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MIOCENE QUANTITATIVE CALCAREOUS NANNOFOSSIL BIOSTRATIGRAPHY FROM SOUTHERN APENNINES FOREDEEP DEPOSITS AND MEDITERRANEAN DSDP SITE 372

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Riassunto. Sui campioni raccolti in nove successioni mioceniche rappresentate prevalentemente da depositi calciclastici e silicoclastici, riferibili alle unità irpine esterne ed affioranti al margine esterno dell'Appennino meridionale (Italia meridionale), è stato condotto uno studio biostratigrafico quantitativo basato sulle associazioni a Nannofossili calcarei. Le analisi quantitative hanno permesso di riconoscere, anche in queste successioni, gran parte degli eventi biozonali noti per l'area mediterranea in accordo con gli schemi biostratigrafici di Fornaciari & Rio (1996) e Fornaciari et al. (1996) per il Miocene inferiore e medio, e di Theodoridis (1984) per il Miocene superiore.

Alcuni tra gli eventi biozonali utilizzati in letteratura, come ad esempio la "first common occurrence" di *Helicosphaera walbersdorfensis* o la "last common occurrence" di *Calcidiscus premacintyrei*, sono stati però di difficile definizione; nell'intervallo MNN6b/7 la "first common occurrence" di *Calcidiscus macintyrei* rappresenta invece, nelle successioni analizzate, un evento più significativo rispetto alla "last common occurrence" di *Calcidiscus premacintyrei*.

Sono stati inoltre identificati nuovi eventi biostratigrafici che migliorano la risoluzione degli schemi biozonali utilizzati: nelle Zone MNN4b e MNN5a è stato riconosciuto un significativo intervallo di paracme di "small" *Reticulofenestra pseudoumbilicus*; il "paracme beginning" ed il "paracme end" di questa specie sono eventi utili nella correlazione delle successioni studiate. Inoltre, la presenza di *Reticulofenestra pseudoumbilicus* è stata riconosciuta a partire dalla Zona MNN2b, in un intervallo quindi molto inferiore rispetto alla nota "first common occurrence" della specie, che definisce la base della Zona MNN6b.

Le distribuzioni osservate nelle successioni dell'Appennino meridionale sono state inoltre confrontate con i risultati ottenuti da uno studio quantitativo svolto sul Pozzo DSDP 372 ubicato nel Mediterraneo occidentale: ciò ha permesso di confermare il valore biostratigrafico di tali distribuzioni nell'area mediterranea.

Abstract. A quantitative biostratigraphic study based on calcareous nannofossil assemblages was carried out in nine Miocene calcareous and siliciclastic foredeep sections, cropping out in the outer part of the Southern Apennines and generally ascribed to the external Irpinian units. Several biozonal events were recognised by means of quantitative analyses, according to the biostratigraphic schemes of Fornaciari & Rio (1996) and Fornaciari et al. (1996) for the lower and middle Miocene and of Theodoridis (1984) for the upper Miocene.

In the lower and middle Miocene interval some biohorizons such as the first common occurrence of *Helicosphaera walbersdorfensis* and last common occurrence of *Calcidiscus premacintyrei* are not always detectable in the studied sections and the first common occurrence of *Calcidiscus macintyrei* appears to be a better biohorizon in the MNN6b/7 than the last common occurrence of *C. premacintyrei*.

New data on abundance patterns of selected calcareous nannofossils have been collected, thus improving the biostratigraphic resolution of the zonal schemes: a paracme interval of small *Reticulofenestra pseudoumbilicus* was noted within Zone MNN4b and MNN5a; the beginning and the end of the paracme are useful events in the studied sections for stratigraphic correlations. Moreover the occurrence of *R. pseudoumbilicus* has been recorded from Zone MNN2b on upwards, fairly below the FCO of the species that defines the base of Zone MNN6b.

The distributions observed in the on-land sections are consistent with those recognised in DSDP Site 372 located in the western Mediterranean Sea, confirming their potential biostratigraphic utility within the Mediterranean region.

Introduction.

Recent studies have been focused on the improvement of the Miocene calcareous nannofossil biostratigraphy within the Mediterranean region (Theodoridis, 1984; Negri, 1989; Di Stefano, 1993; Fornaciari & Rio, 1996; Fornaciari et al., 1996). In particular, Fornaciari & Rio (1996) and Fornaciari et al. (1996) proposed new biostratigraphic schemes based on abundance fluctuations of selected calcareous nannofossil species and these schemes provide a higher biostratigraphic resolution in comparison with the standard zonations of Martini (1971) and Okada & Bukry (1980). In order to provide new data on the applicability of the recently proposed schemes in different areas, a biostratigraphic study based on calcareous nannofossils in Miocene foredeep deposits has been performed. Such deposits are widespread in the Southern Apennines and their biostratigraphic dating is also very useful for the understanding and modelling of

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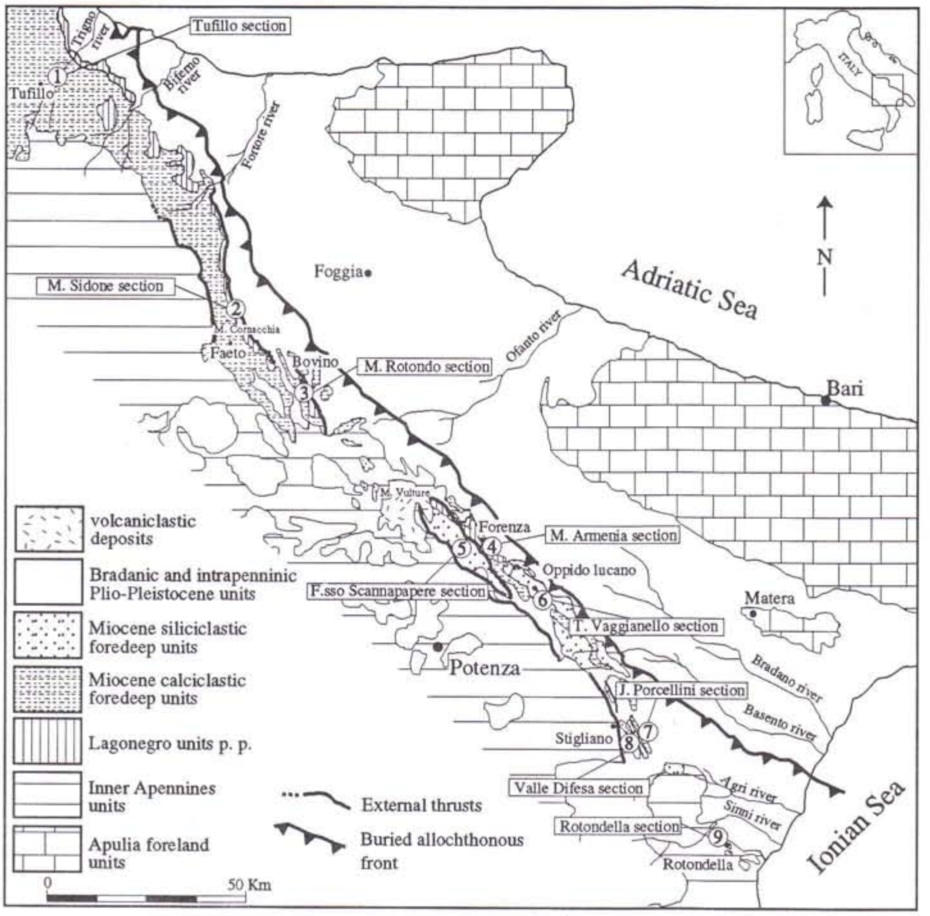


Fig. 1 - Location of the studied sections in Southern Apennines; geological map from Bonardi et al. (1988) and Bigi et al. (1989), modified.

several geological problems (Gallicchio, 1996; Gallicchio & Maiorano, 1997; Gallicchio, 1997).

The biostratigraphic data on the calcareous nannofossil assemblages have been collected by means of quantitative analyses; these are of great utility for the recognition of significant abundance patterns and provided accurate age determinations as well as detailed stratigraphic correlations among the studied sections (Maiorano, 1996).

The investigation was extended to DSDP Site 372, located in the western Mediterranean Sea and representing a reference deep-sea section for the Mediterranean middle Miocene biostratigraphy (Müller, 1978; Theodoridis, 1984; Negri, 1989; Fornaciari et al., 1996). The re-examination of DSDP Site 372 in this study was performed in order to attempt a comparison with the quantitative results obtained from the Southern Apennines sections and to provide useful information on the Miocene Mediterranean calcareous nannofossil biostratigraphy.

Geological framework.

The investigated Miocene carbonatic and siliciclastic turbidite sections crop out in the outer part of the Southern Apennines, between the Trigno river and the neighbourhood of Rotondella (Fig. 1); they are generally ascribed to the outer Irpinian units (Pescatore, 1978; Dazzaro & Rapisardi, 1983; Pescatore, 1988).

The herein discussed calcareous sections (Tufillo, Monte Sidone, Monte Rotondo, Monte Armenia and Rotondella) are mostly referred to the Flysch di Faeto Formation (Crostella & Vezzani, 1964) and to the Tufillo Formation (Selli, 1962) and crop out mostly between the Trigno river and the Monte Vulture. The siliciclastic sections (Fosso Scannapapere, Torrente Vaggianello, Jazzo Porcellini, Valle Difesa) are ascribed to the Serra Palazzo Formation (Selli, 1962) and are widespread in the southern part of the studied area, between the Monte Vulture and Rotondella.

These units were deposited in a NW-SE foredeep domain whose western margin consists of deformed Apennine thrust belt, whereas the eastern one is represented by the undeformed Apulia Foreland (Fig. 1). The studied sections lie stratigraphically on the Oligocene-Miocene portion of the Lagonegro units (*sensu* Cocco et al., 1974) represented by the Numidian Flysch Formation (Ogniben, 1963) or by the Calcareniti, marne ed argille di M. Sidone Formation (Senatore, 1988). They are overlaid by the Marne argillose del Toppo Capuana Formation (Crostella & Vezzani, 1964).

Further lithostratigraphic and sedimentologic details on the Southern Apennines Miocene foredeep deposits are reported in many papers to which the reader is referred (Ippolito & Lucini, 1957; Palmentola, 1969, 1970; Palmentola et al., 1967, Pieri & Walsh, 1967; Boenzi et al., 1968; Ogniben, 1969; Centamore, 1969; Centamore et al., 1971; Rapisardi & Walsh, 1978; Pescatore, 1978, 1988; Ciaranfi et al., 1980; Mostardini & Merlini, 1986; Di Nocera & Torre, 1987; Bonardi et al., 1988; D'Argenio, 1988; Dazzaro et al., 1988; Sgrosso, 1988; Russo & Senatore, 1989; Patacca et al., 1990, 1992; Loiacono & Sbarra, 1991; Boiano et al., 1994; Sbarra, 1995; Gallicchio, 1996). In particular a detailed lithostratigraphic and structural framework of the studied sections is documented in Gallicchio (1996).

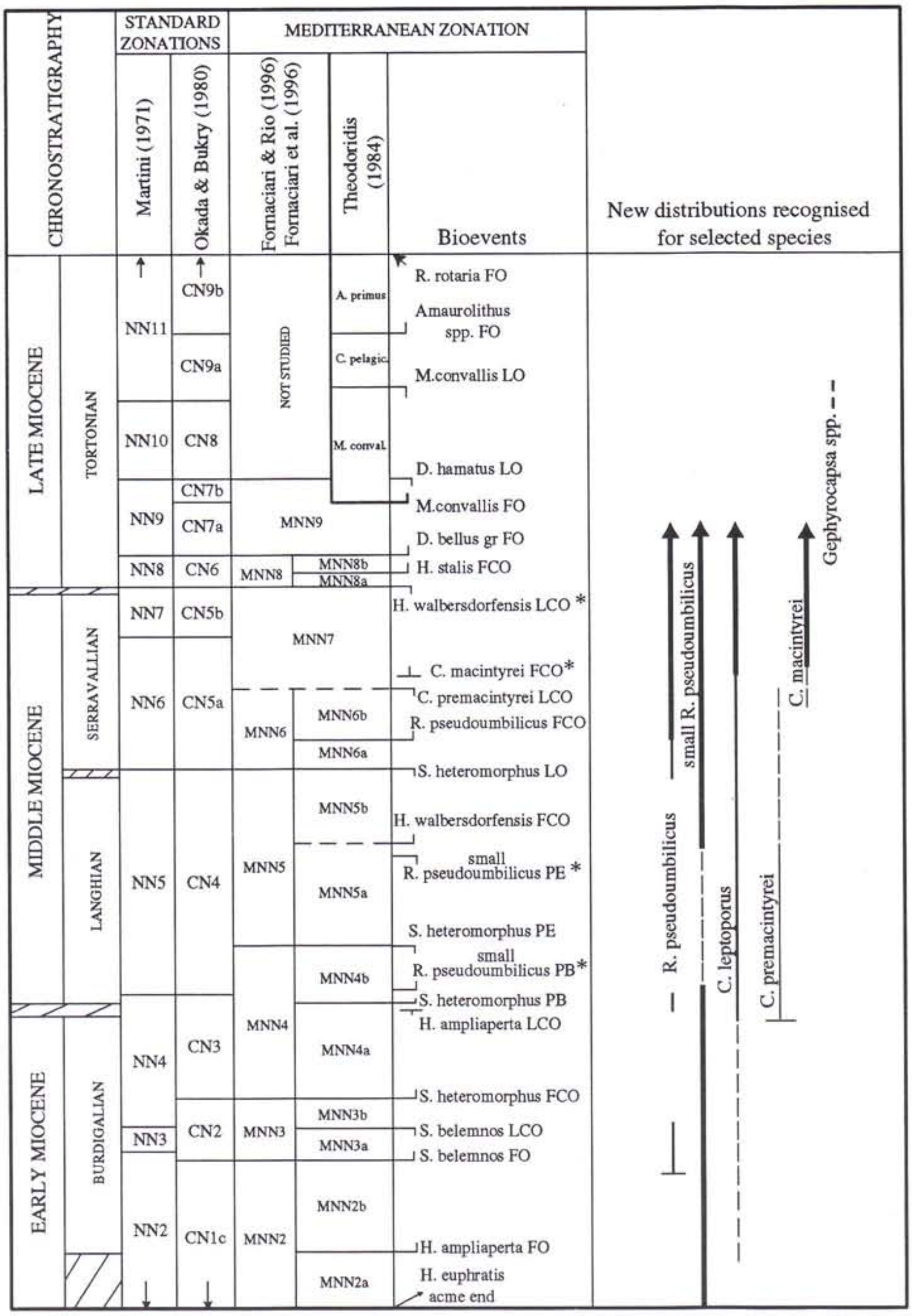


Fig. 2 - Biostratigraphic scheme and distribution of some marker species proposed for the Mediterranean region and comparison with standard zonations. Undetectable biozonal boundaries are traced with dashed lines; * = new biostratigraphic events proposed in the present work. Chronostratigraphy is drawn according to Fornaciari and Rio (1996) and Fornaciari et al. (1996); buffer intervals indicate that at present no formal definition of the boundary stratotype sections is available.

Materials and Methods.

Samples for calcareous nannofossil analyses were prepared from a suspension of unprocessed sediment and water. The solution was spread on a cover glass and dried, then mounted on a glass slide. Light microscope techniques were used at 1000X magnification.

Quantitative analyses were performed according to Rio et al. (1990b), in order to detect the abundance patterns of the marker species. These methods have been already tested in turbidite sediments (Fornaciari & Labaume, 1992; Fornaciari & Rio, 1996; Fornaciari et al., 1996).

Most of the quantitative data were collected by counting 500 specimens in the nannofossil population greater than 4 microns. A number of 30-100 taxonomically related specimens have also been counted in order to document the abundance fluctuations of helicoliths. Abundance patterns of *Discoaster variabilis-exilis* and *Discoaster deflandrei* were plotted as number of specimens/mm^2 and are relative to about 1500 specimens of the total nannofossil assemblage. A supplementary qualitative analysis on about 3000 specimens was performed in all the samples in order to recognise the presence of rare species. Moreover, in the upper Miocene interval, a number of about 10,000 specimens has been scanned in order to get significant abundance fluctuations of *Discoaster* spp. and *Amaurolithus* spp. and the abundance patterns have been plotted as number of specimens/mm^2. The diagrams of the quantitative distribution of the most significant species are shown for each section; distribution charts of the total assemblages are included.

Calcareous nannofossils in the studied material are often poorly preserved. The total abundance in the samples is generally no more than 7-10 specimens per field of view and it is often represented by 3-5 specimens only. Reworked Cretaceous and Cenozoic nannofossils are present. In the siliciclastic sections the number of reworked specimens on 500 nannofossils is generally greater than in the calcareous ones and may reach value up to 40% of the assemblage. However the reworked taxa did not prevent the recognition of the biozonal events; quantitative patterns are in fact comparable with those observed for most of the species in pelagic or hemipelagic sequences.

