NEW RECORD OF MIDDLE JURASSIC RADIOLARIANS AND EVIDENCE OF NEOTETHYAN DYNAMICS DOCUMENTED IN A MÉLANGE FROM THE CENTRAL DINARIDIC OPHIOLITE BELT (CDOB, NE BOSNIA AND HERZEGOVINA)

Branimir Šegvić*,✉, **Duje Kukoč****, **Ivan Dragičević*****, **Alan Vranjković*****, **Vlatko Brčić**°, **Špela Goričan****, **Elvir Babajić**°° and **Hazim Hrvatović**°°°

* *Section des Sciences de la Terre et de l'Environnement, Université de Genève, Switzerland.*
** *Paleontološki Inštitut Ivana Rakovca ZRC SAZU, Ljubljana, Slovenia.*
*** *Faculty of Mining, Geology and Petroleum Engineering, University of Zagreb, Croatia.*
° *Croatian Geological Survey, Zagreb, Croatia.*
°° *Faculty of Mining, Geology and Civil Engineering, University of Tuzla, Bosnia and Herzegovina.*
°°° *Geological Survey of Federation of Bosnia and Herzegovina, Sarajevo-Ilidža, Bosnia and Herzegovina.*
✉ *Corresponding author email: branimir.segvic@unige.ch*

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ABSTRACT

Within the ophiolitic mélange of the Central Dinaridic Ophiolitic Belt (CDOB) that stretches throughout the Balkans region in SE Europe, a latest Bajocian-early Bathonian radiolarian assemblage was obtained from chert-rich shaly to silty matrix. The sampling locality in northern Bosnia and Herzegovina is characterized by a highly-diversified ophiolitic suite, consisting of basic and ultrabasic rocks of different geotectonic provenances. This makes the radiolarian dating a convenient complementary tool for studying the geodynamic history of CDOB within a broader regional context. The host sediments and the nature of their associated crystalline rocks suggest that radiolarian deposition occurred relatively close to the Adria shelf margins, predating or being contemporaneous to the rapid transitions in the Dinaridic Neotethys geotectonic setting, changing from active ridge magmatism to an intraoceanic subduction environment and island-arc volcanism. The minimum age of ophiolite mélange formation is defined by the mineral equilibration ages in metamorphic sole (161±4 Ma), with the obduction tectonics that must have lasted at least until the Oxfordian time (i.e. termination of MOR activity in the Dinarides). This age correlates well with the ages of sediments reported elsewhere in the mélange of the Dinaride-Hellenide orogenic system.

INTRODUCTION

The Jurassic ophiolites found in narrow zones of the Dinarides are part of the Alpine-Himalayan-Tethyan orogenic belt and are characterised by two belts of ophiolites: (1) the Central Dinaridic Ophiolite Belt (CDOB) in the west, and (2) the Vardar Zone (VZ) in the east (Fig. 1). These can be continuously traced to the south into Albania, Macedonia and Greece. Both belts are primarily composed of ophiolitic mélange with ophiolitic blocks and various genetically-related sedimentary rocks (e.g., Dimitrijević et al., 2003). Previously believed that such defined ophiolite domains stood for two discrete Neotethyan oceanic branches (e.g., Spray et al., 1984; Smith and Spray, 1984; Lugović et al., 1991; Robertson et al., 2013), the approaches nowadays advocate the origin of Dinaridic ophiolites from the very same palaeogeographic oceanic branch of Neotethys with a mechanism of westwards sheet thrusting that conditioned their current, klippe-like, structural position within the Dinaride-Hellenide nappe stack (e.g., Çollaku et al., 1992; Pamić et al., 1998; Gawlick et al., 2008; Schmid et al., 2008; Ustaszewski et al., 2010).

Starting in the Middle or late Early Jurassic, the oceanic realm partly preserved in CDOB and VZ experienced an intraoceanic subduction, resulted from the latest Mesozoic to Cenozoic SW-vergent tectonics, following the collision between Adria and Europe-derived units. The initiation of convergence gave rise to incipient intraoceanic subduction and metamorphism at the ophiolite base (e.g., Operta et al., 2003; Karamata, 2006; Šegvić, 2010). Impelled by the former, a system of intraoceanic trenches formed, being progressively filled by gravitational emplacements of chaotic material from the upper plate (radiolarite-ophiolite slide blocks with clayey to sandy matrix) and clastic fragments emanated from the footwall. Due to the constant shortening, tectonically overprinted allochthonous material is reworked into the accretionary prisms, thus defining a widely accepted mechanism of mélange formation in the Dinaride-Hellenide orogeny (e.g., Gawlick et al., 2008; 2009; Bortolotti et al., 1996; 2004). Ultimately, the deposition of ophiolitic mélange evolved with the onward obduction processes of the oceanic lithosphere, with a composite thrust sheets system being created, whereby the mélange is positioned in the footwall of the main ultramafic mass of CDOB (e.g., Pamić et al., 2002; general SW-NE profile in Fig. 2, Dragičević, 1987). Still, the exact way of the Middle Jurassic mélange formation in the Dinarides is poorly known, especially in regard to the provenance of its components and the geotectonic constraints inferred thereof (e.g., Gawlick et al., 2009). Detailed case studies focusing on the age and the composition of the CDOB mélange are thus necessary to complement existing efforts done elsewhere in the Dinarides-Hellenides, shaping a larger picture on the palaeogeography of mélange formation. Biostratigraphic data exist from the ophiolitic mélange in Croatia (Halamić et al. 1999), Serbia (Gawlick et al. 2009; Chiari et al. 2011), Albania (Mirdita Zone, e.g. Kellici et al. 1994; Marcucci et al. 1994; Chiari et al. 2004; Gawlick et al. 2008), and Greece (Danelian and Robertson 2001; Bortolotti et al. 2008; Nirta et al. 2010;

Fig. 1 - Schematic geotectonic map of SE Europe, showing the streaching of the Alpine ophiolite complexes throughout the Balkans. Location of sampling indicated by rectangle. Map modified after Robertson (2002).

