

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



Felix Schlagintweit¹ and Ivo Velić²

¹Lerchenauerstr. 167, D-80935 München, Germany; (ef.schlagintweit@t-online.de)

²Croatian Geological Survey, Sachsova 2, 10000 Zagreb, Croatia; (ivo.velic@hgi-cgs.hr)

doi: 104154/gc.2011.08

Geologia Croatica

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 biostratigraphical 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 Biokovo and in the vicinity of Karlovac (central Croatia) (ANIĆ, 1962; RADOIČIĆ, 1966; GUŠIĆ 1969b). VELIĆ (2005) reported on Aalenian–Bajocian foraminiferal assemblages of southern Croatia, from Biokovo 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 ficcarellii* CHIOCCHINI & 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 Biokovo 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-

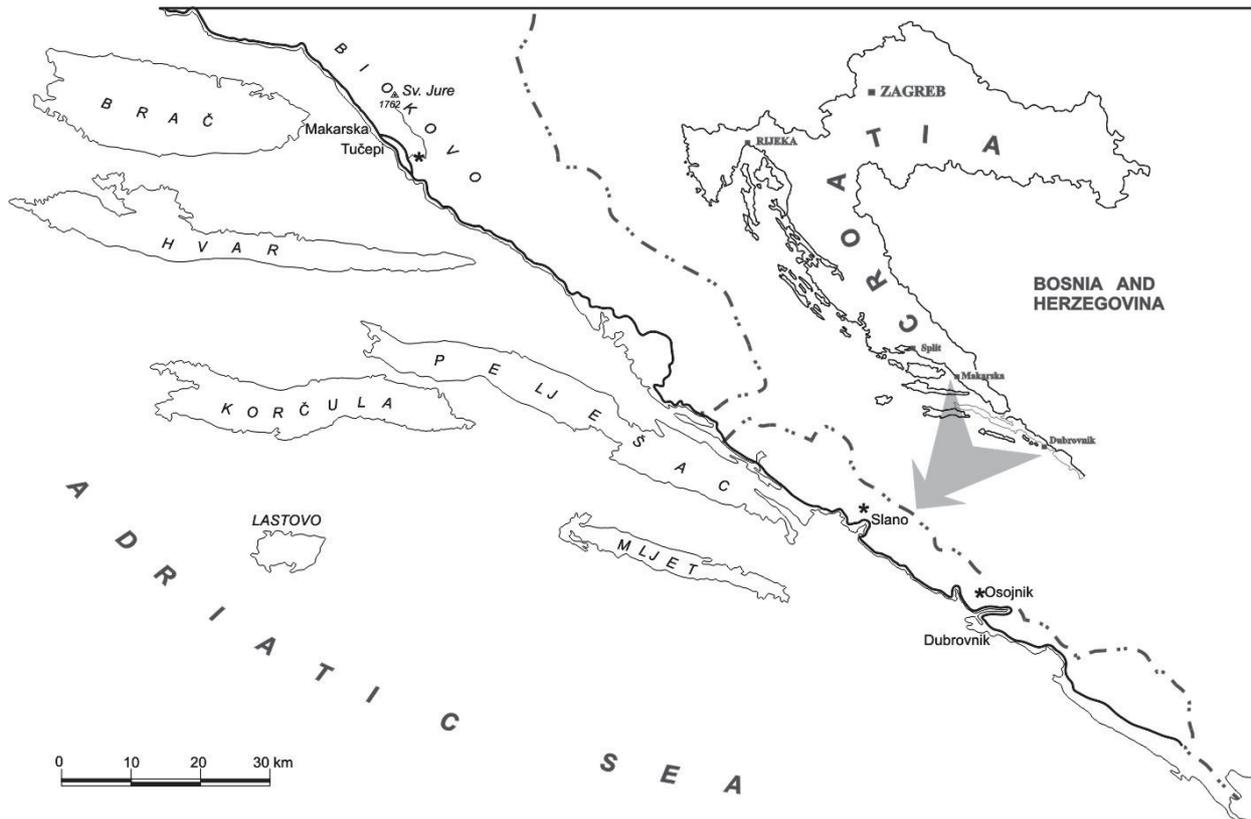


Figure 1: Geographic position of the investigated sections in Croatia (asterisks). OS = Osojnik village 5 km north of Dubrovnik, SL = Slano village about 25 km NW of Dubrovnik, BST = Biokovo section.

velopment 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 thrust over the Palaeogene clastic sediments. Carbonates are in direct contact with clastic 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-

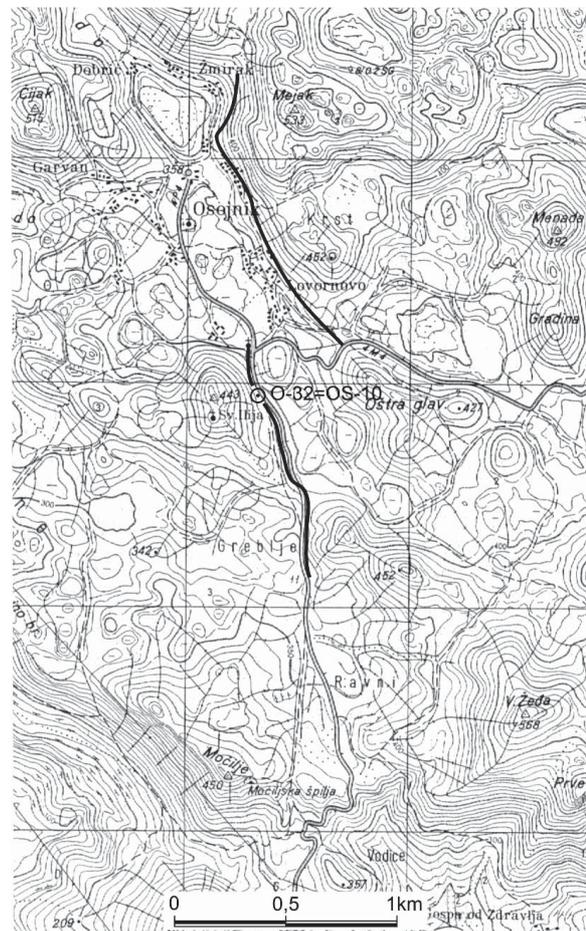


Figure 2: Local geographic map (Dubrovnik sheet, no. 625-3-1), scale 1:25.000 with the position of the Osojnik section and sample O 32 (= O 10) containing the holotype of *Bosniella bassoulleti* n. sp. ⇒

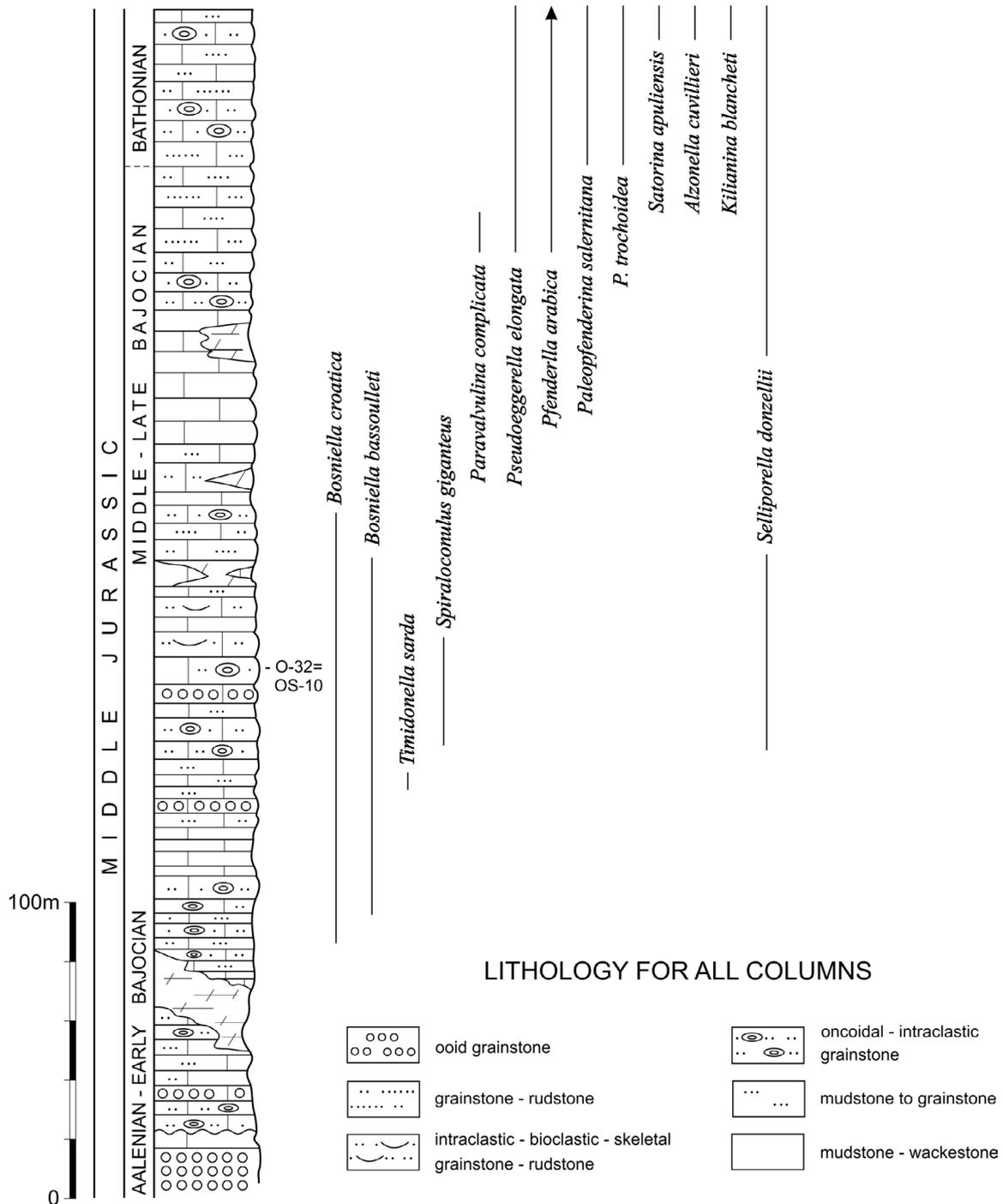


Figure 3: Lithostratigraphy of the Osojnik section and distribution of important larger benthic foraminifera.

