OPHIOLITE-BEARING VERMOSHI FLYSCH (ALBANIAN ALPS, NORTHERN ALBANIA): ELEMENTS FOR ITS CORRELATION IN THE FRAME OF DINARIC-HELLENIC BELT

Michele Marroni*,°,✉, **Luca Pandolfi***,°, **Kujtim Onuzi****, **Silvia Palandri*** and **Abedin Xhomo****

* *Dipartimento di Scienze della Terra, Università di Pisa, Italy.*
** *Institute of Geological Research, Tirana, Albania.*
° *CNR, Istituto di Geoscienze e Georisorse, Pisa, Italy.*
✉ *Corresponding author, e-mail: marroni@dst.unipi.it*

Keywords: nannofossils dating, arenite composition, Dinaric-Hellenic belt, ophiolites, Vermoshi Flysch, Barremian. Northern Albania.

ABSTRACT

The tectonic setting of the Albanian Alps, Northern Albania, is characterized by a thick pile of tectonic units whose uppermost structural level is represented by the Vermoshi Unit, cropping out just few km north of the Shkoder-Péc Line. This unit includes a single formation, the Vermoshi Flysch, characterized by turbidite deposits consisting of arenites, shales and marls. The Vermoshi Flysch has been sampled for paleontological datings and petrographical analyses of the arenite beds along five selected and well exposed sections in the Vermoshi Valley. The nannoplancton and forams associations detected in the analyzed samples point out to a Barremian age, whereas the petrographical modal analysis of arenites indicates that all the samples have a mixed/hybrid silicilastic-carbonate composition, ranging from quartz-rich sublitharenites to quartz-poor litharenites. However, the main feature ot these arenites is the occurrence of fragments derived from an ophiolite sequence. The petrographical data suggest that these deposits can be regarded as supplied by two different source areas, represented by the margins of the basin where the Vermoshi Flysch was deposited. Whereas one of the border was represented by the Adria continental margin, the opposite one was characterized by an advancing nappe, constituted by ophiolites and their sedimentary cover. In this frame, the Vermoshi Flysch can be regarded as the southernmost part of the Vranduk Flysch, cropping out in Serbia and Croatia. This type of deposits, widespread in the Dinaric-Hellenic belt, can be considered as the sedimentary marker of the Late Jurassic - Early Cretaceous tectonic phases related to the closure of the oceanic area present between the Adria and the Eurasia plates.

INTRODUCTION

The features of the turbidite sediments can supply useful data for the reconstruction of collisional belts history. For instance, age and petrography of these deposits can provide constraints not only for the identification of the source areas of foredeep and/or thrust-top deposits but also for the reconstruction of the main tectonics phases. In addition, the analysis of these deposits can be regarded as a valuable tool for regional correlations among different areas of the same collisional belt.

In the Dinaric-Hellenic belt, several turbidite successions, ranging in age from Early Cretaceous to Miocene, occur from Slovenia and Serbia to southern Greece (Fig. 1). Each of these turbidite successions was deposited during the different phases connected with the closure of the Tethys oceanic basin and the following continental collision. These deposits are widespread in Greece and Albania, where they occur as continuous north-south trending belts. This continuity is interrupted in the Albanian Alps, northern Albania, where an east-west trending strike-slip fault, known as Shkoder-Péc fault, occur. Therefore, the correlation among the turbidite bodies cropping out in Greece and Albania and those recognized in Montenegro, Bosnia and Croatia is quite complex, mainly owing the scarceness of reliable data in the link zone between these areas.

In this paper we provide data on the geological setting, the biostratigraphy and the arenite composition of the Vermoshi Flysch, cropping out few km north of the Shkoder-Péc fault, in order to have valuable insights for the reconstruction of the geological history and for the regional correlations across the Dinaric-Hellenic belt.

THE GEOLOGICAL SETTING OF NORTHERN ALBANIA

The Dinaric-Hellenic belt (Fig. 1) is a north-south trending collisional chain of Alpine age, running from Slovenia and Serbia to the Southern Greece. This belt originated by the Mesozoic-Tertiary convergence and subsequent continental collision related to the closure of the eastern branch of the Tethyan oceanic basin (e.g., Aubouin et al., 1970; Bernoulli and Laubscher, 1972; Celet et al., 1980; Dimitrijević, 1982; Robertson and Dixon, 1984; Smith, 1993; Pamić et al., 1998; Robertson and Shallo, 2000; Shallo and Dylek, 2003; Bortolotti et al., 2004a, 2005: Saccani et al., 2008a, 2008b Gaggero et al., 2009, and many others). Following Bortolotti et al. (2005), this oceanic area developed in the Middle to Late Triassic times, after a Late Permian? - Early Triassic rifting phase. Subsequently, an intraoceanic subduction started during the Early Jurassic, leading to continental collision between the Eurasia and Adria Plates, that probably began since Early Cretaceous. After the continental collision, up to the Neogene, west-verging, thick-thinned fold and thrust sheets originated as the result of the continuous convergence that affected the continental margin of the Adria Plate.

The Dinaric-Hellenic belt has been traditionally divided into different tectonostratigraphic zones (Fig. 1), each corresponding approximately to the modern concept of terranes. Each zone consists of an assemblage of variably deformed and metamorphosed tectonic units of oceanic and/or continental origin. In this frame, the Albania is considered to be the western link between the Dinaric and the Hellenic areas (e.g., Aubouin et al., 1970). In this area (IKGJ-INGF-

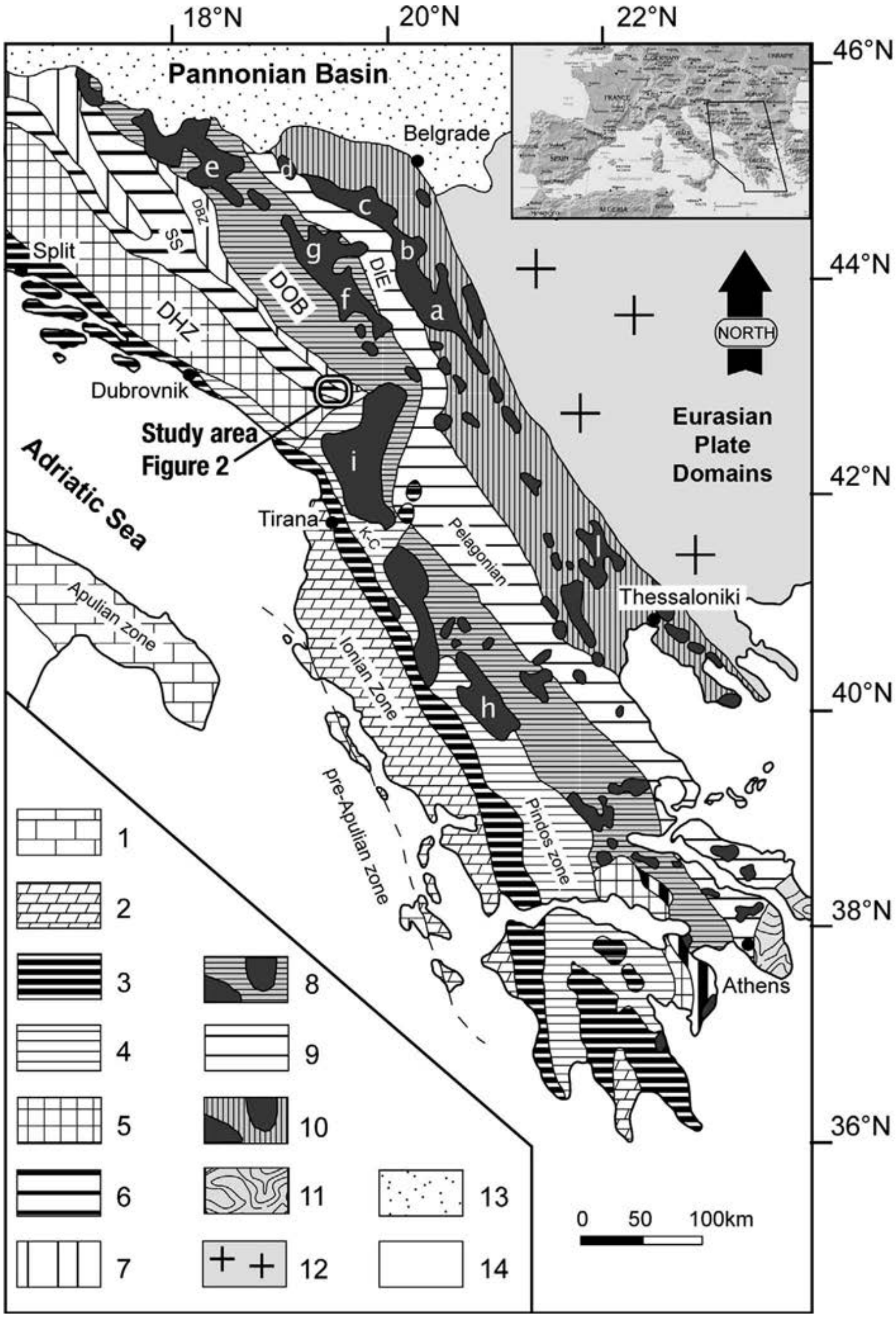

Fig. 1 - Tectonic sketch-map of the Dinaric-Hellenic belt. Legend and abbreviations: 1. Apulian and Pre-Apulian Units; 2. Ionian Units; 3. South Adriatic Units: Kruja, Gavrovo and Tripolitsa; 4. Budva, Krasta-Cukali (K-C) and Pindos Units; 5. Dalmatian-Herzegovian and Parnassus Units (DHZ); 6. Sarajevo-Sigmoid (SS) Unit; 7. East Bosnian-Durmitor Unit (DBZ); 8. Dinaric Ophiolite Belt (DOB); 9. Drina-Ivanjica and Korab-Pelagonian Units (DIE); 10. Vardar Units (VZ); 11. Lavrion Blueschist Unit; 12. Eurasian Plate Domains; 13. Pannonian Basin; 14. Bradanic trough. Ophiolites: a- Ibar; b- Troglav; c- Maljen; d- Zvornik; e- Krivaja-Konjuh; f- Bistrica; g- Zlatibor; h- Pindos; i- Mirdita; l- Guevgueli. The location of Fig. 2 (study area) is indicated.

FGJM, 2002, 2004), three main tectonostratigraphic zones of the Dinaric-Hellenic belt crop out: the deformed Adria zone, the External ophiolite belt and the Korabi zone (e.g., Meco and Aliaj, 2000). In Albania, the units of the deformed Adria zone are, from top to bottom, the Krasta, Kruja and Ionian Units, that crop out in the western areas (Fig. 1). They are characterized by sequences detached from the Adria continental margin, and include Triassic to Paleogene neritic to pelagic carbonates, topped by siliciclastic turbidites. The inception age of the turbiditic deposition ranges from Late Cretaceous, in the Krasta Unit, to Oligocene in the Ionian Unit (Robertson and Shallo, 2000 and references therein). This shift is interpreted as the result of the westward migration of the deformation across the continental margin of the Adria Plate. These units were thrust onto the pre-Apulian zone, which is regarded as the easternmost, undeformed margin of the Adria Plate.

