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NEW CALCAREOUS NANNOFOSSIL DATA ON THE CRETACEOUS-EOCENE AGE OF CORSICAN TURBIDITES

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Key-words: Calcareous Nannofossil Biostratigraphy, Corsica, Cretaceous-Eocene, Turbidites.

Riassunto. È stato condotto uno studio biostratigrafico di dettaglio, basato sulle associazioni a Nannofossili calcarei, dei flysch cretaceo-eocenici della Corsica Alpina. Le formazioni torbiditiche corse studiate sono: Flysch di Macinaggio, Flysch di Tralonca, Flysch di Vezzani, Flysch Calcareo della Balagne, Lydienne (Unità di Toccone), Arenarie di Palasca, Arenarie della Gare de Novella, Arcose dell'Alturaia.

I problemi di conservazione riguardanti la nannoflora calcarea, caratterizzata da associazioni generalmente depauperate per fenomeni di dissoluzione e ricristallizzazione, non hanno permesso di riferire i flysch campionati a precisi intervalli biozonali; inoltre, benchè siano stati esaminati numerosi campioni, gran parte di questi sono risultati sterili. Nonostante ciò, lo studio dei Nannofossili calcarei ha fornito ulteriori dati sull'età dei flysch della Corsica, confermando peraltro, nella maggior parte dei casi, quelle precedenti basate sui Foraminiferi.

Per il Flysch di Macinaggio, riferito in letteratura al Cenomaniano, limitatamente ad un livello fossilifero posto ad una distanza imprecisata rispetto alla base, è stata riconosciuta un'età non più antica del Coniaciano sommitale; per il Flysch Calcareo della Balagne, riferito precedentemente all'Eocene e poi al Senoniano, viene riconosciuta, sulla base dei Nannofossili calcarei, un'età cenomaniana, coniaciana sommitale e campaniana (?); per le Arenarie di Palasca viene confermata l'età eocenica; per la Formazione Lydienne (Unità di Toccone) è stata riconosciuta un'età non più antica dell'Albiano superiore; per le Arenarie della Gare de Novella è stata riconosciuta un'età non più antica dell'Albiano superiore.

In generale questi nuovi dati confermano un'età cretacea più antica per l'inizio della sedimentazione dei flysch della Corsica (Albiano-Cenomaniano) rispetto a quella riconosciuta (Santoniano e Maastrichtiano) per i flysch cretacei dell'Appennino Settentrionale. Le nuove informazioni sull'età ottenute in questo lavoro, unite ai dati di ordine stratigrafico-strutturale e sedimentologico già noti in letteratura, permettono di fare alcune interessanti considerazioni sulla paleogeografia della Tetide occidentale.

Abstract. A detailed biostratigraphical study based on calcareous nannofossils has been carried out on the following Cretaceous-Eocene flysch of Alpine Corsica: Macinaggio Flysch, Tralonca Flysch, Vezzani Flysch, Balagne Calcareous Flysch, Lydienne (Toccone Unit), Palasca Sandstones, Gare de Novella Sandstones, Alturaia Arkoses.

The bad preservation of calcareous nannofloras due to dissolution and overgrowth phenomena, did not permit the recognition of precise biozonal intervals; although many samples were barren, calcareous nannofossils provided further information about the Corsican flysch age and they often confirmed the previous age determination based on Foraminifera.

The Macinaggio Flysch, ascribed in literature to the Cenomanian, has been referred to an age not older than latest Coniacian; the Balagne Calcareous Flysch, previously referred to the Eocene and, subsequently, to the Senonian, is Cenomanian and latest Coniacian-Campanian in age; for the Palasca Sandstones the Eocene age has been confirmed; the Lydienne (Toccone Unit) has been referred to an age not older than Late Albian; in the Gare de Novella Sandstones a Late Albian age has been recognized.

These new data would suggest an older Cretaceous age for the beginning of the Corsican flysch deposition (Albian-Cenomanian) when compared to the Santonian and Maastrichtian ages of the Cretaceous flysch in the Northern Apennine.

These results concerning the age of Corsican flysch together with the stratigraphic-structural and sedimentological data from the literature, provide new interesting considerations about the paleogeography of western Tethys.

Introduction.

The paleogeography of the western Tethys before and during the initial phases of its closure is today documented only by the Cretaceous flysch and their basal complexes. Several authors have shown the close relationships between the Alpine Corsica Units and the Apennine Ligurid ones (Nardi, 1968a; Sagri et al., 1982; Durand Delga, 1984). Recently, some hypotheses considering both these Units involved in the geodynamic framework of the Apennine orogenesis,

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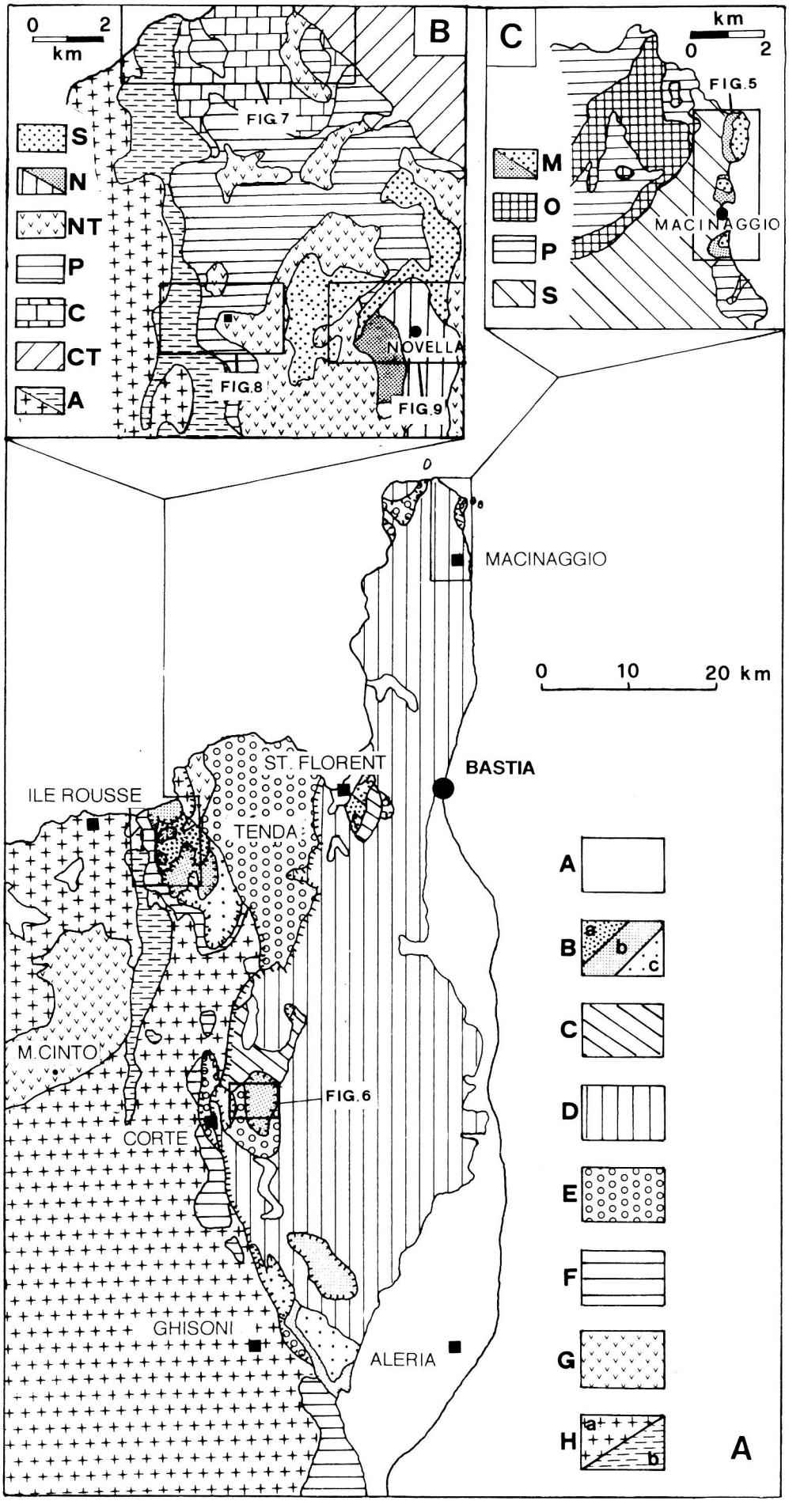
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have been proposed (Abbate et al., 1980; Abbate & Sagri, 1982; Treves, 1984; Principi & Treves, 1984). In these evolutive models the exact age determination of turbidites is most important for the reconstruction of the orogenetic events. Recent investigations based on calcareous nannofossil biostratigraphy of Cretaceous-Eocene flysch in the Northern Apennine (Rio & Villa, 1983; Rio et al., 1983; Monechi & Treves, 1984; Rio & Villa, 1987; Manivit & Prud'Homme, 1990; Marino & Monechi, 1994; Gardin et al., 1994), have shown both a general younger age of these formations, compared with previous literature, and a temporal progradation of the beginning of the turbidite sedimentation from W towards E.

