

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

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Key-words: Pleistocene, Calcareous Nannofossils, Foraminifera, Terrigenous Sediments, Italy.

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 Apenninic 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).

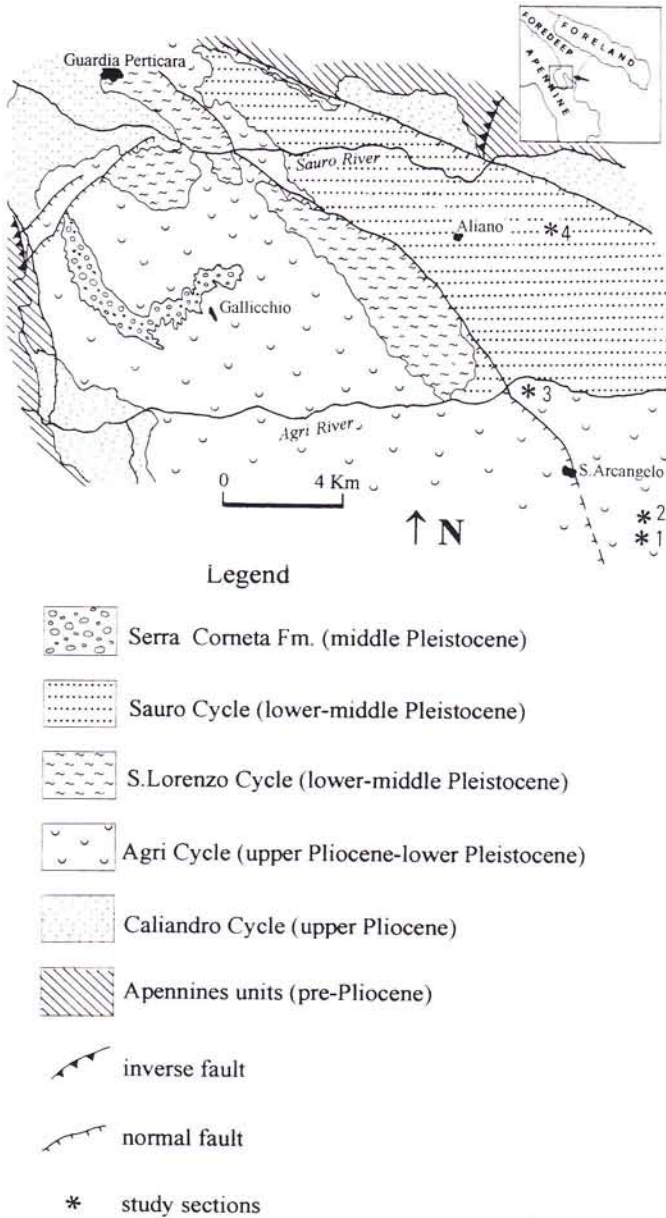


Fig. 1 - Geological scheme of the Sant'Arcangelo Basin (from Pieri et al., 1993, simplified). 1 and 2: Masseria Petto della Serra sections; 3: S. Biagio section; 4: Serra Petrizza section.

However, in the Plio-Pleistocene interval, the calcareous nannofossils provide a 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 quantitative

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

and *Reticulofenestra pseudumbilicus* (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. macintyreii* Zone in the section 2 of Maseria 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. cariacensis* Zone).

