

New Dasycladal algae from the Anisian (Middle Triassic) of Lika (Croatia)

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Abstract

Two new species of dasycladal algae are described from the Anisian limestones of the Lika region in Croatia. *Griphoporella? speleoluka* n. sp. is characterized by very small cylindrical thallus and vesiculiform laterals arranged in close whorls. In consecutive whorls, laterals are positioned one above the other. It differs from other species by smaller dimensions and the arrangement of the laterals. *Palaeodasycladus primus* n. sp. has cylindrical thallus with whorls of inclined laterals up to the third order. Primary laterals are not completely calcified, producing so-called intusannulation. Trichiform or tubular secondary laterals bear bundles of thin, probably trichiform, tertiary laterals. Both of the new species have been found within typical Anisian microfossil assemblage.

Keywords:

Dasycladales; Middle Triassic; Dinarides

1. Introduction

Dasycladalean algae are a group of benthic green calcareous algae that are valuable guide fossils in carbonate sequences and in some levels of the Permian, Middle Triassic, Upper Jurassic, Lower Cretaceous and Palaeocene, there are important lithogenic fossils. Due to their relatively large dimensions, they are easy to find and are a great help in geological mapping. Calcareous algae are very important in the biostratigraphy of carbonate sequences, often together with benthic foraminifera, especially in the Dinaride Mountains. Each finding of these algae completes the picture of their distribution and evolution. This paper describes two new species found in the area of Lika, i.e. the northeastern slopes of Velebit Mountain.

Thick Triassic deposits are present on Velebit Mountain (Herak et al., 1967; Ivanović et al., 1976; Sokač et al., 1976a, b). The Lower Triassic strata are clastic deposits, in the lower part siliciclastic and in the upper part carbonate in composition. In the Middle Triassic, limestones are predominant, often called “algal limestones” due to numerous remains of calcareous algae, together with some dolomite. Partly within the Anisian, and in the Ladinian, intra-platform basin deposits with clastites and pyroclastites, and in places basic effusive were also present (Šćavničar et al., 1984; Belak, 2000; Jelaska et al., 2003; Smirčić et al., 2018, 2020 and references there-

in). These deposits mark the period of intense volcanic activity related to the opening of the Neotethys Ocean (Smirčić et al., 2018; Kukoč et al., 2023 and references therein). During the Carnian and probably Norian the area was emergent, and in some places terrigenous deposits accumulated (clastites, pyroclastites and bauxites). A gradual ingressión restored the marine regime and the ?Norian–Rhaetian “Hauptdolomite” was deposited. The Triassic of Velebit Mountain is quite different from that of SW Croatia that has continuous sedimentation from the Middle to the Upper Triassic (Goričan et al., 2005; Pavičić et al., 2021).

Most research of the Triassic on Velebit Mountain was done in the sixties and seventies within the works on the Basic Geological Map (Ivanović et al., 1976; Sokač et al., 1976a, b). Some of these results were presented in the work of Herak et al. (1967). Newer investigations include only the Middle Triassic of Gornje Pazarište locality (Smirčić et al., 2018, 2020). It is necessary to also mention a review paper by Velić and Velić (2020) on the geology of “Majstorska cesta” road, in which a brief description of the Triassic deposits and an overview of publications from the field trips are given. The history of fossil algae research on Velebit Mountain is presented in the work of Grgasović (2008).

2. Systematic paleontology

Phylum Chlorophyta
Class Ulvophyceae Mattox and Stewart, 1978
Order Dasycladales Pascher, 1931

