

Bollettino della Società Paleontologica Italiana	36 (1-2), 1997	ISSN 0375-7633	261-274	3 pls.	Parma, Dicembre 1997
--	----------------	----------------	---------	--------	----------------------

Micropaleontological record in the Pliocene of Genoa-Arenzano area

Alessandra NEGRI* Camilla PIRINI** Sabrina RAZZORE** Maria Cristina BONCI**
Gabriella CIRONE** Nicoletta MANCIN*** Maurizio VIAGGI****

* Dipartimento di Scienze della Terra, Università di Ancona

** Dipartimento di Scienze della Terra, Università di Genova

*** Dipartimento di Scienze della Terra, Università di Pavia

**** AGIP S. p. A. San Donato Milanese (present adress)

KEY WORDS - Biostratigraphy, Paleoecology, Early Pliocene, Genoa-Arenzano (Italy).

ABSTRACT - This paper aims to analyze microfossil assemblages (diatoms, calcareous nannofossils and foraminifers) found in scattered Pliocene outcrops referred to the Argille di Ortovero Formation. The studied samples were collected in two different areas of the Genoa Province (Arenzano and Genoa town-centre) both from geoenvironmental boreholes and from digs for building foundations.

Biostratigraphically representative species of the different assemblages were recognized; statistic morphofunctional and quantitative analyses were furthermore carried out on benthic and planktic taxa respectively, providing useful data on palaeoenvironmental and palaeoclimatic conditions. The integrated biostratigraphic study allowed to recognize the following Zones: *Thalassiosira convexa* Zone (subzone C), *MNN12* (*Amaurolithus tricorniculatus* Zone), *MPL1* (*Sphaeroidinellopsis seminulina* Zone, post-acme). The presence of *Globorotalia margaritae* (*MPL2*) is furthermore reported from other sections in the same areas.

The present work is part of a more general research on the Pliocene of the western Liguria.

RIASSUNTO - [Record micropaleontologico nel Pliocene dell'area di Genova-Arenzano] - Questo lavoro ha lo scopo di evidenziare le varie associazioni di microfossili (diatomee, nannofossili calcarei e foraminiferi) presenti in lembi pliocenici appartenenti alla Formazione delle Argille di Ortovero. Lo studio interessa due differenti siti della provincia di Genova (Arenzano e Genova centro) ed è stato condotto sia su campioni provenienti da sondaggi eseguiti per opere di edilizia sia su campioni provenienti da scavi durante sbancamenti antropici.

Oltre al riconoscimento delle specie più significative e rappresentative delle diverse associazioni sono state effettuate analisi statistiche morfofunzionali sui taxa bentonici e quantitative sui taxa planctonici, che hanno fornito dati utili per la ricostruzione paleoambientale e paleoclimatica.

Lo studio biostratigrafico integrato ha permesso di definire le seguenti zone: Zona a *Thalassiosira convexa* (sottizona C), *MNN 12* (Zona ad *Amaurolithus tricorniculatus*), *MPL1* (Zona a *Sphaeroidinellopsis seminulina*, post-acme). Va inoltre segnalata la presenza di *Globorotalia margaritae* (*MPL2*) in campioni prelevati in altre successioni delle stesse aree.

Questa ricerca è parte di un più ampio studio sui lembi pliocenici affioranti nella Liguria occidentale.

INTRODUCTION

In the Genoa and Arenzano areas outcrops referred to the Pliocene are recorded along an E-W belt, parallel to the coastline. They mainly consist of firm to stiff blue-gray marls with interbedded macrofossil rich sandy layers.

In this area in the vast majority of cases the Pliocene versus other units boundary is of tectonic origin. However it is very difficult to observe it because of the presence of either alluvial and detritic deposits or intensive urbanization hiding outcrops. Thus the large amount of samples have been recovered by means of geoenvironmental drilling or along quarries.

The present paper, part of a wider research dealing with the western Liguria Pliocene outcro-

ps, aims to compare the microfossil assemblages characterizing the "Argille di Ortovero" Formation in the two above cited areas. Biostratigraphic analyses have been performed on foraminifers, calcareous nannofossils and diatoms. Further statistic morpho-functional analyses on benthic and planktic foraminifers have been carried out to better reconstruct palaeoenvironments and palaeoclimate.

MATERIAL AND METHODS

The studied samples have been recovered in four different sites : Valdolivo and Terralba in the Arenzano area, SM (San Martino) and SR (Via Serra) drill sites in the Genoa town. In the fol-

lowing lines are described the main geological features for each site.

VALDOLIVO BOREHOLE

The outcrop is located S-SE of the Valdolivo village (Text-fig. 1); northward a fault 60° N make the boundary with the Molare Formation (Oligocene). Toward the South an other tectonic boundary separates the Pliocene from the Voltri Group serpentinites and calceschists (Jurassic). East and westward the boundaries are hidden by detrital and pebbly deposits.

The borehole reached a depth of 70 m, however only the topmost 6 m are referred to the "Argille di Ortovero" Formation (Text-fig. 2). Between 6 and 16 m a thick interval consisting of gray to greenish arenites and sands, barren of fossils, has been observed. This interval has been referred to the Molare Formation (Cortesogno *et al.*, 1977; Viaggi, 1986). Between 16 and 70 m conglomerates and breccias are recovered passing toward the base of the drill to weathered green serpentinites related to the Voltri Group.

Biostratigraphic analyses were carried out on 13 samples of the topmost 6 m.

TERRALBA SECTION

The section is located NW of the Arenzano village (Text-fig. 1). Northward the tectonic boundary with the Voltri Group prasinites is observed, while west and southward the contact again of tectonic origin is with the Voltri Group serpentinites and calceschists. Toward the East detrital deposits hide any boundary.

The section (Text-fig. 2) shows 4 m of marls and clayey marls, referred to the "Argille di

Ortovero" Formation, characterized by increasing amount of clasts, toward the base related to the substratum. Between 2.5 and 3 m a coarser layer (sand and pebbles) rich in infralittoral macrofossils has been observed.

Biostratigraphic analyses were carried out on 6 samples.

SM BOREHOLE

In the Genoa area the Pliocene sediments lay on the "Calcarei di Monte Antola" Formation mainly because of tectonic contact, only rarely a transgressive boundary can be observed.

The SM (Text-fig. 3) borehole reached a depth of 50 m, coring a thick succession of blue-gray marls and clayey marls ("Argille di Ortovero" Formation). The borehole did not reach the limestones of the Monte Antola Formation. Two poorly cemented fine sand levels have been observed at 21 and 37 m. Between 48 and 50 m an increase in calcareous fragments is reported.

Biostratigraphic analyses were carried out on 20 samples.

SR BOREHOLE

The borehole (Text-fig. 3) reached 20 m depth. The upper 10 m of the drilling consist of a green-gray silty clay ("Argille di Ortovero" Formation) in which macrofossils have been observed. Between 4.10 and 4.40 m a sandy layer is reported. Breccias in a clayey matrix have been found between 10 and 15 m passing at the base to the limestones of the M. Antola Formation.

Biostratigraphic analyses were carried out on 7 samples.

