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The Sava-Vardar Zone of the Dinarides and Hellenides versus the Vardar Ocean

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Key words: Dinarides-Hellenides, Alps, Periadriatic Lineament and Sava-Vardar suture zone, basic lithologies, back-arc basin, subduction, collision, transpression, indentation, extrusion tectonics

ABSTRACT

The Sava-Vardar Zone (SVZ), about 1000 km long, represents the most internal tectonostratigraphic unit of the Dinarides and Hellenides. The main lithologies of the SVZ are as follows: 1) Cretaceous to Early Paleogene flysch at the base interlayered with subduction-related bimodal basalts and rhyolites; 2) Late Paleogene metamorphic sequences, which originated from adjacent Mesozoic units; 3) Paleogene tectonized ophiolite mélange; 4) Eocene syncollisional granites, 5) Oligocene post-syncollisional granitoids and shoshonites with subordinate andesite-dacites, and 6) postcollisional Neogene volcanic associations. The most widespread Oligocene granitoids and shoshonites can be correlated with penecontemporaneous igneous rocks located along the Periadriatic Lineament.

Cretaceous and Early Paleogene formations of the SVZ originated in a back-arc basin setting that developed along the North Tethyan margin. The SVZ units were affected by Eocene (55-45 Ma) collisional deformation and metamorphism accompanied by synkinematic granite plutonism, generation of a tectonized ophiolite mélange and its thrusting onto the Dinaridic – Hellenidic Ophiolite Zone. The uplifted Dinarides and Hellenides underwent Oligocene transpressional strike-slip faulting accompanied by magmatic processes.

Allochthonous SVZ lithologies of the Zagorje-Mid-Transdanubian Zone, including the Meliata-Bükk area resulted from Tertiary extrusion tectonics. The SVZ and Periadriatic Lineament before the indentation of Apulia probably represented a huge connected structure about 2000 km long, i.e., the collisional area between converging Africa and Eurasia (e.g. suture zone). Or, alternatively, separated sutures of the Alps and SVZ that were finally brought close to each other in the final stage of Alpine convergence, giving thus an apparent continuity between the two features.

ZUSAMMENFASSUNG

Die Sava-Vardar Zone (SVZ), die sich über etwa 1000 km Länge erstreckt, stellt die innerste tektonostratigraphische Einheit der Dinariden und Helleniden dar. Die wichtigsten lithologischen Einheiten der SVZ sind: 1) kretazisch-frühpaläogene Flysch-Ablagerungen, die im basalen Teil mit bimodalen Basalten und Rhyoliten, welche in Zusammenhang mit der Subduktion stehen, wechsellagern; 2) spätpaläogene Sequenzen, die aus den benachbarten mezozoischen Einheiten durch Metamorphose entstanden sind; 3) synkinematische Granitoide; 4) paläogene tektonisierte Ophiolit-Mélange-Massen; 5) oligozäne post-synkollisionale Granitoide und Schoschonite, und 6) tertiäre vulkanische postkollisionale Vergesellschaftungen. Die am meisten verbreiteten oligozänen Granitoide und Schoschonite können mit gleichzeitigen Eruptivgesteinen, die entlang des periadriatische Lineaments eingeschaltet sind, verglichen werden.

Die kretazischen und frühpaläogenen Einheiten der SVZ entstanden innerhalb eines back-arc Beckens, das sich entlang des Randes der nördlichen Tethys bildete. Die SVZ Einheiten wurden durch die eozäne (55-45 Ma) Kollisiondeformation und Metamorphose, begleitet von einem synkinematischen Granit-Plutonismus und der Bildung der tektonisierten Ophiolit-Mélange und deren Obduktion auf die dinarisch-hellenidische Ophiolit-Zone, betroffen. Die herausgehobenen Dinariden und Helleniden wurden von einer transpressionalen strike-slip Verwerfung und magmatischen Prozessen betroffen.

In dieser Arbeit wurden auch die Erscheinungen der allochthonen SVZ Gesteinsfolgen der Zagorje-Mid-Transdanubian Zone, einschließlich des Meliata-Bükk Gebietes, die als Ergebnis der tertiären Extrusiontektonik zu betrachten sind, bearbeitet. Es ist höchst wahrscheinlich, dass das Gebiet der SVZ und des periadriatischen Lineaments, vor der tertiären Einkerbung von Apulia, eine riesengrosse Struktur dargestellt hat, die sich etwa 2000 km lang erstreckte, d.h. ein Kollisionsgebiet (Suture Zone) zwischen den konvergierenden Blöcken Afrika und Eurasia.

1. Introduction

The Alpine belts of the Dinarides and Hellenides links up to the north with the Alps *s.str*. However, to date nobody has precisely defined the Dinarides/Alps boundary in a geological sense. It has been widely accepted since Suess (1875) that the Alps continue southeastward without a break into the Dinarides. This is only partially true because only the southernmost parts of the Alps, i.e., the Southern Alps, continue without a break into a part of the Dinarides, i.e., the External Dinarides (Fig. 1).

Dinarides, Hellenides and Alps represent a complex system of mountain belts. The Dinarides and Hellenides are characterized by a regular pattern in the spatial distribution of characteristic Alpine tectonostratigraphic units (Fig. 2 – Pamić

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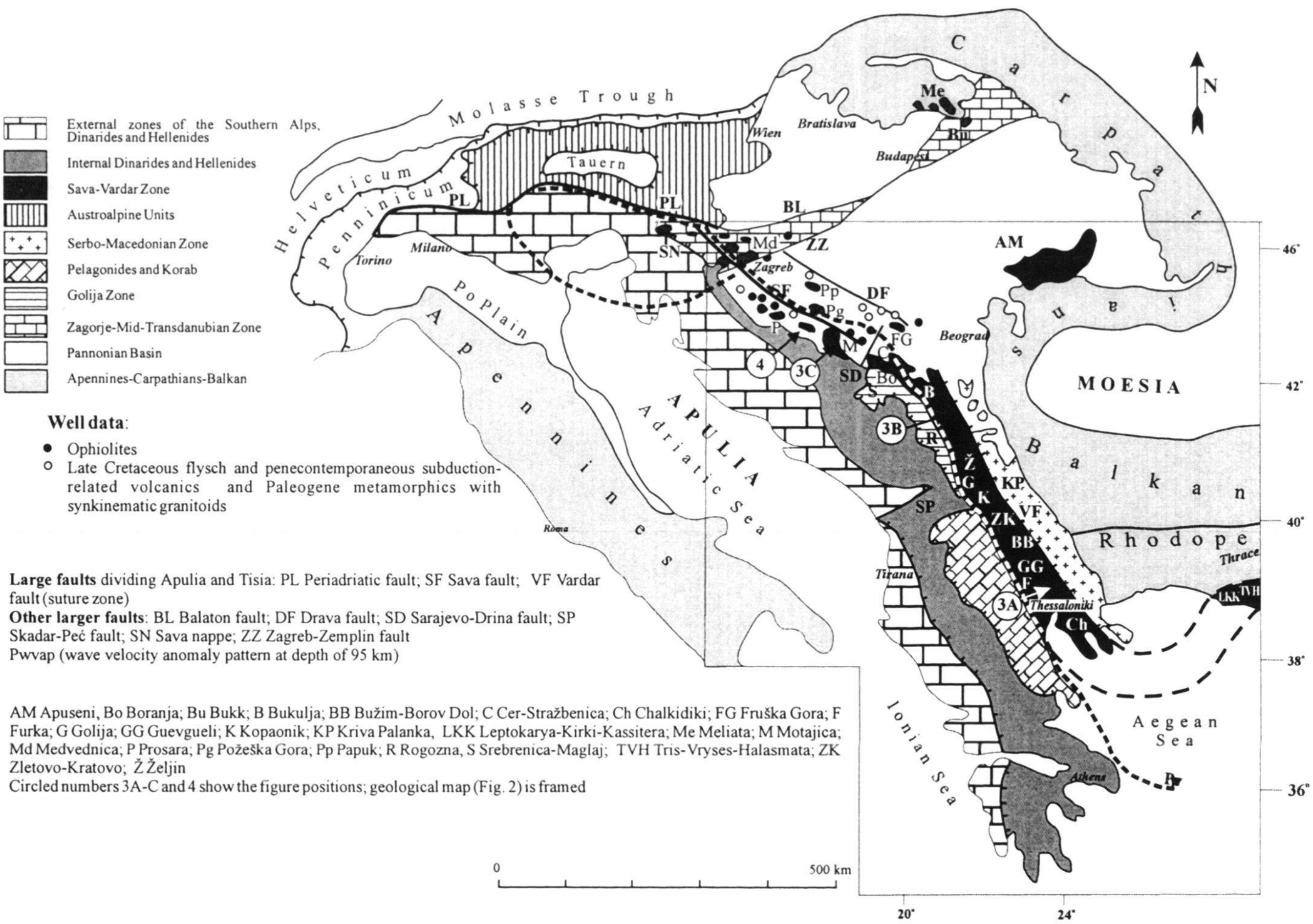

