THE GEOLOGY OF THE ZLATIBOR-MALJEN AREA (WESTERN SERBIA): A GEOTRAVERSE ACROSS THE OPHIOLITES OF THE DINARIC-HELLENIC COLLISIONAL BELT

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ABSTRACT

In this paper, we describe the stratigraphical and structural features of the tectonic units cropping out along the Zlatibor-Maljen geotraverse, located in western Serbia at the boundary with Bosnia-Herzegovina, and we present also a 1:100,000 scale geological map. The study area corresponds to a SSW-NNE geotraverse, where the main oceanic and continental tectonic units of the Dinaric-Hellenic belt are well exposed.

Along this geotraverse, the tectonic pile includes at the top the units derived from the European Plate, here represented only by the Ljig Unit, that was thrust over the oceanic units, cropping out in two distinct massifs, the Zlatibor and Maljen ones. In both massifs the oceanic units consist of a sub-ophiolite mélange overthrust by an ophiolite unit represented exclusively by mantle peridotites with the metamorphic sole at their base. In turn the oceanic units overthrust the Adria-derived units, here represented by the East Bosnian-Durmitor and Drina-Ivanjica Units, respectively located westward and eastward of the Zlatibor Massif. The geological data and the tectonic reconstruction suggest that the ophiolites of the two may have originated in the same composite oceanic basin that experienced oceanic opening, intra-oceanic subduction, development of supra-subduction oceanic basins and finally closure, in a time span ranging from Middle Triassic to Late Jurassic.

The stratigraphical and structural dataset presented in this paper allows some insights about the geodynamic history of the northern area of the Dinaric-Hellenic belt, as well as a comparison with the reconstructions proposed for the southernmost area by other authors.

INTRODUCTION

The Dinaric-Hellenic belt is a 2000 km long collisional chain of Alpine age derived from the Mesozoic to Neogene convergence between the Adria and Eurasia Plates, which led to the complete destruction of the oceanic basin(s) existing between them. Even if the main steps of the chain evolution have been unraveled since long time (e.g., Dimitrijević, 1997), several important aspects of its geodynamic history are still matter of debate. The occurrence of one, two or more oceanic basins, the timing of the main deformation events, the structural position of some tectonic units and the vergence of emplacement of the oceanic units are only some of the aspects that must be still clarified.

In the last years several papers from researchers of different countries have provided many stratigraphical, paleontological, structural, petrographical, geochemical and radiometric data. However, a further valuable tool for solving the open problems of the Dinaric-Hellenic belt consists of a systematic comparison among several geotraverses, where detailed mapping associated to collection of different kinds of data are performed.

In this paper, we present the 1:100,000 scale geological map of the Zlatibor - Maljen geotraverse located in the northern side of the Dinaric-Hellenic belt. This map, produced by a working team of Italian, Serbian and Bosnian researchers, is integrated with a complete set of stratigraphical, paleontological, structural, petrographical and geochemical data. The correlation with the southern part of the Dinaric-Hellenic belt and the consequent implications for its geodynamic evolution are also discussed in light of the recent literature data available for the neighbouring areas.

GEOLOGIC AND GEODYNAMIC OVERVIEW OF THE DINARIC-HELLENIC BELT

The Dinaric-Hellenic belt (Fig. 1) was built-up during a long time span, about 200 Ma, throughout different steps including a sequence of rifting, spreading, obduction, subduction and continental collision phases. In the classic reconstructions, the evolution of the Dinaric-Hellenic belt includes a rifting stage, developed during the Early Triassic along the northern margin of Pangea (Dimitrijević, 1982; Pamić et al., 2002; Robertson, 2002; Dilek et al., 2005), that evolved into Middle to Late Triassic oceanic spreading south of the Eurasia Plate margin (Bortolotti and Principi, 2005; Zelic et al., 2005; Bortolotti et al., 2007; Gawlick et al., 2009). The spreading and drifting phases developed a wide basin characterized by mid-ocean ridge (MOR) oceanic

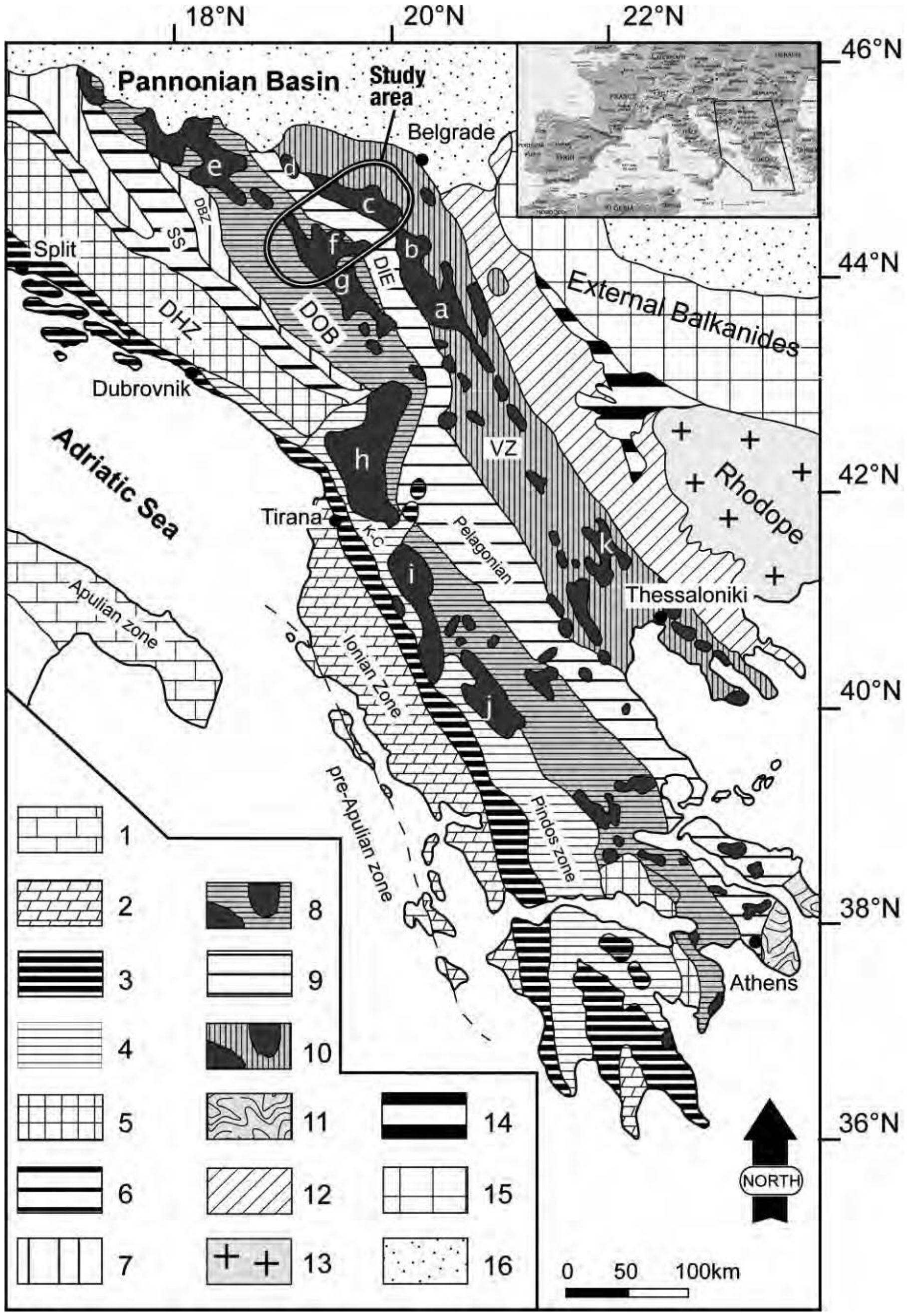

Fig. 1 - Tectonic sketch-map of the Dinaric-Hellenic belt with location of the study area. 1- Apulian and Pre-Apulian zone units; 2- Ionian zone units; 3- South Adriatic zone units: Kruja, Gavrovo and Tripolitsa; 4- Budva, Krasta-Cukali (K-C) and Pindos zone units; 5- Dalmatian-Herzegovian (DHZ) zone units; 6- Sarajevo (SS) zone units; 7- East Bosnian-Durmitor (DBZ) zone units; 8- Dinaric Ophiolite belt (DOB, dark grey: ophiolites); 9- Drina-Ivanjica and Pelagonian zone units (DIE); 10- Vardar zone units (VZ, dark grey: ophiolites); 11- Attic-Cycladic Blueschist units; 12- Internal Dinarides and Hellenides (Serbo-Macedonian Massif); 13- Rhodope Massif; 14- Internal Balkanides; 15- Intermediate and External Balkanides; 16- Pannonian and Tertiary European Foreland basins. Ophiolites: a- Ibar; b- Troglav; c- Maljen; d- Zvornik; e- Krivaja-Konjuh; f- Zlatibor; g- Bistrica; h- North Mirdita; i- South Mirdita; j- Pindos; k- Guevgueli.

lithosphere (Çollaku et al., 1992; Beccaluva et al., 1994; Bébien et al., 1998; Pamić et al., 2002; Bortolotti et al., 2004a; 2008; Saccani et al., 2004). This oceanic basin, without (Ferrière, 1982; Pamić et al., 1998; Bortolotti et al., 2005; Schmid et al., 2008) or with one (Robertson and Karamata, 1994; Karamata et al., 2000; Dimitrijević 2001) or more (Dimitrijević and Dimitrijević, 1973; Robertson and Karamata, 1994; Karamata, 2006) microcontinent(s) within it, was located between the Adria and Eurasia continental margins. Convergence began during the Early Jurassic, with intra-oceanic subduction and formation of an accretionary prism. Subduction caused new oceanic lithosphere to be produced in the related fore-arc (Beccaluva et al., 1994; Shallo, 1994; Pamić, 2002; Bortolotti et al., 2002a and 2002b; Hoeck et al., 2002; Marroni et al., 2004; Dilek et al., 2007; Saccani et al., 2008a; 2011) and back-arc settings (Bébien et al., 1986; Brown and Robertson, 2004; Saccani et al., 2008b). Due to convergence, the oceanic lithosphere of the lower plate was totally destroyed. When the continental margin started to be involved in subduction, an obduction process took place, resulting in the emplacement of supra-subduction zone (SSZ) oceanic lithosphere slices onto the continental margin of the Adria Plate during Middle to Late Jurassic (Smith et al., 1975; Çollaku et al., 1992; Robertson and Karamata, 1994; Dimitrijević, 2001; Pamić et al., 2002; Bortolotti et al., 2004b; 2005; Djerić et al., 2007; Gawlick et al., 2008). Obduction produced first the metamorphic sole and after the mélange at the base of the ophiolite nappe (Smith et al., 1975; Shallo, 1990; Bortolotti et al., 1996; Wakabayashi and Dilek, 2003; Dilek et al., 2005; Gaggero et al., 2009), as well as a foredeep basin in front of it (Mikes et al., 2008; Bortolotti et al., 2009; Luzar-Oberiter et al., 2009; Marroni et al., 2009). Convergence between Adria and Eurasia subsequently led to continental collision, as demonstrated by contractional deformations in the hinterland, i.e. the rim of the Eurasia Plate (Ricou et al., 1998; Kilias et al., 1999; Liati, 2005; Kounov et al., 2010). The age of this stage is still matter of debate; some authors (e.g., Pamić et al., 2002) proposed a Late Jurassic - Early Cretaceous age, whereas others authors (e.g., Schimd et al., 2008) suggested that continental collision occurred later, during the Late Cretaceous - Early Paleogene. The latter reconstruction is supported by findings of pelagic limestones of Early Campanian age interbedded with MORB pillow lavas in the Kozara Mts., northern Bosnia (Ustaszewski et al., 2009). Probably, the different ages proposed for continental collision can be explained by an oceanic closure that occurred in different times along the strike of the convergence zone. After continental collision and up to Neogene time, the ongoing convergence, still active today, mainly affected the continental margin of the Adria Plate, that was progressively deformed in westward-vergent, thrust sheets. However, tectonics continued also in the inner zone of the Dinaric-Hellenic belt, i.e. in the Vardar and Serbo-Macedonian zones, where transition from contractional to extensional deformation occurred at the Eocene-Oligocene boundary (e.g., Dinter and Royden, 1993; Dinter, 1998; Zelic et al., 2010b; Ustaszewski et al., 2010). In the Vardar zone, extensional tectonics was accompanied by emplacement of calc-alkaline granitoids, mainly of Late Eocene - Early Oligocene age (Pamić and Balen, 2001; Pamić et al., 2002; Cvetković et al., 2007; Kovacs et al., 2007; Zelic et al., 2010a; Schefer et al., 2010).

This long-lived geodynamic evolution produced the present-day structure of the northern part of the Dinaric-Hellenic belt, that can be described as an assemblage of NW-SE to N-S trending zones (Fig. 1), corresponding to terranes (see discussion in Bortolotti et al., 2004a). Each zone consists of an assemblage of variably deformed and metamorphosed tectonic units of oceanic and/or continental origin. Along a northern transect of the Dinaric-Hellenic belt, running from Serbia to Bosnia and Croatia, four main zones can be identified (Aubouin et al., 1970; Charvet 1978; Dimitrijević, 1997; Pamić et al., 1998; Karamata, 2006). These zones correspond, from west to east, to: 1- the Deformed Adria zone, 2- the External Ophiolite belt, 3- the Drina-Ivanjica zone and 4- the Vardar zone. These zones are bound to the west by the Undeformed Adria zone, today located in the Adriatic Sea, and to the east by the Sava zone/Serbo-Macedonian-Rhodope Massif, interpreted as part of the deformed margin of Eurasia (Fig. 1).

The Deformed Adria zone consists of a west-verging imbricate stack of tectonic units detached from the continental margin of Adria by a mainly thin-skinned thrust tectonics (Hrvatović and Pamić, 2005; Schimd et al., 2008). According to the overall stratigraphic features and to the age of Alpine deformation, this zone can be subdivided in the northen part of the Dinaric-Hellenic belt into South Adriatic, Budva, Dalmatian-Herzegovian, Sarajevo and East Bosnian-Durmitor Units (Dimitrijević, 1997). On the whole, the sequences of these units are unmetamorphosed, and include Triassic to Paleogene neritic and pelagic carbonate sequences topped by widespread Late Cretaceous to Miocene siliciclastic foredeep deposits. In some of these units, as for instance in the East Bosnian-Durmitor Unit, the succession also includes a Paleozoic basement, regarded as evidence that thick-skinned thrust tectonics also occurred. The westward migration of deformation across the Adria Plate continental margin is well recorded by the inception of foredeep deposition, ranging in age from Late Cretaceous in the Sarajevo zone, to Miocene in the south Adriatic zone. These units were thrust onto the undeformed Adria margin, today recognized by seismic profiles in the Adriatic offshore (Dal Ben, 2002).

Eastwards, the units of the Deformed Adria zone are overthrust by the External Ophiolite belt, that can be described as an assemblage of ocean-derived units cropping out as continous klippen from Argolis, Othrys, Koziakas, Pindos and Vourinous in Greece, to Mirdita in Albania, Bistrica and Zlatibor in Serbia up to Krivaja in Croatia (e.g., Bortolotti et al., 2004a). In the northernmost areas, this belt is characterized by Jurassic ophiolites showing both MOR and SSZ affinity (Pamić and Desmond, 1989; Lugović et al., 1991; Pamić, 1993; Robertson and Karamata, 1994; Pamić et al., 2002; Bazylev et al., 2003; 2009; Slovenec and Lugović, 2009). However, evidence of MOR Middle Triassic ophiolites have also been found by Vishnevskaya et al. (2009). As for Albania and Greece (e.g., Bortolotti et al., 2002a; 2005; in press), the different ophiolite sequences originated in different areas of the same oceanic basin since the Middle Triassic. The External Ophiolite belt shows at its base a sub-ophiolite mélange, consisting of an assemblage of continental and ocean derived units built-up by multistage events, starting in the Middle Jurassic with obduction and ending with the final stages of continental collision (Dimitrijević and Dimitrijević, 1973; Robertson and Karamata, 1994; Babić et al., 2002). The sub-ophiolite mélange probably incorporated fragments of the formations through which it passed, continuing to grow until the last westward movement during obduction and westward emplacement of the ophiolitic units onto the continental margin of Adria (Robertson and Karamata, 1994; Babić et al., 2002; Zelic et al., 2010c).

Further to the east, the External Ophiolite units were thrust onto the Drina-Ivanjica zone (Dimitrijević, 1997) that can be correlated with the Pelagonian and Korab zones in Greece and Albania, respectively. This zone contains an assemblage of tectonic units consisting of a pre-Alpine basement covered by Permian to Early Triassic siliciclastic deposits followed by Middle Triassic - Early Jurassic carbonates and Middle Jurassic radiolarites.

The Drina-Ivanjica zone is topped by the units belonging to the Vardar zone, that represents the easternmost assemblage of tectonic units of the Dinaric-Hellenic belt (e.g., Robertson et al., 2009). This zone, located to the west of the Serbian-Macedonian Massif, consists of a composite assemblage of continental and oceanic-derived units (Ferrière and Stais 1995; Karamata, 1994; 2006; Dimitrijević, 1997; Brown and Robertson, 2004; Saccani and Photiades, 2005; Robertson et al., 2009; Zelic et al., 2010c). The latter include also Triassic and Jurassic ophiolites, that represent the most internal oceanic units of the Dinaric-Hellenic belt. According to Schmid et al. (2008), the ophiolites show age, geochemistry, stratigraphy and deformations similar to those recognized in the External Ophiolite belt. As in the External Ophiolite belt, a sub-ophiolite mélange occurs at the base of the ophiolite sequences (Pamić, 2002; Robertson et al., 2009; Slovenec and Lugović, 2009). However, the Vardar ophiolites are characterized by the occurrence of BABB and CAB basalts as recognized in the southernmost areas of the Dinaric-Hellenic belt by Saccani et al. (2008b), not yet found in the External Ophiolite belt. In the Jadar - Kopaonik - Studenica areas, metamorphic Adria-derived units are exposed below the oceanic-derived units (Zelic et al., 2010c). The Eurasia-derived continental units are represented by both metamorphic and sedimentary rocks grouped by Ustaszewski et al. (2010) in the Sava zone. In Northern Serbia, the Sava zone includes Late Cretaceous turbidite successions (Ljig and Brus Units) considered as witnesses of thrust-top basins located in the hinterland of the forming Dinaric-Hellenic belt (Zelic et al., 2010b).

