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Stratigraphic and structural features of the Bas Ostriconi Unit (Corsica): Palaeogeographic implications

Luca Pandolfi [a,c,*], Michele Marroni [a,c], Alessandro Malasoma [b]

[a] *Dipartimento di Scienze della Terra, Università di Pisa, Via S. Maria 53, 56126 Pisa, Italy*
[b] *TS Lab and geoservices, Via Vecchia Fiorentina, 10, 56023 Cascina (Pisa), Italy*
[c] *Istituto di Geoscienze e Georisorse, CNR, Via S. Maria 53, 56126 Pisa, Italy*

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ABSTRACT

The palaeogeographic origin of the Bas Ostriconi Unit (Balagne area, Alpine Corsica) has long been a matter of debate. This unit is actually detached from its original basement. It is made of Late Cretaceous carbonatic turbidites with lenses of coarse-grained polymict conglomerates (Narbinco Flysch). The turbidites have a mixed siliciclastic-carbonatic composition and are affected by a polyphasic deformation. Here, based on field observations and sampling, we analyse the sedimentary, petrographic, and structural features of the Narbinco Flysch. From these analyses, we derive that the Narbinco Flysch belongs to the sedimentary cover of the Balagne ophiolite Nappe. We also show that the carbonatic turbidites are associated with mixed siliciclastic-carbonatic coarse-grained debris, which is typical of the turbidite sediments deposited during the Late Cretaceous in the Ligure-Piemontese oceanic basin close to the European Margin. Our results thus suggest that, the Bas Ostriconi Unit succession originally formed on the Ligure-Piemontese oceanic crust, then was integrated to the accretionary wedge that was thrusted on the European margin of Corsica during the Eocene collisional events.

1. Introduction

The Balagne region, in northern Corsica, is made of a complex stack of tectonic units stemming from both the oceanic Ligure-Piemontese basin and the adjacent Europe continental margins. These tectonic units represent the uppermost nappes of the Alpine tectonic edifice in Corsica. They include several very low-grade metamorphic units; among these, the Bas Ostriconi Unit crops out in northern Balagne. The Bas Ostriconi Unit consists of a Late Cretaceous sedimentary succession that has been detached from an unknown basement (oceanic vs. continental).

The models proposed for the closure of the Ligure-Piemontese oceanic basin and the Alpine Corsica mountain building (e.g., Argnani, 2012; Dallan and Nardi, 1984; Durand-Delga, 1984; Waters, 1990; Egal, 1992; Malavieille et al., 1998; Marroni and Pandolfi, 2003; Molli, 2008; Molli and Malavieille, 2011; Nardi, 1968; Principi and Treves, 1984 and many others) differ in their interpretation of the Bas Ostriconi Unit, especially its palaeogeographic location during the Mesozoic–Early Tertiary and its subsequent evolution during the closure of the Ligure-Piemontese oceanic basin (for a discussion, see Molli and Malavieille, 2011). For instance, Malavieille et al. (1998) have suggested that the Bas Ostriconi Unit succession formed originally in a basin located close to the Adria continental margin, and then was displaced westward; Durand-Delga (1984) has conversely proposed that the unit formed at the opposite side of the Ligure-Piemontese basin, close to the

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[*] Corresponding author. Dipartimento di Scienze della Terra, Università di Pisa, Via S. Maria, 53, 56126 Pisa, Italy.
E-mail address: pandolfi@dst.unipi.it (L. Pandolfi).

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European continental margin. More recently, Argnani et al. (2006) have proposed an alternative interpretation where the deposits of the Bas Ostriconi Unit were sedimented in a basin located along a transform fault zone separating two subduction zones with opposite dipping.

However, available stratigraphic and structural data are too few to validate any of these scenarios and the interpretations proposed are not supported by reliable constraints.

The aim of this work is to provide detailed stratigraphic, petrographic and structural data to constrain the paleogeography and palaeotectonic evolution of the Bas Ostriconi Unit.

The new data derived from field observations, measurements and sampling. We discuss them in the framework of the geodynamic evolution of the Ligure-Piemontese basin and we propose a correlation between the Bas Ostriconi Unit and the units from northern Apennines and Alpine Corsica.

2. Geological setting

According to Durand-Delga (1984), Corsica can be divided into two distinct geological domains, Hercynian and Alpine Corsica (Fig. 1a). The western domain (i.e. the Hercynian Corsica) is represented mainly by Carboniferous to Permian granitoids intruded into a Palaeozoic basement unconformably covered by Jurassic to Middle Eocene deposits (e.g., Rossi et al., 2009). The eastern domain (i.e. Alpine Corsica) consists of a complex stack of tectonic units

