

CALCAREOUS NANNOFOSSIL AND FORAMINIFERA BIOSTRATIGRAPHY OF PLEISTOCENE TERRIGENOUS SEDIMENTS FROM SOUTHERN ITALY

MARIA MARINO

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Riassunto. È stato condotto uno studio di biostratigrafia integrata basata sui Nannofossili calcarei e sui Foraminiferi di alcune successioni terrigene pleistoceniche affioranti nel Bacino di Sant'Arcangelo (Italia meridionale). Per la biozonazione di questo intervallo di tempo, si è fatto riferimento alle zonazioni di Rio et al. (1990) e di Colalongo e Sartoni (1979).

Sulle associazioni a Nannofossili calcarei sono state condotte analisi quantitative che, nonostante la rarità dei marker pleistocenici e la presenza di coccoliti rimaneggiati di diversi intervalli di tempo, hanno permesso di ottenere datazioni molto dettagliate a livello biozonale. In particolare, il genere *Gephyrocapsa* è risultato essere un taxon estremamente utile per la biostratigrafia del Pleistocene inferiore e medio, anche nei sedimenti terrigeni. Infatti, è stato possibile riconoscere importanti eventi biostratigrafici usati come limiti zonali: comparsa di *Gephyrocapsa oceanica* s.l., scomparsa di large *Gephyrocapsa*, comparsa di *Gephyrocapsa* sp. 3. Inoltre, in prossimità del limite Pliocene-Pleistocene, è stata riconosciuta la presenza di gephyrocapsidi dalle caratteristiche intermedie tra small *Gephyrocapsa* e *G. oceanica* s.l. L'estinzione di *Helicosphaera sellii* è un evento di più difficile definizione nei sedimenti terrigeni, a causa del rimaneggiamento, ma una caduta di abbondanza nella sua distribuzione è stata osservata al top della Zona a large *Gephyrocapsa*. La comparsa di *Gephyrocapsa* sp. 3 è un evento molto ben riconoscibile e utile per la definizione della base della Zona a *Pseudoemiliania lacunosa*.

Sulle associazioni a Foraminiferi sono state condotte analisi qualitative che hanno permesso di riconoscere le Zone a *Globigerina cariacensis* e a *Globorotalia truncatulinoides excelsa*. Nella gran parte dei casi le associazioni a Foraminiferi, meno ricche e diversificate di quelle a Nannofossili, hanno dato un minore dettaglio biozonale per la datazione dei sedimenti studiati.

Abstract. An integrated biostratigraphic study based on calcareous nannofossil and Foraminifera assemblages was carried out on Pleistocene terrigenous sediments of the piggyback Sant'Arcangelo Basin (Southern Italy). The calcareous nannofossil scheme of Rio et al. (1990) and the foraminifera scheme of Colalongo & Sartoni (1979) were followed.

Despite the presence of reworked pre-Pliocene, Pliocene and Pleistocene coccoliths and the scarcity of the significant species, the quantitative and semiquantitative analyses of nannofossil assemblages allowed an accurate identification of biozones. In the terrigenous sediments as well as in the pelagic sediments, the genus *Gephyrocapsa* is a good taxon for Pleistocene biostratigraphy because of its rapid morphologic evolution and relative abundance. Therefore this group has

been used to recognize the following reliable biostratigraphic events: appearance of *Gephyrocapsa oceanica* s.l., disappearance of large *Gephyrocapsa*, appearance of *Gephyrocapsa* sp. 3. Moreover, an apparent evolutionary lineage was noted from the small *Gephyrocapsa* to the *G. oceanica* s.l. specimens near the Plio-Pleistocene boundary. In the studied sediments the base of the small *Gephyrocapsa* Zone is not easily identified because of the reworking of "medium sized" *Gephyrocapsa* and *H. sellii* above this level. However, the distribution pattern of *H. sellii* shows an abundance drop very close to the last occurrence of large *Gephyrocapsa*, at the top of the large *Gephyrocapsa* Zone. The first occurrence of *Gephyrocapsa* sp. 3 is a useful event to define the small *Gephyrocapsa-Pseudoemiliania lacunosa* zonal boundary.

In order to confirm the calcareous nannofossil biozonation, a detailed study of planktonic and benthic Foraminifera was also performed; however the Pleistocene Foraminifera assemblages were found to be less useful.

Introduction.

The Sant'Arcangelo Basin is a piggyback basin (Caldara et al., 1988a; 1988b; Hippolyte et al., 1991; Pieri et al., 1994; Camarlinghi et al., 1994) located on the external thrusts of the Southern Apennine (Appennino lucano) (Fig. 1). The Sant'Arcangelo Basin is a paleogeographic and structural key-element to understand relationships between thrust progradation and sedimentation in the Apeninic thrust belt-foredeep system during the Plio-Pleistocene.

Several papers have described the sedimentary and tectonic history of the basin (Ogniben, 1969a, 1969b; Lentini, 1967, 1968, 1969a, 1969b; Vezzani, 1966, 1967a, 1967b, 1968; Lentini & Vezzani, 1974; Carbone et al., 1991; Hippolyte et al., 1991; Mostardini & Merlini, 1986; Caldara et al., 1988a, 1988b; Patacca & Scandone, 1989; Pieri et al., 1993; Camarlinghi et al., 1994; Pieri et al., 1994; Loiacono et al., 1994; Pieri et al., in press). Some of these works provided the age of the thick Plio-Pleistocene successions mostly on the basis of foraminifers; Hippolyte et al. (1991) based their biozonal determinations on the calcareous nannofossil scheme according to Martini (1971).

