

Triassic–Jurassic intraplate basins in the Dinarides: Myth or reality? The Neo-Tethys geodynamic history along a cross-section through the Inner to Outer Dinarides (Serbia–Montenegro)

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Field Trip Guide
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Abstract. The topic of the field trip will be the Triassic–Jurassic depositional history of the Dinarides with special focus on the relations between areas with shallow-water carbonate production (ramps, platforms) and related deep-water sedimentary successions. To understand the Mesozoic (mainly Triassic–Jurassic) geodynamic evolution of the Western Tethys Realm this is essential, with the Dinarides as a very important and crucial orogen in that region. In fact, the Dinarides are the only mountain range in the Western Tethys Realm which allows insights in the Mesozoic evolution along a relative complete east-west cross-section below the Middle to early Late Jurassic obducted ophiolites, which derive from the Neo-Tethys (or Vardar Ocean in different nomenclature) to the east. Meanwhile it is in general accepted that all ophiolites have their provenance east of today's Dinarides and are not part of small independent and long persistent (~70–80 Ma) oceanic basins between microcontinents (terranes). The Triassic(–Jurassic) central shelf arrangement, that is the area between the tectonic units of the Drina–Ivanjica unit in the east and the Pre-Karst/High Karst units to the west is supposed to consist of a series of shallow-water carbonate production areas (“platforms”) with intermediate long-lasting deep-water basins between these platforms. This scenario of long persisting deep-water basins between “platforms” has also to be restricted to the time span Middle to Late Triassic (Late Pelsonian to Rhaetian; ~40 million years). Only in some areas shallow-water carbonate production prevailed until the Early Jurassic, but carbonate platforms could not be formed in the Early Jurassic after the mass extinction at the Triassic/Jurassic boundary. This area comprises today the East Bosnian–Durmitor megaunit, a unit which experienced during the history of geological studies various interpretations and modifications.

We will discuss the Middle Triassic to Jurassic various deep-water successions in the light of supposed deep-water (intraplate) basins between time-equivalent carbonate platforms in relation to facts regarding:

- A) Carbonate production under tropical shallow-water conditions forming carbonate platforms,
- B) Carbonate platform models with respect to sea-level fluctuations,
- C) Carbonate production during times of environmental crises and perturbations,
- D) Facies models of carbonate platforms, and
- E) The principles of carbonate sequence stratigraphy and highstand shedding.

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The field trip will focus on the various deep-water sedimentary rocks during the Triassic–Jurassic geodynamic history deposited in different basins: rift-basins, shelf areas, oceanic domains, trench-like basins, foreland basins. To understand the complex Triassic to Jurassic sedimentological and geodynamic evolution we will visit and study:

- The Middle Triassic to Middle Jurassic passive margin evolution: all depositional realms from the continental slope to the central shelf.
- The Middle Triassic continental break-up: Anisian demise of shallow-water carbonate production (ramp geometry), horst-and-graben formation (break-up unconformity), and deposition of deep-marine sediments elsewhere (drowning succession).
- Restart of shallow-water carbonate production in the Middle and Late Triassic: the sedimentary sequences in the deep-water depositional realm as mirror of platform progradation (sequence stratigraphy, highstand shedding, and carbonate production potential).
- Reasons for the demise of the Triassic shallow-water platforms and the expression of these events in deep-water settings.
- Condensed Early–Middle Jurassic deep-water sedimentary rocks.
- Active continental margin evolution: Middle to Late Jurassic trench-like basin formation and nappe stacking in front of obducting ophiolites, large-scale mass movements (radiolaritic/argillaceous matrix), *mélange* formation.

The field trip area, that are the main parts of the East Bosnian–Durmitor megaunit, provides well preserved insights in the whole Mesozoic geological/sedimentological/geodynamic evolution of the Dinarides as part of the mountain ranges in the Western Tethys Realm with an identical history and tectonostratigraphy. The sedimentary sequences of the East Bosnian–Durmitor megaunit, that is the lowermost tectonic unit in that part of the cross-section allows a detailed reconstruction of the latest Permian to Middle/early Late Jurassic history of the central shelf area. In Middle Jurassic times in the area of the East Bosnian–Durmitor megaunit new trench-like deep-water basins were formed in the frame of ophiolite obduction, and in front of the west-ward propagating nappe stack. These newly formed deep-water basins in front of advancing nappes received material from the nappe stack bulldozed by the west-direct obducting ophiolites onto the foreland of the wider Adriatic plate, with the Dinarides as part of it. These trench-like foreland basins were later incorporated into the nappe stack of the Dinarides forming today various *mélanges*, originally mainly sedimentary *mélanges*, that are chaotic basin-fills with a general coarsening-upward trend. These *mélanges* in the various basins formed in sequence from east to west contain as reworked material (from cm-sized components to km-sized blocks in a deep-water radiolaritic/argillaceous matrix) all facies zones from the Triassic to Middle Jurassic outer to central passive margin configuration to the oceanic realm, but predominantly from the continental slope and outer (deep-water) shelf environment. We will visit sequences originally deposited on the continental slope, the outer shelf region (Hallstatt facies), and the basinal sequences near to the reef rim, the reef-basin transition, and the open lagoonal area. Furthermore, in cases complete sequences are also preserved in far-travelled nappes bulldozed in front of the obducting ophiolites onto the foreland. These nappes rest above the various sedimentary *mélanges* and below the obducted ophiolites with their ophiolitic *mélanges* at the base.

The whole story is very well visible and preserved in our field trip area, with some special highlights of rather practically nowhere in the Western Tethys Realm preserved sequences, but well exposed in northern Montenegro. The question “Are there Triassic–Jurassic intraplate basins in the Dinarides?” will be answered during the field trip by the various sedimentary rocks and the depositional history through time and space. The history from deposition in a rift setting to a passive continental margin evolution and finally to an active margin setting, in combination with the rules of facies and sedimentology, the principles of carbonate production, basin formation and evolution, beside other conformities with

Key words: *Western Tethys Realm, carbonate sequence stratigraphy, passive continental margin configuration, basin evolution, facies, stratigraphy.*

natural laws, is preserved in the different sedimentary succession like in a book. We will try to read that book, and try to understand why scientists in different times had read this book in a different way and gave us a different translation, i.e. interpretation.

The Mihajlovići section from East Bosnian–Durmitor megaunit at northern Montenegro is the type-locality of the newly defined Early Jurassic (?Middle/Late Hettangian to Late Pliensbachian) Mihajlovići Formation.

Апстракт. Тема теренске екскурзије биће тријаско–јурска депозициона историја Динарида са посебним освртом на односе између продукције плитководних карбоната и пратећих дубоководних седиментних сукцесија. Од пресудног је значаја разумевање мезозојске (првенствено тријаско–јурске) геодинамичке еволуције Западног Тетиса, при чему Динариди представљају веома важан и кључан ороген у том региону. Заправо, Динариди су једини планински венац у домену Западног Тетиса, где су могући увиди у мезозојску еволуцију дуж релативно комплетног профила правца исток–запад испод обдукованих офиолита насталих током средње и раног дела горње јуре, који потичу из Неотетиса (или Вардарског океана по другој номенклатури) на истоку. Међутим, генерално је прихваћено да сви офиолити воде порекло источно од данашњих Динарида и да нису део малих, засебних и дуготрајних (~70–80 мил. г.) океанских басена лоцираних између микроконтинената (терана). За тријаско(–јурски) централни шелфни простор, као подручје између тектонских јединица Дрина–Ивањице на истоку и Прекарста/Високог крша на западу, претпоставља се да се састоји из серија области са плитководном карбонатном продукцијом („платформи“) између којих су се налазили дуготрајни дубоководни басени. Ови дубоководни басени егзистирали су у интервалу од средњег до горњег тријаса (касни пелсон до рет). У појединим областима плитководна карбонатна продукција преовлађавала је све до доње јуре, али након масовног изумирања на граници тријас/јуре, у доњој јури није дошло до формирања карбонатних платформи. Та област данас обухвата Источнобосанско–дурмиторску мегајединицу, јединицу која је доживела током историје геолошких истраживања различите интерпретације и модификације. Средњотријаска до јурска дубоководна сукцесија биће разматрана у светлу претпостављених дубоководних басена (интраплатформних) између временски еквивалентних карбонатних платформи, узимајући у обзир чињенице које се односе на:

- А) Карбонатне продукције у тропским плитководним карбонатним платформама,
- Б) Моделе карбонатних платформи у контексту промена нивоа мора,
- В) Карбонатне продукције током времена криза и поремећаја у окружењу,
- Г) Фацијалне моделе карбонатних платформи, и
- Д) Принципе карбонатне секвенционе стратиграфије.

Током теренске екскурзије фокус ће бити на различитим дубоководним сукцесијама седиментних стена депонованих у различитим басенима током тријаско–јурске геодинамичке историје: рифтним басенима, шелфним областима, океанским доменима, дубљим рововским басенима, ободним басенима. Да би се разумела комплексна тријаско до јурска седиментолошка и геодинамичка историја, обухватићемо:

- Средњотријаску до средњојурску еволуцију пасивне маргине: сви депозициони домени од континенталне падине до средишњег дела шелфа.
- Средњотријаско распадање континената: завршетак анизијске плитководне карбонатне производње (геометрија рампе), формирање

- хорстова и ровова (тектонско-ерозиона дискорданција), и депоновање дубоководних седимената на другим местима (сукцесија потањања).
- Поновно обнављање плитководне карбонатне продукције у средњем и гоњем тријасу: седиментне секвенце дубоководног депозиционог домена као резултат проградације платформи (секвенциона стратиграфија, карбонатна продукција и транспорт материјала током високог нивоа мора).
 - Разлози нестајања тријаских плитководних платформи и испољавање ових догађаја у дубоководним срединама.
 - Кондензоване доњо–средњојурске дубоководне седиментне стене.
 - Еволуција активне континенталне маргине: настанак средње до горње јурских басена типа рова и формирање сложених навлака испред обдукованих офиолита, масовни покрети великих размера (радиоларитско/глиновити матрикс), настанак меланжа.

Подручје екскурзије, које обухвата главне делове Источнобосанско–дурмиторске мегајединице, пружа добро очуван увид у целокупну мезозојску геолошко/седиментолошко/геодинамичну еволуцију Динарида, као дела планинских ланаца домена Западног Тетиса са идентичном историјом и тектоностратиграфијом. Седиментна секвенца Источнобосанско–дурмиторске мегајединице, која представља најнижу тектонску јединицу у том делу профила, омогућава детаљну реконструкцију историје централне шелфне области од најкаснијег перма до доње/средње јуре. Током средње јуре, у области Источнобосанско–дурмиторске мегајединице, настајали су нови дубоководни басени типа рова, у оквиру обдукције офиолита, испред навлаке која је пропагирала ка западу. Новоформирани дубоководни басени испред напредујућих навлака примали су значајне количине материјала из навлачног комплекса, формираног током обдукције офиолита ка западу, на форланду шире Јадранске плоче, чији су део и Динариди. Ови басени типа рова су касније били инкорпорирани у сложену навлаку Динарида, а данас представљени различитим меланжима, који су по пореклу углавном седиментни меланжи и који представљају хаотичне испуне басена са општим трендом укрупњавања навише. Поменути меланжи у различитим басенима, формираним у секвенцама од истока ка западу, садрже прерађен материјал (од компоненти ст-величина до блокова km-димензија у дубоководном радиоларитско/глиновитом матриксу) свих фацијалних зона од тријаске до средњојурске конфигурације пасивне маргине до океанских домена, али претежно са континенталне падине и спољног (дубоководног) шелфног окружења. Током екскурзије посетиће се секвенце примарно депоноване на континенталној падини, спољном региону шелфа (фације Халштата), и басенске секвенце у близини обода спруда, прелаз спруд–басен, и лагунска област. Поред тога, у неким случајевима комплетне секвенце сачуване су такође у удаљеним навлакама сравњеним испред обдукованих офиолита ка ободу-предгорју. Ове навлаке остају изнад различитих седиментних меланжа и испод обдукованих офиолита са њиховим меланжима у бази. Цела ова еволуција је веома добро уочљива и очувана у области наше екскурзије, са неким посебним примерима секвенци које готово нигде другде у западном Тетиском домену нису очуване, али су добро откривене у северној Црној Гори. На питање „Има ли тријаско–јурских интраплатформних басена у Динаридима?“ одговараће се током теренске екскурзије на основу различитих седиментних стена и депозиционе историје кроз време и простор. Историја од депозиције у рифтном окружењу, преко еволуције пасивне континенталне маргине, па до коначног развоја активне маргине, у комбинацији са правилима која се тичу фација и седиментологије, принципа карбонатне продукције, настанка басена и еволуције, поред других усклађености са природним законима, очувана је у различитим седиментним сукцесијама као у књизи. Пробаћемо да прочитамо ту књигу, и покушати да разумемо зашто су научници у различитим

Кључне речи: Домен Западног Тетиса, карбонатна секвенциона стратиграфија, конфигурација пасивне континенталне маргине, еволуција басена, фације, стратиграфија.

времелима читали ту књигу на различит начин и дали нам различит превод, тј. интерпретацију. Локалитет Михајловићи из Источнобосанско–дурмиторске мегајединице у северној Црној Гори је типска локалност за нову дефинисану доњојурску (?средњи/горњи хетанж до горњи плинзбах) Формацију Михајловићи.

1. Introduction

1.1. Geological units/nappes in the Dinarides

During the time of geological studies in the Dinarides and adjacent mountain ranges the tectonic subdivisions experienced various modifications/revisions (Fig. 1). The history of geological studies and tectonic subdivisions is summarized until 1997 in DIMITRIJEVIĆ (1982, 1997) and until 2013 in CHARVET (2013). Interested readers in this discussion are referred also to the publications of SCHMID et al. (2008, 2020), and GAWLICK et al. (2017a).

In the latest Permian started the Mesozoic–Cenozoic Wilson cycle and the related sedimentary rocks were deposited above an unconformity above various older, predominantly Palaeozoic rocks (DIMITRIJEVIĆ, 1997; EBNER et al., 2010; VOZÁROVÁ et al., 2010). It is out of the scope of this work to summarize the various controversial interpretations about the pre-Mesozoic history of the Dinarides, because there are still quite different and controversial interpretations of the mountain building process(es), and the original palaeogeographic arrangement of the different Mesozoic facies belts, especially for Triassic times (DIMITRIJEVIĆ, 1997; KOVÁCS et al., 2010, 2011, 2014 and references therein; GAWLICK et al., 2017a, 2025; GAWLICK & MISSONI, 2019; SUDAR et al., 2023, 2025 and references therein). This results in cases to contradictory interpretations (SPAHIĆ et al., 2020; SPAHIĆ, 2022, 2024) most often not in line with sedimentological/facies rules (READING, 1996; for carbonates: WILSON, 1975; FLÜGEL, 2004; SCHLAGER, 2005), fundamentals of basin evolution (EINSELE 1992), or plate tectonics

(FRISCH et al., 2011; FOSSEN & TEYSSIER, 2025; FRISCH & MESCHÉDE, 2025).

Furthermore, the palaeogeographic position of the ophiolites in the Dinarides, their ages, and their emplacement is still controversial debated (DIMITRIJEVIĆ, 1997; KARAMATA, 2006; GAWLICK et al., 2008, 2016; SCHMID et al., 2008, 2020 and references therein), even meanwhile it is widespread accepted that the ophiolites represent obducted ophiolites with a provenance from an ocean located east of the Dinarides according to present coordinates. Furthermore, the ophiolites in all different tectonic units have a similar age range, that means they derive from a Middle Triassic to Middle Jurassic oceanic domain (DJERIĆ et al., 2024 and references therein). This ocean was the Neo-Tethys Ocean in the sense of SUESS (1888, 1905), or the Vardar Ocean in different nomenclature (SCHMID et al., 2020 and references therein). MISSONI & GAWLICK (2011a, b) see the Vardar Ocean as remaining Late Jurassic–Cretaceous oceanic domain after the partial closure of the Neo-Tethys (western/northwestern part) in late Early to early Late Jurassic times = eastern part of the Neo-Tethys.

These in Middle to early Late Jurassic times obducting ophiolites, today scattered in several tectonic units in the frame of multiphase mountain building processes in the Dinarides, are still named differently in different areas, obviously they all were formed during Middle Triassic to Jurassic times in the same Ocean (GAWLICK et al., 2008; GAWLICK & MISSONI, 2019; DJERIĆ et al., 2024). In our field trip area today the names Dinaridic ophiolite nappes (GAWLICK et al., 2016, 2017a) or West Vardar ophiolites (SCHMID et al., 2008, 2020) are commonly in use. However, all these ophiolites with various names (East/Main/West Vardar, Dinaridic, Mirdita, Pindos,

and Axios) in the Dinarides/Albanides/Hellenides derive all from the same Middle Triassic to Cretaceous ocean: the Neo-Tethys Ocean, the western/northwestern part of which obducted in Jurassic times onto the wider Adria plate forming the Neotethyan belt (MISSONI & GAWLICK, 2011a, b) as part of the Tethysides (ŞENGÖR, 1984).

One of the first over-regional maps of the Balkan Peninsula with a tectonic subdivision was presented by NOPCSA (1921). In the year 1924 KOSSMAT published his outstanding geological overview of the Central Balkan Peninsula (Fig. 1). The subdivision of tectonic units by KOSSMAT (1924) is followed until recent times by most tectonic classifications (compare KOBER, 1952; SIKOŠEK & MEDWENITSCH, 1965), with some modifications in detail, and in cases the tectonic units of KOSSMAT (1924) were renamed. In addition, the overall tectonic units of KOSSMAT (1924) were split into subunits by PETKOVIĆ (1961) or AUBOUIN (1973). Furthermore, the different subunits were also defined in a different way (compare ANĐELKOVIĆ, 1976, 1980; KARAMATA et al., 1996; DIMITRIJEVIĆ, 1997; DIMITRIJEVIĆ & SIKOŠEK, 1997; SCHMID et al., 2008; GAWLICK et al., 2017a; DJERIĆ et al., 2024). However, all these classical tectonic subdivisions were based more or less on an (par)autochthonous concept (KOSSMAT, 1924), that is the geosyncline concept with (Mesozoic, predominantly Triassic) shallow-water successions deposited on ridges or deep-water sediments in (intermediate) troughs.

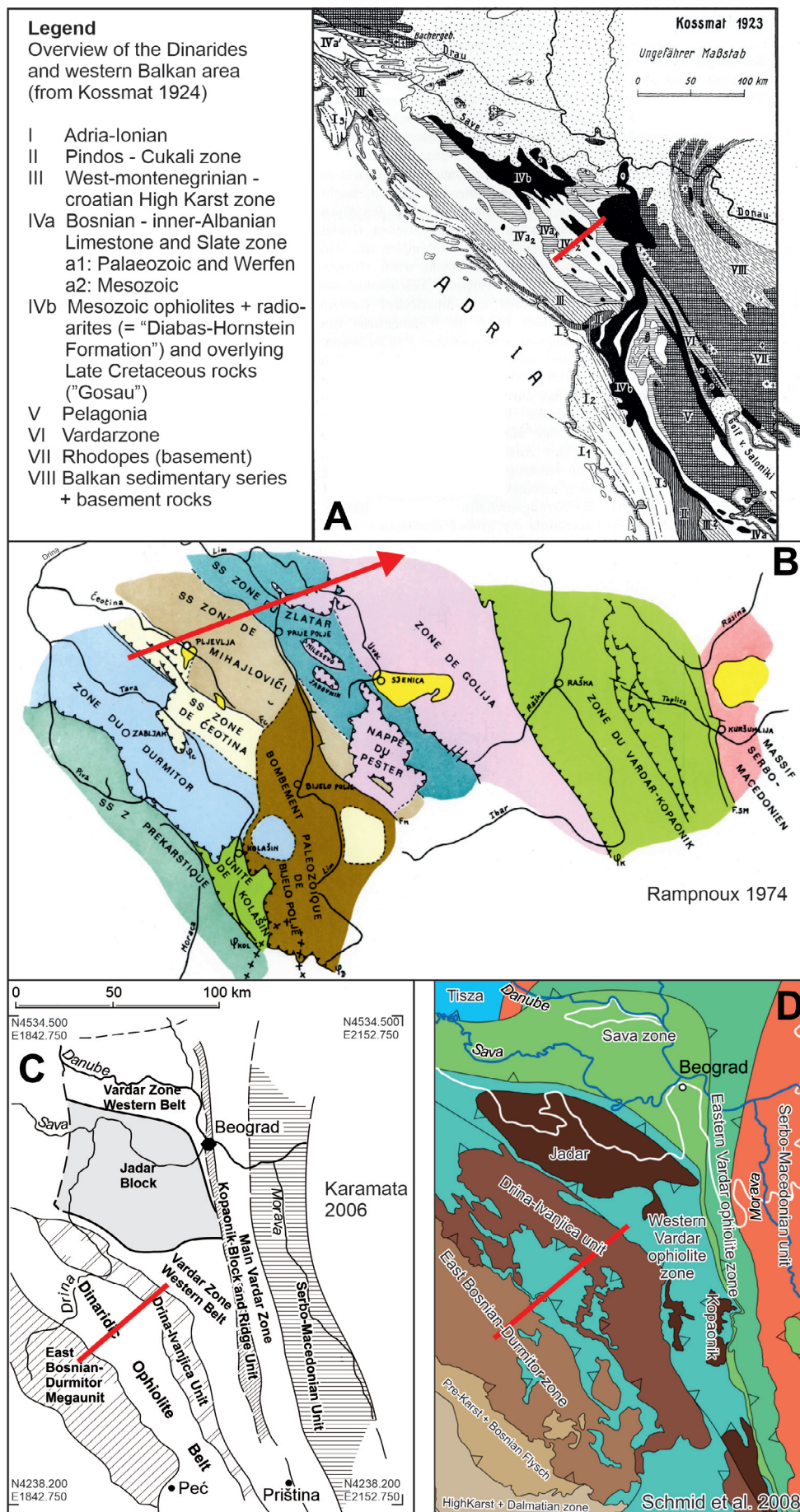
In most cases (limited) thrusting was recognized (KOSSMAT, 1924). This concept reached its zenith with AUBOUIN (1973) on base of AUBOUIN et al. (1970), DERCOURT (1970), and the later published works of CHARVET (1978, 1980), CHAR-

VET et al. (1974), RAMPNOUX (1974), and CADET (1976) with several shallow-water depositional areas (ridges) and the so-called intraplate basins in between them (DERCOURT et al., 1993; MARCOUX & BAUD, 1995).

This fixistic view still follows the positivistic approach to geological problems, a period called “Dark Intermezzo (1925–1965)” by ŞENGÖR & BERNOULLI (2011), which officially ended in the year 1965 when J.T. WILSON laid the foundation for the theory of plate tectonics (WILSON, 1965). While continental drift (WEGENER, 1912) and the existence of far-travelled nappes related to continent motions (ARGAND, 1912, 1924, 1928) from 1965 onwards again slowly got adapted into mountain building processes, the fixistic view, interrupted from time to time by “orogenic phases” (STILLE, 1924, 1949, 1950) was still used widespread. AUBOUIN (1965) clearly preferred the fixistic view and geosynclines (in sense of ÉLIE DE BEAUMONT, 1828, 1829; DANA, 1847, 1863, 1873) rather than plate tectonics. And this concept was used by him and his influential followers consequently to explain the Dinarides (AUBOUIN et al., 1970).

The concept of AUBOUIN (1973) with its general outline of tectonic units, but with some modifications was used also by DIMITRIJEVIĆ (1997), KARAMATA (2006), SCHMID et al. (2008, 2020), or GORIČAN et al. (2022). These general outlines are followed also by the Basic Geological Map of Yugoslavia in the scale of 1:100,000, created on the basis of this fixistic view. In cases the same tectonic units were also named differently (compare KOSSMAT, 1924; AUBOUIN, 1973; DIMITRIJEVIĆ, 1997; SCHMID et al., 2008, 2020; GAWLICK et al., 2017a; DJERIĆ et al., 2024). However, meanwhile

Fig. 1. Some important and still widespread used, but meanwhile historical tectonic units and subdivisions in the Dinarides with special emphasis on the study area in the East Bosnian–Durmitor megaunit of northern Montenegro. The field trip area along the cross-section is roughly indicated by the red lines in the different maps. **A.** Map of the different tectonic units in the Dinarides and western Balkan areas from KOSSMAT (1923) in KOSSMAT (1924) (legend translated by GAWLICK et al., 2017a). **B.** Map of different tectonic units in the transect Montenegro–Serbia according to RAMPNOUX (1974), modified reproduction of RAMPNOUX (1974) by GORIČAN et al. (2022). For details see RAMPNOUX (1974) with an update in GORIČAN et al. (2022). **C.** Tectonic units and terranes of the central Balkan Peninsula in sense of KARAMATA (2006) (compare DIMITRIJEVIĆ, 1997), based on KOSSMAT (1924). For more details see, e.g., AUBOUIN (1973), DIMITRIJEVIĆ (1997), and KARAMATA (2006). Modified from GAWLICK et al. (2017a). **D.** Tectonic subdivision according to SCHMID et al. (2008), modified. Note, that the map of geological units of SCHMID et al. (2008) contrasts in parts the map of geological units presented by SCHMID et al. (2020).



the tectonic subdivision of SCHMID et al. (2008, 2020) is commonly in use, and generally we follow also this nomenclature, but with significant modifications, based on new data.

It is out of the scope to discuss here the general subdivision of the Dinarides in Inner and Outer Dinarides and to enroll the whole history and the change in understanding of the terminology. The same is valid for the various tectonic units named differently by various authors through the time. But some important steps are highlighted to understand the change in the understanding of the different tectonic units related to the change in understanding of mountain building processes.

However, the actual used tectonic subdivision of the different tectonic units is mainly based on the tectonic boundaries/thrust contacts created during Paleogene thrusting. The older orogenesis (Pre-Gosauic: KOSSMAT, 1924) was never taken into account in the subdivision of the tectonic units in the Dinarides. Therefore, all tectonic subdivisions follow in general the concept of thrusting and nappe stacking during Paleogene times valid at least since KÖBER (1922) and KOSSMAT (1924), even if these two concepts are slightly different. One has to recognize, that these concepts are based on the geosyncline theory, and not on plate tectonics in a modern sense. Even at the time plate tectonics was known and used widespread the traditional subdivision of tectonic units was not changed substantially until today (AUBOUIN, 1973; DIMITRIJEVIĆ, 1997; KARAMATA, 2006; SCHMID et al., 2008, 2020).

In this field trip guide book, we use the subdivision of the Dinarides in Inner and Outer Dinarides in a different way: only the units which experienced a Jurassic metamorphic overprint are attributed to the Inner Dinarides, and the units without metamorphic overprint are attributed to the Outer Dinarides, that are all tectonic units west of the metamorphosed Drina-Ivanjica unit. Important to note, that the East Bosnian–Durmitor nappe thrust over the Pre-Karst unit in Jurassic times, whereas the Paleogene thrusting subdivide several units, e.g., the East Bosnian–Durmitor unit. Note, that these

Paleogene thrust fronts do not follow the Jurassic nappe boundaries.

1.2. The autochthonous concept with intraplate basins in the Dinarides versus the allochthonous concept with ophiolite obduction and far-travelled nappes

AUBOUIN et al. (1970), RAMPNOUX (1974), CHARVET (1978, 1980), and later DIMITRIJEVIĆ (1997 and references therein) interpreted the various Triassic (to Jurassic) deep-water successions in the Dinarides as intraplate basins throughout the Middle and Late Triassic. These are namely the Budva, the Bosnian, and the Lim basins (subdivided into the Zlatar and Ćehotina sub-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). The focus here is the Lim basin, but also the believed existence of the Bosnian basin is related to the Lim basin, because in several cases as result of younger tectonic motions, these basins are in parts mixed (see HAAS et al., 2019).

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, 1976, compare DERCOURT et al., 1993). 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, but see position). 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) should connect the “Pindos Basin” (= Pindos nappe, KOSTAKI et al., 2024) to the south with the Slovenian Trough to the north. Other authors (SCHMID et al., 2008, 2020; ROBERTSON et al., 2012 and references therein) connect the “Pindos

Basin“ with the Budva Basin. However, these reconstructions show that still until recent times the fixistic view of the positivists (POPPER, 1935) is still widespread in use and accepted, but the correlation of the various Triassic deep-water sedimentary rocks is different.

This fixistic reconstruction resulted in subsequent times in the application of the “philosophy of terranology“ for the Western Tethys Realm (KOVÁCS et al., 2010 and references therein). The terrane concept (IRWIN, 1972), invented in the '70s –'80s of the 20th century (see ŞENGÖR, 2013 – Terranology: the baconian disease; see also ŞENGÖR & DEWEY, 1990) was applied for the whole Circum-Pannonian region and a lot of megaterranes (in cases composite, mega- and single terranes) were separated and defined, one of them was termed “Adria-Dinaria Megaterrane“ (KOVÁCS et al., 2010).

Furthermore, this autochthonous concept of long-living deep-water “intraplate“ 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. In this model the East Bosnian–Durmitor megaunit is a continental realm west of the Dinaridic Ocean and the Drina-Ivanjica unit a continental realm east of the Dinaridic unit, both are interpreted as small continents, that are terranes in their nomenclature. In this interpretation the Zlatar sub-basin of the Lim Basin is related to the Dinaridic Ocean, but not the Čehotina sub-basin. Nevertheless, on both sides of this “Dinaridic Ocean“ a reliable passive continental margin configuration is not existing: the “Dinaridic Ocean“ is in the Late Triassic flanked by open lagoonal carbonates of the Dachstein Carbonate Platform, characterized by Dachstein Limestones with Lofer cycles (FISCHER, 1964, 1975) which evolved in both the Drina-Ivanjica unit and the East Bosnian–Durmitor megaunit (GAWLICK et al., 2017a).

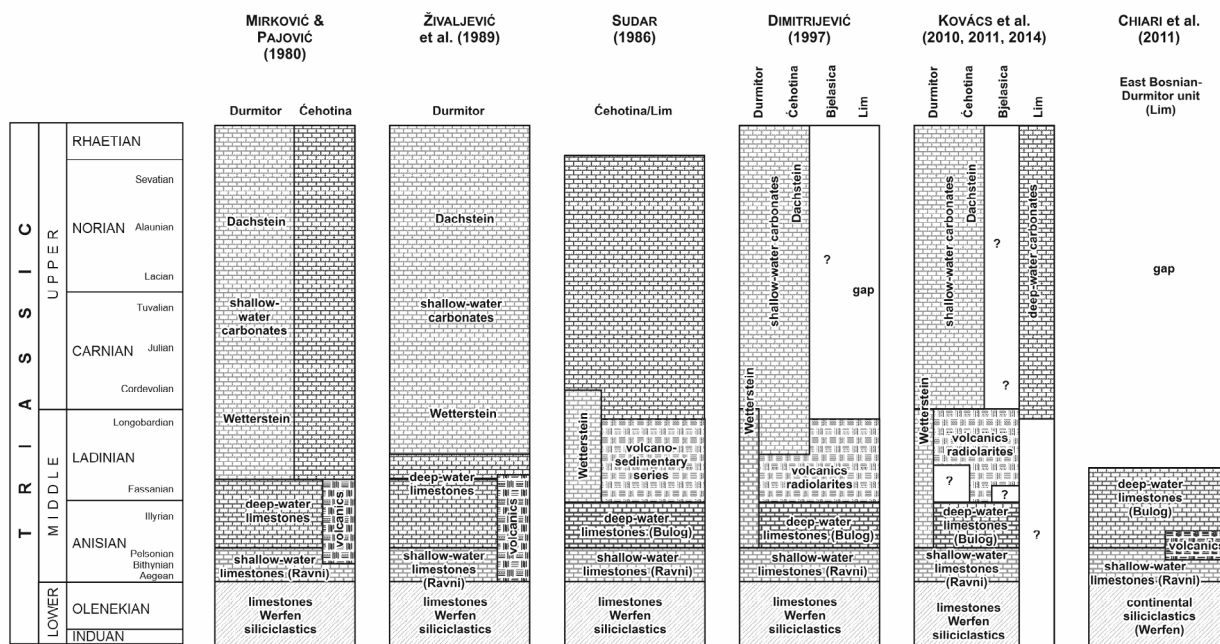
It is far beyond the topic of this paper to discuss the “terrane philosophy“ based on autochthonous views of every tectonic unit in the Inner and Outer Dinarides. But, it should be

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 contrast to the autochthonous models, significant far-distance nappe thrusting was proven and is known since long times (KÖBER, 1914, 1952; MEDWENITSCH, 1956; SIKOŠEK & MEDWENITSCH, 1965; ANĐELKOVIĆ, 1976, 1980) showing the fact that such (par)autochthonous reconstructions have to be modified significantly. However, the existence of nappes (in most models with limited thrusting distance) was also incorporated into most of the classical models (KOSSMAT, 1924; PETKOVIĆ, 1958; DIMITRIJEVIĆ, 1982, 1997), but the general (par)autochthonous concept of the original arrangement of the tectonic units (= facies belts) was not changed significantly up to now (ROBERTSON & KARAMATA, 1994; KARAMATA, 2006; SCHMID et al., 2008, 2020; CHIARI et al., 2011; CVETKOVIĆ et al., 2016), especially for the Mesozoic (Triassic–Jurassic) sequences below the obducted ophiolites (SCHMID et al., 2008, 2020). Nevertheless, since AUBOUIN (1973), in some concepts several nappes were drawn with significant thrusting distance (compare SCHMID et al., 2008; UNEN et al., 2018; BRAVO-GUTIÉRREZ et al., 2024). However, the reconstruction of the arrangement of the Triassic–Jurassic facies belts, in that case the reconstruction based on the deposition of shallow-water carbonates on ridges with several long-living deep-water basins in between, in some reconstructions interpreted as oceans (KARAMATA, 2006; STAMPFLI & KOZUR, 2006; ROBERTSON, 2012) remained (see discussion in SUDAR et al., 2025; MRDAK et al., 2025a, b).

