

The Neogene - Quaternary deposits of the coastal belt between the Tafone and Marta Rivers (Northern Latium)

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ABSTRACT – Four boreholes, out of the several boreholes drilled in the Plio-Pleistocene deposits of the coastal belt of Northern Latium, were analyzed in detail for their micropaleontological content.

Foraminiferal distribution allowed us to reconstruct the biostratigraphy of the core-sampled interval and infer the paleoenvironmental condition of the area.

Benthic foraminiferal assemblages were correlated with sedimentary patterns, sea level and possible climate changes during the Plio-Pleistocene interval, and compared with other outcropping successions and boreholes drilled offshore. In the Early Pliocene-Early Pleistocene interval five planktonic foraminiferal biozones were recognized: the Globorotalia margaritae Zone, the Globorotalia punctulata Zone, the Globorotalia aemiliana Zone, the Globorotalia inflata Zone, and the Globigerina cariacensis Chronozone.

The study reiterates the presence of previously reported Upper Pliocene deposits and discusses their relationships with the Pleistocene marine transgression. Taking into account the different regional interpretations of this sector of Central Italy, a stratigraphic framework was reconstructed showing that during the considered interval sediment deposition of the Neoautochthonous Cycle occurred in belts parallel to the modern coastline.

RIASSUNTO – [I depositi Neogenico-quaternari della fascia costiera compresa tra il torrente Tafone e il fiume Marta (Lazio settentrionale)] – Sono stati presi in esame i sedimenti plio-pleistocenici della fascia costiera del Lazio settentrionale, attraversati da alcuni sondaggi.

Dopo uno studio di tipo litologico, sulle microfaune a foraminiferi di tali depositi è stata condotta un'analisi biostratigrafica tesa a ricostruire la successione stratigrafica dei terreni perforati, ad illustrare le associazioni faunistiche ritrovate, ponendo particolare attenzione alle indicazioni paleoambientali che esse potevano fornire. Per quest'ultimo tipo di indagine sono state studiate le associazioni bentoniche, le quali hanno permesso di stabilire correlazioni tra sedimentazione, livello marino ed oscillazioni climatiche avvenute durante il Plio-Pleistocene, tenendo conto dei risultati ottenuti in successioni limitrofe sia terrigene che di mare profondo.

È stata quindi individuata la sequenza marina depositasi tra il Pliocene inferiore e il Pleistocene inferiore; in questo intervallo cronologico sono state riconosciute la Zona a Globorotalia margaritae, la Zona a Globorotalia punctulata, la Zona a Globorotalia aemiliana, la Zona a Globorotalia inflata e la Cronozona a Globigerina cariacensis.

In base alle conoscenze fino ad oggi acquisite, l'elemento più importante scaturito da questo studio è stato il riconoscimento nell'area di sedimenti appartenenti al Pliocene superiore e l'interpretazione dei rapporti che questi hanno avuto con l'ingressione marina pleistocenica.

È stato così elaborato un quadro stratigrafico complessivo secondo fasce deposizionali disposte parallelamente alla costa allo scopo di chiarire il più possibile le modalità di deposizione del Ciclo Neoautoctono dell'area, tenendo presente le interpretazioni a carattere regionale di questo settore dell'Italia centrale.

INTRODUCTION

The purpose of this study is to investigate the Plio-Pleistocene sediments from the coastal belt of Northern Latium extending between the Tafone to the north and the Marta Rivers to the south. In spite of the numerous detailed (Fazzini *et al.*, 1972) and regional studies (Baldi *et al.*, 1974; Ambrosetti *et al.*, 1978; Pasquaré *et al.*, 1983; Barberi *et al.*, 1994) conducted in the area, no complete picture of the coastal sector of Northern Latium was previously attempted.

Stratigraphic analysis was performed on the cores of some boreholes drilled in the area by "Società Autostrade Tirreniche" of Rome, kindly made available to us by the "C.N.R. – Centro di Studio per la Geologia Tecnica" (National Research Council's Study Center for Engineering Geology) in Rome. In this study, the stratigraphic reconstruction of subsur-

face sequences was attempted, by analyzing the foraminiferal assemblages and by deriving environmental interpretation from them, where possible. Out of the 12 investigated boreholes, four proved to be the most significant ones (B1/07, A1/18, A1/15 and B2/41) for stratigraphic reconstruction of the Neoautochthonous Cycle.

STRATIGRAPHIC SETTING

The coastal belt, which is the focus of this study, is composed of marine and continental sediments of the Neoautochthonous Cycle (Lower Pliocene-Lower Pleistocene). The coastal belt is delimited to the NW by the structural high of Capalbio - Monti Romani, extending approximately in an E-W direction and mostly consisting of Late Palaeozoic phyllitic-quartzitic units and of strips of the reduced Tuscany

Series. Another structural high, which bounds this stretch of coast, is represented by the Tolfa Mountains, where the Cretaceous to Miocene flyschoid formations and the ignimbrites of the Tolfa volcanic complex crop out. Finally, from north (with a boundary coinciding with the Fiora River) to south-east, the Vulsini and Vico volcanic rocks are found.

The Neoautochthonous Cycle of the coastal belt of Northern Latium was studied in detail by Fazzini *et al.* (1972), who recognized two sequences deposited in the Tolfa Mountains from the Lower Pliocene ("partially comprehensive Pliocene" series) to the Middle-Upper Pliocene ("differentiated Pliocene" series). On a regional scale, Baldi *et al.* (1974), Ambrosetti *et al.* (1978), Pasquaré *et al.* (1983) and Barberi *et al.* (1994) outlined the palaeogeographic evolution of the studied area. These authors supposed that the Pliocene initiated with the deposition of deep-water clays of Early Pliocene age, transgressive on Late Miocene evaporitic sediments. By the Middle Pliocene (appearance of *Globorotalia bononiensis*), a regressive cycle started and culminated with the emersion of the whole area in the Late Pliocene. Then, marine sedimentation resumed with the trasgressive sediments of the Pleistocene cycle. Only in the Tarquinia area (Colalongo *et al.*, 1973) as well as in the Fiora River basin (Palieri *et al.*, 1990; Carboni *et al.*, 1994), because of the development of unique environmental setting, the *Globorotalia aemiliana* Zone was recognized (Early-Middle Pliocene).

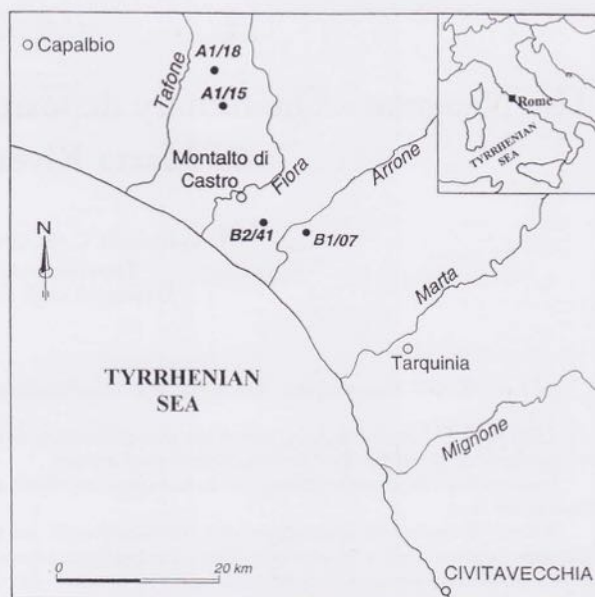
ANALYSIS OF CORES

The boreholes A1/15 and A1/18 were drilled between the Tafone and the Fiora Rivers, B2/41 between the Fiora and the Arrone Rivers and B1/07 on the hydrographic left side of the Arrone River (Text-fig. 1).

The thickness of the drilled sediments ranges between 30 and 40 m. Ground level elevations vary from 35.19 to 51.24 m above sea level (a.s.l.), while the boreholes bottomed at a depth comprised between -4.8 and 15.24 m a.s.l. The recovered sediments generally consist (from top to bottom) of sands, gravels and tuffites, genetically connected with the marine Middle-Late Pleistocene cycle, and of clays with sporadic intercalations of gravelly-sandy layers, attributable to the Neoautochthonous Cycle, in the lower part.

As a whole, 29 samples were analyzed. For each sample, about 200 g of sediment were treated and washed through a 0.88 micron sieve.

The examined sequences were tentatively placed in a chronostratigraphic scheme according to the recently proposed subdivision of the Plio-Pleistocene by Rio *et al.*, 1994, Cita & Castradori, 1995 and Cita *et al.*, 1996. For the micropaleontological data the zonal scheme of Iaccarino & Salvatorini (1982) was adopted and correlated to the Mediterranean zonal



Text-fig. 1 - Location map of the investigated cores.

scheme of Cita (1975), as amended by Sprovieri (1992). Moreover, the age attribution of the upper part of the recovered sediments sometimes had to be derived from the presence of some benthic foraminifers, whose distribution is calibrated to the planktonic foraminiferal zonal scheme (Carboni & Palagi, 1997).