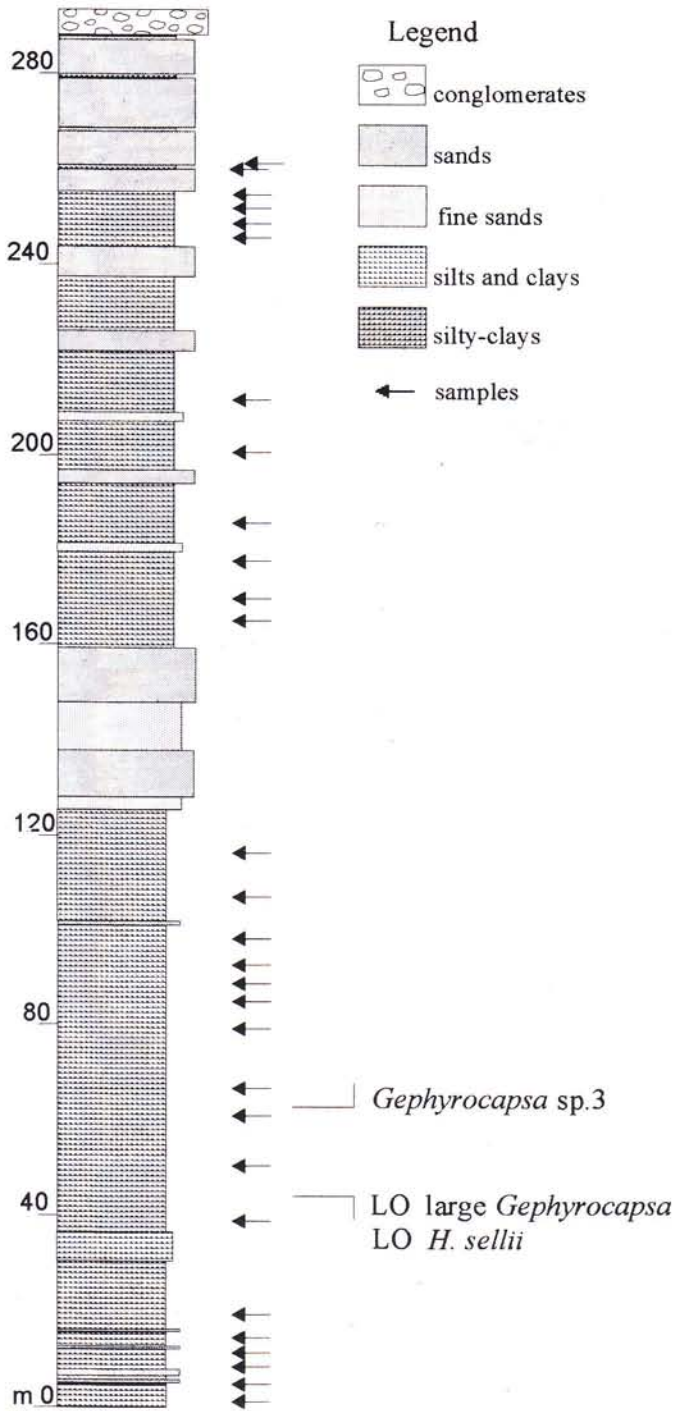
S. Biagio section.

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. macintyreii* Zone). The percentage abundance of *C. macintyreii* 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 pseudumbilicus* characterize the Pleistocene nannofloral assemblages of this section. Moreover, well preserved specimens of *R. pseu-*

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

In the Foraminifera assemblages the Pleistocene markers are absent; *G. cariacensis* 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

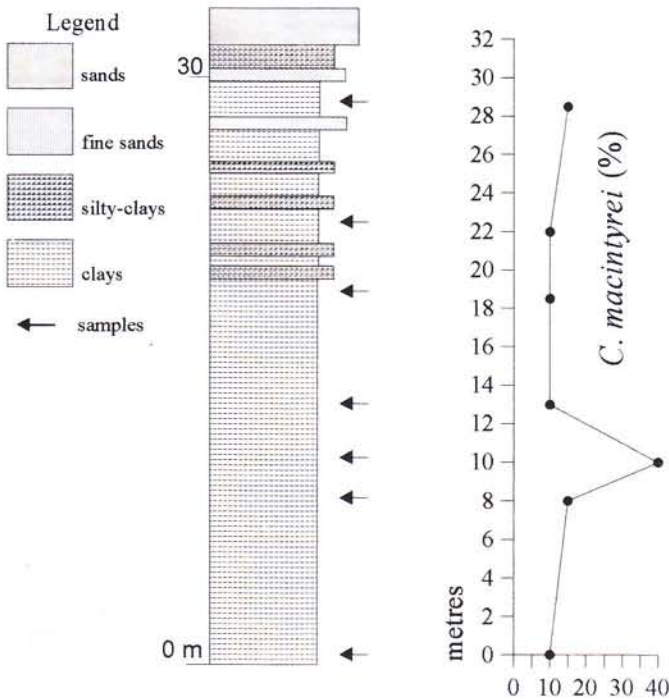


Fig. 4 - San Biagio section: lithology and percentage abundance of *C. macintyreii* in a count of 50 *Calcidiscus* spp.

