Plant and Fungal Systematics 68(2): 294–303, 2023
DOI: https://doi.org/10.35535/pfsyst-2023-0014

ISSN 2544-7459 (print)
ISSN 2657-5000 (online)

Four new species of *Parvoplaca* (*Teloschistales*, *Ascomycota*)

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Article info

Received: 28 Jun. 2023
Revision received: 18 Sept. 2023
Accepted: 3 Oct. 2023
Published: 29 Dec. 2023

Associate Editor

Stefan Ekman

Abstract. The genus *Parvoplaca* is extended with four new species: *P. candanii* from Antarctica, *P. lamprocarpa* from Alaska, and *P. macroborealis* and *P. tenebrosa* from Oregon. Collections identified as *P. tiroliensis* are shown to form two independent clades when DNA was analyzed, but it is currently not clear which clade represents the species in a strict sense. *Parvoplaca athallina* has been considered an Antarctic species, but according to our analyses, the species is shown to be bipolar occurring also in northern Europe, Greenland, Alaska and in California.

Key words: Antarctica, bipolar, *Caloplaca*, DNA, lichen, molecular, taxonomy

Introduction

The lichen genus *Parvoplaca* is a rather small genus in the family *Teloschistaceae* subfamily *Xanthorioideae* and was split from the large genus *Caloplaca* s.lat. Th. Fr. by Arup et al. (2013). It is characterized by a crustose, but usually poorly developed grey thallus and lecanorine, zeorine or sometimes biatorine yellow to orange apothecia that in several species lack anthraquinones completely or produce low amounts of the yellow-orange pigments. The anthraquinones present belong to the chemosyndrome A (Søchting 1997). The spores are polardiblastic with medium to long septum. All species are either corticolous, terricolous or grow on mosses or plant debris on the ground. No saxicolous species are currently known to us. The main distribution seems to be in the Northern Hemisphere, where all but one species occur, including the ones described in this paper, and two species occur in Antarctica. *Parvoplaca* differs from most other genera in the combination of being corticolous or growing on the ground, a poorly developed grey thallus that often is lacking, yellow to orange apothecium discs and usually a rather thin or suppressed thalline margin. Several species also show a tendency to darken or they have lost their orange pigments entirely, similar to the genus *Pyrenodesmia* A. Massal. that, however, only includes saxicolous members. The most similar genus is *Athallia* Arup, Frödén & Søchting that includes some species with a similar combination of characteristics, i.e., *A. saxifragarum* (Poelt) Arup, Frödén & Søchting. Other genera with a morphology similar to *Parvoplaca* have either a different secondary chemistry, different spores or a different ecology.

In Arup et al. (2013), four named species, *P. athallina* (Darb.) Arup, Søchting & Frödén, *P. tiroliensis* (Zahlbr.) Arup, Søchting & Frödén, *P. servitiana* (Szatala) Arup, Søchting & Frödén and *P. suspiciosa* (Nyl.) Arup, Søchting & Frödén, were recognized as belonging to the genus in addition to three possibly undescribed species. Arup et al. (2015) transferred one further species, *P. chelyae* (Pérez-Vargas) Vondrák, Halıcı & Arup, to the genus and also described one new species, *P. nigroblastidiata* Arup, Halıcı & Vondrák. In this paper, we describe four additional species, *P. candanii* from James Ross Island, Antarctic Peninsula, *P. lamprocarpa* from Alaska, and *P. tenebrosa* and *P. macroborealis* from Oregon. This is not a full revision of the genus. We are aware of more taxa in need of taxonomic evaluation, but they are not the topic of this paper.

Materials and methods

Fresh material of *P. candanii* was collected by MGH during a trip to Antarctica and material of *P. macroborealis* and *P. tenebrosa* was collected by B. McCune. The material of *P. alaskana* was collected by B. McCune and T. Tønsberg during biodiversity assessments in Lake Clark National Park (McCune et al. 2018). Material of *P. tiroliensis* that was collected in Italy from the region where the species was described was borrowed from J. Nascimbene's personal herbarium with the aim to

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establish its identity. Collections of the described species are stored in BG, ERCH, LD and OSC. Herbarium locations are indicated after all cited collections.

The specimens were examined by interference contrast and light microscopy. Anatomical features were measured on hand-cut sections or squash preparations mounted in water. Morphological characters were measured on dry material using a dissecting microscope (40×). Spore dimensions are average values from ten measurements per specimen. Data on spore dimensions are presented in the following way: (min. extremes)xx–*mean*–xx(max. extremes). The measurements of anatomical and morphological characters mainly follow the guidelines of Vondrák et al. (2013).

Secondary chemistry

Secondary metabolites were identified and quantified using HPLC according to Søchting (1997). The relative composition of the secondary compounds was calculated based on absorbance at 270 nm according to Søchting (1997). All yellow, orange or reddish-pigmented parts are K+ purple.

DNA extraction

Genomic DNA extraction was performed directly using 5–10 fresh apothecia (fruitbodies). Total DNA was extracted using the DNeasy Plant Mini Kit from Qiagen (Cat. No./ID: 69204) following the accompanying protocol or the sequences were produced using direct PCR according to Arup et al. (2015). PCR was performed to amplify two gene loci: nuclear ribosomal DNA internal transcribed spacer (nrITS) and mitochondrial small subunit (mrSSU) rDNA. The nuclear rDNA ITS gene region was amplified by using the fungal-specific primer ITS1F and the universal primer ITS4 (Gardes & Bruns 1993; White et al. 1990). The mrSSU gene region was amplified by using the primers mtSSU1F (Zhou& Stanosz 2001) and mtSSU3R (Zoller et al. 1999) or mrSSU1 (Zoller et al. 1999) and mrSSU7 (Zhou & Stanosz 2001). ITS and mrSSU were amplified using the primers ITS1F and ITS4, mtSS1F and mtSSU3R in 30 µL reactions containing 15 µL 2×Taq PCR MasterMix, 1 µL each primer solution (10 µM), 12 µL ddH2O and 2 µL genomic DNA, and the PCR cycling conditions comprised of an initial denaturation at 94°C for 5 min; 30–34 denaturation cycles at 94°C for 30 s, annealing at 53–56°C (ITS) or 50–54°C (mrSSU) for 30–60 s, extension at 72°C for 30–60 s; and a final extension at 72°C for 3–8 min. A touchdown procedure was used for some reactions, decreasing 1°C per cycle for the first 6 cycles. The target PCR products were checked by electrophoresis on 1.5% agarose gels. Sequence analyses of the lichen samples obtained from the PCR products were performed by the BM Labosis Laboratory (Ankara, Turkey) or by Macrogen Inc., South Korea, using the same primers as for the PCR. The two resulting strands were assembled using CLC Main Workbench 4.1.2 ™ or Geneious 11.1.5. Subsequent alignments were done in the same programs and adjusted manually. Sequences have been submitted to GenBank as indicated in Table 1.

