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Demise of the Wetterstein Carbonate Platform and onset of the Dachstein Carbonate Platform recorded in deep-water successions of the East Bosnian–Durmitor megaunit (Pliješevina, northern Montenegro, Dinarides)

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Abstract: During the latest Ladinian to earliest Carnian, the Wetterstein Carbonate Platform evolution led to the formation of the first rimmed platforms in the Western Tethys Realm after the Permian/Triassic mass extinction. The overall demise of the Wetterstein Carbonate Platform is related to the Lunz event (Reingraben event, Mid-Carnian Pluvial Episode or Mid-Carnian Wet Intermezzo – Julian 2). However, several questions remain open when comparing the platform demise in the Eastern Alps, the Southern Alps, and the Western Carpathians (ALCAPA) with its demise in the Dinarides/Albanides/Hellenides, where these siliciclastics are practically unknown, except the Outer Dinarides in Croatia or Montenegro (High Karst). Prior to the drowning of the Wetterstein Carbonate Platform in the ALCAPA region with siliciclastics, the platform emerged due to a sea-level drop around the Julian 1/2 boundary (*Carnica* event). The underfilled accommodation space between the platforms is characterized by restricted deep basinal areas with deposition of organic-rich siliceous limestones, followed by the deposition of fine-grained siliciclastics (Reingraben claystones). In contrast to the ALCAPA region a long-lasting stratigraphic gap is common in the Carnian in the Dinarides/Albanides/Hellenides. Carbonate deposition resumed during the Late Carnian after the demise and uplift of the Wetterstein Carbonate Platform. In northern Montenegro, near the village Pliješevina, the final demise of the Wetterstein Carbonate Platform around the Julian 1/2 boundary can be dated by conodont faunas (*Carnica* conodont zone) in a newly detected Carnian basinal sequence. Above the fine-grained resediments of the Wetterstein Carbonate Platform (Zlošnica Formation), less then 3 m of grey "filament"- and radiolarian-rich biomicrites were deposited, followed upsection by a ~6 m-thick sequence of siliceous claystones, black cherts and silicified volcanic ashes (Džeguruša Formation). The carbonate-free intercalated metabentonites of Julian 2 to Tuvalian age are composed of (biogenic) quartz, and clay minerals of the mica-group (mainly illite), montmorillonite, the smectite group, and mixed layer clay minerals. A controversially discussed environmental change around the Julian 1/2 boundary resulted in the demise of the Wetterstein Carbonate Platform and carbonate deposition was replaced by deposition of siliciclastics. Carbonate production reflecting the onset of a precursor of the Dachstein Carbonate Platform evolution started again during the latest Carnian as dated by conodonts.

Keywords: Triassic, *Carnica* event, clay mineralogy, conodont biostratigraphy, Neo-Tethys

Introduction

The Late Triassic sedimentary evolution of the East Bosnian–Durmitor megaunit (Fig. 1) in the Dinarides is interpreted as a relatively continuous succession formed by shallow-water carbonates (Dimitrijević 1997; Kovács et al. 2010, 2014), with the exception of some deep-water successions, deposited according to the autochthonous concept of Rampnoux (1974) in isolated deep-water basins (Lim Basin with Ćehotina and Zlatar sub-basins) situated between shallow-water platforms. In platform areas, the Upper Triassic deposits typically start with shallow-water limestones of the Wetterstein Carbonate Platform evolution in the Lower Carnian (Fig. 2), which are directly overlain by the Upper Carnian to Rhaetian shallow-water limestones of the Dachstein Carbonate Platform (for details Dimitrijević 1997; Kovács et al. 2010). In contrast, siliceous, dm-bedded limestones were deposited in the two intraplatform sub-basins throughout the whole Late Triassic (Rampnoux 1974), i.e. in an autochthonous position.

This concept of carbonate platforms with long-lasting (Middle to Late Triassic) intra-platform basins in between was recently questioned on the basis of the following new data:

- The Upper Triassic deep-water limestones are far-travelled allochthonous nappes. Their provenance area is the open shelf (Fig. 2) area to east of the today´s Dinarides

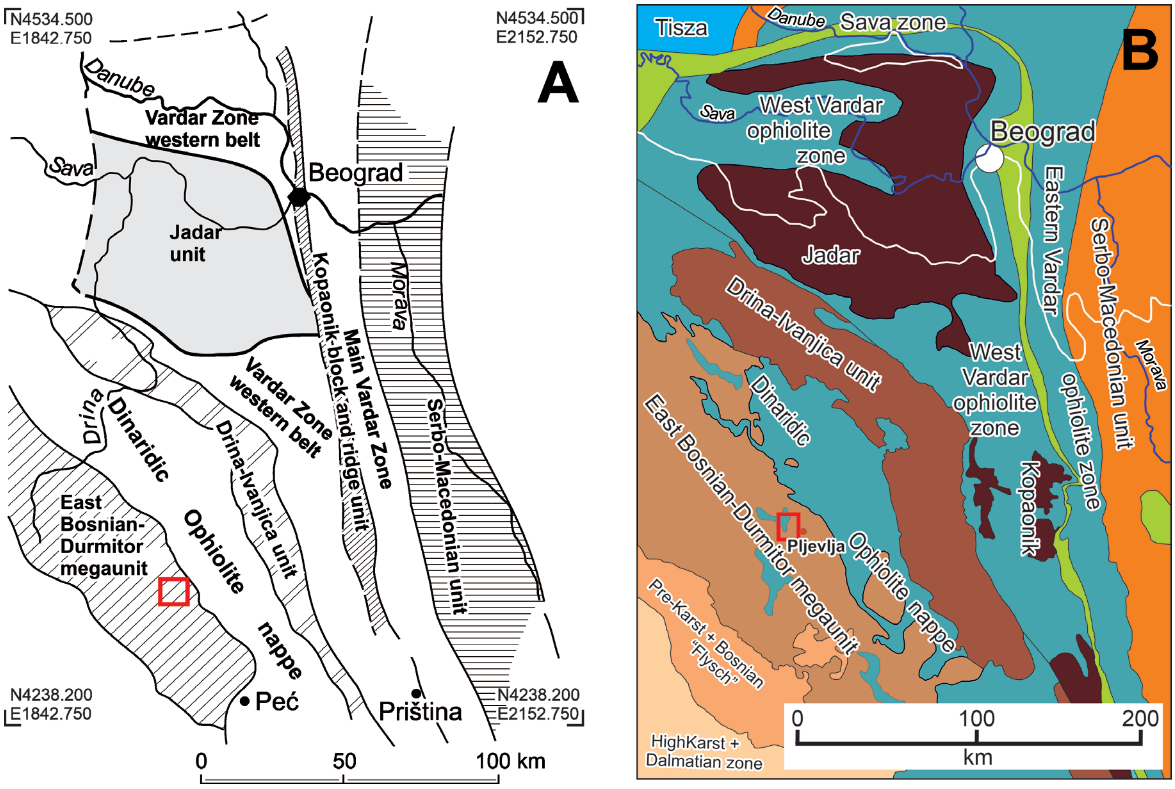


Fig. 1. Overall tectonic maps of the study area between the Drina–Ivanjica unit in the north and the East Bosnian–Durmitor megaunit in the south roughly indicated by the red box (see Fig. 3 for geographical details). **A** — Tectonic units (and terranes) of the central Balkan Peninsula in the sense of Karamata (2006) following in general Kossmat (1924). See also: Aubouin (1973), Dimitrijević (1997). **B** — Tectonic units of the central Balkan Peninsula according to Schmid et al. (2008, 2020). In the area of the East Bosnian–Durmitor megaunit and the Dinaridic Ophiolite nappe redrawn after the results of Gawlick et al. (2017). For an explanation of the different units see Schmid et al. (2008), but compare Gawlick et al. (2017, 2020).

