INTRODUCTION

Mediterranean Plio-Pleistocene benthic foraminifers have been studied by several authors since the last century. Their studies were initially devoted primarily to species recognition and classification (De Amicis, 1895; Fornasini, 1894; Seguenza, 1880; A. Silvestri, 1899; 1904; and O. Silvestri, 1872). With the beginning of systematic oil exploration by the Italian oil company (AGIP) in the 1950's, benthic foraminifers were used as the main biostratigraphic tool, as the great biostratigraphic value of planktonic foraminifers was not yet recognized. Much of our understanding of the biostratigraphic value of Tertiary and Quaternary benthic foraminifers comes from AGIP publications (1957, 1982). In this same period of time many papers, including more or less detailed analyses on the stratigraphic distribution of the Italian Plio-Pleistocene benthic foraminifers, were published by several authors. Only a few of the more than 600 species recognized in the Mediterranean Pliocene and Pleistocene stratigraphic record can be considered as useful biostratigraphic markers in the Mediterranean basin and some of them have been already used to identify benthic foraminifers zonal boundaries (Colalongo and Sartoni, 1979; AGIP, 1982; Colalongo et al., 1982; d’Onofrio, 1983). Furthermore, two stratigraphic intervals characterized by the disappearance, or definite migration from the Mediterranean, of several benthic species have been recently identified (van der Zwaan, 1983; Sprovieri, 1985). These two extinction events, well recognizable in sequences belonging to epibathyal and lower neritic environment (Sprovieri, 1985), are easily correlatable with palaeoceanographic and palaeoclimatic changes and are useful references for correlation within the Mediterranean basin (Rio et al., 1984; Rio and Sprovieri, 1986).

Most of the data on the distribution of the Mediterranean Plio-Pleistocene benthic foraminifers come from land sections or wells drilled for oil researches. During the ODP Leg 107 cruise in the Tyrrhenian basin, three sites (654, 653, 652) have been continuously cored with good to very good recovery in the Plio-Pleistocene sequence. They represent a good opportunity to compare and extend the analysis on the stratigraphic distribution of the benthic foraminifers of this time interval to the deep-sea benthic foraminifers assemblage. Such a stratigraphic study was not reported from the two previous DSDP cruises in the Mediterranean (Leg 13 and Leg 42A), during which complete and continuous Plio-Pleistocene sequences were not cored (apart from Site 132), and the primary focuses were on paleoecological considerations (Ryan et al., 1973; Wright 1978a, b).

This paper is therefore essentially devoted to the analysis of the stratigraphic distribution of the benthic foraminifers in the Tyrrhenian sites and to the identification of a stratigraphic scheme, possibly recognizable also in the Italian land sections. In this respect, biostratigraphic data on benthic foraminifers stratigraphic distribution from land sections are considered. Paleoecological analysis of the benthic foraminifers assemblage and paleoenvironmental evolution in the three sites are discussed in the paper by Hasegawa, Sprovieri, and Poluzzi (this volume).

MATERIALS AND METHODS

The benthic foraminifers assemblages from the Plio-Pleistocene sequences recovered in Site 654, Hole 653A, and Site 652, drilled in the Tyrrhenian Sea during Leg 107 (Fig. 1) were studied. Site 654 was drilled in the upper part of the Sardinian conti-
Figure 1. Location map of the ODP Leg 107 Site 654, Site 653, and Site 652.

The Plio-Pleistocene sequence is 242.7 m thick. Recovery was not very good (about 50%), with several more or less long unrecovered intervals. Site 653 is located one-half kilometer northeast of DSDP Site 132 (Leg 13), on the eastern rim of the Cornaglia basin, at 2817 m depth (40°15.86'N, 11°26.99'E). The Plio-Pleistocene sequence is 214 m thick. The recovery was very good (81.9%), with only few, short unrecovered intervals. Site 652 is located in the lower part of the Sardinian continental margin, at 3446 m depth (40°21.30'N; 12°08.59'E). The Plio-Pleistocene sequence is 188 m thick. Recovery was not very good (61.2%), with several more or less long unrecovered intervals. Sequences from other Leg 107 Sites were not considered since they penetrated only the Pleistocene and a part of the Pliocene and contained numerous unrecovered segments. As reported in Tables 2-4, levels at 15, 45, 75, and 105 cm were analyzed systematically in Hole 653A; in the other sites, the level at 15 cm was analyzed only to better approximate the First Occurrence (FO) or Last Occurrence (LO) of selected species. From levels at 15, 45, 75, and 105 cm of each section of Site 653, 10 cm^2 of sediments were available; from level at 115 cm of each section of Site 652 and Site 654, 20 cm^2 were used.

All the samples, after disaggregation in water, were washed on a 63-μm sieve. All benthic foraminifers > 125 μm were identified and counted. Specimens < 125 μm were classified but not counted. The symbol 0 (for presence) was used in the quantitative range tables (Tables 2–4) for the species recognized in this part of the residue. The number of specimens of each species takes into consideration only the specimens recorded in the residue > 125 μm.

DATA ANALYSIS AND DISCUSSION

In the three sites benthic foraminifers always represent a very small percentage of the faunistic assemblage, generally less than 2%-3%. The most abundant and diversified benthic foraminiferal assemblage is present in Site 654, the least abundant in Site 652. Specimens are well preserved and dissolution was not observed. Very rare specimens of displaced neritic species (Ammonia spp., Elphidium spp., Discorbis spp.) were recognized at only a few levels. Specimens of Cibicides lobatulus, Cibicides refulgens, Hanzawaia rothiensis, and Rosalina cf. nitida, sometime present with several specimens in many samples, are not considered indicative of synsedimentary displacement. These species, essentially with an epiphytic mode of life, can be included in benthic assemblages as consequence of flotation of the algal support once it is removed from its original place by storms.

All in all, 699 samples were studied and 269 species were recognized, the most significant of which are figured in Plates 1-5. In Table 1 the main data of each stratigraphic interval are reported. The distribution of each species, the number of specimens per sample of each species, and the total number of species per sample in each site are reported in Tables 2–4. In Figures 2, 7, and 12, the number of species, the number of specimens, and the diversity index per sample along the three sequences are plotted. The diversity index was calculated (Margalef, 1958; Parisi et al., 1982) as

\[ D = n \text{ species} - 1 / \log n \text{ specimens} \]

Less than half of the benthic foraminifers species recorded from Plio-Pleistocene Italian land sections were recognized in the coeval deep-sea sequences of the three Tyrrhenian sites. Two groups are essentially missing. The first one includes the shallow water, neritic species which, while they comprise large constituents of the benthic foraminiferal assemblage in some Italian land sections, are environmentally excluded from these deep-sea bathyal sediments. The second group is represented by Nodosarids which, while very well diversified in the Pliocene land section interval, are represented here by rare and scattered occurrences.

