CALCAREOUS NANNOFOSSIL DATING OF THE SAN MARTINO FORMATION FROM THE BALAGNE OPHIOLITE SEQUENCE (ALPINE CORSICA): COMPARISON WITH THE PALOMBINI SHALE OF THE NORTHERN APENNINE

Michele Marroni*,**, **Luca Pandolfi**** and **Nicola Perilli***,**

* *Dipartimento di Scienze della Terra, Universita' di Pisa, 56126 Pisa, Italy.*
** *C.N.R., Centro di Studio per la Geologia Strutturale e Dinamica dell'Appennino, 56126 Pisa, Italy.*

Keywords: *ophiolites, sedimentar cover, Balagne nappe, Cretaceous. Corsica.*

ABSTRACT

In the Alpine Corsica, the ophiolitic sequences are regarded as remnants of the Ligure-Piemontese oceanic lithosphere. The best preserved ophiolitic sequences are represented by the succession from the Balagne nappe, northern Corsica. This succession consists of a Jurassic ophiolite sequence topped by a Jurassic - Late Cretaceous sedimentary cover. This sedimentary cover, affected by very-low grade metamorphism, consists of deep-sea deposits, represented by Chert, Calpionella Limestone, San Martino Fm., Lydienne Flysch and Novella Sandstone. The latters two formations are characterized by terrigenous turbidite deposits supplied by Europe/Iberia continental margin.

In this paper the age of the San Martino Fm. and the lower part of the Lydienne Flysch has been determined by the study of the calcareous nannofossil assemblages. The collected data indicate for the San Martino Fm. an age spanning from Early Berriasian to Late Hauterivian - Early Barremian. Moreover, the lower part of the Lydienne Flysch is not older than Late Hauterivian and not younger than Early Barremian.

By comparison with the data available from ophiolite sedimentary cover of Northern Apennine, the San Martino Fm. can be correlated with the lower part of the Palombini Shale. This correlation suggests that the upper part of the Palombini Shale can be considered as time equivalent to the Lydienne Flysch.

INTRODUCTION

The ophiolite sequences from Alpine Corsica are regarded as remnants of the Ligure-Piemontese oceanic lithosphere deformed and metamorphosed during the intraoceanic subduction and the following continental collision between Adria and Europe/Iberia plates. These ophiolite sequences are generally deformed and metamorphosed under high-pressure/low-temperature (HP/LT) conditions during the subduction phases. In these metamorphosed sequences, the age of the sedimentary cover of the ophiolites can be usually assessed by comparison with the weakly metamorphosed ophiolite sequence of the Northern Apennine. However, also in the Alpine Corsica ophiolite sequences affected only by very-low grade metamorphism have been detected, mainly in the Balagne and Nebbio areas, northern Corsica. In these areas, a typical ophiolite sedimentary cover represented by deep-sea deposits has been recognized.

In this paper, the age of the San Martino Fm. and the lower part of the Lydienne Flysch, both belonging to the ophiolite sedimentary cover from Balagne nappe, have been determined by the study of the calcareous nannofossil assemblages in order to provide evidences for its correlation with the Palombini Shale from the ophiolite sequences of Northern Apennine.

GEOLOGICAL SETTING

The Corsica Island is geologically characterized by two different domains, known as Hercynian and Alpine Corsica (Fig. 1). The Alpine Corsica consists of an assemblage of continental- and oceanic-derived units that overlie the Paleozoic basement of the Hercynian Corsica. These units are representative of the Ligure-Piemontese oceanic basin and the neighbouring continental margins of the Europe/Iberia and Adria continental plates (e.g. Dal Piaz et al., 1977; Dallan and Nardi, 1984; Durand-Delga, 1984; Malavieille et al., 1998). The oceanic and continental units of Alpine Corsica are deformed and metamorphosed during the intraoceanic subduction and the following continental collision that affected the Ligure-Piemontese basin during the Late Cretaceous – Eocene convergence between Adria and Europe/Iberia plates. From the Oligocene onwards, the oceanic and continental units of Alpine Corsica was affected by ductile and brittle deformations related to large scale extensional tectonics (Fournier et al., 1991; Jolivet et al. 1991).

The Alpine Corsica is characterized by wide outcrops of the *Schistes lustrés*, complex represented by continental and oceanic sequence strongly deformed and affected by Late Cretaceous – Eocene HP/LT metamorphism (e.g. Harris, 1985; Warburton, 1986, Malavieille et al., 1998). The *Schistes lustrés* complex overlies the tectonic units, known as *parautochtonous* nappes, derived from the Europe/Iberia continental margin (S.Lucia nappe, Caporalino-S.Angelo nappe, Corte units, Palasca unit and Tenda massif following Nardi, 1968a) consisting of Mesozoic to Late Eocene sedimentary successions associated to slices of crystalline basement. In turn, the *Schistes lustrés* complex is overlain by an assemblage of very low-grade metamorphic units (*Nappes supérieures*). These units have been recognized as klippes (Nardi, 1968a; Nardi et al., 1978; Durand-Delga, 1984) in the Balagne, Nebbio and Macinaggio areas. They are mainly represented by ophiolitic units (Balagne and Nebbio units) consisting of a Jurassic ophiolite sequence and the related Late Jurassic-Late Cretaceous sedimentary cover. The Balagne and Nebbio units are generally associated with Macinaggio unit, consisting of Late Cretaceous carbonate Flysch. The relationships between the Balagne, Nebbio and Macinaggio units and the underlying *Schistes lustrés* complex are sealed by the weakly deformed Miocene deposits cropping out in the St.Florent and Francardo areas.