(sedimentary mélanges; Gawlick et al. 2017, 2018; Sudar & Gawlick 2018; Gawlick & Missoni 2019). They were transported to the west in the frame of Middle–Late Jurassic ophiolite obduction (Gawlick et al. 2008; Schmid et al. 2008), and form tectonic outliers on top of the East Bosnian–Durmitor megaunit (Goričan et al. 2022; Mrdak et al. 2022; for Ćehotina sub-basin).

- A continuous Late Triassic shallow-water transition from the Wetterstein Carbonate Platform to the Dachstein Carbonate Platform is not preserved anywhere in the Western Tethys Realm: in most of the mountain ranges in the eastern Mediterranean (i.e. Eastern and Southern Alps, Western Carpathians = ALCAPA; Outer Dinarides), the Wetterstein Carbonate Platform evolution ended with the "Mid-Carnian" Reingraben turnover according to Schlager & Schöllnberger (1974). In the Eastern/Southern Alps, the Western Carpathians, and the External = Outer Dinarides of Croatia and Montenegro (High Karst unit), this event is characterized by the shift from carbonate to siliciclastic deposits (Tollmann 1985; Tišljar et al. 1991; Tišljar 2001; Keim et al. 2006; Havrila 2011). The Wetterstein Carbonate Platforms were overlain by Julian 2 to Tuvalian siliciclastics due to a sea-level rise (Lein 1987; Keim et al. 2006; Lein et al. 2012; Brandner et al. 2016), representing therefore a typical drowning event following the definition of Schlager (1989, 2005). This sea-level rise to highstand is detected in deposits corresponding to the upper Julian 2 (*A. austriacum* ammonoid zone) rather than at the Julian 1/2 boundary (Haq 2018). In contrast, in the Inner Dinarides, a long-lasting stratigraphic gap between these two platform mega-cycles was recognized (Missoni et al. 2012), which is also proven in the Carnian basinal grey siliceous limestones of the former Ćehotina sub-basin of the Lim Basin (Sudar 1986). This long-lasting stratigraphic gap between the Wetterstein and Dachstein Carbonate platforms is characterized by block tilting, emersion and deep erosion (Vlahović et al. 2005 and references therein), and in some cases, by the formation of bauxites (Marković 2002; Pajović et al. 2017 and references therein). However, siliciclastic Julian 2 to Tuvalian deposits were not documented in the Inner or the Outer Dinarides of Serbia and Montenegro, except a few localities in the High Karst unit where sandy limestones and marls with coal interlayers of the so-called Raibl beds of Carnian age were deposited above cherty limestones (Pantić 1956, 1957; Vujisić 1975).
- The Wetterstein Carbonate Platform evolution started in the Inner Dinarides during the latest Ladinian (Drina–Ivanjica unit and units to the east – Missoni et al. 2012; Gawlick

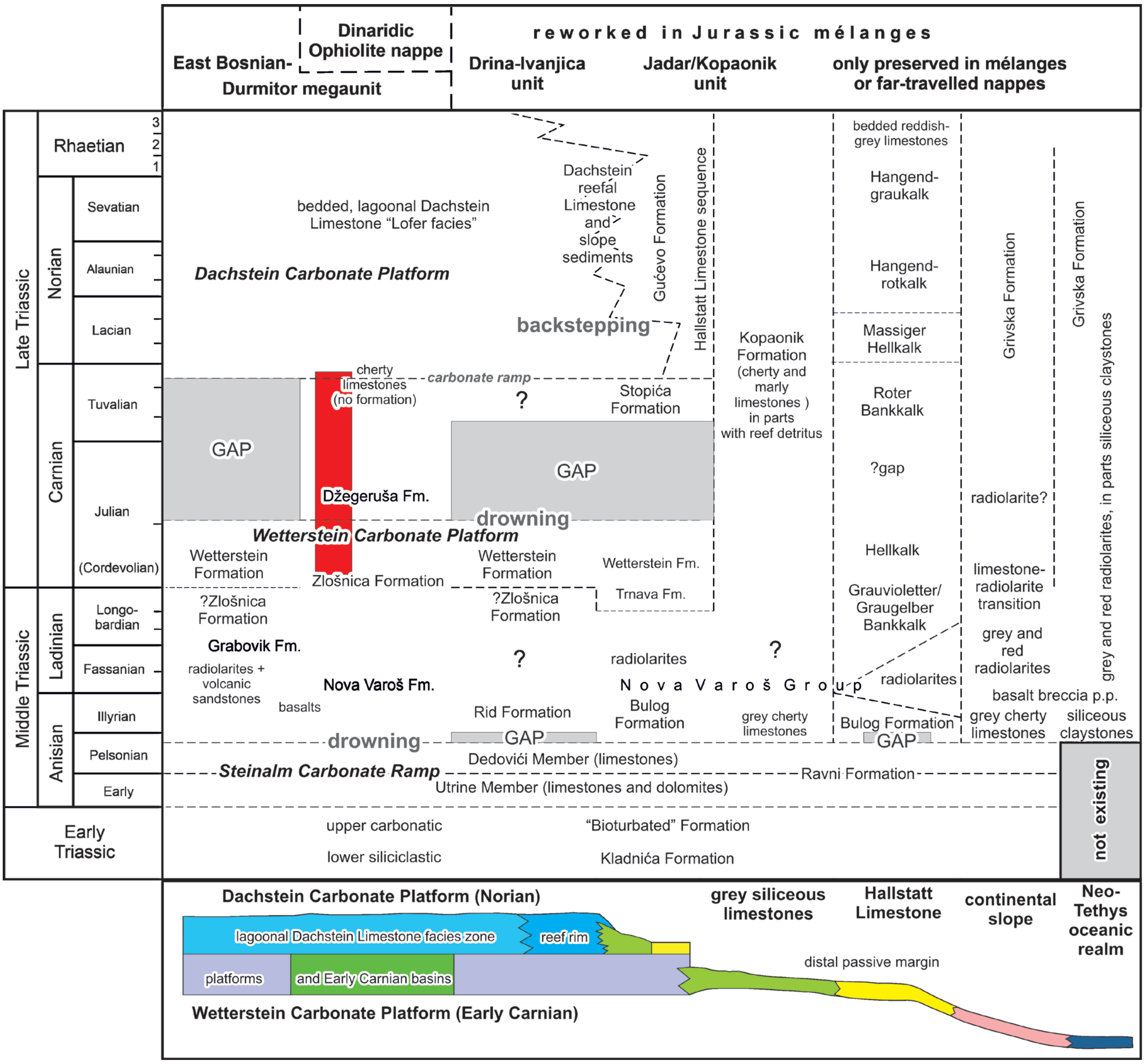


Fig. 2. Triassic stratigraphic table of the Inner Dinarides, modified after Gawlick et al. (2017) and Gawlick & Missoni (2019). Early Triassic to early Middle Triassic modified after Dimitrijević (1997) and Jovanović (1998). Generation of Neo-Tethys oceanic crust started around the Middle/Late Anisian boundary, contemporaneously with the drowning of the Ravni/Steinalm Carbonate Ramp. For description, definition and emendation of several formations see Sudar et al. (2013) and Gawlick et al. (2017, 2023). The geometric arrangement of the different formations is in accordance to the late Triassic carbonate platforms and passive continental margin configuration after Gawlick et al. (2008, 2016), also characteristic for the different defined tectonic units in the Inner Dinarides (Fig. 1). Note: the polyphase younger tectonic motions crosscut in cases the Triassic facies belts. The "Tectonic zone" of the Jurassic Dinaridic Ophiolite nappe is part of the Neo-Tethys derived ophiolites which were obducted and transported westward during Middle–Late Jurassic times (for details see Gawlick et al. 2020; and references therein). The studied section is marked in red.

et al. 2017), whereas the platform started to evolve from the Early Carnian onwards in the East Bosnian–Durmitor megaunit (Gawlick et al. 2017). Between these different (Wetterstein) shallow-water platform areas, deep-water basins formed throughout the earliest Carnian, characterized by the deposition of deep-water siliceous limestones with intercalated carbonate turbidites, e.g., in the eastern part of the East Bosnian–Durmitor megaunit (Gawlick et al. 2017). These short living intra-platform basins were not filled by the prograding platforms because of the overall demise of the Wetterstein Carbonate Platform and equivalents in the Western Tethys Realm (Lein et al. 2012; Chen & Lukeneder 2017). In the aftermath of the significantly reduced shallow-water carbonate production in the Late Carnian, the deposition of the huge Hauptdolomite/Dolomia Principale/Dachstein Carbonate Platform was initiated at the Carnian/Norian boundary. Recently detected Upper Julian siliceous–argillaceous sedimentary rocks were deposited in the underfilled intraplatform-basins between the former shallow-water production areas, e.g., between the Drina–Ivanjica unit to the east and the eastern part of the East Bosnian–Durmitor megaunit to the west (Gawlick et al. 2017).

