PALEOCLIMATOLOGY OF A LATE PLEISTOCENE – HOLOCENE CORE FROM THE TYRRHENIAN SEA (WESTERN MEDITERRANEAN): FORAMINIFERA AND PTEROPODA

A qualitative and quantitative study was conducted on foraminifer, pteropod and heteropod assemblages present in Late Quaternary sediments of core TEV 1 BAN 85, sampled from a small deep basin located off the Tiber delta (Tyrrhenian Sea - Western Mediterranean).

A good agreement between data of planktonic foraminifera and pteropoda is remarked. Detailed analysis of planktonic foraminifera indicates cold water assemblages with transition to temperate and temperate-warm conditions. This succession of assemblages shows that a climatic evolution occurred during the considered sedimentary time span. Analytical data on pteropods and heteropods reveal a sequence of cold, temperate and temperate-warm assemblages, generally with low specific diversity. The pteropod assemblages are characterized by a single subpolar species and by various tropical, subtropical and cosmopolitan species.

Frequency variations of planktonic foraminifera, pteropods and heteropods suggest a climatic trend from cold to temperate-warm and warm, with intervals which can be referred to last Würmian interstadial, to last glacial and to postglacial up to the “Atlantic” phase.

Introduction

As part of the research program on “Evolution and sedimentology of the Tiber delta” (Western Mediterranean - Central Tyrrhenian Sea), the ship Bannock completed a series of 11 core-drilling operations in October 1985. Samples were collected with a 1,000-kg Kullenberg gravity corer.

Coring extended from the Tiber delta to a small, 1,034 m-deep, closed basin located approx. 40 km off the coast.

Core TEV 1 BAN 85, discussed in this paper, is one of the longest cores taken within the above-mentioned basin, which lies E of the Civitavecchia valley and N of the Albano seamount. The location of the core, drilled at 1,000 m of depth and consisting of 5 m of undisturbed sediment, is shown in Fig. 1. Geographic coordinates: lat. 41° 26' 32" N - long. 11° 59' 4".

While research is in progress to identify sedimentation relations with the eustatic fluctuations of the last glacial phases, this paper reports the results of analyses conducted on the foraminifer and pteropod assemblages of core TEV 1 BAN 85, in order to reconstruct the paleoclimatic evolution and the stratigraphy of the sequence.

Materials and methods

The core has a diameter of 9 cm and a total length of 500 cm. The core is composed of a homogeneous uncompacted, finegrained, plastic sediment with high adsorption water content. Its color is mostly ash-grey with two poorly-outlined ochre-grey zones: one close to its top, from 0 to -40 cm, and the other one between -340 and -380 cm. The core was split along its length and 18 samples (each 10 cm long) were collected.

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<th>Samples</th>
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Research conducted jointly with Centro di Studio per la Geologia dell'Italia Centrale (CNR) and supported by a Ministero della Pubblica Istruzione grant 40%.

The most clayey sample is no. 18, while sample no. 2 contains the largest amount of sand and silt. Sample 14 contains rounded pumiceous granules with a size ranging from 500 to 1,000 μ (these granules are frequently encountered in Tyrrhenian Sea cores at different levels; cfr. Borsetti et alii, 1986; Violanti et alii, 1987). Sample 3 contains numerous fecal pellets whose size ranges from 250 to 500 μ. Limonitic nodules are observed in samples 5 and 6. At depth from -460 to -470 cm (sample 2), a significant amount of terrigenous material suggests transport from the continental shelf. This fact is confirmed by the occurrence of numerous well-preserved augite crystals which are comparable with those found on present deltaic shores and coming from the Latium volcanics.

The material was fractionally washed with sieves having a net mesh size of 0.062, 0.088, 0.125, 0.500 and 1 mm. On the whole, the inorganic fraction is scarce, except for sample 2 where it is dominant. The organic fraction, instead, is always abundant and includes foraminifera, pteropods and heteropods, which are the object of this study, and also, in order of decreasing abundance, fragments of other molluscs, ostracods, sponge spicules, radiolarians, echinid remains.

**Foraminifera**

The microfauna consists mainly of perforated, secondly of porcelaneous calcareous foraminifera, whereas arenaceous species are definitely subordinate. Quantitative analyses were conducted on 300 specimens from each sample, while qualitative analyses covered the entire sieved residue.