The units of the deformed Adria zone are overlain by the Mirdita ophiolitic Nappe (Fig. 1), that consists of the Rubik Complex, i.e. a sub-ophiolite mélange, overlaid by three ophiolite units (Bortolotti et al., 2005 and references therein). The sub-ophiolite mélange (Bortolotti et al., 1996), also reported as "carbonate periphery" or "peripheral complex" (Kodra et al., 1993; Shallo 1991, 1992 and 1994), consists of an assemblage of thrust slices of coherent sequences of continental and oceanic origin. According to Shallo (1991, 1992) and Kodra et al. (1993), the slices of continental origin mainly consist of Triassic to Jurassic carbonate successions, generally associated with rifting-related magmatic rocks, whereas the oceanic-derived slices, not thicker than 100 m, are mainly serpentinized lherzolites even if minor bodies of basalts and gabbros also occur. At the base of the sub-ophiolite mélange, an up-to 300 m thick slice of ophiolite-bearing carbonate turbidites of uppermost Tithonian - late Valanginian age, known as Firza flysch, can be recognized (Gardin et al., 1996). The ophiolite nappe consists of three different types of oceanic units. The lowermost unit is represented by the Porava Unit (Bortolotti et al., 2004b, 2008), that is represented by an up-to 500 m thick sequence of MOR pillow basalts alternating with Middle to Late Triassic radiolarites and siliceous shales (Chiari et al., 1996). The Porava Unit is topped by two ophiolitic units both consisting of Jurassic sequences, with different petrochemical features (Shallo et al., 1992; Shallo, 1992, 1994; Beccaluva et al., 1994, Bortolotti et al., 1996; 2002; Saccani et al., 2004). The Western, i.e. the lowermost, Jurassic Unit is characterized by a MOR ophiolite sequence where both MOR and IAT basalts are coexisting. In contrast, the Eastern, i.e. the uppermost, Jurassic Unit shows an up-to 10 km thick coherent sequence originated in a SSZ setting (Beccaluva et al., 1994; Saccani et al., 2004). In both the Western and Eastern Units, the basalts are topped by Middle to Late Jurassic radiolarites, referred as Kalur Cherts (Marcucci and Prela, 1996), in turn unconformably covered by a thick sedimentary sequence that includes the late Oxfordian to Tithonian Simoni Mélange and the late Tithonian to late Valanginian Firza Flysch (Shallo, 1991; Bortolotti et al., 1996; Gardin et al., 1996; Chiari et al., 2007). The ophiolite units and the Rubik Complex are both unconformably covered by an up to 1500 m thick Barremian-Senonian, shallow-water carbonate deposit (IKGJ-INGF-FGJM, 2002, 2004).

In the eastern Albania, the Mirdita ophiolitic Nappe is thrust onto the Korabi zone (Fig. 1). The units from the Korabi zone are characterized by a Paleozoic basement consisting of an Ordovician-Devonian sequence unconformably covered by a Permo-Triassic clastic sequence, grading upwards to Triassic and Jurassic neritic to pelagic, mainly carbonate, deposits (e.g., Robertson and Shallo, 2000).

Finally, transgressive, marine to continental deposits of the Burrel basin, belonging to the Meso-Hellenic trough, unconformably cover the structures of the Mirdita ophiolitic Nappe (Fig. 1). These deposits, ranging in age from Eocene to Miocene, are found as NW-SE striking belts, extending from southern to northern Albania. In the easternmost areas, the nappe pile is unconformably covered by the Neogene "molasse" deposits of the Peri-Adriatic trough (IKGJ-INGF-FGJM, 2002, 2004).

The described zones are continuous from Greece to Northern Albania, while being referred to with different names. Particularly, the Krasta and Kruja units have their equivalents in the Pindos and Gavrovo Units Of Greece, whereas the Mirdita ophiolitic nappe and Korabi zone continue, respectively, into SubPelagonian and Pelagonian zones.

However, this continuity is interrupted toward the north, in the Albanian Alps, by the Shkoder-Péc Line (Dercourt, 1967), regarded as a still active, strike-slip fault, probably located in correspondance of a paleo-transform fault (Saccani et al., 2004).

THE VERMOSHI FLYSCH

North of the Shkoder-Péc Line, five units have been identified in the Albanian Alps, all charaterized by successions detached from the Adria continental margin (reported as zones in the albanian literature). Northwards, these units are thrust by an ophiolite nappe showing the same features of the Mirdita Nappe. From bottom to the top, the units derived from the Adria continental margin are represented by the Cukali, Malesia e Mahde, Valbona, Vermoshi and Gashi units (Fig. 2). The Cukali Unit can be correlated with the

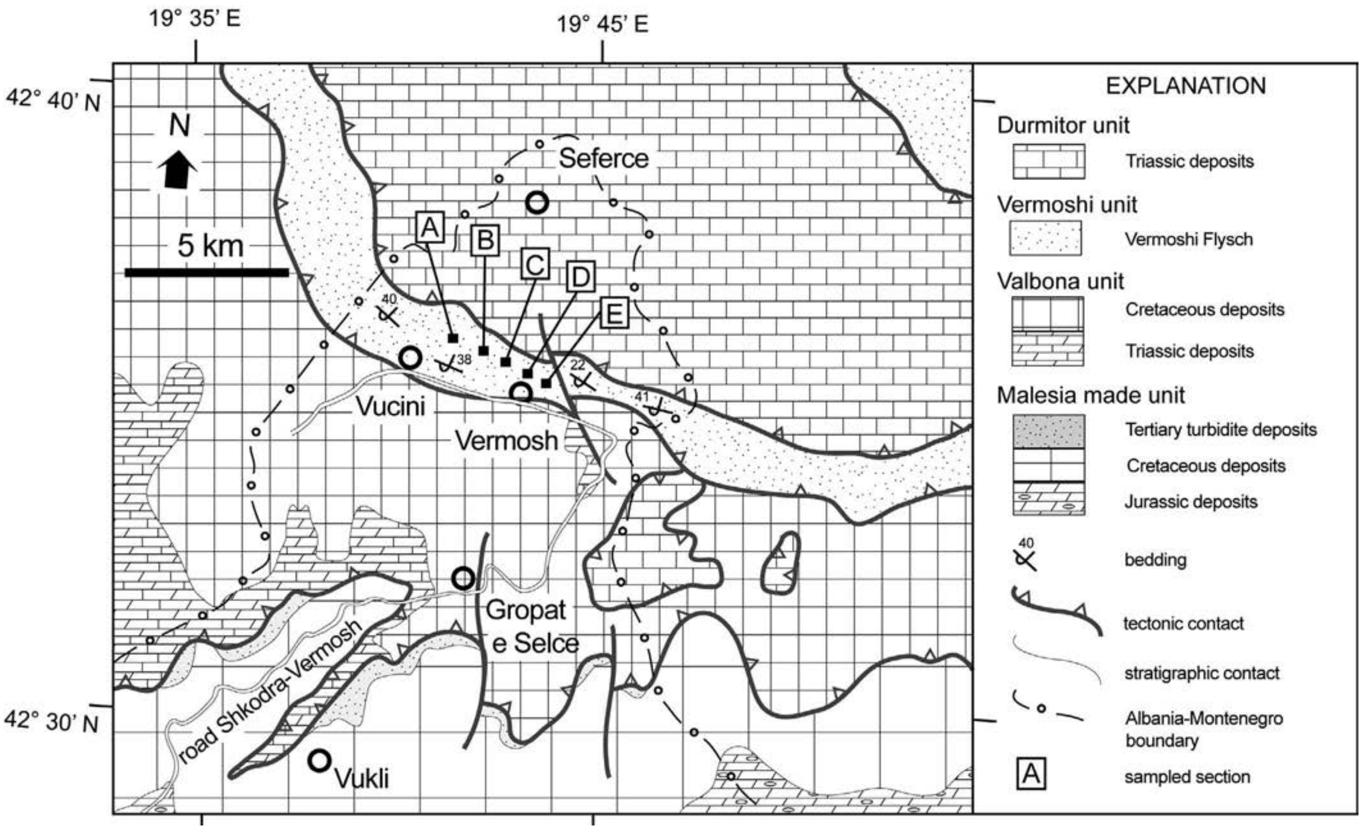

Fig. 2 - Geologic sketch-map of the study area (Albanian part of the Vermoshi Valley).

Krasta one, both characterized by a mainly carbonate succession ranging in age from Trias to Maastrichtian-Eocene turbidite deposits. The main feature of these units is the occurrence of deep-water deposits since Middle Trias. The Valbona and Malesia e Madhe Units display a mainly carbonate succession ranging in age from Permian to Late Cretaceous, topped by Late Cretaceous-Paleogene turbidites. The Valbona and Malesia e Madhe Units are correlated with the Haut Karsts and Pre-Karsts units in the northern area of the Dinarides, whereas in Greece these units are correlated with the Gavrovo and Parnassus Units (Robertson and Shallo, 2000). In the study area, the Malesia e Madhe Unit is topped by the Valbona Unit, in turn thrust by the Gashi Unit, interpreted as detached from the Adria continental margin. This unit corresponds to the southern edge of the East Bosnian-Durmitor Unit, cropping out in Montenegro, Bosnia and Croatia. Between the Malesia e Madhe and Gashi Units, a tectonic slice consisting of a turbidite succession, known as Vermoshi Flysch, crops out (Grillo et al., 1983; Peza et al., 1990; Onuzi and Pajovic, 2004, 2005; Onuzi, et al. 2004). This tectonic slice, here reported as Vermoshi Unit, is the object of the investigations reported in this paper.

The Vermoshi Unit includes a single formation, referred to as the Vermoshi Flysch. The features of this formation are still matter of debate. For instance, a Cretaceous age is reported by Robertson and Shallo (2000) whereas in the 1:200.000 scale map of Albania (IKGJ-INGF-FGJM, 2002, 2004) these deposits are considered Late Jurassic - Early Cretaceous in age. By contrast, the same deposits in the Montenegro geological map are reported as Permian (GSY, Geological Survey of Former Yugoslavia, 1973). In addition, no data on the composition of the arenites from this formation are available. To collect further data on the age and the arenite compostion of the Vermoshi Flysch, the succession cropping out in the Vermoshi Valley, close to the borderline between Albania and Montenegro, has been sampled.