Sequence alignment

Two different alignments were prepared, one for a combined analysis of the genes nrITS and mrSSU and one alignment of only nrITS sequences. The combined analysis included 33 sequences of the subfamily *Xanthorioideae* (Arup et al. 2013) and the ITS alignment included 51 sequences of the genus *Parvoplaca* and phylogenetically closely related genera. In the first alignment, *Cerothallia luteoalba* was used as outgroup, and in the second analysis, *Xanthomendoza mendozae* was used as outgroup with *Pachypeltis castellana* as internal outgroup. The alignment program MAFFT as implemented in Geneious 11.1.5. was chosen for the initial alignments using the option auto and thereafter adjusted manually. Unalignable ends, introns in all the aligned genes and ambiguously aligned parts were excluded from the alignment. The alignments of the two different genes were first analysed separately to check for incongruence between genes, but none were detected. A conflict between the datasets was assumed to be significant if two different relationships were both supported with posterior probabilities of 0.95 or higher.

Phylogenetic analysis

We generated 26 new nrITS sequences and 12 new mrSSU sequences for this study. Phylogenetic relationships were inferred using Maximum Likelihood (ML) as implemented in IQ-TREE (Nguyen et al. 2015) and Bayesian tree inference was carried out using Markov chain Monte Carlo (MCMC) as implemented in MrBayes ver. 3.2.4 (Ronquist et al. 2012). In the combined analysis, the two included genes were treated as separate partitions. A suitable model of molecular evolution was found by IQ-TREE using the option model search in that program evaluating only the 24 models available in MrBayes, and later also used in the Bayesian analyses. For the combined analysis, the SYM+G model was found to be optimal for the nrITS and HKY+I for the mrSSU data set. For the pure ITS data set, SYM+G was again found to be optimal. Three parallel runs with 100,000,000 generations starting with a random tree and employing 6 simultaneous chains were executed, of which 5 were incrementally heated with a temperature of 0.10. Analyses were diagnosed every 1,000 generations in the last 50% of the tree sample and automatically halted when convergence was reached. Convergence was defined as a standard deviation of splits (of frequency 0.1) between runs below 0.01. Every 1,000th tree was sampled. A majority-rule consensus tree was constructed from the post-burn-in tree samples. The consensus trees were visualized using FigTree 1.4.4 and re-drawn in Adobe Illustrator.

Results

The alignment for the first analysis consisted of 33 terminals of 1,339 aligned nucleotide sites, of which 389 were parsimony informative. The nrITS partition consisted of 527 sites (170 informative) and the mrSSU partition of 814 sites (63 informative). The first Bayesian

Table 1. Location, collector and GenBank accession numbers of sequences of species used in the analyses. Sequences in bold are newly produced.

Species	Location and collector	GenBank accession numbers	
		ITS	mrSSU
Amundsenia approximata	Sweden, Arup L08179 (LD)	KJ789965	KJ789974
Austroplaca hookerii	Antarctica, Søchting 7611 (C)	KC179085	KC179484
Austroplaca lucens	Kerguelen, Søchting 7927 (C)	KC179086	KC179485
Cerothallia luteoalba	Sweden, Frödén 1869 (LD)	KC179099	KC179511
Charcotiana antarctica	Antarctica, Bersan A815 (TSB)	KJ789966	KJ789976
Gondwania cribrosa	Australia, Søchting 11581 (C)	KC179102	KC179526
Gondwania regalis	Antarctica, Søchting 11416 (C) ITS; Søchting 11427 (C) mrSSU	KC179103	KC179527
Pachypeltis castellana	Greenland, Søchting 10500 (C) ITS; Søchting 10470 (C) mrSSU	KC170105	KC179547
Pachypeltis invadens	Norway, Elevebakk 03:109, (TROM)	KC179108	KC179548
Parvoplaca athallina 1	Antarctica, Halıcı JR006 (ERCH)	**OR046664**	–
Parvoplaca athallina 2	Antarctica, Søchting US11432 (C)	**OR479893**	–
Parvoplaca athallina 3	Antarctica, Halıcı JR111 (ERCH)	**OR046665**	**OR046659**
Parvoplaca athallina 4	Sweden, Arup L19534 (LD)	**OR479894**	–
Parvoplaca athallina 5	California, Hutten 13147 (YOSE)	**OR479895**	–
Parvoplaca athallina 6	Alaska, Rosentreter 18554 (SRP)	**OR479896**	–
Parvoplaca athallina 7	Antarctica, Halıcı JR305 (ERCH)	**OR046668**	**OR046662**
Parvoplaca athallina 8	Greenland, Søchting US10484 (C)	**OR479897**	–
Parvoplaca athallina 9	Antarctica, Halıcı JR282 (ERCH)	**OR046667**	**OR046661**
Parvoplaca athallina 10	Norway, Arup L14141 (LD)	**OR479898**	–
Parvoplaca athallina 11	Antarctica, Søchting US11393 (C)	KC179111	**OR482922**
Parvoplaca athallina 12	Antarctica, Halıcı JR357 (ERCH)	**OR046669**	–
Parvoplaca athallina 13	Antarctica, Søchting US7889 (C)	**OR479899**	**OR482923**
Parvoplaca athallina 14	Antarctica, Søchting US11558 (C)	**OR479900**	–
Parvoplaca athallina 15	Norway, Arup L18261 (LD)	**OR479901**	–
Parvoplaca athallina 16	Antarctica, Halıcı JR371 (ERCH)	**OR046670**	**OR046663**
Parvoplaca athallina 17	Antarctica, Søchting US11584 (C)	**OR479902**	–
Parvoplaca athallina 18	Antarctica, Halıcı JR272 (ERCH)	**OR046666**	**OR046660**
Parvoplaca candanii	Antarctica, Halıcı 0.322 (ERCH)	**OR048353**	**OR048352**
Parvoplaca chelyae 1	Turkey, Vondrák JV13092 (PRA)	KT161996	–
Parvoplaca chelyae 2	Turkey, Halıcı CL 0.508 (ERCH)	KT162000	–
Parvoplaca chelyae 3	Turkey, Halıcı CL 0.005 (ERCH)	KT161997	–
Parvoplaca chelyae 4	Turkey, Halıcı CL 0.828 (ERCH)	KT161993	–
Parvoplaca chelyae 5	Turkey, Halıcı CL 0.237 (ERCH)	KT161998	–
Parvoplaca lamprocarpa 1	Alaska, Tønsberg 44132 (BG)	**OR479891**	**OR482921**
Parvoplaca lamprocarpa 2	Alaska, McCune 35218 (LD), holotype	**OR479892**	–
Parvoplaca macroborealis 1	USA, Oregon, McCune 37297 (LD), holotype	**OR482586**	**OR482925**
Parvoplaca macroborealis 2	USA, Oregon McCune 28337 (LD)	KC179114	–
Parvoplaca nigroblastidiata 1	Sweden. Nordin 7797 (LD)	KT161980	–
Parvoplaca nigroblastidiata 2	Sweden, Jonsson FU5958 (LD)	KT161986	–
Parvoplaca nigroblastidiata 3	Alaska, Tønsberg 42983 (BG)	KT161982	–
Parvoplaca nigroblastidiata 4	Sweden, Arup L10208 (LD)	KC179113	KC179551
Parvoplaca nigroblastidiata 5	Sweden, Jonsson FU5959 (LD)	KT161988	–
Parvoplaca servitiana 1	Greece, Spribille 16225 (CBFS)	JN641778	–
Parvoplaca servitiana 2	Greece, Spribille 13700 (CBFS)	JN641779	–
Parvoplaca suspiciosa 1	Russia, Hermansson 16839 (priv. herb)	KC179115	–
Parvoplaca suspiciosa 2	Sweden, Hermansson 18005 (priv. herb.)	KT161990	KJ810561
Parvoplaca suspiciosa 3	Russia, Urbanavichene 201-1 (H)	KT161989	–
Parvoplaca tenebrosa	USA, Oregon, McCune 26523 (LD)	KC179112	**OR482924**
Parvoplaca tiroliensis A1	Italy, Nascimbene JN5344 (herb. Nascimbene)	**OR479903**	–
Parvoplaca tiroliensis A2	Italy, Nascimbene JN7310 (herb. Nascimbene)	**OR479904**	–
Parvoplaca tiroliensis A3	Sweden, Frödén 1945 (LD)	KC179116	KC179552
Parvoplaca tiroliensis A4	Sweden, Arup L20277(LD)	**OR479905**	–
Parvoplaca tiroliensis A5	Norway, Arup L03372 (LD)	KT161992	–
Parvoplaca tiroliensis A6	Sweden, Arup L03354 (LD)	KT161991	–
Parvoplaca tiroliensis A7	Austria, Søchting US9238 (C)	**OR479906**	–
Parvoplaca tiroliensis B8	Italy, Nascimbene JN4981 (herb. Nascimbene)	**OR479907**	–
Parvoplaca tiroliensis B9	China, Davydov 6876a (CBFS JV5381)	JN641788	–
Parvoplaca tiroliensis B10	Italy, Nascimbene JN7450 (herb. Nascimbene)	**OR479908**	**OR482926**
Squamulea squamosa	USA, Kansas, Kärnefelt AM960105	KC179125	KC179591
Squamulea subsoluta	Austria, Arup L97072 (LD)	AF353954	KC179592
Teuvoahtiana altoandina	Argentina, Frödén 1700 (LD)	KC179094	KC179503
Xanthocarpia ochracea	France, 1998 Roux (C), ITS; Italy, Arup L97124 (LD), mrSSU	KC179132	KC179616
Xanthomendoza mendozae	Chile, Søchting US 10209, (C)	KC179138	KC179620
Xanthopeltis rupicola	Chile, Frödén 1654 (LD)	KC179146	KC179626