Throughout the core, planktonic specimens definitely outnumber benthonic ones, even though the latter involve the largest number of species. Benthos and plankton percentages in faunal assemblages are displayed in Fig. 2: plankton accounts for 65-80% with a minimum in sample 9 (60.3%) and a maximum in sample 16 (82.3%). Table I lists all planktonic forms identified, as well as their distribution and relative frequency. The species are listed by order of occurrence and alphabetically from bottom to top of the core. Frequency diagrams of the most significant planktonic species are shown in Fig. 3.

**Features of planktonic assemblages**

Qualitative and quantitative analysis of foraminifera allowed identification of three faunal assemblages from bottom to top of the core.
Planktonic assemblages were defined on the basis of occurrence and frequency variations of all the observed forms. Variations concerning the most climatologically significant species (warm, cold and temperate), were emphasized in order to reconstruct the paleoclimatic evolution of the sedimentary sequence.

*Globigerina digita*ta, *Globigerina praedigita*ta, *Globigerinoides elongatus*, *Globigerinoides* *gomitulus*, *Globigerinoides* *ruber*, *Globige*rinoides *trilobus*, *Hastigerina siphonifera*, *Hastigerina pelagica* and *Orbulina universa*, are considered to be warm water species. *Globigerin*oides *bulloides*, *Neo*glob*o*boquadrina *pachyderma*, *Globigerina quinqueloba* and *Globorotalia scitula* are considered cold water forms. Temperate forms are represented by *Globorotalia inflata* and *Globorota*lia *trunctatulino*ides. These organisms, which are the most used in the literature (e.g.: Blanc-*Vernet* et alii, 1969; *Thunell*, 1971; Blanc-*Vernet* et alii, 1983; Monccharmont *Zei* et alii, 1984; Bor*setti et alii*, 1986) to identify climatic fluctuations in the Western Mediterranean, are used in the following paragraph for the construction of the paleoclimatic curve.

The distinctive features of the assemblages are described as follows:

A) -500 to -371 cm (samples 1 to 5)

The assemblage mainly consists of the following forms: *Globorotalia inflata* is abundant in sample 1 (14%), decreases rapidly in sample 2 and disappears in samples 3, 4; *Orbulina universa* and *Globigerina praedigita*ta occur in very low proportions; *Globigerinoides ruber* increases progressively starting from the bottom and reaches peak values in sample 4 (16%). *Glo*big*erina quinqueloba* is initially abundant and then decreases in the upper part of this sedimentary portion, while *Neogloboquad*rina *pachyderma* shows an opposite trend. *Globorotalia scitula* is present with values ranging from 10 to 16%. In this sedimentary interval, complex trends are observed in some forms having the same climatic significance. For instance, sample 3 shows maximum percentage values for *N. pachyderma* and minimum values for *G. quinqueloba*. The cold species *N. pachyderma* is almost exclusively represented by right coiling specimens (Fig. 4) as often observed in the Western Mediterranean; left coiling specimens, typical of the polar and subpolar assemblages (Br & Tolderlund, 1971), are scarce.

In this portion of the core, planktonic assemblages thus indicate globally a cold phase, in the light of the dominance of cold water species.

B) -371 to -105 cm (samples 6 to 14)

The occurrence of the temperate species *G. inflata* is discontinuous and with very low percentages, it reappears with a fairly good frequency in sample 13 (4.50%), along with the first occurrence of *Globorotalia truncatulino*ides. Among the warm water forms, *O. universa* disappears, while *G. ruber*, absent in sample 8, reaches a maximum in sample 11 (11%). Among the cold water species, *G. quinqueloba* and *G. scitula* increase (maximum in sample 8.14% and 19.10% respectively) while *N. pachyderma*, represented only by right coiling individuals, shows values lower than those observed in the previous core section.

This assemblage, similar to the previous one, is clearly cold. The upper part of this sedimentary interval evidences the first clues of a climatic change. In fact, while the ratios between cold and warm water species remain stable on the whole, the reappearance of temperate forms is noted in sample 13 (*G. inflata* and *G. truncatulino*ides).

C) -105 to 0 cm (samples 15 to 18)

*G. inflata* increases up to sample 16 and then quickly drops towards the core top. *G. truncatulino*ides and *G. predigita*ta progressively rise and show a peak between -38 and -28
cm (sample 17), whilst G. ruber stabilizes around 8% on average. Furthermore in sample 14 O. universa reappears and Globigerinoides gomitiatus first occurs. A stock of warm water species represented by Globigerina digitata, Hastingera pelagica and Hastingera siphonifera appears in sample 16 and increases in abundance in sample 17.