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

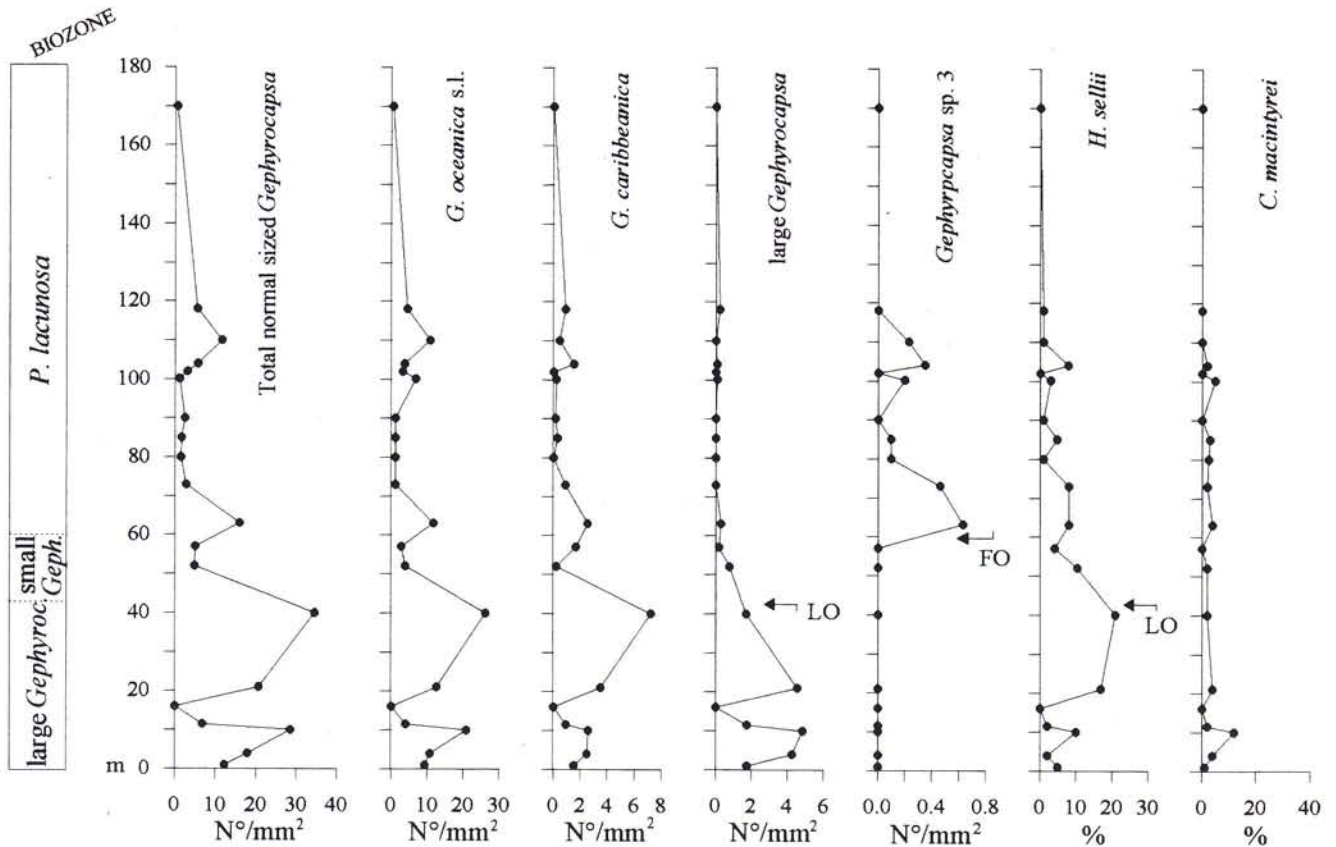


Fig. 6 - Abundance patterns of gephyrocapsids at Serra Petrizza section plotted as number of specimens per mm^2 of slide (see discussion in the text). The *H. sellii* and *C. macintyreii* abundances were plotted as percentages in a count of 100 *Helicosphaera* spp. and 50 *Calcidiscus* spp., respectively.

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-

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 *Gephyrocapsa* have been recognized, according to the scheme of Rio et al. (1990). *C. macintyreii* shows percentage abundances above 10% in the *C. macintyreii* 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.

Acknowledgments.

Thanks are due to S. Monechi for useful discussions on biostratigraphical data of this work. Critical reviews by K. Perch-Nielsen, M. Gaetani and an anonymous referee improved the manuscript.

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Received April 4, 1995; accepted February 14, 1996