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

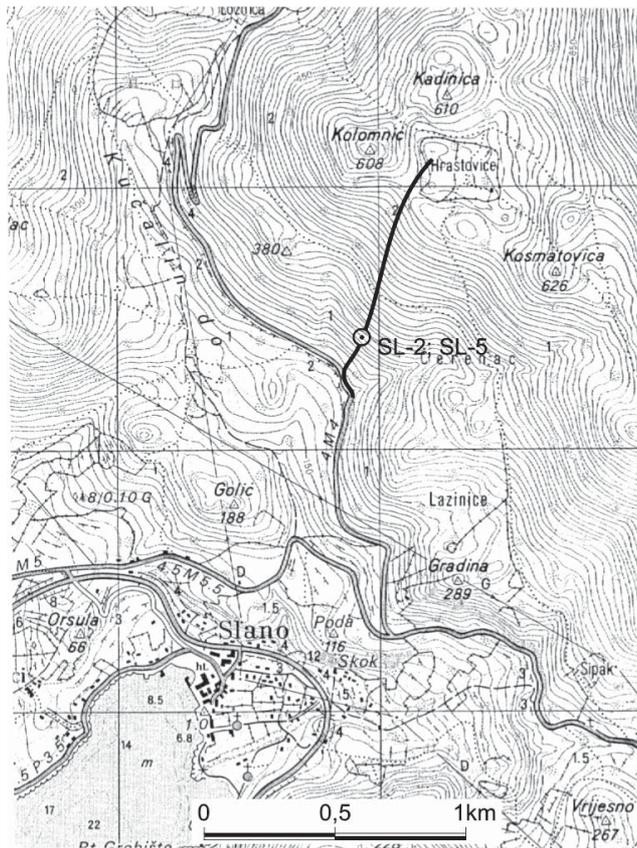


Figure 4: Local geographic map (Slano sheet, no. 624-2-4), scale 1:25,000 with the position of the Slano section, the type-locality of *Dubrovnikella septfontainei* n. gen. n. sp.

(mainly gastropods), corals, stromatoporoids, foraminifera, 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 *Bosniella croatica* and then *Bosniella bassoulleti* n. sp. (Fig. 3). These limestones are overlain by approximately 20 m of mudstone and again bioclastic/intraclastic-oncoidal grainstones which, in addition to the aforementioned biokovinitids, includes (in the order of appearance) *Timidonella sarda* and *Spiraloconulus giganteus*. Above the layers with *Timidonella*, the following ~60 m of the succession is characterized by the first appearance of the biostratigraphically significant dasycladale *Selliporella donzellii* (SARTONI & CRESCENTI), and by the maximum frequency of *B. bassoulleti* n. sp. Within this interval, sample OS-10 (= O-32; Fig. 2) contains the holotype of this species. Between the last appearance of *B. bassoulleti* n. sp. and the first occurrence of the younger Bajocian species *Paravalvulina complicata* there are no other significant foraminifera. Within the range of *P. complicata*, the species *Pseudoeggerella elongata* SEPTFONTAINE with an Upper Bajocian–Bathonian range and *Pfenderella arabica* REDMOND of a wider stratigraphic range appear. The thickness of the Upper Aalenian and Bajocian carbonates, between the Aalenian ooid limestones and the Bathonian limestones is about 360 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, stromatoporoids, calcareous algae, and foraminifera. 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., *Pseudocyclamina 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 dasycladalean 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

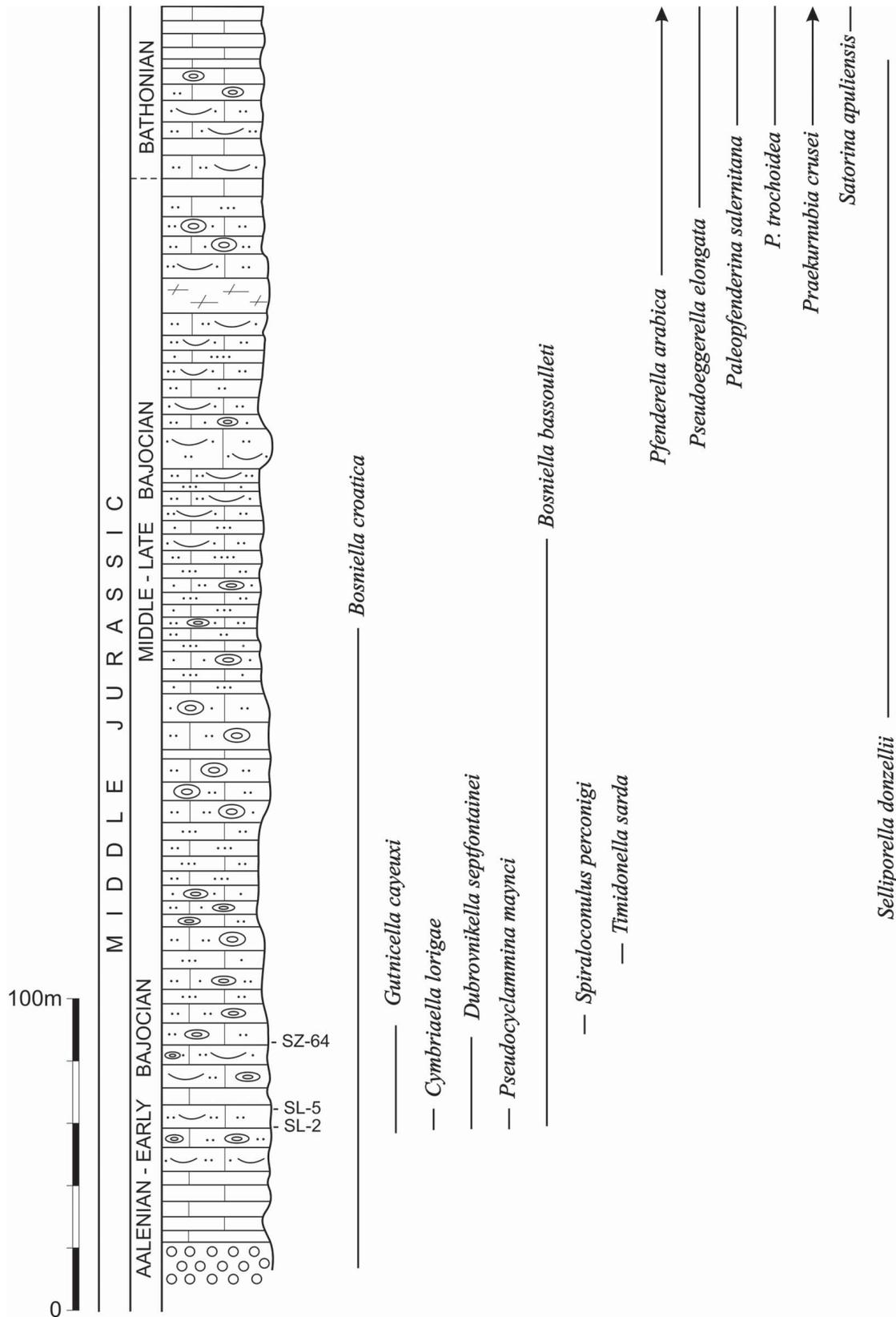


Figure 5: Lithostratigraphy of the Slano section and distribution of important larger benthic foraminifera.

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 for-

aminifers. 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.

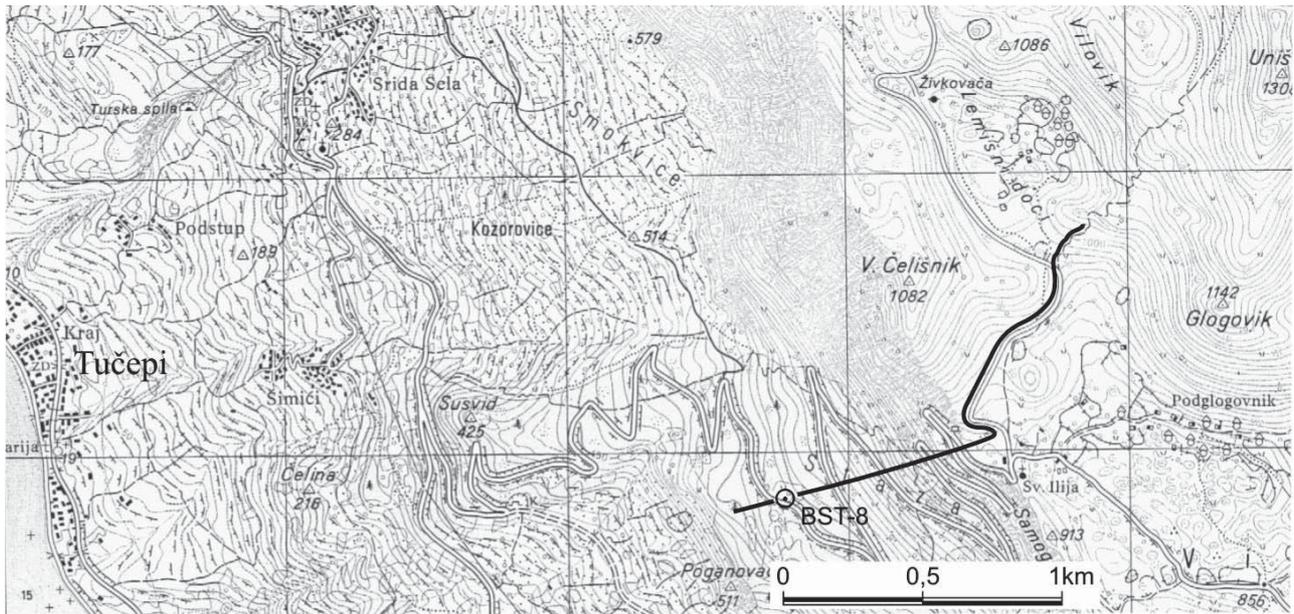


Figure 6: Local geographic map (Makarska sheet, no. 126-1-3), scale 1 : 25.000 with the position of the Biokovo section.

