

## The lichen genus *Rhizocarpon* in mainland Australia

Patrick M. McCarthy<sup>1</sup> and John A. Elix<sup>2</sup>

<sup>1</sup>Australian Biological Resources Study, GPO Box 787, Canberra, ACT 2601, Australia [Patrick.McCarthy@environment.gov.au](mailto:Patrick.McCarthy@environment.gov.au)

<sup>2</sup>Research School of Chemistry, Building 137, Australian National University, Canberra, ACT 2601, Australia, [John.Elix@anu.edu.au](mailto:John.Elix@anu.edu.au)

### Abstract

Two species of the lichen genus *Rhizocarpon* Ramond ex DC. (Rhizocarpaceae, Ascomycota), *R. flavomedullosum* Elix & P.M.McCarthy and *R. vigilans* P.M.McCarthy & Elix, are described as new to science. Six others [*R. adarense* (Darb.) I.M.Lamb, *R. eupetraeoides* (Nyl.) Blomb. & Forssell, *R. geminatum* Körb., *R. intersitum* Arnold, *R. lavatum* (Fr.) Hazsl. and *R. lecanorinum* Anders] are reported from Australia for the first time. Variation in the composition of lichen substances is documented, and a key is provided to the 18 Australian taxa.

### Introduction

*Rhizocarpon* Ramond ex DC. (Rhizocarpaceae) is a genus of c. 200 crustose species with areolate thalli, a usually distinct prothallus, diverse thalline chemistry, innate to superficial lecideine apothecia, mostly anastomosing and conglutinate paraphyses, distinctive 1–8-spored asci and hyaline to greenish black, halonate, ellipsoid ascospores that can be transversely septate or submuriform to densely muriform. Although predominantly free-living, a substantial minority of species are parasitic on other lichens, at least early in their development. The genus is most diverse and abundant on siliceous rocks in montane habitats and at temperate to higher latitudes; it is much rarer or completely absent in the wet and dry tropics and subtropics and in hot-arid regions.

This genus is especially well documented in temperate to boreal Europe and North America (Runemark 1956a, b; Geyer et al. 1984; Clauzade and Roux 1985; Timdal and Holtan-Hartwig 1988; Feuerer 1991; Wirth 1995; Thomson 1997; Brodo et al. 2001; Fryday 2000a, 2002, 2004, 2010; Feuerer and Timdal 2004; Ihlen 2004; Fletcher et al. 2009; Golubkov and Matwiejuk 2009), less so at austral latitudes (Fryday 2000b, 2004; Øvstedal and Lewis Smith 2001; Galloway 2007; Fryday and Kantvilas 2012). Until recently, only nine species were known from Australia, mainly in Tasmania and southern parts of the Great Dividing Range: the pantemperate and rather common *R. badioatrum* (Flörke ex Spreng.) Th.Fr., *R. geographicum* (L.) DC. and *R. reductum* Th.Fr., along with sparse collections of *R. disporum* (Nägeli ex Hepp) Müll.Arg., *R. distinctum* Th.Fr., *R. petraeum* (Wulfen) A.Massal., *R. polycarpum* (Hepp) Th.Fr., *R. superficiale* (Schaer.) Malme and *R. viridiatrum* (Wulfen) Körb. (McCarthy 2014). Fryday and Kantvilas (2012) described a new species, *R. austroamphibium*, from Tasmania and, significantly, highlighted the paucity of Australian species in comparison with the British Isles (39 taxa) and New Zealand (24). They predicted that a careful assessment of unidentified herbarium collections combined with field-work ‘would dramatically increase the number of species reported’.

In this paper 16 species are documented from southern New South Wales, Victoria, South Australia, south-western Western Australia and the Australian Capital Territory; two are newly described and a further six are additions to the national flora. Continuing investigations in these areas, and particularly in Tasmania, are likely to further expand the known diversity of *Rhizocarpon* in Australia.

## Methods

Observations and measurements of photobiont cells, thallus and apothecium anatomy, asci and ascospores were made on hand-cut sections mounted in water and 10% KOH (K). Asci were also observed in Lugol's Iodine (I), with and without pretreatment in K. Chemical constituents were identified by thin-layer chromatography (Elix 2014), high-performance liquid chromatography (Elix et al. 2003) and comparison with authentic samples.

## The Species

### 1. *Rhizocarpon adarensis* (Darb.) I.M.Lamb, *Lilloa* 14: 221 (1948)

*Thallus* epilithic, determinate, pale to vivid yellow-green, areolate; areoles 0.3–3.0 mm wide, smooth, plane to strongly convex, aggregated and angular or scattered and more rounded; medulla mainly yellow, I–. *Prothallus* black, distinct between areoles and at thallus margin. *Apothecia* numerous, usually solitary, black, round to angular, innate between areoles, 0.25–1.50 mm diam.; disc plane to weakly convex; proper margin becoming excluded. *Asci* 60–80 × 14–18 µm. *Ascospores* 8 per ascus, dark green to dark brown, 1-septate, broadly ellipsoid, 11–18 × 5–10 µm.

Detailed descriptions and illustrations are provided in Darbishire (1923, as *Buellia adarensis* Darb., and its synonyms *Buellia flavoplana* Darb., *B. superba* Darb., *B. tristis* Darb. and *B. variabilis* Darb.).

*Chemistry*: Rhizocarpic acid (Table 1).

*Rhizocarpon adarensis* is characterized by its yellow-green, areolate thallus containing only rhizocarpic acid and bordered by a black prothallus, a yellow, non-amyloid medulla, plane to weakly convex apothecia and rather small, 1-septate ascospores. *Rhizocarpon superficiale* is similar but differs in having an inconspicuous prothallus, a white medulla, apothecia with a persistent proper margin, and in containing norstictic or stictic acids in addition to rhizocarpic acid.

*Rhizocarpon adarensis* is reported here for the first time from Australia; it was collected from submontane, siliceous rocks in the Australian Capital Territory. Elsewhere, it occurs in Antarctica and Argentina (Øvstedal and Lewis Smith 2001; Calvelo and Liberatore 2002).

**Specimens examined: Australian Capital Territory:** W slopes of Black Mountain, 35°16'S, 149°06'E, alt. 700 m, on sandstone in *Eucalyptus* woodland, *J.A. Elix* 1386, 1 Dec 1975 (CANB); Black Mountain Reserve, along trail, 35°16'S, 149°06'E, alt. 640 m, on sandstone in dry *Eucalyptus* woodland, *J.A. Elix* 6122, 8 Jul 1979 (CANB).

### 2. *Rhizocarpon badioatrum* (Flörke ex Spreng.) Th.Fr., *Lichenographia Scandinavica* 2: 613 (1874)

Already known from south-eastern Queensland, New South Wales, Victoria and Tasmania (McCarthy 2014), this lichen is newly reported from the Australian Capital Territory. It also occurs in Europe, Macaronesia, southern Africa, South-East Asia, Papua New Guinea, North America, Argentina and Antarctica (Timdal and Holtan-Hartwig 1988; Thompson 1997; Øvstedal and Lewis Smith 2001; Feuerer and Timdal 2004; Fletcher et al. 2009).

*Chemistry*: This species has been reported to produce stictic acid, diffractaic acid or to lack lichen substances (Timdal and Holtan-Hartwig 1988; Fletcher et al. 2009). In fact Timdal and Holtan-Hartwig (1988) treated the stictic acid chemotype as *R. cinereonigrum* Vain., and considered that the diffractaic acid chemotype may also represent an independent species. In the present study, we found that *R. badioatrum* invariably contained bourgeanic acid, a new chemotype (Table 1).