On the whole, the Vardar zone is regarded as a suture zone developed through collision between the Eurasia and the Adria Plates (Pamić et al., 1998; Karamata, 1994; 2006; Pamić, 2002; Robertson et al., 2009), as suggested by the occurrence in its northern border of slices of metamorphic rocks affected by blueschist metamorphism (Majer and Mason, 1983; Milovanović et al., 1995). In this frame, the ophiolites from both the External belt and Vardar zone can be interpreted as parts of a nappe derived from a common, wide oceanic basin, i.e. the Vardar ocean, characterized by MOR, IAT and BABB oceanic sequences (Bortolotti et al., in press). In the Vardar zone, Oligocene to Pliocene magmatic rocks, both intrusive and effusive, showing calc-alkaline affinity are widespread (Pamić and Baljen, 2001; Cvetković et al., 2004; Schefer et al., 2010).

On its eastern boundary, the Vardar zone was overthrust by the Serbo-Macedonian Massif, consisting of an assemblage of tectonic units derived from the Eurasian Plate (Ricou et al., 1998). The Serbo-Macedonian Massif was intruded by calc-alkaline granitoids of Oligocene age (Pamić and Balen, 2001). However, the present-day structural setting of the Serbo-Macedonian Massif has been mainly achieved through extensional tectonics that followed the Cretaceous shortening. These events are regarded as Oligo-Miocene in age, i.e. coeval to those recognized in the Vardar zone (Zelic et al., 2010a; Ustaszewski et al., 2010).

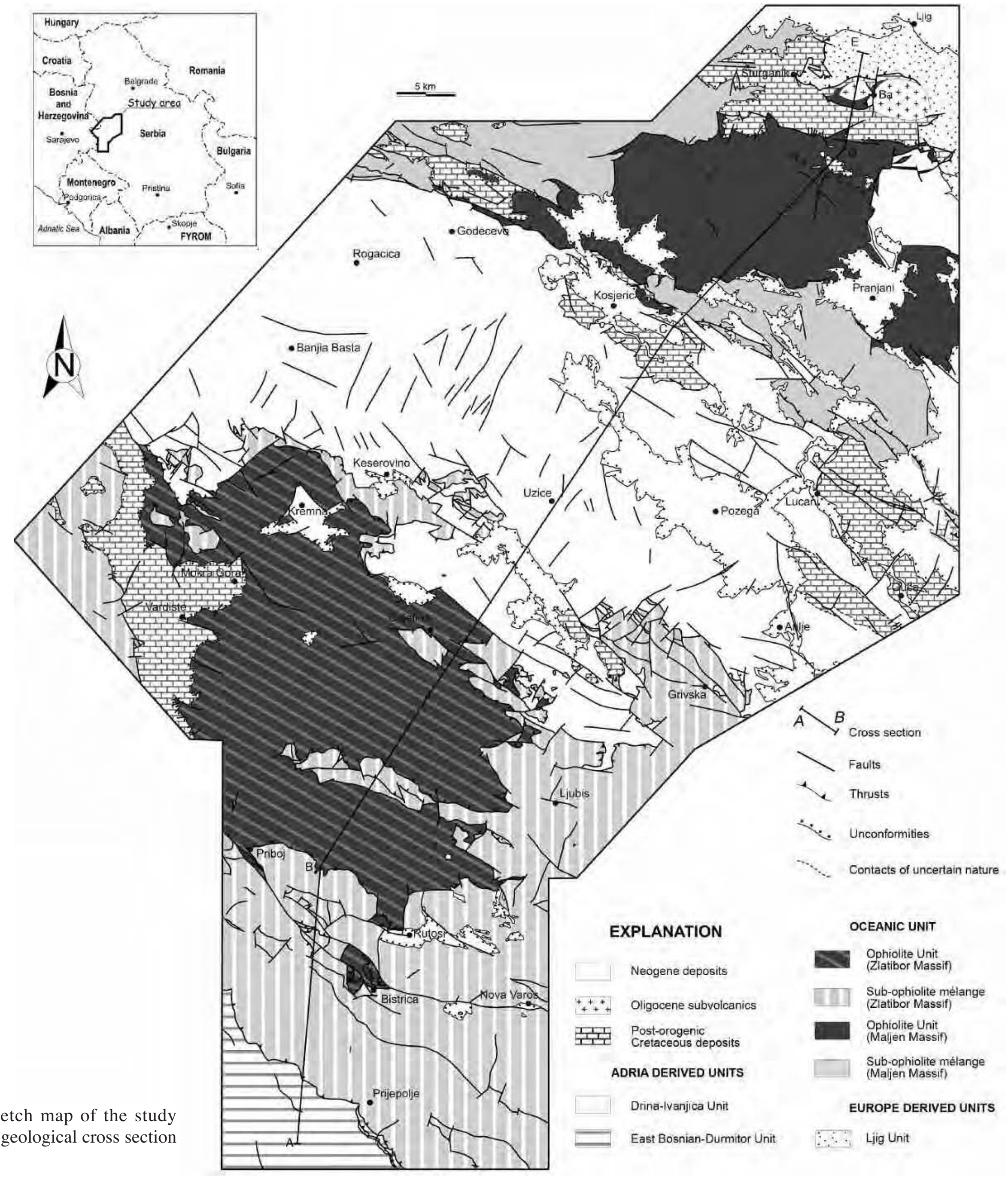

Fig. 2 - Tectonic sketch map of the study area. The trace of the geological cross section of Fig. 3 is indicated.

THE ZLATIBOR-MALJEN GEOTRAVERSE

The study area, located in western Serbia at the boundary with Bosnia-Herzegovina, corresponds to a SSW-NNE geotraverse, about 20 km wide and 60 km long, running from the Zlatibor area in the SSW to the Maljen area in the NNE. The area has been mapped at the 1:25,000 scale and reproduced at the 1:100,000 scale. Along this geotraverse both oceanic and continental units crop out, the latter derived from both the conjugate Adria and Eurasia Plates margins. The Paleozoic formations are undifferentiated in the map. Each unit will be described from a paleontological, stratigraphical and tectonic point of view, with special attention to the oceanic units.

The tectonic pile (Figs. 2 and 3) includes at its top the European-derived units, here represented only by the Ljig Unit. This unit was thrust over the oceanic units, cropping out along the studied geotraverse as two distinct massifs, Zlatibor and Maljen. As recognized along the whole Dinaric-Hellenic belt, both oceanic units consist of a sub-ophiolite mélange overthrust by an ophiolite unit, here represented exclusively by mantle peridotites with metamorphic sole at their base. Most authors working in the Dinaric-Hellenic belt believe that the oceanic units from the two massifs represent remnants of two different oceanic basins (e.g., Dimitrijević and Dimitrijević, 1973; Robertson and Karamata, 1994; Karamata, 2006; Robertson et al., 2009), as also proposed for other areas of the Dinaric-Hellenic belt (Robertson et al., 1991; 1996; Dilek et al., 2005; Smith, 2006; Dilek et al., 2008). Nonetheless, the ophiolites, metamorphic sole and sub-ophiolite mélange show the same stratigraphic, geochemical and structural features as well as the same tectonic setting throughout both massifs. Moreover, the structural data and the tectonic reconstruction seem to indicate that the ophiolites of the two belts could have originated in the same composite oceanic basin that experienced opening, intra-oceanic subduction and development of fore-and back-arc oceanic basin(s) (Aubouin et al., 1970; Rampnoux, 1970; Pamić et al., 1998; Bortolotti et al., 2005; Schmid et al., 2008). In this paper the latter interpretation is adopted and the oceanic units from the Zlatibor and Maljen Massifs are collectively described together.

In turn, the oceanic units overthrust the East Bosnian-Durmitor and Drina-Ivanjica Units, respectively located westward and eastward of the Zlatibor Massif (Fig. 3). According to the interpretation of the ophiolites as generated in a single oceanic basin, both these units would derive from the Adria continental margin. Consequently, the units of the Adria-deformed zone, including that of East Bosnian-Durmitor, and the Drina-Ivanjica Unit will be referred together as Adria-derived units.

This unit pile is unconformably covered by post-orogenic Cretaceous deposits and intruded by a magmatic complex, corresponding in the study area to the Ba quartzlatites. Both the post-orogenic Cretaceous deposits and the Ba magmatic rocks are unconformably covered by Neogene deposits with levels of volcanic and volcanoclastic rocks, not described in this paper.

TECTONIC UNITS

Adria derived-units

In the study area, the Adria-derived units are represented by the East Bosnian-Durmitor and the Drina-Ivanjica Units. Both these units are here assigned to a same paleogeographic domain according to their similar stratigraphical features (see discussion in Schmid et al., 2008 and Robertson et al., 2009). In the literature, the Drina-Ivanjica Unit, was initially correlated (Aubouin et al., 1970; Rampnoux, 1970; Bernoulli and Laubscher, 1972) with the Korab Unit in Albania and with Pelagonian Units in Greece, and viewed as a regional-scale anticline presently cropping out in a large-scale tectonic window. Successively, the Drina-Ivanjica Unit has been interpreted as a microcontinent that rifted apart from Adria (Dimitrijević, 1982; Robertson and Karamata, 1994). In contrast, Pamić et al. (1998) regarded the Drina-Ivanjica Unit as derived from the continental margin of Eurasia. Recently, Bortolotti et al. (2005), for the southern areas, and Schmid et al. (2008), for the northern ones, re-proposed that the Pelagonian-Korab-Drina-Ivanjica Unit was detached from the Adria continental margin and overthrust by the oceanic units during Late Jurassic-Early Cretaceous convergence. The latter interpretation is here adopted.

East Bosnian-Durmitor Unit

This unit occurs in the SSW corner of the map and corresponds to the Lim Unit by Dimitrijević (1997). It is a composite unit made of an assemblage of different sub-units all derived from the same succession. On the whole, it represents the lowermost structural unit of the study area together with the Drina-Ivanjica Unit, both overlain by the sub-ophiolite mélange.

The East Bosnian-Durmitor Unit (Fig. 4) includes a Paleozoic basement unconformably covered by Late Paleozoic deposits that show transition to a Mesozoic sedimentary succession consisting of Triassic siliciclastic rocks and carbonates, Late Triassic - Middle Jurassic mainly carbonate sediments and Middle-Late Jurassic radiolarites.

The Paleozoic basement consists of pre-Devonian metapelites, metasandstones and metacarbonates, up to 250 m thick, affected by greenschist to lower epidote-amphibolite facies metamorphism. These deposits are covered by Devonian sandstones and shales, with lenses of limestones and conglomerates. However, in the study area the Paleozoic basement does not crop out, only its unconformable cover represented by Carboniferous turbidites has been identified. These turbidites have been interpreted as flysch deposits (Karamata, 2006) characterized by slide-blocks of Silurian deep-water sediments and Devonian reef limestones. The Carboniferous turbidites make transition to Late Permian evaporites, red shales and sandstones, not recognized in the study area but cropping out a few kilometres to the north.

In the study area, the Mesozoic succession of the East Bosnian-Durmitor Unit begins with Early Triassic continental sandstones covered by Anisian shallow-water limestones showing a stratigraphic transition to Ammonitico Rosso-type limestones (the latter two reported as Middle Triassic in the map). In the Anisian, shallow-water limestones and rift-related volcanic rocks, mainly andesites, also occur. The Anisian carbonates are directly overthrust by the sub-ophiolite mélange.

However, in the others areas of the Dinaric-Hellenic belt, where the East Bosnian-Durmitor Unit widely crops out the succession is more complete, and the Anisian limestones grade to Ladinian-Carnian siliceous shallow-water and pelagic limestones. The Late Triassic time span corresponds to a general hiatus, whereas the Early and Middle Jurassic are characterized by pelagic cherty limestones and cherts

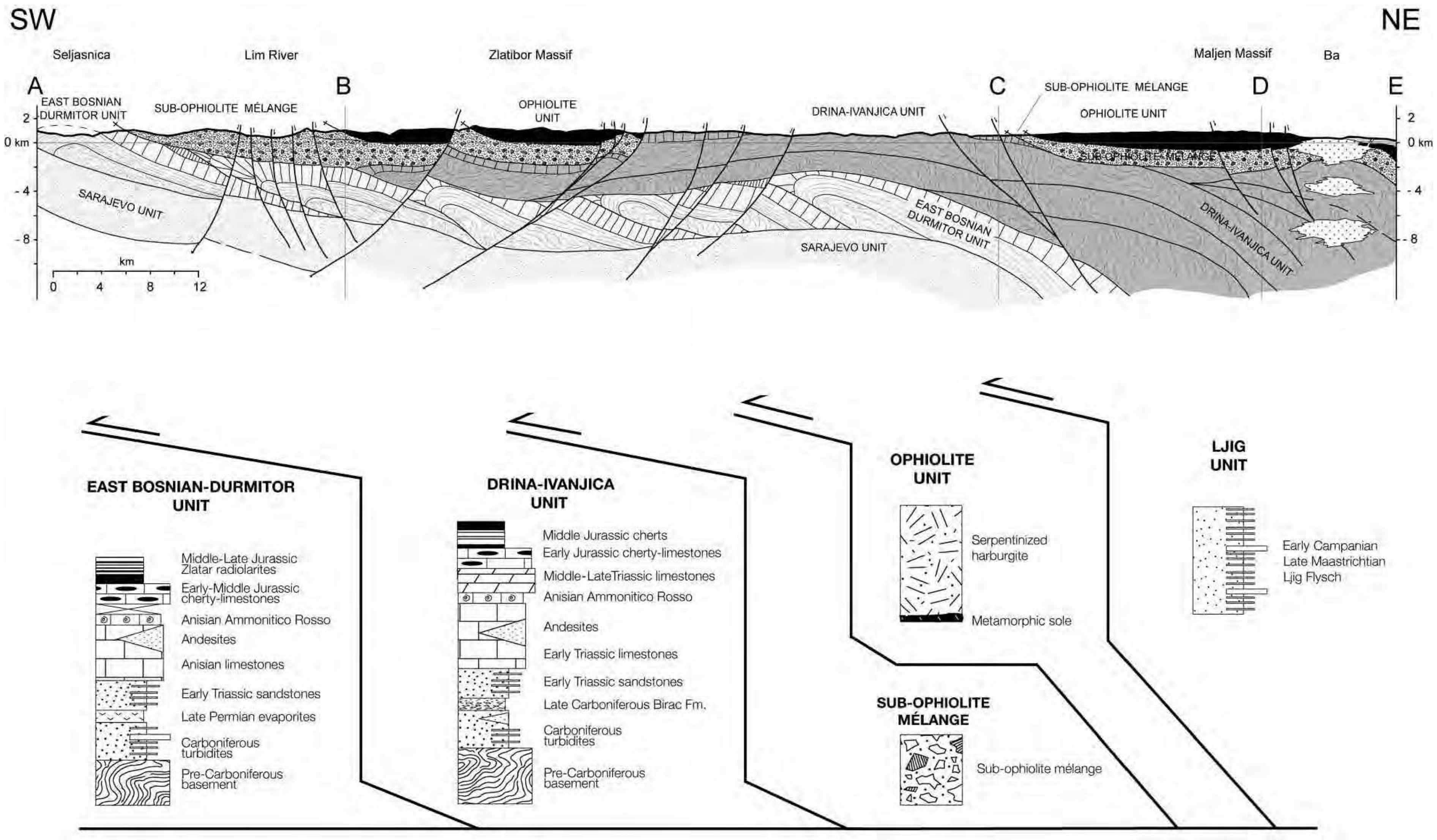

Fig. 3 - Interpretative cross-section and tectonic relationships among the different units along the studied geotraverse. Cross-section trace in Fig. 2.

