ALPINE AND PRE–ALPINE STRUCTURAL UNITS WITHIN THE SOUTHERN CARPATHIANS AND THE EASTERN BALKANIDES

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Abstract: Highly contradictory opinions were, and still are argued in Romania, Yugoslavia and Bulgaria for the area connecting the Carpathian and Balkan structural elements. A new geological map (Fig.1) is proposed showing this region in a unitary view, that however, is in concordance with the present state of knowledge and may satisfactory explain the facts on which previous conflicting models are based.
Key words: Southern Carpathians, Balkan, structural units, correlation

The Alpine tectonic units of the South Carpathians are interposed between the Moesian platform, belonging to stable Europe and the Vardar-Transylvanian oceanic suture. They derived from the European continental margin (Danubian realm) and the Bucovino-Getic microplate (Getic and Supragetic realm). The later was separated from the European plate during Jurassic, by the Civcin-Severin rifting and spreading system (Săndulescu 1984; Kräutner 1996). In the Meso- and Late-Cretaceous compressional stages, the Eoalpine structural units were deformed and successively staked in the Dacidic nappe structures. Thus the Marginal-Dacides (Danubian nappes), External/Outer Dacides (Severin nappe) and Median Dacides (Getic and Supragetic nappes) (Săndulescu 1984) were formed. The Pre-Alpine basements of these Alpine nappes are constituted of Variscan and Pre-Variscan sedimentary and metamorphic sequences, involved in an extensive Variscan nappe structure.

In the Alpine collisional stage, the Cretaceous nappes were dismembered by dextral shear systems related to the Mio-Pliocene transpressional escape tectonics. Thus a chain parallel shear zone obliterated the Meso- and/or Late-Cretaceous nappe contact between the Serbo-Macedonian unit, derived from the Bucovino-Getic microplate and the Vardar oceanic crust. The Cretaceous westward overthrust of the Serbo-Macedonian unit is documented by tectonic windows (Veliki Jastrebac, Paraćin-Kupinovac) in which low- to very low-grade metamorphic sequences of the Vardar zone are exposed. Inside the Carpatho-Balkan area shear zones produced important N-S extension. Evaluations from dismembered marker units (e.g. Tişoviţa - Deli Jovan - Zaglavak - Cerni Vrach ophiolitic sequence; Timok-Pirot-Sofia volcano-sedimentary basin) indicate dextral strike-slip displacements summarising at least 100 km between Mehadia and Kjustendil (35-50% stretch). North of the Danube this extension was associated with a clockwise rotation of about 30°, due to the curved strike-slip paths. The eastern part of the shear system is marked by the Balta-Dzevin and Cerna-Poreč fault zones, which towards the south unifies in the Timok fault system and continues in the Struma tectonic lines. This important shear zone marks the tectonic boundary between the southernmost Carpathian structures and the eastern Balkan structures of Stara Planina, Sredna Gora and Rhodope. North of the map-area of Fig. 1, the clockwise rotation reach 90°, due to the intensive W-E stretch of the Carpathian branch that parallels the South-Transylvanian strike-slip system.

The following structural correlation of the main Alpine and Pre-Alpine units is suggested:

For the ***Serbo-Macedonian*** and ***Supragetic units***, considered by some authors as parts of the same main structural unit (e.g. Săndulescu 1984, Dimitrijević 1997), we suggest rather distinct Alpine tectonic settings. Although both units derived from the same Bucovino-Getic microplate, the western, Serbo-Macedonian part overthrust towards the west the ophiolitic Vardar zone, whereas

the eastern, Supragetic part obviously belongs to the east-vergent Carpathian nappe system. The two units are separated by a prominent (probably dextral) shear zone, some hundred metres wide. It is post Upper Cretaceous in age and mostly covered by younger sediments. The shear zone is exposed at Vršac, between Veliki- and Mali-Jastrebac, north of Lescovac (Dušanovo mylonite zone).