**Selected specimens examined: Australian Capital Territory:** along Kangaroo Creek near Corin Dam, 35°32'S, 148°53'E, alt. 1000 m, on granite in *Eucalyptus* forest, *J.A. Elix* 1343, 25 Nov 1975 (CANB); Booroomba Rocks, 11 km SW of Tharwa, 35°31'S, 149°04'E, alt. 1360 m, on exposed granite in subalpine heath, *J.A. Elix* 6154 (part), 11 Jul 1979 (CANB); below summit, Mt Bimberi, Namadgi National Park, 35°39'27"S, 148°47'20"E, alt. 1882–1900 m, on exposed granite, *P.M. McCarthy* 4132, 4133 (part), 12 Dec 2013 (CANB). **New South Wales:** Northern Tablelands (Jacobs and Pickard 1981): Dilgry Circle Road, Barrington Tops State Forest, 41 km NW of Gloucester, 31°52'S, 151°31'E, alt. 1240 m, on rock face in dry sclerophyll forest with granite boulders, *J.A. Elix* 24925 (part), *H. Streimann* 44551, 44562, 26 Apr 1990 (CANB); Southern Tablelands: 46 km S of Cooma along the Snowy Mountains Highway, alt. 1150 m, on granite in pasture, *J.A. Elix*

5451, 23 Nov 1978 (CANB); Southern Tablelands: Big Badja Hill, 47 km NE of Cooma, 36°00'S, 149°34'E, alt. 1360 m, on metamorphic rock in heath with *Ghania subaequiglumis*, *D. Verdon* 3468, 2 Mar 1978 (CANB). **Victoria:** Midlands (Conn 1993): Horan Track, Tallarook State Forest, 17 km S of Seymour, 37°11'S, 145°10'E, alt. 600 m, on exposed rock outcrop in dry sclerophyll forest, *H. Streimann* 36060, 25 Dec 1985 (CANB); East Gippsland: Mt Ellery, Errinundra National Park, 29 km SSW of Bendoc, 37°24'S, 148°47'E, alt. 1280 m, on large, semi-exposed boulder in wet sclerophyll forest, *H. Streimann* 47913, 17 Apr 1991 (CANB).

### 3. *Rhizocarpon disporum* (Nägeli ex Hepp) Müll.Arg., *Revue Mycologique Toulouse* 1: 170 (1879)

This lichen is known from Europe, Arctic Eurasia, Morocco, Turkey, South Africa, Central Asia, China, North America, Greenland, Bolivia, Chile, Argentina, islands in the South Atlantic Ocean, Antarctica and New Zealand (Timdal and Holtan-Hartwig 1988; Feuerer 1991; Øvstedal and Lewis Smith 2001; Feuerer and Timdal 2004; Galloway 2007; Golubkov and Matwiejuk 2009). In Australia it occurs in New South Wales and the Australian Capital Territory (McCarthy 2014).

**Chemistry:** Chemotypes of this species have been reported to contain stictic acid and/or norstictic acid (Timdal and Holtan-Hartwig 1988; Feuerer and Timdal 2004; Galloway 2007) or to lack lichen substances (Timdal and Holtan-Hartwig 1988). We have encountered a new chemotype in the present study which contains bourgeanic acid (Table 1).

**Specimens examined: Australian Capital Territory:** Mt Tennent, 28 km SSW of Capital Hill, Canberra, 35°34'S, 149°04'E, alt. 1370 m, on rock on dry sclerophyll ridgetop dominated by huge granite boulders, *H. Streimann* 38919, 22 Oct 1987 [stictic acid] (CANB). **New South Wales:** Central Tablelands: just below summit of Mt Canobolas, c. 13 km SW of Orange, 33°20'40"S, 148°58'56"E, alt. c. 1390 m, on weathered volcanic outcrop on heath, with scattered *Eucalyptus* and *Acacia*, *P.M. McCarthy* 4322, 1 Apr 2014 [no lichen substances] (CANB); Southern Tablelands: Blue Lake, S of Mt Twynam, Mount Kosciuszko National Park, 36°24'S, 148°19'E, on schist rocks, *H. Hertel* 31791 & *H. Mayrhofer*, 1 Mar 1985 [stictic acid] (CANB); Southern Tablelands: 8 km E of Cooma on road to Numeralla, 36°11'S, 149°13'E, on granite outcrop in grassland, *W.A. Weber* L-49052 & *D. McVean*, 2 Oct 1967 [bourgeanic acid] (CANB).

### 4. *Rhizocarpon distinctum* Th.Fr., *Lichenographia Scandinavica* 2: 625 (1874)

Previously known from Victoria (McCarthy 2014), this lichen is newly reported from New South Wales and the Australian Capital Territory. It also occurs in western and south-eastern Europe, Arctic Eurasia, Greenland, North America, southern South America, Antarctica and New Zealand (Timdal and Holtan-Hartwig 1988; Feuerer 1991; Øvstedal and Lewis Smith 2001; Feuerer and Timdal 2004; Galloway 2007; Fletcher et al. 2009; Golubkov and Matwiejuk 2009, 2011).

**Chemistry:** *Rhizocarpon distinctum* has been reported to produce stictic acid and accessory gyrophoric acid (Timdal and Holtan-Hartwig 1988; Feuerer 1991; Øvstedal and Lewis Smith 2001; Ihlen 2004; Galloway 2007; Fletcher et al. 2009). In the present study we have found a new chemotype containing norstictic acid, with bourgeanic acid a further accessory substance in this species (Table 1).

**Selected specimens examined: Australian Capital Territory:** summit area, Mt Murray, Namadgi National Park, 35°41'26"S, 148°47'35"E, alt. 1800–1850 m, on exposed granite in *Eucalyptus pauciflora*-dominated forest-scrub, *P.M. McCarthy* 4130 (part), 4141 (part), 4178 (part), 9 Dec 2013 (CANB); scree slope, Mt Ginini, Namadgi National Park, 35°31'47"S, 148°46'41"E, alt. 1665 m, on sheltered granite, *P.M. McCarthy* 4184 (part), 10 Dec 2013 (CANB); summit area, Mt Scabby, Namadgi National Park, 35°45'08"S, 148°54'35"E, alt. 1809 m, on exposed granite, *P.M. McCarthy* 4192 (part), 9 Dec 2013 (CANB); below summit, Mt Bimberi, Namadgi National Park, 35°39'27"S, 148°47'20"E, alt. 1882–1900 m, on granite, *P.M. McCarthy* 4271 (part), 12 Dec 2013 (CANB); Mt Clear, Clear Range, 64 km S of Canberra, 35°53'S, 148°05'E, alt. 1590 m, on exposed granodiorite in *Eucalyptus pauciflora* forest, *H. Streimann* 10587, 1 Oct 1980 [norstictic acid] (CANB). **New South Wales:** Central Tablelands: W face of Mt Canobolas, 33°20'17"S, 148°58'37"E, alt. 1250 m, on weathered volcanic outcrop on heath, with scattered *Eucalyptus*, *J.A. Elix* 45999, 1 Apr 2014 [bourgeanic and stictic acids] (CANB); Central Tablelands: just below summit of Mt Canobolas, c. 13 km SW of Orange, 33°20'40"S, 148°58'56"E, alt. c. 1390 m, on weathered volcanic outcrop on heath, with scattered *Eucalyptus* and *Acacia*, *P.M. McCarthy* 4321, 1 Apr 2014 (CANB).