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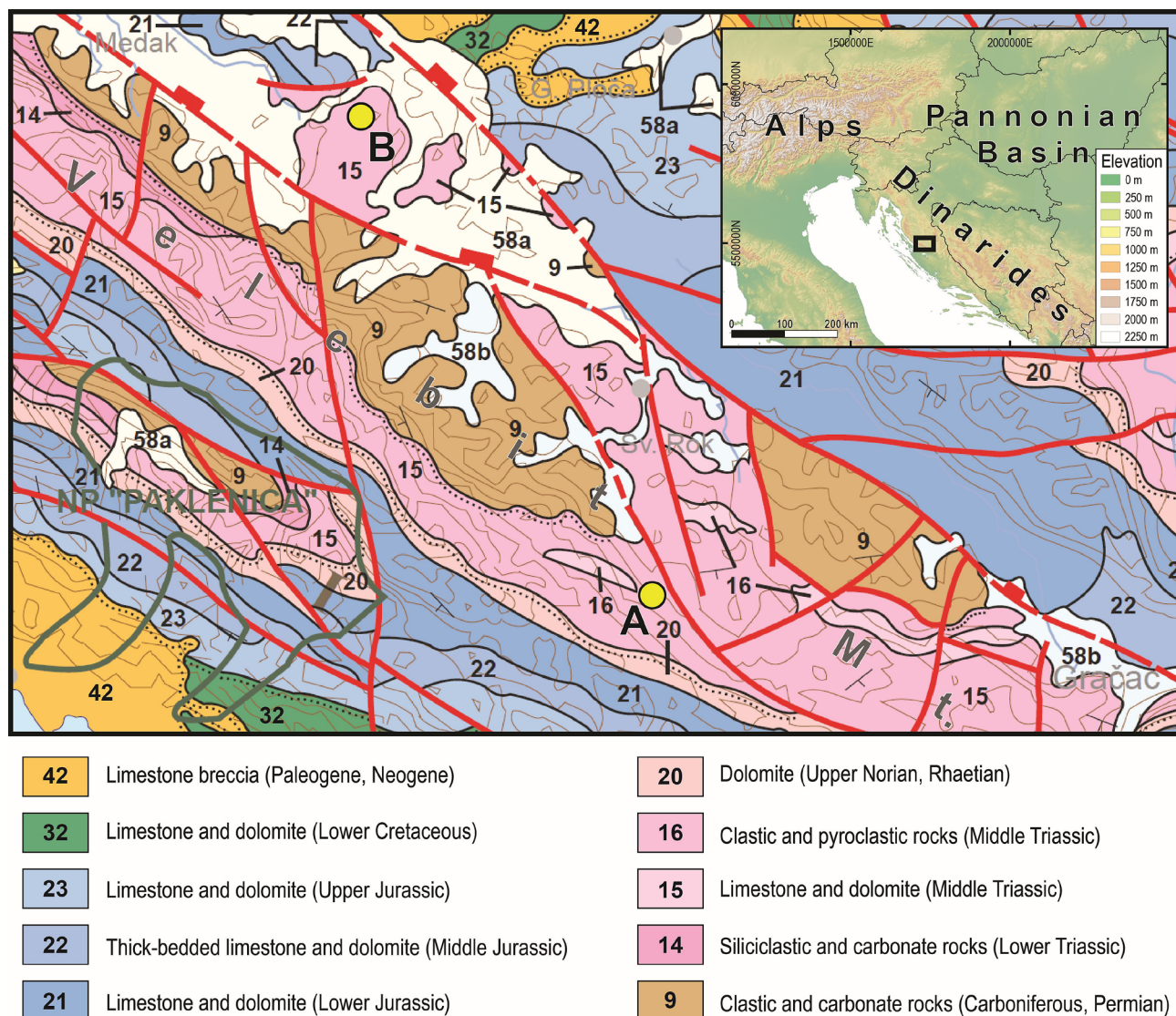


Figure 1: General position of the localities and simplified geological map of the study area (modified after Hrvatski geološki institut, 2009). Type localities: A) *Griphoporella? speleoluka* n. sp.; B) *Palaeodasycladus primus* n. sp.

Family Triploporellaceae Berger and Kaefer, 1992, emend.
 Granier and Bucur in Granier et al., 2013
 Tribe Salpingoporellae Bassoullet et al., 1979
 Subtribe Salpingoporellinae Bassoullet et al., 1979
 Genus *Griphoporella* Pia, 1915
Griphoporella? speleoluka n. sp.

Figure 2A-J

Origin of the name: the new species is dedicated to the memory of my friend and colleague from the Croatian Geological Survey, distinguished Croatian *speleologist* Ozren Lukić - *Luka*, who was killed during the war in Croatia on Velebit Mountain, near Malovan Peak, that is about 10 km ESE from the type locality.