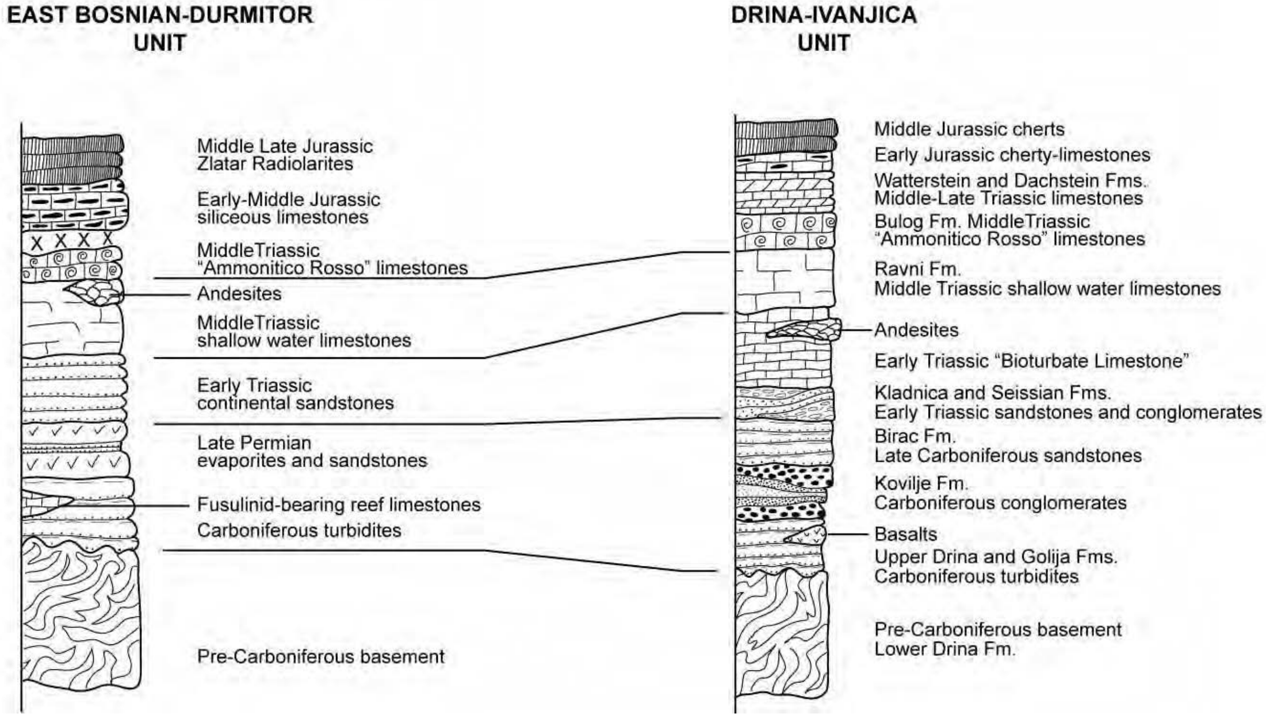

Fig. 4 - Stratigraphic logs of the East Bosnian-Durmitor and Drina-Ivanjica units and their correlation.

(Karamata, 2006). Very thick (up to more than 100 m) Middle-Late Jurassic radiolarite successions (Rampnoux 1970; Vishnevskaya and Djerić, 2009) are typical of the Zlatar area in southern Serbia. The radiolarites are the youngest sediments deposited before the uppermost Late Jurassic to Early Cretaceous obduction of the western belt ophiolites onto the distal Adria continental margin.

On the whole, the succession of the East Bosnian-Durmitor Unit is representative of the distal Adria continental margin that experienced sinking in the Middle to Late Triassic during oceanic opening. The Middle-Late Jurassic radiolarites mark the maximum deepening of this area of the Adria continental margin, immediately before obduction of the ophiolites.

Drina-Ivanjica Unit

This unit that crops out extensively eastwards of the Zlatibor ophiolitic massif, consists (Fig. 4) of a Variscan basement, represented by the lower Drina Formation (Milovanović, 1984; Djoković, 1985; Hrvatović and Pamić; 2005; Trivić et al., 2010), covered by Early/Late Carboniferous to Late Triassic deposits. The lower Drina Formation includes paragneisses, micaschists, amphibolites and minor marble lenses, whose ages range from Cambrian to Silurian according to phytoplankton and spore contents (Ercegovac, 1975). The lower Drina Formation shows a metamorphic imprint under amphibolite P and T conditions, regarded as achieved during the Variscan orogeny.

The lower Drina Formation is conformably covered by the upper Drina Formation, consisting of metasandstones and metapelites with lenses of metavolcanic rocks, mainly metabasalts, and metacarbonates with a Visean/Namurian conodont fauna (Stojanović and Pajić, 1966-71). The upper Drina Formation is conformably covered by the Golija Formation, including metasandstones, metasilstones and metapelites of Visean/Namurian age (Stojanović and Pajić, 1966-71). The Golija Formation is in turn conformably topped by the Kovilje Formation, represented by Early/Late Carboniferous metaconglomerates and metasandstones. The Kovilje Formation makes transition to the Late Carboniferous Birac Formation consisting of (Bashkirian/Moscovian) metasandstones, metalimestones and metapelites (Kubat et al., 1977). According to Dimitrijević (1997), the Birac Formation is directly covered by a Triassic succession starting with metaconglomerates, metasandstones and metapelites of Early Scythian age (Kladnica and Seissian Formations), which are covered in turn by Late Scythian metalimestones ("Bioturbate Limestone" of Dimitrijević, 1997) associated with meta-andesites. At the top, the Anisian Ravni Formation, consisting of shallow water metalimestones, which grade to the red nodular limestones of the Bulog Formation of Anisian age, occurs. The Triassic succession ends with the Watterstein and Dachstein metalimestones ranging in age from Ladinian to Rhaetian. In the study area, no younger deposits have been found at their top. However, outside the study area the succession ends with pelagic, cherty limestones of probably Early Jurassic age, topped by Middle Jurassic cherts (Djerić et al., 2007).

The rocks overlying the lower Drina Formation are metamorphosed up to greenschist facies conditions (Djoković, 1985). Metamorphism was associated to a polyphase deformation that includes two ductile phases, referred to as D_1 and D_2 by Trivić et al. (2010). According to these authors the D_1 phase consists of isoclinal folds with sub-rounded hinges associated to a well-developed axial plane foliation classified as slaty cleavage. The metamorphic mineral associations indicate that the D_1 phase developed at 350°C and around 0.05 GPa (Milovanović, 1984). The following D_2 phase consists of open folds whose axial plane foliation can be classified as a crenulation cleavage. Milovanović (1984) reported K/Ar ages ranging from 179 to 160 Ma for metamorphism associated to the D_1 phase. The same author quoted K/Ar ages ranging from 129 to 139 Ma (Lovrić, unpublished data), obtained from metapelites and metabasites. Even if the ages of the D_1 and D_2 events cannot be unequivocally constrained, the data from Milovanović (1984) seem to indicate that the D_1 phase was achieved before the Late Cretaceous, as also suggested by Trivić et al. (2010).

In the geologic map all the Paleozoic formations are grouped together, whereas the Triassic formations, the Early Scythian Kladnica plus Seissian Formations and the Late Scythian-Rhaetian Formations have been mapped separately.

Oceanic Units

As recognized in the whole Dinaric-Hellenic belt, the oceanic units consist of a sub-ophiolite mélange overthrust by an ophiolite unit with a metamorphic sole at its base. The oceanic units that crop out in the study area in two different massifs, the Zlatibor and Maljen ones, are interpreted as belonging to the same tectonic unit, because of their common geological features. Their linkage was possibly eroded during exhumation of the Drina-Ivanjica Unit, as proposed by Charvet (1978), Bortolotti et al. (2005) and Schmid et al. (2008).

The sub-ophiolite mélange

It consists of several bodies (up to some km in size) derived from both the Adria continental domain (Middle Triassic to Late Jurassic pelagic and platform deposits) and oceanic domains (amphibolites, serpentinized peridotites, gabbros, basalts and cherts). These bodies are often separated by a sedimentary matrix represented by levels of shales, coarse-grained arenites, pebbly mudstones and pebbly sandstones (Fig. 5), originated by erosion of the oceanic and/or continental sequences deformed during obduction. Some bodies are bound by shear zones and can be therefore interpreted as thrust sheets, whereas other bodies can be considered as huge slide-blocks because of their primary stratigraphic relationships with the sedimentary matrix. The sub-ophiolite mélange can be thus regarded as formed through interference of both sedimentary and tectonic processes during emplacement of the ophiolite nappe over the Adria continental margin, related with the marginal stage of obduction (Michard et al., 1991). The mélange probably incorporated fragments of the formations on which the ophiolite nappe passed through, continuing to grow until the last westward movements. During this process, a thick wedge of oceanic and continental units developed at the front of the advancing nappe becoming immediately subjected to erosion. According to Bortolotti et al. (1996), the sub-ophiolite mélange thus contains a mixture of (1) rock types derived from the lower plate, mechanically scraped off and accreted to the upper plate, and (2) gravitationally emplaced slide-blocks derived from the wedge at the front of the advancing nappe. Moreover, post-obduction tectonics erased most of the primary, sedimentary relationships between slide-blocks and mélange matrix, producing tectonic contacts.

The thrust sheets/slide-blocks consist of:

Ophiolites: up to 150-200 m of thick thrust sheets/slide-blocks of serpentinite, basalt and rare gabbro have been identified in the mélange. The mantle rocks include both highly serpentinized hazburgites and lherzolites. However, the ophiolites recognized as thrust sheets/slide-blocks in the mélange are mainly represented by basalt with minor bodies of gabbro. Geochemical analyses of a limited number of selected samples, representative of the magmatic rock-types cropping out in the sub-ophiolite mélange are presented here with the purpose of assessing their magmatic affinity and their tectonic setting of origin. Analytical details are given in Nirta et al. (2010).

The main rock-types found in the sub-ophiolite mélange are: (1) olivine-gabbros, gabbros, and ferrogabbros showing both cumulitic and isotropic textures; (2) volcanic rocks showing various textures and facies; (3) dykes, mostly intruding the gabbroic sequences. No distinction in terms of either rock-type or rock-chemistry was found between the sub-ophiolite mélanges of the Zlatibor and Maljen ophiolites; therefore, these two ophiolitic complexes are described together.

The gabbroic rocks have variable contents of major and trace elements and Mg# (Table 1), which most likely reflect different degrees of fractionation. Olivine gabbros and gabbros are characterized by low to moderate contents of TiO_2, FeO^t, and V. By contrast, the concentrations of these elements are very high in ferrogabbros and, in agreement with the petrographic analyses, reflect crystallization of Fe-Ti oxides. Incompatible elements show generally depleted, flat

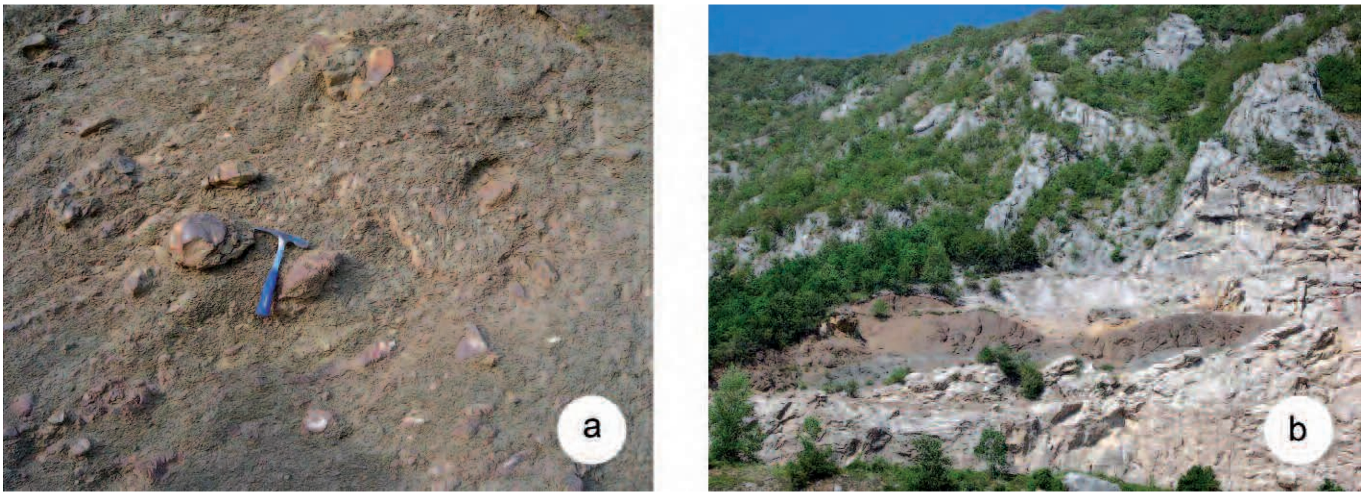

Fig. 5 - Sub-ophiolite mélange. a- Field aspect of the sub-ophiolite mélange matrix consisting of pebbly mudstones. b- Huge slide-blocks of Triassic limestones separated by levels of mudstone and pebbly mudstone representative of the mélange matrix.

Table 1 - Basic petrographic features and whole-rock major and trace element composition of selected rocks from the Zlatibor and Maljen ophiolitic complexes.

	N-MOR gabbro		N-MORB		E-MORB & P-MORB			LKT & CA		
Ophiolite	Maljen	Maljen	Zlatibor	Maljen	Zlatibor	Zlatibor	Maljen	Zlatibor	Maljen	Maljen
Sample	F27	28N	SRB42B	8N	SRB35	SRB60	SBH10	SRB58	4N	42N
Rock	ol-gb	Fe-gb	bas	bas	bas	bas	bas	bas	bas and	bas and
Type					P-MORB	E-MORB	P-MORB	LKT	LKT	CA
Note			dyke in gb					dyke in gb		
Texture	isotr	isotr	aphiric	aphiric	vitroph	aphiric	aphiric	aphiric	aphiric	aphiric
Phases	ol+pl +cpx	pl+cpx +op	pl+cpx laths	pl+cpx laths	pl laths	pl+cpx laths	pl+cpx laths	cpx+pl laths	cpx+pl laths	cpx+pl laths
XRF Analyses:										
SiO_2	46.75	49.20	45.84	44.20	49.57	44.80	46.98	47.81	54.31	52.35
TiO_2	0.42	1.49	1.21	1.81	1.21	2.74	1.80	0.63	0.86	1.06
Al_2O_3	17.36	15.67	16.92	14.65	13.93	15.74	14.30	13.68	13.60	15.60
Fe_2O_3	1.08	1.74	1.19	1.88	1.26	1.12	1.06	1.02	1.23	1.00
FeO	7.22	11.63	7.94	12.53	8.41	7.34	7.04	6.78	8.19	6.68
MnO	0.13	0.16	0.15	0.32	0.15	0.90	0.14	0.14	0.12	0.12
MgO	10.27	7.03	9.92	11.58	6.29	13.05	10.91	15.83	9.29	7.95
CaO	10.36	7.84	13.20	5.58	10.69	4.70	9.76	8.16	5.71	6.68
Na_2O	2.28	2.83	1.87	2.85	3.41	4.54	2.97	1.81	3.94	4.18
K_2O	0.16	0.71	0.03	0.02	1.26	0.23	0.42	0.29	0.27	0.38
P_2O_5	0.03	0.04	0.08	0.13	0.15	0.12	0.42	0.06	0.07	0.19
L.O.I.	3.85	1.82	1.57	4.33	3.75	4.74	4.16	3.91	2.41	3.86
Total	99.91	100.16	99.92	99.9	100.09	100.02	99.95	100.10	100.01	100.04
Mg#	71.7	51.8	69.0	62.2	57.1	76.0	73.4	80.6	66.9	68.0
Zn	41	50	37	128	73	131	103	61	20	63
Cu	96	7	20	56	75	96	77	525	3	5
Sc	17	41	27	52	28	40	25	24	28	22
Ga	15	18	11	22	13	22	22	8	15	19
Ni	53	21	204	62	42	30	90	186	35	30
Co	46	64	46	54	42	61	34	53	43	31
Cr	58	23	349	160	30	68	158	460	16	77
V	209	863	218	382	266	259	255	220	280	148
Rb	6	19	n.d.	4	19	4	3	7	4	12
Ba	82	118	34	102	149	126	167	129	80	110
Sr	213	173	156	77	142	75	286	264	149	119
Zr	26	37	111	141	73	113	140	38	50	146
Y	14	16	32	44	23	45	21	19	26	32
ICP-MS Analyses:										
La	0.68	0.94	1.02	3.13	11.0	7.16	14.65	2.36	2.34	28.1
Ce	2.16	3.11	4.80	11.12	26.9	18.2	32.6	5.90	7.41	64.5
Pr	0.39	0.56	1.07	1.94	3.72	2.88	3.65	1.03	1.22	7.73
Nd	2.20	3.06	6.51	10.6	16.6	14.6	15.41	4.86	6.71	31.1
Sm	0.97	1.17	2.30	3.72	4.37	4.74	3.39	1.59	2.60	6.12
Eu	0.89	0.48	0.80	1.21	1.56	1.28	1.02	1.42	1.59	1.57
Gd	1.54	1.72	3.09	5.31	4.87	5.50	3.41	2.48	4.67	4.87
Tb	0.29	0.31	0.58	0.99	0.82	1.11	0.52	0.41	0.74	0.73
Dy	1.87	2.28	3.96	6.05	5.45	6.59	3.09	2.55	4.68	4.85
Ho	0.41	0.53	0.88	1.32	1.20	1.37	0.63	0.55	1.03	0.98
Er	1.20	1.61	2.40	3.66	3.29	3.88	1.67	1.61	2.98	2.68
Tm	0.19	0.24	0.37	0.57	0.51	0.59	0.24	0.25	0.47	0.39
Yb	1.25	1.60	2.32	3.73	3.29	3.95	1.53	1.68	3.13	2.54
Lu	0.19	0.25	0.35	0.53	0.49	0.58	0.22	0.25	0.47	0.37
Nb	0.26	0.88	0.97	2.75	20.2	6.08	20.7	1.59	0.89	6.17
Hf	0.85	0.84	2.22	2.56	3.41	6.05	3.39	1.32	1.90	3.44
Ta	0.05	0.07	0.15	0.19	1.62	0.61	1.61	0.27	0.14	0.46
Th	0.08	0.09	0.10	0.25	2.22	1.30	2.02	0.94	0.70	6.15
U	0.03	0.03	0.06	0.09	0.66	0.30	0.62	0.27	0.15	1.86
Nb/Y	0.02	0.06	0.03	0.06	0.89	0.16	0.99	0.08	0.03	0.19
Ti/V			34	30	28	64	44	18	19	45
$(La/Yb)_N$	0.39	0.42	0.32	0.60	2.40	1.30	6.85	1.01	0.54	7.91
$(La/Sm)_N$	0.45	0.52	0.29	0.54	1.63	0.98	2.79	0.96	0.58	2.96
$(Sm/Yb)_N$	0.86	0.81	1.10	1.11	1.48	1.33	2.46	1.05	0.92	2.67
Th/Ta	1.60	1.33	0.67	1.34	1.38	1.49	1.26	3.48	5.00	13.46
Ce/Y	0.15	0.19	0.15	0.25	1.18	0.48	1.55	0.32	0.28	2.02
Nb/Yb	0.21	0.55	0.42	0.74	6.16	1.54	13.51	0.95	0.28	2.42
Ta/Hf	0.06	0.08	0.07	0.07	0.47	0.12	0.47	0.20	0.07	0.13

MOR- mid-ocean ridge; MORB- MOR basalt; N- normal-type; E- enriched-type; P- plume-type; LKT- low-K tholeiite; CA- calc-alkaline; ol-gb- olivine-gabbro; Fe-gb- ferrogabbro; gb- gabbro; bas- basalt; bas and- basaltic andesite; isotr- isotropic; vitroph- vitrophiric; ol- olivine; pl- plagioclase; cpx- clinopyroxene; op- opaque minerals; n.d- not detected. Mg# = 100xMg/(Mg+Fe). Fe_2O_3 = 0.15xFeO. Normalizing values for REE ratios are from Sun and McDonough (1989).

