New and poorly known Middle Jurassic larger benthic foraminifera from the Karst Dinarides of Croatia

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ABSTRACT

Some new and poorly known larger benthic foraminifera are described from Middle Jurassic (Upper Aalenian–Bajocian) shallow-water limestones of the Croatian Karst Dinarides. Cymbriaella lorigae FUGAGNOLI is reported for the first time outside its type-locality, the Upper Pliensbachian of the Southern Alps. New taxa described include Bosniella bassoulleti n. sp. and Dubrovnikella septfontainei n. gen., n. sp. (family Biokovinidae). Both Cymbriaella lorigae FUGAGNOLI and Everticyclammina praevirguliana FUGAGNOLI are reported for the first time from Middle Jurassic strata. The new findings enlarge the stratigraphic ranges and allow further insights into the phylogenetic evolution of the larger benthic foraminifera during the Early to Middle Jurassic period.

Keywords: Benthic foraminifera, taxonomy, phylogeny, Middle Jurassic, Karst Dinarides, Croatia

1. INTRODUCTION

Larger benthic foraminifera are widely distributed in Jurassic shallow-water carbonates of the Karst Dinarides. They were studied and illustrated in many palaeontological and/or biostatigraphical papers, mostly during the ’60s and ’70s of the 20th century, especially from the Lower Jurassic and partly from the Middle Jurassic (Bathonian) and Upper Jurassic (Oxfordian and Kimmeridgian) (e.g. RADOIČIĆ, 1966; NIKLER & SOKAČ, 1968; GUŠIĆ 1969a, b, 1977; VELIĆ, 1977, 2007; GUŠIĆ & VELIĆ, 1978; VELIĆ & SOKAČ, 1978). In the earlier Middle Jurassic, in the Croatian part of the Karst Dinarides, Gutnicella cayeuxi (LUCAS) was found together with the most common species Bosniella croatica (GUŠIĆ) in Bioko and in the vicinity of Karlovac (central Croatia) (ANIĆ, 1962; RADOIČIĆ, 1966; GUŠIĆ 1969a, b). VELIĆ (2005) reported on Aalenian–Bajocian foraminiferal assemblages of southern Croatia, from Bioko Mt. and the Dubrovnik area, including important species such as Gutnicella cayeuxi, Timidonella sarda BASSOULLET, CHABRIER & FOURCADE, Spiraloconulus giganteus

CHERCHI & SCHROEDER, Pseudodictyopsella jurassica SEPTFONTAINE & DE MATOS, Marzoella ficcarelli CHIOCCCHINI & MANCINELLI, Paravalvulina complicata SEPTFONTAINE, and Pseudoeggerella elongata SEPTFONTAINE. Based on these findings, four chronostratigraphic zones within older Middle Jurassic deposits were established by VELIĆ (2005). Later, VELIĆ (2007) established seven biostratigraphic zones based on larger benthic foraminifera. During these investigations of Aalenian–Bajocian limestones of Bioko Mt. and the Dubrovnik area, several taxa not previously reported from Croatia were observed, including one new genus and two new species described here.

2. GEOLOGICAL SETTING

During the early Middle Jurassic, two sedimentary provinces with significantly different environments may be distinguished within the area of the Adriatic Carbonate Platform (VLAHOVIĆ et al., 2005, for details). One encompasses platform marginal and peri-marginal dynamics, areas strongly influenced by currents and waves, with the occasional de-
The development and destruction of patch reefs. The second area belongs to the inner platform characterized by protected environments with a steady and uniform sedimentation of thick layers of carbonate mud. In marginal areas, the most common deposits are thick-bedded ooid-intraclast-bioclastic-skeletal-pelletal grainstones and packstones, in places rudstones, rich in fossil remains. In contrast, thick-layered mudstones, rarely wackestones and packstones with very few fossil remains were deposited in the inner platform area.

In the area of southern Croatia, southeast of Split, as well as in Montenegro and Northern Albania, Middle Jurassic sediments were deposited in the first, marginal province. This area includes the localities in Biokovo Mt. and in the vicinity of Dubrovnik (Fig. 1) where the investigated foraminiferal fauna has been found, including the new taxa described in the present paper. Aalenian–Bajocian carbonates of Southern Croatia crop out in the frontal part of the sequence of Mesozoic deposits uplifted and thrusted over the Palaeogene clastic sediments. Carbonates are in direct contact with elastic deposits, stratigraphically ranging from the Late Triassic to the Middle Jurassic. The reversed-overthrust contact extends from the northwestern part of Biokovo Mt. to the east of Konavle, along the border with Montenegro. It is morphologically expressed by the steep slopes of Biokovo Mt., the hills around Dubrovnik and Montene-
gran coastal mountains. Given the position of the Jurassic sediments, they are intensely tectonically disturbed, favouring heavy karstification, disintegration and sliding over the steep slopes of Palaeogene clastics. Sections with fully preserved successions of Jurassic units are rare. Lower Jurassic deposits were mostly tectonically reduced, and are occasionally entirely absent, so that only Middle Jurassic deposits are in contact with the Palaeogene clastic rocks. Contact between Middle and Upper Jurassic carbonates are also tectonically disturbed and continuous transition between them is very rare.