The following biometrical definitions have been adopted in this study:

small *R. pseudoumbilicus*: reticulofenestrids 5-7 micron in size;

R. pseudoumbilicus: reticulofenestrids >7 microns (Raffi & Rio, 1979);

large *R. pseudoumbilicus* reticulofenestrids >12 microns;

Calcidiscus macintyrei: circular *Calcidiscus* ≥11 microns (Rio et al., 1990a);

Coccolithus miopelagicus >13 microns (Perch-Nielsen, 1985).

Adopted zonal scheme.

In the past years various authors (Müller, 1978; Ellis, 1979; Ellis & Lohman, 1979) pointed out the limits of the standard biostratigraphic schemes of Martini (1971) and of Bukry (1973, 1975) within the Mediterranean region, due to the absence or the rarity of several

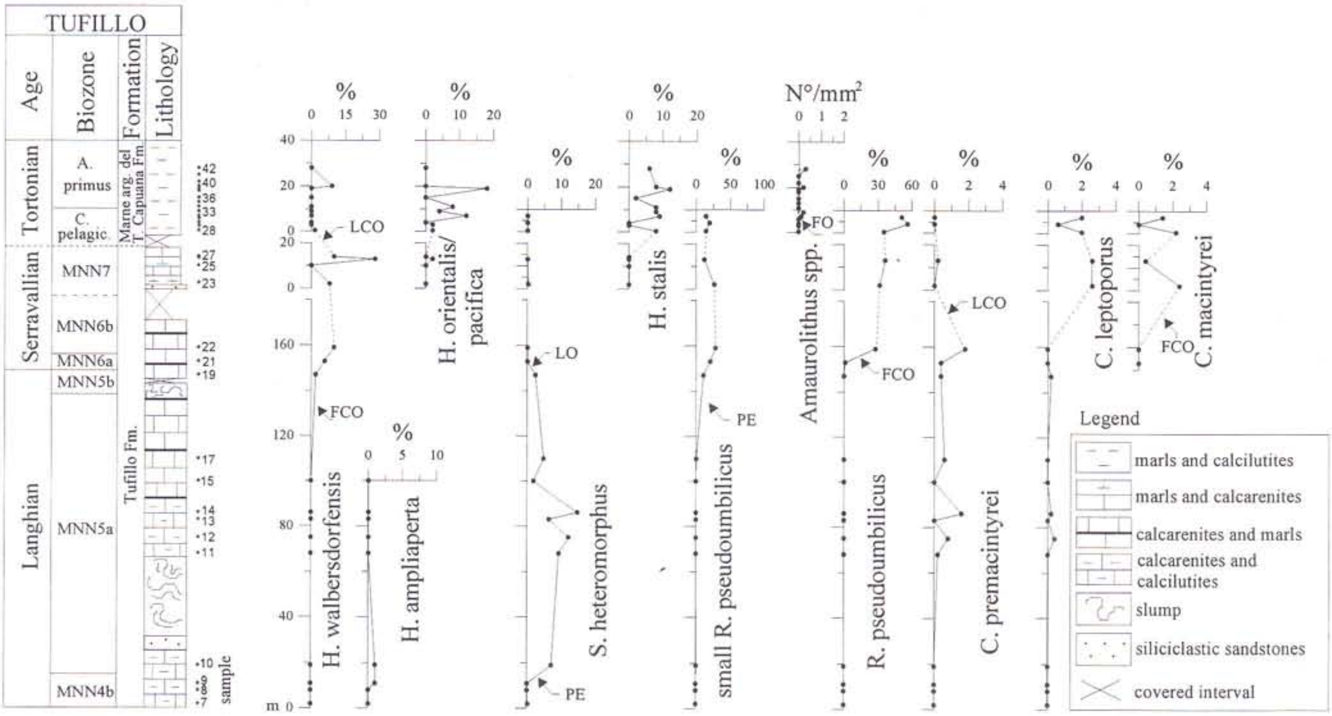


Fig. 3 - Abundance patterns of selected calcareous nannofossils at the Tufillo section. FO = First Occurrence; LO = Last Occurrence; FCO = First Common Occurrence; LCO = Last Common Occurrence; PB = Paracme Beginning; PE = Paracme End.

marker species such as *Discoaster druggii, Triquetrorhabdulus carinatus, Catinaster coalitus* and *Discoaster kugleri*. Some alternative biozonal schemes have been proposed for the Mediterranean region (Cati & Borsetti, 1970, Ellis, 1979; Ellis & Lohman, 1979; Theodoridis, 1984; Negri 1989; Di Stefano, 1993; Fornaciari & Rio, 1996; Fornaciari et al., 1996) in order to improve the low resolution of the standard schemes for regional correlations.

In this study the most recent biostratigraphic schemes (Fornaciari & Rio, 1996; Fornaciari et al., 1996) proposed for the lower and middle Miocene Mediterranean sediments are followed. They are based on quantitative analyses on calcareous nannofossil assemblages carried out on various Italian sections from different depositional settings, as well as on the Langhian and Serravallian stratotype sections. Some of the events are from the zonal schemes of Martini (1971) and Bukry (1973, 1975) and of Theodoridis (1984). The new proposed biohorizons are based not only on FO (first occurrence) and LO (last occurrence), but on significant abundance fluctuations of some species, which allow to recognise supplementary events such as FCO (first common occurrence), LCO (last common occurrence), PB (paracme beginning) and PE (paracme end).

In Fig. 2 a comparison between the standard zonations and the Mediterranean biostratigraphic scheme adopted in this work is shown. In the zonal schemes of Fornaciari & Rio (1996) and Fornaciari et al. (1996) a dashed line was used to indicate those biohorizons not always recognised in the studied material, such as the FCO of *H. walbersdorfensis* and the LCO of *C. premacintyrei*. Additional events as well as significant distributions of species recognised in this study have been included.

For the upper Miocene interval the biozonal scheme of Theodoridis (1984) was followed. The biozones of Theodoridis (1984) provide a better biostratigraphic resolution compared to the standard schemes and to what is known from the Tortonian-Messinian stratotype sections (Martini, 1975; Rio et al., 1976; Mazzei, 1977). Recent studies on the Falconara section (Sprovieri et al., 1996b) confirmed the applicability of the scheme of Theodoridis in the Tortonian-Messinian interval.

Although at present there is no general agreement on the formal definition of the Miocene boundary stratotype sections, the proposal discussed in Fornaciari et al. (1996) and Fornaciari et al. (1997) has been followed in this study in the lower and middle Miocene interval. The FO of *Reticulofenestra rotaria* has been considered for the recognition of the Tortonian/Messinian boundary, according to Langereis et al. (1984).

Biostratigraphic Results.

Tufillo section.

This section was sampled mostly along the Trigno river (154 IV SE, topographic map of Italy) and is referable to the Tufillo Formation. It mainly consists of calcarenites, calcilutites and marls which lie stratigraphical-

TUFILLO

Zone: Fornaciari & Rio (1996); Fornaciari et al. (1996); *Theodoridis (1984)

Sample	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
Age	Burdig.						Langhian												Serravallian		
Zone	MNN 3b						MNN 4b			MNN 5a									MNN5b	MNN6a	
Formation	Numidian Flysch Fm.						Tufillo Fm.														
Total abundance	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	R	F	R	C	R	F
Preservation	VP	VP	VP	VP	VP	VP	VP	VP	VP	VP	VP	VP	VP	VP	VP	VP	VP	VP	VP	VP	VP
Amaurolithus primus																					
Amaurolithus spp.																					
Calcidiscus leptoporus												0.4		0.2					0.2		X
C. macintyrei																					
C. premacintyrei										X	0.2	0.8		1.6			0.6		0.4	R	0.4
Cryptococcolithus mediaperforatus																					
Coccolithus miopelagicus			R				0.6	0.4			1.8	1.8	3	2	3.2	R	2.2		0.8	R	3.2
C. pelagicus	C	C	C	C	C	C	84.8	82.8	80	50.4	65.2	70.6	71.4	29	84.2	F	69.2	F	59.6	F	43.4
Coronocyclus nitescens	R					R															
Cyclicargolithus floridanus	C	F	F	R	F	R	8	8.6	6.2	7.4	0.2	3.4	0.8	1.2	1.2	F	9.6	F	0.4	R	
Discoaster berggrenii																					
D. berggrenii/quinqueramus																					
D. brouweri																					
D. deflandrei	F	F	F	F	F	F															
D. intercalaris																					
D. prepentaradiatus																					
D. surculus																					
D. triradiatus																					
D. variabilis-exilis																					
Discoaster spp.							0.4	1.8	5.2	2	2.2	3	1.8	3.4	1.4		2.8		1		1
Geminilithella rotula			F						0.2	0.4	1		0.4	0.8	0.2	R	0.6	R	0.6		X
Helicosphaera ampliaperta	R	R	R	R	R	R			X	0.2											
H. carteri	F	C	C	C	F	C	5	6	7.6	10.6	14.8	5.8	7.6	4.6	5.2	R	6.8	C	13.4	R	14
H. euphratis			R					0.2	0.2	0.4											0.4
H. orientalis/pacifica																					
H. scissura		F	F		F	R															
H. stalis																					
H. walbersdorfensis			R																0.2		1.2
Lithostromation perdurum																					
Scyphosphaera spp.																					0.2
Sphenolithus abies/neoabies																					
S. heteromorphus							0.2			7.2	9.4	12.2	6.4	14.8	1.8	R	4.8	F	2.4		
S. moriformis	C	C	F	F	F	F				0.2	1.6	0.4	1.6	0.6	0.4	R	0.4	R		F	1
Sphenolithus spp.							0.6														
Reticulofenestra minuta																					
R. minutula	F	F	F	F	F	F				7.4	3.2	0.8	6.4	41.2	2.2	F	2.4	F	10	F	13.4
small R. pseudoumbilicus	C	C	C	C	C	C	0.2			0.4							0.6		10.8	F	20.6
R. pseudoumbilicus																					1.2
"large" R. pseudoumbilicus																					
Rhabdosphaera spp.																					
Triquetrorhabdulus milowii	R																				
REWORKING			F	F			0.2	0.2	0.6	13.6	0.4	0.8	0.6	0.6	0.2				0.2		

Sample	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42
Age	Serravallian						Tortonian														
Zone	MNN6b	MNN 7					C. pelagic. *				A. primus *										
Formation	Tufillo Fm.						Marne argillose del T. Capuana Fm.														
Total abundance	F	F	A	A	A	A	F	A	C	A	C	A	A	C	A	A	A	A	C	A	C
Preservation	VP	P	P	P	VP	P	P	P	P	P	P	P	P	VP	P	VP	P	VP	VP	VP	VP
Amaurolithus primus																		0.1			0.1
Amaurolithus spp.											0.1	0.2						0.1			0.2
Calcidiscus leptoporus		2.6	F	F	2.6	F	2	C	0.6	F	2		F	F	F	F	F	C	F	F	C
C. macintyrei		2.4	R	F	0.4	R	2.2	R	X	R	1.4	F	F	F	F	R	F	F	R	R	R
C. premacintyrei	1.8		X		0.2																
Cryptococcolithus mediaperforatus	0.2																				
Coccolithus miopelagicus	1.2				0.2													X			
C. pelagicus	25.6	21.4	C	C	18.4	C	19.4	C	13.8	C	15.4	C	C	C	C	C	C	C	C	C	C
Coronocyclus nitescens																	X				
Cyclicargolithus floridanus		0.2					0.2		0.4							X					
Discoaster berggrenii																		0.1		0.1	
D. berggrenii/quinqueramus								0.1	0.1										0.1		
D. brouweri									0.1												
D. deflandrei					0.2				0.1		0.1				0.1		0.2			0.1	
D. intercalaris														0.1							
D. prepentaradiatus												0.1									
D. surculus		0.2																			
D. triradiatus									0.1					0.1							
D. variabilis-exilis		1.4	1	10.3	1.1	1.5	3.9	1.1	1.7	0.6	1.3	0.3	2.2	2.5	3	0.2	0.7	0.3	2	4.5	5.6
Discoaster spp.	1	0.4	R	F	0.6	F	0.6	F	F	R	0.4	R	F								
Geminilithella rotula	0.2		F	F	X	F	0.2	F	0.2	F		F	F		R		R		R	R	R
Helicosphaera ampliaperta																				X	
H. carteri	7.6	4.2	F	F	3.2	F	11.6	F	6.8	F	5.4	C	F	F	F	F	C	C	F	C	F
H. euphratis							R														
H. orientalis/pacifica					0.2		0.2	R		F	1.2	R	F			R	F				
H. scissura																					
H. stalis				X			1	X	X	F	0.2	F	F		R		F	R	R	R	R
H. walbersdorfensis	0.8	0.8	R		1.6	R	0.2	X		R									R		
Lithostromation perdurum		X			X				X	X			R			R		R			
Scyphosphaera spp.		X	X	R		X	X			R	X	R	F			R	R	R			
Sphenolithus abies/neoabies		0.8					0.6	F	0.4	F					F		F		R	F	F
S. heteromorphus		0.2	X							X					X	X	X	X			
S. moriformis	0.4		F		1.6	F				R	0.2	F	F			F	F	F			R
Sphenolithus spp.																					
Reticulofenestra minuta																					
R. minutula	4.8	6.8	C	C	23	C	1.6	C	0.4	C	8.4	F	A	C	C	C	C	A	C	C	C
small R. pseudoumbilicus	28.4	26.6	C	C	11.8	C	14.6	A	19.6	A	14.2	C	A	C	C	A	C	A	C	C	A
R. pseudoumbilicus	27.8	31.4	A	A	36.2	A	35.2	A	56.4		51	A	A	C	A	A	A	A	C	F	F
"large" R. pseudoumbilicus				F																	
Rhabdosphaera spp.					X							R					R	F	X		
Triquetrorhabdulus milowii																					
REWORKING	0.2	2.2					10.4		1.4	F	0.2	R		C	F		C	C	C	C	C

Tab. 1 - Calcareous nannofossil range chart of the Tufillo section. Abundances are tabulated as percentage relative to 500 specimens. Ceratoliths and discoasters are reported as N. of specimens/mm^2 relative to about 10,000 coccoliths. *Discoaster* spp. are relative to 500 specimens. X = occurrence recorded out of the counting method. Letters indicate semiquantitative estimate. Total Abundance: A = 20 specimens/field of view; C = 10-20 specimens/field of view; F = 2-10 specimens/field of view; R = 0.1-1 specimen/field of view; B = barren. Relative abundance: VA = 10 specimens/field of view; A = 2-10 specimens/field of view; C = 0.5-1 specimens/field of view; F = 0.02-0.5 specimens/field of view; R = 0.005-0.02. Preservation: VP = very poor; P = poor; M = moderate.

ly on the quartzarenites of the Numidian Flysch; in the upper part it is mainly represented by marly deposits (Marne argillose del Toppo Capuana Formation).

The calcareous nannofossil assemblage allow to recognise an interval between Zone MNN3b and *A. primus* Zone (Tab. 1); a covered interval occurs between MNN7 and the *C. pelagicus* Zone. Quantitative analyses were performed from sample 7 onwards and the abundance patterns of the most significant species allow the recognition of different biozonal events (Fig. 3).

In particular the PE of small *R. pseudoumbilicus*, which represents a new event recognised in this study, is visible between samples 17-19 and it is coincident, in this section, with the FCO of *H. walbersdorfensis*. A rise in abundance of *C. leptoporus* is observed at the MNN6b/7 zonal boundary. The LO of *H. walbersdorfensis*, which indicates the top of the middle Miocene Zone MNN7, was replaced by the LCO of the species since it has been recorded up to the *Amaurolithus primus* Zone; these occurrences might be considered due to reworking, but rare occurrences of *H. walbersdorfensis* can also be noted in the Monte dei Corvi and Contessa Entellina sections (Fornaciari et al., 1996, figs. 10-11) and in the Monte Cantigaglione section (Sprovieri et al., 1996a, fig. 6). This may suggest that the top of MNN7 Zone can be better recognised by the LCO of *H. walbersdorfensis* (Fig. 2). *Amaurolithus* spp. are extremely rare within *A. primus* Zone and were encounterd in a view of 10,000 specimens. The number of reworked specimens is often moderate (<1% on 500 nannofossils) and rarely reaches more than 10% of the assemblage.

Monte Sidone section.

