

Paleotemperature changes and speciation among benthic Foraminifera in the Mediterranean Pliocene

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ABSTRACT — Two discrete, short time intervals, during which two massive extinction events in the Mediterranean benthic foraminiferal population occurred, have been detected in the Pliocene. They are respectively dated between 3.2 and 3.0 MA, when at least 34 species disappeared, and between 2.6 and 2.4 MA, when at least 22 species disappeared. The two time-intervals coincide with two climatic crises, when a sharp temperature decrease occurred: the later is considered to coincide with the onset of the glaciation in the Northern Hemisphere.

Only during stable climatic regimes (subtropical, during the Early Pliocene) or with small climatic fluctuations (temperate, in the upper part of the Pliocene and in the Lower Pleistocene) the appearance of new benthonic foraminiferal species is recognized. Therefore, climatic conditions (and strong climatic fluctuations) played a major role in speciation (and radiation) of the benthonic foraminiferal population during Pliocene and Early Pleistocene in the Mediterranean.

RIASSUNTO — [Oscillazioni delle paleotemperature e della speciazione tra i foraminiferi bentonici mediterranei durante il Pliocene] — La possibilità di riconoscere nel Pliocene e Pleistocene inferiore alcuni dati biocronologici ormai ripetutamente controllati ha permesso di evidenziare nel Pliocene mediterraneo due distinti e brevi intervalli di tempo caratterizzati dalla scomparsa di numerose specie di foraminiferi bentonici. Rispettivamente riferibili agli intervalli compresi tra 3,2 e 3,0 MA e tra 2,6 e 2,4 MA, tali eventi coincidono con due crisi climatiche di intenso raffreddamento, chiaramente messi in evidenza dalle analisi isotopiche: la più recente è considerata rappresentare l'inizio della glaciazione nell'emisfero settentrionale.

Solo negli intervalli durante i quali è stato possibile individuare regimi climatici stabili (subtropicale, nella parte inferiore del Pliocene; temperato e con limitate fluttuazioni nella parte superiore del Pliocene e nel Pleistocene inferiore) è riconoscibile la scomparsa di un certo numero (notevole nel primo caso, modesto nel secondo) di nuove specie di foraminiferi bentonici. Sembra potersi concludere pertanto che le condizioni climatiche (e in particolare ampie fluttuazioni climatiche) giocarono un ruolo determinante nella contrazione ed espansione della diversità tassonomica delle associazioni a foraminiferi bentonici durante il Pliocene e il Pleistocene inferiore mediterraneo.

INTRODUCTION

The detailed analysis of benthonic foraminifera in fairly complete and continuous Pliocene-Early Pleistocene Mediterranean sequences clearly reveals two intervals during which the extinction of many species occurred. These two events occurred during the M. Pl 4 (*Sphaeroidinellopsis subdebiscens*) and M. Pl 5 (*Globigerinoides elongatus*) biozones. These two intervals could not be related to an absolute time scale, since a detailed biochronologic scheme has not been available until now.

A well established sequence of calcareous planktonic events, based on foraminifera and nannoplankton, provides an integrated biostratigraphic framework which allows for detailed subdivision of the Pliocene and Lower Pleistocene (Rio *et al.*, in press). High stratigraphic resolution, with 8 Pliocene and 3 Lower

Pleistocene first-order integrated calcareous plankton intervals has been established (Rio *et al.*, 1984; Rio *et al.*, in press). For instance, the long *Discoaster tamalis* nannoplankton biozone can be subdivided on the basis of the successive extinction levels of *Globorotalia puncticulata* s.s. and of *Sphaeroidinellopsis* spp. (penecontemporaneous with the appearance level of *Globorotalia bononiensis* and of the *Globorotalia crassaformis* group); moreover, the long M. Pl 5 foraminiferal biozone (*Globigerinoides elongatus* zone, Cita, 1975; Rio *et alii*, in press) can be subdivided on the basis of the subsequent extinction levels of *Discoaster tamalis* and *D. pentaradiatus* (Rio *et al.*, in press).