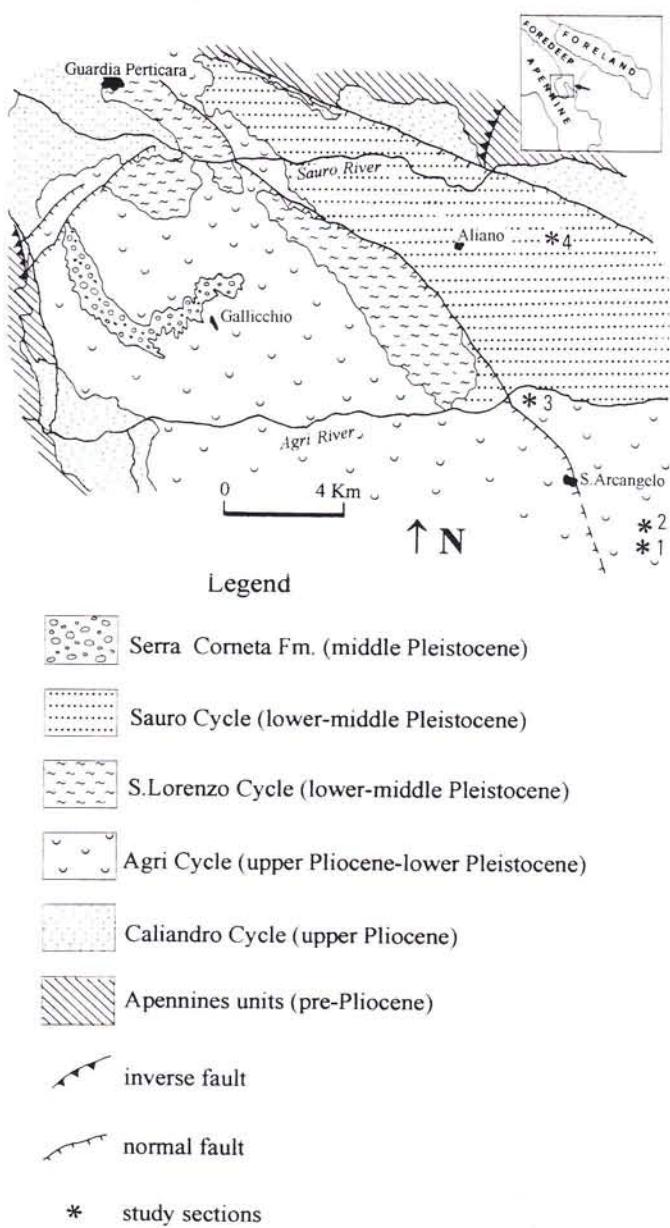


Fig. 1 - Geological scheme of the Sant'Arcangelo Basin (from Pieri et al., 1993, simplified). 1 and 2: Masseria Petto della Serra sections; 3: S. Biagio section; 4: Serra Petrizza section.

However, in the Plio-Pleistocene interval, the calcareous nannofossils provide an higher-resolution biostratigraphy with respect to the foraminifers. In particular, the scheme of Rio et al. (1990) includes eight Pleistocene biozones instead of the three or five biozones proposed in the standard schemes of Martini (1971) and Okada & Bukry (1980), respectively.

In order to obtain a more precise determination of biozones, according to the scheme of Rio et al. (1990), a detailed calcareous nannofossil study of the Pleistocene successions outcropping in the Sant'Arcangelo Basin has been attempted. Also the Foraminifera assemblages contained in the same sediments have been analyzed. In fact, despite the poor and "diluted" planktonic assemblages, the integrated biostratigraphy and the quantitati-

ve analyses carried out on calcareous nannofossil assemblages (Marino, 1992; Marino & Monechi, 1993; Maiorano, 1993; Marino, 1994) show that it is possible to recognize important biochronological events. Moreover, these events are calibrated on paleomagnetic reversals, oxygen isotope stratigraphies, astronomical cyclicity and Geomagnetic Reversal Time Scale (Tauxe et al., 1983; Channell et al., 1990; Channell et al., 1992; Vergnaud Grazzini et al., 1994; Shackleton et al., 1990; Raffi et al., 1993; Ruddiman et al., 1989; Hilgen, 1991; Castradori, 1993; Sanvoisin et al., 1993).

The study sections have been referred to the Agri Cycle and to the Sauro Cycle, according to the new geological map of the northern Sant'Arcangelo Basin (Pieri et al., 1993; Pieri et al., 1994) (Fig. 1). Lentini & Vezzani (1974) attributed these successions to the "Argille marnose grigio-azzurre" Formation, Late Pliocene-Early Pleistocene in age (Lentini & Vezzani, 1974; Caldara et al., 1988b; Hippolyte et al., 1991).

Material and methods.

Two sections have been sampled near Masseria Petto della Serra, where the Agri Cycle outcrops (Pieri et al., 1993, 1994); they largely consist of clay. The S. Biagio section, referred to the Agri Cycle (Pieri et al., 1993, 1994), is characterized by clays, silts and sands; the section becomes richer in coarse sands upwards, gradually turning into the Sandstone of Aliano Formation. The Serra Petrizza section outcrops in the northern part of the Sant' Arcangelo Basin (Sauro Cycle, according to Pieri et al., 1993, 1994): silty-clays, silts and fine sands characterize the regressive succession; upwards an increase in sands and conglomerates of fan-delta and fluvial facies (Pieri et al., 1993) have been noted.

