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Psora altotibetica (Psoraceae, Lecanorales), a new lichen species from the Tibetan part of the Himalayas

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Abstract

In the present study, we describe the new species, *Psora altotibetica*, from nine localities in China (Tibetan area) and Nepal. The study includes analyses of anatomy, secondary chemistry, and DNA sequence data of *P. altotibetica* and presumed close relatives. *Psora altotibetica* resembles *P. indigirkae* morphologically, but is phylogenetically closer to *P. tenuifolia* and *P. vallesiaca*. It differs from *P. indigirkae* in the colour of the apothecia, the size of the ascospores, and in the secondary chemistry. The species is terricolous and was collected in the alpine zone of the Great Himalayas between 4230 and 5000 m altitude. *Psora tenuifolia* and *P. vallesiaca* are here reported as new to China and the Himalayas.

Key words

Asia, Lecanorales, lichenized ascomycetes, taxonomy

Introduction

The genus *Psora* consists of c. 30 species growing on soil and rock, mainly in arid areas, from the arctic to the subtropical regions of the world (Timdal 2002). The current concept of the genus was proposed by Schneider (1980) and emended by Timdal (1984). No world monograph exists, but there are two revisions of the genus in North America (Timdal 1986, 2002) and keys to the species in Europe (Poelt and Vězda 1981) and Asia (Timdal and Zhurbenko 2004). Ekman and Blaalid (2011) published a molecular phylogeny of the Psoraceae, including 18 species of *Psora*.

In the current Chinese checklist (Wei 1991), five species of *Psora* are listed: (1) *P. asahinae* (Zahlbr.) J.C.Wei, (2) *P. asiae-centralis* (H.Magn.) N.S.Golubk., (3) *P. crenata* (Taylor) Reinke, (4) *P. decipiens* (Hedw.) Hoffm., and (5) *P. lurida* (Ach.) DC. However, three species on this list (1, 2, and 5) are currently excluded from *Psora*, and for one (3), the single Chinese record is based on incorrectly identified material [*Psora asahinae* was synonymised with *Psorula rufonigra* (Tuck.) Gotth.Schneider (Schneider 1980), *P. asiae-centralis* was placed in *Toninia* as *T. tristis* ssp. *asiae-centralis* (H.Magn.) Timdal by Timdal (1992), *P. lurida* was placed in *Romjularia* as *R. lurida* (Ach.) Timdal by Timdal (2008), and the report of *P. crenata* is based on the holotype of *Lecidea undulata* H.Magn. (Bohlin 82, S!) which was placed in synonymy with *Anamylopsora pulcherrima* (Vain.) Timdal by Timdal (1991)]. Hence, *P. decipiens* (4) is the only currently known species of *Psora* in China. It is listed from Xizang by Wei (1991) and from Yunnan by Wang (2012, including a beautiful photograph), and is, together with *Psora himalayana* (C.Bab.) Timdal (described from Uttar Pradesh, India, at 4700 ft), the only known *Psora* species in the Himalayas.

On a visit to the herbarium of Institut für Pflanzenwissenschaften, Karl-Franzens-Universität Graz (GZU) in 1992, one of us (ET) discovered an apparently undescribed species of *Psora* collected near the Khumbu Glacier south of Mt Everest (Nepal) by Josef Poelt in 1962. Two years later, ET was asked by Torstein Engelskjøn to identify some specimens collected by him in 1993 in the Rongbuk Valley north of Mt Everest (Tibet) during a joint Chinese-Norwegian scientific expedition. The material comprised the same apparently undescribed species of *Psora*. The material from both expeditions was rather poor and put aside pending richer collections. In 2013, during a visit to GZU, MB was made aware of the *Psora* collection that WO had made in the Himalayas in 1994 and 2000. This collection contained the putative new species, and a renewed study, including DNA analysis, has led us to describe it here as *Psora altotibetica*.

Material and methods

The specimens

This study is based on 15 collections of *Psora* made by WO in the Himalayas in 1994 and 2000, the collection of *Psora altotibetica* by J. Poelt (GZU), the two by T. Engelskjøn

(TROM), two by G. & S. Miehe made in the Himalayas in 1993 (GZU), four collections from the Karakoram Range (Pakistan) in GZU which are here identified as *P. himalayana* and *P. vallesiaca* (Schaer.) Timdal, and two collections of *P. indigirkae* Timdal & Zhurb. from Yakutia in O. Voucher data for these 26 specimens are given in the list of examined specimens and in Table 1. The table also contains voucher data for the specimens of which DNA was downloaded from GenBank or obtained through the Norwegian Barcode of Life project (NorBOL). With the exception of one collection (*P. himalayana*, Zhurbenko 98161), we have examined all collections listed in Table 1 by morphology during this project or previously.

