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PALEOENVIRONMENTAL INTERPRETATION OF CORE BAN88-11GC (EASTERN MEDITERRANEAN, PLEISTOCENE-HOLOCENE) ON THE GROUNDS OF FORAMINIFERA, THECOSOMATA AND CALCAREOUS NANNOFOSSILS

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ABSTRACT - *Paleoenvironmental interpretation of Core BAN88-11GC (Eastern Mediterranean, Pleistocene-Holocene) on the grounds of Foraminifera, Thecosomata and calcareous nannofossils* - Il Quaternario, **4**(1a), 1991, pp. 13-39 - This paper deals with the quantitative variations of planktonic Foraminifera, Thecosomata and calcareous nannofossils from Core BAN88-11GC, recovered in the Eastern Mediterranean during the Cruise Bannock 1988. Sediments are Middle Pleistocene to Holocene in age, spanning about the last 250,000 years. Sapropels S-1 to S-8 (only S-4 is missing) and two tephra layers (Y-5, X-2) are also recorded. Calcareous nannofossils provided the biostratigraphic framework: three biozones (*Gephyrocapsa oceanica* and *Emiliania huxleyi* Zones, *Emiliania huxleyi* Acme Zone) were recognized and correlated to five climatic zones (V, W, X, Y, and Z). Two climatic curves were constructed based on the relative abundance of warm and cold species of Foraminifera and Thecosomata; they are well correlated and point out four warm and three cold intervals. Measurements of maximum diameter of *Orbulina universa* show that larger sizes of this taxon well correlate with positive peaks of the climatic foraminiferal curve, confirming their paleoclimatic significance. Statistical analyses of planktonic Foraminifera were carried out: Factor 1 and Principal Component 1 can be related to water temperature. The Cluster Analysis shows four groups of species (warm, temperate/warm, temperate, cold species). *Globigerinoides gomitulus* seems a useful temperate or temperate/warm water indicator. *Neogloboquadrina dutertrei*, previously considered as low-salinity indicator, seems better related to enhanced circulation and/or high productivity levels. The Pseudothecosomata *Gleba cordata* and the Gymnosomata *Paedoclione doliiformis* are more frequent during some temperate/warm intervals. The tephra deposition seems to affect the Thecosomata assemblages. On the basis of the quantitative study on calcareous nannofossils, it was possible to point out significant variations either in the dominant species (*E. huxleyi, G. oceanica, G. caribbeanica* and "small" *Gephyrocapsa)* or in other taxa, usually less abundant but showing peculiar behaviour (*Helicosphaera carteri* and *Syracosphaera* sp. 1). A comparison between the planktonic Foraminifera and Thecosomata climatic curves and the distribution patterns of dominant nannofossil taxa allowed us to infer that, at least in some cases, temperature controlled the percentage variations of the latter species. Moreover, *H. carteri* clearly increases in abundance whereas *Syracosphaera* sp. 1 sharply decreases or even disappears within all sapropels. Abundance peaks of *H. carteri*, although less striking, are also present in the tephra layers. Such a peculiar behaviour might be explained with turbidity increase in surface waters, due to the Nile runoff in the case of sapropels and to volcanic ash in the case of tephra.

RIASSUNTO - *Interpretazione paleoambientale della Carota BAN88-11GC (Mediterraneo orientale, Pleistocene-Olocene) basata sullo studio di Foraminiferi, Thecosomata e nannofossili calcarei* - Il Quaternario, **4**(1a), 1991, pp. 13-39 - E' stato condotto lo studio quantitativo dei Foraminiferi, Thecosomata e nannofossili calcarei della Carota BAN88-11GC, prelevata nel Mediterraneo Orientale. Sono rappresentati sedimenti pelagici di età compresa tra il Pleistocene Medio e l'Olocene (Zone a *Gephyrocapsa oceanica*, *Emiliania huxleyi* e d'acme di E. huxleyi), i sapropels S-1 a S-8 (escluso S-4, mancante) e due tephra (Y-5, X-2). In base alle percentuali di specie calde e fredde sono state costruite le curve climatiche relative a Foraminiferi e Thecosomata; esse sono in buon accordo e mettono in evidenza oscillazioni calde e fredde. Le variazioni del diametro massimo di *Orbulina universa* si correlano bene con l'andamento delle curve climatiche. L'analisi fattoriale, dei Componenti Principali e la Cluster Analysis mettono in evidenza gruppi di Foraminiferi con differente distribuzione rispetto alla temperatura delle acque. Viene analizzato il significato paleoclimatico di *Globigerinoides gomitulus*; *Neogloboquadrina dutertrei* viene considerata indicativa di correnti di risalita o di alta produttività, più che di ridotta salinità. Si discute il valore paleoambientale del Pseudothecosomata *Gleba cordata* e del Gymnosomata *Paedoclione doliiformis* come indicatori temperato/caldi, là dove risultano assenti o scarse le classiche specie indicatrici climatiche. Viene evidenziata l'influenza negativa della deposizione dei tephra rispetto a quella dei sapropels sulle associazioni a Thecosomata. Lo studio quantitativo della nannoflora calcarea ha permesso di individuare variazioni significative sia nell'ambito delle specie dominanti (*E. huxleyi, G. oceanica, G. caribbeanica*, "piccole" *Gephyrocapsa*) sia in specie mediamente meno abbondanti ma con caratteristici picchi percentuali (*Helicosphaera carteri* e *Syracosphaera* sp. 1). Il confronto delle curve percentuali delle specie dominanti con le curve climatiche basate su Foraminiferi e Thecosomata mette in luce un possibile controllo della temperatura sulla loro distribuzione. Le variazioni percentuali di *H. carteri* e *Syracosphaera* sp. 1 sono reciprocamente opposte all'interno di tutti i sapropels: si registrano netti incrementi della prima specie e decrementi della seconda. Picchi di *H. carteri* si rinvengono anche all'interno dei tephra. Questo fa ipotizzare che incrementi nella torbidità delle acque superficiali (per materiali trasportati dal Nilo nel caso dei sapropels e per prodotti vulcanici nel caso dei tephra) possano essere alla base delle variazioni opposte di queste due specie.

Key-words: Foraminifera, Thecosomata, calcareous nannofossils, Pleistocene, Holocene, climate, Eastern Mediterranean
Parole chiave: Foraminiferi, Thecosomata, nannofossili calcarei, Pleistocene, Olocene, clima, Mediterraneo Orientale

1. INTRODUCTION

The object of the present study is gravity core BAN88-11GC, which comes from Prometheus 2 Area (on the crest of the Eastern Mediterranean Ridge),at a depth of about -1900 m on the plateau lying SW of Prometheus Dome. The coordinates of the site are 33° 49.10' Lat. N, 24° 24.71' Long. E (Fig. 1). The 562 cm of pelagic sediments recovered were preliminarly described and analyzed during the Ban-88 cruise (Board Report, unpublished data).

Light yellowish brown marls (10 YR 6/4) and light grey marls (10 YR 7/2) are the dominant lithologies. Grey marly clays are present between 284÷520 cm. Six sapropel layers (indicated as sapropel S-1, S-3, S-5, S-6, S-7, S-8) and two volcanic ash layers are preserved. The lower of these latter, consisting of hazel-brown volcanic sands, possibly represents tephra X-2, also on the basis of its stratigraphic position. The upper layer, constituted by colourless, transparent volcanic glass, has been correlated with tephra Y-5 (Keller *et al.*, 1978).

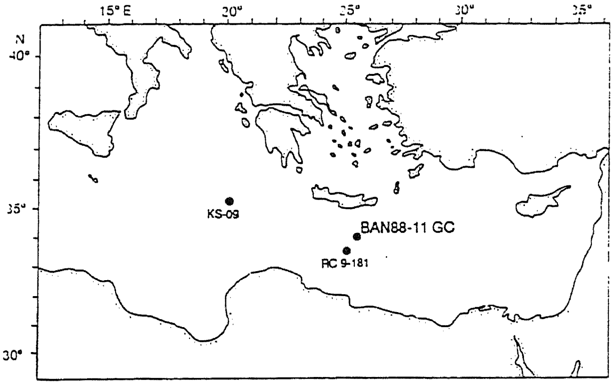

Fig. 1 - Location map of Core BAN88-11GC and of two reference cores.

Localizzazione della carota BAN88-11GC e di alcune carote di riferimento.

About 21 cm from the core-top is the black Marker-bed, Holocene in age, which has been found in the cores from the diapiric areas Prometheus 2 and Olimpi, discovered in the Mediterranean Ridge south of Creta (Ryan *et al.*, 1982; Camerlenghi & Cita, 1987; Camerlenghi *et al.*, 1989). This Marker-bed, lying only a few centimeters above sapropel S-1, contains abundant manganese micronodules and bacterial colonies, and it has been dated to 4000 years B.P. (Cita *et al.*, 1989).

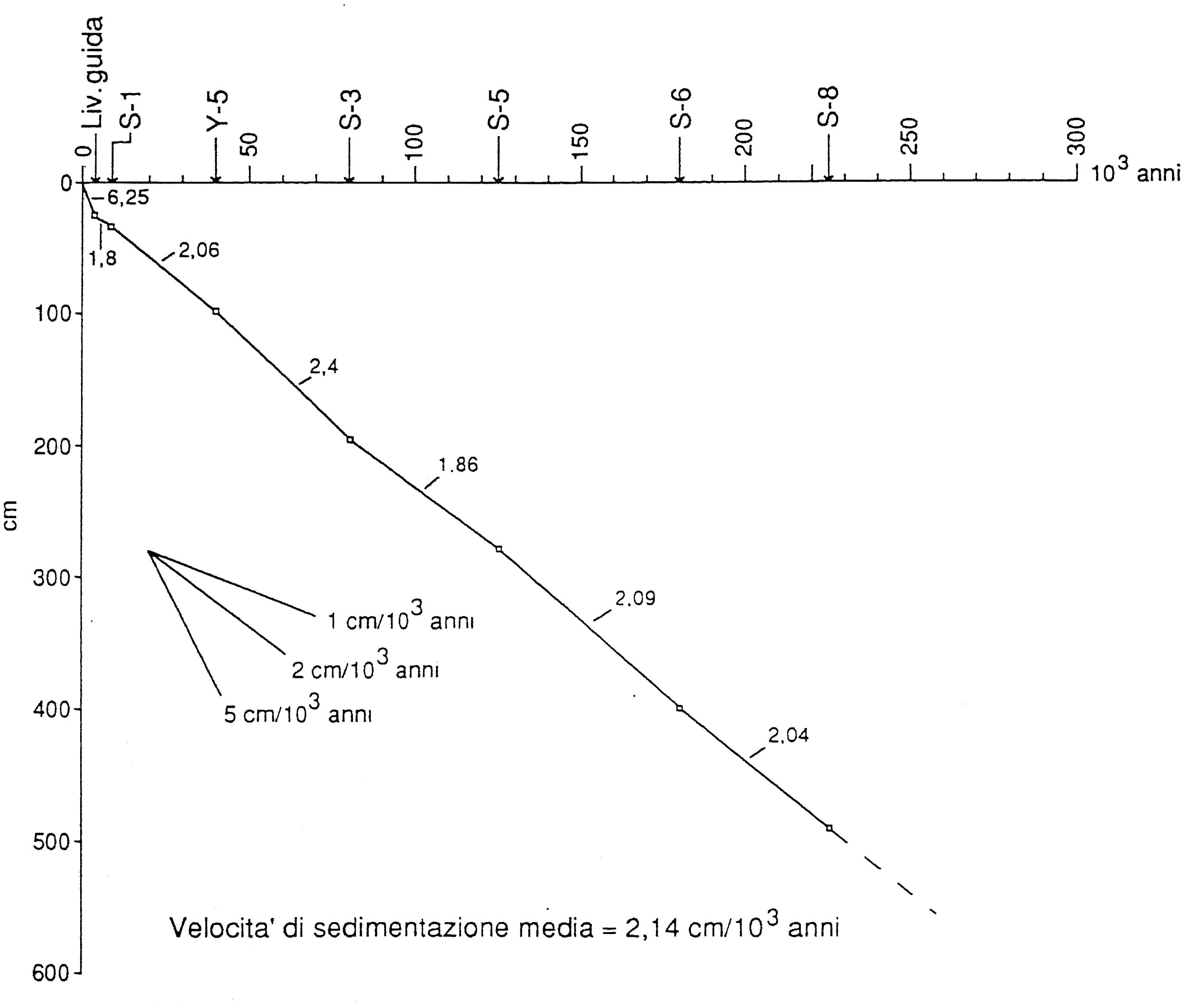

Fig. 2 - Sedimentation rate calculated on litostratigraphic horizons (sapropels, tephras) whose absolute age is rather well-established.

Curva della velocità di sedimentazione calcolata su orizzonti litostratigrafici (sapropels, tephra*) di cui è conosciuta con buona approssimazione l'età assoluta.*

Sediments range in age from Holocene (*Emiliana huxleyi* Acme-zone) to Middle Pleistocene (*Gephyrocapsa oceanica* zone). The estimated average sedimentation rate is about 2.14 cm/1000 years and the involved time interval covers about the last 250,000 years; the rate for the Holocene sediments is about 6.25 cm/1000 years (Fig. 2).

Because of the fine preservation of its litho- and bio-stratigraphic records, core BAN88-11GC represents the reference section for the pelagic sequence in Prometheus 2 Area.

2. SAMPLING AND METHODOLOGY

Seventy-one samples have been analyzed: the standard distance between them is 10 cm, but it is shorter in particularly interesting lithologies (*i.e.* sapropels).

Both presentation and discussion of data are carried out starting from oldest samples.

Calcium carbonate percentages have been measured on about 1 gr of sediment. Different methodologies were required for the preparation of Foraminifera, Thecosomata and calcareous nannofossils samples.

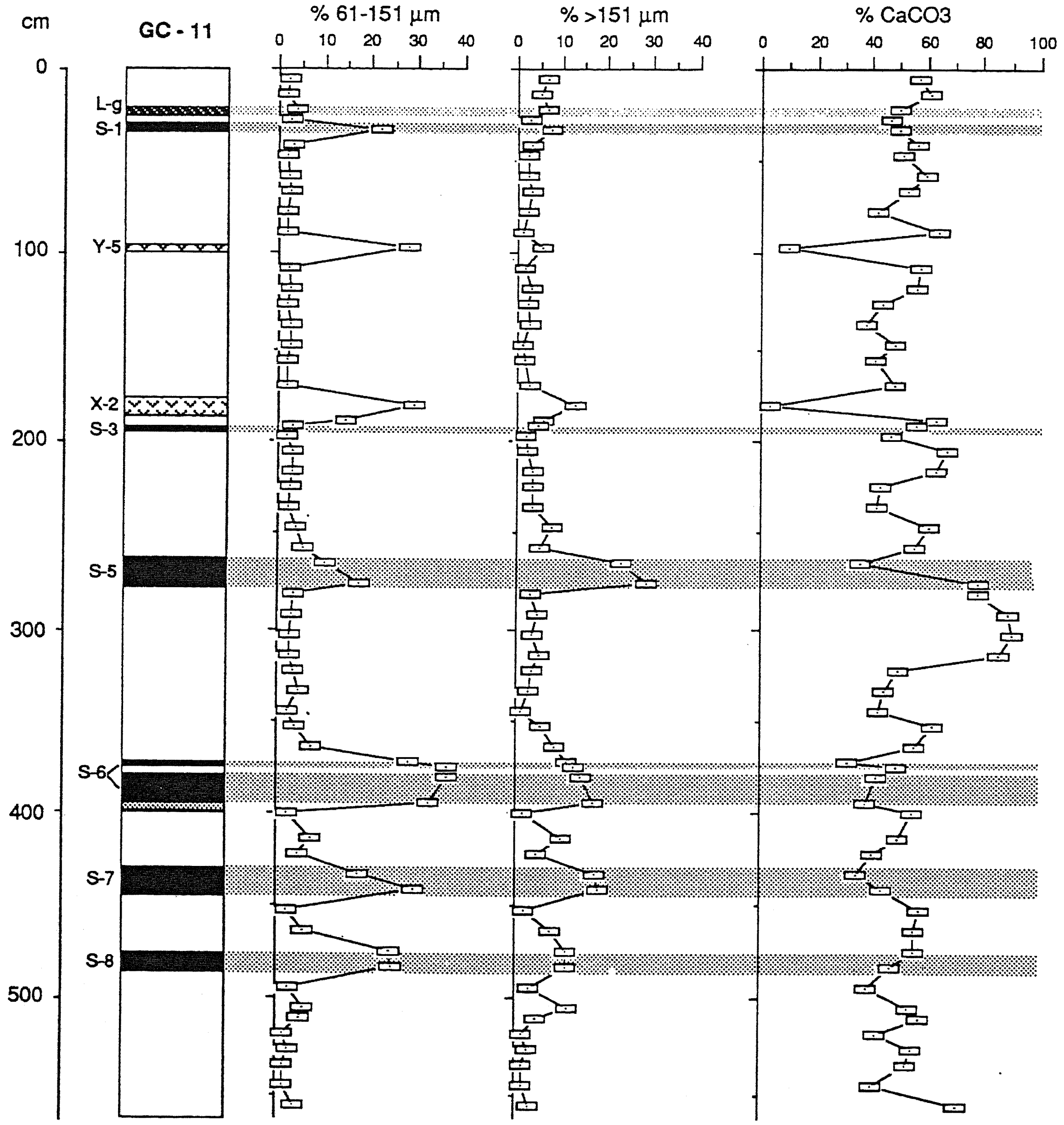

Fig. 3 - Grain-size and CaCO$_3$ percentages, measured in Core BAN88-11GC. The lithologic log is in the left column of this and following figures. L- g = marker bed (see text), s = sapropel, y, x = tephra.

Curve percentuali delle frazioni granulometriche e del carbonato di calcio nella carota BAN88-11GC. La colonna litologica è riportata sul lato sinistro in questa e nelle seguenti figure. L- g = Livello guida (vedi testo), s = sapropel, *y, x =* tephra.

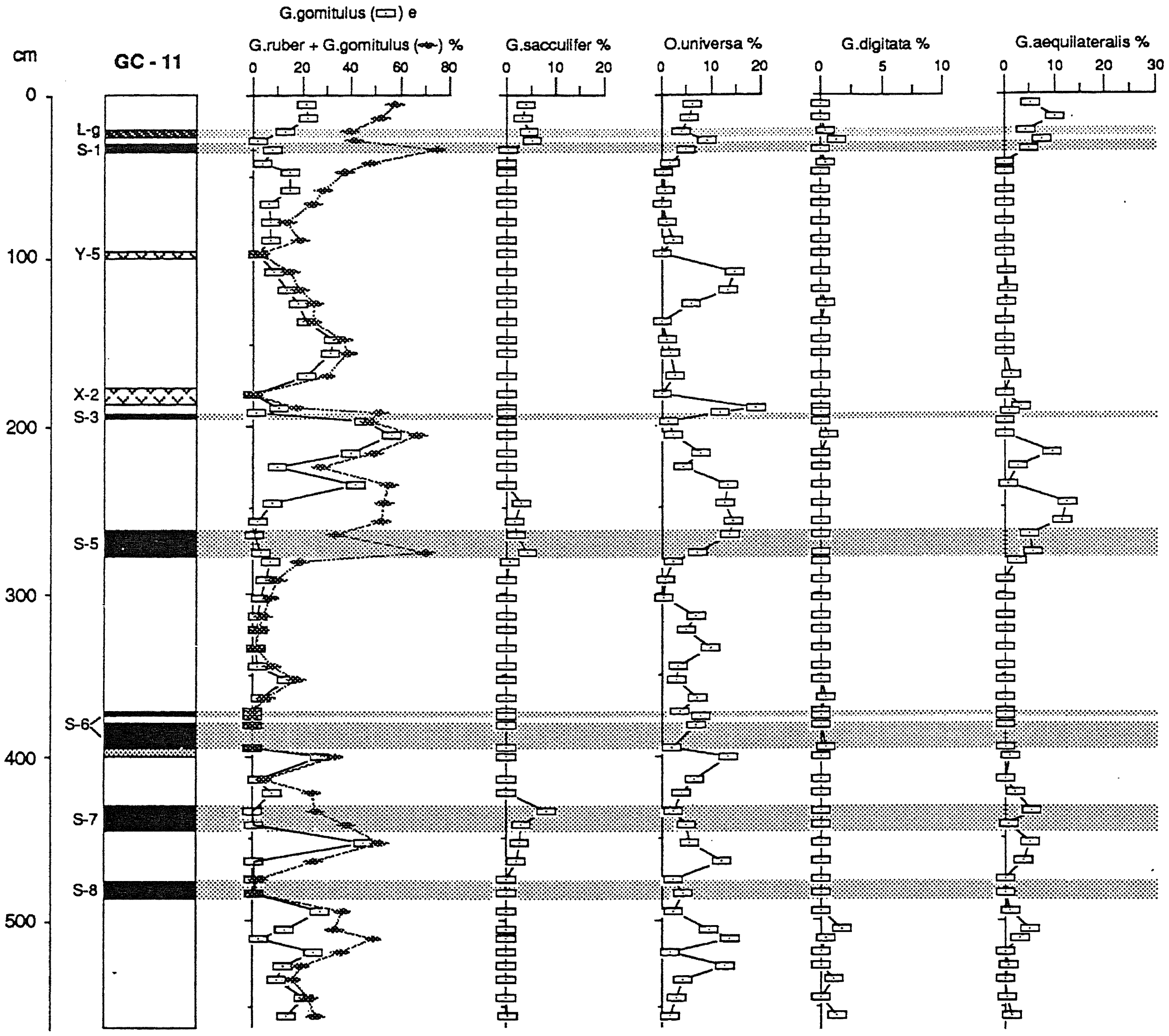

Fig.4a - Percentage curves of planktonic Foramifera used as warm water indicators: *Globigerinoides ruber* (inclusive of *G. gomitulus*, considered as a more temperate form), *Globigerinoides sacculifer*, *Orbulina universa*, *Globigerinella digitata*, *Globigerinella aequilateralis*.