The nannofossil biostratigraphy was carried out on smear slides with an optical microscope (1000X magnification). Neither centrifuging or other methods have been applied in order to retain the original nannofossil assemblages. The biozonal scheme and the quantitative methods of Rio et al. (1990) were followed for the nannofossil quantitative biostratigraphy (Fig. 2). Rio et al. (1990) point out the importance of the evolutionary events within the Pleistocene *Gephyrocapsa* assemblages because of their high abundances, wide geographic distribution and rapid morphological variability. Following Gartner (1977), Rio (1982), Raffi & Rio (1979), Raffi et al. (1993) the genus *Gephyrocapsa* is here split into *Gephyrocapsa oceanica* s.l., small *Gephyrocapsa*, large *Gephyrocapsa* and *Gephyrocapsa* sp. 3. Several events have been recognized on the basis of quantitative analyses: the FO (First Occurrence) of *G. oceanica* s.l., the LOs (Last Occurrences) of large *Gephyrocapsa* and *H. sellii*, the temporary relatively low abundance (corresponding

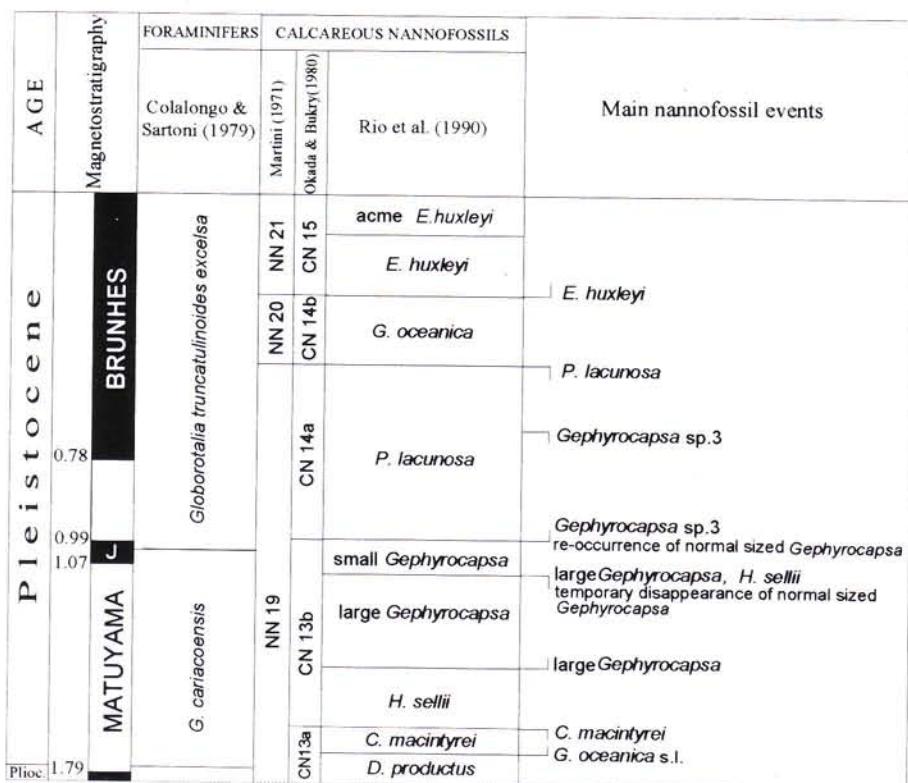


Fig. 2 - Biozonal schemes of Pleistocene calcareous plankton and main nannofossil events. The ages of paleomagnetic reversals are from Shackleton et al. (1990).

to "temporary disappearance" of Rio et al., 1990) of and the FO of *Gephyrocapsa* sp. 3 (= *G. parallela*; see Raffi et al., 1993). The *G. oceanica* s.l. appearance has been defined as the increase of this form above 1% in a count of 300 nannofossils ($>3\mu\text{m}$). The last occurrence of large *Gephyrocapsa* and the first occurrence of *Gephyrocapsa* sp. 3 were established by counting 100 *Gephyrocapsa* spp. ($>4\mu\text{m}$). The abundance pattern of these morphotypes was plotted as number of specimens per mm^2 instead of percentage with respect to a fixed number of gephyrocapsids; this because in those samples with very poor nannofossil assemblages, only 50 gephyrocapsids ($>4\mu\text{m}$) were counted. The low abundance of gephyrocapsids in these samples is probably due to the enrichment in sand lithologies upwards the section that prevents a good preservation of nannofloras; on the other hand, there are not evidences to say if the variation of nannofossil abundance can be also primary in origin. The abundances of *H. sellii* and *C. macintyreai* (form larger than $10\mu\text{m}$ according to the biometric concept of Backman & Shackleton, 1983 and of Rio et al., 1990), were plotted as percentages of the single species within a total count of 100 helicolithids and 50 *Calcidiscus* spp., respectively.

The qualitative Foraminifera analysis was performed on the residual fraction ($>125\mu\text{m}$) of the washed sediment (total weight 400 g) after drying (90°C) and disaggregation in water. The biostratigraphical scheme of Colalongo & Sartoni (1979) was followed for the Foraminifera analyses. The *Globigerina cariacensis* and *Globorotalia truncatulinoides excelsa* Zones were recogni-

zed in Pleistocene sections, despite the absence of these two markers. In fact, the foraminifer biozonal attribution mainly results from the correlation with the calcareous nannofossil biozones recognized in terrigenous sediments, according to the calcareous plankton integrated biostratigraphic scheme of Sprovieri (1993). The stratigraphic intervals referred to the *Calcidiscus macintyreensis*-large *Gephyrocapsa* nannofossil Zones are characterized by Foraminifera assemblages with *Globorotalia inflata*, *Globorotalia oscitans*, *Neogloboquadrina pachyderma* left, *Bulimina elegans marginata*, *B. marginata*, *B. etnea*; *Hyalinea balthica* is only present in samples containing large *Gephyrocapsa* and in younger sediments. In the interval referred to the *Pseudoemiliania lacunosa* Zone, the Foraminifera assemblages also contain rare and scattered specimens of *Globigerinoides tenellus*. *Globorotalia truncatulinoides excelsa*, whose first occurrence is within the Sicilian "stage" (Sprovieri et al., 1980), is absent in the samples where *Gephyrocapsa* sp. 3 is recognized; this confirms the rarity of this taxon in the Mediterranean area (Haq et al., 1977; Thunell, 1979). *Globorotalia* sp., small intermediate morphotypes between *G. inflata* and *Globorotalia bononiensis* (cfr. Brolsma, 1978, pl. 8, fig. 2b-d) are present in several Pleistocene samples.