Among the foraminifera, *Bosniella croatica* and *Gutniella cayeuxi* were already present in the ooid limestones, overlain by about 50 m of thick-layered skeletal-oncoidal 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 oncoid and skeletal grainstones/packstones with *Everticyclammina praevirguliana* FUGAGNOLI (Fig. 7). Above the thin ooid limestones there is a sequence of thick-bedded, oncoidal, skeletal grainstones with rare *G. cayeuxi* and more frequent *Timidonella 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 *Spiralocomulus 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 jursasica* 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 *Pfenderella arabica*, there are no important foraminiferal species. About 10 m above, in the topmost Bajocian beds, *Paravalvulina complicata* and *Pseudoeggerella 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 PALAEOLOGY

The systematics follows the “year 2000 classification” of KAMINSKI (2004). For the diagnosis of genera, we essentially follow LOEBLICH & TAPPAN (1987). The description mainly follows the terminological compendium of HOTTINGER (2006).

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-

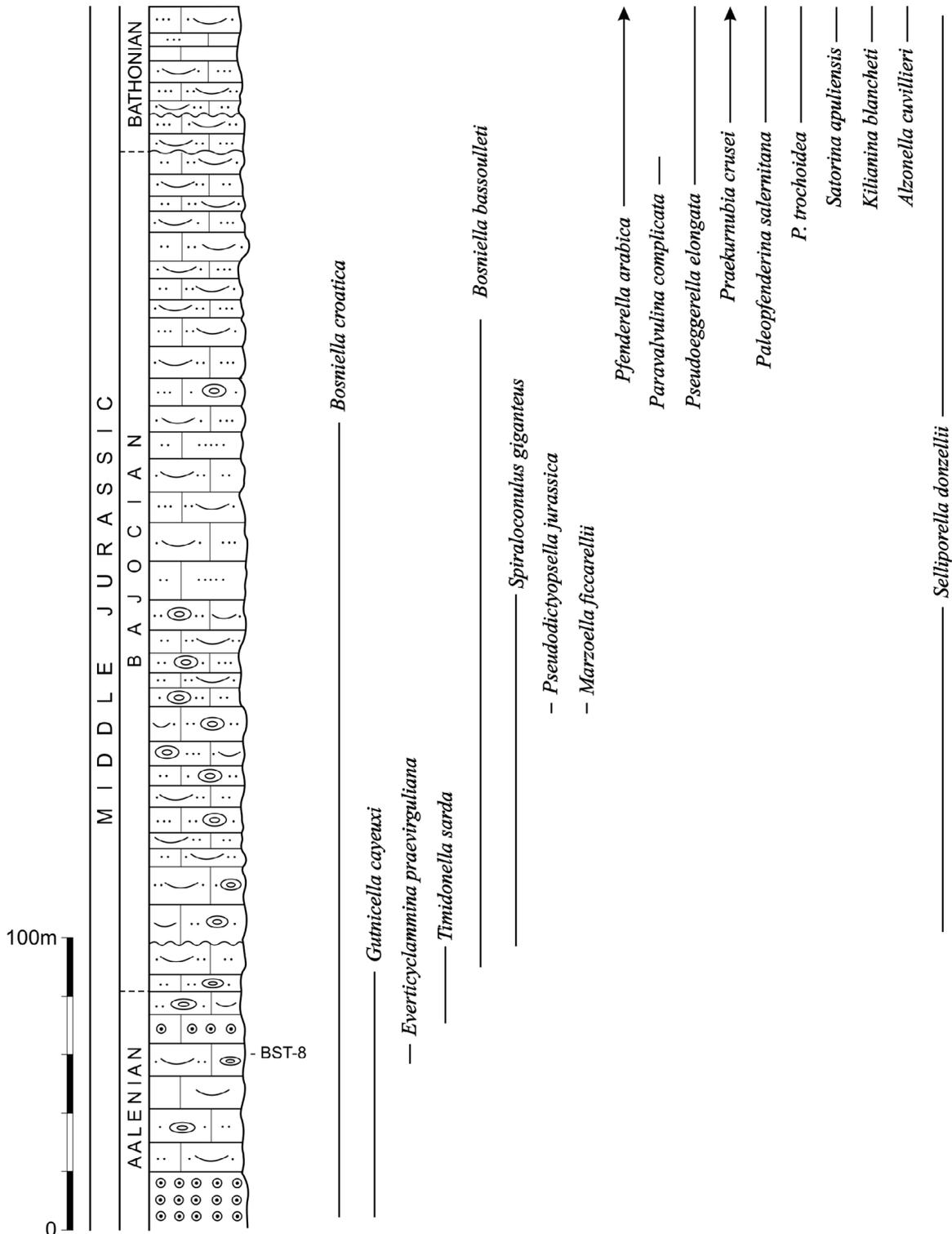


Figure 7: Lithostratigraphy of the Biokovo section and the distribution of important larger benthic foraminifera.

clude *Dubrovnikella septfontainei* n. gen., n. sp. (rare), *Bosniella bassoulleti* n. sp. (rare), *Gutnicella cayeuxi* (rare), *Agerina martana* (FARINACCI) (very rare), small textularids and trochospiral forms, e.g., tetrataxids (common) and a triserial ataxophragmiid foraminifer gen. et sp. indet. (common) (Fig. 9). Thaumaporellaceans 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 Biokoviniidae GUŠIĆ, 1977

Remarks: *Bosniella* was removed from the Biokoviniidae by MIKHALEVICH (2004) due to the lack of endoskeletal

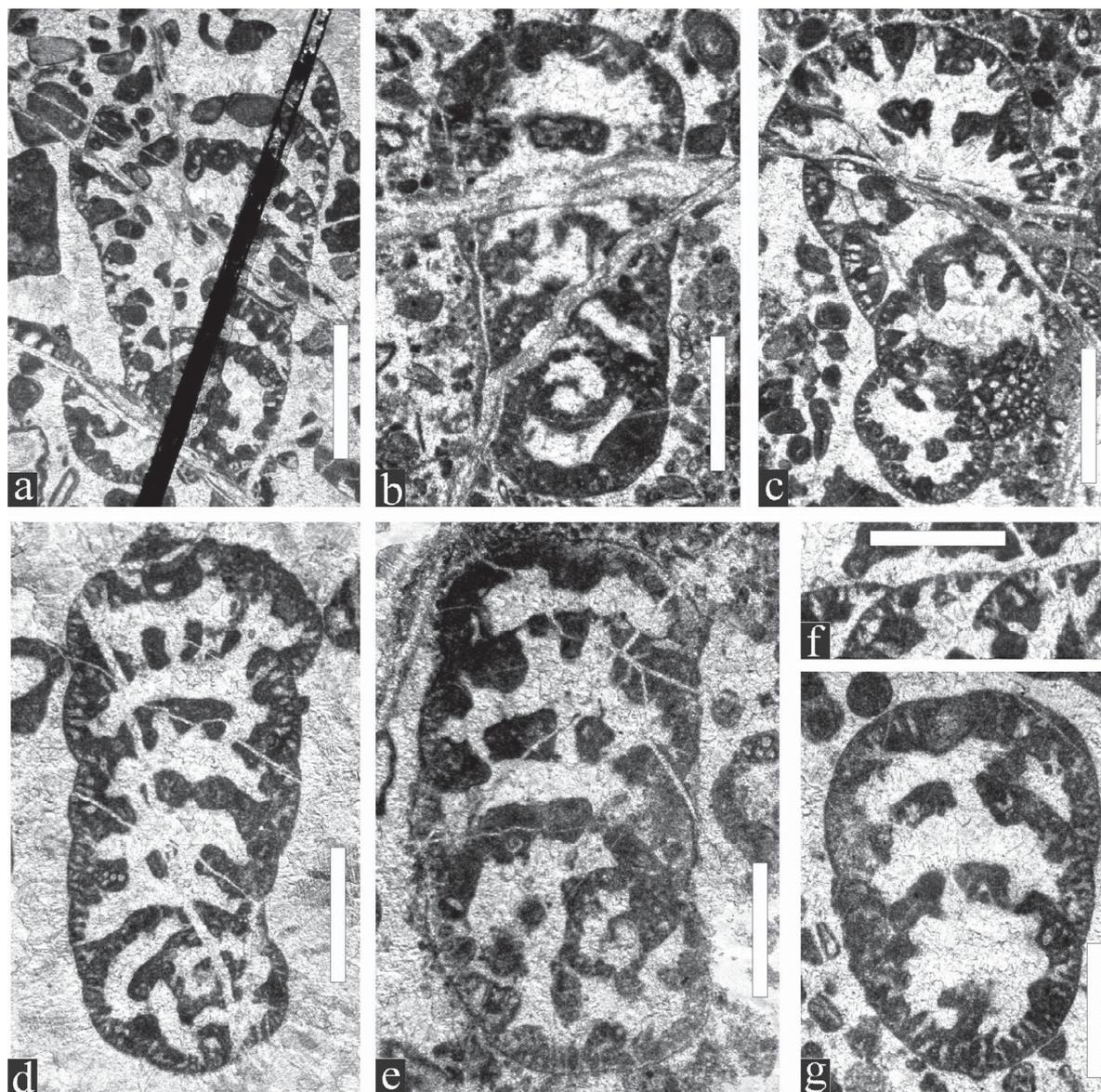


Figure 8: *Cymbriaella lorigae* FUGAGNOLI. Upper Aalenian–Lower Bajocian of the Croatian Karst Dinarides. a) Equatorial section, uncoiled portion with 5 chambers. Note incorporation of small particles (peloids, foraminifera) into the wall and septa. b) Equatorial section, slightly oblique. c) Axial section, slightly oblique. d–e) Equatorial sections with 5 and 3 chambers in the uncoiled portion. Note single aperture in the coiled part becoming multiple in the uncoiled part and both thick wall and septa. f) Detail of a showing alveolar wall. g) Oblique section through the uncoiled part. Scale bar 1mm, except f 0.5 mm. Thin sections: a SL 3A/3, b SL 3B/2, c SL 3B/1, d SL 5B2, e SL 3B/2, g SL 3A.

