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Linoporella buseri Radoičić, 1975, revisited. A Liassic dasycladalean alga from the Dinarides and continental Italy

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Abstract. The Liassic *Linoporella buseri* is re-examined, on the basis of an abundant material of reefal origin, originating from the newly described type-locality in Slovenia. It is compared with the Berriasian–Valanginian type-species *L. capriotica*, studied by Barattolo & Romano (2005). Both species have three orders of laterals. In *L. buseri*, however, apart of other, clear cut differences, the tertiary laterals are usually hair-like, occasionally phloiophorous at tip, forming a distal cortex such as in *L. capriotica*. Consequently, the genus *Linoporella* is slightly emended, to fit observations made on the two species.

Key words: Dasycladales, *Linoporella buseri*, Liassic, Slovenia.

Апстракт. Преиспитана је лијаска алга *Linoporella buseri* на основу обилног материјала спрудног подручја који потиче из накнадно описаног типског локалитета у Словенији. Упоређење је вршено са типском беријаско-валендиском врстом *L. capriotica* према студији Barattolo & Romano (2005). Обје врсте имају по три реда огранака. Међутим, *L. buseri* се разликује по томе што има терцијарне огранке, обично танке, ријетко флоиоформне на врху, гдје формирају кортекс као и *L capriotica*. Сходно овоме, род *Linoporella* је благо емендиран на основу обсервација у обје врсте.

Кључне ријечи: Dasycladales, *Linoporella buseri*, лијас, Словенија.

Geological introduction by late *Stanko Buser*

In 1975, while mapping in the Kanin mountain range of the Julian Alps, a small outcrop of Liassic limestone containing *Linoporella buseri* was discovered at coordinates 46°18'36.9" N; 13°27'51.13" E. So far, it is the only known locality containing this alga in Slovenia (Radoičić, 1975). The site (Fig. 1) is on the left bank of the small Učja river, about 1200 m west of a bridge crossing this river at Žaga, southwest of Bovec, exactly 100 m west of a hay-barn at Hlebišče.

The Liassic limestone containing the algae occurs as a tectonically isolated klippe covering some 500 m^2 along the Idrija fault, between the Upper Triassic Dachstein limestone and the Main dolomite. The klippe forms in the landscape an about 4-m high terrace step. Rare algae are found in the massive primary limestone and also as fragments of rubble at foot of the wall.

The limestone with algae was deposited on the mobile margin of the Julian carbonate platform. In this area, the Dinaric and the Julian carbonate platforms occur directly next to the other, without the intermediate Slovenian basin that pinches out and does not extend farther westward to neighboring Italy. North of the aforementioned locality, at Bovec, a Liassic oolitic and sparitic limestone conformingly overlies the Upper Triassic Dachstein limestone with megalodontids. Both the Dachstein limestone and the Liassic limestone are cut by sedimentary dikes consisting of Liassic red coloured calcareous breccias and crinoid limestone. These dikes are especially frequent in the Kanin Mountains. At Bovec, the oolitic Liassic limestone is overlain by a pelagic limestone of the Ammonitico rosso type containing manganese nodules.

Systematic taxonomy

The following, indicative hierarchy is given provisionally, pending a more general revision of concepts

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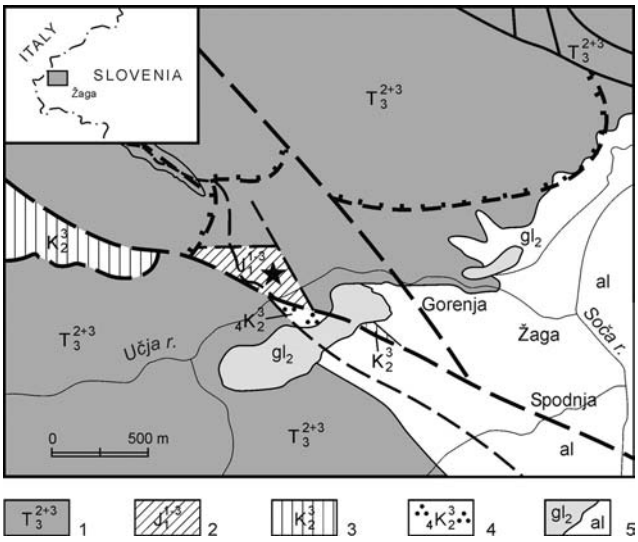