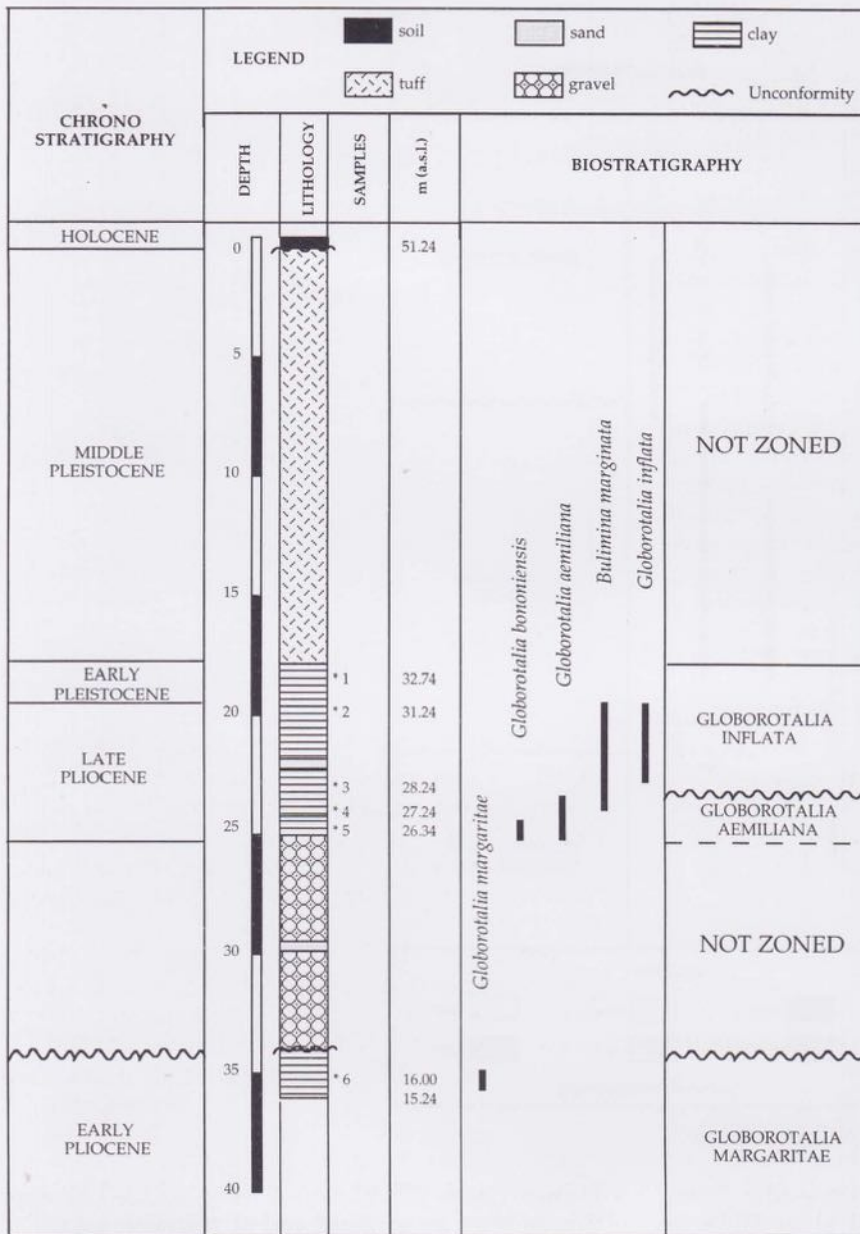
Text-figures 2, 3, 4 and 5 show the biostratigraphic results obtained from each borehole. Table 1 displays the most significant species which are found in the analyzed samples.

CORE B1/07

This borehole is located on the hydrographic left side of the Arrone River, at an elevation of 51.24 m (Text-fig. 2). More precisely, it was drilled into a level surface, ranging in elevation from 35 m to 60 m and genetically connected with the transgressive events of the Middle-Late Pleistocene (Bosi *et al.*, 1990).

The borehole penetrated 36 m of sediments to a depth of 15.24 m a.s.l. (Text-fig. 2). The uppermost 18 m below ground level (blg) are composed of sediments yielding abundant volcanic material, linked to the Middle-Late Pleistocene sedimentary cycle (see also core B2/41). The lowermost 18 m of the core were lithologically subdivided into three parts. The upper part (33.24 m at 26.24 m a.s.l.), consists of blue-grey clays, altered to yellowish in the first meters, with two intercalated sandy layers; the second part (26.24 at 17 m a.s.l.) is almost exclusively composed of gravels in a sandy matrix; the third lowermost part consists of blue-grey clays (17 m a.s.l. to bottom depth).

The clayey sediments of the upper part rest



Text-fig. 2 - Core B1/07. Litho-biostratigraphy.

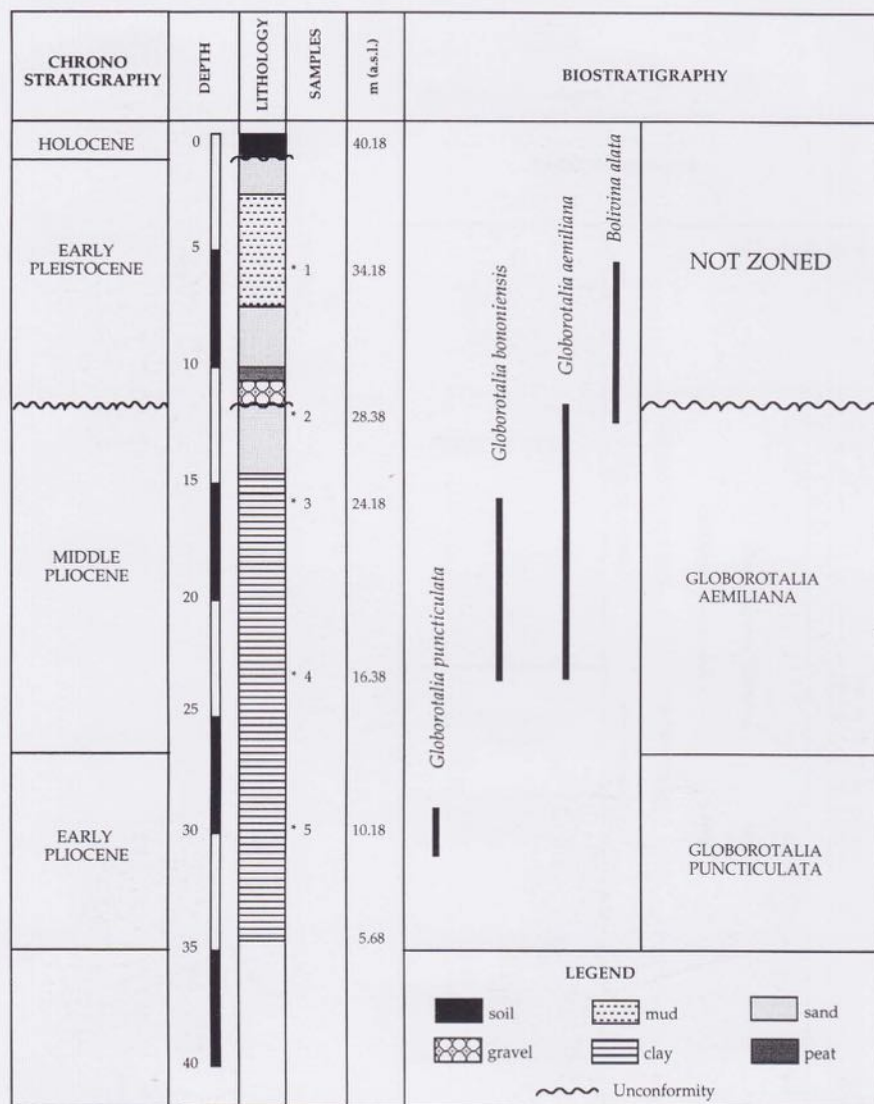
unconformably on the gravelly layer, possibly infilling erosional channel.

Six samples were analyzed for foraminiferal content. Sample 6 (at 16.00 m a.s.l., in the bottom clays), was attributed to the *Globorotalia margaritae* Zone, based on the presence of the nominal marker; sample 5 (at 26.34 m a.s.l., in the clays above the gravels) and sample 4 (at 27.24 m a.s.l., from clays between the two sandy layers) were attributed to the *Globorotalia aemiliana* Zone, based on the presence of the nominal marker; samples 3 and 2 (at 28.24 m a.s.l. and 31.24 m a.s.l. respectively in the clays) were ascribed to the *Globorotalia inflata* Zone, given the presence of rare specimens of *G. inflata*; in the

absence of age-diagnostic taxa, sample 1, (at 32.74 m a.s.l., in the topmost clays), was tentatively attributed to the uppermost part of the *Globorotalia inflata* Zone of Early Pleistocene age, on the basis of stratigraphic relationships and faunal similarities with foraminiferal assemblages from a well known stratigraphic position (Carboni & Palagi, 1997).

CORE A1/18

This borehole was drilled between the Tafone and Fiora rivers at a ground level of 40.18 m a.s.l. to a bottom depth of 5.68 m a.s.l. The core is 34.50 m thick (Text-fig. 3). Below one meter of colluvium,



Text-fig. 3 - Core A1/18. Litho-biostratigraphy.

sediments are dominantly silty and clayey-silty, down to a depth of about 8 m bgl (39.18 m to 31.18 m a.s.l.); then, they are followed by alternating 1-m thick layer of gravel, sand and silt down to a depth of 15 m bgl (31.18 m to 25.38 m a.s.l.). Below this interval, blue-grey clays are encountered down to

bottom depth (25.38 m to 5.68 m a.s.l.). The upper 3 m of clays are oxidized and of yellowish color.

Five samples were studied: three from the blue-grey clays (5-3) and two within the silt-sand-gravel alternations (2-1). Micropalaeontological analysis showed that from the lowest sample (5) to the high-

EXPLANATION OF PLATE 1

- Figs 1-3 - *Globorotalia puncticulata* (Deshayes). 1) Umbilical view; core A1/18, sample 5; 2) Spiral view; core A1/18, sample 5. 3) Edge view; core A1/18, sample 5.
- Figs 4-6 - *Globorotalia margaritae* Bolli & Bermudez. 4) Edge view; core B1/07, sample 6. 5) Umbilical view; core B1/07, sample 6. 6) Spiral view; core B1/07, sample 6.
- Figs 7-8 - *Globorotalia bononiensis* Dondi & Papetti. 7) Umbilical view; core A1/15, sample 14. 8) Spiral view; core A1/15, sample 14.
- Figs 9-10 - *Globorotalia aemiliana* Colalongo & Sartoni. 9) Umbilical view; core B1/07, sample 4. 10) Spiral view; core B1/07, sample 4.
- Fig. 11 - *Sphaeroidinella dehiscens* (Parker & Jones). Umbilical view, core A1/15, sample 4.

