Rivista Italiana di Paleontologia e Stratigrafia	volume 105	numero 1	tavole 1-2	pagine 101-128	Aprile 1999

THE BASAL COMPLEX STRATIGRAPHY OF THE HELMINTHOID MONTE CASSIO FLYSCH: A KEY TO THE EOALPINE TECTONICS OF THE NORTHERN APENNINES

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Received December 2, 1998; accepted March 3, 1999

Key-words: Eoalpine tectonics, Ligurids, nannofossil biostratigraphy, petrography.

Riassunto. Nell'ambito del Complesso di base del flysch ad elmintoidi di M.Cassio affiorante nella sua localit tipo, sono state riconosciute torbiditi cenomaniane potenti 200 m. Queste torbiditi che in passato non erano distinte dalle Arenarie di Ostia, sono indicate nel presente lavoro come Arenarie di Case Baruzzo (CBS), consistono essenzialmente di strati spessi marnoso-siltosi a base arenitica fine e rappresentano il primo apporto silicoclastico nella successione dell'Unit tettonica Cassio.

Le CBS seguono in discontinuit le Argille a palombini hauteriviano-aptiane che risultano associate a scaglie tettoniche di formazioni giurassico-cretaciche ad affinit Astroalpina (Radiolariti, Scisti ad aptici e Maiolica). Sulle CBS si sovrappongono in discontinuit le Argille varicolori santoniano-campaniane che risultano interessate da deformazioni tettoniche precedenti alla completa litificazione.

La composizione petrografica delle CBS mostra due petrofacies che indicano (1) la diretta provenienza dalle rocce di copertura oceanica che rappresentano il loro substrato e (2) una zona sorgente extrabacinale, impostata sul margine Austroalpino, molto simile a quella delle Arenarie di Ostia coniaciano-santoniane, affioranti a SW dell'Unit Cassio e tettonicamente indipendenti. Le CBS cenomaniane si configurano quindi come un corpo torbiditico silicoclastico distinto dalle Arenarie di Ostia dell'Unit Media Val Taro che a loro volta sono tempo-equivalenti alle Argille varicolori.

L'inizio degli apporti torbiditici terrigeni risulta Cenomaniano nel Complesso di base del Flysch di M.Cassio (CBS), Coniaciano nell'Unit Media Val Taro (Arenarie di Ostia) e Campaniano nella pi interna Unit Gottero (torbiditi a strati sottili nella Formazione di Val Lavagna).

Per queste tre Unit che occupano una posizione strutturale alta nell'edificio appenninico tosco-emiliano si ipotizzano per il Cretacico superiore posizioni paleogeografiche relative simili a quelle attuali, in un contesto di evoluzione tettono-stratigrafica controllata da un prisma di accrezione Alpino-vergente. La tettonica a polarit alpina avrebbe controllato la migrazione verso ovest dei depocentri dei bacini, dalle torbiditi terrigene cenomaniane alimentate dall'Austroalpino, alle torbiditi terrigene campaniano-maastrichtiane alimentate dal margine Europeo.

L'assenza di apporti ofiolitici nelle Unit Cassio, Media Val Taro e Gottero ne indica la sedimentazione in una porzione del Bacino Ligure dove la tettonica subduttiva eoalpina non ha prodotto obduzioni di litosfera oceanica. Viceversa, un cospicuo detritismo ofiolitico cretacico avrebbe potuto svilupparsi verso sud, oltre un'importante discontinuit litosferica impostata sulla traccia di una faglia trasforme giurassica che avrebbe potuto agire come fascia transpressiva durante la tettonica convergente cretacico-paleogenica. In questo settore meridionale del Bacino Ligure sarebbero sedimentate le unit caratterizzate da apporti ofiolitici (Ottone-Caio). Queste ultime sarebbero state sovrascorse dalle Unit Gottero, Media Val Taro e Cassio durante la chiusura dell'Eocene medio (Fase ligure), prima della rotazione antioraria appenninica.

Abstract. Below the Monte Cassio helminthoid Flysch of the type locality, a well exposed basal complex outcrops in which Cenomanian turbidites of up to 200 m thickness are recognized. The bulk of these turbidites, named here Case Baruzzo Sandstone (CBS), consists of thick-bedded silty marlstones with a fine arenaceous base and represents the oldest siliciclastic input within the succession of the Cassio tectonic unit.

The Case Baruzzo Sandstone lies unconformably on the Palombini shale of Hauterivian-Aptian age and on stratified packets of Jurassic-Cretaceous formations with Austroalpine affinity (Radiolarites, Aptici Shale and Maiolica). The Cenomanian CBS are unconformably overlain by Varicoloured Clay of Santonian - Campanian age and affected by soft-sediment deformations.

The petrography of the CBS shows two petrofacies indicating (1) a direct provenance from their substrate and (2) an extrabasinal source similar to the terrigenous framework of the tectonically independent Coniacian-Santonian Ostia Sandstone outcropping southwest of the Cassio Unit. Because of its Cenomanian age the CBS must be considered as a siliciclastic wedge distinct from the younger Ostia Sandstone belonging to the Media Val Taro Unit and time correlative to the Varicoloured Clay of the Cassio Unit.

The initiation of the turbidite sandstones terrigenous supply is Cenomanian into the Cassio Basal Complex (CBS), Coniacian into the Media Val Taro Unit (Ostia Sandstone) and Campanian into the more internal Gottero Unit (fine-grained turbidites interbedded within the Val Lavagna Formation).

It is proposed that the relative positions of the highest tectonic units outcropping in the Emilian Apennines (i.e. Gottero, Media Val Taro and Cassio Units) during Late Cretaceous were not very different to the present setting, and that their tectono-stratigraphic evolution was related to Alpine-vergent accretionary wedges. The Alpine tectonic polarity should have controlled the westwards migra-

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tion of the basinal depocentres and the evolution from the Adriatic-margin supply of the Cenomanian turbidites to the European-margin supply of the Maastrichtian turbidites.

During the middle Eocene tectonic phase, before the counter-clockwise apenninic rotation, the ophiolite-free Cretaceous Ligurian Units (i.e. Gottero, Media Val Taro, Cassio) overthrusted the Ligurian Units characterized by late Cretaceous ophiolitic detritus, known as Ottone and Caio Units, along a significant lithospheric discontinuity which acted as a transpressive fracture zone.

Introduction.

The basic geological structure of the Northern Apennines thrust-and-fold belt results from the stacking of the oceanic crust Ligurian sequences, deposited in the Ligurian-Piedmont Ocean, on the continental crust Tuscan-Umbrian sequences of the Adriatic promontory of the African plate (Abbate & Sagri, 1982). Although the basic geometry and stratigraphy of the Northern Apennines were established some thirty years ago (Sestini, 1970; Elter, 1973), major problems remain unsolved concerning detailed regional correlation, depositional history, paleogeography and tectonic evolution.

Two contrasting geodynamic settings have been envisaged for the subduction processes pre-dating the late Eocene-Oligocene continental collision. According to some, the whole Ligurian oceanic lithosphere subduced beneath the Sardinian-Corsican margin, as an east-verging accretionary prism (Treves, 1984; Principi & Treves, 1984). Others maintain that a large portion of the Ligurian oceanic lithosphere was first subducted beneath the African (Adriatic) margin as a west-verging accretionary prism and that the west-dipping subduction was a younger process (Gelati & Pasquar, 1970; Haccard et al., 1972; Sturani, 1973; Elter & Pertusati, 1973; Boccaletti et al., 1980; Galbiati, 1990; Elter & Marroni, 1991; Elter, 1993; Casnedi *et al.*, 1993; Marroni & Pandolfi, 1996).

The major paleogeological problems of the oceanic Ligurian Domain are the paleogeography of the Helminthoid Flysch basins and the timing and polarity of the tectonic deformations related to subduction. A particularly intense matter of debate is represented by the original location of the basin of the Helminthoid Monte Cassio Flysch, outcropping in the northeastern side of the chain, from the Monferrato Hills to Modena Province (Zanzucchi, 1980; 1988). The composition of the Monte Cassio Flysch is characterized by the presence of coeval shallow water bioclastic detritus and the lack of ophiolitic detritus (Fontana *et al.*, 1994). The stratigraphic substrate is characterized by the occurrence of conglomerates (Salti del Diavolo Conglomerate) with a South Alpine (Adriatic) provenance (Sames, 1967; Elter *et al.*, 1966) and by slabs of Jurassic and lower Cretaceous rocks (Radiolarites, Aptici Shale and Maiolica) derived from the Adriatic margin (Braga, 1957; Zanzucchi, 1961b; Vercesi & Cobianchi, 1998). These features led to the location of the Monte Cassio basin in the northern and external part of the Ligurian-Piedmont Ocean, close to the Adriatic margin (Elter *et al.*, 1966; Abbate & Sagri, 1970; Monteforti, 1972; Elter, 1973; Zanzucchi, 1980; Abbate & Sagri, 1982; Sestini *et al.*, 1986). However, the Cassio tectonic Unit occupies an elevated geometrical position in the chain which would suggest an original internal and southwestern location of its basin.

Since the facies and the depositional environment of the various Helmintoid Flysch outcrops in the Northern Apennines are very similar, clues to their paleogeography can be provided by the integrated study of their stratigraphic substratum, which are referred to in the literature as basal complexes. These complexes are heavily affected by tectonics, which limits their stratigraphic analysis. Today the stratigraphy of the basal complexes associated with the various Helminthoid Flysches is sufficiently known and reflects an articulated Cretaceous paleogeography of the Ligurian-Piedmont Ocean controlled by compressional tectonics (Zanzucchi, 1980; Labesse, 1981; Rio & Villa, 1987).

In the present work we will report data on the field stratigraphy, structural setting, calcareous nannofossil biostratigraphy, and petrography of arenites from the lower part of the Cassio Basal Complex, aiming to restore the stratigraphic succession at the base of the Monte Cassio Flysch in the type area of the unit, between the Baganza and Ceno Valleys SW of Parma (Fig. 1). In particular, we will deal with siliciclastic turbidites known as Case Baruzzo Sandstone (CBS, Scabiazza Sandstone and Ostia Sandstone of the literature). They represent the first significant input of terrigenous clastics into the Cassio basin. We compare this event with the features of other terrigenous clastic wedges present in the Ligurian Ocean in order to discuss their significance in the context of the Alpine Late Cretaceous tectonic convergence.

Regional geological framework.

Fig. 1 represents a schematic structural map essentially based on the "Carta strutturale dell'Appennino settentrionale" by Boccaletti & Coli, 1982. It shows the main tectonic units outcropping in the northwestern portion of the Northern Apennines, the stacking of which is shown in the schematic cross-section at the base of the figure. The considered segment of the Apennines can be subdivided into three wide structural sectors, characterized by specific tectono-stratigraphic features and bounded by major regional overthrusts.

The *inner sector* corresponds to the western portion of the chain and is characterized by widespread outcrops of Ligurian Units with Jurassic oceanic crust

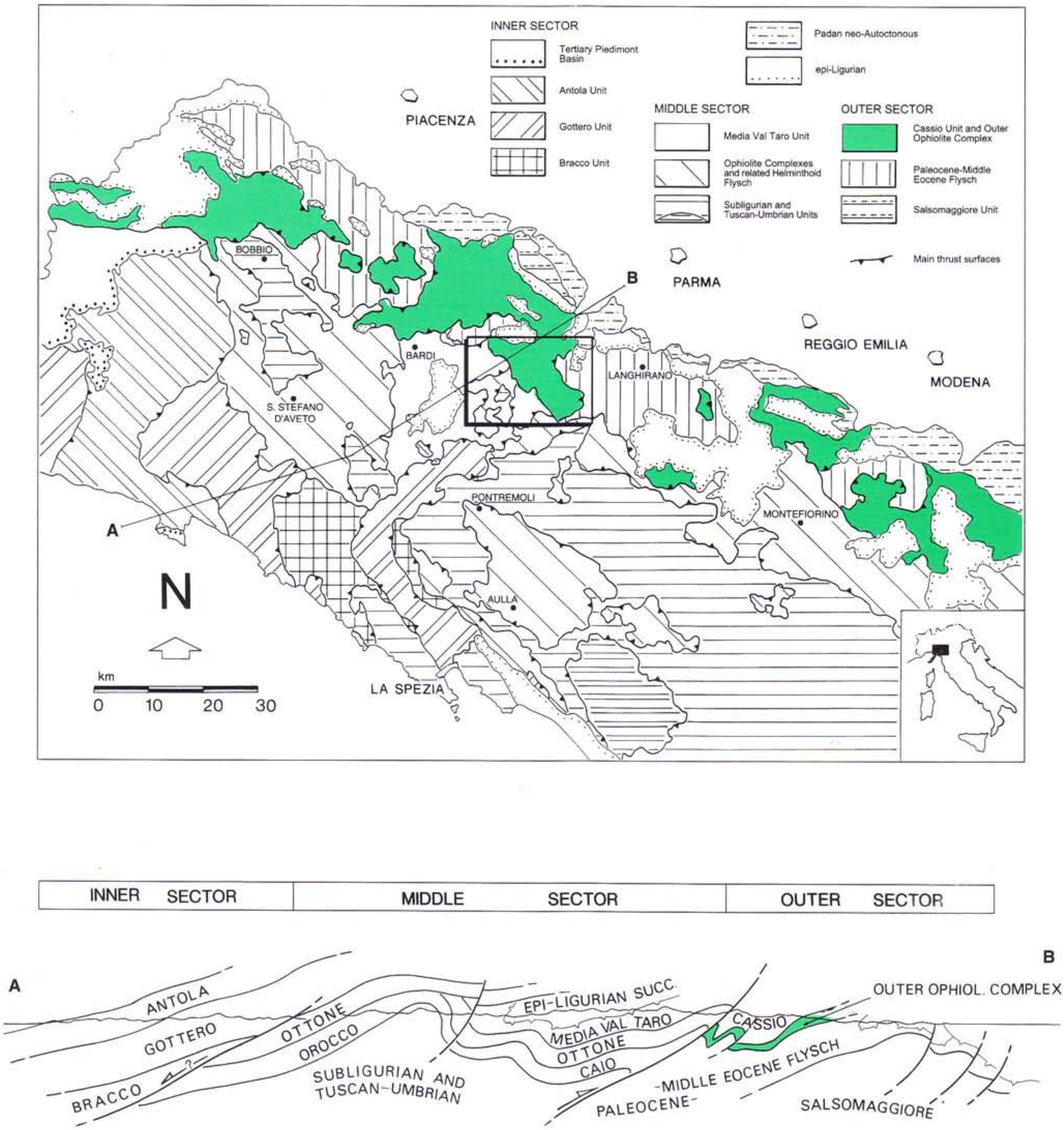


Fig. 1 - Schematic tectonic map of the Northwestern Apennines (modified after Boccaletti and Coli, 1982). The cross section along the indicated trace shows the three structural sectors of the Apennines. **Inner sector.** 1 - Bracco Unit with the Tavarone Units (Decandia & Elter, 1972; Meccheri *et al.*, 1986), corresponds to Vara Supergroup p.p. (Abbate & Sagri, 1970). 2 - Gottero Unit (Casnedi, 1982; Nilsen & Abbate, 1985), corresponds to Vara Supergroup p.p. (Abbate & Sagri, 1970). 3 - Antola Unit (Boccaletti & Coli ed., 1982; Elter & Marroni, 1991), corresponds to Antola and Albirola Formations p.p. (Abbate & Sagri, 1970). 4 - the Tertiary Piedmont Basin. **Middle sector.** 1 - Tuscan-Umbrian Units (Apennine backbone) and the Subligurian Units (Elter, 1973). 2- Ophiolite Complexes and the related Helminthoid Flysch including: Casanova Complex (Passerini, 1962; 1965; Elter et al., 1991); Ragola Unit (Pagani *et al.*, 1972; Terranova & Zanzucchi, 1982); M.Tane Unit (Elter & Marroni, 1991; Elter *at al.*, in press); Ottone Unit (Bertotti *et al.*, 1986; Elter *et al.*, in press); Orocco - Caio Unit (Zanzucchi, 1980); M. Venere-Monghidoro Unit (Bettelli *et al.*, 1987); corresponding to Trebbia Supergroup and Sambro Group p.p. (Abbate & Sagri, 1970). 3 - Media Val Taro Unit: Cretaceous ophiolite-free succession surrounding by a helminthoid flysch (Vescovi *et al.*, in press), corresponding to Taro Sequence p.p. (Abbate & Sagri, 1970). **Outer sector.** 1 - Salsomaggiore Unit (Zanzucchi, 1980; 1988). 2 - Paleocene-middle Eocene Flysch, including the Coscogno Mélange (Bettelli et al., 1987). 3 - Cassio Unit (Papani & Zanzucchi, 1970), including the underlying Ophiolitic Complex (Boccaletti & Colli ed., 1982); corresponds to the Baganza Group (Abbate & Sagri, 1970),

substrate (*i.e.* Bracco and Tavarone Units; Decandia & Elter, 1972; Abbate *et al.*, 1988) and by the outcrop of a major turbiditic clastic wedge derived from European margin (Gottero Sandstone; Marroni & Pandolfi, 1996), overthrusted by Antola helminthoid flysch; the Epi-Lugurian Succession (sensu Ricci Lucchi & Ori, 1985) is missing.

The *middle sector*, corresponding to the central portion of the chain, is characterized by widespread outcrops of the ophiolite bearing Ottone and Orocco (Caio) Units (Zanzucchi, 1980; Bertotti *et al.*, 1986; Elter & Marroni, 1991). According to Piccardo *et al.* (1990) the ophiolitic detritus derived from transitional-to-normal MOR basalts and poorly depleted mantle ultramafics. Along the Taro Valley, the latter units are overthrusted by the Middle Taro Valley Unit, that, in turn, is locally overthrusted by a "spur" of the Gottero Unit characterized by polyphased tectonic deformation (Vescovi, 1991). On a wide portion of this sector, the Epi-Ligurian Succession (Mutti *et al.*, 1995) is preserved on top of the Middle Taro Valley Unit.

The *outer sector* corresponds to the eastern part of the chain, bordered by the Po River Plain. It is characterized by widespread outcrops of Paleocene to middle Eocene Flysch (*Alberese*), roughly similar to the late Cretaceous Helminthoid Flysch from which they are differentiated by higher contents of sandy detritus (Abbate & Sagri, 1967). The Alberese type Flysch is overthrusted by the Cassio Unit, often with the interposition of a problematic ophiolitic unit (Prinzera Unit in Zanzucchi, 1994; Groppallo complex in Marroni & Tribuzio, 1996). The Epiligurian Succession is locally paraconformable (Iaccarino & Rio, 1972; Iaccarino *et al*, 1974) and more complete than in the middle sector (Papani *et al.*, 1987).

Study area.

The study area is located between the Pessola and Baganza Valleys (Fig. 1 and 2), at the boundary between the middle and outer structural sectors of the Northern Apennines outlined in Fig. 1. The area is well suited for the investigation of the Monte Cassio Flysch and its Basal Complex (Fig. 3 and 4), as defined by Sestini (1970).