Curve percentuali dei Foraminiferi planctonici indicativi di acque calde: Globigerinoides ruber *(comprensivo di* G. gomitulus, *interpretato come variante di acque più fresche),* Globigerinoides sacculifer, Orbulina universa, Globigerinella digitata, Globigerinella aequilateralis.

For the microfaunal analyses, 4÷5 cc of sediment from each sample have been washed and sieved into two grain size fractions 61÷151 µm and >151 µm; the residues have been dried and weighted.

D. Violanti studied Foraminifera, G. Grecchi planktonic malacofaunas, D. Castradori calcareous nannofossils.

2.1 Foraminifera

All planktonic foraminiferal specimens in each fraction >151 µm have been counted and taxonomically determined (totally about 300 tests), and the P/P+B ratio has been calculated. *Neogloboquadrina pachyderma* and *Globigerina bulloides* have been considered as cold-water indicators, while *Globigerinoides ruber*, *G. sacculifer*, *Orbulina universa*, *Globigerinella digitata* and *G. aequilateralis* as warm-water indicators (Parker, 1958; Cita *et al.*, 1973; Montcharmont *et al.*, 1984). For each sample, the algebraic sum of warm-water species percentages (positive values) and cold-water species percentages (negative values) gives the climatic curve.

The study has also dealt with the percentage variations of *Neogloboquadrina dutertrei*, which was often seen as a low-salinity indicator (Ruddiman, 1971; Vergnaud-Grazzini *et al.*, 1977; Thunell *et al.*, 1977; Cita *et al.*, 1982) or was correlated to convergence and upwelling areas (Phleger *et al.*, 1953; Bè & Tolderlund, 1971; Srinivasan & Kennett, 1976).

On the whole residue of each sample, the maximum diameter of *Orbulina universa* has also been measured; this is directly correlatable with climatic fluctuations (Colombo & Cita, 1980; Mairani, 1987; Violanti & Saccà, 1989).

In the statistical analyses, species percentages lower than 1 ÷ 2% as well as desultory occurrences were neglected. Factor Analysis, Main Components Analysis and Cluster Analysis have been carried out on 23 species (total = 33), using respectively the "statistical library" and a program by Davis (1986), modified by Corselli.

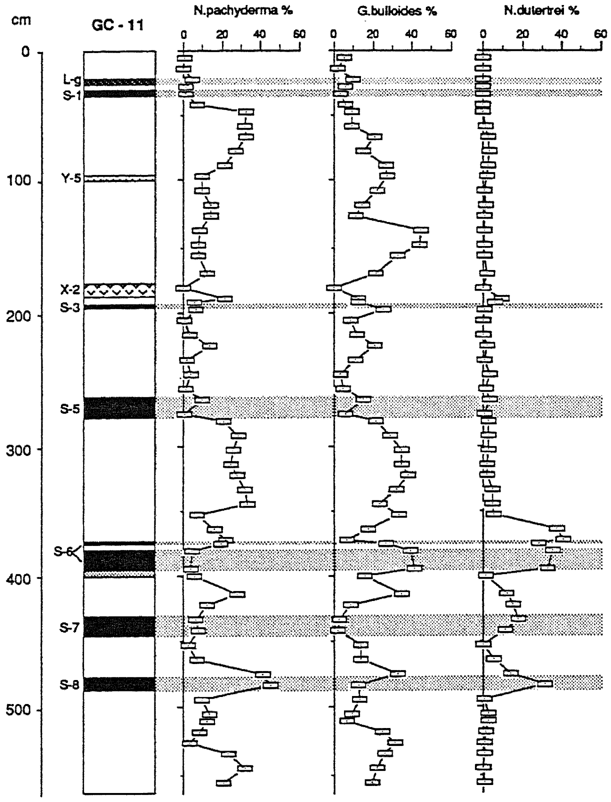

Fig. 4b - Percentage curves of planktonic Foraminifera used as cold water indicators: *Neogloboquadrina pachyderma*, *Globigerina bulloides*. On the right, percentage curve of *Neogloboquadrina dutertrei*, a high productivity indicator.

Curve percentuali dei Foraminiferi planctonici indicativi di acque fredde: Neogloboquadrina pachyderma, Globigerina bulloides. *A destra è indicata la curva percentuale di* Neogloboquadrina dutertrei, *indicativa di alta produttività.*

2.2 Molluscs

The study of malacological associations has been carried out on fractions >151 µm. A total of 6000, mainly fragmented specimens was contained in 23 samples out of the 61 examined ones. They belong to the order Thecosomata, and are chiefly ascribed to suborder Euthecosomata (14 species), except for two species of suborder Pseudothecosomata (Corselli & Grecchi, in press). Thecosomata are usually phytophagous organisms, occasionally feeding on floating organic particles (Tregouboff & Rose, 1957). Sixteen species have been identified, four of which (Euthecosomata) are defined as climatic indicators in previous paleoecologic studies on the Mediterranean. *Limacina inflata*, *L. trochiformis* and *Cavolinia inflexa* are warm-water species; *Limacina retroversa* is the only cold-water indicator (Furnestin, 1979; Grecchi, 1984; Grecchi & Bertolotti, 1988; Biekart, 1989; Violanti & Saccà, 1989). The number of specimens found is recorded for each species, and their percentages have allowed to draw the climatic curve.

This latter is built, like the foraminiferal climatic curve, through the algebraic sum of warm-water species percentages (positive values) and cold-water species percentages (negative values). Also the Pseudothecosomata *Gleba cordata* and the Gymnosomata *Paedoclione doliiformis* have been considered: they turn out to be frequent during warm periods.

2.3 Nannoflora

The quantitative analysis of calcareous nannofossils has been carried out on the above mentioned 61 samples. For each sample a permanent smear-slide has been prepared with Canada Balsam. In order to preserve the original assemblages composition no particular methodology has been used during the samples preparation (*i.e.* ultrasounds, centrifuge). The material density has been specially regarded, because, if too high, it can interfere with the counting and make quantitative analysis unreliable.

This latter was done on a 1250X polarizer microscope, because of the easy samples preparation and the relatively short time required for the analysis. Unfortunately, this methodology does not allow a detailed classification of some taxa, such as *Gephyrocapsa*. In this case a semplified taxonomy has been used, based on previous works: Gartner (1977), Rio (1982), Rio *et al.* (1990). The taxa are divided as follows: a) *G. oceanica* s.l. has an open central area and its dimensions are from 3.5 to 5.5 µm; b) *G. caribbeanica* has the same dimensional range, but its central area is very small; c) "small" *Gephyrocapsa* spp. is the name used for all specimens smaller than 3.5 µm (in agreement with Rio, 1982); d) "large" *Gephyrocapsa* (very rare in the studied interval) has a well visible central area and is larger than 5.5 µm.

We believe neither this taxonomic classification nor the approximations used affect the results of the work.

At first, 300 specimens for each smear-slide had been counted, in randomly chosen areas. The fact that a few forms (*Emiliania huxleyi*, *Gephyrocapsa oceanica*, *G. caribbeanica*, "small" *Gephyrocapsa* spp.) were remarkably more frequent than the others has led us to continue the quantitative analysis, until 100 specimens of all the other species were counted. This method has shown some otherwise unclear percentage patterns of significant species.

3. GRAIN SIZES

Percentage variations of grain-size fractions 61÷151 µm and >151 µm are plotted in Fig. 3. Values of both fractions are generally lower than 5% in marls and clayey marls; they are much higher in sapropels and volcanic ashes (fraction 61÷151 µm: maximum value 36% in sapropel S-6, cm 382; fraction >151 um: maximum value 29% in sapropel S-5, 276 cm). Percentages are also fairly high in fine sands (473 cm, above S-8 and 394 cm, at the base of sapropel S-6).

4. CALCIUM CARBONATE

Percentages of calcium carbonate are high in most of the samples (average 52.95%) (Fig. 3); they are very low only in the two volcanic ash layers (3% and 9% respectively), while the highest values (78÷80%) occur at the base of sapropel S-5 and in the underlying interval. In the upper samples of S-5 and in the other sapropels, percentages are around the average.

Almost the whole interval between the two tephra layers (181÷95 cm) is characterized by percentages lower than the average.

Calcium carbonate content is correlatable to primary productivity (Arrhenius, 1952), and its values in BAN88-11GC are similar to those of adjacent cores (Olausson, 1960; Mullineaux & Lohman, 1981; Cita *et al.*, 1982). The fact that percentages are lower in some sapropels, especially in S-5, is probably due to dispersion of carbonate in the organic matter at the bottom (Thunell *et al.*, 1977; Parisi, 1987a).

5. RESIDUES COMPOSITION

Marls washing residues contain only 2÷5% inorganic matter: carbonatic aggregates, rare iron oxides, quarz and mica. In sapropels dark aggregates with organic carbon are abundant; in volcanic layers glass and/or ashes are frequent. The sample taken at 181 cm in tephra Y-5 is almost barren (only sporadic Foraminifera are found in fraction 61÷151 µm). Authigenic gypsum cristals are common at 483÷473 cm, 441÷433 cm, 394÷387 cm, 276 cm. Biogenic matter mainly consists of Foraminifera; Thecosomata often are abundant; otoliths and fish remains, young bivalves, echinoids spines are rare. Tests are generally very well preserved. Filled and/or encrusted Foraminifera and Thecosomata shells are found, together with consolidated carbonatic aggregates, in the core upper part (117÷6 cm).

6. FORAMINIFERA

6.1 Environmental indicators

Warm-water species (Fig. 4a): *Globigerinoides ruber* (including *G. gomitulus*, considered as a variety) (D'Onofrio, 1958) is common; in many intervals it is very frequent, and its maximum (72.32%) is found in sapropel S-1. Relative maximum values are at 510 cm (49.32%), 453 cm (51.33%), at the base of sapropel S-5 (276 cm, 69.66%) and at 206 cm (66.66%). In sapropels S-8 and S-6 (483÷472 cm, 394÷372 cm), which generally yield cold-water faunas, this species is absent or sporadic. *G. gomitulus*, here interpreted as a morphotype of *G. ruber* and better liking temperate waters (D'Onofrio, 1958; Violanti & Saccà, 1989), has its maximum frequences at 236÷196 cm and 188÷107 cm. On the contrary, it is scarce in "warm" sapropels S-7, S-5, S-1.

Globigerinoides sacculifer is absent in most samples. It is found only where *G. ruber* is particularly frequent: in sapropels S-7 (maximum value = 9%) and S-5, and in the core-top samples.

Orbulina universa is contained in almost all samples. Its percentages are generally lower than or equal to 10%; the maximum value (19%) is in sapropel S-3. Its percentage curve is well correlatable with that of *G. ruber*, even though this latter shows more marked oscillations; only at 450÷490 cm the patterns are fairly different (decrease of *O. universa).*

Globigerinella digitata was added to warm-water indicators in the study standard program (ESCO - unit of Milan) based on Parker (1962) and Thunell *et al.* (1977); it had been neglected in previous works concerning the Eastern Mediterranean (Cita *et al.*, 1973; Cita *et al.*, 1982). In core BAN88-11GC, anyway, *G. digitata* is sporadic, and it never represents more than 2% of the total. Its maximum frequence is correlatable with medium or low values of *G. ruber.*

Globigerinella aequilateralis (= *Hastigerina siphonifera)* occurs in few intervals; its pattern resembles that of *G. sacculifer*, but its percentages are a little higher. The highest frequences are found at 510÷423 cm, in sapropel S-5 up to 216 cm (maximum value 12% at 246 cm) and in the core-top samples.

Cold-water species (Fig. 4b): *Neogloboquadrina pachyderma* is common in polar and subpolar associations (Imbrie & Kipp, 1971). It shows remarkable oscillations, reaching its maximum value in S-8 (483 cm, 45%); very high are also its percentages at the core-base, at about 344÷282 cm and 87÷47 cm. The coiling direction of its test is as well controlled by water temperature: left-coiling tests are more frequent in cold waters, right-coiling ones in warm waters. As a matter of fact, left-coiling tests prevail in Pleistocene sediments of the Mediterranean. The same happens in core BAN88-11GC, whereas right-coiling tests are absent or rare: their frequence is higher only in and above sapropel S-5, and in the Holocene core-top samples.

Globigerina bulloides shows percentage variations strongly similar to those of *N. pachyderma*. Nevertheless, in the interval 157÷137 cm, the two species show some discrepancies: *G. bulloides* reaches here its maximum value (44.66%), while *N. pachyderma* has a marked reduction. The decrease of *G. bulloides* in the core-top samples seems to begin earlier than that of *N. pachyderma*, and it is also smoother.

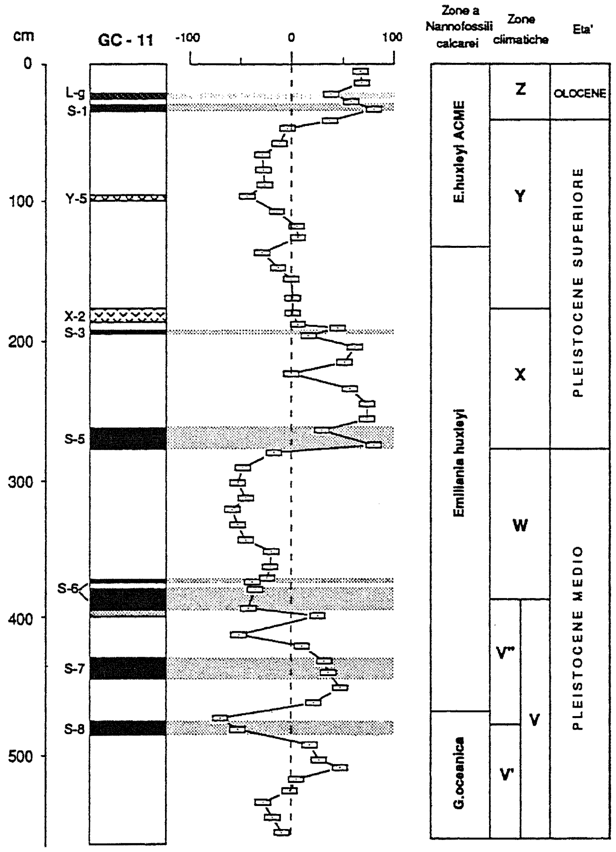

Fig. 5 - Foraminiferal climatic curve, constructed by the sum of planktonic warm water species (*Globigerinoides ruber* etc.) (with positive values) and cold water species (*Neogloboquadrina pachyderma* etc.) (with negative values).

Curva climatica ottenuta dai Foraminiferi planctonici, sommando le percentuali (con segno positivo) delle specie di acque calde (Globigerinoides ruber *ecc.) e le percentuali (con segno negativo) delle specie di acque fredde* (Neogloboquadrina pachyderma *ecc.).*

Neogloboquadrina dutertrei (=*N. eggeri*) (Fig. 3b) is most abundant in sapropels S-8, S-7, S-6. Percentages are highest in S-8 and S-6, where they reach their maximum (about 40%). In S-6 the curve reflects very well the division into two parts of this sapropel. While high percentages in sapropels S-6 and S-8 are recorded also in other Eastern Mediterranean cores (Parisi, 1987a), in sapropel S-7 *N. dutertrei* is elsewhere generally absent. In all the other samples of core BAN88-11GC this taxon is rare or absent; a slight increase is observed near sapropel S-3 (188 cm, 9.33%).

6.2 Climatic curve

The climatic curve (Fig. 5) is characterized, from the bottom up to the sapropel S-6, by wide and fairly sharp oscillations; negative values (corresponding to a cold climate) are found in sapropels S-8 and S-6, whereas a short positive interval (corresponding to a warm climate) is observable in sapropel S-7. Above, two ample cold intervals are separated by a warm one. This warm interval abruptly begins at the base of sapropel S-5, is interrupted by minor, temperate phases and gradually decreases, until the upper cold interval begins. From sapropel S-1 to the core-top another warm phase is evident.

6.3 Measure of *Orbulina universa* diameter

For each sample, diameter fluctuations of the largest test of *Orbulina universa* (indicated as maximum diameter) are plotted in Fig. 6, together with the average value of the five largest tests (average diameter). The dashed line corresponds to samples where *Orbulina universa* has not been found among the 300 specimens

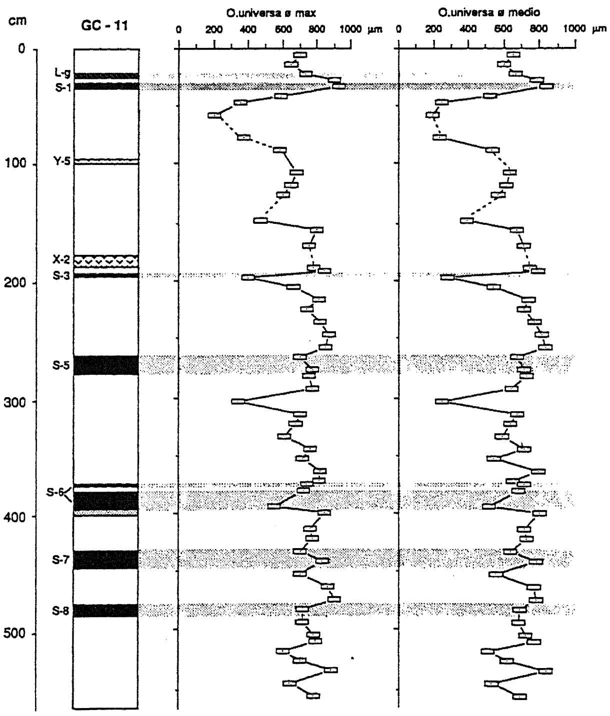

Fig. 6 - Diameter variations of the five largest tests of *Orbulina universa* in each sample. On the left the largest specimen diameter is reported, on the right the mean value.

Variazioni del diametro di Orbulina universa, *misurato sui cinque esemplari di dimensioni maggiori nei singoli campioni. A sinistra è indicato il diametro del guscio più grande, a destra il valore medio.*

counted. The two curves are very similar, and the difference between the maximum and average values of each sample is quite small. The correlation with the climatic curve is remarkable, especially in the medium and upper part of the core: smallest diameters correspond to negative climatic peaks and viceversa. For instance, the warm interval above sapropel S-5 coincides with large diameters of *O. universa*. The correlation is less effective in the lower part of the core, up to sapropel S-6; this had been already recorded in core BAN84-27 (Violanti & Saccà, 1989).

6.4 Benthic Foraminifera

In the >151 µm fraction benthic Foraminifera are rare (ratio P/P+B = 98÷99%), if not absent, like in sapropels; the minimum value of P/P+B ratio (96.66%) is at 127 cm and 206 cm. In the 61÷151 µm fraction these organisms are more frequent, especially in the lower part of the core.

Small-size species have been found in the fine fraction of sapropel S-7 (433 cm). They were also recorded by Vismara Schilling (1986) in the same sapropel of core 41 from Area 4 (Calabrian Ridge) and 30, Cobblestone Area 3 (Mediterranean Ridge). Their presence can be attributed to bioturbations.