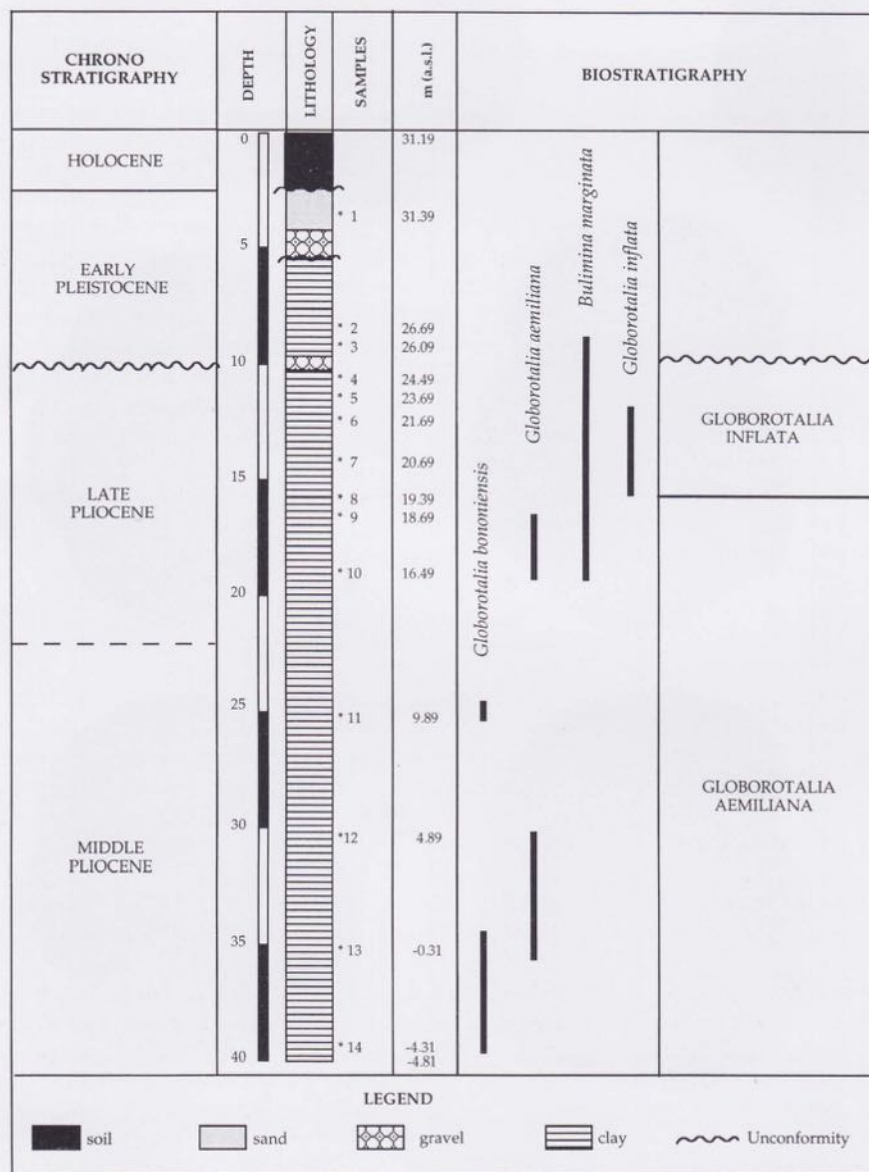


est one (1), organic components diminish, abrasion of foraminiferal tests strongly increases and the representatives of the genus *Globorotalia* become progressively less abundant and are almost absent in the highest sample (1). Moreover, foraminiferal size increases overall from sample 5 to 3, whereas it is below average in samples 1 and 2. Finally, benthic foraminifers are dominant in samples 1 and 4. The basal sample (5) was attributed to the *Globorotalia punctulata* Zone based of the presence of rare specimens of the zonal marker; samples 4, 3 and 2 were attributed to the *Globorotalia aemiliana* Zone. The uppermost sample (1) is devoid of age-diagnostic species; however, it was considered to be of Pleistocene age, as it is housed within the informal unit of "Sabbie e Ghiaie silicee di Mandria Polidori"

(Ambrosetti *et al.*, 1981). The last meter of the alluvial cover was considered to be of Holocene age.

CORE A1/15

This borehole was drilled between the Tafone and Fiora Rivers at a ground level of 35.19 m a.s.l. to a bottom depth of 4.81 m below sea level (b.s.l.); the core is 40 m-thick (Text-fig. 4). Below 2.5 m of Recent alluvium, there are 3 m of silt and yellowish sand with siliceous gravel and metamorphic clasts, that are very likely to belong to the "Sabbie e Argille sabbiose di Mandria Polidori" ("Sands and Siliceous Gravels of Mandria Polidori" Unit, Ambrosetti *et al.*, 1981). The rest of the core is composed of blue-grey and greenish-grey clays, with oxidized patinas and



Text-fig. 4 - Core A1/15. Litho-biostratigraphy.

yellowish colouring down to 16 m bgl (29.69 m to 19.19 m a.s.l.). A 1 m-thick layer of gravelly-sandy silt interrupts the clay succession at 25.50 m a.s.l.

Out of the 14 collected samples, six are from the blue-grey clays (14-9), five from the yellowish clays (8-4), two from the clay above the gravelly layer (3-2) and one (1) from the yellowish silty sand. From micropalaeontological analysis, the following results were obtained: samples 14 to 9 are attributable to the *Globorotalia aemiliana* Zone, although the nominal marker is present discontinuously; samples 8, 7 and 6 were attributed to the *Globorotalia inflata* Zone of Late Pliocene age, based on the presence of *Bolivina alata*, *Bulimina fusiformis* and rare specimens of *Globorotalia inflata*; samples 5 and 4 were still attributed to the *Globorotalia inflata* Zone, although the marker was not identified, as they yield a foraminiferal assemblages similar to those of the underlying sample. Sample 3 and 2 yielding only poorly diagnostic benthic foraminifers (i.e. *Florilus boueanus*, *Elphidium crispum*, *Valvulineria bradyana*) were attributed again to the *Globorotalia inflata* Zone (Early Pleistocene); sample 1 was considered to be of Pleistocene age, as it is housed within the informal unit of the "Sabbie e Ghiaie silicee di Mandria Polidori" (Ambrosetti *et al.*, 1981).

In this core, intense reworking of Lower-Middle Pliocene faunas is evident throughout as suggested by the occurrence of specimens of *Globorotalia puncticulata* and *G. bononiensis*.

CORE B2/41

This borehole is located on the left side of the Fiora River, along the Via Aurelia, approximately opposite the built-up area of Montalto di Castro. The borehole was drilled at a ground level of 37.51 m a.s.l. to a bottom depth of 2.51 m a.s.l. and penetrates 35m of sediments (Text-fig. 5). In the upper part of the core, 17.60 m-thick, Middle Pleistocene sediments were recovered; these sediments dominantly consist of gravelly-silty-sandy, m-scale alternations, locally cemented, fossiliferous and rich in volcanic minerals from the neighbouring Bolsena and Vico volcanic complexes (Bosi *et al.*, 1990). The rest of the core consists of highly fossiliferous dark-grey clays; some sandy layers occur at 16.91 m and 10 m a.s.l. and sandy-gravelly layers are present from 10 m to 5.51 m a.s.l.

Four samples (4-1) were collected from the clayey and the sandy-clayey layers. Given the lack of planktonic markers and a general faunal scarcity, sample 4 was attributed to the *Globorotalia inflata* Zone of Late Pliocene age, based on the presence of *Bulimina fusiformis*. On the basis of the presence of *Bulimina elegans* and *Bulimina elegans marginata*, samples 2 and 3 were attributed to the upper part of *Globorotalia inflata* Zone of Early Pleistocene age. Sample 1 shows not only an increase in abundance of

Bulimina elegans marginata, but also the presence of *B. etnea*; thus, this sample was attributed to the *Globigerina cariacensis* Chronozone (Early Pleistocene). The about 18 m sediments that separate the uppermost sample studied from the ground level were interpreted as of Middle Pleistocene age, based on the presence of volcanic material from the Bolsena and Vico volcanic complex (Bosi *et al.*, 1990), except for the uppermost meter which was considered as the Holocene cover. It is worth mentioning that in sample 4 foraminiferal taxa, very scarce overall, display a small size below the average and a poor state of preservation; the planktonic specimens are rare but the presence of ostracods was detected.

DESCRIPTION OF FORAMINIFERAL ASSEMBLAGES

Foraminiferal assemblages recovered in the four boreholes are characterized as follows:

Globorotalia margaritae ZONE (B1/07)

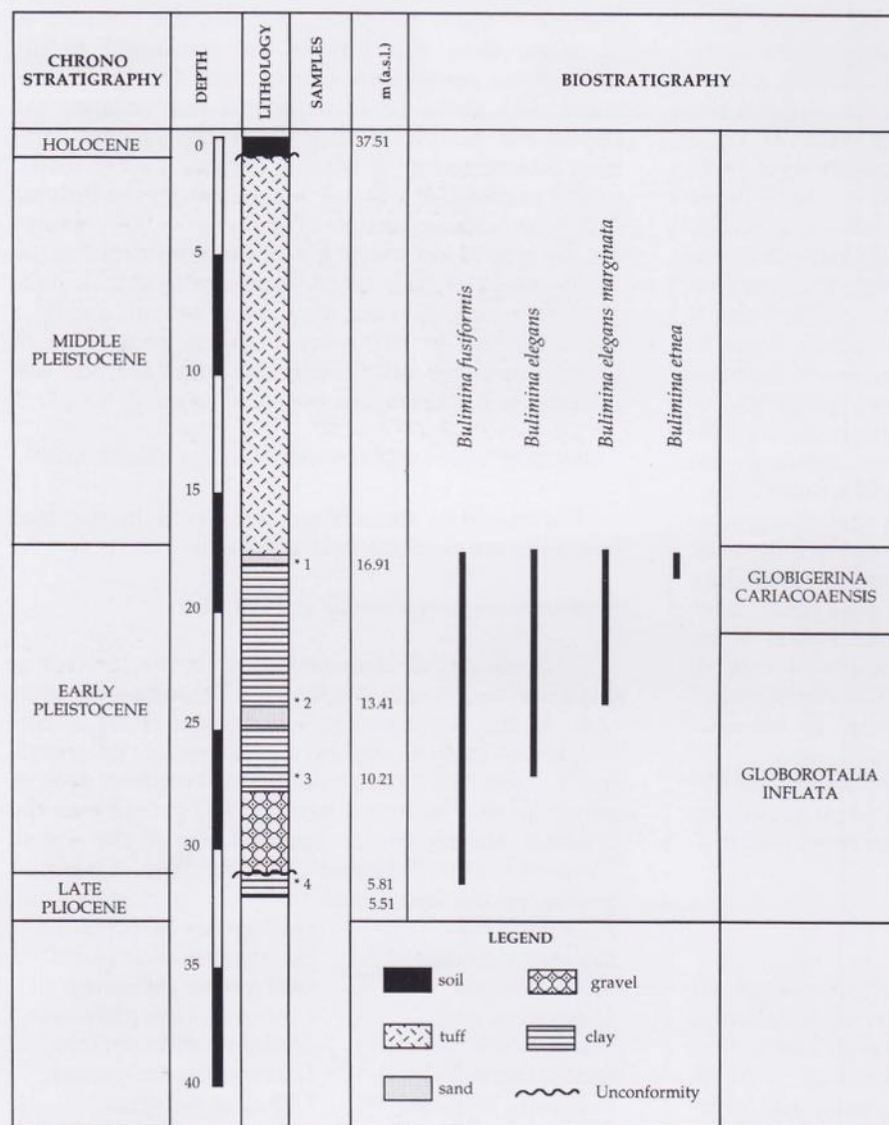
This zone was identified only in the lowermost clay (few meter) in borehole B1/07 based on the presence of the nominal marker. Foraminiferal assemblages are characterized by a great variety of genera, species and individuals and by an excellent state of preservation. Planktonic foraminifers prevail over the benthics, among which representative of the genera *Uvigerina* and *Bulimina* are abundant. Common species are (see below and Table 1):