In the attempt to better precise the biostratigraphic age of Corsican Cretaceous-Eocene flysch, numerous samples have been collected in the various turbidite formations of Corsica in order to carry out a detailed biostratigraphic study based on calcareous nannofossils.

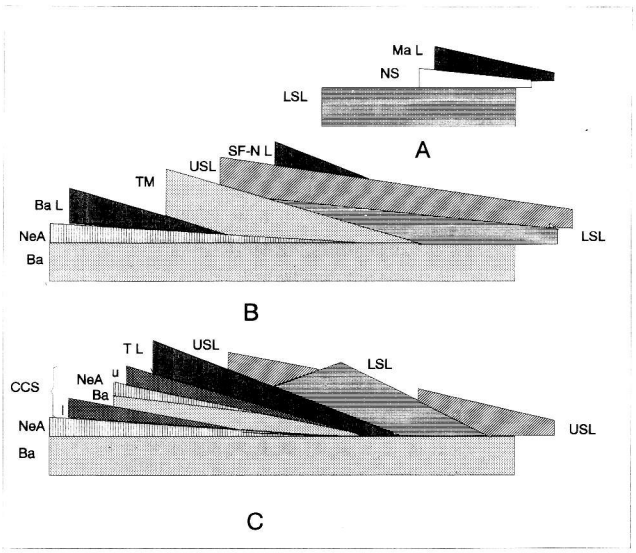


Fig. 2 - Structural schemes of the Alpine Corsica. A) Macinaggio transverse; B) Lozari (Balagne)-Bastia transverse; C) Corte-Castagniccia transverse (by Durand Delga, 1984, modified and simplified).
LEGENDA: MaL) Macinaggio Unit (Ligurids s.l.); NS) Nappe Supérieure; SF-N L) Saint Florent-Nebbio Unit (Ligurids s.l.); USL) Upper Calcschists with Ophiolites Unit (Inzecca "Schistes Lustrés" Unit); LSL) Lower Calcschists with Ophiolites Unit (Bastiese "Schistes Lustrés" Unit); TM) Tenda Massif Unit; Ba L) Complex of the Balagne Units (Ligurids s.l.); TL) Tralonca (or St. Lucia) Unit (Ligurids s.l.); CCS) Complex of Corte Slices (l = lower, u = upper); NeA) Eocenic Neoautochthonous cover; Ba) Hercynian crystalline basement.

An outline of Alpine Corsica Units.

In the north-eastern part of Corsica various west-verging Units overlie the Hercynian crystalline rise and its autochthonous Eocene covers (Fig. 1). The geometric succession, from botton to top, is the following (Fig. 1-2):

a) Para-autochthonous Units of Tenda and Corte;

b) Calcschists with Ophiolites Units (Schistes Lustrés);

c) Nappe supérieure;

d) Ligurids s.l.

The para-autochthonous Unit of the Tenda Massif consists of granites and deformed Hercynian metamorphic rocks affected by alpine metamorphism (Nardi et al., 1978; Gruppo Ofioliti, 1977; Cohen et al., 1981). Nardi (1968a), and Nardi et al. (1978) attribute it to the Briançonnai Domain, and Durand Delga (1984) agrees with this paleogeographic location. Corte Slices Unit consists of metamorphic rocks with a sedimentary origin (limestones and schists) referred by some authors to the Briançonnai Domain (Nardi, 1968a; Baud et al., 1977; Nardi et al., 1978), to the Prepiedmont Domain by others (Amaudric du Chaffault, 1975; Durand Delga, 1984).

The Calcschists with Ophiolites are actually an ophiolitic complex variously affected by high-pressure metamorphism. At least two groups of units can be differentiated (Durand Delga, 1984): a lower one (Bastiese), with both metamorphic and deformed Units, and an upper one (Inzecca), less deformed and weakly metamorphosed. The reconstructed oceanic sequences of these units end with clayey-calcareous sediments such as the Palombini Shales or with a clayey-arenaceous flysch (Erbajolo Flysch). According to Durand Delga (1984) these units, together with the Ligurids s.l. ones (Tralonca or Santa Lucia, Vezzani,

Fig. 1 - Geologic scheme of Corsica, Balagne and Macinaggio areas. The squares, labeled as Fig. 5-9, indicate the sampling localities.
LEGENDA: Fig. 1A - A) Neogene-Quaternary sediments; B) Ligurids: a) Paleogenic sediments; b) Cretaceous sediments more or less metamorphic; c) Ophiolites; C) "Nappe Supérieure", non metamorphic (mostly) carbonatic succession (Late Triassic-Jurassic); D) "Schistes Lustrés": Calcschists and Ophiolites (Mesozoic); E) "Corte-Tenda Unit": Granites, Gneiss and "roches brunes" (Paleozoic-Mesozoic); F) Neoautochthonous (Middle Eocene); G) Monte Cinto volcanites, lacustrines and fluvial lacustrine deposits (Upper Carboniferous-Permian); H): a) granites and other similar rocks (Early Carboniferous); b) gneissic slices (Silurian?).
Fig. 1B - S) Alturaia Arkoses; N) Novella Unit; NT) Navaccia and Toccone Units; P) Palasca Sandstones Unit; C) Balagne Calcareous Flysch (Macinaggio Unit); CT) Corte-Tenda Unit; A) Autochthonous: basement and cover.
Fig. 1C - M) Macinaggio Flysch, Ligurids s.l. (heavy dots), Cretaceous flysch; Nappe Supérieure (fine dots), Trias; O) Serpentinites and Gabbros; P) pillow-lavas; S) Schistes Lustrés.

Macinaggio Units) and together with the composite Balagne (see later) and St. Florent nappe piles, represent the oceanic paleogeographic domain located in an inner part with respect to the Prepiedmont Domain. Nardi (1968a) locates them on a western oceanic arm in comparison to the Apenninic Ligurian one.

The "Nappe supérieure" Unit consists of carbonatic Triassic-Jurassic sediments. According to Nardi (1968a,b) these continental covers occupied a transitional paleogeographic domain between the oceanic area of the Calcschists with Ophiolites and the non metamorphic Ligurid ones. On the other hand Durand Delga (1984) includes this unit in the Prepiedmont Domain.

The Ligurids s.l. in this area of the Alpine Corsica consist of small parts of carbonatic-arenaceous flysch sequences, partly referable to the Helminthoid Flysch. According to Nardi (1968a) they were part of an inner unit in the basin of the Apennine Ligurids. Durand Delga (1984) considers these sequences (Macinaggio and S. Lucia al Mercurio, or Tralonca) within and partially over the continental Piedmont Domain.

The western part of Alpine Corsica consists of a series of units with a Ligurian affinities (Balagne and in the Nebbio-Saint Florent area).

In the Balagne the structure of the Ligurian Units according to Nardi et al. (1978) is the following (from bottom to top) (Fig. 3A):

a) Macinaggio Unit (Balagne Calcareous Flysch);

b) Palasca Unit;

c) Toccone Unit;

d) Navaccia Ophiolitic Unit (with semiautochthonous: Alturaia Arkoses);

e) Novella Unit.

On the other hand, Durand Delga (1984) describes the structural edifice of Balagne with two big Units (from the bottom to the top) (Fig. 3B):

a) Nappe du Bas Ostriconi (Balagne Calcareous Flysch);

b) Nappe de la Balagne (Navaccia and Novella, Alturaia and Palasca).

The Macinaggio Unit (Bas Ostriconi) mostly consists of Balagne Calcareous Flysch Auctt. (Narbinco Flysch according to Durand Delga, 1984) referable by Nardi et al. (1978) to the Macinaggio Flysch (Laporte, 1954; Nardi, 1968a).

