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Upper Triassic and Middle Jurassic radiolarians from the ophiolitic mélange of the Dinaridic Ophiolite Belt, SW Serbia

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With 8 figures

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Abstract: The Dinaridic Ophiolite Belt of western and southwestern Serbia is made of ophiolites and wide-spread mélanges containing different components up to nappe-size, now interpreted as radiolaritic-ophiolitic trench fill in front of advancing nappes. The matrix of the components and blocks consists mainly of fine- to partly coarse-grained, radiolaritic, ophiolitic siliciclastics, further of shales, radiolaritic marls and rare radiolarites. Westnorthwest of Sjenica in the central Dinaridic Ophiolite Belt occur an albite granite olistolith together with ophiolitic material, spilite olistoliths, Late Triassic radiolaritic olistoliths, and various carbonate components. From the radiolaritic matrix, which is in the surrounding of the albite granite olistolith, we isolated a radiolarian fauna of Middle Jurassic age. The Middle Jurassic age of these matrix radiolarites proves directly the sedimentary emplacement of the different blocks. The age range of the Sjenica mélange and the sedimentary emplacement of the olistoliths in the Dinaridic Ophiolite Belt seems to be similar to the radiolaritic-ophiolitic wildflysch in the Mirdita Ophiolite Zone of Albania to the south and the ophiolitic mélange areas in Medvenica and Kalnik Mts. to the northwest.

Key words: Dinarides, trench fill, stratigraphy, Dinaridic Ophiolite Belt, Sjenica mélange, Tethys Ocean.

Introduction

The Dinaridic Ophiolite Belt (DIMITRIJEVIĆ 2001; DIMITRIJEVIĆ et al. 2003; KARAMATA et al. 2000; KARAMATA 2006) with its widespread mélange areas is an important link within the Alpine-Dinaridic-Albanic-Hellenic orogenic system. The Dinaridic Ophiolite Belt, as northward continuation of the Mirdita ophiolites from northern Albania into Kosovo and Serbia through Bosnia to Croatia forms together with the Western Hellenic ophiolites in Greece and southern Albania a relatively continous ophiolitic belt (= western ophiolite zone in Fig. 1A).

The geological history of these relatively poorly investigated and therefore unknown mélanges is important for the understanding of the Triassic-Jurassic paleogeography and the tectonic evolution of the northwestern Neotethys realm. This western ophiolite zone is controversially discussed as remnant of an in situ oceanic basin (DIMITRIJEVIĆ 1997; DIMITRIJEVIĆ & SIKOŠEK 1997; DIMITRIJEVIĆ et al. 2003; KARAMATA 2006 with references), which may correlate with the independent Pindos Ocean between Pelagonia (and equivalents) to the east and Apulia to the west (e.g. ROBERTSON & SHALLO 2000; STAMPFLI et al. 2001; DILEK & FLOWER 2003; CSONTOS & VÖRÖS

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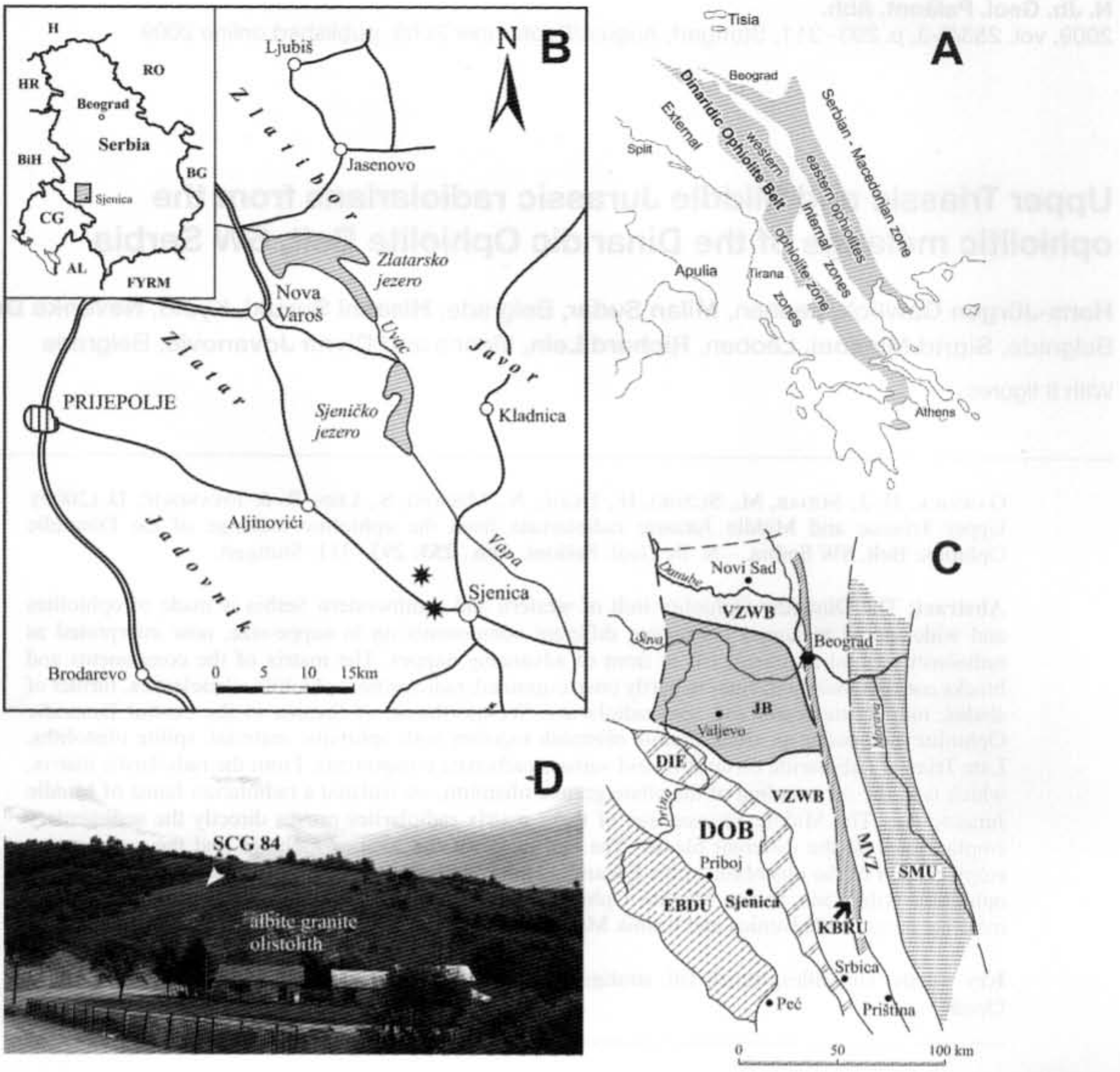

Fig. 1. A. Regional geological setting showing the external zones, the western ophiolite zone (Dinaridic, Mirdita, Hellenic ophiolites), the internal zones (Korabi-Pelagonian Microcontinent = Pelagonian zone, Korab zone, Drina-Ivanjica Element) and the eastern ophiolites (Vardar zone). For details, e.g. AUBOUIN 1973; SMITH & SPRAY 1984; DIMITRIJEVIĆ 1997, 2001; CHANNELL & KOZUR 1997; STAMPFLI et al. 2001; KARAMATA 2006. **B.** Locations of the investigated parts of the Sjenica mélange in the central Dinaridic Ophiolite Belt area, indicated by black stars. **C.** Tectonic units and terranes of part of the Balkan Peninsula in the sense of 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. **D.** Northwestward view to the albite granite olistolith with the radiolaritic matrix in the surrounding (SCG 84 = sample point).

2004; KARAMATA 2006; STAMPFLI & KOZUR 2006; DILEK et al. 2005, 2007), or as ophiolite nappe overthrusted by westward obduction in Jurassic times from the Vardar segment (BORTOLOTTI et al. 2005; GAWLICK et al. 2006a, 2008; SCHLAGINTWEIT et al. 2008; SCHMID et al. 2006, 2008). The Dinaridic Ophiolite Belt of Serbia may resemble the geodynamic history of the Mirdita ophiolites, where westward thrusting in late Middle Jurassic times over the Pelagonian units is newly discussed (BORTOLOTTI et al. 2004, 2005; BORTOLOTTI & PRINCIPI 2005; GAWLICK et al. 2006a, 2008). Jurassic and ?Cretaceous subduction processes, which are related to the partial closure of the Neotethys Ocean are indicated by trenches, filled with radiolaritic-ophiolitic allochthonous material up to nappe size. Nearly contemporaneous tectonic overprint and incorporation of the trench fills in the accretionary prism led to mélange formation. Younger structural and metamorphic overprints as well as westward directed tectonic movements led to further tectonic shortening in the obducted accretionary prism as well as in the overthrusted units. Due to this process the possibility of tectonically incorporated slivers scraped off the footwall, i.e. Pelagonia, should be another feature of these mélanges (Schmid et al. 2008). However, these complex processes formed in line with the mélanges are not understood, and are still under discussion (e.g. Karamata 2006; Gawlick et al. 2008; Schlagintweit et al. 2008; Schmid et al. 2008). Important reasons for this relatively unknown plate tectonic arrangement during the mentioned processes are: 1) the overprint of the area by younger tectonic movements (Cretaceous to Neogene), 2) lack of knowledge on the existence of a continuous oceanic suture zone, and 3) a lack of detailed investigations of different mélanges associated with the ophiolite suite. A direct age for these matrix-sediments in the Dinaridic Ophiolite Belt is missing.