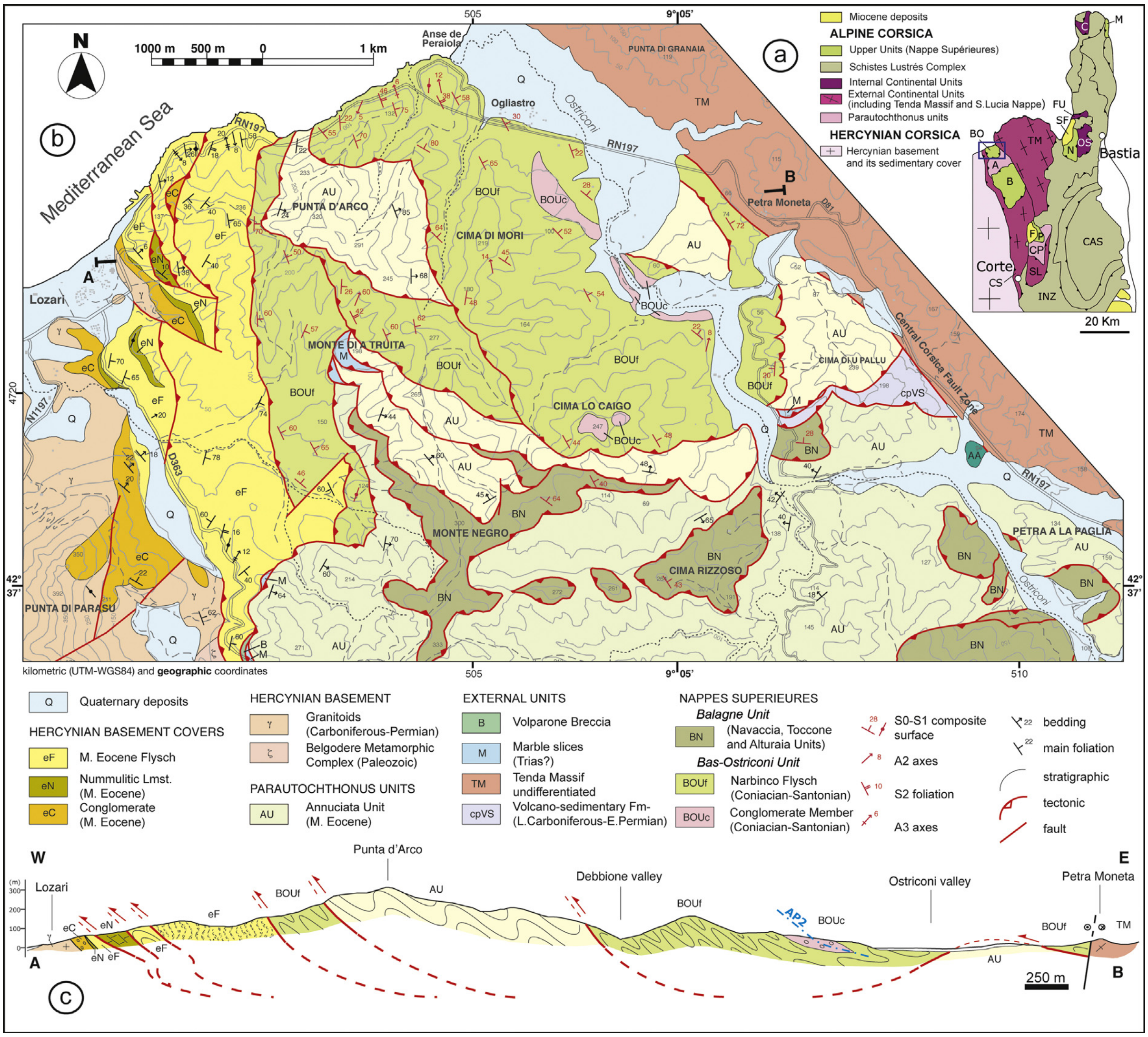


Fig. 1. Geology of the study area: a: tectonic sketch map of north-western Corsica. The boxed area indicates the location of b. 1 – Miocene deposits (SF – Saint-Florent basin; F – Francardo basin). 2 – Nappe supérieures (M – Macinaggio Unit; N – Nebbio Unit; BO – Bas Ostriconi Unit; B – Balagne Nappe; P – Pineto Unit). 3 – Schistes lustrés Complex (CAS – Castagniccia Unit; INZ – Inzecca Unit). 4 – Internal Continental Units (C – Centuri Unit; FU – Farinole Unit; OS – Oletta-Serra di Pigno Unit). 5 – External Continental Units (TM – Tenda Massif; SL – S. Lucia Unit; CS – Sorte slices). 6 – Parautochthonus Units (A – Annunciata Unit; CP – Caporalino–S. Angelo Unit); b: geological map of the Bas Ostriconi Unit in northern Balagne (from original geological survey); c: geological cross section A–B, the location is indicated in b.

derived from both oceanic and continental domains. The oceanic units are remnants of the Ligure-Piemontese oceanic basin, which was existing between the European and the Adria continental margins during the Middle to Late Jurassic (e.g., Marroni and Pandolfi, 2007). Then, from Late Cretaceous to Late Eocene times, the European and Adria plates entered into convergence, and this led to the progressive closure of the Ligure-Piemontese basin. An intra-oceanic subduction first operated, followed by a continental subduction and collision (e.g., Molli, 2008). The convergence ceased by the Early Oligocene. It was then followed by large-scale extension (e.g., Zarki-Jakni et al., 2004).

The subduction-related tectonic events are well recorded in the "Schistes lustrés Complex". This metamorphic complex consists of ophiolitic and continental sequences that were deformed under eclogite and blueschist facies conditions (e.g., Vitale Brovarone et al., 2013) from the Late Cretaceous to the Early Tertiary (Vitale Brovarone and Herwartz, 2013 and references therein) in an east-dipping subduction zone (e.g., Molli and Malavieille, 2011).

The Schistes lustrés Complex is underlain by several tectonic units known as the "External Continental Units" (S. Lucia Nappe, Corte Units, and Tenda Massif; Egal, 1992). Those are considered as fragments of the European continental margin that were involved in the collision (e.g., Malasoma et al., 2006). Although most of these units are commonly regarded as weakly metamorphosed, some are affected by a HP/LT metamorphism of Tertiary age likely related to the collisional tectonics (e.g., Maggi et al., 2012).

At the top of the Schistes lustrés Complex, an assemblage of very low-grade metamorphic units (*nappes supérieures*; Durand-Delga, 1984) crops out. These units are mainly represented by ophiolitic units (Balagne, Nebbio, Pineto, and Bas Ostriconi Units) associated with Late Cretaceous carbonate turbidites (i.e. Bas Ostriconi and Macinaggio Units).

The tectonic units of Alpine Corsica are sealed by Miocene (Burdigalian–Langhian) sedimentary basins that crop out in the Saint-Florent and Francardo areas (Cavazza et al., 2001 and references therein).

3. Geology of northern Balagne

The study area is located in the Balagne region (northern Corsica), an area extending from L'Île Rousse and the Ostriconi Valley to Ponte Leccia. The region hosts a stack of tectonic units (*Nappes supérieures Auctt.*), derived from both oceanic and continental domains, belonging to "Alpine Corsica" (Rossi et al., 2001 and references therein). The whole unit stack is folded in a large-scale synform having a north–south trend. In the western side of the Balagne area, the units stack is thrust westwards onto the Hercynian basement and its Middle Eocene sedimentary cover. To the east, the broad-scale structure is bounded by a large-scale, high-angle fault that separates the Balagne area from the Tenda Massif (Fig. 1). This fault is generally regarded as part of a major north–south-trending transcurrent fault system (Central Corsica Fault Zone, Lacombe and Jolivet, 2005). The uppermost units (cf. *Nappes supérieures Auctt.*) are represented by the oceanic Balagne Nappe, which crops out in the area between Novella and the Asco Valley and by the Bas Ostriconi Unit, which crops out in the area between the Lozari Village and the lower Ostriconi Valley (Fig. 1b). The Balagne Nappe is made of a Jurassic ophiolite sequence and of an Upper Jurassic–Upper Cretaceous sedimentary cover that includes pelagic and deep-sea mixed carbonate-siliciclastic turbidite deposits. The Balagne Nappe consists of three different tectonic units referred to as the Navaccia, Toccone, and Alturaja Units (Marroni and Pandolfi, 2003). The Balagne ophiolite sequence is made of an oceanic basement represented by mantle ultramafics, intruded by a gabbroic complex and covered by basalts showing pillow lava to pillow breccia textures (Marroni and Pandolfi, 2003). According to Durand-Delga et al. (1997) and Saccani et al. (2000), the geochemical features of the basalts reveal an E-MORB affinity, typical of a crust developed during the first stage of oceanic spreading. The ophiolites are overlain by radiolarian-bearing cherts (Middle Callovian–Kimmeridgian), the Calpionella Limestone (Tithonian–Early Berriasian) generally characterized by interbedded coarse mixed-debris strata (e.g., in the San Colombano area), the San Martino Formation (Early Berriasian–Late Hauterivian/Early Barremian) and the Lydienne Flysch (Late Hauterivian/Early Barremian to Early Turonian). The Lydienne Flysch shows vertical and lateral stratigraphic relationships with the Toccone Breccia, the Novella Sandstone (cf. Gare de Novella Sandstone) and the Alturaja Arkose (Late Barremian–Aptian, Marroni et al., 2004 and references therein).