As to the cold water forms, mention should be made of the sharp drop of G. scitula, absent in samples 16 and 17, and G. quinqueloba which, in the last sample, is very rare.

Temperate-warm species increase in frequency and reach their peak in sample 17. At the same time, cold water forms definitely decrease, with a minimum frequency again in sample 17. The temperature increase, already foreshadowed in assemblage B, becomes more pronounced in this assemblage.

In conclusion, the sediments of this core portion were deposited during a temperate-warm phase, whose optimum is recognized in sample 17 (-38 to -28 cm).

**Concluding remarks**

Based on quantitative analyses, cumulative frequency curves for warm, cold and temperate species were constructed. The inferred paleoclimatic curve was plotted by means of the algebraic sum of frequency percentages of warm (positive values) and cold (negative values) indicators (Fig. 5), (Cox et alii, 1977). A curve was also plotted for Neogloboquadridina dutertrei (Fig. 5). The frequency of this form is related to salinity conditions (Be & Tønderlund, 1971; Ruddiman, 1971). This species occurs with low percentages throughout the core and disappears in samples 16 and 17, where a temperature increase is recorded.

The paleoclimatic curve indicates a cold episode in the basal part of the core (assemblage A) which shows some fluctuations. This phase is followed by a very cold period, in which two maximum cold peaks (sample 6, -341 cm and sample 8, -282 cm) are recorded (assemblage B). Finally, a warm episode (assemblage C) is obser-
PALEOClimATOLOGY OF A CORE FROM THE TYRRHENIAN SEA

Fig. 3 — Frequency diagrams of the most significant planktonic species.
— Diagrammi di frequenza delle specie planktoniche più significative.

ved, which reaches its optimum between -38 and -28 cm, i.e. in the area of maximum diffusion of warm and temperate indicators and of maximum contraction of cold indicators. The last core sample evidences a cooler fluctuation.

The basal part of the core (-500 to -371 cm) may therefore be ascribed to the last interstadial; the second part (-371 to -105 cm) to a cold period referable to the last stadial phase of the last glaciation; the terminal part of the core (-105 to 0 cm) represents a temperate and temperate-warm period which can be ascribed to the Holocene.

Comparison with other studies in nearby areas indicates that the best correlations are possible with the area N of the one from which core TEV 1 BAN 85 originates.

The assemblages examined here are similar with those of core 1 MO 67 (BLANC-VERNET et alii, 1969), sampled off Provence coast. The climatic curves of cores 1 MO 67 and TEV 1 BAN 85 show a similar pattern, thereby reflecting the same climatic trend with transition from an interstadial to a post-glacial period.

Also the data from four holes located in small Northern Tyrrhenian Sea basins (BORSETTI et alii, 1986) agree with our data. In the above cores, climatic evolution agrees with the one recognized for core TEV 1 BAN 85. Percentages of cold, temperate and warm species and thickness of sedimentary sequences ascribed to the various climatic phases are comparable.

An Upper Pleistocene microfauna similar to the one studied here was encountered in core PC-19 from the Central Tyrrhenian Sea (VIOLANTI et alii, 1987). Also in that core, right coiling specimens of N. pachyderma are prevailing.

In Southern Tyrrhenian Sea, cores KET 8019 and KET 8003 (Sgarrella, 1988) indicate in the phase referred to the post-glacial period, a warm peak shown by letter c and a following cold trend. This peak well agrees to the climatic "optimum" evidenced, in core TEV 1 BAN 85, by Foraminifera and Pteropoda assemblages.

In the gulf of Pozzuoli (BONADUCE et alii, 1986), planktonic foraminiferal fauna from core GP 83-89 evidence Holocene sediments. The assemblage is more scarce than the one studied.
Pteropoda and Heteropoda

Qualitative and quantitative analyses were conducted on the pteropod and heteropod assemblages occurring in the samples investigated for microfaunal analysis. The sieving residues of each sample (> 63 μ) were divided into unsorted fractions of 300 or more specimens. Computation was made of absolute abundance of pteropods and heteropods for each sample (Fig. 6) and of relative abundance of the single species observed for each unit volume of sediment (31.80 cc) (Fig. 7).