In the Dinaridic Ophiolite Belt, most conspicuous features include a Jurassic ophiolitic mélange with large gravity slides and different olistoliths. The emplacement of partly huge ultramafic masses is characterized by a metamorphic sole on their base (Karamata 2006). According to Dimitrijević (1997) and Dimitrijević & Sikošek (1997) this mélange was deposited over Late Triassic (?platform) carbonates or cherty hemipelagic limestones followed by a thin succession of Early Jurassic platy limestones with cherty nodules or by hemipelagic sedimentary rocks of Ammonitico Rosso facies. The mélange was formed in the first stage by the deposition of huge olistostromes with a mostly argillaceous or sandy matrix, seldom by deposition of cherty limestones, cherty shales or radiolarites. Triassic limestones and radiolarites, as well as gabbros, pillow lavas, ultramafics and radiolarites, which derived from an originally complete ophiolitic sequence through oceanic uppermost mantle and crust, as well as some exotic granites (e.g. albite granite or completely mysterious blocks of the Straža Granite with an established age of 315 Ma), are chaotically intermixed components and olistoliths in the mélange (Dimitrijević & Dimitrijević 1973; Dimitrijević 1997; Karamata et al. 1980; Karamata 2006). These components were actually interpreted as: 1) remnants of an ocean, which opened in the Dinarides since the Middle Triassic and closed at the end of the Late Jurassic (Dimitrijević & Dimitrijević 1973; Dimitrijević 1997; Karamata 2006), and 2) as re-sedimented primary Triassic-Jurassic sedimentary cover of the Drina-Ivanjica Element (DIE – in Fig. 1C) (e.g. Dimitrijević et al. 2003; Karamata 2006).

The beginning of the closure of this oceanic domain in the late Early to Middle Jurassic (around 180 Ma to 150 Ma, Karamata 2006 with references) is indicated by the age of the metamorphic sole beneath the obducted ophiolites as a first expression of tectonic compression. This means, the formation of the mélange with a complex history of the primary sedimentary emplacement and the younger tectonic incorporation of different blocks should not have started before the Late Jurassic due to the final closure of this ocean. A comparison with the sedimentological and stratigraphic results of similar ophiolitic mélanges in adjacent areas (e.g. in Croatia: Halamić et al. 1999; Babić et al. 2002; Goričan et al. 1999b, 2005; or in Albania: Gawlick et al. 2005, 2006c, 2008; Schlagintweit et al. 2008) clearly show an incomplete information of the formation of the mélanges of the Dinaridic Ophiolite Belt and missing information of the palaeogeographic derivation of the different clasts and ?tectonic slivers in the mélanges. This confusing complexity of the Dinaridic Ophiolitic Belt zones belongs to both, the lack of biostratigraphic data of the partly radiolaritic matrix, and the lack of detailed analysis of olistolith-components at regional scale in the mélange areas. Only scarce data exist from different blocks and ?tectonic slivers in the mélange areas (e.g. Karamata et al. 2000; Dimitrijević 1997; Goričan et al. 1999a; Dimitrijević et al. 2003). Different Triassic radiolarites present as blocks in the mélange indirectly prove a Triassic age of the oceanic crust (e.g. Obradović & Goričan 1988; Goričan et al. 1999a), whereas a Jurassic age is known so far only from different blocks (Dimitrijević et al. 2003).

The aim of this paper is to present the first results of age analysis of the Jurassic matrix radiolarites in the area of Sjenica (NW Serbia; Fig. 1B, D), based on biostratigraphic data. In the surrounding of an albite granite olistolith of Abeško Brdo (Fig. 2), radiolarites occur as matrix of this mélange in the central Dinaridic Ophiolite Belt. Here we present the first

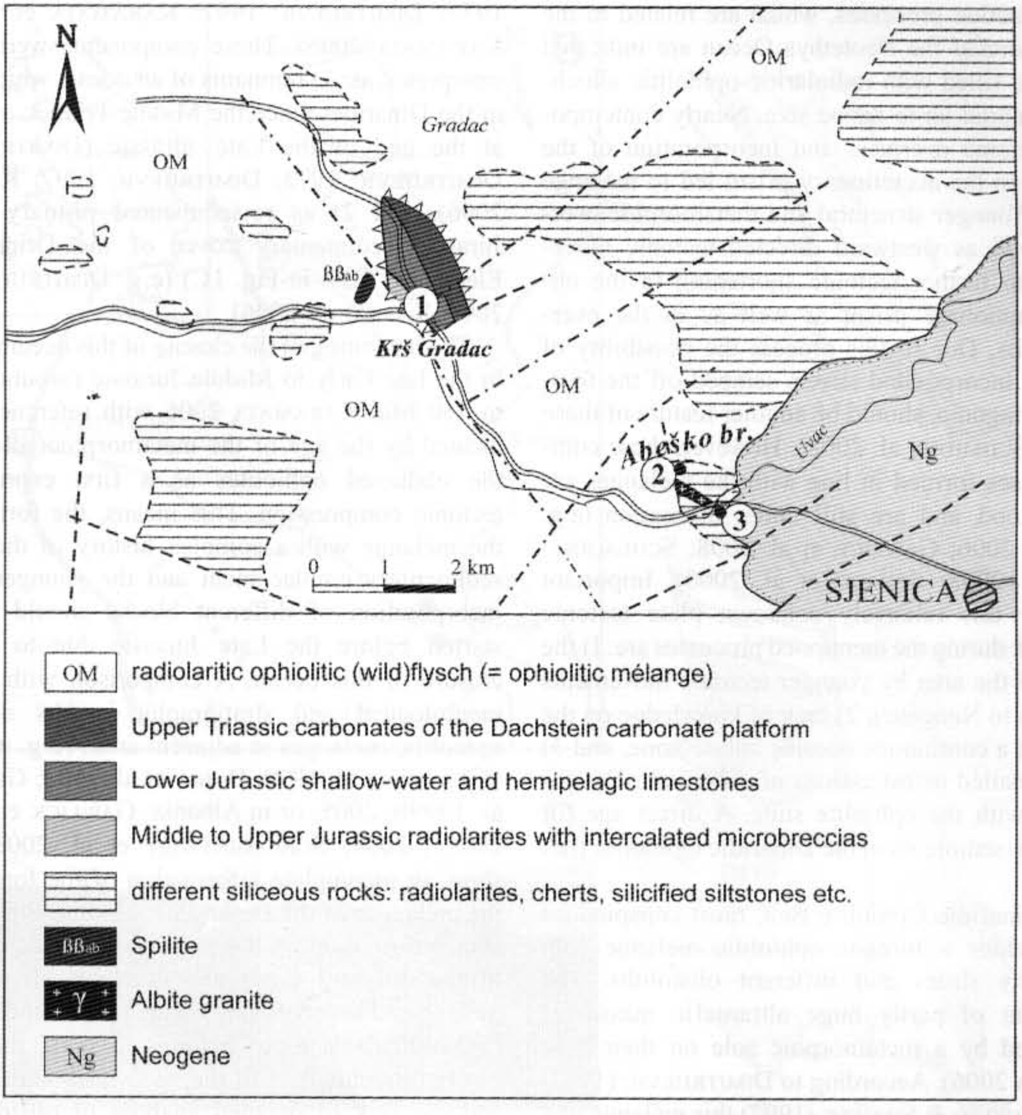

Fig. 2. Modified section of the Geological map of Republic Serbia 1:50000, Prijepolje 2, (surroundings of Sjenica town, SW Serbi; RADOVANOVIĆ et al. 2004). **1** = Site of the sample SCG 91 from the radiolarite matrix above the Triassic-Jurassic/?Lower Cretacous tectonic window of Krš Gradac section 8 km west of Sjenica, **2** = sites of the samples SCG 84 and SCG 85 from the radiolarite matrix near the albite granite olistolith of the Abeško Brdo, **3** = sites of the samples SCG 82 and SCG 83 from the Upper Triassic radiolaritic olistolith.

direct radiolarian dating of the argillaceous/sandy-silty to partly radiolaritic matrix of the mélange. Additionally, in the vicinity of the mentioned locality we reinvestigated a Late Triassic radiolaritic block in the ophiolite mélange (first decribed by GORIČAN et al. 1999a) to get more precise information on the facies and age of this block. Also the Upper Triassic to Upper Jurassic/?Lower Cretaceous section Krš Gradac (Figs. 2-3) is revisited.

