AGE OF THE JURASSIC RADIOLARIAN CHERT FORMATION FROM THE ZLATAR MOUNTAIN (SW SERBIA)

Nevenka Djerić*,✉, Nataša Gerzina* and **Stefan M. Schmid****

* *Faculty of Mining and Geology, University of Belgrade, Kamenička 6, Belgrade, Serbia (e-mail: djeranen@eunet.yu),*
** *Geologisch-Paläontologisches Institut, Basel University, Bernoullistr. 35, 4058 Basel, Switzerland (Stefan.Schmid@unibas.ch).*
✉ *Corresponding author, e-mail: djeranen@eunet.yu*

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ABSTRACT

Detailed micropaleontological research of the Jurassic siliceous rocks in the Pavlovića Brod locality, located on the eastern flanks of the Zlatar Mt. in the Internal Dinarides, adjacent to the Dinaridic Ophiolite Belt, was performed. According to the determined radiolarian associations, the investigated cherts and radiolarites are of Middle Jurassic age. Radiolarian 2-7 UAZ from late Aalenian to early Callovian have been determined for the first time.

INTRODUCTION

Siliceous sedimentary rocks as cherts and radiolarites are widespread in Serbia. They mostly occur in the internal parts of the Dinarides, close to ophiolitic units and/or within ophiolitic mélange formations, less frequently in other geological environments. Maximum accumulation of radiolarian cherts occurred in the Middle to Late Triassic, and in Middle to Late Jurassic, occasionally extending into the Cretaceous.

Such siliceous sediments are best exposed in western Serbia. Within the Serbian part of the internal Dinarides, Triassic as well as Jurassic radiolarians were described for the first time by Goričan (pers. comm. 1988; 1990) and by Obradović and Goričan (1988) and Obradović et al. (1986, 1987/1988). Recent studies on radiolarian cherts in Serbia stressed their importance for solving stratigraphic, paleogeographic, tectonic and paleotectonic questions (Goričan et al., 1999, Karamata et al., 2004, Djerić and Vishnevskaya, 2005, 2006, Vishnevskaya et al., 2006).

Despite the available data, our knowledge of the Mesozoic Radiolaria from Serbia is still insufficient. Particularly scarce are published data regarding Middle Jurassic Radiolaria on which this study concentrates. The information on Middle Jurassic Radiolaria from SW Serbia presented here comes from a section which crops out at the locality "Pavlovića Brod" (Zlatar Mt., SW Serbia at 19°56.5'E longitude, 43°26.0'N latitude, Figs. 1 and 2). While only micropaleontological investigations regarding the Lower and Middle Triassic carbonate deposits, based on micropaleontological examination of thin sections and conodont analysis, have been performed so far at the mentioned locality (Mitrović et al., 1972; Sudar, 1977; 1986), data on the overlying Jurassic radiolarian cherts from this locality are presented for the first time in this paper.

GEOLOGICAL SETTING

In the internal Dinarides in general, radiolarian cherts can be found in 3 different tectonic settings: (1) Jurassic radiolarites as part of the in-situ preserved stratigraphic cover of an ophiolitic sequence which represents obducted ocean floor (Dinaric Ophiolite Belt and/or West Vardar Ophiolite Belt, corresponding to the Mirdita ophiolites of Albania) (2) Radiolarian chert sequences of either Triassic or Jurassic age which are incorporated into a mélange formation underlying the obducted (Dinaric or West Vardar) ophiolites, in the form of gravitationally emplaced olistoliths or "olistoplaka" (Dimitrijević, 1997), or alternatively, as tectonically incorporated slivers scraped off the footwall, i.e. the Adriatic margin (Schmid et al., submitted) and, (3) Jurassic-age radiolarian cherts that are integral part of an in situ passive margin sedimentary sequence preserved at the footwall of the ophiolitic mélange. Radiolarites in settings (2) and (3) were originally deposited onto older carbonaceous platform sediments of the distal Adriatic margin, indicating drowning below the CCD. This drowning either occurred in Triassic times (documented in blocks within ophiolitic mélange only, i.e. Obradović and Goričan, 1988; Goričan et al., 1999) or in Jurassic times within continental margin sequences of the internal Dinarides (also documented outside mélange formations, i.e. in East Bosnian Durmitor Unit, Drina-Ivanjica Unit; Dimitrijević, 1997; 2001).

Radiolarian cherts of Jurassic age, overlying the obducted ophiolites, appear to be preserved in Albania only (Prela et al., 2000; Chiari et al., 1994), due to the unconformable cover of the ophiolites in Bosnia and Serbia with fluvial conglomerates and sandstones (Pogari Formation: Blanchet et al., 1970; Pamić and Hrvatović, 2000) and/or platform carbonates and reefal build-ups after a latest Jurassic erosional event.

