Atti Soc. tosc. Sci. nat., Mem., Serie A, 114 (2009)
pagg. 75-83, figg. 6, tabb. 2

N. Perilli (*), R. Catanzariti (**), A. Cascella (***), D. Nannini (*)

THE CALCARI DI GROPPO DEL VESCOVO FORMATION (SUBLIGURIAN UNITS; NORTHERN APENNINES, ITALY): NEW DATING BASED ON CALCAREOUS NANNOFOSSILS

Abstract - New dating based on calcareous nannofossils recovered from the Calcari di Groppo del Vescovo Fm. is presented in this paper. This unit and the Argille e calcari di Canetolo Fm. belong to the Canetolo Unit (Subligurian Units) which is interposed between the Ligurian and Tuscan Units. Due to tectonics, the lateral extension and thickness of the outcrops of the Calcari di Groppo del Vescovo Fm. are limited and the contact with the Argille e calcari di Canetolo Fm. is usually tectonized. The aim of this paper is to refine the dating of the Calcari di Groppo del Vescovo Fm. in order to clarify the relationship with the Argille e calcari di Canetolo Fm. in the investigated areas of the Ligurian-Emilian-Tuscan Apennine. Based on semiquantitative analysis of the assemblages, the Calcari di Groppo del Vescovo Fm. ranges in age from Early Eocene (NP11) to Middle Eocene (NP14). Our data point out for the first time the existence of latero-vertical relationships between this unit and the Argille e calcari di Canetolo Fm. which dates from Late Paleocene (NP5) to Early Eocene (NP11) and Middle Eocene (NP14 to NP15) in age.

Key-words - Marly calcareous turbidites, Calcareous nannofossils, Biostratigraphy, Eocene, Subligurian Units, Northern Apennines.

Riassunto - *La formazione dei Calcari di Groppo del Vescovo (Unità Subliguri, Appennino Settentrionale, Italia): nuovi dati basati sui nannofossili calcarei*. La formazione dei Calcari di Groppo del Vescovo e la formazione delle Argille e calcari di Canetolo appartengono all'Unità di Canetolo (Unità Subliguri), che nell'area studiata è interposta tra le Unità Toscane e le Unità Liguri. Lo scopo di questo lavoro è quello di datare la formazione dei Calcari di Groppo del Vescovo e di chiarire i rapporti stratigrafici tra questa unità e la formazione delle Argille e calcari di Canetolo, sulla base dei risultati biostratigrafici acquisiti durante la realizzazione dei Fogli 233 Pontremoli, 234 Fivizzano e 250 Castelnuovo Garfagnana (Appennino Ligure-Tosco-Emiliano) nell'ambito del Progetto CARG. L'analisi semiquantitativa delle associazioni a nannofossili calcarei presenti nelle torbiditi calcareo-marnose appartenenti alla la formazione dei Calcari di Groppo del Vescovo consente di attribuire questa unità all'intervallo di tempo compreso tra l'Eocene Inferiore (NP11) e l'Eocene Medio (NP14). Questi dati permettono di riconoscere per la prima volta l'esistenza di rapporti latero-verticali tra la formazione dei Calcari di Groppo del Vescovo e la formazione delle Argille e calcari di Canetolo, poiché le successioni attribuite a quest'ultima formazione sono riferite al Paleocene Inferiore-Eocene Inferiore (NP5-P11) ed all'Eocene Medio (NP14-NP15).

Parole chiave - Torbiditi calcareo marnose, Nannofossili calcarei, Biostratigrafia, Eocene, Unità Subliguri, Appennino Settentrionale.

Introduction

Middle Campanian-Middle Eocene thick successions of marly calcareous turbidites crop out extensively in the Northern Apennines. They are characteristic of the External Ligurian Units and the Canetolo Unit Auctt. while they are absent in the Tuscan Units (Fig. 1). In the External Ligurian Units marly calcareous turbidites represented the bulk of the Helminthoid Flysch Auctt. (Marroni *et al.,* 1992; Catanzariti *et al.,* 2002). They also characterize the Flysch di Vico and the Flysch di Monte Penice formations of the Vico and Penice subunits (Labaume, 1992, Elter *et al.,* 1997), which are assigned to the External Ligurian Units by Catanzariti *et al.* (2002). In the Canetolo Unit (Plesi, 1975b), marly calcareous turbidites are represented by the Calcari di Groppo del Vescovo Fm. Due to tectonics, the lateral extension and thickness of the outcrops of this formation are limited and the contact with the under- and overlying pelitic-dominat successions is badly exposed or hidden. Therefore, in literature there are still diverse opinions concerning the stratigraphic relationships among the formations of the Canetolo Unit and, in particular, between the Calcari di Groppo del Vescovo Fm. and the Argille e Calcari di Canetolo Fm. Early geological studies placed the Calcari di Groppo del Vescovo Fm. above the Argille e Calcari di Canetolo Fm. (Barbieri & Zanzucchi 1963; Monteforti & Raggi 1975). According to Plesi (1975b) the Canetolo Unit includes the Argille e calcari inferiori Fm., the Calcari del Groppo del Vescovo Fm. and the Argille e calcari superiori Fm. (which is similar to the Argille e calcari inferiori Fm.), although Plesi (1974) recognized lens-shaped intercalations of Calcari di Groppo del Vescovo Fm. within the Eocene «argille e calcari» Fm. Later (Fig. 2), the Calcari di Groppo del Vescovo Fm. was placed below the Argille e Calcari di Canetolo Fm. (Cerrina Feroni *et al.,* 1991; Plesi *et al.,* 1998) or the Canetolo Fm. (Plesi *et al.,* 1993).

The most complete succession of the Canetolo Unit is described by Cerrina Feroni *et al.* (1991). It is exposed between Parma and Enza Valleys (Fig. 2a) and includes: 1) an Upper Cretaceous siliciclastic substratum (Arenarie di Ostia Fm.) overlaid by Upper Cretaceous–Lower Paleocene pelitic-calcareous complex (Complesso dei calcari verdi manganesiferi Fm.) and 2) a shaly-calcareous succession composed of Upper Paleocene-Lower

(*) Dipartimento di Scienze della Terra, Università degli Studi di Pisa, via Santa Maria 53, 56126 Pisa, Italy. E-mail: perilli@dst.unipi.it; nannini@dst.unipi.it
(**) Istituto di Geoscienze e Georisorse, via Moruzzi 1, 56124 Pisa, Italy. E-mail: catanzariti@igg.cnr.it
(***) Istituto Nazionale di Geofisica e Vulcanologia, via della Faggiola 32, 56126 Pisa, Italy. E-mail: cascella@pi.ingv.it