This work, relies on the field mapping of the area of Fig. 2 which allowed the preparation of the three cross-sections of Fig. 3, the base for the reconstruction of the stratigraphic sections of Prelerna, Case Baruzzo and Praquarola shown in Fig. 5 to 7. The three cross-sections shown in Fig. 3 cut the south-westernmost portion of the Outer Structural Sector exposing the best outcrops of the Cassio Basal Complex. Cross-section A shows a partially overturned succession because of late overthrust by the Ophiolitic Complex and by the previously deformed Ostia Sandstone of the Middle Structural Sector. In cross-section B the CBS shows clear evidence of SW-verging deformations. In fact, the CBS is affected by wide overturned folds with well exposed hinges (Fig. 8); these folds show weakly developed axial plane cleavages, NW-SE axial trends and overturnings towards SW. Within the CBS some minor N-verging folds are also present; they are inducted by low-angle shear planes clearly postdating the SW-verging folds (Fig. 9). In the T. Grontone area a paraconformable contact of the CBS with the overlying Varicoloured Clay is also exposed; the latter are affected by tight-to-isoclinal folds, related with shear surfaces that transposed the original bedding when the beds were only partially lithified. In cross-section C the Cassio succession overthrust on the Ophiolitic Complex is shown. In the Praquarola area, the CBS unconformably overlay the Palombini shale and the tectonically embedded Jurassic-lower Cretaceous (Radiolarites - Aptici Shale - Maiolica) slabs which are thought to be their original stratigraphic substrate.

Stratigraphy of the Cassio tectonic Unit.

The stratigraphic units constituting the Cassio tectonic Unit are reconstructed in Fig. 4 together with the successions of the Media Val Taro and Gottero tectonic Units, discussed in the following sections. The Cassio Unit is equivalent to the Baganza Group of Abbate & Sagri (1970). The upper part of the Cassio Unit corresponds to the Monte Cassio Flysch and Viano Clay formations of Zanzucchi (1961a), Abbate & Sagri (1967; 1970), Papani & Zanzucchi (1970), Iaccarino & Rio (1972) and Iaccarino *et al.* (1974). The Monte Cassio Flysch consists of a more than 1500 m thick succession of basin plain carbonate-rich thick-bedded turbidites, of latest Campanian to Paleocene age (Rio *et al.*, 1983; Iaccarino & Rio, 1972; Iaccarino *et al.*, 1974). It was deposited below the carbonate dissolution depth (CCD) (Sagri, 1973; Sagri, 1979a; Sagri & Marri, 1980). Parea (1961, 1965a, 1965b) has shown NW and SW provenances for the mud-rich turbidites and the sand-rich turbidites, respectively. Fontana *et al.* (1994) have shown that the terrigenous input of the Monte Cassio Flysch is from the Austro-Southalpine basement. The deposition of the Monte Cassio, as well as of other Helminthoid Flysches of the Northern Apennines, has been linked to the infilling of an oceanic trench during plate convergence (Sagri, 1979b; Treves, 1984; Principi & Treves, 1984; Marroni *et al.*, 1992).

The basin-plain turbidites of the Monte Cassio Flysch rest on strongly dismembered units (Basal Complex) by Zanzucchi (1961a) and Braga (1965), that have been interpreted as an accretionary prism derived from

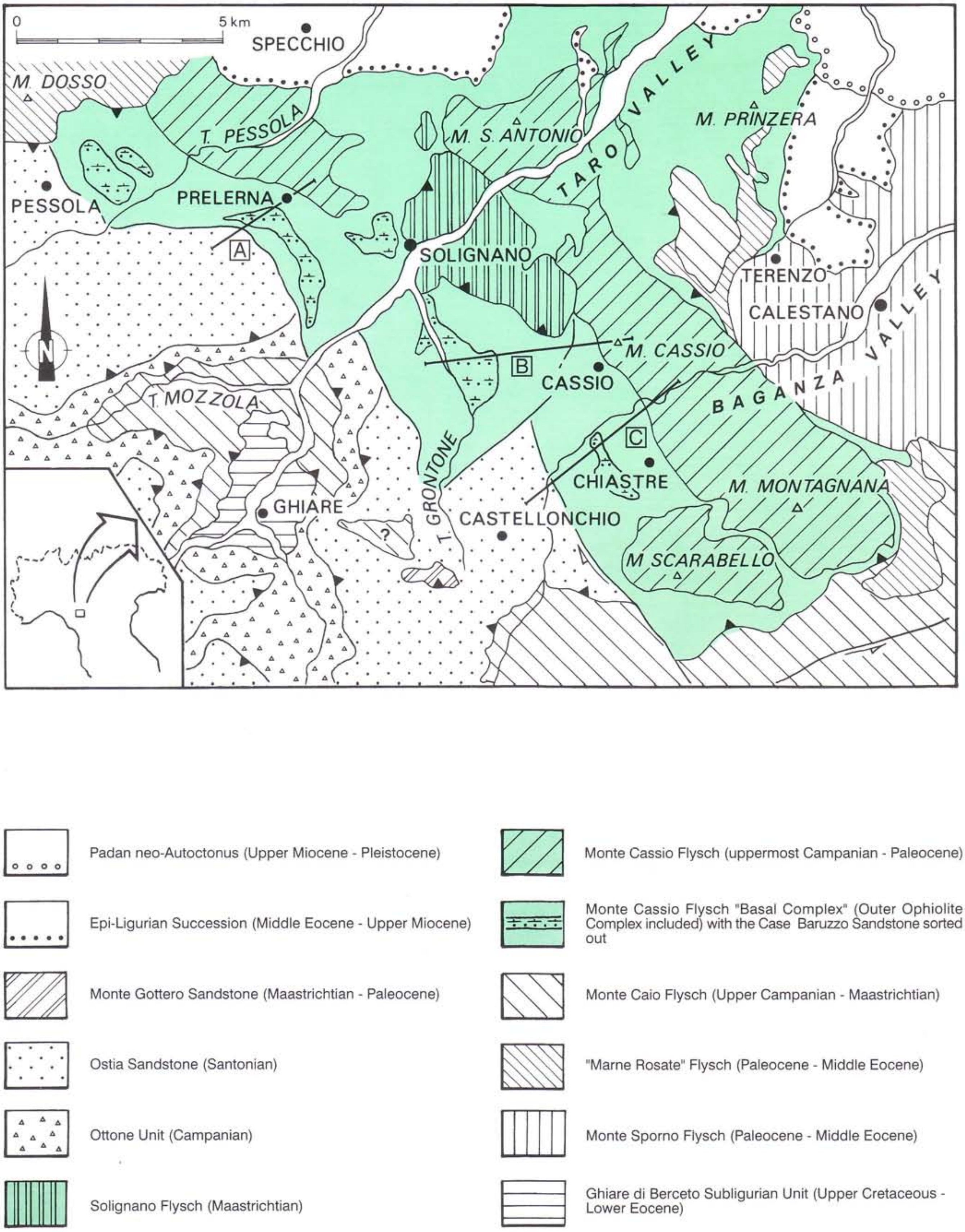


Fig. 2 - Schematic geologic map of the investigated area (squared in Fig. 1). A, B and C are the traces of the cross sections reported in Fig. 3. Within the Basal Complex of the Monte Cassio Flysch only the Case Baruzzo Sandstone is mapped.

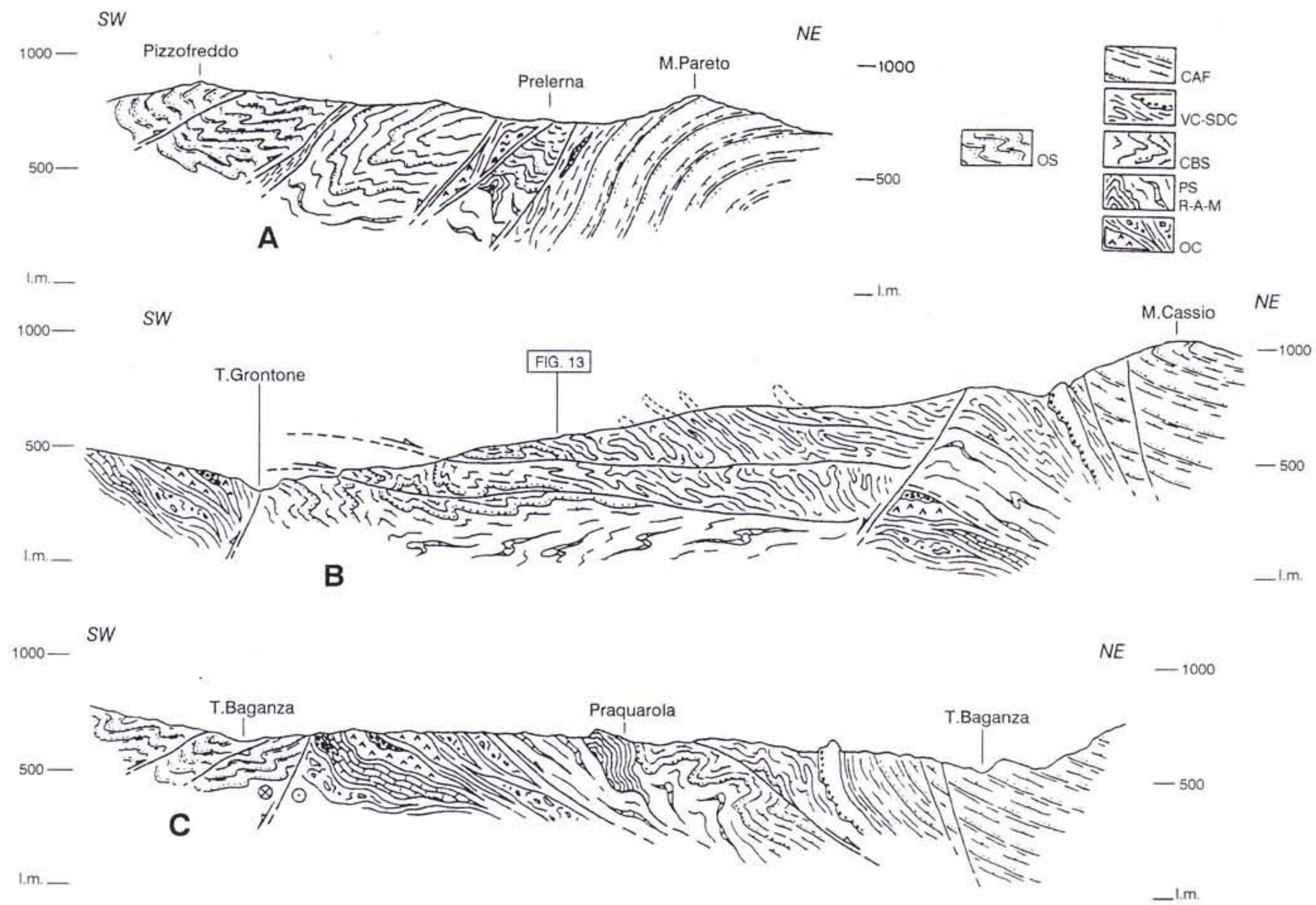


Fig. 3 - Geological cross section through the Basal Complex of the Monte Cassio Flysch (locations in Fig. 2). CAF: Monte Cassio Flysch (Maastrichtian); SDC: Salti del Diavolo Conglomerates (early Campanian); VC: Varicoloured Clay (Coniacian-Santonian); CBS: Case Baruzzo Sandstone (Cenomanian-Turonian); PS: Palombini Shale (Hauterivian-Aptian); R-A-M: Radiolariti, Aptici Shale and Maiolica tectonic slices of the Jurassic-Cretaceous portion of the Adriatic margin Sequence; OC: Ophiolitic Complex with large ultramafic bodies (uncertain in age); OS: Ostia Sandstone *Auctt.*(Coniacian-Santonian).

the offscraping of oceanic successions (Bettelli *et al.*, 1994). Because of the pervasive tectonic disruption, the stratigraphy of the basal complex remains controversial. There is a wide consensus, however, in considering as the basal portion of the Cassio Unit a basin plain succession of dark grey shales interbedded with fine-grained thin-bedded calcareous turbidites, referred to in this paper as the Palombini Shale of the Grontone Torrent (PS in Fig. 4). Calcareous nannofossils suggest a Hauterivian to Aptian age for the Palombini Shale unit (Villa in Vescovi *et al.*, in press).

Plurimetric slabs of Jurassic to lower Cretaceous Radiolarites, Aptici Shale and Maiolica (R-A-M in Fig. 4) are embedded within the Palombini Shale; they have been interpreted as olistholits (Zanzucchi, 1961a; 1980) and as offscraped slices of the original oceanic sequences (Plesi *et al.*, 1993).

Above the Palombini Shale the siliciclastic deposits focused in the present work are present. In the Baganza Valley (Fig. 2 and 3) this Unit has been referred to as "Basal Complex Sandstone" (Istituto di Geologia di Parma, 1964; Zanzucchi, 1980). It is here referred to as Case Baruzzo Sandstone (CBS). It should be noted that, on a regional scale, the siliciclastic portion of the Cassio Unit lying above the Palombini Shale, is often referred to in the literature as Scabiazza Sandstone (Ludwig, 1929; Braga, 1965; Abbate & Sagri, 1970; Bettelli *et al.*, 1987; Ghiselli *et al.*, 1991). Because of polyphasic deformation (Ghiselli *et al.*, 1994) the stratigraphic relationships between the Cassio Unit and the Scabiazza Sandstone in its type area (Trebbia Valley; Piacenza Province) are not fully understood and therefore we avoid the use of this formational term in the Parma Apennines. The contact between the Palombini Shale and the CBS is poorly exposed and assumed as unconformable (Zanzucchi, 1980). On top of the CBS a pelagic varicoloured claystone unit is present (VC in Fig. 4) which contains thin-bedded arenaceous turbidites (Vescovi, 1986) and the Salti del Diavolo Conglomerate; the base of the Salti del Diavolo Conglomerate marks a major discontinuity (Zanzucchi, 1980). The conglomerates are made up of elements of Permian to Late Cretaceous age. They are very similar to those cropping out in the South-Alpine succession (Sames, 1963; 1967; Elter et al., 1966; Giam-

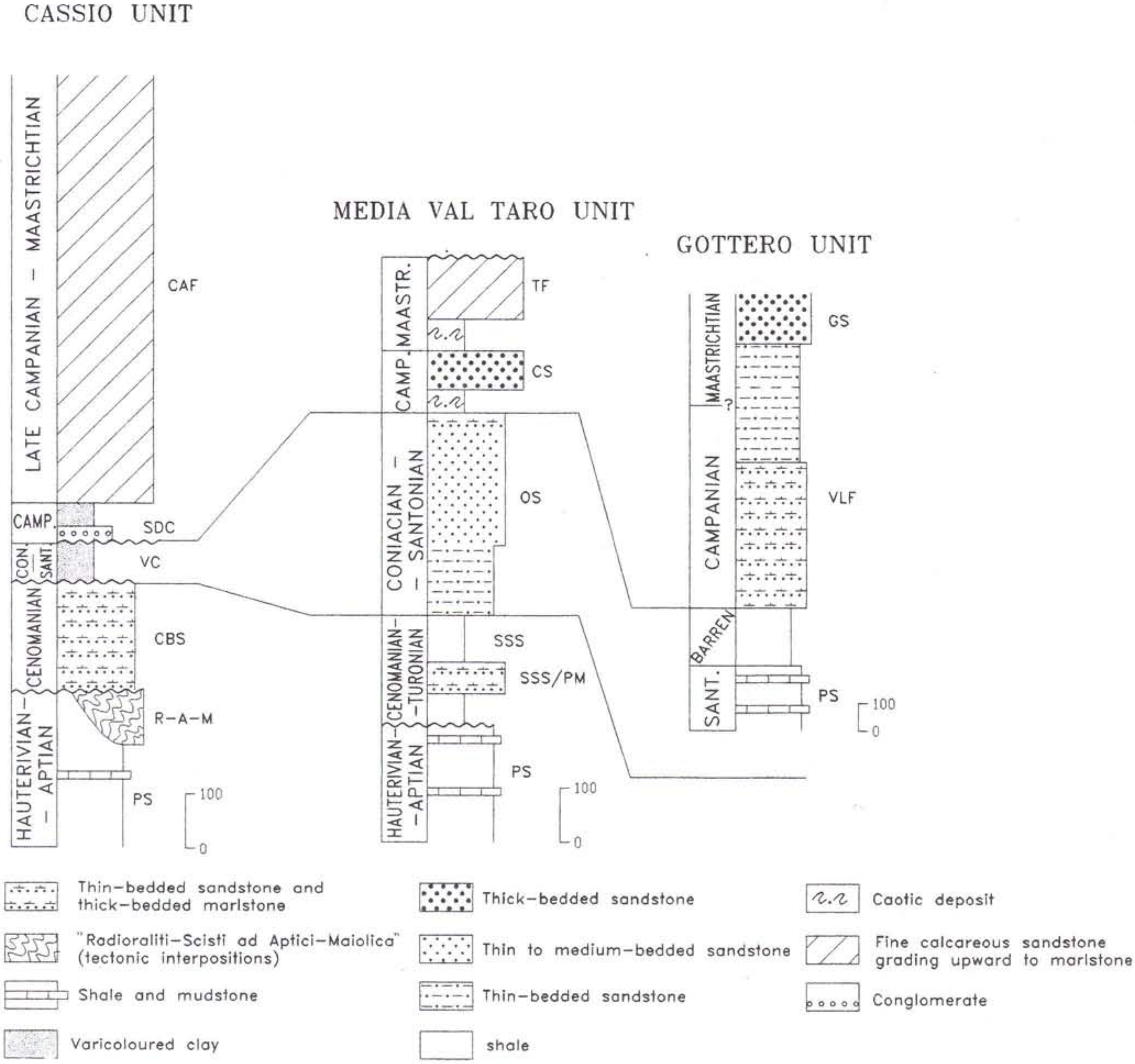


Fig. 4 - Columnar logs showing the main lithostratigraphic features of the Gottero, Media Val Taro and Cassio Units. Abbreviations as in Fig. 3. TF: Testanello Flysch; CS: Campi Sandstone; PM: Pontolo Marl; SSS: S.Siro Shale; GS: Gottero Sandstone; VLF: Val Lavagna Formation;

metti, 1966) and have been dated as earliest Campanian by Rio & Villa (1987).

The strongly deformed setting and the low carbonate content of the Varicoloured Clay have made their dating particularly difficult; they have often been ascribed to the Cenomanian in the past (Zanzucchi, 1955; Papani, 1967; Rio & Villa, 1987). In the work area only Coniacian to Santonian ages have been documented (Rio & Villa, 1987; Perilli & Rio in Cerrina Feroni et al., 1990).

Sampling, analytical methods.

Laboratory work aimed to determine the age and provenance of the Case Baruzzo Sandstone and the Varicoloured Clay formations was based on calcareous nannofossil biostratigraphy and sandstone petrography.

