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MAASTRICHTIAN TO EOCENE CALCAREOUS NANNOFOSSIL BIOSTRATIGRAPHY FROM THE TABIAGO SECTION, BRIANZA AREA, NORTHERN ITALY

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Abstract. Calcareous nannofossil biostratigraphic investigations have been carried out on samples collected from the Tabiago section, Brianza, northern Italy. This section records early Maastrichtian (CC23b nannofossil zone) to early Eocene (NP10 nannofossil zone) calcareous nannofossil assemblages. The Cretaceous-Tertiary transition is characterized by major changes in sedimentation rates and two likely stratigraphic gaps. The Cretaceous Brenno Formation was deposited with a high sedimentation rate (~20 m/m.y.), whilst the Tabiago Formation of Paleogene age records a drastic decrease (~10 m/m.y.). The absence of the CC26 zonal marker *Micula prinsii* may indicate a stratigraphic hiatus or an extremely condensed level in the latest Maastrichtian. However, only two samples have been collected and analyzed in this interval due to low exposure of the outcrop, and the absence of *M. prinsii* could be the result of diagenetic overprint or insufficient sampling. A stratigraphic hiatus or a very condensed interval corresponds to the upper part of NP1 nannofossil zone and Pα foraminiferal Zone and P1a Subzone in the early Paleocene. The poor exposure of the outcrop prevents to precisely locate the zonal boundaries between NP4 and NP5 and between NP9 and NP10 and impedes the documentation of possible further stratigraphic gaps or condensed intervals.

Riassunto. La sezione di Tabiago in Brianza (Italia settentrionale) è stata analizzata biostratigraficamente sulla base del contenuto in nannofossili calcarei. La successione esaminata copre l'intervallo dalla Zona CC23b alla Zona NP10 con una età compresa tra il Maastrichtiano inferiore e l'Eocene inferiore. La transizione Cretacico-Paleogene è caratterizzata da un importante cambiamento nel tasso di sedimentazione e da due probabili lacune stratigrafiche. In particolare, il tasso di sedimentazione nella Formazione di Brenno di età cretacica è stato stimato in ~20 m/m.y., mentre nella Formazione di Tabiago di età paleogenica il tasso diminuisce drasticamente a ~10 m/m.y. L'assenza di *Micula prinsii*, specie indice della Zona CC26, suggerisce la presenza di una lacuna o di un intervallo significativamente condensato nel Maastrichtiano sommitale, anche se non si può escludere che tale assenza sia dovuta alla diagenesi o ad un campionamento insufficiente (solo due campioni sono stati analizzati per la parziale copertura dell'intervallo). Nel Paleocene basale una lacuna o un livello estremamente condensato interessa la parte superiore della Zona a nannofossili NP1 e per i foraminiferi la Zona Pα e alla Sottozona P1a. Inoltre, la posizione dei limiti tra le Zone a nannofossili NP4 e NP5 e tra NP9 e NP10 non ha potuto essere identificata in modo preciso per la cattiva esposizione dei relativi intervalli impedendo di fatto il riconoscimento di ulteriori lacune o livelli condensati.

Introduction

Calcareous nannofossils are an outstanding tool for biostratigraphic analyses since they are extremely abundant in pelagic carbonates and largely cosmopolitan. Several biostratigraphic zonations have been published in the last three decades for both Upper Cretaceous and Lower Cenozoic (e.g. Thierstein 1976; Martini 1971; Sissingh 1977; Roth 1978; Okada & Bukry 1980; Perch-Nielsen 1985; Bralower et al. 1995). These biozonations have been successfully used to correlate biostratigraphic ages of outcrops and oceanic sections and have been integrated with other biostratigraphic zonations (e.g., ammonites, planktonic foraminifers, calpionellids,

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diatoms, and radiolarians), chemostratigraphy, and magnetostratigraphy (e.g. Monechi & Thierstein 1985; Bralower et al 1995; Hardenbol et al. 1998).

The present study was designed to support detailed field mapping of the pelagic facies (*"Scaglia lombarda"* Auct.) in the framework of the forthcoming sheet "Seregno" of the New Geological Map of Italy at the 1: 50 000 scale (CARG Project).

The main goal of this study is to provide a detailed sequence of calcareous nannofossil events in the Tabiago section, Brianza area, northern Italy (Fig. 1). This section was previously investigated by Premoli Silva & Luterbacher (1966) and Kleboth (1982) by means of planktonic foraminifers. Planktonic foraminifers indicate that the interval investigated in this study spans the Maastrichtian to Paleocene and encompasses the Cretaceous/Tertiary (K/T) boundary (Premoli Silva & Luterbacher 1966). Our calcareous nannofossil investigations have allowed to refine the biostratigraphy obtained from the planktonic foraminifers and possibly outline the presence of unconformities/stratigraphic gaps.

Geological Setting

Pelagic sedimentation prevailed around the Cretaceous/Paleogene boundary in the study area (Premoli Silva & Luterbacher 1966; Poletti et al. 2004). The sedimentary succession of the Southern Alps was deposited at a passive margin of the Adriatic-Apulian microplate, where a thinned continental crust faced the Jurassic Alpine Tethys. Passive margin evolution is recorded since the Sinemurian and is associated with the break-up of the Alpine Tethys (Bernoulli 1964; Bertotti et al. 1993). This scenario evolved during pronounced thermal subsidence and led to reduced sediment accumulation from the Bajocian to the Aptian, when radiolarian and nannoconid oozes were deposited (Winterer & Bosellini 1981; Baumgartner et al. 1995). After a stage of intrabasinal carbonate resedimentation during the Albian, flysch successions fed by an early orogenic wedge of the Alpine belt were deposited since the Cenomanian and comprise up to about 2.5 km in thickness (Bersezio et al. 1993). Deposition of clastic debris in the uppermost Cretaceous flysch unit (Bergamo Flysch Formation) gradually ended in late Campanian *Globotruncanita calcarata* zone (Kleboth 1982), when pelagic sedimentation resumed.

Although in general the facies of the post-Campanian pelagic succession resembles the *Scaglia* facies, well known in the Apennines and eastern Southern Alps (Veneto and Trentino), correlation with formally-established units of the *Scaglia* facies (*Scaglia Bianca*, *Rossa*, and *Cinerea*: Cita Sironi et al. 2006) would be misleading for the Brianza region. There, the lithostratigraphy proposed by Kleboth (1982) is preferred. The pelagic succession is thus divided into two formations: a lower Brenno Formation and an upper Tabiago Formation.

The Brenno Formation (= "Brenno Stage" Auct.) reaches up to 200 m in thickness and consists of white to pinkish calcareous marlstones to micritic limestones and subordinate clastic layers (Kleboth 1982). Marlstones and limestones are commonly arranged in couplets as a probable response to orbitally-controlled fluctuations of plankton productivity and clayey input from emerged areas. On fresh surfaces, a brownish colour associated with conchoidal fracture and abundant Cretaceous foraminifers, commonly recognized with the hand lens, are distinctive characteristics. Thin beds of hybrid arenites containing quartz and white mica flakes as well as carbonate, cherty, and granitoid rock fragments are diffuse, whereas siliciclastic conglomerates are confined to a single ~1 m-thick layer at Tabiago (Premoli Silva & Luterbacher 1966). *Inoceramus* lags have been observed in a single layer (sample TT 8) and may suggest downslope transport from the continental shelf.