Benthic assemblages generally show a good diversity. Nevertheless, they are quite poor in the samples between sapropels S-8 and S-7, around sapropel S-5 (cm 304÷246) and above sapropel S-1. The most frequent species, *Articulina tubulosa*, *Eponides tumidulus*, *Gyroidinoides neosoldanii*, are also commonly found in Mediterranean deep sediments (Cita & Zocchi, 1978; Parisi, 1982; Katz & Thunell, 1984). *Bulimina striata mexicana* seems to be confined to the cold interval above sapropel S-6. *Globobulimina affinis*, which seems well adapted to waters with a low oxygen content (Mullineaux & Lohman, 1981), is abundant in some samples; they are similar, for the microfaunal content and stratigraphic position, to those described by Vismara Schilling (1986) as transitional to sapropels. *Hoeglundina elegans* is a deep, relatively warm species (Lutze, 1977), common in the Oxygen Minimum Zone (Hermelin & Shimmield, 1990). It occurs at 236÷117 cm and is abundant below sapropel S-3. *Cibicidoides pseudoungerianus*, which is characteristic of shelf and upper slope, is more common in the upper part of the core, where also *Melonis barleanum*, *Trifarina angulosa*, *Quinqueloculina seminulum*, *Triloculina trigonula* are represented; these taxa suggest a sediment transport from shallower areas.

6.5 Statistical analysis

Factor analysis, Principal Components Analysis and Cluster Analysis were performed on 23 out of 33 determined planktonic species. The following species have been neglected because sporadic or represented by percentages lower than 1÷2%: *Globigerina calida*, *G. praecalida*, *G. rubescens*, *Globigerinoides helicinus*, *Globigerinita uvula*, *Hastigerina pelagica*, *G. riedeli*, *Turborotalita humilis*, *Candeina nitida*, *Orbulina suturalis*. *Globigerinoides gomitulus* has been analyzed separately by *G. ruber* in order to verify both the paleoclimatic significance of the former and a possible difference in the paleoenvironmental interpretation of the two taxa.

Table 1 - Values of planktonic Foraminifera Factors 1 and 2. Species with less than 1÷2% values (*Globigerina rubescens*, *Hastigerina pelagica*) were disregarded.

Valori dei Fattori 1 e 2 relativi ai Foraminiferi planctonici. Sono state trascurate le specie (Globigerina rubescens, Hastigerina pelagica *ecc.) con valori inferiori all'1÷2%.*

N.	SPECIE	FATTORE 1	FATTORE 2
1	Globigerina calabra	0.234	- 0.347
2	Globigerina cariacoensis	0.515	- 0.243
3	Globigerina falconensis	- 0.064	0.044
4	Globigerina obesa	- 0.536	- 0.299
5	Globigerina quinqueloba	0.371	- 0.332
6	Globigerinoides conglobatus	- 0.176	0.022
7	Globigerinoides elongatus	- 0.423	0.179
8	Globigerinoides gomitulus	- 0.217	0.696
9	Globigerinoides ruber	- 0.683	- 0.192
10	Globigerinoides sacculifer	- 0.714	- 0.419
11	Globigerinoides trilobus	- 0.363	- 0.316
12	Globigerinoides tenellus	- 0.554	- 0.192
13	Beella digitata	- 0.150	0.081
14	Beella praedigitata	- 0.201	0.462
15	Globigerinita glutinata	0.315	- 0.203
16	Globorotalia inflata	0.053	0.478
17	Globorotalia scitula	0.511	- 0.115
18	Globorotalia trunc.excelsa	- 0.083	0.203
19	Globigerinella aequilateralis	- 0.791	- 0.225
20	Orbulina universa	- 0.322	- 0.072
21	Neogloboquadrina dutertrei	0.309	- 0.540
22	Neogloboquadrina pachyderma	0.665	- 0.209
23	Globigerina bulloides	0.672	0.113
	Contributo del fattore	4.575	2.196
	% di Varianza estratta	19.891	9.549

The aim of the statistical analyses here illustrated is to understand the relationships between the species, controlled by indipendent variables, such as Factors and Principal Components. Cluster Analysis produces a correlation index which is the higher, the closer the affinities; therefore, it better shows the paleoenvironmental affinities.

Factor and Principal Component Analysis

Factors 1 and 2 have been considered; the species used for the analyses, their numbers in the plots and factors values are listed in Table 1. In Fig. 7 Factors 1 and 2 are plotted on a diagram. Factor 1 turns out to represent 19.89% of the total variance, while Factor 2 only accounts for 9.54%. On the basis of Factor 1, a group of species, with positive values, is clearly characterized; it consists of the following taxa: *Neogloboquadrina pachyderma, Globigerina bulloides, Globigerina cariacoensis, Globorotalia scitula, Globigerina quinqueloba, Neogloboquadrina dutertrei, Globigerinita glutinata, Globigerina calabra.* A second group shows mostly negative Factor 1 values and comprises: *Globorotalia inflata, Globigerina falconensis, Globorotalia truncatulinoides excelsa, Globigerinella digitata, G. praedigitata, Globigerinoides conglobatus, Globigerinoides gomitulus.* A third group has negative values ranging from -0.32 to -0.79: *Orbulina universa, Globigerinoides trilobus, Globigerinoides elongatus, G. tenellus, G. sacculifer, G. ruber, Globigerina obesa, Globigerinella aequilateralis.* In the light of the present species distribution in the oceans (Bè & Tolderlund, 1971; Thunell, 1978; Hemleben *et al.*, 1989), Factor 1 appears to be strictly related to temperature.

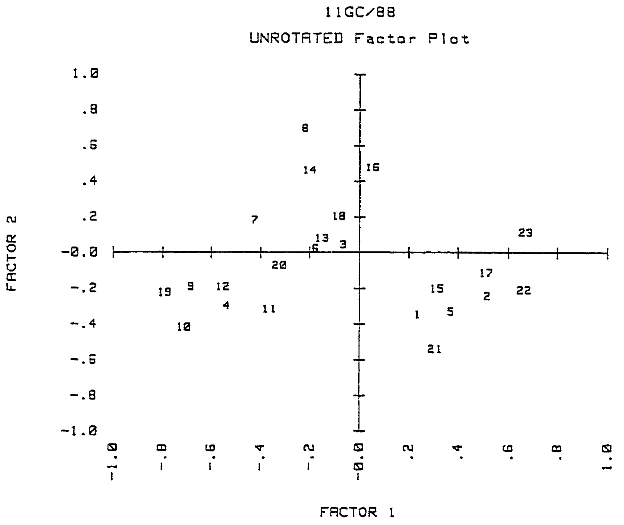

Fig. 7 - Distribution of planktonic Foraminifera on the basis of Factor 1 and 2. See Table 1 for the species numbers and Factors values plotted in the figure.

Ripartizione dei Foraminiferi planctonici in base ai Fattori 1 e 2. Le specie corrispondenti ai numeri nel grafico, ed i relativi valori dei Fattori, sono indicati in Tabella 1.

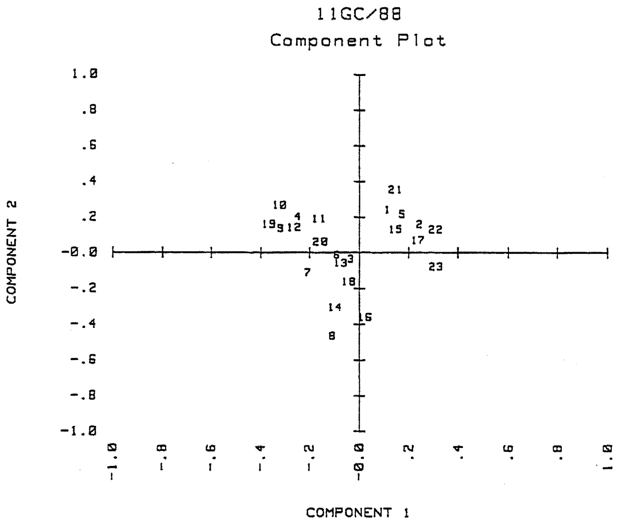

Fig. 8 - Distribution of planktonic Foraminifera on the basis of Principal Components 1 and 2. See Table 2 for the species numbers and Components values plotted in the figure.

Ripartizione dei Foraminiferi planctonici in base ai Componenti Principali 1 e 2. Le specie corrispondenti ai numeri nel grafico, ed i relativi valori dei Componenti, sono indicati in Tabella 2.

Table 2 - Values of planktonic Foraminifera Principal Components 1 and 2.

Valori dei Componenti Principali 1 e 2 relativi ai Foraminiferi planctonici.

N.	SPECIE	COMPON. 1	COMPON. 2
1	Globigerina calabra	0.113	0.239
2	Globigerina cariacoensis	0.244	0.157
3	Globigerina falconensis	- 0.033	- 0.036
4	Globigerina obesa	- 0.248	0.202
5	Globigerina quinqueloba	0.176	0.213
6	Globigerinoides conglobatus	- 0.090	- 0.014
7	Globigerinoides elongatus	- 0.206	- 0.112
8	Globigerinoides gomitulus	- 0.107	- 0.468
9	Globigerinoides ruber	- 0.317	0.136
10	Globigerinoides sacculifer	- 0.323	0.265
11	Globigerinoides trilobus	- 0.162	0.188
12	Globigerinoides tenellus	- 0.264	0.141
13	Beella digitata	- 0.074	- 0.060
14	Beella praedigitata	- 0.097	- 0.307
15	Globigerinita glutinata	0.147	0.130
16	Globorotalia inflata	0.024	- 0.363
17	Globorotalia scitula	0.238	0.069
18	Globorotalia trunc.excelsa	- 0.042	- 0.164
19	Globigerinella aequilateralis	- 0.366	0.159
20	Orbulina universa	- 0.156	0.060
21	Neogloboquadrina dutertrei	0.148	0.353
22	Neogloboquadrina pachyderma	0.311	0.128
23	Globigerina bulloides	0.313	- 0.079
	Contributo del fattore	4.971	2.664
	% di Varianza estratta	21.613	11.581

The interpretation of Factor 2 is more difficult: according to its values, in fact, *Globigerinoides gomitulus, Globigerinella praedigitata, Globorotalia inflata* (which has the highest positive values) are opposite *Neogloboquadrina dutertrei* (with the negative maximum). A scarcely differentiated group has the most negative values (ranging from -0.41 to -0.33) in *Globigerinoides sacculifer, G. trilobus, Globigerina calabra, G. quinqueloba.*

The species distribution based on the Principal Components 1 and 2 (Table 2, Fig. 8) resembles that based on the Factor Analysis. The First Component accounts for 21.61% of the total variance, whereas the Second Component represents 11.58%. The values

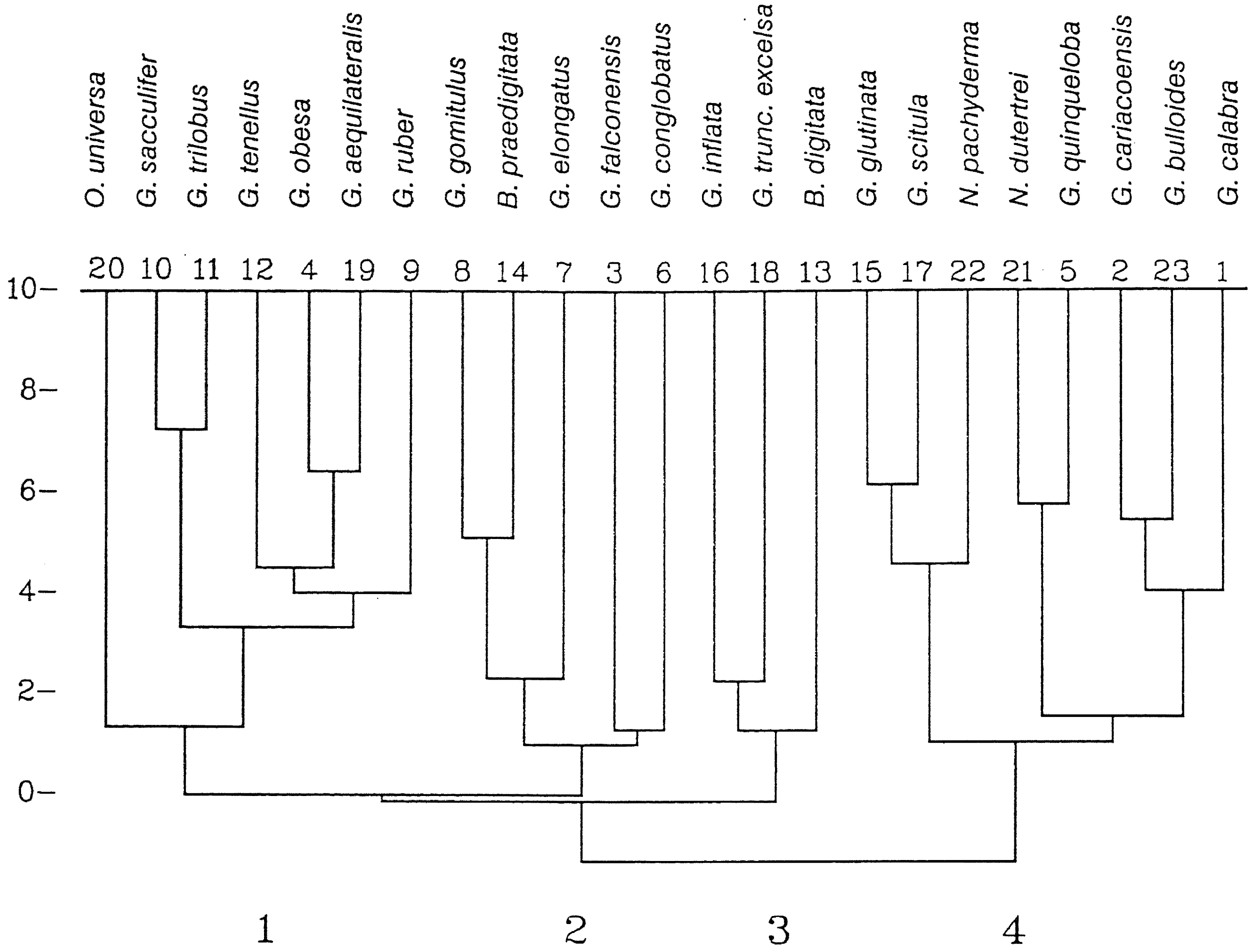

Fig. 9 - Cluster analysis dendrogram, showing the affinities among the planktonic Foraminifera from Core BAN88-11GC. Four groups, correlatable to the water temperature, can be detected.

Dendrogramma ottenuto con la Cluster analisi, che evidenzia le affinità relative dei Foraminiferi planctonici nella carota BAN88-11GC. Si osservano quattro gruppi, dipendenti dalla temperatura delle acque.

range is narrower than in the case of Factors; species distribution according to Principal Components 1 is the same as that according to Factor 1; distribution for Component 2 is almost specular to that for Factor 2.

Therefore Factor 1 and Component 1 seem closely related to water temperature, as well as Factor 2 and Component 2 could suggest chemical or biological factors. In fact, the sharp separation of *N. dutertrei*, *G. sacculifer*, *G. trilobus* from *G. gomitulus*, *G. praedigitata*, *G. inflata* cannot be explained on the basis of their depth habitat, but should be due to a different response of the species to environmental conditions (*i.e.* salinity, feeding-behaviour, etc.).

Cluster Analysis

The correlation coefficient has been used for Cluster Analysis, which was carried out on the same 23 species considered in the Factor and Principal Components Analyses; results are graphically shown in Fig. 9. A pretty high similarity level (0.72÷0.55) comes out between *G. sacculifer* and *G. trilobus*, *G. obesa* and *G. aequilateralis*, *G. glutinata* and *G. scitula*, *N. dutertrei* and *G. quinqueloba*, *G. cariacoensis* and *G. bulloides*. Wider groups are singled out on the basis of lower similarity levels. A first group comprises warm-water species, often recorded in tropical or subtropical associations (Parker, 1962; Bè & Tolderlund, 1971): *G. sacculifer*, *G. trilobus*, *G. tenellus*, *G. obesa*, *G. aequilateralis*, *G. ruber*, *O. universa*. Two other groups have lower reciprocal affinities and consist of temperate or warm/temperate species: *G. gomitulus*, *G. praedigitata*, *G. elongatus*, *G. falconensis*, *G. conglobatus and G. inflata*, *G. truncatulinoides excelsa*, *G. digitata*. A last group shows a negative similarity value to the preceding groups (-0.13) and comprises cold-water species: *G. glutinata*, *G. scitula*, *N. pachyderma*, *N. dutertrei*, *G. quinqueloba*, *G. cariacoensis*, *G. bulloides*, *G. calabra*.

6.6 Discussion

The paleoclimatic interpretation of core BAN88-11GC, based on species percentage variations, climatic

Table 3 - Environmental parameters of *Globigerinoides ruber* and *Neogloboquadrina dutertrei.* Data from Bè & Tolderlund (1971) and Hemleben *et al.* (1989).

Parametri ambientali, relativi a Globigerinoides ruber e Neogloboquadrina dutertrei. *Ricavato da Bè & Tolderlund (1971) e da Hemleben et al. (1989).*

SPECIE	PROFONDITA'	TEMPERATURA	SALINITA'	SIMBIONTI	CIBO
	(metri)	(°C)	(per mille)		
G. ruber	0/-50	16/31	22/49	Dinoflagellate	Zooplancton
N. dutertrei	-25/-100	13/33	25/46	Crisofite (facolt.)	Fitoplancton

curve and statistical analyses, is similar to that of previous works on the Eastern Mediterranean. The climatic curve shows a very good correlation both with the corresponding part of the theoretical isotopic curve (Emiliani, 1966) for the Atlantic ocean, and with the curves drawn for cores KS-09 (Cita *et al.*, 1977) and BAN84-27 (Violanti & Saccà, 1989). Factor and Principal Components Analyses confirm that *Globigerinoides ruber* and *G. gomitulus* belong to quite different climatic environments. The ecology of *G. ruber* is now fairly well known, thanks to several studies on living populations (Bè *et al.*, 1977; Fairbanks & Wiebe, 1980; Hemleben & Spindler, 1983) and to laboratory cultures (Hemleben *et al.*, 1989). Some of the data are summerized in Table 3. *G. ruber* is widespread in tropical areas at a depth of -10/-50 m (Bè & Tolderlund, 1971), it has a wide temperature-range (16°÷31° C) and an equally wide salinity range (22‰÷49‰); it bears symbionts and is mainly carnivorous.

The ecology of *Globigerinoides gomitulus* (more likely *G. ruber gomitulus*) is not known; it is only recorded in Mediterranean Pliocene and Pleistocene sediments (Parker, 1958; D'Onofrio, 1958; Mistretta, 1962; Violanti & Saccà, 1989). Instead, Kennett & Srinivasan (1983) consider *G. gomitulus* close to *G. conglobatus.* On the basis of a comparison between the percentage curves of *G. ruber* and *G. gomitulus*, the former seems to be more abundant during the warmest intervals of the climatic curve and also into warm sapropels S-1, S-5 and S-7; *G. gomitulus*, on the contrary, is more frequent in temperate/warm intervals and outside sapropel layers. Either Factor 1 and Component 1 Analyses, or Cluster Analysis, put *G. gomitulus* in a separate group from that of *G. ruber.* It follows that it is probably related to cooler waters.

Globigerinella digitata (and *G. praedigitata*, here distinct) should be a temperate/warm species rather than a warm one.

In the light of data on living *N. dutertrei* distribution (Table 3), its previous interpretation as low-salinity indicator (Ruddiman, 1971; Thunell *et al.*, 1977; Cita *et al.*, 1982; Thunell *et al.*, 1983; Violanti *et al.*, 1987), should be revised. In the North Atlantic Ocean (Fairbanks & Wiebe, 1980; Fairbanks *et al.*, 1980) this species is very abundant at a depth of -25/-50 m, which corresponds to the thermocline (a high primary-productivity zone) and to the Deep Clorophyll Maximum (DCM). Its temperature range is 13°÷33° C, its salinity range is 25‰÷46‰; it almost exclusively feeds on unicellular algae (diatoms and coccolithids) (Hemleben *et al.*, 1989). It is especially widespread on continental margins, and in convergence and upwelling areas. Its distribution, rather than by water temperature, seems affected by thermic stratification and nutrients abundance (Phleger *et al.*, 1953; Bè & Tolderlund, 1971). In core BAN88-11GC *N. dutertrei* is frequently found in sapropels S-6, S-8 and, unlike the other Eastern Mediterranean cores, also in sapropel S-7.