This composite section was sampled near Castelluccio Valmaggiore from Serra Pizzuta to Monte Cornacchia (163 III SE, topographic map of Italy); it mainly consists of alternated calcilutites, calcarenites and marls referable to the Flysch di Faeto Formation, and in the upper part of marly deposits (Marne argillose del Toppo

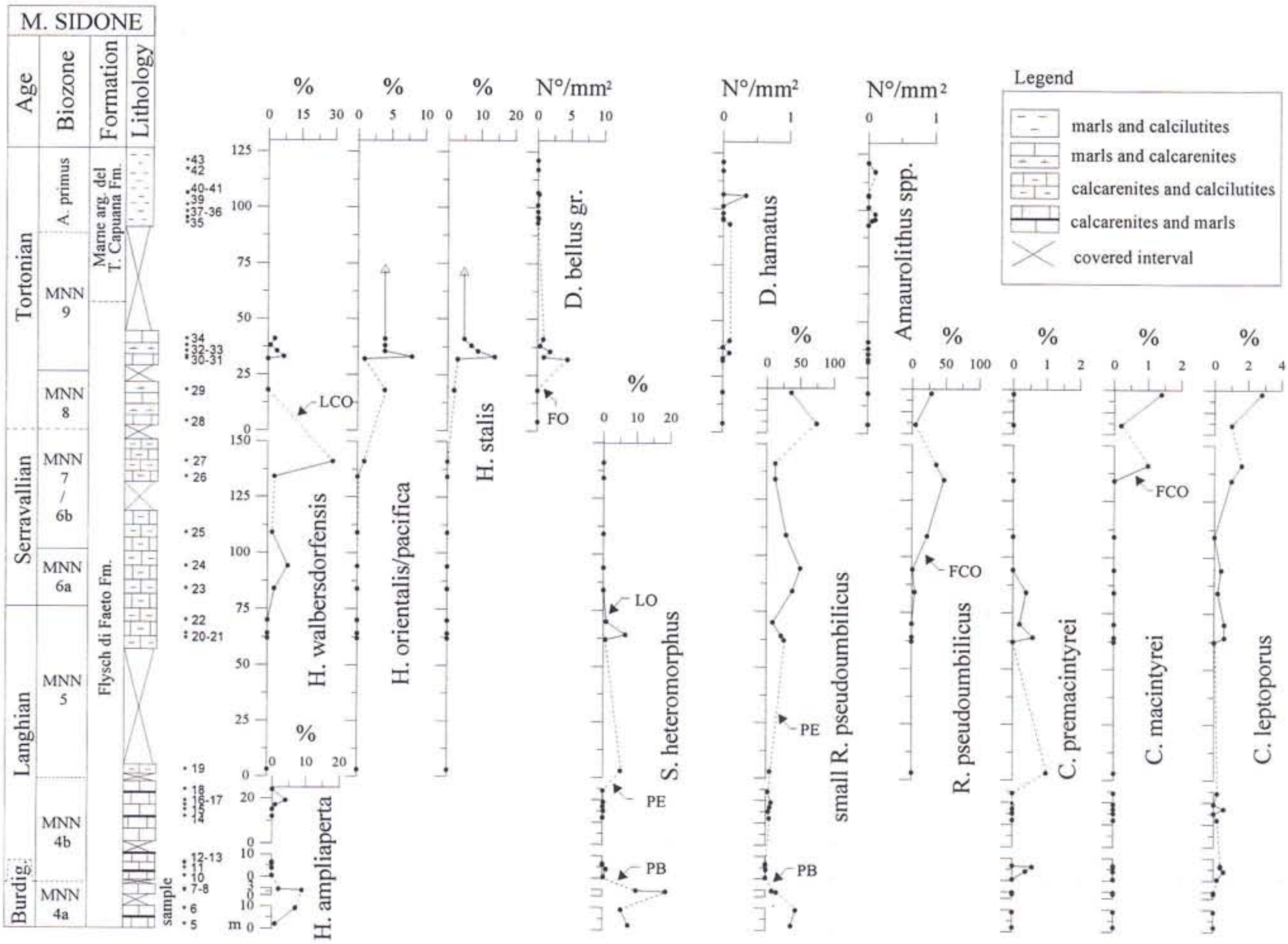


Fig. 4 - Abundance patterns of selected calcareous nannofossils at the Monte Sidone section. See legend of Fig. 3.

Tab. 2 - Calcareous nannofossil range chart of the Monte Sidone section. Abundance are reported as percentage relative to 500 specimens. From sample 30 onwards the abundance of discoasterids and ceratolithids is tabulated as N° of specimens/mm^2 and relative to about 10,000 coccoliths. Letters indicate semiquantitative estimate. See legend of Tab. 1.

MONTE SIDONE

Age	Burd.				Langhian														Serrav.					Tortonian															
Zone (Fornaciari & Rio (1996); Fornaciari et al. (1996); * Theodoridis (1984))	MNN 4a				MNN 4b										MNN 5				MNN 6a		MNN6 b/7			MNN 8	MNN 9						A. primus *								
Formation	Flysch di Faeto Fm.																														Marne arg. del T. Capuana Fm.								
Sample	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43
Total abundance	C	C	C	F	B	C	C	C	F	C	C	C	C	F	F	F	F	F	F	C	C	C	F	A	C	A	C	C	C	C	F	C	C	C	C	C	C	A	A
Preservation	P	M	P	P		P	P	P	P	P	P	P	P	P	VP	VP	VP	VP	VP	VP	VP	VP	P	M	P	VP	M	P	P	M	M	P	P	P	P	P	P	P	P
Amaurolithus primus																																	0.1						
Amaurolithus spp.																																0.1		0.1				0.1	
Calcidiscus fuscus	X						0.2							0.4	0.6		0.4																						
C. leptoporus						0.2	0.6	0.4	0.4	0.2	X	0.6		0.2	0.2	X	0.6	0.6	0.2	0.4	X	1	1.6	1	2.8	C	C	C	C	C	F	C	C	C	A	C	A	A	A
C. macintyrei																						X	1	0.2	1.4	R	F	F	F	F	R	F	C	F	C	F	F	F	F
C. premacintyrei							0.4	0.6	X			X			1	X	0.6	0.2	0.4	X	X												R						
Coccolithus miopelagicus	0.2	0.2	1.4	4.6		0.6	1.6	1	2.4	1	1.2		1.6	0.2	X	2.2	1	1.2	0.2	1.6	1.2	1.6	0.2	1.4			X						R			X			
C. pelagicus	27.2	29	32.6	37.2		67.2	72.2	78.6	82	63.6	65.4	71.2	68.4	75	57.6	53	49.4	48	37.4	27.8	38.2	12.6	25	6.4	16.6	C	C	C	C	C	F	F	C	C	C	C	C	A	C
Coronocyclus nitescens																X	X																						
Cyclicargolithus floridanus	3.2	4.4	5.4	11.4		10	4.2	3.2	2	5.4	3.6	5.6	7.6	2.8	6	2	1.6	6.2										X			R			X					
Cryptococcolithus mediaperforatus							0.2		0.2			0.2			1.2	0.2	0.2		X	0.2	0.2	0.4			0.2	R	R	R	R	R	F	F	F	F	F	F	R	F	C
D. perplexus												1.8		6.8	0.6								0.4	1.2	3.2	A	C	A	A	A	F	C	F		F	F	C	C	A
D. productus	C	C	C			A	C	C								C	C	C	F	C		C	F	A	F	A	C	A	A	A	F	C	C	A	A	A	A	A	A
Discoaster adamanteus												X																											
D. asymmetricus																																		0.1					
D. bellus																										4.5	0.9	1.9	0.4	0.8		0.1				0.2			
D. bellus/berggrenii																														1.2		5.3	4.3	0.3					
D. berggrenii/quinqueramus																														0.3					1.2	3.5	5	12	1.9
D. berggrenii																																	0.1	0.6		0.2	0.1	0.6	
D. brouweri																										1.3		0.3		0.3	0.1	0.8	0.7					0.6	
Discoaster cfr. D. challengeri																																		0.3					
D. deflandrei	0.6		0.6	0.4									0.2																		0.1			0.5					
D. exilis																															0.5			0.2					
D. hamatus																												0.1		0.1	0.1					0.3			
D. hamatus/berggrenii																																0.1							
Discoaster cfr. D. hamatus																										0.1	0.1												
D. intercalaris																																	0.3	2.7	0.6			0.2	
Discoaster neoerectus																																		0.3					
Discoaster neohamatus																										0.1										0.1			
D. prepentaradiatus																															0.1	0.1							
D. quinqueramus																															3	1.7	6.7	1.5	0.4	0.9	0.9	5.2	2.4
D. surculus																															0.1								
D. tamalis																															0.1	0.1	0.1	0.1		0.3	0.1	0.1	0.4
D. triradiatus																															0.1	0.1			0.1			0.1	
D. variabilis																								0.6	0.1	0.8	0.2	0.8		0.1	0.9	1.8	1.8	1.3	0.8	1.5	1.7	3.4	5.3
D. variabilis/exilis	X	X		0.2		2.6	X	1.2			X		X		X			X				X																	
Discoaster spp.										1.6	1	1.2			0.4				0.2			0.2							0.19										
Geminilithella rotula	0.8	0.2	0.4	0.2		X	0.4	0.2	0.2		0.2	X	0.4		2.6	1.6	1.8		0.4	0.4	X	X	0.2	0.2	0.2	F	F	C	F	C	C	F	C	C	C	C	C	C	C
Helicosphaera ampliaperta	0.2	1	0.8	0.2							X	X	0.8													X	X							X	X				
H. carteri	11.4	8.2	6.2	3.4		18.2	15	13.6	11.6	17	17	8.4	16.6	8.6	14.4	11.8	4	28.2	11.6	14.8	7.6	9.8	14	0.2	4.4	C	C	C	C	C	C	C	C	C	C	C	C	C	C
H. euphratis							X	0.2		X		X	0.4	X						0.4	X	0.2				R		R	R		F			R					
H. mediterranea																																		X					
H. orientalis/pacifica																							0.2		0.2	R	R	R	R	R	R	R	R		C	F	F	R	R
H. perch-nielseniae										0.2																													
H. scissura		X	X									X																					R						
H. stalis																									0.2	F	F	F	R	R	C	F	C	C	C	C	C	C	C
H. walbersdorfensis															X			X	0.4	1.2	0.2	0.2	5.8				F	R	R	R	R				X				
Helicosphaera spp.																		0.2																				F	
Lithostromation perdurum																										R								F	F	R		F	
Pontosphaera spp.											0.4																												
Pyrocyclus spp.	0.2																					0.2		X					R						R			R	
Reticulofenestra minuta	A	A	A			A	C	C	C	F	F		F		A	A	C	C	C	A		A	F	A	F	A	C	A	A	A	F	C	C	A	A	C	A	A	A
Reticulofenestra minutula	8.2	5.2	4.4	2		0.2	0.4	0.2	0.4			1.8	0.4		0.2	0.4	4.8	1.6	1.6		0.8	5.2	2.4	8.6	C	A	A	C	A	A	C	A	A	C	F	C	A	C	A
small R. pseudoumbilicus	37.6	44.6	16	9.6		0.2	0.6	0.2		5	8.2	1.4	1.6	0.2	5.2	26.4	22	9.4	38.8	50.2	29	12.8	12.8	74	36.6	A	A	C	A	A	C	C	F	C	F	C	A	C	C
R. pseudoumbilicus			0.2									0.2							4.2	12	22.8	47.4	35.6	5	28.6	C	F	F	F	C	F	A	A	C	A	A	A	A	A
"large" R. pseudoumbilicus																																						C	
Rhadbosphaera spp.																		0.2		X		0.2	X				R	R		F	F	R		R			F	R	
Scyphosphaera spp.											X														0.2		R	R										F	
Sphenolithus abies/neobies												5.6		5										1.8							R		F	R		R		F	F
S. heteromorphus	7.6	5.4	18.8	10		0.2	1			X	0.2	X	0.2		5.2	0.6	6.6	0.8								X				X				X		X			
S. moriformis	2.2	1.8	13	20.8		0.6	2.8	0.2	0.8	5.8	2.8	1.4	1.8	0.4	4.4	1.6	7	3.2	4	1.6		7.8	0.6		4.8	F	R	F						R			F		R
Tetralithoides symeonidesii											X																							R					
Triquetrorhabdulus rugosus																															R	R	R	R	R	R			R
T. serratus																																R							
REWORKING	0.6		0.2			X	0.2	0.4		0.2		0.6	X	0.4	0.4	0.2	X	0.2	0.4	0.2	X	0.4	0.2	X	0.6	R	C	F			C			C	F	C			C

Capuana Formation). It lies stratigraphically on the Calcarenite, marne ed argille di Monte Sidone Formation (Senatore, 1988), Aquitanian-Burdigalian in age (Russo & Senatore, 1989).

Calcareous nannofossils observed in 38 samples (Tab. 2) were referred to an interval between MNN4a and the *A. primus* Zone; an unrecovered biozonal interval occurs between MNN9 and the *A. primus* Zone. In Fig. 4 the abundance fluctuations of the most significant species can be observed. The PB and PE of small *R. pseudoumbilicus* are detectable in this section; the PB is coincident with the PB of *S. heteromorphus* and the PE is located between the PE of *S. heteromorphus* and the LO of *S. heteromorphus*. On the other hand the FCO of *H. walbersdorfensis* is not identified since the species is not recorded in the interval just below the LO of *S. heteromorphus*. The PE of small *R. pseudoumbilicus* can be useful in this case to subdivide MNN5; the LCO of *C. premacintyrei* is not a significant event: the species is rare in the section and the last occurrences are recorded below the FCO of *R. pseudoumbilicus*. The FCO of *C. macintyrei* is an alternative event to the LCO of *C. premacintyrei*. As also remarked in the Tufillo section a rise in abundance of *C. leptoporus* occurs with the FCO of *C. macintyrei* and the LO of *H. walbersdorfensis* was replaced by the LCO of the species. Reworked specimens of *Discoaster hamatus* have been recorded within the *A. primus* Zone.

Monte Rotondo section.

The section was sampled in the neighbourhood of Bovino (174 I SE, topographic map of Italy), near Monte Rotondo and Monte Castro locality; it mainly consists of a lower and middle part of calcarenites, calcilutites and marls (Flysch di Faeto Formation) and of an upper marly interval (Marne argillose del Toppo Capuana Formation).

The total assemblage observed in the 18 collected samples is reported in Tab. 3; this allowed to refer the investigated section to an interval between MNN5 and *C. pelagicus* Zone; a stratigraphic discontinuity occurs between samples 12-13. The main quantitative results are reported in Fig. 5. The FCO of *H. walbersdorfensis* is not useful in this section to subdivide MNN5 since the species was observed from sample 12 onward only. Small specimens of *Gephyrocapsa* spp. (about 2 microns in size) have been observed within the *M. convallis* Zone (Tab. 3). It is noteworthy that specimens of small *Gephyrocapsa* have been previously recorded in the upper Miocene Mediterranean record by Bonci et al. (1991) within the Zones NN11-NN12 of Martini (1971), by Pujos (1987) in the equatorial Pacific Ocean and by Gartner (1992) in the North Atlantic within the range of *M. convallis*.

Rare and scattered reworked specimens have been recorded in this section.

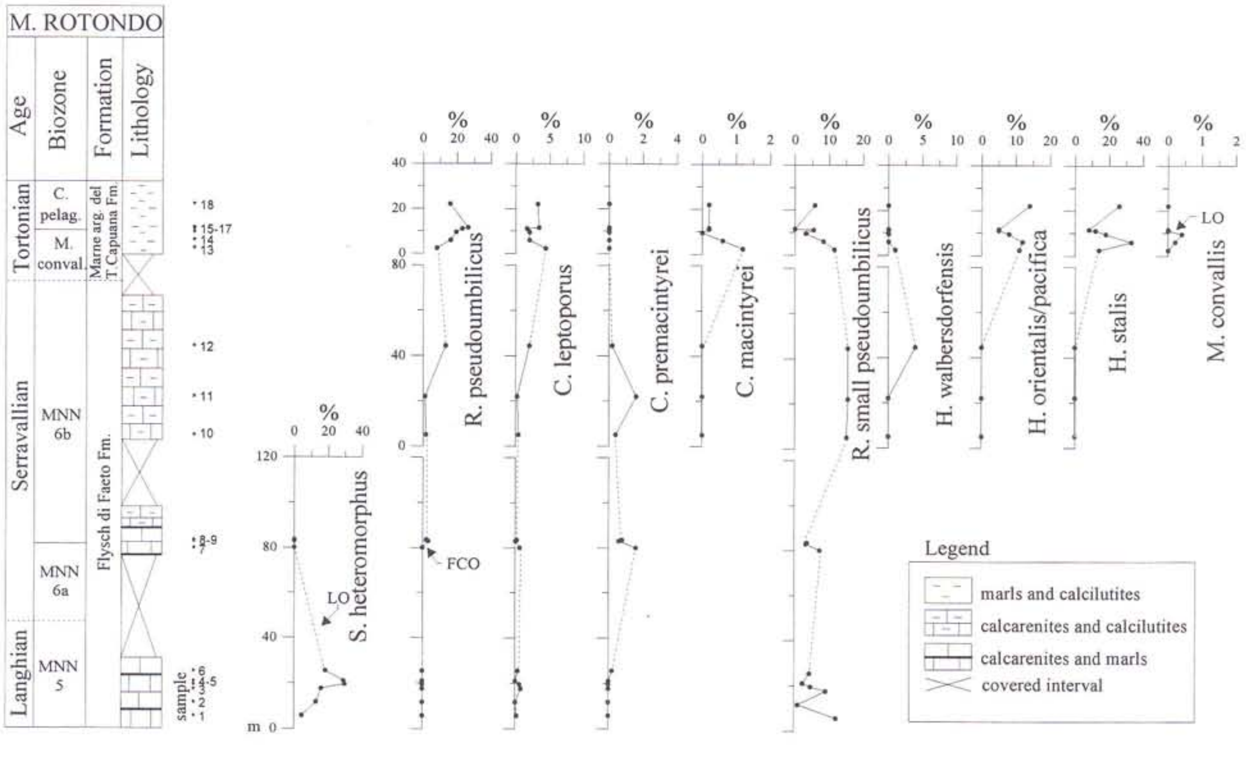


Fig. 5 - Abundance patterns of selected calcareous nannofossils at the Monte Rotondo section. See legend of Fig. 3.