In this section the general trend of the faunistic assemblage is briefly reported, and the stratigraphic distribution of some species is discussed at the light of the calcareous plankton biostratigraphy and in the rigid time framework provided by the integrated calcareous plankton stratigraphy recognized in the three sites (Glacon, Rio, and Sprovieri, this volume; Rio, Raffi, and Villa, this volume). These species were selected on the base of their abundance along the sequences and/or on the base of their potential biostratigraphic interest for the Mediterranean Plio-Pleistocene stratigraphic record, also with reference to the data from the Italian land sections. The stratigraphic distribution of the most important of them in the three sites is reported in Figures 3, 8, and 13, in which the appearance and disappearance levels are traced in coincidence with the first or last sample in which the species is recorded. Their frequency distribution (percentage) is plotted in Figures 4-6, 9-11, and 14-16, in which only data from samples with at least six specimens are reported. Only a small number of species is common and continuously present in the samples within their stratigraphic range. Furthermore, their first and last occurrence is rarely comparable among the sites and with the same events recognized in land sections. Generally their disappearance levels predate, and the appearance level postdates, the corresponding events identified in land sections. Even in the stratigraphic interval identified from these deep-sea bathyal sediments the FO or LO of very few species occur at the same stratigraphic level. The disappearance levels of several species are earlier and earlier and the appearance levels of several species are younger and younger from Site 654 to Site 653 and Site 652 (Figs. 3, 8, and 13). The disappearance level of some species, such as Parrellaoides bradyi and Quinqueloculina bicarinata and the appearance level of Gyroidinoides altiformis, Articulina tubulosa, and Cibicides kullenbergi seem to have different, even opposite trends when biostratigraphically and biochrono logically evaluated. Nevertheless, in the identification of these
are rare, essentially present in a short interval at the base of the
Pliocene (MP11-base MP12 biozones); Miliolids are well represented
essentially in the latest Pliocene and in the Pleistocene intervals;
Fissurina spp., Lagenina spp., and Oolina spp. are represented by
many species all along the sequences but with very rare specimens;
agglutinated forms, essentially represented by 
*Bigenerina* nodosaria, Karreriella spp., and Martinottiella spp.,
are generally common but decrease in the late Pleistocene.

The *Sphaeroidinellopsis* spp. (MP1) biozone is characterized
by a greater number of species in Site 654 (in which only the upper
most part of this biozone is present), but the same few species
*Dentalina* filiformis, *Gyrocochilina* solidanii, *Globocassidulina*
subglobosa, *Oridorisalis* stellatus, and, in the upper part,
*Uvigerina pygmaea* are common in the three sites. An increase in
the number of species occurs in the *Globorotaliida margaritae*
(MP2) biozone. The benthic assemblage is dominated by
*Siphonina* reliculata, *Cibicidoides*? *italicus*, *Oridorsalis* stellatus,
*Parrella* braudyi, *P. robertsonianus*, and *Pullenia* spp.;
in Site 654 *Planulina* arimimensis and *Sphaeroidina* bulloides
are common. In the basal part of this interval *Uvigerina pygmaea*
is relatively common for a short interval. In the three Tyrrenian
sites in the interval straddling the MP1-MP2 zonal boundary,
brilliant, yellow to reddish sediments contain hematite,
limonite, sulfur, and sulfates. A large amount of nutrients
were also probably carried from weathered exposed sediments
into the basin together with these iron oxides, favoring the dominance
of *Uvigerina pygmaea*; according to many authors (Phleger
and Sourat, 1973; Boltovskoy and Wright, 1976; Brolsma,
1978; Streeter and Shackleton, 1979; Douglas and Voëckhuff,
1981; van der Zwaan, 1982; Katz and Thunell, 1984), *Uvigerina*
is considered to be very tolerant of low oxygen levels. *Vaginulina*
elegans and *Vaginulina* carinatae are present, with one specimen,
only in one sample of this interval in Site 654. They belong
to a group of several species, many of which belonging to *Vagi-
nulina* and *Vaginulina*, which disappear, according to data
from land sections (Sprovieri, 1978; AGIP, 1982; Sprovieri,
1983), in the middle-upper part of the *Sphaeroidinellopsis subde-hiscens* (MP4) biozone. *Ellipsoglandulina* varsarveli, which disappears in the MP4 biozone in land sections, is present,
rare, only in a few samples of this interval in Site 654.