The sampled sections are the Prelerna, Case Baruzzo and Praquarola sections depicted in Fig. 5, 6 and 7, respectively. The type section of the Ostia Sandstone near Belforte was also sampled for petrographic comparisons. Due to the dominance of the fine grain size of the deposits the samples analyzed for sandstone petrography were few. The total number of samples analyzed for nannofossil biostratigraphy was 51.

The thin-section petrographic study was made with two distinct procedures depending on the grain size of the deposits. The medium-to-coarse grained sandstones, needed for the conventional point-counting

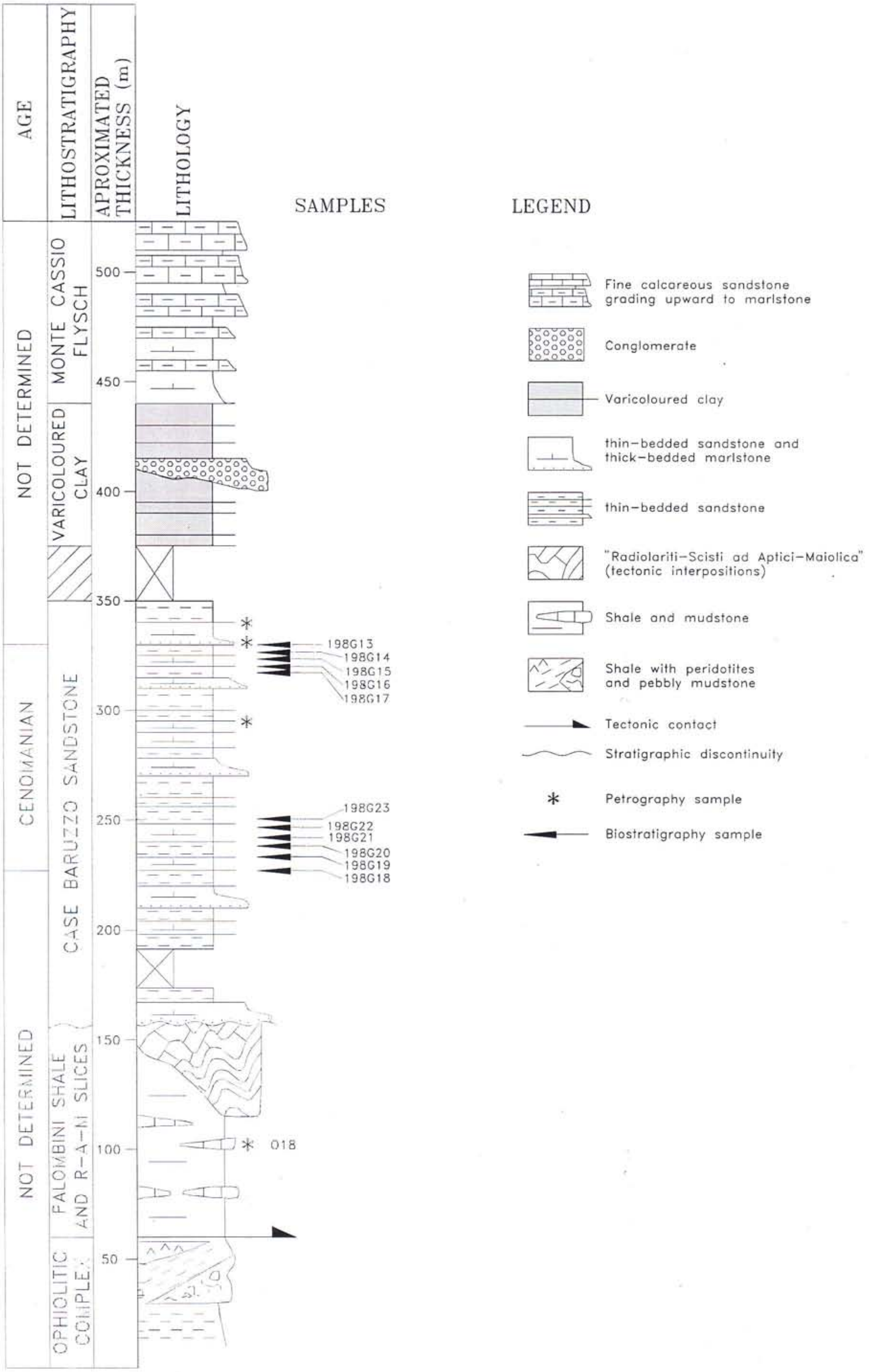


Fig. 5 - Prelerna section. Lithostratigraphic column reconstructed along cross section A of Figure 3.

analysis, are present only in the CBS and the Varicoloured Clay turbidite beds of the Case Baruzzo section as well as in the Ostia Sandstones. Other beds, such as the CBS outcropping in the Prelerna and Praquarola sections, have a much coarser or a much finer grain size; these microconglomerates and very fine sands were treated with semiquantitative analyses of selected samples.

Quantitative modal analyses were based on point counting 250 terrigenous framework grains. Polymineralic grains were distinguished according to the dimension of their internal constituents into Coarse- and Fine-grained types using the 62 micron limit (Dickinson, 1970). According to the method used here the lithic population contains only the fine-grained rocks plus carbonate fragments of any texture. The quarzose and feldspathic populations contain the >62 micron crystals of quartz and feldspar, respectively, internal to polymineralic grains (Zuffa, 1985).

In clastic deposits the analysis of diagenetic modifications (eg. textural relations, interstitial constituents) is very informative; nevertheless diagenetic events are not discussed here since the aim of this study is the recognition of framework petrofacies for stratigraphic purposes. In general, calcite cements of different generations are the most important authigenic phase; in particular, calcite expresses replacive patches which may obscure primary textural relations. Samples were selected for the microscopic study only if low in calcite substitutions.

The calcareous nannofossil biostratigraphy study was carried out with the polarizing optical microscope using standard techniques of preparation (smear slide). The contents in calcareous nannofossils of most of the nannofossiliferous samples is moderately high, on average 2 to 5 specimens per field of view at a magnification of approx. 1200X. However, preservation is generally poor as testified by the dominance of the dissolution resistant species of *Watznaueria* (Tab. 1, 2, and 3). Confident recognition of species is often impossible and we have restricted our analysis to the index species listed in Appendix. The quantitative evaluation of the abundance of recognizable forms was made by counting 500 specimens. This count excluded the detection of the presence of rare index species and therefore, we scanned single slides for several hours looking for rare index species. Species which were detected out of the 500 counting are reported as "K" in the range charts shown in Tab. 1-3. The collected biostratigraphic data are shown in Tables 1, 2, and 3 and in Fig. 5-7, where age assignments are shown. Detailed discussion on the taxonomy of each species is well beyond the scope of this study and has already been discussed in detail by many authors. Appendix 1, however, lists the references to original taxonomic descriptions, and any subsequent emendments together with brief remarks.

A plethora of calcareous nannofossil biostratigraphic schemes have been proposed in the past years for the late Cretaceous time interval and have been reviewed by Mortimer (1987) and Bralower et al. (1995). In this paper we refer to the chronobiostratigraphic frame reported in Fig. 10, where the main calcareous nannofossil biohorizons (datum events) are correlated to the standard chronostratigraphy; the chronology of Gradstein et al. (1994) is used for stage boundaries. Correlation between calcareous nannofossil biohorizons and stage boundaries as shown in Fig. 10 is uncertain (Bralower *et al.*, 1995) and may, therefore, undergo future revision.

STRATIGRAPHIC UNIT	AGE	SAMPLE	COUNTED SPECIMENS	*C. cuvillieri*	*C. kennedyi*	*C. exiguum*	*H. chiastia*	*R. asper*	*E. floralis*	*L. alatus*	*L. acutus*	*Eiffellithus* spp.	*E. turriseiffelii*	*E. gorkae*	*E. eximius*	*M. decoratus*	*Q. gartneri*	*M. furcatus*	*R. angustiforata*	*P. columnata* group	*P. creatacea* group	*Ch. litterarius*	*T. exiguus*	*T. phacelosus*	*C. crenulatus*	*Z. compactus*	*R. angustus*	*R. splendes*	*L. carniolensis*	*Nannoconus* spp.	*Watznaueria* spp.
CASE BARUZZO SANDSTONE	CENOMANIAN	198G13	500	-	1.0	0.2	-	0.6	0.8	K	-	-	1.4	0.8	-	-	-	-	2.8	1.8	-	0.8	1.6	1.4	2.4	3.6	0.4	1.6	1.2	1.2	69.6
		198G14	500	-	0.6	0.6	-	0.8	K	-	-	-	1.8	0.6	-	-	-	-	2.4	1.4	-	0.8	2.8	1.2	3.2	5.2	1.4	2.2	0.4	1.6	62.0
		198G15	500	0.2	-	-	0.2	0.2	K	-	-	-	0.4	-	-	-	-	-	1.4	0.2	-	K	0.8	-	2.0	1.2	0.6	0.6	0.4	0.8	86.0
		198G16	500	-	1.0	0.2	-	0.4	1.0	-	cf	-	3.4	0.4	-	-	-	-	4.2	1.4	0.2	1.2	1.6	1.0	4.4	3.6	1.0	1.8	1.2	0.8	63.6
		198G17	500	-	0.2	0.2	0.6	1.6	1.0	-	cf	-	2.0	0.4	-	-	-	-	3.0	2.4	-	1.2	2.6	1.4	3.2	4.0	0.4	1.0	1.4	0.8	71.2
		198G23	500	-	0.2	0.6	0.4	0.8	1.0	-	-	-	2.6	0.8	-	-	-	-	1.4	2.4	0.2	0.6	0.6	0.2	2.0	3.0	0.8	1.0	0.6	0.8	76.0
		198G22	300	0.3	K	-	-	0.6	2.0	-	-	-	1.0	1.3	-	-	-	-	2.0	0.6	-	0.0	1.0	-	3.0	1.6	1.0	0.6	-	1.6	72.6
		198G21	500	K	-	0.2	0.2	1.4	0.4	cf	-	0.2	0.8	1.0	-	-	-	-	0.2	0.8	0.2	1.2	0.4	K	1.8	3.2	-	0.2	-	2.6	75.0
		198G20	300	0.3	0.3	-	0.3	1.6	1.0	-	cf	-	3.6	1.3	-	-	-	-	3.0	1.6	-	-	1.0	K	3.3	2.0	0.6	-	-	-	63.0
		198G19	300	-	1.3	-	-	0.3	1.3	K	K	0.6	2.0	-	-	-	-	-	2.3	3.3	-	0.6	1.0	-	3.3	1.3	0.3	-	-	-	64.0
		198G18	300	-	-	0.3	-	-	5.0	-	-	1.0	0.3	-	-	-	-	-	K	0.3	-	-	K	-	1.0	2.3	0.6	-	-	2.0	68.6

Tab. 1 - Distribution of selected calcareous nannofossil species in the Prelerna section, and inferred chronostratigraphic interpretation. (-) counting is 0.0.

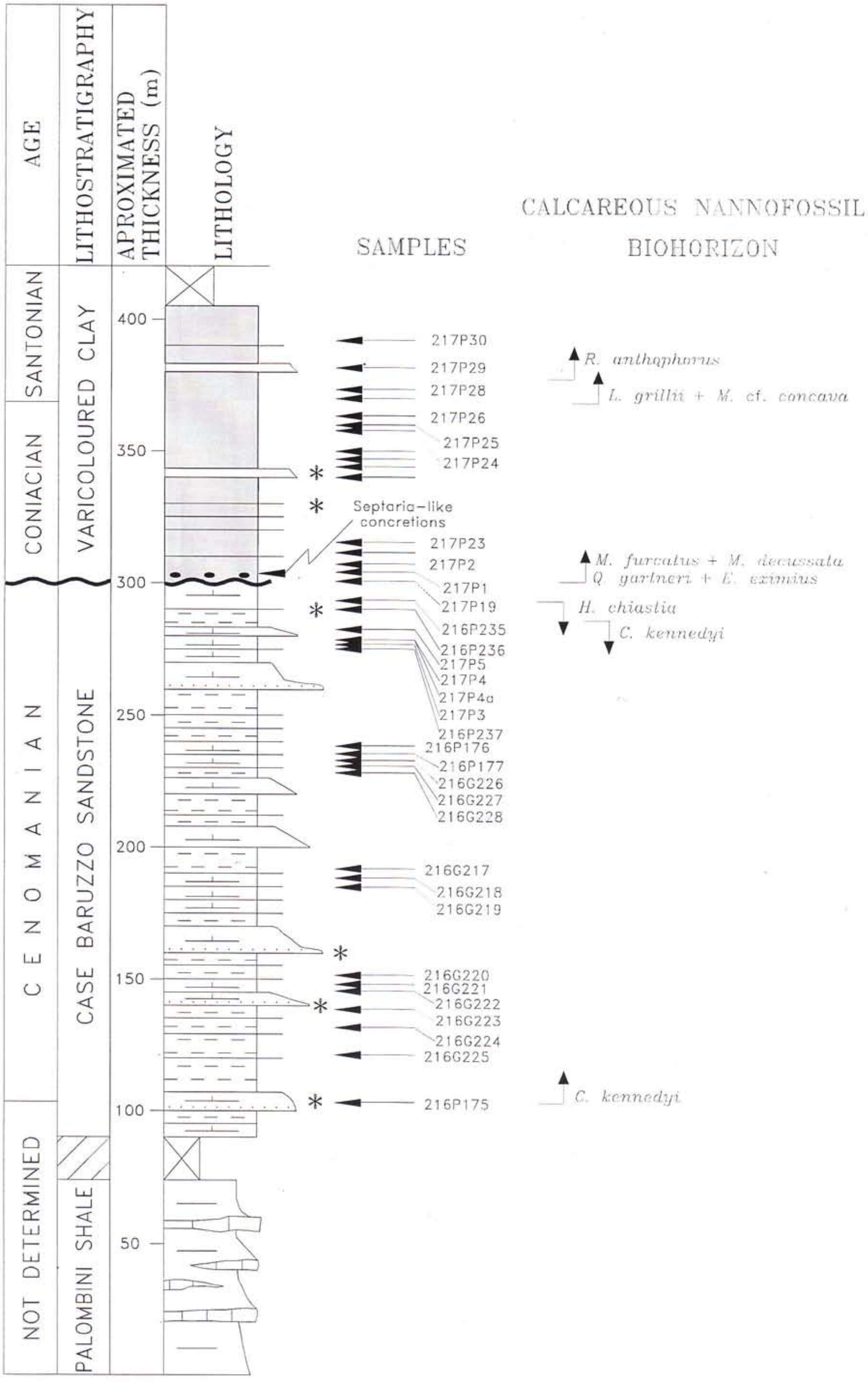


Fig. 6 - Case Baruzzo section. Lithostratigraphic column reconstructed along cross section B of Figure 3.

Case Baruzzo sandstone.

The term Case Baruzzo Sandstone was introduced by Monteforti (1972) with reference to the outcrops in the Grontone Torrent Valley (Fig. 11), regarded as the type area in which the columnar log presented in Fig. 6 were reconstructed. The CBS have also been logged in the Prelerna section (Fig. 5) where the basal and upper contacts are poorly exposed, and in the Praquarola section (Fig. 7), where only about 50 m of the CBS outcrop. It should be noted that in the previous literature only the succession of the Praquarola section (Fig. 7) was considered as belonging to the Cassio succession whereas the successions logged in the Prelerna and Case Baruzzo sections were considered as belonging to the Ostia Formation (Istituto di Geologia di Parma, 1964); because of their peculiar lithofacies the sandstones have been named Case Baruzzo Sandstone (Monteforti, 1972) and Ostia Sandstone of the Grontone (Plesi *et al.*, 1993). As shown here, field evidence, petrographic and biostratigraphic data all suggest the correlatable aspects of the three sections and their assignment to the succession of the Monte Cassio.

