LOWER CRETACEOUS NANNOFOSSIL BIOSTRATIGRAPHY OF THE CALPIONELLA LIMESTONE AND THE PALOMBINI SHALE IN SOUTHERN TUSCANY (ITALY)

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ABSTRACT

Four Lower Cretaceous sections of the Calpionella Limestone and the Palombini Shale have been investigated in Southern Tuscany (Italy). The Mt. Alpe Chert, the Calpionella Limestone and the Palombini Shale, belonging to the allocthonous Internal Ligurid Units, represent the typical sedimentary cover on top of the Western Tethys ophiolites. This sequence, widespread in the whole Alpine belt, is generally dismembered and metamorphosed. Samples collected from both siliceous and calcareous deposits, are often barren of calcareous nannofossils.

A careful field investigation allowed the identification of sections that are almost complete and not metamorphosed, and show well-preserved lithological and sedimentological features. Most samples are characterized by rich and well-preserved calcareous nannofossil assemblages. The following calcareous nannofossil Zones have been recognized: *Nannoconus colomii*, *Cretarhabdus angustiforatus*, *Calcicalathina oblongata* and the middle-upper part of *Lithraphidites bollii*. In addition, the following nannofossil events have been identified: first occurrence (FO) of *Cretarhabdus angustiforatus*, FO of *Rucinolithus wisei*, FO of *Percivalia fenestrata*, FO of *Tubodiscus jurapelagicus*, FO of *Tubodiscus verenae*, FO of *Calcicalathina oblongata*, last occurrence (LO) of *Rucinolithus wisei*, LO of *Tubodiscus verenae* and FO of *Rucinolithus terebrodentarius*.

The stratigraphic contact between the Mt. Alpe Chert and the Calpionella Limestone lies in the upper part of the *Cretarhabdus angustiforatus* Zone (late Berriasian), whereas the contact between the Calpionella Limestone and the Palombini Shale lies in the lowest part of the *Calcicalathina oblongata* Zone (earliest Valanginian). The sampled uppermost part of the Palombini Shale is referred to the middle-upper part of the *Lithraphidites bollii* Zone (late Hauterivian-early Barremian). In the investigated sector of the Ligurian-Piedmont basin, the Lower Cretaceous pelagic carbonate sedimentation of the Calpionella Limestone, overlying the Mt. Alpe Chert, starts during the early Berriasian and becomes increasingly shaly from the early Valanginian.

Key words: Biostratigraphy, calcareous nannofossils, Early Cretaceous, Southern Tuscany, Italy.

RESUMEN

Han sido estudiadas en Toscana meridional (Italia) cuatro secciones en las Calizas con Calpionella y Arcillas Palombini correspondientes al Cretácico Inferior. El Chert de Mt. Alpe, las Calizas con Calpionella y las Arcillas Palombini, pertenecientes a las Unidades Internas Ligures alóctonas, representan la secuencia típica de cobertera sedimentaria ubicada al techo de las ofiolitas del Tetis occidental. Esta secuencia, ampliamente extendida en toda la banda Alpina, está generalmente fragmentada y metamorfizada; las muestras procedentes de depósitos tanto silíceos como calcáreos son, a menudo, estériles.

Un estudio detallado de campo ha permitido la identificación de secciones que no se encuentran fragmentadas ni metamorfizadas y, además, muestran rasgos litológicos y sedimentológicos bien preservados. Así mismo, muchas de la muestras recogidas están caracterizadas por la presencia de asociaciones de nanofósiles calcáreos ricas y bien conservadas. En las secciones estratigráficas estudiadas han sido reconocidas las siguientes biozonas de nanofósiles calcáreos: *Nannoconus colomii*, *Cretarhabdus angustiforatus*, *Calcicalathina oblongata* y la parte superior de *Lithraphidites bollii;* además de los siguientes eventos: primera aparición (FO) de *Cretarhabdus angustiforatus*, FO de *Rucinolithus wisei*, FO de *Percivalia fenestrata*, FO de *Tubodiscus jurapelagicus*, FO de *T. verenae*, FO de *Calcicalathina oblongata*, última aparición (LO) de *R. wisei*, LO de *T. verenae* y FO de *R. terebrodentarius*.

El límite estratigráfico entre el Chert de Mt. Alpe y las Calizas con Calpionella se sitúa en la parte superior de la Zona de *Cretarhabdus angustiforatus* (Berriasiense superior), mientras que el límite estratigráfico entre las Calizas con Calpionella y las Arcillas Palombini se coloca en la parte inferior de la Zona de *Calcicalathina oblongata* (Valanginiense basal). Las muestras de la parte más alta de las Arcillas Palombini se atribuyen a la

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parte superior de la Zona de *Lithraphidites bollii* (Hauteriviense terminal-Barremiense basal). Por consiguiente, la sedimentación pelágica carbonática del Cretácico Inferior recubre el Chert de Mt. Alpe en el sector investigado de la cuenca Ligur-Piemontesa durante el Berriasiense, incrementándose su contenido arcilloso en el Valanginiense basal.

Palabras clave: Bioestratigrafía, nanofósiles calcáreos, Cretácico Inferior, Toscana meridional, Italia.

INTRODUCTION

During the Middle-Late Jurassic time interval, the oceanic Ligurian-Piedmont basin, located between Europe and Adria continental margin, was involved in the radiolaritic sedimentation of the Mt. Alpe Chert (Baumgartner, 1984 and Conti & Marcucci 1986). Beginning from the Jurassic/Cretaceous boundary, the siliceous sedimentation was replaced by the calcareous sedimentation of the Calpionella Limestone. From the Valanginian, the clastic input from the continental area became progressively dominant in the basin giving rise to the Palombini Shale deposition, which was characterized by siliceous and marly limestones within claystones and marlstones.

The Lower Cretaceous pelagic sedimentary cover of the oceanic Western Tethys lithosphere is represented by the Calpionella Limestone and the Palombini Shale and is correlated to the Maiolica Formation of the Tuscan-Umbrian-Marchean and Southern Alps paleogeographic domains. The latest Tithonian-early Aptian Maiolica was deposited on the continental margin of the Adria plate, bordering the opening oceanic Tethys to the southeast (Kalin *et al.*, 1979; Winterer & Bosellini, 1981; Erba & Quadrio, 1987).

At present, in the Tethyan area several studies are published on calcareous nannofossil biostratigraphy of Lower Cretaceous Tethyan successions deposited on continental crust (e.g. Umbria-Marchean basin: Bralower *et al.*, 1989; Southern Alps: Erba & Quadrio, 1987; Channel & Erba 1992; Channel *et al.*, 1995; Vocontian Trought: Gardin & Manivit, 1993; Galician margin: Applegate & Bergen, 1988). However, up to now only very few data are available on calcareous nannofossil biostratigraphy of coeval carbonate pelagic successions deposited above oceanic crust (Cobianchi & Villa, 1992) exposed in the Northern Apennines.

In the Northern Apennines (Italy), the remnants of the Western Tethys oceanic lithosphere (Abbate *et al.*, 1980) and their Middle Jurassic-Lower Cretaceous pelagic sedimentary cover are superbly exposed (Principi *et al.*, 1992; and reference therein). Nevertheless, the primary lithostratigraphic features of the Lower Cretaceous sedimentary successions are not frequently preserved and the stratigraphic boundaries between the Calpionella Limestone and the Palombini Shale or between them and the underlying formations do not crop out. Moreover, the samples collected from the Calpionella Limestone and the Palombini Shale are frequently barren of calcareous nannofossils.

Nevertheless, a few areas have been found in the Northern Apennines such as the Vara Valley (Perilli & Nannini, in press) and Southern Tuscany, where these formations are fossiliferous and contain nicely preserved and diversified nannofossil assemblages. Furthermore, in these areas, the Calpionella Limestone and the Palombini Shale are well-exposed and display clear relationships between them, as well as with the underlying Mt. Alpe Chert, or with the ophiolite succession.

This work deals with calcareous nannofossil biostratigraphy of the Lower Cretaceous pelagic cover of the Western Tethys ophiolites represented by the Calpionella Limestone and the Palombini Shale, belonging to the Bracco/Val Graveglia Unit and cropping out in Southern Tuscany. A good biostratigraphic resolution contributes to enlighten the stratigraphic framework of the studied formations and the sedimentary evolution of the Ligurian-Piedmont Basin during the Early Cretaceous.

The accuracy and the reliability of the achieved results are supported by the great number of samples analyzed, the high number of fields of view observed for each smear slide, the rich and nicely preserved calcareous nannofossil assemblages and the total number of genera and species recognized.