<i>Bolivina italica</i>	<i>Globigerina apertura</i>
<i>Bolivina punctata</i>	<i>Globigerina decoraperta</i>
<i>Bulimina</i> spp.	<i>Globigerina falconensis</i>
<i>Lenticulina</i> spp.	<i>Globigerinoides obliquus</i>
<i>Marginulina costata</i>	<i>Globigerinoides trilobus</i>
<i>Marginulina glabra</i>	<i>Globorotalia margaritae</i>
<i>Nodosaria raphanus</i>	<i>Orbulina universa</i>
<i>Oridorsalis umbonatus</i>	
<i>Planulina ariminensis</i>	
<i>Siphonina reticulata</i>	
<i>Uvigerina peregrina</i>	
<i>Uvigerina pygmaea</i>	
<i>Uvigerina rutila</i>	

The foraminiferal assemblages indicate a circalittoral environment evidenced by the abundance of planktonic foraminifers and uvigerinids and buliminids among the benthics.

Globorotalia puncticulata ZONE (A1/18)

This zone was identified only in one sample from the lowermost clays in borehole A1/18, based on the presence of the nominal marker. The rare and ill-preserved individuals of *Globorotalia margaritae* observed in the assemblage were interpreted as reworked. The foraminiferal assemblage of this zone retains the variety and abundance already recorded in the underlying zone with planktonic foraminifers



Text-fig. 5 - Core B2/41. Litho-biostratigraphy.

prevailing over the benthics. The most common species are (see below and Table 1):

Anomalinoidea helacinus *Globigerina apertura*

Bolivina spp.

Bulimina spp.

Lenticulina spp.

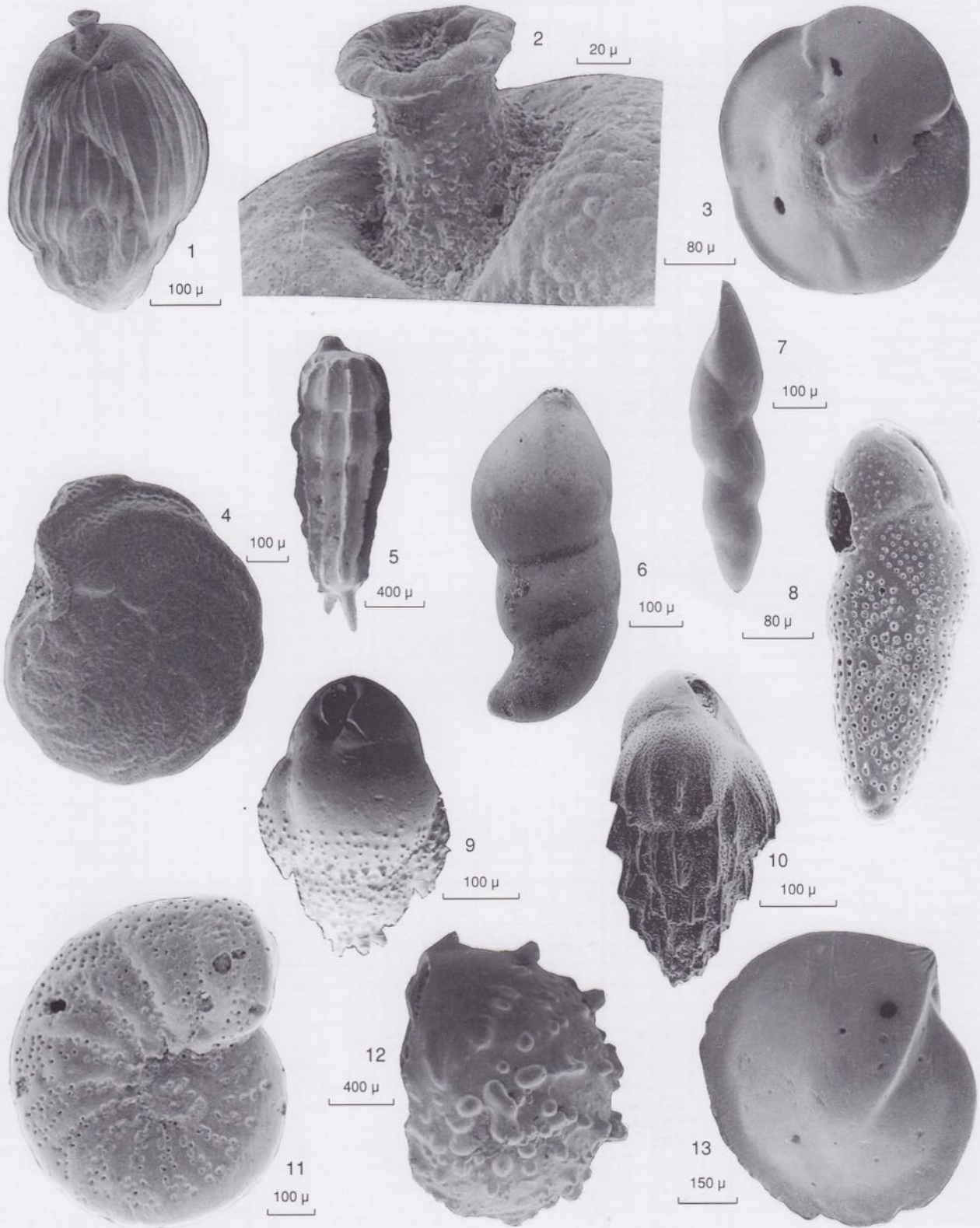
Globigerina bulloides

Globigerina decoraperta

Globigerina falconensis

EXPLANATION OF PLATE 2

- Figs 1-2 - *Uvigerina rutila* Cushman & Todd. 1) Side view; core B1/07, sample 6. 2) Apertural view of the specimen of fig. 1, detail.
 Fig. 3 - *Oridorsalis umbonatus* (Reuss). Ventral view; core A1/15, sample 14.
 Fig. 4 - *Planulina ariminensis* d'Orbigny. Side view; core B2/41, sample 3.
 Fig. 5 - *Marginulina costata* (Batsch). Side view; core B1/07, sample 6.
 Fig. 6 - *Marginulina glabra* d'Orbigny. Side view; core A1/15, sample 14.
 Fig. 7 - *Pleurostomella alternans* Schwager. Side view; core A1/15, sample 12.
 Fig. 8 - *Bolivina punctata* d'Orbigny. Side view; core B1/07, sample 6.
 Fig. 9 - *Bulimina minima* Tedeschi & Zanmatti. Side view; core B1/07, sample 6.
 Fig. 10 - *Bulimina costata* d'Orbigny. Apertural view; core A1/15, sample 14.
 Fig. 11 - *Anomalinoidea helacinus* (Costa). Side view; core A1/15, sample 14.
 Fig. 12 - *Lenticulina spinulosa* (Costa). Side view; core B1/07, sample 6.
 Fig. 13 - *Lenticulina cultrata* (de Montfort). Side view; core A1/15, sample 12.



SPECIES	CORES-SAMPLES					A1/18					A1/15										B2/41				B1/07					
	5	4	3	2	1	14	13	12	11	10	9	8	7	6	5	4	3	2	1	4	3	2	1	6	5	4	3	2	1	
<i>Ammonia beccarii</i>																	x	x		x					x	x			x	
<i>Ammonia inflata</i>																				x										
<i>Anomalinoidea helicinus</i>						x	x	x	x																					
<i>Bolivina alata</i>				x	x		x	x	x	x	x	x	x	x	x	x				x	x	x	x			x	x	x		
<i>Bolivina catanensis</i>					x					x		x			x	x														
<i>Bolivina dilatata</i>	x	x				x	x	x	x	x	x				x	x	x								x					
<i>Bolivina italica</i>	x																							x						
<i>Bolivina punctata</i>	x	x	x	x		x	x	x	x	x	x													x						
<i>Bulimina basispinosa</i>							x	x	x											x						x				
<i>Bulimina costata</i>	x	x	x	x	x	x	x	x	x	x	x				x		x							x	x					
<i>Bulimina elegans</i>																					x	x	x							
<i>Bulimina elegans marginata</i>																						x	x							
<i>Bulimina elongata</i>													x	x												x	x			
<i>Bulimina etnea</i>																							x							
<i>Bulimina fusiformis</i>												x	x	x	x	x				x	x	x	x							
<i>Bulimina lappa</i>	x					x															x	x	x		x	x	x			
<i>Bulimina marginata</i>										x	x	x	x	x	x	x	x				x	x		x	x	x				
<i>Bulimina minima</i>					x				x												x	x			x					
<i>Cancris auriculus</i>															x						x									
<i>Cassidulina laevigata carinata</i>					x						x		x	x	x						x				x		x			
<i>Elphidium crispum</i>																				x	x		x			x	x			
<i>Favulina hexagona</i>							x									x					x							x		
<i>Florilus boueanus</i>																				x	x		x		x		x	x		
<i>Heterolepa floridana</i>						x	x				x		x	x	x	x								x						
<i>Lenticulina calcar</i>	x					x		x			x																			
<i>Lenticulina cultrata</i>		x					x	x							x	x	x							x	x					
<i>Lenticulina gibba</i>	x																													
<i>Lenticulina inornata</i>						x	x		x															x						
<i>Lenticulina spinulosa</i>																								x						
<i>Marginulina costata</i>	x																							x						
<i>Marginulina glabra</i>	x					x																		x						
<i>Melonis padanus</i>							x					x	x	x	x	x										x	x			
<i>Nodosaria raphanus</i>	x																							x						
<i>Oridorsalis umbonatus</i>	x	x				x	x	x	x															x	x	x				
<i>Planulina ariminensis</i>	x	x				x	x	x	x												x			x	x	x				
<i>Pleurostomella alternans</i>	x	x	x					x	x	x	x	x	x	x											x	x	x	x		
<i>Pullenia bulloides</i>						x			x		x	x	x	x	x															
<i>Siphonina reticulata</i>			x			x	x				x	x	x	x	x	x														
<i>Stainforthia complanata</i>														x	x	x	x	x	x		x	x					x	x		
<i>Uvigerina peregrina</i>		x	x	x		x	x	x	x	x	x	x	x	x	x									x	x	x				
<i>Uvigerina pygmaea</i>	x	x	x	x		x	x	x	x	x	x	x	x	x	x	x								x						
<i>Uvigerina rutila</i>	x	x	x	x		x											x							x						
<i>Valvulineria bradyana</i>														x	x	x	x	x	x		x	x					x	x		
<i>Globigerina apertura</i>		x	x	x		x																		x						
<i>Globigerina bulloides</i>		x	x	x	x		x	x	x		x	x	x	x	x						x			x	x	x	x			
<i>Globigerina decoraperta</i>	x	x	x	x	x		x		x	x		x		x	x									x	x	x	x			
<i>Globigerina falconensis</i>					x		x	x				x		x	x						x			x	x	x				
<i>Globigerinita glutinata</i>							x	x		x	x		x	x		x														
<i>Globigerinoides elongatus</i>												x	x	x	x						x				x	x	x			
<i>Globigerinoides obliquus</i>	x	x	x	x		x	x	x	x	x														x	x	x				
<i>Globigerinoides ruber</i>		x	x	x								x	x	x	x	x					x		x			x	x	x		
<i>Globigerinoides sacculifer</i>	x	x	x	x							x	x	x	x	x	x														
<i>Globigerinoides trilobus</i>	x	x	x	x	x		x	x	x	x	x													x						
<i>Globorotalia aemiliana</i>			x	x	x			x	x		x	x													x	x				
<i>Globorotalia bononiensis</i>			x	x			x	x		x															x					
<i>Globorotalia crassaformis</i>			x	x	x							x															x			
<i>Globorotalia inflata</i>													x	x	x						x	x					x	x		
<i>Globorotalia margaritae</i>																									x					
<i>Globorotalia puncticulata</i>	x																													
<i>Orbulina universa</i>	x						x	x	x	x	x	x	x	x	x	x									x	x	x	x		
<i>Sphaeroidinella dehiscens</i>																														
<i>Turborotalia quinqueloba</i>														x	x	x	x	x	x		x	x						x		