Previous studies suggest that the Balagne Nappe recorded five deformation phases, from D1 to D5. The D1 phase is interpreted as the Latest Cretaceous/Palaeocene episode of deformation of the accretionary wedge that formed in an east-dipping subduction zone. The Late Eocene D2 phase was related to the final emplacement of the nappe onto the Europe/Corsica continental margin. A subsequent D3 deformation phase was characterized by sinistral strike-slip faulting of Late Eocene–Early Oligocene age. Eventually, two extensional D4 and D5 phases occurred during the Early Oligocene–Late Miocene extension, possibly as a result of the gravitational collapse of the Alpine belt (Marroni and Pandolfi, 2003 and references therein).

The Bas Ostriconi Unit shows a succession that includes Late Cretaceous carbonatic turbidites with lenses of coarse-grained polymict conglomerates referred to as the Narbinco Flysch. It is divided into three subunits bounded by north–south-trending westward vergent thrusts (Fig. 1c): between Palasca and the Ostriconi Valley, the "Annunciata Unit" (cf. Palasca Unit after Nardi et al., 1978), belonging to the "parautochthonous domain" (Durand-Delga, 1984; Nardi et al., 1978), extends below the oceanic units. It consists of well-bedded, siliciclastic turbidites of Middle Eocene age, known as Annunciata Formation (Durand-Delga, 1984). During our fieldwork, we found no evidence of stratigraphic relationships between the Narbinco Flysch and the Annuciata Formation.

Below the *Nappes supérieures* and the Annunciata Unit, several tectonic slices derived from the European continental margin crop out (Fig. 1; Marroni and Pandolfi, 2003;

Nardi et al., 1978). These slices, that are correlated with the External Continental Units, include basement rocks (Permian granitoids and their Palaeozoic host rocks), Volparone Breccia (polymict coarse-grained deposits), marbles and metalimestones. These units recorded different phases of deformation of Alpine age, associated with metamorphic recrystallization of mineral assemblages indicative of HP/LT metamorphism (Malasoma and Marroni, 2007).

Finally, the lowermost structural level of the Balagne area is represented by the Hercynian Corsica domain, which consists of gneisses, micaschists, and associated amphibolites of Palaeozoic age (Belgodere Complex) intruded by granitoids of Carboniferous–Permian age and cut by a Permian dyke complex (e.g., Menot and Orsini, 1990). This basement is covered by conglomerates showing a transition to nummulite-bearing limestones and siliciclastic turbiditic deposits of Middle Eocene, mainly of Lutetian age.

4. Stratigraphy and petrography of the Bas Ostriconi succession

The Bas Ostriconi Unit is made of Late Cretaceous carbonate turbidites – the Narbinco Flysch – with lenses of coarse-grained polymict conglomerates.

The Narbinco Flysch (cf. Flysch Calcareo of Nardi et al., 1978) is characterized by medium- to coarse-grained arenites up to fine-grained rudites capped by thick marls or calcareous marls with an arenite/pelite ratio generally $<< 1$ (Fig. 2a and b). The Narbinco Flysch is also characterized by lenticular coarse-grained megaripple beds (from coarse sands up to small pebbles, F6 facies of Mutti, 1992) directly capped by marls and calcareous marls (Fig. 2c). The sharp change in grain size as well as the presence of megaripples indicates a sediment by-pass zone (Mutti, 1992). These features are common in the sedimentary cover of the Balagne Nappe (cf. Lydienne Flysch, Toccone Breccia, and Novella Sandstones). The conglomerates (Fig. 2d) are characterized by a clast-supported texture (F3 facies of Mutti, 1992) consistent with their deposition in poorly evoluted turbidites (Mutti, 1992).

According to Marino et al. (1995), the nannofossils found in the Narbinco Flysch indicate an age not older than Latest Coniacian, probably Campanian according to the occurrence of *Quadrum Gothicum* (Deflandre).

We sampled 22 arenites to fine-grained rudites from the Narbinco Flysch and 15 clasts from the Conglomerates lithofacies, on which we performed petrographic thin-section analysis. Note that we selected samples representative of the lithological distribution and showing a low degree of alteration. Among these samples, we selected 10 medium–coarse-grained arenites from the Narbinco Flysch, to perform modal analysis and compared the results with those on the Corsica arenites data set (Bracciali et al., 2007 and references therein). We also performed petrographic analysis on thin sections from conglomerates clasts, to identify representative rock types of the source areas.

The clasts in the conglomerates are igneous (intrusive, volcanic and sub-volcanic rocks), low-grade and very low-grade metamorphic and carbonate sedimentary rocks. Intrusive rocks are represented by monzogranites (Fig. 2e), while volcanic rocks are characterized by dacites and pyroclastic rhyolites with variable amounts of quartz. Pebbles of sub-volcanic dacite and rhyolite porphyries were also observed. Low-grade metamorphic pebbles are common; they are muscovite-bearing micaschists and muscovite and/or biotite-bearing gneisses. Limestone pebbles are carbonate platform derived rocks, mainly oolitic grainstones and micritic mudstones of Triassic–Jurassic age. The allochems in the grainstone pebbles are peloids, ooids, and undeterminable benthonic foraminifera and macrofossil fragments (Fig. 2f).