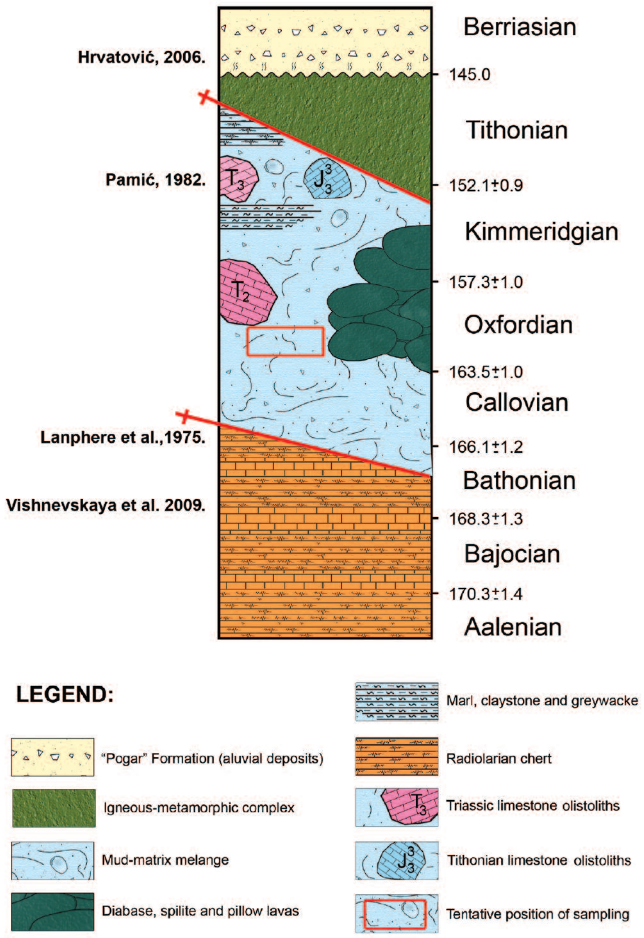

Fig. 2 - Composite stratigraphic section of the Papratnica section. Sampling position indicated within the sequence. Constructed after basic geological map of Yugoslavia, sheet Vareš (Pamić, 1970). Time scale after Gradstein et al. 2012.

Chiari et al. 2012). All obtained ages are coherent, yielding a Middle Jurassic age of mélange. So far, Middle Jurassic radiolarians in the Bosnian part of CDOB were described only from non-ophiolitic sequences (Vishnevskaya et al., 2009). In this paper, new evidence is presented on the age of Jurassic radiolarian chert recovered from the mélange of the biggest ophiolite complex in the central CDOB, the Krivaja-Konjuh Ophiolite Complex (KKOC, NE Bosnia and Herzegovina), in which diverse oceanic rock suites testify to the different stages of ocean evolution (Pamić et al., 1977; Lugović et al., 1991; 2006; Babajić, 2009; Šegvić, 2010). Obtained radiolarian ages along with the mélange composition and isotopic ages of its crystalline components are discussed in terms of their significance for the Jurassic Neotethyan evolution in its Dinaridic segment.

GEOLOGICAL SETTING

The Krivaja-Konjuh Ophiolite Complex (of about 650 km^2 in northern Bosnia and Herzegovina (Fig. 1, Pamić and Hrvatović, 2000). The two KKOC structural subunits - Krivaja, the western subunit consisting of amalgamated peridotite blocks, and Konjuh, the eastern coherent peridotite synform - are thrust onto the ophiolitic mélange and overstepped by the Cretaceous basinal Pogari Formation (Pamić, 1970; Hrvatović, 2006). Ophiolite mélange forms the largest part of the KKOC (Fig. 3). It presents a chaotic tectono-sedimentary mixture made up of detached ‘pocket’ to ‘mountain’-size blocks and boulders of oceanic crust rocks along with Palaeozoic to Jurassic carbonates and clastics (Tari, 2002). More precisely, the lithology of the mélange comprises a sheared pelitic to silty matrix in which greywacke fragments predominate over basalt and tuff, diabase, gabbro, serpentinized peridotite with metamorphic rocks, shale, radiolarite, and exotic blocks of recrystallized pseudo-oolitic and nodular Middle to Late Triassic to Late Jurassic (Tithonian) limestones and dolomite limestones (Pamić, 1968; 1982, Fig. 2). Poorly preserved microfossils of Jurassic foraminifera (*Vidalina martana, Glomospira* sp., *Cristellaria* sp.) are reported extremely rarely in micrites interlayered with shale and greywacke (Pamić and Hrvatović, 2000). This roughly defines the Jurassic age of the KKOC (Pamić and Hrvatović, 2000). The K-Ar isotopic ages of 174-157 Ma from amphiboles separated from the metamorphic base favour the latter (Lanphere et al., 1975; Majer et al., 1979). Breccias and conglomerates of the overstepping Cretaceous succession contain ophiolitic fragments and, thus constrain the youngest possible age of the Bosnian CDOB mélange (Fig. 3, Jovanović et al., 1978, Pamić and Hrvatović, 2000; Hrvatović, 2006, and references therein).