The Supragetic nappe system includes a Pre-Alpine basement of medium-grade metamorphics, assigned to the Precambrian, intruded by 500 Ma granitoids (Bozica, Doganica) and covered by Variscan low-grade metamorphics derived from Ordovician – Lower Carboniferous sedimentary and volcanic educts. A large zone of retrogressive rocks developed below these Paleozoic schists. We interpret this retrogressive zone by Variscan overprint in the Pre-Ordovician basement. A model-representation of these relationships and the suggested correlation of national terminologies is given in Fig. 2. Two main Alpine structural units have been separated on the map.

The *upper Supragetic* tectonic unit *(Bocşa – Bukovik – Vlasina nappe)* includes the medium-grade metamorphics of Bocşița-Drimoxa, Božica, Vranjska Banja type, as well as large zones of Variscan retrogressive overprint on these metamorphics (Stajevas, Dragoicinska, Vlasina). In the areas of Vărădia, Bukovik, Mali Jastrebas, western Seličevica, Babiča Gora, Čemernik and Vlasina the Variscan retrograde rocks are prevailing represented by albite-porphyroblast schists and albite gneisses. In the northern Banat the Bocşița-Drimoxa metamorphics (Bocşa nappe of Iancu 1985) overthrust eastwards the Low-grade Lescovița type Devonian (Valea Satului formation of the Moniom nappe), involving also slides of Mesozoic sediments. In the area of Vlasina and eastern Čemernik similar tectonic relationships may be inferred, whereas between Bukovik and Vlasotince, strike-slip contacts prevail.

The *lower Supragetic* tectonic unit (*Locva-Moniom – Ranovac – Poružnica nappe)* includes the Ordovician – Lower Carboniferous low-grade metamorphics of the Locva Mts. and their older basement of Oravița type, as well as the coeval metamorphics south of the Danube, exposed in the Ranovac, Busur, Poružnica, Sedi Vrh, eastern Babička Gora, eastern Vlasina area, till near the Bulgarian Trekljano in the south. From the north towards the south, these rocks overthrust successively Getic, Tumba-Penkjovci and Kraishte units.

The ***Tumba-Penkjovci units*** include only Ordovician - Lower Carboniferous sedimentary deposits, which are definitely different compared to the Supragetic Paleozoic, but of obvious affinity with the Getic Kučaj-Iskâr type Paleozoic sequence, especially for the Upper Devonian – Lower Carboniferous flysch deposits. These very low-grade or non metamorphic deposits form tectonic slides, that are interposed between the Supragetic and Kraishte units.

In the ***Kraishte units*** we include the tectonic sheets interposed between the Supragetic/Tumba-Penkjovci and the Getic nappes. They are characterised mainly by thick flysch deposits in the Upper Jurassic (Ruj flysch), large development of carbonate rich Triassic deposits and a specific Pre-Alpine basement (Frološ, Diabas-Phyllitoid, Osogovo-Ograzden). The northernmost outcrops of Kraishte units are represented by the Leskovic phyllites and the slice of Ruj flysch near Popovac. The western part of the Triassic sequence was overthrust eastwards on the Jurassic flysch – Zemen nappe/scale. The Ruj flysch was fed from the Supragetic realm (Dimitrijević 1997). This could suggest that prior to the Cretaceous compression the Getic and Supragetic realms were separated by a flysch trough. But it may be also speculated that during Jurassic both, Kraishte and Supragetic units belonged to the continental slope towards the Vardar ocean. The Pre-Alpine Kraishte basement includes medium-grade metamorphics of Ljuckan-Ograzden-Verila-Osogovo-Jaresnik type, intruded by Pre-Ordovician granitoids (Bosilegrad) and covered by fossil bearing Tremadocian detrital sediments (apatite sandstones) (Fig. 2). This old continental basement is tectonically overlain by a Vendian-Cambrian low-grade metamorphic island arc sequence / or

oceanic crust, including basic volcanics (Frološ) and intrusivs (Struma Diorite complex with gabbros and pyroxenites) (Zagorcev 1987). Obduction or napping resulted in intensive mylonitization of the Struma Diorites (Lisetski Diorite) and the interposed tectonic slab of Lisina low-grade metamorphics and phyllonites.