The Tabiago Formation is a Cenozoic hemipelagic succession as defined by Kleboth (1982), measuring up to 130 m in the Tabiago section. There, the upper boundary is not exposed. The lower part of this formation consists of reddish, pinkish, grey and varicoloured calcareous marlstones to marly limestones cyclically alternating with clayey marlstones (Poletti et al. 2004). In particular, an 11 m-thick marly unit (marly bank in Poletti et al. 2004) has been described in the middle part of the section, overlain by 20 m-thick turbiditic beds. These turbidites consist mainly of dm-thick beds of fine calcirudites to coarse-grained calcarenites containing abundant shallow-water benthic foraminifers (*Assilina*, *Asterocyclina*, *Discocyclina*, *Nummulites*, *Operculina* among others: Fig. 2), with subordinate glauconite and phosphate, all assumed to represent downslope transport. The Tabiago Formation passes upwards to grey clayey and silty marlstones that cannot be included in a generic *Scaglia* facies (Gavazzi et al. 2003). The informal name "Gallare Marls" is used by ENI/AGIP petroleum geologists for identical and coeval facies cored in oil drillings (Di Giulio et al. 2001), and could be extended to the Brianza outcrops as well. Possibly almost 100 m of such marlstones are exposed in a small stream near Ceresa di Cibrone. From ENI/AGIP seismic profiles (Pieri & Groppi 1981), it appears that all this tightly folded Cretaceous-Paleogene succession is thrusted over a Miocene succession belonging to the Gonfolite Lombarda Group (Sciunnach & Tremolada 2004). The thrust seemingly pre-dates the unconformably overlying Messinian to Holocene succession and could be thus ascribed to a Late Miocene (probably

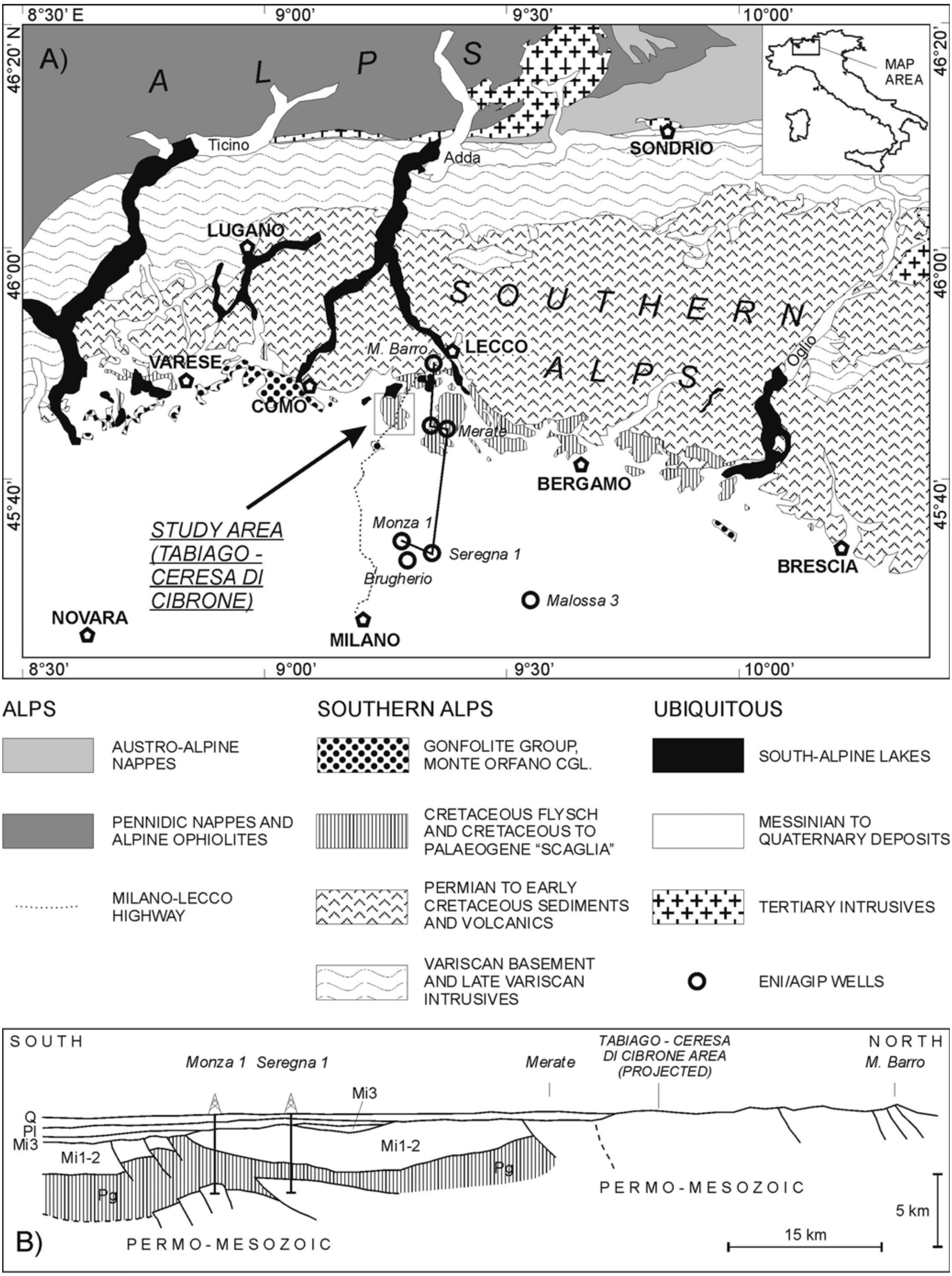

Fig. 1 - A) Tectonic map of the western Southern Alps. B) Simplified seismic section along the N-S trace in A (redrawn after Pieri & Groppi 1981): Pg = Paleogene; Mi1-2 = Lower to Middle Miocene; Mi3 = Upper Miocene (essentially Messinian); Pl = Pliocene; Q = Quaternary.