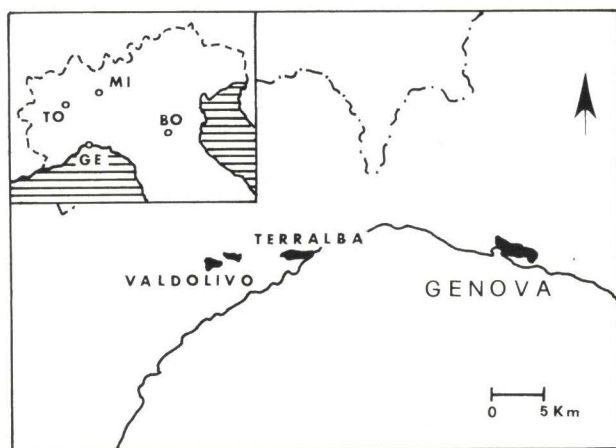
RESULTS

DIATOMS

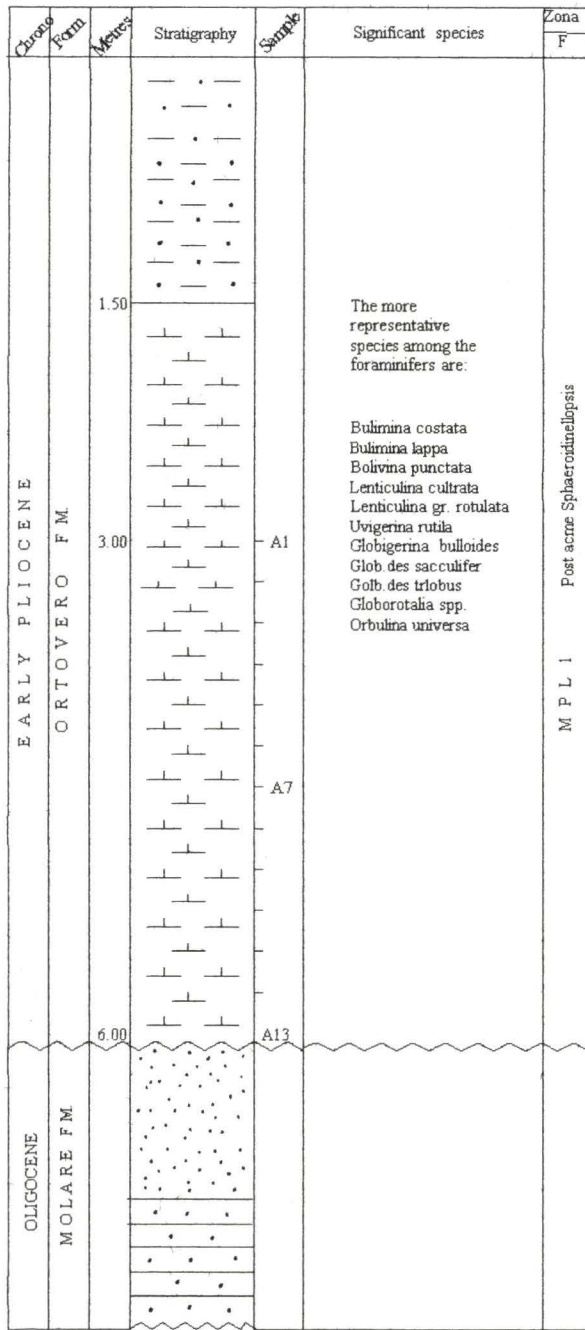
Samples from SM and Valdolivo boreholes report the occurrence of diatoms. The SM boreholes yielded a moderately preserved and diversified assemblages. The following taxa are well represented (see also Bonci *et al.*, 1993): *Thalassionema* group (pennates), *Coscinodiscus*, *Azpeitia* and *Thalassiosira* (centrales).

CALCAREOUS NANNOFOSSILS

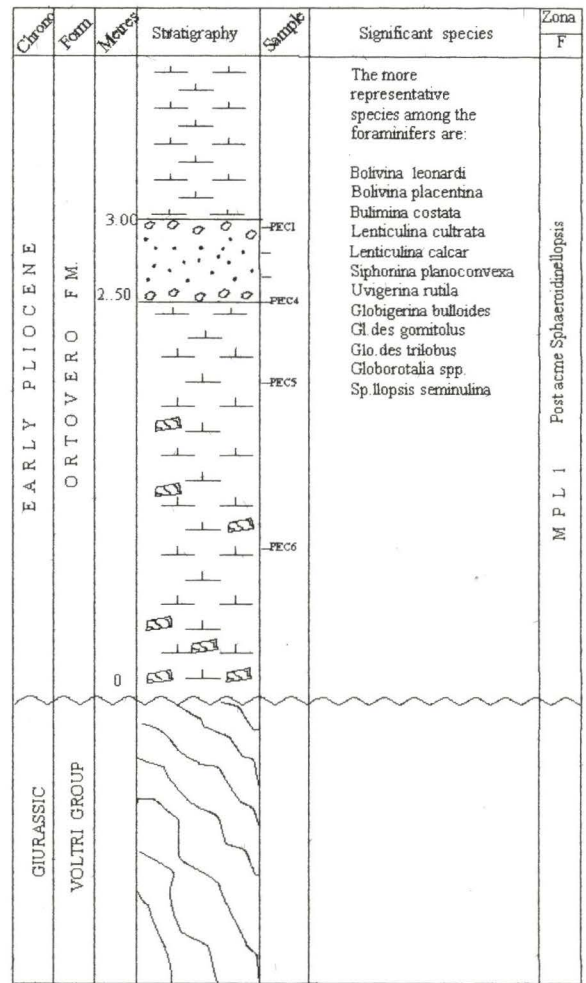
Calcareous nannofossil analyses were carried out on selected samples (15) from the drill sites SM and SR (Pl. 1). The assemblage show modera-



Text-fig. 1 - Location of the studied successions.



Valdolivo borehole

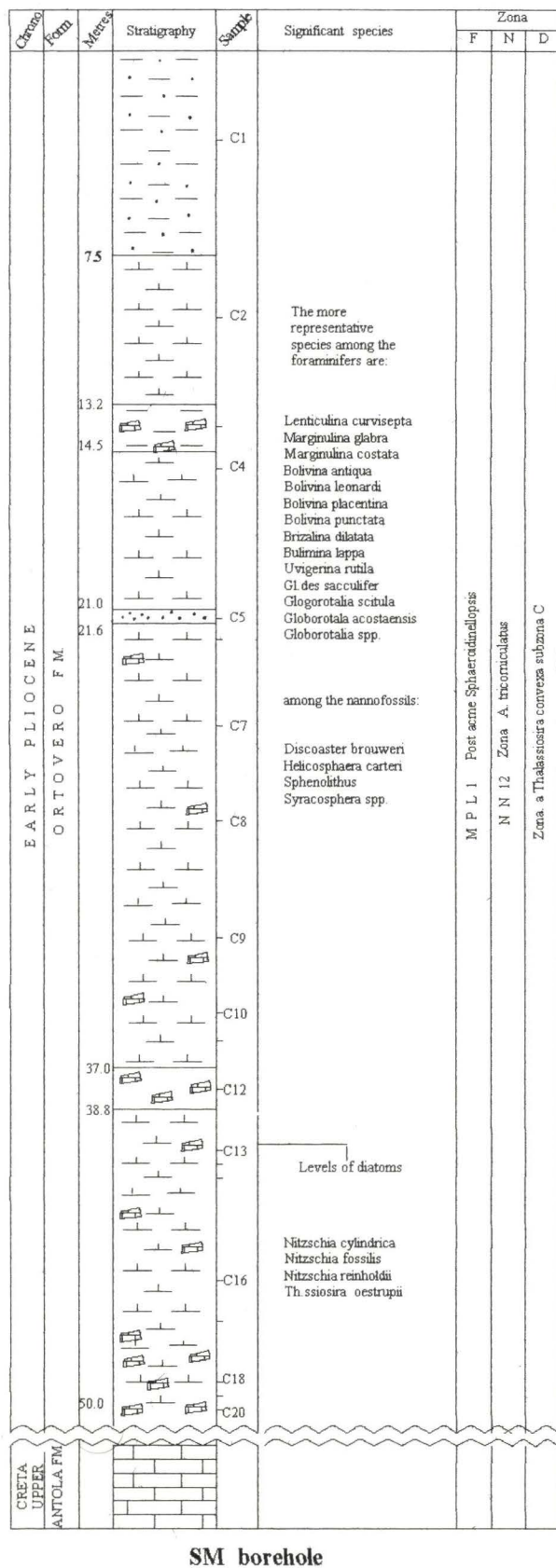


Terralba section

 Sand
  Pebbles
  Sandstone
  Silty clay
  Marl
  Calcschists
  Calcschist fragments