STRATIGRAPHIC UNIT	AGE	SAMPLE	COUNTED SPECIMENS	*C. cuvillieri*	*C. kennedyi*	*C. exiguum*	*H. chiastia*	*R. asper*	*E. floralis*	*L. alatus*	*L. acutus*	*Eiffellithus* spp.	*E. turriseiffelii*	*E. eximius*	*Q. gartneri*	*L. maleformis*	*M. furcatus*	*L. moratus+E. eptapetalus*	*M. decussata*	*M.* cf. *concava*	*L. grillii*	*R. anthophorus*	*L. cayeuxii*	*R. angustiforata*	*P. columnata* group	*P. creatacea* group	*Ch. litterarius*	*T. exiguus*	*T. phacelosus*	*C. crenulatus*	*Z. compactus*	*R. angustus*	*R. splendes*	*Nannoconus* spp.	*M. decoratus*	*Watznaueria* spp.
VARICOLOURED CLAY	SANTONIAN	217P30	/	/	/	/	/	/	/	/	/	/	/	/	/	/	P	/	P	P	P	/	/	/	/	/	/	/	/	/	/	/	/	/	/	C
		217P29	500	-	-	-	-	-	0.2	/	/	1.0	2.8	3.0	-	-	0.4	-	-	1.8	0.6	0.8	cf	9.0	2.6	3.2	1.2	2.4	1.2	1.4	2.2	0.4	0.4	0.2	K	50.0
		217P28	300	-	-	-	-	-	0.6	/	/	1.3	-	-	-	-	-	-	-	4.0	0.3	-	-	2.6	0.3	0.3	0.3	0.3	0.0	2.0	2.3	0.3	-	-	-	67.6
	CONIACIAN	217P26	500	-	-	-	0.2	-	1.8	/	/	0.4	0.2	-	K	-	0.2	0.2	K	-	-	-	cf	5.0	1.0	0.8	0.8	1.8	1.0	1.0	2.2	-	0.4	1.4	K	68.8
		217P25	500	-	-	-	-	-	0.6	/	/	1.0	1.6	2.0	0.4	0.2	K	-	0.4	-	-	-	-	4.8	0.8	2.4	0.4	3.4	1.8	0.8	1.8	-	-	0.2	-	63.6
		217P24	300	-	-	-	-	-	2.0	/	/	1.3	0.3	0.3	1.0	-	-	-	-	-	-	-	-	1.3	0.6	2.3	-	1.6	-	-	1.6	-	-	-	-	76.3
		217P23	500	-	-	-	-	-	1.4	/	/	0.6	1.8	1.6	2.0	0.2	0.2	-	1.0	-	-	-	-	5.2	-	1.2	1.8	1.8	1.2	3.8	2.6	0.2	-	0.4	-	60.4
		217P2	/	/	/	/	/	/	P	/	/	P	/	/	/	/	P	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	C
		217P1	500	-	-	-	-	-	1.6	/	/	0.4	1.0	0.8	-	-	0.6	0.2	1.6	-	-	-	-	1.2	1.0	0.8	0.0	1.2	0.2	3.0	3.6	-	-	1.2	-	70.0
		217P19	300	-	-	-	-	-	1.6	-	-	-	-	-	0.6	-	0.2	K	K	-	cf	-	-	-	1.0	-	0.3	-	-	-	1.3	-	-	2.0	-	83.0
CASE BARUZZO SANDSTONE	CENOMANIAN	216P235	500	-	-	-	0.2	0.2	0.8	-	-	0.4	0.2	-	-	-	-	-	-	-	-	-	-	1.4	-	-	-	0.6	-	1.8	1.8	-	-	2.2	-	81.0
		216P236	500	-	K	-	0.6	cf	2.2	-	-	0.6	-	-	-	-	-	cf	-	-	-	-	-	3.0	0.8	0.6	-	0.2	-	1.8	1.6	-	0.2	1.0	-	77.8
		217P5	500	0.2	0.2	-	-	0.2	2.6	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.6	0.4	0.2	-	0.2	-	0.8	2.2	-	-	0.8	-	87.0
		217P4	500	-	0.2	-	K	0.6	2.6	-	-	0.2	-	-	-	-	-	-	-	-	-	-	-	0.4	0.8	-	-	0.4	-	0.6	1.0	-	-	1.2	-	86.0
		217P4a	500	-	K	-	0.4	-	6.0	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.6	0.8	0.2	-		-	0.2	1.8	0.2	-	1.2	-	79.4
		217P3	500	-	0.4	-	-	K	3.4	-	K	0.2	0.2	-	-	-	-	-	-	-	-	-	-	0.8	0.8	0.2	-	0.6	-	3.2	3.4	0.2	-	1.2	cf	76.0
		216P237	500	0.2	0.2	0.2	0.4	0.6	1.2	-	-	-	0.4	-	-	-	-	-	-	-	-	-	-	1.2	-	-	-	0.2	-	1.2	1.4	0.4	0.2	2.8	-	78.8
		216P176	500	-	K	K	0.4	-	2.0	-	-	0.6	K	-	-	-	-	-	-	-	-	-	-	1.2	0.8	-	0.8	0.4	0.2	0.8	1.8	0.4	0.4	1.8	-	80.0
		216P177	500	-	0.4	0.2	0.2	-	1.8	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2.0	K	0.4	0.2	0.2	0.4	1.6	1.8	0.4	0.6	1.6	-	76.8
		216G226	500	cf	0.4	-	0.4	0.8	1.6	-	-	-	0.8	-	-	-	-	-	-	-	-	-	-	1.4	0.6	-	0.6	0.6	0.4	2.0	3.4	0.4	1.2	1.4	-	74.6
		216G227	500	-	-	-	-	-	1.6	K	-	0.2	-	-	-	-	-	-	-	-	-	-	-	0.2	0.6	-	-	0.6	K	1.8	1.0	-	0.4	3.2	-	80.6
		216G228	500	-	0.4	-	-	0.2	2.0	-	-	-	0.4	-	-	-	-	-	-	-	-	-	-	2.0	1.4	-	0.6	0.4	0.2	1.2	2.0	0.6	0.4	0.6	-	75.4
		216G217	500	K	0.2	0.2	0.2	1.2	1.4	K	-	0.8	0.2	-	-	-	-	-	-	-	-	-	-	1.2	0.4	0.4	0.4	0.2	0.2	1.8	1.6	-	1.6	1.2	-	78.2
		216G218	500	-	0.6	-	-	K	2.6	0.0	K	-	0.2	-	-	-	-	-	-	-	-	-	-	1.2	1.4	-	-	-	-	1.6	1.6	-	0.4	3.0	-	78.0
		216G219	500	-	0.6	-	0.2	K	0.8	cf	-	-	0.6	-	-	-	-	-	-	-	-	-	-	1.2	1.8	K	0.2	0.4	0.2	1.4	2.8	-	-	1.6	-	81.2
		216G220	500	-	cf	-	-	0.2	0.6	K	-	-	0.4	-	-	-	-	-	-	-	-	-	-	1.8	1.4	-	-	K	-	0.6	0.8	-	0.6	0.2	-	80.0
		216G221	500	-	0.4	-	0.2	-	2.0	-	-	-	0.2	-	-	-	-	-	-	-	-	-	-	2.0	0.8	0.2	0.4	0.4	-	1.4	0.6	-	-	0.6	-	80.8
		216G222	500	-	0.2	0.2	0.2	0.6	1.8	-	-	-	0.8	-	-	-	-	-	-	-	-	-	-	1.8	1.0	-	-	0.2	0.2	1.6	2.0	-	0.4	1.4	-	76.2
		216G223	500	0.2	0.2	-	-	-	1.0	-	-	0.2	-	-	-	-	-	-	-	-	-	-	-	1.8	0.6	-	0.2	0.2	-	1.8	1.4	-	-	1.4	-	80.8
		216G224	500	0.2	0.2	0.2	K	0.2	1.6	cf	-	-	0.8	-	-	-	-	-	-	-	-	-	-	2.0	0.4	0.2	0.4	1.0	0.8	1.4	1.2	0.6	0.2	1.4	-	77.8
		216G225	500	0.2	0.2	K	0.4	0.2	0.8	-	cf	-	1.2	-	-	-	-	-	-	-	-	-	-	2.0	1.0	K	K	-	K	2.6	1.6	0.8	0.4	0.4	-	77.8
		216P175	300	-	0.6	-	-	-	0.6	-	-	-	0.6	-	-	-	-	-	-	-	-	-	-	1.6	1.0	-	0.3	-	-	0.6	0.3	-	1.0	1.0	-	88.0

Tab. 2 - Distribution of selected calcareous nannofossil species in the Case Baruzzo section, and inferred chronostratigraphic interpretation. (-) counting is 0.0; (/) not checked.

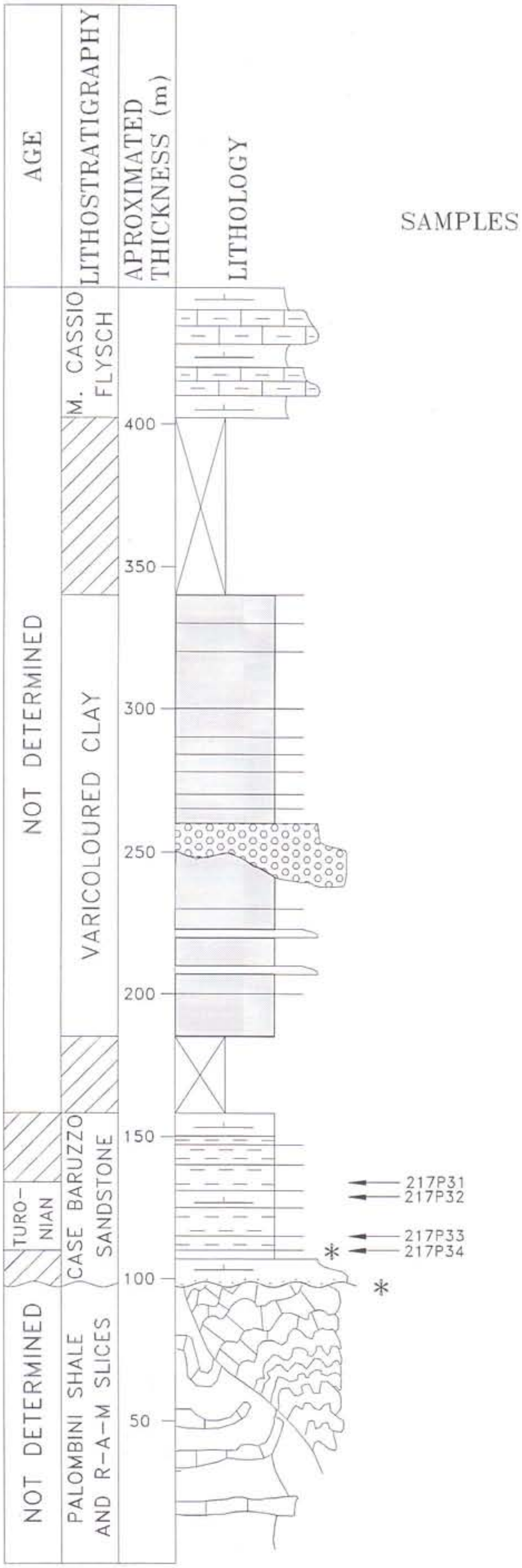


Fig. 7 - Case Praquarola section. Lithostratigraphic column reconstructed along cross section C of Figure 3.

The CBS consists of a turbidite succession with an estimated total thickness of up to about 200 m exhibiting the lithofacies listed below in order of decreasing volumetric abundance.

1) Thick and very thick-bedded (up to 10 m) turbidites showing a thin coarse-grained litharenitic sole followed by a few cm thick, fine-grained sandstone interval, with even lamination, grading into a thick interval of gray silty marlstone; the basal portion of these thick-bedded turbidites is petrographically characterized by a lithic Q F L mode with the Rock Fragments population dominated by carbonate grains.

2) Thin to medium-bedded turbidite sandstones, fine to very fine-grained, horizontally laminated and often rich in coal fragments, gently grading upwards into a light gray silty marl.

3) Medium to thick-bedded turbidites, with thin soles of coarse to medium-grained whitish breccia, overlain by light gray marly limestones; as shown in the following the basal rudites have a calcilithic composition (Valloni *et al.*, 1991), rich in biogenic chert fragments.

4) Medium to thin-bedded greenish fine-grained turbidite sandstones representing interbeds in the uppermost portion of the CBS near the contact with the Varicoloured Clay; petrographically they represent quartzofeldspathic arenites.

5) Medium to thick-bedded coarse-grained turbidites, representing intercalations in the basalmost portion of the CBS, whose framework is dominated by coeval bioclasts (Calcarenites).

Petrography.

With reference to the five CBS lithofacies listed above the petrographic descriptions of the Calclithic rudite, Lithic arenite and Quartzo-feldspathic arenite deposits are given below whereas the Calcarenite deposits are discussed in the next paragraph concerning the substrate of the CBS.

Calcilithic rudites.

Two samples from the Prelerna and one sample from the Praquarola sections representing the fine ruditic sole of thick turbiditic calcareous mudstones were analyzed; their framework compositions are very similar and grain abundances are as follows:

- Prevailing micritic limestones (sparse pelagic fauna), plus subordinate fossiliferous limestone fragments and recrystallyzed carbonate laminites;

- Abundant biogenic chert fragments (radiolaria common), frequently replaced by micro-cryptocrystalline calcite;

- Common siliceous shale fragments with laminated texture;

Fig. 8 - SW-verging overturned folds affectig the Case Baruzzo Sandstone. Right bank of the Grontone Torrent (cross-section B, Figures 2 and 3).

- 1 to 10 % (on total framework) accessory grains comprising quartzo-feldspathic phanerites and minor shists, sandstones and siltstones.

Lithic arenites.

Three samples, collected in the basal portion of medium to thick bedded turbidites of the Case Baruzzo Section were selected for the microscopic analysis (Fig. 6). Post-depositional changes are severe and take the form of calcite substitution patches and grain pseudomorphs; they total 14-19 % on total rock and hamper the reconnaissance of the original detrital association.

The Q-F-L+C mode is lithic with quartzose grains of the order of 40% and feldspathic grains up to 20%. Recalculation of the lithic grains (L+C) shows the dominance of sedimentary rock fragments and a characteristic 10-20% of volcanic grains with vitric, porphyric and rhyolite-like structures. Recalculation of the sedimentary grain population shows the dominance of carbonate fragments whereas siliciclastic rock fragments are almost absent. The carbonate grain varieties are essentially micritic rock fragments more or less recrystallized.

Quartzo-feldspathic arenites.

In the Case Baruzzo section (Fig. 6), in close proximity to the contact with the overlying Varicoloured Clay, fine-grained greenish sandstone interbeds occur; one of these beds was sampled for semiquantitative petrographic analysis.

The framework grains are fully interlocked by quartz and feldspar (albite?) overgrowths; also common are late-calcite replacive patches. The greenish appearance of the rock is due to the diffuse alteration of unstables (including feldspars) into chlorite-like minerals.

The framework composition is dominated by quartz (almost 50% of total framework) and less abundant feldspars. Microcrystalline silica grains undergoing recrystallization are common and increase the quartzose character of the rock. Polymineralic grains are essentially represented by quartz-mica shists which total about

STRATIGRAPHIC UNIT	AGE	SAMPLE	COUNTED SPECIMENS	*C. cuvillieri*	*C. kennedyi*	*C. exiguum*	*F. oblonga*	*R. asper*	*E. floralis*	*Eiffellituhs* spp.	*E. turriseiffelii*	*E. gorkae*	*E. eximius*	*M. decoratus*	*Q. gartneri*	*M. furcatus*	*E. eptapetalus*	cf. *Micula* spp.	*R. angustiforata*	*P. columnata* group	*P. creatacea* group	*Ch. litterarius*	*T. exiguus*	*T. phacelosus*	*C. crenulatus*	*Z. compactus*	*R. angustus*	*R. splendes*	*L. carniolensis*	*Nannoconus* spp.	*Watznaueria* spp.
C. BARUZZO SANDSTONE	TURONIAN	217P31	500	–	–	–	0.2	0.6	1.6	1.2	2.2	0.6	–	K	0.2	–	0.6	K	3.8	1.4	0.6	0.2	2.4	0.8	1.8	1.8	1.2	0.2	0.2	0.2	70.0
		217P32	500	–	–	–	0.6	0.6	0.2	0.6	0.6	0.2	–	–	0.2	–	0.6	K	3.0	1.0	0.6	0.2	2.0	–	1.4	1.0	0.2	0.6	–	1.4	77.0
		217P33	500	K	–	–	0.4	0.2	0.8	0.4	1.2	0.2	–	K	0.2	–	1.0	K	2.8	0.8	0.2	0.2	0.8	0.2	1.8	3.2	0.2	0.8	0.2	1.0	74.0
		217P34	500	0.2	K	–	0.6	0.4	1.0	1.0	1.0	0.2	–	K	0.4	–	0.2	0.2	3.2	1.4	1.4	0.2	2.4	–	1.2	2.4	–	–	–	–	73.6

Tab. 3 - Distribution of selected calcareous nannofossil species in the Case Praquarola section, and inferred chronostratigraphic interpretation. (-) counting is 0.0.

10% on total framework. Among accessory grains the dense minerals such as Garnet, Rutile, Sphene and Picotite are often encountered as well as sparse grains of Glauconite.

Age.

The calcareous nannofossil contents of the CBS from the Case Baruzzo (Fig. 6 and Tab. 2) and Prelerna (Fig. 5 and Tab. 1) sections are similar and can be confidently assigned to the Cenomanian because of the almost continuous presence of *Corollithion kennedyi* and *Helenea (Microstaurus) chiastia* and the absence of *Quadrum gartneri* and other post Cenomanian markers. The stratigraphically important Cenomanian species *Lithraphidites acutus* and *Lithraphidites alatus* are very rare and their occurrence has been detected only after lengthy searching. *Microrhabdulus decoratus* and *Axopodorhabdus albianus* have not been found. The absence of *Microrhabdulus decoratus* seems to be ecologically controlled since it is very rare even in the overlying Turonian-Coniacian sediments (Tab. 1 and 3). The presence of *L. acutus* makes it possible to assign the CBS of the Case Baruzzo and Prelerna sections to the late Cenomanian (see Fig. 10). A more detailed age assignment is impossible since calcareous nannofossils provide a relatively poor resolution in the time interval (Fig. 10). It should be noted that *C. kennedyi* is missing in the uppermost sample in the Case Baruzzo section (Fig. 6)

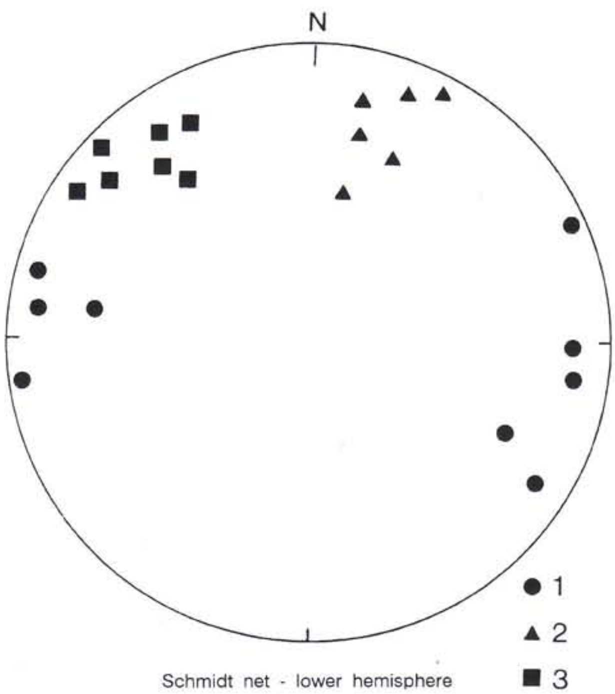


Fig. 9 - Fold axes within the Case Baruzzo Sandstone, along the cross-section B (Fig. 3). (1): First phase folds, overturned towards SW; (2): Second phase superposed gentle folds; (3): N-verging drag folds related to low-angle late thrust planes.

and, with all uncertainities of the single-sample information, this might suggest a terminal Cenomanian age for the top of the unit (see Fig. 10).

The four samples collected in the CBS oucropping in the Praquarola section (Fig. 7) contain nannofossil assemblages (Tab. 3) different from those recovered in the former two sections. *Corollithion kennedyi*, that characterizes the CBS in the Case Baruzzo and Prelerna sections, is virtually missing and *Q. gartneri* and *Eprolithus eptapetalus* are present. *Helenea chiastia* is present with atypical specimens and is probably reworked. These findings suggest a Turonian age for the CBS outcropping in the Praquarola section. In particular, the absence of *Eiffelithus eximius* (well represented in the area) would suggest an early Turonian age for this portion of the CBS (Figs. 7, 10 and Tab. 3). Apparently, the CBS at Praquarola are younger than those sampled in the Case Baruzzo and Prelerna sections, although it is difficult to estimate how large the age contrast is.

Substrate of the CBS: Palombini Shale and R-A-M slabs.

The stratigraphic base of the CBS crops out in the Taro Valley, approximately 1 km SW of Prelerna (Fig. 3, section A) and in the Baganza Valley, at Praquarola (Fig. 3, section C). In the former the contact with the underlying Palombini Shale is poorly exposed. In the latter the contact with the Palombini Shale and the embedded R-A-M slabs appears unconformable, as already pointed out by Zanzucchi (1980). The presence of an unconformity between the Palombini Shale and the CBS is in agreement with the available biostratigraphic data, that suggest Hauterivian-Aptian for the Palombini Shale (Villa in Vescovi., in press) and a Cenomanian age for the CBS (present work). A hiatus of a minimum duration of 14-15 my is thus present (see time scale of Gradstein *et al.*, 1994).