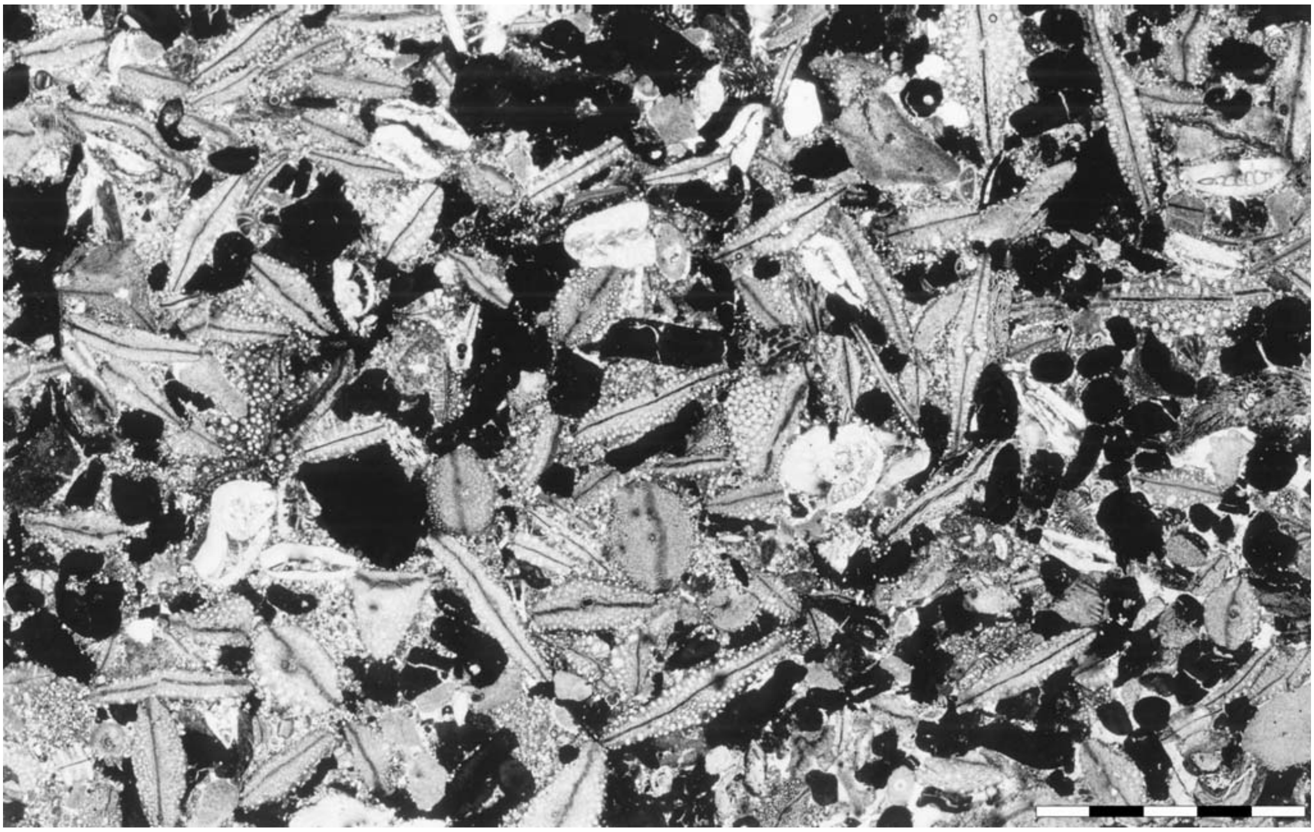

Fig. 2 - Photomicrograph of a thin section of fine-grained calcirudite from the Tabiago Formation (Rio Gambaione Quarry, sample 227.2.1) with dominant large benthic foraminifera (mainly discocyclinids and subordinate nummulitids), some coralline algae and a few intraclasts. Scale bar: 5 mm. Sample coordinates: Gauss-Boaga/Roma 40 (West Zone) 1 522 196 E, 5 066 282 N.

Tortonian) tectonic climax (late "Lombardic Phase" of Schumacher et al. 1996).

According to biostratigraphic data available in the literature (Premoli Silva & Luterbacher 1966; Kleboth 1982), the Brenno Formation spans the late Campanian to late Maastrichtian (*Globotruncanita calcarata* to *Abathomphalus mayaroensis* Zones), while the Tabiago Formation is dated as Paleocene to Middle Eocene (*Parasubbotina pseudobulloides* to possibly *Hantkenina aragonensis* Zones). The formational boundary between the two units coincides with the K/T boundary (Kleboth 1982). A stratigraphic gap is commonly recognised in the Lower Paleocene (Premoli Silva & Luterbacher 1966; Kleboth 1982). For the "Gallare Marls", biostratigraphic analyses performed with planktonic foraminifers (Premoli Silva & Luterbacher 1966; Gavazzi et al. 2003; I. Premoli Silva unpubl. data) and calcareous nannofossils (Gavazzi et al. 2003; F. Tremolada unpubl. data) indicate a Middle Eocene age.

A sharp decrease in sedimentation rate appears to have occurred across the K/T boundary. In fact, the Brenno Formation was deposited at ~20 m/m.y. (undecompacted thickness), whereas the Tabiago Formation at ~10 m/m.y. In the pelagic realm, such a drop in sedimentation rate may suggest reduced carbonate production, and/or the occurrence of hiatuses, following the K/T biotic crisis. A subsequent increase in sedimentation rate seems to be recorded in the overlying and less calcareous "Gallare Marls", and was seemingly triggered by a renewed siliciclastic input.

Material and Methods

Biostratigraphic investigations were performed on 64 samples collected from limestones, marly limestones, and marlstones of the classic Tabiago section (Fig. 3), near the small town of Tabiago. The section consists of two portions exposed on either side of the road cut of the Milano-Lecco highway. The Milano section is located on the western side of the Milano-Lecco highway leading to Milano, whilst the Lecco section on the eastern side leading to Lecco. Samples were prepared as smear slides by using the standard techniques described in Bown & Young (1998). No ultrasonic cleaning or centrifuge concentration were applied in order to retain the original biogenic composition of rock samples. Calcareous nannofossils were analyzed under the light microscope at 1250x magnification following the taxonomic schemes of Thierstein (1976), Romein (1977), Aubry (1984, 1988, 1989, 1990), Perch-Nielsen (1985), Varol (1998), and Burnett (1998). All specimens were identified at the species level. The CC biozonation of Sissingh (1977), with a few modifications proposed by Monechi & Thierstein (1985), Bralower et al. (1995), and Gardin et al. (2001), was adopted in the Cretaceous portion of the Tabiago section. The Paleocene biostratigraphic zonation is that of Martini (1971) refined by Perch-Nielsen (1985). Etching (E index) and overgrowth (O index) of calcareous nannofloras were estimated by using the categorization described by Roth (1978) and Bown & Young (1998).