N-MORB (normal mid-ocean ridge basalt) normalized patterns (Fig. 6). All samples show depletion in light rare earth elements (LREE) with respect to heavy REE (HREE) (Fig. 6b). The gabbroic rocks have Ta/Yb and Th/Yb ratios comparable to those of N-MORBs (Fig. 7). In summary, the overall geochemical features indicate that the gabbroic rocks have a N-MORB affinity and were generated in a mid-ocean ridge.

The volcanic and subvolcanic rocks can be subdivided into three chemically distinct groups.

Group 1 shows a clear sub-alkaline nature (Nb/Y < 0.1) and mainly consists of rather primitive basalts (Mg# = 69-62). One of their most distinctive features is their generally high content of TiO_2, Zr, and Y (Table 1). They have flat N-MORB normalized incompatible element patterns (Fig. 6a), which generally range from 1 to 2 x N-MORB composition (Sun and McDonough, 1989). Nonetheless, little depletions of Nb, La, and Ce are observed in a few samples. The REE patterns (Fig. 6b) are consistent with N-MORB compositions, as they have LREE/MREE (medium REE) and LREE/HREE depletions (e.g., LaN/SmN = 0.29-0.54) and an overall enrichment in HREE of 15-20 x chondrite (Fig. 7). These rocks plot in N-MORBs fields in the most common discrimination diagrams (not shown). In summary, the overall geochemical features of Group 1 basalts lead to their classification as N-MORBs generated at a mid-ocean ridge.

Group 2 consists of basalts which range from sub-alkaline to transitional and show high TiO_2, P_2O_5, Zr, and Y contents, whereas Ni, Cr, and Co are generally low (Table 1). Group 2 basalts display incompatible element patterns enriched in large ion lithophile elements (LILE) with respect to high field strength elements (HFSE), which regularly decrease from Ba to Yb, coupled with LREE/HREE enriched patterns (Fig. 6c, d). Nonetheless, two distinct subgroups of samples can be identified. The first sub-group (e.g., samples SRB35, SBH10) has alkaline nature (Nb/Y = 0.89 - 0.99) and shows high abundance in LILE compared to HFSE, as well as high LREE/HREE ratios (e.g., La N/YbN = 2.40-6.85). This sub-group is also characterized by high ratios of incompatible elements, such as Ce/Y,

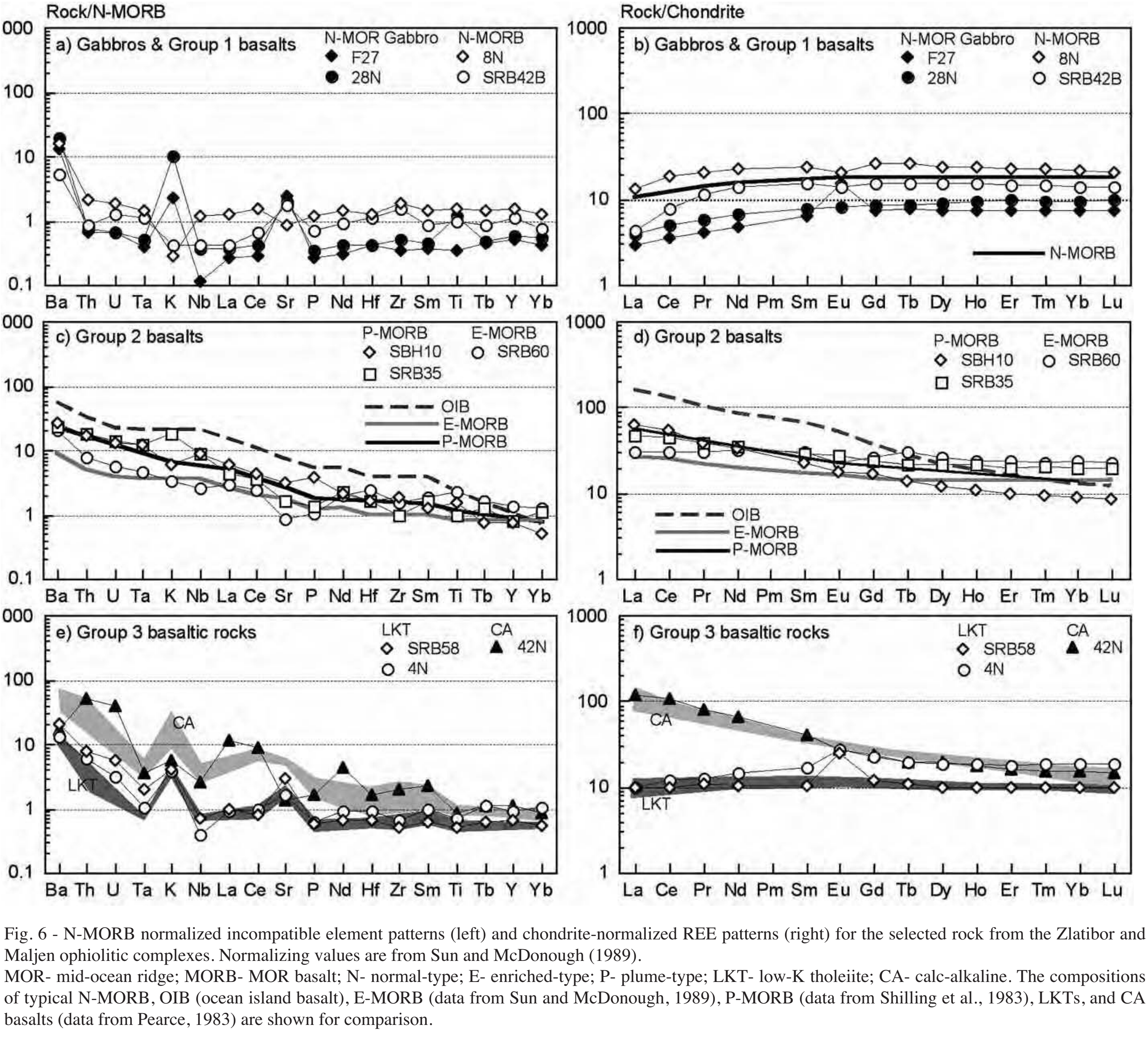

Fig. 6 - N-MORB normalized incompatible element patterns (left) and chondrite-normalized REE patterns (right) for the selected rock from the Zlatibor and Maljen ophiolitic complexes. Normalizing values are from Sun and McDonough (1989).
MOR- mid-ocean ridge; MORB- MOR basalt; N- normal-type; E- enriched-type; P- plume-type; LKT- low-K tholeiite; CA- calc-alkaline. The compositions of typical N-MORB, OIB (ocean island basalt), E-MORB (data from Sun and McDonough, 1989), P-MORB (data from Shilling et al., 1983), LKTs, and CA basalts (data from Pearce, 1983) are shown for comparison.

Nb/Yb, Ta/Hf, Th/Yb, Ta/Yb (Table 1, Fig. 7). The second sub-group (e.g., sample SRB60) has a sub-alkaline nature (Nb/Y = 0.16) and shows lower abundances of LILE compared to the first sub-group, as well as relatively lower LREE/HREE ratios (e.g., La N/YbN = 1.30). Accordingly, this sub-group is also characterized by comparatively lower incompatible element ratios (Table 1, Fig. 7). The first subgroup has an overall geochemistry resembling that of typical plume-type MORB (P-MORB) (Shilling et al., 1983), while the chemistry of the second sub-group is similar to that of E-MORBs (Sun and McDonough, 1989). Though variable, the general enrichment in Th, Ta, Nb, and LREE with respect to HREE suggests that these basalts most likely originated within an oceanic setting from partial melting of a depleted mantle variably influenced by an OIB-type (ocean island basalt) component and were erupted either in seamount or off-axis tectonic settings.

Group 3 consists of basalts and basaltic andesites showing a clear sub-alkaline nature (Nb/Y < 0.19). As a distinguishing feature, this group has incompatible element patterns characterized by positive anomalies of Th, La, Ce and negative anomalies of Ta, Nb, Ti (Fig. 6e), which clearly indicate an orogenic affinity. However, two distinct subgroups of samples can be identified. The first sub-group has relatively low TiO_2, P_2O_5, Zr, and Y contents (Table 1), a mild depletion in HFSE with respect to N-MORB (Fig. 6e), and flat or LREE depleted patterns (Fig. 6f). The overall geochemistry of the rocks of this sub-group is similar to that of low-K tholeiites (LKT) generated in island arc orogenic settings (Pearce, 1983). The second sub-group has comparatively higher TiO_2, P_2O_5, Zr, and Y contents (Table 1), no depletion in HFSE with respect to N-MORB, a marked Th, U, La, Ce enrichment with respect to N-MORB (Fig. 6e), and a significant LREE/HREE enrichment (Fig. 6f). The overall geochemistry of the rocks of this sub-group is similar to that of calc-alkaline basalts (CAB) generated in island arc or continental arc orogenic settings (Pearce, 1983). The marked enrichment in Th with respect to Ta and Yb (Fig. 7) of Group 3 rocks is a clear indicator of supra-subduction zone-imprint.

Cherts: the age of these rocks, determined by radiolarian biostratigraphy, played a key role for understanding the tectonic evolution of the oceanic units in the Dinaric-Hellenic belt. All the available data, show that Serbian radiolarites can be found in two settings: 1) radiolarites of Middle-Late Jurassic age at the top of the sedimentary sequence of the Adria passive continental margin, which are preserved in some places at the footwall of the sub-ophiolite mélange; 2) radiolarites, of Middle-Late Triassic and Middle-Late Jurassic age, incorporated either into the sub-ophiolite mélange as slide-blocks ("olistoplaka" of e.g., Dimitrijević, 1997), or alternatively, as thrust sheets scraped off the footwall, i.e. the Adriatic continental margin, during the westward emplacement of the oceanic units (e.g., Schmid et al., 2008).

The radiolarites that cover at the top the Adria margin sequence located below the sub-ophiolite mélange have been found in a few localities of SW Serbia:

1) Zaboj (Aalenian; Vishneskaya et al., 2009);
2) Pavlovića Brod (Late Aalenian-Late Bajocian and Late Bajocian-Early Callovian; Djerić et al., 2007);
3) Zlatar Mt. (Late Bajocian to Early Callovian; Djerić et al., pers.communication) and Krš Gradac (Late Bathonian-Early Callovian and Middle Oxfordian-Early Tithonian; Vishneskaya et al., 2009).

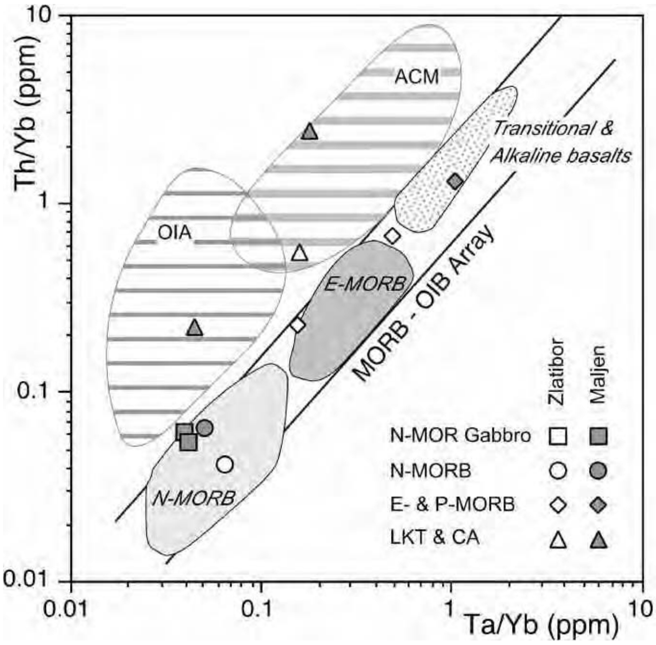

Fig. 7 - Ta/Yb vs. Th/Yb diagram (Pearce, 1983) for the selected rocks from the Zlatibor and Maljen ophiolitic complexes.
MOR- mid-ocean ridge; MORB- MOR basalt; N- normal-type; E- enriched-type; P- plume-type; LKT- low-K tholeiite; CA- calc-alkaline; OIA- ocean island arc; ACM- active continental margin. The compositional fields of N-MORB, E-MORB, and transitional to alkaline basalts from the Albanide-Hellenide ophiolites are shown for comparison (data from Saccani et al., 2011). Data for OIA and ACM are from Pearce (1983).

In the sub-ophiolite mélange, the Triassic radiolarite slide-blocks and/or thrust sheets have been found in few localities of W and SW Serbia:

1) Ovčar-Kablar gorge, where the radiolarites are associated with cherty and micritic limestones of latest Illyrian-Longobardian in age (latest Anisian-Late Ladinian, Obradović, 1986; Obradović and Goričan, 1988) and to the Late Carnian-Early Norian (Vishnevskaya et al., 2009, Djerić and Gerzina, 2008);
2) Čačak, where the radiolarites associated with pillow lavas are dated as Ladinian-Norian (Obradović et al., 1986a; Obradović and Goričan, 1988) and late Early to Middle Norian (Vishnevskaya et al., 2009);
3) Bistrica-Priboj, where the radiolarites of Ladinian age are associated with pillow lavas (Obradović and Goričan, 1988);
4) Sjenica, where the radiolarites are referred to the latest Carnian-late Middle Norian (Goričan et al., 1999), Norian (Vishnevskaya et al., 2009) and Late Carnian-Early Norian (Gawlick et al., 2009);
5) Visoka (Radoševo), where Ladinian and Late Ladinian-Carnian radiolarites are associated with pillow lavas (Vishnevskaya et al., 2009);
6) Zaboj 2, where radiolarites dated as latest Carnian-Early Norian are associated with basalt (Vishnevskaya et al., 2009).

The Jurassic radiolarites found as slide-blocks and/or thrust sheets most likely derived from the Adria continental margin. These cherts have been found in four localities of SW Serbia:

1) Mali Rzav River (latest Bajocian-Early Bathonian; Vishnevskaya et al., 2009);
2) Komarani (from Late Bajocian to Early Callovian; Djerić et al., 2010);

3) Abeško brdo (Late Bathonian-Early/Middle Callovian; Gawlick et al., 2009);
4) Nova Varoš - Bistrica (Late Bajocian to Middle Callovian-Early Oxfordian; Obradović and Goričan, 1988; Obradović et al., 1986b, updated).

In the study area, the chert thrust sheets/slide-blocks consist of up to 100 m thick successions of well-bedded radiolarites and red siliceous shales. Even if most blocks show roughly the same stratigraphic features, the radiolarian assemblages reveal different ages.

All the collected samples derive from cherts associated with basalts. Fourteen radiolarian cherts (07SRB30, 07SRB33a, 07SRB40, 07SRB41, 07SRB59, 07SER6Na, 07SER6Nb, 07SER10N, 07SER11N, 07SER31, 07SER38Na, 07SER38Nb, 07SER38Nc, 07SER41N) have been etched according to the method of Dumitrica (1970), and Pessagno and Newport (1972). Only four samples (07SRB33a, 07SRB40, 07SRB41, 07SER31) yielded radiolarians with moderate preservation.

For the taxonomy and the ranges of Middle and Late Triassic radiolarian markers, we referred principally to De Wever et al. (1979), Kozur and Mostler (1979; 1981; 1994), Dumitrica et al. (1980), Kozur (1996), Kozur et al. (1996; 2009), Tekin (1999), Goričan et al. (2005), Tekin and Mostler (2005), Bragin (2007), Tekin and Göncüoglu (2007); for the taxonomy and the ranges of Middle Jurassic markers we referred to Baumgartner et al. (1995; 1995b), Sykora and Ožvoldová (1996), Hull (1997), Halamić et al. (1999), Chiari et al. (2002), Suzuki and Gawlick (2003), O'Dogherty et al. (2006). Moreover, we followed the taxonomy of radiolarian genera proposed by O'Dogherty et al. (2009a; 2009b).

From the analyzed samples radiolaria ranging in age from Middle Triassic to Middle Jurassic were obtained (see Table 2 for the distribution of radiolarian species).

The age of sample 07SRB40 is Late Anisian-Early Ladinian for the occurrence of *Paroertlispongus multispinosus* Kozur and Mostler. The first appearance of this species is in the *Tetraspinocyrtis laevis* zone (early Illyrian) and its last appearance is in the late Fassanian (Kozur and Mostler, 1994; Kozur, 1996 and Goričan et al., 2005). The age of sample 07SER31 is Early Carnian for the presence of *Capnuchosphaera triassica* De Wever and *Pseudostylosphaera gracilis* Kozur and Mock. The ranges of these species are respectively Early Carnian-Early Norian (Tekin, 1999) and Late Ladinian-Early Carnian (Tekin 1999 and Tekin and Mostler, 2005). The age of sample 07SRB33a is Early Carnian for the presence of the genus *Praeorbiculiformella* with the genera *Pseudostylosphaera* and *Divatella*. The ranges of these genus are respectively Early-Late Carnian, late Olenekian-Early Carnian and Early Carnian (O'Dogherty et al., 2009a). The age of sample 07SRB41 is latest Bajocian-Early Bathonian to Middle Bathonian (UAZ. 5-6) for the presence of *Guexella nudata* (Kocher), *Protunuma*(?) *lanosus* Ožvoldová and *Theocapsomella medvednicensis* (Goričan).