Field occurrence

The studied sections crop out along the eastern side of the Vermoshi Valley, between the Vucini and Vermosh Villages (Fig. 2). In the study area, the Vermoshi Flysch is strongly deformed by overturned, close folds associated to brittle shear zones parallel to the axial plane of the folds. These folds (Fig. 3a), characterized by an axial plane folia-

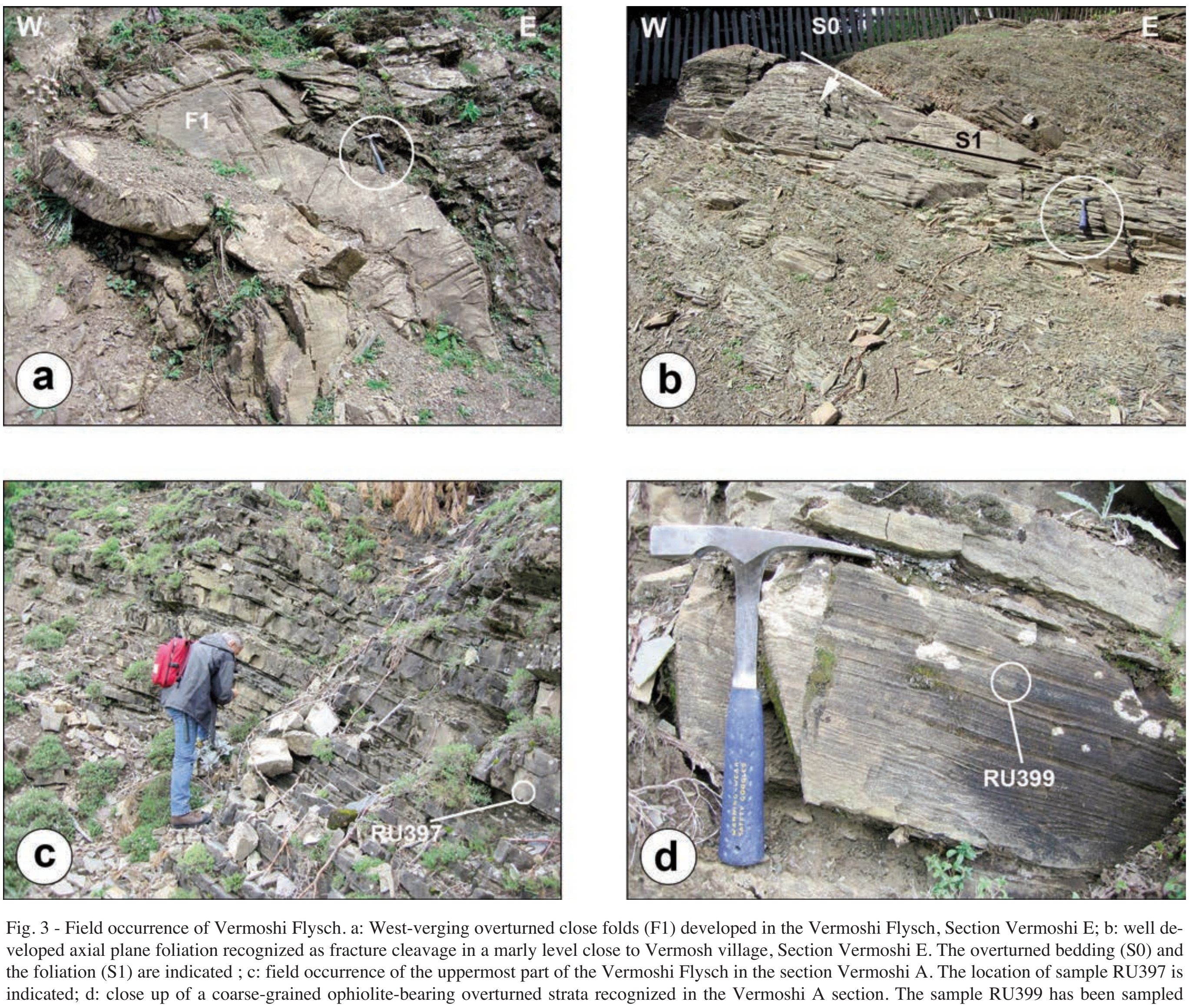

Fig. 3 - Field occurrence of Vermoshi Flysch. a: West-verging overturned close folds (F1) developed in the Vermoshi Flysch, Section Vermoshi E; b: well developed axial plane foliation recognized as fracture cleavage in a marly level close to Vermosh village, Section Vermoshi E. The overturned bedding (S0) and the foliation (S1) are indicated ; c: field occurrence of the uppermost part of the Vermoshi Flysch in the section Vermoshi A. The location of sample RU397 is indicated; d: close up of a coarse-grained ophiolite-bearing overturned strata recognized in the Vermoshi A section. The sample RU399 has been sampled from this strata.

tion recognized as fracture cleavage (Fig. 3b), developed under a very low-grade metamorphism, as suggested by the recrystallization of white mica, quartz, oxides and calcite.

Owing to the strong deformation, the thickness of the succession cannot be estimated accurately, but, probably, is lower than 500 m. The succession has been sampled in five different sections, namely A, B, C, D and E, where the lithotypes of the Vermoshi Flysch are well exposed (see Table 1 for sections location). In the sections A, B, and C the Vermoshi Flysch is characterized by thin-bedded turbidites consisting of thin to medium beds (10-60 cm) of coarse- to fine-grained arenites and coarse-grained siltites, alternating with 10 to 100 cm thick beds of shales, shaly marls and minor marls and varicoloured shales (Fig. 3c). The coarse- to medium-grained arenites are often characterized by well-developed thin traction carpets. These strata are generally well graded only in their uppermost part where current ripples and sinusoidal lamina can be present (Fig. 4d). The arenites have been sampled for the arenite petrography. The sections D and E, cropping out in the lower areas of the valley, probably represent the lowermost level of the exposed Vermoshi Flysch. These sections are characterized by turbidites represented by up-to 2-2.5 m thick beds of marls and shaly marls alternating with thin beds of shales (Fig. 4b). Beds 10 to 30 cm thick of medium to coarse-grained arenites also occur (Fig. 4a) and they have been sampled for the arenite petrography.

Biostratigraphy

The biostratigraphical study of the Vermoshi Flysch is based on the analysis of calcareous nannofossils that represent a reliable method for dating turbiditic sediments affected by deformation and low-grade metamorphism (e.g., Marroni et al., 1992; Gardin et al., 1994; Marino et al., 1995).

Sampling was performed on the marly levels of the turbidite sequences of Vermoshi A, B, C, D and E (Fig. 2 and Table 1), and a total of 53 samples were collected and analyzed.

Table 1 - Location of the Vermoshi Flysch studied sections.

Section	Latitude	Longitude	Hight
A	42°35'41.72" N	19°41'49.84" E	1107 m
B	42°35'37.36" N	19°42'09.84" E	1112 m
C	42°35'33.82" N	19°42'29.92" E	1094 m
D	42°35'23.68" N	19°42'48.50" E	1027 m
E	42°35'26.12" N	19°42'36.49" E	1034 m

All the samples were investigated using smear slides (Bown and Young, 1998) and standard light microscope techniques. On each slide, about 200 fields of view were scanned at magnification of 1250x and all coccoliths encountered were counted to estimated their aboundances (Table 3).

A preliminary investigation revealed that most of examinated samples (36) were completely barren, while only 17 samples showed oligotypical assemblages, characterized by rare and poorly preserved coccoliths, the most of those were often fragmented and affected by dissolution or strong overgrown. This impoverishment and bad preservation of the assemblages could be related to the deformation by folding under very low-grade metamorphism that affected the turbidite successions.

The species distribution ranges and taxonomical descriptions adopted in this study are related to previous biostratigraphical works (Thierstein, 1973, 1976; Hill, 1976; Wind and Çepek, 1979; Bralower et al., 1989; Perch-Nielsen, 1985; Bown, 1998; Tremolada and Erba, 2002, Lozar and Tremolada, 2003).

Samples ALB 45, ALB 51, ALB 53 bear the most significant, though poorly preserved, nannofossil assemblages characterized by the occurrence of *Assipetra infracretacea, Assipetra terebrodentarius, Braarudosphaera* sp., *Diazomatolithus lehmanii, Retecapsa angustiforata, Rucinolithus wisei*, *Nannoconus* sp., *Watzanaueria barnesiae, W. britanni-*

Sections	Samples	*Assipetra infracretacea*	*Assipetra terebrodentarius*	*Braarudosphaera sp.*	*Calcicalathina oblongata*	*Cruciellipsis cuvillieri*	*Diazomatolithus lehmanii*	*Nannoconus sp.*	*Retecapsa angustiforata*	*Rucinolithus wisei*	*Watznaueria barnesae*	*Watznaueria britannica*	*Zeugrhabdotus embergeri*	*Zeugrhabdotus scutula*
Vermoshi A	ALB 25										VR			
Vermoshi B	ALB 29										VR			
Vermoshi D	ALB 45		P					VR		P	VR	VR	P	
	ALB 47							VR			VR			
	ALB 48										P			
	ALB 49							VR			R		VR	
	ALB 50										VR	VR		
	ALB 51		P					VR		P	VR		R	
	ALB 53	VR	VR	R			VR	VR	VR	P	F	R	VR	R
	ALB 56										VR			
	ALB 59	P									R	P	VR	
Vermoshi E	ALB 64										VR			
	ALB 65										P			
	ALB 66										VR			
	ALB 67							VR			VR		VR	VR
	ALB 70	P	VR		P	P?	VR	R	VR		F	R	VR	R
	ALB 74										VR			

Table 2 - Calcareous nannofossils distribution in the fossiliferous samples.

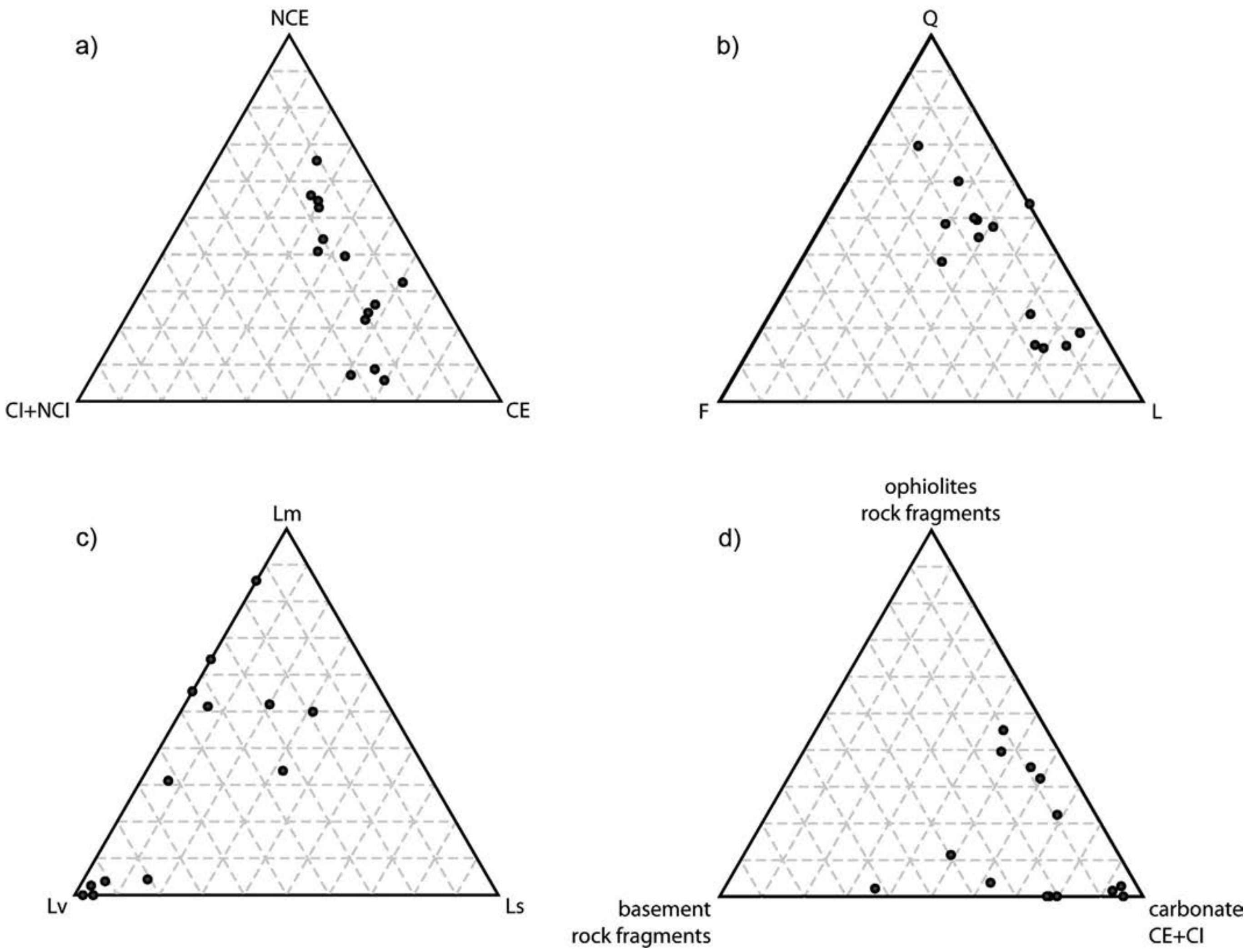

Fig. 4 - Ternary plots showing framework modes of arenites from Vermoshi Flysch plotted on: a: (NCE CI+NCI CE, Zuffa, 1980); b: (Q F L, Dickinson, 1985); c: (Lm Lv Ls, Ingersoll and Suczek, 1979); d: Continental basement-derived RF vs Ophiolite-derived RF vs Carbonate (CE+CI).