The ophiolite mélange was studied and sampled in the vicinity of the village Papratnica and the homonymous creek located east of Žepče in northern Bosnia and Herzegovina (locality no. 1 in Fig. 3, GPS coordinates N 44°25’1.95’’ E 17°59’0.39’’). The sampling area presents the NW peak segment of the KKOC, which is detached from the main ophiolite mass. The Papratnica mélange deposits were selected for sampling because they comprise carbonate blocks and pillow lavas, hence being roughly correlated to the olistostrome part of the CDOB ophiolitic mélange (Pamić, 1968). In stratigraphical sense, the base of Papratnica section commences with tens of metres thick, highly altered bodies of pillow lavas, having no direct contact with radiolarian cherts (Fig. 2). Apparently, the former are continuously overlain by the greenish-black to reddish-black sheared shales intercalated with mudstones, siltites, and sandstones. The section ends with a several metres wide carbonate block (Fig. 4b). The nearly 100 m thick Papratnica mélange succession holds numerous clast horizons containing radiolarian chert, one of which was logged and sampled at the second metre of the section. This outcrop sampled for radiolarians is approximately 4 m thick and consists of layered dark grey fine-grained shales with embedded chert blocks (Fig. 4a). The proportion of pelitic interlayers is relatively high, accounting for approximately 30% of the

Fig. 3 - Detailed geological map of the sampling area within the western portion of the Krivaja-Konjuh ophiolite complex (KKOC). 1- sampling location, this work; 2- sampling location of the non-ophiolitic chert succession described in Vishnevskaya et al. (2009). Map modified after Jovanović et al. (1978), Pamić (1970), and Dragičević (1987).

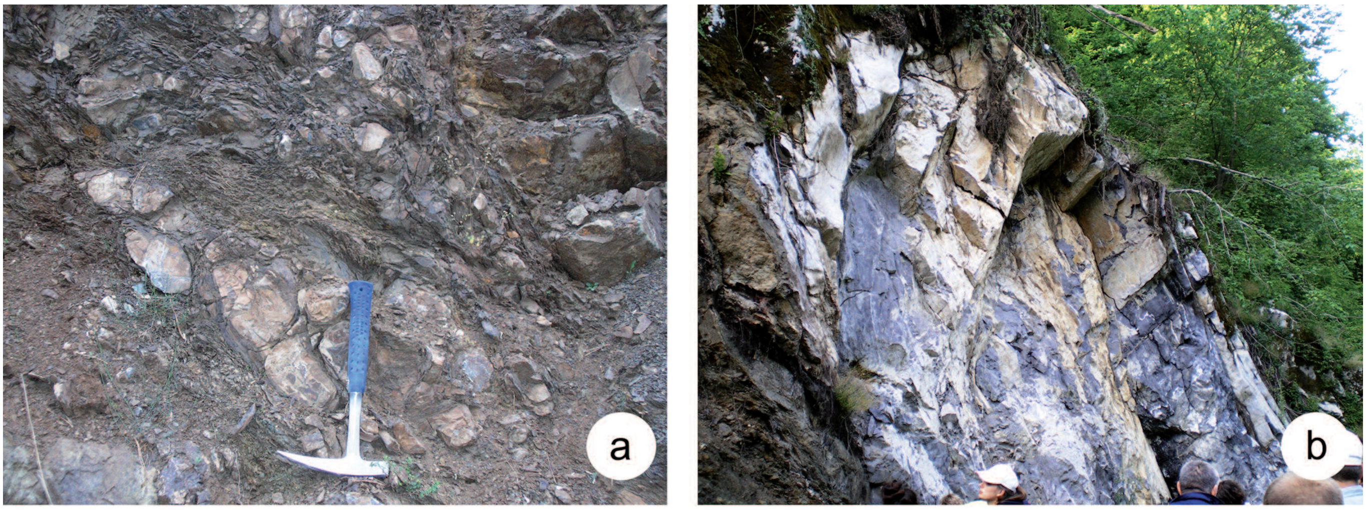

Fig. 4 - a) layered dark grey fine-grained shales with embedded chert blocks; b) the large limestone olistolith that tops the Papratnica section.

sampled section. The succession is pervasively sheared and, as a result of shearing, the siliceous-shaly beds are disrupted, boudinaged, and some of them brecciated. Due to the complex and chaotic nature of mélange, it was not possible to log a complete Papratnica section, which means that the position of studied radiolarians within the mélange column is approximate (Fig. 2).

The black and vitreous subangular to rounded chert clasts vary from 2 to 10 cm in diameter, whereas in some other levels of the Papratnica section they are up to 20 cm in diameter. Thin-section analyses showed that the sampled clasts consist of angular chert fragments (0.5-2 cm) that are imbedded in the cryptocrystalline siliceous matrix. Both the former and the latter contain circular or elliptical areas (ca. 0.05 mm in diameter) filled with microcrystalline quartz. These areas represent complete and nicely preserved radiolarian skeletons. The rock itself is determined as autoclastic radiolarian-chert microbreccia (cf. Kolodny et al., 2005, and references therein). The texture of microbreccia is clast-supported with a medium packing density, whilst the matrix presents a loosely-packed packstone. Such biosiliceous sediments originated from the radiolarian skeleton deposition that characterised large portions of the deep Jurassic Tethys, both in its continental margin and ocean floor settings (e.g., Aiello et al., 2008). No index fossils are reported from the background fine-clastic sedimentary rocks and, therefore, the general Jurassic age of the mélange is inferred based on stratigraphically uncharacteristic microfossils found in platy limestones that are interlayering with shales (Pamić et al., 2002). Thin section analyses of the large limestone olistolith topping the Papratnica section (Figs. 2, 4b) revealed a structureless micrite devoid of any recognizable carbonate grains. Based on previous studies of carbonate olistoliths in a wider area (Pamić, 1968; Pamić et al., 1979), we presume that the block is Triassic in age.