Further improvement comes from the possibility of associating absolute ages with some of the first-order fossil events, with an accuracy of about 0.2 MA. On the basis of these biochronologic levels, estimates of sediment accumulation rates have been made for three

different continuous Pliocene-Lower Pleistocene sequences in Sicily (Capo Rossello-Punta Piccola; Monte San Nicola, near Gela) and in the Tyrrhenian basin (Site 132, DSDP, Leg 13); these estimates match well the lithological variations recognizable in the sequences. By linear interpolation of the sediment accumulation rates, the ages of intervening events, considered as second order biochronologic events, have been deduced. Their accuracy is confirmed by cross-checking in the three sections. These bioevents always follow in the same order, as previously determined in many other Mediterranean and extra-Mediterranean sequences. This suggests that no major diachroneity exists. On the basis of these data, reported and discussed in Rio *et al.* (in press), the Pliocene and Lower Pleistocene have been subdivided into time-intervals with a mean duration of 0.2 MA., which is estimated to be the maximum error inherent in the age-determination of the first-order biochronologic events. Therefore, all of the paleontologic, sedimentologic, tectonic and climatic events can be biostratigraphically correlated to this biochronologic scale, and their timing and rates of change can be determined.

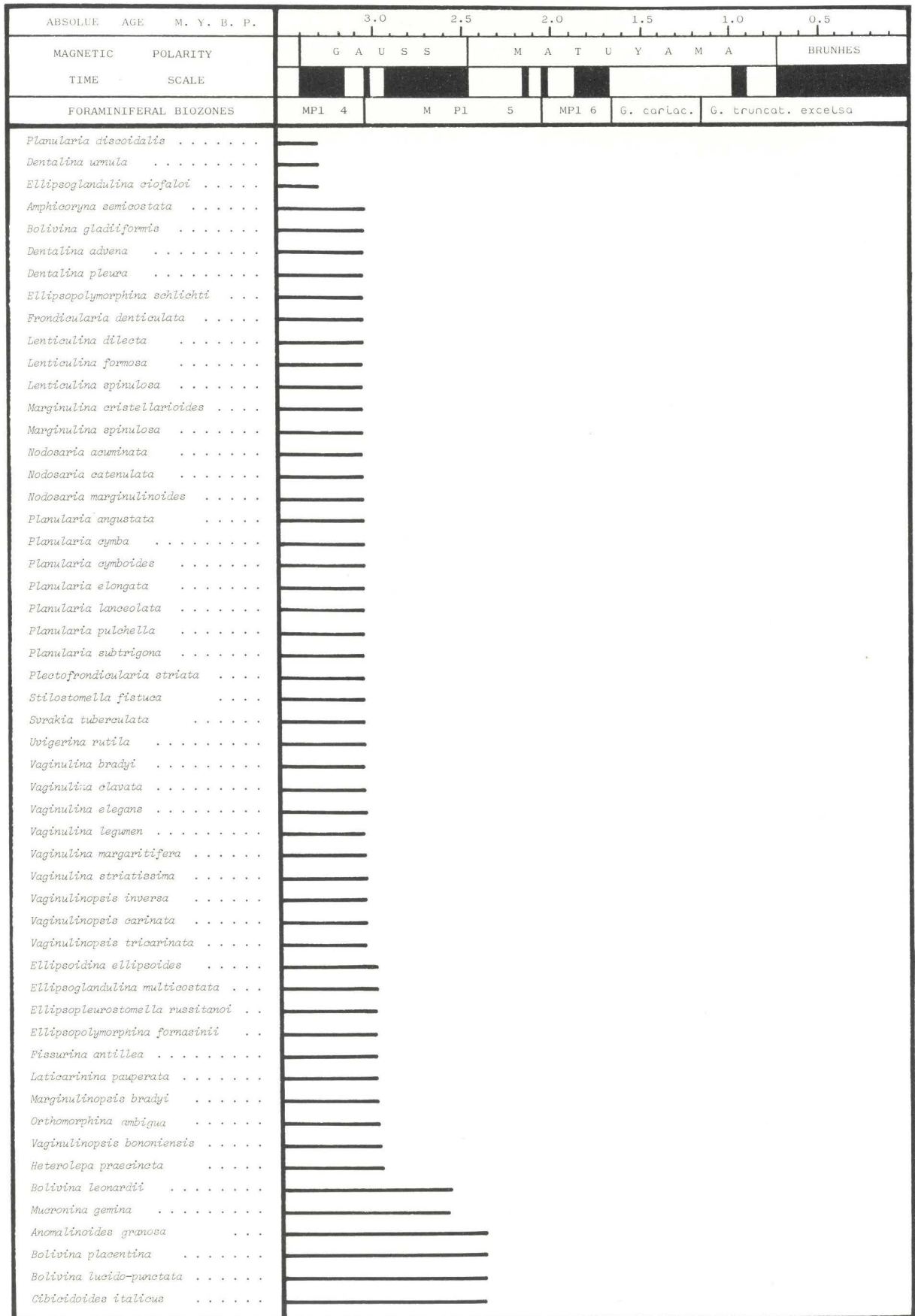
BENTHIC FORAMINIFERA SPECIATION IN THE MEDITERRANEAN PLIOCENE AND LOWER PLEISTOCENE