The ***Getic units***, according to usual concepts, include the Getic nappe with its continuation in the Kučaj-Ljubaš and Sredna Gora zones. However, coeval platform environments in the Jurassic and Triassic suggest that the Sasca-Gornjak nappe (formerly assigned to the Supragetic units), the Suva Planina and the Dušnik units also belonged to the Getic domain. The later two units are bound by strike-slip faults. The absence of Triassic deposits in the northern part of this 400 km long Getic realm is interpreted by denudation/exondation and Jurassic transgression. According to the record of Sinaia flysch between Cozla and Svinecea (Pop et al. 1997), the Jelova metamorphics (formerly considered in Danubian position) also belong to the Getic units. Striking differences are to be mentioned in the Pre-Alpine Getic basement north and south of the Danube. This basement consists of mainly medium-grade metamorphics in the Romanian Carpathians and of prevailing very low-grade to non metamorphic Paleozoic deposits in Serbia and Bulgaria (Kučaj-Ljubaš-Iskâr zone). It is suggested that the Pre-Variscan nappe structure in the Getic basement (Iancu et al. 1988) counts for this different lithologic constitution (Fig. 2). According to the structural model of Fig. 2 the two lower Variscan units include gneissic rocks, amphibolites and micaschists of Sebeş-Lotru and Osanica type, in which lenses of retrogressed eclogites and serpentinites are intercalated within an amphibolite facies tectonic sheet (Vaideeni) (Sabău 1994, Iancu et al. 1998). The medium-grade basement of the upper unit (Bozovici / Pârvova-Milatovac nappe, or Kučaj-Svoge unit), is transgressively covered by Tremadocian clastic sediments and by a thick Silurian-Lower Carboniferous sequence, widely extended in the Homolje - Kucaj – Ljubaš - Iskâr/Svoge zone. On the Romanian side the Ordovician part of this pile crops out in a restricted area (Bozovici Formation) and its Lower Carboniferous part in the Drencova-Cozla tectonic window. The Kucaj-Iskâr Paleozoic sequence was intruded by the 304 Ma Gornjani I-type granitoids and is tectonically covered by the Jelova/Ravensca amphibolites (Jelova nappe). The top of the Variscan nappe pile is represented by Sebeş-Lotru type gneisses of the Bârzu/Nera unit (Iancu et al. 1998).

The ***Severin nappe***, derived from the Jurassic Civcin-Severin rifting system, consists mainly of calcareous Sinaia flysch covering Middle Jurassic radiolarites and manganese jaspers (Pop et al. 1997). Locally an upper tectonic sheet (Obârşia scale) may be distinguished, that includes a tectonic melange with Jurassic ophiolites. South of the Danube, in the Kiloma tectonic window, a formation with Jurassic basic metavolcanics and black shales may represent an other tectonic sheet derived from the Civcin-Severin rift. It is in a tectonic position that could by coeval to the East-Carpathian "Black-Flysch" nappe.

In the ***Danubian units*** distinction between Lower- and Upper-Danubian nappes may be clearly followed from Romania through Serbia into Bulgaria (Fig.1).

The *Upper Danubian* Presacina-Cornereva nappe (including the Presacina and Sirinia sedimentation zones) correlates south of the Danube with the Deli Jovan – Ravna Reka blocks and with the Bulgarian Komska nappe (including the Visočka sedimentation zone). In the basement of these units, a Pre-Alpine nappe structure is proved by Upper-Carboniferous sediments covering transgressively the overthrust of the Poiana Mraconia crystalline and the coeval Gabrovnica metamorphics, over the Cambrian-Vendian Tişoviţa - Deli Jovan - Zaglavak - Cerni Vrach oceanic crust and its Lower Cambrian Berkovica-type island-arc cover (Haydoutov 1989). The oceanic crust show a classical sequence of pillow-lava, sheeted dykes, gabbroic cumulates, dunitic cumulates and harzburgitic tectonites (Mărunţiu 1984, Haydoutov 1989). This ophiolitic pile is separated from the underlying migmatic Neamţu-Stakevci-Brzisk metamorphics by the Corbu mylonite zone (Mărunţiu and Seghedi 1983). We consider that this mylonitic belt extends towards south at least into the