Fig. 1. Tectonic scheme of the Alps, Dinarides, Hellenides and Pannonian Basin showing the position of the Sava-Vardar Zone; simplified according to Dimitrijević (1999)

et al. 1998). The regular pattern, however, cannot be traced further into the Alps northwest of Zagreb (Fig.1). In the central parts of the Dinarides, which were not affected by the indenting of Apulia and Moesia, the following NW-SE striking and SW-verging Alpine tectonostratigraphic units can be distinguished from southwest to northeast: 1) the Adriatic-Dinaridic carbonate platform of the Apulian shelf margin, including the narrow Dalmatia Zone in the SW (the External Dinarides); 2) carbonate-clastic sedimentary sequences of the Tethyan passive continental margin ("flysch bosniaque" including "zone prekarstique" of the French geologists, e.g. Aubouin et al. 1970); 3) ophiolites, including genetically related sedimentary formations (Tethyan open-ocean realm), i.e., the Dinaride Ophiolite Zone, and 4) sedimentary, igneous and metamorphic rocks of the Tethyan active continental margin represented by the Vardar Zone. Kossmat (1924) first defined the Vardar Zone, restricting its occurrence to southern Serbia, Macedonia and northern Greece. Afterwards it was recognized that the zone continues further northward and northwestward (Aubouin 1973) in the area of the Sava River (Fig. 2). The tectonostratigraphic units 2 to 4 define the Internal Dinarides also referred to as the Supradinaric Zone (Herak 1986). This regular pattern is interrupted by allochthonous Paleozoic-Triassic nappes of the Golija Zone which were emplaced due to out of sequence thrusting onto the northeastern and eastern parts of the Internal Dinarides (Rampnoux 1970).

All the mentioned tectonostratigraphic units of the Dinarides continue southeastward without a break into the Hellenides, but under different names. This causes difficulties in correlation (Mercier 1968, Aubouin et al. 1970, Papanikolau 1984, Frasheri et al. 1996) which we attempt to overcome (Fig. 2).

The Adriatic–Dinaridic carbonate platform terminates along the Skadar–Peć Line. Southwestward the External Hellenides comprise the Gavrovo Zone of Greece (corresponding to the Kruja Zone in Albania) and the Ionian Zone. Additionally, the Sazani Zone (Aubouin & Ndojaj 1964, Frasheri et al. 1996) corresponding to the most external parts of the Apulian foreland was defined in southern Albania. For convenience we shall link this latter unit with the Gavrovo Zone (Dalmatia–Gavrovo Zone of Fig. 2).

Concerning the internal units, the most prominent is the continuous prolongation of the Dinaride Ophiolite Zone into the Mirdita Zone (Albania) and the Subpelagonian Zone (Greece). For convenience we define the term, the Dinaridic–Hellenidic Ophiolite Zone. Elongated and interrupted Dinaride Radiolarite zones are equivalent in lithostratigraphy to Budva Zone (Montenegro), Cukali-Krasta Zone (Albania) and Pindos Zone (Greece) – the Radiolarite Bosnia-Pindos Zone. Hellenidic equivalents of the Bosnian flysch Zone are defined by interrupted zones of Beotia flysch which is thrust by the Dinaride-Hellenide Ophiolite Zone (Aubouin 1973).

The Vardar Zone continues without break from the Aegean Sea in the south via Belgrade and along the southern margin of the Sava Depression up to Zagorje-Mid-Transdanubian Zone in the northwest. The Vardar Zone is underthrust by the Pelagonides in the south and further northeastward by the Korab and Golija Zone (Rampnoux 1970, Aubouin 1973).

The southern parts of the Dinaridic–Hellenidic Ophiolite Zone are also in contact with the Pelagonides consisting mainly of Variscan basement with Late Carboniferous intrusives (Vavassis et al. 2000) followed by Permian and Middle Triassic syn-rift deposits and volcanics. These are overlain by Late Triassic platform carbonates, then deep water Jurassic sediments and obducted ophiolites. These nappes are more or less affected by metamorphism depending on their degree of subduction during the Alpine cycle. We shall retain the term Pelagonides for all these units.

Further eastward the Pelagonides are thrust by the Vardar (Axios in Greece) Zone which is divided into three subzones in Greece (Mercier 1968) which can be continuously traced into the northeastern Dinarides (Dimitrijević 1995). Because the Vardar Zone continues westnorthwestward into the area of the Sava River, we shall use the term Sava-Vardar Zone (SVZ) for convenience.

All these correlations indicate that the tectonostratigraphic units of the Dinarides and Hellenides may have been generated within continuous sedimentary realms which we shall call the Dinaridic-Hellenidic Tethys for convenience. It is equivalent to the term Vardar ocean proposed by Dercourt (1972), Dercourt et al. eds. (1993), Stampfli (2000) and Stampfli et al. (1998).

Within the paleogeographic subdivision of the Dinarides and Hellenides, the SVZ occupies an obvious structural position. It represents the most internal unit built into the Dinarides and Hellenides, originating along the northern active margin of the Dinaridic-Hellenidic Tethys. The northwesternmost outcrops of ophiolite mélange of the SVZ, located only about 60 km away from the easternmost parts of the Periadriatic Lineament, are found westward of the Zagreb-Zemplin Line (Pamić 1996), in the Zagorje-Mid-Transdanubian Zone (Fig. 1) that is characterized by mixed Alpine and Dinaridic tectonostratigraphic units (Pamić & Tomljenović 1998).

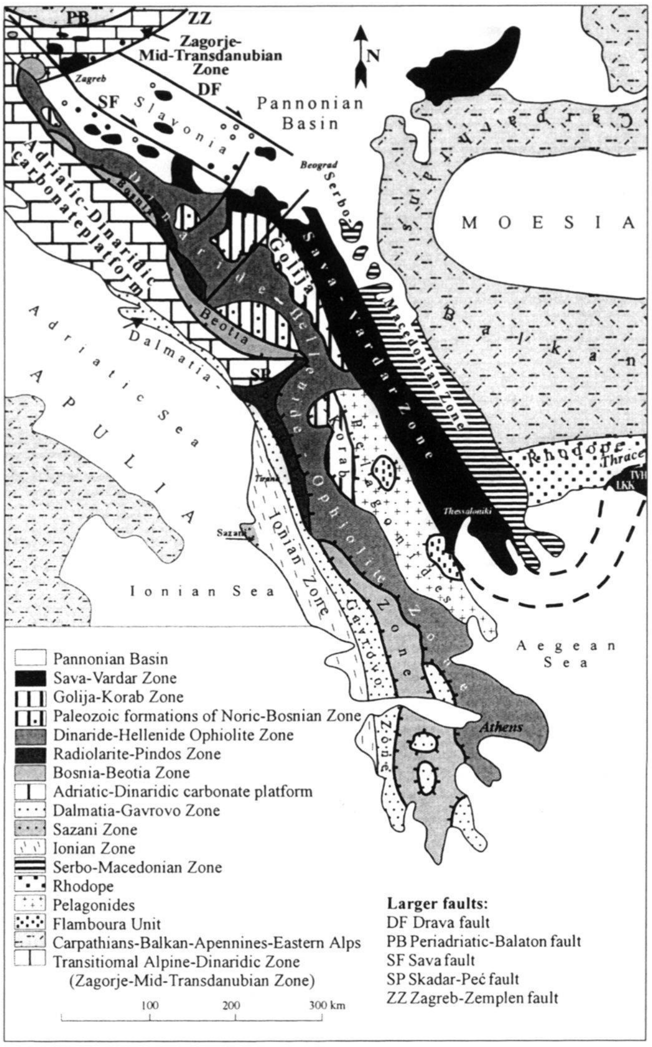

Fig. 2. Simplified paleogeographic and structural map of the Dinarides and Hellenides modified according to Aubouin et al. (1970), Papanikolau (1984), Frasheri et al. (1996) and Dimitrijeviç (1999)

The aim of this paper is to provide a new look at the Vardar Ocean, outlining some basic geological features of the Dinaridic-Hellenidic SVZ. In terms of magmatic manifestations the SVZ has some features in common with the area located along the Periadriatic Lineament, both of them being parts of the collisional area between converging Africa and Eurasia, i.e., the suture zone. In this paper, the allochthonous lithologies of the SVZ, scattered in the southern and western parts of the Pannonian Basin, will also be considered (Fig. 1).