analysis halted after 1,600,000 generations and a 50% majority-rule tree with posterior probabilities is shown in Fig. 1. The second analysis of only nrITS data consisted of 51 terminals of 530 sites of which 114 were parsimony informative. This analysis halted after 346,000 generations and the 50% majority-rule tree with posterior probabilities is shown above the branches in Fig. 2. The Maximum Likelihood analysis yielded trees very similar to the Bayesian one and only these are shown. Maximum Likelihood bootstrap values are shown under the branches in the same figure.

The analysis of the combined data set of ITS and mrSSU sequences show the new species to be positioned well within the the genus *Parvoplaca* (Fig. 1). The genus has full support with *Xanthomendoza* and *Pachypeltis* in a sister position, similar to the results presented by Arup et al. (2013), where the genus was first recognized. In the second analysis with only ITS sequences, nine monophyletic, fully supported clades representing species are found in addition to two species represented by only one sequence each (Fig. 2). The whole genus split at the bottom in two clades, however, one without support, with a larger supported clade including seven species. Of these, four are very similar to the appearance of *P. tiroliensis* s.lat., whereas, *P. candani*, *P. tenebrosa* and *P. macroborealis* differ from the other four. The unsupported clade contains *P. lamprocarpa*, described here, and the two dark-fruited species, *P. servitiana* and *P. suspiciosa*, together with the orange-fruited *P. nigroblastidiata*.

Discussion

We are now recognizing 11 species in the genus *Parvoplaca* with *P. tiroliensis* as type. At the time of recognition of the genus (Arup et al. 2013), there was no problem selecting this species as type. Based on the data presented