First KÖBER (1914) recognized the ophiolites in the Dinarides as a far-travelled nappe, especially the ophiolites of the Dinaridic Ophiolite Belt (AUBOUIN, 1973; DIMITRIJEVIĆ, 1982, 1997; KARAMATA, 2006) = West Vardar Ophiolites (SCHMID et al. 2008, 2020) = Dinaridic Ophiolite nappes (GAWLICK et al., 2016; GAWLICK & MISSONI, 2019). However, the major change of

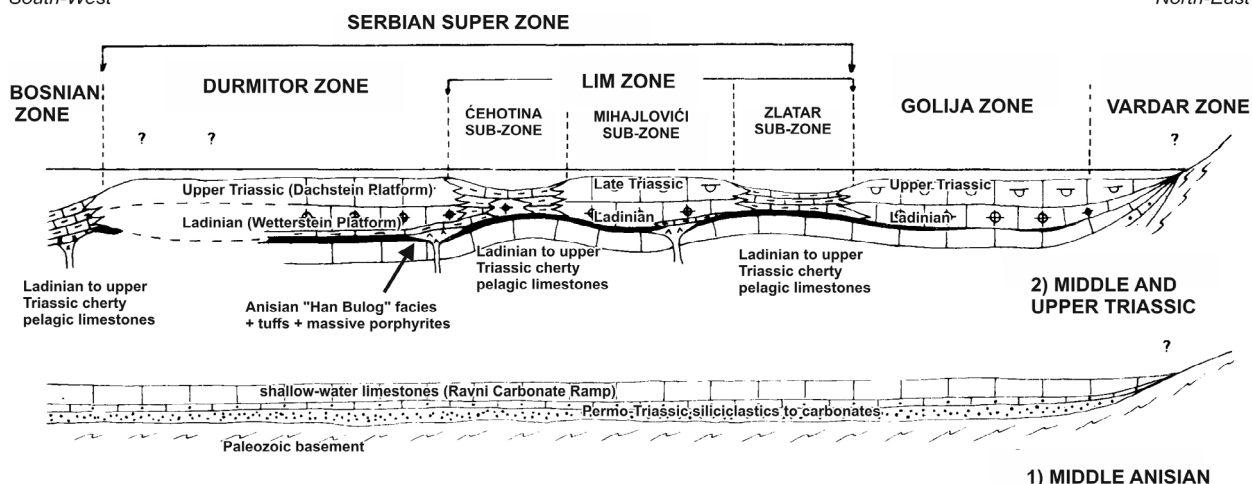
A) History: Triassic stratigraphy of the East Bosnian-Durmitor megaunit (1980-2014, various authors)



B) Triassic palaeogeography/facies belts (Pantić & Rampoux 1972, Rampoux 1974)

South-West

North-East



C) Different nomenclature and recent position of the ophiolites

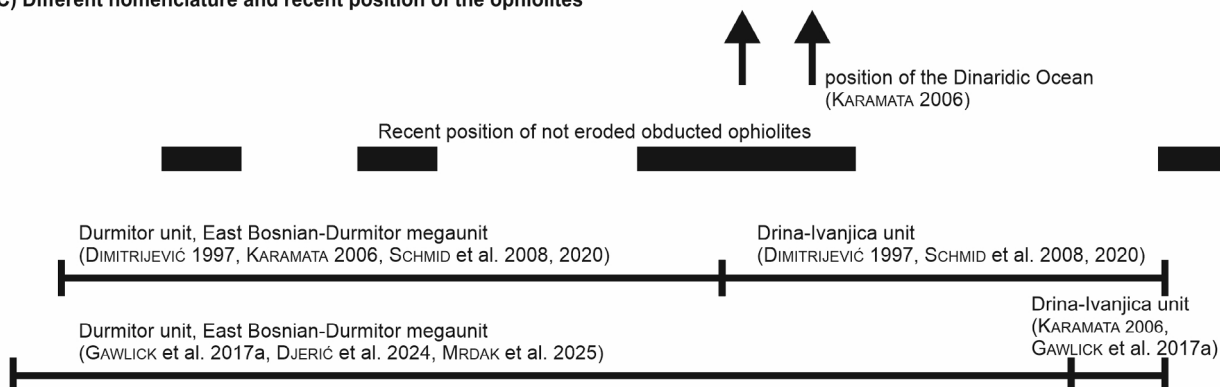


Fig. 2. A) History of used stratigraphic tables/successions for the Triassic in the East Bosnian–Durmitor megaunit and adjacent areas (MIRKOVIĆ & PAJOVIĆ, 1980; SUDAR, 1986; ŽIVALJEVIĆ, 1989; DIMITRIJEVIĆ, 1997; KOVÁCS et al., 2010, 2011, 2014; CHIARI et al., 2011) along **(B)** a reconstruction of a cross-section through the Dinarides from the Drina–Ivanjica unit (= Golija zone) to the western part of the East Bosnian–Durmitor megaunit (= Serbian Super Zone) in Triassic times. In general all used stratigraphic tables for the Triassic **(A)** follow the reconstruction of the depositional areas of PANTIĆ & RAMPNOUX (1972) and RAMPNOUX (1974). **B)** In Montenegro MIRKOVIĆ & PAJOVIĆ (1980) and ŽIVALJEVIĆ (1989) interpreted the onset of the Wetterstein Carbonate Platform generally directly above the Ravni Carbonate Ramp with few exceptions. In that case the deposition of the Ravni Formation lasted until the Ladinian. Furthermore, a Late Pelsonian to Late Illyrian gap above the Ravni Formation in horst position was not recognized. **C)** Note, that in the nomenclature of PANTIĆ & RAMPNOUX (1972) and RAMPNOUX (1974) the Serbian Super Zone consists of the Durmitor zone (= East Bosnian–Durmitor megaunit of DIMITRIJEVIĆ, 1997) and the Lim zone. In contrast, SCHMID et al. (2008, 2020) include the Lim zone into the Drina–Ivanjica unit (= Golija zone of PANTIĆ & RAMPNOUX, 1972; RAMPNOUX, 1974). In the reconstruction of KARAMATA (2006) the Golija zone corresponds to the Drina–Ivanjica unit, the Zlatar sub-zone is part of the Dinaridic Ocean, and the Durmitor unit consists of the Durmitor Zone, the Če(h)otina sub-zone, and the Mihajlovići sub-zone.

the (par)autochthonous concepts in the 21st century, that means the reinterpretation of the existence of an autochthonous oceanic domain between the Drina–Ivanjica unit and the East Bosnian–Durmitor megaunit (Durmitor nappe: HRVATOVIĆ, 2006) as obducted ophiolites, affected only the interpretation of the provenance of the ophiolites, but not the original Triassic–Jurassic passive continental margin configuration. Still the existence of various intraplate basins is discussed and preferred until recent times (HAAS et al., 2019; JOVANOVIĆ et al., 2025) contrasting the improvement of the emplacement of the Triassic open-marine limestones in all studied areas in Middle–Late Jurassic times (MISSONI et al., 2012; GAWLICK et al., 2017a, b, 2018; SUDAR et al., 2013, 2023b, 2025; SUDAR & GAWLICK, 2018).

Only a palaeogeographic derivation of the ophiolites from an ocean to the east (Neo-Tethys Ocean, Vardar Ocean in different nomenclature), and west-directed Jurassic ophiolite obduction (GAWLICK et al., 2008, 2016; SCHMID et al., 2008, 2020) is meanwhile the preferred and widespread accepted interpretation (DJERIĆ et al., 2024 and references therein), following KOBER (1914), and BERNOULLI & LAUBSCHER (1972).

Nevertheless, a Middle–Late Jurassic west-directed transport of the Triassic–Jurassic outer shelf sedimentary sequences (Hallstatt successions: LEIN, 1987; KRZYSTYN, 2008), which get imbricated and bulldozed by the obducting ophiolites to the west, proven by the formation of various trench-like basins fills in front of the Hallstatt nappes (Hallstatt mélanges in sense of FRISCH & GAWLICK, 2003) was not adapted in modern tectonic cross-sections, which are based predominantly on Paleogene shortening (SCHMID

et al., 2008, 2020; BRAVO-GUTIÉRREZ et al., 2024 and references therein, compare KOBER, 1914, 1952; SIKOŠEK & MEDWENITSCH, 1965). But, meanwhile for the most “intraplate basins” in the Dinarides (Fig. 2) between the High Karst unit in the west to the Drina–Ivanjica unit in the east (AUBOUIN et al., 1970; AUBOUIN, 1973), that are

A) the Bosnian trough (Bosnian zone: PANTIĆ & RAMPNOUX, 1972, Zone Bosniaque + Zone Serbe in parts: CHARVET, 1980) between the High/Pre-Karst units and the East Bosnian–Durmitor megaunit, that is the Kuči unit in the sense of BEŠIĆ (1950); MIRKOVIĆ (1980), and MIRKOVIĆ & PAJOVIĆ (1980) or the Sarajevo sigmoid (DIMITRIJEVIĆ, 1997), and
B) the Lim Basin with the Če(h)otina and Lim sub-basins with the Mihajlovići ridge in between (PANTIĆ & RAMPNOUX, 1972; RAMPNOUX, 1974) in the East Bosnian–Durmitor megaunit, or between the East Bosnian–Durmitor megaunit and the Drina–Ivanjica unit (Golija Zone: PANTIĆ & RAMPNOUX, 1972; RAMPNOUX, 1974; Drina–Ivanjica Element: DIMITRIJEVIĆ, 1997), a far-distance transport from the outer shelf (open-marine and deep-water Hallstatt shelf/zone) is proven. In most cases the Middle–Late Triassic (to Jurassic) open-marine successions are up to km-sized blocks in a Middle–Late Jurassic argillaceous matrix (e.g., MISSONI et al., 2012; GAWLICK et al., 2017a, b, 2018; GAWLICK & MISSONI, 2019; SUDAR et al., 2025), situated below the ophiolitic mélange at the base of the obducted ophiolites.

In other cases, these Middle–Late Triassic (to Jurassic) open-marine successions are far-travelled nappes bulldozed in front of the obducting ophiolites to the west (GAWLICK et al.,

2017a, b, 2018, 2023; MISSONI & GAWLICK, 2019; SUDAR & GAWLICK, 2018; GORIČAN et al., 2022; SUDAR et al., 2023a, b, 2025; MRDAK et al., 2024, 2025a, b; ZÖHRER et al., 2026). Nappes from various positions of the

- A) Continental slope (“Meliata facies”), with the classical Late Triassic Grivska Formation (SUDAR & GAWLICK, 2018),
- B) Outer shelf region, with the various coloured Hallstatt Limestone successions (LEIN, 1987; KRISTYN, 2008), known since long times also in the Dinarides (SUDAR, 1986),
- C) The facies belt between the various coloured Hallstatt Limestones and the reef rim, that is the grey Hallstatt facies in the sense of LEIN (1987), or the Gučevo Formation (SUDAR, 1986) in the Dinarides, and
- D) From the reef rim transitional to the open shelf (ZÖHRER et al., 2021, 2026) are known.

The outer shelf facies belts: Dinarides versus Eastern Alps/Western Carpathians

In contrast to the Northern Calcareous Alps or the Western Carpathians, the Late Triassic depositional history of the Dinarides is slightly different, but the overall trends of deposition are identical. In the northern area (ALCAPA units – see SCHMID et al., 2008 with references therein) the Dachstein reefs generally prograded in direction to the open-marine Hallstatt shelf (KRISTYN et al., 2009 and references therein) above a relative complete Carnian mixed thick siliciclastic-carbonate sedimentary sequence (TOLLMANN, 1976) after the demise of the Wetterstein Carbonate Platform around the Julian 1/2 boundary (LEIN et al., 2012).

In the Dinarides carbonate production started in the central to outer shelf in the middle Late Carnian after the demise of the Wetterstein Carbonate Platform (MISSONI et al., 2012) and siliciclastic sedimentary rocks are practically missing. In the central shelf, that is the East Bosnian–Durmitor megaunit, the gap in carbonate production is even longer and lasted until the latest Carnian after the uplift and tilting of

the Wetterstein Carbonate Platform (MRDAK et al., 2023). This resulted in deposition of deeper-marine sedimentary successions throughout the whole latest Carnian (Tuvanian 2)–Norian–Rhaetian above the Early Carnian Wetterstein Carbonate Platform situated in central shelf position transitional to the outer deep-marine shelf (SUDAR, 1986; MISSONI et al., 2012). These deeper-marine limestones deposited in the transitional zone of the central to outer shelf above middle Late Carnian shallow-marine limestones show a general deepening trend (Waxeneck Formation in the Northern Calcareous Alps: KRISTYN et al., 1990; or Stopića Formation in the Dinarides: MISSONI et al., 2012).

In the Northern Calcareous Alps these latest Carnian–Rhaetian deep-water limestones are also in some areas present and resemble Hallstatt Limestones (LEIN, 2000, compare CORNELIUS, 1939: Pseudo Hallstatt Limestone). In the Dinarides these sequences were named Gučevo Formation by SUDAR (1986) in the Inner Dinarides, or Gradac Formation for the far-travelled nappes in northern Montenegro (SUDAR, 1986). SUDAR (1986) pointed out the similarities between the Gučevo and the Gradac formations, but at that time the (par)autochthonous concept had the climax, and several principles of carbonate production (FLÜGEL, 2004; SCHLAGER, 2005 and references therein) were not known or simply ignored. However, today also identical successions are known between the Gučevo Fm. type area in the Jadar unit (SUDAR, 1986) and the Gradac Fm. in northeast Montenegro (SUDAR, 1986) or in the wider area of Bič Mt. i.e. in the Sutjeska River gorge near Rudo town (JOVANOVIĆ et al., 2025). This clearly evidence far-distance thrusting of these open-marine successions from the outer shelf area that is the area east of the Drina–Ivanjica unit.

However, an emendation of the Gučevo/Gradac formations and related successions is out of the scope of this field trip guide book. Even the Gučevo Formation (UROŠEVIĆ & SUDAR, 1980; SUDAR, 1986) has priority compared with the term Gradac Formation (SUDAR, 1986) the need of the definition of a type-section and type-region is necessary.

Despite the geodynamic concept a clear lithological definition with the underlying and overlying lithostratigraphic units is needed, that is somewhat problematic in the type region, i.e. the Gučevo Mt. (SUDAR, 1986). Furthermore, all known sections differ slightly in their overall sedimentological evolution and their underlying lithostratigraphic units, if they are preserved or outcropping. A common feature of all sections related to this facies belt is the intercalation of turbidites with shallow-water material from the nearby Dachstein Carbonate Platform within a matrix of grey bedded “filament”- and radiolarian-rich wacke- to packstones. Therefore, the Gučevo Formation can be correlated in general with the grey Hallstatt facies of the Northern Calcareous Alps (LEIN, 1987), but with some differences. In contrast to the Northern Calcareous Alps, where the sedimentation throughout the Carnian is more or less continuous, that means the long-lasting gap of non-deposition from the higher Julian to the middle Late Carnian does generally not exist except one tectonic unit (KRYSŲYN et al., 1990; LEIN, 2000), in the Dinarides also the tilted and deeply eroded Wetterstein Carbonate Platform was flooded in the Late Carnian. First evolved reefal shallow-water carbonates (Stopića Formation) above the deeply eroded and karstified Wetterstein Carbonate Platform. These shallow- water reefal limestones of the Stopića Formation underwent a deepening-upward trend during the Late Carnian, and in most cases grey open-marine limestones deposited (Gučevo Formation *sensu stricto*) whereas in other cases also various coloured and siliceous bedded limestones deposited. In rare cases also various coloured limestones were deposited, which resemble the Norian part of a typical Hallstatt Limestone succession, but with different underlying lithostratigraphic units.

Lithofacies, microfacies characteristics, and sedimentological features of this Late Carnian to Rhaetian sedimentary succession depend highly on the pre-existing morphology and is therefore highly variable. A common feature that defines the palaeogeographic position of

the depositional realm of the Gučevo Formation is the influence of the evolving Dachstein Carbonate Platform during Norian–Rhaetian times.

If the Gučevo Formation with its variable litho- and microfacies will be a united relatively inhomogenous Formation or if the Gučevo Formation can be subdivided in several members a re-evaluation of all known sections in the Dinarides is necessary. Furthermore, a detailed comparison with related Late Carnian to Rhaetian succession in other mountain ranges like the Albanides (Korabi unit) Northern Calcareous Alps (Mürzalpen nappe), the Inner Western Carpathians (Silica unit), and the Codru-Moma nappe stack in the Apuseni Mts. is necessary.

Here we use for related sedimentary succession, presented during this field trip, the name Gučevo facies rather than the term Gradac Formation. An emendation of the Gučevo Formation has to be a topic of an independent publication.

2. Triassic–Jurassic geodynamic history and stratigraphy

To reconstruct the Triassic–Jurassic geodynamic evolution through time and space in detail and to distinguish the various lithologies, a high-resolution litho- and biostratigraphy is the necessary base. In cases the various lithologies are defined as basin-wide useable formations, in other cases several formations are united into a group, because the included formations are characterized by facies transitions, mixed lithologies, or are not mappable lithostratigraphic units. The Triassic(–Jurassic) lithostratigraphic table based on GAWLICK et al. (2017a) for the Inner to Outer Dinarides in Serbia and adjacent countries is used herein. This stratigraphical table experienced up to now several slight modifications and updates in respect to newly achieved data sets (GAWLICK & MISSONI, 2019; GAWLICK et al., 2020; ĐAKOVIĆ et al., 2021; MRDAK et al., 2023; SUDAR et al., 2023b, 2025; DJERIĆ et al., 2024). The used names in this stratigraphic table are in parts classical

names in use since more than hundred years in the entire Dinarides. Other lithostratigraphic used, but not formalized formations were introduced later (compare SUDAR, 1986). Additional lithostratigraphic names which were adopted from other regions in the Western Tethys Realm for the whole Dinarides are partly summarized in DIMITRIJEVIĆ (1997). The Triassic part of this lithostratigraphic table is used in Bosnia and Herzegovina (SUDAR et al., 2025) and also in Montenegro (MRDAK et al., 2023, 2024, 2025a, b; ĐAKOVIĆ et al., 2025) for the reason of comparable studies.

To invent for identical lithostratigraphic units in different countries/areas independent formations with definition of a separate type-section confuse only readers not firm with the topic, hamper the scientific progress, and result often in local or regional insufficient interpretations which cannot be easily compared (and corrected) with the over-regional tectonostratigraphic evolution, that is the geodynamic evolution of the birth and death of an oceanic realm (Wilson cycle).

The used Triassic stratigraphic table (Fig. 3) from the Inner to Outer Dinarides contrasts in parts significantly the existing older stratigraphic columns of the study area as presented by PANTIĆ & RAMPNOUX (1972), RAMPNOUX (1974), MIRKOVIĆ & PAJOVIĆ (1980), SUDAR (1986), ŽIVALJEVIĆ et al. (1989), DIMITRIJEVIĆ (1997), KOVÁCS et al. (2010, 2011, 2014), or CHIARI et al. (2011) (Fig. 2A), especially for the East Bosnian-Durmitor mega-unit and adjacent areas, but also for the outer shelf region (Fig. 3). In fact, all these older stratigraphic columns follow the positivistic concept of PANTIĆ & RAMPNOUX (1972) and RAMPNOUX (1974) (Fig. 2B) based on AUBOIN et al. (1970) (see discussion above). On the ridges a continuous shallow-water carbonate evolution throughout the Middle to Late Triassic (for a time span of more than 40 million years!) is proposed in contrast to a continuous deep-water sedimentation in the basins between the ridges. On the ridges shallow-water carbonate deposition is locally only interrupted for the short time interval Late Anisian to Early Ladinian by the eruption of volcanics and associated volcano-sedimentary rocks.

In some stratigraphic columns also a continuous shallow-water evolution from the Middle Anisian Ravni Carbonate Ramp (DIMITRIJEVIĆ, 1982, 1997) to the end of the Dachstein Carbonate Platform is indicated. Another important difference is the proposed onset of the Wetterstein Carbonate evolution either in the Late Anisian or at least in the Ladinian.

The Late Triassic shallow-water carbonate platform is attributed to the Dachstein Platform evolution, but the age of the transition from the Wetterstein to the Dachstein shallow-water carbonates is not clearly defined. The long-lasting Carnian gap was never recognized. The new Stratigraphic Table (Fig. 3) follows strictly the rules of a plate tectonic (Wilson) cycle, the associated formation of basins, their geometry and basin fill according to sedimentological and facies laws combined with high resolution stratigraphy including sequence stratigraphy, even in metamorphosed sequences. This approach allows a reliable, and in parts even geometrical reconstruction of lost or overthrust facies belts, because two independent mountain building processes (Jurassic, Paleogene) destroyed the Triassic-Jurassic passive continental margin facies belt arrangement. Furthermore, the younger Paleogene orogenesis with limited nappe thrusting crosscut the structures of the older Jurassic orogen. In addition, Neogene strike-slip tectonics resulted also not only in a lateral offset of structures and facies belts but also of the thrust structures. The effect of the still unexplored Late Jurassic to Early Cretaceous mountain uplift and unroofing is practically not known. The resulting complex structure with strike-slip faults and thrust fronts of different age, in cases in fact low-angle normal faults, or faults of different character and offset resulted in the today's arrangement of tectonic units. A reliable stratigraphic table with a clear definition of the formations is the only base to reconstruct the multiphase geodynamic history of a mountain range.

DIMITRIJEVIĆ (1997) named the area between the front of the Durmitor nappe (HRVATOVIĆ, 2006), that is the Pre-Karst unit, and the (Dinaridic) Ophiolite Belt the East Bosnian-

Durmitor block (DIMITRIJEVIĆ, 1974). This unit should correspond according to DIMITRIJEVIĆ (1997) to a part of the “Paleozoic Schist and Mesozoic Limestone Zone” of PETKOVIĆ (1961) or the “Zone Serbe” of RAMPNOUX (1969) or AUBOUIN (1973). According to DIMITRIJEVIĆ (1997) the Durmitor Block and the Ćehotina unit have a similar Triassic evolution, but the Lim unit has a long-lasting stratigraphic gap, that should be a Late Triassic hiatus. In fact, DIMITRIJEVIĆ (1997) did not accept the results of SUDAR (1986) and the Late Triassic age data achieved by conodont faunas. CHIARI et al. (2011) follow in general the view of DIMITRIJEVIĆ (1997), and according to them the Triassic depositional history started with Early Triassic continental siliciclastic sedimentary rocks followed upsection by early Middle Triassic shallow-water limestones. These shallow-water limestones are overlain by Ammonitico Rosso-type limestones (Bulog Group: SUDAR et al., 2023b), volcanic rocks, and siliceous shallow-water to (hemi)pelagic limestones (Ladinian–Carnian). The younger Late Triassic should be characterized by a general hiatus (Fig. 2A), subsequently followed by Jurassic sedimentary rocks.

In contrast, the now used Triassic–Jurassic Stratigraphic Table for the Inner to Outer Dinarides (Fig. 3) follows strictly the geodynamic evolution of the birth and death of an oceanic domain (Wilson Cycle) that is the history of the lost Neo-Tethys Ocean and its western passive continental margin. This Triassic–Jurassic stratigraphic table is in its general outline and tectonostratigraphy practically identical to those of the Northern Calcareous Alps (GAWLICK & MISSONI, 2019). This evolution is subdivided into three characteristic stages:

1. The latest Permian to Middle Triassic graben stage (rifting). This part of the evolution is not the topic of our field trip. Only the youngest sedimentary rocks, these are the Anisian shallow-water carbonates of the Ravni Formation are of importance for our presented history. The shallow-water carbonates of the Ravni Formation were formed in an epicontinental sea, first under restricted marine conditions (Aegean–Bithynian = Utrine Mem-

ber), and under fully open-marine conditions in its younger parts (Pelsonian = Dedovići Member). In some areas deeper-marine sediments were deposited in newly formed depressions (“Trebević limestones” by SUDAR, 1986, now Trebević Member in SUDAR et al., 2025) as forerunner of the continental break-up in the Late Pelsonian.

2. The Middle Triassic to Middle Jurassic passive continental margin evolution from the Late Pelsonian break-up to the Middle Jurassic onset of ophiolite obduction. This passive continental margin stage can be subdivided in two substages: A) a Middle–Late Triassic stage with the formation of predominantly Late Triassic carbonate platforms (Wetterstein and Dachstein Carbonate Platforms) and their transition to the open-marine outer shelf to continental slope, and B) the Early to Middle Jurassic hemipelagic shelf evolution after the demise of the Dachstein Carbonate Platform during the Triassic/Jurassic mass extinction.
3. The Middle to early Late Jurassic active continental margin evolution characterized by ophiolite obduction with formation of various mélanges, trench-like foreland basins, nappe stacking and metamorphism of the wider Adria plate with the Dinarides as part of it.

For a more detailed description interested readers are referred to GAWLICK et al. (2017a) and GAWLICK & MISSONI (2019) with references therein.

3. Definition of an intraplate basin

According to FLÜGEL (2004) many basins occur in cratonic positions and represent intraplate or intrashelf basins (e.g., (hemi) pelagic epeiric basins). The term “platform” is here not used in the sense carbonate platform or carbonate shelf, the term platform is in that case used here as parts of continental cratons (e.g., Kongo craton, Kalahari craton, Fennoscandian craton) = platforms (v. BUBNOFF, 1926, 1930; compare STILLE, 1924; SCHMIDT-THOMÉ,

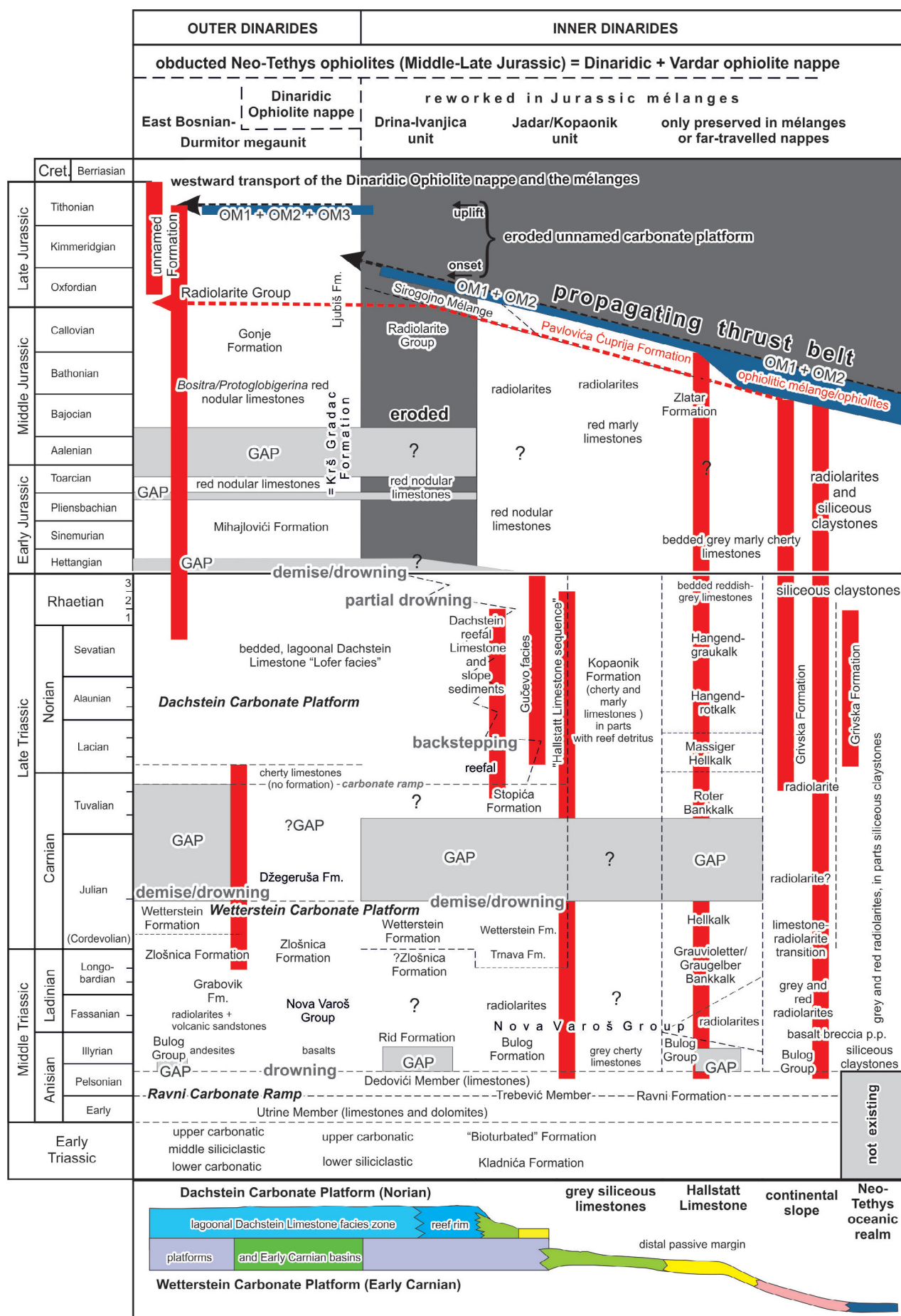


Fig. 3. The Triassic–Jurassic stratigraphic table of the Inner to Outer Dinarides (East Bosnian–Durmitor megaunit), modified after GAWLICK et al. (2017a) and GAWLICK & MISSONI (2019). Note, that the Pre-Karst unit west of the East Bosnian–Durmitor megaunit has in Triassic–Jurassic times an identical depositional history as the East Bosnian–Durmitor megaunit. The Early Triassic to Middle Jurassic lithological successions follow the arrangement of the different facies belts in a passive continental margin setting. This carbonate dominated passive margin setting in Triassic times is characterized by the formation of huge rimmed platforms. In the Late Triassic the Dachstein Carbonate Platform shows all classical facies belts as defined by the carbonate platform of WILSON (1975), slightly modified and modernized by FLÜGEL (2004). 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, b, 2025). The geometric arrangement of the different formations is in accordance with the Late Triassic carbonate platforms and passive continental margin configuration after GAWLICK et al. (2008, 2016), also characteristic for the different tectonic units defined in the Dinarides (Fig. 1). The Grabovik Formation was introduced by KITTL (1904) and on base of the definition of KITTL (1904) formalized by SUDAR et al. (2025). The commonly used terms Volcanogenic sedimentary series (ANDELKOVIĆ, 1967, 1976, 1980), Volcanogenic sedimentary formation (ŽIVALJEVIĆ et al., 1989), or Volcanogenic sedimentary formation of Kovač Mt. (SUDAR, 1986) which correspond to the Porphyry–hornfels formation (ĆIRIĆ, 1954; JOVANOVIĆ & JOVANOVIĆ, 2006) are until now widespread used, but not valid names. The red lines mark the sections we will visit during this field trip. The names in red indicate the *mélanges* we will visit.

1972) which were flooded for long times (v. BUBNOFF, 1930). Such epeiric basin in cratons correspond to the model of anteklises and synklises (SCHATSKY, 1947; BELOUSSOV, 1962; SCHMIDT, 1969) in old consolidated continental realms (= cratons = platforms). This terminology was used during the time the geosyncline theory dominated the geodynamic views, but should not be used anymore today (compare EINSELE, 1992: continental or interior sag basins).

For passive continental margin settings, an intraplateau basin is defined as a deep-water depositional realm situated between two carbonate platforms with lively carbonate production. A basin between the continental realm, i.e. the shore line and a platform (or rising reef rims) is defined as deep lagoon or empty bucket (SCHLAGER, 2005 and references therein).

After the demise of the Middle Anisian shallow-water carbonate ramp and the formation of a horst-and-graben morphology in the Dinarides no significant shallow-water carbonate production can be recognized (SUDAR et al., 2013, 2023b; GAWLICK et al., 2023). The Late Pelsonian break-up unconformity is contemporaneous with the demise of the Ravni Carbonate Ramp, and marked by a drowning unconformity (GAWLICK et al., 2023; SUDAR et al., 2025 and references therein). This change was termed by SCHLAGER & SCHÖLLNBERGER (1974) as Reiflinger Wende = Reiflinger turnover, and can be traced throughout the whole Western Tethys Realm. Therefore, the late Middle Anisian to Early Car-

nian deep-water sedimentary rocks cannot be attributed as “intraplateau basin”, because during this time span no platforms existed. Exceptions are the Illyrian atoll-reefs in the middle of the deep-water shelf (MRDAK et al., 2024 and references therein), a short Late Illyrian shallow-water carbonate production interval on some of the flooded horsts (SUDAR et al., 2013: Rid Formation) or the proximal shelf area, and a short-living shallow-water carbonate production areal in the Early Longobardian.

In the latest Ladinian respectively in the Early Carnian the first important carbonate platform cycle started with the evolution of the Wetterstein Carbonate platforms *sensu stricto* (compare VELLEDEITS et al., 2011). These Wetterstein platforms established predominantly on top of in parts preexisting morphological highs and started from there to prograde rapidly towards the basins (grabens/halfgrabens) formed during the Late Anisian extension. While the carbonate production of the Wetterstein Carbonate Platform evolution stopped abruptly around the Julian 1/2 boundary (for the Dinarides: MRDAK et al., 2023 and references therein), not all preexisting deep-water areas could be filled by the carbonates of this platform. During the short time span of the Wetterstein Carbonate Platform evolution in the Julian 1, that means that during the existence of several independent platforms also short-living intraplateau basins could be recognized. Such a basin is in the East Bosnian–Durmitor megaunit the Džegeruša ba-

sin that remained underfilled between the Wetterstein Platforms which evolved in the areas of the Durmitor Mt. and the Drina-Ivanjica unit. This basin remains deep during practically the entire “Middle”-Late Carnian, but cannot be attributed during this time span as “intraplatform basin”, because shallow-water carbonate production stopped with the demise of the Wetterstein Carbonate Platform. No platform = no intraplatform basin, but a deep-water depositional realm. This basin remained only deep in respect to the lack of sediment supply. In this aspect the Dinarides contradict the Eastern Alps or Western Carpathians, where these basins were filled by the “Middle”-Late Carnian siliciclastic sediments (SCHLAGER & SCHÖLLNBERGER, 1974; TOLLMANN, 1985; HAVRILA, 2011; AUBRECHT et al., 2017).