Geological setting

Most deposits developed in the ophiolitic mélange occur in the western and northwestern region of Sjenica, besides Neogene limnic material (Fig. 2). In argillaceous/sandy/silty to radiolaritic, partly sheared matrix, sedimentary rocks occur as different clasts, blocks and slides together with tectonic slices of various size (dm to km), forming this mélange.

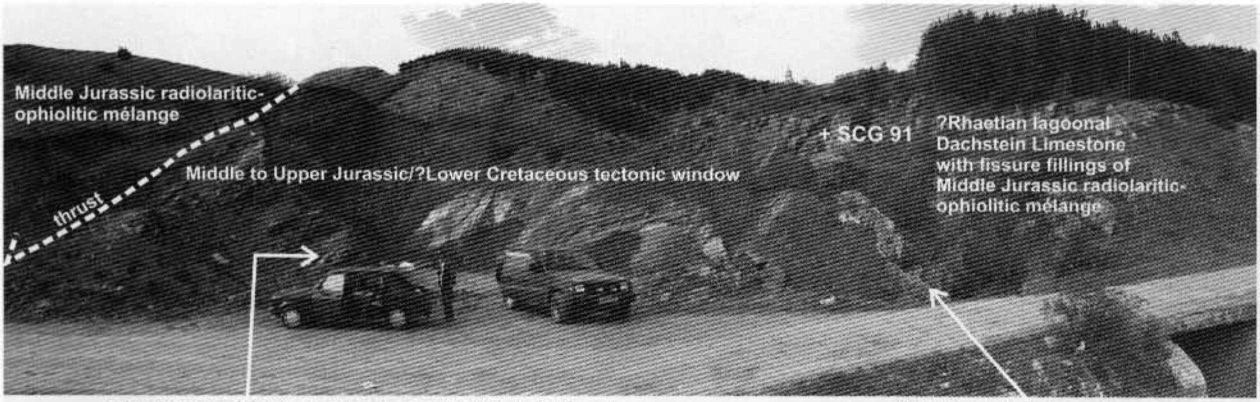

Fig. 3. Locality of the Upper Triassic to Upper Jurassic/?Lower Cretaceous Krš Gradac section overthrusted by the Middle Jurassic radiolaritic-ophiolitic mélange in ?Lower Cretaceous times. Sample SCG 91 comes from a radiolaritic-ophiolitic fissure filling in the Upper Triassic (Rhaetian) lagoonal Dachstein Limestone (Fig. 4).

In the locality Krš Gradac 8 km west of Sjenica (Fig. 2, point 1; coordinates: x 4794921, y 7414369), a tectonic slice occurs below the Middle to early Late Jurassic mélange.

In an old quarry of Abeško Brdo (Fig. 1D; Fig. 2, point 2; coordinates: x 4793454, y 7416424), occurs an olistolith with a length of 100 m, which consists of albite granite with a narrow rim of metamorphosed basaltic rock.

This granite which is composed of albite to oligoclase, quartz, and subordinate chloritized ?hornblende is fully consistent with the plagiogranites of the ophiolitic association. Locally, epidotization occurs at rims. The chemical characteristics of this extremely sodic granite (5.09 % Na_2O) show a high content of SiO_2 (67.56 %) and very low contents of K_2O (0.94 %) and CaO (2.77 %) in relation to the Na_2O contents (Karamata 1958).

The investigated radiolarites surround the northwestern part of the albite granite olistolith (Fig. 1D, Fig. 2), and are part of this widespread mapable radiolaritic-ophiolitic mélange in the area of Sjenica (Fig. 2). These radiolarites are part of the argillaceous/sandy to silty, and partly cherty to shaly sedimentary sequence with frequent and typical ophiolite detritus. The contact of the radiolarites with the mentioned olistolith is primary stratigraphical, but is partly highly sheared with fracturing due to polyphase tectonic overprints after deposition near the contact of the olistolith. The block-in-matrix structure, formed by a sedimentary input is primarily a sedimentary feature which later experienced younger strong tectonic overprint.

Along a small local road and south of the main road (Fig. 2, point 3; coordinates: x 4793447, y 7416431) occurs a Late Triassic radiolaritic olistolith slightly sheared on its rim and surrounded by olistostromal material. This olistolith consists of a 11 m thick radiolaritic succession of reddish to greenish, bedded (beds up to several cm thick) radiolarite partly with thin interlayers of siliceous shales. This radiolarite contains a radiolarian association of latest Carnian to late Middle Norian age (Goričan et al. 1999a). The age determination of this radiolaritic olistolith proves the existence of an Late Triassic oceanic basin in the provenance area of the blocks and slides in the Dinaridic Ophiolite Belt.

Stratigraphic results

Krš Gradac

The mélange, which occurs also in fissures in the Upper Triassic shallow-water carbonates (equivalent to lagoonal Dachstein Limestone), contains Middle Triassic radiolarians (Fig. 4) beside the Jurassic radiolarians *Stylocapsa oblongula* Kocher, *Williriedellum crystallinum* Dumitrica and ?*Gongylothorax* sp. (Fig. 4). For example in the Northern Calcareous Alps, these radiolarians indicate a Middle to early Late Jurassic age, *W. crystallinum* is a typical species of Callovian to Oxfordian cherty rocks (e.g., Suzuki et

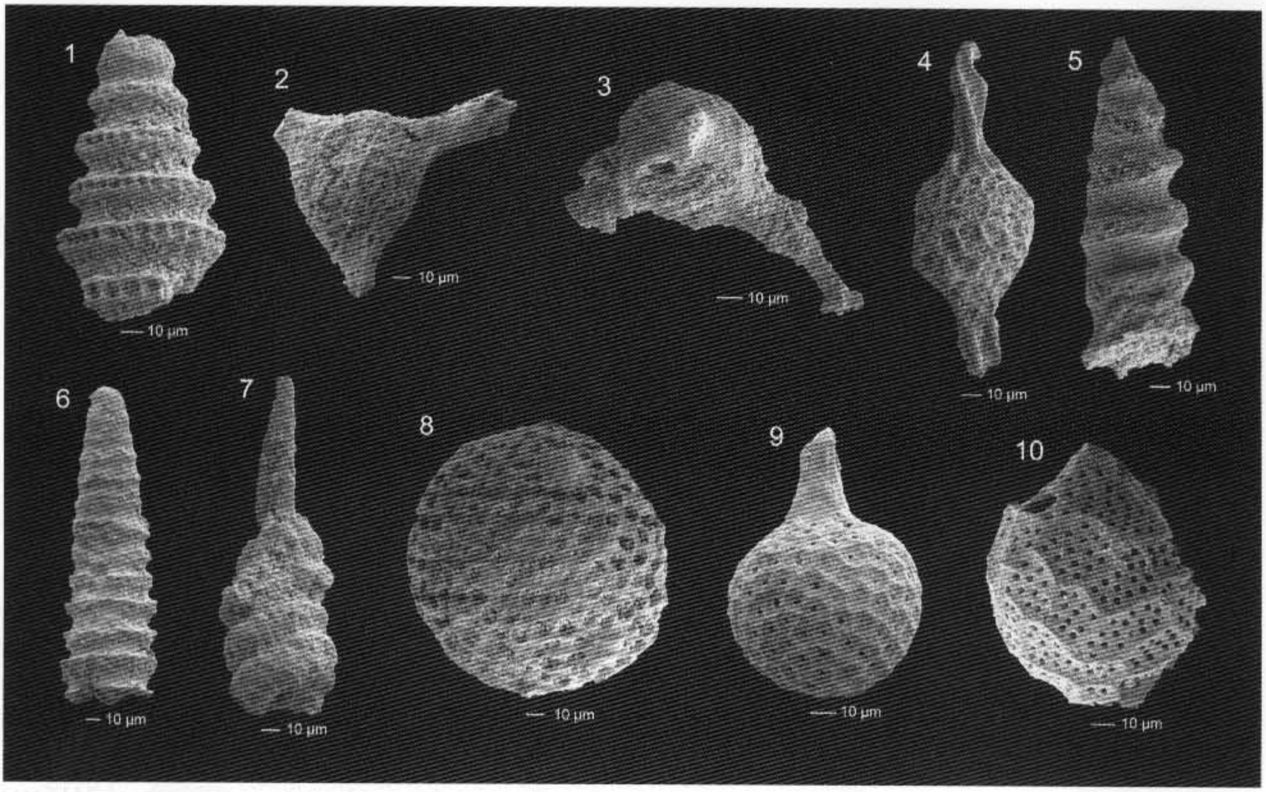

Fig. 4. Lower Ladinian and Middle to Upper Jurassic radiolarians from fissure fillings in Upper Triassic shallow-water limestones of the radiolaritic-ophiolitic matrix of the Sjenica mélange (Krš Gradac, sample SCG 91). **1.** *Annulotriassocampe sulovensis* (KOZUR & MOCK, 1981) in KOZUR & MOSTLER, 1981. **2.** *Capnuchosphaera* sp. **3.** *Poulpus* sp. **4.** *Pseudostylosphaera* cf. *goestlingensis* (KOZUR & MOSTLER, 1979). **5.** *Triassocampe brevis* (KOZUR & MOSTLER, 1994). **6.** *Triassocampe* sp. **7.** *Yeharaia* cf. *annulata* NAKASEKO & NISHIMURA, 1979. **8.** ?*Gongylothorax* sp. **9.** *Stylocapsa oblongula* KOCHER, 1981. **10.** *Williriedellum crystallinum* DUMITRICA, 1970.