GEOLOGICAL OUTLINE AND PREVIOUS DATING

The Northern Apennines are built of several east- and northeastwards-verging thrust sheets, stacked during Tertiary tectonic phases. Two major groups of nappes are distinguished: the oceanic (Ligurid) and the continental (Tuscan) nappes. The Ligurid nappes, overriding the Tuscan nappe, are divided into Internal and External Ligurid Units (Elter & Pertusati, 1973; Elter, 1975).

The Internal Ligurid Units are represented by the Jurassic ophiolite sequences and their sedimentary covers; the ophiolites are interpreted as remnants of oceanic lithosphere of the Western Tethys accreted during the Middle Jurassic-Early Cretaceous spreading/drifting phase (Abbate *et al.*, 1980 and 1992a). The sedimentary cover of the Lower-Middle Jurassic ophiolite sequences includes middle Callovian-upper Santonian pelagic deposits which consist of: Mt. Alpe Chert (Barret, 1982; Baumgartner, 1987; Conti & Marcucci, 1986), Calpionella Limestone and Palombini Shale (Decandia & Elter, 1972; Bortolotti, 1983; Abbate *et al.*, 1992b). The Palombini Shale grades upwards into a coarsening-upwards, thick, turbidite sequence (early Campanian-early Paleocene), interpreted as deep-sea trench deposits: the Val Lavagna Shale, and Gottero Sandstone (Marroni & Perilli, 1990). This sequence is overlain by lower Paleocene (Passerini & Pirini, 1964; Marroni & Perilli, 1990) mass-gravity deposits of the Colli Tavarone Formation (Marroni & Meccheri, 1994).

Although there are many recent papers concerning the age of Tethyan Mt. Alpe Chert, based on the analysis of radiolarian assemblages (Baumgartner, 1984, 1987; Conti & Marcucci, 1986, 1991, and bibliography therein), very few and fragmentary biostratigraphic data (mainly based on calpionellids and foraminifera) are available for the Calpionella Limestone and the Palombini Shale. As regards the Calpionella and Palombini Shale, many of the data published in the '60s and '70s, derived from scattered outcrops, where the stratigraphic relationships between these formations, and between them and the underlying Mt. Alpe Chert (and/or ophiolites) are doubtful or unknown.

In the Northern Apennines the Mt. Alpe Chert, (0-200 meters thick) is referred to: middle Oxfordian/early Kimmeridgian-Tithonian by Conti *et al.* (1985); late Oxfordian-Tithonian/late Berriasian by Picchi (1985); late Oxfordian-early Tithonian by Nozzoli (1986); and middle Callovian/Kimmeridgian-Tithonian/Berriasian by Abbate *et al.* (1992b). The Calpionella Limestone (0-200 meters thick, more frequently 0-50 m) is referred to: Tithonian-Neocomian by Ghelardoni *et al.* (1965) and Abbate (1969); Berriasian-Valanginian by Dallan *et al.* (1968) and Decandia & Elter (1972); or Berriasian by Andri & Fanucci (1973). The base of this formation has been assigned to the late Berriasian by Picchi (1985) and middle/late Berriasian by Conti & Marcucci (1991). Recently, Cobianchi & Villa (1992) referred the Calpionella Limestone to late Tithonian-Valanginian/(?) early Hauterivian, whereas Abbate *et al.* (1992a) assigned this formation to the Berriasian-Valanginian. The Palombini Shale, belonging to the Bracco/Val Graveglia Unit, stratigraphically overlaying the Calpionellla Limestone is referred to: Berriasian-Barremian by Casella & Terranova (1963); Valanginian-Aptian by Ghelardoni *et al.* (1965); (?)Tithonian-Aptian/Albian by Abbate (1969); Valanginian by Dallan *et al.* (1968), and to the Hauterivian/(?)Aptian by Decandia & Elter (1972). Cobianchi & Villa (1992) assigned this formation to late Hauterivian-late Aptian, while Abbate *et al.* (1992b) referred the Palombini Shale to Berriasian-Hauterivian.

The aforementioned Upper Jurassic-Lower Cretaceous sedimentary cover of the Western Tethys ophiolites is correlated to the upper part of the Diaspri or Calcari Diasprigni and the Maiolica of the Tuscan-Umbrian-Marchean and Southern Alps paleogeographic domains.

METHODS

Semiquantitative analysis of the calcareous nannofossils was mainly performed under the light microscope, at 1250X magnification. Using a drop of bidistilled water and a flat toothpick in order to obtain a uniform rippled distribution, a small amount of sediment was dispersed on a cover glass and dried on a hot plate; the cover glass was then permanently attached to a glass slide with a mounting medium (Permount). For each smear slide (40x24 mm), at least 10 complete longitudinal random traverses were analyzed (1 traverse $\cong$ 170 fields). In order to check the presence of rare or very rare species, some very concentrated smear slides have been prepared; and more than 3000 fields have been observed. A special effort has been made to determine accurately nannofossil events with particular attention to the First Occurrence (FO) and the Last Occurrence (LO) of the zonal markers (verifying their presence and/or their absence).

Six classes of total abundance and six classes of relative abundance of calcareous nannofossils were distinguished. Total abundance: Very Abundant = (VA) if the calcareous nannofossils were > 75% compared to the total particles; Abundant= (A) if there were > 50% and < 75%; Common = (C) if there were > 25% and < 50%; Few = (F) if there were > 10% and < 25%; Rare = (R) if there were > 1% and < 10%; and Very Rare (VR) if there were < 1%. Relative abundance**:** Very Abundant = (VA) 10 specimens in each field of view; Abundant = (A) 1-9 specimens in each field of view; Common = (C) 1 specimen in 2-10 fields of view; Few = (F) 1 specimen in 11-100 fields of view; Rare = (R) 1 specimen in 101-200 fields of view; and Very Rare = (VR) 1 specimen in >201 fields of view.

Furthermore, four classes of preservation were distinguished: Good = (G) the majority of the species are recognizable even if some are slightly etched and/or overgrown; Moderate = (M) only the resistant species are well recognizable, whereas the non-resistant species are heavily etched and/or overgrown (in particular their processes and their central area) and sometimes the identification of the species is difficult; Bad = (B) only few species are recognizable and no morphological features are visible at parallel nicols; Very Bad = (VB) only few specimens are recognizable at crossed nicols.

The majority of the 195 studied samples are marlstones, shaly marlstones and marly claystones; among them 38 (mainly from the Palombini Shale) are barren.

LOCATION OF SECTIONS AND LITHOSTRATIGRAPHY

The stratigraphic sections crop out in Southern Tuscany, in the Castellina Mountains and Livorno Mountains (Fig. 1). The sampled interval include the top of the Mt. Alpe Chert, the Calpionella Limestone and the Palombini Shale. The stratigraphic boundaries between the Mt. Alpe Chert and Calpionella Limestone and between the Calpionella Limestone and the Palombini Shale are exposed in the Castellina Mountains. The uppermost part of the Palombini Shale has been sampled at Chioma section.

Castellina Mountains: the Mt. Vitalba and the Poggio Vitalba sections are located 40 km southeast of Livorno.