Material and repository: 16 thin-sections marked U-5073 (HPM10971-HPM10986) with 23 specimens of the new species. Holotype is from the thin-section U-5073/2 (HPM10972), illustrated in **Figure 2A**. Paratypes are from thin sections U-5073/1 (HPM10971) (see **Figure 2J**), U-5073/2 (HPM10972) (see **Figure 2B, H**),

U-5073b (HPM10973) (see **Figure 2G**), U-5073b/3 (HPM10975) (see **Figure 2F, I**) and U-5073b/16 (HPM10984) (see **Figure 2C-E**). Thin-sections are stored at the Department of Geology and Paleontology of the Croatian Natural History Museum, Demetrova 1, Zagreb, Croatia. Inventory numbers are in parenthesis.

The type locality: outcrop of the light-gray limestone with recognizable fragments of fossil algae south of Liskovi dolac, 2 km WNW from the northern portal of the Sv. Rok Tunnel (see **Figure 1A**). The coordinates are: 44°18'41.7"N 15°39'26.0"E. This locality is also near the road "Majstorska cesta", described by **Velić and Velić (2020)**.

Diagnosis: *Griphoporella? speleoluka* n. sp. has very small cylindrical thallus and vesiculiform laterals arranged in close whorls. In consecutive whorls laterals are positioned one above the other.

Dimensions: d = 0.25-0.32 mm, d = 0.10-0.12 mm, d/D = 0.36-0.44, h = 0.05-0.06 mm, p = 0.04 mm, w = 11-15, α = 70-90°. Symbols after **Pia (1920)**.

Description: specimens of the new alga are not well preserved and are often recrystallized. The thallus is made of sparite calcite crystals, that represents the fill of the mold cavity formed by dissolution of the primary aragonite algal thallus. The shape of the thallus is preserved due to the very thin micritic layer. The outer surface of the thallus is sometimes eroded (see **Figure 2A**), and sometimes the inner part is eroded (see **Figure 2J**). Calcification probably reached the stem, since the whole vesiculiform lateral can be preserved (see **Figure 2A, E-F**). The thallus is cylindrical (see **Figure 2A-B**). The specimen from **Figure 2G** is peculiar and probably shows the phenomenon of a divided thallus, when the thallus is divided in two growing upward, as described by **Sokač and Grgasović (2009)** in the species *Salpin-goporella muehlbergi* (Lorenz). The shape of the lateral is vesiculiform, e.g. the lateral has a stalk that abruptly expands into a vesicle (bubble), that is visible on the longitudinal (see **Figure 2A-B, H**) and cross-sections (see **Figure 2C, E-F**). In tangential sections (see **Figure 2A-B**) the vesicle is represented by a circle. The specimen from **Figure 2F** shows a coupling of laterals in pairs, which is not visible in other specimens. The arrangement of the laterals is in close whorls (see **Figure 2A-J**). This is most noticeable in the tangential sections (see **Figure 2D, G**), that also show that laterals in consecutive whorls are positioned one above the other. Laterals in the same whorl are a little bit closer than in the consecutive whorls. The number of branches in a whorl is estimated at 11-15. Laterals are perpendicular to the stem (see **Figure 2B, H-J**), or slightly inclined upward (see **Figure 2A**).

Generic attribution: although the shape and arrangement of laterals are well recognizable in the new species, its generic attribution is difficult. Considering the vesiculiform shape of the laterals, it could belong to the genus *Gyroporella*, *Anisoporella* or *Griphoporella*. The type species of the genus *Gyroporella* Gumbel, 1872, emend. Benecke 1876 is *G. vesiculifera* Gumbel, 1872, characterized by vesiculiform laterals with aspondyl arrangement (**Pia, 1920**). However, some well-preserved specimens of *G. vesiculifera*, as those in **Zanin Buri (1965)**, suggest that this species could have euspondyl arrangement of laterals, so several authors mentioned the need to re-study the type material of this species (**Barattolo et al., 1993; Radoičić, 2005**).