2. Basic features of the Dinaridic-Hellenidic SVZ

The SVZ can be traced along strike for about 1000 km. It stretches from the Zagreb-Zemplin Line in the northwest extending in an ESE direction south of the Sava River to Belgrade from where it deflects in a SSE direction to the Vardar River until Thessaloniki in Greece in the southeast. South of the Thessaloniki area the SVZ sharply deflects in a NE-direction extending to southeast Thrace (Fig. 2). Another branch of the SVZ extends northeastward from the Belgrade area into the southern Apuseni mountains and will not be considered in this paper. In its northwestern parts, the SVZ is directly thrust onto the Dinaridic-Hellenidic Ophiolite Zone (Pamić 1993). Further eastward it is thrust onto the Golija–Korab Zone and Pelagonides, respectively. Robertson & Karamata (1994) presented the hypothesis that the Golija Zone and Pelagonides represented a continental block (e.g. the Drina–Ivanjica microcontinent –first proposed by Dimitrijević (1982) during the Mesozoic separating the Vardar Ocean in the east from the Dinaridic-Hellenidic Tethys in the west.

Farther eastward the eastern margin of the SVZ is overthrusted by the Serbo-Macedonian unit which forms the westernmost marginal part of the Rhodope (Ricou et al. 1998). Here, the tectonic units of the Dinarides are strongly deformed and reduced due to Tertiary indenting of Moesia (Kázmér & Dunkl 1997). Along its entire strike the northern part of the SVZ is largely covered by Tertiary sediments of the South Pannonian Basin which are strongly reduced and wedge out along the adjoining area of Rhodope and the southeasternmost SVZ.

In the first modern geodynamic interpretations of this part of the Alpine-Himalaya belt, Dercourt (1972) proposed the term Vardar Ocean for an oceanic domain which existed during the Alpine cycle between Apulia and Moesia. Afterwards the term Vardar Ocean has been used in modified ways up to the present time in palinspastic interpretations of this part of the Tethys Ocean (Dercourt et al. eds. 1993, Robertson & Karamata 1994, Stampfli 2000, Stampfli & Marchant 1995, Ziegler & Stampfli 1999, Karamata et al. 2000).

The Vardar Zone, as defined by Kossmat (1924), represents a 40–70 km wide zone, wedged between the Pelagonides in the west and the Rhodope in the east (Fig. 2). It is characterized, particularly in its eastern parts, by steeply inclined imbricate structures largely composed of Cretaceous/Paleogene flysch formations, ophiolite mélange, Paleozoic (?) and Alpine metamorphic sequences, granitoids and volcanics, transgressed by marine Oligocene conglomerates and sandstones with Tertiary andesites, as well as by Neogene sedimentary formations of th Pannonian Basin. Triassic clastics and carbonates, Jurassic limestones, shales, radiolarites as well as plagiogranites play a subordinate role. Based on our present knowledge, however, these Mesozoic lithologies mainly represent smaller or larger and frequently mappable fragments embedded in an ophiolite mélange (Dimitrijević 1982, 1995, Dimitrijević & Dimitrijević 1987, Pamić 1993, Papanikolau 1996/97). Some of them were involved in the first Late Jurassic obduction of ophiolites. This is illustrated by correlation stratigraphic charts prepared for three different areas of the SVZ (Fig. 3).

In the SVZ of Serbia, **Early Cretaceous "Paraflysch"**, as named by Dimitrijević & Dimitrijević (1987), can be traced along strike for about 250 km. These sediments are largely composed of fossiliferous Valanginian-Hauterivian to Albian-Cenomanian microconglomerates, arenites and siltstones. The paraflysch sequences are unconformably overlain by a **Turonian to Maastrichtian flysch** which is composed in its lower parts of clastics containing redeposited Albian-Cenomanian limestones and of "preflysch" marls and limestones. Most of the overlying Late Cretaceous flysch is composed of fossiliferous calcarenite, breccia, sandstone, siltstone, marl and shale sequences (Obradović 1987) as seen in Figs. 3A and B. Similar flysch sequences are missing within the Dinaridic Ophiolite Zone.

In the northwestern part of the SVZ of North Bosnia (Fig. 3C), Late Cretaceous-Early Paleogene flysch sequences do occur, while the underlying older Cretaceous sequences are poorly preserved (Jelaska 1978, Pamić et al. 1998). Here, the lower parts of the Late Cretaceous-Early Paleogene flysch sequences are sometimes interlayered with contemporaneous subduction-related basalts, rhyolites and ignimbrites intruded

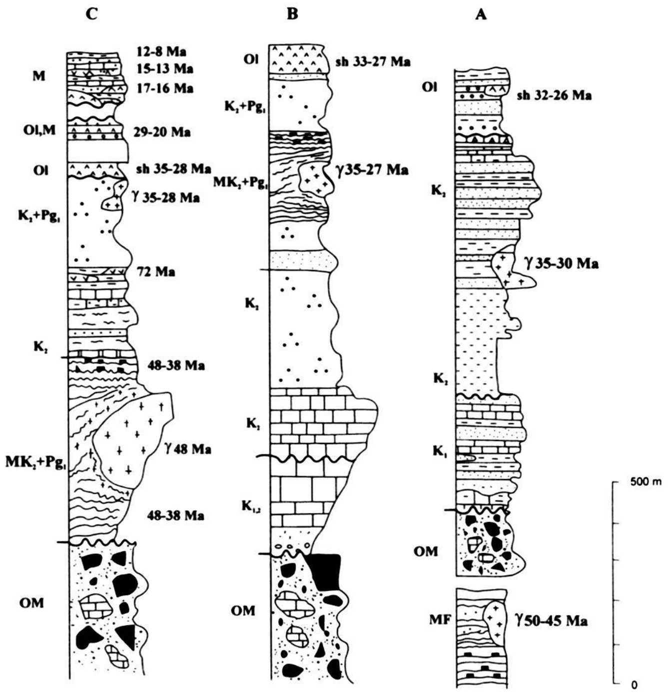

Fig. 3. Geological columns of the Sava-Vardar Zone; A southern part; B northern part (modified according to Dimitrijević, 1995); C northwestern part
M Miocene clastics, subordinate limestones interlayered with volcanics varying in ages (Pannonian Basin); Ol,M Egerian-Eggenburgian sediments interlayered with volcanics; Ol marine clastics interlayered with volcanics; g Alpine syncollisional and post-syncollisional granitoids; sh shoshonites with subordinate high-K calc-alkaline volcanics; MK_2+Pg_1 metamorphic sequences originating from Late Cretaceous-Early Paleogene flysch; K_2-Pg_1 Late Cretaceous-Early Paleogene flysch at the base interlayered with basalt and rhyolite; K_2 Late Cretaceous flysch; $K_{1,2}$ Early Cretaceous and lowermost Late Cretaceous flysch; K_1 Early Cretaceous flysch; OM ophiolite mélange; MF Alpine metamorphic formations of unknown age