Fig. **1,** Upper Triassic; **2,** Lower Jurassic (Liassic); **3,** Senonian pink marly limestone and marl; **4,** Kampanian–Maastrichtian flysch; **5.** Glacial sedimnets and Aaluvial.

governing the definition of a genus in certain fossil Dasycladales. A few comments are given below.

Family *Triploporellaceae* (PIA, 1920) BERGER & KEAVER, 1992
Tribe *Triploporelleae* (PIA, 1920) BUCUR, 1993

Genus ***Linoporella*** STEINMANN, 1899, emend.

Emendation of the genus. BARATTOLO & ROMANO (2005, p. 238) provided the following emendation of the genus *Linoporella*, in the wake of their outstanding revision of the Berriasian-Valanginian type-species *Linoporella capriotica* STEINMANN: "Cylindrical to slightly club-shaped simple thallus. Primary laterals arranged in close whorls. Short primary laterals and long, thin secondary laterals. Tertiary laterals are phloiophorous in shape and form a cortex. Reproductive organs probably placed within the central stem (endosporate-type)." Previous emendations of *Linoporella* were proposed, first by BASSOULLET *et al*. (1978), calling for the occurrence of only two orders of laterals, then by DIENI *et al*. (1985), based on the presence of three orders in *Linoporella buseri*. As shown by GAWLICK *et al*. (2006, p. 116), the genus *Pentaporella* SENOWBARI-DARYAN is a junior synonym of *Linoporella*.

A re-description of *L. buseri* is given below. It includes the occasional presence of a distal enlargement of the tertiary laterals, forming a cortex. Consequently, a slight emendation of the genus *Linoporella* is proposed as follows: "Thallus simple, cylindrical to slightly club-shaped. Main axis cylindrical or slightly intusannulated, bearing contiguous whorls of up to three orders of laterals. Primary laterals comparatively short and thick, oblique or perpendicular to the main axis, tubular or slightly widening outwards. Elongated, tubular and comparatively slender secondary laterals are clustered at tip of the primaries. Slender tertiary laterals are clustered at tip of the secondaries. They are either hair-like throughout, or phloiophorous at tip, forming a distal cortex. Reproductive organs probably placed within the central stem (endosporate-type)."

Systematics. Reference is made to the work of BARATTOLO & ROMANO (2005, p. 238) for discussion on the species referable to *Linoporella* and its probable endospory. Consequently, at a higher level, diagnosis of the family *Triploporellaceae*, as far as applicable, should be emended to include endospory. Herein, the following diagnosis proposed by BUCUR (1993, p. 78) for the tribe *Triploporelleae* is provisionally taken into account: "Thallus cylindrical, claviform, moniliform or spherical; ramifications of the first and second order, possibly the third or fourth." On the other hand, the subtribe *Linoporellinae* PIA, 1927, nom. transl. should be emended, for, according to BERGER & KEAVER (1992, p. 38) it includes taxa with only two orders of laterals, while three are present in *Linoporella*.

Recently, BUCUR *et al*. (2009) created another new genus, *Steinmanniporella* (type-species the Upper Jurassic *S. kapelensis,* sub-tribe *Linoporellinae*), with only two orders of laterals instead of three in the type-species *L. capriotica*. Purpose was to include four Upper Jurassic to Paleocene species originally assigned to the genus *Linoporella*. Endospory is inferred or taken as possible for both *Linoporella* and *Steinmanniporella*. Worth mentioning, quoting SOKAČ & NIKLER (1976) "Spores [= cysts] can sometimes be observed in the wider part of both the primary and secondary branches" of the Upper Jurassic–Lower Cretaceous *Linoporella ? svilajaensis*.