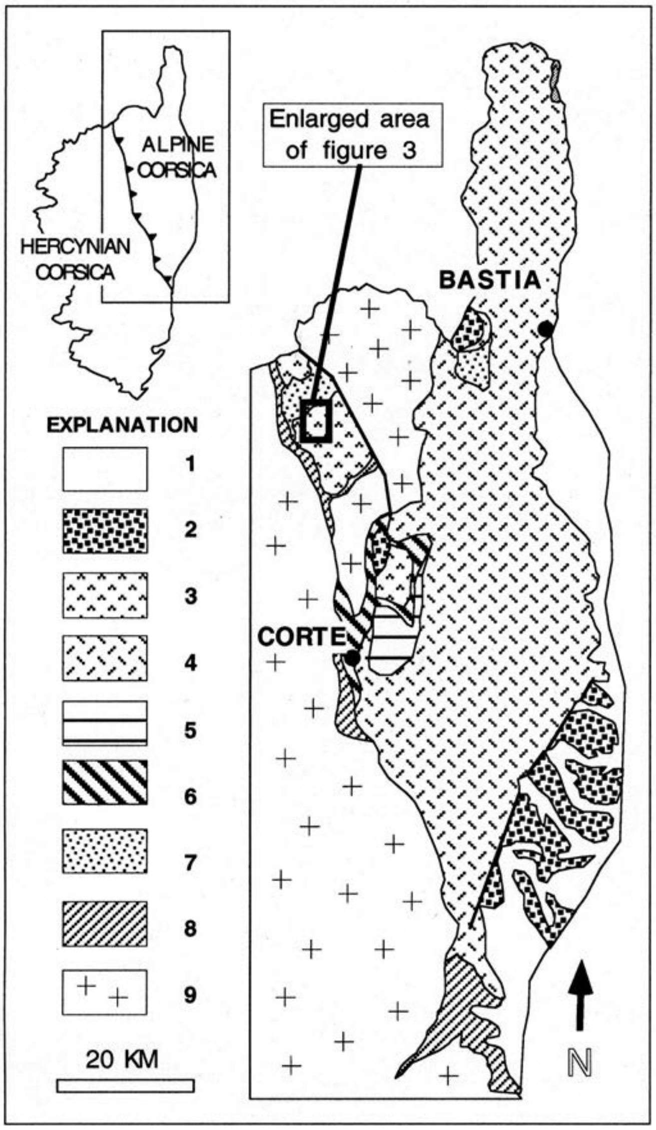

Fig. 1 - Sketch-map of Alpine Corsica. Explanation: 1. Plio-Pleistocene deposits; 2. Miocene deposits; 3. Balagne Nappe, Macinaggio unit and Nebbio Unit; 4. Schistes Lustrés Complex; 5. St. Lucia unit; 6. Corte thrust-sheet; 7. Palasca unit; 8. Sedimentary cover of the Hercynian Corsica; 9. Hercynian Corsica and Tenda Massif. The enlarged area of figure 3 is indicated.

THE BALAGNE NAPPE

In the northern Corsica, the Balagne area is characterized by an imbricate stack of tectonic units thrust over the Hercynian basement and its Middle Eocene sedimentary cover. The uppermost tectonic unit of the imbricate stack is represented by the Balagne nappe that overlains the *parautochtonous* Palasca nappe. Several slices derived from the Hercynian basement and its sedimentary cover are recognized below the Palasca nappe (Nardi et al., 1978; Durand-Delga, 1984).

The Balagne nappe is subdivided in two main tectonic units known as Toccone and Navaccia units. Both units are affected by a polyphase deformation history developed under very low-grade metamorphic conditions (Egal, 1992).

The succession of the Balagne nappe (Fig. 2) can be reconstructed in the Navaccia unit where a complete stratigraphic succession from Jurassic ophiolites up to the Late Cretaceous sedimentary cover has been recognized (Bosma, 1956; Lacazedieu, 1974; Nardi et al., 1978; Dallan and Nardi, 1984; Durand-Delga, 1984). The ophiolite sequence consists of mantle lherzolites and gabbroic complex associated with a volcanic sequence. The volcanic sequence consists of massive and pillow lava basalts cut by basaltic dykes with porphyric texture. According to Dal Piaz et al. (1977) and Durand-Delga et al. (1997), the geochemical features of the basalts reveal an affinity typical of a crust developed in the first stage of the oceanic spreading. In the volcanic sequence levels of terrigenous debris made up of quartz and minor feldspar fragments have been described (Durand-Delga et al., 1997). The basalts are covered by Chert (Callovian-Early Kimmeridgian; De Wever et al., 1987) and Calpionella Limestone (Tithonian-Early Berriasian; Bosma, 1956; Lacazedieu, 1974; Routhier, 1956; Nardi, 1968b). The latter are characterized by the occurrence of continental-derived debris as recognized in the basalts (cfr. San Colombano Limestone, Durand-Delga et al., 1997). The Calpionella Limestone grades upward to San Martino Fm. that consists of calcareous turbidites represented by 100 m thick limestones and shales interbedded with minor siliciclastic turbidites consisting of quartz-rich siltites and shales. This formation has been correlated with the Palombini Shale cropping out in the northern Apennine (Nardi, 1968a; Durand-Delga, 1984), but no biostratigraphical data are available to support this interpretation. The San Martino Fm. shows a transition to the Lydienne Flysch, whose age is referred by Marino et al. (1995) as not older than Early Albian and not younger than Early Turonian by nannofossils assemblage. The Lydienne Flysch, up to 300 m thick, consists of thin bedded, mixed turbidites showing stratigraphic relationships with Novella (cfr. Gare de Novella) Sandstone. The 200 m thick Novella Sandstone is represented by amalgamated beds of coarse grained arenites and rudites. The Novella Sandstone displays Middle to Late Cenomanian forams (Lacazedieu, 1974; Durand-Delga et al., 1978), whereas a not older than Late Albian nannofossils assemblage has been found by Marino et al. (1995). According to Sagri et al. (1982) and Durand-Delga et al. (1997) both Lydienne Flysch and Novella Sandstone are supplied by the Corsica crystalline basement.

In the Toccone unit, the stratigraphic succession includes the San Martino Fm., the Lydienne Flysch and the Toccone Breccia. The last formation was probably heteropic with the Lydienne Flysch and Novella Sandstone (Nardi et al., 1978).

It is noteworthy that the occurrence of deposits supplied from the Corsica Paleozoic basement throughout the whole succession of the Balagne nappe suggests its paleogeographic location close to the Europe/Iberia continental margin (Durand-Delga, 1984; Durand-Delga et al., 1997).

SAMPLED SUCCESSION

The San Martino Fm. has been mainly sampled (Fig. 2 and 3) along the railway (F of Fig. 3) from Ponte Leccia to Ile Rousse (42°34'8"N 9°7'25"E). This succession, up to 60 m thick, occurs at the core of a first-phase anticline of San Martino Fm. refolded by the second folding phase. In the limbs of this structure a stratigraphic transition from San Martino Fm. to Lydienne Flysch has been detected. From the bottom (66 CON) to the top (90 CON) of the section, 25 samples have been collected. Two samples (66 and 67 CON) have been collected in the lowermost part of the Lydienne Flysch (E and D of Figure 3). In addition, samples (1-10 CON and 36 CON) from San Martino hill (A and B of Figure 3) have been collected but, unfortunately, they are barren. Also the samples collected along the road to Novella (C of Figure 3) are barren.

