

Plio-Pleistocene foraminiferal assemblages of the Monte Mario site (Rome, Italy)

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ABSTRACT - Tunnel construction at Monte Mario hill (Rome) facilitated detailed study of the Monte Mario historical succession. Qualitative and quantitative analyses were performed on foraminiferal assemblages in order to define new stratigraphical and palaeoecological constraints for this historical site. From a chronostratigraphic point of view, micropalaeontological data assign the basal part of the succession (Monte Vaticano Formation) to the Early Pliocene (Zanclean Stage, upper part of Globorotalia puncticulata Zone) based on the presence of the marker species *Globorotalia puncticulata*. The presence of *Dentoglobigerina altispira altispira*, a well-known indicator of the upper Zanclean Stage in the Latium area, confirms the age assignment in agreement with nannoplankton data. The upper part of the Monte Mario Formation is attributed entirely to the Early Pleistocene (Calabrian - Santernian substage) based on the presence of *Bulimina etnea*. Palaeoecological reconstructions are based on quantitative proxies (percentages of single taxa, inbenthic and oxyphilic species, diversity indices, %P [(P/P+B)%]) that were used to evaluate important palaeoenvironmental and palaeoclimatic conditions.

Pliocene deposits (Monte Vaticano Formation) record an upper bathyal environment characterised by warm oligotrophic water and well-oxygenated bottom water. Pleistocene sediments (Monte Mario Formation) record highly variable environments controlled by sea level oscillations caused by the combined effects of tectonics and climate change. The deepest environments are recorded in the Pleistocene Farneto silts and represent an upper circalittoral environments that are characterised by cold water with enriched organic matter content and nearly eutrophic conditions. A more oxygenated, shallow-water environment with widespread vegetated cover is recorded from the Grey sands with *Arctica islandica* Member to the basal part of the Yellow sands with "panchina" Member. More marginal environments developed successively as a result of a shallowing trend. Lagoon/brackish lagoon environments characterised by oligospecific euryhaline foraminiferal assemblages develop to the Yellow sands with silty intercalations Member. The last member, Clays and *Cerastoderma*-bearing sands, is characterised by the re-establishment of normal marine infralittoral conditions of nutrient input and fresh-water influence. The succession ends with a more confined brackish lagoon environment, which relates to the progradational step of the uppermost portion of the Monte Mario Formation.

RIASSUNTO - [Le associazioni a foraminiferi del Plio-Pleistocene del sito di Monte Mario (Roma)] - I lavori per la costruzione della Galleria "Giovanni XXIII" che attraversa tutto l'alto strutturale di Monte Mario, hanno permesso una nuova campionatura e quindi la possibilità di rivedere, nella sua totalità, tutta la successione di questo sito storicamente noto per la stratigrafia plio/pleistocenica dell'area laziale. Sebbene lo studio faccia parte di una ricerca multidisciplinare più ampia che ha coinvolto più aspetti della geologia, dalla paleontologia al paleomagnetismo, qui vengono presentati nuovi dati di carattere paleoambientale e stratigrafico evidenziati dall'analisi qualitativa e quantitativa condotta sulle associazioni a foraminiferi.

Da un punto di vista bio e cronostatigrafico la parte basale della successione (Formazione di Monte Vaticano) è attribuibile allo Zancleano superiore, Zona a *Globorotalia puncticulata*. La presenza di livelli ricchi di *Dentoglobigerina altispira altispira*, riconosciuti nell'area laziale al top dello Zancleano, permettono quindi una più precisa collocazione cronostatigrafica di questi sedimenti che trova conferma dai dati sulle associazioni a nannoplancton calcareo. La parte superiore della successione (Formazione di Monte Mario) comprende cinque membri ed è stata attribuita interamente al Pleistocene inferiore, Calabrian - sottopiano Santernian - per la presenza sin dalla base di *Bulimina etnea*.

Da un punto di vista paleoecologico, l'utilizzo dell'analisi quantitativa e di alcuni indici quali quello di diversità, rapporto plancton/benthos, percentuali dei maggiori taxa infaunali ed ossifili, ha permesso di effettuare alcune considerazioni di carattere paleoambientale e paleoclimatico. I sedimenti pliocenici sono caratterizzati da un ambiente profondo (batiale superiore) con acque calde, oligotrofiche e fondali ben ossigenati. I depositi pleistocenici sono invece contraddistinti da una maggiore variabilità ambientale dovuta all'effetto combinato della tettonica e dei cambiamenti climatici. Le condizioni di maggiore profondità si registrano in corrispondenza dei Limi di Farneto relativi ad un ambiente circalitorale superiore caratterizzato da acque fredde, con fondali ricchi di sostanza organica tendenti all'eutrofizzazione. Ambienti di acque basse con copertura vegetale e quindi condizioni più ossigenate si verificano dalle Sabbie grigie con *Arctica islandica* fino alle Sabbie gialle con "panchina". Il trend regressivo che caratterizza tali sedimenti è marcato dall'instaurarsi di ambienti sempre più marginali (laguna, laguna salmastra) fino al passaggio con il continentale (Sabbie gialle con intercalazioni siltose). Alla base dell'ultimo membro (Argille e sabbie con *Cerastoderma*) si registra un breve episodio di ambiente di acque basse francamente marine, rapidamente sostituito verso l'alto da ambienti transizionali, caratterizzati da associazioni tendenti all'oligotopia ad evidente influenza salmastra, indicativi di una fase di avanzata progradazione della parte superiore della Formazione di Monte Mario.

INTRODUCTION

The Monte Mario succession has been studied by various authors since the end of the 19th century due to its structural and stratigraphic characteristics. The earliest researchers highlighted the regional importance of this

site, which has all of the features of the Neogene succession of central Italian basins (Brocchi, 1820; Ponzi, 1872; Blanc et al., 1953). The international scientific value of the "Monte Mario section" was permanently recognised at the 18th IGC in London, 1948, which established this site as one of the four most

significant sections for geological, stratigraphical and palaeoenvironmental studies of the Plio/Pleistocene boundary.

At regional level, three Plio-Pleistocene sedimentary cycles characterise the Tuscany and Latium successions (Barberi et al., 1994). The first cycle spans from the *Sphaeroidinellopsis seminulina* s.l. to the *Globorotalia puncticulata* Zone and is truncated by deposits related to the *Globorotalia aemiliana* Zone (second cycle). The third cycle occurred in the lower part of the Early Pleistocene (Ambrosetti & Bonadonna, 1967; Bonadonna, 1968; Conato et al., 1980; Marra et al., 1995). At the Monte Mario site, the last cycle lies directly on Early Pliocene deposits (first cycle; Cosentino et al., 2009); the unconformity separating the Plio-Pleistocene deposits is related to the “Acquatraversa” erosional phase and is connected to the sea level drop that resulted from both tectonic uplift and glacio-eustatic changes. Since the Middle Pleistocene, a regressive trend occurred in the Rome area and shifted the Tyrrhenian coast from Rome to its present position (Malatesta, 1978; Milli, 1997; Florindo et al., 2007).

Previous foraminiferal studies based on data collected on outcrops and cores only partially described the chronostratigraphic and palaeoenvironmental evolution

of the succession in the Monte Mario area (Marra et al., 1995; Bergamin et al., 2000). Tunnelling for the “Giovanni XXIII” gallery by the Astaldi S.p.A. presented the opportunity to continuously sample the entire Monte Mario hill succession. This multidisciplinary study encompasses palaeontological (ostracods, nannoplankton and foraminifers), palaeomagnetic and structural analyses (Cosentino et al., 2009), whereas the current paper describes the main foraminiferal fauna results.

The aim of this paper is to provide a detailed description of the foraminiferal assemblages present at the historical Monte Mario site as well as the most significant taxa association, which are illustrated in four plates and described according to their age and stratigraphic position. For the chronostratigraphic and geological framework of this site, including palaeomagnetic, tectonic, and sequence stratigraphical reconstruction, we refer to Cosentino et al. (2009).

STRATIGRAPHY AND LITHOLOGY

The succession includes two lithological formations: Monte Vaticano and Monte Mario. These formations are separated by a sharp unconformity that was identified by

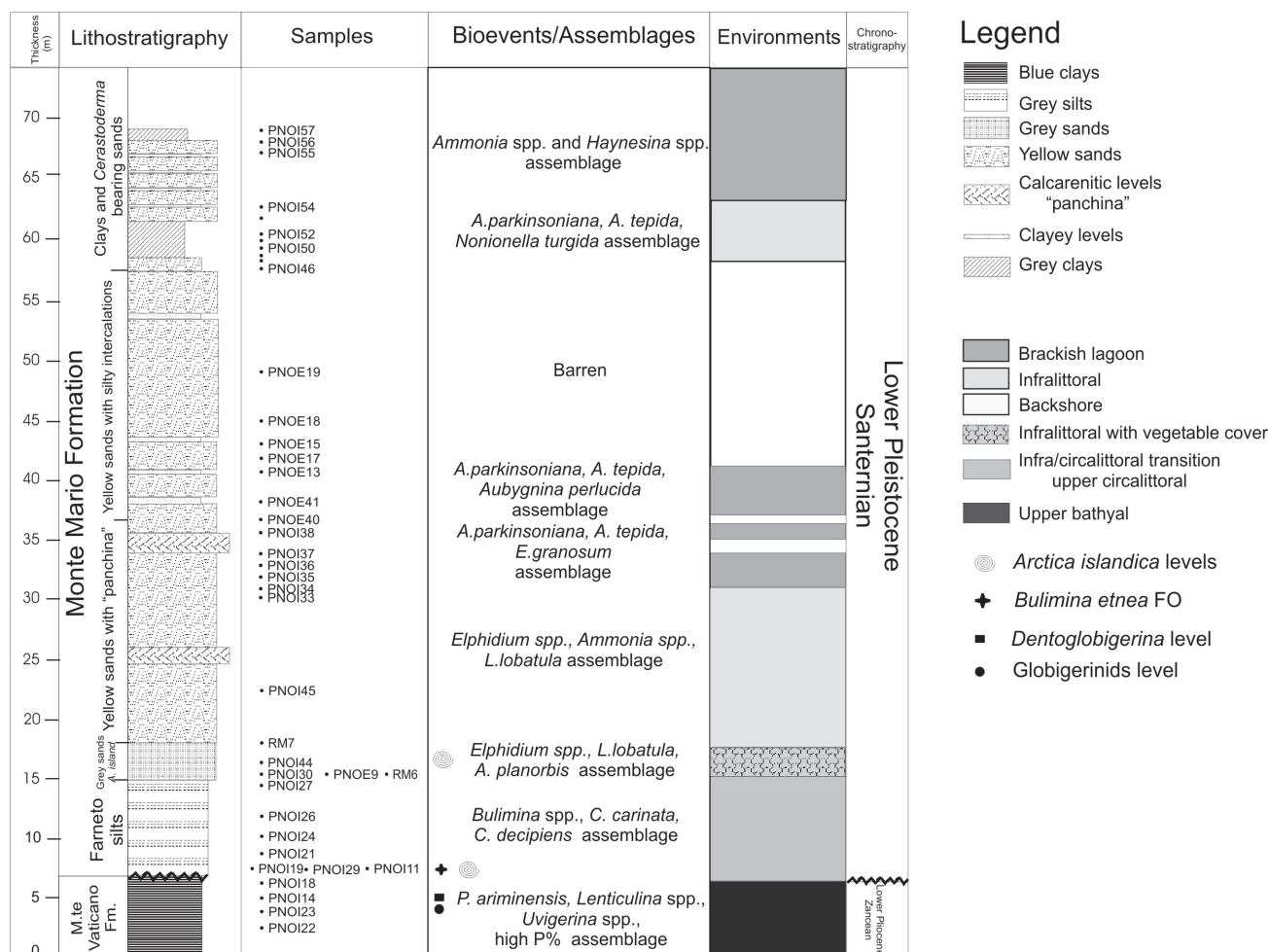


Fig. 1 - Lithological, chronostratigraphical and palaeoecological scheme of Monte Mario succession.

Blanc (1955) as the “Acquatraversa erosional phase” (Bonadonna, 1968). The Monte Vaticano Formation is composed mainly of blue-grey marls with regular intercalations of grey sands (“Marne Vaticane” Auct.). These sediments are attributed to the Lower Pliocene, Late Zanclean, *Globorotalia puncticulata* Zone (Iaccarino, 1985) based on the presence of the marker species.