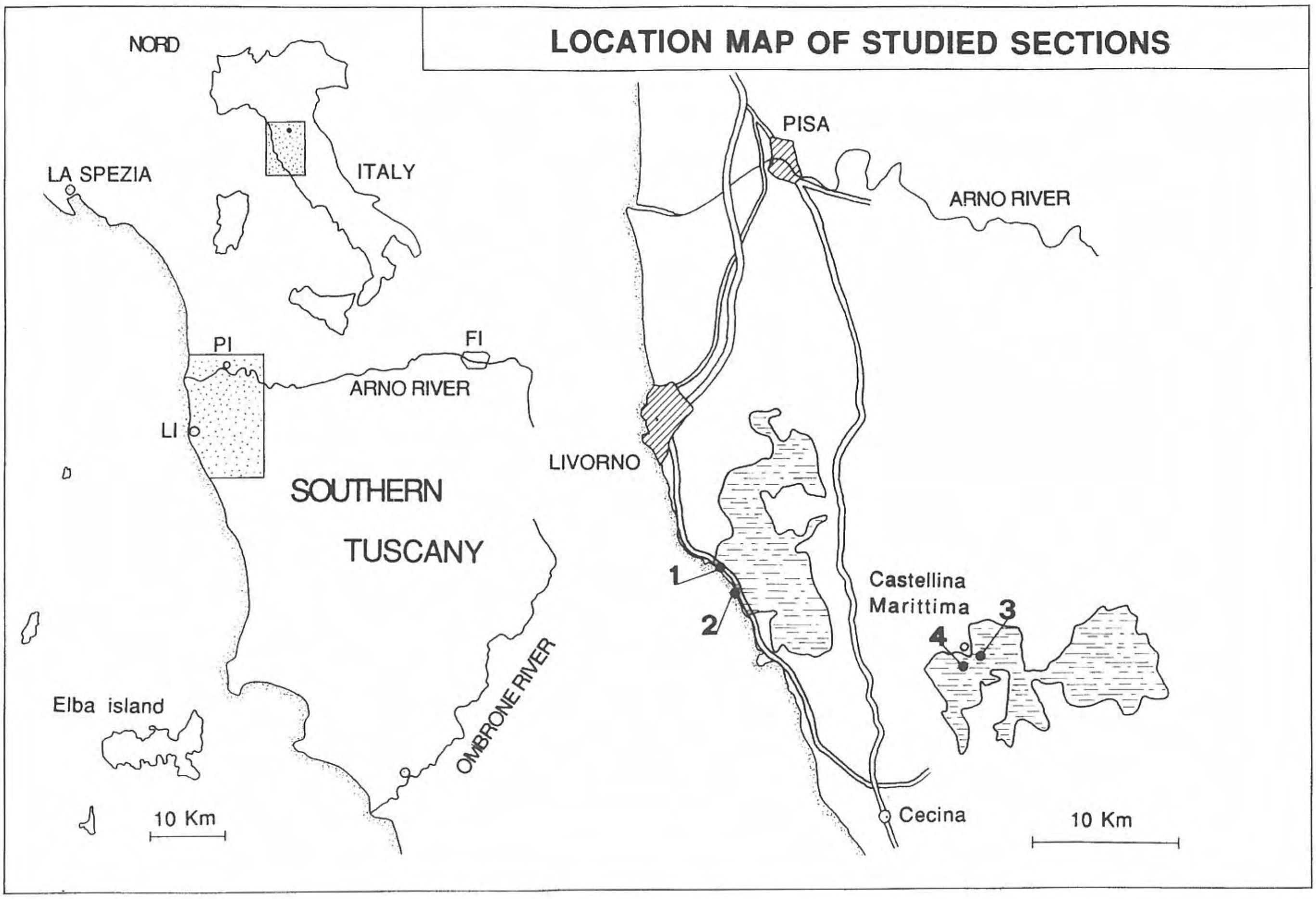

Figure 1. Study area and location of the sections: 1) Romito section; 2) Chioma section; 3) Mt. Vitalba section; 4) Poggio Vitalba section. Hatched areas represent the main outcrops of the Internal Ligurids.

In the Mt. Vitalba section (Fig. 2), the ophiolite sequence is overlain by the Mt. Alpe Chert, which is represented by thin, well-stratified, sometimes graded, red radiolarites. The Mt. Alpe Chert grades upwards to the Calpionella Limestone through a 7 meter thick silty-marly interval representing the transitional litofacies between the Mt. Alpe Chert and the Calpionella Limestone; this interval is correlated to the Nisportino Formation (Bortolotti *et al.*, 1994). It consists of shaly-silty marlstones with intercalations of red siliceous claystones, green siliceous marlstones, red radiolarites and, in the upper part, white siliceous limestones. The Calpionella Limestone is represented by medium to thick strata of white siliceous micritic limestones, with rare and thin to medium thick intercalations of marlstones.

At Mt. Vitalba section 18 samples were collected; 2 of them are barren of nannofossils. The total abundance of nannofloras ranges from common to rare and the preservation is generally moderate. The nannofossil assemblages are richer and more diversified in the upper part of the transitional silty-marly interval and above the first limestone bed.

At the Poggio Vitalba section (Fig. 3), the Mt. Alpe Chert does not crop out. The Calpionella Limestone lies on a few meters-thick clayey marlstone level. The Calpionella Limestone consists of medium to thick strata of white siliceous limestones with chert nodules and marlstones scattered throughout the formation. The marlstone beds become more shaly and frequent towards the top. In fact, the transition between the Calpionella Limestone and the Palombini Shale is marked by an increase in the black marly claystones and reduction of the siliceous limestone layers, which become thinner. The Palombini Shale consists of thick siliceous, micritic limestones, with a typical dove to grey colour and anvil-like profile, and intercalations of medium to thick, pale brown to black, shaly marlstones and claystones; the thickness of the pelites ranges from some decimetres to about one meter.

At Poggio Vitalba section, 97 samples were collected: 45 from the Calpionella Limestone and 52 from the Palombini Shale; 19 samples (mainly from the Palombini Shale) are barren of nannofossils. The total abundance ranges from abundant to rare, and the preservation from good to bad. About 30% of the fossiliferous samples (mainly from the Calpionella Limestone) contain diversified and well-preserved nannofloras. The nannofossil assemblages of the samples from the Palombini Shale display evidence of etching.

Livorno Mountains: the Romito and Chioma sections crop out 15 km south of Livorno.

The Romito section crops out along the Aurelia road.

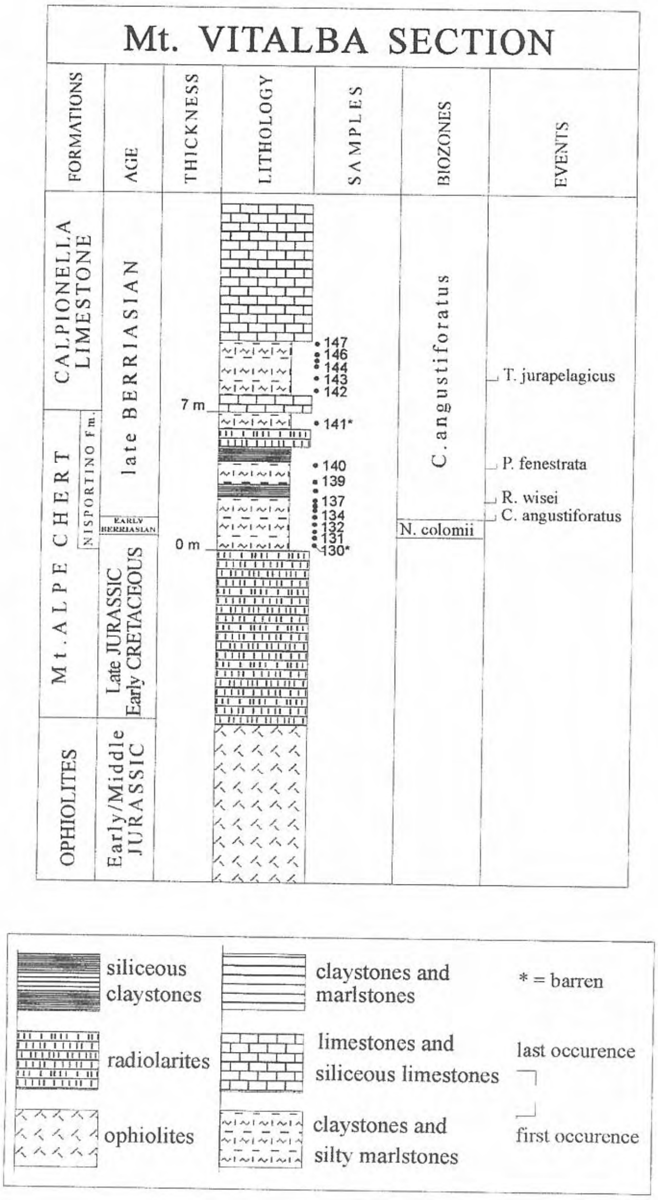

Figure 2. Lithostratigraphy and calcareous nannofossil biostratigraphy of the Mt. Vitalba section.

A coarse ophiolitic breccia mainly with gabbroic clasts grades upwards to stratified red radiolarites, through a red unfossiliferous level of siliceous claystones. The Mt. Alpe Chert grades upwards to the Palombini Shale through a shaly level characterized by intercalations of red siliceous shales, green siliceous marlstones and micritic siliceous limestones. In the upper part of the section the siliceous limestones with anvil-like profile are more frequent and are interbedded with pale brown to black shaly marlstones; nodular cherts are very rare. In the upper part of the outcrop, the Palombini Shale are folded and disrupted.

At Romito section 23 samples have been collected, but 15 are barren of calcareous nannofossils. The total abundance of nannofossils ranges from rare to very rare and the preservation is generally bad.