Linoporella buseri RADOIČIĆ, 1975
Pls. 1, 2

1975 *Linoporella buseri* sp. nov. – RADOIČIĆ, p. 277, fig. 1. [Liassic of the Julian Alps, Slovenia].
1978 *Linoporella ? buseri* RADOIČIĆ, 1975 – BASSOULLET *et al*., p. 147, pl. 17, figs. 10-12. [Review work, the genus is emended].
1985 *Linoporella buseri* – DIENI *et al*., p. 14. [three orders of laterals occur; the genus is emended].
1994 *?Linoporella buseri* RADOIČIĆ – CHIOCCHINI *et al*., pl. XXXIV, fig. 3, 4. [Sinemurian, Latium, Italy].
2001 *Palaeodasycladus asteriscus* n. sp. – SOKAČ, p. 166, pls. 39, 40. [Lower Liassic, Croatia].
2005 *Linoporella buseri* RADOIČIĆ – BARATTOLO & ROMANO, p. 238. [Species referable to the genus].

Type specimens, depository. The holotype is depicted in Pl. 1, Fig. 2. All other herein-illustrated specimens from the type-locality are isotypes. The holotype and the isotypes are housed in the R. RADOIČIĆ collection, in the Geological Institute of Serbia, Belgrade.

Diagnosis, revisited. The short diagnosis given in RADOIČIĆ (1975) is elaborated as follows. "Thallus simple, cylindrical, rounded or slightly acuminated at tip. Main axis cylindrical or slightly intusannulated, bearing contiguous whorls of up to three orders of laterals. Primary laterals rather stout, tubular, proximally and distally constricted (spindle-like), first horizontal or slightly tilted in main portion of the thallus, markedly tilted at the apex. Four or five, tubular and comparatively slender, more or less diverging and curved second order laterals are clustered at tip of the primaries. In most cases, three hair-like tertiary laterals are clustered at tip of the secondaries. Occasionally, the tertiaries are phloiophorous at tip, apparently forming a cortex. Calcareous skeleton solid, forming a sleeve, assumed of primary aragonitic origin. Endospory inferred.

Description. The calcareous skeleton is massive, neither undulated or fissurated, cylindrical with no evidence of a capitulum-shaped head. As shown by Pl. 1, Fig. 1 and Pl. 2, Fig. 5, the axial cavity is cylindrical, even if slightly altered, matching the axis. Occasionally however, as shown by a nice oblique-longitudinal section illustrated by SOKAČ (2001, pl. 39, fig. 1), the stipe is slightly intusannulated.

Primary laterals: due to the alteration of the axial cavity, the proximal constriction denoting the attachment of the primaries to the axis is seldom left, such as in Pl. 1, Fig. 6 and, pro parte, Pl. 1, Fig. 1. As shown for example by Pl. 1, Fig. 1, in the main, cylindrical portion of the thallus, the primaries are perpendicular or slightly oblique to the stipe. But there are exceptions, such as in the oblique section shown in Pl. 2, Fig. 5, with primary laterals oriented at 45°. On the other hand, at or close the apex of the thallus, the primaries are characteristically oblique (Pl. 1, Fig. 7; Pl. 2, Figs. 1, 8).

Second order laterals: the quite irregular orientation of the 4-5, tubular second order laterals is best shown in the tangential section of Pl. 1, Fig. 11. Close to the apex of the thallus (Pl. 2, Fig. 7), the secondaries keep their modest width throughout their length.

Third order laterals: although often obliterated by microbioerosion, clusters of three, hair-like tertiaries are found in most sections of *L. buseri*, in both the main cylindrical portion (Pl. 1, Fig. 2; Pl. 2, Fig. 10) and the apex of the alga (Pl. 2, Fig. 6; Pl. 1, Fig. 7). Occasionally, however, as shown by the tangential section of Pl. 1, Fig. 11, the tertiary laterals are phloiophorous at tip, apparently forming a cortex. The same applies to certain sections illustrated by SOKAČ (2001; pl. XXXIX, figs. 1-3), under the name of *Palaeodasycladus asteriscus*.