The unconformity includes a *hiatus* ranging from the Middle Pliocene to the basal part of the Pleistocene (Calabrian - Santernian) and is marked by a glauconite-rich layer (the basal part of the Farneto silts).

The Monte Mario Formation is subdivided into five lithological members (Fig. 1): Farneto silts, Grey sands with *Arctica islandica*, Yellow sands with “panchina,” Yellow sands with silty intercalations, and Clays and *Cerastoderma*-bearing sands (Cosentino et al., 2009). The basal member consists of about 8 m of sandy clays and clays with frequent peaty and oxidised levels (Sabbie argillose grigie ad *Arctica islandica* by Bonadonna, 1968; Limi di Farneto by Marra et al., 1993). The second member consists of a 3 m-thick, fossiliferous, medium-coarse-grained grey sands (Sabbie argillose grigie ad *Arctica islandica* by Bonadonna, 1968). The third member consists of 18 m of medium-fine-grained yellow sands with rare gravel intercalations. These sediments are characterised by cross-stratification, which is typical of a littoral marine environment (Sabbie gialle marine di Monte Mario by Bonadonna, 1968). The fourth member comprises 3 to 10 m-thick beds of massive, medium-coarse-grained yellow sands (Yellow sands with silty intercalations by Cosentino et al., 2009). The last member includes 12 m of clays, silty clays, silts and sands that, in their upper part, are thinly bedded and contain the intertidal and estuarine *Cerastoderma lamarcki* (Clays and *Cerastoderma*-bearing sands, Cosentino et al., 2009).

On the whole, this formation was attributed to the Lower Pleistocene, Calabrian stage, Santernian substage, *Globigerina cariacensis* Zone because *Bulimina etnea* is present since the basal part of the section.

MATERIALS AND METHODS

Foraminiferal analyses were carried out on 41 samples collected from the “Giovanni XXIII” tunnel, including four samples from the Monte Vaticano Fm., seven samples from the Farneto silts Member, four samples from the Grey sands with *Arctica islandica*, nine samples from the Yellow sands with “panchina” Member, six samples from the Yellow sands with silty intercalations Member and eleven samples from the Clays and *Cerastoderma*-bearing sands Member (Fig. 1).

Sediment was washed through 63 and 125 µm mesh sieves. The finest fraction was subjected to qualitative analysis; coarser fraction was considered for quantitative analysis and was split into aliquots containing at least 300 specimens. Of the sediment samples, 28 contained sufficient foraminiferal fauna for quantitative analysis, 5 were barren and 8 contained very scarce foraminifera. The homogeneity of the assemblages allowed assessing the mean percentages of single taxa, which facilitated an overview of the assemblage composition and the

immediate comparison among the different members. The mean percentages of single species were calculated separately for planktonic and benthic assemblages and are summarised in the tables. The assemblages were analyzed to identify the taxa yielding the highest percentage values. The generic attribution of benthic taxa follows Loeblich & Tappan (1987); species and their ecological characteristics were mainly determined based on previous studies of the Mediterranean benthic species (Cimernan & Langer, 1991; Sgarrella & Moncharmont-Zei, 1993). Information on the planktonic foraminifers ecological preferences and stratigraphic distribution were evaluated by comparison with similar studies carried out in the Mediterranean area (Iaccarino, 1985; Hemleben et al., 1989; Iaccarino et al., 2007).

Palaeobathymetric considerations were assessed based on the ecological characteristics of the single species and the %P [(P/P+B)%] (Van der Zwaan et al., 1990). Species diversity was described using the α -index (Fisher et al., 1943), which reliably accounts for rare

Oxyphilic taxa	Inbenthic taxa
<i>Asterigerinata mariae</i>	<i>Angulogerina angulosa</i>
<i>Asterigerinata mamilla</i>	<i>Brizalina alata</i>
<i>Asterigerinata planorbis</i>	<i>Brizalina spathulata</i>
<i>Adelosina</i> spp.	<i>Bolivina catanensis</i>
<i>Cibicides</i> sp.	<i>Bolivina dilatata</i>
<i>Cibicoides robertsonianus</i>	<i>Bolivina punctata</i>
<i>Cibicides ungerianus</i>	<i>Buccella frigida granulata</i>
<i>Cibicoides pseudoungerianus</i>	<i>Bulimina corsiniana</i>
<i>Cibicides ungerianus</i>	<i>Bulimina costata</i>
<i>Elphidium aculeatum</i>	<i>Bulimina elegans marginata</i>
<i>Elphidium advenum</i>	<i>Bulimina etnea</i>
<i>Elphidium crispum</i>	<i>Bulimina fusiformis</i>
<i>Elphidium macellum</i>	<i>Bulimina marginata</i>
<i>Gavelinopsis praegeri</i>	<i>Cassidulina carinata</i>
<i>Hanzawaia boueana</i>	<i>Fursenkoina schreiberiana</i>
<i>Heterolepa dertonensis</i>	<i>Globobulimina affinis</i>
<i>Heterolepa floridana</i>	<i>Globobulimina pyrula</i>
<i>Lenticulina</i> spp.	<i>Globocassidulina subglobosa</i>
<i>Lobatula lobatula</i>	<i>Gyroidina soldanii</i>
<i>Neoconorbina orbicularis</i>	<i>Gyroidina umbonata</i>
<i>Oridorsalis umbonatus</i>	<i>Haynesina</i> sp.
<i>Planorbulina mediterraneensis</i>	<i>Hoeglundina elegans</i>
<i>Planulina ariminiensis</i>	<i>Karrierella bradyi</i>
<i>Pseudotriloculina rotunda</i>	<i>Karrierella gaudryoides</i>
<i>Pyrgo bulloides</i>	<i>Melonis barleeanum</i>
<i>Pyrgo depressa</i>	<i>Praeglobobulimina ovata</i>
<i>Pyrgo inornata</i>	<i>Pullenia bulloides</i>
<i>Quinqueloculina</i> spp.	<i>Sphaeroidina bulloides</i>
<i>Rosalina</i> spp.	<i>Spiroplectammina wrightii</i>
<i>Sigmoilinita tenuis</i>	<i>Uvigerina peregrina</i>
<i>Siphonina reticulata</i>	<i>Uvigerina pygmaea</i>
<i>Spiroloculina excavata</i>	<i>Uvigerina rutila</i>
	<i>Valvulineria bradyana</i>

Tab. 1 - List of the oxyphilic and inbenthic taxa according to previous studies (i.e., Corliss, 1985; Corliss & Chen, 1988; Murray, 1991; Kaiho, 1994, 1999; De Stiger et al., 1998; Den Dulk et al., 2000).

species and increases only slightly with sample size. The α -index assumes that the number of individuals of each species follows a logarithmic series (Murray, 1991). The Shannon index, which accounts for both the abundance and the evenness of species, was also calculated in order to supplement the information given by the α -index (Murray, 1991). Diversity indices were calculated by means of the PAST (PALaeontological STATistics) data analysis package (ver. 1.38). For each sample, the frequencies of inbenthic and oxyphilic taxa (Báldi & Hohenegger, 2008) were calculated in order to evaluate bottom water oxygenation. Inbenthic and oxyphilic taxa are listed in Tab. 1 according to the life strategies reported in previous studies (i.e., Corliss, 1985; Corliss & Chen, 1988; Murray, 1991; Kaiho, 1994, 1999; De Stiger et al., 1998; Den Dulk et al., 2000).

Digital images of selected species were acquired by Scanning Electron Microscope (SEM, FEI Quanta 400) at the Laboratory of Electron Microscopy and Microanalysis, Earth Science Department, University "La Sapienza," Rome.

The studied samples are housed at the Micropalaeontology Laboratory of the Earth Science Department of the University "La Sapienza" of Rome.

RESULTS - FORAMINIFERAL ASSEMBLAGES

MONTE VATICANO FORMATION (SAMPLES PNOI22, PNOI23, PNOI14, PNOI18; FIG. 1)

PLANULINA ARIMINENSIS, LENTICULINA SPP., UVIGERINA SPP. AND HIGH P/P+B VALUE ASSEMBLAGE

The foraminiferal assemblage of the Monte Vaticano Formation is abundant (80-90%) and very well preserved (Tab. 2). Planktonic taxa (24 species) are dominant, but even the benthic assemblage is well diversified (76 species). In the grey sands locally intercalated in the marls, foraminifers are scarce and specimens are badly preserved.

Plankton is mainly represented by the following species: *Globorotalia* gr. *puncticulata*, *Globigerina bulloides*, *Globigerina praecalida*, *Globigerina falconensis*, *Globigerinella siphonifera*, *Globigerinoides trilobus*, *Globigerinoides sacculifer*, *Globigerinoides* gr. *obliquus*, *Globigerinita glutinata*, *Globoturborotalita apertura*, *Sphaeroidinellopsis seminulina* and *Orbulina universa*. Sample PNOI14 is characterised by common *Dentoglobigerina altispira altispira* (11.76%), and shows a composition very similar to the uppermost Zanclean sediments observed at the Latium coastal site Lido delle Sirene, between Tor Caldara and Anzio (Carboni & Di Bella, 1997). This level also records a strong increase in *S. seminulina* (10.46%).

Sample PNOI23 is very rich in Globigerinids. The most abundant are *Globigerina bulloides* (32%) and *Globigerina praecalida* (11%) both characterised by a large intraspecific variability. Notably, some *Globigerina praecalida* show a tendency towards elongation of the last chambers, leading to *Globigerina affinis calida calida* (Colalongo & Sartoni, 1977) or *Globigerina calida calida* (Parker, 1962). Moreover, specimens of *Globigerina bulloides* show a greater number of

