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ORIGINAL ARTICLE

Onset and demise of the Wetterstein Carbonate Platform in the mélange areas of the Zlatibor Mountain (Sirogojno, SW Serbia)

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Abstract A kilometer-sized block in the Sirogojno carbonate-clastic mélange provides a complete succession of the Wetterstein Carbonate Platform evolution. The platform starts its progradation in Early Carnian times over hemipelagic Late Ladinian cherty limestones with fine-grained allodapic limestone intercalations. Shallow-water reef-slope, reefal to back-reef/lagoonal limestones evolved in the Early Carnian. The top of the platform is recrystallized and partly slightly dolomitized, and in parts karstification is visible. After a period of omission caused by uplift, new subsidence started in the early Late Carnian. This is documented by a flooding respectively drowning sequence of the same age, starting with reefal carbonates and rapidly followed by hemipelagic-influenced limestones. The evolution of the onset and the drowning of the Wetterstein Carbonate Platform prove a paleogeographic derivation of this block from the outer shelf-area facing the Neotethys Ocean, but still in a shallow-water carbonate platform position transitional to the Hallstatt facies zone. This paleogeographic position is especially confirmed by the new pulse of subsidence in the Late Carnian after a long lasting phase of omission. The evolution of the Wetterstein Carbonate Platform in the Inner Dinarides corresponds to successions known from the Northern Calcareous Alps or the southern Western Carpathians. In the Late Triassic both regions belong to the same northeast–southwest striking shelf area facing the Neotethys Ocean to the east and southeast, respectively.

Keywords Stratigraphy · Dinarides · Triassic · Conodonts · Neotethys Ocean · Drowning

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Introduction

Triassic shallow- and deep-water carbonates occur together with Triassic radiolarites widespread as olistoliths and slides in the Middle to early Late Jurassic mélanges of the Dinaridic Ophiolite Belt in the Zlatibor Mountain (Fig. 1; compare Dimitrijević 1997; Dimitrijević et al. 2003). The carbonate slides should have derived from the Drina-Ivanjica Unit (Fig. 1), forming there the original sedimentary cover (Dimitrijević and Dimitrijević 1991; Dimitrijević 1997), which was disintegrated in Late Jurassic times.

The key for the reconstruction of the Jurassic history of mélange formation is the knowledge of the paleogeographic derivation of different slides in the Triassic passive continental margin arrangement facing the Neotethys Ocean further to the east. The overall arrangement of the Late Triassic facies belts is shown in Fig. 2. Especially for

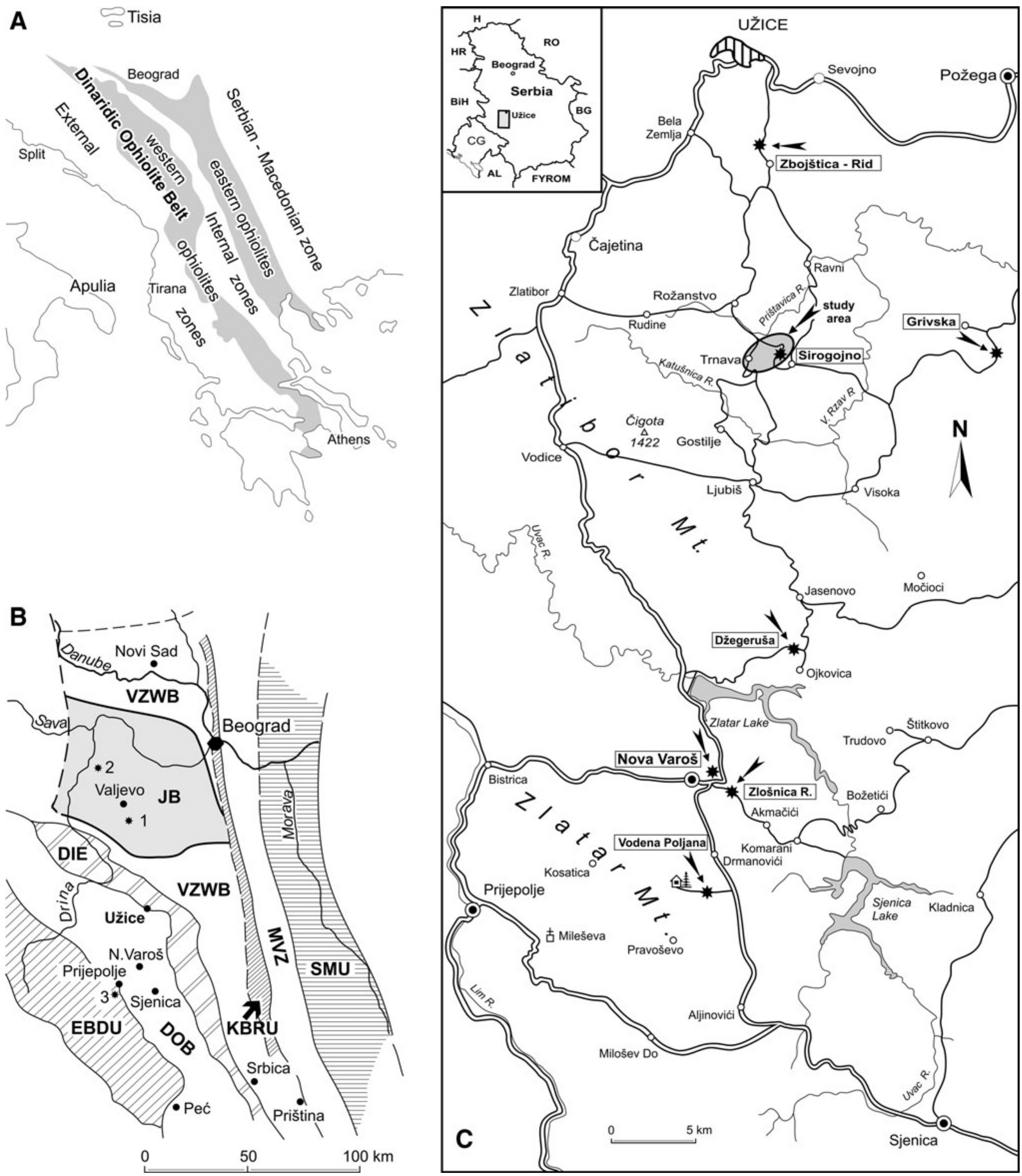


Fig. 1 **a** Regional geological setting showing the External zones, the western ophiolites (Dinaridic, Mirdita, Hellenic ophiolites), the Internal zones (“Korabi-Pelagonian Microcontinent” = Pelagonian Zone, Korab Zone, Drina-Ivanjica Element; see also Schmid et al. 2008, 2010) and the eastern ophiolites (Vardar Zone). For details, see e.g., Aubouin (1973), Smith and Spray (1984), Dimitrijević (1997, 2001), Channell and Kozur (1997), Stampfli et al. (2001), and Karamata (2006). **b** Tectonic units and terranes of the Balkan Peninsula sensu Karamata et al. (2000) and Karamata (2006). *SMU* Serbian-Macedonian Unit, *MVZ* Main Vardar Zone, *KBRU* Kopaonik Block and Ridge Unit, *VZWB* Vardar Zone Western Belt, *JB* Jadar Block, *DIE* Drina-Ivanjica Element, *DOB* Dinaridic Ophiolite Belt, *EBDU* East Bosnian-Durmitor Unit. Localities with meta-andesites of the Porphyrite-Chert Formation in the *JB*: *1* Podbukovi, *2* Tronoša Monastery, and in *EBDU*: *3* vicinity of Prijepolje. **c** Study area with the investigated Wetterstein Carbonate Platform blocks in the Zlatibor Mountain (northwest of the village Sirogojno, SW Serbia) and other localities with bentonite layers intercalated with bedded cherty limestones in *DOB*

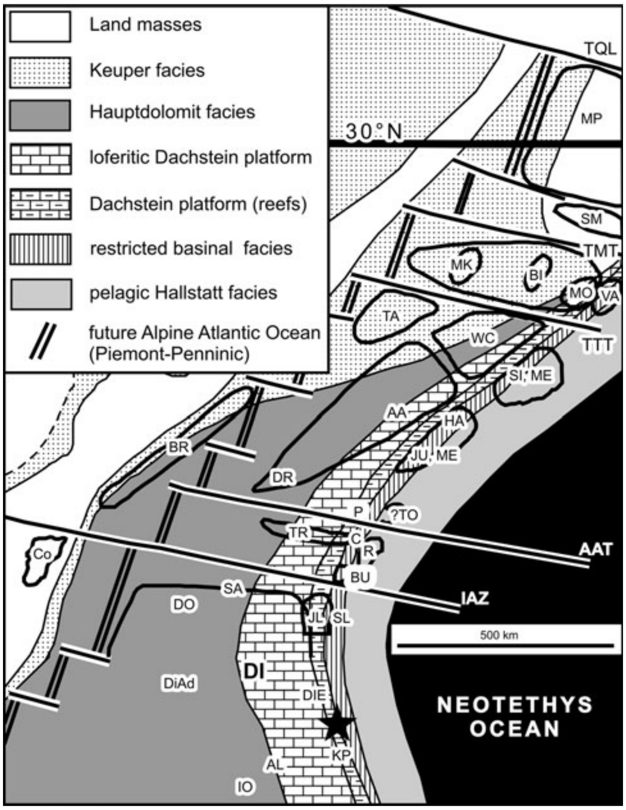


Fig. 2 Paleogeographic position and facies zones of the northwestern Neotethys passive margin for Late Triassic times (modified after Krystyn and Lein in Haas et al. 1995; Gawlick et al. 2009a). The *star* marks the study area west of the Drina-Ivanjica Units (compare to Fig. 1). *IAZ* future Iberia-Adria-Zone, *AAT* future Austroalpine-Adria strike-slip fault, *TTT* future Tisza-Tatra strike-slip fault, *TMT* future Tisza-Moesia strike-slip fault, *TQL* Tornquist Line. *AA* Austroalpine, *AL* Albanides, *BI* Bihor, *BR* Brianconnais, *BU* Bükk, *C* Csovar, *Co* Corsica, *DI* Dinarides, *DiAd* Dinaridic/Adriatic platform, *DIE* Drina-Ivanjica units, *DO* Dolomites, *DR* Drau-Range, *HA* Hallstatt zone, *IO* Ionian, *JU* Juvavicum, *JL* Julian Alps, *KP* Korabi/Pelagonia, *ME* Meliata units, *MK* Mecsec, *MO* Moma unit, *MP* Moesian platform, *P* Pilis-Buda, *R* Rudabanya units, *SA* Southern Alps, *SI* Silicica units, *SL* Slovenian trough, *SM* Serbo-Macedonian unit, *TA* Tatricum, *TO* Tornaicum, *TR* Transdanubian Range, *VA* Vascau unit, *WC* central Western Carpathians

the Late Triassic the facies zones arrangement (Hauptdolomit[Dolomia Principale]/Dachstein Carbonate Platform and equivalents to the Hallstatt facies belt) is proven from the Austroalpine/Western Carpathian domain (Haas et al. 1995; Gawlick et al. 1999) to the Albanides (Gawlick et al. 2008). In the Inner Dinarides, the detailed reconstruction of the Triassic facies belts is still at the beginning (Pilger 1941; Sudar 1986; Dimitrijević and Dimitrijević 1991; Dimitrijević 1997; Gawlick et al. 2009b; Schefer et al. 2010).