### 5. *Rhizocarpon eupetraeoides* (Nyl.) Blomb. & Forssell, *Enumeratur Plantae Scandinaviae* 93 (1880)

*Thallus* epilithic, determinate, yellow-green to yellow-grey, areolate; areoles 0.3–1.5 mm wide, smooth, plane to moderately convex, aggregated and angular or scattered and more rounded; medulla white, I+ blue-violet or, rarely, I– in part. *Prothallus* black, distinct between areoles and at thallus margin. *Apothecia* numerous, usually solitary, black, round to angular, innate between areoles, 0.3–1.5 mm diam.; disc plane to weakly convex; proper margin becoming excluded. *Asci* 60–80 × 14–18 µm. *Ascospores* 8 per ascus, dark green to dark brown, 1-septate, broadly ellipsoid, 22–34 × 9–17 µm, rarely simple or with 1 or more additional transverse or oblique septa.

Detailed descriptions are given in Matwiejuk (2008) and Fletcher et al. (2009) and illustrations are provided in Runemark (1956a, as *R. atroalbescens* (Nyl.) Zahlbr.).

**Chemistry:** Previously, this species has been reported to produce rhizocarpic acid together with norstictic or psoromic acids (Runemark 1956a; Matwiejuk 2008), or with norstictic or bourgeanic acid (Fletcher et al. 2009). The Australian specimens contained rhizocarpic and bourgeanic acids or rhizocarpic acid alone (Table 1).

*Rhizocarpon eupetraeoides* is characterized by its yellow-green to yellow-grey, areolate thallus, the prominent black prothallus, plane to weakly convex apothecia, 1-septate ascospores and, in Australia, by the presence of rhizocarpic and bourgeanic acids. *Rhizocarpon adarensense* and *R. superficiale* are similar, but differ in having significantly smaller ascospores and a uniformly I– medulla.

*Rhizocarpon eupetraeoides* is reported here for the first time from Australia; it was collected from montane, siliceous rocks in southern New South Wales. Elsewhere, it occurs in northern Eurasia, North America, Greenland and Japan (Runemark 1956b [as *R. atroalbescens*]; Thomson 1997; Matwiejuk 2008; Fletcher et al. 2009).

**Specimens examined: New South Wales:** Southern Tablelands: at head of Merricumbene Creek, 11 km S of Monga, 35°16'S, 149°06'E, alt. 820 m, on metamorphic rocks on open rocky ridge, *J.A. Elix 6417*, 21 Nov 1979 (CANB); Southern Tablelands: Scottsdale Bush Heritage Reserve, 4 km N of Bredbo, 35°55'06"S, 149°08'09"E, alt. 680 m, on exposed sandstone rocks in grassland, *J.A. Elix 46082*, 7 May 2014 (CANB).

## 6. *Rhizocarpon flavomedullosum* Elix & P.M.McCarthy, sp. nov. Figs 1A, 2C

MycoBank No.: MB810877

Characterized by the grey, minutely areolate thallus, a non-amyloid medulla that is intensely yellow above (containing rhizocarpic acid), prominent apothecia and pigmented, 1-septate ascospores (14–)18(–21) × (6–)8(–10) μm.

Type: Australia. New South Wales: Southern Tablelands: Badja State Forest, 9 km NE of Numeralla along road to Jerangle, 36°07'39"S, 142°22'45"E, alt. 1095 m, on sandstone in open *Eucalyptus* woodland, *J.A. Elix 39918*, 14 Nov 2007; holotype: CANB.

**Thallus** crustose, epilithic, effuse to determinate, areolate, matt, smooth, grey to dark grey, 1–3 cm wide, 0.05–0.20 mm thick; areoles contiguous, angular and irregular, 0.1–0.3(–0.5) mm wide, ±plane to weakly concave, often with slightly raised edges. **Cortex** poorly defined, c. 10 μm thick, often subtending a hyaline necral layer up to 10–15 μm thick; cells rounded, 5–8 μm diam., thick-walled, with a dark olive-brown distal wall; inward-facing wall hyaline. **Algal layer** continuous, 20–60(–100) μm thick; cells green, globose, chlorococcoid, 8–15 μm diam. **Medulla** 0.10–0.15 mm thick, I–, intensely yellow above; lower medulla white; hyphae 3–5 μm wide, larger, thin-walled and more compacted above, more irregular in shape and loosely arranged below. **Prothallus** prominent, marginal, black, 0.2–0.4 mm wide, usually also apparent between the areoles. **Apothecia** numerous, dull black, usually solitary, occasionally paired or in small clusters or short rows, lecideine, roundish, immersed at first but soon broadly adnate, (0.25–)0.44(–0.64) mm wide [*n* = 30], not subtended by algae; disc black, epruinose, plane or markedly convex; proper excipulum thin, black, becoming excluded in older; convex apothecia, in section 35–65 μm thick, outer part brown-black, K–, N+ intense purple-brown, inner part brown. **Epihymenium** 8–12 μm thick, dark brown to brown-black, K+ weak violet-black, N+ intense purple-brown. **Hypothecium** 100–130 μm thick, medium to dark brown, K–, N+ intense orange-brown. **Hymenium** 90–160 μm thick, colourless, not interspersed, I+ blue; **paraphyses** richly branched and anastomosing, 1.5–1.8 μm wide, shortly septate, scarcely swelling at the apices and lacking a sharply delimited cap. **Asci** cylindrical to clavate, 50–65 × 15–25 μm, 8-spored, *Rhizocarpon*-type, the spores irregularly biseriolate or massed. **Ascospores** dark green-blue to dark brown, 1-septate, usually straight, narrowly ellipsoid, often with a thick, well-defined, hyaline, 4–8 μm wide perispore when immature, not constricted at the septum, (14–)18(–21) × (6–)8(–10) μm [*n* = 50]; apices rounded to subacute. **Pycnidia** not seen.

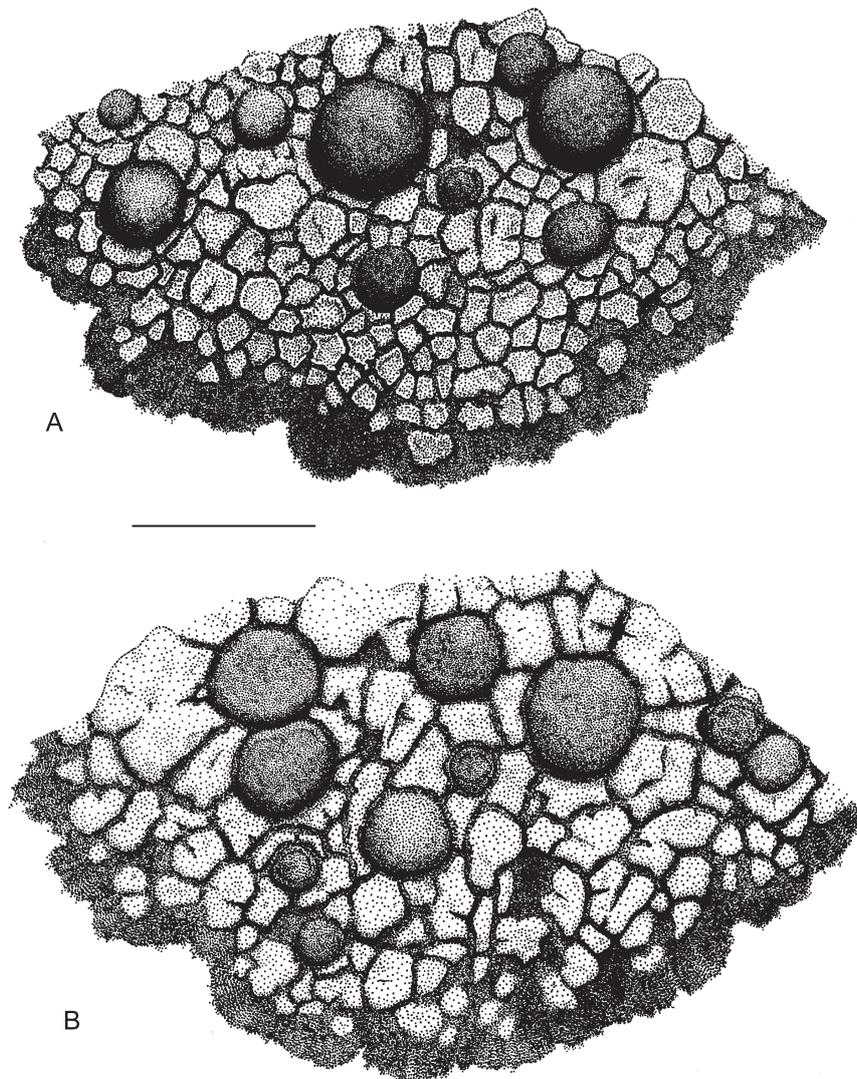
**Chemistry.** Medulla K–, C–, PD–, UV–; containing rhizocarpic acid (major), ±bourgeanic acid (major) (Table 1).