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 Biokoviniidae 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 Biokoviniidae.

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 Bassoulet 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-*

	d	dup	hup	h	n	thin section
1	1.5	2.3	3.0	4.4	5	SL 3A/3
2	0.9	1.15	1.25	2.2	3	SL 3B/2
3	-	1.6	-	3.25	3	SL 3B/1
4	1.25	1.55	-	3.2	5	SL 5B/2
5	2.5	2.55	2.55	2.95	3	SL 3B/2
6	-	1.3	-	-	-	SL 3A
min.	0.9	1.3	1.25	2.2	3	
max.	2.5	2.55	3.0	4.4	5	

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.

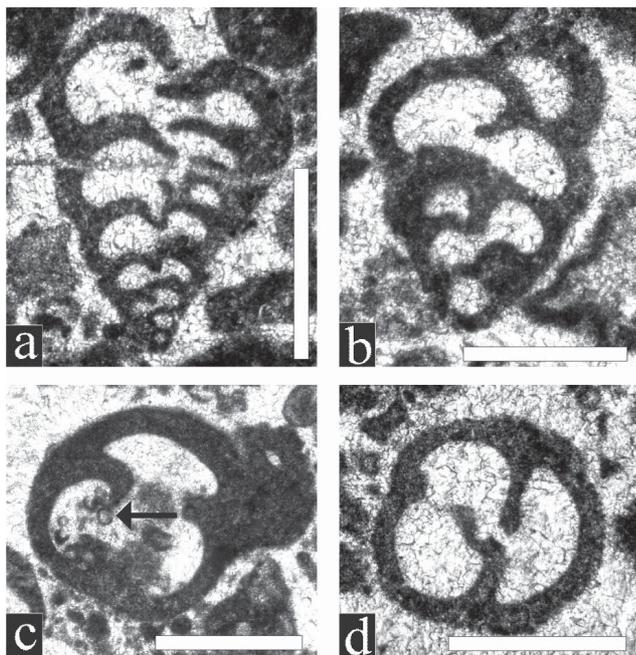


Figure 9: Triserial ataxophragmiid foraminifera gen. et sp. indet. a) Longitudinal section. b) Oblique longitudinal section. c) Oblique transverse section; note tiny sphaeroids (?coccoid cyanobacteria) inside the chamber (arrow). d) Transverse section. Scale bars 0.5 mm. Thin sections: a SL 3/B, b SL 3A, c O 32/B, d SZ 64/3.

soulleti, rare *Spiraloconulus giganteus*, *Siphovalvulina variabilis*, triserial ataxophragmiid foraminifer gen. et sp. indet. (Fig. 9), bioclasts 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 often not 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-

	Phylum Foraminifera d'ORBIGNY		Class Foraminifera d'ORBIGNY
Order	Foraminiferida d'ORBIGNY		Loftusiida KAMINSKI & MIKHALEVICH
Suborder	Textulariina DELAGE & HEROUARD		Biokovinina KAMINSKI & MIKHALEVICH
Superfamily	Biokovinacea GUŠIĆ	Biokovinoidea GUŠIĆ	Biokovinacea GUŠIĆ
Family (Genus)	Biokoviniidae GUŠIĆ (<i>Biokovina</i> GUŠIĆ) (<i>Bosniella</i> GUŠIĆ)	Biokoviniidae GUŠIĆ (<i>Biokovina</i> GUŠIĆ) Charentiidae LOEBLICH & TAPPAN (<i>Bosniella</i> GUŠIĆ)	Biokoviniidae GUŠIĆ (<i>Biokovina</i> GUŠIĆ) (<i>Bosniella</i> GUŠIĆ)
authors	LOEBLICH & TAPPAN 1987	MIKHALEVICH 2004	KAMINSKI 2004

Table 2: Systematic position of the genera *Bosniella* GUŠIĆ and *Biokovina* GUŠIĆ within the Foraminiferida after LOEBLICH & TAPPAN (1987), MIKHALEVICH (2004) and KAMINSKI (2004).

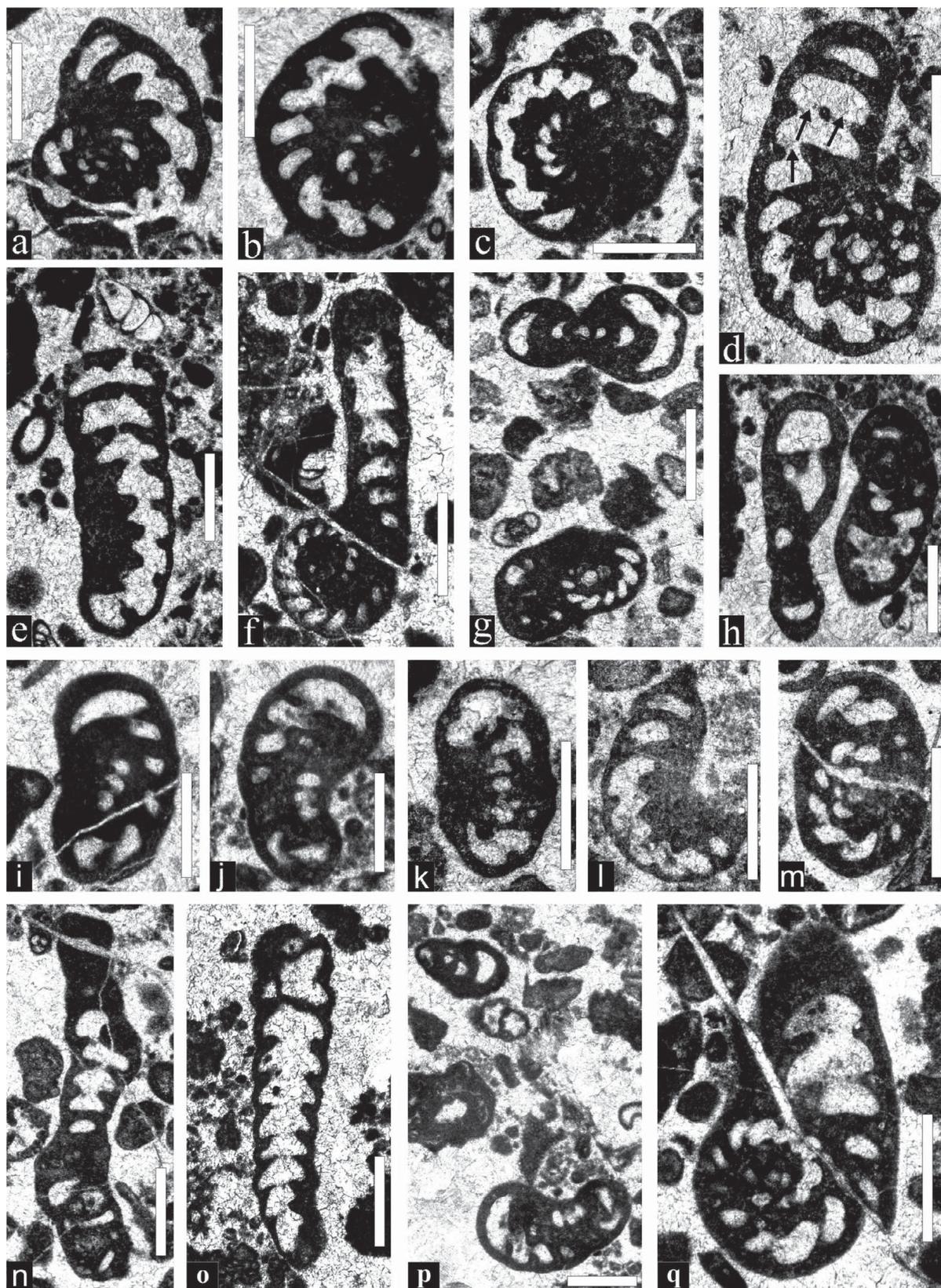


Figure 10: *Bosniella bassoulleti* n. sp. Upper Aalenian–Lower Bajocian of the Croatian Karst Dinarides. a–c, e–q Isotypes. d Holotype. a–d) Equatorial sections, in part slightly oblique. Holotype specimen (d) with uncoiled part consisting of three chambers; note multiple foramina evolving in the uncoiled portion (arrows). e–f) Specimens with prominent uncoiled part with 6 (?7) 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.