The Italian peninsula, strongly affected by tectonics during the Pliocene and Early Pleistocene, is a classical region for the study of sediments of this stratigraphic interval. Especially suitable for biostratigraphic and paleoenvironmental studies are the continuous, highly fossiliferous sequences outcropping in Sicily, with a thickness of a few hundreds of meters. The lower part of this sequence is always represented by the cream colored marlstones «Trubi» of Early Pliocene age, followed upwards by the gray marls of the Monte Narbone formation (Late Pliocene), and terminating with the overlying interbedded clayey marls, sands and calcarenites of the Agrigento formation (Latest Pliocene-Earliest Pleistocene). This sequence represents a regressive sedimentary cycle, with a gradually decreasing depositional depth. The epibathyal paleoenvironment of the «Trubi», with an estimated sedimentation depth between about 600 and 1000 meters, gradually evolved into an outer neritic environment (upper part of the Monte Narbone formation), followed by a shallower neritic environment of the Agrigento formation (Sprovieri, 1978).

Foraminifera are always very abundant throughout the Pliocene and Pleistocene sequence. Drastic, but temporary impoverishment of the benthic foraminiferal assemblages are only recorded at different levels

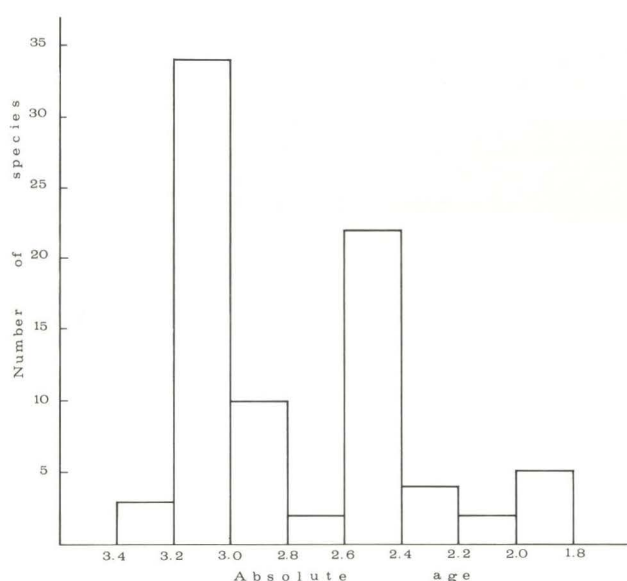
within the upper part of biozone M Pl 5 (*Globigerinoides elongatus* zone) and in the M Pl 6 (*Globorotalia inflata*) zone, in association with sapropelitic layers. In the «Trubi» marlstone planktonic foraminifera are abundant; benthic foraminifera, generally represented by a low percentage (maximum 15%) display a particular high taxonomic diversity (more than 400 different species) in the upper part of this lithologic unit. Recent studies in several more or less complete sections of «Trubi» in Sicily (d'Onofrio, 1964; Di Grande, 1968; Casale, 1969; Sprovieri, 1974, 1976, 1978, 1979a, 1981) demonstrated that the number of benthic foraminifera species rapidly increases upwards in the sections from Northern Sicily, but slowly and gradually in the sections outcropping in Southern Sicily. Only in the lower part of the M Pl 4 biozone do the benthic foraminiferal assemblages from the two areas attain a comparable, and maximum diversification both from a quantitative and qualitative point of view. Most of these species are recorded since the Miocene (primarily, since the Tortonian) and they repopulated the Mediterranean sea floor after the well known Messinian salinity crisis (Ruggieri, 1967; Hsu *et al.*, 1973; Ruggieri and Sprovieri, 1976, 1978; Cita, 1982). Alternately, other species are unknown from Mediterranean pre-Pliocene sediments. Because of the peculiarity of the repopulation of the Mediterranean basin during the earliest Pliocene (immigration from the Atlantic into a previously sterilized basin) and of the very limited information on the benthonic foraminiferal population living at that time in the Atlantic Ocean near the «portal» (the Gibraltar threshold) through which the immigration took place, it is difficult to determine if they must be considered as new species. The period of radiation (due to immigration and probably speciation) was quite long, beginning at the base of the Pliocene (about 5.3 MA) and continuing until the extinction level of *Globorotalia puncticulata* s.s. (about 3.3 MA). No benthic foraminifera became extinct during this time-interval, while within planktonic foraminifera the successive extinctions of *Globigerina nepenthes* and *Globorotalia margaritae* occur. Instead, a massive extinction event within the benthic population occurred from about 3.2 MA (just above the *Globorotalia puncticulata* s.s. LAD) to about 3.0 MA (*Sphaeroidinellopsis* spp. LAD). At least 34 benthic species (among which *Uvigerina rutila* must be pointed out) (fig. 1; tab. 1), disappeared, with a net loss of about 10% of the benthic foraminiferal population. In the next two time-intervals (from about 3.0 MA to about 2.6 MA (*Discoaster tamalis* LAD)) the number of extinctions gradually but rapidly decreases, again not being balanced by any appearances. Two species disappeared from about 2.8 MA to 2.6 MA,