The most striking feature of the new species is the intense yellow colour of the upper medulla due to the presence of rhizocarpic acid. While *R. geminatum* can occasionally contain medullary rhizocarpic acid, that lichen has a darker and more robust thallus, larger apothecia, mainly bisporous asci and much larger, muriform ascospores. The north-western North American *R. sulphurosum* (Tuck. ex Willey) Lendemer also has yellow medulla, but its peltate areoles have a pale margin, it has (1 or)2-spored asci and much larger, 3-septate to muriform ascospores (Feurer and Timdal 2004; Lendemer et al. 2010). *Rhizocarpon superficiale* has dark,

1-septate ascospores of similar dimensions to *R. flavomedullosum*, but the thallus is green-yellow, the areolae are up to 1.5(–2.5) mm wide, containing rhizocarpic and stictic or perlatolic acids (in Australia), and the larger apothecia remain plane to weakly convex with a usually persistent margin (Fletcher et al. 2009). Although *R. flavomedullosum* is broadly similar to the newly described *R. vigilans* (see below) in its thalline and apothecial morphology (see below), the thallus of the latter has larger, paler and plane to convex areoles with a uniformly white, amyloid medulla.

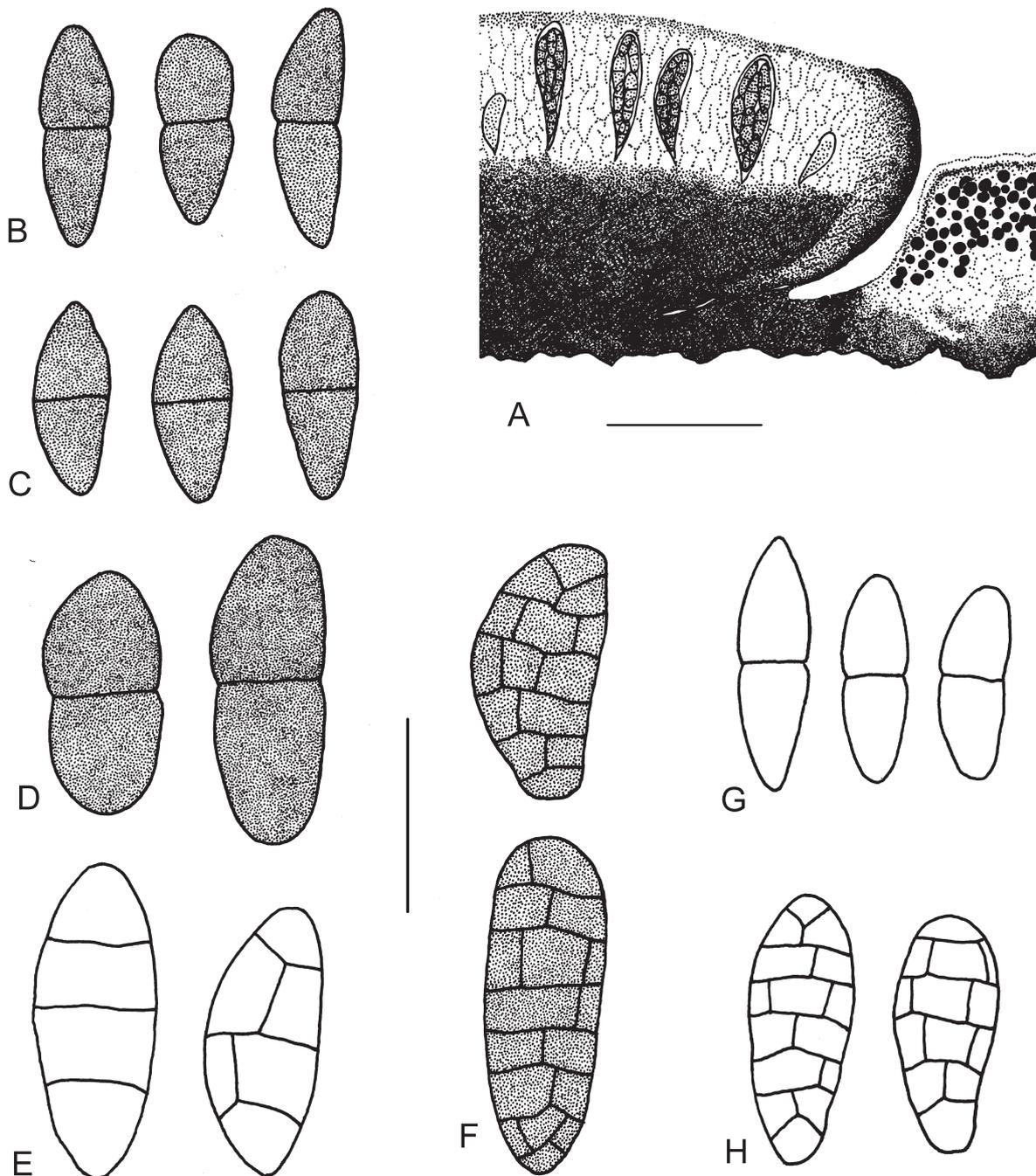
**Etymology:** The epithet *flavomedullosum* refers to the intensely yellowish upper medulla.

**Distribution and habitat:** This species is known from exposed and sheltered siliceous rocks (sandstone, schist and granite) in the Southern Tablelands of New South Wales and nearby on mountain tops in the southern Australian Capital Territory. Associated lichens included *Buellia bogongensis* Elix, *B. homophylia* (C.Knight) Zahlbr., *Lecanora farinacea* Fée, *Menegazzia aeneofusca* (Müll.Arg.) R.Sant., *Ramboldia petraeoides* (Nyl. ex C.Bab. & Mitt.) Kantvilas & Elix, *Rhizocarpon distinctum*, *R. geographicum*, *R. intersitum*, *R. reductum*, *Umbilicaria cylindrica* (L.) Delise ex Duby, *Xanthoparmelia lithophiloides* (Kurok.) Elix, *X. metaclystoides* (Kurok. & Filson) Elix & J.Johnst., *X. metamorphosa* (Gyeln.) Hale, *X. neotinctina* (Elix) Elix & J.Johnst., *X. subprolixa* (Nyl. ex Kremp.) O.Blanco, A. Crespo, Elix, D.Hawksw. & Lumbsch and *X. tasmanica* (Hook.f. & Taylor) Hale.