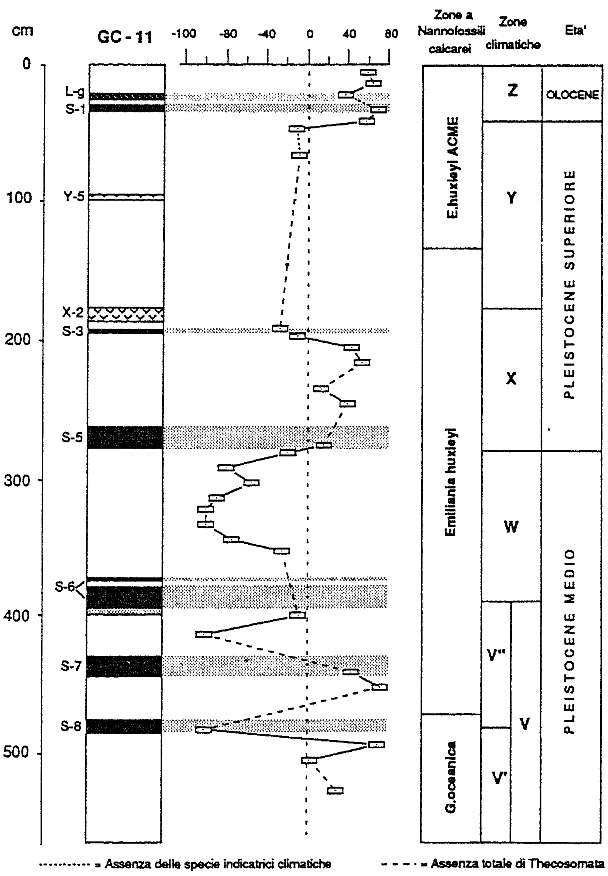

Fig.10 - Climatic curve based on Thecosomata Euthecosomata.

Curva climatica ottenuta mediante i Thecosomata Euthecosomata.

Table 4 - Percentage values of the four climatic indicators *Limacina inflata, Limacina trochiformis, Cavolinia inflexa, Limacina retroversa.*

Valori percentuali ottenuti per le quattro specie indicatrici climatiche Limacina inflata, Limacina trochiformis, Cavolinia inflexa, Limacina retroversa.

campione	cm dal top	Sapropel	Tephra	L.retroversa	L.inflata	L.trochiformis	L.bulimoides	C.acicula	C.virgula	S.subula	H.striata	C.pyramidata	C.cuspidata	Cuvierina sp.	D.trispinosa	D.quadridentata	C.inflexa	P.apicifulva	G.cordata	P.doliiformis
sec.1 cm 6	6			0	358	93	0	19	47	224	0	77	5	0	0	0	18	6	9	10
sec.1 cm 15	15			0	198	71	0	29	13	0	0	107	2	0	0	0	6	3	4	6
sec.1 cm 23	23			0	36	20	9	4	17	0	0	73	0	0	0	0	4	2	3	3
sec.1 cm 27	27	sopra S-1		0	0	0	15	0	0	0	0	22	5	0	13	0	0	0	0	0
sec.1 cm 32	32	dentro S-1		0	437	0	0	0	168	0	0	45	0	0	4	0	48	1	6	24
sec.1 cm 40	40	sotto S-1		0	278	0	14	19	0	0	0	152	0	0	21	0	0	0	5	6
sec.2 cm 5	47			8	0	0	0	0	0	0	0	61	0	0	0	0	0	0	0	0
sec.2 cm 15	57			0	0	0	0	0	0	0	0	97	0	0	0	0	0	0	0	0
sec.2 cm 25	67			6	0	0	0	0	0	0	0	63	0	0	0	0	0	0	0	0
sec.2 cm 35	77			0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
sec.2 cm 45	87			0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
sec.2 cm 55	97		Y-5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
sec.2 cm 65	107			0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
sec.2 cm 75	117			0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
sec.2 cm 85	127			0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
sec.2 cm 95	137			0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
sec.2 cm 105	147			0	0	0	0	0	0	0	1	43	0	0	0	0	0	0	0	0
sec.2 cm 115	157			0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
sec.3 cm 5	171			0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
sec.3 cm 15	181		X-2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
sec.3 cm 22	188	sopra S-3		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
sec.3 cm 25	191	dentro S-3		11	0	0	0	0	0	0	0	19	0	0	10	0	0	0	0	0
sec.3 cm 30	198	sotto S-3		4	2	0	0	0	0	0	0	12	0	0	1	0	0	0	0	0
sec.3 cm 40	206			0	20	0	0	0	0	0	0	25	3	0	0	0	2	0	0	0
sec.3 cm 50	216			0	68	15	0	0	7	0	0	59	6	1	0	0	4	1	3	0
sec.3 cm 60	226			0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
sec.3 cm 70	236			17	38	0	0	0	16	10	3	72	4	0	0	0	0	1	0	8
sec.3 cm 80	246			0	46	21	0	0	22	0	3	102	5	0	0	1	18	2	0	4
sec.3 cm 92	258	sopra S-5		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
sec.3 cm 100	266	dentro S-5		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
sec.3 cm 110	276	dentro S-5		22	40	0	0	15	42	0	0	0	0	0	39	0	9	0	0	0
sec.3 cm 116	282	sotto S-5		68	38	0	0	8	0	0	0	25	3	0	17	0	0	2	11	4
sec.4 cm 10	294			225	0	0	0	0	8	0	0	46	5	0	0	0	0	0	4	0
sec.4 cm 20	304			61	0	0	0	0	2	0	0	49	0	0	0	0	0	6	25	0
sec.4 cm 30	314			277	0	0	0	0	6	0	0	28	0	0	0	0	0	3	1	0
sec.4 cm 40	324			381	0	0	0	0	2	0	0	2	0	0	0	0	0	0	0	0
sec.4 cm 50	334			212	0	0	0	0	1	0	0	1	0	0	0	0	0	0	0	0
sec.4 cm 60	344			38	0	0	0	0	12	0	0	1	0	0	0	0	0	0	0	0
sec.4 cm 70	354			1	0	0	0	0	1	0	0	2	0	0	0	0	0	0	0	0
sec.4 cm 80	364	sopra S-6		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
sec.4 cm 88	372	dentro S-6		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
sec.4 cm 92	376	infra S-6		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
sec.4 cm 98	382	dentro S-6		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
sec.4 cm 110	394	dentro S-6		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
sec.4 cm 115	399	sotto S-6		3	0	0	0	0	0	0	0	31	1	0	0	0	0	0	0	0
sec.5 cm 10	413			47	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
sec.5 cm 20	423	sopra S-7		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
sec.5 cm 30	433	dentro S-7		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
sec.5 cm 38	441	dentro S-7		46	108	30	0	0	26	0	0	1	0	0	0	0	0	0	1	0
sec.5 cm 50	453	sotto S-7		0	18	0	0	0	0	0	0	7	0	0	0	0	0	0	0	0
sec.5 cm 60	463			0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
sec.5 cm 70	473	sopra S-8		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
sec.5 cm 80	483	dentro S-8		66	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
sec.5 cm 90	493	sotto S-8		0	46	10	0	0	3	4	0	15	5	0	0	0	4	1	0	0
sec.5 cm 100	503			11	8	5	0	0	37	0	1	16	2	0	0	0	0	0	0	0
sec.5 cm 107	510			0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
sec.5 cm 115	518			0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
sec.6 cm 5	525			0	5	0	0	0	0	0	0	12	0	0	0	0	0	0	0	0
sec.6 cm 15	535			0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
sec.6 cm 25	545			0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
sec.6 cm 35	555			0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

As seen above, on the basis of living populations, we can infer that the abundance of this species suggests enhanced circulation and higher productivity, rather than low salinity.

7. PLANKTONIC MOLLUSCS

7.1 Planktonic molluscs - I

Thecosomata, very good biological indicators among molluscs (Furnestin, 1979), have proved very useful in the climatic interpretation. In particular, four species belonging to suborder Euthecosomata (*Limacina inflata, L. trochiformis, Cavolinia inflexa, L. retroversa*) have been frequently used because particularly sensitive to temperature and salinity changes (Grecchi, 1984; Grecchi & Bertolotti, 1988; Biekart, 1989; Violanti & Saccà, 1989).

Limacina inflata is considered as a mesopelagic, subtropical species (Van der Spoel, 1967; Bè & Gilmer, 1977). It lives at a depth ranging from -200 to -1000 m (Almogi-Labin & Reiss, 1977), and tolerates temperature oscillations between 14° and 28° C (Van der Spoel, 1967)

Table 5 - Distribution and numerical presence of Thecosomata and Gymnosomata observed in Core BAN88-11GC.

Distribuzione e presenza numerica dei Thecosomata e dei Gymnosomata rinvenuti nei campioni della carota BAN88-11GC.

campione	cm dal top	totale Euthecosomata	% L.inflata	% L.trochiformis	% C.inflexa	% L.retroversa	differenza %
sec.1 cm 6	6	841	45,77	11,05	2,14	0	58,96
sec.1 cm 15	15	426	46,47	16,66	1,4	0	64,53
sec.1 cm 23	23	163	22,08	12,26	2,45	0	36,79
sec.1 cm 27	27	55	0	0	0	0	0
sec.1 cm 32	32	702	62,25	0	6,83	0	69,08
sec.1 cm 40	40	482	57,26	0	0	0	57,26
sec.2 cm 5	47	69	0	0	0	11,59	-11,59
sec.2 cm 15	57	97	0	0	0	0	0
sec.2 cm 25	67	69	0	0	0	8,69	-8,69
sec.2 cm 35	77	0	0	0	0	0	0
sec.2 cm 45	87	0	0	0	0	0	0
sec.2 cm 55	97	0	0	0	0	0	0
sec.2 cm 65	107	0	0	0	0	0	0
sec.2 cm 75	117	0	0	0	0	0	0
sec.2 cm 85	127	0	0	0	0	0	0
sec.2 cm 95	137	0	0	0	0	0	0
sec.2 cm 105	147	44	0	0	0	0	0
sec.2 cm 115	157	0	0	0	0	0	0
sec.3 cm 5	171	0	0	0	0	0	0
sec.3 cm 15	181	0	0	0	0	0	0
sec.3 cm 22	188	0	0	0	0	0	0
sec.3 cm 25	191	40	0	0	0	27,5	-27,5
sec.3 cm 30	196	19	10,52	0	0	21,05	-10,53
sec.3 cm 40	206	50	40	0	4	0	44
sec.3 cm 50	216	160	42,5	9,37	2,5	0	54,37
sec.3 cm 60	226	0	0	0	0	0	0
sec.3 cm 70	236	160	23,75	0	0	10,62	13,13
sec.3 cm 80	246	218	21,1	9,63	8,25	0	38,98
sec.3 cm 92	258	0	0	0	0	0	0
sec.3 cm 100	266	0	0	0	0	0	0
sec.3 cm 110	276	167	23,95	0	5,38	13,17	16,16
sec.3 cm 116	282	159	23,89	0	0	42,76	-18,87
sec.4 cm 10	294	284	0	0	0	79,22	-79,22
sec.4 cm 20	304	112	0	0	0	54,46	-54,46
sec.4 cm 30	314	311	0	0	0	89,06	-89,06
sec.4 cm 40	324	385	0	0	0	98,96	-98,96
sec.4 cm 50	334	214	0	0	0	99,06	-99,06
sec.4 cm 60	344	51	0	0	0	74,5	-74,5
sec.4 cm 70	354	4	0	0	0	25	-25
sec.4 cm 80	364	0	0	0	0	0	0
sec.4 cm 88	372	0	0	0	0	0	0
sec.4 cm 92	376	0	0	0	0	0	0
sec.4 cm 98	382	0	0	0	0	0	0
sec.4 cm 110	394	0	0	0	0	0	0
sec.4 cm 115	399	35	0	0	0	8,57	-8,57
sec.5 cm 10	413	47	0	0	0	100	-100
sec.5 cm 20	423	0	0	0	0	0	0
sec.5 cm 30	433	0	0	0	0	0	0
sec.5 cm 38	441	211	51,18	14,21	0	21,8	43,59
sec.5 cm 50	453	25	72	0	0	0	72
sec.5 cm 60	463	0	0	0	0	0	0
sec.5 cm 70	473	0	0	0	0	0	0
sec.5 cm 80	483	68	0	0	0	100	-100
sec.5 cm 90	493	87	52,87	11,49	5,59	0	68,95
sec.5 cm 100	503	80	10	6,25	0	13,75	2,5
sec.5 cm 107	510	0	0	0	0	0	0
sec.5 cm 115	518	0	0	0	0	0	0
sec.6 cm 5	525	17	29,41	0	0	0	29,41
sec.6 cm 15	535	0	0	0	0	0	0
sec.6 cm 25	545	0	0	0	0	0	0
sec.6 cm 35	555	0	0	0	0	0	0

and salinity oscillations between 35.5‰ and 36.7‰ (Bè & Gilmer, 1977), up to 41‰ in the Gulf of Aqaba (Red Sea) (Almogi-Labin, 1982). The abundance of this species undergoes remarkable seasonal fluctuations (Bè & Gilmer, 1977).

L. trochiformis is a epiplanktonic, tropical species (Furnestin, 1979), bearing temperature changes between 13.8° and 27.9° C and salinity oscillations between 35.5‰ and 36.8‰ (Van der Spoel, 1967), up to the extreme value of 41‰ in the Gulf of Aqaba (Almogi-Labin, 1982). It preferably lives at a depth of -99/-165 m (Van der Spoel, 1967).

Cavolinia inflexa, represented in the Mediterranean by the subspecies *imitans*, has subtropical affinities (Colantoni *et al.*, 1970; Furnestin, 1979; Grecchi & Bertolotti, 1988); it lives between the surface and -250m (Bè & Gilmer, 1977). Its temperature span is 16°÷28° C and the salinity tolerance is between 35.6‰ and 36.6‰ (Van der Spoel, 1967).

L. retroversa is considered to be an epipelagic, subarctic species (Furnestin, 1979). It generally lives at a depth of -150 m (Van der Spoel, 1967) and does daily as well as seasonal vertical migrations (Bè & Gilmer, 1977). The recorded temperature range is 2°÷19° C (Bè & Gilmer, 1977), the salinity range is 31‰÷36‰ (Van der Spoel, 1967).

7.2 Climatic curve

The climatic curve is based on the percentages of the four indicators with reference to the total Euthecosomata. Values are positive for warm species, negative for cold ones (Table 4).

Cold periods are more evident than warm ones, though more precise data cannot be obtained because climatic indicators are missing in many intervals (Table 5).

A correlation of the climatic curve with climatic zones (Ericson & Wollin, 1968) and calcareous nannofossils zones (Parisi *et al.*, 1987; see below, calcareous nannofossils) shows a good agreement of data (Fig. 10).

Starting from the core-base, values are initially positive (warm climate), with one oscillation toward zero (503 cm) and a positive peak (493 cm). This interval is comprised in the climatic zone V, subzone V' (Parisi & Cita, 1982). A marked cold peak is observed in sapropel S-8 (483 cm). This layer lies at the limit between subzones V' and V", and its upper boundary is only a little lower than that of the *Gephyrocapsa. oceanica* zone. Positive values are present at 453 cm and are followed by two negative (colder) intervals: a marked peak at 413 cm and a moderately negative one at 399 cm. The values are still positive inside sapropel S-7, still belonging to subzone V" (Cita *et al.*, 1982), and become negative below S-6. The cold climate continues in S-6, and then for the whole interval between S-6 and S-5; values are here strongly negative, except for a short interval (294 cm), which shows a tendency toward warmer climate. Sapropel S-6 corresponds to the boundary between the climatic zones V and W; the latter is considered to be cold (Cita *et al.*, 1982; Parisi, 1987b). A new warm interval begins at the bottom of S-5, which also corresponds to the Middle-Late Pleistocene boundary and to the passage from zone W to zone X. This latter is related to the interglacial Riss-Würm, and its upper boundary is above sapropel S-3. The positive interval ends at 206 cm, and then, just below sapropel S-3, a new, moderately negative interval begins, which seems to last up to cm

43. Between S-3 and cm 43, however, data are very scarce, perhaps because of the occurrence of tephra levels (X-2 and Y-5). Thus, the curve is not reliable. Nevertheless, the sediments from just above X-2 to the Pleistocene/Holocene boundary should correspond to the climatic zone Y (Würmian glaciation). A last warm interval beginning just below S-1 (cm 40), is interrupted by a relatively colder peak inside the Marker-bed. Sapropel S-1 and the Marker-bed belong to the climatic zone Z, corresponding to the Würmian postglacial (Holocene). The curve is not very different from those provided by other cores from the same area (BAN82-GC18, BAN84-27); it is also well comparable with that based on planktonic Foraminifera (Fig. 5).

7.3 Planktonic molluscs - II

Specimens of Gymnosomata have been often found in the residues together with the already mentioned Thecosomata. They have proved useful in integrating data from the climatic indicators. Heteropoda, other molluscs larvae, Ostracoda, Echinoida, Porifera and otoliths, all sporadically found, have been neglected.

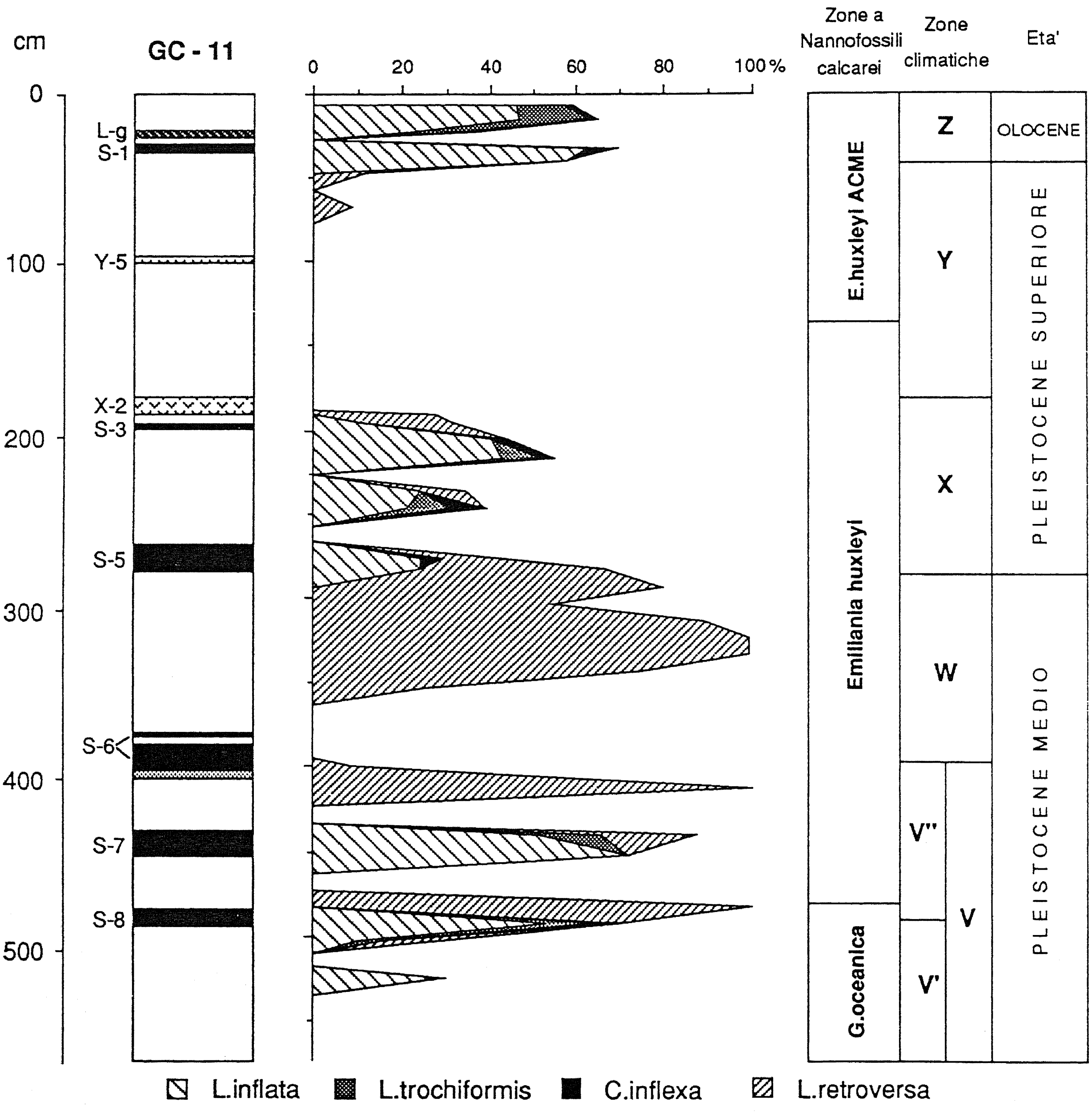

Fig. 11 - Comparison of the percentage curves of the four climatic indicators (*Limacina inflata, Limacina trochiformis, Cavolinia inflexa, Limacina retroversa*).

Confronto fra le curve percentuali ottenute per le quattro specie indicatrici climatiche (Limacina inflata, Limacina trochiformis, Cavolinia inflexa, Limacina retroversa).