Carbonate production recovered during the Late Carnian, first in the Inner Dinarides (Tuvanian 2: SUDAR, 1986; MISSONI et al., 2012), and later also in the Outer Dinarides. Here carbonate production started again in the latest Carnian respectively around the Carnian/Norian boundary (MRDAK et al., 2023) and gave rise for the evolution of the huge Dachstein Carbonate Platform. The enormous carbonate production of this Dachstein platform was able to fill all remaining older depressions in the shelf area in the Early Norian. The reef belt of this rimmed carbonate platform was palaeogeographically situated in the eastern part of the Drina-Ivanjica unit to the Jadar unit and all areas west of this position are characterized by deposition of shallow-water carbonates in a lagoonal area, that is the cyclic lagoonal Dachstein Limestone in Lofer Facies (FISCHER, 1964; HAAS, 1991). That means that the entire East Bosnian-Durmitor megaunit was in Late Triassic times part of the shallow-water lagoonal area of this Dachstein Carbonate Platform.

4. The Field Trip

The field trip will provide insights in the geodynamic history of the Dinarides along an east-west trending cross-section from the Drina-

Ivanjica unit in Serbia to the East Bosnian-Durmitor megaunit in northern Montenegro (Figs. 1, 3). This cross-section comprises the domain of the imagined deep-water Lim Basin with the Zlatar and Čehotina sub-basins with the Mihajlovići ridge in the central part. We will see the overall Triassic-Jurassic sedimentary sequence of the East Bosnian-Durmitor megaunit, and the overthrust units including the ophiolitic mélanges below the ophiolitic nappe stack.

Two days of the field trip are designed for stops in southwestern Serbia (Fig. 4) and two days of the field trip will be in northern Montenegro (Fig. 5).

The description of the localities follows not exactly the order these localities which will be visited. The sections are ordered to their occurrence in the different tectonic units respectively their original palaeogeographic provenance.

4.1. Ophiolitic mélanges

For a comprehensive review about the ophiolitic mélanges in Serbia the interested reader is referred to DJERIĆ et al. (2024). Important is to understand, that the different ophiolitic mélanges differ in their component spectrum and age. DJERIĆ et al. (2024) could distinguish three different types of ophiolitic mélanges:

1. OM1 type: Intra-oceanic ophiolitic mélanges. Indicate the time span from the onset of intra-oceanic subduction until ophiolite obduction. Together with age data from the metamorphic soles (184–157 Ma, with a peak between 179–162 Ma: LANPHERE et al., 1975; KARAMATA & LOVRIĆ, 1978; RODDICK et al., 1979; SPRAY & RODDICK, 1980; SPRAY et al., 1984; BEBIEN et al., 1997; DIMO-LAHITTE et al., 2001; KARAMATA, 2006; BOROJEVIĆ ŠOŠTARIĆ et al., 2014; Toarcian to Middle Oxfordian according to HESSELBO et al., 2020), these mélanges provide exact data for the shortening time span of one (= western) half of a stacked and later obducted oceanic domain, that is the Neo-Tethys Ocean. For the Dinarides the time span between Toarcian and Callovian/Oxford-

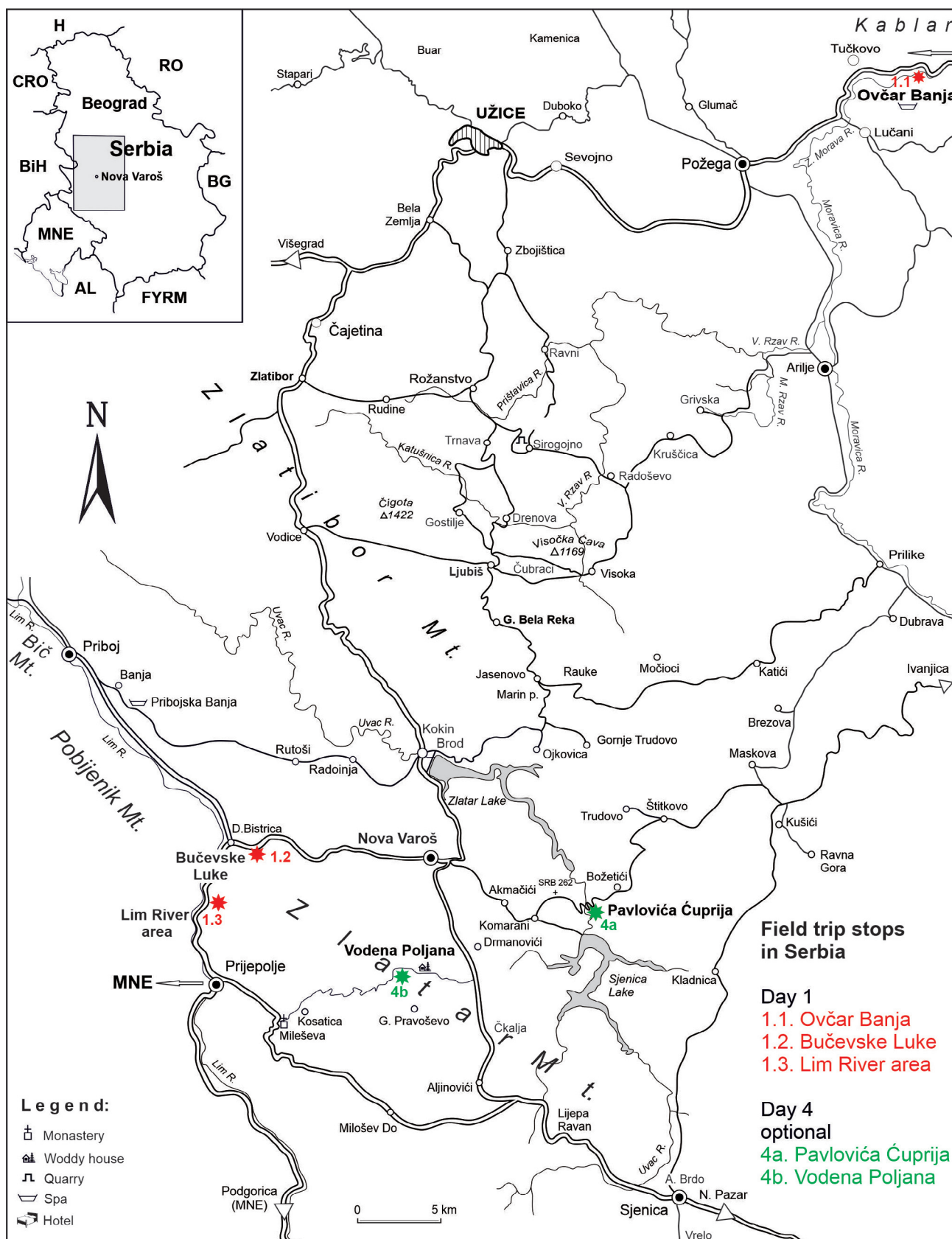


Fig. 4. Localities to be visited in southwestern Serbia. First day: **1.1.** Ovčar Banja section in the Ovčar–Kablar gorge; **1.2.** Bučevske Luke section on the road Nova Varoš–Donja Bistrica; **1.3.** Lim River area. First or fourth day: Optional **4a.** Pavlovića Čuprija area or **4b.** Vodena Poljana area on the Zlatar Mt. within the Zlatar (Hallstatt) Mélange.

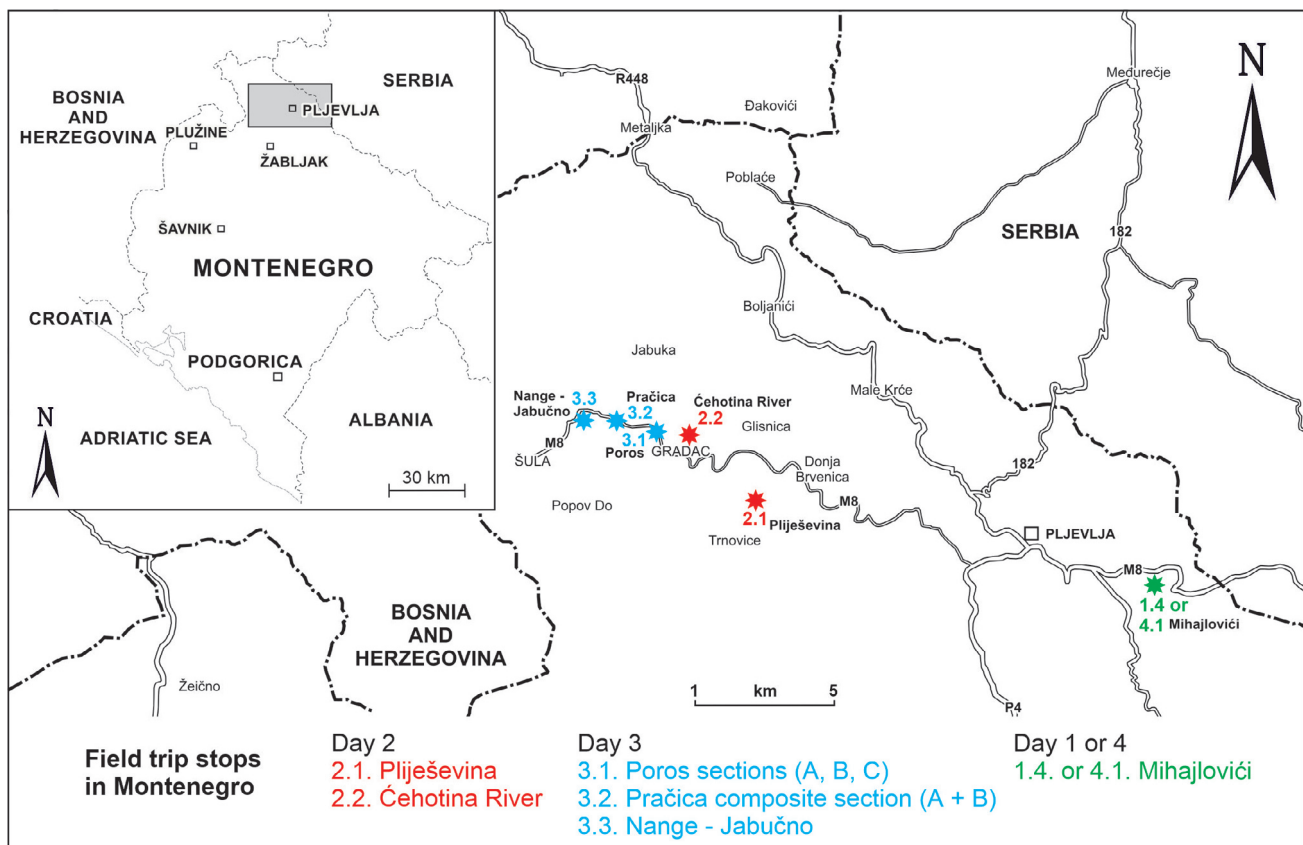


Fig. 5. Localities to be visited in northern Montenegro. First or fourth day: 1.4. or 4.1. Mihajlovići section; Second day: 2.1. Pliješevina section; 2.2. Čehotina River section; Third day: various sections along the road from Gradac to Šula: Poros sections (3.1. Poros A, Poros B, Poros C), 3.2. Pračica composite section (Pračica A + Pračica B); 3.3. Nange-Jabučno.

ian can be attributed to the intraoceanic subduction.

2. OM2 type: Ophiolitic mélanges with incorporated continental blocks, mainly scrapped of from the sedimentary cover rocks of the wider Adria plate with the Dinarides as part of it. Predominantly blocks from the continental slope were incorporated into this type of ophiolitic mélanges that are blocks from the Grivska Formation and from the underlying sedimentary sequence. This type defines together with matrix age dating the onset of ophiolite obduction. For the Dinarides the time span between (?Late Bajocian) Bathonian to Middle Oxfordian can be attributed for the emplacement of the ophiolites on the wider Adria plate, i.e. obduction started in the Middle Jurassic and ended in the early Late Jurassic (GAWLICK et al., 2016; GAWLICK & MISSONI, 2019; DJERIĆ et al., 2024;

compare SCHMID et al., 2008, 2020). This type of ophiolitic mélange can be compared with the Meliata mélange in the Inner West Carpathians (PLAŠIENKA, 2018 and references therein) or the Florianikogel Formation in the southeastern part of the Northern Calcareous Alps (GAWLICK et al., 2009 and references therein).

3. OM3 type: Ophiolitic mélanges with fluvial transported sedimentary rocks (predominantly ophiolitic material, radiolarites, and components from the shallow-water carbonate platform formed on top of the obducted ophiolites: GAWLICK et al., 2008, 2020; SCHLAGINTWEIT et al., 2006) at their base or incorporated younger blocks in the basal shear zone. This type of the ophiolitic mélange can be overlain by OM1 or OM2 type ophiolitic mélanges. For the Dinarides the time span from the Tithonian onwards can be attribu-

ted for further transport along a flat thrust segment to both sides of the updoming continental metamorphosed crust (GAWLICK et al., 2020).

Ovčar Banja section

Age: Middle Anisian (Pelsonian) to Middle Jurassic;

Provenance: Continental slope of the western Neo-Tethys passive continental margin;

Formations: Ravni Formation, Bulog Formation, Nova Varoš Group, Grivska Formation;

Location: Between Čačak and Požega.

The section Ovčar Banja is located along the old and today closed part of the main road from Čačak to Požega, aside the tunnel of Ovčar Banja (Fig. 4, stop 1.1). The slightly folded but complete Middle Triassic (Anisian: Pelsonian) to Middle Jurassic sedimentary succession (compare ŽIVKOVIĆ, 1932) was deposited at the foot-wall of the continental slope of the western passive continental margin of the Neo-Tethys Ocean (Fig. 3). The section is preserved in a more than 100 m-sized block in the ophiolitic mélange below the obducted Neo-Tethys ophiolites, and was first described in detail by DJERIĆ et al. (2024). In the older literature only parts of the section were described (ŽIVKOVIĆ, 1932; OBRADOVIĆ, 1986; OBRADOVIĆ & GORIČAN, 1988; DJERIĆ & GERZINA, 2008; VISHNEVSKAYA et al., 2009), which provide some sedimentological and biostratigraphic insights. Neither the provenance of this section was interpreted nor the whole sedimentary succession and its depositional history were studied in detail.

During the study of blocks and pebbles from various ophiolitic mélanges in the whole Western Tethys Realm this facies belt (defined as Meliata facies in the Western Carpathians: PLAŠIENKA, 2018 and references therein, GAWLICK & MISSONI, 2019) a relative complete view of the depositional history of several parts of the continental slope could be reconstructed, but a lot of details remain unknown. However, these studies on the various blocks and pebbles incor-

porated in the different ophiolitic mélanges allowed to reconstruct the original provenance area of similar, but today totally dismembered, sedimentary successions. Important was also the detection of complete Middle–Late Triassic successions deposited on the oldest Neo-Tethys Ocean floor near to the continental slope (GAWLICK et al., 2008, 2017a; DJERIĆ et al., 2024).

However, complete sedimentary successions from the most distal part of the passive continental margin transitional to the oceanic crust were so far unknown in all mountain ranges in the eastern Mediterranean. The section Ovčar Banja was described completely for the first time in DJERIĆ et al. (2024), and at least the Middle–Late Triassic part of the sedimentary succession could be dated relatively precisely by conodonts and radiolarians. The Jurassic part of the succession remained undated, but by lithological comparisons with other sections from the outer shelf to the continental slope the Early Jurassic siliceous sedimentary rocks can be clearly distinguished from the Middle Jurassic radiolarites. Theoretically at least the Middle Jurassic radiolarites provide a chance to date them with radiolarian assemblages. These radiolarites appear near to the top of the section and are highly fractured. In addition, the so far prepared radiolarian samples yielded only strongly recrystallized radiolarians, which even could not be determined on genus level. To date the Early Jurassic by means of radiolarians is rather impossible and not expectable, because Early Jurassic (to Aalenian) radiolarians are relatively filigran (O'DOHERTY et al., 2010) and become easily solved in the water column (DECKER, 1991; DE WEVER et al., 2001). These Early Jurassic radiolarian assemblages are nowhere preserved on deep-marine oceanic crust, a reason why Early Jurassic oceanic crust was never found (and can be never found) in the obducted ophiolites in the eastern Mediterranean mountain belts. Therefore, the section Ovčar Banja is crucial for the detailed reconstruction of the depositional and sedimentological history of the oldest (Late Anisian) part of the Neo-Tethys Ocean.

The section starts with the Middle Anisian massive to thick-bedded shallow-water limesto-

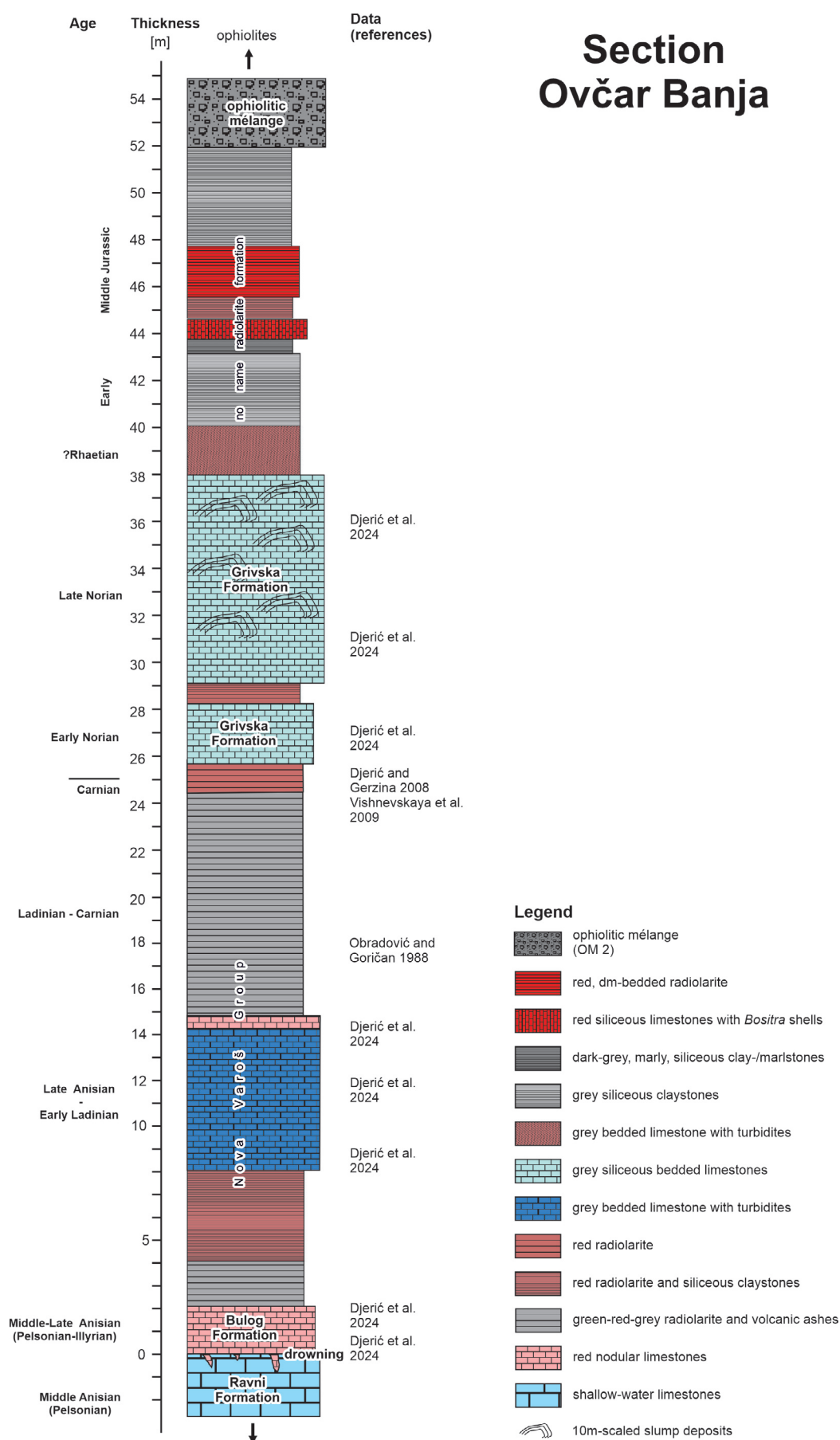


Fig. 6. Middle Triassic to Middle Jurassic section Ovčar Banja. The section starts with Middle Triassic (Pelsonian) shallow-water limestones. The Late Pelsonian drowning marks the break-up unconformity and is contemporaneous with the opening of the Neo-Tethys Ocean. During the time span Middle Triassic to early Middle Jurassic the lithological evolution mirrors a continuous deepening trend. In the Middle Jurassic a slight uplift can be recognized by the onset of deposition of siliceous Bositra Limestones. This uplift is most likely contemporaneous with the onset of ophiolite obduction and formation of a bulge. After deposition of the Bositra Limestone again a deepening-trend can be observed with deposition of clayey radiolarites. These clayey radiolarites are overlain by various mass-transport deposits of the ophiolitic *mélange*, in the higher part extremely sheared. Characteristic sedimentological features of the Triassic part of the section are shown in Fig. 7. The Jurassic part of the section is protected by metallic net, overgrown by vegetation and therefore not very photogenic.

nes of the Ravni Formation (Dedovići Member) (Figs. 6, 7). The shallow-water limestones of the Ravni Formation were still formed in the epicontinental sea (graben) earlier as the continental break-up (SUDAR et al., 2013). The upper part of the Ravni Formation is dissected by neptunian dikes (Fig. 7) filled with micritic and in parts laminated red limestones (Bulog Limestones), as widespread known from the upper Ravni Formation in the Dinarides (SUDAR et al., 2023a, b, 2025; GAWLICK et al., 2023; MRDAK et al., 2025). The age of these neptunian dikes could not be dated by conodonts. Directly above appear deposits (Fig. 7) with a mixture of red nodular limestone clasts and blocks of the Ravni Formation. It cannot be decided if the neptunian dikes are filled with blocks resting in a red limestone matrix or if mass-transport deposits deposited, which would correspond to the Komarani Formation (SUDAR et al., 2023b).

Upsection follows the drowning sequence with red nodular limestones of the Bulog Formation (SUDAR et al., 2013, 2023b and references therein), dated by *Nicoraella germanica* (TATGE), *Paragondolella bulgarica* BUDUROV & STEFANOV, and *Pg. bifurcata* BUDUROV & STEFANOV as Late Pelsonian (DJERIĆ et al., 2024). The Bulog Limestone deposition continues most probably to the Early Illyrian, as indicated by the occurrence of *Pg. hanbulogi* SUDAR & BUDUROV in the uppermost part, but without the classical Late Pelsonian conodonts. The Bulog Limestone is overlain by green-grey Late Anisian radiolarites with intercalated volcanic ash layers, subsequently followed by red radiolarite and red siliceous claystone. These radiolarites could not be dated directly by radiolarians, but their Middle to Late Illyrian age is proven by conodonts from the Bulog Limestone below, and the grey bedded limestones above. These grey deep-water limestones with

intercalated turbidites deposited around the Anisian/Ladinian boundary. Their age is proven by the occurrence of *Pg. trammeri* (KOZUR) in the lowermost part, *Neogondolella pseudolonga* KOVACS, KOZUR & MIETTO in the middle part, and the co-occurrence of *Ng. excentrica* BUDUROV & STEFANOV together with *Pg. trammeri* in the uppermost part of the succession (compare DJERIĆ et al., 2024), which comprises also red nodular limestones. Of importance is the appearance of turbidites within these slightly siliceous limestones indicating a short living (latest Anisian to ?earliest Ladinian) shallow-water carbonate production areal in the outer shelf area. The thin red nodular limestones on top of the grey bedded slightly siliceous limestones indicate the onset of condensation and are overlain by various coloured (grey, red, green) Ladinian–Carnian radiolarites with intercalated volcanic ashes in parts (latest Anisian–Late Ladinian, OBRADOVIĆ, 1986; OBRADOVIĆ & GORIČAN, 1988). Important to recognize, that an Early Carnian carbonate influenced interval could not be detected in the middle to higher part of this radiolarite package. The highstand shedding of the Wetterstein Carbonate Platform obviously did not reach this part of the depositional realm, which is the footwall of the continental slope. The only hint can be the fact, that the radiolarites in the higher part contain a little carbonate content. This contrasts the Norian evolution, when the grey siliceous limestones of the Grivska Formation (SUDAR & GAWLICK, 2018) perfectly mirror the evolution of the Dachstein Carbonate Platform. To note, that the slightly siliceous limestones from the Grivska Formation appear mainly as slump deposits deriving from the upper slope, whereas the autochthonous limestones are highly siliceous.

The Norian siliceous bedded deep-water limestones deposited above Late Carnian to



Fig. 7. Field views of the Ovčar Banja section. **1.** Middle Anisian Ravni Formation (Dedovići Member) dissected by neptunian dikes filled with red micrite (Bulog Formation) and medium-grained breccias. The components in these breccias consist exclusively of the upper Ravni Formation. **2.** Uppermost part of the Ravni Formation (Dedovići Member) dissected by various neptunian dikes filled with breccias and red micrite. In fact, it cannot be decided if here a network of neptunian dikes or mass-transport deposits (Komarani Formation) is preserved. To the left the contact to the overlying Bulog Formation is preserved. **3.** Ladinian to Early Carnian radiolarite sequence. In the upper part appear greenish clayey radiolarites which resembles the Upper Ladinian “Pietra Verde”. **4.** The upper radiolarites (Early Carnian) are slightly calcareous and clayey in their uppermost parts. **5.** Overview of the Middle to Late Triassic radiolarite to the Norian Grivska Formation succession. **6.** Contact between the ?late Early Norian to Middle Norian radiolarite and the Upper Norian siliceous limestones of the Grivska Formation.

earliest Norian red radiolarites (DJERIĆ & GERZINA, 2008; VISHNEVSKAYA et al., 2009) (Fig. 8). However, the contact between the radiolarite and the Grivska Formation is ?tectonically overprinted, although it cannot be excluded that here a slump contact is preserved with a slight erosion at the base of the Grivska Formation. Anyhow, deposition of the sedimentary sequence seems to be more or less complete. A younger Early Norian age of the lower Grivska Formation is confirmed by the appearance of *Epigondolella rigoi* NOYAN & KOZUR. This Early Norian limestone interval reflects the highstand shedding of the middle Late Triassic platform evolution, that is the higher Lacinian 1 to Lacinian 2 first shallow-water carbonate production phase of the Dachstein Carbonate Platform evolution (KRYSTYN et al., 2009; ZÖHRER et al., 2026 and references therein). The thin intercalated red radiolarite to siliceous claystone interval may represent the Middle Norian, a time when the Dachstein Carbonate Platform suffered (GAWLICK & BÖHM, 2000). Whereas in the Early Norian siliceous limestones the fine-grained turbiditic layers contain rare conodonts, in the Late Norian conodonts (e.g., *Eg. cf. bidentata* MOSHER) occur only in slump deposits deriving from the upper continental slope, as in most Grivska Limestone blocks incorporated in ophiolitic mélanges elsewhere (SUDAR & GAWLICK, 2018).

Above the Grivska Formation deposited red/violet-grey siliceous claystones or clayey radiolarites, which may represent the time span Rhaetian to Early Jurassic/early Middle Jurassic. Carbonate production decreased generally at the base of the Middle Rhaetian, indicated by the partial drowning and backstepping of the Dachstein Carbonate Platform (KRYSTYN et al.,

2009; MISSONI & GAWLICK, 2011a, b), and stopped practically by the mass extinction at the Triassic/Jurassic boundary. The Grivska Formation mirrors this evolution by their age range until the Rhaetian (SUDAR & GAWLICK, 2018). The lithological change from the red/violet-grey siliceous claystones or clayey radiolarites to grey siliceous claystones with spicules most likely corresponds to the Triassic/Jurassic boundary, but this cannot be proven biostratigraphically. The slightly marly dark grey siliceous claystones are most likely an expression of the Toarcian black shale event. However, above these dark grey siliceous claystones red siliceous limestones with *Bositra* shells deposited indicate a clear Middle Jurassic age. Deposition of *Bositra* shell-bearing sedimentary rocks started generally in the latest Toarcian/Aalenian (BÖHM, 1992), with its peak in Bajocian–Bathonian times (GAWLICK et al., 2009 and references therein). The turnover from siliceous claystones/radiolarites to siliceous carbonates indicates an uplift of the depositional realm. This uplift can be easily explained by formation of a bulge in front of the obducting ophiolites. While ophiolite obduction started probably in the Late Toarcian (KARAMATA, 2006), but for sure in the Bajocian (GAWLICK et al., 2016) this uplift clearly improves these age data. Upsection follow dm-bedded red radiolarites.

The change from clayey radiolarites to massive bedded ribbon radiolarites with the *Bositra* Limestone at their base is in line with the evolution of the radiolarian faunas. The significant lithological change is in line with the turnover in the radiolarian faunas from more filigran types to robust forms (O'DOHERTY et al., 2010) around the Aalenian/Bajocian transition. In con-

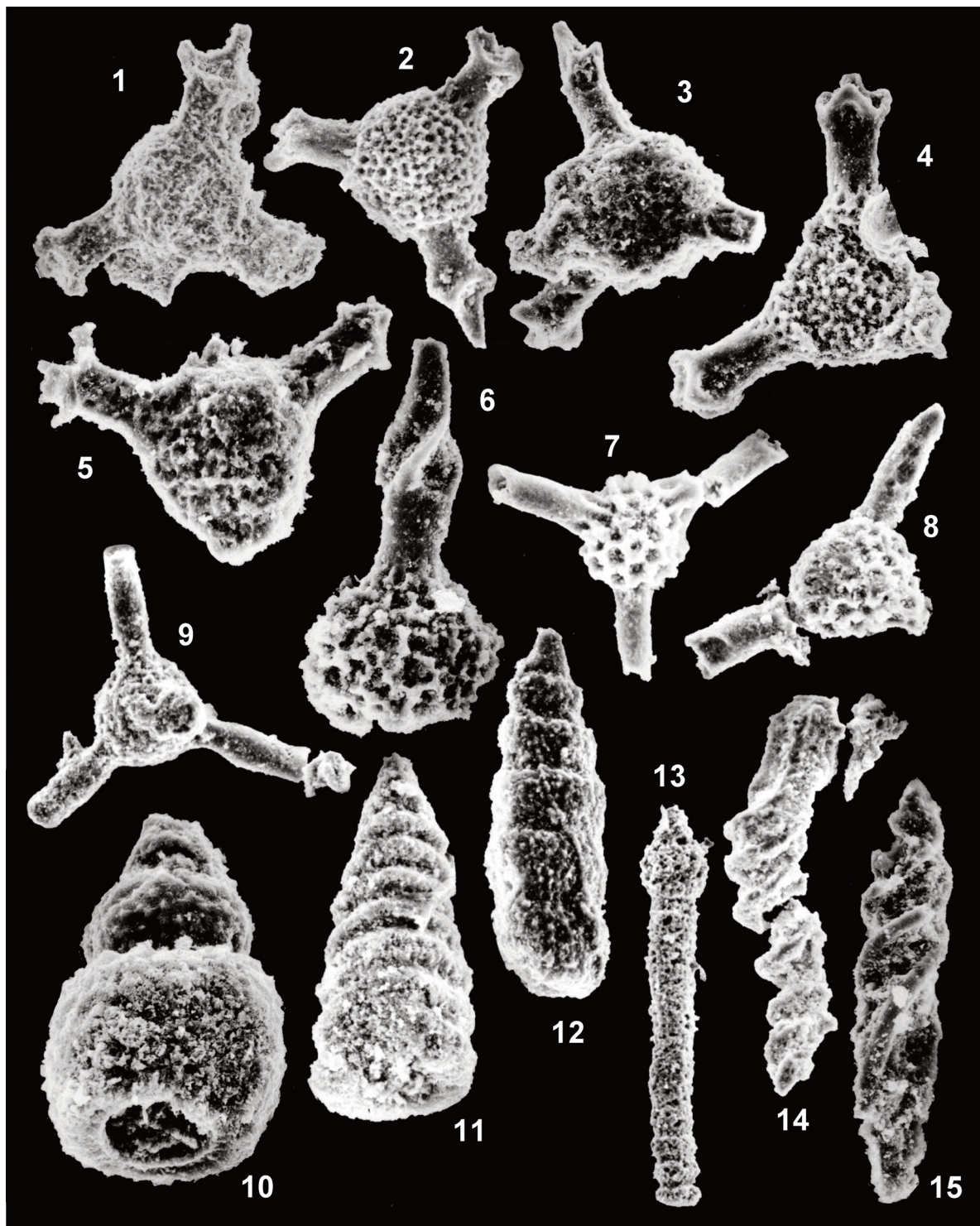


Fig. 8. Early Norian radiolarians from the Ovčar Banja section. Samples were collected at successive stratigraphic levels: sample 103 (Early Norian), sample 102 (latest Carnian–earliest Norian to Early Norian), 80 cm above sample 103, and sample 100 (latest Carnian–earliest Norian to Early Norian), 180 cm above sample 103 (DJERIĆ & GERZINA, 2008). **1.** *Capnuchosphaera theloides minor* BRAGIN, sample 100, x200; **2.** *Capnuchosphaera theloides* DE WEVER, sample 102, x200; **3.** *Capnuchosphaera concava* DE WEVER, sample 102, x200; **4.** *Capnuchosphaera concava* DE WEVER, sample 103, x200; **5.** *Capnuchosphaera* cf. *tricornis* DE WEVER, sample 103, x200; **6.** *Capnuchosphaera* cf. *deweveri* KOZUR & MOSTLER, sample 103, x200; **7.** *Capnodoce crystallina* PESSAGNO, sample 103, x200; **8.** *Capnodoce* cf. *anapetes* DE WEVER, sample 102, x200; **9.** *Loffa* ? *mulleri* PESSAGNO, sample 102, x200; **10.** *Canesium lentum* BLOME, sample 103, x200; **11.** *Japono-campe nova* (YAO), sample 102, x200; **12.** *Pachus multi-nodosus* TEKIN, sample 103, x200; **13.** *Xiphothecella rugosa* (BRAGIN), sample 102, x100; **14.** *Spongotortilispinus carnicus* (KOZUR & MOSTLER), sample 100, x350; **15.** *Spongotortilispinus tortilis* (KOZUR & MOSTLER), sample 103, x350.

trast to the filigran forms the more robust radiolarian assemblages of the Middle Jurassic could be deposited also in deep-water setting before they became solved. Higher up in the section the depositional realm received again fine-grained siliciclastic sediments in an increasing amount. Finally mass-transport deposits appear in the section, which contain exclusively ophiolitic clasts. Upsection the tectonic overprint increases and the general feature below the ophiolites is that of a typical ophiolitic mélange (OM2-type: DJERIĆ et al., 2024).