Biostratigraphic results.

The sampled silty-clay lithologies contained well preserved nannofossils and Foraminifera, while the silty-sands were barren. Generally, the samples were characterized by abundant inorganic content; abundant pre-

Masseria Petto della Serra sections

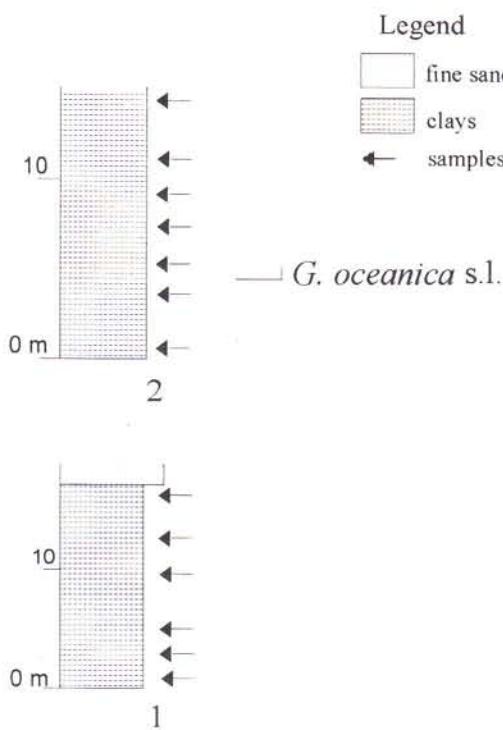


Fig. 3 - Masseria Petto della Serra sections: lithology and nannofossil events.

Pleistocene reworked specimens were recognized especially in nannofossil assemblages.

Several nannofossil biozones were recognized according to the scheme of Rio et al. (1990): *Dictyococcites productus*, *Calcidiscus macintyreui*, large *Gephyrocapsa*, small *Gephyrocapsa* and *Pseudoemiliania lacunosa* Zones. The *Helicosphaera sellii* Zone was not recognized because the sampling of the Pleistocene successions did not recover this stratigraphical interval. The Foraminifera assemblages were referred to the *Globigerina cariacensis* and *Globorotalia truncatulinoides excelsa* Zones, according to the scheme of Colalongo e Sartoni (1979).

Masseria Petto della Serra sections.

Two sections have been sampled near Masseria Petto della Serra, southeast of Sant'Arcangelo village (Km 118 of the S.S. 92; F° 211 of the "Carta Geologica d'Italia", 1:100.000; I SW); section 2 stratigraphically overlies section 1 (Fig. 3). Nannofloral assemblages show the interesting variations in gephyrocapsid population which characterize the interval across the Plio-Pleistocene boundary.

Calcareous nannofossil assemblages of section 1 were referred to *Dictyococcites productus* Zone (Late Pliocene-Early Pleistocene) (Tab. 1). This biostratigraphic in-

AGE		CALCAREOUS NANNOFOSSILS										FORAMINIFERA												
		NANNOFOSSILS Riot et al. (1990)		PLANKTONIC FORAMINIFERA Colalongo & Sartoni (1979)		Samples		ABUNDANCE PRESERVATION REWORKING		Samples		Samples		Samples		Samples		Samples		Samples				
LATE PLIOCENE / EARLY PLEISTOCENE	ZONES	D. productus	G. inflata	C	P	F	X	C	F	A	A	A	A	V	F	R	F	R	A	R	F	R	F	R
6	C P F	X C F 1 A A 1 1 . F A A C C A A A r V F . C																						
5	C P R	. C R . A A . . . R A A F C A A A x V R . R																						
4	A P F	. C R . A A . . . F A A F C A A A A r . R . F																						
3	A P R	. C R . A A . . . R A A F C A A A x V R X F																						
2	A P R	X C F . A A . . . R A A F C A A A x . R . F																						
1	C P F	X C F . A A . . 1 R A A F C A A A x V R . F																						

Tab. 1 - Calcareous nannofossil and planktonic foraminifera distribution chart of section 1 (Masseria Petto della Serra). Legend for calcareous nannofossils. Total abundance (1000X): A = > 30 specimens/view; C = 10-30 specimens/view; F = 2-10 specimens/view; R = 0.1-1 specimens/view; V = < 0.1 specimens/view; ST = barren. Species relative abundance: VA = > 10 specimens/view; A = 2-10 specimens/view; C = 0.1-1 specimens/view; F = 0.04-0.1 specimens/view; R = 0.02-0.04 specimens/view; V = < 0.02 specimens/view; X = present in additional view; 1 = one specimen. Total nannofossil reworking: A = > 5 specimens/view; C = 1-4 specimens/view; F = 1-0.1 specimens/view; R = 0.1-0.01 specimens/view; a, c, f, r, rr, x = reworked specimens. Preservation: V = very poor; P = poor; M = medium. Legend for forams: * = present; 1 = one specimen.