2.1. The Osojnik section

The Middle Jurassic deposits of the Osojnik section were investigated along the road connecting the village of Osojnik with Dubrovnik (Figs. 1–2). About 2 km south-southeast of the village, the road crosses the tectonic boundary between the folded Lower Jurassic (Pliensbachian) Lithiotis limestones, (about 30 m in thickness), and massive Aalenian ooid grainstones. The latter are overlain by bioclastic-oncoidal and intraclast grainstones, in places rudstones with recrystallized skeletons and debris of calcareous algae, molluscs
(mainly gastropods), corals, stromatopores, foraminifers, etc. (Fig. 3). Within this section, approximately 40 m above the ooid grainstones, an approximately 20 m thick zone of late-diagenetic dolomite occurs, followed by bioclastic-oncoidal grainstones containing the first specimens of late-diagenetic dolomite occurs, followed by bioclastic-oncoidal grainstones, an approximately 20 m thick zone of etc. (Fig. 3). Within this section, approximately 40 m above (mainly gastropods), corals, echinoderms, stromatopores, calcareous algae, and foraminifers. In the initial part of the sequence and within a further ~60 m thick interval, a rich assemblage of index foraminifera has been observed. In addition to *Bosniella croatica*, which starts within the ooid limestones, *Gutnicella cayeuxi, Cymbriaella lorigae, Dubrovnikella septfontainei* n. gen., n. sp., *Pseudocyclammina maynci HOTTINGER and Bosniella bassoulleti* n. sp. appear almost in the same horizon (Fig. 5). Most of the cited species have a rather narrow stratigraphic range, so that above this biohorizon, for another 30 m, only *G. cayeuxi* extends until the appearance of *Spiraloconulus perconigi* (ALLEMAN & SCHROEDER). After a further 20 m, *Timidonella sarda* was determined, and around 70 m above that, the range of the dasycladale alga *Selliporella donzellii* begins. In the next 30 m of the column, together with *S. donzellii*, the only foraminifera occurring is *B. croatica* (also indicating its last appearance) and *B. bassoulleti* n. sp., the last appearance of which is determined after a further 30 m. In the next 70 m, there are no significant microfossils except *S. donzellii*. After 15–20 m of massive late-diagenetic dolomite, skeletal-intraclastic grainstones and skeletal wackestones containing *Pfenderella arabica* occur; 20 m above *Pseudoeggerella elongata* and finally an additional 20 m or so, a Bathonian assemblage with *Paleopfenderina salernitana*, etc. occurs (Fig. 5). The thickness of the Upper Aalenian and Bajocian carbonates in the Slano section between the Aalenian ooid limestones and the Bathonian limestones is about 350 m.

### 2.2. The Slano section

The Middle Jurassic part of the Slano section is measured northeast of Slano on the slopes of the Kosmatovica and Kolomnić hills (Fig. 4). As in the Osojnik profile, the Middle Jurassic succession starts with Aalenian ooid limestone, whose thickness is unknown due to the tectonic contact with the Lower Jurassic carbonates. The ooid limestones are followed by approximately 20 m of layered mudstones and wackestones. In the next 270 m of the profile, massive late-diagenetic dolomites, and oncoid-intraclastic-bioclastic grainstones prevail, with rudstones in places in alternation with skeletal-intraclastic grainstones/rudstones. These deposits are mostly thick layered (0.6 m to 1.5 m) and rarely even massive. There are interbeds or thin intervals of mud-supported intraclastic-skeletal limestones, prevailing after the aforementioned massive late-diagenetic dolomites at the end of the Bajocian and beginning of the Bathonian limestones. Fossil remains and debris belong mostly to molluscs (predominantly gastropods), corals, echinoderms, stromatopores, calcareous algae, and foraminifers. In the initial part of the sequence and within a further ~60 m thick interval, a rich assemblage of index foraminifera has been observed. In addition to *Bosniella croatica*, which starts within the ooid limestones, *Gutnicella cayeuxi, Cymbriaella lorigae, Dubrovnikella septfontainei* n. gen., n. sp., *Pseudocyclammina maynci HOTTINGER and Bosniella bassoulleti* n. sp. appear almost in the same horizon (Fig. 5). Most of the cited species have a rather narrow stratigraphic range, so that above this biozone, for another 30 m, only *G. cayeuxi* extends until the appearance of *Spiraloconulus perconigi* (ALLEMAN & SCHROEDER). After a further 20 m, *Timidonella sarda* was determined, and around 70 m above that, the range of the dasycladale alga *Selliporella donzellii* begins. In the next 30 m of the column, together with *S. donzellii*, the only foraminifera occurring is *B. croatica* (also indicating its last appearance) and *B. bassoulleti* n. sp., the last appearance of which is determined after a further 30 m. In the next 70 m, there are no significant microfossils except *S. donzellii*. After 15–20 m of massive late-diagenetic dolomite, skeletal-intraclastic grainstones and skeletal wackestones containing *Pfenderella arabica* occur; 20 m above *Pseudoeggerella elongata* and finally an additional 20 m or so, a Bathonian assemblage with *Paleopfenderina salernitana*, etc. occurs (Fig. 5). The thickness of the Upper Aalenian and Bajocian carbonates in the Slano section between the Aalenian ooid limestones and the Bathonian limestones is about 350 m.

### 2.3. The Biokovo Mount section

The Biokovo Mt. profile was measured east of Tučepi along the Staza–Lemišini Doci road in the Biokovo Nature Park (Fig. 6). As in the case of the Osojnik and Slano sections, the oldest Middle Jurassic carbonates are thick layered and massive ooid limestones of Aalenian age. The lithological features of the Upper Aalenian–Bajocian carbonates of the Biokovo section, in continuous succession over ooid limestones, are very similar to those in the Osojnik and Slano sections. In the older parts, bioclastic-skeletal-oncoid and
intraclastic grainstones to rudstones prevail, in places with interbedded oolites and skeletal wackestones and mudstones. Among the skeletal remains there is fossil debris and sections of molluscs, corals, stromatoporoids, algae, and foraminifers. Skeletal and bioclastic grainstones/mudstones are most common in the younger part of the column, and they often alternate with intraclastic grainstones. Local emergence horizons rarely occur.