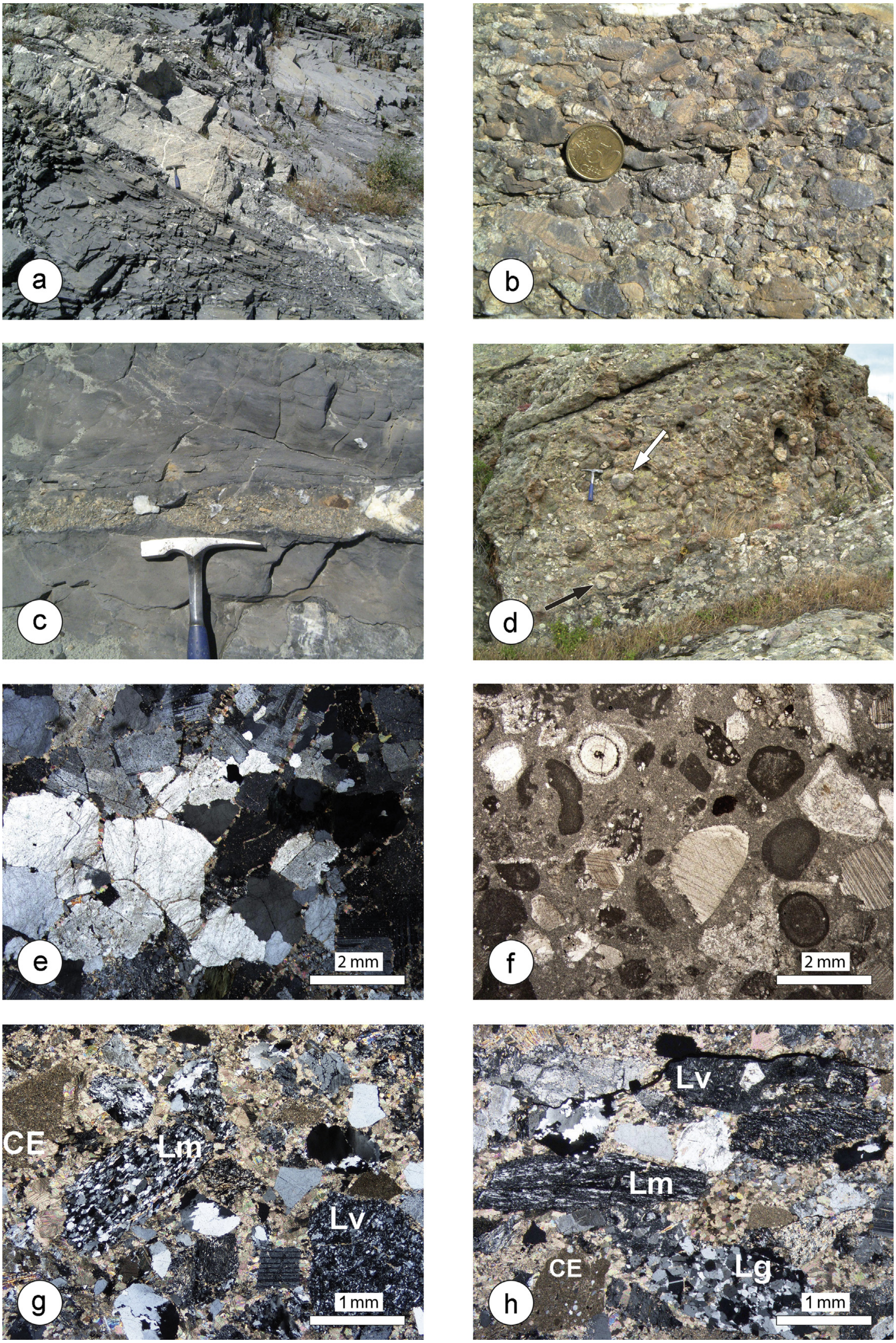
We performed a modal analysis on the arenitic fraction to estimate the contribution of the different rock types recognized in the ruditic fraction. We conducted point counting (500 points) of arenites using the Gazzi–Dickinson technique (Dickinson, 1970; Gazzi, 1966; Ingersoll et al., 1984; Zuffa, 1987) to minimize the dependence of arenite composition on grain size. All point-counted arenites were stained for plagioclase and K-feldspar using the sodium cobaltinitrite (Houghton, 1980) and Alizarin-red-S plus potassium ferricyanide solutions for carbonate identification (Lindholm and Finkelman, 1972). The calculated grain parameters are reported in the Table of Fig. 3a.

The analysed arenites from the Narbinco Flysch (Figs. 2g–h and 3) are sublitharenites and subarkoses ($Q_{40}F_{28}L_{32}$) characterized by a mixed siliciclastic-carbonate framework composition ($NCE_{85}NCI + CI_{1}CE_{14}$) showing a volcanoclastic-dominated composition of the fine-grained lithic fragments ($Lm_{28}Lv_{71}Ls_{1}$).

The extrabasinal siliciclastic framework is characterized by a widespread presence of mono- and polycrystalline quartz (38 ± 5%), plagioclase (18 ± 5%), and K-feldspar (10 ± 3%). Lithic volcanic fragments are widespread (28 ± 4%) and include rhyolite and dacite fragments (Fig. 3a) with a porphyritic texture. Intrusive derived lithic fragments, such as granitoids, are widespread as coarse-grained rock fragments (12 ± 3%). Metamorphic rock fragments include coarse-grained gneisses and fine-grained low-grade schists, micaschists, and metaquartzites (fine-grained lithic fragments 15 ± 3%). Lithic sedimentary fragments (fine-grained arenites and siltstones) are scarce or lacking. Ophiolite-derived fragments, such as serpentinites, gabbros, MOR basalts or radiolarites were never observed. Clasts of aphyric to porphyritic basalts were found throughout the entire stratigraphic succession. These rocks were classified as transitional to tholeiitic within-plate basalts by Marroni et al. (2001).

Carbonate extrabasinal fragments represent an important part of the total framework (14 ± 3%). This group is represented by limestone fragments generally composed by oolitic grainstones (Fig. 3), and micritic mudstones.

The observations above thus show that both the arenites and the conglomerates from the Narbinco Flysch have a mixed siliciclastic-carbonatic composition stemming mainly from acidic volcanics, extrabasinal platform carbonates, granitoids, and low-grade metamorphic source rocks. We found no evidence of fragments of lower continental crust or subcontinental mantle or of fragments derived from ophiolite sequences. The composition of the


a
b
c
d
e
2 mm
f
2 mm
CE
Lm
Lv
g
1 mm
Lv
Lm
CE
Lg
h
1 mm

Narbinco Flysch is thus similar to that of the Lydienne Flysch, the Toccone Breccia and the Novella Sandstone (Bracciali et al., 2007), which altogether belong to the Cretaceous turbiditic cover of the Balagne Nappe (Fig. 3).

