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The Bulog Formation in the type area (Sarajevo) and related Middle and Late Triassic open-marine sedimentary successions in the Dinarides of Bosnia and Herzegovina

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Abstract. The type area of the Bulog Formation in the area of Sarajevo is revisited in order to solve the still open question of the palaeogeographic provenance of the type-section of the late Pelsonian-Illyrian Bulog Formation and other related Middle Triassic and also Late Triassic open-marine sedimentary sequences. We revisited the type-section and re-evaluated existing data from several known Middle Triassic Bulog Limestone-bearing successions and the Late Triassic Hallstatt Limestones around Sarajevo. Besides their uniform underlying, that are the Middle Anisian (Pelsonian) shallow-water limestones of the Ravni Carbonate Ramp we studied especially their overlying sedimentary sequences and compared these sequences with other related Middle-Late Triassic sedimentary successions in Bosnia and Herzegovina. In addition, we studied some new sections in the area of Sarajevo resp. Bosnia and Herzegovina to compare the type area in an over-regional scale. The result shows a parautochthonous position of the type-locality in the palaeogeographic realm of the later East Bosnian-Durmitor megaunit like several other related successions not only in Bosnia and Herzegovina, also in Serbia and Montenegro. The type-section of the Bulog Formation is overlain by limestones of the prograding Wetterstein Carbonate Platform that means the Bulog Formation was deposited in a central shelf area where later the Early Carnian Wetterstein Carbonate Platform and the Norian-Rhaetian Dachstein Carbonate Platform evolved. Other sections of the Bulog Formation in the area of Sarajevo belong to the dismembered Hallstatt Limestone succession that means they were transported from the outer shelf to their actual position during the Middle-Late Jurassic orogenesis. On the basis of these results and the end of a more than hundred years lasting controversial discussion the way is now open for 1) a stable lithostratigraphic nomenclature for the entire Triassic of the Inner Dinarides to at least the East Bosnian-Durmitor megaunit, and for 2) a reliable time-space reconstruction of the Middle Triassic opening history of the Neo-Tethys Ocean, and 3) a palaeogeographic restauration of the Dinaridic segment of the Triassic western passive continental margin of the Neo-Tethys. In addition, the ?latest Illyrian to latest Longobardian Grabovik

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Formation, deposited above the Bulog Formation and below the evolving Early Carnian Wetterstein Carbonate Platform, is emended and formalized. Furthermore, we demonstrate, that the dismembered Hallstatt Limestone succession derive from the outer shelf and is part of the allochthonous and far-travelled Zlatar (Hallstatt) Mélange overlain by an ophiolitic mélange, described here for the first time from the Sarajevo area.

Key words: *Neo-Tethys, Triassic, Conodonts, Microfacies, Palaeogeography*

Апстракт. Типска област Формације Булог у региону Сарајева је поново посећена да би се решило још увек отворено питање палеогеографског порекла типског локалитета каснопелсонско-илирске Формације Булог и других сродних средњотријских, а такође и горњотријаских отворено морских седиментних секвенци. Поново је истражен типски профил и оцењени су постојећи подаци из неколико познатих средњотријаских сукцесија Булошких кречњака и каснотријаских халштатских кречњака околине Сарајева. Осим подинских униформних творевина, средњо-анизијских (пелсонских) плитководних кречњака Карбонатне рампе Равни, нарочито су изучаване њихове повлатне седиментне секвенце и упоређиване са другим сродним средњо-горњотријаским седиментним секвенцама у Босни и Херцеговини. Поред тога, у околини Сарајева (у Босни и Херцеговини) изучавано је и неколико нових локалитета ради упоређивања типске области у односу на шири регионални простор. Резултат показује параутохтону позицију типског локалитета у палеогеографском домену касније Источнобосанско-дурмиторске мега-јединице слично неким другим сродним сукцесијама, не само у Босни и Херцеговини, него такође у Србији и Црној Гори. Типски профил Формације Булог лежи испод кречњака проградирајуће Ветерштајнске карбонатне платформе, што значи да је Формација Булог била депонована у области средишњег шелфа где су се касније развиле ранокарнијска Ветерштајнска и норичко-ретска Дахштајнска карбонатна платформа. Остали профили са Формацијом Булог у области Сарајева припадају поремећеној Халштатској кречњачкој сукцесији што указује на то да су транспортовани из спољашњег шелфа у своју данашњу позицију током средњо-касно јурске орогенезе. На бази ових резултата, а на крају више од сто година трајања контраверзне дискусије отворен је пут за 1) стабилну литостратиграфску номенклатуру целог тријаса Унутрашњих Динарида, односно Источнобосанско-дурмиторске мегајединице, и за 2) поуздану временско-просторну реконструкцију средњотријаске историје отварања Неотетиског океана, као и за 3) палеогеографско установљавање Динаридског сегмента тријаске западне пасивне континенталне маргине Неотетиса. Поред тога, прилагођена је и формализована дефиниција ?најкасније илирске до најкасније лонгобардске Формације Грабовик, депоноване изнад Формације Булог и испод касније присутне ранокарнијске Ветерштајнске платформе. Надаље, демонстрирано је да поремећена сукцесија Халштатских кречњака потиче са спољашњег шелфа и да је део алохтоног и из даљине дошлог Златарског (Халштатског) Меланжа преко кога лежи офиолитски меланж. Овај други, транспортовани меланж је овде, у области Сарајева, описан по први пут.

Кључне речи: *Неотетис, тријас, конодонти, микрофације, палеогеографија*

Introduction

In the Middle Anisian started the opening of the Neo-Tethys and is characterized by a significant change in deposition in the whole Western Tethys Realm from shallow-marine carbonate ramp to deep-marine hemipelagic platform deposition (Gawlick et al. 2021 and references therein), termed Reifling turnover by Schlager & Schöllnberger (1974). In the Dinarides, the evolution of the shallow-water Ravni Carbonate Ramp ended relatively abrupt in the late Pelsonian (Middle Anisian, Gradstein et al. 2020): a rapid decrease of carbonate production is accompanied by formation of a horst-and-graben topography (break-up unconformity) and the subsequent widespread deposition of 1) deep-marine red nodular limestones (Bulog Formation) (Sudar et al. 2013; 2023a, b, c; Gawlick et al. 2023 and references therein) or 2) oligomictic breccia sequences which consists of components of the underlying Ravni Carbonate Ramp in a "Bulog Limestone" matrix (Sudar et al. 2013; Gawlick et al. 2023), the Komarani Formation (Sudar et al. 2023c and references therein). This drowning of the Ravni Carbonate Ramp (see Sudar et al. 2013 for a review) is related to the continental breakup and the onset of formation of the Neo-Tethys oceanic crust, as described widespread in the Dinarides/Albanides/Hellenides (Gawlick et al. 2008; Oszvárt et al. 2012; Djerić et al. 2024; Kostaki et al. 2024 and references therein).

Sudar et al. (2023c) described and figured the general evolution of the revisited type-section of the Bulog Formation in Han Vidović (Sarajevo, Bosnia and Herzegovina). Here, a detailed description with a revision of the existing biostratigraphic age data respectively a revision of existing conodont faunas from the upper part of the Bulog Formation is added by an analysis of the microfacies characteristics of the type-section. Furthermore, we dated the neptunian dikes in the underlying shallow-water Ravni Formation filled with red nodular limestones. The Grabovik Formation is dated by the underlying Bulog Formation and newly detected overlying bedded grey siliceous limestones with turbiditic intercalations as ?latest Illyrian to Ladinian. The Anisian to Early Carnian evolution of the type section of the Bulog Formation is compared with other sedimentary successions in the wider area around Sarajevo and other sections in eastern Bosnia and Herzegovina (Fig. 1).

We describe, that the sections of the dismembered Hallstatt Limestone succession in the Trebević Mt. near Brus (Fig. 2) is part of the Zlatar (Hallstatt) Mélange and is overlain by an ophiolitic mélange containing Late Triassic blocks of the Grivska Formation.

The Grabovik Formation (Kittl 1904) is emended and formalized.

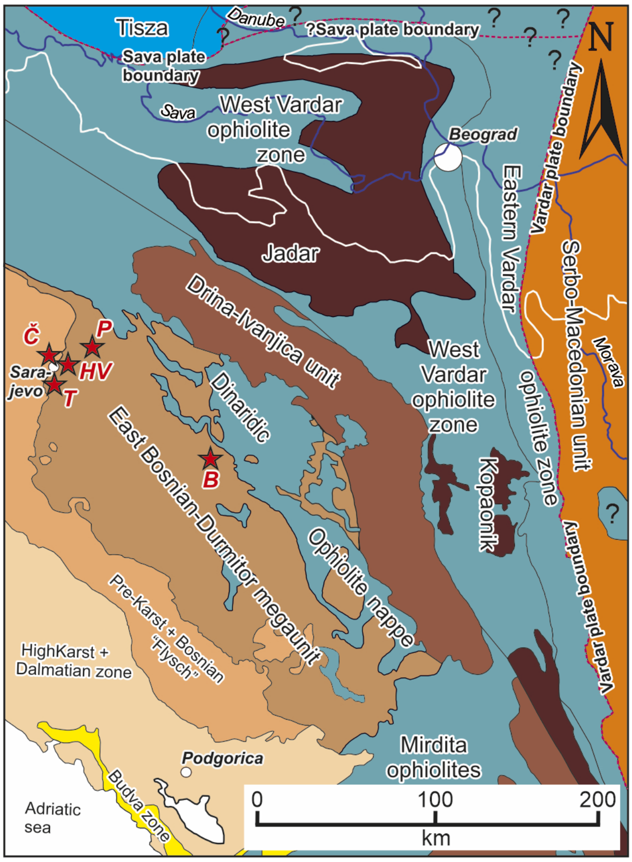

Fig. 1. Overall tectonic map of the Dinarides in Bosnia and Herzegovina, Serbia, Montenegro, and adjacent countries redrawn after Schmid et al. (2008, 2020), Sudar et al. (2023c) based on new results (Gawlick et al. 2017a, 2023; Djerić et al. 2024; compare also Radivojević 2023). Red stars indicate the studied sections: HV – Han Vidović (type-section of the Bulog and Grabovik formations), P – Pridvorica (reference section for the Bulog and Grabovik formations), T – Trebević Mt. (Studenkovići, Blizanac, Draguljac, Brus), Č – Čavljak (Sedrenik plateau), B – Brodan.

The reference area near Sarajevo: history and open questions

The reference region with the type-section of the Bulog Formation (Bulog Limestone/"Buloger Kalke") is located in the area of Sarajevo in Bosnia and Herzegovina and belong tectonically to the East Bosnian-Durmitor megaunit (Schmid et al. 2008, 2020) (Fig. 1), or Durmitor nappe (Hrvatović 2006), in which the Triassic formations can be internally folded and imbricated. According to Kittl (1904) the type area is located around the village Bulozi (old name Han Bulog), with the type-section Han Vidović (Hauer 1896) (Fig. 2) east of Sarajevo. To assign the region around the village Bulozi as type area is based on the studies of Hauer (1884, 1892), who investigated the cephalopods from the "Oberer Muschelkalk of Han Bulog". Later, Hauer (1888, 1896) added cephalopd determinations from Haliluci south of the type-section Han Vidović, the second important ammonoid-bearing locality in these red nodular limestones in the Sarajevo area. The brachiopods from both localities were studied by Bittner (1890, 1892). Hauer (1888, 1896) compared lithology and ammonoid species with those of the Schreyeralm Limestone (first described by Mojsisovics 1869, 1882; and later by Assereto 1971; Krystyn & Schöllnberger 1972), with the type-locality between Gosau and Hallstatt in the Northern Calcareous Alps at the western footwall of Mt. Plassen (Tollmann 1976). The Schreyeralm Limestone is the oldest member of the deep-marine open shelf Hallstatt Limestone sequence (see Krystyn 2008 for a review).

Hauer (1896) assigned as type-locality of the "Muschelkalk of Han Bulog" the road serpentine near Han Vidović (Fig. 2), one of the three "Hans" (han = old Turkish word, forerunner for today inns or motels/hotels with meaning for the quarter over the night for travellers and their horses with beds and food) in the area of Han Bulog (Stary Han Bulog, Novi Han Bulog, and Han Vidović; compare Kittl 1904). Dimitrijević (1969, 1997) named these Anisian red nodular limestones following Kittl (1904) Bulog Limestone (the often used name Han Bulog Limestone in the older literture was never valid). Later, after the first attemps of Huckriede (1958), Fischer & Jacobshagen (1976) started with first systematic studies on the conodont faunas of the Bulog Limestone of various Bulog Limestone successions throughout the Dinarides. Fischer & Jacobshagen (1976) studied the Bulog Limestones also from the type area around Sarajevo, and assigned them as Hallstatt Limestones, like most occurrences of the Bulog Limestones in the Dinarides (see Wendt 1973).

As stated by Kittl (1904) the Bulog Limestone in the type region around the village Bulozi (Buloger Kalke and not Kalke von Han Bulog: see detailed explanation in Kittl 1904) is overlain by a series of claystones, volcanic ashes, volcanic sandstones, siliceous sedimentary rocks, and grey micritic siliceous limestones, the "Graboviker Schichten" (the until now not formalized Grabovik Formation). This fact doubts a derivation of the Bulog Limestone in the type area (road curves near the village Vidovići = type-locality according to Hauer 1896) and near the village Bulozi (locality Han Bulog in the earlier literature; see Kittl 1904; Sudar 1986; Sudar et al. 2023a, c) from the outer shelf facing the newly formed oceanic realm to the east (the Neo-Tethys Ocean) from the Late Pelsonian onwards. In this outer shelf depositional realm sedimentary rocks similar to the Grabovik Formation are not known yet (see Gawlick et al. 2017a, b, 2018), but their existence cannot be totally excluded. This uncertainty was the reason why the Bulog Formation was not officially emended and formalized until recent times (Sudar et al. 2023a, c).

For these reasons it was necessary to revisit the type-locality Han Vidović near Sarajevo in Bosnia and Herzegovina with special focus on the overlying sedimentary rocks, i.e. the "Graboviker Schichten" and their overlying Late Triassic sedimentary rocks. As recognized by Kittl (1904) the surrounding of the type area of the Bulog Limestone is built by the Wetterstein Carbonate Platform, but the Late Anisian to Ladinian basinal sedimentary rocks show always a tectonic contact to these shallow-water carbonates, as also known from the Late Triassic Hallstatt Limestones in the surroundings of Sarajevo.

As the first, Sudar et al. (2013) described the history and nomenclature of the Bulog Formation. The uncertainities about 1) possible synonyms

(Schreyeralm Limestone), 2) the exact palaeogeographic position and 3) the overlying sedimentary succession of the Bulog Limestone were pointed out. But, the crucial question of the original overlying sequence remains: A) Wetterstein Carbonate Platform (above Ladinian basinal sedimentary rocks) or B) the Hallstatt Limestone sequence. Schreyeralm Limestone and Bulog Formation would be therefore two different names for the same sedimentary succession, i.e. synonyms. Nevertheless, some open points concerning the palaeogeographic position remained, i.e. the original depositional realm of the Bulog Limestone was still unclear. But, an answer to this open question is crucial for the emendation and formalization of the Bulog Formation. Furthermore, the reconstruction of existing deep-marine intraplatform basins in the central shelf of the Dinarides (Rampnoux 1974; Charvet et al. 1974; Charvet 1980) neglecting the results of Kober (1952) or Medwenitsch (1958) had a big impact in the reconstruction of the geodynamic history of the Dinarides and the defintion of the tectonic units (e.g., Dimitrijević 1997; Karamata 2006; Schmid et al. 2008).

After the revision of the type-locality Sudar et al. (2023a, c) emended the Bulog Formation. Sudar et al. (2023c) stated also, that a transfer of the name "Schreyeralm Limestone" as the lowermost part of a Hallstatt Limestone sequence to the Dinarides is not practicable: occurrences of Middle-Late Anisian red nodular limestones above the shallow-water limestones of the Ravni Formation but with limited stratigraphic preservation (i.e. missing Late Ladinian to Early Carnian sequences) cannot be assigned in moment to any palaeogeographic domain in the Dinarides. Therefore Sudar et al. (2023c) plead for the use of the term Bulog Formation for all Middle-Late Anisian (?Early Ladinian) red nodular limestone sequences in the Dinarides to avoid more confusion.

Bulog Limestone: part of a Hallstatt Limestone succession or not?

The idea, to assign all Bulog Limestone sections in the Dinarides to a Hallstatt Limestone succession was introduced by Jacobshagen (1967) based on his studies on the Anisian to Carnian open-marine Hallstatt Limestone succession of Epidaurus/Greece (compare Krystyn 1983). Nevertheless, in the Dinarides studies focussed only on the Anisian to Illyrian/?Early Ladinian red nodular limestones, their faunal content and some sedimentological aspects regarding the fossil accumulations (Wendt 1973). But, the overlying sedimentary rocks above the Bulog Formation were never studied in detail, even they are of special palaeogeographic importance. Keep in mind, that the Anisian/Ladinian boundary shifted to the base of the *Eoprotrachyceras curionii* Zone (Brack et al. 2005 and references therein), and that in the older literature most parts of the Bulog Limestone successions were attributed to the Ladinian.

However, already Kittl (1904) mentioned the volcano-sedimentary siliciclastic and siliceous sedimentary rocks of the "Graboviker Schichten" as overlying sedimentary succession of the red nodular Bulog limestones in the type area, and not Hallstatt Limestones. Nevertheless, the deposition of late Illyrian to Ladinian siliceous sedimentary rocks with intercalated volcanic ash layers or even volcanic sandstones is a widespread phenomenon in the Dinarides (e.g., Gawlick et al. 2012, 2017a, b, 2018; Mrdak et al. 2024a) and seem not to characterize the original depositional area on the shelf of any Bulog Limestone succession, including the type-section. Known Bulog Limestone successions deposited on the outer (Hallstatt) shelf or the continental slope have various overlying sedimentary rocks, but never thick sequences of volcanic sandstones intercalated in siliceous sedimentary rocks (Sudar 1986; Gawlick et al. 2017a, b, 2018; Djerić et al. 2024). Furthermore, according to the studies of Gawlick et al. (2017a) and Mrdak et al. (2024a and references therein) intense middle/late Illyrian volcanisms and deposition of their erosional products seems to be a characteristic feature of the Outer Dinarides (Fig. 1: all tectonic units west of the Drina-Ivanjica unit in our definition, compare Schmid et al. 2008, 2020), that is predominantly the proximal to central shelf area of the western passive continental margin of the Neo-Tethys. That means, that sedimentary rocks similar to the Grabovik Formation are not known in the outer shelf depositional realm (reefal Dachstein Limestone facies zone to Hallstatt Limestone facies zone – Fig. 3). But, their occurrence there cannot be totally excluded and they may have been deposited in some areas. In addition, Middle Triassic sedimentary sequences formed at the continental slope or deposited on the oldest (proximal) parts of the Neo-Tethys Ocean show a general deepening trend throughout the Anisian-Ladinian with deposition of radiolarites from the late Illyrian onwards (Djerić et al. 2024 and references therein) and have in their sedimentological record no signs of intense volcanic activity in Late Anisian-Ladinian times. Also, in the outer (Hallstatt) shelf facies zone in cases radiolarites deposited (Gawlick et al. 2017b), but volcanics or erosional products of volcanics are missing in the Middle Triassic Hallstatt Limestone successions.

Due to all these sedimentological characteristics and uncertainties in the Anisian-Ladinian, in fact only the depositional characteristics in the Late Triassic, i.e. shallow-water carbonate platforms or open-marine deposits indicate the palaeogeographic provenance of a Bulog Limestone succession (for a review see Gawlick et al. 2023). While in the proximal to central shelf areas in the Late Triassic shallow-marine carbonate platforms evolve, i.e. the Early Carnian Wetterstein Carbonate Platform and the Norian-Rhaetian Dachstein Carbonate Platform, in the outer shelf area exclusively hemipelagic limestones deposited (Lein 1987), e.g., the various coloured Hallstatt Limestones (Fig. 3).

Where Middle-Late Triassic deep-marine limestone successions were formed?

In more recent times in turn of the reconstruction of the Anisian break-up of the Neo-Tethys Ocean a great variability of sedimentary rocks overlying the Bulog Limestones in the Dinarides was described: e.g., radiolarites to siliceous grey bedded limestones (Gawlick et al. 2012), polymictic breccias (Sudar et al. 2013; Gawlick et al. 2017a, b), or the since Kittl (1904) known volcano-sedimentary siliciclastic and siliceous sedimentary rocks (see Sudar et al. 2023c for a review). In addition, the Early Carnian Wetterstein Carbonate Platform evolved in the hanging wall of a lot of Bulog Limestone sections, whereas others are overlain by a Hallstatt Limestone succession. This is crucial for both palaeogeographic and geodynamic reconstructions, because Aubouin et al. (1970), Charvet (1978, 1980) and Charvet et al. (1974) for Bosnia and Herzegovina, and Rampnoux (1970, 1974) for Serbia and Montenegro reconstructed long-lasting Anisian to Jurassic deep-water basins in the middle of the Late Triassic shallow-water carbonate platforms. These authors follow with the reconstruction of the existence of such deep-water basins the classical idea of Mojsisovics (1903) for the Northern Calcareous Alps. After a period of allochthonous interpretations of the Hallstatt successions (Lein 1987 for definition) the authochthonous model was renewed by Zankl (1967, 1971) with a lot of followers elsewhere in the Western Tethys Realm. Since Gawlick (1996) improved the mélange character for the so-called Hallstatt north-channel in the Northern Calcareous Alps practically all known Hallstatt Limestone occurrences in the Western Tethys Realm could be attributed to be mélanges formed in Middle-Late Jurassic times (Gawlick & Missoni 2019 and references therein). However, the existence of long-existing deep-water basins in the middle of carbonate platforms experienced also in the Dinarides a lot of followers (Dimitrijević 1997) until recent times (Haas et al. 2019), even that since Missoni et al. (2012) and Gawlick (2017a, b, 2018) a mélange character for most occurrences of Hallstatt Limestone succession was proven. In addition, the existence of long-existing (more then 35 Ma years!) deep-water basins in shallow-water production areals contradicts the calculation of carbonate production of carbonate platforms (Schlager 2005 and references therein).

The evidence, that the Triassic intraplatform basins are in fact Middle-Late Jurassic trench-like basins, filled with Triassic-Jurassic limestones from the outer (Hallstatt) shelf in an argillaceous-radiolaritic matrix (Gawlick et al. 2017a, b, 2018) raised the possibility to solve also the problems regarding the Bulog Formation. In fact, except the existence of short-living Early Carnian intraplatform basins between the Wetterstein Carbonate

Platforms (Gawlick et al. 2017a; Mrdak et al. 2023) the whole Outer Dinarides are chacterized in the Late Triassic by the evolution of shallow-water carbonate platforms. Despite the newly achieved data and facts the myth of long-living intraplatform basins (Lim Basin, Bosnian trough) in the Outer Dinarides remain (Haas et al. 2019) and tectonic reconstructions and definitions were not changed (Schmid et al. 2020).

However, to assign the Bulog Limestone in the type area around Sarajevo as part of the Hallstatt Limestone succession implies, that at least some Bulog Limestone successions in the type area would represent overthrust units identical to those described below the Dinaridic Ophiolite nappe (Gawlick et al. 2017a, b, 2018), e.g., the Sirogojno carbonate-clastic Mélange and the Zlatar (Hallstatt) Mélange in SW Serbia. A deposition in long-living Middle-Late Triassic parautochthonous deep-water basins with limited East-West extend, i.e. the former Zlatar and Čehotina subbasins of the Lim Basin (Rampnoux 1974), and in the type area of the Bulog Limestone the so-called Bosnian trough (Charvet et al. 1974; Charvet 1980) is rather unrealistic in an area of shallow-water carbonate platforms with enormous carbonate production. Not only the Zlatar sub-basin, also the Čehotina sub-basin of the Lim Basin in northern Montenegro consists of various far-travelled open-marine sedimentary successions from the outer shelf area (Goričan et al. 2022; Mrdak et al. 2024b).

While the short-living Early Carnian Wetterstein Carbonate Platform could not fill the Middle-Late Anisian horst-and-graben topography, and under-filled deep-water basins remained between the Wetterstein platforms, i.e. in the East Bosnian-Durmitor megaunit (Gawlick et al. 2017a; Mrdak et al. 2023), the Norian-Rhaetian Dachstein Carbonate Platform with its long-lasting enormous amount of carbonate production filled these remaining Carnian basins rapidly, i.e. in the Early Norian after a long-lasting period (Middle to latest Carnian) of no carbonate production in the Outer Dinarides. Furthermore, all studied areas in Serbia or Montenegro with continous Middle-Late Triassic deep-water successions in the area where the Lim Basin should be located according to Rampnoux (1974) (compare Pantić & Rampnoux 1972), or occurrences of only Late Triassic deep-water sedimentary rocks could be attributed to derive from the outer (Hallstatt) shelf or continental slope (Fig. 3). They are either embedded in a Middle–Late Jurassic mélange (Gawlick et al. 2016, 2017a, b, 2018; Sudar et al. 2018) or represent far-travelled nappes (Gawlick & Mrdak in Goričan et al. 2022).

Geological and geographical setting

Most of the studied sections (type-locality Han Vidović, reference section Pridvorica, sections at Mt. Trebević), are located around Sarajevo in the East Bosnian-Durmitor megaunit (Figs. 1, 2). Also, the section Brodan belongs to the East Bosnian-Durmitor megaunit (Fig. 1). Only the section Čavljak (Sedrenik plateau) is located most probably in the Pre-Karst unit (Fig. 1) according to Schmid et al. (2008, 2020). However, it is not of any meaning for the Triassic palaeotopography and palaeogeography to which Palaeogene tectonic unit (or nappe) the sections are attributed. In Triassic times all these sections are part of the same east-west trending depositional belt, and the distance beween the eastern Pre-Karst unit (or nappe) and the western East Bosnian–Durmitor megaunit (or nappe) is very limited.

The type-locality of the Middle–Late Anisian Bulog Formation, Han Vidović east of Sarajevo, is according to most authors part of the East Bosnian–Durmitor megaunit (Dimitrijević 1997; Gawlick et al. 2023; Sudar et al. 2023c) (Fig. 1), or part of the East Bosnian–Durmitor thrust sheet (Schmid et al. 2008, 2020 following Rampnoux 1974).

Since Kittl (1904) beside Anisian also Carnian cephalopod limestones in the area around Sarajevo are known, which were also studied for conodont faunas by Charvet et al. (1974), Fischer & Jacobshagen (1976) and later Sudar (1986). These Carnian cephalopod limestones are part of the Hallstatt Limestone sequence as confirmed by Wendt (1973), Fischer & Jacobshagen (1976), and Sudar (1986). This fact resulted in the reconstruction of a deep-water basin in the East Bosnian– Durmitor megaunit, the “Zone Bosniaque + Zone Serbe“ (Aubouin et al. 1970; Charvet et al. 1974; Charvet 1980) or "Bosnian Basin". However, the existence of such a long-living deep-water basin with deposition of Middle to Late Triassic deep-water sedimentary successions in the central shelf area could be never proven (see Gawlick et al. 2017a, b, 2018; Sudar & Gawlick 2018), and all such sedimentary succession are part of the far-travelled Zlatar (Hallstatt) Mélange (Gawlick & Missoni 2019 for a review).

Therefore, most of the sections are part of the sedimentary sequence of the Pre-Karst and East Bosnian–Durmitor megaunit, while the sections in Mt. Trebević area belong to the far-traveled Zlatar (Hallstatt) Mélange on top of the East Bosnian-Durmitor megaunit (Fig. 1), with a depositional realm on the outer shelf (Fig. 3. – Hallstatt Limestone facies zone).

Results

The studied Middle to Late Triassic successions in Bosnia and Herzegovina were plotted into the Triassic Stratigraphic Table for the Inner to Outer Dinarides (Fig. 3) to show the differences in the palaeogeographic provenance of the different sedimentary successions with the late Pelsonian – Illyrian Bulog Formation.