0 50 100 cm

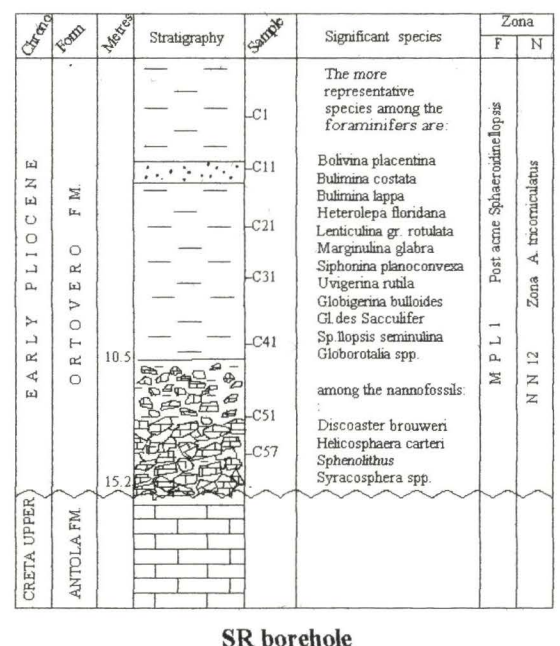
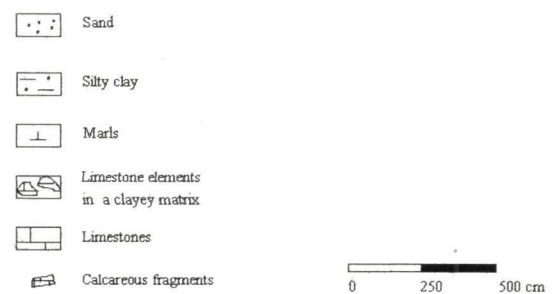
Text-fig. 2 - Stratigraphic logs of Valdolivo borehole and Terralba section in the Arenzano area



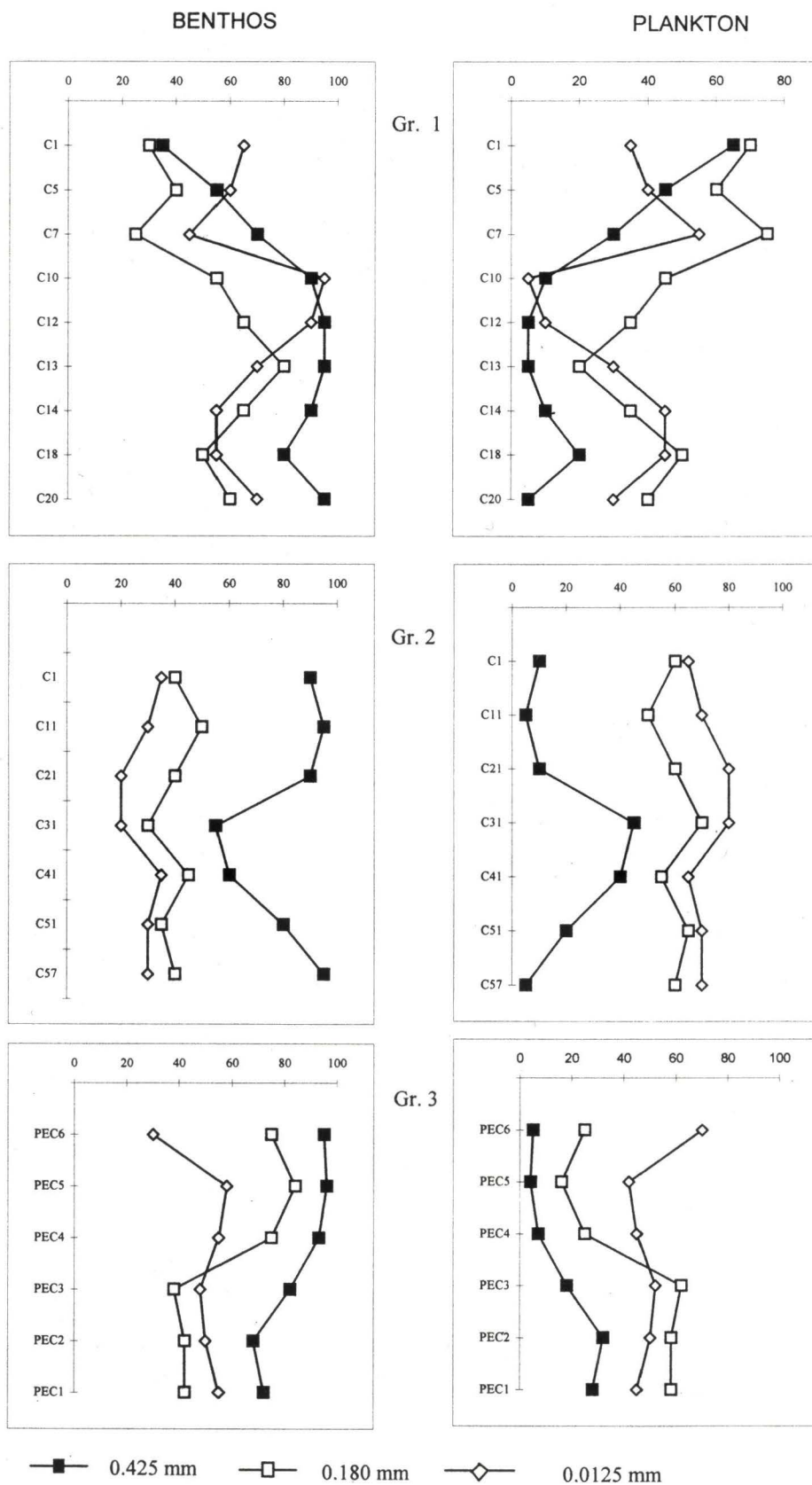
te to good preservation and nannofossils are abundant throughout the two sites. Analyses were carried out either quantitatively and semiquantitatively following the methodology described in Rio *et al.* (1990) to define zonal boundaries in the biostratigraphic scheme of the same authors.

In particular the frequency of the genus *Amaurolithus* and *Discoaster* were evaluated counting the number of specimens observed in 1000 fields of view at 1250 X magnification. The frequencies of the *Helicosphaera* species were evaluated counting 100 specimens of the same genus. Finally a semiquantitative estimate of the total assemblage was carried out. Results are shown in Tab. 1.

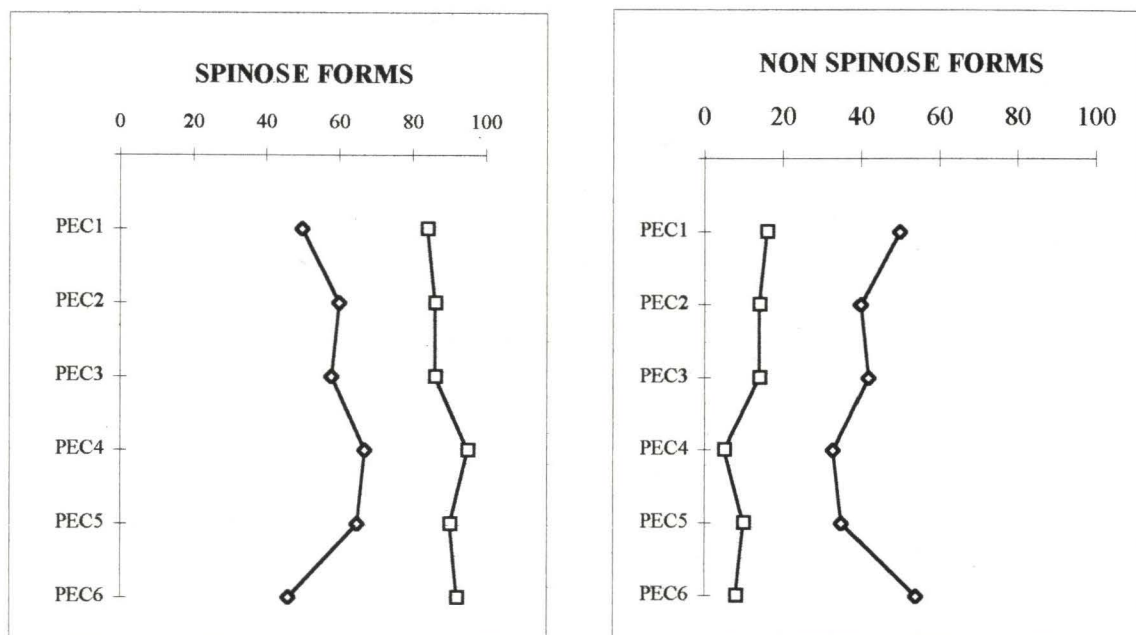
SM Borehole - The *Discoaster* assemblage, mainly consisting of *D. brouweri* shows a decreasing trend toward the base of the core. Very rare



Text-fig. 3 - Stratigraphic logs of SM and SR boreholes in the Genoa Area



Text-fig. 4 - Plankton/benthos ratio : Gr. 1 : SM Borehole (Genoa) ; Gr.2 : SR Borehole (Genoa) ; Gr.3 : PEC section (Terralba)



Text-fig. 5 - Trend of spinose and non spinose forms of plankton (Terralba section).

and scattered *D. calcaris*, *D. neorectus* and *D. pseudovariabilis* have been also found. No *Discoaster quinqueramus* has been observed.