The benthic foraminiferal assemblage of the *Globorotalia margaritae-Globorotalia puncticulata* zone (MP3) is well comparable
with the MP3 biozone of the Tyrrhenian sites. The abundant occurrence of *Uvigerina rutila*, a widely used biostratigraphic
marker of the lower part of the Mediterranean Pliocene in the
Italian land sections, is recorded in the upper part of this interval
in Site 654. In land sections this species ranges up to the upper
part of the *Sphaeroidinellopsis subdehiscentes* zone (Sprovieri,
1978; Colalongo and Sartoni, 1979; Colalongo et al., 1982;
AGIP, 1982; Sprovieri, 1983). In Hole 653A *Anomalinoidea helinus* disappears in the middle part of MP3 biozone (Sample
17X-6, 15 cm; 153.26 mbsf); in Site 654 and in the Italian land sections this species ranges up to the upper part of the *Globigeri-
noidees elongatus* (MP5) biozone (Sprovieri, 1978; Colalongo
and Sartoni, 1979; Colalongo et al., 1982; AGIP, 1982; van der
Zwaan, 1983; Sprovieri, 1985). In the middle-lower part of
MP3 biozone *Cylindroclavulina* rudis appears with rare specimens
and ranges up to the very base of MP5 in Site 654. This species is generally well represented in this interval in the Italian
land sections (Sprovieri, 1977, 1978, 1979; AGIP, 1982), where it disappears in the upper part of the Pliocene. In the *Spha-
roidinellopsis subdehiscentes* (MP4) biozone, the extinction level event at about 3.2–3.1 Ma (the mid-Pliocene event, according
to Rio et al., 1984), easily recognizable in land sections (Sprovieri,
1985) is not detected in the three deep-sea Tyrrhenian sequences.
It is well marked by the disappearance of several species of *Len-
ticulina, Marginulina, Planulularia, Vaginulina,* and *Vaginulina*,
Figure 2. Plot of number of species, number of specimens, and diversity index of the benthic foraminifera in the Plio-Pleistocene sequence of Site 654. Black vertical bars = recovered intervals.
Figure 3. Stratigraphic distribution chart of the biostratigraphically most important benthic foraminifers in the Plio-Pleistocene sequence of Site 654. Black vertical bars = recovered intervals.
Figure 5. Frequency distribution (percentage) chart of benthic foraminifers species reported in Figure 3. C. ital. = Cibicidoides(?) italicus; P. rob. = Parrelloides robertsonianus; Q. bic. = Quinqueloculina bicarinata; Pl. arim. = Planulina ariminensis; C. rudis = Cylindroclavulina rudis; B. inaur. = Buliminella inauris; C. wue. = Cibicides wuellestorfi. Black vertical bars = recovered intervals.
Figure 6. Frequency distribution (percentage) chart of benthic foraminifers species reported in Figure 3. Gy. alt. = Gyrodioides altiformis; O. umb. = Oridorsalis umbonatus; O. stain. = Orthomorphina stainforthi; A. tub. = Articulina tubulosa; C. kull. = Cibicidoides kullenbergi; H. bal. = Hyalinea baltica; K. nov. = Karreriella novangliae. Black vertical bars = recovered intervals.
Figure 7. Plot of number of species, number of specimens, and diversity index of the benthic foraminifers in the Plio-Pleistocene sequence of Hole 653A. Black vertical bars = recovered intervals.
Figure 8. Stratigraphic distribution chart of the biostratigraphically most important benthic foraminifers in the Plio-Pleistocene sequence of Hole 653A. Black vertical bars = recovered intervals.
Figure 9. Frequency distribution (percentage) chart of benthic foraminifers species reported in Figure 8. O. stell. = Oridorsalis stellatus; G. laev. = Gyroidinoides laevigata; A. hel. = Anomalinoidea helicus; C. ital. = Cibicidoides Italicus; M. perp. = Martinottiella perparva; P. brad. = Parreolides bradyi. Black vertical bars = recovered intervals.
Figure 10. Frequency distribution (percentage) chart of benthic foraminifers species reported in Figure 8. Q. bic. = Quinqueloculina bicarinata; P. rob. = Parrellaides robertsonianus; S. ret. = Siphonina reticulata; K. gaud. = Karreriella gaudryinoides; L. paup. = Laticarinina pauperata; O. umb. = Oridorsalis umbonatus. Black vertical bars = recovered intervals.
**PLIO-PLEISTOCENE BENTHIC FORAMINIFER STRATIGRAPHIC DISTRIBUTION**

<table>
<thead>
<tr>
<th>Epoch</th>
<th>Species</th>
</tr>
</thead>
<tbody>
<tr>
<td>Early Pliocene</td>
<td>Amaurolithus tricorniculatus</td>
</tr>
<tr>
<td></td>
<td>Ceratolit. rugosus</td>
</tr>
<tr>
<td></td>
<td>R. psedoun</td>
</tr>
<tr>
<td></td>
<td>Discocaster tenualis</td>
</tr>
<tr>
<td>Late Pliocene</td>
<td>Pastinella brouweri</td>
</tr>
<tr>
<td></td>
<td>Dict. bras.</td>
</tr>
<tr>
<td>Pleistocene</td>
<td>Pseudoemiliania lacunosa</td>
</tr>
<tr>
<td></td>
<td>Gephyra oceanica</td>
</tr>
<tr>
<td></td>
<td>Emil. nux.</td>
</tr>
</tbody>
</table>

- **C. wuel.** = Cibicides wulfrani
- **C. kull.** = Cibicidoides kullenbergi
- **G. alt.** = Gyroidinoides altiformis
- **Pl. arim.** = Planulina ariminesis
- **A. tub.** = Articulina tubulosa
- **H. balt.** = Hyalinea baltica
- **K. nov.** = Karlissello novangliae

Black vertical bars = recovered intervals.

Figure 1. Frequency distribution (percentage) chart of benthic foraminifers species reported in Figure 8.

- C. wuel. = Cibicides wulfrani
- C. kull. = Cibicidoides kullenbergi
- G. alt. = Gyroidinoides altiformis
- Pl. arim. = Planulina ariminesis
- A. tub. = Articulina tubulosa
- H. balt. = Hyalinea baltica
- K. nov. = Karlissello novangliae

Black vertical bars = recovered intervals.
Figure 12. Plot of number of species, number of specimens, and diversity index of the benthic foraminifers in the Plio-Pleistocene sequence of Site 652. Black vertical bars = recovered intervals.
Figure 13. Stratigraphic distribution chart of the biostratigraphically most important benthic foraminifers in the Plio-Pleistocene sequence of Site 652. Black vertical bars = recovered intervals.
Figure 14. Frequency distribution (percentage) chart of benthic foraminifers species reported in Figure 13. O. stell. = Oriddorsalis stellatus; A. hel. = Anomalinoideas helcinus; Gy. laev. = Gyroidinoideas laevigata; P. rob. = Parrelloides robertsonianus; C. ital. = Cibicidoides(?) italicus. Black vertical bars = recovered intervals.
Figure 15. Frequency distribution (percentage) chart of benthic foraminifers species reported in Figure 13. P. brad. = Parrelloides bradyi, M. perpar. = Martinottiella perparva; Q. bica. = Quinqueloculina bicarinata; S. ret. = Siphonina reticulata; L. paup. = Laticarinina pauperata. Black vertical bars = recovered intervals.
Figure 16. Frequency distribution (percentage) chart of benthic foraminifers species reported in Figure 13. C. wue. = Cibicidoides wuellestorfi; Gy. alt. = Gyroidinoides altiformis; C. kull. = Cibicidoides kullenbergi; O. umb. = Oridorsalis umbonatus; A. tub. = Articulina tubulosa. Black vertical bars = recovered intervals.
Tyrrhenian sites, and their distribution is not stratigraphically significant. In the three sites, the few recorded species belonging to the group of species that disappears at the top of MP14 biozone in land sequences are definitively not present in sediments younger than the extinction level of *Sphaeroidinellopsis* spp. and therefore their distribution, even if not comparable, is not inconsistent with their recognized range in land sections.