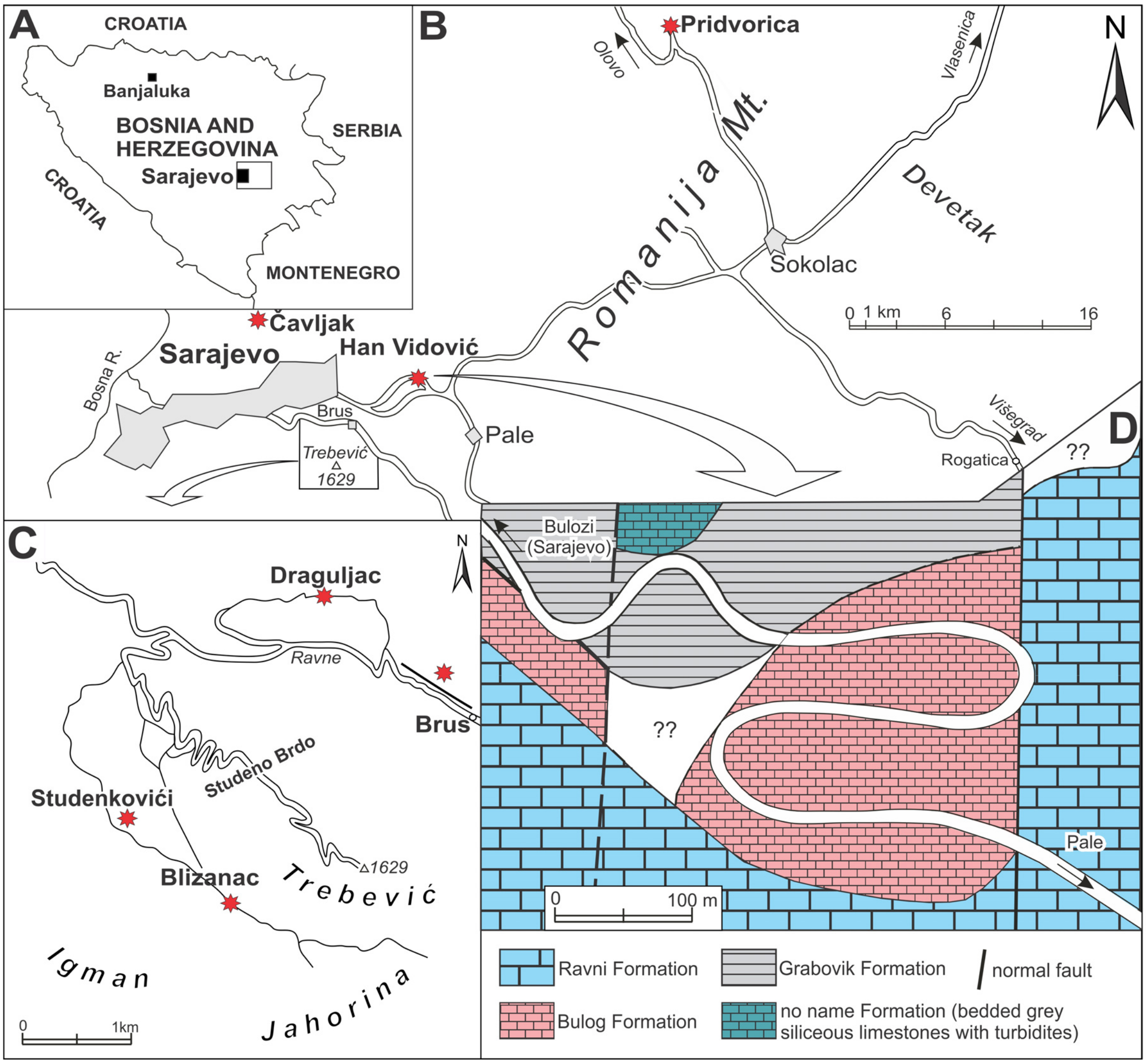

*Fig. 2. Regional sketch map of the studied sections in the surroundings of Sarajevo in Bosnia and Herzegovina (**A**) and geographic position of the reference section Pridvorica north of Sokolac town (**B**). **C**. Geographic position of the studied sections in Trebević Mt. area. **D**. Geological map in the surroundings of the type-section Han Vidović after Fischer & Jacobshagen (1976), Sudar (1986) and own observations.*

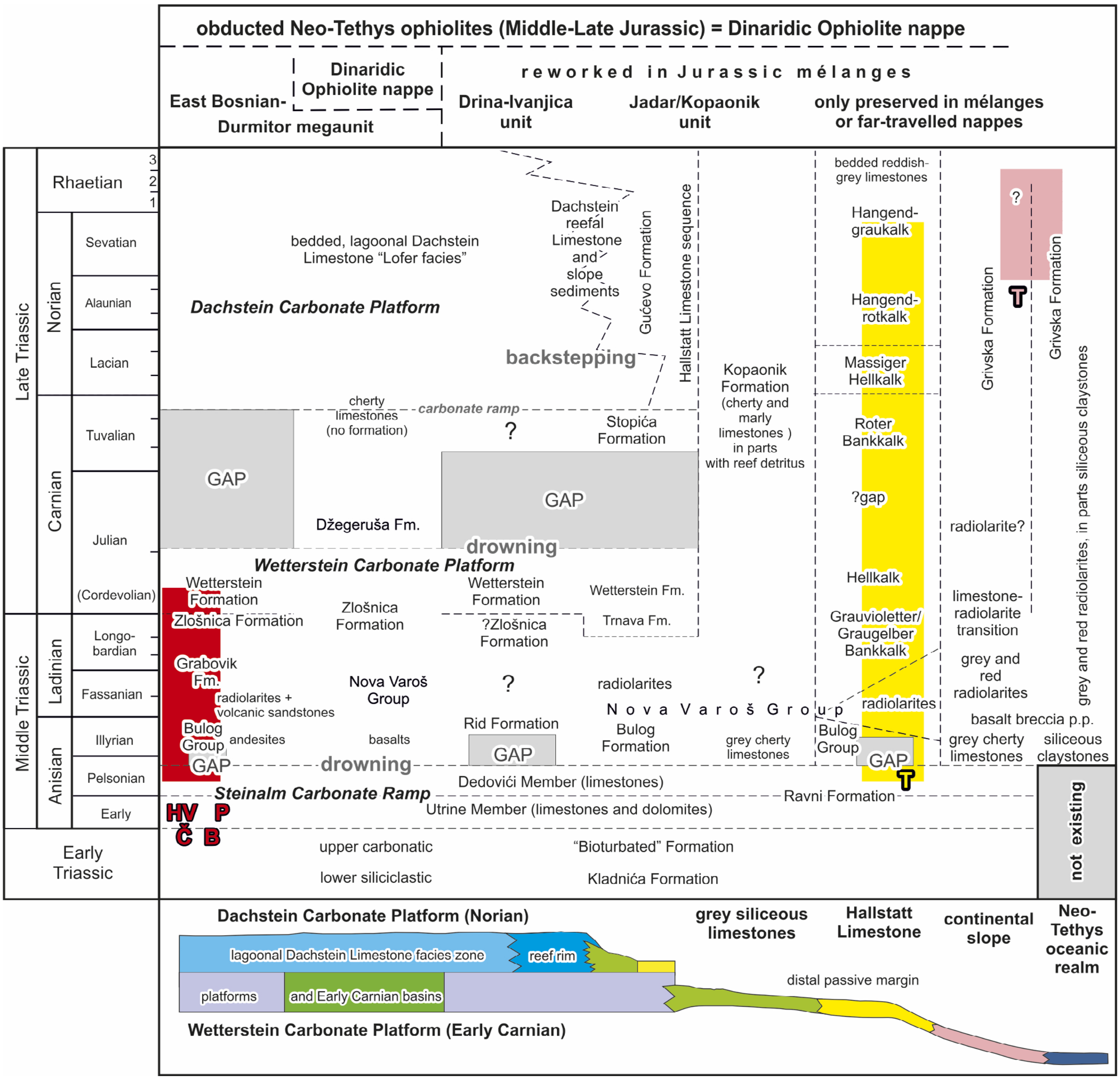

Fig. 3. Triassic stratigraphic table of the Inner to Outer Dinarides modified after Gawlick *et al. (2017a, 2023) and* Gawlick *&* Missoni *(2019). Early Triassic to early Middle Triassic modified after* Dimitrijević *(1997) and* Jovanović *(1998). Generation of Neo-Tethys oceanic crust started around 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),* Sudar *&* Gawlick *(2018),* Gawlick *et al. (2017a, 2023), and* Sudar *et al. (2023a, c). 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 Dinarides (Fig. 1). The studied sections HV – Han Vidović (type-section of the Bulog and Grabovik formations), P – Pridvorica (reference section for the Bulog and Grabovik formations), Č – Čavljak (Sedrenik plateau), B – Brodan, are marked in red. The transported sections in the Trebević Mt. are indicated in yellow (T: Studenkovići, Blizanac, Draguljac, Brus = Jurassic Zlatar (Hallstatt) Mélange) and rosé (Grivska Formation block in the Jurassic ophiolitic mélange near Brus above the Zlatar Mélange). The section Čavljak (Sedrenik plateau) is part of the Pre-Karst unit, but note that the general tectonostratigraphic evolution of the Pre-Karst unit follows relatively exactly the sedimentary evolution of the East Bosnian-Durmitor megaunit.*

The biostratigraphic age dating of the revised and newly studied sections follow the slightly revised conodont biostratigraphic age ranges, which are given according to Krystyn (1983), Krystyn et al. (2009), and Chen et al. (2016), but we also take in consideration other recently published conodont age ranges (Orchard 2010; Kiliç et al. 2017; Plasenicia et al. 2018; Smirčić et al. 2018; Rigo et al. 2018; Kolar-Jurkovšek & Jurkovšek 2019; Kiliç 2021; Karádi et al. 2021, Karádi 2024). Beside the taxonomic determinations from the above mentioned papers, we use the nomenclature of Budurov & Sudar (1990) and Chen et al. (2016). However, even if some biostratigraphic age ranges of some conodont species seem to be slightly inaccurate, the biostratigraphic age based on assemblage-level composition is more accurate than age based on stratigraphic ranges of individual conodont species. In addition, the used age ranges of the Late Illyrian conodont assemblages in the East Bosnian-Durmitor megaunit in Montenegro were recently improved by their correlation with ammonoid-bearing levels (Mrdak et al. 2024a; Đaković et al. 2025).

For the abrevations of conodont genera, and the names of their authors, as the authors of the other conodont taxa, in the whole text and in Figs. 4, 9, 11, 14, and 16 see the Appendix 1.

Studied sections

We describe the studied Middle to early Late Triassic sections with the Middle–Late Anisian Bulog Formation in order to their palaeogeographic position during Triassic times. First described are the parautochthonous sections in the Sarajevo area starting with the type-section. It follows the description of the Middle to early Late Triassic parautochthonous sections in eastern Bosnia and Herzegovina. The transported, i.e. allochthonous, Middle to Late Triassic sections with the Middle–Late Anisian Bulog Formation south of Sarajevo in the Trebević Mt. are described subsequently in a separate chapter.

Sarajevo area

In the surroundings of Sarajevo (Figs. 1, 2) we studied and revised several sections of the Bulog Formation, i.e. the type-section of the Bulog and Grabovik formations: Han Vidović, the section Čavljak (Sedrenik plateau), and sections at Mt. Trebević (Fig. 2B, 2C). In addition, we revised the Hallstatt Limestone occurrences in the Trebević Mt. (Fig. 2C) and describe a newly detected ophiolitic mélange with blocks of the Grivska Formation incorporated.

Han Vidović section: type-locality of the Bulog Formation

The type-section (Figs. 4, 5) of the Bulog Formation (Hauer 1896) is located in the double serpentine on the old road from Pale to Sarajevo (N 43°51’7, 75“ E 18°30’55, 36“) (Fig. 2D). The interested reader on the history of previous studies of the type-section is referred to Sudar et al. (2023c and references therein).

In the type area the late Pelsonian to Illyrian Bulog Formation overly the shallow-water limestones of the Pelsonian Ravni Formation (dated by Pia 1935a, b) as drowning sequence. The predominantly red nodular limestones of the Bulog Formation in the type region are overlain by the volcanoclastic-sedimentary sequence of the here formalized Grabovik Formation (= Graboviker Schichten, Kittl 1904; see also Sudar 1986), which could not be exactly dated because of missing ammonoids or conodonts (Sudar 1986). Whereas the underlying condensed red nodular limestones of the Bulog Formation were dated by conodonts as *Aplococeras avisianum* Zone (Sudar 1986: late Illyrian – see discussion in Mrdak et al. 2024a), the overlying sequence of the Grabovik Formation was not exactly known (compare Sudar 1986: Fig. 29) and was for the first time described and dated by Sudar et al. (2023a) as Early Carnian (Fig. 4).

Here we re-evaluated the existing conodont faunas of the Bulog Formation from Sudar (1986), add some new samples taken at similar positions as those samples described in Sudar (1986), and sampled the neptunian dikes in the Ravni Formation and the sedimentary succession above the Grabovik Formation (Fig. 4).

The shallow-water Ravni Formation is crosscutted by two generations of neptunian dikes (Figs. 4, 5). The older generation is filled with a medium-dark red limestone with rare thin-shelled bivalves and is of late Pelsonian age, dated by following conodont fauna: *Nic. kockeli, Pg. bifurcata,* and *Pg. bulgarica* (sample BK 1/1). The younger generation of neptunian dikes crosscut the older generation and is filled by a dark-red slightly siliceous micritic limestone and could be dated by a rich conodont fauna as late Illyrian: *Gl. tethydis*, *Pg. eotrammeri*, *Pg. excelsa*, *Pg. fueloepi*, *Pg. szaboi*,

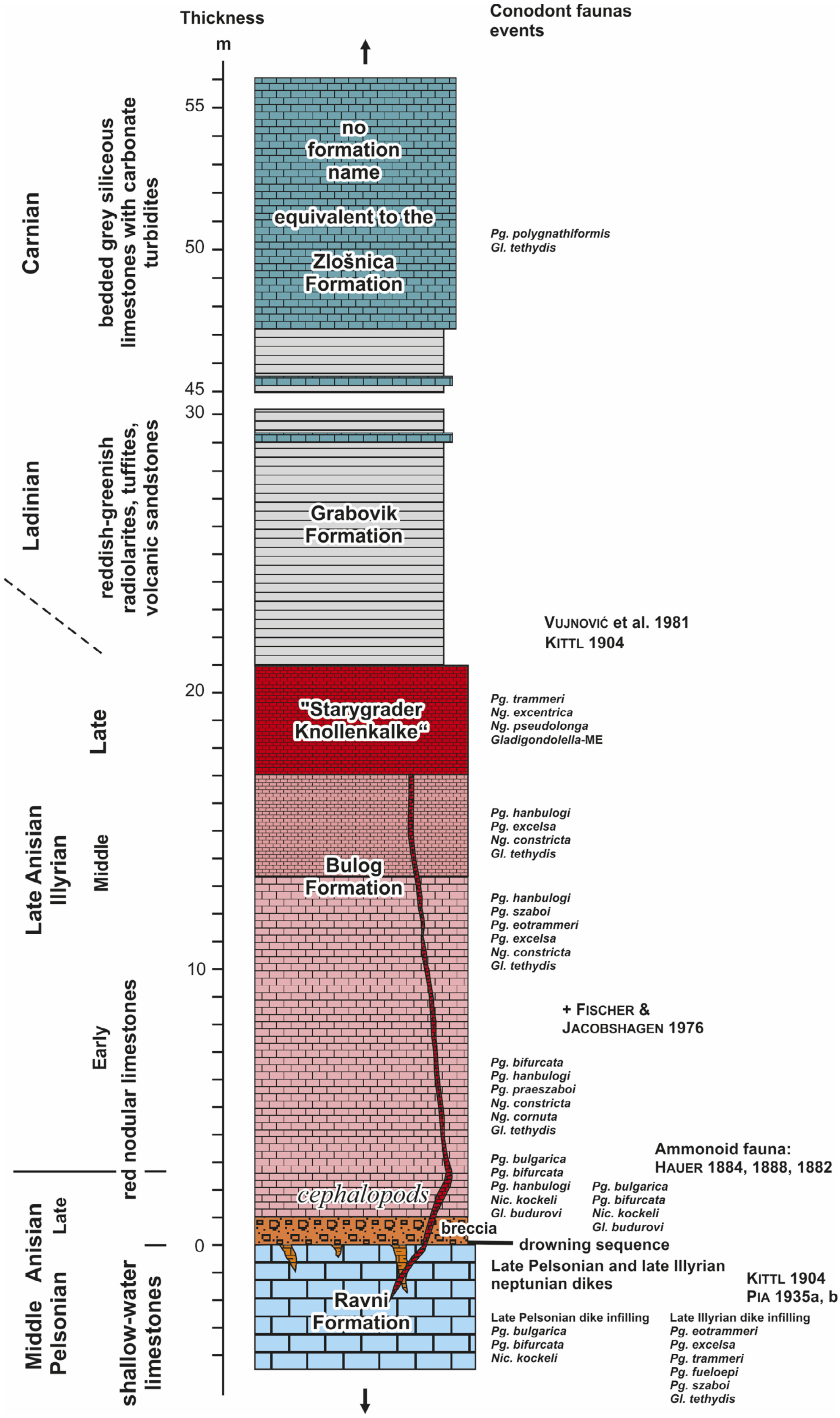

Fig. 4. *Pelsonian to Early Carnian sedimentary succession along the old road from Pale to Sarajevo: Han Vidović – type-section of the Bulog Formation and type-section of the Grabovik Formation. Measured thickness and biostratigraphic ages of the Bulog Formation according to* Pia *(1935a, b),* Hauer *(1884, 1892),* Fischer *&* Jacobshagen *(1976),* Sudar *(1986), and own new samples. Slightly modified after* Sudar *et al. (2023a, c) according to new results. Revised conodont ages of the different members of the Bulog Formation, and the neptunian dike infillings according to* Chen *et al. (2016).*

and *Pg. trammeri* (sample BK 1/2). The litho- and microfacies of the younger neptunian dike infilling corresponds to the lithofacies of the highest part of the Bulog Limestone succession, which could be dated by *Ng. excentrica*, *Ng. pseudolonga*, *Pg. trammeri*, and the *Gladigondolella*-ME as late Illyrian (sample MS 63/2023). Equivalent neptunian dikes of late Pelsonian and late Illyrian age could be also dated widespread in the Dinarides of Serbia (Gawlick et al. 2023; Sudar et al. 2013, 2023a. c). These ages correspond also to the age of the deposition of the Komarani Formation (Sudar et al. 2023c).

Whereas the most parts of the Ravni Formation consists of microbial limestones (Fig. 6) in the highest part of the Ravni Formation appear oncoids and crinoid fragments indicating an opening of the afore more restricted depositional environment. Foraminifera and calcareous algae are common only in the higher part. The rich calcareous algae flora was described in detail by Pia (1935a, b). Directly above the Ravni Formation a roughly one meter thick breccia layer (Figs. 4, 5) was deposited. Angular components of the Ravni Formation are common beside clasts of the lowermost Bulog Limestone. This breccia layer was deposited slightly after the formation of the first generation of neptunian dikes filled with light red biomicrites. Components of the Ravni Formation or other components are missing in the neptunian dike infilling. This clearly indicate that the dikes were filled earlier as the deposition of the breccia layer. But the deposition of this 1 m-thick breccia layer is still of late Pelsonian age proven by the occurrence of following conodont assemblage: *Gl. budurovi*, *Nic. kockeli*, *Pg. bifurcata*, and *Pg. bulgarica*. This breccia layer here can be attributed as part of the lower Komarani Formation (Sudar et al. 2023c), in a relative distal position.

After that breccia layer follow medium-dark red nodular limestones with the famous ammonoid-rich bed. The condensed cephalopod layer above the breccia level contain a lot of different ammonoid species known from the *Schreyerites binodosus* Zone of the late Pelsonian, described by Hauer (1884, 1892), and also from the *Paraceratites trinodosus* Zone (early Illyrian). This is also confirmed by the conodont fauna: *Gl. budurovi*, *Nic. kockeli*, *Pg. bifurcata*, *Pg. bulgarica*, and *Pg. hanbulogi* indicating a late Pelsonian and an early Illyrian age. This ammonoid-rich bed is recrystallized and the organisms in the predominatly wackestones cannot be determined accurately. Only thin-shelled bivalves ("filaments") and recrystallized grains are visible (Fig. 6). Hardground clasts with thick Fe/Mn-crusts are common. This clearly improves that the formation of the neptunian dikes in the Ravni Formation and the breccia layer above the Ravni Formation (=drowning event) is late Pelsonian, as the condensed bed with ammonoid faunas from the late Pelsonian and the early Illyrian (*Schreyerites binodosus* and *Paraceratites trinodosus* zones) was formed above.

The part of the Bulog Formation directly above the condensed ammonoid bed is early Illyrian in age, as confirmed also by the conodont faunas. From the lower part above the condensed layer rich in cephalopods an early Illyrian conodont fauna with *Gl. tethydis*, *Ng. constricta*, *Ng. cornuta*, *Pg. bifurcata*, *Pg. hanbulogi*, and *Pg. praeszaboi* was isolated. The predominantly wacke- to packstones contain a various microfauna, i.e. small gastropods, foraminifera, thin-shelled bivalves, broken ammonoid shells, crinoid fragments, and micrite clasts. In the highest part of the thicker bedded medium-red nodular limestone the conodont fauna indicate an early-middle Illyrian age: *Gl. tethydis*, *Ng. constricta*, *Pg. eotrammeri*, *Pg. excelsa*, *Pg. hanbulogi*, and *Pg. szaboi*. This part of the section is characterized by a higher condensation rate. Formation of small hardgrounds and deposition of different microfacies types is typical. Radiolaria- and "filament"-bearing wackestones with micrite clasts are separated from turbiditic "filament"-rich wacke- to packstones by a hardground (Fig. 6). Higher up in the section the red nodular limestone becomes thinner bedded, but the conodont fauna indicates still an early-middle Illyrian age: *Gl. tethydis*, *Ng. constricta*, *Pg. excelsa*, and *Pg. hanbulogi*. Anyhow, for this part of the succession slightly below the late Illyrian dark-red and siliceous limestones a middle Illyrian age is most likely. In this part of the section also brecciated monomictic to oligomictic limestone layers deposited, most probably seismites. Wheras the components consists of "filament"-rich wackestones the matrix consists of radiolaria-rich

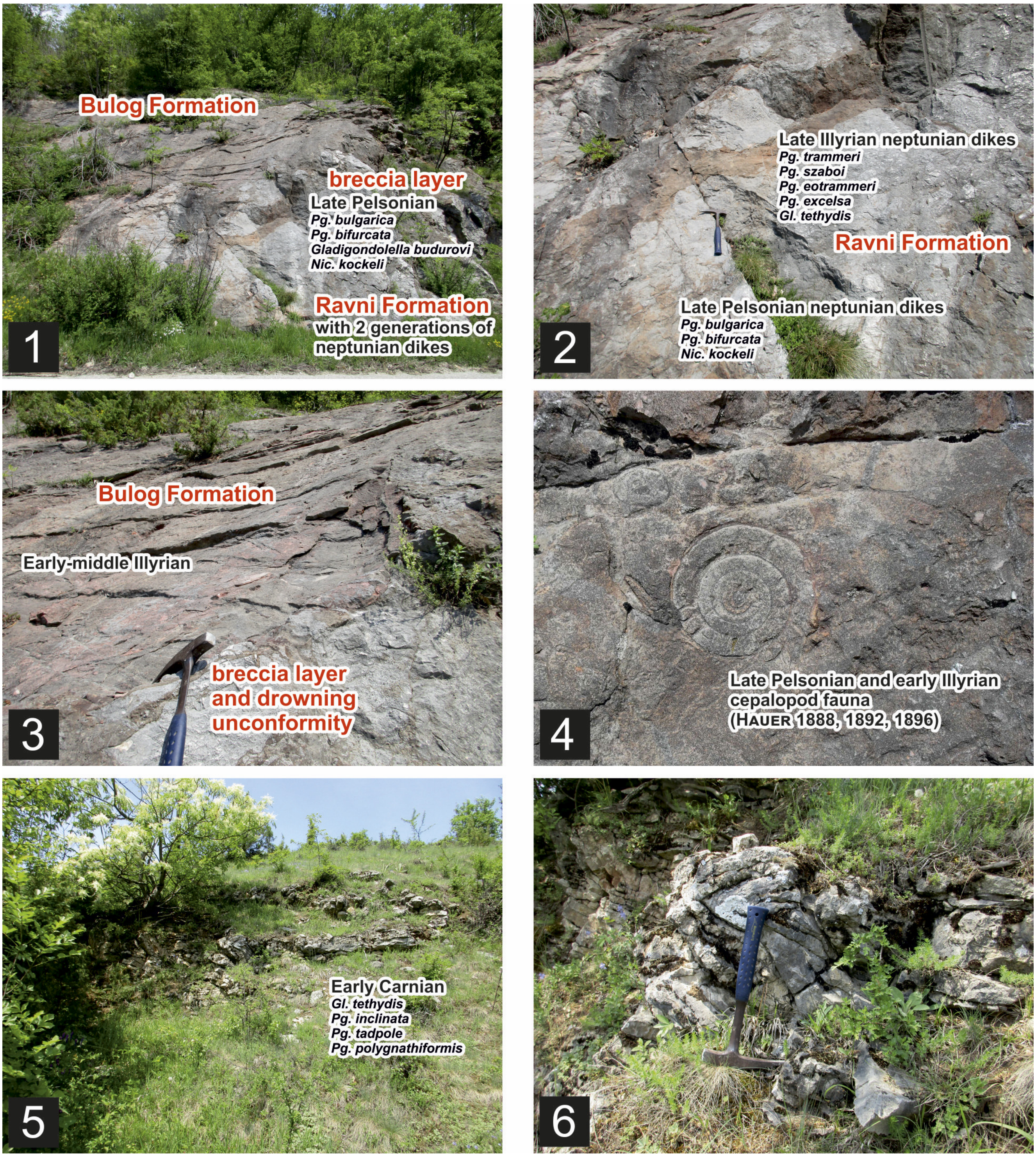

***Fig. 5**. Macroscopic view and field situation of the Middle Anisian to Early Carnian sedimentary succession along the old road from Pale to Sarajevo; Han Vidović, type-section of the Bulog and Grabovik formations. The Grabovik Formation crops out in small outcrops between the vegetation along the road above the Bulog Formation and the overlying grey siliceous bedded Early Carnian limestones. **1.** Contact between the middle Pelsonian shallow-water Ravni Formation and the overlying deep-water late Pelsonian to Illyrian Bulog Formation. The uppermost part of the Ravni Formation is intensivly dissected by two generations of neptunian dikes. **2.** Detail of a late Pelsonian neptunian dike infilling. Note that the neptunian dike infilling contain no Ravni Formation components. **3.** Above the Ravni Formation a breccia layer (Komarani Fm.) deposited and is overlain by medium-dark red nodular limestones which contain the ammonoid-bearing bed. **4.** Ammonoid-bearing layers rich in the cephalopods above the breccia layer. **5.** Series of the Early Carnian grey dm-bedded siliceous limestones with intercalated turbidites consisting of shallow-water grains above the Grabovik Formation. **6.** Slump deposit intercalated in the series of the Early Carnian grey bedded siliceous limestones.*

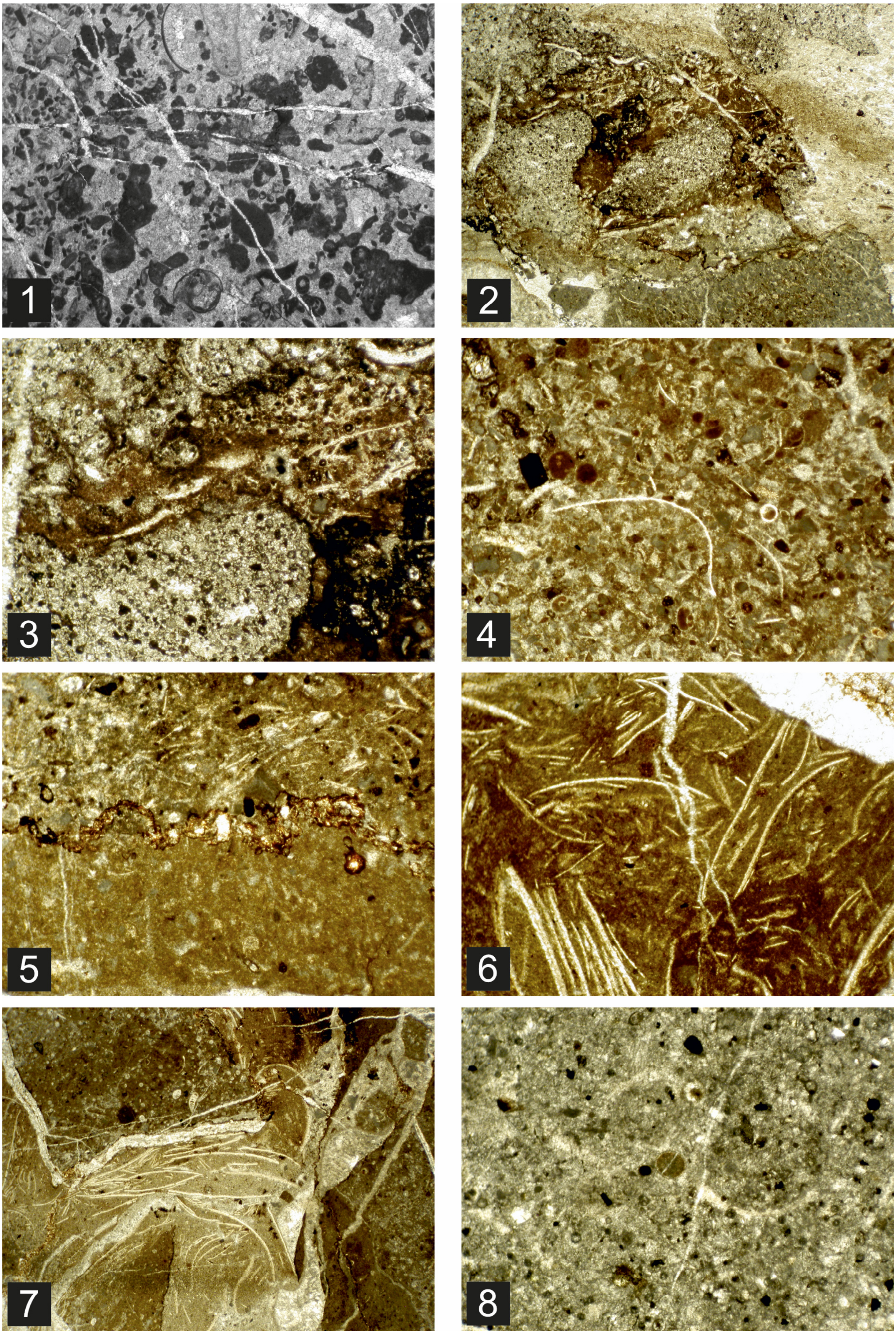
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Fig. 6. *Previous page: Microfacies characteristics of the Pelsonian Ravni Formation and the late Pelsonian to late Illyrian Bulog Formation from the type-section Han Vidović.* ***1.*** *Upper part of the Ravni Formation. Microbial fabrics with few micrite grains and shells. Sample MS 360. Width of the photo 1.4 cm.* ***2.*** *Lowermost late Pelsonian Bulog Formation, condensed horizon above the breccia layer. Slightly recrystallized wackestone with hardgrounds, and semi-lithified clasts with "filaments". Sample MS 353. Width of the photo 1.4 cm.* ***3.*** *Recrystallized and condensed late Pelsonian ammonoid-bearing layer with hardgrounds. Most components are strongly recrystallized and shells can be only recognized by their shape. Sample MS 353. Width of the photo 0.5 cm.* ***4.*** *Early-middle Illyrian packstone with several bioclasts (thin shelled bivalves, gastropods, broken foraminifera, broken ammonoid shells), hardground clasts, and micrite clasts. Sample MS 353. Width of the photo 0.5 cm.* ***5.*** *Early/middle Illyrian layered packstones with hardground contact. Wheras the lower part contain rare thin shelled bivalve fragments, micrite clasts, a foraminifera, and a juvenile ammonoid shell the upper layer consists of in parts densely packed thin shelled bivalves, hardground clast, and broken shell fragments. Sample MS 356. Width of the photo 0.5 cm.* ***6.*** *"Filament"-wackestone. Early/middle Illyrian. Sample MS 356. Width of the photo 0.5 cm.* ***7.*** *Slightly secondary brecciated early/middle Illyrian wacke- to packstone. Some parts are enriched with thin shelled bivalves whereas other parts consists of a radiolarian-rich wackestone with ostracod shells, and foraminifera. Sample MS 356-2. Width of the photo 1.4 cm.* ***8.*** *Late Illyrian wackestone with few recrystallized radiolarians and pyrite clasts. Sample MS 60. Width of the photo 0.5 cm.*

wackestones with few foraminifera. This dark-red and slightly siliceous limestone can be attributed to the late Illyrian by following conodont fauna: *Ng. excentrica*, *Ng. pseudolonga*, *Pg. trammeri*, and *Gladigondolella*-ME. This uppermost part of the succession was named "Starygrader Knollenkalke" by Kittl (1904), but we still attribute these red limestones to the Bulog Formation as in the late Illyrian a variety of red nodular limestones were deposited (Gawlick et al. 2023; Sudar et al. 2023a, c). These "Starygrader Knollenkalke" correspond to the Member 3 of the Bulog Limestone succession in Serbia (Klisura quarry, Sirogojno: Sudar et al. 2013, 2023b) and indicate a markant shift in the lithology related to the tectonic motions around the middle/late Illyrian boundary, and correspond also to the formation of the second generation of neptunian dikes (Gawlick et al. 2021, 2023). As stated in Sudar et al. (2023c) not everywhere the different members of the late Pelsonian to ?early Illyrian Bulog Formation can be distuinguised, and therefore members were not yet defined in the Bulog Formation. Nevertheless, in case of future definition of members in the Bulog Formation the highest member has to be named Starygrad Member. In addition, the "Starygrader Knollenkalke" correspond to the red nodular limestones of the upper cephalopod-bearing horizons of the section Haliluci. The described ammonoid fauna from this part of the section Haliluci (Hauer 1896) correspond to the late Illyrian (see Fischer & Jacobshagen 1976; Krystyn 1983). The FAD of *Halilucites* Diener is normally above the FAD of *Aploceras* D'Orbigny (compare Brack et al. 2005; Vörös 2014). Recrystallized siliceous wackestones with radiolarians, pyrite, and micrite clasts are characteristic for the highest part of the Bulog Limestone succession. Conodonts from this part of the section transitional to the Grabovik Formation could not be isolated.