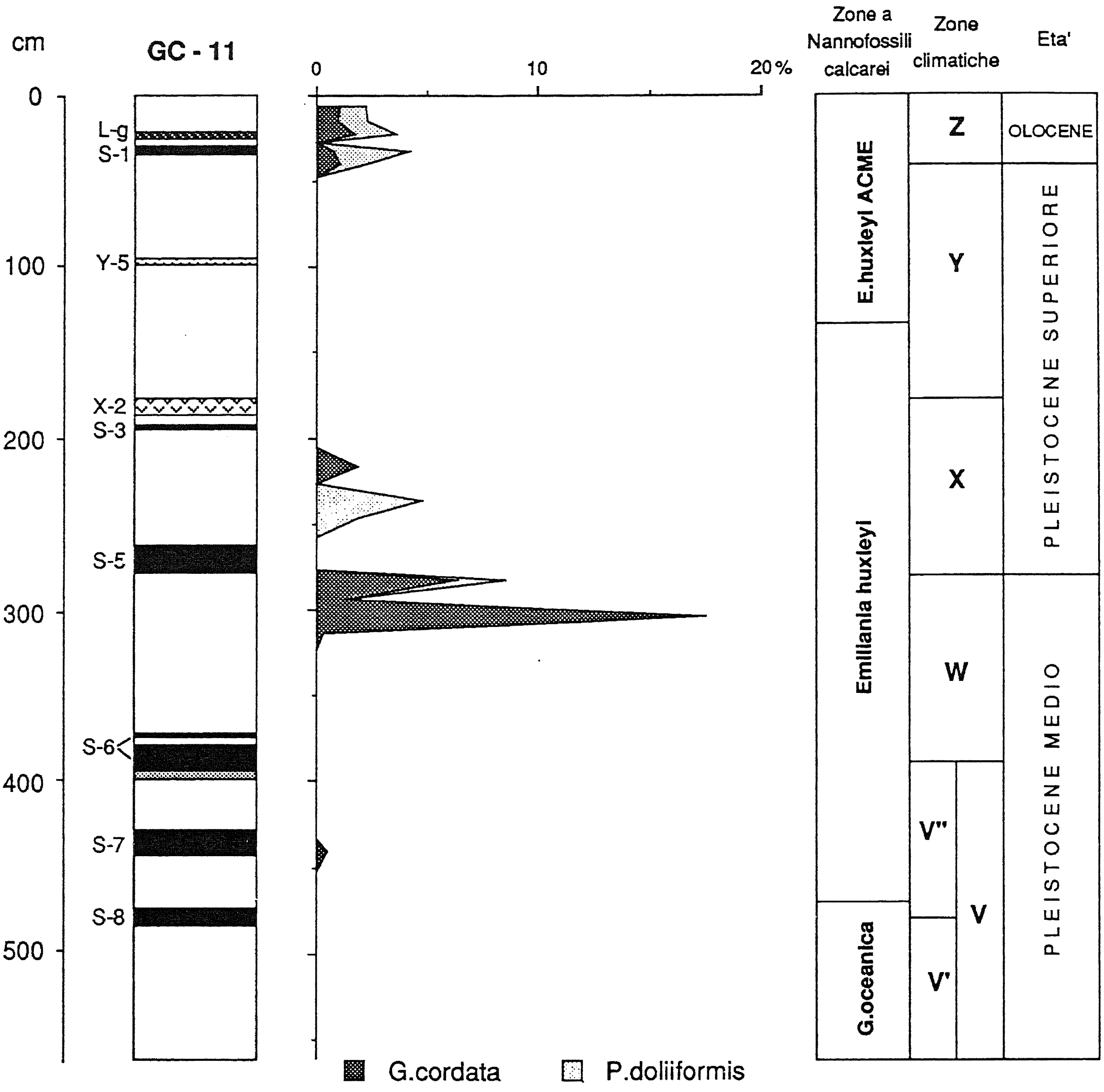

Fig. 12 - Comparison of the percentage curves of *Gleba cordata* and of *Paedoclione doliiformis*.
Confronto fra le curve percentuali ottenute per Gleba cordata *e per* Paedoclione doliiformis.

Recently, Grecchi & Bertolotti (1988) have pointed out that *Gleba cordata* (Pseudothecosomata) and *Paedoclione doliiformis* (Gymnosomata) (Grecchi, 1987) are almost exclusively related to warm intervals.

G. cordata autoecology is not properly documented. So far, it has been found only in the warm, central-Eastern Atlantic waters, in the Mozambique Channel (Indian ocean) and, perhaps, in limited areas of the Western Atlantic (Van der Spoel, 1976). Its embryonal shell has always been found, in the Mediterranean sediments, in climatic warm zones and/or together with warm indicators (Grecchi, 1984).

As an adult, *P. doliiformis* is a good swimmer, feeding on Thecosomata; as a veliger, it is passively carried by currents, feeding on phytoplankton (Lalli & Conover, 1973; 1976).It is considered to be neotenous (Lalli & Conover, 1973; Grecchi, 1987), and it is hermaphroditic. Fertilization would appear reciprocal and is probably simultaneous. The present distribution of *P. doliiformis* seems to be limited to the Atlantic Ocean (Van der Spoel, 1976), but, according to Lalli (in Van der Spoel, 1976), it is much more widespread than recorded, because often erroneously ascribed to other species of Gymnosomata and Thecosomata. Specimens of *G. cordata* have been found at 441 cm (in sapropel S-7), 314 cm, 304 cm, 294 cm, 282 cm (below S-5), 216 cm, 40 cm (below S-1), 32 cm (in S-1), 23 cm, 15 cm, 6 cm (Table 4). *P. doliiformis* has been found at 282 cm (below S-5), 246 cm, 236 cm, 40 cm (below S-1), 32 cm (in S-1), 23 cm, 15 cm, 6 cm. The species at 282 cm was present in 11 samples, 7 of which correspond to warm periods, and 4 to cold periods; nevertheless, one of these (282 cm), just below sapropel S-5, yielded also the warm indicator *L. inflata.* The other three "cold" samples (314, 304, 294 cm) are only a little older. Since these samples correspond to the upper portion of the climatic zone W, the interval 314÷282 cm may be considered as tending to a warm climate: warm and cold indicators are found together (Grecchi, 1984). The percentage of *G. cordata* for core BAN88-11GC results to be 72.7% in warm intervals. The value for *P. doliiformis* is 100%: 7 out of the 8 samples correspond to warm periods and one (282 cm) yields *L. inflata* (Tables 5 and 6).

The analysis of core BAN82-18GC, from the Herodotus Abyssal Plain (Eastern Mediterranean), showed a similar pattern (Grecchi & Bertolotti, 1988). *P. doliiformis,* in fact, occurred in the interglacial periods (correlatable with climatic zones X and Z) and was particularly abundant between S-5 and S-3. Four samples (out of the total 14) belonging to the climatic zone W, and yielding 32 specimens of *P. doliiformis* out of the total 1063 specimens, contained warm indicators (Grecchi & Bertolotti, 1984). *P. doliiformis* has been found also in recent sediments of the Gulf of Aqaba (Almogi-Labin & Reiss, 1977; Almogi-Labin, 1982) and of the Gulf of Aden (Ivanova, 1985).

7.4 Percentage curves

The percentage curves concern the four Euthecosomata climatic indicators (Fig. 11). *L. retroversa* is the most representative, followed by *L. inflata*; *L. trochiformis* and *C. inflexa* have not proved relevant. The climatic curve has also been compared with the percentage curves of *G. cordata* and *P. doliiformis*, with respect to the total species found (Fig. 12). The result is that where the climatic curve markedly tends to a peak (304 cm) because the cold species *L. retroversa* decreases, *G. cordata* is very abundant. *P. doliiformis* is the most abundant species at cm 236. This information indicates both that the tendency toward a colder climate as suggested by the scarcity of warm species is apparent, and that the Euthecosomata curve may be considered conform to the Foraminifera climatic curve, where (Fig. 5) the "cold" peak is not present.

7.5 Discussion

We have found in the same sample, taxa providing opposite climatic indications (Table 5). This fact can be explained if the seasonal fluctuations of Thecosomata are considered. As a matter of fact, species tolerating opposite climatic conditions may alternatively be more abundant during the year (Chen & Bè, 1964; Cifelli & McCloy, 1983), the phenomenon being more conspicuous than with Foraminifera (De Castro Coppa *et al.*, 1980; Dreuser & Ross, 1989). Planktonic Foraminifera are found in many samples where Thecosomata are not represented; possibly, this is due to vertical, daily migrations of the latter in the water column (Bè & Gilmer,

Table 6 - Percentages of the Pseudothecosomata *Gleba cordata* and the Gymnosomata *Paedoclione doliiformis.*

Valori percentuali ottenuti per lo Pseudothecosomata Gleba cordata *e per il* Gymnosomata Paedoclione doliiformis.

campione	cm dal top	totale esemplari	% G.cordata	% P.doliiformis
sec.1 cm 6	6	866	1,03	1,15
sec.1 cm 15	15	439	0,91	1,36
sec.1 cm 23	23	171	1,75	1,75
sec.1 cm 27	27		0	0
sec.1 cm 32	32	733	0,81	3,27
sec.1 cm 40	40	493	1,01	1,21
sec.2 cm 5	47		0	0
sec.2 cm 15	57		0	0
sec.2 cm 25	67		0	0
sec.2 cm 35	77		0	0
sec.2 cm 45	87		0	0
sec.2 cm 55	97		0	0
sec.2 cm 65	107		0	0
sec.2 cm 75	117		0	0
sec.2 cm 85	127		0	0
sec.2 cm 95	137		0	0
sec.2 cm 105	147		0	0
sec.2 cm 115	157		0	0
sec.3 cm 5	171		0	0
sec.3 cm 15	181		0	0
sec.3 cm 22	188		0	0
sec.3 cm 25	191		0	0
sec.3 cm 30	196		0	0
sec.3 cm 40	206		0	0
sec.3 cm 50	216	164	1,82	0
sec.3 cm 60	226		0	0
sec.3 cm 70	236	169	0	4,73
sec.3 cm 80	246	244	0	1,78
sec.3 cm 92	258		0	0
sec.3 cm 100	266		0	0
sec.3 cm 110	276		0	0
sec.3 cm 116	282	176	6,25	2,27
sec.4 cm 10	294	288	1,38	0
sec.4 cm 20	304	143	17,48	0
sec.4 cm 30	314	315	0,31	0
sec.4 cm 40	324		0	0
sec.4 cm 50	334		0	0
sec.4 cm 60	344		0	0
sec.4 cm 70	354		0	0
sec.4 cm 80	364		0	0
sec.4 cm 88	372		0	0
sec.4 cm 92	376		0	0
sec.4 cm 98	382		0	0
sec.4 cm 110	394		0	0
sec.4 cm 115	399		0	0
sec.5 cm 10	413		0	0
sec.5 cm 20	423		0	0
sec.5 cm 30	433		0	0
sec.5 cm 38	441	212	0,47	0
sec.5 cm 50	453		0	0
sec.5 cm 60	463		0	0
sec.5 cm 70	473		0	0
sec.5 cm 80	483		0	0
sec.5 cm 90	493		0	0
sec.5 cm 100	503		0	0
sec.5 cm 107	510		0	0
sec.5 cm 115	518		0	0
sec.6 cm 5	525		0	0
sec.6 cm 15	535		0	0
sec.6 cm 25	545		0	0
sec.6 cm 35	555		0	0

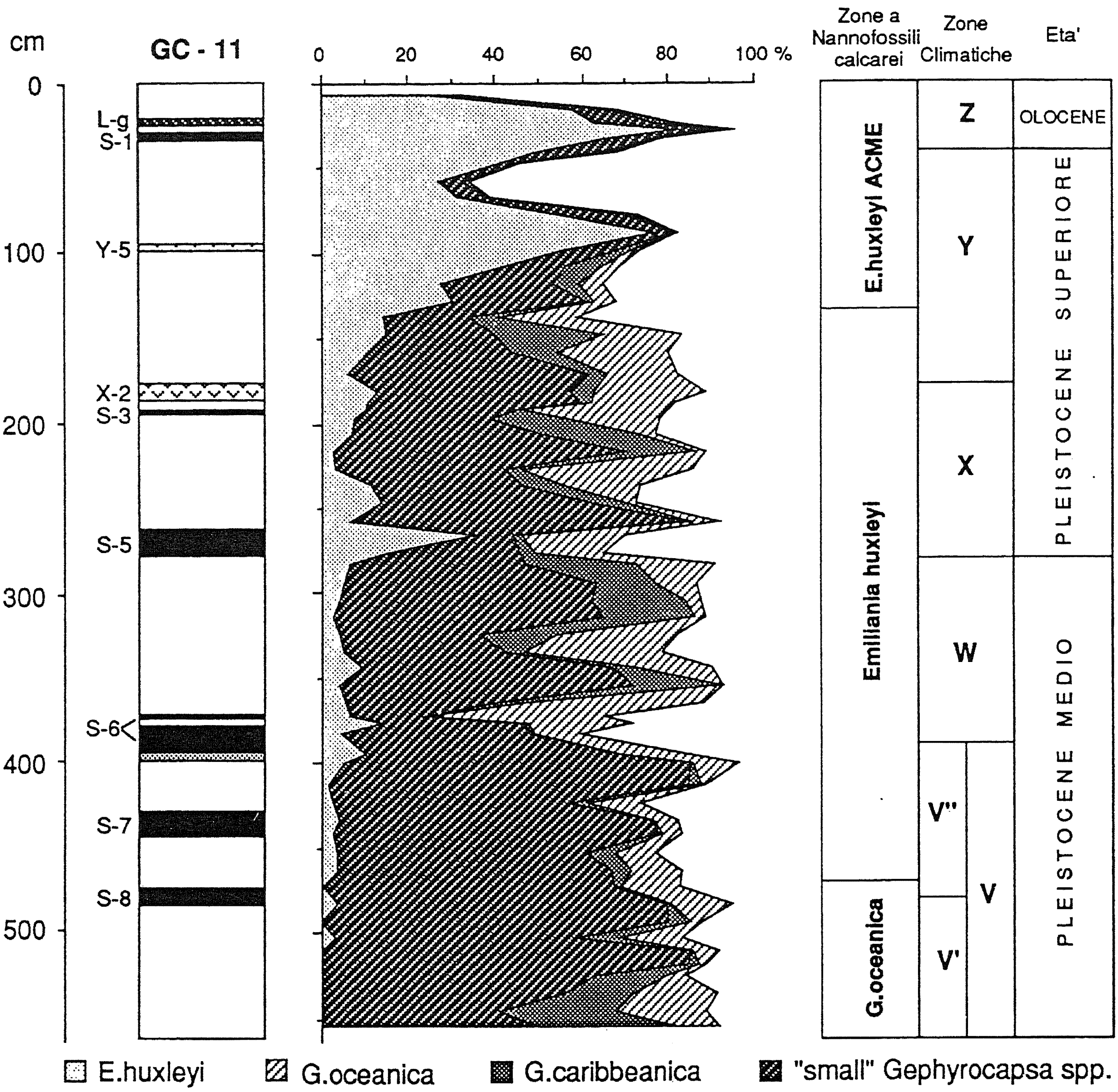

Fig. 13 - Cumulative curve of dominant species in the calcareous nannofossil assemblages. These species were disregarded in the second part of the quantitative analysis (see text).

Curva cumulativa relativa all'abbondanza percentuale delle specie dominanti nell'associazione a Nannofossili calcarei. Queste specie sono state escluse nella seconda fase dell'analisi quantitativa (v. testo).

1977). As it frequently occurs near sapropelitic events (Vismara Schilling, 1984), sometimes surface waters are oxigenated, while the underlying ones are anoxic; in this case, the most sensible among Thecosomata (as climatic indicators are), are not able to survive. Foraminifera on the contrary, living in the surface waters, are not affected, and will then be found in the sediments. A further reduction of Thecosomata in the sediment can be produced by dissolution: during sapropel deposition, anoxic bottom waters have a higher acidity (Table 5, Fig. 10).

Data from *G. cordata and P. doliiformis* help in the climatic curve reconstruction where climatic indicators are scarce or of little significance.

The lack of climatic indicators in sediments yielding more tolerant species, may point to unusual chemical and physical conditions; this situation occurs between sapropel S-1 and the Holocene Marker-bed and between the two tephra layers (Y-5, X-2). The interpretation is very difficult. In the latter case, volcanic ashes, slowly reaching the sea-bottom, can have considerably increased water turbidity, thus reducing drastically the activity of phytoplankton, on which Thecosomata feed. Very tolerant Thecosomata occur at 67 cm, whereas climatic indicators are absent. The same happens between S-1 and the Marker-bed.

8. CALCAREOUS NANNOFOSSILS

8.1 Biostratigraphy

Following Gartner's (1977) zonation, two bio-horizons have been recognized in the studied core, which correspond with the First Appearance of *E. huxleyi* and the beginning of its maximum frequency.

The First Appearance of *E. huxleyi* is very difficult to determine because specimens are scarce and very small-sized. Thierstein *et al.* (1977) have correlated this event with the upper portion of the isotopic stage 8 (see also Rio *et al.*, 1990) and calculated an age of 268,000 years; their work has been carried out on a S.E.M. Using an optical microscope, some authors have placed the First Appearance of *E. huxleyi* in the Eastern Mediterranean just above the sapropel S-8; it corresponds to the isotopic stage 7 and to an age of 220,000 years (Blechschmidt *et al.*, 1982; Sigl & Müller, 1975; Erba in Parisi *et al.*, 1987). Some specimens, tentatively ascribed to *E. huxleyi,* have been observed a few centimeters below sapropel S-8 in the studied core. Nevertheless, the First Appearance of this species has been placed at 473 cm (just above S-8) where the first certain specimens of *E. huxleyi* were found. This is in agreement with the cited papers on the Eastern Mediterranean.

The definition of the *E. huxleyi* Acme is quite controversial. Gartner (1977) first defined the event as the first stratigraphic interval where this species is dominant. If we explain this definition as the first interval where percentages of *E. huxleyi* are higher than all the others, the event in core BAN88-11GC should be placed at 127 cm from the core-top. Thierstein *et al.* (1977) observe that the increase of *E. huxleyi* abundance corresponds to the decrease of *G. caribbeanica;* they indicate this event as the point where *E. huxleyi* begins its increment, to become the dominant species. Such an event in the studied core would be at 171 cm. On the contrary, Rio *et al.* (1990) consider an "increase-event of *E. huxleyi*": it is defined as the medium point of the line joining those samples which contain less and more than 20% of this species. Excluding 266 cm sample (see below), because it is not the beginning of a continuous increase, the event as described by Rio *et al.* (1990) would lie at 132 cm from the core-top.

In conclusion, as seen above, the Acme (or also an increase in frequency) of *E. huxleyi* has not an univocal definition. The corresponding stratigraphic interval can thus change of a few centimeters. In the stratigraphic column of Fig. 13, the event has been positioned on the basis of the definition given by Rio *et al.* (1990), which appears as the most functional.

Above this biohorizon, some anomalies in the assemblage composition have been observed. Abundant specimens of taxonomic groups such as "small" *Reticulofenestra* spp. and *Dictyococcites* sp., have been found in some samples; these organisms are usually absent in this stratigraphic level. The same samples contained also reworked forms (*Sphenolithus* sp.) and diagenetic structures, never observed in other samples. As a consequence, quantitative data of the core upper portion seem less reliable.

8.2 Quantitative analysis

Percentages of all the identified taxa are shown in Table 7. We will first analyze the variations of the dominant taxa (Figs. 13, 14) for the whole core length, and then those of two less abundant but significant species.

- *Emiliania huxleyi*: its abundance (Fig. 14) clearly increases from the bottom to the top of the core. Its curve can be divided into two portions, the first of which extending from the base up to 171 cm, where the Acme begins. Percentages in this interval range from 0 to 15.3%, except for the 266 cm sample, where the species reaches 35% of the total. This peak corresponds to the top of sapropel S-5: here, the foraminiferal climatic curve points out a relatively cooler interval inside a warm period.
  Gartner (1988), though recognizing its opportunistic and cosmopolitan character (McIntyre & Bè, 1967; McIntyre, Ruddiman & Jantzen, 1972; Roth & Coulbourn, 1982), ascribes to *E. huxleyi* a preference for temperate/cold, nutrients-rich waters. Therefore, it is not clear whether the increase of *E. huxleyi* at medium/high latitudes (clearly pointed out by previous authors) is due to the species ecology, or rather, to a reduction of the less cosmopolitan species. Thus, to give a paleoecological significance to the Acme of *E. huxleyi* seems debatable, though a certain control, at least by temperature, is quite likely.
  In the core upper portion (from 171 cm to the top) percentages range from 10.66% to 81.66%. Repeated reductions correspond to the levels, rich in "small" *Reticulofenestra* spp. and *Dictyococcites* sp.; the presence of these layers, affected by diagenesis and probably reworked, make data useless in determining their climatic significance.