Petto Serra 2		AGE	EARLY PLEISTOCENE PLIOC.	NANNOFOSSILS Rio et al. (1990)	PLANKTONIC FORAMINIFERA Colalongo & Sartori (1979)	Samples
ZONES	D.productus	C.macintyrei	G.caricaensis	G.inflata		
7	A P R	.	C F A A	Braunodiscphaera bigelowii	ABUNDANCE PRESERVATION	
6	C V F	.	C R A A 1	Calcidiscus leptoporus		
5	C P R	.	C R A A . 1 1	Calcidiscus macintyrei		
4	C P R	.	C R A A 1 1 . 1 . . .	Coccolithus pelagicus		
3	C V R	X C F A A	C A F F A A A A x X V F	Dictyococtites productus		
2	A M R	.	C F A A	Discoaster asymmetricus		
1	A P R	.	C R A A 1 1 . . 1 . .	Discoaster brouweri		
			A C F F A A A A x R R R	Discoaster pentadactylus		
			V R	Discoaster surculus		
				Discoaster sp.		
				Gephyrocapsa caribbeanica		
				Gephyrocapsa oceanica s.l.		
				small Gephyrocapsa		
				Helicosphaera carteri		
				Helicosphaera sellii		
				Pontosphaera spp.		
				Pseudomicilia lacunosa		
				Reticulofenestra minuta		
				Reticulofenestra pseudounbilicus		
				small R. pseudounbilicus		
				Rhabdospiraera spp.		
				Syracosphaera spp.		
				Globigerina apertura		
				Globigerina bulbosa		
				Globigerina bulloides		
				Globigerina falconensis		
				Globigerina incompta		
				Globigerina microfoliata		
				Globigerina quinqueloba		
				Globigerinita spp.		
				Globigerinoides conglobatus		
				Globigerinoides diminutus		
				Globigerinoides elongatus		
				Globigerinoides elongatus		
				Globigerinoides ruber		
				Globorotalia acostaeensis		
				Globorotalia inflata		
				Globorotalia obesa		
				Globorotalia oscitans		
				Globorotalia sp.		
				Neoglob. pachyderma lelt		
				Orbulina bilobata		
				Orbulina universa		
				Bulimina elegans		
				Bulimina marginata		
				Bulimina marginata		

Tab. 2 - Calcareous nannofossil and planktonic foraminifera distribution chart of section 2 (Masseria Petto della Serra). See legend of Tab. 1.

terval is characterized by abundant small *Gephyrocapsa* and by the absence of *Discoaster brouweri* (Tab. 1). *Gephyrocapsa oceanica* s.l. ($\geq 4 \mu\text{m}$) is absent and gephyrocapsids from 3.5 to nearly 4 μm in size, with a relatively large central opening and a clear central bar, were noted.

The abundance of these morphotypes is the major diagnostic element to recognize the *D. productus* Zone; in fact, *D. brouweri* may be absent also in the *D. brouweri* Zone, below its extinction. Pliocene reworked specimens as *Discoaster* spp. (counted over 20,000 coccoliths)

San Biagio		AGE	EARLY PLEISTOCENE PLIOC.	NANNOFOSSILS Rio et al. (1990)	PLANKTONIC FORAMINIFERA Colalongo & Sartori (1979)	Samples
ZONES	D.productus	C.macintyrei	G.caricaensis	G.inflata		
7	C M C	.	C R I A C C A A A C C A A A c R R . F	Braunodiscphaera bigelowii	ABUNDANCE PRESERVATION	
6	C V C	.	F R . A C F A A A F C A A A c . F , F	Calcidiscus leptoporus		
5	C P C	X F R 1 A C F A A A F C A A A c . F , C	Calcidiscus macintyrei			
4	C P C	X F R . R C R A A A F C A A A c R R . C	Coccolithus pelagicus			
3	C P C	X C F . A C R A A A C C A A A c . R , C	Dictyococtites productus			
2	C V C	.	A A R A A A F C A A A c R R X C	Discoaster asymmetricus		
1	A M F	X C R . A C R A A A F C A A A f R R . C	Discoaster brouweri			
				Discoaster pentadactylus		
				Discoaster surculus		
				Discoaster sp.		
				Gephyrocapsa caribbeanica		
				Gephyrocapsa oceanica s.l.		
				small Gephyrocapsa		
				Helicosphaera carteri		
				Helicosphaera sellii		
				Pontosphaera spp.		
				Pseudomicilia lacunosa		
				Reticulofenestra minuta		
				Reticulofenestra pseudounbilicus		
				small R. pseudounbilicus		
				Rhabdospiraera spp.		
				Syracosphaera spp.		
				Globigerina apertura		
				Globigerina bulbosa		
				Globigerina bulloides		
				Globigerina falconensis		
				Globigerina incompta		
				Globigerina microfoliata		
				Globigerina quinqueloba		
				Globigerinita spp.		
				Globigerinoides conglobatus		
				Globigerinoides diminutus		
				Globigerinoides elongatus		
				Globigerinoides elongatus		
				Globigerinoides ruber		
				Globorotalia acostaeensis		
				Globorotalia inflata		
				Globorotalia obesa		
				Globorotalia oscitans		
				Globorotalia sp.		
				Neoglob. pachyderma lelt		
				Orbulina bilobata		
				Orbulina universa		
				Bulimina elegans		
				Bulimina marginata		
				Bulimina marginata		

Tab. 3 - Calcareous nannofossil and planktonic foraminifera distribution chart of San Biagio section. See legend of Tab. 1.

and *Reticulofenestra pseudoumbilicus* (form larger than 7-8 μm , *sensu* Raffi & Rio, 1979) are listed in Tab. 1. The Foraminifera assemblages confirm the attribution to the upper part of Late Pliocene, close to the Plio-Pleistocene boundary.