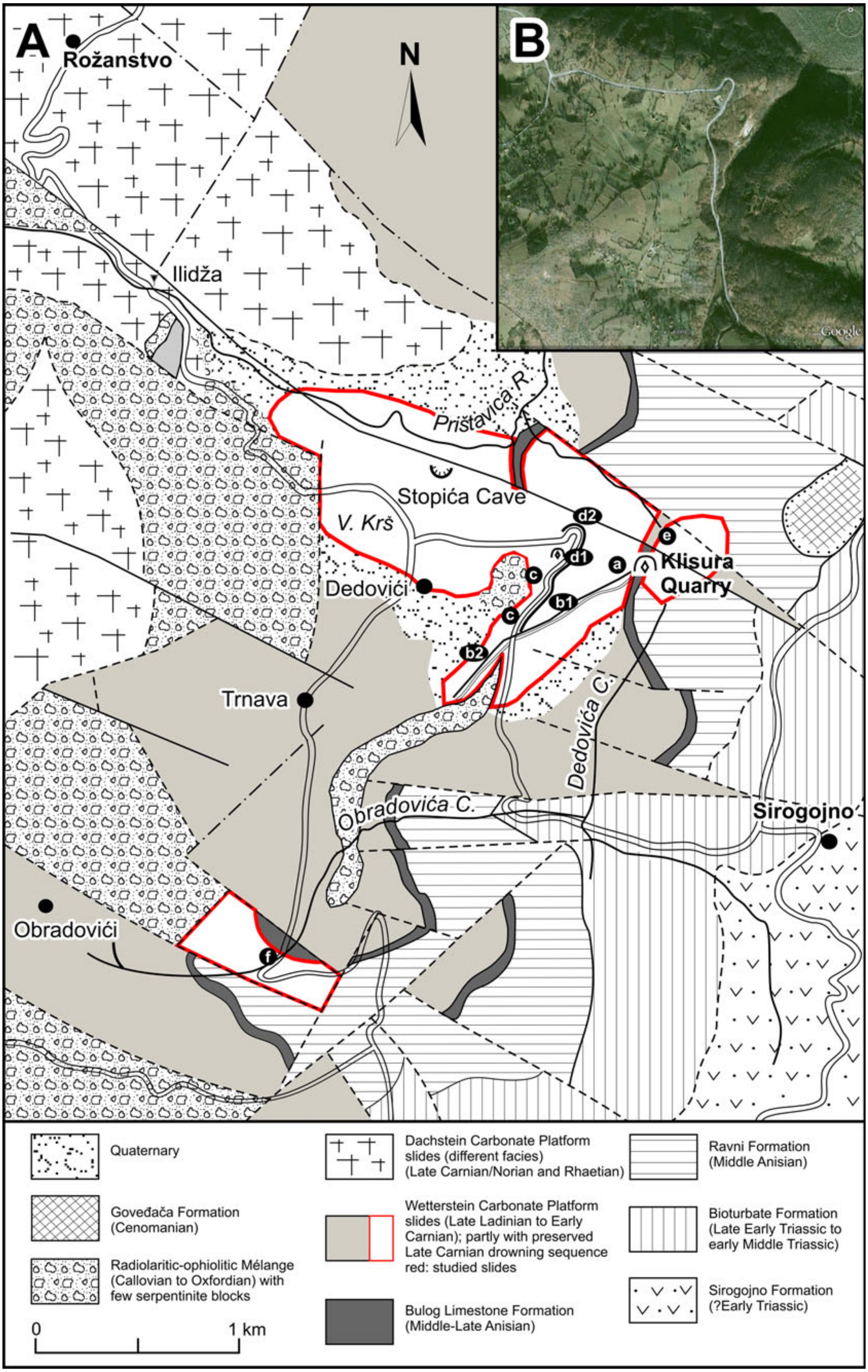
According to Sudar et al. (2008), the slides of the Sirogojno carbonate-clastic mélange differ in age, facies, and paleogeographic origin. The carbonate rocks originated from a relatively broad Triassic shelf facing the Neotethys Ocean (Fig. 2), maybe also from the Drina-Ivanjica Unit but also from further east. In contrast, the Middle to Late Triassic radiolarites and the ophiolitic rocks, which occur mostly on top the Sirogojno carbonate-clastic mélange, belong to the late Middle to early Late Jurassic radiolaritic-ophiolitic mélange and ophiolite nappes, which derive from the Neotethys Ocean floor (Gawlick et al. 2008; Schmid et al. 2008; Lein et al. 2010). For a different view, see e.g., Karamata (2006).

The carbonate blocks in the Sirogojno carbonate-clastic mélange reach sizes of several tens to hundreds of meters, partly kilometers, and include predominantly rocks of Triassic age (olistoplaka in the sense of Dimitrijević and Dimitrijević 1991). In most slides, only parts of the sedimentary evolution are preserved (compare Dimitrijević and Dimitrijević 1991). Some of them, however, provide complete sedimentary successions. We investigated a huge slide with a well-preserved Late Ladinian to Late Carnian section, northwest of the village Sirogojno (Figs. 1, 3), in which the onset and the drowning/demise of the Wetterstein Carbonate Platform is preserved. The age range of the Wetterstein Carbonate Platform remains until now enigmatic, but should be part of a complete shallow-water evolution from the Ladinian/Carnian to the Rhaetian, according to Dimitrijević and Dimitrijević (1991). The Wetterstein Formation should pass directly into the Carnian/Norian/?Rhaetian Dachstein Formation without interruption of e.g., siliciclastics, drowning-sequences or longer-lasting gaps, as known from other areas in the Alpine-Carpathian-Dinaridic realm. Hemipelagic intercalations were not recognized by Dimitrijević and Dimitrijević (1991). Exact biostratigraphic data were not available from the succession, only a relatively detailed description of the microfacies of the reefal to lagoonal shallow-water carbonates was used before to determine facies and age (Dimitrijević and Dimitrijević 1991).

Today, these carbonate slides occur tectonically on top of the Drina-Ivanjica Paleozoic as well as below of the late Middle to early Late Jurassic ophiolitic mélange and the ophiolites, respectively (Ampferer 1928) as interpreted by Dimitrijević and Dimitrijević (1991) (Fig. 3).

Stratigraphy and facies

The investigated complete section of the Wetterstein Carbonate Platform evolution (Fig. 4) is well exposed in the Klisura (or Dedovića) quarry and its surroundings (Fig. 3). The whole succession of the Wetterstein Carbonate Platform evolution, according to stratigraphic and facies characteristics, can be separated into the following parts: lowermost part (hemipelagic limestones with resedimented limestone intercalations; a to b1 in Figs. 3, 4), central part


A
B
Rožanstvo
N
Ilidža
Prištavica R.
Stopića Cave
V. Krš
d2
d1
e
a
Klisura Quarry
c
b1
Dedovići
c
b2
Trnava
Dedovića C.
Obradovića C.
Sirogojno
Obradovići
f
Google
Quaternary
Goveđača Formation (Cenomanian)
Radiolaritic-ophiolitic Mélange (Callovian to Oxfordian) with few serpentinite blocks
0
1 km
Dachstein Carbonate Platform slides (different facies) (Late Carnian/Norian and Rhaetian)
Wetterstein Carbonate Platform slides (Late Ladinian to Early Carnian); partly with preserved Late Carnian drowning sequence red: studied slides
Bulog Limestone Formation (Middle-Late Anisian)
Ravni Formation (Middle Anisian)
Bioturbate Formation (Late Early Triassic to early Middle Triassic)
Sirogojno Formation (?Early Triassic)

◀ **Fig. 3** **A** Modified section of the geological map of Republic Serbia, Užice 4, 1:50,000 (area between Obradovići, Sirogojno and Rožanstvo in the Zlatibor Mountain, SW Serbia; Radovanović and Popević 1999). The investigated slide blocks are marked by *red lines*. *Locality a* type section of the Klisura Member of the Trnava Formation. *Locality b1–b2* type-section of the uppermost Ladinian to lowermost Carnian Trnava Formation. *Locality c* Trnava and Wetterstein formations: from the prograding platform to lagoonal dolomitic limestone and completely recrystallized limestones, respectively (Lower Carnian). *Locality d1–d2* Late Carnian drowning sequence (Stopića Formation) of the Wetterstein Carbonate Platform. *Locality e* Lower Carnian (?Cordevolian) Trnava Formation underlying the Wetterstein Formation. *Locality f* Lower Carnian Trnava Formation on the road from Trnava towards Obradovići. **B** Photo from Google Earth showing the morphological situation with Klisura quarry and the exact situation of the roads. The whole area consists of blocks and slides of different sizes, different ages, and different facies. The complete area mapped only as Wetterstein Formation needs to be re-mapped on the basis of the new results

(prograding platform and overlying shallow-water carbonates; b2 to c in Figs. 3, 4), and upper part (omission and flooding/drowning sequence; d1 and d2 in Figs. 3, 4). The lower part of the succession is preserved in the Klisura quarry, the lower central part on the small road from the quarry in a southwestward direction (Fig. 3). The upper central and the upper part of the succession, i.e., the flooding and drowning event, respectively, is preserved in an old quarry and locally along the main road Sirogojno-Rožanstvo (d1 and d2 in Fig. 3). In the brooklet of the Dedovića creek northeast of the Klisura quarry (e in Fig. 3) and along the road from Trnava to Obradovići also blocks of the Trnava Formation underlying the Wetterstein Formation (f in Fig. 3) occur.

The investigated big slide block and the overlying Stopića Formation as well as smaller blocks of the Trnava and Wetterstein Formations northeast of Klisura quarry and east of Obradovići in Fig. 3 are surrounded by red lines.