During the time interval represented by the MP15 biozone, a remarkable change in the composition of the benthic foraminiferal assemblage occurs. In Site 654 the disappearance of *Bolivina lucana, Bolivina lucido-punctata, Buliminella inauris, Fissurina lacunata, Martinottiella perparva, Paonosphaera testacea, Spirorotalia rorbimorpha,* and *in the middle lower part,* the disappearance of *Anomalinooides helicinus* in the upper part, the appearance of *Anomalinoides helicinus* in the upper part, and the appearance of *Buliminella multicamera and Rutherfordoides tenuis* in the middle-upper part are correlatable with the disappearance of *Anomalinoides helicinus* in the upper part, *Bolivina lucana, Martinottiella perparva, Paonosphaera testacea, Spirorotalia rorbimorpha,* and *in the middle lower part,* the disappearance of *Anomalinooides helicinus* in the upper part, the appearance of *Anomalinoides helicinus* in the upper part, and the appearance of *Buliminella multicamera and Rutherfordoides tenuis* in the middle-upper part are correlatable with the same events in land sections (Barbieri, 1976; Sprovieri, 1978, 1985; AGIP, 1982; van der Zwaan, 1983). The last three events are included in the upper Pliocene event (van der Zwaan, 1983; Rio et al., 1984; Sprovieri, 1985), a turn-over in the benthic foraminiferal assemblage which occurred at 2.3–2.2 Ma. In the other two sites this event is not recognizable. Many species that disappear in land sections at this level are missing or have disappeared at lower levels, and many species which appear at this level are not represented or first occur higher in the sections. In the upper part of the MP15 interval, *Parrellaides bradyi* and *P. robertsonianus* decrease, *Cibicidoides pachyderma, Cibicidoides wuellerstorfi, Globocassidulina subglobosa, Gyroidinoides spp.,* *Mi­liolids (essentially Quinqueloculina spp.,* *Oridorsalis stellatus,* and *Sigmoidooids schlumbergeri* increase and dominate more or less continuous intervals. *Cibicidoides* (Littorina) *italicus* disappears at the base of the MP15 biozone, respectively in Sample 15R-6, 70 cm (135.60 mbsf) in Site 654, in Sample 15X-2, 15 cm (128.16 mbsf) in Site 653, and in Sample 12R-3, 116 cm (107.16 mbsf) in Site 652. In the three Tyrrhenian sites *Siphonina reticulata* disappears in this biozone. The more detailed nanofossil biostratigraphy in this stratigraphic interval is evidence that this event occurred in slightly, but significantly, different time intervals in the three sites. It disappeared first in Site 652 (Sample 12R-2, 69 cm; 105.20 mbsf) at the top of the *Discococeras tamalis* nanofossil biozone, then in Site 653 (Sample 14X-1, 15 cm; 117.46 mbsf), at the base of the *Discococeras pentalidiss* nanofossil biozone, and then in Site 654 (Sample 14R-1, 70 cm; 118.40 mbsf), near the top of the *Discococeras pentalidiss* nanofossil biozone. *Siphonina reticulata* is found today in the Mediterranean (Parker, 1958; Bizon and Boroulet, 1984) from 80 m to a maximum depth of about 1000–1200 m. The delayed disappearance from Site 652 to Site 653 and Site 654 (from east to west and from the deepest to the shallowest part of the Sardinian escarpment) may indicate the different time interval in which the three sites exceeded the depth of approximately 1200 m. Site 652 became deeper in an older interval than Site 653 which, in turn, crossed this depth before than Site 654. In Samples 653 and 654 *Gyroidinoides altiformis* appears, with rare specimens, in the upper part of MP15 biozone, respectively just above and below the base of the *Discococeras brouweri* nanofossil biozone. In Site 652 the disappearance of *Gyroidinoides altiformis* is well above the base of the *Discococeras brouweri* biozone, but this appearance level may be not coincident with the Pliocene re-entrance of *Gyroidinoides altiformis* into the Mediterranean, due to the sedimentary hiatuses detected in the interval belonging to the MP15 in this site (Glacon, Rio, and Sprovieri, this volume).

In the *Globorotalia inflata* (MP16) biozone, *Quinqueloculina bicarinata* and *Parrellaides bradyi* disappear and *Cibicidoides kullenbergi* is for the first time present, more or less common, in the foraminiferal assemblage of the deep-sea Tyrrhenian record, but these three events are not stratigraphically comparable in land sections, where they occur at different stratigraphic levels (AGIP, 1982).

In the Pliocene segments two intervals can be distinguished (Figs. 2, 7, and 12). In the lower part, up to about the base of the glacial Pliocene, above the top of the small *Gephyrocapsa* nanofossil biozone, the benthic assemblage is still relatively abundant and diversified, then it decreases with large fluctuations in number of species and specimens and in the diversity index; in correspondence with warm intervals, benthic assemblage is generally less abundant and less diversified, in accordance with what already recognized by Blanche-Vernet et al. (1983). In Hole 653A and in Site 652 *Cibicidoides pachyderma* sharply decreases in coincidence with the entrance of *Cibicidoides kullenbergi* (Tables 3 and 4). In Site 654 *Cibicidoides pachyderma* is scattered in this stratigraphic interval, but in some levels it is present with high frequencies; coincident with these peaks *Cibicidoides kullenbergi* is rare or absent, but is frequent in levels in which *Cibicidoides pachyderma* is rare or absent (Fig. 17). *Cibicidoides kullenbergi* is a well identified component of the NADW water masses foraminiferal assemblage today (Lohman, 1978). Peaks abundance of this species in the Pliocene interval of Site 654 may be indicative of short, stronger influence of NADW-type water masses in the Tyrrhenian basin at the depth of Site 654 (about 2000–2400 m depth) during the Pleistocene interval, when prevailing Mediterranean-type water masses, with *Bolivia* spp., *Bulima* spp., *Gyroidinoides* spp., *Uvigerina* spp., *Cassidulina carina,* and *Cibicidoides pachyderma* (cf. Parker 1958), were present.