The range of *Guexella nudata* is UAZ. 5-8 (Baumgartner et al., 1995a); the first appearance of *Protunuma*(?) *lanosus* is in the latest Bajocian-early Bathonian (UAZ. 5) and its last appearance is in the late Callovian (Sykora and Ožvoldová, 1996; Halamić et al., 1999; Suzuki and Gawlick, 2003); at last, the range of *Theocapsomella medvednicensis* is UAZ. 5-6 (Halamić et al., 1999 and O'Dogherty et al., 2006).

Carbonates: all the thrust sheets/slide-blocks consisting of carbonate successions have been mapped with the same symbol. The thrust sheets/slide-blocks are characterized by a thickness up to 200-250 m and a width up to some km^2. Their relationship with the matrix of the mélange is generally tectonic, but primary relationships can be observed in several places too (Fig. 8). In these last occurrences, the shaly matrix is injected in the open fractures of the blocks and small carbonate fragments are inserted in the matrix surrounding the main block. The carbonate slide-blocks consist of Triassic shallow-water massive limestones up to several hundreds of meters thick. The occurrences of corals, gasteropods and crinoids indicate their origin as carbonate platform deposits. In addition, thrust sheets/slide-blocks consisting of thin-bedded cherty limestones of Ladinian to Carnian age (Grivska Formation), characterized by an association of radiolarians, sponge spicules, ostracods and filaments, have been identified. This formation shows everywhere deformations characterized by polyphase folding structures. Thrust sheets/slide-blocks of well bedded red nodular limestones that can be correlated with the Bulog Formation of Anisian age, as well as thin bedded limestones with chert interlayers of probably Jurassic age are also common.

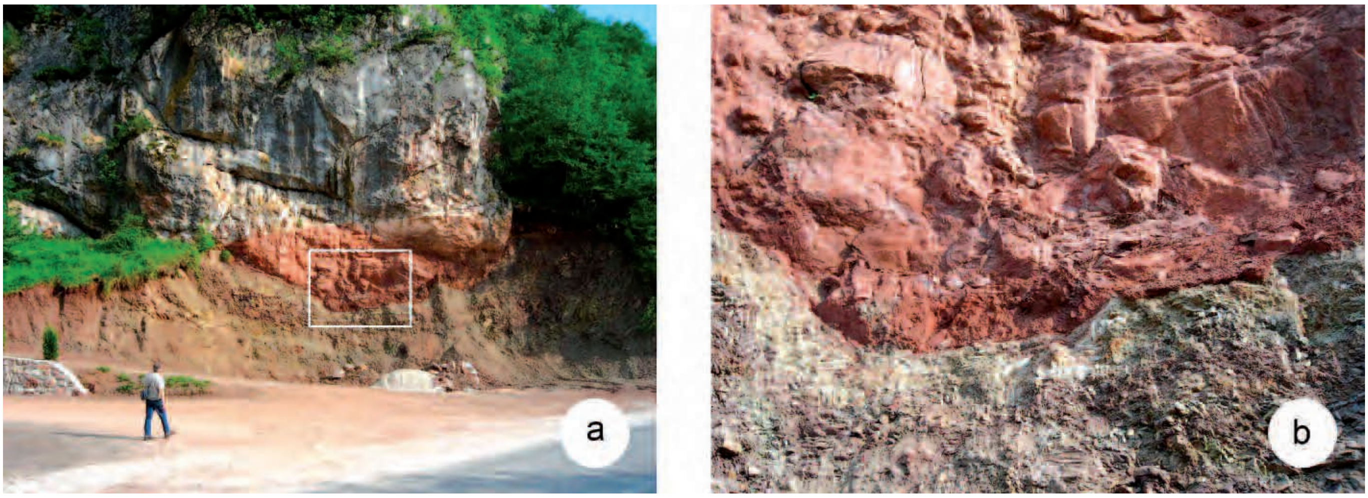

Fig. 8 - Relationships between slide blocks and mélange matrix. a- Triassic limestone slide-block and surrounding mélange matrix. b- Close-up of Fig. 8a.

Table 2 - Distribution of the Middle-Late Triassic and Middle Jurassic radiolarians in the sampled sections.

Samples Taxa	07SRB40	09SER31	07SRB33a	07SRB41
Archaecenosphaera sp.		X		
Archaeodictyomitra sp. cf. *A. patricki* Kocher				X
Archaeodictyomitra sp.				X
Capnuchosphaera triassica De Wever		X		
Capnuchosphaera sp.		X		
Divatella sp.			X	
Eucyrtidiellum unumaense s.l. (Yao)				X
Eucyrtidiellum sp.				X
Guexella nudata (Kocher)				X
Guexella sp. cf. *G. nudata* (Kocher)				X
Oertlispongus sp. cf. *O. inaequispinosus* Dumitrica, Kozur and Mostler	X			
Pantanellium sp.				X
Paroertlispongus multispinosus Kozur and Mostler	X			
Paroertlispongus sp. cf. *P. multispinosus* Kozur and Mostler	X			
Praeorbiculiformella sp. cf. *P. vulgaris* Kozur and Mostler			X	
Praeorbiculiformella sp.			X	
Protunuma(?) *lanosus* Ožvoldová				X
Pseudostylosphaera gracilis Kozur and Mock		X		
Pseudostylosphaera sp. cf. *P. gracilis* Kozur and Mock		X	X	
Pseudostylosphaera sp.		X		
Saitoum sp. cf. *S. levium* De Wever				X
Spongotortilispinus tortilis (Kozur and Mostler)		X	X	
Spongotortilispinus sp. cf. *S. tortilis* (Kozur and Mostler)			X	
Theocapsomella medvednicensis (Goričan)				X
Theocapsomella sp. cf. *T. medvednicensis* (Goričan)				X
Theocapsomella sp.				X
Tranhsuum sp.				X
Triactoma(?) sp.				X
Tritrabs sp.				X
Unuma sp.				X
Welirella sp. cf. *W. fleuryi* (De Wever)		X		

Metamorphic rocks: thrust sheets/slide-blocks up to 50 m-thick of very low-grade metamorphic rocks consisting of metapelites and metasiltites with a polyphase deformations history have been identified west of the Zlatibor Massif. These rocks probably derived from a Late Paleozoic succession analogous to that recognized in the Drina-Ivanjica and East Bosnian-Durmitor Units.

Granitoids: according to Robertson et al. (2009), thrust sheets/slide-blocks of granitoid rocks, up to hundreds of meters in size, dated at 315 Ma (Late Carboniferous) by U-Pb isotopes (Karamata et al., 1994), have been recognized in the sub-ophiolite mélange. These bodies occur a few km outside the mapped area.

The upper age of the sub-ophiolite mélange is constrained by the age of the oldest fossiliferous sediments recognized at its top, represented by the marly-carbonate formation that ranges in age from Albian to Cenomanian (Pejović and Radoičić, 1971; Banjac, 1994). In addition, the sub-ophiolite mélange is regarded as younger than the obduction inception that occurred in the uppermost Middle Jurassic. Thus, the age of the sub-ophiolite mélange can be bracketed between Oxfordian and Aptian. However, the time span for formation of the sub-ophiolite mélange is probably shorter, as recognized in Albania, where the age of the conglomerates that unconformably cover the peridotites is Barremian.

The metamorphic sole

The metamorphic sole occurs as a discontinuous thrust sheet below the peridotites of the Zlatibor Massif, but some outcrops have been identified also in the Maljen Massif. The metamorphic sole mainly consists of coarse-grained garnet-bearing mafic granulites, medium to coarse-grained amphibolites and fine-grained amphibolites.

In the Zlatibor Massif, the metamorphic sole occurs mainly in its western side, where the coarse-grained garnet-bearing mafic granulites are widespread (Milovanović, 1988; Operta et al., 2003). These rocks occur as isolated thrust sheet fragments, up to 100 m-thick, along the western edge of the Zlatibor Massif, showing tectonic relationships with all the surrounding rocks.

The garnet-bearing mafic granulites (Fig. 9a, b) are characterized by coarse-grained, equigranular foliated textures, consisting of plagioclase (partly transformed into secondary

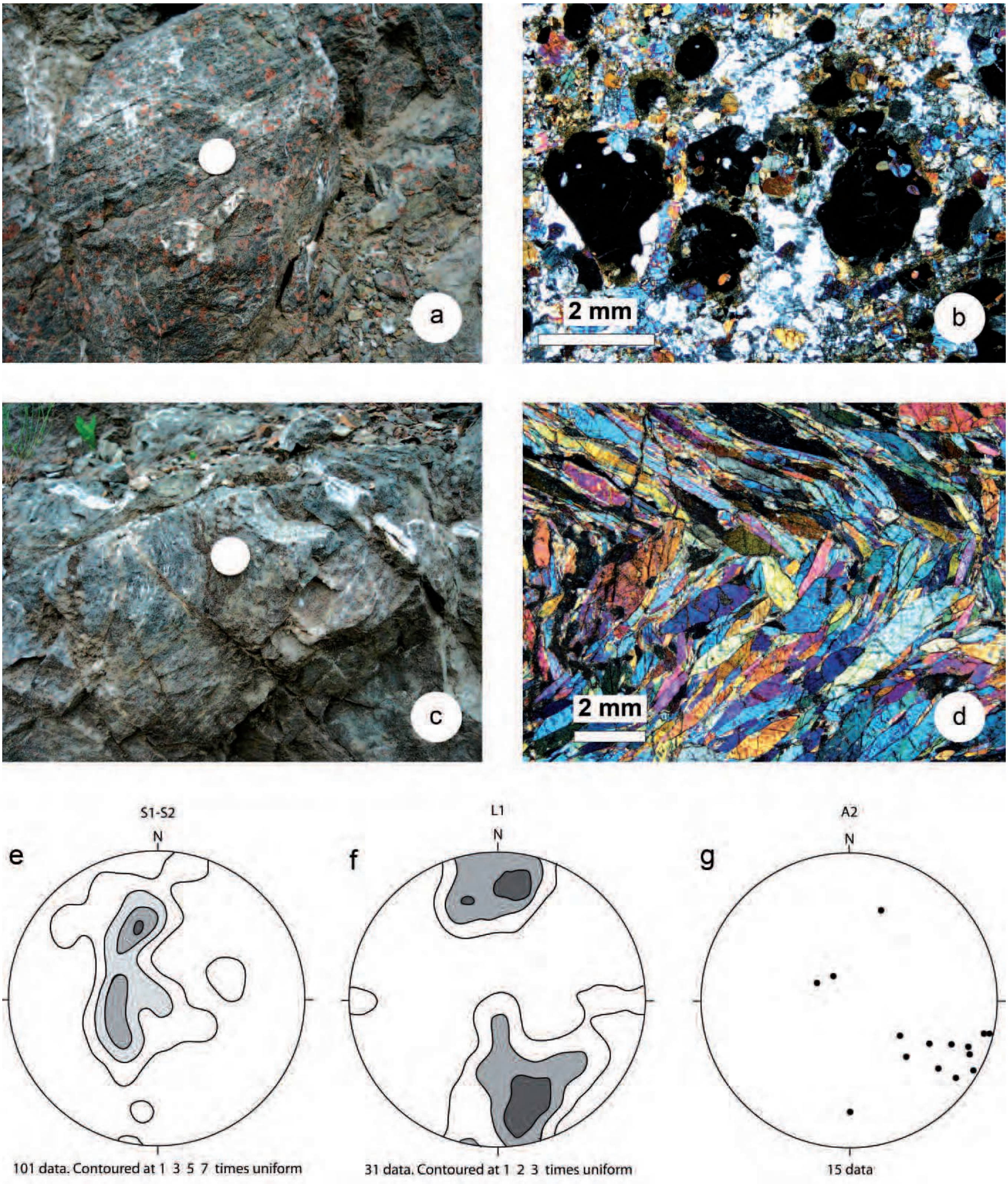

Fig. 9 - Metamorphic sole. a) Field occurrence of garnet-bearing mafic granulites, Bistrica area; b) photomicrograph of garnet-bearing mafic granulites characterized by a rough foliation defined by bands of nematoblastic plagioclase and amphiboles where garnet occurs as porphyroblasts; c) field occurence of medium-to coarse-grained amphibolites. The main foliation consists of lens-shaped centimetric domains with a broad compositional banding characterized by different amounts of plagioclase and amphibole; d) photomicrograph of medium-to coarse-grained amphibolites showing a late F_2 micro-folding of the main S_1 foliation. Equal area, lower hemisphere stereographic representation of structural data from the metamorphic sole. e) S_1-S_2 foliation; f) L_1 mineral lineation; g) A_2 axes.

prehnite), clinopyroxene, amphibole and large, up to 1-2-cm. garnet. In thin section, the most abundant mineral is amphibole (up to 40%), while the relative abundance of plagioclase, clinopyroxene, and garnet is quite variable. Corundum has been reported by Operta et al. (2003). A rough foliation is defined by bands of nematoblastic plagioclase and amphibole where the garnet occurs as porphyroblasts. The chemical composition of these rocks (high mg-number, low SiO_2/Al_2O_3 values, REE pattern, positive Eu anomalies) is consistent with cumulate gabbroic protoliths, indicating an ocean crustal origin. The maximum P-T condition still remains uncertain, but the available data indicate T > 800°C (Milovanović et al., 2004) whereas the Al and Si isopleths of amphiboles pressures indicate a range of P from 6 to 1.2 GPa (Milovanović et al., 2004). These parameters indicate HP facies conditions, hardly matching with the described mineral assemblage represented by diopside and garnet (Gaggero et al., 2009). These rocks are crosscut by thin secondary veins of epidote, prehnite, chlorite, and tremolite, related to retrograde events.

The medium to coarse-grained amphibolites (Fig. 9c, d) consist of green to brown-green amphibole coexisting with plagioclase and minor clinopyroxene and clinozoisite. Rutile, titanite, and ilmenite rarely occur as accessory phases. The main foliation consists of lens-shaped centimetric domains showing a broad compositional banding characterized by different amounts of plagioclase and amphibole. Bands parallel to the main foliation are characterized by grain-size reduction and development of nematoblastic to decussate clinopyroxene, granoblastic plagioclase and clinozoisite. In some thin sections, the grain-size reduction affected up to 90% of the rock, with relic domains of coarser fabric preserved as lens-shaped domains aligned along the main foliation. In these rocks, NNW-SSE trending mineral (Fig. 9e, f) and stretching lineations are associated to top-to-the-NNW kinematic indicators as C-type shear bands and σ-type garnet porphyroblasts. In addition, folding associated to a spaced cleavage developed under retrograde greenschist facies metamorphism marked by the crystallization of epidote, prehnite, chlorite and tremolite has been observed.

The fine-grained amphibolites consist of brown-green amphibole, plagioclase, clinozoisite and minor accessory phases, such as ilmenite, rutile, quartz and apatite. These rocks are characterized by a main foliation represented by oriented amphibole- and plagioclase-rich bands. In addition, coarse, relic mineral grains including amphiboles and plagioclase rotated along the main foliation can be observed. Folds that deform the main foliation have been recognized in some thin sections. These folds with SE-NW trending axes (Fig. 9d and g) are associated to a greenschist facies metamorphic overprint and characterized by crystallization of actinolite, albite, epidote, chlorite and titanite.

In medium- to coarse-grained amphibolites and fine-grained amphibolites, the occurrence of bands parallel to main foliation characterized by amphibolite recrystallization, grain-size reduction and relics of coarse crystals of plagioclase and amphibole indicates that the amphibole-facies metamorphism was associated with two distinct deformation phases, as recognized in Albania (Carosi et al., 1996; Gaggero et al., 2009). The first-phase structures are preserved in the studied lithologies in different extents; completely preserved in the coarse-grained garnet-bearing mafic granulites, well preserved in the medium- to coarse-grained amphibolites and poorly preserved in the fine-grained amphibolites.

Selected samples from the metamorphic sole were analysed in order to determine the mineral chemistry of the metamorphic minerals. They were analysed using a CAMECA "SX50" electron microprobe, equipped with four wavelength-dispersive spectrometers, at the CNR Istituto di Geoscienze e Georisorse, Padova, Italy. Running conditions were 15 kV accelerating voltage and 15 nA beam current on a Faraday cage. Natural and synthetic silicates and oxides were used as standards. The PAP method (Pouchou and Pichoir, 1985) was used for the correction of all data.

Sample SBH27, collected on the eastern side on the Zlatibor Massif, can be classified as a coarse-grained amphibolite with relics of clinopyroxene. Samples SBH32a, SRB45 and SRB62 were collected in the western side of the Zlatibor Massif in the Bistrica area. Samples SBH32a and SRB45 are medium-grained amphibolites characterized by a foliation made of amphibole + plagioclase. Sample SRB62 is a coarse-grained garnet-bearing mafic granulite, characterized by the following metamorphic mineral assemblage: amphibole + plagioclase + garnet. Relics of clinopyroxene are also present.