Monte Vaticano Formation			
Upper bathyal - <i>P. ariminensis</i> , <i>Lenticulina</i> spp., <i>Uvigerina</i> spp., high value of P/P+B assemblage			
Benthos	% media		% media
<i>Amphicoryna</i> cfr. <i>proxima</i>	1,09	<i>Pandaglandulina dinapoli</i>	0,77
<i>Anomalinoides</i> sp.	1,09	<i>Planularia auris</i>	1,42
<i>Anomalinoides hellicinus</i>	2,29	<i>Planulina ariminensis</i>	7,48
<i>Astaculus crepidulus</i>	1,52	<i>Plectofrondicularia semicosta</i>	0,26
<i>Bigerina nodosaria</i>	3,06	<i>Praeglobobulimina ovata</i>	1,55
<i>Brizalina alata</i>	0,43	<i>Pullenia bulloides</i>	0,69
<i>Bolivina dilatata</i>	0,66	<i>Quinqueloculina</i> cfr. <i>neapolitana</i>	1,20
<i>Bolivina leonardii</i>	0,86	<i>Quinqueloculina padana</i>	0,43
<i>Bolivina pseudoplicata</i>	1,09	<i>Saracenaria italica</i>	1,57
<i>Bolivina punctata</i>	1,29	<i>Sigmolinita tenuis</i>	1,20
<i>Bulimina costata</i>	2,11	<i>Sigmolopsis celata</i>	1,86
<i>Cancris auriculus</i>	0,43	<i>Siphonina reticulata</i>	3,61
<i>Cibicides</i> sp.	2,08	<i>Sphaeroidina bulloides</i>	3,12
<i>Cibicidoides robertsonianus</i>	0,54	<i>Spiroplectammina wrightii</i>	0,66
<i>Cibicides ungerianus</i>	5,42	<i>Stilostomella</i> sp.	0,86
<i>Cibicidoides pseudoungerianus</i>	2,83	<i>Stilostomella adolphina</i>	2,87
<i>Dentalina inflexa</i>	0,26	<i>Stilostomella hispida</i>	0,26
<i>Dentalina leguminiformis</i>	4,87	<i>Stilostomella monilis</i>	0,43
<i>Favulina hexagona</i>	0,54	<i>Uvigerina peregrina</i>	3,58
<i>Fissurina apiculata</i>	0,56	<i>Uvigerina pygmaea</i>	0,94
<i>Fissurina bradyi</i>	0,43	<i>Uvigerina rutila</i>	0,51
<i>Fissurina marginata</i>	0,26	<i>Vaginulinopsis</i> sp.	2,18
<i>Gavelinopsis praegeri</i>	0,43	<i>Vaginulinopsis bononiensis</i>	0,26
<i>Globobulimina affinis</i>	2,81	<i>Vaginulinopsis carinata</i>	0,26
<i>Globobulimina pyrula</i>	1,68	<i>Vulvulina pennatula</i>	0,26
<i>Globocassidulina subglobosa</i>	0,54	Fisher_alpha	29,31
<i>Gyroidina soldanii</i>	0,66	Shannon_H	3,22
<i>Gyroidina umbonata</i>	0,43	Plancton	83.89%
<i>Hanzawaia boueana</i>	1,41	<i>Dentoglobigerina altispira altispira</i>	2,94
<i>Heterolepa dertonensis</i>	0,26	<i>Globigerina apertura</i>	4,49
<i>Hoeglundina elegans</i>	0,43	<i>Globigerina bulloides</i>	15,25
<i>Karrierella bradyi</i>	1,09	<i>Globigerina decoraperta</i>	2,35
<i>Karrierella gaudryoides</i>	0,26	<i>Globigerina druryi</i>	1,21
<i>Lagena radiata</i>	0,26	<i>Globigerina falconensis</i>	10,27
<i>Lagena semistriata</i>	0,43	<i>Globigerina praecalida</i>	5,50
<i>Lagena striata</i>	0,66	<i>Globigerinita glutinata</i>	0,33
<i>Lenticulina cultrata</i>	2,66	<i>Globigerinoides elongatus</i>	0,32
<i>Lenticulina curvisepta</i>	0,69	<i>Globigerinoides conglobatus</i>	0,25
<i>Lenticulina echinata</i>	1,57	<i>Globigerinoides</i> gr. <i>obliquus</i>	7,71
<i>Lenticulina inornata</i>	0,77	<i>Globigerinoides ruber</i>	2,63
<i>Lenticulina peregrina</i>	0,54	<i>Globigerinoides sacculifer</i>	3,69
<i>Lenticulina rotulata</i>	5,03	<i>Globigerinoides trilobus</i>	6,94
<i>Marginulina costata</i>	0,91	<i>Globorotalia</i> sp.	0,26
<i>Marginulina hirsuta</i>	0,66	<i>Globorotalia crassaformis</i>	1,38
<i>Marginulinopsis</i> cfr. <i>nana</i>	0,91	<i>Globorotalia puncticulata padana</i>	6,55
<i>Martinottiella comunis</i>	0,43	<i>Globorotalia puncticulata puncticulata</i>	10,86
<i>M. genuina</i>	0,26	<i>Globorotalia scitula</i>	0,09
<i>Nodosaria</i> sp.	0,43	<i>Hastigerina siphonifera</i>	2,10
<i>Nodosaria ovicola</i>	0,43	<i>Neogloboquadrina pachyderma</i>	0,36
<i>Nonion fabum</i>	0,26	<i>Orbulina universa</i>	11,36
<i>Oridosalis umbonatus</i>	1,52	<i>Sphaerodinellopsis seminulina</i>	2,93
<i>Orthomorphina stainforthi</i>	0,51	<i>Turborotalita quinqueloba</i>	0,24

Tab. 2 - Mean percentages of each species, %P [(P/P+B)%], and diversity indices in the Monte Vaticano Formation.

chambers (often five) in the last whorl and an open coiling, leading to *Globigerina calabra* (Pl. 2). The increase in cold-water mixed-layer species like *G. bulloides* (Rohling et al., 1993) is associated with a strong decrease of the genus *Globigerinoides* (2%), which typically represents warm, oligotrophic waters (Pujol & Vergnaud-Grazzini, 1995; Hemleben et al., 1989). Frequent species of *O. universa* indicate deep waters and mixed-layer conditions (Rohling et al., 1993).

The benthic assemblage is dominated by *Planulina ariminensis* (7.48%), *Lenticulina* spp. (11.39%, *L. cultrata*, *L. echinata*, *L. rotulata*), and *Uvigerina* spp. (5.03%, *U. peregrina*, *U. rutila*). Living counterpart taxa occupy the bathyal and/or lower circalittoral environments and they are associated with other typical

circalittoral taxa, including the following: *Hoeglundina elegans*, *Anomalinoidea helicinus*, *Sphaeroidina bulloides*, *Pyrgo depressa*, *Siphonina reticulata*, *Dentalina leguminiformis*, *Globobulimina pyrula*, *Bolivina punctata*, *Bigennerina nodosaria*, *Stilostomella* spp., *Plectofrondicularia semicosta*, and *Lagena* spp. The benthic assemblage is characterised by dominant oxyphilic taxa (35.57%) and high diversity values (α -index 29.31; H 3.22), which suggest oligotrophic, well-oxygenated conditions at the bottom waters.

The high percentage of plankton (83.89%) and the circalittoral benthic assemblage indicate an upper epibathyal environment (300-350 m depth).

The presence of *Globorotalia puncticulata*, which is always present and abundant (10.86%), allows these sediments to be attributed to the Early Pliocene, Zanclean Stage, *Globorotalia puncticulata* Zone.

MONTE MARIO FORMATION

Farneto silts Member (samples PNOI19, PNOI29, PNOI11, PNOI21, PNOI24, PNOI26, PNOI27; Fig. 1)

BULIMINA spp., *CASSIDULINA* *CARINATA* AND *CRIBROELPHIDIUM* *DECIPIENS* ASSEMBLAGE

This foraminiferal assemblage is abundant and well preserved in all samples of this member (Tab. 3). Planktonic taxa (11 species) are scarce (10.36% mean value of the total assemblage), and the benthic fraction is abundant and well diversified (91 species). This assemblage is characterised by dominant *Bulimina fusiformis*, *Bulimina elegans marginata*, *Bulimina marginata*, *Bolivina* spp. and *Cassidulina carinata* along with frequent *C. decipiens* (11.99%), *Elphidium* spp. (*E. granosum*, *E. macellum*) and *Textularia* spp. (mainly *T. bockii*). On the whole, the number of inbenthic taxa (38.48%) exceeds oxyphilic taxa (18.56%); the diversity degree is high (α -index 15.67; H 3.10), although it presents a decrease in comparison to the Marne Vaticane Formation assemblage. The planktonic assemblage is represented by rare specimens of *Globigerinoides ruber*, *Globigerinoides trilobus*, *Globigerinoides elongatus*, *Globorotalia inflata*, *Globorotalia oscitans*, *Globigerina falconensis*, *Globigerina bulloides* and *Turborotalita quinqueloba*. The low frequencies of planktonic taxa and the abundance of infralittoral species indicate a generally shallow-water environment (infralittoral, 40-30 m depth), although some depth fluctuations are highlighted (upper circalittoral, 70-75 m depth).

At the base of the Farneto silts (PNOI11, PNOI19, PNOI29), the increase of typical infralittoral species (*Elphidium* spp., *Ammonia beccarii*, *Textularia* spp., *Lobatula lobatula*, and *Nonion fabum*) in combination with reduced plankton content (<5%) indicates a shallow-water environment (infralittoral). In samples PNOI21, PNOI24 and PNOI26, slightly deeper, infra/circalittoral transition and/or upper circalittoral conditions are recorded by increased Buliminidae (14.75%), *C. carinata* (13.01%), Bolivinidae (6.77%) and typical circalittoral species like *Valvulineria bradyana* and *M. barleanum*.

In the upper part of the member (PNOI27), an increase

in shallow-water species (*Quinqueloculina* spp., *Triloculina* spp., *Adelosina* spp., *Rosalina* spp., *Lobatula lobatula*, *Asterigerinata* spp.) indicates a bathymetric decrease. Significantly increased oxyphilic and epiphytic taxa suggest a bottom covered with vegetation.

From the bio-chronostratigraphic perspective, the presence of *Bulimina etnea* in the lowermost sample (PNOI19) allows these sediments to be attributed to the Early Pleistocene, Calabrian Stage, Santernian substage (*Globigerina cariacensis* Zone).

Monte Mario Formation			
Farneto silts			
Infra/circalittoral transition - <i>Bulimina</i> spp., <i>C. carinata</i> , <i>C. decipiens</i> assemblage			
Benthos	% media		% media
<i>Adelosina clarensis</i>	0,08	<i>Lagena striata</i>	0,08
<i>Adelosina pulchella</i>	0,08	<i>Lobatula lobatula</i>	1,00
<i>Ammonia beccarii</i>	4,96	<i>Melonis</i> spp.	0,08
<i>Ammonia inflata</i>	1,02	<i>Miliolinella subrotunda</i>	0,15
<i>Ammonia parkinsoniana</i>	0,24	<i>Neoconorbina orbicularis</i>	0,55
<i>Ammonia tepida</i>	0,32	<i>Nonion</i> sp.	0,08
<i>Angulogerina angulosa</i>	0,31	<i>Nonion fabum</i>	0,55
<i>Asterigerinata mamilla</i>	0,31	<i>Nonionella turgida</i>	0,08
<i>Asterigerinata mariae</i>	0,08	<i>Pandaglandulina dinapoli</i>	0,23
<i>Asterigerinata planorbis</i>	0,23	<i>Pleurostomella alternans</i>	0,08
<i>Aubygnina perlucida</i>	0,08	<i>Pseudotriloculina rotunda</i>	1,26
<i>Bigennerina nodosaria</i>	0,47	<i>Pyrgo bulloides</i>	0,08
<i>Brizalina alata</i>	0,59	<i>Pyrgo depressa</i>	0,08
<i>Brizalina spatulata</i>	2,35	<i>Pyrgo inornata</i>	0,23
<i>Bolivina catanensis</i>	0,93	<i>Quinqueloculina bosciana</i>	0,16
<i>Bolivina dilatata</i>	0,38	<i>Quinqueloculina lata</i>	0,08
<i>Bolivina pseudoplicata</i>	0,75	<i>Quinqueloculina padana</i>	0,08
<i>Bolivina punctata</i>	0,08	<i>Quinqueloculina pygmaea</i>	0,53
<i>Bolivina striatula</i>	0,16	<i>Quinqueloculina seminulum</i>	1,02
<i>Bolivina subspinescens</i>	1,53	<i>Quinqueloculina stelligera</i>	0,16
<i>Buccella frigida granulata</i>	0,31	<i>Reussella spinulosa</i>	2,30
<i>Bulimina corsiniana</i>	0,55	<i>Rosalina floridana</i>	0,08
<i>Bulimina elegans marginata</i>	1,69	<i>Saracenaria italica</i>	0,08
<i>Bulimina etnea</i>	0,32	<i>Sigmoilinita tenuis</i>	0,54
<i>Bulimina fusiformis</i>	2,20	<i>Sigmoilopsis celata</i>	1,08
<i>Bulimina marginata</i>	9,99	<i>Siphonotextularia concava</i>	0,54
<i>Buliminella</i> sp.	0,08	<i>Sphaeroidina bulloides</i>	0,08
<i>Cassidulina carinata</i>	13,01	<i>Spiroloculina excavata</i>	0,00
<i>Cibicides ungerianus</i>	0,16	<i>Spiroplectammina wrightii</i>	0,78
<i>Cibicidoides pseudoungerianus</i>	0,00	<i>Textularia agglutinans</i>	0,30
<i>Coriphostoma perforata</i>	1,51	<i>Textularia bockii</i>	6,64
<i>Criboelphidium decipiens</i>	11,99	<i>Textularia conica</i>	0,90
<i>Dorothy gibbosa</i>	0,47	<i>Textularia sagittula</i>	0,24
<i>Egerella bradyi</i>	0,08	<i>Triloculina</i> sp.	0,08
<i>Elphidium</i> sp.	0,53	<i>Triloculina</i> cfr. gibba	0,24
<i>Elphidium advenum</i>	7,02	<i>Triloculina plicata</i>	1,49
<i>Elphidium crispum</i>	0,31	<i>Triloculina tricarinata</i>	0,63
<i>Elphidium granosum</i>	5,03	<i>Valvulineria bradyana</i>	3,08
<i>Elphidium incertum</i>	0,08		
<i>Elphidium macellum</i>	1,01	Fisher_alpha	15,67
<i>Fissurina</i> sp.	0,00	Shannon_H	3,10
<i>Fissurina apiculata</i>	0,08		
<i>Fissurina castanea</i>	0,08	Plankton	10,36
<i>Fissurina orbignyana</i>	0,15	<i>Globigerina bulloides</i>	9,34
<i>Florilus citai</i>	0,08	<i>Globigerina falconensis</i>	28,65
<i>Gavelinopsis praegeri</i>	0,61	<i>Globigerinita glutinata</i>	3,13
<i>Globocassidulina subglobosa</i>	0,60	<i>Globigerinoides conglobatus</i>	2,78
<i>Gyroidina umbonata</i>	0,08	<i>Globigerinoides</i> gr. obliquus	5,28
<i>Hanzawaia boueana</i>	0,32	<i>Globigerinoides ruber</i>	27,71
<i>Haynesina</i> sp.	0,55	<i>Globorotalia inflata</i>	4,38
<i>Haynesina depressula</i>	0,54	<i>Globorotalia oscitans</i>	7,50
<i>Karrirella bradyi</i>	0,00	<i>Globorotalia scitula</i>	1,25
<i>Lagena laevis</i>	0,08	<i>Orbulina universa</i>	5,00
<i>Lagena longirostris</i>	0,08	<i>Turborotalita quinqueloba</i>	5,00
<i>Lagena radiata</i>	0,08		

Tab. 3 - Mean percentages of each species, %P [(P/P+B)%], and diversity indices in the Monte Mario Formation: Farneto silts Member.

