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# Triassic and Jurassic Radiolarians from Sedimentary Blocks of Ophiolite Mélange in the Avala Gora Area (Belgrade Surroundings, Serbia)

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**Abstract**—Blocks of cherty rocks and Aptychus Limestone embedded into ophiolite mélange south of Avala Gora (Serbia) contain radiolarians of different ages. We distinguished here Late Jurassic (middle Oxfordian–early Tithonian), Middle–Late Jurassic (Bathonian–early Tithonian), and Middle Triassic (early Ladinian) radiolarian assemblages. The respective stratigraphic data suggest that the ophiolite mélange was formed after the early Tithonian.

*Keywords:* radiolarians, stratigraphy, Triassic, Jurassic, ophiolite mélange, cherts, Serbia.

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## INTRODUCTION

The study of radiolarians is of great significance for stratigraphic and geologic research within mobile belts comprising areas of complicated structure, where cherts, spilite-cherty sequences, and chaotic complexes with frequently occurring radiolarian cherts are widespread. Age data of cherty rocks are of great and even decisive importance for dating the ophiolite complexes, mélange and olistostrome bodies. Serbia, where rock complexes of this kind are well known, is no exception. In Serbia, a series of works devoted to the study of radiolarians and dating the cherty rocks have been published in recent years (Obradović and Goričan, 1988; Goričan et al., 1999; Vishnevskaya and Djerić, 2005, 2006a, 2006b; Djerić and Vishnevskaya, 2006; Gawlick et al., 2007; Djerić et al., 2007; Djerić nd Gerzina, 2008; Vishnevskayaet et al., 2009). We follow these investigations, aiming at taxonomic and age analysis of the radiolarian assemblages from cherty rocks in the ophiolite mélange of the Avala Gora area to the south of Belgrade. The work is based on the results of fieldwork in 2007, by Russian and Serbian researchers.

## TECTONIC OVERVIEW

As can be seen from available tectonic schemes, the vicinity of Belgrade belongs to the so-called Vardar zone (Fig. 1) with widespread ophiolite thrust sheets (Ivković et al., 1975; Filipović et al., 1975; Pavlović et al, 1980; Dimitrijević, 1997). Kossmat (1924), who first distinguished this zone, defined it to comprise Southern Serbia, Macedonia, and Northern Greece. Later on, rock complexes of the Vardar zone were discovered in the Belgrade region (Milovanović, 1950) and further northwestward and west-northwestward in the Sava River basin (Aubouin, 1973). Structural ensembles of the Vardar zone belong to its Main and Western tectonic belts (Karamata et al., 1997, 2000). Ophiolites of the Main belt are interpreted as relicts of the oceanic lithosphere that originally floored one branch of the Tethyan basin, which opened in the Early Paleozoic and closed in the terminal Jurassic (Karamata, 2006). That branch extended northwestward throughout Serbia between the Serbo-Macedonian massif and the Kopaonik block, which is a remnant of longitudinal ridge dividing the Vardar zone into two ophiolite belts (Karamata, 2006; Čanović and Kemenci, 1997).

There are also alternative viewpoints on the tectonic associations of ophiolites from the Belgrade vicinity. According to one of them, the belt of ophiolitic, magmatic, and metamorphic rocks extending from Zagreb to Belgrade typifies the Northwestern Vardar (Pamić, 1993) or Sava–Vardar zone (Pamić, 2002). Schmid et al. (2008) who avoid usage of the name Vardar, regard the Sava zone as corresponding to the suture between the Dacia–Tissa megacomplexes and Inner Dinarides. South of Belgrade, this zone extends as a narrow belt of the Late Cretaceous flysch with ophiolites (Schmid et al., 2008), being comparable with the Senonian flysch belt in the ter-