There is much evidence, however, suggesting a stratigraphic relationship between the CBS and the Palombini Shale. A granule-size sample of the Palombini Shale from the Prelerna Section (sample O18 in Fig. 5) shows a relatively distinct composition with abundant algal, briozoan and other fossiliferous limestones, abundant micritic fossiliferous and pelagic limestones and subordinate fossil fragments of probable intrabasinal origin with small amounts of rhyolite-like fragments, schist fragments of several textures, quartz, sandstone and siliceous-shale grains. Such a composition is quite similar to the one detected at the base of the CBS near Praquarola (Fig. 3, section C), close to the contact with the Jurassic Radiolarites (Fig. 7). Here, a bioclastic calcarenite located close to the contact with the underlying Radiolarites, contains limestones and fossil fragments of the same varieties and in the same relative proportions

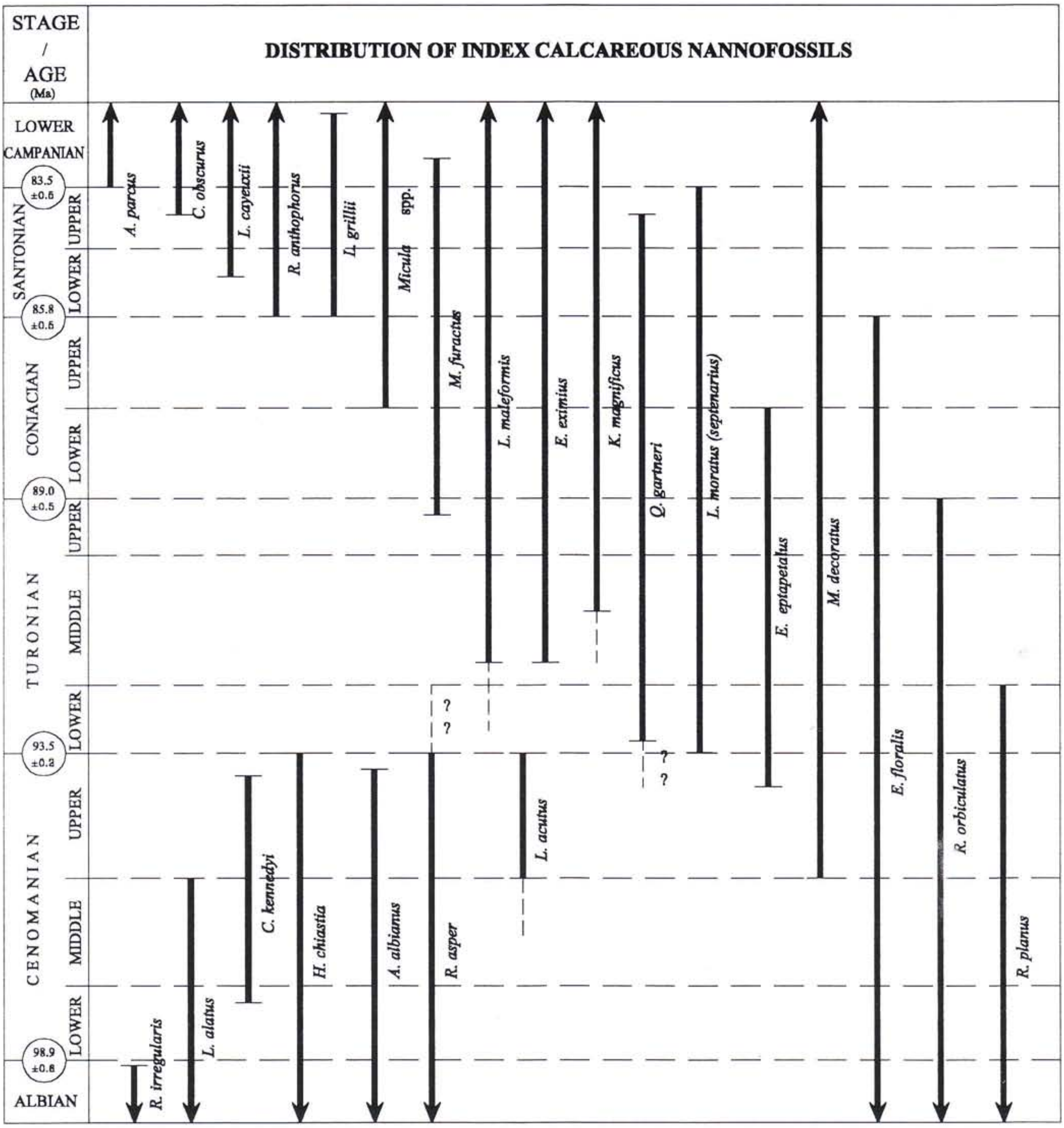


Fig. 10 - Adopted distribution model of index calcareous nannofossils species *versus* standard chronostratigraphy utilized for age assignements. Age of stage boundaries are after Gradstein *et al.* (1994). Data of distribution model of index calcareous nannofossils species after are Varol (1992), Perch-Nielsen (1985) and Bralower & Siesser (1992)

as the underlying Palombini Shale as well as 10% of the distinctive quartzose, rhyolite-like and shist grains found in the Palombini Shale sample above. At the same time, relevant amounts (about 30 % on total framework) of biogenic chert and minor siliceous-shale, characteristic of the CBS Calcilithic Rudites, appear.

Other evidence of a stratigraphic relationship between the CBS and the Palombini Shale is the presence, within the coarse-grained arenites in the lowermost portion of the CBS, of numerous angular clasts of greenish chert exactly resembling the angular elements of the autoclastic breccia sampled within the Jurassic Radiolarites embedded in the Palombini Shale (Fig. 12).

The discontinuity of the Septaria-like concretion surface.

The contact between the CBS and the overlying Varicoloured Clay is well exposed in the Grontone Val-

Fig. 11 - Marlstone turbidite interbeds in the lower portion of the Case Baruzzo Sandstone in their type area.

ley (Fig. 3, cross-section B). We interpret the contact as originally stratigraphic in spite of the fact that it is sharp and disturbed because of tectonic deformations affecting both Varicoloured Clay and the uppermost part of the CBS. In the Case Baruzzo section (Fig. 6), at the contact between the CBS in their thin-bedded lithofacies, and the Varicoloured Clay, a surface is present characterized by the discontinuous occurrence of Septaria-like concretions of light grey silty marls, enriched with barite (Fig. 13). The barite enriched concretions suggest condensed sedimentation at the contact between the CBS and the Varicoloured Clay, in accordance with the large biostratigraphic hiatus.

Samples collected just below (N°216P235) and immediately above (N°217P19) this surface yield vastly different calcareous nannofossil assemblages (Tab. 2) suggesting the presence of a major hiatus. Specifically, the uppermost sample collected in the CBS yielded the Cenomanian assemblage commented above, while the lowermost sample of the Varicoloured Clay contains, among others, *Marthasterites furcatus*, *Eiffelithus eximius* and *Micula decussata* which indicate a late Coniacian age. The hiatus associated with the surface of the Septaria-like concretions may have a duration in excess of 5-6 my i.e., the entire Turonian and the early Coniacian are missing (Fig. 10).

Concerning the causative mechanism of this hiatus, it should be noted that the passage from the Cenomanian to the Turonian is characterized globally by a major oceanographic anoxic event (Bonarelli bed in the Adriatic foreland) and by a severe shallowing of the CCD that prompted the deposition of carbonate variegated clay in the Atlantic Ocean and caused widespread hiatuses in the oceanic realms (Kenneth, 1982). These hiatuses are also found in the Lombardy basin (Bersezio & Fornaciari, 1994), where, however, tectonics may have played a major role, since they grossly correspond with pre-Gosau Alpine tectonic phase.

Top of the CBS: Varicoloured Clay.

The Varicoloured Clay was investigated only in their basal 100 metres. Actually the entire succession shows a severe folding deformation with large-scale isoclinal folds, usually dismembered. Sometimes the deformation took place when the sediments were poorly consolidated as indicated by boudinage and hydroplastic extensional fractures.

In correspondence with the base of the Varicoloured Clay, adjacent to the Septaria-like concretions, fluid escape structures are present (Fig. 13 A). In addition, the Septaria-like concretions show fractures filled with very fine greenish chlorite sandstone (Fig. 13 D), very similar to the fine-grained beds intercalated within the uppermost portion of the CBS.

Petrography.

In the Varicoloured Clays of the Case Baruzzo section occasional sandstone turbidite beds are intercalated; in the lower portion of the CBS three coarse-grained samples (Fig. 6) were collected for point counting.

Post-depositional alteration of sandstone deposits is moderate, within 5% of the total rock; it consists of calcite in the form of grain pseudomorphs and irregular patches as well as of authigenic barite in irregular substitution patches representing the most original feature. Accessory grains are essentially represented by white and brown mica totalling 3-4 % on total rock.

Detrital modes are shown in Fig. 14. The framework composition (Q,F,L+C) is represented by 30-40 % of quartzose grains and by lithic grains in excess of the feldspathic ones.

In the quartzose grains granitoid fragments are quite common. In the feldspathic grains perthitic structures are present and the K-feldspars largely exceed plagioclases. In the lithic grains (pole L+C) all basical rock types are represented although volcanics alone total

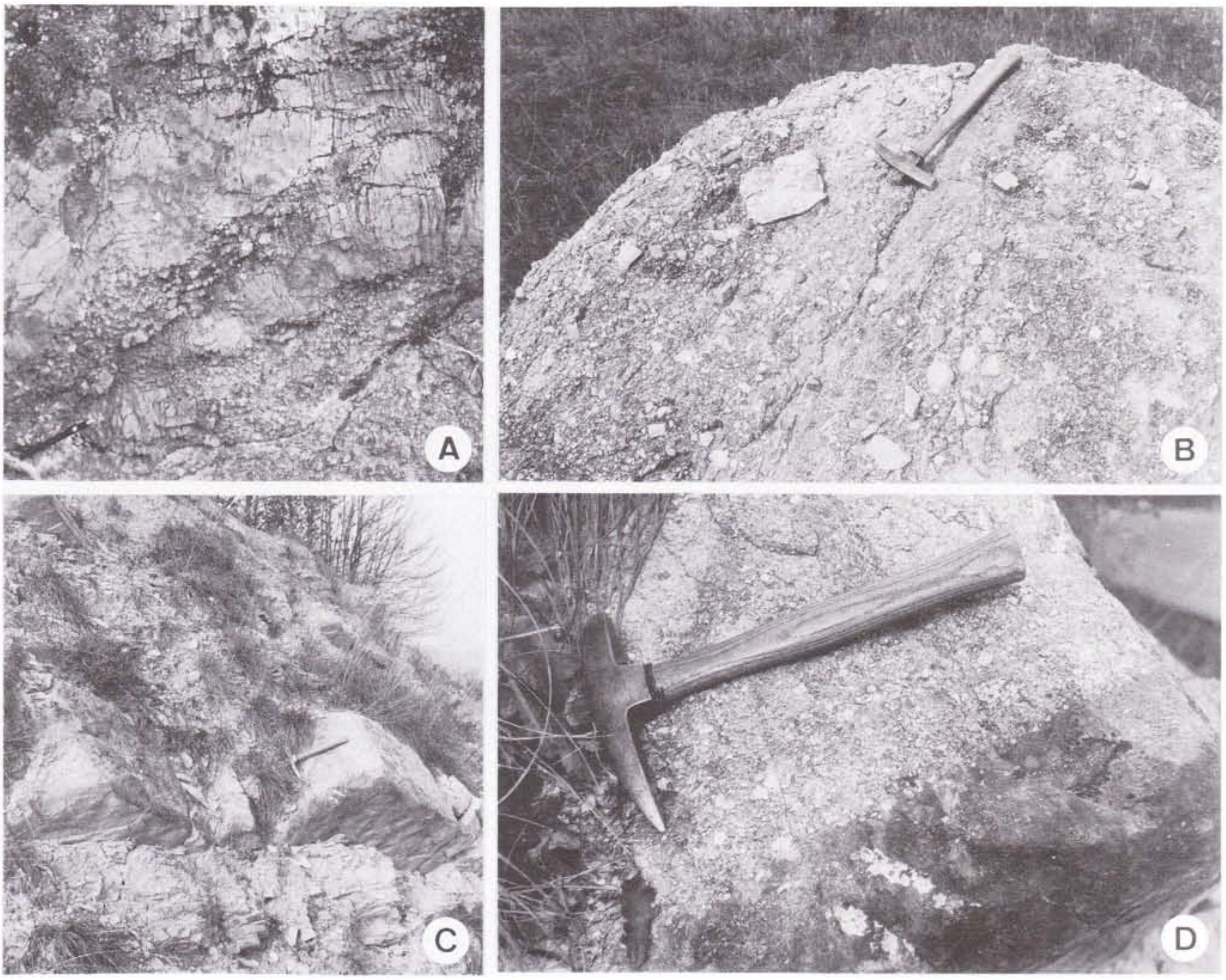


Fig. 12 - (A): slice of strongly brecciated Radiolarite tectonically interposed within the Palombini Shale of the Grontone Torrent (pencil at the lower left gives scale). (B): sedimentary breccias deposited on A and derived from Radiolarites and Maiolica limestone. (C, D): coarse basal intervals of the Case Baruzzo Sandstone beds consisting of sedimentary breccias strictly comparable to B.

about one half of the lithic population (Fig. 14). The volcanic fragments are frankly acid and have a structure from vitric to porphyric with quartz and alcali feldspar phenocrystals.

Age.

The age of the Varicoloured Clay of the Monte Cassio Unit has been partially studied by Rio & Villa (1987) and by Perilli & Rio (in Cerrina Feroni *et al.*, 1990), who have documented Santonian and Campanian ages. In the present work we have examined the calcareous nannofossil contents of the lower part of the Varicoloured Clay outcropping in the Case Baruzzo section (Fig. 6). Results reported in Tab. 2 and in Fig. 6 indicate that this portion of the Varicoloured Clay extends from the late Coniacian to the early Santonian. Combining the present data with data in the literature, it results that a fairly regular biostratigraphic progression is present in this Formation, from the late Coniacian to the late Campanian. Unfortunately, it is impossible to evaluate the sediment accumulation rates of the Varicoloured Clay because the severe deformation prevents an estimate of the actual thickness.

CBS and Ostia Sandstone relations.

As mentioned previously, the CBS and the major packages of the arenaceous turbidites intercalated in the Varicoloured Clay have been ascribed in the literature to the Ostia Sandstones (Cerrina Feroni *et al.*, 1990; Ghiselli et al., 1991; Elter & Marroni, 1991), a major siliciclastic wedge of the Cretaceous Ligurian-Piedmont Ocean. In particular, Costa et al., (1995) have interpreted the type Ostia Sandstone and the CBS as belonging to a unique stratigraphic succession that was dismembered and displaced by a Santonian extensional tectonic phase. In the following, we face the problem of the stratigraphic relationships between the type Ostia Sandstone outcropping in the Taro Valley (Parma Province) and the

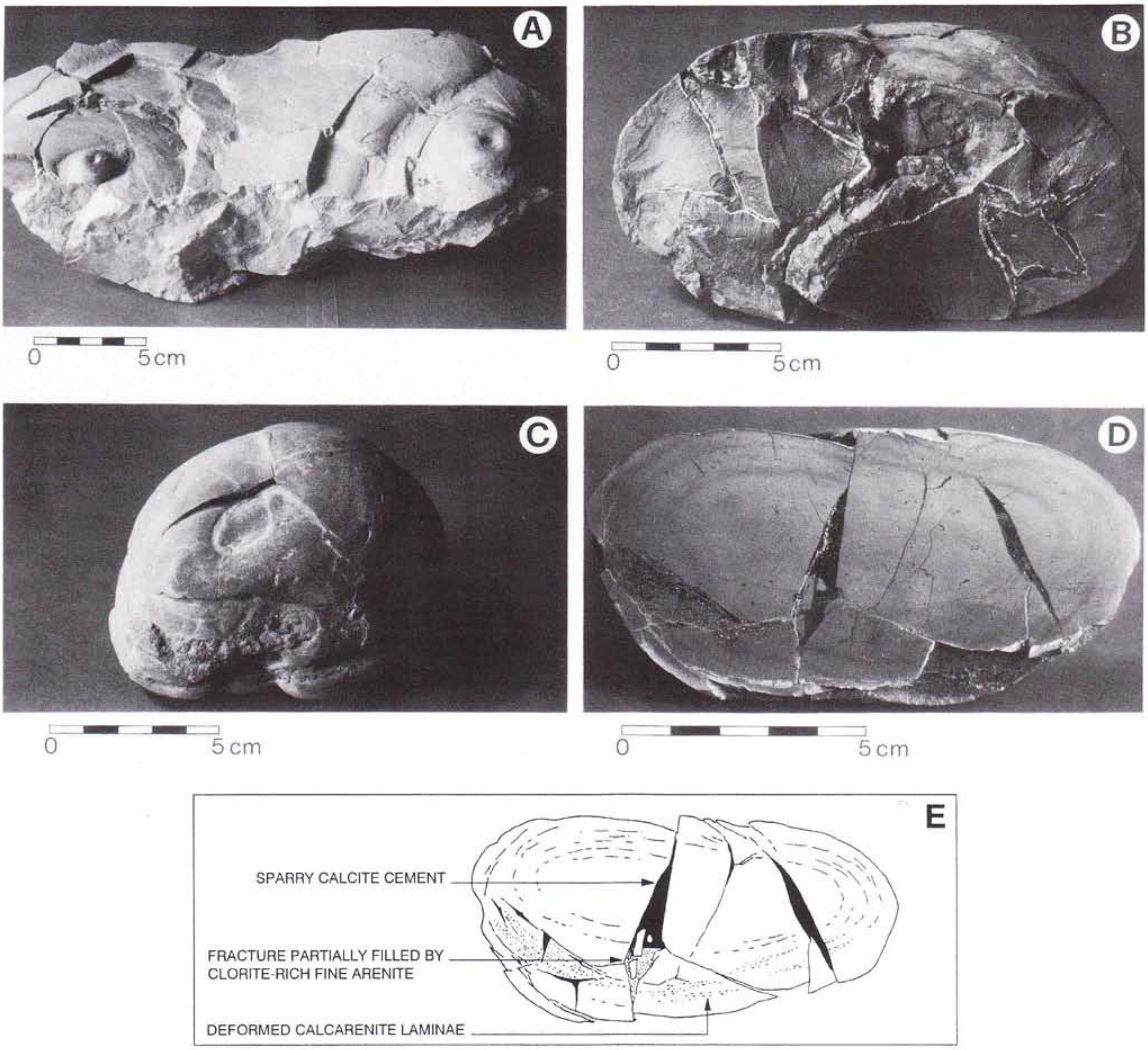


Fig. 13 - Concretions contained in the Varicoloured Clay, just above the stratigraphic contact with the Case Baruzzo Sandstone (Fig. 3, cross-section B). (A) silty-marl intercalations affected by hydroplastic deformation and showing fluid escape structures; (B, C) barite nodules resembling septarian concretions; (D) the structure of the fractures filling is depicted in the drawing (E) from a polished section.

succession of the Monte Cassio Flysch. We will show that the CBS of the Cassio Unit and the type Ostia Sandstone have to be considered as two distinct depositional episodes with different stratigraphic evolutions.

