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Review paper
Прегледни рад

Neoproterozoic–Paleozoic evolution of the Drina Formation (Drina–Ivanjica Entity)

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Abstract. This paper addresses a Drina-Ivanjica basement member, Drina Formation, characterized by ŕ controversial Neoproterozoic to Carboniferous age. The Drina Formation is also informally referred to as the "Lower Drina Formation" and the "Upper Drina Formation" including the Golija Formation as a conditional analog unit of the latter. A review of the biostratigraphic, sedimentary and paleogeographic constraints identified Drina Formation (Inner Dinarides) as a migrated crustal segment derived from a marginal section of northern Gondwana, being, however, of Neoproterozoic–Early Paleozoic age.

The presence of arenites, pelites, conglomerates, scarce limestones, basic (sub)volcanics and tuffs of the volcano-sedimentary Drina Formation metamorphosed up to greenschist and locally up to amphibolite facies, coupled with the absence of felsic volcanism implies a passive margin setting. Considering the age, such environment was probably associated with the perplexed Lower Paleozoic Avalonian-Cadomian arc, situated along the former north Gondwanan active margin. More precisely, the Drina Formation originated from a depositional junction between the Gondwana sediment supplier (Sahara metacraton) and Cadomian arc. A comparison with the regional Early Paleozoic succession of the "Kučaj Unit" (eastern Serbia) yields the absence of typical anchimetamorphic Silurian to Lower Devonian deep-marine fossil-bearing succession. The volcano-sedimentary passive margin system of Drina Formation is overlain by a late Variscan convergence-related voluminous clastic sequence allocated as the Golija Formation.

Key words: Drina–Ivanjica, Neoproterozoic–Paleozoic, Drina Formation, Avalonian–Cadomian arc.

Апстракт. Фокус овог рада је Дринска формација, део Дринско-ивањичког бејсмента контроверзне неопротерозојско-карбонске старости. Корелацијом биостратиграфских, палеогеографских и геодинамичких података изведени су закључци о неопротерозојско–ранопалеозојској старости Дринске формације, као дела некадашње северногондванске маргине.

Присуство аренита, пелита, конгломерата, базичних (суб)вулканита и туфова као доминантних литотипова Дринске формације (уз нешто карбоната), метаморфисаних претежно у фацији зелених шкриљаца, а локално и у амфиболитској фацији, маркира сложене тектонске догађаје маргиналног дела северне Гондване. Средина настанка Дринске формације је вероватно била позиционирана између главне области ерозије тј. сахарског кратона и ободног кадомског лука (гондвански систем континенталних и вулканских лукова). Упоредном анализом са регионално метаморфисаном доњопалеозојском сукцесијом "Кучајске јединице" (источна Србија) уочава се одсуство (средње- и горњо-)ордовицијумских, силурских и доњодевонских творевина у метаморфитима Дринске формације, што упућује на највероватнији доњи ордовицијум као терминални период формирања протолита. Присуство измењених базичних стена, са друге стране, указује на реликте неопротерозојско – доњопалеозојског вулканогено-седиментног лучног система. Махом кластична доњокарбонска повлатна сукцесија тзв. Голијске формације маркира касноварисцијску (највероватније конвергентну) фазу развоја овог тектонски одвојеног сегмента северне Гондване.

Кључне речи: Дрина–Ивањица, неопротерозоик–доњи палеозоик, Дринска формација, Авалонско-кадомски лук.

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Introduction

Positioned south of the European Variscides, basement units of Southeast Europe (SEE) – Dinarides and their lateral extension into Eastern Alps and Carpathian-Balkan-Hellenic arc represent a highly composite aggregation of displaced contrasting continental fragments derived from ancient plate boundaries. The Variscan configuration of these units was entirely reactivated during early and late Alpine tectonic processes. Opposite to considerably well-explored Alpine configuration, Variscan and pre-Variscan evolution of Dinarides, i.e. Adria and Apulia microplates, just recently draw certain attention by applying means of paleo-continental dating or ancient paleo-positioning (SIEGESMUND et al., 2018). However, differentiating the Variscan- and pre-Variscan imprints across SEE basement units requires much more effort in comparison to the European Variscides, predominantely because of the several thermal episodes which obliterated early magmato-sedimentary record, contemporaneous rapid exhumation and erosion of the Variscan peripheral thickened crust (NEUBAUER & HANDLER, 1999), in addition to the terminal late-Alpine thrusting and nappe stacking.

The Drina–Ivanjica Entity (DIE) of western Serbia and eastern Bosnia and Herzegovina represent a highly complex tectonometamorphic amalgamation of Paleozoic and Mesozoic age units (*sensu* ĐOKOVIĆ, 1985; JURKOVIĆ, 2006). A recent discovery of Neoproterozoic palynomorphs within the Drina Formation (ĐAJIĆ, 2010; ĐAJIĆ et al., 2012) indicated that juvenile DIE is in fact a pre-Phanerozoic system which probably underwent the peri-Gondwanan "rift-drift" stage further implying Lower Paleozoic tectonic transport and Variscan accretion. Considering the polydeformational, protracted plate-tectonic evolution of the SEE basement inliers, in this contribution we rather focus on the multi-disciplinary factual base, in particular we follow a limited set of Early and Late Paleozoic paleogeography and plate-tectonic models. By using the Drina Formation as the key spatio-temporal marker, this review study provides a pioneering, yet a crude reconstruction of the juvenile Neoproterozoic – Early Paleozoic DIE.