Figure 5: Lithostratigraphy of the Slano section and distribution of important larger benthic foraminifera.
Among the foraminifera, *Bosniella croatica* and *Gutnicella cayeuxi* were already present in the ooid limestones, overlain by about 50 m of thick-layered skeletal-oncocoidal grainstones with interbedded skeletal wackestones, followed by another, but thinner package, i.e. about 10 m thick, of ooid limestones. Within the interval between the base and these thinner ooid limestone beds there are bioclastic oncocoidal and skeletal grainstones/packstones with *Everticyclammina praevirguliana* FUGAGNOLI (Fig. 7). Above the thin ooid limestones there is a sequence of thick-bedded, oncocoidal, skeletal grainstones with rare *G. cayeuxi* and more frequent *Timi donella sarda*. The latter is found in the younger strata, beneath the local emergence horizon, characterized by the first occurrences of *Bosniella bassoulleti* n. sp. and *Spiralocoma giganteus*. Among the cited species, *B. croatica*, *B. bassoulleti* n. sp. and *S. giganteus* continue after emergence, while 15 m above the emergence the alga *Selliporella donzellii* appears.

In the middle part of the Bajocian column, about 80 m above the mentioned emergence horizon, *Pseudodictyopsella jurisica* and *Marzoella ficcarellii* occur, these being up to now their first, and only occurrences in the Karst Dinarides. Approximately 40 m above the last occurrence of *S. giganteus*, after a further 60 m of the column, *B. croatica* disappears, and after another 30 m also *B. bassoulleti* n. sp. disappears. In the following 40 m of the column to the first occurrence of *Pfendrerella arabica*, there are no important foraminiferal species. About 10 m above, in the topmost Bajocian beds, *Paravalvulina complicata* and *Pseudoeoggerella elongata* appear, and after a further ca. 10 m there is an emergence breccia with black pebbles (originating from marsh deposits on the tidal flat). About 15 m above the emergence horizon the next emersion level follows, and then layers with *Paleopfenderina salernitana* and other Bathonian foraminifera. The thickness of the Upper Aalenian and Bajocian carbonates in the Biokovo profile between the Aalenian ooid limestones and the Bathonian limestones cannot be accurately determined due to tectonic disintegration and gentle folding, but is estimated at about 350 m.

### 3. SYSTEMATIC PALAEOONTOLOGY


#### Class Foraminiferida

Order *Loftusiida* KAMINSKI & MIKHALEVICH, 2004
Suborder *Orbitolinina* KAMINSKI & MIKHALEVICH, 2004
Superfamily *Pfenderinacea* SMOUT & SUDGEN, 1962
Family *Hauraniidae* SEPTFONTAINE, 1988
Subfamily *Hauraniinae* SEPTFONTAINE, 1988

**Genus Cymbriaella** FUGAGNOLI, 1999

*Cymbriaella lorigae* FUGAGNOLI, 1999
(Figs. 8a–g, Fig. 14a pars)

**Description:** Large test consisting of a more or less planispirally coiled initial portion (1.5 to 2 whorls) and a rather large uncoiled portion with 4 to 5 chambers, separated by thick septa. In the uncoiled portion, chamber width increases moderately. Test wall thick, alveolar with incorporated foreign material (e.g., peloids, small foraminifera). Single foramen in the initial part; in longitudinal sections rather broad multiple (up to 4–5) foramina are discernible in the uncoiled portion (Fig. 8d). Dimensions see Table 1.

**Remarks and comparisons:** *Cymbriaella lorigae* was described from the Pliensbachian of the Southern Alps (FUGAGNOLI, 1999) and the stratigraphic range can now be extended to include the Upper Aalenian–Lower Bajocian interval. Besides the Italian and Croatian records, the species was recently also reported from the Liassic of Turkey (ÖZKAYMAK et al., 2010). The Middle Jurassic specimens from Croatia agree closely with the Lower Jurassic material described by FUGAGNOLI (1999).

**Microfacies:** Intraclastic pack- to rudstones with debris of molluscs, and gastropods. The associated foraminifera in-
include *Dubrovnikella septfontainei* n. gen., n. sp. (rare), *Bosniella bassouleti* n. sp. (rare), *Gutnicella cayeuxi* (rare), *Agerina martana* (FARINACCI) (very rare), small textularids and trochospiral forms, e.g., tetrataxids (common) and a triserial ataxophragmid foraminifer gen. et sp. indet. (common) (Fig. 9). Thaumatoporellaceans with free, attached, and cryptobiotic specimens are abundant (see SCHLAGINTWEIT & VELIĆ, 2011).

Occurrences: Slano section (Figs. 4, 5); rare at Biokovo Mt. section (Figs. 6, 7).

Suborder *Biokovinina KAMINSKI, 2004*
Superfamily *Biokovinacea GUŠIĆ, 1977*
Family *Biokovinidae GUŠIĆ, 1977*
Remarks: *Bosniella* was removed from the Biokovinidae by MIKALEVICH (2004) due to the lack of endoskeletal
structures as reported from Bosniella (see Tab. 2). This view was corrected in the “year 2000 classification” of KAMINSKI (2004) with the creation of the suborder Biokovinina KAMINSKI and the maintenance of Bosniella within the Biokovinidae by giving the wall structure a higher hierarchy than the presence/absence of the endoskeleton. The absence/presence of endoskeletal structures can instead be taken into consideration to differentiate the two subfamilies within the Biokovinidae.

