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Bivalve taxonomic diversity throughout the Italian Pliocene as a tool for climatic-oceanographic and stratigraphic inferences

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ABSTRACT

Key words: Bivalves; Diversity; Mediterranean; Pliocene.

The state of research on the evolution of marine bivalve taxonomic diversity of the Mediterranean Pliocene is analysed. The following assertions are discussed: 1) The Early Pliocene malacofauna is characterized by a high number of warm-water taxa and a high taxonomic diversity with respect to that of the present time. 2) The first appreciable extinction event in the Mediterranean Pliocene approximates or just follows the FO of *Globorotalia bononiensis*. 3) The second appreciable extinction event is between the LAD of *Discoaster tamalis* and the LAD of *Discoaster surculus*. 4) A third minor extinction event is penecontemporaneous with the FO of *Globorotalia inflata*.

Taking into account the available data on the Pliocene extinction events it has been possible to distinguish 4 different molluscan units with different climatic-oceanographic significance.

INTRODUCTION

The immigration and local extinctions in the Mediterranean throughout the Pleistocene of alternatively tropical and celtic-boreal marine molluscs has been, since De Stefani (1876), a suitable phenomenon for working out an ecobiostratigraphic framework. The decrease in taxonomic diversity throughout the Pliocene has been well known since Levi (1900); Ruggieri (1950; 1957) pointed out the relevance of this phenomenon, but common opinion up to the 50's was that Pliocene marine mollusc fauna was stable and represented by warm-water taxa, which disappeared at the P/P boundary (Gignoux, 1954) or in the uppermost Piacenzian. Only since the 60's it has been definitively acknowledged that the Pliocene was characterized by a progressive decrease in marine mollusc taxonomic diversity as a consequence of progressive climatic cooling (Ruggieri, 1962; 1967). Therefore, thanks to their high extinction rate (over 30%), Pliocene molluscs resulted potentially useful as a tool for climatic-oceanographic and chronological inferences. In particular, the knowledge of the stratigraphic range of the molluscs, calibrated by biostratigraphic and magneto-biostratigraphic data could well play an important role in the stratigraphic classification of the shallow water environment sections, where calcareous plankton is scanty and less significant.

Most of the remarks on the Neogene mollusc fauna are still qualitative. Nevertheless during the last 15 years a list of the Mediterranean Pliocene bivalves has been worked out (Marasti & Raffi, 1980); this list, although subject to continuous revision, has allowed a first approach to the analysis of the molluscan taxonomic diversity from the Pliocene to the Recent (Marasti & Raffi, 1980; Raffi & Marasti, 1982; Raffi *et al.* 1985). As a consequence in recent years it has become possible to clarify the patterns of Pliocene Mediterranean extinctions (regional disappearances+ true extinctions), even if many problems are still open (Raffi & Marasti, 1982; Raffi *et al.*, 1985, 1989).

Monegatti, Pantoli & Raffi (work in progress) have revised the list of Marasti and Raffi (excluding Paleotaxodonta) and all the data available on the Italian Pliocene distribution of bivalves. On the whole they took into account a stock of 348 species of infralittoral and circalittoral environments. These data show the possibility of working out a chronological framework of the Italian Pliocene based on marine molluscs (and in particular on the bivalves).

THE EARLY PLIOCENE MALACOFAUNA IS CHARACTERIZED BY A HIGH NUMBER OF WARM-WATER TAXA AND A HIGH TAXONOMIC DIVERSITY WITH RESPECT TO THAT OF THE PRESENT TIME

The malacofauna of the Lower Pliocene* of Italian authors (Zanclean+Lower Piacenzian=Tabianian *sensu* Mayer, 1867), the top of which is calibrated at about 3-3.2 Ma, is characterized by the presence of the genus *Strombus* (*S. coronatus* Defrance) and by a relatively high specific diversity of warm-water taxa, in particular Terebridae and Conidae. The specific diversity of genus *Conus* s.l. in the Mediterranean Pliocene is a problem that it is still open, nevertheless, it is not lower than 20-30 species; at the present time only one species (*Conus ventricosus* Gmelin) is with certainty an inhabitant of the Mediterranean. The Pliocene survivors of this genus are now spread along the western coast of Africa, south of Rio de Oro. Terebridae are represented by about ten species, 6 of them live today along the coasts of western Africa south of Cape Barbas (Rio de Oro) (Bouchet, 1982). Among the Pliocene bivalves at least 10 survivors are today exclusive of the tropical west Africa (inner tropical in the meaning of Hall, 1964) and they will probably increase in number thanks to the progress of the malacological research in tropical west Africa.