**Fig. 1.** *Rhizocarpon* species, habit. **A**, Thallus of *R. flavomedullosum* (holotype); **B**, Thallus of *R. vigilans* (holotype). Scale: 1 mm.

**Additional specimens examined: Australian Capital Territory:** summit of Mt Aggie, Brindabella Range, 43 km WSW of Canberra, 35°28'S, 148°46'E, alt. 1490 m, on sheltered schist rock ledges on exposed summit, J.A. Elix 11620 & P.W. James, 21 Jan 1984 (CANB); summit area, Mt Murray, Namadgi National Park, 35°41'26"S, 148°47'35"E, alt. 1800–1850 m, on exposed granite in *Eucalyptus pauciflora*-dominated forest-scrub, P.M. McCarthy 4174 (part), 9 Dec 2013 (CANB).



**Fig. 2.** *Rhizocarpon* species, apothecial anatomy and ascospores. **A**, Sectioned apothecium and adjacent thallus from the holotype of *R. vigilans* (semi-schematic); **B–H**, Ascospores. **B**, *R. vigilans* (holotype); **C**, *R. flavomedullosum* (holotype); **D**, *R. badioatrum* (McCarthy 4263); **E**, *R. distinctum* (McCarthy 4141); **F**, *R. intersitum* (McCarthy 4187); **G**, *R. polycarpum* (McCarthy 4130); **H**, *R. reductum* (McCarthy 4184). Scales: A = 0.1 mm; B–H = 20 µm.

### 7. *Rhizocarpon geminatum* Körb., *Systema Lichenum Germaniae* 259 (1855)

*Thallus* epilithic, determinate, medium to dark grey, areolate; areoles 0.3–0.6(–1.0) mm wide, smooth, plane to strongly convex or almost cushion-like, aggregated and angular or rounded in outline; medulla I–. *Prothallus* black, distinct between areoles and at thallus margin. *Apothecia* numerous, usually solitary, black, initially innate between areoles, becoming rather prominent, 0.35–0.90 mm diam.; disc plane to convex, often slightly glossy; proper margin thick, usually persistent, K+ purple-red in section. *Ascospores* (1–)2(–4) per ascus, dark olive-brown, muriform, narrowly to broadly ellipsoid, 36–50 × 17–25 µm. Detailed descriptions of this species can be found in Feuerer (1991), Feuerer and Timdal (2004), Galloway (2007) and Fletcher et al. (2009) and an illustration in Wirth (1995, p. 810).

*Chemistry*: This species has been reported to produce stictic acid and/or norstictic acid, to lack lichen substances or, occasionally, to contain accessory rhizocarpic acid in the medulla (Feuerer 1991; Timdal and Holtan-Hartwig 1988; Øvstedal and Lewis Smith 2001; Feuerer and Timdal 2004; Fletcher et al. 2009; Galloway 2007). We have observed a new chemotype containing only bourgeanic acid as well as the chemotypes with stictic acid and its satellite compounds (constictic, cryptostictic and peristictic acids) or norstictic acid, ±accessory bourgeanic acid (Table 1).

*Rhizocarpon geminatum* is characterized by its dark grey convex-areolate thallus, a non-amyloid medulla, innate apothecia, moderately large ascospores usually in 2-spored asci and a variable chemistry.

Reported here for the first time from Australia, it was collected from montane, siliceous rocks in the Australian Capital Territory, in the south and central-west of New South Wales and in alpine Victoria. Elsewhere, it occurs in Europe, Arctic Eurasia, Greenland, Turkey, Central Asia, North America, Bolivia, Argentina, islands in the South Atlantic Ocean, Antarctica and New Zealand (Clauzade and Roux 1985; Timdal and Holtan-Hartwig 1988; Feuerer 1991; Øvstedal and Lewis Smith 2001; Feuerer and Timdal 2004; Galloway 2007; Fletcher et al. 2009).

**Specimens examined:** **Australian Capital Territory:** summit of Sentry Box Mountain, Namadgi National Park, 35°49'34"S, 148°54'11"E, alt. 1720 m, on sheltered granite, *P.M. McCarthy* 4104, 4114 (part), 4121, 12 Dec 2013 [bourgeanic and norstictic acids] (CANB). **New South Wales:** Central Tablelands: W face of Mt Canobolas, c. 13 km SW of Orange, 33°12'17"S, 148°58'37"E, alt. 1250 m, on weathered volcanic outcrop, *J.A. Elix* 45998, *P.M. McCarthy* 4323, 4329, 1 Apr 2014 [bourgeanic acid]; *J.A. Elix* 45997 (part), 1 Apr 2014 [stictic acid] (CANB); Southern Tablelands: Molonglo River Falls, 2 km S of Captains Flat, 35°48'S, 149°35'E, alt. 870 m, on granite in open *Eucalyptus* woodland, *J.A. Elix* 30033A, 17 Mar 1993 [bourgeanic and stictic acids] (CANB); Southern Tablelands: Round Mountain, 28 km NE of Khancoban, Mount Kosciuszko National Park, 36°15'S, 148°35'E, alt. 1750 m, on basalt among sparse shrubby vegetation, *H. Streimann* 35113 & *J.A. Curnow*, 9 Apr 1985 [bourgeanic acid] (CANB). **Victoria:** Eastern Highlands (Conn 1993): 'Ruined Castle', Bogong High Plains, 16.5 km SSE of Mount Beauty, 36°52'S, 147°15'E, alt. 1620 m, on exposed basalt rocks in subalpine grassland, *J.A. Elix* 40576, 17 Mar 1993 [bourgeanic acid] (CANB); Eastern Highlands: Alpine Road, Alpine National Park, 34 km WNW of Omeo, 37°02'S, 147°14'E, alt. 1580 m, on semi-exposed rock on *Eucalyptus pauciflora*-dominated ridge, *H. Streimann* 49495 (part), 2 May 1992 [bourgeanic acid] (CANB); Eastern Highlands: Dargo High Plains, Alpine National Park, 41 km NNW of Dargo, 37°06'S, 147°09'E, alt. 1620 m, on exposed basalt outcrop in swampy, subalpine grassland, *H. Streimann* 53195, 17 Dec 1993 [bourgeanic acid] (CANB).

### 8. *Rhizocarpon geographicum* (L.) DC., *Flore Française* 2: 365 (1805)

This is among the most widely recognizable lichens in Europe and North America; it also occurs in Arctic Eurasia, North Africa, Turkey, Southern Africa, Central Asia, South America, islands in the South Atlantic Ocean, Antarctica and New Zealand. It is found in all States and the Australian Capital Territory, and it can be very abundant in suitable habitats, especially exposed, montane siliceous rocks in south-eastern Australia.

The most common chemotypes contain rhizocarpic and either psoromic or barbatic acids, rarely with accessory bourgeanic acid or gyrophoric acid (Feuerer and Timdal 2004; Fletcher et al. 2009). We have discovered two new chemotypes in the present study (Table 1).

**Specimens examined:** [*Chemotype 1*: containing rhizocarpic acid (minor), alectoronic acid (minor), α-collatolic acid (minor) and psoromic acid (major)] **Australian Capital Territory:** summit of Bimberi Peak, Namadgi National Park, 35°39'S, 148°47'E, alt. 1910 m, on granite rocks in alpine grassland, *J.A. Elix* 6598, 2 Dec 1979 (CANB). **New South Wales:** Southern Tablelands: 10 km E of Cooma along the Numeralla road, 36°11'S, 149°15'E, alt. 910 m, on granite rocks, *J.A. Elix* 1463, 1524, 19 Jan 1976 (CANB); Southern Tablelands: Brown Mountain, below the road, 17 km SE of Nimmitabel, 36°36'S, 149°23'E, alt. 1155 m, on granite rocks in *Eucalyptus* woodland, *J.A. Elix* 1571, 20 Jan 1976 (CANB).