Upsection, above the late Illyrian Bulog Limestone, follows the ?late Illyrian-Ladinian Grabovik Formation, in the higher part with increasing carbonate content. It cannot be decided by the isolated conodont faunas from the Bulog Limestone below if the Grabovik Formation starts to deposit in the late Illyrian or at the base of the Ladinian. But an onset of deposition of the Grabovik Formation around the Anisian/Ladinian boundary is most likely, because the youngest ammonites in the section Haliluci belong to the *Nevadites secedendis* Zone (see above), i.e. the highest part of the Illyrian. Also, in comparison with other sections in the Dinarides, especially in the East Bosnian-Durmitor megaunit, a latest Illyrian onset of deposition of the Grabovik Formation is most likely. Intense volcanism in this part of the Dinarides is always dated to start around the middle/late Illyrian boundary (Gawlick et al. 2023 and references therein), and therefore the erosional products of these volcanics start to deposit contemporaneously; this is around the middle/late Illyrian boundary (compare Mrdak et al. 2024a). Completely silicified beds in the lower part of the Grabovik Formation, rich in fine-grained sandstones or siltstones consisting of reworked volcanics, are composed of layered turbiditic and primary carbonatic sediments enriched in thin-shelled bivalves ("filaments"). Volcanic sandstones and siltstones dominate the lower part of the Grabovik Formation, siliceous claystones and chert layers as well as siliceous volcanic ash layers are intercalated. The Grabovik

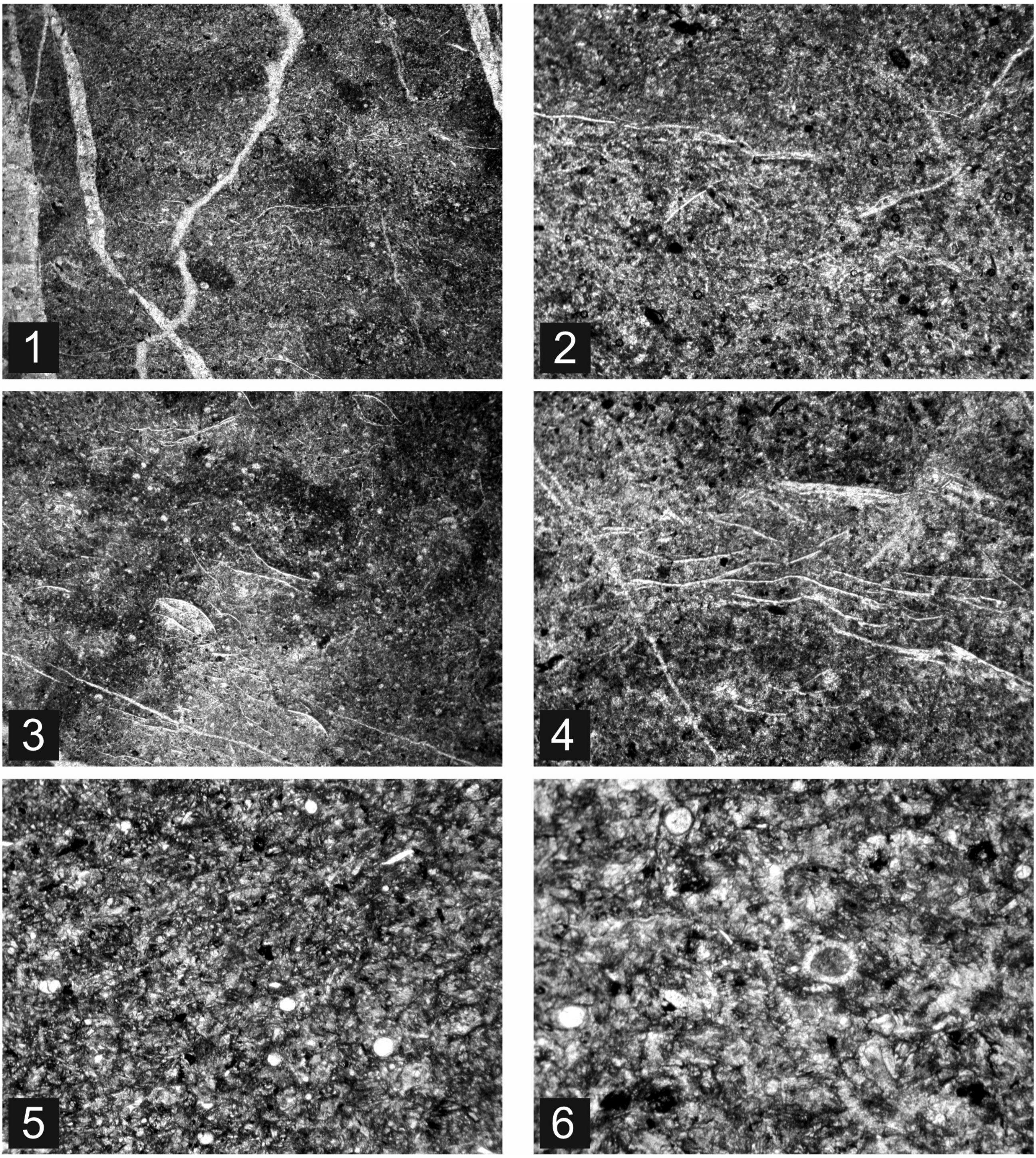

Fig. 7. *Microfacies of the late Ladinian Grabovik Formation and the layered Early Carnian grey siliceous limestones with intercalated carbonate turbidites with components of shallow-water origin from the section Han Vidović.* ***1.*** *Fine-grained bioturbated "filament"- and radiolaria-bearing pack- to grainstone. The fine-grained turbidic layers consist predominantly of micrite clasts and some broken organisms. Sample BIH 14. Width of the photo 1.4 cm.* ***2.*** *The lower part of the photograph shows a fine-grained pack- to grainstone layer, with thin-shelled bivalve fragments, broken foraminifera, micrite clasts and few clasts with micritic envelopes. In the upper part of the photograph is finer-grained and show a wacke- to packstone with recrystallized clasts, also broken foraminifera are visible. Sample BIH 14. Width of the photo 0.5 cm.* ***3.*** *"Filament"- radiolarian wackestone, slightly bioturbated. All radiolarians are recrystallized to calcite. Sample BIH 13. Width of the photo 1.4 cm.* ***4.*** *Turbiditic layer with thin-shelled bivalves between fine-grained packstone layers with recrystallized components and few recrystallized radiolarians. Sample BIH 13. Width of the photo 0.5 cm.* ***5.*** *Silicified volcanic ash layer with recrystallized radiolarians. The radiolarian tests are filled with quartz. Sample KON 59. Width of the photo 0.5 cm.* ***6.*** *Sample KON 59, other view. Some radiolarians are filled with mud and the test is well preserved while others are completely recrystallized and filled with quartz. Width of the photo 0.25 cm.*

Formation shows a fining-upward trend and in the higher part claystones and volcanic ash layers beside chert layers are common. In contrast, resedimented volcanics (sandstones) are very rare in the upper part of the Grabovik Formation. Rare intercalated siliceous limestones beds in the higher part of the Grabovik Formation consists of radiolarian wackestones. This upper part of the Grabovik Formation resembles lithologically what is called "Pietra Verde" in the Dinarides.

Above the Grabovik Formation follows in the type area Han Vidović in direct continuation of the Anisian-Ladinian succession a roughly 20 m-thick series of thin-bedded grey siliceous limestones with chert nodules with intercalated carbonate turbidites (Fig. 7). Upsection the content of intercalated carbonate turbidites increases reflecting the progradation of the Wetterstein Carbonate Platform. An Early Carnian age is confirmed by the conodont assemblage *Gl. tethydis* together with *Pg. polygnathiformis* (sample BIH 13) 2 metres above the "Pietra Verde". In sample BIH 14 only *Gladigondolella*-ME could be isolated (Middle Triassic to Early Carnian). This Early Carnian age is in line with sample BIH 13 or the conodont assemblages isolated from the age equivalent lithofacies in the section Pridvorica.

The higher part of the whole sedimentological evolution with the coarse-grained fore-slope reefal rud- to floatstones is separated from the Han Vidović section by normal faults with a slight lateral and vertical offset. But it is undoublty that these near-reef limestones from the slope of the Wetterstein Carbonate Platform were originally the normal overlying of the Anisian to earliest Carnian succession of the type-section. The microfacies (Fig. 8) shows the typical characteristics of the cement-crust dominated reefal framework of the Wetterstein reefs with various incrusting organisms (compare Flügel 1989 – "Algen/Zement-Riffe"; Emmerich et al. 2005), or more generally "cement-supported framework" (Riding 2002). The reef-builder "*Tubiphytes*" *obscurus* Maslov is common in the thin sections. Also dasycladalean algae from the back-reef area were transported into the adjacent basin and appear together in rudstones with fore-reefal materal. *Salpingolorella sturi* (Bystrický) is typical for the Late Ladinian to Early Carnian (Wetterstein Carbonate Platform) (Bystrický 1967), but is also know from the Early Norian (rare occurrences, Patrulius 1970). The thickness of the here preserved Wetterstein Carbonate Platform is rather thin and does not exceed 40 m (Sudar 1986) and is topped by a thin series of open-marine deep-water limestones (Fig. 8) above an unconformity. *Pg. nodosa* together with *Pg. polygnathiformis* indicate a latest Tuvalian age for the lowermost part of these open-marine limestones. Higher up follows in the area around Sarajevo, i.e. in the East Bosnian-Durmitor megaunit lagoonal Dachstein Limestone (Norian-Rhaetian). The transition between the latest Carnian deep-water limestones and the shallow-water Norian lagoonal Dachstein Limestone is not outcropping in the area around the type-section, but a rapid shallowing is expectable. However, this situation with a long-lasting gap in the Carnian and the onset of carbonate formation in the latest Carnian resemble the situation known from East Bosnian-Durmitour megaunit in northern Montenegro, where the onset of carbonate production also started in the latest Carnian and led to the formation of the Norian-Rhaetian Dachstein Carbonate Platform (Mrdak et al. 2023). Also in Serbia a similar situation is known from the type area of the Zlošnica Formation with the overlying fine-grained siliciclastic sedimentary rocks of the Džegeruša Formation. Above the Džegeruša Formation and below the shallow-water Norian Dachstein Limestone a thin series of siliceous limestones deposited (Gawlick et al. 2017a), which cannot be exactly dated. Only some broken pieces of a *Pg*. cf. *polygnathiformis* could be isolated beside an undeterminable *Paragondolella* sp. with few knots on the platform, known only from late Tuvalian forms. Here the lagoonal Dachstein Limestones follows after a covered part in the section in a thickness of less then 10 meters.

Čavljak (Sedrenik plateau) section

At the section Čavljak (Sedrenik plateau) (Figs. 2B, 9) in an altitude of 1300 m and around 9 km north of the central part of the Sarajevo town i.e. in the vicinity of the old Motel within the wider NE suburb of the Sarajevo town, the shallow-water

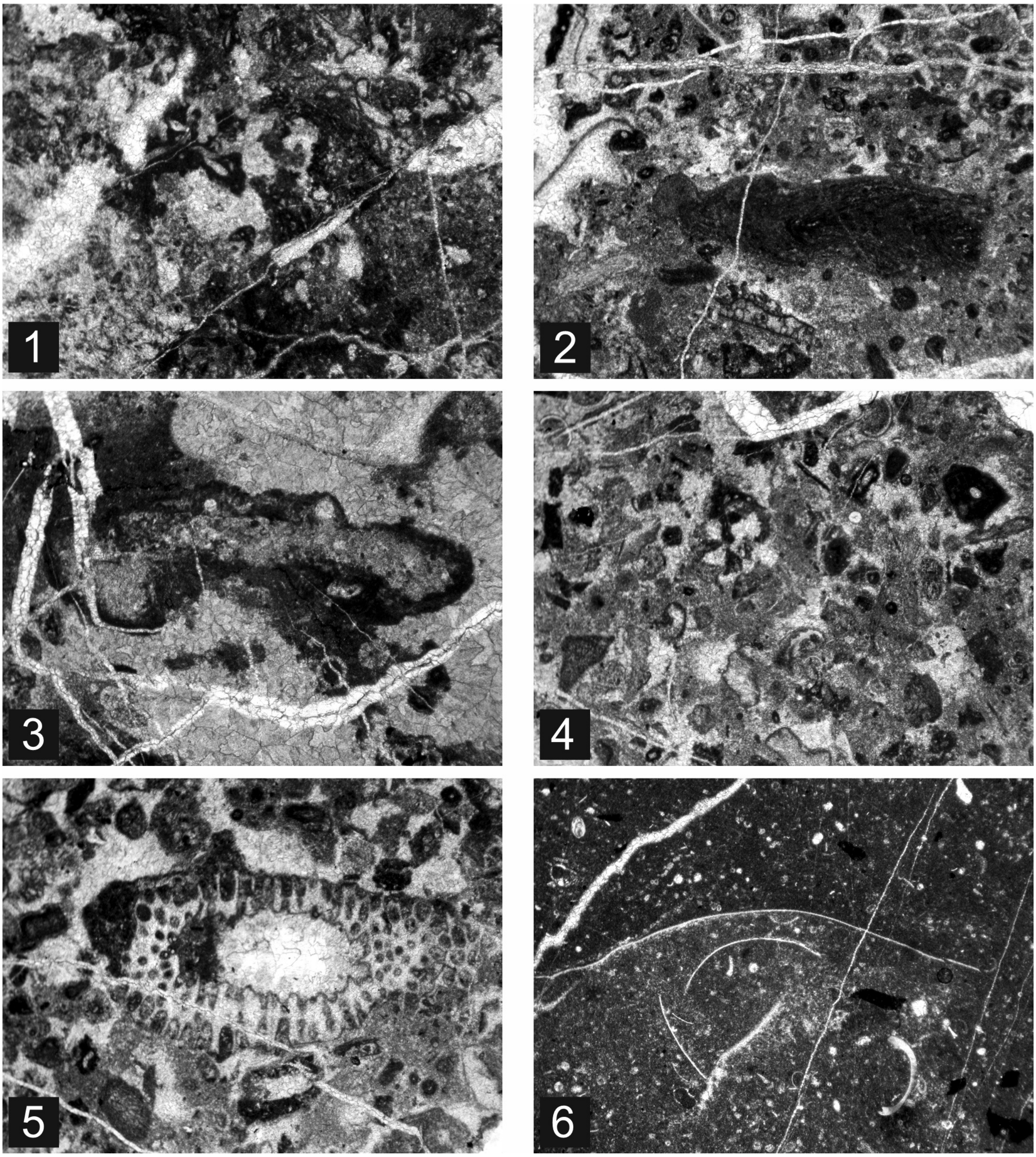

Fig. 8. *Microfacies of the foreslope rudstones of the Wetterstein Carbonate Platform and the overlying latest Carnian open-marine limestones from the Han Vidović section.* ***1****. Fore-reefal limestone with encrusting organisms. Sample MS 341. Width of the photo 0.5 cm.* ***2.*** *Turbididic coarse-grained limestone with shallow-water organisms, micrite clasts. Some components are incrusted. Sample MS 342. Width of the photo 0.5 cm.* ***3.*** *Encrusted recrystallized reef builder. Typical is the enormous amount of calcite cement between the reefal organisms formig the typical "cement-crust"-reefs of the Wetterstein Carbonate Platform (*GAWLICK *et al., 2006 and references therein). Sample MS 343-1. Width of the photo 0.5 cm.* ***4.*** *Turbiditic layer with "Tubiphytes" obscurus* MASLOV*, micrite clasts, and broken fragments of shallow-water organisms. Sample MS 343-2. Width of the photo 0.5 cm.* ***5.*** *Salpingolorella sturi (*BYSTRICKÝ*) from a component in fore-reef rudstones. Sample MS 342. Width of the photo 0.5 cm.* ***6.*** *Radiolaria-"filament"-bearing wackestone with a bivalve shell from the latest Carnian open-marine limestones above the reefal rudstones and floatstones of the Wetterstein Carbonate Platform. Sample MS 344. Width of the photo 0.5 cm.*

limestones of the Ravni Formation are overlain by Bulog Limestones, dated by conodonts as late Pelsonian to Early/Middle Illyrian.

The shallow-water limestones of the Ravni Formation are dissected by neptunian dikes filled with red biomicrites with broken crinoids and "filaments" (Fig. 10). In contrast to various other localities (including the type-locality) in the Dinarides (Gawlick et al. 2023 and references therein) here only one neptunian dike generation, that is the older (late Pelsonian) one, could be detected. Directly above the grey Middle Anisian shallow-water limestones an open-marine red-grey limestone bed with some shallow-water debris and microbial clasts (Fig. 10) could be dated by *Pg. bulgarica* and *Nicoraella* sp. as late Pelsonian (sample BIH 19).

Upsection follows a roughly 15 m-thick series of a thick bedded to massive red limestone with thin-shelled bivalve layers. The lower part of this part of the succession is most probably early Illyrian in age by the occurrence of *Pg. bifurcata*, *Pg. hanbulogi* and *Pg. praeszaboi* (sample BIH 22). Higher up, above a condensed level, the conodonts *Gl. budurovi* and *Gl. tethydis* indicate only an Illyrian age (sample BIH 22a), even if a late Pelsonian age could not be excluded for the lower part of this red nodular limestone succession. Above the condensed hardground layer with few cephalopods and "filaments" follow predominantly radiolaria-wackestones with few broken "filaments". Clasts surrounded by Fe/Mn-crusts consists of radiolarian-rich wackestones (Fig. 10).

Higher in the succession follow a 3 m-thick series of red nodular radiolaria-rich limestones with chert layers, indicating that the rapid deeping of the depositional realm is continous throughout the Illyrian. The age of this part of the succession is still (early)/ middle Illyrian, based on the occurrence of *Gl. tethydis*, *Ng. constricta*, *Pg. excelsa* and *Pg. hanbulogi*. These siliceous dm-bedded red limestones are overlain by dm-bedded red radiolarites and chert layers. The chert layers consists of primary fine-grained limestone beds with turbiditic thin-shelled bivalve layers (Fig. 10), overlain by a series of approx. 5 m-thick red radiolarites. This improve a continous deepening of the depositional realm, a decrease in carbonate production and an increase of deposition of radiolarian ooze in the late Illyrian. These red radiolarites contain a very poor preserved radiolarian fauna: *Striatotriassocampe* sp., *Paraoerlitispongus multispinosus* Kozur & Mostler, and *Archaeocenosphaera* sp. On base of this radiolarian fauna the age of the radiolarite is most probably late Illyrian. The genus *Striatotriassocampe* Kozur & Mostler first appears in the *Ladinocampe multiperforata* Zone (= uppermost *Reitziites reitzi* Zone (Kozur & Mostler 1994), whereas *Paraoerlitispongus multispinosus* Kozur & Mostler, has its FAD in the Upper Anisian *Tetraspinocyrtis laevis* Zone (Kozur 1996). However, by the occurrence of conodonts in the siliceous limestones below the radiolarites/cherts and the bad preserved radiolarian fauna a late Illyrian age of this part of the succession is most likely. These radiolarites are in turn overlain by grey siliceous limestones with volcanic ash layers ("Pietra Verde"). Volcanic sandstone intercalations are missing, but the part between the radiolarites and the grey siliceous limestones is only badly out-cropping in the forest. These siliceous limestones consist in their lower part of grey radiolaria-rich siliceous biomicrites and higher in the section appear intercalated turbidite layers with shallow-water grains from the evolving Wetterstein Carbonate Platform. Here this part of the succession could not be exactly dated, only broken pieces of *Paragondolella* sp. could be isolated (sample BIH 21), indicating most probably a latest Ladinian or early Carnian age.

The depositional trend of the late Pelsonian drowning sequence above the shallow-water limestones of the Ravni Formation is characterized by a general deepening trend (Figs. 9, 10). Directly above the shallow-water limestones of the Ravni Formation a layer of mixed shallow- and deep-water grains deposited and indicate the drowning of the Ravni Carbonate Ramp. This layer as well as the shallow-water limestones of the Ravni Formation are dissected by nepuntian dikes filled with red biomicrite of the lowermost Bulog Formation, in cases with some shallow-water grains and is most probably of late Pelsonian age, although the dikes could not be dated by conodonts. Higher up in the succession the Bulog Limestone consists of radiolarian- and thin-shelled bivalve bearing wacke- to

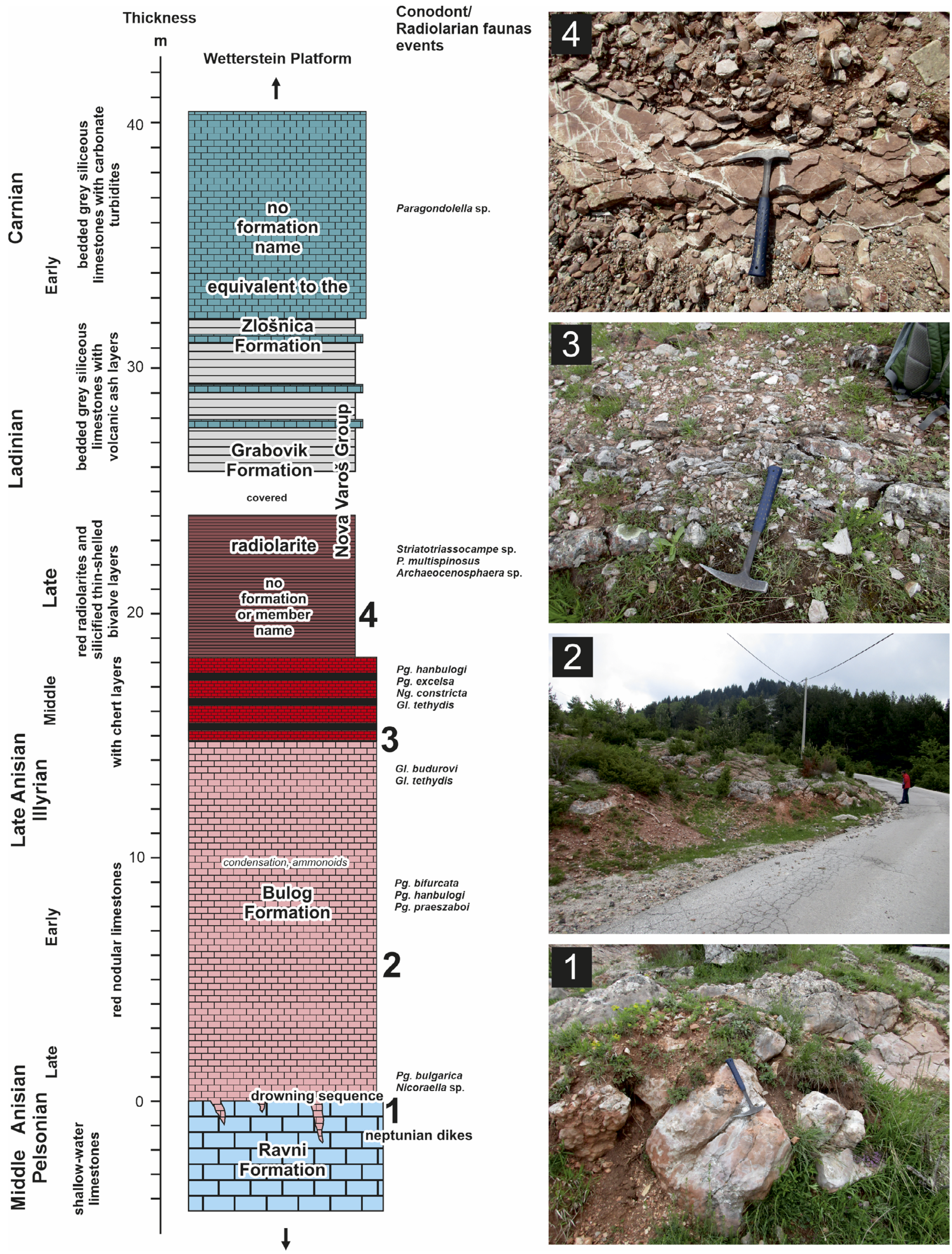

Fig. 9. Middle Anisian to Early Carnian sedimentary succession at Čavljak (Sedrenik plateau). In the measured section the different formations and their ages are assigned. The photos show characteristic sedimentological features of the section. ***1.*** *Pelsonian Ravni Formation dissected by nepunian dikes filled with light red biomicrites and angular components of the uppermost Ravni Formation.* ***2.*** *Field view of the bedded red nodular limestones of the Bulog Formation above the Ravni Formation shallow-water limestones.* ***3.*** *Topmost part of the Bulog Formation: 3-5 cm bedded red limestones with red chert nodules and layers.* ***4.*** *Late Illyrian red radiolarite.*

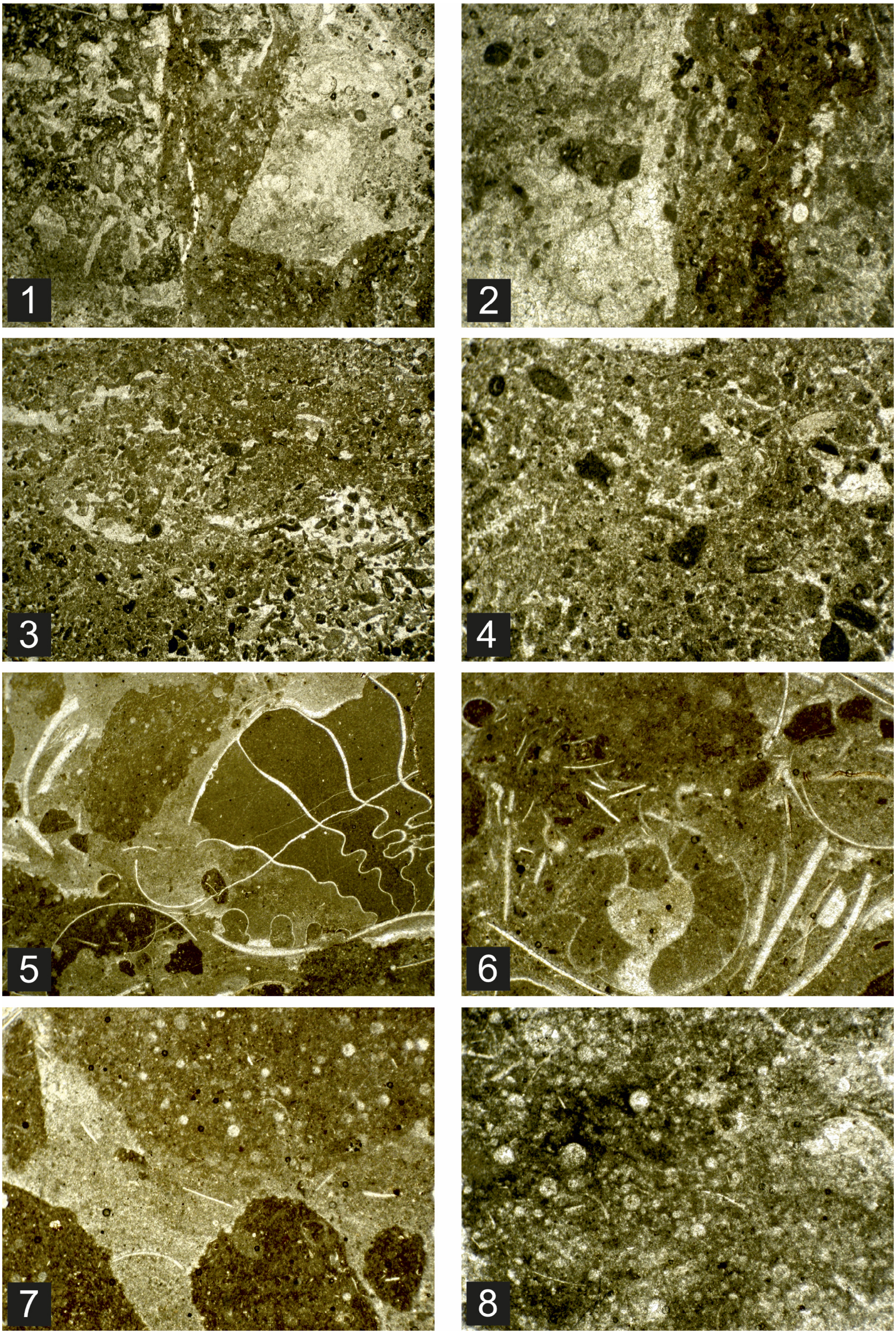
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Fig. 10. Previous page: Microfacies characteristics of the Pelsonian – Illyrian sedimentary rocks of the sedimentary succession at Čavljak (Sedrenik plateau). 1. Neptunian dike infilling in the Pelsonian shallow-water limestones of the Ravni Formation. These wackestones show beside small clasts of the Ravni Formation also broken crinoids and "filaments". Sample BIH 18. Width of the photo 1.4 cm. 2. Enlargement of 1, other view. The border of the neptunian dike infilling directly to the Ravni Formation is marked by a thin micrite layer. The limestones of the Ravni Formation are slightly recrystallized. In the fine-grained infilling broken pieces of thin-shelled bivalves ("filaments") are visible. Width of the photo 0.5 cm. 3. The first layer of the late Pelsonian drowning sequence contain beside broken thin-shelled bivalves a lot of micrite grains beside few broken foraminifera. Packstone to grainstone. Sample BIH 19. Width of the photo 1.4 cm. 4. Enlargement of 3, other view. Packstone with microbial micrite clasts, and broken thin-shelled bivalves. Width of the photo 0.5 cm. 5. Middle Illyrian hardground layer with ammonoid shells and thin-shelled bivalves. The components in the micritic "matrix" show a slightly different facies: pure radiolarian wackestones and radiolarian wackestones with few thin-shelled bivalves dominate. Sample BIH 22. Width of the photo 1.4 cm. 6. Ammonoid-bearing wackestone with a lot of broken thin-shelled bivalves and few recrystallized radiolarians. Sample BIH 22. Width of the photo 0.5 cm. 7. Sample BIH 22, different insight. View on the different clasts in the micritic matrix with some thin-shelled bivalves and recrystallized radiolarians. In some components small clasts of hardground formation are preserved. The big clast in the upper part of the photo consists of a radiolarian wackestone. Width of the photo 0.5 cm. 8. Late Illyrian siliceous radiolarian wacke- to packstone with few broken thin-shelled bivalves. Sample BIH 21. Width of the photo 0.5 cm.

packstones, in cases with recrystallized radiolarians, and in the lower part with few broken crinoids. Only in few layers stratigraphic condensation could be observed (Fig. 9) with ammonoids and hardground clasts (Fig. 10). Higher up the amount of biogenic silica increases and radiolarian wacke- to packstones dominate. In cases silicified layers enriched in thin-shelled bivales are preserved. The late Illyrian ~6 m-thick red radiolarites/cherts are overlain by a ~7 m-thick series of silicified micritic carbonate layers, silicified claystones and intercalated thin volcanic ash layers. This lithology resemble the upper Grabovik Formation, but is here much finer-grained. We assign the late Illyrian to ?Ladinian lower radiolaritic part and the upper more carbonaceous and siliciclastic part to the Nova Varoš Group without clear indication to which formation these two lithologies may belong, because the studies on the late Illyrian – Ladinian very variable lithologies is still ongoing. Anyhow, this means, that the red radiolarites/cherts of the lower part below the siliceous grey limestone succession are most likely an equivalent of the upper Bulog Formation ("Starygrader Limestones") to lower Grabovik Formation of the type-locality, where reddish-greenish radiolarites intercalated by volcanic ash layers and volcanic sandstones deposited. The upper part of this part of the section consisting of silicified micritic carbonate layers, silicified claystones and intercalated thin volcanic ash layers differs also from the Grabovik Formation, and resembles more the Nova Varoš Formation in Serbia. Upsection follows an at least 20 m-thick series of dm-bedded grey siliceous limestones with intercalated carbonate turbidites with shallow-water grains. In the upper part of the succession the amount of intercalated turbidites and the grain-size increases indicating the progradation of the Wetterstein Carbonate Platform. This part of the section is very similar to the Zlošnica Formation as defined in Serbia, but the exact age in this section is unclear in moment, therefore we assign it not to any formation, even though upsection the prograding Wetterstein Carbonate Platform with coarse-grained reefal float- to rudstones follow.