Grey sands with Arctica islandica Member (samples PNOI30, PNOE9, RM6, PNOI44; Fig. 1)

ELPHIDIUM spp., *LOBATULA* *LOBATULA* AND *ASTERIGERINATA* *PLANORBIS* ASSEMBLAGE

The foraminiferal assemblage is similar to the assemblage of the Farneto silts Member (Tab. 4). Planktonic assemblage (14 taxa) displays low frequencies (11.00%) and is represented mainly by *Globigerinoides ruber* (41.71%), *Globigerina bulloides* (28.29%) and *Globorotalia inflata* (8.46%). The benthic assemblage dominates (80 taxa), and is characterised by high

frequencies of infralittoral taxa (*Elphidium* spp. 15.75%, *A. planorbis* 11.90%, *L. lobatula* 12.27%, *Ammonia beccarii* 6.60%, *Nonion fabum* mean 5.16%). In sample PNOI45 abundant species with an epiphytic mode of life (keeled *Elphidium*, *Asterigerinata planorbis*, *Lobatula lobatula*, *Neoconorbina orbicularis*, *P. mediterraneanensis*, miliolids) are observed. The highest infralittoral oxyphilic percentage (59.49%) and degree of diversity (α -index 16.34; H 3.31) of all of the M. Mario Formation foraminiferal fauna, suggest an infralittoral environment with a well-oxygenated and vegetated bottom (about 30 m depth). The inbenthic taxa are very scarce (10.25%) and represented mainly by *B. frigida granulata*, *C. carinata*, *B. marginata* and *S. wrightii*.

The presence, always rare, of *Bulimina etnea* allows the assignment of these sediments to the Early Pleistocene, Santerian Stage (*Globigerina cariacensis* Zone).

Yellow sands with "panchina" Member (samples RM7, PNOI45, PNOI33-PNOI38, PNOE40; Fig. 1)

This member is characterised by marked environmental variability and ranges from a normal marine infralittoral environment to a brackish/fresh-brackish lagoon and an upper shoreface-backshore environment (Tab. 5).

Monte Mario Formation			
Grey sands with <i>Arctica islandica</i>			
Infra/circalittoral transition - <i>Elphidium</i> spp., <i>L. lobatula</i> and <i>A. planorbis</i> assemblage			
Benthos	% media		% media
<i>Adelosina cliarensis</i>	0,41	<i>Neoconorbina orbicularis</i>	2,91
<i>Adelosina duthiersi</i>	0,17	<i>Planorbulina mediterranensis</i>	1,83
<i>Adelosina pulchella</i>	1,72	<i>Pseudotriloculina</i> sp.	0,42
<i>Ammonia beccarii</i>	6,60	<i>Quinqueloculina annectens</i>	0,17
<i>Ammonia inflata</i>	0,32	<i>Quinqueloculina auberiana</i>	0,12
<i>Ammonia parkinsoniana</i>	0,76	<i>Quinqueloculina boschiana</i>	0,23
<i>Ammonia tepida</i>	0,16	<i>Quinqueloculina disparilis</i>	0,32
<i>Angulogerina angulosa</i>	0,16	<i>Quinqueloculina pygmaea</i>	0,33
<i>Asterigerinata mamilla</i>	0,74	<i>Quinqueloculina seminulum</i>	2,31
<i>Asterigerinata mariae</i>	0,33	<i>Quinqueloculina stelligera</i>	0,41
<i>Asterigerinata planorbis</i>	11,90	<i>Quinqueloculina tubulosa</i>	0,09
<i>Astronion</i> sp.	0,08	<i>Reussella spinulosa</i>	0,97
<i>Aubygnina perlucida</i>	0,55	<i>Rosalina bradyi</i>	0,09
<i>Brizalina aenariensis</i>	0,08	<i>Rosalina floridana</i>	1,23
<i>Brizalina alata</i>	0,08	<i>Sigmollinita tenuis</i>	2,04
<i>Brizalina spathulata</i>	0,08	<i>Siphonaperta aspera</i>	0,58
<i>Bolivina catanensis</i>	0,24	<i>Siphonaperta dilatata</i>	0,08
<i>Bolivina dilatata</i>	0,08	<i>Spiroloculina excavata</i>	0,09
<i>Bolivina italica</i>	0,25	<i>Spiroplectammina wrightii</i>	1,47
<i>Bolivina subspinescens</i>	0,09	<i>Textularia agglutinans</i>	0,08
<i>Buccella frigida granulata</i>	5,70	<i>Textularia bockii</i>	1,57
<i>Bulimina costata</i>	0,08	<i>Textularia concava</i>	0,54
<i>Bulimina elegans marginata</i>	0,16	<i>Textularia conica</i>	0,45
<i>Bulimina elongata</i>	0,16	<i>Textularia sagittula</i>	0,25
<i>Bulimina marginata</i>	0,88	<i>Triloculina adriatica</i>	0,16
<i>Cancris auriculus</i>	3,03	<i>Triloculina austriaca</i>	0,09
<i>Cassidulina carinata</i>	2,25	<i>Triloculina cfr. gibba</i>	0,09
<i>Cibicides refulgens</i>	1,58	<i>Triloculina plicata</i>	2,30
<i>Coriphostoma perforata</i>	0,40	<i>Triloculina schreiberiana</i>	0,44
<i>Croboelphidium decipiens</i>	2,00	<i>Triloculina tricarinata</i>	0,25
<i>Cycloforina contorta</i>	0,94	<i>Valvulineria bradyana</i>	0,17
<i>Dorothia gibbosa</i>	0,90		
<i>Elphidium</i> sp.	0,44	Fisher_alpha	16,34
<i>Elphidium aculeatum</i>	0,16	Shannon_H	3,31
<i>Elphidium advenum</i>	5,55		
<i>Elphidium complanatum</i>	1,41	Plancton	11,00
<i>Elphidium crispum</i>	3,11	<i>Globigerina bulloides</i>	28,29
<i>Elphidium granosum</i>	1,62	<i>Globigerina falconensis</i>	3,84
<i>Elphidium incertum</i>	0,23	<i>Globigerina rubescens</i>	1,83
<i>Elphidium macellum</i>	3,23	<i>Globigerinita glutinata</i>	0,86
<i>Fissurina apiculata</i>	0,09	<i>Globigerinoides elongatus</i>	3,37
<i>Fissurina orbygniana</i>	0,08	<i>Globigerinoides ruber</i>	41,71
<i>Nonion fabum</i>	5,16	<i>Globigerinoides trilobus</i>	0,48
<i>Gavelinopsis praegeri</i>	0,12	<i>Globorotalia</i> sp.	1,73
<i>Guttulina</i> sp.	0,08	<i>Globorotalia crassaformis</i>	1,73
<i>Guttulina communis</i>	0,24	<i>Globorotalia inflata</i>	8,46
<i>Gyroidina soldanii</i>	0,08	<i>Globorotalia oscitans</i>	2,40
<i>Hanzawaia boueana</i>	1,13	<i>Hastigerina siphonifera</i>	0,86
<i>Haynesina depressula</i>	0,28	<i>Neogloboquadrina pachyderma</i>	3,27
<i>Lobatula lobatula</i>	12,27	<i>Orbulina universa</i>	0,96
<i>Miliolinella subrotunda</i>	0,57		

Tab. 4 - Mean percentages of each species, %P [(P/P+B)%], and diversity indices in the Monte Mario Formation: Grey sands with *Arctica islandica* Member.

Monte Mario Formation			
Yellow sands with "panchina"			
Infralittoral - <i>Elphidium</i> spp., <i>Ammonia</i> spp. and <i>L. lobatula</i> assemblage			
Benthos	%media		%media
<i>Ammonia beccarii</i>	8,61	<i>Rosalina floridana</i>	0,99
<i>Ammonia inflata</i>	2,65	<i>Rosalina globularis</i>	0,33
<i>Ammonia parkinsoniana</i>	6,29	<i>Textularia bockii</i>	2,98
<i>Ammonia tepida</i>	0,33	<i>Textularia conica</i>	0,66
<i>Asterigerinata planorbis</i>	7,61	<i>Textularia sagittula</i>	0,66
<i>Aubygnina perlucida</i>	2,98	<i>Textularia truncata</i>	0,33
<i>Brizalina aenariensis</i>	0,33	Fisher_alpha	11,86
<i>Brizalina spathulata</i>	0,99	Shannon_H	4,11
<i>Bolivina dilatata</i>	0,99	Plancton	7,83%
<i>Buccella frigida granulata</i>	2,65	<i>Globigerina bulloides</i>	15,38
<i>Bulimina fusiformis</i>	0,99	<i>Globigerina falconensis</i>	11,54
<i>Cancris auriculus</i>	1,32	<i>Globigerinita glutinata</i>	3,85
<i>Cassidulina carinata</i>	2,32	<i>Globigerinoides elongatus</i>	7,70
<i>Coriphostoma perforata</i>	2,32	<i>Globigerinoides conglobatus</i>	7,70
<i>Croboelphidium decipiens</i>	5,96	<i>Globigerinoides ruber</i>	26,90
<i>Elphidium</i> sp.	0,66	<i>Globigerinoides trilobus</i>	7,70
<i>Elphidium aculeatum</i>	0,66	<i>Globorotalia crassaformis</i>	3,85
<i>Elphidium advenum</i>	17,88	<i>Globorotalia inflata</i>	3,85
<i>Elphidium crispum</i>	0,66	<i>Neogloboquadrina pachyderma</i>	11,54
<i>Elphidium granosum</i>	5,30		
<i>Elphidium macellum</i>	3,31	Brackish lagoon	
<i>Elphidium</i> cfr. punctatum	0,33	A. parkinsoniana, A. tepida and E. granosum assemblage	
<i>Fissurina pseudorbygniana</i>	0,33		
<i>Fursenkoina schreiberiana</i>	0,99	Benthos	%media
<i>Gavelinopsis praegeri</i>	0,66	<i>Ammonia parkinsoniana</i>	52,33
<i>Haynesina depressula</i>	1,32	<i>Ammonia tepida</i>	36,64
<i>Heterolepa floridana</i>	0,33	<i>Elphidium granosum</i>	11,03
<i>Lobatula lobatula</i>	5,96	Fisher_alpha	0,58
<i>Neoconorbina terquemi</i>	4,30	Shannon_H	0,95
<i>Nonion fabum</i>	1,65		
<i>Planorbulina mediterranensis</i>	1,65	Backshore	
<i>Reussella spinulosa</i>	0,99	Barren and/or reworked foraminiferal fauna	
<i>Rosalina bradyi</i>	0,33		

Tab. 5 - Mean percentages of each species, %P [(P/P+B)%], and diversity indices in the Monte Mario Formation: Yellow sands with "panchina" Member.

ELPHIDIUM spp., *AMMONIA* spp. AND *LOBATULA* *LOBATULA*
ASSEMBLAGE

This assemblage occurs from the base of the member (RM7, PNOI45, PNOI33) and represents normal marine infralittoral conditions (about 30 m depth) based on the dominance of shallow-water taxa (mainly *A. beccarii* 8.61% and *A. parkinsoniana* 6.29%) and epiphytic species such as *Elphidium* spp. (*E. advenum* 17.88%, *E. granosum* 5.30%, *E. macellum* 3.31%, *Criboelphidium decipiens* 5.96%), *Asterigerinata planorbis* (7.61%) and *Lobatula lobatula* (5.96%). Oxyphilic taxa are dominant (44.34%). Although species diversity is reduced, the value remains typical of normal marine shelf deposits (α -index 11.86, H 3.11). The inbenthic species (10.25%) are characterised by *B. frigida granulata*, *C. carinata* and *H. depressula*.

