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Abstract: Oceanic radiolarite components from the Middle Jurassic ophiolitic mélange between Trnava and Rožanstvo in the Zlatibor Mountains (Dinaridic Ophiolite Belt) west of the Drina–Ivanjica unit yield Late Triassic radiolarian ages. The microfacies characteristics of the radiolarites show pure ribbon radiolarites without crinoids or thin-shelled bivalves. Beside their age and the preservation of the radiolarians this points to a deposition of the radiolarites on top of the oceanic crust of the Neo-Tethys, which started to open in the Late Anisian. South of the study area the ophiolitic mélange (Gostilje–Ljubiš–Visoka–Radoševo mélange) contains a mixture of blocks of 1) oceanic crust, 2) Middle and Upper Triassic ribbon radiolarites, and 3) open marine limestones from the continental slope. On the basis of this composition we can conclude that the Upper Triassic radiolarite clasts derive either from 1) the younger parts of the sedimentary succession above the oceanic crust near the continental slope or, more convincingly 2) the sedimentary cover of ophiolites in a higher nappe position, because Upper Triassic ribbon radiolarites are only expected in more distal oceanic areas. The ophiolitic mélange in the study area overlies different carbonate blocks of an underlying carbonate-clastic mélange (Sirogojno mélange). We date and describe three localities with different Upper Triassic radiolarite clasts in a mélange, which occurs A) on top of Upper Triassic fore-reef to reefal limestones (Dachstein reef), B) between an Upper Triassic reefal limestone block and a Lower Carnian reef limestone (Wetterstein reef), and C) in fissures of an Upper Triassic lagoonal to back-reef limestone (Dachstein lagoon). The sedimentary features point to a sedimentary and not to a tectonic emplacement of the ophiolitic mélange (=sedimentary mélange) filling the rough topography of the topmost carbonate-clastic mélange below. The block spectrum of the underlying and slightly older carbonate-clastic mélange points to a deposition of the sedimentary ophiolitic mélange east of or on top of the Drina–Ivanjica unit.

Keywords: Neo-Tethys, trench-like basins, synorogenic deposition, evolving thrust belt, Triassic palaeogeography.

Introduction

Latest Ladinian and Late Triassic ribbon radiolarites are of special interest, because only these sediments undoubtedly represent the original sedimentary cover of the Neo-Tethys ocean crust (for review see Gawlick & Missoni 2015). In contrast, Late Anisian to early Late Ladinian radiolarites were deposited on ocean floor or on subsided continental margins, where these Late Anisian to early Late Ladinian radiolarites were widespread and also formed in relatively shallow water depths (Gawlick et al. 2012a; Gawlick & Missoni 2015). Therefore, Late Anisian to early Late Ladinian radiolarites either derive from the distal shelf to continental slope region or the oceanic realm, as also expressed in a characteristic microfacies (e.g., Gawlick & Missoni 2015; Gawlick et al. 2016a, b). In contrast, latest Ladinian to Rhaetian ribbon radiolarites were absent in continental-margin settings and clearly indicate deposition on the ocean floor (Krische et al. 2014; Gawlick & Missoni 2015). The absence of ribbon radiolarites on the continental margin is due to the fact that supply from shallow-water carbonate ramps and platforms led to the accumulation of a thick pile of carbonate mud on the distal shelf and partly even in the proximal oceanic domain (Gawlick & Böhm 2000). This is valid for the late Middle and Late Triassic except the Julian stage. Accordingly, radiolarites of this age can only be expected in more distal oceanic areas (Gawlick et al. 2008; Krische et al. 2014).

Synorogenic erosion and deposition is a characteristic feature of evolving thrust belts. The structures of the Jurassic orogeny in the eastern Mediterranean mountain chain are often masked by the younger and polyphase tectonic motions (Schmid et al. 2008). In addition, synorogenic sedimentary basin fills or mass transport deposits in trench-like basins in front of a propagating nappe stack, are commonly overprinted by multiple deformational events or reworked by tectonics, showing the typical features of a mélange. To distinguish a tectonic from a sedimentary mélange (Hsü 1968, 1974; Gawlick & Frisch 2003; Gawlick et al. 2008, 2012b, 2016a; Festa et al. 2010a, b; Plašienka 2012) is especially complicated in cases, in which the synorogenic basin fills were incorporated into the nappe stack becoming sheared forming olistostromal carpets (Festa et al. 2016).

To unravel the depositional characteristics of synorogenic sedimentary successions (mélanges) accompanied by component analysis provide an excellent possibility to reconstruct the geodynamic history of an evolving mountain belt. Component analyses of conglomerates, breccia layers or turbidite beds are a common tool in sedimentary geology. One classical approach is provenance analysis, the reconstruction of the source area from the clast spectrum of the re-sedimented rocks (Blatt 1967; Zuffa 1980, 1985; Lewis 1984). Whereas the detailed provenance analyses of siliciclastic material is common, provenance analyses of carbonate or radiolarite clasts in conglomerates or breccias remain rare (Gawlick et al. 2008, 2009a, 2015, 2016a, b; Krische et al. 2014). For reliable results, a macroscopic description of the incorporated clasts has to be combined with microfacies analyses (Flügel 2004) and age dating. Carbonate and radiolarite clasts should be dated by their microfossil content, if possible. Such analyses provide the possibility of an exact reconstruction of the provenance area. The proof of a single component may change plate tectonic and palaeogeographic reconstructions substantially.

Of special interest and still controversial is the original emplacement and genesis of the ophiolitic mélange in the Inner Dinarides, especially in the Dinaridic Ophiolite Belt. Three different possibilities are discussed in the moment: A) a tectonic mélange formed on the base of the overriding ophiolite sheets of the Zlatibor mafic and ultramafic massifs, B) a sedimentary mélange formed in front of the obducted ophiolites in trenches or foredeeps, or C) an original sedimentary olistostrome and mass transport dominated deep-water basin fill in front of an advancing nappe stack later incorporated in the nappe stack forming an olistostromal carpet below the overthrusted units (Fig. 1).

Radiolarite and carbonate clasts from the Gostilje–Ljubiš–Visoka–Radeševo ophiolitic mélange south of our study area were recently investigated in detail by Gawlick et al. (2016b). The age of the ophiolitic mélange was dated as late Middle to early Late Jurassic by means of radiolarians. The components in the mélange were attributed to oceanic and distal continental slope provenance. The mélange was attributed to be a sedimentary mélange, but the question of exact timing of its emplacement in its present geographical position in the Dinaridic Ophiolite Belt west of the Drina–Ivanjica unit could not be solved. At present it is commonly believed that ophiolite obduction on the Adria margin started in the Late (latest) Jurassic and that the ophiolite nappes including their underlying mélange were emplaced in the area of the Dinaridic Ophiolite Belt around the Jurassic/Cretaceous-boundary or the Early Cretaceous (Djerić et al. 2007; Schmid et al. 2008). However, Gawlick et al. (2009b, 2016b) proved that the onset of obduction onto the Adria continental margin of the Inner Dinarides was Middle Jurassic, and therefore contemporaneous with the onset of obduction in the Albanides (Gawlick et al. 2008) or Hellenides (Baumgartner 1985; Ozsvárt et al. 2012; Ferriére et al. 2016). Gawlick et al. (2016b) speculated therefore that ophiolite obduction started in the middle Middle Jurassic, affecting at that time the most distal parts of the Adria margin, and continued until the early Late Jurassic reaching at that time the area of the Drina–Ivanjica unit. Later, in the Latest Jurassic to earliest Cretaceous, new tectonic motions probably related to mountain uplift (Missoni & Gawlick 2011a, b) resulted in the ongoing westward transport of the ophiolite nappe stack including the underlying mélanges. The final emplacement of the mélanges and the nappes in the area of the Dinaridic Ophiolite Belt, meaning to the west of the Drina–Ivanjica unit is therefore much younger than the formation of the mélanges.

On basis of the commonly accepted reconstruction of the Triassic to Early Jurassic shelf (passive continental margin) (compare Gawlick et al. 1999, 2008; Haas et al. 2011; Kovács et al. 2011) and the reconstruction of the westward propagating nappe stack during Middle to early Late Jurassic times (Gawlick et al. 2008, 2012b; Schmid et al. 2008) we present here new data which clearly indicate, that 1) the deposition of the ophiolitic mass transport deposits on top of a carbonate-clastic trench-like basin fill with material from the back-reef to fore-reef facies belt of the destroyed Triassic-Jurassic passive margin of Adria took place in late Middle to early Late Jurassic times in 2) an area east of or on top of the Drina–Ivanjica unit.

A primary sedimentary origin of the ophiolitic mélange today below the ophiolites of Zlatibor Mountains can be proven. In addition, the earliest stage of the deposition of such a sedimentary ophiolitic mélange above an older trench-like basin filled with km-sized slide-blocks on top is described here for the first time. The earliest mass transport deposits reflecting synorogenic erosion of the advancing ophiolite nappe stack fill the rough topography of the older basin fill.