Eastern Bosnia and Herzegovina

Pridvorica section

In a sedimentary succession in the village Pridvorica (near the Sokolac town on the northern slope of Romanija Mt.) approximately 50 km north-east of Sarajevo (Fig. 2B), a Bulog Limestone section discussed as proposal for the Neostratotype of the Illyrian (Vujnović et al. 1981; Marić et al. 1982), we reach the same result as at the type-locality Han Vidović near Sarajevo. However, this sections is highly enigmatic because of 1) the enormous thickness of the Bulog Limestone (more then 60 m) and 2) an existing at least 20 m-thick level with an enormous amount of shallow-water material in the central part of the section (between 25 m and 45 m measured thickness – Fig. 11) above the 1st ammonoid layer. In addition, older conodonts appear in red nodular limestones (*Pg. bifurcata)*. From this level onwards to the 2nd ammonoid-bearing horizon also volcanic material is present in the section (Vujnović et al. 1981). During our field work (May 2018) it turned out, that a detailed reinvestigation of the whole succession today is practically impossible because of the dense vegetation, in cases the section is covered by a lot of fallen blocks and in parts also by building waste. The section needs to be digged out again to restudy it in detail. Therefore we had only the existing samples of M. Sudar from the sample campaigns in the 1980s (conodont samples and thin sections) to re-evalutate the section. Anyhow, even we could not resample some citical parts of the described and figured section, we were able to revise the existing sample material (Sudar & Budurov 1983; Sudar 1986), and to give a general outline of the Anisian part of the section. But, for some parts of the today practically totally covered section we can point out only the existing problems and discuss similarities with other known sections in the East Bosnian-Durmitor megaunit. The importance of the whole Anisian to Early Carnian succession in Pridvorica in comparison with the sedimentary successions with preserved Bulog Limestones in the area of Sarajevo is the great similarity of the tectonostratigraphic evolution mirrored in the lithological evolution known also from the type area including the type-section Han Vidović.

The drowning sequence of the Ravni Carbonate Ramp is the late Pelsonian-Illyrian Bulog Limestone, followed by the Grabovik Formation and a siliceous limestone succession, in the upper part with intercalated carbonate turbidites from the prograding Wetterstein Carbonate Platform (Fig. 11). Grains with micritic envelopes, broken coated grains, and the reef-building organism “*Tubiphytes*“ occur in these carbonate turbidites, indicating a shallow-water origin.

Above the shallow-water limestones of the Ravni Formation deposition of the red nodular limestones of the Bulog Formation started in the late Pelsonian (Vujnović et al. 1981; Marić et al. 1982) as confirmed by ammonoid (Mudrenović in Vujnović et al. 1981) and conodont age dating (Ljiljana Jeličić in Vujnović et al. 1981; Sudar & Budurov 1983) (Fig. 11).

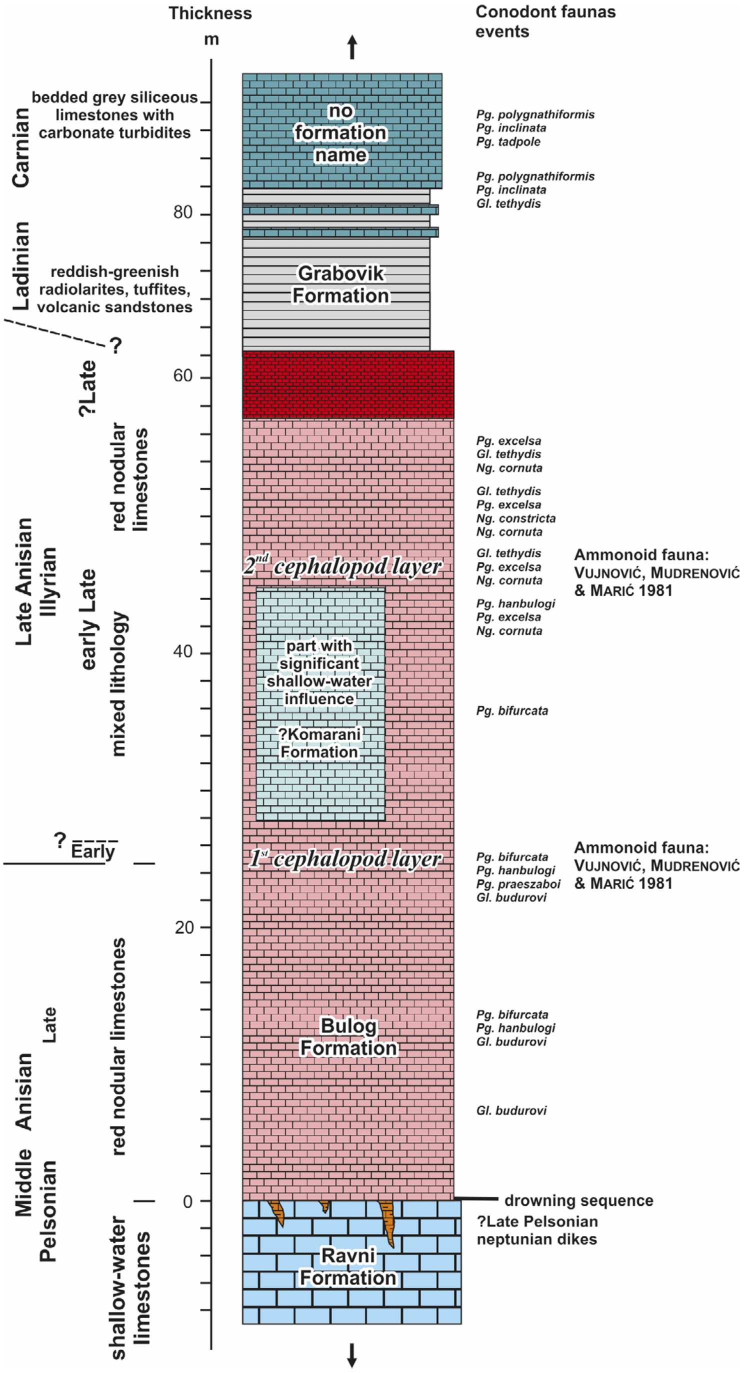

Fig. 11. *Pelsonian to Early Carnian sedimentary succession in the village Pridvorica. Conodont samples described in Sudar & Budurov (1983) and Sudar (1986) are re-evaluated and added by new samples in the Carnian part of the section. First analysis of the microfacies result in the detection of an at least 20 m-thick intervall of intercalated shallow-water limestones and older Bulog Limestone. As the section is totally covered by waste and bushes it cannot be decided if this part of the series consists of a oligomictic breccia made of shallow-water Ravni Formation limestone blocks with a red matrix or intercalated fore-reefal blocks of a contemporaneously formed carbonate atoll around a volcano (compare Mrdak et al. 2024a) in a red Bulog Limestone matrix. As in this level also older conodonts like Pg. bifurcata are proven the assigment of the breccias to the Komarani Formation is most likely.*

The Middle Anisian shallow-water limestones of the Ravni Formation are dissected by neptunian dikes filled with red biomicritic limestones of the Bulog Formation. The infillings of the neptunian dikes are not dated by conodonts, but a late Pelsonian age for these neptunian dikes can be estimated.

The overlying more than 20 m-thick red nodular limestone sequence starts with thick-bedded grey-red biomicrites with thin-shelled bivalve fragments and foraminifera. Above follows the first condensed red nodular limestone level with ammonoids (1st cephalopd level in Fig. 11), overlain by an appr. 20 m-thick series of bedded red-grey limestones up to the 2nd cephalopod layer (Fig. 11) of ?late Illyrian age. The ammonoid fauna of the 2nd ammonoid-bearing level was compared with the upper ammonid-level of the famous ammonoid-bearing locality Haliluci (section figured in Fischer & Jacobshagen 1976), and therefore with the late Illyrian. Krystyn (1983) stated, that in this in Haliluci at least 1.5 m-thick ammonoid-bearing part of the section several ammonoid zones appear in the mixed fauna from the *Kellnerites* Zone (= *Reitziites reitzi* Zone) to the *Nevadites secedensis* Zone. This is also confirmed by the FAD of *Pg. eotrammeri* which normally appear not earlier as in the *Aplococeras avisianum* Zone according to Krystyn (1983).

However, the older ammonoid fauna described by Hauer (1896) derive not from this section. These ammonoids derive from finding places higher on the road (Hauer 1896). Also Balini (1998) stated, that in the type area of the Bulog Formation, i.e. the section Han Vidović and Haliluci at least four ammonoid zones can be recognized from the *Schreyerites binodosus* Zone to the *Nevadites secedensis* Zone.

In contrast, the conodonts, even several meters higher, in the Pridvorica succession not clearly evidence a late Illyrian age for this part of the Bulog Limestone. Above the last middle/?late Illyrian conodont sample, in the upper part of the here more siliceous Bulog Limestone, no conodont faunas could be extracted to improve the exact age.

According to Vujnović et al. (1981) and Marić et al. (1982) on base of the determined ammonoids from both fossiliferous horizons in the Pridvorica section belong only to the ammonoid *Paraceratites trinodosus* Zone at the base of the lower Illyrian (Anisian). The most representative and abundant genera, concerning the number of species, among the cephalopod association of Pridvorica section are:

1st cephalopod layer: ammonoids of the genera *Monophyllites*, *Arcestes*, *Kellnerites*, *Proteusites*, *Megaphyllites*, *Sturia*, *Ptychites*, and *Gymnites*;

2nd cephalopod layer: ammonoids of the genera *Sagecaras*, *Megaphyllites*, *Procladicites*, *Ptychites*, *Sturia*, *Japonites*, *Gymnites*, and *Monophyllites*.

This age interpretation of Vujnović et al. (1981) and Marić et al. (1982) is not in accordance with the range of characteristic ammonoid genera summarized in Vörös (2014): the FAD of the genera *Monophyllites* and *Sturia* is in the *Aplococeras avisianum* Zone (or *Aplococeras avisianum* subzone – compare Balini et al. 2010; Vörös 2003, 2014; Jenks et al. 2015). Also the FAD of the genus *Gymnites* in Nevada is similar to the FAD of *Monophyllites* and *Sturia*. In contrast, the genus *Ptychites* has its last occurrence in the *Paraceratites trinodosus* Zone. The genus *Proteusites* should be restricted to the Pelsonian, but was recently also found in the *Aplococeras avisianum* Zone (Đaković et al. 2025). The genus *Kellnerites* appear in the lower *Reitziites reitzi* Zone. Also Krystyn (1983) stated, that according to the described ammonoid fauna both ammonoid-bearing levels correspond to the higher *Parakellnerites* Zone (equivalent to the *Aplococeras avisianum* Zone of Vörös 2003, 2014 or Jenks et al. 2015) and contain a mixed fauna. It has to be noted, that the lower 1st cephalopod horizon contain significantly more ammonoids from the Pelsonian to basal Illyrian, and that in the upper level predominantly ammonoids from the *Aplococeras avisianum* Zone appear, but also with ammonoids from significantly older horizons. However, this ammonoid fauna described by Vujnović et al. (1981) and Marić et al. (1982) needs a complete modern revision, if this fauna is still accessible.

The mentioned authors conclude that this fauna corresponds to those described from Han Bulog (= Han Vidović type-section), Haliluci, Palež and Volujak (Marić et al. 1982, p. 71). Similar conclusion were made by Sudar & Budurov (1983) on the base of biostratigraphic analysis of conodonts from the same section. They separate the conodont zones *Pg. bifurcata*-A.Z. and *Ng. cornuta*-R.Z., what indicate that the vertical distribution of Bulog Limestones of Pridvorica is restricted to the *Paraceratites trinodosus* Zone, i.e. the Lower Illyrian (Anisian Stage).

In general, up to 1st cephalopod layer the sedimentological evolution of the section resembles in its evolution all known sections where a drowning of the Ravni Carbonate Ramp in the late Pelsonian is preserved (Gawlick et al. 2023; Sudar et al. 2023b and references therein). By this, it has to be noted, that Vujnović et al. (1981) in their description of the type-locality give a list of ammonoid genera of mixed ages. In fact they summarize the findings of Hauer (1888, 1892, 1896) from different localities in their list.

However, from the 1st cephalopod layer with the mixed fauna, and of an age of at least not older as the *Aplococeras avisianum* Zone also shallow-water limestones appear in the section together with Bulog Limestones containing *Pg. bifurcata*. In addition, also the 2nd cephalopod layer still contain older ammonoids and the younger ammonoids in this layer indicate an age not older as the *Aplococeras avisianum* Zone.

On base of these results we assign the lower (late Pelsonian) part of the section to the Bulog Formation, the part of the section between the two cephalopod accumulations to the Komarani Formation again overlain by red nodular limestones of the Bulog Formation. The highest part of the Bulog Formation could not be dated but correspond to the highest part of the type-section of the Bulog Formation. Also in the Han Vidović section more siliceous red nodular limestones deposited. In contrast to the type-section, where this part of the section could be dated by conodonts (Fig. 4) the more siliceous sedimentary rocks in the section Pridvorica are not dated yet.

Komarani Formation: This roughly 20 m-thick part of the succession between the two cephalopod layers contain beside volcanic material (Vujnović et al. 1981) a significant amount of shallow-water material, in cases even with reef organisms like “*Tubiphytes*“ *obscurus* Maslov (Fig. 12.5), various foraminifera beside the predominant micrite clasts and other broken shallow-water organisms. Interstringly in this level appear *Pg*. *bifurcata, an* at least an earliest Illyrian conodont species, wheras all other species are significant for the early/middle Illyrian. In fact, a detailed resampling of the red nodular limestones in this part of the section would be necessary to solve this inconsistency. In moment it cannot be excluded, that our *Pg*. *bifurcata* probably resemble not rare specimen appearing in the *Pg*. *mesotriassica* (Kozur & Mostler) fauna (Karádi-Kapiller, pers. comm.). However, our specimen determined as *Pg*. *bifurcata* is different from *Pg*. *mesotriassica* figured by Kozur & Mostler (1982). But, on base of the conodont faunas for the higher part of the shallow-water-bearing part of the section an at least middle Illyrian age is proven, but an early late Illyrian (*Aplococeras avisianum* Zone) for this part of the succession is proven by ammonoids below and above the Komarani Formation. Also, the roughly 50 cm-thick 2nd ammonoid-bearing level of the *Aplococeras avisianum* Zone contain a significant amount of clasts of volcanic origin (Vujnović et al. 1981).

In the highest part of the Illyrian succession the red siliceous nodular limestones changed into siliceous grey bedded limestones rich in radiolarians which are overlain first by volcanics and volcanic sandstones (Grabovik Formation). Above these volcanics follow a roughly 40 m-thick series of volcanic sand- and siltstones with intercalated volcanic ash layers. In general the whole siliciclastic succession shows a fining-upward trend. In the higher part only volcanic siltstones with intercalated volcanic ash layers are common. This part is highly siliceous, but the radiolarians are completely recrystallized to quartz and cannot be isolated. However, both of these two mentioned parts belongs to the Grabovik Formation. The lower part of the Grabovik Formation above the Bulog Formation crops out in the small valley. Upsection the Grabovik Formation is mostly covered in the grasland area of the gentle slope towards the shallow-water limestones of the Wetterstein Formation. In the transitional area between the grasland slope and the forest first siliceous limestone layers are outcroping representing the higher part of this series. These siliceous limestone layers are intercalated in the series of silicified volcanic ashes and siliceous clay- to siltstone. Above this more fine-

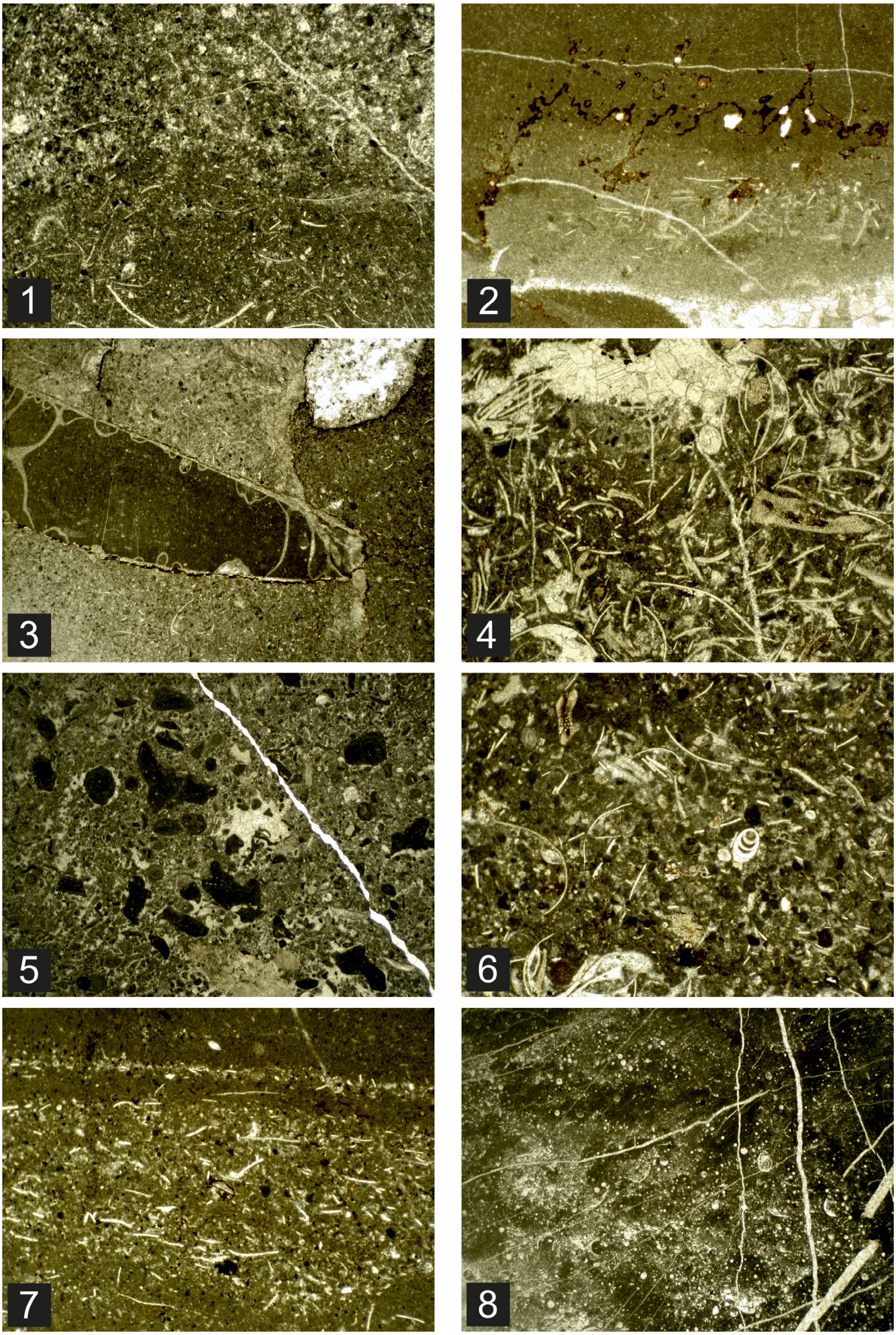
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Fig. 12. *Previous page: Microfacies characteristics of the Bulog Formation of the section Pridvorica. Samples from* Sudar *&* Budurov *(1983).* ***1.*** *Late Pelsonian turbiditic wackestone. In the lower part of the thin section thin-shelled bivalves and ostracods appear. In contrast, in the upper part thin-shelled bivalves are rare and micrite clasts, peloids and recrystallized limestone clasts are common. Sample MS 708. Width of the photo 0.5 cm.* ***2.*** *Late Pelsonian turbiditic wackestone with hardground formation. Thin-shelled bivalve fragments are enriched in channels. Sample MS 710. Width of the photo 0.5 cm.* ***3.*** *Late Pelsonian bioturbated wacke- to packstone with an orthoconal ammonid. Thin-shelled bivalve fragments beside peloids are common. Sample MS 712. Width of the photo 0.5 cm.* ***4.*** *Lower part of the condensed first ammonoid level around the Pelsonian/Illyrian boundary with thin-shelled bivalves and crinoids. Bioturbated. Sample MS 716. Width of the photo 0.5 cm.* ***5.*** *Early/middle Illyrian turbiditic shallow-water limestone (packstone) with "Tubiphytes" obscurus* Maslov*, various micrite clasts and crinoids. Sample MS 720. Width of the photo 1.4 cm.* ***6.*** *Condensed second ammonoid level of the Aplococeras avisianum Zone. Packstone with thin-shelled bivalves, crinoids and a foraminifera. Micrite clasts are common. Sample MS 723. Width of the photo 0.5 cm.* ***7****. Turbiditic ?Late Illyrian wackestone. In the turbidite layers thin-shelled bivalves and micrite clasts are common. The mud- to wackestone matrix is except ostracod shells practically free of organisms. Sample MS 726. Width of the photo 0.5 cm.* ***8.*** *Topmost part of the Bulog Limestone succession. Radiolarian-"filament" micrite, siliceous. The radiolarians are all recrystallized to calcite. Slightly bioturbated. Sample MS 732. Width of the photo 1.4 cm.*

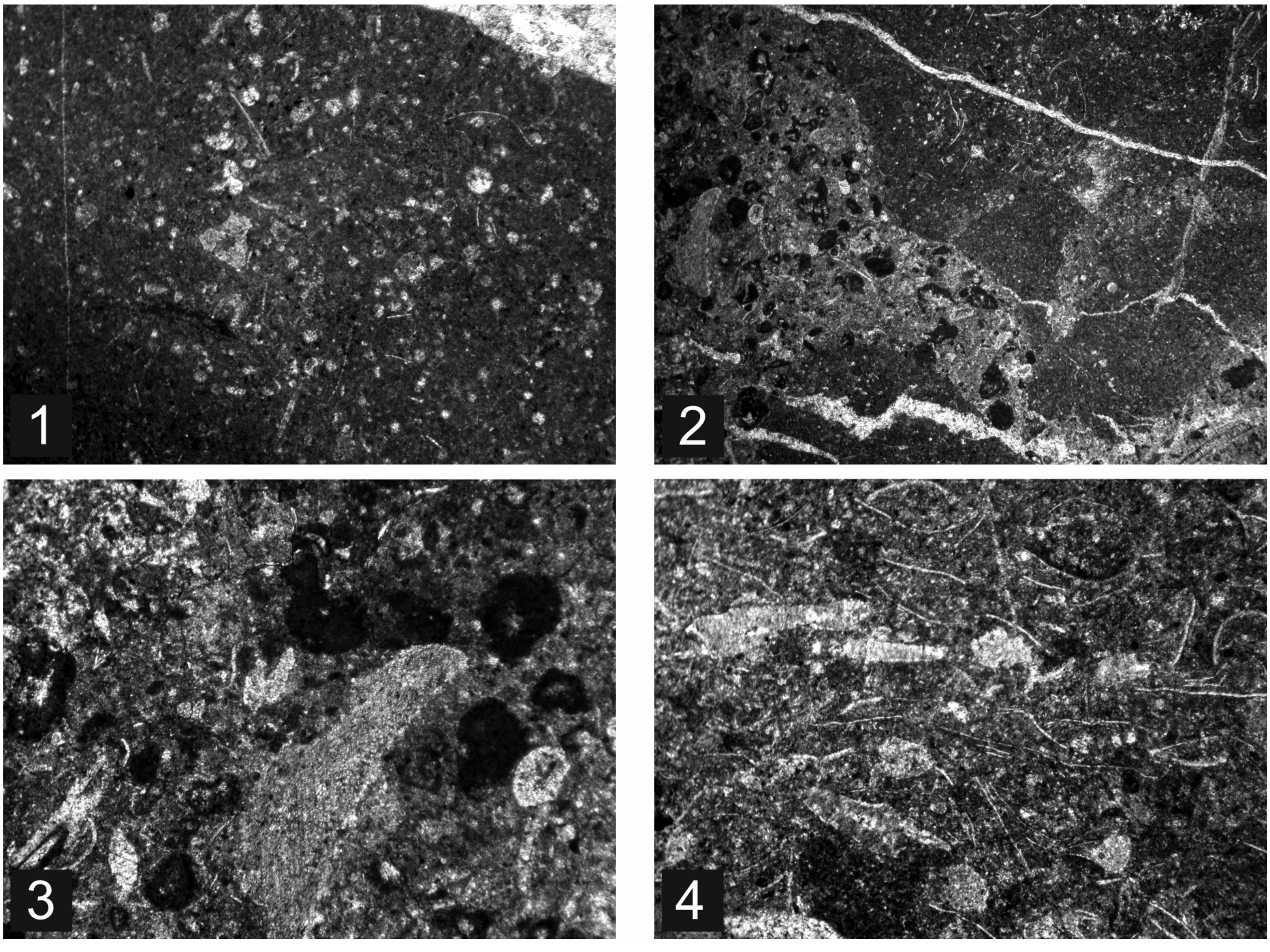

Fig. 13. *Microfacies of the layered Early Carnian grey siliceous limestones with intercalated carbonate turbidites with components of shallow-water origin from the section Pridvorica.* ***1****. Radiolaria-, spicula-, and "filament"-bearing wackestone with horizontal view of a brachialia of crinoids of the Osteocrinus-facies. Sample BIH 8. Width of the photo 0.5 cm.* ***2.*** *Bioturbated turbidite in a "filament"- and radiolaria-bearing matrix. In the turbiditic layer crinoids, micrite clasts and the reef-builder "Tubiphytes" is preserved. Sample BIH 9. Width of the photo 1.4 cm.* ***3.*** *Enlargement of the turbiditic layer with shallow-water grains: "Tubiphytes", micrite clats, and a clast with a microbial crust. In addition ostracod shells and brachialia of crinoids of the Osteocrinus-facies are preserved. Sample BIH 9. Width of the photo 0.5 cm.* ***4.*** *Enrichment of crinoid-fragments of the Osteocrinus-facies in a "filament"- radiolaria-bearing wackestone. In addition, siliceous spicules are visible. Sample BIH 10. Width of the photo 0.5 cm.*

grained upper part with siliceous ash layers follows in a small side valley a series of bedded siliceous limestones with intercalated turbidites in the higher part, which indicate the onset of the evolving Wetterstein Carbonate Platform. The onset of the progradation of the Wetterstein Carbonate Platform could be dated as Early Carnian by means of following conodont faunas: sample BIH 9 with *Pg. inclinata*, *Pg. polygnathiformis*, and *Pg. tadpole*, and sample BIH 10 with *Gl.* cf. *malayensis*, *Pg. inclinata*, and *Pg. polygnathiformis*.

In thin sections very often crinoids of the *Osteocrinus*-facies are preserved (Fig. 13), which is characteristic for the latest Ladinian to Early-Middle Carnian (Kristan-Tollmann 1970; Tollmann 1976). The mass-occurrence of crinoids of the *Osteocrinus*-facies is in the Early/Middle Carnian. Beside the radiolarians also siliceous spicula are visible in the microfacies (Fig. 13). Siliceous sponges have their second maximum in the Mediterranean Triassic in the Early Carnian (Mostler 1971). In the limestone turbidites appear beside crinoids of the *Osteocrinus*-facies fragments of foraminifera and reef-building organisms of the "*Tubiphytes*" group. Grains with micritic envelopes indicative for a shallow-water origin are common. Higher up in the section the amount of the carbonate turbidites and their grain-size increases.

Above the Anisian to Early Carnian sedimentary succession of the section Pridvorica follow according to Vujnović et al. (1981) the limestones of the Wetterstein and Dachstein Carbonate platforms. On top of the Dachstein Carbonate Platform Early Jurassic limestones should be preserved which are overthrust by the ophiolitic mélange/ophiolites (Diabase-Hornstein Formation in Vujnović et al. 1981).

Section northwest of Brodan

In eastern Bosnia and Herzegovina, along the road Višegrad-Brodare-Rudo-Uvac (on Lim River) and roughly 8 km northwest of Brodan a roughly 6 m-thick section of the drowning sequence of the Ravni Carbonate Ramp north of the road tunnel is outcropping (Fig. 14).

The by small neptunian dikes (filled with red micrite) dissected shallow-water limestones of the Ravni Formation with coated grains and microbial components show a continuous deepening in the uppermost part. In the topmost part wacke- to packstones, in parts also grainstones with thin shelled bivalves, gastropods, ostracods, and crinoid fragments appear (Fig. 15). Above, directly on top of the shallow-water limestones follows a densely packed and slightly bioturbated lumachelle layer (Fig. 15). This layer could not be exactly dated; only broken pieces of robust forms of the genera *Paragondolella* could be isolated. These *Paragondolella* sp. point to a ?late Pelsonian to early/middle Illyrian age (sample BIH 4). Upsection follows a 3 m-thick series of condensed red and reddish-grey nodular bioturbated, but originally laminated limestones. The age is middle and late Illyrian based on following mixed conodont assemblage: *Gl. budurovi*, *Gl. tethydis*, *Ng. cornuta*, *Pg. excelsa,* and *Pg. liebermani* (sample BIH 5). The bioturbation is most probably the reason for mixing the conodont faunas of slightly different age. Whereas the grey-reddish layers are wacke- to packstones with micrite grains, recrystallized radiolarians, and few thin-shelled bivalves the red layers consist of thin shelled bivalve-rich wackestones. Both types are mixed in one bed. These red nodular limestones are overlain by a series of thin-bedded and in parts laminated red radiolarite with intercalated volcanic ash layers. The bed thickness decreases upsection and the colour turned to greenish-grey. In addition, the amount of silicified claystones increases. Some of the layers in the red radiolarite sequence consists of completely silicified layers made of thin-shelled bivalves and indicate secondary silicification of an original limestone layer while the green-grey radiolarite layers are completely silicified.