ca, Zeugrhabdothus embergeri and *Z. scutula*. The extremely rare presence of badly preserved specimens of *Rucinolithus wisei*, whose last occurrence is documented at lowermost upper Valanginian (Duchamp et al., 2007), can be related to reworking that often affects turbiditic deposits. These samples indicate a Barremian age due to the occurrence of A*ssipetra terebrodentarius* and *Zeugrhabdothus scutula* and the absence of *Calcicalatina oblongata* (Valanginian-lower Barremian after Thierstein, 1976).

ALB 70 is characterized by rare and poorly preserved specimens of *Assipetra infracretacea, Assipetra terebrodentarius, Diazomatolithus lehmanii, Retecapsa angustiforata, Nannoconus* sp., *Watzanaueria barnesiae, W. britannica, Zeugrhabdothus embergeri* and *Z. scutula*. Based on the fact that very rare and strongly overgrown remnants of *Calcicalatina oblongata* could be related to reworking, this sample is still referable to Barremian.

All the remaining fossiliferous samples bear extremely rare and not meaningful calcareous nannofossil assemblages and therefore they do not provide any new biostratigraphical information.

The study of the arenite thin sections showed the presence of *Paleodictyoconus arabicus*, a typical lower Cretaceous orbitolinid foraminifer. According to Schroeder and Cherchi (2007 and reference therein), the stratigraphic range of this specimen spans from Barremian to lowermost Aptian with its maximum development in the upper Barremian.

Therefore, the calcareous nannofossil and foram assemblages provide evidences for a Barremian age of the Vermoshi Flysch.

Arenite petrography

29 thin sections from Vermoshi Flysch (24 arenites and 4 rudites from four different areas, Vermoshi A, B, D and E sections; Fig. 2 and Table 1) were analyzed by means of polarizing microscope. A modal analysis was performed on 14 selected medium- to coarse-grained arenites. Point counting (500 points) of arenites was performed using the Gazzi-Dickinson technique (Gazzi, 1966; Dickinson, 1970; Ingersoll et al., 1984; Zuffa, 1987) to minimize the dependence of arenite composition on grain size. All point-counted arenites were stained using the Alizarin-red-S plus potassium ferrycyanide solutions for carbonate identification (Lindholm and Finkelman, 1972). The point counting results are reported in Table 3 and plotted on the triangular diagrams of Fig. 4.

No large differences can be recognized in the framework composition of arenites from the Vermoshi Flysch. They range from quartz-rich sublitharenites to quartz-poor litharenites (Fig. 5b) and feature a volcanoclastic to meta-

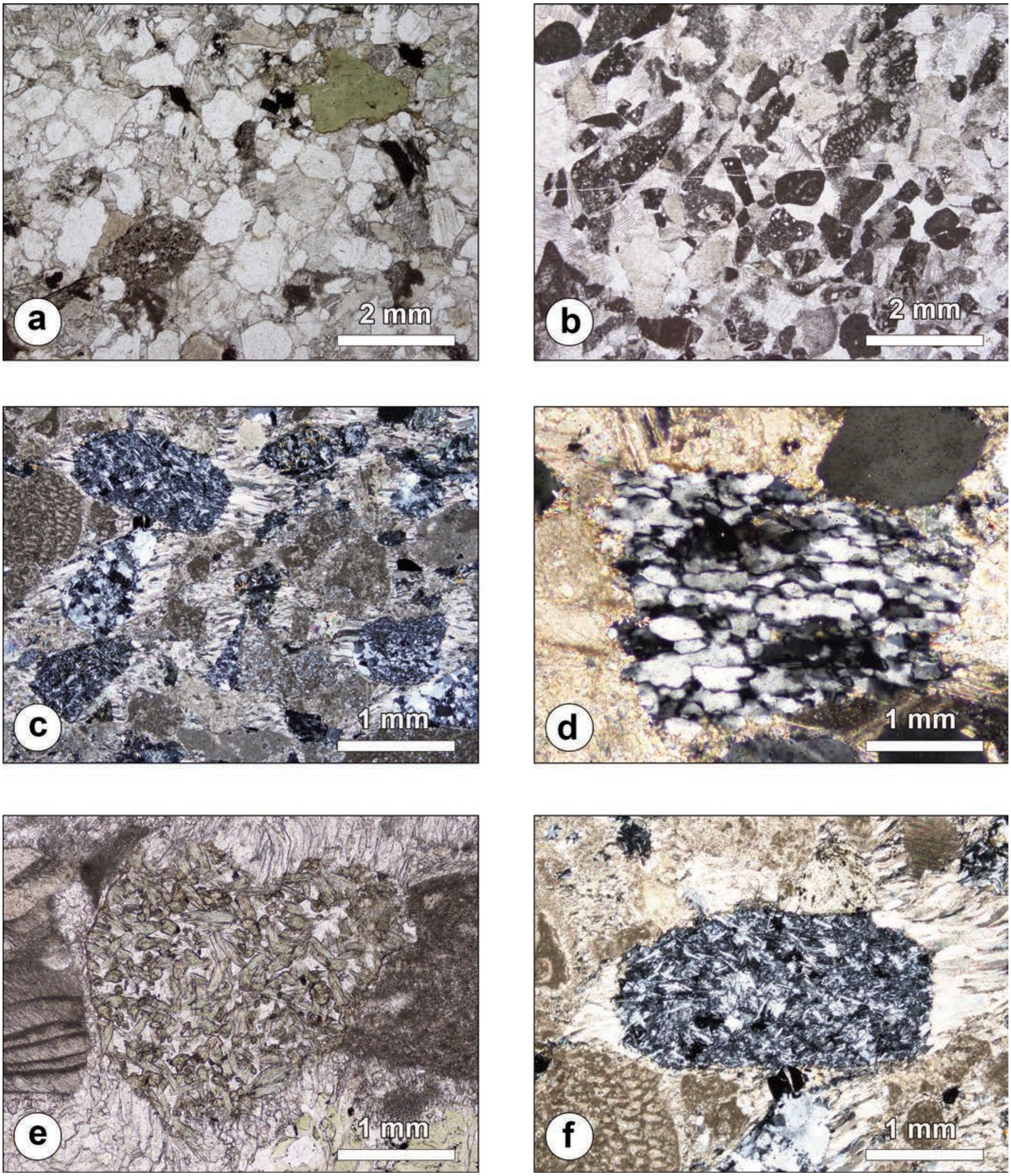

Fig. 5 - Photomicrographs of the studied Vermoshi Flysch arenites. a: siliciclastic end member petrofacies (sample RU398); b: carbonatic end member petrofacies (sample RU400); c: ophiolite-bearing hybrid arenites (sample RU405b) showing the typical petrofacies of the Vermoshi Flysch. Crossed polars; d: fine-grained schist rock fragment (sample RU398). Crossed polars; e: femic volcanic rock fragments (sample RU403); f: medium-femic volcanic rock fragments (sample RU403). Crossed polars.

morphoclastic composition of the fine-grained lithic fragments (Fig. 5b). According to Zuffa (1980) the total framework is characterized by a mixed siliciclastic-carbonate (Fig. 5a,b,c) framework composition (Fig. 4a), where the important carbonatic intrabacinal contribution (CI, up to the 30%) allows classifying part of these rocks as hybrid arenites (Zuffa, 1980).

The extrabasinal siliciclastic framework is characterized by a common presence of mono- and polycrystalline quartz (2÷39% of the total framework), plagioclase (0÷5%) and K-feldspar (0÷7%). Felsic intrusive coarse-grained rock fragments, such as granitoids, are uncommon (0÷3% of the total framework), while low-grade metamorphic rock fragments are quite widespread and include coarse-grained gneisses, metaquartzites, fine-grained schists (Fig. 5d) and mica-schists (1÷11% of the total framework).

The presence of ophiolite-derived rock fragments (Fig. 5c, d), represents one of the most striking features of several Vermoshi Flysch arenites. The presence of these rock fragments is particularly apparent in the lithic volcanic and subvolcanic fragments (0÷17% of the total framework), that mainly include aphyric to porphyritic basalts (Fig. 5e), andesitic basalts (Fig. 5f) and andesites. The presence of rock fragments derived from an ophiolitic suite is supported by the widespread occurrence of mantle-derived rock fragments (serpentinized peridotites and serpentinites, up to 17% of the total framework, Fig. 6a) and single crystals ("picotite" spinel and clinopyroxene), and by the presence of intrusive femic rock fragments such as gabbros (up to 4% of the total framework). Moreover, sedimentary siliceous rocks such as red radiolarian-bearing wackestones and silicified siltstones point to a source area characterized also by the sedimentary cover of an ophiolite sequence (Fig. 6b).

Moreover, minor felsic volcanic rock fragments (rhyolite and dacite fragments with porphyritic texture) can be also recognized (0÷4% of the total framework). It is worth noting that the presence of a very low grade metamorphism in these rock fragments, as well as their felsic character, could suggest a source area not related to that of the ophiolites, but rather associated with the volcanics rocks of a continental margin.

Another striking feature of the Vermoshi Flysch arenites is the widespread presence of carbonate rock fragments (Tab. 3 and Figs. 4 and 5b). In all the studied samples both intra- (7÷30% of the total framework) and extra-basinal (22÷61%) carbonate fragments have been recognized. Carbonate extrabasinal fragments are represented by carbonate platform-derived rocks, mainly mudstones, wackestones and grainstones, of Jurassic - Early Cretaceous age (Fig. 6c). The allochems in the grainstone fragments are peloids, ooids, minor benthic foraminifera and undeterminable macrofossil fragments. The intrabasinal carbonate fragments are instead represented by mudstone, showing deformed and squeezed soft margins (Fig. 6d) and by isolated bioclasts, mainly benthic foraminifera (including several fragments of *Paleodictyoconus arabicus* Fig. 6e) and macrofossils (undeterminable lamellibranchia and rudista fragments, Fig. 6f).

