Геолошки анали Балканскога полуострва Annales Géologiques de la Péninsule Balkanique	79 (1)	1–19	Београд, јул 2018 Belgrade, July 2018

DOI: 10.2298/GABP1879001S

Original scientific paper
Оригинални научни рад

Emendation of the Grivska Formation in its type area (Dinaridic Ophiolite Belt, SW Serbia)

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Abstract. Age, microfacies and depositional realm of the Grivska Formation is controversially discussed due to the fact that detailed investigations are missing. Based on reinvestigations of the type locality of the Grivska Formation and in adjacent areas, the following results can be drawn: 1) The Grivska Formation is of Late Triassic (Early Carnian to Rhaetian) age according to conodont dating. 2) Sedimentological and microfacies studies evidenced that the Grivska Formation was deposited on the continental slope and transitional to the Neo-Tethys Ocean. Based on the results of these investigations in the type area and several reference sections in the Dinaridic Ophiolite Belt, the Grivska Formation is emended and clearly defined. In the Dinaridic Ophiolite Belt, the Grivska Formation occurs only as clasts and blocks in the ophiolitic mélange.

Key words: Neo-Tethys continental slope, Late Triassic, stratigraphy, microfacies, ophiolitic mélange.

Апстракт. Старост, микрофације и област депозиције Формације Гривска су различито и често контроверзно приказиване услед недостатка детаљних истраживања. Након најновијих проучавања Формације Гривска на типском локалитету и у његовој ближој околини констатовано је следеће: 1) на основу конодонтске фауне утврђено је да је старост Формације Гривска горњи тријас (доњи карн до рет) и 2) да су њене творевине, према седиментолошким и микрофацијалним изучавањима, депоноване на континенталној падини на прелазу ка Неотетиском океану. На основу резултата ових поновних истраживања типске области и неколико референтних профила у Динаридском офиолитском појасу, карактеристике Формације Гривска су измењене и она је наново прецизно дефинисана. Карактеристично је да се ова формација у Динаридском офиолитском појасу појављује само у кластима или и у блоковима у офиолитском меланжу.

Кључне речи: Неотетиска континентална падина, горњи тријас, стратиграфија, микрофације, офиолитски меланж.

Introduction

Grey cherty limestone sequences occur quite common in the Triassic and Jurassic sedimentary successions of the Western Tethys realm: similar depositional and diagenetic conditions led to the formation of grey cherty limestones elsewhere. In the Serbian geological literature (e.g., Pantić, 1969, 1971; Pantić & Mojsilović, 1968; Pantić-Prodanović, 1975), most Triassic grey cherty limestones were exclusively assigned to the Ladinian. First corrections of the estimated Ladinian age range were made by Sudar (in Urošević & Sudar, 1980), based on conodont investigations in the Gučevo Mt. (Jadar Unit, NW Serbia). The grey cherty limestones from the Gučevo Mt. yielded Late Carnian and Early Norian conodonts. Later, conodont faunas with similar age ranges were found in grey cherty limestones from many other regions in western Serbia (Sudar, 1981, 1986).

Since the 1980 and 1990s, at the beginning of the work on the Thematic Geological Map of Serbia (1:50000) the Grivska Formation was informally introduced by Dimitrijević & Dimitrijević (1987, 1991): the definition of this formation, based not only on a chronostratigraphic approach anymore included lithostratigraphic and facies aspects as well. Sections in the area of Grivska village (Mali Ostreš) and Rid (Zbojštica) in Zlatibor Mt. were used to define the Grivska Formation.

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Based only on rare palaeontological data from thin sections DIMITRIJEVIĆ & DIMITRIJEVIĆ (1991, p. 32) concluded: *"These beds seem to be synchronous with the lower part of Wetterstein Formation (Ladinian)"*.

First biostratigraphic investigations on several grey cherty limestone successions in the area of the Dinaridic Ophiolite Belt were carried out by M.N. SUDAR (in ANĐELKOVIĆ & SUDAR, 1990). In the surroundings of Nova Varoš, SUDAR (1986) dated grey cherty limestones, by means of conodonts, as Late Ladinian to Early Carnian: these grey cherty limestones were formerly believed to be of Jurassic age (according to DIMITRIJEVIĆ & DIMITRIJEVIĆ, 1975: Fig. 4). Based on conodont dating, SUDAR (1986, 1996, unpubl. data) was able to distinguish Ladinian, Carnian and Norian grey cherty limestones. However, these age data were only rarely used in the continuing geological mapping in this part of Serbia.

Considering the lithofacies of the rocks, DIMITRIJEVIĆ & DIMITRIJEVIĆ (1991) and KOVÁCS et al. (2010, 2011, 2014) interpreted the Grivska Formation as hemipelagic sedimentary rocks, deposited on the platform slope, the toe-of-slope and in the basin near to the slope. Subsequently, based only on macroscopic attributes and regardless to in most cases unknown age and without detailed microfacies investigations, the term "Grivska Formation" has been used for all grey cherty limestone successions in the Dinaridic Ophiolite Belt (Fig. 1; DIMITRIJEVIĆ, 1997; DIMITRIJEVIĆ et al., 2003; RADOVANOVIĆ, 2000*; RADOVANOVIĆ et al., 2004; CHIARI et al., 2011), or in the Vardar Zone Western Belt (TOLJIĆ et al., 2013).

To summarize, the term "Grivska Formation" in the Inner Dinarides has been used until nowadays in a confusing and misleading way for all Middle Triassic to Middle (?) Jurassic grey cherty limestone successions. It must be noted, that in most cases no biostratigraphic investigations were carried out.

A recent description/definition of the depositional environment/facies of the "Grivska Formation" was given by TOLJIĆ et al. (2013) on the base of former confusing and misleading usage of the Grivska Formation. TOLJIĆ et al. (2013, p. 52) described grey cherty limestones in the vicinity of Ležimir in the southern part of Fruška Gora Mt. (northern Serbia, Vardar Zone Western Belt) and attributed them to the Grivska Formation. These authors gave the following statement, but without presenting any new data or aspects to the discussion related to the "Grivska Formation problem": "*The overlying metamorphosed nodular limestones and carbonate schists are the metamorphosed equivalents of the Middle-Upper Triassic (-Lower Jurassic?) siliceous thin-bedded distal carbonates of the Grivska Formation (Fig. 7b, DIMITRIJEVIĆ and DIMITRIJEVIĆ, 1991). This formation, which displays a wide transition in space and time from distal carbonate shelf, slope deposition to basal carbonate turbidites overlain by Lower-Middle Jurassic radiolarites, is a typical marker that testifies the gradual deepening of the Adriatic carbonate platform. The intercalated meta-volcanic and volcanoclastic material is an equivalent of the Anisian–Ladinian break-up volcanism that took place during the opening of the Neotethys/Vardar Ocean (PAMIĆ, 1984). The upper meta-radiolarites are metamorphosed equivalents of the Upper Triassic–Middle Jurassic distal oceanic pelagic sediments and radiolarites (Fig. 7a) well known in the internal Dinaridic units (e.g., DJERIĆ et al., 2007 and references therein). This typical Middle Triassic–Middle Jurassic facies can only be assigned to the distal Adriatic continental margin and its adjacent oceanic domain by correlation with the similar metamorphosed and non-metamorphosed facies observed in the Drina-Ivanjica and Jadar-Kopaonik units of the Dinarides (DIMITRIJEVIĆ, 1997).*"

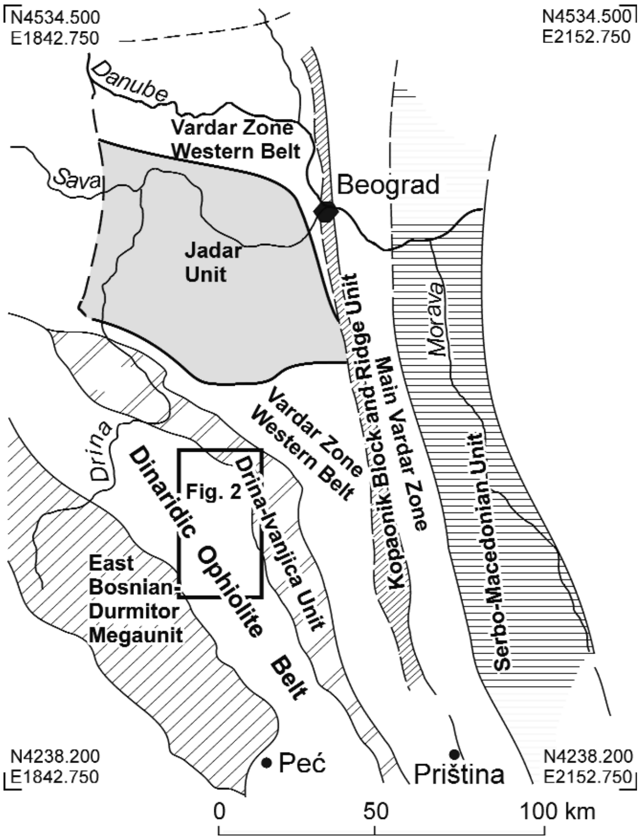

Fig. 1. Tectonic units of the central Balkan Peninsula simplified after KARAMATA (2006), based on KOSSMAT (1924). For details see GAWLICK et al. (2017).

* RADOVANOVIĆ, Z., 2000. Explanatory Booklet for the Geological map of the Republic of Serbia (1:50000), Sheet Prijepolje 2. Archives of the Geological Survey of Serbia, Belgrade (in Serbian).