<u>Amphibole</u>: amphiboles (Fig. 10 and Table 3a) from sample SBH27 are classified as Mg-hornblende and show core-to-rim zonation. The Si contents range between 6.61 and 7.41 apfu and $Mg/(Mg + Fe^{2+})$ ratios range from 0.76 to 0.81. From core to rim, the amphiboles show a progressive increase in Si content. Amphiboles from sample SBH32a

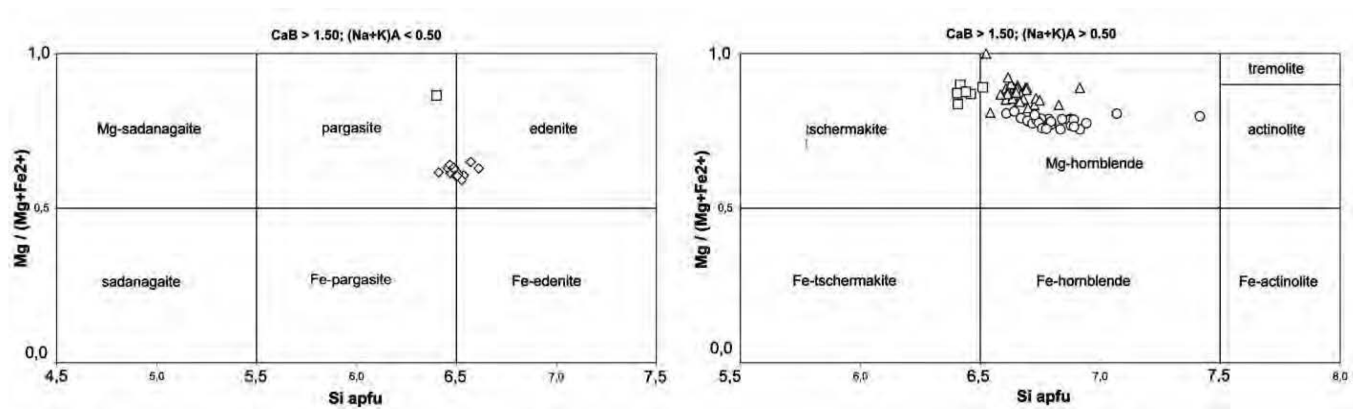

Fig. 10 - Composition of amphiboles from amphibolites and granulites of the metamorphic sole, following the classification of Leake et al. (1997).

Table 3a - Mineral chemistry of amphiboles from amphibolites and granulites of the metamorphic sole.

Amphibole	SBH27-a1	SBH27-a2	SBH27-b1	SBH27-b2	SBH27-aa13	SBH27-aa10	SBH32a-a7	SBH32a-a8	SBH32a-a9	BH32a-a10	SRB45-1	SRB45-2	SRB45-17	SRB45-35	SBH32a-b9	SRB62-a10	SRB62-a15	SRB62-c4	SRB62-c5	SRB62-c8
	rim	core	rim	core	rim	core														
Wt %																				
SiO2	52.77	46.64	50.45	46.64	49.38	47.35	44.08	43.96	44.19	45.14	47.73	47.58	47.70	47.51	44.28	45.39	45.04	45.63	45.28	44.81
TiO2	0.20	0.87	0.42	0.82	0.64	0.83	1.19	1.08	1.10	0.75	0.43	0.36	0.22	0.41	1.09	1.59	1.60	1.82	2.08	2.50
Al2O3	5.74	11.78	8.82	11.60	9.65	11.51	13.04	12.96	13.02	12.34	12.97	12.97	12.80	12.93	12.76	12.63	12.84	12.70	11.93	12.18
Cr2O3	0.14	0.13	0.14	0.21	0.44	0.26	0.14	0.10	0.06	0.05	0.04	0.00	0.12	0.07	0.10	0.14	0.10	0.08	0.24	0.07
FeO	8.04	8.85	7.14	9.25	8.82	8.92	13.16	13.12	13.07	13.13	6.91	6.91	6.78	6.82	13.62	7.42	7.49	7.60	8.40	7.99
MnO	0.16	0.23	0.21	0.13	0.17	0.32	0.36	0.34	0.25	0.28	0.15	0.08	0.04	0.13	0.24	0.01	0.03	0.05	0.22	0.04
MgO	17.35	14.79	16.57	15.30	15.68	15.00	11.36	11.51	11.65	11.95	16.24	16.22	16.26	15.88	11.21	16.21	15.89	15.90	15.89	15.51
CaO	13.01	12.37	12.94	12.70	12.71	12.52	12.08	12.04	11.84	11.95	12.28	12.45	11.94	12.08	12.00	11.72	11.78	11.64	11.75	11.73
Na2O	0.79	1.63	1.28	1.69	1.51	1.82	1.80	1.59	1.76	1.57	1.63	1.43	1.62	1.76	1.73	2.41	2.54	2.43	2.62	2.46
K2O	0.07	0.03	0.04	0.06	0.08	0.05	1.12	1.19	1.17	1.09	0.04	0.08	0.07	0.12	1.07	0.02	0.00	0.01	0.03	0.01
TOT	98.27	97.32	98.01	98.39	99.07	98.57	98.33	97.88	98.11	98.24	98.42	98.08	97.57	97.73	98.09	97.54	97.31	97.87	98.42	97.30
Cations																				
Si	7.414	6.669	7.069	6.609	6.942	6.703	6.471	6.455	6.466	6.570	6.637	6.640	6.627	6.669	6.503	6.417	6.404	6.439	6.400	6.407
Al (iv)	0.586	1.331	0.931	1.391	1.058	1.297	1.529	1.545	1.534	1.430	1.363	1.360	1.373	1.331	1.497	1.583	1.596	1.561	1.600	1.593
∑ *T cations*	*8.000*	*8.000*	*8.000*	*8.000*	*8.000*	*8.000*	*8.000*	*8.000*	*8.000*	*8.000*	*8.000*	*8.000*	*8.000*	*8.000*	*8.000*	*8.000*	*8.000*	*8.000*	*8.000*	*8.000*
Al (vi)	0.364	0.653	0.526	0.546	0.540	0.624	0.727	0.698	0.711	0.687	0.763	0.772	0.723	0.809	0.712	0.521	0.555	0.551	0.386	0.458
Ti	0.021	0.094	0.105	0.087	0.068	0.088	0.110	0.119	0.110	0.082	0.045	0.038	0.104	0.043	0.120	0.169	0.172	0.193	0.221	0.269
Cr	0.016	0.015	0.016	0.023	0.049	0.029	0.016	0.011	0.007	0.006	0.005	0.000	0.013	0.008	0.011	0.016	0.012	0.009	0.027	0.008
Fe(iii)	0.019	0.228	0.000	0.318	0.081	0.161	0.042	0.136	0.167	0.199	0.401	0.387	0.423	0.291	0.066	0.492	0.396	0.426	0.465	0.310
Fe(ii)	0.927	0.830	0.837	0.778	0.957	0.894	1.574	1.475	1.433	1.399	0.403	0.419	0.365	0.509	1.607	0.385	0.494	0.470	0.528	0.645
Mn	0.019	0.027	0.025	0.016	0.020	0.038	0.045	0.042	0.032	0.035	0.017	0.010	0.005	0.016	0.030	0.001	0.004	0.006	0.026	0.004
Mg	3.635	3.153	3.461	3.232	3.286	3.166	2.486	2.519	2.541	2.592	3.366	3.374	3.367	3.324	2.455	3.416	3.368	3.344	3.347	3.305
∑ *C cations*	*5.000*	*5.000*	*4.969*	*5.000*	*5.000*	*5.000*	*5.000*	*5.000*	*5.000*	*5.000*	*5.000*	*5.000*	*5.000*	*5.000*	*5.000*	*5.000*	*5.000*	*5.000*	*5.000*	*5.000*
Ca	1.958	1.894	1.943	1.927	1.914	1.900	1.900	1.894	1.856	1.863	1.829	1.862	1.778	1.817	1.887	1.775	1.795	1.760	1.779	1.797
Na	0.042	0.106	0.057	0.073	0.086	0.100	0.100	0.106	0.144	0.137	0.171	0.138	0.222	0.183	0.113	0.225	0.205	0.240	0.221	0.203
∑ *B cations*	*2.000*	*2.000*	*2.000*	*2.000*	*2.000*	*2.000*	*2.000*	*2.000*	*2.000*	*2.000*	*2.000*	*2.000*	*2.000*	*2.000*	*2.000*	*2.000*	*2.000*	*2.000*	*2.000*	*2.000*
Na	0.174	0.347	0.291	0.390	0.325	0.398	0.413	0.346	0.354	0.308	0.269	0.249	0.215	0.297	0.380	0.437	0.495	0.426	0.496	0.480
K	0.012	0.006	0.008	0.011	0.014	0.009	0.210	0.222	0.219	0.202	0.007	0.015	0.012	0.022	0.200	0.004	0.000	0.002	0.006	0.002
∑ *A cations*	*0.186*	*0.353*	*0.298*	*0.401*	*0.339*	*0.407*	*0.623*	*0.569*	*0.573*	*0.510*	*0.275*	*0.263*	*0.228*	*0.319*	*0.580*	*0.441*	*0.495*	*0.428*	*0.502*	*0.482*
Mg/(Mg+Fe")	0.84	0.80	0.78	0.81	0.79	0.76	0.76	0.61	0.63	0.64	0.89	0.89	0.83	0.88	0.61	0.87	0.90	0.87	0.88	0.86

The structural formulae were calculated assuming 23 oxygens pfu, and the classification of Leake et al. (1997) was adopted. Site assignment and ferric iron contents were calculated using the scheme proposed by Schumacher in Leake et al. (1997).

Table 3b - Mineral chemistry of garnets and pyroxenes from amphibolites and granulites of the metamorphic sole.

Garnet	SRB62-a2	SRB62-a8	SRB62-a11	SRB62-a12	SRB62-c12
	Grt	Grt	Grt	Grt	Grt
Wt%					
SiO2	41.11	41.26	41.33	41.48	41.45
TiO2	0.01	0.09	0.12	0.03	0.08
Al2O3	22.80	23.10	23.25	23.01	23.21
Cr2O3	0.08	0.14	0.04	0.02	0.05
FeO	15.84	15.28	15.07	15.98	16.24
MnO	0.47	0.49	0.51	0.53	0.40
MgO	14.35	13.96	13.95	14.18	14.30
CaO	6.83	6.99	6.98	6.53	6.36
Na2O	0.02	-	0.04	-	-
K2O	-	-	-	-	-
sum	101.51	101.31	101.30	101.78	102.08
Cations					
Si	5.984	6.001	6.002	6.010	5.990
Ti	0.001	0.009	0.013	0.003	0.008
Al	3.910	3.961	3.980	3.929	3.952
Fe	1.928	1.858	1.830	1.936	1.962
Mn	0.058	0.061	0.063	0.066	0.049
Mg	3.113	3.028	3.021	3.064	3.080
Ca	1.065	1.090	1.087	1.014	0.984
sum	16.060	16.009	15.995	16.022	16.026
Pyr	50.5	50.2	50.3	50.4	50.7
Alm	31.3	30.8	30.5	31.8	32.3
Grs	17.3	18.1	18.1	16.7	16.2
Sps	0.9	1.0	1.0	1.1	0.8
Xmg	0.62	0.62	0.62	0.61	0.61

Pyroxene	SRB62-a3	SBH27-aa1
	Cpx	Cpx
Wt%		
SiO2	51.35	54.52
TiO2	0.64	0.03
Al2O3	6.23	1.18
Cr2O3	0.13	0.07
Fe2O3	4.75	4.57
MnO	-	0.26
MgO	13.93	15.22
CaO	22.17	24.93
Na2O	0.86	0.31
K2O	0.02	0.04
TOT	100.08	101.14
Cations		
Si	1.877	1.982
Al	0.123	0.018
Al	0.145	0.033
Fe(iii)	0.002	0.007
Cr	0.004	0.002
Ti	0.018	0.001
Fe(ii)	0.143	0.132
Mn	0.000	0.008
Mg	0.759	0.825
Ca	0.868	0.971
Na	0.061	0.022
K	0.001	0.002
TOT	4.001	4.002

The structural formulae of garnets were calculated assuming 24 oxygens and all Fe as Fe^{2+}.
The structural formulae of pyroxenes were calculated assuming 6 oxygens pfu, and site assignment and ferric iron contents were calculated using the scheme proposed by Morimoto et al. (1989).

are classified as pargasite/edenite with Si contents ranging between 6.41 and 6.61 apfu and $Mg/(Mg + Fe^{2+})$ ratios ranging from 0.60 to 0.65. Amphiboles from sample SRB45 are Mg-hornblende with Si contents ranging between 6.52 and 6.91 apfu and $Mg/(Mg + Fe^{2+})$ ratios ranging from 0.81 to 1.00. Amphiboles from sample SRB62 are classifiable as tschermakite with Si contents ranging between 6.40 and 6.51 apfu and $Mg/(Mg + Fe^{2+})$ ratios ranging from 0.84 to 0.89.

Garnets: they show no chemical zoning and are rich in the pyrope (Pyr) component, with moderate grossular (Grs) and spessartine (Sps) ($Pyr_{50,2-50,7}$ $Alm_{30,5-32,3}$ $Grs_{16,2-18,1}$ $Sps_{0,8-1,1}$). The XMg ratio, ranging between 0,61 and 0,62, is homogeneous (Table 3b).

Clinopyroxene: The analysed relics of clinopyroxene in both samples SBH27 and SRB62 are classified as diopside (Table 3b). In terms of quadrilateral components, their composition is $En_{41.4-42.2}$ $Fs_{7.1-7.9}$ $Wo_{47.4-49.6}$.

The age of the metamorphic sole is poorly constrained. The only ages for the amphibolites, obtained by the K/Ar method, range from 181 to 146 Ma (Lanphere et al., 1975; Karamata, 2006; Karamata et al., 2005). However, these data are poorly reliable and more accurate dating is required to provide useful constraints for the development of the metamorphic sole.

Ophiolite unit

The ophiolite unit mainly includes peridotites that crop out in both the Zlatibor and Maljen Massifs.

The Maljen peridotites (Bazylev et al., 2009, and references therein) are prevalently spinel-bearing mantle harzburgites showing variable degrees of depletion. A number of small bodies of cumulate peridotites are known at the western margin of the massif. The most residual mantle peridotites of the Maljen Massif are depleted spinel-bearing harzburgites with quite uniform mineralogy, which consists of primary spinels, olivines, orthopyroxenes and clinopyroxenes. All the clinopyroxenes are of subsolidus origin and occur either as exsolution lamellae within the orthopyroxene grains or form rare small xenomorphic grains near the orthopyroxene grain boundaries. Cumulate peridotites showing plagioclase replaced by secondary minerals also occur.

In the Zlatibor Massif the peridotites mainly consist of spinel-bearing depleted lherzolites with minor spinel-bearing hazburgites and dunites (Bazylev et al., 2009, and references therein). The peridotites are intensively serpentinized at the base of the massif, and are cut by magnesite veins in the their upper part. In the central part of the massif they are commonly coarse-grained rocks, only slightly or moderately serpentinized. The less serpentinized peridotites contain remnants of all the primary minerals, such as spinel, olivine, orthopyroxene and clinopyroxene. Medium-grade metamorphism is revealed by the occurrence of Ca-amphibole and chlorite.

The geochemical data (Bazylev et al., 2009) clearly indicate that the Maljen depleted harzburgites originated in a suprasubduction setting, probably at a back-arc basin spreading center. The most remarkable feature of the Zlatibor Massif is the widely variable depletion degree of the mantle peridotites, which range from depleted lherzolites to depleted harzburgites. Such a rock association is indicative of a progressive, multi-stage melt extraction occurring at a suprasubduction zone, where depleted lherzolites that are residual after MORB-melt extraction can be successively modified by subduction-related fluids and re-melted and then transformed into variably depleted harzburgites.

Europe-derived unit

In the study area, the oceanic units are overthrust by the Ljig Unit, consisting of turbidites probably deposited in a thrust-top basin located in the hinterland of the Dinaric-Hellenic belt (Zelic et al., 2010b). This area was probably characterized by a substrate represented by continental units deformed since Late Cretaceous time, during the mature stage of collision between Adria and Eurasia.

Ljig Unit

The Ljig Unit includes only one formation, the Ljig Flysch, about 800 m thick, here correlated to the Brus Flysch cropping out in the Kopaonik area (Zelic et al., 2010c, and references therein). Its base and top are not exposed. Two main facies associations can be recognized (Fig. 11): the first one consists of thin-bedded turbidites, characterized by thin to medium bedded fine to medium grained siliciclastic arenites, showing a sandstone to shale ratio generally > 1, alternating with carbonate-free mudstones. These turbidites display Td-e and subordinately Tc-e base missing Bouma sequences and abundant traction plus fall-out structures, such as ripples and climbing ripples. Subordinate medium- to coarse-grained arenites showing the complete Ta-e Bouma sequence are also found. The stratigraphic and sedimentological features of these deposits point to low-density turbidity currents as the main type of parental flow.

The second facies association is characterized by medium to coarse-grained turbidites, showing a sandstone to shale ratio generally >> 1. The turbidite sequence consists of several medium-to coarse-grained arenites showing the complete Ta-e Bouma sequence, but coarse-grained metric beds showing traction carpet and cross-bedding features also occur. These beds are often amalgamated and characterized by local scours filled by coarse-grained arenites and fine-grained rudites. The stratigraphic and sedimentological features of these deposits indicate medium-to high-density turbidity currents as the main type of parental flow.

The arenites of the Ljig Flysch have a siliciclastic composition, ranging from subarkose to arkose, and are characterized by prevalent monocrystalline quartz and feldspar fragments. Lithic fragments are mainly derived from granitoids and low-grade metamorphic rocks, such as micaschists and gneiss, but acidic volcanics and carbonate rock fragments are also present. Basic and ultrabasic rock derived clasts are rare. The cement is spathic calcite, whereas the matrix consists of variable amounts of pseudomatrix.

The nannofossils assemblage detected in the mudstones (unpublished data on samples: LJ1-LJ4, SER07/03, 21N, 21Na, 21Nb, 21Nc, 25Na, 25Nb, 25Nc) indicates an Early Campanian-Late Maastrichtian age (biozone CC20-CC25; Sissingh, 1977).