The ternary diagrams indicate that the source areas of these sediments were mainly characterized by a continental basement made up of metamorphic rocks, felsic volcanics and granitoids and the relative sedimentary covers, represented by extrabasinal non coeval carbonate rock successions. Moreover a source area represented by an ophiolite sequence characterized by mantle rocks (serpentinized peridotites), intrusive (gabbros), volcanic sequence (basalts, andesite basalts and andesites) and their sedimentary cover (radiolarites) can be recognized. This source area can be related to a typical suprasubduction ophiolite sequence as those cropping out in northern Albania (e.g., Bortolotti et al., 1996 and reference therein). Some studied samples are instead characterized by the absence of ophiolite rock fragments and the arenites framework is mainly represented by carbonate debris (Fig. 4d and Table 3).

In this frame, the intrabasinal coeval carbonate fragments widespread in all the studied thin sections can be partially derived from the carbonate platform developed since the Late Jurassic up to the Late Cretaceous at the top of the ophiolite nappe. Thus, the intrabasinal coeval carbonate fragments detected in the Vermoshi Flysch can be supplied by the Adria continental margin and/or by an advancing ophiolite nappe.

THE VERMOSHI FLYSCH IN THE FRAME OF THE DINARIC-HELLENIC BELT

The data collected and presented in this study indicate that the Vermoshi Flysch can be regarded as turbidite deposits of Barremian age, characterized by arenites showing mixed/hybrid silicilastic-carbonate composition (*sensu* Zuffa, 1980), ranging from quartz-rich sublitharenites to quartz-poor litharenites. The arenites framework is mainly represented by both intrabasinal and extrabasinal carbonates, but fragments of siliciclastic extrabasinal rocks, as coarse-grained granitoids, gneisses, mica-schists, metaquartzites, fine-grained schists and mica-schists can also be observed. In addition, some arenite samples are characterized by the occurrence of ophiolite fragments, as basalt, andesites, gabbros and serpentinized peridotites. The collected data indicate two possible source areas, represented by the Adria continental margin and by an advancing ophiolite nappe.

This type of Early Cretaceous deposits is widespread in the whole Dinaric-Hellenic belt, both north and south of the Shkoder-Péc Line. They are regarded as the sedimentary marker of the Late Jurassic - Early Cretaceous tectonic phases related to the closure of the oceanic area between Adria and Eurasia Plates (Bortolotti et al. 2005 and quoted references).

North of the Shkoder-Péc Line, ophiolite-bearing, late Tithonian-Valanginian turbidite deposits, known as Bosnian Flysch, are recognized as a continuous, about 600 km long, NW-SE trending belt, cropping out from Serbia to Bosnia and Montenegro (Blanchet et al., 1969; 1970; Aubouin et al., 1970; Mikes et al. 2008). These deposits are overlain by the Ophiolite Nappe in the northern area, whereas in the southern areas they are topped by East Bosnian-Durmitor Unit. The Bosnian Flysch consists mainly of two distinct formations reported, from bottom to top, as Vranduk and Ugar formations (Olujiç 1978; Hrvatoviç 1999, Mikes et al. 2008). The Vranduk Formation, more than 1000 m thick, consists of monotonous pelagic turbidites represented by beds of siliciclastic arenites, marls, shales, cherty limestones and grey radiolarites. In turn, the Ugar Formation (Hrvatoviç 1999), whose thickness exceeds 2000 m, is represented by thin-bedded marly to micritic limestones and red or grey shales, intercalated with calcareous turbidites. The top of the Ugar Formation consists of coarse-grained carbonate mass flow deposits, several tens of metres thick (Mikes et al., 2008).

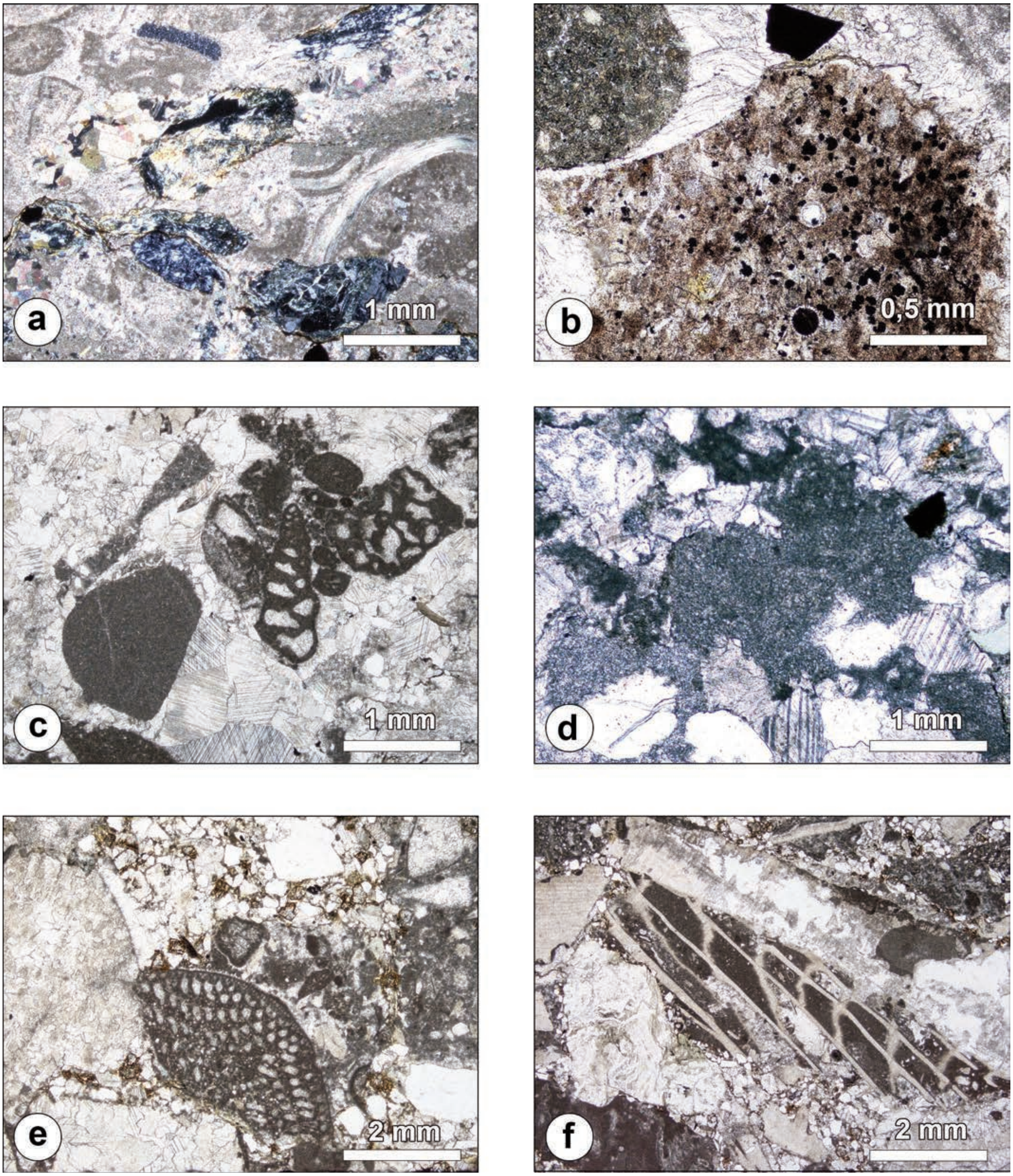

Fig. 6 - Photomicrographs of the studied Vermoshi Flysch arenites. a: serpentinite rock fragments in an ophiolite-bearing arenites (sample RU404b). Crossed polars; b: close up of radiolarian-bearing wackestone fragment (sample RU404b); c: carbonate extrabasinal fragments (mudstone and benthic foraminifera-bearing grainstone, sample RU396); d: carbonate intrabasinal coeval mudstone showing deformed and squeezed soft margins (sample RU395); e: carbonate intrabasinal coeval benthic foraminifera (Paleodictyoconus arabicus, sample RU404a); f: carbonate intrabasinal coeval macrofossil fragment (probable rudista, sample RU404b).

Table 3 - Modal analysis of the Vermoshi Flysch arenites.