M. ROTONDO

Age	Langhian						Serravallia						Tortonian					
Zone: Fornaciari et al. (1996) *Theodoridis (1984)	MNN5						MNN6a	MNN 6b					M. convallis *			C. pelagicus *		
Formation	Flysch di Faeto Fm.												Marne argillose del T. Capuana Fm.					
Sample	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
Total abundance	C	F	C	F	F	A	C	F	F	C	F	F	C	C	C	C	F	F
Preservation	VP	VP	VP	P	P	M	M	VP	VP	M	P	M	M	M	M	P	VP	VP
Braarudosphaera bigelowii	.	.	.	.	.	.	.	.	.	.	.	.	.	.	X	.	X	.
Calcidiscus fuscus	.	.	.	.	.	.	0.2	0.2	.	.	.	.	0.2	.	0.2	0.2	.	.
C. leptoporus	0.2	.	0.8	0.6	.	0.4	0.6	.	0.2	0.4	0.2	2	4.4	2	2	1.6	3.4	3.2
C. macintyrei	.	.	.	.	.	.	.	.	.	.	.	.	1.2	0.6	X	0.2	0.2	0.2
C. premacintyrei	.	.	.	.	.	0.2	1.6	0.6	0.8	0.4	1.6	0.2	.	X	.	.	.	.
Coccolithus miopelagicus	0.2	0.4	.	1.4	0.8	2.2	2.8	0.8	0.8	1.6	0.6	2.8	0.4	0.2	.	.	0.4	.
C. pelagicus	56.2	39.8	41	35.4	38.2	40.6	51.8	49	35.8	55	42	31	41.2	28.4	27.6	35.4	31.8	36.4
Cryptococcolithus mediaperforatus	.	.	.	.	.	.	.	.	.	.	.	.	0.2	0.4	0.8	0.4	X	0.2
Cyclicargolithus floridanus	1.4	0.8	5.6	1.4	.	0.6	2.6	0.6	0.2	4.8	0.6	0.4	X	0.4	.	.	.	.
Dictyococcites perplexus	13.2	37.2	8	9.4	11.2	2.2	10.2	24.8	38.4	.	30	6	1.4	0.6	5	0.6	.	0.4
D. productus	.	.	.	.	.	.	.	.	.	.	.	.	C	F	F	F	.	C
Discoaster adamanteus	.	.	.	.	.	.	.	.	0.2	.	.	.	.	.	.	.	.	.
D. bellus	.	.	.	.	.	.	.	.	.	.	.	.	.	0.1	.	0.1	.	.
D. bergrrenii	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	0.1
D. brouweri	.	.	.	.	.	.	.	.	.	.	.	.	0.4	.	.	.	0.5	0.1
D. challengeri	.	.	.	.	.	.	.	.	.	.	.	.	.	0.7	.	.	.	.
D. deflandrei	.	.	.	.	0.4	0.2	.	.	.	.	.	.	.	0.1	.	.	.	.
Discoaster cfr D. neohamatus	.	.	.	.	.	.	.	.	.	.	.	.	.	0.1	.	.	.	.
D. prepentaradiatus	.	.	.	.	.	.	.	.	.	.	.	.	.	0.1	0.1	.	.	.
Discoaster variabilis/exilis	.	.	.	0.2	.	.	0.8	.	.	.	.	.	2.4	2	1.5	18.4	2.6	0.4
Discoaster cfr D. quinqueramus	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	0.1	.
Discoaster spp.	.	.	0.4	.	0.4	.	1.6	.	.	.	.	0.2	0.4	0.6	.	.	0.2	.
Geminilithella rotula	.	.	.	.	.	.	.	0.2	0.4	0.2	.	0.2	2	6.4	4.2	3.2	3	5
small Gephyrocapsa	.	.	.	.	.	.	.	.	.	.	.	.	A	C	R	R	.	F
Helicosphaera ampliaperta	.	.	0.8	0.4	.	.	.	.	.	.	.	.	.	.	.	.	.	.
H. carteri	4.8	6.2	9.2	10	9.2	1.6	6	13	10.8	14.2	3.4	14.2	20.6	14.4	20.4	16.2	20.8	16.8
H. euphratis	.	.	.	.	.	0.2	.	.	0.2	.	.	0.2	0.2	0.4	X	0.6	0.4	.
H. orientalis/pacifica	.	.	.	.	.	.	.	.	.	.	.	.	2.8	2.8	2.4	1	1.4	4
H. stalis	.	.	.	.	.	.	.	.	.	.	.	.	3.4	8.6	5	2.4	2.2	7.2
H.walbersdorfensis	.	.	.	.	.	.	.	.	.	.	.	0.4	0.2	X	.	.	.	.
Helicosphaera spp.	.	.	.	.	.	.	.	.	0.2	.	.	0.2	.	0.2	X	.	.	.
Lithostromation perdurum	.	.	.	.	.	.	.	.	.	.	.	.	.	X	X	.	X	.
Minylitha convallis	.	.	.	.	.	.	.	.	.	.	.	.	X	0.2	0.4	.	.	.
Pontosphaera spp.	.	.	.	.	.	.	.	.	.	.	.	.	0.6	.	0.2	.	0.4	0.8
Pyrocyclus spp.	.	.	.	.	.	.	.	.	.	0.2	.	.	X	.	X	0.6	0.2	X
Reticulofenestra minuta	.	.	.	.	.	.	.	.	.	.	.	.	F	F	F	F	.	C
R. minutula	1.6	1.2	5.6	5.4	8	29	14.2	2.8	3.2	6.2	3.8	12.8	0.6	2.2	4.2	5	1	0.4
small R. pseudoumbilicus	12.2	1	9.2	4.8	2.4	4.4	7.4	3.4	3.6	15.2	15.6	15.6	11.6	8.4	3.2	5.4	.	5.8
R. pseudoumbilicus	.	.	.	.	.	.	.	3.4	2.2	1.8	1.2	13.4	8.2	16.2	19.4	23	26.4	15.8
Rhabdosphaera spp.	.	.	.	.	.	.	.	.	.	.	.	.	X	1.4	0.2	0.6	.	0.2
Scapholithus fossilis	.	.	.	.	.	.	.	.	.	.	.	.	.	0.2	.	.	.	.
Scyphosphaera spp.	.	.	.	.	.	.	.	.	.	.	.	.	0.2	0.6	X	.	0.2	0.2
Sphenolithus abies/neoabies	.	.	.	.	.	.	.	.	.	.	.	.	.	0.6	3.4	2.8	1.2	.
S. moriformis	5.4	0.2	3.6	1	0.4	0.2	0.2	1.2	3	.	0.6	0.2	0.6	X	.	.	.	1.6
S. heteromorphus	4.6	12.8	15.8	29.8	29	18.2	.	.	.	.	0.2	.	.	X	.	.	.	.
Syracosphaera spp.	.	.	.	.	.	.	.	.	.	.	.	.	0.2	.	.	X	.	0.2
Tetralithoides symeonidesii	.	.	.	0.2	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Triquetrorhabdulus rugosus	.	.	.	.	.	.	.	.	.	.	.	.	.	X	.	.	.	.
REWORKING	0.2	0.4	.	.	.	.	.	.	.	.	0.2	0.2	.	3	0.4	0.6	0.4	0.2

Tab. 3 - Calcareous nannofossil range chart of the Monte Rotondo section. Abundances are reported as percentage relative to 500 specimens. From sample 13 onwards the abundance of discoasterids is tabulated as N° of specimens/mm² and relative to about 10,000 coccoliths. Letters indicate semiquantitative estimate. See legend of Tab. 1.

M. ARMENIA																																			
Age	Zone Fornaciari et al. (1996)	Formation	Sample	Total abundance	Preservation	Calcidiscus fuscus	C. leptoporus	C. macintyrei	C. premacintyrei	Coccolithus miopelagicus	C. pelagicus	Cryptococcolithus mediaperforatus	Coronocyclus nitescens	Cyclicargolithus floridanus	Dictyococcites perplexus	D. productus	Discoaster deflandrei	D. variabilis/exilis	Discoaster spp.	Geminilithella rotula	Helicosphaera ampliaperta	H. carteri	H. euphratis	H. walbersdorfensis	Pontosphaera spp.	Rhabdosphaera spp.	Reticulofenestra minuta	R. minutula	small R. pseudoumbilicus	R. pseudoumbilicus	Sphenolithus heteromorphus	S. moriformis	Sphenolithus spp.	Tetralithoides symeonidesii	REWORKING
Serrav.	MNN6a	Flysch di Faeto Fm.	12	F	VP	0.2	.	.	.	0.4	C	.	.	.	F	F	.	.	.	.	.	0.2	.	0.2	.	.	.	.	F	F	0	0.2	.	.	.
Langhian	MNN 5b		11	F	P	.	.	.	0.2	2	67.6	.	.	0.2	0.4	.	.	.	0.2	0.6	.	20	.	0.6	.	.	.	3.2	0.2	.	1	0.6	2.8	.	0.4
			10	F	M	0.6	X	.	X	1.8	59.8	0.2	.	7.8	4	.	.	.	1.2	5.4	.	5	.	0.2	0.2	.	.	5.4	0.6	X	6.6	0.2	0.8	.	0.2
			9	F	M	1.2	.	.	0.6	3	64.6	0.2	.	1.8	2	C	.	.	0.8	4.6	.	3.8	.	0.2	0.8	.	F	0.6	0.8	0.4	12.2	0.6	1.6	.	0.2
			8	F	M	0.6	X	.	0.2	3.4	65.2	X	.	2	1.4	C	.	.	1	3.8	.	7.4	.	X	.	.	F	1.6	1.8	.	9.6	0.2	1.4	.	0.4
			7	F	P	0.2	.	.	0.2	4.6	61	X	.	0.2	0.6	C	0.2	.	0.4	3	.	7.4	X	0.4	.	.	R	.	0.8	X	18.8	.	1.8	.	0.4
			6	F	M	0.6	.	.	0.8	6.8	57.2	0.4	X	0.2	3.4	.	.	0.2	2	1.6	X	5.8	.	0.2	.	.	.	.	8.8	.	11.6	0.2	.	0.2	.
	MNN 5a		5	F	P	X	.	.	0.8	1.4	34.6	2	.	.	36	C	.	.	1.2	1.2	.	6.4	.	.	0.2	.	F	.	2.8	.	11.2	1.2	0.4	.	0.6
			4	C	M	0.6	0.6	?	0.2	4.4	47	0.2	.	0.8	18	C	.	.	0.4	2	.	6.4	.	.	0.2	.	.	.	5	.	13.4	0.4	.	X	0.4
			3	F	M	0.6	.	.	X	2.8	55.8	0.6	.	6.2	2.6	C	X	.	0.2	0.2	.	16	0.2	X	0.2	X	F	.	.	.	14.2	.	.	0.2	0.2
	MNN 4b		2	F	P	.	0.4	.	X	3.2	63	0.2	.	8.8	.	.	.	.	.	0.2	.	19.4	0.4	.	.	.	.	.	.	.	.	4.2	.	X	0.2
			1	F	VP	.	0.6	.	0.4	1.2	64.8	.	.	8.2	0.4	.	.	.	0.2	0.2	0.4	20	.	.	.	.	.	.	0.8	.	0.2	2.6	.	.	.

Tab. 4 - Calcareous nannofossils range chart of the Monte Armenia section. Abundance are reported as percentage relative to 500 specimens. Letters indicate semiquantitative evaluation. See legend of Tab. 1.

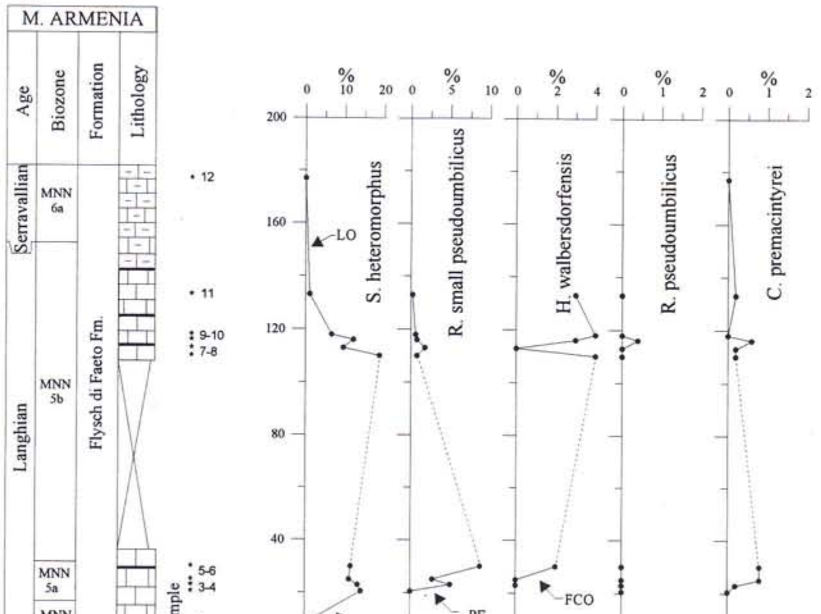


Fig. 6 - Abundance patterns of selected calcareous nannofossils at the Monte Armenia section. See legend of Fig. 3.

Monte Armenia section.

The section crops out near Forenza between Masseria Morlino and Monte Armenia (187 I SE, topographic map of Italy); it is represented by calcarenites and calcilutites with interbedded marly layers and is referable to the Flysch di Faeto Formation.

According to the total nannofossil assemblage recognised in 13 samples (Tab. 4) the section was referred to an interval between Zones MNN4b and MNN6a; the most relevant quantitative results are shown in Fig. 6.

Particularly it is visible that the PE of small *R. pseudoumbilicus* occurs between the PE of *S. heteromorphus* and the FCO of *H. walbersdorfensis*; the latter event is detectable between samples 5-6. Very rare reworked specimens occur in this section.

Fosso Scannapapere section.

The section was sampled southwest of the Forenza neighbourhood along the Fosso Scannapapere (187 I SE, topographic map of Italy).

It mainly consists of siliciclastic sandstones and marls; in the lower part of the section quartzarenite deposits, referable to the Numidian Flysch have been sampled. In the upper siliciclastic deposits (Serra Palazzo Formation) 18 samples have been considered for quantitative analyses; the complete section can be referred to an interval between Zones MNN3a and MNN5a. The total nannofossil assemblages can be found in Tab. 5 and the quantitative data of selected species are reported in Fig. 7. Common occurrences of *R. pseudoumbilicus* are observed within Zone MNN3a-3b, well below the FCO of the species which defines the top of Zone MNN6a. Moreover occurrences of *H. ampliaperta* as well as of *R. pseudoumbilicus* are recorded within the paracme interval of *S. heteromorphus* as also documented by Fornaciari et al. (1996). At the top of the section the PB of small *R. pseudoumbilicus* occurs between the PB and PE of *S. heteromorphus*. The high number of reworked specimens recorded in this section (Tab. 5) did not prevent the recognition of the biozonal events.