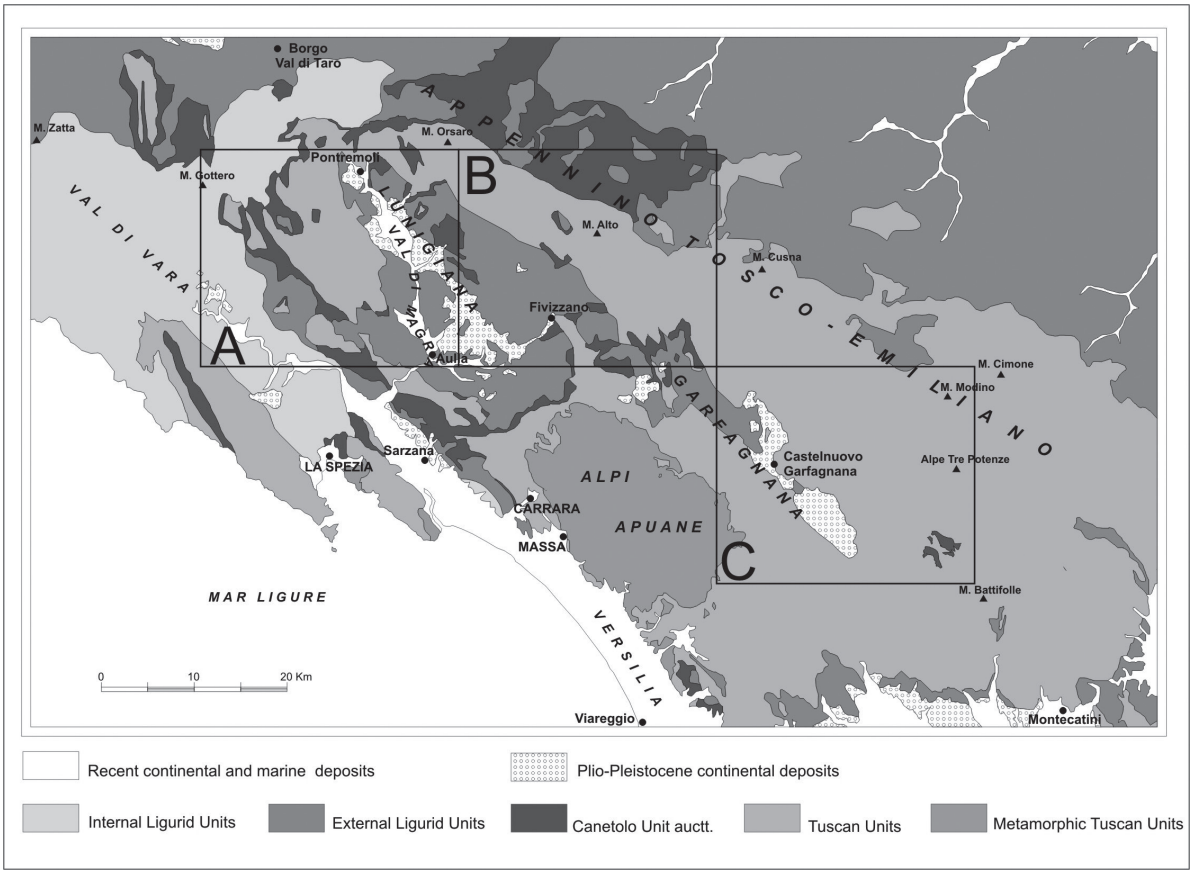

Fig. 1 - Geological sketch of the Northern Apennines, main tectonic units. The sampled sections are located within the Sheets 233 Pontremoli (A), 234 Fivizzano (B) and 250 Castelnuovo Garfagnana (C) of the Geological Map of Italy at 1:50,000 scale of the CARG Project.

Eocene (Argille e Calcari di Rio Canalgrande Fm.) which grades up to the Lower-Middle Eocene Calcari di Groppo del Vescovo Fm. that is in turn topped by Middle Eocene Argille e Calcari di Canetolo Fm. In the Taro Valley (Fig. 2b), Plesi *et al.* (1993) recognized a similar succession which also includes two portions: 1) the lower one is composed of Upper Cretaceous arenaceous deposits (Arenarie di Ostia Fm.) grading up to an Upper Cretaceous–Lower Paleocene pelitic interval (Argille varicolori Fm.) which is overlaid by Upper Cretaceous-Lower Eocene alternance of calcarenites and sandstones (Rio Nicola Fm.) and 2) the upper one is composed of Lower Eocene marly calcareous turbidites (Calcari di Casacca Fm. = Calcari di Groppo del Vescovo Fm.), disrupted succession of Middle Eocene pelitic to pelitic-calcareous deposits (Canetolo Fm.) and Eocene polymictic breccias (Brecce di Rio Prato dei Rossi Fm.).

This paper aims to improve the dating of the Calcari di Groppo del Vescovo Fm. of the Canetolo Unit, sampled in different areas of the Ligurian-Emilian-Tuscan Apennines (Fig. 1), in order to make clear the stratigraphic relationships with the Argille e Calcari di Canetolo Fm.

Lithostratigraphy of the Canetolo unit

In the investigated areas of Pontremoli, Fivizzano and Castelnuovo Garfagnana (Ligurian-Emilian-Tuscan Apennine), the Canetolo Unit is interposed between the Ligurian and Tuscan units. Its Paleo-Eocene portion includes the Argille e Calcari di Canetolo and the Calcari di Groppo del Vescovo formations.

Argille e Calcari di Canetolo Fm

It usually consists of dark grey to black laminated pelites (showing pervasive foliation and a diffuse scaly fabric) with intercalations of calcarenites, lithic siltites and fine grained arenites. Due to tectonics, the formation frequently consists of sometimes folded slabs and chunks of pelitic-calcareous alternances intercalated or floating within the pelitic-dominat successions (i.e broken formation). The less disrupted successions of Argille e Calcari di Canetolo Fm. consist of pelitic to pelitic-calcareous lithofacies with intercalations of siltites, lithic arenites and thick marly calcareous turbidites. Intercalations of intrabacinal debris flows and slumps are also present. The marly calcareous turbidites (similar to that of Calcari di Groppo del Vescovo Fm.) are