Zaglavak area. It is suggested that the mylonitic belt represents an early-Paleozoic obduction zone, affected (at least in the Romanian part) by a hot-slab metamorphism induced by the cca. 7 km thick ophiolitic slab. The Zaglavak - Cerni Vrach oceanic crust is unconformable covered by the Berkovica island-arc sequence, which consists of a lower basic meta-volcano-sedimentary formation (Stublica), followed by a meta-pelitic-carbonatic formation (Zdravcenica) and a metaturbiditic sequence (Iavorov and Slivaška formations) with metakeratophyres (Haydoutov 1989). The Berkovica Group was intruded by the Pre-Devonian Jania granitoids and it is unconformable covered by the basal conglomerates of the Devonian Inovo formation, which is considered equivalent to the Dâlgi Djal formation in Bulgaria (formerly assigned to the Lower Ordovician, Haydoutov 1989).

In *Lower-Danubian* position the Romanian Lainici nappe (including the Cerna sedimentation zone) extends towards south through the Serbian Miroč sedimentation zone into the Bulgarian Orešenec (Novo Korito – Belogradčik sedimentation zone) and Kutlov (Mihailovgrad sedimentation zone) units. In the basement of these units, Pre-Alpine nappe structure is known especially in the Romanian part. There, the overthrust of Drăgşan metamorphics on Lainici-Păiuş crystalline schists, Pan African granitoids and their Paleozoic low-grade metamorphic sedimentary cover (Valea de Brazi formation) is sailed by Lias deposits (Berza et al. 1983, Liégeois et al. 1996). South of the Danube the continuation of these Pre-Alpine units and the correlation of basement metamorphics remains still under debate. For the basement rocks of the Miroč anticline it is suggested that they are equivalent with the retrogressive part of the Drăgsan Group (Berza, pers. com.). More to the south, in the Vrska Čuka – Belogradčik zone, the greenschist formation was considered coeval with the Berkovica metamorphics (Bulgarian geol. map. 1:100 000). But having in mind that the Berkovica island-arc covers an oceanic crust and that the Lower-Danubian basement is prevailing of continental type, it is more likely that these greenschists belong either also to a retrogressive Drăgsan basement or to the Paleozoic cover of the Lainici-Păiuş Group, together with the Devonian – Lower Carboniferous Raianovska Formation (Fig. 2). In the highest Bulgarian unit (Kutlovska) the low-grade Sredogriv basement sequence is of Inovo type with olistolites of basic rocks. Thus, at least partly, it was fed from the obducted Tişoviţa-Berkovica slab. Concluding it is suggested that the Miroč anticline exposes the Variscan Drăgşan nappe, whereas more to the south the Paleozoic cover of the Lainici-Păiuş unit is exposed in the Lower Danubian basement cores.