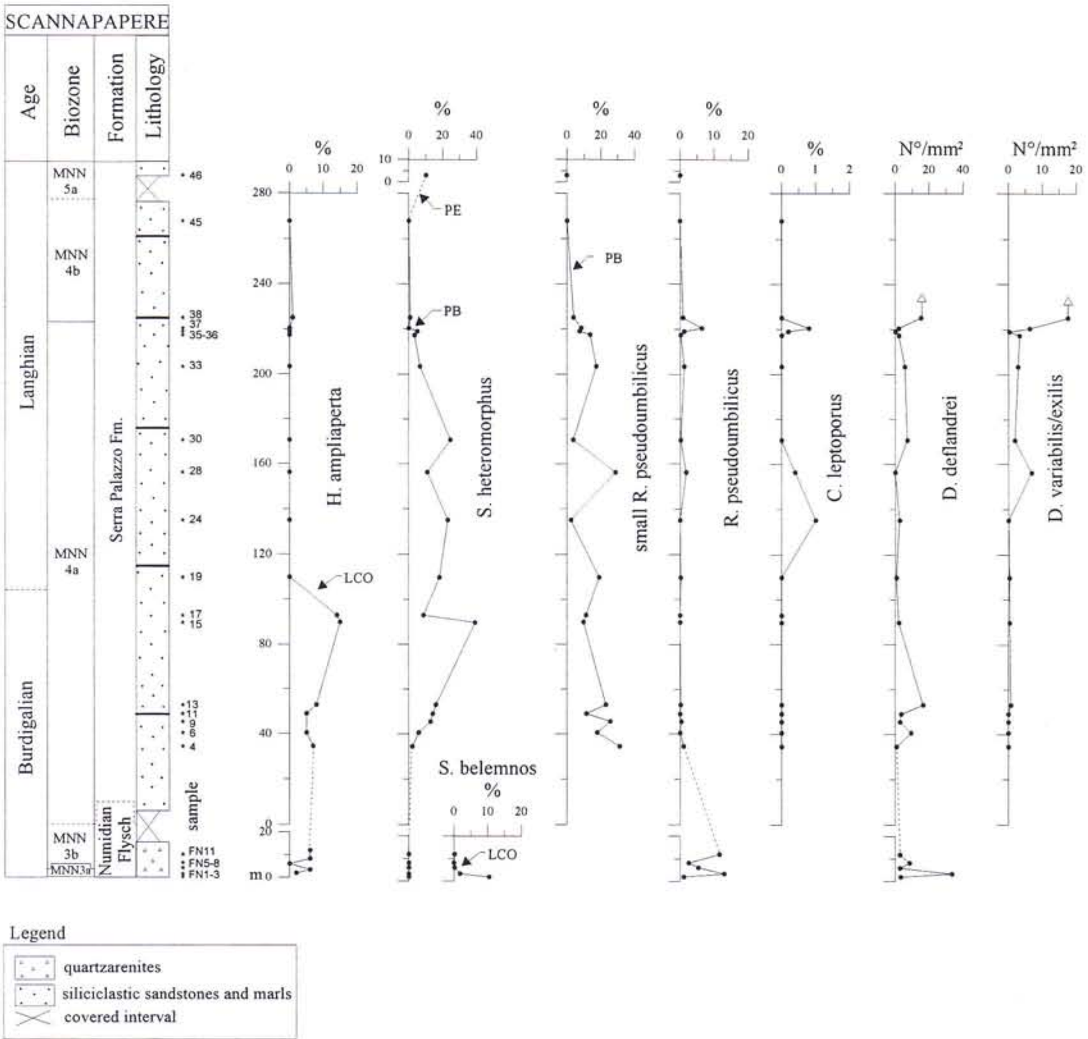


Fig. 7 - Abundance patterns of selected calcareous nannofossils at the Fosso Scannapapere section. See legend of Fig. 3.

F. SCANNAPAPERE

Sample	FN1	FN3	FN5	FN8	FN11	4	6	9	11	13	14	15	17	19	22	23	24	28	30	33	35	36	37	38	45	46
Age	Burdigalian													Langhian												
Zone (Fornaciari & Rio (1996), Fornaciari et al. (1996))	MNN 3a		MNN 3b			MNN 4a																	MNN 4b			MNN5a
Formation	Numidian Flysch					Serra Palazzo Fm.																				
Total Abundance	F	C	F	F	F	VP	F	F	F	F	F	C	F	F	B	B	F	F	F	C	C	F	F	F	F	F
Preservation	P	M	P	P	M	M	P	P	P	P	VP	P	P	P			VP	P	P	P	P	P	P	P	P	P
Calcidiscus fuscus																	0.2			0.2	1.4	0.2		0.2		
C. leptoporus			0.2	0.2							R						1	0.4	X		X	0.2	0.8	X		
C. premacintyrei																		0.2		X	X					0.2
Coccolithus pelagicus	51.6	49.4	61.2	61.2	50.4	11.6	16.2	13.4	28.4	16.4	A	35.8	57.6	47.2			33.6	42.6	49.8	38.2	29	39.6	49	61.2	76.6	73.6
C. miopelagicus	2.6	0.6	0.8			0.6	0.6	0.4		0.6	F	1	0.6	1			1.2	0.8	1.4	1.4	0.4	2.6	2	0.4		
Cryptococcolithus mediaperforatus													0.2						X		0.6					
Coronocyclus nitescens	0.4	X	2.8	1.2	1.8			0.4																		
Cyclicargolithus floridanus	5.2	6.2	3.2	7.4	6.8	22.4	16.2	15.4	16.6	17.6	A	0.8	3.4	5			1.8	3.2	2.6	8.8	11.6	8.8	3.2	3	1.4	1.4
Dictyococcites perplexus	9.4	1.6		3.2		X	2.6	0.4	17.6	0.4	A	1.6	1.4	1			28.2			1.2	8.8		0.6	0.4		
D. productus						F	F	R	F				R	R			F			F	F		R	F		
Discoaster deflandrei	0.4	3.2	0.2		1.4		3.4	0.2	0.2	0.6		0.2		X			X		0.4	0.4	0.2	X	X	0.2		
D. variabilis/exilis										X		X	0.2	X				0.4	0.2	0.2	0.4	0.4	4	0.2		
D. woodringii						0.4																				
Discoaster spp.				1.8			0.8	2.4		0.2		0.4	0.4				0.2	3.4			0.4	0.4	0.8		1	0.8
Geminilithella rotula	0.6	1.8	1.4	1.8	1						R		0.2				0.2			0.6	1.4	0.6	1	0.2	0.2	0.2
Helicosphaera ampliaperta	0.2	0.2	X	0.6	X	0.4	0.6		X	0.8		1	2											0.2		
H. carteri	3.8	1.8	9.2	4.4	4	3.4	2	1.8	3.4	6.4	C	4.8	7	3.4			5.4	1.4	15.4	15.6	10.8	20.6	11.4	22.4	19.6	13.6
H. euphratis			X		0.2	0.2	X			0.2		X	0.2	X				X	0.2		0.4	1.6	0.8			
H. obliqua																				0.2						
H. perch-nielseniae																				X	0.2	X				
H. scissura	0.6	0.2	0.4	0.4	1.4	0.4	1.2		0.2	2.8	F		X	0.2			X	X			X			0.8		
H. walbersdorfensis																						X				
Helicosphaera spp.	0.2	0.4		X		X	1.6	0.6	1.2	0.6			0.2	X			X			0.4	1.8	0.4	X			
Pontosphaera spp.																					X					
Pyrocyclus orangensis					0.2												X				X					
Reticulofenestra minuta						F		F	A	C		F		C			R		F							
Reticulofenestra minutula		2	6.6	11.6	11	1.2	1	0.2	0.6	0.2	R	0.4	0.6	0.2			0.2	0.4	0.6	0.2	2.6	0.6	0.4	0.6		
small R. pseudoumbilicus	11.2	14.8	7.6	2.2	7.8	31	17.8	25.4	11.4	22.8	A	9.6	11.2	18.8			2.2	28.6	3.6	17.2	13.6	7.4	8.4	3.8		
R. pseudoumbilicus	1.2	13	5.4	2.6	11.6	1		0.4		0.2	R			0.2				1.8	0.2	1.2	0.2	1.2	6.4	0.8		
Rhabdosphaera spp.			X										X								X					
Sphenolithus abies/neobies		0.4				2.8	25	15	4.4	0.2	C		0.6	0.8			1.8	3.8	X	0.6	2	0.4	3	3.2		
S. belemnos	10.4	1.8	0.2		0.2																					
S. conicus		0.2																								
S. dissimilis	0.8	0.4	X																							
S. heteromorphus						2	5.8	12.8	14.2	16	A	39.2	8.6	18			23	11	24.4	6.6	3.4	5.2		0.8		10.2
S. moriformis		0.2		0.2	0.2				0.4	0.4		4.4		0.2			X				0.2				0.6	
Sphenolithus spp.					0.2	0.8		0.6				0.2	1	0.4								1				
Tetralithoides symeonidesii																			X		X					
Thoracosphaera spp.							0.2												0.2			0.2				
Triquetrorhabdulus milowii		1	0.6	X	0.6																					
REWORKING	1.4	0.8	0.2	1.2	1.2	21.8	5	10.6	1.4	13.6	C	0.6	4.6	3.6			1	2	1	7	10.6	8.8	8.2	1.6	0.6	

Tab. 5 - Calcareous nannofossils range chart of the Fosso Scannapapere section. Abundance are reported as percentage relative to 500 specimens. Letters indicate semiquantitative evaluation. See legend of Tab. 1.

Torrente Vaggianello section.

The section was sampled southwest of Oppido lucano, along the Vaggianello stream (188 III SW, topographic map of Italy). It mainly consists of siliciclastic sandstones in the lower part and of alternating limestones, marls and silts in the upper part; it can be referred to the Serra Palazzo Formation.

The nannofossil assemblages observed in 16 samples is documented in Tab. 6; the most significant quantitative results are reported in Fig. 8. The section can be

T. VAGGIANELLO Age	Zone Fornaciari et al. (1996)	Formation	Sample	Total Abundance	Preservation	Calcidiscus leptoporus	C. macintyrei	C. premacintyrei	Coccolithus miopelagicus	C. pelagicus	Cryptococcolithus mediaperforatus	Cyclicargolithus floridanus	Dictyococcites perplexus	D. productus	Discoaster deflandrei	D. variabilis/exilis	Discoaster spp.	Geminilithella rotula	Helicosphaera ampliaperta	H. carteri	H. euphratis	H. walbersdorfensis	H. waltrans	Helicosphaera spp.	Reticulofenestra minutula	small R. pseudoumbilicus	R. pseudoumbilicus	Rhabdosphaera spp.	Scapholithus fossilis	Sphenolithus abies/neoabies	S. heteromorphus	Sphenolithus moriformis	Sphenolithus spp.	REWORKING
Serravallian	MNN 7	Serra Palazzo Fm.	16	R	VP	R			X	F										R						R						R		F
			15	F	VP	F	X		X	F			C							X						R	X							F
			14	F	VP	1	X	0.2	0.8	F	0.2	0.2	F					0.2		0.4					F	R	1			0.2				5.8
			13	F	VP	3	0.2		1.4	C	X	1		A		0.4				5.8	0.8	0.4		1.8	C	C	1.6	X		0.6				21.2
			12	F	VP		0.2	0.2	3.6	46	0.2	0.4	10.4					0.4		6.2	0.6			1	8.2	3.6	3			0.6	0.2			15.2
			11	F	VP	2.2	0.2		0.6	53	0.2	0.2	18				0.2	0.2		11.8		0.6		1	5.4	2.2	1.4			0.4				2.6
			10	F	P	2.6	0.2	0.4	0.2	C		0.2	C	C		0.2		0.2		13	0.2	0.2		0,2	C	F	1.2		0.2	1				20
			9	F	P	1			0.2	49.6	0.4		11.2			0.4		0.4		10.2		0.6			3.4	4	12.8	0.2			X			5.6
			8	F	P	0.8			0.8	40.2	0.8	0.4	3.2	C		0.6	0.4	0.4		10.2	0.4	0.2		0.2	18.8	9.2	2.2			1	0.2			10
	MNN 6b		7	F	P	0.6		3	2	54			0.6			1				5.6					12.2	19.8								1.2
			6	F	P			0.8	0.8	C			F	F						5.8		0.2			C	F	6			1				3.8
			5	F	P	1		0.6	0.6	C	0.2		F	R		1.6		1	0.2	5.6	0.2		X	0.2	C	F	5.8			0.2	0.2		0.2	6.2
Lang.	MNN 4a		4	F	M			0.2	0.2	37		1.2						0.2		11.2					3.8	5.2					40.8			0.2
			3	F	P					52.4		1.6							0.4	14					4.6	15.2					11.2	0.2		0.4
Burd.			2	F	VP					16.4		2.4			0.4	5.2			1.2	3.2					24.4	10.2	1.6			0.6	11.6	0.4		22.4
			1	F	VP				0.2	11.4		2.8			1.2	3			1.6	1.6					26.2	19.6	3.6			1.4	11.6			15.8

Tab. 6 - Calcareous nannofossil range chart of the Torrente Vaggianello section. Abundance are reported as percentage relative to 500 specimens. Letters indicate semiquantitative estimate. See legend of Tab. 1.

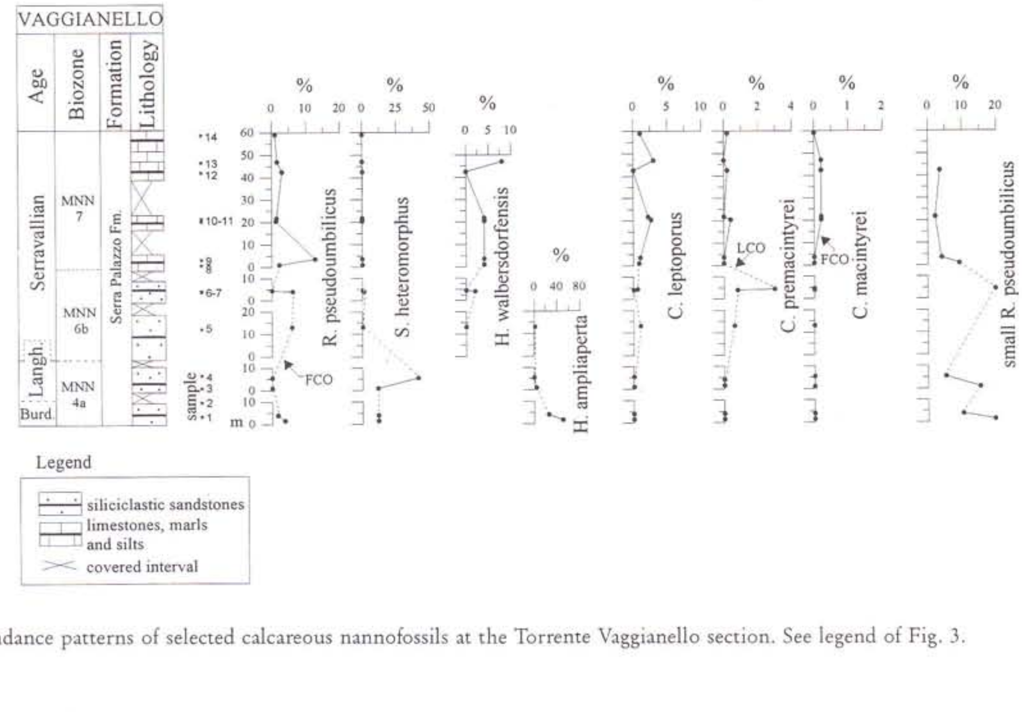


Fig. 8 - Abundance patterns of selected calcareous nannofossils at the Torrente Vaggianello section. See legend of Fig. 3.

referred to an interval between MNN4a and MNN7 with a major stratigraphic discontinuity between samples 4-5. In the lower part of the section the presence of *S. heteromorphus*, *H. ampliaperta* and small *R. pseudoumbilicus* represent MNN4a; *R. pseudoumbilicus* is recorded from MNN4a upward. The LCO of *C. premacintyrei* as well as the FCO of *C. macintyrei* can be observed in this section. Reworked specimens were found with percentages that varie from 0.2 up to 20% of the assemblage.

Jazzo Porcellini section.

The section was sampled near Stigliano along the Vallone della Difesa, at the Jazzo Porcellini locality (200 II NW, topographic map of Italy). In the lower and middle part it is represented by silicilastic sandstones overlying the Numidian Flysch (Gallicchio, 1996) and by limestones, marls and silts referable to the Serra Palazzo Formation. In the upper part it mainly consists of marly deposits referable to the Marne argillose del Toppo Capuana Formation.

The nannofossil assemblages observed in 30 samples are reported in Tab. 7; the quantitative results of the significant species are shown in Fig. 9. The Jazzo Porcellini section has been referred to an interval between Zone MNN4a and Zone MNN8.

In sample 9, within the paracme interval, an abundance peak of *S. heteromorphus*, probably due to reworking, is recorded. Several Cretaceous and Paleogene specimens occur in the same sample (Tab. 7). However, it is noteworthy that also Fornaciari et al. (1996) recorded a characteristic abundance peak of *S. heteromorphus* within the paracme interval of the species and correlatable among a few sections.

The FCO of *H. walbersdorfensis* as well as the LCO of *C. premacintyrei* were not detected in this section, probably due to stratigraphic discontinuities. The LCO of H. walbersdorfensis may be doubtfully placed at the top of the section, between samples 29-30. The number of reworked specimens is considerable in this section and reaches values up to 40% of the assemblage.

Valle Difesa section.