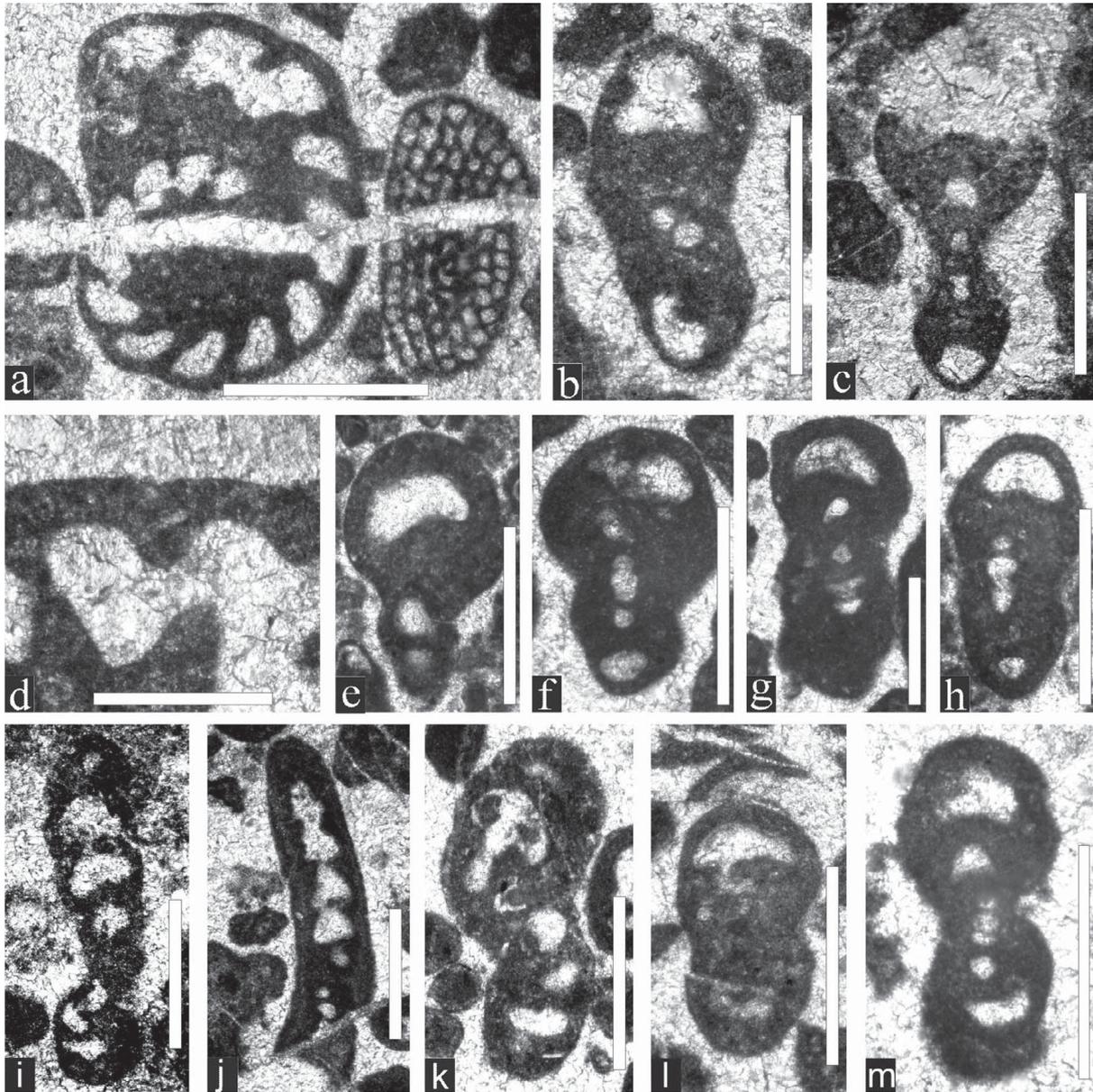


Figure 11: *Bosniella bassoulleti* n. sp. Upper Aalenian–Lower Bajocian of the Croatian Karst Dinarides. a–m Isotypes. a) Equatorial section; on the right *Gutnicella cayeuxi* (Lucas). b–c) (Sub)axial sections, in part slightly oblique. Note distinct biumbonal depression in c and oscillating coiling direction in b. d) Magnification from the holotype specimen of Fig. 10d showing the poorly recognizable keriothecal wall structure. e–i) (Sub)axial sections, in part slightly oblique. Note significant increase in chamber width within the ultimate whorl in e and f. j) Broken uncoiled portion; note the more or less constant chamber width. k–m) (Sub)axial sections. Note sigmoidal test bending of specimen shown in k. Scale bar 0.3 mm in d, all other pictures 0.5 mm. Thin sections: a SL 4a/1, b, i SL 2/1, c SL 3/b/2, d Os 10/1, e, f, g, h, m O 32/b, j SL 3A/3, k SL 4/4, l Os 10.

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-

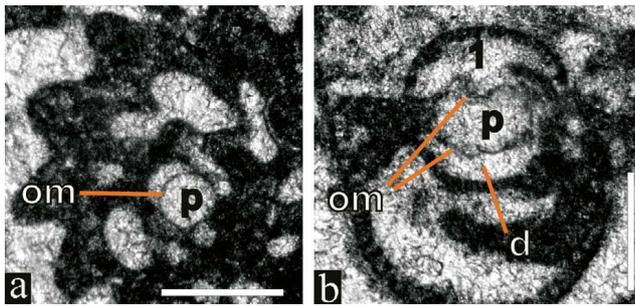


Figure 12: Simple embryonic apparatus of *Bosniella bassoulleti* n. sp. (a) and complex embryonic apparatus of *Dubrovnikella septfontainei* n. sp. (b). d = deuteroconch, p = protoconch, om = organic membran, 1 = first post-embryonic chamber. a sample Os 10, b sample SL 5B/2 (see also Fig. 16i). Scale bars 0.2 mm.

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 uncoiled part remaining constant (Fig. 10f), and others with increasing width (Fig. 10o).

B. croatica (GUŠIĆ) (Early-Middle Jurassic of Croatia = former *Mesoendothyra croatica*, according to BASSOULLET, 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; BASSOULLET, 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 foraminifera is triggered by the trophic regime. The genera *Cymbriaella*, *Bosniella* and *Lituolipora* 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 subspherical 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 *Gutnicella cayeuxi*, 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* cenozoone (Bajocian) has been established in the Taurus Mountains of Turkey (ALTINER & SEPTFONTAINE, 1979), later modified to a *Timidonella sarda*-*Selliporella donzellii* zone (EKMEKÇI & 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 $\frac{1}{2}$ to $\frac{3}{4}$.

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 canaliculated inner layer and an outer imperforate layer*” (KAMINSKI, 2004, p. 250). In contrast to other representatives of the Biokoviniidae, such as *Bosniella* GUŠIĆ and *Biokovina* GUŠIĆ, the pores in the wall of *Dubrovnikella* are distinctly coarser; it is noteworthy that in the diagnosis of the family Biokoviniidae provided by LOEBLICH & TAPPAN (1987, p. 91) the wall is said to be “coarsely perforate”. For the superfamily Biokovinea, LOEBLICH & TAPPAN (1985, p. 94) characterize the wall as “finely agglutinated, with outer imperforate layer and coarsely perforate or canaliculated inner layer in later stage”. *Biokovina* is unique within the biokoviniids 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 Biokoviniidae GUŠIĆ is *Trochamijiella* 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 protocanaliculate or canaliculated*” (ATHERSUCH et al. 1992, p. 7) it cannot be included in the Biokoviniidae sensu GUŠIĆ 1977 (see also LOEBLICH & TAPPAN, 1987). The complex embryonal apparatus consisting of a protoconch and deuteroconch or spheroconch (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 *Lituolipora* GUŠIĆ & VELIĆ and *Cymbriaella* FUGAGNOLI. *Lituolipora* with a more irregular coiling and a discoidal 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 Kosmatovica and Kolomnić hills (Fig. 4).

Type-level: Thick-bedded, light-brownish, skeletal-bioclastic-oncoidal 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 cayeuxi* and in association with *Bosniella bassoulleti*, *Cymbriaella lorigae*, *Spiraloconus perconigi*, *Pseudocyclammina maynci*, small foraminifera, bioclasts of corals, echinoderms, molluscs, thaumatoporellaceans etc., but before the first appearance of rare *Timidonnella 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 biumbilicate, later with a slight tendency to be streptospiral, consisting of $\frac{1}{2}$ 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.