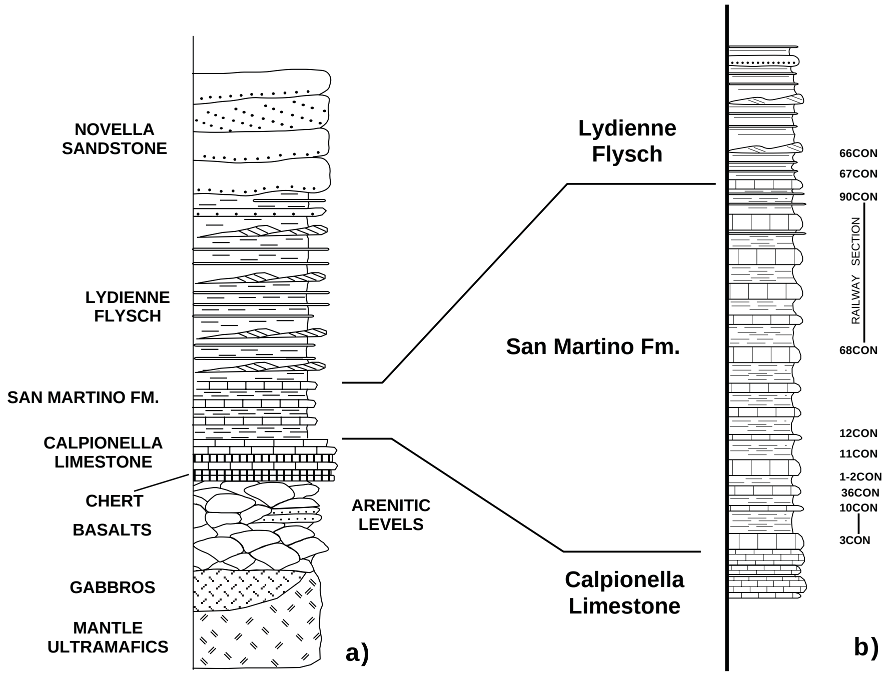

Fig. 2 - a. Schematic log of the Navaccia unit. b- Stratigraphic log including upper part of the Calpionella Limestone, San Martino Fm and lower part of the Lydienne Flysch. The location of the studied samples are indicated in Fig. 3. (A: 1-2 CON; B: 3-10 CON, 36 CON; C: 11-12 CON; D: 66 CON; E: 67 CON; F: 68-90 CON).

The sampled sections of San Martino Fm. consist of fine grained limestones (calcilutites and rare fine calcsiltites) alternating with marlstones and shales (Fig. 4). Subordinate siliciclastic fine grained turbidites can be also recognized in the upper part of the studied section. The calcareous beds, characterized by a thickness ranging from 10 cm up to 1 m, show a good lateral continuity. Due to the presence of pure traction and subordinate traction plus fall-out structures like plane laminae, convolute laminae and ripples, these deposits can be interpreted as the product of low density turbidity currents (cfr. Bouma missing beds, Tb-e, Tc-e or F9a facies of Mutti, 1992). The Te Bouma interval consists of marlstones, whereas carbonate-free shales represent the hemipelagic background sedimentation. A sand to shale ratio close to 1 can be usually recognized. Both marlstones and limestones has been sampled for nannofossil analysis. The calcilutites consist of calcareous nannofossils (Fig. 5a), micritic mudstone and subordinate monocrystalline quartz, feldspars and undeterminable phyllosilicate fragments (Fig. 5 a and b). In the sampled strata a pervasive calcite recrystallization (Fig. 5b and d) and a scattered silicification (Fig. 5a and d) affects both limestone and marlstone beds. A widespread silicification can replace more than 50% of the original carbonate framework in the calcilutites while a scattered pattern of authigenic quartz (less than 5% of the original framework) affects the marlstones (Fig. 5d).

The upper part of the San Martino Fm. is characterized by the occurrence of siliciclastic turbidites consisting of quartz-rich siltites and shales. The presence of these beds marks the gradual transition to the overlying Lydienne Flysch. In the Lydienne Flysch, the coeval calcareous debris is almost absent and the beds are characterized by terrigenous mixed siliciclastic-carbonatic composition (Marroni and Pandolfi, in prep). The succession consists of thin bedded turbidites ranging in grain size from medium sand to siltstone interbedded with lenticular coarse grained beds characterized by the presence of megaripple scale-cross stratification. The two samples (66 and 67 CON) collected from the lowermost part of the Lydienne Flysch are the only two marlstone beds recognized in this formation during the field work (fig. 5c).

CALCAREOUS NANNOFOSSILS

Materials and methods

The sampled lithologies include limestones, marlstones and marly claystone. Due to the calcite recrystallization and the silicification observed at meso- and microscopic scale, both smear slides and ultra-thin sections have been prepared to investigated calcareous nannofossil contents.

Smear slides: In order to retain the original calcareous nannofossil assemblages, without modifying their ratio with other fragments (e.g., micarbs, large carbonate fragments, quartz, etc.), a small amount of sediment was grated and smeared on a cover glass using a drop of bidistillated water. Dried on a hot plate, the cover glass was then permanently attached on a glass slide. As reported in Table I, the majority of the samples are barren or yielded extremely rare calcareous nannofossil specimens, whereas large fragments of carbonate and micarbs are abundant; other fragments include quartz grains (rare) and oxides (very rare). Due to the paucity of calcareous nannofossils, in order to increase the assemblage concentration some smear slides (i.e. 66, 67, 70, 73, 74, 75, 78, and 90 CON) had been re-prepared as follow: 1 gr. of sediment was crushed in an agate mortar and subsequently removed from the mortar to a test-tube, using bidistillated water; the obtained suspension was three times centrifuged and immerged in an ultrasound-tank for few seconds. Few drops of suspension were then uniformly distributed on a cover glass, that was dried and attached on a glass slide as above reported. Unfortunately, these smear slides are only slightly richer of calcareous nannofossils than those prepared with previous method. On the basis of the very low nannofossil abundance recognized during the preliminary investigation of the smear slides, a semiquantitative analysis was adopted. Observation were performed using a Light Microscope at 1200X magnification; for each fossiliferous smear slide more than 3000 fields have been at least checked along parallel transverses, whilst for the re-prepared samples, almost 5000 fields have been observed.