Several species (*Uvigerina costata-caudata, Articulina tubulosa, Buliminata etnea, Paromalina crassa, Rectobolivina zitteli, Loxostomum karrerianum, Paromalina coronata, Bolivinita quadrilatera*) appear in land sections in the lowermost part of the early Pliocene, below or above the first occurrence of *Hyali-
neal baltica (Sprovieri, 1978; AGIP, 1982; d’Onofrio, 1983; Sprovieri, 1985), but few of them are recorded in the Tyrrhenian deep-sea record. Only Articulina tubulosa is consistently present and common. In Hole 653A it appears with small specimens in Sample 10H-3, 130 cm (83.90 mbsf), at the base of the Calcidiscus macintyrei biozone, just above the Pliocene/Pleistocene boundary. In Sites 652 and 654, this species first appears above the base of the Helicosphaera selli nannofossil biozone, but its FO may be here not recognized due to the poor recovery in the basal part of the Pleistocene interval in these two sites. Unexpected, Hyalinea baltica is present and common in several samples of Site 654 and in some samples of Site 653. This species, living today from 50 to about 1000 m in depth (Parker, 1958; van Morkhoven et al., 1986), had evidently a wider bathymetric range during the early Pleistocene. In both sites the appearance level of this species just precedes the base of the large Gephyrocapsa nannofossil biozone (Glaçon, Rio, and Sprovieri, this volume) and therefore this event in the deep-sea sequences is well comparable with the same event in land-based sequences, where it first occurs in the same biostratigraphic position (Rio, 1982; Ruggieri et al., 1984). The last occurrence of Oridorsalis umbonatus, a species not living today in the Mediterranean sea (Parker, 1958; Blanc-Vernet, 1969; Blanc-Vernet et al., 1983) is recorded in Sample 3R-3, 68 cm in Site 654; in Site 653 it is present up to the uppermost sample (1H-1, 75 cm), belonging to the Emiliania huxleyi biozone. This event is recorded in all Sites 652 and 654, this volume; Glaçon, Rio, and Sprovieri, this volume; in Site 652 it disappears in Sample 2R-3, 47 cm. The last occurrence of Oridorsalis stellatus is recorded in Sample 9R-1, 70 cm (70.00 mbsf) in Site 654 (base of the Helicosphaera selli biozone), in Sample 8H-6, 74 cm (68.71 mbsf) in Hole 653A (large Gephyrocapsa biozone) and in Sample 10R-1, 116 cm (85.36 mbsf) in Site 652 (base of the Calcidiscus macintyrei nannofossil biozone).

**Benthic Foraminifer Biostратigraphy**

Benthic foraminifers zonal schemes for the Italian Plio-Pleistocene sequences have yet been proposed (AGIP, 1982; Colalongo and Sartoni, 1979; Colalongo et al., 1982) (Fig. 18) and compared with planktonic foraminifers zonal schemes. Since no reference to nannofossil biostratigraphy is given, the stratigraphic and biochronological identification of their zonal boundaries are often not well detailed. These benthic foraminifers biostatiographic schemes could not be adopted in the deep-sea Tyrrhenian record since they are based on zonal markers that are rare, scattered, and diachronous (Uvigerina rutila, Anomalinoïdes helicinu or not present at all (Uvigerina bulimina, Bulimina marginata) and therefore this event in the deep-sea sequences is well comparable with the same event in land-based sequences, where it first occurs in the same biostratigraphic position (Rio, 1982; Ruggieri et al., 1984).

The basal boundary of this zone is coincident with the base of the Pliocene, defined by the re-establishment of a permanent marine faunistic assemblage (Cita, 1975). The upper boundary is coincident with the extinction level of the nominal taxon. The biocenological evaluation of this event is at 2.82 Ma in Hole 653A, 2.9 Ma in Site 654, 2.92 Ma in Gela (Sprovieri, unpubl. data), and 2.91 Ma in Punta Piccola (Sprovieri and Barone, 1982; Rio et al. 1984). Therefore a biocenological age of 2.9 Ma is assumed for this event. The discontinuous record in the interval of MP15 in Site 652, with at least two long hiatuses (Glaçon, Rio, and Sprovieri, this volume) does not allow a reliable biocenological evaluation of this event. In Site 654 the disappearance level of Cibicidoides(?) italicus is only about 0.7 m above the top of Kaena magnetic polarity subchron, recognized (Channell et al., this volume) at 136.30 mbsf. In Site 652 the extinction level of this species was detected just below the top of the Kaena subchron, recognized (Channell et al., this volume) at 106 mbsf. The good correlation with these paleomagnetic data represents a strong support to the proposed biocenological evaluation of the extinction level of Cibicidoides(?) italicus. In the very basal segment, belonging to the MP11 and basal MP12 planktonic foraminifers biozones, the marker is generally missing or very rare and the benthic foraminifer assemblage, still not diversified, is dominated by Globocassidulina subglobosa, Oridorsalis stellatus, and Uvigerina pygmaea, indicative of slightly under-oxygenated bottom conditions (Hasegawa, Sprovieri, and Poluzzi, this volume; Mckenzie and Sprovieri, this volume). In the long following interval, stable, well-oxygenated, epibathyal marine conditions are recognized, with more or less frequent and consistent influence of NADW (North Atlantic Deep Water) water masses (Hasegawa, Sprovieri, and Poluzzi, this volume). In the long interval belonging to this biozone a strong increase in the number of species gradually occurs. In land sections Nodosarids are frequent in the faunistic assemblage of this interval, and decrease in coincidence with the mid-Pliocene event, at about 3.2-3.1 Ma (Rio et al., 1984; Sprovieri, 1985). The extinction level of the zonal marker is generally abrupt (Figs. 5, 9,
PLIO-PLEISTOCENE BENTHIC FORAMINIFER STRATIGRAPHIC DISTRIBUTION

<table>
<thead>
<tr>
<th>Age</th>
<th>PLIO-PLIOCENE</th>
<th>MIDDLE PLIO-PLIOCENE</th>
<th>EARLY PLIO-PLIOCENE</th>
<th>ST. BENTHIC FORAMS</th>
</tr>
</thead>
<tbody>
<tr>
<td>5.0—4.0 Mya</td>
<td>1.0 Mya</td>
<td>3.0 Mya</td>
<td>5.0 Mya</td>
<td>3.0 Mya</td>
</tr>
<tr>
<td>Ammonia and Elphidium</td>
<td>H. balthica</td>
<td></td>
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<td></td>
<td></td>
<td>H. helicina</td>
<td>A. helicina</td>
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<tr>
<td></td>
<td></td>
<td></td>
<td>Marginulinida spp.</td>
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<td></td>
<td></td>
<td></td>
<td>U. rutila</td>
<td></td>
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<td></td>
<td></td>
<td></td>
<td>S. etnea</td>
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<td></td>
<td></td>
<td></td>
<td>F. marginata</td>
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<td></td>
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<td>U. rutila</td>
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<td></td>
<td>S. marginata</td>
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<td></td>
<td>E. marginata</td>
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<td></td>
<td>A. helicina</td>
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<td></td>
<td>B. elegans</td>
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<td>U. rutila</td>
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<td>F. marginata</td>
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<td>H. helicina</td>
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<td>S. basispinosa</td>
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<td></td>
<td></td>
<td></td>
<td>C. italicus</td>
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</table>