The mixed composition of the Narbinco Flysch suggests a source area located in the uppermost part of a continental lithosphere, likely a continental margin having a Triassic–Jurassic carbonate platform. This source area can be identified in the European margin represented by the Hercynian basement and its Triassic–Jurassic sedimentary cover.

5. Deformation history of the Bas Ostriconi Unit

We analysed the deformations of the Bas Ostriconi Unit based on a 1:10,000 geological map (Fig. 1b) that we built from our field observations and measurements. During the survey, we collected mesoscopic structural data in the entire study area. We performed additional microstructural analyses on thin sections of samples collected during fieldwork. From this tectonic analysis, we infer a deformation history that likely includes four phases of deformation, hereafter referred to as D1, D2, D3, and D4. The four phases were recognised throughout the whole Bas Ostriconi Unit.

As we could observe in the fine-grained rocks (mainly siltstones and mudstones of the Narbinco Flysch), the D1 phase is characterised by a pervasive S1 foliation parallel or at low angle to the S0 bedding. Several bedding-parallel calcite veins, with a thickness ranging from 2–3 mm to 6–7 cm, can be assigned to the D1 phase. We could not identify any folds related to the D1 phase. The S1 foliation is well recognizable in the hinge zone of the F2 folds (see below), where the crosscutting relationship between S1 and S2 foliations is well preserved. Along the F2 fold limbs, a composite foliation resulting from the overlap of the S1 and S2 foliations can be observed. Along the S1 foliation, asymmetric pressure shadows have grown around pyrite crystals. When restored from the subsequent deformation phases, these structures suggest a top-to-the-west sense of shear (Fig. 4a). The original attitude of the S0/S1 surface has been modified by the subsequent deformation phases, particularly by the D2 phase (Fig. 5a).

At the microscopic scale (Fig. 4b), the S1 foliation, in pelites, appears as a penetrative and continuous slaty cleavage characterized by elongated quartz–albite–calcite–mica aggregates surrounded by fine-grained, aligned recrystallized phyllosilicates (white mica, chlorite and stilpnomelane). This deformation mechanism mainly consists of moderate recrystallization associated with pressure-solution parallel to the S1 foliation.

The most widespread structures in the field are those related to the D2 phase. The structures are mainly asymmetric F2 folds with interlimb angles ranging from 45° to 75°. Most F2 folds show a fairly similar geometry with subrounded to rounded hinge zones (Fig. 4c). The more competent layers are affected by boudinage along the F2 fold limbs whereas the fine-grained layers show pinch and swell structures. The asymmetry of the F2 folds, as seen also at map-scale, suggests a westward vergence. The F2 folds show a S2 foliation everywhere parallel or sub-parallel to the F2 fold axial planes. Generally, the S2 foliation is refracted at the boundary between the different layers, because of the strong contrast of competence between the layers with different grain sizes. Fibrous, calcite veins at high angle to the bedding S0 generally developed during the D2 phase. During the D2 phase, low-angle thrusts that bound the subunits of the Bas Ostriconi Unit developed. These high to medium (from 40° to 70°) angle thrusts strike from north–south to NNE–SSW and dip from east to ESE. Kinematic indicators, such as S–C structures, reveal a top-to-the-west sense of shear on these thrusts.

The stereographic plots show that F2 folds have subhorizontal A2 axes with a NW–SE direction (Fig. 5b). The S2 foliation is generally subhorizontal or at low angle (Fig. 5c). The PA2 axial planes show NW–SE strike with dipping ranging from subhorizontal to vertical, likely as a result of their overprinting by the subsequent deformation phases (Fig. 5d).

The S2 foliation is a crenulation cleavage characterised by a gradational transition between cleavage domains and microlithons (Fig. 4b). During the D2 phase, recrystallization of quartz and calcite occurred.

The D3 phase is characterised by gentle to open, asymmetric F3 folds with interlimb angles ranging from 80° to 130°. The A3 axes show a north–south trend, whereas the AP3 axial planes are subhorizontal or low-angle surfaces generally westward dipping (Fig. 4d). The interference pattern derived from the overprinting of F3 folds onto the F2 folds is generally a type 3 of Ramsay (1967); the two generation of folds have sub-parallel axes and orthogonal axial planes (Fig. 5a–d). In the F3 hinge zones, the S3 axial-plane foliation is represented by a spaced, disjunctive cleavage. It seems that, during D3 phase, some of the D2 thrust faults were reactivated as low-angle normal faults as suggested by the occurrence of a different generation of kinematic indicators along the same shear zone.

The whole stack of tectonic units that crops out in the Balagne region (Bas Ostriconi Unit included) was then deformed in a broad synform during the D4 phase. The F4 folds have north–south-trending axes and sub-vertical AP4 axial planes. A well-developed sub-vertical joint system is associated with the D4 phase. The joints are generally arranged in two (centimetric to decimetric) pervasive conjugate systems, trending from N 70°E to N 20°E.

6. The Narbinco Flysch as part of the sedimentary cover of the Balagne Nappe

The collected data indicate a resemblance between the stratigraphic and structural features of the Bas Ostriconi Unit and of the Balagne Nappe.

Fig. 2. Stratigraphy features of the Narbinco Flysch. a: field view of the Narbinco Flysch in the Ostriconi area (RN197); b: ruditic polymict levels associated with the Narbinco Flysch, Ostriconi Plage; c: lenticular coarse-grained beds megaripple directly capped by marls and calcareous marls; d: meter-thick level of polymict well-rounded and matrix-supported conglomerates associated with the Narbinco Flysch, Cima lo Caigo area; e: photomicrographs of granitoid pebbles (black arrow in d); f: carbonate platform limestone pebbles (white arrow in d) from conglomerates associated with the Narbinco Flysch; g and h: photomicrographs of the typical petrofacies of the Narbinco Flysch arenites. CE: extrabasinal micritic mudstone rock fragment; Lm: low-grade metamorphic rock fragment; Lv: volcanic rock fragment; Lg: granitoid rock fragment. Samples BS77 (g) and BS79 (h).