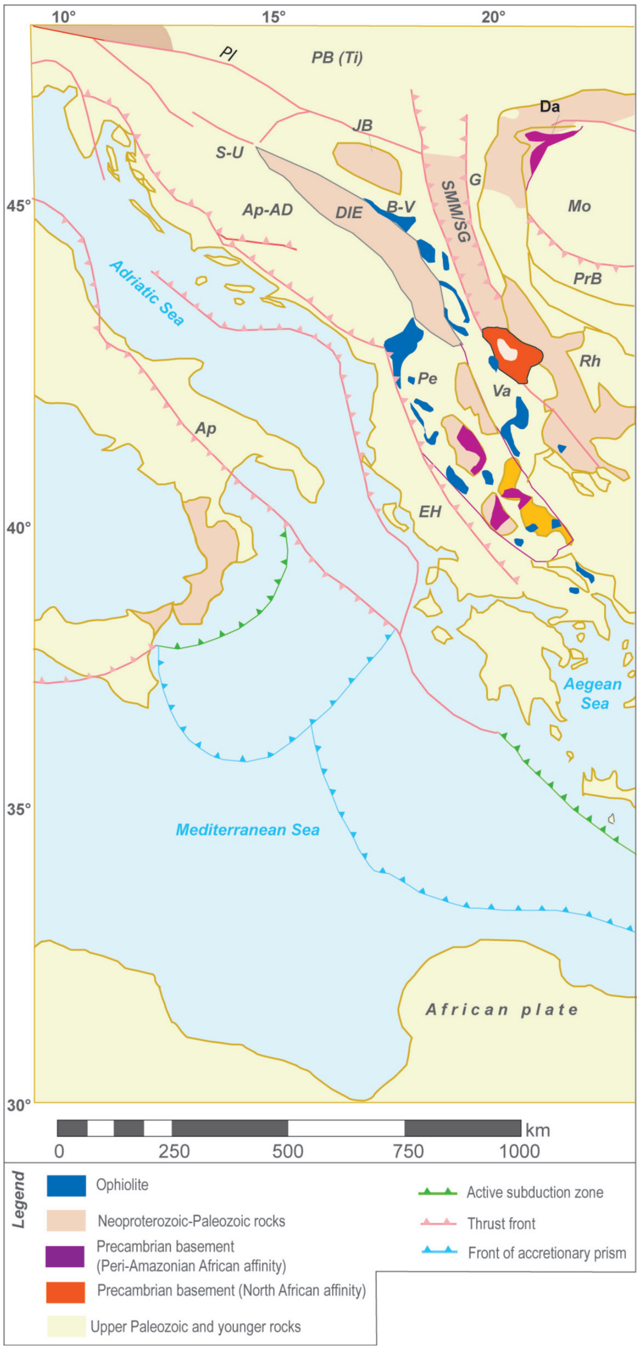

Fig. 1. Map of the basement systems of former Yugoslavia and the Eastern Mediterranean (from ZLATKIN et al., 2014 and references cited therein, modified and corrected). **Ap,** Apulia; **Ap-AD,** Apulia-Adria; **B-V,** Bukulja-Venčac; **Da,** Danubian; **DIE,** Drina–Ivanjica Entity; **EH,** External Hellenides; **G,** Geticum; **JB,** Jadar Block; **Mo,** Moesia; **PB (Ti),** Pannonian basin (Tiszia); **PrB,** Prebalkan; **SMM/SG,** Serbo–Macedonian–Supragetic; **S-U,** Sana–Una Palezoic; **Va,** Vardar Zone.

Regional-tectonic framework

Considering the fact that the Central European basement is dominated by the ancient continental masses of Gondwana, Baltica and Laurentia, the poorly constrained SEE basement inliers (Fig. 1) seem to be a cluster of pan-African fragments of the island and volcanic arcs. This basement amalgamation consists of fragments that tectonically migrated throughout Paleozoic, Mesozoic and Cenozoic. Incipient by a Mid-Cambrian accretion of the South American (Amazonian) Moesian microplate (BALINTONI & BALICA, 2016), a set of Avalonian (Danubian basement, *sensu* BALINTONI et al., 2014; PLISSART et al., 2017) and Cadomian fragments (Getic/Supragetic Unit, Serbo-Macedonian Unit, *sensu* e.g. HIMMERKUS et al., 2006, 2007, 2009; STAMPFLI & KOZUR, 2006; VON RAUMER & STAMPFLI, 2008; VOZÁR, 2010; STAMPFLI et al., 2013; ANTIĆ et al., 2016; BALINTONI et al., 2014; SPAHIĆ & GAUDENYI, 2018) were drifted towards the paleo-North until accreting throughout mid-late Paleozoic with the SW Baltica promontory i.e. the Moesian microplate. Outlying the Moesian accretionary configuration, separated by the Vardar–Axios Zone it appears that the lattermost far-travelled Avalonian-Amazonian fragment (ZLATKIN et al., 2014; ZLATKIN et al., 2017) incorporated within SEE is the Pelagonic Massif. Together with the DIE, these two pre-Variscan systems embody the Alpine basement of the prominent Dinarides–Hellenides orogen, positioned in the very center of the late Mesozoic Alpine suture referred to as the Vardar Zone (e.g., DIMITRIJEVIĆ, 1999; ZELIĆ et al., 2010; SACCANI et al., 2011 and references therein; SCHENKER et al., 2015).

