trends and events preceding this Messinian Salinity Crisis. In particular, a detailed study of the planktonic environment of the eastern Mediterranean Sea permits the reconstruction of the climatic history of this part of the basin during the time span from 9.7 to 6.6 Ma. During that timespan the eastern Mediterranean Sea is confirmed as having a strong sensitivity to the climatic changes that occurred.

Material and Methods

The study area

This paper is based on a study of one of the very few complete hemipelagic successions of the Upper Miocene in Mediterranean, found in Gavdos island (SW Crete) (Fig. 1). The so-called Metochia section (100 m thick), (Fig. 2), contains rhythmic alternations of poorly to non-bioturbated brown-grey sapropelic and

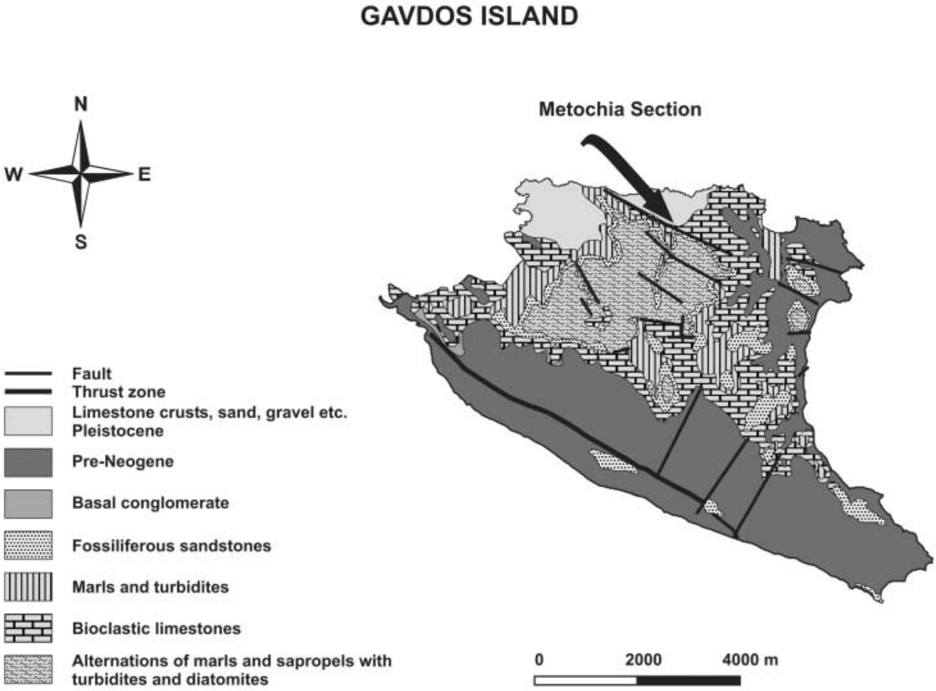

Fig. 1: Location map of the studied area.

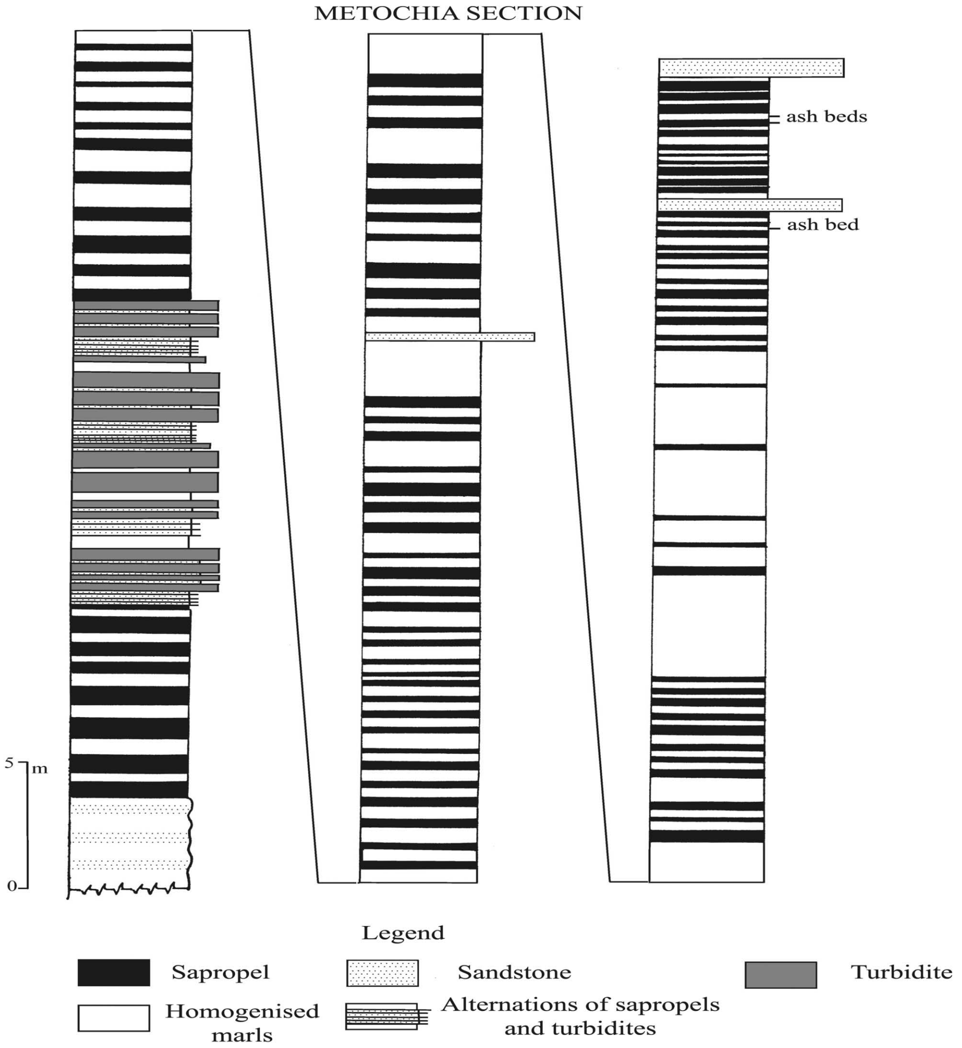

Fig. 2: Lithostratigraphical column of the Metochia section.

bioturbated, white-grey marl beds. The sapropel-bearing succession in the Metochia section is overlain in stratigraphic continuity by cyclically bedded diatomites of Messinian age (TRIANTAPHYLLOU *et al.*, 1999).