Anatomy

Microscope sections were cut on a freezing microtome and mounted in water, 10% KOH (K), lactophenol cotton blue, a modified Lugol's solution in which water was replaced by 50% lactic acid, and chlor-zinc-iodine. Amyloid reactions were observed in the modified Lugol's solution after pretreatment in K. Chlor-zinc-iodine was used to locate remnants of algae in the cortex, and polarized light was used to locate crystals of secondary metabolites and calcium oxalate. Calcium oxalate was identified by adding 25% sulphuric acid to the section; the oxalate crystals dissolve and needle shaped crystals of calcium sulphate precipitate. Ascospore measurements are given as X ± 1.5×SD, where X is the arithmetic mean and SD – the standard deviation.

Secondary chemistry

Thin-layer chromatography (TLC) was performed in accordance with the methods of Culberson (1972), modified by Menlove (1974) & Culberson and Johnson (1982). All specimens were examined by TLC, with the exception of Miehe & Miehe 9573/23/03 and Obermayer 4502, which were omitted due to being represented by richer material from the same localities.

DNA extraction, PCR and sequencing

We performed DNA extraction, PCR amplification, PCR purification, and cycle sequencing as described by Bendiksby and Timdal (2013). DNA was extracted from apothecia of 13 specimens (Table 1; GenBank Accession Numbers KU863631–KU863656). All DNA isolates produced for the present study are deposited in the DNA collection at Natural History Museum, University of Oslo. We amplified and sequenced the nuclear ribosomal internal transcribed spacer (ITS) and the mitochondrial ribosomal small subunit (mtSSU) using the primer pairs ITS5/ITS4 (White et al. 1990) and mtSSU1/mtSSU3R (Zoller et al. 1999), respectively.

Table 1. *Psora* specimens used in this study with voucher information, major lichen substances, and GenBank accession numbers. New sequences are indicated by accession numbers in bold.

Taxon, Specimen	Voucher Information	Major Lichen Substances	GenBank Accession Number	
			ITS	mtSSU
P. altotibetica 1	China, Xizang, *Obermayer* 5282 (GZU), holotype	gyrophoric acid	**KU863638**	**KU863651**
P. altotibetica 2	China, Xizang, *Miehe & Miehe* 9573/23/02 (GZU)	gyrophoric acid	**KU863639**	**KU863652**
P. altotibetica 3	China, Xizang, *Obermayer* 5223 (GZU)	gyrophoric acid	**KU863640**	**KU863653**
P. altotibetica 4	China, Xizang, *Obermayer* 4365 (GZU)	gyrophoric acid	**KU863642**	**KU863655**
P. altotibetica 5	China, Xizang, *Obermayer* 3967 (GZU)	gyrophoric acid	**KU863641**	**KU863654**
P. altotibetica 6	China, Xizang, *Obermayer* 4485 (GZU)	gyrophoric acid	**KU863643**	**KU863656**
P. altotibetica	China, Xizang, *Engelskjøn* T-030b (TROM L-42812)	gyrophoric acid	-	-
P. altotibetica	China, Xizang, *Engelskjøn* T-036 (TROM L-42813)	gyrophoric acid	-	-
P. altotibetica	China, Xizang, *Miehe & Miehe* 9573/23/03 (GZU)	-	-	-
P. altotibetica	China, Xizang, *Obermayer* 4350 (GZU)	gyrophoric acid	-	-
P. altotibetica	China, Xizang, *Obermayer* 4502 (GZU)	-	-	-
P. altotibetica	China, Xizang, *Obermayer* 4981 (GZU)	gyrophoric acid	-	-
P. altotibetica	Nepal, *Poelt* 1138 (GZU)	gyrophoric acid	-	-
P. californica	USA, California, *Timdal* SON139/04 (O-L-60112)	bourgeanic acid, gyrophoric acid	EF524322	EF524292
P. globifera 1	Greenland, *Timdal* 10149 (O-L-139171)	no substances	EF524323	EF524294
P. globifera 2	Norway, *Klepsland* JK11-L619 (O-L-183774)	no substances	**KU873928**	-
P. globifera 3	Norway, *Bendiksby et al.* 12914 (O-L-184327)	no substances	**KU873930**	-
P. globifera 4	Norway, *Klepsland* JK11-L213 (O-L-177145)	no substances	**KU873929**	-
P. globifera 5	Norway, *Hjelmstad* s.n. (O-L-184143)	no substances	**KU873932**	-
P. himalayana	Russia, Yakutia, *Zhurbenko* 98161 (M-0066792)	-	AY425635	-
P. himalayana	Pakistan, *Miehe & Miehe* 3529 (GZU)	no substances	-	-
P. himalayana	Pakistan, *Poelt* K91-416	no substances	-	-
P. hyporubescens	USA, California, *Bratt & Timdal* 7052 (O-L-22483), holotype	anthraquinones, gyrophoric acid	EF524311	EF524295
P. indigirkae 1	Russia, Yakutia, *Haugan & Timdal* YAK19/03 (O-L-19148), holotype	bourgeanic acid, gyrophoric acid	EF524302	-
P. indigirkae 2	Russia, Yakutia, *Haugan & Timdal* YAK17/24 (O-L-19086), paratype	bourgeanic acid, gyrophoric acid	**KU863631**	**KU863644**