Ultra-thin sections: in order to verify the degree of depletion of calcareous nannofossil assemblages during the smear slide preparation, some ultra-thin sections (66-67, 70, 73 and 90 CON) have been also prepared. According to the standard techniques, the thickness of thin section is reduced to 10-5 mm; to improve the Light Microscope resolution the borders of the ultra-thin sections were further thinned up to 5-3 mm. A semiquantitative analysis has been also adopted for the investigation of nannofacies in ultra-thin section; for each section about 1000 fields have been randomly investigated at 1200X magnification.

Assemblages

Smear slides: as reported in Table I, in the majority of the fossiliferous samples only extremely rare specimens of *Watznaueria barnesae* and *Watznaueria* sp.1 are usually present. Indeed, few samples from the lower portion of the Railway section and one sample from its upper part are characterized by rare or very rare and badly preserved, but age significant, nannofossil assemblages. Along with *Watznaueria barnesae* and *Watnzaueria* sp. 1 the assemblages include extremely rare specimens of *Assipetra infracretacea* (68, 73, 74, 78 and 90 CON), *Micrantholithus obtusus* (70 CON), *Braarudosphaera bigelowii* (73 CON), *Conusphaera mexicana* (70, 73, 75, 78 and 90 CON), *Litraphidites carniolensis* (70 and 73 CON) and *Rucinolithus* spp. (68 and 73 CON) *Zeughrabdothus embergeri* (73 CON). Furthermore, the assemblages of the samples 66 and 67 CON from the lower part of the Lydienne Flysch are characterized by the occurrence of *Watznaueria barnesae*, *Watznaueria* sp. 1, *Nannoconus steinmannii*, *Nannoconus globulus*, *Nannoconus colomii*, *Micrantholithus hoschulzii*, *Micrantholithus obtusus*, *Assipetra infracretacea*, *Braarudosphaera bigelowii*, *Conusphaera mexicana*, *Litraphidites carniolensis*, *Rucinolithus* spp. and *Zeughrabdothus embergeri.*

Ultra-thin sections: At Light Microscope, the fine grained mudstones are characterized by the occurrence of detritic small quartz grains (rare), diagenetic crystal of quartz (frequent) and a significant amount of diffuse authigenic quartz (Fig. 5). Nicely recognizable at 500X and 800X magnification, diagenetic quartz represents the 30-40% of the whole sediment. In spite of this heavy diagenetic overprint, using 1250X magnifications, part of the micrite is still made up of nannoconids (rare to common) that with a narrow central cavity are referable to the *Nannoconus steinmannii* group (few to common) along with *Nannoconus globulus* (rare) and extremely rare specimens of *Nannoconus colomii* (Fig. 5 l-n). The other species recognized in the ultra-thin sections are *Watznaueria barnesae* (rare to few), *Zeugrhabdothus embergeri* (rare to few), *Micrantholithus hoschulzii* (rare to few), *Assipetra infracretacea* (very rare) and *Conusphaera mexicana* (few specimens). Therefore, the analysis of the ultra-thin sections point out that nannoconids are a significant component of the nannofacies, heavily destroyed during the preparation of the smear slides. Moreover, in ultra-thin section from Lydienne Flysch, few specimens of planctonic foraminifera referable to *Hedbergella* spp. have been also recognized in the sample 66 CON.

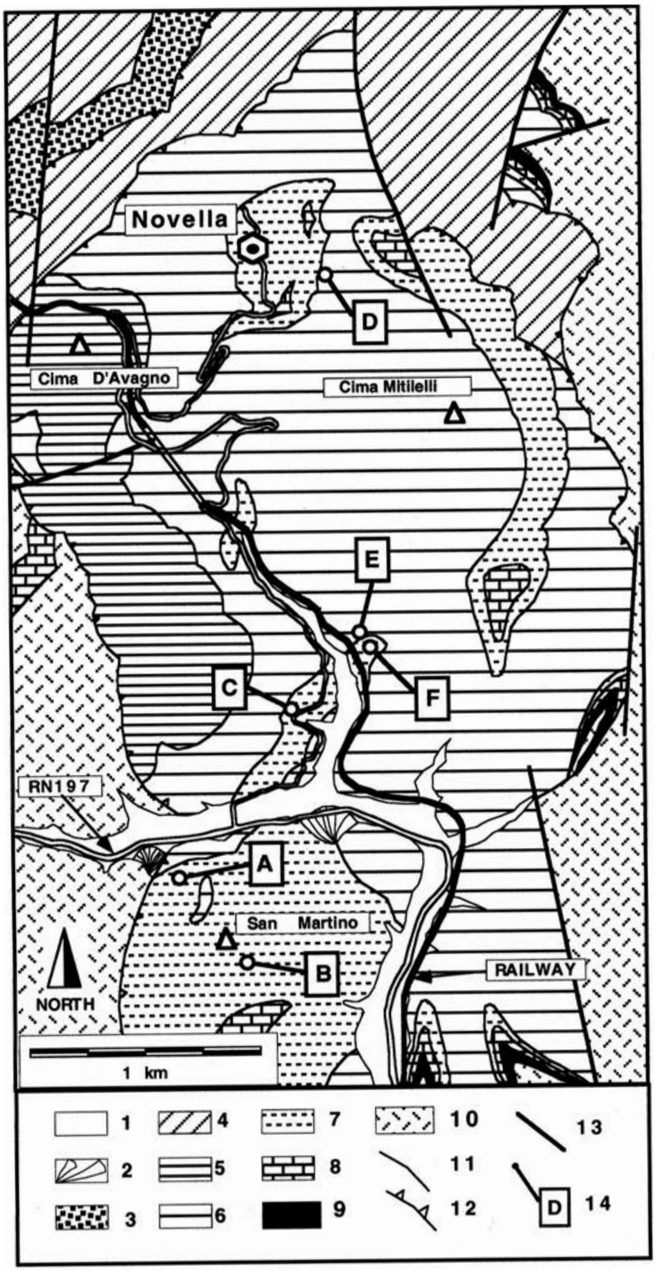

Fig. 3 - Geological sketch-map of the study area. The location of the sampled areas are indicated. Explanation: 1. Alluvial Quaternary deposits; 2. Alluvial fans; 3. Palasca tectonic unit; 4. Alturaia Arkose; 5. Novella Sandstone; 6. Lydienne Flysch; 7. San Martino Formation; 8. Calpionella Limestone; 9. Chert; 10. Basalts; 11. Stratigraphic limits; 12. Thrusts; 13. Faults; 14. Location of sampled areas; for symbols see Fig. 2.