The stratigraphic position of the section is known from magneto-, cyclo- and biostratigraphic data (HILGEN, 1991; KRIJGSMAN *et al.*, 1995; HILGEN *et al.*, 1995; ANTONARAKOU, 2001). Based on these, the section covers the time span from 9.7 to 6.6 Ma, a period of supposedly substantial changes in the Mediterranean – Atlantic connections.

Micropaleontological analyses

Samples of about 20 g were taken at 20 cm intervals through the sediment, washed over a 125 μm mesh sieve using distilled water and dried at 50° C. Qualitative and quantitative analyses have been performed on the planktonic foraminiferal assemblage for the fraction >125 μm, split into aliquots each containing at least 300 specimens of planktonic foraminifera. All the shells present in these subsamples were identified and counted and the data expressed as percentages of the total number of planktonic foraminifera.

The planktonic foraminiferal biostratigraphy used in this paper is the one employed in earlier papers and consists of eleven bioevents (KRIJGSMAN *et al.*, 1995), which are accurately dated using the astronomical calibrated time-scale (Table 1):

The Tortonian/Messinian boundary is usually recognized at the First Regular Occurrence (FRO) of *Globorotalia conorniozea* at 7,24 Ma (HILGEN *et al.*, 1995). The ecostratigraphic division of the succession is accomplished using the plankton. Planktic foraminifera are unicellular open marine organisms that have often been used as water mass indicators in the recent oceans and ancient sediments. The distribution and geochemistry of planktonic foraminifera make up an important component of the marine sediment archive of past global environmental changes. Correct interpretation of the past climatic record left by fossil planktonic foraminifera in terms of oceanographic characteristics requires an understanding of the modern ecology, life cycle and shell calcification processes.

In addition, the planktonic foraminifera are short-lived and respond rapidly to the environmental changes. Moreover, the distribution of forams is strongly controlled by surface sea-water distribution.

The faunal assemblages of planktonic foraminifera represent useful tools for the reconstruction of the Sea Surface Temperature. Such reconstructions of past ocean variability rely on statistical relationships between recent surface sediment faunal distributions and compiled SST observations. The rationale for these reconstructions is based on many previous empirical observations (BÉ & TOLDERLUND, 1971; BÉ, 1977), in which the distribution of the recent planktonic foraminifera is thought to be closely related to the distribution of specific water masses, and hence to specific SST. The SST record was determined using the method, which considers the foraminiferal assemblage and the relative abundance of each species as indicators of particular environmental conditions, in which the temperature of the uppermost water column is the main variable.

However, one of the most significant limitations in the application of this SST technique to Mediterranean Sea sediments is the absence of good modern analogues. In particular, some of the faunas observed in our section (for example, *G. scitula* and *T. quinqueloba*) have no modern analogues in the Mediterranean Sea. In this case, the use of extra-Mediterranean analogues would likely compromise the reliability of the results obtained from this method, since faunas in such a basin will bear a strong overprint of biological controls and of specific adaptation. The parameters influencing these organisms are considerably more complex than simple temperature effects. Species living at different depths in the water column provide different sorts of information, not necessarily directly connected to the water temperature. The application of SST is, however important to establish a raw paleoclimatic indicator on which the comparison of other proxies can be made.

Results

The relative abundances of 11 dominant planktonic foraminifera species are presented here in order to examine the changes in sea-surface conditions and climatic changes. These are: *G. apertura, G. bulloides, G. trilobus, G. nepenthes, G. conomiozea, G. menardii, G. scitula, N. acostaensis (s), N. acostaensis (d)* and *T. quinqueloba*. We observed large variations in the relative abundances of these dominant taxa, which may indicate that considerable past changes in surface waters occurred in this part of the Mediterranean Basin during the Late Miocene.

Ecological habits of the dominant planktonic foraminifera species

Globigerina bulloides d' Orbigny

It occurs predominantly in cold subpolar water (BÉ & TOLDERLUND, 1971), in upwelling areas (KROON & GANSSEN, 1988). *Globigerina bulloides* is present in surface sediments throughout the entire Mediterranean Sea making up from 5 to 40% of the most ubiquitous and abundant species in western basin sediments. The lowest percentages of this species are found in the extreme southeastern Mediterranean, where surface water temperature reach 25-26.5° C in the summer. The systematic decrease in *Globigerina bulloides* from west to east clearly demonstrates its temperature dependence. *Globigerina bulloides* is an eurythermic species which flourishes wherever surface waters are eutrophicated, such as in coastal upwelling areas (e.g. THIEDE, 1983; ZHANG, 1985; SAUTTER & THUNELL, 1991), regions off major river mouths (VAN LEEUWEN, 1989) and nutrient-rich marginal basins (BARMAWIDJAJA *et al.*, 1989).

Globigerina falconensis Blow

Generally, *Globigerina falconensis* is a species whose geographic, depth and seasonal distribution patterns are poorly known, because many published plankton haul data lump this species together with *Globigerina bulloides*. Plankton tow data from the western North Atlantic (BÉ *et al.*, 1971) and surface sediment data from the South Atlantic (VAN LEEUWEN, 1989) and southern Indian Ocean (MALMGREN & KENNETT, 1977) indicate that this species prefers to live in the cool subtropical regions.

Globigerinita glutinata (Egger)

It is one of the most ubiquitous species, whose distribution ranges from Antarctic through tropical to subarctic waters.

In the Mediterranean Sea, *Globigerinita glutinata* is present at low density. Low abundances are found at the end of summer in the surface waters of the Gulf of Lion and of the Balearic Basin. It is prolific in winter and occurs preferentially within a 100-200m depth interval along the North African coast. Generally, *Globigerinita glutinata*, is a surface dweller (RAVELO *et al.*, 1990) whose abundances show no relationship with either sea surface temperature or sea surface productivity (BÉ & HUTSON, 1977).

Turborotalita quinqueloba Nattland

This small species is restricted to cool water masses in the Atlantic. It lives in the photic zone and bears symbiots (HEMLEBEN *et al.*, 1989). According to OTTENS (1992), the highest frequencies are found in regions where no Deep Chlorophyll increases production during the spring from subpolar to tropical regions, in relation to certain light and/or fertility conditions. Within the Mediterranean, there are several areas of moderately high frequencies (1-10%) of *Turborotalita quinqueloba*. The region directly east of the Straits of Gibraltar is marked by cool surface water flowing in from the North Atlantic. *Turborotalita quinqueloba* is a small sized species whose test diameter seems to increase with decreasing sea surface temperature (KROON *et al.*, 1988). In standard size fraction counts, its relative abundance, therefore, increases from low to high latitude, (e.g. BÉ & HAMLIN, 1967; BÉ & TOLDERLUND, 1971) and explains why this species is generally classified as a cool-water species (e.g. BÉ & HUTSON, 1977; PUJOL, 1980). *Turborotalita quinqueloba*, clearly prefers the period of high phytoplankton productivity in the well mixed, cold waters that are characteristic of the winter water masses (REYNOLDS & THUNELL, 1985).