The demise of the Wetterstein Carbonate Platform (latest Ladinian to earliest Julian) in the Western Tethys Realm in the Julian is related to the Reingraben turnover (Schlager & Schöllnberger 1974), and the change from carbonate to siliciclastic sediments. The exact age and reasons of the demise are still controversially discussed (Dozet & Buser 2009; Stefani et al. 2010; Lein et al. 2012; Kohút et al. 2017). Meanwhile a plethora of terms were invented to describe this "Mid-Carnian" Global Event, e.g., as "The Mysterious Mid-Carnian Global Event", or "Wet Intermezzo" by Ogg (2015). Generally the "Mid-Carnian" turnover is believed to be an environmental change attributed to Wrangellia LIP (Dal Corso et al. 2018, 2020 and references therein).

The aim of this paper is to present the first, exact biostratigraphic data based on conodont assemblages in northern Montenegro in a complete Carnian sedimentary succession characterized by the occurrence of Lower Julian 2 to Upper Tuvalian fine-grained silicified siliciclastic sedimentary rocks, which were previously never detected in northern Montenegro (see Basic Geological Map of S.F.R.Y. 1:100,000 Mirković et al. 1978; and Geological Map of Montenegro 1:200,000 Mirković et al. 1985). Previous studies interpreted these rocks as parts of the Middle Triassic volcano-sedimentary successions. We describe an approximately 11 metres-thick Carnian succession with a less than 3 metres-thick grey siliceous limestone succession of the *Carnica* conodont zone (Julian 1/Julian 2 boundary) deposited below the Julian 2 to Late Tuvalian fine-grained silicified siliciclastic sedimentary rocks of the Džegeruša Formation (Fig. 2).

Remarks to the subdivision of the Carnian

The Carnian stage originally was subdivided by Mojsisovics et al. (1895) into three substages, based on specific ammonoid zones: "Cordevolian", Julian, Tuvalian. However, Krystyn (1978) determined that the stratotypes of the "Cordevolian" and the Julian referred to the same time interval and were synonymous. Therefore, stratigraphers often combine the "Cordevolian" and Julian into a single Lower Carnian (Ogg 2012; Ogg & Chen 2020). In contrast, the use of the "Middle Carnian" ("upper" Julian, *Trachyceras aonoides* and *Austrotrachyceras austriacum* zones, compare Kozur 2003a, b) is widespread. The "Cordevolian" is also used informally in recent biostratigraphic age range tables, e.g., for conodonts (Chen et al. 2016). Therefore the "Cordevolian" informally refers to the Early Carnian, with its writing in brackets (Cordevolian) in the stratigraphic table (Fig. 2), and Middle Carnian with quotation marks "Middle Carnian" in text and figures.

Methods and samples

The studied section in northern Montenegro (Fig. 3) near the village Pliješevina (locality Donja Tikova) belongs to the East Bosnian–Durmitor megaunit of the Dinarides (Fig. 1). Twelve important and indicative samples are highlighted in Fig. 4. To investigate volcanic ash layers a Panalytical X'Pert3 Powder Diffractometer with a Cu anode measuring from 0°–90° was used for XRD measurements. A copper anode is used as the radiation source to generate the low-energy X-rays, and a characteristic line spectrum (Kα and Kβ components) is emitted under a high voltage of 40 kV and a current of 40 mA. Monochromators are used to reduce the K component to the Kα1 wavelength. The acquired angular range is between 2.51 °2Θ and 65.99 °2Θ, the step size of the measurements covers 0.0167 °Θ, and the goniometer speed is 0.5 °2Θ/minute.

Microfacies analysis was carried out according to Flügel (2004). Conodonts were used for biostratigraphy and estimation of the diagenetic overprint using the Conodont Colour Alteration Index (CAI) method (Epstein et al. 1977; Rejebian et al. 1987). The conodont-bearing samples (Fig. 4) were dissolved in acetic acid (ca. 8 %) to avoid any influence on the conodont apatite by the solving process. Residue was dried with max. 50 °C to avoid any influence on the CAI or internal structure or colour of conodonts. CAI-values were visually determined using a standard set and following the

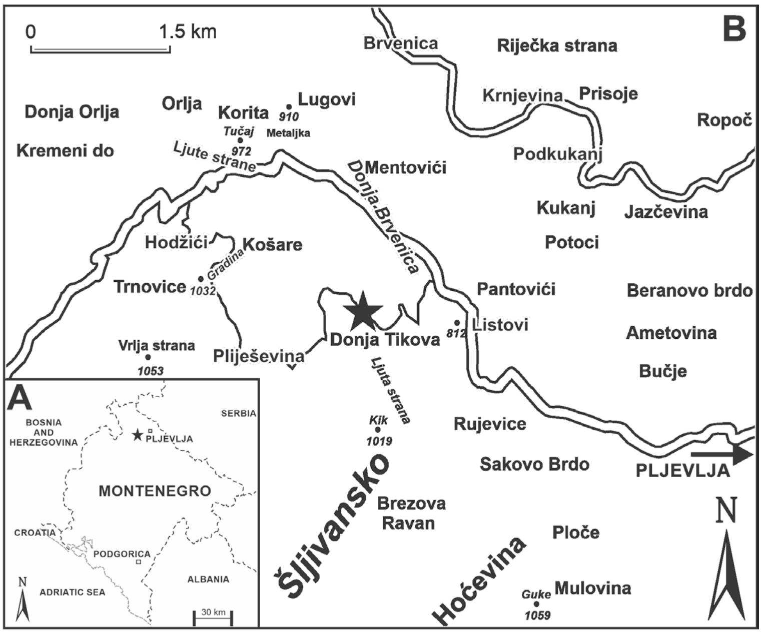
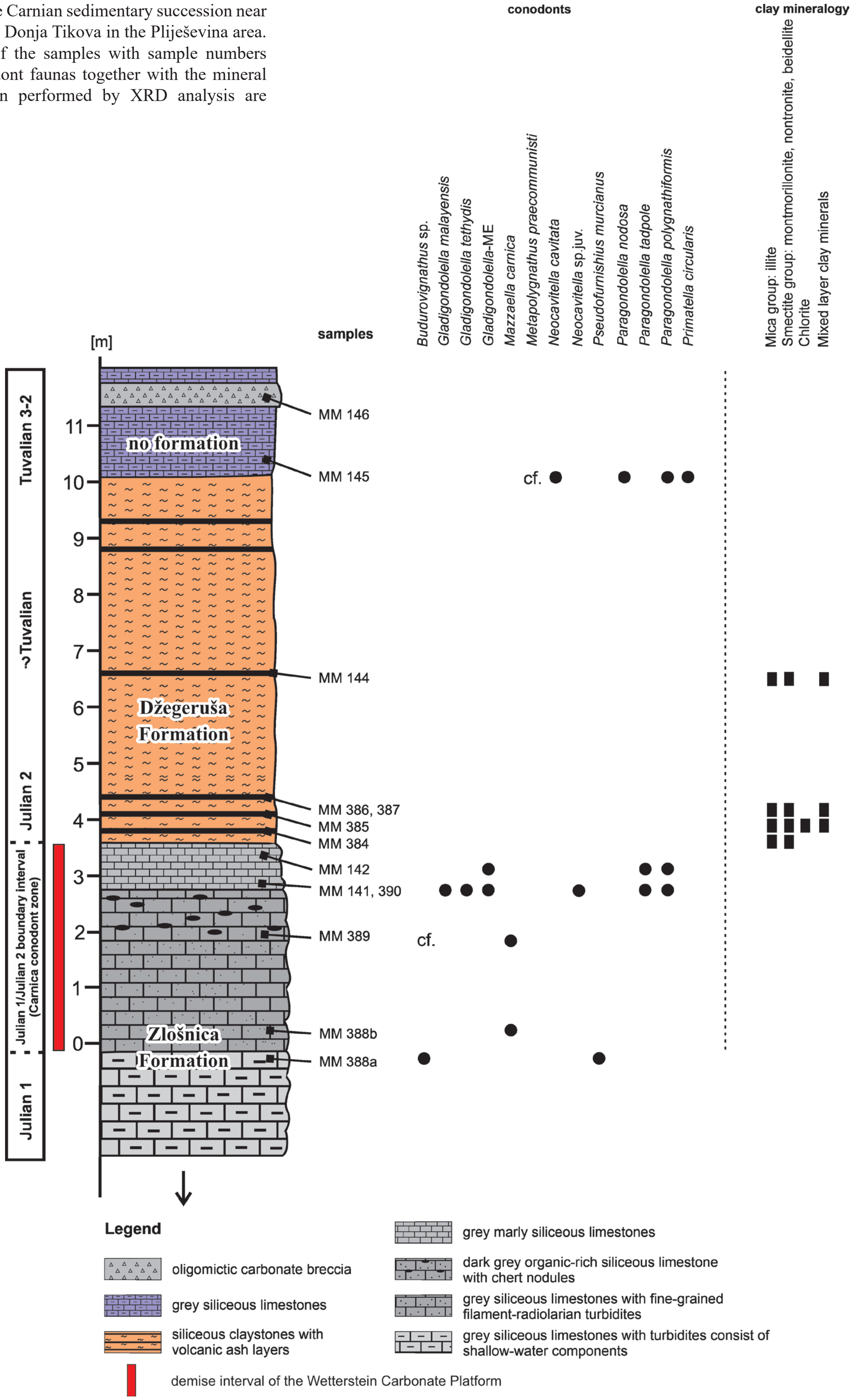