Tab. 1



Tab. 1 (continue)

ABSOLUTE AGE	M. Y. B. P.	3.0 2.5 2.0 1.5 1.0 0.5									
MAGNETIC TIME	POLARITY SCALE	G A U S S			M A T U Y A M A				BRUNHES		
FORAMINIFERAL	BIOZONES	MP1 4	M P1 5		MP1 6	G. cariac.	G. truncat. excelsa				
<i>Dimorphina tuberosa</i>		_____									
<i>Lenticulina ariminensis</i>		_____									
<i>Lenticulina echinata</i>		_____									
<i>Lenticulina spinata</i>		_____									
<i>Lenticulina submamilligera</i>		_____									
<i>Marginulina coarctata</i>		_____									
<i>Martinottiella perparva</i>		_____									
<i>Nodosaria pentecostata</i>		_____									
<i>Nodosaria acutecostata</i>		_____									
<i>Orthomorphina bassanti</i>		_____									
<i>Planularia gemata</i>		_____									
<i>Planularia reniformis</i>		_____									
<i>Uvigerina longistriata</i>		_____									
<i>Vaginulina patens</i>		_____									
<i>Vaginulina sulcata</i>		_____									
<i>Buliminoides diaphana</i>		_____									
<i>Heterolepa dertonensis</i>		_____									
<i>Anomalinoidea helicina</i>		_____									
<i>Lenticulina convergens</i>		_____									
<i>Cibicidoides abnerianus</i>		_____									
<i>Nodosaria antennula</i>		_____									
<i>Bulimina minima</i>		_____									
<i>Cibicidoides robertsonianus</i>		_____									
<i>Cibicidoides cicatricosus</i>		_____									
<i>Cylindrocavallina rudis</i>		_____									
<i>Lingulina seminuda</i>		_____									
<i>Marginulina crebriacosta</i>		_____									
<i>Psammospaera testacea</i>		_____									
<i>Bulimina basispinosa</i>		_____									
<i>Uvigerina torquata</i>		_____									
<i>Bulimina marginata</i>		_____									
<i>Gyrogoninoides altiformis</i>		_____									
<i>Astrononion sallentinum</i>		_____									
<i>Euxenkoina tenuis</i>		_____									
<i>Globobulimina ovula</i>		_____									
<i>Orthomorphina stainforthi</i>		_____									
<i>Uvigerina mediterranea</i>		_____									
<i>Craeiloculina staurostoma</i>		_____									
<i>Gyrogoninoides delicata</i>		_____									
<i>Uvigerina bradyana</i>		_____									
<i>Bulimina elegans marginata</i>		_____									
<i>Islandiella ionica</i>		_____									
<i>Articulina tubulosa</i>		_____									
<i>Uvigerina costato-caudata</i>		_____									
<i>Bulimina etnea</i>		_____									
<i>Hyalinea baltica</i>		_____									
<i>Paromalina crassa</i>		_____									
<i>Rectobolivina zitteli</i>		_____									
<i>Coryphostoma karreerianum</i>		_____									
<i>Paromalina coronata</i>		_____									
<i>Bolivinita quadrilatera</i>		_____									



Text-fig. 1 - Histogram of the species extinctions in the different time-intervals. Absolute age in MA.

while at least 10 species became extinct from about 3.0 to 2.8 MA, with the greatest number of them disappearing at a level slightly younger than 3.0 MA. Such extinctions, therefore, may represent a sort of «queue» of the major extinction event of the previous time-interval.