Geological setting

The study area is located west of the Drina–Ivanjica unit in the most eastern part of the Dinaridic Ophiolite Belt south of Užice (Fig. 2a). This part of the Dinaridic Ophiolite Belt consists of a series of different mélanges or olistostromal bodies (Fig. 2b), which should derive from the Drina–Ivanjica unit, first described by Dimitrijević (1982), but in a different meaning: Dimitrijević (1982) interpreted the reworked carbonate clasts as part of the original sedimentary cover of the Drina–Ivanjica unit. Recent investigations have pointed out, that the different carbonate blocks in the study area derive

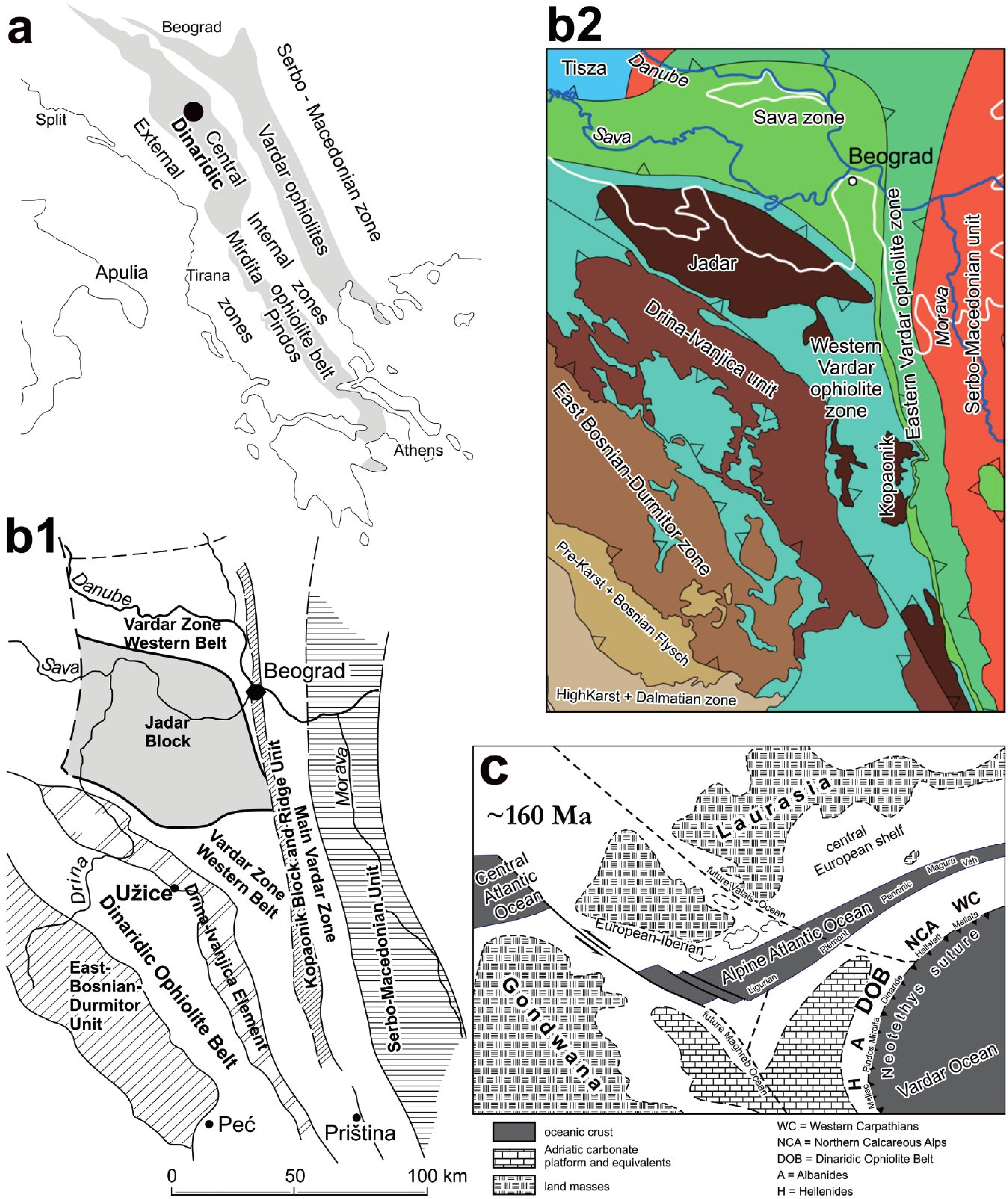

Fig. 1. Study area south of Užice. **a** — Regional geological setting showing the External zones, the central ophiolite zone (Dinaridic–Mirdita–Pindos ophiolites), the Internal zones (Pelagonian zone, Korabi zone, Drina–Ivanjica Element/unit) and the Vardar ophiolites. For details, e.g.: Aubouin 1973; Dimitrijević 1997; Karamata 2006. **b1** — Tectonic units and terranes of the central Balkan Peninsula in the sense of Karamata (2006). **b2** — Tectonic units of the central Balkan Peninsula according to Schmid et al. (2008) (from Schmid et al. 2008, modified). For detailed explanation see Schmid et al. (2008). **c** — Palaeogeographic position of the Dinaridic Ophiolite Belt (DOB) as part of the Neotethyan Belt (modified after Frisch 1979; Missoni & Gawlick 2011a, b).

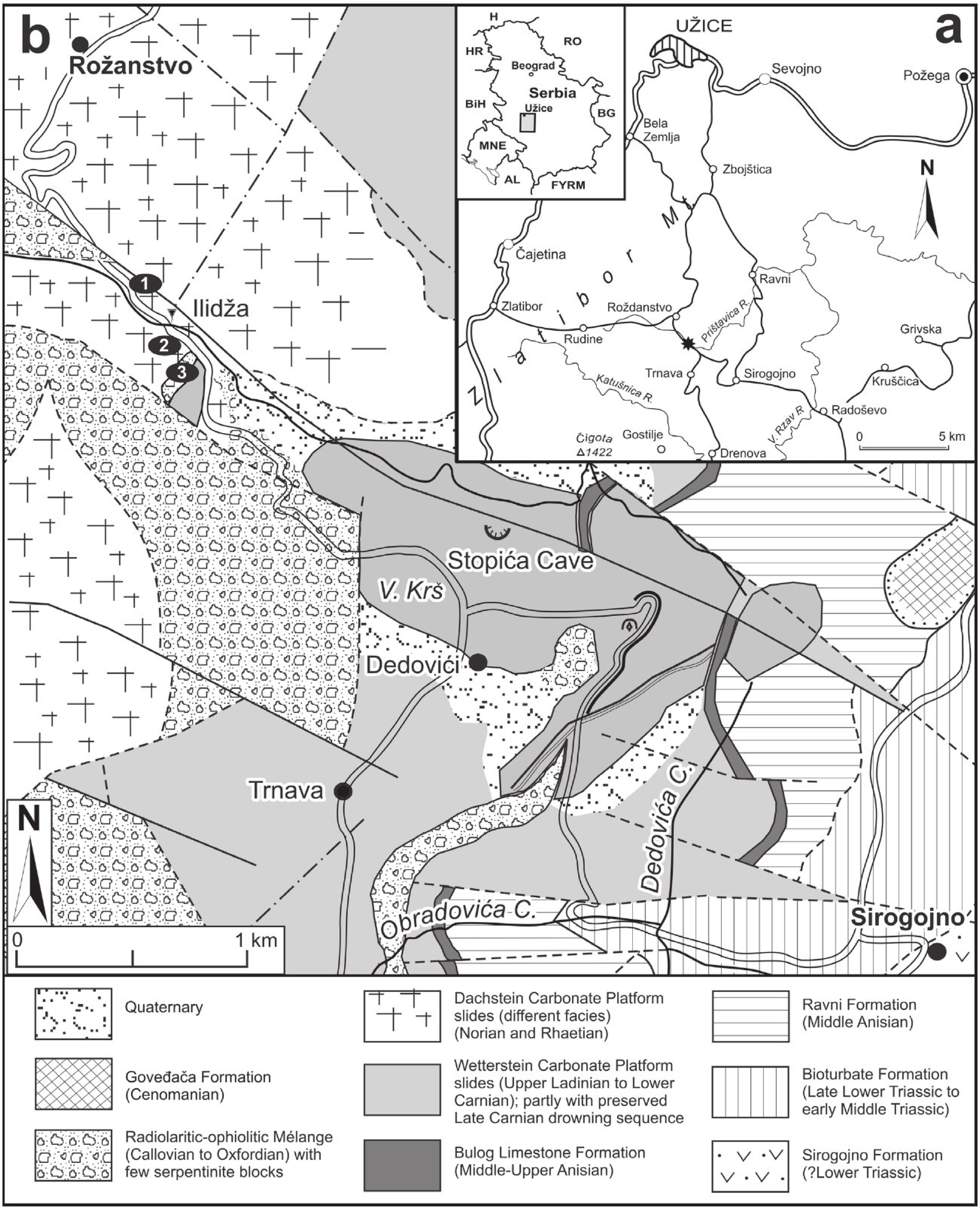

Fig. 2. a — Geographical sketch map showing the study area (marked by an asterisk) of the ophiolitic mélange between Trnava and Rožanstvo in southwest Serbia. **b** — Modified geological map of the Geological map of the Republic of Serbia, Užice 4, 1:50,000 and Missoni et al. (2012) (area between Trnava, Sirogojno and Rožanstvo in the Zlatibor Mountain, SW Serbia; Radovanović & Popević 1999). The investigated radiolarite components from the ophiolite mélange in fissures, on top or aside different slide blocks are marked by numbers. **Locality 1** — Sample SRB 207 from a fissure filling in back-reef to lagoonal Upper Triassic Dachstein Limestone. **Locality 2 —** Samples SCG 48a and b overlying a Late Triassic fore-reef to reefal block. **Locality 3** — Samples SCG 50-52 from the ophiolitic mélange between a Late Triassic fore-reef to reefal block and an Early Carnian reefal block of the Wetterstein Formation.