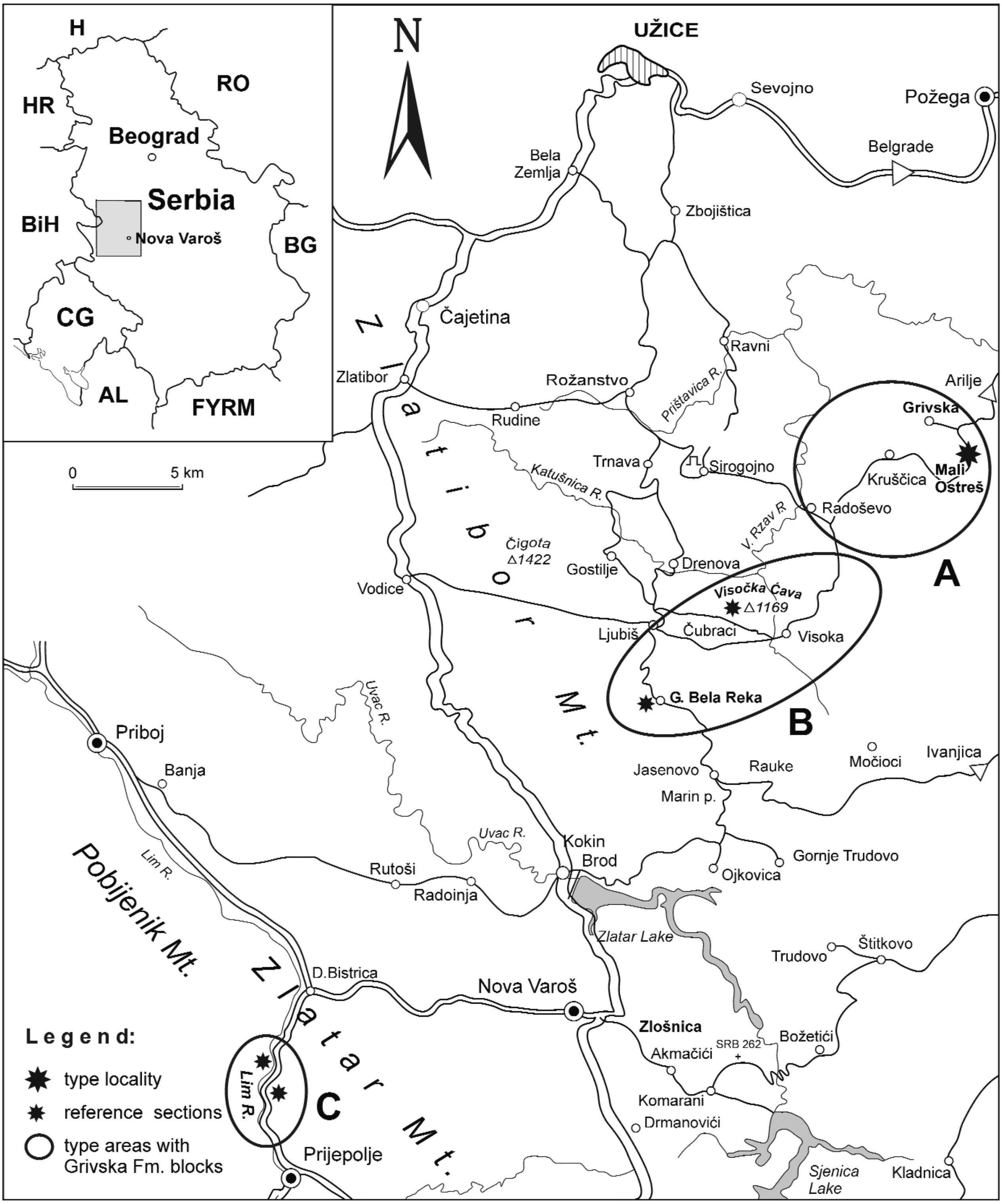

Fig. 2. Studied localities and areas in the Dinaridic Ophiolite Belt with Grivska Formation blocks in the ophiolitic mélange. **A**. Area of the type locality Mali Ostreš. **B**. Visoka area with the sections of Visočka Ćava peak and Gornja Bela Reka. **C**. The Lim River area.

This statement clearly demonstrates the high need for detailed investigations to solve this confusion and the need for a formal definition of the Grivska Formation that is based on a solid data base from the type area. The reinvestigation of the type locality Mali Ostreš south of the village Grivska in Zlatibor Mt. (Fig. 2) and the detailed analysis of cherty limestone blocks in the ophiolitic mélange, allow for the first time a correct definition of the still enigmatic Grivska Formation.

In Zlatibor Mountain, the ophiolitic mélange (Gostilje-Ljubiš-Visoka-Radoševo mélange: Gawlick et al., 2016b) contains a mixture of blocks of:

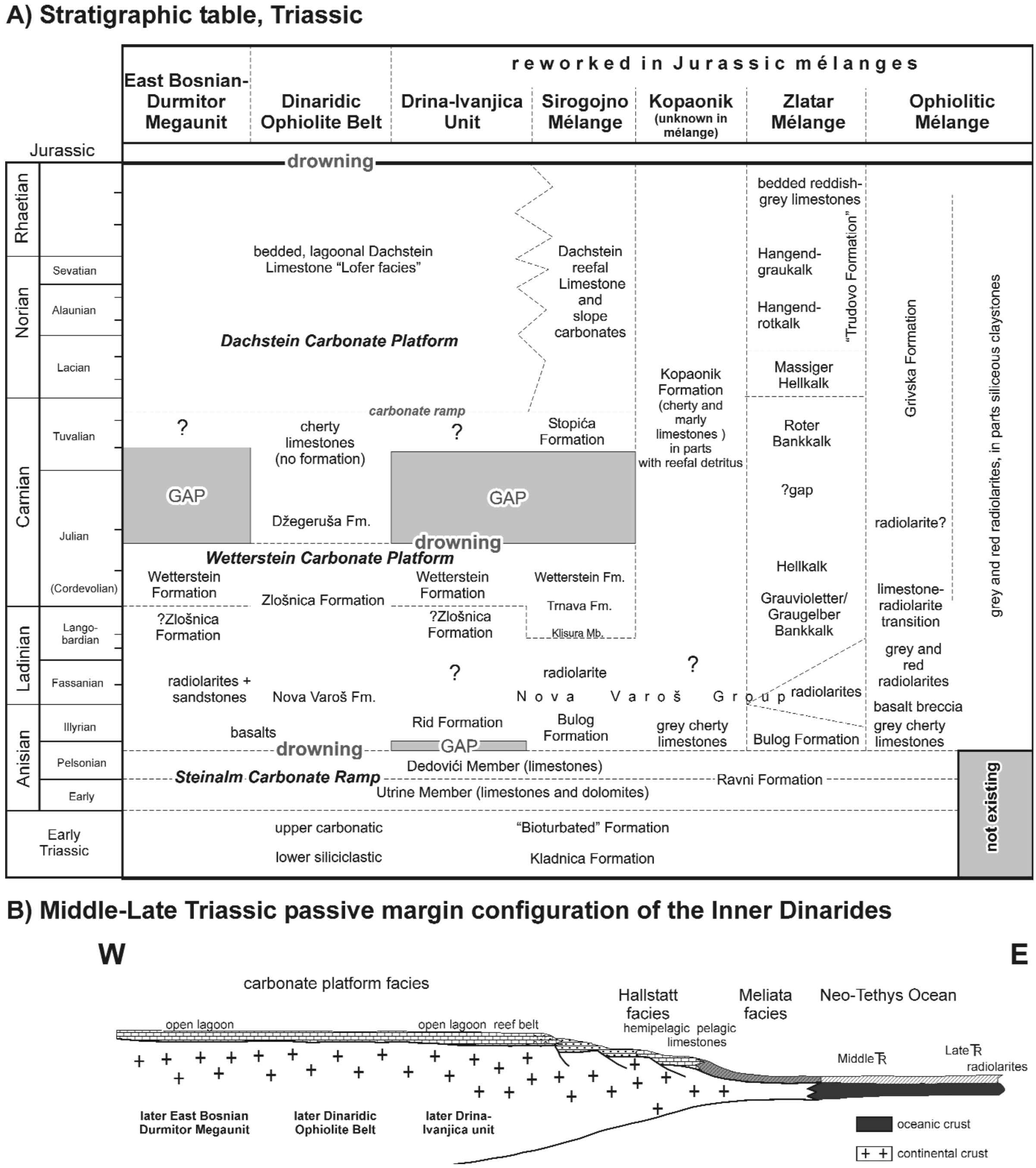

Fig. 3. **A.** Stratigraphic table for the Triassic of the Inner Dinarides. Early Triassic to early Middle Triassic after DIMITRIJEVIĆ (1997). Neo-Tethys oceanic realm after GAWLICK et al. (2016a, b); continental slope after GAWLICK et al. (2016a) and this study; Hallstatt Limestone facies zone after SUDAR (1986), SUDAR et al. (2010), GAWLICK & MISSONI (2015), GAWLICK et al. 2017a); open shelf with shallow-water influence after SUDAR (1986) and SCHEFER et al. (2010); Late Triassic reef rim and lagoonal area after MISSONI et al. (2012), SUDAR et al. (2013) and DIMITRIJEVIĆ (1997). **B.** Middle to Late Triassic passive margin configuration after GAWLICK et al. (2008, 2016a, 2017a). Generation of oceanic crust started in the Late Anisian in the Neo-Tethys realm.

1) Oceanic crust,
2) Middle and Triassic ribbon radiolarites, and
3) Open marine grey cherty limestones.

The age determination and the litho- and microfacies characterization of these grey cherty limestone blocks in the ophiolitic mélange in the type-area of the Grivska Formation are in the focus of the present paper. For a detailed analysis of the ophiolitic mélange in the type area of the Grivska Formation see GAWLICK et al. (2016b).

In addition to the reinvestigation of the type area of the Grivska Formation, three other reference areas were studied and here referred to as reference sections: section Gornja Bela Reka, section Visočka Ćava peak, and sections along the river Lim along the road from Donja Bistrica to Prijepolje (Fig. 2). In all these areas, the Grivska Formation occurs as metre- to several hundred metres-sized blocks in the ophiolitic mélange.

Biostratigraphic age of the Grivska Formation

In the region between the villages Visoka and Grivska and also in the area of the river Lim, several large metre- to several hundred metres-sized limestone blocks occur in the ophiolitic mélange. Gawlick et al. (2016b) grouped the lithologies and microfacies of the different limestone blocks as follows:

1. Thin to decimeter-bedded, micritic cherty limestones, occasionally with very fine-grained turbiditic layers or marly layers. This limestone type is present in metre- to several hundred metres-sized blocks. The larger blocks can have a preserved sequence of several tens to hundred metres in thickness and show slump folds in places. This Early Norian limestone type is the most common one in this ophiolitic mélange area.
2. Grey, thin-bedded cherty limestones with intercalated turbidites with filaments and radiolarians. Litho- and microfacies is similar to the Early Norian thin to decimetre-bedded, micritic cherty limestones, but they cannot be dated more precisely than Late Triassic (Carnian to Rhaetian).
3. Bedded, micritic cherty limestones with thick chert layers and up to cm-thick greenish-grey marly layers. This type is Middle to Late Norian in age.