al. 2001; SUZUKI & GAWLICK 2003 b; MISSONI et al. 2005). The Middle Triassic radiolarian fauna consists of *Annulotriassocampe sulovensis* (KOZUR & MOCK in KOZUR & MOSTLER), *Pseudostylosphaera* cf. *goestlingensis* (KOZUR & MOSTLER), *Triassocampe brevis* (KOZUR & MOSTLER), *Yeharaia* cf. *annulata* NAKASEKO & NISHIMURA, *Triassocampe* sp., *Capnuchosphaera* sp. and *Poulpus* sp. According to KOZUR & MOSTLER (1994), the age of the typical *Annulotriassocampe* species like *A. sulovensis* ranges from middle Fassanian to Late Triassic. The stratigraphic age range of *Y. annulata* is Early to Middle Fassanian according to KOZUR & MOSTLER (1994), and Late Anisian to Early Ladinian (Fassanian) according to SUGIYAMA (1997). *Capnuchosphaera* sp. ranges in age from Early Ladinian to Norian (DE WEVER et al. 2001). Thus, the age determination of these Triassic radiolarian fauna is Early Ladinian (Fassanian).

The tectonic slice below the mélange (Fig. 3) is made of the following stratigraphic sequence: uppermost Triassic platform carbonates of the Dachstein Formation are followed by Lower Jurassic shallow-water carbonates and later (late Lower Jurassic) hemipelagic sedimentary rocks (LEDEBUR 1941; GRUBIĆ 1980) on top of the drowned Upper Triassic – Lower Jurassic platform (*Ammonitico Rosso* facies – Krš Gradac Formation in the sense of RADOVANOVIĆ et al. 2004). Also Middle to Late Jurassic radiolarites are present (for comparison: Zlatar Formation, RADOVANOVIĆ et al. 2004) as well as Middle/Upper Jurassic to ?Lower Cretaceous shallow-water organisms in the intercalated microbreccias (RAMPNOUX 1969, RADOIČIĆ in ĆIRIĆ 1984).

In this area (Fig. 2), also fragments from the oceanic crust are present with overlying sediments that had originally formed a complete ophiolitic sequence through oceanic uppermost mantle and crust, beside different types of radiolarites, cherts and silicified siltstones (e.g. GRUBIĆ 1980; ĆIRIĆ 1984). Our data confirm GRUBIĆ (1980), who interpreted the mélange as overthusted over the Upper Triassic to Upper Jurassic/?Lower Cretaceous succession of Krš Gradac. We contrast, however, his interpretation, that these radiolarites with the intercalated microbreccias/allodapic layers should belong to the mélange, with new biostratigraphic data by means of radiolarians from fissures in the Upper Triassic (Rhaetian) lagoonal Dachstein limestone. We confirm RAMPNOUX (1969), that the Upper Triassic (Rhaetian) to Upper Jurassic/?Lower Cretaceous sedimentary succession is a complete section with a hardground on top of the *Ammonitico rosso* facies. Contrary to other sites in the western ophiolite zone with ophiolite obduction in the early Upper Jurassic (GAWLICK et al. 2008; SCHLAGINTWEIT et al. 2008; SCHMID et al. 2008), this thrusting is younger and must belong to a younger (?Lower Cretaceous; GAWLICK et al. 2006b) tectonic event. We interpret the Upper Triassic to Upper Jurassic/?Lower Cretaceous succession of Krš Gradac, therefore, as a tectonic window (Fig. 2) or as a tectonically incorporated sliver scraped off the footwall due to younger tectonic shortening.

Abeško Brdo

Westnorthwest of Sjenica in the central Dinaridic Ophiolite Belt occurs an albite granite olistolith together with ophiolitic material, spilite olistoliths, Late Triassic radiolaritic olistoliths, and various very small but still undeterminable carbonate components. The described Middle Jurassic radiolarian assemblage derived from a single section at Abeško Brdo (sample SCG 84, see Figs. 1D and 2 for the location of the sample).

In any case, considering the microfacies of the radiolaritic sediments (see Fig. 5), it must be kept in mind that due to mobilization and resedimentation processes their stratigraphic classification might be misinterpreted. However, regarding the fragility of the subjects and the rough resolution of the radiolarian biostratigraphy, the probability of receiving radiolarians of substantial older stratigraphic levels seems to be neglectable. The partly sheared, mostly grey but partly greenish-reddish radiolaritic matrix consists of relatively homogeneous, bioturbated and therefore not laminated wackestones to packstones without any older component.

Overall, 38 individual species and 4 taxa defined on the open nomenclature from the mentioned SCG 84 sample have been determined (Fig. 6): *Archaeodictyomitra amabilis* AITA, *Archaeodictyomitra mitra* DUMITRICA, *Archaeodictyomitra rigida* PESSAGNO, *Archaeodictyomitra* sp. B sensu WEGERER, SUZUKI & GAWLICK, *Dictyomitrella kamoensis* MIZUTANI & KIDO, *Eucyrtidiellum circumperforatum* CHIARI, MARCUCCI & PRELA, *Eucyrtidiellum semifactum* (NAGAI & MIZUTANI), *Eucyrtidiellum unumaense dentatum* BAUMGARTNER, *Eucyrtidiellum unumaense pustulatum* BAUMGARTNER, *Eucyrtidiellum unumaense unumaense* (YAO), *Eucyrtidiellum unumaense* (YAO), *Hsuum maxwelli* PESSAGNO, *Helvetocapsa* cf. *matsuokai* (SASHIDA), *Hemicryptocapsa* sp. A, *Hiscocapsa magnipora* (CHIARI, MARCUCCI & PRELA), *Lithocampium* sp. E, *Parvicingula spinata* (VINASSA), *Praezhamoidellum* aff. *buekkense* KOZUR, *Praezhamoidellum buekkense* KOZUR, *Praezhamoidellum* cf. *parvipora* (TAN), *Praezhamoidellum* sp. C, *Protunuma lanosus* OZVOLDOVA in SYKORA & OZVOLDOVA, *Protunuma ochiensis* MATSUOKA, *Protunuma turbo* MATSUOKA, *Pseudodictyomitra* cf. *venusta* (CHIARI, CORTESE & MARCUCCI), *Quarticella ovalis* TAKEMURA, *Spongocapsula krahsteinensis* SUZUKI & GAWLICK in GAWLICK et al., *Stichocapsa convexa* YAO, *Stichocapsa japonica* YAO, *Striatojaponocapsa* cf. *conexa* (MATSUOKA, *Striatojaponocapsa* cf. *synconexa* O'DOGHERTY et al., *Tetracapsa himedaruma* (AITA), *Tricolocapsa* aff. *fusiformis* YAO, *Tricolocapsa fusiformis* YAO, *Tricolocapsa* sp. S sensu BAUMGARTNER et al., *Tricolocapsa tetragona* MATSUOKA, *Triversus hungaricus* (KOZUR), *Unuma gordus* HULL, *Williriedellum dierschei* SUZUKI & GAWLICK in GAWLICK et al., *Williriedellum marcucciae* CORTESE, and *Zhamoidellum exquisitum* HULL. For taxonomy see e.g. BAUMGARTNER et al. (1995b), SUZUKI & GAWLICK (2003b), O'DOGHERTY et al. (2006), SUZUKI & GAWLICK (2009).

The Unitary Assoziation Zonation of BAUMGARTNER et al. (1995a) is not applicable for the radiolarian age determination. There are no overlapping age ranges (U.A.-Zones) of the individual species in sample SCG 84, e.g. *Eucyrtidiellum unumaense dentatum* – U.A.-Zone 6-7, *Tricolocapsa* sp. S – U.A.-Zone 4-5, *Tricolocapsa tetragona* – U.A.-Zone 5-5, *Quarticella ovalis* – U.A.-Zone 4-4. To define their age is not possible. Only the combination of both, the Unitary Assoziation Zonation of BAUMGARTNER et al. (1995a) and the revisited age ranges (e.g. SUZUKI & GAWLICK 2003a, b; BECCARO 2004, 2006; O'DOGHERTY et al.