The radiolarites described here, found at the locality Pavlovića Brod, in SW Serbia, on the eastern flanks of the Zlatar Mt. area, about 15 km SE of Nova Varoš (Figs. 1 and 2; 19°56.5'E longitude, 43°26.0'N latitude) could in principle be part of an ophiolitic mélange, which structurally underlies the ophiolites of the Dinaric Ophiolite Belt (Karamata et al., 1997), obducted in Late Jurassic times (Pamić et al., 2002). Typically, such mélanges contain Triassic as well as Jurassic radiolarian cherts, occasionally in stratigraphic contact with pillow basalts (i.e. Obradović and Goričan, 1988; Goričan et al., 1999). Alternatively, they could also represent the stratigraphical cover of a carbonate platform sequence of Triassic age, which belongs to the Drina-Ivanjica

Unit, i.e. part of a continental margin formation, which tectonically underlies the ophiolitic mélange. Since modern structural work is lacking in the area, we cannot firmly decide between the latter two possibilities, but at this stage we definitely prefer the hypothesis that the studied chert sequence is part of a drowned carbonate platform, which belongs to the Drina-Ivanjica Unit (referred to as "Golija Zone" by Rampnoux, 1974).

In any case, the contact of these radiolarites with the underlying Triassic carbonate sequences is stratigraphical. Contrary to a widely accepted opinion among Serbian geologists, the 35 m thick association of siliceous rocks (cherts and radiolarites) at Pavlovića Brod (considered a member of the "Zlatar Formation"), does not represent the sedimentary cover of oceanic crust, but rather that of the distal Adriatic margin (Schmid et al., 2006 and submitted), or alternatively, that of an exotic terrane (Drina-Ivanjica terrane of Karamata et al., 2004), irrespective of the question as to whether this sequence is part of an ophiolite-bearing mélange or not.

METHODS

The described radiolarian assemblages come from a single section at Pavlovića Brod (Fig. 1). The section starts with Carnian to Norian biomicrites in Hallstatt-type facies (Sudar, pers. comm. 2006); the older Triassic substratum in the nearby area is characterized by Han Bulog limestones of late Anisian age and other facies types (Sudar, 1977, 1986); The radiolarian cherts stratigraphically overlie a micrite of unknown (possibly Early Jurassic) age.

Ten samples were collected from the radiolarian cherts that stratigraphically overlie the carbonates. Seven samples (for stratigraphic position see Fig. 1) were productive and could be analyzed. Six samples (NĐ 41, NĐ 42, NĐ 43, NĐ 44, NĐ 45, NĐ 47) are pure radiolarian cherts and were only treated with diluted 5-7% hydrofluoric acid, following the method of Pessagno and Newport (1972). Sample NĐ 46 contains some carbonate; it was treated first with acetic and then with HF acids. In all samples Nassellarians are much more abundant than Spumellarians. The residues of the acid treatment, which yielded well preserved faunas, were studied for biostratigraphic purposes. The biostratigraphical zonation was performed according to Baumgartner et al. (1995b).

The SEM LEITZ-AMR-1600T microscope at the ¨Ivan Rakovec¨ Paleontological Institute of RZC SAZU (Ljubljana) was utilized for precise identification and illustration of the radiolarians (see Plates 1 and 2).

SECTION DESCRIPTION AND BIOSTRATIGRAPHY

According to the sedimentological investigation, nine units (packages) could be distinguished (Fig. 1) amongst the siliceous deposits of the Pavlovića Brod section. The radio-