Taxon, Specimen	Voucher Information	Major Lichen Substances	GenBank Accession Number	
			ITS	mtSSU
P. indigirkae 3	Russia, Yakutia, *Zhurbenko* 92185 (O-L-118686), paratype	bourgeanic acid, gyrophoric acid	**KU863632**	**KU863645**
P. nitida	Mexico, Baja California, *Timdal* SON33/06 (O-L-15546)	gyrophoric acid	EF524313	EF524296
P. pacifica	USA, California, *Rosentreter* 14580 (O-L-126265)	gyrophoric acid, unknown accessory	EF524314	EF524297
P. peninsularis	Mexico, Baja California, *Timdal* SON32/07 (O-L-15539), holotype	norstictic acid	EF524320	EF524298
P. russellii	Mexico, Baja California, *Timdal* SON31/03 (O-L-15531)	norstictic acid	EF524321	EF524300
P. tenuifolia 1	Russia, Yakutia, *Haugan & Timdal* YAK17/26 (O-L-19088)	norstictic acid, zeorin	EF524309	EF524303
P. tenuifolia 2	China, Xizang, *Obermayer* 4487 (GZU)	norstictic acid, zeorin	**KU863636**	**KU863649**
P. tenuifolia 3	China, Xizang, *Obermayer* 5236 (GZU)	zeorin	**KU863637**	**KU863650**
P. tenuifolia	China, Sichuan, *Obermayer* 9791 (GZU)	norstictic acid, zeorin	-	-
P. tenuifolia	China, Xizang, *Obermayer* 4525 (GZU)	zeorin	-	-
P. testacea	Greece, *Rui & Timdal* TH06/04 (O-L-59263)	atranorin	EF524315	EF524301
P. tuckermanii	USA, Arizona, *Rui & Timdal* US240/05 (O-L-59926)	no substances	EF524317	EF524304
P. vallesiaca 1	Greece, *Rui & Timdal* 7993 (O-L-15186)	norstictic acid	EF524324	EF524291
P. vallesiaca 2	China, Xizang, *Obermayer* 3227 (GZU)	norstictic acid	**KU863633**	**KU863646**
P. vallesiaca 3	China, Xizang, *Obermayer* 5279 (GZU)	no substances	**KU863635**	**KU863648**
P. vallesiaca 4	Pakistan, *Poelt* K91-705 (GZU)	norstictic acid	**KU863634**	**KU863647**
P. vallesiaca 5	Norway, *Bendiksby et al.* 12979 (O-L-184392)	norstictic acid	**KU873926**	-
P. vallesiaca 6	Norway, *Klepsland* JK11-L624 (O-L-183778)	norstictic acid	**KU873927**	-
P. vallesiaca 7	Norway, *Klepsland* JK11-L601 (O-L-183760)	norstictic acid	**KU873931**	-
P. vallesiaca	China, Xizang, *Obermayer* 4482 (GZU)	norstictic acid	-	-
P. vallesiaca	Pakistan, *Poelt* s.n. (GZU)	norstictic acid	-	-

Data analyses

Sequences were assembled and edited using SEQUENCHER v.4.1.4 (Gene Codes Corporation, Ann Arbor, Michigan, U.S.A.). Alignments were established in BIOEDIT 7.2.3 (Hall 1999) using the "ClustalW/Multiple alignment" option with subsequent manual adjustments. We analysed and summarized the data with parsimony and Bayesian phylogenetic methods, including model testing, as described in Bendiksby et al. (2015). The nuclear and mitochondrial datasets were analysed separately and in combination (concatenated) with indels treated as missing data.

Results

Species identifications

The 24 Central Asian specimens were identified by morphology and secondary chemistry as *Psora altotibetica* (13), *P. himalayana* (2), *P. vallesiaca* (5), and *P. tenuifolia* Timdal (4).

Anatomy

The following key characters for including *P. altotibetica* in *Psora* were observed in the new species: the upper cortex contained remnants of algae throughout both the lower stainable layer and the upper epinecral layer ('Scheinrindentyp' of Poelt 1958); the hypothecium contained calcium oxalate crystals; the epihymenium contained orange crystals which dissolved in K with a purple diffusion (assumed to be anthraquinones); and the ascus contained a well-developed, amyloid tholus with a central, deeper amyloid tube structure (*Porpidia*-type).

The following species level characters were observed in *P. altotibetica*: Upper cortex composed of thin-walled hyphae with rounded lumina; lower cortex composed of mainly periclinally oriented hyphae; crystals of calcium oxalate and assumedly gyrophoric acid (dissolving in K) present both in upper cortex and medulla; no crystals in lower cortex; ascospores 9–14 × 5–7 μm.

Secondary Chemistry

The results of the TLC examinations are given in Table 1. All examined specimens of *P. altotibetica* contained gyrophoric acid; no traces of fatty acids were detected.