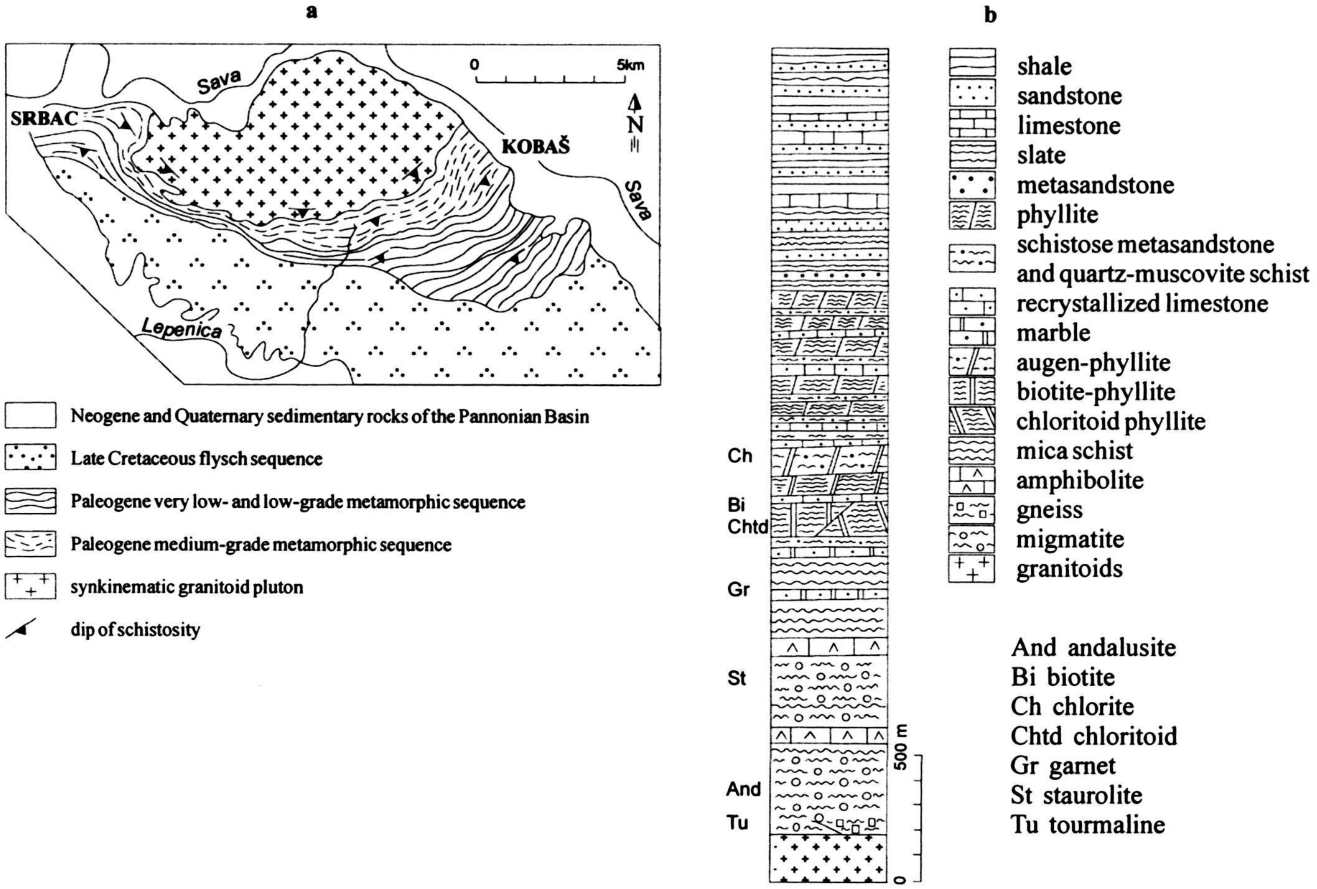

Fig. 4. a) Geological map of Mt. Motajica; b) Columnar section showing progressive zonation of metamorphics from overprinted unmetamorphosed Upper Cretaceous flysch sediments to very low-, low- and medium-grade metamorphic rocks

by small bodies of contemporaneous A-type granites. The latter originated by fractional crystallization from primary tholeiitic basalt magma (Pamić et al. 2000a). However, such rhyolites with ignimbrites, to date not yet studied, also occur within the Late Cretaceous flysch in the southern parts of the Vardar Valley in North Macedonia. In the SVZ south of Belgrade, Senonian flysch sequences include at their base trachydacitic volcanoclastic debris-flows (Karamata et al. 1999).

The greatest misunderstanding about the SVZ concerns the **metamorphic sequences**. Kossmat (1924) mapped the Paleozoic(?) "Veles Series" largely composed of phyllite, metagraywacke, chlorite-amphibolite and marble, within which Paleozoic microfossils were found (Grubić & Ercegovac 1975). However, low-grade metamorphic rocks identified as "Veles Series", also occur in the northern part of the SVZ in Serbia, where Triassic to Cenomanian fossils were found in these low-grade metamorphic rocks (Dimitrijević 1995).

The only area where metamorphic rocks, previously assigned to the Paleozoic or even pre-Paleozoic without any evidence, were studied in detail, is located in Motajica and Prosara mountains, found in the northwestern part of the SVZ in northern Bosnia (Pamić & Prohić 1989, Pamić et al. 1992). Here, complete sequences are found which show a progressive zonation from unmetamorphosed Upper Cretaceous sedimentary and igneous rocks to very low-, low- and medium-grade metamorphic rocks. This interpretation is indicated by several lines of evidence: 1) gradual change in fabrics; 2) illite-crystallinity and vitrinite data in lower grade parts, 3) mineral zonation of chlorite to biotite to garnet to staurolite ± andalusite in higher grade parts and 4) the oxygen isotopic composition (Fig. 4). In this area, fold and thrust structures are north-vergent, in contrast to the common SW-vergence observed in the Dinarides. Parts of such complete progressive sequences with remnants of the Late Cretaceous protolith can be recognized in some adjacent areas (e.g. Mt. Bukulja), in cores from several deep oil wells and also in the southeastern parts of the SVZ of Serbia (Aleksić & Pantić 1972, Pamić 1993).

This progressive metamorphism of Upper Cretaceous rocks is supported by paleontological and geochronological data. The slates and phyllites of lower grade parts of these metamorphic sequences yielded a Late Cretaceous-Early Pale-

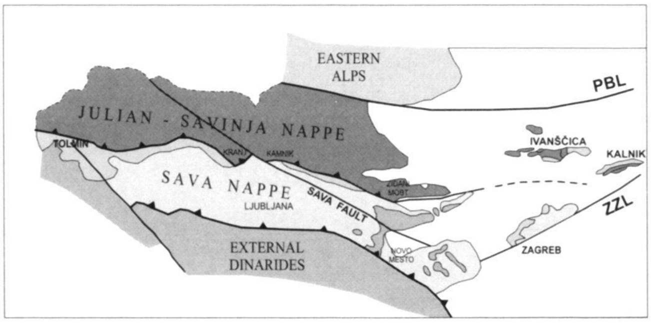

Fig. 5. Sketch map of Hrvatsko Zagorje and Central Slovenian areas.

ogene microflora (Pantić & Jovanović 1970). Within medium-grade rocks from deep oil wells K-Ar ages of 48 (hornblende) and 38 (biotite) Ma were measured (Lanphere & Pamić 1992).

These mutually consistent analytical data provide reliable evidence that the SVZ contains **Late Paleogene metamorphic sequences** which were previously interpreted to be Paleozoic and pre-Paleozoic without any evidence. These sequences resulted from Mesoalpine metamorphism affecting Late Cretaceous-Early Paleogene flysch and older Mesozoic protoliths. These reliably documented examples question the age of all other metamorphic formations within the SVZ, previously presumed to be of Paleozoic age and for that reason the term "Veles Series" should be abandoned.

The tectonized ophiolite mélange is a characteristic chaotic tectonostratigraphic unit of the SVZ, made of fine-grained, sheared, shaly-silty matrix containing fragments of predominant graywackes but also ophiolites, mica schists, amphibolites, cherts, shales and exotic blocks of sedimentary rocks, particularly limestones of different Mesozoic and Paleocene ages, originating from different environments (e.g. Dimitrijević & Dimitrijević 1975, Majer & Karamata 1981). Fragments of ophiolites and sedimentary rocks are commonly of cm to m in size. However, mappable masses of km – and tens of kilometer in size are also found. These are either included within the mélange or thrust over it.

In the ophiolite mélange of the Dinaridic–Hellenidic Ophiolite Zone, genetically related to Late Jurassic/Early Cretaceous first ophiolite obduction following a stage of Jurassic intra-oceanic subduction (Fig. 6A – Pamić et al. 2001), distinct olistostrome signatures are preserved, the youngest exotic limestone being of Tithonian age. Ophiolites included in mélange display N-MORB signatures (Pamić et al. 2001). In the Central Dinarides, this ophiolite mélange is unconfomably overlain by the Pogari Formation of Cretaceous age (Jovanović 1957). By contrast, the more intensely deformed ophiolite mélange of the SVZ, which includes youngest limestone exotics of Late Cretaceous/Paleocene age, is the product of a second and later ophiolite emplacement in an accretionary prism (see Fig. 5B). This is Dimitrijević's (1995) "recycled mélange" which is the result of the ocean–continent subduction which took place from Late Cretaceous to Lutetian collisional deformation (Pamić et al. 1998, Pamić et al. 2001). This strongly tectonized ophiolite mélange, which is in some areas metamorphosed up to greenschist facies conditions (Dimitrijević 1995), is overlain by Cretaceous–Paleogene flysch formations.

However, in some areas of the tectonized ophiolite mélange of the SVZ outcrops of pristine Jurassic olistostrome mélange do also occur, probably as an unrecycled remnants (Dimitrijević 1995). Since the youngest limestone blocks contain Paleocene index fossils mélange must be of Paleocene or younger age.

No characteristic fossils, except some Early Cretaceous angiosperms, have yet been found in graywackes and shales of the SVZ ophiolite mélange. K-Ar ages on mafic ophiolite fragments, which display BARB signatures, range mainly from 110 to 63 Ma (Pamić 1997). Lherzolite samples yielded a Sm-Nd age of 135 Ma (Lugović et al. 1991). However, in some parts of the SVZ, unrecycled ophiolite mélange formation, containing ophiolite fragments with K-Ar ages of 190-157 Ma, are also preserved (Pamić et al. 1998). This suggests a two-stage evolution for the SVZ. For example, the Guevgueli ophiolite massif, which is found within the SVZ (Tajder 1938), as a remnant fragment involved in the first Late Jurassic obduction of ophiolites, is one of the largest Mesozoic oceanic fragments of Europe (about 2000 km^2). It is disconformably overlain by Upper Jurassic clastics (e.g. Arsovski & Bogoevski 1997, Michard et al. 1998).