Grivska village - Mali Ostreš locality

The locality Mali Ostreš near the village Grivska on the road between Visoka and Arilje (Figs. 2-A, 4) was assigned by Dimitrijević & Dimitrijević (1987, 1991) as the type section of the Grivska Formation. According to our studies, the age of the different grey cherty limestone blocks is within the age range from the Early Carnian to the Rhaetian. The following conodont samples from different blocks in the locality Mali Ostreš near the village Grivska yielded poor conodont faunas

- Sample SRB 484: (Anisian to) Early Carnian based on *Gladigondolella tethydis* (Huckriede) and *Gladigondolella*-ME Kozur & Mostler;
- Sample MS 1472: Late Carnian–Early Norian based on *Paragondolella* sp. and *Epigondolella* sp.;
- Sample A 4794: Early Norian (Lacian 2-3) founded upon *Ancyrogondolella triangularis* Budurov;
- Sample SRB 482-2: Early-Middle Norian based on *Epigondolella* sp.;
- Sample MS 1473: Early-Middle Norian determined with *Epigondolella* sp.;
- Sample MS 1474T: Lower, Middle Norian founded upon *Epigondolella* sp. (cf. *abneptis* (Huckriede);
- Sample SRB 415: Middle Norian based on *Epigondolella* sp.;
- Sample MS 1474: Eadly Norian (Lacian 2-3) determined with *Ancyrogondolella triangularis* Budurov;
- Sample MS 1478/1T: Early Norian (Lacian 2-3) founded upon *Ancyrogondolella triangularis* Budurov and *Epigondolella abneptis* (Huckriede);
- Sample MS 1478/1: Late Norian (Sevatian) based on *Epigondolella abneptis* (Huckriede) and *Epigondolella bidentata* Mosher;
- Sample A 4795-99: Late Norian to Early Rhaetian determined with *Epigondolella bidentata* Mosher and *Misikella* sp.;
- Sample MS: 1478: Late Norian to Early Rhaetian founded upon *Epigondolella bidentata* Mosher.

Identical age data and the same microfacies were reported from different cherty limestone blocks in the ophiolitic mélange nearby Mali Ostreš along the road from Grivska to Visoka (Gawlick et al., 2016b).

Visočka Ćava peak

In the northern and southern surroundings of Visočka Ćava peak (1169 m, Fig. 2-B) many blocks of grey cherty limestones of different size occur in the ophiolitic mélange. The microfacies show predominantly radiolarian filament-wackestones, while fine-grained turbiditic layers are rarely present. Some of these blocks yielded Late Carnian to Middle Norian conodonts (Gawlick et al., 2016b):

- Samples MS 1647, MS 1649: latest Carnian (Late Tuvalian) based on *Paragondolella nodosa* (Hayashi) and *Paragondolella polygnathiformis* (Budurov & Stefanov);
- Samples MS 1615, MS 1618, MS 1646: earliest Norian (Early Lacian) determined with *Epigondolella abneptis* (Huckriede), *Epigondolella echinata* (Hayashi) and *Metapolygnathus communisti* Hayashi;
- Samples MS 1625, MS 1648: middle Early Norian, (late Middle Lacian) founded upon *Epigondolella abneptis* (Huckriede), *Norigondolella hallstattensis* (Mosher) and *Norigondolella navicula* (Huckriede);
- Samples MS 1612, MS 1622: Early Norian (late Middle Lacian to early Late Lacian) based on *Ancyrogondolella triangularis* Budurov, *Epigondolella abneptis* (Huckriede) and *Norigondolella hallstattensis* (Mosher);

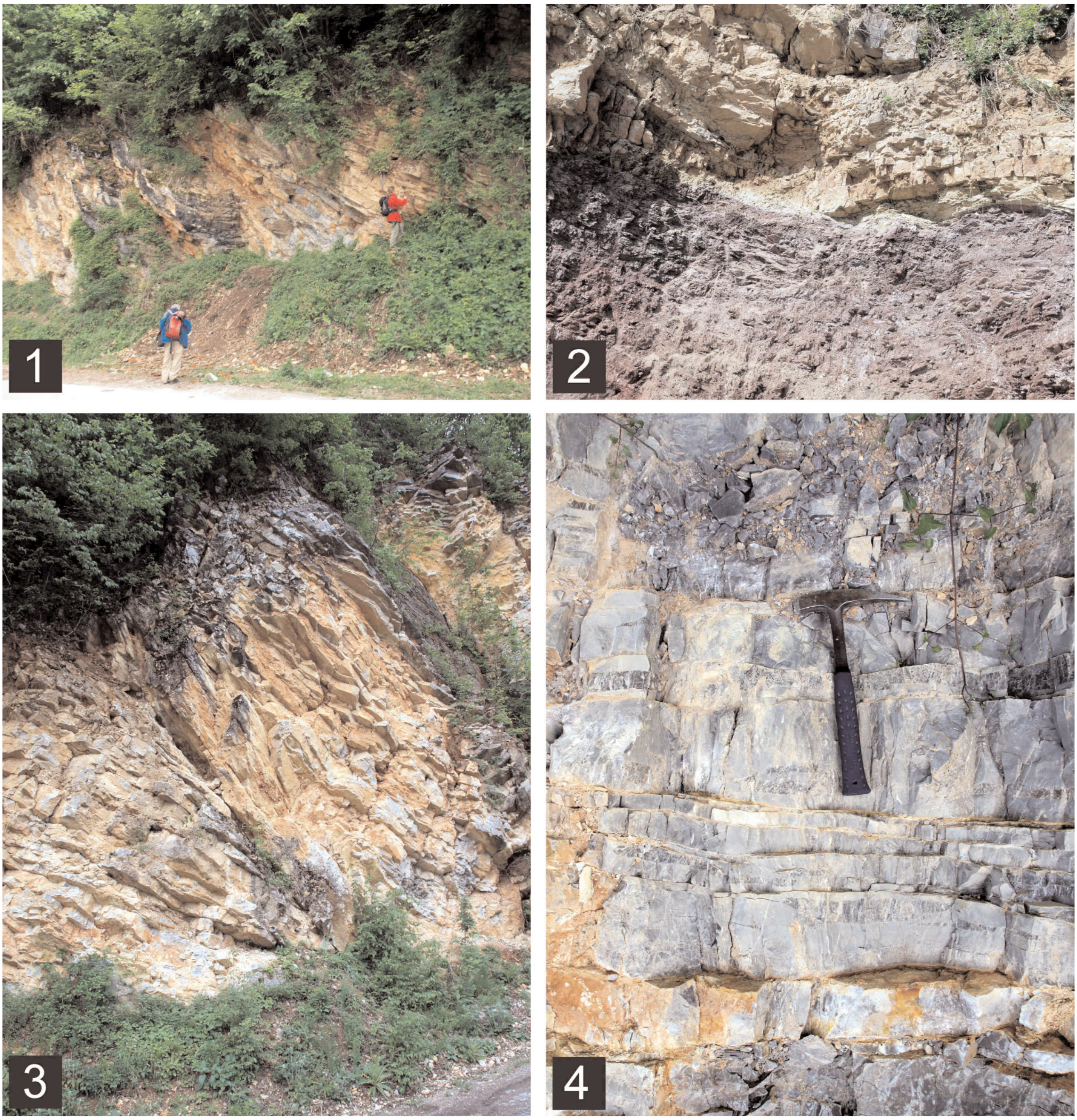

Fig. 4. Type locality of the Grivska Formation in Grivska village – Mali Ostreš locality. **1**. Typical dm-bedded grey cherty limestone succession. **2**. A Grivska Formation block on top embedded in the ophiolitic mélange. **3**. Several Grivska Formation blocks are overprinted by young faulting. **4**. Lithological features of Grivska Formation: dm-bedded grey limestones with irregular distributed grey chert nodules.

- Samples MS 1614, MS 1630: Middle Norian (Middle-Late Alaunian) determined with *Epigondolella abneptis* (HUCKRIEDE) and *Epigondolella postera* (KOZUR & MOSTLER).

Gornja Bela Reka

Opposite of the woodwork in the village Gornja Bela Reka, a big block of grey cherty limestones occurs within the ophiolitic mélange (Figs. 2-B, 5). The age is dated by conodonts as earliest Norian to Middle? Norian:

- Sample A 4587: Early to Middle? Norian based on *Epigondolella* sp. This sample was collected from the beds below the slump deposits.
- Sample SRB 570: earliest Norian founded upon *Norigondolella navicula* (HUCKRIEDE) and *Carnepigondolella pseudodiebeli* (KOZUR). This sample was collected from the basal part of the slump deposit.

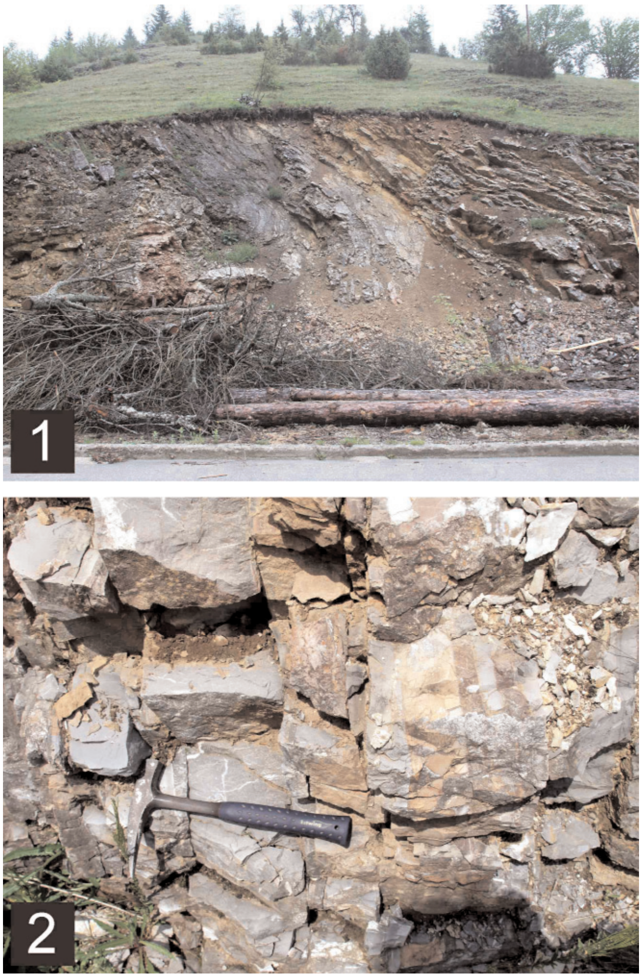

Fig. 5. Outcrop situation of the Grivska Formation in the area of Gornja Bela Reka. **1**. Early Norian half-meter thick bedded grey silicified limestones occurring opposite of the timber in Gornja Bela Reka. This limestone succession is a block in the ophiolitic mélange. **2**. Detail from the succession. Certain beds are very finely laminated, and certain layers are silicified. Intraformational monomictic breccia horizons occur rarely.