RADIOLARIAN DATING

A well-preserved radiolarian assemblage was extracted from a chert sample. The sample was treated with diluted (5%) hydrofluoric acid. The identified radiolarians are listed in Table 1 and illustrated in Plate 1. The assemblage was dated according to the Unitary Association Zones (UAZ) established by Baumgartner et al. (1995b). The genera designations follow the revision in the Catalogue of Mesozoic radiolarian genera (O'Dogherty et al., 2009).

The radiolarians are characteristic of the uppermost Bajocian-lower Bathonian UAZ 5 of Baumgartner et al. (1995b). This assignment is based on the co-occurrence of *Unuma latusicostatus* (Aita), last appearing in UAZ 5, and *Eucyrtidiellum semifactum* Nagai and Mizutani first appearing in UAZ 5. Another species that, according to Baumgartner et al. (1995b), suggests the upper age limit in UAZ 5 is *Striatojaponocapsa synconexa* O'Dogherty, Goričan and Dumitrica (it was *Tricolocapsa plicarum* ssp. A in Baumgartner et al., 1995a). It is now known that *Striatojaponocapsa synconexa* extends at least to UAZ 6-7 (Prela et al., 2000; O'Dogherty et al., 2006). *Eucyrtidiellum unumaense dentatum* Baumgartner has a stratigraphic range from UAZ 6 to UAZ 7, which is in disagreement with the inferred assignment to UAZ 5. We note, however, that the record of this species in the database of Baumgartner et al., (1995b) is scarce. In addition, the closely related *Eucyrtidiellum unumaense pustulatum* Baumgartner, having a comparatively more complex ornamentation, first occurs in UAZ 5. The range of *Eucyrtidiellum unumaense dentatum* is thus likely to be extended to UAZ 5.

COMPARISON WITH PREVIOUSLY REPORTED RADIOLARIAN AGES IN CORRELATIVE OPHIOLITE COMPLEXES

The latest Bajocian-early Bathonian age of the KKOC is consistent with other ages reported from radiolarian-bearing rocks in ophiolite complexes throughout the Dinarides and Hellenides (Fig. 5). In these complexes, Jurassic radiolarites were found in mélange units, as well as in direct stratigraphic contact with basalts. The ophiolitic mélange on Mt. Medvednica (NW Croatia), located north westwards of the KKOC, contains radiolarites dated as latest Bajocian - early Bathonian (UAZ 5) and late Bathonian - early Callovian (UAZ 7) (Halamić et al., 1999). Near Sjenica (SW Serbia), Gawlick et al. (2009) reported a Bathonian to early-middle Callovian age from the radiolarian-rich matrix of the

Table 1 - Occurrence of radiolarian taxa in the analysed sample. The second column gives the zone range of species according to Baumgartner et al. (1995b).

Radiolarians	**UAZ 95**
Archaeodictyomitra rigida Pessagno	-
Archaeodictyomitra suzukii Aita	-
Archaeodictyomitra sp.	-
Canoptum krahsteinense (Suzuki and Gawlick)	-
Dictyomitrella (?) *kamoensis* Mizutani and Kido	3-7
Eoxitus baloghi Kozur	-
Eucyrtidiellum semifactum Nagai and Mizutani	5-7
Eucyrtidiellum unumaense dentatum Baumgartner	6-7
Helvetocapsa matsuokai (Sashida)	-
Hemicryptocapsa marcucciae (Cortese) (= *Williriedellum* sp. A of Baumgartner et al. 1995a)	4-8
Hemicryptocapsa yaoi (Kozur)	-
Paronaella broennimanni Pessagno	4-10
Praewilliriedellum sp. aff. *P. convexum* (Yao)	-
Praewilliriedellum sp. aff. *P. himedaruma* (Aita)	-
Protunuma lanosus Ožvoldova	-
Quarticella sp.	-
Semihsuum amabile (Aita)	4-7
Stichocapsa (?) *magnipora* Chiari, Marcucci and Prela	-
Stichomitra (?) *takanoensis* Aita gr.	3-7
Striatojaponocapsa synconexa O'Dogherty, Goričan and Dumitrica (= *Tricolocapsa plicarum* ssp. A of Baumgartner et al. 1995a)	4-5
Transhsuum brevicostatum (Ožvoldova) gr.	3-11
Transhsuum maxwelli (Pessagno) gr.	3-10
Triactoma (?) sp.	-
Unuma sp.	-
Unuma gordus Hull (= *Unuma* sp. A of Baumgartner et al. 1995a)	4-6
Unuma latusicostatus (Aita)	2-5
Yaocapsa sp. A	-
Age (UAZ 95)	**5**