Finally, the climatic curve of the sequence (Fig. 7) was plotted by the algebraic sum of the percentages of the relative abundance of cold water species (− sign) and of warm water species (+ sign) for each level, according to the methodology of Buccheri (1984).

Features of assemblages

The identified pteropod and heteropod assemblages generally show a low specific diversity. Most of the sequence (from -500 to -165 cm) evidences a well-marked oligotypp, while the upper part of the core is characterized by a higher specific diversity reaching its peak in sample 16 (from -58 to -48 cm), where 10 species are recorded.

In total, 12 taxa of Pteropoda were identified, belonging to the following suborders:

Euthecosomata: Limacina bulbiloides (D’Orbigny), Limacina inflata (D’Orbigny), Limacina retroversa (Fleming), (f. balea Möller and f. retroversa (Fleming), dominant), Clio cuspidata (Bon), Clio pyramidata Linne, Creseis acicula Rang, Creseis virgula Rang, Styliola subula (Quoy & Gaimard), Diacria trispinosa (ins. Leseur) (Blainville), Hyaloyclis striata (Rang), Cavoliniia inflata (Leseur).

Pseudothecosomata: Peracis apicifultva Mei- senheimer.

Among Heteropoda rare fragments of Atlanta cfr. inflata Souleyet were identified. Juvenile forms and embryonal portions dominate in the assemblages. Adult specimens are mostly scarce and belong to few species: L. retroversa (both f. retroversa and f. balea; several intermediates between these forms have been also found; adult stage of f. balea is present in numerous samples - 3,5,6,7,8,10,12) L. inflata and L. bulbiloides (rare), C. pyramidata, C. inflata and D. trispinosa (very rare). The last three species are found in the adult stage only in samples 14 and 16.

The species found in the sedimentary sequence are typical of different ecological conditions; they characterize cold, temperate and warm waters.

The cold water species are represented in these sediments only by the epipelagic, boreal guest, Limacina retroversa, at present absent from the Mediterranean (Frog & Pastouret, 1972), where it seems to have disappeared in the lowermost Holocene. This species has been widely used as good paleoenvironmental indicator of cold periods of the glacial Pleistocene (Van Straten, 1966; Frog, 1967; Pastouret, 1970; Buccheri & Torelli, 1981; Torelli & Buccheri, 1983; Buccheri, 1984, 1985). Its temperature range is 2-19 °C with optimum between 7 and
12 °C (Be & Gilmer, 1977); its salinity ranges from 31.06 to 36‰; *f. balea* endures a minimum of 2.6 °C (Van der Spoel, 1967).

The temperate water species are represented by epi- and mesopelagic *Clio pyramidata*, whose temperature range is 7-27.8 °C and salinity 35.5-36.7‰ (Van der Spoel, 1967; Be & Gilmer, 1977; Buccheri & Torelli, 1981; Buccheri & Di Stefano, 1984).

The remaining species, making up the most numerous group, are regarded as warm water forms, i.e. with tropical and subtropical affinity, and as cosmopolitan forms. They all live in the Mediterranean at present. Some authors consider as cold-tolerant subtropical forms the following species: *Limacina inflata*, *L. bulimoides*, *Clio cuspidata*, *Peraclis apicifilva* and as warm-tolerant tropical and subtropical the following species: *Creses acicula*, *C. virgula*, *Stylola subula*, *Hyaloclysis striata* (cfr. Buccheri & Torelli, 1981). Furthermore, the distribution of many pteropod species is also controlled by salinity variations.

**Analysis of quantitative and qualitative data**

Quantitative analysis of each sample yielded a curve of absolute abundance of the assemblages which has a rather fluctuating pattern (Fig. 6). Initially, from bottom to top, up to sample 6 (-341 cm), a very low biological productivity is noted (in the range of 100 specimens or less per unit of sample). This low productivity is associated to a low specific diversity, as shown by qualitative analysis of the assemblages (Fig. 7). Subsequently, up to sample 12 (-165 cm), productivity globally increases with more or less wide fluctuations. Specimen abundance reaches sometimes high values, like in sample 10. Qualitative
analysis up to sample 12 still reveals a very low specific diversity.

In the upper part of the core (from sample 13 to 17), absolute abundance, which drops suddenly from sample 12 to 13, steadily increases, with a peak of 1,257 specimens in sample 17. The top of the core, instead, shows a decline in the total number of specimens.