[*Chemotype 2*: containing rhizocarpic acid (minor), 2-O'-methylperlatolic acid (major), bourgeanic acid (major or minor), confluent acid (minor) and 2-O'-methylanziaic acid (major or minor)] **Australian Capital Territory:** summit of Mt Aggie, Brindabella Range, 35°27'S, 148°46'E, alt. 1490 m, on exposed schistose rocks, *J.A. Elix* 5833, 28 Mar 1979 (CANB); summit of Bimberi Peak, Namadgi National Park, 35°39'S, 148°47'E, alt. 1910 m, on granite rocks in alpine

grassland, *J.A. Elix* 6596, 6597, 2 Dec 1979 (CANB); Mt Coree summit, W side, 28 km W of Canberra, 35°18'S, 148°49'E, alt. 1400 m, on exposed rock, *D. Verdon* 1526 (part), 23 Jul 1975 (CANB). **Victoria:** Eastern Highlands: 'Ruined Castle', Bogong High Plains, 16.5 km SSE of Mt Beauty, 36°52'S, 147°15'E, alt. 1620 m, on exposed basalt rocks in subalpine grassland, *J.A. Elix* 40579 (part), 17 Mar 1993 [bourgeanic acid] (CANB).

**9. *Rhizocarpon intersitum*** Arnold, *Verhandlungen der Zoologisch-Botanischen Gesellschaft Wien* 27: 554 (1877)

*Thallus* epilithic, determinate, crustose, verruculose-areolate, whitish grey to grey or grey-brown, occasionally greenish or pink-tinged, epruinose; areoles contiguous or dispersed, 0.2–0.6(–0.8) mm wide, smooth, plane to strongly convex or almost bullate, aggregated and angular or scattered and more rounded, matt or slightly glossy, smooth; medulla white, I–. *Prothallus* prominent, black, distinct between areoles and at thallus margin. *Apothecia* 0.25–0.70 mm wide, abundant, lecideine, roundish, usually solitary, innate between areoles; disc black, epruinose, plane to convex; proper margin, thin, black, becoming excluded, in section c. 30 µm thick, with a dark brown external zone, K–, N–, paler within. *Epihymenium* dark brown to dark purple-brown, K–, N–. *Hypothecium* dark brown to dark reddish brown, K–, N–. *Hymenium* colourless to pale greenish in places, not interspersed, I+ blue. *Asci* 110–125 × 25–32 µm. *Ascospores* (4–)8 per ascus, dark grey-green to dark brown or blackish, submuriform to muriform, with 9–18 cells in optical section, oblong to elongate-ellipsoid and often slightly bent or broadly ellipsoid, 24–35 × 10–18 µm.

*Chemistry:* *Rhizocarpon intersitum* has been reported to produce stictic acid or to lack lichen substances (Timdal and Holtan-Hartwig 1988; Fryday 2010). In Australia it invariably contains gyrophoric acid (Table 1).

This lichen resembles two other Australian species with grey thalli and dark muriform ascospores, *R. disporum* and *R. geminatum*. However, *R. intersitum* has predominantly 8-spored asci producing smaller ascospores, while the asci of *R. disporum* and *R. geminatum* are monosporous and predominantly bisporous, respectively. Moreover, those lichens have a more complex and varied thallus chemistry, but they lack the gyrophoric acid of *R. intersitum* (Table 1). *Rhizocarpon austroamphibium*, an endemic and montane-aquatic species from Tasmania, also contains gyrophoric acid, but it has a smooth thallus, innate white-margined apothecia, mainly 2–4-spored asci, larger ascospores and anomalous simple paraphyses. Superficially, *R. intersitum* resembles the northern-temperate to boreal *R. grande* (Flörke) Arnold, another species that commonly contains gyrophoric acid. However, *R. grande* usually has an I+ blue medulla (although this reaction is sometimes rather weak or even absent), a K+ red epihymenium, and somewhat larger ascospores, 24–46 µm long. While the distinction between these two species is not clear-cut, we prefer to assign the Australian material to *R. intersitum* pending a detailed reassessment aided by molecular analyses.

Reported here for the first time from Australia and the Southern Hemisphere, *R. intersitum* is rather common on exposed alpine siliceous rocks in the Australian Capital Territory, southern New South Wales, Victoria and Western Australia. It was previously known from south-western and north-eastern U.S.A., Scotland, Scandinavia and Central Europe (Clauzade and Roux 1985; Timdal and Holtan-Hartwig 1988; Fryday 2010).

**Selected specimens examined: Australian Capital Territory:** along Kangaroo Creek near Corin Dam, 35°32'S, 148°53'E, alt. 1000 m, on granite in *Eucalyptus* forest, *J.A. Elix* 2314, 25 Nov 1975 (CANB); summit area, Mt Murray, Namadgi National Park, 35°41'26"S, 148°47'35"E, alt. 1800–1850 m, on exposed granite, in *Eucalyptus pauciflora*-dominated forest-scrub, *P.M. McCarthy* 4175, 4176, 9 Dec 2013 (CANB); scree slope, Mt Ginini, Namadgi National Park, 35°31'47"S, 148°46'41"E, alt. 1665 m, on sheltered granite, *P.M. McCarthy* 4187 (part), 10 Dec 2013 (CANB); summit, Sentry Box Mountain, Namadgi National Park, 35°49'34"S, 148°54'11"E, alt. 1720 m, on granite, *P.M. McCarthy* 4113 (part), 4296 (part), 12 Dec 2013 (CANB); below summit, Mt Bimberi, Namadgi National Park, 35°39'27"S, 148°47'20"E, alt. 1882–1900 m, on granite in *Eucalyptus pauciflora*-dominated vegetation, *P.M. McCarthy* 4267, 12 Dec 2013 (CANB); Booroomba Rocks track, Namadgi National Park, 35°33'57"S, 148°59'36"E, alt. 1169 m, on sheltered granite in eucalypt-dominated forest, *P.M. McCarthy* 4223, 13 Dec 2013 (CANB); Orroral Valley Lookout, Namadgi National Park, 34 km SW of Canberra, 36°32'S, 148°53'E, alt. 1350 m, on granite in dry sclerophyll forest, *H. Streimann* 53676, 29 Mar 1994 (B, CANB). **New South Wales:** Northern Tablelands: Dilgry Circle Road, Barrington Tops State Forest, 41 km NW of Gloucester, 31°52'S, 151°31'E, alt. 1240 m, on granite in dry sclerophyll forest, *J.A. Elix* 24925 (part), 26 Apr 1990 (CANB); Southern Tablelands: Bemboka River Road, Glenbog State Forest, 15 km ESE of Nimmitabel, 36°33'S, 149°30'E, alt. 1080 m, on granite boulder in dry sclerophyll forest, *H. Streimann* 43870, 1 Apr 1990 (CANB); Southern Tablelands: Steeple Flat, 10 km SE of Nimmitabel, 36°32'S, 149°21'E, alt. 1100 m, on granite in flat, swampy valley, *D. Verdon* 1441, 16 Jul 1975 (CANB); Southern Tablelands: Bradleys Creek, flowing out of the Yaouk Bill Range, 35°53'S, 148°53'E, alt. 1240 m, on granite in *Eucalyptus* forest, *D. Verdon* 1743, 18 Aug 1975 (CANB); Southern Tablelands: SE of Rossi, Braidwood district, 35°27'S, 149°48'E, on boulder in remnant wet sclerophyll forest, *W.A. Weber* L-49315, 19 Dec 1967 (CANB); South Coast: Tuross Cascades, Badja State Forest, 61 km SW of Moruya, 36°14'S, 149°31'E, alt. 600 m, on semi-shaded boulder in dry sclerophyll forest, *H. Streimann* 60357, 30 Mar 1998 (CANB). **Victoria:** Eastern Highlands: Mt Ellery, Errinundra National Park, 29 km SSW of Bendoc, 37°24'S, 148°47'E, alt. 1280 m, on large, semi-exposed boulder in wet sclerophyll forest, *H. Streimann* 47916 (part), 17 Apr 1991 (CANB). **Western Australia:** Jarrah Forest (Thackway and Cresswell 1995): summit of Toolbrunup Peak, Stirling Range National Park, 40 km SW of Borden, 34°23'S, 118°03'E, alt. 980 m, on exposed volcanic rock amongst pockets of

dense, shrubby vegetation, *J.A. Elix 41519*, 17 Sep 1994 (CANB).