The first occurrence of *G. oceanica* s.l. defines the base of the *C. macintyrei* Zone in the section 2 of Masseria Petto della Serra. *G. oceanica* s.l. appears with very few and scattered specimens (Tab. 2), as it was found by Rio et al. (1990) in the lower Pleistocene Mediterranean ODP Sites. The presence of common specimens of *N. pachyderma* left confirms the Pleistocene age-assignment (*G. cariocoensis* Zone).

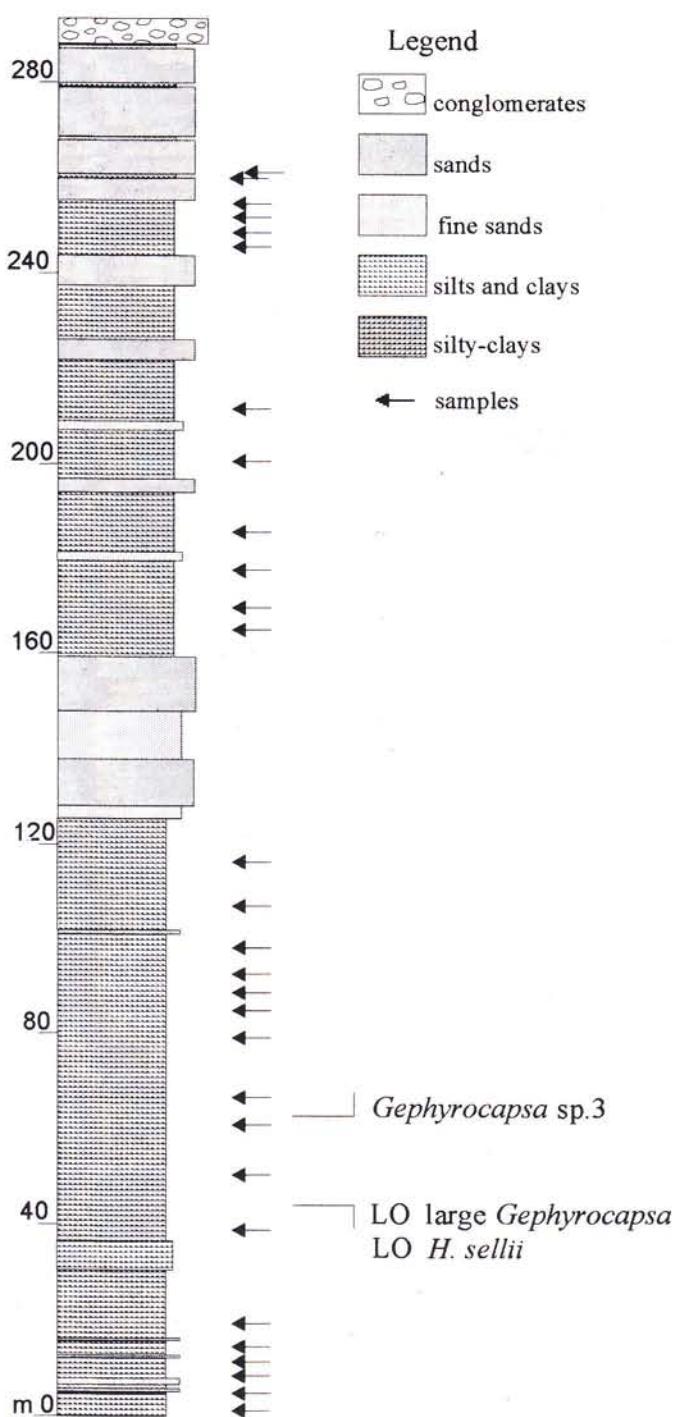
S. Biagio section.

The study section outcrops near San Biagio locality, south of Alianello village (F° 211 of the "Carta Geologica d'Italia", 1:100.000; I NW). The samples collected in the San Biagio section (Fig. 4) contain a calcareous nannofossil assemblage Early Pleistocene in age (Tab. 3, *C. macintyrei* Zone). The percentage abundance of *C. macintyrei* varies from 10% to 15% up to 40% in a count of 50 *Calcidiscus* spp. (Fig. 4). Reworked specimens of this species were found after its disappearance generally with percentages below 5%. Common reworked specimens of *Reticulofenestra pseudoumbilicus* characterize the Pleistocene nannofloral assemblages of this section. Moreover, well preserved specimens of *R. pseu-*

doumbilicus were found in the Mediterranean sediments of Early Pleistocene age (Stradner, 1973).

In the Foraminifera assemblages the Pleistocene markers are absent; *G. cariocoensis* and the increase in abundance of *N. pachyderma* left were not recognized; *Bulimina elegans marginata* and *Bulimina* cfr. *B. elegans* characterize the benthic Foraminifera assemblages.