In the Chioma section (Fig. 4) the Palombini Shale is well-exposed along the coastline for more than 100

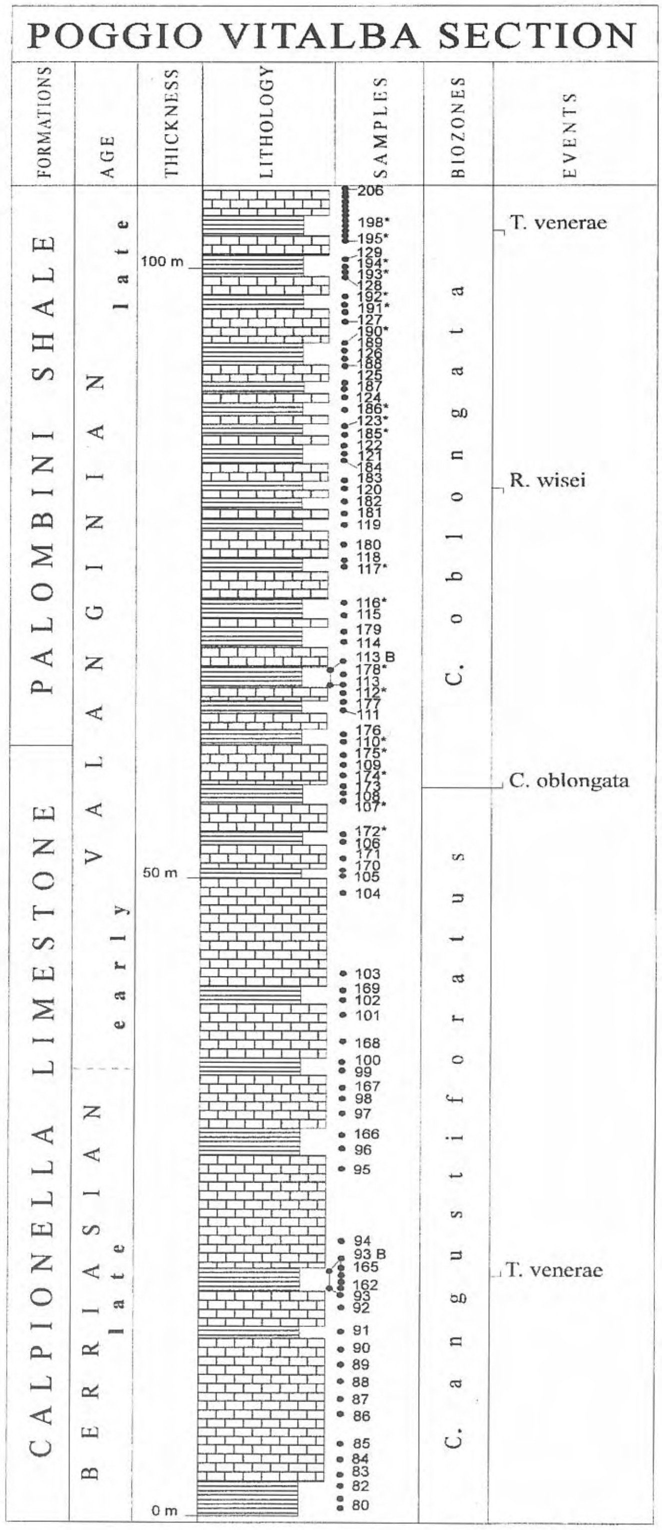

Figure 3. Lithostratigraphy and calcareous nannofossil biostratigraphy of the Poggio Vitalba section (see legend in Fig. 2).

meters, but the contact with the underlying formation does not crop out. The lower part of the section is characterized by thick strata of siliceous limestones intercalated with laminated, black, sometimes slightly marly, claystones and rare quartz-arenites. The thicker beds show a detritic base which grades upwards to

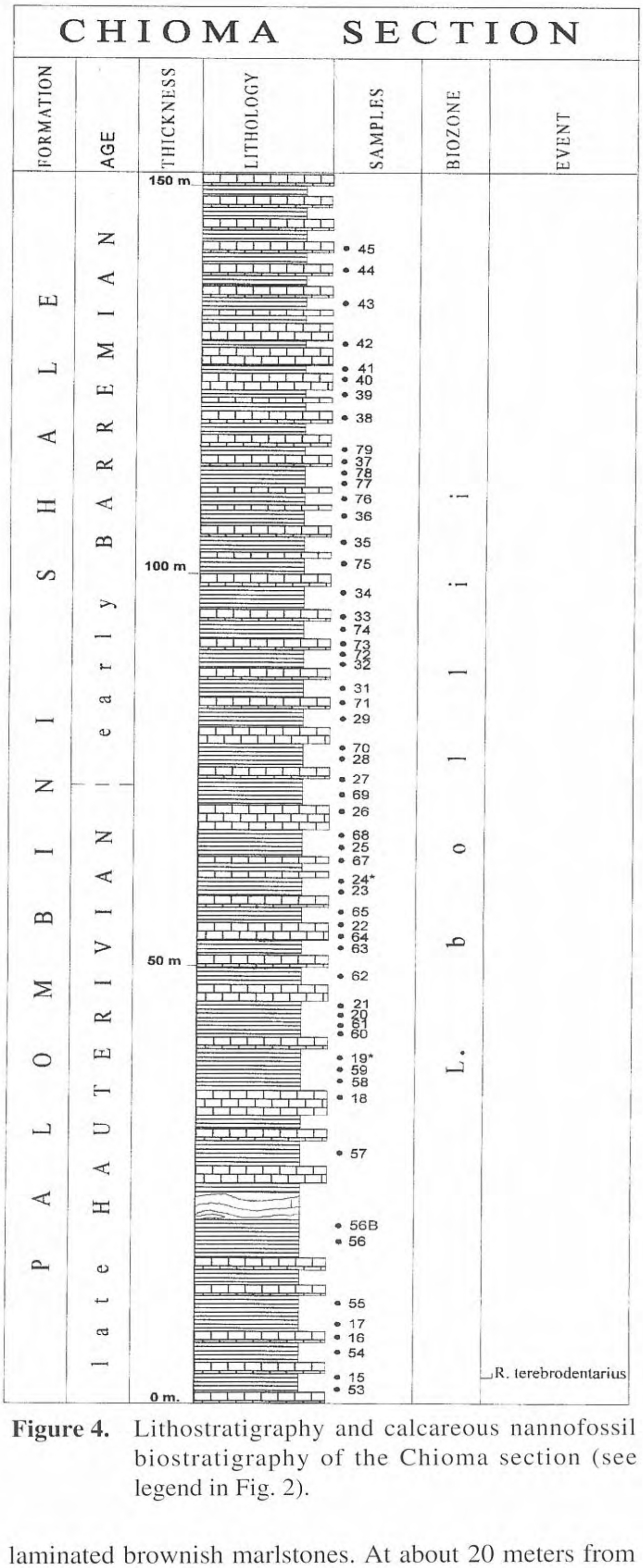

Figure 4. Lithostratigraphy and calcareous nannofossil biostratigraphy of the Chioma section (see legend in Fig. 2).

laminated brownish marlstones. At about 20 meters from the base of the section, disrupted and folded layers are present. Above this level the marly claystones and the laminated shaly marlstones increase in frequency and the limestones become rare. In fact, in the middle part of the section, the Palombini Shale is represented by a monotonous alternance of medium to thick strata of shaly marlstones and thin, sometimes medium, stratified siliceous limestones. Finally, in the upper part of the section the siliceous limestones increase either in thickness or in frequence, and they become predominant compared to the shaly marlstones, part of which are very thin.

At Chioma section 57 samples have been collected and only 2 are barren of calcareous nannofossils. The nannofossil assemblages recognized at Chioma section are less diversified than those from the Poggio Vitalba section. The total abundance ranges from common to rare, and the nannofossils are moderately preserved. Less than 40% of the samples are characterized by diversified nannofossil assemblages, while the other fossiliferous samples are characterized by a low number of species (5-10) and specimens, that are generally badly preserved.

BIOSTRATIGRAPHY

Coccoliths and nannoconids are the most important biogenic constituents of the studied mudstones, marlstones and limestones; in more than 50% of the samples they constitute from 25% to 75% of the whole rock and often represent the bulk of the micritic fraction. In fact, they are the dominant biogenic constituents of the Tethyan Lower Cretaceous pelagic sediments and are extensively used in biostratigraphy.

Since the seventies, many zonations based on calcareous nannofossils have been proposed for the Early Cretaceous: Thierstein, 1971, 1973, 1976; Deres & Acheriteguy, 1972, 1980; Sissingh, 1977; Roth, 1978; Perch-Nielsen, 1979, 1985; Bralower, 1987; Erba & Quadrio, 1987; Channell *et al.*, 1987; Erba, 1989; Applegate & Bergen, 1988; Bralower *et al.*, 1989; Channell & Erba, 1992; Channell *et al.*, 1995; Mutterlose, 1992a, 1992b. Many of these zonations are based on pelagic sequences from the Tethyan realm. In particular, Bralower, 1987; Channell *et al.*, 1987; Erba & Quadrio, 1987; Erba, 1989; Bralower *et al.*, 1989; Channell & Erba, 1992 carried out calcareous nannofossil zonations on several Lower Cretaceous land-sections from Italy.

Many of these authors attributed: the first occurrence (FO) of *Cretarhabdus angustiforatus* to the late Berriasian; the FO of *Calcicalathina oblongata* to the earliest Valanginian; the last occurrence (LO) of *Tubodiscus verenae* to the late Valanginian; the FO of *Lithraphidites bollii* to the early Hauterivian; the LO of *Cruciellipsis cuvillieri* to the late Hauterivian, the LO of *Lithraphidites bollii* to the early Barremian and the LO of *Calcicalathina oblongata* to the early Barremian.