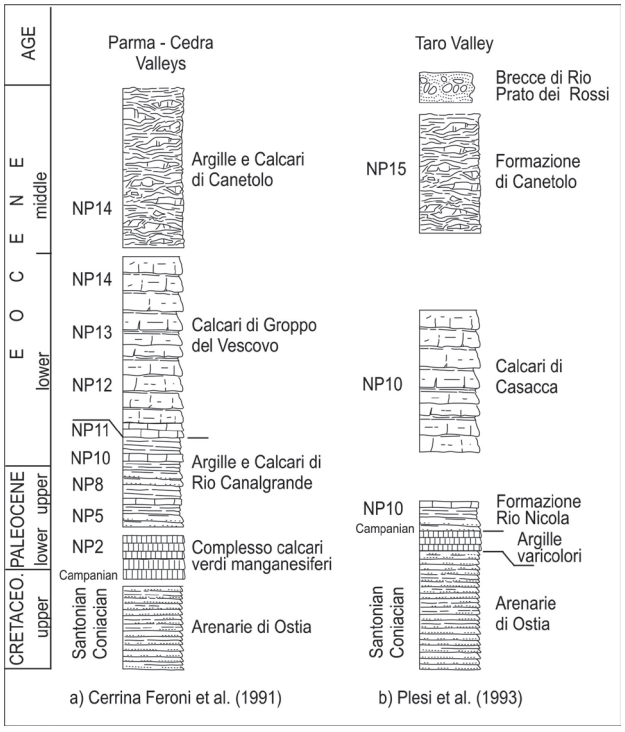

Fig. 2 - Lithostratigraphy of the Canetolo Unit in the (2a) Parma and Cedra Valleys (Cerrina Feroni *et al.*, 1991) and in the (2b) Taro Valley (Plesi *et al.*, 1993). CRETACEO. = CRETACEOUS. Arenarie di Ostia Fm. (cfr. Arenarie di Scabiazza Fm.); Complesso calcari verdi manganesiferi Fm. (= Marne di Rio Terre Rosse Fm.); Argille e Calcari di Rio Canalgrande Fm. (= Rio Canalgrande Fm.); Argille varicolori Fm. (cfr. Marne di Rio Terre Rosse Fm.); Rio Nicola Fm. (cfr. Rio Canalgrande Fm.); Calcari di Casacca Fm. (cfr. Calcari di Groppo del Vescovo Fm.); Formazione di Canetolo (cfr. Argille e Calcari di Canetolo Fm.). NP = Calcareous nannofossil zones of Martini (1991).

characterized by bioclastic calcarenites and calcirudites; bioclasts are mainly benthic (*Nummulites* and *Discocyclina*) and planctonic (*Globorotalia* and *Globigerina*) foraminifera. The thickness of the Argille e Calcari di Canetolo Fm. can reaches 100-200 m, but the lens-shape lithosomes are usually 20 to 50 m thick. Although in a few localities the uppermost part of the Argille e Calcari di Canetolo Fm. shows intercalations of marly calcareous turbidites, the contact, where exposed with Calcari di Groppo del Vescovo Fm. is usually sharp.

Calcari di Groppo del Vescovo Fm

The formation consists of medium to thick (20-80 cm) or very thick (2-5 m) marly calcareous turbidites with the base of the strata sometimes represented by coarse-grained bioclastic-rich calcarenites or calcirudites. The bioclastic fraction includes benthic (*Orbitoides*, *Nummulites*, *Discocyclina*) and planctonic (*Morozovella*, *Globoratalia* and *Globigerina*) foraminifera. This unit also comprises thin to medium thick intercalations of marly to siliceous calcilutites, fine grained arenites and pelites. The marly calcareous turbidites show parallel to convolute laminations and rare flute or groove casts. The Calcari di Groppo del Vescovo Fm. usually consists of lenticular lithosomes up to 30 to 100 m thick; the widest outcrops range in thickness from 100 to 200 m and can reach a lateral extension up to few kilometers. The contact between Calcari di Groppo del Vescovo Fm. and Argille e Calcari di Canetolo Fm. is usually sharp, though in a few places marly calcareous turbidites are also present in the overlying Argille e Calcari di Canetolo Fm.

Previous datings of the Calcari di Groppo del vescovo Formation

First datings of Calcari di Groppo del Vescovo Fm. were based on foraminifera mainly recovered from the calcarenitic and calciruditic portion of the marly calcareous turbidites (Tab. 1). Barbieri & Zanzucchi (1963) assigned this formation to the upper part of Eocene. Abbate (1969) recovered assemblages referable to the Middle Eocene, though the author did not excluded the presence of the Upper Eocene. Monteforti & Raggi (1968) and Abbate & Sagri (1970) dated the Calcari di Groppo del Vescovo Fm. to the Paleocene-Middle Eocene whilst Montanari & Rossi (1982) described only Early Eocene assemblages. Subsequently, Cerrina Feroni *et al.* (1991) recovered calcareous nannofossil assemblages from the Calcari di Groppo del Vescovo Fm. spanning in age from Early Eocene to Middle Eocene (NP12-NP14) and Plesi *et al.* (1993) documented an Early Eocene (NP10) calcareous nannofossil record, from the lower portion of this formation (Fig. 2 and Tab. 1).

Material and methods

The studied marly to marly calcareous samples have been collected from scattered outcrops where the geometric contact between the Argille e Calcari di Canetolo Fm. and Calcari di Groppo del Vescovo Fm. is exposed or from outcrops where the thicker lithosomes of the marly calcareous turbidites of Calcari di Groppo del Vescovo Fm. are embedded within Argille e Calcari di Canetolo Fm. In particular, the samples were not collected along a complete lithostratigraphic section but they were collected along limited transects (composite sections) where the Calcari di Groppo del Vescovo Fm. is well exposed or where the contact between the Calcari di Groppo del Vescovo Fm. and the Argille e Calcari di Canetolo Fm. crops out. The semiquantitative analysis of the simple smear slides has been performed with the light microscope at 1250 magnifications. In order to check also the presence of rare or very rare taxa, in each smear slides more than 2000 fields of view have been analyzed. Calcareous nannofossil nomenclature follows Perch-Nielsen (1985) and Bown (1998). The stratigraphic ranges of the key species (Fig. 3) are based on Perch-Nielsen (1985). The adopted zones are those defined by Martini (1971) and Okada & Bukry (1980) and the magneto-chronostratigraphy is based on Gradstein & Ogg (2006). For conservation of space: First Occurrence (FO); Last Occurrence (LO).

Tab. 1 - Previous ages assigned to the Calcari di Groppo del Vescovo Fm. based on foraminifera (f) and calcareous nannofossils (cn).

Authors	**Areas**	**Ages**
Barbieri & Zanzucchi (1963)	(Upper-Middle) Taro Valley	Upper part of Eocene (f)
Monteforti & Raggi (1968)	Mt. Senario	Paleocene-Middle Eocene (f)
Abbate (1969)	La Spezia	Middle Eocene-(?)Late Eocene (f)
Abbate & Sagri (1970)	Northern Apennines	Paleocene-Middle Eocene (f)
Montanari & Rossi (1982)	Northern Apennines	Early Eocene (f)
Cerrina Feroni *et al.* (1991)	Cedra Valley (Marma)	Early-middle Eocene (cn)
Plesi *et al.* (1993)	(Middle) Taro Valley	Early Eocene (cn)