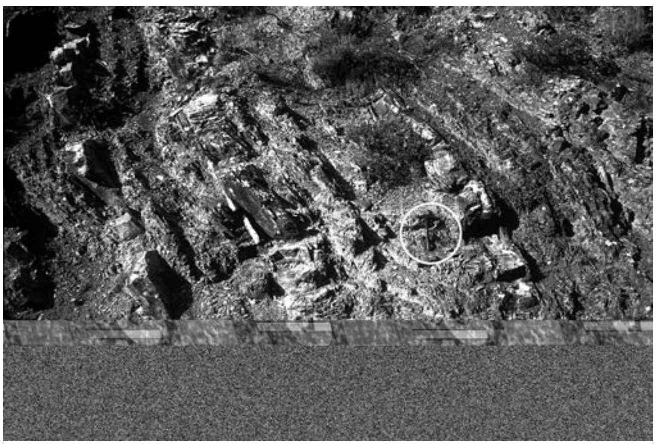

Fig. 4 - Outcrop of San Martino Fm. along the Railway Ponte Leccia-Ile Rousse. Hammer for scale. The bedding is overturned.

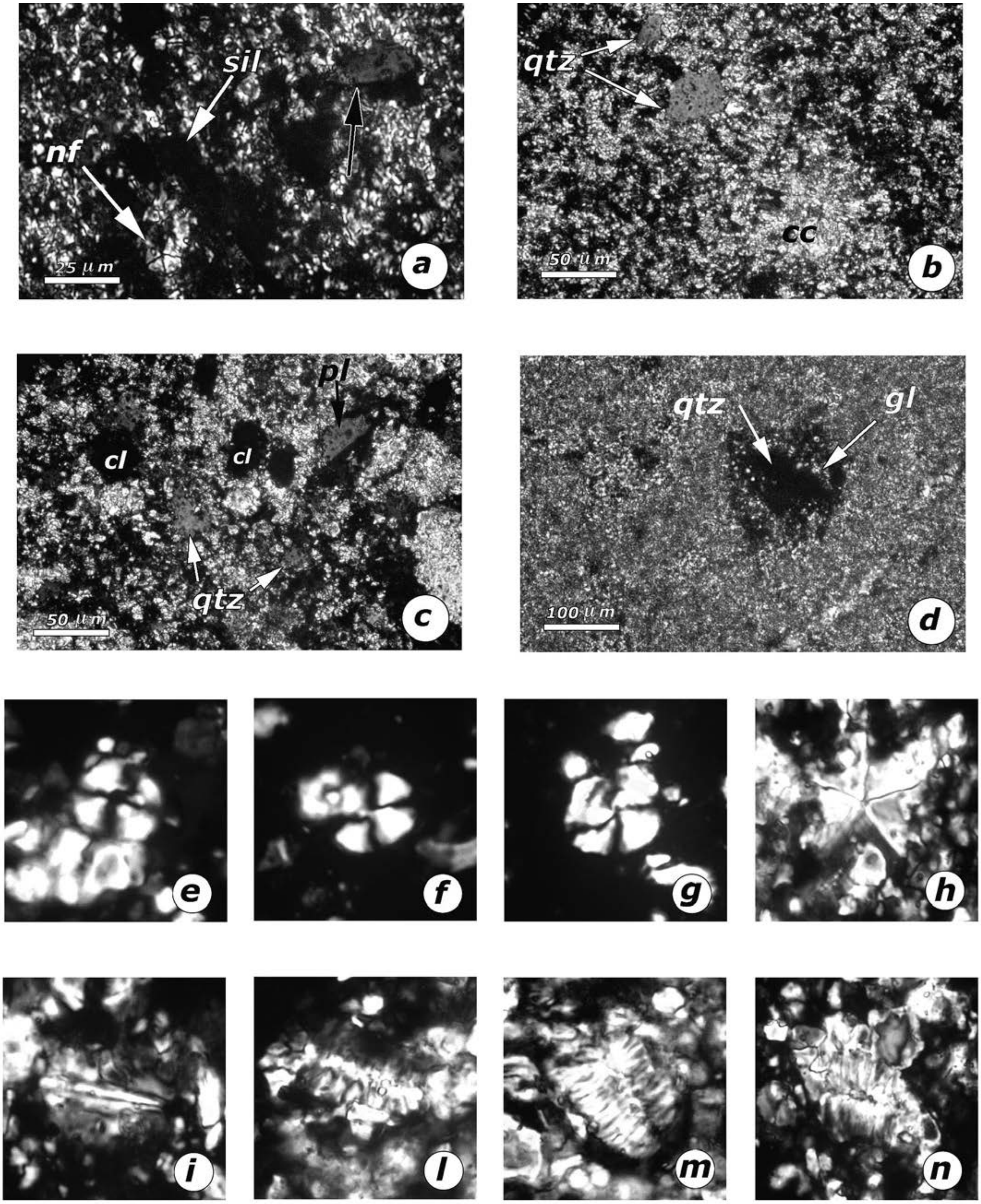

Fig. 5 - Ultrathin section photomicrographs of limestones and calcareous marlstones from San Martino Fm.: a. close up of a typical microfacies of calcilutite from sample 63 CON, XPL. Black arrow indicates a detrital quartz grain whereas white arrows indicate a *Micrantholithus hoschulzii* (nf) and a silicified area (sil). b. Photomicrograph of calcilutite from a limestone bed, 36 CON, XPL. Some detrital quartz grains (qtz) and an area characterized by recrystallization of calcite (cc) are indicated by arrows; c. Photomicrograph of a marlstone from the base of Lydienne Flysch, sample 67 CO, XPL. Notice the widespread occurrence of detrital grains made up by quartz (qtz), plagioclase (pl) and chlorite (cl). The dark area around the patchy calcite suffered a severe silicification; d. Photomicrograph of calcilutites from a limestone bed (sample 63 CO, XPL). A detrital quartz grain (qtz) is characterized by the presence of syntaxial quartz overgrowth. The ghost line (gl) indicate the original shape of the quartz grain. e-f. *Watznaueria barnesae.* g. *Watznaueria* sp. 1 h. *Micrantholithus hoschulzii.* i. *Lithraphidites carniolensis.* l-m. *Nannoconus steinmannii.* n. *Nannoconus colomii.* Magnification of Fig. 5 e-n about 3200x.