Among the placoliths *Coccolithus pelagicus* and *Geminolithella rotula* are commonly recorded, *Calcidiscus leptoporus* and *Calcidiscus macintyreii* occur rare but continuous. *Reticulofenestra pseudumbilica* is recorded almost in all the studied samples and, worth of note, in samples 18, 16 and 4 abundant small reticulofenestrids are present.

Amaurolithus delicatus occurs rare and

discontinuous and *Amaurolithus tricorniculatus* is present only in the topmost sample of the section.

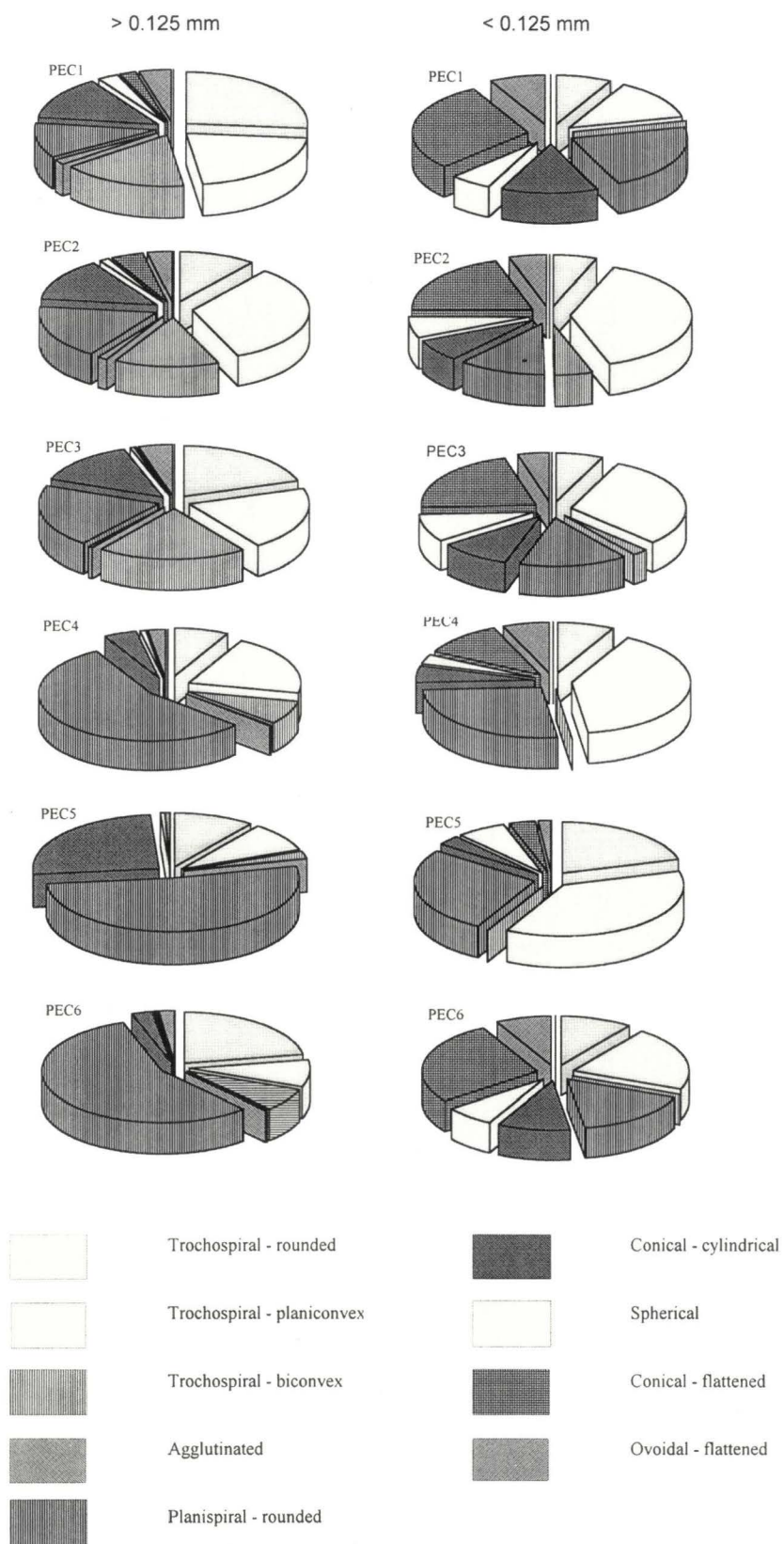
The Helicoliths, common throughout the section, mainly consist of *Helicosphaera carteri* with subordinate *H. intermedia*. No specimens of *Helicosphaera sellii* have been found.

Finally *Scyphosphaera* spp., *Syracosphaera* spp., are common throughout the borehole together with *Sphenolithus* spp. and *Rhabdosphaera* spp.

Worth of note the occurrence of common Cretaceous reworked specimens.

	samples	<i>A. delicatus</i>	<i>A. tricorniculatus</i>	<i>Ceratholithus</i> sp. ?	<i>D. asymmetricus</i>	<i>D. brouweri</i>	<i>D. calcaris</i>	<i>D. intercalaris</i>	<i>D. pentaradiatus</i>	<i>D. pseudovariabilis</i>	<i>D. surculus</i>	<i>D. variabilis</i>	<i>D. neorectus</i>	<i>Discoaster</i> sp.	<i>H. intermedia</i>	<i>H. carteri</i>	<i>H. cf. walbersdorffensis</i>	<i>H. cf. sellii</i>	<i>H. sellii</i>	<i>C. pelagicus</i>	<i>C. macintyre</i>	<i>C. leptopus</i>	<i>G. rotula</i>	<i>S. abies</i>	small * placoliths	small <i>gephyrocapsa</i> ?	<i>R. pseudumbilica</i>	<i>Scyphosphaera</i> spp.	<i>Portosphaera</i> spp.	<i>Rhabdosphaera</i> spp.	<i>Syracosphaera</i> spp.	<i>Brauniosphaera</i> spp.	<i>Cretaceous</i> rev.	siliceous remains	preservation	
SM	1	1	1	0	0	46	0	0	1	0	0	3	0	0	0	100	0	0	0	0	0	0	0	0												
SM	3	3	0	0	0	22	0	0	7	0	7	9	0	17	0	100	0	0	0	0	0	0	0	0												
SM	4	1	0	0	0	30	0	0	0	0	2	1	2	4	4	94	2	0	0	0	0	0	0	0	A											
SM	5	1	0	0	0	5	0	0	0	1	2	0	0	0	4	96	0	0	0	0	0	0	0	0												
SM	7	0	0	0	0	6	0	6	1	0	4	1	0	2	0	98	0	2	0	0	0	0	0	0												
SM	10	0	0	0	0	1	0	0	2	0	0	3	0	0	0	100	0	0	0	0	0	0	0	0												
SM	13	0	0	0	0	0	0	0	0	0	0	0	0	0	0	100	0	0	0	0	0	0	0	0												
SM	16	0	0	0	0	1	0	0	2	0	2	0	0	1	0	100	0	0	0	0	0	0	0	0												
SM	18	1	0	0	0	2	0	0	0	0	0	0	0	0	1	99	0	0	0	0	0	0	0	0	A											
SM	19	0	0	0	0	0	0	0	0	0	0	0	0	0	0	100	0	0	0	0	0	0	0	0												
SR	1	0	0	0	0	29	0	1	2	0	2	2	3	6	1	99	0	0	0	0	0	0	0	0	AA	R	F	C	C	C	C	C	C	C	M	G
SR	3	0	0	0	0	80	1	2	2	0	1	1	3	12	0	100	0	0	0	0	0	0	0	0	AA	R	F	C	C	C	C	C	C	C	M	G
SR	13	5	0	0	1	70	1	2	9	2	16	16	0	11	6	94	0	0	0	0	0	0	0	0	AA	R	F	C	C	C	C	C	C	C	M	G
SR	23	7	0	4	1	107	0	1	0	0	11	3	1	3	0	100	0	0	0	0	0	0	0	0												
SR	33	1	0	0	0	21	0	2	6	0	0	0	0	3	0	100	0	0	0	0	0	0	0	0												
Number of specimens per 1000 fields of view at 1250X															% per 100 counted specimens					A = abundant, 1 or more specimens every field of view; C = common, 1 spec. every 2-10 f. of v.; F = few, 1 specimen every 11-50 f. of v.; R = rare, 1 spec. every 51-200 f. of v.; RR = very rare, less than one spec. every 200, f. of v.																