**10. *Rhizocarpon lavatum* (Fr.) Hazsl., *Magyar Birodalom Zuzmó-Flórája* 206 (1884)**

*Thallus* epilithic, pale grey to pale ochre-brown, rimose to areolate; areoles 0.4–0.8(–1.0) mm wide, smooth, plane, rounded to angular, matt; medulla I–. *Prothallus* black or indistinct. *Apothecia* scattered, sessile, black, epruinose, 0.5–2.5 mm diam.; disc weakly concave to weakly convex, sometimes with a central umbo; proper margin thick, persistent, with a dark brown external zone, paler within, K–; epihymenium olive-green to olive-brown, K± purple-red in patches. *Asci* 100–160 × 30–50 µm. *Ascospores* 8 per ascus, persistently colourless or becoming faintly brown with age, muriform, with 9–28 cells in optical section, elongate-ellipsoid to ellipsoid or slightly ovoid, 30–50 × 13–21 µm. Detailed descriptions of this species can be found in Feuerer (1991); Ihlen (2004); Galloway (2007); Fletcher et al. (2009); and illustrations in Wirth (1995, p. 807) and Ihlen (2004).

*Chemistry*: Research has shown that this species invariably lacks lichen substances (Feuerer 1991; Ihlen 2004; Galloway 2007; Fletcher et al. 2009; Joshi et al. 2010; Timdal and Holtan-Hartwig 1988), and this is also true of the Australian specimen examined (Table 1).

*Rhizocarpon lavatum* is characterized by the pale grey to pale brown, rimose to areolate thallus, a non-amyloid medulla, rather large and sometimes umbonate apothecia with a thick, swollen margin, moderately large, colourless, muriform ascospores with numerous septa and in lacking lichen substances. Reported here for the first time from Australia, it was collected from montane, siliceous rocks in southern New South Wales. Elsewhere, it is known from the British Isles, continental Europe, Scandinavia, Svalbard, the Ukraine, North America, North Africa, East Asia and New Zealand (Timdal and Holtan-Hartwig 1988; Feuerer 1991; Galloway 2007; Ihlen 2004; Fletcher et al. 2009; Joshi et al. 2010).

**Specimen examined: New South Wales:** Southern Tablelands: 2 km NE of Mt Kosciuszko, Mount Kosciuszko National Park, 38°20'S, 148°16'E, alt. 2150 m, on siliceous rock outcrop in alpine herbfield, *H. Streimann 7632* (part), 14 Mar 1979 (CANB).

**11. *Rhizocarpon lecanorinum* Anders, *Hedwigia* 64: 261 (1923)**

*Thallus* epilithic, bright yellow to yellow-green, areolate; areoles 0.5–1.5 mm wide, often crescent-shaped and surrounding an apothecium, to angular to orbicular; medulla I+ blue. *Prothallus* black, distinct, at margins and between areoles. *Apothecia* frequent, black, epruinose, 0.3–1.0 mm diam.; disc plane to weakly convex; proper exciple persistent but indistinct; epihymenium pale red-brown, hymenium pale greenish to green-blue. *Asci* 75–85 × 35–45 µm, 8-spored. *Ascospores* colourless at first, but soon dark greenish to brown-black, submuriform, with 15–38 cells in optical section, ellipsoid or slightly curved, 34–55 × 15–24 µm.

Detailed descriptions of this species can be found in Runemark (1956a); and Galloway (2007): illustrations in Runemark (1956a); Wirth (1995, p. 815); Brodo et al. (2001, p. 636); Fletcher et al. (2009).

*Chemistry*: This species contains rhizocarpic and stictic acids, with or without accessory gyrophoric acid (Timdal and Holtan-Hartwig 1988; Galloway 2007; Fletcher et al. 2009). However, bourgeanic acid is common in Australian specimens, either as an accessory substance to stictic acid or co-occurring with rhizocarpic acid (Table 1).

*Rhizocarpon lecanorinum* is characterized by the yellow, crescent-shaped areoles often enclosing prominent apothecia, a pale olive-brown to red-brown epihymenium and usually pale green hymenium, greenish to brown-black, submuriform ascospores. It is chemically distinct from *R. geographicum* as it lacks psoromic, 2'-*O*-methylperlatolic or barbatic acids. Reported here for the first time from Australia, it was collected from montane, siliceous rocks in the Australian Capital Territory and Victoria. Elsewhere, it is known from the British Isles, continental Europe, Scandinavia, the high Arctic, Turkey, Macaronesia, southern Africa, Central Asia, China, North America and New Zealand (Runemark 1956b; Timdal and Holtan-Hartwig 1988; Galloway 2007; Fletcher et al. 2009).

**Selected specimens examined: Australian Capital Territory:** Ginini Flats, Brindabella Range, 40 km SW of Canberra, 35°31'S, 148°47'E, alt. 1540 m, on granite in open subalpine forest, *J.A. Elix 5877*, *D. Verdon 4515*, 28 Mar 1979 [bourgeanic and stictic acids] (CANB); summit area, Mt Scabby, Namadgi National Park, 35°45'08"S, 148°54'35"E, alt. 1809 m, on exposed granite, *P.M. McCarthy 4190* (part), 9 Dec 2013 (CANB); scree slope, Mt Ginini, Namadgi National Park, 35°31'47"S, 148°46'41"E, alt. 1665 m, on sheltered granite, *P.M. McCarthy 4187* (part), 10 Dec 2013 [bourgeanic and stictic acids] (CANB). **Victoria:** Snowfields: Mt Hotham, 32 km SE of Bright, 36°59'S, 147°08'E, alt. 1800 m, on exposed rocks in subalpine meadow, *H. Streimann 50671*, 29 Dec 1992 [bourgeanic acid] (CANB); Eastern Highlands: Mt Buller, 36 km ESE of Mansfield, 37°09'S, 146°26'E, alt. 1790 m, on semi-exposed rock face in subalpine herbfield, *H. Streimann 50711*, 30 Dec 1992 [bourgeanic and gyrophoric acids] (CANB), *H. Streimann 50719*, 30 Dec 1992 [bourgeanic, gyrophoric and stictic acids] (CANB).

## 12. *Rhizocarpon polycarpum* (Hepp) Th.Fr., *Lichenographia Scandinavica* 2: 617 (1874)

Previously known from Western Australia (McCarthy 2014), this species also occurs in Europe, Arctic Eurasia, North Africa, Turkey, the Bering Strait, North America, southern South America, islands in the South Atlantic Ocean, Antarctica and New Zealand (Timdal and Holtan-Hartwig 1988; Fryday 2000b; Øvstedal and Lewis Smith 2001; Calvelo and Liberatore 2002; Feuerer and Timdal 2004; Galloway 2007; Fletcher et al. 2009; Golubkov and Matwiejuk 2009).