The relative abundance curve of the species shows a sharp faunal variation in the composition of the assemblages, which occurs in the upper part of the core.

In the first part of this sequence oligotypic assemblages are evidenced: from bottom to sample 5 (-371 cm), the boreal guest _L. retroversa_ dominates, with a high frequency (75-90%). Its climatic meaning is mitigated by the presence of the temperate species _C. pyramidata_, absent from sample 6 to sample 8, and by the low-frequency warm water species _C. cuspidata_ (2.5-

10%). From sample 6 to sample 8 (-282 cm), _L. retroversa_ is the only species recorded (relative abundance 100%); it reaches an absolute abundance of 500 specimens in sample 7.

From sample 9 to 12 (-263 to -165 cm), 2 or sometimes 3 temperate and subtropical species with very low frequency are found again (_C. pyramidata_, _C. cuspidata_, _C. inflexa_, _C. virgula_), together with _L. retroversa_, always present with relative abundance values (88-98%).

Sample 13 (-147 cm) marks the beginning of the expansion of tropical, subtropical and cosmopolitan species, along with the gradual decrease of _L. retroversa_. This species is present up to sample 15 (-77 cm) where its frequency reaches its minimum value in the whole sequence (21%). In this portion of the core (from sample 13 to 15), the temperate species _C. pyramidata_ rises up to 45%, the tropical species _L. inflata_ and the cosmopolitan species _D. trispinosa_ occur for the first time in the sequence respectively with a maximum frequency of 32 and 20%. The other warm species (_C. inflexa_, _L. bulimoides_, _P. apicifulva_) and the only heteropod (_Atlantic cfr. inflata_) are present with an extremely low relative abundance.

From sample 16 (-58 cm) to the core-top, specific diversity further increases, paralleled by the above quoted sharp rise of total absolute abundance. Along with the absence of _L. retroversa_, the topmost part of the sequence exhibits a progressive decline in the temperate species _C. pyramidata_, which reaches its minimum percentage (5.72%), at the same time of a strong increase of the warm species _L. inflata_ (55% at the core-top with 445 specimens).

Finally this terminal part of the sequence shows the appearance of the subtropical species _S. subula_, which reaches 25.45% in sample 17. This species is likely to mark an important bioevent in the Western Mediterranean area: indeed it reappears during the Holocene, in concomitance with the disappearance of the subartic species _L. retroversa_ and generally strengthens the hypothesis of a climatic optimum during the Holocene at about 6,500 yr B.P. (Buccheri & Torelli, 1981).

Paleoclimatic remarks and comparisons

The quantitative analysis of pteropod assemblages allowed to construct the paleoclimatic curve of the sedimentary sequence. The curve shows a well-defined transition from cold (negative) to warm (positive) values.

Composition and paleoecological meaning of the assemblages suggest a fairly detailed climatic evolution.
From bottom upwards in the general cold phase ending at about -165 cm (sample 12), some fluctuations are noted. From -500 to -400 cm a slight tendency towards higher temperatures is noted, where the occurrence of the subpolar species L. retroversa is indeed countered by the temperate species C. pyramidata and, to a lesser extent, by C. cuspidata, warm water species.

From -400 to -282 cm a particularly cold phase can be observed, which displays a wide cold fluctuation reaching a glacial maximum in the -351 to -282 cm interval (samples 6-8), in which temperate species disappear and only the cold species L. retroversa is present.

This phase is followed by two positive fluctuations (samples 9, 11), where very low percentages of temperate and warm water species reappear.

Slight temperatures rises (samples 1, 4, 9, 11) are related to a tendency towards low values of the absolute abundance curve, while temperature decreases (sample 3, 7, 10, 12) are related to some higher values of absolute abundance. This fact can be attributed to contraction or expansion of the population of the single cold water species, L. retroversa, which dominates in the first part of the sequence (from bottom up to sample 12) as displayed by its relative abundance curve.

The last phase (-165 cm to core-top) definitely indicates a progressive trend of the climatic curve towards warmer temperatures displaying a cool interval followed by a temperate phase.
and a warm temperate one. This pattern is clearly defined by the faunal data: a first increment of warm species after the glacial phase, the appearance of *L. inflata*, as well as the start of a strong decline of the cold species *L. retroversa*, are displayed by species relative abundance.