Upsection the section is covered by trees and vegetation and is not well outcropping. The thickness cannot be measured. From the dm-bedded grey siliceous limestones above the radiolarite conodonts could not be extracted. Also radiolarians from these siliceous limestones could not be extracted. From equivalent dm-bedded siliceous limestones in a similar stratigraphic position from the locality Varoški Creek 2 km west of Fojnica near the Gacko-Mostar road Mostler & Krainer (1993/94) described a well-preserved Ladinian

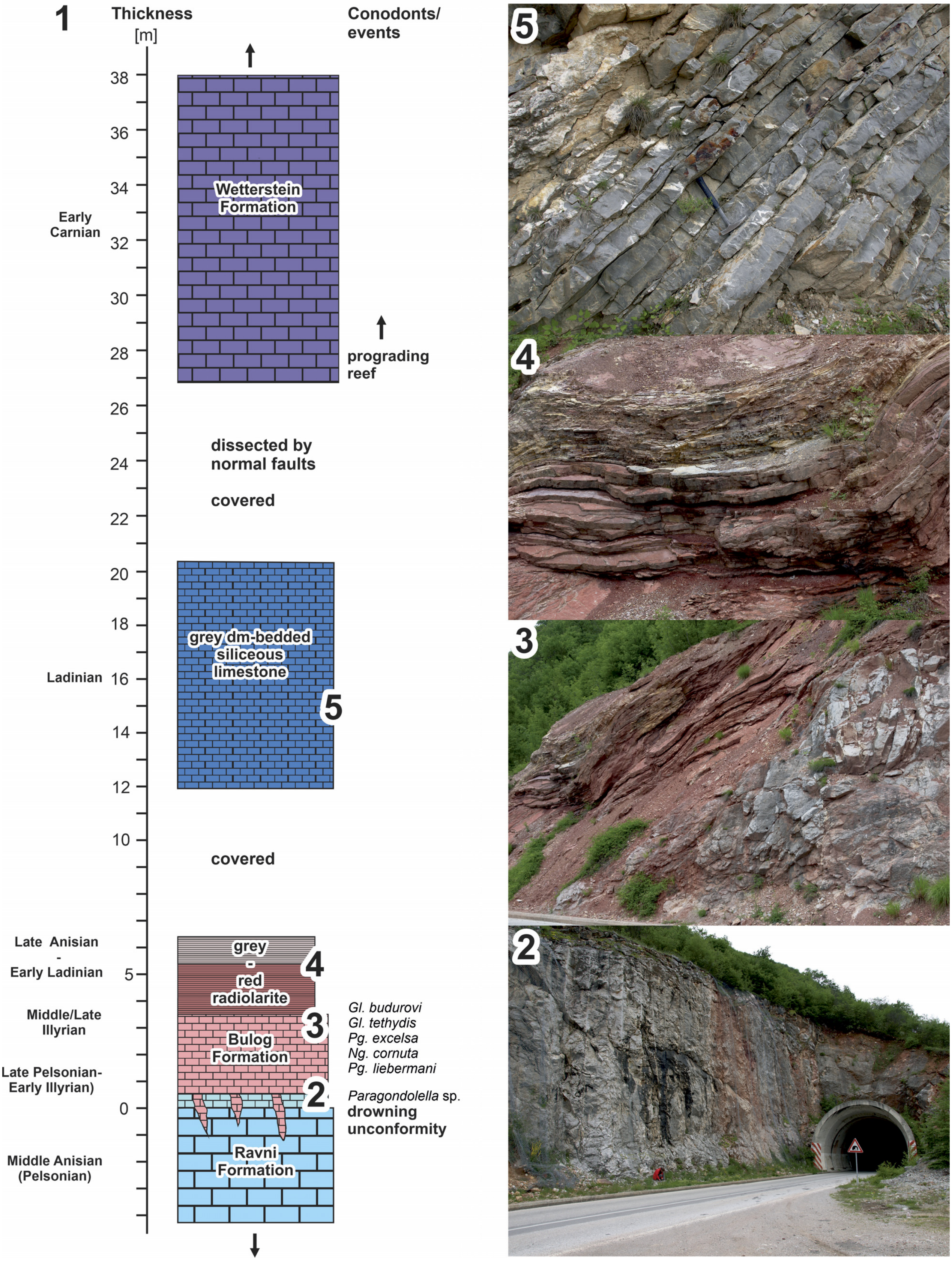

Fig. 14. *Middle Anisian to Early Carnian section along the road to Rudo, roughly 8 km northwest of Brodan. The section cannot be measured exactly in several parts because it is covered above the Late Anisian to Early Ladinian grey radiolarite and dissected by normal faults with limited offset below the Wetterstein Carbonate Platform evolution.*

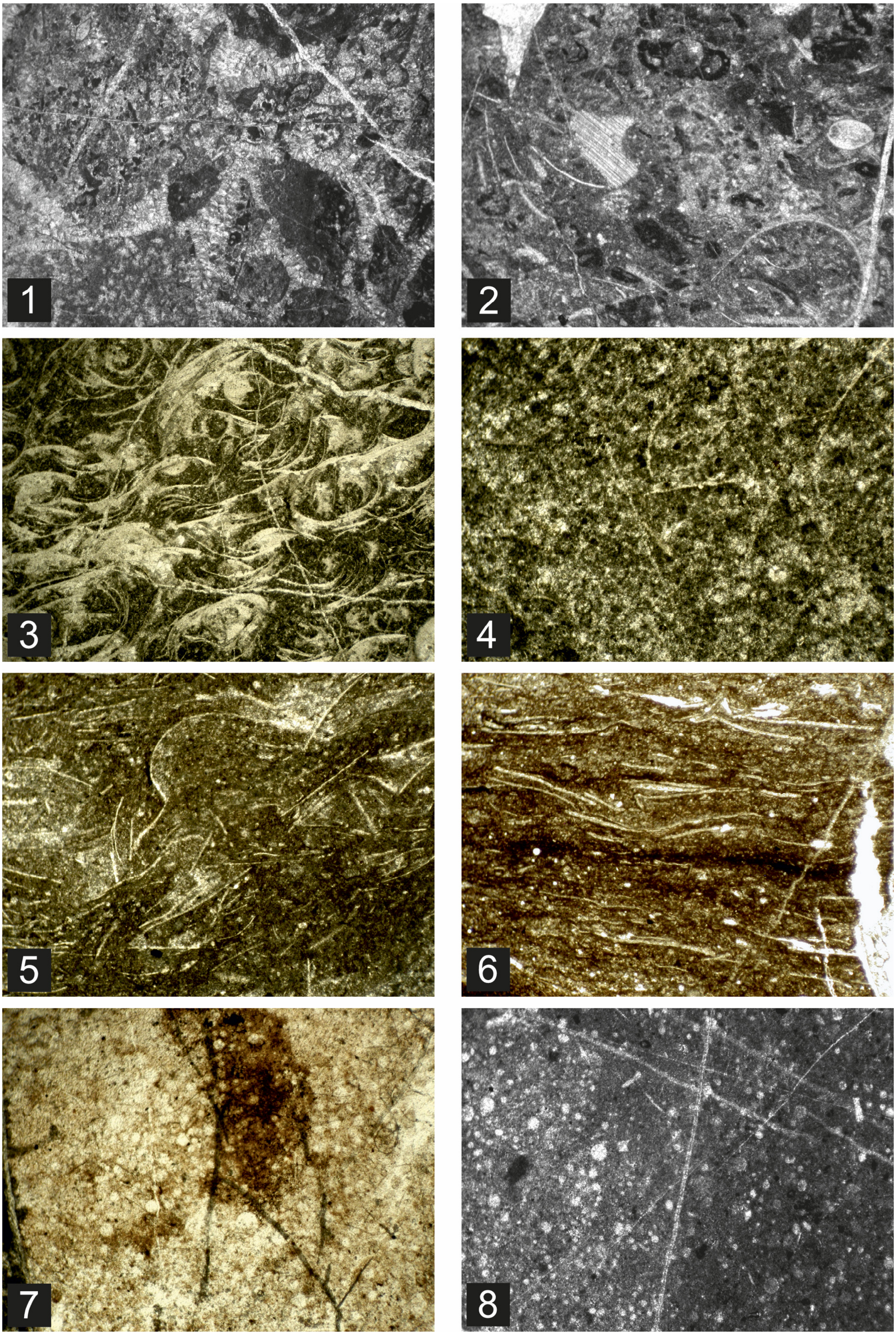
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Fig. 15. *Previous page: Microfacies of the Middle Anisian to Early Carnian sedimentary succession along the road to Rudo, roughly 8 km northwest of Brodan.* ***1***. *Microbial grainstone, brecciated. Most carbonate components except the micrite clasts are recrystallized. Ravni Formation. Sample BiH 2, width of the photo 1.4 cm.* ***2***. *Packstone with microbial clasts, ostracods, thin-shelled bivalves and a crinoid. Onset of the drowning sequence above the shallow-water Ravni Formation. Sample BiH 3, width of the photo 0.5 cm.* ***3.*** *Lumachelle of thin-shelled bivalves and peloids. Base of the Bulog Formation. Sample BiH 4, width of the photo 1.4 cm.* ***4.*** *"Filament"-bearing bioturbated pack- to grainstone with micrite clasts and peloids. Sample BiH 5, width of the photo 0.5 cm.* ***5.*** *Bioturbated packstone with thin-shelled bivalves and recrystallized radiolarians. Sample BiH 5, width of the photo 0.5 cm.* ***6.*** *Laminated, totally silicified wackestone with thin-shelled bivalves and radiolaria. Sample BiH 6-1, width of the photo 0.5 cm.* ***7.*** *Silicified radiolarian wacke- to packstone with bioturbation. All radiolarians are recrystallized to quartz. Sample BiH 6-1, width of the photo 0.5 cm.* ***8.*** *Siliceous radiolarian-wackestone. The radiolarians are recrystallized to calcite. Sample BiH 1, width of the photo 0.5 cm.*

radiolarian fauna. At that time this sample (No. 88-272) from a floated block, collected by L. Krystyn (Vienna) contained no conodonts; but in the papers of Kozur & Mostler (1996a, b) the residue of this sample recovered *Bgn*. *mungoensis*, the conodont index species of the middle to late Longobardian *Bgn*. *mungoensis* Zone. Furthermore, according to Tekin & Mostler (2005a, b) the age of these siliceous limestones could be attributed to the uppermost Ladinian on base of the well-preserved radiolarian fauna. In the Durmitor Mt., in Montenegro, the dm-bedded siliceous Ladinian limestones contain no datable conodont fauna (Mrdak et al. 2024a). But in all cases, including the sections Pridvorica, Han Vidović, and sections in Serbia (Gawlick et al. 2017c) above the Bulog Formation (in cases with overlying radiolarites) and below the siliceous bedded limestone succession with intercalated limestone turbidites of Early Carnian age, the lithological evolution is identical.

Higher up the section Brodan is cut by a series of normal faults with limited vertical offset, but the Wetterstein Limestone should be the normal overlying of this series, even the transition from these dm-bedded siliceous Ladinian limestones to the siliceous limestone series with intercalated turbiditic carbonate layers is not outcropping in this covered and dissected part of the sedimentary succession.

Trebević Mt. area south of Sarajevo

Zlatar (Hallstatt) Mélange

In the following chapters we describe various parts of a dismembered Hallstatt Limestone succession, which are preserved in the Trebević Mt. south of Sarajevo. Note, that the Anisian part (exclusivly the late Pelsonian Bulog Formation) belongs not to the Hallstatt Limestone succession, but has the same palaeogeographic provenance. The evolution of the open-marine Hallstatt Limestones started after the drowning of the Ravni Carbonate Ramp related to the break-up and the opening of the Neo-Tethys Ocean in the late Pelsonian.

Studenkovići and Blizanac sections

On the SW slopes of the Trebević Mt. (Fig. 2C), north of the village Studenkovići, i.e. in the hamlet Tripkovići Sudar (1986) described and dated with conodont assemblages the reddish-grey limestone successions of the "Trebević brachiopod limestones" (Kittl 1904) and the Bulog Limestones. Wendt (1973) interpreted those brachiopod-limestones as fissure infillings and concluded that the brachiopod-limestones in the neptunian dikes and the age-equivalent overlying Bulog Limestones represent two different ecological environments.

Close to the Studenkovići section, in the southwestern direction on the SW slopes of Trebević Mt., in vicinity of a village with the same name, the Blizanac section is situated (Fig. 2C). Two hundred meters before the first houses of the village the limestones of the Ravni and the Bulog formations are outcropping.

The section **Studenkovići** starts with a series of 9 m-thick thin-bedded grey limestones which contain beside open-marine organisms like conodonts, also various foraminifera including *Meandrospira pusilla* (Ho) (Sudar 1986), and in cases dasycladalean algae like *Physoporella pauciforata* Gümbel (see also Pia 1935a, b), and brachiopods (Bittner 1902; Kittl 1904; Sudar 1986). After the revision of the conodont faunas (Sudar and Gawlick in 2015 and 2018, not published) a ?latest Bithynian to early Pelsonian age of this part below the Dedovići Member is most likely and also proven by following conodont fauna: *Gl. budurovi*, and *Pg. bulgarica*. In addition, Kittl (1904) described a Pelsonian ammonoid fauna. Sudar (1986) separated this lowermost part of the section as Trebević Member from the Ravni Formation *sensu stricto*.

Upsection follows a 5 m-thick series of thick-bedded grey shallow-water limestones without open-marine organisms, but various foraminifera and dasycladalean algae (Sudar 1986). This part of the section corresponds to the Dedovići Member of the Ravni Formation, i.e. the Pelsonian. This part of the section is topped by a 0.5 m-thick layer of open-marine reddish limestones, with a rich conodont fauna of late Pelsonian age. Following, also revised, conodonts could be determined (samples MS 41/2, 41/3 and 41/4): *Gl. budurovi*, *Nic. kockeli*, and *Pg. bulgarica*. This red limestone with a late Pelsonian conodont fauna above the Dedovići Member of the Ravni Formation marks the true drowning event of the Ravni Carbonate Ramp as elsewhere in the Dinarides (Sudar et al. 2023c; Gawlick et al. 2023 and references therein).

Two meters higher in the section, in a thin bed of a red nodular limestone with ammonoids the last late Pelsonian conodont fauna with *Gl. budurovi*, *Nic. kockeli*, and *Pg. bulgarica* could be extracted (sample MS 38). Upsection follows a series of 23 m red nodular limestones. For the lower part (~12 m, samples MS 36, 307, 35/1) a late Pelsonian age can be confirmed on base of following conodont fauna: *Pg. bulgarica*, and *Pg. hanbulogi*.

The last 10 meters of the section (samples MS 34, 33 and 306) are on base of following conodont faunas with *Gl. tethydis*, and *Pg. praeszaboi* early Illyrian in age. However, a roughly 20 m-thick late Pelsonian to early Illyrian succession of Bulog Limestones is rather thick and known only from few localities in the Dinarides, e.g., the section Pridvorica in Bosnia and Herzegovina (see above) or the Klisura quarry section near Sirogojno in SW Serbia (Sudar et al. 2013). However, even in these sections a thickness of 20 m is not reached.

If the nearby outcropping latest Carnian grey-red open-marine limestones with *Pg. nodosa* (sample MS 300) belong to the section or not cannot be clarified in the totally covered area. If these latest Carnian open-marine limestones are part of the section the missing part in the covered area should be the upper part of the Bulog Formation, the Grabovik Formation and at least the basinal equivalents of the Wetterstein Carbonate Platform. In that case this section would be similar to the type-section Han Vidović. On the other hand, the latest Carnian open-marine grey-red limestones can be also correlative with the Late Triassic Hallstatt Limestone section in Brus, and therefore completely different to the type-section. Here only detailed mapping around the section, fresh outcrops in the covered parts and above the latest Carnian grey-red open-marine limestones can clarify the evolution of the section and therefore its palaeogeographic provenance. Nevertheless, the missing middle Illyrian to late Carnian part of a complete succession to find in the covered part is not expectable. The covered part can comprise only a section with a thickness of appr. 10 meters, what is much too less thickness for the higher part of the Bulog Formation, the Grabovik Formation and the Early Carnian bedded siliceous limestones. Even a complete Hallstatt Limestone succession to find is rather unrealistic. Also in that case the upper part of the Bulog Formation, the Ladinian Grauvioletter-Graugelber Bankkalk or a radiolarite equivalent, and the Early Carnian Hellkalk should exist in the covered area. It seems more convincing that here in the area several blocks with a provenance from the open shelf (Hallstatt shelf) are preserved, i.e. the Zlatar Mélange. More than a century ago Kittl (1904) stated that Mt. Trebević south of Sarajevo is composed of several second order "nappes" and may represent a huge imbricate structure. In fact Kittl (1904) recognized the mélange character of that area and the included Middle-Late Triassic open-marine limestones.

Untypical for the section Studenkovići is the early onset of open-marine conditions below the Dedovići Member of the Ravni Formation with a mixture of open-marine organisms and shallow-water organisms. Such sections are so far not known in the Dinarides and are only described in detail from the Northern Calcareous Alps (Gawlick et al. 2021 and references therein). Only Kittl (1904) mentioned near Blizanac from the "lower Muschelkalk" some bivalve findings. Here, in this section, around the Bithynian/Pelsonian boundary sedimentation changed from a restricted environment

(Utrine Member of the Ravni Formation equivalent to the Gutenstein Formation) to an open-marine environment. In cases open-marine shallow-water carbonates formed (Dedovići Member of the Ravni Formation equivalent to the Steinalm Formation) and in other areas more deep-marine limestones deposited (Trebević limestones – "Krečnjaci Trebevića" of SUDAR 1986 equivalent to the Annaberg Formation in the Northern Calcareous Alps) which can be overlain by prograding shallow-water limestones of the Dedovići Member of the Ravni (Steinalm) Carbonate Ramp. This situation seems the most

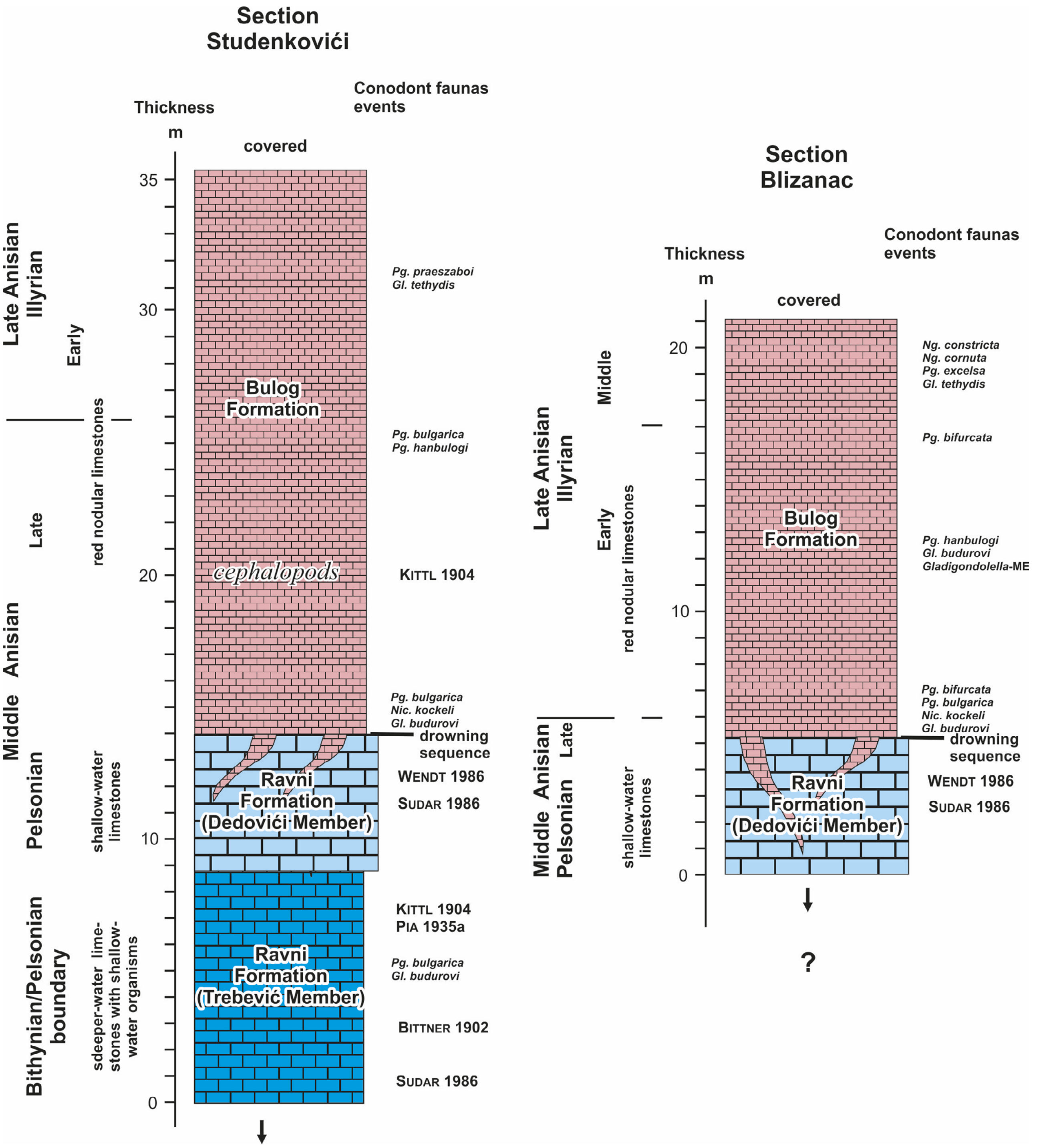

Fig. 16. *Pelsonian to early/?middle Illyrian Bulog Limestone section Studenkovići and Pelsonian to early/middle Illyrian section (Ravni Formation – Bulog Formation) Blizanac in the Trebević Mt. south of Sarajevo. Redrawn after SUDAR (1986). Conodonts from SUDAR (1986), re-evaluated. Revised conodont ages of the different members of the Bulog Formation according to Chen et al. (2016).*

reasonable explanation for the depositional history of the Studenkovići section south of Sarajevo in the Trebević Mt.

The section **Blizanac** starts with grey shallow-water limestones of the Ravni Carbonate Ramp (Dedovići Member). The drowning sequence starts with grey-red late Pelsonian open-marine limestones with following conodont fauna: *Gl*. *budurovi*, *Pg*. *bulgarica*, and *Pg*. *hanbulogi* in the samples MS 314 and 315.

In this lowermost 6 m-thick part of the roughly 20 m-thick Bulog Limestone succession also foraminifera beside some other carbonate clasts appear (details in Sudar 1986). This part with a mixture of shallow-water organisms and grains resembles the Dedovići Member of the Ravni Carbonate Ramp, but contain already deep-water organisms like conodonts. As in this part of the succession *Pg*. *bifurcata* appear, a depositional age around the Bithynian/Pelsonian boundary can be excluded, i.e. this part of the section cannot be assigned to the Trebević Member without more detailed studies of the underlying limestones. Above this part of the section condensation starts with deposion of the Bulog Limestone. The first sample (MS 308/1) contain a late Pelsonian conodont fauna with following taxa: *Gl*. *budurovi*, *Nic*. *kockeli*, *Pg*. *bifurcata*, and *Pg*. *bulgarica*.

The overlying appr. 15 m-thick series of red nodular Bulog Limestone is exclusively of early/?middle Illyrian age, as proven by conodont faunas all over the section. In the lower part following conodont fauna prove an early Illyrian age: *Gl*. *budurovi*, *Pg*. *bifurcata*, *Pg*. *hanbulogi*, and *Gladigondolella*-ME in the samples (MS 309/2, 310).

Only the uppermost part of the section, i.e. the last 6 meters can be probably of middle Illyrian age, because the last occurrence of *Pg*. *bifurcata* is 4 meters below the top of the outcropping section. This part of the section contain following conodonts: *Gl*. *tethydis*, *Ng*. *constricta*, *Ng*. *cornuta*, and *Pg*. *excelsa*.

Draguljac and Brus sections

In contrast to the Middle Triassic sedimentary successions of Studenkovići and Blizanac in the wider area of Brus (Trebević Mt.) Late Triassic open-marine Hallstatt Limestone successions are preserved. The first description and assignment to Hallstatt Limestones of the open-marine limestones of Draguljac is based on the description of brachiopods by Bittner (1892), who compared the species-poor fauna from the limestones of Draguljac with brachiopod faunas from Carnian Hallstatt Limestones in the Northern Calcareous Alps (Mt. Röthelstein near Bad Aussee). Also Kittl (1904) assigned the *Halobia*- and cephalopod-bearing open-marine limestones from Draguljac to the Carnian. In that area, i.e. the Draguljac-Brus region, Kittl (1904) mentioned also tuffitic sandstones and “Pietra Verde” and assigned these sedimentary rocks to the Ladinian. But Kittl (1904) recognized that these “Pietra Verde” appearances near Draguljac appear in a higher niveau as usual. Kittl (1904) described from this area also an isolated block of a red nodular limestone of Ladinian age.

The rich ammonoid fauna from the Draguljac area was first described by Kittl (1904) as Early Carnian (*Trachyceras aonoides* Zone) and derive from the basal part of the “section Brus” (compare Wendt 1973). Later, Diener (1916) described from these open-marine limestones a rich ammonoid fauna. Wendt (1973) added a Julian ammonoid fauna from a fissure filling and improved on base of that fauna the existence of the Lower Carnian, which normally is often missing or not datable in the preserved sequences below the long-lasting higher Julian to middle Late Carnian gap. However, in the measured section of Sudar (1986) this ammonoid layer is not indicated in the position between the Early and Late Carnian part of the section Brus (Fig. 17). Milojković (1925) added from the area of Draguljac some more ammonoids of the Carnian *Trachyceras aonoides* Zone. Besides, he emphasized that near the fortress Draguljac was found a sufficiently high number of cephalopods similar to the fauna from Han Bulog Limestone horizons. This was the reason for his conclusion that beside the *Trachyceras aonoides* Zone exists also a lower Zone which corresponds to the Han Bulog cephalopod layer. Milojković (1925) does not recognize, that a complete succession is not preserved, even if he followed Kittl (1904) that the “Pietra Verde” (= ophiolitic mélange, see below)

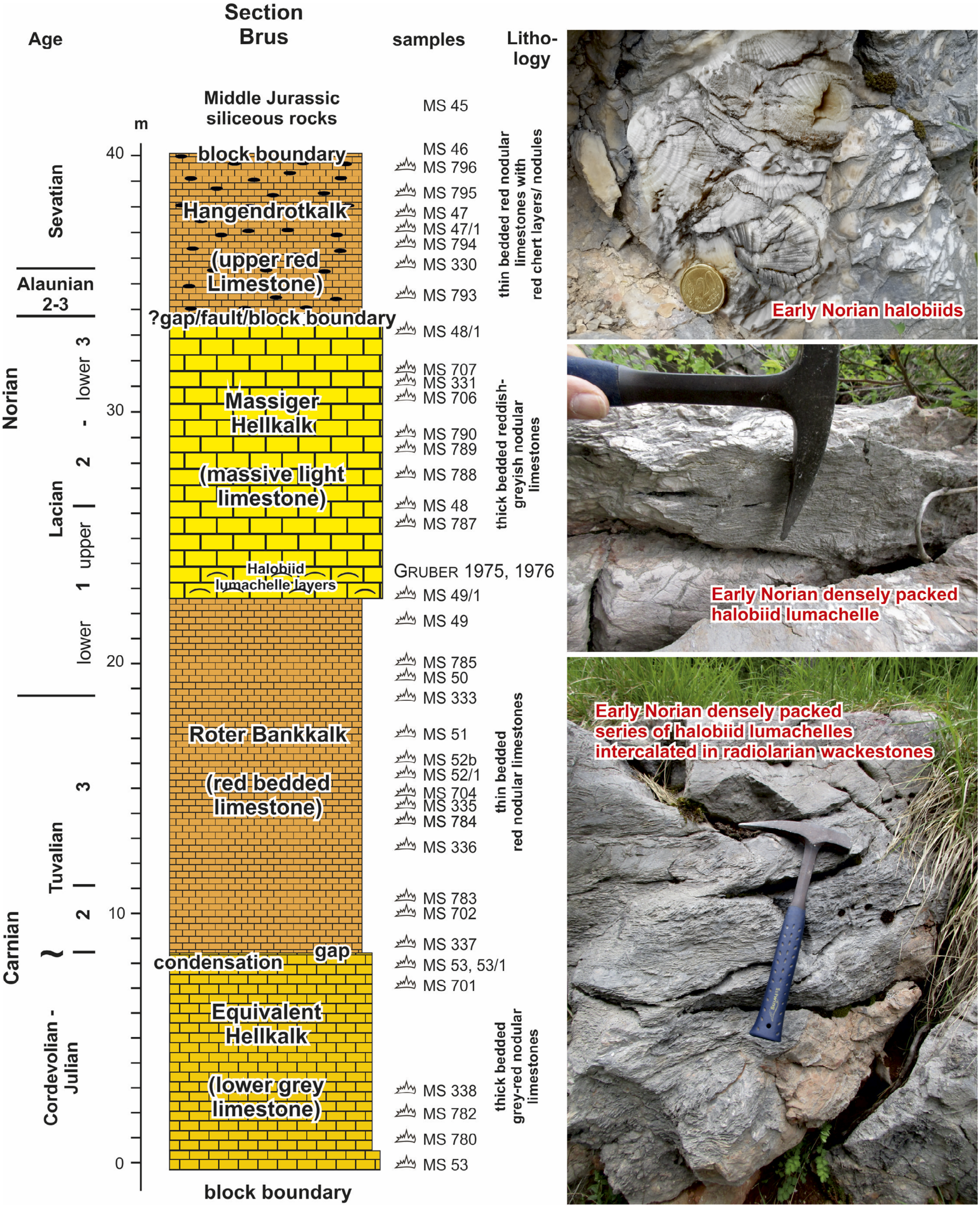

Fig. 17. *Late Triassic Hallstatt Limestone succession of the section Brus-Draguljac in the Trebević Mt. south of Sarajevo. Redrawn after* SUDAR *(1986) and according to our revision. Note the long-lasting gap in the Carnian part of the sequence. Also the latest Early Norian to Middle Norian part of the section is missing. Sample positions are indicated. The photos on the right side show the Early Norian series of the Halobia lumachelle layers intercalated in fine-grained grey wackestones.*

correspond to the Grabovik Formation, and that also Ladinian red nodular limestones appear.

Later, Mudrenović (1988) described a rich Carnian ammonoid fauna from the section Brus, which is not part of the section described by Sudar (1986) or the section Brus-Draguljac described here or in the older literature (Wendt 1973; Gruber 1975, 1976; Fischer & Jacobshagen 1976). In fact, the fauna described by Mudrenović (1988) derive from a block in polymictic mass-transport deposits, and in a distance of about 2-2,5 km east from the Draguljac locality.

Also the Carnian (*Trachyceras aonoides* Zone) ammonoid fauna described by Fischer & Jacobshagen (1976) came from an ammonoid-bearing bed near the Draguljac fortress. This is also confirmed by the conodont assemblages from nearby samples, dated by Fischer & Jacobshagen (1976) as Julian. Higher up in the section Late Carnian conodonts appear (Fischer & Jacobshagen 1976; Sudar 1986).

The position of the conodont faunas described by Charvet et al. (1974) cannot be reconstructed in the "Draguljac section", but their stratigraphic ages are in line with younger results (Fischer & Jacobshagen 1976; Sudar 1986). In the microfacies of the topmost Early Carnian condensation is visible and hardground formation, as well as neptunian dikes (Fig. 18.1). Most probably from one of these dikes Wendt (1973) isolated his ammonoid fauna, which corresponds to the ammonoid faunas described by Kittl (1904), Diener (1916), Fischer & Jacobshagen (1976), and Mudrenović (1988). All these ammonoid faunas from different places in the entire area belong to the *Trachyceras aonoides* Zone (Julian 1). Similar red nodular limestones with condensation we could find in the forest between the "Draguljac section" and the section Brus. But, our sample of a condensed red-yellowish nodular limestone yielded a ?late Anisian to Ladinian conodont fauna with *Gl*. *tethydis*, *Pg*. *trammeri*, and *Gladigondolella*-ME, and not a Carnian conodont fauna. In addition, this sample contains turbidites with shallow-water organisms (Fig. 18.1). Such red-yellowish limestones with turbidites from a nearby shallow- water carbonate production area are only known from the late Illyrian (Mrdak et al. 2024a) or the earliest Longobardian (our unpublished data). This finding confirms the finding of Kittl (1904) of a Ladinian red nodular limestone with *Daonella* sp. in the area between the "section Draguljac" and the section Brus. Other red limestone blocks appear in the forest between the fortress and the section Brus, which obviously do not belong to one of the two sections. But to sample and map this forest is in moment still not commendable as in this forest still fresh round craters are visible which are most probably the result of quite recent detonations of landmines in this area.