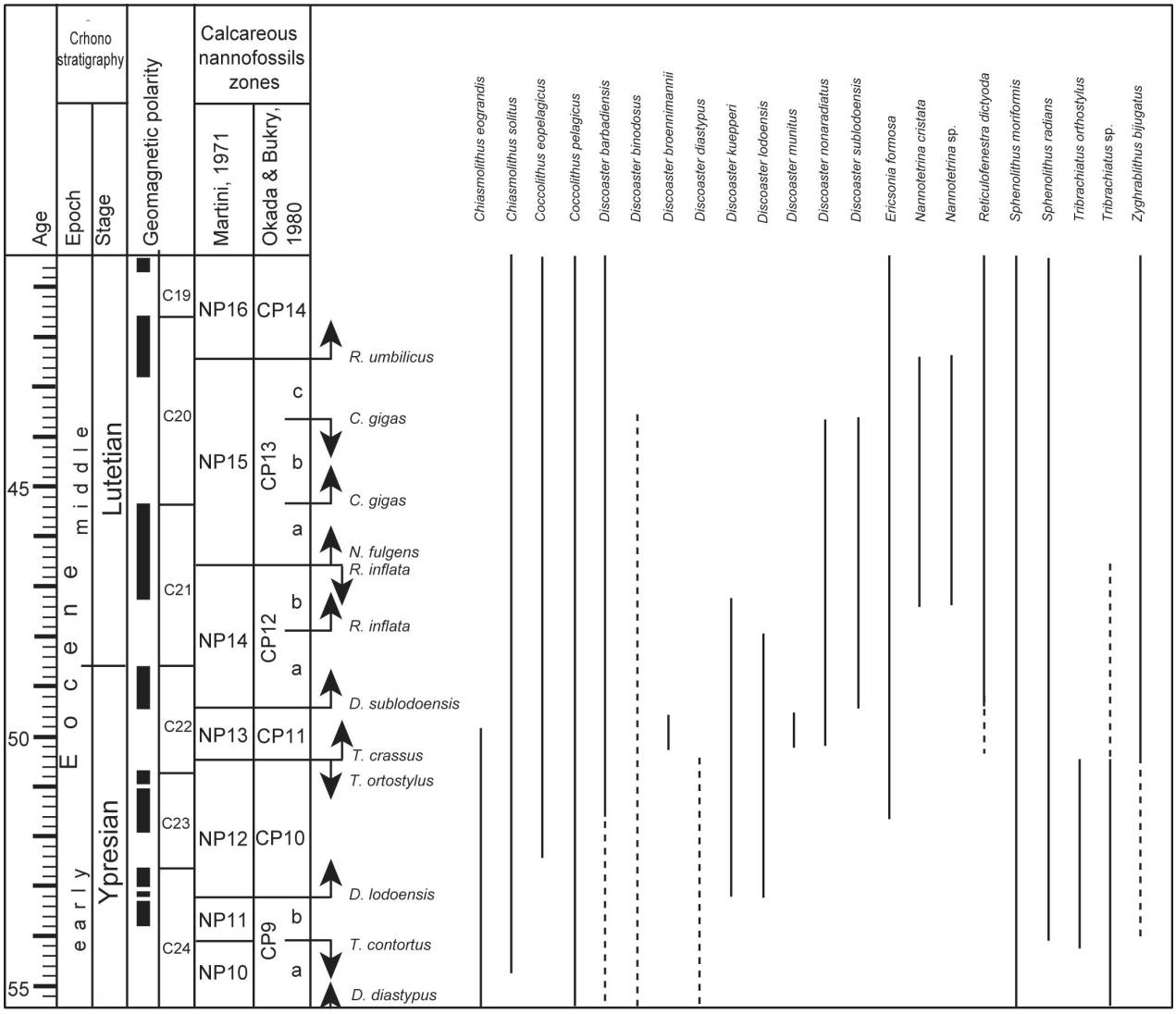

Fig. 3 - Range of the recognized age significant species based on Perch-Nielsen (1985), adopted zones are defined by Martini (1971) and Okada & Bukry (1980), magnetostratigraphy and chronostratigraphy is based on Gradstein & Ogg (2006).

Range of the recognized Eocene age significant species

In most of the samples, calcareous nannofossils are common, the preservation of the assemblages is generally moderate to poor and some of the Early-Middle Eocene markers are present. The recognized taxa include coccoliths belonging to the families Coccolithaceae, Discoasteraceae and Prinsiaceae as well as Eocene nannoliths belonging to the genera *Nannotetrina, Tribrachiatus* and *Zygrablithus*.

The *Coccolithaceae* is represented by common *Coccolithus pelagicus* and few to rare specimens of *Coccolithus eopelagicus*, *Chiasmolithus eograndis*, *Chiasmolithus solitus* and *Ericsonia formosa*. Among these species, *Chiasmolithus eograndis* (NP10/CP9 to NP13/CP11) and *Chiasmolithus solitus* (NP10/CP9 to NP16/CP14) are characteristic of the investigated time interval along with *Ericsonia formosa* which appears in the Early Eocene and is frequent in the Eocene-Lower Oligocene successions of the Northern Apennines (Catanzariti & Perilli, 2009). Scattered specimens of *Coccolithus crassus* (cfr. *Toweius crassus*) are also present in our material.

The *Discoasteraceae* includes *Discoaster barbadiensis* (NP10/CP9 to NP20/CP15) and rare to few specimens of *Discoaster lodoensis* and *Discoaster sublodoensis* (NP14/CP12a to NP15/CP13). The FO of these two latter markers defines the base of NP12/CP10 and NP14/CP12 zones, respectively. Other species are *Discoaster binodosus* irregularly distributed from Early to Middle Eocene, *Discoaster diastypus* (NP10/CP9 to NP12/CP10), *Discoaster nonaradiatus* (NP13/CP11 to NP15/CP13b), *Discoaster kuepperi* (NP12/CP10 to