			SAMPLE	BS65	BS73	BS74	BS77	BS79	BS80	BS82	BS83	BS84	BS85
			LAT (N)	42°39'26"	42°39'19"	42°39'19"	42°39'23"	42°39'22"	42°39'21"	42°39'32"	42°39'32"	42°39'32"	42°39'27"
			LONG (E)	9° 3'12"	9° 3'27"	9° 3'26"	9° 3'21.39"	9° 3'22.30"	9° 3'24"	9° 3'15"	9° 3'13"	9° 3'13"	9° 3'18"
			arenite grain size	medium	medium coarse	medium coarse	medium coarse	medium coarse	medium	medium coarse	medium	medium	medium coarse
			sorting (according Longiaru *et alii*, 1987)	B	B/C	B	B/C	B/C	B/C	C	B/C	C	B
			counted points	500	500	500	500	500	500	500	500	500	500
NCE	Q		Q coarse quartz single crystal	1	7	6	9	8	6	1	0	2	6
			Q medium quartz single crystal	87	84	39	44	57	67	49	76	51	45
			Q medium quartz polycrystalline	19	18	25	31	32	27	37	33	33	32
			Q quartz in granitoid r.f.	23	13	18	15	12	13	19	16	12	11
			Q quartz in low grade metamorphic r.f.	6	4	20	24	19	25	12	31	23	13
			Q quartz in felsic volcanic r.f.	18	9	9	11	8	8	22	16	7	17
			Q quartz in arenites r.f.	2	0	1	0	0	2	1	2	0	0
	F		K-feldspar single crystal	15	33	22	13	24	36	14	15	19	15
			K-feldspar in granitoid r.f.	16	9	3	7	12	13	18	12	12	13
			K-feldspar in low grade metamorphic r.f.	1	0	0	2	1	0	0	2	0	0
			K-feldspar in felsic volcanic r.f.	2	7	0	2	1	8	12	7	2	0
			Pl plagioclase single crystal	16	29	37	35	49	38	37	18	53	49
			Pl plagioclase in granitoid r.f.	8	9	33	17	18	23	33	11	19	24
			Pl plagioclase in low grade metamorphic r	1	2	5	9	12	11	3	8	7	9
			Pl plagioclase in felsic volcanic r.f.	1	4	7	7	0	2	5	4	0	4
	L	Lm	low grade metamorphic r.f.	23	38	33	31	25	23	30	31	28	32
			very low grade metamorphic arenite r.f.	10	2	0	4	1	2	0	0	5	2
		Lv	felsic volcanic r.f.	83	71	55	105	75	80	83	65	88	99
			femic volcanic r.f.	0	2	1	4	9	2	0	4	2	0
			phyllosilicate single crystal	5	2	8	0	2	2	3	0	0	0
			phyllosilicate in crystalline s.l. r.f.	2	0	12	2	1	0	0	8	2	0
			phyllosilicate in low grade metamorphic r.	1	2	5	11	0	0	9	4	2	6
			heavy mineral s.l.	5	0	1	0	4	3	1	0	1	2
			oxide single crystal	0	2	1	0	5	0	0	1	2	0
			organic matter	2	0	8	2	0	0	0	1	0	0
CE			micritic mudstone r.f.	69	40	32	35	29	29	37	41	49	32
			grainstone r.f.	6	13	15	13	7	11	18	18	14	9
			bioclast	1	4	2	7	8	0	0	5	0	0
			dolomia r.f.	3	4	11	9	7	2	12	3	5	6
NCI			pelitic rip-up (clay chips) r.f.	5	7	8	2	3	0	1	11	5	4
			Limeclast	2	2	5	7	9	4	3	7	7	3
			undeterminated r.f.	4	4	1	0	1	0	2	0	0	2
			alterite	15	7	11	9	3	4	1	1	9	6
			total framework (counted points)	452	428	434	467	442	441	463	451	459	441
			framework	452	428	434	467	442	441	463	451	459	441
			siliciclastic matrix	27	21	18	15	12	13	7	11	9	18
			patchy calcite	15	31	17	11	17	17	21	18	21	17
			calcite pore-filling cement	1	2	15	0	4	4	9	2	9	11
			post-depositional metamorphic calcite	5	18	16	7	25	25	0	18	2	13
			total counted points	500	500	500	500	500	500	500	500	500	500

a

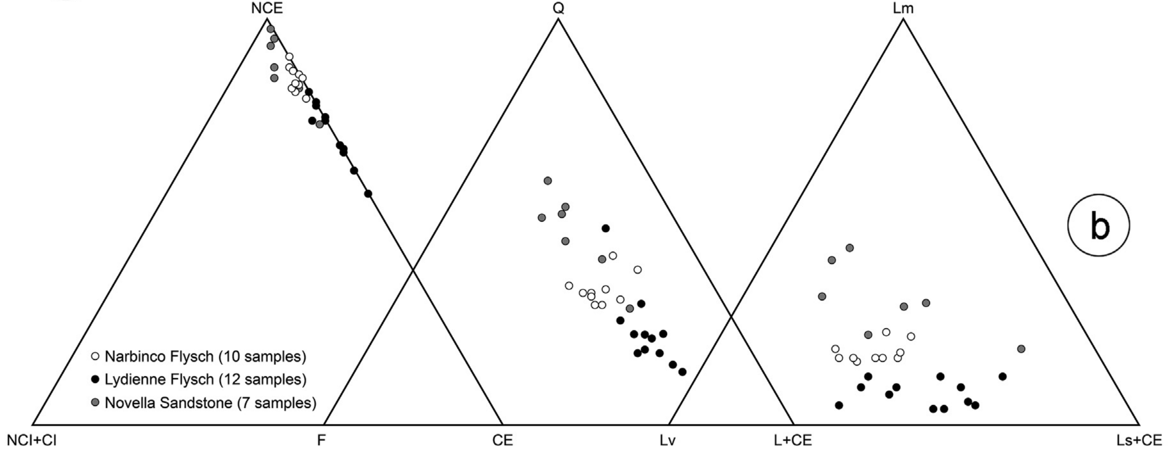


Fig. 3. Petrographic features of the Narbinco Flysch: a: modal point count data for the Narbinco Flysch arenites (according to Zuffa, 1980); b: ternary plots showing framework modes of arenites from the Narbinco Flysch plotted on: NCE CI + NCI CE (Zuffa, 1980); Q F L + CE (Dickinson, 1985); Lm Lv Ls + CE (Ingersoll and Suzcek, 1979). Modal data from Novella Sandstone and Lydienne Flysch are plotted (according to Bracciali et al., 2007).