Dimensions. Measurements carried out on numerous topotype specimens of *L. buseri* are as follows:

Outer diameter (D): 1.0–2.9 mm.
Diameter of the axis, or axial hollow (d): 0.36–1.5 mm.
d/D ratio: 0.28–0.51.
Distance between the whorls (h): 0.46–0.60 mm.
Number of primary laterals (w): 12–20 per whorl.
Length of the primary laterals (l): 0.28–0.48 mm.
Thickness of the primary laterals (p): 0.11–0.20 mm.
Number of secondary laterals (w'): 4–5 per cluster.
Length of the secondary laterals (l'): 0.21–0.32 mm.
Thickness of the secondary laterals (p'): 0.04–0.12 mm.
Number of tertiary laterals (w''): three per cluster.
Calcified length of the tertiary laterals (l''): 0.21–0.32 mm.

Thickness of the tertiary laterals (p''): in most cases ca. 0.4 mm; in one case 0.13 mm at tip, forming a cortex.

Euendolithic microorganisms. Many fragments of *L. buseri* and accompanying dasycladalean algae are more or less heavily altered, eroded or even disintegrated by one or several epi- and/or euendolithic microrganisms. Microbioerosion was at work on the margin of the skeleton (e.g. Pl. 1, Fig. 11, 12) and penetrated the first order laterals, spreading laterally (Pl. 1, Fig. 5; Pl. 2, Fig. 10). Seldom (Pl. 2, Fig. 11), a yet unidentified, calcifying euendolithic microorganism is embedded in the bioeroded cavities, forming ca. 0.3 mm-wide rosettes. Interestingly, similar processes of bioerosion were also at work in some of the specimens of *L. buseri* of Italy and Croatia.

Comparisons. The Berriasian–Valanginian type-species *Linoporella capriotica* also has three orders of laterals. In this species however, the thallus is cylindrical to slightly club-shaped, the primary laterals are shorter, compared to *L. buseri*, the secondaries (2–5 in number) much longer, and the tertiaries (2–3 in number) phloiophorous, forming a distal cortex, according to BARATTOLO & ROMANO (2005).

Accompanying biota. Numerous pieces of a large (outer diameter up to 3.5 mm) dasycladalean alga, provisionally named *Palaeodasycladus* ? sp. (Pl. 2, Figs. 11-14), are present in the type-material of *L. buseri*. The thallus looks simple, cylindrical or slightly club-shaped, with a wide, intusannulated axial cavity and, separately, up to five orders of slender laterals. An ad hoc description and correct naming of this taxon is beyond the scope of this article, also because it requires a reconsideration of the systematic taxonomy adopted by SOKAČ (2001). Other biota include *Dinarella* ? sp. (Pl. 2, Fig. 9), *Involutina liassica* (foraminifer), *Rivularia* ? sp. ("Porostromata"), brachiopods and bivalves.

Distribution, depositional environment. So far, *Linoporella buseri* was reported from the Liassic of Slovenia, Croatia and continental Italy. The stratum-typicum of *L. buseri* consists of coarse grained grainstones containing numerous, freshly broken pieces of dasycladalean algae. As shown by the presence of isopachous and palisade cements, part at least of the deposit is of meteoric, phreatic or upper intertidal origin. Comparable environments are reported for the other occurrences of the species.

Conclusions

Further to the work of BARATTOLO & ROMANO (2005), the genus *Linoporella* is again slightly emended, to com-

ply with observations carried out on numerous topotype specimens of *Linoporella buseri*. *Linoporella* now comprises three species, all with three orders of laterals: the Rhaetian *L. rhaetica* (SENOWBARI-DARYAN), the Liassic *L. buseri* RADOIČIĆ and the Berriasian–Valanginian *L. capriotica* (OPPENHEIM). Four other, Upper Jurassic to Paleocene species originally assigned to *Linoporella*, all with two orders of laterals, are transferred by BUCUR *et al*. (2009) to their new genus *Steinmanniporella*.