Fig. 3. A — Geographic sketch map of Montenegro with position of the studied section in northern Montenegro (compare Fig. 1). **B** — Studied section near the village Donja Tikova appr. 14 km south-west of the city Pljevlja.

Fig. 4. The Carnian sedimentary succession near the village Donja Tikova in the Pliješevina area. Position of the samples with sample numbers and conodont faunas together with the mineral compostion performed by XRD analysis are indicated.



classification schemes of Epstein et al. (1977) and Rejebian et al. (1987), see also Gawlick et al. (1994). Age ranges of the conodonts are given according to Chen et al. (2016), and we use the nomenclature of Budurov & Sudar (1990) and Chen et al. (2016). Even if age ranges of some individual conodont species are different from other recently published conodont age ranges (Orchard 2010; Kiliç et al. 2017; Plasencia et al. 2018; Kiliç 2021), the biostratigraphic age based on assemblage-level composition is more accurate than age based on stratigraphic ranges of individual conodont species.

Results

The Carnian section near the village Donja Tikova in the Pliješevina area (Figs. 4, 5) is dated by conodont faunas. A series of dm- to 30 cm-bedded siliceous limestones with intercalated turbidites and shallow-water material (Zlošnica Formation – Gawlick et al. 2017) is overlain by turbiditic grey siliceous limestones without shallow-water material (Fig. 4). The frequency of turbidite intercalations decreases upwards and a series of 1 m-thick dark-grey siliceous limestones with chert nodules was deposited around the Julian 1/Julian 2 boundary. These siliceous limestones are overlain by ~1 m-thick grey marly siliceous limestones with radiolarians and "filaments". Upsection, the change in deposition from siliceous limestones to carbonate-free siliciclastic sedimentary rocks (Džegeruša Formation) is sharp. The ~6.5 m-thick, predominantly laminated, reddish-brown, low-energy, turbiditic clay- to siltstones with intercalated volcanic ash layers (Fig. 5) are overlain by a series of grey dm-thick, irregular bedded, siliceous limestones that alternate with oligomictic carbonate breccias (Fig. 4) containing shallow-water organisms. The Julian/Tuvalian boundary lies within the siliciclastic series and cannot be determined. The series of siliceous limestones that overlies the fine-grained siliclastic sedimentary series belongs to the uppermost Tuvalian (no formation).

Conodont biostratigraphy and microfacies

The lowermost grey siliceous bedded limestones with turbidites consisting of shallow-water grains are dated by the occurrence of *Budurovignathus* sp. and *Pseudofurnishius murcianus* (van den Boogaard) as Julian 1. In the lower part of

Fig. 5. Outcrop situation of the Carnian sedimentary succession near the village Donja Tikova in the Pliješevina area. **1** — Small local quarry with exposes the Carnian siliciclastics. **2** — Contact between the grey marly siliceous limestones and the silicilastics. **3** — Layered silt- and claystones with intercalated volcanic ash layers.