The type Ostia Sandstone belongs to the Media Val Taro Unit, whose schematic stratigraphy is shown in Fig. 4 (Vescovi *et al.*, in press). The succession begins with the Palombini Shale of Monte Rizzone (fairly similar and time-equivalent with the Palombini Shale of the Grontone Torrent), that is unconformably overlain by a shaly unit (San Siro Shale) containing marly turbidites (Pontolo Marl) very similar to the medium to thick-bedded turbidite lithofacies of the CBS, in its turn overlain by the Ostia Sandstone with a probable unconformable contact, passing conformably to another arenaceous turbiditic unit named Campi Sandstone of Campanian age (Vescovi *et al.*, in press). The youngest formation of the Media Val Taro succession is a Campanian-Maastrichtian Helminthoid Flysch (Testanello Flysch), similar to the Monte Caio Flysch.

The reason why in the literature the Ostia Sandstone has often been lumped with the CBS and the turbidites intercalated in the Varicoloured Clay of the Monte Cassio succession (Ghiselli *et al.*, 1991; Elter & Marroni, 1991; Plesi *et al.*, 1993; Costa *et al.*, 1995) is certainly due to their similar petrographic (litharenitic) composition. However, Villa (1991) has shown that the Ostia Sandstone in the type locality is late Coniacian-Santonian in age, in sharp contrast with the late Cenomanian age of the CBS reported in this work. In the

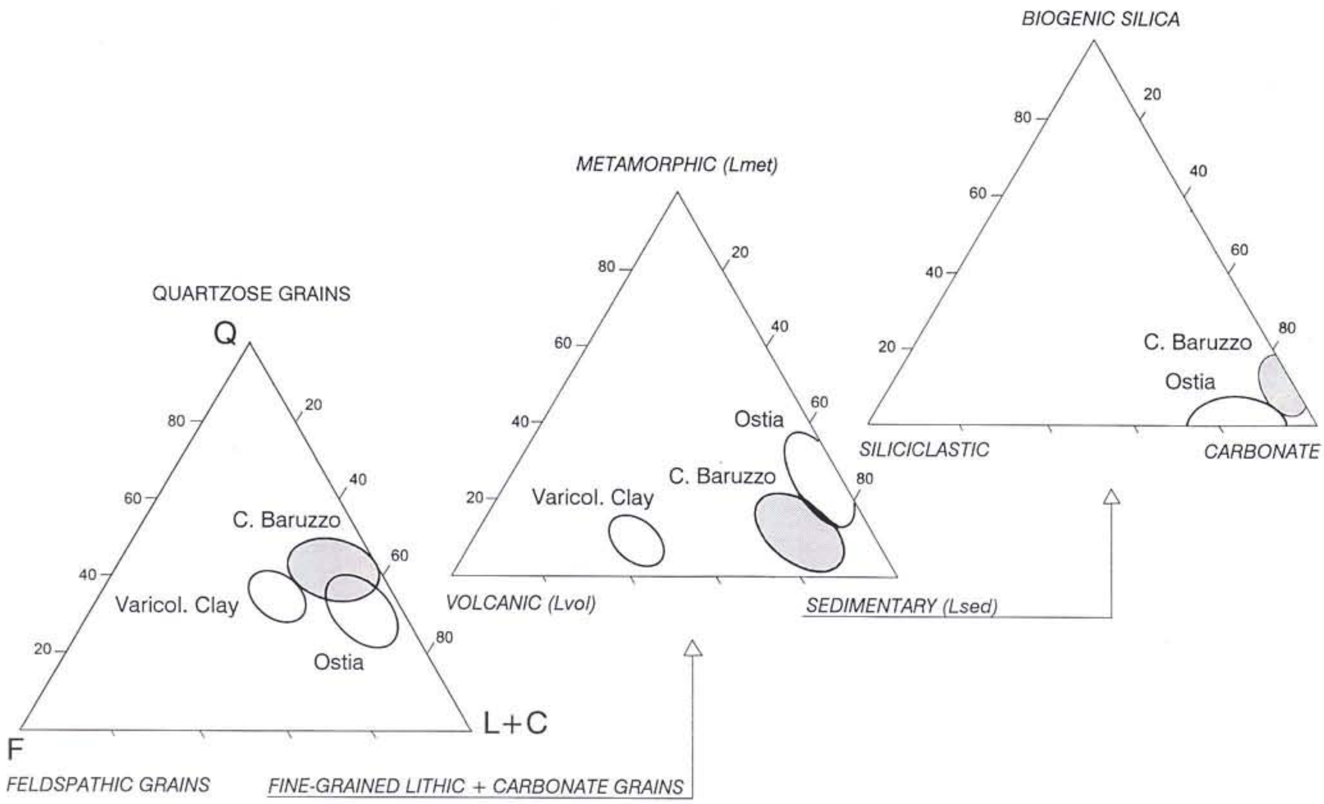


Fig. 14 - Petrographic composition of sandstone samples of the Case Baruzzo Sandstone, Ostia Sandstone and Varicoloured Clay. In order of increasing detail detrital modes are as follows: Q,F,L+C = Essential Framework grains; Lmet, Lvol, Lsed = Lithic Fraction of the Essential Framework grains; Biogenic silica, Siliciclastic, Carbonate grains = Sedimentary grain population of the Lithic Fraction. The two daughter diagrams are obtained by simply recalculating the counts of the poles L+C and Lsed and thus subjected to increasing statistical error. The number of counts available for the Lsed pole expansion is about one hundred.

Monte Cassio succession the "Ostia Sandstone time" is represented by the late Coniacian-Santonian Varicoloured Clay. Former petrographic studies do not compare specifically CBS and Ostia Sandstone. Plesi et al. (1993) report Q F L compositions indicating that CBS are poorer in feldspars with respect to the Ostia Sandstone.

We have analysed the petrographic composition (Fig. 14) of the Santonian Ostia Sandstone in the type area near the village of Belforte (Taro valley) for comparison with the Cenomanian CBS and the Santonian thin bedded turbidites intercalated in the Varicoloured Clay petrographically described in the previous sections.

Petrography of the Ostia Sandstone.

Three sandstone samples with medium-coarse grain size and the lowest possible alteration were selected for point counting. The post depositional alteration of the Ostia Sandstone is strong and represented by calcite substitutions of framework and intergranular materials. Calcite substitution patches and grain pseudomorphs total 18-22 % of the total rock which implies that the detrital mode is subjected to an intrinsical error. Among the accessory grains of the framework sparse intrabasinal pelitic fragments and picotite grains are present (Mezzadri, 1964).

Modal compositions (Fig. 14) of the essential framework grains (Q,F,L+C) plot in the Lithic sandstone field of the diagram with quartzose grains ranging 20-40% and lithic grains largely exceeding feldspar grains (F/L+C >1/3).

The lithic grains (pole L+C) constitute the most abundant framework constituent and are dominated by sedimentary types, among which carbonates strongly prevail on siliciclastics.

Petrographic comparisons.

The CBS of Cenomanian age and the Ostia Sandstone of Santonian age are petrographically very similar (Fig. 14). They represent a quite unique case in which such similarity is maintained at successive levels of analytical detail (Di Giulio & Valloni, 1992). This explains the fact that, in the past, the two deposits were considered the same formation. According to Folk's (1974) terminology both sandstones should be termed Calclithites because of the prevalence of the carbonate grain population.

In terms of the Q,F,L+C mode the CBS and Ostia Sandstone compositional fields have some overlap although the CBS tends to be richer in quartzose and feldspathic grains. For discriminating purposes formal

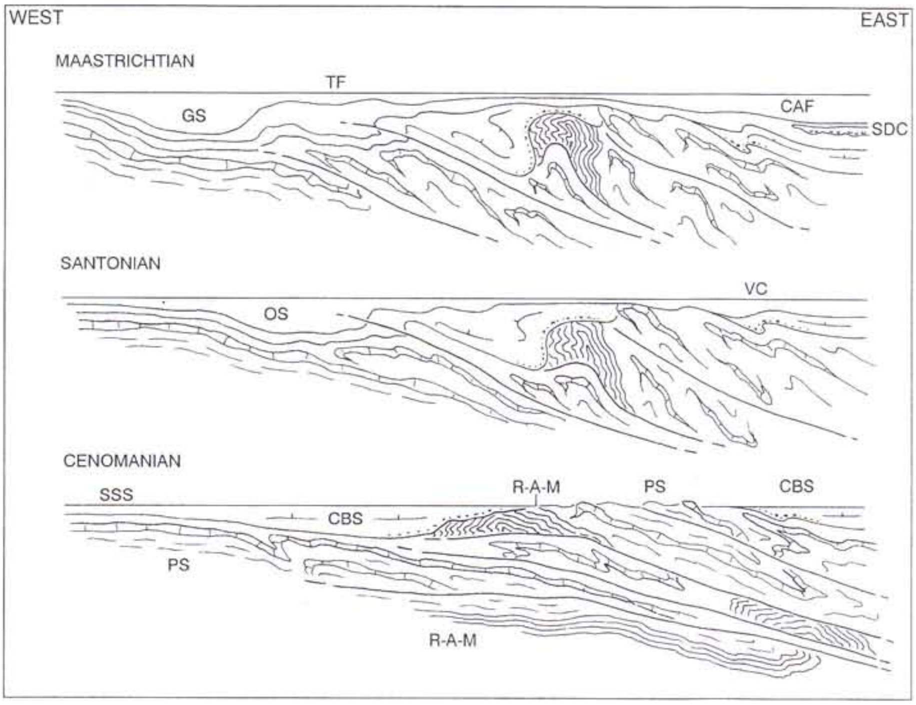


Fig. 15 - Evolutionary scheme of the Alpine-vergent accretionary prism controlling the migration of the Cassio, Media Val Taro and Gottero turbidite basins (abbreviations in Fig. 4).

point counting of the lithics population is particulary effective. The diagrams representing grain proportions within the lithic population (Fig. 14) indicate that:

(1) Santonian-age Ostia Sandstone samples have a characteristic 20-30% of metamorphic grains whereas the Cenomanian CBS samples have a characteristic 10-20% of volcanic grains;

(2) Among sedimentary lithics the Ostia Sandstone has a characteristic 10-30 % of siliciclastic grains (e.g. siltite and shale) which probably represents the best parameter for its distinction from the CBS;

(3) Among carbonate grain varieties the Ostia Sandstone shows distinctive quartz-impure calcilutites and marls.

With respect to the possible compositional parentages of the sandstones intercalated in the Varicoloured Clays, it is well evident (Fig. 14) that they have no affinity with the coeval Ostia Sandstones. On the contrary a linkage can be seen with the Cenomanian CBS which contains significant amounts of the same acid volcanics which characterize the compositional mode of the Varicoloured Clay.

As far as source areas are concerned the overall composition of the Calclithites of the Santonian Ostia Sandstone and of the Cenomanian CBS indicates a wide spectrum of source rocks that is well documented in the Adriatic continental margin (cf. Fontana, 1991). The wide spectrum of exposed lithologies indicates a distant source located in the overriding plate that fed the CBS in the Cenomanian and the Ostia Sandstone during the Santonian.

The composition of the Santonian arenites intercalated in the Varicoloured Clay on top of the CBS still indicates a provenance from the Adriatic continental margin with the addition of significant exposures of the crystalline basement. This evolution towards a smaller spectrum of exposed lithologies comprising the exposure of the crystalline basement indicates that the paleo-

PLATE 1

All specimens ca. 2000X

Fig. 1, 2 - *Lithraphidites alatus.* Fig. 1: Case Baruzzo section - 217 P3; parallel light. Fig. 2: Case Baruzzo section - 216 G220; parallel light.

Fig. 3, 5 - *Lithraphidites acutus.* Fig. 3: Case Baruzzo section - 217 P3; crossed nicols. Fig. 4, 5: Prelerna section - 198 G19; crossed nicols.

Fig. 6, 7 - *Lucianorhabdus maleformis.* Case Praquarola section - 217 P33; Fig. 6: parallel light. Fig. 7: crossed nicols.

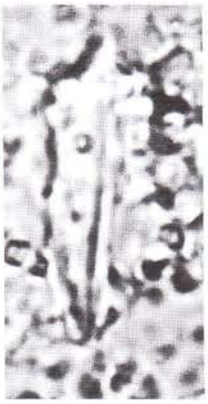
Fig. 8, 9 - *Quadrum gartneri.* Fig. 8: Case Praquarola section - 217 P32; crossed nicols. Fig. 12: Case Baruzzo section - 217 P3; crossed nicols.

Fig. 10, 14 - *Quadrum* sp. Fig. 10: Case Praquarola section - 217 P34; crossed nicols. Fig. 14: Case Baruzzo section - 217 P3; crossed nicols.

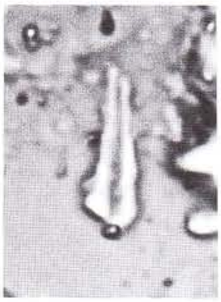
Fig. 13 - *Quadrum intermedium.* Case Baruzzo section - 217 P21; crossed nicols.

Fig. 11, 12, 15 - *Micula decussata.* Case Praquarola section - 217 P32; Fig. 1: parallel light. Fig. 2: crossed nicols. Fig. 3: Case Baruzzo section - 217 P21; crossed nicols.

Figs 16, 18 - *Eprolithus eptapetalus.* Fig. 16: Case Baruzzo section - 217 P19; crossed nicols. Fig. 17: Case Praquarola section. 217 P32; crossed nicols. Fig. 18: 217 P33; crossed nicols.



1 *L. alatus*

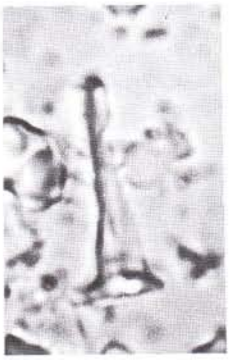


2 *L. alatus*

3 *L. acutus*

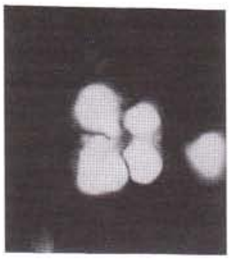
4 *L. acutus*

5 *L. acutus*



6 *L. maleformis*

7 *L. maleformis*

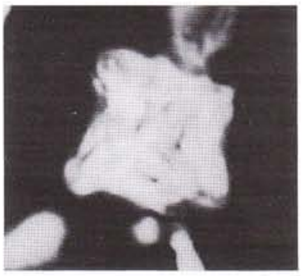


8 *Q. gartneri*

9 *Q. gartneri*

10 *Quadrum* sp.

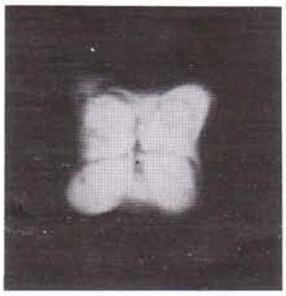
11 *M. decussata*



12 *M. decussata*

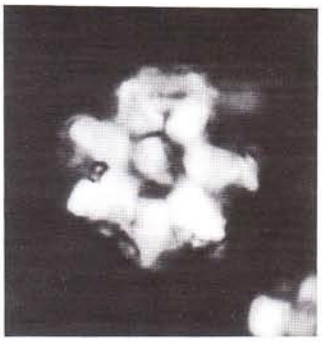
13 *Q. intermedium*

14 *Quadrum* sp.



15 *M. decussata*

16 *E. eptapetalus*



17 *E. eptapetalus*

18 *E. eptapetalus*

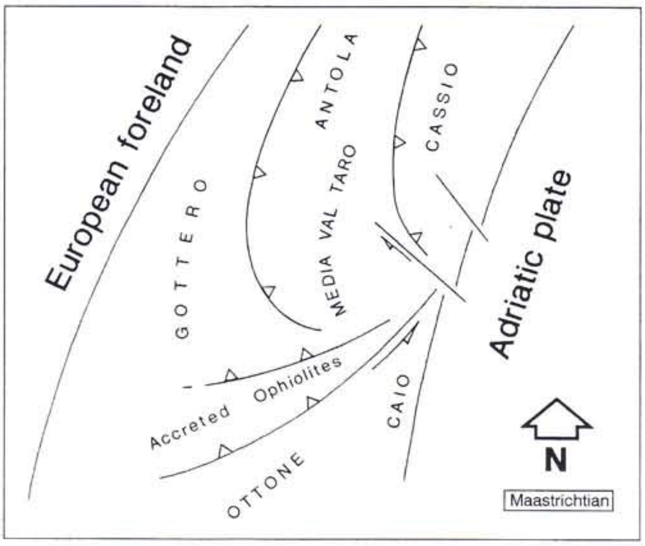


Fig. 16 - Paleogeographic reconstruction of the Ligurian domain during the Late Cretaceous; restoration is obtained by clockwise rotations of the Italian peninsula and of the Corsica-Sardinia massif. The Cassio, Media Val Taro and Gottero units are deformed by W-verging structures and are separated from the southern ligurian units (Ottone, Caio) by a transpressive zone with accreted ophiolites rejuvenating an old Jurassic transform zone and accomodating the N-S late Cretaceous convergence of the Adriatic plate relative to the European plate.

geographic position of the Cassio sequence was closer to the Adriatic margin than the Ostia-Media Val Taro Sequence.

Basin paleogeography and evolution.

The interpretation of the paleogeography and evolution of the basin also requires an investigation into the age and provenance of the Gottero Sandstone.

The Monte Gottero Sandstone outcrops in the inner sector of the Northern Apennines (Fig. 1); together with the underlying Val Lavagna Shale, the Gottero Sandstone represents a deep-sea fan deposit (Nilsen & Abbate, 1985) up to 2000 m thick. As far as provenance is concerned, Valloni & Zuffa (1984) and Wildi (1985), on the basis of the framework detrital modes and the heavy mineral contents respectively, indicate a Continental Block source from the European margin.

In the westernmost areas, the Val Lavagna Shale and the Monte Gottero Sandstone have been assigned Campanian-early Maastrichtian and late Maastrichtian-early Paleocene ages respectively (Passerini & Pirini, 1964; Marroni & Perrili, 1990; Marroni & Pandolfi, 1996). In an easterly position, between La Spezia and the middle Taro Valley (Fig. 1), the base of the Gottero Sandstone, sampled near Borgo Val di Taro (Parma Province) and Zeri (Massa-Carrara Province), contains a nannofossil assemblage indicative of a Coniacian-Santonian age (Fornaciari and Rio in Vescovi *et al.*, in press).

The Coniacian - Santonian age of the Gottero outcropping in the easterly areas and the petrographic composition of the Campi Sandstone, covering the Ostia sandstone in the Media Val Taro Unit being very similar to the composition of the Gottero Sandstone (Vescovi *et al.*, in press), both indicate that the Ostia Sandstone could have been sedimented immediately to the east of the Gottero basin.

The Ostia Sandstone, in its turn, has affinities with the CBS of the Cassio Sequence which, according to the data of the previous paragraphs, was deposited in the vicinity of the Adriatic margin. From West to East, the paleogeographic positions of the three sequences is thus: Gottero, Media Val Taro (Ostia) and Cassio (CBS).

With reference to the inception of the terrigenous turbidite sedimentation we have shown that it occurred during the Cenomanian in the Cassio Basin (CBS), the late Coniacian in the Media Val Taro Basin (Ostia), and the Campanian - Maastrichtian in the Val Lavagna - Gottero Basin. Such migration should imply Alpine-verging tectonics as clearly expressed in the Gottero Sequence (Marroni & Pandolfi 1996). The reconstruction here proposed is that during late Cretaceous time, a westward prograding clastic wedge should have been present in this part of the Ligurian-Piedmont Ocean (Fig. 15).