Tab. 1 - Distribution of the calcareous nannofossils in SM and SR boreholes (Genoa).



Text-fig. 6 - Morphofunctional benthic analyses related to the Terralba samples.

SR Borehole - The *Discoaster* assemblage is well represented in all the samples. Also in this borehole rare *D. calcaris*, *D. neorectus* and *D. pseudovariabilis* have been found, while no *Discoaster quinqueramus* is reported.

Reticulofenestra pseudumbilica is present in almost all the samples. Worth of note the occurrence in all the samples of abundant small reticulofenestrids.

Amaurolithus delicatus is always showing a slight birefringence (diagenesis ?) and is absent at the top of the borehole. Few specimens dubitatively referred to *Ceratholithus* have been found in sample SR 23.

Helicoliths are common throughout the section and mainly consists of *Helicosphaera carteri* with subordinate *H. intermedia*. No specimens of *Helicosphaera sellii* have been found.

Finally, *Scyphosphaera* spp., *Syracosphaera* spp., are common throughout the borehole together with *Sphenolithus* spp. and *Rhabdosphaera* spp.

Also in these samples worth of note is the occurrence of common Cretaceous reworked specimens.

Valdolivo borehole and Terralba section - Qualitative analyses performed on samples from these two sites confirm the occurrence of *Amaurolithus delicatus* and the absence of *Helicosphaera sellii*. The assemblages show the same features as SM and SR boreholes.

FORAMINIFERS

Foraminifer analyses have been carried out on all samples from the four sites. The assemblage is

always rich and well preserved, showing similar features in the four studied sections (Pls. 2-3).

Benthic forms are always prevailing on planktic ones and mainly consist of the following taxa: *Lenticulina* (*L. cultrata*, *L. rotulata*), *Marginulina* (*M. costata*, *M. glabra*), *Bolivina* (*B. placentina*, *B. punctata*) and *Uvigerina* (*U. rutila*). Planktic foraminifers consist of the following species: *Globigerina bulloides*, *Globigerinoides* (*Gl. trilobus*, *Gl. gomitulus*, and *Gl. sacculifer*), *Orbulina universa*, *Neoglobobulimina acostaensis* and *Globorotalia* spp.

All samples show also ostracods, mollusks (gastropods and pelecypods), echinids, radiolarians and sponge spicules.

The Plankton-Benthos ratio (P/B) shows decreasing values toward the top of the succession and in correspondence of coarser levels (Text-fig. 4). However planktic assemblages show higher abundances in residues 0.180 and 0.125 mm, and mainly consist of spinose species (Text-fig. 5).

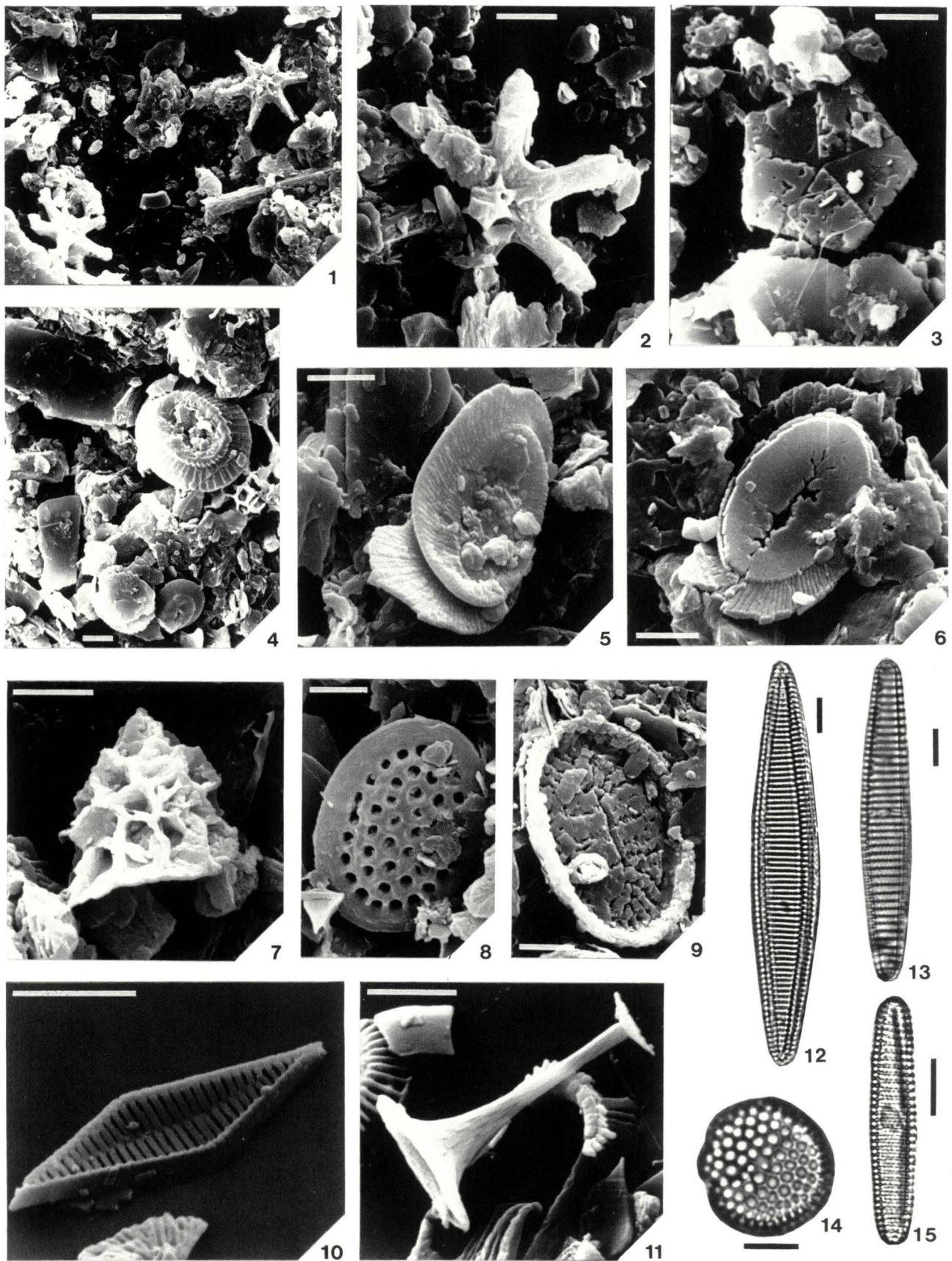
Morphotypical benthic analyses allow to recognize 9 different groups representing either the infauna and epifauna (Corlyss & Fois, 1990):

- 1) Trochospiral-rounded (*Ammonia*, *Gyroidina*)
- 2) Trochospiral-planoconvex (*Heterolepa*, *Cibicides*)
- 3) Trochospiral-biconvex (*Planulina*)
- 4) Agglutinated (*Dorothia*, *Martinottiella*)
- 5) Planispiral-rounded (*Lenticulina*, *Hastigerina*, *Melonis*)
- 6) Conical-cylindrical (*Nodosaria*, *Bulimina*, *Uvigerina*)
- 7) Spherical (*Sphaeroidina*)
- 8) Conical-flattened (*Bolivina*, *Brizalina*, *Plectofrondicularia*)
- 9) Ovoidal-flattened (*Siphonina*, *Cassidulina*).