Serra Petrizza section



San Biagio section

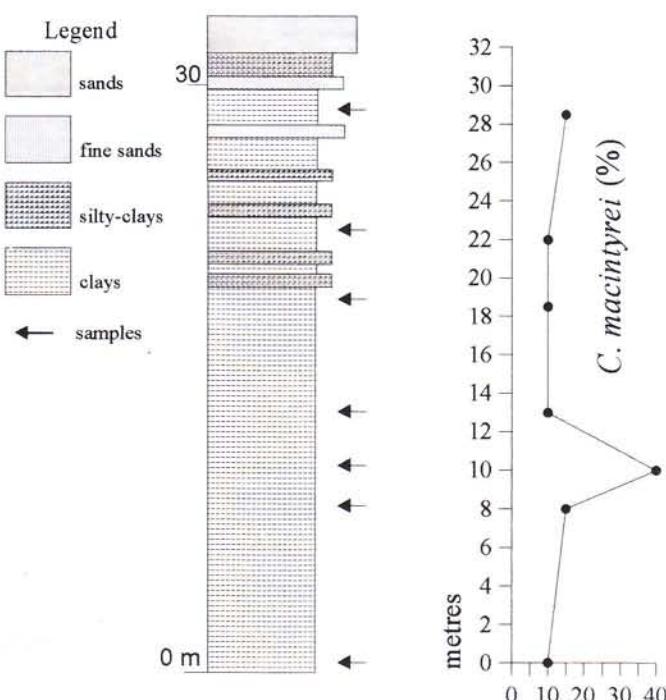


Fig. 4 - San Biagio section: lithology and percentage abundance of *C. macintyrei* in a count of 50 *Calcidiscus* spp.

Fig. 5 - Serra Petrizza section: lithology and main nannofossil events.

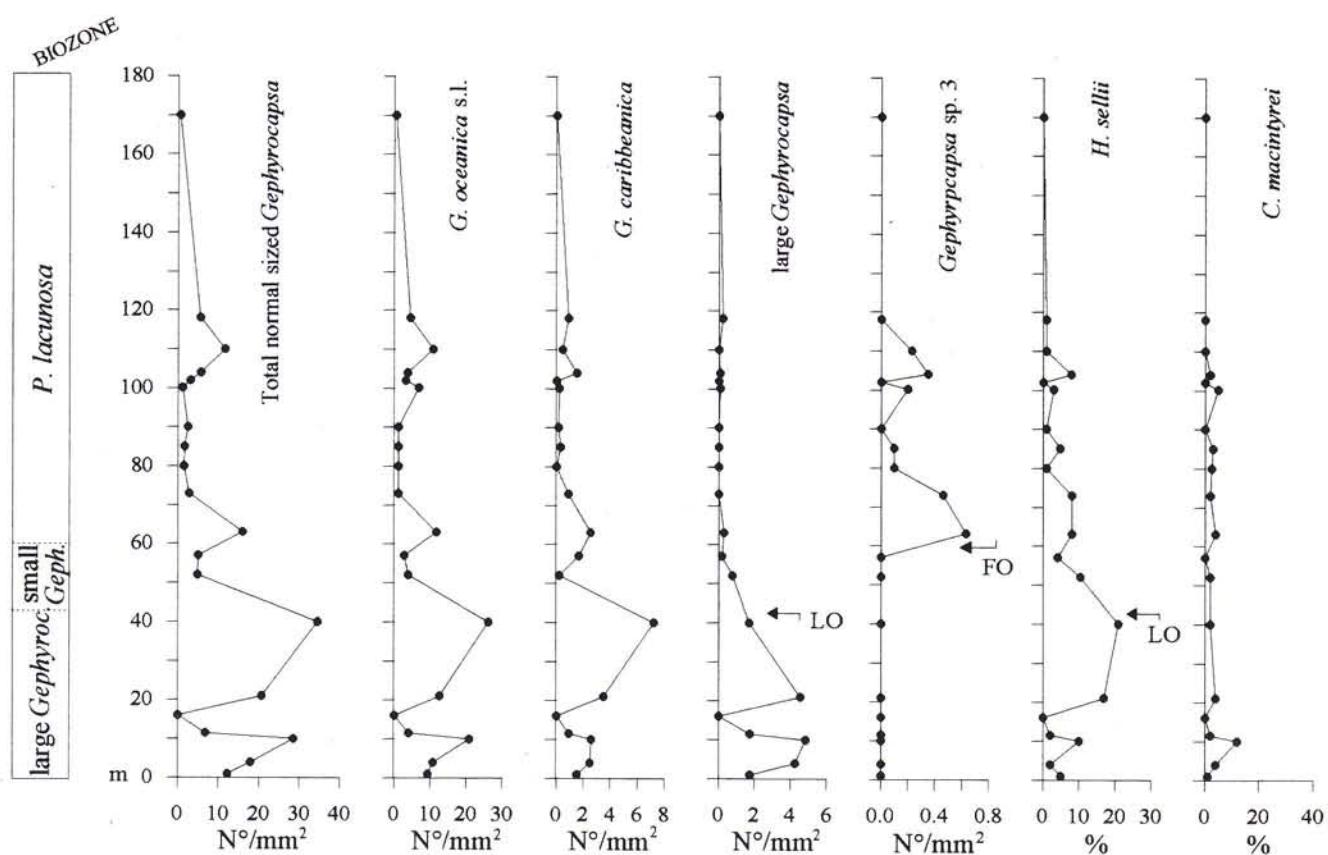


Fig. 6 - Abundance patterns of gephyrocapsids at Serra Petrizza section plotted as number of specimens per mm^2 of slide (see discussion in the text). The *H. sellii* and *C. macintyrei* abundances were plotted as percentages in a count of 100 *Helicosphaera* spp. and 50 *Calcidiscus* spp., respectively.

Serra Petrizza section.

A stratigraphical succession, three hundred metres thick, has been measured between the Casa Leo and Serra Petrizza localities, east-northeast of Aliano village (F° 211 of the "Carta Geologica d'Italia", 1:100.000; I SW). The calcareous nannofossil biostratigraphy allows to refer the basal samples of the section to the large *Gephyrocapsa* Zone (Fig. 5 and 6, Tab. 4). The large *Gephyrocapsa* specimens are very few and rarely exceed 5.5 m in size. The abundance drop of large *Gephyrocapsa* occurs between the samples 7 and 8 and upwards this taxon becomes very rare. At the same level the percentage of *H. sellii* decreases below 8% in a count of 100 helicolithids (Fig. 6). For the pelagic sediments of the Mediterranean area, the LO of *H. sellii* is defined by its drop below 1% with respect to 50 helicolithids (Rio et al., 1990). These data point out that the reworking in terrigenous sediments makes it difficult to recognize the disappearance events.