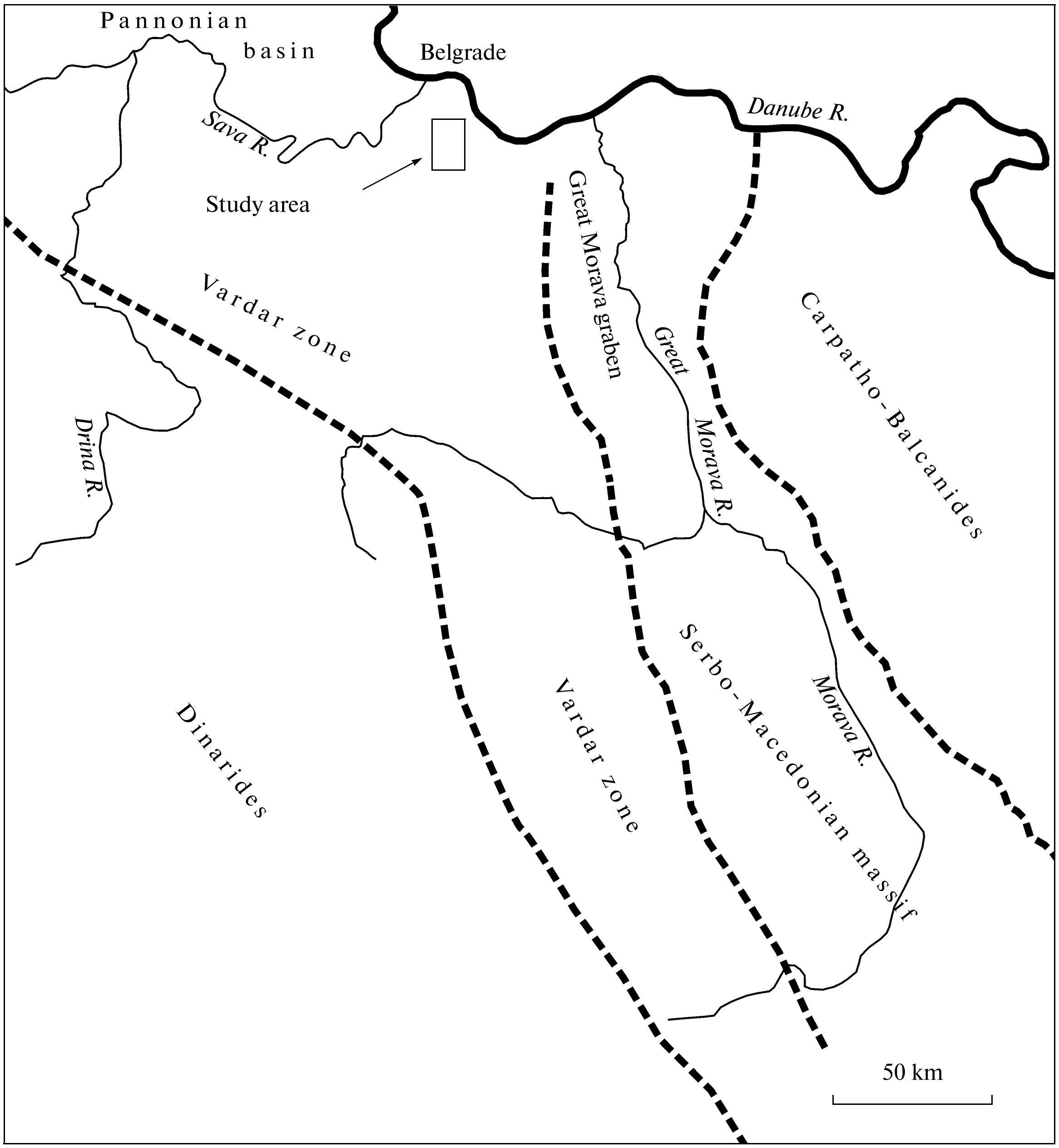


**Fig. 1.** Main tectonic zones in central part of the Balkan Peninsula (Marović et al., 2002).

minology of Dimitrijević, (1997). Accordingly, the Sava zone separates the Dinarides (Western belt of the Vardar zone inclusive) from the Carpathian–Balkan orogen comprising the Main belt of the Vardar zone (Schmid et al., 2008). On the other hand, Marović et al. (2002) considered the Vardar zone as a structural formation of the Dinarides, recognizable between the Serbia–Macedonia massif to the east and Golia zone to the west.

## GEOLOGY OF THE STUDY AREA

The study area is situated south of Belgrade between Avala Gora and the Bela Reka and Ripanj villages (Fig. 2), where Mesozoic to Cenozoic magmatic and sedimentary rocks are exposed. The Mesozoic complexes correspond to (1) ophiolite mélange with erratic blocks of serpentinized peridotites and other rocks of variable composition set into a tectonized matrix; (2) Aptychus limestones and marls; (3) spilitic volcanics; (4) terrigenous-carbonate deposits of the

Lower Cretaceous paraflysch; and (5) lower part of the Cretaceous–Paleogene terrigenous flysch. The best place to study the ophiolite mélange is between the Ripanj and Bela Reka villages south of the Avala Gora. The mélange bodies of chaotic structure include size-variable blocks composed of fine-grained micaceous sandstone, tectonized sandy marl, gray chert, fragments of red to brown-red cherts, and blocks of brecciated Dogger–Malm limestones and spilites set into foliated clay matrix. Pelagic and hemipelagic sediments derived from oceanic crust and represented by cherts and Aptychus limestone or marl commonly occur in association with spilitic basic volcanics. All the respective rock suites were dislocated at the time of the Late Jurassic collision (Toljić, 2006). The geological position of spilitic volcanics is variable. Small spilite blocks are frequent components of ophiolite mélange. Spilitic dykes and synsedimentary lava flows are intercalated with Upper Jurassic sediments (Aptychus limestones and marls). Finally, spilites occur in association with carbonate rocks at the base of the Cretaceous–Paleogene flysch (Toljić, 2006).