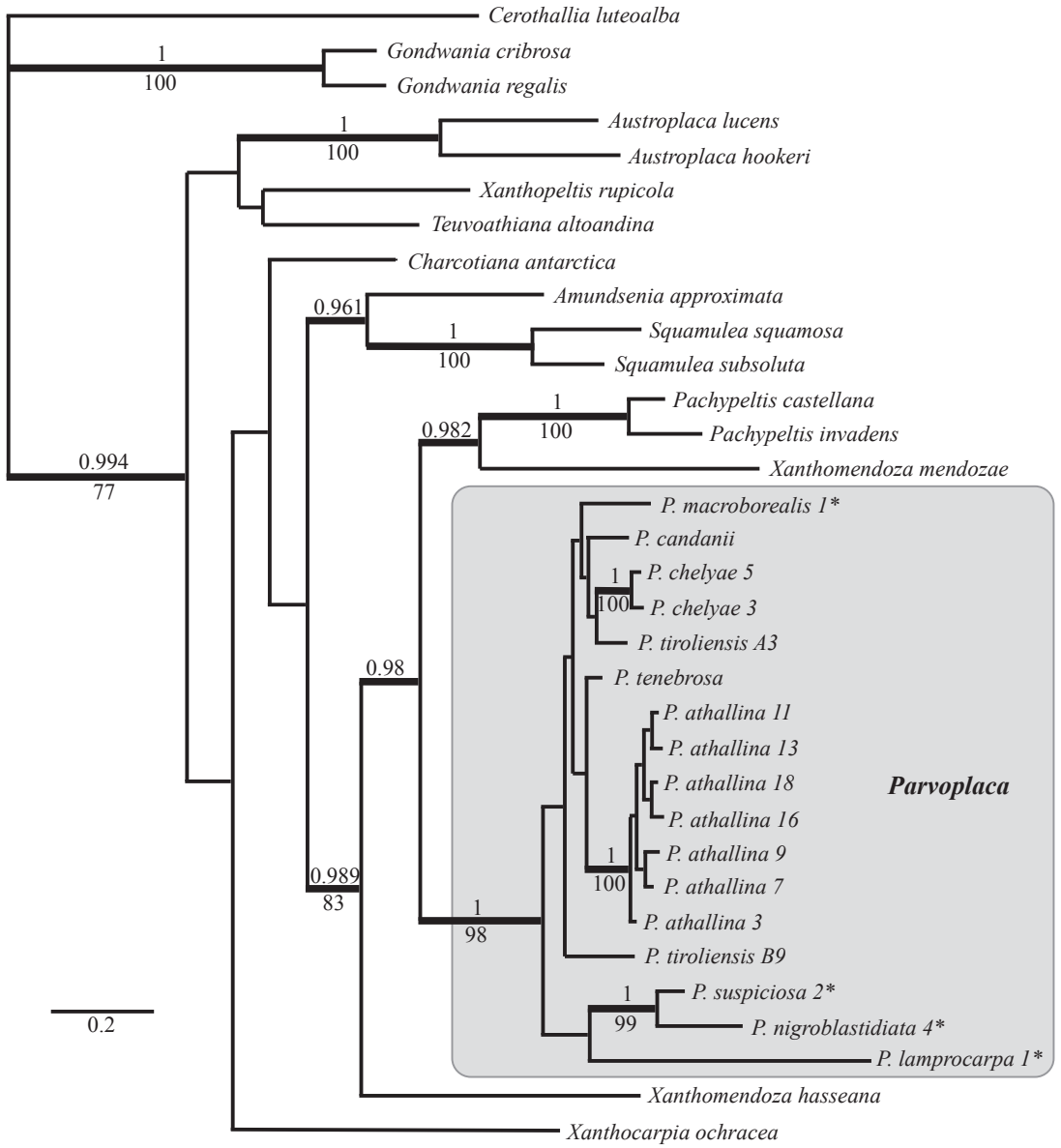

Figure 1. Majority-rule consensus tree based on a Bayesian MCMC analysis of a combined data set of the nuITS and mtSSU genes showing the phylogentic relationship of *Parvoplaca* to the nearest genera. Posterior probabilities ≥ 0.95 are shown above the branches and Maximum Likelihood bootstrap values ≥ 75 are shown below the branches. Species marked with an * are corticolous, all other *Parvoplaca* are terricolous, muscicolous or occurs on plant debris.

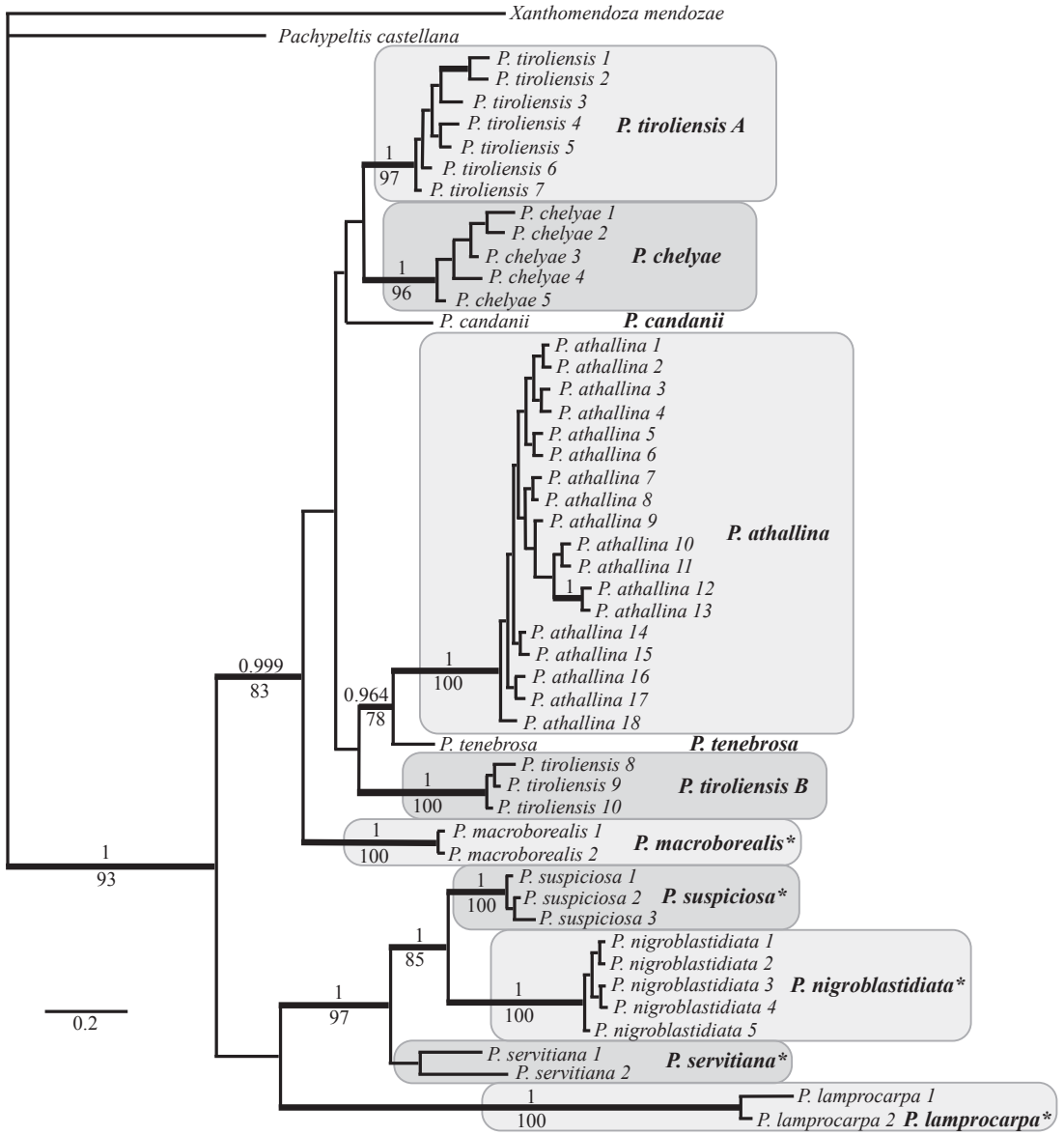

Figure 2. Majority-rule consensus tree based on a Bayesian MCMC analysis of ITS data of *Parvoplaca*. Branches with posterior probabilities higher or equal to 0.95 are shown in bold. Posterior probabilities ≥ 0.95 are shown above the branches and bootstrap values ≥ 75 are shown below the branches. Species marked with an * are corticolous, all other *Parvoplaca* are terricolous, muscicolous or occurs on plant debris.

here, there are, however, two candidate clades for the application of the name *P. tiroliensis* as there are no molecular data from the more than 120 year old type collection. Clade A includes a mixture of northern European sequences and sequences from Austria and Italy, whereas, clade B includes two sequences from Italy together with a Chinese sequence. Since the type locality for *P. tiroliensis* is situated in South Tyrol, northeastern Italy, both clades are possible representatives. None of the sequenced specimens are from the type locality, only as close as possible to the same region. Specimens of the two clades are more or less identical and cannot be separated by morphology, anatomy, chemistry, ecology or altitude; in other words, they are cryptic species. Also *P. athallina* and *P. chelyae* are very similar to *P. tiroliensis* and difficult to determine, but the name *P. athallina* can be safely applied to the clade including Antarctic specimens and *P. chelyae* to the clade including specimens from the Canary Islands, where their respective type localities are situated. If one of the two candidate clades is considered to represent *P. tiroliensis* in a strict sense, then the other clade needs a name and there are at least two names to explore, viz. *Caloplaca arctica* H. Magn. and *C. jungermanniae* subsp. *subolivaceum* (*Callopisma subolivaceum* (Th.Fr) Räsänen). However, in our opinion the genetic profile of a specimen from the type locality needs to be established before any decision can be made, unless a differentiating character can be found.