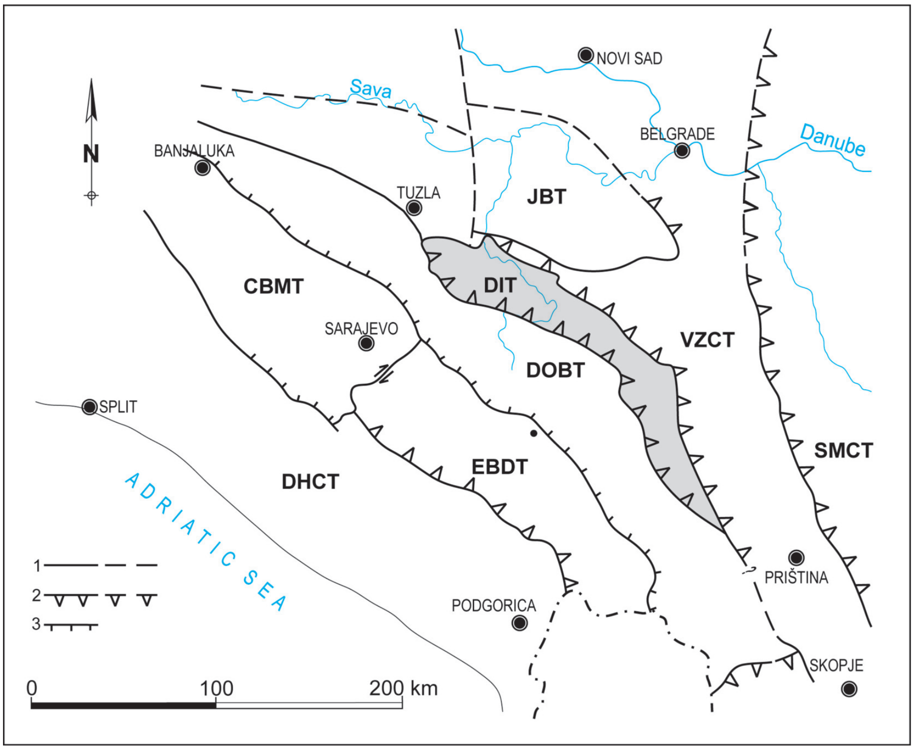

Fig. 2. Main tectonic units of central-western Serbia, Bosnia and Herzegovina: **SMCT,** The Serbian-Macedonian composite terrane; **VZCT,** The Vardar Zone composite terrane; **JBT,** The Jadar Block terrane; **DIT,** The Drina–Ivanjica terrane; **DOBT,** The Dinaric Ophiolite Belt terrane; **EBDT,** The East Bosnian–Durmitor terrane; **CBMT,** The Central Bosnian Mts. terrane; **DHCT,** The Dalmatian-Herzegovinian composite terrane. **1.** Fault, **2.** Thrust (nappe), **3.** Tectonic boundary, unspecified (redrawn from KARAMATA, 2006).

The perplexing DIE is an elongated ribbon-shaped basement segment between the Vardar Zone on the East, the Dinaride Ophiolite belt and External Dinarides on the West-Southwest. In the North, the Jadar unit is situated within the Vardar Zone, along the southern Pannonian basin margin (Fig. 2). The DIE is comprised of a northern flank or the Drina block and a southern limb often referred to as the Ivanjica block (Fig. 3). The Drina Formation is exposed in the vicinity of the Drina River from where it extends towards Southeast to Golija Mt. slopes and farther towards the Ibar River where it reaches a thickness of 600–700 m. The overlying Golija Formation has the thickness of 1000 m (ĐOKOVIĆ, 1985).

The Drina Formation can be characterized by the presence of various greenschists, phyllites, metasandstones, metapelites, metaconglomerates, occasionally calcschists and marbles of ambiguous Paleozoic age (ĐOKOVIĆ, 1985; TRIVIĆ et al., 2010). Pioneering authors, however, indicated a "pre-Devonian" (ĆIRIĆ & VON GÄRTNER, 1962) or speculated "Vendian" – Early Paleozoic age (POPOVIĆ, 1984) for this formation. The next unit, Golija Formation, is generally characterized by a voluminous clastic input, general absence of basic volcanism and sporadic occurences of limestones. The "Kovilje Conglomerates" according to ĐOKOVIĆ (1985) represent a marker formation comprised of anchimetamorphosed conglomerates and coarse to very-coarse grained arenites (predominantly quartzarenites) found between Golija and Birač formations. Birač Formation, the youngest unit in the DIE Paleozoic succession, consists of slightly metamorphosed siliciclastics and adjoining pelagic sediments with rare goniatids and floral fragments. The DIE as a segment of the SEE Variscan basement is unconformably overlain by an early Mesozoic sequence.

Mesozoic configuration places the Dinarides into a Late and post-Late Jurassic Southwest-vergent fold-and-thrust belt situated between the Southern Alps in the Northwest and the Albanides/Hellenides in the Southeast (TARI-KOVAČIĆ, 2002). The entire Mesozoic sequence of the DIE unconformably overlies Neoproterozoic–Late Paleozoic basement formations. The earliest Triassic Kladnica Formation comprises sandstones and conglomerates and is succeeded by the Early Triassic "Seiss Formation" and Bioturbated Formation. The Middle Triassic succession is comprised of shallow-water calcareous Ravni Formation, "Porphyrite-chert"