The figured thin-section as well as the positive conodont samples (for exact position of the samples see Figs. 3, 4) and their faunal content are listed in Table 1. Conodonts from the different limestones and dolomitic limestones were treated with acetic acid and represent the first exact biostratigraphic data of the succession. Also, the radiolarians were treated with acetic acid. In addition, we figure the different hemipelagic series with shallow-water debris.

Lower part of the succession: hemipelagic limestones with fine-grained allodapic limestone intercalations

The succession starts with bedded cherty limestones on top of the green bentonite layers, which forms a thrust or low-angle normal fault (Sudar et al. 2008) on top of the Late Anisian Bulog Limestone Formation (Fig. 4). This bentonite layer is in the Serbian geological literature known as tuffitic "pietra-verde" facies. In the Zlatibor Mountain (e.g., villages of Sirogojno, Zbojštica—Rid, Džegeruša, Grivska) and in the Zlatar Mountain (e.g., near the town Nova Varoš, valley of Zlošnica River, close to Vodena Poljana forest house), these bentonite layers are intercalated in bedded cherty limestones. These cherty limestones, mostly Middle (different levels of the Ladinian) to Late Triassic (rarely) in age are usually attributed to the Grivska Formation (Dimitrijević and Dimitrijević 1991; Radovanović and Popević 1999). On the other hand, Middle/?Late Triassic volcanism appears in the Dinarides also as huge masses of meta-andesites (porphyrites) as part of the Porphyrite-Chert Formation (Ćirić 1954, 1984). Occurrences are known from the Jadar Block (NW Serbia: localities Podbukovi, Tronoša Monastery), near to the town Prijepolje in the East Bosnian-Durmitor Unit, and in Montenegro.

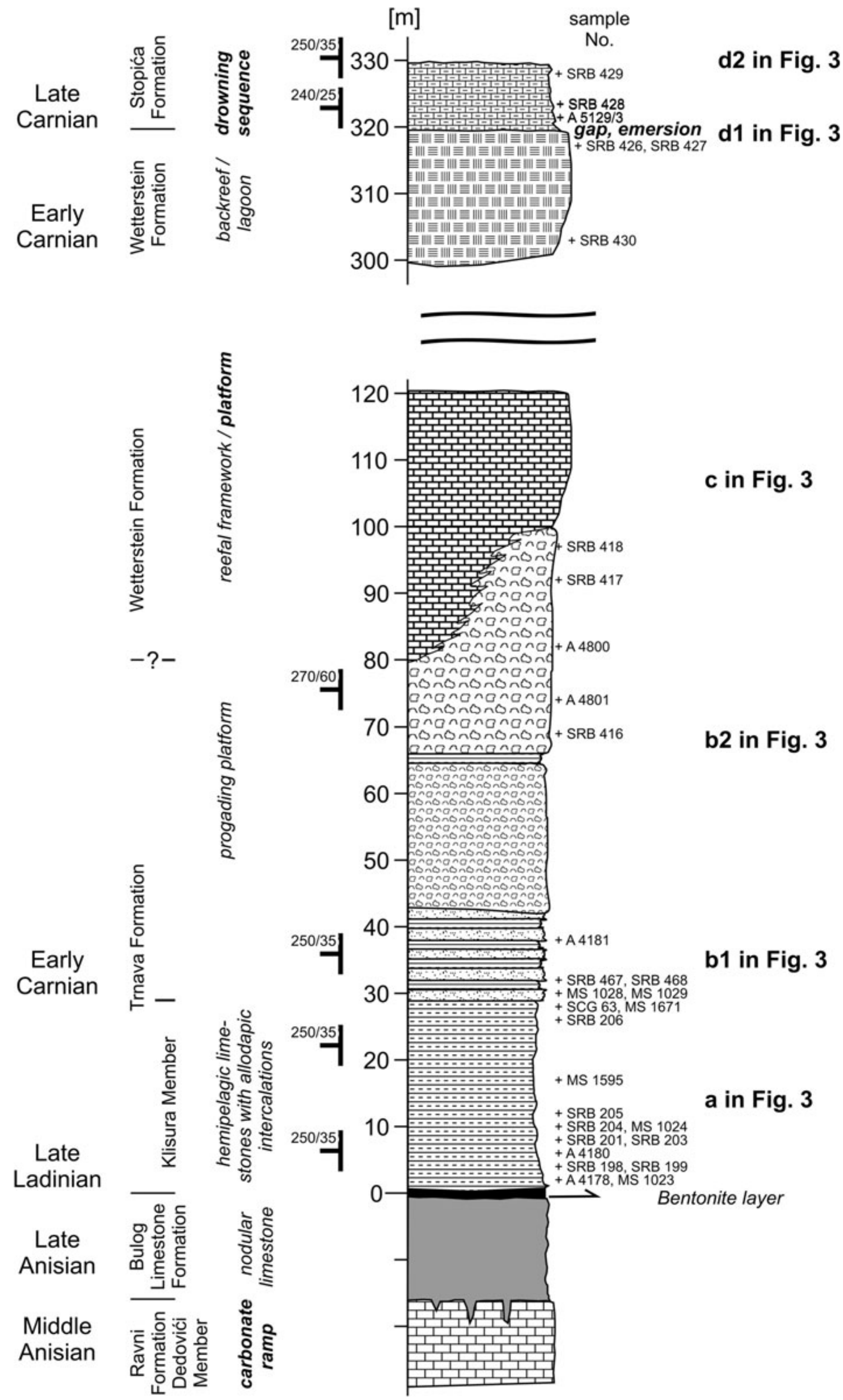
The cherty limestones (Fig. 5) at the base of the succession in the Klisura quarry contain fine-grained allodapic layers (Fig. 5e, f) with fine-grained shallow-water debris (Klisura Member of the Trnava Formation in Fig. 4). The age of this lower part of the whole succession is Late Langobardian, dated by means of conodont taxa (Table 1). Up-section follows an around 30-m-thick succession of bedded limestones with identical microfacies characteristics, partly with some chert nodules of latest Ladinian age (Table 1). In this part of the succession, shallow-water debris is missing, radiolarian-filament wackestones dominate (Fig. 5a–c).

This part of the succession, represented by a basal main bentonite layer and thin-bedded cherty limestones, were named by Dimitrijević and Dimitrijević (1991) as Klisura Member of the Wetterstein Limestone Formation and should "represent a lagoonal deposit of a quiet subtidal to intertidal" environment. In fact, this part of the succession represents the lowermost part of the prograding platform containing conodonts and radiolaria and is therefore not part of the Wetterstein Formation. The microfacies resemble mainly a hemipelagic sequence defined in the Kopaonik area as part of the Kopaonik Formation by Schefer et al. (2010). It is also equivalent to the upper Reifling Formation of the Northern Calcareous Alps and Western Carpathians. This part of the succession proves the existence of a shallow-water carbonate platform in far distance.

Central part of the succession: prograding platform and shallow-water carbonates

Up-section, the shedding of shallow-water debris increased rapidly and pure filament limestone with chert nodules became rare (upper part of the Trnava Formation in Fig. 4). The first coarse-grained shallow-water debris (Figs. 4, 6a–d) from a nearby prograding carbonate platform occurs together with the first appearance of the conodont taxon *Gondolella polygnathiformis* indicating an Early Carnian

Fig. 4 Sedimentary succession showing the evolution of the Wetterstein Carbonate Platform from its progradation in Early Carnian to its final drowning in Late Carnian. New nomenclature of the formations (compare Dimitrijević and Dimitrijević 1991: the whole succession was originally placed in the Wetterstein Limestone Formation). Sample numbers are indicated in the section. The Anisian part of the section is described in Sudar et al. (2008). Compare Table 1 for conodont samples



(Cordevolian) age (for age dating see Table 1). Up-section, the content of reefal shallow-water debris increases rapidly (Fig. 6e, h), and the around 100-m-thick succession of the prograding platform shows a coarsening- and shallowing upward trend, still of Early Carnian (Cordevolian) age (Table 1; Fig. 4).

According to Dimitrijević and Dimitrijević (1991), these two parts (Trnava Formation in Fig. 4) of the sedimentary succession resemble lithologically the Grivska Formation (named after the village Grivska northeast of Sirogojno, type section), and should represent a basinal time and facies equivalent of the Wetterstein Carbonate Platform of

Table 1 Conodont taxa and biostratigraphic ages of the samples in the different parts of the investigated succession; for sample locations compare Figs. 3 and 4

Formation and age locality	Sample number	Conodont taxa
Locality a		
Trnava Formation, Klisura Member Late Langobardian	MS 1671	*Gladigondolella tethydis* (Huckriede)
Trnava Formation, Klisura Member Late Langobardian	SCG 63	*Gondolella inclinata* Kovács
Trnava Formation, Klisura Member Late Langobardian	SRB 206	*Gondolella inclinata* Kovács *Gondolella foliata* (Budurov) *Budurovignathus mungoensis* (Diebel)
Trnava Formation, Klisura Member Late Langobardian	MS 1595	*Gondolella* cf. *foliata* (Budurov) *Gondolella inclinata* Kovács
Trnava Formation, Klisura Member Late Langobardian	MS 1024	*Gladigondolella tethydis*-ME sensu Kozur & Mostler *Gondolella* sp.
Trnava Formation, Klisura Member Late Langobardian	SRB 204	*Gondolella* cf. *inclinata* Kovács *Gladigondolella tethydis*-ME sensu Kozur & Mostler *Neocavitella* sp.
Trnava Formation, Klisura Member Late Langobardian	SRB 203	*Gladigondolella tethydis* (Huckriede) *Gondolella inclinata* Kovács
Trnava Formation, Klisura Member Late Langobardian	SRB 201	*Budurovignathus mungoensis* (Diebel) *Gondolella* cf. *inclinata* Kovács *Gladigondolella tethydis* (Huckriede) *Gladigondolella tethydis*-ME sensu Kozur & Mostler
Trnava Formation, Klisura Member Late Langobardian	A 4180	*Gladigondolella tethydis* (Huckriede) *Gladigondolella tethydis*-ME sensu Kozur & Mostler
Trnava Formation, Klisura Member Late Langobardian	SRB 198	*Gondolella inclinata* Kovács *Muelleritortis firma* (Goričan) - radiolaria
Trnava Formation, Klisura Member Late Langobardian	MS 1023	*Gladigondolella tethydis*-ME sensu Kozur & Mostler
Trnava Formation, Klisura Member Late Langobardian	A 4178	*Budurovignathus longobardicus* (Kovács) *Gladigondolella tethydis* (Huckriede)
Locality b1		
Trnava Formation, prograding platform Cordevolian	A 4181	*Gondolella polygnathiformis* Budurov & Stefanov
Trnava Formation, prograding platform Cordevolian/Julian	SRB 467	*Gondolella foliata* (Budurov)
Trnava Formation Cordevolian	MS 1029	*Gondolella polygnathiformis* Budurov & Stefanov *Gondolella inclinata* Kovács *Budurovignathus mostleri* (Kozur)
Trnava Formation Cordevolian	MS 1028	*Gondolella polygnathiformis* Budurov & Stefanov
Locality b2		
Trnava Formation, coarse-grained prograding platform sediments with intercalated filament limestones Cordevolian	A 4800	*Gladigondolella malayensis* Nogami
Locality b1		
Stopića Formation Drowning sequence Tuvalian 2	SRB 428	*Gondolella polygnathiformis* Budurov & Stefanov *Gondolella carpathica* (Mock)
Locality d2		
Stopića Formation Drowning sequence Tuvalian 2	SRB 429	*Gondolella polygnathiformis* Budurov & Stefanov *Gondolella carpathica* (Mock)