- *Gephyrocapsa oceanica:* a comparison of its percentage curve (Fig. 14) with the climatic curves (Figs. 5, 10) shows that, though a strong control by temperature is not evident, abundance peaks of this species always correspond to cold intervals or, at least, to relative cooling during warm periods. In the core upper part, the drastic reduction of *G. oceanica* corresponds with the beginning of *E. huxleyi* Acme, and lasts also in the anomalous samples discussed above.
  Previous authors attribute a wide geographic and ecologic distribution to this species, though all agree on its preference for warm, subtropical waters (McIntyre & Bè, 1967; Bartolini, 1970; Gartner *et al.*, 1987;

Table 7 - Percentages of calcareous nannofossil taxa (or groups of taxa), based on countings of 300 specimens for each sample.
Percentuali dei singoli taxa (o gruppi di taxa) relativi al conteggio di 300 esemplari di nannofossili calcarei su tutta l'associazione.

CAMPIONE	cm dal top	*E.huxleyi* %	*G.oceanica* %	*G.caribbeanica* %	"small" *Gephyrocapsa* spp. %	"large" *Gephyrocapsa* spp. %	*H.carteri* %	*Syracosphaera* sp.1 %	*Syracosphaera* spp. %	"small" *Reticulofenestra* spp. %	*C.leptoporus* %	*Rhabdosphaera* spp. %	*Umbellosphaera* spp. %	Holococcoliti spp.	*Pontosphaera* spp. %	*C.pelagicus* %	*Ceratolithus* spp. %	*Schyphosphaera* spp. %	*Toracosphaera* spp. %	*Umbilicosphaera* spp. %	*Dictyococcites* spp. %	*S.fossilis* %	ALTRI %
sec.1 cm 6	6	24,7	0,0	2,3	5,3	0,0	0,7	7,0	2,0	24,0	1,0	3,0	1,7	0,0	0,3	0,0	0,0	0,0	0,0	0,0	26,7	0,3	1,0
sec.1 cm 15	15	57,7	0,7	1,3	8,7	0,0	0,0	13,3	4,3	4,3	0,0	1,0	0,7	0,0	0,0	0,0	0,0	0,0	0,0	0,3	6,7	0,7	0,3
sec.1 cm 23	23	62,7	0,7	4,3	14,0	0,0	0,7	9,7	1,7	0,0	1,0	1,7	0,3	0,3	0,0	0,0	0,0	0,0	0,0	1,7	0,0	0,7	0,7
sec.1 cm 27	27	81,7	4,7	0,7	7,7	0,0	2,0	0,0	1,3	0,3	0,0	1,0	0,3	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,3
sec.1 cm 32	32	65,0	0,3	1,0	11,7	0,0	2,3	1,7	3,0	1,7	0,7	4,0	0,7	0,7	0,0	0,0	0,0	0,0	0,0	0,7	5,0	0,3	1,3
sec.1 cm 40	40	49,0	1,0	2,0	16,3	0,0	0,7	6,0	2,7	7,0	0,0	1,3	0,7	0,0	0,0	0,0	0,0	0,0	0,0	0,0	11,0	0,7	1,7
sec.2 cm 5	47	40,7	0,3	0,3	4,3	0,0	1,0	8,3	1,3	8,3	0,3	0,7	0,3	0,7	0,0	0,0	0,0	0,0	0,0	0,0	31,7	0,7	1,0
sec.2 cm 15	57	27,0	0,3	1,3	5,7	0,0	2,0	6,7	3,3	13,7	1,0	0,3	1,3	0,0	0,0	0,0	0,0	0,0	0,0	0,0	35,0	0,0	2,3
sec.2 cm 25	67	31,3	0,7	0,7	6,3	0,0	0,3	13,3	5,7	10,7	0,3	0,0	1,0	0,0	0,0	0,7	0,0	0,0	0,0	0,0	26,7	0,0	2,3
sec.2 cm 35	77	54,0	1,3	2,0	15,7	0,0	1,0	9,0	3,3	3,7	0,3	0,3	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,3	6,7	0,0	2,3
sec.2 cm 45	87	76,3	0,3	1,0	4,7	0,0	1,3	3,7	2,7	1,0	0,0	0,0	0,7	0,0	0,0	0,0	0,0	0,0	0,0	0,0	6,7	0,0	1,7
sec.2 cm 55	97	55,0	2,0	3,3	13,0	0,0	8,7	2,0	6,3	2,3	0,7	0,3	1,0	0,3	0,0	0,7	0,0	0,0	0,0	0,0	3,3	0,0	1,0
sec.2 cm 65	107	42,0	4,3	8,3	14,3	0,0	0,7	20,0	6,0	1,3	0,0	0,0	1,7	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,3	1,0
sec.2 cm 75	117	27,3	6,0	5,7	26,0	2,3	1,7	14,7	5,0	1,7	1,0	0,7	1,7	0,0	0,0	0,3	0,0	0,0	0,0	0,0	5,0	0,7	0,3
sec.2 cm 85	127	30,3	5,0	2,3	30,3	0,0	2,7	17,3	6,7	0,0	0,0	1,0	0,7	0,0	0,0	0,0	0,0	0,0	0,0	0,3	0,0	2,7	0,7
sec.2 cm 95	137	14,3	18,0	7,3	19,3	1,3	2,0	20,0	9,7	0,0	1,3	1,7	1,0	0,7	0,0	0,7	0,0	0,0	0,0	0,0	0,0	1,0	1,7
sec.2 cm 105	147	14,7	18,3	24,7	25,3	0,0	1,3	8,0	2,0	1,3	0,3	0,3	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	2,0	0,0	1,7
sec.2 cm 115	157	10,7	26,3	10,3	33,0	0,0	3,7	4,0	4,7	2,7	0,7	0,7	0,7	0,0	0,3	0,3	0,0	0,0	0,3	0,0	0,7	0,3	0,7
sec.3 cm 5	171	6,0	16,0	5,0	55,0	0,0	1,7	11,7	1,3	0,0	0,3	0,3	0,7	0,0	0,3	0,3	0,0	0,0	0,0	0,0	0,0	0,3	1,0
sec.3 cm 15	181	13,0	26,0	5,7	44,3	0,0	1,0	2,3	3,0	0,3	0,3	1,0	0,7	0,0	0,3	0,0	0,0	0,0	0,0	0,3	0,0	0,7	1,0
sec.3 cm 22	188	10,7	19,7	2,7	48,7	0,0	3,0	2,0	5,0	0,0	3,0	1,7	1,0	0,0	1,3	0,0	0,0	0,0	0,0	0,0	0,0	1,3	0,0
sec.3 cm 25	191	10,0	34,0	1,0	35,0	0,0	5,7	0,0	5,0	0,0	0,0	1,3	0,7	4,0	2,3	0,0	0,0	0,0	0,0	0,3	0,0	0,3	0,3
sec.3 cm 30	196	7,7	21,3	17,7	31,3	0,0	1,3	9,7	5,7	0,0	0,0	2,3	0,0	0,7	0,3	0,0	0,0	0,0	0,0	0,3	0,0	0,3	1,3
sec.3 cm 40	206	7,3	4,0	22,3	43,3	0,0	0,0	15,3	4,3	1,0	0,0	1,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,3	0,0	0,0	1,0
sec.3 cm 50	216	2,7	2,7	16,3	67,0	0,0	0,0	4,3	3,7	0,0	0,3	0,3	0,3	0,0	0,0	0,0	0,0	0,0	0,0	0,3	0,0	0,0	2,0
sec.3 cm 60	226	3,0	40,0	3,7	39,0	0,0	1,3	1,7	5,3	0,0	0,0	2,3	0,0	1,0	0,0	0,0	0,0	0,0	0,0	0,3	0,0	1,7	0,7
sec.3 cm 70	236	11,3	18,0	9,7	34,7	0,3	3,7	6,0	5,3	0,0	1,3	4,3	1,0	0,0	0,7	0,3	0,0	0,0	0,0	0,0	0,0	1,3	2,0
sec.3 cm 80	246	14,0	2,7	8,3	47,7	0,0	1,3	15,7	5,0	0,0	0,0	2,0	1,3	0,0	0,0	0,0	0,0	0,0	0,0	0,3	0,0	0,7	1,0
sec.3 cm 92	258	6,7	6,7	0,7	77,7	1,0	2,0	0,0	2,3	0,0	1,0	0,7	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,3	0,0	1,0	0,0
sec.3 cm 100	266	35,0	23,7	2,3	8,7	0,7	10,0	0,7	5,7	0,3	1,3	4,0	0,3	0,0	2,3	0,0	0,0	0,7	0,3	0,3	0,0	0,3	3,3
sec.3 cm 110	276	15,3	15,7	3,3	30,3	0,7	17,3	2,0	6,3	0,0	1,0	2,7	2,0	0,7	1,0	0,3	0,3	0,0	0,0	0,0	0,0	1,0	0,0
sec.3 cm 116	282	6,7	18,3	28,0	40,0	0,0	2,0	4,0	1,3	0,0	0,0	0,7	0,0	0,0	0,3	0,0	0,0	0,0	0,0	0,0	0,0	0,3	0,3
sec.4 cm 10	294	5,0	9,7	13,7	58,3	0,0	0,7	10,0	1,0	0,3	0,0	0,3	0,0	0,0	1,0	0,0	0,0	0,0	0,0	0,3	0,0	0,0	0,7
sec.4 cm 20	304	4,3	3,7	22,3	57,7	0,0	0,0	8,7	1,0	0,0	0,0	1,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,3	0,0	0,0	1,0
sec.4 cm 30	314	2,3	2,7	21,3	62,7	0,0	0,7	7,3	0,7	0,0	0,0	1,0	0,0	0,0	0,3	0,0	0,0	0,0	0,0	0,0	0,0	0,0	1,0
sec.4 cm 40	324	4,3	28,0	18,0	31,7	0,0	3,3	10,0	3,7	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	1,0
sec.4 cm 50	334	5,3	32,3	3,7	37,3	0,0	8,7	8,7	0,0	0,0	0,3	0,0	0,3	1,0	0,3	0,0	0,0	0,3	0,0	0,0	0,0	0,0	1,7
sec.4 cm 60	344	9,0	18,0	5,3	58,0	0,0	0,0	4,0	2,0	0,0	0,0	0,3	0,3	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	3,0
sec.4 cm 70	354	4,3	0,7	20,3	67,7	0,0	0,7	4,0	1,7	0,0	0,0	0,0	0,0	0,0	0,3	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,3
sec.4 cm 80	364	5,7	43,0	6,0	33,7	0,0	6,7	0,3	3,0	0,0	0,7	0,3	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,3	0,3
sec.4 cm 88	372	6,7	40,7	0,7	17,3	0,0	26,7	0,3	2,7	0,0	3,0	0,7	0,3	0,3	0,3	0,3	0,0	0,0	0,0	0,0	0,0	0,0	0,0
sec.4 cm 92	376	13,7	23,7	2,0	32,0	0,0	16,7	0,7	6,7	0,3	2,7	0,0	0,0	0,3	0,3	0,3	0,0	0,3	0,0	0,0	0,0	0,0	0,3
sec.4 cm 98	382	4,7	10,7	0,3	44,0	0,0	29,0	1,3	7,3	0,0	2,0	0,0	0,0	0,7	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
sec.4 cm 110	394	10,3	15,0	0,7	58,0	0,0	8,3	2,7	4,0	0,0	0,0	0,0	0,3	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,7
sec.4 cm 115	399	5,3	11,0	0,3	80,0	0,0	0,3	0,0	0,7	0,0	2,3	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
sec.5 cm 10	413	1,7	1,0	3,0	83,0	0,0	0,0	8,3	1,7	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	1,0	0,3
sec.5 cm 20	423	2,7	12,7	4,3	54,0	0,0	9,7	4,7	4,3	0,0	5,3	1,0	0,3	0,3	0,3	0,0	0,0	0,0	0,0	0,0	0,0	0,3	0,0
sec.5 cm 30	433	4,3	5,7	0,3	72,0	0,0	7,3	0,0	3,3	0,0	1,3	1,0	0,3	0,0	1,0	0,0	0,0	0,0	0,3	2,0	0,3	0,0	0,7
sec.5 cm 38	441	2,7	4,7	0,7	75,0	0,3	9,0	1,3	2,0	0,0	0,0	2,0	1,0	0,0	0,3	0,0	0,0	0,0	0,0	0,7	0,0	0,3	0,0
sec.5 cm 50	453	3,7	9,0	7,3	57,0	0,0	0,7	19,0	2,3	0,0	0,0	1,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
sec.5 cm 60	463	3,7	11,7	4,7	63,0	0,0	3,3	8,0	2,0	0,0	0,3	1,3	0,3	0,3	0,0	0,0	0,0	0,0	0,0	0,0	0,0	1,0	0,3
sec.5 cm 70	473	0,7	13,3	1,7	65,7	0,0	6,7	0,3	2,7	0,0	4,3	1,0	0,0	0,0	0,7	0,0	0,0	0,7	0,0	0,0	0,0	1,3	0,0
sec.5 cm 80	483	3,7	14,0	1,0	76,0	0,0	4,0	0,0	0,0	0,0	0,0	0,7	0,3	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,3
sec.5 cm 90	493	0,0	2,7	5,3	80,0	0,0	1,3	6,0	2,7	0,0	0,3	0,7	0,3	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,3	0,3
sec.5 cm 100	503	3,3	14,3	10,7	55,0	0,0	0,7	11,3	2,7	0,0	0,0	0,7	0,7	0,0	0,0	0,0	0,0	0,0	0,0	0,3	0,0	0,0	0,3
sec.5 cm 107	510	0,0	6,3	0,7	85,0	1,0	0,3	1,0	2,3	0,0	0,0	1,7	0,7	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,7	0,3
sec.5 cm 115	518	0,0	1,7	2,3	84,7	0,0	0,3	7,7	2,3	0,3	0,0	0,3	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,3	0,0
sec.6 cm 5	525	0,0	4,7	17,0	62,7	0,0	0,7	11,0	2,7	0,0	0,0	0,7	0,0	0,3	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,3
sec.6 cm 15	535	0,0	19,3	16,3	55,7	0,3	0,0	5,0	1,7	0,0	0,0	0,3	0,0	0,0	0,3	0,0	0,0	0,0	0,0	0,0	0,0	0,3	0,7
sec.6 cm 25	545	0,3	20,7	27,3	40,3	0,0	0,7	5,0	2,0	0,0	1,0	0,3	0,0	0,0	1,0	0,0	0,0	0,0	0,0	0,0	0,0	0,3	2,0
sec.6 cm 35	555	0,0	10,3	31,7	49,7	0,0	0,0	4,0	1,0	0,7	0,0	0,3	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,3	0,0	0,0	2,0

Gartner, 1988; Roth & Colbourn, 1982; Muller, 1985) and, probably, for surface waters with low nutrients content (Gartner *et al.*, 1987; Gartner, 1988).

The results of this work are then partly in contrast with previous ones, concerning temperature control on *G. oceanica*. No hypothesis can be put forward on how water fertility affects this organism.

Moreover, the understanding of the ecologic significance of *G. oceanica* s.l. is probably affected by the taxonomic problems of the group.

- *Gephyrocapsa caribbeanica:* the correlation between its percentage curve (Fig. 14) and the climatic curves (Figs. 5, 10), is not very clear. In the cold interval between S-6 and S-5, *G. caribbeanica* relatively increases in abundance. In the core upper portion, a strong reduction is related to the *E. huxleyi* Acme.

Previous authors attribute a preference for temperate/cold waters to this species (McIntyre & Bè, 1967; Bartolini, 1970; Gartner, 1972; McIntyre, Ruddiman & Jantzen, 1972; Roth & Colbourn, 1982); the results of this study seem to agree, at least in part, in spite of the taxonomic problems.

- "small" *Gephyrocapsa* spp.: the percentage curve of this group (Fig. 14) is characterized by a sharp increase in the core lower portion, just below sapropel S-8. This pattern has been already observed (Erba, pers. comm.) in the Eastern Mediterranean, in the same stratigraphic position. In the core upper part, "small" *Gephyrocapsa* undergo a slow reduction, consisting of successive steps; minimum values correspond to *E. huxleyi* Acme, like in the cases of the other *Gephyrocapsa* species.

The ecologic significance of "small" *Gephyrocapsa* spp. has been discussed by Gartner *et al.* (1987) and Gartner (1988). The group (and particularly *G. ericsonii* and *Gephyrocapsa* sp. A, not separately identified in this study) is considered as indicator of temperate/cold, nutrients-rich waters. The same characteristics have been ascribed to *E. huxleyi*, which is seen as a Late-Pleistocene substitute of the "small" *Gephyrocapsa*.

A comparison between the "small" *Gephyrocapsa* spp. percentage curve and the climatic curves (Figs. 5, 10) shows that they are not temperature-controlled; the curves, in fact, are directely correlate in some intervals, whereas in some others they are in opposition.

The ecologic interpretation of "small" *Gephyrocapsa* spp. is doubtful, because their sensitivity to water-fertility cannot be verified.

The abundance curves of *Helicosphaera carteri* and *Syracosphaera* sp. 1 (Fig. 15) are peculiar and very interesting in their pattern. Percentage variations in Fig. 15 are referred to the counting of 100 specimens of all the species except the dominant ones (second counting stage, see first paragraph) (Table 8). The curves reveal a pattern which was already clear after the quantitative analysis of 300 specimens of the whole association (Table 8). Some rare specimens of close species (*i.e. H. wallichi*) have been included in *H. carteri*.

Two major features characterize the curves of *H. carteri* and *Syracoshpaera* sp.: 1) percentage changes of the two species are opposite; 2) both positive peaks of *H. carteri* and negative ones of *Syracosphaera* sp. 1 occur into sapropels (S-1, S-3, S-5, S-6, S-7, S-8) and tephra (Y-5 and X-2). The direct correlation between sapropels and *H. carteri* abundance is as strong as to reflecte the subdivision of S-6, consisting of two separate layers.

On the basis of these data, a paleoecologic and/or paleoceanographic interpretation can be tried.

Previous authors do not agree on the ecologic significance of *H. carteri*. Some of them ascribe a slight preference for warm, subtropical waters to it (McIntyre & Bè, 1967; Roth & Colbourn, 1982). Bartolini (1970) considers this species as a cold one; Muller (1985) observes that *H. carteri* seems to decrease in sapropel layers of Eastern Mediterranean, possibly because of a salinity reduction in surface waters.

No one of the previous authors has ever ascribed any ecologic significance to *Syracosphaera* sp. 1.

Neither does the problem apparently offer an easier solution if we look at it from the opposite point of view: the paleoceanographic and paleoecologic significance of sapropels (see below for tephra). In fact, many are the hypotheses on the causes that led to the formation of these isochronous layers in the Eastern Mediterranean: a) precipitation increase and greater fresh-water input into the Mediterranean Sea (Bradley, 1938; Kullenberg, 1952; Vergnaud-Grazzini *et al.*, 1977; Rossignol-Strick *et al.*, 1982), especially during interglacial stages (Ryan, 1972; Rossignol-Strick, 1983); b) input of fresh or melt waters from the Black Sea (Olausson, 1961; Ryan, 1972; Stanley & Maldonado, 1977; Thunell *et al.*, 1977; Thunell *et al.*, 1983; Olausson, 1989) or from the Gibraltar Strait (Huang & Stanley, 1972); c) a primary productivity increase during reverse circulation periods due to the post-glacial fresh-water input (Sutherland *et al.*, 1984).

Foraminifera and Thecosomata climatic curves show (Figs. 5, 10) that sapropels of core BAN88-11GC, save S-6 and S-8, yield warm faunal assemblages.

The anomaly of sapropel S-6 is confirmed by previous authors (Cita & Grignani, 1982; Thunell & Williams, 1983; Thunell *et al.*,1983; Parisi, 1987b), whereas that of S-8 is only partly so.

Parisi (1987b) for instance, suggests that S-6 is the only sapropel which is also related to a productivity increase (inferred from the $\partial\ ^{13}C$ isotopic curve). She proposes that the common origin of the other sapropels is a fresh-water input from the Nile, during times when biomass in surface water is normal.