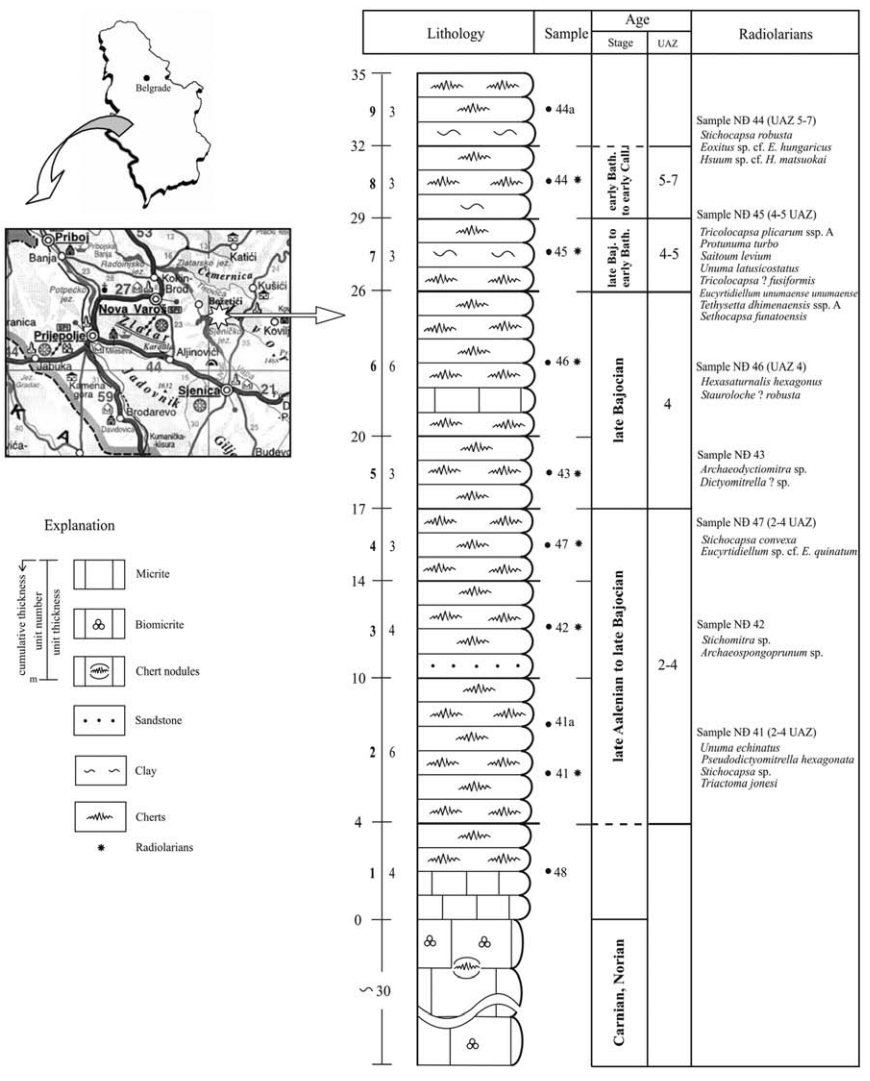

Fig 1 - Location and lithostratigraphic column of the Pavlovića Brod section, showing the principal radiolarian markers; UAZ after Baumgartner et al. (1995b).