Tab. 1 - Distribution of significant taxa recognized in the cores.

<i>Marginulina costata</i>	<i>Globigerinoides obliquus</i>
<i>Marginulina glabra</i>	<i>Globigerinoides trilobus</i>
<i>Oridorsalis umbonatus</i>	<i>Globorotalia puncticulata</i>
<i>Planulina ariminensis</i>	<i>Orbulina universa</i>
<i>Siphonina reticulata</i>	
<i>Uvigerina peregrina</i>	
<i>Uvigerina pygmaea</i>	
<i>Uvigerina rutila</i>	

As a whole, the depositional environment is still circalittoral.

Globorotalia aemiliana ZONE (B1/07, A1/18, A1/15)

This zone or portions of this zone were identified in boreholes B1/07, A1/18 and A1/15. The marker species is discontinuously present, but some specimens of *Globorotalia bononiensis* were also found in the interval considered. The upper part of the *Globorotalia aemiliana* Zone is characterized by the appearance of *Bulimina marginata*. This event allows us to indicate that (1) the *G. aemiliana* Zone is best represented and probably complete only in borehole A1/15 where it is about 24 m-thick; (2) in borehole A1/18, the absence of *B. marginata* suggests that the upper part of the zone is probably missing as supported also by the less thick (only about 15 m) sequence attributable to the *G. aemiliana* Zone; and (3) in borehole B1/07 the *G. aemiliana* Zone was identified only in less than 3 m of sediments. The co-occurrence of the zonal marker with *G. bononiensis* and *B. marginata* indicates that only part of the upper portion of the *G. aemiliana* Zone is probably represented at this site.

The faunal assemblages of the *G. aemiliana* Zone include much fewer planktonic foraminifers with respect to the previous zones, whereas benthic foraminifers tend to increase in abundance throughout. The state of preservation worsens and, as a whole, both the variety and number of species and genera decrease. Moreover, reworking increases as indicated by the presence of some specimens of *Globorotalia margaritae* and *Globorotalia puncticulata* (Early Pliocene) throughout the interval.

Common species in this zone are (see below and Table 1):

<i>Anomalinoidea helacinus</i>	<i>Globigerina bulloides</i>
<i>Bolivina aenariensis</i>	<i>Globigerina decoraperta</i>
<i>Bolivina catanensis</i>	<i>Globigerina falconensis</i>
<i>Bulimina basispinosa</i>	<i>Globigerina umbilicata</i>
<i>Bulimina costata</i>	<i>Globigerinoides elongatus</i>
<i>Cassidulina laevigata carinata</i>	<i>Globigerinoides obliquus</i>
<i>Heterolepa floridana</i>	<i>Globigerinoides ruber</i>
<i>Planulina ariminensis</i>	<i>Globigerinoides sacculifer</i>
<i>Pleurostomella alternans</i>	<i>Globorotalia aemiliana</i>
<i>Pullenia bulloides</i>	<i>Globorotalia bononiensis</i>
<i>Siphonina reticulata</i>	<i>Orbulina universa</i>
<i>Uvigerina peregrina</i>	

The depositional environment becomes slightly shallower than in the previous zones shifting towards

the circalittoral-infralittoral transition, as indicated by the decrease in abundance of planktonic foraminifers as well as of the uvigerinids among the benthics.

Globorotalia inflata ZONE

Above the *G. aemiliana* Zone, the faunal assemblages become increasingly poor with an overall decrease in abundance of planktonic foraminifers especially of representatives of the genus *Globorotalia*. The marker species is frequently missing or, when present, is represented by few individuals. In the case of borehole B2/41, the *G. inflata* Zone could be identified only relying on the presence of *Bulimina fusiformis*, *Bulimina elegans*, and *Bulimina elegans marginata* in the upper part. Beside such a bias, borehole B2/41 is the only site where the upper boundary of the *G. inflata* Zone was recovered and falls within the same sedimentary facies. In all the other boreholes the *G. inflata* Zone is truncated by an unconformity (A1/15), is totally missing (A1/18) or a drastic facies change prevents to estimate how much of the zone is really represented in the cored successions (B1/07).

Foraminiferal assemblages are dominated by benthic taxa, especially buliminids, and reworking of Lower and Middle Pliocene sediments (presence of *Globorotalia puncticulata*, *G. bononiensis*, *G. aemiliana*) is prominent. Characteristic species are (see below and Table 1):

<i>Bolivina alata</i>	<i>Globigerina bulloides</i>
<i>Bolivina catanensis</i>	<i>Globigerinita glutinata</i>
<i>Bulimina basispinosa</i>	<i>Globigerinoides elongatus</i>
<i>Bulimina elegans</i>	<i>Globigerinoides ruber</i>
<i>Bulimina elegans marginata</i>	<i>Globorotalia inflata</i>
<i>Bulimina elongata</i>	<i>Orbulina universa</i>
<i>Bulimina fusiformis</i>	<i>Sphaeroidinella dehiscens</i>
<i>Bulimina marginata</i>	<i>Turborotalita quinqueloba</i>
<i>Cancris auriculus</i>	
<i>Cassidulina laevigata carinata</i>	
<i>Favulina exagona</i>	
<i>Heterolepa floridana</i>	
<i>Pleurostomella alternans</i>	
<i>Siphonina reticulata</i>	
<i>Stainforthia complanata</i>	

The depositional environment is typical of the infralittoral-circalittoral transition, due to the sharp decline in planktonic foraminiferal abundance and to the absence of uvigerinids among the benthics. The dominance of *Bulimina* spp. suggest that the sea floor was silty (Van der Zwaan & Jorissen, 1991).

The depositional environment evolved from infralittoral (sample 3 and 4), with scarce planktonic and typical shallow-water foraminifers, to circalittoral (sample 1 and 2).

Globigerina cariacensis CHRONOZONE

This zone was identified only in borehole B2/41 based on the age-diagnostic benthic foraminifer

Bulimina etnea in association with *Bulimina elegans marginata* in the absence of the planktonic marker species. Foraminiferal assemblages are again rich, abundant and in a good state of preservation. They are characterized by a P/B ratio < 1 and planktonic foraminifers are a minor component of the assemblages. The particularly rich benthic fauna includes very abundant buliminids, *Cassidulina carinata* and *Valvulineria bradyana*. Other characteristic species are (see below and Table 1):

<i>Ammonia beccarii</i>	<i>Globigerina bulloides</i>
<i>Bolivina alata</i>	<i>Globigerinita glutinata</i>
<i>Bulimina elegans marginata</i>	<i>Globigerinoides elongatus</i>
<i>Bulimina elongata</i>	<i>Globigerinoides ruber</i>
<i>Bulimina etnea</i>	<i>Globigerinoides sacculifer</i>
<i>Bulimina fusiformis</i>	<i>Turborotalita quinqueloba</i>
<i>Bulimina marginata</i>	
<i>Cancris auriculus</i>	
<i>Cassidulina laevigata carinata</i>	
<i>Favulina exagona</i>	
<i>Heterolepa floridana</i>	
<i>Stainforthia complanata</i>	
<i>Valvulineria bradyana</i>	

The depositional environment is typical of the circalittoral environment, because *Bolivina* spp. and *Bulimina* spp. are abundant.

Some foraminiferal assemblages recovered from boreholes A1/15 and B1/07 are devoid of planktonic or benthic marker species but are typically characterized by infralittoral species (i.e. *Ammonia* spp., *Florilus boueanus*, *Cibicides lobatulus*). They were attributed to the Lower Pleistocene on the basis of the stratigraphic position and lithostratigraphic data.

CONCLUDING REMARKS

Considering the four boreholes all together, the cored sediments, below the Holocene alluvium, are spanning the time interval from the Early Pliocene to the Middle Pleistocene. The composite succession, however, is interrupted by several hiatuses, commonly at different levels and of different duration from

site to site (see Text-fig. 6). As a matter of fact, the *Globorotalia margaritae*, *Globorotalia puncticulata*, *Globorotalia aemiliana*, *Globorotalia inflata*, and *Globigerina cariacensis* Zones are recognized, whereas the *Globorotalia margaritae*/*Globorotalia puncticulata* Zone was not documented in the study area.