**Genus Bosniella GUŠIĆ, 1977**

*Bosniella bassoulleti* n. sp.

(Figs. 10/a–q, Figs. 11/a–m, Fig. 12a)

Origin of the name: Dedicated to Jean-Paul Bassoullet for his numerous outstanding contributions to the knowledge of Jurassic larger benthic foraminifera.

Holotype: Specimen in equatorial section figured in (Fig. 10d). Thin section Os 10.

Isotypes: Specimens figured in (Figs. 10a–c, e–q, Figs. 11a–m). Thin sections O 32/a and –/b, SL 2, SL 2/1, SL 3A/3, SL 3B/2, SL 4A, SL 4A/1, SZ 64/4, SZ 64/5 (for abbreviations of sample locations see Fig. 1).

Depository: Croatian geological survey, Sachsova 2, 10000 Zagreb, Croatia.

Type-locality: Dubrovnik area, southern Croatia, the road connecting the village of Osojnik with Dubrovnik (Figs. 2).

Type-level: Thick-bedded, light-brownish coloured to white limestone, skeletal and bioclastic-oncoidal grainstone/packstone (Figs. 2, 3; samples O-32 and OS-10) of back reef environment with numerous sections of *B. bas-
soulleti, rare Spiraloceras giganteus, Siphonovalvulina variabilis, triserial ataxophragmiid foraminifer gen. et sp. indet. (Fig. 9), bicrystals of thaumatoporellaceans, corals, molluscs, etc.

Diagnosis: A representative of the genus *Bosniella* showing a planispiral discoidal test, varying from partly involute and widely umbilicate to involute, often with slightly undulating growth direction and a prominent uncoiled portion. Chambers numerous in the coiled part, becoming moderately broader during growth, in the uncoiled portion either constant in width or expanding. Foramen single, interiomarginal in the coiled part becoming multiple in the uncoiled part. Wall microgranular with keriothecal texture.

Description: Test free, lenticular, more or less planispirally coiled initially, with 2–2½ whorls and a maximum of up to 14 chambers in the last whorl in adult specimens; the adult part may be uncoiling. The coiling is not often exactly planispiral but may show a slight inclination towards the plane of the previous whorl or an oscillating inclination that may result in an s- or sigmoid shape in axial sections (Figs. 11b, i, k). In most cases, the umbilicus is well pronounced (e.g. Fig. 10g, upper specimen, Fig. 11c, m). The first chamber (protoconch) is subsphaerical (diameter up to 0.11 mm), enclosed by a thin wall (membrane) with a thickness of about 0.005 mm (Fig. 12a). In the coiled portion, chamber width gradually increases, often distinctly so in the last half of the final whorl, resulting in a more or less asymmetry in axial sections (Fig. 10g, upper specimen, Figs. 11c, e). In equatorial sections, the chambers are becoming higher during ontogeny but also show a flattened top with angular peripheries; in the older parts, chamber peripheries are more rounded (Figs. 10a–b, d, 11a). In the same way, the diameter of the single foramen near the chamber base also increases. Sutures between subsequent chambers are poorly developed (e.g. Figs. 10a, 11a). The ultimate chambers often show upward growth towards the previous whorl resulting in a massive thickening of the chamber wall (Figs. 10a, 11a). This seems to be the preparation of the test to uncoil, in broadening the junction between the coiled and uncoiled parts (Figs. 10e–f).

The planispiral stage is often followed by an uncoiled, more or less rectilinear, stage. The shape may vary from cy-

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Table 1: Dimensions of *Cymbriaella lorigae* FUGAGNOLI, Upper Aalenian–Lower Bajocian of Croatia. d = diameter coiled portion (in equatorial sections), dup = diameter uncoiled portion, hup = height uncoiled portion, h = total test height (or length), n = number of chambers in the uncoiled portion.

Figure 10: Bosniella bassoulleti n. sp. Upper Aalenian–Lower Bajocian of the Croatian Karst Dinarides. a–c, e–q Isotypes. d Holotype. a–d Equatorial sections, in part slightly oblique. Holotype specimen (d) with uncoiled part consisting of three chambers; note multiple foramina evolving in the uncoiled portion (arrows). e–f Specimens with prominent uncoiled part with 6 (?) chambers in f. In e the chambers of the uncoiled part widen continuously, whereas in f the width remains more or less constant. g–h) Two specimens in different sections. Note distinct biumbonal depression of the upper specimen in g cut in axial section and also the change of growth direction in the ultimate whorl. i–m) Oblique sections. n) Subaxial section; note irregular planispiral coiling resulting in a bent test. o) Specimen with large uncoiled portion. p) Two specimens, small juvenile specimen above in subaxial section, the other one below in oblique section. q) Equatorial section, slightly oblique; coiled portion showing 2 ½ whorls, uncoiled portion with 4 chambers. Scale bar 0.5 mm for all pictures. Thin sections: a, i–j, p O 32b, b, d, g Os10/1, c, h O 32a, e SZ 64/4, f SL 2/1, k O 35, l SL 2/1, m SL 4/1, n, q SL 4a, o SZ 64/5.
lindrical with chamber width remaining more or less constant (e.g. Fig. 10f), to expanding (cylindroconical), with chamber width increasing successively (Fig. 10o). Occasionally, there are specimens displaying chambers not rectilinearly arranged, but with varying growth directions (with respect to the previous chamber). Successive change of chamber growth direction may result in an overall sigmoid appearance (Fig. 10n). Chamber shape of the uncoiled part in axial sections is variable, mostly hemispherical with flat or concave base, in cases also with flattened top (trapezoid, e.g. third ultimate chamber in Fig. 10e). The distal end of the uncoiled part is mostly broadly rounded (Fig. 10f, o) or more rarely acutely rounded (Fig. 10e). The septa of the uncoiled portion are pierced by several (“multiple”) foramina (Fig. 10d), often not detectable. In oblique sections, the chamber lumina are in direct contact to each other giving the impression of a broad single foramen in the centre (Figs. 10o, q). The test wall is finely agglutinating; the fine keriothecal structure is indistinct and not always detectable (Fig. 11d), presumably due to diagenetic processes.