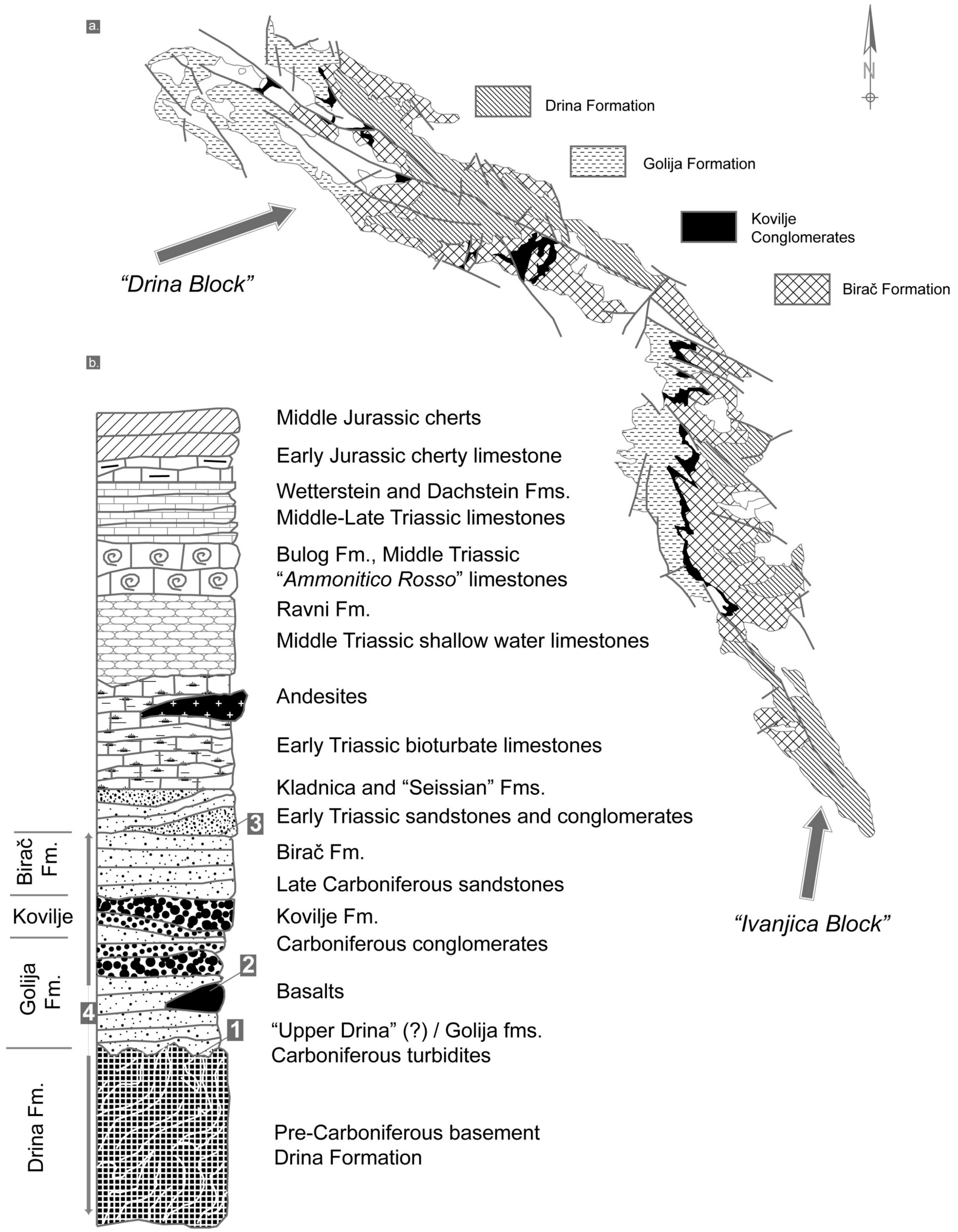

Fig. 3. **a.** The geologic map positioning the Drina Formation within the Drina- and Ivanjica segments (after Đoković, 1985). **b.** The condensed lithological column indicating the "Lower Drina Formation" and the "Upper Drina Formation" are actually the Drina Formation (column modified after Dimitrijević, 1997). Numbers indicate the raised issues associated with the proposed plate-tectonic solutions: **1,** The unconformity represents hiatus between the Neoproterozoic-Cambrian "Lower Drina Formation" and the Carboniferous "Upper Drina Formation". It could actually represent two different formations; **2,** Questionable occurrence of meta-basic rocks in both formations, missed in the lower section of the column; **3,** There should be an unconformity between the Late Carboniferous and the Early Triassic; **4,** The interrelationships between the entire set of Paleozoic formations are ongoing work.

Formation continuing into the Bulog Formation (*Ammonitico Rosso* limestones). Middle to Late Triassic is presented by Wetterstein and Dachstein formations. Deep water Lower Jurassic cherty limestones and Lower to Middle Jurassic cherts are distal depositional sequences towards the Vardar Zone. For a detailed review of the DIE Mesozoic formations see Porkoláb et al. (2018).

The controversial Alpine evolution of the DIE during Mesozoic is related to a number of ophiolite-bearing systems and their emplacement onto marginal crustal segments of the Dinarides. The concept of "multiple-oceans" (Dimitrijević & Dimitrijević, 1973; Dimitrijević, 1997) portrays a Middle Triassic–uppermost Jurassic Intradinaridic ocean (Dimitrijević, 2001) lately also explained via Triassic seapaths between the isolated continental segments of the Dinarides (Argnani, 2018). Another concept advocating the "single-ocean" model or "two ophiolites-single ocean" places underthrusting Adriatic distal passive margin (including DIE) below the oceanic upper plate (e.g., Porkoláb et al., 2018; Schmid et al., 2008; Toljić et al., 2018).