This interpretation, however, does not explain the entire stacking of the Ligurian units. At present, the Gottero, Media Val Taro and Cassio ophiolite-free units overthrust the Bracco, Ottone and Outer Ophiolitic Complex, ophiolite-bearing successions (Fig. 1). The absence of ophiolitic detritus in the Gottero, Media Val Taro and Cassio sequences recognized here as well as in the recent literature implies that in the northern portion of the Ligurian-Piedmont Ocean the oceanic lithosphere had been completely subducted by an early Cretaceous east-dipping plane. On the contrary, in the southern portion of the Ligurian-Piedmont Ocean, large ophiolitic slices were obducted which provided detritus to the Ottone and Caio successions (Bertotti et al., 1986).

According to Vescovi (1993), these obducted ophiolites should have been oriented transversely to the Ligurian-Piedmont Ocean, probably along an ancient Jurassic transform fault zone (Fig. 16).

Only in the middle Eocene Ligurian tectonic phase, the Gottero, Media Val Taro and Cassio northern Ligurian Units, previously deformed by west-verging tectonic structures, were thrusted towards south-east above the ophiolitic units and related Helminthoid flysch.

In this reconstruction, during the middle Eocene collision, the ophiolitic ridge separating the northern and southern domains of the Ligurian-Piedmont Ocean acted as a kinematic release with transpressive lateral shift (Fig. 16); after the collision, the ophiolitic ridge was strongly displaced by the well known Neogene thrusting of the Apennines.

The late Cretaceous strike-slip fault systems causing the closure of the Ligurian-Piedmont Ocean accomodate the northward motion of the Africa-Adria plate (Vandenberg *et al.*, 1978; Savostin *et al.*, 1986; Dewey *et al.*, 1989; Heller *et al.*, 1989); the oblique left-lateral convergence could have caused the tectonic slicing of oceanic fragments of the ancient transform zone (Abbate et al., 1994; Marroni & Treves, 1998).

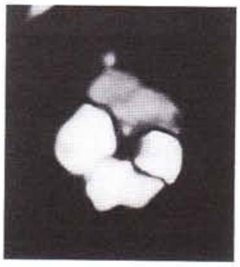
Conclusions.

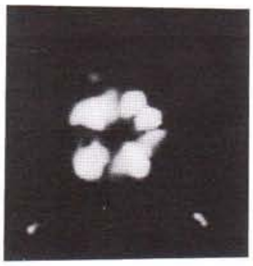
The integration of structural, lithostratigraphic, biostratigraphic and petrographic data on the helminthoid bearing Monte Cassio Flysch in its type area located between Baganza and Ceno valleys lead to the revision of the stratigraphic successions and, consequently, to new paleogeographic reconstructions.

The stratigraphic succession, extended from the lower Cretaceous to the upper Campanian, comprehends: 1) a basal carbonate-rich pelagic shaly unit (Palombini Shale of the Grontone Torrent) containing slabs of Jurassic-lower Cretaceous allochtonous material, 2) an up to 200 m thick siliciclastic turbiditic unit (Case Baruzzo Sandstone) and 3) a clay-rich pelagic unit (Varicouloured Clay) containing thin-bedded terrigenous turbidites and a major coarse-grained episode (Salti del Diavolo Conglomerate).

Contrary to previous reconstructions the Cenomanian-lower Turonian Case Baruzzo Sandstone must be considered as a distinct siliciclastic wedge from the Ostia Sandstone, dated in their type locality to the late Coniacian-Santonian (Villa, 1991) and time correlative to the Varicoloured Clay.

Field data provide evidence that the basal complex of the Monte Cassio Flysch has been affected by late Cretaceous tectonic deformations which, in the case of the Case Baruzzo Sandstone, are likely to be west (Alpine) vergent. Tectonic deformations may be related to the evolution of an alpine-vergent ligurian prism related to an east-dipping subduction zone which controlled the sedimentation of the Monte Cassio succession which shows three major stratigraphic discontinuities (Fig. 4):

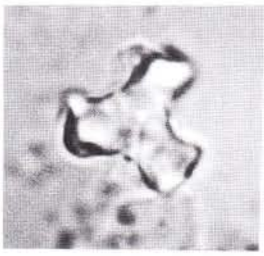

1 *E.* cf. *rarus*


2 *E. octopetalus*

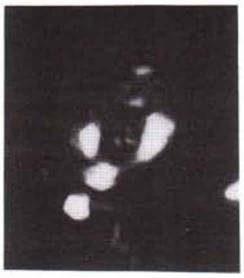

3 *E. floralis*


4 *L. moratus*


5 *H. chiastia*


6 *M. furcatus*


7 *R. asper*


8 *F. oblonga*


9 *C. kennedyi*


10 *C. kennedyi*

PLATE 2

All specimens ca. 2000X

Fig. 1 - *Eprolithus* cf. *rarus*. Case Baruzzo section - 216 P236; crossed nicols.
Fig. 2 - *Eprolithus octopetalus*. Case Baruzzo section - 216 P236; crossed nicols.
Fig. 3 - *Eprolithus floralis*. Case Baruzzo section - 216 P236; crossed nicols.
Fig. 4 - *Lithastrinus moratus*. Case Baruzzo section - 217 P21; crossed nicols.
Fig. 5 - *Helenea chiastia*. Case Baruzzo section - 216 P236; crossed nicols.
Fig. 6 - *Marthasterites furcatus*. Case Baruzzo section - 217 P21; parallel light.
Fig. 7 - *Rhagodiscus asper*. Case Praquarola section - 217 P31; crossed nicols.
Fig. 8 - *Flabellites oblonga*. Case Praquarola section - 217 P34; crossed nicols.
Fig. 9, 10 - *Corollithion kennedyi*. Fig. 9: Prelerna section - 198 G 14; crossed nicols. Fig. 10: Case Praquarola section - 217 P34; crossed nicols.

1 - at the base of the CBS, onlapping both the Palombini Shale and the Jurassic-lower Cretaceous tectonic slabs, with an angular unconformity;

2 - at the top of the CBS, where a large biostratigraphic hiatus is observed in coincidence with an interval containing barite-rich Septaria-like concretions;

3 - at the base of the Salti del Diavolo Conglomerates.

The CBS-Palombini Shale discontinuity is considered to be the result of the mid-Cretaceous tectonic accretion of the prism.

The CBS-Varicoloured Clay discontinuity corresponds to the global oceanographic shallowing of the CCD around Cenomanian-Turonian boundary. However, the timing of the CBS-Varicoloured Clay hiatus (Turonian-Coniacian) also corresponds to a major Turonian unconformity in the Lombardy Basin (Bersezio et al., 1993; Bersezio & Fornaciari, 1994) and grossly to the pre-Gosau Alpine tectonic phase.

The Salti del Diavolo Conglomerate discontinuity is well correlated to the discontinuity between the *Conglomerati di Sirone* and the *Flysch di Bergamo* in the Lombardy Basin that has been connected to the intra-Gosau Alpine event (Bersezio & Fornaciari, 1994).

We have compared the depositional history of the Cassio Basal Complex with the stratigraphy of the Media Val Taro and the Gottero Tectonic Units, outcropping to the west of the Cassio Unit.

Stratigraphic and petrographic data suggest an original position of the Media Val Taro Basin in between the Cassio Basin, adjacent to the African margin, and the Gottero Basin, adjacent to the European margin. These successions contain siliciclastic turbiditic wedges (CBS, Ostia Sandstone and Gottero Sandstone) the age of which is progressively younger moving from the African to the European margin (Fig. 15).

The older turbidites (Cenomanian-lower Turonian CBS) are fed by sources outcropping in the Adriatic continental margin; the large spectrum of lithologies, which is also characteristic of the compositionally very similar detritus of the Coniacian-Santonian Ostia Sandstone, indicate that these two formations are supplied by a relatively large drainage system acting on the overriding Adriatic plate.

The provenance of the Santonian arenites intercalated in the Varicoloured Clay (Cassio succession) and the Santonian-Maastrichtian Gottero Formation is from the Adriatic and from the European blocks, respectively; at this time the crystalline basement is also outcropping in both source areas.

A migration of the syntectonic clastic depocenters, from the Austroalpine-supplied Cenomanian turbidites (CBS) to the European-supplied Maastrichtian turbidites (Gottero Sandstone), linked to the alpine-verging tectonic progradation, is thus inferred.

We suggest that the paleogeographic relative positions of the CBS, Ostia Sandstone and Gottero Sandstone are located within a northern sector of the Ligurian Basin, where the offscraping of obducted oceanic lithosphere slices should not have been possible.

Acknowledgements.

This study was realized with the financial support of the "Centro CNR di Studio per la Geodinamica Alpina" (University of Padova). The field work was carried out as part of the Geologic Mapping Project of the Emilia Apennines, sponsored by Geological Survey of the Regione Emilia-Romagna; sincere thanks are due to Dr. R. Pignone, Head of the Geological Survey of the Regione Emilia-Romagna. The authors are very grateful to G. Zanzucchi for the stimulating discussions and to M. Gaetani, R. Gelati and K. Von Salis for the critical review of the paper.

REFERENCES

Abbate E. & Sagri M. (1967) - Suddivisioni litostratigrafiche nei calcari ad Elmintoidi Auctt. della placca dell'Ebro-Antola e correlazioni con terreni simili affioranti tra Voghera e Castelnuovo ne' Monti (Appennino settentrionale). *Mem. Soc. Geol. It.*, v. 6, pp. 23-65, Roma.

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

Abbate E. & Sagri M. (1982) - Le unit torbiditiche cretacee dell'Appennino settentrionale ed i margini continentali della Tetide. *Mem. Soc. Geol. It.*, v. 24, pp. 115-126, Roma.

Abbate E., Bortolotti V., Conti M., Marcucci M., Principi G., Passerini P. & Treves B. (1988) - Apennines and Alps ophiolites and the evolution of the Western Tethys. *Mem. Soc. Geol. It.* (1986), v. 31, pp. 23-44, Roma.

Abbate E., Bortolotti V., Passerini P., Principi G. & Treves B. (1994) - Oceanisation processes and sedimentary evolution of the Northern Apennine Ophiolite Suite: a discussion. *Mem. Soc. Geol. It.*, v. 48, pp. 117-136, Roma.

Bersezio R. & Fornaciari M. (1994) - Syntectonic Upper Cretaceous deep-water sequences of the Lombardy Basin (Southern Alps, Northern Italy). *Eclogae geol. Helv.*, v. 87, pp. 833-862, Basel.

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. *Gologie Alpine*, v. 69, 3-20, Grenoble.

Bertotti G., Elter P., Marroni M., Meccheri M. & Santi R. (1986) - Le Argilliti a blocchi di M. Veri: considerazioni sulla evoluzione tettonica del Bacino Ligure nel Cretacico superiore. *Ofioliti*, v.11, pp. 193-220, Firenze.

Bettelli G., Bonazzi U. & Panini F. (1987) - Schema introduttivo alla geologia delle Liguridi dell'Appennino modenese e delle aree limitrofe. *Mem. Soc. Geol. It.*, v. 39, pp. 91-125, Roma.

Bettelli G., Capitani M. & Panini F. (1994) - The mesoscopic structures of a strongly deformed multilayered sequence: a hypothesis of the origin of the "block-in-matrix" fabric and the layer-parallel extension shown by Ligurian dismembered formations of the Baganza Supergroup outcropping in the Reggio Emilia and Modena Apennines. In Post Congress Field Trip N. 3 - Excursion Guidebook - "The chaotic rocks in the southeastern sector of the Emilia Apennines". 1st European Congress on Regional Geological Cartography and Information Systems, June 13-16 1994, Bologna.

Boccaletti M. & Coli M. ed. (1982) - Carta Strutturale dell'Appennino settentrionale (Scala 1:250.000). C.N.R. Prog. Final. Geodinamica, pubbl. n. 429, Roma.

Boccaletti M., Coli M., Decandia F.A., Giannini E. & Lazzarotto A. (1980) - Evoluzione dell'Appennino Settentrionale secondo un nuovo modello strutturale. *Mem. Soc. Geol. It.*, v. 21, pp. 359-373, Roma.

Braga G. (1957) - Segnalazione di scisti ad aptici e di calcari di tipo maiolica nell'Appennino di Piacenza. *Atti Ist. Geol. Univ. Pavia*, v. 7, pp. 87-104, Pavia.

Braga G. (1965) - Geologia delle Valli del Nure e del Perino (Appennino piacentino). *Atti Ist. Geol. Univ. Pavia*, v. 17, pp. 3-49, Pavia.

Bralower T.J. Leckie M.R., Sliter W.V. & Thierstein H.R. (1995) - Integrated microfossil biostratography. *Geocronology Time Scales and global Stratigraphic Correlation, SEPM Special pub.*, v. 54, pp. 65-79, London.

Bralower T.J. & Siesser W.G. (1992) - Creatceous calcareous nannofossil biostratography of Sites 761, 762, and 763, Exmouth and Wombat Plateau, northwest Australia. In U. von Rad, B.U. Haq, *et al.* (Eds.), Proc. ODP Sci. Results, v. 122, pp. 529-556.

Casnedi R. (1982) - Sedimentazione e tettonica delle Unit Liguridi nell'Appennino Nord-occidentale. *Atti Ist. Geol. Pavia*, v. 30, pp. 42-66, Pavia.

Casnedi R., Galbiati B., Vernia L. & Zanzucchi G. (1993) - Note descrittive della Carta Geologica delle ofioliti del Gruppo di M. Penna e di M. Aiona (Appennino ligure-emiliano). *Atti Tic. Sc. Terra*, v. 36, pp. 231-268, Pavia.

Cerrina Feroni A., Elter P., Plesi G., Rau A., Rio D., Vescovi P. & Zanzucchi G. (1990) - Carta Geologica dell'Appennino Emiliano-Romagnolo 1: 50.000 - Foglio 217 Neviano degli Arduini. Selca, Firenze.

Costa E., Frati G. & Villa G. (1995) - Notq illustrative della Carta Geologico-strutturale delle Liguridi Esterne nell'area tra la media Val Ceno e la Val d'Arda (Provv. di Parma e Piacenza). *Atti Tic. Sc. Terra*, v. 38, pp. 3-29, Pavia.

Decandia A. & Elter P. (1972) - La "zona" ofiolitifera del Bracco, nel settore compreso tra Levanto e la Val Graveglia. *Mem. Soc. Geol. It.*, v. 11, pp. 503-530, Pavia.

Dewey J.F., Helman M.L., Turco E., Hutton D.H.W. & Knott S.D. (1989) - Kinematics of the Western Mediterranean. In M.P. Coward, D. Dietrich, R.G. Park (Eds), Alpine Tectonics, *Geol. Soc. Spec. Publication*, v. 45, pp. 265-283, Boulder.

Dickinson W. R. (1970) - Interpreting Detrital Modes of Greywacke and Arkose. *J. Sedim. Petrology*, v. 40, pp. 695-703, Tulsa.

Di Giulio A. & Valloni R. (1992) - Analisi Microscopica delle Areniti Terrigene: Parametri petrografici e composizioni modali. *L'Ateneo Parmense Acta-Naturalia*, v. 28, pp. 55-101, Parma.

Elter P. (1973) - Lineamenti tettonici ed evolutivi dell'Appennino settentrionale. In "Moderne vedute sulla Geologia dell'Appennino", *Acc. Naz. Lincei*, v. 183, pp. 97-118, Roma.

Elter P. (1993) - Detritismo ofiolitico e subduzione: riflessioni sui rapporti Alpi-Appennino. *Mem. Soc. Geol. It.*, v. 49, pp. 205-215, Roma.

Elter P. & Marroni M. (1991) - Le Unit Liguri dell'Appennino settentrionale: sintesi dei dati e nuove interpretazioni. *Mem. Descr. Carta Geol. d'It.*, v. 46, pp. 121-138, Roma.

Elter P. & Pertusati P.C. (1973) - Considerazioni sul limite Alpi-Appennino e sulle sue relazioni con l'arco delle Alpi occidentali. *Mem. Soc. Geol. It.*, v. 12, pp. 359-375, Roma.

Elter G., Elter P., Sturani C. & Weidmann M. (1966) - Sur la prolungation du domaine de l'Apennin dans le Monferrat et les Alpes et sur l'origine de la Nappe de la Simme s.l. des Pralpes romandes et chaiblaisiennes. *Bulletin Lab. Geol. Min. Geophys. et Muse Geol. Univ. Lausanne*, n. 167, pp. 279-377, Lausanne.

Elter P., Ghiselli F., Marroni M. & Ottria G. (in press) - Note illustrative della Carta geologica d'Italia alla scala 1: 50.000, Foglio 197 - Bobbio. Istituto Poligrafico e Zecca dello Stato, Roma.

Elter P., Marroni M., Molli G. & Pandolfi L. (1991) - Le caratteristiche stratigrafiche del Complesso di M. Penna/Casanova (Alta Val Trebbia, Appennino settentrionale). *Atti Tic. Sc. Terra*, v. 34, pp. 97-106, Pavia.

Folk R. L. (1974) - Petrology of Sedimentary Rocks. Hemphill's Austin TX, 182 pp.

Fontana D. (1991) - Detrital carbonate grains as provenance indicators in the Upper Cretaceous Pietraforte Formation (Northern Apennines). *Sedimentology*, v. 38, pp. 1085-1095, Oxford.

Fontana D., Spadafora E., Stefani C., Stocchi S., Tateo F., Villa G. & Zuffa G.G. (1994) - The Upper Cretaceous Helminthoid Flysch of the Northern Apennines: provenance and sedimentation. *Mem. Soc. Geol. It.*, v. 48, pp. 237-250, Roma.

Galbiati B. (1990) - Considerazioni sulle fasi iniziali dell'orogenesi nell'Appennino settentrionale. *Atti Tic. Sc. Terra*, v. 33, pp. 255-269, Pavia.

Gelati R & Pasquar G. (1970) - Interpretazione geologica del limite Alpi - Appennino in Liguria. *Riv. It. Pal. Strat.*, v. 76, pp. 513-578, Milano.

Ghiselli F., Ottria G. & Perilli N. (1991) - Nuovi dati biostratigrafici sulle Arenarie di Scabiazza in base ai Nannofossili Calcarei (Val Trebbia, Appennino settentrionale). *Atti Tic. Sc. Terra*, v. 34, Note brevi, pp. 75-84, Pavia.

Ghiselli F., Ottria G., Piccin A. & Vercesi P.L. (1994) - Assetto strutturale delle "Arenarie di Scabiazza" tra le Valli Trebbia e Tidone (Appennino settentrionale). *Atti Tic. Sc. Terra (Serie speciale)*, v. 1, pp. 93-104, Pavia.

Giammetti F. (1966) - Gli inclusi ignimbritici nel conglomerato dei Salti del Diavolo (Val Baganza). *L'Ateneo Parmense - Acta Naturalia*, v. 3, pp. 223-248, Parma.