In conclusion, the SVZ ophiolite mélange displays characteristics which are distinct from ophiolite mélanges of the Dinaridic–Hellenidic Ophiolite Zone. They show differences in the age of ophiolites, in the stratigraphy and age of exotic limestones and of the underlying or overlying sedimentary sequences, and also in the mode of emplacement.

Granitoid rocks are very common in the SVZ and their age is found in Table 1. Three main groups of granitoids can be distinguished. 1) Some smaller bodies of subduction-related A-type granites (Rb-Sr isochron 72 Ma), associated with basalts and rhyolites which are interlayered in the basal parts of Late Cretaceous flysch (Pamić et al. 1988); 2) More widespread are collisional I-type, A-type and S-type granites which intrude Late Cretaceous flysch, their Rb-Sr isochron ages giving 55 and 48 Ma ages (Lanphere & Pamić 1992). 3) Post-syncollisional granitoids which predominate and range mainly between 35 and 28 Ma (Delaloye et al. 1989, Knežević et al. 1994). These granitoids are age equivalents of the Periadriatic tonalites (von Blanckenburg et al. 1998 and papers therein). The Furka plagiogranites of Macedonia which are associated with ophiolites, are 145-143 Ma old (Šoptrojanova 1967) and they also occur in adjacent North Greece as well (Bebien & Mercier 1977). They represent remnant fragments of mélanges of the Dinaridic–Hellenidic Ophiolite Zone.

Tertiary volcanics. Based on concordant geological and radiometric ages, five Tertiary volcanic formations can be distinguished in the adjoining area of the northwestern SVZ and southern and southwestern Pannonian Basin (Table 1): 1) Lower Oligocene shoshonites; 2) Egerian-Eggenburgian calc-alkaline andesites with basalts and dacites; 3) Karpatian shoshonites; 4) Badenian calc-alkaline basalts, andesites, dacites and rhyolites, and 5) post-Badenian basalts and alkali basalts (Knežević et al. 1991, Pamić & Pécskay 1996, Pamić 1997). In the eastern and southeastern SVZ in southern Serbia and northern Macedonia, Tertiary volcanics, particularly Oligocene shoshonites and high-K calc-alkaline volcanics, are much more common. They form large bodies, covering up to 1200 km^2 (e.g. Zletovo–Kratovo) – Fig. 1. Based on numerous petrological papers (Karamata et al. 1992 and papers therein) these can be correlated with those of the northwestern SVZ. Anyhow, these Oligocene volcanics, together with the accompanying penecontemporaneous granitoids, i.e., the age equivalents of the Periadriatic tonalites, are the most widespread igneous rocks of the SVZ.

Kossmat (1924) has already extended the same tectonostratigraphic units into the Greek part of the SVZ and North Hellenides, respectively. There, in the Greek SVZ, going from the east to the west, Mercier (1968, 1973) separated three subzones, subsequently modified by Papanikolau (1984, 1996/97). However, Ricou et al. (1998) separate the western subzone composed of SW-verging nappes and the eastern one characterized by steeply dipping faults and shear zones.

Late Cretaceous–Early Paleogene Melissochori flysch sequence and strongly tectonized ophiolite mélange, e.g. the Edessa mélange of Vergély (1984) represent the most characteristic units of the Greek SVZ (Ricou et al. 1998). Recently, outcrops of Paleogene ophiolite mélange were found in the Thessaloniki area (Michard et al. 1998) and another places (Degna & Robertson 1994). Also, continuous Late Cretaceous volcanic–sedimentary sequences occur at the base of a Late Cretaceous flysch, affected by very low- and low-grade metamorphism (Migiros et al. 1997).

In the southeasternmost parts of the SVZ in the Chalkidiki area, the large Sithonia pluton (350 km^2), which intruded into the Melissochori flysch accompanied by ophiolite mélange (Burg et al. 1995) and adjacent granite plutons are products of Eocene (Rb-Sr and K-Ar ages 54.6 – 44.5 Ma) synkinematic magmatic activity (Juteau et al. 1986, Christofides et al. 1990). However, strongly differentiated post–syncollisional granitoid plutons (most common K-Ar ages: 33–27 Ma) frequently occur in the surrounding southeastern and eastern Rhodope mountains in Thrace, e.g. Tris-Vryses-Halasmata plutons and Leptokarya-Kirki-Kassitera plutons – see Fig.1 – (Pe-Piper et al. 1998, Christofides et al. 1995, Soldatos et al. 1998, Yanev & Bardintzeff 1997, and papers therein). There penecontemporaneous Oligocene (K-Ar ages: 35–29 Ma) shoshonites are also very common (Eleftheriades & Lippolt 1984, Eleftheriades et al. 1989, 1995) – see Table 1.

Alpine metamorphic formations also frequently occur in the Greek SVZ (Mercier 1973, Papanikolau 1984, 1996/97). Michard (1993) described very low- and low-grade metamorphic sequences in the Thessaloniki area. However, most of the

Table 1. Radiometric ages of Tertiary plutonic and volcanic rocks of the Sava–Vardar Zone
PB Pannonian Basin; SS Sava segment of the SVZ; VS Vardar segment of the SVZ; ZMTZ Zagorje-MidTransdanubian Zone
* Rb-Sr isochron ages, all others are whole rock and mineral K-Ar ages

Table 1. Radiometric ages of Tertiary plutonic and volcanic rocks of the Sava – Vardar Zone

Locality	Age (Ma)	References
Neogene postorogenic volcanics		
Post-Badenian alkali basalts, South PB	9.5 – 8.4	Pamić (1997)
Badenian basalts, andesite, dacites and alkali-feldspar rhyolites, South PB	14.5 – 12.4	
Karpatian shoshonites, South PB	16.8 – 15.4	
Egerian – Eggenburgian postcollisional calc-alkaline volcanics		
Hrvatsko Zagorje, ZMTZ	22.8 – 19.7	Šimunić & Pamić (1993)
Oil wells, South PB	25.9 - 24	Pamić & Pécskay (1996)
Early Oligocene post-syncollisional granitoids		
Mt. Boranja, SS	33.7 – 29.6	Delaloye et al. (1989)
Mt. Cer, SS	33 - 22	Knežević et al. (1994)
Mt. Bukulja, VS	27	Karamata et al. (1990)
Mt. Kopaonik, VS	35.3 – 29.8	
Mt. Željin, VS	27	
South Rhodope, VS	32 - 28	Eleftheriadis et al. (1995)
Thrace, VS	32 - 28	Pe-Piper et al. (1998)
Early Oligocene post-syncollisional shoshonites and high-K calc-alkaline volcanics		
Mt. Fruška Gora, SS	36 – 31.6	Knežević et al. (1991)
Oil well, South PB	37.1	Pamić (1997)
Srebrenica –Maglaj, SS	30.4 – 28.5	Pamić et al. (2000a)
Rogozna, VS	33 - 27	Cvetković et al. (1995)
Mt. Kopaonik, VS	32 - 29	Karamata et al. (1992)
Zletovo – Kratovo, VS	32 - 26	
Bučim – Borov Dol, VS	27.5 – 24.7	
Kriva Palanka, VS	25.3	
South Rhodope, VS	34 - 30	Eleftheriadis & Lippolt (1984)
East Rhodope, VS	33 - 27	Eleftheriadis et al. (1989)
Central Rhodope, VS	35 - 29	Eleftheriadis et al. (1995)
Middle Eocene syncollisional granitoids		
Mt. Motajica, SS	48.7*	Lanphere & Pamić (1992)
Mt Prosara, SS	48.7*	
Sithonia, Chalkidiki and adjacent	47.4 – 44.5	Christofides et al. (1990)
plutons, southeasternmost VS	54.6 – 50.4*	Juteau et al. (1986)

PB Pannonian Basin; SS Sava segment of the SVZ; VS Vardar segment of the SVZ; ZMTZ Zagorje-Mid-Transdanubian Zone
* Rb-Sr isochron ages, all others are whole rock and mineral K-Ar ages

Alpine metamorphic rocks from the Greek SVZ were not yet petrologically studied in detail.

In conclusion, despite some correlation difficulties due to different local names of the mapped units and different approaches by many authors, it is obvious that the Hellenidic parts of the SVZ have the same basic geological signatures as their northern and northwestern Dinaridic equivalents.

3. Sava-Vardar Zone lithologies in the southern and northwestern Pannonian Basin

Some of the most characteristic SVZ lithologies occur at the surface and in the subsurface of the southern and southwestern Pannonian Basin (Fig. 1). In the South Pannonian Basin, Upper Cretaceous sediments, in some places with olistoliths of glaucophane schist found in the Mts. Fruška Gora and Požeška Gora, are interlayered with basalts and rhyolites (ignimbrites), intruded by penecontemporaneous A-type granites and associated with Paleogene low-grade metasediments (K-Ar age 44 Ma). These were thrust onto Neogene sediments of the Pannonian Basin, the youngest ones of which are Pannonian in age. Some of these rocks were drilled in the basement of the Drava Depression, whereas mafic ophiolites (K-Ar whole rocks ages: 110-63 Ma) are common in basement of the Sava Depression (Majer & Lugović 1991, Pamić 1997, 1998, Belak & Tibljaš 1998).