The Palasca Unit consists of coarse silicoclastic turbidite sediments (Palasca Sandstones = Annunciata Flysch according to Durand Delga, 1984) with silty and clayey intercalations. The Palasca Sandstones are considered para-autochthonous by Nardi et al. (1978) and Durand Delga (1984). Nevertheless according to Nardi et al. (1978), at Punta d'Arco these sandstones might be stratigraphically related to the Balagne Calcareous Flysch.

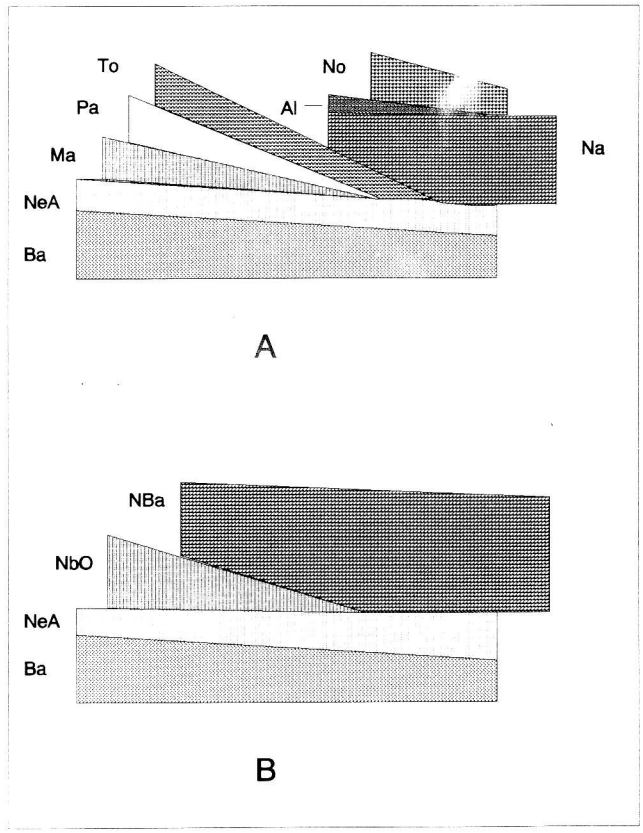


Fig. 3 - Tectonic units of the Balagne area. A) According to Nardi et al. (1978) simplified; B) according to Durand Delga (1984).
LEGENDA: No) Novella Unit; Al) Alturaia Arkoses; Na) Navaccia Unit (Ophiolites and cover); To) Toccone Unit; Pa) Palasca Unit; Ma) Macinaggio Unit (Balagne Calcareous Flysch); NBa) "Nappe de la Balagne"; NbO) "Nappe du bas Ostriconi"; NeA) Eocenic Neoautochthonous cover; Ba) Hercynian crystalline basement.

The Toccone Unit consists of polygenic breccias underlying the "Lydienne" and intercalated with it. These breccias also occur in other units (see below).

The Navaccia Unit represents the Balagne Ophiolite Unit which consists of gabbros and serpentinites as oceanic basement covered by basalts, Jurassic cherts and Lower Cretaceous limestones. The sequence ends with the "Lydienne" (spongolites, silts and clays) in which the Toccone Breccias are intercalated (Nardi et al., 1978).

The Alturaia Arkoses, whose age is unknown, are considered by Nardi et al. (1978) lying in unconformity (semi-autochthonous) on the series of the Navaccia Unit.

The Novella Unit (the uppermost one according to Nardi et al., 1978), consists of the "Lydienne" followed by Gare de Novella Sandstones (silicoclastic turbidites with clays and marls, rarely, intercalations).

According to Durand Delga (1984) a composite unit (Nappe de la Balagne) consisting of ophiolitic basement and sedimentary cover (up to the Lydienne)

lies on the Nappe du bas Ostriconi. This Unit is stratigraphically overlain by the Toccone Breccias and the Novella Sandstones, in heteropic position, which are, in turn, overlain by the Alturaia Arkoses; the latter are followed, in the Mitilelli area, by the Mitilelli Flysch (Palasca Sandstones pp.), whilst in other areas they are unconformably overlain by the para-autochthonous Annunciata Flysch (Palasca Sandstones pp.)

Methods.

The studied flysch sequences are mostly characterized by lithologies not suitable for the preservation of calcareous nannofossils. The frequent incipient metamorphism destroyed some of the assemblages. Sampling was performed mainly on hemipelagites and marly levels of the turbidites, which are more suitable for the nannoflora study. The biostratigraphical study based on calcareous nannofossils has been carried out on 290 samples; all the sampled levels have been treated with hydrochloric acid in order to verify the presence of calcium carbonate. The nannofossil investigation has been carried out under the light microscope at 1500 magnification.

Biostratigraphy.

Recent biostratigraphical works based on calcareous nannofossils resulted in a more precise age of the Cretaceous and Tertiary flysch of the Northern Apennine. Calcareous nannofossil events, on which the standard biozonation schemes of the Mediterranean are based for this interval of time, have been also recognized in turbidite successions, where calcareous nannofloras turn out to be generally well represented. Nevertheless several authors (Rio & Villa, 1983; Marino & Monechi, 1994) have shown the problematical character of some events in turbidite facies due to preservation and reworking of nannofloras. In fact, some species, sensitive to dissolution and overgrowth, may not be preserved in the assemblage; moreover the extinction events are not always reliable because of reworking.

The present study points out that most samples are barren and the nannofossil assemblages are characterized by an extreme scarcity of coccoliths and relevant oligotypical phenomena. The total nannoflora abundance ranges from 1 specimen per 10 fields of view to 1 specimen per 100 fields of view. This is to be related to the different metamorphic grade that affected the flysch sequences and that caused the impoverishment/destruction of the nannofloras. Surprisingly, in the recognized assemblage it is often noted absence of several taxa such as *Aspidolithus*, *Eiffellithus*, *Microrhabdulus* and *Watznaueria* that are notoriously resistent to dissolution (Thierstein, 1976; Roth, 1983). This lack has been also observed in several bad preserved samples of the Cretaceous Helminthoid Flysch of the Northern Apennines (Marino & Monechi,

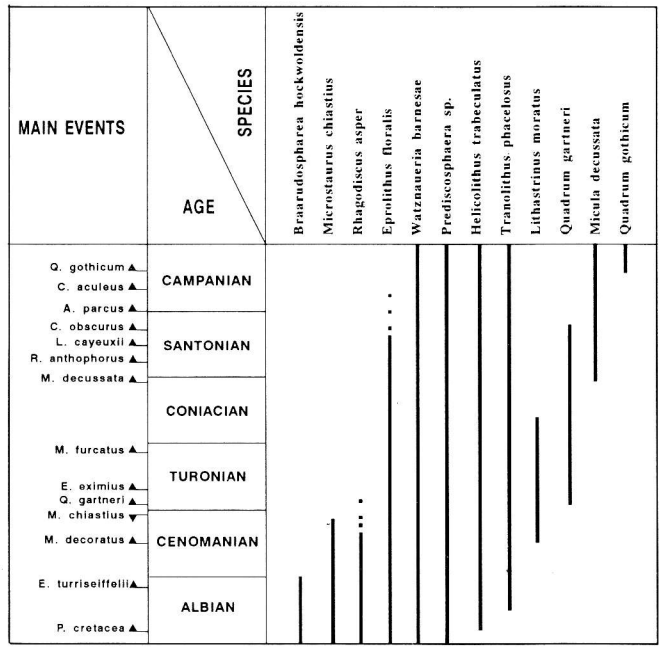


Fig. 4 - Range of calcareous nannofossil species found in the Cretaceous Corsican Flysch correlated with the main events and age.