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Резиме

Linoporella buseri RADOIČIĆ 1975, преиспитивање. Лијаска дазикладалеска алга из Динарида и континенталне Италије

Фамилија *Triploprellaceae* (PIA,1920) BERGER & KEAVER, 1992
Трибус *Triploporelleae* (PIA, 1920) BUCUR, 1993

Род ***Linoporella*** STEINMANN, 1899, emend.

BARATTOLO & ROMANO (2005, p. 238) дали су следећу емендацију рода *Linoporella* у свијетлу изразито добре ревизије типске беријаско-валендиске врсте *L. capriotica*: "Једноставан цилиндричан или благо кијичаст талус. Примарни огранци сложени у густе пршљенове. Кратки примарни и дуги танки секундарни огранци. Терцијарни огранци су флоиоформног облика и чине кортекс. Репродуктивни органи вјероватно су смјештени унутар централне стабљике (ендоспоратни тип)". Раније емендације биле су предложене најприје од BASSOULLET *et al*. (1978), позивајући се само на два реда огранака, док се емендација DIENI *et al*. (1985) базирала на присуству три реда огранака код врсте *Linoporella buseri*. Сагласно преиспитивању врсте *L. buseri*, род *Linoporella* је поново благо емендиран: "Једноставан цилиндричан или благо кијичаст талус. Главна оса, цилиндрична или слабо интусанулатна, носи слијед пршљенова са три реда огранака. Примарни огранци су релативно кратки и дебљи, искошени или управни на главну осу, цјевасти или мало дистално проширени. Издужени, тубуларни и релативно танки секундарни огранци чине скупину на врху примарних огранака. Танки терцијарни чине такође скупину на врху секундарних огранака. Они су или сасвим танки, или на врху флоиоформни, те формирају кортекс. Репродуктивни органи вјероватно унутар централне стабљике (ендосоратни тип).

Linoporella buseri RADOIČIĆ, 1975
Таб. 1, 2

Холотип: Пресјек приказан на табли 1, сл. 2. Сви остали пресјеци на таблама 1 и 2 су изотипови.

Ревидирана дијагноза: једноставан талус заобљеног или благо заоштреног врха. Главна оса, цилиндрична или интусанулатна, носи пршљенове са три реда огранака. Претежно јаки примарни огранци проксимално и дистално су стањени (вретенаси). Најприје су, у главном дијелу талуса, хоризонтални или благо нагнути, а упадљиво нагнути у апикалном дијелу. Примарни огранци дају скупину од 4–5 тубуларних, танких мање или више дивергентних и повијених секундарних огранака. Ови потоњи, најчешће носе скупину од три истањена терцијарна огранка. Кречњачки скелет је чврст, примарно највјероватније арагонитски. Репродуктивни огрaни ендоспоратног типа.

PLATE 1

Linoporella buseri RADOIČIĆ. All specimens from the type-level.

Fig. 1. Oblique section in the main, cylindrical portion of the thallus. Third order laterals, are visible on the eroded margin of the calcareous skeleton. Thin section RR3121, ×14.

Fig. 2. The holotype. Oblique section in the main, cylindrical portion of the thallus. Slender third order laterals, are clearly visible. Thin section RR3101, ×13.

Fig. 3. Oblique section in the main, cylindrical portion of the thallus. Although hardly visible, slender third order laterals are present. Thin section RR3108, ×14.

Fig. 4. Almost transversal section in the main, cylindrical portion of the thallus. Note the wide axial cavity and the relatively thick first, second and third order laterals. Thin section RR3132, ×14.

Fig. 5. Oblique section in the main, cylindrical portion of the thallus. Slender third order laterals are visible. Note bioerosion penetrating and progressively destroying the first order laterals. Thin section RR3121, ×11.

Fig. 6. Broken oblique section in the main, cylindrical portion of the thallus. Three orders of laterals are clearly visible despite bioerosion. Thin section RR3105, ×12.

Fig. 7. Broken oblique section close to the apex of the thallus. Three orders of laterals are present, oblique to the bioeroded axial cavity. Thin section RR3129, ×20.

Fig. 8. Two, partly broken oblique sections, with three orders of laterals. The right hand side section is heavily bioeroded. Thin section RR3128, ×17.