Figure 18. Benthic foraminifers zonal schemes for the Italian Plio-Pleistocene record.
<table>
<thead>
<tr>
<th>Absolute Age (Ma)</th>
<th>Chrono Stratigraphy</th>
<th>Planktonic Foraminifera Biozones</th>
<th>Calcareous Nannoplankton Biozones</th>
<th>Integrated Calcareous Plankton Intervals</th>
<th>Benthonic Foraminifera Biozones</th>
</tr>
</thead>
<tbody>
<tr>
<td>4.66</td>
<td>Zanclean</td>
<td>M Pl 2</td>
<td>Amaurolithus tricorniculatus</td>
<td>ICPI 2</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>M Pl 1</td>
<td>tricorniculatus</td>
<td>ICPI 1</td>
<td></td>
</tr>
<tr>
<td>4.13</td>
<td>Piacenzian</td>
<td>M Pl 3</td>
<td>R. pseudoumbil.</td>
<td>ICPI 3</td>
<td>Cibicidoides italicus</td>
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<td></td>
<td></td>
<td>M Pl 4</td>
<td>C. rugosus</td>
<td>ICPI 4</td>
<td></td>
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<tr>
<td>3.50</td>
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<td>D. pentaradiatus</td>
<td>ICPI 5</td>
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<td>Discosaster tamalis</td>
<td>ICPI 6</td>
<td>Parrelloides robertsonianus</td>
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<td>Selinuntian</td>
<td></td>
<td></td>
<td>ICPI 7</td>
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</tr>
<tr>
<td>2.10</td>
<td>Pliocene</td>
<td>M Pl 6</td>
<td>Dict. productus</td>
<td>ICPI 8</td>
<td>Gyroidinoides altiformis</td>
</tr>
<tr>
<td>1.67</td>
<td>Pleistocene</td>
<td><em>Globorotalia truncatulinoides</em></td>
<td>Emiliania huxleyi</td>
<td>ICPI 9</td>
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<tr>
<td></td>
<td></td>
<td><em>excelsa</em></td>
<td><em>Emiliania huxley</em></td>
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<tr>
<td></td>
<td></td>
<td><em>G. oceanica</em></td>
<td><em>Pseudoemiliania lacunosa</em></td>
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<tr>
<td></td>
<td></td>
<td>Small Gephyr.</td>
<td>H. sellii</td>
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<tr>
<td></td>
<td></td>
<td><em>Globigerina caricaeensis</em></td>
<td><em>C. macintyrei</em></td>
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<td></td>
<td></td>
<td><em>M Pl 6</em></td>
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<td><em>M Pl 5</em></td>
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<td><em>M Pl 4</em></td>
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<td><em>M Pl 3</em></td>
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<td><em>M Pl 2</em></td>
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<td></td>
<td><em>M Pl 1</em></td>
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</table>

Figure 19. Mediterranean Plio-Pleistocene benthic foraminifers biostratigraphic scheme proposed in this paper (right column) and correlation with calcareous plankton biostratigraphic schemes. Plankton foraminiferal biozones from Cita (1973, 1975), as emended by Rio et al. (1984); calcareous nannofossil biozones from Rio, Raffi, and Villa (this volume) and Glacon, Rio, and Sprovieri (this volume); integrated calcareous plankton intervals from Rio et al. (1984) and Rio and Sprovieri (1986).
PLIO-PLEISTOCENE BENTHIC FORAMINIFER STRATIGRAPHIC DISTRIBUTION

and 14) and therefore easily recognizable both in the deep-sea record and in the Italian land sections.

Paraellinoides robertsonianus Interval Zone

The base of this interval is coincident with the extinction of Cibicidoides(?) triangularis. The top of the zone is coincident with the Pliocene re-entrance of Gyroidinoides altiformis into the Mediterranean basin. The biochronological evaluation of this event is at 2.37 Ma in Site 653A, 2.5 Ma in Site 654, and 2.42 Ma in Capo Rossello (reported as Gyroidinoides longispina in Sprovieri, 1978), and 2.34 Ma in Gela (Sprovieri, unpubl. data). In Site 652 it was not calibrated, due to the sedimentary hiatuses in the MP15 interval of this sequence (Glaçon, R. and Sprovieri, this volume). A biochronological evaluation of 2.4 Ma is assumed for this event. In this interval the nominal taxon (with Paraellinoides bradyi and intermediate morphotypes) is well represented, as a consequence of the intensification of NADW influence in the Mediterranean basin, due to the progressively increasing depth of the Tyrrhenian basin (Hasegawa, Sprovieri, and Poluzzi, this volume). The top of this zone approaches the base of the "Glacial Pliocene," evaluated at 2.47 Ma by Shackleton et al. (1984).

Gyroidinoides altiformis Interval Zone

The base of this interval is defined by the Pliocene re-entrance into the Mediterranean basin of the zonal marker. Its top coincides with the appearance of Articulina tubulosa. The nominal taxon is a common species in the upper Miocene Mediterranean sequences (AGIP, 1982), but is absent in most of the Pliocene. It reappears in the upper part of MP15 planktonic foraminifera biozone, when it is again an important constituent of the Pliocene-Pleistocene boundary (Hyalinea baltica, this volume). A biochronological evaluation of 2.4 Ma is assumed for this event. In this interval the nominal taxon (with Gyroidinoides altiformis and intermediate morphotypes) is well represented, as a consequence of the intensification of NADW influence in the Mediterranean basin, due to the progressively increasing depth of the Tyrrhenian basin (Hasegawa, Sprovieri, and Poluzzi, this volume). The top of this zone approaches the base of the "Glacial Pliocene," evaluated at 2.47 Ma by Shackleton et al. (1984).