Globorotalia scitula (Brady)

Globorotalia scitula is generally associated with cool water (BÉ & HUTSON, 1977; HEMLEBEN *et al.*, 1989). This species was widespread in the Mediterranean at glacial times but is conspicuously absent during the Holocene and Eemian (JORISSEN *et al.*, 1993). This pattern suggests that *Globorotalia scitula* can be used as a cool water indicator in the Mediterranean.

Globorotalia menardii Tjalsma

Globorotalia menardii is a tropical-subtropical species that lives preferentially in subsurface waters below 50 meters and probably descends to bathypelagic depths in late ontogeny. It is a good warm-water indicator species and easily recognisable but is not as abundant as *Globigerinoides sacculifer*. It is important that *Globorotalia menardii* shows a relationship to salinity. This species is found in subtropical to tropical water (BÉ & TOLDERLUND, 1971; BÉ & HUTSON, 1977; BÉ, 1977) and has been used extensively as a stratigraphic - climatic indicator in the tropical Atlantic. It is significant that *Globorotalia menardii* is absent from the Mediterranean surface sediments (PARKER, 1958; TODD, 1958) and is found in only small quantities in the water column (CIFELI, 1974) as the Mediterranean represents a high salinity environment that otherwise supports such tropical species as *Globigerinoides ruber* and *Globigerinoides sacculifer* (PARKER, 1958; THUNELL, 1978).

Globoturborotalita nepenthes (Todd)

Globoturborotalita nepenthes in Kennett (1985), favored tropical to warm subtropical areas from the equator. According to ZACHARIASSE *et al.*, (1979), *Globoturborotalita nepenthes* prefers mixing and a relative high nutrient level.

Globigerinoides trilobus (Reuss)

Globigerinoides trilobus, contains two major phenotypes; with and without sac-like final chamber (*Globigerinoides sacculifer* and *Globigerinoides trilobus*), which represent the overlapping part of a recent gradational series. In our samples we have incorporated both phenotypes in *Globigerinoides trilobus*. Within the Mediterranean these species are most frequent in the warm eastern basin where surface temperatures range from 23.50°C to 26.50°C in the summer. The cool Aegean Sea and the area associated with bottom water formation in the western basin are regions where *Globigerinoides sacculifer* is least frequent. The progressive increase in *G. sacculifer* from west to east reflects its strong temperature dependence. *Globigerinoides sacculifer* and *trilobus* are the most prolific and widespread species among the warm water planktonic foraminifera. It attains its highest frequencies in tropical waters, especially in the central equatorial regions of the Atlantic, Indian and Pacific Oceans. These species make up 20 per cent or more of the planktonic foraminifera in all tropical seas and in wide areas of subtropical waters. They occur over a surface temperature range of 15°C to 30°C, with peak abundance primarily between 24° and 30°C.

Globoturborotalita apertura group

In this group we have included the species *Globoturborotalita apertura* and *Globigerinoides obliquus*. These species live in the low fertility mixed layer of the tropical and subtropical regions (BÉ & HUTSON, 1977; FAIRBANKS *et al.*, 1982; THUNELL & REYNOLDS, 1984; RAVELO *et al.*, 1990).

Globorotalia conomiozea Kennett

This species lives in warm-subtropical assemblages but also in cool subtropical areas (KENNETT, 1973). It appears preferentially at mid to high latitudes. The FOD of *G. conomiozea* in the Mediterranean Sea is the result of migration of the North Atlantic bioprovinces, not an in situ evolution (ZACHARIASSE, 1975; SIERRO, 1985; SIERRO *et al.*, 1993).

Neogloboquadrina sp. Group

The living representatives of *Neogloboquadrina* belong to one biogeographic cline (SRINIVASAN & KENNETT, 1976) and feed

Table 1
Planktonic foraminifera bioevents.

Bioevents	Stratigraphic level	Astronomical Age (Ma)
G. nicolae FO	99.25 - 99.35 m	6.82 - 6.83
G. conomiozea FRO	90.25 - 90.33 m	7.23 - 7.24
G. menardii 5 FO	87.90 - 87.97 m	7.35
G. falconarae LO	85.20 - 85.69 m	7.44 - 7.46
G. menardii 4 LCO	84.12 - 84.24 m	7.50 - 7.51
S. seminulina HRO	79.06 - 79.31 m	7.72 - 7.73
S. seminulina LRO	74.44 - 74.60 m	7.91 - 7.92
G. falconarae FS	57.31 - 57.84 m	8.42 - 8.44
G. falconarae LCO	44.10 - 44.27 m	8.86
G. menardii 4 LCO	29.35 - 29.76 m	9.31 - 9.32
N. acostaensis HRO	9.81 - 9.93 m	9.54

exclusively on phytoplankton (HEMLEBEN *et al.*, 1989). Phytoplankton in the tropical oceanic regions is highly abundant in Deep Chlorophyll Maximum (DCM) layers and highest abundances of tropical neogloboquadrinids, therefore, occur in the DCM layer (FAIRBANKS *et al.*, 1982; RAVELO *et al.*, 1990). Also cooler-water morphotypes seem to exploit food sources, which are associated with the (seasonal) DCM layer (REYNOLDS & THUNELL, 1986; SAUTTER & THUNELL, 1991). Elevated percentages of sinistrally coiled morphotypes correlate with glacial isotope stages (RUDDIMAN *et al.*, 1989), whereas dextrally coiled morphotypes show no such a relationship. This suggests that the sinistral form is a cooler-water morphotype than the dextral form. *Neogloboquadrina acostaensis* is rather tolerant of salinity changes and able to profit from favourable nutrient conditions.

Ecostratigraphy

The faunal abundance patterns shown in Figs 3 to 13 provide many interesting clues for interpreting the changes in surface water conditions in this region. The compositional changes and frequency variations in combination with the ecological attributes mentioned above, of the planktic foraminiferal assemblages, allow identifying eleven ecozones in the studied area (DRINIA & ANTONARAKOU, 2003). The bioevents, which characterize the bottom and top of every two successive ecozones, have been used to define the ecozone boundary. The eleven ecozones are defined as follows:

Ecozone 1 (9.7-9.52 Ma), Fig. 3. It is characterized by the relatively high abundances of *G. trilobus* and *G. nepenthes*, which are warm species. The planktonic microfauna during this period is however dominated by cold taxa among which *G. falconensis, G. bulloides, N. acostaensis* dextral and *G. glutinata* are the most abundant. There is therefore a lack of supportive data to confirm the slightly warm trend indicated by the foraminiferal community.