Fig. 9. Oblique section in the main, cylindrical portion of the thallus, with three orders of relatively slender laterals. Note the irregular, bioeroded axial cavity. Topotype specimen, ×28.

Fig. 10. Oblique – tangential section. Clusters of five second order laterals arise from the top of the primaries. Slender third order laterals are hardly visible on the bioeroded margin of the skeleton. Thin section RR3141, ×20.

Fig. 11. Slightly oblique, tangential section. Clusters of four, rather slender second order laterals arise from the top of the primaries. Clusters of three third order laterals (arrow) are also visible. In this section, the tertiaries are phloiophorous at tip, indicating the presence of a distal cortex. Thin section RR3103, ×14.

Fig. 12. Longitudinal section of the main, cylindrical portion of the thallus. Primary and secondary laterals are rather thick. Third order laterals look missing, or are bioeroded. Thin section RR3111, ×20.

Fig. 13. Slightly oblique, tangential section. The spindle-like, bioeroded primary laterals bear clusters of four secondaries (arrow). Thin section RR3113, ×14.

Fig. 14. Two transversal sections, showing the presence of third order laterals at bottom of the picture. Thin section RR3124, ×13.

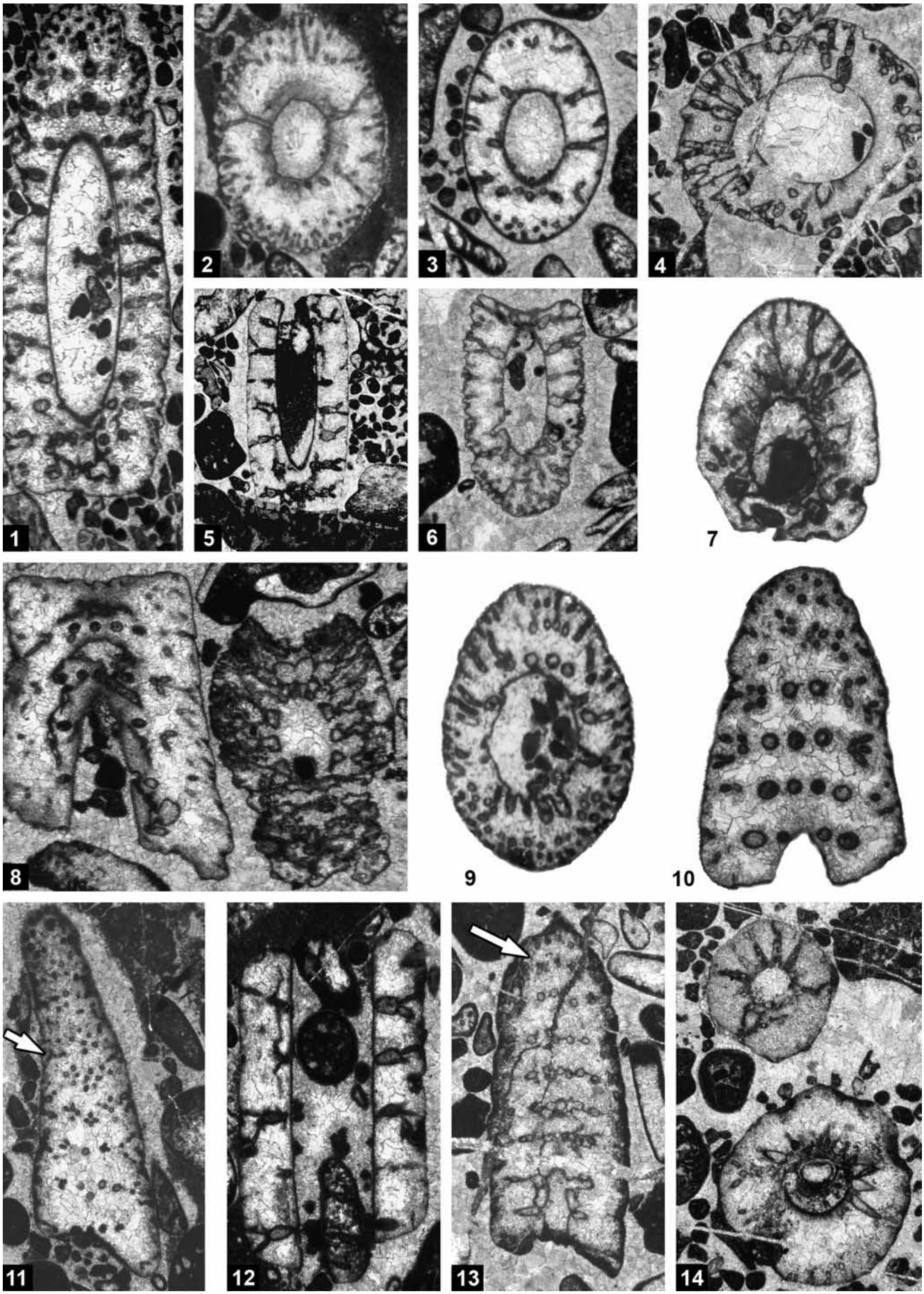
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PLATE 2