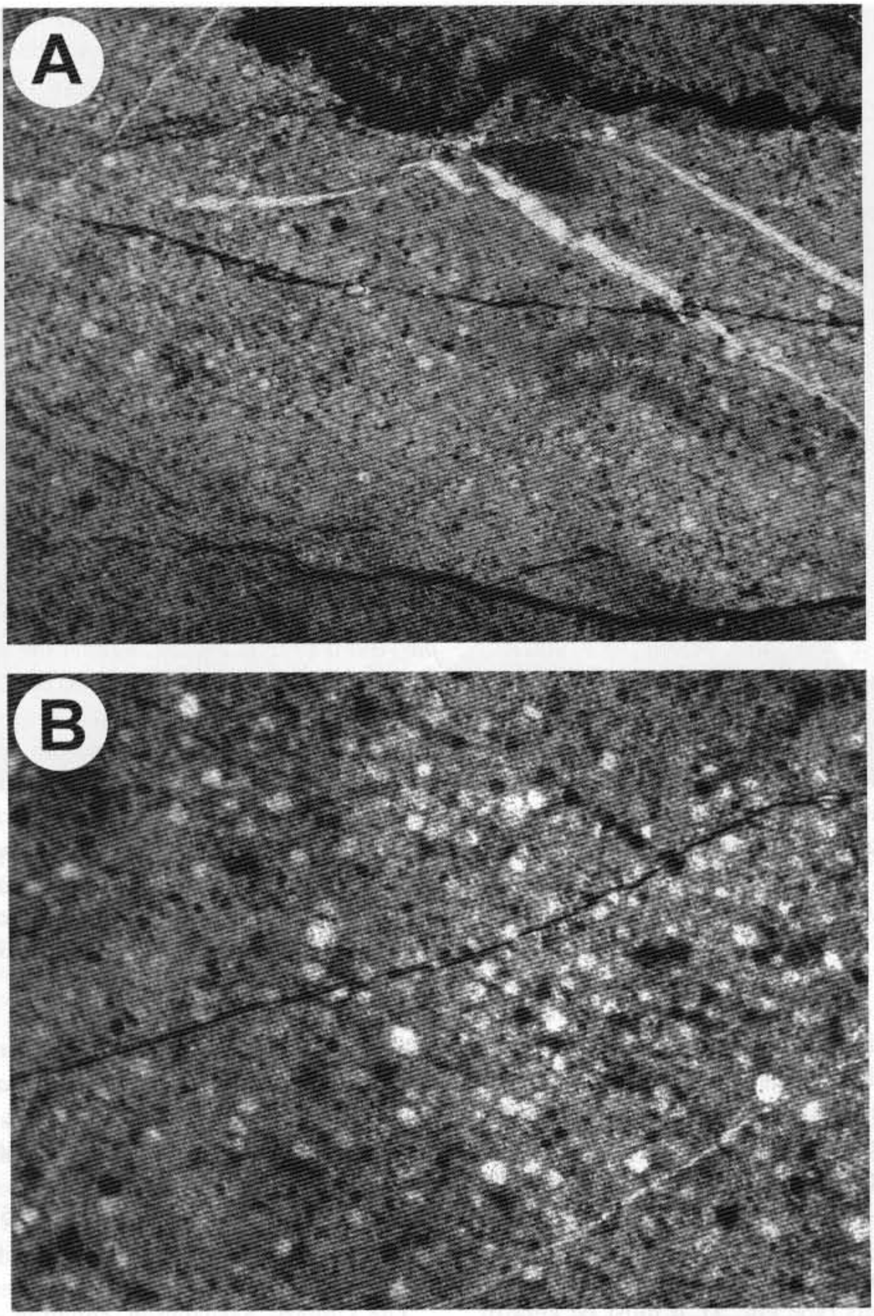

Fig. 5. Microfacies of the Middle Jurassic matrix of the Sjenica mélange (Abeško Brdo, sample SCG 85-2). **A.** Greenish-reddish radiolarite. Relatively homogenous, not laminated radiolarian wackestone to packstone. Width of the photo = 0.9 cm. **B.** Radiolarian packstone. Most radiolarians are recrystallized and filled with quartz. Only few radiolarians are well preserved. Width of the photo = 0.5 cm.

2006; GAWLICK et al. 2007; SUZUKI & GAWLICK 2009) of different species forms a base for the age determination. On the base of the Jurassic radiolarian zonation according to SUZUKI & GAWLICK (2003 a) the age of the sample SCG 84 should be Callovian.

Because of the occurring *Dictyomitrella kamoensis* and *Eucyrtidiellum unumaense dentatum* the age of this radiolarian fauna is can roughly be determined as (Bathonian) to Callovian (compare BAUMGARTNER et al. 1995 a). Especially *Protunuma lanosus* occurring together with the other species is characteristic for the Callovian, e.g. for the Northern Calcareous Alps in the *Protunuma lanosus* subzone of SUZUKI & GAWLICK (2003a). However, *Zhamoidellum ovum* as indicative species for the Callovian and younger ages in the Northern Calcareous Alps, is missing in the sample SCG 84. Instead, in the sample SCG 84 were found *Tricolocapsa fusiformis, Tricolocapsa* aff. *fusiformis, Striatojaponocapsa* cf. *conexa* and *Striatojaponocapsa* cf. *synconexa*, which are characteristic for the *Striatojaponocapsa plicarum* to *S. conexa* zone of Japan (e.g. MATSUOKA 1983; HATAKEDA et al. 2007). Further, a radiolarian fauna comparable to sample SCG 84 was recently described by SUZUKI & GAWLICK (2009) from below the Hallstatt salt mine in the Northern Calcareous Alps (sample BNU), which corresponds with the boundary between the *Striatojaponocapsa plicarum* and *Striatojaponocapsa conexa* zones. But in contrast to sample SCG 84 the sample BNU from the Northern Calcareous Alps contains the radiolarian species *Tricolocapsa fusiformis, Striatojaponocapsa conexa, Striatojaponocapsa plicarum, Zhamoidellum ovum, Gongylothorax favosus* among others indicating a Lower to Middle Callovian age.

Due to the missing of *Zhamoidellum ovum* and *Gongylothorax favosus* in the sample SCG 84 we suggest for this radiolarian fauna an age of (Late) Bathonian to Early/Middle Callovian.

A second radiolarian assemblage studied here derived from the Late Triassic radiolaritic block south of the road Sjenica-Prijepolje (SCG 82, see Fig. 2). Completing former stratigraphic results from this radiolaritic olistolith (GORIČAN et al. 1999a), the present study precises the age of the whole block.

The radiolarian sample, SCG 82, contains the following radiolarian taxa (Fig. 8): *Canesium* cf. *lentum* BLOME, *Capnuchosphaera* cf. *crassa* YEH, *Capnuchosphaera lea* DE WEVER, *Capnuchosphaera* cf. *triassica* DE WEVER, ?*Ferresium* sp., *Nakasekoellus* cf. *pessagnoi* (NAKASEKO & NISHIMURA), *Paronaella* cf. *trammeri* (KOZUR & MOSTLER), *Pseudostylosphaera* cf. *japonica* (NAKASEKO & NISHIMURA), ?*Risella* sp., *Sarla* cf. *robusta* TEKIN, *Syringocapsa turgida* BLOME, *Triassocampe* sp., *Weverella* sp., *Xiphothecaella longa* (KOZUR & MOCK in KOZUR & MOSTLER) and *Xiphothecaella* sp.

This bioturbated radiolarite (Fig. 7) is rich in *Capnuchosphaera*, which proves an Early Carnian to Middle Norian age (SUGIYAMA 1997). *Capnuchosphaera lea* DE WEVER has been known from the Upper Carnian to Lower Norian only (TEKIN 1999). *Xiphothecaella longa* (KOZUR & MOSTLER) and *Syringocapsa turgida* BLOME, are also frequent in the Upper Carnian to Lower Norian, but range in age to the ?late Middle Norian (TEKIN 1999). According to TEKIN (1999) *Capnuchosphaera crassa* YEH had their last occurrence in the Lower Norian. The age of the assemblage is therefore Late Carnian to Early Norian.

The occurrence of *Ferresium* and *Risella* is not consistent, because these genera are regarded to be somewhat younger forms (Late Norian to Rhaetian). The specimens found in sample SCG 82 would, therefore, be older than known so far or represent precursor forms.

In the Upper Anisian to Lower Carnian, radiolarites are widespread not only in the oceanic realm. They occur also in the distal shelf areas of the Neotethys realm (Meliata facies = continental slope). This facies belt is also characterized by Bódvalenke-type Hallstatt successions, which occur also as slide blocks in the mélange, with reddish, cherty limestones to red cherts in the Middle Triassic to Lower Carnian (e.g. KOVÁCS et al. 1989; DIMITRIJEVIĆ et al. 2003). In contrast, Upper Triassic radiolarites are – as expected – unknown from the distal continental shelf margins towards the Neotethys Ocean (GAWLICK et al. 1999, 2008). Highstand shedding from the late Middle and Upper Triassic shallow-water carbonate ramps and platforms transport a huge amount of micrites to the distal shelf and partly to the oceanic domain (GAWLICK & BÖHM 2000). These radiolarites can only be expected in distal oceanic areas (GAWLICK et al. 2008). For this reason, Late Triassic radiolarites are of special interest: they indicate fragments of the Neotethys oceanic realm in the source area.