The Lim River

A more than 100 metres-sized block of bedded grey, and occasionally reddish-grey bedded cherty limestones in the ophiolitic mélange of the Dinaridic Ophiolite Belt is preserved along both sides of the Lim river (Figs. 2-C, 6). The age of this succession is dated by means of conodonts as Early to Late Norian.

On the first road curve after Donja Bistrica towards Prijepolje (eastern side of the river Lim), an Early Norian (Early–Middle Lacian) age is proven by conodonts (sample MS 2017 with *Epigondolella abneptis* (Huckriede) transitional to *Ancyrogondolella triangularis* Budurov, *Norigondolella* sp. (cf. *navicula* (Huckriede); and sample MS 2019 with *Norigondolella hallstattensis* (Mosher). Radiolarians from this part of the succession allow the same age assignment (Bragin et al., 2017).

On the western side of the river Lim and in southward direction of the first road curve after Donja Bistrica towards Prijepolje along the railway, only 2 samples contained badly preserved and scarce conodont fauna: SRB 552 with *Epigondolella* sp. (aff. juv. *bidentata*) and sample SRB 627 with *Neohindeodella* sp. These conodont faunas suggest a Late Norian age.

Microfacies characteristics and depostional environment of the Grivska Formation

Grivska village – Mali Ostreš locality

In the surroundings of Grivska village, including the type locality, different blocks of Carnian to Rhaetian age show more or less the same lithological features and similar microfacies throughout the whole stratigraphic sequence. In the different stratigraphic levels the sequence varies in the thickness of the individual beds and the amount of chert nodules and chert layers. Slump structures are visible in some blocks, mostly in those of Early Norian age. Radiolarians are the dominant organisms. Fragments of thin-shelled bivalves (“filaments”) occur only rarely (Fig. 7). Due to the scarcity of conodont faunas in the series, it is not possible to attribute the slightly different lithological characteristics to specific stratigraphic levels. Early Norian fine-grained turbiditic resediments like in the block in Gornja Bela Reka are missing in the area of Grivska village.

Gornja Bela Reka

The big block consist of a sedimentary succession of Early to ?Middle Norian bedded grey cherty limestones. Chert nodules and chert layers are common. Synsedimentary slump deposits are another characteristic sedimentological feature. The microfacies of the limestone layers surrounding the slump structures show typical radiolarian wackestone microfacies (Fig. 8). Very fine-grained turbiditic layers with bioclasts (rarely with foraminifera) of shallow-marine origin were encountered in the slump deposits. The age, litho- and microfacies characteristics are similar to the limestone blocks in the area of Visoka or Grivska.

Fine-grained turbidites in the Early Norian slump deposits which contain micrite clasts aside few shallow-water organisms like foraminifera is particularly interesting, since such turbidites have never been reported from blocks of the Grivska Formation in the type area.

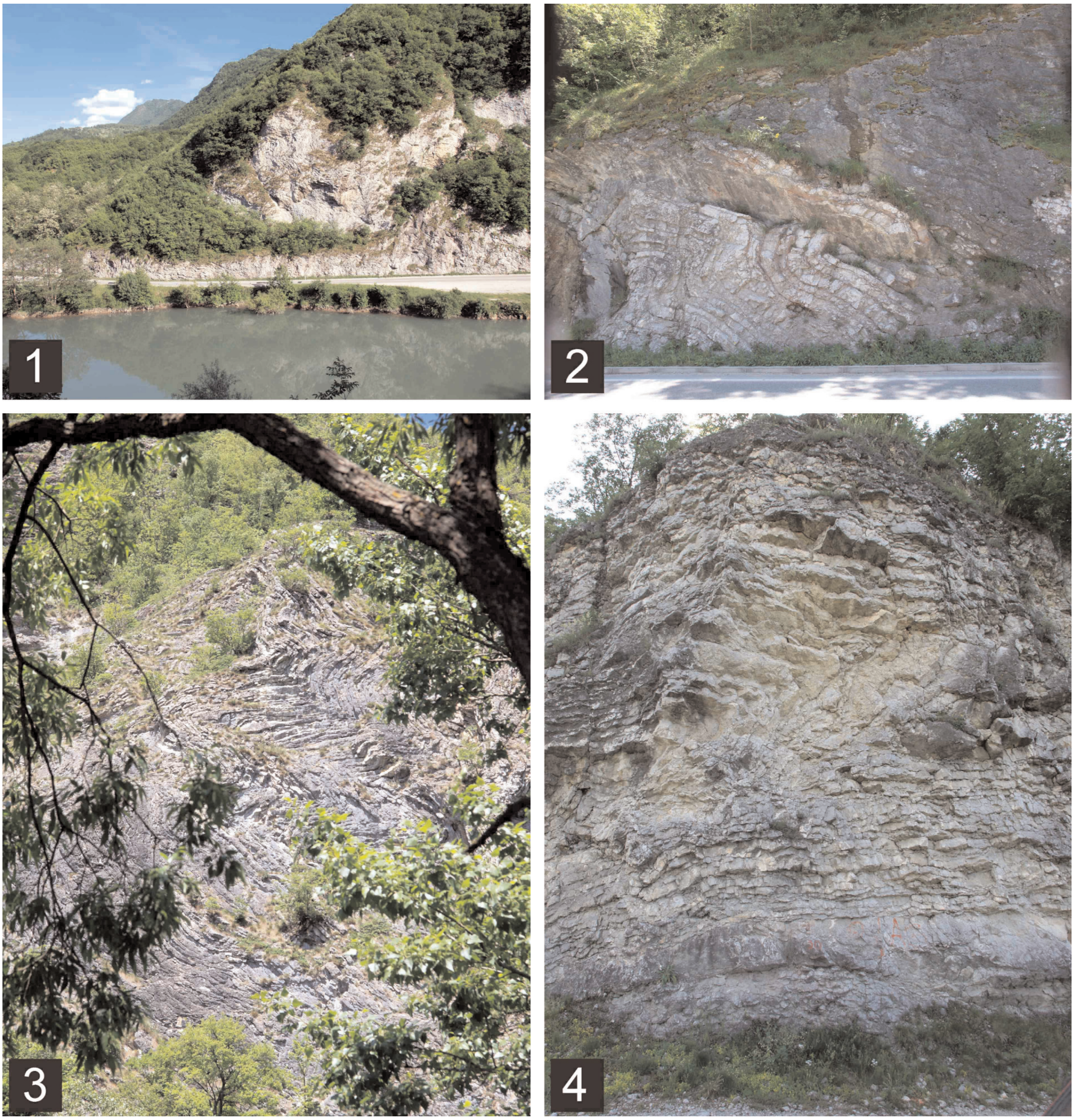

Fig. 6. Outcrop situation of the Grivska Formation on both sides along the river Lim (photos 1 and 2 show the eastern side, and photos 3 and 4 show the western side of the Lim river). **1**. Road cut of Norian dm-bedded cherty limestones, occasionally with slump folds. **2**. Slump fold of most probably Early Norian age on the road cut. **3**. Middle-Late Norian thin-bedded cherty limestones forming a huge slump deposit. **4.** Early to ?Middle Norian dm-bedded cherty limestones, occasionally the beds are amalgamated.

The Lim River

Along both sides of the Lim river, a large block of the Grivska Formation underlain and overlain by the ophiolitic mélange is preserved with huge slump deposits in all stratigraphic levels. The thickness of the Norian succession could not be determined, because it is several times doubled due to slumping. The microfacies characteristics of the Norian grey cherty limestones show only radiolarian wacke- to packstones with occasionally occurring filaments (Fig. 9). There is no difference in the microfacies characteristics of the Early Norian cherty limestones and the reddish-grey Middle/Late Norian cherty limestones. Layers with resediments are missing in this block.