Above these Carnian ammonoid-bearing beds of the Brus section Kittl (1904) dated the overlying red bedded limestones with a *Halobiid*-fauna as Late Carnian and the upsection following white-grey limestones on base of the bivalve fauna ("*styriaca*" beds) as lowermost Norian according to Gruber (1975, 1976) (compare Kittl 1912). This contrasts the measured section of Sudar (1986) who found below the bivalve lumachelle beds dated by Gruber (1975, 1976) in direction to Brus an Early to Late Carnian complete section without a Carnian ammonoid-bearing bed. The earliest Carnian (Fig. 17, sample MS 53/1) is dated by following conodont fauna: *Gl*. *malayensis*, *Pg*. *inclinata*, *Pg*. cf. *polygnathiformis*, and *Gladigondolella*-ME. Higher up in the section the conodont faunas still indicate an earliest Carnian age (samples MS 780, 782). The determined conodont fauna with *Ncv*. *cavitata*, *Pg*. cf. *foliata*, *Pg*. *inclinata*, *Pg*. *polygnathiformis*, and *Gladigondolella*-ME is characteristic for this earliest Carnian level. In addition, turbidites with grains including reef-builders from the Wetterstein Carbonate Platform are a characteristic feature for that stratigraphic level (Fig. 18). Higher up in this part of the section intercalated turbidites disappear and darker grey wackestones with a lot of thin-shelled bivalves deposited. This level represents the drowning of the Wetterstein Carbonate Platform, confirmed by the occurrence of following conodont fauna (sample MS 701): *Gl*. *tethydis*, *Mazz*. *carnica*, *Pg. polygnathiformis*, and *Gladigondolella*-ME. The *Carnica* event marks the onset of the drowning of the Wetterstein Carbonate Platform and is related to a sea-level drop (Krystyn et al. 2008; Lein et al. 2012). This level is also in the Dinarides characterized by the deposition of turbidite-free biomicritic limestones (Mrdak et al. 2023 and references therein). A little higher

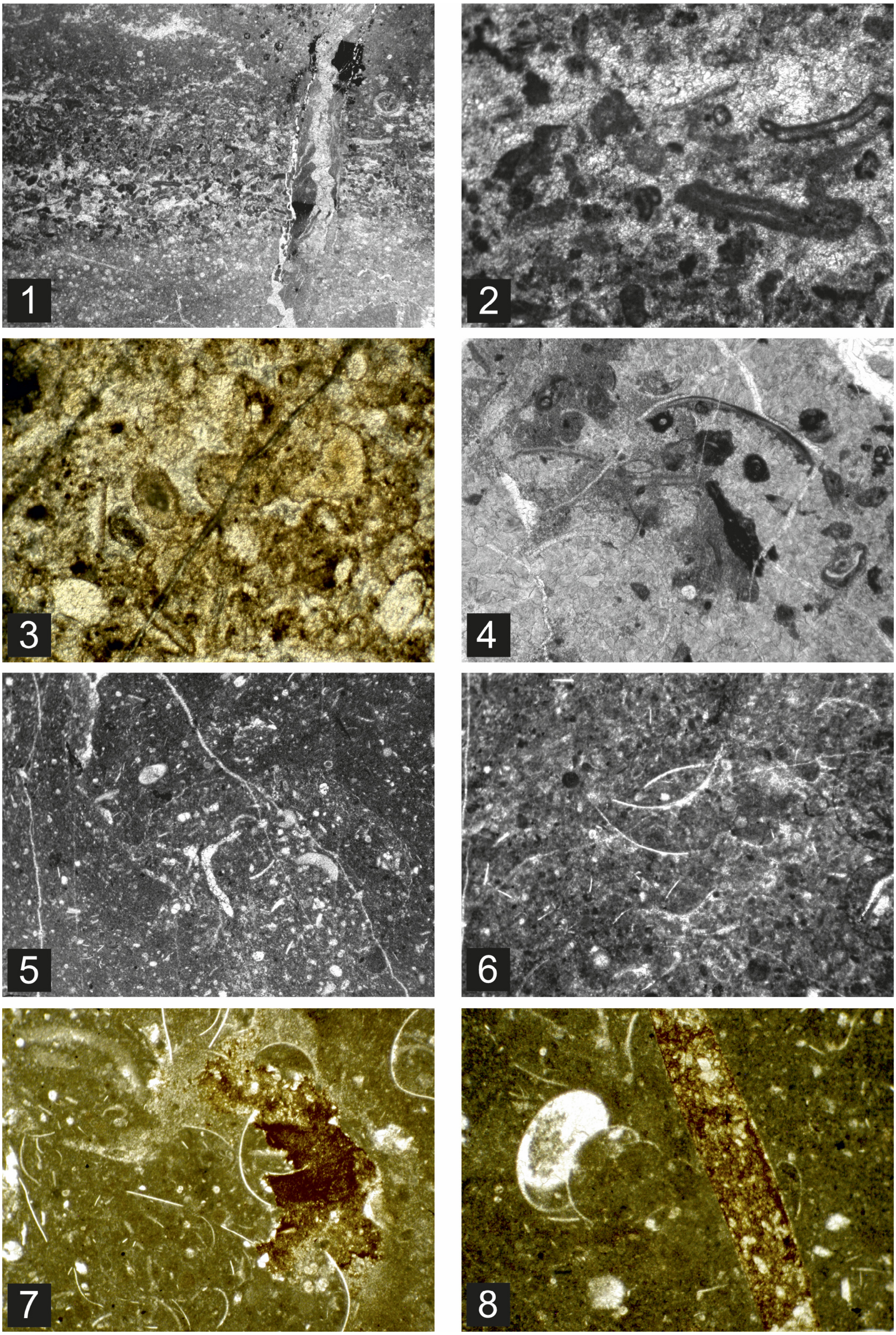
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***Fig. 18.** Previous page: Microfacies characteristics of the ?Late Anisian/Ladinian to Early Carnian part of the dismembered Hallstatt Limestone succession in the Draguljac-Brus area. The ?Late Anisian/Ladinian sample derive from an isolated outcrop between the Late Carnian-Norian section Draguljac and the Carnian-Norian section Brus (compare Sudar 1986). For exact sample position see Sudar (1986) and Fig. 17. **1.** Turbiditic yellowish grey-red radiolaria-"filament" wackestone with intercalated grey grainstone turbidites consisting of shallow-water material. Recrystallized radiolarians are the predominant organisms in the matrix and appear in rock-forming quantities. Sample BiH 15/1. Width of the photo 1.4 cm. **2.** Enlargement of the turbiditic layer of 1. Beside micrite clasts and peloids "Tubiphytes" obscurus Maslov, other incrusting organisms and broken foraminifera occur. Width of the photo 0.5 cm. **3.** Silicified turbiditic layer with crinoids and bio-fine-debris from the ?Late Anisian/Ladinian. Sample BiH 15/2. Width of the photo 0.5 cm. **4.** Earliest Carnian coarse-grained turbidite. Grainstone to rudstones with broken shells, encrusted components, broken foraminifera and the reef builder "Tubiphytes". The material derives from the Wetterstein Carbonate Platform. Sample MS 338. Width of the photo 0.5 cm. **5.** Earliest Carnian bioturbated turbiditic packstone with ostracods, broken shells, crinoids and recrystallized radiolarians. Sample MS 338/1. Width of the photo 0.5 cm. **6.** Carnica conodont Zone. Bioturbated "filament"-rich packstone with peloids, micrite clasts and some recrystallized radiolarians. Shallow-water grains are missing. Sample MS 53/1. Width of the photo 0.5 cm. **7.** "Filament"-rich wackestone with recrystallized radiolarians from the topmost part of the Early Carnian (Carnica-event). Characteristic is subsolution. The subsolution cavities are filled with a red mud without organisms. Sample MS 53. Width of the photo 0.5 cm. **8.** "Filament"-bearing wackestone with a gastropod dissected by a fissure filled with red mud containing dolomite and quartz grains. Sample MS 53. Width of the photo 0.5 cm.*

in the section intense condensation and subsolution is preserved (sample MS 53). In addition, small fissures are formed indicating tectonic motions. From this level, but another block Kittl (1904) isolated a rich ammonoid fauna of the *Trachyceras aonoides* Zone. This level was also found by Mudrenović (1988) in a block in the mass-transport deposits around 250 meters to the East on the road from Brus. From neptunian dikes in the Draguljac area Wendt (1973) most probably isolated his ammonoid fauna. Important to note, that all these ammonoid faunas described from the Draguljac-Brus area represent the topmost *Trachyceras aonoides* Zone, as proven by the occurrence of *Mazz*. *carnica* below this ammonoid-bearing level resp. neptunian dike infilling. The *Carnica* conodont Zone (Krystyn 1983) comprises the uppermost *Trachyceras aonoides* Zone to the lowermost *Austrotrachyceras austriacum* Zone and marks the Julian 1/2 boundary (Chen et al. 2016). In the section Brus only the lower part of the *Carnica* Zone is preserved, and sediments of the higher Julian, i.e. the *Austrotrachyceras austriacum* Zone are missing after formation of neptunian dikes and deposition of condensed red nodular limestones. The gap of deposition started definitively exactly at the Julian 1/2 boundary and lasted until the Tuvalian 2 (see below).

After a long-lasting gap (higher Julian to lower Tuvalian) deposition of reddish-grey thin-bedded limestones started. From the basalmost part of these reddish-grey limestones only *Pg*. *polygnathiformis* (sample MS 337) could be isolated, but one meter higher up in the section Tuvalian 2 is proven by the occurrence of *Pg*. *carpathica*, *Pg*. *polygnathiformis*, and *Neocavitella* sp. (samples MS 702, 783). These limestones are characterized by the occurrence of crinoids, thin-shelled bivalves, brachiopod shells, and broken gastropods (Fig. 19). The boundary between the Tuvalian 2 and the Tuvalian 3 could not be exactly determined. The upsection following samples contain only the conodont *Pg*. *polygnathiformis* (samples MS 336, 784, 704). In sample MS 52/1 appear *Pg*. *polygnathiformis* together with *Pg*. *nodosa* indicating the lower Tuvalian 3. This part of the section is characterized by condensation (Fig. 19). Upsection follows a roughly 3 m-thick series of the highest Tuvalian with the conodont *Mp*. *praecommunisti*. Bioturbated wacke- to packstones rich in thin-shelled bivalves, in cases with lumachelle layers (Fig. 19) are a characteristic microfacies feature of the highest Tuvalian. In cases also condensation could be observed. The Carnian/Norian boundary is indicated by the first appearance of *Nrg*. *navicula* together with *Mp*. *communisti* in sample MS 333. A change in lithology cannot be observed. Deposition of the reddish-grey thin-bedded limestone cross the Carnian/Norian boundary and also the microfacies characteristics is very similar to the topmost Carnian microfacies (Fig. 19). This part of the section can be assigned to the Roter Bankkalk (red bedded nodular limestone). The conodonts *Nrg*. *navicula* together with *Mp*. *communisti* appear also upsection up to the *Halobiid*-lumachelle layers, described by Gruber (1975, 1976) as earliest Norian (samples MS 785, MS 49, MS 49/1). However, with the onset of deposition of the lumachelle-layers the colour of the limestones change to grey, and the beds are dm-bedded (= Massiger Hellkalk/massive light-grey limestone) (Fig. 17).

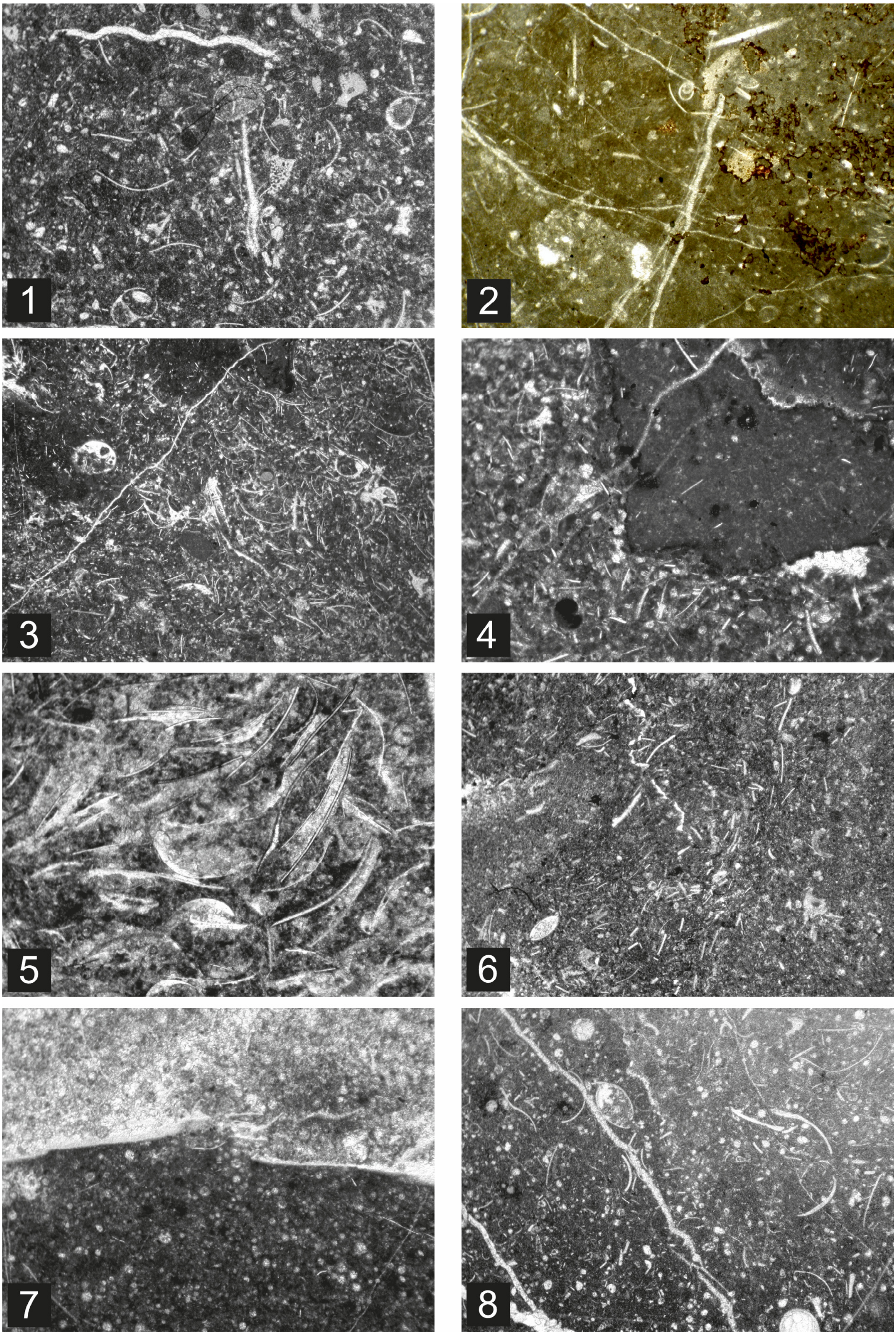
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Fig. 19. *Previous page: Microfacies characteristics of the Late Carnian Hallstatt Limestone of the Brus (1-7) and Draguljac (8) sections. For exact sample position see Fig. 17 and Sudar (1986).* ***1.*** *Late Tuvalian bioturbated packstone with "filaments", brachiopod shells, crinoids, and broken gastropods. Sample MS 335. Width of the photo 0.5 cm.* ***2.*** *Late Tuvalian "filament"-bearing bioturbated wackestone with condensation. The right side of the photo shows several small components coated with Fe/Mn-rims. Sample MS 52/1. Width of the photo 0.5 cm.* ***3.*** *Late Tuvalian bioturbated "filament"-lumachelle with few micrite clasts. Sample MS 52/1. Width of the photo 1.4 cm.* ***4****. Enlargement of 3, other view. In the "filament"-rich bioturbated wackestone occur wackestone clasts with few broken shell fragments and few recrystallized radiolarians, and a gastropod filled with micrite. The clasts have a small rim of a dark Mn/Fe-crust around. Sample MS 52b. Width of the photo 0.5 cm.* ***5.*** *Latest Tuvalian lumachelle of thin-shelled bivalves ("daonellas" or "halobiids"). Such turbiditic lumachelle layers are characteristic in many late Tuvalian Hallstatt Limestone successions. Sample MS 51. Width of the photo 0.5 cm.* ***6.*** *Earliest Norian slightly recrystallized wackestone with broken thin-shelled bivalves, small crinoids, and ostracods. Bioturbated. Sample MS 333. Width of the photo 0.5 cm.* ***7.*** *Laminated radiolarian wackestone. The lower wackestone layer contain recrystallized radiolarians. The upper layer is completely silicified and contains beside recrystallized radiolarians few "filaments". Sample MS 50/1. Width of the photo 0.5 cm.* ***8****. Latest Carnian (highest Tuvalian) bioturbated wackestone rich in thin-shelled bivalves, recrystallized radiolarians, some ostracod shells, and few broken crinoids. Sample MS 320 from Draguljac section. Width of the photo 0.5 cm.*

Upsection follow a roughly 10 m-thick series of bedded grey radiolaria- and "filament"-bearing wackestones. In the lower part of the Massiger Hellkalk above the lumachelle layers an early Lacian age is still proven by the occurrence of *Mp. communisti* together with *Eg. quadrata* (sample MS 787). Here also several clasts and in rare cases duostominid foraminifera are existing (Fig. 20.1). The conodont assemblages above this level indicate a continuous deposition of these wackestones throughout the Lacian 2 to the ?lowermost Lacian 3. *Ag. triangularis* appear together with *Nrg. navicula* in sample MS 48, followed by the appearance of *Eg. rigoi* and *Nrg. navicula* in the samples MS 788 and MS 789. The first *Ag. spatulata* appear in sample MS 790 together with *Ag. triangularis*, and *Nrg. navicula*. Other forms of the *Ag. triangularis* fauna sensu Karádi (2024) also appear. In sample MS 706 the first *Nrg. hallstattensis* together with *Eg. rigoi* occur, indicating a higher Lacian 2 age (also sample MS 707). Also the highest sample MS 48/1 in this part of the section indicate still a similar age by the occurrence of *Nrg. hallstattensis* together with *Eg. rigoi*.

The stratigraphic interval Lacian 3 to Alaunian 1 could not be proven, that means that the section here is not continuous and complete. It cannot be decided if the section is here interrupted by a fault, or if a block boundary is existing or if here a Late Triassic feature (tectonics) is preserved. The first sample above the Massiger Hellkalk (sample MS 793) contains *Nrg. steinbergensis* and *Eg. postera*, indicating at least an Alaunian 2, but most probably an Alaunian 3 age. This younger age is more convincing, because the sample MS 330 contains *Nrg. steinbergensis* together with *Eg. bidentata*, characteristic for an upper Norian (Sevatian) age. A hiatus or a fault is not visible in the field in this part of the section. In the higher part of the section only *Eg. bidentata* could be isolated (samples MS 794, MS 47/1, MS 47, MS 795, MS 796). The late Alaunian to Sevatian consists of thin-bedded red nodular limestones with chert layers and nodules. These red nodular limestones are moderately condensed and contain recrystallized radiolarians and are in cases rich in thin-shelled bivalve accumulations (Fig. 20). In cases also neptunian dikes filled with red mud appear. The topmost sample of the section, still a siliceous grey limestone consists of a turbiditic wacke- to mudstone, rich in recrystallized radiolarians, but without "filaments". The typical change in colour and an increasing thickness around the Alaunian/Sevatian boundary could not be observed. Litho- and microfacies of the late Alaunian and Sevatian part of the sequence are similar. Therefore we don´t separate here the Hangendgraukalk (Sevatian) from the Hangendrotkalk (Alaunian) as it is typical for most Hallstatt Limestone sections. However, also in Serbia several sections are existing without the characteristic change from red to grey limestones (Gawlick et al. 2017b, 2018).

The end of the section is characterized by the occurrence of a siliceous marly limestone with a characteristic microfacies of the Middle to early Late Jurassic (Fig. 21). This clearly evidence that the section Brus is in fact at least one block (if not two blocks) in a Jurassic matrix, i.e. part of the Zlatar (Hallstatt) Mélange. This Jurassic "radiolaritic-argillaceous" matrix separates these bigger block(s) from the mass-transport deposits, which follow "upsection" along the road (Fig. 22).

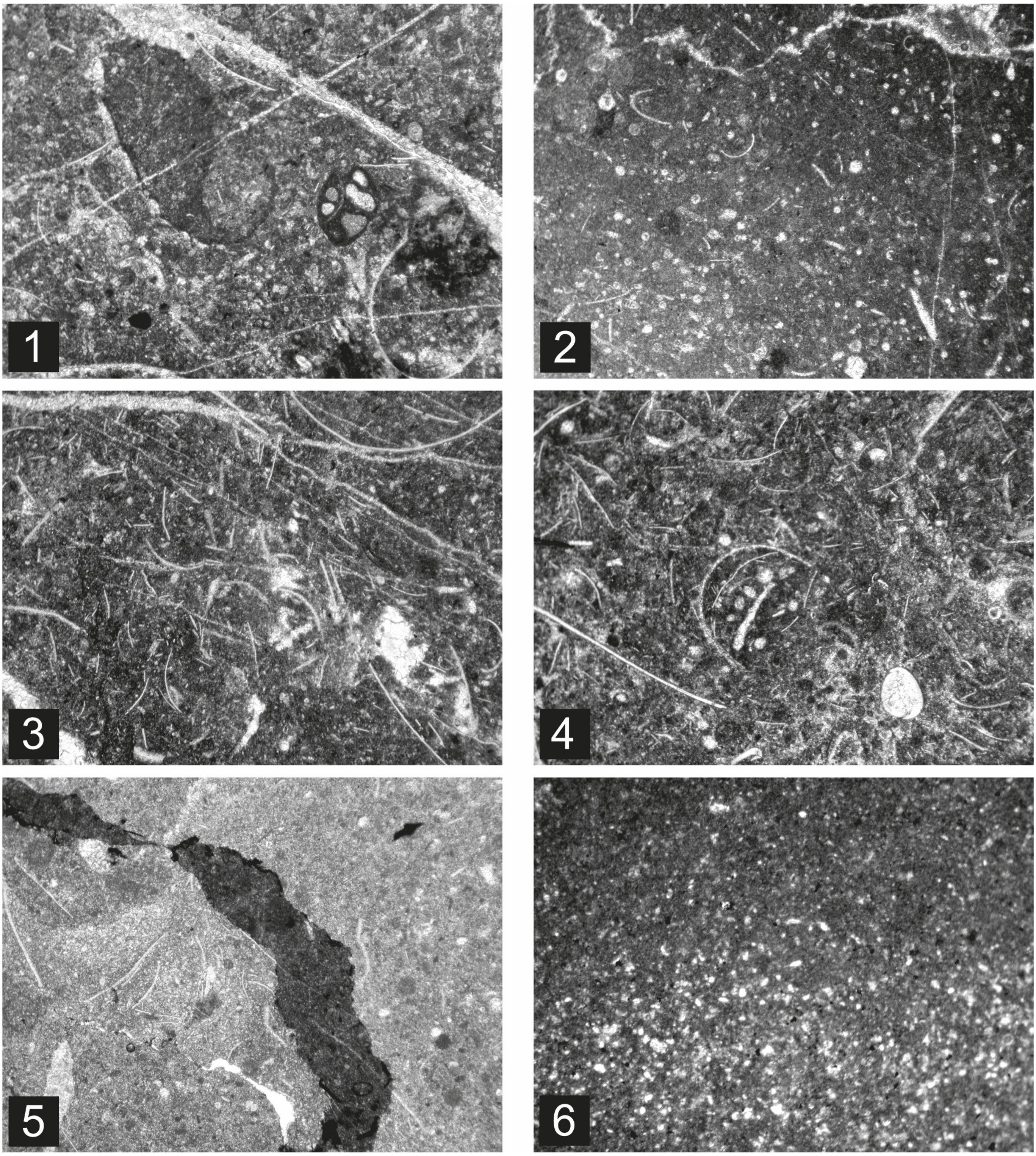

Fig. 20. *Microfacies characteristics of the Norian Hallstatt Limestone of the Brus section. For exact sample position see* Sudar *(1986) and Fig. 17.* ***1.*** *Basal part of the Early Norian (lower Lacian). Slightly recrystallized wackestone to packstone with broken shell fragments, a duostominid foraminifera and a micrite clast. Sample MS 49/1. Width of the photo 0.5 cm.* ***2.*** *Lacian (Massiger Hellkalk) wackestone rich in recrystallized radiolarians with few "filaments". Bioturbated. Sample MS 48/1. Width of the photo 0.5 cm.* ***3****. Middle Norian (Alaunian) wacke- to packstone with a bioturbated lumachelle of thin-shelled bivalves ("Halobiids"). Sample MS 330. Width of the photo 0.5 cm.* ***4.*** *Higher Alaunian wackestone rich in thin-shelled bivalves, few ostracods and unknown organisms with a micritic rim. Sample MS 47/2. Width of the photo 0.5 cm.* ***5.*** *Topmost Alaunian slightly recrystallized wackestone with "filaments", recrystallized radiolarians, and few micrite clasts. Bioturbated. The wackestone is dissected by fissures filled with a dark not recrystallized micrite with some micrite clasts and few undeterminable broken organisms. Sample MS 47. Width of the photo 0.5 cm.* ***6****. Late Norian (Sevatian) not bioturbated turbiditic wackestone with recrystallized carbonate grains and a few radiolarians. Sample MS 46. Width of the photo 0.5 cm.*

Furthermore, Kittl (1904) recognized in the Draguljac area in contrast to all other areas in the surroundings of Sarajevo a much more variable lithology in the open-marine limestones, change in dipping from place to place, and very often the occurrences of "Jaspis" (= radiolarite), and he reconstructed two different stratigraphic successions. The Hallstatt Limestone succession he placed tectonically above the Anisian-Ladinian succession. Especially the Carnian-Norian Hallstatt Limestone succession of the Brus section with its faunistic content shows an equivalence to the Hallstatt Limestone succession as known from the Salzkammergut in the Northern Calcareous Alps (compare Schlager 1969; Krystyn 1974, 2008; Lein 1987; Gruber 1975). In addition, the added finding of the ?late Illyrian red-yellowish limestone with turbidites from a shallow-water carbonate production area is in line with a Hallstatt Limestone succession, even if in the typical Hallstatt Limestone successions of the Northern Calcareous Alps (Krystyn 2008 and references therein) or the Dinarides of Serbia (Gawlick et al. 2017b, 2018) shallow-water debris is not typical. In contrast, in the Albanides (Gawlick & Missoni 2019) or the Hellenides (Kostaki et al. 2024) in certain levels the Hallstatt Limestone successions contain shallow-water debris.

However, after the first description and age determination with conodont faunas including measuring of the sections Draguljac and Brus by Sudar (1986) it was pointed out that both sections form not a continous section from the Early Carnian to the Middle/Late Norian. Together with the descriptions of the faunal content and the age determinations of Kittl (1904, 1912), Fischer & Jacobshagen (1976), and Wendt (1973) compared with the position of the described faunas a duplication of a Hallstatt Limestone succession can be excluded. The facies characteristics of the "marker levels" is in both sections different as well as the measured thickness and the tectonic overprint. The Early Carnian ammonoid-bearing level in the "Draguljac section" differs from that in the Brus section. The *Halobia* lumachelle beds (Gruber 1975, 1976) in the Early Norian are missing in the Draguljac area (Sudar 1986). The "Draguljac section" is highly disturbed by tectonic boundaries (?faults or ?block contacts), whereas the Brus section is tectonically practically unaffected.

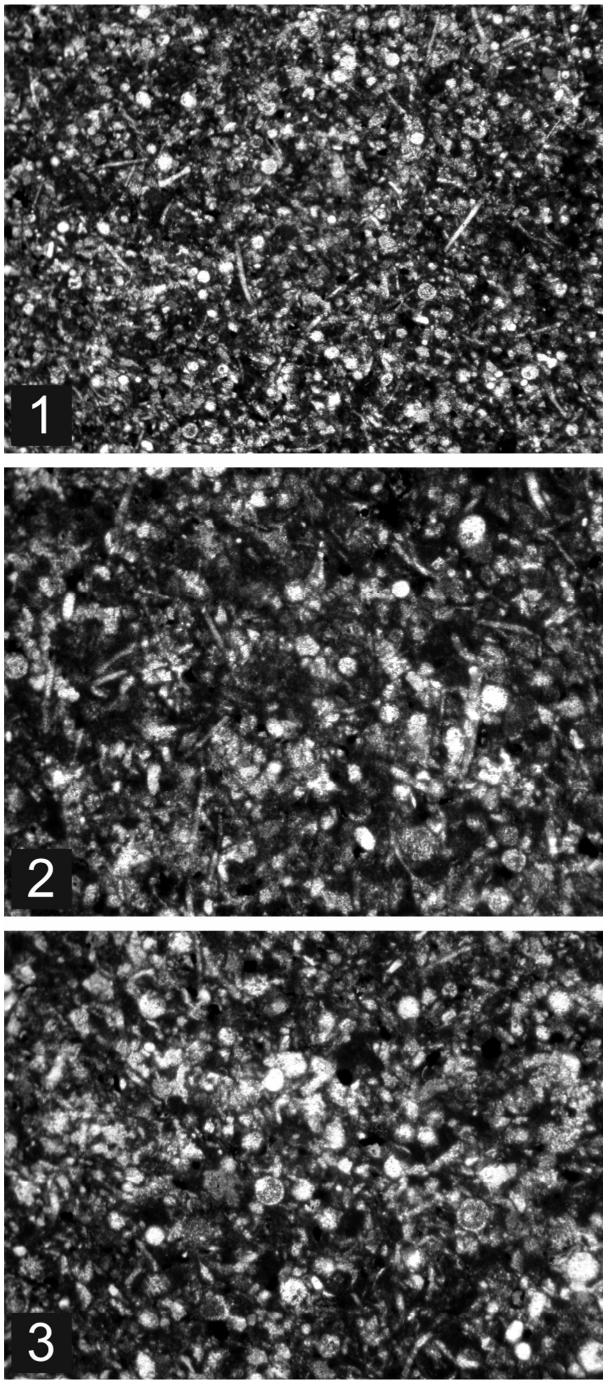

Fig. 21. *Microfacies characteristics of a ?late Middle Jurassic siliceous marly limestone between the section Brus and the mass-transport deposits along the road from Brus to Draguljac, and after Brus to the East.* ***1.*** *Radiolarian packstone with recrystallized radiolarians and few sponge spicules. Sample MS 45. Width of the photo 0.5 cm.* ***2.*** *Enlargement of 1, other view. Beside recrystallized radiolarians (in the middle of the photo a cross-section of an Archaeodictyomitra Pessagno is visible) sponge spicules and silicified broken shell fragments (?Bositra shells) are visible. Width of the photo 0.25 cm.* ***3.*** *Enlargement of 1, other view. The preservation of the totally recrystallized radiolarians is very poor. Only few of them are filled with micrite. The cross-section of the radiolaria in the middle shows a sunken head, typical for Middle to early Late Jurassic radiolarians. Width of the photo 0.25 cm.*


Road to Brus
Mass transport deposits
Zlatar (Hallstatt) Mélange
Late Triassic
Hallstatt Limestone
components and blocks
1
Various Late Triassic Hallstatt
Limestone clasts
- Roter Bankkalk (Late Carnian)
- Massiger Hellkalk (Early Norian)
- Hangendrotkalk (Middle Norian)
2
Various Late Triassic Hallstatt
Limestone clasts
- Roter Bankkalk (Late Carnian)
- Massiger Hellkalk (Early Norian)
- Hangendrotkalk (Middle Norian)
3
Various Late Triassic Hallstatt
Limestone clasts
- Roter Bankkalk (Late Carnian)
- Massiger Hellkalk (Early Norian)
- Hangendrotkalk (Middle Norian)
4
Ophiolitic Mélange
Grivska Formation block
latest Triassic
5
Grivska Formation block
latest Triassic
6
Grivska Formation
7
8

***Fig. 22.** Previous page: Field views of the polymictic mass-transport deposits (Zlatar Mélange) along the road Draguljac-Brus. These mass-transport deposits consists of blocks of a dismembered Late Triassic Hallstatt Limestone succession. Field views from the ophiolitic mélange above the Zlatar Mélange with an incorporated block of the Grivska Formation including their microfacies characteristics. **1** Field view of the series of polymictic mass-transport deposits along the road to Brus. **2-4.** Polymictic debris flows with various red and grey limestone clasts of the dismembered Late Triassic Hallstatt Limestone succession. In the different flows the grain size of the incorporated blocks varies. All blocks are angular to subangular. The block size varies from several centimeters to 10 centimeters. In cases are also meter-sized blocks incorporated. **5**. Ophiolitic mélange outcrop on a newly created parking and touristic place east of Brus. The ophiolitic mélange is preserved above the mass-transport deposits of the Zlatar Mélange. The position of the incorporated block of the Grivska Formation is indicated. **6.** Grivska Formation block in the radiolaritic-argillaceous matrix of the ophiolitic mélange. **7.** Lithological features of the few centimeters to dm-bedded Grivska Formation. The siliceous grey limestones contain red chert nodules and are intercalated by red chert layers. **8.** Microfacies of the Grivska Formation. Beside few broken thin-shelled bivalves ("filaments") recrystallized radiolarians and sponge spicules are common. Sample BiH 17. Width of the photo 0.5 cm.*

However, Sudar et al. (2015) discussed a complete (dismembered) Hallstatt Limestone succession (sections Brus and Draguljac on the NE slopes of the Trebević Mt.) in the Sarajevo area. On the NE side of the asphalt road Sarajevo-Jahorina (Fig. 2C) the overlying Late Triassic (including the Ladinian red nodular limestone: Kittl 1904) deep-water sedimentary rocks of the Bulog Limestone of the sections Studenkovići and Blizanac are preserved (see discussion there).