Table 1 continued

Formation and age locality	Sample number	Conodont taxa
Locality e		
Trnava Formation ?Cordevolian	SRB 465	*Gladigondolella tethydis*-ME sensu Kozur & Mostler
Locality f		
Trnava Formation Cordevolian	SRB 467	*Gladigondolella tethydis* (Huckriede) *Gladigondolella tethydis*-ME sensu Kozur & Mostler *Gondolella inclinata* Kovács *Gondolella polygnathiformis* Budurov & Stefano

Ladinian age. Characteristic of the Grivska Formation are up to decimeter-thick carbonate beds intercalated by marls and clays, in parts with coarser-grained allodapic layers. Chert nodules are common. Our investigations of the type section, and also earlier ones of M. Sudar, show a Norian to Rhaetian age.

Up to now the name Grivska Formation is a potpourri for all Ladinian to Late Jurassic bedded limestones with cherts in the Dinaridic Ophiolite Belt (e.g., Dimitrijević 1997; Radovanović and Popević 1999, and many others). Due to the fact that in this case the name Grivska Formation summarizes a lot of genetically different sedimentary successions, we restrict the name Grivska to Triassic hemipelagic sequences and advocate for the name Grivska Group. This group should contain in future all different Middle and Late Triassic hemipelagic bedded cherty limestones with shallow-water debris. The originally introduced (Triassic to Jurassic) Grivska Formation needs a complete revision, a modern definition, and a new type-section.

In the studied section, the Late Ladinian Klisura Member resembles lithologically the Grivska Formation, but is different in age and microfacies characteristics. The Early Carnian sequence with its shallowing-upward cycle and the coarse-grained turbidites intercalated with hemipelagic limestones represents a different type of sedimentary rocks. For this sequence, we introduce the name Trnava Formation of the Grivska Group, and for their basal part (first 29 m of the hemipelagic limestones) we redefine the Klisura Member (tuffitic “pietra-verde” facies).

Trnava Formation

Validity: Valid, description in this paper.

Type area: Zlatibor Mountain, Sirogojno carbonate-clastic mélange.

Type section: Section along the small road from the Klisura quarry to the main road from the village Sirogojno to Rožanstvo (marked as b1–b2 in Fig. 3).

Reference section: In the Dedovića creek northeast of the Klisura quarry, slightly deformed succession underlying the Wetterstein Formation.

Synonyms: Parts of the Wetterstein Limestone Formation in sense of Dimitrijević and Dimitrijević (1991).

Derivation of name: After the village Trnava west of the type section in the Zlatibor Mountain (Figs. 2, 3).

Lithology: Bedded cherty limestones; near the base with fine-grained allodapic limestones intercalated in hemipelagic limestones, to the top coarse-grained reefal debris with thin intercalations of hemipelagic limestones. Chert layers or nodules are present, mostly in the lower parts (Klisura Member).

History: Formerly interpreted, together with the Klisura Member, as part of the Wetterstein Limestone Formation in sense of Dimitrijević and Dimitrijević (1991). The term Klisura Member is now corrected and represents a series of hemipelagic limestones with intercalated fine-grained allodapic limestones partly with cherts and metabentonites (section marked as a in Fig. 4).

Origin, facies: The formation shows a coarsening-upward and shallowing-upward trend caused by a prograding platform.

Age: Late Ladinian (latest Langobardian) to Early Carnian (Cordevolian) according to conodont taxa.

Thickness: In the type area around 100 m.

Lithostratigraphically higher rank: Grivska Group.

Subdivision: The redefined Klisura Member represents the lower part of the Trnava Formation.

Underlying units (footwall boundary): Bulog Limestone Formation (Anisian: Late Pelsonian to Illyrian; Sudar et al. 2008) with tectonic contact.

Overlying units (hanging wall boundary): Wetterstein Formation (corrected name).

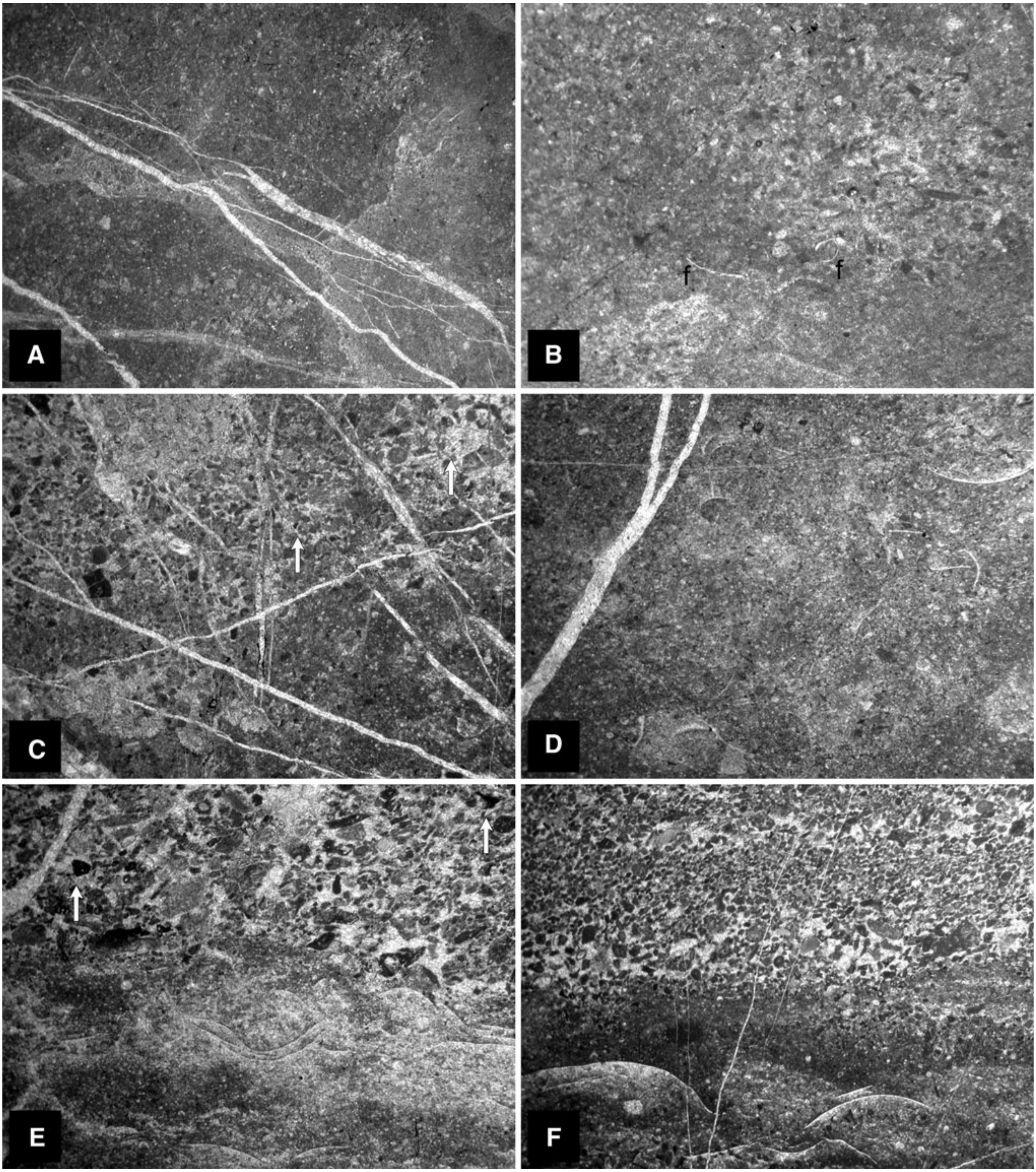
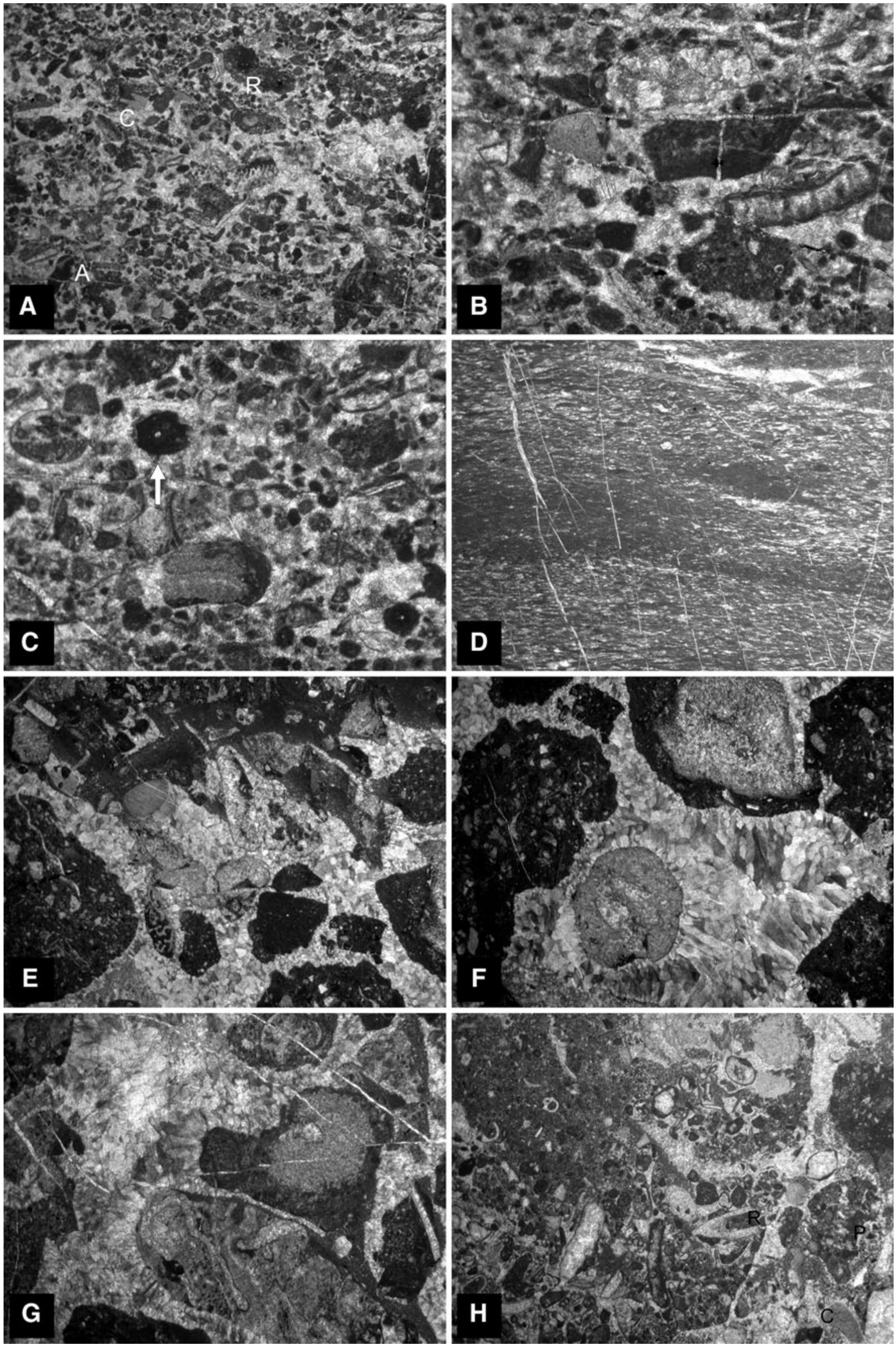