Parvoplaca athallina was described in 1912 from Graham Island in Antarctica (Darbishire 1912) and has been regarded as an Antarctic species ever since. However, our results clearly show that it also occurs in Norway and Sweden in Europe, in Greenland, in Alaska and in Yosemite National Park in California. It can thus be considered bipolar and belonging to a very small group of *Teloschistaceae* species with this distribution pattern. Within the family, only *Xanthomendoza borealis* (Lindblom & Søchting 2008), *Austroplaca sibirica* (Søchting

& Arup 2021) and *A. soropelta* (Søchting & Castello 2012) have been firmly documented to be bipolar using molecular data. In the Northern Hemisphere, *P. athallina* has previously been confused with *P. tiroliensis* from which it can be separated only by molecular methods.

The occurrence of cryptic species that cannot be recognized by any other means than DNA is really not practical, in particular for amateur lichenologists. If the similar species would form a separate monophyletic clade it would have been a possible solution to unite them all under one name, but the molecular data implies that these taxa are the result of convergent evolution in independent linages mixed with other morphologically recognizable species. Only *P. chelyae* and *P. tiroliensis* seem to be sister species, but this relationship has no support with the currently available data. Thus, for the time being, we recommend to keep the use of already described species, even if cryptic.

Taxonomy

Parvoplaca candanii Halıcı & Søchting, sp. nov. (Fig. 3A–G)

MycoBank MB 849837

Diagnosis: Differs from other terricolous species of the genus by its continuous, well developed chalky white thallus.

Type: Antarctic Peninsula, James Ross Island: Berry Hill Mesa, 63°48′S, 57°50′W, alt. 345 m, 11 January 2017, G. Halıcı, ERCH JR 0.322 (ERCH – holotype).

Etymology. Named in honor of Prof. Dr. Mehmet Candan, a lichenologist from Turkey and the best friend of the third author MGH.

Description. Thallus continuous, crustose, pale grey to chalky white, well developed. Apothecia abundant, zeorine, 0.3–0.5 mm diam., rounded, adnate to slightly stipitate, concave to more or less flat; disc orange; young apothecia vivid orange-yellow, epruinose, some parts of older apothecia darker with an olivaceous tinge; proper margin entire, smooth, paler than disc, in section consisting of a prosoplectenchymatous tissue, 30–40 µm thick in the basal portion. Thalline margin slightly raised above or level with disc, pale yellowish, never grey, K+ violet, N+ red, 40–80 µm, smooth, with fairly well-delimited paraplectenchymatous cortex, 30–60 µm thick, with numerous green algae of 11–18 × 7–15 µm. Epihymenium yellowish orange-brown, granular, inspersed; 10–20 µm thick, K+ violet-red. Hymenium hyaline, (50–)60–80(–90) µm, without oil droplets. Paraphyses with 1–2(–3) tip cells slightly to distinctly swollen, simple to dichotomously branched, 4.5–7.5 µm thick at top and 1–1.5 µm in the middle section, with few oil droplets. Hypothecium

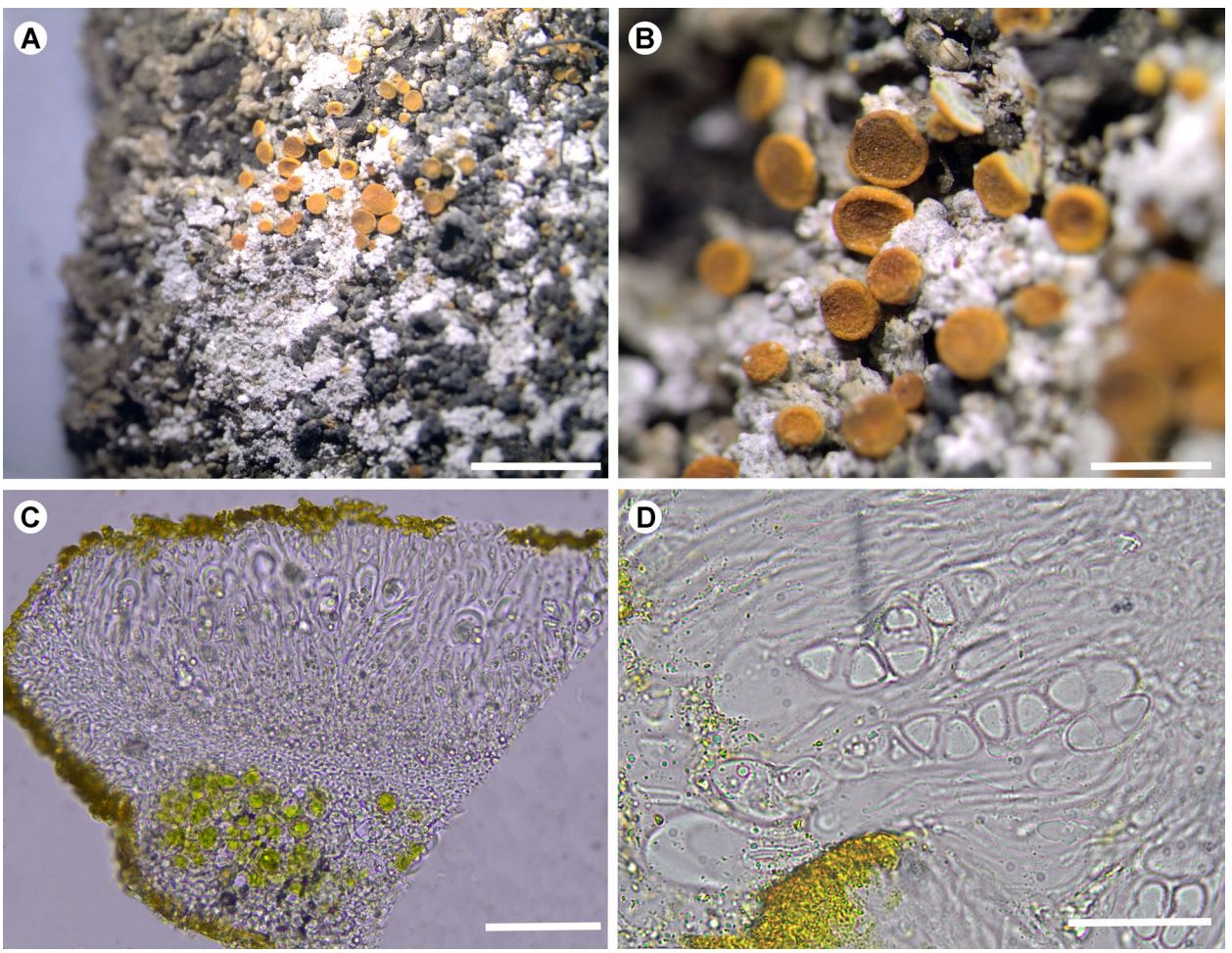

Figure 3. *Parvoplaca candanii*. A – habitus; B – apothecia and chalky white thallus in closer view; C – section of apothecium; D – asci, paraphyses and ascospores. Halıcı, holotype. Scales: A = 5 mm; B = 1 mm; C = 50 µm; D = 25 µm.