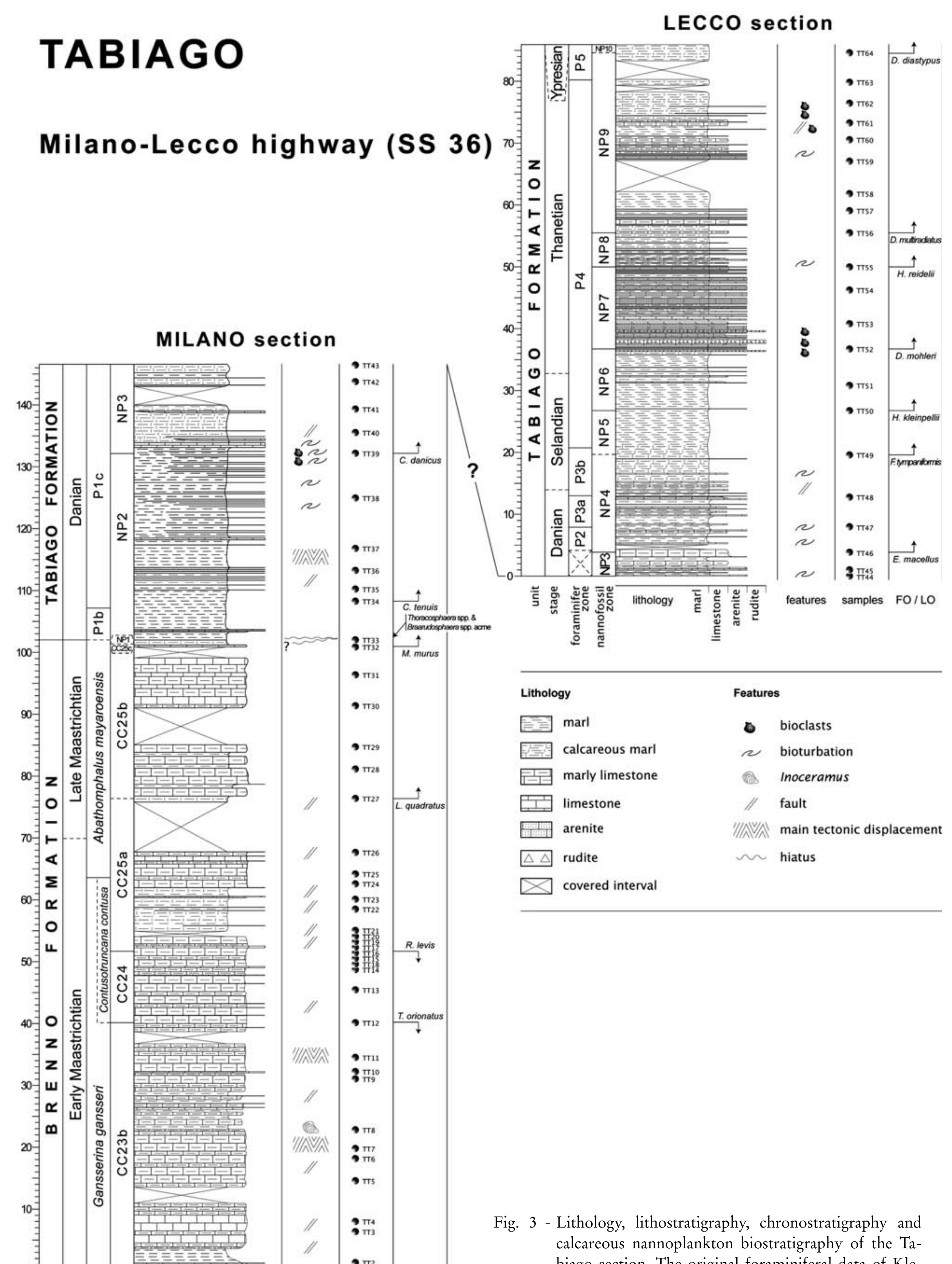

Fig. 3 - Lithology, lithostratigraphy, chronostratigraphy and calcareous nannoplankton biostratigraphy of the Tabiago section. The original foraminiferal data of Kleboth (1982) are also plotted by using the biozonation of Premoli Silva & Sliter (1995) with some modifications from Olsson et al. (1999).

Calcareous nannofossil biostratigraphy

Cretaceous

Calcareous nannofossils are abundant and show generally moderate to good preservation. A few samples at the top of this interval are characterized by poorer preservation (E3, O3; Appendix a). All specimens were identified at the species level, although fragile taxa display somewhat altered morphological characteristics in moderately- or poorly-preserved nannofloral assemblages. The bottom of the studied section is assignable to the Early Maastricthian CC23b nannofossil zone, based on the occurrence of *Uniplanarius trifidus* and *Tranolithus orionatus*, and the absence of *Eiffellithus eximius* and *Aspidolithus parcus* in the lowermost sample investigated (TT 1, Fig. 3). The planktonic foraminiferal assemblage indicates the *Gansserina gansseri* zone (Kleboth 1982), which correlates with the CC23b nannofossil zone. The base of CC24 is defined by the Last Occurrence (LO) of *T. orionatus*. This event is recorded in sample TT 12 together with the LO of *U. trifidus*. The most abundant taxa in this interval are *Watznaueria barnesiae*, *Eiffellithus turriseiffelii*, *Micula decussata*, *Quadrum* spp., *Cretarhabdus* spp., *Cribrosphaerella ehrenbergii*, and *Zeughrabdotus erectus*. The LO of *Reinhardtites levis*, which defines the base of CC25a, was observed in sample TT 16. The sedimentary interval between the LO of *R. levis* and the first occurrence (FO) of *Lithastrinus quadratus* (sample TT 27) is characterized by low-diversity nannofossil assemblages and fairly abundant specimens of large-sized *Arkhangelskiella* (*A. cymbiformis*) specimens. The genus *Arkhangelskiella* here shows a maximum diameter >10 μm. This peculiarity has already been documented in the Tethys area (e.g. Perch-Nielsen 1985; Gardin 2002). In addition, this interval records the FO of *Lithastrinus prequadratus* in sample TT 22. The FO of *Lithastrinus quadratus* was observed in sample TT 27 and marks the base of CC25b according to Perch-Nielsen (1985). Sample TT 32 contains a calcareous nannofloral assemblage characterized by high abundances of *Micula* spp. and placolith-bearing taxa. This sample has been assigned to CC25c based on the presence of *Micula murus*.

The following sample (TT 33) shows a major change in the calcareous nannofossil assemblage. Two smear slides were obtained from sample TT 33 with a spacing of 4 cm. Cretaceous coccoliths are absent and calcareous nannofossil communities are dominated by *Braarudosphaera* and *Thoracosphaera* in the lower smear slide (TT 33bottom). Blooms of these taxa characterize the Cretaceous/Tertiary transition in a number of proximal and open-ocean settings (e.g. Bramlette & Martini 1964; Perch-Nielsen 1969; Romein 1977; Thierstein 1981). In particular, their acme peaks have been described slightly above the K/T boundary layer in several low latitude sections (e.g. Perch-Nielsen 1969; Seyve 1990; Gardin & Monechi 1998), indicating that sample TT 33bottom can be assigned to the NP1 zone (Martini 1971). Since the FOs of *Nephrolithus frequens* and *Micula prinsii* were not observed, the entire CC26 nannofossil zone and, probably, the upper part of the CC25c nannofossil subzone may be missing in the Tabiago section. However, because of poor exposure only two samples were collected in this portion of the section and *M. prinsii* is difficult to identify in moderately- to poorly-preserved calcareous nannofossil assemblages. The taxon *N. frequens* is generally rare at low latitudes and its absence could be the result of bioprovincialism. The FO of *M. prinsii* has been dated at 66.15 Ma in modern timescales (e.g. Hardenbol et al. 1998), and if we assume that its absence is a primary signal, the possible hiatus between zones CC25c to NP1 corresponds to at least 1.15 Myr. Alternatively, the uppermost Maastrichtian could be represented by an extremely condensed interval in the Tabiago section.