Moreover, quite a few authors ascribed: the FO of *Rucinolithus wisei* (Thierstein, 1971, 1973, 1976; Applegate & Bergen, 1988; Bralower *et alii*, 1989; Gardin & Manivit, 1993), the FO of *Percivalia fenestrata* (Thierstein, 1971, 1973, 1976; Applegate & Bergen, 1988; Channell *et al.*, 1987; Bralower *et al.*, 1989; Gardin & Manivit, 1993) and the FO of *Tubodiscus jurapelagicus* (Applegate & Bergen, 1988; Bralower *et al.* 1989; Gardin & Manivit, 1993) to the late

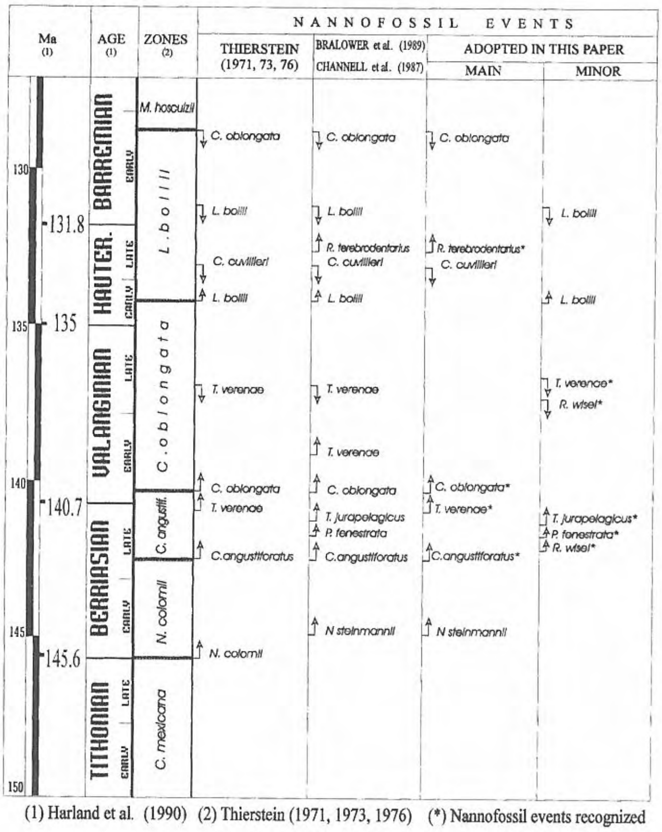

Figure 5. Summary figure of calcareous nannofossil zonations and nannofossil events considered in this paper for the early Berriasian-early Barremiam interval.

Berriasian, within the *Cretarhabdus angustiforatus* Zone. The FO of *Tubodiscus verenae* has been found just below (Thierstein, 1971, 1973, 1976; Erba & Quadrio, 1987), coincident (Sissingh, 1977; Roth, 1978) or above (Perch-Nielsen, 1985; Bralower, 1987; Channell *et al.*, 1987; Channell & Erba, 1992) the FO of *Calcicalathina oblongata*. Finally, the LO of *Rucinolithus wisei* has been placed in the early Valanginian (Thierstein, 1971, 1973, 1976; Bralower *et al.*, 1989) or late Valanginian (Applegate & Bergen, 1988; Mütterlose & Wise, 1990).

The FO of *Nannoconus bucheri* has been attributed to the upper part of the *Calcicalathina oblongata* Zone, before the FO of *Lithraphidites bollii* (Thierstein, 1971, 1973, 1976; Deres & Acheriteguy, 1980; Perch-Nielsen, 1985; Erba 1989; Channell *et al.*, 1995) and the FO of *Rucinolithus terebrodentarius* (Bralower, 1987; Channell *et al.*, 1987; Applegate & Bergen, 1988; Channell & Erba, 1992) has been observed within the *Lithraphidites bollii* Zone, just above the LO of *Cruciellipsis cuvillieri*.

In the studied sections, following Thierstein (1971, 1973, 1976) the recognized Zones are: *Nannoconus colomii, Cretarhabdus angustiforatus, Calcicalathina oblongata* and the middle-upper part of the *Lithraphidites bollii* (Fig. 5). Nine nannofossil events were recognized: FO of *Cretarhabdus angustiforatus*, FO of *Rucinolithus wisei,* FO of *Percivalia fenestrata*, FO of *Tubodiscus jurapelagicus*, FO of *Tubodiscus verenae*, FO of *Calcicalathina oblongata*, LO of *Rucinolithus wisei,* LO of *Tubodiscus verenae* and FO of *Rucinolithus terebrodentarius*.

Generally the nannofacies, especially in the marlstone and marly claystone intervals, are characterized by the dominance of the Ellipsagelosphaeraceae. The genus *Watznaueria* is dominant and is represented by common to abundant *W. barnesae* and very rare to few *W. biporta, W. britannica* and *W. communis* (Perilli in preparation); in the range charts all these species are listed as *Watznaueria* spp. However, the nannofossil assemblages are frequently diversified; 25 genera and 42 species have

Assipetra infracretacea (Thierstein, 1973) Roth (1973)
Biscutum constans (Gorka, 1957) Black in Black & Barnes (1959)
Braarudosphaera bigelowii (Gran & Braarud, 1935) Deflandre (1947)
Braarudosphaera regularis Black (1973)
Calcicalathina sp. A (Bergen, 1994)
Calcicalathina oblongata (Worsley, 1971) Thierstein (1971)
Conusphaera mexicana Trejo (1969)
Cretarhabdus angustiforatus (Black, 1971a) Bukry (1973)
Cretarhabdus conicus Bramlette & Martini (1964)
Cretarhabdus octofenestratus Bralower in Bralower, Monechi & Thierstein (1989)
Cruciellipsis cuvillieri (Manivit, 1966) Thierstein (1971)
Cyclagelosphaera deflandrei (Manivit, 1966)
Cyclagelosphaera margerelii Noel (1965)
Diadorhombus rectus Worsley (1971)
Diazomatolihus lehmanii Noel (1965)
Glaukolithus diplogrammus (Deflandre in Deflandre & Fert, 1954) Reinhardt (1964)
Haqius circumradiatus (Stover, 1966) Roth (1978)
Lithraphidites bollii (Thierstein, 1971) Thierstein (1973)
Lithraphidites carniolensis Deflandre (1963)
Manivitella pemmatoidea (Deflandre in Manivit, 1965) Thierstein (1971)
Micrantholithus hoschulzii (Reinhardt, 1966a) Thierstein (1971)
Micrantholithus obtusus Stradner (1963)
Microstaurus chiastius (Worsley, 1971) Grun in Grun & Allemann (1975)
Nannoconus bucheri Bronnimann (1955)
Nannoconus colomii (de Lapparent, 1931) Kamptner (1938)
Nannoconus globulus Bronnimann (1955)
Nannoconus kamptneri Bronnimann (1955)
Nannoconus steinmannii Kamptner (1931)
Nannoconus wassallii Bronnimann (1955)
Percivalia fenestrata (Worsley, 1971) Wise, 1983
Rhagodiscus asper (Stradner, 1963) Reinhardt (1967)
Rhagodiscus nebulosus Bralower in Bralower, Monechi & Thierstein (1989)
Rucinolithus terebrodentarius Covington &Wise (1987)
Rucinolithus wisei Thierstein (1971)
Speetonia colligata Black (1971a)
Tubodiscus jurapelagicus (Worsley, 1971) Roth (1973)
Tubodiscus verenae Thierstein (1973)
Watznaueria barnesae (Black in Black & Barnes, 1959) Perch-Nielsen (1968)
Watznaueria biporta Bukry (1969)
Watznaueria britannica (Stradner, 1963) Reinhardt (1964)
Watznaueria communis (Reinhardt, 1964) Perch-Nielsen (1968)
Zeugrhabdotus embergeri (Noel, 1959) Perch-Nielsen (1984a)