40–60 µm thick, hyaline to pale grey. Asci cylindrical, 40–55 × 15–20 µm, 8-spored. Ascospores polardiblastic, ellipsoid and colorless, (14–)15.5–*17*.0–18.5(–20.5) × (7–)8–*9.0*–10(–11) µm, septum (2.5–)3.5–4.5(–5.5) µm, length/width: (1.55–)1.66–*1.93*–2.19 (–2,64); septum/length: (0.1–)0.19–*0.25*–0.31(–0.35). Pycnidia not observed.

Chemistry. Thallus K–, C–, KC–, PD–, medulla in section K + violet-red (Sedifolia grey); apothecial disk K+ dark violet-red, C–.

Distribution and ecology. The single specimen belonging to *Parvoplaca candanii* grows on soil mixed with *Psoroma* sp. at 354 m altitude without sea spray on James Ross Island (Antarctic Peninsula) with lichens such as *Physconia muscigena*, and *Lecidella* sp.

Notes. This species is characterized by the very well developed chalky white thallus. It can be confused with Antarctic endemic species *P. athallina* and *P. tiroliensis* described from Europe. Of these species, *P. athallina* has a bluish-grey thallus which is densely covered by apothecia and it also has shorter ascospores (13–15 µm vs. 14–20 µm). The ascospore sizes of *P. candanii* and *P. tiroliensis* are similar, but the latter has a disappearing thallus (Søchting & Øvstedal 1992).

Parvoplaca lamprocarpa Arup & Søchting, sp. nov. (Fig. 4)

MycoBank MB 8498312

Diagnosis: Similar to *Parvoplaca macroborealis*, but differs in the smaller apothecia, shorter spores and the presences of pycnidia.

Type: Alaska, Lake & Peninsula Co., Lake Clark National Park, SW end of Pickeral Lake, *Picea* woodland and lakeshore, on hardwood bark, 59.94621°N, 154.75756°W, NAD83, elev. 86 m, 3 July 2014, McCune 35218 (LD – holotype).

Etymology. The name reflects the bright orange apothecia from the greek words *lamprós* which means bright or shining and *carpus* which means fruit.

Description. Thallus discontinuous to more or less continuous, up to 25 mm diam., pale to beige to dark grey, 0.1–0.2 mm thick, even to slightly uneven; prothallus not observed. Apothecia present and fairly abundant, scattered or slightly aggregate, adnate to sessile, round to irregular, zeorine, 0.3–0.9 mm diam.; disc flat to convex, yellow-orange to orange; proper margin raised above disc and conspicuous to almost excluded in convex apothecia, 20–100 µm thick, slightly paler than disc, even and somewhat waxy, consisting of radiating, hyphae with long and narrow to short cells, 4–10 × 2–3.5 µm; thalline margin as thin, grey film up to 20 µm thick in upper part and up to 35 µm in lower, often inconspicuous, with paraplectenchymatous cortex; epihymenium brownish orange, granular inspersed; hymenium 65–80 µm thick, hyaline; hypothecium 70–80 µm thick, hyaline; paraphyses simple, 1.5–2.0 µm broad with upper cells hardly wider, up to 3.0 µm; asci cylindrical, 50–60 × 14–16 µm, 8-spored; spores

Figure 4. *Parvoplaca lamprocarpa*. Habitus showing the intensely orange apothecia and the grey rather thin thallus with small orange pycnidia. McCune 35218, holotype (LD). Scale = 1 mm.

polardiblastic, ellipsoid to broadly ellipsoid, (9.3–)10.5–*11.65*–12.5(–13.8) × (5.5–)6.0–*6.59*–7.0(–8.0) µm, septum (2.7–)3.0–*3.70*–4.5(–5.5) µm (n = 20), ratio of spore length/width 1.57–*1.77*–2.08(–2.17), ratio of septum/spore length (0.23–)0.27–*0.32*–0.37(–0.42). Pycnidia present, orange, 0.1–0.15 mm, slightly protruding; conidia bacilliform, 2.5–3.0 × 1 µm.

Chemistry. The apothecial disc and true exciple contain parietin as a major compound, and small amounts of fallacinal, emodin, teloschistin and parietinic acid, which corresponds to chemosyndrome A of Søchting (1997). The thallus and thalline margin contain no anthraquinones, but the pigment sedifolia-grey, which reacts K+ violet and N+ brownish red.

Habitat and distribution. The new species is so far known only from Lake Clark National Park in Alaska. It was found there on two different localities, once on *Populus balsamifera* and once on an unknown hardwood in a *Picea* forest, near a lake. Rather few accompanying species were found in the collections, only fragments of *Phaeophyscia*, probably *P. ciliata* (Hoffm.) Moberg, *Scutula circumspecta* (Vain.) Kistenich et al., *Bacidia rosellizans* S. Ekman and a *Biatora*.

Remarks. This species is characterized by the very intense orange apothecia on a rather thin and inconspicuous thallus. It resembles *P. macroborealis* and may, as this species, have a rather thin grey thalline margin, but differs in the smaller spores with a longer septum/spore length ratio, in having pycnidia and in the narrower paraphysis tips. *Athallia pyracea* is also similar, but has a less distinct thallus that usually shows some shades of yellow or orange, the spores are in general slightly longer with a longer septum (10.0–15.0 µm and 3.8–5.5 µm versus 10.5–12.5 µm and septum 3.0–4.5 µm), and pycnidia are rare or absent in *A. pyracea*.

Additional specimens examined. USA. Alaska, Lake & Peninsula Co., Lake Clark National Park, shore of Lake Clark, W of Hatchet Point, on fallen trunk of *Populus balsamifera*, T. Tønsberg 44132 (BG).

Parvoplaca macroborealis Arup & Søchting, sp. nov. (Fig. 5)

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Diagnosis: Similar to *Athallia borealis*, but differs in larger apothecia that are zeorine, not biatorine, also similar to *Parvoplaca lamprocarpa*, but differs in longer spores with a smaller septum/spore length ratio, in lacking pycnidia and in the wider paraphysis tips.

Type: Oregon, Wheeler Co., Umatilla National Forest, Forest service Road 24, 4 km towards Tamarack Lookout, of Route 207 between Hardman and Spray, on twigs of *Juniperus*, *Juniperus* – *Pinus ponderosa* savanna with volcanic boulders and thin soil, elev. 1331 m, 44.93523°N, 119.67256°W, 25 March 2017, B. McCune 37297 (LD – holotype; OSC – isotype).

Etymology. The new species is similar to *Caloplaca borealis*, but generally larger.