Planktonic foraminifers are very scarce (mean value 7.83% of the total assemblage) and are represented mainly by small-sized specimens (*Globigerinoides ruber*, *G. trilobus*, *Globigerina bulloides*, *G. falconensis*, *N. pachyderma*, *Orbulina universa*).

AMMONIA *PARKINSONIANA*, *A. TEPIDA* AND *ELPHIDIUM*
GRANOSUM ASSEMBLAGE

This assemblage extends from PNOI34 to the top of the member and indicates a shallowing trend and the development of marginal environments (<10 m depth). The foraminiferal assemblage shows an oligospecific feature according to the α -index and H values that are below 1. It is composed entirely of inbenthic, low-salinity-tolerant species (*A. tepida* 36.64%, *A. parkinsoniana* 52.33%, and *E. granosum* 11.03%). Oxyphilic species are absent. A similar association is recorded frequently in brackish lagoon settings in modern and in ancient deltaic sediments (Jorissen, 1988; Serandrei Barbero et al., 1997; Fiorini & Vaiani, 2001; Donnici & Serandrei Barbero, 2002).

A second brackish lagoon episode recorded at PNOI38 is followed by backshore sediments bearing rare mollusc fragments and reworked foraminiferal specimens (PNOI40).

Yellow sands with silty intercalations Member
(samples PNOE41, PNOE13, PNOE17, PNOE15,
PNOE18, PNOE19; Fig. 1)

Microfauna is very scarce or totally absent in the sandy layers (PNOE17, 15 18, 19). Rare reworked and badly preserved specimens, indicating a backshore setting sporadically occur in the silty intercalations.

AMMONIA *PARKINSONIANA*, *A. TEPIDA* AND *AUBYGNINA*
PERLUCIDA ASSEMBLAGE

This assemblage is recorded in the silty intercalations (PNOI41 and PNOE13) and is characterised by foraminiferal fauna like those in the Yellow sands with “panchina” Member (Tab. 6). It shows a low diversity value (α -index 1.11 and H 1.27) and is dominated by inbenthic and low-salinity-tolerant species such as *A. parkinsoniana* (47.30%) and *A. tepida* (31.30%). These species are associated with *Aubygnina perlucida*,

Monte Mario Formation	
Yellow sands with silty intercalations	
Fresh-brackish lagoon	
<i>A. parkinsoniana</i> , <i>A. tepida</i> and <i>A. perlucida</i> assemblage	
Benthos	%media
<i>Ammonia parkinsoniana</i>	47,30
<i>Ammonia tepida</i>	31,30
<i>Aubygnina perlucida</i>	7,56
<i>Criboelphidium decipiens</i>	10,34
<i>Haynesina depressula</i>	3,50
Fisher_alpha	1,11
Shannon_H	1,27
Backshore	
Barren and/or reworked foraminiferal fauna	
Clays and Cerastoderma bearing sands	
Inner infralittoral	
<i>A. parkinsoniana</i> , <i>A. tepida</i> and <i>N. turgida</i> assemblage	
Benthos	%media
<i>Ammonia beccarii</i>	4,30
<i>Ammonia parkinsoniana</i>	32,50
<i>Ammonia tepida</i>	17,88
<i>Asterigerinata planorbis</i>	7,61
<i>Aubygnina perlucida</i>	2,98
<i>Bolivina pseudoplicata</i>	1,32
<i>Brizalina</i> spp.	1,32
<i>Bulimina elongata</i>	0,99
<i>Cancris auriculus</i>	0,99
<i>Criboelphidium decipiens</i>	5,96
<i>Elphidium advenum</i>	1,65
<i>Elphidium complanatum</i>	0,99
<i>Elphidium granosum</i>	5,30
<i>Fursenkoina schreibersiana</i>	0,99
<i>Globocassidulina subglobosa</i>	1,32
<i>Lobatula lobatula</i>	5,96
<i>Nonion fabum</i>	1,65
<i>Nonionella turgida</i>	6,29
Fisher_alpha	6,85
Shannon_H	2,43
Brackish lagoon	
<i>Ammonia</i> spp. and <i>Haynesina</i> spp. assemblage	
Benthos	%media
<i>Ammonia parkinsoniana</i>	53,00
<i>Ammonia tepida</i>	23,50
<i>Aubygnina perlucida</i>	10,80
<i>Haynesina depressula</i>	6,50
<i>Haynesina germanica</i>	6,20
Fisher_alpha	1,11
Shannon_H	1,27

Tab. 6 - Mean percentages, %P [(P/P+B)%], of each species in the Monte Mario Formation: Yellow sands with silty intercalations Member and Clays and *Cerastoderma*-bearing sands Member.

Cribroelphidium decipiens and *Haynesina depressula*, which are generally common in lagoonal environments (Albani et al., 1998). Therefore, it can be assumed that these sediments record the development of a brackish lagoon that was confined in a backshore environment (0-2 m depth).

Clays and Cerastoderma-bearing sands Member (samples PNOI 46-PNOI48, PNOI50-PNOI57; Fig. 1)

AMMONIA PARKINSONIANA, *A. TEPIDA* AND *NONIONELLA TURGIDA* ASSEMBLAGE

This association is present from the base of the interval; its foraminiferal content indicates the reestablishment of a normal marine shallow-water environment (15-20 m depth). The foraminiferal assemblage is well preserved and diversified (Tab. 6, α -

index 6.85 and H 2.43) and composed by shallow-water oxyphilic species (15.22%; *Ammonia* spp., *Nonion fabum*, *Aubygnina perlucida*, *Elphidium* spp.) associated with organic matter-tolerant taxa, mainly inbenthic species (3.30%), including *Nonionella turgida*, *Brizalina aenariensis* and *Bulimina elongata* (Sgarrella & Moncharmont-Zei, 1993; Morigi et al., 2005).

AMMONIA SPP. AND *HAYNESINA* SPP. ASSEMBLAGE

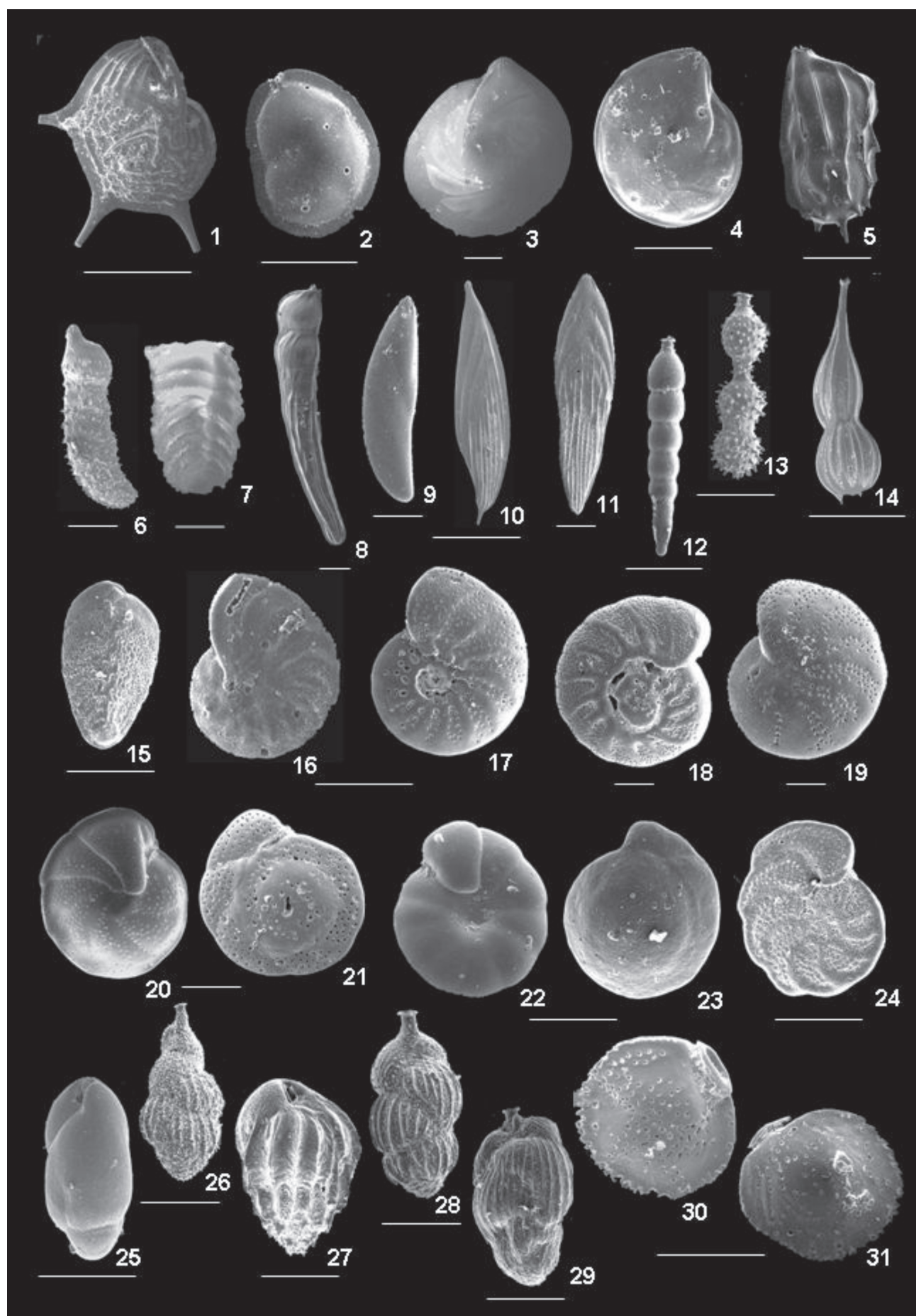
From PNOI 50, the foraminiferal assemblage is marked by an increase in *Ammonia parkinsoniana* (53.00%) and *Ammonia tepida* (23.50%), which suggests greater inputs of fresh water and organic matter (Tab. 6). The sequence ends (PNOI56 - PNOI57) with a regressive trend; developing marginal and confined environments (0-2 m depth) are shown by the oligotypic associations according to the significant percentages of inbenthic taxa

EXPLANATION OF PLATE 1

Foraminifers from Monte Vaticano Formation.

- Fig. 1 - *Lenticulina echinata* (d'Orbigny): lateral view, sample PNOI23 (scale bar = 400 μ m).
- Fig. 2 - *Lenticulina peregrina* (Swager): lateral view, sample PNOI18.
- Fig. 3 - *Lenticulina cultrata* (de Montfort): lateral view, sample PNOI23.
- Fig. 4 - *Lenticulina rotulata* (Lamarck): lateral view, sample PNOI22.
- Fig. 5 - *Marginulina costata* (Batsch): lateral view, sample PNOI22.
- Fig. 6 - *Marginulinopsis* cfr. *nana* (Costa): lateral view, sample PNOI22.
- Fig. 7 - *Vulvulina pennatula* (Batsch): lateral view, sample PNOI22.
- Fig. 8 - *Vaginulinopsis bononiensis* (Fornasini): lateral view, sample PNOI22.
- Fig. 9 - *Astacolus crepidulus* (Fichtel & Moll): lateral view, sample PNOI18.
- Fig. 10 - *Planularia auris* (Defrance): lateral view, sample PNOI22.
- Fig. 11 - *Plectofrondicularia semicosta* (Karrer): lateral view, sample PNOI22.
- Fig. 12 - *Stilostomella adolphina* (d'Orbigny): lateral view, sample PNOI14.
- Fig. 13 - *Stilostomella hispida* (d'Orbigny): lateral view, sample PNOI22.
- Fig. 14 - *Amphicoryna* cfr. *proxima* (Silvestri): lateral view, sample PNOI14 (scale bar = 200 μ m).
- Fig. 15 - *Bolivina leonardii* Accordi & Selmi: lateral view, sample PNOI14.
- Figs. 16-17 - *Anomalinoidea helacinus* (Costa), sample PNOI23.
16 - umbilical view.
17 - spiral view.
- Figs. 18-19 - *Anomalinoidea ornatus* (Costa), sample PNOI23.
13 - spiral view.
14 - umbilical view.
- Figs. 20-21 - *Cibicidoides pseudoungerianus* (Cushman), sample PNOI18.
20 - umbilical view.
21 - spiral view.
- Figs. 22-23 - *Cibicidoides robertsonianus* (Brady), sample PNOI18.
22 - umbilical view.
23 - spiral view.
- Fig. 24 - *Planulina ariminensis* d'Orbigny: spiral view, sample PNOI23.
- Fig. 25 - *Praeglobobulimina ovata* (d'Orbigny): lateral view, sample PNOI22.
- Fig. 26 - *Uvigerina pygmaea* (d'Orbigny): lateral view, sample PNOI22.
- Fig. 27 - *Bulimina costata* d'Orbigny: lateral view, sample PNOI14.
- Fig. 28 - *Uvigerina peregrina* Cushman: lateral view, sample PNOI14.
- Fig. 29 - *Uvigerina rutila* Cushman & Todd: lateral view, sample PNOI22.
- Figs. 30-31 - *Siphonina reticulata* (Czjzek), sample PNOI18.
30 - lateral view.
31 - lateral view.