Table 1. Calcareous nannofossil species recognized in this study

Samples	Abundance	Preservation	*Watznaueria spp.*	*A. infracretacea*	*C. cuvillieri*	*D. lehmanii*	*Z. embergeri*	*C. deflandrei*	*C. margerelii*	*C. mexicana*	*M. chiastius*	*N. colomii*	*N. kamptneri*	*N. globulus*	*N. steinmannii*	*H. circumradiatus*	*G. diplogrammus*	*L. carniolensis*	*B. costans*	*M. pemmatoidea*	*M. hoschulzii*	*M. obtusus*	*B. regularis*	*R. asper*	*C. octofenestratus*	*C. conicus*	*C. angustiforatus*	*Rucinolithus sp.*	*R. wisei*	*R. nebulosus*	*P. fenestrata*	*T. jurapelagicus*
147	F	M	A	F			F		C		F			VR	F							R		F							F	
146	F	M	A	F	R	F	F	R							F						VR		VR		R			VR				
145	C	G	A	F	F	C	C	F	C	R	F	VR	F	VR	C			R			F	F			R				R		R	VR
144	C	G	A	F	C	F	C	C	C	R	F		F		C	VR		R			F	F		R							R	
143	C	G	A	F	F	F	C		C	F				VR	F			VR														VR
142	C	G	A	F	C	C	C	F	A	F	F			R	F	VR	VR		R		F	R	VR			VR	VR		VR	VR	VR	
140	C	G	A	C	C	F	F	F	C		F				F			R	VR	VR	R	R			R		R	R			R	
139	C	M	A	F	C	F	C	R	C	R	F	R	R	R	F	VR		R		VR							R					
138	VR	M	C	VR			VR								R																	
137	F	B	A	F	F	F	F	R	F		R			F													cf	VR	VR			
136	R	M	A	C	R	F		VR	F	R	F	VR	VR	R	R										F	VR						
135	VR	B	F	VR			VR	VR																								
134	F	M	A		R		F	C	C	R	R		cf	F	R				VR							VR	VR	R				
133	R	B	A	F	R	F	F	R	F		F	R			R			R							VR	R						
132	R	B	C	C		R	F	R	F		F			R	VR		VR											VR		VR		
131	R	M	A	C	F	F	F	F	C	VR	C	cf	cf	R		R									VR			VR				

Table 2. Range chart of calcareous nannofossils of Mt. Vitalba section (see text for simbols).

been recognized (Tab. 1). The nannoconids are usually represented by *Nannoconus steinmannii*, whereas *Nannoconus globulus*, *Nannoconus kamptneri* and *Nannoconus colomii* are subordinate; *Nannoconus bucheri* and *Nannoconus wassallii* are observed only in the Chioma section. The peak abundance of nannoconids seems to be related to the carbonate content, as derived from thin sections of limestones; the micrite is characterized by the dominance of nannoconids with a narrow axial canal.

Nannoconus colomii Zone

Definition - Interval from the first occurrence of *Nannoconus colomii* to the first occurrence of *Cretarhabdus angustiforatus*; author: Whorsley, 1971 and emended by Thierstein, 1971.

Remarks - The base of this Zone, which is correlatable with a sharp increase in nannoconid abundance (Erba, 1989) has not been recognized in the investigated sections. The poor and badly preserved calcareous nannofossil assemblages of the few samples referred to this Zone (Tab. 2) include few to common/abundant *A. infracretacea, C. margerelii, D. lehmanii, M. chiastius, Watznaueria* spp., *Z. embergeri*, and very rare to few *C. mexicana, C. conicus, C. octofenestratus, C. cuvillieri, C. deflandrei, G. diplogrammus, H. circumradiatus, L. carniolensis, R. nebulosus, Rucinolithus* sp. The nannoconids are characterized by the presence of specimens larger than 8 μ such as *N. steinmannii, N. globulus*, and very rare specimens of *N. colomii.*

Reference section - This Zone has been recognized at Mt. Vitalba section.

Age - The rare and badly preserved nannofossil assemblages from this zone allow us to ascribe the few basal meters of Mt. Vitalba section to an age probably not older than early Berriasian; the upper part of the *Nannoconus colomii* Zone is correlated with the NK-1 of Bralower *et al.* (1989).

Cretarhabdus angustiforatus Zone

Definition - Interval from the first occurrence of *Cretarhabdus angustiforatus* to the first occurrence of *Calcicalathina oblongata*; author Thierstein, 1971.

Remarks - *C. angustiforatus* first occurs in the lower part of the Mt. Vitalba section and is generally rare or frequent, sometimes it is absent. In the upper part of the Mt. Vitalba section, *R. wisei* occurs slightly before *P. fenestrata;* both species are rare and not well-preserved. Nicely preserved and more frequent specimens of *R. wisei* and *P. fenestrata* were observed in the lower part of the Poggio Vitalba section together with *D. rectus*, *S. colligata* and *T. jurapelagicus;* this latter taxon first occurs in the upper part of the Mt. Vitalba section. *S. colligata, D. rectus* and *T. jurapelagicus* are rare and occur sporadically. Besides, *R. wisei, D. rectus* and *S. colligata* are always easily recognizable, while *P. fenestrata* and *T. jurapelagicus* are sometimes hard to distinguish from similar species (e.g., *R. nebulosus* and *T. verenae*). Transitional forms between *T. jurapelagicus* and *T. verenae* occur in the lower part of the Poggio Vitalba section before the FO of *T. verenae,* which appears in the lower part of the Poggio Vitalba section. Upwards, slightly below the boundary between the Calpionella Limestone and the Palombini Shale *C. oblongata* first occurs.

In addition, the assemblages belonging to this Zone (Tab. 2 and 3) are characterized by the presence of few to common/abundant *A. infracretacea, C. cuvillieri, C. margerelii, D. lehmanii, N. steinmannii, Watznaueria* spp., *Z. embergeri*. Other species generally present

Samples	Abundance	Preservation	Watznaueria spp.	A. infracretacea	D. lehmannii	Z. embergeri	C. deflandrei	C. margerelii	C. cuvillieri	C. mexicana	N. colomii	N. kamptneri	N. globulus	N. steinmannii	L. carniolensis	M. chiastius	M. obtusus	M. hoschulzii	B. regularis	B. bigelowii	R. asper	M. pemmatoidea	H. circumradiatus	B. costans	G. diplogrammus	C. angustiforatus	C. octofenestratus	C. conicus	P. fenestrata	R. wisei	Rucinolithus sp.	D. rectus	S. colligata	T. jurapelagicus	T. verenae	Calcicalathina sp. A	C. oblongata
206	C	M	VA	C	F		F	F	C	C	R	F	F	VA	R		R	F	R		F								R		F						VR
205	C	M	A	C	F	F	F	C	F	C	R	R	F	C				R	R										R		R						
204	F	M	A	C	F	C		F	C			R			R	R		R					VR						R		R						
203	R	M	A	C	R			C	F						R							VR							VR				VR				
202	F	M	C	C	C	F		C	F	R		R		F		R	R	F		VR						R	R		R		F					VR	VR
201	VR	B	C	C				R																													
200	R	M	A	C	F	F		F	R				R																								
199	R	M	C	C		F				R																								VR			
197	R	M	A	F	R	F	F	C	F	A			F	C			R	F								R			F					VR	VR		
196	R	M	A	F			R	C	F			VR		F				F			R						R				F			VR		VR	
184	C	G	A	C	A	C	F	A	C	C	R	R	F	C	F	F	C	C	R	VR	C					F		R	R				VR				R
183	A	G	A	C	C	C		C	C	F		R		C		R						VR				R		R	R		R			VR	VR		VR
120	F	M	A	C	C	F		C	F	R				F	F			R			F	VR		F	VR	R	R		F	R	R			VR			
182	R	G	C	F		C	F	C	C							F					R					R			R								
171	F	G	VA	C		C	R	C		F				F	F	C	R	R			F	VR		C		R	R				F		cf	VR			
119	C	G	A	C	C	FC	F	C	C	F				F	R	F	F	F			F	VR	R	F		R	R	R	F			F		VR	VR		R
179	F	M	A	F	F	C		C	R					F	F	F		R			F	VR	VR	F			R							VR		VR	
114	C	G	VA	F	C	F		C	C	F		R		F	F	F	F	F		VR		VR	VR	R		R	F	R	R		R	R			VR	VR	
113B	A	G	A	C	C	C	C	C	A	F	R	VR		C	F		R	F	F		F	VR	VR			R	F		F	R	R		VR	VR			
113	F	M	A	C	F	C		F	C	R					R	R		F											R	VR					VR		VR
175	VR	VB	F											F																							
109	F	M	C	R		R		F						R																	R				cf		
173	F	R	A	C	F	C		F	R	R			F	F	R			R			F		VR			R		R	R	VR				VR	VR		VR
171	C	M	A	F		F	F	C	C	C				A			R	F								R	R		R								
170	F	M	A	A	F	C	F	A	C	C		R	F	C	R		F	F					VR			R			F			cf		VR	F		
105	A	G	A	C	F	C	C	C	F	A	VR	R	F	VA			R	R	R	R							R		VR					VR			
104	R	M	C	R																																	
103	VR	B	F	R			R	F								R																					
169	R	B	A	C	F	F	R	F		R				F												R											
102	R	B	C	C	F	R	R	F	F			R		R					R																		
100	C	G	A	C	C	C	R	C	C	C		R	R	F	F	F		R	R			VR	VR			F		R	R	F	R			R	VR		
99	R	M	A	F	F	R	R	F	F	F				F	R														R	R	F						
166	C	G	A	C		R	F	C		R	R		R	F				F			F		VR			R			F					R			
96	C	G	A	C	R	F	F	C	C			R		F	F			VR			R	VR	VR		R		R		F	R	F	R		VR	VR		
95	F	M	A	F	F	F	R	C	F	F				F				F									R		R		R			VR			
93B	C	G	A	F	C	C	F	C	C	F		F	F	A	F	F		F				VR	VR	R		F		R	R	R	F			F	R		
164	C	G	A		A	C	R	A	C	F	F	R	R	A	R		C	C	R		F					F		R	R	R	F		R		VR		
163	C	G	A	C	F	C	F	C	C		R	R	R	A	R		R	R		R	F					R							R	R	cf		
93	A	G	A	F	A	C	C	A	C	C	F	F	F	A	F	F	C	C	R		R	VR	R			F	F	R	F	F	R	F	R	R	cf		
91	R	M	A	F	R	F		C	F					F	R						F									F							
82	R	M	A	F	F	F	F	C						C				R		R							F		R								
81	F	M	A	R	F	F	R	C	F			R		C	R	F		R	R										R								
80	F	M	C	F	C	F	F	A	F	R	VR	R	R	F			F									R			R	VR							