mélange. The stratigraphic range of *Hemicryptocapsa tetragona* (Matsuoka), found in sample SCG 84 of Gawlick et al. (2009), is confined to UAZ 5 (Baumgartner et al., 1995b) and, therefore, the corrected age of this sample should be latest Bajocian to early Bathonian (UAZ 5). In the Mirdita Zone in Albania, the ophiolitic mélange ranges in age from the late Bajocian - early Bathonian to the Oxfordian; late Bajocian - early Bathonian radiolarian cherts systematically occur at the base of the chaotic mass-flow deposits (Gawlick et al., 2008). In southern Albania, UAZ 5 radiolarian cherts were found on top of polymictic breccia above basalt (see section Lubonja in Chiari et al., 2004). Radiolarites in direct stratigraphic contact with basalts were also found at several localities and were dated as latest Bajocian - early Bathonian (UAZ 5) to late Bathonian - early Callovian (UAZ 7) (Prela et al., 2000; Chiari et al., 2004). Further south, in Greece, radiolarites of latest Bajocian - early Bathonian (UAZ 5) and middle Bathonian (UAZ 6) ages were documented in the ophiolite complexes of the western ophiolite belt Pindos (UAZ 5 in a block preserving the contact between chert and basalt, Nirta et al., 2010), Othrys (UAZ 6 in chert included in the Agoriani Mélange, Bortolotti et al., 2008) and Koziakas (UAZ 6 in a thick boudinaged chert succession without stratigraphic contact with other formations, Chiari et al., 2012). In the Vourinos Massif, radiolarites of latest Bajocian - early Bathonian (UAZ 5) to middle Bathonian (UAZ 6) age were found in direct contact with basalts (Chiari et al., 2003). In our short review (Fig. 5), only radiolarian data that restrict the age to a single UAZ are presented. The published ages from several other localities are more broadly defined but also cluster around UAZs 5 to 7. For a complete review of radiolarian ages in ophiolitic units of Albania and Greece, the reader is referred to a recent compilation available in Bortolotti et al., (2013).

DISCUSSION AND CONCLUSIONS

Biosiliceous sedimentary rocks are widely known in the Dinarides, having originated in different geological settings throughout the Mesozoic (e.g., Vishnevskaya and Djerić, 2009; Vishnevskaya et al., 2009). They mostly appear as radiolarian cherts, both Triassic and Jurassic in age, found as blocks incorporated within the chaotic mélange sequences (e.g., Dimitrijević, 1997), and occasionally forming the interpillow matrix of the ophiolite extrusives (e.g., Halamić et al., 1999). The Jurassic radiolarian chert is also reported from non-ophiolite sequences of passive Adria margins where it stands as the ophiolitic mélange footwall (Vishnevskaya et al., 2009, Fig 2). Biostratigraphy makes an essential tool for revealing the age of sediments and,

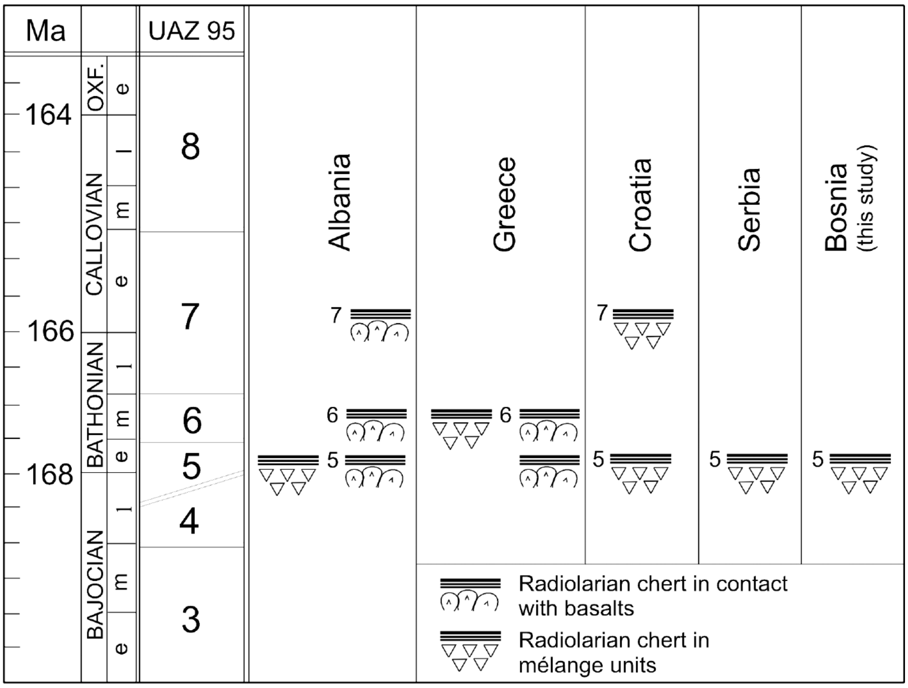

Fig. 5 - Radiolarian age constraints in ophiolite complexes of the Central Dinaridic Ophiolite Belt. Data from the Mirdita Zone, Albania (Chiari et al., 2004), the western ophiolite belt in Greece (Chiari et al., 2003; Bortolotti et al., 2008; Nirta et al., 2010), Croatia (Halamić et al. 1999), Serbia (Gawlick et al. 2009) and Bosnia (this study). Numerical ages are given according to Gradstein et al. (2012). The UAZ 95 column refers to Unitary Association Zones of Baumgartner et al. (1995b).

from this, deriving the age on thrusting events that have led to the ophiolite mélange formation in the footwall of obducted ophiolites. Additionally, a variety of tectono-stratigraphic units is found incorporated in the mélange, originated in different geological periods and settings, thus making mélange a valuable source of information for the ocean evolution reconstruction.