All specimens are from the type-level of *Linoporella buseri* RADOIČIĆ.

Fig. 1. *Linoporella buseri* RADOIČIĆ. Asymmetry suggests the oblique section is close to the apex of the thallus. Only two orders of laterals are visible next to the eroded margin of the skeleton. Third order laterals are possibly missing. Thin section RR3118, ×16.

Fig. 2. *Linoporella buseri* RADOIČIĆ. Oblique section of a small specimen. Second order laterals are hardly visible on the bioeroded margin of the calcareous skeleton. Third order laterals are possibly missing. Thin section RR3104, ×27.

Fig. 3. *Linoporella buseri* RADOIČIĆ. Oblique section of a small specimen with three orders of relatively thick laterals. Thin section RR3138, ×27.

Fig. 4. *Linoporella buseri* RADOIČIĆ. Transversal section of a large specimen. Although bioeroded, third order laterals (arrow) are present. Thin section RR3132, ×18.

Fig. 5. *Linoporella buseri* RADOIČIĆ. Oblique section in the main, cylindrical part of a large specimen with oblique primary laterals. Although bioeroded, rather thick third order laterals (arrow) are present. Thin section RR3133, ×20.

Fig. 6. *Linoporella buseri* RADOIČIĆ. Tangential section, transversal to the rounded apex of a rather large specimen. Clusters of three, hair-like third order laterals arise from the tip of the secondaries. Thin section RR3140, ×16.

Fig. 7. *Linoporella buseri* RADOIČIĆ. Deep tangential, slightly oblique section cutting the tip of the axial cavity, just below the rounded apex. Four second order laterals are clustered at tip of very short primaries. Hair-like third order laterals are visible at the margin of the section. Thin section RR3111, ×25.

Fig. 8. *Linoporella buseri* RADOIČIĆ. Oblique section close to the rounded apex. Clusters of five, rather slender second order laterals arise from the tip of the primaries. Note bioerosion (arrow). Thin section RR3101, ×28.

Fig. 9. Oblique section of a piece of *Dinarella* ? sp. Thin section RR3105, ×30.