Whereas in the section Brus the lower Carnian to Early/Middle Norian is preserved in a roughly 40 m-thick section (Sudar 1986) in direction Brus along the road higher up appear a series of polymictic mass-transport deposits. The component spectrum consists of grey and red Hallstatt Limestone components (see section Brus by Sudar 1986). Around 2-2,5 km before the Brus-Draguljac section by Sudar (1986) and almost 250 metres forward to the East from Brus touristic/parking place, on the same road, Mudrenović (1988) described a rich ammonoid fauna of the Carnian age, *Trachyceras aonoides* Zone of the Julian.

These mass-transport deposits are separated from the section Brus by a siliceous marly limestone of ?late Middle to early Late Jurassic age (Fig. 21). The radiolarians in this siliceous marly limestone are completely recrystallized, but cross-sections of some radiolarians and the typical microfacies point clearly to a ?late Middle to early Late Jurassic age of this rock. By this, these siliceous sedimentary rocks are the original matrix between the blocks (e.g., section Draguljac, section Brus) and the mass-transport deposits in the Draguljac-Brus area. The Hallstatt Limestones in the Draguljac-Brus area and in the whole Trebević Mt. area are therefore part of the Hallstatt Mélange, or Zlatar Mélange in the Dinarides, as known everywhere in the different mountain ranges in the Circum-Pannonian region (Gawlick & Missoni 2019 and references therein).

Ophiolitic Mélange

Above the polymictic mass-transport deposits overlying the section Brus, in eastern direction, appear a series of siliceous sedimentary rocks with intercalated volcanic sandstone turbidites and volcanic components in a newly prepared parking place area which provides insights of this normally covered mélange. Kittl (1904) assigned such occurrences in the region as part of the Ladinian "Pietra Verde". However, beside the volcanic components in this siliceous-argillaceous matrix appear also various radiolarite components, and a block consisting of grey siliceous limestones with red chert nodules. This limestone block could not be dated exactly; only a ramiform *Hindeodella* sp. could be isolated (sample BIH 17). In the microfacies beside few fragments of thin-shelled bivalves, recrystallized radiolarians and a high amount of sponge spicules are visible. This microfacies together with the ramiform conodont element *Hindeodella* sp. point to a latest Triassic age of that block. A Ladinian age as supposed by Kittl (1904) for this mélange can be excluded. Also from a more than 2 cm big radiolarite component (sample BIH 16) no determinable radiolarian fauna could be extracted.

However, the composition of the various components in this argillaceous-radiolaritic matrix with fine-grained volcanic sandstone turbidites, various radiolarite components and this big limestone block, which we assign to the Grivska Formation (Sudar & Gawlick 2018) clearly indicate the existence of an ophiolitic mélange above the Hallstatt Limestone blocks and mass-transport deposits consisting of various Hallstatt Limestone components.

Definition of the Grabovik Formation

Validity: Valid (Grabovik Formation), introduced by Kittl (1904) as Graboviker Schichten. Defined and formalized here.

Type area: Area around Sarajevo, especially the area of the villages Bulozi and Vidovići.

Type section: Because until now the type-section for this Formation was never defined (see Kittl 1904), the overlying siliceous volcano-sedimentary siliciclastics with intercalated volcanic ash layers above the Bulog Formation type-section in the Han Vidović section are assigned also as type-section for the Grabovik Formation.

Reference section: Section Pridvorica.

Derivation of name: River Grabovica north of Sarajevo.

Synonyms: In moment not known. Widespread the terminology "volcano-sedimentary sequence" is used (Dimitrijević 1997: Ladinian volcanogenic-sedimentary formation; note: herein the red radiolarites which deposited in cases above the Bulog Formation are included).

Lithology: Siliceous sandstones, siltstones, claystones, volcanic ash layers, in the higher part with intercalated siliceous mudstones, chert layers, and radiolarites. The sand- and siltstones consist of reworked material from volcanics, most probably of Illyrian age. Volcanic sandstones are common in the lower part of the Grabovik Formation and very rare in the higher part. In the higher part dominate siliceous layers, volcanic ashes are few silicified fine-grained radiolarian-rich limestone beds. The higher part corresponds lithologically to the "Pietra Verde", whereas the lower part is more similar to the "volcano-sedimentary series" in the literature of the Dinarides (Grubić 1980; Dimitrijević 1997; Hrvatović 2006; Rampnoux 1974).

Fossils: Kittl (1904) described from the type-section some rare *Daonella* sp.

Chronostratigraphic age: Ladinian, as defined by the age of the underlying Pelsonian-Illyrian Bulog Formation and the overlying earliest Carnian grey-bedded siliceous limestone succession with intercalated turbidites.

Biostratigraphy: No determinable fossils know, except *Daonella* sp.

Thickness: Variable. In the type section about 25 m. In other sections up to 50 m.

Subdivision: No subdivision. In the today badly exposed type-section of the Grabovik Formation it cannot be decided if the formation has to be subdivided into two members: A) a lower member consisting of volcanic sandstones and volcanic siltstones, siliceous claystones to radiolarites, and in cases with intercalated volcanic ashes, and B) a higher member consisting of silicified volcanic ashes, radiolarites, and some siliceous micritic limestone intercalations. The lower member would in that case correspond to the series known as "volcano-sedimentary sequence" in the literature of the Dinarides (see above), and the upper member would in that case correspond to the series named "Pietra Verde" in the older literature of the Dinarides (Kovács et al. 2010, 2011 and references therein).

Underlying units (foot wall boundary): Bulog Formation. Directly above the red nodular limestones of the Bulog Formation at the base of the Grabovik Formation Vujnović et al. (1981) described the occurrence of *Daonella* shells (see also Kittl 1904).

Overlying units (hanging wall boundary): In the type-region: Early Carnian dm-bedded grey siliceous limestones with intercalated turbidites which consist of shallow-water material shed from the evolving Wetterstein Carbonate Platform. These Early Carnian limestone successions with turbidites from the Wetterstein Carbonate Platform overly elsewhere in the East Bosnian-Durmitor megaunit the various latest Anisian – Ladinian sedimentary successions (Gawlick et al. 2017a; Mrdak et al. 2024a).

Geographic distribution: So far in moment only known from the wider area around Sarajevo. If other age equivalent sedimentary successions, predominantly occurring in the East Bosnian-Durmitor megaunit (Albania, Bosnia and Herzegovina, Montenegro, Serbia) can be attributed to be part of the Grabovik Formation or they belong to the Grabovik Formation is not studied yet. The Nova Varoš Formation in Serbia (Gawlick et al. 2017a) differs from the Grabovik Formation by the occurrence of basalts at the base and the deposition of radiolarites above the basalts. It can be expected, that most occurrences of the "volcano-sedimentary series" in the Dinarides are in fact belong to the Grabovik Formation. Critical is the fact, that wrongly also parts of the ophiolitic mélanges were often mapped as "volcano-sedimentary series". Without improvement of every occurrence known and mapped all areas which are assigned to belong to the "volcano-sedimentary series" needs to be revisited. In cases similar successions as the Grabovik Formation, i.e. in Montenegro in the East Bosnian-Durmitor megaunit, are significantly older than the Grabovik Formation in the type region. In Durmitor Mt. a middle Illyrian volcanic sandstone series overlain by the Komarani and Bulog Formations was recently dated by ammonoid and conodont faunas (Mrdak et al. 2024a), whereas a lot of other occurrences are equivalent to the Grabovik Formation (unpublished data).

Lateral units: Radiolarites. Dm-bedded grey bedded siliceous limestones.

Remarks: In Serbia the Grabovik Formation is included in the Nova Varoš Group with a similar lithology variety (volcanic sandstones and siltstones, radiolarites), but differs from the Nova Varoš Formation. The Grabovik Formation should be included as independent formation into the Nova Varoš Group, whereas the various radiolarites (in cases deposited above volcanics, in cases deposited above the Bulog Fm.) should be separated as own formation. Problem is the different biostratigraphic onset of radiolarite deposition above the Bulog Formation, the appearance of the intense middle/late Illyrian volcanism, and several other lithofacies types deposited during the middle-late Illyrian, a time span of intense tectonic motions. Note, that the onset of intense volcanism in the middle Illyrian (*Reitziites reitzi* Zone) is slightly older than the tectonic motions forming a second horst-and-graben morphology (Mrdak et al. 2024a), predominantly in the Outer Dinarides (i.e. the East Bosnian-Durmitor megaunit, the Pre- and High Karst units). Various lithologies deposited in several basins between the structural highs formed in late Pelsonian and late Illyrian times related to the opening of the Neo-Tethys Ocean to the east of the later Inner Dinarides. Later, after the onset of intense volcanism in the middle Illyrian subsequently followed by intense extensional tectonics around the middle/late Illyrian boundary in the Outer Dinarides made the palaeotopographic situation even more complex. Further detailed studies in a regional scale are necessary, not only in Bosnia and Herzegovina and Serbia where meanwhile a fairly well understood late Anisian – Ladinian palaeotopography is reconstructable. Especially in Montenegro first detailed studies (Mrdak et al. 2024a, 2025) point to a similar situation as known from Serbia or Bosnia and Herzegovina, but studies in a regional scale are still missing in moment, but there is also progress in the understanding of age equivalent sedimentary successions (Mrdak et al. 2024a, and references therein).

Discussion

The depositional area of the Anisian (late Pelsonian) to ?Fassanian Bulog Formation (Sudar et al. 2023b) in the Dinarides is the central to the open shelf area (= outer shelf) to the Late Triassic reef margins and open lagoon depositional realm (= central shelf), i.e. the Hallstatt Limestone depositional realm after the demise of the Ravni Carbonate Ramp, when open-marine sediments were deposited practically everywhere. Age, microfacies characteristics, and tectonostratigraphy in both palaeogeographic regions are slightly different but generally very similar. Whereas in the open shelf area the overlying sedimentary sequence consists only of open-marine deep-water limestones (Hallstatt Limestone sequence – Fig. 3) in the central shelf area the Bulog Formation is overlain by various latest Anisian – Ladinian deep-water sedimentary rocks (radiolarites, siliceous bedded limestones, siliceous volcano-siliciclastic sedimentary rocks with volcanic ash intercalations = Nova Varoš Group – Fig. 3). Only in cases shallow-water carbonates deposited during short time intervals. In the Early Carnian started the evolution of huge shallow-water carbonate platforms, first the earliest Carnian Wetterstein

Carbonate Platform with its demise in the Middle Carnian (*Carnica*-event: Mrdak et al. 2023 and references therein) and later the Norian-Rhaetian Dachstein Carbonate Platform with its demise at the Triassic/Jurassic boundary. However, whereas in a cross-section Serbia-Montenegro through the Dinarides the deposition of the Bulog Formation as drowning sequence of the Ravni Carbonate Ramp in practically all facies belts from the continental slope to the central shelf is fairly well understood (Sudar et al. 2013, 2023a, b; Gawlick et al. 2017a, 2023; Djerić et al. 2024; Mrdak et al. 2024a, 2025), in the type-region around Sarajevo in Bosnia and Herzegovina the provenance and depositional realm of the Bulog Formation was still unraveled.

There were still several possibilities of the palaeo- geographic position of the sections in the type area around the village Bulozi and the wider area around Sarajevo discussed:

I. A condensed parautochthonous deep-water Middle-Late Anisian red nodular limestone sedimentary sequence (Bulog Formation) overlain by open-marine deep-water Middle to Late Triassic limestones which resemble a Hallstatt Limestone succession. This sequence should have been deposited in a parautochthonous deep-water basin in the realm of the later East Bosnian-Durmitor megaunit as a more westward located counterpart of the Lim Basin, here called Bosnian trough. This Bosnian trough should be located between the todays East Bosnian-Durmitor megaunit and the Pre-Karst unit, whereas the Lim Basin (with its sub-basins) should be located in the todays East Bosnian-Durmitor megaunit.

II. A condensed parautochthonous deep-water Middle-Late Anisian red nodular limestone sedimentary sequence overlain by Late Triassic shallow-water carbonate platforms. This sequence was everywhere formed in the realm of the later East Bosnian-Durmitor megaunit, or

III. A far-travelled condensed deep-water Middle-Late Anisian red nodular limestone sedimentary sequence overlain by open-marine deep-water Middle to Late Triassic Hallstatt Limestones. In that case the sequence would derive from the outer shelf of the Neo-Tethys passive continental margin, where Hallstatt Limestone successions formed. This would mean that the Bulog Formation in the type area is part of the Zlatar (Hallstatt) Mélange, which rests tectonically on top of the East Bosnian-Durmitor megaunit.

To solve this open question was not only important for the lithostratigraphy in the Dinarides, i.e. is the Bulog Limestone a synonym of the Schreyeralm Limestone as part of the outer shelf Hallstatt Limestone succession in the Eastern Alps or an independent formation formed originally in central shelf position (Sudar et al. 2023b for discussion). Furthermore, to solve this question was important for the palaeogeography of the Dinarides in general. Especially the question if in the Dinarides deep-water basins throughout the whole Triassic existed in a central shelf position or not is crucial for the reconstruction of all younger tectonic motions and the correlation of tectonic units.

The Bulog Limestone was from the early beginning of studies compared with the Schreyeralm Limestone in the Northern Calcareous Alps (Hauer 1888, 1896), for lithological and faunistic reasons. The first modern studies about the depositional realm and the microfauna of the Bulog Limestones by Wendt (1973) and Fischer & Jacobshagen (1976) throughout the Dinarides and also Hellenides end up, that all Bulog Limestones were assigned as Hallstatt Limestones. This is in a certain way not wondering, if the faunal content, the microfacies, the lithological features, and the depositional rates are compared both Schreyeralm and Bulog Limestone are very similar. In addition, also the underlying shallow-water carbonates of the Schreyeralm Limestone and the Bulog Limestones (Steinalm resp. Ravni Carbonate Ramp carbonates) are identical elsewhere. The problem appears if lithostratigraphic names are also used for palaeogeographic reconstructions.

The Hallstatt Limestone succession (at least the various coloured Hallstatt Limestone sequence – Fig. 3) is interpreted since Nowak (1911) as to be deposited south of the today’s southern rim of the Northern Calcareous Alps, the type region of the Hallstatt Limestones. Later, e.g., Spengler (1919, 1943) and Tollmann (1976, 1981, and 1985) came for different reasons to the similar conclusion that the Hallstatt Limestone succession was deposited in an outer shelf position. Note, that these models are reflecting still an interpretation following the geosyncline model. However, translated to plate tectonics, the various coloured Hallstatt Limestones were deposited in outer shelf position (Lein 1985, 1987; Gawlick et al. 1999) and not in intraplatform basins (Zankl 1967; Tollmann 1976). But, it is beyond the topic of the paper to discuss here the history of the changing models about the various Hallstatt successions in the Northern Calcareous Alps. To go deeper into this topic, the interested reader is referred to Frisch & Gawlick (2003) and Missoni & Gawlick (2011a, b) and the historical summaries including references therein.

Following parautochthonous concepts, that means the believing of the existence of deep-water basins in the middle of shallow-water carbonate platforms, and to name all open-marine Triassic successions Hallstatt Limestones the way is open to confuse unexperienced readers not firm with the controversial discussions about the depositional realms of the Triassic in the Western Tethys Realm. Therefore, the name Hallstatt Limestone should only be used for the characteristic Middle-Late Triassic open-marine limestone sequences as defined by Mojsisovics (1892), later revised by Schlager (1969), Krystyn et al. (1971), and Krystyn (1974). The interested reader is also referred to the more modern revisions from Lein (1987) and Krystyn (2008). Also for the Dinarides the term Hallstatt Limestone succession with its different characteristic members (Fig. 3) is used at least since Sudar (1986), but was never transferred into the official nomenclature of the lithostratigraphy of the Dinarides (Dimitrijević 1997). Today it is proven, that all Hallstatt Limestone successions represent far-traveled nappes or mélanges transported to their actual position in the frame of Middle-Late Jurassic ophiolite obduction (Gawlick et al. 2017a, b, 2018 and references therein for Serbia; Gawlick & Missoni 2015; Goričan et al. 2022 and references therein, Mrdak et al. 2023, 2024b for Montenegro; this paper for Bosnia & Herzegovina; compare: Gawlick et al. 2008 for Albania; Kostaki et al. 2024 and references therein for Greece). Their provenance area, i.e. their original depositional realm is the Middle Triassic to Middle Jurassic outer shelf facing the Neo-Tethys Ocean to the east. Therefore it is highly important to have a stable and reliable lithostratigraphic nomenclature which includes also the specific litho- and microfacies characteristics and their under- and overlying sedimentary sequences.

Intraplatform basins in the Dinarides?

Aubouin et al. (1970), Rampnoux (1974), Charvet (1978, 1980), and later Dimitrijević (1997 and references therein) interpreted the various Triassic deep-water successions in the Dinarides as intraplatform basins throughout the Middle and Late Triassic. These are namely the Budva, the Bosnian, and the Lim basins. The Budva Basin to discuss is out of the scope of this paper and the interested reader is referred to Goričan et al. (2022 and references therein). Aubouin et al. (1970), Charvet et al. (1974), and Charvet (1980) assigned the region around Sarajevo with Bulog and Hallstatt Limestones as part of the “Zone Bosniaque + Zone Serbe in parts”, and correlated this zone with the Mirdita zone in Albania and the zone maliaque? in Greece (Charvet et al. 1974; Rampnoux 1974; Cadet et al. 1978, compare Dercourt et al. 1993; Charvet 2013). The “Bosnian Basin” (placed between the “Durmitor“ and the High Karst/Pre-Karst units: Blanchet et al. 1970) legend was born, which remains until today (Haas et al. 2019): one of the Triassic-Jurassic deep-water troughs between the Drina-Ivanjica unit to the east and the Adriatic Carbonate Platform basement to the west (Vlahović et al. 2005) which should connect the “Pindos Basin“ (= Pindos nappe, Kostaki et al. 2024) to the south with the Slovenian Trough to the north. Nevertheless, this reconstruction resulted in subsequent times in the application of the “philosophy of terranology“ (Kovács et al. 2010 and references therein). The terrane concept was applied for the whole Circum-Pannonian region and a lot of megaterranes (in cases composite and single terranes) were separated and defined, one of them was termed “Adria-Dinaria Megaterrane“ (Kovács et al. 2010). This autochthonous concept of long-living deep-water “intraplatform“ basins resulted at the end in the reconstruction of a parautochthonous oceanic domain (Dinaridic Ocean of Karamata 2006 and references therein) between the Drina-Ivanjica unit to the east and the East Bosnian-Durmitor megaunit to the west. It is far beyond the topic of this paper to discuss the “terrane philosophy“ based on autochthous views of every tectonic unit. But it should be recognized that autochthonous concepts are always preferred in geological reconstructions in comparison with the more complex allochthonous reconstructions, also in the Dinarides (for discussion see SCHMID et al. 2008; GAWLICK et al. 2016, 2017a), in most cases also ignoring data and facts.

In the Albanides an allochthonous origin of the Hallstatt Limestone successions, which are incorporated in various mélanges in the surroundings and below the obducted Mirdita ophiolites (GAWLICK et al. 2008, 2014; GAWLICK & MISSONI 2019) is proven. In the Dinarides the systematic study and description of various Hallstatt Mélanges started in 2012 (MISSONI et al. 2012). Later (GAWLICK et al. 2017a, b; 2018), the understanding of the Zlatar (Hallstatt) Mélange resulted in the fact, that the Zlatar subbasin of the Lim Basin (RAMPNOUX 1974) never existed. Only HAAS et al. (2019) believed still in an existence of a deep-water basin in central shelf position. The allochthony of the deep-water Late Triassic limestone succession (see SUDAR 1986) in the so-called and believed Čehotina subbasin of the Lim Basin (RAMPNOUX 1974) was disproved by GORIČAN et al. (2022), MRDAK et al. (2024b). In addition, ZÖHRER (2024) described in the “Čehotina subbasin“ also various Dachstein reef and fore-reef limestones similar to those known in the Sirogojno carbonate-clastic Mélange (ZÖHRER et al. 2021 and references therein) with the difference that the preserved sections in northern Montenegro comprise longer stratigraphic ranges (latest Carnian to late Norian). Also in the Hellenides the Pindos unit (= Hallstatt Limestones) is meanwhile proven to be allochthonous (KOSTAKI et al. 2024) and forms not a Triassic deep-water basin or even an ocean in central shelf position (ROBERTSON et al. 2012 and references therein).

In the northward continuation of the Hellenides/Albanides and Dinarides in Serbia and Montenegro the situation was never studied in detail. Therefore, the type area of the Bulog Formation and the various Hallstatt Limestone successions in the area around Sarajevo remain still a deep-water intraplatform basin in central shelf position of the Dinarides (AUBOUIN et al. 1970; CHARVET 1978, 1980). Our results now clearly evidence, that also these Hallstatt Limestone successions were transported from the outer shelf region in Jurassic times to the actual position as part of the Middle-Late Jurassic Zlatar (Hallstatt) Mélange. South of Sarajevo the Zlatar Mélange rests on top of the parautochthonous Triassic-Jurassic sequence of the East Bosnian-Durmitor megaunit and is overlain by an ophiolitic mélange with blocks of the Grivska Formation incorporated.

A typical feature in the Hallstatt Limestone successions in the Dinarides is the long-lasting stratigraphic gap in the Carnian. As the youngest Early Carnian sediments could be dated by ammonites from neptunian dike infilling as *Aonides* Zone (DIENER 1916; FISCHER & JACOBSHAGEN 1976) and the overlying reddish limestones as higher Tuvalian (SUDAR 1986) a stratigraphic gap similar in duration to the known gap above the Wetterstein Carbonate Platform in the Sirogojno carbonate-clastic Mélange (MISSONI et al. 2012) is proven. A long-lasting stratigraphic gap was recently also recognized in the East Bosnian-Durmitor megaunit in northern Montenegro (MRDAK et al. 2023), but with a little longer duration.

In addition, it has to be clearly stated, that during the time span Late Anisian to Ladinian the deep-water successions elsewhere in the Dinarides were not deposited between carbonate platforms (Fig. 23). After the drowning of the Ravni Carbonate Ramp the shallow-water carbonate production system could not recover despite various events, that are predominantly the intense Illyrian and late Ladinian volcanic activities. Only in small areas and in a restricted time span shallow-water carbonate production could be recognized, mainly on newly formed structural highs like evolving volcanoes (MRDAK et al. 2024a), or horst structures which came for a short time interval into a position for shallow-water carbonate production (GAWLICK et al. 2017a). In all other areas deep-water sedimentation prevailed from the late Anisian to the latest Ladinian resp. to the base of the Carnian (Fig. 23). First, the evolution of the Wetterstein Carbonate Platform since the latest Ladinian (but mainly in the earliest Carnian) marks the onset of significant shallow-water carbonate production under tropical/subtropical conditions. But even the Wetterstein Carbonate Platform was during their very short life-span in the earliest Carnian not able to fill the existing deep-water realms with carbonates. After the demise of the Wetterstein Carbonate Platform around the Julian 1/Julian 2 boundary between the platforms remain deep-water basins (Džegeruša Basin – Gawlick et al. 2017a; Mrdak et al. 2023), which were not filled before the evolution of the Dachstein Carbonate Platform started. From the Early Norian onwards the enormous carbonate production of the Dachstein Carbonate Platform filled all remaining depressions in the central shelf area and only lagoonal carbonates formed. The outer shelf (Hallstatt shelf) remained a deep-water environment, and the open-marine hemipelagic Hallstatt Limestones deposited,

Therefore, Middle Triassic deep-water sedimentary rocks are in fact not characteristic for any depositional realm between the continental slope and the central shelf area, in cases not even for the proximal shelf areas. In addition, the reconstruction of a simple palaeotopography with few elevated highs and basins between as presented by Aubouin et al. (1970), Rampnoux (1974), and Charvet et al. (1978) with a lot of subsequent followers until today (Haas et al. 2019) is rather unrealistic as meanwhile at least two different times of the formation of a horst-and-graben topography were recognized (Gawlick et al. 2023; Sudar et al. 2023a, b; Mrdak et al. 2024a) elsewhere in the Dinarides. During the Carnian and only during the time-span of the evolving Wetterstein Carbonate Platform significant thicknesses of carbonates accumulated. After the demise of this platform only in few areas thin siliciclastic-dominated sedimentary rocks deposited. Most sections show a long-lasting Carnian gap in deposition, as proven in the outer shelf region (Gawlick et al. 2017b, 2018, this paper), the area of the reef-belt (Missoni et al. 2012), or the central shelf area like the East Bosnian-Durmitor megaunit (Gawlick et al. 2017a; Mrdak et al. 2023).

Only the Norian-Rhaetian time-span, that is at least the longest period in the Triassic after the drowning of the Ravni Carbonate Ramp, is definitivly indicative for a palaeogeographic provenance of a Triassic deep-water sequence. All Norian-Rhatian deep-water limestone successions were transported to their actual position from the outer (Hallstatt) shelf, exclusively. Furthermore, we tried in the descriptions of the sections to work out also some characteristcs for the Middle Triassic. On this base also a relative reliable decision of the original provenance area can be made, but these criteria are not 100% indicative, because in the Middle Triassic with their variable topography always regional exceptions can be expected.

The first deepening event around the Bithynian/ Pelsonian boundary

The Ravni Formation consists of a lower Utrine Member, deposited under semi-restricted depositional environment conditions in a relatively shallow-water environment (Dimitrijević 1997). The upper Dedovići Member is characterized by more open-marine conditions, but the microfacies, flora and fauna shows carbonate production also in a shallow-marine depositional environment. The Trebević Member (Sudar 1986) in the Trebević Mt. (Studenkovići section) is situated below the Dedovići Member and is characterized by a mixture of open-marine and deeper-water organisms and shallow-water organisms. This significant change in the facies conditions around the Bithynian/ Pelsonian boundary is so far not known in the Dinarides and marks the first indication of the opening of the Neo-Tethys Ocean, as known from the Northern Calcareous Alps. There, in the Northern Calcareous Alps this characteristic level is named Annaberg Formation (Gawlick et al. 2021). The first deepening event creates regional depressions in the shallow-water depositional realm of the Ravni/ Steinalm Carbonate Ramp at a time carbonate production could not counterbalance the creation of new accomodation space easily. In these depressions limestones with open-marine and deeper-water organisms deposited, as proven in the Northern Calcareous Alps (Annaberg Formation) or in the Dinarides (Trebević Member – Sudar 1986).

However, this first deepening event marks the change from deposition in a semi-restricted environment to deposition under open-marine conditions, i.e. the change from the Utrine Member to the

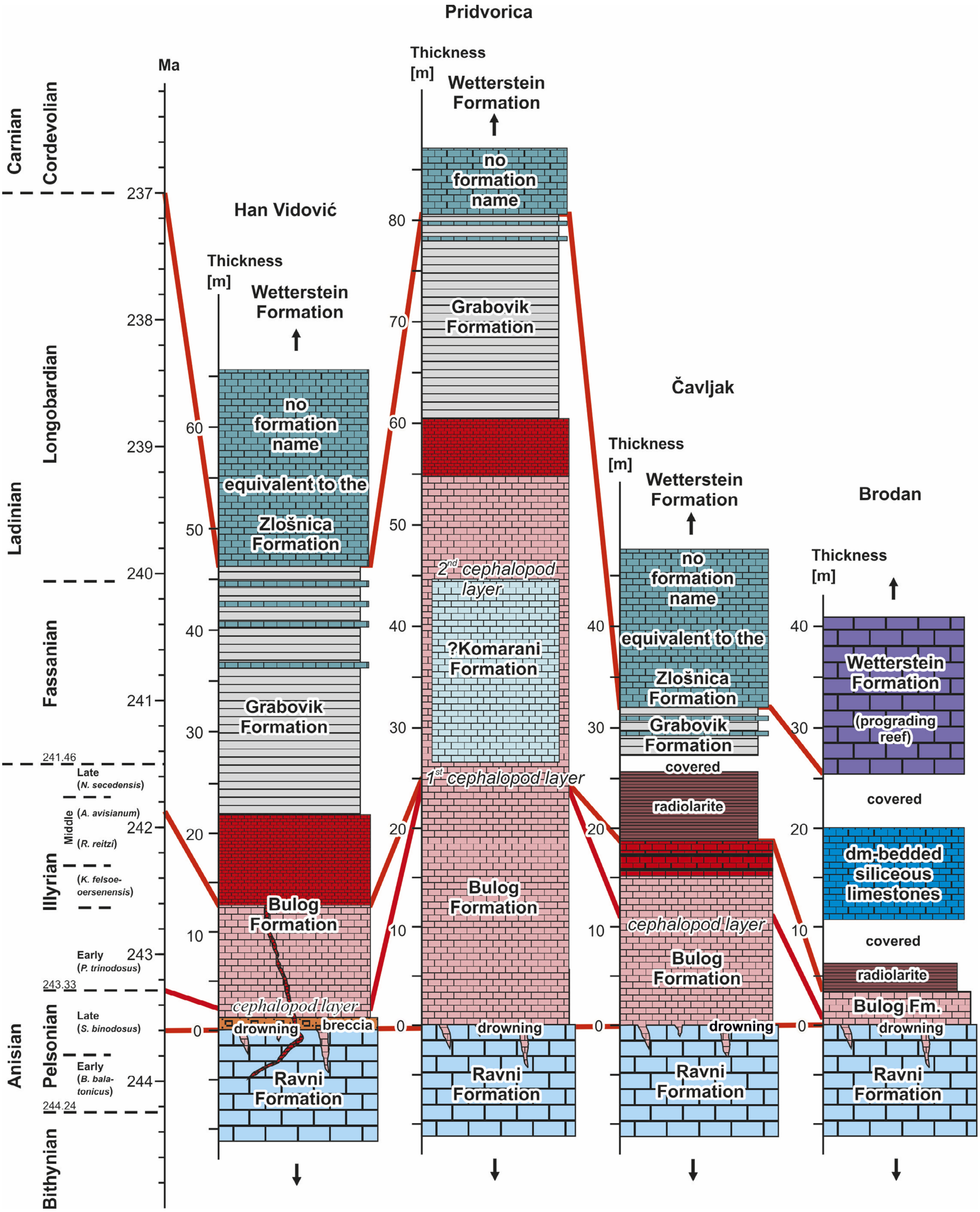

Fig. 23. Thickness and age correlation of the type-section Han Vidović and the sections Pridvorica, Čavljak, and Brodan (simplified columns). Absolute ages (Ma) from OGG et al. (2020). Sections Han Vidović and Pridvorica after SUDAR et al. (2023c), in cases corrected and modified on base of new data.