1994). On the contrary, the genera *Lithastrinus*, *Quadrum*, *Eprolithus*, *Micula*, and *Rucinolithus* are relatively more represented. Varol (1992) mentions the species of Polycyclolithaceae as "ideal group for high resolution biostratigraphy", because these taxa are "less affected by provincialism, adverse environmental and preservation factors and are therefore persistently present". However, these genera are represented by poorly preserved specimens, and overgrowth hampers the determination at specific level. The scarcity of the nannofossil assemblages has been evidenced by Manivit (personal communication, 1990) in some samples from the Balagne Calcareous Flysch. As a consequence of low diversity, scarcity and poor preservation of nannofloras, the studied units have been attributed to time intervals rather than biozones. The biostratigraphical framework adopted in this study is based on species ranges documented by previous works (Thierstein, 1976; Sissingh, 1977; Verbeek, 1977; Roth, 1978; Doeven, 1983; Perch-Nielsen, 1979; 1985; Gartner in Robaszynsky et al., 1990) (Fig. 4). The age determination of the Corsica flysch indicates an age "not older than ...", according to what has been mentioned above.

The analyzed samples contain assemblages indicative of two distinct time intervals in the Cretaceous (late Albian-Cenomanian and latest Coniacian), and of the middle Eocene in the Tertiary. Some of the assemblages have been referred to the Albian-Cenomanian (Fig. 4) based on the presence of *Rhagodiscus asper* (Stradner), *Microstaurus chiastius*

(Worsley), *Tranolithus phacelosus* (Stover), *Prediscosphaera* sp., *Watznaueria barnesae* (Black), *Lithastrinus moratus* Stover. In fact *Tranolithus phacelosus* appears in the Late Albian and *Microstaurus chiastius* gets exctint in the Late Cenomanian. *Quadrum gartneri* Prins & Perch-Nielsen is absent in these assemblages; this is generally a common species in the studied flysch and its first occurrence is a significant event in the Early Turonian (Verbeek, 1977; Sissingh, 1977; Gartner in Robaszynsky et al., 1990).

The latest Coniacian can be recognized by the occurrence of *Micula decussata* Vekshina and *Micula* sp., associated with *Quadrum gartneri*, *Quadrum* sp., *Eprolithus floralis* (Stradner) and *Watznaueria barnesae*. It is difficult to document if the taxa indicative of a younger age, such as *Lucianorhabdus*, *Reinhardtites*, *Calculites* and *Aspidolithus*, are absent in these assemblages, as a consequence of poor preservation or because the sediments are not younger than the latest Coniacian. Specimens of *Quadrum* cf. *gothicum* (Deflandre) (Campanian age) together with *M. decussata* have been recognized, but it can not be excluded that they are very overgrowth specimens of *Q. gartneri*. Anyway, typical Campanian species such as *Calculites obscurus* (Deflandre), *Aspidolithus parcus* (Stradner), *Ceratolithoides aculeus* (Stradner) are absent.

The middle Eocene has been recognized only in one sample in which the assemblage is characterized, in addition to other species, by *Sphenolithus spiniger* (Bukry), *Dictyococcites scrippsae* Bukry & Percival, *Cyclicargolithus floridanus* (Roth & Hay).

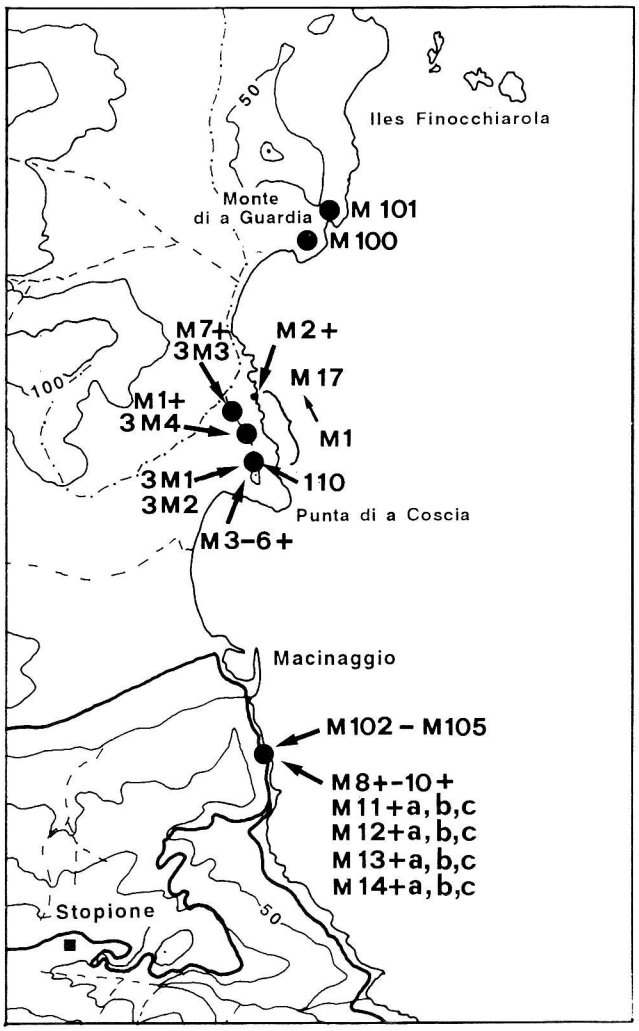


Fig. 5 - Sampling localities of Macinaggio Flysch.

Biostratigraphic results.

The following turbidite formations of the Alpine Units of Corsica have been sampled:

A. Eastern area:

1) Macinaggio Flysch (Ligurid Units s.l.);
2) Tralonca Flysch (Santa Lucia Unit);
3) Vezzani Flysch (Ligurid Units s.l.).

B. Balagne area (according to Nardi et al., 1978):

1) Balagne Calcareous Flysch (Macinaggio Unit);
2) Toccone Breccias and Lydienne (Toccone Unit);
3) Palasca Sandstones (Palasca Unit);
4) Gare de Novella Sandstones (Novella Unit);
5) Alturaia Arkoses (Semi-autochthonous overlain Navaccia Unit);

A. Eastern area.

Macinaggio Flysch (Ligurid Unit s.l.).

It is present in small outcrops around and in the northern part of the Macinaggio Bay. It consists of thin and medium-thick layers of sandstones, calcarenites and conglomerates. Parea (1965) measured some current marks indicative of a southern and south-western source of sediments. According to Sagri et al. (1982) the sandstones are feldspathic graywackes with low maturity. As regards the age, Magné & Raoult in Durand Delga & Vellutini (1977) recognized the Late Cenomanian for the presence of *Rotalipora* cf. *brotzeni* (Sigal), *Praeglobotruncana* cf. *stephanii* (Gandolfi) or *P. gibba* Klaus, *Globotruncana* cf. *renzi* (Gandolfi) and *Hedbergella* sp. Lluch (1983) in Durand Delga (1984) reports the same age for the presence of *Paraphyllum* cf. *primaevum*. Samplings for the calcareous nannofossil assemblage have been done on the ridge of Punta di a Coscia, near the contact with the underlying "Nappe supérieure" (Fig. 5, samples M1-M17, M1+-M7+), south-east of Monte di a Guardia (M100-M101) and along the road D80 between Macinaggio and Callela (samples M8+-M14+; M102-M105).

Biostratigraphical results. Only three out of 42 samples yielded nannofossils: M12+c, M14+ and M105, all coming from the area south of Macinaggio. Very rare and poorly preserved specimens of *Micula* sp., *Micula decussata*, *Watznaueria barnesae*, *Rucinoli-*

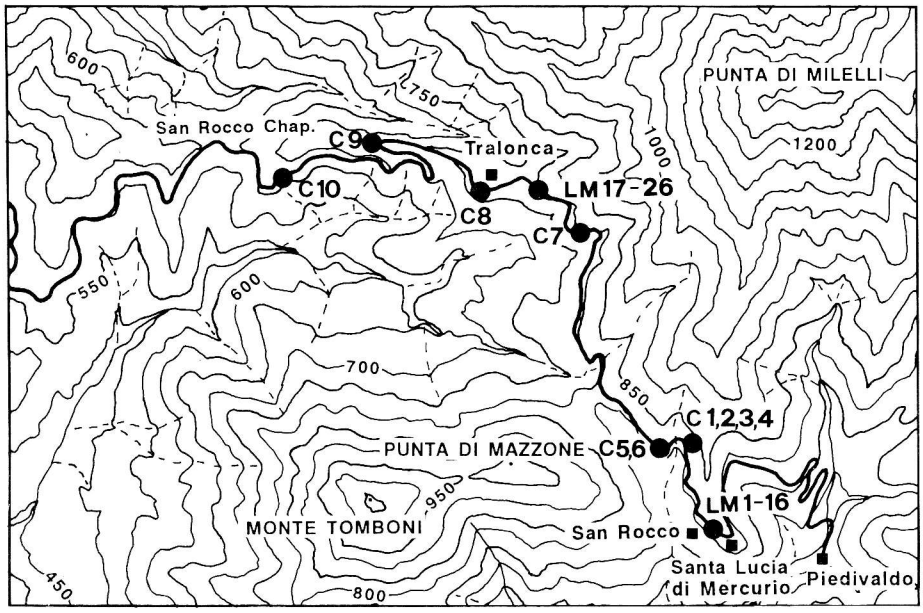


Fig. 6 - Sampling localities of the Tralonca Flysch.

thus sp. and *Eprolithus* sp. suggest a very uncertain age determination, not older than latest Coniacian for the presence of *M. decussata.*

Tralonca Flysch (Ligurid Unit s.l.).