Remarks and comparisons: The differences of *Bosniella bassoulleti* n. sp. to the other three species of the genus *Bosniella* can be summarized as follows:

*B. oenensis* GUŠIĆ (Pliensbachian of Bosnia): As axial sections were not available in the material on which the original description was based, information on the type of coil-
ing (involute or evolute) were not provided. GUŠIĆ (1977, p. 14) further remarked that “some specimens are likely to have developed an uncoiled stage”. With respect to these two points, the original description has been completed by FUGAGNOLI & LORIGA BROGLIO (1998), based on material from the Pliensbachian of the Southern Alps. Accordingly, the coiling is involute with a marked umbilical depression and a prominent uncoiled adult part of the test is well developed in most specimens (see also BOUDAGHER-FADEL & BOSENCE, 2007). Outer test dimensions of B. oenensis and B. bassoulleti n. sp. are comparable.

The photographs provided by GUŠIĆ (1977) and FUGAGNOLI & LORIGA BROGLIO (1998) show that the number of chambers in the last whorl, being ~ 7 to 9, is reduced compared to B. bassoulleti n. sp. (11 to 14). This difference is caused by more massive septa in B. oenensis (0.12–0.13 mm, acc. to FUGAGNOLI & LORIGA BROGLIO, 1998) and more delicate in B. bassoulleti n. sp. (thickness 0.04–0.08 mm), with the thickest septa observed in the uncoiled portion. FUGAGNOLI & LORIGA BROGLIO (1998) stated that the chambers within the uncoiled part are “progressively expanding”. In B. bassoulleti n. sp. we observed both specimens with chamber width in the last remaining part (Fig. 10f), and others with increasing width (Fig. 10a).

B. croatica (GUŠIĆ) (Early-Middle Jurassic of Croatia: former Mesoendothyra croatica, according to BASSOLLETTI, 1994): Above all, this species is smaller with diameter of the coiled part of 0.5 mm and length (= height) of test (including uncoiled portion) of 0.75 to 1.0 mm (see GUŠIĆ, 1969, p. 67). Another difference is that the aperture in the coiled part of B. croatica is positioned at the very base of the chambers, whereas in B. bassoulleti n. sp. it is situated somewhat above, more towards the centre of the septum.

B. fontainei BASSOULLET (Aalenian-Bajocian of Thailand) is distinguished from B. bassoulleti n. sp. by a distinctly less developed uncoiled stage, and a more globular test with smaller biumbonal depressions. The globular test results from a more involute type of coiling, with largely overlapping whorls, as visible in axial sections (e.g., BASSOULLET 1994, pl. 1/8–9, 12).

Both Bosniella croatica and Bosniella fontainei display a test dimorphism (GUŠIĆ, 1977; BASSOLLETTI, 1994; FUGAGNOLI & LORIGA BROGLIO, 1998). As discussed by FUGAGNOLI (2004, Fig. 5), the occurrence/absence of tests showing di- or trimorphism in complex large benthic Lower Jurassic foraminifers is triggered by the trophic regime. The genera Cymbriaella, Bosniella and Lithoquillipa are interpreted as characterizing oligotrophic conditions. For Bosniella croatica, GUŠIĆ (1977, p. 14) remarks that the dimorphism concerns “mainly the size of the tests and of the proloculus, while the general shape and basic growth pattern is the same for both types”. Furthermore, GUŠIĆ states that in microspheric tests “the proloculus could not be observed” and “no uncoiled stage has been observed”. In accordance with this, FUGAGNOLI & LORIGA BROGLIO (1998, p. 64) also noticed “a more developed uncoiled stage of megalospheric forms”. In Bosniella fontainei it seems to be just the opposite, with uncoiled megalospheric and coiled microspheric forms. A discrete dimorphism is not well pronounced in Bosniella bassoulleti; in fact, the assumed megalospheric specimens with subphaerical proloculus are observable in both coiled (Fig. 11f, m) and uncoiled (Fig. 10d) forms. Specimens sectioned in the median plane without a detectable proloculus are assumed to represent microspheric forms. A possible difference in test morphology seems to be that microspheric forms are more flattened lenticular than the macrospheric ones.

Stratigraphy: Bosniella bassoulleti appears within the upper part of the stratigraphic range of Timidonella sarda and Gutticella caveuxi, and has its maximum abundance immediately above the disappearance of these two species (see VELIĆ, 2007 for details). It disappears a little below the level with mass abundance of Selliporella donzellii, indicative of the Bajocian–Bathonian interval (e.g. GRANIER & DELOFFRE, 1994). For instance, a Selliporella donzellii cеноzone (Bajocian) has been established in the Taurus Mountains of Turkey (ALTINER & SEPTFONTAINE, 1979), later modified to a Timidonella sarda-Selliporella donzellii zone (EKMEKCI & ALTINER, 2008). According to these data, the stratigraphic range of B. bassoulleti can be considered as Late (or latest) Aalenian–?Early Bajocian.

Microfacies: Same as for Cymbriaella lorigae (SL samples).

Occurrences: Osojnik section (Figs. 2, 3) and Slano section (Figs. 4, 5).