THE FIRST APPRECIABLE EXTINCTION EVENT IN THE MEDITERRANEAN PLIOCENE APPROXIMATES OR JUST FOLLOWS THE FO OF *GLOBOROTALIA BONONIENSIS*, CALIBRATED AT ABOUT 3-3.2 MA

Marasti & Raffi (1976, 1977), Raffi & Marasti (1982) have provided evidence of this first extinction phase in the Mediterranean Pliocene. Within the bivalves the percentage of extinction is between 15 and 23%; so at least 53 species and no more than 80 species out of 348 disappeared from the Mediterranean (Fig. 1) in correspondence to or just after the FO of *Globorotalia bononiensis* and *G. crassaformis* (Monegatti, Pantoli & Raffi, in progress). The taxonomic diversity of Terebridae and Conidae decreased severely but these two taxa were still well represented in the Mediterranean after this extinction event. In particular at least five species of Terebridae were still living in the Mediterranean: *Hastula farinesi* (Fontannes), *Subula fuscata* (Brocchi), *Strioterebrum reticulare* (Pecchioli), *Strioterebrum pliocenicum* (Fontannes), *Terebra acuminata* (Borson). In the present-day these species are spread along the western coast of Africa south of Cape Barbas. It is at this time that *Strombus coronatus* disappeared definitively in the Italian Pliocene.

It is already well known that this extinction event, which is well correlatable with the changes recorded in the mammal faunas (Torre, 1987) and in the vegetal environments (Suc, 1984), corresponds to the first important Pliocene cooling phenomenon of our hemisphere (Raffi and Marasti, 1982; Raffi et al. 1985). Furthermore, we point out that this extinction event, marked by the disappearance in the Mediterranean of most of the tropical fauna, is well correlatable with the first appearance of immigrants of Pacific origin and the disappearance of southern boreal taxa in the classical section of Tjornes (Northern Iceland) (Bardarson, 1925; Strauch, 1963; Cronin, 1991).

THE SECOND APPRECIABLE EXTINCTION EVENT IS BETWEEN THE LAD OF *DISCOASTER TAMALIS* AND THE LAD OF *D. SURCULUS*

It has already been noted that some molluscs of warm-water affinity thrived in the Mediterranean up to a time not defined between the LAD of *D. tamalis* and the LAD of *D. surculus* (Raffi et al., 1989b), which are calibrated respectively at about 2.6 and 2.4 m.y.a. (Rio et al., 1990). Terebridae, which were still represented by at least 5 species, disappeared definitively and the specific diversity of Conus decreased from 10-15 species to 1-3 species (only *Conus striatulus* Brocchi and *Conus ventricosus* Gmelin are cited with certainty after this extinction event).

Within the bivalves only 11 species "probably" disappear at this time [e.g. *Dymia fragilis* (Koenen), *Neopycnodonte navicularis*, *Korobkovia oblonga*, etc.]. Taking into account all the doubtful cases, this number could well increase remarkably (up to about 40). In any case the extinction percentage at 2.4 Ma is with certainty much lower than at 3 m.y.a. (Fig. 1).

This extinction episode appears well correlatable with the first major northern hemisphere glacial event, that is, with the beginning of the glacial Pliocene (Shackleton *et al.*, 1984).

A THIRD MINOR EXTINCTION EVENT IS PENECONTEMPORANEOUS WITH THE FO OF *GLOBOROTALIA INFLATA*

Only three species [*Pecten flabelliformis* (Brocchi), *Chlamys scabrella* (Lamarck) and *Pelecyora islandicoides* (Lamarck)] are known to disappear approximately in correspondence with the FO of *G. inflata*, which has been calibrated at about 2.1-2 Ma; nevertheless this extinction event is easily recognizable and useful for biostratigraphic purposes because these species were very common up to the FO of *G. inflata* (Fig. 1).

Few species (e.g. *Venus libellus*, *Laevicardium subturgidum millasiense*, etc.) disappeared in the Po Basin just before the first appearance of the boreal guests; this datum needs nevertheless to be reconfirmed in other basins.