Scale bar = 250 μ m (unless reported differently).



such as *Haynesina germanica* (6.20%) that are typically tolerant of high organic matter and low oxygen content (Murray, 2006).

BIOSTRATIGRAPHICAL CONSIDERATIONS

Based on the bio- and chronostratigraphic framework used in this study, the lower part of the Monte Mario section (Monte Vaticano Formation) is attributed to the Early Pliocene, Zanclean Stage, *Globorotalia puncticulata* Zone according to the presence of *Globorotalia puncticulata*. At regional level, these sediments belong to the first sedimentary cycle of the neoautochthonous Central Italian basins and, more precisely, could be correlated with the upper part of this sedimentary sequence (Barberi et al., 1994).

High frequencies of *G. puncticulata padana* allow the upper part of the Monte Vaticano Formation to be attributed to the Zanclean Stage, confirming previous results based on nannoplankton data (NN16a nannofossil zone: Rio et al., 1990) specifically at 3.81-3.70 Ma (Cosentino et al., 2009). Moreover, the presence of *Dentoglobigerina altispira* represents a useful

biostratigraphical proxy of regional value for the Zanclean Stage. Foraminiferal analyses highlight the presence of stratigraphic levels rich in *Globigerina* spp. and in *G. bulloides* and *G. praecalida* both showing large intraspecific variability. Two morphological trends are pointed out: *G. bulloides* morphotypes leading to *G. calabra* and *Globigerina praecalida* morphotypes leading to *G. calida*. Additional study on other Early Pliocene central Italian sites will attempt to enhance knowledge of the Pliocene Central Italy succession, which usually lacks common foraminiferal markers.

Pleistocene sediments (Monte Mario Formation) belong entirely to the third cycle and directly overlie Pliocene deposits by means of an unconformity. The unconformity includes a *hiatus* of different temporal extension across the region; at the Monte Mario site, the gap ranges from about the Early Piacenzian to the Early Calabrian (about 2 Ma, Cosentino et al., 2009) and was induced by regional uplift.

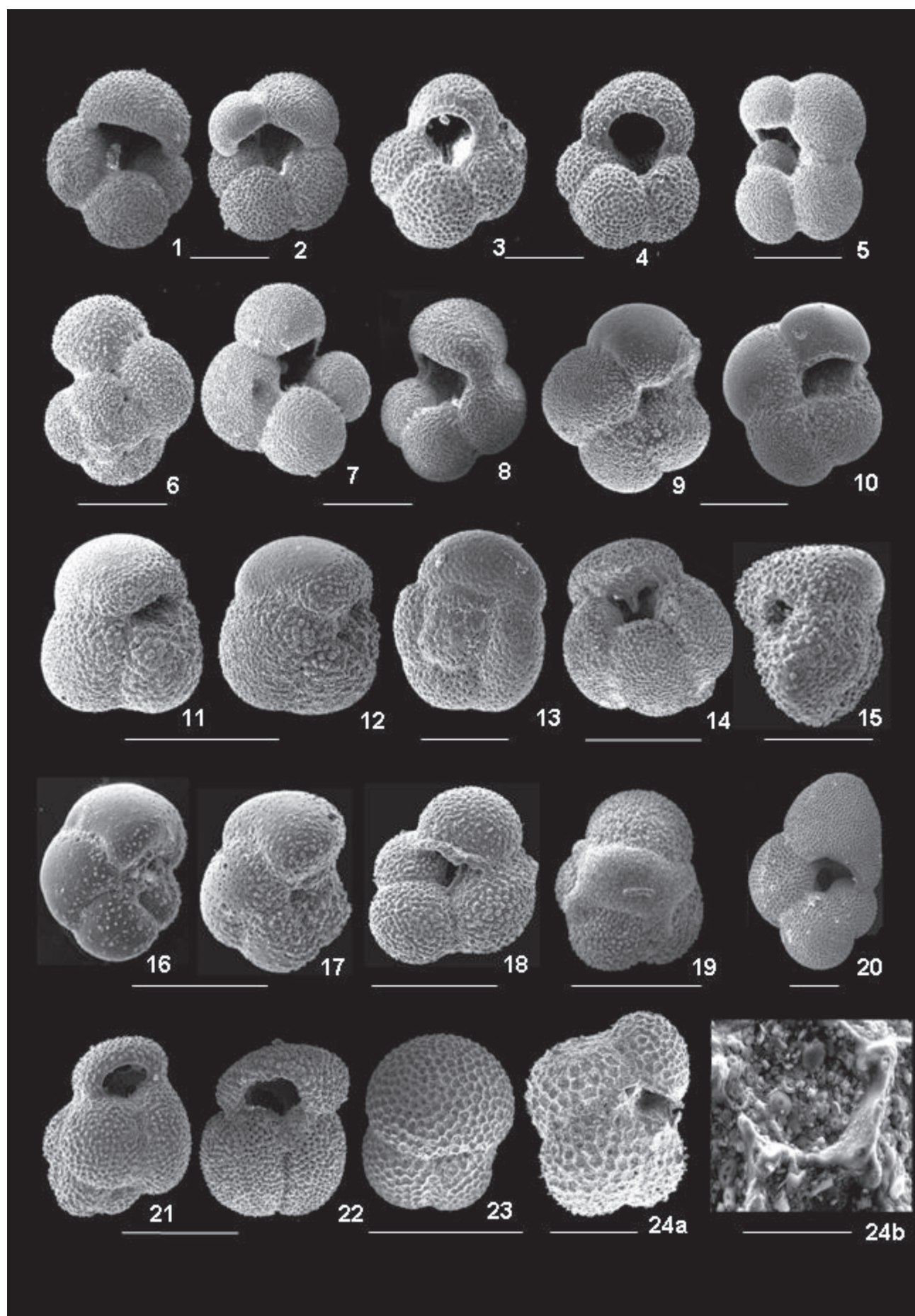
The presence of *Bulimina etnea* at the base of the Monte Mario Formation (Farneto silts Member) allows assigning these sediments to the Santernian. Moreover, foraminiferal assemblages enriched in Cassidulinidae and

EXPLANATION OF PLATE 2

Foraminifers from Monte Vaticano Formation.

- Figs. 1-2 - *Globigerina bulloides* d'Orbigny, sample PNOI23.
1 - umbilical view.
2 - umbilical view five-chambered morphotype.
- Fig. 3 - *Globoturborotalita decoraperta* (Takayanagi & Saito): umbilical view, sample PNOI14.
- Fig. 4 - *Globoturborotalita apertura* (Cushman): umbilical view, sample PNOI23.
- Figs. 5-8 - *Globigerina* gr. *praecalida*, sample PNOI23.
5 - umbilical view elongated morphotype with five chambers in last whorl.
6 - spiral view.
7 - open umbilical morphotype.
8 - open umbilical morphotype.
- Figs. 9-10 - *Globorotalia puncticulata puncticulata* (Deshayes), sample PNOI22.
9 - umbilical view, typical morphotype.
10 - umbilical view, *Globorotalia bononiensis* trend morphotype.
- Figs. 11-13 - *Globorotalia puncticulata padana* Dondi & Papetti, sample PNOI22.
11 - umbilical view.
12 - umbilical view.
13 - spiral view.
- Fig. 14 - *Dentoglobigerina altispira altispira* Cushman & Jarvis: umbilical view, sample PNOI14.
- Figs. 15-17 - *Globorotalia crassaformis* Galloway & Wissler, sample PNOI18.
15 - lateral view.
16 - umbilical view.
17 - umbilical view.
- Fig. 18 - *Globigerina falconensis* Blow: umbilical view, sample PNOI18 (scale bar = 200 µm).
- Fig. 19 - *Globigerinita glutinata* (Egger): morphotype with bulla covering the umbilical part, sample PNOI14.
- Fig. 20 - *Globigerinoides sacculifer* (Brady): umbilical view, sample PNOI22.
- Fig. 21 - *Globigerinoides elongatus* (d'Orbigny): umbilical view, sample PNOI14.
- Fig. 22 - *Globigerinoides obliquus obliquus* Bolli: umbilical view, sample PNOI22.
- Fig. 23 - *Globigerinoides trilobus* (Reuss): umbilical view, sample PNOI22.
- Fig. 24 - *Sphaeroidinellopsis seminulina* (Schwager), sample PNOI14: a) umbilical view, b) detail of the test, note the presence of nannoplankton specimens (*Gephyrocapsa* sp., *Helicosphaera sellii*, *Pseudoemiliania lacunosa*) (scale bar = 15 µm).

Scale bar = 250 µm (unless reported differently).



Buliminidae, such as those recorded in the Farneto silts, are very common in Early Pleistocene (Santernian) sediments from Central Italian basins (Chiani-Tevere Formation). Therefore, similar palaeoenvironmental conditions developed at regional level at the beginning of the third cycle (Borzi et al., 1998; Girotti & Mancini, 2003). The absence of stratigraphic markers from Yellow sands with “panchina” Member to the top of the section, precludes a more precise biostratigraphic assignment. The attribution of the whole formation to the Santernian is possible according to the reconstruction based on sequence stratigraphy (Cosentino et al., 2009).

PALAEOENVIRONMENTAL AND PALAEOCLIMATIC CONSIDERATIONS

Microfaunal analysis of the Monte Mario succession (Monte Vaticano and Monte Mario formations) provides new and more detailed palaeoenvironmental and biostratigraphical constraints on the Plio-Pleistocene sequence in the urban area of Rome. Palaeoenvironmental conditions are deduced from the percentages of each taxa

[(P/P+B)%], diversity indices, and inbenthic and oxyphilic species. In particular, data show that diversity indices correlate positively with oxyphilic taxa and negatively with inbenthic species. The planktonic fraction correlates well with the diversity indexes (Tab. 7).

Pliocene deposits (Monte Vaticano Formation) record high palaeo-depth (upper bathyal conditions), warm oligotrophic water (high diversity) and a well-oxygenated bottom (dominant oxyphilic taxa). They are consistent with isotopic stratigraphy, which records a subtropical climate for the Mediterranean basin from 5.3 to 3.3 Ma (Sprovieri, 1985). Globigerinids-rich levels coupled with decreased *Globigerinoides* spp. probably indicate changing palaeoceanographic conditions related to temperature and vertical circulation effects (nutrient content) of the cooling trend that characterised the upper part of the Early Pliocene (Rio et al., 1990; Shackleton et al., 1990; Hohenegger et al., 2008; Cosentino et al., 2009). This cooling trend could have accelerated the regressive trend caused by regional uplift (Barberi et al., 1994).