The second smear slide, prepared from the top of sample TT 33 (TT 33top), contains high abundances of reworked Cretaceous taxa such as *Watznaueria* spp., *Prediscosphaera* spp., *Nannoconus* spp., *Cretarhabdus* spp., and *E. turriseiffelii*, together with the typical nannofloral assemblage of NP2, including *Cruciplacolithus primus* and *Cruciplacolithus tenuis*, which marks the base of NP2 (Martini 1971; Perch-Nielsen 1985). This finding indicates that NP1 is confined to sample TT33bottom. In addition, no specimens of *Neobiscutum romeinii* and *Neobiscutum parvulum*, whose stratigraphic range is restricted to NP1, have been observed in the Tabiago section. Blooms of these taxa generally postdate that of *Thoracosphaera* spp. and have been documented in several Tethys sections (e.g. Gardin & Monechi 1998; Gardin 2002).

A similar early Paleocene planktonic foraminiferal fauna was observed in both thin sections cut across sample TT 33. Contrary to what was observed in the calcareous nannofossil assemblages, no differences could be detected from bottom to top except for a slightly more accentuated bioturbation in the bottom of the thin section. Based on the occurrence of a few *Subbotina triloculinoides* and rare *Praemurica inconstans* specimens, this very rich assemblage has been assigned to Subzone P1b of Zone P1 defined by Olsson et al. (1999), in agreement with Premoli Silva & Luterbacher's attribution (1966). These results indicate that the foraminiferal Zone Pα (=*Parvularugoglobigerina eugubina* Zone) and Subzone P1a are lacking. Premoli Silva & Luterbacher (1966) have documented the absence of Zone Pα and Subzone P1a in a number of sections in the Lombardy basin and on the Trento high. As a result, the integration of calcareous nannofossil and foraminiferal data suggests that NP1 is greatly condensed or partially missing in the Tabiago section.

Paleogene

The preservation of Paleogene calcareous nannofossils ranges from moderate to poor, although their abundance is extremely high (Appendix b). Nannofossil assemblages from TT 33top to TT 38 display significant abundances of *Praeprinsius dimorphosus*, whereas taxa such as *Coccolithus pelagicus*, *Cruciplacolithus primus*, *Placozygus sigmoides*, and *Markalius inversus* represent relatively minor components. The FO of *Chiasmolithus danicus*, which marks the base of NP3, was observed in sample TT 39. The base of NP4 is defined by the FO of *Ellipsolithus macellus*, which lies in sample TT 46, associated with the FO of *Neochiastozygus saepes*. The taxon *E. macellus* is relatively rare and displays a patchy occurrence. The interval between samples TT 38 and TT 47 is characterized by a nannofloral assemblage dominated by the genus *Prinsius* (especially *P. martinii*). Sample TT 49 records the FO of *Fasciculithus tympaniformis*, the bioevent that defines the base of NP5. The FOs of other *Fasciculithus* species such as *F. magnus*, *F. bitectus, F. ulii*, *F. pileatus*, and *F. janii*, which generally predate the FO of *F. tympaniformis* (Perch-Nielsen 1985), were observed in the same sample. It may be assumed that the true FOs of *F. magnus*, *F. bitectus*, *F. ulii*, *F. pileatus*, and *F. janii* fall between samples TT 48 and TT 49, which lie 6.8 m apart. Unfortunately, the poor exposure of the outcrop prevents a more accurate sampling that would clarify the presence of unconformities. Sample TT 50 is characterized by the FO of *Heliolithus kleinpellii*, which indicates the base of the NP6 nannofossil zone. In this sample, the calcareous nannofossil assemblage consists mainly of *Toweius* spp., *C. pelagicus*, *Sphenolithus* spp., *Bomolithus* spp., and *Fasciculithus* spp. The base of NP7 is defined by the FO of *Discoaster mohleri*, which lies in sample TT 52. The FOs of *Heliolithus reidelii* and *Discoaster nobilis* define the base of NP8 and CP7 nannofossil zone (Okada & Bukry 1980), respectively. These taxa were first observed in sample TT 55. The base of NP9 was placed in sample TT 56 based on the FO of *Discoaster multiradiatus*. Sample TT 58 records the FOs of *Fasciculithus schaubii* and *Fasciculithus richardii*, whereas their LOs were observed in sample TT 61. In addition, sample TT 58 contains the FO of *Zyghrablithus bijugatus*. The moderate to fairly poor preservation of nannofloras between sample TT 59 and TT 63 hindered the identification of the calcareous nannofossil assemblage that characterizes the Paleocene-Eocene Thermal Maximum at the top of NP9. The uppermost sample investigated in this study (TT 64) records the FO of *Discoaster diastypus*, which defines the base of NP10 of Early Eocene age. The NP9/NP10 zonal boundary cannot be precisely marked since a low-resolution sampling due to poor exposure of the outcrop (Fig. 3). Thus, it is unclear if the Paleocene-Eocene Thermal Maximum interval is absent and the NP9-NP10 transition is characterized by major changes in sedimentation rate or stratigraphic gaps.

Conclusions

Several important nannofossil events have been recognized and most zonal markers display a continuous occurrence in the Tabiago section. The investigated section spans, almost continuously, the early Maastrichtian CC23 to the Early Eocene NP10 nannofossil zone. Limited tectonic displacements, such as faults and folds, observed in outcrops are below biostratigraphic resolution. The Cretaceous and Tertiary intervals investigated show prominent variations in sedimentation rate. The Brenno Formations is characterized by a sedimentation rate of ~20 m/m.y., whilst the Tabiago Formation is marked by dramatic decrease to ~10 m/m.y. Two major stratigraphic gaps seem to be associated with the Cretaceous-Tertiary transition. The first possible hiatus has been observed in the latest Maastrichtian, where the absence of the zonal marker *M. prinsii* may imply that the whole of the CC26 zone and possibly a part of the CC25c subzone may be missing or extremely condensed. Since only one sample was collected between TT 31 and TT 33bottom due to poor exposure of the outcrop, it is unclear if the lack of *M. prinsii* represents a primary signal, the result of diagenetic alteration or insufficient sampling. The sample TT 33bottom contains a nannofloral assemblage dominated by pentaliths (e.g. *Braarudosphaera* spp.) and *Thoracosphaera* spp. indicating the early Paleocene NP1, whereas sample TT 33top shows the FO of *C. tenuis*, which occurs at the base of zone NP2. Thin-section investigations performed on planktonic foraminifers reveal the absence of the foraminiferal Zone Pα and Subzone P1a. This indicates that the NP1 zone is markedly reduced as a result of a low sedimentation rate or a stratigraphic hiatus. Insufficient sampling due to poor exposure of the outcrop prevents to clarify if the transitions between NP4 and NP5 and between NP9 and NP10 record some unconformities or reduced sedimentation rate.