Table 1

Fm.	Age	Samples	Abundance	Preservation	*W. barnesae*	*Watznaueria* sp. 1	*A. infracretacea*	*N. steinmannii*	*N. colomii*	*N. globulus*	*M. hoschulzii*	*M. obtusus*	*B. bigelowii*	*C. mexicana*	*L. carniolensis*	*Rucinolithus* spp.	*Z. embergeri*
Lydienne Flysch	Late Hauterivian-Early Barremian	67	RF	MB	R		R	VR						VR		VR	VR
		67 u.s.	F	M	F		VR	F	VR	R	F						R
		66	RF	BM	R	VR	VR	VR		VR							
		66 u.s.	FC	M	F	VR	VR	C	VR	R	R		VR		VR		RF
S. Martino Fm.	Early Berrasian-Late Hauterivian	90	VR	VB	R	VR	VR							VR			
		90 u.s.	R	MB	VR			R		VR							VR
		89	R	B													
		88	VR	VB													
		87	VR	VB													
		86	VR	VB													
		85	VR	VB	VR												
		84	VR	VB													
		83	VR	VB	VR												
		82	VR	VB													
		81	VR	VB													
		80	VR	VB	VR												
		79	VR	VB													
		78	VR	VB	VR		VR							VR			
		77	VR	VB													
		76	VR	VB													
		75	R	B	R	VR								VR			
		74	R	B	R	VR	VR										
		74 u.s.	R	B	R			R									VR
		73	RF	B	R	VR	VR						VR	VR	VR	VR	VR
		73 u.s.	R	MB	VR			R							VR		VR
		72	VR	VB	R												
		71	VR	VB													
		70	VR	VB	VR							VR		VR	VR		
		70 u.s.	F	M	VR			F		VR		VR			VR		VR
		69	VR	VB													
		68	VR	VB			VR									VR	

Range chart of the Railway sections. Total abundance (C = Common: 1 or >1 specimen/s in each field of view; F = Few: 1 specimen in 2-10 fields of view; R = rare : 1 specimen in 11-30 fields of view; VR = Very rare : 1 specimen in more than 30 fields of view). Species abundance (C = Common: 1 specimen in each field/s 1-10 of view; F = Few: 1 specimen in 10-100 fields of view; R = rare : 1 specimen in 101-300 fields of view; VR = Very rare : 1 specimen in more than 300 fields of view). Preservation: M= Moderate (specimes show some dissolution and/or overgrowth; identification of species not impaired); B= Bad (specimes show significant dissolution and/or overgrowth; identification of species impaired but some still possible); VB = Very Bad (specimes show strong dissolution and/or overgrowth; identification of species is difficult and only few specimens are recognizable); u.s. = ultra-thin section; (1) age based also on the presence of *Hedbergella* spp (sample 66 CON).

Remarks

Hence, on the basis of the few useful fossiliferous samples, the following points should br underline:

1) The age of sampled succession is certainly post FO of *Nannoconus steinmannii*, that is the most proved and reliable Early Cretaceous Tethyan nannofossil event placed in the lower part of the Berriasian age (Bralower et al., 1989; Erba and Quadrio, 1987; Erba, 1989 and 1994). Since *Nannoconus steinmannii* disappears slightly below the well documented early Aptian “nannoconids crisis” (Erba, 1994), the entire sampled succession should be at

least referred to a time interval not older than Early Berriasian, and not younger than Early Aptian.

2) In the ultra-thin sections (fig. 5) the nannoconids with a narrow axial cavity as *Nannoconus steinmannii* are significantly present along with *Nannoconus globulus and Nannoconus colomii*. Instead, the absence of nannoconids referable to *Nannoconus truitti* group, that appears in the Barremian time (Bralower et al., 1989; Erba, 1989 and 1994; Cobianchi et al., 1997) is not referable to diagenetic and metamorphic depletion. Hence, the San Martino Formation is not older than Early Berriasian and not younger than Early Barremian.
3) The lower part of the Lydienne Flysch is not older than Late Hauterivian due to the presence of *Hedbergella* spp. (Coccioni & Premoli Silva, 1994; Cobianchi et al., 1997), and not younger than Early Barremian on the basis of the above-mentioned dominance of nannoconid specimens with narrow axial canal and the absence of specimens referable to *Nannoconus truitti* group;
4) If the base of the Lydienne Flysch can be probably referred to Late Hauterivian-Early Barremian time interval, the age reported in Marino et al. (1995) for this formation, as not older than Early Albian and not younger than Early Turonian, must be discussed. The succession sampled by Marino et al. (1995) is located in the northern side of the Balagne area where the upper part of the Lydienne Flysch crops out. Consequently, the age documented by Marino et al. (1995) can be likely referred to the younger levels of the Lydienne Flysch, whereas the age reported in this work is related to the older part of the same formation.