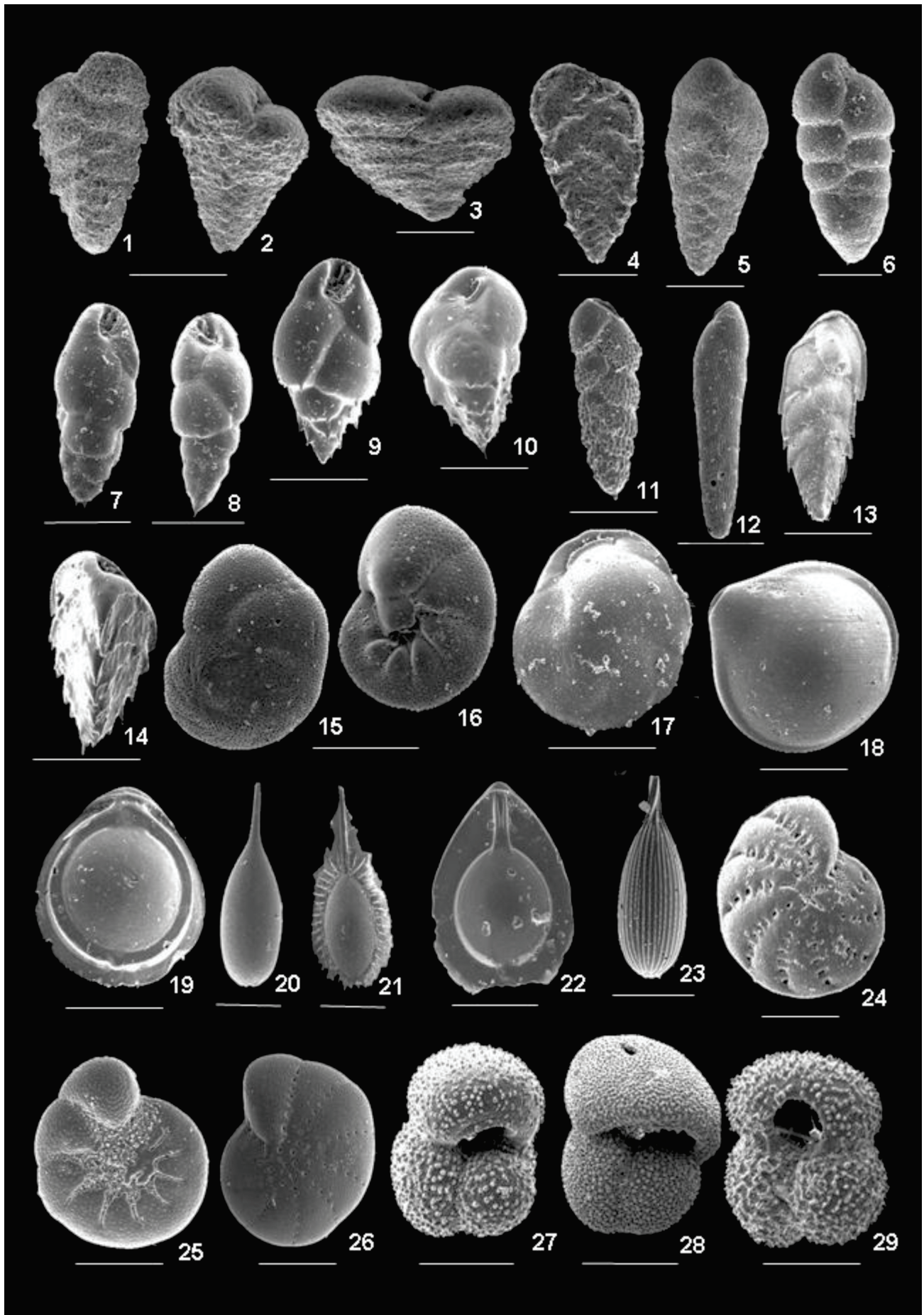
Pleistocene sediments (Monte Mario Formation) present a wide variety of environments controlled by sea

EXPLANATION OF PLATE 3

Foraminifers from Monte Mario Formation - Farneto silts Member.

- Fig.1 - *Spiroplectinella wrighti* (Silvestri): lateral view, sample PNOI27.
- Fig. 2 - *Textularia bocki* Höglund: lateral view, sample PNOI29.
- Fig. 3 - *Textularia conica* d'Orbigny: lateral view, sample PNOI11.
- Fig. 4 - *Siphotextularia concava* (Karrer): lateral view, sample PNOI21.
- Fig. 5 - *Textularia sagittula* Defrance: lateral view, sample PNOI27.
- Fig. 6 - *Karrierella bradyi* (Cushman): lateral view, sample PNOI11.
- Fig. 7 - *Bulimina corsiniana* Perconig: lateral view, sample PNOI27.
- Fig. 8 - *Bulimina elegans marginata* Fornasini: lateral view, sample PNOI27.
- Fig. 9 - *Bulimina marginata* d'Orbigny: lateral view, sample PNOI29.
- Fig. 10 - *Bulimina etnea* Seguenza: lateral view, sample PNOI29.
- Fig. 11 - *Bolivina subspinescens* Cushman: lateral view, sample PNOI27.
- Fig. 12 - *Bolivina striatula* (Cushman): lateral view, sample PNOI29.
- Fig. 13 - *Brizalina alata* (Seguenza): lateral view, sample PNOI21.
- Fig. 14 - *Reussella spinulosa* Reuss: lateral view, sample PNOI29.
- Figs. 15-16 - *Valvulineria bradyana* (Fornasini), sample PNOI21.
15 - spiral view
16 - umbilical view.
- Fig. 17 - *Cassidulina carinata* Silvestri: 12) lateral view, sample PNOI21.
- Fig. 18 - *Fissurina eburnea* (Buchner): lateral view, sample PNOI27.
- Fig. 19 - *Fissurina* sp.: lateral view, sample PNOI21.
- Fig. 20 - *Lagena laevis* (Montagu): lateral view, sample PNOI27 (scale bar = 150 µm).
- Fig. 21 - *Lagena radiata* (Seguenza): lateral view, sample PNOI27 (scale bar = 150 µm).
- Fig. 22 - *Lagena longirostris* Seguenza: lateral view, sample PNOI27 (scale bar = 200 µm).
- Fig. 23 - *Lagena striata* (d'Orbigny): lateral view, sample PNOI29 (scale bar = 150 µm).
- Fig. 24 - *Elphidium advenum* (Cushman): lateral view, sample PNOI11 (scale bar = 200 µm).
- Fig. 25 - *Elphidium granosum* (d'Orbigny): lateral view, sample PNOI11 (scale bar = 200 µm).
- Fig. 26 - *Criboelphidium decipiens* (Costa): lateral view, sample PNOI21 (scale bar = 200 µm).
- Fig. 27 - *Globorotalia oscitans* Todd, sample PNOI30: umbilical view (scale bar = 10 µm).
- Fig. 28 - *Globorotalia inflata* (d'Orbigny): umbilical view, sample PNOI30.
- Fig. 29 - *Globigerinoides ruber* (d'Orbigny): umbilical view, sample PNOE9 (scale bar = 200 µm).

Scale bar = 250 µm (unless reported differently).



Fm/member	Marne Vaticane	Farneto silts	Grey sands A.islandica	Yellow sands with "panchina"		Yellow sands silty intercalations	Clays Cerast. sands	
Environments	Upper bathyal	Infra/ circalittoral transition		Infralittoral	Brackish	Fresh - Brackish	Brackish	Infralittoral
Plancton %	83,89	10,36	11,00	7,83	0	0	0	0
Oxyphilic taxa %	35,57	18,56	59,49	44,34	0	0	0	15,22
Inbenthic taxa %	23,41	38,48	11,69	10,25	100	100	100	3,30
Fisher_alpha	29,31	15,67	16,34	11,86	0,58	1,11	1,11	6,85
Shannon_H	3,22	3,10	3,31	3,11	0,95	1,27	1,27	2,43

Tab. 7 - Summarizing table related to mean percentages of oxyphilic and inbenthic taxa, diversity indices and %P in each member and formation.

level oscillations due to the combined effects of tectonics and climate change. A first transgressive cycle ranges from the Farneto silts Member (upper circalittoral and infra/circalittoral transition) to the Yellow sands with "panchina" Member (backshore environment). Farneto silts represent the deepest Pleistocene environments and have an assemblage of *Bulimina* spp., *Cassidulina carinata* and *Criboelphidium decipiens* that is indicative of an upper circalittoral environment. The high percentage of inbenthic species and the decrease in diversity index suggest a high productivity in the bottom waters leaning

towards eutrophic conditions. The increases in Cassidulinidae and Buliminidae suggest a cooling trend; this trend is confirmed by the presence of the nordic guest *Arctica islandica*, which is recorded from the base of the Farneto silts to the Grey sands containing the *Arctica islandica* Member (Fig. 1). In particular, the occurrence of *C. carinata* which prefers cold and productive bottom-waters (Hald & Vorren, 1987; Mackensen & Hald, 1988), and of *Bulimina* spp. is in agreement with the fine grain-size sediments of this member (Jorissen, 1988). The remarkable decrease in water temperature may correlate

EXPLANATION OF PLATE 4

Foraminifers from Monte Mario Formation - Grey sands with *Arctica islandica* Member.

- Fig. 1 - *Planorbulina mediterraneensis* d'Orbigny: unattached side, sample RM6.
 Fig. 2 - *Elphidium macellum* (Fichtel & Moll): lateral view, sample RM6.
 Fig. 3 - *Elphidium incertum* (Williamson): lateral view, sample RM7.
 Fig. 4 - *Elphidium crispum* (Linnè): lateral view, sample PNOE9.
 Fig. 5 - *Sigmoilinita tenuis* (Czjzek): lateral view, sample PNOI30 (scale bar = 50 µm).
 Figs. 6-7 - *Triloculina schreiberiana* d'Orbigny, sample RM7.
 6 - lateral view.
 7 - face view.
 Figs. 8-9 - *Buccella frigida granulata* (di Napoli), sample PNOE9.
 8 - ventral view.
 9 - spiral view.
 Fig. 10 - *Siphonaperta aspera* (d'Orbigny): sample PNOE9.
 Figs. 11-12 - *Quinqueloculina* cfr. *disparilis* d'Orbigny, sample RM6.
 11 - face view.
 12 - lateral view.
 Fig. 13 - *Quinqueloculina seminulum* (Linnè): lateral view, sample RM6.

Foraminifers from Monte Mario Formation - Yellow sands with "panchina" Member, Yellow sands with silty intercalations Member and Clays and *Cerastoderma*-bearing sands Member.

- Fig. 14 - *Nonion fabum* (d'Orbigny): lateral view, sample PNOI33.
 Fig. 15 - *Haynesina depressula* (Walker & Jacob): lateral view, sample PNOI41 (scale bar = 100 µm).
 Fig. 16 - *Ammonia beccarii* (Linnè): spiral view, sample RM5.
 Fig. 17 - *Ammonia tepida* Cushman: ventral view, sample PNOI52.
 Fig. 18 - *Cancris auriculus* (Fichtel & Moll): ventral view, sample RM5.
 Figs. 19-20 - *Asterigerinata planorbis* (d'Orbigny), sample RM5.
 19 - spiral view.
 20 - ventral view.
 Figs. 21-22 - *Lobatula lobatula* (Walker & Jacob), sample RM5.
 21 - ventral view.
 22 - spiral view.
 Fig. 23 - *Ammonia parkinsoniana* (d'Orbigny): ventral view, sample PNOI50.
 Figs. 24-25 - *Rosalina bradyi* Cushman, sample RM5.
 24 - spiral view.
 25 - ventral view.

Scale bar = 250 µm (unless reported differently).



with the MIS 58 glacial period and fits within the context of the regional cooling. The association of frequent *G. ruber*, which is commonly considered a warm-water, stratified and oligotrophic species (Hemleben, 1989; Pujol & Vernaud-Grazzini, 1995), with temperate and cool taxa such as *G. bulloides*, *T. quinqueloba*, *G. inflata* (Rohling et al., 1993) could reflect the influence of marked seasonality.

An oxygenated, shallow-water environment is recorded in the Grey sands with *Arctica islandica* Member (*Elphidium* spp., *Lobatula lobatula* and *Asterigerinata planorbis* assemblage), which contains the highest frequencies of oxyphilic and epiphytic taxa. Widespread vegetated bottoms are recorded through the base of the Yellow sands with “panchina” Member (*Elphidium* spp., *Ammonia* spp. and *Lobatula lobatula* assemblage). The progressive disappearance of the nordic guest *Arctica islandica* and the development of vegetated bottoms with frequent miliolids could be related to climate amelioration (MIS 57, Cosentino et al., 2009).

More marginal environments developed successively as the result of a shallowing trend of the sea-level. Lagoon/brackish lagoon environments characterised by oligospecific euryhaline foraminiferal assemblages (*Ammonia parkinsoniana*, *A. tepida* and *Elphidium granosum* assemblage) developed to the Yellow sands with silty intercalations Member (*Ammonia parkinsoniana*, *A. tepida* and *Aubygnina perlucida* assemblage). Cosentino et al. (2009) attributed this sea-level drop to the following glacial phase MIS 56.