* - The Lower Pliocene Mediterranean malacofauna consists of a prevailing stock of species already present in the Early Messinian and a new stock of species never cited with certainty in the Mediterranean Miocene; within bivalves the "new stock" (excluding Paleotaxodonta) is represented by 30% of the whole Pliocene fauna (Marasti & Raffi, 1980).

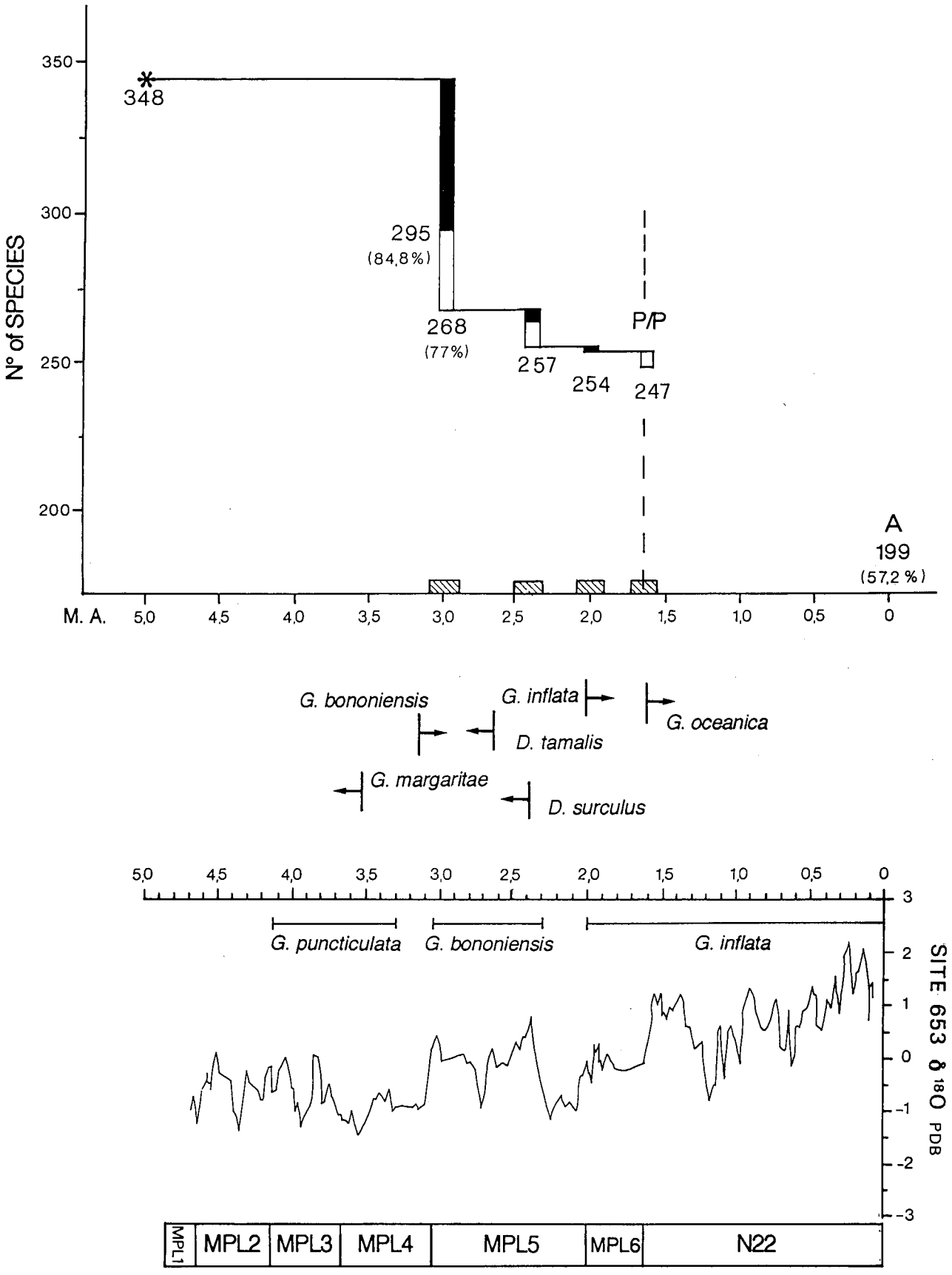

Fig. 1 — The above diagram shows the extinction phases of bivalves (excluding Paleotaxodonta) in the Italian Pliocene, calibrated by magneto-biostratigraphic data. The vertical black columns represent the stock of species which became extinct with certainty in correspondence to a particular time, while the vertical white columns represent all doubtfull cases. The extinction phases appear well correlatable with the $\delta\,^{18}O$ peaks of the oxygen isotopic curve of site 653, Tyrrhenian Basin (Thunnel *et al.*, 1990).