The genus *Anisoporella* was established by **Botteron (1961)** from the Anisian of Mont d'Or (Vanoise, France) with the type species *Anisoporella occidentalis*. It is characterized by vesiculiform laterals arranged in regularly spaced double whorls. The genus *Oligoporella* has a comparable arrangement of laterals, but it has piriform laterals (**Grgasović, 2022**). A similar species with double whorls of vesicular laterals was described by **Zanin Buri (1965)** from the Lower Anisian of Valle dei Grassi Lunghi (Lombardia, Italy) as *Gyroporella anisica*. The author ascribed the new species to the genus *Gyroporel-*

la after the vesiculiform type of laterals. She was aware that the type species of the genus is characterized by the aspondyl arrangement of laterals (**Pia, 1920**), but confront this by the fact that some authors include in this genus species with an euspondyl arrangement. She did not include it in the genus *Anisoporella* because "laterals more often appear to be metaspondyl than euspondyl", that is clearly a misinterpretation of having double rows of laterals, not metaspondylity. **Hurka (1969)** changed that and attributed *G. anisica* to the genus *Anisoporella*, but stating that only the species of the genus *Gyroporella* are vesiculiform and aspondyl and the genus *Anisoporella* is vesiculiform and euspondyl, ignoring the double whorls of laterals that are present in both species. The problem of attribution of algae with single whorls of vesiculiform laterals remains in more recent papers. **Senowbari-Daryan et al. (1994)** followed the (mis)conclusion of **Hurka (1969)** that genus *Anisoporella* "was introduced for dasyclad algae with euspondyle vesiculiform branches", and transferred *Gyroporella lukicae* Sokač and Velić, 1982 to the mentioned genus. **Radoičić (2005)** replied that the affiliation of the species *G. lukicae* to the genus *Anisoporella* was incorrect, due the presence of the double whorls, and keep it on in the genus *Gyroporella*. **Bucur (2000)** transferred the species *Pseudoepimastopora cretacea* Dragastan, 1969 to the genus *Anisoporella*. However, he stated that it differs from Triassic species of *Anisoporella* in having only one row of ramifications in each verticil, thus the question mark. The same author considers *Gyroporella lukicae* Sokač and Velić, 1982 the younger synonym of *Anisoporella? cretacea*. Later **Bucur et al. (2005, 2008)** also pointed out that the affiliation of the species *A.? cretacea* to the genus *Anisoporella* was incorrect, since the genus *Anisoporella* has vesiculiform laterals in an euspondyl arrangement, but with double verticils and concluded that morphological features of the skeleton of this alga are closer to those of the genus *Griphoporella*, as described and emended by **Barattolo et al. (1993)**. Later **Bucur and Shlagintweit (2009)** and **Bucur et al. (2014)** transfer the entire group of species, comprising *Pseudoepimastopora jurassica* Endo, 1961, *Pseudoepimastopora cretacea* Dragastan, 1967, *Epimastopora cekici* Radoičić, 1970 and *Gyroporella lukicae* Sokač and Velić, 1982 to the genus *Griphoporella*.

The genus *Griphoporella* was established by **Pia (1915)** with the type species *Gyroporella curvata* Gumbel, 1872. The author stated that *Griphoporella curvata* is characterized by a cylindrical simple thallus and by such a thin calcareous skeleton that it is often impossible to give any indication on the shape and distribution of the primary laterals. He acknowledged the possibility that the laterals were slightly phloioform. Subsequently **Pia (1920)** did not exclude that the distribution of the laterals was of euspondyle type. **Barattolo et al. (1993)** made a revision of the type species and the genus, based on the material from the type locality. The new diagnosis defined

laterals as slightly phloioform with a subterminal narrowing, followed by a terminal enlargement, and arranged in alternate, very close verticils (euspondyle type).

I decided to include the new species in the genus *Griphoporella*, but with a question mark. The reason for this decision is that, although stated as phloioform, the shape of the laterals in the type species of the genus *Griphoporella* does not differ much from the vesiculiform type. Although, if the calcification is more complete, the shape is more phloioform. Laterals are arranged in whorls, but in the new species the whorls are separated from each other, and in *G. curvata* are very close. In this decision I follow **Bucur et al. (2005, 2008, 2014)** and **Bucur and Shlagintweit (2009)**. Differences between other genera are even bigger. The type species of the genus *Gyroporella* has vesiculiform laterals but an aspondyle arrangement of laterals (as far as we know). The arrangement of laterals is the main taxonomic criterion in the taxonomy of Dasycladales, used in the family level, so no species with aspondyl and euspondyl arrangement should be in the same genus. Species of the genus *Anisoporella* looks quite similar to the new species, but they have double whorls. This phenomenon is considered important on the generic level to distinguish genera *Physoporella* and *Oligoporella* (**Grgasović, 2022**), so the new species does not quite fit here. I support the already mentioned idea of a review of the type species, but also the entire genus *Gyroporella* and similar genera.