A second extinction acme is recognized from about 2.6 to 2.4 MA (between *Discoaster tamalis* and *Discoaster pentaradiatus* LADs) (text-fig. 1; tab. 1), when at least 22 species disappeared. Since only two species, *Bulimina basispinosa* and *Uvigerina torquata* appeared (just above the *D. tamalis* LAD, at about 2.6 MA) a further net loss affected the benthic foraminiferal population.

Only a small number of species disappeared in younger intervals, and were balanced by a gradual appearance of new species (tab. 1) from about 2.2 MA, until a level just above the *Cyclococcolithus macintyreii* LAD, at about 1.5 MA.

All the results on the distribution of benthic foraminifera discussed above are essentially based on data obtained from epibathyal and outer neritic sediments outcropping in Sicily and in the Vrica section, the latter for the interval referable to the Latest Pliocene and Early Pleistocene (see d'Onofrio, 1981). Very few Plio-Pleistocene sections have been studied to date in detail in Northern and Central Italy (Iaccarino, 1967; Barbieri, 1967; d'Onofrio, 1968; Bosio *et al.*, 1981). Thus, for these regions the most useful data, even if not so accurately defined, come from the Atlas of the Agip Mineraria (1982). No

major discrepancies appear in comparing the ranges of the species recognized from the different geographic areas. Therefore the conclusions here reported might be of general value for all the Italian Plio-Pleistocene sequences. Less detailed data are available from Plio-Pleistocene land sections outcropping in other parts of the Mediterranean basin. Therefore it is preliminarily suggested that these results from Italian peninsula might be applicable to the whole Mediterranean area, with the realization that minor discrepancies might occur. Data from DSDP Leg 42A (Bizon *et al.*, 1978) (even if not all the species here recorded were considered) are in agreement with the results reported in this paper.

CLIMATIC CHANGES AND BENTHIC SPECIATION

According to the well established isotopic stratigraphy based on benthic and planktonic foraminifera, several major climatic changes occurred during Neogene time. Concerning the Pliocene and the Early Pleistocene (Shackleton and Opdyke, 1973 1976; Keigwin and Thunell, 1979; Keigwin, 1982, 1982a; Thunell and Williams, 1983), a subtropical climate is inferred for the Mediterranean basin from about 5.3 to 3.3 MA (M Pl 1 - M Pl 3 and basal part of the M Pl 4 biozone). A short sharp global cooling has been recorded at about 3.2 MA. Originally correlated with the onset of the Pliocene glaciation in the Northern Hemisphere (Berggren, 1972; Shackleton and Opdyke, 1976; Thunell, 1979, 1979a; Keigwin and Thunell, 1979; Berggren and Schnitker, 1981; Keigwin, 1982, 1982a; *inter alios*), this cooling is now considered to predate Northern Hemisphere glaciation. The short duration of this event and the rapid reestablishment of the previous climatic conditions, as demonstrated by the reoccurrence of similar oxygen isotopic values as before the event, confirm this recent interpretation (Thunell and Williams, 1983).

The new climatic regime, related to the inception of a permanent ice sheet in the polar regions of the Northern Hemisphere, began at about 2.5 MA. It is manifested by a sharp shift in $\delta^{18}\text{O}$ values and by persistent wide fluctuations of the oxygen isotopic record. This climatic change cannot be compared with the really cold climatic regime occurring during the Middle and Late Pleistocene, but it displays values markedly cooler than that which existed during the earlier Pliocene. After 2.5 MA, an almost constant climatic trend, characterized by recurrent temperature fluctuations of moderate intensity is recorded up to about 0.8 MA (base of Glacial Pleistocene, just above the top of the Jaramillo subchron, according to Shackleton and Opdyke, 1976). Two of the cooler fluctuations in this

time-span straddle the N/Q boundary at the top of the Olduvai subchron (Shackleton and Opdyke, 1976; Thunell and Williams, 1983).

At about 0.8 MA, another change in the character of isotopic record occurs (Shackleton and Opdyke, 1976; Prell, 1982; Thunell and Williams, 1983) and large changes within the faunal and floral assemblages are recorded both in marine (Cita *et alii*, 1973; Ciaranfi and Cita, 1973; Thunell, 1979; Buccheri, 1983; Sprovieri; in press; *inter alios*) and continental (Zagwijn, 1974, 1974a, 1975) environments. It is at that time that the cold, glacial Pleistocene regime began.