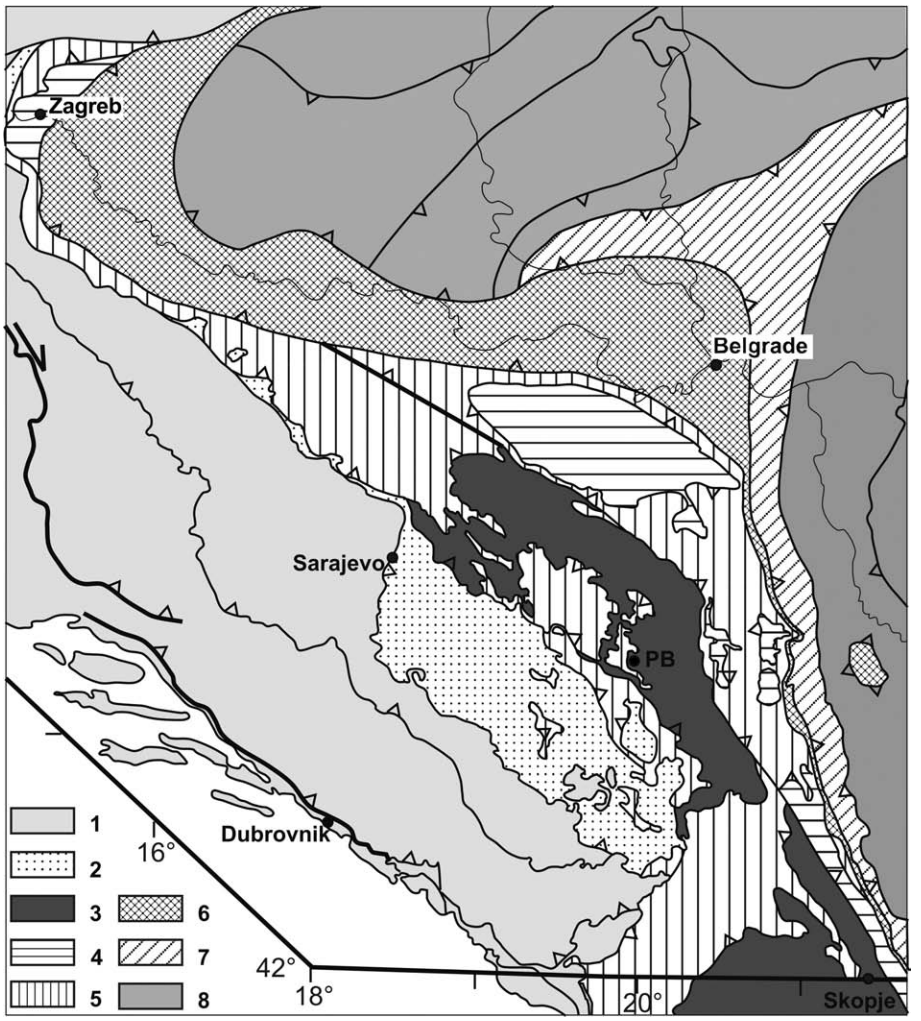

Fig. 2 - Tectonic sketch of the Dinarides (after Schmid et al., 2006), indicating the studied locality. The units mapped are, from external to internal: 1) External Dinarides (without subdivisions); 2) East Bosnian - Durmitor Unit; 3) Drina Ivanjica Unit (parallelized with the Korab Unit of Albania or the Pelagonian Massif of Greece, part of the Internal Dinarides); 4) Jadar and Kopaonik blocks (part of the Internal Dinarides); 5) Dinaric and Western Vardar ophiolites (parallelized with the Mirdita ophiolites of Albania, obducted onto the internal Dinarides in Jurassic times); 6) Sava Belt (Paleogene suture zone); 7) Eastern Vardar Ophiolites; 8) "European" units (Tisza-Dacia and Carpatho-Balkan). PB-Pavlovića Brod.

larian assemblages found in the nine units are the following (Fig. 3):

The **first unit** (4 m thick), composed of red chert with limestone clasts, does not contain a microfauna (sample NĐ 48).

The **second unit** (6 m) contains red thin-bedded cherts that gradually grades into green cherts. A Late Aalenian to Early Callovian age (2-7 UAZ) of the red chert (sample NĐ 41) is confirmed by the presence of *Triactoma jonesi*, *Unuma echinatus* and *Pseudodictyomitrella hexagonata.* According to Beccaro et al. (2002), *Unuma echinatus* is known from the interval 1-7 UAZ. *Pseudodictyomitrella hexagonata* is characteristic of the Aalenian-middle Bajocian (*Lupherium officerense* subzone; Grill and Kozur, 1986). However, this species was also found in the middle Callovian-early Oxfordian (Suzuki and Gawlick, 2003). *Stichocapsa convexa* is characteristic of the 1-11 UAZ (Baumgartner et al., 1995a). The radiolarian association also includes *Ristola* sp. cf. *R. praemirifusus*, *Stichocapsa* sp., *Acaeniotylopsis* ? sp., *Emiluvia* sp., *Paronaella* sp., and *Guexella* ? sp. Considering the stratigraphic position of sample NĐ 41 within the section (Fig 1), the inferred age of this second unit is bracketed between Late Aalenian and late Bajocian (2-4 UAZ).

Sample NĐ 42 was taken from the **third unit** (4 m), made up of dark-gray to black bedded chert, with interlayers of green sandstone. The sample is characterized by a poor and badly preserved radiolarian association. The age of the unit could not be determined because it contains only *Stichomitra* sp. and *Archaeospongoprunum* ? sp.

The uppermost horizons of the **fourth unit** (3 m), consisting of turbiditic greenish-gray chert, contain the next datable sample (NĐ 47). The radiolarian fauna is moderately-well preserved, but relatively diverse. On the basis of the presence of *Stichocapsa convexa an* early-mid Aalenian to early Tithonian age (1-11 UAZ) could be inferred. The following species were also determined from this chert: *Eucyrtidiellum* sp. *Eucyrtidiellum* sp. cf. *E. quinatum*, and *Amphipyndax* ? sp. Considering the stratigraphic position of sample NĐ 47 within the entire section (see Fig 1 and age of the eighth unit discussed below), the age of this unit ranges between Late Aalenian and late Bajocian (2-4 UAZ).

The **fifth unit** (3 m) is made of red, thin-bedded chert. Sample NĐ 43, from which a small number of radiolarians was extracted, was taken from this unit. Due to poor preservation, only two species were determined: *Archaeodictyomitra* sp. and *Dictyomitrella* ? sp. For this reason, a precise age determination is rather difficult.

Turbiditic greenish-gray chert, with interlayers of limestone, constitutes the **sixth unit** (6 m). Radiolarians are poorly preserved. According to the presence of *Hexasaturnalis hexagonus* (1-4 UAZ) and *Staurolonche* ? *robusta* (4-10 UAZ), this unit is of late Bajocian age (UAZ 4) (sample NĐ 46). The species determined as *Trillus* sp., and *Parahsuum* ? sp. are also present in the radiolarian association.