Ecozone 2 (9.52-9.24 Ma), Fig. 4. The composition of the planktic microfauna is rather similar to the previous one, described in ecozone 1, but it differs by the higher percentages of *G. trilobus* and the appearance of *N. acostaensis* sinistral which indicates cooler environmental conditions, the absence of the tropical species *G. menardii*, the further reduction of *G. nepenthes* and the increase in cool-water faunal composition.

Ecozone 3 (9.24-8.81 Ma), Fig. 5. It is characterized by high values of the cool-water species *G. bulloides*, a rather constant low percentage of *G. nepenthes* and *T. quinqueloba*, fluctuating percentages of *G. scitula* and a peak in abundance in the middle part of the ecozone of *G. trilobus*.

Ecozone 4 (8.81-8.4 Ma), Fig. 6. The microfauna shows a significant presence of *G.*

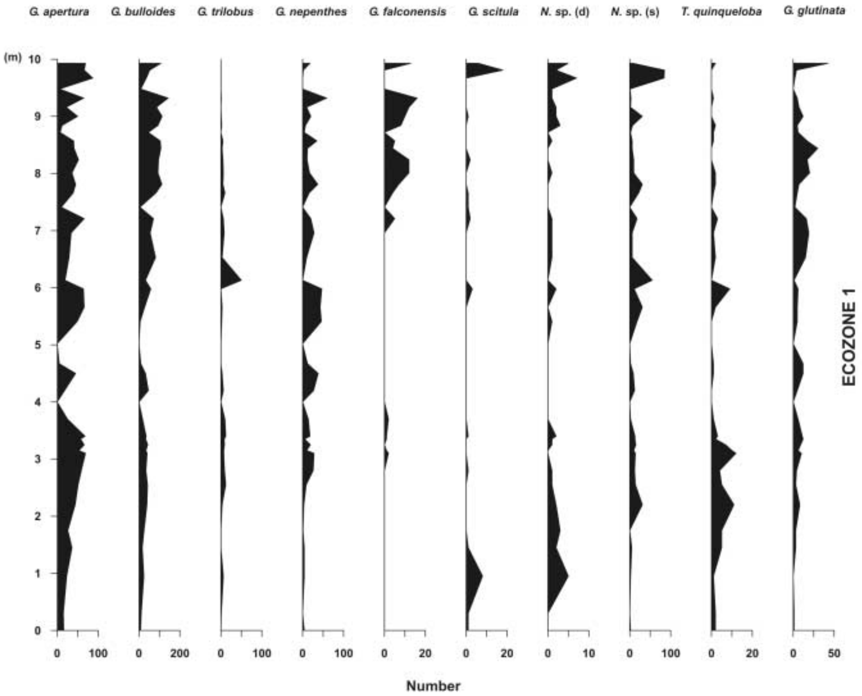

Fig. 3: Relative frequencies % of planktic foraminifera of the Ecozone 1.

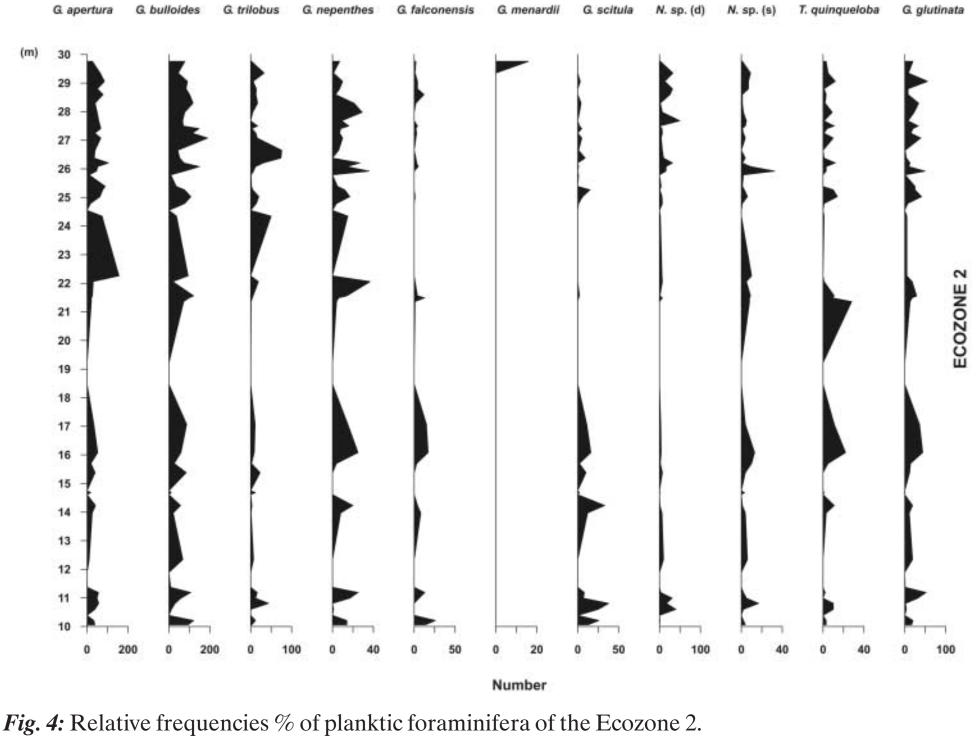

Fig. 4: Relative frequencies % of planktic foraminifera of the Ecozone 2.