In general, the depositional history of the Triassic part of the section mirrors

- A) The continuous deepening throughout the Middle–Late Triassic time span; and
- B) The sedimentological evolution on the distal passive continental margin respectively the footwall of the continental slope, which is the onset and flowering of carbonate platforms, their demise and aftermath.

The generally siliceous sedimentary rock deposition (mainly radiolarites and siliceous claystones) is only interrupted by short time lasting siliceous limestone intercalations around the Anisian/Ladinian boundary and in the Norian. The earliest Carnian Wetterstein Carbonate Platform evolution is practically not recognizable in the sedimentary succession. Only slightly more carbonatic radiolarites in the latest Ladinian–Carnian radiolarite interval may indicate the shedding from this platform evolution, but cannot be dated exactly.

The Early Jurassic part of the section mirrors the deposition of a shelf area without carbonate production with deposition of deep-water clayey siliceous sedimentary rocks. In the Middle Jurassic the lithological changes mirror the onset of ophiolite obduction first by uplift and later by the occurrence of mass-transport deposits consisting of reworked ophiolitic material.

Lim River area

Age: Norian; blocks in the Middle Jurassic ophiolitic mélange;

Provenance: Continental slope of the western Neo-Tethys passive continental margin;

Formations: Grivska Formation;

Location: Between Donja Bistrica and Prije-polje.

Type area of the parautochthonous intraplate basin (Lim basin) as defined by PANTIĆ & RAMPNOUX (1972) and RAMPNOUX (1974). However, these authors included also occurrences of the various coloured Hallstatt Limestone successions into the Lim basin, e.g., those in the Zlatar Mt. (Pavlovića Čuprija area, Vodena Poljana area – see below). These various coloured Hallstatt Limestone successions appear as blocks in the Middle–Late Jurassic Zlatar (Hallstatt) Mélange (see below).

Grey siliceous (cherty) limestones deposited in different depositional realms and different time spans during the Triassic and Jurassic in the Dinarides, but their biostratigraphic age dating was always critical in respect to the lack of datable organisms. In most cases such bedded grey siliceous limestones were assigned to the Ladinian (e.g., PANTIĆ, 1969, 1971; PANTIĆ & MOJSILOVIĆ, 1968; PANTIĆ-PRODANOVIĆ, 1975) and attributed to the Grivska Formation. The Grivska Formation (DIMITRIJEVIĆ & DIMITRIJEVIĆ, 1987, 1991) was interpreted as the age-equivalent of the Wetterstein Formation (platform), i.e. the Ladinian, ignoring existing conodont ages (UROŠEVIĆ & SUDAR, 1980; SUDAR, 1981, 1986). Nevertheless, such grey and bedded siliceous open marine deep-water limestones rarely deposited in the Ladinian (Fig. 3). During Ladinian times various sedimentary rocks deposited, including grey siliceous bedded limestones in very rare cases (MISSONI et al., 2012), but in comparison with other deep-water sedimentary rocks such lithologies are rather rare. In fact, most grey siliceous bedded deep-water limestones deposited in the Late Triassic (Fig. 3).

A reinvestigation of the type-locality and area beside various other Grivska Formation sections (MISSONI et al., 2012; GAWLICK et al., 2017a; SUDAR & GAWLICK, 2018) clarified, that the Grivska Formation is exclusively of Late Triassic age and can be subdivided in two parts. Most

sections formerly attributed to the Grivska Formation do not belong to the Grivska Formation; they have a different age and a different depositional realm and history as the type-locality (details in GAWLICK et al., 2017a; SUDAR & GAWLICK, 2018).

The first and oldest part of the Grivska Formation is Early Carnian in age and reflects the highstand shedding of the Wetterstein Carbonate Platform. The second and younger part is Late Carnian to Rhaetian and reflects the carbonate export from a forerunner of the Norian-Rhaetian Dachstein Carbonate Platform and from the Dachstein Carbonate Platform evolution. All occurrences of the Grivska Formation are blocks of different sizes in the ophiolitic *mélange* (SUDAR & GAWLICK, 2018).

Remarkable is the occurrence of huge slump deposits in most of the studied sections of the Grivska Formation. Intense reworking of the Grivska Formation, deposited mainly on the upper continental slope, started in the Middle Norian (Late Alaunian), culminated in the late Norian (Sevastian) and ended in the Early Rhaetian. During that time intense tectonic motions somewhere in the Western Tethys Realm, most likely in the area of a forerunner of the Periadriatic Lineament, triggered most probably intense earthquakes. These earthquakes caused mass movements downslope elsewhere in the Western Tethys Realm and the formation of new basins. Characteristic are the Seefeld basins in the Eastern and Southern Alps, formed in the restricted lagoon (Hauptdolomit/Dolomia Principale facies belt) exactly at that time (KÖSTER et al., 1988; COZZI, 2000, 2001; DONOFRIO et al., 2003).

The formation of new basins with intense mass movements deriving not exactly from adjacent graben flanks is not only recognized in the lagoonal area of the Dachstein Carbonate Platform, they were also described from the open shelf area, which is the Hallstatt facies (GAWLICK, 1998, 2000; MISSONI & GAWLICK, 2008). The component spectrum of the breccias or the facies of the slump deposits show a different provenance as the underlying sedimentary sequences. This implies basin formation in a strike-slip regime, that are pull-apart basins

rather than in a simple extensional regime with formation of grabens and half-grabens. This is different from all occurrences in different facies belts in the Dinarides, where the reworked material shows not a different palaeogeographic provenance. Here only mass movements of not fully consolidated sediments from adjacent slopes were transported into the basin. In case of the Grivska Formation the reworked sediments derive from the upper part of the continental slope and slid down to the footwall of the continental slope, where rather thick grey siliceous and bedded limestones deposited. These siliceous limestones deposited at the footwall of the continental slope contain only in very rare cases conodonts, because it is not their living environment. Only in rare “filament-bearing” turbidites some small or juvenile conodonts can be extracted.

The block at the Lim River area can act as a typical and well visible example of large-scaled slump deposits in basinal sequences. Therefore, also the thickness of the section cannot be measured. The slumps are also characterized by a slightly different microfacies and faunal content which allow differentiating the different depositional characteristics on the continental slope during Late Triassic times. To note, that the topographic difference between the upper continental slope to the footwall of the continental slope transitional to the Neo-Tethys oceanic crust should exceed 2500–3000 m, which should have reached a water depth of about 3–3.5 km using a calculation based on SCLATER et al. (1971).

Along the road from Donja Bistrica to Prijepele on both sides of Lim River (Fig. 4, stop 1.3) a more than 100 m-sized block or slice (Fig. 9) of bedded grey, and occasionally reddish-grey bedded cherty limestones is incorporated into the ophiolitic *mélange* (OM2 sensu DJERIĆ et al., 2024) below the Dinaridic Ophiolite nappe stack. The Middle Jurassic ophiolitic *mélange* outcrops beneath and above this block and represents its matrix. The age of these grey siliceous and generally dm-bedded limestones is Norian, as dated by means of conodonts (SUDAR & GAWLICK, 2018) and occasionally moderately preserved radiolarians (BRAGIN et al., 2019).



Fig. 9. Previous page: Lim River area with outcrop photos of the Grivska Formation on both sides along the River Lim (photos 1 to 4 show the eastern side, and photos 5 and 6 show the western side of the Lim River). Photo 1 after SUDAR & GAWLICK (2018). **1.** Road cut of Late Norian dm-bedded cherty limestones, occasionally with slump folds and overlain by Early–Middle Norian slump deposits. **2.** Enlargement of the Late Norian folded dm-bedded siliceous limestones with overlying thick slump deposits. **3.** and **4.** Folded dm-bedded siliceous limestones along the road. **5.** Slump deposits of Early Norian (Early–Middle Lacin) age, occasionally with fine-grained turbidites containing few conodonts, predominantly of Early Norian age. **6.** Thick slump deposits, overlain by dm-bedded grey siliceous limestones, most likely of Late Norian age. In the Early to ?Middle Norian dm-bedded cherty limestones slump deposits the beds are occasionally amalgamated.

On the eastern side of the Lim River, that is directly along the main road, in one slump deposit an Early Norian (Early–Middle Lacin) age is proven by conodonts (sample MS 2017 with *Eg. abneptis* transitional to *Ancyrogondolella triangularis* BUDUROV, *Norigondolella* sp. (cf. *navicula* (HUCKRIEDE); and one sample (MS 2019) with *Nrg. hallstattensis* (MOSHER). This part of the section is located in the first road curve after Donja Bistrica in direction to Prijepolje. The other parts of the section along the road cannot be sampled, because the pavement at the side of road is narrow and very near to the section and the traffic is very dense.

On the western side of the Lim River, near the first road curve after Donja Bistrica, close to the bridge, there is a continuation of the section from the eastern side of the Lim River. The latest Carnian–Early Norian age of these grey to yellowish-grey platy and locally thick-bedded micritic limestones with frequent layers and nodules of white and pink cherts is proven by radiolarian assemblages (BRAGIN et al., 2019) (Fig. 10), which is consistent with the conodont-based age from the eastern side of the Lim River and indicates a phase of sedimentary starvation around the Carnian/Norian boundary. On this side of the Lim River it is possible to go along the railway in direction to Prijepolje and sample the lower part of the section, that are grey and in cases reddish siliceous dm-bedded limestones mainly below the thick slump deposits. These grey–reddish siliceous limestones are of Late Norian age and contain *Epig.* sp. (aff. juv. *bidentata*) (sample SRB 552) and *Neohindeodella* sp. (sample SRB 627). In contrast to the Early Norian, which appear in the slump horizons, the Late Norian part of the succession is extremely poor in conodonts. Reason is most probably, that the Late Norian represents the parautoch-

thonous part of the sequence, deposited in a deep-water setting at the footwall of the continental slope, an area which is not the living area of conodonts. In contrast, the Early Norian conodonts appear in the slump deposits deriving from the upper part of the continental slope, a much better environment for the conodonts. The deep-water environment is confirmed by the microfacies characteristics. The whole succession consists exclusively of bioturbated radiolarian wacke- to packstones; microfacies types with few “filaments” are very rare.

The age of the Early Norian siliceous limestones corresponds to the age of the early Dachstein Carbonate Platform and mirrors therefore the highstand shedding of that platform. The Early Norian part of the Grivska Formation seems to be rather thick in comparison with the Middle or Late Norian part, but an exact thickness cannot be measured, because the strata are several times doubled due to slumping. Younger normal faults and slight folding complicate the situation additionally. Middle Norian could not be proven by conodonts and is represented most likely by the reddish and slightly marly siliceous limestones with limited thickness, but none of the processed conodont samples yielded conodonts. The Late Norian is again predominantly grey and also in total thicker, and mirrors the second main stage of the Dachstein Carbonate Platform evolution with highstand shedding.

Reasons for the scarcity of conodonts in the Middle–Late Norian are on one hand the deep-water conditions of the depositional realm of the Grivska Formation and on the other hand the change of the living habitat of the conodonts. During Norian times they restrict their living habitat from the entire shelf area to reef near environments.

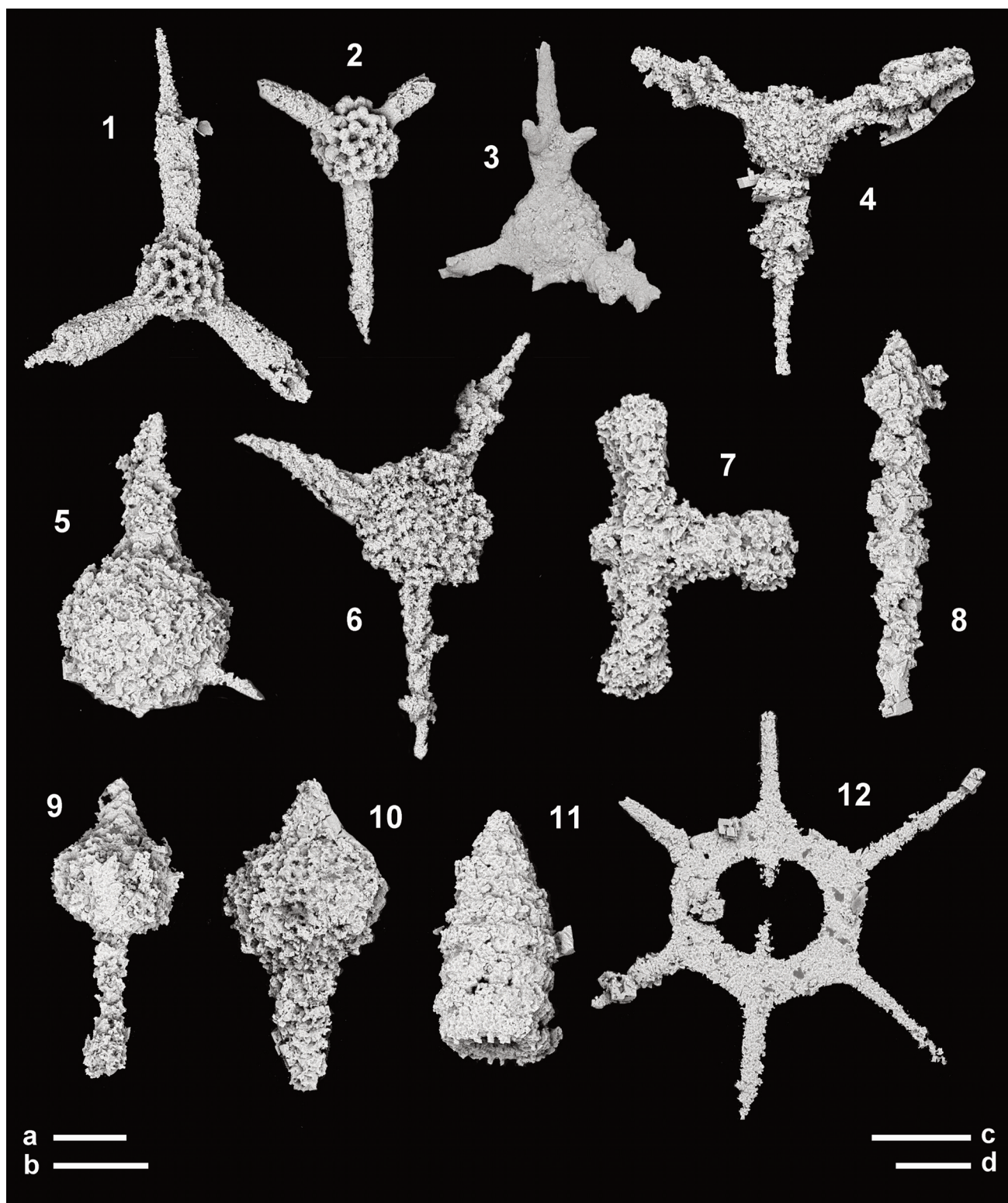


Fig. 10. Latest Carnian to Early Norian radiolarians from the Lim River area (BRAGIN et al., 2019). **1.** *Capnodoce anapetes* DE WEVER, sample 15-21-2; **2.** *Capnodoce sarisa* DE WEVER, sample 15-21-2; **3.** *Capnuhosphaera* cf. *tricornis* DE WEVER, sample 15-21-2; **4.** *Sarla hadrecaena* (DE WEVER), sample 15-21-2; **5.** *Monocapnuhosphaera* sp. B sensu TEKIN (1999), sample 15-21-2; **6.** *Ellisus* cf. *siscwaiensis* (CARTER), sample 15-21-2; **7.** *Triassocrucella* cf. *triassica* (KOZUR & MOSTLER), sample 15-21-2; **8.** *Xiphothecaella longa* (KOZUR & MOCK), sample 15-21-2; **9.** *Spinosicapsa* spp., sample 15-20-1; **10.** *Spinosicapsa* spp., sample 15-21-2; **11.** *Corum* sp., sample 15-20-1; **12.** *Praehexasaturnalis tenuispinosus* (DONOFRIO & MOSTLER), sample 15-20-1. Scale bars 100 μm: a (1, 2, 4, 6); b (3, 5); c (7, 11); d (8–10, 12).

4.2. The Middle/Late Jurassic Hallstatt (Zlatar) Mélange

The Hallstatt (Zlatar) Mélange = Pavlovića Ćuprija Formation (GAWLICK et al., 2017a, b, 2018) in the Zlatar Mountain was according to PANTIĆ & RAMPNOUX (1972) and RAMPNOUX (1974) defined together with the occurrences of the Grivska Formation as parautochthonous deep-water intraplateau basin, that is the Zlatar sub-basin of the Lim basin.

For a comprehensive review of the different Hallstatt mélanges in the Western Tethys Realm the interested reader is referred to GAWLICK & MISSONI (2019). Generally, two different types of Hallstatt mélanges can be distinguished:

1. Hallstatt mélanges which consist of reworked material from the outer shelf region in the Middle to early Late Jurassic (Bathonian–Oxfordian) radiolaritic matrix (GAWLICK & FRISCH, 2003; GAWLICK et al., 2007; for Dinarides: GAWLICK et al., 2017a, b, 2018). In the outer shelf region during Middle–Late Triassic times the characteristic Hallstatt Limestone sequence was deposited (for details: LEIN, 1987; KRYSŤYN, 2008), that is the various coloured Hallstatt Limestone sequence. In Jurassic times the different facies belts of the outer shelf cannot be distinguished anymore. After the demise of the Dachstein Carbonate Platform the shelf sediments became uniform.
2. Hallstatt mélanges which consist of reworked material from the outer shelf region between the various coloured Hallstatt Limestone facies and the reef rim of the carbonate platforms in a late Middle to early Late Jurassic (Callovian–Oxfordian) radiolaritic matrix. Predominantly the reef rim of the flat-topped Dachstein Carbonate Platform is used as a reference facies belt. This open-marine deep-water facies belt is termed the grey Hallstatt facies by LEIN (1987), comparable with the Gučevo facies of SUDAR (1986). Grey siliceous bedded deep-marine limestones and deep-water dolomites dominate the component spectrum (GAWLICK, 1996). Intercalated turbidites with shallow-water material shed from the adjacent platforms are a typical sedimento-

logical feature. In cases also reworked blocks from the Dachstein Carbonate Platform reef rim, that are reefal and fore-reefal limestones or dolomites appear (GAWLICK et al., 2003; MISSONI & GAWLICK, 2011a, b; for Dinarides: MISSONI et al., 2012; ZÖHRER et al., 2021).

Stacking of the outer shelf area (Hallstatt shelf) propagated from the distal shelf area to the central shelf area due to the west-directed ophiolite obduction from (late) Bajocian times onwards. Therefore, the earliest formed trench-like basins with reworked Hallstatt material in a radiolaritic matrix are slightly older as the later formed basins. Stacking of the outer shelf started in Bathonian times and continued until the Callovian (GAWLICK & MISSONI, 2019; for Dinarides: GAWLICK et al., 2017a, b, 2018). The next generation of basins started to form in Callovian times, and resedimentation lasted until the Early/Middle Oxfordian, whereas in the youngest generation of trench-like basins resedimentation started around the Callovian/Oxfordian boundary. In rare cases such a nappe stack consisting of Hallstatt nappes was bulldozed by the obducting ophiolite nappe stack to the foreland. Such a Hallstatt nappe stack is preserved in the Vodena Poljana area (GAWLICK et al., 2018).

Bučevske Luke locality

Age: Bajocian to Callovian radiolaritic matrix; Late Triassic Hallstatt Limestone blocks in mass-transport deposits;

Provenance: Blocks from the outer shelf (various coloured Hallstatt Limestone facies);

Formation: Pavlovića Ćuprija Formation (Zlatar Mélange);

Location: Zlatar Mt. west of Nova Varoš, road between Nova Varoš to Prijepolje.

The section Bučevske Luke is located on the main road from Nova Varoš to Prijepolje near to the small town Donja Bistrica (Fig. 4, stop 1.2). Traditionally this locality was interpreted as a limestone block in the ophiolitic mélange until recent times (CVETKOVIĆ et al., 2017). It is interpreted that this some tens of metres thick block

of red and white limestone should represent a block scrapped off from the lower plate during ophiolite obduction. However, until that time practically no studies were carried out at that locality. The age of the radiolarites below the limestones was never studied, and age and provenance of the limestones remain also unknown.

In fact, the limestones are not a single block as believed and described earlier. We see amalgamated mass-transport deposits which consists of polymictic breccias with dm-sized clasts at the base, and m-sized blocks in the upper part of the outcrop. The mass-transport deposits occur in a channel fill above argillaceous and carbonaceous grey-black radiolarites (GAWLICK et al., 2018). This clearly shows that these limestones were not tectonically incorporated into the radiolaritic-argillaceous matrix, but sedimentary. Furthermore, ophiolitic material (e.g., sandstone turbidites made of ophiolitic material) could nowhere be detected in the radiolaritic sedimentary rocks. Also, ophiolite components are missing in the mass-transport deposits. The outcrop is overlain by an ophiolitic mélange as everywhere the Hallstatt (Zlatař) Mélange (= Pavlovića Čuprija Formation) is preserved (GAWLICK et al., 2017a, b, 2018).

The limestone components are grey and red radiolaria- and “filament”-bearing open marine limestones, which correspond by their microfacies and age to a reworked Late Triassic Hallstatt Limestone sequence. Conodonts from the various limestone components and blocks are preserved only as broken pieces as result of intense fracturing of the clasts and blocks, and could be therefore rarely isolated or determined (details in GAWLICK et al., 2018). However, determinable conodonts show exclusively Norian ages.

The radiolaritic sequence, in fact clayey radiolarites to siliceous claystones, below the mass-transport deposits yielded poor to moderately preserved radiolarian faunas, which could be dated as Bajocian to Bathonian (GAWLICK et al., 2018) on base of few species, which could be determined on species level. These radiolarites are in parts strongly silicified, tectonized and fractured. Two meters

below the contact radiolarites/mass-transport deposits occur, also in a channel fill, a reddish crinoidal limestone (Fig. 11). Such crinoidal turbidites were so far not detected in the Dinarides in the radiolaritic sequences of the trench-like basins fills with an infilling with blocks from the outer shelf region, that is the various coloured Hallstatt Limestone facies (details see LEIN, 1987; KRYSŤYN, 2008). In contrast, in the type-region of the Hallstatt Limestones, that are the Northern Calcareous Alps such crinoidal limestone turbidites are well-known from the trench-like basins fills, which carry the Hallstatt Limestone blocks (GAWLICK et al., 2007; MISSONI & GAWLICK, 2011a, b). These crinoidal limestones derive from areas with low sedimentation rates, that are the uplifted nappe fronts of the advancing Hallstatt nappes and their slopes, and can be compared with the depositional characteristics of the Middle Jurassic Vils Formation in the Northern Calcareous Alps (GAWLICK et al., 2009 and references therein).

The Bajocian–Bathonian sedimentary succession without allochthonous material underlies the mass-transport deposits (debris flows) consisting exclusively of far-transported Hallstatt Limestone components. This all confirms that the emplacement of this debris flow is therefore younger as Bathonian, similar as the emplacement of the mass-transport deposits of Pavlovića Čuprija or Vodena Poljana areas (GAWLICK et al., 2017a, b, 2018) or elsewhere in the Western Tethys Realm (GAWLICK & MISSONI, 2019).

The sedimentary rocks of the outer shelf region (Hallstatt facies) are found predominantly in sedimentary mélanges (GAWLICK & MISSONI, 2019 and references therein) and are interpreted to be incorporated in the deep-water troughs in front of the advancing nappe stack. Only in the Dinarides of Serbia or the Hellenides in Greece complete Hallstatt nappes were bulldozed by the obducting ophiolites onto the foreland. In the Dinarides such a Hallstatt nappe stack is preserved in the Vodena Poljana area (GAWLICK et al., 2017a, b), and in Greece the Pindos nappes (KOSTAKI et al., 2024). Generally, the thrust sheets of the former passive margin were successively fragmented

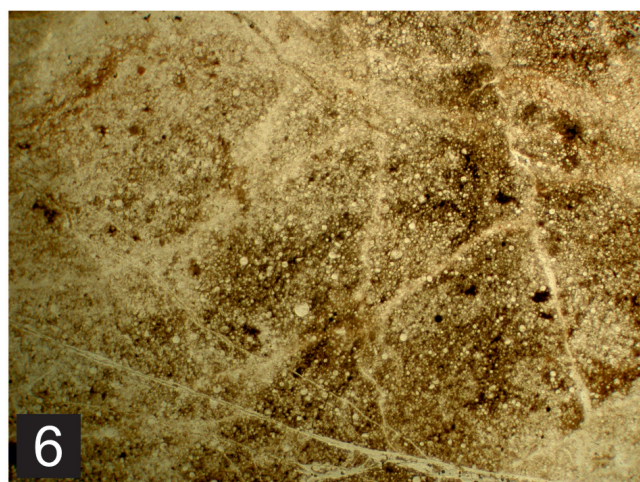


Fig. 11. Locality Bučevske Luke. Several Hallstatt Limestone mass-transport deposits above Middle Jurassic radiolarites. In channels appear occasionally crinoidal turbidites in the radiolarite sequence. **1.** and **2.** Showing the contact in some details of the various Hallstatt Limestone mass-transport deposits, which consists exclusively of Late Triassic components from the various coloured Hallstatt Limestone sequence. The contact of the mass-transport deposits to the underlying radiolaritic sequence is erosive. Therefore, the Bajocian–Bathonian age of the siliceous sequence can be only taken as minimum age of emplacement, which is most likely, younger (most probably Callovian). **3.** Overall photo of the locality with the achieved age data (from GAWLICK et al., 2017a). **4.** Detail from the lower part of the amalgamated mass-transport deposits showing the sedimentological character and various red and grey Hallstatt Limestone clasts. **5.** Microfacies from the intercalated crinoidal turbidite, preserved in a channel fill in the radiolaritic sequence. Width of the photo: 1.4 cm. **6.** Microfacies of the Bajocian–Bathonian radiolarites. Most radiolarians are recrystallized and appear as microquartz. Width of the photo: 1.4 cm.

and incorporated into the nappe stack in front of the westward obducting ophiolites, i.e. in a first stage the continental slope (Meliata facies, Grivska Formation), and later the outer shelf region (Hallstatt facies). The block composition of the Hallstatt Mélange is typical for the early evolution in mountain building process of the Neotethyan Belt (MISSONI & GAWLICK, 2011a, b). In the final stage, the nappe stack propagated from the outer to the inner shelf region (GAWLICK et al., 1999) forming a thin-skinned orogen.

Later, but still in the early Late Jurassic, the Hallstatt Mélange and various other mélanges, became overthrust by the ophiolitic mélange and the overlying ophiolites, in fact by the further westward transport of the obducted ophiolites in the frame of mountain uplift and unroofing (GAWLICK et al., 2020). This type of overthrust is related to the gravitational collapse (see RATSCHBACHER et al., 1991), is characterized by the appearance of OM3 type ophiolitic mélanges (see DJERIĆ et al., 2024), and the tectonic contacts are in fact low-angle normal faults.

The sedimentary basin fill of the Zlatar Mélange (= Pavlovića Čuprija Formation) is preserved below the Dinaridic Ophiolite nappe and is interpreted to be transported westward to its final position between the Drina–Ivanjica unit to the east and the East Bosnian–Durmitor megaunit to the west (GAWLICK et al., 2016, 2020), together with the ophiolitic mélanges and the ophiolites on top from the Tithonian onwards and lasted at least to the time around the Jurassic/Cretaceous boundary, when the Vranduk Formation and equivalents started to fill the underfilled remaining foreland basins (MIKES et al., 2008; GAWLICK et al., 2008).

Vodena Poljana area

Age: Hallstatt sequence nappe stacks with Middle to early Late Jurassic radiolaritic deep-water basin fill with a reworked Triassic open-marine Hallstatt Limestone sequence in between;

Provenance: Components from the outer shelf area (Hallstatt facies), Middle Jurassic basin formed above the Triassic to Middle Jurassic sedimentary sequence of the outer shelf area (various coloured Hallstatt Limestone facies belt);

Formations: Pavlovića Čuprija Formation, Zlatar Mélange; Hallstatt Limestone sequence;

Location: Zlatar Mt., between Nova Varoš and Sjenica.

The Hallstatt (Zlatar) Mélange (= Pavlovića Čuprija Formation) of the Vodena Poljana area (Fig. 4, stop 4b) is an optional stop during the field trip.

Lower Hallstatt nappe (Fig. 12): Above the shallow-water limestones of the Ravni Formation (Dedovići Member) the red nodular deep-water limestones of the Bulog Limestones were deposited (drowning sequence – SUDAR et al., 2013, 2023a, b, 2025 and references therein). A Late Pelsonian age of the Bulog Limestone sequence above the Ravni Formation could not be proven (SUDAR, 1986). Only Early–Middle Illyrian conodont assemblages could be isolated (SUDAR, 1986; GAWLICK et al., 2018). In the Late Illyrian deposition changed from red nodular limestones to reddish-violet radiolarites, in the upper part also greenish radiolarites appear. The overlying grey thick bedded to massive limestone (Hellkalk = massive grey limestone) with recrystallized radiolarians and thin-shelled bivalves reach the Julian 1/2 boundary. After a

gap, deposition of red nodular and dm-bedded limestone (Roter Bankkalk = red bedded limestone) started in the Middle Tuvanian, subsequently followed by the Early Norian (Lacian 1–2) Massiger Hellkalk (= massive grey limestone), and the latest Lacian to late Middle Norian (Alaunian) Hangendrotkalk (= upper red limestones), and the subsequent following Sevatian Hangendgraukalk (= upper grey limestone) which is in the Vodena Poljana area also red or reddish. Both the Roter Bankkalk and the Hangendrotkalk are characterized by the occurrence of red and grey chert nodules. The Hangendgraukalk (generally Late Norian) could not be distinguished lithologically from the Hangendrotkalk, but is proven by conodont assemblages (GAWLICK et al., 2018) and contain only few or no chert nodules. Above the red nodular limestone sequence dm-bedded grey siliceous limestones deposited. The lithological change is most likely in the Rhaetian, but could not be dated by conodonts. Upsection the amount of spicules and marl intercalations increases. This part of the section comprises most likely the Early Jurassic. Radiolarians from this part of the section are very badly preserved, but the occurrence of saturnallid radiolarians indicates an Early Jurassic age.

The turnover to radiolarite sedimentation is most probably around the Aalenian/Bajocian boundary, as elsewhere in the Western Tethys Realm. Deposition of siliceous sedimentary rocks starts with a thin-bedded radiolarite sequence. The lower radiolarite is condensed, strongly sili-cified and reddish to reddish-grey. Upsection the radiolarite colour changed to grey or blackish-grey. This part of the section contains Bathonian-Callovian radiolarian faunas (GAWLICK et al., 2018) and in the higher part the first polymictic mass-transport deposits are intercalated in this radiolarite succession. In this part of the radiolarite sequence appear various mass-transport deposits and blocks exclusively of various coloured Hallstatt Limestone facies belt provenance. Moreover, the component spectrum comprises in the lower mass-transport deposits only Late Triassic Hallstatt Limestone clasts (Fig. 12). Occasionally Early Jurassic spicula-

rich siliceous limestone clasts appear. Generally, the matrix between the components consists of a reddish and slightly siliceous matrix. Higher up in the basin fill the component spectrum is more variable, older Middle Triassic limestone clasts beside (Triassic) radiolarite clasts appear. Furthermore, the component size in the mass-transport deposits increases. The components are all angular, subangular or in cases also slightly rounded.

With the lithological change in the radiolarite sequence from reddish-grey colours to grey and in cases black colours a change in the basin geometry is indicated, which is confirmed by the appearance of the first mass-transport deposits soon after the lithological change in the radiolarite sequence. The change in the basin geometry and the first mass-transport deposits indicate an advancing Hallstatt nappe and the formation of a trench-like foreland basin. This trench-like foreland basin receives only material from the advancing upper Hallstatt nappe. The sedimentological trend is characterized by a coarsening-upward trend. Furthermore, the components in the upsection following mass-transport deposits and the blocks incorporated in the radiolarite matrix indicate deeper erosion into the upper Hallstatt nappe, down to the Anisian Ravni Formation. In the upper part of the basin fill m-sized to 10–20 m-sized blocks dominate (Fig. 12), and finally blocks of up to several 100 m appear showing a clear coarsening-upward trend of the basin fill. In this part of the basin fill blocks of the Ravni Formation are common. At the footwall of Mt. Krševa/Gulaver the thrust contact between the upper Hallstatt nappe (Ravni Formation) and the Hallstatt (Zlatař) Mélange is visible. This contact is relatively high in the mountains and will not be visited during this field trip. At least three hours climbing is necessary to reach these outcrops.

Upper Hallstatt nappe (Fig. 12): The sedimentary mélange (Zlatař Mélange) is overthrust by the Ravni Formation and its overlying Middle to Late Triassic Hallstatt sequence. The Zlatař Mélange is squeezed between two Hallstatt nappes.