The **seventh unit** is made of 3 m thick red chert. Sample

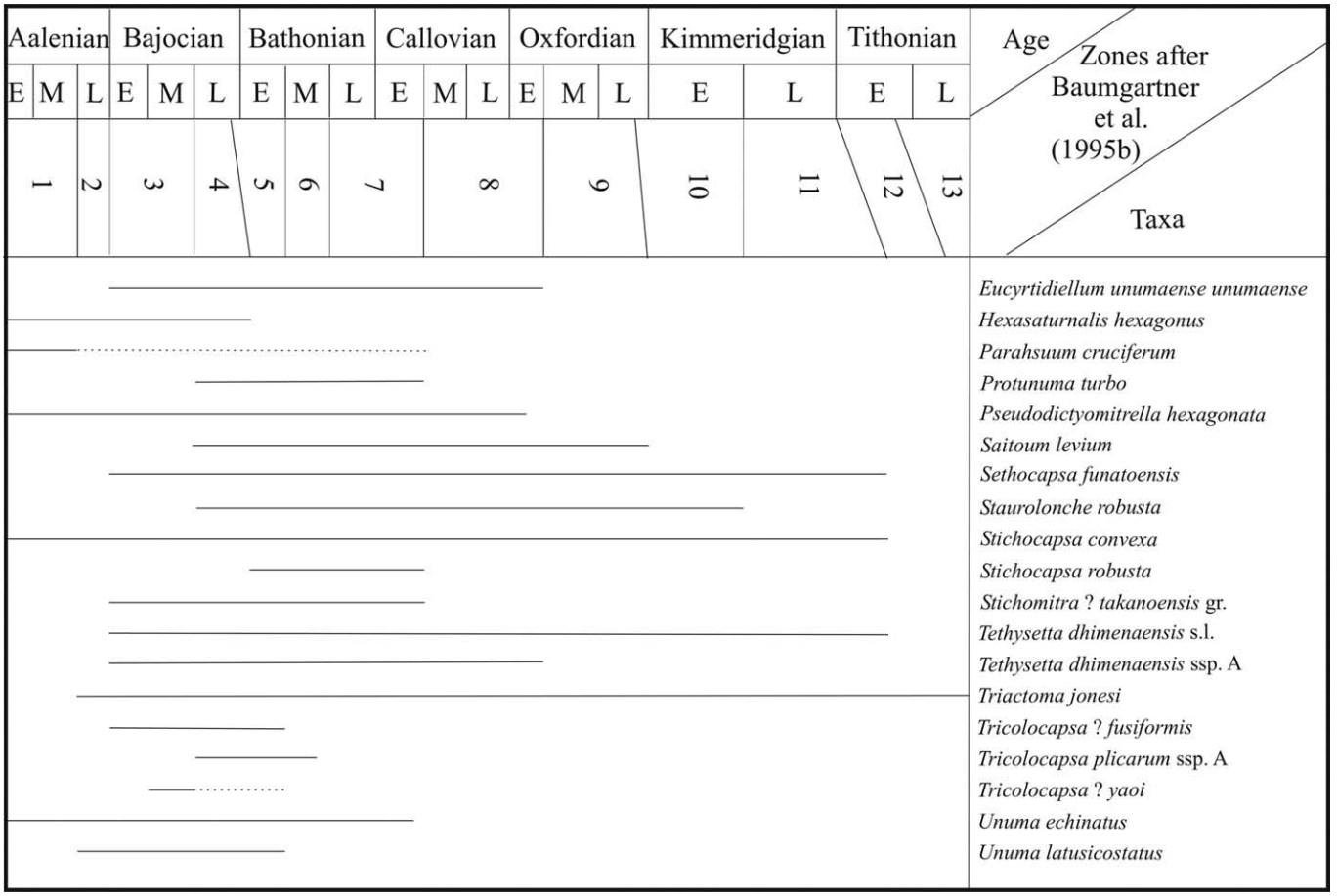

Fig. 3 Stratigraphic ranges of selected taxa from Pavlovića Brod. Dotted lines show supposed stratigraphic ranges of taxa. See text for discussion of the age ranges.

NĐ 45 was taken from the uppermost layers of this unit. It contains many and diverse radiolarians. Associations UAZ 4 and 5 were determined by the presence of *Tricolocapsa plicarum* ssp. A (4-6 UAZ, Prela et al., 2000), *Protunuma turbo* (4-7 UAZ), *Unuma latusicostatus* (2-5 UAZ), *Tricolocapsa ? fusiformis* (3-5 UAZ) and *Saitoum levium* (4-9 UAZ). The association of radiolarians also contains the following species: *Transhsuum* sp. cf. *T. maxwelli* gr., *Transhsuum* sp. cf. *T. brevicostatum* gr., *Tethysetta dhimenaensis* s.l., *Tethysetta dhimenaensis* ssp. A, *Stichomitra ? takanoensis* gr, *Stichomitra* sp. cf. *S. tairai*, *Tricolocapsa* sp. cf. *T. formosa*, *Eucyrtidiellum unumaense unumaense*, *Stichocapsa* sp. cf. *S. japonica*, *Sethocapsa funatoensis*, *Sethocapsa* sp., *Hsuum* sp., *Pantanellium* sp. cf. *P. riedeli*, *Williriedellum* sp. cf. *W. carpathicum*, *Protunuma* sp. cf. *P. lanosus* and *Tricolocapsa ? yaoi*. The age of this assemblage, according to the existing literature (Baumgartner et al., 1995a,b), is Late Bajocian to early Bathonian.

The **eighth unit** (3 m) contains reddish, thin-bedded chert with clayey interlayers (sample NĐ 44). Radiolarians are abundant, relatively well-preserved, and diverse. A latest Bajocian to early Callovian age (5-7 UAZ) was determined for this unit on the basis of the presence of the species *Stichocapsa robusta*. The following species were also identified from the radiolarian association: *Eoxitus* sp. cf. *E. hungaricus*, *Hsuum* sp. cf. *H. matsuokai*, *Parahsuum cruciferum*, *Dictyomitrella* sp., and *Xitus* sp.