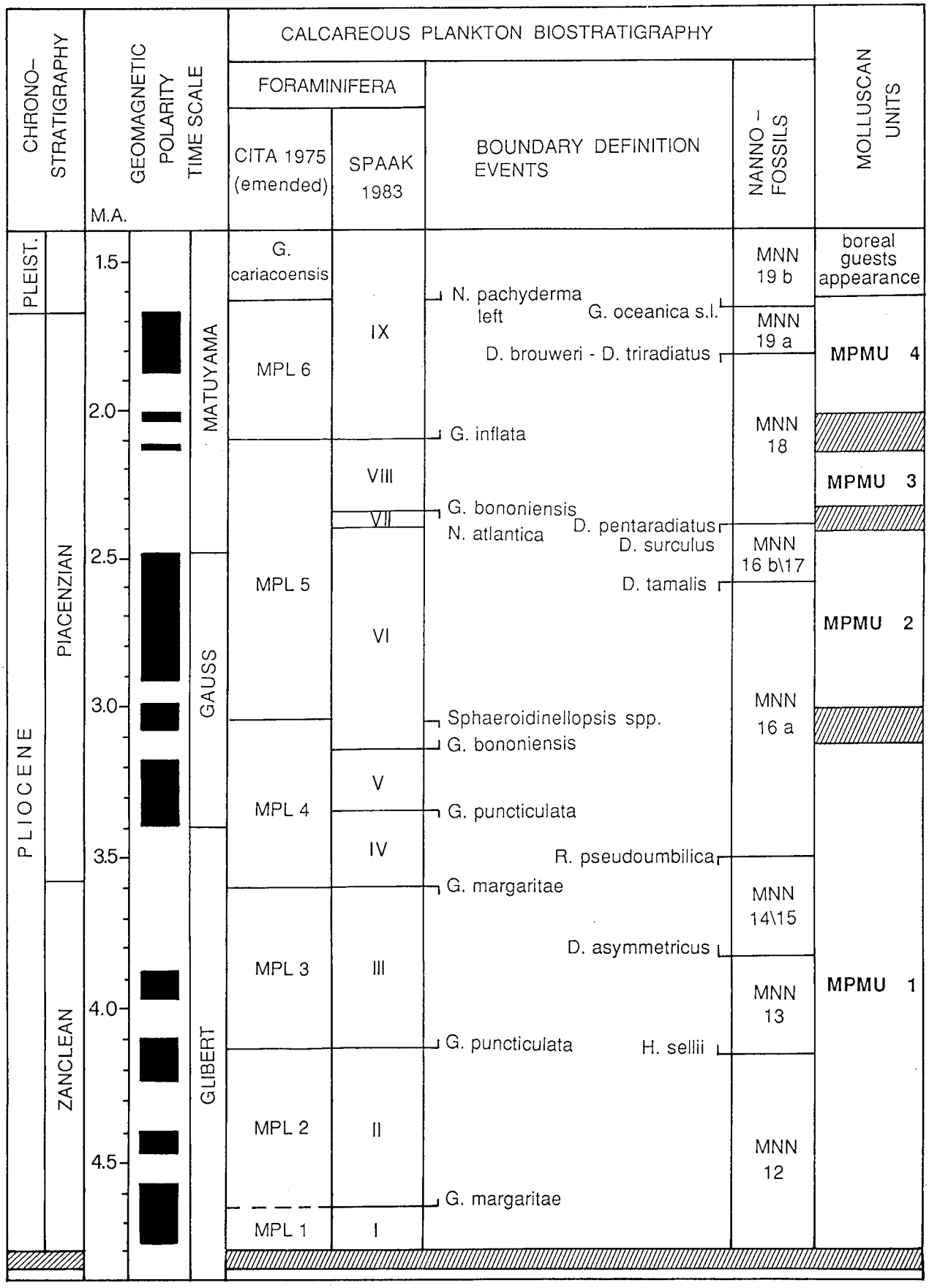

Fig. 2 — Mediterranean Pliocene Molluscan units (MPMU) correlated to the calcareous plancton biostratigraphy, to the Standard Global Chronostratigraphic Scale and to the Geomagnetic Polarity Time Scale (Rio *et al.*, 1990).