The second transgressive episode is recorded in the Clays and *Cerastoderma*-bearing sands Member and is marked, at the base of the member, by the reestablishment of normal marine infralittoral conditions (*Ammonia parkinsoniana*, *A. tepida* and *Nonionella turgida* assemblage) characterised by nutrient input and fresh-water influence. The slight sea level rise associated with warm ostracofauna (Faranda & Gliozzi, 2008) could be related to MIS 55.

The top of the stratigraphic succession records a more confined brackish lagoon environment (*Ammonia* spp. and *Haynesina* spp. assemblage), indicating a progradational phase of the upper portion of the Monte Mario Formation (Cosentino et al., 2009).

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REFERENCES

- Albani A.D., Favero V.M. & Serandrei Barbero R. (1998). Distribution of Sediment and Benthic Foraminifera in the Gulf of Venice, Italy. *Estuarine, Coastal and Shelf Science*, 46: 251-265.
- Ambrosetti P. & Bonadonna F.P. (1967). Revisione sui dati sul Plio-Pleistocene di Roma. *Atti della Accademia Gioenia di Scienze Naturali in Catania*, 18: 33-81.
- Báldi K. & Hohenegger J. (2008). Paleoeecology of benthic foraminifera of the Baden-Sooss section (Badenian, Middle Miocene, Vienna Basin, Austria). *Geologica Carpathica*, 59 (5): 411-424.
- Barberi F., Buonasorte G., Cioni R., Fiordelisi A., Foresi L., Iaccarino S., Laurenzi M.A., Sbrana A., Vernia L. & Villa I.M. (1994). Plio-Pleistocene geological evolution of the geothermal area of Tuscany. *Memorie Descrittive della Carta Geologica D'Italia*, XLIX: 9-22.
- Bergamin L., Carboni M.G., Di Bella L., Marra F. & Palagi I. (2000). Stratigraphical and paleoenvironmental features of the Pleistocene sediments of M. Mario (Rome). *Eclogae Geologicae Helvetiae*, 93: 265-275.
- Blanc A.C. (1955). Ricerche sul Quaternario laziale. III – Avifauna artica, crioturbazioni e testimonianze di soliflussi nel Pleistocene medio-superiore di Roma e di Torre in Pietra. Il periodo glaciale Nomentano nel quadro della serie di glaciazioni riconosciute nel Lazio. *Quaternaria*, 2: 187-200.
- Blanc A.C., Tongiorgi E. & Trevisan E. (1953). Le Pliocene et le Quaternaire aux alentours de Rome. INQUA IV^e Congrès International – Roma, Pisa 1953. Programme de excursion aux alentours de Rome: 1-35.
- Bonadonna F.P. (1968). Studi sul Pleistocene del Lazio. V – La biostratigrafia di Monte Mario e la “Fauna Malacologica Mariana” di Cerulli Irelli. *Memorie della Società Paleontologica Italiana*, 7: 261-321.
- Borzi M., Carboni M.G., Cilento G., Di Bella L., Florindo F., Girotti O., Piccardi E. & Sagnotti L. (1998). Bio- and magneto-stratigraphy in the Tiber valley revised. *Quaternary International*, 47/48: 65-72.
- Brocchi G. (1820). Dello stato fisico del suolo di Roma ed illustrazione della carta geognostica di questa città. *Stamperia de Romanis*, 281 pp., 1 carta geologica.
- Carboni M.G. & Di Bella L. (1997). The Plio-Pleistocene of the Anzio coast (Rome). *Bollettino della Società Paleontologica Italiana*, 36 (1-2): 135-159.
- Cimerman F. & Langer M. (1991). Mediterranean Foraminifera. *Slovenska Akademija Znanosti in Umetnosti, Academia Scientiarum Artium Slovenica, Classis IV: Historia Naturalis*, 30: 118 pp.
- Colalongo M.L. & Sartoni S. (1977). *Globigerina calabra* nuova specie presso il limite Plio/Pleistocene della sezione della Vrica (Calabria). *Giornale di Geologia*, 42: 205-220.
- Conato V., Esu D., Malatesta A. & Zarlenga F. (1980). New data on the Pleistocene of Rome. *Quaternaria*, 22: 131-176.
- Corliss B.H. (1985). Microhabitats of benthic foraminifera within deep-sea sediments. *Nature*, 314: 435-438.
- Corliss B.H. & Chen C. (1988). Morphotype patterns of Norwegian Sea deep-sea benthic foraminifera and ecological implications. *Geology*, 16: 195-236.
- Cosentino D., Cipollari P., Di Bella L., Esposito A., Faranda C., Giordano G., Gliozzi E., Mattei M. & Mazzini I. (2009). Tectonics, sea-level changes and paleoenvironments in the early Pleistocene of Rome (Italy). *Quaternary Research*, 72: 143-155.
- De Stiger H.C., Jorissen F.J. & Van der Zwaan G.J. (1998). Bathymetric distribution and microhabitat partitioning of live (Rose Bengal stained) benthic foraminifera along a shelf to bathyal transect in the southern Adriatic Sea. *Journal of Foraminiferal Research*, 28: 40-65.
- Den Dulk M., Reichert G.J., Van Heyst S., Zachariasse W.J. & Van der Zwaan G.J. (2000). Benthic foraminifera as proxies of organic matter flux and bottom water oxygenation? A case history from the northern Arabian Sea. *Palaeogeography, Palaeoclimatology, Palaeoecology*, 161: 337-359.
- Donnici S. & Serandrei Barbero R. (2002). The benthic foraminiferal communities of the northern Adriatic continental shelf. *Marine Micropaleontology*, 44: 93-123.
- Faranda C. & Gliozzi E. (2008). The ostracod fauna of the Plio-Pleistocene Monte Mario succession (Roma, Italy). *Bollettino della Società Paleontologica Italiana*, 47 (3): 215-267.
- Fiorini F. & Vaiani S.C. (2001). Benthic foraminifer and transgressive-regressive cycles in the Late Quaternary subsurface sediments of the Po Plain near Ravenna (Northern Italy). *Bollettino della Società Paleontologica Italiana*, 40 (3): 357-403.
- Fisher R.A., Corbet A.S. & Williams C.B. (1943). The relation between the number of species and the number of individuals in

- a random sample of an animal population. *Journal of Animal Ecology*, 12: 42-58.
- Florindo F., Karner D.B., Marra F., Renne P., Roberts A. & Weaver R. (2007). Radiometric age constraints for glacial terminations IX and VII from aggradational sections of the Tiber River delta in Rome, Italy. *Earth and Planetary Science Letters*, 256: 61-80.
- Girotti O. & Mancini M. (2003). Plio-Pleistocene stratigraphy and relations between marine and non marine successions in the middle valley of the Tiber river (Latium, Umbria). *Italian Journal of Quaternary Sciences*, 16 (1 bis): 89-106.
- Hald M. & Vorren T.O. (1987). Foraminiferal stratigraphy and environment of Late Weichselian deposits on the continental shelf off Troms, Northern Norway. *Marine Micropaleontology*, 12: 129-160.
- Hemleben C., Spindler M. & Anderson O.R. (1989). Modern planktonic foraminifera. Springer-Verlag, New York, 363 pp.
- Hohenegger J., Andersen N., Báldi K., Coric S., Pervesler P., Rupp C. & Wagreich M. (2008). Paleoenvironment of the Early Badenian (Middle Miocene) in the southern Vienna Basin (Austria) – multivariate analysis of the Baden-Soos section. *Geologica Carpathica*, 59: 461-487.
- Iaccarino S. (1985). Mediterranean Miocene and Pliocene planktic foraminifera. In Bolli H.H., Sanders J.B. & Perck-Nielsen K. (eds.), "Plankton Stratigraphy": 283-314.
- Iaccarino S., Premoli Silva I., Biolzi M., Foresi L.M., Lirer F., Turco E. & Petrizzo M.R. (2007). Practical manual of Neogene Planktonic Foraminifera. International School on Planktonic Foraminifera, 6th course, Perugia 19-23 February 2007, University of Perugia: 1-181.
- Jorissen F.J. (1988). Benthic foraminifera from the Adriatic Sea; principles of phenotypic variations. *Utrecht Micropalaeontological Bulletin*, 37: 1-174.
- Kaiho K. (1994). Benthic foraminiferal dissolved-oxygen index and dissolved-oxygen levels in the modern ocean. *Geology*, 22: 719-722.
- Kaiho K. (1999). Effect of organic carbon flux and dissolved oxygen on the benthic foraminiferal oxygen index (BFOI). *Marine Micropaleontology*, 37: 67-76.
- Langer M.R. (1993). Epiphytic foraminifera. *Marine Micropaleontology*, 20: 235-265.
- Loeblich A.R. & Tappan H. (1987). Foraminiferal Genera and their Classification. 970 pp. Van Nostrand Reinhold Company.
- Mackensen A. & Hald M. (1988). *Cassidulina teretis* Tappan and *C. laevigata* d'Orbigny: their Modern and Late Quaternary distribution in Northern Sea. *Journal of Foraminiferal Research*, 18: 16-24.
- Malatesta A. (1978). Torre in Pietra. *Quaternaria*, 20: 203-577.
- Marra F., Carboni M.G., Di Bella L., Faccenna C., Funicello R. & Rosa C. (1995). Il substrato plio-pleistocenico nell'area romana. *Bollettino della Società Geologica Italiana*, 114: 195-214.
- Milli S. (1997). Depositional setting and high frequency sequence stratigraphy of the Middle-Upper Pleistocene to Holocene deposits of the Roman Basin. *Geologica Romana*, 33: 99-136.
- Morigi C., Jorissen F.J., Fraticelli S., Horton B.P., Principi M., Sabbatini A., Capotondi L., Curzi P.V. & Negri A. (2005). Benthic foraminiferal evidence for the formation of the Holocene mud-belt and bathymetrical evolution the central Adriatic Sea. *Marine Micropaleontology*, 57: 25-49.
- Murray J.W. (1991). Ecology and paleoecology of benthic foraminifera. New York, Longman Scientific & Technical, 397 pp.
- Murray J.W. (2006). Ecology and applications of Benthic Foraminifera. Cambridge University Press, 426 pp.
- Parker F.L. (1962). Planktonic foraminiferal species in Pacific sediments. *Micropaleontology*, 8: 219-254.
- Ponzi G. (1872). Del bacino di Roma e sua natura. *Regia Tipografia*, 51 pp., 1 carta geologica.
- Pujol C. & Vergnaud-Grazzini C. (1995). Distributions patterns of living planktic foraminifera as related to regional hydrography and productive systems of the Mediterranean Sea. *Marine Micropaleontology*, 25: 187-217.
- Rio D., Raffi I. & Villa G. (1990). Pliocene-Pleistocene calcareous nannofossil distribution in the western Mediterranean. In Kastens K.A., Mascle J. et al. (eds.), Proceedings of the Ocean Drilling Program, Scientific Results 107: 513-533.
- Rohling E.J., Jorissen F.J., Vergnaud-Grazzini C. & Zachariasse W.J. (1993). Northern Levantine and Adriatic Quaternary planktic foraminifera; Reconstruction of paleoenvironmental gradients. *Marine Micropaleontology*, 21: 191-218.
- Serandrei Barbero R., Albani A.D. & Zecchetto S. (1997). Palaeoenvironmental significance of a benthic foraminiferal fauna from an archaeological excavation in the Lagoon of Venice, Italy. *Palaeogeography, Palaeoclimatology, Palaeoecology*, 136: 41-52.
- Sgarrella F. & Moncharmont Zei M. (1993). Benthic Foraminifera of the Gulf of Naples (Italy): systematics and autoecology. *Bollettino della Società Paleontologica Italiana*, 32 (2): 145-264.
- Shackleton N.J., Berger A. & Peltier W.R. (1990). An alternative astronomical calibration of the lower Pleistocene timescale based on ODP Site 677. *Transactions of the Royal Society of Edinburgh: Earth Science*, 81: 251-261.
- Sprovieri R. (1985). Paleotemperatures changes and speciation among benthic foraminifera in the Mediterranean Pliocene. *Bollettino della Società Paleontologica Italiana*, 24: 13-21.
- Van der Zwaan G.J., Jorissen F.J. & De Stigter H.C. (1990). The depth dependency of planktonic/benthic foraminiferal ratios: Constraints and applications. *Marine Geology*, 95: 1-16.

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