Post-orogenic Cretaceous deposits

The oceanic units as well as the Drina-Ivanjica Unit are topped by sedimentary, mainly carbonate, deposits whose ages probably span from Early to Late Cretaceous. In these different settings, the Cretaceous succession shows some marked differences; therefore they will be described separately and reported as Mokra Gora, Kosjerić and Guča Groups, the first lying onto the ophiolites, and the latters onto the Drina Ivanjica Unit. These deposits seal the Late Jurassic-Early Cretaceous structures of the internal side of the Dinaric-Hellenic belt. The stratigraphic relationships between the Mokra Gora Group and the oceanic units in both the Zlatibor and the Vardar areas have been well assessed since long time (Fotić, 1962; Bortolotti et al., 1971; Pejović and Radoičić, 1971; Banjac, 1994; Djerić et al., 2009). The relationships between the Drina-Ivanjica succession and the Kosjerić and Guča Groups are instead still matter of debate. Most of the authors (e.g., Dimitrijević, 1997; Dimitrijević, and Dimitrijević, 1976; Karamata and Oić, 1996; Schmid et al., 2008) propose stratigraphic, although unconformable,

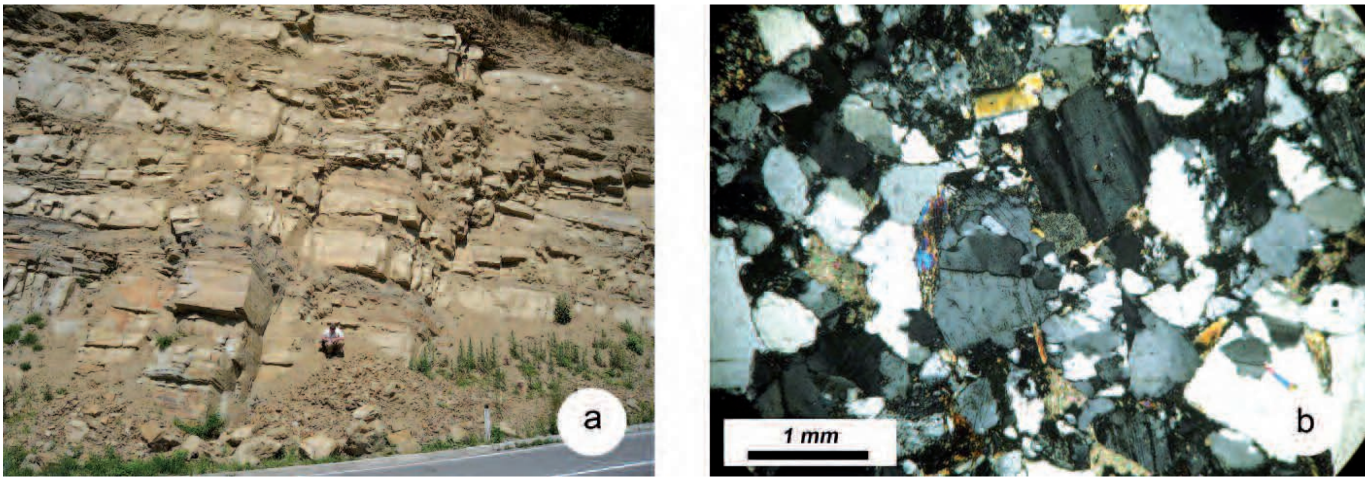

Fig. 11 - The Ljig Flysch. (a) Field occurence and (b) coarse-grained arenite photomicrograph. Photomicrograph in crossed polars.

contacts between the Kosjerić and Guča Groups with the underlying rocks, that were thus exhumed to the surface at the end of the Late Jurassic. However, the main exhumation of the lowermost, Adria-derived units took place in the internal side of the Dinaric-Hellenic belt during the Oligo-Miocene extensional tectonic phase (e.g., Zelic et al., 2010a), as suggested by data reported by Ustaszewski et al (2010). This age of exhumation of the lowermost, Adria-derived units has been recognized along the Albania-Greece geotraverse (Bortolotti et al., 2005; Muceku et al., 2008). In this frame, the relationships between the Cretaceous deposits and the Drina-Ivanjica succession are controlled by low-angle normal faults. Further detailed data are necessary to unravel these tectonic relationships

Mokra Gora Group. The Mokra Gora Group (new name) (Fig. 12) represents the sedimentary cover of both ophiolites and mélange, and it was deposited during the transgression that followed the local emersion and erosion of the obducted ophiolites. It provides indications concerning the paleogeography of the oceanic units and the emplacement time of these units onto the Adria continental margin. The post-obduction sedimentation above the oceanic units is generally Early to Late Cretaceous in age and consists of a lower clastic formation followed by a shallow water carbonate formation and finally a rudist reefeal bioconstruction. In the study area, the unconformable deposition of these deposits onto the ophiolite and mélange units is evident in both the western ophiolites (Mokra Gora-Vardiste area; Fotić, 1962; Bortolotti et al., 1971; Pejović and Radoičić, 1971; Banjac, 1994) and eastern ones (Delici and Sturganik-Ravna Gora areas, Djerić et al., 2009). Deposits related to a Cretaceous transgression are recorded in several areas of the Balkan region (e.g., Zepce-Zavidoviči-Maglaj area in Bosnia-Herzegovina; Jovanović, 1961; Neubauer et al., 2003; Hrvatović, 1999; 2006) as well as in Albania (Gawlick et al., 2008) and Greece (Photiades et al., 2007, and references therein). The subaerial weathering and pedogenesis of the oceanic units led to the formation of a m-thick alteration surface topped by Fe-Ni rich horizons and patches of laterites and siliceous duricrusts. This weathering surface is followed by an ophiolite-bearing clastic formation deposited in a fluvial environment grading in turn to limestones and pelites of brackish water environment. The latter deposits are topped by marine middle- to inner-shelf bioclastic micritic limestones with interbedded thin marlstones (marly-carbonate formation) and finally by a rudist reef formation, lying in some places above the previous formation through an unconformity. The

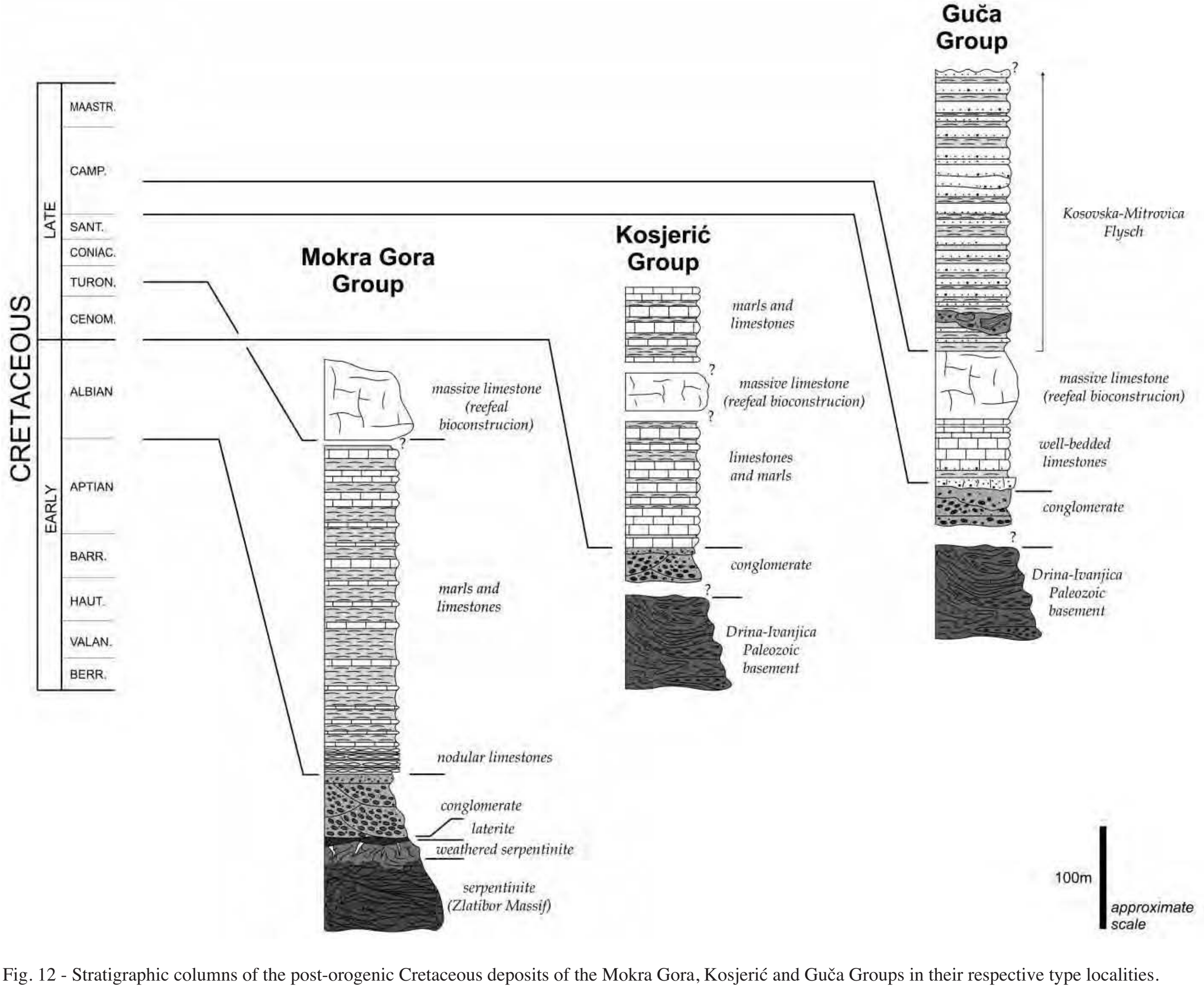

Fig. 12 - Stratigraphic columns of the post-orogenic Cretaceous deposits of the Mokra Gora, Kosjerić and Guča Groups in their respective type localities.

substratum of the basal clastic formation is generally represented by peridotites of the ophiolite unit, whereas the observed contacts with the mélange are always tectonic. The thickness and facies of the transgressive sediments are very variable in the study area. For instance, the thickness of the continental deposits at the base of the succession increases moving from east (Deliçi area, few meters to about 20 m) to the western outcrops (Mokra Gora-Vardiste, about 60 m); west of the study area, similar deposits at the top of the ophiolites reach a thickness of more than 300 m (Pogari Formation, Zepçe-Zavidoviçi-Maglaj area, Hrvatović, 2006). The lithofacies of the marly-carbonate formation show differences from site to site reflecting thus variations in the depositional environment, linked with an uneven and tectonically controlled substratum.

Age determinations were possible through the fossils associations in the marine deposits, whereas in the basal clastic deposits they were hampered by the extreme scarcity of fossils. The marly-carbonate formation ranges in age from Albian to Cenomanian (Pejović and Radoiçić, 1971; Banjac, 1994). The rudist reef limestone formation has been dated to the Middle Turonian-Santonian (Milovanović, 1934; Radoçić and Schlagintweit, 2007).

The presence of a Tithonian-Neocomian and Barremian resedimented fauna in the Pogari Formation basal conglomerate cropping out in Bosnia (Jovanović, 1961; Hrvatović, 2006), allows us to attribute the sedimentation of the basal portion of the Mokra Gora Group to the post-Barremianan.

These deposits probably formed during a time of widespread tectonic collapse, involving the orogenic belt after obduction and related compression (uppermost Late Jurassic - Early Cretaceous). The increase of the relief energy related to the compressional phase, triggered sedimentation of coarse-grained deposits by high-energy rivers, whereas the subsequent orogenic collapse promoted the development of a carbonatic transgressive sequence. The Cretaceous transgressive deposits are generally weakly deformed into gentle folds; intensive folding is locally visible along the thrust zones. In the Ba area the tectonic superposition of the Ljig Flysch onto the Mokra Gora Group is postdated by a Tertiary quartz-latite intrusion that seals their tectonic contact.

Kosjerić Group. The Kosjerić Group (new name) (Fig. 12) consists of a continental to transitional clastic formation passing upwards to a shallow marine carbonatic formation. The clastic formation consists of well-rounded and poorly-sorted conglomerates and siltstones related to fluvial and littoral environments. The fluvial deposits are generally cross-laminated, red colored, with patches of lateritic material, whereas the littoral deposits are light yellowish with diffuse rudist and other neritic macrofossils fragments. The clasts of conglomerate deposits mainly consist of quartz, marble, phyllite, gneiss and other metamorphic rock fragments. The clastic deposits pass upwards to a shallow marine carbonate sequence mainly consisting of well-bedded bioclastic wackestones and packstones alternating with marls. Locally, the well-bedded limestones seem to be heteropic with variable thicknesses (tens of meters) of massive reefeal bioconstructions with abundant rudists. However the stratigraphic position of the massive reefeal bioconstructions is still not well assessed. In the Kosjerić area the clastic formation has a thickness of some tens of meters whereas the carbonate formation reaches more than 200 m. In the Kosjerić area, Radoiçić and Schlagintweit (2007) attributed a Cenomanian-Turonian age to the carbonatic sequence.

Guča Group. This sequence (Fig. 12) includes a basal formation characterized by transitional to littoral clastic deposits evolving into a middle formation of shallow marine carbonates and finally an upper formation consisting of siliciclastic turbidites. The basal clastic deposits are siliciclastic conglomerates, locally with clasts and blocks of massive limestones, passing upwards to hybrid arenites. The thickness of this formation ranges from few meters (Guča) to tens of meters (Lucani). The transition to the carbonate formation is gradual, through an increase in hybrid arenites and calcareous sandstones. The carbonate formation starts with well bedded limestones and calcareous sandstones that pass upwards to rudist-bearing massive limestones. The thickness of these shallow water deposits is highly variable in the study area ranging from about 20 m in the Lucani area up to 200 m south of Guča.

The turbiditic formation starts gradually above the massive reefeal limestone with a thin bedded turbidite facies locally interfingered with slumps and debris flow deposits (Lucani area) evolving upwards into thick bedded turbidites. The turbidites show an arkose to lithic arkose composition; the blocks in the debris flow deposits consist of phillades, gneiss and marbles and a few massive limestones. The turbidite formation is known as Kosovska Mitrovica Flysch (Dimitrijević and Dimitrijević, 1987) and lies above the eastern border of the Drina-Ivanjica Unit from the Lucani area to the north, to the Majden area (FYROM) to the south.

Radoičić et al. (2010) report an earliest Campanian age for the base of the shallow marine carbonate member. Our data allow to attribute a Campanian age (CC20 to CC22 zone of Sissingh, 1977; samples: TU1-TU26, 31Na, 31Nb, 31Nc) to the lower part of the turbiditic formation of the Guča Group cropping out in the Lucani area. According to an old paper by Cirić (1958) the age of the flysch in the Guča area spans from Maastrichtian to ?Danian.

The Ba intrusion

The study area is characterized by the occurrence of an intrusive body, known as the Ba intrusion, (also reported as the 'Slavkovica intrusion'), which consists of about 2 km^2 wide quartzlatites body. In thin section these rocks consist of quartz, k-feldspar, biotite, plagioclase, and hornblende as phenocrysts, in a groundmass of k-feldspar and quartz. Accessory minerals are magnetite, apatite, and zircon. Even if no datings are available yet, the Ba intrusion can be correlated with those recognized in the internal side of the Dinaric-Hellenic belt. This area is in fact characterized by intrusions of Cenozoic calc-alkaline granitoids whose ages fall in the Oligo-Miocene time span (Schefer et al., 2010, and references therein). As assessed for the Kopaonik granitoids (Zelic et al., 2010a), the source of these magmatic rocks can be identified in a mantle wedge strongly modified by subduction-induced metasomatism, linked with subduction of the oceanic lithosphere under the Eurasia continental crust.

TECTONIC SETTING

The reconstructed tectonic setting of the study area consists of a pile of units derived from three different domains (Figs. 2 and 3). The lowermost tectonic units, the East Bosnian-Durmitor and Drina-Ivanjica Units, are here interpreted as belonging to the Adria continental margin. The succession of the Drina-Ivanjica Unit is representative of the oceanward side of the Adria continental margin, close to the ocean-continent transition, whereas the East Bosnian-Durmitor Unit can be located in the more internal areas of the same continental margin. These units were imbricated – with the Drina-Ivanjica Unit thrust over the East Bosnian-Durmitor one – probably during the uppermost Late Jurassic-Early Cretaceous convergent phase, as pointed out by the ages of their successions, not younger than the Late Jurassic. The thrust surface separating these units can be located now below the oceanic units of the Zlatibor Massif (Fig. 3).

At the top of the Adria-derived units, the oceanic units crop out both in the Zlatibor and Maljen Massifs at the core of the first-order, synforms. They include, from bottom to top: a sub-ophiolite mélange, a metamorphic sole and an ophiolite unit consisting of peridotites. The continuity of these units can be traced along the whole length of the Zlatibor-Maljen geotraverse, as demonstrated in the Mokra Gora tectonic window, where the sub-ophiolite mélange crops out beneath the ophiolite unit. The separation of these oceanic units into two different belts is a result of continental collision which developed large, gentle synclines and anticlines that deformed both the continental and the oceanic units. At the core of the anticlines, the continental units, i.e. the East Bosnian-Durmitor and Drina-Ivanjica Units are exposed, whereas the oceanic units are preserved in the synclines. This reconstruction confirms that the oceanic units belong to a single nappe, emplaced at the top of the Adria-derived units and issued from a single oceanic domain, as suggested by their lithological, geochemical, stratigraphical and deformation features. The age of exhumation of the Drina-Ivanjica Unit is still matter of debate; if its relationships with the Cretaceous successions are stratigraphic, then exhumation could have occurred before the Late Cretaceous, whereas if these relationships are tectonic, then exhumation could be younger, probably Oligo-Miocene in age, as proposed for the internal side of the Dinaric-Hellenic belt (Kilias et al., 2001; Bortolotti et al., 2005; Muceku et al., 2008; Ustaszewski et al., 2010; Zelic et al., 2010a). In the eastern side of the study area, the oceanic units are covered by the Lijg Unit, one of the Europe-derived continental units, as proposed by Zelic et al. (2010b).