The section was sampled near Stigliano at the Piceca locality (200 II NW, topographic map of Italy); it mainly consists of siliciclastic sandstones and of alternating limestones, marls and silts in the uppermost part and is referable to the Serra Palazzo Formation. The biostratigraphic study performed on 21 samples allows to recognise an interval between Zones MNN4a and

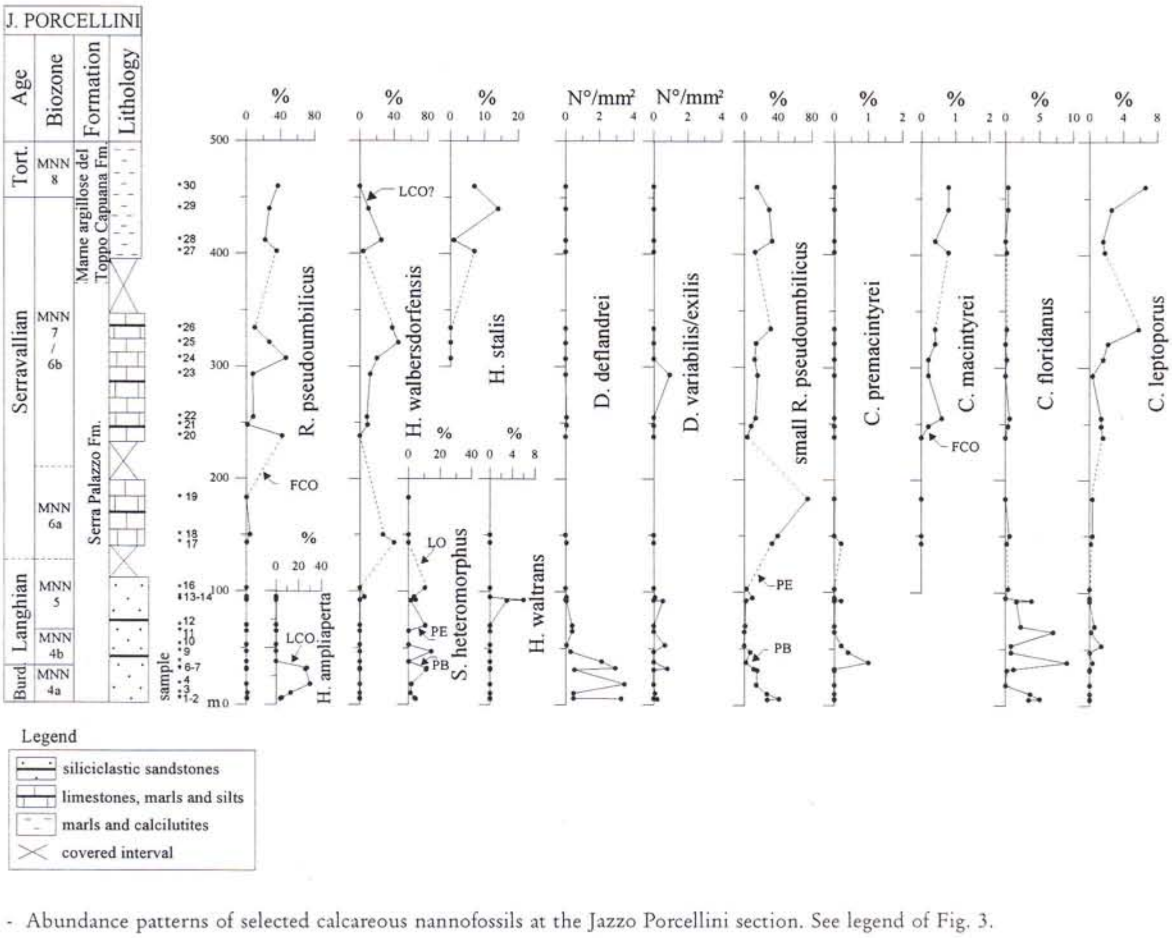


Fig. 9 - Abundance patterns of selected calcareous nannofossils at the Jazzo Porcellini section. See legend of Fig. 3.

JAZZO PORCELLINI																													
Age	Burdigalian						Langhian									Serravallian													Torton.
Zone Fornaciari et al. (1996)	MNN 4a						MNN 4b				MNN 5					MNN 6a			MNN 6b / 7										MNN8
Formation	Serra Palazzo Fm.																									M. arg. del T. Cap. Fm.			
Sample	1	2	3	4	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
Total Abundance	C	C	F	F	C	C	C	F	C	C	C	F	F	C	C	C	F	F	F	F	F	C	F	C	F	F	F	F	C
Preservation	M	M	P	VP	P	P	VP	VP	VP	P	VP	P	P	P	VP	P	M	R	P	P	VP	P	M	M	M	M	P	P	M
Calcidiscus fuscus	0.2															0.2													
C. leptoporus							0.4		1.4	0.2	0.6		X			0.2	0.4	0.4	1.6	1.4	1.4	0.4	1.6	2.2	5.8	1.8	1.6	2.6	6.6
C. macintyrei																				0.2	0.6	0.2	0.2	0.4	0.4	0.8	0.4	0.8	0.8
C. premacintyrei							1	0.4	0.2			X	0.2			0.2	X				X			X					
Cryptococcolithus mediaperforatus																0.4	X							0.2		0.6	X		
Coccolithus miopelagicus	0.6		0.2	0.2		0.8	2.4	X	0.6	3.4	2.2	0.6	1	2	1.4	0.2	0.6	2	2.4	0.6	1.2		0.4	1.4	0.8	0.2	0.6		0.2
C. pelagicus	24.6	24.6	26	21.4	38.2	43	70.4	38.2	80.6	71.8	70.4	25.2	20	58.4	58.2	22.2	21.4	14.2	41.6	33.8	37.8	28.4	17.2	21.8	21.8	24.2	28.2	28.4	20.8
Cyclycargolithus floridanus	3.4	5	3.6		0.2	1.2	9	0.8	0.8	7	2.2	1.6	3.8		0.4	0.2	0.6			0.4	0.6		0.2		0.2	0.2		0.4	0.4
Geminilithella rotula	0.2	0.2	0.2						0.4	0.2	0.4	0.8	0.8	0.6	0.6	0.2	0.2	X		0.2		0.2		0.4		1	0.8	0.2	1
Dictyococcites perplexus				6.2							0.8						0.2			15.4	4.2	5		1.8		0.6	0.8	1.2	
D. productus													C								C			A	C	C	F	C	C
Discoaster deflandrei	2.4	0.2	1.2	3	0.8	2	0.6	0.2	X	0.2	X	X		X		X				X	0.2					0.2			
D. exilis								1.2				0.4	0.2				0.4		0.6				0.4						
D. moorei								X	X			0.2		X			0.2												X
D. musicus														0.4		X													
D. variabilis/exilis	0.2			1.8	0.6	0.2														0.4		0.4							
D. variabilis												0.8	0.2						0.4				0.2						0.2
Discoaster spp.									2						4	0.4					0.8								
Helicosphaera ampliaperta	X	1.2	2	0.6	5.6	1.6																							
H. carteri	11.6	12	11	2	15.4	7.8	10.4	8.6	9.8	13.2	7	12.8	18.4	16	21.2	11.4	11.4	2.4	6.8	12	18.6	9.6	9.6	9.4	14.8	8.4	5.6	3.4	12.2
H. euphratis	0.2	X	0.4		0.2					0.2		X	0.2			0.6	0.2			0.2	0.8	0.2			0.2	0.6	X		
H. orientalis																								0.2					0.2
H. perch-nielseniae			X													X													
H. scissura	0.4	0.2	0.8	X																									
H. stalis																										0.8	0.2	1.2	1.4
H. walbersdorfensis														1		8	4.8	1.6		0.4	3.4	2	2.6	8.4	10.6	0.8	2	0.8	
H.waltrans												0.6	1.2																
Helicosphaera spp.												0.8	0.8								0.2					0.2			0.2
Lithostromation perdurum								X	X								X								X				
Pyrocyclus inversus																								0.2					
Reticulofenestra minuta	A	F	C			C				A			C			A	F	A		A		F		C	C				C
R. minutula	19	5.6	16	21.6	6.4	13.4		17.4	1		2.8	6	8.2	2.4		10	6.8	0.6		8.8	7.6	26	4.2	8	0.8	F	F	F	1.2
small R. pseudoumbilicus	27.2	41	26.6	14.2	15.4	11.4	1.8	7.2		0.2	1	2	2.2	10	2.6	32.8	39.4	75.2	4	8.4	13.6	15.8	12.6	13.8	31.4	13	32.8	29.4	15
R. pseudoumbilicus	0.8	0.6	1.2													0.2	4.2		41.8	1.2	8	7.4	46.4	26.8	9.8	35.4	21.8	26.6	36.8
Rhabdosphaera spp.										0.4			0.2			0.4	X				0.2			0.2	0.2		0.2	0.6	
Sphenolithus abies/neoabies	0.4		0.2		0.2	1								0.4		0.4	0.2		0.2	0.2			3.2		0.2	1.2	1.4	0.6	0.4
S. heteromorphus	4.4	3.8	1.2	1.8	11	11.4		14.4			10.4	1.4	4.4	3.4	10.2							0.2	X			0.2	0.2		0.2
S. moriformis	0.6	0.2			1.6	4.8	4	0.2	1.8	1	1.6		0.4		1		0.4	3.2				0.2		0.8					0.4
Sphenolithus spp.									0.2														0.2			0.2			
Syracosphaera spp.																	X				X			X					
Tetralithoides symeonidesii									X																				
Triquetrorhabdulus rugosus																					X			X				0.2	
REWORKING	3.8	5.4	9.4	20	4.4	1.4		11.4	1.2	2.2	0.6	46.8	37.8	5.4	0.4	12	8.6	0.4	0.6	16.4	0.8	4	1	4	3	8.6	2	2.6	2

Tab. 7 - Calcareous nannofossil range chart of the Jazzo Porcellini section. Abundance are reported as percentage relative to 500 specimens. Letters indicate semiquantitative estimate. See legend of Tab. 1.

MNN6b/7 (Tab. 8). The quantitative patterns of selected species are shown in Fig. 10.

The FCO of *H. walbersdorfensis* and the LCO of *C. premacintyrei* are not usable in this section to subdivide Zone MNN5 and MNN6b/7 respectively; on the other hand the FCO of *C. macintyrei* provides a useful event within the MNN6b/7 interval and is associated with an increase in abundance of *C. leptoporus*. Numerous reworked specimens were found in this section with percentages that may reach values up to 30%.

VALLE DIFESA

Sample	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
Age	Langhian												Serravallian								
Zone: Fornaciari et al. (1996)	MNN 4a			MNN 4b		MNN 5							MNN 6a		MNN 6b/7						
Formation	Serra Palazzo Fm.																				
Total Abundance	C	F	F	F	C	F	F	F	F	F	F	F	F	F	C	C	F	F	F	F	F
Preservation	M	M	P	M	VP	M	M	M	P	VP	VP	VP	VP	P	M	M	P	P	P	P	P
Calcidiscus fuscus	.	.	.	.	.	.	.	0.2	0.2	.	.	.	.	.	.	.	.	.	.	.	.
C. leptoporus	X	.	.	0.4	0.2	.	.	0.2	0.2	0.2	.	.	0.2	.	.	X	0.6	0.6	3.4	1.6	0.8
C. macintyrei	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	X	0.6	0.4	0.2
C. premacintyrei	X	.	0.6	0.2	.	.	0.6	X	0.2	.	.	.	X	0.2	X	.	X	.	.	.	.
Coccolithus miopelagicus	5.4	0.8	0.4	2.2	1.2	1	1.4	2.2	0.2	.	0.8	0.4	3.4	1.2	1.2	1.2	0.6	1.4	0.4	3.8	4.2
C. pelagicus	36	34.6	61.4	72.4	84.6	63.6	41.8	44	59.2	82	45.8	44.8	61.6	33.2	25.8	20.6	32.8	42.6	35.8	43.4	44.4
Cryptococcolithus mediaperforatus	0.2	.	.	.	.	0.4	X	.	.	.	.	.	.	0.4	0.2	X	X	0.4	0.2	0.2	0.2
Cyclicargolithus floridanus	5.2	8.4	6.6	6.8	2.8	.	0.2	1.8	6	2.2	1.6	1.8	.	0.2	0.2	1	0.4	.	0.2	.	0.2
Geminilithella rotula	1.2	0.4	0.2	.	.	0.4	0.2	0.2	0.8	X	1	0.4	.	X	0.2	.	.	X	0.4	0.6	0.2
Dictyococcites perplexus	1	1	5.6	.	.	0.2	.	1.2	0.4	1	.	0.2	6.6	6.4	.	.	0.6	24.2	17.6	4.2	9.2
D. productus	.	F	.	.	C	C	.	.	.	.	.	A	.	.	.	A	A	C	.	VA	VA
Discoaster deflandrei	X	0.4	.	0.4	X	X	X	.	.	.	.	X	.	.	X	X	X	.	.	X	.
D. exilis	X	2.4	.	0.4	.	X	1.8	X	X	X	1.2	0.4	.	.	.	1.2	0.2	.	.	.	.
D. variabilis/exilis	.	.	.	.	.	1.6	.	0.6	.	.	.	.	0.6	X	0.4	.	.	.	.	.	.
D. variabilis	.	0.6	.	.	.	X	.	.	.	.	X	.	.	.	.	X	.	.	.	.	.
Discoaster spp.	0.2	0.4	0.4	.	.	.	3	.	0.2	0.4	.	.	.	.	.	.	.	.	.	0.2	.
D. mooreei	.	.	.	.	.	.	X	.	.	.	.	.	.	.	.	.	.	.	.	.	.
D. signus	.	0.6	.	.	.	.	1.6	.	.	.	.	.	.	.	.	.	.	.	.	.	.
D. musicus	.	.	.	.	.	0.4	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Helicosphaera ampliaperta	.	0.4	.	1.2	0.4	.	.	.	.	0.2	.	.	.	.	X	X	.	.	.	.	.
H. carteri	9	11.2	9.2	9.4	8.6	12.6	5.4	9.2	7.2	4.6	3	10.6	4.8	7	11.6	5.8	11.2	14.8	5.6	13.6	15
H. euphratis	.	0.2	0.2	X	.	.	.	.	0.2	.	.	.	.	0.2	X	X	X	0.2	.	X	0.4
H. obliqua	.	X	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
H. orientalis	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	0.2	.	.
Helicosphaera stalis	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	0.2	.	.
H. walbersdorfensis	.	.	.	.	.	.	.	1	.	.	.	0.2	0.4	1.4	2.6	1	5.4	3.4	X	3	3.8
H.waltrans	.	.	.	.	.	.	.	X	.	.	.	.	.	0.2	.	.	.	.	.	.	.
Helicosphaera spp.	.	.	.	.	.	.	.	.	0.4	0.2	0.2	0.2	.	.	.	.	.	.	.	.	.
Rhabdosphaera spp.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	0.6	.	0.8
Reticulofenestra minuta	.	R	.	F	F	C	.	.	C	C	.	A	F	.	A	A	A	C	F	A	A
R. minutula	0.2	6.2	2.2	2	0.2	5.8	8.2	24.4	4.8	.	11.2	2	7.6	25.2	5.6	6.4	6	1	2.8	5	4.4
R. pseudoumbilicus	.	.	.	0.6	0.2	0.2	.	.	.	.	.	0.6	0.2	X	17.4	18	19.6	4	18	3	3
small R. pseudoumbilicus	8.6	21.6	0.8	1	0.6	2.2	4	2.2	1	3.6	1.2	1.8	9	13.8	24.8	37	18.2	4.6	10.6	12	6.4
Sphenolithus abies/neoabies	.	.	.	0.2	.	0.2	.	.	.	.	.	0.2	.	.	0.8	0.4	.	0.2	0.6	.	.
S. heteromorphus	30.4	7.6	9.6	.	X	5.8	23	5	1.2	2.2	2.2	11.6	.	.	.	X	X	.	0.4	0.2	.
S. moriformis	1.6	.	0.2	X	1.2	0.2	0.2	.	.	.	.	.	1	1.4	.	0.2	1	0.2	.	1.4	1.6
Sphenolithus spp.	0.6	.	2.2	0.2	.	0.2	X	.	.	.	X	.	0.4	.	.	.	.	0.2	.	.	.
Syracosphaera spp.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	0.2	.
Tetralithoides symeonidesii	X	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	0.2	X
Triquetrorhabdulus rugosus	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	X	X
REWORKING	0.4	3.2	0.4	2.4	X	5.4	8.6	7.8	17.8	3.4	31.8	24.8	4.2	9.2	9.2	7.2	3.4	2.2	2.4	7	5.2

Tab. 8 - Calcareous nannofossil range chart of the Valle Difesa section. Abundance are reported as percentage relative to 500 specimens. Letters indicate semiquantitative estimate. See legend of Tab. 1.

Rotondella section.

The section was sampled in the neighbourhood of Rotondella and along the Canale Ruggero (212 III NW, topographic map of Italy); the section, referable to the Flysch di Faeto Formation, mainly consists of calcarenites, calcilutites and marls in the lower part and of limestones, marls and silts upwards.