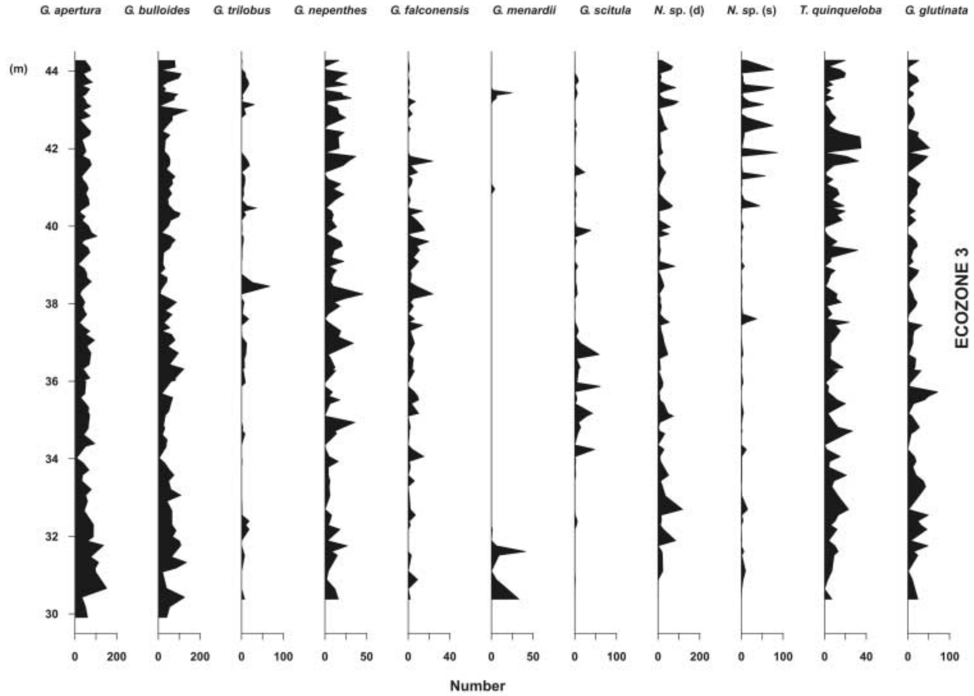

Fig. 5: Relative frequencies % of planktic foraminifera of the Ecozone 3.

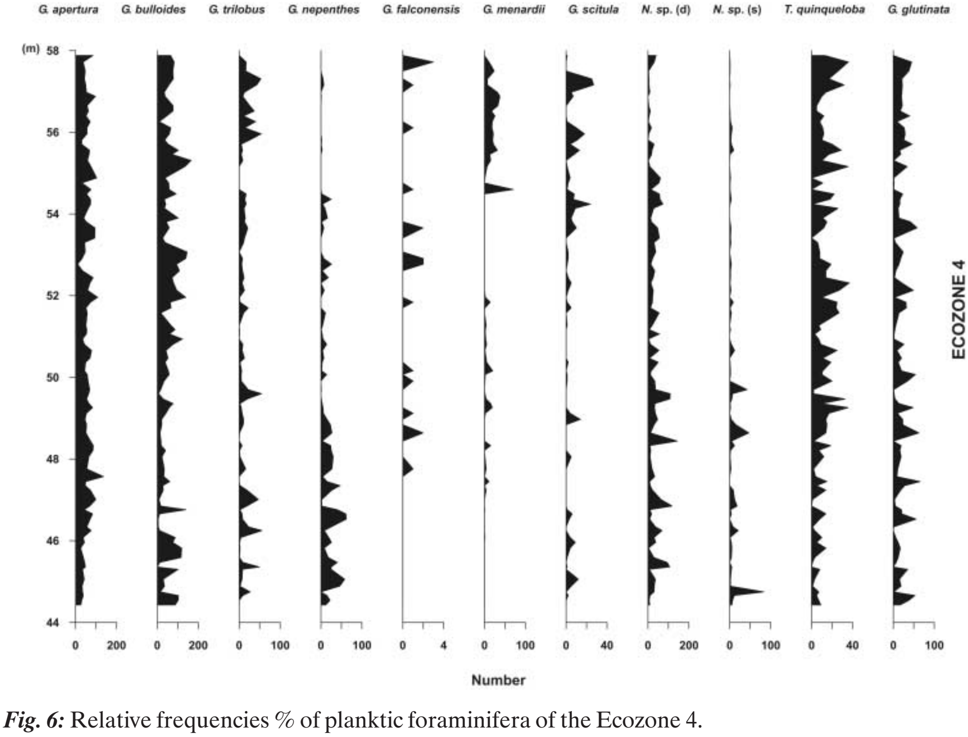

Fig. 6: Relative frequencies % of planktic foraminifera of the Ecozone 4.

falconensis and *G. bulloides*, which are cool water species, a common occurrence of *T. quinqueloba*, a decreasing value of *G. nepenthes*, and in some levels *G. trilobus*.

Ecozone 5 (8.4-7.85 Ma), Fig. 7. It is especially characterized by the presence of *G. falconensis*, the decreasing percentage values of *G. bulloides* and the three peak abundances of *G. trilobus* at the expense of *G. bulloides*. The near absence of *G. bulloides* and the highest percentage value of *G. trilobus* in association with the common occurrence of *G. nepenthes* in the upper part of this zone reveal that a significant change took place around 7.9 Ma.

Ecozone 6 (7.85-7.65 Ma), Fig. 8. In this ecozone an abrupt change occurs in the overall faunal association. The assemblages are characterized by the low percentages of *G. menardii* form *4* and *G. falconensis*, the high percentages of *T. quinqueloba*, the absence of *G. bulloides* and the fluctuating variations of *G. scitula*. The faunal composition of this interval indicates the onset of a warm period.

Ecozone 7 (7.65-7.4 Ma), Fig. 9. As before, *T. quinqueloba* is the dominant taxon. An increase in the percentages of *G. nepenthes*, *G. apertura-G. obliquus* group, *O. universa*, together with a strong decrease of *G. bulloides* and *G. falconensis* indicate that the climate was obviously warmer.

Ecozone 8 (7.4-7.32 Ma), Fig. 10. This interval is basically defined by the peaks in frequency of the warm-water species *G. nepenthes* and *G. apertura-G. obliquus* group. The normal occurrence of *N. acostaensis* sinistral in combination with the peaks in abundance of the cool-water species *G. scitula, T. quinqueloba, G. glutinata* and *G. falconensis* indicates that this time interval was slightly cooler than ecozone 7.