Discussion

The Phanerozoic evolution of the former Yugoslavia and SEE can beyond question be qualified as one of the most intricate in global scale, as it goes back to (i) the Late Neoproterozoic Cadomian orogeny (e.g., Antić et al., 2016; Avigad et al., 2017), (ii) subsequent Neoproterozoic–Early Paleozoic peri-Gondwanan wrenching (e.g., Merdith et al., 2017) coupled with the (iii) subduction-related back-arc extension (Nance & Linnemann, 2008). These Early Paleozoic events are superseded by the two major orogenic imprints – Variscan and Alpine. (iv) The Variscan imprint was confirmed in earlier exploration stages (Đoković, 1985). This event aggregated previously detached arc crustal segments of North Gondwana margin with the already assembled Laurasia. (v) Alpine orogenic cycle initially dismembered the Pangean Supercontinent upon which (vi) far-travelled SEE Mesozoic microplates (*sensu* Szederkényi et al., 2012 and references therein) accreted (Upper Cretaceous-Paleogene) into the Eurasian promontory (vii) experiencing during syn- and post-orogenic collapse (*sensu* Costa & Rey, 1995) differential late Paleogene–Neogene extensional and rotational motions (Márton et al., 2007).

Coupling the Drina Formation with the peri-Gondwanan framework

Further complications in reconstructing perplexing history of the Drina Formation are associated with the ambiguity whether this basement system was involved within the Late Neoproterozoic Cadomian and Late Paleozoic Variscan orogenic cycles. A structural record of the Cadomian event (Late Proterozoic to Early Cambrian, *sensu* D'Lemos et al., 1990) is poorly preserved outside the northern Armorican Massif, Bohemian Massif, and southwestern Iberian Massif (Eguíluz et al., 2000 and references therein). Nevertheless, certain basement segments of the Central European Variscides contain deformations of a minor intensity governed by the Cadomian orogenic cycle (Behr, 1983). However, the eventual imprints of Cadomian event have not been investigated within SEE yet. The published paleo-tectonic models of the Variscan orogenic cycle emphasize that the central domain of North Africa was not involved in the Variscan collision (e.g., Nance & Linnemann, 2008; Stampfli et al., 2013). Instead, a limited number of recent reconstructions propose that the former North African segments of modern-day SEE originated from the large-scale Hun arc complex (e.g., Stampfli et al., 2002; Stampfli & Kozur, 2006) including the Apulia/Adria microplate, a former member of the North African promontory (Franke et al., 2017; Casas & Murphy, 2018). A member of this Early Cambrian E–W-oriented Cadomian aggregation is the Drina–Ivanjica entity, recently recognized as a subsided passive margin devoid of the Variscan imprint (Ebner et al., 2008) which is contrary to the previous observations (Đoković, 1985).

Following a limited factual base of the earlier investigations of the Drina Formation (Ćirić & von Gärtner, 1962; Ercegovac, 1974; Filipović et al., 1979; Milovanović, 1984; Đoković, 1985; Filipović & Sikošek, 1999; Trivić et al., 2010; Đajić, 2010; Đajić et al., 2012), we initially correlate the sedimentary record (protoliths) with the existing sedimentary, metamorphic (Đoković, 1985) paleogeographic and paleo-tectonic reconstructions (Stampfli et al., 2002; von Raumer et al., 2003; von Raumer & Stampfli, 2008; Korn et al., 2010;Franke et al., 2017; Li et al., 2017).

The Drina Formation: Reassessing the age and primeval deposition

The entire Neoproterozoic–Paleozoic evolution of the DIE remains to be a somewhat underexplored and controversial topic. A pioneering study of the Drina Formation described the DIE basement as a set of the Paleozoic formations ranging in age from the Early Paleozoic to the Carboniferous (Đoković, 1985). However, the age of the Drina Formation and a set of succeding formations are poorly constrained (Dimitrijević, 2001) and even nowadays remains to be a contradiction. Namely, a recent discovery of the Neoproterozoic palinomorph record (Đajić, 2010; Đajić et al., 2010) indicated a Neoproterozoic age, somewhat complementary with earlier dating (Ercegovac, 1974) which pointed Cambrian to Ordovician age. Đoković (1985), however, extended the age of the metamorphic Drina Formation from the confirmed Cambrian up to the Silurian, Devonian, and reaching Early Carboniferous. In this description, the "Upper Drina Formation" is to some extent a synonymous term for the Golija Formation (Fig. 3). Regionally, in SEE (eastern Serbia), typifying Silurian has, however, a distinctive set of graptolite facies (Krstić et al., 2005) embedded into the Late Ordovician to Early Carboniferous "Kučaj Unit". Furthermore, basement greenschist-facies rocks of the Supragetic basement (Vlasina Complex, adjoining the "Kučaj Unit") contain a set of remarkable fossil remnants of the Ordovician inarticulate brachiopod fauna (Pavlović, 1962). An absence of the phytoplankton: Sphaeromorphitae, *Mirchystridium* sp., *Veryhachium* sp., *Balitesphaeridium* sp., rather indicates a missing part of the Ordovician, Silurian and Early Devonian column (Ercegovac, 1974) within the Drina Formation. In addition to the inconclusive Silurian and Devonian age, another highly ambiguous issue is a continuation of the Drina Formation into the Lower Carboniferous, represented by a clastic sequence with fragments, blocks and autochonous levels of metalimestones with Early Carboniferous conodonts of *Gnathodus bilineatus* and *Lochrieia nodosa* zones (Djordjijevski-Kalambokis et al., 1990; Filipović & Sikošek, 1999 and references therein). These Early Carboniferous rocks are ambiguously considered as the "Upper Drina Formation", a spatio-temporal continuation of the "Lower Drina" (Dimitrijević, 1997; Fig. 3). For a comparison, the Early Carboniferous of the adjacent Jadar block (in Alpine configuration) is marked by the abundance of the provincial ammonoid faunas (Korn et al., 2010) indicating autonomous developments of the DIE and Jadar system (Đoković & Pešić, 1985).