It consists of slightly metamorphic fine and coarse grained sandstones intercalated with calcarenites. The composition is similar to the Palasca Sandstones of Punta d'Arco (Sagri et al., 1982). The flysch has been referred to the late Cretaceous for the presence of the genus *Globotruncana* (Nardi, 1968a). In the overlying part, Durand-Delga (1984) recognized the Senonian age by the presence of Globotruncanidae and *Paraphyllum.*

Fine grained flyschoid levels were sampled for calcareous nannofossil study, along the road that goes towards Corte from S. Lucia di Mercurio to S. Rocco Chapel (Fig. 6) (samples C1-C10; LM1-LM26).

Biostratigraphical results. All samples were barren of calcareous nannofossils because metamorphism affected the flysch and prevented the preservation of nannofossils.

Vezzani Flysch (Ligurid Unit s.l.).

This Ligurid Flysch outcrops SE from Corte, at the spring of the Tagnone River. It consists of metamorphic and highly tectonized turbidites, composed of sandstone layers intercalated with shale levels. No samples were collected for micropaleontological analysis because no significant calcareous levels are present in this flysch.

B. Balagne area.

Calcareous Flysch of the Balagne (Macinaggio Unit).

It is represented by highly deformed and folded calcareous flysch, consisting of grey marls (few centimeters to over a meter in thickness), with calcareous sandstones and conglomerates at the bottom. The hemipelagites are highly bioturbated and without calcium carbonate (Sagri et al., 1982). It has been considered Eocene in age for a long time, and was then referred to the Senonian, based on the presence of *Pithonella ovalis* (Kaufmann) (Nardi et al., 1978).

Sampling (Fig. 7) was performed along the coastal road that goes from the Ostriconi Village to Lozari, and from Pieve locality to the mule-track that goes to Bocca di Cento Chiave and from this last one to the ridge, towards Punta d'Arco.

Biostratigraphical results. Only 20 samples out of 150 were fossiliferous. The recognized assemblages can be referred to the Cenomanian, to the latest Coniacian and to the Campanian (?). The most significant samples are L5b1-5, L25b7 and L3Ab7, coming from Ogliastro area (Fig. 7).

In sample L25b7 the following forms are present: *E. floralis*, *Eprolithus* sp., *Rucinolithus* sp., *Lithastrinus moratus*, *W. barnesae*, *Braarudosphaera* sp., *B. hockwoldensis* Black and fragments of *Thoracosphaera* sp. The assemblage is scarce and poorly preserved; based on the presence of *L. moratus* and on the absence of *Q. gartneri*, the sample can be referred to Cenomanian. According to Perch Nielsen (1985) *B. hockwoldensis* ranges up to the Upper Albian, although this species is often recorded in the Cenomanian assemblages of the Northern Apennine turbidites (Marino & Monechi, 1994).

Sample L3Ab7 is characterised by the following forms: *Q. gartneri*, *E. floralis*, *Eprolithus* sp., *Micula decussata*, *Quadrum* cf. *gothicum*. The assemblage is very scarce and not greatly age-diagnostic. The presence of *M. decussata* allows to define an age not older than

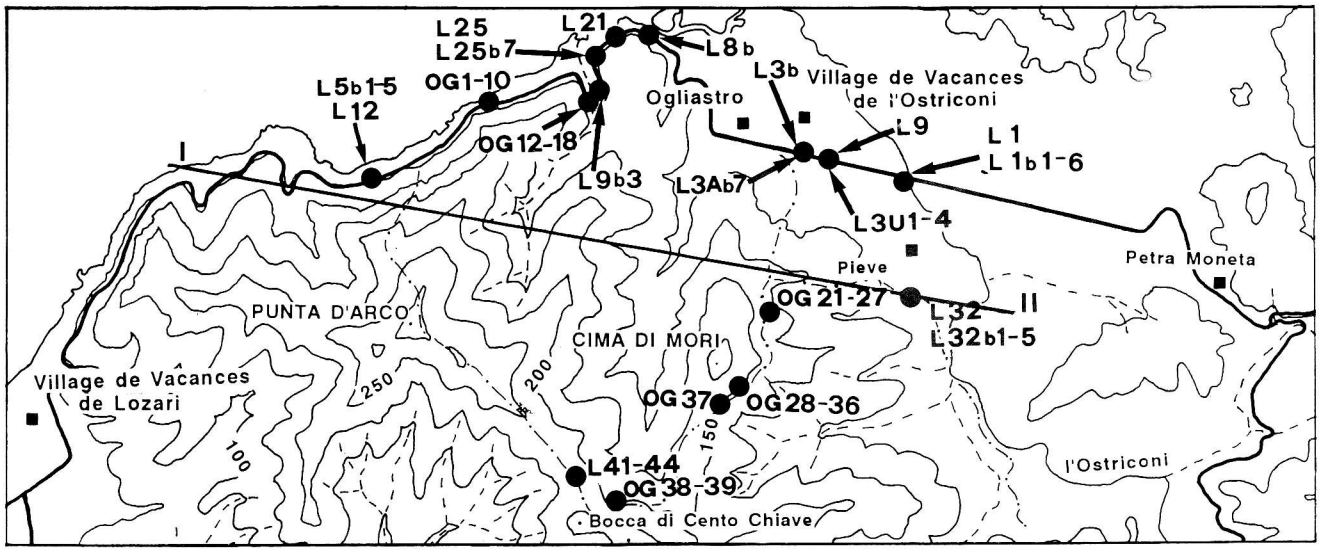


Fig. 7 - Sampling localities of Lydienne, Balagne Calcareous Flysch and Punta d'Arco Sandstones; I-II) location of cross section (Fig. 8).

latest Coniacian (Sissingh, 1977; Perch-Nielsen, 1985); *Quadrum* cf. *gothicum* might indicate the Campanian, but this age attribution is uncertain due to the poor preservation that affects the specimens of the genus *Quadrum* and making uncertain the presence of *Q. gothicum*. Moreover, other typical Campanian forms are absent.

Samples L5b1-5 contain: *W. barnesae*, *Q. gartneri*, *E. floralis*, *Rucinolithus* sp., *Hexalithus* sp., *M. decussata*, *Quadrum* cf. *gothicum*. The low species diversity makes the assemblage not very significant; the age is not older than latest Coniacian for the presence of *M. decussata*. Very rare *Quadrum* cf. *gothicum* would indicate a Campanian age, but as mentioned above, they might be overgrowth specimens of *Q. gartneri*. Again, typical Campanian forms are absent in the assemblage.

Samples L5b1-5 have been collected in an outcrop (Fig. 7) referred to "Sandstones of Punta d'Arco (Palasca)" by Nardi et al. (1978); the attribution of this outcrop to the Balagne Flysch both based on the relevant quantity of marls and marly clays and on the recognized latest Coniacian age assignment.

The other fossiliferous samples (L3U1-4, L9, L21, L3b, L8b-L9b3, L25, L41, OG 10, 12, 13, 18, 35, 38; Fig. 7) contain very rare specimens of *W. barnesae*, *Rucinolithus* sp., *Cretarhabdus* sp. and *Eprolithus* sp., that indicate a generic Cretaceous age.

Lydienne (Toccone Unit).

According to Nardi et al. (1978), this formation consists of variously coloured spongolites in thin layers with rare intercalations of silts and shales. Samples have been collected in some lithologies referred by these authors to the Lydienne and p.p. to Toccone Breccias; they crop out on the left side of the Ostriconi river and in the northern and southern part of Pieve (Fig. 7). These outcrops consist of coarse grained sandstones with shales, calcarenites and marly limestones. In the southern part of Pieve, overlying the sampled marls, there are clays in which siliceous chert levels and polygenic breccias are intercalated (samples L1; L1b1-6; L32; L32b1-5).