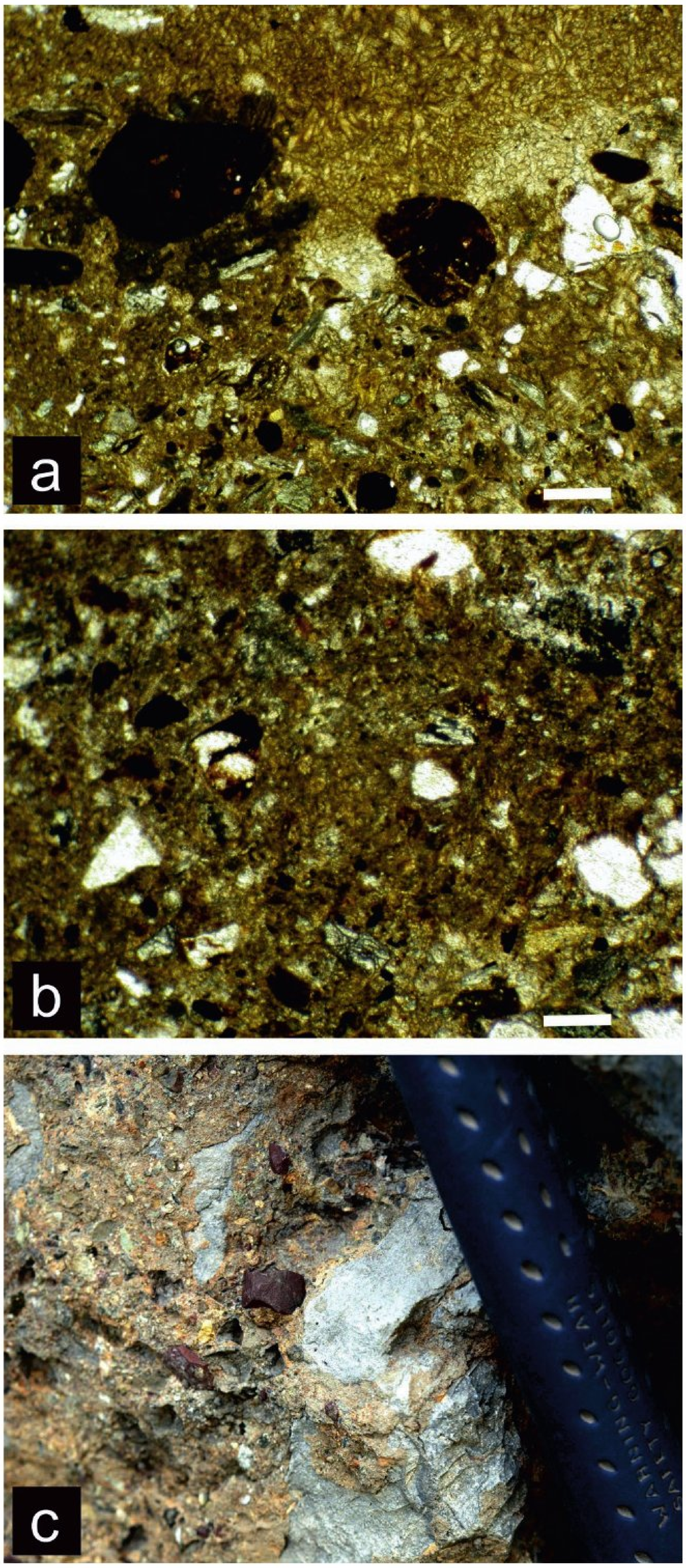

Fig. 3. Occurrence of the ophiolitic mélange in fissures of the back-reef to lagoonal Dachstein Limestone between Trnava and Rožanstvo. **a** — Microfacies of some clasts of the fine-grained ophiolitic mélange which occurs in the fissures. Beside different volcanic clasts also clasts of dark red radiolarites with recrystallized radiolarians occur. Scale bar = 1 mm. **b** — Fine-grained ophiolitic mélange consisting of volcanite grains and radiolarite grains in a glass matrix. Scale bar = 1 mm. **c** — Field view of the fissures in the Dachstein Limestone filled with coarse-grained ophiolitic mélange. Violet-reddish and reddish radiolarite clasts beside the dark volcanic clasts are well visible.

from a provenance area far to the east from the Drina–Ivanjica unit (Missoni et al. 2012; Sudar et al. 2013; Gawlick et al. 2016b). The overlying late Middle to early Late Jurassic ophiolitic mélange (Gostilje–Ljubiš–Visoka–Radoševo mélange: Gawlick et al. 2016b) is topped by the mafic and ultramafic Dinaridic ophiolite nappes, which represent far travelled ophiolite sheets from the Neo-Tethys, which was located far to the east.

The studied ophiolitic mélange can be considered as a sedimentary trench-like basin fill (sedimentary mélange). The ophiolitic mélange overlies the carbonate-clastic basin fill of the Sirogojno mélange (Missoni et al. 2012; Sudar et al. 2013) and beside numerous different components from the ophiolite suite it contains several radiolarite components from the original sedimentary cover of the ocean floor.

Sampled sites, material and methods

Beside a lot of outcrops of the ophiolitic mélange south of the study area the outcrops between Rožanstvo and Trnava near Ilidža (Fig. 2) provide the rather rare possibility to study components from the ophiolitic mélange which occur in fissures of underlying limestone blocks (Fig. 3), fill depressions between different limestone blocks or lie directly on top of limestone blocks. Different components of the ophiolite suite dominate the component spectrum. Radiolarite components occur more rarely. The matrix consists of fine- and coarse-grained sand made of eroded ophiolitic and radiolaritic material.

We studied more than 10 different radiolarite pebbles of different colours (greenish, reddish, red, violet) for the microfacies characteristics and the biostratigraphic age. Six radiolarian samples yielded determinable and moderately preserved radiolarian assemblages.

Results

Lithology and microfacies

Apart from the biostratigraphic age, microfacies analysis of both radiolarites and limestones provides information about their depositional setting (e.g., relative water depth, transport regime, environment — e.g., bioturbating biota, oxygen content) and diagenetic overprint. Whereas microfacies analysis of limestones is a common tool to describe their depositional setting (Flügel 2004), microfacies analyses of radiolarites remain rare, but, besides the overall lithofacies and the sedimentation rate (Jenkyns & Winterer 1982; De Wever et al. 2001; Baumgartner 2013), they provide a powerful tool for the reconstruction of the depositional realm of radiolaritic sequences (Gawlick & Missoni 2015; Gawlick et al. 2016a). In certain cases the microfacies of the radiolarites is typical of an age range. Microfacies differences not only reflect the relative water depth (deposition on shelf areas versus

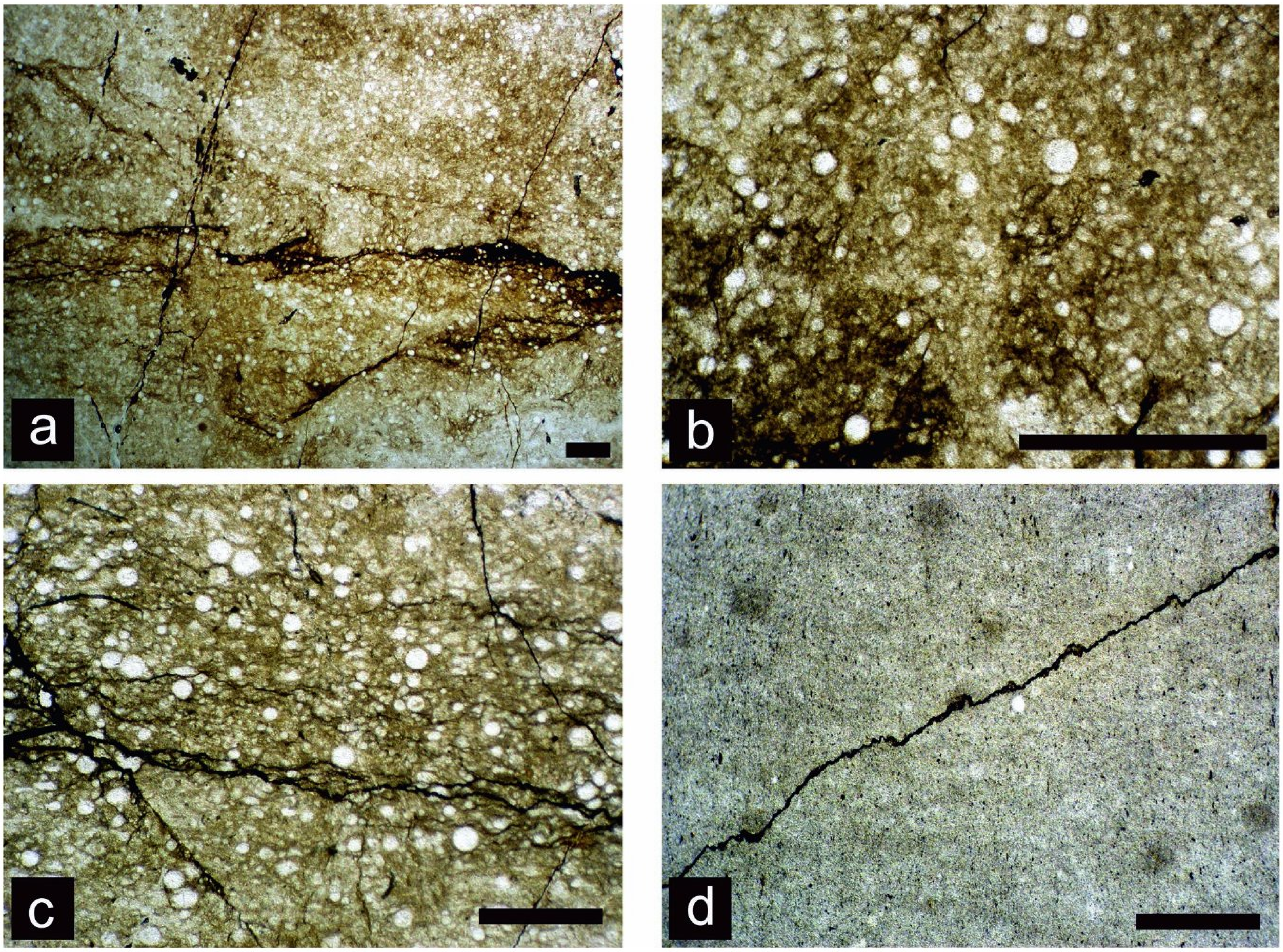

Fig. 4. Microfacies of the Late Triassic radiolarite components in the ophiolitic mélange near Ilidža on top of the carbonate-clastic mélange. **a** — Bioturbated reddish-grey radiolarian packstone. Sample SCG 50, Scale bar = 1 mm. **b** — Enlargement of 1. The radiolarians are recrystallized and occur as microquartz. The matrix is not completely slicified, in places the muddy matrix is still preserved and therefore the preservation of the radiolarians is moderate. Scale bar = 1 mm. **c** — Bioturbated violet-greyish radiolarian wackestone to packstone in a muddy and only slightly slicified matrix. All radiolarians are preserved as microquartz. Sample SCG 51, Scale bar = 1 mm. **d** — Completely slicified greyish radiolarite. The radiolarians occur as microquartz and are visible only as ghosts in the thin section. The preservation of the radiolarians is still rather good. Sample SCG 52, Scale bar = 1 mm.

deposition on oceanic crust), the sizes of the radiolarians and accompanying organisms (filaments, shells) also differ in relation to their age (Fig. 4).