The peculiarity of S-6 is also reflected in *H. carteri* percentages, reaching here the maximum value of 80%. It is difficult to say whether this peak is due to the temperature decrease (which is recorded by the climatic curve) or, rather, to the productivity increase hypothesized by Parisi (1987b). The fact that another abundance peak is observed at 334 cm (between S-5 and S-6), in a cold interval, seems to support the idea of a partial temperature control on this species. Anyhow, neither temperature nor water-fertility can be the only cause of the variations of *H. carteri* (and *Syracosphaera* sp.1), because it is abundant in all sapropels.

A first interpretation of nannofossils percentage changes could be then sought in an increase of $CaCO_3$ dissolution: in fact, the oxidation of organic matter would raise the bottom-water pH. Dissolution and diagenesis resistant species would so relatively increase in abundance with respect to the more sensitive forms.

Nevertheless, this theory does not apply to core BAN88-11GC for two reasons: 1) calcareous nannofossils assemblages yielded by sapropels do not seem to have undergone processes changing their composition or preservation; 2) *H. carteri* is considered to have a medium to low resistance to diagenesis (Roth & Colbourn, 1982).

Another possible hypothesis is the formation of a sharp pycnocline as the result of water stratification during sapropels deposition. *H. carteri* is a large-size species as compared to most of the other more common nannofossils: its relative abundance in the sediment could result greater because of a higher speed in reaching the bottom. But to have a real sorting, currents would be required to carry away (where to?) smaller nannofossils; these would then float for thousands of years above the pycnocline, unable to reach the bottom. Moreover, such a system would produce a concentration of all large-size species, and an impoverishment of all smaller species, which is not the case of the studied core.

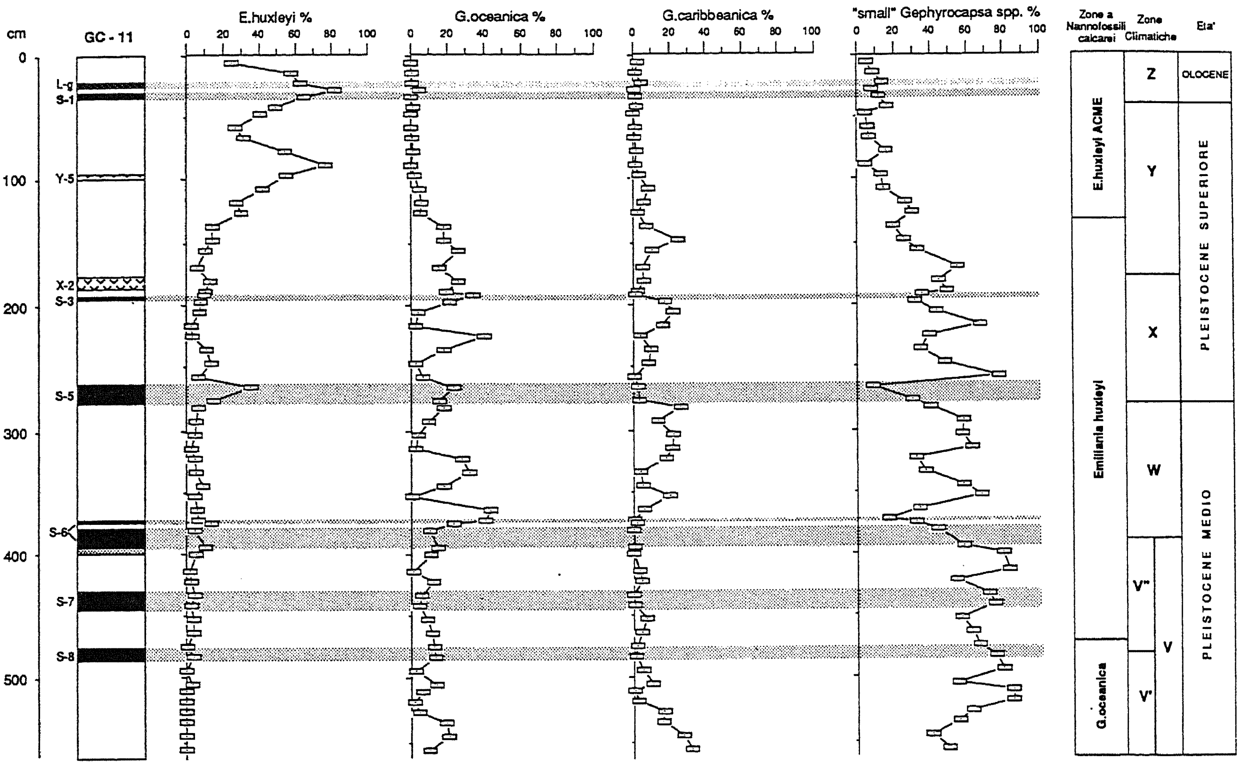

Fig. 14 - Percentage curves of *Emiliania huxley*, *Gephyrocapsa oceanica*, *Gephyrocapsa caribbeanica* and "small" *Gephyrocapsa* spp.

Curva dell'abbondanza percentuale di Emiliania huxleyi, Gephyrocapsa oceanica, Gephyrocapsa caribbeanica *e "small"* Gephyrocapsa *spp.*

Salinity and water turbidity can be considered as possible primary causes, since we have already excluded temperature and primary productivity. Salinity fluctuations during the sapropels deposition could be led by Black Sea waters or by rivers (the Nile especially). Nevertheless, *B. bigelowi*, which is considered as a low-salinity indicator, is not found in the core. This fact raises some doubts about considerable salinity reductions during the studied interval.

A turbidity increase in the surface waters would result in a change of the nannofloral assemblages (primary producers): they are in fact very strictly related to light. The cause of the increment could be due to a larger volume of fine detritus carried by rivers (Nile) or to volcanic ashes deposited on the sea surface and slowly decanted to the bottom (tephra layers). In fact, in these layers, *H. carteri* and *Syracosphaera* sp. 1 show very similar, though less marked, variations. Owing to turbidity, *H. carteri* would then become more frequent because probably more opportunistic and less light-dependent; *Syracosphaera* sp. 1, on the contrary, would be reduced, because apparently it is a more specialized species, unable to adapt itself to the quick environmental change.

9. CONCLUSIONS

The quantitative study of Foraminifera, Thecosomata and nannofossils contained in core BAN88-11GC has led to the following conclusions:

- deposition seems to be continuous; it is only partly disturbed by transport and reworking in the core

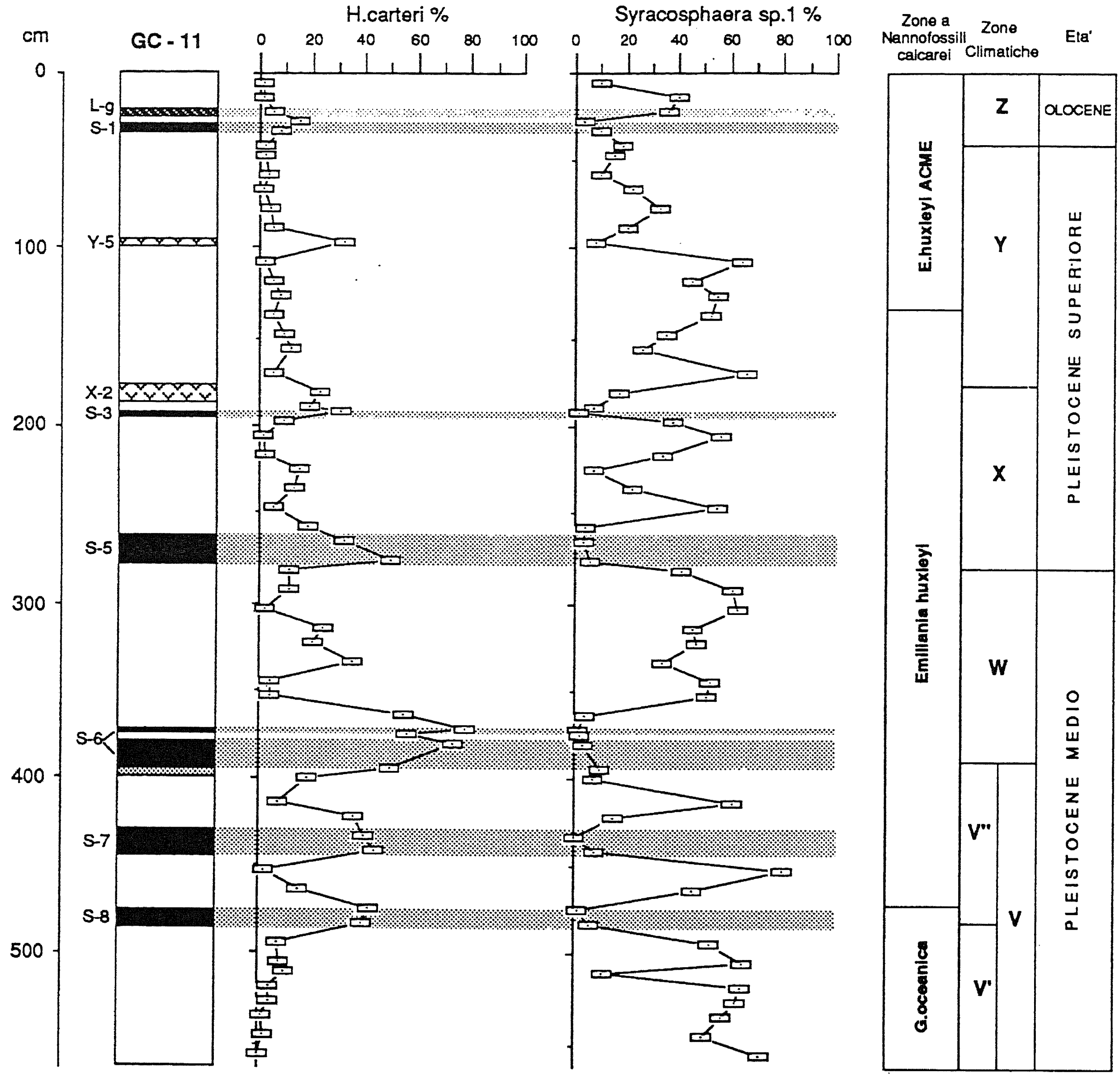

Fig. 15 - Percentage curves of *Helicosphaera carteri* and *Syracosphaera* sp. 1, considered in the second part of the quantitative analysis (see text).

Curva dell'abbondanza percentuale di Helicosphaera carteri *e* Syracosphaera *sp. 1, relativa alla seconda fase dell'analisi quantitativa (v. testo).*

uppermost portion;

- the stratigraphic position of quantitatively defined biostratigrahic events has been precisely stated; these are the *E. huxleyi* Acme, the abundance increase of "small" *Gephyrocapsa* spp. (just below sapropel S-8) and the First Appearance of *E. huxleyi*;
- climatic zones V, W, X, Y and part of Z have been recognized;
- the patterns of climatic curves based on Foraminifera and Thecosomata are well correlatable with some sapropels (S-1, S-5, S-7, warm sapropels; S-6 and S-8, cold sapropels) as well as with other previously known Eastern Mediterranean climatic curves.

Concerning Foraminifera, data suggest as follows:

- *Globigerinoides gomitulus* (or *G. ruber gomitulus*) may represent a temperate or temperate/warm water indicator; it seems anyway a cooler form than *G. ruber;*
- high percentages of *Neogloboquadrina dutertrei* suggest waters with good circulation and high productivity, rather than low salinity. This is supported by the absence of low-salinity species among Thecosomata and calcareous nannoplankton.

Quantitative analyses on Thecosomata point out that:

- the climatic curve based on Thecosomata shows marked cold intervals and less marked warm ones;

- percentage curves reveal that warm indicators *L. trochiformis* and *C. inflexa* are scarce; the climatic curve is therefore almost totally based on *L. retroversa* (cold indicator) and *L. inflata* (warm indicator);
- *G. cordata* and *P. doliiformis* have proved very useful in those intervals where warm indicators are scarce or absent;
- we hypothesize that the prolonged absence of Thecosomata, especially between the two tephra layers,

Table 8 - Percentagesof the "non-dominant" calcareous nannofossil taxa, based on countings of 100 specimens for each sample, excluding the dominant taxa, *Emiliania huxleyi* and *Gephyrocapsa* spp.

Percentuali dei taxa "minori" relativi al conteggio di 100 esemplari di nannofossili, escluse le forme dominanti (Emiliania huxleyi *e* Gephyrocapsa *spp.*).

CAMPIONE	cm dal top	*H.carteri* %	*Syracosphaera* sp.1 %	*Syracosphaera* spp. %	"small" *Reticulofenestra* spp. %	*C.leptoporus* %	*Rhabdosphaera* spp. %	*Umbellosphaera* spp. %	Holococcoliti spp.	*Pontosphaera* spp. %	*C.pelagicus* %	*Ceratolithus* spp. %	*Schyphosphaera* spp. %	*Toracosphaera* spp. %	*Umbilicosphaera* spp. %	*Dictyococcites* spp. %	*S.fossilis* %	ALTRI %
sec.1 cm 6	6	1	10	3	34	1	5	3	0	1	0	0	0	0	0	40	1	1
sec.1 cm 15	15	1	40	13	15	0	4	2	0	0	0	0	0	0	1	21	2	1
sec.1 cm 23	23	5	36	13	3	4	10	4	2	2	0	0	0	0	8	3	4	6
sec.1 cm 27	27	15	3	26	2	2	21	5	4	1	0	1	0	0	6	6	4	4
sec.1 cm 32	32	8	10	14	7	2	16	3	3	1	0	0	0	0	2	23	4	7
sec.1 cm 40	40	2	18	9	23	0	4	2	0	0	0	0	0	0	0	35	2	5
sec.2 cm 5	47	2	15	3	15	1	1	1	1	0	0	0	0	0	0	58	1	2
sec.2 cm 15	57	3	10	5	21	4	1	2	0	0	0	0	0	0	0	53	0	1
sec.2 cm 25	67	1	22	9	32	3	0	2	0	0	1	0	0	0	0	43	0	2
sec.2 cm 35	77	4	33	13	13	1	2	1	0	1	0	0	0	0	1	24	0	7
sec.2 cm 45	87	5	20	14	11	1	4	4	1	1	1	0	0	0	1	29	0	8
sec.2 cm 55	97	32	8	22	8	2	2	5	1	1	2	0	0	0	0	12	0	5
sec.2 cm 65	107	2	64	18	5	0	0	6	0	0	0	0	0	0	0	0	1	4
sec.2 cm 75	117	5	45	16	5	3	2	5	0	0	1	0	0	0	0	15	2	1
sec.2 cm 85	127	8	55	21	0	0	3	2	0	0	0	0	0	0	1	0	9	1
sec.2 cm 95	137	5	52	25	0	3	4	2	2	0	1	0	0	0	0	0	2	4
sec.2 cm 105	147	9	35	15	8	2	3	2	1	1	1	0	0	0	1	14	0	8
sec.2 cm 115	157	12	26	20	10	7	4	6	1	2	2	0	0	1	0	3	1	5
sec.3 cm 5	171	5	66	12	0	1	3	2	0	1	1	0	0	0	1	0	3	5
sec.3 cm 15	181	23	17	19	1	4	11	7	0	5	0	0	1	0	1	0	3	8
sec.3 cm 22	188	19	7	29	0	13	10	8	0	6	1	0	0	1	1	0	7	0
sec.3 cm 25	191	31	1	22	0	1	9	2	16	9	1	1	0	0	1	0	4	2
sec.3 cm 30	196	9	38	25	0	1	13	0	2	2	1	0	0	0	3	0	1	5
sec.3 cm 40	206	1	56	20	3	1	11	0	0	0	0	0	0	0	1	0	1	6
sec.3 cm 50	216	2	34	35	0	1	11	1	0	1	0	0	0	0	2	4	0	9
sec.3 cm 60	226	15	7	33	0	0	16	0	6	3	1	0	0	0	2	0	11	6
sec.3 cm 70	236	13	22	24	0	4	16	4	0	2	1	0	0	0	0	0	4	10
sec.3 cm 80	246	5	55	18	0	0	9	6	0	0	0	0	0	0	1	0	3	3
sec.3 cm 92	258	18	4	36	0	6	5	1	0	0	0	0	0	0	13	0	14	3
sec.3 cm 100	266	32	3	20	1	5	15	1	0	7	0	0	2	1	1	0	1	11
sec.3 cm 110	276	50	6	18	0	3	7	6	2	3	1	1	0	0	0	0	3	0
sec.3 cm 116	282	11	41	16	0	3	17	1	1	2	0	0	0	0	0	1	3	4
sec.4 cm 10	294	11	61	13	2	0	6	0	0	0	0	0	0	0	1	1	0	4
sec.4 cm 20	304	2	63	10	0	1	12	1	1	1	0	0	0	0	1	0	2	6
sec.4 cm 30	314	24	46	11	0	5	6	0	0	2	0	0	0	0	0	1	1	4
sec.4 cm 40	324	20	47	22	0	0	7	0	0	1	0	0	0	0	0	0	0	3
sec.4 cm 50	334	35	34	9	0	2	5	1	4	2	0	0	1	0	0	0	0	7
sec.4 cm 60	344	4	52	21	0	1	6	1	2	0	0	0	0	0	0	0	0	13
sec.4 cm 70	354	4	51	18	0	8	10	0	0	2	0	0	0	0	0	0	1	8
sec.4 cm 80	364	55	4	25	0	6	2	0	0	0	0	0	0	0	0	1	2	5
sec.4 cm 88	372	78	1	7	0	8	2	1	1	1	1	0	0	0	0	0	0	0
sec.4 cm 92	376	56	2	24	1	11	1	0	1	1	1	0	1	0	0	0	0	1
sec.4 cm 98	382	73	3	18	0	5	0	0	1	0	0	0	0	0	0	0	0	0
sec.4 cm 110	394	50	10	30	0	0	4	1	2	0	0	0	0	0	0	0	0	3
sec.4 cm 115	399	18	7	10	0	43	5	4	1	5	3	0	1	0	1	0	1	1
sec.5 cm 10	413	7	61	16	0	3	5	1	0	1	0	0	0	0	0	0	3	3
sec.5 cm 20	423	36	15	17	0	18	6	2	1	2	0	0	1	0	1	0	1	0
sec.5 cm 30	433	40	0	20	0	8	8	2	0	4	0	0	0	1	11	1	3	2
sec.5 cm 38	441	44	8	17	0	2	11	4	2	1	0	0	1	0	6	0	2	2
sec.5 cm 50	453	2	80	12	0	0	4	0	1	0	0	0	0	0	1	0	0	0
sec.5 cm 60	463	15	46	14	0	2	10	2	1	0	1	0	0	0	0	0	7	2
sec.5 cm 70	473	42	1	11	0	19	11	0	0	2	1	0	3	0	2	0	6	2
sec.5 cm 80	483	39	6	22	0	6	19	3	3	0	0	0	0	0	0	0	0	2
sec.5 cm 90	493	7	52	21	0	1	15	1	0	1	0	0	0	0	0	0	1	1
sec.5 cm 100	503	8	65	11	0	0	6	2	0	0	0	0	0	0	2	0	4	2
sec.5 cm 107	510	10	11	26	0	7	20	8	0	2	0	0	0	0	3	0	6	7
sec.5 cm 115	518	4	64	22	1	0	4	1	0	0	0	0	0	0	0	0	2	2
sec.6 cm 5	525	4	62	22	0	1	4	0	1	0	0	0	0	0	0	0	2	4
sec.6 cm 15	535	1	57	24	0	0	8	2	0	1	0	0	0	0	0	0	2	5
sec.6 cm 25	545	2	50	22	0	7	8	0	0	0	0	0	0	0	0	0	1	10
sec.6 cm 35	555	0	71	14	2	1	3	0	0	0	0	0	0	0	3	0	0	6

may have been initially influenced by the deposition of tephra themselves.

The quantitative study of calcareous nannofossils has allowed to:

- point out percentage changes of the dominant species and, where possible, determine their ecologic significance as compared to climatic curves based on planktonic Foraminifera and Thecosomata;
- show percentage variations of *H. carteri* and *Syracosphaera* sp. 1, which are in phase opposition in all sapropels and tephra layers; they should hypothetically be related to the waters turbidity.

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REFERENCES

Almogi-Labin A. (1982) - *Stratigraphic and paleoceanographic significance of Late Quaternary Pteropods from deep-sea cores in the Gulf of Aqaba (Elat) and northernmost Red Sea.* Mar. Micropaleont., **7**, 53-72.

Almogi-Labin A. & Reiss Z. (1977) - *Quaternary Pteropods from Israel.* Rev. Espan. Micropaleont., **9**(1), 5-84.

Arrhenius G. (1952) - *Sediments cores from the East Pacific.* Repts. Swed. Deep-Sea Exped., **5**(1), 1-89.

Bartolini C. (1970) - *Coccoliths from sediments of the western Mediterranean.* Micropaleont., **16**(2), 129-154.