In the neighborhood of Zagreb, in the southwesternmost Pannonian Basin of the Zagorje-Mid-Transdanubian Zone (ZMTZ) – Pamić & Tomljenović (1998) or the Sava Zone (Haas et al. 2000), characterized by mixed Alpine and Dinaridic lithologies, outcrops of the SVZ ophiolite mélange containing Upper Cretaceous and Paleocene exotic limestones are common. Basalts interlayered in graywackes and shales yielded K-Ar ages of 94-85 Ma (Pamić 1997) whereas mafic fragments in the mélange from some areas yielded K-Ar ages of 189-185 Ma (Šimunić & Pamić 1993). This suggests that remnants of a pristine unrecycled Jurassic olistostrome mélange are also preserved in this area. The tectonized ophiolite mélange is overthrust by Triassic formations. However, both of them are disconformably overlain by fossiliferous Late Cretaceous-Paleocene flysch (Šikić 1995 ed., Pamić 1996, 1997, Tomljenović & Pamić 1998).

In the western extension of the ZMTZ in Central Slovenia, outcrops of ophiolite mélange have not been described. However, Mioč (1995) claims that ophiolites do also occur in Slovenia. Central Slovenia, spatially defined by the Smrekovec Line (the easternmost Periadriatic Lineament) in the north, the northeastern margin of the Adriatic-Dinaridic carbonate platform in the southwest and the Zagreb-Zemplin Line in the southeast, is composed largely of Paleozoic and Triassic formations of the Sava nappe and Julian-Savinja nappes (Mioč 1995). In tectonic windows beneath the Sava nappe along its frontal part, Jurassic and Cretaceous platy limestone, shale, mudstone and chert of the Slovenian trough crop out (Cousin 1972) – see Fig. 5. These can be correlated with those of the Bosnia-Beotia Zone. A few tens of kilometer to the south of the easternmost Periadriatic Line, the Julian-Savinja nappe is underthrust by a discontinuous zone of Late Cretaceous-Early Paleogene flysch that can be traced for about 80 km up to the eastern parts of Julian Alps (Buser & Draksler 1990 – Fig. 1). The flysch can be correlated to the complete Late Cretaceous flysch sequences from the southeasternmost parts of the SVZ (see Fig. 3B). Both flysch zones outcrop on the frontier between Slovenia and Italy.

In the northeastern extension of the ZMTZ in Hungary, ophiolites have been penetrated by deep wells in the substratum of the Pannonian Basin. However, in the northeasternmost prolongation of this zone, in the Bükk area (Sarvaskö and Darno), allochthonous blocks of ophiolites do occur. These consist of MORB basalts, diabases, gabbros and black radiolarites embedded in silty-shaly matrix (Fig. 1). Actually, this is an ophiolite mélange that also contains exotic blocks of Triassic limestones and Ladinian-Carnian and Callovian-Oxfordian radiolarites. The K-Ar ages of these ophiolites are 166-152 Ma, suggesting that they may be remnants of the Dinaridic–Hellenidic Ophiolite Zone (e.g. Balla 1984, Dosztaly & Józsa 1992, Kovács et al. 1996/97). Consequently, they can be correlated with other Jurassic supra-subduction ophiolites of the Dinarides and Hellenides.

In adjacent southwestern Slovakia i.e., in the Meliata area, which is only a few tens of kilometer from Mt. Bükk, allochthonous blocks of ophiolites do also occur (Fig. 1). These ophiolites are represented by basalts, diabases, dolerites and serpentinized ultramafics, meter to hectometer in size, which are included in a Middle to Late Jurassic shaly-silty-sandy matrix. Besides these lithologies, the ophiolite mélange includes fragments of Triassic clastics and carbonates, as well as Ladinian-Carnian and Liassic to Callovian-Oxfordian limestones and radiolarites. The neighbouring ophiolite-bearing Bórka unit was affected by high-pressure metamorphism (Mello et al. 1983, Hovorka & Meres 1989, Kozur & Mock 1995, Vozárova & Vozár 1996/97, Mock et al. 1998). Hence, these ophiolites are of Dinaridic-Hellenidic Ophiolite Zone affinity.

In conclusion, in contrast to the SVZ units which form a distinctly individualized geotectonic zone built into the Dinarides-Hellenides mountain systems, all the SVZ lithologies within the ZMTZ including the Bükk and Meliata areas, are discontinuous bodies which represent allochthonous and displaced blocks included in postorogenic collage of the southwestern Pannonian Basin. Ophiolites from the ZMTZ with all their signatures can be correlated with the ophiolites from the SVZ. On the other hand, the Bükk-Meliata ophiolites with all their signatures can be better correlated with the ophiolites from the Dinaride-Hellenide Ophiolite Zone (Pamić et al. 2001)

4. Discussion and conclusions

According to proposed geodynamic concepts on the evolution of the Dinarides (Pamić et al. 1998), intra(?)-oceanic subduction processes and first obduction of Jurassic ophiolite mélange of the Dinaridic–Hellenidic Ophiolite Zone onto the Apulian marginal units already took place in Late Jurassic/Early Cretaceous times, thus documenting shortening of the Dinaridic-Hellenidic Tethys (Fig. 6A). It is possible and very probable indeed, that emplacement of the Golija-Korab Zone (Rampnoux 1970), took place during a tectonic phase younger than the Late Jurassic/Early Cretaceous movements. This opinion is supported by the fact that ophiolites are overthrust by Paleozoic-Triassic formations of the Golija–Korab Zone which are unconformably overlain by fossiliferous Lower Cretaceous clastics grading laterally into Urgonian type limestones. These clastics contain re-deposited ophiolitic fragments which, in turn, are overlain by Upper Cretaceous carbonate sediments. This interpretation either implies that the Paleozoic-Triassic nappes of the Golija–Korab Zone are derived from the NE margin of the Dinaridic Tethys and/or that younger out of sequences thrusting did occur during subsequent tectonism.

The later shortening within the Dinaridic-Hellenidic Tethys was accompanied by the generation of a magmatic arc which was located northeast of the obducted ophiolites and along the northern Tethyan margin (Fig. 6B). Within the trench, associated with the presumed magmatic arc, Cretaceous-Early Paleogene flysch sequences accumulated; they are interlayered by penecontemporaneous basalts and rhyolites accompanied by granites. These sequences cannot be found anywhere in the association with pristine Jurassic mélange formations of the Dinaridic–Hellenidic Ophiolite Zone. Sea floor spreading may have continued in the remnant ocean after the first obduction of ophiolitesas supported by ophiolite fragments (110-63 Ma old) incorporated in the adjacent SVZ ophiolite mélange. Persisting subduction processes along this arc-trench system were the driving mechanism for magmatic activity during the Late Cretaceous-Early Paleogene (Migiros et al. 1997, Ricou et al. 1998, Pamić et al. 1998). This is actually the period of time during which the main lithological units of the SVZ were formed.

Correspondingly, in the area of this magmatic arc, granite plutonism and bimodal basalt-rhyolite volcanism were active. The subduction zone dipped towards the north beneath Eurasia and the Tisia/Moesia continental fragments, respectively, which got their present position during the Berriasian as suggested by paleomagnetic data (Márton 2000). The Eurasian continental margin formations, composed largely of Variscan crystalline rocks were also partially subducted, as indicated by migmatite, granite and amphibolite xenoliths found in Upper Cretaceous volcanic rocks.

Based on geochemical data of volcanics (Pamić et al. 2000a) the presumed Late Cretaceous-Early Paleogene arc-trench system of the Dinaridic-Hellenidic Tethys can be conceived as a back-arc basin, spatially related to the southern active Eurasian continental margin. This magmatic arc probably formed the westernmost part of the huge Tethyan subduction zone that stretched eastwards to Iran and Afghanistan (Camoin et al. 1993). Such Alpine subduction-related igneous rocks have up to date not yet been found in the area of the Alps. However, south of the easternmost parts of the Periadriatic Lineament in neighbouring Slovenia, Late Cretaceous flysch sequences of the SVZ affinity do occur (Mioč & Pamić 2000) – see Fig. 5.