Practically all radiolarite components from the ophiolitic mélange between Trnava and Rožanstvo are violet-greyish, violet-reddish or red, in some cases manganese-rich, as typical for condensed oceanic ribbon radiolarites (e.g., Baumgartner 2013). They are completely bioturbated and therefore massive, in some cases mud-rich. All radiolarite components show a more or less similar microfacies. Carbonate free radiolarian wackestones to packstones in a muddy, in some cases completely silicified matrix are dominant. Filaments or crinoids, as typical for shelf or continental slope near radiolarites are completely missing in these radiolarite components (Gawlick et al. 2016a), they do not even occur as silicified ghosts. This microfacies resembles oceanic radiolarites as described by Gawlick et al. (2008, 2016a, b).

Radiolarian dating

All samples with identifiable radiolarians derive from the ophiolitic mélange on top of different carbonate blocks or fissure fillings. Samples SCG 48a and 48b derive from the ophiolitic mélange overlying a Late Triassic fore-reef to reefal block (reefal Dachstein Limestone). Samples SCG 50, 51 and 52 derive from the ophiolitic mélange filling a depression between the Late Triassic fore-reef to reefal block and an Early Carnian reefal limestone block (Wetterstein Formation). Sample SRB 207 derives from a fissure infilling in Late Triassic lagoonal to back-reef limestone (lagoonal Dachstein Limestone).

The preservation of all radiolarians is rather poor, sometimes poor to moderate. In some cases they can be determined only on the family level.

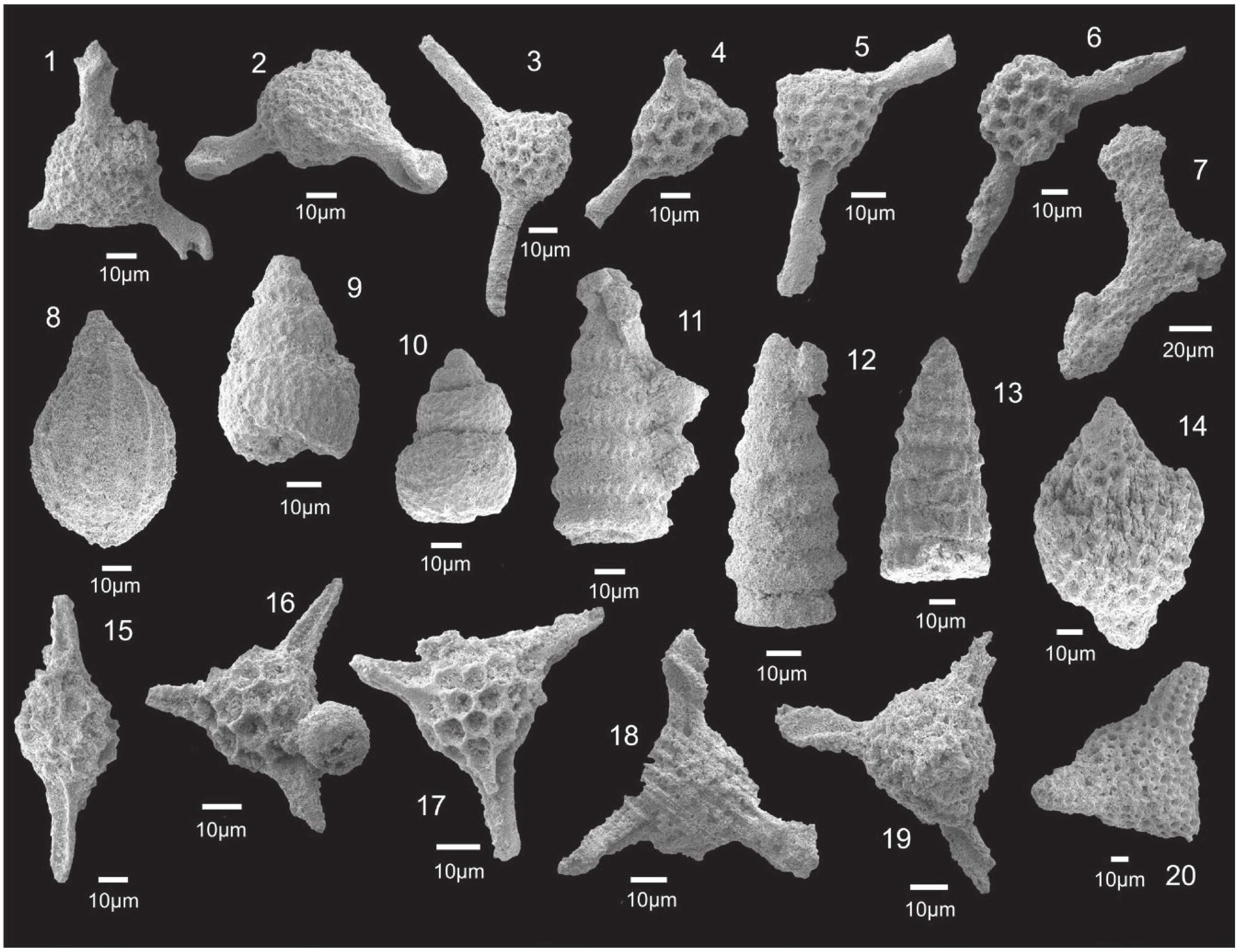

Fig. 5. Late Triassic radiolarians from radiolarite components from the ophiolitic mélange on top of a Late Triassic fore-reef to reefal block. **1–14** — Radiolarians from sample SCG 48a (late Carnian to middle Norian): **1–2** — *Capnuchosphaera* sp. cf. *C. triassica* De Wever; **3** — *Capnodoce* sp. cf. *C. sarisa* De Wever; **4** — *Capnodoce* sp. cf. *C. anapetes* De Wever; **5** — *Capnodoce* sp. cf. *C. crystallina* Pessagno; **6** — *Capnodoce* sp. cf. *C. extenta* Blome; **7** — *Triassoastrum* sp. cf. *T. noricum* (Kozur & Mock); **8** — *Praeprotunuma antiqua* Tekin; **9** — *Canesium*? sp.; **10** — *Canesium* sp.; **11–12** — *Japonocampe* sp. cf. *J. mundum* (Blome); **13** — *Corum* sp. cf. *C. speciosum* Blome; **14** — *Spinosicapsa* sp.; **15–20** — Radiolarians from sample SCG 48b (late Norian–Rhaetian): **15** — *Pantanellium* sp.; **16–17** — *Betraccium* sp. aff. *B. inornatum* Blome; **18** — *Ferresium* sp.; **19** — *Cantalum* sp.; **20** — *Tetraporobrachia* sp. cf. *T. composita* Carter.

Samples SCG 48a and b

Small reddish-grey radiolarite components from the ophiolitic mélange on top of a Late Triassic fore-reef to reefal block. Samples SCG 48a and SCG 48b are characterized by presence of two distinctive assemblages:

SCG 48a (Fig. 5): *Canesium* sp., *Capnodoce* sp. cf. *C. anapetes* De Wever, *C.* sp. cf. *C. extenta* Blome, *C.* sp. cf. *C. crystallina* Pessagno, *C.* sp. cf. *C. sarisa* De Wever, *Capnuchosphaera* sp. cf. *C. triassica* De Wever, *Corum* sp. cf. *C. speciosum* Blome, *Japonocampe* sp. cf. *J. mundum* (Blome), *Spinosicapsa* sp., *Praeprotunuma antiqua* Tekin, *Triassoastrum* sp. cf. *T. noricum* (Kozur & Mock). Taxa of this assemblage are common from the Upper Carnian to Lower Norian and probably Middle Norian and are present in numerous localities of the Mediterranean, western North America, Japan and Far Eastern Russia (De Wever et al. 1979; Nakaseko & Nishimura 1979; Pessagno et al. 1979; Blome 1983, 1984; Bragin 1991, 2007; Sugiyama 1997; Tekin 1999). Due to relatively poor preservation the majority of taxa were determined in open nomenclature, and the age should be determined in the broad interval — from Upper Carnian to Middle Norian.