Paleoecologically, from the Early Pliocene to the Early Pleistocene the depositional environment changed from a circalittoral to an infralittoral environment and again to circalittoral in the Early Pleistocene. This interpretation is supported by the changes in faunal composition; the Lower Pliocene assemblages exhibit a greater variety of species and a better preservation with respect to the assemblages of Piacentian and Gelasian (Middle and Upper Pliocene) in which a significant reworking was observed and preservation is increasingly poor.

The most prominent hiatus was observed in borehole B1/07 (Text-fig. 2) where sedimentation above the *Globorotalia margaritae* Zone is expressed only by 10 m-thick gravelly layer, cut at the top by erosional channels, and normal marine sedimentation resumed after more than 1.0 m.y. in the *Globorotalia aemiliana* Zone (see Text-fig. 6).

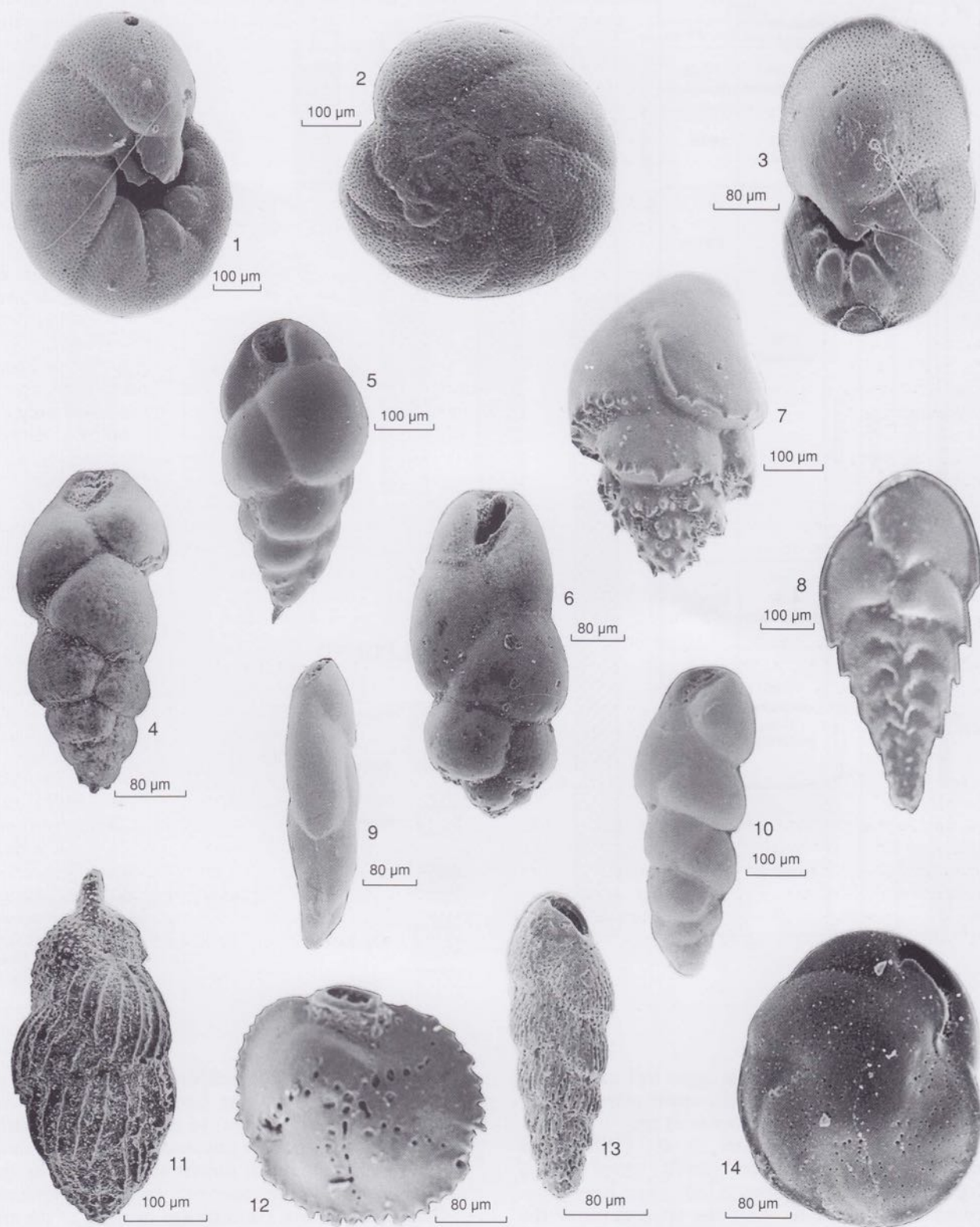
The absence of the *Globorotalia margaritae*/*Globorotalia puncticulata* (concurrent) Zone suggests that there is a sedimentation hiatus of about 0.5 m.y., a duration comparable with that reported by Rio *et al.* (1988) in the lower part of the stratotype section of the Piacentian Stage.

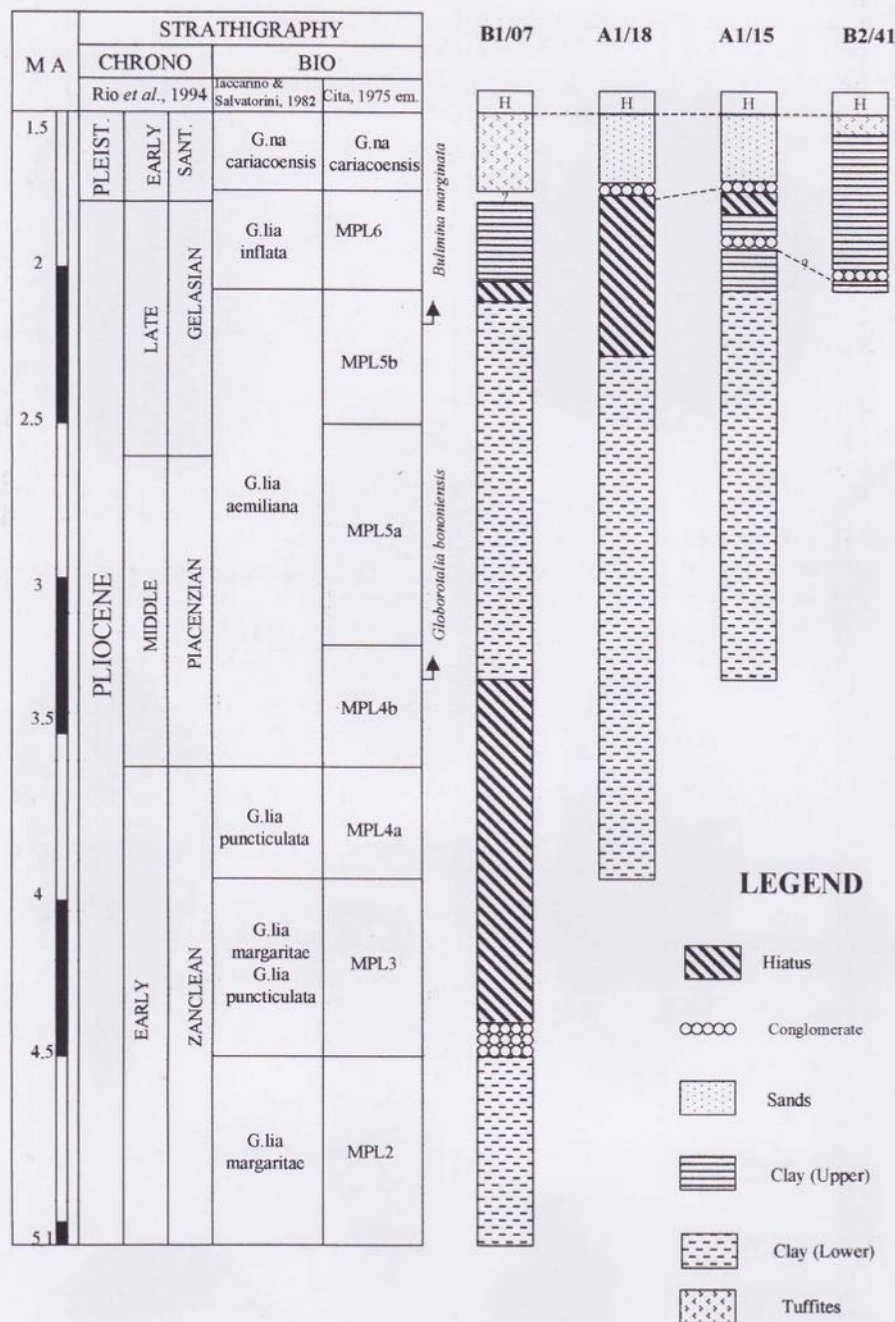
The erosional surface at the top of the gravelly layers, of submarine or subaerial origin, is interpreted as possibly being originated during a period of low stand of sea level within the time span from the Early to the Middle Pliocene.

Gravelly layers also occur (1) within the *Globorotalia inflata* Zone (Gelasian) in boreholes A1/15 and B2/41 (based on their stratigraphic position these gravelly layers are possibly coeval) where, however, their presence could not be proved as being associated with a sedimentary gap; and (2) just below the Pleistocene sands in boreholes A1/18 and A1/15 where they are recorded above a sedimentary hiatus of about 0.5

EXPLANATION OF PLATE 3

- Figs 1-2 - *Valvulineria bradyana* (Fornasini). 1) Ventral view; core B2/41, sample 3. 2) Spiral view; core B2/41, sample 3.
 Fig. 3 - *Cancris auriculus* (Fichtel & Moll). Ventral view; core B2/41, sample 3.
 Fig. 4 - *Bulimina fusiformis* Williamson. Apertural view; core A1/15, sample 7.
 Fig. 5 - *Bulimina elegans* d'Orbigny. Apertural view; core B2/41, sample 2.
 Fig. 6 - *Bulimina lappa* Cushman & Parker. Apertural view; core A1/15, sample 14.
 Fig. 7 - *Bulimina marginata* d'Orbigny. Side view; core B2/41, sample 2.
 Fig. 8 - *Bolivina alata* (Seguenza). Side view; core B2/41, sample 2.
 Fig. 9 - *Stainforthia complanata* (Egger). Side view; core B2/41, sample 3.
 Fig. 10 - *Bulimina elongata* d'Orbigny. Apertural view; core A1/15, sample 7.
 Fig. 11 - *Uvigerina pygmaea* d'Orbigny. Side view; core A1/15, sample 14.
 Fig. 12 - *Siphonina reticulata* (Czjzek). Side view; core A1/18, sample 3.
 Fig. 13 - *Bolivina italica* Cushman. Apertural view; core B1/07, sample 6.
 Fig. 14 - *Cassidulina laevigata carinata* Silvestri. Apertural view; core B2/41, sample 3.