Ecozone 9 (7.32-7.23 Ma), Fig. 11. The composition of the planktic microfauna of this short time interval is rather similar to the previous one. The FO of *G. menardii* form *5* at 7,369 Ma (KRIJGSMAN, 1997) indicates a temperature increase. The first regular

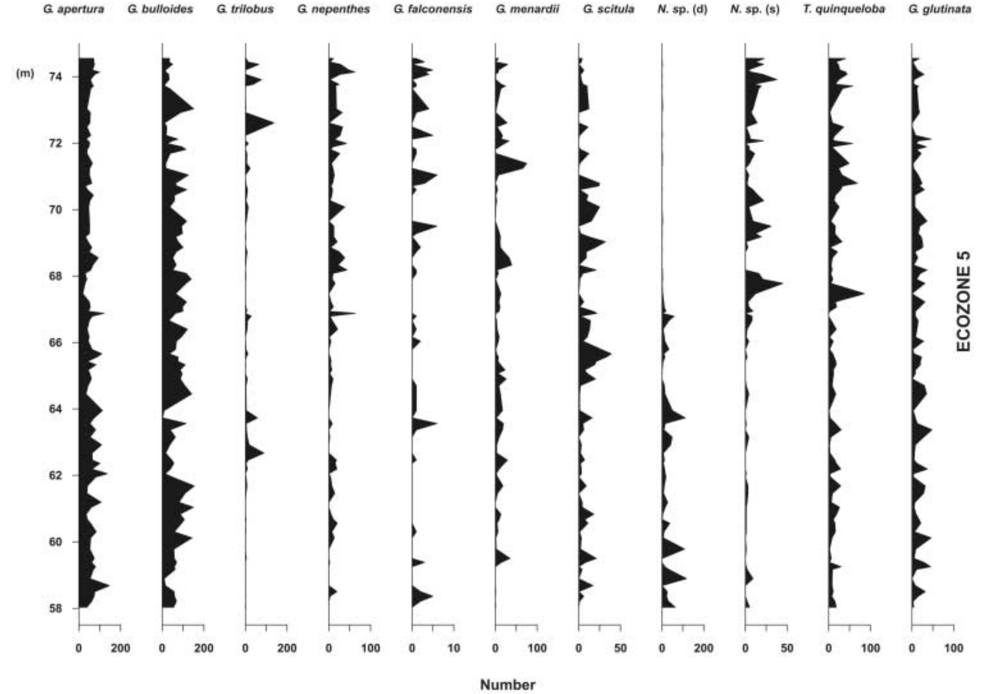

Fig. 7: Relative frequencies % of planktic foraminifera of the Ecozone 5.

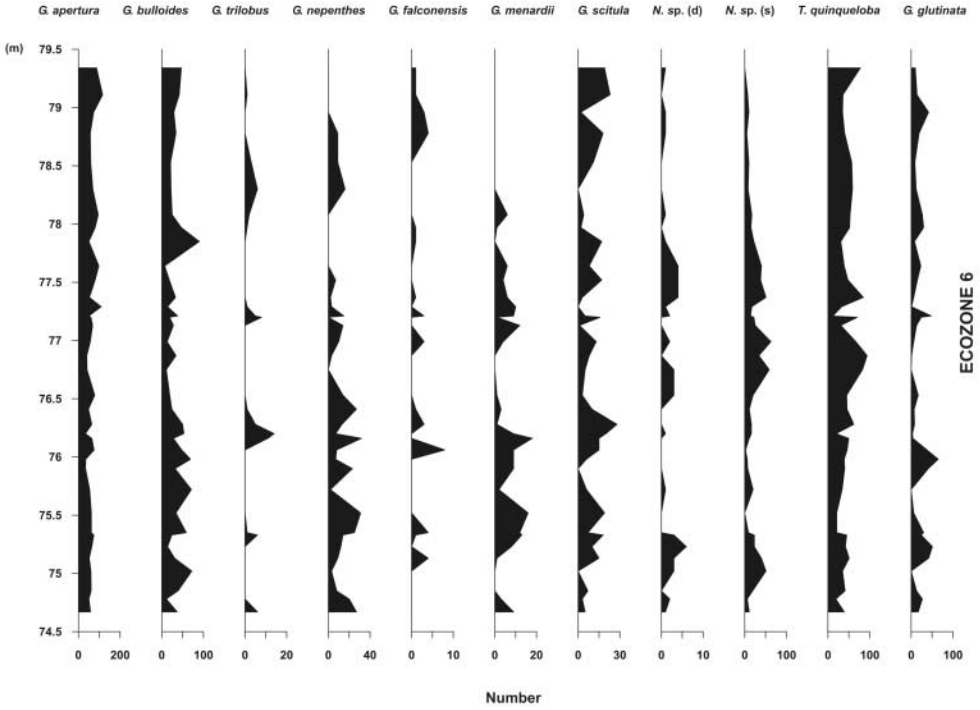

Fig. 8: Relative frequencies % of planktic foraminifera of the Ecozone 6.

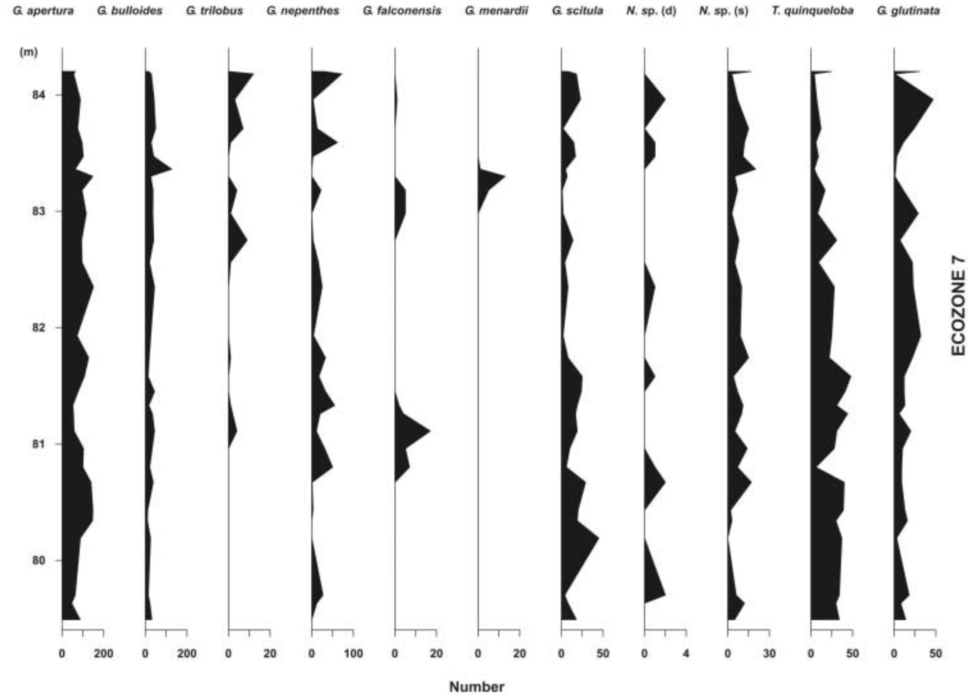

Fig. 9: Relative frequencies % of planktic foraminifera of the Ecozone 7.