Sample SCG 48b (Fig. 5): *Betraccium* sp. aff. *B. inornatum* Blome, *Cantalum* sp., *Ferresium* sp., *Pantanellium* sp., *Tetraporobrachia* sp. cf. *T. composita* Carter. This assemblage is younger. *Betraccium inornatum* Blome is known from the Upper Norian of Oregon (Blome 1983), from the Rhaetian of Turkey (Tekin 1999), and from the Upper Norian of the New Siberian Islands (Russia, Arctic) (Bragin 2011), while *Tetraporobrachia composita* Carter was reported from the Rhaetian of British Columbia (Carter 1993) and from the Upper Norian of Turkey (Bragin & Tekin 1996) and Greece

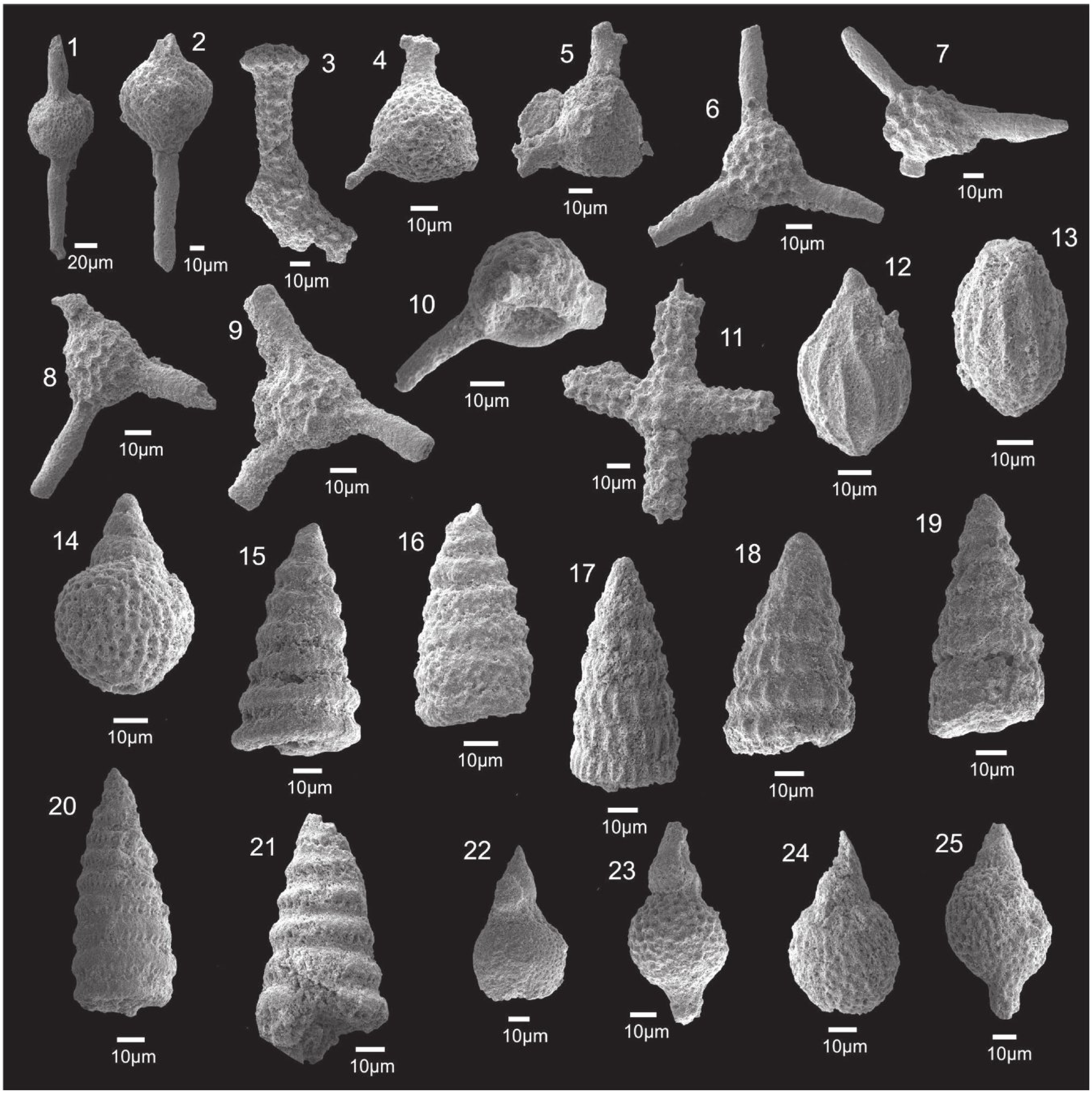

Fig. 6. Late Triassic (latest Carnian to early Norian) radiolarians from sample SCG 50. **1–2** — *Tubospongopallium* sp.; **3** — *Triassoastrum* sp.; **4** — *Monocapnuchosphaera* sp.; **5** — *Capnuchosphaera* sp.; **6–7** — *Capnodoce crystallina* Pessagno group; **8** — *Capnodoce* sp. cf. *C. crystallina* Pessagno; **9** — *Capnodoce anapetes* De Wever; **10** — *Poulpus* sp. cf. *P. piabyx* De Wever; **11** — *Crucella tenuis* Tekin; **12** — *Praeprotunuma antiqua* Tekin; **13** — *Praeprotunuma* sp. cf. *P. antiqua* Tekin; **14** — *Canesium* sp.; **15** — *Canoptum*? sp.; **16** — *Pachus* sp.; **17** — *Corum regium* Blome; **18** — *Corum* sp. cf. *C. regium* Blome; **19** — *Corum* sp. cf. *C. speciosum* Blome; **20** — *Japonocampe* sp. aff. *J. longulum* (Blome); **21** — *Japonocampe* sp. cf. *J. mundum* (Blome); **22** — *Spinosicapsa extansa* (Tekin); **23** — *Spinosicapsa* sp. cf. *S. turgida* (Blome); **24–25** —*Spinosicapsa* sp.

(Bragin et al. 2014). Therefore this assemblage can be dated as Upper Norian–Rhaetian.

Sample SCG 50

Reddish Mn-rich massive radiolarite (Fig. 4) from a depression-fill between a Late Triassic fore-reef to reefal block (Dachstein Limestone) and an Early Carnian reefal block. The microfacies shows a bioturbated radiolarian packstone. Other organisms are missing. The following taxa were determined (Fig. 6): *Canesium* sp., *Canoptum*? sp., *Capnodoce anapetes* De Wever, *C. crystallina* Pessagno group, *Capnuchosphaera* sp., *Corum regium* Blome, *C.* sp. cf. *C. regium* Blome, *C.* sp. cf. *C. speciosum* Blome, *Crucella tenuis* Tekin, *Japonocampe* sp. aff. *J. longulum* (Blome), *J.* sp. cf. *J. mundum* (Blome), *Monocapnuchosphaera* sp., *Pachus* sp., *Poulpus* sp. cf.

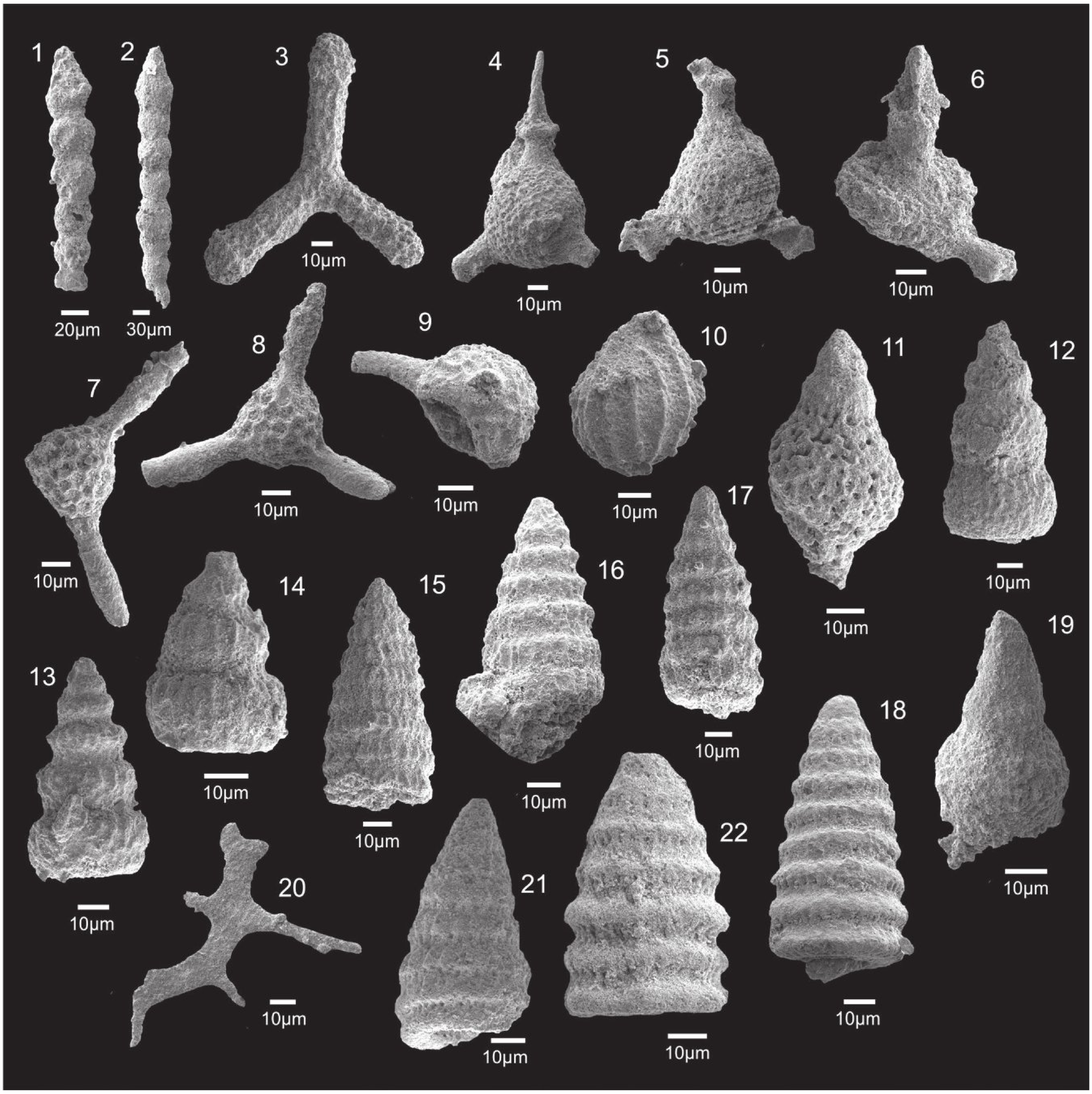

Fig. 7. Late Triassic radiolarians from radiolarite components from the ophiolitic mélange. **1–19** — Radiolarians from sample SCG 51 (latest Carnian to early Norian): **1–2** — *Xiphothecaella* sp. cf. *X. longa* (Kozur & Mock); **3** — *Triassoastrum*? sp.; **4** — *Capnuchosphaera theloides* De Wever; **5** — *Capnuchosphaera* sp. cf. *C. triassica* De Wever; **6** — *Capnuchosphaera* sp.; **7–8** — *Capnodoce crystallina* Pessagno group; **9** — *Poulpus* sp. cf. *P. piabyx* De Wever; **10** — *Praeprotunuma* sp. cf. *P. antiqua* Tekin; **11** — *Spinosicapsa* sp. cf. *S. yazgani* (Tekin); **12** — *Pachus* sp. cf. *P. multinodosus* Tekin; **13** — *Pachus* sp. cf. *P. firmus* Blome; **14** — *Xipha* sp. cf. *X. pessagnoi* (Nakaseko & Nishimura); **15** — *Corum speciosum* Blome; **16** — *Corum* sp. cf. *C. speciosum* Blome; **17** — *Corum* sp. cf. *C. regium* Blome; **18** — *Canoptum* sp. cf. *C. macoyense* Blome; **19** — *Spinosicapsa* sp. cf. *S. turgida* (Blome). **20–22** — Radiolarians from sample SCG 52 (Carnian to middle Norian): **20** — Saturnalidae gen. indet; **21** — *Corum* sp. cf. *C. speciosum* Blome; **22** — *Japonocampe* sp. cf. *J. mundum* (Blome).