The uppermost, **ninth unit** (3 m) , made of red chert with clayey interlayers, does not contain any fauna (sample NĐ 44a).

CONCLUSIONS AND DISCUSSION

Siliceous deposits from the Pavlovića Brod locality consist of radiolarian cherts with clayey and limestone interlayers. On the basis of radiolarians determinations the analyzed cherts were deposited between Late Aalenian and early Callovian. The radiolarian assemblages of our study area, and from Serbia in general, indicate clear Tethyan affinities and can be correlated with radiolarian Zones 2-7 of the Tethys (Baumgartner et al., 1995b).

The radiolarian assemblages constrain the age of drowning of the carbonate platform of the Inner Dinarides (or alternatively, the Drina-Ivanjica terrane according to the scheme of Karamata et al., 1997) to the earliest Middle Jurassic (Aalenian). At this same time drowning is also observed elsewhere in the carbonate platform of the Internal Dinarides, such as, for example, at two nearby localities which are part of the East Bosnian-Durmitor Unit: Zaboj (8 km south of Sjenica, Djerić and Vishnevskaya, 2006) and Krš Gradac (5 km NW of Sjenica, East Bosnian-Durmitor Unit, Rampnoux, 1974, Djerić, 2002). The duration of the radiolarian cherts deposition is longer (Aalenian to early Callovian) than that observed at the Zaboj locality (Aalenian-Bajocian), but shorter than that observed at the Krš Gradac locality (Bajocian to early Tithonian). Radiolarite deposition was followed by overthrusting of the ophiolitic mélange, related to obduction of the Dinaric ophiolites in latest Jurassic to earliest Cretaceous times.

Drowning of the distal Adriatic margin below the CCD postdates the Triassic ocean floor formation in the

Neotethys realm (Meliata and/or Maliac Ocean), only recorded within blocks that were incorporated into the ophiolitic mélange during obduction (Obradović and Goričan, 1988; Goričan et al., 1999). Interestingly, this drowning coincides with the onset of intraoceanic subduction within the Jurassic parts of Neotethys, which led to formation of the metamorphic sole yielding radiometric ages between 174 and 157 Ma (Dimo-Lahitte et al., 2001). Radiolarite deposition was followed by obduction of the Jurassic Dinaric ophiolites. Final obduction onto the Adriatic margin, however, did not start until latest Jurassic times, judging from the age-range of radiolarite deposition (Tithonian, Djerić, 2002) at the nearby Krš Gradac locality.

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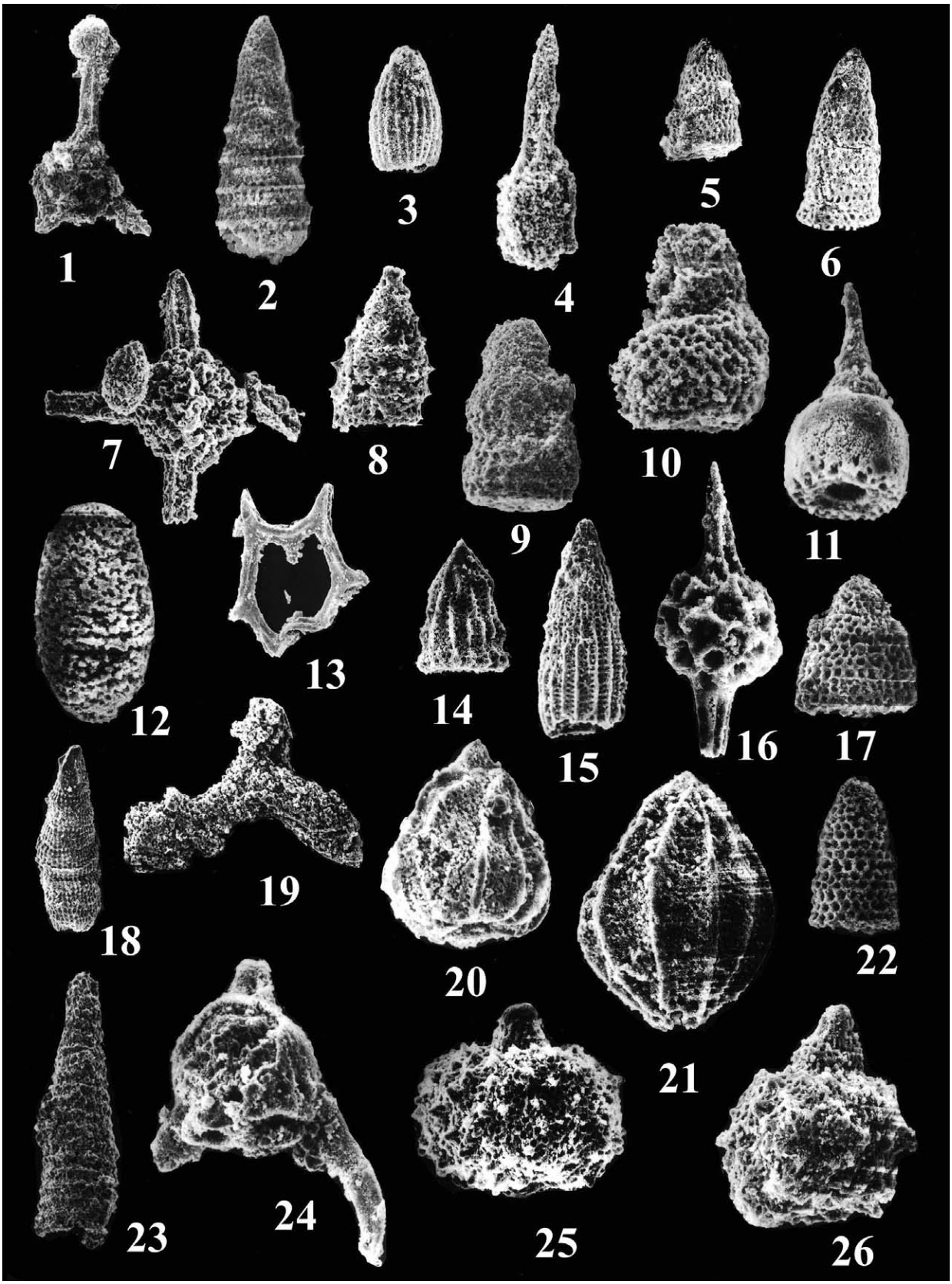