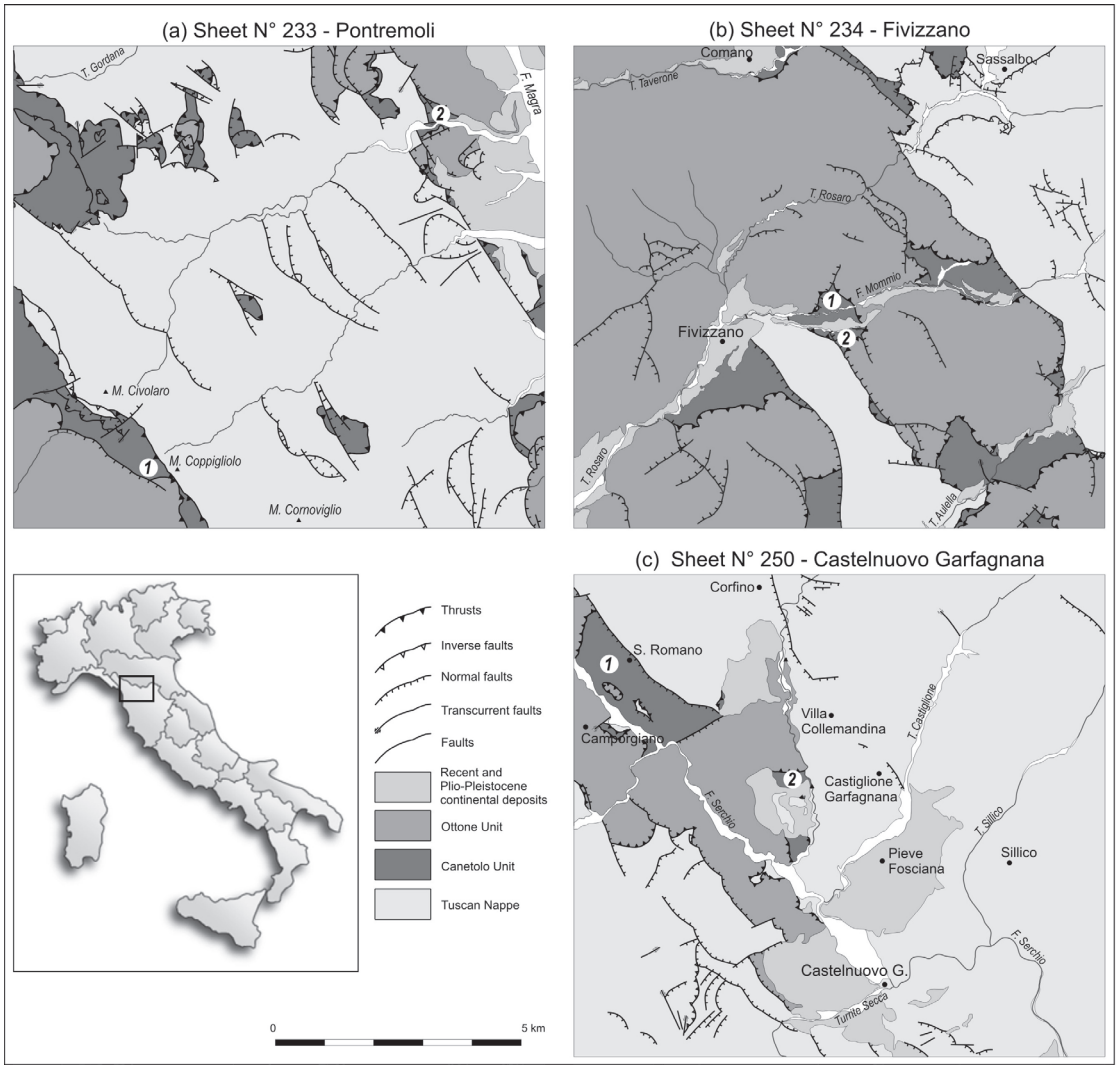

Fig. 4 - Location of the sampled sections. 4a) 1 Castagnetoli, 2 Corlaga. 4b) 1 Signano-Turano, 2 Collegnago. 4c) 1 S. Romano in Garfagnana, 2 Mozzanella.

NP14/CP12), *Discoaster broennimannii* and *Discoaster munitus.* These two latter species are present within the NP13 Zone.
The *Prinsiaceae* only includes the genus *Reticulofenestra.* It is represented by the first typical *Reticulofenestra* species grouped as *Reticulofenestra dictyoda* which also comprises *Reticulofenestra samodurovii*. The appearance of specimens belonging to this genus could be helpful to place the boundary between the biozones NP12/CP10 and NP13/CP11.
The *Sphenolitaceae* includes the long range species: *Sphenolithus moriformis* (Early Paleocene-Late Miocene) and *Sphenolithus radians*. This latter taxon is present from Early Eocene (NP11/CP1) to the Late Eocene (NP19/CP15).
The genus *Nannotetrina* is characteristic of the Middle Eocene and *Nannotetrina cristata* is one of the first species belonging to this genus which appears in the uppermost part of the NP14 Zone (i.e. CP12b). In the studied assemblages, only *Nannotetrina cristata* is easily recognizable whilst the other specimens belonging to this genus are grouped as *Nannotetrina* spp.
The Early Eocene genus *Tribrachiatus* is represented by specimens of *Tribrachiatus orthostylus*. The FO of this marker occurs just before the LO of *Tribrachiatus contortus* which can be used to approach the base of the biozone NP11/CP9b. Other specimens belonging to this genus are grouped as *Tribrachiatus* spp.
The genus *Zygrablithus* is represented by *Zygrablithus bijugatus* which occurs, for the first time, sporadically in the Late Paleocene (NP8/CP7) and becomes continuous and numerically more consistent in the Early Eocene (NP10/CP8).

Adopted schema and identified biozones

The calcareous nannofossil markers present in the studied assemblages allow us to recognize the NP11 to NP15 zones of Martini (1971), correlable with the CP9b to CP13 zones of Okada and Bukry (1980). They span the Early Eocene to Middle Eocene time interval (Fig. 3).

Discoaster binodosus Zone NP11
Definition. This short zone spans the interval between the LO of *Tribrachiatus contortus* to the FO of *Discoaster lodoensis.* It corresponds to the CP9b Sub-zone.
Remarks. Because *Tribrachiatus contortus* is absent in our material, the FOs of *Tribrachiatus orthostylys* and *Sphenolithus radians* are useful in identifying the base of this zone. The assemblages assigned to the NP11 Zone are also characterized by the presence of *Chiasmolithus eograndis*, *Coccolithus eopelagicus*, *Coccolithus pelagicus*, *Discoaster barbadiensis, Discoaster binodosus, Discoaster diastypus*, *Zygrablithus bijugatus* and *Chiasmolithus solitus*.

Tribrachiatus orthostylus Zone NP12
Definition. Interval from the FO of *Discoaster lodoensis* to the LO of *Tribrachiatus orthostylus.* The NP12 Zone corresponds to the CP10 Zone.
Remarks. Both markers are present in the assemblages assigned to this zone, which are also characterized by the presence of *Discoaster kuepperi*. The assemblages of the NP12 Zone also include *Chiasmolithus eograndis*, *Coccolithus eopelagicus*, *Coccolithus pelagicus*, *Discoaster barbadiensis*, *Discoaster binodosus*, *Sphenolithus radians* and *Zygrablithus bijugatus*.

Discoaster lodoensis Zone NP13
Definition. This short zone covers the interval from the LO of *Tribrachiatus orthostylus* to the FO of *Discoaster sublodoensis*. It corresponds to the CP11 Zone.
Remarks. The co-occurrence of *Chiasmolithus eograndis*, *Discoaster lodoensis* and the first specimens of *Reticulofenestra* characterize the assemblages of this zone. Other frequent taxa in the samples assigned to the NP13 Zone are *Coccolithus eopelagicus, Coccolithus pelagicus*, *Discoaster barbadiensis, Ericsonia formosa*, *Sphenolithus moriformis*, *Sphenolithus radians* and *Zygrablithus bijugatus* whereas *Discoaster binodosus, Discoaster broennimannii, Discoaster kuepperi* and *Discoaster munitus* are rare and *Coccolithus crassus* very rare.