The overlying deposits of the Neocomian paraflysch (the Topčiderska Reka Formation) are represented by calcirudite, calcarenite, argillite, aleurolite, marl and clay limestone strata with more or less perceptible structural features characteristic of turbidites. The Berriasian–Valanginian deposits have been distinguished in the study area based on paleontological data, and marly rocks bearing middle–upper Neocomian cephalopods are known from northerly areas. Jurassic and Lower Cretaceous deposits are discordantly overlain by the Upper Cretaceous–Paleogene flysch. The Mesozoic rock complexes are intruded by numerous andesite, latite, quartz latite, dacite, and lamprophyre dykes of the Tertiary. The youngest deposits of the study area are represented by Miocene to Pliocene strata of clastic carbonate sediments, which are slightly deformed, and by the Quaternary alluvial and colluvial accumulations.

## INVESTIGATION METHODS

Following the conventional technique for extracting radiolarians (Pessagno and Newport, 1972), samples of radiolarian cherts were decomposed in diluted fluoric acid (5–10% HF); macerates from five samples yielded satisfactorily preserved radiolarians. Specimens of microfossils selected under a LOMO-MBS-9 stereomicroscope were studied in detail, measured and photographed using a scanning electron microscope at the Paleontological Institute, Russian Academy of Sciences. All the material examined is deposited at the Geological Institute, Russian Academy of Sciences.

Radiolarian assemblages macerated from the Triassic and Jurassic cherts sampled in the Avala Gora ophiolite mélange consist of taxa typical of the Tethyan Superrealm. Consequently it was possible to use the Triassic and Jurassic radiolarian zonations suggested for the Mediterranean and other circum-tropical regions (Kozur and Mostler, 1994; Baumgartner et al., 1995; Bragin, 2000) for their age determination. The radiolarians with the best preservation, allowing species level identification, are certainly of prime significance for age determination of host deposits. Species identified in open nomenclature (“conformis”, “affinis” and “ex grege”) have been only used in stratigraphic considerations in some cases, and with precautions.

## DESCRIPTION OF OUTCROPS AND AGE OF CHERTS

Field observations in the Belgrade vicinity have focused on deposits underlying the Neocomian paraflysch. The chert samples studied were mostly collected from exotic blocks in mélange and from successive outcrops of cherty rocks. They characterize the following three localities (Fig. 2): Bela Reka railway station (07-34); Bela Reka, Minel (07-35), and Ripanj (07-36).

### *Section Bela Reka, Railway Station*

Coordinates of section at the Bela Reka railway station are 44°39′21.59″N and 20°28′23.54″E. A block of Aptychus Marl here is composed of alternating gray to gray-red laminated marl and cherty argillite beds, which are 7 m thick in total. Marls and argillites with characteristic, very fine horizontal microlayering contain Aptychus remains of the Late Jurassic–Early Cretaceous (Tithonian–Valanginian) in some horizons (Anđelković, 1973; Pantić, 1986; Toljić, 2006). Ercegovac (1974) who studied the spore-pollen spectra of the rocks, determined their age as corresponding to the Dogger–Malm interval. Samples described below have been collected from thin interlayers of radiolarian chert in the section.

Sample 07-34-8 yielded the following radiolarians (Plate I): *Bistarkum* sp., *Emiluvia ordinaria* Ozvoldova, *E. orea* Baumgartner, *E. pessagnoi* Foreman s.l., *?Halesium* sp. ex gr. *H. (?) lineatum* Jud, *H.* sp., *Homoeoparonaella* sp. aff. *H. speciosa* (Parona), *Mirifusus dianae* (Karrer), *Podobursa spinosa* Ozvoldova, *P.* sp., *Tetratrabs bulbosa* Baumgartner, and *Triactoma blakei* (Pessagno). For five species listed above (*Emiluvia orea, E. ordinaria, Tetratrabs bulbosa, Triactoma blakei*), the upper limit of the stratigraphic distribution corresponds to the upper Kimmeridgian–lower Tithonian, i.e., to Zone 11 of unitary radiolarian associations (Baumgartner et al., 1995). One species (*Emiluvia ordinaria*) appears in the middle–upper Oxfordian, precisely in Zone 9 of unitary associations (Baumgartner et al., 1995). An earlier appearance in the Bajocian–lower Oxfordian is characteristic of two other species (*Mirifusus dianae,*