The samples 8 and 9 have been referred to the small *Gephyrocapsa* Zone, despite the temporary disappearance of medium sized *Gephyrocapsa* and the small *Gephyrocapsa* dominance are not evident because of reworking and "dilution" of nannofossils. Moreover, Raffi et al. (1993) show the temporary disappearances of medium sized *Gephyrocapsa* occurring at several Pleistocene stratigraphic levels.

The first occurrence of *Gephyrocapsa* sp. 3 occurs in sample 10 and it defines the base of the *P. lacunosa* Zone. Generally *Gephyrocapsa* sp. 3 is 4-4.5 μm in size, but close to its appearance also measures 3.5 to 4 μm ; its abundance is very low (0.1-0.6 specimens per mm^2). This is probably due to the terrigenous nature of the studied section, whose upper part corresponds to the proximal facies of the fan-delta system and to a fluvial system (Fig. 5). For the same reason, the drop in abundance of *Gephyrocapsa* sp. 3 at the top of the section (Fig. 6) cannot be surely interpreted as its last occurrence.

The analyses of Foraminifera assemblages allow to recognize *Bulimina etnea*, *Hyalinea balthica*, *Globigerinoides tenellus* and *Globorotalia inflata*. *G. truncatulinoides excelsa*, a very rare taxon in Mediterranean sections, is absent in all the samples.

Conclusions.

The quantitative study on the nannofossil assemblages is necessary to recognize biozonal events and to obtain precise age-assignment for the terrigenous sediments. The Pleistocene Foraminifera assemblages are less meaningful to detailed biostratigraphy because the markers are very rare or absent.

The genus *Gephyrocapsa* has proven to be a good taxon for the Pleistocene biostratigraphy of the terrige-

EARLY / MIDDLE PLEISTOCENE										AGE	
										Serra Petrizza ZONES	CALCAREOUS NANNOFOSSILS
Pseudoemiliana lacunosa											NANNOFOSSILS Rio et al. (1990)
Globorotalia truncatulinoides excelsa										PLANKTONIC FORAMINIFERA Colalongo & Sartoni (1979)	FORAMINIFERA
Samples											
large Gephyrocapsa	small G.									ABUNDANCE	
G. cariacensis										PRESERVATION	
										REWORKING	
1	C P C									Braarudosphaera bigelowii	
2	A M C									Calcidiscus leptoporus	
3	C M C									Calcidiscus inacintyreai	
4	C P C									Coccolithus pelagicus	
5	R V V									Dictyococcites productus	
6	C P F F									Gephyrocapsa caribbeanica	
7	C P F									Gephyrocapsa oceanica s.l.	
8	C P F									small Gephyrocapsa	
9	C P C									large Gephyrocapsa	
10	C P C									Gephyrocapsa sp. 3	
11	C V C									Helicosphaera carteri	
12	C V F									Helicosphaera sellii	
13	F P C									Pontosphaera spp.	
14	F V F									Pseudoemiliana lacunosa	
15	C P C									Reticulofenestra minuta	
16	C V C									Reticulofenestra minutula	
17	C V C									Reticulofenestra pseudoumbilicus	
18	C P F									small R. pseudoumbilicus	
19	C V F									Rhabdosphaera spp.	
20	F V F									Scyphosphaera spp.	
21	F P F									Syracosphaera spp.	
22	C V F										
23	ST										
24	ST										
25	C V F										
26	ST										
27	ST										
28	ST										
29	ST										
30	ST										
31	ST										

Tab. 4 - Calcareous nannofossil and planktonic foraminifera distribution chart of Serra Petrizza section. See legend of Tab. 1.

nous sediments. *Gephyrocapsa oceanica* s.l., large *Gephyrocapsa*, *Gephyrocapsa* sp. 3 and small *Gephyrocapsa* represent morphotypes whose distribution is very useful for the Pleistocene calcareous nannofossil zonation. First appearance and last appearance of gephyrocapsids have been recognized, according to the scheme of Rio et al. (1990). *C. macintyreui* shows percentage abundances above 10% in the *C. macintyreui* Zone; reworked specimens of this species (percentage abundances below 5%) have been found in the large *Gephyrocapsa* and *P. lacunosa* Zones. The LO of *H. sellii* is defined by an abundance drop below 8% (in a count of 100 helicolithids) compared to an abundance drop below 1% as in pelagic sediments (Rio et al., 1990). Because of the reworking, in terrigenous sediments the appearance data are more reliable biostratigraphic events than the last occurrences.

Previous workers referred the Pleistocene marine units in the S. Arcangelo Basin to the Early Pleistocene,

both on the basis of Foraminifera (*H. balthica* Zone, Lentini & Vezzani, 1974) and qualitative nannofossil analyses (NN19 Zone, "for the presence of *G. oceanica* and *P. lacunosa*", Hippolyte et al., 1991). The presence of *Gephyrocapsa* sp. 3 in the Serra Petrizza section and the recognition of the *P. lacunosa* Zone suggest that the marine sedimentation in the S. Arcangelo Basin extended up to the Middle Pleistocene. Therefore, the scheme of Rio et al. (1990) and the calcareous nannofossil quantitative analyses improve the biostratigraphic resolution and provide new chronostratigraphic data on the sedimentary evolution of the Plio-Pleistocene Sant'Arcangelo Basin.

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