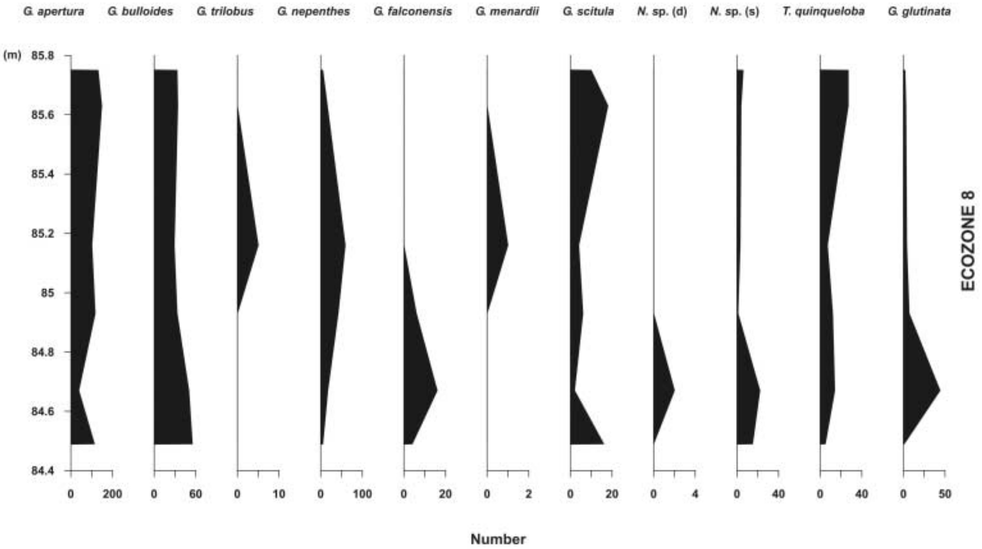

Fig. 10: Relative frequencies % of planktic foraminifera of the Ecozone 8.

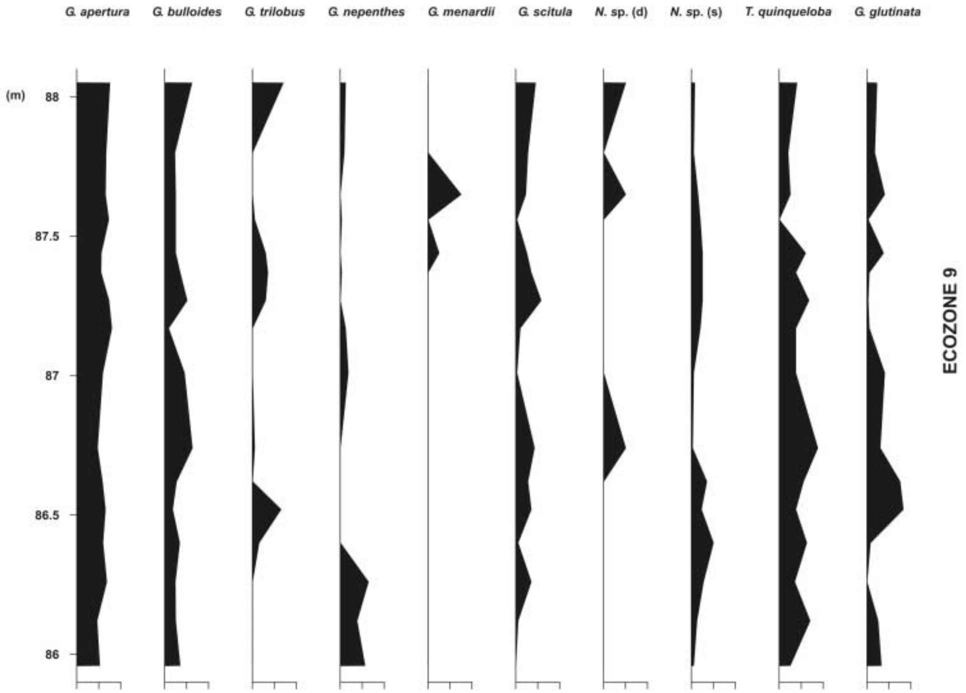

Fig. 11: Relative frequencies % of planktic foraminifera of the Ecozone 9.

occurrence of the *Globorotalia conomiozea* group marks the boundary with the ecozone 10.

Ecozone 10 (7.23-7.12 Ma), Fig. 12. It is composed of high percentage values of the warm-water species *G. apertura-G. obliquus group* and *G. trilobus* and low percentage values of the cold water species *G. falconensis* and *N. acostaensis* sinistral.

Ecozone 11 (7.12-6.68 Ma), Fig. 13. The most prominent feature of this ecozone is the normal occurrence of the cold-water species *G. conomiozea* in combination with the increase in abundance of *N. acostaensis* sinistral, *G. falconensis* and *G. bulloides*, which indicate the establishment of cold water climatic conditions.

Discussion

Late Miocene Mediterranean paleoceanographic model

According to GEBHARDT (1999), during the Tortonian, stable environmental conditions with highly oxygenated waters were established in the western Mediterranean (BIZON, 1985). A stronger inflow of cool surface water from the Atlantic and absence of temperature fluctuations is indicated by the nature of calcareous nannofossils (MÜLLER, 1985) and planktonic foraminifera (ZACHARIASSE & SPAAK, 1983). In addition, the higher amount of radiolaria in the Tortonian samples maybe caused by higher nutrient input from Atlantic surface waters (see also BRASIER, 1995).

Since the Middle Miocene, paleoenvironmental differences are indicated between the eastern and western Mediterranean basins (e.g. BIZON, 1985; MÜLLER, 1985). The eastern basins experienced less oxygen supply due to their more restricted configuration (e.g. CITA & ZOCCHI, 1978; KATZ & THUNNELL, 1984) resulting in less diverse faunas.

The eastern Mediterranean has been the focus of intensive studies during the last decades. The crucial importance of this small and marginal basin is in its capability to register