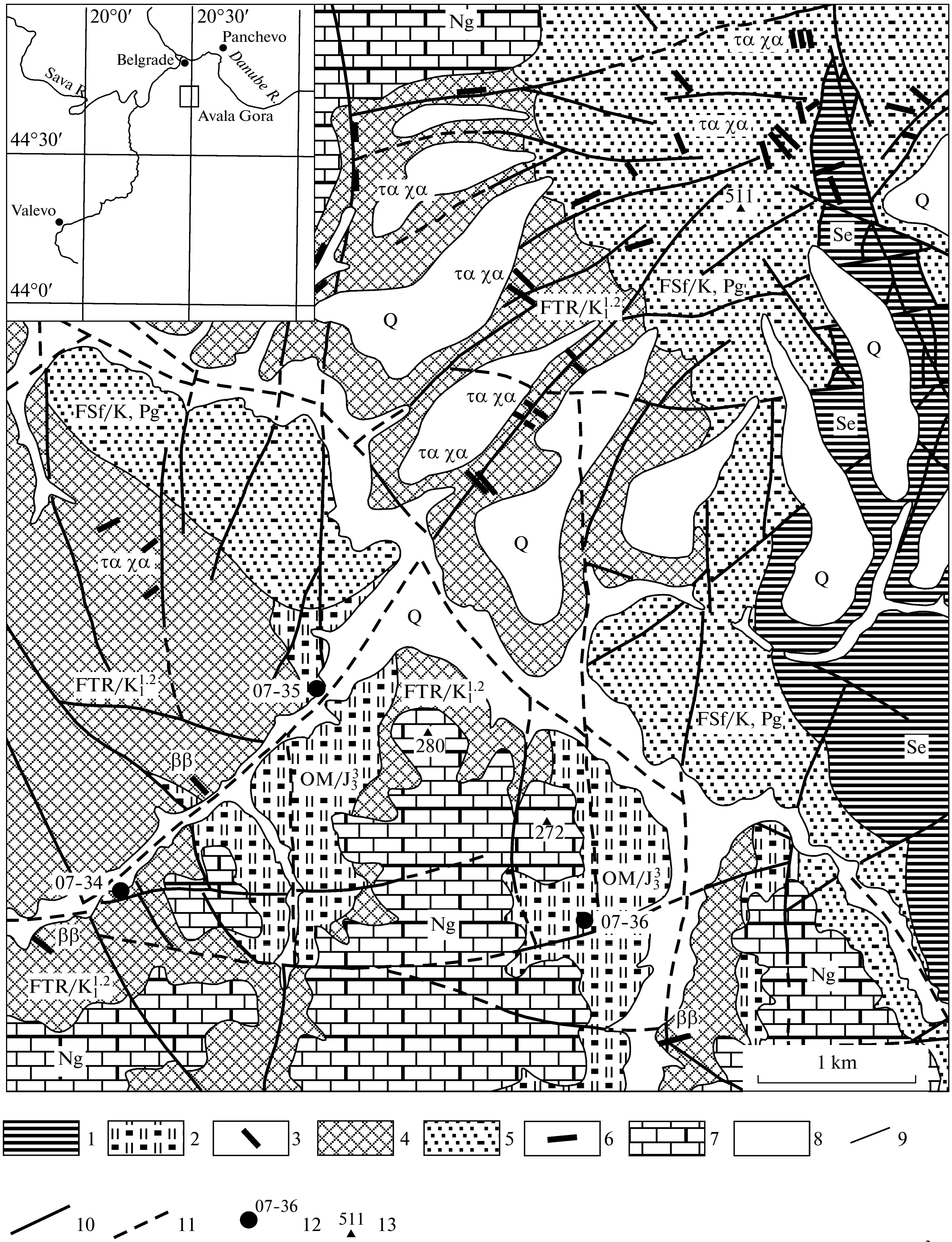


**Fig. 2.** Schematic geological structure of the Mt. Avala area (Toljić, 2006): (1) serpentinite (Se); (2) ophiolite mélange (OM/$J_3^3$); (3) spilite (ββ); (4) Neocomian paraflysch (FTR/$K_1^{1.2}$); (5) Cretaceous–Paleogene flysch (FSf/K, Pg); (6) Tertiary magmatic rocks (τα χα): andesite, latite, quartz latite, dacite and lamprophyre; (7) Neogene deposits (Ng); (8) Quaternary deposits(Q); (9) geological boundaries; (10) faults; (11) presumed faults; (12) radiolarian occurrence localities; (13) altitudes.