Molecular data

Altogether 26 DNA sequences were generated from 13 specimens for the present study (13 ITS and 13 mtSSU), including two specimens of *P. indigirkae* from Yakutia in O. In addition, seven unpublished ITS sequences of *P. globifera* (Ach.) A.Massal. and *P. vallesiaca* from Norway were generated by the lichen DNA barcode project, OLICH, at the Norwegian Barcode of Life (NorBOL). Moreover, 24 ITS and mtSSU sequences from 13 *Psora* specimens were downloaded from GenBank. GenBank accession numbers of all 57 sequences are given in Table 1.

Alignments and phylogenetic analyses

The ITS matrix of 32 accessions was 676 basepairs long and contained 181 parsimony-informative characters. The basepairs and parsimony-informative characters for the mtSSU matrix of 25 accessions were 881 and 28, respectively. The estimated best fit model of evolution for ITS was SYM+G and for mtSSU it was HKY+I+G. Both parsimony jackknife and Bayesian trees of ITS vs mtSSU were congruent but resolved to various extents (not shown). Therefore, for the final analyses, a concatenated dataset of 1557 bp was used. In the Bayesian analysis of the concatenated dataset, the average standard deviation of split frequencies had fallen to 0.0045 at termination (four million generations) and the first 1000 saved trees (i.e. 25%) were discarded as burn-in. The Bayesian 50% majority rule consensus tree, rooted with *P. testacea*, is presented with both Bayesian and parsimony branch support superimposed (Fig. 1). The molecular data group, with high support, multiple accessions of each species according to species determination based on morphology. The single exception is one accession of *P. himalayana*, which falls out nested within a *P. vallesiaca* clade. The latter consists of strongly supported subclades. *Psora tenuifolia* is strongly supported as phylogenetic sister species to *P. altotibetica*. The *P. tenuifolia* – *P. altotibetica* clade is in turn sister to the *P. vallesiaca* clade. A clade consisting of *P. hyporubescens* Timdal and *P. pacifica* Timdal is also strongly supported. Apart from this, the molecular data does not support any further inter-species relationships.

Discussion

Psora tenuifolia is the sister species of *P. altotibetica* in our phylogeny (Fig. 1). It differs in having thinner, ascending, less pruinose, more white-edged squamules containing zeorin and usually norstictic acid, and in having a well-developed lower cortex composed of mainly anticlinally oriented hyphae which are densely covered by calcium oxalate crystals (Timdal 1986). *Psora tenuifolia* was previously known from Alaska and arctic Canada (Timdal 1986) and from Yakutia (Zhurbenko 2003). In two specimens (Obermayer 4525 and 5236) norstictic acid was not detected by TLC; these specimens