Biostratigraphical results. The samples collected in the northern part of Pieve (L1 and L1b) are barren. In the southern part of Pieve, some grey calcareous-marly levels are fossiliferous (Fig. 7; samples L32b1-5). The most significant assemblage is present in sample L32 which contains: *Cyclagelosphaera margerelii* Noel, *Watznaueria barnesae*, *W. biporta* Bukry, *W.* cf. *manivitae* (Bukry), *Manivitella pemmatoidea* (Deflandre), *Tranolithus phacelosus*, *Eprolithus* sp., *Zeughrabdotus embergeri* (Noel), *Braarudosphaera* sp., *Eiffellithus* sp. and *Nannoconus* sp.

The assemblage can be referred to an age not older than the Late Albian for the occurrence of *T. phacelosus*, *Eiffellithus* sp. and not younger than Early Turonian for the absence of *Quadrum gartneri*, which is quite common in the studied assemblages and whose first occurrence marks the base of the Turonian.

Palasca Sandstones (Palasca Unit).

This silicoclastic flysch almost entirely consists of coarse sandstones with thick beds and rare levels of silts and shales. Levels of polygenic conglomerates (ophiolitic) are present near the base (Nardi et al., 1978). The presence of negative cycles might indicate an external location of these turbidites (Sagri et al., 1982).

In some areas, the upper contact appears to grade upwards into thin-bedded calcareous turbidite

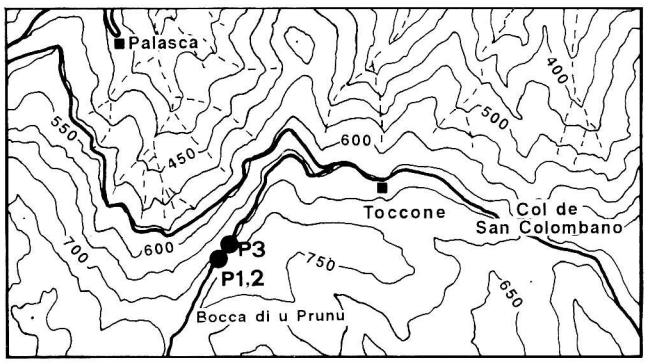


Fig. 8 - Palasca Sandstones sampling area.

rocks of the Balagne Calcareous Flysch; according to several authors the contact can be tectonic due to overthrusting of the former over the latter. The Flysch has been referred to the Senonian (North of Novella; Durand Delga et al., 1977) based on the presence of *Globotruncana*, Rotaliidae and *Paraphyllum*, and to the Late Lutetian based on the presence of *Discocyclina* and *Nummulites brongniarti* D'Archiac & Haime (Chapelle of Annunziata; Lacazedieu & Parsy, 1970; Lacazedieu, 1974); fragments of *Orthophragmina* (along the road of Novella; Bonnal, 1972). Extensive sampling has been performed on the Poggio Punta d'Arco (L12) and near Toccone Village along the road that leads from Palasca to Bocca di u Prunu (Fig. 8; samples P1-3).

Unfortunately, most samples are unfossiliferous and only sample P1 and sample P3, near Toccone, contain calcareous nannofossils of Middle Eocene age.

Biostratigraphical results. In sample P1 the assemblage is characterized by the presence of *Sphenolithus moriformis* (Brönnimann & Stradner), *S. spiniger* Bukry, *Coccolithus pelagicus* (Wallich), *Zyghrablithus bijugatus* (Deflandre), *Cyclicargolithus floridanus* (Roth & Hay), *Dictyococcites scrippsae* Bukry & Percival, *Discoaster* sp. (rosette shaped *Discoaster*). Age: Middle Eocene (Zones NP14-NP15 of Martini, 1971). Sample P3 contains *Coccolithus* sp., *Sphenolithus* sp. Age: Tertiary.

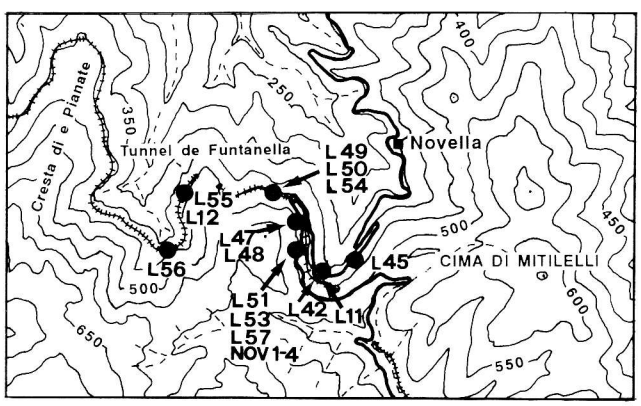


Fig. 9 - Gare de Novella Sandstones sampling area.

Gare de Novella Sandstones (Novella Unit).

It is represented by a silicoclastic flysch which consists of medium to coarse grained sandstones, with few conglomeratic elements and with an erosional or amalgamated base (Sagri et al., 1982). Clayey layers are rare. Locally, several clayey-silty-marly interlayers are present in a short stratigraphic interval. It consists of feldspathic graywackes with medium compositional maturity belonging to a canalized fan based on the presence of positive cycles (Sagri et al., 1982). According to Nardi et al. (1978) they are stratigraphically intercalated to the "Lydienne" heteropic with Toccone Breccias. According to Durand Delga (1984) they are heteropic with the uppermost part of "Lydienne" only.

The Gare de Novella Sandstones have been referred to the Cenomanian based on the presence of *Rotalipora reicheli* Mornod, *R. turonica* Brotzen, *R. cushmani* (Morrow), *Globotruncana stephanii*, *Orbitolina* (*conoidea?*), *Praeglobotruncana delrioensis* (Plummer), *Praeglobotruncana* gr. *stephanii* (Lacazedieu & Parsy, 1970).

Near the station of Novella, along the railway track, at the two ends of Avagno Bridge and on the track of the road that goes above the station, the flysch shows a facies relatively rich in marly interbeds, in which our samples have been collected (samples L47-54; L42, L45; NOV 1-4; Fig. 9).

Biostratigraphic results. Half of the twenty samples collected are unfossiliferous. The others (L53, NOV1-3) contain rare and poorly preserved assemblages represented by *Rhagodiscus asper*, *Watznaueria barnesae*, *Corollithion* sp., *Braarudosphaera* sp., *Discorhabdus* sp., *Cretarhabdus* sp., *Ahmuellerella* sp., *Microstaurus chiastius*, *Nannoconus* sp., *Watznaueria britannica* (Stradner), *Watznaueria ovata* (Bukry), *Cretarhabdus crenulatus* Bramlette & Martini, *Glaucolithus diplogrammus* (Deflandre), *Helicolithus trabeculatus* (Gorka), *Prediscosphaera* sp., *Chiastozygus litterarius* (Gorka), *Zeugrhabdotus embergeri* (Noel), *Rucinolithus irregularis* Thierstein and *Cyclagelosphaera margerelii*. This assemblage indicates a Late Albian age interval (presence of *H. trabeculatus*, *R. asper* and *Prediscosphaera* sp., and absence of *Q. gartneri* which is relatively frequent in the Balagne Calcareous Flysch). Other samples (L51, L50) contain very rare specimens of *W. barnesae*, *Eprolithus* sp. and *Cretarhabdus* sp., indicative of a generic Cretaceous age.

Alturaia Arkoses.

They consist of an arkosic flysch with very few fine calcareous levels. It has been referred to "post-Cenomanian, pre-Lutetian, Turonian-Senonian" age

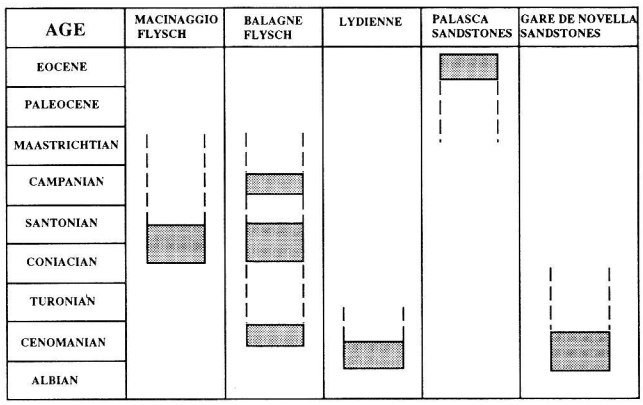


Fig. 10 - Stratigraphic scheme of the studied units based on the calcareous nannofossil data. Dotted lines show possible older and younger age.