In the last part of the sequence (-115 to 0 cm) the stabilization of the curve at positive values is related to the disappearance of boreal species and to a significant expansion of tropical, subtropical and cosmopolitan species ("Mediterranean pteropods", *Auct.*) after the last Würmian glaciation (cfr. *Buccheri & Torelli*, 1981; *Buccheri & Di Stefano*, 1984), including *S. subula*, whose reappearance, as previously pointed out, occurs during the Holocene.

In the studied sequence, the different climatic phases recognized are referable to the last glacial and to the postglacial according with the indications provided by the most significant pteropods. The expansion in the Western Mediterranean of "Mediterranean pteropods" occurs after the last glaciation (*Buccheri & Torelli*, 1981).

Within the cold phase referable to the last glacial the first slightly warmer fluctuations (at the basal part of the sequence) could be related to an interstadial phase.

This is followed by the last stadial cold phase of the last glaciation with a maximum cold peak and some fluctuation towards higher temperatures. Then, a progressive temperature increase with still negative values takes place, which could be correlated with the "tardiglacial" phase. Finally, a postglacial temperate-warm interval is recorded, which reaches its maximum positive value between -38 and to top (samples 17, 18). The interval with the warmest phase can be correlated with the climatic optimum of the "Atlantic phase".

Similar studies conducted by different authors on pteropods and heteropods in the Mediterranean Quaternary sequences allow a comparison of the data obtained in this work with those of some cores sampled in the Western Mediterranean area.

In the north-western basin (Provence), *Blanc-Vernet et alii* (1969) analyzed a sedimentary sequence (core 1 MO 67) whose upper portion can be correlated with the sequence in study. This sequence shows parallel climatic phases with similar patterns of pteropod assemblages, from the Würm III/IV interstadial (where pteropods are scarce or absent), followed by the glacial phase (with abundant *L. retroversa*) and then by the postglacial period (with appearance and settlement of warm water species), to the climatic optimum of the Holocene "Atlantic phase".

In the Sardinian basin, Western Tyrrenian Sea, *Buccheri & Torelli* (1981) and *Torelli & Buccheri* (1981) analyzed seven cores Late Quaternary in age by means of pteropod assemblages. This sequence can be compared only with the upper part of the sequence discussed here and its climatic pattern shows a similar trend. Also the behaviour of some indicator species, including *L. retroversa*, *C. pyramidata*, *L. inflata*, *S. subula*, is closely parallel. Reappearance of *L. inflata* just below the postglacial sediments (Holocene) seems to be a concordant datum for the Mediterranean (cfr. *Buccheri & Torelli*, 1981).

Other partial similarities can be found with the Holocene cores of the gulf of Pozzuoli, investigated by *Buccheri & Di Stefano* (1986). Their initial portion is likely to correspond to the Holocene terminal one of the sequence here investigated. In the lower part of the cores, the authors report a climatic optimum which is more recent than 7,000 yr B.P. (bottom of the core) and the pteropod assemblage is very similar to the one considered in this study.

**General conclusions**

The foraminifera, pteropod and heteropod assemblages in the studied sedimentary sequence yielded interesting paleoclimatic data.

The results obtained for planktonic foraminifera and planktonic gastropods, led to a concordant and well-defined paleoclimatic interpretation.

In the analyzed sequence some major paleoclimatic events were pointed out. These events were correlated with late Pleistocene and Holocene climatic phases based on quantitative and qualitative presence of some species of foraminifera and pteropods characterizing glacial and postglacial sediments. Indeed climatic fluctuations in the Late Quaternary induced considerable variations in the faunal composition of these assemblages.

From bottom to top of the examined sedimentary sequence, an interstadial phase can be recognized, showing a cold climate with cool fluctuations (last Würmian interstadial). This phase is followed by the last Würmian stadial phase, characterized by the glacial maximum. These two phases show generally cold foraminiferal faunas, characterized by *G. quinqueloba* and *G. scitula*, as well as pteropod assemblages from oligotrophic (cold phase) to monotypical (glacial maximum), always dominated by the boreal species *L. retroversa*.

These cold phases are followed by a temperate and temperate-warm trend, evidenced by ap-
PALEOClimATOLOGY OF A CORE FROM THE TYRRHENIAN SEA

pearance and settlement of the “Mediterranean pteropod complex” reported by various authors in the Mediterranean area. According to some authors, this complex defines the glacial-postglacial boundary (cfr. Buccheri & Torelli, 1981). As regards foraminifera, gradual temperature increase is displayed by the increasing number of temperate, and temperate-warm water forms (G. inflata, G. truncatulinoides and O. universa) and by the appearance of H. siphonifera, H. pelagica and G. digitata.