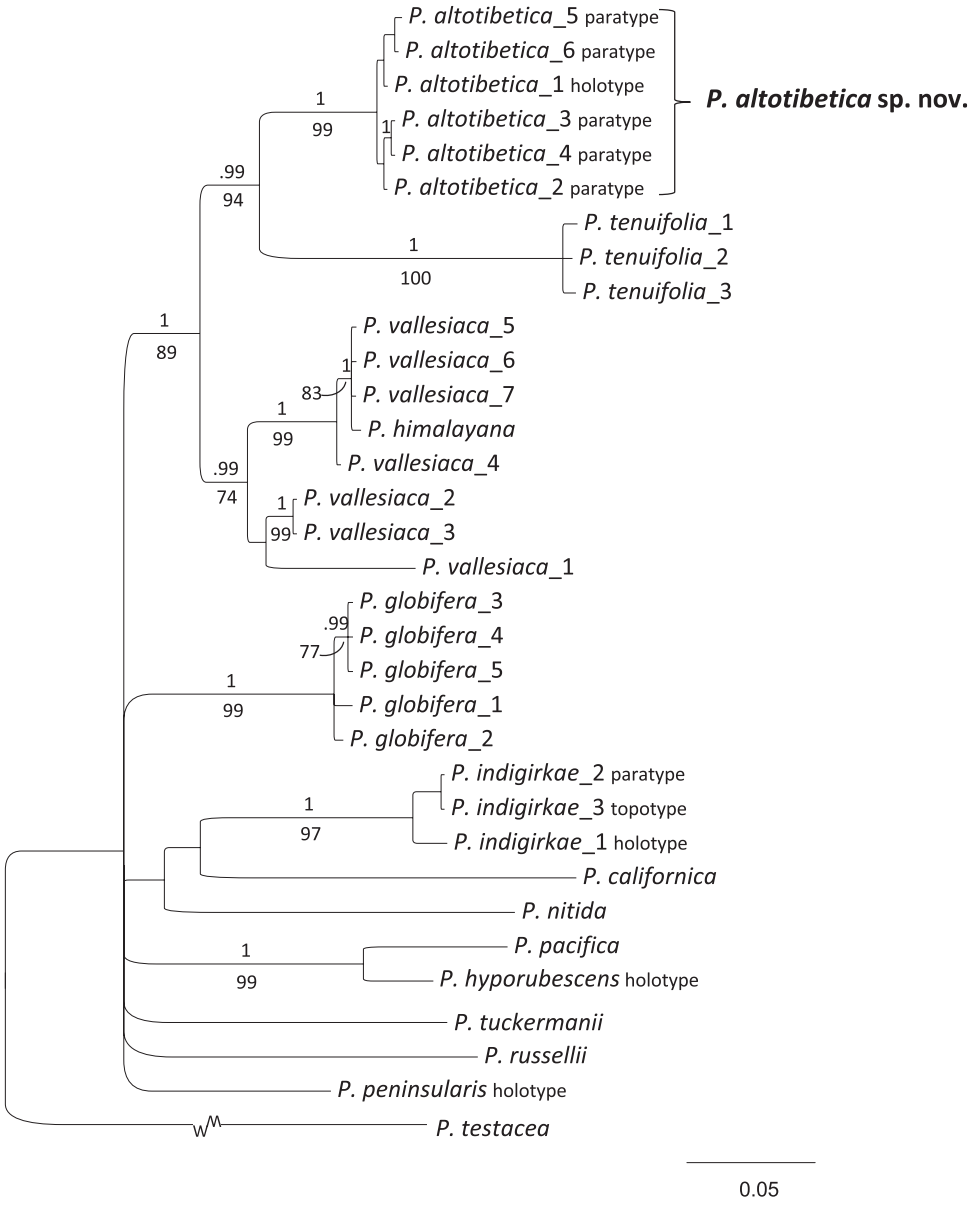

Figure 1. The Bayesian 50% majority rule consensus tree based on a concatenated alignment of ITS and mtSSU sequences of 33 accessions of 14 *Psora* species (see Table 1). Parsimony jackknife support values above 50% are shown below branches and Bayesian posterior probabilities above. The curly branch leading to *P. testacea* has been shortened to reduce the size of a broad figure.

represent a previously unknown chemotype of *P. tenuifolia*. The species is here reported as new to China (Sichuan and Xizang) and the Himalayas. One collection (Obermayer 4487) is a mixture of *P. altotibetica* and *P. tenuifolia*.

Psora vallesiaca is the phylogenetic sister species of the *P. altotibetica* - *P. tenuifolia* clade (Fig. 1). It differs from *P. altotibetica* in having less pruinose squamules with a more up-turned and white-edged margin, and in containing norstictic acid. It is morphologically more similar to *P. tenuifolia* than to *P. altotibetica*; see Timdal (1986) for discussion on the differences between *P. tenuifolia* and *P. vallesiaca*. Two specimens here identified as *P. vallesiaca* (Obermayer 4482 and 5279) do not contain lichen substances and were first thought to represent *P. himalayana*. We obtained sequences from the latter, and it clusters with *P. vallesiaca* in our phylogeny (Fig. 1, specimen *P. vallesiaca* 3). The sequence of *P. himalayana* downloaded from GenBank (specimen not examined by us, chemistry unknown) also clusters with those of *P. vallesiaca* in our phylogeny. Timdal (1986) remarked that *P. himalayana* and *P. vallesiaca* are sometimes difficult to distinguish morphologically, but that the chemistry is diagnostic. It now seems that there is a norstictic acid deficient chemotype of *P. vallesiaca*, making the taxonomic status of *P. himalayana* in need of revision. *Psora vallesiaca* is here reported as new to China (Sichuan and Xizang) and the Himalayas.

The other species of *Psora* known from the Himalayas, *P. decipiens*, differs in having orange to red or rose, more regularly rounded squamules with a usually more upturned and crenulate margin, in having strictly marginal apothecia, and in lacking lichen substances or more rarely containing norstictic acid or very rarely hyposalazinic and hypostictic acids (see, e.g., Timdal 2002).

Nine other *Psora* species contain gyrophoric acid (Timdal 1986, 2002, Timdal and Zhurbenko 2004). Five of those are in our phylogeny (Fig. 1; i.e. *P. californica* Timdal, *P. hyporubescens*, *P. indigirkae*, *P. nitida* Timdal, and *P. pacifica*), but none are closely related to *P. altotibetica*. *Psora indigirkae* is the morphologically most similar *Psora* species, but differs from *P. altotibetica* in having brown apothecia, often with a reddish hue, larger ascospores (14–17 × 7–8 µm; n=50), and in its secondary chemistry: gyrophoric acid is accompanied by bourgeanic acid (Timdal and Zhurbenko 2004). None of the four remaining gyrophoric acid containing *Psora* species are morphologically similar to *P. altotibetica*. *Psora nipponica* (Zahlbr.) Gotth.Schneider and *P. rubiformis* (Ach.) Hook. have, e.g., a lower cortex similar to that of *P. tenuifolia* (Timdal 1986), *P. montana* Timdal has medium to castaneous brown squamules and brown, more plane apothecia, and *P. russellii* (Tuck.) A.Schneider has larger, more rounded squamules, often with a central depression, and almost always contains norstictic acid as the major compound (gyrophoric acid being minor to trace or lacking).