Dedovići Member in the Dinarides, or the change from the Gutenstein Formation to the Steinalm Formation in the Northern Calcareous Alps. In most but not all cases carbonate production during that time span around the Bithynian/Pelsonian boundary to the Pelsonian could counterbalance the increasing subsidence and fill the newly formed basins by the shallow-water limestones of the Dedovići Member, i.e. by progradation of the Ravni Carbonate Ramp.

The final drowning of the Ravni Carbonate Ramp with an abrupt change in the depositional regime happenend in the late Pelsonian, i.e. the deposition of shallow-water limestones changed to deposition of deep-water limestones (Bulog Formation). The creation of a smooth relief around the Bithynian/ Pelsonian boundary explains also the thickness differences of Dedovići Member sections. In the newly formed depressions the thickness of the Dedovići Member is often significantly higher compared with areas with less subsidence. In these areas also the facies change from the Utrine Member to the Dedovići Member is more gradual and not interrupted by a deeper-marine intercalation (compare the Northern Calcareous Alps: Gawlick et al. 2021). However, systematic studies of the Early-Middle Anisian evolution of the Ravni Formation are not carried out yet in the Dinarides. But it seems that in the Outer Dinarides the thickness of the Ravni Formation is relatively homogeneous, wheras in the Inner Dinarides the thicknesses of Ravni Formation, especially of the Dedovići Member are highly variable. That could mean, that the occurrence of the Trebević Member is most probably also a reliable palaeogeographic indicator and mark depositional areas near to the later Neo-Tethys Ocean.

Depositional realm of the Bulog Formation

Similar sections as in the type area of the Bulog Formation around Sarajevo are known from Serbia (Sudar et al. 2013, 2023a, b; Gawlick et al. 2017a, b, 2023) and Montenegro (Gawlick et al. 2012, Goričan et al. 2022; Mrdak et al. 2024a). In all cases the Bulog Formation is overlain in the Late Triassic by shallow-water carbonates (Wetterstein and Dachstein Carbonate platforms). Therefore the Bulog Formation is definitively not identical with the Schreyeralm Limestone in the Northern Calcareous Alps. Both red nodular limestones (Schreyeralm and Bulog) represent the drowning sequence of the Steinalm/Ravni Carbonate Ramp, but the overlying sedimentary succession is different. Whereas the Schreyeralm Limestone is overlain by a complete Ladinian to Rhaetian Hallstatt Limestone sequence, the Bulog Formation *sensu stricto* is overlain by the Wetterstein and Dachstein Carbonate platforms after the deposition of various Ladinian deep-water sedimentary rocks.

As the demise of the Wetterstein Carbonate Platform is dated as basal Julian 2 or slightly earlier around the Julian 1/2 boundary (Krystyn et al. 2008; Feist-Burkherdt et al. 2008; Lein et al. 2012; Mrdak et al. 2023; Tekin et al. 2024) a long lasting gap is proven between the demise of the Wetterstein Carbonate Platform and the overlying basinal limestones which form the base of the Norian-Rhaetian Dachstein Carbonate Platform. A deep erosion of the Wetterstein Carbonate Platform is indicated by the enormous reduced thickness of the platform carbonates, which can reach in the Dinarides, i.e. the Hochkarst nappe ~300 m (Gawlick et al. 2012). A similar gap between the Wetterstein Carbonate Platform and the overlying open-marine limestones is proven in the Sirogojno carbonate-clastic Mélange, where the gap above the Wetterstein Carbonate Platform lasted until the Tuvalian 2 (Missoni et al. 2012), or in northern Montenegro in the East Bosnian-Durmitor megaunit, where carbonate production after the demise of the Wetterstein Platform started again in the latest Tuvalian (Mrdak et al. 2023). On base of this general tectonostratigraphy of the overlying Late Triassic sedimentary sequence above the Ravni Carbonate Ramp with its drowning sequence of the Bulog Formation and equivalents a relative exact reconstruction of the original shelf position of every section can be drawn.

Above the late Pelsonian/early Illyrian variable drowning sequence of the Ravni Carbonate Ramp the overlying middle/late Illyrian to Ladinian sedimentary sequences vary in cases even more in the different palaeogeographic domains. Whereas in central shelf position the Bulog Formation is overlain by various deep-water sedimentary rocks of the Nova Varoš Group (Gawlick et al. 2017a), including the herein defined Grabovik Formation the depositional realm of the Bulog Formation deposited in an outer (Hallstatt) shelf to continental slope position is less variable. Especially the volcanics and volcano-sedimentary rocks are missing in this palaeogeographic domain, i.e. the outer shelf (compare Djerić et al. 2024).

In contrast, radiolarites are not a characteristic sedimentary rock for any palaeogeographic domain. Radiolarites deposited in the short time interval of the middle/late Illyrian to Ladinian practically everywhere from the central to distal shelf in the graben structures (Gawlick et al. 2012, 2017a; Goričan et al. 2022), which are formed:

A) in the frame of the early opening of the Neo-Tethys Ocean in the late Pelsonian (Gawlick et al. 2008; Oszvárt et al. 2012; Sudar et al. 2013), or

B) in the frame of the onset of intense volcanism around the middle/late Illyrian in central shelf position.

The main but not first deepening event in the late Pelsonian is characterized by the drowning of the Ravni Carbonate Ramp (Sudar et al. 2013) and equivalents in the whole Western Tethys Realm and is known as Reifling turnover (Schlager & Schöllnberger 1974), whereas the second significant deepening event seems to be related to the onset of intense volcanism in the Illyrian. This volcanisms could be recognized practically exclusively in proximal to central shelf position and marks a new event in the stepwise deepening of the depositional realms in the Western Tethys Realm (compare Gawlick et al. 2021 and references therein).

In addition, by the lithological and microfacies characteristics of isolated Bulog Limestone successions it cannot be decided from which palaeogeographic domain such a Bulog Limestone succession derives. In a lot of cases the underlying shallow-water limestones of the Ravni Carbonate Ramp are dissected by one or two generations of neptunian dikes. In some cases the Ravni Formation uplifted in the late Pelsonian and emerged until their flooding in the late(st) Illyrian. Here the late Pelsonian to late Illyrian gap is a primary stratigraphic gap. This is indicated also by intense recrystallisation and sometimes karstification of the Ravni Formation. In other cases the Ravni Formation was faulted down and get dissected, newly formed neptunian dikes are filled with late Pelsonian open-marine sediments and above Bulog Limestone deposited. In few cases such blocks were uplifted again around the middle/late Illyrian boundary and the Bulog Limestone including the dissected Ravni Formation eroded. Later, in the latest Illyrian after a period of erosion such horsts also get flooded again. Here the long lasting gap until the late Illyrian is an erosional gap. This is indicated by the late Pelsonian neptunian dike infillings and much less recrystallisation of the Ravni Formation. Furthermore, the overlying sedimentary sequence above the Bulog Formation varies from place to place, and is often not very characteristic for any palaeogeographic domain, except the occurrence of thick volcanics or volcanic sandstones. Only the overlying Late Triassic sedimentary sequence allows a definite characterization of the palaeogeographic domain where the Bulog Formation was formed.

If the Bulog Formation is in the Late Triassic overlain by the shallow-water carbonates of the Wetterstein and Dachstein Carbonate platforms the depositional realm was the (proximal to) central shelf area. In contrast, in more distal shelf areas where no Late Triassic shallow-water platforms formed, the Bulog Formation is overlain by Late Triassic open-marine deep-water limestones, named Hallstatt Limestones elsewhere in the Western Tethys Realm (Kovács et al. 2010, 2014 and references therein). Even if the Hallstatt Limestone succession vary in the different areas, i.e. the Eastern Alps (Northern Calcareous Alps) – the type area of the Hallstatt Limestone (Hauer 1853; Schlager 1969; Tollmann 1976; Krystyn 1974, 2008 and references therein), the Western Carpathians resp. the Pelso-unit (Kovács et al. 2014; compare Plašienka 2018), the Dinarides (Sudar 1986) and other related areas (see Gawlick & Missoni 2019), their overall tectonostratigraphy, lithostratigraphy, and microfacies characteristics is practically everywhere the same. Differences are only that in the more northern areas (Eastern Alps, Inner Western Carpathians) the Hallstatt Limestones are practically free of shallow-water influence; that is, that turbidites consisting of shallow-water material from adjacent shallow-water carbonate platforms are missing. Shallow-water debris was only deposited in the so-called grey Hallstatt Facies (Lein 1987), which is equivalent to the Gučevo Limestone (Sudar 1986) or the upper Kopaonik Formation (Schefer et al. 2010). In the various coloured Hallstatt Limestone successions only the change in colour and depositional rate during the time differs (Gawlick & Böhm 2000) following the progradational phases of the platforms in central shelf position, which export during these times enormous amount of fine-grained material to the open shelf. This high-stand-shedding principle (Schlager 2005 and references therein) is perfectly reflected in the lithostratigraphy of the Hallstatt Limestone sequences. In contrast, in the more southern domains, i.e. the Dinarides, Albanides, and Hellenides the Hallstatt Limestone sequences contain in cases carbonate turbidites with material from platform areas.

The reconstructed Hallstatt Limestone succession from the Trebević Mt. (Fig. 24) follows the overal Middle-Late Triassic lithostratigraphy as elsewhere in the Western Tethys realm. The preserved thicknesses in the different parts of the depositional history is rather low, and condensation in several levels is a typical feature. This evolution fits quite well to the described sedimentological cha-

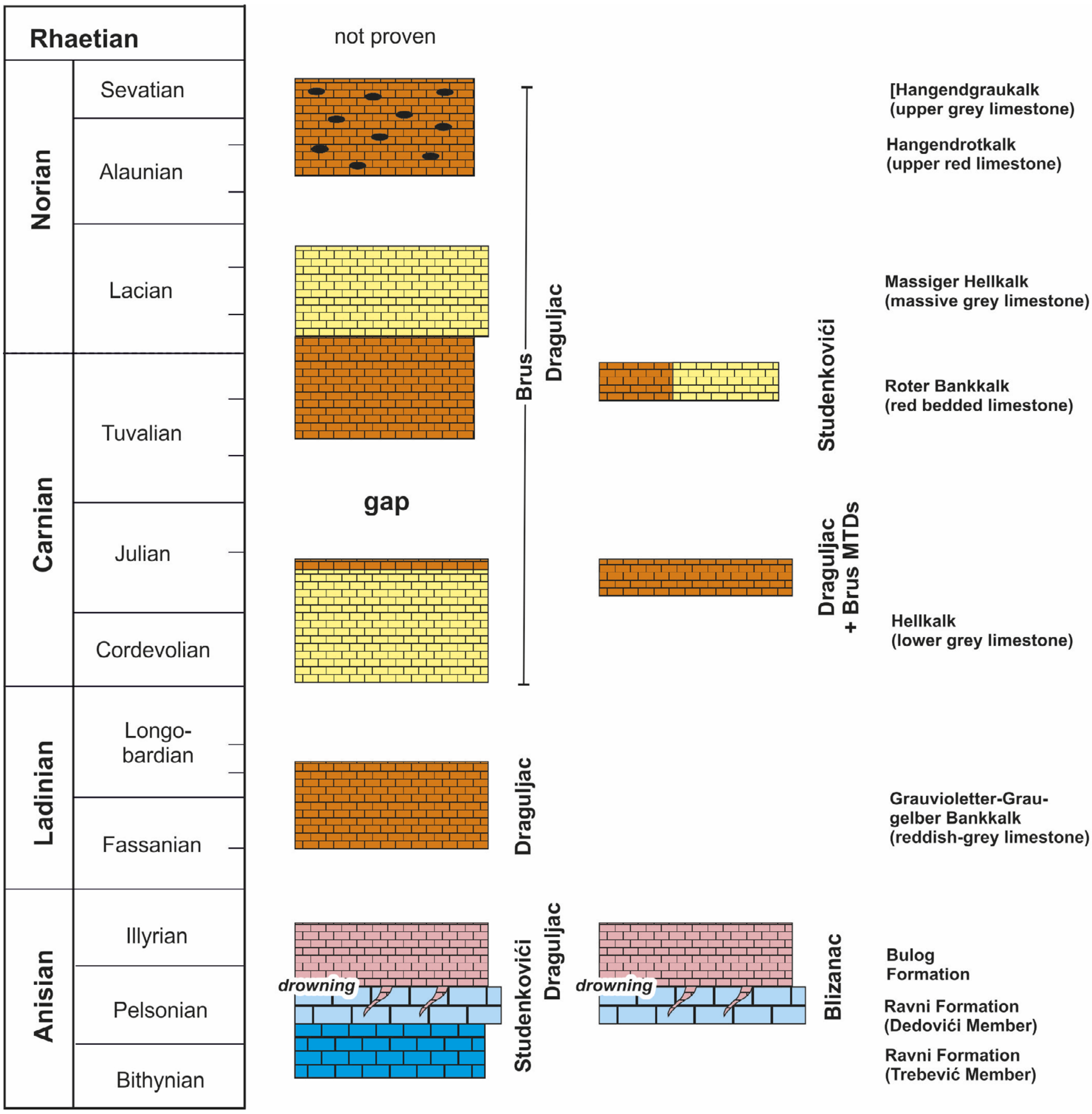

Fig. 24. Reconstruction of the dismembered Hallstatt Limestone sequence in the Trebević Mt. The overall evolution of the Hallstatt Limestone succession follows the trend as known in the Dinarides. Typical is the long-lasting stratigraphic gap from the Julian 1/2 boundary to the middle late Tuvalian. See text for explanation.

racteristics of the famous fossil-bearing type of Hallstatt Limestones as described by Krystyn (2008). Also the continous deposition of bedded red nodular limestones with chert nodules throughout the Alaunian-Sevatian is a characteristic sedimentological feature of this type of Hallstatt Limestones. These Hallstatt Limestones derive from remaining structural highs from the outermost part of the shelf, where reduced thickness and fossil-accumulations is a typical feature. Only the Studenkovići section with the Trebević Member around the Bithynian/ Pelsonian boundary is untypical for this facies belt.

Conclusions

The depositional history and the palaeogeographic provenance of the Bulog Formation is important to understand the early opening history of the Neo-Tethys Ocean, and the transport processes including mélange formation in the frame of the Middle-Late Jurassic ophiolite obduction, which resulted in the formation of the Neotethyan orogenic belt along the whole western Neo-Tethys.

Based on the results in the type area of the Late Pelsonian-Illyrian Bulog Limestone it can be concluded:

A) That the Bulog Formation *sensu stricto* (type section) deposited in a central shelf position and is overlain by the shallow-water carbonates of the Wetterstein Carbonate Platform and later the Dachstein Carbonate Platform.

B) The Bulog Limestone type section derives definitively not from the outer shelf region, as other Bulog Limestone and Hallstatt Limestone successions in the Sarajevo area.

C) The Late Triassic Hallstatt Limestones in the area around Sarajevo represent far-travelled blocks or nappe remnants from the outer shelf area facing the Neo-Tethys Ocean to the east. The far-travelled Hallstatt Limestone blocks in the Sarajevo area correspond to the Zlatar (Hallstatt) Mélange in SW Serbia (Gawlick et al. 2017a, b, 2018).

D) An autochthonous Late Triassic deep-water basin in the Sarajevo and adjacent areas (Zone Bosniaque and Zone Serbe, "Bosnian trough"), as postulated by Charvet et al. (1974) and Charvet (1980) cannot be confirmed. Also in Serbia originally the allochthonous Hallstatt Limestone sequences were interpreted to be deposited in a parautochthonous position (= Lim Basin) as proposed by Rampnoux (1970).

Above the Zlatar (Hallstatt) Mélange follow an ophiolitic mélange with incorporated blocks of the Grivska Formation, which derive from the continental slope transitional to the oceanic realm. The rounded components at the base of this ophiolitic mélange characterize this ophiolitic mélange as OM3-type ophiolitic mélange, as definded by Djerić et al. (2024), wheras the higher part of the ophiolitic mélange corresponds to OM2-type ophiolitic mélange (Djerić et al. 2024) with incorporated blocks from the continent near to continental slope sedimentary sequence.

The results of this study clearly show, that the Middle Triassic open-marine sedimentary rocks including the Bulog Formation in area around Sarajevo have two different palaeogeographic provenances:

1) A parautochthonous provenance: the Bulog Formation and its overlying deep-marine Ladinian to earliest Carnian sedimentary rocks are overlain by the shallow-marine carbonates of the Wetterstein and Dachstein Carbonate platforms with its significant late Early Carnian to latest Late Carnian stratigraphic gap.

2) An outer shelf provenance: the Bulog Formation is overlain by Ladinian to Norian deep-marine limestones with its significant late Early Carnian to middle Late Carnian stratigraphic gap.

We recognize in the area of Sarajevo three different tectonic units:

1) The parautochthonous East Bosnian-Durmitor megaunit at the base.

2) The Zlatar (Hallstatt) Mélange as allochthonous and far-travelled tectonic unit above the parautochthonous East Bosnian-Durmitor mega-unit.

3) An ophiolitic mélange in the highest structural position. This ophiolitic mélange is related to the known Middle to early Late Jurassic ophiolite obduction in the Dinarides.

A parautochthonous Middle-Late Triassic deepwater basin (Zone de Serbe, Bosnian Trough) in the realm where the Wetterstein and Dachstein Carbonate Platforms formed was never existing.

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Резиме

Формација Булог у типској области (Сарајево) и сродне средњо и горњотријаске отворено морске седиментне сукцесије у Динаридима Босне и Херцеговине

Решење питања депозиционе историје и палеогеографског порекла Формације Булог важно је због разумевања историје раног отварања Неотетиског океана, и транспортних процеса који су укључили формирање меланжа у оквиру средњо-каснојурске офиолитске обдукције, што је резултовало настанком Неотетиског орогеног појаса дуж целог западног Неотетиса.

Почетак отварања Неотетиса у средњем анизику окарактерисано је значајним променама у депозицији у целој области Западног Тетиса од плитководне карбонатне рампе до дубоководне морске хемипелашке платформне депозиције. Тај догађај познат је у геологији као Рајфлиншки обрт.

У Динаридима, еволуција плитководне Карбонатне рампе Равни завршила се релативно нагло у касном пелсону: убрзано смањење карбонатне продукције праћено је формирањем хорст и грабен топографије и каснијом широко распрострањеном депозицијом дубоководних морских црвених квргавих кречњака (Формација Булог) или секвенцом олигомиктне бречe састављеном од компоненти подинске Кречњачке рампе Равни у матриксу Булошких кречњака, односно Формацијом Комарани.

Ово потањање Карбонатне рампе Равни везано је с континенталним разламањем и почетком формирања Неотетиске океанске коре, како је нашироко описано у Динаридима, Албанидима, и Хеленидима.

Депозициона област анизијске (касно пелсонске до ?фасанске) Формације Булог у Динаридима је простор отвореног шелфа, тј. домен депозиције Халштатских кречњака до средишњег дела шелфа. Старост, микрофацијалне карактеристике, и тектоностратиграфија у оба региона се мало разликују. Док се у области отвореног шелфа повлатна седиментна секвенца састоји само од отворено морских дубоководних кречњака (Халштатска кречњачка секвенца), у области средишњег дела шелфа Формација Булог је покривена различитим касноанизијско-ладинским дубокоморским седиментним стенама (радиоларитима, силицијским банковитим кречњацима, силицијским вулканогено-силицикластичним седиментним стенама са вулканским интеркалацијама = различити чланови Групе Нова Варош). Само у ретким случајевима плитководни карбонати се депонују током краткотрајних временских интервала. У раном карну започела је еволуција плитководних карбонатних платформи, прва је најранија карнијска Ветерштајнска карбонатна платформа са престанком у средњем карну (*Carnica*-догађај) а касније норичко-ретска Дахштајнска карбонатна плат-

форма са завршетком на граници тријас-јура. Међутим, док је у пресеку кроз Динариде на потезу Србија-Црна Гора депозиција Формације Булог као потањајуће секвенце Карбонатне рампе Равни прилично добро разумљива, практично у свим фацијалним појасевима од континенталне падине до средишњег шелфа, у типском региону око Сарајева у Босни и Херцеговини порекло и депозициони домен Формације Булог још увек су остали неразјашњени.

Пресудна за ову реконструкцију је тријаска палеогеографска позиција типског локалитета Формације Булог, и одговарајућих профила у области околине Сарајева. У том контексту могуће је издвојити, тј. дискутовати неколико следећих могућности за издвајање палеогеографских позиција локалитета у типској области околине села Булози. То су:

А) кондензована параутохтона дубоководна средњо-касноанизијска седиментна секвенца црвених квргавих кречњака (Формација Булог) која лежи испод отворено морских дубоководних средњо до каснотријаских кречњака који наликују сукцесији Халштатских кречњака. Ова секвенца је вероватно била депонована у параутохтном дубоководном басену у области касније Источнобосанско-дурмиторске мегајединице као северозападног продужетка Басена Лим, овде названог Босански трог;

Б) параутохтона кондензована дубоководна средњо-касноанизијска седиментна секвенца црвених квргавих кречњака која лежи испод каснотријаске плитководне карбонатне платформе. Ова секвенца је свугде настајала на просторима касније Источнобосанско-дурмиторске мегајединице, или

Ц) из даљине транспортоване кондензоване дубоководне средњо-касноанизијске седиментне секвенце црвених квргавих кречњака покривених са отворено морским дубоководним средњо до горњотријаским Халштатским кречњацима. Ова секвенца вероватно потиче са спољашњег шелфа Неотетиске пасивне континенталне маргине, где су сукцесије Халштатских кречњака и настале. То значи да је Формација Булог у типској области вероватно део Златарског (Халштатског) Меланжа, који се тектонски налази на врху Источнобосанско-дурмиторске мегајединице.

Решавање овог отвореног питања није важно само за литостратиграфију Динарида, односно да ли су Булошки кречњаци синоним Шрајералмских кречњака из дела спољашњег шелфа сукцесије Халштатских кречњака Источних Алпа или су они као независна формација првобитно настали у средишњем делу шелфа (види дискусију у Sudar et al. 2023b).

Међутим, означити Булошке кречњаке у типској области околине Сарајева као део сукцесије Халштатских кречњака подразумева, да би бар неке сукцесије Булошких кречњака у типској области представљале навучене јединице идентичне онима описаним испод Динаридске офиолитске навлаке, као што су нпр. Сирогојно карбонатно-кластични Меланж и Златарски (Халштатски) Меланж у ЈЗ Србији. Поред тога, депозиција дуготрајног средњо-горњотријаског параутохтоног дубоководног басена са ограниченим пружањем правца исток-запад, тј. пређашњим Златарским подбасеном Лимског басена (у типској области званим Босански трог) прилично је нереална у области плитководних карбонатних платформи са огромном карбонатном продукцијом. Такође, Чехотина подбасен Лимског басена у северној Црној Гори, састављен је од различитих из даљине „допутовалих“ отворено морских седиментних сукцесија из области спољашњег шелфа. Краткотрајна ранокарнијска Ветерштајнска карбонатна платформа није могла да буде запуњена средњо-касноанизијском хорст и грабен топографијом, па су недовољно запуњени дубоководни басени заостали између платформи, тј. у Источнобосанско-дурмиторској мегајединици. Каснија, норичко-ретска Дахштајнска карбонатна платформа са њеном дуготрајном, великом количином карбонатне продукције испунила је брзо ове заостале карнијске басене, и то већ у доњем норичком кату. Надаље, све истраживане области у Србији и Црној Гори у региону где је лоциран Лимски басен с континуираним средњо-каснотријаском дубоководном сукцесијама, или појаве само каснотријаских дубоководних седиментних стена могле би да буду окарактерисане да потичу са спољашњег шелфа или са континенталне падине. Оне су, или уметнуте у средњо-горњојурски меланж, или су сачуване као делови из далека путујућих навлака. Такође, наши резултати са планине Требевић сада јасно доказују да су ове сукцесије Халштатских кречњака биле транспортоване током јуре из спољашњег шелфног региона у садашњи положај као део средњо-касног јурског Златарског (Халштатског) Меланжа. Јужно од Сарајева Златарски Меланж лежи на врху параутохтоне тријаско-јурске секвенце Источнобосанско-дурмиторске мегајединице и покривен је са офиолитским меланжом са убаченим блоковима Формације Гривске. Заобљене компоненте у бази овог офиолитског меланжа карактеришу га као ОМ3-тип офиолитског меланжа, дефинисаног од стране Djerić et al. (2024). По истим ауторима виши део офиолитског меланжа одговара ОМ2-типу са убаченим блоковима са континента у близини инкорпориране континенталне седиментне секвенце.

Резултати ове студије јасно показују да средњо-тријаске отворено маринске седиментне стене, укључујући и Формацију Булог у области околине Сарајева, имају следећа, два различита палеогеографска порекла:

1) Параутохтоно порекло: Формација Булог и њене повлатне дубокоморске ладинске до најраније карнијске седиментне стене су покривене са плитководним морским карбонатима Ветерштајнских и Дахштајнских карбонатних платформи са њиховим значајним касним рано карнијским до најкаснијим касно карнијским стратиграфским седиментационим прекидом.

2)Порекло са спољашњег шелфа: Формација Булог лежи испод ладинских до норичких дубоководних морских кречњака са њиховим значајним касним рано карнијским до средњо касно карнијским прекидом у седиментацији.

У области Сарајева могуће је разликовати три различите тектонске јединице:

1) Параутохтону Источнобосанско-дурмиторску мегајединицу у основи.

2) Златарски (Халштатски) Меланж као алохтону и из даљине транспортовану тектонску јединицу изнад параутохтоне Источнобосанско-дурмиторске мегајединице.

3)Офиолитски меланж у највишој структурној позицији. Овај офиолитски меланж је сродан са познатом средњо до ранојурско офиолитском обдукцијом у Динаридима.

Параутохтони средњо-каснотријаски дубоководни басен (Српска зона, Босански трог) није никада постојао у простору околине Сарајева где су настајале Ветерштајнске и Дахштајнске карбонатне платформе.

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Appendix 1. *List of the conodont taxa and their abbreviations used in the text and on Figs. 4, 9, 11, 14 and 16 (conodonts are listed according to the alphabetic order).*

Conodonts	Abbreviations
Ancyrogondolella BUDUROV	*Ag.*
Ancyrogondolella spatulata (HAYASHI)	*Ag. spatulata*
Ancyrogondolella triangularis BUDUROV	*Ag. triangularis*
Budurovignathus KOZUR	*Bgn.*
Budurovignathus mungoensis (DIEBEL)	*Bgn. mungoensis*
Epigondolella MOSHER	*Eg.*
Epigondolella bidentata MOSHER	*Eg. bidentata*
Epigondolella postera (KOZUR & MOSTLER)	*Eg. postera*
Epigondolella quadrata ORCHARD	*Eg. quadrata*
Epigondolella rigoi NOYAN & KOZUR	*Eg. rigoi*
Gladigondolella MÜLLER	*Gl.*
Gladigondolella budurovi KOVÁCS & KOZUR	*Gl. budurovi*
Gladigondolella cf. *malayensis* NOGAMI	*Gl.* cf. *malayensis*
Gladigondolella tethydis (HUCKRIEDE)	*Gl. tethydis*
Mazzaella KILIC, PLASENCIA, ISHIDA & HIRSCH	*Mazz.*
Mazzaella carnica (KRYSTYN)	*Mazz. carnica*
Metapolygnathus HAYASHI	*Mp.*
Metapolygnathus communisti HAYASHI	*Mp. communisti*
Metapolygnathus praecommunisti MAZZA, RIGO & NICORA	*Mp. praecommunisti*
Neocavitella SUDAR & BUDUROV	*Ncv.*
Neocavitella cavitata SUDAR & BUDUROV	*Ncv. cavitata*
Neogondolella BENDER & STOPPEL	*Ng.*
Neogondolella constricta (MOSHER & CLARK)	*Ng. constricta*
Neogondolella cornuta BUDUROV & STEFANOV	*Ng. cornuta*
Neogondolella excentrica BUDUROV & STEFANOV	*Ng. excentrica*
Neogondolella pseudolonga KOVÁCS, KOZUR & MIETTO	*Ng. pseudolonga*
Nicoraella KOZUR	*Nic.*
Nicoraella kockeli (TATGE)	*Nic. kockeli*
Norigondolella KOZUR	*Nrg.*
*Norigondolella hallstattensis (*MOSHER)	*Nrg. hallstattensis*
Norigondolella navicula (HUCKRIEDE)	*Nrg. navicula*
Norigondolella steinbergensis (MOSHER)	*Nrg. steinbergensis*
Paragondolella MOSHER	*Pg.*
Paragondolella bifurcata BUDUROV & STEFANOV	*Pg. bifurcata*
Paragondolella bulgarica BUDUROV & STEFANOV	*Pg. bulgarica*
Paragondolella carpathica (MOCK)	*Pg. carpathica*
Paragondolella eotrammeri KRYSTYN	*Pg. eotrammeri*
Paragondolella excelsa (MOSHER)	*Pg. excelsa*
Paragondolella fuelopi (KOVÁCS)	*Pg. fuelopi*
Paragondolella hanbulogi SUDAR & BUDUROV	*Pg. hanbulogi*
Paragondolella inclinata (KOVÁCS)	*Pg. inclinata*
Paragondolella liebermani (KOVÁCS & KRYSTYN)	*Pg. liebermani*
Paragondolella nodosa (HAYASHI)	*Pg. nodosa*
Paragondolella polygnathiformis BUDUROV & STEFANOV	*Pg. polygnathiformis*
Paragondolella praeszaboi (KOVÁCS, PAPSOVA & PERRI)	*Pg. praeszaboi*
Paragondolella szaboi (KOVÁCS)	*Pg. szaboi*
Paragondolella tadpole (HAYASHI)	*Pg. tadpole*
Paragondolella trammeri (KOZUR)	*Pg. trammeri*