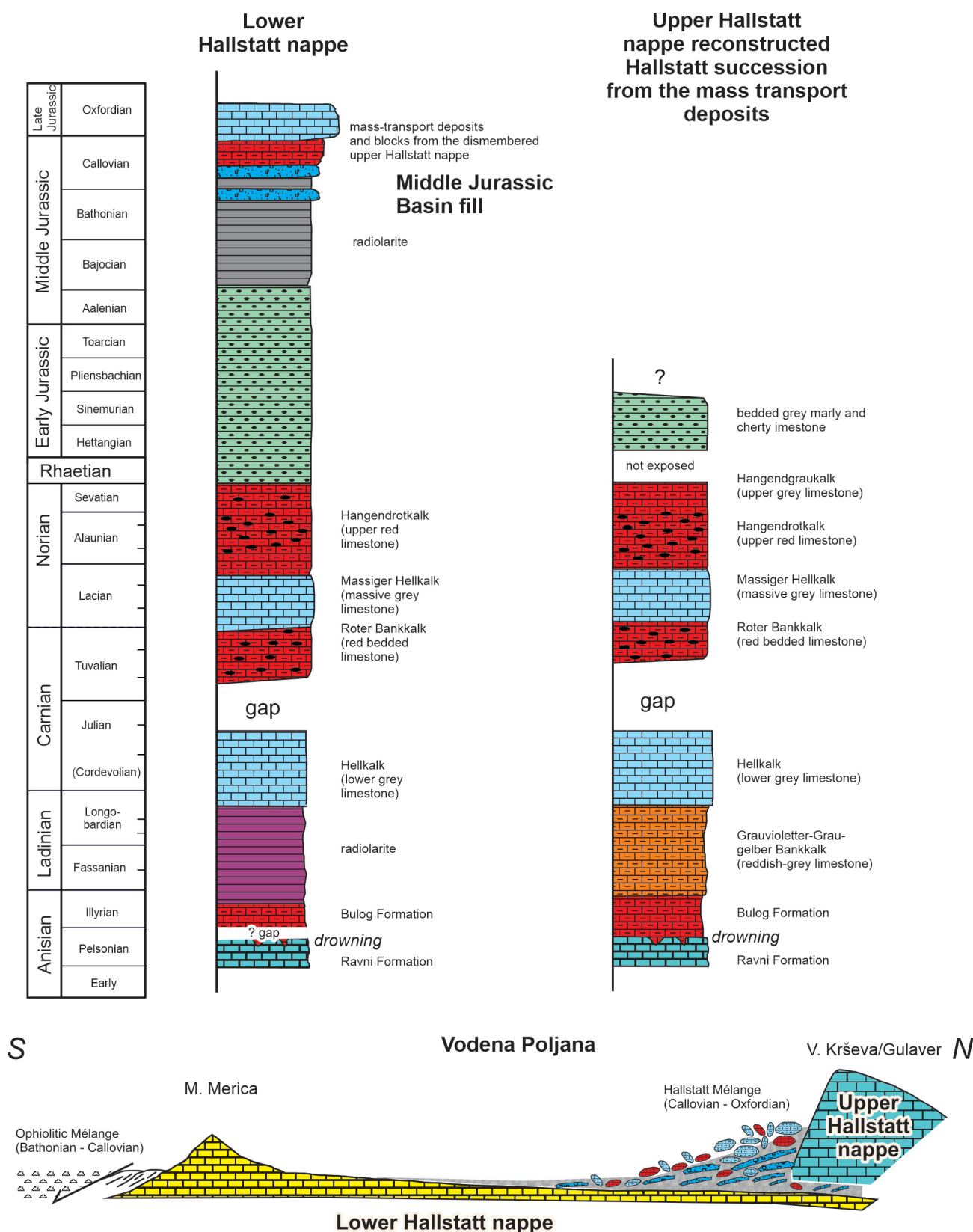


Fig. 12. Hallstatt Limestone sequence nappe stack of the Vodena Poljana area, modified and added after GAWLICK et al. (2017a, 2018). The lower Hallstatt nappe comprises a sedimentary sequence from the Middle Anisian (Ravni Formation, Dedovići Member) to the Middle Jurassic. The lower Hallstatt nappe carries the Hallstatt (Zlatar) Mélange, which were overthrust by the upper Hallstatt nappe. The thrust contact between the Hallstatt (Zlatar) Mélange and the Ravni Formation of the upper Hallstatt nappe is visible at the footwall of Mt. Krševa relatively high up in the mountains.

The sedimentary succession of the Upper Hallstatt nappe differs slightly from the Lower Hallstatt nappe. The sequence is reconstructed from the reworked pebbles and blocks in the *mélange* and remnants of the Middle-Late Triassic Hallstatt Limestone sequence which are preserved north of Mt. Krševa/Gulaver.

The sedimentological evolution starts with shallow-water limestones of the Ravni Formation (Dedovići Member), in cases dissected by neptunian dikes (Fig. 13). This drowning sequence of the Ravni Carbonate Ramp is well preserved in the active quarry at the main road from Nova Varoš to Sjenica, which belongs to the upper Hallstatt nappe (details in GAWLICK et al., 2018). Above the Late Anisian Bulog Formation during the Ladinian the reddish-grey limestones of the Grauvioletter-Graugelber Bank- kalk (reddish-grey or various coloured limestone) deposited, overlain by the Early Carnian Hellkalk (= lower grey limestone). Higher Julian or lower Tuvalian strata could not be improved. The Roter Bank- kalk (= red bedded limestone) contains red chert nodules and in cases chert layers. The Early Norian Massiger Hellkalk is overlain by red nodular limestones with red chert nodules (Hangendrotkalk = upper red limestone). The Hangendgraukalk (= upper grey limestone) is reddish-grey and free of chert nodules. In contrast to the lower Hallstatt nappe in the upper Hallstatt nappe the Hangendgraukalk can be easily lithologically distinguished from the Hangendrotkalk. Occasionally appear grey marly and siliceous limestones with spicules, which we attribute to the Early Jurassic. A biostratigraphic age dating of these pebbles in the mass-transport deposits was not possible.

For more details about the stratigraphy of the matrix and ages (based mainly on conodonts) and microfacies of the reworked components and blocks the interested reader is referred to GAWLICK et al. (2017a, 2018).

Pavlovića Ćuprija area

Age: Middle to early Late Jurassic radiolaritic deep-water basin fills with a reworked Triassic

open-marine various coloured Hallstatt Limestone sequence;

Provenance: Components from the outer shelf area (Hallstatt facies), Middle Jurassic basin formed above the Triassic to Middle Jurassic sedimentary sequence of the East Bosnian-Durmitor megaunit;

Formations: Pavlovića Ćuprija Formation, Zlatar Mélange;

Location: Zlatar Mt., west of Nova Varoš.

The Hallstatt (Zlatar) *Mélange* (= Pavlovića Ćuprija Formation) of the Pavlovića Ćuprija area is an optional stop during this field trip (Fig. 4, stop 4a). Depending on the time schedule we will visit only one of the most characteristic sedimentary *mélange* areas in the Zlatar Mt. We will visit either the Pavlovića Ćuprija area or the Vodena Poljana area to give insights into a late Middle to early Late Jurassic trench-like basin fill: in both cases a completely reworked Middle-Late Jurassic Hallstatt Limestone sequence is incorporated as mass-transport deposits or huge blocks in a radiolaritic matrix. These occurrences of the various coloured Hallstatt Limestone sequences were formerly seen as autochthonous open-marine sequences, deposited in an intraplatform basin between long-living Middle to Late Triassic Carbonate platforms, that is the Zlatar sub-basin of the Lim basin (PANTIĆ & RAMPNOUX, 1972; RAMPNOUX, 1974).

The sedimentary basin fill starts with a roughly up to 100 m-thick sequence of Middle Jurassic (DJERIĆ et al., 2007) reddish-violet siliceous claystones to radiolarites on the western side of the Uvac River (Fig. 14). This clayey radiolarite is defined as Zlatar Formation (GAWLICK et al., 2017a) and deposited below the sedimentary succession with the reworked material from the outer (Hallstatt) shelf region (= Pavlovića Ćuprija Formation) (Fig. 15). In fact, the radiolaritic-argillaceous matrix between the different mass-transport deposits and blocks (Fig. 16) can lithologically not be distinguished from the radiolarite sequence of the Zlatar Formation. The only difference is the occurrence of mass-transport deposits and slide

blocks in this deep-water matrix. The whole basin fill is at least more than 800 meters (GAWLICK et al., 2017a, 2018), but can only be roughly estimated based on the general dipping of the different strata. Furthermore, overlying rocks,

that are the ophiolitic mélanges and ophiolites of the Dinaridic Ophiolite nappe stack, are not preserved in that area. Therefore, the original thickness of this basin fill can be even thicker as preserved today.



Fig. 13. Field views of the Zlatar (Hallstatt) Mélange in the Vodena Poljana area. The different mass-transport deposits and blocks are incorporated in a radiolaritic matrix. **1.** Area with various blocks from the dismembered Hallstatt Limestone sequence including the underlying Ravni Formation in a radiolaritic matrix. **2.** Different view with different Hallstatt Limestone and Ravni Formation blocks. **3.** Late Triassic Hangendrotkalk block in a Callovian radiolaritic matrix. **4.-6.** Different mass-transport deposits with grey and red Hallstatt Limestone components. Most components are angular to subrounded.

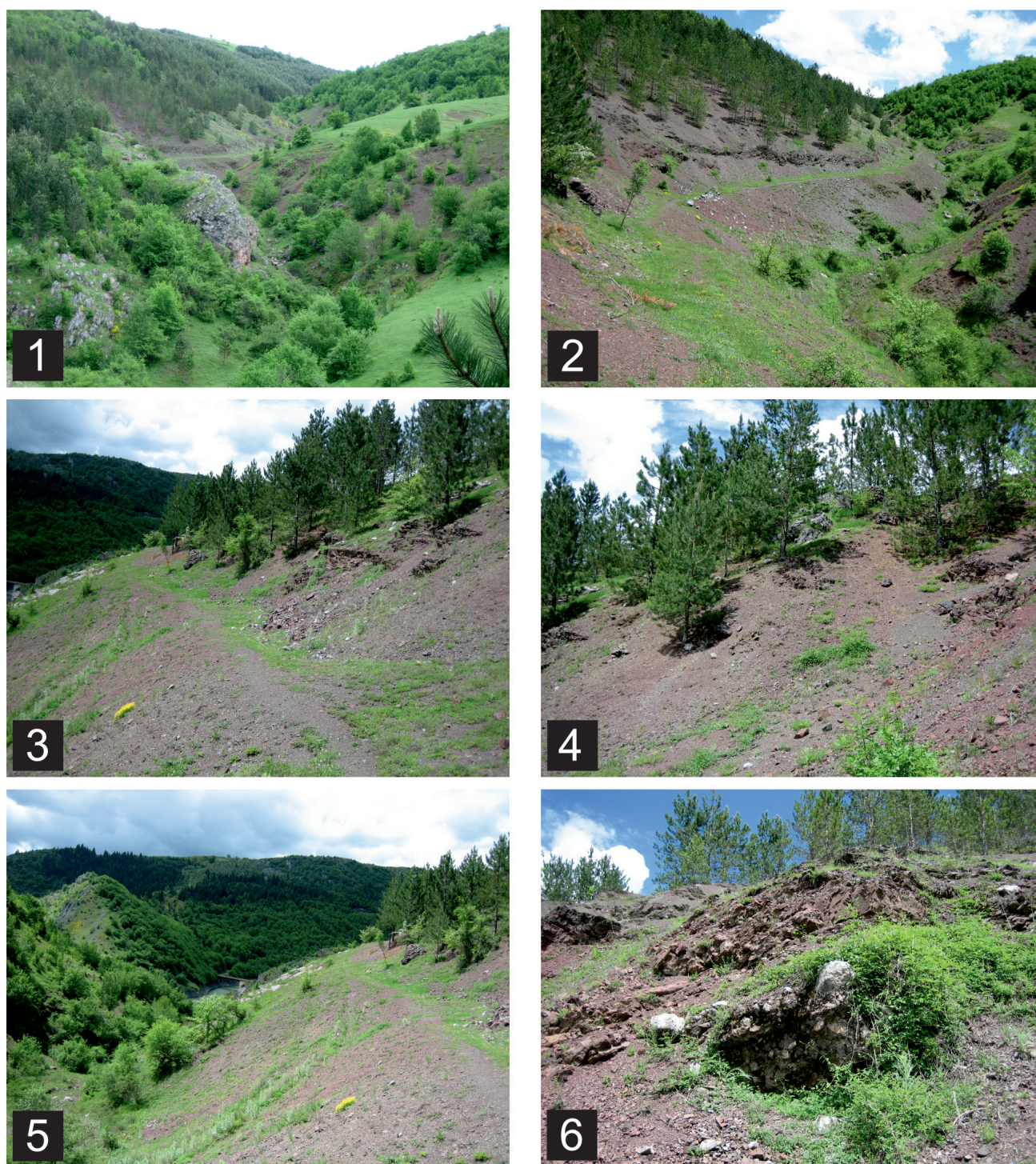


Fig. 14. Field photos of the lower part of the basin fill of the Pavlovića Ćuprija Formation (=Zlatar Mélange). **1.** Overview photo (view to the east) of the basal part of the basin fills. In the background the lowermost part of the basin fill is visible (see photo 2) which consists exclusively of red-violet siliceous claystones and clayey radiolarites of Middle Jurassic age (DJERIĆ et al., 2007). This part of the section corresponds to the Zlatar Formation. In the frontal part the middle part of the Pavlovića Ćuprija Formation is visible with 100 m-sized blocks of Hallstatt Limestones. Modified after GAWLICK et al (2017a). **2.** Type section of the Zlatar Formation at the base of the Zlatar Mélange basin fills (Pavlovića Ćuprija Formation). **3.** and **4.** Transition of the Zlatar Formation to the Pavlovića Ćuprija Formation visible by the onset of first mass-transport deposits in the radiolarite sequence. **5.** View to the west: overview above the middle and upper part of the basin fill with blocks of various sizes and age (but all from the Anisian to Late Triassic Hallstatt Limestone sequence) in the radiolarite matrix. **6.** Mass-transport deposits in the lower part of the basin fill. The mass-transport deposits do not exceed few meters in thickness and the pebble size is between few centimeters and a decimeter.



Fig. 15. Polymictic mass-transport deposits with components of a reworked Hallstatt Limestone sequence and blocks surrounded by radiolarites. **1.** Polymictic breccia with angular clasts from the Middle to Late Triassic Hallstatt sequence. Note beside the occurrence of grey and red limestone clasts the occurrence of red Middle Triassic radiolarite components. **2.** Grey and red subangular limestone clasts in a red marly and only slightly siliceous matrix. **3.** Various predominantly grey, but also red Hallstatt Limestone clasts in a mass-transport deposit near to the base of the Pavlovića Čuprija Formation. **4.** Meter to tens of meters sized blocks and breccias in the middle part of the basin fill surrounded by the radiolaritic matrix. **5.** Block of Hangendrotkalk surrounded by radiolarite. **6.** Block of Hangendgraukalk surrounded by radiolarite.

The various components in the polymictic mass-transport deposits are angular and sub-angular (Fig. 15). Beside the Hallstatt Limestone clasts appear Middle Triassic red radiolarite clasts, which contain beside recrystallized radiolarians also thin-shelled bivalves, in parts enriched in thin lumachelle layers. Only Triassic limestone and radiolarite clasts could be detected in the basin fill. Upsection in the basin fill appear tens of m-sized Hallstatt Limestone blocks surrounded by the radiolaritic-argillaceous matrix (Fig. 16), Jurassic components are missing in the component spectrum in contrast to the component spectrum in the Voden Polja na area. The reconstructed Early to Late Triassic sedimentary sequence (Fig. 17) starts with limestones of the “Bioturbated” Formation of late Early Triassic age. Upsection components of both members of the Ravni Formation (Utrine and Dedovići Members) could be determined.

The drowning section above the Dedovići Member of the Ravni Formation starts with Late Pelsonian limestones of the Bulog Formation. The Dedovići Member is intensively dismembered by neptunian dikes of Late Pelsonian age. In cases above the dissected Ravni Carbonate Ramp breccias of the Komarani Formation (SUDAR et al., 2023) are preserved. The occurrence of these breccias indicates that the deposition of the reworked Hallstatt Limestone sequence mirrors the depositional environment in graben position. This is also confirmed by the deposition of Late Illyrian to Fassanian radiolarites, which indicate deposition in a deep-water environment rather than deposition on a horst, where condensed various coloured Hallstatt Limestones of the Grauvioletter-Graugelber Bankkalk (reddish-grey limestone) were formed. However, components of the Ladinian Grauvioletter-Graugelber Bankkalk (reddish-grey limestone) were also rarely detected, but these limestones contain in contrast to the Grauvioletter-Graugelber Bankkalk (reddish-grey limestone) *sensu stricto* chert nodules. The occurrence of grey latest Ladinian to Early Carnian grey Hellkalk (lower grey limesto-

ne) components and blocks indicate the influence of the highstand shedding of the evolving Wetterstein Carbonate Platform.

Higher Julian and lower Tuvanian limestones could not be detected in the mass-transport deposits or the blocks (Fig. 17). A gap in deposition during that time span, as elsewhere in the Dinaridic realm, is the most convincing explanation for the missing of such components, even if blocks with the transition from the Early Carnian to the Late Carnian with the gap are not preserved (or detected) in the basin fill. The Late Carnian limestones are extreme condensed and contain chert nodules and in cases also chert layers. Lithologically the Roter Bankkalk (red bedded limestone) cannot be distinguished from the late Early to Middle-Late Norian Hangendrotkalk (upper red limestone). Here, in the late Early Norian red nodular limestone chert nodules are missing.

The Early Norian is characterized by deposition of the Massiger Hellkalk (massive grey limestone), which reflects the highstand shedding of the first cycle of the evolution of the Dachstein Carbonate Platform. The second main cycle of the progradation of the Dachstein Carbonate Platform in the late Middle to Late Norian is normally reflected by the lithological change from the Hangendrotkalk (upper red limestone) to the Hangendgraukalk (upper grey limestone). This change could not be observed in the blocks of the Pavlovića Ćuprija basin fill (Fig. 17). The only difference of the Late Norian Hallstatt Limestones is the overall missing of chert nodules, but also, they appear in cases.

For more details about the basin fill, available conodont faunas and details about the microfacies, radiolarian assemblages from the matrix beside other sedimentological details the interested reader is referred to GAWLICK et al. (2018).

4.3. The East Bosnian–Durmitor megaunit

The Triassic to Middle Jurassic sedimentary succession of the later East Bosnian–Durmitor megaunit was deposited in central shelf posi-

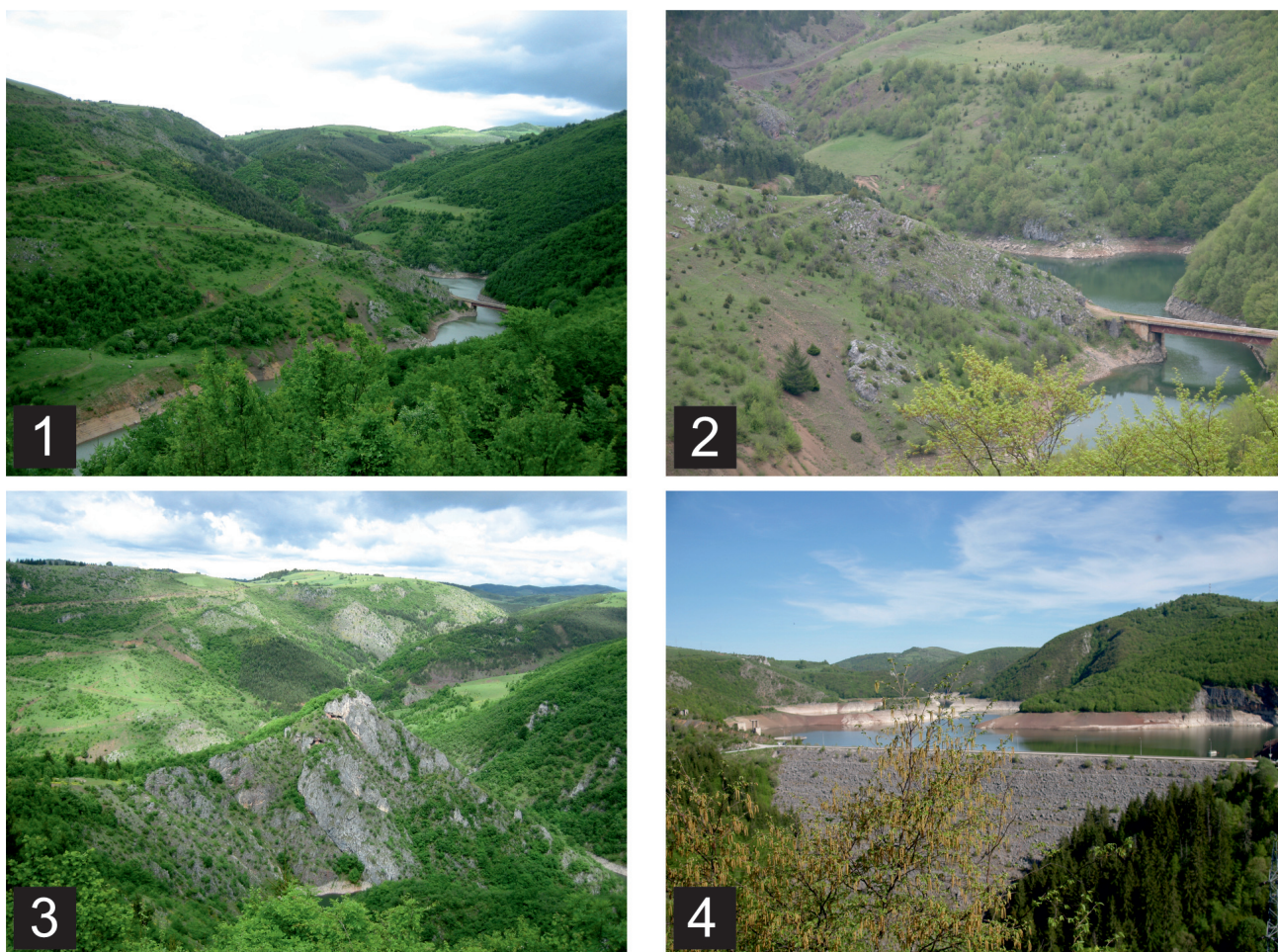


Fig. 16. Overview photos of the late Middle Jurassic basin fill of Pavlovića Ćuprija area. **1.** View along the Uvac River in south-eastern direction. Well visible is the occurrence of various blocks surrounded by radiolarites. **2.** Enlargement of 1 around the bridge with several Hallstatt Limestone blocks in the radiolarite matrix. **3.** View to the northwest with in cases huge slide blocks of several hundred to kilometer-size in the upper part of the basin fill. **4.** View behind the dam on the Sjenica Lake with relative low-water level. In cases of low-water level the contacts between the radiolarite matrixes and the different blocks is perfectly visible.

tion. The geological/sedimentological evolution is characterized by the deposition of shallow-water carbonates in the Anisian with the drowning sequence in the Late Pelsonian elsewhere and the formation of a horst-and-graben topography. For details about the Late Anisian to Ladinian depositional history the interested reader is referred to SUDAR et al. (2013, 2023a, b, 2025), GAWLICK et al. (2017a, 2023), and MRDAK et al. (2023, 2024, 2025a, b).

The next cycle of shallow-water carbonate production is represented by the Early Carnian Wetterstein Carbonate Platform. After the demise of the Wetterstein Carbonate Platform

carbonate production started again in the latest Carnian after a very long recovery period. During Norian–Rhaetian times the entire area was part of the lagoon of the Dachstein Carbonate Platform.

The diagenetic overprint of the East Bosnian–Durmitor megaunit is low to moderate and does not exceed 150–180 °C as determined by Colour Alteration Index data (MRDAK et al., 2023, 2024, 2025a). This diagenetic overprint contrasts significantly the diagenetic overprint of the overlying nappe stack, which does not exceed 60–90 °C, also determined on base of Colour Alteration Index data.

The sedimentological evolution of East Bosnian–Durmitor megaunit differs not significantly from the Drina–Ivanjica unit to the east. The facies show transitional character and the Triassic facies of the Drina–Ivanjica unit is quite similar, but shows in general a little more open-marine influence (compare MISSONI et al., 2012; SUDAR et al., 2013; GAWLICK et al., 2017a and references therein). Completely different is the diagenetic/thermal overprint of both units. In contrast to the East Bosnian–Durmitor megaunit the Drina–Ivanjica unit experienced a Late Jurassic metamorphic overprint (PORKOLÁB et al., 2019; GAWLICK et al., 2020 and references therein). Therefore, we attribute all non metamorphosed Triassic–Jurassic sequences to the East Bosnian–Durmitor megaunit where in addition also the different facies belts and their changes can be traced from the western (proximal) to eastern (distal) central shelf area, and the metamorphosed Triassic–Jurassic sequences to the Drina–Ivanjica unit. This contrasts the view of SCHMID et al. (2008, 2020) significantly and has as consequence, that the border between the Inner and Outer Dinarides is the contact between the metamorphosed units to the non metamorphosed units, and the western rim of the East Bosnian–Durmitor megaunit, where the facies transition to the slightly more in proximal shelf position deposited sedimentary sequences of the Pre-Karst unit is observable (MRDAK et al., 2025b). The diagenetic overprint of the East Bosnian–Durmitor megaunit and the Pre-Karst unit is identical. The Paleogene tectonics has in general minor influence on the architecture of the orogen (bauplan) of the Dinarides as the Jurassic one, and the shortening is limited (BRAVO-GUTIÉRREZ et al., 2024 and references therein).

Pliješevina section

Age: Early Carnian to Carnian/Norian boundary;

Provenance: East Bosnian–Durmitor megaunit;

Formations: Zložnica and Džegeruša formations;

Location: South-east of Gradac and south-west of Pljevlja near the village Donja Tikova.

The section Pliješevina (Fig. 5, stop 2.1) comprises the entire Carnian in deep-water facies. Of importance is the occurrence of a roughly 6 m-thick sequence of fine-grained siliceous siliciclastic sedimentary rocks, which were deposited above Early Carnian (Julian 1) deep-water limestones and below latest Carnian deep-water limestones with intercalated turbidites and microbreccias at the base of the shallow-water limestones of the Dachstein Carbonate Platform. Previous studies interpreted these rocks as parts of the Middle Triassic volcano-sedimentary successions despite the fact, that the Late Anisian to Early Ladinian volcano-sedimentary successions differ significantly in lithology, facies and component composition of the siliciclastic sedimentary rocks. However, Carnian fine-grained silicified siliciclastic sedimentary rocks were previously never detected or described in northern Montenegro (see e.g., Basic Geological Map of SFRY 1:100 000, Explanatory booklets of Sheets Pljevlja (MIRKOVIĆ & PAJOVIĆ, 1980), Gacko (MIRKOVIĆ, 1980), Žabljak (ŽIVALJEVIĆ et al., 1989); and Geological Map of SR Montenegro 1:200 000, ŽIVALJEVIĆ, 1989).

The section starts with a series of dm- to 30 cm-bedded siliceous limestones with intercalated turbidites with shallow-water material (Zložnica Formation – GAWLICK et al., 2017a). The thickness of the lowermost part of the succession can be only hardly estimated in the mainly covered area with bushes. This part of the sequence is age equivalent with the Wetterstein Carbonate Platform (Julian 1) in the East Bosnian–Durmitor megaunit (GAWLICK et al., 2017a; MRDAK et al., 2024) or elsewhere in the Dinarides (MISSONI et al., 2012; SUDAR et al., 2025). The age is proven by following conodont fauna: *Pseudofurnishius murcianus* VAN DEN BOOGAARD, and *Budurovignathus* sp. (MRDAK et al., 2023).

In the Early Carnian deep-water limestones the frequency of turbidite intercalations decreases upwards and a series of dark-grey siliceous limestones with occasionally preserved chert nodules were deposited around

the Julian 1/Julian 2 boundary. This part of the series contains beside the age diagnostic conodont *Mazzaella carnica* (KRISTYN) also *Neocavittella* sp. These siliceous limestones are overlain by ~1 m-thick grey marly siliceous limestones with radiolarians and filaments. The age of this part is also the *Mazzaella carnica* conodont Zone by the appearance of *Mazz. carnica*, *Gladigondolella malayensis* NOGAMI, *Pg. polygnathiformis* BUDUROV & STEFANOV, and *Pg. tadpole* (HAYASHI). The entire “drowning sequence” equivalent is represented by these turbiditic grey siliceous

micritic limestones without shallow-water material (Fig. 18).

The approximately 11 m-thick Middle-Late Carnian part of succession starts therefore with a less than 3 m-thick dark-grey siliceous limestone succession of the *Mazzaella carnica* conodont Zone (Julian 1/2 boundary) deposited below the Julian 2 to Late Tuvalian fine-grained silicified siliciclastic sedimentary rocks of the Džegeruša Formation. These dark-grey siliceous limestones correspond to the Göstling Formation in the North-

Pliješevina section

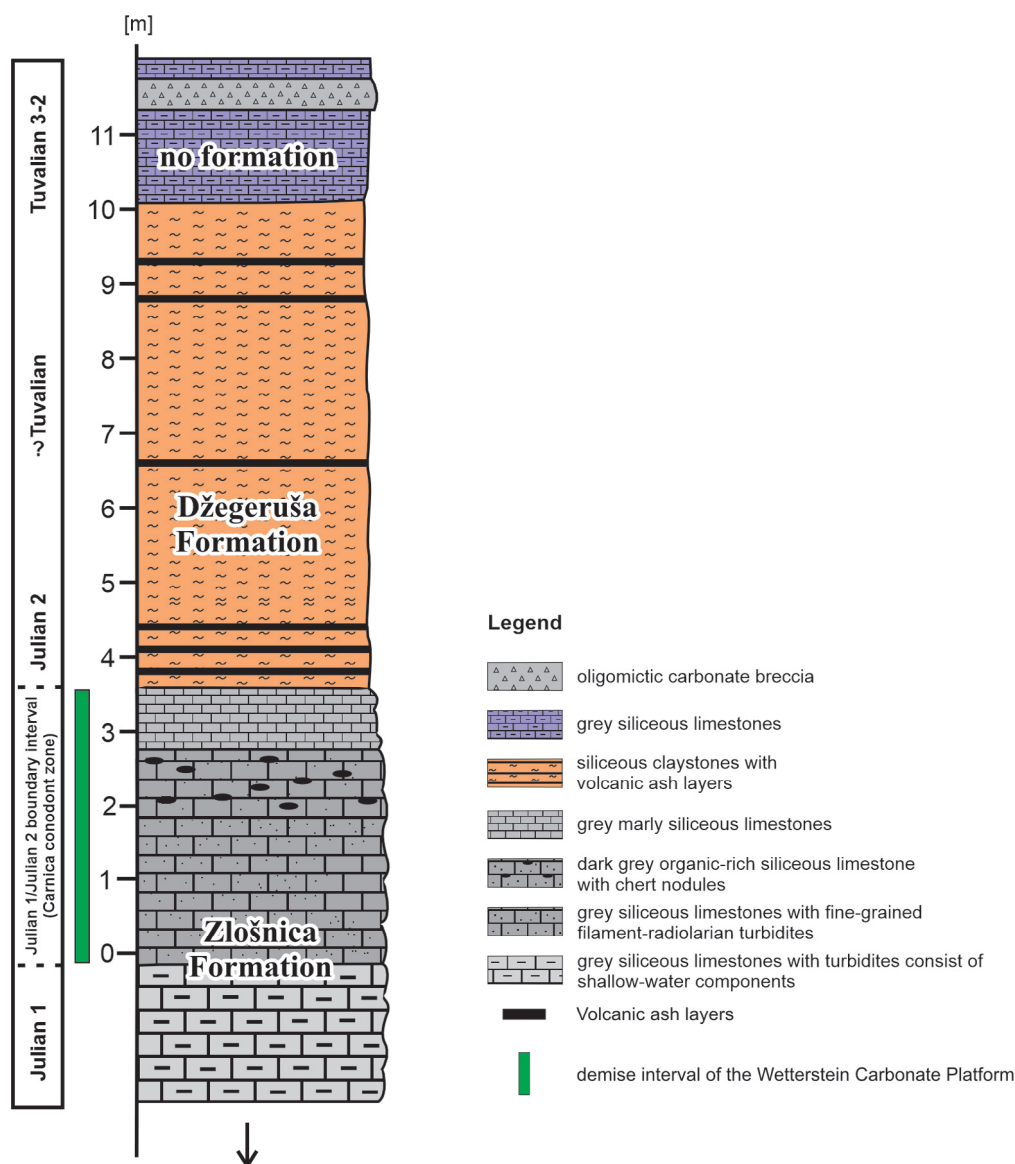


Fig. 18. The Carnian sedimentary succession near the village Donja Tikova in the Pliješevina area. Modified after MRDAK et al. (2023).

ern Calcareous Alps (LEIN et al., 2012), which also represent the basinal expression of the onset of the demise of the Wetterstein Carbonate Platform.

Upsection, the change in deposition from siliceous limestones to carbonate-free siliciclastic sedimentary rocks (Džegeruša Formation) is sharp (Fig. 19). The ~6.5 m-thick, predominantly laminated, reddish-brown, low-energy turbiditic clay to siltstones contain intercalated volcanic ash layers (Figs. 18, 19) and are overlain by a series of grey dm-thick, irregular bedded, siliceous limestones that alternate with oligomictic carbonate breccias containing shallow-water organisms. The Julian/ Tuvalian boundary lies within the siliciclastic series and cannot be determined (a continuous sedimentation through

the whole Julian–Tuvalian time span cannot be proven). The series of siliceous limestones that overlies the fine-grained siliciclastic sedimentary series belongs to the upper-most Tuvalian (no formation name), as proven by the appearance of following conodonts: *Neocavitella cavitata* SUDAR & BUDUROV, *Metapolygnathus* cf. *praecommunisti* MAZZA, RIGO & NICORA, *Pg. polygnathiformis*, *Pg. nodosa* (HAYASHI), and *Primatella circularis* (ORCHARD). Higher up in the succession oligomictic carbonate breccias appear, which contain clasts of the evolving Dachstein Carbonate Platform. This breccia level most probably marks the Carnian/Norian boundary and is a widespread known characteristic lithostratigraphic horizon (see below; ZÖHRER et al., 2026 and references therein).