The intervals during which speciation took place (negative when dealing with disappearance, positive with appearance) in benthic Plio-Pleistocene foraminiferal assemblages are coeval with these climatic events. The subtropical climate of the Early Pliocene favored the general repopulation of the Mediterranean, specifically, a massive immigration from the Atlantic with a (very probable) great increase of the species diversity. Many species not recorded from older sediments in the Mediterranean first appeared at this time. The sudden and sharp cooling at about 3.2 MA caused a remarkable loss in the number of species, while no new species appeared to balance such a decrease. Only a very small taxonomic reduction is recognizable from about 3.0 to 2.6 MA, a time-interval characterized by a rapid reestablishment of the previous warm climate. The extinctions recorded in this time-interval are mainly centered in level just above 3.0 MA, and may be a continuation of the previous massive extinction event. From 2.6 to 2.4 MA a second extinction acme is recorded in the Mediterranean basin, in association with another major cooling. The loss in number of species was less severe than the first event. Evidently this second climatic crisis affected a benthic population already depauperated by the previous cooling which decimated the species that were not adaptable to cold conditions. After 2.5 MA only a few species disappeared. From about 2.2 MA till about 1.4 MA (Early Emilian) some new species gradually appeared. The new appearances are most frequent close to the *Globorotalia truncatulinoides* FAD, at about 2.0 MA (Rio *et al.*, 1984), near the N/Q boundary, when some immigrants from the Atlantic (even more frequent among the molluscan assemblage (Ruggieri and Sprovieri, 1979)) are also recorded (« Northern Guests »), and above the *C. macintyreii* LAD, at about 1.5 MA (Rio *et al.*, in press), when the well known Early Pleistocene benthic species (*Hyalinea baltica*, *Rectobolivina zitteli*, *Coryphostoma karerrianum*, *Bolivinita quadrilatera*) appeared successively over a short time interval.

CONCLUSIONS

A close relationship between paleoclimatic conditions and speciation in the benthic foraminiferal assemblages is recognizable. Stable climatic conditions resulted in an increase in the number of species, while « cold » climatic fluctuations caused a remarkable decrease in species diversity. The « warm » Early Pliocene is a time-period of appearance of several new species; on the other hand, first appearances are also recorded during the cooler Late Pliocene and Early Pleistocene. As a matter of fact, that new benthic species first appeared in the Mediterranean during the latest Pliocene and the earliest Pleistocene (after the beginning of the Northern Hemisphere glaciation till the beginning of the Glacial Pleistocene) when the climatic fluctuations recurrently occurred but in a climatic regime of relative stability without strong climatic changes. Once the benthic foraminiferal assemblage became adapted to the new climatic conditions (the first new species appeared about 0.3 MA after the beginning of the Glacial Pliocene regime) species diversity began to increase again.

A similar correlation with climatic events was recently proposed by Thunell (1981) for the planktonic foraminifera. Therefore, it can be concluded that major climatic fluctuations and their impact on the water masses (upwelling, current migrations, salinity variations, stagnation, nutrient supply) played a major role in the speciation (and radiation) of the foraminiferal faunas during the Pliocene and the Early Pleistocene in the Mediterranean basin.

SPECIES LIST

The species of benthonic foraminifera which disappeared (first group) or appeared (second group) during the Late Pliocene-Early Pleistocene time-interval are listed below, in alphabetic order per genera and species. Because they are generally well known and figured in many papers, only references are here included for their identification. Their distribution in the Pliocene and Early Pleistocene interval is reported in tab. 1.

- Anomalinoides granosa* (Hantken) - Foraminiferi padani (1982), t. 49, f. 8.
- Anomalinoides helicina* (Costa) - Foraminiferi padani (1982), t. 49, f. 9.
- Amphicoryna semicostata* (Costa) - Foraminiferi padani (1982) t. 19, f. 8.
- Bolivina gladiiformis* Conato - Conato (1964), t. 1, f. 3.
- Bolivina leonardii* Accordi e Selmi - Foraminiferi padani (1982), t. 30, f. 5.
- Bolivina lucido-punctata* Conato - Conato (1964), t. 1, f. 4.
- Bolivina placentina* Zanmatti - Foraminiferi padani (1982), t. 30, f. 7.