Discoaster sublodoensis Zone NP14
Definition. Interval from the FO of *Discoaster sublodoensis* to the FO of *Nannotetrina fulgens*. The NP14 Zone corresponds to the CP12 Zone.
Remarks. *Discoaster sublodoensis* is extremely rare in our material and it is frequently represented by poorly preserved specimens which are difficult to distinguish from similar *Discoaster.* Consequently the absence of *Chiasmolithus eograndis* helps to recognize the base of this zone and the presence of specimens of *Nannotetrina* sp. allow us to recognize the upper part of this zone, which corresponds to the CP12b of Okada & Bukry (1980). Other species include *Coccolithus eopelagicus*, *Coccolithus pelagicus*, *Discoaster barbadiensis*, *Discoaster binodosus*, *Discoaster nonaradiatus*, *Discoaster* cf. *saipanensis*, *Reticulofenestra dictyoda*, *Sphenolithus moriformis*, *Sphenolithus radians* and *Zygrablithus bijugatus*.

Dating of the Calcari di Groppo del Vescovo Formation

The following paragraph reports the synthesis of the datings achieved for the Calcari di Groppo del Vescovo Fm. which were obtained during the realization of the Sheets 233 Pontremoli, 234 Fivizzano and 250 Castelnuovo Garfagnana of the Geological Map of Italy at 1:50,000 scale of the CARG Project (Puccinelli *et al.,* 2010a, 2010b, 2010c).
In the *Pontremoli area*, the Calcari di Groppo del Vescovo Fm. was sampled nearby Castagnetoli and Corlaga villages (Figs. 4a, 5a). In both localities the presence of *Coccolithus crassus* (cfr. *Toweius crassus*) and the absence of *Tribrachiatus orthostylus* allow us to recognize the NP13 Zone. However the majority of the assemblages are referable to the NP12 Zone for the concomitant occurrence of *Discoaster lodoensis* and *Tribrachiatus orthostylus* along with *Sphenolithus*

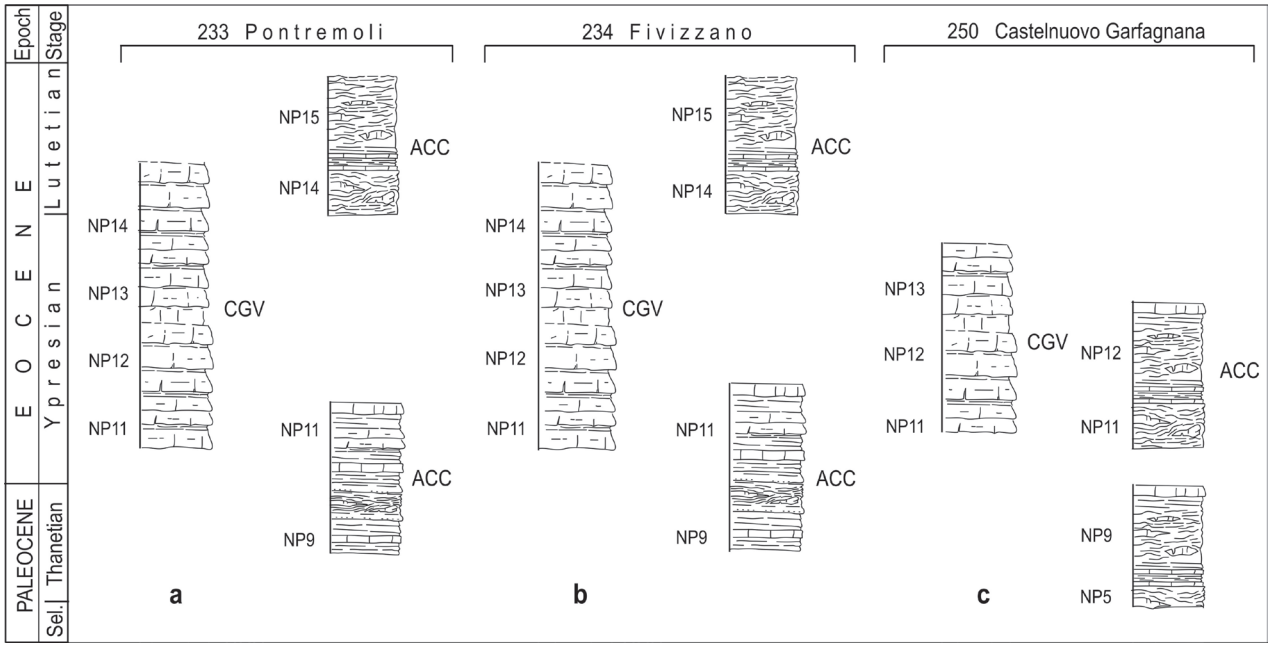

Fig. 5 - Schematic lithostratigraphic composite sections of the Calcari di Groppo del Vescovo unit (CGV) and ages based on the calcareous nannofossil assemblages recovered from this unit outcropping in the Sheets 233 Pontremoli (5a), 234 Fivizzano (5b) and 250 Castelnuovo Garfagnana (5c) of the Geological Map of Italy at 1:50,000 scale of the CARG Project. Lithostratigraphic sections and ages of the Argille e calcari di Canetolo Fm. (ACC) are based on Puccinelli *et al.* (2010a, 2010b, 2010c). ACC and CGV are the codes adopted in the Sheet of the Geological Map of Italy of the CARG Project for the Calcari di Groppo del Vescovo and Argille e calcari di Canetolo units respectively. Sel. = Selandian. For cronostratigraphy and nannofossil zones see Figure 3.

radians. In a few samples the presence of *Sphenolithus radians* and *Discoaster barbadiensis* permits us the recognition of the NP11 Zone and the occurrence of *Nannotetrina cristata* identifies the NP14 Zone.
In the *Fivizzano area*, the Calcari di Groppo del Vescovo Fm. was sampled between Signano and Turano (Figs. 4b, 5b). The assemblages recovered from the lowermost part of the formation are referable to the NP11 Zone according to the presence of *Tribrachiatus orthostylus* and the absence of *Discoaster lodoensis.* At Collegnago, the assemblages recovered from the Calcari di Groppo del Vescovo Fm., above the Argille e Calcari di Canetolo Fm., are characterized by the concomitant presence of *Discoaster lodoensis* and *Tribrachiatus orthostylus* which led us the identification of the NP12 Zone. Other assemblages, recovered from scattered sampling, could be assigned to the NP13 Zone due to the presence of *Discoaster lodoensis* and *Reticulofenestra dictyoda* and to the NP14 Zone for the presence of *Nannotetrina cristata*.
In the *Castelnuovo Garfagnana area*, nearby Mozzanella and S. Romano in Garfagnana (Figs. 4c, 5c), some scattered samples collected from the Calcari di Groppo del Vescovo Fm. allow us the identification of the NP12 Zone for the co-occurrence of *Discoaster lodoensis* and *Tribrachiatus orthostylus* and of the NP13 Zone based on the concomitant presence of *Discoaster lodoensis* and *Reticulofenestra dictyoda.* From this area it has also been recovered assemblage referable to the NP11 Zone.
The above reported data support latero-vertical relationships between Argille e Calcari di Canetolo and Calcari di Groppo del Vescovo formations (Fig. 6) as the oldest and youngest assemblages recovered from Calcari di Groppo del Vescovo Fm. are referable to the NP11 to NP14 biozones respectively and the assemblages recovered from Argille e Calcari di Canetolo Fm. range from NP9 to NP12 Zone and from NP14 to NP 15 Zone (Puccinelli *et al.,* 2010a, 2010b, 2010c). The overlap between the ages of Argille e Calcari di Canetolo Fm. and the ages of Calcari di Groppo del Vescovo Fm. makes possible to hypothesize that the latter unit is a member intercalated within Argille e Calcari di Canetolo Fm. (Tab. 2), though the contact between these two units is badly exposed and usually tectonized, due to the different mechanical features of the monotonous pelitic-dominant lithofacies of Argille e Calcari di Canetolo Fm. (usually outcropping as «broken formation») and of the marly calcareous turbidites of Calcari di Groppo del Vescovo unit (usually represented by lenticular lithosome embedded within the Argille e Calcari di Canetolo Fm.).