(Durand Delga, 1984). Samples have been collected along the railway track which goes from the station of Novella towards Palasca, beyond the tunnel of Funtanella (Fig. 9). All the analyzed samples (L55-L56) are unfossiliferous.

Conclusions.

The obtained biostratigraphical results are modest considering the quantity of samples collected and analyzed. Most of the nannofossil assemblages have a very low abundance and diversity and are mostly characterized by species very resistent to dissolution and overgrowth. This is due to the weak metamorphism that affected the flysch sequences. As a consequence, the age cannnot be precisely defined and the identification of biozones is prevented.

It is on our opinion however, that the new data, which are consistent with the previous ones based on Foraminifera, form a significant contribution to the knowledge of the Cretaceous Flysch of Corsica. The results may be synthetized as follows (Fig. 10):

1) The age recognized for the Macinaggio Flysch is not older than latest Coniacian.

2) The ages recognized in the Balagne Calcareous Flysch (correlated with the Macinaggio Flysch by Nardi et al., 1978), are Cenomanian, latest Coniacian and an uncertain Campanian.

3) The Lydienne (Toccone Unit) tectonically overlying the Balagne Calcareous Flysch, is not older than Late Albian and not younger than Early Turonian.

4) For the Palasca Sandstones a Middle Eocene age has been confirmed.

5) An age not older than Late Albian has been documented in the Gare de Novella Sandstones.

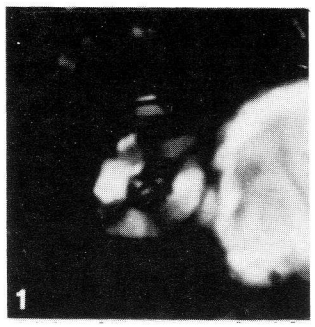
The low number of fossiliferous samples, the extreme tectonic nature of the contacts and, sometimes, the uncertain stratigraphic position of the sampling, make possible to suppose that the ages of these sediments range in wider intervals than those documented above:

- The Macinaggio Flysch might be referred to the Cenomanian, if it is correlated to the Balagne Calcareous Flysch, as indicated by Nardi et al. (1978).
- If the Punta d'Arco Sandstones (Palasca Sandstones) are in stratigraphic succession with the Balagne Calcareous Flysch, the uppermost part of the last one might be referred to the terminal stages of the Late Cretaceous or even to the Tertiary. We cannot exclude the presence of older intervals in the Palasca Flysch (the Senonian age in the Annunciata/Mitilelli Flysch documented by Durand Delga (1984) and the uncertain position of samples L5b1-5 discussed in the biostratigraphic chapter).
- The Toccone Breccias and Lydienne (not older than Late Albian) cropping out in Pieve and the Balagne Calcareous Flysch (Cenomanian and latest Coniacian in age) may be lumped together; in this case, the relationship between these sequences, in the Balagne area, can be hypothesized as shown in Fig. 11.

PLATE 1

Calcareous nannofossils from Flysch of Corsica. All figures x 2900.

Fig. 1, 2 - *Cretarhabdus* cf. *crenulatus* Bramlette & Martini, 1964. Gare de Novella Sandstones, sample NOV 1 (1, crossed-nicols; 2, transmitted light).
Fig. 3 - *Watznaueria barnesae* (Black in Black & Barnes, 1959). Gare de Novella Sandstones, sample L53, crossed-nicols.
Fig. 4 - *Discorhabdus* sp. Gare de Novella Sandstones, sample NOV 1, crossed-nicols.
Fig. 5 - *Micula* sp. Macinaggio Flysch, sample M12+c, crossed-nicols.
Fig. 6 - *Quadrum* sp. Macinaggio Flysch, sample M12+c, crossed-nicols.
Fig. 7, 8 - *Quadrum gartneri* Prins & Perch-Nielsen in Manivit et al., 1977. Balagne Calcareous Flysch, sample L5b (7, crossed-nicols; 8, transmitted light).
Fig. 9, 10 - *Lithastrinus moratus* Stover, 1966. Balagne Calcareous Flysch, sample L25b7 (9, crossed-nicols; 10, transmitted light).
Fig. 11 - *Quadrum gartneri* Prins & Perch-Nielsen. Balagne Calcareous Flysch, sample L5b5, crossed-nicols.
Fig. 12 - *Micula* sp. Balagne Calcareous Flysch, sample L5b5, crossed-nicols.
Fig. 13, 14 - *Lithastrinus moratus* Stover, 1966. Balagne Calcareous Flysch, sample L5b5 (13, transmitted light; 14, crossed-nicols).
Fig. 15, 16 - *Quadrum* cf. *gothicum* (Deflandre, 1959). Balagne Calcareous Flysch, sample L5b5 (15, transmitted light; 16, crossed-nicols).
Fig. 17, 18 - *Lithastrinus moratus* Stover, 1966. Balagne Calcareous Flysch, sample L25b7 (17, crossed-nicols; 18, transmitted light).
Fig. 19 - *Lithastrinus moratus* Stover, 1966. Balagne Calcareous Flysch, sample L25b7, crossed-nicols.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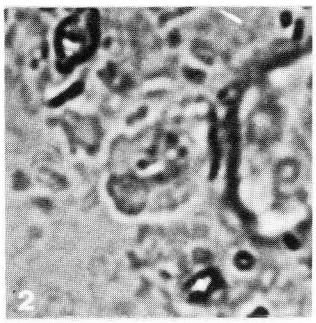
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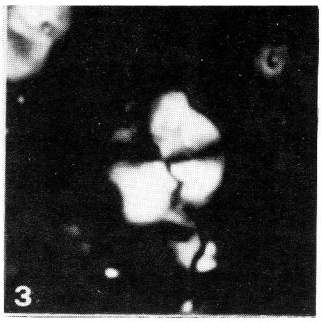
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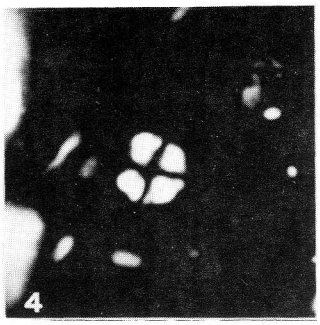
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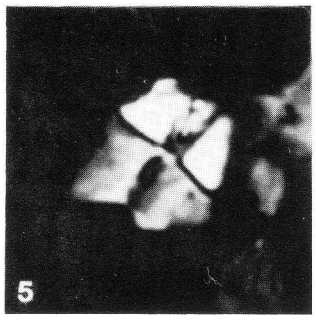
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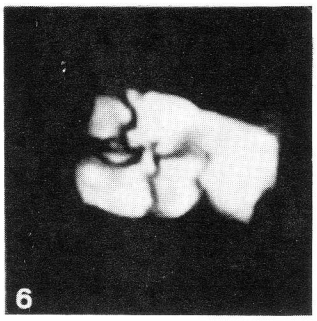
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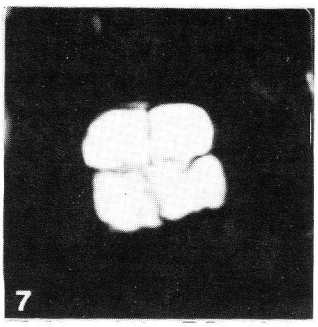
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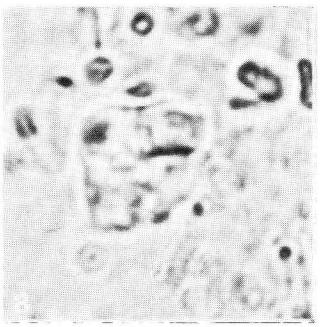
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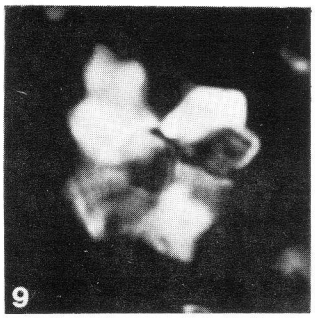
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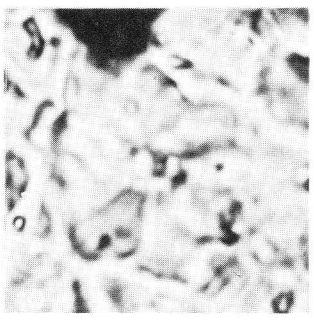
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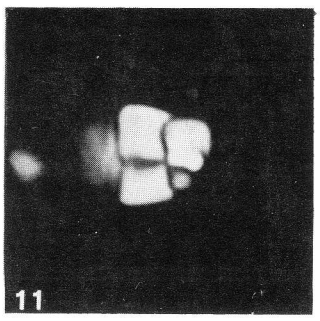
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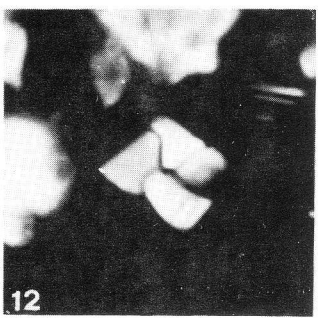
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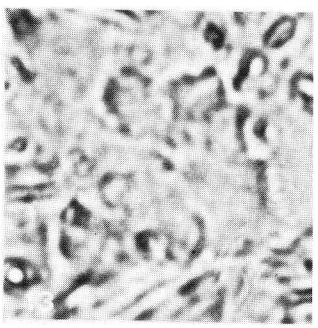
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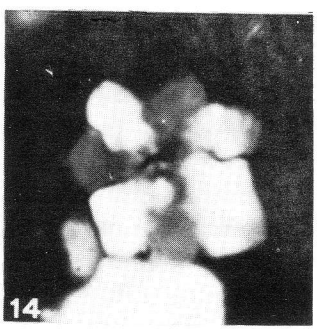
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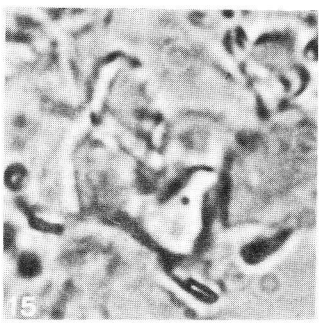
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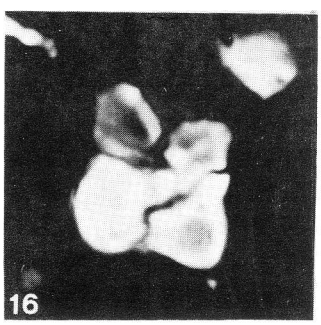
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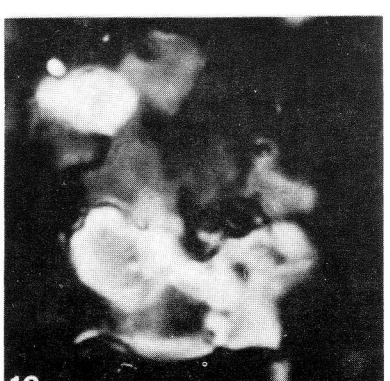
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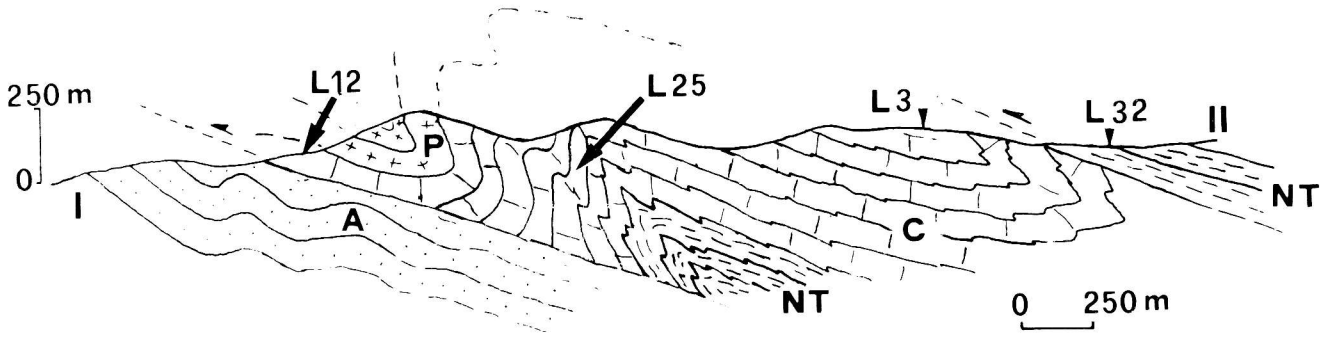