Regional comparisons and correlations

Lack of stratigraphic data from contact areas with ophiolites feed the actual controversial discussion about the tectonic interpretation of the ophiolites and the mélanges point. Formation and paleogeographic position of the Middle Jurassic mélanges as well as the derivation of the components are still unknown. Only comparisons with other areas in the Dinaridic-Hellenic and East Alpine realm can assist in understanding the palaeogeographic situation.

According to actual results the age of the mélange in the Dinaridic Ophiolite Belt is similar to the radiolaritic carbonate-clastic trench fills situated in front of advancing nappes in the Northern Calcareous Alps

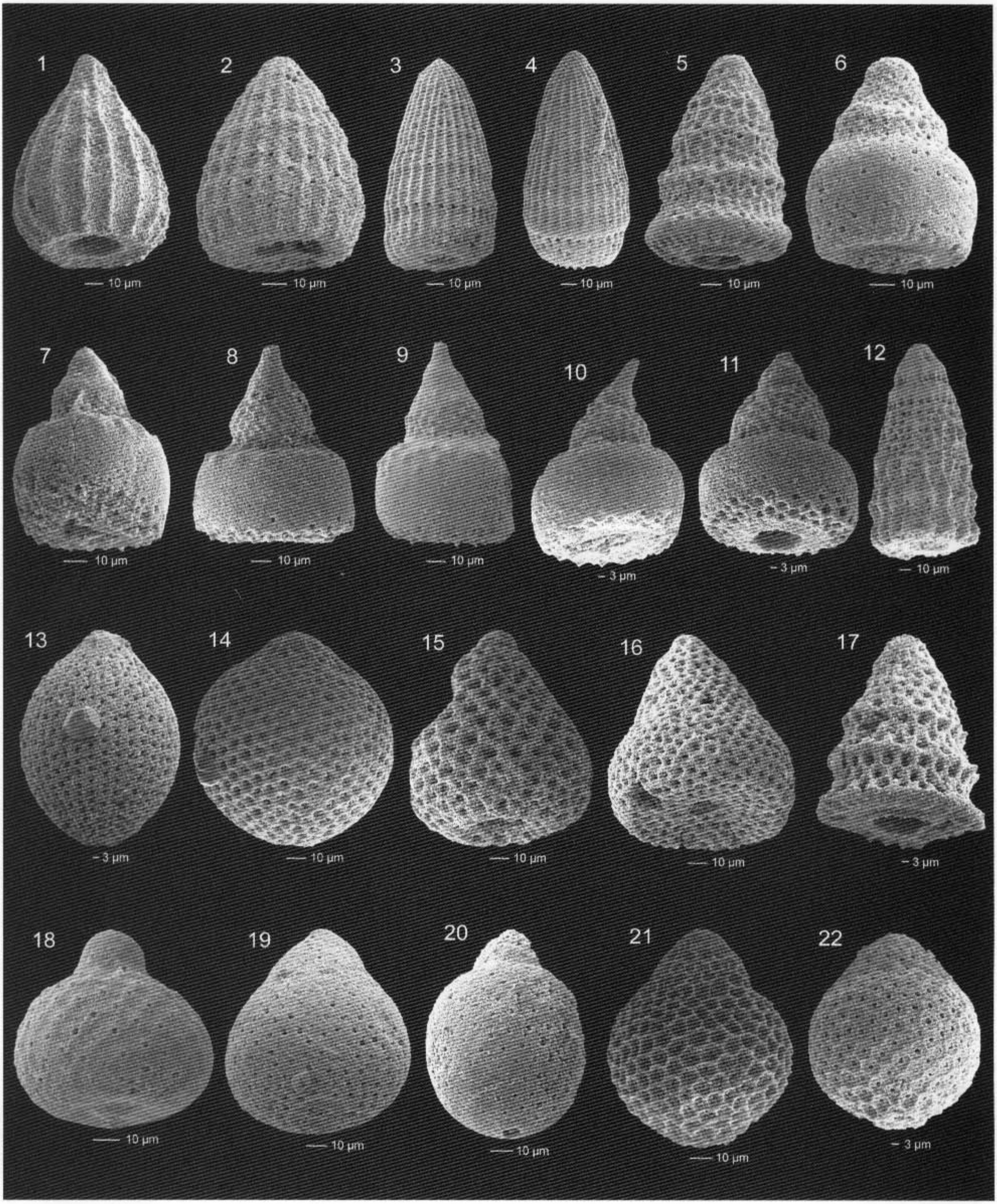

Fig. 6a (Legend see p. 304)

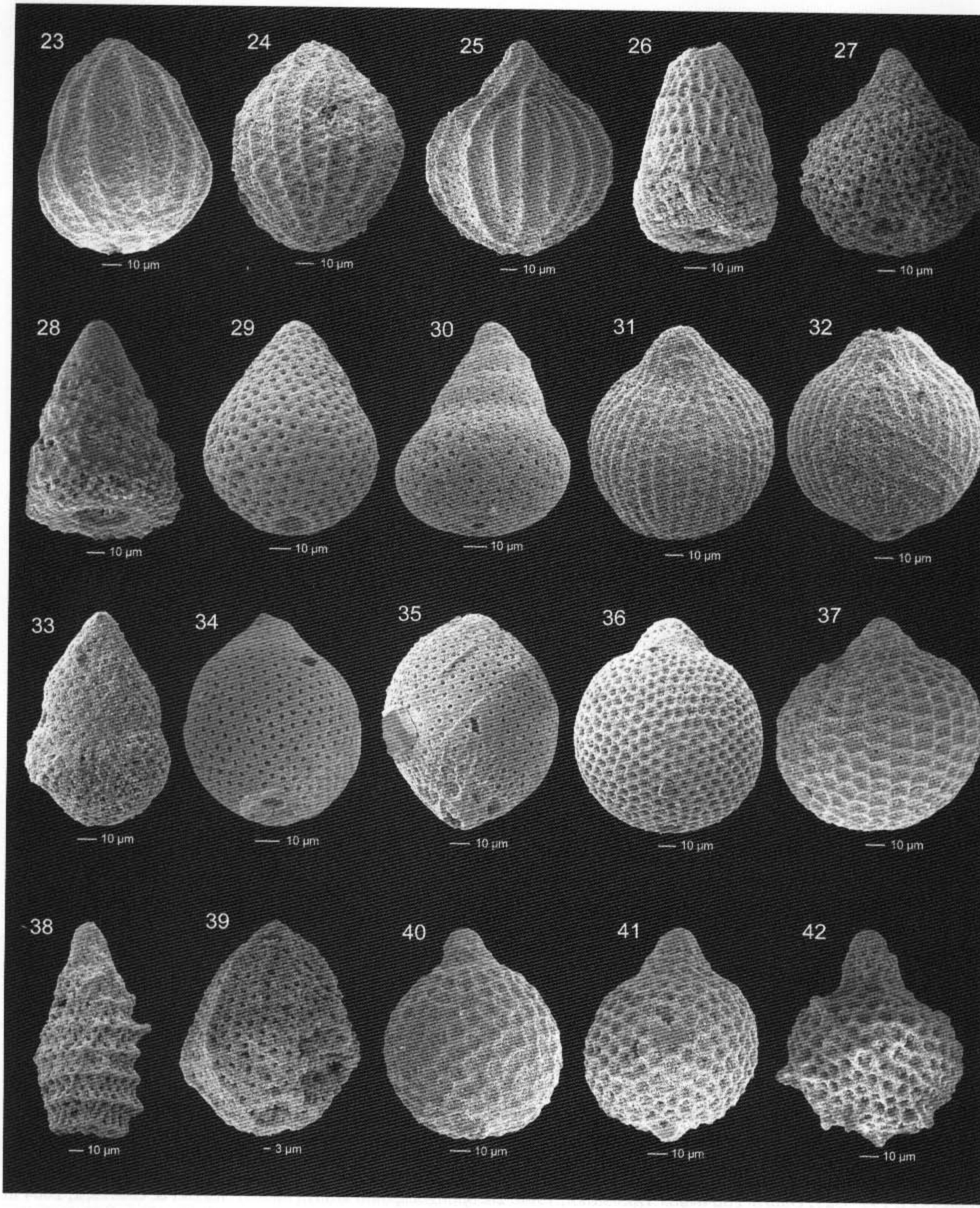

Fig. 6b (Legend see p. 304)

(?Bajocian/Bathonian-Oxfordian; GAWLICK & FRISCH 2003; MISSONI et al. 2001, 2005; GAWLICK et al. 2007; AUER et al. 2009), and in the Middle Jurassic of the Western Carpathians (e.g., KOZUR & MOCK 1985, 1995; KOZUR et al. 1996). Here, the mélange formation (Hallstatt Mélange in the Eastern Alps, Meliata Mélange in the Western Carpathians) is interpreted as to be a result of the partial closure of the Neotethys (Meliata) Ocean (e.g., KOZUR 1991; CHANNELL & KOZUR 1997; CSONTOS & VÖRÖS 2004; GAWLICK et al. 1999; FRISCH & GAWLICK 2003). Similar ?Early/Middle Jurassic (late Early Jurassic to Bajocian in BABIĆ et al. 2002; Bajocian-Callovian in HALAMIĆ et al. 1998, 1999) mélanges as those in the Dinaridic Ophiolite Belt occur in Croatia (e.g. HALAMIĆ et al. 1999; BABIĆ et al. 2002), Bosnia and Herzegovina (HRVATOVIĆ 2006), Albania (BORTOLOTTI et al. 2005; GAWLICK et al. 2008) or Greece (STAMPFLI et al. 2003; BORTOLOTTI et al. 2004), as well as in the Darnó unit of Hungary (KOVÁCS et al. 2008).