		SAMPLE	RU395	RU396	RU397	RU398	RU399	RU400	RU402a	RU402b	RU402c	RU 403	RU 404a	RU 404b	RU 405a	RU 405b
		sampled section	A	A	A	A	A	A	B	B	B	D	D	D	E	E
		arenite grain size	medium coarse	medium coarse	medium	medium coarse	medium coarse	medium coarse	medium coarse	medium coarse	medium coarse	medium coarse	coarse	medium coarse	medium coarse	medium coarse
		sorting (according Longiaru *et. alii,* 1987)	B	B/C	B	B/C	B	B/C	B	B/C	B	B	B/C	B	B	B/C
		counted points	500	500	500	500	500	500	500	500	500	500	500	500	500	500
NCE	Q	Q medium quartz single crystal	2.34	1.39	13.02	20.86	5.71	0.99	5.28	6.54	6.47	1.84	1.39	2.53	2.80	5.73
		Q coarse quartz single crystal	0.00	0.00	1.40	3.36	0.48	0.00	0.00	0.47	0.25	0.46	0.23	0.69	0.70	1.19
		Q medium quartz polycrystalline	1.04	0.46	3.72	10.31	3.33	0.74	0.72	2.57	0.00	1.38	1.39	1.15	0.70	1.91
		Q fine quartz polycrystalline	0.00	0.23	0.00	0.96	0.00	0.00	0.00	0.23	0.00	0.00	0.00	0.23	0.47	0.00
		Q micro quartz polycrystalline	0.00	0.00	0.00	0.00	1.67	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
		Q quartz in granitoid r.f	0.00	0.69	0.70	0.24	1.43	0.00	1.20	0.47	1.49	0.00	0.23	0.00	0.00	0.48
		Q quartz in low grade metamorphic r.f	0.26	0.23	1.86	3.36	2.62	0.25	1.92	2.80	3.73	0.69	1.86	0.92	1.64	1.19
		Q quartz in sandstone r.f.	0.00	0.46	0.00	0.00	0.24	0.00	1.44	0.23	0.00	0.00	0.00	0.00	0.00	0.00
		Q quartz in felsic volcanic r.f	0.00	0.00	0.00	0.00	0.95	0.00	0.00	0.00	0.50	0.92	0.46	0.00	0.00	0.24
	K	K-feldspar single crystal	0.00	0.69	4.19	6.24	1.67	0.50	2.40	1.40	2.74	0.92	1.16	0.69	0.00	0.72
		K-feldspar in granitoid r.f	0.00	0.00	1.86	0.00	0.95	0.25	0.00	0.47	0.00	0.00	0.00	0.23	0.00	0.00
		K-feldspar in low grade metamorphic r.f	0.00	0.46	0.00	0.72	0.48	0.00	0.00	0.47	0.25	0.00	0.70	1.15	0.00	0.24
		K-feldspar in femic subvolcanic r.f.	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	2.80	2.39
	P	P plagioclase single crystal	0.00	0.46	1.63	2.64	0.24	0.74	0.72	0.70	0.75	0.46	1.39	0.00	0.00	1.19
		P plagioclase in low grade metamorphic r.f	0.00	0.00	0.00	0.72	0.71	0.00	0.00	0.00	0.00	0.00	0.00	0.46	0.00	0.00
		P plagioclase in femic porphiric volcanic r.f	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.46	0.23	0.48
		P plagioclase in femic subvolcanic r.f.	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.69	1.40	0.48
		P plagioclase in gabbro r.f.	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.23	3.25	2.53	0.00	1.19
	L — Lm	Low grade metamorphic r.f	0.00	1.16	5.58	4.32	4.76	1.49	3.84	3.04	4.48	0.92	0.00	0.00	1.17	0.72
	L — Lv	Femic volcanic r.f.	0.00	0.00	2.33	0.72	0.95	0.00	0.00	0.00	0.00	1.84	6.03	7.60	8.88	6.44
		Medium volcanic r.f.	2.60	0.69	4.65	0.00	0.00	0.00	0.00	0.00	0.00	1.38	8.82	5.53	1.64	2.63
		Felsic volcanic r.f.	0.52	0.23	2.33	0.48	2.14	0.25	1.44	1.64	3.73	0.92	0.00	0.00	0.93	1.67
		Serpentinite r.f.	0.00	0.00	1.86	1.20	1.67	0.00	0.00	0.00	0.00	13.10	8.82	11.98	16.59	15.51
	L — Ls	Siltite silicoclastica	0.00	0.00	1.16	0.00	4.52	0.00	2.40	1.17	0.50	1.84	0.46	0.23	1.64	0.48
		Radiolarite	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.38	0.00	0.92	0.00	0.24
	Phyllosilic.	Phyllosilicate single crystal	0.00	0.23	0.93	3.60	1.19	0.25	0.00	0.93	0.00	0.00	0.00	0.23	0.93	0.00
		Phyllosilicate in low grade metamorphic r.f	0.00	0.00	0.00	1.92	0.00	0.00	0.00	0.00	0.50	0.00	0.00	0.00	0.00	0.24
	Heavy min.	Cpx single crystal	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.92	1.86	2.07	6.31	5.25
		Cpx in gabbro r.f.	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.46	1.16	1.15	0.00	0.48
		Cpx in femic subvolcanic r.f.	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.92	0.00	0.00	2.57	0.95
		Cpx in serpentinite r.f.	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.87	0.00
		"Picotite" spinel single crystal	0.00	0.69	0.93	0.00	0.71	0.00	0.00	0.00	0.00	0.00	0.70	0.46	1.40	0.95
		"Picotite" spinel in serpentinite r.f.	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.38	0.00	0.00	0.00	0.48
CE	Lc	Grainstone r.f.	20.52	21.30	8.84	4.56	5.48	14.89	21.10	14.72	13.68	38.62	22.51	20.74	5.37	4.53
		Wackstone r.f.	5.97	7.87	0.93	1.20	11.90	12.16	4.32	8.41	6.22	6.21	3.25	1.15	0.00	0.72
		Mudstone r.f.	30.39	31.94	18.14	16.55	22.62	39.45	28.78	31.07	34.83	14.94	9.74	12.21	21.03	23.63
		Dolomia r.f.	0.78	0.00	0.00	0.00	0.00	0.00	0.48	0.00	0.25	0.00	0.00	0.00	0.00	0.00
NCI		Pelitic rip-up (clay chips) r.f.	0.00	0.00	0.70	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.93	0.00	0.00	0.00
CI		Isolated bioclast	14.55	10.88	10.23	6.47	9.29	11.66	10.07	8.18	7.46	3.22	12.99	9.68	10.28	8.83
		Soft mudstone r.f.	15.58	12.73	4.19	3.60	6.43	11.91	10.07	10.28	8.46	3.68	8.35	9.22	6.07	6.68
		Alterite	2.60	2.08	2.79	1.20	1.67	3.72	0.48	3.50	1.00	0.00	1.39	2.76	0.00	0.95
		Limeclast	2.86	5.09	6.05	4.80	6.19	0.74	3.36	0.70	2.74	1.38	0.93	2.30	2.57	1.19
		Total framework %	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00
		Framework	77.00	86.40	86.00	83.40	84.00	80.60	83.40	85.60	80.40	87.00	86.20	86.80	85.60	83.80
		Siliciclastic matrix	0.40	0.00	2.40	4.60	1.40	0.00	1.00	0.60	2.20	0.00	0.20	0.00	1.60	0.60
		Carnonatic matrix	4.80	2.20	4.00	2.80	4.40	2.60	2.40	3.40	4.60	1.60	2.40	3.20	2.00	5.20
		Calcite pore-filling cement	11.20	5.40	2.00	4.00	4.80	12.60	7.60	5.40	8.80	9.20	7.60	5.80	3.00	6.60
		Patchy calcite	5.80	3.60	5.60	0.00	5.40	4.20	5.60	2.20	4.00	2.20	0.80	4.20	4.60	3.80
		Post depositional calcite veins	0.80	2.40	0.00	5.20	0.00	0.00	0.00	2.80	0.00	0.00	2.80	0.00	3.20	0.00
		Total %	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00

According to the calpionellids and foraminifera assemblages by Mikes et al. (2008), the age of the Vranduk Formation ranges from Tithonian to Berriasian-Valanginian. However, in northern and central Bosnia, the Vranduk Formation show a continuous succession ranging in age from Berriasian up to Cenomanian (Cadet 1968; Cadet and Sigal 1969; Charvet 1978) or from Barremian to Campanian (Blanchet, 1970). Recently, Djeriç et al. (2007) reported an Oxfordian radiolarite intercalation from the Vranduk Formation. In contrast, the Ugar Formation is referred to the late Albian - Maastrichtian time (Cadet 1968; Charvet 1978; Olujiç et al. 1978), although a Paleocene age for the top is suggested by (Olujiç et al., 1978).

From the petrographic point of view the Vranduk Formation is an ophiolite-bearing lithoarenite where the carbonate rock fragments are subordinate respect to the continental basement-derived rock fragments. In turn, the Ugar Formation is characterized by a lithoarenitic framework dominated by carbonate fragments (both coeval and not-coeval), subordinate continental basement-derived rock fragments and minor ophiolite-derived debris (Mikes et al., 2008). The today relationships indicate that the Vranduk and Ugar Formations occur as two different tectonic slices, with the oldest succession at the top of the youngest one. Dimitrijević (1982) and Schmid et al. (2008) suggest that the pristine relationships between the Vranduk and Ugar Formations were represented by an angular unconformity marked by a hiatus.

North of the Shkoder-Péc Line, ophiolite-bearing turbidite deposits, assigned to the late Tithonian - Berriasian by Calpionellids microfaunas (Blanchet et al., 1970), occur in the lower part of the Maglaj sequence (Blanchet et al., 1970), which overlies the ophiolites of the Bosnian area. The Maglaj sequence is topped by a clastic, pelagic sequence of Albian - Cenomanian age.

South of the Shkoder-Péc Line, the deposits correlated with the Vermoshi Flysch are also well represented. In Albania, the Firza Flysch (Gardin et al., 1996), also known as Sandstone-Calcareous Flysch (Shallo, 1990 and Kodra et al., 1993), crops out as a tectonic slice below the sub-ophiolite mélange, that is in turn topped by the ophiolite units. According to Gardin et al. (1996), the Firza Flysch is characterized by an uppermost Tithonian - late Valanginian turbidite succession where the ophiolite-bearing arenites and rudites are widespread. Also in the Pindos area, northern Greece, the Dendra Group, which is overthrust by the ophiolite nappe, is characterized by the Agios Nicolaos Formation, consisting of calcareous and ophiolite-bearing turbidites of Berriasian age (Terry and Mercier, 1971; Jones and Robertson, 1991).

However, these deposits have been also found at the top of the ophiolite units. For instance, in the Mirdita Nappe the ophiolite sequence is unconformably topped by a sedimentary mélange, known as Simoni Mélange, showing a stratigraphic transition to a turbidite succession of Tithonian - late Valanginian age, that have been also reported as Firza Flysch (Gardin et al., 1996). In Greece, an ophiolite-bearing turbidite deposits of Early Cretaceous age, reported as Beotian Flysch (Celet et al., 1976; Clément, 1976), crops out in the Western Pindos, Othrys, Iti, Parnasse, Beotian and Geranees Mountains areas. The Beotian Flysch, sometimes associated with a sedimentary mélanges, is generally recognized as a tectonic slice at the top of the ophiolite nappe (Aubouin and Bonneau, 1977; Jaeger and Chotin, 1978). In the Iti and Geranees Mountains areas, the Calpionellids recognized in the lowermost portion of the Beotian Flysch indicates a Tithonian age. However, in the Western Pindos, Othrys, Parnasse and Beotian areas the lowermost portion of the Beotian Flysch generally displays middle Berriasian Calpionellids. In two sections of Beotian Flysch a late Cretaceous microfaunes are reported (Celet et al., 1976).

On the whole, along the Dinaric-Hellenic belt, the ophiolite-bearing turbidite deposits of Early Cretaceous age can be detected in two different geological settings. In the first one, they are an independent tectonic unit (Firza Flysch *p.p.*, Bosnian Flysch, Agios Nicolaos Formation) at the top or in the Adria-derived units and below the ophiolite nappe; in the second one, they are at the top of the ophiolite nappe, with both stratigraphic (Firza Flysch *p.p.*, Maglaj sequence) and tectonic relationships (Beotian Flysch) with the oceanic sedimentary cover. These occurrences correspond, in our reconstruction (Fig. 7), to a different geodynamic setting of the basin where the turbidites were deposited. The first occurrence, (tectonic slice below the ophiolite nappe) corresponds to an original location of the turbidite succession in a foredeep basin located on the Adria continental margin and bounded by the advancing ophiolite nappe. The present-day tectonic setting would be thus acquired during the Late Cretaceous - Tertiary tectonics resulting in a detachment of the turbidite succession from its substratum and its subsequent thrusting onto the Adria-derived continental units. In contrast, the second occurrence (tectonic slice or unconformable deposits at the top of the ophiolite nappe) derived from a pristine location of the sedimentary basin at the top of the advancing ophiolite nappe. In this second occurrence, the turbidite succession can be interpreted as deposited in a thrust-top-basin during the first phase of the ophiolite nappe emplacement. This is confirmed by the finding of stratigraphic relationshisps of the Firza Flysch with the top of the Simoni Mélange, that in turn unconformably covered the ophiolites.