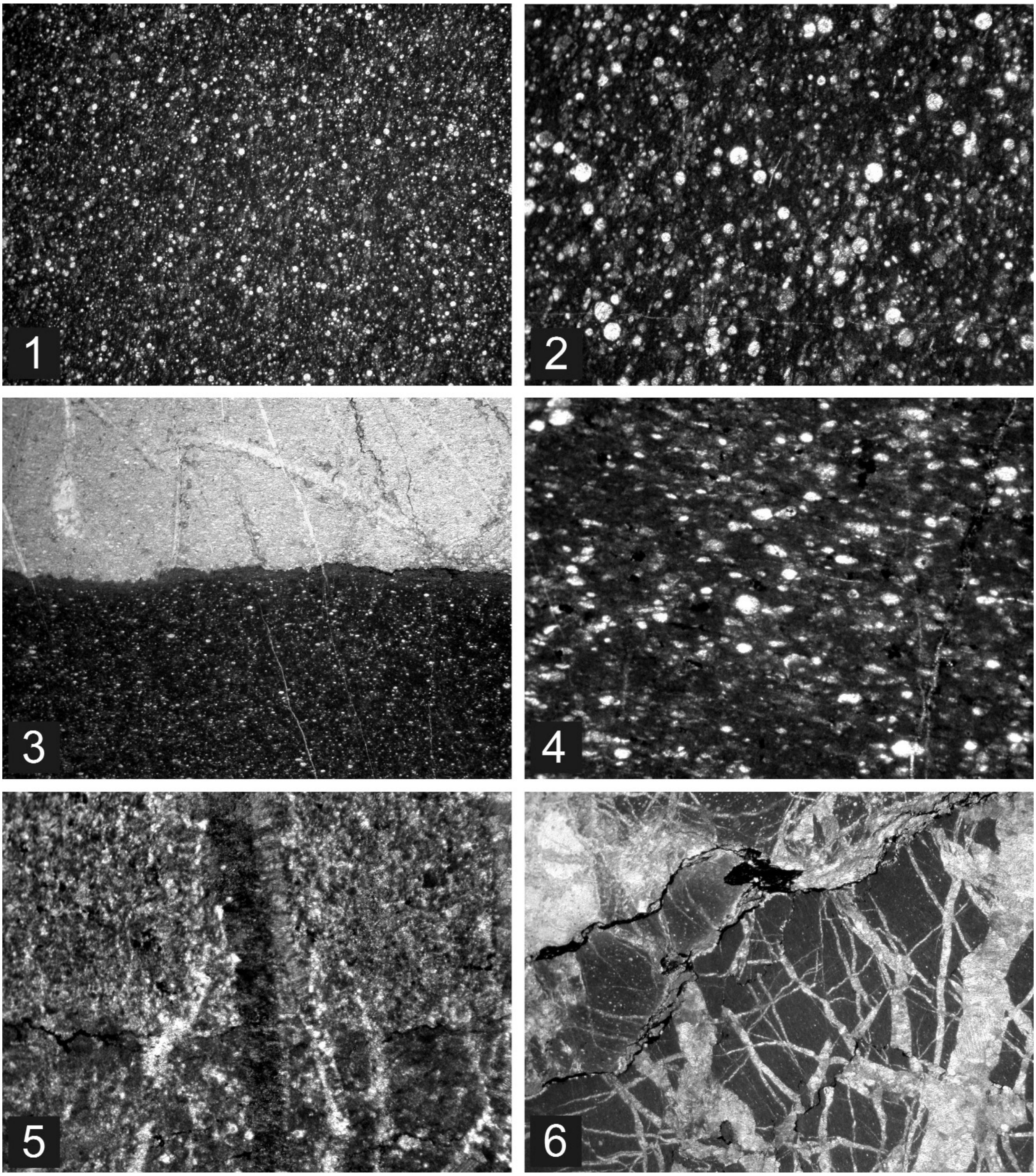

Fig. 7. Microfacies characteristics of the Late Triassic Grivska Formation from the type locality. Sediment was formed in a deep-marine depositional environment. **1**. Bioturbated radiolarian wacke- to packstone. Sample SRB 412. Width of the photograph: 1.4 cm. **2**. Enlargement of Fig. 1. Calcite filled molds of radiolarians, and with rare broken filaments. Width of the photograph: 0.5 cm. **3**. Radiolarian wackestone (lower part of the photograph) in contact with a fully silicified layer with similar microfacies. Sample SRB 414. Width of the photograph: 1.4 cm. **4**. Enlargement of the lower part from 3. Radiolarian wackestone with filaments. Width of the photograph: 0.5 cm. **5**. Layered Late Triassic wackestone with radiolarians (lower layer) and micrite clasts (upper layer). Sample SRB 484. Width of the photograph: 1.4 cm. **6**. Tectonized mud- to wackestone with recrystallized radiolarians. Sample SRB 415. Width of the photograph: 1.4 cm.

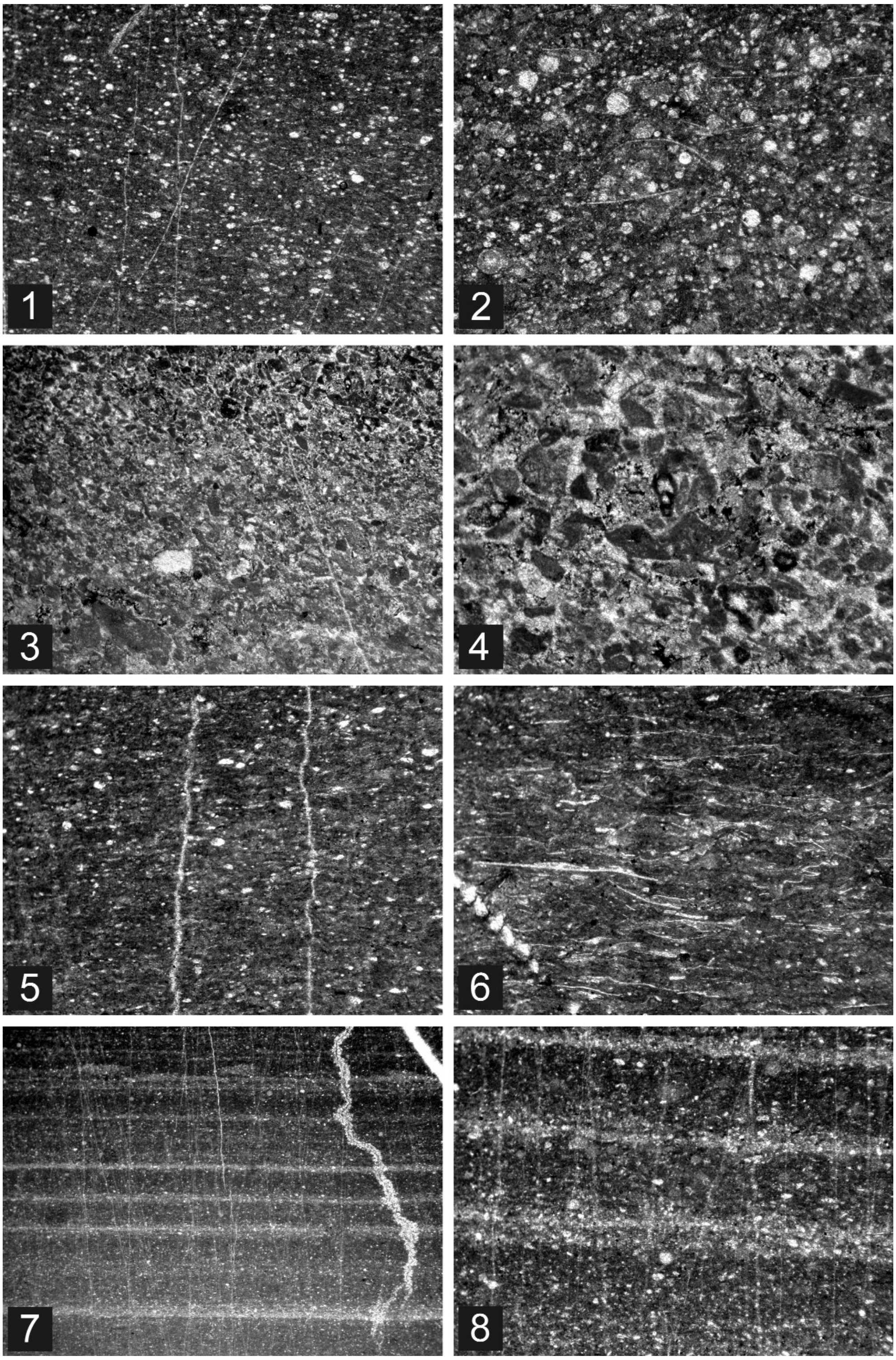

Fig. 8. Microfacies of the Grivska Formation of the Gornja Bela Reka section. **1**. Bioturbated radiolarian-filament wackestone. Radiolarians are recrystallized to calcite. Sample SRB 247. Width of the photograph: 1.4 cm. **2**. Radiolarians and filaments occur in a clotted muddy matrix. Sample SRB 248-1. Width of the photograph: 0.5 cm. **3**. Graded turbiditic layer from a slump deposits. Most clasts are micritic with rare preserved foraminifera. Sample SRB 248-2. Width of the photograph: 1.4 cm. **4**. Enlargement of Fig. 3. Micrite clasts with foraminifera. Width of the photograph: 0.5 cm. **5**. Layered muddy radiolarian-filament wackestone. Sample SRB 496. Width of the photograph: 0.5 cm. **6**. Laminated filament-wackestone with rare recrystallized radiolarians. Sample SRB 570. Width of the photograph: 0.5 cm. **7**. Laminated radiolarian-wackestone derived from a Grivska Formation block in the ophiolitic mélange, around one kilometre south of Gornja Bela Reka. All radiolarians are recrystallized to calcite. Sample SRB 498. Width of the photograph: 1.4 cm. **8**. Enlargement of Fig. 7. The coarser-grained layers with enriched radiolarians are diffuse silicified. Width of the photograph: 0.5 cm.