Especially in the Mirdita zone reddish radiolarites of Upper Carnian to Lower Norian age were found as primary cover of ocean floor basalt below the Middle Jurassic radiolaritic-ophiolitic trench fill (GAWLICK et al. 2008). These radiolarites correspond in facies and radiolarian fauna to the radiolaritic block in the Sjenica mélange. Triassic radiolarites and remnants of ophiolite sequence of Middle and Late Triassic age occur in the Mirdita zone (CHIARI et al. 1996; BORTOLOTTI et al. 2006; GAWLICK et al. 2006a, 2008) in a Bajocian to Oxfordian matrix (e.g., CHIARI et al. 2004; GAWLICK et al. 2008). Late Triassic ocean floor is also known from the Vardar zone in Serbia (OBRADOVIĆ & GORIČAN 1988). Comparable are also occurrences of Middle and Late Triassic radiolarites on top of the ocean floor basalts in the Kalnik Mountain of Croatia (GORIČAN et al. 2005).

Biostratigraphic data collected by means of radiolarians confirm that a continuos belt of a Triassic oceanic lithosphere existed from Croatia over Albania to southern Greece. This implies that a Triassic Ocean (since late Anisian, GAWLICK et al. 2006a), characterized by MORB magmatism, was located between Adria-Apulia and Asia (BORTOLOTTI et al. 2005, 2006; BORTOLOTTI & PRINCIPI 2005). Remnants of this Middle to Late Triassic ocean floor were also found in the Western Carpathians (KOZUR et al. 1996; KOVÁCS et al. 2008). Moreover, Middle to Late Triassic radiolarites occur together with ophiolite components also as components in Upper Cretaceous sedimentary rocks (Gosau) in the Northern Calcareous Alps (SUZUKI et al. 2007; SCHUSTER et al. 2007).

Discussion and conclusions

The Dinaridic Ophiolite Belt separates the Drina-Ivanjica Element (DIE, Fig. 1C) from the East Bosnian-Durmitor Unit (EBDU, Fig. 1C), continuing into the Mirdita Ophiolite zone in Albania. Triassic to Jurassic ocean floor is also documented in the Vardar segment of the Neotethys (= Vardar) Ocean to the east (PAMIĆ et al. 2002; KARAMATA 2006). Besides, from

Fig. 6. Bathonian to Early or Middle Callovian radiolarian fauna of the radiolaritic matrix of the Sjenica mélange (in alphabetic order) (Abeško Brdo, sample SCG 84). **1.** *Archaeodictyomitra amabilis* AITA, 1987. **2.** *Archaeodictyomitra mitra* DUMITRICA, 1997 in DUMITRICA et al. 1997. **3.** *Archaeodictyomitra rigida* PESSAGNO, 1977. **4.** *Archaeodictyomitra* sp. B sensu WEGERER, SUZUKI & GAWLICK, 2001. **5.** *Dictyomitrella kamoensis* MIZUTANI & KIDO, 1983. **6.** *Eucyrtidiellum circumperforatum* CHIARI, MARCUCCI & PRELA, 2002. **7.** *Eucyrtidiellum semifactum* (NAGAI & MIZUTANI, 1990). **8.** *Eucyrtidiellum unumaense dentatum* BAUMGARTNER, 1995 in BAUMGARTNER et al. 1995b. **9.** *Eucyrtidiellum unumaense pustulatum* BAUMGARTNER, 1984. **10.** *Eucyrtidiellum unumaense* (YAO, 1979). **11.** *Eucyrtidiellum unumaense unumaense* (YAO, 1979). **12.** *Hsuum maxwelli* PESSAGNO, 1977. **13.** *Helvetocapsa* cf. *matsuokai* (SASHIDA, 1999) in SASHIDA et al. 1999. **14.** *Hemicryptocapsa* sp. A. **15.** *Hiscocapsa magnipora* (CHIARI, MARCUCCI & PRELA, 2002). **16.** *Lithocampium* sp. E. **17.** *Parvicingula spinata* (VINASSA, 1899). **18.** *Praezhamoidellum* aff. *buekkense* KOZUR, 1984. **19.** *Praezhamoidellum buekkense* KOZUR, 1984. **20.** *Praezhamoidellum* cf. *parvipora* (TAN, 1927). **21.** *Praezhamoidellum* sp. C. **22.** *Praezhamoidellum* sp. C. **23.** *Protunuma lanosus* OZVOLDOVA, 1996 in SYKORA & OZVOLDOVA, 1996. **24.** *Protunuma ochiensis* MATSUOKA, 1983. **25.** *Protunuma turbo* MATSUOKA, 1983. **26.** *Pseudodictyomitra* cf. *venusta* (CHIARI, CORTESE & MARCUCCI, 1997). **27.** *Quarticella ovalis* TAKEMURA, 1986. **28.** *Spongocapsula krahsteinensis* SUZUKI & GAWLICK, 2004 in GAWLICK et al. 2004. **29.** *Stichocapsa convexa* YAO, 1979. **30.** *Stichocapsa japonica* YAO, 1979. **31.** *Striatojaponocapsa* cf. *conexa* (MATSUOKA, 1983). **32.** *Striatojaponocapsa* cf. *synconexa* O'DOGHERTY et al., 2006. **33.** *Tetracapsa himedaruma* (AITA, 1987). **34.** *Tricolocapsa* aff. *fusiformis* YAO, 1979. **35.** *Tricolocapsa fusiformis* YAO, 1979. **36.** *Tricolocapsa* sp. S sensu BAUMGARTNER et al., 1995 in BAUMGARTNER et al. 1995b. **37.** *Tricolocapsa tetragona* MATSUOKA, 1983. **38.** *Triversus hungaricus* (KOZUR, 1985). **39.** *Unuma gordus* HULL, 1997. **40.** *Williriedellum dierschei* SUZUKI & GAWLICK, 2004 in GAWLICK et al. 2004. **41.** *Williriedellum marcucciae* CORTESE, 1993. **42.** *Zhamoidellum exquisitum* HULL, 1997.