While a group of authors indicated a complete succession from Cambrian to Lower Carboniferous, including the embedded metabasic rocks (e.g. Đoković, 1985; Trivić, 2010; Fig. 3), Filipović & Sikošek (1999) limited a "pre-Variscan succession" (Drina Formation) to Cambrian–Lower Ordovician. After Silurian hiatus, Filipović & Sikošek (1999) describe a siliciclastic succession of Variscan age, locally with Devonian–Early Carboniferous olistoliths, ending with the Early to Middle Carboniferous flysch (a tentative analogue of the Culm flysch) further implying another occurrence of metamorphic basic rocks. Extensive field-work covering the entire DIE indicates that orthobasic rocks and their tuffs occur within the ("Lower") Drina Formation, while a limited evidence of basic tuffs within the, so-called, "Upper Drina Formation" or "siliciclastic Variscan succession" (Fig. 3) was reported by Djordjijevski-Kalambokis et al. (1990), Filipović & Sikošek (1999).

The basic/metabasic rocks as conditional markers of crustal extension and the subsequent oceanization are in modern-day Central Europe and SEE, nevertheless, distributed on the both sides of Early Paleozoic Gondwana and formerly juxtaposed Laurasia. These occurrences of (meta)basic rocks are often referred to as "Variscan ophiolites" (e.g., Ivan & Méres, 2012; Plissart et al., 2017). The presence of early Paleozoic (meta)basic rocks in Central Europe and SEE can be recognized either as a remnant of the formerly accreted Cadomian arc which was in turn developed in a back-arc position during Neoproterozoic to Ordovician times (opening of the proto-Rheic Ocean), or as the result of Devonian back-arc plate divergence of internal parts of the orogen. Development of basaltic magmatism along the outskirts of Laurasia (*sensu* Franke, 2006) was probably induced by the shrinking Rheic Ocean and the effect of the descending plate beneath mainland Laurasia or by the interchanging episodes of transpression and transtension between neighboring microcontinents (Franke et al., 2017). Here are some of the examples of the recognized Cadomian arc remnants in Central and Southeastern Europe: the Rothstein Formation (Linnemann, 2007), the Neukirchen metabasic complex of the Bohemian Massif (Behr, 1983 and references therein), the Brno Massif (Finger et al., 2000), the Sandykly basement metasandstones (Menderes Massif) with flattened clasts of basic volcanic rocks (Gürsu & Göncüglu, 2006). Devonian development of a within-plate (meta)basic rock system is documented across Central Europe (e.g., Schlaegel-Blaut & Heinisch, 1991). In SEE, in the Western Greywacke zone (Austria), the greenschists are intercalated within calcareous phyllites with a presence of mafic tuff of 384.5±1.9 Ma U-Pb zircon age. This age indicates rudimentary development of oceanic systems at the Middle to Upper Devonian boundary (Dum et al., 2012). Metabasites of the Gemeric Superunit (Western Carpathians) display transitional character exhibiting N-MORB, E-MORB and BABB types (Ivan & Méres, 2012).

Early to Late Paleozoic geodynamic reconstruction

In general, the Drina Formation can be characterized as a greenschist (locally amphibolite, Trivić et al., 2010) rock system of the mixed volcano-sedimentary protolith - rudites, arenites, pelites, basic (sub)volcanics and tuffs, sporadically limestones (Đoković, 1985) resembling to a passive margin assembly (Vrabec et al., 2009) juxtaposed to an ancient extensional system.

Mid-Edicarian deposition along the extended margin of northern Gondwana (Fig. 5) is dominated by an intensive weathering of the Cadomian orogen and protracted sediment transport into the former (Garfunkel, 2015). The available Cambrian paleo-conti-

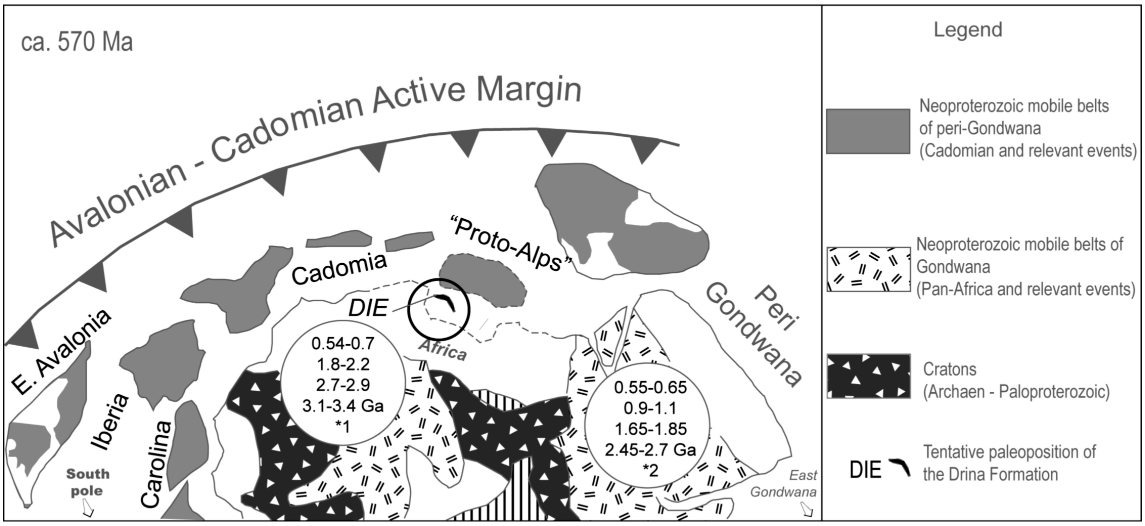

Fig.4. A paleogeographic scenario of the Cadomian-Avalonian active margin and related major peri-Gondwanan terranes at ca. 570 Ma (modified after Linnemann et al., 2007 and references therein). Drina Ivanjica, i.e. Drina Formation as a member of the "Proto-Alps" or "Paleo-Adria", accommodated between North African- i.e. north Gondwanan margin and Cadomian terranes. Sources of detrital zircon ages (white circles): *1 – Detrital zircon ages from the compilation of Nance & Murphy (1994 and references therein). *2 – Detrital zircon ages from Avigad et al. (2003).