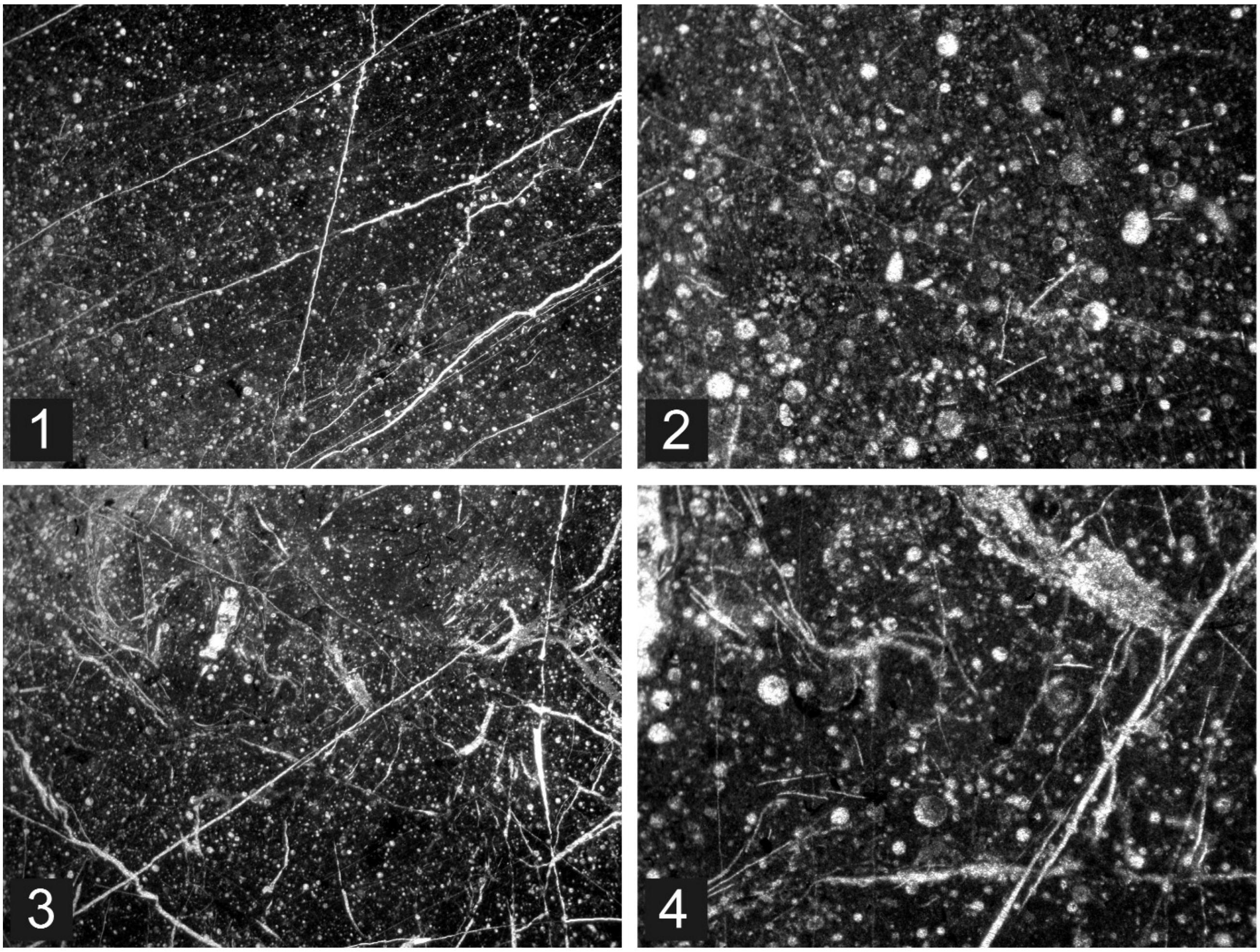

Fig. 9. Microfacies characteristics of the Lower Norian Grivska Formation along the road Bistrica-Prijepolje (Donja Bistrica). **1.** Radiolarian-wackestone to packstone, bioturbated. Sample BI-3. Width of the photograph: 1.4 cm. **2.** Enlargement of Fig. 1. With some broken filaments. All radiolarians are recrystallized to calcite. Width of the photograph: 0.5 cm. **3.** Filament-radiolarian packstone, bioturbated. Sample BI-5. Width of the photograph: 1.4 cm. **4.** Enlargement of 3. All radiolarians are recrystallized to calcite. Filaments are better preserved. Width of the photograph: 0.5 cm.

Definition of the Grivska Formation

Validity: Valid, emendation in GAWLICK et al. (2017a). After the informal description in an unpublished report by DIMITRIJEVIĆ et al. (1982)* the first more detailed investigations on this formation were published in DIMITRIJEVIĆ & DIMITRIJEVIĆ (1987, 1991).

Type section/area: Grivska village (Mali Ostreš locality – Fig. 2-A) and adjacent areas. Here the Grivska Formation occurs as blocks in the ophiolitic mélange. No continuous section of the whole Late Triassic is preserved.

Reference sections/areas: 1) Blocks of latest Carnian (Late Tuvalian) to Early and Middle Norian of the cherty limestone succession in the vicinity of Visočka Ćava peak (Fig. 2-B), 2) Block of Early to ?Middle Norian bedded grey cherty limestone in Gornja Bela Reka village and blocks in the surrounding areas (Fig. 2-B). 3) Early to Late Norian, 100 m thick and km-sized block of bedded grey cherty limestones along the road Bistrica-Prijepolje (Fig. 2-C).

Synonyms: See the historical review in the Introduction of the present paper.

Derivation of name: Name refers to Grivska village (Mali Ostreš section) along the road Visoka–Arilje (Fig. 2-A).

Lithology: Generally thin- to medium-bedded micritic grey cherty limestones, typically of radiolarian wackestone microfacies with rare filaments (Figs. 7, 8, 9).

* DIMITRIJEVIĆ, M.N., DIMITRIJEVIĆ, M.D., RADOVANOVIĆ, Z., PANTIĆ-PRODANOVIĆ, S., JOVIČIĆ, A., DOBRIĆ, D. & MILOVANOVIĆ, LJ. 1982. Formacija Grivske (Tematska geološka karta – Projekat D2, Godišnji izveštaj za 1981. godinu) [*Grivska Formation, Thematic Geologic Map – Project D2, Annual report for 1981 – in Serbian*]. Unpubl. report, Geological Institute, Beograd, 61–70.

Greenish-grey marl intercalations occur locally. More massive grey cherty limestones occur in places as well. Chert nodules and chert layers commonly occur in all slightly different lithological types, but their density differs in respect to the age. Very fine-grained turbiditic carbonate or marly layers also occur locally. This type of with fine-grained resediments were encountered either as several metres thick blocks or as tens of metres thick blocks with preserved slump folds.

Origin, facies: The Grivska Formation represents distal toe-of-slope and basin facies; it was formed on the continental slope of the Neo-Tethys Ocean or on the ocean floor near to the continental slope.

Chronostratigraphic age: Late Triassic (Early Carnian to Rhaetian; compare Gawlick et al., 2016b, 2017a), based on conodont and radiolarian dating.

Thickness: Approximately 300 m. The thickness cannot be exactly measured since the Grivska Formation is only preserved as isolated blocks in the ophiolitic mélange. Each block has only a limited stratigraphic age range in the dismembered succession.

Lithostratigraphically higher rank: Grivska Group (Missoni et al., 2012).

Underlying units (foot wall boundary): Late Anisian to Late Ladinian radiolarites, in the earliest Carnian radiolarites with intercalated micritic limestone layers (Gawlick et al. 2016b), as preserved in one block in the Visoka area. The higher Julian ("Middle Carnian" siliciclastic event) has not been proven, but radiolaritic-argillaceous sedimentary rocks can be expected.

Overlying units (hanging wall boundary): Not known.

Geographic distribution: Mélange areas of the Dinaridic Ophiolite Belt, mainly in the ophiolitic mélange. In these mélanges, the Grivska Formation occurs as redeposited clasts and blocks reaching several 100 metres in size. These blocks derived from the distal continental slope or the proximal oceanic realm as evidenced from the whole component spectrum in the ophiolitic mélange (Gawlick et al. 2016b). In tectonic units to the east of the Dinaridic Ophiolite Belt it can be expected that the continental slope is incorporated in the Middle-Late Jurassic accretionary wedge and, therefore, only metamorphosed sedimentary rocks are preserved. Similar grey cherty and marly limestone successions are widespread in the Inner Dinarides east of the Dinaridic Ophiolite Belt. However, they differ slightly in their lithofacies and microfacies characteristics. Schefer et al. (2010) defined the Kopaonik Formation in the Kopaonik Unit (Kopaonik Mt.). The Kopaonik Formation is characterized by fine-grained resediment layers in practically all stratigraphic levels, by a higher marl content and a radiolarian poor microfacies. Sudar (1986) introduced the Gučevo Formation in the Jadar Unit for a similar rock type (see remarks). According to our present-day knowledge the stratigraphic range of the Gučevo Formation is Carnian to Norian, and the stratigraphic range of the Kopaonik Formation is Late Anisian to ?Early Jurassic (see remarks). In the area of Ležimir in the southern Fruška Gora Mt. (northern Serbia, Vardar Zone Western Belt) Toljić et al. (2013) assigned metamorphosed nodular limestones and carbonate schists to the Grivska Formation, but without detailed age dating and microfacies analysis. Parts of these occurrences may belong to the Grivska Formation, but further studies are needed. Late Triassic cherty limestones in the Lim Unit of the East Bosnian-Durmitor Megaunit, and a Late Triassic reefal and slope facies (Dimitrijević, 1982, 1997; Dimitrijević & Sikošek, 1997) most probably do not belong to the Grivska Formation, but detailed studies on these successions are lacking.

Lateral units: Towards the ocean radiolarites and towards the distal open shelf Hallstatt Limestones.

Remarks: If we define the Grivska Group as consisting of all Middle to Late Triassic grey cherty limestone successions representing open-marine (hemi- or eu-pelagic) sedimentary rocks, i.e. deposited in the outer shelf region (Hallstatt facies zone) following formation has to be included: the Grivska Formation, parts of Kopaonik Formation, and the Trnava Formation. The Klisura Member, as the lowermost part of the Trnava Formation (Fig. 3) would be today more convincingly placed into the Nova Varoš Group (Gawlick et al., 2017a). As transitional sedimentary succession between the formations of the Nova Varoš Group and the open marine limestones with chert nodules and layers of resediments from the prograding Wetterstein Carbonate Platform (=Trnava Formation), the Klisura Member can also attributed as a part of the Trnava Formation in the Grivska Group.

The Rid section is located near to the village Zbojštica, south of Užice (Fig. 2). It was described for the first time by Dimitrijević & Dimitrijević (1991) as belonging to their Grivska Formation. But this grey cherty limestone succession is of Late Anisian age and it is a part of the original Mesozoic succession of the Drina-Ivanjica Unit, as described by Sudar et al. (2013). Palaeogeographically, the Late Anisian (Middle/Late Illyrian) sedimentary rocks of the Rid section were deposited more continentward than the coeval Bulog Formation which was formed on the outer shelf. For this type of Anisian grey cherty limestone successions with intercalations containing redeposited shallow-water grains the name Rid Formation was introduced by Sudar et al. (2013). The Rid Formation, therefore, is not part of the Grivska Group. Further detailed investigations are needed on the metamorphosed Kopaonik Formation to clarify the differences between the Middle Triassic and Late Triassic part of the succession. Although no radiolaritic Middle Triassic interval has been reported from the Kopaonik Formation, it was probably overlooked or wrongly attributed to other formations due to the fact that all successions in the Kopaonik Unit underwent intense tectonics and metamorphism. The question if the Gučevo Formation belongs to the Grivska Group or is a synonym of the Grivska Formation is still open.

The (latest Ladinian) to Early Carnian thin- to medium-bedded fine grained cherty limestones with intercalated volcanic ash layers and thin claystone layers in the area of Nova Varoš were earlier classed into the Grivska Formation (Dimitrijević 1997). Although the lithological features of this succession are occasionally macroscopically similar to those of the Grivska Formation, the microfacies characteristics are different (Gawlick et al. 2017a). In addition, the overlying und underlying sedimentary rocks are also different. Therefore, Gawlick et al. (2017a) introduced the name Zlošnica Formation for this succession. The ?Late Ladinian to Early Carnian ("Cordevolian") Zlošnica Formation can be roughly seen as a mixture of the Raming and Partnach Formations in the Northern Calcareous Alps (Gawlick et al., 2017a for details).

The Late Triassic successions in the eastern regions of the East Bosnian-Durmitor Megaunit (Lim Unit) e.g., Sutjeska canyon in the vicinity of Rudo (Sudar, unpublished data) and in the Gradac area around Pljevlja (Sudar 1986) are not investigated in detail. Whether these grey cherty limestone sequences are part of the Grivska Formation or they belong to other formations can only be decided after detailed stratigraphic and microfacies studies.