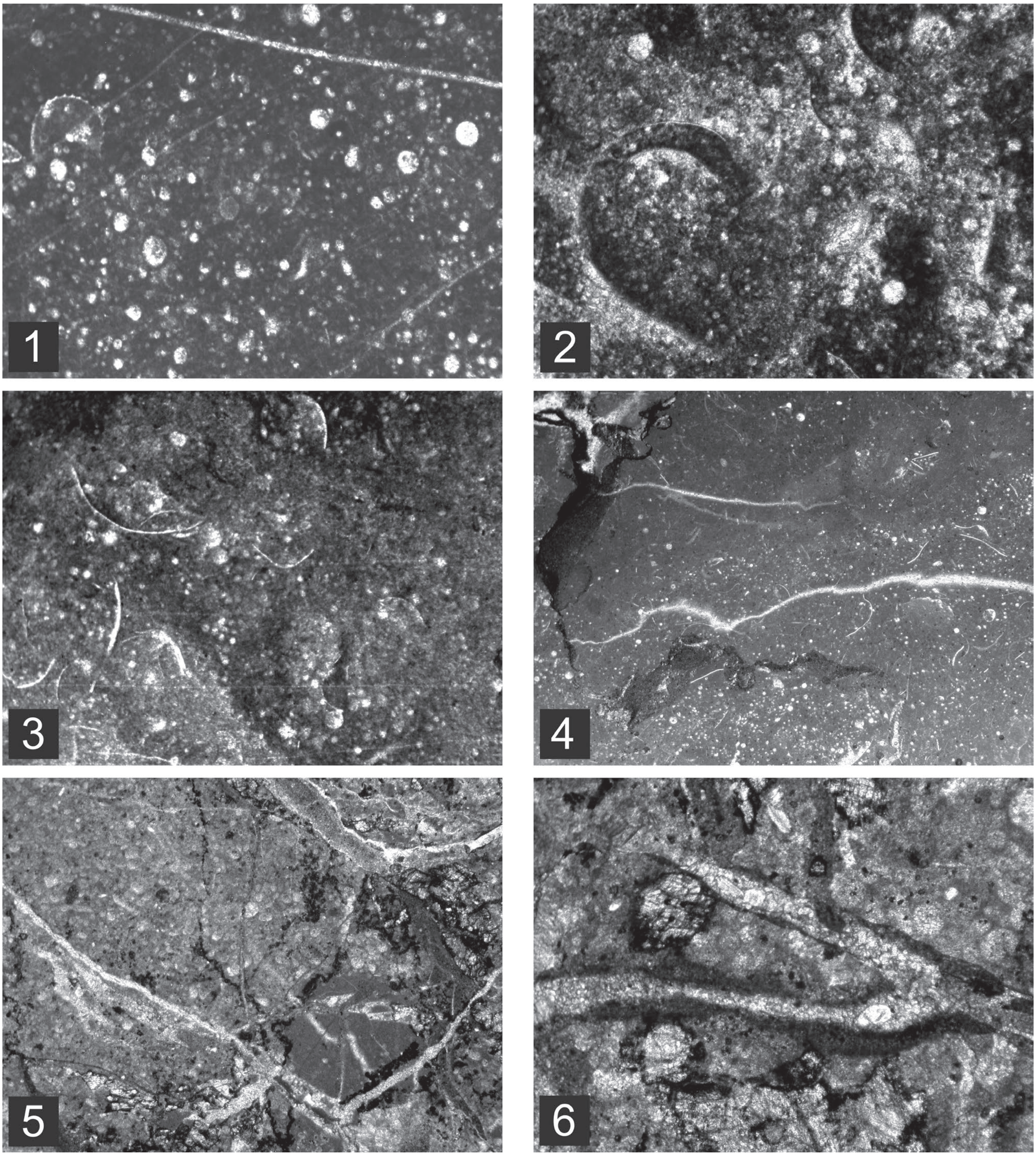


Fig. 6. Microfacies characteristics of the Carnian limestones in Pliješevina area (Donja Tikova section). **1** — Dark grey bioturbated siliceous wacke- to packestone with recrystallized radiolarians and few broken "filaments" (Julian 1/Julian 2 boundary interval), and an ammonoid shell. Sample MM 388. Width of the photograph: 0.5 cm. **2** — Turbiditic and bioturbated radiolarian- and "filament" wacke- to packstone with micrite clasts and diffuse silicification (Julian1/Julian 2 boundary interval). All radiolarians are recrystallized to calcite. Sample MM 389. Width of the photograph: 0.5 cm. **3** — Marly radiolarian-"filament" wacke- to packestone with diffuse silification (Julian 1/Julian 2 boundary interval), with few turbiditic micrite grains. Sample MM 142. Width of the photograph: 0.5 cm. **4** — Turbiditic wackestone with radiolarians, spicula, "filaments", and micrite clasts (uppermost Tuvalian age). Sample MM 145. Width of the photograph: 1.4 cm. **5** — Oligomictic carbonate breccia with components of fine-grained shallow-water debris and radiolarians beside a component of a radiolarian wackestone (uppermost Tuvalian). Sample MM 146. Width of the photograph: 1.4 cm. **6** — Sample MM 146. different view. Encrusted and recrystallized shallow-water organism (uppermost Tuvalian). Width of the photograph: 0.5 cm.

the Julian 1/Julian 2 boundary interval, deposits consist of organic-rich, dark grey to medium grey, siliceous limestones with fine-grained, "filament"-radiolarian turbidites that are embedded in a predominantly radiolarian wackestone matrix (Fig. 6-1). Resediments with shallow-water material are missing in this part of the section, and only micrite clasts occur (Fig. 6-2). The age is constrained on basis of *Mazzaella carnica* (Krystyn), indicating the *Carnica* conodont zone.

The overlying ~1 m-thick interval of dm-bedded, medium-grey, siliceous, turbiditic and bioturbated radiolarian- and "filament" wacke- to packstones (Fig. 6-2) contains the conodonts *Mazzaella carnica* (Krystyn) and *Budurovignathus* sp. The uppermost part of the Julian limestone succession consists of ~1 m-thick grey, marly, siliceous limestones, i.e. bioturbated radiolarian-"filament" wackestones (Fig. 6-3) with a diverse conodont assemblage: *Gladigondolella malayensis* Nogami, *Gladigondolella tethydis* (Huckriede), *Gladigondolella*-ME sensu Kozur & Mostler, *Neocavitella* sp. juv., *Paragondolella tadpole* (Hayashi), and *Paragondolella polygnathiformis* (Budurov & Stefanov). This part of the succession was deposited above the last occurrence of *Mazzaella carnica* (Krystyn) and is therefore most likely basal Julian 2 in age (Tekin et al. 2024). The increasing clay content in these medium-grey, siliceous limestones point to the onset of the deposition of fine-grained siliciclastics, which overlie the siliceous limestones with a sharp contact.

The upper part of the section above the siliciclastic interval consists of 1.5 m grey siliceous limestones with "filaments" and radiolarians (Fig. 6-4) and contain *Metapolygnathus* cf. *praecommunisti* Mazza, Rigo & Nicora, *Neocavitella cavitata* Sudar & Budurov, *Paragondolella nodosa* (Hayashi), *Paragondolella polygnathiformis* (Budurov & Stefanov), and *Primatella circularis* (Orchard). Near the top of the section, a 0.5 m-thick oligomictic carbonate breccia contains shallow-water debris and open marine radiolarian-wackestone components (Fig. 6-5, 6-6) is intercalated. The age of the upper part of this section represents the topmost part of the Tuvalian.

Clay mineralogy

The Julian 2 to Upper Tuvalian reddish-brown, fine-grained siliciclastic part (Figs. 4, 5) of the whole succession contains intercalations of black, totally silicified radiolarites, and several greyish volcanic ash layers. About 8 cm above the grey, marly, siliceous limestones, the carbonate-free, silicified, fine-grained, brownish clay- to siltstone sequence contains the first intercalations of greenish-grey volcanic ash layers. These volcanic ash layers are composed of quartz and clay minerals of the smectite group, and the mica group (Table 1). The smectite group is mainly composed of montmorillonite, and the mica group of illite. The clay minerals do not show a regular crystal lattice, but the diffractograms indicate amorphous portions. The XRD diffractograms shows no sharp peaks for the clay minerals, but a broad band of scattering, resulting in weak signals (sample MM 384). Higher up in the succession, carbonate-free, greenish-grey layers (samples MM 385, 386, 387, 144) are composed of (biogenic) quartz, and clay minerals of the mica group (mainly illite), the smectite group and mixed layer clay minerals (Fig. 7, Table 1). The sample MM 385 also contains chlorite in small quantities. The smectite group shows the quantitatively highest proportion and is mainly composed of montmorillonite. Additionaly, there are proportions of beidellite and saponite. The mica group is mainly represented by illite. The mixed layer minerals are primarily rectorite, but the proportion of chlorite also indicates corrensite. The expression of the peaks of the clay minerals indicates a low degree of crystallization. This clay-mineral composition defines these layers as metabentonites, i.e. as altered volcanic ash layers.

Table 1: Qualitative and quantitative results of the XRD measurements. *Mica group: Illite; **Smectite group: montmorillonite, nontronite, and beidellite.

sample number / clay mineralogy	MM 144	MM 384	MM 385	MM 386	MM 387
Quartz	42	53	19	34	42
Mica group*	29	24	42	36	33
Smectite group**	20	23	31	18	15
Chlorite			2		
Mixed layer clay minerals	9		6	12	10

Conodont Colour Alteration (CAI)

The diagenetic overprint of the succession was estimated using the Conodont Colour Alteration Index (CAI) method (for details see Epstein et al. 1977; Rejebian et al. 1987), calibrated with other temperature sensitive methods (Nöth 1991; Königshof 1992; see Rantitsch et al. 2020; for further methods and details). All condonts through the whole Carnian show relative homogenous CAI values of CAI <1.5 (Fig. 8), which correspond to a diagenetic overpring between 50–90 °C (mean ~70 °C; Epstein et al. 1977, Burnett et al. 1994), and indicate a burial of a few km below the current position.

Discussion

In contrast to the Eastern and Southern Alps or the Western Carpathians, the Carnian sedimentary evolution in the Dinarides is poorly known. Whereas in the Eastern and Southern Alps or in the Western Carpathians the demise of the Wetterstein Carbonate Platform from the Julian 1/2 boundary onwards as a consequence of the Carnian Crisis (see Ogg 2015 for a review) is fairly well documented (Feist-Burkhardt et al. 2008; Lein et al. 2012), it is assumed that a more or less continuous deposition of shallow-water carbonates took place in the Dinarides (Marcoux & Baud 1995; Dimitrijević 1997).