- Bulimina minima* Tedeschi e Zanmatti - Foraminiferi padani (1982), t. 25, f. 10.
- Buliminoides diaphana* (Conato) - Conato (1964), t. 1, f. 9.
- Cibicidoides cicatricosus* (Schwager) - Brady (1884), t. 94, f. 8.
- Cibicidoides italicus* (di Napoli) - Foraminiferi padani (1982), t. 51, f. 5.
- Cibicidoides robertsonianus* (Brady) - Foraminiferi padani (1982), t. 52, f. 3.
- Cylindroclavulina rudis* (Costa) - Foraminiferi padani (1982), t. 4, f. 1.
- Dentalina advena* (Cushman) - Brady (1884), t. 63, f. 1.
- Dentalina pleura* Costa - Fornasini (1894), t. 1, ff. 21, 22.
- Dentalina urnula* d'Orb. - d'Orbigny (1846), t. 2, ff. 31, 32.
- Dimorphina tuberosa* d'Orb. - Foraminiferi padani (1982), t. 38, f. 4.
- Ellipsoidina ellipsoides* Seg. - Foraminiferi padani (1982), t. 38, f. 4.
- Ellipsoglandulina multicosata* (Gall. and Morrey) - Galloway and Morrey (1929), t. 16, f. 13.
- Ellipsoglandulina ciofaloi* (Silvestri) - Silvestri (1903), f. 4.
- Ellipsopleurostomella schlichti* (Silvestri) - Loeblich and Tappan (1984), f. 597, 5, 6.
- Ellipsopolymorphina fornasinii* (Galloway) - Foraminiferi padani (1982), t. 38, f. 5.
- Fissurina antillea* (Cushman) - Cushman (1923), t. 7, ff. 10, 11.
- Frondicularia denticulata* Costa - Foraminiferi padani (1982), t. 16, f. 6.
- Heterolepa dertonensis* (Ruscelli) - Foraminiferi padani (1982), t. 51, f. 8.
- Heterolepa praecincta* (Karrer) - Foraminiferi padani (1982), t. 40, f. 8.
- Laticarinina pauperata* (Parker and Jones) - Foraminiferi padani (1982), t. 50, f. 8.
- Lenticulina ariminensis* d'Orb. - Foraminiferi padani (1982), t. 9, f. 1.
- Lenticulina convergens* (Born.) - Brady (1884), t. 69, f. 6.
- Lenticulina crassa* (d'Orb.) - Foraminiferi padani (1982), t. 9, f. 6.
- Lenticulina dilecta* (Seg.) - Foraminiferi padani (1982), t. 9, f. 9.
- Lenticulina echinata* (d'Orb.) - Foraminiferi padani (1982), t. 9, f. 10.
- Lenticulina formosa* (Cushman) - Cushman (1923), t. 29, f. 1; t. 30, f. 6.
- Lenticulina spinata* (Schubert) - Casale (1969), t. 3, f. 13.
- Lenticulina spinulosa* (Costa) - Foraminiferi padani (1982), t. 10, f. 9.
- Lenticulina submamilligera* (Cushman) - Cushman (1923), t. 28, f. 3.
- Lingulina seminuda* Hantken - Foraminiferi padani (1982), t. 15, f. 4.
- Marginulina coarctata* Silvestri - Foraminiferi padani (1982), t. 12, f. 3.
- Marginulina crebricosta* Seg. - Foraminiferi padani (1982), t. 12, f. 4.
- Marginulina cristellarioides* Czjzek - Fornasini (1894), t. 2, f. 16.
- Marginulina spinulosa* (Costa) - Foraminiferi padani (1982), t. 12, f. 10.
- Martinottiella perparva* (Cushman) - Foraminiferi padani (1982), t. 5, f. 7.
- Marginulinopsis bradyi* (Goess) - Brady (1884), t. 65, ff. 12, 13.
- Mucronina gemina* (Silv.) - Foraminiferi padani (1982), t. 24, f. 1.
- Orthomorphina ambigua* (Neug.) - Brady (1884), t. 62, f. 3.
- Orthomorphina bassanii* (Forn.) - Foraminiferi padani (1982), t. 24, f. 9.
- Planularia angustata* (Costa) - Foraminiferi padani (1982), t. 11, f. 4.
- Planularia cymba* d'Orb. - Foraminiferi padani (1982), t. 11, f. 4.
- Planularia cymboides* d'Orb. - d'Orbigny (1846), t. 3, ff. 30, 31.
- Planularia discoidalis* Costa - Fornasini (1894), t. 3, ff. 18, 19.
- Planularia elongata* d'Orb. - Fornasini (1894), t. 3, ff. 11-14.
- Planularia gemmata* (Brady) - Brady (1884), t. 71, ff. 6, 7.
- Planularia lanceolata* d'Orb. - d'Orbigny (1846), t. 3, ff. 41, 42.
- Planularia reniformis* d'Orb. - d'Orbigny (1846), t. 3, ff. 39, 40.
- Planularia subtrigona* (de Amicis) - Foraminiferi padani (1982), t. 11, f. 7.
- Plectofrondicularia striata* (d'Orb.) - Foraminiferi padani (1982), t. 24, f. 7.
- Psammosphaera testacea* (Flint) - Cushman (1918), t. 15, ff. 1-3.
- Stilostomella fistuca* (Schwager) - Foraminiferi padani (1982), t. 36, f. 1.
- Svratkina tuberculata* (Bolk. and Wright) - Cushman (1931), t. 11, f. 5.
- Uvigerina rutila* Cushman and Tood - Foraminiferi padani (1982), t. 34, f. 5.
- Uvigerina longistriata* Perconig - Foraminiferi padani (1982), t. 33, f. 8.
- Vaginulina bradyi* Cushman - Foraminiferi padani (1982), t. 15, f. 5.
- Vaginulina clavata* Costa - Foraminiferi padani (1982), t. 15, f. 6.
- Vaginulina elegans* d'Orb. - Foraminiferi padani (1982), t. 15, f. 8.
- Vaginulina legumen* (Linneo) - Foraminiferi padani (1982), t. 15, f. 9.
- Vaginulina margaritifera* Batsch - Foraminiferi padani (1982), t. 15, f. 9.
- Vaginulina patens* Brady - Brady (1884), t. 67, f. 16.
- Vaginulina striatissima* Schrodt - Foraminiferi padani (1982), t. 15, f. 10.
- Vaginulinopsis bononiensis* (Forn.) - Foraminiferi padani (1982), t. 16, f. 4.
- Vaginulinopsis carinata* Silv. - Foraminiferi padani (1982), t. 16, f. 5.
- Vaginulinopsis inversa* (Costa) - Fornasini (1894), t. 2, ff. 31-33.
- Vaginulinopsis sulcata* (Costa) - Foraminiferi padani (1982), t. 16, f. 1.
- Vaginulinopsis tricarinata* (d'Orb.) - Foraminiferi padani (1982), t. 16, f. 3.
- Vulvulina pennatula* (Batsch) - Foraminiferi padani (1982), t. 3, f. 4.
- Articulina tubulosa* (Seg.) - Foraminiferi padani (1982), t. 7, f. 9.
- Astrononion sallentinum* Salvatorini - Salvatorini (1969), t. 6, ff. 12-13.
- Bolivinita quadrilatera* (Schwager) - Foraminiferi padani (1982), t. 23, f. 7.
- Bulimina basispinosa* Tedeschi and Zanmatti - Foraminiferi padani (1982), t. 25, f. 9.
- Bulimina elegans marginata* Fornasini - d'Onofrio (1981), t. 39, f. 4.