P. piabyx De Wever, *Praeprotunuma antiqua* Tekin, *Tubospongopallium* sp., *Spinosicapsa extansa* (Tekin), *S.* sp. cf. *S. turgida* (Blome), *S.* sp., *Triassoastrum* sp. Tekin (1999) restricted the stratigraphic interval of *Crucella tenuis*, *Praeprotunuma antiqua*, and *Spinosicapsa extansa* to uppermost Carnian–Lower Norian. Considering this conclusion, the age of this sample ranges between the latest Carnian and Early Norian.

Sample SCG 51

Violet-reddish massive radiolarite with some mud lenses (Fig. 4) from a depression-fill between a Late Triassic fore-reef to reefal block (Dachstein Limestone) and an Early Carnian reefal block (Wetterstein Limestone). The microfacies shows a radiolarian wacke- to packstone with red mud lenses. The following taxa were determined (Fig. 7): *Canoptum* sp. cf. *C. macoyense* Blome, *C. crystallina* Pessagno group, *Capnuchosphaera theloides* De Wever, *C.* sp. cf. *C. triassica* De Wever, *Capnuchosphaera* sp., *Corum* sp. cf. *C. regium* Blome, *C. speciosum* Blome, *Crucella*? sp., *Xipha* sp. cf. *X. pessagnoi* (Nakaseko & Nishimura), *Pachus* sp. cf. *P. firmus* Blome, *P.* sp. cf. *P. multinodosus* Tekin, *Poulpus* sp. cf. *P. piabyx* De Wever, *Praeprotunuma* sp. cf. *P. antiqua* Tekin, *Spinosicapsa* sp. cf. *S. yazgani* (Tekin), *Spinosicapsa* sp. cf. *S. turgida* (Blome), *Triassoastrum*? sp., *Xiphothecaella* sp. cf. *X. longa* (Kozur & Mock). This assemblage is very similar to SCG 50 and has a similar age: Uppermost Carnian–Lower Norian.

Sample SCG 52

Greyish-greenish massive radiolarite (Fig. 4) from a depression-fill between a Late Triassic fore-reef to reefal block (Dachstein Limestone) and an Early Carnian reefal block (Wetterstein Limestone). The original microfacies of this radiolarite is masked by the intense silicification, radiolarians are only visible as ghosts. Due to poor preservation only a few specimens were determined (Fig. 7): *Canesium*? sp., *Canoptum* sp., *Capnodoce*? sp., *Corum* sp. cf. *C. speciosum* Blome, *Crucella* sp., *Japonocampe* sp. cf. *J. mundum* (Blome), *Tubospongopallium* sp., Saturnalidae gen. indet., *Triassoastrum*? sp. The age of the sample is Upper Triassic, Carnian to Middle Norian according to the presence of *Corum* sp. cf. *C. speciosum* Blome and *Japonocampe* sp. cf. *J. mundum* (Blome).

Sample SRB 207

Reddish-violet muddy radiolarite from a fissure fill consisting of ophiolitic mélange in lagoonal to back-reef Late Triassic Dachstein Limestone. The following taxa were determined (Fig. 8): *Braginella* sp. cf. *B. rudis* (Bragin), *Cantalum*? sp., *Ferresium* sp. cf. *F. triquetrum* Carter, *Ferresium* sp., *Sarla*? sp., Saturnalidae gen. indet., *Serilla* sp. cf. *S. ellisensis* (Carter). *Ferresium triquetrum* is present in the Rhaetian of British Columbia (Carter 1993) and from the Upper Norian of Turkey (Bragin & Tekin 1996). *Serilla ellisensis* is known from the Rhaetian of British Columbia (Carter 1993), while *Braginella rudis* was reported from the Upper Norian of Far East Russia (Bragin 1991), Japan (Sugiyama 1997) and Greece (Bragin et al. 2014). The age of this radiolarian assemblage is Upper Norian–Rhaetian.

Sedimentology

The ophiolitic mélange overlies different Triassic carbonate blocks filling the rough topography of an older carbonate-clastic basin fill (Fig. 9; Sirogojno carbonate-clastic mélange: Missoni et al. 2012; Sudar et al. 2013). Coarse-grained turbidites and mass transport deposits beside fine-grained radiolaritic-argillaceous sediments and turbidites consisting of ophiolitic sand and radiolarites (Fig. 3) are the dominant sedimentary rocks and occur in fissures of the underlying carbonate rocks (Fig. 3) or fill the depressions between huge slide blocks. The sedimentological features document clearly a sedimentary rather than a tectonic genesis of the ophiolitic mélange west of the Drina–Ivanjica unit. Fine-grained turbidites consisting of ophiolitic sand occur beside coarse-grained mass transport deposits and m-sized blocks. Matrix radiolarites are missing in this lowermost part of the ophiolitic mélange.

In this early stage of erosion and redeposition of the ophiolitic nappe stack only Upper Triassic radiolarites occur beside ophiolite components. Higher up in the mélange we also find Middle Triassic radiolarites and radiolarite/limestone components/blocks from the continental slope as described by

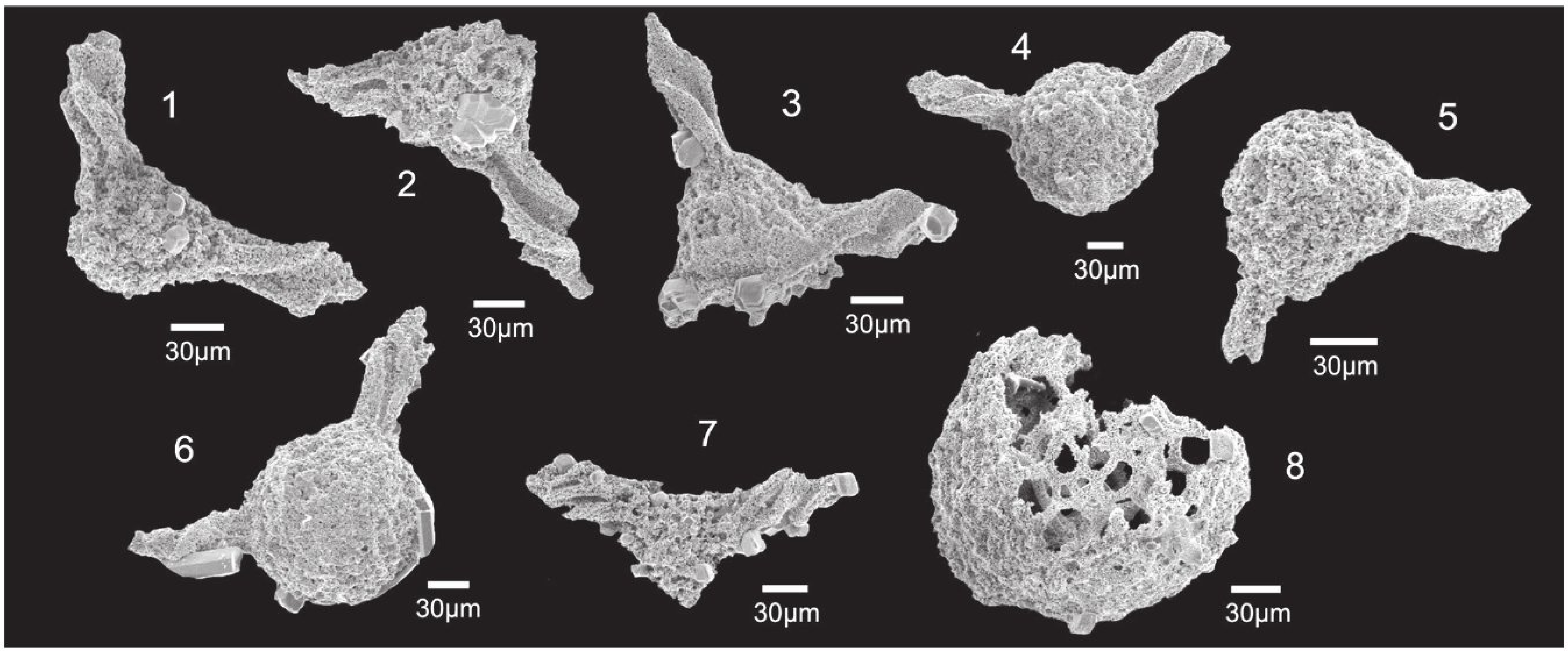

Fig. 8. Late Triassic (late Norian–Rhaetian) radiolarians from radiolarite from sample SRB 207. **1–2** — *Ferresium*? sp.; **3** — *Ferresium* sp. cf. *F. triquetrum* Carter; **4–5** — *Sarla*? sp.; **6** — *Cantalum*? sp.; **7** — *Serilla* sp. cf. *S. ellisensis* (Carter); **8** — *Braginella* sp. cf. *B. rudis* (Bragin).