Fig. 11 - Schematic cross section through the Balagne Calcareous Flysch outcropping area (Fig. 7) with the probable collocation of fossiliferous samples. Legenda: A) Autochthonous sediments (Middle Eocene); P) Punta d'Arco Sandstone (Palasca, Middle Eocene); C) Balagne Calcareous Flysch (Cenomanian-Campanian); NT) Lydienne+Toccone (Albian-Cenomanian).

- Considering the relatively basal position of the fossiliferous samples in the Gare de Novella Sandstones, it is not possible to exclude also for this formation an age younger than Late Albian.

The new data would indicate that the beginning of the turbidite sedimentation in the Alpine Corsica Units, is late Early Cretaceous in age (not older than Late Albian), unlike recent data concerning Cretaceous flysch in the Northern Apennine, whose lowermost part has been referred to a younger age (Rio et al., 1983; Gardin et al., 1994; Marino & Monechi, 1994).

From a paleogeographic point of view, a strong vicinity to the European margin is well demonstrated by the presence of sialic, even coarse grained material, in the Cretaceous basal complexes (Toccone-Lydienne) of the Corsican flysch. In the Balagne area the Navaccia Unit (where in the Col de St. Colombano succession the carbonatic pelagic Jurassic sediments overlying the basalts contain elements of crystalline substratum and of carbonatic platform) shows that this vicinity is an old heritage.

Moreover, the presence in the flysch of a great quantity of silicoclastic material, similar in composition to the rocks of the Corsican massif, and the transitional nature of the flysch depositional environment between rifted continental margins and orogenic continental margins, confirm also the proximal nature of the turbidite basins (Sagri et al., 1982). The possible location of some of these flysch in a trench position (Balagne Calcareous Flysch, Macinaggio and probably Novella), might be indicated by their deposition below the CCD (Sagri et al., 1982). In agreement with Sagri et al., 1982 data an oceanic depositional substratum, as supported also by Nardi et al., 1978 instead of a sialic (European margin) depositional substratum (as partially supported by Durand Delga, 1984) for the Corsica Cretaceous turbidites seems preferable.

According to Abbate & Sagri, 1982 and Sagri et al., 1982, the increasing of siliciclastic material in the western coming Cretaceous turbidites of Northern Apennines and Corsica shows that the active (uplifting) convergent margin in the Upper Cretaceous was represented by the European side during the initial phases of the Western Tethys closure.

The resulted older age of the base of Corsican turbidites (Cenomanian-Coniacian) with respect to those of the Northern Apennines (Santonian?-Campanian-Maastrichtian; see Gardin et al., 1994) fits with Abbate and Sagri's opinion (1982). In fact, the migration of the trench basins is one of the most important constraint to restore the structural frame of a convergent margin when other evidences, as the magmatic arc, are missing.

The age of the Corsican turbidites could demonstrate that an eastward migration, even if slow, is hypotisable also for the Cretaceous turbidite basins as well as for the Tertiary turbidite basins of the Northern Apennines (see Principi & Treves, 1984 with references).

The presence of Lutetian sediments (Punta d'Arco Sandstones, Palasca Sandstones) stratigraphically covering, at least in part, the Cretaceous turbidites and the presence of neoautochthonous Lutetian sediments tectonically overlain by the ligurid turbidites, demonstrate that the ligurid nappes in Corsica took place after this time interval.

On the other hand, the evidence of older emplacements (Middle-Late Paleocene to Lower Middle Eocene) of the Apenninic Ligurid nappes (see Principi & Treves, 1984 with references) induces to consider the Corsican Eocene events as late tectonic phases of the Corsican-Northern Apennines accretionary wedge, probably as backthrusts produced during the Europe-Adria collision (Principi & Treves, 1984).

Acknowledgements.

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