Nannofossils are rare and poorly preserved in this section; quantitative distribution of 21 samples was collected by counting the most significant species in 300 fields of view. Results are reported in Tab. 9 and Fig. 11.

The LO of *S. heteromorphus* between samples 3-4 was recognised; the common occurrences of *R. pseudoumbilicus* and of *C. macintyrei* allow to recognise the MNN6b/7 interval. The abundance pattern of *C. premacintyrei* is not useful in this section.

DSDP Leg 42, Site 372 - western Mediterranean Sea.

Site 372, which represents a reference section for the lower and middle Miocene biostratigraphy in the Mediterranean region, is located on the Menorca Rise of the Balearic Basin (40°01.86' N, 04°47.79' E). The main quantitative results are shown in Fig. 12 and may be summarized as follows:

a) The abundance pattern of small *R. pseudoumbilicus* shows a distinct paracme interval within Zones MNN4b and 5a; the PB occurs shortly above the PB of *S. heteromorphus* and the PE slightly below the FCO of *H. walbersdorfensis*. This is well comparable with results obtained in the on-land sections confirming the biostratigraphic value of the newly recognised events;

b) The distribution of *R. pseudoumbilicus* is similar to the one observed in the Fosso Scannapapere section: the species is recorded well below its FCO and was noted within Zones MNN 2b-3a-3b-4b.

Moreover, in the lower part of the section the FO of *H. mediterranea* was recorded below the FO of *H. ampliaperta*, within Zone MNN2a (core 39). On the contrary Fornaciari et al. (1996) documented the FO of *H. mediterranea* above the FO of *H. ampliaperta* in the Mediterranean region. It is possible that the presence of several unrecovered intervals at Site 372 prevented the recognition of *H. ampliaperta* below core 39. However, according to Theodoridis (1984) and Perch-Nielsen (1985) the occurrences of *H. mediterranea* precedes that of *H. ampliaperta*; moreover recently de Kaenel & Villa (1996) recorded at the Iberia Abissal Plain (ODP Leg 149) the FO of *H. mediterranea* below the FO of *H. ampliaperta*.

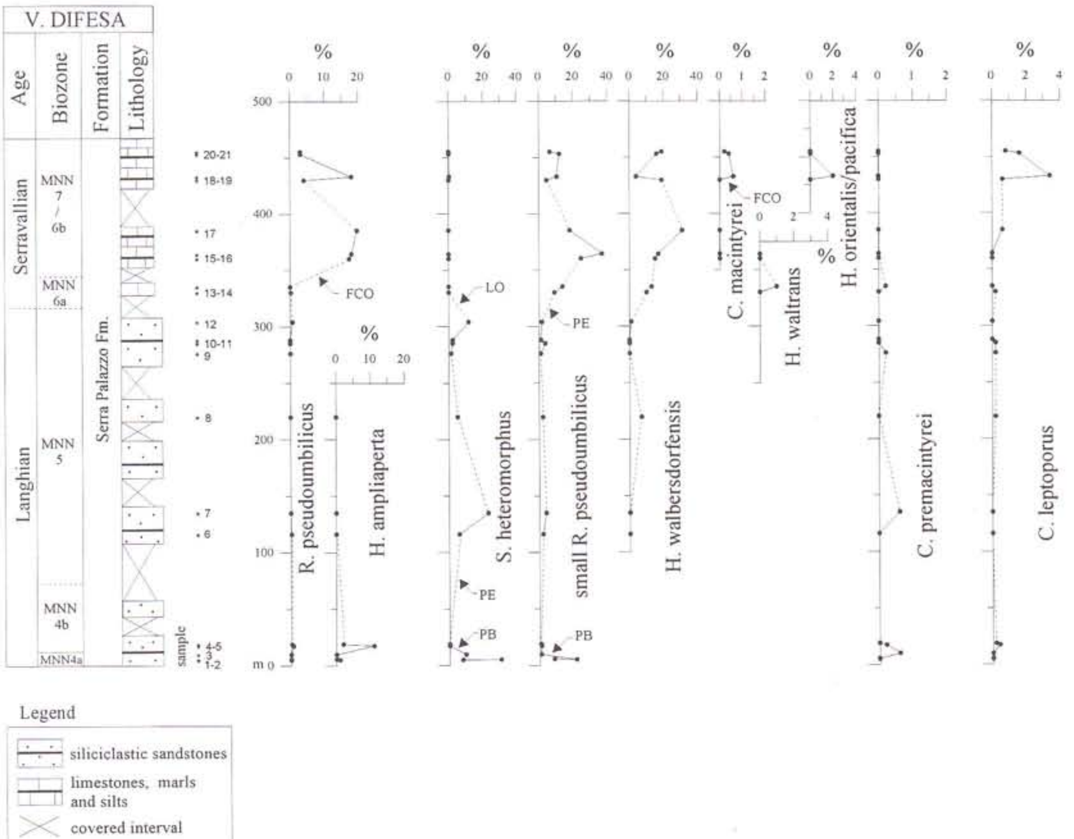


Fig. 10 - Abundance patterns of selected calcareous nannofossils at the Valle Difesa section. See legend of Fig. 3.

ROTONDELLA																																
Age	Zone Fornaciari et al. (1996)	Formation	Sample	Total abundance	Preservation	Calcidiscus fuscus	C. leptoporus	C. macintyrei	C. premacintyrei	Coccolithus miopelagicus	C. pelagicus	Cryptococcolithus mediaperforatus	Cyclicargolithus floridanus	Dictyococcites perplexus	D. productus	Discoaster deflandrei	Geminilithella rotula	Helicosphaera ampliaperta	H. carteri	H. euphratis	H. walbersdorfensis	H. waltrans	Helicosphaera spp.	Reticulofenestra minuta	R. minutula	small R. pseudoumbilicus	Reticulofenestra pseudoumbilicus	Sphenolithus abies/neoabies	S. heteromorphus	S. moriformis	Sphenolithus spp.	REWORKING
Serravallian	MNN 7 / 6b	Flysch di Faeto Fm.	19	F	VP	.	15	3.8	.	0.6	C	.	.	A	F	.	.	.	3.4	0.6	.	.	.	.	F	F	16	.	0.2	2.6	0.6	3.8
			18	F	VP	.	2.4	0.2	.	.	23.4	.	0.6	11.5	F	.	0.2	.	1.7	.	.	.	.	.	4.3	5.1	7.5	0.4	.	0.6	0.4	10.7
			17	F	P	.	1.7	0.4	.	.	C	.	0.6	R	F	.	.	.	0.2	.	.	.	0.2	.	F	.	6.4	0.2	.	0.2	0.6	5.4
			16	F	VP	.	3.6	0.4	.	0.2	F	.	.	R	R	.	.	.	0.6	.	.	.	.	R	F	.	14.5	.	.	0.4	1.9	0.7
			15	F	P	.	2.1	.	.	.	27.2	.	0.4	9.2	F	.	.	.	3.4	.	.	.	.	.	6.6	7.7	14.1	0.6	0.2	0.4	1.3	4.4
			14	F	VP	.	1.1	0.4	.	0.2	22.5	.	0.2	1.6	.	.	.	.	1.7	.	.	.	.	.	.	4.3	23	0.2	.	0.2	.	2.1
			13	F	P	.	5	0.2	.	0.2	A	.	0.4	C	C	.	0.2	.	3.4	.	0.2	0.2	.	R	15	18.8	24	1.1	0.2	0.4	1.1	2
			12	F	P	.	5.8	1.5	.	0.2	A	0.2	0.4	F	F	.	.	.	3	0.2	.	.	0.2	.	F	.	12.5	.	0.2	1.7	1.3	2.7
			11	F	R	.	8	0.8	.	.	41.2	.	.	A	.	.	.	.	1.6	.	.	.	.	.	4.8	3.6	8.4	.	.	.	1.2	1.2
			10	F	VP	.	15.5	0.7	.	0.9	C	.	.	F	R	.	.	.	0.4	.	.	.	.	.	F	.	27.3	.	.	1	.	1.1
			9	F	P	.	8.1	2.3	.	0.7	A	.	.	A	.	.	.	.	1.5	.	.	.	.	.	1.5	3	9.5	.	.	.	1.7	1.7
			8	F	P	.	7.1	0.2	.	0.7	C	0.2	.	A	.	.	.	.	0.4	.	.	.	.	.	.	6.9	0.4	.	0.6	0.7	.	1.3
			7	F	VP	.	5	0.9	.	0.9	C	.	0.2	R	.	.	.	.	0.7	.	.	.	.	.	F	.	42	.	.	7.1	.	0.7
			6	F	P	.	20.2	0.2	0.6	3	A	.	.	C	F	.	1.1	.	14.3	0.4	.	.	.	.	25.3	41.3	28.6	.	.	.	.	1.3
			5	F	VP	.	11.4	1.3	.	2.3	C	.	0.6	F	F	.	.	.	2.3	.	.	.	.	.	F	F	10.3	.	.	0.7	1.5	0.4
			4	F	VP	.	2.6	0.2	.	2.8	C	.	0.6	C	C	.	.	.	3.6	.	.	.	.	.	F	F	1.9	.	.	.	0.9	2.1
Lang.	MNN 5		3	F	P	0.4	0.4	.	.	.	C	.	17.4	R	.	1.2	.	0.2	14.6	.	.	.	.	.	F	.	.	.	11.9	0.2	.	6.1
			2	F	VP	.	1.9	.	.	.	C	.	3.6	.	.	.	.	.	6.8	.	.	.	.	.	R	.	.	.	40	.	.	0.6
			1	F	VP	.	1.1	.	2.9	14.2	A	.	R	.	.	1.1	.	.	F	.	.	.	.	.	R	.	.	.	24.4	F	.	.

Tab. 9 - Calcareous nannofossil range chart of the Rotondella section. Abundance are reported as N° of specimens/mm² and relative to 300 fields of view. Letters indicate semiquantitative estimate. See legend of Tab. 1.

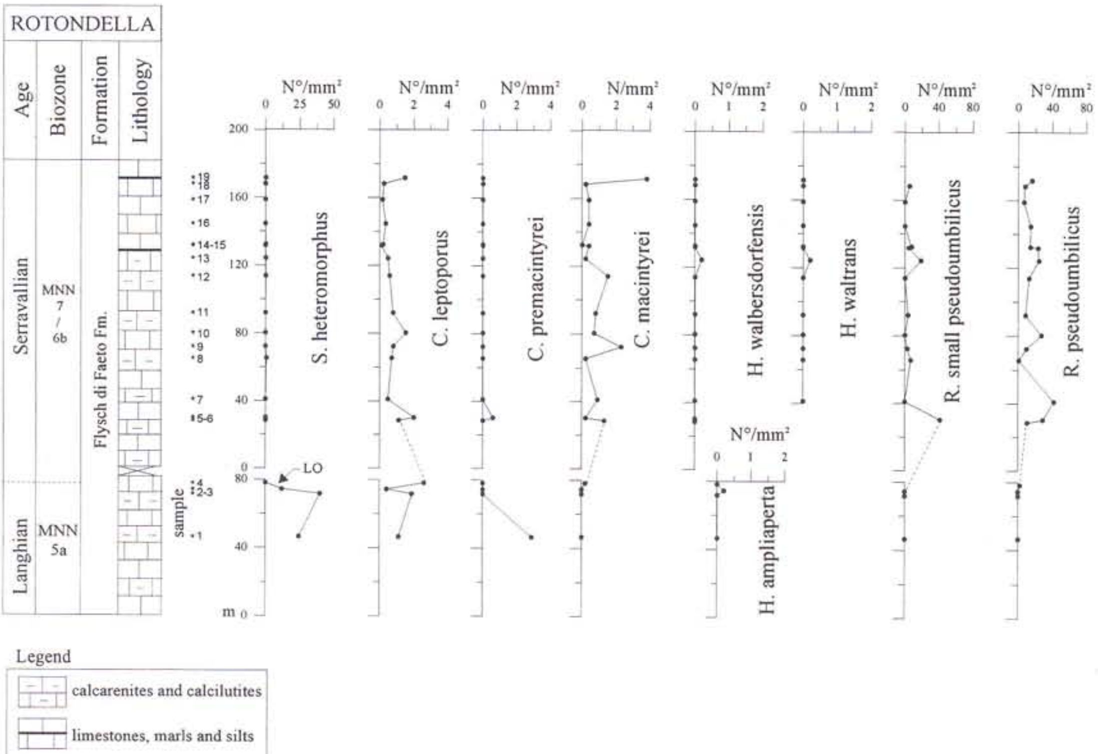


Fig. 11 - Abundance patterns of selected calcareous nannofossils at the Rotondella section. See legend of Fig. 3.

Comparison with previous age assignements in the Southern Apennines sections.

The previous biostratigraphic data on the studied deposits (Serra Palazzo and Flysch di Faeto formations) are mostly based on planktonic foraminiferal assemblages; the comparison between the results obtained in this study and the previous ones thus is not simple, mainly because these latter refer to biostratigraphic and chronostratigraphic terminologies that can be considered out of use at present. Moreover, the correlation between the calcareous nannofossil scheme adopted in this study and the foraminiferal biostratigraphy is not completely established.

For these reasons a synthesis of the main foraminiferal biostratigraphic results obtained in the foredeep sections by previous authors is shown in Tab. 10. In Tab. 11 a tentative correlation between the past chronostratigraphic units adopted in the studied turbidite deposits and the chronostratigraphy used in this study is presented.

The obtained biostratigraphic results provide, for the Serra Palazzo and Flysch di Faeto formations, an age close to the Burdigalian/Langhian boundary (Zones MNN4a-4b) and the Serravallian-Tortonian (Zones MNN7-9) following the chronostratigraphy proposed by Fornaciari et al. (1996). In the upper marly portion of the studied sections (Marne argillose del Toppo Capuana Formation) the interval between MNN7 and *A. primus* Zone has been found.

Previous studies often referred the studied deposits to the upper Langhian - Tortonian (Tab. 10); the discrepancies with the present results mainly concern the age assigned to the lower part of the investigated deposits and this is mainly due to differences in the chronostratigraphic terminology (Tab. 11).

On the other hand, a slightly younger biozonal assignement was inferred by Palmentola (1970) that recognised the *O. suturalis* subzone since the lower part of Serra Palazzo Formation, as well as by Patacca et al. (1991) which recorded *O. suturalis* and *O. bilobata* from the lower part of the Tufillo and Flysch di Faeto formations. Patacca et al. (1992) also suggested a Langhian age for the "Apennine Numidian quartzarenites" (stratigraphically underlying the studied deposits); however they did not record the presence of *Praeorbulina glomerosa sicana* within the "Numidian interval" (tab. 3, p. 323) but referred to data from Carbone et al. (1987).

For the moment the conflicting data in the lower part of the studied sections cannot be interpreted sati-

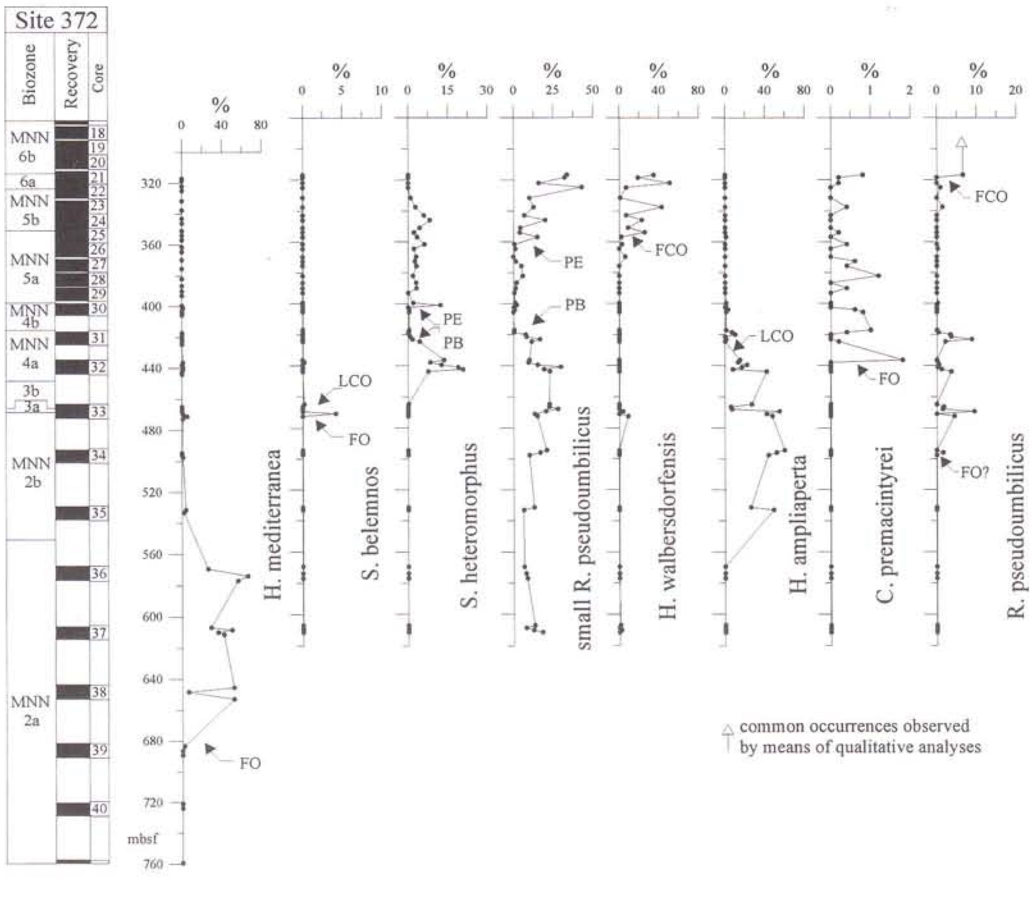


Fig. 12 - Abundance patterns of selected calcareous nannofossils at DSDP Site 372. See legend of Fig. 3.