COMPARISON WITH THE PALOMBINI SHALE FROM NORTHERN APENNINE

In Northern Apennine as well as in the Western Alps, the Palombini Shale, everywhere associated to Chert and Calpionella Limestone represent the lower part of the deep-sea cover belonging to the typical Jurassic ophiolite sequence derived from the Ligure-Piemontese oceanic basin. In Alpine Corsica, the Jurassic ophiolite sequence from the Balagne nappe indicates a similar sedimentary cover, where the Chert and the Calpionella Limestone show a transition to San Martino Fm. (Nardi, 1968a; Durand-Delga, 1984). On the basis of both stratigraphic position and lithostratigraphic features the San Martino Fm. has been correlated with the Palombini Shale (Nardi, 1968a; Durand-Delga, 1984). In the Northern Apennine, the Palombini Shale occur in the succession of different tectonic units belonging to the Internal Liguride domain, respectively known as Bracco/Val Graveglia, Colli/Tavarone, Gottero and Portello units, (e.g. Decandia and Elter, 1972; Abbate et al., 1980; Marroni and Pandolfi, 1996; Ducci et al., 1997). In all these units, the Palombini Shale shows the same statigraphical and tectonic setting. By the available data, the base of the Palombini Shale from Internal Liguride units has been assigned to the lower part of the *Calcicalathina oblongata* zone (Early Valanginian) by nannofossil assemblages (Perilli and Nannini, 1997; Perilli, 1997). The top of the Palombini Shale has been in turn assigned to *Calculithes obscurus* zone (Late Santonian–Early Campanian) by Marroni and Perilli (1990). These data are coherent with the sedimentological features of the Palombini Shale, that suggest a low sedimentation rate in a deep-sea anorogenic setting as expected for a pelagic cover of the oceanic crust before the inception of any convergence-related tectonic event (Marroni et al., 1992). The data obtained for the San Martino Fm., indicating an age not older than Early Berriasian and not younger than Early Barremian, confirms the correlation with the Palombini Shale from Northern Apennine whose age ranges from Early Valanginian to Late Santonian–Early Campanian (Marroni and Perilli, 1990; Perilli and Nannini, 1997; Perilli, 1997). In this picture, the San Martino Fm. can be correlated with the lower part of the Palombini Shale from the Northern Apennine. Consequently, the upper part of this formation can be considered as time equivalent to the Lydienne Flysch. Accordingly, in the upper part of the Palombini Shale from the Portello unit, several medium-coarse grained beds, showing a mixed siliciclastic-carbonatic composition (fig. 6), have been recognized (Pandolfi, 1997). These beds are characterized by a composition made up of low grade metamorphic rocks, granitoid, acidic volcanics and Jurassic carbonate platform fragments. This composition, that points to a continental margin as source area, can be compared to that recognized in the Lydienne Flysch (Pandolfi, unpublished data). This correlation fits very well the proposed reconstruction of the Ligure-Piemontese oceanic basin during the “mid”-Cretaceous, where the Balagne nappe is probably representative of an area close to the Europe/Iberia continental margin (Durand-Delga et al., 1997), whereas the Internal Liguride units are located in the inner part of the same basin (Abbate et al., 1980; Marroni et al., 1992; Gardin et al., 1994). In this setting all the terrigenous deposits found in the ophiolitic successions from Internal Liguride units and Balagne nappe were supplied by the Europe/Iberia continental margin, characterized by a sharp ocean-continent transition inherited from the processes related to the oceanic opening (e.g. Amaudric du Chaffaut et al., 1984).

CONCLUSIONS

In this paper the age of the San Martino Fm. and the lower part of the Lydienne Flysch has been determined by the study of the calcareous nannofossil assemblages.

All the fossiliferous samples show scarce and bad preserved nannofossil assemblages that can be probably explained by concurrent diagenetic and metamorphic deple-

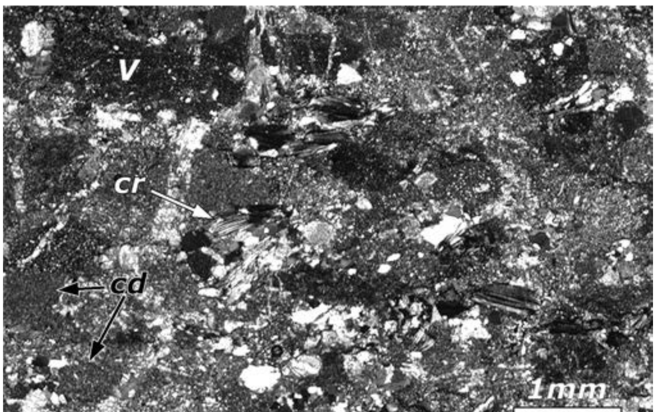

Fig. 6 - Photomicrograph of coarse grained beds belonging to the Palombini Shale of Internal Liguride units (Portello unit, Northern Apennine). A mixed composition characterized by carbonatic (cd), acidic volcanic (v) and crystalline (cr) debris can be recognized.

tion; also the samples preparation of the smear slide partly destroy the nannofossil assemblages. Nevertheless, the integrated study of smear slides and ultra-thin sections allow to recognize age-diagnostic nannofossil assemblages useful to improve the datings the San Martino Formation and the base of the Lydienne Flysch. All the species recognized are compatible with the age assigned and the identification of reworking is impaired.

On the basis of collected data the San Martino Fm. indicate an age not older than Early Berriasian and not younger than Early Barremian. In addition, the lower part of the Lydienne Flysch is not older than Late Hauterivian and not younger than Early Barremian. Because of the underlying Calpionella Limestone are assigned to the Tithonian-Early Berriasian on the basis of calpionellids (Bosma, 1956; Routhier, 1956; Nardi, 1968b), an Early Berrasian age for the base San Martino Fm should be inferred. In turn, the top of San Martino Fm. can be referred to Late Hauterivian to Early Barremian time span by the stratigraphic relationships with the Lydienne Flysch. Furtherly, these datings implie that the base of the Lydienne Flysch is older than reported by Marino et al. (1995).

By comparison with the data available from ophiolite sedimentary cover of Northern Apennine, the San Martino Fm. can be correlated with the lower part of the Palombini Shale. In this picture, the Lydienne Flysch can be regarded as time equivalent to the upper part of the Palombini Shale, where several medium-coarse grained beds showing the same composition of the Lydienne Flysch have been recognized (Pandolfi, 1997).

Acknowledgements

This research was supported by C.N.R., Centro di Studio per la Geologia Strutturale e Dinamica dell'Appennino (Pisa) and by M.U.R.S.T. (COFIN). The authors are much indebted to the two anonimous referres for the careful and constructive review.

REFERENCES

Abbate E., Bortolotti V. and Principi G., 1980. Apennine ophiolites: a peculiar oceanic crust. Ofioliti, Special Issue on Tethyan ophiolites, vol.I, western area, G.Rocci Ed., 5:59-96.

Amaudric du Chaffaut S., Bourbon M, de Graciansky P.C. and Lemoine M., 1984. Du Brianconnais à la Corse: modifications longitudinales d'une marge continentale passive de la Téthys Ligure. Mem. Soc. Geol. It., 28: 269-283.

Bosma W., 1956. Contribution à la géologie de la Balagne (Corse). Thése, Portieljie Ed.. 128 pp.

Bralower T.J., Monechi S. and Thierstein H.R., 1989. Calcareous Nannofossil Zonation of the Jurassic-Cretaceous Boundary Interval and Correlation with the geomagnetic Polarity Timescale. Marine Micropaleontology, 14: 153-235.

Cobianchi M., Luciani V. and Bosellini A., 1997. Early Cretaceous nannofossil and planctonic foraminifera from northern Gargano (Apulia, southern Italy). Cretaceous Research, 18: 249-293.