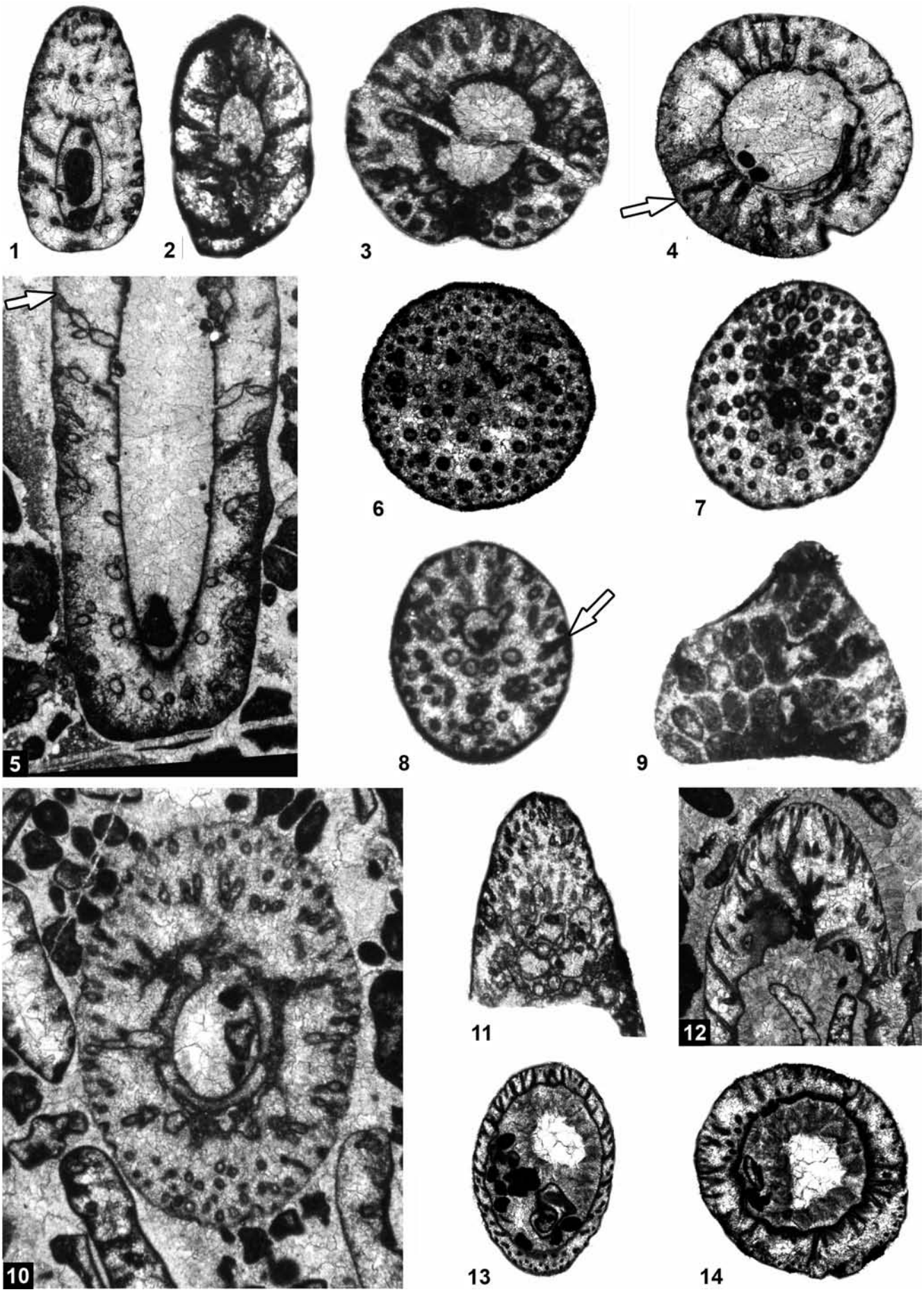
Fig. 10. *Linoporella buseri*. Oblique section in the main, cylindrical portion of a rather large specimen, with three orders of laterals. Note pervasive bio-erosion around the axial cavity. Thin section RR3132, ×30.

Fig. 11. Oblique-tangential section of a piece of *Palaeodasycladus* ? sp. In this specimen, cavities generated by bio-erosion are filled by a yet unidentified calcifying organism forming rosettes. Thin section RR3103, ×17.

Fig. 12. Oblique section of a piece of *Palaeodasycladus* ? sp. with up to five orders of laterals. The axial cavity is heavily bioeroded. Thin section RR3130, ×12.

Fig. 13. Oblique section questionably corresponding to the capitulum-shaped head of *Palaeodasycladus* ? sp. 1. Note the wide axial cavity. Thin section RR3144, ×11.

Fig. 14. Transversal section of *Palaeodasycladus* ? sp. 1. Thin section RR3144, ×12.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