Text-fig. 6 - Correlation of the investigated cores plotted against chrono- and biostratigraphy. Absolute ages according to Rio *et al.*, 1994.

m.y. and 0.1 m.y. spanning the upper half and the top of the Gelasian, respectively; the upper gravelly layers are interpreted as Early Pleistocene in age.

According to Ambrosetti *et al.*, (1987) and Pasquare *et al.* (1983) the middle sector of the Tyrrhenian portion of Central Italy must have experienced a gradual uplift after the appearance of the *Globorotalia bononiensis* in the Middle Pliocene until complete emersion of the area in the Late Pliocene. This assumption is consistent with the regressive facies characterizing the *Globorotalia aemiliana* Zone.

However, the hypothesized hiatus of about 2.6 m.y., reported by these authors (see also Barberi *et al.*, 1994) and related by them to the emersion of area, can not be confirmed by this study. According to our data, the hiatus is much shorter as supported by the occurrence of marine sediments of the *Globorotalia inflata* Zone of Late Pliocene age in three of the four boreholes. The culminating phase of the Late Pliocene regression is best expressed by sample 4 from borehole B2/41, then followed by the transgressive sequence inferred as Early Pleistocene in age.

Sedimentary hiatus are reported in the literature at various levels during the Pliocene. For instance, Rio *et al.* (1988) reported a sedimentary gap of about 0.5 m.y. in the lower part of the stratotype section of the Piacentian Stage, and minor hiatuses also occur in the Plio-Pleistocene deep-sea succession from the Tyrrhenian sea (DSDP Site 132 Cita, 1973; Thunell, 1979; ODP Site 653 Rio *et al.*, 1990b).

During the time span covered by the studied sequence, the deep-sea record also shows a progressive cooling of waters masses (based on oxygen isotopes) beginning around 3.2-3.0 Ma B.P. (Shackleton *et al.*, 1990) and, according to Keigwin (1987), culminating around 2.6-2.4 Ma at the onset of the Arctic glaciation. Then, we can not rule out that the effects of the local uplifting might have been enhanced by a lowering of sea level due to the glaciation onset.

An overall review of the data gives a more detailed picture of the Neautochthonous sedimentation the study area. As a matter of fact, the available data indicate that the Neautochthonous cycle of the area comprises three separate cycles (Text-Fig. 6): the first of Early Pliocene age, the second in the Middle to Late Pliocene, and the third one in the Early Pleistocene. Moreover, sedimentation is likely to have occurred along two belts, running parallel to the present-day coast. In the first belt (0-35 m a.s.l.; B2/41), Miocene sediments are overlain only by transgressive Lower Pleistocene (marine facies) and Middle-Upper Pleistocene sediments. This interpretation relies both on holes drilled by ENEL near the Tafone River (Pian dei Gangani), as indicated by Radtke (1983), and on data reported by Ambrosetti *et al.* (1981) and Bosi *et al.* (1990). The second belt (35-80 m a.s.l.) includes the remaining boreholes analyzed in this study. This second belt houses argillaceous and argillaceous-sandy sediments of the Upper Miocene and of the entire Pliocene cycle, which are transgressively covered by sandy-conglomeratic deposits of Early-Middle Pleistocene age. Finally, the upper part of these Lower Pleistocene deposits appears to have been truncated by marine and/or continental Middle Pleistocene successions, closely related to the Vulsini and Vico volcanic complexes.

LIST OF SPECIES

Ammonia beccarii (Linné, 1758)

1758 *Nautilus beccarii* LINNÉ, p. 710; in PLANCUS p. 8, pl. 1, figs. 1a-c.

Ammonia inflata (Seguenza, 1862)

1862 *Rosalina inflata* SEGUENZA, p. 106, pl. 1, fig. 6.

Anomalinoidea helicinus (Costa, 1855); (Pl. 2, fig. 11).

1855 *Nonionina helicina* COSTA, p. 123, pl. 1, figs. 18a-b-c.

Bolivina alata (Seguenza, 1862); (Pl. 3, fig. 8).

1862 *Vulvulina alata* SEGUENZA, p. 115, pl. 2, figs. 5-5a.

Bolivina catanensis Seguenza, 1862

1862 *Bolivina catanensis* SEGUENZA, p. 113, 125, pl. 2, figs. 3-3b.

Bolivina dilatata Reuss, 1850

1850 *Bolivina dilatata* REUSS, p. 381, pl. 48, fig. 15.

Bolivina italica Cushman, 1936; (Pl. 3, fig. 13).

1936 *Bolivina italica* CUSHMAN, p. 56, pl. 8, fig. 6.

Bolivina punctata d'Orbigny 1839b; (Pl. 2, fig. 8).

1839 *Bolivina punctata* d'ORBIGNY, p. 63, pl. 8, figs. 10-12.

Bulimina basispinosa Tedeschi & Zanmatti, 1957.

1957 *Bulimina aculeata* d'ORBIGNY var. *basispinosa* TEDESCHI & ZANMATTI, p. 248, tfs. 2a-c.

Bulimina costata d'Orbigny, 1826; (pl. 2, fig. 10).

1826 *Bulimina costata* d'ORBIGNY, p. 269; in FORNASINI, 1901, p. 174, pl. 1.

Bulimina elegans d'Orbigny, 1826; (Pl. 3, fig. 5).

1826 *Bulimina elegans* d'ORBIGNY, p. 270; in PARKER, JONES & BRADY 1865, pl. 3, fig. 64.

Bulimina elegans marginata Fornasini, 1902.

1902 *Bulimina elegans* d'ORBIGNY var. *marginata* FORNASINI, p. 376, pl. O, figs. 7, 14, 33, 39.

Bulimina elongata d'Orbigny, 1846; (Pl. 3, fig. 10).

1846 *Bulimina elongata* d'ORBIGNY, p. 187, pl. 11, figs. 19-20.

Bulimina etnea Seguenza, 1862.

1862 *Bulimina etnea* SEGUENZA, p. 108, 125 pl. 1, fig. 9.

Bulimina fusiformis Williamson, 1858; (Pl. 3, fig. 4).

1858 *Bulimina pupoides* d'ORBIGNY var. *fusiformis* WILLIAMSON, p. 63, pl. 5, figs. 129-130.

Bulimina lappa Cushman & Parker, 1937; (Pl. 3, fig. 6).

1937 *Bulimina elongata* d'ORBIGNY var. *lappa* CUSHMAN & PARKER, p. 51, pl. 7, fig. 8.

Bulimina marginata d'Orbigny, 1826; (Pl. 3, fig. 7).

1826 *Bulimina marginata* d'ORBIGNY, p. 269, pl. 12, figs. 10-11.

Bulimina minima Tedeschi & Zanmatti, 1957; (Pl. 2, fig. 9).

1957 *Bulimina aculeata* d'ORBIGNY var. *minima* TEDESCHI & ZANMATTI, p. 249, fig. 3.

Cancris auriculus (Fichtel & Moll, 1798) (Pl. 3, fig. 3).

1798 *Nautilus auriculus* FICHTEL & MOLL, p. 108, pl. 20, figs. a-c.

Cassidulina laevigata carinata Silvestri, 1896; (Pl. 3, fig. 14).

1896 *Cassidulina laevigata* d'ORBIGNY var. *carinata* SILVESTRI, p. 104, pl. 2, fig. 10 a-c.

Elphidium crispum (Linné, 1758)

1758 *Nautilus crispum* LINNÉ, p. 709, fig. 1d.

Favulina hexagona (Williamson, 1848)

1848 *Entosolenia squamosa* MONTAGU var. *hexagona* WILLIAMSON, p. 20, pl. 2, fig. 23.

Florilus boueanus (d'Orbigny, 1846)

1846 *Nonionina boueana* d'ORBIGNY, p. 108, pl. 5, figs. 11-12.

Globigerina apertura Cushman, 1918; (Pl. 4, fig. 8).

1918 *Globigerina apertura* CUSHMAN, p. 57, pl. 12, figs. 8a-c.

Globigerina bulloides d'Orbigny, 1826; (Pl. 4, figs. 9, 10).

1826 *Globigerina bulloides* d'ORBIGNY, p. 277, mod. 17, 76.

Globigerina decoraperta Takayanagi & Saito, 1962; (Pl. 4, fig. 1).

1962 *Globigerina druryi* AKERS subsp. *decoraperta* TAKAYANAGI & SAITO, p. 85, pl. 28, figs. 10a-c.

Globigerina falconensis Blow, 1959

1959 *Globigerina falconensis* BLOW, p. 177, pl. 9, figs. 40a-c, 41.

Globigerinita glutinata (Egger, 1893)

1893 *Globigerina glutinata* EGGER, p. 371, pl. 13, figs. 19-21.

Globigerinoides elongatus (d'Orbigny, 1826)

1826 *Globigerina elongata* d'ORBIGNY, p. 277; in FORNASINI 1899, p. 207, fig. 1.

Globigerinoides obliquus obliquus Bolli, 1957

1957 *Globigerinoides obliquus obliquus* BOLLI, p. 113, pl. 25, figs. 10 a-c.

Globigerinoides ruber (d'Orbigny, 1839a); (Pl. 4, fig. 6).

1839a *Globigerina rubra* d'ORBIGNY, p. 82, pl. 4, figs. 12-14.

Globigerinoides sacculifer (Brady, 1877); (Pl. 4, fig. 7).

1877 *Globigerina sacculifera* d'ORBIGNY, p. 535; in BRADY 1884, p. 604, pl. 80, figs. 11-17, pl. 82, fig. 4.

Globigerinoides trilobus (Reuss, 1850); (Pl. 4, figs. 4, 5).

1850 *Globigerina triloba* REUSS, p. 374, pl. 47, figs. 11a-c.

Globorotalia aemiliana Colalongo & Sartoni, 1967; (Pl. 1, figs. 9, 10).

1967 *Globorotalia hirsuta aemiliana* COLALONGO & SARTONI, p. 3, pl. 30, figs. 1a-c.