Table 3. Range chart of calcareous nannofossils of Poggio Vitalba section (see text for simbols).

include rare to few/common *C. mexicana*, *C. angustiforatus*, *C. octofenestratus*, *C. deflandrei*, *L. carniolensis*, *M. hoschulzii*, *M. chiastius*, *N. globulus*, *Rucinolithus* sp., and *R. asper*; and very rare to few *B. constans*, *B. bigelowii*, *B. regularis*, *C. conicus*, *G. diplogrammus*, *H. circumradiatus*, *M. pemmatoidea*, *M.*

obtusus, N. colomii, N. kamptneri and *R. nebulosus.* The calcareous nannofossil assemblages of this biozone, compared to those of the *Nannoconus colomii* Zone, display an increase in total abundance and relative abundance. On the contrary, they are not very diversified from those belonging to the *Calcicalathina oblongata* Zone.

Reference sections - This zone has been easily recognized at Mt. Vitalba and Poggio Vitalba sections. The calcareous nannofossil assemblages from the upper part of the Mt. Vitalba section are correlated with the assemblages of the basal part of the Poggio Vitalba section.

Age - Late Berriasian-earliest Valanginian based on the presence of *R. wisei, P. fenestrata, T. jurapelagicus* and *T. verenae;* this Zone corresponds to the NK-2 of Bralower *et al.* (1989).

***Calcicalathina oblongata* Zone**

Definition - Interval from the first occurrence of *Calcicalathina oblongata* to the first occurrence of *Lithraphidites bollii*; author: Thierstein, 1971.

Remarks - Almost all samples referred to this biozone belong to the Palombini Shale, and the nannofossil assemblages of this biozone are similar to those of the *Cretarhabdus angustiforatus* Zone. The zonal marker is present only in few samples, with very rare specimens. Besides, *T. jurapelagicus* and *T. verenae* occur sporadically in relative abundance ranging from very rare to few. *R. wisei* disappears in the upper part of the Poggio Vitalba section slightly before the LO of *T. verenae*; both species are absent in the Romito section.

The assemblages (Tab. 3) comprise few/common to abundant *A. infracretacea, C. margerelii, C. cuvillieri, D. lehmanii, N. steinmannii, Watznaueria* spp., *Z. embergeri* and rare to few *C. mexicana, C. angustiforatus, C. deflandrei, L. carniolensis, M. chiastius, M. hoschulzii, M. obtusus, P. fenestrata* and *R. asper*. Species with scattered occurrence and relative abundance ranging from very rare to few are: *B. costans, B. bigelowii, B. regularis, Calcicalathina* sp. A, *C. conicus, C. octofenestratus, D. rectus, G. diplogrammus, H. circumradiatus, M. pemmatoidea, N. colomii, N. kamptneri, N. globulus, Rucinolithus* sp., *R. wisei* and *S. colligata*. In the recognized *Cretarhabdus angustiforatus* and *Calcicalathina oblongata* Zones the nannoconids are abundant and well-preserved but not diversified; as a matter of fact *N. steinmannii* is always predominant.

Reference sections - This Zone has been recognized at Poggio Vitalba and Romito sections. The nannofossil assemblages from the upper part of the Poggio Vitalba section are correlated with the impoverished nannofloras of the Romito.

Age - The reported assemblages are characterized by the occurrence of *C. oblongata, T. verenae*, and *R. wisei*; the two latter species disappear in the upper part of the Poggio Vitalba section (within the Palombini Shale). These data allow us to refer these assemblages to the lower and middle part of the *Calcicalathina oblongata* Zone, early to late Valanginian in age which is correlated with the NC 3 of Roth (1978), Bralower (1987), Channell *et al.* (1987) and Channell & Erba (1992).

***Lithraphidites bollii* Zone**

Definition - Interval from the first occurrence of *Lithraphidites bollii* to the last occurrence of *Calcicalathina oblongata*; author: Thierstein, 1971.

Remarks - All samples referred to this biozone belong to the Palombini Shale and are characterized by the absence of *C. cuvillieri* and the presence of *C. oblongata* together with *R. terebrodentarius*. The absence of *C. cuvillieri*, from the lowest samples collected at Chioma section, is not related to preservation or paleoecological causes. In fact, *C. cuvillieri* is always present and quite abundant in the early Berriasian-late Hauterivian Tethyan sediments (quoted literature). Besides, the absence of *C. cuvillieri* is consistent with the FO of *R. terebrodentarius*, considered coincident or slightly younger than the LO of *C. cuvillieri* (Bralower, 1987; Channell *et al.*, 1987; Applegate & Bergen, 1988; Channell & Erba, 1992). Within this zone, as well as in the *Cretarhabdus angustiforatus* and *Calcicalathina oblongata* Zones, very similar forms to *R. terebrodentarius* (Bralower *et al.*, 1989; Applegate & Bergen, 1988) were observed and reported in the range charts as *Rucinolithus* sp.

L. bollii has been found only in 2 samples. It must be noticed that there is no disagreement on the FO and the LO of *L. bollii,* but frequently this species is rarely or very rarely present, and sometimes heavely overgrown and not easily recognizable (Bralower, 1987; Applegate & Bergen, 1988). Moreover, in 2 samples from Chioma section, very strongly overgrown specimens of *Lithraphidites* sp. are present some of which are dubiously listed as *L.* cf. *bollii.*

The assemblages belonging to this biozone (Tab. 4), are characterized by the predominance of *Watznaueria* spp. and the presence of rare to common/abundant *C. angustiforatus, C. margerelii, D. lehmanii, L. carniolensis, M. hoschulzii, M. obtusus, M. chiastius, N. globulus, N. steinmannii, R. asper, R. terebrodentarius*, and *Z. embergeri*. Other species occasionally present include very rare to rare/few *A. infracretacea, B. bigelowii, B. regularis, Calcicalathina* sp. *A, C. oblongata, C. mexicana, C. conicus, C. octofenestratus, C. deflandrei, G. diplogrammus, H. circumradiatus, M. pemmatoidea, N. bucheri, N. colomii, N. kamptneri N. wassallii, P. fenestrata, Rucinolithus* sp. and *S. colligata.*

Reference section - As said above, the upper part of the *C. oblongata* and the lower part of the *Lithraphidites bollii* Zone have not been found in all the investigated section. The middle-upper part of *Lithraphidites bollii* Zone has only been recognized at Chioma section.