The new species differs from other species of genera *Griphoporella* and *Gyroporella* by smaller dimensions and well-defined whorls. The most similar is *Griphoporella minuta* Bucur and Peybernes, described in **Bucur et al. (2020)**, that differ in slightly larger dimensions ($D = 0.55$ mm), a larger central cavity ($d/D = 0.095$) and less close laterals.

Species from the genus *Anisoporella* have whorls made of two rows of laterals.

Stratigraphical position: the new species has been found with typical Anisian assemblage: algae *Macroporella alpina* Pia, *Poncetella helvetica* (Pia) and *Pseudodiplopora proba* (Pia), as well as foraminifera *Meandrospira dinarica* Kochansky-Devidé and Pantić and *Pilamina densa* Pantić. The algal association is typical for Anisian *Physoporella pauciforata* Range Zone (**Granier and Grgasović, 2000; Grgasović and Sokač, 2003; Grgasović, 2022**) ranging from the Upper Aegean to the Lower Illyrian. Foraminifera *M. dinarica* and *P. densa* have roughly the same age (**Rettori, 1995; Velić, 2008; Gale et al, 2022, 2023**).

Family Dasycladaceae Kützing,
Genus *Palaeodasycladus* (Pia, 1920) 1927
Palaeodasycladus primus n. sp.

Figure 2K

Origin of the name: the new species is named as being the oldest representative of the genus (latin *primus* = the first one).

Material and repository: thin-section U-3243/2 (HPM10989) (see **Figure 2K**). The only specimen of the new taxon is a holotype. We made six other thin-sections from the same sample U-3243 (HPM10987-HPM10993), but there are no more fragments of the new alga. Thin-sections containing the described new algae are stored at the Department of Geology and Paleontology of the Croatian Natural History Museum, Demetrova 1, Zagreb, Croatia. Inventory numbers are in parenthesis.

The type locality: limestone outcrop NNE from “Vrh pločavi” (643 m), around hundred meters SSW from the road Medak-Sveti Rok (see **Figure 1B**). The coordinates are: 44°25'22.8"N, 15°33'17.5"E.

Diagnosis: *Palaeodasycladus primus* n. sp. has cylindrical thallus with whorls of inclined branches up to the third order. Primary laterals are relatively large and horizontally flattened, and are not completely calcified, producing so-called intusannulation. Tubular or slightly trichiform secondary laterals bear bundles of thin, probably trichiform, tertiary laterals. Laterals are inclined upwards and arranged in close whorls.

Description: description is difficult, since there is only one specimen of the new alga, but it is well preserved and shows all the important details of the new alga. The thallus is cylindrical and slightly curved. As in most of the other Dasycladales, it is built of sparry calcite, that represent the fill of the mold cavity formed by dissolution of the primary aragonite algal thallus. The outline of the laterals is well defined due to the thin micritic layer, probably of primary origin (see discussion in **Conrad and Varol, 1990**). There is also some micritic overgrowth, possibly made by epilithic microbes. Laterals have several orders. Laterals of the first order are large and oval (the middle part of **Figure 2K**). They are horizontally flattened, which can be concluded after closeness of the secondary and tertiary laterals (the lower and upper part of **Figure 2K**). Primary laterals are not completely calcified, e.g. calcification does not reach the stem, producing so-called intusannulation (see discussion in **Sokač (2001)**). There are also creases on the outer surface of the thallus between whorls, that can be interpreted as slight annulation. Secondary laterals are growing on the top of the primary ones. They are tubular, or slightly tapered at the distal part (trichiform). The lower two “rings” on **Figure 2K** probably cut through secondary laterals, so their number is 3-4. Each secondary lateral bears a turf of tertiary laterals, that is nicely visibly on the left and on the upper part of **Figure 2K**. The number of tertiaries in one turf is probably five. Due to a lack of calcification, the shape of tertiary laterals is difficult to discern, but they seem to be trichiform. All laterals are inclined upwards. Laterals are arranged in whorls that are very close to each other. The number of primary laterals in one whorl can be estimated as 12. Alga is probably cladosporous and the formation of gametes probably takes place in large primary laterals, although there are no cysts to prove this.