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Nannofossil zones (Sissingh 1977)	sample	Etching	Overgrowth	Abundance	*Watznaueria* spp.	*Tegumentum stradneri*	*Biscutum constans*	*Biscutum magnum*	*Zeugrhabdotus elegans*	*Zeugrhabdotus erectus*	*Zeugrhabdotus diplogrammus*	*Zeugrhabdotus trivectis*	*Prediscosphaera cretacea*	*Prediscosphaera spinosa*	*Prediscosphaera ponticula*	*Prediscosphaera grandis*	*Chiastozygus litterarius*	*Chiastozygus platyrhethus*	*Ahmuellerella octoradiata*	*Arkhangelskiella cymbiformis*	*Arkhangelskiella cymbiformis* >10µm	*Arkhangelskiella specillata*	*Arkhangelskiella maastrichtiana*	*Cribrosphaerella ehrenbergii*	*Microrhabdulus decoratus*	*Ceratolithoides aculeus*	*Ceratolithoides kamptneri*	*Rhagodiscus angustus*	*Rhagodiscus splendens*	*Placozygus fibuliformis*	*Placozygus sigmoides*	*Kamptnerius magnificus*	*Gartnerago obliquum*	*Staurolithites imbricatus*	*Staurolithites ellipticus*	*Staurolithites zoensis*	*Manivitella pemmatoidea*	*Cretarhabdus crenulatus*	*Cretarhabdus conicus*	*Cretarhabdus striatus*	*Eiffellithus turriseiffelii*	*Eiffellithus gorkae*	*Tranolithus minimus*	*Tranolithus orionatus*	*Quadrum gartneri*	*Uniplanarius sissinghii*	*Uniplanarius trifidus*	*Reinhardtites* spp.	*Reinhardtites levis*	*Lithraphidites carniolensis*	*Lithraphidites praequadratus*	*Lithraphidites quadratus*	*Micula decussata*	*Micula concava*	*Micula murus*	*Thoracosphaera* spp.	*Braarudosphaera* spp.	
NP1	TT 33bottom	E3	O3	C																																																		R				A	A	Hiatus?
CC25c	TT 32	E3	O3	F	F						R											F				F																														R			C			R		
CC25b	TT 31	E2	O2	F	F	R	R				R										R				F																				R															R			F					
	TT 30	E1	O1	F	C		R				R		R				R		R	R	R			F	R	R	R																	R															R		R	F					
	TT 29	E1	O1	F	F		R						R							R				R																				R			R													R		R	C					
	TT 28	E2	O2	A	A	R	R				R		R	R						R	R			R	R			R		R																	R															R		R	C					
	TT 27	E1	O1	A	A	R					R		R				R				R			F		R	R				R										R			R															R	R	F					
CC25a	TT 26	E2	O1	A	C	R	R				R		R				R			F	R			F		R																	R															R			F					
	TT 25	E2	O2	A	C	R	R										R			R	R	R		F	R	R	R	R											R	R														R			F					
	TT 24	E2	O2	C	C	R	R	R			R						R	R		R	F			R							R	R											R	R									R	R		F	F					
	TT 23	E1	O2	A	A						R		R	R		R				R	F			R	R	R				R									R	R		F										R			R	F					
	TT 22	E2	O1	F	F								R							R	F			F		R							R	R				R		F	R			R					R	R		F	R					
	TT 21	E1	O1	A	A	R														F	F	R	R						R															R																	R	F					
	TT 20	E2	O2	C	C				R		R		R				R		R	R	C			R	R																R	R	R											R								
	TT 19	E1	O1	C	C		R						R		R	R	R		R	F	R	R	R		R		R																F												R	F					
	TT 18	E2	O1	C	C	R			R		F		F							R	F			C	R	R					R	R							R	R		R	R								R			F	F					
	TT 17	E1	O1	F	F	F	R		R		R		R	F			R			F	F			R												R		R																		R			F	F					
CC24	TT 16	E1	O1	A	F		R	R	R		F		R							F	R			C		R		R												R		R	R	R								R	R			F					
	TT 15	E2	O2	F	F	R	R						R	R						F				F	R	R						R											F	R			R				R	R			F	F					
	TT 14	E1	O1	A	C	R	R		R	R	R		R		R		R		R	R		R		C	R	R		R	R	R			R									F									R	R			F	F					
	TT 13	E2	O2	A	C		R						R				R			C	R			R	R													R	R		R	F	R																			
CC23b	TT 12	E1	O1	A	C		F		R	R	F		F		R	R	R			R				R		R						R						R	R	R	F	R		R			R	R	R	R			F	F					
	TT 11	E2	O2	C	F		R				F		F	R			R			R				F	R	R		R			R			R	R	R		F		R	F			R		R	R	R					F	F					
	TT 10	E2	O2	A	C	R	F		R		R		C							F		R		C	R	R					R		R								F	R		F	R						R	R	R	R			F	R					
	TT 9	E2	O2	C	C	R	F		R		F	R	R							F				C		R		R													R		R	F	R		R	R	R	R	R		R			F	F					
	TT 8	E1	O1	A	C	R	R		R	R	R		F	R	R		R	R	R	R	R			C	R	R							R					R	R			F						R	R	R	R	R			F						
	TT 7	E1	O1	A	A	R	F			R	C	R	R	R			R			R		R		F	R			R			R		R						F	R		F								R			R			R						
	TT 6	E2	O2	A	A	R	F				F		F	R	R		R			F				C	R	R								R							F			C	R		R		R	F	R	R	R			C						
	TT 5	E2	O2	A	A	R	F		R	R	F		R	R	R	R	R			F				C	R	R		R				R								F			F	R		R			R	R	R	R			F	F					
	TT 4	E2	O2	A	A		F				C		F	R	R		R			F				C						R										F			F	R					R	R	R				F	F					
	TT 3	E1	O2	C	C		R		R	R	F	R	F	R	R					F		R		F	R	R		R	R							R			F			C	R	R	R	R	R	R	R	R				F	F					
	TT 2	E1	O1	A	A		R			R	F		F	R	R		R			R				F				R						R		R		F	R		F						R	R	R	R			F	F					
	TT 1	E1	O1	A	A					R	R		F	R						F				C				F						R				R			F			R		R	R		R				R						

Appendix a - Distribution chart of calcareous nannofossils observed in the Cretaceous portion of the Tabiago section. The gray pattern indicates the event defining calcareous nannofossil zones. Total calcareous nannofossil abundance: A= Abundant= >50 specimens/Microscope field of view (FOV); C= Common= 10-50 specimens/FOV; F= Few= 1-10 specimens/FOV; R= Rare= <1 specimen/FOV.
Single taxon abundance: A= Abundant= >10 specimens/FOV; C= Common= 1-10 specimens/FOV; F= Few= 1 specimen/2-50 FOV; R= Rare= 1 specimen/>50 FOV.