Author	Formation	Biostratigraphic reference	Biozone	Age
Selli (1962)	Serra Palazzo F.	Selli (1957)		late Langhian-early Helvetian
Selli (1962)	Tufillo F.	Selli (1957)		late Langhian - early Helvetian
Crostella & Vezzani (1964)	Flysch di Faeto F.			Helvetian-early Tortonian
Casnedi (1964)	Serra Palazzo F.	Selli (1957)	lower part of *Orbulina universa* Zone	early Helvetian
Wezel (1966)	Serra Palazzo F.	Wezel (1966)	*Globorotalia fohsi* Zone	early-middle Helvetian
Palmentola et al. (1967)	Stigliano F./Serra Palazzo F. boundary	Crescenti (1966)	*Globigerinoides trilobus* Zone	Langhian
Pieri & Radina (1967)	Stigliano F./ Serra Palazzo F. boundary	Crescenti (1966)	*Globigerinoides trilobus* Zone	Langhian
Boenzi et al. (1968)	lower part of Serra Palazzo F.	Crescenti (1966)	*Globigerinoides trilobus* Zone	Langhian
Palmentola (1970)	Serra Palazzo F.	Cati et al. (1968)	*Orbulina* s.l. Zone, subzone *O. suturalis-Globoquadrina altispira/Globorotalia miozea*	late Langhian-Serravallian
Palmentola (1970)	Flysch di Faeto F.	Cati et al. (1968)	*Orbulina* s.l. - *Globorotalia menardii* Zones, subzone *Globorotalia ventriosa* and *Globorotalia nepenthes*	middle-late Serravallian /early-middle(?)Tortonian
Ciaranfi et al. (1973)	Serra Palazzo F .	Cati et al. (1968)	*Orbulina* s.l. Zone, subzone (?) *Globoquadrina altispira*	Serravallian
Pieri & Walsh (1973)	Serra Palazzo F.	Cati et al. (1968)	*Globigerinoides trilobus* Zone, subzone *Globigerinoides bisphericus* and in the upper part *Praeorbulina glomerosa* s.l. Zone - *Orbulina* s.l Zone.	middle Langhian - early Serravallian
Rapisardi & Walsh (1978)	Flysch di Faeto F.		significant specimens: *G. trilobus, G. altispira, G. dehiscens, O. suturalis, O. universa*	Langhian - Serravallian
Di Nocera & Torre (1987)	Flysch di Faeto F.			late Langhian - Serravallian
Russo & Senatore (1989)	Flysch di Faeto F.	Iaccarino (1985)	*Praeorbulina glomerosa* s.l., - *Globorotalia acostaensis* Zones	early Langhian - early Tortonian
Russo (1988) Russo & Senatore (1989)	Marne argillose del Toppo Capuana F.	Iaccarino (1985)	*Globorotalia acostaensis* - *Globigerinoides extremus* Zones	early-late Tortonian
Patacca et al. (1991)	Tufillo F. and Flysch di Faeto F.		*Orbulina* is present in the lower part	Serravallian-Tortonian

Tab. 10 - Main previous biostratigraphic results in the investigated deposits (Flysch di Faeto Formation, Serra Palazzo Formation, Marne argillose del Toppo Capuana Formation).

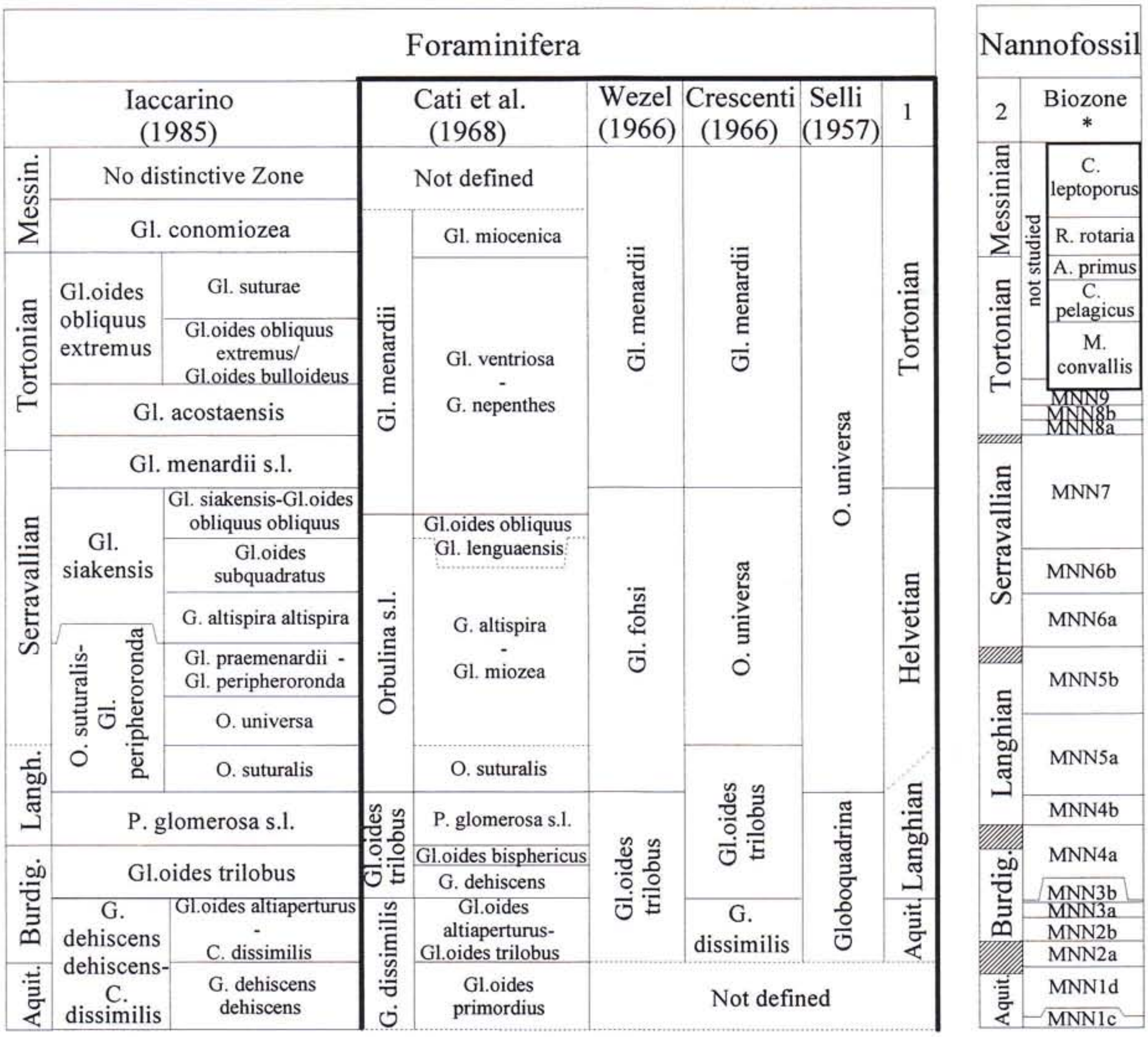
sfyingly. Different intervals of sampling or sligthly different ages in various sections can be invoked. It is unlikely that reworking phenomena prevented the recognition of "younger" assemblages in the studied sections and at the same time generated a sequence of biostratigraphic events comparable to those observed in pelagic and hemipelagic sediments by other authors, as well as in the DSDP Site 372 in this work.

Conclusions.

The quantitative calcareous nannofossil biostratigraphic study performed in nine Miocene Southern Apennines foredeep sections provided new information on the applicability of the recently proposed Mediterranean biozonal schemes. Several biozonal events proposed by Fornaciari & Rio (1996) and Fornaciari et al. (1996) in the lower and middle Miocene sections and by Theodoridis (1984) in the upper Miocene interval have been found. A Burdigalian-upper Tortonian interval between MNN3a and the *Amaurolithus primus* Zone was identified and new biostratigraphic events were proposed.

Within the lower and middle Miocene record the LCO of *H. ampliaperta*, the PB of *S. heteromorphus*, the PE of *S. heteromorphus*, the LO of *S. heteromorphus* and the FCO of *R. pseudoumbilicus*, provide a good biostratigraphic resolution of the studied sections and all furnished useful events for stratigraphic correlation.

On the other hand, some of the biohorizons of the above mentioned zonal schemes, such as the FCO of *H. walbersdorfensis* and the LCO of *C. premacintyrei*, were not always identified. *H. walbersdorfensis* is often not recorded in the interval just below the LO of *S. heteromorphus* and the rare occurrences of *C. premacinty-*



Tab. 11 - Tentative correlations between the foraminifera biostratigraphic schemes and chronostratigraphy adopted in previous age assignements in the foredeep deposits and the biostratigraphic and chronostratigraphic scheme adopted in this work. In column 1 is reported the chronostratigraphy adopted in Selli (1957) and Crescenti (1966); in column 2 the one proposed in Fornaciari & Rio (1996) and Fornaciari et al. (1996) and adopted in this work; the Tortonian-Messinian boundary has been traced according to Langereis et al. (1984). *: Biozone of Fornaciari & Rio (1996) and Fornaciari et al. (1996) in the lower-middle Miocene and of Theodoridis (1984) in the upper Miocene.

rei prevented to obtain significant abundance patterns for the recognition of the LCO of this species.

This quantitative study provides new stratigraphic ranges and biostratigraphic events, which improve the lower and middle Miocene Mediterranean biostratigraphy:

- *R. pseudoumbilicus* has been recorded well below the FCO of the species, in the turbidite deposits as well as in DSDP Site 372. Discontinuous occurrences were noted within Zones MNN2b-3a-3b-4b. It is noteworthy that this is quite useful in the biostratigraphic analyses of the on-land deposits, since the presence of *R. pseudoumbilicus* may wrongly suggest a younger age of the section;

- a distinctive paracme interval of small *R. pseudoumbilicus* was identified within Zones MNN4b and MNN5a: the PB occurs slightly above the PB of *S. heteromorphus* and represents an additional event for the recognition of MNN4b. The PE occurs shortly below the FCO of *H. walbersdorfensis* and can be considered an alternative event to subdivide MNN5. The occurrence of the paracme interval in the same stratigraphic position at Site 372 confirms its potential value for stratigraphic correlation within the Mediterranean region;

- the FCO of *C. macintyrei* is well detectable in the studied sections and represents a more reliable event than the LCO of *C. premacintyrei* within the MNN6b/7 interval. An increase in abundance of *C. leptoporus* was also noted with the FCO of *C. macintyrei*;

- the LCO of *H. walbesdorfensis* appears to be a better biohorizon than the LO of the species for the recognition of the top of Zone MNN7.

At Site 372 the FO of *H. mediterranea* precedes the FO of *H. ampliaperta*.

In the upper Miocene record the *M. convallis*, *C. pelagicus* and *A. primus* Zones of Theodoridis (1984) were recognised. In the upper part of the *M. convallis* Zone abundant specimens referable to *Gephyrocapsa* spp. (about 2 microns in size) were recorded.

The quantitative biostratigraphy was helpful in the stratigraphic reconstruction of the studied deposits, although these are often affected by stratigraphic discontinuities. The recognition of several new biozonal horizons improves the stratigraphic framework of the Miocene foredeep deposits in the Southern Apennines.

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Appendix

List of calcareous nannofossils considered in this work.

Amaurolithus primus (Bukry & Percival, 1971) Gartner & Bukry, 1975
Braarudosphaera bigelowii (Gran & Braarud, 1935) Deflandre, 1947
Calcidiscus leptoporus (Murray & Blackman, 1898) Loeblich & Tappan, 1978
Calcidiscus fuscus (Backman, 1980) Janin, 1987
Calcidiscus macintyrei (Bukry & Bramlette, 1969) Loeblich & Tappan, 1978
Calcidiscus premacintyrei Theodoridis, 1984
Catinaster coalitus Martini & Bramlette, 1963
Coccolithus miopelagicus Bukry, 1971
Coccolithus pelagicus (Wallich, 1877) Schiller, 1930
Coronocyclus nitescens (Kamptner, 1963) Bramlette & Wilcoxon, 1967
Cryptococcolithus mediaperforatus (Gartner, 1992) de Kaenel & Villa, 1996
Cyclicargolithus floridanus (Roth & Hay in Hay et al., 1967) Bukry, 1971
Dictyococcites productus (Kamptner, 1963) Backman, 1980
Dictyococcites perplexus Burns, 1975
Discoaster adamanteus Bramlette & Wilcoxon, 1967
Discoaster asymmetricus Gartner, 1967
Discoaster bellus Bukry & Percival, 1971
Discoaster berggrenii Bukry, 1971
Discoaster brouweri (Tan, 1927) Bramlette & Riedel, 1954
Discoaster challengeri Bramlette & Riedel, 1954
Discoaster deflandrei Bramlette & Riedel, 1954
Discoaster exilis Martini & Bramlette, 1963
Discoaster hamatus Martini & Bramlette, 1963
Discoaster intercalaris Bukry, 1971
Discoaster moorei Bukry, 1971
Discoaster musicus Stradner, 1959
Discoaster neohamatus Bukry & Bramlette, 1969
Discoaster neoerectus Bukry, 1971
Discoaster pentaradiatus (Tan, 1927) Bramlette & Riedel, 1954
Discoaster prepentaradiatus Bukry & Percival, 1971
Discoaster quinqueramus Gartner, 1969
Discoaster signus Bukry, 1971
Discoaster surculus Gartner, 1967
Discoaster tamalis Kamptner, 1967
Discoaster triradiatus Tan, 1927
Discoaster variabilis Martini & Bramlette, 1963
Discoaster variabilis/exilis (*sensu* Rio et al. 1990a)
Discoaster woodringii Bramlette & Riedel, 1954
Geminilithella rotula (Kamptner, 1956) Backman, 1980
Helicosphaera ampliaperta Bramlette & Wilcoxon, 1967
Helicosphaera carteri (Wallich, 1877) Kamptner, 1954
Helicosphaera euphratis Haq, 1966
Helicosphaera mediterranea Müller, 1981
Helicosphaera orientalis Black, 1971
Helicosphaera pacifica Müller & Brönnimann, 1974
Helicosphaera perch-nielseniae Haq, 1971
Helicosphaera scissura Miller, 1981

Helicosphaera stalis Theodoridis, 1984
Helicosphaera vedderi Bukry, 1981
Helicosphaera walbersdorfensis (Müller, 1978) Theodoridis, 1984
Helicosphaera waltrans Theodoridis, 1984
Lithostromation perdurum Deflandre, 1942
Minylitha convallis Bukry, 1973
Pyrocyclus inversus Hay & Towe, 1962
Pyrocyclus orangensis (Bukry, 1971) Backman, 1980
Reticulofenestra minuta Roth, 1970
Reticulofenestra minutula (Gartner, 1967) Haq & Berggren, 1978
Reticulofenestra pseudoumbilicus (Gartner, 1967) Gartner, 1969
small *Reticulofenestra pseudoumbilicus* (5-7 micron)
"large" *Reticulofenestra pseudoumbilicus* (> 12 micron)
Scapholithus fossilis Deflandre in Deflandre & Fert, 1954
Sphenolithus abies Deflandre in Deflandre & Fert, 1954
Sphenolithus abies/neoabies (*sensu* Rio et al., 1990b)
Sphenolithus belemnos Bramlette & Wilcoxon, 1967
Sphenolithus dissimilis Bukry & Percival, 1971
Sphenolithus conicus Bukry, 1971
Sphenolithus heteromorphus Deflandre, 1953
Sphenolithus moriformis (Bronnimann & Stradner, 1960) Bramlette & Wilcoxon, 1967
Sphenolithus neoabies Bukry & Bramlette, 1969
Tetralithoides symeonidesii (Theodoridis, 1984)
Triquetrorhabdulus milowii Bukry, 1971
Triquetrorhabdulus rugosus Bramlette & Wilcoxon, 1967
Triquetrorhabdulus serratus (Bramlette & Wilcoxon, 1967) Olafsson, 1989
Zygrhablithus bijugatus (Deflandre in Deflandre & Fert, 1954) Deflandre, 1959

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