- Bulimina etnea* Seg. - Foraminiferi padani (1982), t. 27, f. 1.
Bulimina marginata d'Orb. - Foraminiferi padani (1982), t. 27, f. 8.
Coryphostoma karrerianum (Brady) - d'Onofrio (1981), t. 39, f. 8.
Cruciloculina staurostoma (Schlunmb.) - Foraminiferi padani (1982), t. 8, f. 1.
Fursenkoina tenuis (Seg.) - Foraminiferi padani (1982), t. 28, f. 8.
Globobulimina ovula (d'Orb.) - Foraminiferi padani (1982), t. 27, f. 10.
Gyroidinoides altiformis (R.E. and K.C. Stew.) - Parker (1958), t. 3, ff. 10-12.
Gyroidinoides delicata (Parker) - Parker (1958), t. 3, ff. 7-9.
Hyalinea baltica (Schroeter) - Foraminiferi padani (1982), t. 49, f. 5.
Islandiella ionica d'Onofrio - d'Onofrio, t. 35, ff. 1-4.
Orthomorphina stainforthi Perconig - Foraminiferi padani (1982), t. 25, f. 3.
Paromalina coronata (Parker and Jones) - Brady (1884), t. 97, ff. 1, 2.
Paromalina crassa (Cushman) - Murray (1971), t. 85.
Rectobolivina zitteli (Karrer) - Foraminiferi padani (1982), t. 35, f. 3.
Uvigerina bradyana Forrn. - Foraminiferi padani (1982), t. 33, f. 1.
Uvigerina costato-caudata Sprovieri - Sprovieri, (1983), t. 1.
Uvigerina mediterranea Hofker - Foraminiferi padani (1982), t. 33, f. 9.
Uvigerina torquata Wezel - d'Onofrio (1981), t. 36, f. 8.

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