Suborder Biokovinacea GUŠIĆ, 1977
Superfamily Biokovinacea GUŠIĆ, 1977
Family Biokovinidae GUŠIĆ, 1977
Dubrovnikella n. gen.

Origin of the name: The genus refers to the city of Dubrovnik on the Adriatic coast of Croatia.

Type species: Dubrovnikella septfontainei n. gen. n. sp.

Diagnosis: Test free, irregularly planispirally to streptospirally coiled in early stage, nautiloid in form; later a slight tendency to uncoil may be present. Wall thin, finely agglutinating, with inner alveolar layer and outer imperforate epidermis. Alveoli simple, more or less parallel and more or less of equal diameter. Septa short and not alveolar. No en-
doskeletal structures present. Aperture single, basal in the early stage, later becoming cribrate with only a few large openings. Most likely dimorphic. Megalospheric embryonic stage complex, bilocular, consisting of a large thin-walled subglobular megalosphere and a deuteroconch enveloping the former $1/2$ to $3/4$.

Comparisons: The characteristic features enable the inclusion of *Dubrovnikella* n. gen. into the suborder Biokovinina KAMINSKI, defined as follows: “Test free or attached, may be coiled in the early stage, later uncoiled or branched. Wall finely agglutinated, traversed by pores, or with a coarsely perforate or canalculated inner layer and an outer imperforate layer” (KAMINSKI, 2004, p. 250). In contrast to other representatives of the Biokovinidae, such as *Bosniella* GÜŚIĆ and *Biokovina* GÜŚIĆ, the pores in the wall of *Dubrovnikella* are distinctly coarser; it is noteworthy that in the diagnosis of the family Biokovinidae provided by LOEBLICH & TAPPAN (1987, p. 91) the wall is said to be “coarsely perforate”. For the superfamily Biokovinacea, LOEBLICH & TAPPAN (1985, p. 94) characterize the wall as “finely agglutinated, with outer imperforate layer and coarsely perforate or canalculated inner layer in later stage”. *Biokovina* is unique within the biokovinids by possessing endoskeletal pillars. Such elements are lacking in *Dubrovnikella* n. gen. as well as in *Bosniella*. Both *Bosniella* and *Biokovina* may develop a straight uncoiled test portion, whereas in *Dubrovnikella* only in rare specimens, a slight tendency to uncoil was observed. A third genus that has been described as belonging to the Biokovinidae GÜŚIĆ is *Tromajmiijella* ATHERSUCH, BANNER & SIMMONS, 1992 (see also KAMINSKI, 2004, p. 250). As this genus has a test wall that “is solid and is not known to become protocanalicate or canalculated” (ATHERSUCH et al. 1992, p. 7) it cannot be included in the Biokovinidae sensu GÜŚIĆ 1977 (see also LOEBLICH & TAPPAN, 1987). The complex embryonal apparatus consisting of a protoconch and deuteroconch or spherocochn (Fig. 12b) is reported from other Lower Jurassic foraminifera, e.g. *Orbitopsella* MUNIER-CHALMAS, 1902 (e.g. HOTTINGER, 1967, 2006, Fig. 41h) or *Cymbriaella* FUGAGNOLI, 1999 and Middle Jurassic larger benthic foraminifera, e.g. *Bostia* BASSOULLET, 1998. *Dubrovnikella* can generally be compared to some extent with *Litoulipora* GÜŚIĆ & VELIĆ and *Cymbriaella* FUGAGNOLI. *Litoulipora* with a more irregular coiling and a disoidal test form, has a microgranular wall “traversed by large pores that open both to exterior and interior” (LOEBLICH & TAPPAN, 1987, p. 91) whereas in *Dubrovnikella* the pores are covered to the exterior by a thin imperforate layer. *Cymbriaella* has a prominent uncoiled test portion, thick septa and an exoskeleton of beams and rafters; short beams are also present in the deuteroconch (see genus diagnosis of FUGAGNOLI, 1999, p. 103).

**Dubrovnikella septfontainei** n. gen. n. sp.
(Figs. 12b, 13a–l, Figs. 14a–p)

Origin of the name: Dedicated to Michel Septfontaine for his numerous outstanding contributions to the knowledge of Jurassic larger benthic foraminifera.

Holotype: Slightly oblique equatorial section of a macrospheric specimen figured in (Fig. 13c). Thin section SL 2.

Isotypes: Specimens figured in (Fig. 13a–b, d–l, Fig. 14a–m). Thin sections SL 2, SL 2–1, SL 2–2, SL 2–3, SL 2–5, SL 3A, SL 3B–1, SL 3B–2, SL 4A–1, SL 4A–4, SL 5B, SL 5B–2, SZ 64–3 (for abbreviations of samples see Fig. 1).

Depository: Croatian geological survey, Sachsova 2, 10000 Zagreb, Croatia.

Type-locality: Slano section northeast of Slano village, about 25 km NW of Dubrovnik (Fig. 1), on the slopes of Komatovica and Kolomnić hills (Fig. 4).

Type-level: Thick-bedded, light-brownish, skeletal-bioclastic-oncocoidal grain- to rudstones (Fig. 5; samples SL-2 to SL-5) of back-reef environment within the lower part of the stratigraphic range of *Gutnicella cayenx* and in association with *Bosniella bassoulleti*, *Cymbriaella lorigae*, *Spiralocoanus perconigii*, *Pseudocyclammina maynii*, small foraminifera, bioclasts of corals, echinoderms, molluscs, thamnotoporellaceae etc., but before the first appearance of rare *Timidinella sarda*.

Diagnosis: Being monotypic so far, the diagnosis is that for the genus.