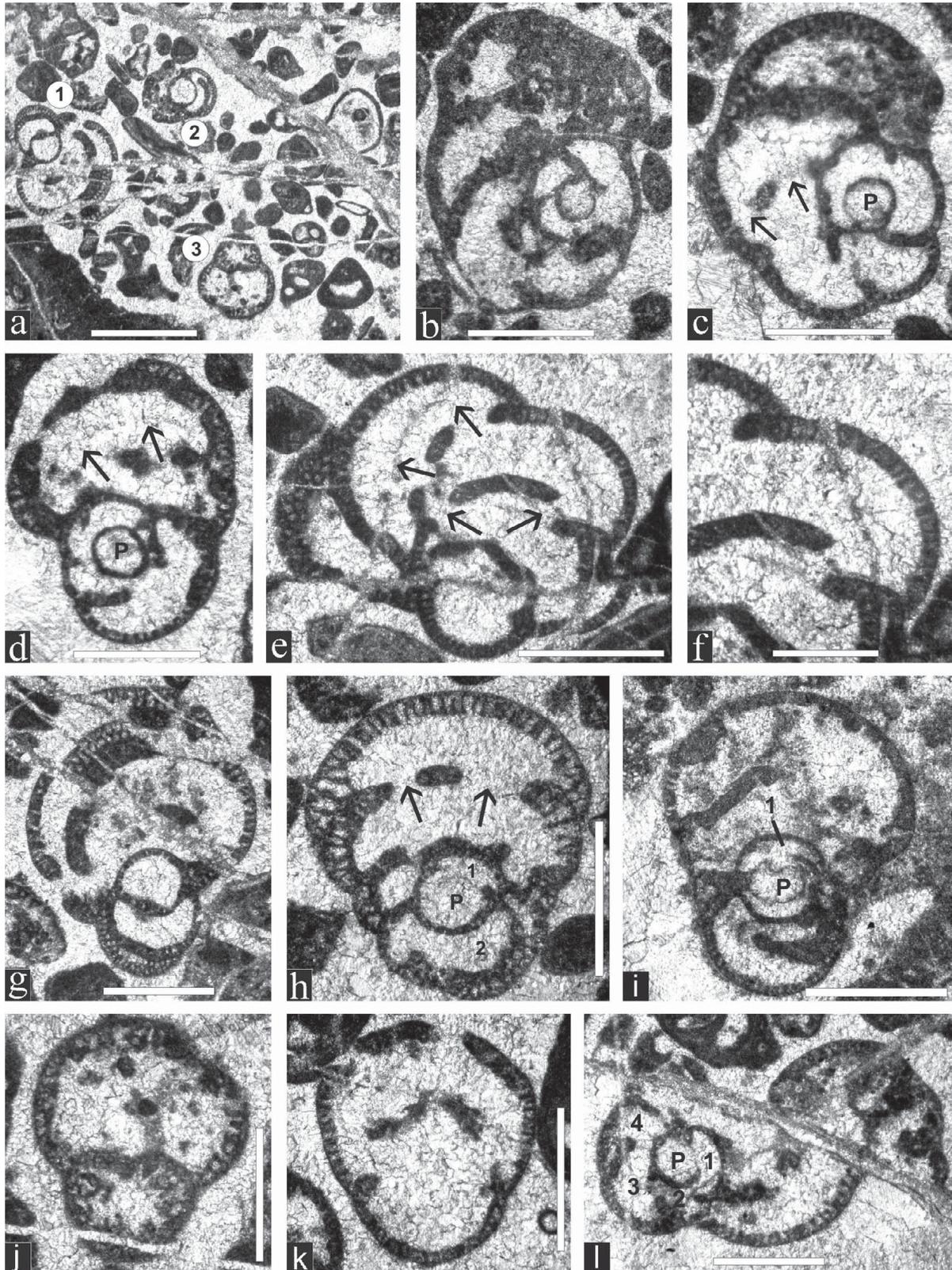


Figure 13: *Dubrovnikella septfontainei* n. gen., n. sp. Upper Aalenian–Lower Bajocian of the Croatian Karst Dinarides. a) Grainstone with three specimens of *Dubrovnikella septfontainei* and other small benthic foraminifera. b–d) Equatorial sections, slightly oblique; c = holotype specimen. e) Oblique 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, j 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, k SL 2-3, l SL 4a-4.

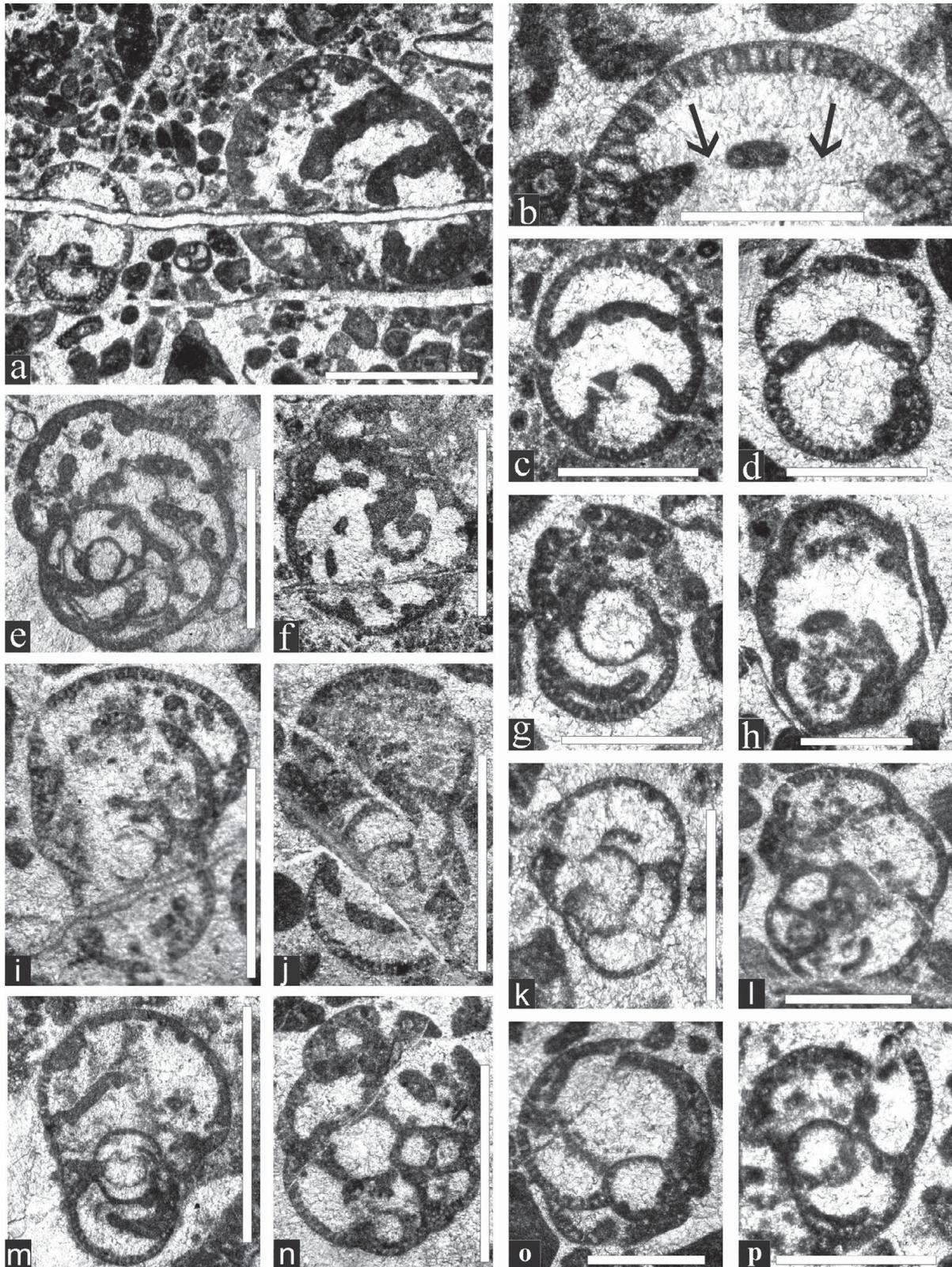


Figure 14: *Dubrovnikella septfontainei* n. gen., n. sp. Upper Aalenian–Lower Bajocian of the Croatian Karst Dinarides. a) Poorly sorted packstone with *Dubrovnikella septfontainei* n. gen., n. sp. (left) and *Cymbriaella lorigae* FUGAGNOLI (right). b) Detail of Fig. 13h showing palisade-like parallel-arranged 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 chambre). 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.

Suborder Loftusiina KAMINSKI & MIKHALEVICH, 2004
Superfamily Loftusiacea BRADY, 1884
Family Everticyclamminidae SEPTFONTAINE, 1988
Genus Everticyclammina REDMOND, 1964
Everticyclammina praevirguliana FUGAGNOLI, 2000
 (Figs. 15a–d)

Remarks: The Croatian specimens of *Everticyclammina praevirguliana* agree closely with the Late Sinemurian–Pliensbachian 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–Pliensbachian 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 *Timidonella sarda*.

Microfacies: Intraclastic-bioclastic oncoidal and skeletal grainstone to packstone, rarely wackestone of back reef environment. *Everticyclammina praevirguliana* is associated with rare *Bosniella croatica*, *Gutnicella cayeuxi*, *Cymbriaella 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 shows a “small dip” at the Triassic/Jurassic boundary. Within the Jurassic period, KUZNETSOVA et al. (1996, p. 121) recognized two major evolutionary stages (megaphases): early to middle Jurassic and the late Jurassic to early Cretaceous. Concerning the appearance of “many species”, the authors recognize “obvious markers” at the base of the Bathonian, the upper Bathonian, the beginning of the Oxfordian and at the base of the Tithonian. More detailed information concerning this topic is provided by the data compilation of KA-

MINSKI et al. (2010, Fig. 5) showing that the origination rate of agglutinated foraminiferal genera had its Phanerozoic maximum in the Hettangian. This prominent peak was named the “Hettangian origination” by KAMINSKI et al. (2010), actually covering the Hettangian–Pliensbachian interval and “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 Pliensbachian) 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 Pliensbachian. Our data allows the enlargement of the stratigraphic range into the Lower Bajocian.

Haurania HENSON: Independent of the morphological intricacies (*Haurania* vs *Amijiella*), 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–Pliensbachian of the Southern Alps, Italy. As its ancestor, a species of *Amobaculites* 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 recoarensis* described by CATI (1959) from the Pliensbachian of the Southern Alps. According to BASSOULLET (1997) and VELIĆ (2007) it is known from the Latest Early Sinemurian to the earliest Lower Pliensbachian.