Firstly, the overall features indicate that the Narbinco Flysch (Fig. 6) can be regarded as Late Cretaceous, probably Campanian, deep-sea turbidites deposited in the Ligure-Piemontese basin with supply from an upper continental crust belonging to a continental margin characterised by a Triassic–Jurassic carbonate platform. Both the arenites and the conglomerates from the Narbinco Flysch are characterised by a mixed siliciclastic-carbonatic composition

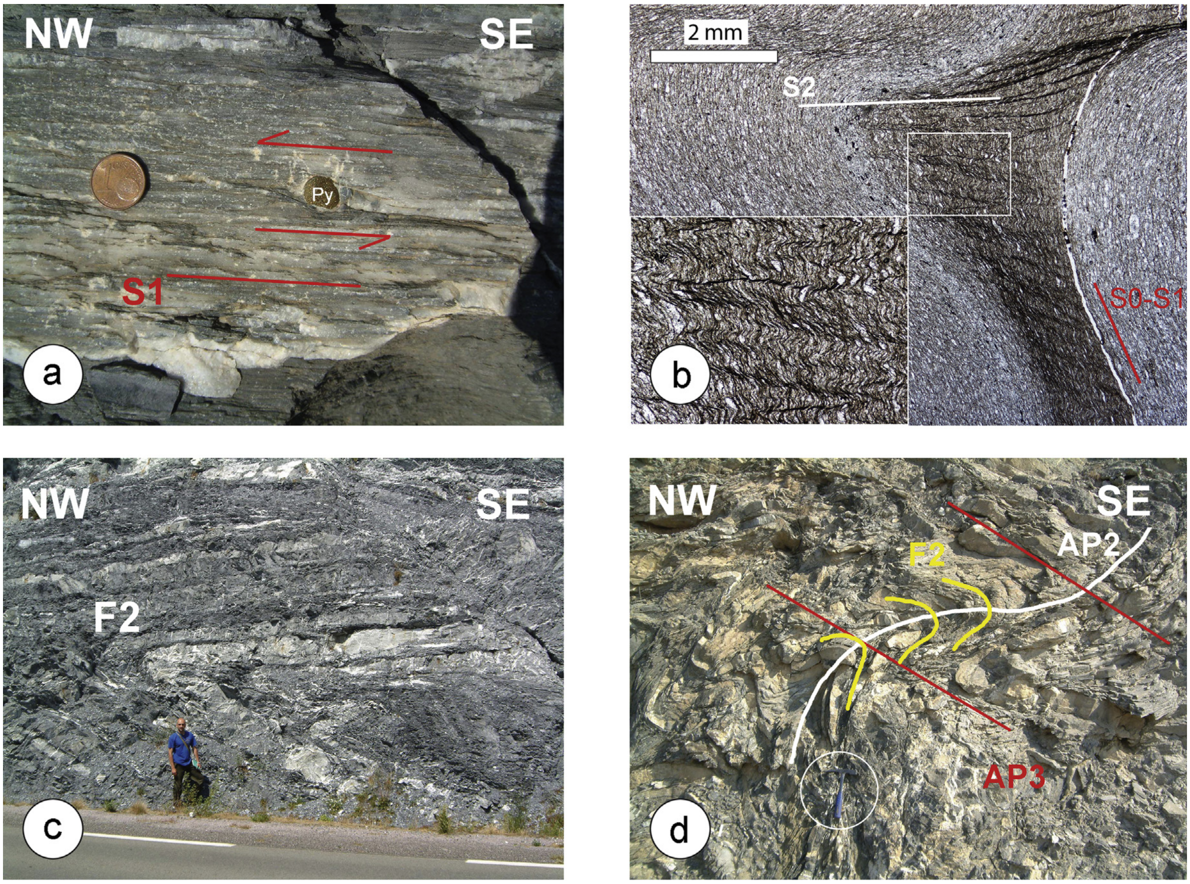


Fig. 4. Structural features of the Narbinco Flysch: a: S1 foliation with asymmetric pressure shadows grow around pyrite crystal in a normal limb of F2 fold. The arrows indicate the sense of shear after restoration from subsequent deformation phases; b: microphotograph of the relationships between the S1 and S2 foliations in the hinge zone of the F2 folds of c. A close up of the boxed area is shown in the left corner; c: mesoscale isoclinal F2 folds; d: interference between F2 and F3 folds. The F2 hinges, the AP2 and the AP3 axial planes are shown.

mainly derived from acidic volcanics, extrabasinal platform carbonates, granitoids, and low-grade metamorphic rocks. The same features can be recognized in the sedimentary cover of the Balagne Nappe where the San Martino Formation, the Lydienne Flysch, the Toccone Breccia, the Novella Sandstone, and the Alturaja Arkose are regarded as Early Berriasian–Late Cenomanian deep-sea deposits (Marroni and Pandolfi, 2003) characterized by large volumes of arenites and fine-grained conglomerates with mixed siliciclastic-carbonatic composition (Bracciali et al., 2007). Taking into account the reconstruction proposed for the Ligure-Piemontese basin during the Late Cretaceous (Marroni and Pandolfi, 2007 and references therein) we propose (Fig. 6A) that the source area of the deposits of the succession of the Balagne Nappe and the Bas Ostriconi Unit were located in the same sector of the European margin, where the upper continental crust and its sedimentary cover were exposed (Durand-Delga et al., 1997; Sagri et al., 1982). A source area from the opposite continental margin, i.e. that of the Adria plate, can be excluded due to the lack of fragments derived from a lower continental crust and a subcontinental mantle (Bracciali et al., 2007).

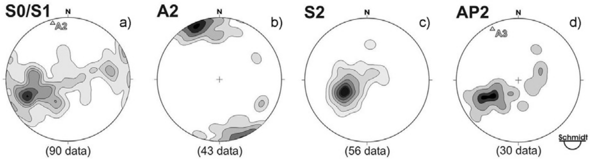


Fig. 5. Contour diagram of equal-area, lower hemisphere stereographic representation of structural data from Bas Ostriconi Unit of D1, D2 and D3 tectonic phases: a: S0/S1 bedding S0 and main foliation S1, contours at 0.5%, 2%, 3%, 4%, 5%. A2 (triangle) indicates the reconstructed A2 folds axis; b: A2 axis contours at 0.5%, 1%, 3%, 5%, 10%; c: S2 foliation, contours at 0.5%, 2%, 3%, 4%, 5%, 8%; d: axial planes AP2 of the F2 folds. Contours at 1%, 3%, 6%, 10%. A3 (triangle) indicates the reconstructed A3 folds axis.