Fig. 5 Thin-section photographs of characteristic microfacies of the redefined Klisura Member of the Trnava Formation; Langobardian 3 based on conodonts (Table 1). **a** Radiolaria-filament wackestone, slightly bioturbated. Sample SRB 199. Width of photo: 1.4 cm. **b** Another view of sample SRB 199. Beside the recrystallized radiolaria (*round calcite dots*) and some filaments (*f*), micrite components occur. Width of photo: 0.5 cm. **c** Intercalated fine-grained allodapic limestone with components of shallow-water origin (*arrowed*) in a radiolaria-filament matrix. Sample SRB 201. Width of photo: 1.4 cm. **d** Radiolaria-filament wackestone, slightly bioturbated. Sample SRB 203. Width of photo: 1.4 cm. **e** Crinoid-rich allodapic limestone overlying a filament wackestone. Beside the crinoids shallow-water components occur (*arrowed*). The contact is erosional. Sample SRB 204. Width of photo: 1.4 cm. **f** Two graded allodapic limestones with mainly shallow-water components on top of a filament-radiolaria wackestone with erosional contact. Sample SRB 205. Width of photo: 1.4 cm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◀ **Fig. 6** Thin-section photographs of characteristic microfacies of the prograding platform. Early Carnian Trnava Formation with allodapic limestones, reef slope sediments and reefal framework of the prograding Wetterstein Carbonate Platform. **a** Relatively coarse-grained allodapic limestone intercalated with filament wackestone. Beside mostly micrite clasts crinoids (*C*), algae (*A*), and remnants of reef builders (*R*) occur. Sample A 4181. Width of photo: 1.4 cm. **b** Other view of sample A 4181. The algal remnants are encrusted in contrast to the crinoid fragments. Width of photo: 0.5 cm. **c** Sample A 4181, other view. As reef builder "*Tubiphytes* sp." (similar to *Crescentiella* in the sense of Senowbari-Daryan et al. 2008; *arrowed*) occurs associated with several micrite clasts. Width of photo: 0.5 cm. **d** Layer consisting of flattened micrite clasts, mainly peloids. Sample SRB 416. Width of photo: 1.4 cm. **e** Coarse-grained reef debris with reef-derived organisms mixed with crinoids. Some encrusting organisms are visible. Sample A 4801. Width of photo: 1.4 cm. **f** Sample A 4801, other view. Encrusted reef builders and several fine-grained fore-reef clasts occur next to non-encrusted reef builders; rich in cement. Width of photo: 1.4 cm. **g** Cement-rich reef rudstone with several encrusted reef builders. Sample SRB 417. Width of photo: 1.4 cm. **h** Relatively fine-grained reef rudstone with packstone clasts, crinoids, and reef builders. Sample SRB 418. Width of photo: 1.4 cm

Geographic distribution: Only known from the type area, but should occur below the Wetterstein Formation all over the Dinarides.

Lateral units: Basinal sediments, in detail unknown. To the outer shelf region, these basinal sediments are represented by the Early Carnian parts of the Kopaonik Formation (Schefer et al. 2010).

Remarks: The Trnava Formation corresponds to the Raming Formation in the Eastern Alps and the southern Western Carpathians (Tollmann 1966; compare Lein 1989).

Wetterstein Formation

Up-section, in the central part of the succession (Wetterstein Formation in Fig. 4), reefal framework is relatively well preserved (Wetterstein Limestone Formation according to Dimitrijević and Dimitrijević 1991; Fig. 6f, g). The transition between the coarse-grained reefal debris (foreslope) and the reef is gradual and is not exact determinable in the field. Following the guidelines for stratigraphic nomenclature (Salvador 1994; Steininger and Piller 1999; Remane et al. 2005), the correct name is Wetterstein Formation. We define, in contrast to Dimitrijević and Dimitrijević (1991), the Wetterstein Formation without the underlying progradation sequence (Trnava Formation with its hemipelagic Klisura Member at the base) and without the overlying drowning sequence (newly introduced as the Stopića Formation). Both can be separated from the Wetterstein Formation with respect to lithology, microfacies, and age.

The Early Carnian Wetterstein Formation contains in the study area beside reef builders (mainly sponges; Fig. 6) occasionally also some lagoonal material (Fig. 7a–c) with calcareous algae (details in Dimitrijević and Dimitrijević 1991: pl. 4, Fig. 2). The upper part of the platform succession is strongly recrystallized, partly dolomitized and partly karstified (Fig. 7d–f). Therefore, this limestones as well as the dolostones provide only scarce information about microfacies characteristics and organisms. The Wetterstein Formation represents the coarse-grained slope sediments, the reefal framework, and the lagoonal sediments.

Upper part of the succession: omission and flooding/drowning sequence

After a gap, the recrystallized and partly dolomitized upper part of the succession is overlain by a flooding respectively drowning sequence. At the base, reefal limestones with some corals occur as well as abundant "*Tubiphytes* sp." and some large gastropods. Here, we still use the name "*Tubiphytes*" for these types of organisms or interaction of organisms to avoid a decision between the genus names *Shamovella* (see Riding 1993) or *Crescentiella* (Senowbari-Daryan et al. 2008). According to Senowbari-Daryan et al. (2008), a revision of "*Tubiphytes*" and similar morphotypes, which occur abundant in the Ladinian to Early Carnian reefs, is in preparation. Up-section crinoidal sands with shallow-water debris (Fig. 8a–e) follow amongst others with "*Tubiphytes* sp." (Fig. 8f) and foraminifera (e.g., *Tolypammina gregaria* Wendt). This sandy material is intercalated by micritic limestones with filaments. These lithologies represent a drowning event after a phase of omission and karstification. The lower, 4-m-thick part of the reefal framework, in parts with gastropods (Fig. 8g) and crinoid debris cannot be dated, but up-section the occurrence of the conodont taxa *Gondolella polygnathiformis* and *Gondolella carpathica* in the filament-bearing biomicrites indicate a middle Late Carnian age (Tuvalian 2; Table 1). Therefore, the onset of the sequence, the reefal limestones with crinoidal sands could start probably slightly earlier, i.e., in the earliest Late Carnian (Tuvalian 1).

This part of the sequence resembles the base of Late Carnian Waxeneck Formation (Fig. 8h) in the Northern Calcareous Alps (Krystyn et al. 1990). Here in the Zlatibor area, the drowning sequence is introduced as the Stopića Formation.

Stopića Formation

Validity: Valid, description in this paper.

Type area: Zlatibor Mountain, Sirogojno carbonate-clastic mélange.

Type section: Section along the main road from the villages Sirogojno to Rožanstvo south of Stopića cave (locality d1-d2 in Fig. 3).