Plate 1 - 1. *Acaeniotylopsis* ? sp., NĐ 41, x100; 2. *Amphipyndax* ? sp., NĐ 47, x200; 3. *Archaeodictyomitra* sp., NĐ 43, x200; 4. *Archaeospongoprunum* ? sp., NĐ 42, x200; 5. *Dictyomitrella* ? sp., NĐ 43, x 200; 6. *Dictyomitrella* sp., NĐ 44, x 100; 7. *Emiluvia* sp., NĐ 41, x100; 8. *Eoxitus* sp. cf. *E. hungaricus Kozur*, NĐ 44, x300; 9. *Eucyrtidiellum* sp., NĐ 47, x200; 10. *Eucyrtidiellum* sp. cf. *E. quinatum Takemura*, NĐ 47, x200; 11. *Eucyrtidiellum unumaense unumaense* (Yao), NĐ 45, x300; 12. *Guexella* ? sp., NĐ 41, x150; 13. *Hexasaturnalis hexagonus* (Yao), NĐ 46, x300; 14. *Hsuum* sp., NĐ 46, x200; 15. *Hsuum* sp. cf. *H. matsuokai* Isozaki and Matsuda, NĐ 44, x150; 16. *Pantanellium* sp. cf. *P. riedeli Pessagno*, NĐ 45, x300; 17. *Parahsuum* ? sp., NĐ 46, x300; 18. *Parahsuum cruciferum* Takemura, NĐ 44, x100; 19. *Paronaella* sp., NĐ 41, x100; 20. *Protunuma* sp. cf. *P. lanosus* Oš voldova, NĐ 45, x300; 21. *Protunuma turbo* Matsuoka, NĐ 45, x300; 22. *Pseudodictyomitrella hexagonata* (Heitzer), NĐ 41, x200; 23. *Ristola* sp. cf. *R. praemirifusus* Baumgartner and Bartolini, NĐ 41, x100; 24. *Saitoum levium* De Wever, NĐ 45, x300; 25. *Sethocapsa* sp., NĐ 45, x300; 26. *Sethocapasa funatoensis* Aita, NĐ 45, x300.