Our data on radiolarians from the CDOB ophiolitic mélange in Bosnia and Herzegovina point to their latest Bajocian to early Bathonian age. Assuming the formation of mélange to be primarily a tectonic event, the reported time span thus documents the likely minimum ages of sedimentation of a siliceous sequence that made up the mélange. In other words, the recovered ages do not necessarily coincide with the exact timing of the mélange formation. A somewhat different line of reasoning is demonstrated by Gawlick et al. (2008), wherein the cherty sediments from an analogue ophiolite mélange in northern Albania are considered to represent the matrix of an already disturbed oceanic sequence, thus conveniently marking the age of mélange formation. As of yet, in the Dinarides, geographically the closest dated MOR-affiliated rocks from the ophiolite upper plate that tectonically overlies the analysed mélange are olivine-bearing cumulate gabbros reported from the southern slopes of the Kozara Mountain, located about 50 km westwards from the sampling locality of Papratnica (Fig. 1; Ustaszewski et al., 2009). With the Sm-Nd age of approx. 158±7.6 Ma, these gabbros stand for the youngest possible age of sea-floor spreading in this segment of the Neotethys. The latter thus effectively precludes the possibility that the mélange formation was completed by mid-Jurassic times, but suggests it must have continued until after the MOR-type crust has ceased to generate which, given the possible analytical errors, might have lasted even until the Oxfordian-Kimmeridgian boundary. This stage was eventually completed with the main branch of the Dinaridic Neotethyan closure by the earliest Cretaceous at latest (Pamić et al., 2002), where only a few marginal back-arc basins remained opened thereafter (e.g., the Kozara basin, Ustaszewski et al., 2009; Repno Oceanic Domain, Šegvić et al., in review). The age of MOR-type gabbros further corresponds to the K-Ar metamorphic ages of sub-ophiolitic soles recovered from the Krivaja-Konjuh ophiolite complex (161±4 Ma; Lanphere et al., 1975) and the nearby Borja ophiolite complex (Fig. 1, 171.4±3.7 Ma; Lugović et al., 2006), suggesting that the late ridge magmatism in the Dinaridic Neotethys was complemented by the near-ridge sole metamorphism, giving birth to the initial intraoceanic thrusting (e.g., Operta et al., 2003; Šegvić, 2010). Moreover, the established sole age denotes the earliest possible inception of the mélange formation through the infill of the newly formed subduction trenches by gravitation that derived hangingwall material. In the Papratnica mélange, fragments of metamorphic rocks are associated with mafic and ultramafic slide blocks that occur higher in the succession than the cherty sequence sampled for radiolarians (Fig. 2, Pamić, 1968). Another piece of evidence sheds light on the rapid evolution of the marginal Dinaridic Neotethys and the coeval mélange formation. The pillow basalts containing radiolarian chert cropping out near the Ograjina River, situated a few kilometres away from the studied section, are proven to be of island-arc tholeiite (IAT) affinity (Simat, 2010). Analogue geochemistry is reported from the rest of the pillow basalts cropping out in the KKOC, and their origin is linked to advanced subduction processes and mantle wedge metasomatism, giving rise to IAT magmatism at ophiolite upper plate (Babajić, 2009). Given a subduction angle of 30° and an average subduction velocity of 5 cm *per annum* (for comparison the subduction of large Pacific plate is the fastest recent analogue, being subducted at the rate of 10 cm *per annum*, Dewey, 1981) will require approx. 3-4 Ma for the subducted material to attain a 110 km depth, given that most of the arc volcanism generates at this distance from the Benioff Zone (Murphy, 2006). In addition, the contribution from the subducted slab to island-arc lava sources appear to occur approximately 5 Ma prior to eruption (Turner, 2002), therefore making it no less than 10 Ma from the onset of intraoceanic subduction (i.e. subophiolitic sole formation) to the first appearance of IAT lavas. The latter would also mean that the formation of ophiolitic mélange in the Dinarides lasted at a minimum 10 Ma, encompassing both the primary sedimentation and the tectonic incorporation of the broad-provenanced olistoliths blocks.

A large grey carbonate olistolith, recognised in the Papratnica mélange sequence, is by the analogy with the equivalent mapped carbonate blocks defined as Triassic in age (Fig. 2; Pamić, 1968). These limestones are apparently fully recrystallized, however, still featured by the preserved fossil remains that include the brachiopod macrofauna (*Rhynchonella vivida, Rhynchonella* cf. *mentzelli, Spirigera (Stolzenburgiella) bukowskii,* and *Spirigera (Pexidella) munster*), which along with the foraminifers (*Meandrospira dinarica*, *Frondicularia* sp., and *Pilammina densa*) indicate the Anisian pelagic to hemipelagic sedimentation (Pamić, 1968). Such peculiar Triassic components might be comparable to the so-called Hallstatt facies, usually comprising grey cherty limestones that can vary into red-bedded or light-coloured massive limestones known to have been deposited on the distal deeper shelf of the continental margin, being reworked and found in the Jurassic mélange of the Northern Calcareous Alps in Austria (e.g., Mandl, 2000), but also in the contemporary mélange of the Mirdita Zone in northern Albania (Gawlick et al., 2008), and elsewhere along the Middle Jurassic suture zone (Karamata et al., 1980; Robertson et al., 2013). This allows us to suggest that similar depositional conditions might have prevailed along the north-eastern portions of, at the time, the still integral Adriatic microcontinent (platform fragment of Gondwana), enabling the deposition of peculiar greyish Anisian limestones. Frontal to CDOB mélange, a discontinuous radiolarite zone up to 800 m thick is situated, with a radiolarite sequence that covers a large stratigraphic interval from Middle Jurassic to Early Cretaceous (Pamić. 1982). The most complete section, Jezeračka Rijeka (locality no. 2 in Fig. 3), is composed of three lithostratigraphic units - varicoloured radiolarian chert (Bajocian to Oxfordian), red clayey chert and subordinately cherty limestone (Kimmeridgian to early Tithonian), and clayey cherty limestone with calpionellids (Tithonian - Berriasian) (Vishnevskaya and Djerić, 2009; Vishnevskaya et al., 2009). This succession of facies along with local enrichment in sponge spicules is indicative of continental slopes of the passive margin setting (Vishnevskaya et al., 2009). The fact that this sequence does not make part of the neighbouring mélange is in favour of the hypothesis that, most likely, mainly the distal portions of the passive continental Triassic margin of the Adriatic microplate were dismembered and thereupon obliterated during the mélange formation, preserved in mélange in form of exotic limestone blocks of Triassic up to Tithonian age (Pamić, 1982).