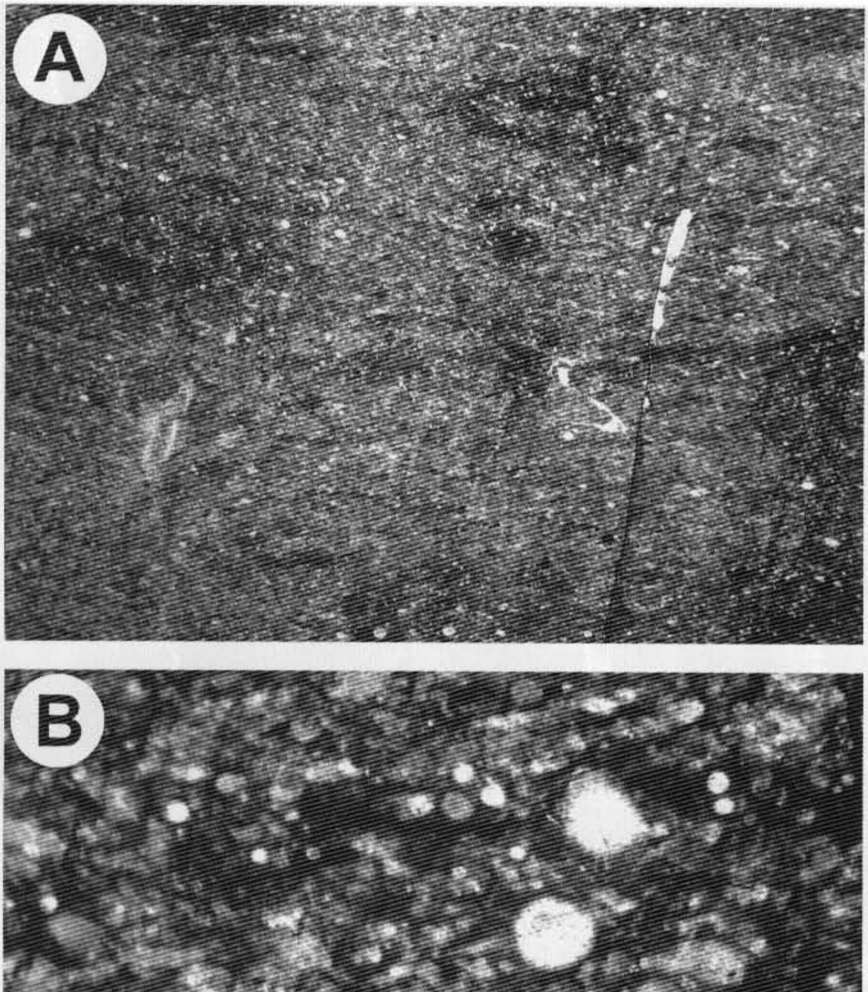

Fig. 7. Microfacies of the Late Carnian to Early Norian red radiolarite of a block in the Sjenica mélange (sample SCG 83). **A**) Bioturbated radiolarian packstone, slightly sheared. In the massive radiolaritic part, the radiolarians are recrystallized to quartz and not well preserved. Width of the photo = 1.25 cm. **B**) Enlarged detail from a more sheared part of 5A. The radiolarians are partly filled with massive quartz. Only few radiolarians are well preserved. Width of photo = 0.5 cm.

the Vardar Zone (Kopaonik Mountain, southern Serbia) Late Triassic cherty metamorphosed limestones overthrusted by ophiolite complexes have been reported in SUDAR & KOVÁCS (2006).

The dating of the radiolaritic matrix of the Sjenica mélange is the first direct dating in the central Dinaridic Ophiolite Belt. It proves that different blocks were emplaced in Middle Jurassic times.

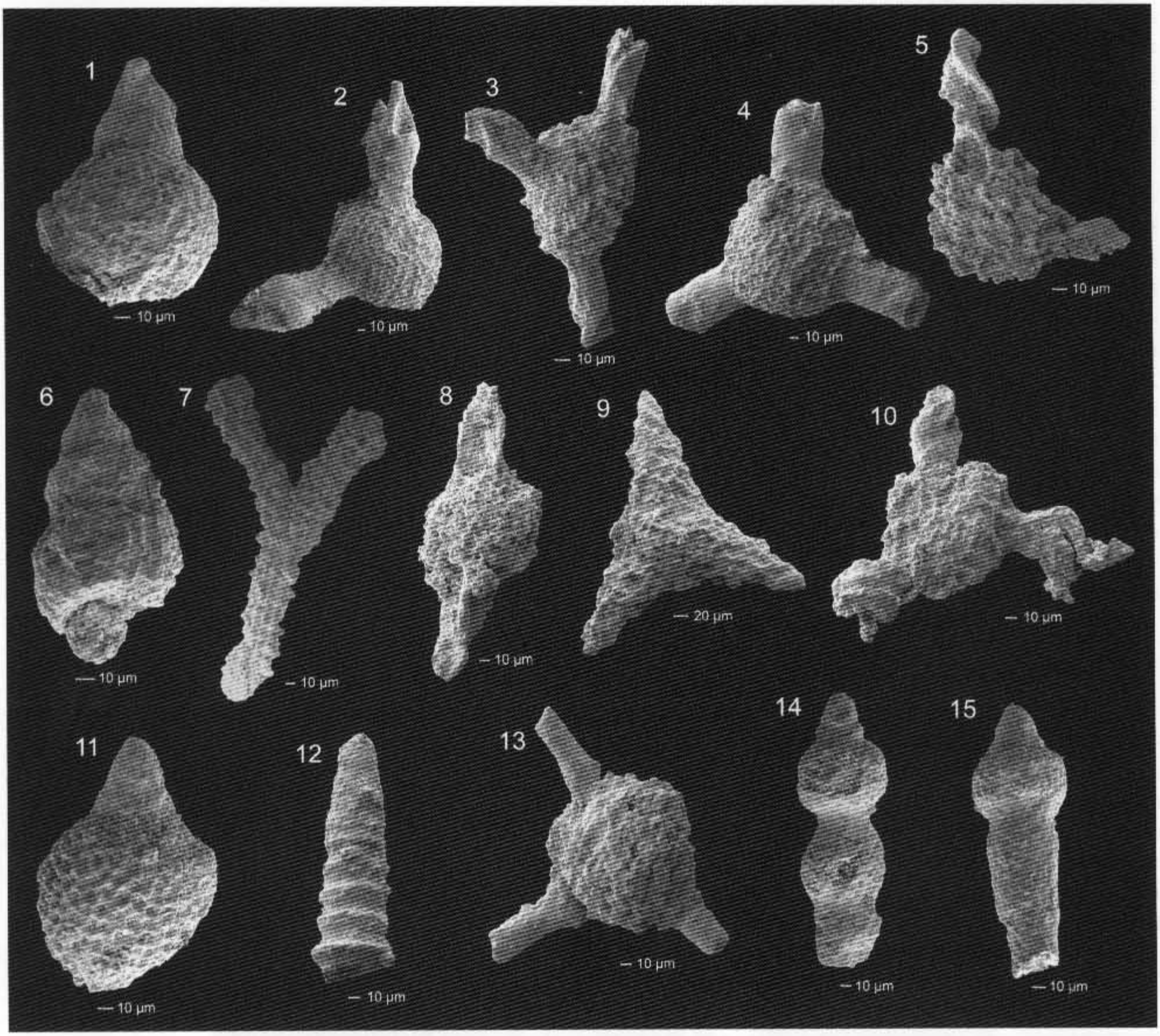

Fig. 8. Upper Carnian to Lower Norian radiolarian assemblage from sample SCG 82 of the Triassic radiolaritic block of the Sjenica mélange (in alphabetic order). **1.** *Canesium* cf. *lentum* BLOME, 1984. **2.** *Capnuchosphaera* cf. *crassa* YEH, 1990. **3.** *Capnuchosphaera* cf. *triassica* DE WEVER, 1979 in DE WEVER et al. 1979. **4.** *Capnuchosphaera lea* DE WEVER, 1979 in DE WEVER et al. 1979. **5.** ?*Ferresium* sp. **6.** *Nakasekoellus* cf. *pessagnoi* (NAKASEKO & NISHIMURA, 1979). **7.** *Paronaella* cf. *trammeri* (KOZUR & MOSTLER, 1978). **8.** *Pseudostylosphaera* cf. *japonica* (NAKASEKO & NISHIMURA, 1979). **9.** *Risella* sp. **10.** *Sarla* cf. *robusta* TEKIN, 1999. **11.** *Syringocapsa turgida* BLOME, 1984. **12.** *Triassocampe* sp. **13.** *Weverella* sp. **14.** *Xiphothecaella longa* (KOZUR & MOCK, 1981) in KOZUR & MOSTLER 1981. **15.** *Xiphothecaella* sp.

The whole Sjenica mélange succession is interpreted as to be a primary sedimentary synorogenic radiolaritic trench-fill sequence, that formed simultaneously along with nappe emplacement and ophiolite accretion and was overprinted by contemporaneous and younger tectonics forming a typical mélange. This formation mélange was deposited during the Middle Jurassic period contemporaneously with nappe thrusting that in some parts of the Neotethys realm had started somewhat earlier in late Early Jurassic times (e.g. BABIĆ et al. 2002; compare discussion in GAWLICK et al. 2008). The depositional area could be interpreted to have been a deep-water trough in front of advancing nappes.

These results are in good agreement with known situations from other areas in the Alpine-Dinaridic-Hellenic mountain chain. This mélange in the Dinaridic Ophiolite Belt is a syntectonic sequence reflecting the Middle to Late Jurassic orogeny in the Neotethys realm and is interpreted as deep-water chaotic sediment that was deposited in a trench-like basin in front of advancing and rising ophiolitic nappes with lateral chaotic infill in sense of PICKERING et al. (1989). The block of Carnian-Norian radiolarite in the mélange derived from the Triassic Neotethys ocean floor.

That a Middle Jurassic age was substantiated for the ophiolitic-radiolaritic wildflysch in the Dinaridic Ophiolite Belt is consistent with the time span of the radiolaritic carbonate-clastic trench fills (wildflysch) in the Northern Calcareous Alps, the Western Carpathians as well as to the ophiolitic-radiolaritic trench fills (wildflysch) in the Mirdita zone. The situation in the Dinaridic Ophiolite Belt confirms that of the Albanides („Mirdita mélange") and the Medvednica and Kalnik Mountains in Croatia.

To clearify the paleogeographic derivation of different blocks and the time span of their emplacement in detail, widespread further investigations in a larger regional scale are necessary. Only a detailed component analysis of the "mélange" with dating of the matrix should allow a reconstruction of the source area.

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