Description. Thallus discontinuous to more or less continuous, up to 20 mm diam., pale to dark to brownish grey, 0.05–0.2 mm thick, even to slightly uneven; prothallus not observed. Apothecia present and fairly abundant, scattered or aggregate, adnate to sessile, round to irregular, lecanorine, 0.3–1.3 mm diam.; disc somewhat concave to slighty convex, sometimes flexuouse, bright orange; proper margin raised above to level with disc, even to weakly crenulate, 25–100 µm thick, slightly paler than disc, consisting of radiating hyphae with long and narrow to short cells, 4–10 × 2–3(–4.5) µm; thalline margin medium grey to almost black, in young apothecia conspicuous, up to 50 µm thick, but often reduced with time to a thin film or excluded, indistinctely paraplectenchymatous; epihymenium brownish-orange, granular inspersed; hymenium 85–90 µm thick, hyaline; hypothecium ~150 µm thick, hyaline; paraphyses simple or slightly branched above, 1.5–2.5 µm broad with upper cells wider, up to 5.0 µm; asci cylindrical, 54–60 × 14–17 µm, 8-spored; spores polardiblastic, ellipsoid to broadly ellipsoid, (13.5–)14.0–*15.49*–17.0(–18.0) × (5.5–)6.0–*6.44*–7.0(–7.3) µm, septum (2.8–)3.0–*3.41*–4.0 µm (n=20), ratio of spore length/width 1.92–*2.42*–2.83, ratio of septum/spore length 0.17–*0.22*–0.28. Pycnidia not observed.

Figure 5. *Parvoplaca macroborealis*. Habitus showing the orange apothecia on a grey thallus. Note the grey thalline margin present especially in the younger apothecia, but often reduced in older ones. McCune 37297, holotype (LD). Scale = 1 mm.

Chemistry. The apothecial disc and true exciple contain parietin as a major compound, and small amounts of fallacinal, emodin, teloschistin and parietinic acid, which corresponds to chemosyndrome A of Søchting (1997). The thallus and thalline margin contains no anthraquinones, but probably the pigment *Sedifolia*-grey, which reacts K+ violet and N+ brownish red, but the spot test reaction is hardly detectable.

Distribution and ecology. So far this species is only known from Wheeler County in Oregon where it is found in Umatilla National Forest (Fig. 6) on three localities

Figure 6. *Pinus ponderosa* savanna with thin soil where *P. macroborealis* was found on twigs of *Juniperus*.

fairly close to one another. In all three cases the new species was found on decorticated twigs of *Juniperus* in a *Juniperus – Pinus ponderosa* savanna with volcanic boulders and thin soil at elevations between 1,312 and 1,358 m. The lichen community seems rich in lichen species according to the accompanying species on the twigs. *Melanohalea elegantula* (Zahlbr.) O. Blanco et al. and *M. exasperatula* (Nyl.) O. Blanco et al. are among the dominant species, but several crustose species also accur, such as *Lecanora laxa* (Śliwa & Wetmore) Printzen, *Rinodina pyrina* (Ach.) Arnold, *Amandinea punctata* (Hoffm.) Coppins. & Scheid., *Candelaria pacifica* Westb. & Arup, *Letharia vulpina* (L.) Hue s.lat. and unidentified species of *Buellia*, *Lecidella* and *Bryoria*. The composition indicates a somewhat enriched environment, perhaps by dust from the vulcanic boulders.

Notes. *Caloplaca macroborealis* and *Caloplaca borealis* (Vain.) Poelt are similar in their grey thin thallus and orange apothecia that are sometimes grey on the outside of their apothecial margin. The grey color in *C. borealis* is not due to a thalline margin being present, it has biatorine apothecia, the outher part of the proper margin just turns grey to black rather often. In *P. macroborealis* the grey color is caused by a thalline margin that is often present in young apothecia, but often reduced and inconspicuous in older ones. The apothecia in *C. borealis* are normally smaller than in *P. macroborealis*, 0.2–0.4(–0.6) mm, whereas those in *P. macroborealis* are up to 1.3 mm in diameter. *Athallia pyracea* is also similar, but has a less distinct thallus that usually shows some shades of yellow or orange, the spore septum is generally longer, 3.8–5.5 µm versus 3.0–4.0 µm.

Additional specimens examined. Oregon, Wheeler Co., Fairway Campground on Route 207 between Hardman and Spray, Umatilla National Forest, elev. 1312 m, 44.95516°N, 119.71145°W, 25 March 2017, B. McCune 37295 (OSC); ibid. Forest Service Road 24, 400 m off Route 207 between Hardman and Spray, Umatilla National Forest, elev. 1358 m., 44.955361°N, 119.69696°W, 25 March 2017, *B. McCune* 37298 (OSC).

Etymology. The name reflects the similarity with *Caloplaca borealis*, but *P. macroborealis* is larger.

Parvoplaca tenebrosa Arup & Søchting, sp. nov.
(Fig. 7)

MycoBank MB 849833

Diagnosis: Morphologically similar to dark-fruited forms of *Parvoplaca tiroliensis*, but differs in the complete lack of anthraquiniones in the apothecia and presence of a K+ violet, N+ red pigment in the apothecium cortex and a K+ brownish, N– red pigment in the epihymenium.

Type: Oregon, Lake Co., Fremont Nation Forest. above Cottonwood Meadow Lake, on *Grimmia* on rock outcrops, semi-open mixed-conifer forest, rhyolite bedrock with ash soils, elev. 2010 m, 42°17.125′N 120°38.913′W, June 2002, B. McCune 26523 (LD – holotype).

Description. Thallus discontinuous, as a thin blackish grey film over the bryophyte, somewhat uneven; prothallus not observed. Apothecia present, aggregate, adnate,

Figure 7. *Parvoplaca tenebrosa.* Habitus showing the dark, almost black apothecia and the dark inconspicuous thallus. McCune 26523, holotype (LD). Scale = 1 mm.

round to somewhat irregular, zeorine, 0.2–0.65 mm diam.; disc somewhat concave to flat, blackish brown; proper margin raised above to level with disc, even, 35–70 µm thick, concolorous with disc, K–, consisting of radiating hyphae with elongate cells, 5–10 × 2 µm; thalline margin blackish grey, very inconspicuous, up to 30 µm thick, but often strongly supressed, cortex of inflated cells, 15–25 µm thick, pigmented part K+ violet, N+ red, inner parts with small POL+ crystals, not dissolving in K; epihymenium grey- to olive-brown, K+ brownish purple; N–; hymenium ~75 µm thick, hyaline; hypothecium ~50 µm thick, hyaline; paraphyses simple or sometimes branched once above, 1.5–2.0 µm broad with upper cells wider, up to 6.0 µm, sometimes with oil droplets; asci cylindrical, 55–65 × 14–17 µm, (4–)8-spored; spores polardiblastic, fusiform to broadly ellipsoid, 10.0–*13.42*–15.5 × 7.0–*8.17*–10.0 µm, septum 3.0–*3.41*–4.0 µm (n=9), ratio of spore length/width 1.25–*1.66*–2.0, ratio of septum/spore length 0.25–*0.26*–0.35, spores in 4-spored asci may be longer, up to 20 µm. Pycnidia not observed.