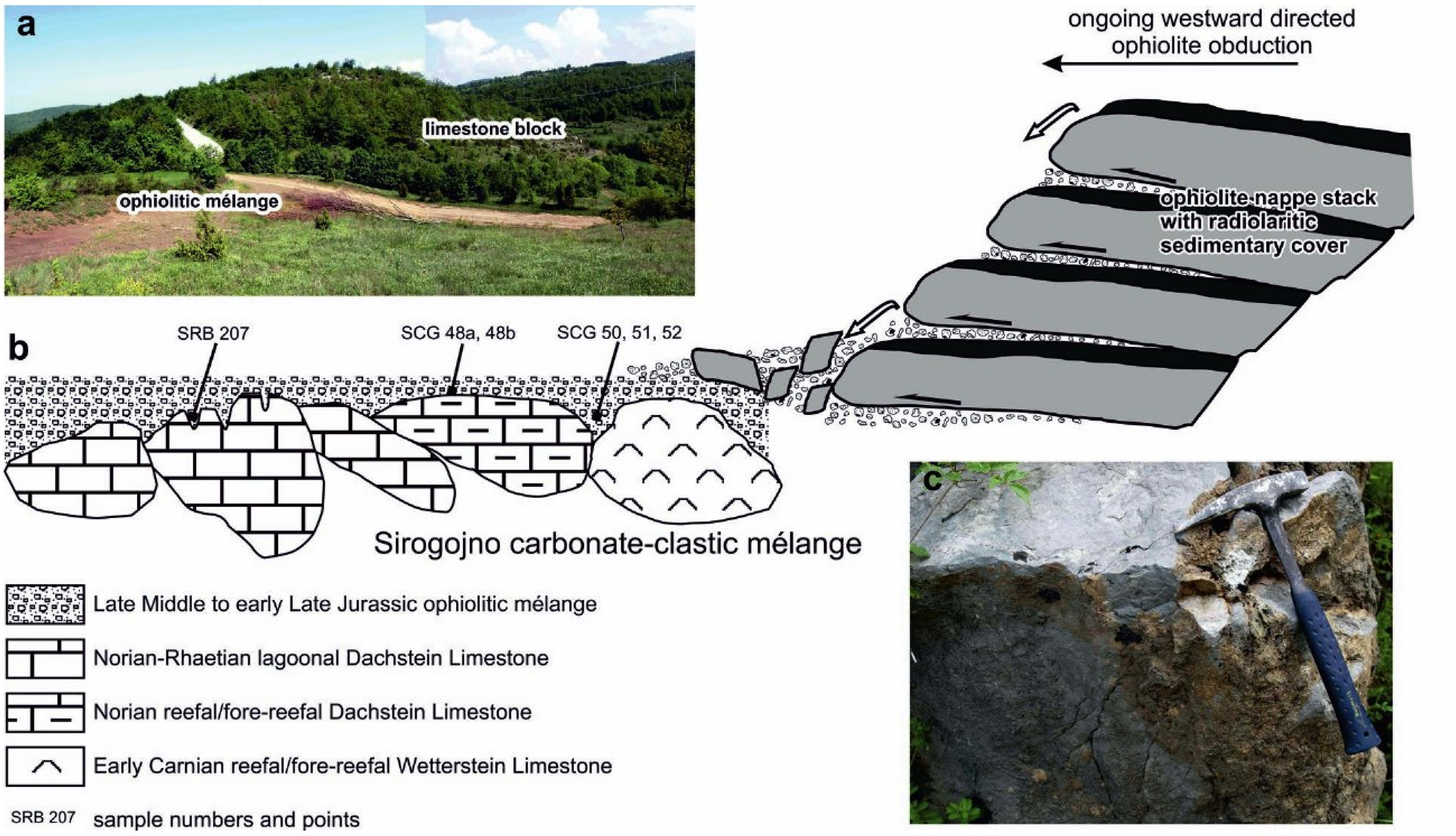

Fig. 9. The ophiolitic mélange on top of the carbonate-clastic mélange below filling depressions and fissures. **a** — Field situation: a huge limestone block covered by the ophiolitic mélange. The limestone block is more stable against weathering and therefore forms positive relief. **b** — Reconstruction of the depositional realm, provenance area of the ophiolitic mélange (Neo-Tethys ophiolite nappe stack) and sample positions. **c** — Ophiolitic mélange as fissure filling in lagoonal Dachstein Limestone.

Gawlick et al. (2016b). This clearly indicates 1) deeper erosion of the sedimentary cover on top of the oceanic crust (Late Anisian to Jurassic) including the tectonic incorporation of blocks from the continental slope in the course of westward obduction or 2) erosion of the sedimentary cover of ophiolites in a higher nappe position (Fig. 10b,c), a more convincing possibility (Fig. 9; see also discussion). Therefore we assign the ophiolitic mélange in the eastern part of the Dinaridic Ophiolite Belt originally to be a sedimentary mélange, deposited in a trench-like basin in front of the westward propagating ophiolite sheets.

Discussion

Although there are contrasting models about the palaeogeography in Triassic–Jurassic times in the western Tethyan realm (e.g., Stampfli & Kozur 2006; Schmid et al. 2008; Missoni & Gawlick 2011b; Robertson 2012; Gawlick et al. 2016a,b), there is progress in the reconstruction of the age of lost oceanic domains and in the understanding of geodynamic processes in the Tethyan realm. Many new biostratigraphic data on Triassic and Jurassic radiolarites in mélange areas have recently been obtained in the Dinarides, Albanides and Hellenides (e.g., Gawlick et al. 2008, 2016a,b; Vishnevskaya et al. 2009; Djerić et al. 2010, 2012; Chiari et al. 2011, 2013; Ozsvárt et al. 2012; Bragin et al. 2014; Ferrière et al. 2015, 2016; Gawlick & Missoni 2015), but still a lot of questions remain open. Detailed microfacies investigations and biostratigraphic data allow detailed information about the depositional history for both the carbonate (e.g., Flügel 2004) and the radiolarite sequences. Such combined investigations on radiolarites remain rare (e.g., Gawlick et al. 2009a, 2016a,b; Krische et al. 2014; Gawlick & Missoni 2015), but the reconstruction of the depositional environment of radiolarites provides a number of answers for the open questions.

The investigations of the resedimented Late Triassic oceanic ribbon radiolarite clasts in the ophiolitic mélange between Trnava and Rožanstvo result in a reconstruction of their primary depositional realm and give further evidence on the Triassic–Jurassic geodynamic history as well as on the palaeogeographic evolution of the Inner Dinarides, especially the Dinaridic Ophiolite Belt.

Blocks from the Neo-Tethys ocean floor with the preserved sedimentary cover occur rarely in the different mélanges of the Dinaridic Ophiolite Belt. One Late Ladinian (to Carnian) basalt-radiolarite block was described by (Vishnevskaya et al. 2009), probably another one by Gawlick et al. (2016b) whereas younger ocean floor blocks were not detected. Descriptions of Upper Triassic ribbon radiolarites from the ocean floor also remain rare (Obradović & Goričan 1988; Goričan et al. 1999; Gawlick et al. 2009b, 2016b; Vishnevskaya et al. 2009). Middle Triassic radiolarite blocks are more common (summarized in Chiari et al. 2011).

There is a controversy about the genesis of the ophiolitic mélange: A) Tectonic origin with incorporation of blocks from