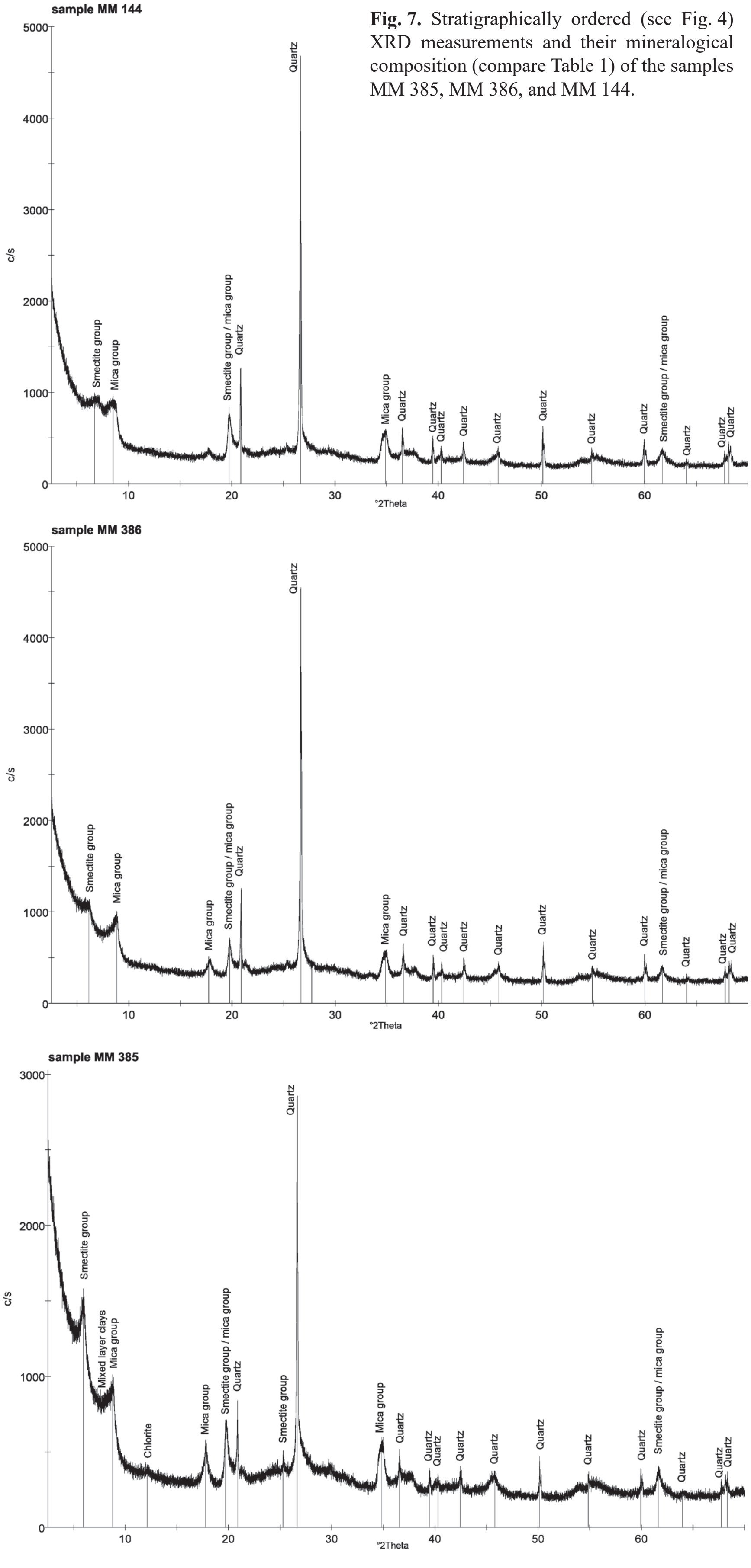


Fig. 7. Stratigraphically ordered (see Fig. 4) XRD measurements and their mineralogical composition (compare Table 1) of the samples MM 385, MM 386, and MM 144.

Therefore, any significant collapse of the carbonate production during the Early Carnian was formerly not detected. Periods of karst bauxite formation on top of the Wetterstein Carbonate Platform with, in some cases, deep erosion, were described at many localities (Grubić 1975; Marković 2002; Pajović et al. 2017), and reflect overlooked emergence intervals with hiatuses in marine deposition (e.g., altered siliciclastic rocks), but this bauxite level was never connected to the "Mid-Carnian" turnover. Although a longer lasting stratigraphic gap was assumed to exist in the shallow-water carbonate depositional areas for parts of the Dinarides as a consequence of the emergence of the platforms, a demise of the Wetterstein Carbonate Platform due to the Carnian crisis was never considered.

During the late Middle to early Late Triassic, the western/north-western Neo-Tethys shelf consisted of a number of isolated and attached Wetterstein Carbonate Platforms separated by short-lived intraplatform basins, as also documented in the Dinarides (Gawlick et al. 2017 and references therein). In the more northern areas (Eastern/Southern Alps, Western Carpathians) these intraplatform basins between the demised and karstified Wetterstein Carbonate Platforms were filled by siliciclastics (Reingraben, Lunz and Raibl Formations – Schlager & Schöllnberger 1974; Lein 1985; Tollmann 1985; Feist-Burkhardt et al. 2008; Havrila 2011; Lein et al. 2012; Aubrecht et al. 2017; Kohút et al. 2017) and give way for a relatively uniform shallow-water carbonate production from the Late Carnian onwards elsewhere. In contrast, such Carnian siliciclastics were never described in the Dinarides, with the exception of some occurrences in the External/Outer Dinarides (High Karst unit) of Croatia (Vlahović et al. 2005), Bosnia and Herzegovina and Montenegro (Pantić 1956, 1957; Vujisić 1975). In the Dinarides, more or less continuous shallow-water carbonate production throughout the Carnian to the latest Triassic seems to be proven