Articulina tubulosa Assemblage Zone

The base of the interval is coincident with the appearance of the nominal taxon. The top is coincident with the Recent. The appearance level of Articulina tubulosa is biostratigraphically evaluated at 1.6 Ma in Hole 653A, in which a small hiatus is present at the Pliocene-Pleistocene boundary level (Glaçon, R. and Sprovieri, this volume), at 1.62 Ma in DSDP Site 125 (Leg 13) (Raffi and Sprovieri, 1984), at 1.71 Ma in the Vrica section (D’Onofrio, 1983; Rio et al., 1988). In Site 654 and in Site 652 this event is evaluated at about 1.49 Ma, but it is preceded in the two sequences by long intervals with very poor recovery, and therefore the first occurrence of this species in these sequences may be not recorded. In DSDP Site 132 (Leg 13) Articulina tubulosa is present from Core 7 (54-63 mbsf) (Ryan et al., 1973). No detailed indications of the range of this species are given, but also in this site the appearance of Articulina tubulosa can be evaluated just above the base of the Calticus macintyrei biozone, recognized in Section 8-1 (Raffi and Rio, 1979). A biostratigraphic age of about 1.62 Ma is assumed for the appearance level of Articulina tubulosa. It is therefore correlatable with the Pliocene/Pleistocene boundary, as defined in the Vrica section (Calabria, Italy) (Aguirre and Pasini, 1985). This species is generally abundant in deep-sea sediments, sometime with well-developed specimens characterized by a very long tubular segment. A decrease in the number of species and specimens and in the diversity index is recorded in the three sites at the base of the Pliocene/Pleistocene boundary (Figs. 2, 7, and 12), practically coincident with the base of this biozone. This event may be correlated with the increasing well-oxygenated bottom conditions recognized at the base of the Pleistocene (Hasegawa, Sprovieri, and Poluzzi, this volume). Articulina tubulosa is a bathyal species (Parker, 1958; Blanc-Vernet, 1969; Wright, 1978a), and therefore the basal boundary of this biozone is better recognized in deep-sea and bathyal sequences. In sequences deposited in shallower depth environment this boundary can be approximated by the appearance level of Bulimina marginita (Colalongo and Sartoni, 1979; Colalongo et al., 1982; d’Onofrio, 1983 and Uvigerina costata-caudata) (Sprovieri, 1981) slightly below, and by the appearance of Bulimina eutea (Sprovieri, 1978; Colalongo and Sartoni, 1979; Colalongo et al., 1982; d’Onofrio, 1983) above.

Hyalinea baltica Assemblage Subzone

The base of the interval is coincident with the appearance of the nominal taxon. The top is coincident with the Recent. The biostratigraphical evaluation of the appearance level of Hyalinea baltica is at 1.33 Ma in Hole 653A and in Site 654, where it is recorded in the upper part of the Helicosphaera sellii nannofossil biozone, slightly predating the base of the large Gephyrocapsa biozone. In land sections this event also occurs in the upper part of the Helicosphaera sellii nannofossil biozone, just below the first appearance level of the large Gephyrocapsa (Rio, 1982; Ruggieri et al., 1984) and is therefore synchronous with the same event in the deep-sea Tyrrhenian record. Hyalinea baltica is essentially a neritic and epibathyal species (Parker, 1958; Wright, 1978a), and therefore the base of this subzone is easily recognized in land sections where H. baltica represents a frequent element of the foraminiferal benthic assemblage from this level up to the Recent (Ruggieri et al., 1984; Parker, 1958). In the deep-sea Mediterranean record this zonal boundary is less frequently recognized, since Hyalinea baltica is rare, scattered, or absent in the most sequences (ODP Leg 107, Sites 650, 651, 652, 655; DSDP Leg 13 (Ryan et al., 1973), DSDP Leg 42A (Ryan et al., 1973)). The first appearance level of Hyalinea baltica well above the base of the Pliocene-Pleistocene boundary as defined in its type section, is coincident with the lithologic level which defines the base of the Emilian subsection in its type section (Santerno section, Emil region, Italy) (Ruggieri et al., 1975) and differentiates the underlying Santernoan from the Emilian sediments.
TAXONOMIC AND BIOSTRATIGRAPHIC NOTES

Articulina tubulosa (Seguenza)

This species is a persistent and frequent element of the Pleistocene deep-sea benthic assemblage in the Mediterranean basin. It is characterized by having the last chambers arranged in more or less long, uniserial, tubular form; smaller specimens, with reduced quinqueloculina stage, generally display longer tubular arrangement of the last chambers. Sometimes the uniserial part of the test is broken off, and the specimen may be misidentified with Quinqueloculina (essentially Quinqueloculina venusta), but a careful examination of the apertural region of the specimen reveals the break. This species appears close to the Pleistocene boundary and is definitely not present in older sediments.

Cibicides wuellestorfi (Schwager)
(Plate 5, Figs. 10–12)


This species is generally not abundant in the Tyrrhenian sites; in the three sites it is present only in the MP15 biozone, from just below the last occurrence of Siphonina reticulata to just above the appearance of Gyroidinoides altiformis. Our specimens have a strongly compressed, trochospiral test with a flat or slightly concave spiral side and a moderately convex ventral side; the aperture is slit-like at the base of the apertural face and extends onto the spiral side.

Cibicides (1) italica (Di Napoli)
(Plate 5, Figs. 7–9)


This very characteristic and stratigraphically useful species is known only in the Mediterranean basin. It is tentatively ascribed to Cibicides considering its highly vaulted spiral side, the granular aspect of the umbilical region, the very fine pores on the spiral side, and the aperture restricted to the umbilical side. It is frequent in late Miocene (AGIP, 1982) and early to middle late Pliocene stratigraphic intervals and disappears well below the Discoaster tamalis extinction level (Glacon, Rio, and Sprovieri, this volume) at about 2.9 Ma.

Cibicides kullenbergi Parker
(Plate 4, Figs. 22–24)

Cibicides kullenbergi Parker, 1953, Swedish Deep-Sea Exp., vol. 7, no. 1, p. 49, pl. 11, figs. 7, 8.

Our specimens are characterized by a trochospiral test with the umbilical side more convex than the spiral side, which is completely covered by a translucent, glassy thickening with few relatively large pores; a distinct, rounded keel is present around the periphery; on the umbilical side the intercalary sutures are flush with the surface, strongly limbate, and strongly recurved backward; the umbilicus is closed by a large, glassy knobby. In the three sites the species is present only in the Pleistocene and the uppermost Pliocene. In older sediments it may be confused with specimens of Cibicides agrigentinus (Schwager) which can be distinguished by its more flat, equally biconvex test, less rounded keel, less limbate and less recurved ventral sutures, and a smaller umbilical knob. In all the samples in which Cibicides kullenbergi has its maximum abundance, Cibicides pachyderma abundance sharply decreases.