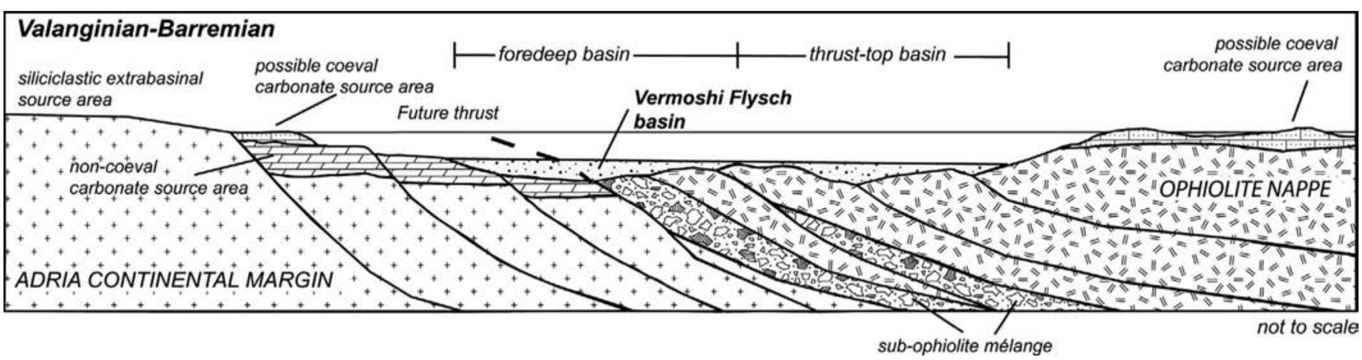

Fig. 7 - Geodynamic reconstruction of the Vermoshi Flysch basin during the Valanginian-Barremian.

In this frame, the Vermoshi Flysch, that is found as tectonic slice below the ophiolite nappe, can be interpreted as derived from a foredeep basin, that developed since Late Jurassic up to Early Cretaceous on the Adria continental margin in front of the advancing ophiolite nappe. This reconstruction is confirmed by the arenite petrography data that indicate two possible different source areas, represented by a continental margin and an ophiolite nappe (fig. 7).

While the ophiolite-bearing debris derived from the advancing ophiolite nappe (including ophiolite sequence and its sedimentary cover, sub-ophiolite mélange and possible slices of Adria derived continental crust), the ophiolite-lacking arenites might be derived from a source area located in the Adria continental margin that collect debris only from the continental crust and its carbonate sedimentary cover.

In this reconstruction, the present-day tectonic setting of the Vermoshi Unit is proposed as acquired during the Late Cretaceous - Tertiary collisional tectonics, during the west-verging deformations that affected the Adria continental margin. In this frame, the occurrence of the Vermoshi Unit sandwiched between the Gashi (East Bosnian-Durmitor Unit) and Valbona Units can be probably regarded as the result of an out-of-sequence thrust event that lead the Gashi Unit onto the Vermoshi one, after the thrusting of the latter onto the Valbona Unit.

CONCLUSIONS

The present study allows the interpretation of the Vermoshi Flysch as turbidite deposits of Barremian age. These deposits are characterized by arenites showing mixed/hybrid silicilastic-carbonate composition (*sensu* Zuffa, 1980) ranging from quartz-rich sublitharenites to quartz-poor litharenites. The arenite framework is mainly represented by both intrabasinal and extrabasinal carbonates fragments, but debris derived from siliciclastic extrabasinal rocks also occur. In addition, some samples are characterized by the occurrence of fragments derived from an ophiolite sequence and its sedimentary cover. The collected data indicate two different source areas, represented by a continental margin and by an advancing ophiolite nappe. On the whole, the Vermoshi Flysch can be correlated with the ophiolite-bearing turbidite deposits of Early Cretaceous age, that are widespread in the whole Dinaric-Hellenic belt. For these deposits two types of sedimentary basins of origin are postulated: a foredeep basin, that developed since Late Jurassic up to Early Cretaceous on the Adria continental margin, and a thrust-top-basin located over an advancing ophiolite nappe. For the Vermoshi Flysch an origin from a foredeep basin is here proposed, according to its present day tectonic occurrence below the East Bosnian-Durmitor Unit, topped in turn by the main ophiolite nappe. In this frame, the Vermoshi Flysch can be regarded as the southernmost part of the Vranduk Flysch, cropping out in Serbia and Croatia.

ACKNOWLEDGEMENTS

This research was supported by M.A.E. Project of Scientific & Technological Cooperation Programme between the Republic of Italy and the Republic of Albania (2005 – 2007) “Geopotential maps on scale 1:50.000” (Albania-Montenegro border area)” and PRIN 2006, Project “Structural evolution and stratigraphic setting of the Ibar/Kopaonik and Guevgueli ophiolite sequences (Republic of Serbia-Montenegro and Greece) and comparison with Albanian ophiolites”. Funds by C.N.R., “Istituto di Geoscienze e Georisorse”, Pisa, Italy are also acknowledged.

REFERENCES

Auboin J., Blanchet R., Cadet P., Celet P., Charvet J., Chorovic J., Cousin M. and Rampnoux J.P., 1970. Essai sur la géologie des Dinarides. Bull. Soc. géol. France, 12 (7): 1060-1095.

Aubouin J. and Bonneau M., 1977. Sur la présence d’un affleurement de flysch éocrétacé (Béotien) au front des unités du Koziakas (Thessalie, Grèce): la limite entre les zones externes et les zones internes dans les Héllénides. C.R. Acad. Sci. Paris, 284: 2075-2078.

Beccaluva L., Coltorti M., Premti I., Saccani E., Siena F. and Zeda O., 1994. Mid-ocean ridge and supra-subduction affinities in ophiolitic belts from Albania. In: Beccaluva L. (Ed), “Albanian ophiolites: state of the art and perspectives”. Ofioliti, 19 (1): 77-96.

Bernoulli D. and Laubscher H., 1972. The palinspastic problem of the Hellenides. Ecl. Geol. Helv., 65: 107-118.

Blanchet R., Cadet J.P., Charvet J. and Rampnoux J.P., 1969. Sur l’existence d’un important domaine du flysch tithonique - crétacé inférieur en Yougoslavie: l’unité du flysch bosniaque. Bull. Soc. Géol. France, 11 (7): 871 - 880.

Blanchet R., Duran Delga M., Moullade M. and Sigal J., 1970. Contribution a l’étude du Crétacé des Dinarides internes: la région de Maglaj, Bosnie (Yugoslavie). Bull. Soc. Géol. France, 12 (7): 1003-1009.

Bortolotti V., Carras N., Chiari M., Fazzuoli M., Marcucci M., Photiades A. and Principi G., 2003. Argolis Peninsula in the paleogeographic and geodynamic frame of the Hellenides. Ofioliti, 28: 79-94.

Bortolotti V., Chiari M., Kodra A., Marcucci M., Mustafa F., Principi G. and Saccani E., 2004b. New evidences for Triassic magmatism in the northern Mirdita zone ophiolites (Albania). Ofioliti 29: 247-250.

Bortolotti V., Chiari M., Marcucci M., Marroni M., Pandolfi L., Principi G. and Saccani E., 2004a. Comparison among the Albanian and Greek ophiolites, in search of constraints for the evolution of the Mesozoic Tethys ocean. Ofioliti, 29: 19-35.

Bortolotti V., Chiari M., Marcucci M., Photiades A., Principi G. and Saccani E., 2008. New geochemical and age data on the ophiolites from the Othrys area (Greece): implication for the Triassic evolution of the Vardar Ocean. Ofioliti, 33 (2): 135-151.

Bortolotti V., Kodra A., Marroni M., Mustafa F., Pandolfi L., Principi G. and Saccani E., 1996. Geology and petrology of the ophiolitic sequences in the Mirdita region, northern Albania. Ofioliti, 21: 3-20.

Bortolotti V., Marroni M., Pandolfi L., Principi G. and Saccani E., 2002. Alternation of MOR and SSZ Basalts in Albanian Ophiolites: Evidences of interactions between Mid-Ocean Ridge and subduction-related processes in an infant arc setting. J. Geol., 110: 561-576.

Bortolotti V., Marroni M., Pandolfi L. and Principi G., 2005. Mesozoic to Tertiary tectonic history of the Mirdita ophiolites, Northern Albania. Island Arc, 14 (4): 471-493.

Bown P.R., 1998. Calcareous Nannofossil biostratigraphy. British Micropal. Soc. Publ. Series, 7, 314 pp.

Bown P.R., and Young, J.R., 1998. Introduction. In: P.R. Bown (Ed.). Calcareous Nannofossil Biostratigraphy. British Micropal. Soc. Pubbl. Series, Chapman and Hall/Kluwer Academic, p. 1-15.

Bralower T.J., Monechi S. and Thierstein H.P., 1989. Calcareous nannofossil zonation of the Jurassic Cretaceous boundary interval and correlation with the geomagnetic polarity timescale. Marine Micropal., 14: 153-235.

Cadet J.P. and Sigal J., 1969. Sur la stratigraphie et l'extension du flysch éocretacé en Bosnie Hercégovine méridionale. C.R.S. Soc. Géol. France, 2: 52–53.

Celet P., Clement B. and Ferrière J., 1976. La zone béotienne en Grèce: Implications paléogéographiques et structurales. Eclogae Geol. Helv., 69 (3): 577-599.

Celet P., Courtin B. and Ferrière J., 1980. Les ophiolites des Héllénides centrales dans leur contexte géotectonique. In: A. Panayiotou (Ed.), Ophiolites, Proceed. Intern. Ophiolite Symp., Cyprus 1979. Geol. Surv. Dept., Cyprus, p. 360-371.

Charvet J. 1978. Essai sur un orogène alpin: Géologie des Dinarides au niveau de la transversale de Sarajevo (Yougoslavie). Publ. Soc. Géol. Nord, 2: 1-554.

Chiari M., Marcucci M., Cortese G., Ondrejickova A. and Kodra A., 1996. Triassic Radiolarian assemblages in the Rubik area and Cukali zone, Albania. Ofioliti, 21: 77-84.

Chiari M., Bortolotti, V., Marcucci M. and Principi G., 2007. New data on the age of the Simoni Mélange, Northern Mirdita ophiolite nappe, Albania. Ofioliti, 32 (1): 53-56.

Clément B., 1976. Relations structurales entre la Zone du Parnasse et la Zone Pélagonienne en Béotie (Gréce continentale). 6th Coll. Geology of the Aegean region. Inst. Geol. Min. Expl., Athens, p. 237-251.

Dercourt J., 1967. Sur l'accident de Scutari-Pec, la signification paléogeographique de quelques series condensées en Albanie septentrionale. Ann. Soc. Géol. Nord, 9: 1-109.

Dickinson W.R., 1970. Interpreting detrital modes of greywacke and arkose. J. Sedim. Petrol., 40: 695-707.

Dickinson W.R., 1985. Interpreting provenance relations from detrital modes of sandstones. In: G.G. Zuffa (Ed.), Provenance of arenites: NATO ASI series, p. 333-362.

Dimitrijević M.D., 1982. Dinarides: an outline of tectonics. Earth Evol. Sci., 2: 4-23.

Djerić N., Gerzina N. and Schmid S.M., 2007. Age of the Jurassic Radiolarian Chert Formation from the Zlatar Mountain (SW Serbia). Ofioliti, 32 (2): 101-108.