The boundaries among the tectonic units generally correspond to cataclastic shear zones whose features mainly depend on the lithology where deformation developed. The kinematic indicators, as S-C structures in foliated cataclasites or mineral steps in cataclasites developed in carbonates, show a top-to-the-NW sense of shear. However, in some outcrops these shear sense indicators are overprinted by analogous structures showing both top-to-the-SE and top-to-the–NW sense of shear. These shear zones, along which entire stratigraphic levels are elided, can be regarded as polyphase shear zones with a first phase characterized by a reverse sense of shear followed by a second phase with an opposite one. For instance, along the shear zone at the base of the sub-ophiolite mélange west of the Zlatibor Massif top, the uppermost levels of the East Bosnian-Durmitor Unit, i.e. the Jurassic formations, were erased, probably during the second phase when the shear zone worked as a normal fault. Similarly, the eastern border of the Drina-Ivanjica Unit is characterized by the tapering of the Triassic sedimentary covers due to top-to-the-SE shear zones associated with the extensional phases that followed compression.

In the Ba-Slavkovica Ljig area, the relationships between the oceanic units and the Ljig Unit are sealed by the intrusion of the Ba quartz-latites and covered by the Neogene deposits, as well as the thrust of the Ljig Unit above the Cretaceous deposits of the Mokra Gora Group. Uplift of the magmatic body produced extensional shear zones associated with gentle to open folds with sub-horizontal axial surfaces and reverse faults that locally cut the previous tectonic contacts.

Mainly around the Maljen Massif, the relationships among all the units are cut by high angle faults, that, although complex, show mainly NW-SE and NE-SW trends. The NW-SE trend faults, according to kinematic indicators as slickensides, slickenfibers, fractures and mineral steps, can be classified as purely normal to transtensive structures. The faults are concentrated along the boundaries of the Drina-Ivanjica Unit and probably developed during the Oligocene-Miocene extensional tectonics, coeval to the calc-alkaline magmatism. In this frame, the NE-SW trend faults can be regarded as strike-slip to transtensive structures that accommodated areas characterized by different extension rate.

THE ZLATIBOR-MALJEN GEOTRAVERSE: A TENTATIVE RECONSTRUCTION OF ITS MESOZOIC GEODYNAMIC HISTORY AND CORRELATION WITH THE ALBANIA-GREECE GEOTRAVERSE

The data collected along the Zlatibor-Maljen geotraverse, integrated with the ones available from the literature, allow us to propose a tentative reconstruction of the Mesozoic geodynamic history of the Dinaric-Hellenic belt in its northwestern areas. This history developed throughout an Early to lowermost Middle Triassic rifting stage followed by the uppermost Middle Triassic opening of a wide oceanic basin. This basin subsequently suffered a convergence stage, probably in the Early Jurassic, followed by continental collision, during an age span from Early to Late Cretaceous. The main steps of this evolution were:

Early to lower Middle Triassic: in this time span, the domain from which the East Bosnian-Durmitor and Drina-Ivanjica Units originated was characterized by a continental to shallow water environment, where mainly carbonate sediments were deposited. The magmatic activity, recognized in the Drina-Ivanjica Unit during the Early Triassic and in the East Bosnian-Durmitor Unit in the lowermost Middle Triassic can be related to thinning of the continental crust during the rifting process active since the Permian-Early Triassic boundary in an area of the Pangea corresponding to the future Adria Plate. Evidence of this regional Permian-Early Triassic rifting can be identified in all the Adria-derived units from Greece to Albania (Dimitrijević, 1997; Brown and Robertson, 2004; Robertson et al., 2009).

Upper Middle to Late Triassic: during the Middle Triassic rifting resulted in the opening of a wide oceanic basin south of the Eurasian Plate, as suggested by the occurrence of pelagic deposits along the continental margin, as cherty limestones and cherts, ranging in age from Ladinian to Carnian, found in the East Bosnian-Durmitor Unit. Moreover, development of a Triassic oceanic basin is supported by the finding in the sub-ophiolite mélange of MORBs and Triassic cherts, ranging in age from Late Anisian-Early Ladinian to Early Carnian. These data suggest that slices of the Triassic oceanic crust were preserved along the Zlatibor - Maljen geotraverse, as recognized in the sub-ophiolite mélange of Bosnia and Serbia (Vishnevskaya et al., 2009), and of Albania and Greece as well (Saccani et al., 2003; 2008; Bortolotti et al., 2004b; Saccani and Photiades, 2005; Photiades et al., 2007; Bortolotti et al., 2008). The interpretation of the MOR basalts immediately below the metamorphic sole and the mantle peridotites in both the Zlatibor and the Maljen Massifs as a tectonic unit of Triassic age, as also recognized in Albania and Greece (cfr. Porava Unit in Bortolotti et al., 2004a; Migdalitsa Unit, in Bortolotti et al. 2003 and Fourka Unit in Ferrière, 1982 and Bortolotti et al., 2008), can be regarded as a valuable working hypothesis.

Early Jurassic: a major change in the oceanic basin is suggested by the occurrence of the earliest Middle Jurassic subduction-related magmatic sequences, i.e. the IAT basalts found in the ophiolite sequences and/or in the sub-ophiolite mélange in the northern part (Pamić et al., 2002; Marroni et al., 2004a; Robertson et al., 2009) as well as in the southern one of the Dinaric-Hellenic belt (Shallo, 1992; 1994; Beccaluva et al., 1994; Hoxha and Boullier, 1995; Bortolotti et al., 1996; 2005; Robertson and Shallo, 2000). This finding requires a previous intra-oceanic subduction event, whose inception can be identified in the Early Jurassic, considering a time span of about 15-20 Ma as necessary for the subducted crust to reach melting depths (Bortolotti et al., 2005; in press).

Middle to Late Jurassic: the ophiolites of the study area, although repesented only by the oceanic mantle section, are representative of a large, composite basin located in a suprasubduction zone. Only scattered radiometric ages (163-148 Ma; Bazylev et al., 2009) are available for the mantle section of these ophiolites. Even if not completely reliable, these ages fit with those detected in the southern continuation of the ophiolite belt in Albania and Greece. The Zlatibor ophiolites can thus be correlated with those cropping out from Albania to Western Greece, where they can be divided into two different Jurassic oceanic sequences, derived from the same oceanic basin. The westernmost one can be interpreted as a portion of trapped MORB oceanic crust, modified by the later subduction-related magmatism (Bortolotti et al., 2002a). Nonetheless, alternative interpretations, suggest that the MORB crust was itself generated in the suprasubduction setting (see Insergueix-Filippi et al., 2000; Bébien et al., 2000; Barth et al., 2008; Dilek et al., 2008). In Albania, the radiolarian cherts, found at the top of these basalts (JOa ophiolites by Bortolotti et al., in press), range in age from latest Bajocian-Early Bathonian to Late Bathonian-Early Callovian, (Prela et al., 2000; Chiari et al., 2002; 2004). On the contrary, the easternmost ophiolite sequence provides clear evidence of its origin in the suprasubduction oceanic basin, probably in a fore-arc position (Beccaluva et al., 1994; Shallo, 1994; Pamić, 2002; Bortolotti et al., 2002a; Hoeck et al., 2002; Marroni et al., 2004; Dilek et al., 2007; Saccani et al., 2008a). In Albania the radiolarian associations found in the cherts either at the top or intercalated in the volcanics yielded ages similar to those found in the JOa belt, in particular a time interval comprised between Late Bajocian/latest Bajocian-Early Bathonian and Middle Callovian-Early Oxfordian (Chiari et al., 1994; 2002).

Differently, the Maljen ophiolites can be correlated with those from the Guevgueli area cropping out in eastern Greece. These sequences are representative of an oceanic basin that opened in back-arc position (Bébien et al., 1986; Brown and Robertson, 2004; Saccani et al., 2008b) during the Middle-Late Jurassic boundary (Zachariadis et al., 2006; Danelian et al., 1996). Probably, immediately after the opening of the back-arc basin, convergence caused obduction of the ophiolites and the progressive closure of the oceanic basin, leading to continental collision. Obduction, that took place during the intra-oceanic stage (*sensu* Michard et al., 1991), formed the metamorphic sole at the base of the mantle section, and then caused emplacement of the ophiolite nappe onto the Adria continental margin during the marginal stage (*sensu* Michard et al., 1991). The age of the metamorphic sole in the southern Dinaric-Hellenic belt spans from 162.1±2.4 to 174.0±2.5 Ma in Albania (Dimo-Lahitte et al., 2001), and from 168±2.4 to 172.9±3.1 Ma in Greece (Liati, 2005). In the southern Dinaric-Hellenic belt less reliable data roughly indicate the same age (from 181 to 146 Ma; Okrush et al., 1978; Karamata et al., 2005; Karamata, 2006). These data are coherent with an obduction process that occurred since the uppermost Middle Jurassic and resulted in the closure of the oceanic basin and the subsequent inception of continental collision. The age of this closure is however still matter of debate. In the southern areas, the collected data suggest an uppermost Late Jurassic closure of the oceanic basin, whereas in the northern areas the findings of Late Cretaceous MOR basalts (Ustaszewski et al., 2009) suggest that closure occurred later. These differences can be explained by a diachronous oceanic closure: Late Jurassic in the southernmost areas of the oceanic basin and Late Cretaceous in the northernmost ones.

Early to Late Cretaceous: starting from Early Cretaceous, compression-related deformation migrated into the Adria continental margin. This progressive deformation affecting the Adria-derived units is well documented by shifting in the age of the turbidites at the top of the successions, as well as by the time of inception of deformation in each unit. With its progressive migration towards the internal areas of the Adria Plate, further deformations affected the already deformed areas, mainly through out-of-sequence thrusts and/or strike-slip faults that accommodated areas with different rates of shortening.

CONCLUSIONS

Taking into account all the collected data along the Zlatibor-Maljen geotraverse, some final remarks can be proposed.

Our tectonic reconstruction based on the geological mapping suggests the presence of a single, wide oceanic nappe, consisting of a sub-ophiolite mélange and an ophiolite unit, thrust over the Drina-Ivanjica and the East Bosnian-Durmitor continental Units. These continental units, here interpreted as derived from the Adria continental margin, are exposed in correspondance of large, regional antiformal structures. The oceanic units are in turn cropping out in correspondance of large anticlinal structures, i.e. in the Zlatibor and Maljen areas. The oceanic units are overthrust by the Ljig Unit, consisting of turbidites deposited in a thrust-top basin located on the Eurasia Plate, i.e. the hinterland of the Dinaric-Hellenic belt.

All the mapped structures resulted from a long-lived geodynamic history related to convergence between Adria and Eurasia, that since the Middle Triassic were separated by a wide oceanic basin. The large scale structures originated during the closure of this oceanic basin and the subsequent continental collision. However, the most evident structure is the NW-SE trending antiform, where the Drina-Ivanjica Unit crops out, that divides the ophiolitic nappe into two belts, as presently observed in the whole Dinaric-Hellenic chain. This structure can be interpreted as resulting from the continuous convergence that produced an overthickening of the tectonic pile at depth, whereas the upper structural levels were dominated by extension.

Closure of the oceanic basin occurred probably at the Late Jurassic-Early Cretaceous boundary but it was accomplished later in the northernmost geotraverse, during the Late Cretaceous. The proposed reconstruction implies that all the ophiolites of the Dinaric-Hellenic belt originated from a single ocean domain. In the study area, this ocean developed in Middle Triassic and was characterized by a very long life, from Middle Triassic to Late Jurassic (about 100 Ma). This long-lived oceanic basin was composite and characterized since the Early Jurassic by east-dipping intra-oceanic subduction leading to the birth of fore- and back-arc SSZ oceanic basins during the Middle Jurassic. In the uppermost Middle-Late Jurassic, convergence caused the large-scale obduction of the oceanic units onto the Adria margin. The subsequent continental collision produced a westward emplacement of the oceanic units over the Adria continental margin for more than 200 km.

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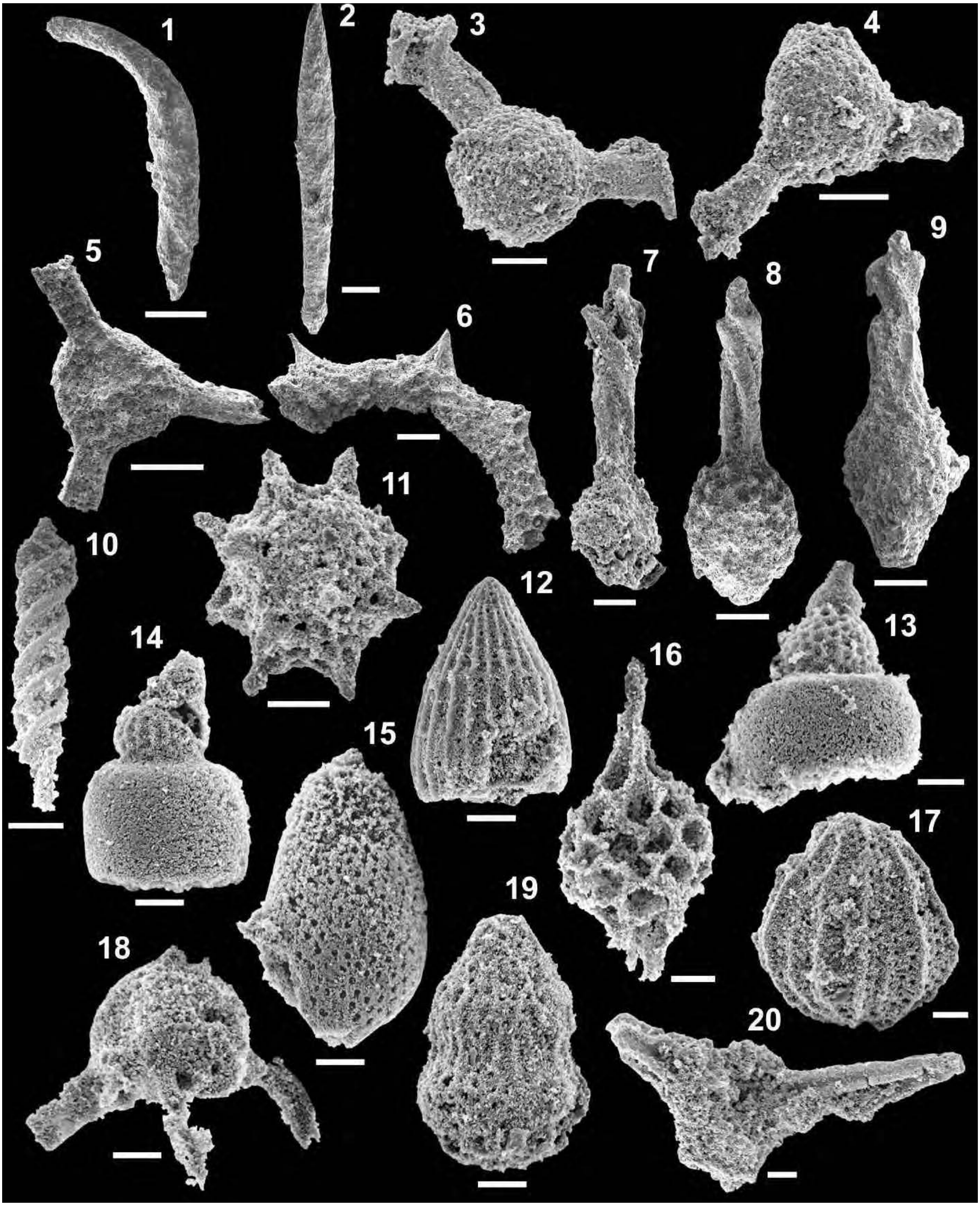

Plate 1 - 1-2) Middle Triassic radiolarians, 3-11) Late Triassic radiolarians, 12-20) Middle Jurassic radiolarians. Scale bar 50*μ* (1-11), 20*μ* (12-20).
1) *Oertlispongus* sp. cf. *O. inaequispinosus* Dumitrica, Kozur and Mostler, 07SRB40; 2) *Paroertlispongus multispinosus* Kozur and Mostler, 07SRB40; 3) *Capnuchosphaera triassica* De Wever, 07SER31; 4) *Capnuchosphaera* sp., 07SER31; 5) *Divatella* sp., 07SRB33a; 6) *Praeorbiculiformella* sp. cf. *P. vulgaris* Kozur and Mostler, 07SRB33a; 7) *Pseudostylosphaera gracilis* Kozur and Mock, 07SER31; 8) *Pseudostylosphaera* sp. cf. *P. gracilis* Kozur and Mock, 07SER31; 9) *Pseudostylosphaera* sp. cf. *P. gracilis* Kozur and Mock, 07SRB33a; 10) *Spongotortilispinus tortilis* (Kozur and Mostler), 07SER31; 11) *Welirella* sp. cf. *W. fleuryi* (De Wever), 07SER31; 12) *Archaeodictyomitra* sp. cf. *A. patricki* Kocher, 07SRB41; 13) *Eucyrtidiellum unumaense* s.l. (Yao), 07SRB41; 14) *Eucyrtidiellum* sp., 07SRB41; 15) *Guexella nudata* (Kocher), 07SRB41; 16) *Pantanellium* sp., 07SRB41; 17) *Protunuma*(?) l*anosus* Ožvoldová, 07SRB41; 18) *Saitoum* sp. cf. *S. levium* De Wever, 07SRB41; 19) *Theocapsomella medvednicensis* (Goričan), 07SRB41; 20) *Triactoma*(?) sp., 07SRB41.