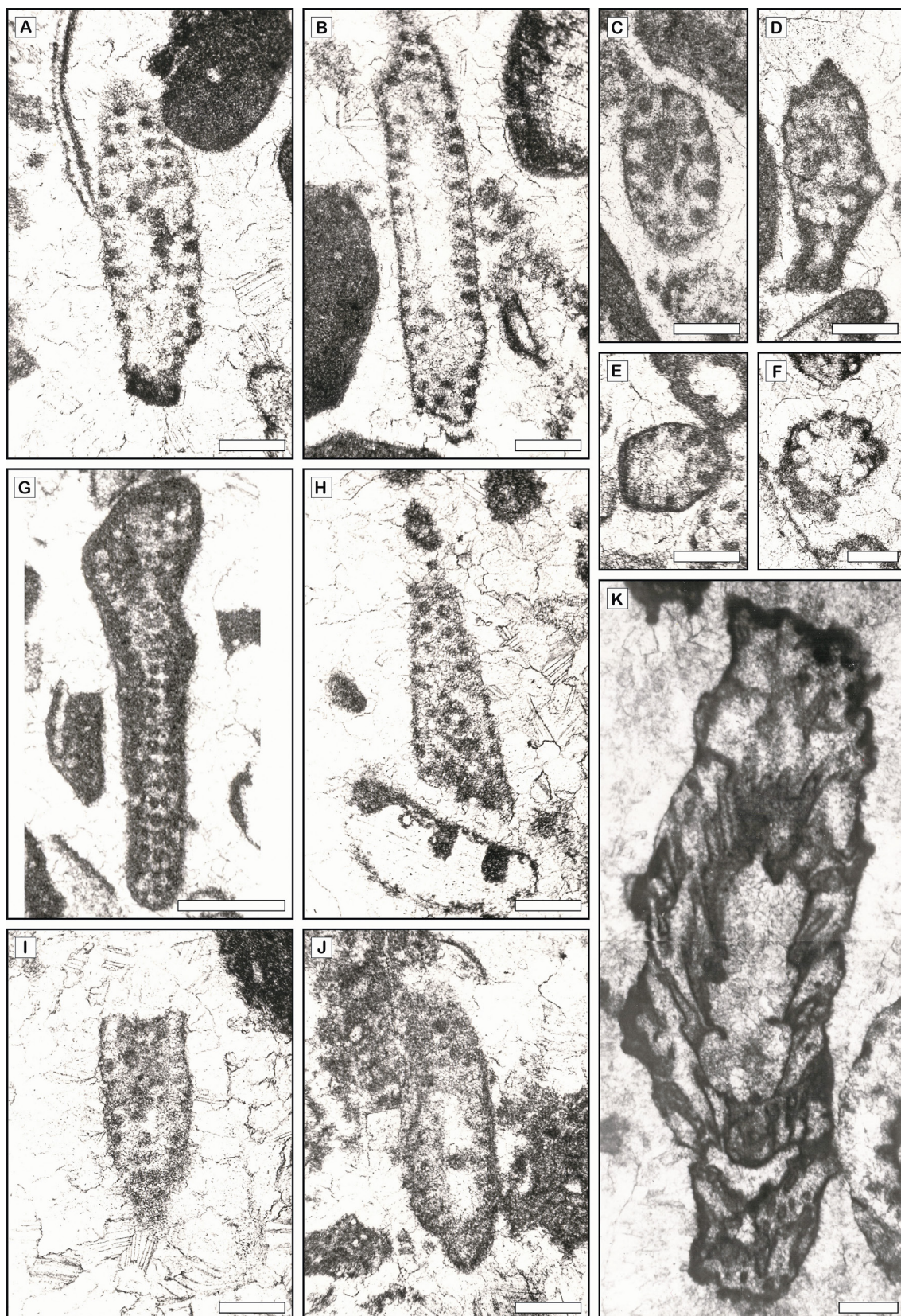


Figure 2: (A-J) *Griphoporella? speleoluka* n. sp. A) Oblique, slightly longitudinal section, holotype, thin-section U-5073/2; B) Longitudinal, slightly oblique section, thin-section U-5073/2; C) Oblique section, thin-section U-5073b/16; D) Tangential section, thin-section U-5073b/16; E) Cross section, thin-section U-5073b/16; F) Cross-section, thin-section U-5073b/3; G) Tangential-longitudinal section, thin-section U-5073b; H) Oblique section, thin-section U-5073/2; I) Oblique, slightly longitudinal section, thin-section U-5073b/3; J) Oblique section, thin-section U-5073/1. (K) *Palaeodasycladus primus* n. sp., oblique, slightly longitudinal section, holotype, thin-section U-3243/2. A-J) scale bar 0.2 mm, K) scale bar 0.5 mm.