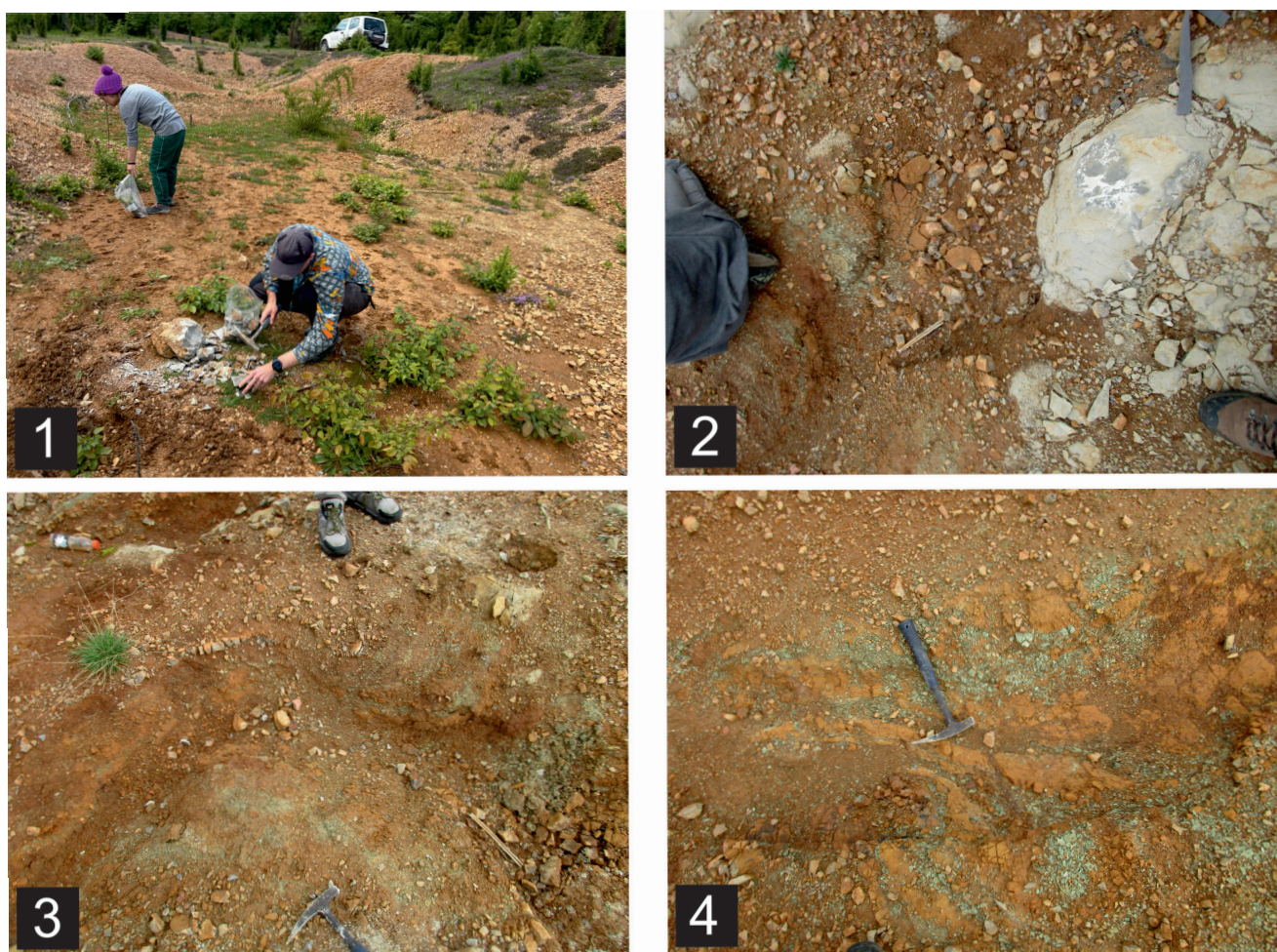


Fig. 19. Outcrop situation of the Carnian (Julian 1/2 boundary to Tuvalian) sedimentary succession near the village Donja Tikova in the Pliješevina area. **1.** Small local quarry with exposures of Carnian siliciclastics above the dark-grey marly limestones of the Julian 1/2 boundary. **2.** Contact between the dark-grey marly siliceous limestones and the fine-grained siliciclastics with greenish volcanic ash layers. **3.** Excavation of the sedimentary series of the late Middle Carnian to Tuvalian fine grained siliciclastics with intercalated volcanic ash layers. **4.** Layered silt- and claystones with intercalated greenish volcanic ash layers.

For more details about the section, e.g., conodont faunas, microfacies characteristics, or clay mineralogy including the sample numbers the interested reader is referred to MRDAK et al. (2023).

Mihajlovići section

Age: Late Triassic to Middle/Late Jurassic sedimentary succession; Middle Jurassic ophiolitic mélange;

Provenance: East Bosnian–Durmitor megaword; ophiolitic mélange with material from the Neo-Tethys Ocean floor;

Formations: From lagoonal Dachstein Limestone (Norian–Rhaetian) to grey oncolidal limestones (Mihajlovići Formation), overlain by the Krš Gradac Formation (red nodular limestones) and the radiolarites of the Gonje Formation;

Location: Village Vijenac on the road from Prijepolje (Jabuka) to Pljevlja.

The description of the section Mihajlovići in the village Vijenac follows the recent published papers of this locality (GAWLICK et al., 2020; ĐAKOVIĆ et al., 2021; GORIČAN et al., 2022). For more details interested readers are referred to these publications.

Approximately 10 km ESE from Pljevlja, a latest Triassic to Middle Jurassic sedimentary succession is developed (Fig. 5, stop 1.4 or 4.1). The section starts at the parking place of a restaurant, where the latest Triassic lagoonal Dachstein Limestone is outcropping. The lagoonal Dachstein Limestone is recrystallized and is characterized in its topmost part by an erosional unconformity (karstification). Above the unconformity deposited oncolidal shallow-water limestones, which fill also the karst depressions. The gap between the lagoonal Dachstein Limestone and the overlying Early Jurassic oncolidal limestones cannot be exactly dated, but is most likely related to the global sea-level drop at the Triassic/Jurassic boundary. Flooding of the emerged Dachstein Carbonate Platform is widespread dated as Middle/Late Hettangian. Therefore, between these two formations a

longer gap with erosion/karstification is normal sedimentological feature elsewhere in the Western Tethys Realm.

Along the road to the Jurassic part of the succession and on the eastern slope of the small hill with the preserved Jurassic part of the section (Fig. 20) these oncolidal limestones of the Mihajlovići Formation (introduced below) can be studied. This part of the succession contains only rarely some open-marine organisms like crinoids. Higher up in the Early Jurassic oncolidal limestones the mainly grainstones and packstones contain benthic foraminifera and crinoid ossicles, with rare detritus of open marine organisms. In contrast, in its lower part, the limestones contain a lot of micro-oncolids, the number and size of which decreases upsection, whereas the number of benthic foraminifera and crinoid ossicles increases. This indicates a slight deepening trend. Based on foraminifera assemblages, RABRENOVIĆ et al. (2012) and GAWLICK et al. (2020) assigned Middle/Late Hettangian to Sinemurian age to this member. Exact dating is only possible based on the ammonites above this part of the succession, from which ammonites could be isolated and allowed to date the stratigraphic range of the oncolidal limestones until the Late Pliensbachian. This ammonite-bearing wacke- to packstones contain brachiopod and bivalve shells, crinoid ossicles, rare foraminifera and ammonoid shells. Micro-oncolids are very rare. This Late Pliensbachian part of the section is bounded by a lower and an upper gap/hardground. The lower hardground separates the predominantly grey and high energy shallow-water oncolidal limestones from the reddish-grey deeper-water ammonite bearing Late Pliensbachian limestones. Based on microfacies analysis and overall composition of foraminifera assemblages, Early Pliensbachian to early Late Pliensbachian age was assigned to this member by ĐAKOVIĆ et al. (2021, see discussion therein). Yet, the biostratigraphic resolution of foraminifera (BLAU, 1987a, b; BLAU & GRÜN, 1994, 1997) is not precise enough to allow this subdivision. However, the higher part of this roughly 1 m-thick Late

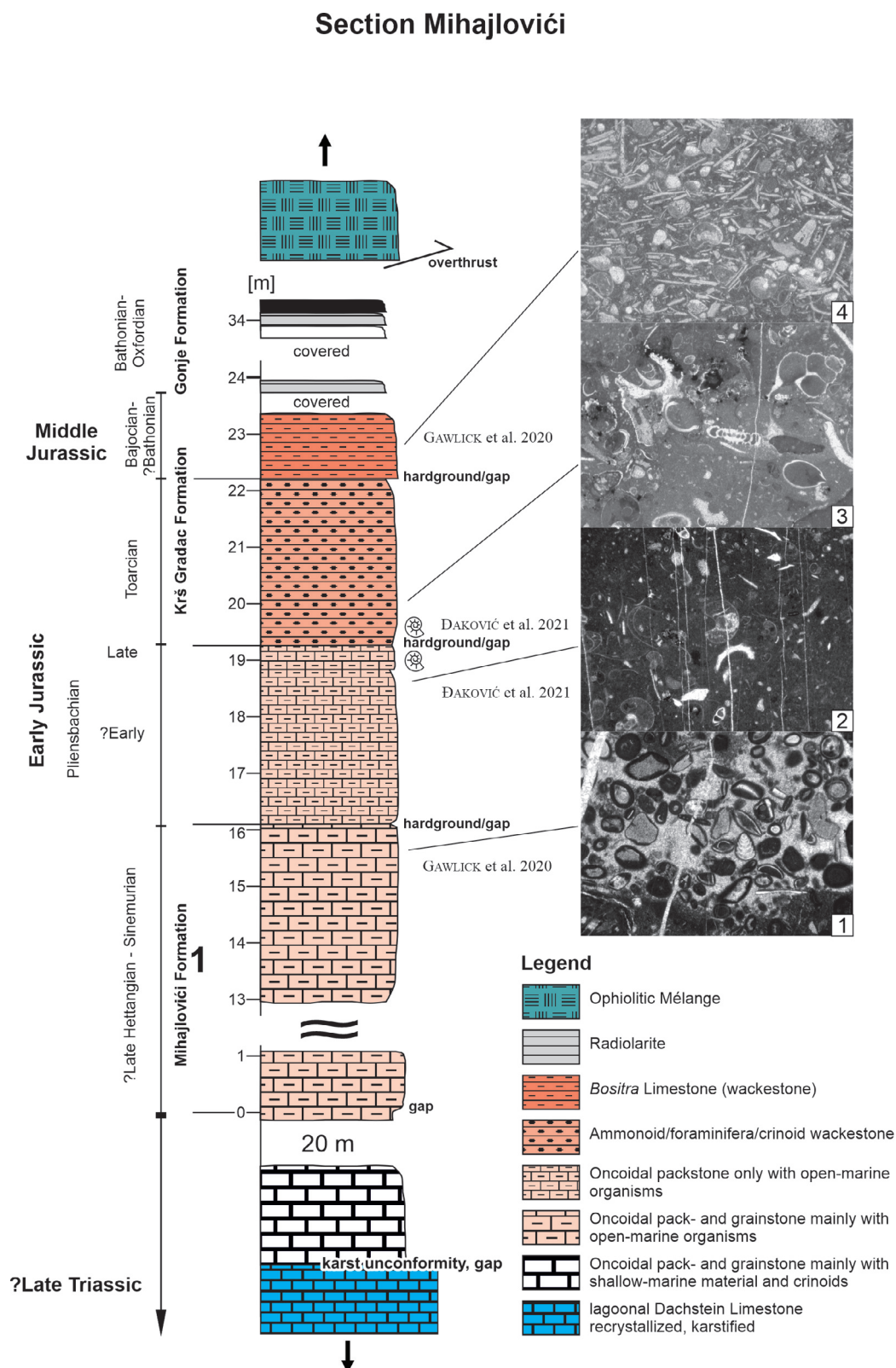


Fig. 20. Section Mihajlovići, redrawn and added after GAWLICK et al. (2020), ĐAKOVIĆ et al. (2021), and GORIČAN et al. (2022) with indication of the Jurassic formations and the characteristic microfacies of the different formations. **1.** The higher Mihajlovići Formation consists of oncooidal limestones with open-marine organisms like crinoids. **2.** The Late Pliensbachian hardground with ammonites shows a wacke-to packstone microfacies with exclusively open-marine organisms like ammonites. **3.** Packstone facies of the lower Krš Gradac Formation with gastropods, broken shells, and involutinid foraminifera. **4.** The Middle Jurassic is characterized by the Bositra microfacies.

Pliensbachian part of the succession contains ammonoids of the *Fucinieras lavinianum* Zone, i.e. early Late Pliensbachian (ĐAKOVIĆ et al., 2021). Microfacies types are characteristic of a low-energy deeper-water environment, indicating a continuous deepening and decrease in carbonate production. The exact biostratigraphic age dating by ammonites shows, that the deepening in this part of the Dinarides is younger as known from the Southern Alps (JADOUL et al., 2005; JADOUL & GALLI, 2008; MASETTI et al., 2017) or the Apennines (MANCINELLI et al., 2005), where the deepening of the Calcare Grigi Group and equivalents was dated as Early Sinemurian (MASETTI et al., 2017).

The upper hardground marks the change in deposition to red nodular limestones (Toarcian to Middle Jurassic).

Directly above a Fe/Mn-crust marking the hardground, a rich ammonoid fauna of Middle Toarcian age was described by many authors (RADOIČIĆ-BRSTINA, 1956; METODIEV et al., 2013; ĐAKOVIĆ et al., 2021). For this reason, a general Toarcian age was assigned to this part of the section by GAWLICK et al. (2020) and ĐAKOVIĆ et al. (2021), since the rest of these red nodular limestones do not contain age diagnostic fossils like ammonites. Further deepening continues after this gap/hardground, reflected by the formation of red nodular and condensed limestones (Ammonitico Rosso Facies: FLÜGEL, 2004 and references therein). Ammonoids, foraminifera and crinoids are common in wackestones and packstones.

After another gap/hardground deposited condensed nodular *Bositra* Limestones (FLÜGEL et al., 2004 and references therein), which contain juvenile ammonoids, crinoids and bivalves. The microfacies with a lot of lithoclasts and Fe/Mn crusts are characteristic for a very slow sedimentation, typical for a hemipelagic open marine environment with reduced carbonate production. Based on high abundance of *Bositra* shells, and *Globochaete* spores and rare foraminifera, a Bajocian/Bathonian age was assigned by RABRENOVIĆ et al. (2012), GAWLICK et al. (2020) and ĐAKOVIĆ et al. (2021).

These Toarcian to Bathonian–(Callovia) red nodular limestones are assigned to the Krš

Gradac Formation in SW Serbia. The Krš Gradac Formation is overlain by dark gray and dark red radiolarites of Gonje Formation of Bathonian to Oxfordian age (GAWLICK et al., 2020) as dated on base of radiolarian assemblages of the type section Krš Gradac. In Montenegro, GORIČAN et al. (2022) have dated two samples of red radiolarites from this formation, several kilometers to the east of Mihajlovići section, determining in them radiolarian associations of Middle–Late Oxfordian to Late Oxfordian–Early Kimmeridgian, and Late Oxfordian–Early Kimmeridgian to Late Kimmeridgian–Early Tithonian. However, these ages show that radiolarite deposition lasted from the Middle Jurassic to the higher part of the Late Jurassic and improve, that the emplacement of the ophiolites in that area is not older as Late Kimmeridgian/Early Tithonian, and therefore age equivalent to the emplacement of the ophiolites in the Krš Gradac section in southwest Serbia (GAWLICK et al., 2020). In Krš Gradac below the ophiolites an OM3 is proven, which is covered in the area of the Mihajlovići section. The succession in Mihajlovići is overthrust by ophiolitic mélange (GORIČAN et al., 2022), but it cannot be decided if it is an OM2 or OM3. However, the dark-grey radiolarites between the *Bositra* Limestones and the red radiolarite of a nearby section is not dated. The red radiolarite is missing in the section Mihajlovići.

Definition of the Mihajlovići Formation

Validity: Valid, description herein.

Type section/area: Section Mihajlovići in northern Montenegro.

Reference section/area: Krš Gradac section in southwestern Serbia.

Synonyms: No synonyms known. Mapped as part of the Dachstein Carbonate Platform.

Derivation of name: After the section Mihajlovići.



Fig. 21. Previous page: Outcrop situation of the latest Triassic to Late Jurassic Mihajlovići succession. **1. and 2.** Triassic/Jurassic boundary: the latest Triassic Dachstein Limestone is characterized by karstification, visible by the yellowish to reddish colours and recrystallized. Above the karst unconformity thick-bedded oncoidal limestones of the Early Jurassic filled the karst unconformity. **3.** Thick-bedded oncoidal limestones (Sinemurian). **4.** Transition of the thick-bedded Sinemurian oncoidal limestones to the thin-bedded slightly reddish oncoidal limestones of Pliensbachian age. **5.** View on the Toarcian hardground with the overlying red limestones of Middle Jurassic age. **6.** Toarcian hardground with ammonoid shell. **7.** Thin-layered red Bositra Limestone of Middle Jurassic age above the Toarcian hardground. **8.** Ophiolitic mélangé above the Middle Jurassic to Oxfordian radiolarite on the opposite side of the road in the hanging wall of the Jurassic part of the Mihajlovići succession.

Lithology: Massive to thick-bedded oncoidal limestones.

History: No history, not detected or studied. First description in GAWLICK et al. (2017a). Later studied in more detail by GAWLICK et al. (2020). Hanging wall boundary exactly dated in ĐAKOVIĆ et al. (2021).

Origin, facies: Deposition on top of the drowned Dachstein Carbonate Platform after their demise at the Triassic/Jurassic boundary and the age-equivalent mass extinction.

Chronostratigraphic age: ?Middle/Late Hettangian to Late Pliensbachian in the type area. In more distal areas of the shelf the chronostratigraphic age can be probably slightly shorter. In contrast, deposition of these oncoidal limestones in direction to the Adriatic Carbonate Platform basement according to VLAHOVIĆ et al. (2005), that is the *Lithiotis* platform may last a little longer. Shelf area, formed on top of a topographic high, the drowned Dachstein Carbonate Platform. Thickness: 20–30 m according to the present knowledge.

Underlying units (footwall boundary): Rhaetian lagoonal shallow-water limestones of the Dachstein Carbonate Platform. Between the lagoonal Dachstein Limestone and the oncoidal limestones of the Mihajlovići Formation a gap appears. This gap comprises the sea-level regression-lowstand to transgression. The transgression and flooding of the emerged and slightly karstified Dachstein Limestones is dated on different places in the Western Tethys Realm as Middle/Late Hettangian (BÖHM, 2003; HAAS, 2012; CSÁSZÁR et al., 2012).

Overlying units (hanging wall boundary): Krš Gradac Formation. Red nodular limestones, dated by ammonoids (ĐAKOVIĆ et al., 2021 and references therein).

Geographic distribution: Expectable all over the Dinarides/Albanides/Hellenides in the transitional area between the Adriatic Carbonate Platform basement and the open-marine shelf area, where red nodular limestones were deposited directly above the shallow-water limestones of the Dachstein Carbonate Platform. In Montenegro this facies is, except the Mihajlovići section, known also in the area of Lipova Ravan, north of Nikšić (M. ĐAKOVIĆ, unpublished data), mapped as Late Triassic in the Basic Geological Map.

Lateral units: Limestones below and of the *Lithiotis* Platform *sensu stricto* (Pliensbachian–Toarcian: SCHLAGINTWEIT et al., 2006; GAWLICK & SCHLAGINTWEIT, 2019) in direction to the more proximal (western) areas and red nodular limestones in direction to the Neo-Tethys to the east.

Remarks: The Mihajlovići Formation resembles in lithology and in microfacies age equivalent oncoidal limestones in the Southern Alps (Italy) (BERNOULLI et al., 1990; JADOUL et al., 2005; JADOUL & GALLI, 2008) or the Transdanubian Range (Hungary) (HAAS, 2012 and references therein; CSÁSZÁR et al., 2012). In the Southern Alps in cases this facies deposited with some microfacies variations until the Toarcian (MASETTI et al., 2012). Originally the oncoidal limestone below the red nodular limestone sequence was included in the Krš Gradac Formation (GAWLICK et al., 2017a) as lowermost member of the Krš Gradac Formation. Reason was lithology and microfacies of the uppermost part of the oncoidal limestone succession: "... grey-

reddish thick-bedded nodular limestone sequence with oncoids, ammonoids, ostracods, rare radiolarians, benthic foraminifera and crinoids with an Early Toarcian hardground on top dated by ammonites (ĆIRIĆ, 1954)" (GAWLICK et al., 2017a). In the Mihajlovići section this uppermost part of the oncoidal limestone sequence was recently exactly dated with ammonites as Late Pliensbachian (ĐAKOVIĆ et al., 2021), and the hardground with ammonites above is Early Toarcian (RABRENOVIĆ et al., 2012; ĐAKOVIĆ et al., 2021). This Early Toarcian hardground marks also an abrupt change in lithofacies to red nodular limestones, whereas the Late Pliensbachian part marks the transition from shallow-water oncoidal limestones without open-marine organisms, to condensed red nodular limestones. Therefore on base of these results the lower member of the former Krš Gradac Formation could be separated and is now defined as Mihajlovići Formation.

4.4. The Late Jurassic nappe stack in northern Montenegro

In the area between Gradac and Šula in northern Montenegro, situated around and west of the Čehotina River, various different Middle and Late Triassic deep-water limestone successions in a far-travelled nappe stack are preserved. Therefore, this area was according to PANTIĆ & RAMPNOUX (1972) and RAMPNOUX (1974) defined as (par)autochthonous deep-water intraplateau basin, that is the Čehotina sub-basin of the Lim basin.

However, beside several sedimentary successions in that area which belong to the East-Bosnian Durmitor megaunit in that area also exists preserved sedimentary sequences which derive from the outer (Hallstatt) shelf or the continental slope. The (par)autochthonous sequences below the far-travelled nappe stack preserve the Late Pelsonian drowning of the Ravni Carbonate Ramp and its overlying deep-water drowning sequence, which are the different formations of the Bulog Group (SUDAR et al., 2023b). Above the Bulog group follows a

lithologically variable Ladinian deep-water sedimentary sequence (MRDAK et al., 2025a, b), in most cases topped by limestones of the prograding Wetterstein Carbonate Platform. The drowning sequence of the Wetterstein Carbonate Platform around the Julian 1/2 boundary was described by SUDAR (1986) and MRDAK et al. (2023), and is part of our field trip programme. In the Late Triassic (Norian–Rhaetian) elsewhere in northern Montenegro lagoonal Dachstein Limestone was formed after the flooding of the emerged Wetterstein Carbonate Platform throughout the Middle–Late Carnian (MRDAK et al., 2023; ĐAKOVIĆ et al., 2024; MRDAK, 2025; MRDAK et al., 2025a, b). That means, that in northern Montenegro a Middle to Late Carnian stratigraphic gap exist, that is a time of no deposition or no formation of sediments. Only in rare cases, in remaining deep-water depressions between the formerly prograding Wetterstein Carbonate Platforms a thin series of siliciclastic sedimentary rocks were deposited, that is the Džergeruša Formation (GAWLICK et al., 2017a), which is proven in southwestern Serbia and northern Montenegro (MRDAK et al., 2023).

However, these deep-water siliceous fine-grained siliciclastic sedimentary rocks deposited locally in the Middle–Late Carnian can not be attributed to an intraplateau basin. After the demise of the Wetterstein Carbonate Platform around the Julian 1/2 boundary no shallow-water carbonate production could be recognized throughout the Middle–Late Carnian. Carbonate production in northern Montenegro, i.e. in the East Bosnian–Durmitor megaunit started again in the latest Carnian respectively around the Carnian/Norian boundary and gave rise for the evolution of the huge Norian–Rhaetian Dachstein Carbonate Platform with its reef rim in the area between the Drina–Ivanjica unit and the Jadar unit, where carbonate production started earlier (Tuvalian 2: MISSONI et al., 2012).

All sections described in this chapter should be – according to PANTIĆ & RAMPNOUX (1972) and RAMPNOUX (1974) – part of the Čehotina sub-basin of the Lim basin, but were never studied in detail like most of the sections in the entire

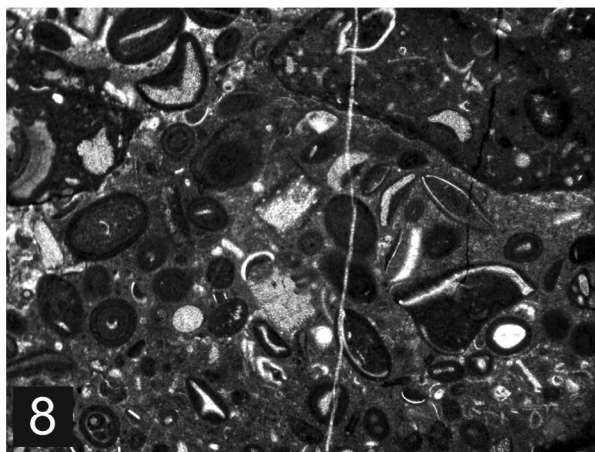
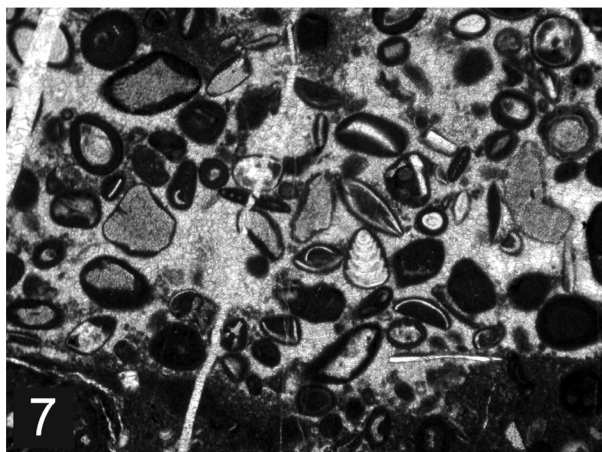
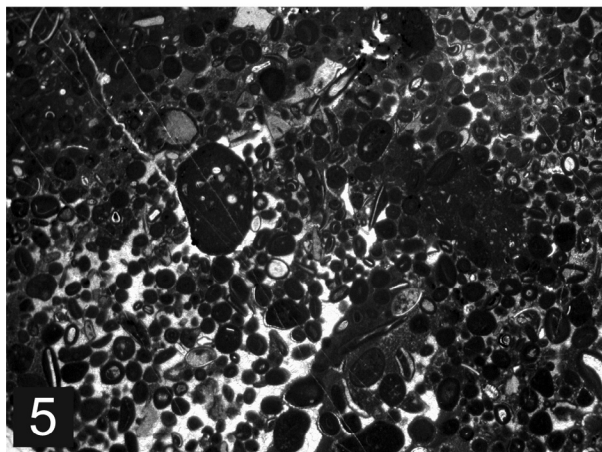
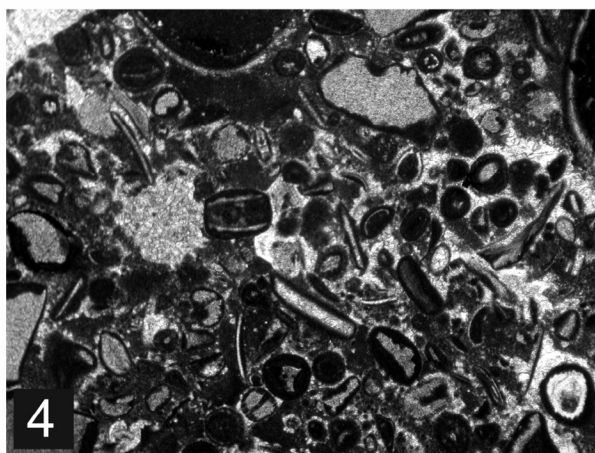
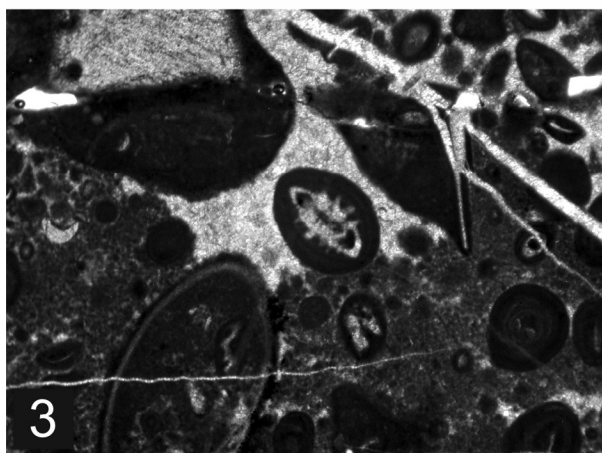
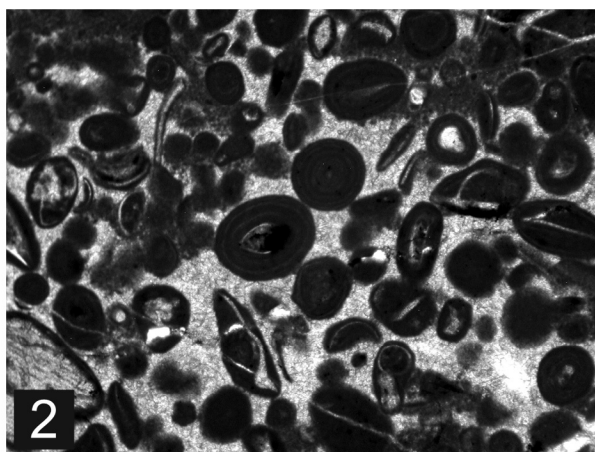
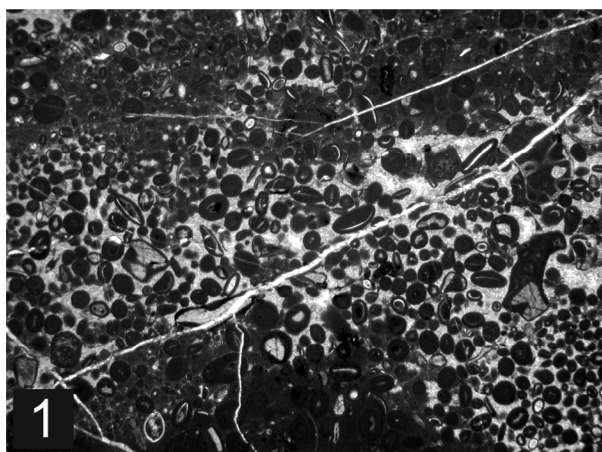


Fig. 22. Characteristic microfacies of the oncoidal limestones of the Mihajlovići Formation from the type-locality. The identical microfacies characteristics of the reference section Krš Gradac in Serbia is figured in GAWLICK *et al.* (2020). **1.** Oncoidal pack- to grainstone. The core of the oncoids consists of different organisms or broken shells, e.g., bivalves, crinoids, foraminifera. Sample SRB 535. Width of the photo 1.4 cm. **2.** Oncoidal grainstone. The different oncoids have layered micritic rims. Sample SRB 535. Width of the photo 0.5 cm. **3.** Oncoidal pack- to grainstone. In the middle an oncoid with *Involutina liassica* JONES as core. The micritic layers are in cases multiple, but often are also single rims. Sample SRB 535. Width of the photo 0.5 cm. **4.** Oncoidal pack- to grainstone with a lot of crinoids as core. Sample SRB 536. Width of the photo 0.5 cm. **5.** The size of the different oncoids is variable. Some oncoids have determinable foraminifera (e.g., *Involutina liassica* JONES) as core. Sample SRB 537. Width of the photo 1.4 cm. **6.** In the grainstone part appear plenty crinoidal fragments, whereas in the packstone part foraminifera and bivalve shells are more common. Sample SRB 538. Width of the photo 1.4 cm. **7.** Detail of 6, oncoidal grainstone with foraminifera and crinoids. Width of the photo 0.5 cm. **8.** Detail of 6, oncoidal packstone with shell fragments in the core of the oncoids. Width of the photo 0.5 cm.

area. Only the sections along the Čehotina River Canyon and a section near Rudine (Rudine–Veliko Brdo) were described by SUDAR (1986), and belong to this unit. The section in the area Velepölje–Crno Brdo–Vrbica northeast of Gradac (SUDAR, 1986) does not belong to this unit and was attributed by MRDAK (2025) to the East Bosnian–Durmitor megaunit.

The description of the sections is arranged according to the facies belts from proximal to distal, that is in direction to the outer (Hallstatt) shelf respectively the continental slope. The sections Poros A, B, C and the Pračica sections A and B derive from the Dachstein Carbonate Platform reef rim transitional to the outer shelf. The section Čehotina River represents a provenance area from the reef near outer shelf that is the grey Hallstatt Facies (Gučvo facies). The section Nange–Jabučno derives from the Middle Triassic to Middle Jurassic continental slope, that is the most distal facies of the passive continental margin facing the Neo-Tethys to the east and is the earliest nappe formed by the onset of ophiolite obduction in the Middle Jurassic. This nappe rests on top of the nappe stack bulldozed by the obducting ophiolites in westward directions. Today this nappe stack is preserved in the pull-apart structure related to the creation of the Miocene Pljevlja basin with its coal-bearing sedimentary rocks and represents one of the far-travelled nappe stacks in the Outer Dinarides. In this nappe stack several facies belts are preserved in complete successions, which are very rarely preserved in all different mountain ranges in the Western Tethys Realm and provide unique insights in the evolution of the different facies belts of the outer shelf region, very often only

preserved as blocks of variable size in the different radiolaritic-argillaceous mélanges (GAWLICK & MISSONI, 2019 for an overview).