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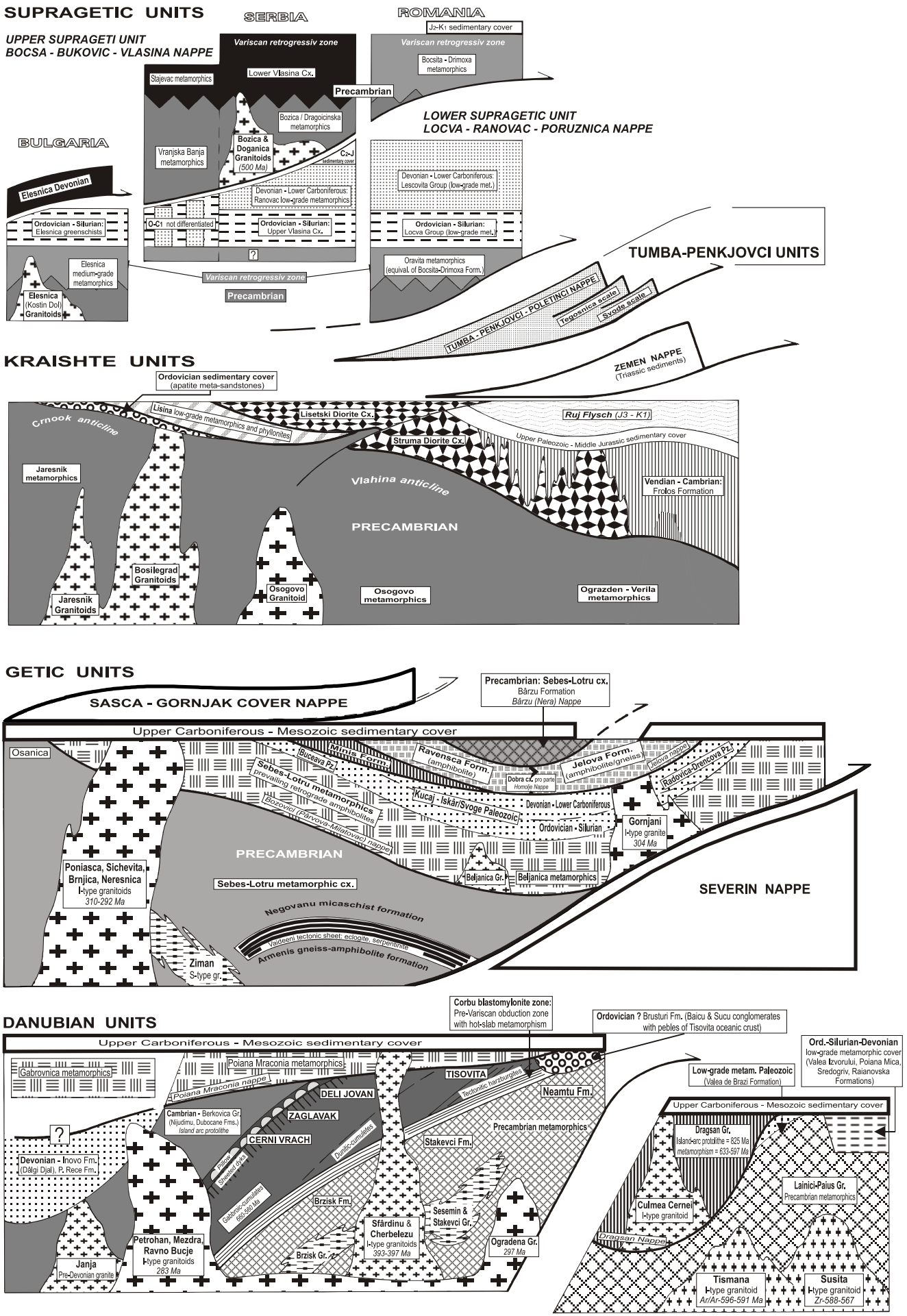