Description: Test involute, subglobular to nautiloid in form, initially planispirally later may be slightly streptospirally coiled. Test usually higher than wide (height/thickness up to 1.55); thickness ranges from 0.6 mm to 1.15 mm, height 0.8 to 1.45 mm. Chambers broad with crescent-shaped chamber lumina; test periphery broadly rounded. Early coiling planispiral involute and bi umbilicate, later with a slight tendency to be streptospiral, consisting of 1½ to 2 whorls with few chambers each (Figs. 13b–c). The first whorl comprises 4 to 5 chambers. During ontogeny, chambers continuously increase in size, becoming distinctly higher than long. In equatorial section they first appear rhombic later becoming more crescent-shape. An uncoiling of the last 1 to 2 chambers is rarely observable (Figs. 13e–f). Sutures are depressed and recurved. The megalosphere (proloculus) is globular to subglobular, mostly laterally flattened and enclosed by a thin microcrystalline (originally organic) membrane (Fig. 12b). Its inner diameter (d) ranges from 0.15 mm to 0.23 mm, most values about 0.2 mm. The height (h) of the proloculus ranges from 0.13 mm to 0.21 mm, most frequently about 0.16 mm; the d/h ratio is 1.0 to 1.54, mostly about 1.25. The proloculus is enveloped by a semi-spherical deuteroconch of reduced height. The wall is thin and finely agglutinating with an inner alveolar layer with simple parallel pores (diameter 0.01 to 0.02 mm) and a thin outer imperforate epidermis (thickness 0.006 to 0.015 mm). The septa are solid and not alveolar. The aperture is basal single in the early stage, later becoming cribrate with only a few broad openings. No endoskeletal structures are present.

Remarks and comparisons: Being so far monospecific, see comparisons for the genus.

Stratigraphy: According to the foraminiferal assemblage at the type locality (Fig. 4), the stratigraphic range of *Dubrovnikella septfontainei* n. gen. n. sp. can be considered as latest Aalenian-earliest Bajocian.
Figure 13: *Dubrovnikella septfontainei* n. gen., n. sp. Upper Aalenian–Lower Bajocian of the Croatian Karst Dinarides. a) Grainstone with three specimens of *Dubrovnikella septfontainei* and other small benthic foraminifera. b–d) Equatorial sections, slightly oblique; c = holotype specimen. e) Oblique section. f) Detail from e showing wall structure. g–i) Oblique axial sections. Note two large chamber openings in (h) and embryonic apparatus in (i) detail of which is shown in Figure 12b. j–k) Tangential sections of the test. l) Broken equatorial section.

*Scale bar* 1 mm for a, all other pictures 0.5 mm. Thin sections: a, g) SL 2-2, b SL 2-5, c-d SL 2, e SL 3A-2, f SL 3A, h SL 4A-1, i SL 5B/2, j SL 2-3, k SL 4a-4.
Figure 14: *Dubrovnikella septfontainei* gen., sp. Upper Aalenian–Lower Bajocian of the Croatian Karst Dinarides. a) Poorly sorted packstone with *Dubrovnikella septfontainei* gen., sp. (left) and *Cymbriaella longica* FUGAGNOLI (right). b) Detail of Fig. 13h showing palisade-like parallel-arranged alveoli open towards the chamber and covered by a thin outer layer of the wall (epidermis); note two large intercameral foramina (arrows). c–d) Axial tangential sections; note single aperture in c (lowest chamber). e–f) Equatorial sections; note cryptoendolithic thaumatoporellaceans inside the test (e). g) Oblique axial section of megalospheric juvenile specimen. h) Oblique section. i–j) Axial sections; note broad final whorl in (i). k) Oblique equatorial section. l) Equatorial section, most likely of a microspheric specimen. m) Oblique axial section of a macrospheric specimen (detail shown in Fig. 12b). n) Oblique equatorial section. o–p) Oblique sections.

*Scale bar* 1 mm for a, e–f, i–j, m–n, all other pictures 0.5 mm. Thin sections: a, c, f SL 3B-2, b, p SL 4A-1, d, n SL 2-3, e SZ 64-3, g SL 2-2, h SL 4A-4, i SL 3B-1, j SL 4B, k SL 3A-3, l SL 3B-1, m SL 5B-2, o SL 2-1.
Remarks: The Croatian specimens of *Everticyclammina praevirguliana* agree closely with the Late Sinemurian–Plenuschian material of the Southern Alps of Italy described by FUGAGNOLI (2000). For other Liassic occurrences see BOUDAGHER-FADEL et al. (2001). In addition, *E. praevirguliana* was also reported (without illustration) from the Sinemurian-Plenuschian of East Timor (HAIG et al., 2007). The stratigraphic range can now be extended to include the Upper Aalenian–Lower Bajocian interval. BOUDAGHER-FADEL et al. (2007) introduced a mid Sinemurian *Everticyclammina praevirguliana* biozone for different sections in the Mediterranean realm.

Stratigraphy: *Everticyclammina praevirguliana* illustrated in this paper is of Alenian age – it is accompanied by *Gutnicella cayeuxi*, but somewhat earlier of the first occurrences of *Timidondella sarda*.

Microfacies: Intraclastic-bioclastic oncoidal and sketal grainstone to packstone, rarely wackestone of back reef environment. *Everticyclammina praevirguliana* is associated with rare *Bosniella croatica*, *Gutnicella cayeuxi*, *Cymbriella lorigae*, frequent small valvulinids and mostly oncolithized gastropod bioclasts.

Occurrences: Biokovo Mt. section.