EXPLANATION OF PLATE 1

- Fig. 1 - Coccoliths and Discoasters nannofacies. Genoa SM.
 Fig. 2 - *Discoaster surculus* Martini & Bramlette. Genoa SM.
 Fig. 3 - *Braarudosphaera bigelowi* Deflandre. Genoa SM
 Fig. 4 - Coccoliths nannofacies (*Coccolithus pelagicus* Schiller). Genoa SM.
 Fig. 5 - *Helicosphaera carteri* Kamptner. Genoa SM.
 Fig. 6 - *Helicosphaera carteri* Kamptner. Genoa SM.
 Fig. 7 - *Sphenolithus abies* Deflandre. Genoa SM.
 Fig. 8 - *Pontosphaera multipora* (Kamptner). Genoa SM.
 Fig. 9 - *Syracosphaera* sp. Genoa SM.
 Fig. 10 - *Scapholithus* sp. Genoa SM.
 Fig. 11 - *Discosphaera tubifer* (Murray and Blackman) Ostenfeld. Genoa SM.
 Fig. 12 - *Nitzschia reinholdii* Kanaya & Koizumi. Genoa SM.
 Fig. 13 - *Nitzschia fossilis* (Frenguelli) Kanaya & Koizumi. Genoa SM.
 Fig. 14 - *Thalassiosira oestrupii* (Ostenfeld) Proshkina-Lavrenko. Genoa SM.
 Fig. 15 - *Nitzschia cylindrica* Burckle. Genoa SM.

The bar scale is 10 mm for Fig. 1, 2 mm for Figs. 2-11, 5 mm for Figs. 12-15



The analyses evidenced that frequencies are biased by taxa dimensions.

All the studied successions show the steady occurrence of all the morphogroups among forms larger than 0.125 mm; trochospiral-planiconvex and planispiral-rounded prevail. Worth of note the total absence of Miliolidae and the very rare occurrence of agglutinated.

As far as the forms smaller than 0.125 mm are concerned an increase in trochospiral-biconvex and conical-flattened forms versus the planispiral-rounded has been evidenced. Spherical and conical-cylindrical forms show on the contrary steady values.

Morphometric analyses yielded comparable results for the studied sites, thus we report as representative the pie-diagrams related to the Terralba samples (Text-fig. 6). Here, as far as the fraction larger than 0.125 mm is concerned, prevailing trochospiral and planispiral forms are evidenced. Conical-flattened are also well represented together with ovoidal-flattened. Worth of note is however the steady frequency shown by planispiral-rounded forms. A decrease in the frequency of trochospiral-rounded and biconvex forms is also observed from the top to the base of the section. A similar trend is shown by the planispiral-rounded forms in the fraction smaller than 0.125 mm.

Planktic foraminifers analyses yielded comparable results between samples from the SR borehole and Terralba section. In fact they are both characterized by frequent *Sphaeroidinellopsis seminulina* together with *Globigerina bulloides*, *Globigerinoides* (*Gl. sacculifer*, *Gl. trilobus* and *Gl. gomitulus*) and *Neogloboquadrina acostaensis*; *Globorotalia scitula* is rare and the zonal marker (*Globorotalia margaritae*) is completely absent.

In the SM and Valdolivo sites, the total absence of planktic markers species has been observed.

In the studied successions the steady occurrence of "small" *Globorotalia* spp. has been noted. These specimens show some analogies with

Neogloboquadrina acostaensis, but differ because of the test structure and for the presence of a lip in correspondence of the opening (Pl. 2, figs. 13-16). In our opinion, because of their common occurrence, these forms could be of regional interest and thus are worth of more accurate studies.

DISCUSSION

The foraminifer assemblages occurring in Terralba section and SR borehole show frequent *Sphaeroidinellopsis seminulina* suggesting the presence of the MPL1 (*Sphaeroidinellopsis* spp. Zone, post-acme) (Sprovieri, 1992, 1993). The occurrence of *Globorotalia margaritae*, absent in the studied sites, is however reported either in samples from a locality close to the Terralba section (Viaggi, 1986), and from sites in the Genoa area as Piani di S. Andrea/S. Chiara (Mastrorilli, 1969) and Calata Gadda (Bonci, pers. comm., 1994), thus indicating the presence of the MPL2 Zone.

As far as the SM and Valdolivo boreholes the total absence of planktic markers make difficult the biozonal attribution, however the occurrence of the benthic forms *Lenticulina*, *Brizalina* and *Uvigerina* allows to refer the samples to the *Uvigerina rutila* and *Marginulina* spp. Zone of the Early Pliocene (AGIP, 1982).

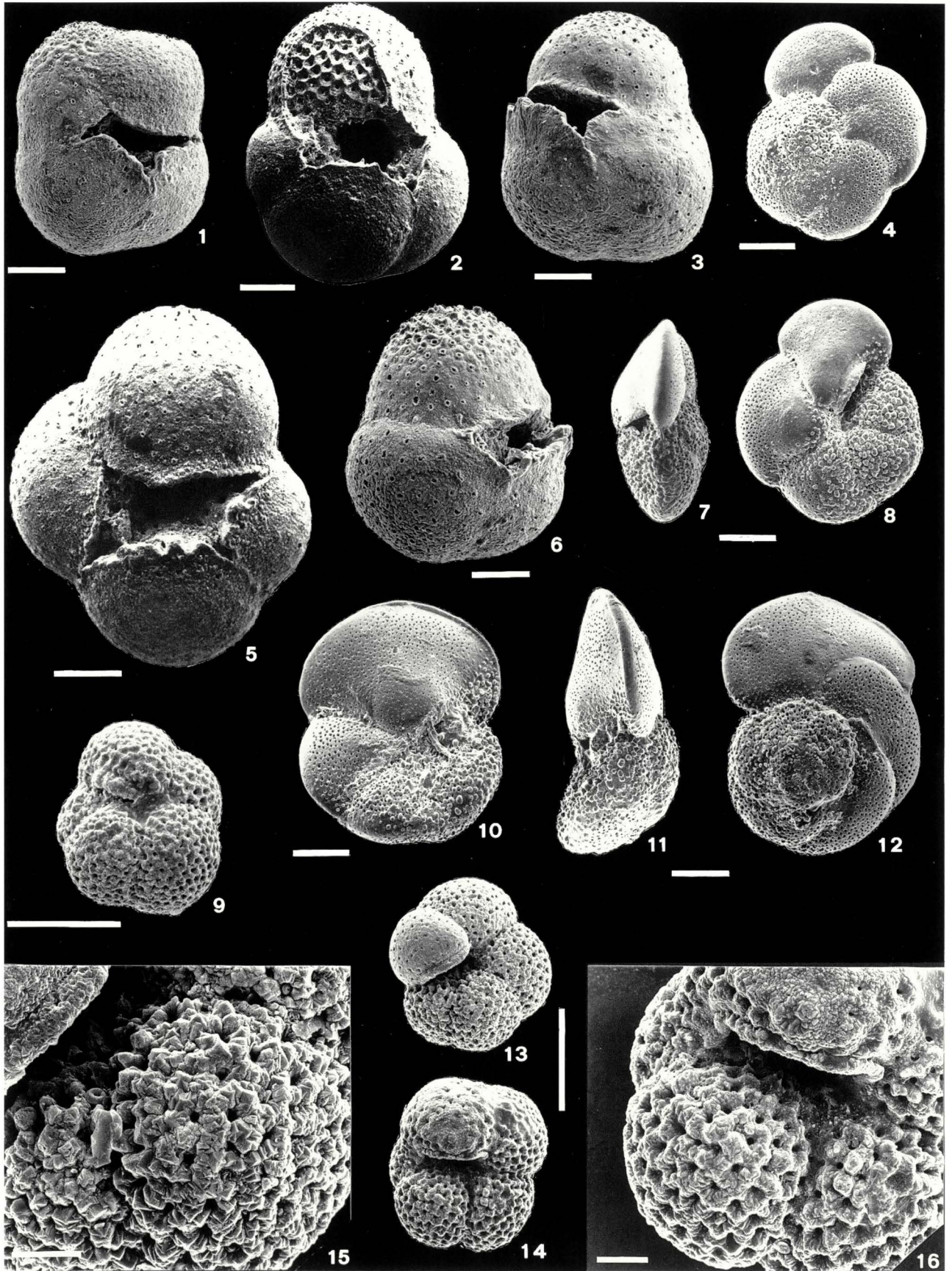
Furthermore, at the base of the SM borehole the occurrence of *Nitzschia cylindrica*, *N. reinholdii*, *N. fossilis* and *Thalassiosira oestrupii* evidenced the subzone C of the *Thalassiosira convexa* Zone of the Early Pliocene (lower part) in the scheme of Barron (1985) (Bonci et al., 1993).