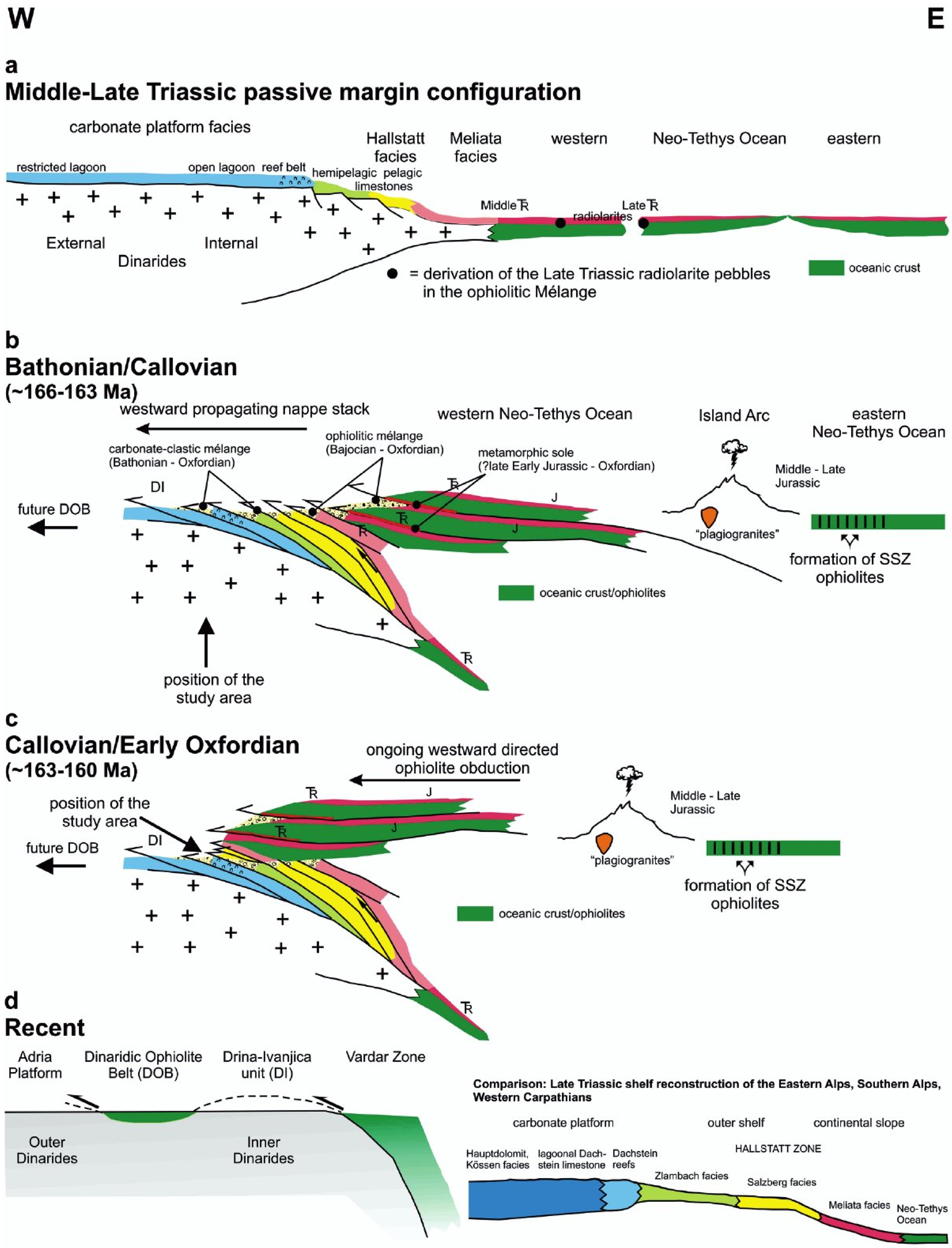

Fig. 10. Reconstruction of the Triassic shelf and provenance of the studied Late Triassic radiolarite in the ophiolitic mélange near Ilidža. **a** — Middle to Late Triassic passive margin configuration after Gawlick et al. (2008). Generation of oceanic crust started in the Late Anisian in the Neo-Tethys realm. The formation of an oceanic basin (Dinaridic Ocean) between the External (Triassic restricted lagoon) and Internal Dinarides (Triassic open lagoon, reef belt and transitional facies) is not possible due to the missing facies transitions from the lagoon to the open marine environment. **b** — Middle Jurassic westward directed ophiolite obduction, imbrication of the former passive margin and mélange formation. For the position of the formation of the plagiogranites see Michail et al. (2016). **c** — Ongoing westward directed ophiolite obduction. The older carbonate-clastic basin fill is overlain by the mass transport deposits of the ophiolitic mélange. The location of the study area is indicated. **d** — Recent position of the Dinaridic Ophiolite Belt with its sub-ophiolitic mélanges on the basis of Kober (1914) concerning the genesis and emplacement of the ophiolites and related radiolaritic-ophiolitic trench fills. Ages after Cohen et al. (2013, updated). Late Triassic shelf configuration of the Eastern and Southern Alps and the Western Carpathians modified after Gawlick et al. (1999) for comparison with **a**.

the overridden plate, B) Sedimentary origin (olistostrome), or C) original sedimentary trench-fill later incorporated in the nappe stack. The area where the ophiolitic mélange of the Dinaridic Ophiolite Belt was formed is completely unclear. Several hypotheses exist: 1) Formation of the ophiolitic mélange either in the framework of intra-oceanic subduction, or 2) on the base of ophiolite sheets when obduction starts with incorporation of blocks from the overridden lower plate. Gawlick et al. (2016b) showed, that the ophiolite mélange of the Dinaridic Ophiolite Belt was first formed as sedimentary trench-fill later incorporated in the nappe stack. But the question of where the ophiolitic mélange was formed remains unclear. Solution of this geographical question is important for the still controversial discussed problem: Do the ophiolites including the ophiolitic mélange of the Dinaridic Ophiolite Belt represent far-travelled and obducted ophiolites from the Neo-Tethys to the east (e.g., Gawlick et al. 2008, 2009b, 2016b; Schmid et al. 2008) or are they relics of an autochthonous oceanic realm between the Durmitor mega-unit to the west and the Drina–Ivanjica unit to the east (e.g., Dimitrijević 1997; Karamata 2006)? For a recent review on this problem see Gawlick et al. (2016b). In addition, it is believed that the different carbonate blocks in the area west of Sirogojno derive from the Drina–Ivanjica unit directly to the east (e.g., Dimitrijević & Dimitrijević 1973, Dimitrijević 1997). Missoni et al. (2012) and Sudar et al. (2013) showed that the different blocks of the carbonate-clastic Sirogojno Mélange (Sudar et al. 2013) derive from a provenance area east of the Drina–Ivanjica unit (Fig. 10a).

The studied ophiolitic mélange between Trnava and Rožanstvo filled the depression of an older trench-like basin fill with a rough topography (Fig. 9). In the first phase of deposition the turbidites and mass-flow deposits filled the fissures and depression of the older topography. It is important is to note, that the underlying blocks derive exclusively from the Late Triassic back- to fore-reef facies belt (Fig. 10). Therefore this ophiolitic mélange on top of the carbonate-clastic Sirogojno Mélange was transported later to its recent position west of the Drina–Ivanjica unit. The Late Triassic sedimentary succession of the Drina–Ivanjica unit comprises lagoonal Dachstein Limestones (Dimitrijević & Dimitrijević 1991; Dimitrijević 1997).

The ophiolitic mélange is, according to recent descriptions and definitions (summarized in Chiari et al. 2011; Gawlick et al. 2016a) a typical sub-ophiolitic mélange and consists of a mixture of blocks and slices of the oceanic domain (e.g., oceanic rocks: ultramafic rocks, gabbroic and basaltic rocks; oceanic sediments: ophicalcites, radiolarites, deep-sea muds; amphibolites) and the obducted former distal passive margin, namely the continental slope (Meliata facies: Fig. 10a). These blocks are incorporated in a sedimentary matrix, very often turbiditic argillaceous-radiolaritic sediments and coarser-grained sands, consisting of erosional products of the ophiolite nappe stack. Such a mélange can incorporate fragments of the underlying sequences during the process of overthrusting. Therefore, such a sub-ophiolite mélange contains blocks from the lower plate and gravitationally emplaced blocks derived from the thick wedge of oceanic and continental crust at the front of the advancing nappe pile. In addition, as described by Gawlick et al. (2008) and Missoni & Gawlick (2011a) trench-like basins were formed in front of the advancing nappes. These deep-water basins were supplied by the erosional products of the advancing nappe stack. Several types of mass transport deposits (for a review on Mass Transport Deposits see: Shanmugam 2015) are incorporated in such a turbiditic radiolaritic-argillaceous matrix. Later, these trench-like basins were incorporated in the nappe stack and became partly sheared, forming the typical features of a mélange.

During ongoing westward directed ophiolite obduction and imbrication of the older (Triassic–Middle Jurassic) sedimentary succession of the former passive continental margin facing the Neo-Tethys Ocean to the east (Fig. 10a), now in a lower plate position, a series of trench-like basins were formed in front of the propagating nappe stack (Fig. 10b,c). The first basin formed in the course of ophiolite obduction contains material from the ophiolite nappe stack and the continental slope (Meliata facies belt, Fig. 10a), later incorporated into the nappe stack. Imbrication of the former passive margin led to the formation of a series of such trench-like basins of the westward propagating nappe stack (Fig. 10b,c). In the next phase, the former distal passive margin became incorporated into the nappe stack (Hallstatt facies belt with the various coloured Hallstatt Limestones: Lein 1987; Sudar et al. 2010). In a later stage the facies belts of the reef-near open marine facies belt and the fore-reef to back-reef facies belt became imbricated. These basins formed in front of the propagating nappe stack contain in the first stage of redeposition only resedimented material from the adjacent nappe front, as described in detail for the Northern Calcareous Alps by Gawlick et al. (1999, 2012b) and Missoni & Gawlick (2011a,b). All these basin fills are characterized by a coarsening-upward cycle with huge slide blocks on top of the basin fill, which may in some cases also represent remnants of the overriding nappe (Gawlick et al. 2012b). A little later, ongoing westward directed ophiolite obduction also affected these basin fills: Redeposition of material derived from the advancing ophiolite nappe stack in the area where the Sirogojno carbonate-clastic mélange was formed filled in the first stage of deposition the remaining topography of the older basin fill (Figs. 9, 10c), but still in an area east of the Drina–Ivanjica unit.

The final emplacement of the ophiolites and the mélanges west of the Drina–Ivanjica unit (Fig. 10d), namely in the area of the Dinaridic Ophiolite Belt occurred later, most probably in the latest Jurassic or earliest Cretaceous in the course of ongoing westward transport of the ophiolites and the mélanges (Schmid et al. 2008; Djerić et al. 2012).

Conclusions

Late Triassic radiolarites are of special interest for the reconstruction of the Jurassic geodynamic history of the

Neo-Tethys oceanic domain, because they indicate fragments of the Neo-Tethys oceanic realm. The Late Triassic radiolarite components in the ophiolitic mélange on top of the carbonate-clastic mélange in the eastern part of the Dinaridic Ophiolite Belt suggest the following conclusions:

- The ophiolitic mélange in the Dinaridic Ophiolite Belt is of primary sedimentary origin.
- Deposition of the mass transport deposits of the ophiolitic mélange took place in a deep-water trench-like basin formed in the late Middle Jurassic east of the Drina–Ivanjica unit.
- The Late Triassic ribbon radiolarites represent erosional products of the original sedimentary cover of the Middle Triassic to Early Jurassic Neo-Tethys ocean floor.
- Older components like Middle Triassic radiolarites or components from the distal continental margin are missing in the early mass transport deposits. The components represent erosional products of an ophiolite sheet from more distal oceanic areas, which were in a relatively high nappe position at that time.
- The ophiolites of the Dinaridic Ophiolite Belt including the ophiolitic mélange derived as far-travelled oceanic sheets from the Neo-Tethys Ocean to the east.

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