Another similarity between the Balagne Nappe and the Bas Ostriconi Unit is their deformation history. The D1 phase recognised in the Balagne Nappe (Marroni and Pandolfi, 2003) developed during a horizontal shortening episode characterized by a top-to-the-west sense of shear. This deformation produced isoclinal folds having a penetrative and continuous foliation and developed under very low-grade metamorphic conditions. The D2 phase, recognised in the Balagne Nappe (Marroni and Pandolfi, 2003), was also a compressive episode that produced

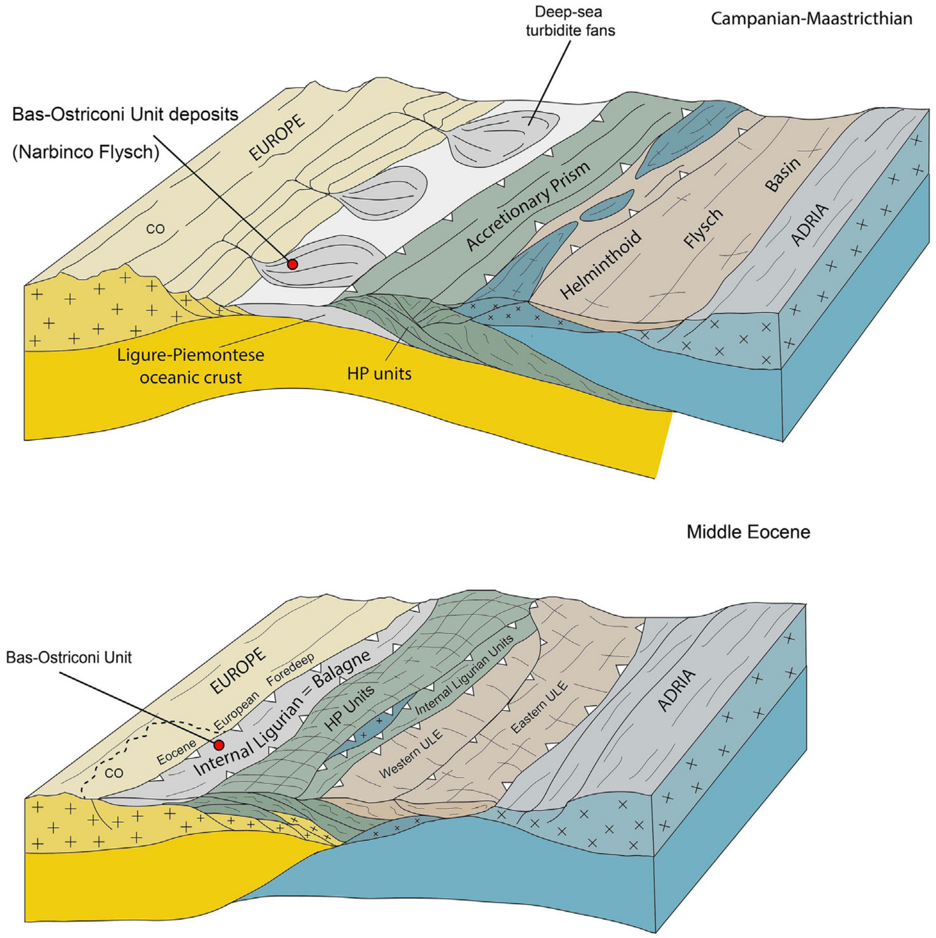


Fig. 6. Palaeotectonic 3D sketch maps of the evolution of Ligure-Piemontese oceanic basin along the Corsica–northern Apennine transect during Late Cretaceous (A) and Middle Eocene (B) times. The reconstructions are mainly based on Marroni et al., 2001; Bracciali et al., 2007; Molli, 2008; Marroni et al., 2010; Molli and Malavieille, 2011; Saccani et al., 2015, and on the present results.

top-to-the-west, low-angle thrusts and asymmetric F2 folds having a widespread S2 foliation represented by crenulation cleavage. Altogether, these features suggest that the D1 and D2 phases identified in the Balagne Nappe and in the Bas Ostriconi Unit are similar. The D1 and D2 compressive phases in the Balagne Nappe are interpreted as achieved during the Latest Cretaceous–Late Eocene time span (Fig. 6B) by coherent underplating at moderately deep structural levels (Marroni and Pandolfi, 2003) in the accretionary wedge connected to an east-dipping subduction zone (D1 phase) and the subsequent thrusting of the wedge onto the European continental margin (D2 phase).

A resemblance can be proposed between the D3 and D4 phases in the Bas Ostriconi Unit and the D4 and D5 phases in the Balagne Nappe. These deformations are related to the extensional tectonics that affected Alpine Corsica from the Early Oligocene on.

One difference is the lack, in the Bas Ostriconi Unit, of the D3 phase identified in the Balagne Nappe, which consists of NNW–SSE strike-slip faulting associated with upright folds. However, its absence in the Bas Ostriconi Unit could be related to the lack of outcrops having recorded the D3 deformation.

Taking into account these similarities between the successions of the Balagne Nappe and the Bas Ostriconi, Unit, we propose that the Narbinco Flysch was the uppermost portion, of probably Campanian age, of the ophiolite sedimentary cover of the Balagne Nappe. In this picture, the Narbinco Flysch likely detached from its oceanic basement during the pre-Oligocene deformation phases.

7. Conclusions

In this paper, we have shown that the Bas Ostriconi Unit succession and the turbidite sedimentary cover of the Balagne Nappe have common source areas, stratigraphic features, structural evolutions, and geometric positions. We inferred that the Narbinco Flysch was the uppermost part of the Balagne ophiolite sedimentary cover.

The Narbinco Flysch is characterized by the association of mixed siliciclastic-carbonatic coarse-grained debris with intrabasinal carbonatic ooze as detected in several turbidite deposits of the Ligure-Piemontese basin. These deposits were supplied by the European continental margin during the Late Cretaceous as suggested by the various provenance analyses that have been made for the Monte Verzi Marls

(Internal Ligurian Units, eastern Liguria, Marroni et al., 2010 and references therein) and for the Marina di Campo Flysch (Cretaceous Flysch Unit, Elba Island, Bortolotti et al., 2001 and references therein). Our results suggest that the Narbinco Flysch deposited onto the Ligure-Piemontese oceanic basin, in an area located close to the European continental margin. At the same time, the sedimentary basin close to the Adria continental margin was filled with carbonate oozes and clastic deposits (Helminthoid Flysch; Marroni et al., 2010 and references therein). Therefore, the sedimentation of significant volumes of carbonate oozes supplied by continental margins can be regarded as a distinctive feature of the Ligure-Piemontese basin from the Campanian up to the end of Cretaceous.

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