Based on the above discussion, the following conclusions can be put forth:

1. The composite and chaotic nature of the material that numbers the fragments of the oceanic lithosphere and the associated sediments recovered from ophiolite mélange of the CDOB (the Papratnica section in KKOC, NE Bosnia and Herzegovina) corroborates recent approaches advocating the mélange formation in the ophiolite footwall wherein the radiolarite-ophiolite sequence originated from the obducted plate, whilst exotic limestone blocks must have provenanced from the Triassic continental margins.
2. he analysed radiolarian assemblage yielded the biostratigraphic age corresponding to the latest Bajocian to early Bathonian, being as such the first record on the age of radiolarians from an ophiolitic mélange sequence from the Bosnian (central) portion of the CDOB.
3. Given the age of MOR-provenanced cumulate gabbros (158±7.6 Ma) from the nearby upper-plate ophiolites of Mt. Kozara, known to be the youngest ocean ridge rocks of this segment of the Neotethys, we infer that the mélange formation process could have lasted even until the Oxfordian-Kimmeridgian boundary (i.e. cessation of ocean spreading). Hence, the reported radiolarian age designates the time of sedimentation that might have preceded or, eventually, it coincided with the mélange formation in this segment of the Dinarides.
4. The age of the metamorphic sole reported from the CDOB mélange blocks (161±4 Ma) overlaps with the crystallisation ages of MOR-affiliated gabbros. This has a two-fold signification: firstly, it denotes a rapid ocean setting transition, from an active ridge spreading to incipient intraoceanic subduction and, secondly, it stands for the earliest possible onset of the mélange formation in the Dinarides.
5. IAT pillow basalts are also known from the mélange and, referring to the beginning of intraoceanic subduction (i.e. sole metamorphism), it must have taken at least 10 Ma for arc-lavas to form. This further defines a minimum duration of thrusting tectonics that led to the genesis of the CDOB mélange.
6. Anisian(?) limestones reported in the mélange of the KKOC originally made part of the continental shelf of the Middle Triassic Adriatic microcontinent (to be disintegrated by Late Triassic into three separate entities, one being the Adria plate (e.g., Vlahović et al., 2005), suggesting that principally the distal shelf portions of the passive continental margin had been incorporated into the obducted mélange, thus effectively constraining the magnitude of westward thrusting.
7. Final remarks on ophiolite thrusting in the Dinarides are in line with the fact that the ages of the upper-plate ophiolite suite - MOR gabbros (as young as 158±7.6 Ma) and metamorphic sole (as young as 160±4 Ma) - apparently mark younger ages (up to the Oxfordian) than the latest Bajocian to early Bathonian sedimentation ages of the ocean-floor pelagic cover, which made up the mélange sampled for this study. The obduction tectonics (i.e. mélange formation) was, therefore, not completed by the time indicated by the upper limit of radiolarian age (early Bathonian), but instead, it must have lasted at least until about the Oxfordian time. This corresponds well to the biostratigraphic data from the Serbian segment of the CDOB (Gawlick et al., 2009) and northern Albania (Chiari et al., 2004), where sediments forming the mélange are as young as Callovian and early Oxfordian. This work also shows that biostratigraphy is an important tool for dating sediments and, from this, it serves as a venue to put constraints on thrusting events that caused the ophiolite mélange formation. However, it does not by itself provide an age of mélange, which is basically a tectonic event. The biostratigraphic dating therefore needs to be combined with a vigorous mélange compositional analysis, principally of its crystalline components, in order to infer more on the time and palaeogeography of its genesis.