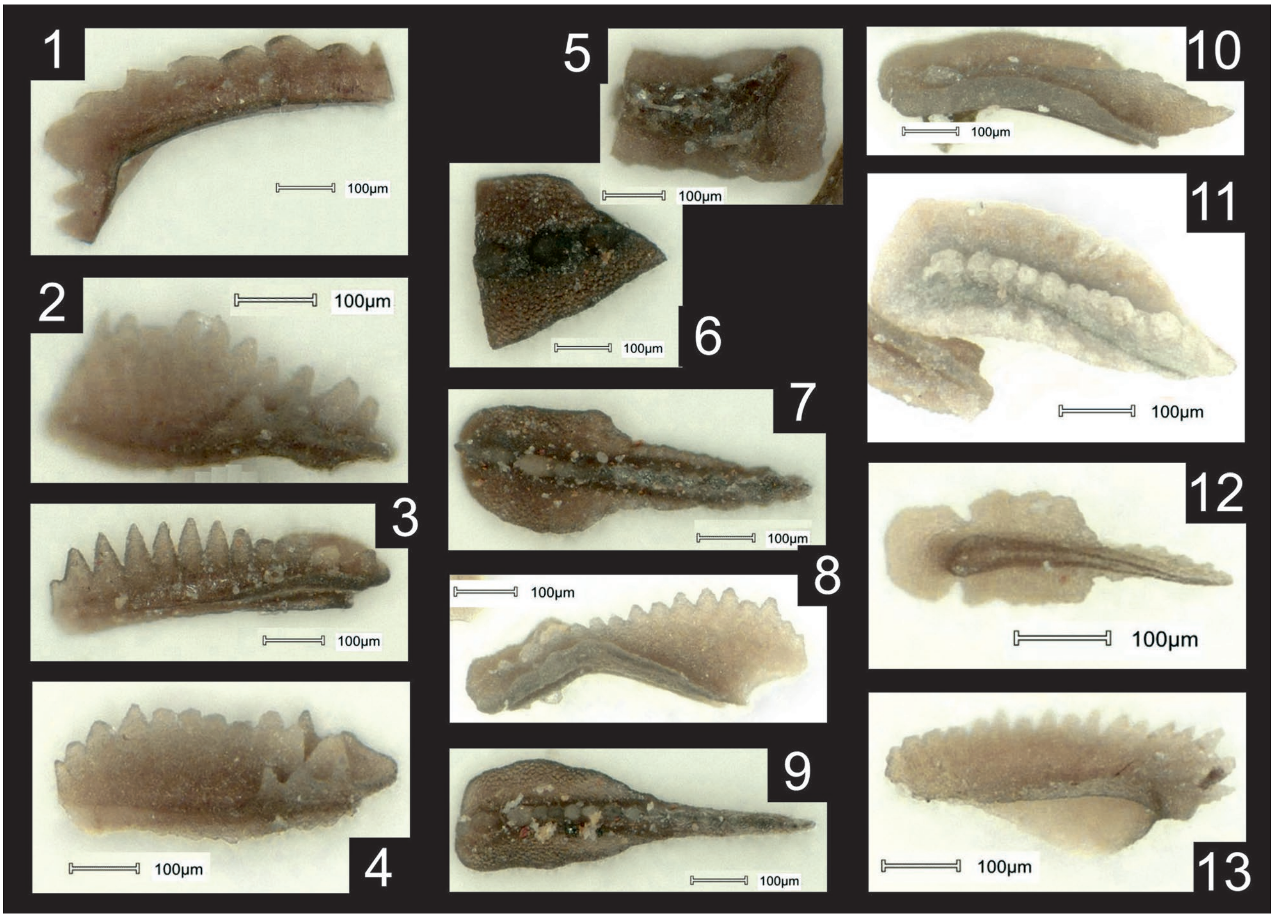


Fig. 8. Photos of some conodonts showing all homogeneous CAI-values of CAI <1.5. **1** — *Cratognathodus* sp. as part of the *Gladigondolella*-ME sensu Kozur & Mostler*,* sample MM 390. **2** — *Mazzaella carnica* (Krystyn), sample MM 388b. **3** — *Paragondolella tadpole* (Hayashi)*,* sample MM 390. **4** — *Mazzaella carnica* (Krystyn), sample MM 388b. **5** — *Mazzaella carnica* (Krystyn), basal view, sample MM 388b. **6** — *Gladigondolella* sp.*,* central part of the P-element, sample MM 390. **7** — *Paragondolella tadpole* (Hayashi)*,* sample MM 390. **8** — *Paragondolella nodosa* (Hayashi), sample MM 145. **9** — Transitional form between *Paragondolella tadpole* (Hayashi) and *Paragondolella polygnathiformis* (Budurov & Stefanov), sample MM 390. **10** — *Paragondolella polygnathiformis* (Budurov & Stefanov), sample MM 145. **11** — *Metapolygnathus* cf. *praecommunisti* Mazza, Rigo & Nicora, sample MM 145. **12** — *Primatella circularis* (Orchard), sample MM 145. **13** — *Neocavitella cavitata* Sudar & Budurov, sample MM 145.

by biostratigraphic distribution of shallow-water organisms (summarized in Dimitrijević 1997). Nevertheless, Missoni et al. (2012) detected a long-lasting gap (upper Julian to Tuvalian 2) on top of the Wetterstein Carbonate Platform, which evolved in the area of the today´s Drina–Ivanjica unit (Fig. 1). In addition, Gawlick et al. (2017) described the deposition of fine-grained, carbonate-free siliceous claystones (Džeguruša Formation: Fig. 2) in a lower Carnian short-lived intraplatform basin in south-western Serbia, which was between the Wetterstein Carbonate Platform of the Drina–Ivanjica unit to the east and the Wetterstein Carbonate Platform of the East Bosnian–Durmitor megaunit to the west (i.e., prior to the deposition of the shallow-water limestones of the Dachstein Carbonate Platform evolution). This basin remained deep and received only fine-grained siliciclastics that were unable to fill it. However, the onset and duration of recovery of shallow-water carbonate production in the realm of the later East Bosnian–Durmitor megaunit remains undated.

In the basinal Donja Tikova section, the break-down of shallow-water carbonate production, i.e., the demise of the Wetterstein Carbonate Platform, and the subsequent upper Julian to Tuvalian geological evolution is completely mirrored in the depositional history. Carbonate production completely stopped after the "*Carnica* event" around the Julian 1/2 boundary as documented by the deposition of carbonate-free siliceous clay- to siltstones with intercalated volcanic ash layers.

Age equivalent Upper Julian to late Tuvalian (~235–228 Ma: Ogg & Chen 2020) volcanic activity was for a long time practically not described in the Western Tethys Realm (Kovács et al. 2010; compare Maury et al. 2008), but recently Aubrecht et al. (2017) and Dunkl et al. (2019 and references therein) performed detrital zircon age dating. Dunkl et al. (2019) described intense volcanic activity, in the Transdanubian Range and Southern Alps with mean ages between 239 Ma and 228 Ma with two major periods of activity of zircon-bearing volcanism at 238 Ma and around 229–228 Ma.