Coccioni R. and Premoli Silva I., 1994. Planktonic foraminifera from the Lower Cretaceous of Rio Argos section (southern Spain) and biostratigraphic implication. Cretaceous Research, 15, 645-687.

Dallan L. and Nardi R., 1984. Ipotesi dell'evoluzione dei domini "liguri" della Corsica nel quadro della paleogeografia e della paleotettonica delle unità alpine. Boll. Soc. Geol. It., 103: 515-527.

Dal Piaz G.V. et al., 1977. I complessi ofiolitici e le unità cristalline della Corsica alpina. Ofioliti, 2 (2-3): 265-324.

Decandia F.A. and Elter P., 1972. La "zona" ofiolitifera del Bracco, nel settore compreso tra Levanto e la Val Graveglia. Mem. Soc. Geol. It., 11: 503-530.

De Wever P., Danielan T., Durand-Delga M., Cordey F. and Kito F., 1987. Datations des radiolarites post-ophiolitiques de Corse alpine à l'aide des radiolaires. C. R. Acad. Sci. Paris, 305: 893-900.

Ducci M., Lazzaroni F., Marroni M., Pandolfi L. and Taini A., 1997. Tectonic framework of the Northern Ligurian Apennine, Italy. C. R. Acad. Sci. Paris, 324: 317-324.

Durand-Delga M., 1984. Principaux traits de la Corse Alpine et corrélations avec les Alpes Ligures. Mem. Soc. Geol. It., 28: 285-329.

Durand-Delga M., Priou-Lacazedieu A., Poignant A.F. and Raoult J.F., 1978. Age crétacé de formation détritiques de la nappe ophiolitifère de Balagne (Haute-Corse) et ses conséquences. C. R. Acad. Sci. Paris, 286:303-306.

Durand-Delga M., Peybernès B. and Rossi P., 1997. Arguments en faveur de la position, au Jurassique, des ophiolites de Balagne (Haute-Corse, France) au voisinage de la marge continentale européenne. C. R. Acad. Sci. Paris, 325: 973-981.

Egal E., 1992. Structures and tectonic evolution of the external zone of Alpine Corsica. Journ. of Structural Geology, 14: 1215-1228.

Erba E., 1989. Upper Jurassic to Lower Cretaceous Nannoconus distribution in some sections from Northern and Central Italy. Mem. di Scienze Geologiche, 41: 255-261.

Erba E., 1994. Nannofossils and superplumes: the early Aptian "nannoconods crisis". Paleoceanography, 9: 483-501.

Erba E. and Quadrio B., 1987. Biostratigrafia a nannofossili calcarei, calpionellidi e foraminiferi planctonici della Maiolica (Titoniano superiore-Aptiano) nelle Prealpi bresciane (Italia settentrionale). Riv. It. di Paleont. e Stratigrafia, 93: 3-108.

Fournier M., Jolivet L., Goffé B. and Dubois R., 1991. The Alpine Corsica metamorphic core complex. Tectonics, 10: 1173-1186.

Gardin S., Marino M., Monechi S. and Principi G., 1994. Biostratigraphy and sedimentology of the Cretaceous Ligurid Flysch: paleogeographic implications. Mem. Soc. Geol. It., 48: 219-235

Harris L., 1985. Progressive and polyphase deformation of the Schistes Lustrés in Cap Corse, Alpine Corsica. Journ. of Structural Geology, 7(6): 637-650.

Lacazedieu A., 1974. Contribution à l'étude géologique de la partie nord-est de la Balagne sédimentaire (Corse). Thése Doct.3e cycle, Univ. Paul Sabatier, Toulouse, 138pp.

Jolivet L., Daniel J.M. and Fournier M., 1991. Geometry and Kinematics of ductile extension in Alpine Corsica. Earth. Planet. Sci. Lett., 104. 278-291.

Malavieille J., Chemenda A. and Larroque C., 1998. Evolutionary model for the Alpine Corsica: mechanism for ophiolite emplacement and exhumation of high-pressure rocks. Terranova, 10(6): 317-322

Marino M., Monechi S. and Principi G., 1995. New calcareous nannofossil data on the Cretaceous-Eocene age of corsican turbidites. Riv. It. Paleontologia e Stratigrafia, 101 (1): 49-62.

Marroni M. and Pandolfi L., 1996. The deformation history of an accreted ophiolite sequence: the Internal Liguride Units (Northern Apennines, Italy). Geod. Acta, 9 (1): 13-29.

Marroni M. and 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, 15: 251-269.

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

Mutti E., 1992. Turbidite sandstones. AGIP - Istituto di Geologia Università di Parma, 275pp., San Donato Milanese.

Nardi R., 1968a. Le unità alloctone della Corsica e la loro correlazione con le unità delle Alpi e dell'Appennino. Mem. Soc. Geol. It., 7 (2): 323-344.

Nardi R., 1968b. Contributo alla geologia della Balagne (Corsica nord-occidentale). Mem. Soc. Geol. It., 7 (2): 471-489.

Nardi R., Pucinelli A. and Verani M., 1978. Carta geologica della Balagne "sedimentaria" (Corsica) alla scala 1:25.000 e note illustrative. Boll. Soc. Geol. It., 97: 3-22.

Pandolfi L., 1997. Stratigrafia ed evoluzione strutturale delle successioni torbiditiche cretacee della Liguria orientale (Appennino Settentrionale). PhD Thesis, Pisa University. 175pp.

Perilli N., 1997. Lower Cretaceous nannofossil biostratigraphy of the Calpionella Limestone and the Palombini Shale in Southern Tuscany (Italy). Rev. Esp. de Paleont., 12: 1-14.

Perilli N. and Nannini D., 1997. Calcareous nannofossil biostratigraphy of the Calpionella Limestone and Palombini Shales (Bracco/Val Graveglia Unit) in the Eastern Ligurian Apennines (Italy). Ofioliti, 22: 213-225.

Routhier P., 1956. Etude géologique de la Balagne sédimentaire (Corse septentrionale). Bull. Serv. Carte géol. France, 249: 265-293.

Sagri M., Aiello E. and Certini L., 1982. Le unità torbiditiche cretacee della Corsica. Rend. Soc. Geol. It., 5: 87-91.

Warburton J., 1986. The ophiolite-bearing schistes lustrés nappe in Alpine Corsica: a model for the implacement of ophiolites that have suffered HP/LT metamorphism. Geol. Soc. of Am. Mem., 164: 313-331.

Received, September 1, 2000
Accepted, November 20, 2000