Dimensions: $D = 1.82$ mm, $d = 0.36$ mm, $d/D = 0.20$, $h = 0.71$ mm, $p = 0.23$ mm, $l = 0.34$ mm, $w = ?12$, $p' = 0.09$ mm, $l' = 0.54$ mm, $w' = ?3-4$, $p'' = 0.05$ mm, $l'' = 0.32$ mm, $w'' = 5$, $\alpha = 55^\circ$. Symbols after **Pia (1920)**.

Generic attribution: the species doubtlessly belongs to the genus *Palaeodasycladus* (**Pia, 1920**) **1927**, primarily by having the three orders of branches (**Barattolo et al., 1994**; **Sokač, 2001**). Distinguishing from the Jurassic taxa of the genus is not easy, due to the high morphological variability of the genus *Palaeodasycladus*. The most similar is *P. mediterraneus* (Pia), that differs by phloioform secondary and tertiary laterals (**Sokač, 2001**; **Barattolo et al., 1994**). A detailed description of the rich material from this genus from Velebit Mountain is given by **Sokač (2001)**, and some additional data are provided by **Barattolo et al. (2012)**. This species is widespread in the Mediterranean region (**Sokač, 2001** and references there) and has been found also on Ivanščica Mountain in Northern Croatia (**Vukovski et al., 2023**).

Stratigraphical position: the new species has been found with typical Anisian assemblage: algae *Teutloporella tabulata* Pia, *Macroporella alpina* Pia and *Scinderella scopuliformis* Grgasović and Sokač, as well as foraminifera *Meandrospira dinarica* Kochansky-Devidé and Pantić. The algal association is typical for Anisian *Physoporella pauciforata* Range Zone (**Granier and Grgasović, 2000**; **Grgasović and Sokač, 2003**; **Grgasović, 2022**) ranging from the Upper Aegean to the Lower Illyrian. *Scinderella scopuliformis* is described from Ivanščica Mountain within the same Zone (**Grgasović et al., 2002**). Foraminifera *M. dinarica* has roughly the same range (**Rettori, 1995**; **Velić, 2008**; **Gale et al., 2022, 2023**).

3. Conclusions

From the Anisian strata of Lika, e.g. from the north-eastern slopes of Velebit Mountain, two new species of Dasycladal algae are described. *Griphoporella? speleoluka* n. sp. represent the new species of this poorly known genus and it is dedicated to the late Croatian speleologist Ozren Lukić – Luka. *Palaeodasycladus primus* n. sp. represents the oldest representative of the genus (*primus* = the first one) that flourished in the Early Jurassic. The accompanying algae and foraminifera determined the Anisian age of both new species.

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SAŽETAK

Nove dazikladalne alge iz anizika (srednjega trijasa) Like

Opisane su dvije nove vrste dazikladalnih algi iz anizičkoga vapnenca Like u Hrvatskoj. *Griphoporella? speleoluka* n. sp. karakterizirana je vrlo malim valjkastim talusom i vezikuliformnim ograncima raspoređenim u gustim pršljenima. U uzastopnim pršljenima ogranci su postavljene jedan iznad drugoga. Od sličnih vrsta razlikuje se manjim dimenzijama i rasporedom ogranaka. *Palaeodasycladus primus* n. sp. ima cilindrični talus s pršljenima kosih ogranaka do trećega reda. Primarni ogranci relativno su veliki i horizontalno splošteni te nisu potpuno kalcificirani stvarajući takozvanu intusanulaciju. Trihoformni ili cjevasti sekundarni ogranci nose snopove tankih, vjerojatno trihoformnih, tercijarnih ogranaka. Obje nove vrste pronađene su unutar tipične anizičke mikrofossilne zajednice.

Ključne riječi:

Dasycladales, srednji trijas, Dinaridi

Author's contribution

Tonći Grgasović: conceptualization, reserch, writing, editing.