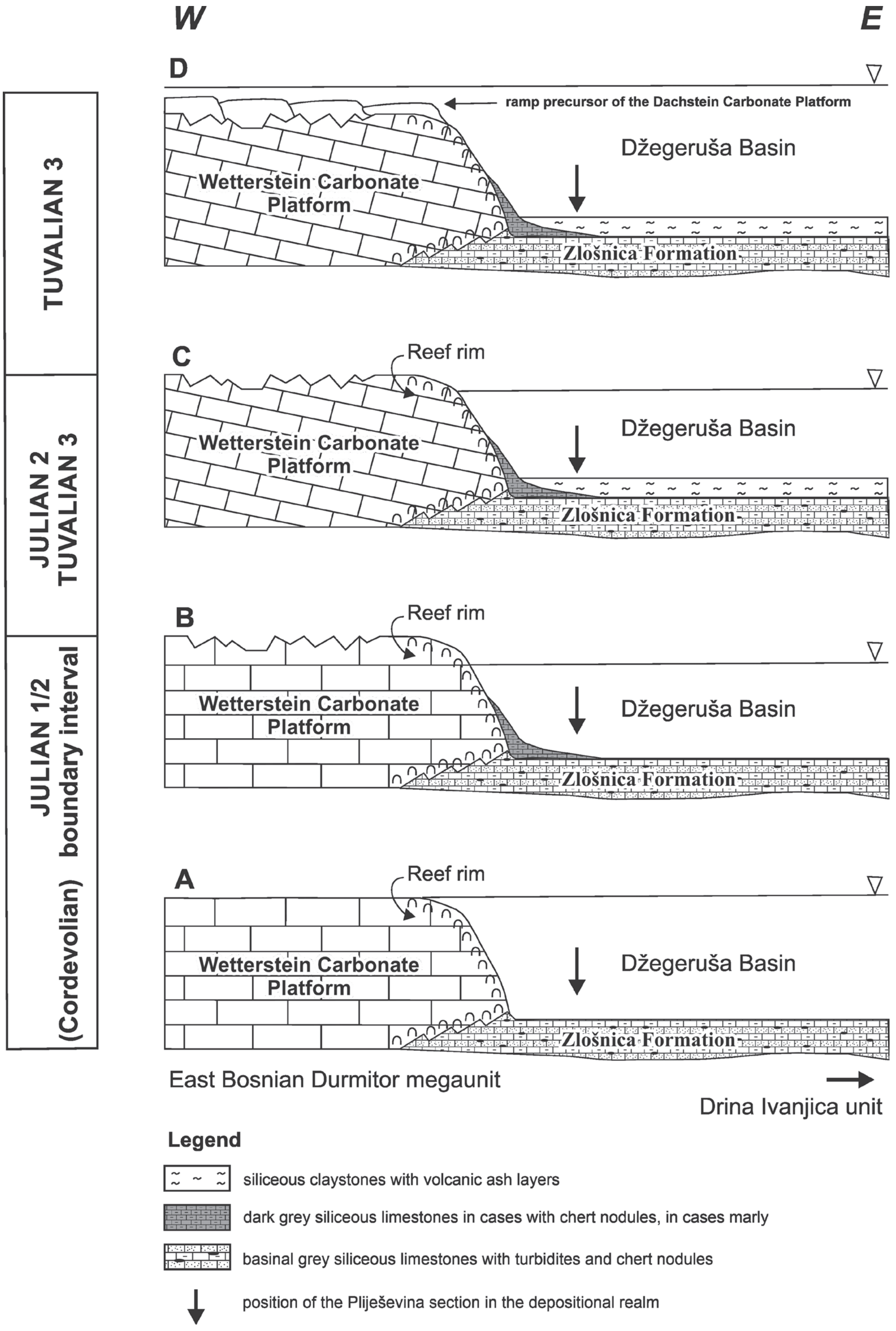


Fig. 9. Evolution of the short-living intraplatform basin (Džegeruša Basin) between the Wetterstein Carbonate Platform of the Drina–Ivanjica unit to the east and the East Bosnian–Durmitor megaunit to the west during the Carnian. A sea-level drop around the Julian 1/Julian 2 boundary interval followed by volcanic activity led to a rapid decrease of carbonate production and the demise of the Wetterstein Carbonate Platform. The deposition of siliceous and in parts organic-rich limestones (*Carnica* event) predates the final demise (ALCAPA) or the uplift (Dinarides) of the Wetterstein Carbonate Platform. **A** — In the earliest Carnian the Wetterstein Carbonate Platform of the East Bosnian–Durmitor megaunit prograded northwards in direction to the Drina–Ivanjica unit, where another platform formed (Gawlick et al. 2017). **B** — Around the Julian 1/Julian 2 boundary interval the platform emerged due to a sea-level drop, and the underfilled accomodation space between the platform areals became a restricted deep lagoon with deposition of in parts organic-rich siliceous limestones (*Carnica* event), followed by the deposition of fine-grained siliciclastics (Reingraben claystones). **C** — During Julian 2 to Tuvalian 3 times fine-grained siliciclastics and volcanic ashes deposited in the underfilled deep-lagoonal basin (Džegeruša Formation). The Wetterstein Carbonate Platform uplifted and tilted. **D** — In latest Carnian the onset of a precursor of the Dachstein Carbonate Platform deposition resulted in deposition of deeper-marine limestones in the Džegeruša Basin.

Whereas the 238 Ma mean age significantly precedes the demise of the Wetterstein Carbonate Platform, the 229–228 Ma mean age is much younger. The older event correlates with the widespread appearance of volcanic ash layers in middle Longobardian basinal limestones (Gawlick et al. 1994) shortly before the main evolution of the Wetterstein Carbonate Platform (Missoni & Gawlick 2011 and references therein). The younger 229–228 Ma volcanic event can be most likely correlated with the Pb–Zn-bearing volcanics in Šula (see Basic Geological Map of S.F.R.Y. 1:100,000; Mirković et al. 1978 and Mirković & Pajović 1980) north of our study area, in a time span with significant Pb–Zn ore formation in the Western Tethys Realm (Melcher et al. 2023). This event also correlates with the age of the Szinva Metabasalt in the Bükk Mts. (Nemeth et al. 2023 and references therein), which is intercalated in Upper Carnian (Less et al. 2005) grey siliceous limestones. In Permian–Triassic times, the Bükk Mts. and the Jadar unit of the Inner Dinarides experienced a nearly identical sedimentological history (Filipović et al. 2003), which implies a palaeogeographic connection between these two different units during the Late Triassic. However, both peak volcanic events do not correlate with the demise of the Wetterstein Carbonate Platform. Also, the existing radiometric age data from the Wrangellia LIP (~232 and 229 Ma = Tuvalian; see Ogg & Chen 2020) are younger than the *Carnica* event and the subsequent deposition of intercalated siliceous claystones and volcanic ashes.

However, according to conodont data (*Carnica*-event), the demise of the Wetterstein Carbonate Platform is older than the onset of the deposition of siliciclastic sediments. The significant decrease in carbonate production seems to be related to the first negative $\delta^{13}C_{carb}$-excursion (Richoz et al. 2016) above the late Julian 1 Raming Formation (Northern Calcareous Alps). This late Julian 1 negative $\delta^{13}C_{carb}$-excursion probably correlates with the negative $\delta^{13}C_{carb}$-excursion at the base of the *A. austriacum* zone in the Dolomites (Dal Corso et al. 2012), in the area of Lunz (Northern Calcareous Alps), or in the Transdanubian Range (Dal Corso et al. 2015). A connection of this negative $\delta^{13}C_{carb}$-excursion with the volcanic activity in the Wrangellia terrane is discussed by Dal Corso et al. (2015).

Carnian depositional history

Redeposition of shallow-water material from the Wetterstein Carbonate Platform decreased around the Julian 1/Julian 2 boundary due to a sea-level drop (Krystyn et al. 2008; Lein et al. 2012; Fig. 9). Deposition of grey, siliceous, micritic limestones, in cases with increased organic content, is characteristic for the *Carnica* conodont zone. The organic-rich and in some cases radiolarian-rich siliceous micrites of the upper Zlošnica Formation correspond to the Göstling Limestone in the Northern Calcareous Alps (Tollmann 1985; Lein et al. 2012). Deposition of the *Mazzaella carnica*-bearing limestones in a slightly restricted depositional environment is indicated by a higher content of organic matter and by the appearance of *Pseudofurnishius murcianus* bellow the *Carnica*-zone. The siliceous, marly and lighter-grey, marly limestones in the higher part of the Julian 1/Julian 2 boundary interval were deposited in a more open-marine depositional environment, as indicated by the appearance of *Gladigondolella* species. The final demise of carbonate production is indicated by deposition of a carbonate-free siliciclastic succession. Recovery of carbonate production started in the Dinarides in uppermost Tuvalian as proven by the deposition of siliceous limestones.

Conclusions

- A complete Carnian basinal sedimentary succession is described in Montenegro for the first time. This sedimentary succession preserves the *Carnica* event, the Reingraben turnover (Mid-Carnian Pluvial episode, Mid-Carnian Wet Intermezzo), and the aftermath of carbonate production in the uppermost Carnian which led to the evolution of the Hauptdolomite/Dolomia Principale/Dachstein Carbonate Platform developing elsewhere in the Western Tethys Realm.
- The demise of the Wetterstein Carbonate Platform in the East Bosnian–Durmitor megaunit coincides with the *Carnica* event around the Julian 1/2 boundary and is related to a major sea-level drop (Krystyn et al. 2008; Lein et al. 2012) and predates the Reingraben turnover (Hornung et al. 2007).
- All formerly-discussed reasons (Ogg 2015) for this "Mid-Carnian" Global Event do not seem to explain the long-lasting stratigraphic gap between the Wetterstein Carbonate Platform evolution and the late onset of the Dachstein Carbonate Platform evolution in the Dinarides. The reason for this phenomenon is still unexplored but provides the possibility for additional triggering factors of the Mid-Carnian event, which may work in concert with the actual discussed reasons, mainly the Wrangellia Large Igneous Province event (Greene et al. 2010).
- Restart of carbonate production in the uppermost Carnian made way for the evolution of the shallow-water carbonates of the Hauptdolomite/Dolomia Principale/Dachstein Carbonate Platform in the East Bosnian–Durmitor megaunit during the Norian–Rhaetian.
- The diagenetic overprint proves a burial of the section of more than 2 km and indicate an eroded nappe stack on top of the parautochthonous Carnian sequence of the East Bosnian–Durmitor megaunit in northern Montenegro.
- The Global Change related to the "Mid-Carnian" turnover (Dal Corso et al. 2020) is for the first time proven in the Triassic depositional record of Montenegro.

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