Biokovina GUŠIĆ: So far monospecific with *Biokovina gradacensis* described by GUŠIĆ (1977) from the Pliensbachian of Croatia. The possible total stratigraphic range extends from the uppermost Late Sinemurian to the lowermost Late Pliensbachian (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/Amijiella*), *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-

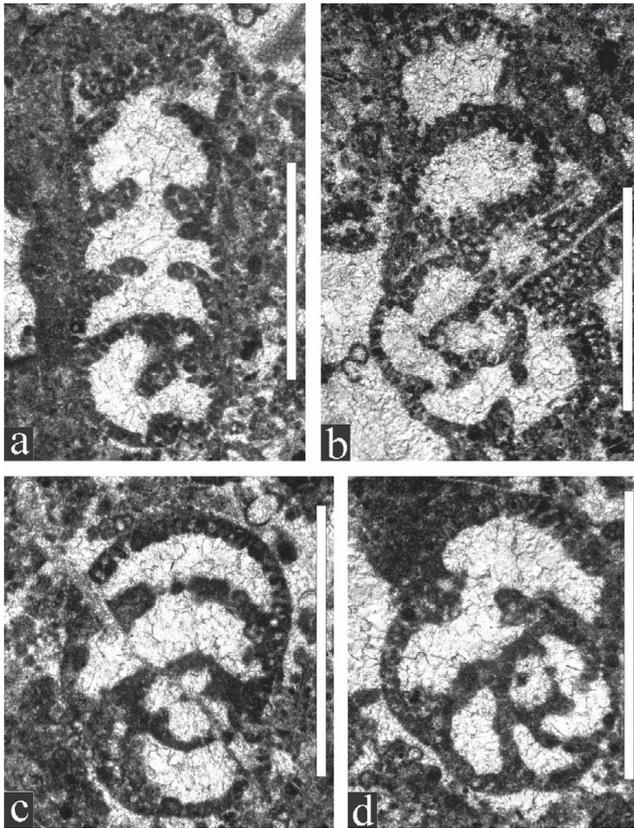


Figure 15: *Everticyclammina praevirguliana* FUGAGNOLI from the Upper Aalenian–Lower Bajocian of Mount Biokovo section. a–b) Slightly oblique equatorial section of uncoiled specimen. c) Oblique axial section. d) Equatorial section. Due to the size of the proloculus in b–d, these can be referred to megalospheric forms. As the uncoiled portion of the microspheric specimen should not exceed two chambers, figure a can also be considered megalospheric. Note that the proloculus is not visible due to oblique sectioning.

Scale bars 1 mm. Thin sections: a BST 8-2, b, d BST 8-3, c BST 8.

vival phase” in the aftermath of the end-Triassic mass-extinction, then increasing steadily during the Sinemurian (“recovery phase”) (e.g. WILMSEN & NEUWEILER, 2007, Fig. 17; ROMANO et al., 2008, Fig. 6). For the Hettangian to Lower Sinemurian Tethyan shallow-water carbonates, assemblages of small-sized textularids and miliolids together with opportunistic taxa such as *Duotaxis*, are recorded (e.g. BOUDAGHER-FADEL & BOSENCE, 2007), interpreted as reflecting eutrophic conditions (FUGAGNOLI, 2004). Especially in the Late Sinemurian to Early Pliensbachian interval, larger benthic foraminifera show a progressive diversification (e.g. BOUDAGHER-FADEL & BOSENCE, 2007). There is a significant reduction of larger benthic foraminifera in the Toarcian, following a step-by-step extinction of several species and genera during the Pliensbachian (see BASSOULLET, 1997, Tab. 51; VELIĆ, 2007, Fig. 7). This extinction event can be seen in connection with a general biological crisis of other groups such as ammonoids that have been linked with the Toarcian oceanic anoxic event (OAE) (e.g. JENKYN, 1988; WIGNALL & HALLAM, 1997; CECCA & MACCHIONI, 2004; BILOTTA et al., 2010). Many platforms were drowned, resulting in the disappear-

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. LI). *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, *Spiraloconus* ALLEMAN & SCHROEDER, *Gutnicella* MOULLADE, HAMAN & HUDDLESTON or *Dubrovni-*

	ed	dup	ad max	ad min	n	ne	thin section
1	1.2	-	-	-	12	-	O 32b
2	1.08	-	-	-	12	-	Os 10
3	1.16	-	-	-	12	-	O 32a
4	1.72	0.57	-	-	11	3	Os 10
5	2.08	0.56	-	-	-	4	SZ 64/4
6	1.72	0.35	-	-	14	6	SL 2/1
7	1.02	-	0.54	0.25	-	-	Os 10
8	1.46	-	0.47	0.25	-	-	O 32a
9	1.04	-	-	-	-	-	O 32b
10	1.12	-	-	-	-	-	O 32b
11	0.76	-	-	-	-	-	O 35
12	0.96	0.38	-	-	-	3	SL 2/1
13	0.8	-	-	-	12	-	SL 4/1
14	2.1	0.37	-	0.25	-	-	SL 4A
15	1.92	0.45	-	-	-	7	SZ 64/5
16	1.44	-	-	-	12	4	SL 4A
17	0.95	0.5	-	-	13	-	SL 4A/1
18	0.78	-	0.34	0.25	-	-	Os 10
19	0.65	-	0.28	0.20	-	-	SL 2/1
20	0.76	-	0.36	0.18	-	-	O 32b
21	1.0	-	0.37	0.25	-	-	SL 4/4
22	1.0	-	0.56	0.30	-	-	O 32b
23	0.62	-	0.42	0.23	-	-	O 32b
24	1.13	-	0.52	0.39	-	-	O 32b
25	0.72	-	0.35	0.25	-	-	O 32b
min.	0.62	0.37	0.28	0.18	11	3	
max.	2.1	0.57	0.56	0.39	14	7	
mean	1.17	-	0.42	0.25	-	-	

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.

kella n. gen. Previously, the Middle Jurassic shallow-water carbonates of the Karst Dinarides were considered to be poor in benthic foraminifera. New investigations, however, have shown that these are distinctly richer in taxa than the Lower Jurassic strata; many of these representing index forms (VELIĆ, 2007). Our new findings can be considered as further evidence of this observation.

ACKNOWLEDGMENT

Field and laboratory investigations were supported by the Croatian Geological Survey and the Croatian Ministry of science, education and sports of the Republic of Croatia, projects 1951953068-0241 “Microfossil assemblages in carbonate deposits of the Karst Dinarides”, and 181-1811096-1093 “Basic geological map of the Republic of Croatia 1:50.000”. We kindly acknowledge the helpful comments of the two reviewers Ivan GUŠIĆ (Zagreb) and Kemal TASLI (Mersin). A warm thank to Julie ROBSON for the English review of the paper.