Bè A.W.H., Anderson O.R., Spindler M., Hacunda J. & Tuntivate-Choy S. (1977) - *Laboratory and field observations of living planktonic foraminifera.* Micropaleont., **23**, 155-179.

Bè A.W.H. & Gilmer R.W. (1977) - *A zoogeographic and taxonomic review of Euthecosomatus Pteropoda.* Ocean. Micropaleont., **1**, 733-808.

Bè A.W.H. & Tonderlund D.S. (1971) - *Distribution and ecology of living planktonic Foraminifera in surface waters of the Atlantic and Indian Oceans.* In: Funnel B.M. & Riedel W.R. (Eds.) - *The Micropaleontology of the Oceans*, 105-149.

Biekart J.W. (1989) - *Euthecosomatous Pteropods as paleohydrological and paleoecological indicators in a Tyrrhenian deep-sea core.* Paleogeogr., Paleoclim., Paleoecol., **71**, 205-224.

Blechschmidt G., Cita M.B., Mazzei R. & Salvatorini G. (1982) - *Stratigraphy of the Western Mediterranean and Southern Calabrian Ridges, Eastern Mediterranean.* Mar. Micropaleont., **7**, 101-134.

Bradley W.H. (1938) - *Mediterranean sediments and Pleistocene sea levels.* Science, **88**, 376-379.

Bukry D. (1974) - *Coccoliths as paleosalinity indicators. Evidence from Black Sea.* Am. Ass. Petrol. Geol. Mem., **20**, 353-363.

Camerlenghi A. & Cita M.B. (1987) - *Setting and tectonic evolution of some Eastern Mediterranean deep-sea basins.* Mar. Geol., **75**, 31-55.

Chen C. & Bè A.W.H. (1964) - *Seasonal distribution of Euthecosomatus Pteropoda in the surface waters of five stations in the Western North Atlantic.* Bull. Mar. Sc. Gulf Caribb., **14**(2), 185-220.

Cifelli R. & McCloy C. (1983) - *Planktonic Foraminifera and Euthecosomatus Pteropods in the surface waters of North Atlantic.* J. Foram. Res., **13**(2), 91-107.

Cita M.B., Aghib F., Arosio S., Folco E., Sarto L., Erba E. & Rizzi A. (1989) - *Bacterial colonies and manganese micronodules related to fluid escape on the crest of the Mediterranean Ridge.* Riv. It. Paleont. Strat., **95**(3), 315-336.

Cita M.B., Broglia C., Malinverno A., Spezzi Bottiani G., Tomadin L. & Violanti D. (1982) - *Late Quaternary pelagic sedimentation on the Southern Calabrian Ridge and Western Mediterranean Ridge, Eastern Mediterranean.* Mar. Micropaleont., **7**, 135-162.

Cita M.B., Camerlenghi A., Erba E., McCoy F.W., Castradori D., Cazzani A., Guasti G. Giambastiani M., Lucchi R., Nolli V., Pezzi G., Redaelli M., Rizzi E., Torricelli S. & Violanti D. (1989) - *Discovery of mud diapirism on the Mediterranean Ridge. A preliminary report.* Boll. Soc. Geol. It., **108**, 537-543.

Cita M.B., Chierici M.A., Ciampo G., Moncharmont Zei M., D'Onofrio S., Ryan W.B.F. & Scorziello R. (1973) - *The Quaternary Record in the Tyrrhenian and Ionian basins of the Mediterranean Sea.* In: Ryan W.B.F., Hsu K.J. *et al.* (Eds.) - *Initial Reports. DSDP.* **13**, 1263-1339.

Cita M.B. & Grignani D. (1982) - *Nature and origin of Late Cenozoic Mediterranean sapropels.* In: Schlanger S.O. & Cita M.B. (Eds.) - *Nature and origin of Cretaceous carbon rich facies.* Accademic Press, New York, 165-198.

Cita M.B., Vergnaud-Grazzini C., Robert C., Chamley H., Ciaranfi N. & D'Onofrio S. (1977) - *Paleoclimatic record of a long deep sea core from the Eastern Mediterranean.* Q.. Res., **8**, 205-235.

Cita M.B. & Zocchi M. (1978) - *Distribution patterns of*

Benthic Foraminifera on the floor of the Mediterranean Sea. Oceanologica Acta, **1**, 445-462.

Colombo M.R. & Cita M.B. (1980) - *Changes in size and test porosity of* Orbulina universa *d'Orbigny in the Pleistocene record of Cape Bojador (DSDP Site 397), Eastern North Atlantic.* Mar. Micropaleont., **5**(1), 13-29.

Corselli C. & Grecchi G. (in stampa) - *Considerazioni sui Thecosomata attuali del Bacino Mediterraneo*, Atti 3° Congr. Soc. It. Malacologia.

Davis J.C. (1986) - *Statistics and data analysis in geology*, John Wiley & Sons: 1-646.

De Castro Coppa M.G., Russo B. & Sgarrella F. (1980) - *Distribuzione stagionale e verticale dei Foraminiferi planctonici del Golfo di Napoli.* Boll. Soc. Nat. Napoli, **89**, 1-25.

Deuser W.G. & Ross E.M. (1989) - *Seasonally abundant plaktonic foraminifera of the Sargasso Sea: succession, deep-water fluxes, isotopic compositions and paleoceanographic implications.* J. Foram. Res., **19**(4), 268-293.

D'Onofrio S. (1958) - *I Foraminiferi di una carota sottomarina del medio Adriatico*, Giorn. Geol., s. 2, **27**, 147-190.

Emiliani C. (1966) - *Paleotemperature analysis of Caribbean cores P 6304-8 and P 6304-9 and generalized temperature curve for the last 425000 years.* J. Geol., **74**, 109-126.

Erba E., Parisi E. & Cita M.B. (1987) - *Stratigraphy and sedimentation in the western Strabo Trench, Eastern Mediterranean.* Mar. Geol., **75**, 57-75.

Ericson D.B. & Wollin G. (1968) - *Pleistocene climates and chronology in deep-sea sediments.* Science, **162**, 1227-1234.

Fairbanks R.G. & Wiebe P.H. (1980) - *Foraminifera and Chlorophyll Maximum: vertical distribution, seasonal succession, and paleoceanographic significance,* Science **209**(4464), 1524-1525.

Fairbanks R.G., Wiebe P.H & Bè A.W.H. (1980) - *Vertical distribution and isotopic composition of living planktonic foraminifera in the Western North Atlantic,* Science, **207**(4426), 61-63.

Furnestin M.L. (1979) - *Planktonic molluscs as hydrological and ecological indicators.* In: Van Der Spoel S. *et al.* (Eds.) - *Pathways in Malacology*, 175-194.

Gartner S. (1972) - *Late Pleistocene calcareous nannofossils in the Caribbean and their interoceanic correlations.* Paleogeogr., Paleoclim., Paleoecol., **12**, 169-191.

Gartner S. (1977) - *Calcareous nannofossils biostratigraphy and revised zonation of the Pleistocene.* Mar Micropaleont., **2**, 1-25.

Gartner S. (1988) - *Paleoceanography of the Mid-Pleistocene.* Mar. Micropaleont. **13**(1), 23-46.

Gartner S., Chow J. & Stanton R.J. jr. (1987) - *Late Neogene paleoceanography of the eastern Caribbean, the Gulf of Mexico and the eastern equatorial Pacific.* Mar Micropaleont., **12**(3), 255-304.

Grecchi G. (1984) - *Molluschi planctonici e bentonici in sedimenti sapropelitici del Quaternario della Dorsale Mediterranea.* Boll. Malacologico, **20**(1-4), 1-34.

Grecchi G. (1987) - *Revisione tassonomica degli esemplari fossili e subfossili di* Clio polita *rinvenuti in Mediterraneo e in Mar Rosso.* Boll. Malacol., **23**(9-10), 297-303.

Grecchi G. & Bertolotti M.G. (1988) - *Interpretazione paleoclimatica della carota CG18-BAN-82 basata sull'analisi di Thecosomata Euthecosomata del Quaternario del Mediterraneo orientale.* Boll. Mus Region. Sc. Nat. Torino, **6**(1), 73-132.

Hemleben C. & Spindler M. (1983) - *Recent advances in research on living planktonic Foraminifera.* In: Meulenkamp E. (Ed.) - *Reconstruction of marine paleoenvironments.* Utrecht Micropaleont. Bull., **30**, 141-170.

Hemleben C., Spindler M.& Anderson O.R. (1989) - *Modern planktonic foraminifera.* Springer-Verlag, 1-363.

Hermelin J.O.R. & Shimmield G.B. (1990) - *The importance of the Oxygen Minimum Zone and sediment geochemistry in the distribution of recent benthic foraminifera in the northwest Indian Ocean.* Mar. Geol., **91**, 1-29.

Huang T.C. & Stanley D.J. (1972) - *Western Alboran Sea: sediment dispersal, ponding and reversal of currents.* In: Stanley D.J. (Ed.) - *The Mediterranean Sea: a natural sedimentation laboratory.* Dowden, Hutchinson & Ross, Stroudsbourg, 521-559.

Imbrie J. & Kipp N.G. (1971) - *A new micropaleontological method for quantitative paleoclimatology: application to a late Pleistocene Caribbean core.* In: Turekian K. (Ed.) -*The Late Cenozoic Glacial Ages.* Yale Univ. Press, 71-181.

Ivanova E.V. (1985) - *Late Quaternary biostratigraphy and paleotemperatures of the Red Sea and the Gulf of Aden based on planktonic Foraminifera and Pteropods.* Mar. Micropaleont., **9**, 335-364.

Lalli C.M. & Conover R.J. (1973) - *Reproduction and development of* Paedoclione doliiformis, *and a comparison with* Clione limacina *(Opisthobranchia: Gymnosomata).* Mar. Biol., **19**(1), 13-22.

Lalli C.M. & Conover R.J. (1976) - *Microstructure of the veliger shells of Gymnosomatous Pteropods (Gasteropoda: Opisthobranchia).* The Veliger, **18**(3), 237-240.

Lutze G.F. (1977) - *Neogene benthonic foraminifera from Site 369, Leg 41.* In: Lancelot Y., Seibold E. *et al.* (Eds.) - *Initial Reports. DSDP 41.* 659-666.

Katz M.E. & Thunell R.C. (1984) - *Benthic foraminiferal biofacies associated with Middle Miocene to Early Pliocene oxygen-deficient conditions in the Eastern Mediterranean.* J. Foram. Res., **14**(3), 187-202.

Keller J., Ryan W.B.F., Ninkovich D. & Altherr R. (1978) - *Explosive volcanic activity in the Mediterranean over the past 200,000 yr as recorded in deep-sea sediments.* Geol. Soc. Am. Bull., **89**, 591-604.

Kennett J.P. & Srinivasan M.S. (1983) - *Neogene Planktonic Foraminifera. A Phylogenetic Atlas.* Hutchinson Ross Publ. Company, 265 pp.

Kullenberg B. (1952) - *On the salinity of the water contained in marine sediments.* Goteborg Kongl. Vet. Vitterh. Sam. Handl., B, **6**(6), 1-337.

Mairani A. (1987) - *Variazioni del diametro di* Orbulina universa *in due carote di mare profondo del Mediterraneo orientale. Significato paleoclimatico.* Tesi ined., Univ. Milano, 200 pp.

McIntyre A. & Bè A.W.F. (1967) - *Modern Coccolithophoridae of the Atlantic Ocean. Placoliths and Cirtholiths.* Deep-Sea Res., **17**, 561-597.

McIntyre A., Ruddiman W.F. & Jantzen R. (1972) - *Southward penetrations of the North Atlantic Polar Front: faunal and floral evidence of large-scale surface water mass movements over the last 225,000 years.* Deep-Sea Res., **19**, 61-77.

Mistretta F. (1962) - *Foraminiferi planctonici del Pliocene inferiore di Altavilla Milicia (Palermo, Sicilia).* Riv. It. Paleont. Strat., **68**(1), 97-114.

Moncharmont Zei M., Russo B., Sgarrella F., Bonaduce G. & Mascellaro P. (1984) - *Paleoclimatic record from 4 cores (Gulf of Taranto, Ionian Sea). Evidence from Foraminifera and Ostracoda.* Boll. Soc. Paleont. It., **23**(1), 21-51.

Müller C. (1985) - *Late Miocene to Recent Mediterranean biostratigraphy and paleoenvironments based on calcareous Nannoplakton.* In: Stanley D.J. & Wezel F.C. (Eds.) - *Geological evolution of the Mediterranean Sea.* 471-485.

Mullineaux L.S. & Lohmann G.P.(1981) - *Late Quaternary stagnations and recirculation of the Eastern Mediterranean: changes in the deep water recorded by fossil benthic foraminifera.* J. Foram. Res., **11**(1), 20-39.

Olausson E. (1960) - *Sediment cores from the Mediterranean Sea and Red Sea.* Repts. Swedish Deep-sea Exped. 1947-1948, **8**(3), 287-321.

Olausson E. (1961) - *Studies of deep-sea cores.* Repts. Swedish Deep-sea Exped. 1947-1948, **8**(4), 323-438.

Olausson E. (1989) - *Carbon and oxygen isotopic composition of foraminifera in two cores from Bannock Basin Area (Eastern Mediterranean),* In: *Anoxic Basins of the Eastern Mediterranean.* Ric. Scient. Educ. Perm., **72**, 42-44.

Parisi E. (1982) - *Distribuzione dei Foraminiferi bentonici in una carota della Dorsale Mediterranea (Pleistocene medio e superiore).* Riv. It. Paleont. Strat., **88**(4), 641-677.

Parisi E. (1987a) - *Evoluzione paleoclimatica e paleoambientale del Mediterraneo orientale dal Pleistocene all'Attuale.* Tesi di Dottorato Univ. Milano, 413 pp.

Parisi E. (1987b) - *Carbon and Oxygen isotope composition of Globigerinoides ruber in two deep-sea cores from the Levantine Basin (Eastern Mediterranean).* Mar. Geol., **75**, 201-219.

Parisi E & Cita M.B. (1982) - *Late Quaternary paleoceanographic changes recorded by deep-sea benthos in the Western Mediterranean Ridge.* Geogr. Fis. Din. Quatern., **5**, 102-114.

Parisi E., Erba E. & Cita M.B. (1987) - *Stratigraphy and sedimentation in the anoxic Bannock Basin (Eastern Mediterranean).* Mar. Geol., **75**, 93-117.

Parker F.L. (1958) - *Eastern Mediterranean Foraminifera.* Repts Swedish Deep Sea Exped. 1947-1948, **8**, 219-283.

Parker F.L. (1962) - *Planktonic foraminiferal species in Pacific sediments,* Micropaleont., **9**(2), 219-254.

Phleger F.B., Parker F.L. & Peirson J.F. (1953) - *North Atlantic Foraminifera,* Repts Swed. Deep-Sea Exped. **7**(1), 3-122.

Rio D. (1982) - *The fossil distribution of Coccolithophore Genus Gephyrocapsa Kamptner and related Plio-Pleistocene chronostratigraphic problems.* Init. Repts. DSDP, **68**, 325-343.

Rio D., Raffi I. & Villa G. (1990) - *Pliocene-Pleistocene calcareous nannofossils distribution patterns in the Western Mediterranean.* In: Kastens K.A., Mascle J. *et al.* - Proceedings ODP Science *Results.* **107**, 513-533.

Rossignol-Strick M. (1983) - *African monsoons, an immediate climate response to orbital insolation.* Nature, **303**(5921), 46-49.

Rossignol-Strick M., Nesteroff W., Olive P. & Vergnaud-Grazzini C. (1982) - *After the deluge: Mediterranean stagnation and sapropel formation.* Nature, **295**(5845), 105-110.

Roth P.H. & Coulbourn W.T. (1982) - *Floral and solution patterns of coccoliths in surface sediments of the North Pacific.* Mar. Micropaleont., **7**(1), 1-52.

Ruddimann W.F. (1971) - *Pleistocene sedimentation in the equatorial Atlantic: stratigraphy and climatology.* Geol. Soc. Am. Bull., **82**, 283-302.

Ryan W.B.F. (1972) - *Stratigraphy of Late Quaternary sediments in the Eastern Mediterranean.* In: Stanley D. J. (Ed.) - *The Mediterranean Sea: a natural sedimentation laboratory.* Dowden, Hutchinson & Ross, Stroudsbourg, 149-170.

Ryan W.B.F., Kastens K.A. & Cita M.B. (1982) - *Geological evidence concerning compressional tectonics in the Eastern Mediterranean.* In: Le Pichon X. *et al.* (Eds.) - *Geodynamic of the Hellenic Arch and Trench.* Tectonophysics, **86**, 213-242.

Sigl W. & Muller C. (1975) - *Identification and correlation of stagnation layers in cores from the eastern Mediterranean.* Rapp. CIESM, **23**, 277-279.

Srinivasan M.S. & Kennett J.P. (1976) - *Evolution and phenotipic variation in the Late Cenozoic Neogloboquadrina dutertrei plexus.* In: Takayanagi Y. & Saito T. (Eds.) - *Progress in Micropaleontology.* 329-355.

Stanley D.J. & Maldonado A. (1977) - *Levantine Sea - Nile cone lithostratigraphy evolution: quantitative analysis and correlation with paleoclimatic and eustatic oscillations in the Late Quaternary.* Sedim. Geol., **23**, 37-65.

Sutherland H.E., Calvert S.E. & Morris R.J. (1984) - *Geochemical studies of the recent sapropel and associated sediment from the Hellenic Outer Ridge, Eastern Mediterranean Sea. 1: Mineralogic and chemical composition.* Mar. Geol., **56**, 93-118.

Thierstein H.R., Geitzenauer K.R., Molfino B. & Shackleton N.J. (1977) - *Globàl synchroneity of Late Quaternary coccolith datum levels: validation by oxygen isotopes.* Geol., **5**, 400-404.

Thunell R.C. (1978) - *Distribution of recent planktonic Foraminifera in surface sediments of the Mediterranean Sea.* Mar. Micropaleont., **3**(2), 147-173.

Thunell R.C. & Williams D.F. (1983) - *Paleotemperature and paleosalinity of the eastern Mediterranean during the Late Quaternary.* Paleogeogr., Paleoclim., Paleoecol., **44**, 23-39.

Thunell R.C., Williams D.F. & Kennett J.P. (1977) - *Late Quaternary paleoclimatology, stratigraphy and sapropel history in Eastern Mediterranean deep-sea sediments.* Mar. Micropaleont., **2**, 371-388.

Thunell R.C., Williams D.F. & Cita M.B. (1983) - *Glacial anoxia in the Eastern Mediterranean.* J. Foram. Res., **13**(4), 283-290.

Tregouboff G. & Rose M. (1957) - *Manuel de Planctonologie Mediterranéenne.* C.N.R.S., **1**, 587 pp.

Van Der Spoel S.(1967) - *Euthecosomata, a group with remarkable developmental stages (Gastropoda, Pteropoda).* Noord. en Zoon, 375 pp.

Van Der Spoel S. (1976) - *Pseudothecosomata, Gymnosomata and Heteropoda (Gastropoda).* Bohn, Scheltema & Holkema, 484 pp.

Vergnaud-Grazzini C., Ryan W.B.F. & Cita M.B. (1977) - *Stable isotopic fractionation, climate changes and episodic stagnation in the Eastern Mediterranean during the Late Quaternary.* Mar. Micropaleont.,**2**, 353-370.

Violanti D., Parisi E. & Erba E. (1987) - *Fluttuazioni climatiche durante il Quaternario nel Mar Tirreno, Mediterraneo occidentale (carota PC-19 Ban 80).* Riv. It. Paleont. Strat., **92**(4), 515-570.

Violanti D. & Saccà D. (1989) - *Foraminiferi planctonici ed oscillazioni climatiche nella carota BAN84-27 (Mediterraneo Orientale).* Riv. It. Paleont. Strat., **94**(3), 455-476.

Vismara Schilling A. (1984) - *Holocene stagnation event in the Eastern Mediterranean. Evidence from Deep-sea Benthic Foraminifera in the Calabrian and Western Mediterranean Ridges.* Proc. 2nd. Int. Symp. Benthic Foram., 585-596.

Vismara Schilling A. (1986) - *Foraminiferi bentonici profondi associati ad eventi anossici del Pleistocene medio e superiore nel Mediterraneo orientale.* Riv. It. Paleont. Strat., **92**(1), 103-148.

Wright R. (1978) - *Neogene paleobathymetry of the Mediterranean based on benthic foraminifers from DSDP 42A,* In: Hsu K.J., N.Montadert L. *et al.* - *Initial Reports DSDP* **42A**, 837-844.

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