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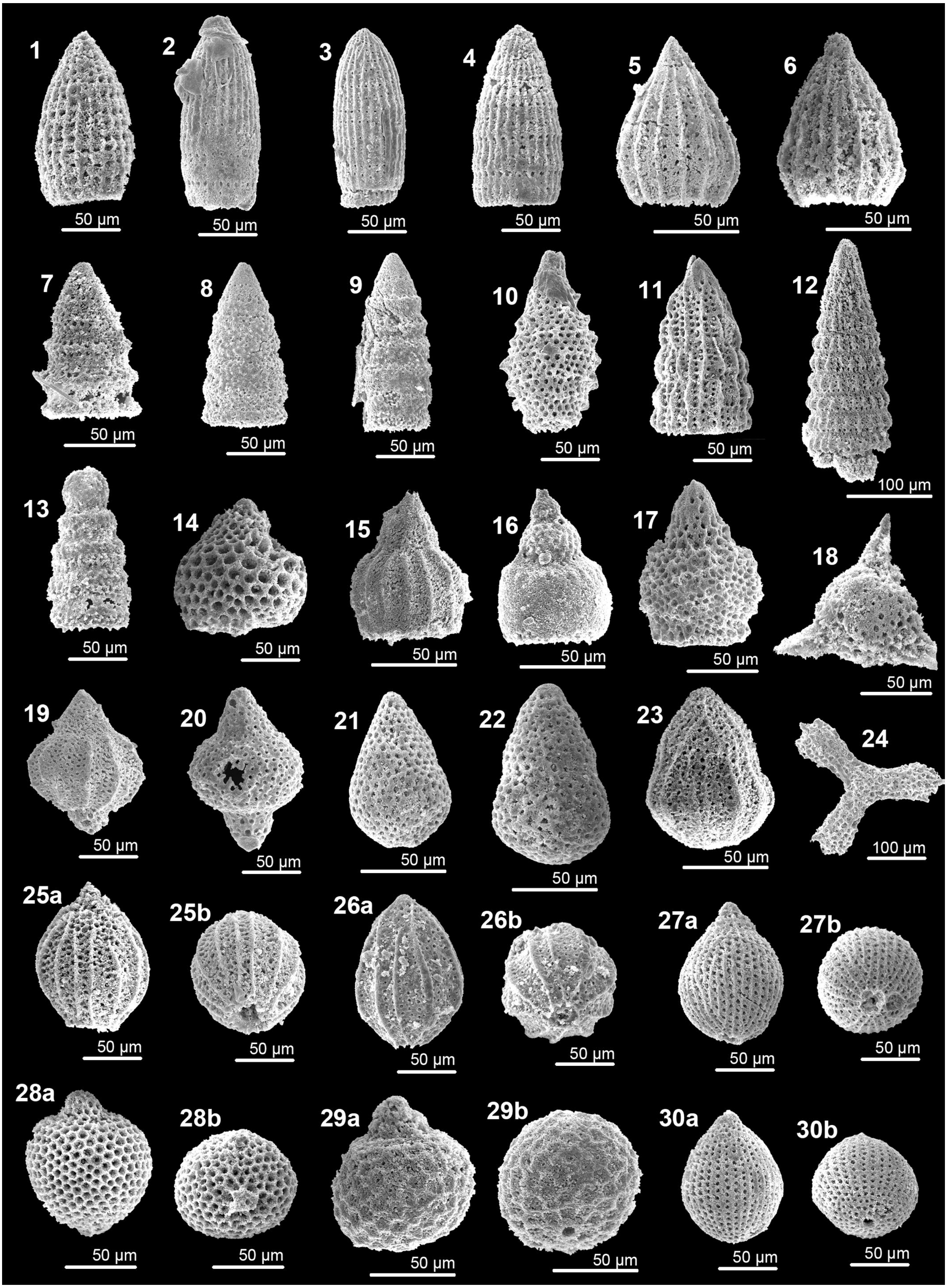
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29a
29b
30a
30b
50 µm
100 µm

Plate 1 **-** Middle Jurassic radiolarians from the analysed sample. For each specimen, the scaning electron microscograph number is indicated. The rock sample, residue and illustrated specimens are stored at the Ivan Rakovec Institute of Paleontology, ZRC SAZU, Ljubljana, Slovenia. 1) *Archaeodictyomitra rigida* Pessagno, 100233. This specimen has less costae and larger pores than the type material but it fits well in the variability of *Archaeodictyomitra rigida* as considered by O'Dogherty et al. (2006); 2, 3) *Archaeodictyomitra suzukii* Aita, 2- 100114, 3- 100124; 4) *Archaeodictyomitra* sp., 100230; 5, 6) *Semihsuum amabile* (Aita), 5- 100132, 6- 100115; 7) *Dictyomitrella* (?) *kamoensis* Mizutani and Kido, 100150; 8, 9) *Canoptum krahsteinense* (Suzuki and Gawlick), 8- 100226, 9- 100227; 10) *Eoxitus baloghi* Kozur, 100101; 11) *Transhsuum maxwelli* (Pessagno) gr., 100134; 12) *Transhsuum brevicostatum* (Ožvoldova) gr., 100133; 13) *Stichomitra* (?) *takanoensis* Aita gr., 100228; 14) *Stichocapsa* (?) *magnipora* Chiari, Marcucci and Prela, 100104; 15: *Eucyrtidiellum semifactum* Nagai and Mizutani, 100105. This specimen has longer plicae than the holotype but it conforms well with other specimens included in the variability of *Eucyrtidiellum semifactum* (see Baumgartner et al., 1995a, pl. 3016, fig. 3(H) and Figs. 1, 2, respectively); 16) *Eucyrtidiellum unumaense dentatum* Baumgartner, 100149; 17) *Quarticella* sp., 100126; 18) *Triactoma* (?) sp., 100235; 19) *Unuma latusicostatus* (Aita), 100116; 20: *Yaocapsa* sp. A, 100236. The species is close to *Yaocapsa* sp. aff. *Y. mastoidea* (Yao) (it was *Stichocapsa* sp. E in Baumgartner et al., 1995a, p. 524, pl. 4042, figs. 1, 2) but differs from the latter by having faint ridges that connect the adjacent pores; 21) *Praewilliriedellum* sp. aff. *P. convexum* (Yao),100124. The species differs from the type material (in Yao, 1979) by having a higher and wider abdomen; 22) *Praewilliriedellum* sp. aff. *P. himedaruma* (Aita), 100237. The species differs from the type material (in Aita, 1987) by having abdomen narrower than the last segment; 23) *Protunuma lanosus* Ožvoldova, 100117; 24) *Paronaella broennimanni* Pessagno, 100229; 25a-b) *Unuma* sp., 25a- 100122, 25b- antapical view, 100121; 26a-b) *Unuma gordus* Hull, 26a- 100231, 26b- antapical view, 100232; 27a-b) *Striatojaponocapsa synconexa* O'Dogherty, Goričan and Dumitrica, 27a- 100154, 27b- antapical view, 100155; 28a-b) *Hemicryptocapsa marcucciae* (Cortese), 28a- 100138, 28b- antapical view, 100137; 29a-b) *Hemicryptocapsa yaoi* (Kozur), 29a- 100110, 29b- antapical view, 100111; 30a-b) *Helvetocapsa matsuokai* (Sashida), 30a- 100239, 30b- antapical view, 100238.