Conclusive remarks

Up to now the stratigraphy of the Canetolo Unit is still not clear. The reasons that make difficult to understand the stratigraphic relationship between the pelitic to pelitic-calcareous and the marly calcareous lithofacies which characterize the (Paleocene-Eocene) upper por-

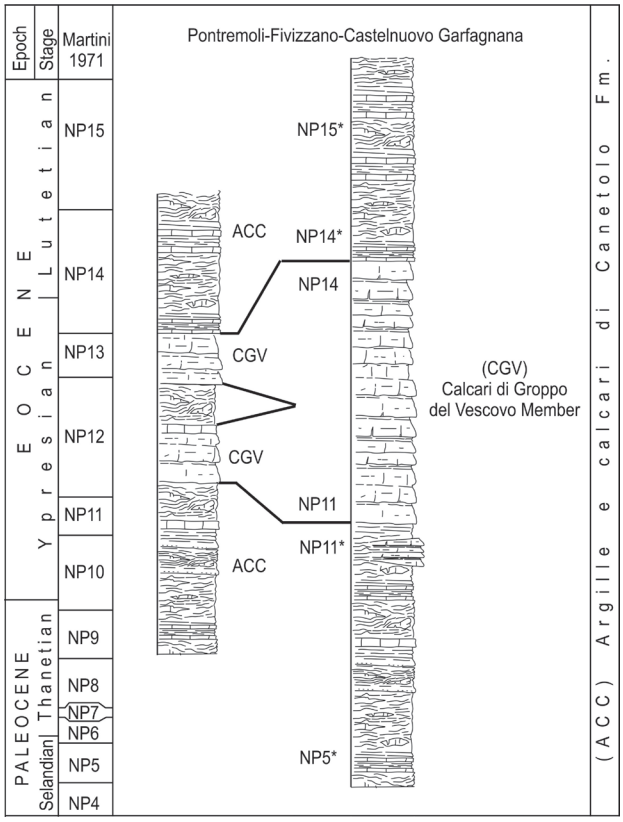

Fig. 6 - Ages of the Calcari di Groppo del Vescovo and proposed lithostratigraphy of the Lower Paleo-Middle Eocene succession belonging to the Canetolo Unit outcropping in the Sheets 233 Pontremoli, 234 Fivizzano and 250 Castelnuovo Garfagnana (Geological Map of Italy at 1:50,000 scale of the CARG Project). * Ages of Argille e calcari di Canetolo Fm. are from Puccinelli *et al.* (2010a, 2010b and 2010c).

tion of the Canetolo Unit Auctt. are: 1) the lithological similarities of the pelitic to pelitic-calcareous successions, which has led to a proliferation of formational names (Tab. 2); 2) the bad exposures where it is visible the contact between the pelitic-dominant successions of the Argille e Calcari di Canetolo Fm. and the marly calcareous turbidites belonging to the Calcari di Groppo del Vescovo Fm.; 3) the discontinuous and scarce biostratigraphic record of the deposits assigned to the Canetolo Unit.

In this paper, for the first time, is refined the age of the Calcari di Groppo del Vescovo Fm. using calcareous nannofossils. Based on semiquantitative analysis, the assemblages recovered from the Calcari di Groppo del Vescovo Fm. are referable to the NP11, NP12, NP13 and NP14 zones and allow us to assign this unit to an Early-Middle Eocene age. These datings support the existence of latero-vertical relationship between the Argille e Calcari di Canetolo and the Calcari di Groppo del Vescovo units (Fig. 5), because in the Pontremoli, Fivizzano and Castelnuovo Garfagnana areas the successions assigned to the Argille e Calcari di Canetolo Fm. range from Late Paleocene (NP5) to Early Eocene (NP11) and Middle Eocene (NP14 to NP15) in age.

Therefore: 1) the Argille e Calcari di Canetolo Fm. underlying the Calcari di Groppo del Vescovo Fm. are correlable with the Argille e calcari inferiori Fm. (Plesi 1975b), the Argille e Calcari di Rio Canalgrande Fm. (Cerrina Feroni *et al.,* 1991; Plesi *et al.,* 1998) and the Rio Nicola Fm. (Plesi *et al.,* 1993) and 2) the Argille e Calcari di Canetolo Fm. overlying the Calcari di Groppo del Vescovo Fm. are correlable with the Argille e calcari superiori Fm. (Plesi 1975b), the Argille e Calcari di Canetolo Fm. (Cerrina Feroni *et al.,* 1991; Plesi *et al.,* 1998) and the Canetolo Fm. (Plesi *et al.,* 1993). Consequently, 1) it is not excluded that all these units could be considered members of Argille e Calcari di Canetolo Fm. and 2) also the marly calcareous turbidites of the Calcari di Groppo del Vescovo Fm. should be considered a lithostratigraphic member of Argille e Calcari di Canetolo Fm. (Tab. 2).

In summary, from the Late Paleocene to Middle Eocene, the sedimentary basin of the Canetolo Unit was characterized by a discontinuous deep pelagic sedimentation which was intermittently reached by marly calcareous turbiditic deposits similar to that of the Helminthoid Flysch Auctt. in the External Ligurian Domain. According to this scenario, the palaeogeographic area of the Canetolo Unit was probably not far from the sedimentary basins of the Penice and Vico sub-units because both are characterized by Upper Paleocene-Middle Eocene marly calcareous turbidites belonging to the Flysch di

Tab. 2 - Proposed correlation between Argille e calcari di Canetolo Fm. and the member of the Calcari di Groppo del Vescovo with respect to the units distinguished by Plesi (1975b), Cerrina Feroni *et al.* (1991) and Plesi *et al.* (1993).