**Plate I**

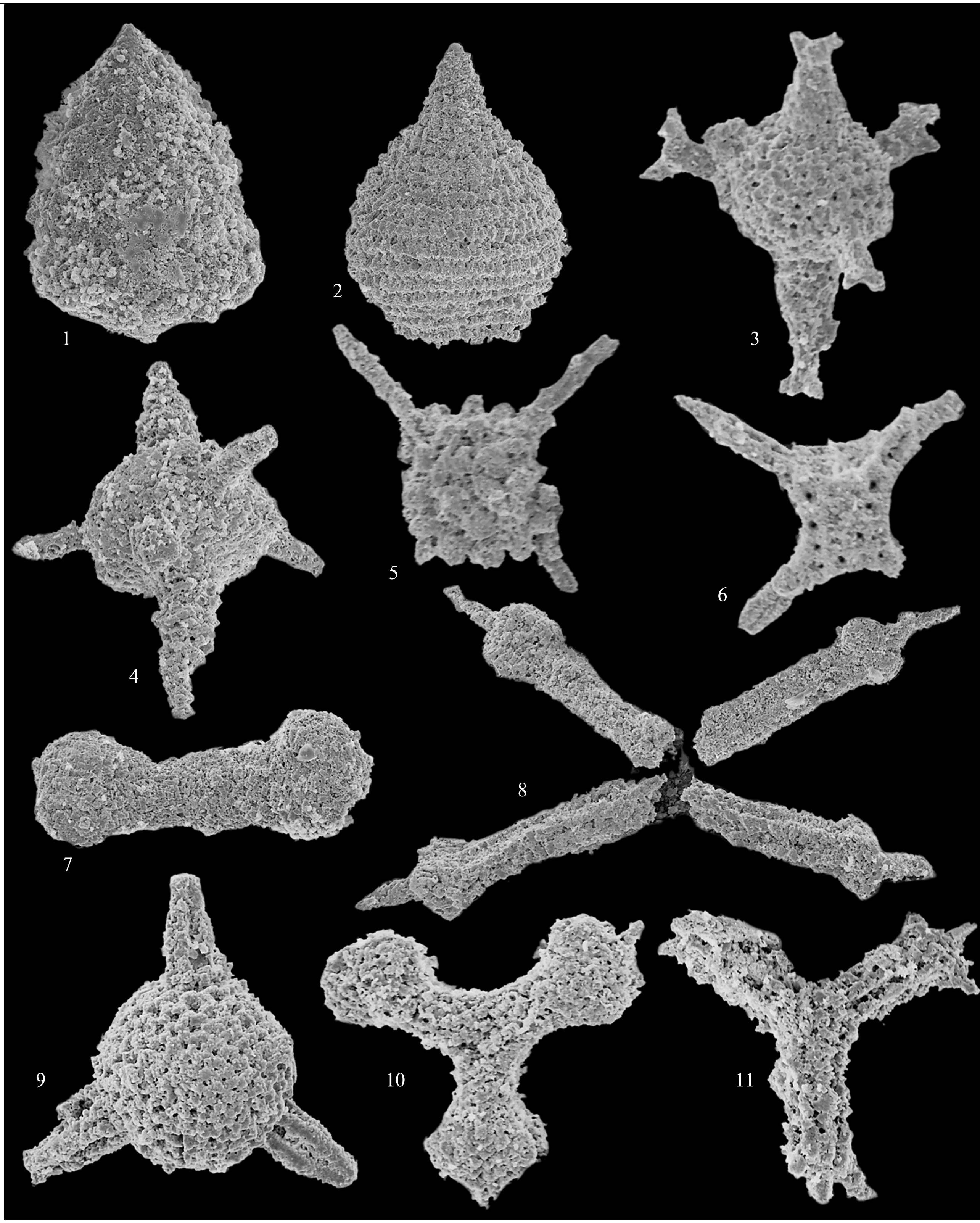


**Plate I.** Late Jurassic radiolarians from the Bela Reka locality:

(1) *Spongocapsula* sp., ×180; (2) *Mirifusus dianae* (Karrer), ×180; (3) *Podobursa spinosa* Ozvoldova, ×200; (4) *Podobursa* sp., ×200; (5) *Emiluvia orea* Baumgartner, ×200; (6) *Emiluvia ordinaria* Ozvoldova, ×200; (7) *Bistarkum* sp., ×135; (8) *Tetratrabs bulbosa* Baumgartner, ×135; (9) *Triactoma blakei* (Pessagno), ×180; (10) *Paronaella ?* sp., ×200; (11) *Tritrabs ?* sp., ×200. All specimens are from Sample 07-34-8 (Bela Reka).