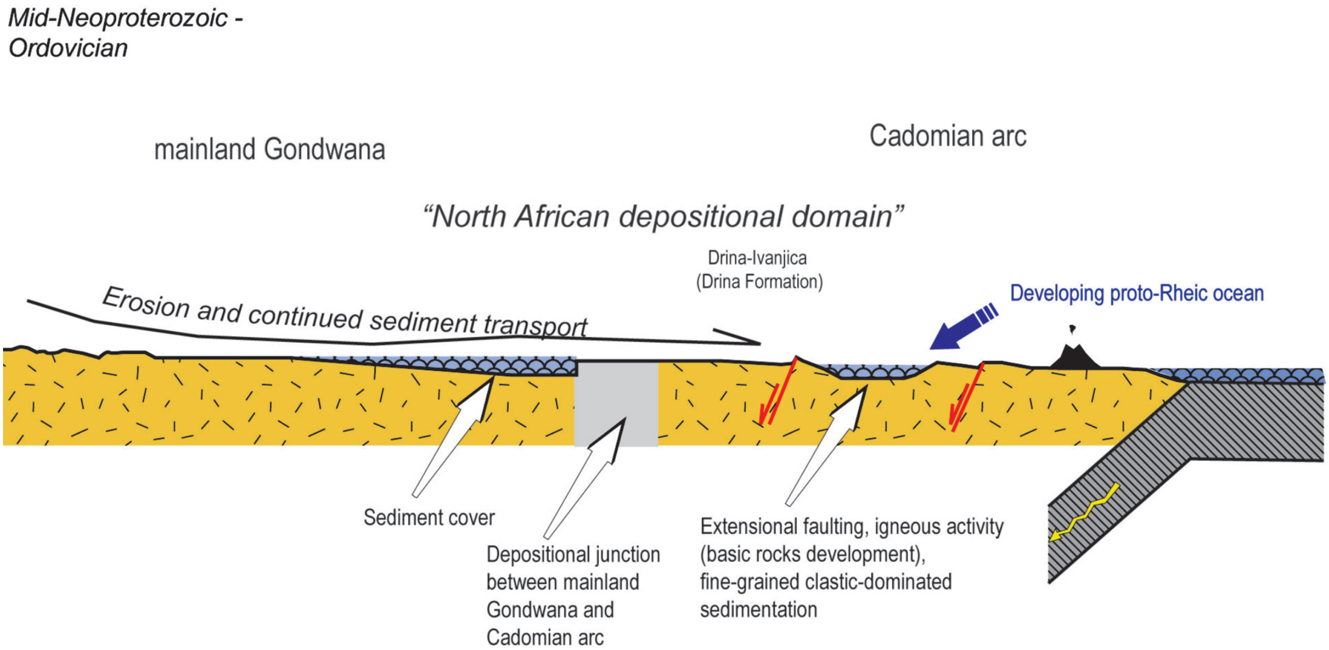

Fig. 5. Cross section delineating north Gondwana and Cadomian depositional domain from the Mid Ediacaran to Ordovician. The tentative proposition of the Drina–Ivanjica, "Lower Drina Formation" (inlet from Garfunkel, 2015, modified).

nental- and paleogeographic reconstructions place the "paleo-Dinarides" either as a crustal segment being already shifted away of the West African (Saharan) craton (Li et al., 2017) or as a segment still attached to the Ordovician north Gondwana (Siegesmund et al., 2018). The Late Ordovician location of the Adria microplate, on the basis of the age of the Cambrian-Ordovician magmatism, the detrital zircon signature and other stratigraphic criteria also suggest a proximity of northern Gondwana (Casis & Murphy, 2018 and references therein). Rare detrital zircon age spectra results of modern-day remnants of the "Paleo-Adria", e.g. Austroalpine basement (Tauern Window, paragneisses) exhibit Ediacaran sources, with lesser input of Cryogenian, Tonian and Stenian sources and subordinate Paleoproterozoic and Neoarchean ages (Siegesmund et al., 2018). Such detrital mixture of sources points to the northeastern Saharan Metacraton and the Northern Arabian–Nubian Shield (Sinai) excluding Baltican inheritance. The volcano-sedimentary protolith record of Neoproterozoic age (Đajić, 2010, Đajić et al., 2012) was under influence of material eroded and transported from the pre-Pan-African basement (Siegesmund et al., 2018). Consequently, we place a juvenile environment in which the Drina Formation originated as a proto-segment of the Apulia/Adria (Casis & Murphy, 2018) or the "Paleo-Adria" (Franke et al., 2018) as a crustal segment still connected to north Gondwana during Neoproterozoic to Early Paleozoic times (Fig. 4). According to several models, "Paleo-Adria" aggregation was detached from the Gondwana somewhere between Late Silurian and Late Carboniferous (von Raumer & Stampfli, 2008) or was accreted onto Laurasia together with north Gondwana (Franke et al., 2017).