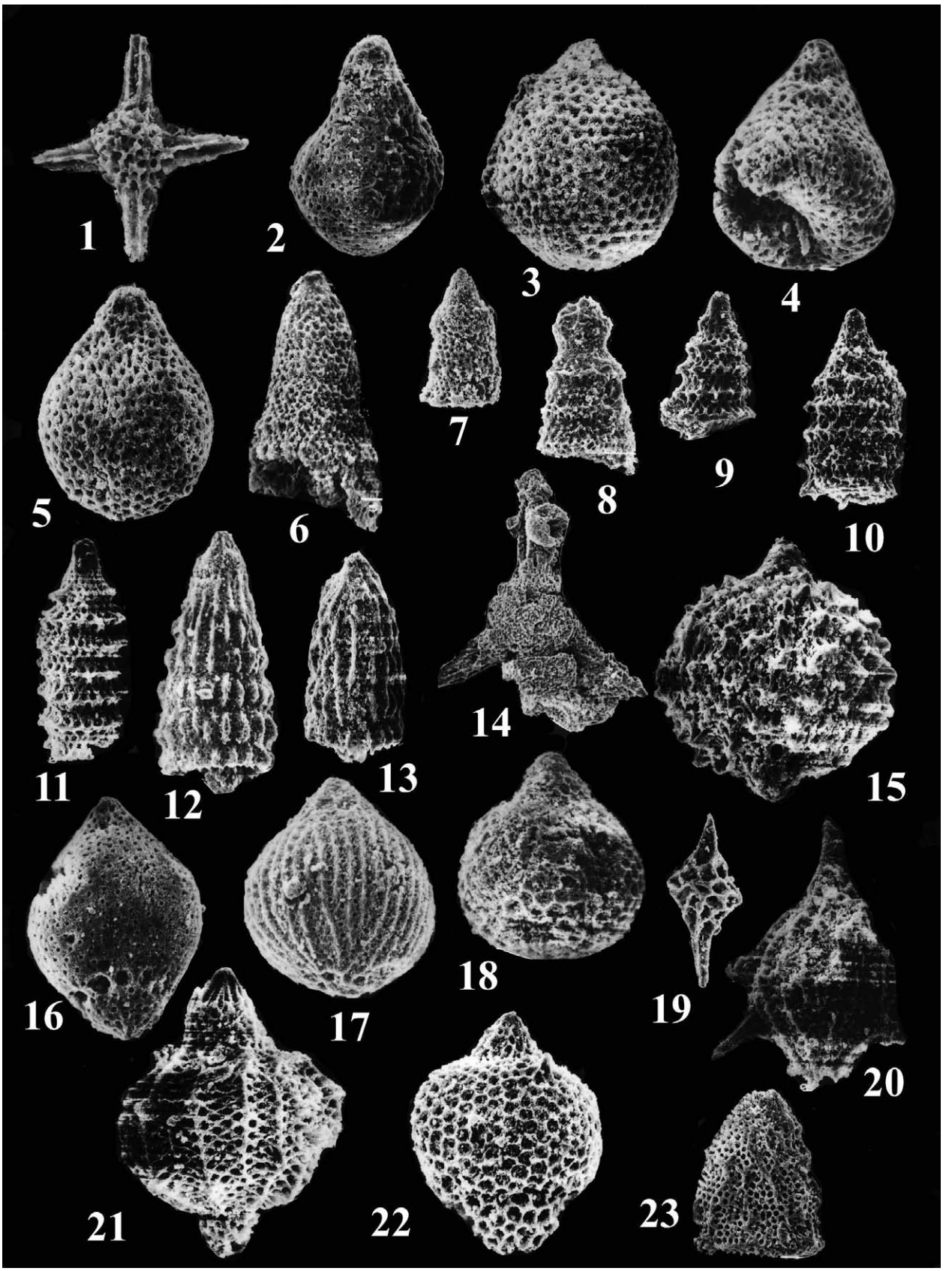

Plate 2 - 1. *Stauroloche* ? *robusta* Rüst, NĐ 46, x300; 2. *Stichocapsa convexa* Yao, NĐ 47 x 300; 3. *Stichocapsa* sp., NĐ 41, x 300; 4. *Stichocapsa* sp. cf. *S. japonica* Yao, NĐ 45, x300; 5. *Stichocapsa robusta* Matsuoka, NĐ 44, x300; 6. *Stichomitra* sp., NĐ 42, x200; 7. *Stichomitra* sp. cf. *S. tairai* Aita, x200; 8. *Stichomitra* ? *takanoensis* gr. Aita, NĐ 45, x200; 9., 10. *Tethysetta dhimenaensis* s.l. (Baumgartner), NĐ 45, x200; 11. *Tethysetta dhimenaensis* ssp. A (Baumgartner et al.), NĐ 45, x200; 12. *Transhsuum* sp. cf. *T. brevicostatum* gr. (Ošvoldova), NĐ 45, x200; 13. *Transhsuum* sp. cf. *T. maxwelli* gr. (Pessagno), NĐ 45, x200; 14. *Triactoma jonesi* (Pessagno), NĐ 41, x100; 15. *Tricolocapsa* sp. cf. *T. formosa* Chiari, Marcucci and Prela, NĐ 45, x300; 16. *Tricolocapsa* ? *fusiformis* Yao, NĐ 45, x300; 17. *Tricolocapsa plicarum* ssp. A Baumgartner et al., NĐ 45, x300; 18. *Tricolocapsa* ? *yaoi* (Kozur), NĐ 45, x300; 19. *Trillus* sp., NĐ 46, x200; 20. *Unuma echinatus* Ichikawa et Yao, NĐ 41, x100; 21. *Unuma latusicostatus* (Aita), NĐ 45, x300; 22. *Williriedellum* sp. cf. *W. carpathicum* Dumitrica, NĐ 45, x270; 23. *Xitus* sp., NĐ 44, x200.