Gradstein F.M, Agterberg F.P., Ogg J.G., Hardenbol J., van Veen P., Thierry J. & Huang Z. (1994) - A Mesozoic time scale. *Journ. Geph. Res.*, v. 99, pp. 24.051-24.074, Boulder.

Haccard D., Lorenz C. & Grandjacquet C. (1972) - Essai sur l'volution tectogntique de la liaison Alpes-Apennins (de la Ligurie la Calabre). *Mem. Soc. Geol. It.*, v. 11, pp. 309-341, Roma.

Heller F., Lowrie W. & Hirt A.M. (1989) - A review of palaeomagnetic and magnetic anisotropy results from the Alps. In M.P. Coward, D. Dietrich, R.G. Park (Eds.), Alpine Tectonics, *Geol. Soc. Spec. Publication*, v. 45, pp. 399-420, Boulder.

Iaccarino S. & Rio D. (1972) - Nannoplancton calcareo e Foraminiferi della serie di Viano (Val Trasinaro - Appennino settentrionale). *Riv. It. Paleont. Strat.*, v. 78, pp. 641-678, Milano.

Iaccarino S., Papani G., Rio D. & Zanzucchi G. (1974) - Considerazioni sul contatto Flysch-Tongriano nell'Appennino emiliano. *L'Ateneo Parmense-Acta Naturalia*, v. 10, pp. 381-408, Parma.

Istituto di Geologia di Parma (1964) - Carta Geologica alla scala 1: 100.000 della Provincia di Parma e zone limitrofe. Litografia Artistica Cartografica, Firenze.

Kenneth J.P. (1982) - Marine Geology. V. of 813 pp., Prentice Hall.

Labesse B. (1981) - Existence d'une lacune importante dans le Crtac suprieur des series ligures de l'Apennin Septentrional (Italie). *Comptes rendus Acad. Sc.*, v. 293, srie II, pp. 997-1002, Paris.

Ludwig O. (1929) - Geologische Untersuchungen in der Gegend von Bobbio im Nord Apennin. *Geol. Rundsch.*, v. 20, pp. 33-66, Stuttgart.

Marroni M., Monechi S., Perilli N., Principi G., & Treves B. (1992) - Late Cretaceous flysch deposits of the Norhern Apennines, Italy. Age of inception of Orogenesis-Controlled sedimentation. *Cretaceous Research*, v. 13, pp.487-504, London.

Marroni M. & Pandolfi L. (1996) - The deformation history of an accreted ophiolite sequence: the Internal Liguride units (Northern Apennines, Italy). *Geodinamica Acta*, v. 9, pp. 13-29, Paris.

Marroni M. & Perilli N. (1990) - The age of the ophiolite sedimentary cover from the Mt.Gottero Unit (Internal Ligurid Units, Northern Apennines): new data from Calcareous Nannofossils. *Ofioliti*, v. 15 (2), pp. 251-267, Firenze.

Marroni M. & Treves B. (1998) - Hidden Terranes in the Northern Apennines, Italy: A Record of Late Cretaceous-Oligocene Transpressional Tectonics. *Journal of Geology*, v. 106, pp. 149-162, Chicago.

Marroni M. & Tribuzio R. (1996) - Gabbro-derived granulites from External Liguride units (Northern Apennine, Italy): implications for the rifting processes in the western Tethys. *Geol. Rundsch*, v. 85, pp. 239-249, Stuttgart.

Meccheri M., Marroni M., Casella A., Della Croce G. & Giampietri L. (1986) - L'Unit Colli-Tavarone nel quadro dell'evoluzione stratigrafica e strutturale del Dominio Ligure (Appennino settentrionale). *Ofioliti*, v. 11 (3), pp. 275-293, Firenze.

Mezzadri G. (1964) - Petrografia delle "Arenarie di Ostia". *Rend. Soc. Mineral. It.*, v. 20, pp. 193-228, Pavia.

Monteforti B. (1972) - La Regione di Berceto (Appennino parmense). *Mem. Soc. Geol. It.*, v. 11, pp. 47, 64, Roma.

Mortimer C.P. (1987) -- Upper Cretaceous calacreous nannofossil biostratigraphy of the Southern Norwegian and Danish North Sea area. *Abh. Geol. Bundesanst.*, v. 39, pp. 143-175.

Mutti E., Papani L., di Biase D., Davoli G., Mora S., Segadelli S. & Tinterri R. (1995) - Il Bacino Terziario Epimesoalpino e le sue implicazioni sui rapporti tra Alpi e Appennino. *Mem. Soc. Geol. Padova*, v. 47, pp. 217-244, Padova.

Nilsen T.H. & Abbate E. (1985) - Gottero turbidite system, Italy. In A.H. Bouma, W.R. Normark and N.E. Barnes (Eds.), Submarine fans and related turbidite system, Springer-Verlag, pp. 199-204, New York.

Pagani G., Papani G., Rio D., Torelli l., Zanzucchi G. & Zerbi M. (1972) - Osservazioni sulla giacitura delle ofioliti nelle alte valli del T. Ceno e del F. Taro. *Mem. Soc. Geol. It.*, v. 11, pp. 531-546, Roma.

Papani G. (1967) - Segnalazione di flysch calcareo-marnoso nummulitifero nella zona di Vernasca (Preappennino piacentino orientale). *Boll. Soc. Geol. It.*, v. 86, pp. 469-494, Roma.

Papani G, Tellini C., Torelli L., Vernia L. & Iaccarino S. (1987) - Nuovi dati stratigrafici e strutturali sulla "Formazione di Bismantova" nella "sinclinale" Vetto-Carpineti (Appennino Reggiano-Parmense). *Mem. Soc. Geol. It.*, v. 39, pp. 245-275, Roma.

Papani G. & Zanzucchi G. (1970) - Flysch di M. Cassio. Studi illustrativi della Carta Geologica d'Italia, Formazioni geologiche. *Serv. Geol. d'Italia*, v. 4, pp. 63-72, Roma.

Parea G.C. (1961) - Contributo alle conoscenze del Flysch ad Elmintoidi dell'Appennino settentrionale. Strutture sedimentarie, modo di deposizione e direzione di apporto. *Boll. Soc. Geol. It.*, v. 80, pp. 185-214, Roma.

Parea G.C. (1965a) - La provenienza dei sedimenti nel flysch campaniano-maestrichtiano dell'Appennino settentrionale tra il Passo dei Giovi e la valle del Panaro. *Boll. Soc. Geol. It.*, v. 84, pp. 217-221, Roma.

Parea G.C. (1965b) - Caratteri sedimentologici delle torbiditi pre-oligoceniche dell'Appennino settentrionale. *Boll. Soc. Geol. It.*, v. 84, pp. 223-266, Roma.

Passerini P. (1962) - Giacitura delle ofioliti fra il M. Aiona e Rovegno. *Boll. Soc. Geol. It.*, v. 81, pp. 139-146, Roma.

Passerini P. (1965) - Rapporti tra le ofioliti e le formazioni sedimentarie fra Piacenza e il Mare Tirreno. *Boll. Soc. Geol. It.*, v. 84, pp. 93-176, Roma.

Passerini P. & Pirini C. (1964) - Microfaune paleoceniche nelle formazioni dell'arenaria di M. Ramaceto e degli argilloscisti di Cichero. *Boll. Soc. Geol. It.*, v. 83, pp. 211-218, Roma.

Perch-Nielsen K. (1985) - Mesozoic calcareous nannofossils. In H.M. Bolli, J.B. Saunders and K. Perch-Nilesen (Eds.), Plankton Stratigraphy, Cambridge University Press, pp. 329-426, Cambridge.

Piccardo G.B., Rampone E. & Vannucci R. (1990) - Upper mantle evolution during continental rifting and ocean formation: evidences from peridotite bodies of the western Alpine-northern Apennine system. *Mem. Soc. Gol. France*, v. 156, pp. 323-333, Paris.

Plesi G., Bianchi L., Chicchi S. & Daniele G. (1993) - Le Unit liguri ed emiliane della media Val di Taro e la loro evoluzione strutturale. *Atti Tic. Sc. Terra*, v. 36, pp. 183-229, Pavia.

Principi G. & Treves B. (1984) - Il sistema corso-appenninico come prisma di accrezione. Riflessi sul problema generale del limite Alpi-Appennino. *Mem. Soc. Geol. It.*, v. 28, pp. 549-576, Roma.

Ricci Lucchi F. & Ori G.G. (1985) - Field Excursion D: synorogenic deposits of a migrating basin system in the NW Adriatic Foreland: examples from Emilia-Romagna region, Northern Apennines. In P. Allen, P. Homewood and G. Williams (Eds), International Symposium on Foreland Basins, Excursion Guidebook, pp. 137-176, Cardiff.

Rio D. & Villa G. (1987) - On the age of the "Salti del Diavolo" conglomerates and of the M. Cassio flysch "basal complex" (Northern Apennines, Parma province). *Giornale di Geologia*, v. 49, pp. 63-73, Bologna.

Rio D., Villa G. & Cantadori M. (1983) - Nannofossil dating of the Helminthoid Flysch Units in the Northern Apennines. *Giornale di Geologia*, v. 45, pp. 57-86, Bologna.

Sagri M. (1973) - Sedimentazione torbiditica nell'Appennino settentronale: velocit di accumulo, litologia, morfologia del fondo. *Boll. Soc. Geol. It.*, v. 92, pp. 233-272, Roma.

Sagri M. (1979a) - Upper Cretaceous carbonate turbidites of the Alps and Apennines deposited below the calcite compensation depth. *Journ. Sed. Petrol.*, v. 49, pp. 23-28, Tulsa.

Sagri M. (1979b) - Upper Cretaceous trench wedge turbidides in the Northern Apennines (Italy). *Rend. Soc. Geol. It.*, v. 2, pp. 27-28, Roma.

Sagri M. & Marri C. (1980) - Paleobatimetria e ambienti di deposizione delle unit torbiditiche cretaceo-superiori dell'Appennino settentrionale. *Mem. Soc. Geol. It.*, v. 21, pp. 231-240, Roma.

Sames C.W. (1963) - Beitrag zur Gliederung des Kreideflysch zwischen Bobbio und Berceto im Nordapennin (Italien). *Geol. Jb.*, v. 81, pp. 481-518, Hannover.

Sames C.W. (1967) - Sui conglomerati medio-cretacei della geosinclinale emiliana e la loro importanza per la paleogeografia. *Boll. Soc. Geol. It.*, v. 86, pp. 49-58, Roma.

Savostin L.A., Sibuet J.C., Zonenshain L.P., Le Pichon X. & Roulet M.J. (1986) - Kinematic evolution of the Tethys belt from the Atlantic ocean to the Pamirs since the Triassic. *Tectonophysics*, v. 123, pp. 1-35, Amsterdam.

Sestini G. (1970) - Flysch Facies and Turbidite Sedimentology. In: G. Sestini (Ed.), Developments of the Northern Apennines Geosyncline, *Sedimentary Geology*, v. 4 (3/4), pp. 559-597, Amsterdam.

Sestini G., Bruni P. & Sagri M. (1986) - The flysch basins of the Northern Apennines: A review of facies and of Cretaceous-Neogene evolution. *Mem. Soc. Geol. It.*, v. 31, pp. 87-106, Roma.

Sturani C. (1973) - Considerazioni sui rapporti tra Appennino settentrionale ed Alpi occidentali, in: "Moderne vedute sulla Geologia dell'Appennino". *Acc. Naz. Lincei*, v. 183, pp. 119-145, Roma.

Terranova R. & Zanzucchi G. (1982) - Il Gruppo ofiolitico dei Monti Maggiorasca e nero (Appennino ligure-emiliano): Carta Geologica e interpretazioni geodinamiche. *Mem. Soc. Geol. It.*, v. 24, pp. 127-138, Roma.

Treves B. (1984) - Orogenic belts as accretionary prisms: the example of the Northern Apennines. *Ofioliti*, v. 9, pp. 577-618, Firenze.

Valloni R. & Zuffa G. G. (1984) - Provenance changes for arenaceous formations of the Northern Apennines, Italy. *Geol. Soc. Am. Bull.*, v. 95, pp. 1035-1039, Boulder.

Valloni R., Amorosi A., Cibin U., De Donatis M., De Nardo M.T., Farina M., Ghiselli F., Martelli L., Martini A., Ottria G., Piccin A., Pizziolo M. & Severi P. (1991) - Proposta di classificazione macroscopica delle areniti. *L'Ateneo Parmense - Acta Naturalia*, v. 27, pp. 1-22, Parma.

Vandenberg J., Klootwijk C.T. & Wonders A.A.H. (1978) - Late Mesozoic and Cenozoic movements of the Italian Peninsula: further palaeomagnetic data from the Umbrian sequence. *Geol. Soc. Am. Bull.*, v. 89, pp. 133-150, Boulder.

Varol O. (1992) – Taxonomic revision of the Polycyclolithaceae and its contribution to Cretaceous biostratigraphy. *Newsl. Stratigr.*, v. 27, pp. 93-127, Berlin-Stuttgart.

Vercesi P.L. & Cobianchi M. (1998) - Stratigrafia di un frammento di Margine continentale giurassico: La successione di Case Caldarola (Appennino piacentino). *Boll. Soc. Geol. It.*, v. 117, pp. 537-554, Roma.

Vescovi P. (1986) - L'assetto strutturale della Val Baganza tra Berceto e Cassio (PR). *L'Ateneo Parmense-Acta Naturalia*, v. 22, pp. 85-111, Parma.

Vescovi P. (1991) - L'assetto strutturale delle Arenarie di M. Gottero tra Borgo Val di Taro e Pontremoli (Provv. di Parma e Massa). *Mem. Descr. Carta Geol. d'Italia*, v. 46, pp. 341-354, Roma.

Vescovi P. (1993) - Schema evolutivo per le Liguridi dell'Appennino settentrionale. *Atti Tic. Sc. Terra*, v. 36, pp. 89-112, Pavia.

Vescovi P., Andreozzi M., De Nardo M.T., Lasagna S., Martelli L., Rio D., Tellini C. & Vernia L. (in press) - Note Illustrative del Foglio 216 - Borgo Val di Taro della Carta Geologica d'Italia alla scala 1: 50.000. Istituto Poligrafico e Zecca dello Stato, Roma.

Villa G. (1991) - Biostratigrafia a nannofossili calcarei delle Arenarie di Ostia nella localit tipo e nella zona di Berceto (Prov. di Parma). *Mem. Descr. Carta Geol. d'It.*, v. 46, pp. 433-443, Roma.

Wildi W. (1985) - Heavy mineral distribution and dispersal pattern in Penninic and Ligurian flysch basins (Alps, Northern Apennines). *Giornale di Geologia*, v. 47 (1-2), pp. 77-99, Bologna.

Zanzucchi G. (1955) - Su una placca di argilla medio-cretacica nella "formazione ofiolitifera" del M. Prinzera (Parma). *Atti Soc. It. Sc. Nat.*, v. 94, pp. 369-377, Milano.

Zanzucchi G. (1961a) - Studio geo-tettonico sul flysch della Val Baganza (Parma). *Boll. Soc. Geol. It.*, v. 80, pp. 133-158, Roma.

Zanzucchi G. (1961b) - Scisti ad Aptici nelle argille scagliose ofiolitifere della Val Baganza (Parma). *Atti Soc. It. Sc. Nat.*, v. 100 (1), pp. 61-71, Roma.

Zanzucchi G. (1980) - I lineamenti geologici dell'Appennino parmense. Note illustrative alla Carta geologica e Sezioni geologiche della Provincia di Parma e zone limitrofe (1:100.000). Volume dedicato a S. Venzo, STEP, pp. 201-233, Parma.

Zanzucchi G. (1988) - Ipotesi sulla posizione paleogeografica delle "Liguridi esterne" cretacico-eoceniche nell'Appennino settentrionale. *Atti Tic. Sc. Terra*, v. 31, pp. 327-339, Pavia.

Zanzucchi G. (1994) - Appennino ligure-emiliano. Guide Geologiche Regionali a cura della Societ Geologica Italiana. Vol. 6, BE.MA. Editrice, Milano.

Zuffa G.G. (1985) - Optical analysis of arenites: influence of methodology on compositional results. In: G.G. Zuffa ed., Provenance of arenites. NATO-ASI series, Reidel, Dordrecht, pp. 165-189.

APPENDIX

Calcareous nannofossil species considered in this study in alphabetic order of species.

Lithraphidites acutus Verbeekand and Manivit, 1977 in Manivit et al., 1977
Lithraphidites alatus Thierstein, 1972 in Roth and Thierstein, 1972
Retecapsa angustiforata Black, 1971
Rhagodiscus angustus (Stradner, 1963) Reinhardt, 1971
Reinhardtites anthophorus (Deflandre, 1959) Perch-Nielsen, 1968 emend. Prins and Sissingh, 1977
Rhagodiscus asper (Stradner, 1963) Reinhardt, 1967 = *Parhabdolithus asper*
Lithraphidites carniolensis Deflandre, 1963
Lucianorhabdus cayeuxii Deflandre, 1959
Helenea chiastia (Worsley, 1971) Bralower *et al.*, 1989 = *Microstaurus chiastius*
Prediscosphaera columnata (Stover, 1966) Manivit, 1971, in Manivit et al., 1971;
Zeugrhabdotus compactus (Bukry, 1969) Perch-Nielsen, 1984
Micula concava (Stradner in Martini and Stradner, 1960) Verbeek, 1976
Cretarhabdus crenulatus Bramlette and Martini, 1964
Prediscosphaera cretacea (Arkhangelsky, 1912) Gartner, 1968
Cruciellipsis cuvilleri (Manivit, 1966) Tierstien, 1971 emend Wind and Cepek, 1979
Microrhabdulus decoratus Deflandre, 1959
Micula decussata Vekshina, 1959
Eprolithus eptapetalus Varol, 1992
Corollithion exiguum Stradner, 1961
Tranalithus exiguus Stover, 1966
Eiffellithus eximius (Stover, 1966) Perch-Nielsen, 1968
Eprolithus floralis (Stradner, 1962) Stover, 1966
Marthasterites furcatus (Deflandre in Deflandre and Fert, 1954) Deflandre, 1959
Quadrum gartneri Prins and Perch-Nielsen, 1977
Eiffellithus gorkae Reinhardt, 1965
Lithastrinus grillii Stradner, 1962
Quadrum intermedium Varol, 1992
Corollithion kennedyi Crux, 1981
Chiastozygus litterarius (Gorka, 1957) Manivit, 1971
Lucianorhabdus maleformis Reinhardt, 1966
Lithastrinus moratus Stover, 1966
Flabellites oblonga (Bukry, 1969) Crux, 1982
Eprolithus octopetalus Varol, 1992
Tranalithus phacelosus (Stover, 1966) Sissingh, 1977
Eprolithus rarus Varol, 1992
Rhagodiscus splendens (Deflandre, 1953) Verbeek, 1977
Eiffellithus turriseiffelii (Deflandre in Deflandre and Fert, 1954) Reinhardt, 1965