Nannofossil zones (Martini 1971)	sample	Etching	Overgrowth	Abundance	*Thoracosphaera* spp.	*Braarudosphaera* spp.	*Cruciplacolithus tenuis*	*Cruciplacolithus primus*	*Coccolithus pelagicus*	*Markalius inversus*	*Praeprinsius dimorphosus*	*Placozygus sigmoides*	*Prinsius petalosus/tenuiculum/africanus*	*Chiasmolithus* cf. *edwarsii*	*Chiasmolithus bidens*	*Chiasmolithus danicus*	*Prinsius bisulcus*	*Prinsius martinii*	*Neochiastozygus saepes*	*Neochiastozygus perfectus*	*Neochiastozygus junctus*	*Ellipsolithus macellus*	*Ellipsolithus distichus*	*Ericsonia subpertusa*	*Ericsonia robusta*	*Fasciculithus tympaniformis*	*Fasciculithus* spp.	*F. ulii/pileatus/janii/magnus/bitectus*	*F. schaubii/richardii*	*Sphenolithus primus*	*Sphenolithus anarrophus*	*Heliolithus kleinpellii*	*Bomolithus elegans*	*Toweius* cf. *pertusus*	*Toweius pertusus*	*Toweius eminens*	*Discoaster* spp. (unidentifiable forms)	*Discoaster mohleri*	*Heliolithus reidelii*	*Discoaster nobilis*	*Discoaster multiradiatus*	*Zyghrablithus bijugatus*	*Discoaster diastypus*
NP10	TT 63	E3	O3	F					F																	R	R			F					F	R	F				F	F	R
NP9	TT 62	E2	O2	C					C	R														F	R	C	F			F	R				C	R	F				F	F	
	TT 61	E3	O3	C					C						R		R				R	R		F	R	C	F		F	F	R				C	R	F				C	F	
	TT 60	E2	O2	C	R				F	R		R					R							F	R	F	F		F	F	R				F	F	F	R			F	F	
	TT 59	E2	O3	C					F			R					R							R	R	F	F		F	F	R				F		F			R	F	F	
	TT 58	E2	O2	C					F			R			R							R	R			F	F		R	R	R				C		R			R	R	F	
	TT 57	E3	O3	C					F	R					R		R							R	R	F	R			F					F	R	F	R			F		
	TT 56	E2	O2	C	R				F													R				F	R			F	R				F		F			R	R		
NP8	TT 55	E3	O3	A					F			R			R		R									F	C			F	R	R	R		C		R	R	R	R			
NP7	TT 54	E3	O3	A		R			C	R					R						R	R		R		F	F			F	R	R			F		R	R					
	TT 53	E3	O3	C	R				F						R		R									R	F			R			R		F			F					
	TT 52	E3	O3	F					F			R										R				R	R			F	R	F	F		F			R					
NP6	TT 51	E2	O2	F			R		F															R		F	F			F		R	R		F								
	TT 50	E3	O3	F	R				F						R			R		R						F	F	F		R		F	R	F									
NP5	TT 49	E3	O3	C					C	R									R							R	R	R		R				R									
NP4	TT 48	E2	O2	R					F			R					R	R				R		R																			
	TT 47	E3	O3	A	R				F									A	R																								
	TT 46	E2	O2	A			R		F	R	R					R		A	R			R																					
NP3	TT 45	E3	O3	A					F			R				R		A																									
	TT 44	E3	O3	A	R		R		R							R		A																									
	TT 43	E3	O3	A					R	R	R			R		R		A																									
	TT 42	E2	O3	A				R	F		F		F			R		A																									
	TT 41	E3	O3	A			R		F		C	R	C			R		A																									
	TT 40	E3	O3	A	R		R	R	F		C		A					A																									
	TT 39	E3	O3	A					R		C	R	A			R		A																									
NP2	TT 38	E3	O2	A			R	R	F	R	C		C					C																									
	TT 37	E3	O3	A			R	R	F	R	A		R					R																									
	TT 36	E3	O3	A			F	R	R	R	A	R	R																														
	TT 35	E3	O3	A			R	R	F	R	A		R																														
	TT 34	E3	O3	C			F	R	F	R	C	R	R																														
	TT 33top	E3	O3	F	R		R	R	F	R	F	R																															
NP1	TT 33bottom	E3	O3	C	A	A																																					

hiatus

Appendix b - Distribution chart of calcareous nannofossil zonal markers and selected taxa observed in the Paleogene portion of the Tabiago section. Abundances of calcareous nannofossils as in Appendix “a”.

REFERENCES

Aubry M.-P. (1984) - Handbook of Cenozoic calcareous nannoplankton. Book 1: Ortholithae (Discoasters). Micropaleontology Press, American Museum of Natural History, 1-266, New York.

Aubry M.-P. (1988) - Handbook of Cenozoic calcareous nannoplankton. Book 2: Ortholithae (Holococcoliths, Ceratoliths, Ortholiths and others). Micropaleontology Press, American Museum of Natural History, 1-279, New York.

Aubry M.-P. (1989) - Handbook of Cenozoic calcareous nannoplankton. Book 3: Ortholithae (Pentaliths, and others), Heliolithae (Fasciculiths, Sphenoliths and others). Micropaleontology Press, American Museum of Natural History, 1-279, New York.

Aubry M.-P. (1990) - Handbook of Cenozoic calcareous nannoplankton. Book 4: Heliolithae (Helicoliths, Cribriliths, Lopadoliths and others). Micropaleontology Press, American Museum of Natural History, 1-381, New York.

Baumgartner P.O., Martire L., Gorican S., O'Dogherty L., Erba E. & Pillevuit A. (1995) - New Middle and Upper Jurassic radiolarian assemblages co-occurring with ammonites and nannofossils from the Southern Alps (Northern Italy). In: Baumgartner P.O. et al. (Eds) - Middle Jurassic to Lower Cretaceous Radiolaria of Tethys: Occurrences, systematics, biochronology. *Mém. Géol.,* 23: 737-750, Lausanne.

Bersezio R., Fornaciari M., Gelati R., Napolitano A. & Valdisturlo A. (1993) - The significance of the Upper Cretaceous to Miocene clastic wedges in the deformation history of the Lombardian southern Alps. *Géol. Alp.,* 69: 3-20, Grenoble.

Bernoulli D. (1964) - Zur geologie des Monte Generoso. *Beitr. geol. Karte Schweiz* N.F., 118: 1-134, Bern.

Bertotti G., Picotti V., Bernoulli D. & Castellarin A. (1993) - From rifting to drifting: tectonic evolution of the South-Alpine upper crust from the Triassic to the Early Cretaceous. *Sed. Geol.,* 86: 53-76, Amsterdam.

Bown P.R. & Young J.R. (1998) - Techniques. In: Bown P. (Ed.) - Calcareous Nannofossil Biostratigraphy. Kluwer Academic Publishers, 16-28, London.

Bralower T.J., Leckie R.M., Sliter W.V. & Thierstein H.R. (1995) - An integrated Cretaceous microfossil biostratigraphy. In: W.A. Berggren, Kent D.V., Aubry M.P. & Hardenbol J. (Eds) - Geochronology, time scales and global stratigraphic correlation. SEPM *Spec. Publ*., 54: 65-79, Tulsa.

Bramlette M.N. & Martini E. (1964) - The great change in calcareous nannoplankton fossils between the Maastrichtian and Danian. *Mar. Micropaleont.,* 10: 291-322, Amsterdam.

Burnett J.A. (1998) - Upper Cretaceous. In: Bown, P. (Ed.) - Calcareous Nannofossil Biostratigraphy. Kluwer Academic Publishers, 132-199, London.