**Plate II**

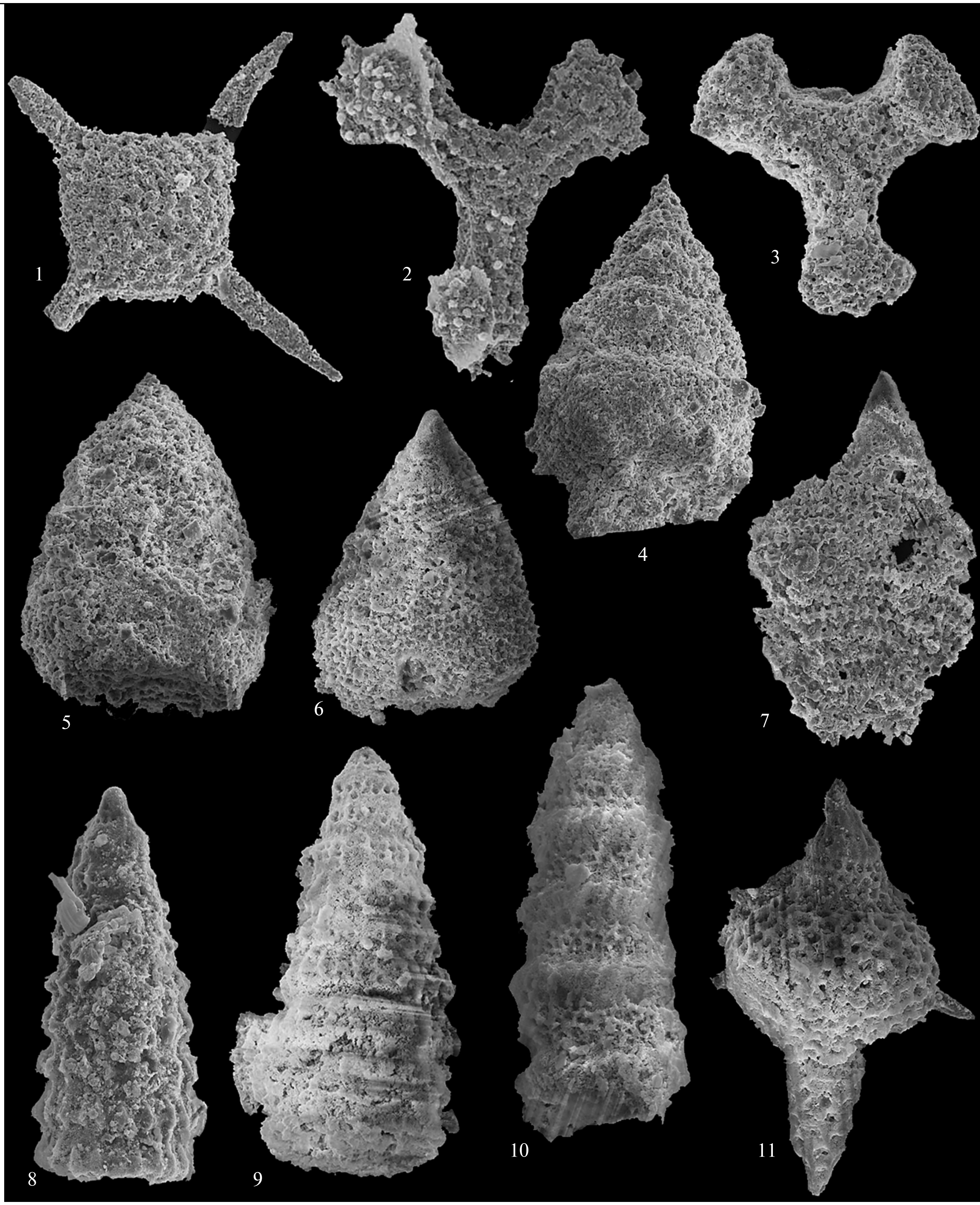


**Plate II.** Middle–Late Jurassic radiolarians from the Bela Reka and Ripanj localities:
(1) *Emiluvia pessagnoi* s.l. Foreman, ×200; (2) *Halesium* sp. ex gr. *H. (?) lineatum* Jud, ×200; (3) *Paronaella ?* sp., ×200; (4) *Spongocapsula* sp. cf. *S. perampla* (Rust), ×230; (5, 6) *Spongocapsula* sp., ×230 (both); (7) *Mirifusus dianae* (Karrer), ×80; (8) *Transhsuum* sp. ex gr. *T. brevicostatum* Ozvoldova, ×300; (9) *Cinguloturris* sp. cf. *C. cylindra* Kemkin et Rudenko, ×300; (10) *Cinguloturris carpatica* Dumitrica, ×350; (11) *Podobursa* sp., ×280. Specimens 1 and 2 are from Sample 07-34-8 (Bela Reka), specimens 3–5 from Sample 07-36-1 (Ripanj), and specimens 6–11 from Sample 07-34-5 (Bela Reka).

*Podobursa spinosa*). Consequently, the age of the sample in question can be determined as corresponding to the middle Oxfordian–early Tithonian.

Radiolarians identified in Sample 07-34-5 (Plate II) from the same outcrop are *Cinguloturris carpatica* Dumitrica, *C.* sp. cf. *C. cylindra* Kemkin et Rudenko, *Transhsuum* sp. ex gr. *T. brevicostatum* Ozvoldova, *Mirifusus dianae* (Karrer), *Podobursa* sp., and *Spongocapsula* sp. The distribution range of *Cinguloturris carpatica* extends from the upper Bathonian–lower Callovian (Zone 7 of unitary assemblages) to upper Kimmeridgian–lower Tithonian (Zone 11 in unitary radiolarian zonation after Baumgartner et al., 1995). *Mirifusus dianae* has a wider stratigraphic range. Zone 11 corresponds to upper distribution limit of *Transhsuum brevicostatum*. *Cinguloturris cylindra* appears only in the middle–upper Tithonian (Zone 12). However, the last taxon is determined in open nomenclature for the poorly preserved radiolarian specimens, and thus the implications of other species are preferable. Accordingly, we can argue for a late Bathonian–early Tithonian age for the considered sample.

### *Section Bela Reka, Minel*

At the Bela Reka locality, outcrops of the designated section are exposed in direct proximity to Minel Factory (44°39′54.16″N; 20°29′13.06″E), where we sampled light red to brown cherts over 10 m in total thickness. The respective block of cherty rocks is the largest one in the Belgrade vicinity mélange, and its rocks retain primary sedimentary fabrics. The sampled cherts are composed of cryptocrystalline chalcedony, radiolarian skeletons, quartz flakes, iron oxides, pyrite, and subordinate jasper lenticules suggesting that the basin of siliceous sedimentation was set far apart from areas of volcanic activity (Pavlović c et al., 1980).