Strong collisional deformation took place by the end of Middle Eocene times (55-45 Ma) and was followed by the termination of NE and N-dipping subduction zone, closure of this part of the Tethys, and uplift of the Dinarides. This phase was characterized by: 1) strong tectonization (recycling) of the pristine Jurassic olistrostrome mélange, including incorporation of Cretaceous-Early Paleogene ophiolite and sedimentary fragments and their final thrusting on top of the main mass of the Dinaridic and Hellenidic ophiolites that were previously obducted during the Late Jurassic/Early Cretaceous (the Dinaridic–Hellenidic Ophiolite Zone); 2) medium-grade metamorphism of the Upper Cretaceous-Paleogene trench-sediments and older Mesozoic formations; 3) synkinematic granite plutonism, and 4) underplating of Apulia beneath Eurasia or the Tisia fragment. By this Late Eocene final orogenic phase, the structuration of the Dinarides was completed (Pamić et al. 1998) – Fig. 6C. Outcrops of such Late Eocene collision-related granitoids and metamorphic sequences have up to date not yet been found in the area of the adjacent Periadriatic Lineament.

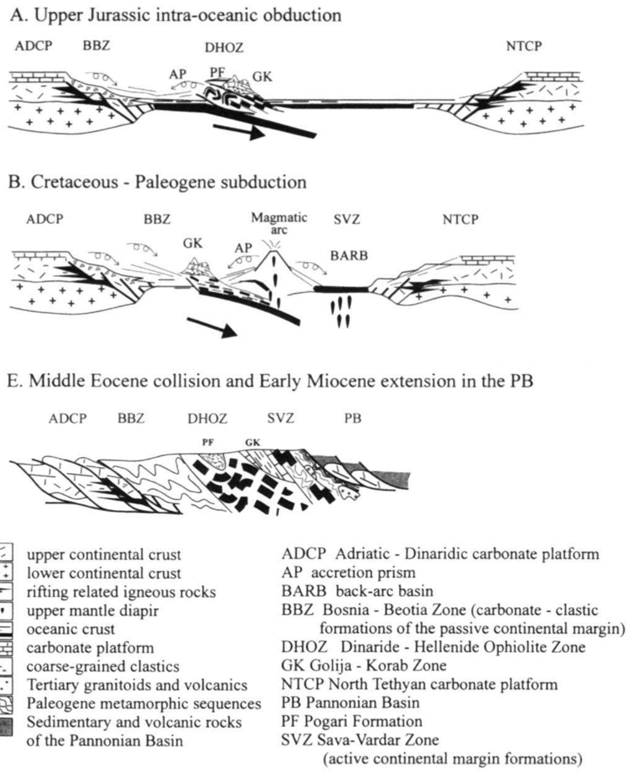

Fig. 6 Tentative models of the Alpine geodynamic evolution of the Dinarides and Hellenides, modified after Pamić & Tomljenović (2000)

This geodynamic interpretation is generally compatible with the geodynamic evolution of the Hellenides also characterized by two-stage generation and emplacement of ophiolites and Lutetian main compressional deformational event accompanied by synkinematic metamorphism and granitoid plutonism (Ricou et al. 1998).

The Eocene collisional phase was followed by Oligocene transpression, characterized by strong dextral strike-slip faulting (Laubscher 1971, 1983) related to the northwestward indenting of of Apulia (Stampfli & Marchant 1997). In the area of the Periadriatic Lineament and the SVZ of the Dinarides this first postorogenic, but still syncollisional stage was accompanied by Early Oligocene granite plutonism, associated with penecontemporaneous shoshonitic volcanism and plutonism (e.g. Biella) and subsequent Egerian-Eggenburgian calc-alkaline andesite-dacite volcanism.

The magmatic processes were controlled by S-dipping subduction in the Alpine Tethys and N-and NE-dipping subduction in the Dinaridic-Hellenidic Tethys. It means that the main Early Paleogene SV suture Zone was transformed during the Oligocene into the strong dextral strike-slip fault system which controlled the post-syncollisional magmatic activity. Reaching this evolutionary stage, the SVZ reached the same geotectonic setting as the PL area.

Based on a correlation with structural data from recent convergent plate margins, and according to available field and geochemical analytical data for the Dinarides and Hellenides, Middle Eocene and Oligocene magmatic processes were controlled by: 1) subducted Mesozoic-Early Paleogene Tethyan oceanic crust, probably in terms of the "slab breakoff model" (von Blanckenburg & Davis 1995, Stampfli & Marchant 1997); 2) metasomatized upper mantle wedges, probably underlain by an upper mantle diapir, and 3) overlying Eurasian continental crust (Pamić & Palinkaš 2000). Geochronologically, petrologicaly and geochemically, Early Oligocene SVZ granite plutonism and shoshonite volcanism, correspond to the Periadriatic tonalite and shoshonite plutonism and the shoshonite and high-K calc-alkaline volcanism in the adjacent Alps (Venturelli et al. 1984, von Blanckenburg et al. 1998). The former, in turn, shows a positive geochemical correlation with the Egerian-Eggenburgian calc-alkaline andesite association in the adjacent ZMTZ.

The Eocene syncollisional granite plutonism which was accompanied by regional metamorphism and Oligocene post-syncollisional granite plutonism with penecontemporaneous volcanism were also active in the southeasternmost SVZ of the Hellenides and their Rhodope framework (Table 1 –Papanikolau (1996/97, Ricou et al. 1998).

After the Oligocene, transpressional deformation of the area northeast of the uplifted Alps, Dinarides and Hellenides gave way to dynamic processes which controlled the evolution of the Pannonian Basin. The dynamics changed fundamentally and were controlled by Carpathian slab roll-back and intra-Carpathian and intra-Dinaridic extrusion (escape) tectonics, which were the driving forces during the postorogenic evolution. Diapirism of the upper mantle and attenuation of the lower continental crust gave rise to extensional processes, i.e., the evolution of the Pannonian Basin (Royden et al. 1983, Kázmér & Kovács 1985, Csontos 1995, Tari & Pamić 1998).

The Sava segment of the SVZ includes Early Oligocene granitoids and penecontemporaneous shoshonites with subordinate high-K calc-alkaline volcanics and in this respect can be conceived as a southeastern branch of the Periadriatic Lineament. Further southeastward, in the Vardar segment of the SVZ, the same Oligocene igneous rocks are even much more abundant. Hence, in the present structure this is a huge and continuous Oligocene Periadriatic–Sava–Vardar magmatic belt related to dextral strike-slip fault system which can be traced along strike for almost 2000 km. According the current opinion (Stampfli 2000) the magmatic processes were related to S-dipping subduction along the PL area and to NE-dipping subduction in the SVZ. However their suture zones are finally brought close to each other or even joined in the final stages of convergence giving thus continuity between the two features.

This plate convergence, e.g. the suture zone in the Periadriatic-Dinaridic–Hellenidic region has been recently indicated by seismic tomography (Yoshioka & Wortel 1995). In the Dinarides and Hellenides, at a depth of 95 km and 195 km the tomography results show a continuous belt of high velocity anomalies extending from the northern end of the Adriatic Sea along the northern and eastern Dinarides to the southeast up to the Aegean Sea (see Pwvap zone in Fig. 1.) These high velocity anomalies are considered to be the image of the subducted lithosphere (Spakman 1990, 1991). This geometry probably came into existence by tear, originally present in the northwestern part of the plate convergence zone (e.g. the Periadriatic area) which extended laterally toward the southeast (Wortel & Spakman 1992). The modeling results indicate that the lateral migration of slab detachment may be expected in subduction zones with slow convergence rate. The Dinaridic–Hellenidic subduction zone is indeed characterized by such convergence conditions in the order of centimeters per year (Yoshioka & Wortel 1995). These data also suggest that it seems improbable that Oligocene magmatic products that are superficially so similar do not derive from similar underlying processes.

This deep subsurface structure is superficially interrupted and partly transected by the transitional ZMTZ which is composed of allochthonous lithologies derived from the Periadriatic area and sandwiched between the triple junction area of the easternmost Alps, the northwesternmost Dinarides and the western Tisia. If current extrusion tectonic ideas are correct, it becomes obvious that the ZMTZ was not yet incorporated in the present structures of the adjoining area of the Alps, Dinarides and Tisia before Oligocene times when these processes just started. Consequently, this zone still did not exist when the final Alpine collisional processes were taking place.

Based on the data presented and the geodynamic interpretation, the SVZ represents the integral and most internal tectonostratigraphic unit built into the Dinarides-Hellenides, which originated during the final Alpine evolution of the Dinaridic-Hellenidic Tethys. The difference in geological and isotope ages between the subduction-related bimodal basalt-rhyolite volcanism with A-type granite plutonism (72 Ma) and the final synkinematic I-type, A-type and S-type granite plutonism (48 Ma) is likely to represent the duration (ca 24 Ma) of the presumed back-arc basin system of the Dinaridic-Hellenidic Tethys.