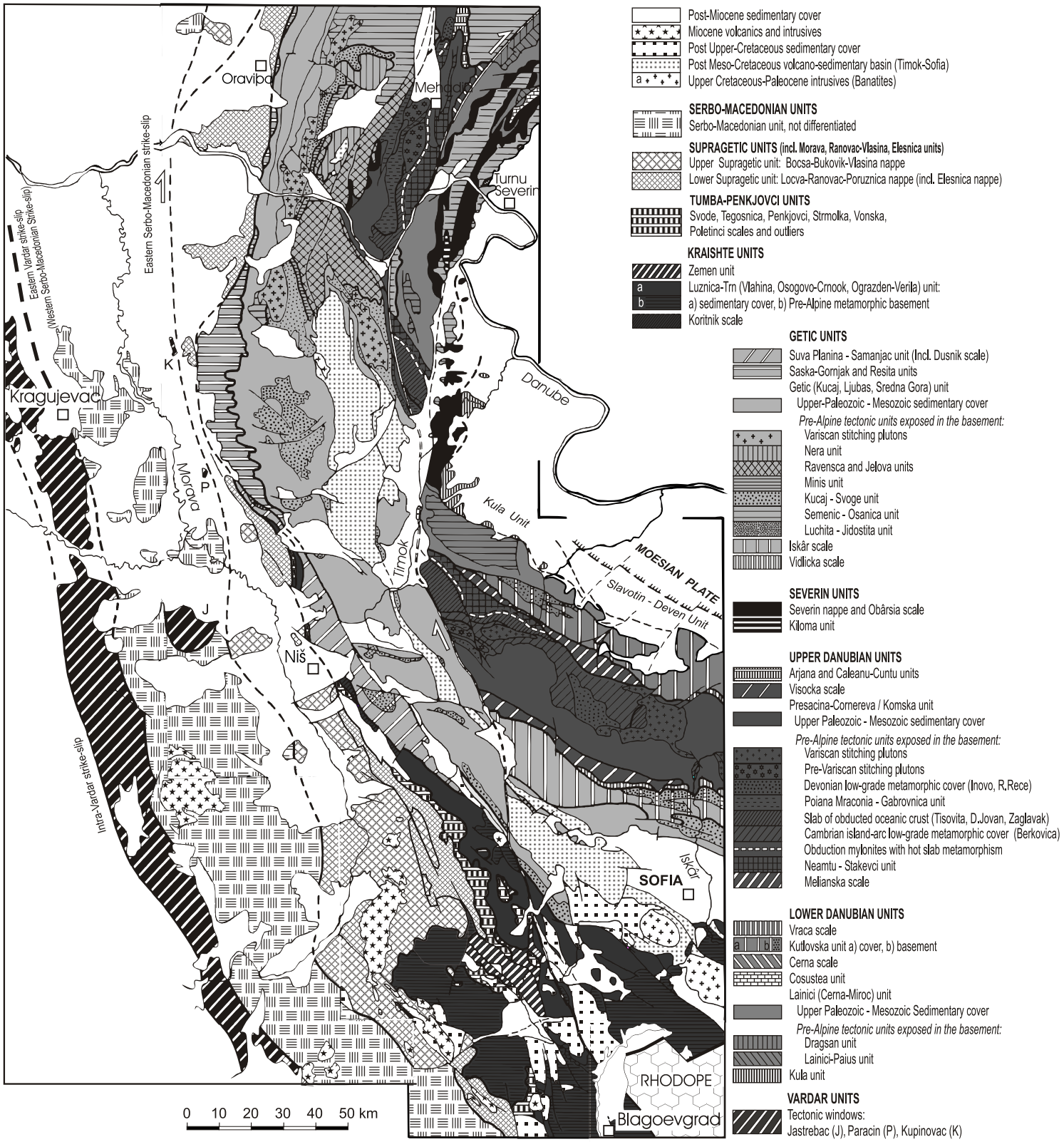
Fig.1 Tectonic sketch of the Carpatho-Balkanides between Mehadia, Oravița, Niš and Sofia