Radiolarians from Sample 07-35-1 (Plate III) are classed with *Transhsuum* sp. cf. *T. brevicostatum* (Ozvoldova), *H.* sp., *Pseudoeucyrtis* sp. cf. *P. reticularis* Matsuoka et Yao, and *Stichomitra (?) tairae* Aita. Among them, only *Stichomitra (?) tairae* is fully identified. The distribution interval of this species ranges from the Callovian up to the Kimmeridgian (Aita, 1987). The stratigraphic ranges of the other taxa are much wider (Baumgartner et al., 1995). Hence, the sampled cherts are of Callovian–Kimmeridgian age.

### *Section Ripanj*

Outcrops of the section in Ripanj village weresampled close to the confluence of the Palanka Creek and Topćiderska Reka (44°39′15.84″N; 20°30′18.22″E). Here in tectonized foliated matrix of mélange, there are set blocks (up to 1 m across) of fine-grained micaceous sandstone and smaller exotic blocks of sandy Aptychus marl, which are widespread in the Ripanj surroundings. The other exotic components of the mélange are spilite blocks (up to 1 m across) and abundant small fragments of red and red-brown cherts. Two samples collected from the section were found to contain radiolarians.

Sample 07-36-1 contains abundant but poorly preserved radiolarians. We managed to determine only two species among them: *Spongocapsula* sp. cf. *S. perampla* (Rust) and *S.* sp. (Plate II). The respective host rock is of the Middle–Late Jurassic age based on the stratigraphic range of *Spongocapsula perampla*, which spans Zones 6–11 of the middle Bathonian–lower Tithonian in the unitary radiolarian zonation (Baumgartner et al., 1995).

Sample 07-36-2 from the same outcrop bears Triassic radiolarians (Plate III) whose assemblage includes *Eptingium* sp. cf. *E. manfredi* Dumitrica, *Pseudostylosphaera coccostyla* (Rust), *P.* sp. cf. *P. longispinosa* Kozur et Mostler, *Spongostylus tricostatus* Kozur, Krainer et Mostler, *S.* sp., *Triassistephanidium laticorne* Dumitrica, and *Triassocampe* sp. In the Mediterranean sections, all these taxa are characteristic of the Middle Triassic. The distribution range of *Pseudostylosphaera coccostyla* corresponds to a stratigraphic interval from the upper Anisian to the lower Ladinian, and this species is known from the Alpine region, Japan, China, and eastern Russia (Nakaseko and Nishimura, 1979; Kozur and Mostler, 1981; Bragin, 1986, 2000; Goričan and Buser, 1990; Feng and Liu, 1993; Kozur et al., 1996). The species *Triassistephanidium laticorne* has been found in the lower Ladinian of Romania and Austria (Dumitrica, 1978; Kozur et al., 1996), and *Spongostylus tricostatus* occurs in the upper Anisian and lower Ladinian of Austria and Slovenia (Goričan and Buser, 1990; Ramovš and Goričan, 1995; Kozur et al., 1996). *Eptingium manfredi* s.l. is known worldwide as species characteristic of the upper Anisian and lower Ladinian (Kozur et al., 1996). Finally, the occurrence of *Pseudostylosphaera longispinosa* is confined to the lower Ladinian in the Alpine region (Kozur and Mostler, 1981; Goričan and Buser, 1990). Hence, we conclude that the sampled rock is of early Ladinian age.

## CONCLUSION

1. The ophiolite mélange of the Avala Gora area includes blocks and smaller fragments of cherty rocks bearing radiolarian assemblages of the Middle Triassic (early Ladinian), Middle–Late Jurassic, and Late Jurassic proper (middle Oxfordian–early Tithonian). We failed to find cherts younger in age than the early Tithonian, and mélange of the study area could therefore have only been formed after the early Tithonian.

2. Based on the composition and age of erratic components, the mélange of the Avala Gora area is comparable with mélanges studied previously in Serbia, in the south of the Vardar zone (Djerić and Vish-