Taxonomy

***Psora altotibetica* Timdal, Obermayer & Bendiksby, sp. nov.**
Mycobank: MB 816840
Fig. 2

Diagnosis. Similar to *Psora indigirkae*, but apothecia black, ascospores shorter, and bourgeanic acid absent from the thallus.

Figure 2. *Psora altotibetica*, part of holotype. Scale bar = 1 mm.

Type. CHINA. Xizang: Himalaya Range, 165 km SSE of Lhasa, 40 km W of Lhünze, little village on way to Nera Tso (=Ni La Hu), 28°23'N, 92°05'E, 4300–4400 m alt., dry-valley, N-exposed dry slopes, on the ground, 1 Aug 1994, W.Obermayer 5282 (holotype: GZU!).

Description. Thallus squamulose; squamules up to 3 mm wide, rounded, adnate, dispersed to adjacent, weakly concave to plane; upper surface medium brown, dull, becoming moderately to densely pruinose, smooth when young, later with fissures in the cortex; margin concolorous with upper side or partly white, straight to slightly down-turned or slightly up-turned, entire; upper cortex 40–60 µm thick, composed of pale brown, thin-walled hyphae with rounded lumina, containing remnants of algae throughout (Chlor-zinc-iodine!), containing crystals of gyrophoric acid (assumedly, dissolving in K) and (in pruinose squamules) crystals of calcium oxalate; epinecral layer hardly developed. Medulla not amyloid, containing both lichen substances (dissolving in K) and calcium oxalate; lower cortex poorly developed, composed of mainly periclinally oriented, pale brown hyphae, not containing crystals; lower surface brown. Apothecia up to 1.2 mm diam., marginal or submarginal on the squamules, plane and indistinctly marginate when young, soon becoming convex and immarginate, black, epruinose or faintly white pruinose at the margin. Hypothecium colourless, containing crystals of calcium oxalate; epihymenium yellowish brown, containing orange crystals dissolving in K, K+ purple. Ascus clavate, with a well-developed, amyloid tholus containing a deeper amyloid tube, lacking an ocular chamber (*Porpidia*-type); ascospores ellipsoid, simple, hyaline, 9–14 × 5–7 µm (n = 30). Conidiomata not seen.

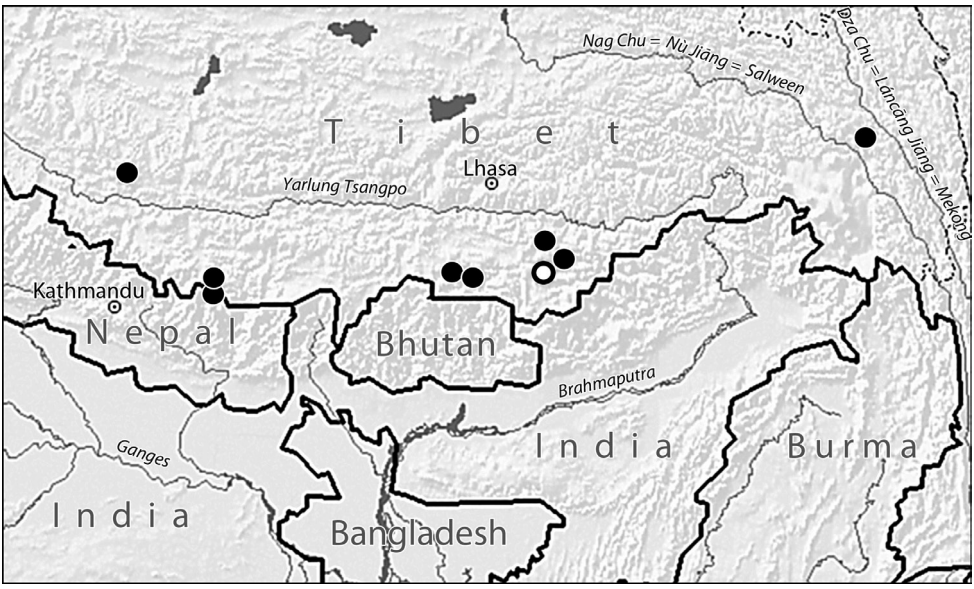

Figure 3. *Psora altotibetica*, known distribution. Open circle = holotype locality.

Chemistry. Gyrophoric acid (by TLC); upper cortex and medulla K–, C+ faintly red, KC+ faintly red, P–.

Habitat and distribution. The species is terricolous and known from nine localities in China (Tibet) and Nepal at altitudes between 4230 and 5000 m (Fig. 3).

Etymology. The name refers to its occurrence at high altitude in the Tibetan part of the Himalayas.