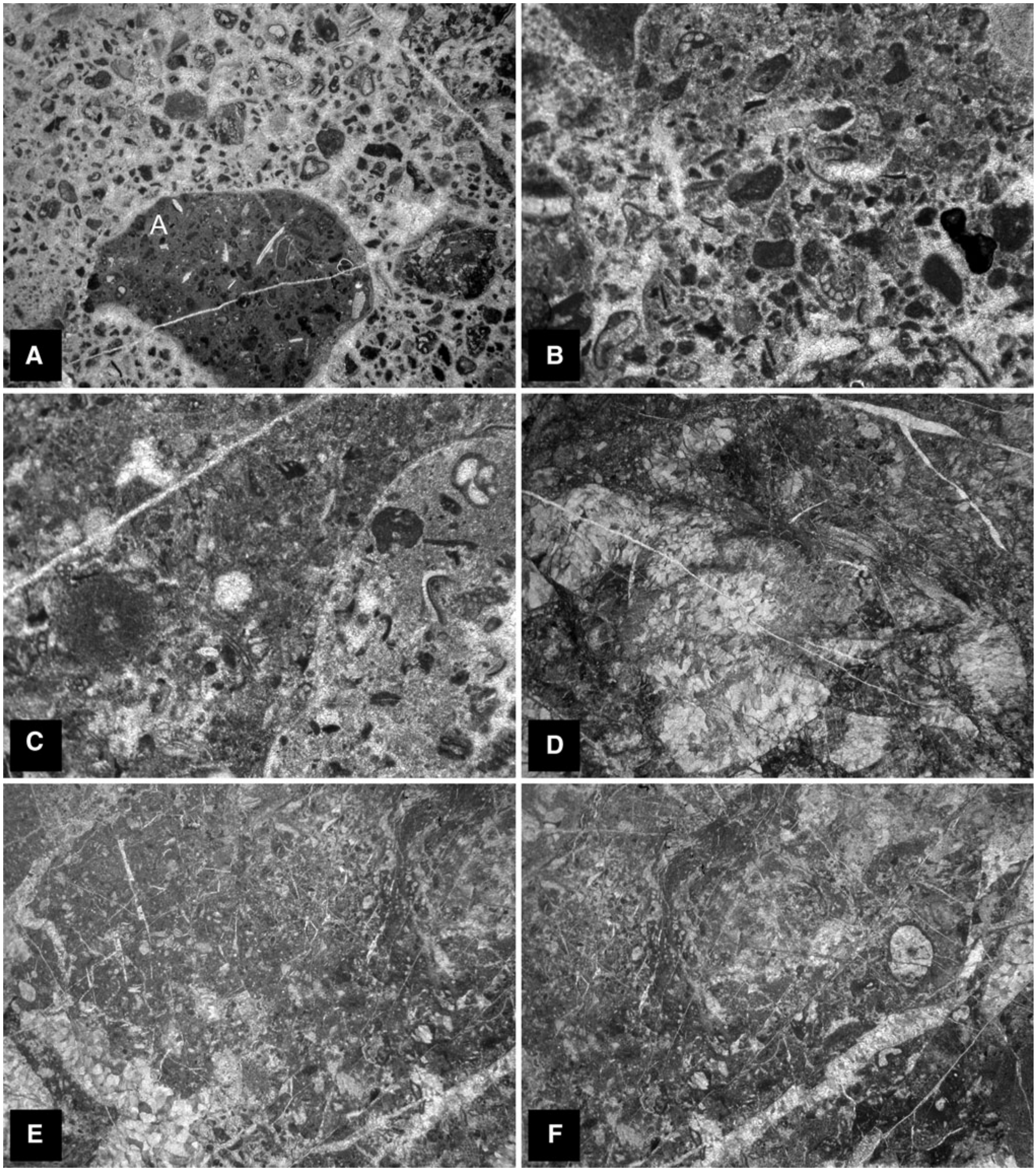


Fig. 7 Upper part of the Wetterstein Formation. Lagoonal deposits and completely recrystallized back-reef limestone below the drowning sequence. **a** Lagoonal Wetterstein Formation from the base of V. Krš (see Fig. 3) with lithoclasts (e.g., big micrite clast), algal debris and small benthic foraminifera. Sample SRB 430. Width of photo: 1.4 cm. **b** Sample SRB 430, other view. Lagoonal grainstone containing many lithoclasts and foraminifera (e.g., *Diplotremina* sp.). Width of photo: 0.5 cm. **c** Sample SRB 430, other view. Wacke- to packstone with lithoclasts, encrusted components, and several foraminifera. Width of photo: 0.5 cm. **d** Completely recrystallized back-reef framework below the drowning sequence. Sample SRB 426. Width of photo: 1.4 cm. **e** and **f** Recrystallized back-reef limestone with reef builders and encrusting organism. Sample SRB 427. Width of photo: 1.4 cm

Reference section: Unknown in the Dinarides.

Synonyms: Newly introduced.

Derivation of name: After the Stopića cave north of the type section in the Zlatibor Mountain. Compare to Fig. 3.

Lithology: Limestones partly with frame-building organism and decimeter-bedded fine- and coarse-grained crinoidal sand with shallow-water debris and hemipelagic influence (e.g., filaments, conodonts).

History: Formerly mapped as part of the Wetterstein Limestone Formation (Dimitrijević and Dimitrijević 1991).

Origin, facies: Flooding respectively drowning sequence of the Wetterstein Carbonate Platform.

Age: Late Carnian on the basis of conodont dating (Table 1). At the moment, only Tuvalian 2 is proven.

Thickness: In the type area only a 10 m thick succession is preserved. The upper part is eroded.

Lithostratigraphically higher rank: None.

Underlying units (footwall boundary): Wetterstein Formation after a gap (most probably the whole Julian).

Overlying units (hanging wall boundary): Unknown.

Geographic distribution: At the moment, only known from the type area. Similar drowning sequences of Late Carnian are known from the Eastern Alps (Northern Calcareous Alps) and the Western Carpathians. Paleogeographically bordering the outer (distal) regions of the Late Triassic shallow-water carbonate shelf facing the Neotethys Ocean.

Lateral units: Unknown.

Remarks: The Stopića Formation resembles the Late Carnian Waxeneck Formation in the Northern Calcareous Alps (Lein and Zapfe 1971; Lein 1972; Krystyn et al. 1990). Lithological affinities of the basal part of the Stopića Formation to some parts of the Wetterstein Formations are evident. A lithostratigraphic separation can be difficult in the case of "continuous" shallow-water carbonate development. When the lithostratigraphic marker (e.g., siliciclastics of the Lunz event) is missing, as in the Zlatibor Mountain, the boundary to the underlying Wetterstein Formation is often marked by an emersion horizon (compare Krystyn et al. 1990).

Discussion

The onset and drowning of the Wetterstein Carbonate Platform in the Zlatibor Mountain is directly comparable with other Wetterstein Carbonate Platform successions known from the Alpine/Carpathian realm, especially with the well-investigated successions in the Northern Calcareous Alps (Krystyn and Lein 1996; Krystyn et al. 2008). The lower part of the succession corresponds to the Raming Formation of the Northern Calcareous Alps (Lein 1989); the general evolution of the platform itself was pointed out by Dimitrijević and Dimitrijević (1991). The drowning sequence is of similar age as that known from the outer shelf area in the Northern Calcareous Alps (Lein 1972; Krystyn et al. 1990) and of the Silica unit in the southeastern part of the West Carpathians (Channell et al. 2003; Haas 2004), but corresponds paleogeographically to a more internal part of the shelf transitional to the Hallstatt zone facing the Neotethys Ocean.

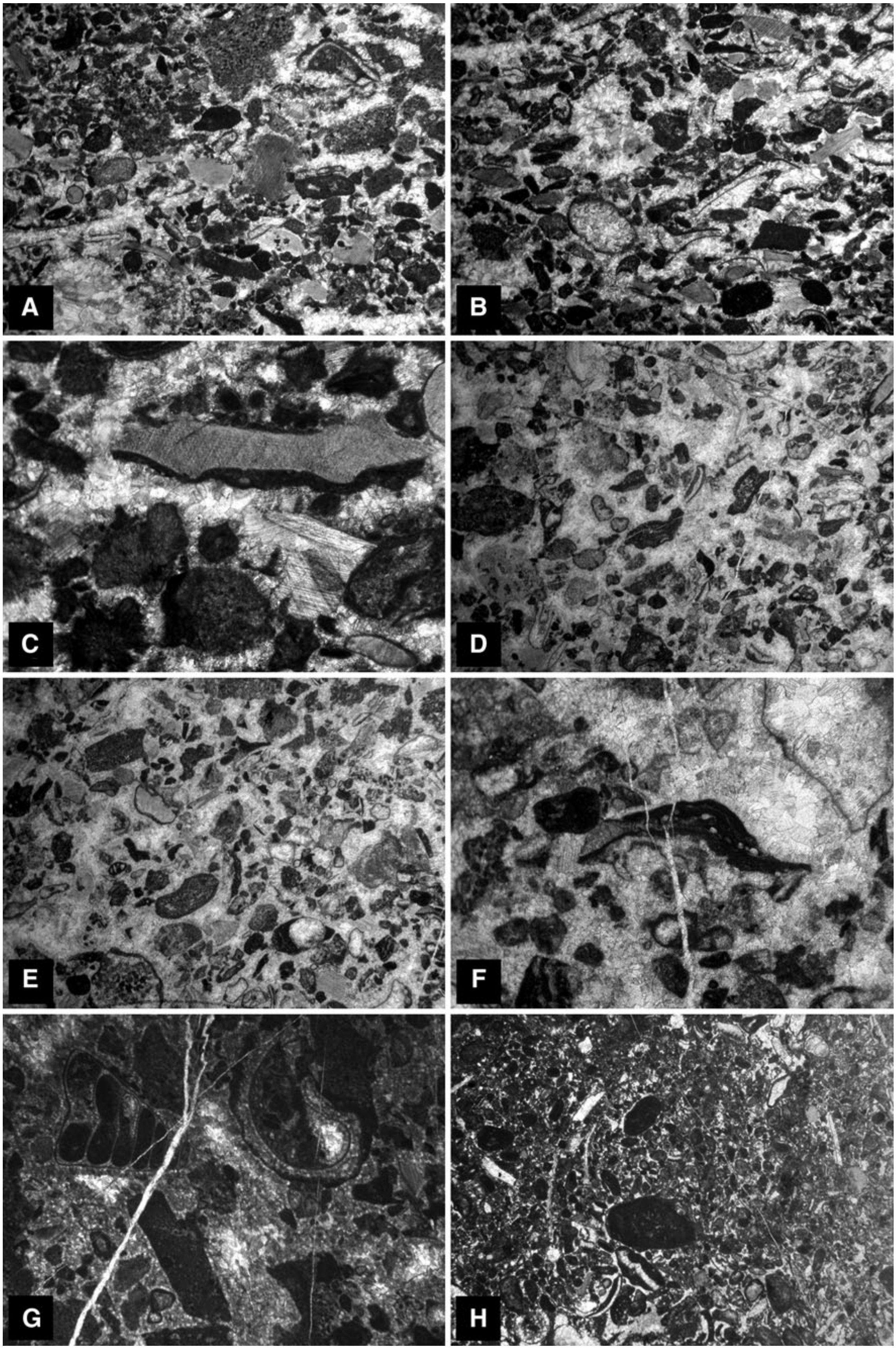
Four main reasons of drowning events are generally discussed:

1. Mass extinctions, possibly caused by environmental deterioration (Flügel 2004)
2. Large (relative) sea-level changes, caused by tectonic plus eustatic events (e.g., Schlager 1981, 2010; Purdy and Bertram 1993)
3. Repeated emergence and submergence due to small-scale sea-level changes (Schlager 1998; Wilson et al. 1998), or
4. Changes in sedimentation, especially the increase of siliciclastic input (Schlager 1989)

These changes commonly produce a drowning unconformity (Schlager 1989) formed by a relative sea-level rise or highstand, because drowning can occur only if the platform top is flooded (Schlager 2005). The lithological change from shallow-marine carbonates to hemipelagic deeper slope sediments is termed a drowning unconformity. Further, drowning of carbonate platforms is reflected by a drastic change in microfacies, sediment composition, and dominant grain types (see Flügel 2004: pp 756–757).