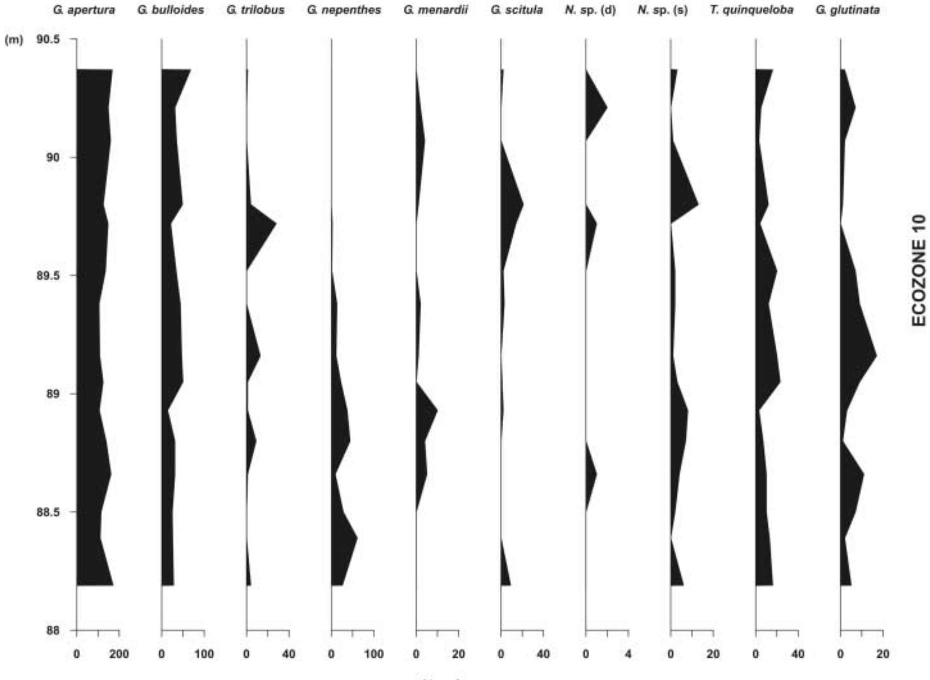

Fig. 12: Relative frequencies % of planktic foraminifera of the Ecozone 10.

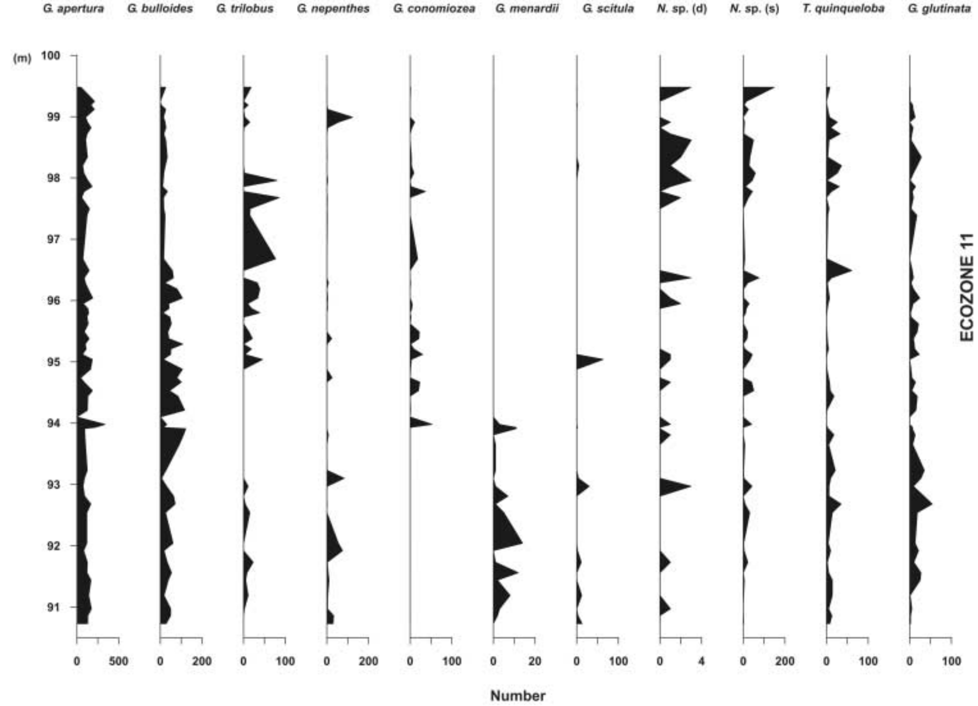

Fig. 13: Relative frequencies % of planktic foraminifera of the Ecozone 10.

and amplify the smallest climatic variations occurring at the mid-latitude regions. Quantitative and qualitative modifications of the planktonic foraminiferal communities observed in the Metochia section exhibit a sequence of biological events summarized in 11 successive main time intervals, which are identified as ecozones.

However, two prominent shifts in faunal parameters divide the period recorded in the Metochia section into three major time slices that will be discussed in chronological order.

Long-term changes reflected by the abundance fluctuations pattern are determined by a cooling trend from 9,7 to 7,6. From 7,6 to 7,2 Ma, *G. menardii* is the most common group together with *G. apertura – G. obliquus* and *G. nepenthes*, which are warm water indicators. The cool water species are more restricted. The LCO of *G. menardii* form 4 at 7.5 Ma and the FO of *G. menardii* form 5 at 7.369 Ma (KRIJGSMAN *et al.*, 1997) further indicate a temperature increase. HODELL *et al.* (1994), who worked on Moroccon (extra-Mediterranean) material, found benthic isotopic evidence for a warming trend that started a bit later and crossed the Tortonian/Messinian boundary. Together with a warming, the vertical circulation slowed down. A similar scenario was postulated earlier by VERGNAUD-GRAZZINI (1983). Constriction of the Atlantic-Mediterranean connections could further contribute to increasing residence time of deeper waters.

On approaching the Tortonian/Messinian boundary interval (at 7,24 Ma), the more or less stable conditions present before were subject to more profound changes. The subsequent influx of *G. conomiozea* suggests biogeographical changes related to cooling (ZACHARIASSE, 1979; CHAMLEY *et al.*, 1986).

The extra-Mediterranean isotope record of HODELL *et al.* (1994) suggests a more prolonged cool period than our record, but the start of the 'siphon event' (influx of deep, cold Atlantic waters through the Rifian Corridor) proposed by BENSON *et al.* (1991) could be biostratigraphically correlated to this cooling. Moreover, the manganese- and vanadium-records, carried out by KOUWENHOVEN *et al.* (1999), both indicate reduced ventilation of the deep Mediterranean waters.

According to KOUWENHOVEN *et al.* (1999), a major shift towards more restricted benthic faunas starts during the earliest Messinian. The faunal trends indicate that oxygen levels at the seafloor diminished further.

Conclusions

A detailed study of the planktonic environment of the Metochia section has permitted the reconstruction of the climatic history of this part of the eastern Mediterranean basin from 9.7 to 6.8 Ma. Our evidence indicates that the eastern Mediterranean was predominantly influenced by climatic factors at ~ 7,5 and ~ 7.24 Ma. During 7,4-7,24 Ma, a warming may have led to a first slowing down of the vertical circulation of the Mediterranean water masses. At 7,24-6,68 Ma time interval a cooling event is evident. Our results coincide with those recorded in the Monte del Casino section in northern Italy (KOUWENHOVEN *et al.* 1999).

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