Other specimens examined. *Psora altotibetica*. CHINA. Xizang: Shegar, Rongbuk Valley, S of Rongpu-si, 5000 m alt., moraine hill, 7 Jul 1993, T.Engelskjøn T-030b (TROM L-42812); 5000 m alt., rock base, patchwise on silt, 7 Jul 1993, T.Engelskjøn T-036 (TROM L-42813); Upper Tsangpo basin, N of Saga, 29°34'N, 85°15'E, alt. 4760 m, 28°W, grazed stony relicts of *Juniperus* dwarf-scrub, on ground, 26 Aug 1993, G.Miehe. & S.Miehe 9573/23/02 (GZU) & 9573/23/03 (GZU); 120 km SSW of Quamdo (=Changtu), 10 km S of Bamda, 30°09'N, 97°17'E, 4500–4700 m alt., on mosses, overhang, NNW-exp., 6 Aug 1994, W.Obermayer 3967 (GZU); Himalaya Range, 160 km S of Lhasa, dry valley of Kuru river, 10 km NW Lhozag, 28°24'N, 90°39'E, 4230 m alt., N-exposed steep rocks in a glen, on soil, 17 Jul 1994, W.Obermayer 4350 (GZU) & 4365 (GZU); Himalaya Range, 170 km S of Lhasa, between Lhozhag and Lhakhang Dzong, W-facing slopes of Dhalari mountain, 28°20'N, 90°58'E, 4300 m alt., NNW-exposed, ±underhang, 20 Jul 1994, W.Obermayer 4485 (GZU) & 4502 (GZU); Himalaya Range, 170 km SE of Lhasa, 110 km SSE of Tsetang (Nedong), 28°35'N, 92°23'E, 4700 m alt., alpine meadows with *Kobresia pygmaea*, ground with *Ochotona*-burrows, 26 Jul 1994, W.Obermayer 4981 (GZU); Himalaya Range, 130 km SE of Lhasa, 50 km SSE of Tsetang (Nedong), on way to the pass Putrang La, 28°52'N, 92°06'E, 4400 m alt., dry slope, on soil, 2 Aug 1994,

W.Obermayer 5223 (GZU). NEPAL. Mahalangur Himal, Khumbu, Moränen des Khumbu-Gletschers bei Lobuche, 4950–5000 m alt., Sep 1962, J.Poelt 1138 (GZU).

Psora himalayana. PAKISTAN. Karakorum, Naz Bar (Yasin), 36°17–25'N, 73°0–17'E, 3400–3470 m alt., subalpine Juniperus communis dwarf-scrub with Juniperus macropoda trees in Seriphidium maritimum steppe; on silt in rock crevices, 11 Sep 1990, G.Miehe & S.Miehe 3529 (GZU); Karakorum, Baltistan, Haramosh Range, "Alm" Pakora SE Ganto La, 35°41'N, 75°21'E, 3600–3800 m alt., pasture and rocks around the alm, rocky slopes, 3 Jul 1991, J.Poelt K91-416 (GZU).

Psora indigirkae. RUSSIA. Sakha Republic: Momskii region, along the river Indigirka, c. 48 km NNW of Tyubelyakh, 65°48'N, 142°53'E, 200–300 m alt., on calcareous soil in limestone cliffs, 20 Jul 1992, R.Haugan & E.Timdal YAK17/24 (O L-19086); c. 54 km N-NNW of Tyubelyakh, 65°51'N, 143°01'E, 200–300 m alt., 20 Jul 1992, M.P.Zhurbenko 92185 (O L-118686).

Psora tenuifolia. CHINA. Sichuan: Tibetan fringe mountains (=Hengduan Shan), Shaluli Shan, on the outskirts of Yajiang, 200 m E of the river Yalong Jiang, 30°02'22"N, 101°00'16"E, 2610 m alt., NE-exposed dry slopes with schist outcrops, on thin soil crust (over schist), 12 Aug 2000, W.Obermayer 9791 (GZU); Xizang: Himalaya Range, 170 km S of Lhasa, between Lhozhag and Lhakhang Dzong, W-facing slopes of Dhalari mountain, 28°20'N, 90°58'E, 4300 m alt., NNW-exposed, ±underhang, 20 Jul 1994, W.Obermayer 4487 (GZU); Himalaya Range, 175-180 km S of Lhasa, between Lhozhag and Lhakhang Dzong, Kuru river valley, pass, 28°12'N, 91°00'E, 3600 m alt., on soil, 21 Jul 1994, W.Obermayer 4525 (GZU); Himalaya Range, 210 km SE of Lhasa, 15 km ESE of Lhünze, way to Qayü, dry-valley of Subansiri, 28°24'N, 92°37'E, 4100–4200 m alt., on soil (+ mosses), 31 Jul 1994, W.Obermayer 5236 (GZU).

Psora vallesiaca. CHINA. Sichuan: Shalui Shan Mts, 30 km NE Batang, S Yidun, 30°16'N, 99°25'E, 3750–3800 m alt., on marble outcrops, soil, 25 Jun 1994, W.Obermayer 3227 (GZU); Xizang: Himalaya Range, 165 km SSE of Lhasa, 40 km W of Lhünze, little village on way to Nera Tso (=Ni La Hu), 28°23'N, 92°95'E, 4300–4400 m alt., dry-valley, N-exposed dry slopes, on the ground, 1 Aug 1994, W.Obermayer 5279 (GZU); Himalaya Range, 170 km S of Lhasa, between Lhozhag and Lhakhang Dzong, W-facing slopes of Dhalari mountain, 28°20'N, 90°58'E, 4300 m alt., NNW-exposed, ±underhang, 20 Jul 1994, W.Obermayer 4482 (GZU); PAKISTAN. Karakorum, Baltistan, Haramosh Range, between "Alm" Matumdus (3620 m, 35°42'N, 75°23'E) and Hemasil in the Basna Valley, 3100–3200 m alt., 7 Jul 1991, J.Poelt K91-705 (GZU); Karakorum, Baltistan, Basna valley, Basnald, 2500 m alt., 10 Jul 1991, J.Poelt s.n. (GZU).