Age - The previously reported assemblages are characterized by the absence of *C. cuvillieri*, the presence of *C. oblongata* and of *R. terebrodentarius* and the scattered specimens of *L. bollii* and *L.* cf. *bollii.* The occurrence of *R. terebrodentarius* from the lowest samples collected at Chioma section, allow us to refer these assemblages to the middle-upper part of

Samples	Abundance	Preservation	*Watznaueria spp.*	*Z. embergeri*	*C. margerelii*	*R. asper*	*M. hoschulzii*	*M. obtusus*	*B. regularis*	*B. bigelowii*	*A. infracretacea*	*D. lehmannii*	*M. pemmatoidea*	*H. circumradiatus*	*L. carniolensis*	*G. diplogrammus*	*M. chiastius*	*C. mexicana*	*C. oblongata*	*Calcicalathina sp. A*	*C. angustiforatus*	*C. octofenestratus*	*C. conicus*	*P. fenestrata*	*S. colligata*	*C. deflandrei*	*B. costans*	*N. steinmannii*	*N. colomii*	*N. kamptneri*	*N. globulus*	*N. wassallii*	*N. bucheri*	*R. terebrodentarius*	*Rucinolithus sp.*	*L. bollii*
44	VR	B	F				VR				VR																									
43	VR	B	C	R							R																									
42	R	M	A	F	F		F	R			F				F						VR	R						F			R			R		
41	R	B	C	R	F			R		R					R	R					R							R								
40	VR	B	C	VR	F		VR								VR																					
39	VR	C	C	R			VR				R																	C						VR		
79	F	M	A		C				R					VR	F		F				R							C		R	F	R		F		
37	VR	M	C	R	F						R	F																								
78	F	M	A	C	C	F	F	F		F			R	R	F		F	R	VR		R		R	R				F			F		VR	R		
77	F	G	A	F		F	F	F	R			F	R	R	F	R	C	R	VR		F	F		R		C		C		VR	C	VR	VR	F		VR
76	F	B	A	F	C				VR		R						R	R				R						F			R			VR		
36	R	M	C		F	F						F			R	VR				VR	R							F			R					
75	VR	B	C								VR																							VR		
35	R	M	C	F	C	R						R			F		F	R												VR				F		
34	C	G	A	C	C		R	R				F	R	R	F		F	R			R	R						C	R		F	VR	VR	F		
33	VR	B	C					VR							R													VR								cf
74	C	G	A	C		R	R	R		VR	R	F	F		F	R	C	R	VR		R	R				R					R			R		
73	C	M	C	F					R							R	F	R	VR			F							R		C	VR	R			
32	F	M		F	F		F	R	F		F	R			F		C	VR	VR		R			VR		VR		F			R					
31	F	M	A		F							F		VR	R		R									VR		VR					VR	F		
30	VR	B	C		F			R									R																			
71	F	G	A	F	C		F	R		F		F		R	F	F		R	VR		VR	F		R				F	R		F		cf	R		
29	F	M	A	F			F	F			F				R			VR										C			F			R		
70	R	M	A		F	R	R	VR	F				R		R	R	F																			
27	F	M	A	F	C		F	R	R	R		F	VR	R	F	R	R	R	VR			F		R		R		F	VR	VR	F	VR	cf	F	F	cf
68	C	M	C		F	R	R						R	R	F	VR	F		VR		R		R		F			F			F		VR			
25	C	G	A	F	F	R	F	F	R	R	R	F		VR	C	R	F		VR		F	R	VR	R				F		F	R			R		
67	C	M	A	F	F		F	F	R		VR	R			VR		F				R		R	R				F			F			R		VR
23	F	M	A	F	C	F	F	R				F		R	F		F	VR			F	F					VR							R		
65	R	B	F	F	R						R									VR														R		
22	F	M	C	F	F	R		R		R		R				VR		R			R										R					
21	F	M	A	R	C		F	F	R		F	R	R	R	F		R		VR		R	F		VR	cf			F						R	R	
20	C	M	A	F	C	F	C	F	R	F	R	F	R	R	F	VR	F	R			R	F		VR				R		R	R		VR	F		
61	F	M	C	F	C	F		F	VR		R	F	R		F		F	F			F	R	R					C			F	cf	VR		R	
60	F	M	A	C	C	F	C	F	F		F	F	R	R			F	R			F	R						C	R	R	C	VR	VR	R		
57	VR	VB	F														F																			
56B	VR	M	C	R	F						F		VR			R	F														VR			VR	R	
55	C	M	A	C	C	R	F	F	R		F	F		R	C	VR	C	R	R		R	F		VR	cf			F			R			R		
17	R	M	A	F	C			R		R	F	F	F	R	F	R	F	R	VR															R		
16	C	M	VA	C	C			C	F		C	F	R	R	F		VR	R	VR		F							C	R	R	F			R		
54	F	C	C	F	C		F	R				R	R	R	R		R				R							F							R	
15	F	M	A	F	F	R	F	R	F	F	F	F	R	R	R	R			VR		F	F						R						F		
53	F	M	A	F	F	R	F	R	F																											

Table 4. Range chart of calcareous nannofossils of Chioma section (seė text for simbols).

Lithraphidites bollii Zone, which is correlated with the NC 5b/NC 5c of Bralower (1987), Channell *et al.*, (1987), Channell & Erba (1992) and the CC 5 of Sissingh (1977) and Perch-Nielsen (1985). Therefore these assemblages are assignable to the late Hauterivian/early Barremian.

CONCLUSIONS

Four unmetamorphosed Lower Cretaceous sections, belonging to the Bracco/Val Graveglia Unit, have been investigated in Southern Tuscany (Italy). The Bracco/Val Graveglia Unit consists of Jurassic ophiolite sequence and its thick sedimentary cover, interpreted as remnants of the Western Tethys oceanic lithosphere. The studied succession includes the Calpionella Limestone and the Palombini Shale. They are correlated to the Maiolica, of the Tuscan-Umbrian-Marchean and Southern Alps paleogeographic domains, which was deposited on the continental margin bordering the Ligurian-Piedmont Basin to the southeast.

In the studied area, the Mt. Alpe Chert, made up of well-bedded ribbon radiolarites, passes to the Calpionella Limestone throughout a thin silty-marly interval. The Calpionella Limestone includes grey to dove siliceous and marly limestones with rare intercalations of grey marlstones or clayey marlstones and grades upwards to the Palombini Shale. This latter consists of grey marlstones and grey to dark marly claystones, with intercaled grey to dove siliceous and marly limestones. In the investigated sections the studied formations are continuously exposed and with well-preserved lithostratigraphic features. Besides, the majority of the collected samples shows rich, diversified and nicely preserved calcareous nannofossil assemblages.

Altogether, 25 genera and 42 species have been recognized. In more than 30% of the fossiliferous samples, the total number of species ranges from 10 to 25, the total abundance ranges from few to common and the preservation ranges from moderate to good. The total abundance shows some relatively high fluctuations depending on the lithology: marlstones and marly limestones are frequently characterized by richer assemblages compared to those of limestones and calcareous claystones. Likewise, the preservation strongly depends on the lithology: the marlstones show the best preserved nannofloras, whereas the marly claystones and calcareous claystones display specimens with evidence of dissolution. On the other hand, overgrowth generally characterizes the limestones and the siliceous limestones.

Following Thierstein (1971, 1973, 1976) the recognized Zones are: *Nannoconus colomii*, *Cretarhabdus angustiforatus*, *Calcicalathina oblongata* and the middle-upper part of *Lithraphidites bollii*. In addition, the detected nannofossil events are: FO of *Cretarhabdus angustiforatus*, FO of *Rucinolithus wisei*, FO of *Percivalia fenestrata*, FO of *Tubodiscus jurapelagicus*, FO of *Tubodiscus verenae*, FO of *Calcicalathina oblongata*, LO of *Rucinolithus wisei*, LO of *Tubodiscus verenae* and FO of *Rucinolithus terebrodentarius*. In the Chioma section the co-occurence of *Calcicalathina oblongata* and of *Rucinolithus terebrodentarius* is reported.

The stratigraphic contact between Mt. Alpe Chert and Calpionella Limestone lies in the upper part of the *Cretarhabdus angustiforatus* Zone (late Berriasian), between the FO of *Percivalia fenestrata* and the FO of *Tubodiscus jurapelagicus*. The stratigraphic contact between Calpionella Limestone and Palombini Shale lies in the lowest part of *Calcicalathina oblongata* Zone (earliest Valanginian), slightly above the FO of the zonal markers. Consequently, the Calpionella Limestone ranges from the late Berriasian (upper part of *Cretarhabdus angustiforatus* Zone) to the earliest Valanginian (lower part of the *Calcicalathina oblongata* Zone). At Poggio Vitalba, the overlaying Palombini Shale is referred to the Valanginian part of the *Calcicalathina oblongata* Zone. Moreover, the uppermost part of the Palombini Shale, sampled at Chioma, is ascribed to the middle-upper part of *Lithraphidites bollii* Zone, which is late Hauterivian-early Barremian in age.

In the studied section, the pelagic coccoliths-bearing sedimentation of the Calpionella Limestone took place within the late Berriasian. Later on, during the early Valanginian the clastic input increases and gives rise to the Palombini Shale deposition, which was ubiquitous in the whole Ligurian-Piedmont basin at least until the early Barremian. Consequently, in the investigated sector of the Ligurian-Piedmont basin, the coccolith-bearing sedimentation is younger than the corresponding late Titonian beginning of the biogenic calcareous sedimentation of the Maiolica in Tuscan-Umbrian-Marchean and Southern Alps paleogeographic domains. On the contrary, the onset of the Valanginian clastic input is earlier in the Ligurian-Piedmont than in the Tuscan-Umbrian-Marchean and Southern Alps basins, where it is represented by the late Aptian Scaglia.

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