Globorotalia bononiensis Dondi, 1962; (Pl. 1, figs. 7, 8).

1962 *Globorotalia bononiensis* DONDI, p. 162, fig. 41.

Globorotalia crassaformis crassaformis (Galloway & Wissler, 1927)

1927 *Globigerina crassaformis* GALLOWAY & WISSLER, p. 41, pl. 7, fig. 12.

Globorotalia inflata (d'Orbigny, 1839c); (Pl. 4, figs. 2, 3).

1839c *Globigerina inflata* d'ORBIGNY, in BACKER-WEBB P. - BERTHELOT S., p. 134, pl. 2, figs. 7-9.

Globorotalia margaritae Bolli & Bermudez, 1965; (Pl. 1, figs. 4-6).

1965 *Globorotalia margaritae* BOLLI & BERMUDEZ, p. 139, pl. 1, figs. 16-18.

Globorotalia puncticulata (Deshayes, 1832); (Pl. 1, figs. 1-3).

1832 *Globigerina puncticulata* DESHAYES, p. 170; in FORNASINI 1899, p. 210, tf. 5.

Heterolepa floridana (Cushman, 1918)

1918 *Truncatulina floridana* CUSHMAN, p. 62, pl. 19, fig. 2.

Lenticulina calcar (Linné, 1758)

1758 *Nautilus calcar* LINNÉ, p. 709; in PLANCUS 1739, pl. 1, figs. 3g-i, 41-n.

Lenticulina cultrata (de Montfort, 1808); (Pl. 2, fig. 13).

1808 *Robulus cultratus* de MONTFORT, p. 215, p. 214 tf.

Lenticulina gibba (d'Orbigny, 1826).

1826 *Cristellaria gibba* d'ORBIGNY, p. 292, pl. 7, figs. 20-21.

Lenticulina inornata (d'Orbigny, 1846).

1846 *Robulina inornata* d'ORBIGNY, p. 102, pl. 4, figs. 25-26.

Lenticulina spinulosa (Costa, 1894); (Pl. 2, fig. 12).

1894 *Cristellaria spinulosa* COSTA; in FORNASINI 1894, p. 221, pl. 3, fig. 29.

Marginulina costata (Batsch, 1791); (Pl. 2, fig. 5).

1791 *Nautilus costatus* BATSCHE, pl. 1, figs. 1a-g.

Marginulina glabra d'Orbigny, 1826; (Pl. 2, fig. 6).

1826 *Marginulina glabra* d'ORBIGNY, p. 259; in PARKER, JONES & BRADY 1865, pl. 1, fig. 36.

Melonis padanus (Perconig, 1952)

1952 *Nonion padanus* PERCONIG, p. 131, pl. 5, figs. 9-10.

Nodosaria raphanus (Linné, 1758).

1758 *Nautilus raphanus* LINNÉ, p. 711; in PLANCUS, 1739, p. 15, pl. 1, fig. 6.

Orbulina universa d'Orbigny, 1839a; (Pl. 4, fig. 11).

1839a *Orbulina universa* d'ORBIGNY, p. 2, pl. 1, fig. 1.

Oridorsalis umbonatus (Reuss, 1850); (Pl. 2, fig. 3).

1851 *Rotalina umbonata* REUSS, p. 75, pl. 5, fig. 35.

Planulina ariminensis d'Orbigny, 1826; (Pl. 2, fig. 4).

1826 *Planulina ariminensis* d'ORBIGNY, p. 280, pl. 14, figs. 1-3bis.

Pleurostomella alternans Schwager, 1866; (Pl. 2, fig. 7).

1866 *Pleurostomella alternans* SCHWAGER, p. 238, pl. 6, figs. 79-80.

Pullenia bulloides (d'Orbigny, 1846)

1846 *Nonionina bulloides* d'ORBIGNY, p. 107, pl. 5, figs. 9-10.

Siphonina reticulata (Czjzek, 1848); (Pl. 3, fig. 12).

1848 *Rotalina reticulata* CZJZEK, p. 145, pl. 13, figs. 7-9.

Sphaeroidinella dehiscens (Parker & Jones, 1865); (Pl. 1, fig. 11).

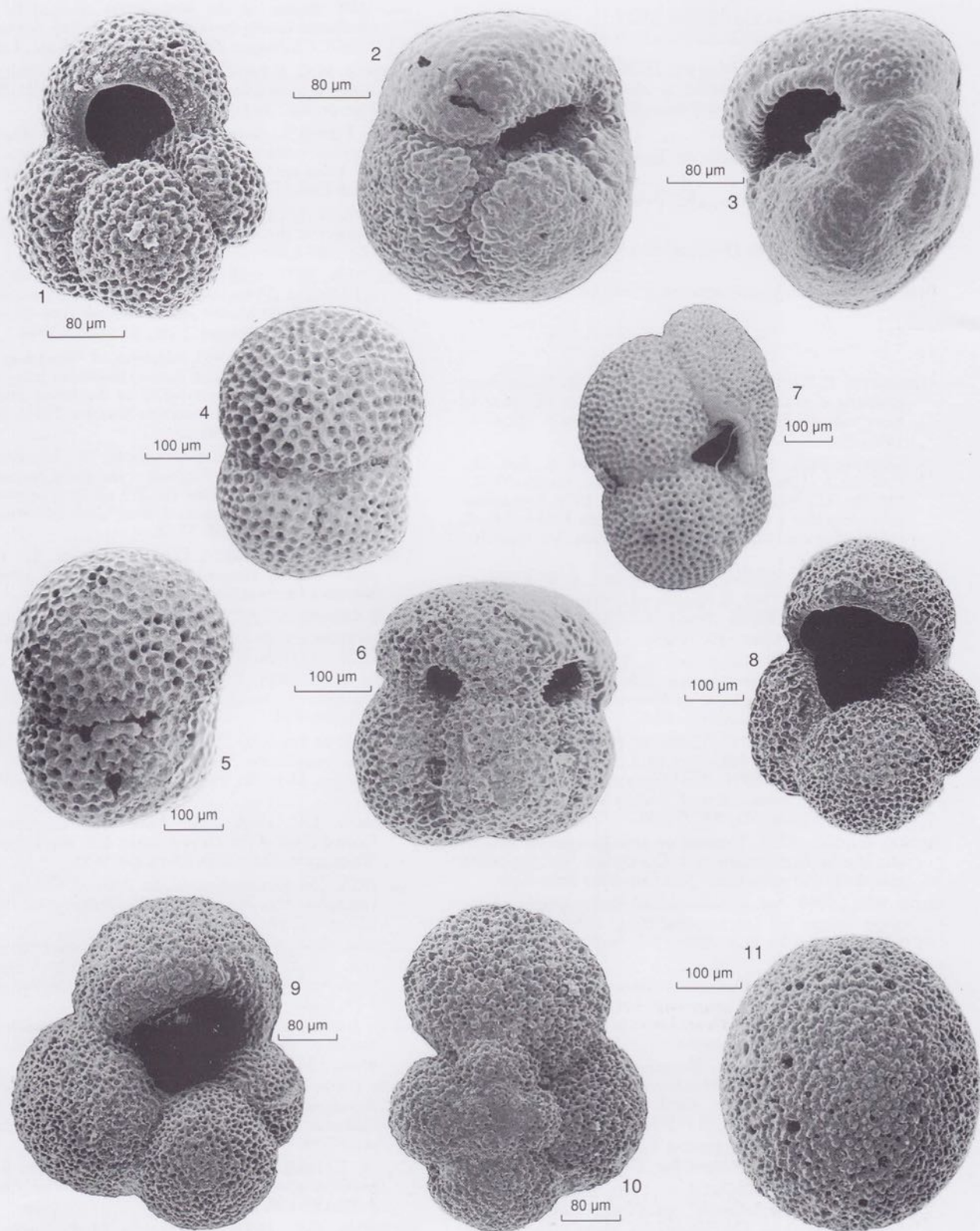
1865 *Sphaeroidina bulloides* d'ORBIGNY var. *dehiscens* PARKER & JONES, p. 369, pl. 19, figs. 5a-c.

Stainforthia complanata (Egger, 1893); (Pl. 3, fig. 9).

1893 *Virgulina schreibersiana* CZJZEK var. *complanata* EGGER, p. 292, pl. 8, figs. 91-92.

EXPLANATION OF PLATE 4

- Fig. 1 - *Globigerina decoraperta* Takayanagi & Saito. Umbilical view; core A1/18, sample 5.
 Figs 2-3 - *Globorotalia inflata* (d'Orbigny). 2) Umbilical view; core A1/15, sample 7. 3) Edge view; core A1/15, sample 7.
 Figs 4-5 - *Globigerinoides trilobus* (Reuss). 4) Umbilical view; core A1/18, sample 5. 5) Spiral view; core A1/18, sample 5.
 Fig. 6 - *Globigerinoides ruber* (d'Orbigny). Edge view; core A1/18, sample 3.
 Fig. 7 - *Globigerinoides sacculifer* (Brady). Umbilical view; core A1/18, sample 3.
 Fig. 8 - *Globigerina apertura* Cushman. Umbilical view; core B1/07, sample 6.
 Figs 9-10 - *Globigerina bulloides* d'Orbigny. 9) Umbilical view; core B1/07, sample 2. 10) Spiral view; core B1/07, sample 2.
 Fig. 11 - *Orbulina universa* d'Orbigny. core A1/15, sample 7.



Turborotalita quinqueloba (Natland, 1938)

1938 *Globigerina quinqueloba* NATLAND, p. 149, pl. 6, fig. 7.

Uvigerina peregrina Cushman, 1923.

1923 *Uvigerina peregrina* CUSHMAN, p. 166, pl. 42, figs. 7-10.

Uvigerina pygmaea d'Orbigny, 1826; (Pl.3, fig. 11).

1826 *Uvigerina pygmaea* d'ORBIGNY, p. 269, pl. 12, fig. 8-9.

1884 *Uvigerina pygmaea* d'ORBIGNY; in BRADY 1884, p. 575, pl. 74, figs. 11-12.

Uvigerina rutila Cushman & Todd, 1941; (Pl.2, figs 1, 2).

1941 *Uvigerina rutila* CUSHMAN & TODD, p. 78, pl. 20, figs. 16-22.

Valvulineria bradyana (Fornasini, 1900); (Pl.3, figs 1, 2).

1900 *Discorbina bradyana* FORNASINI, p. 393, pl. 43.

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