These progressive changes, recorded in the foraminiferal assemblages are evidenced also by means of pteropod faunas. The transition of the curve to the temperate-warm range (positive values), marks the beginning of the Holocene and the last part includes the “Atlantic” phase corresponding to the last “climatic optimum” recorded in the curve.

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RIASSUNTO

Sono state studiate, qualitativamente e quantitativamente, le associazioni a foraminiferi, pteropodi ed eteropodi contenute nei sedimenti tardo-pi Beirutici ed oloelencoli della crosta TVE BN 185, prelevata in un piccolo bacino profondo antistante il delta del Tevere (mare Tirreno - Meditarraneo occidentale).

L’analisi di dettaglio dei foraminiferi planctonici ha consentito il riconoscimento di associazioni a carattere freddo con transizione al temperato e al temperato-caldo, la cui successione testimonia l’evoluzione climatica avvenuta durante la sedimentazione. I dati analitici sugli eteropodi ed eteropodi di hanno permesso di rilevare nella sequenza associazioni generalmente a bassa diversità specifica a carattere freddo, temperato o temperato-caldo caratterizzate rispettivamente da una sola specie subpolare e da diverse specie tropicali, subtrofiche e cospropolite.

Le variazioni di frequenza dei foraminiferi planctonici, degli eteropodi ed eteropodi hanno permesso di individuare un trend climatico da freddo a temperato-caldo e caldo, con intervalli attribuibili all’ultimo interstadiale würmiano, all’ultimo glaciale e al postglaciale fino alla fase “atlantica”.

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BIBLIOGRAPHY


PLATE I

Fig. 1a - *Neogloboquadrina dutertrei* (D’ORBIGNY); umbilical view; sample 4.
Fig. 1b - *Neogloboquadrina dutertrei* (D’ORBIGNY); spiral view; sample 4.
Fig. 2 - *Globigerina calida* PARKER; umbilical view; sample 16.
Fig. 3 - *Neogloboquadrina pachyderma* (EHRENBERG); umbilical view; sample 5.
Fig. 4 - *Globigerinella glutinata* (EGGER); umbilical view; sample 3.
Fig. 5 - *Globigerina quinqueloba* NATLAND; umbilical view; sample 4.
Fig. 6a - *Globorotalia scitula* (BRADY); umbilical view; sample 13.
Fig. 6b - *Globorotalia scitula* (BRADY); spiral view; sample 13.
Fig. 7a - *Globorotalia truncatulinoides* (D’ORBIGNY); umbilical view; sample 17.
Fig. 7b - *Globorotalia truncatulinoides* (D’ORBIGNY); spiral view; sample 17.
Fig. 7c - *Globorotalia truncatulinoides* (D’ORBIGNY); side view; sample 17.
Fig. 8 - *Globigerina borealis* BRADY; umbilical view; sample 4.

TAVOLA I

Fig. 1a - *Neogloboquadrina dutertrei* (D’ORBIGNY); lato ombelicale; campione 4.
Fig. 1b - *Neogloboquadrina dutertrei* (D’ORBIGNY); lato spirale; campione 4.
Fig. 2 - *Globigerina calida* PARKER; lato ombelicale; campione 16.
Fig. 3 - *Neogloboquadrina pachyderma* (EHRENBERG); lato ombelicale; campione 5.
Fig. 4 - *Globigerinella glutinata* (EGGER); lato ombelicale; campione 3.
Fig. 5 - *Globigerina quinqueloba* NATLAND; lato ombelicale; campione 4.
Fig. 6a - *Globorotalia scitula* (BRADY); lato ombelicale; campione 13.
Fig. 6b - *Globorotalia scitula* (BRADY); lato spirale; campione 13.
Fig. 7a - *Globorotalia truncatulinoides* (D’ORBIGNY); lato ombelicale; campione 17.
Fig. 7b - *Globorotalia truncatulinoides* (D’ORBIGNY); lato spirale; campione 17.
Fig. 7c - *Globorotalia truncatulinoides* (D’ORBIGNY); vista laterale; campione 17.
Fig. 8 - *Globigerina borealis* BRADY; lato ombelicale; campione 4.
PLATE II