Poros sections: section Poros A

Age: Late Triassic, Late Carnian to Middle Norian;

Provenance: From the outer shelf area near to the Dachstein Carbonate Platform reef-rim to open marine grey Hallstatt facies;

Formations: Dachstein reefal and fore-reefal limestone and variation of the Gučvo facies;

Location: West of Gradac on the road from Gradac to Šula, southeast of the village Poros.

The section Poros A (Fig. 5, stop 3.1) comprises reefal to fore-reefal Dachstein Limestones with intercalated open marine limestones. These open-marine “filament”-rich wacke- to packstones with intercalated carbonate turbidites with shallow-water clasts and organisms resembles the Gučvo facies, even the Gučvo facies in the type area is metamorphosed. Together with the other reef-near sections of that area this clearly evidences the transition of the reef-near depositional realm of the Gučvo facies without coarse-grained reefal material or reef or fore-reef intercalations to the Dachstein Carbonate Platform reef rim (ZÖHRER *et al.*, 2026). Moreover, it obviously demonstrates that the Dachstein Carbonate Platform reef rim was during the entire Norian a relatively wide facies belt, that is today not anymore preserved in the Inner Dinarides, that is the area of today’s Drina–Ivanjica unit to the Jadar unit.

The sedimentary succession of the section (Fig. 23) starts in the latest Carnian, as proven by the co-occurrence of the conodonts *Mp. praecommunisti*, *Mp. communisti* HAYASHI, and an *Carnepigondolella* sp. Around the Carnian/Norian boundary an oligomictic microbreccia was deposited with a mixture of open-marine limestones and reefal derived grainstone components. Upsection follow coarse-grained turbidites, both intercalated in thick-bedded open-marine micritic limestones, which could not be dated exactly, but they are most likely lowermost Lacian in age. In this part also siliceous limestones with massive chert intercalations (nodules and layers) are common (Fig. 24).

During the Lacian 1/2 the section shows a general shallowing-upward trend with massive reefal limestones and reefal rudstones and floatstones in the Lacian 1/2 (Fig. 24). Various reef builders including corals are common (Fig. 24). Intercalations of open-marine “filament”-bearing limestones are common, which contain *Nrg. navicula*, *Eg. rigoi*, and early forms of *Ag. triangularis* beside various forms of the *Ag. triangularis* group sensu KARÁDI (2024). The section ends with open-marine bedded grey limestones with *Nrg. hallstattensis* and transitional forms between *Ag. triangularis* and *Ag. spatulata* (HAYASHI). This clearly indicates that the reefal evolution in this section was terminated at the

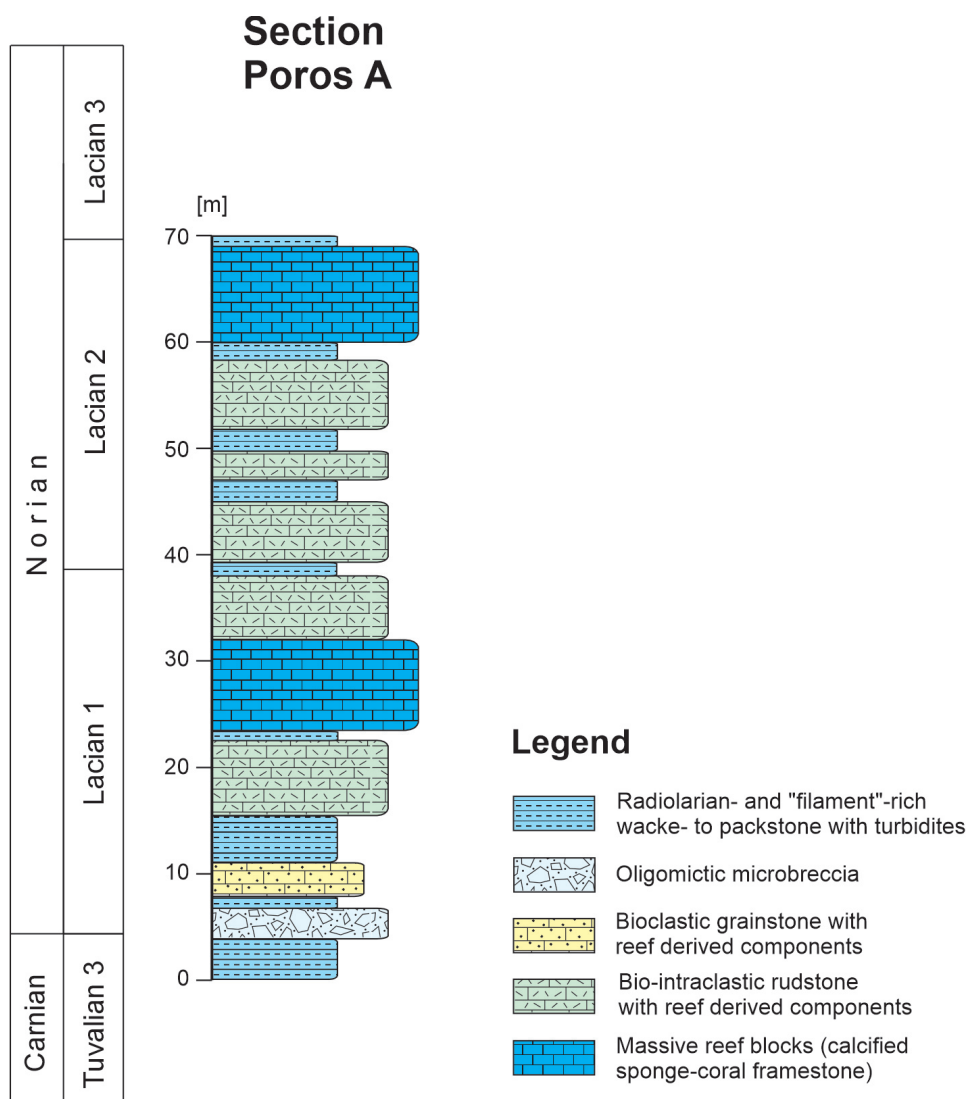


Fig. 23. Section Poros A with the characteristic lithofacies evolution. The age diagnostic conodont assemblages are described in the text. Redrawn after ZÖHRER et al. (2026).

Lacian 2/3 boundary, and therefore age-equivalent to the other sections in that area. A similar age of the backstepping of the Dachstein Carbonate Platform reef rim was dated in the Northern Calcareous Alps by KRISTYN et al. (2009). Also, in the basinal sequences elsewhere in the Western Tethys Realm the change from the Massiger Hellkalk to the condensed red nodular limestones of the Hangendrotkalk (LEIN, 1987; KRISTYN, 2008) is time-equivalent to this backstepping event, showing that the highstand shedding from the Dachstein Carbonate Platform to the adjacent outer shelf, that is the Hallstatt shelf, ended during that time (GAWLICK & BÖHM, 2000). This event is also visible in all open-marine sedimentary successions all over the Dinarides with a characteristic change in lithology and microfacies and known since long times (SUDAR, 1986).

The Early Norian reefal-to fore-reefal limestones contain beside foraminifera also cha-

racteristic reef builders and microproblematica. For details including the sample numbers the interested reader is referred to ZÖHRER et al. (2026).

Poros sections: section Poros B

Age: Late Triassic, Late Carnian to Middle Norian;

Provenance: From the outer shelf area near to the Dachstein Carbonate Platform reef-rim to open marine grey Hallstatt facies;

Formations: Forerunner of the Dachstein Carbonate Platform, Dachstein reefal and fore-reefal limestone and variation of the Gučevo facies;

Location: West of Gradac on the road from Gradac to Šula, east to southeast of the village Poros.



Fig. 24. Field views of the section Poros A. **1.** Upper part of the section Poros A, thick-bedded Early Norian fore-reefal limestones. **2.** Reefal rudstones bed with various reef builders. **3.** Recrystallized Early Norian corals. **4.** Massive earliest Norian siliceous limestones with massive chert intercalations (nodules and layers).

The section Poros B (Fig. 5, stop 3.1) comprises a similar stratigraphic range as the Poros A section, but in a different facies and lithological evolution. This sedimentary succession derives from a more distal part (Figs. 25, 26) of the reef belt. The section starts in the Late Carnian (higher Tuvalian) with massive reefal limestones (calcified sponge-coral framestones) intercalated in reefal rudstones. These shallow-water limestones are overlain by "filament"-rich wacke- to packstones and topped by an oligomictic microbreccia. This microbreccia was deposited around the Carnian/Norian bound-

ary and could be dated here by the occurrence of *Nrg. navicula* as Norian. Beside *Nrg. navicula* appear *Mp. communisti*, conodonts of the *Primatella* group and *Quadralella* ("Paragondolella") *tuvalica* (MAZZA & RIGO), indicating the incorporation of latest Carnian deep-water components.

Above the breccia a relatively thick series of open-marine limestones deposited, in cases with chert nodules. This part of the sections comprises the entire Lacian 1. In the lower part appear *Mp. communisti* together with conodonts of the *Primatella* group (lower Lacian 1), while

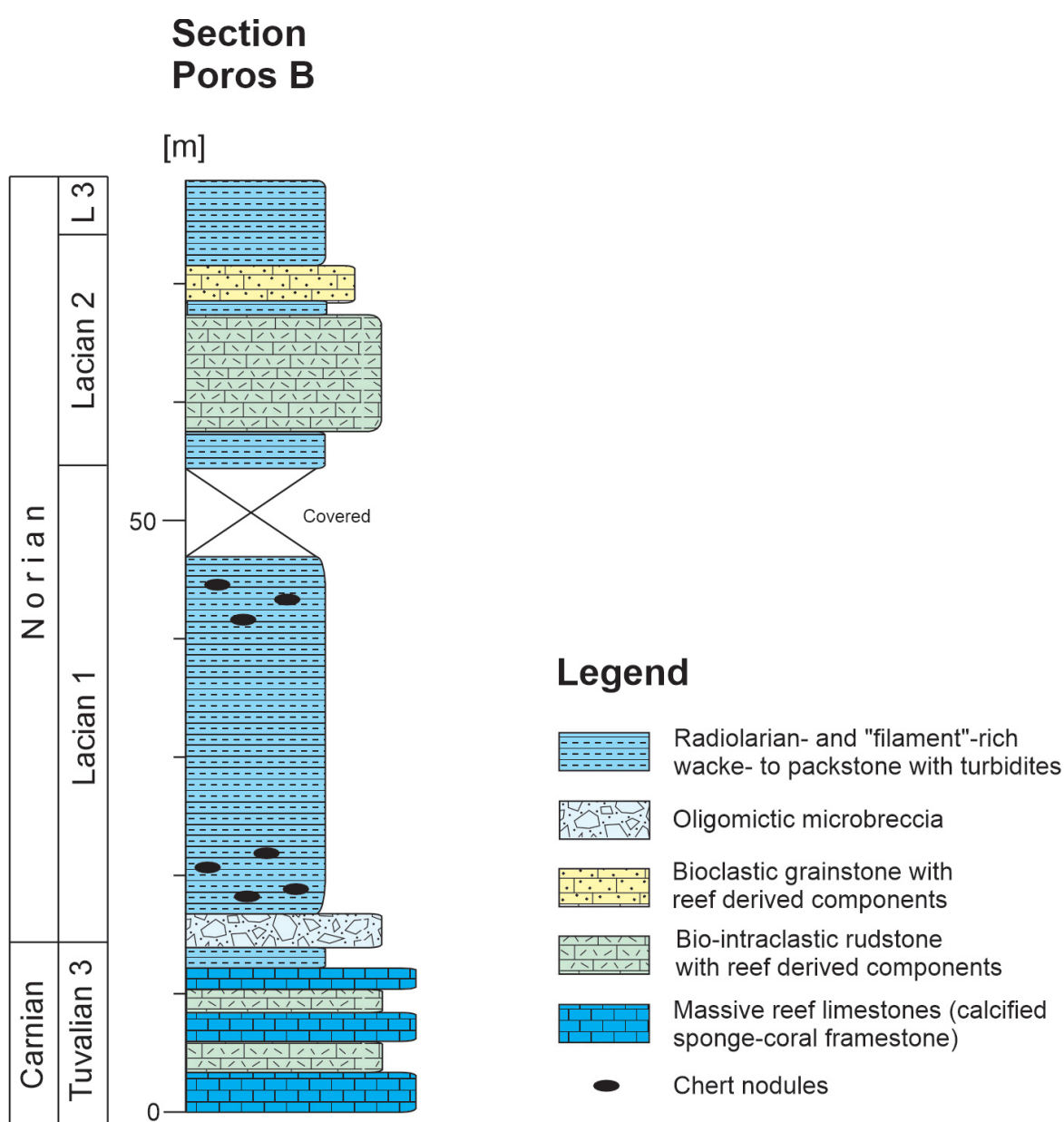


Fig. 25. Section Poros B with the characteristic lithofacies evolution. The age diagnostic conodont assemblages are described in the text. Redrawn after ZÖHRER et al. (2026).



Fig. 26. Field views of the section Poros B. **1.** Latest Carnian reefal limestone. Thick bedded to massive. **2.** Reef framework with various reef builders and micro encrusters from the latest Carnian part of the section Poros B. **3.** Thin bedded latest Carnian siliceous limestones as drowning sequence of the latest Carnian reef interval below the Carnian/Norian boundary breccia. **4.** Open-marine yellowish-orange fine-grained limestone intercalations in the Early Norian (Lacian 2) coarse-grained fore-reefal rudstones.

in the higher part also *Eg. quadrata* ORCHARD and later *Eg. rigoi* together with *Nrg. navicula* appear. Above the first appearance of an early *Ag. triangularis* starts the deposition of fore-reefal limestones, mainly reefal rudstones. Above these fore-reefal rudstones a series of “filament”-rich wacke- to packstone deposited. In the lower part these series contain still turbiditic grainstones with reworked reefal grains and organisms. This part of the succession is still Lacian 2 by the co-occurrence of the condont species *Eg. rigoi* and specimen of the *Ag. triangularis* group sensu KARÁDI (2024). The carbonate turbidite free highest part of the section contains beside *Eg. rigoi* specimen of the *Ag. triangularis* group and also *Ag. spatulata*. This indicates also a significant decrease in the shedding of shallow-water grains from the Lacian 2/3 boundary onwards.

The reefal limestones contain beside several foraminifera also characteristic sponges and microproblematica. For more details regarding this topic including the sample numbers the interested reader is referred to ZÖHRER et al. (2026).

Poros sections: section Poros C

Age: Late Triassic, Norian–Rhaetian;

Provenance: From the outer shelf area near to the Dachstein Carbonate Platform reef-rim to open marine grey Hallstatt facies;

Formations: Dachstein fore-reefal limestone and variation of the Gučevo facies;

Location: West of Gradac on the road from Gradac to Šula, south of the village Poros.

On the road west of Gradac in direction to Šula (Fig. 5, stop 3.1) a more than 120 m-thick overturned Late Triassic succession of bedded late Early Norian to Rhaetian siliceous hemipelagic limestones is exposed above Early Norian fore-reef Dachstein limestones.

The section starts with a roughly 20 m-thick reef to fore-reef limestone succession with deep-water matrix in the upper part (Lacian 2 in age with following conodonts: transitional form between *Eg. quadrata* to *Eg. rigoi*, and *Nori-*

gondolella sp.) (Fig. 27). Near the base the reef to fore-reef limestone is thick-bedded to massive, higher up in the section variously bedded. We consider these reef limestones as part of the lower Dachstein Reef Limestone, interestingly with a deepening upward sequence from the middle Lower Norian onwards. However, the section is slightly tectonized, with folded slump deposits in the central part (Fig. 28), so that only some parts of the section can be accurately measured.

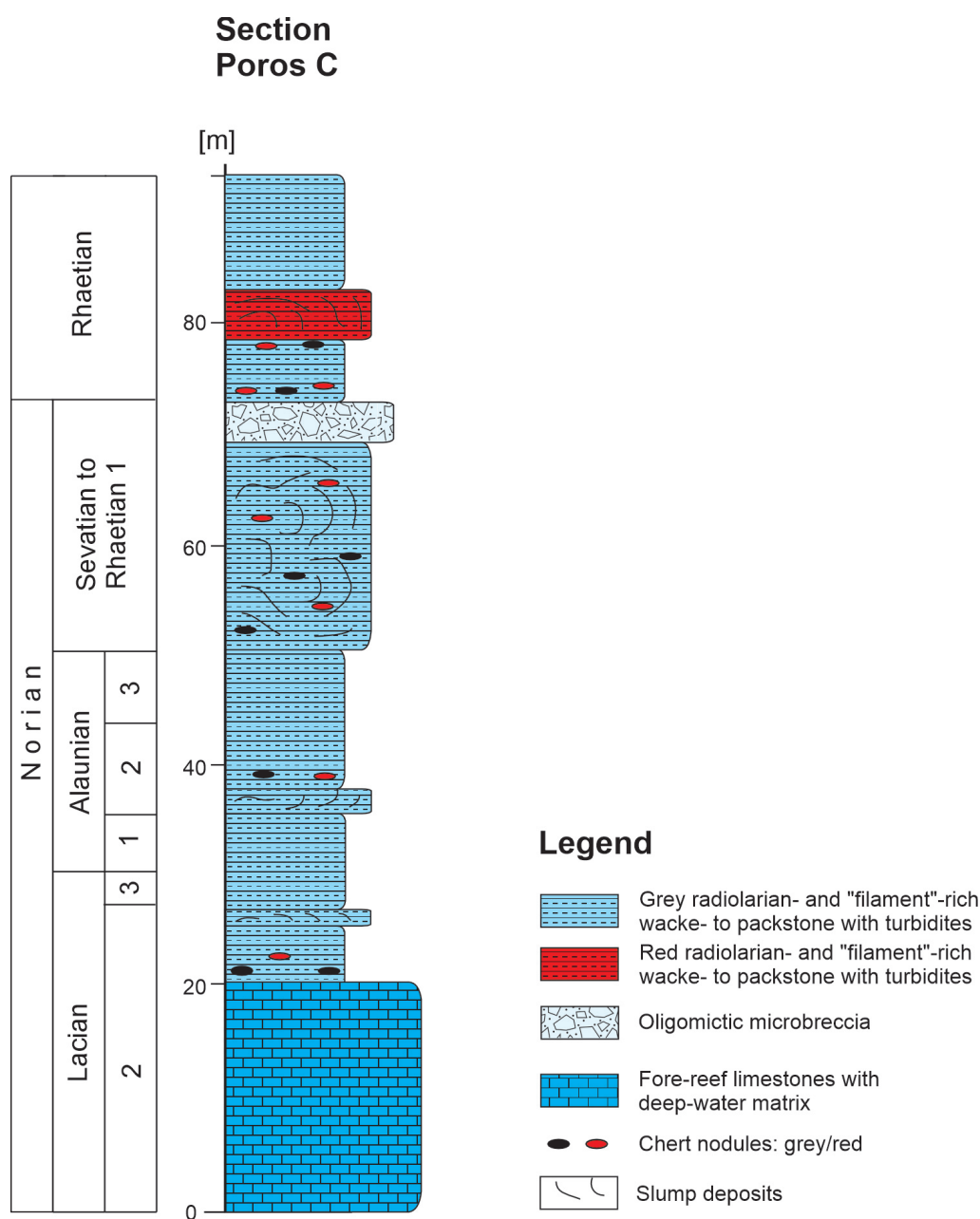


Fig. 27. Section Poros C west of Gradac on the road from Gradac to Šula, south of the village Poros. The age diagnostic conodont assemblages are described in the text. Redrawn after GORIČAN et al. (2022), MRDAK et al. (2022, 2024), and ZÖHRER et al. (2026).

Around the Lacian 2/3 boundary the depositional characteristics change relatively abruptly from shallow- to deep-water limestones. Above the fore-reefal Dachstein Limestones a roughly 30 m-thick part consists of dm-bedded deep-water limestones with chert nodules and layers, grey limestones and reddish limestones. Conodont dating shows that the age of this part of the section is Lacian 3 to Alaunian 3 in the upper part. The drowning sequence of the Dachstein fore-reef limestone could be dated as Lacian 2/3 boundary to Lacian 3 by following conodonts: *Nrg. hallstattensis*, specimen of the *Ag. triangularis* fauna sensu KARÁDI (2024), and *Ag. spatulata*. This Lacian part of the deep-water limestone succession is roughly 10 m-thick. The Alaunian part of the section is roughly 20 m-thick and contains slump deposits and some breccia layers in the higher Alaunian 1 to the Alaunian 2. The age is proven by following conodonts: *Nrg. steinbergensis* (MOSHER), specimen of the *Ag. triangularis* fauna sensu KARÁDI (2024), *Eg. slovakensis* KOZUR, and *Eg. serrulata* ORCHARD. Carbonate turbidites in this part of the section are rare.

Upsection, in the higher Norian (highest Alaunian? to Sevatian) follows a series of slump deposits with carbonate turbidite intercalations. The appearance of *Eg. bidentata* throughout this part of the section proves a Sevatian age of the roughly 25 m-thick part of the succession with slump deposits. In addition, *Nrg. steinbergensis* appears sporadically. The appearance of *Ag. spatulata* indicates also reworking of older strata. The slump deposits are overlain by polymictic breccias (debris flows) and turbiditic microbreccias, which contain older clasts, as proven by the appearance of *Pg. polygnathiformis* (Carnian, most likely latest Carnian), *Nrg. navicula* (Lacian 1/2), and *Eg. slovakensis* (Alaunian 3). The overlying dm-bedded grey- reddish siliceous limestones with red chert nodules are Rhaetian in age, dated with the appearance of *Misikella posthernsteini* KOZUR & MOCK and *Mis. hernsteini* (MOSTLER). In this (lower) Rhaetian part of the section also slump deposits appear with reddish dm-bedded highly siliceous limestones with chert nodules. Chert nodules and layers are more abun-

dant than in the limestones below. Sponge spicules are abundant but no radiolarians have been found.

The relatively parallel bedded series of grey siliceous and slightly marly limestones (bed thickness 5–10 cm) above the last slump deposit could not be dated exactly, but they are still Triassic in age, as proven by the appearance of *Neohindeodella* sp. in the highest part of the section. This part of the section should be Rhaetian 2/3 in age, but earliest Jurassic for the highest parts of the folded sequence cannot be excluded.

The higher Lacian to upper Norian part of the succession corresponds to the reef-near facies belt in open shelf position, known in the type-area in the Northern Calcareous Alps as the Gosausee Limestone facies (KRISTYN et al., 2009), which correspond to the Gučevo facies. The section Poros C (Fig. 27) shows during the Norian a general deepening trend. This contrasts the Northern Calcareous Alps, where the Late Norian reef prograded over the deep-water limestones.

In the lowermost part of the overlying Rhaetian grey siliceous limestones above the slump horizon occur yellowish siliceous marls with a high amount of clay minerals of the mica group but also with a remarkable amount of mixed-layer clay minerals which point to deposition of most probably far-transported (wind-blown) volcanic ash (Fig. 29). Such volcanic ash is so far also not proven in the ALCAPA region, where marly sediments (Zlambach marls and equivalents: TOLLMANN, 1976; KRISTYN, 2008) replace in the Rhaetian the formation of Hallstatt Limestones. In contrast, in the Dinarides such marls are not known and deposition of siliceous limestones continues, but the Rhaetian microfacies resemble those of the Zlambach Formation (GAWLICK et al., 2018). Only deposits indicating intense tectonic motions like mass-transport deposits or slumps are similar in both palaeogeographic different domains (see above).

Beside the direct biostratigraphic age dating, age equivalent event deposits, the deposition of volcanic ashes around the Norian/Rhaetian boundary can be an indicative lithostratigraphic marker for the Norian/Rhaetian



Fig. 28. Field views of the overturned section Poros C. **1.** Massive to thick-bedded Early Norian fore-reef limestones with intercalated open-marine conodont-bearing limestones. **2.** The higher Lacian 2 “drowning” succession of the Early Norian fore-reef limestones: bedded siliceous deep-water limestones. **3.** View along the road of the late Early Norian to Rhaetian deep-water limestones of the Gučevo facies. **4.** Late Norian slump deposits. **5.** Detail of the Late Norian slump deposits. **6.** Late Norian to Early Rhaetian dm-bedded grey to reddish deep-water limestones with chert nodules. **7.** Detail of the latest Norian breccia levels with reworked older components. **8.** Rhaetian slump deposits consisting of red-grey siliceous dm-bedded limestones, in parts with claystone layers containing mixed-layer clay minerals.

boundary. Intense volcanic activity is known from northern Peru or the Canadian Cordillera (WOTZLAW et al., 2014), where the Norian/Rhaetian boundary was dated precisely by zircons (~205.5 Ma).

The Early Norian fore-reefal limestones contain beside several foraminifera also characteristic sponges and microproblematica. For more details regarding sedimentological and microfacies details including the sample numbers the interested reader is referred to GORIČAN et al. (2022) and ZÖHRER et al. (2026).

Pračica composite section (Pračica A + Pračica B)

Age: Late Triassic, Carnian/Norian boundary to Late Norian;

Provenance: From the outer shelf area near to the Dachstein Carbonate Platform reef-rim to open marine grey Hallstatt facies;

Formations: Dachstein reefal and fore-reefal limestone and progradation above the Gučevo facies;

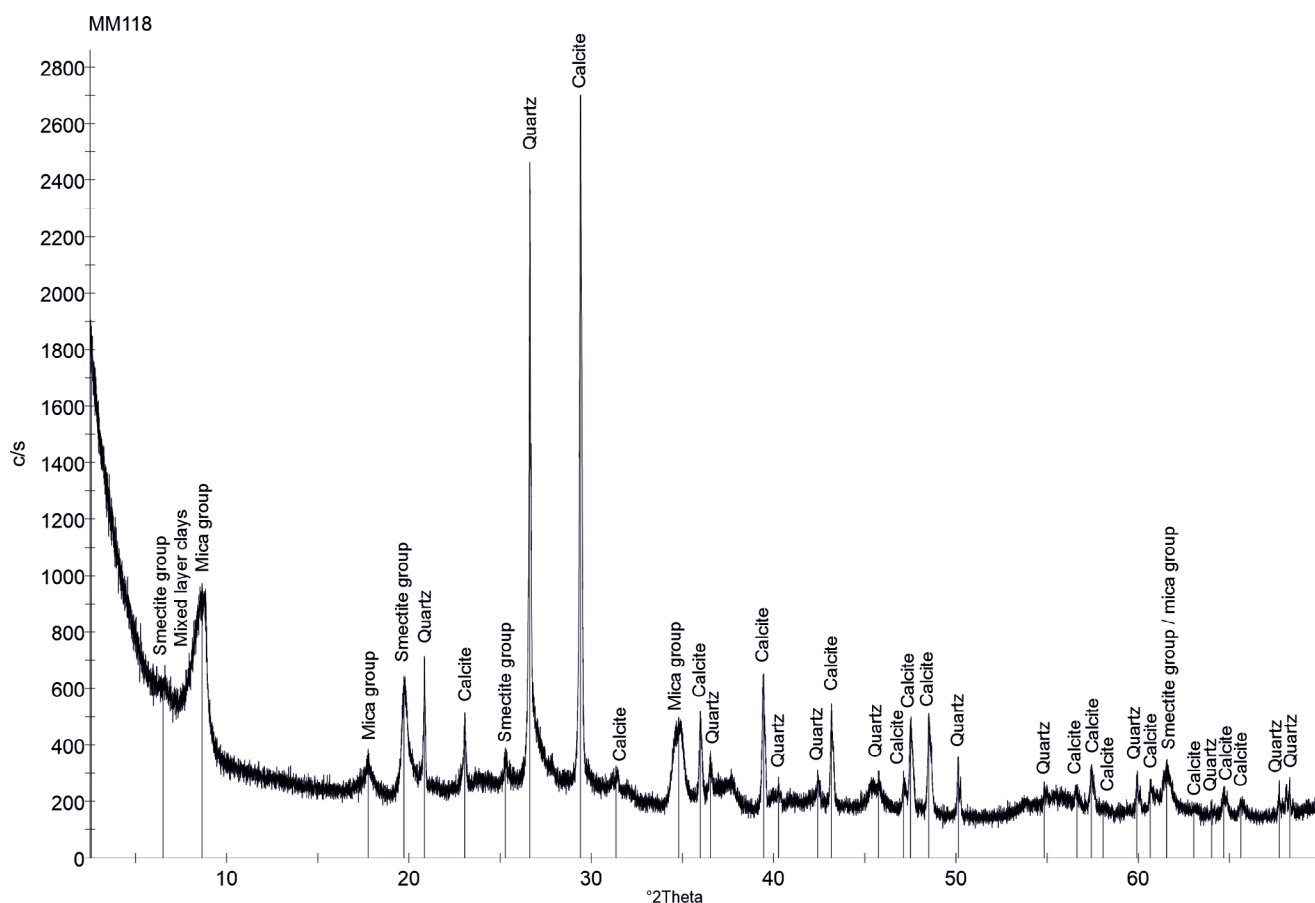


Fig. 29. Clay mineralogy of a yellowish siliceous marl layer above the Rhaetian slump horizon in the Rhaetian part of the section Poros C. Note the remarkable amount of mixed-layer clay minerals and clay minerals of the smectite group beside calcite, quartz and clay minerals of the mica group.

Location: West of Gradac on the road from Gradac to Šula, in the village Pračica.

The Pračica composite section (Fig. 5, stop 3.2) consists in fact of two different sections, the section Pračica A and the section Pračica B. Both sections are overturned. While the lowermost part of both sections is practically identical in their sedimentological evolution, litho-und microfacies, and both sections are only separated by a young normal fault both sections are summarized in one composite section. Furthermore, the section Pračica A preserves only the lowermost part of the entire sedimentological evolution. But, the contact to the underlying (Zlatar) Mélange unit is only preserved in the Pračica A section.

At the base of the section Pračica A a radiolaritic mélange with various small blocks and some mass-transport deposits is preserved (Figs. 30, 31). The outcrop situation of this mélange is rather poor in the forest or the grassland area. Beside the reddish-greenish and in cases grey radiolarites limestone clasts are intercalated into the radiolaritic sequence. The limestone clasts derive from the various-coloured Hallstatt Limestone sequence. Beside components from both grey limestone intervals (Massiger Hellkalk and Hangendgraukalk) also components from the Hangendrotkalk could be detected, but not dated by conodonts as they are too small for a reliable conodont sample.

The Pračica A sections starts above the contact to the radiolarite with a microbreccia deposited around the Carnian/Norian boundary. The upper part of the breccia contains *Nrg. navicula* and *Mp. communisti* indicating a lowermost Norian age. The overlying radiolaria- and “filament“-rich wacke- to packstone with chert nodules contain in the upper part *Eg. rigoi* and an early *Ag. triangularis* which indicate an Early Lacian 2 age.

The section Pračica B starts with an identical sedimentological evolution. Above the microbreccia with *Nrg. navicula* and *Primatella primitia* (MOSHER) evolved a more than 50 m-thick sequence of dm-bedded grey open-marine siliceous limestones. The typical micro-

facies consists of radiolarian- and “filament“-bearing wacke- to packstones, in cases rich in chert nodules. A Lacian 1 to Early Lacian 2 age is proven by the occurrence of *Nrg. navicula* together with *Eg. rigoi* and *Ag. triangularis*. In the (higher) Lacian 2, above these open-marine limestones occur a series of microbreccias and slump deposits. These series contain also shallow-water grains from the nearby Dachstein Carbonate Platform. Above these microbreccias and slump deposits again a series of radiolaria- and “filament“-bearing dm-bedded limestones deposited. The age range of these series is higher Lacian to Middle Alaunian, as proven by the occurrence of *Ag. spatulata* and *Nrg. hallstattensis* beside specimen of the *Ag. triangularis* group in the lower part, and the occurrence of *Nrg. steinbergensis*, specimen of the *Ag. triangularis* group, and specimen of the Early Alaunian genus *Epigondolella* MOSHER.

The shedding of reefal material started in the Middle-Upper Alaunian, as proven by the appearance of *Eg. slovakensis* together with *Nrg. steinbergensis*. Higher up in the section a shallowing-upward trend can be observed, and rudstones and massive reef blocks dominate. The rarely intercalated finer-grained turbidites could not be dated by conodonts. But an Upper Norian (Sevatian) age of this fore-reefal Dachstein Limestone is most likely, as elsewhere in the Western Tethys Realm (KRYSTYN et al., 2009; MISSONI & GAWLICK, 2011a, b).

The reefal limestones contain beside several foraminifera also characteristic corals, sponges and microproblematica. For more details in this topic including the sample numbers the interested reader is referred to ZÖHRER et al. (2026).