Formations	Formations	Formations	**Member**	**Formation**
Argille e calcari superiori	Argille e calcari di Canetolo	Formazione di Canetolo		**Argille e calcari di Canetolo**
Calcari di Groppo del Vescovo	Calcari di Groppo del Vescovo	Calcari di Casacca	**Calcari di Groppo del Vescovo**	
Argille e calcari inferiori	Argille e calcari di Rio Canalgrande	Formazione di Rio Nicola		
Plesi, 1975b	Cerrina Feroni *et al.*, 1991	Plesi *et al.*, 1993	***this paper***	
Parma Valley	Parma-Cedra Valleys	Taro Valley	**Pontremoli, Fivizzano and Castelnuovo Garfagnana areas**	

Penice Fm. and Flysch di Vico Fm. and by the Upper Paleocene to Middle Eocene pelitic to pelitic-calcareous sedimentation of the Argille e calcari di Canetolo Fm. (Elter *et al.*, 1997).

Acknowledgements

We thank to G. Ottria and L. Pandolfi for the profitable discussion and A. Puccinelli and G. D'Amato Avanzi for the help in the field, during the realization of the Pontremoli, Fivizzano and Castelnuovo Garfagna geological maps.

References

Abbate E., 1969. Geologia delle Cinque Terre e dell'entroterra di Levanto (Liguria orientale). *Memorie della Società Geologica d'Italia* 8 (4): 923-1014, Roma.

Abbate E., Sagri M., 1970. The eugeosynclinal sequences. In: Sestini G. (ed.), Development of the Northern Apennines geosyncline. *Sedimentary Geology* 4: 251-340, Amsterdam.

Barbieri F., Zanzucchi G., 1963. La stratigrafia della Valle di Roccaferrara (Appennino Parmense). *Atti Soc. Tosc. Sci. Nat.* 102: 155-210, Pisa.

Bown P.R., 1998. Calcareous Nannofossil Biostratigraphy. British Micropalaeontology Society Publication Series. Kluwer Academic Publishers, 314 pp, Dordrecht.

Catanzariti R., Ottria G., Cerrina Feroni A., 2002. Tavole stratigrafiche della Carta geologico-strutturale dell'Appennino emiliano-romagnolo in scala 1:250.000. SELCA, Firenze.

Catanzariti R., Perilli N., 1999. Calcareous nannofossil: the key to reveal the relations between the Macigno and Monte Modino Sandstone, two widespread clastic wedges of the Northern Apennines. *Rivista Italiana di Stratigrafia e Paleontologia* 115 (2): 233-252, Milano.

Cerrina Feroni A., Martinelli P., Perilli N.M.L., 1991. Stratigrafia e struttura dell'Unità di Canetolo in Val Cedra (Appennino parmense). *Memorie Descrittive della Carta Geologica d'Italia* 46: 301-312, Roma.

Elter P., Ghiselli F., Marroni M., Ottria G., 1997. Foglio 197 Bobbio della Carta Geologica d'Italia alla scala 1:50.000. Note Illustrative. Istituto Poligrafico dello Stato, Roma, 106 pp.

Gradstein, F.M., Ogg, J.G., 2006. Chronostratigraphic data base and visualization; Cenozoic-Mesozoic-Paleozoic integrated stratigraphy and user-generated time scale graphics and charts. *Geo Arabia* 11: 181-184.

Labaume P., 1992. Evolution téctonique et sédimentaire des fronts de chaine sous-marins. Exemples des Apennins du Nord, des Alpes Françaises et de Sicile. Université Montpellier II. Thèse de docteur d'Etat, 476 pp.

Marroni M., Monechi S., Perilli N., Principi G., Treves B., 1992. Cretaceous flysch deposits of the Northern Apennines, Italy; age of inception of orogenesis-controlled sedimentation. C*retaceous Research* 13: 487-504, Amsterdam.

Martini E., 1971. Standard Terziary and Quaternary calcareous nannoplankton zonation. In: Farinacci A. (ed.), Proceedings II Planktonic Conference, Roma, pp. 739-785.

Montanari L., Rossi M., 1982. Evoluzione delle unita stratigrafico-strutturali terziartie del nordappenino. 1) Unità di Canetolo. *Bollettino della Società Geologica d'Italia* 101: 275-289, Roma.

Monteforti B., Raggi G., 1968), Osservazioni su una sezione geologica fra il Monte Penna e il Monte Gazzo (alta e media Val di Taro - Appennino Ligure). *Atti Soc. Tosc. Sci. Nat.*, *Mem.*, Serie A 74: 549-565, Pisa.

Monteforti B., Raggi G., 1975. Per la geologia dell'entroterra di La Spezia tra Sarzana e Zignago. *Boll. Soc. Geol. It.* 94: 927-943.

Okada H., Bukry D., 1980. Supplementary modification and introduction of code numbers to the low-latitude coccolith biostratigraphic zonation (Bukry, 1973; 1975). *Marine Micropaleotology* 5: 321-325, Amsterdam.

Perch-Nielsen K., 1985. Cenozoic calcareous nannofossils. In: Bolli H.M., Saunders J.B., Perch-Nielsen K. (eds.), Plankton stratigraphy. Cambridge University Press, London, pp. 427-554.

Plesi G., 1974. L'Unità di Canetolo nella struttura di Bobbio (Val Trebbia), Montegroppo (Val Gotra) e lungo la trasversale Cinque Terre-Pracchiola. *Atti Soc. Tosc. Sci. Nat.*, *Mem.*, Serie A 81: 121-151, Pisa.

Plesi G., 1975a. La giacitura del Complesso Bratica-Petrignacola nella serie del Rio di Roccaferrara (Val Parma) e dei flysch arenacei tipo Cervarola nell'Appennino settentrionale. *Bollettino della Società Geologica d'Italia* 94: 157-176, Roma.

Plesi G., 1975b. La nappe de Canetolo. *Bullettin Societè Géologique. de France* 6: 979-983, Paris.

Plesi G., Bianchi L., Chicchi S., Daniele G., 1993. Le Unità Liguri ed Emiliane della media Val di Taro e la loro evoluzione strutturale. *Atti Ticinensi di Scienze della Terra* 36: 183-229, Pavia.

Plesi G., Bonanni G, Botti F., Daniele G., Palandri S., 1998. Processi e tempi di costruzione della catena appenninica nelle sue fasi oligo-mioceniche: l'esempio della finestra di Pracchiola (biostratigrafia, petrografia e analisi strutturale, con Carta Geologico-Strutturale scala 1: 20.000). *Bollettino della Società Geologica d'Italia* 117: 841-894, Roma.

Puccinelli A., Damato Avanzi G., Perilli N., 2010a. Foglio 233 Pontremoli della Carta Geologica d'Italia alla scala 1:50.000. Note Illustrative. (in stampa).

Puccinelli A., Damato Avanzi G., Perilli N., 2010b. Foglio 234 Fivizzano della Carta Geologica d'Italia alla scala 1:50.000. Note Illustrative (in stampa).

Puccinelli A., Damato Avanzi G. & Perilli N., 2010c. Foglio 250 Castelnuovo Garfagnana della Carta Geologica d'Italia alla scala 1:50.000. *Note Illustrative* (in press).

(ms. pres. il 31 dicembre 2009; ult. bozze il 3 luglio 2010)