Cita Sironi M.B., Abbate E., Aldighieri B., Balini M., Conti M.A., Falorni P., Germani D., Groppelli G., Manetti P., Pampaloni M.L., Petti F.M. & Pichezzi R.M. (2006) - Carta Geologica d'Italia 1: 50.000, Catalogo delle Formazioni - unità tradizionali. Quad. APAT. Ser. III 7/VI, Roma.

Di Giulio A., Carrapa B., Fantoni R., Gorla L. & Valdisturlo A. (2001) - Middle Eocene-Early Miocene sedimentary evolution of the Western Lombardy South Alpine foredeep (Italy). *Int. J. Earth Sc.,* 90: 534-548, Kiel.

Gardin S. (2002) - Late Maastrichtian to early Danian calcareous nannofossils at Elles (Northwest Tunisia). A tale of one million years across the K-T boundary. *Palaeogeogr. Palaeoclim. Palaeoecol.,* 178: 211-231, Amsterdam.

Gardin S. & Monechi S. (1998) - Paleoecological change in middle to low-latitude calcareous nannoplankton at the Cretaceous/Tertiary boundary. *Bull. Soc. Géol. Fr.,* 169: 709-723, Paris.

Gardin S., Del Panta F., Monechi S. & Pozzi M. (2001) - A tethyan reference section for the Campanian and Maastrichtian stages: the Bottaccione section (Central Italy); review of data and new calcareous nannofossil results. In: Odin G.S. (Ed.) - The boundary between the Campanian and the Maastrichtian stages: characterisation and correlation from Tercis-les-Bains to Europe and other continents. *Developments in Paleontology and Stratigraphy,* 19: 745-757, Amsterdam.

Gavazzi A., Miletta S., Sciunnach D. & Tremolada F. (2003) - Eocene plagioclase-arenites from the Southern Alps: record of a "meso-alpine" volcanic arc. *Ann. Univ. Sc. Budapestinensis, Sect. Geol.,* 35: 102-103, Budapest.

Hardenbol J., Thierry J., Farley M.B., Jacquin T., de Graciansky P.-C. & Vail P.R. (1998) - Mesozoic and Cenozoic Sequence Chronostratigraphic Framework of European Basins. *SEPM Spec. Publ.,* 60: 3-15, Tulsa.

Kleboth P. (1982) - Stratigraphie und Sedimentologie der Höheren Oberkreide und des Alttertiärs der Brianza (Provinz Como, Italien). *Mem. Sci. Geol*., 35: 214-282, Padova.

Martini E. (1971) - Standard Tertiary and Quaternary calcareous nannoplankton zonation. In: Farinacci A. (Ed.) - Proceedings of the II Planktonic conference, 739-785, Rome.

Monechi S. & Thierstein H.R. (1985) - Late Cretaceous-Eocene nannofossil and magnetostratigraphic correlations near Gubbio, Italy. *Mar. Micropaleont.*, 9: 419-440, Amsterdam.

Okada H. & Bukry D. (1980) - Supplementary modifications and introduction to code numbers to the low latitude coccolith biostratigraphic zonation. *Mar. Micropaleont*., 5: 321-325, Amsterdam.

Olsson R. K., Hemleben Ch., Berggren W. A. & Huber B. T. (1999) - Atlas of Paleocene Planktonic Foraminifera. *Smithsonian Contributions to Paleobiology,* 85: iii-v, 1-252, Washington, D.C.

Perch-Nielsen K. (1969) - Die coccolithen einiger danischer Maastrichtien- und Danienlokalitaten. *Bull. Geol. Soc. Denmark*, 19: 51-68, Copenhagen.

Perch-Nielsen K. (1985) - Mesozoic calcareous nannofossils. In: Bolli H.M., Saunders J.B. & Perch-Nielsen K. (Eds) - Plankton Stratigraphy, 329-426, Cambridge University press, Cambridge.

Pieri M. & Groppi G. (1981) - Subsurface geological structure of the Po Plain, Italy. Pubbl. 414 C.N.R., 1-11, Roma.

Poletti L., Premoli Silva I., Masetti D., Pipan M. & Claps M. (2004) - Orbitally driven fertility cycles in the Paleocene pelagic sequence of the Southern Alps (Northern Italy). *Sed. Geol.,* 164: 35-54, Amsterdam.

Premoli Silva I. & Luterbacher H.P. (1966) - The Cretaceous/Tertiary boundary in the Southern Alps. *Riv. It. Pal. Strat.,* 72: 1183-1266, Milano.

Premoli Silva I. & Sliter W.V. (1995) - Cretaceous planktonic foraminiferal biostratigraphy and evolutionary trends from the Bottaccione section, Gubbio, Italy. *Paleontographia Italica,* 82: 1-89, Pisa.

Romein A.J.T. (1977) - Calcareous nannofossils from the Cretaceous/Tertiary boundary interval in the Barranco del Gredero (Caravaca, Prov. Murcia, SE Spain). *II Proceedings of the Koninklijke Nederlandse Akademie van Wetenschappen*, 80: 269-279, Wetenschappen.

Roth P.H. (1978) - Cretaceous Nannoplankton Biostratigraphy and Oceanography of the Northwestern Atlantic Ocean. In: Benson W.E., Sheridan R.E. et al. - *Initial Report* DSDP Leg 44, 44: 731-759, Washington D.C.

Schumacher M.E., Schönborn G., Bernoulli D. & Laubscher H.P. (1996) - Rifting and collision in the Southern Alps. In: Pfiffner O.A., Lehner P. et al. (Eds) - Deep structure of the Swiss Alps: Results of the National Research Program 20, Birkhäuser, 186-204, Basel.

Sciunnach D. & Tremolada F. (2004) - The Lombardian Gonfolite Group in central Brianza (Como and Milano Provinces, Italy): Calcareous nannofossil biostratigraphy and sedimentary record of neo-alpine tectonics. *Ecl. Geol. Helv.,* 97/1: 119-131, Basel.

Seyve C. (1990) - Nannofossil biostratigraphy of the Cretaceous-Teriary boundary in the french Basque Country. *Bull. Cent. Rech. Explor. Prod. Elf-Aquitaine,* 14: 553-572, Pau.

Sissingh W. (1977) - Biostratigraphy of Cretaceous calcareous nannoplankton. *Geol. Mijnb.*, 56: 37-65, Amsterdam.

Thierstein H.R. (1976) - Mesozoic calcareous nannoplankton biostratigraphy of marine sediments. *Mar. Micropaleont.*, 1: 325-362, Amsterdam.

Thierstein H.R. (1981) - Late Cretaceous nannoplankton and the change at the Cretaceous/Tertiary boundary. In: Warme J.E. et al. (Eds) - The Deep Sea Drilling Project: a decade of progress. *SEPM Spec. Publ.*, 32: 355-394, Tulsa.

Varol, O. (1998) - Paleogene. In: Bown P. (Ed.) - Calcareous Nannofossil Biostratigraphy. Kluwer Academic Publishers, 201-224, London.

Winterer E.L. & Bosellini A. (1981) - Subsidence and Sedimentation on Jurassic Passive Continental Margin, Southern Alps, Italy. *AAPG Bull.,* 65: 394-421, Tulsa.