Fig. 2 Structural framework of the Pre-Alpine basements in the main Alpine nappe systems of the Carpatho-Balkanides between Oravița, Niš and Sofia


SUPRAGETIC UNITS
SERBIA
ROMANIA
UPPER SUPRAGETI UNIT
BOCSA - BUKOVIC - VLASINA NAPPE
Variscan retrogressiv zone
J2-K1 sedimentary cover
Bocsita - Drimoxa metamorphics
Stajevac metamorphics
Lower Vlasina Cx.
Precambrian
Bozica / Dragoicinska metamorphics
LOWER SUPRAGETIC UNIT
LOCVA - RANOVAC - PORUZNICA NAPPE
BULGARIA
Vranjska Banja metamorphics
Bozica & Doganica Granitoids (500 Ma)
C2-J sedimentary cover
Elesnica Devonian
Devonian - Lower Carboniferous: Ranovac low-grade metamorphics
Devonian - Lower Carboniferous: Lescovita Group (low-grade met.)
Ordovician - Silurian: Elesnica greenschists
O-C1 not differentiated
Ordovician - Silurian: Upper Vlasina Cx.
Ordovician - Silurian: Locva Group (low-grade met.)
TUMBA-PENKJOVCI UNITS
Elesnica medium-grade metamorphics
Oravita metamorphics (equival. of Bocsita-Drimoxa Form.)
Elesnica (Kostin Dol) Granitoids
TUMBA - PENKJOVCI - POLETINCI NAPPE
Tegosnica scale
Svrode scale
ZEMEN NAPPE (Triassic sediments)
KRAISHTE UNITS
Ordovician sedimentary cover (apatite meta-sandstones)
Crnook anticline
Lisina low-grade metamorphics and phyllonites
Lisetski Diorite Cx.
Ruj Flysch (J3 - K1)
Upper Paleozoic - Middle Jurassic sedimentary cover
Struma Diorite Cx.
Jaresnik metamorphics
Vlahina anticline
Vendian - Cambrian: Frolos Formation
PRECAMBRIAN
Bosilegrad Granitoids
Osogovo Granitoid
Osogovo metamorphics
Ograzden - Verila metamorphics
Jaresnik Granitoids
GETIC UNITS
SASCA - GORNJAK COVER NAPPE
Precambrian: Sebes-Lotru cx.
Bârzu Formation
Bârzu (Nera) Nappe
Upper Carboniferous - Mesozoic sedimentary cover
Osanica
Buceava Pz.
Minis Form.
Ravensca Form. (amphibolite)
Jelova Form. (amphibolites/gneiss)
Jelova nappe
Radovica-Drencova Pz.
Sebes-Lotru metamorphics prevailing retrograde amphibolites
Dobra cx. pro parte Homoje Nappe
Kucaj - Iskâr/Svoge Paleozoic
Devonian - Lower Carboniferous
Ordovician - Silurian
Bozovici (Târnova-Miletovac) nappe
Gornjani I-type granite 304 Ma
PRECAMBRIAN
Poniasca, Sichevita, Brnjica, Neresnica I-type granitoids 310-292 Ma
Beljanica Gr.
Beljanica metamorphics
Sebes-Lotru metamorphic cx.
SEVERIN NAPPE
Negovanu micaschist formation
Variceni tectonic sheet: eclogite, serpentinite
Armenis gneiss-amphibolite formation
Ziman S-type gr.
DANUBIAN UNITS
Corbu blastomylonite zone: Pre-Variscan obduction zone with hot-slab metamorphism
Ordovician ? Brusturi Fm. (Baicu & Sucu conglomerates with pebles of Tisovita oceanic crust)
Ord.-Silurian-Devonian low-grade metamorphic cover (Valea Izvorului, Poiana Mica, Sredogriv, Raianovska Formations)
Upper Carboniferous - Mesozoic sedimentary cover
Gabrovnica metamorphics
Poiana Mraconia metamorphics
Poiana Mraconia nappe
TISOVITA
Tectonitic harzburgites
Neamtu Fm.
Low-grade metam. Paleozoic (Valea de Brazi Formation)
DELI JOVAN
Cambrian - Berkovica Gr. (Nijudimu, Dubocane Fms.) Island arc protolithe
ZAGLAVAK
Precambrian metamorphics
CERNI VRACH
Stakevci Fm.
Dragsan Gr. Island-arc protolithe = 825 Ma metamorphism = 633-597 Ma
Devonian - Inovo Fm. (Dâlgi Djal), P. Rece Fm.
Dunitic-cumulates
Pillow
Sheeted dykes
Gabbroic-cumulates 499-380 Ma
Brzisk Fm.
Sesemin & Stakevci Gr.
Lainici-Paius Gr. Precambrian metamorphics
Culmea Cernei I-type granitoid
Sfârdinu & Cherbelezu I-type granitoids 393-397 Ma
Ogradena Gr. 297 Ma
Dragsan Nappe
Petrohan, Mezdra, Ravno Bucje I-type granitoids 283 Ma
Brzisk Gr.
Janja Pre-Devonian granite
Tismana I-type granitoid Ar/Ar-596-591 Ma
Susita I-type granitoid Zr-588-567