PLIOCENE PATTERNS OF EXTINCTION AND MOLLUSCAN UNITS

In conclusion, Pliocene was characterized by a progressive decrease in taxonomic diversity due to readily detectable extinction phases controlled by climatic coolings recorded all over the world in the paleontological and isotopic record.

The most important extinction event occurred at about 3 Ma but this does not mean that the climatic change at 3 m.y.a. was more severe than the following ones; some survivors of this crisis disappeared in the subsequent at about 2.4 Ma and some of the survivors of this last extinction event disappeared in the following event at about 2 m.y.a. Therefore the Pliocene pattern of marine mollusc extinctions records the progressive, step by step, establishment of cooler climatic conditions.

The immigration of the boreal guests in the Mediterranean has to be considered as the final act of this Pliocene climatic cooling (Raffi, 1986).

In conclusion, despite the numerous doubts on the Pliocene Mediterranean distribution of the molluscs, it has been possible to distinguish 4 different faunal units (Mediterranean Pliocene Marine Molluscan Units = MPMU) with different climatic-oceanographic significance (Fig. 2):

1) The first unit (MPMU1) is characterized by a high number of tropical species and in particular by a high taxonomic diversity of Conidae and Terebridae. Its upper limit is defined by:

   a) the disappearance of more than 50 species of bivalves (*Hoernesarca rollei* (Hoernes), *Pinctada margaritifera studeri* (Mayer), *Chlamys latissima* (Brocchi), *Callista italica* (Defrance), *Pelecyora gigas* (Lamarck), *Pseudoxyperas proaspersa* (Sacco), *Tugonia anatina* (Gmelin), etc.);
   b) the disappearance of *Strombus coronatus* (Defrance) and the drastic decrease of the taxonomic diversity of Conidae and Terebridae. The upper limit of this unit approximates or just follows the FO of *G. bononiensis* and *G. crassaformis* in the Mediterranean.

2) The second unit (MPMU2) is between the extinction of the large stock of tropical taxa which characterized the MPMU1 and the final disappearance of the Terebridae, which in this unit were still represented by five species. The disappearance of this stock is associated with the further drastic decrease of taxonomic diversity of Conidae and the disappearance of a small stock of bivalves. The upper limit of this unit approximates or just predates the LAD of *D. surculus*.

3) The third unit (MPMU3) is still characterized by the presence of three typical Neogene species *Ch. scabrella*, *P. flabelliformis* and *P. islandicoides*. This unit is approximately between the LAD of D. *surculus* and the FO of *G. inflata*.

4) The fourth unit (MPMU4) is between the LO of the three species which characterize the MPMU3 and the FO of the boreal guests. Therefore this unit approximates the MPL6 biozone.

Units 3 and 4 have a taxonomic composition very similar to that of the present-day Mediterranean even if they are still characterized by 20-30% of species (about 20 % in the bivalves) of warm-water affinity which will disappear during the Pleistocene.

It is evident that units 2, 3 and 4, are characterized respectively by the "lack" of the species which disappeared in the immediately previous crisis and by the particular stock of survivors which disappeared in the immediately successive crisis. We point out that the lack of the species can also be controlled by local environmental factors (e.g. edaphic factors); therefore it is imperative that the use of this scheme be always associated with paleoecological analysis.

The four faunistic informal units represent four particular time intervals of the climatic-oceanographic evolution of the Mediterranean. In short the four faunistic units represent the stages of transition from a Mediterranean biogeographic unit with tropical characters (presence of *Strombus*, high diversity of Conidae and Terebridae, high number of other tropical taxa) comparable to that of the present-day Senegalese Coast to a biogeographic unit comparable, even if with an appreciably higher taxonomic diversity, to that of the present day Mediterranean. We refer to Raffi *et al.* (1985, 1989), Raffi (1992) for a more detailed analysis of the decrease in the taxonomic diversity of the Mediterranean Pliocene and its climatic-oceanographic significance (*).

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