The calcareous nannofossil assemblages recovered in the SM and SR successions show rare *A. delicatus*, no *Discoaster quinqueramus*, no *H. sellii*. The occurrence of *D. calcaris*, *D. neorectus* and *D. pseudovariabilis*, species characterizing the Late Miocene sediments, is also reported. Such an assemblage can be referred to the MNN 12 Zone (*Amaurolithus tricorniculatus*) of Rio et al. (1990)

EXPLANATION OF PLATE 2

- Figs. 1-3, 5-6 - *Sphaeroidinellopsis seminulina*. Umbilical view. Terralba
 Figs. 4, 7, 8 - *Globorotalia margaritae* Bolli & Bermudez. 4) Spiral view; 7) Lateral view; 8) Umbilical view. Genoa, Calata Gadda.
 Figs. 10-12 - *Globorotalia margaritae* Bolli & Bermudez. 10) Umbilical view; 11) Lateral view; 12) Spiral view. Genoa, Calata Gadda.
 Figs. 13, 15 - *Globorotalia* sp. 13) Umbilical view; 15) Detail of the test structure. Genoa SM.
 Figs. 14, 16 - *Globorotalia* sp. 14) Umbilical view; 16) Detail of the test structure. Genoa SM.

The scale bar is 100 mm for Figs. 1-14, 20 mm for Figs. 15-16.



of Early Pliocene age.

The first calcareous nannofossil biozone of the Pliocene is in fact defined at the top by the *Amaurolithus* spp. LO and/or by the FO of *Helicosphaera sellii*; the *Ceratholithus* FO occurs in this zone, but not at its base. The base of the MNN 12 Zone can be assumed to be corresponding to the top of the CN 9 Zone of Okada & Bukry, (1980) (Late Miocene) defined by LO of *Discoaster quinqueramus*. This species is however very rarely occurring in the Mediterranean area. The base of Zone CN9 is defined by the FO of *D. quinqueramus*, but inside this zone a third event is recorded *i.e.* the *Amaurolithus* spp. FO. Thus in the Mediterranean area, Zone CN9b and the first part of the MNN 12 are quite similar and the biostratigraphic attribution to one or the other biozone appear confuse when, as in this case, the Messinian evaporites are not present. The occurrence of Pliocene marker species that although rare are found in the Late Miocene sediments (*i.e.* *H. sellii*, *D. tamalis*, *D. asymmetricus*, Negri & Vigliotti, in press; Krjigsman *et al.*, in press) adds further difficulties.

However in the topmost sample of the SR borehole the occurrence of rare specimens related to the Pliocene *Ceratholithus* genus casts out doubts. In the SM site either the foraminifer and diatom assemblages allow the attribution to Early Pliocene age. The presence of *D. calcaris*, *D. neo-rectus* and *D. pseudovariabilis*, species characterizing the Late Miocene sediments, thus can be due to diffuse reworking effects and the two successions can be related to the *Amaurolithus tricorniculatus* Zone (MNN 12).

The benthic foraminifers morphofunctional analyses can also suggest hypotheses about the palaeoenvironment and the palaeoclimate charac-

terizing the deposition of the "Argille di Ortovero" Formation.

Both epifauna (trochospiral-rounded, trochospiral-planiconvex, trochospiral-biconvex forms) and infauna (planispiral-rounded, conical-cylindrical, spherical, conical-flattened forms) are generally well represented. This suggests a well diversified biocoenosis related to the epibathial zone (600-1200 m). The very rare occurrence or total absence of calcareous imperforate or agglutinated specimens also testify the absence of littoral environments, thus the occurrence of *Elphidium* and *Ammonia* can be related to resedimentation effects (*e.g.* turbidites). Water currents could be responsible for a selective removal of planktic forms characterized by thin tests.

In the diatom assemblage the abundant occurrence of the *Thalassionema* group can be related to upwelling high productivity.

Finally, the occurrence of the planktic foraminifers *Globigerina bulloides*, *Globigerinoides conglobatus* and *Globigerinoides sacculifer* according to Boltovskoy & Wright (1976) suggests an intermediate subtropical to temperate paleoclimate.

CONCLUSIONS

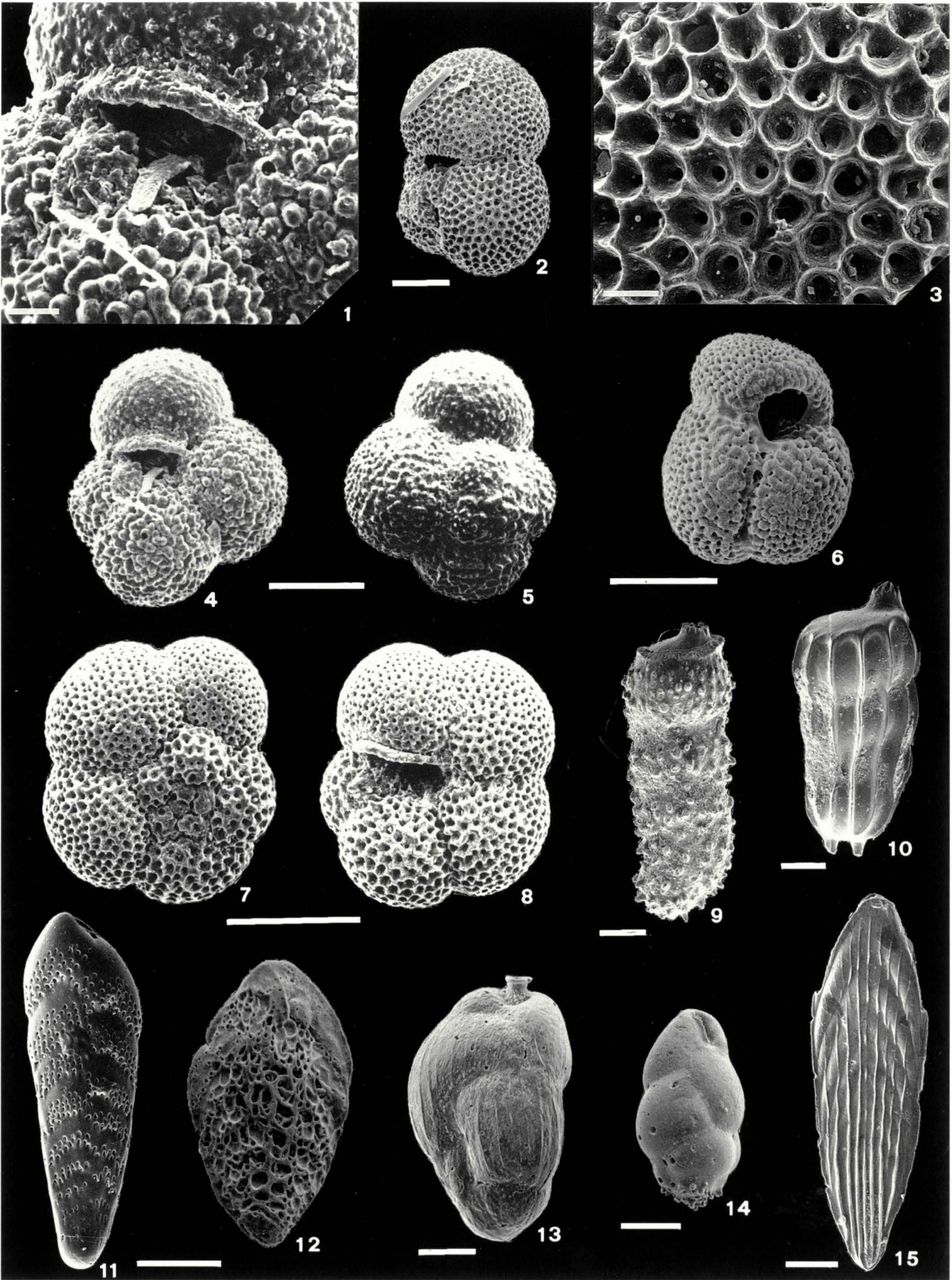
Results of the integrated micropaleontological (diatoms, calcareous nannofossils, planktic and benthic foraminifers) stratigraphic studies performed on 4 different succession referred to the "Argille di Ortovero" Formation can be summarized in the following points:

– All the successions show comparable lithological features, consisting of prevailing blue gray clayey marls and interbedded sandy-pebbly layers. The substratum is on the contrary different in each site: Voltri Group, "Calcari di M. Antola" Formation, Molare Formation.

EXPLANATION OF PLATE 3

- Figs. 1, 4, 5 - *Globigerina falconensis* Blow. 1) Detail of the aperture; 4) Umbilical view; 5) Spiral view. Genoa SM.
 Figs. 2, 3 - *Globigerinoides trilobus* (Reuss). 2) Umbilical view; 3) Detail of the wall. Genoa SM.
 Fig. 6 - *Globigerinoides obliquus* Bolli. Umbilical view. Genoa SM.
 Figs. 7, 8 - *Neogloboquadrina acostaensis* (Blow). 7) Spiral view; 8) Umbilical view. Genoa SM.
 Fig. 9 - *Marginulina* cf. *hirsuta* d'Orbigny. Genoa SM.
 Fig. 10 - *Marginulina costata* (Batsch). Genoa SM.
 Fig. 11 - *Bolivina punctata* D'Orbigny. Genoa SM.
 Fig. 12 - *Bolivina leonardii* Accordi & Selmi. Genoa SM.
 Fig. 13 - *Uvigerina rutila* Cushman & Todd. Genoa SM.
 Fig. 14 - *Bulimina lappa* Cushman & Parker. Genoa SM.
 Fig. 15 - *Plectofrondicularia semicosta* (Karrer). Genoa SM.

The scale bar is 100 mm for Figs. 2, 4-15, 20 mm for Figs. 1, 3.



- The integrated biostratigraphic analyses point out an Early Pliocene age testified by the occurrence of the *Thalassiosira convexa* Zone, subzone C (Barron, 1985) in the diatom assemblage, the MNN 12 Zone (*Amaurolithus tricorniculatus*) (Rio *et al.*, 1990) in the calcareous nannofossil assemblage and finally by the MPL1 and *Uvigerina rutila* and *Marginulina* spp. Zones of the planktic and benthic foraminifers biostratigraphic schemes by Sprovieri (1992, 1993) and AGIP (1982).

- The benthic foraminifer morphofunctional analyses evidenced sedimentary deposition in small and moderately deep basins close to steep coast with active landslides testified by the occurrence of diffuse clasts at the base of the succession.

ACKNOWLEDGEMENTS

We thank A. Rizzi (C.N.R., Centro Studi Stratigrafia e Petrografia delle Alpi Centrali, Milano) for the S.E.M. photographs.

This work was supported by "Progetti di ricerca di Ateneo" (University of Genoa, ex 60%) Resp. C. Pirini.

REFERENCES

- AGIP, 1982, Foraminiferi padani (Terziario e Quaternario). Atlante iconografico e distribuzione stratigrafica. 52 tavv.
- BARRON, J. A., 1985, Late Eocene to Holocene diatom biostratigraphy of the Equatorial Pacific Ocean, Deep Sea Drilling Project LEG 85. *In* Mayer, L., Theyer, F., *et al.*, Initial Reports of the DSDP, 85: 413-456.
- BOLTOVSKOY, E. & WRIGHT, R., 1976, Recent Foraminifera: 515 pp, Dr. Junk, W. publisher, The Hague.
- BONCI, M. C., CIRONE, G., PIRINI, C. & RAZZORE, S., 1993, Ritrovamento di livelli a diatomee nel Pliocene di Genova (Formazione delle Arigille di Ortovero): *Paleopelagos*, 3: 75-86, 2 tavv.
- CORLYSS, B. H. & FOIS, E., 1990, Morphotype analysis of deep-sea benthic foraminifera from the northwest Gulf of Mexico: *Palaos*, 5: 589-605.
- CORTESOGNO, L., GIAMMARINO, S. & TEDESCHI, D., 1977, Età dei lembi terziari di Lerca e Sciarborasca (Liguria occidentale) e loro implicazioni nell'evoluzione neotettonica del Gruppo di Voltri: *Boll. Soc. Geol. It.*, 96: 365-375.
- KRIJGSMAN, W., HILGEN, F.J., NEGRI, A., WIJBRANS, J.R. & ZACHARIASSE, W.J., (in press), The Monte del Casino Section (Northern Apennines, Italy): a potential Tortonian/Messinian boundary Stratotype?: *Palaeogeography, Palaeoclimatology, Palaeoecology*.
- MASTRORILLI, I., 1969, I Molluschi del Pliocene ligure nella Collezione dell'Istituto di Geologia dell'Università di Genova e i microfossili delle formazioni che li ricettavano: I) I reperti provenienti dalle marne di Genova: *Atti Ist. Geol. Univ. Genova*, 7 (1): 85-228, 20 tavv.
- NEGRI, A. & VIGLIOTTI, L., (in press), Calcareous nannofossil biostratigraphy and paleomagnetism of the Monte Tondo and Monte del Casino sections (Romagna Apennine, Italy). *In* Montanari, A., Odin, G.S. & Coccioni, R. (eds), *Miocene Integrated Stratigraphy*, Elsevier.
- OKADA, H. & BUKRY, D., 1980, Supplementary modification and introduction of code number to the low-latitude coccolith biostratigraphic zonation: *Mar. Micropal.*, 5: 321-325.
- RIO, D., RAFFI, I. & VILLA, G., 1990, Plio-Pleistocene calcareous nannofossil distribution pattern in the Western Mediterranean. *In* Kastens, K.A., Mascle, J., *et al.*, *Proceedings ODP Scient. Results*, 107: 513-553.
- SPROVIERI, R., 1992, Mediterranean Pliocene biochronology: an high resolution record based on quantitative planktonic Foraminifera distribution: *Riv. It. Paleont. Strat.*, 98 (1): 61-100, 5 pls.
- , 1993, Pliocene-Early Pleistocene astronomically forced planktonic Foraminifera abundance fluctuations and chronology of mediterranean calcareous plankton bioevents: *Riv. It. Paleont. Strat.*, 99 (3): 371-414.
- VIAGGI, M., 1986, Nuove osservazioni sedimentologiche, stratigrafiche e strutturali sui lembi terziari di Lerca-Sciarborasca (Liguria occidentale): 173 pp, Università di Genova, Tesi inedita.

(manuscript received November 30, 1996
accepted June 30, 1997)

Alessandra NEGRI
Dipartimento di Scienze della Terra
Via Breccie Bianche, 60131 Ancona, Italy

Camilla PIRINI
Sabrina RAZZORE
Maria Cristina BONCI
Gabriella CIRONE
Dipartimento di Scienze della Terra
Corso Europa 26, 16132 Genova, Italy

Nicoletta MANCIN
Dipartimento di Scienze della Terra
Corso Strada Nuova 65, 27100 Pavia, Italy

Maurizio VIAGGI
AGIP S. p. A., 20097 San Donato Milanese, Italy