Duchamp-Alphonse S., Gardin S., Fiet N., Bartolini A., Blamart D. and Pagel M., 2007. Fertilization of the northwestern Tethys (Vocontian basin, SE France) during the Valanginian carbon isotope perturbation: Evidence from calcareous nannofossils and trace element data. Palaeog., Palaeocl., Palaeoec., 243:132–151

Gaggero L., Marroni M., Pandolfi L. and Buzzi L., 2009. Modeling the oceanic lithosphere obduction: constraints from the metamorphic sole of Mirdita Ophiolites (northern Albania). Ofioliti, 3 (1): 17-42.

Gardin S., Kici V., Marroni M., Pandolfi L., Pirdeni A. and Xhomo A., 1996. Litho- and biostratigraphy of the Firza flysch, ophiolite Mirdita nappe, Albania. Ofioliti, 21: 47-54.

Gardin S., Marino M., Monechi S. and Principi G., 1994. Biostratigraphy and sedimentology of Cretaceous ligurid flysch: paleogeographic implication. Mem. Soc. Geol. It., 48: 219-235.

Gazzi P., 1966. Le arenarie del flysch sopracretaceo dell'Appennino modenese: correlazioni con il Flysch di Monghidoro: Mineral. Petrogr. Acta, 12: 69-97.

Grillo V., Turku I. and Nicolas M., 1983. Research tematiko-resumptive of rilevues for research: the region polimetaleve Dukagjin - Vermosh. I.S.P.G.J. Tirana.

GSY, Geological Survay of Former Yugoslavia, 1973. Geological map and explanatory text of the sheet 628 "Berane". Savezni Geol. Zavod, Beograd.

Hill M.E., 1976. Lower Cretaceous calcareous nannofossils from Texas and Oklahoma. Palaeont. Abteil. B, 156: 103-179

Hrvatović H., 1999. Geoloski vodiç kroz Bosnu i Hercegovinu. Geol. Survey Bosnia and Herzegovina, Sarajevo, 203 pp.

IKGJ-INGF-FGJM, 2002. Albania Geology and Geological Map, 1:200.000 scale. SHGJSH, Tirana, Albania.

IKGJ-INGF-FGJM, 2004. Albania Geology and Geological Map, 1:200.000 scale. SHGJSH, Tirana, Albania.

Ingersoll R.V., Bullard T.F., Ford R.L., Grimm J.P., Pickle J.D., and Sares S.W., 1984. The effect of grain size on detrital modes: a test of the Gazzi-Dickinson point counting method. J. Sedim. Petr., 54: 212-220.

Ingersoll R.V. and Suzcek C.A., 1979. Petrology and provenance of Neogene sands from Nicobar and Bengala fans, DSDP sites 211 and 218. J. Sedim. Petr., 49: 1217-1228.

Jaeger P. and Chotin P., 1978. La série du flysch béotien (Tithonique-Berriasien supérieur) au front du Koziakas (Mouzaki, Province de Karditsa, Grèce). C. R. Soc. Géol. France, 1: 28-31.

Jones G. and Robertson A.H.F., 1991. Tectonostratigraphy and evolution of the Mesozoic Pindos ophiolite and related units, northwestern Greece. J. Geol. Soc. London, 148: 267-288.

Kodra A., Vergely P., Gjata K., Bakalli F. and Godroli M., 1993. La formation volcano-sédimentaire du Jurassique supérieur: témoin de l'ouverture du domaine ophiolitique dans les Albanides internes. Bull. Soc. Géol. France, 164 (1): 61-67.

Lindholm R.C. and Finkelman R.B., 1972. Calcite staining: semiquantitative determination of ferrous iron: J. Sedim. Petr., 42: 239-242.

Longiaru S., 1987. Visual comparators for estimating the degree of sorting from plane and thin section: J. Sedim. Petr., 57: 791-794.

Lozar F. and Tremolada F., 2003. Calcareous nannofossil biostratigraphy of Cretaceous sediments recovered at ODP Sites 1149 (Leg 185, Nadezhda Basin, Western Pacific). In: J.N. Ludden, T. Plank and C. Escutia (Eds), Proc. ODP Sci. Results, 185: 1-21.

Luzar-Oberiter B., Mikes T., von Eynatten, H. and Babić L., 2009. Ophiolitic detritus in Cretaceous clastic formations of the Dinarides (NW Croatia): evidence from Cr-spinel chemistry. Intern. J. Earth Sci., in press. DOI 10.1007/s00531-008-0306-3.

Marcucci M. and Prela M., 1996. The Lumi i zi (Puke) section of the Kalur Cherts: radiolarian assemblages and comparison with other sections in northern Albania. Ofioliti, 21: 71-76.

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

Marroni M., Treves B., Monechi S., Principi G and Perilli N., 1992. Late Cretaceous flysch deposits of the Northern Apennines, Italy. Age of inceptions of orogenesis-controlled sedimentation. Cretaceous Res., 13: 487-540.

Meco S. and Aliaj S., 2000. Geology of Albania. Beitrage zur regionalen Geologie der Erde, Stuttgart, Berlin, Germany, 246 pp.

Mikes T., Christ D., Petri R., Dunkl I., Frei D., Báldi-Beke M., Reitner J., Wemmer K., Hrvatović H. and von Eynatten H., 2008. Provenance of the Bosnian Flysch. Swiss J. Geosci. 101: 31-54.

Olujiç J., Pamić O., Pamić J., Milojević R., Veljković D. and Kapeler I., 1978. Explanatory notes of the Basic Geological Map, Sheet Vares L34-133, Federal Geol. Inst., Belgrade, 68 pp.

Onuzi, K. and Pajovic M., 2004. Geological map 1:50 000 scale of Sheet 1 Vermosh Planshetit and exploratory text. IKGJ, Tirana

Onuzi K., Pajovic M., Hoxha J. and Radusinovic S., 2004. Geological map 1:50 000 scale of Sheet 2 Gusia and exploratory text. IKGJ, Tirana.

Onuzi K. and Pajovic M., 2005. Correlation of the Geological maps 1:50 000 scale of the Albanian Montenegro border area. (Novi Sad). IKGJ, Tirana.

Pamić J, Gusić I. and Jelaska V., 1998. Geodynamic evolution of the central Dinarides. Tectonophysics, 297: 251-268.

Perch-Nielsen K., 1985. Mesozoic calcareous nannofossils. In: H. M. Bolli, I.B. Saunders, and K. Perch-Nielsen, (Eds.), Plankton stratigraphy. Cambridge Univ. Press, Cambridge, p. 329-425.

Peza L.H., Skopje D., Turku I. and Terolli I., 1990. Geology of Vermosh region. Bull. Shenk. Gjeol., 4, 39-55.

Robertson A.H.F and Dixon J.E., 1984. Introduction: aspects of the geological evolution of the Eastern Mediterranean. In: J.E. Dixon and A.H.F. Robertson (Eds.), The geological evolution of the Eastern Mediterranean. Geol. Soc. London, Spec. Publ., 17: 1-74.

Robertson A.H.F. and Shallo M., 2000. Mesozoic-Tertiary tectonic evolution of Albania in its regional eastern Mediterranean context. Tectonophysics, 316: 197-254.

Saccani E., Beccaluva L., Coltorti M. and Siena F., 2004. Petrogenesis and tectono-magmatic significance of the Albanide - Hellenide Subpelagonian ophiolites. Ofioliti, 29:75-93.

Saccani E., Bortolotti V., Marroni M., Pandolfi L., Photiades A. and Principi G., 2008a. The Jurassic association of backarc basin ophiolites and calc-alkaline volcanics in the Guevgueli Complex (Northern Greece): implication for the evolution of the Vardar Zone. Ofioliti, 33 (2): 209-227.

Saccani E., Photiades A., Santato A. and Zeda O., 2008b. New evidence for supra-subduction zone ophiolites in the Vardar Zone of northern Greece: implications for the tectono-magmatic evolution of the Vardar oceanic basin. Ofioliti, 33 (1): 65-85.

Schmid S.M., Bernoulli D., Fügenschuh B., Matenco L., Schefer S., Schuster R., Tischler M. and Ustaszewski K., 2008. The Alpine-Carpathian-Dinaridic orogenic system: correlation and evolution of tectonic units. Swiss J. Geosci., 101: 139-183.

Schroeder R. and Cherchi A., 2007. Upper Barremian-lowermost Aptian orbitolinid foraminifers from the Grand Banks continental rise, northwestern Atlantic (DSDP leg 43, site 384, 1979): Deep Sea Drilling Project Reports and Publications, 43, p. 575-583. doi:10.2973/dsdp.proc.43.118.1979.

Shallo M. and Dylek Y., 2003. Development of the ideas on the origin of Albanian ophiolites. In: Y. Dilek and S. Newcomb (Eds.), Ophiolite concept and the evolution of geological thought. Geol. Soc. Am., Special Pap., 373: 351-364.

Shallo M., 1991. Ophiolitic mélange and flyschoidal sediment of the Tithonian - lower Cretaceous in Albania. Terra Nova, 2: 476-483.

Shallo M., 1992. Geological evolution of the Albanian ophiolites and their platform periphery. Geol. Runds., 81 (3): 681-694.

Shallo M., 1994. Outline of the Albanian Ophiolites. In: L. Beccaluva (Ed.), "Albanian ophiolites: state of the art and perspectives". Ofioliti, 19 (1): 57-75.

Shallo M., Kodra A. and Gjata K., 1992. Geotectonics of the Albanian ophiolites. In: Malpas et al. (Eds.), Proceed. Intern. Ophiolite Symp. "Troodos ophiolite and oceanic lithosphere", Cyprus, 1990, p. 265-269.

Smith A.G., 1993. Tectonic significance of the Hellenic-Dinaric ophiolites. In: H.M. Prichard, T. Alabaster, N.B.W. Harris and C.R. Neray (Eds.), Magmatic processes and plate tectonics. Geol. Soc London Spec. Publ., 76: 213-243.

Terry J. and Mercier M., 1971. Sur l'existence d'une série détritique berriasienne intercalée entre la nappe des ophiolites et le flysch éocène de la nappe du Pinde (Pinde septentrional, Grèce). C.R. S. Soc. Géol. France, 2: 71 -73.

Thierstein H. R., 1973. Lower Cretaceous calcareous nannoplankton biostratigraphy. Abhandl. Geol. Bund., 29: 1-52

Thierstein H.R., 1976. Mesozoic calcareous nannoplankton biostratigraphy of marine sediments. Marine Micropal., 1: 325-362.

Tremolada F. and Erba E., 2002. Morphometric analyses of Aptian Assipetra infracretacea and Rucinolithus terebrodentarius nannoliths: Implications for taxonomy, biostratigraphy and paleoceanography. Marine Micropal., 44: 77-92.

Wind F.H. and Cepek P., 1979. Lower Cretaceous calcareous nannoplankton from DSDP Hole 397A (Northwest African Margin). In: U. von Rad, W.B.F. Ryan, et al. (Eds), Init. Repts. DSDP, 47: 241-255.

Zuffa G.G., 1980. Hybrid arenites: their composition and classification. J.ournal of Sedim. Petrology, 49: 21-29.

Zuffa G.G., 1987. Unravelling hinterland and offshore paleogeography from deepwater arenites. In: J.K. Leggett and G.G. Zuffa (Eds.), Marine clastic sedimentology: Concepts and case studies. Graham & Trotman, London, p. 39-61.

Received, May 27, 2009
Accepted, December 9, 2009