Chemistry. Apothecia and thallus without anthraquinones, but epihymenium with a grey-brown pigment, K+ brownish purple, N–. This pigment reminds of Verrucarioides-brown in Meyer & Printzen (2000), but is probably not identical with that.

Distribution and ecology. So far this species is only known from the type locality in Lake County, Oregon, where it was found on high altitude growing in a bryophyte cushion of the genus *Grimma* on rock outcrops in a semi-open mixed coniferous forest. It was associated with *Phaeophyscia decolor* (Kashiw.) Essl. and *Parvoplaca tiroliensis* s.lat. (McCune pers. com.)

Etymology. The name *tenebrosa* means dark and refers to the dark apotheca of the species.

Notes. *Parvoplaca tenebrosa* is morphologically very similar to forms of *P. tiroliensis* with dark apothecia where the anthraquinone crystals are few or entirely lacking. Such forms have also been recognized as separate species, *Caloplaca friesii* Magn., that was based on *Caloplaca ferruginea* var. *melanocarpa* Th. Fr. Also anatomically such forms are very similar to the new species, but they differ in their set of pigments. A brownish pigment in the

cortex of *P. tenebrosa* reacts K+ violet and N+ red and in the type of *C. friesii* this pigment seems to be lacking. Furthermore, the epihymenium of *P. tenebrosa* is N– but in *C. friesii* it is dull orange reddish. *Caloplaca friesii* is currently regarded as a synonym of *Parvoplaca tiroliensis*, but their relationship needs further studies. Very dark forms of *P. tiroliensis* have a brownish pigment in the cortex that reacts K+ reddish that *C. friesii* seems to lack.

Acknowledgements

Juri Nascimbene is sincerely thanked for the loan of material of *P. tiroliensis* from Italy. Bruce McCune and Tor Tønsberg are thanked for putting material of the new species at the first authors disposal and B. McCune is thanked for supplying a habitat photo for *P. macroborealis*. The third author thanks Erciyes University for their financial support to conduct the field work on James Ross Island, Antarctica and to the J.G. Mendel Station for infrastructure and facilities. This study was financially supported by TUBITAK 118Z587 coded project. The studies of the third author are also supported by Turkish Academy of Sciences.

References

Arup, U., Søchting, U. & Frödén, P. 2013. A new taxonomy of the family *Teloschistaceae*. *Nordic Journal of Botany* 31: 16–83. https://doi.org/10.1111/j.1756-1051.2013.00062.x

Arup, U., Vondrák, J. & Halıcı, M. G. 2015. *Parvoplaca nigroblastidiata*, a new corticolous lichen (*Teloschistaceae*) in Europe, Turkey and Alaska. *The Lichenologist* 47: 379–385. https://doi.org/10.1017/S0024282915000389

Darbishire, O. V. 1912. The lichens of the Swedish Antarctic Expedition. *Wissenschaftliche Ergebnisse der Schwedichen Südpolar-Expedition* 4: 1–74.

Gardes, M. & Bruns, T. D. 1993. ITS primers with enhances specificity for basidiomycetes. Application for the identification of mycorrhizae and rusts. *Molecular Ecology* 2: 113–118. https://doi.org/10.1111/j.1365-294X.1993.tb00005.x

Lindblom, L. & Søchting, U. 2008. Taxonomic revision of *Xanthomendoza borealis* and *Xanthoria mawsonii* (*Lecanoromycetes*, *Ascomycota*). *The Lichenologist* 40: 399–409. https://doi.org/10.1017/S0024282908007937

McCune, B., Arup, U., Breuss, O., Di Meglio, E., Di Meglio, J., Esslinger, T. L., Magain, N., Miadlikowska, J., Miller, A. E., Muggia, L., Nelson, P. R., Rosentreter, R., Schultz, M., Sheard, J. W., Tønsberg, T. & Walton, J. 2018. Biodiversity and ecology of lichens of Katmai and Lake Clark National Parks and Reserves, Alaska. *Mycosphere* 9: 859–930.

Meyer, B. & Printzen, C. 2000. Proposal for a standardized nomenclature and characterization of insoluble lichen pigments. *The Lichenologist* 32: 571–583. https://doi.org/10.1006/lich.2000.0294

Nguyen, L.-T., Schmidt, H. A., von Haeseler, A. & Quang Minh, B. 2015. IQ-TREE: A fast and effective stochastic algorithm for estimating Maximum-Likelihood phylogenies. *Molecular Biology and Evolution* 32: 268–274. https://doi.org/10.1093/molbev/msu300

Ronquist, F., Teslenko, M., van der Mark, P., Ayres, D. L., Darling, A., Höhna, S., Larget, B., Liu, L., Suchard, M. A. & Huelsenbeck, J. P. 2012. MrBayes 3.2: efficient Bayesian phylogenetic inference and model choice across a large model space. *Systematic Biology* 61: 539–542. https://doi.org/10.1093/sysbio/sys029

Søchting, U. 1997. Two major anthraquinone chemosyndromes in *Teloschistaceae*. *Bibliotheca Lichenologica* 68: 135–144.

Søchting, U. & Arup, U. 2021. *Austroplaca sibirica* (lichenized *Ascomycota*, *Teloschistaceae*) – a bipolar lichen with an austral origin documented by molecular data. *Graphis Scripta* 33: 12–16.

Søchting, U. & Castello, M. 2012. The polar lichens *Caloplaca darbishirei* and *C. soropelta* highlight the direction of bipolar migration. *Polar Biology* 35: 1143–1149. https://doi.org/10.1007/s00300-012-1161-z

Søchting, U. & Øvstedal, D. O. 1992. Contributions to the *Caloplaca* flora of the western Antarctic region. *Nordic Journal of Botany* 12: 121–134. https://doi.org/10.1111/j.1756-1051.1992.tb00208.x

Vondrák, J., Frolov, I., Arup, U. & Khodosovtsev, A. 2013. Methods for phenotypic evaluation of crustose lichens with emphasis on *Teloschistaceae*. *Chornomorski Botanical Journal* 9: 382–405. http://dx.doi.org/10.14255/2308-9628/13.93/6

White, T. J., Bruns, T. D., Lee, S. & Taylor, J. 1990. Application and direct sequencing of fungal ribosomal DNA for phylogenetics. In: Innis, M. A., Gelfand, D. H., Sninsky, J. J. & White, T. J. (eds) *PCR protocols: a guide to methods and applications*. Academic Press, San Diego, p. 315–322.

Zoller, S., Scheidegger, C. & Sperisen, C. 1999. PCR primers for the amplification of mitochondrial small subunit ribosomal DNA of lichen-forming ascomycetes. *The Lichenologist* 31: 511–516. https://doi.org/10.1006/lich.1999.0220

Zhou, S. & Stanosz, G. R. 2001. Primers for amplification of mtSSU rDNA, and a phylogenetic study of *Botryosphaeria* and associated anamorphic fungi. *Mycological Research* 105: 1033–1044. https://doi.org/10.1016/S0953-7562(08)61965-6