Post-Miocene sedimentary cover
Miocene volcanics and intrusives
Post Upper-Cretaceous sedimentary cover
Post Meso-Cretaceous volcano-sedimentary basin (Timok-Sofia)
Upper Cretaceous-Paleocene intrusives (Banatites)
SERBO-MACEDONIAN UNITS
Serbo-Macedonian unit, not differentiated
SUPRAGETIC UNITS (incl. Morava, Ranovac-Vlasina, Elesnica units)
Upper Supragetic unit: Bocsa-Bukovik-Vlasina nappe
Lower Supragetic unit: Locva-Ranovac-Poruznica nappe (incl. Elesnica nappe)
TUMBA-PENKJOVCI UNITS
Svode, Tegosnica, Penkjovci, Strmolka, Vonska,
Poletinci scales and outliers
KRAISHTE UNITS
Zemen unit
Luznica-Trn (Vlahina, Osogovo-Crnook, Ograzden-Verila) unit:
a) sedimentary cover, b) Pre-Alpine metamorphic basement
Koritnik scale
GETIC UNITS
Suva Planina - Samanjac unit (Incl. Dusnik scale)
Saska-Gornjak and Resita units
Getic (Kucaj, Ljubas, Sredna Gora) unit
Upper-Paleozoic - Mesozoic sedimentary cover
Pre-Alpine tectonic units exposed in the basement:
Variscan stitching plutons
Nera unit
Ravensca and Jelova units
Minis unit
Kucaj - Svoge unit
Semenic - Osanica unit
Luchita - Jidostita unit
Iskâr scale
Vidlicka scale
SEVERIN UNITS
Severin nappe and Obârsia scale
Kiloma unit
UPPER DANUBIAN UNITS
Arjana and Caleanu-Cuntu units
Visocka scale
Presacina-Cornereva / Komska unit
Upper Paleozoic - Mesozoic sedimentary cover
Pre-Alpine tectonic units exposed in the basement:
Variscan stitching plutons
Pre-Variscan stitching plutons
Devonian low-grade metamorphic cover (Inovo, R.Rece)
Poiana Mraconia - Gabrovnica unit
Slab of obducted oceanic crust (Tisovita, D.Jovan, Zaglavak)
Cambrian island-arc low-grade metamorphic cover (Berkovica)
Obduction mylonites with hot slab metamorphism
Neamtu - Stakevci unit
Melianska scale
LOWER DANUBIAN UNITS
Vraca scale
Kutlovska unit a) cover, b) basement
Cerna scale
Cosustea unit
Lainici (Cerna-Miroc) unit
Upper Paleozoic - Mesozoic Sedimentary cover
Pre-Alpine tectonic units exposed in the basement:
Dragsan unit
Lainici-Paius unit
Kula unit
VARDAR UNITS
Tectonic windows:
Jastrebac (J), Paracin (P), Kupinovac (K)
Oravica
Merdare
Turnu Severin
Kragujevac
Danube
Morava
Kula Unit
Timok
MOESIAN PLATE
Slavotin - Deven Unit
Niš
Iskâr
SOFIA
RHODOPE
Blagoevgrad
Eastern Vardar strike-slip
(Western Serbo-Macedonian Strike-slip)
Eastern Serbo-Macedonian strike-slip
Intra-Vardar strike-slip
K
P
J
0 10 20 30 40 50 km