The studied drowning sequence follows platform deposits, which show signs of emergence/subaerial exposure such as karstification, strong recrystallization, and dolomitization. All these features, especially the karst phenomena, are missing in the overlying drowning sequence. The long-lasting omission of the platform cannot be explained solely by a sea-level drop; in fact, the Julian is also characterized by periods with higher sea level. Only uplift of the Wetterstein Carbonate Platform can explain the long-lasting omission of the platform, followed by rapid subsidence.

The reasons for this rapid subsidence are not fully understood. It occurs widespread on the distal continental margin of southeast Europe facing the Neotethys Ocean. Our data fits with sequences widespread known in the Alpine-Carpathian realm (e.g., Lein 1981, 1985; Channell et al. 2003; Haas 2004). Especially in areas transitional to the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◀ **Fig. 8** Drowning sequence (Stopića Formation) of the Wetterstein Carbonate Platform, Late Carnian. **a** Coarse-grained crinoid-rich grainstone with many different shallow-water clasts. Several components are encrusted. Sample SRB 428. Width of photo: 1.4 cm. **b** Sample SRB 428, other view. Encrusted and non-encrusted crinoids occur amongst micrite clasts. Shells are scarce. Width of photo: 1.4 cm. **c** Sample SRB 428, other view. Most organisms are intensely encrusted or have micritic envelopes. Width of photo: 0.5 cm. **d** Fine-grained grainstone with crinoids and shallow-water debris. Sample SRB 429. Width of photo: 1.4 cm. **e** Sample SRB 429, other view. Most organisms are encrusted; some remnants of reef builders are also visible. Width of photo: 1.4 cm. **f** Sample SRB 429, other view. "*Tubiphytes* sp." in the center occurs as reef builder. Width of photo: 0.5 cm. **g** Grainstone with encrusted components and gastropods. Sample A 5129/3. Width of photo: 1.4 cm. **h** Coarse-grained crinoid-bearing grainstone with numerous different shallow-water clasts. Several components are encrusted. Type area of the Waxeneck Formation, Northern Calcareous Alps, Mürzalpen nappe, section Schwarzkogel (Naßköhr). Sample H 217. Width of photo: 1.4 cm, 90° tilted

outer shelf, early Late Carnian hemipelagic sediments cover the Early Carnian Wetterstein Carbonate Platform after a time of omission similar to those in the Zlatibor Mountain. This indicates clearly new phase of subsidence in the outer shelf area facing the Neotethys Ocean. This Late Carnian subsidence pulse contrasts the evolution in the Outer Dinarides, whereas the Late Ladinian to Early Carnian evolution is similar. In the Outer Dinarides, the platforms were partly uplifted and eroded only after the Early Carnian and partly covered with Early Carnian (Julian) continental siliciclastics (e.g., Velić et al. 2002; Velić 2007; Missoni et al. 2010). In the area of the Outer Dinarides, omission of the platform lasted until the Late Norian. In this area, shallow-water carbonates (dolomites and rarely limestones) topped the Wetterstein Carbonate Platform after a long-lasting phase of omission.

The similar Late Ladinian to Early Carnian evolution of the Wetterstein Carbonate Platform in both the Outer and Inner Dinarides confirm the existence of a coherent carbonate shelf extending from the Western Carpathians to the Dinarides. Facies and sedimentological characteristics in the Outer Dinarides show a proximal shelf evolution and in the central Inner Dinarides that of a more outer shelf setting, but still on a shallow-water carbonate platform position transitional to the Hallstatt Zone. The hemipelagic sequences of the outer shelf (Hallstatt Zone) nearer to the Neotethys Ocean are preserved further to the east (Schefer et al. 2010) or as components in the Middle to Early Late Jurassic mélanges in the Dinaridic Ophiolite Belt (e.g., Gawlick et al. 2010; Sudar et al. 2010).

Age and provenance of the Sirogojno carbonate-clastic mélange succession is of special interest for the reconstruction of the Middle and Late Jurassic geodynamic evolution of the Dinarides as well as for the reconstruction of the shelf arrangement facing the Neotethys Ocean to the east. The Sirogojno mélange consists of different carbonate blocks of Triassic age (e.g., Hips et al. 2011; Gawlick et al. 2010) of both deep- and shallow-water origin derived from an outer carbonate shelf position, as proven by facies analysis and conodont dating. The carbonate-clastic mélange in the Sirogojno area is relatively devoid of matrix, only in some fissures of lagoonal Dachstein Limestone blocks remnants of the matrix (radiolarites, ophiolite components) are preserved. This resembles the situation in Krš Gradac quarry near the town Sjenica (Gawlick et al. 2009b), where a Middle to early Late Jurassic radiolarite matrix with Triassic radiolarite components occurs between blocks of lagoonal Dachstein Limestone, here proven by means of radiolarians. The carbonate-clastic mélange topped the ophiolitic mélange and seems to be of a similar age range. According to earlier interpretations, the provenance area of the Triassic shallow- and deep-water carbonate blocks is the Drina-Ivanjica Unit High further to the east, where they should have formed the original sedimentary cover (Dimitrijević 1997). However, these clasts and the kilometer-sized slide blocks are derived mostly from a carbonate platform area transitional to the Hallstatt Zone facing the Neotethys Ocean to the east. Hemipelagic limestones (e.g., Hallstatt Limestones) from the outermost shelf area, which was located originally further to the east, are missing in this mélange.

We consider therefore a polyphase westward transport of the ophiolitic mélange and the ophiolite nappes as well as westward transport of the carbonate-clastic mélange (compare Schmid et al. 2008; Gawlick et al. 2008, 2009b). Westward-directed thrusting in Jurassic times occurs widespread in the Dinaridic-Albanide realm, but the exact age of the emplacement is still a matter of controversial discussion: Middle to early Late Jurassic or latest Jurassic to earliest Cretaceous. New data (Gawlick et al. 2010; Sudar et al. 2010; Lein et al. 2010) confirm a polyphase thrusting of the ophiolithic mélange, the ophiolite nappes, and of the carbonate-clastic mélange in westward directions.

An autochthonous position of a Triassic Ocean (Dinaride or Pindos Ocean) between the Outer Dinarides and the Drina-Ivanjica Unit as a northward continuation of Pelagonia/Korabi Units in Greece and Albania, as proposed by another group of authors (e.g., Stampfli and Kozur 2006; Robertson et al. 2009), can be excluded.

Conclusions

- The Triassic sequence in Zlatibor Mountain does not consist of an originally complete shallow-water succession from Ladinian to Rhaetian times.
- The Triassic successions consist of different slides and are part of a carbonate-clastic mélange; each block provides its own sedimentary history and may be derived

from different areas of the passive margin facing the Neotethys Ocean. Such a scenario is also well known from the Northern Calcareous Alps, the Western Carpathians, and the Albanides.

- The investigated Wetterstein Carbonate Platform sequence corresponds to known sequences in the Alpine-Carpathian domain, where they mark the transitional realm between platforms and the outer shelf of the Hallstatt Zone.
- Similarities in the setting as well as in the sedimentary and stratigraphic evolution of the studied slide block point out that both regions (Alpine-Carpathian realm and Dinarides) are part of the same continental margin facing the Neotethys Ocean to the east in Triassic to Jurassic times (Fig. 2; Gawlick et al. 2008; Missoni and Gawlick 2010, 2011).

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References

Ampferer O (1928) Zur Tektonik und Morphologie des Zlatibormassivs. Denkschr Akad Wiss math-natw Kl 101:361–424

Aubouin J (1973) Des tectoniques superposées et leur signification par rapport aux modeles géophysiques: l′exemple des Dinarides; paleotectonique, téctonique, tarditectonique, neotectonique. Bull Soc géol France 15(7):426–460

Channell JET, Kozur HW (1997) How many oceans? Meliata, Vardar, and Pindos oceans in the Mesozoic Alpine paleogeography. Geology 25:183–186

Channell JET, Kozur H, Sievers T, Mock R, Aubrecht R, Sykora M (2003) Carnian–Norian biomagnetostratigraphy at Silická Brezová (Slovakia): correlation to other Tethyan sections and to the Newark Basin. Palaeogeogr Palaeoclimatol Palaeoecol 191:64–109

Ćirić B (1954) Einige Betrachtungen über die Diabas-Hornstein Formation der Dinariden. Vesn Zavoda geol geofiz istraž NRS 11:31–88 (in Serbo-Croatian, German summary)

Ćirić B (1984) Complexe ophiolitique et formations comparable dans les Dinarides. Raspr Zavoda geol geofiz istraž 23:1–44

Dimitrijević MD (1997) Geology of Yugoslavia. Geological Institute Gemini, Belgrade

Dimitrijević MD (2001) Dinarides and the Vardar Zone: a short review of the geology. In: Downes H, Vaselli O (eds) Tertiary magmatism in the Dinarides. Acta Vulcanol 13:1–8

Dimitrijević MN, Dimitrijević MD (1991) Triassic carbonate platform of the Drina-Ivanjica element (Dinarides). Acta Geol Hung 34:15–44

Dimitrijević MN, Dimitrijević MD, Karamata S, Sudar M, Gerzina N, Kovács S, Dosztály L, Gulácsi Z, Less G, Pelikán P (2003) Olistostrome/mélanges—an overview of the problems and preliminary comparison of such formations in Yugoslavia and NE Hungary. Slovak Geol Mag 9:3–21

Flügel E (2004) Microfacies of carbonate rocks—analysis, interpretation and application. Springer, Berlin Heidelberg New York, p 976

Gawlick HJ, Frisch W, Vecsei A, Steiger T, Böhm F (1999) The change from rifting to thrusting in the Northern Calcareous Alps as recorded in Jurassic sediments. Geol Rundsch 87:644–657

Gawlick HJ, Frisch W, Hoxha L, Dumitrica P, Krystyn L, Lein R, Missoni S, Schlagintweit F (2008) Mirdita Zone ophiolites and associated sediments in Albania reveal Neotethys Ocean origin. Int J Earth Sci 97:865–881

Gawlick HJ, Missoni S, Schlagintweit F, Suzuki H, Frisch W, Krystyn L, Blau J, Lein R (2009a) Jurassic tectonostratigraphy of the Austroalpine domain. J Alp Geol 50:1–152