Čehotina River section

Age: Middle to Late Triassic, Middle Anisian to Middle Norian boundary;

Provenance: From the outer shelf area under influence of the Dachstein Carbonate Platform reef-rim; open marine grey Hallstatt facies;

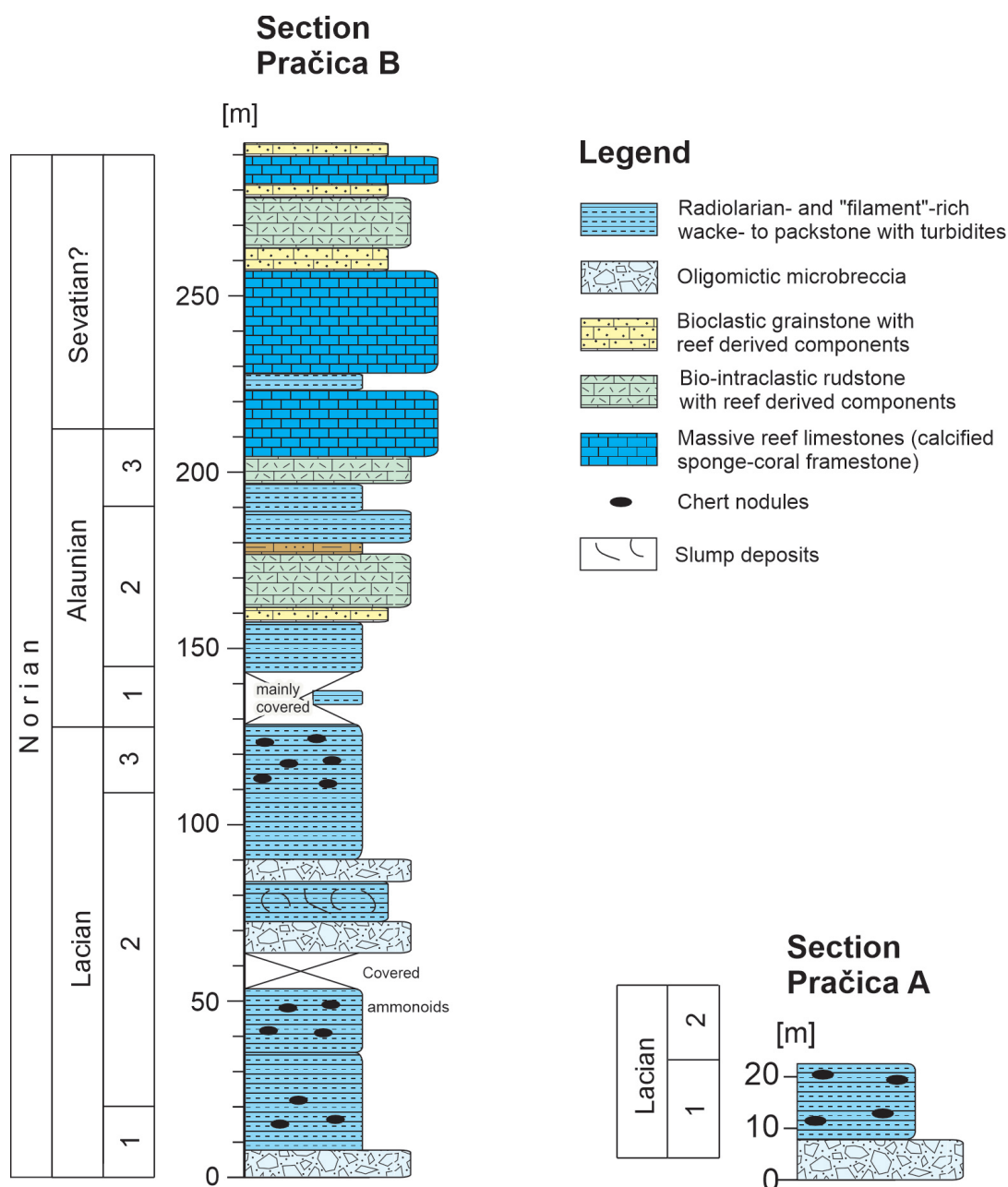


Fig. 30. Pračica composite section (Pračica A and Pračica B) with the characteristic lithofacies evolution. The composite section consists of two overlapping sections around the Carnian/Norian boundary: the lower part of the section is doubled by tectonics. The age diagnostic conodont assemblages are described in the text. Redrawn after ZÖHRER et al. (2026).

Formations: Ravni Formation, Rid Formation, grey siliceous limestones of the Nova Varoš Group, Wetterstein Formation, Stopića Formation, and Gučevo facies (named Gradac Formation in that section by SUDAR, 1986);

Location: North of Gradac on the old path from Gradac along the Čehotina River.

The Čehotina River section (Fig. 5, stop 2.2) starts with the Middle Pelsonian Dedovići Mem-

ber of the Ravni Formation (Fig. 32). The higher part of the Dedovići Member is highly recrystallized and karstified. Above the Ravni Formation follows a series of roughly 20 m-thick siliceous deep-water limestones with reworked shallow-water organisms in intercalated coarse-grained reefal rudstones and turbidites. Bivalve lumachelle layers occur occasionally. In this part of the succession, which we assign to the Rid Formation (SUDAR et al., 2013)



Fig. 31. Field views of the overturned sections Pračica A and Pračica B. **1.** Contact of the basal part of the Pračica A section to the underlying radiolaritic mélangé. The basal part of the section Pračica A consists of a breccia deposited around the Carnian/Norian boundary. **2.** Detail of the Carnian/Norian boundary breccia from the section Pračica A. **3.** Old and inactive quarry of the late Early to Middle Norian part of the Pračica B succession. Dm-bedded series of grey siliceous limestones with chert nodules. **4.** Early to Middle Norian part of the Pračica B succession. Dm-bedded series of grey siliceous limestones with chert nodules and the first intercalated turbidites with shallow-water grains. **5.** Late Middle Norian to Late Norian part of the Pračica B section. Reefal rudstones with intercalated reefal floatstones and few coarse-grained turbidites. **6.** Late Norian reef framework with micro encrusters, sponges and corals.

a ?Middle to Late Illyrian age is proven by the occurrence of *Gl. tethydis* (HUCKRIEDE), *Pg. excelsa* (MOSHER), and *Pg. eotrammeri* KRISTYN, in the

middle part, and the occurrence of *Gl. tethydis*, *Pg. fueloepi* (KOVÁCS) and *Pg. trammeri*, in its upper part.

The Early Ladinian cannot be exactly dated by the appearing conodont assemblage with *Gl. tethydis*, *Pg. fueloepi*, and *Pg. trammeri*, as age diagnostic conodonts are missing. The lithological change from the shallow-water organisms bearing Late Illyrian Rid Formation to condensed grey siliceous dm-bedded limestones we assign as transition from the Anisian (Illyrian) to the Ladinian (Fassanian). Shallow-water carbonate production normally declined around the Anisian/Ladinian boundary and the Ladinian is normally characterized by condensed sedimentation. An exception is the occurrence of a short interval of shallow-water carbonate production in the Early Longobardian, which is dated in other sections very exactly as Longobardian 1 (MRDAK, 2025), but not in the Čehotina River section. However, a Ladinian age for this shallow-water interval is also proven in the Čehotina River section by the occurrence of Late Anisian to Ladinian conodonts below and the appearance of *Pg. polygnathiformis* together with *Gl. tethydis* from the deep-water limestones with intercalated turbidites above this condensed Ladinian (roughly 10 m-thick) interval. This turbiditic Early Carnian sequence deposited below the evolving and prograding Wetterstein Carbonate Platform with its shallowing-upward trend. Various shallow-water organisms from the Wetterstein Limestones with a thickness of not more than 20 meters in the Čehotina River section were described by SUDAR (1986).

The top of the Wetterstein Limestone is recrystallized and karstified. The preserved thickness of ~20 meters of the Wetterstein Carbonate Platform indicate deep erosion of the normally up to several 100 m-thick Wetterstein Formation sequence. Above this unconformity starts the evolution of a few meters thin reefal limestone (Stopića Formation) which fills the erosional relief on top of the Wetterstein Carbonate Platform. These reefal limestones with corals are overlain by middle Late Carnian (Tuvalian 2) deep-water limestones with turbidites and bivalve layers (Fig. 33). The Late Carnian (Tuvalian 2–3) age is proven by the appearance of *Pg. carpathica* (MOCK) and *Pg. polygnathiformis* in the lower part of the deepening sequence

and the co-occurrence of *Pg. nodosa* together with *Pg. polygnathiformis* in its higher part.

The sedimentological trend, the age, lithofacies and microfacies evolution of this Late Carnian part of the succession is absolute identical with the evolution of the type-section in the Sirogojno carbonate-clastic Mélange (MISONI et al., 2012), which derived from a depositional realm situated palaeogeographically east of the Drina–Ivanjica unit in transition to the Jadar unit. This Late Carnian sedimentary sequence is also quite similar to the litho- and microfacies evolution of the Gučevo facies in the type-area, with the difference, that the Gučevo facies in the type-area represents a slightly deeper and more distal depositional environment.

Therefore, it is here generally referees as Gučevo facies, the lower Norian part of the succession consists predominantly of thick-bedded siliceous limestone with chert nodules and intercalated turbidites (Fig. 33). The turbidites contain shallow-water grains and organisms. Only in the lowermost part an earliest Norian (Lacian 1-1) thin-bedded siliceous limestones without intercalated turbidites deposited. Their age is proven by the co-occurrence of *Metapolygnathus* sp. and *Eg. quadrata*. In the higher, thick-bedded part the appearance of *Ag. triangularis*, various species of the *Ag. triangularis* fauna sensu KARÁDI (2024) prove a Lacian 2 age. Higher in the succession appear *Ag. triangularis* together with *Ag. spatulata* indicating an age around the Lacian 2/3 boundary. Their appearance coincides with the lithological change to thinner-bedded siliceous limestones, rich in chert nodules, and with much less and finer-grained limestone turbidites. In this level appears also a breccia layer accompanied by a bivalve lumachelle (Fig. 34) with *Halobia mediterranea* GEMMELLARO. The biostratigraphic age of the halobiid bivalve is in line with the conodont fauna with *Ag. triangularis* and *Ag. spatulata*.

In the Lacian 3 part of the sedimentary succession appears a transitional form between *Nrg. navicula* and *Nrg. hallstattensis* beside various forms of the *Ag. triangularis* fauna sensu KARÁDI (2024). The Middle Norian (Alaunian) is characterized by thin-bedded siliceous

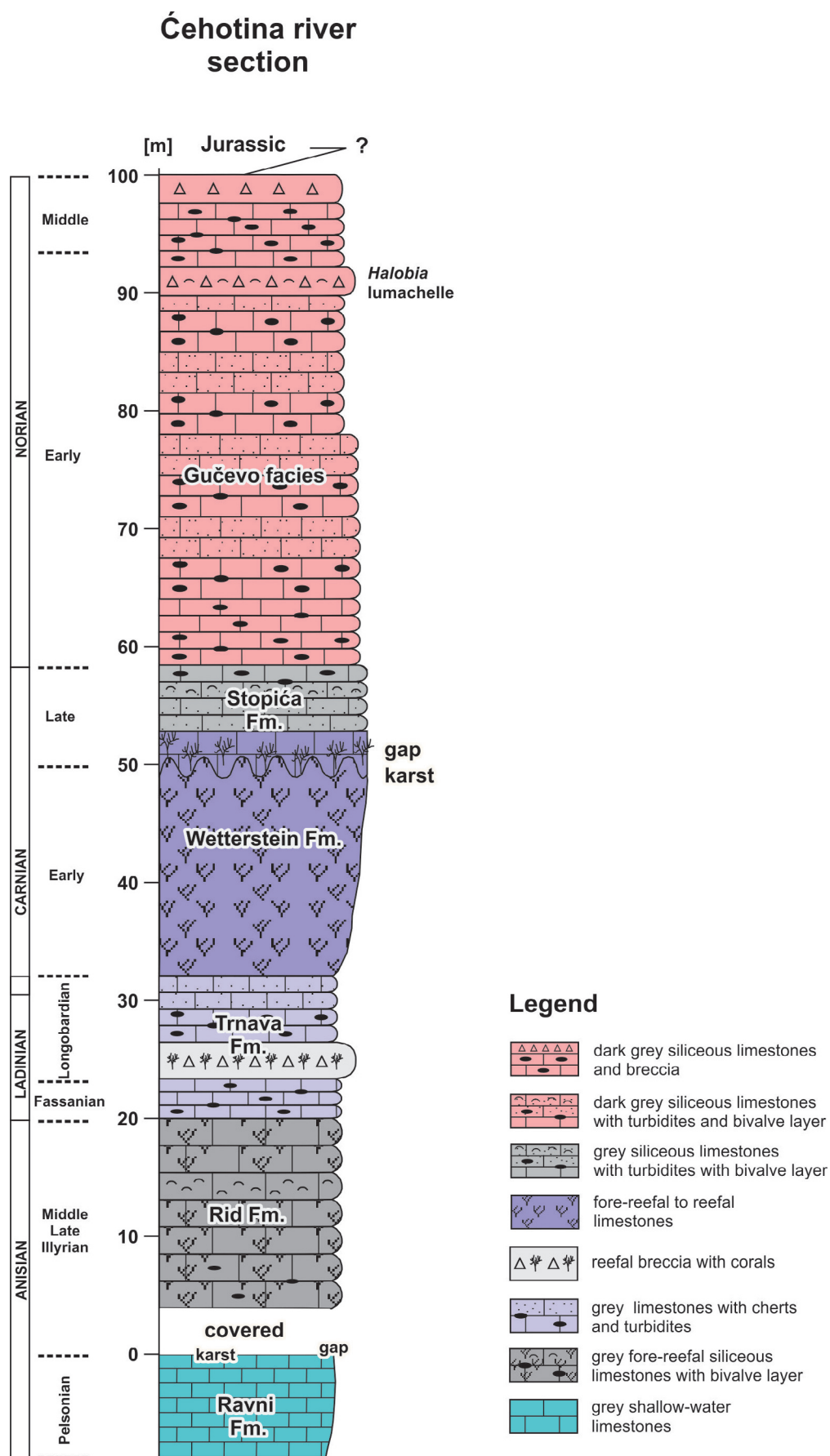


Fig. 32. Middle Anisian to Norian section of the Čehotina River. Redrawn and added after SUDAR (1986) and MRDAK (2025).



Fig. 33. Field photos from some characteristic lithologies of the Middle Anisian to Middle Norian Čehotina River section. **1.** Nodular grey thin-bedded Late Carnian Stopića Formation, which represent the drowning sequence of the Wetterstein Carbonate Platform. **2.** Thick-bedded Early Norian grey siliceous limestones. **3.** Halobiid lumachelle layer (Fig. 34) above a breccia horizon around the Lacinian 2/3 boundary. **4.** Thin-bedded grey siliceous limestones of Middle Norian age with chert layers.

deep-marine limestones with plenty of chert nodules and chert layers. Their Alaunian age is proven by the occurrence of *Eg. slovakensis* and *Eg. postera*.

The Alaunian part of the deep-water Triassic sedimentary succession is overlain by a breccia of so far unknown age, but the mass-transport deposits above this breccia layer, which consist of Late Triassic deep-water limestone components are of Late Jurassic age. These mass-transport deposits contain various shallow-water carbonate clasts and organisms of a late Jurassic shallow-water carbonate platform. Their age is most likely Tithonian, but an exact age is not proven yet due to the scarcity of determinable and age diagnostic

shallow-water organisms. However, these mass-transport deposits with reefal material are the sedimentary base of the latest Jurassic to Early Cretaceous Vranduk Formation, which can be studied along the road from Gradac to Crno Brdo in a preserved thickness of several hundred meters.

Nange-Jabučno section

Age: Late Triassic to Late Jurassic;

Provenance: From the continental slope;

Formations: Grivska Formation, unnamed Formation (Early Jurassic), Zlatar Formation, unnamed Formation (Late Jurassic).

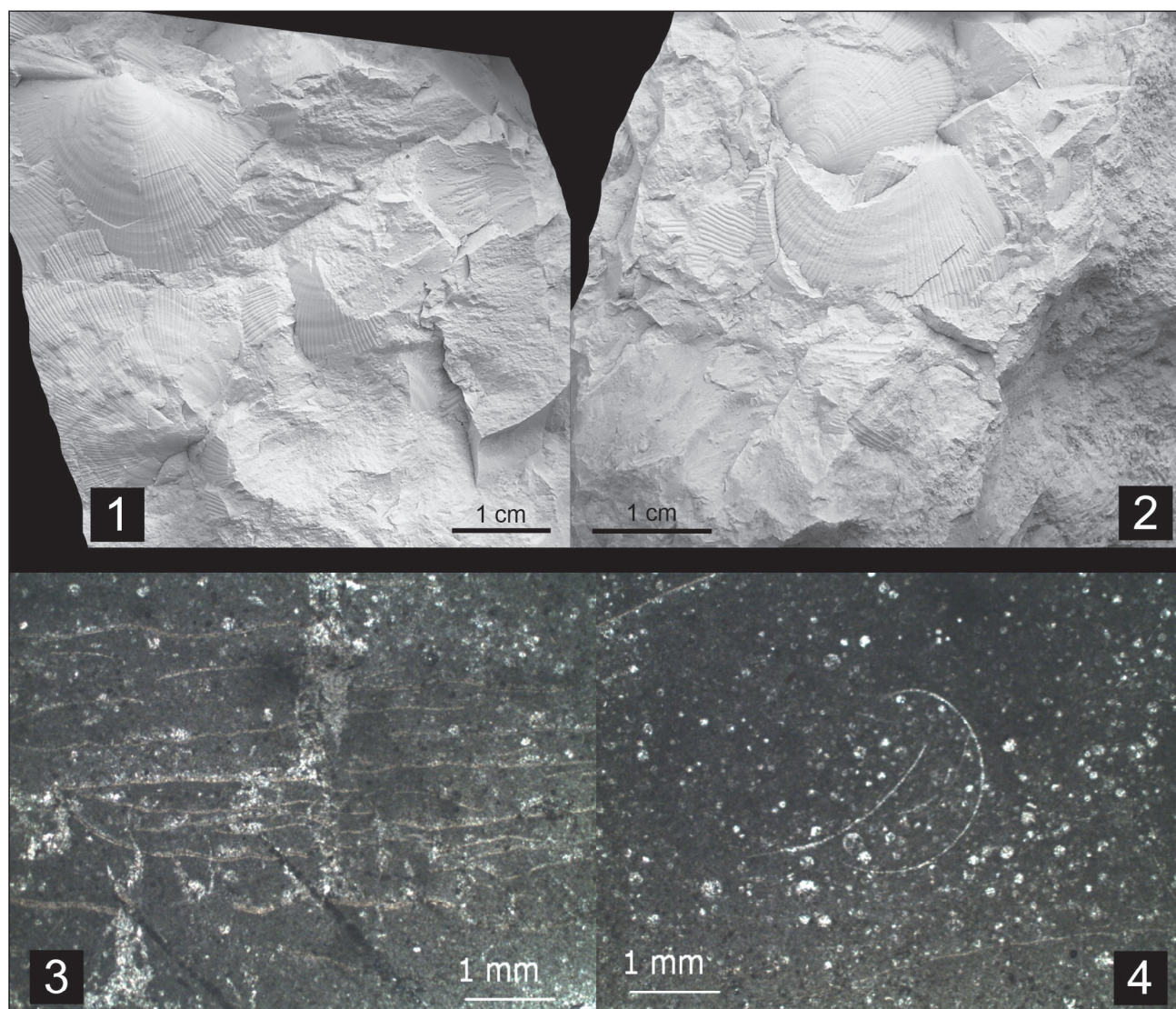


Fig. 34. Čehotina River section. **1-2.** Lumachelles of monospecific assemblages of *Halobia mediterranea* GEMMELLARO, **3-4.** Gray radiolarian wacke- to packstone, with mass occurrences of *Halobia* shells (**3**, sample number ČEH-6A/25) or rare "filaments" (**4**, sample number ČEH-4/25). Lacinian 2/3 boundary.

Location: West of Gradac on the road from Gradac to Šula, in the village Pračica.

The section Nange–Jabučno (Fig. 5, stop 3.3) and further in direction Poros shows a completely different Late Triassic evolution in comparison with the Poros C or Čehotina River sections. While in the Poros C section and Čehotina River section Jurassic strata are missing, the Jurassic evolution in the section Šula to Poros is practically complete.

The section Nange–Jabučno (Fig. 35) starts with thin-bedded grey siliceous limestones with fine-grained turbidite layers. In contrast to the

other sections these turbidites contain no shallow-water debris. Upsection follow grey and thick-bedded siliceous limestones, again with turbidite layers without shallow-water debris (only automicrite clasts). The age of these two parts of the section cannot be proven due to the lack of conodonts or other age diagnostic organisms. Radiolarians could not be isolated from this part of the succession, and halobiid bivalves are missing. A Late Carnian age for the lowermost part of the Nange section is most likely, as the overlying lower lumachelle layers (Fig. 36) contain monospecific assemblages of *Halobia lenticularis* (GEMMELLARO) (Fig. 37), of Late Carnian age.

Nevertheless, the dipping in the upper part of this Late Carnian deep-water limestones below the lumachelle layers changes rapidly without any clear direction indicating slump deposits; this maybe can explain the exceptionally thick sedimentary sequence of this (Carnian) part.

The interval of deposition of lumachelle layers is quite thick, and consists predominantly of *Halobia lenticularis* (GEMMELLARO) layers (compare GORIČAN et al., 2022). The determined bivalves originate from the lower levels of lumachelle layers around the Carnian/Norian boundary. The lower levels seem to consist only of this monospecific bivalve accumulation. In total the main lumachelle levels appear in a thickness of roughly 3–4 meters in the series of exclusively grey siliceous dm-bedded limestones with plenty of halobiids, which contain no conodonts except some broken multielements.

The higher lumachelle layers contain also few different halobiid shells, which can be determined as *Halobia* cf. *austriaca* MOJSISOVICS, which would indicate a lowermost Norian age. A consequent layer-by-layer sampling is needed, especially of the upper lumachelle layers to prove a possible homogeneity or age change.

Above these lumachelle layer intervals follow a roughly 40 m-thick series of grey siliceous limestones, in cases with chert nodules and chert layers. The series is in this part predominantly thin-bedded (5–10 cm), turbidites are generally missing with one exception in the middle part of this series. This fine-grained turbidite layer with filaments most likely corresponds to the resedimentation event in the latest Middle to Late Norian.

However, also this part of the section cannot be exactly dated by conodonts: the sediments consist of radiolarian biomicrites without resediments. Only *Neohindeodella triassica* (MÜLLER) indicating a Triassic age, could be isolated, also in the more marly thin-bedded part in the highest part of this series (most probably Rhaetian). On top of these marly siliceous limestones appear a 1–2 cm-thick layer of grey claystones, which marks also an abrupt change in the microfacies characteristics. The Late Triassic

is characterized by radiolarian wacke- to packstones with few broken “filaments”. Other organisms are generally missing.

Upsection follow grey thin-bedded radiolaria-spicula rich biomicrites, which resembles the Early Jurassic successions known widespread in the Western Tethys Realm. The Triassic part of the section can be attributed to the Grivska Formation.

Due to the limited outcrop situation the transition from the spicula-rich grey siliceous limestones to the overlying radiolarite could not be dugged out. The overlying grey-green radiolarite (radiolarite-spiculite in fact) is nodular bedded and in the upper part characterized by slumps and intense synsedimentary deformation. In addition, the general dipping of the succession changes exactly on this level due to a tilting of the basin floor.

The overlying bedded mainly reddish, but also greenish radiolarite is outcropping in a small local quarry. The greenish parts of this sequence in the quarry represent most probably silicified volcanic ash layers, but this cannot be proven anymore due to intense silification. The characteristic clay minerals for volcanic ashes are below the detection limit.

These Callovian to Oxfordian radiolarites (GORIČAN et al., 2022) contain beside radiolarians also sponge spicules in rock forming quantities. The preservation of the radiolarians is only moderate. For details on the radiolarian fauna see GORIČAN et al. (2022).

After the basin tilt, with the onset of deposition of the red-green radiolarites the dipping of the upsection following Late Jurassic sedimentary sequence is parallel and with a similar, but slightly flatter dipping due to later folding. This indicates deposition during a period of relative tectonic quiescence. Upsection the radiolarite is again only badly outcropping and the contact to the overlying yellowish-reddish siliceous claystones is not visible. In this roughly 30 m-thick succession of siliceous claystones 5–10 cm-thick turbidite layers are intercalated. One type of turbidites consists predominantly of siliciclastic material, with a lot of volcanic clasts and some heavy minerals, but also radiolarites. The other type of tur-

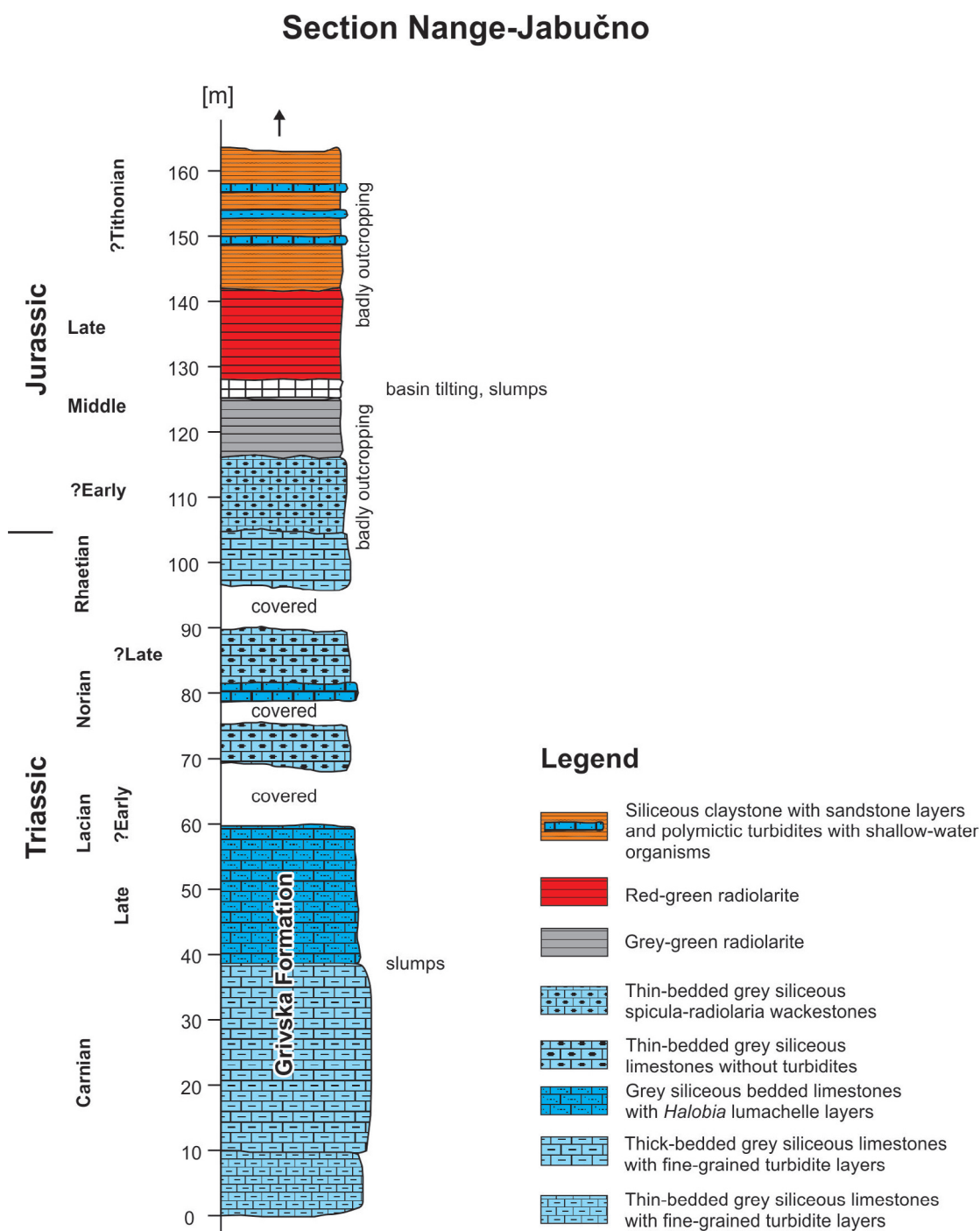


Fig. 35. Late Triassic to late Jurassic section Nange-Jabučno with its characteristic lithological evolution (after GORIČAN *et al.*, 2022). In the entire section age diagnostic organisms are very rare. Only the halobiid lumachelle layers and the red-green radiolarite could be dated by halobiids and radiolarians.

bidites consists of carbonate-siliciclastic layers with similar siliciclastic material, but also with various radiolarite components and shallow-water grains from a shallow-water carbonate platform. In moment the appearing shallow-water organisms in these turbidites are not determined on

species level, but they are similar to those described recently in the Krš Gradac section in southwestern Serbia by GAWLICK *et al.* (2020 and references therein). Therefore, we assign this part of the succession to the Tithonian. Interestingly this sedimentary succession indicates a deposi-



Fig. 36. Late Triassic to Late Jurassic outcrop photos of the section Nange-Jabučno. **1.** Outcrop situation of Late Carnian to ?Early Norian halobiid lumachelle layers interval. **2.** Early Norian thick-bedded siliceous limestones of the Grivska Formation. **3.** Transition from the thick-bedded to thinner-bedded siliceous limestones with chert layers. Most probably still Early Norian. **4.** Thin-bedded siliceous limestones with thick chert layers. Most probably Middle to Late Norian. **5.** Outcrop situation of the Middle to Late Jurassic radiolarites. On the left side of the photo dark-green to grey radiolarites are outcropping with a different dipping as the red-green radiolarites in the small quarry. **6.** Enlargement of the thin-bedded red-green radiolarites of late Middle to early Late Jurassic radiolarites.

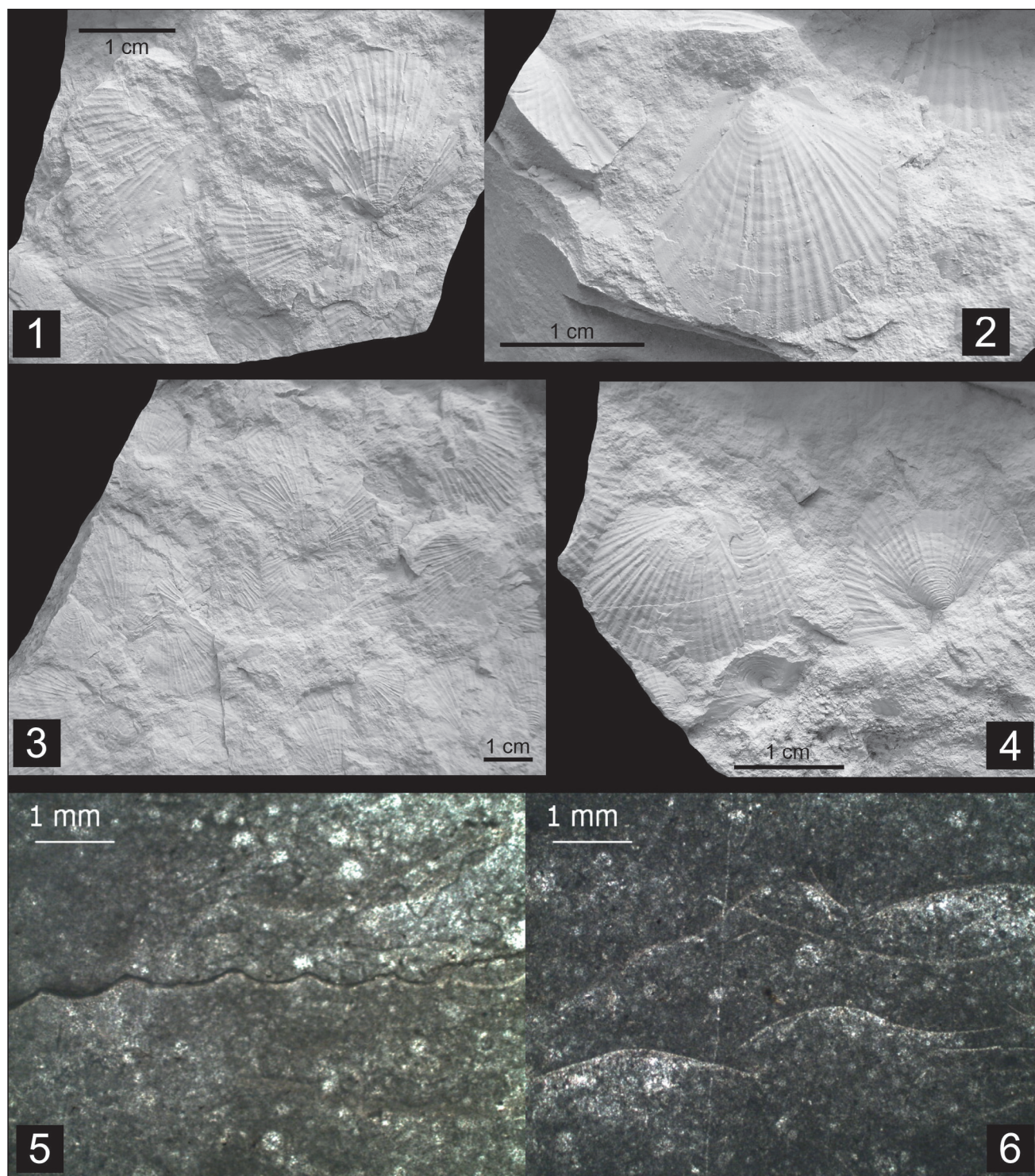


Fig. 37. Nange-Jabučno section. **1-4.** Halobiids from the lumachelles of Late Carnian (de CAPOA BONARDI, 1985; LEVERA, 2012) monospecific assemblages of *Halobia lenticularis* (GEMMELLARO). **5-6.** Microfacies photos of the yellowish-light brownish coloured radiolarian wacke-to packstone, with single valves of *Halobia* shells (5) or "filament" accumulations (6), sample number NAN-1A/25).

tional area in that basin more proximal as visible in the Čehotina River section or along the road from Gradac to Crno Brdo.

These latest Jurassic sedimentary rocks from the red-green radiolarites onwards seal

the emplacement of the Gradac-Šula nappe stack on top of the East Bosnian-Durmitor mega-unit with further west-directed transport in the frame of Tithonian to Early Cretaceous mountain uplift and unroofing to its final position.

5. Conclusions

All Middle–Late Triassic open-marine and deep-water sedimentary successions in the Outer Dinarides are bulldozed in the frame of Middle to Late Jurassic ophiolite obduction from the continental slope to outer shelf area to their position. They appear either as blocks in a Middle–Late Jurassic radiolarite matrix and represent trench-like deep-water basins fills, that are sedimentary mélanges or they represent far-travelled nappes 1) first bulldozed by the west-directed obducting ophiolites to their foreland, and 2) experienced further west-directed transport by gliding in the frame of mountain uplift and unroofing.

The existence of long-living deep-water intraplate basins in the Dinarides is a myth and a legend, invented by positivists in the sense of POPPER (1935) (compare ŠENGÖR, 2013).

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