The Early Jurassic or Early to Late Jurassic cherty limestone successions (e.g., Strmenica site on the Jadovnik Mt. or section on the eastern side of Trijebinska Reka valley near the town Sjenica) were classed also to the "Grivska Formation" (Dimitrijević, 1997; Radovanović et al., 2004; Radovanović & Popević, 2005) although they show significantly different litho- and microfacies characteristics. Accordingly, the definition of a new formation is needed. These successions belong to the parautochthonous basement of the Dinaridic Ophiolite Belt with completely different under- and overlying sedimentary sequences.

Discussion

Biostratigraphic age dating accompanied by detailed microfacies studies as a need for the definition of formations based on the rules of lithostratigraphy were not carried out during production of the Thematic Geological Map of Serbia (1:50000). Therefore, it was not possible to elaborate up-to-date geological maps, i.e. mapping of formations. As a result, the geological maps produced during and since that period show the estimated age of the mapped rocks regardless to their facies characteristics.

More recent investigation on several grey cherty limestone successions including biostratigraphic age dating and microfacies analysis pointed out, that in former times similar depositional and diagenetic conditions in different time spans existed. Therefore, a mixture of different formations with similar lithological characteristics was incorporated into the Grivska Formation. In fact, the grey cherty limestone successions differ significantly in their age range, microfacies characteristics and the underlying or overlying sedimentary successions. To solve this problem, Missoni et al. (2012) defined the latest Ladinian to Early Carnian Trnava Formation, with the Late Ladinian Klisura Member at its base, as a part of the Grivska Group. Sudar et al. (2013) defined the Illyrian Rid Formation.

Missoni et al. (2012, p. 102) wrote about the history and the general usage of the term "Grivska Formation": *"Up to now the name Grivska Formation is a potpourri for all Ladinian to Late Jurassic bedded limestones with cherts in the Dinaridic Ophiolite Belt (e.g., Dimitrijević, 1997; Radovanović and Popević, 1999; and many others). Due to the fact that in this case the name Grivska Formation summarizes a lot of genetically different sedimentary successions, we restrict the name Grivska to Triassic hemipelagic sequences and advocate for the name Grivska Group. This group should contain in future all different Middle and Late Triassic hemipelagic bedded cherty limestones with shallow-water debris. The originally introduced (Triassic to Jurassic) Grivska Formation needs a complete revision, a modern definition, and a new type-section."* These first steps to disentangle the Gordian knot of the Grivska Formation potpourri without a detailed reinvestigation of the type locality and based on the statements of Dimitrijević (1997) resulted in this inaccurate interpretation of the Grivska Group as "*hemipelagic bedded cherty limestones with shallow-water debris"* (Missoni et al., 2012), now exactly specified.

Based on the new studies and the microfacies, lithofacies, and depositional characteristics of the different limestone blocks in the ophiolitic mélange the Grivska Formation consists of two groups of sedimentary rocks:

1) Dm-bedded, micritic cherty limestones, occasionally with very fine-grained turbiditic layers or marly layers of commonly Early Norian age. Slump folds are a typical sedimentological feature. The microfacies show mainly radiolarian wackestones occasionally with intercalated turbidites with filaments and radiolarians. The microfacies characteristics of the dm-bedded and the thinly-bedded Carnian or Middle Norian to Rhaetian grey cherty limestones are practically identical. This microfacies resemble the microfacies known from the Early Norian Massiger Hellkalk of the Hallstatt Facies Zone, or the Pötschen Limestone of the Meliata Facies Zone (Gawlick et al., 2016b). Lithology and microfacies combined point to an intermediate type between Hallstatt and Pötschen facies, i.e. deposition on the continental slope.

2) The Middle/Late Norian to Rhaetian is made of bedded greyish to reddish cherty limestones with occasionally thick chert layers and greenish-grey marls. Lithology and microfacies resemble the Pötschen Limestone of the Meliata Facies Zone (continental slope: Fig. 3).

The onset of development of the Wetterstein Carbonate Platform in the latest Ladinian led to increasing export of carbonate mud towards the outermost shelf area and this resulted in a change in deposition on the continental slope. Towards the distal passive margin, the Late Ladinian radiolarite/limestone succession is substituted more and more by Early Carnian pure grey cherty limestones (GAWLICK et al., 2016b). On the continental slope, the radiolaritic successions progressed to more and more carbonate dominated sediments. Parts of the Kopaonik Formation (SCHEFER et al., 2010) and the Trnava Formation (MISSONI et al., 2012) clearly document a high carbonate mud export from the Wetterstein Carbonate Platform area towards the Neo-Tethys Ocean.

Increasing carbonate production, especially during the Early Carnian Wetterstein Carbonate Platform and Late Carnian to Rhaetian Dachstein Carbonate Platform evolutions, is manifested in an increasing amount of carbonate turbidites beside the export of carbonate mud from the platform towards the open shelf elsewhere in the western Tethyan realm (highstand shedding in sense of DROXLER & SCHLAGER, 1985; GAWLICK & BÖHM, 2000). This model works also for practically the entire Jurassic before planktonic carbonate production starts in rock forming quantities (BRALOWER et al., 1991; FLÜGEL, 2004 with references therein). The carbonate export to the open shelf environments was mainly triggered in Early-Middle Jurassic times by the evolution of the Adria Carbonate Platform (VLAHOVIĆ et al. 2005) and in the Late Jurassic by the Adria Carbonate Platform and the newly formed Plassen Carbonate Platform and its equivalents (SCHLAGINTWEIT et al., 2008).

The facies characteristics of the Grivska Formation can slightly differ in respect to the depositional realm respectively the water depth on the continental slope with deepening towards the oceanic depositional realm. Whereas in the upper part of the continental slope – especially in the latest Ladinian to early Early Carnian – relatively carbonate-rich grey limestones were deposited (see: lateral units in chapter Definition of the Grivska Formation) the lower part of the continental slope is characterized by a radiolarite-limestone succession (e.g., GAWLICK et al. 2016b). Similar Carnian sedimentary sequences can also be expected on the continental slope near to the oceanic realm, but with increasing radiolarite content (compare GAWLICK et al. 2008). In contrast to the evolution of the Norian-Rhaetian Dachstein Carbonate Platform with an enormous amount of carbonate export in direction to the distal passive margin respectively the Neo-Tethys oceanic realm, the export of calcareous mud from the Wetterstein Carbonate Platform to the outer shelf areas is seen as much lower, deduced from existing sedimentary outer shelf sedimentary successions (e.g., GAWLICK & MISSONI, 2015). In the Norian–Rhaetian, the calcareous mud from the Dachstein Carbonate Platform is clearly visible also in the continental slope near oceanic domain (e.g., GAWLICK et al., 2016a) whereas, in contrast, in the latest Ladinian to Early Carnian radiolarite/limestone sequences were deposited in this depositional realm. In cases the mixed radiolarite/limestone deposition could be replaced by pure radiolarite deposition in the latest Ladinian or the "Middle" Carnian before the rapid earliest Carnian Wetterstein Carbonate Platform progradation of after the demise of the Wetterstein Carbonate Platform.

Conclusions

The reinvestigation of the type area around the village Grivska and in adjacent areas (GAWLICK et al., 2016b, 2017a) and this contribution points out, that

1) All cherty limestone successions in the type area have a Late Triassic (Early Carnian to Rhaetian) age,
2) The cherty limestones in the type area occur as blocks in the ophiolitic mélange,
3) The microfacies of all cherty limestones is characterized by radiolarian- and filament-bearing wackestones; only occasionally (in the Early Norian) fine-grained turbiditic limestone intercalations occur. Shallow-water components derived from platforms are practically missing, only very fine-grained resediment layers occur in slump deposits,
4) There is a remarkable lithological change around the Ladinian/Carnian boundary from radiolarites (Late Anisian to Ladinian) to more calcareous deposits. This change from radiolarite to cherty limestone deposition is triggered by the onset of the Wetterstein Carbonate Platform evolution and the increase of carbonate export to the outer shelf during that time.

The distal shelf area is characterized by the deposition of a Hallstatt Limestone sequence as typical elsewhere (e.g., KRYSTYN, 2008; GAWLICK et al., 2017a, b) and grey cherty limestone were deposited on the continental slope and the proximal parts of the oceanic domain. According to the age and the microfacies (GAWLICK et al., 2016b), the limestones of the Grivska Formation were deposited on the continental slope or in the proximal oceanic realm (Fig. 10) and are comparable to the Pötschen Formation (type locality) in the Northern Calcareous Alps (compare MISSONI & GAWLICK, 2011) or to the grey cherty limestones of the Meliata facies (type locality) in the Western Carpathians (see GAWLICK & MISSONI, 2015).

The reconstruction of the Triassic-Jurassic tectonostratigraphic evolution of the Inner Dinarides is based on the tectonic events forming the depositional realms for the different sedimentary successions (=lithostratigraphic units), and place the formations in respect to their event-related deposition within a palaeogeographic domain (Gawlick et al., 2017a). On this base it is possible to define the Triassic-Jurassic history of the Inner Dinarides with special emphasis on the area of the Dinaridic Ophiolite Belt as history of the eastern shelf of a continent (Adria or Apulia in the literature) facing the Neo-Tethys Ocean to the east (Fig. 10). Continental rifting in this domain started with graben formation in the Late Permian and the oceanic break-up started in the Late Pelsonian respectively around the Pelsonian/Illyrian boundary. Partial closure of the Neo-Tethys Ocean (= western Neo-Tethys Ocean) started most probably around the Early/Middle Jurassic boundary and westward-directed ophiolite obduction started in the Middle Jurassic (~Bajocian), creating the ophiolitic mélange with components from the continental slope (cherty limestones of Grivska Formation) incorporated. The ophiolite obduction lasted until the Late Jurassic.

In the Dinaridic Ophiolite Belt, this type of open-marine cherty limestones (= the Grivska Formation) occur only as blocks in the ophiolitic mélange and are therefore very important for palaeogeographic reconstructions and the reconstruction of the Triassic-Jurassic geodynamic history of the Inner Dinarides. The sedimentary rocks of the continental slope (Grivska Formation) and the outer shelf region (Hallstatt facies) are found only in sedimentary mélanges and are interpreted to be incorporated in the deep-water troughs in front of the advancing nappe stack. The thrust sheets of the former passive margin were successively fragmented and incorporated into the nappe stack in front of the westward obducting ophiolites, i.e. the continental slope (Meliata facies, Grivska Formation) in the first stage of obduction, and later also the outer shelf region (Hallstatt facies).