Gawlick HJ, Sudar M, Suzuki H, Djerić N, Missoni S, Lein R, Jovanović D (2009b) Upper Triassic and Middle Jurassic radiolarians from the ophiolite mélange of the Dinaridic Ophiolite Belt, SW Serbia. N Jb Geol Paläont Abh 253:293–311

Gawlick HJ, Sudar M, Lein R, Missoni S, Jovanović D, Suzuki H (2010) The Hallstatt Mélange occurrence of Vodena Poljana in the Inner Dinarides (Zlatar Mountain, SW Serbia). J Alp Geol 52:116–118

Haas J (2004) Magyarország Geológiája Triász. Elte Eötvös Kiadó, Budapest, p 384

Haas J, Kovacs S, Krystyn L, Lein R (1995) Significance of Late Permian–Triassic facies zones in terrane reconstructions in the Alpine–North Pannonian domain. Tectonophysics 242:19–40

Hips K, Haas J, Vido M, Barna Z, Jovanović D, Sudar MN, Siklósy Z (2011) Selective blackening of bioclasts via mixing-zone aragonite neomorphism in Late Triassic limestone, Zlatibor Mountains, Serbia. Sedimentology 58:854–877

Karamata S (2006) The geological development of the Balkan Peninsula related to the approach, collision and compression of Gondwanan and Eurasian units. In: Robertson AHF, Mountrakis D (eds) Tectonic development of the eastern Mediterranean region. Geol Soc Lond Spec Publ 260:155–178

Karamata S, Dimitrijević MD, Dimitrijević MN, Milovanović D (2000) A correlation of ophiolitic belts and oceanic realms of the Vardar Zone and the Dinarides. In: Karamata S, Janković S (eds) Proceedings of the international symposium "Geology and Metallogeny of the Dinarides and the Vardar Zone", Acad Sci Arts Republic of Srpska, Coll Monogr 1, Dept Nat Math Techn Sci, vol 1, pp 61–69

Krystyn L, Lein R (1996) Triassische Becken- und Plattformsedimente der östlichen Kalkalpen. Exkursionsführer Sediment ′96. Ber Geol Bundesanst 33:1–23

Krystyn L, Lein R, Mello J, Riedel W, Piller W (1990) "Tisovec Limestone"—an example of the problems of lithostratigraphic correlation between the Northern Calcareous Alps and the central West Carpathians. In: Minaríková D, Lobitzer H (eds) Thirty years of geological cooperation between Austria and Czechoslovakia, Geological Survey Vienna, Geological Survey Prague, pp 125–136

Krystyn L, Lein R, Richoz S (2008) Der Gamsstein: Werden und Vergehen einer Wettersteinkalk-Plattform. J Alp Geol 49:157–172

Lein R (1972) Stratigraphie und Fazies der Obertrias der Mürztaler Kalkalpen. Diss Univ Wien, p 144

Lein R (1981) Deckschollen aus Hallstätter Buntkalken in Salzbergfazies in den Mürztaler Alpen südlich von Mariazell (Steiermark). Mitt Ges Geol Bergbaustud Österr 27:207–235

Lein R (1985) Das Mesozoikum der Nördlichen Kalkalpen als Beispiel eines gerichteten Sedimentationsverlaufes infolge fortschreitender Krustenausdünnung. Arch Lagerstforsch Geol Bundesanstalt 6:117–128

Lein R (1989) Neufassung des Begriffes Raminger Kalk (Oberladin-Unterkarn) auf mikrofazieller Grundlage. 4. Treffen dtsprach Sedimentologen, Innsbruck, p 2

Lein R, Zapfe H (1971) Ein karnischer Dachsteinkalk mit Pachydonten in den Mürztaler Alpen, Steiermark. Anz Öster Akad Wiss math-natw Kl 108:133–139

Lein R, Sudar M, Gawlick HJ, Missoni S, Suzuki H, Jovanović D (2010) Triassic and Jurassic radiolarians from the Dinaridic Ophiolite Belt (Zlatibor area, SW Serbia). Geologica Balcanica 39:335–336

Missoni S, Gawlick HJ (2010) Evidence for Jurassic subduction from the Northern Calcareous Alps (Berchtesgaden; Austroalpine, Germany). Int J Earth Sci. doi:10.1007/s00531-010-0552-z

Missoni S, Gawlick HJ (2011) Jurassic mountain building and Mesozoic–Cenozoic geodynamic evolution of the Northern Calcareous Alps as proven in the Berchtesgaden Alps (Germany). Facies 57:137–186. doi:10.1007/s10347-010-0225-1

Missoni S, Velić I, Gawlick H-J, Tišljar J, Vlahović I (2010) How many middle Triassic carbonate platforms in the Outer Dinarides? New insights from Velebit Mountains (Croatia). J Alp Geol 52:185–186

Pilger A (1941) Paläogeographie und Tektonik Jugoslawiens zwischen der Una und dem Zlatibor-Gebirge. N Jb Min Geol Paläont 85, Beil-Bd, Abt B:383–462

Purdy EG, Bertram GT (1993) Carbonate concepts from the Maldives, Indian Ocean. Am Assoc Petrol Geol Stud Geol 34:1–56

Radovanović Z, Popević A (1999) Geological map of the Republic of Serbia, Užice 4, 1:50000. Ministry of Science and Environmental Protection, Republic of Serbia

Remane J, Addate T, Berger JP, Burkhalter R, Dall'Agnolo S, Decrouez D, Fisher H, Funk H, Furrer H, Graf HR, Gouffon Y, Heckendorn W, Winkler W (2005) Richtlinien zur stratigraphischen Nomenklatur des Schweizerischen Komitee fur Stratigraphie. Eclogae Geol Helv 98:385–405

Riding R (1993) *Shamovella obscura*: the correct name for *Tubiphytes obscurus* (Fossil). Taxon 42:71–73

Robertson A, Karamata S, Šarić K (2009) Overview of ophiolites and related units in the Late Paleozoic–Early Cenozoic magmatic and tectonic development of Tethys in the northern part of the Balkan region. Lithos 108:1–36

Salvador AE (ed) (1994) International stratigraphic guide. A guide to stratigraphic classification, terminology, procedure, 2nd edn. Geol Soc Am

Schefer S, Egli D, Missoni S, Bernoulli D, Fügenschuh B, Gawlick H-J, Jovanović D, Krystyn L, Lein R, Schmid S, Sudar MN (2010) Triassic metasediments in the Internal Dinarides (Kopaonik area, southern Serbia): stratigraphy, paleogeography and tectonic significance. Geol Carpath 61:89–109

Schlager W (1981) The paradox of drowned reefs and carbonate platforms. Geol Soc Am Bull 92:197–211

Schlager W (1989) Drowning unconformities on carbonate platforms. In: Crevello PD, Wilson JL, Sarg JF, Read JF (eds) Controls on carbonate platform and basin development. SEPM Spec Publ 44:15–25

Schlager W (1998) Exposure, drowning and sequence boundaries on carbonate platforms. Int Assoc Sedimentol Spec Publ 25:3–21

Schlager W (2005) Carbonate sedimentology and sequence stratigraphy. SEPM Concept Sedimentol Paleont 8:1–200

Schlager W (2010) Ordered hierarchy versus scale invariance in sequence stratigraphy. Int J Earth Sci 99(Suppl 1):S139–S151

Schmid SM, Bernoulli D, Fügenschuh B, Matenco L, Schefer S, Schuster R, Tischler M, Ustaszewski K (2008) The Alpine-Carpathian-Dinaride-orogenic system: correlation and evolution of tectonic units. Swiss J Geosci 101:139–183

Schmid SM, Bernoulli D, Fügenschuh B, Matenco L, Oberhänsli R, Schefer S, Ustaszewski K (2010) Correlation of major tectonic units from the Alps to western Turkey. Geologica Balcanica 39:352–353

Senowbari-Daryan B, Bucur IO, Schlagintweit F, Sasaran E, Matyszkiewicz J (2008) *Crescentiella*, a new name for *"Tubiphytes" morronensis* Crescenti, 1969: an enigmatic Jurassic-Cretaceous microfossil. Geol Croatica 61:185–214

Smith AG, Spray JG (1984) A half-ridge transform model for the Hellenic-Dinaric ophiolites. In: Dixon JE, Robertson AHF (eds) The geological evolution of the Eastern Mediterranean. Geol Soc Lond Spec Publ 17:629–644

Stampfli GM, Kozur H (2006) Europe from the Variscan to the Alpine cycles. In: Gee DG, Stephenson RA (eds) European lithosphere dynamics. Geol Soc Mem 32:57–82

Stampfli GM, Borel GD, Cavazza W, Mosar J, Ziegler PA (2001) The paleotectonic atlas of the periTethyan domain. CD-ROM, Eur Geophys Soc

Steininger F, Piller W (1999) Empfehlungen (Richtlinien) zur Handhabung der stratigraphishen Nomenklatur. Cour Forsch-Inst Senckenberg 209:1–19

Sudar M (1986) Triassic microfossils and biostratigraphy of the Inner Dinarides between Gučevo and Ljubišnja Mts., Yugoslavia. Geol an Balk poluo 50:151–394 (in Serbian with English summary)

Sudar M, Gawlick H-J, Lein R, Missoni S, Jovanović D, Krystyn L (2008) Drowning and block tilting of Middle Anisian carbonate platform in the Middle Jurassic Zlatibor mélange of the Dinaridic Ophiolite Belt (SW Serbia). J Alp Geol 49:106–107

Sudar M, Gawlick HJ, Missoni S, Suzuki H, Jovanović D, Lein R (2010) The carbonate-clastic radiolaritic mélange of Pavlovica Cuprija: a key to solve the palaeogeography of the Hallstatt Limestones in the Zlatar Mountain (SW Serbia). J Alp Geol 52:53–57

Tollmann A (1966) Geologie der Kalkvoralpen im Ötscherland als Beispiel alpiner Deckentektonik. Mitt Geol Ges Wien 58:103–207

Velić I (2007) Velebit Mt. In: Grgasović T, Vlahović I (eds) Field trip guidebook and abstracts of the 9th international symposium on fossil algae. Croatian Geol Surv, Zagreb, pp 7–11

Velić I, Vlahović I, Maticec D (2002) Depositional sequences and palaeogeography of the Adriatic carbonate platform. Mem Soc Geol It 57:141–151

Wilson PA, Jenkyns HC, Elderfield H, Larson RL (1998) The paradox of drowned carbonate platforms and the origin of Cretaceous Pacific guyots. Nature 392:889–894