The suggested position of juvenile Drina–Ivanjica Entity implies, that during Late Ordovician, Silurian and Early Devonian, this marginal system of North Africa was a continental fragment outboard the modern-day North African coast. Another argument for the passive margin setting is lack of typifying felsic volcanism of the Cadomian age. A tentative paleo-location of the juvenile Drina succession was in a vicinity of the continental Cadomian arc which was affected by the Neoproterozoic–Cambrian epicontinental sedimentation (*sensu* Garfunkel, 2016; Fig. 5). The Drina Formation was probably juxtaposed next to the contemporaneous Cadomian peri-Gondwanan active margin system (von Raumer & Stampfli, 2008).

According to some recent reconstructions the "Paleo-Adria" travelled over 6500 km between the Silurian (opening of the Palaeotethys) and the Devonian (360 Ma) prior to the Variscan accretion (Franke et al., 2017). However, the presence of metabasic rocks intermixed with Neoproterozoic sedimentary succession of the Drina Formation rather indicates a vicinity of precursory proto-Rheic Ocean further implying a pre-Silurian detaching or different paleogeographic location of "Paleo-Adria" in particular Adria/Apulia. Tentatively, the location was more to the west in Ordovician reference relative to the the location reference proposed by Franke et al. (2017; Fig. 10a).

The "Paleo-Adria" arrival and Pangea assembly are either interpreted as Late Devonian–Carboniferous dextral shearing (Franke et al., 2017) or are often associated with Late Carboniferous and earliest Permian collision (Winchester & Pace TMR Network Team, 2002; e.g. Kroner & Romer, 2013). Regionally, in the Northwestern Dinarides (Croatia, Figs. 1, 2) the $^{40}Ar/^{39}Ar$ extracted from detrital white mica of the very low-grade basement rocks of the Paleozoic Sana-Una Unit ("Paleo-Adria") gave the inferior Variscan age of ~335 Ma (Ilić et al., 2005) relative to a predominant younger Alpine overprint time span (e.g. Late Jurassic–Lower Cretaceous, Porkoláb et al., 2018; Lower–Upper Cretaceous, Borojević-Šoštarić et al., 2012).

The subsequent Carboniferous accretion with SE Laurussia should be marked by a set of ductile fabric documented within the Drina Formation (Đoković, 1985). However, recent dating of samples taken from metamorphic Paleozoic units in Serbia by applying the Illite crystallinity and K/Ar methods, indicate the latest Jurassic–earliest Cretaceous timing of metamorphism (130–145 Ma, Porkoláb et al., 2018). Nevertheless, the Early Carboniferous siliciclastic system (Filipović & Sikošek, 1999) should mark a descending plate position of the Drina–Ivanjica during a Late Paleozoic convergence. To summarize, it is obvious that further investigations of the Paleozoic evolution of "Paleo-Adria", particularly of the Drina–Ivanjica are necessary.

Conclusions

The presented results show that the Drina Formation was a segment of the stabilized peripheral Cadomian platform or the pre-Variscan basement of "Paleo-Adria" (Apulia/Adria microplate in Alpine configuration). This subsided continental margin was filled with the mixture of flat-lying sediments. The biostratigraphic comparison with the paleogeographically similar "Kučaj Unit", yields that the Drina Formation is exclusivelly of Neoproterozoic–Early Ordovician age, consequently ruling out any connection with the Lower Carboniferous flysch system of the Drina-Ivanjica basement (informally called "Upper Drina Formation"). The overall reconstruction places the juvenile Drina Formation into the, so-called, *North African depositional domain*, passive margin in the West and North African (Saharan) meta-craton and peri-Gondwanan Cadomian magmatic-arc system. This significantly differs from the older, ca. 700 Ma felsic magmatic intrusions of peri-Amazonian Pelagonian micro-fragment.

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Резиме

Неопротерозојско–палеозојска еволуција Дринске формације (Дринско-ивањички бејсмент)

Анализа биостратиграфских података, као и палеогеографских и палеотектонских реконструкција у овом раду усмерена је у правцу решавања отворених питања везаних за Дринско-ивањички бејсмент који изграђује неколико недовољно јасно дефинисаних метаморфних формација. Дринска формација представља најстарију неопротерозојско-доњопалеозојску јединицу Дринско-ивањичког бејсмента и представљена је аренитима, пелитима, конгломератима, мање кречњацима, базичним (суб)вулканитима и туфовима регионално метаморфисаним до фације зелених шкриљаца односно локално до амфиболитске фације.

Биостратиграфски потврђена неопротерозојска старост Дринске формације упућује на палеогеографски положај ове јединице који је био у склопу некадашње северне маргине суперконтинента Гондване. Даљом палеотектонском и петролошком анализом и прегледом већ публикованих палеоконтиненталних позиција, користећи пре свега, присуство измењених базичних комплекса, указано је на могућност да је Дринска формација чинила раскршће између унутрашњег дела суперконтинента (део изнад Сахарског кратона) и ободног дела активне маргине (северна Гондвана) - тзв. кадомског острвског лука који је био активан од неопротерозоика.

Палеопалинолошка истраживања ранијег датума указују на могућност да горњоордовицијумске, силурске и девонске творевине нису присутне у метаморфитима Дринске формације. Компаративна палеогеографска анализа са доњопалеозојском “Кучајском јединицом” (источна Србија) указује на одсуство силурских и доњодевонских творевина које су у поменутој јединици развијене као дубоководне фације граптолитских шкриљаца. Постојање киселих магматита кадомске старости (700 Ма) у оквиру Пелагонијског масива јасно указује да не постоји палеогеографска сличност између овог периамазонског сегмента северне Гондване и најстаријих делова Дринско-ивањичког ентитета.

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