Plate III

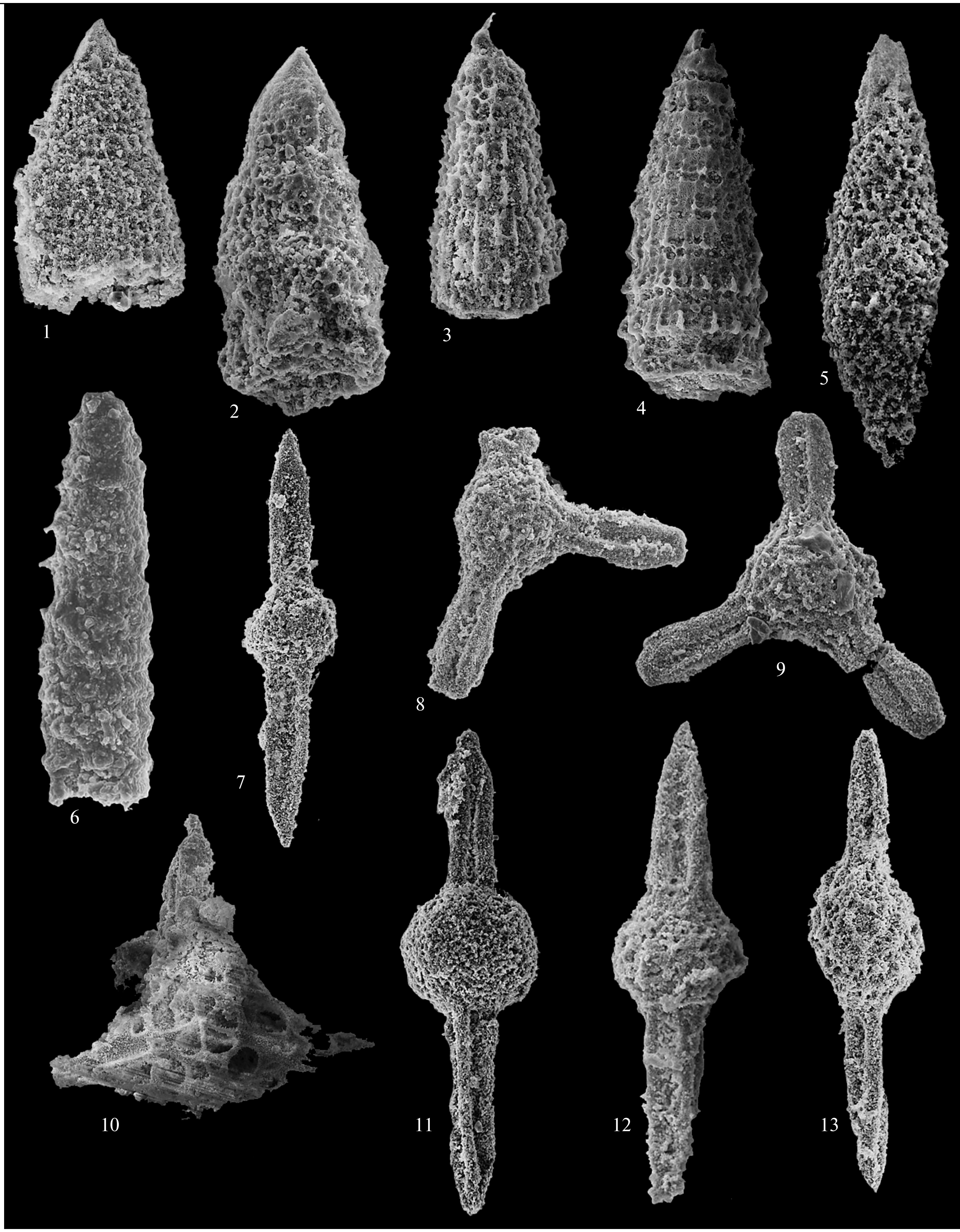

**Plate III.** Middle–Late Jurassic radiolarians from the Bela Reka (Minel) localities and Middle Triassic radiolarians from the Ripanj localities:

(1) *Hsuum* sp., ×300; (2) *Stichomitra (?) tairae* Aita, ×320; (3) *Hsuum* sp., ×260; (4) *Transhsuum* sp. cf. *T. brevicostatum* (Ozvoldova), ×300; (5) *Pseudoeucyrtis* sp. cf. *P. reticularis* Matsuoka et Yao, ×320; (6) *Triassocampe* sp., ×300; (7) *Spongostylus tricostatus* Kozur, Krainer et Mostler, ×180; (8, 9) *Triassistephanidium laticorne* Dumitrica, ×190 (both); (10) *Eptingium* sp. cf. *E. manfredi* Dumitrica, ×180; (11) *Pseudostylosphaera* sp. cf. *P. longispinosa* Kozur et Mostler, ×200; (12) *Spongostylus* sp., ×240; (13) *Pseudostylosphaera coccostyla* (Rust), ×200. Specimens 1–5 are from Sample 07-35-1 (Bela Reka, Minel), specimens 6–12 from Sample 07-36-2 (Ripanj).

nevskaya, 2006; Vishnevskaya et al., 2009). Cherts from the mélanges and ophiolite complexes range in age from middle Triassic to Late Jurassic and were probably deposited in a paleo-oceanic basin closed in the terminal Jurassic time.

3. As, based on their taxonomic composition, radiolarian assemblages from the cherty rocks of the Avala Gora area mélange are typical of the Tethyan Superrealm, they can be confidently dated and correlated. Two species of Middle Triassic radiolarians (*Spongostylus tricostatus* and *Triassistephanidium laticorne*) are recorded in Serbia for the first time, and indicate the occurrence of Triassic cherty rocks in the Belgrade region.

## ACKNOWLEDGMENTS

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