Fig. 1 - *Globorotalia inflata* (D’ORBIGNY); umbilical view; sample 17.
Fig. 2 - *Globigerinoides ruber* (D’ORBIGNY); umbilical view; sample 17.
Fig. 3 - *Globigerina praedigitata* PARKER; umbilical view; sample 17.
Fig. 4 - *Globigerina quinqueloba* NATLAND; umbilical view; sample 4.
Fig. 5 - *Globigerina borealis* BRADY; umbilical view; sample 4.
Fig. 6 - *Peraclis apicifulva* MEISENHEIMER; broken specimen; sample 16.
Fig. 7a - *Diacria trispinosa* (ms. LESUEUR) (BLAINVILLE); embrional part of shell; sample 13.
Fig. 7b - *Diacria trispinosa* (ms. LESUEUR) (BLAINVILLE); detail of fig. 7a.
Fig. 8a - *Crescis acicula* RANG; sample 16.
Fig. 8b - *Crescis acicula* RANG; embrional part of specimen of fig. 8a.
Fig. 9 - *Clio cuspidata* (Bosc); embrional part of shell; sample 1.

TAVOLA II

Fig. 1 - *Globorotalia inflata* (D’ORBIGNY); lato ombelicale; campione 17.
Fig. 2 - *Globigerinoides ruber* (D’ORBIGNY); lato ombelicale; campione 17.
Fig. 3 - *Globigerina praedigitata* PARKER; lato ombelicale; campione 17.
Fig. 4 - *Globigerina quinqueloba* NATLAND; lato ombelicale; campione 4.
Fig. 5 - *Globigerina borealis* BRADY; lato ombelicale; campione 4.
Fig. 6 - *Peraclis apicifulva* MEISENHEIMER; esemplare rotto; campione 16.
Fig. 7a - *Diacria trispinosa* (ms. LESUEUR) (BLAINVILLE); parte embrionale della conchiglia; campione 13.
Fig. 7b - *Diacria trispinosa* (ms. LESUEUR) (BLAINVILLE); dettaglio della fig. 7a.
Fig. 8a - *Crescis acicula* RANG; campione 16.
Fig. 8b - *Crescis acicula* RANG; parte embrionale dell’esemplare della fig. 8a.
Fig. 9 - *Clio cuspidata* (Bosc); parte embrionale della conchiglia; campione 1.
PLATE III

Fig. 1 - Cavolinia inflexa (LeSueur); embrional part of shell; sample 16.
Fig. 2 - Limacina inflata (D’Orbigny); frontal-apical view of shell; sample 14.
Fig. 3 - Limacina bulimoides (D’Orbigny); sample 16.
Fig. 4 - Hyaloclylis striata (Rangan); sample 18.
Fig. 5a - Clio pyramidata Linne; broken specimen; sample 16.
Fig. 5b - Clio pyramidata Linne; embrional part of specimen of fig. 5a.
Fig. 6 - Limacina retroversa (Fleming) (L. retroversa Möller); sample 3.
Fig. 7 - Styliola subula (Quoy & Gaimard); young specimen; sample 16.
Fig. 8a - Atlanta cfr. inflata Souleyet; apical view; sample 16.
Fig. 8b - Atlanta cfr. inflata Souleyet; detail of embrional part of specimen of Fig. 8a.

TAVOLA III

Fig. 1 - Cavolinia inflexa (LeSueur); parte embrionale della conchiglia; campione 16.
Fig. 2 - Limacina inflata (D’Orbigny); vista apicale-frontale della conchiglia; campione 14.
Fig. 3 - Limacina bulimoides (D’Orbigny); campione 16.
Fig. 4 - Hyaloclylis striata (Rangan); campione 18.
Fig. 5a - Clio pyramidata Linne; esemplare rotto; vista frontale campione 16.
Fig. 5b - Clio pyramidata Linne; parte embrionale dell’esemplare della fig. 5a.
Fig. 6 - Limacina retroversa (Fleming) (L. retroversa Möller); campione 3.
Fig. 7 - Styliola subula (Quoy & Gaimard); individuo giovane; campione 16.
Fig. 8a - Atlanta cfr. inflata Souleyet; vista apicale; campione 16.
Fig. 8b - Atlanta cfr. inflata Souleyet; dettaglio della parte embrionale dell’esemplare della Fig. 8a.