In conclusion the presented seismic tomography data indicate that the Late Paleogene magmatic associations of the entire Periadriatic-Sava-Vardar magmatic belt must have been generated under one and the same geotectonic setting, e.g. Africa-Eurasia suture zone (Dewey 1977) that was dominated by the break off of the subducted lithospheric slab consisting of Mesozoic oceanic crust, at depths of 90-100 km, regardless whether the slabs were originally related to N- or S-dipping

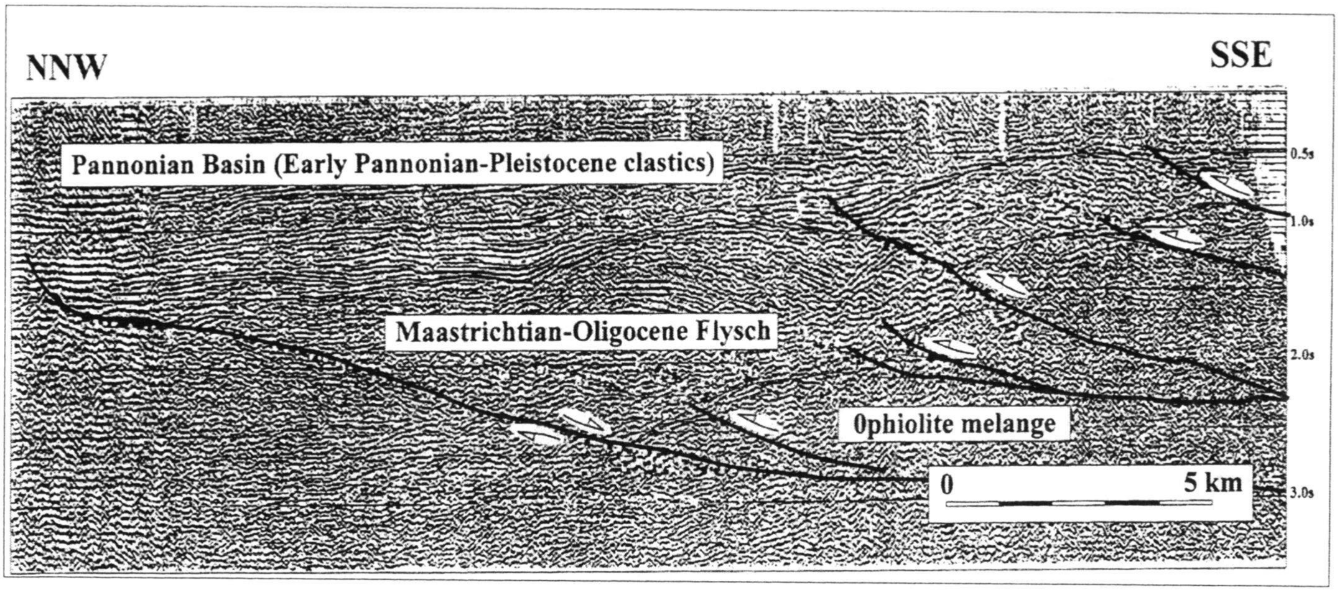

Fig. 7. Seismic cross-section across the southern margin of the Pannonian Basin (Tari & Pamić, 1998)

subduction zones or both. This is indicated by the contemporaneous occurrence of these magmatic associations along the entire Periadriatic-Sava-Vardar magmatic belt, 1700 km long, and the compatibility of all geological, geochronological, petrological and geochemical data available, and particularly Sr, Nd and O isotopic compositions (Pamić et al. 2001b).

It is much more complicated to explain the emplacement and geodynamic evolution of the allochthonous SVZ lithologies found in the western and southern Pannonian Basin. Upper Cretaceous subduction-related volcanics with A-type granites and Late Cretaceous/Paleogene mélanges found at depths of 2000-4500 m in basement beneath the Neogene fill of the South Pannonian Basin might represent fragments which were exhumed during Oligocene transpression from the northwest SVZ underplating Eurasia. Superficial occurrences of Upper Cretaceous flysch sediments with penecontemporaneous basalts and rhyolites and Paleogene metamorphic rocks of the Mts. Fruška Gora, Požeška Gora and Papuk (Fig. 1) in the South Pannonian Basin can be best explained by northward thrusting from the northwestern SVZ root area and neotectonic faulting, which took place in post-Pannonian times (Pamić 1998).

In the area adjoining the South Pannonian Basin and the SVZ, strong compressional tectonic activity occurred again at the beginning of the Pliocene (5-4 Ma). This is indicated by: 1) reflection seismic data displaying that units of the SVZ are thrust onto Tisia (Tari & Pamić 1998) –see Fig. 7; 2) klippen-like bodies composed of the SVZ units that were reversely transported northwards over Neogene sedimentary sequences as young as Pannonian in age (Šparica & Pamić 1986), and 3) northern vergences of thrusts both in the northern marginal parts of the SVZ and the klippen-like bodies within the South Pannonian Basin. This new tectonic regime reflects an increase in intraplate compressional stress producing localized deformations and broad buckling and uplift of the Pannonian Basin (Pamić 1998). This strong tectonic event is characteristic for the Pannonian Basin as a whole (Horváth et al. 1996).

Occurrences of SVZ ophiolites and associated lithologies within the ZMTZ are commonly explained to be related to strike-slip movement in the northernmost root area of the Internal Dinarides, i.e., the northwesternmost SVZ, which took place during the Tertiary evolution of the southwestern Pannonian Basin and the Alcapa Zone, respectively (Csontos 1995, Pamić 1996, Pamić & Tomljenović 1998). However, the occurrences of the SVZ lithologies in the western parts of the ZMTZ in Slovenia, particularly Cretaceous flysch sequences of the SVZ affinity suggest a possible westward continuation of the SVZ towards the Periadriatic Lineament (Mioč 1995, Mioč & Pamić 2000) –Fig. 5.

It is a well known fact that in the present structure of the Periadriatic Lineament area there are no outcrops of Alpine subduction- and collision-related magmatic formations (Schmid et al. 1989). Based on the occurrences of SVZ lithologies westward of the Zagreb-Zemplin Line in the ZMTZ, it can be surmised that the westernmost parts of the SVZ were originally located somewhere in the area between the present Periadriatic Lineament and the Zagreb-Zemplin Line. This presumption is compatible with strong N-S crustal shortening in the Alps, amounting to 120-550 km, due to Oligocene northwestward movement of the rigid Apulia indenter (e.g. Ziegler et al. 1996). In the first palinspastic consideration of the Alps and Dinarides Laubscher (1971) came to the conclusion that the compression and strong N-S shortening in the Alps must have been followed by strong dextral strike-slip faulting amounting to about 300 km from the area of the Periadriatic Lineament towards the east up to Zagreb. Recently, this hypothesis has been elaborated and experimentally documented in the idea on the escape (extrusion) tectonics (Kázmér & Kovács 1985, Ratschbacher et al. 1991) which explains allochthonous Paleozoic and Mesozoic fragments included in the southwestern Pannonian Basin as the result of eastward tectonic transport from the adjoining area of the Southern and Eastern Alps. If we accept that Paleozoic and Mesozoic tectonostratigraphic units and Paleogene tonalites of the ZMTZ originated via eastward extrusion somewhere from the adjoining area of the Southern and Eastern Alps, then the accompanying SVZ lithologies including ophiolite fragments must have had the same source area.

If the Apulia indentation processes did indeed take place, then the pre-Oligocene northern margin of Apulia must have been located south of its present position. The strongest effect of the indentation of Apulia is manifested in the Alps, i.e., in the area of the present Periadriatic Lineament. However, both the Alps and the Dinarides–Hellenides developed along the northeastern margin of Apulia and this is why we postulate that the indentation processes must also have marginally affected the adjacent Dinarides, as shown by the gradual change of strike from WNW–ESE in the Alps to NW–SE one in the Dinarides. Due to this NNW directed indenting of Apulia, the Alpine tectonostratigraphic units of the Internal Dinarides become narrower and finally wedge out towards the NW. They gradually die out and almost disappear approaching the area of Periadriatic Lineament. It could be postulated that in this area, original subduction- and collision-related formations partly disappeared during final Eocene subduction in the interior along the subduction zone (e.g. the present Periadriatic Lineament –Mioč, 1995), and partly were affected by subsequent Oligocene extrusion tectonics.

The presented evolution of the SVZ is not necesserily in agreement with paleogeographic and palinspastic interpretations of this part of the Mediterranean realm currently proposed by Channel & Kozur (1997) but it is close to Stampfli's (2000) proposal. The presented interpretations also adresses the problem of the existence of numerous "oceans" (Piedmont, Penninic, Vardar, Dinaridic, Meliata, Mirdita) in this comparatively small part of Europe stretching along strike for about 2000 km. However, a final solution is beyond the scope of this paper. Its intention was to give analytical data on the SVZ and the correlation with the Periadriatic Lineament area, which suggests an alternative or additional geodynamic consideration. It is the fact that all these alleged "oceans" represented separate and small oceanic domains during the Alpine evolution, spatially not far from each other, within the western parts of the Tethys Ocean. These numerous "oceans" cannot be found on the recent palinspastic maps (Dercourt et al. eds. 1993; Yilmaz et al. 1996), except in those proposed by Stampfli (2000).

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