4. REMARKS ON THE PHYLOGENETIC EVOLUTION OF LOWER TO MIDDLE JURASSIC LARGER BENTHIC FORAMINIFERA

The phylogenetic and morphostructural evolution of Jurassic larger benthic foraminifera has been a topic of research and discussion for decades (HOTTINGER, 1967; SEPTFONTAINE, 1980, 1988; SEPTFONTAINE et al., 1991; KUZNETSOVA et al., 1996; BOUDAGHER-FADEL, 2008; KAMINSKI et al., 2010). In 1980, SEPTFONTAINE presented a useful hierarchical grouping, starting with the outer morphology (type of coiling), presence/absence of exoskeletal and/or endoskeletal elements and other features (mainly aperture). The temporal evolution of these elements has been the basis for phylogenetic considerations (SEPTFONTAINE, 1988). With respect to the end-Triassic mass extinction (e.g. TANNER et al., 2004), the calculated diversity curve for agglutinated foraminifera of KAMINSKI et al. (2010) only agrees closely with the Late Sinemurian–Plenuschian as characterized by the first appearance of some larger agglutinated foraminiferal genera, derived from *Lituola*, such as *Cymbriaella*, *Haurania*, *Orbitopsella*, *Everticyclammina*, *Lituosepta*, *Biokovina* etc.” Considering the first appearances of these genera, however, there are differing data obtainable from the literature:

*Cymbriaella* FUGAGNOLI: So far monospecific *Cymbriaella lorigae* described by FUGAGNOLI (1999) from the Domerian (= Upper Plenuschian) of the Southern Alps, Italy. Actually we don’t know of any other record in the literature. The first appearance at the base of the Hettangian as indicated by BOUDAGHER-FADEL (2008, p. 171 and Fig. 4.6), cannot be understood. It is noteworthy that FUGAGNOLI (2004, p. 114) again reinstated the restriction to the Upper Plenuschian. Our data allows the enlargement of the stratigraphic range into the Lower Bajocian.

*Haurania* HENSON: Independent of the morphological intricacies (*Haurania vs Amijella*), the first hauraniids appear in the uppermost Late Hettangian (VELIĆ, 2007, Fig. 2a).

*Orbitopsella* MUNIER-CHALMAS: First appearance of the genus is in the Late Sinemurian (BASSOULLET, 1997, Tab. 51; VELIĆ, 2007, Fig. 7)

*Everticyclammina* REDMOND: The oldest representative is *Everticyclammina praevirguliana* described by FUGAGNOLI (2000) from the Late Sinemurian–Plenuschian of the Southern Alps, Italy. As its ancestor, a species of *Ammobaculites* was assumed. The genus *Everticyclammina* might originate in the uppermost Early Sinemurian (BASSOULLET, 1997, Tab. 51; VELIĆ, 2007, Fig. 2c) or middle Sinemurian according to BOUDAGHER-FADEL (2008).

*Lituosepta* CATI: So far monospecific with *Lituosepta recoaensis* described by CATI (1959) from the Plenuschian of the Southern Alps. According to BASSOULLET (1997) and VELIĆ (2007) it is known from the Latest Early Sinemurian to the earliest Lower Plenuschian.

*Biokovina* GUŠIĆ: So far monospecific with *Biokovina gradacensis* described by GUŠIĆ (1977) from the Plenuschian of Croatia. The possible total stratigraphic range extends from the uppermost Late Sinemurian to the lowermost Late Plenuschian (BASSOULLET, 1997; CHIOCCHINI et al., 1994, 2008).

Summarizing these data, there is a more or less parallel appearance of different genera in the Late Sinemurian, whereas in the Hettangian-Lower Sinemurian there is a lack of larger agglutinated benthic foraminifera. In addition to the 5 genera mentioned above, (except Haurania/Amijella), *Lituolipora* GUŠIĆ & VELIĆ also appears at the beginning of the Late Sinemurian (VELIĆ, 2007). These data do not show a Hettangian but instead a (Late) Sinemurian origination event. This fits better with the data of other invertebrates, showing a minimum number of genera in the Hettangian, the “sur-
ance of favourable shallow-water facies, e.g., the Trento plateau in the southern Alps (e.g. FUGAGNOLI & LORIGA BROGLIO, 1998) or the Saharan Platform (e.g. WILMSEN & NEUWEILER, 2007). It is worth mentioning, that this extinction event in platform-dwelling larger benthic foraminifera didn’t happen exactly at the Pliensbachian-Toarcian boundary, but covered the whole Pliensbachian (BASSOULLET, 1997, Tab. L1). Biokovina and Orbitopsella did not survive the intra-Pliensbachian extinction as was the general assumption also for Cymbriaella prior to our new data. Then in the Late Aalenian, Cymbriaella lorigae and Everticyclammina praevirguliana are recorded again and the new genus Dubrovnikella appeared. Until now, there were no records of Everticyclammina known from the Late Pliensbachian until the Callovian/Oxfordian (FUGAGNOLI, 2000, Fig. 4). The Late Aalenian Croatian findings fill this gap.

After the Toarcian crisis, some new genera arose such as Timidonella BASSOULLET, CHABRIER & FOURCADE, Spiraloconulus ALLEMAN & SCHROEDER, Gutnicella MOULLADE, HAMAN & HUDDLESTON or Dubrovni-

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Table 3: Dimensions of Bosniella bassoulleti n. sp., Upper Aalenian–Lower Bajocian of Croatia. ed = equatorial diameter (mm), dup = diameter uncoiled part (mm), ad max = maximum axial diameter (mm), ad min = minimum axial diameter at umbilical region (mm), n = number of chambers in the last whorl, ne = number of chambers in the uncoiled test portion. Mean values were not calculated for those parameters with only a few data available.
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