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References

Bendiksby M, Timdal E (2013) Molecular phylogenetics and taxonomy of *Hypocenomyce* sensu lato (Ascomycota, Lecanoromycetes) – extreme polyphyly and morphological/ecological convergence. Taxon 62: 940–956. doi: 10.12705/625.18

Bendiksby M, Haugan R, Spribille T, Timdal E (2015) Molecular phylogenetics and taxonomy of the *Calvitimela aglaea* complex (Tephromelataceae, Lecanorales). Mycologia 107: 1172–1183. doi: 10.3852/14-062

Culberson CF (1972) Improved conditions and new data for the identification of lichen products by a standardized thin-layer chromatographic method. Journal of Chromatography 72: 113–125. doi: 10.1016/0021-9673(72)80013-X

Culberson CF, Johnson A (1982) Substitution of methyl tert.-butyl ether for diethyl ether in the standardized thin-layer chromatographic method for lichen products. Journal of Chromatography 238: 483–487. doi: 10.1016/S0021-9673(00)81336-9

Ekman S, Blaalid R (2011) The devil in the details: interactions between the branch-length prior and likelihood model affect node support and branch lengths in the phylogeny of the Psoraceae. Systematic Biology 60: 541–561. doi: 10.1093/sysbio/syr022

Hall TA (1999) BioEdit: A user-friendly biological sequence alignment editor and analysis program for Windows 95/98/NT. Nucleic Acids Symposium Series 41: 95–98.

Menlove JE (1974) Thin-layer chromatography for the identification of lichen products. Bulletin of the British Lichen Society 34: 3–5.

Poelt J (1958) Die lobaten Arten der Flechtengattung *Lecanora* Ach. sensu ampl. in der Holarktis. Mitteilungen der Botanischen Staatssammlung München 2: 411–589.

Poelt J, Vězda A (1981) Bestimmungsschlüssel europäischer Flechten. Ergänzungsheft II. Bibliotheca Lichenologica 16: 1–390.

Schneider G (1980) Die Flechtengattung *Psora* sensu Zahlbruckner – Versuch einer Gliederung. Bibliotheca Lichenologica 13: 1–291.

Timdal E (1984) The delimitation of *Psora* (Lecideaceae) and related genera, with notes on some species. Nordic Journal of Botany 4: 525–540. doi: 10.1111/j.1756-1051.1984.tb02059.x

Timdal E (1986) A revision of *Psora* (Lecideaceae) in North America. The Bryologist 89: 253–275. doi: 10.2307/3243197

Timdal E (1991) *Anamylopsora*, a new genus in the Lecideaceae. Mycotaxon 42: 249–254.

Timdal E (1992, '1991') A monograph of the genus *Toninia* Massal. (Lecideaceae, Ascomycetes). Opera Botanica 110: 1–137.

Timdal E (2002) *Psora*. In: Nash III TH, Ryan BD, Gries C, Bungartz F (Eds) Lichen Flora of the Greater Sonoran Desert Region, Vol. 1. Lichens Unlimited, Arizona State University, Tempe, 418–430.

Timdal E (2008) *Romjularia*. In: Nash III TH, Gries C, Bungartz F (Eds) Lichen Flora of the Greater Sonoran Desert Region, Vol. 3. Lichens Unlimited, Arizona State University, Tempe, 287–289.

Timdal E, Zhurbenko MP (2004) *Psora indigirkae*, a new species from eastern Siberia, with key to the Asian species of *Psora*. Symbolae Botanicae Upsalienses 34: 25–29.

Zhurbenko MP (2003) New and rare lichen species (Lichenes) from Sakha-Yakutiya Republic and Magadan region. Botanicheskii Zhurnal 88: 111–118.

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. doi: 10.1017/S0024282999000663

Wang L-S (2012) 中国云南地衣 [Zhongguo Yunnan di yi; Lichens of Yunnan in China]. Shanghai ke xue ji shu chu ban she, Shanghai, 1–238. [In Chinese]

Wei JC (1991) An enumeration of lichens in China. International Academic Publishers, Beijing, 1–278.

White TJ, Bruns T, Lee S, Taylor JW (1990) Amplification and direct sequencing of fungal ribosomal RNA genes for phylogenetics. In: Innis MA, Gelfand DH, Sninsky JJ, White TJ (Eds) PCR protocols: A guide to methods and applications. Academic Press, New York, 315–322. doi: 10.1016/b978-0-12-372180-8.50042-1