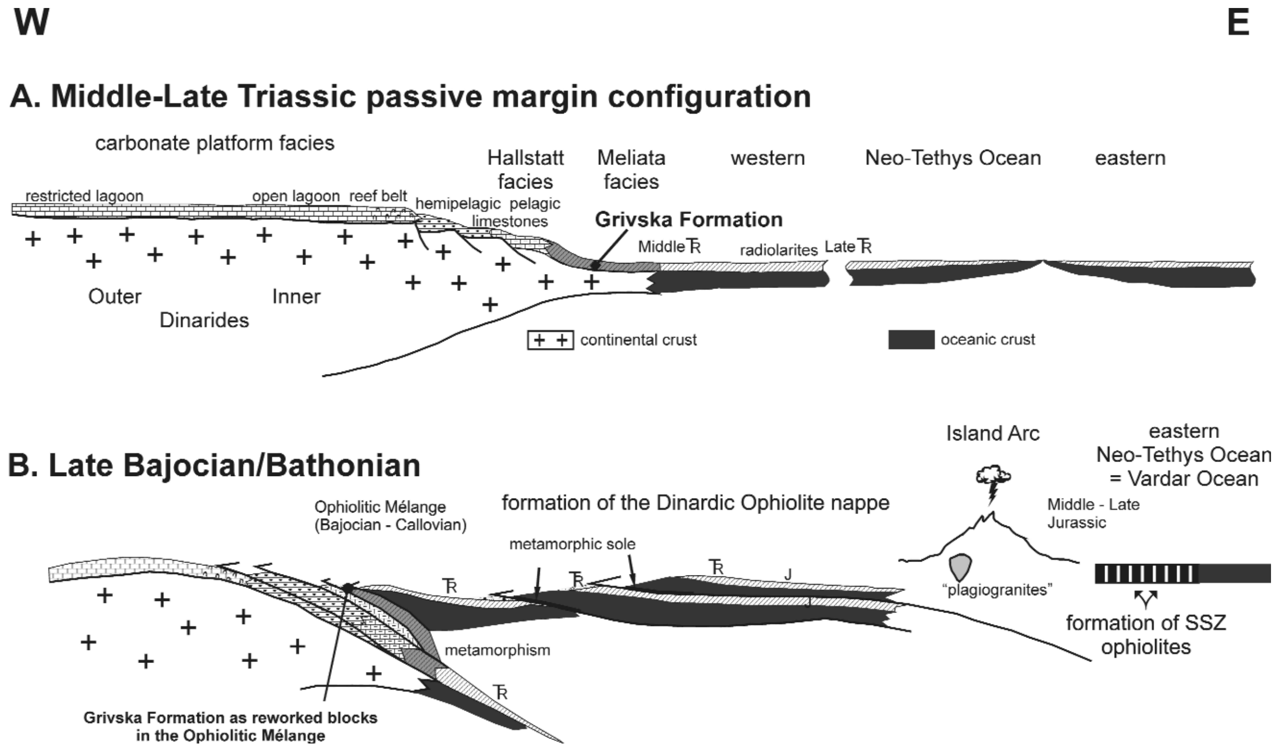

Fig. 10: Triassic-Jurassic evolution of the western Neo-Tethys margin after Gawlick et al. (2016b). **A**. Middle to Late Triassic passive margin configuration (compare Fig. 2). Generation of oceanic crust started in the Late Anisian in the Neo-Tethys realm. The formation of an oceanic basin (Dinaridic Ocean) between the Outer (Triassic restricted lagoon) and Inner Dinarides (Triassic open lagoon, reef belt and transitional facies) is not possible due to the missing facies transitions from the lagoon to the open marine environment. **B**. Onset of ophiolite obduction in the Bajocian and formation of the ophiolitic mélange. The most westward trench-like basin is filled with ophiolitic material mixed with material from the continental slope (Grivska Formation).

Acknowledgements

The research of M. Sudar was supported by the Ministry of Education, Science and Technological Development of the Republic of Serbia (Project ON-176015) and also by the

Serbian Academy of Sciences and Arts (Project F-12). In the frame of the CEEPUS Network CIII-RO-0038 Earth-Science Studies in Central and South-Eastern Europe (H.-J. Gawlick). Reviews and suggestions of Roman Aubrecht (Bratislava, Slovakia) and János Haas (Budapest, Hungary) helped to improve the quality of the manuscript and are gratefully acknowledged.

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Резиме

Формација Гривска у типској области (Динаридски офиолитски појас, ЈЗ Србија): измена и дефинисање

Секвенце сивих кречњака са рожнацима су често присутне у тријаским и јурским седиментним сукцесијама у домену западног Тетиса: слични депозициони и дијагенетски услови омогућили су њихово образовање на различитим местима.

Формацију Гривска су неформално установили Dimitrijević & Dimitrijević (1987, 1991). Користећи само ретке палеонтолошке податке из препарата, Dimitrijević & Dimitrijević (1991, стр. 32) су закључили: „*Изгледа да су ови слојеви синхрони са доњим делом Ветерштајн формације (ладин).*“ Касније је, само на основу видљивих макроскопских карактеристика литофација, у већини случајева без пратеће одредбе старости, као и без детаљнијих микрофацијалних истраживања, назив „Формација Гривска“ коришћен за све сиве кречњаке са рожнацима у Динаридском офиолитском појасу (Сл. 1; Dimitrijević, 1997; Dimitrijević et al., 2003; Radovanović, 2000; Radovanović et al., 2004; Chiari et al., 2011), или у западном појасу Вардарске зоне (Toljić et al., 2013). У унутрашњим Динаридима термин „Формација Гривска“ све до данас је погрешно употребљаван за све средњотријаске до средњо (?горњо) јурске сиве кречњаке са рожнацима. Важно је да се напомене да старост већине наведених секвенци сивих кречњака са рожнацима уопште није била адекватно истраживана.

Новија истраживања неколико сукцесија сивих кречњака са рожнацима, која су обухватила биостратиграфска одређивања старости и микрофацијалну анализу, указала су да се раније њихова старост процењивала само на основу макроскопски видљивих литолошких карактеристика. Игноришући чињеницу да у различитим распонима времена могу да постоје слични депозициони и дијагенетски услови, мешавина различитих формација је била приписивана Формацији Гривска. У суштини сиви кречњаци са рожнацима се значајно разликују по старосном рангу, микрофацијалним карактеристикама, као и по подинским или повлатним секвенцама.

Поновна истраживања на типском локалитету Мали Остреш јужно од села Гривска на Златибору (Сл. 2-А), као и детаљне анализе појединих блокова са рожнацима у офиолитском меланжу из других области (Gawlick et al., 2016b, 2017a), омогућила су по први пут исправну дефиницију још увек у одређеној мери енигматичне Формације Гривска и тиме јасно указала на следеће:

1) Сви кречњаци са рожнацима у типској области су горњотријаске старости (доњи карн – рет),

2) Сви кречњаци са рожнацима у типској области су блокови у офиолитском меланжу,

3) Карактеристична микрофација је векстон са радиоларијама и филаментима; само се понегде (у доњем нору) појављују танки слојеви финозрних турбидитских кречњака. Плитководне компоненте са платформе практично недостају; веома финозрни реседиментовани слојеви су ретки у специфичним стратиграфским слојевима,

4) Око ладинско/карнијске границе карактеристике горњоанизијске до ладинске депозиције мењају се постепено од радиоларијског до израженијег кречњачког таложења. Ова промена, од радиоларијске до депозиције кречњака са рожнацима је покретач који је повезан за почетак еволуције Ветерштајнске карбонатне платформе и пораст карбонатне продукције током времена.

Област дисталног шелфа је окарактерисана депозицијом секвенце Халштатских кречњака типичних на многим местима (нпр. Krystyn, 2008; Gawlick et al., 2017a, b), док су на континенталној падини и проксималним деловима океанског домена депоновани сиви кречњаци са рожнацима. На основу старости и микрофација (Gawlick et al. 2016a) кречњаци са рожнацима Формације Гривска су се таложили на континенталној падини или на проксималној океанској области (Сл. 10) и могу да се упореде са Формацијом Печен (типски локалитет) у Северним Кречњачким Алпима (упореди Missoni & Gawlick, 2011) или са сивим кречњацима са рожнацима Мелијата фације (типски

локалитет) у Западним Карпатима (види Gawlick & Missoni, 2015).

Реконструкција тријаско-јурске тектоностратиграфске еволуције унутрашњих Динарида заснована је на тектонским догађајима који су створили депозиционе просторе за различите седиментне сукцесије (= литостратиграфске јединице), и за место формације везаних за те догађаје у оквиру палеогеографског домена (Gawlick et al., 2017a). На основу тога, могуће је дефинисати тријаско-јурску историју унутрашњих Динарида, са специјалним нагласком на Динаридски офиолитски појас, као историју источног шелфа континента (Адрија или Апулија у литератури) окренутог према Неотетиском океану ка истоку (Сл. 10). Ширење је у овом домену започело формирањем грабена у горњем перму док је разламање океанског простора отпочело у горњем пелсону односно приближно око границе пелсон/илир. Делимично затварање Неотетиског океана (= западни Неотетис) највероватније је почело око границе доња/средња јура и обдукција офиолита у правцу запада започела је у средњој јури (~ бајес), образујући најмлађи офиолитски меланж са компонентама из континенталне коре (кречњаци са рожнацима Формације Гривска). Обдукција је трајала до горње јуре.

У Динаридском офиолитском појасу овакав тип кречњака са рожнацима појављује се само у виду класта или блокова у офиолитском меланжу и зато су веома важни за палеогеографске реконструкције, као и за реконструкцију тријаско-јурске геодинамичке историје унутрашњих Динарида. Седиментне стене континенталне падине (Формација Гривска) и спољњег региона шелфа (Халштатска фација) налазе се само у седиментним меланжима, а интерпретиране су као саставни део дубоководних трогова испред система навлака. Навучени делови раније пасивне маргине су били сукцесивно фрагментирани и уклопљени у системе навлака формираних испред офиолита који су се обдуковали ка западу, тј. творевине континенталне падине (Мелијата фација, Формација Гривска) у првом стадијуму обдукције, а касније и региони спољњег шелфа (Халштатска фација).

Manuscript recieved January 29, 2018
Revised manuscript accepted April 23, 2018