REFERENCES

- ALTINER, D. & SEPTFONTAINE, M. (1979): Micropaléontologie, stratigraphie et environnement de déposition d'une série Jurassique à facies de plate-forme dans la region de Pinarbasi (Taurus Oriental, Turquie).— *Rev. de Micropal.*, 22, 3–18.
- ANIĆ, D. (1962): Beiträge zur Kenntnis der Jura- und Kreideschichten des östlichen Teiles des Biokovo Gebirges.— *Geol. vjesnik*, 15, 161–176.
- ATHERSUCH, J., BANNER, F.T. & SIMMONS, M.D. (1992): On *Trochamijiella gollesstanehi*, gen., nov. et sp. nov. (Foraminifera, Loftusiacea), an index for the Middle Eastern marine Late Bathonian.— *J. Micropaleontol.*, 11/1, 7–12.
- BASSOULLET, J.-P. (1997): Les Grands foraminifères.— In: CARIOU, E. & HANTZPERGUE, P. (coord.): *Biostratigraphie du Jurassique ouest-européen et Méditerranéen: zonations parallèles et distribution et microfossiles*. Bulletin des Centres de Recherches Exploration-Production Elf-Aquitaine Mémoire, 17, 293–304.
- BASSOULLET, J.-P. (1994): *Bosniella fontainei* nov. sp., (Foraminifère, Biokoviniidae) du Jurassique Moyen de Thaïlande.— *Géobios*, 27, 403–411.
- BOUDAGHER-FADEL, M.K. (2008): Evolution and geological significance of larger benthic foraminifera.— *Dev. in Palaeontol. Stratigraphy*, 21, 1–544.
- BOUDAGHER-FADEL, M.K., ROSE, E.P.F., BOSENCE, D.W.J. & LORD, A.R. (2001): Lower Jurassic Foraminifera and calcified microflora from Gibraltar, western Mediterranean.— *Palaeontology*, 44/4, 601–621.
- BOUDAGHER-FADEL, M.K. & BOSENCE, D.W.J. (2007): Early Jurassic benthic foraminiferal diversification and biozones in shallow-marine carbonates of the Tethys.— *Senck. lethaea*, 87/1, 1–39.
- BILOTTA, M., VENTURI, F., SASSAROLI, S. (2010): Ammonite faunas, OAE and the Pliensbachian-Toarcian boundary (Early Jurassic) in the Apennines.— *Lethaia*, 43/3, 357–380. doi: 10.1111/j.1502-3931.2009.00201.x
- CATI, F. (1959): Nuovo lituolide nei Calcari Grigi liassici del vicentino.— *Giorn. di Geol.*, 27, 1–10.
- CECCA, F. & MACCHIONI, F. (2004): The two Early Toarcian (Early Jurassic) extinction events in ammonoids.— *Lethaia*, 37, 35–56. doi: 10.1080/00241160310008257
- CHIOCCHINI, M., FARINACCI, A., MANCINELLI, A., MOLINARI, V. & POTETTI, M. (1994): Biostratigrafia a foraminiferi, dasicladali e calcionelle delle successioni carbonatiche mesozoiche dell'Appennino Centrale (Italia).— *Stud. Geol. Camerti*, Vol. spec. „Biostratigrafia dell'Italia centrale”, 9–129.
- CHIOCCHINI, M., CHIOCCHINI, R.A., DIDASKALOU, P. & POTETTI, M. (2008): Ricerche micropaleontologiche e biostratigrafiche sul Mesozoico della piattaforma carbonatica laziale-abruzzese (Italia centrale).— *Mem. Descr. Carta Geol. Ital.*, 84, 5–170.
- EKMEKÇI, E. & ALTINER, D. (2008): *Timidonella? primitiva* n. sp. (Foraminifera) from the Middle Jurassic of the Eastern Taurides (Southern Turkey): Remarks on evolutionary steps of Hauraniids.— *Turk. J. Earth Sci.*, 17, 73–84.
- FUGAGNOLI, A. (1999): *Cymbriaella*, a new foraminiferal genus (Textulariina) from the Early Jurassic of the Venetian Prealps (North-eastern Italy).— *Rev. de Micropal.*, 42, 99–110.
- FUGAGNOLI, A. (2000): First record of *Everticyclammina* REDMOND 1964 (*E. praevirguliana* n. sp.; Foraminifera) from the Early Jurassic of the Venetian Prealps (Calcari Grigi, Trento Platform, Northern Italy).— *J. Foramin. Res.*, 30/2, 126–134. doi: 10.2113/0300126
- FUGAGNOLI, A. (2004): Trophic regimes of benthic foraminiferal assemblages in Lower Jurassic shallow water carbonates from north-eastern Italy (Calcari Grigi, Trento Platform, Venetian Prealps).— *Palaeogeog., Palaeoclimatol., Palaeoecol.*, 205/1–2, 111–130. doi: 10.1016/j.palaeo.2003.12.004
- FUGAGNOLI, A. & LORIGA BROGLIO, C. (1998): Revised biostratigraphy of Lower Jurassic shallow water carbonates from the Venetian Prealps (Calcari Grigi, Trento Platform, Northern Italy). *Studi Trentini Sci Nat – Acta Geol.*, 73 (1996), 35–73.
- GRANIER, B. & DELOFFRE, R. (1994): Inventaire critique des algues dasycladales fossiles II^e Partie – les algues dasycladales du Jurassique et du Crétacé.— *Rev. Paléobiol.*, 12, 19–65.
- GUŠIĆ, I. (1969a): Some new and inadequately known Jurassic foraminifera from Central Croatia.— *Geol. vjesnik*, 22, 55–88.
- GUŠIĆ, I. (1969b): Biostratigraphic and micropaleontologic characteristics of some Jurassic cross-sections in central Croatia.— *Geol. vjesnik*, 22, 89–97.
- GUŠIĆ, I. (1977): A new foraminiferal family, Biokoviniidae, from the Jurassic of the Dinarides and its phylogenetic relationships.— *Palaeontol. Jugoslavica*, 18, 7–31.
- GUŠIĆ, I. & VELIĆ, I. (1978): *Lituolipora polymorpha* n. gen., n. sp. (Foraminifera, Lituolacea?) from the Middle Liassic of the Outer Dinarids in Croatia and the establishment of a new family, Lituoliporidae.— *Geol. vjesnik*, 30, 73–93.
- HAIG, D.W., MCCARTAIN, E., BARBER, L. & BACKHOUSE, J. (2007): Triassic-Lower Jurassic foraminiferal indices for Bahamian-type carbonate-bank limestones, Cablac Mountain, East Timor.— *J. Foramin. Res.*, 37/3, 248–264. doi: 10.2113/gsjfr.37.3.248
- HOTTINGER, L. (1967): Foraminifères imperforés du Mésozoïque marocain.— *Edit. Serv. Geol. Maroc*, 1–128.
- HOTTINGER, L. (2006): Illustrated glossary of terms used in foraminiferal research.— *Carnets de Géologie – Notebooks on Geology Mem 2006/02 (CG2006_M02)*.
- JENKYN, H.C. (1988): The Early Toarcian (Jurassic) anoxic event: Stratigraphic, sedimentary and geochemical evidence.— *Am. J. Sci.*, 288, 102–151.
- KAMINSKI, M.A. (2004): The year 2000 classification of the agglutinated foraminifera.— In: BUBÍK, M. & KAMINSKI, M.A. (eds): *Proc. 6th Int. Workshop agglutinated foraminifera*, Grzybowski Foundation Special Publication, 8, 237–255.
- KAMINSKI, M.A., SETOYAMA, E. & CETEAN, C.G. (2010): The Phanerozoic diversity of agglutinated foraminifera: origination and extinction rates.— *Acta Palaeontol. Pol.*, 55/3, 529–539. doi: 10.4202/app.2009.0090

- KUZNETSOVA, K.I., GRIGELIS, A.A., ADJAMIAN, J., JARMAK-ANI E. HALLAQ, L. (1996): Zonal stratigraphy and Foraminifera of the Tethyan Jurassic (Eastern Mediterranean).— Amsterdam, Gordon and Breach Publ., 256 p.
- LOEBLICH, A.R., Jr. & TAPPAN, H. (1985): Some new and redefined genera and families of agglutinated Foraminifera I.— *J. Foramin. Res.*, 15/2, 91–104.
- LOEBLICH, A.R., Jr. & TAPPAN, H. (1987): Foraminiferal genera and their classification.— 2 volumes (Van Nostrand Reinhold) New York, 1–970.
- MIKHALEVICH, V. (2004): On the new understanding of the order Lituolida LANKESTER, 1885 (Foraminifera).— *Acta Palaeontologica Romaniae*, 4, 247–267.
- NIKLER, L. & SOKAČ, B. (1968): Biostratigraphy of the Jurassic of Velebit (Croatia).— *Geol. vjesnik*, 21, 161–176.
- ÖZKAYMAK, A., İŞİNTEK, İ., GÜNGÖR, T. & ALTINER, D. (2010): Foraminiferal content and age of the Lower-Middle Jurassic Homa-Akdağ (Afyonkarahisar, Sandıklı, Turkey) sedimentary sequence. 63rd Geol Congr of Turkey, 5–9 April 2010, Ankara, Abstracts Book, 62–63.
- RADOIČIĆ, R. (1966): Microfaciès du Jurassique des Dinarides externes de la Yougoslavie.— *Geologia*, 9, 5–378.
- ROMANO, R., MASETTI, D., CARRAS, N., BARATTOLO, F. & ROGGI, G. (2008): The Triassic/Jurassic boundary in a peritidal carbonate platform of the Pelagonian domain: the Mount Messapion section (Chalkida, Greece).— *Riv. Ital. Paleontol. S.*, 114, 431–452.
- SCHLAGINTWEIT, F. & VELIĆ, I. (2011): Foraminiferan tests and dasy-cladalean thalli as cryptic microhabitats for thaumaporellacean algae from Mesozoic (Early Jurassic – Late Cretaceous) platform carbonates.— *Facies*. doi: 10.1007/s10347-010-0263-8
- SEPTFONTAINE, M. (1980): Les Foraminifères imperforés des milieux de plate-forme au Mésozoïque: Détermination pratique, interprétation phylogénétique et utilisation biostratigraphique.— *Rev. Micropal.*, 23, 169–203.
- SEPTFONTAINE, M. (1988): Vers une classification évolutive des Lituolidés (foraminifères) jurassiques en milieu de plate-forme carbonatée. *Rev. Paléobiol.*, vol. spec. 2 (Benthos '86), 229–256.
- SEPTFONTAINE, M., ARNAUD-VANNEAU, A., BASSOULLET, J.P., GUŠIĆ, I., RAMALHO, M. & VELIĆ, I. (1991): Les Foraminifères imperforés des plate-formes carbonatées jurassiques: état des connaissances et perspectives d'avenir.— *Bull. Soc. Vaud. Sc. Nat.*, 80/3, 255–277.
- TANNER, L.H., LUCAS, S.G. & CHAPMAN, M.G. (2004): Assessing the record and causes of Late Triassic extinctions.— *Earth Sci. Rev.*, 65, 103–13.
- VELIĆ, I. (1977): Jurassic and Lower Cretaceous Assemblage-zones in Mt. Velika Kapela, central Croatia.— *Acta Geol.*, 9, 15–37.
- VELIĆ, I. (2005): Benthic foraminifera assemblages and stratigraphic subdivision of the Middle Jurassic in Karst Dinarides, Adriatic carbonate platform.— In: VELIĆ, I., VLAHOVIĆ, I. & BIONDIĆ, R. (eds.): 3rd Croatian Geological Congress, Opatija, 2005, Abstracts book, Croatian geological Survey, Zagreb, 159–160.
- VELIĆ, I. (2007): Stratigraphy and palaeobiogeography of Mesozoic benthic foraminifera of the Karst Dinarides (SE Europe).— *Geol. Croat.*, 60, 1–113.
- VELIĆ, I. & SOKAČ, B. (1978): Biostratigraphic analysis of the Jurassic and Lower Cretaceous in wider region of Ogulin (central Croatia).— *Geol. vjesnik*, 30, 309–337.
- VLAHOVIĆ, I., TIŠLJAR, J., VELIĆ, I. & MATIČEC, D. (2005): Evolution of the Adriatic Carbonate Platform: Palaeogeography, main events and depositional dynamics.— *Palaeogeogr., Palaeoclimatol., Palaeoecol.*, 220, 333–360.
- WIGNALL, B. & HALLAM, A. (1997): Mass extinctions and their aftermath.— Oxford University Press, 320 p.
- WILMSEN, M. & NEUWEILER, F. (2007): Biosedimentology of the Early Jurassic post-extinction carbonate depositional system, central High Atlas rift basin, Morocco.— *Sedimentology*, 55, 773–807. doi: 10.1111/j.1365-3091.2007.00921.x

Manuscript received January 31, 2011

Revised manuscript accepted March 24, 2011

Available online June 09, 2011