Cibicides ornatus (Costa)
(Plate 4, Figs. 6–8)

Nonionina ornata Costa, 1856, Atti Acc. Pont., vol. 7, p. 203, pl. 17, figs. 17a–c.

This generally common species in the Mediterranean Pliocene and Pleistocene sediments is referred to Cibicides for its slit-like, peripheral aperture at the base of the last chamber extending onto the spiral side. Van Morkhoven et al. (1986) list this species as a suspected synonym of Cibicides incrassatus (Fichtel and Moll), an Oligocene to Recent species. Even if the two taxa are quite similar, we prefer to consider Cibicides ornatus as a distinct form for its non-limbate umbilical sutures, less recurved intercalary sutures on the spiral side, less regular and less flat spiral knob, perforated by smaller pores, and the more rounded periphery without a clear imperforate band. This species disappears at different levels of the Pliozone in the Tyrrhenian deep-sea record, but it ranges to Pleistocene in land-based sequences (AGIP, 1982; d'Onofrio, 1983).

Cibicides pachyderma (Rzehak)
(Plate 4, Figs. 9–11)


The subequal trochospiral test, with subcarinate, non-limbose periphery (but lobate in the last chambers of the large specimens) has the spiral side covered by a calcite lamina which completely masks the spiral sutures.

Eggerella bradyi (Cushman)
(Plate 1, Figs. 7–8)


The species has a small, subcylindrical, inflated, finely agglutinated, tri-serial test. This may be confused with immature specimens of Karriera bradyi (Cushman) in which the biserial final ontogenetic stage is not developed. Even if Karriera bradyi generally has a little more coarsely agglutinated surface, the two species may sometimes have been confused together in the specimen count.

Gyroidinoides altiformis Stewart and Stewart

Gyroidina soldanii d'Orbigny var. altiformis Stewart and Stewart, 1930, J. Paleont., vol. 4, no. 1, p. 67, pl. 9, fig. 2.

The species has a high trochospiral test, with oblique intercalary sutures on the spiral side, acute periphery, and open umbilicus. It is a common element of the Miocene sediments (AGIP, 1982); it is not present in lower and basal upper Pliocene interval, and it re-entered the Mediterranean basin in the upper part of the Pliozone (upper part of the MP15 planktonic foraminiferal biozone), quite coincident with the glacial Pliocene event (at about 2.4 Ma), and is living in the Mediterranean basin today (Parker, 1958).

Gyroidina cf. neosoldanii (Brotzen)


In the complicated taxonomy of Gyroidina soldanii (d'Orb.) and Gyroidina neosoldanii (Parker 1958; Todd, 1958; Lohman, 1978), the concept of Parker (1958) is followed here, including specimens with slightly compressed tests, subcarinate periphery, small almost closed umbilicus, and radial sutures.

Oridoras reussi (Reuss)
(Plate 2, Figs. 4–6)

Rotalina umbonata Reuss, 1851, Deutsch Geol. Ges., Zeitscr., vol. 3, p. 75, pl. 5, fig. 35.

In our samples the species is generally common; rare specimens with an acute periphery designated as Truncatulinina tener by Brady, from which Oridoras reussi can hardly be distinguished (Lohman, 1978; Corliss, 1979), are included. We consider Oridoras reussi distinguished from Oridoras stellatus (Silvestri) which is characterized by prominent stellate sutures around the umbilicus. The two species have different stratigraphic ranges: Oridoras stellatus is common in the Pliozone (and pre-Pliozone) interval and disappears in the basal Pleistocene, just below the appearance of Hyalinea bacillifera. Oridoras reussi is more frequent from the uppermost Pliozone and disappears from the Mediterranean basin in the upper part of the NN21 nanofossil biozone. Parker (1958), Blanc-Vernet (1969), and Blanc-Vernet et al. (1983) have all demonstrated that this species is not present in the Mediterranean uppermost Pleistocene and Recent sediments. Its stratigraphic distribution makes it possible to recognize the presence of Recent or sub-Recent sediments in the Mediterranean top core, where this form is not present.
Parrelloides bradyi (Trauth)-Parrelloides robertsonianus (Brady)
(Plate 5, Figs. 1–6)


Even if the two morphotypes may be easily distinguished by the smaller size, reduced number of chambers per whorl (7–9), and oblique intercameral sutures on the spiral side of Parrelloides bradyi, in agreement with Belanger and Berggren (1986) and van Morkhoven et al. (1986), we consider them as representing, respectively, the macroospheric and microospheric forms of the same species. Parrelloides bradyi Trauth, therefore, ought to be considered a junior synonym of Parrelloides robertsonianus (Brady). We refer these forms, following Beldford (1966) to Parrelloides, because of their radial wall structure as opposed to the granular wall of Cibicidoides.

These taxa are present, as common components of the benthal benthic assemblage, only in the Neogene, pre-Pleistocene sediments of the Mediterranean basin, and are still living today in the Atlantic Ocean.

Pullenia osloensis Feyling-Hanssen
(Plate 3, Figs. 15–16)


Slightly compressed, subcircular, five chambers per whorl and slightly depressed sutures characterize this species and distinguish it from the more spherical, four-chambered Pullenia bulloides.

Pyrgo depressa (d’Orbigny)


The strongly depressed, subrounded test with acute periphery is characterized by its elongate, slit-like aperture, which distinguishes this species from Pyrgo murrhyana (Schwager) with a rounded aperture at the end of a non-protruding tube.

Pyrgo lucernula (Schwager)


The strongly protruding, tubular neck supporting its circular aperture is the characteristic feature of this inflated, circular to elongate species.

Stilosomella antillea (Cushman)


This species, with an elongate, uniserial, rectilinear test, is distinguished from Stilosomella montis (Silvestri) by its subovate, non-sub-ovate, subovate, and microspheric forms of the same species.

Uvigerina pygmaea d’Orbigny


Our specimens always exhibit blade-like costae in all the chambers, but in the last one or two chambers, the ornamentation is generally represented by fine, short spines evenly distributed on the surface.

ACKNOWLEDGMENTS

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REFERENCES


Pliopleistocene Benthic Foraminifer Stratigraphic Distribution
PLIO-PLEISTOCENE BENTHIC FORAMINIFER STRATIGRAPHIC DISTRIBUTION

PLIO-PLEISTOCENE BENTHIC FORAMINIFER STRATIGRAPHIC DISTRIBUTION