*Chemistry*: Reported to produce only stictic acid or to lack lichen substances (Timdal and Holtan-Hartwig 1988; Øvstedal and Lewis Smith 2001; Galloway 2007; Fletcher et al. 2009) or to contain norstictic and stictic acids (Feuerer and Timdal 2004), the Australian specimens either lacked lichen substances or contained bourgeanic acid, the latter a new chemotype of this species (Table 1).

**Specimens examined: Australian Capital Territory**: scree slope, Mt Ginini, Namadgi National Park, 35°31'47"S, 148°46'41"E, alt. 1665 m, on sheltered granite, *P.M. McCarthy 4180* (part), 10 Dec 2013 [bourgeanic acid] (CANB). **New South Wales**: Southern Tablelands: just S of Rawson Pass, Mount Kosciuszko National Park, 36°27'S, 148°15'E, alt. 2130 m, on granite outcrop in alpine heath, *J.A. Elix 4254*, 9 Feb 1978 [no lichen substances] (CANB); Southern Tablelands: 2 km NE of Mt Kosciuszko, Mount Kosciuszko National Park, 36°20'S, 148°16'E, alt. 2150 m, on granite outcrop in alpine herbfield, *H. Streimann 7632* (part), 14 Mar 1979 (CANB). **Victoria**: East Gippsland: Three Sisters Track, 23 km NNE of Cann River, 37°23'S, 149°06'E, alt. 920 m, on sandstone rocks in dry sclerophyll forest, *J.A. Elix 19532* & *H. Streimann*, 27 Sep 1985 [bourgeanic acid] (CANB); Eastern Highlands: Mt Nelse, 19 km SSE of Mount Beauty, Alpine National Park, 36°51'S, 147°20'E, alt. 1880 m, on exposed granite in alpine grassland, *J.A. Elix 40640* & *H. Streimann* (part), 19 Feb 1994 [bourgeanic acid] (CANB).

## 13. *Rhizocarpon reductum* Th.Fr., *Lichenographia Scandinavica* 2: 633 (1874)

Previously known from Western Australia, Queensland, New South Wales, the Australian Capital Territory and Victoria (McCarthy 2014), this lichen is reported here for the first time from South Australia. It also occurs in the British Isles, continental Europe, Arctic Eurasia, Morocco, Tunisia, Turkey, the Ukraine, Central Asia, China, South Africa, North America, Venezuela, Bolivia, Chile, Argentina, the Falkland Islands, Antarctica and New Zealand (Timdal and Holtan-Hartwig 1988 [as *R. obscuratum*]; Feuerer 1991 [as *R. obscuratum*]; Øvstedal and Lewis Smith 2001 [as *R. obscuratum*]; Calvelo and Liberatore 2002; Feuerer and Timdal 2004 [as *R. obscuratum*]; Galloway 2007; Fletcher et al. 2009).

The very closely related *R. postumum* (Nyl.) Arnold, from northern Europe and New Zealand, contains only stictic acid and its satellites, and it has smoother apothecial discs and smaller, submuriform ascospores (Ihlen 2004; Galloway 2007; Fletcher et al. 2009). Because we have observed a continuum of ascospore septation from submuriform to eumuriform and variation in the roughness of the disc (see Fryday 2002), we have not attempted to segregate these species in Australia.

*Chemistry*: *Rhizocarpon reductum* has been reported with stictic acid or lacking lichen substances (Timdal and Holtan-Hartwig 1988; Feuerer and Timdal 2004; Galloway 2007; Fletcher et al. 2009), or containing stictic and norstictic acids (Feuerer and Timdal 2004; Fletcher et al. 2009). The most common chemotype in Australia contains both hypostictic and stictic acids as major substances along with associated satellite compounds (constictic, cryptostictic, menegazziaic and peristictic acids), but additional chemotypes comprising gyrophoric and bourgeanic acids, or bourgeanic acid alone were also seen (Table 1).

**Selected specimens examined: Australian Capital Territory**: Canberra Nature Park, Aranda Bushland, 4 km W of Canberra, 35°16'08"S, 149°04'51"E, alt. 650 m, on sandstone in road cutting in open *Eucalyptus* woodland, *J.A. Elix 38911*, 8 Jun 2008 [hypostictic and stictic acids] (CANB); below summit, Mt Bimberi, Namadgi National Park, 35°39'27"S, 148°47'20"E, alt. 1882–1900 m, on exposed granite, *P.M. McCarthy 4140*, 12 Dec 2013 [stictic acid] (CANB); scree slope, Mt Ginini, Namadgi National Park, 35°31'47"S, 148°46'41"E, alt. 1665 m, on sheltered granite, *P.M. McCarthy 4180*, *4181*, *4184*, *4187*, *4188*, 10 Dec 2013 [bourgeanic and stictic acids] (CANB); Molonglo Gorge, 15 km ESE of Canberra, 35°21'S, 149°15'E, alt. 700 m, on exposed rock in open *Eucalyptus-Callitris* woodland, *H. Streimann*, 21 May 1983 [hypostictic and stictic acids] (CANB). **New South Wales**: Northern Tablelands: turnoff to Top Congi, 11 km E of Bendemeer along road to Walcha, 30°52'20"S, 151°16'12"E, alt. 1015 m, on quartzite stones in remnant *Eucalyptus-Acacia* woodland, *J.A. Elix 36264*, 27 Apr 2005 [stictic acid] (CANB); North Coast: Mt Coramba, 12 km NW of Coffs Harbour, 30°13'S, 153°03'E, alt. 580 m, on rock in temperate rainforest, *J.A. Elix 42710*, 19 Apr 1998 [stictic acid] (CANB); Central Tablelands: Mt Canobolas, summit area, 13 km SW of Orange, 33°20'40"S, 148°58'56"E, alt. 1380–1395 m, on volcanic rock in rocky area with scattered *Eucalyptus* and *Acacia*, *J.A. Elix 46026*, 1 Apr 2014 [bourgeanic acid] (CANB); Southern Tablelands: Hanging Mountain, Hanging Mountain Forest Reserve, 24 km SW of Moruya, 36°01'S, 149°52'E, alt. 550 m, on rocks in dry sclerophyll forest, *J.A. Elix 25515*, 20 Jun 1990 [bourgeanic acid] (CANB); Southern Tablelands: summit of Big Badja Hill, 78 km S of Braidwood, 36°00'S, 149°34'E, alt. 1360 m, on rock in dry sclerophyll forest, *J.A. Elix 26275*, 4 Aug 1991 [hypostictic and stictic acids] (CANB); Southern Tablelands: Bulee Gap, 8 km NE of Nerriga, Morton National Park, 35°05'18"S, 150°08'22"E, alt. 690 m, on sandstone in open *Eucalyptus* woodland, *J.A. Elix 39719*, 31 Oct 2007 [hypostictic

and stictic acids] (CANB); Southern Tablelands: between Braidwood and Hoskinstown, on boulder, *D. McVean* 659, Aug 1965 [bourgeanic and gyrophoric acids] (CANB). **Queensland:** Darling Downs (Anonymous 1975): 7 km NE of Wallangarra, Girraween National Park, 28°53'07"S, 151°57'52"E, alt. 990 m, on granite rocks in dry *Eucalyptus-Callitris* woodland, *J.A. Elix* 43167, 3 May 2005 [hypostictic and stictic acids] (BRI, CANB). **South Australia:** Southern Lofty (Barker et al. 2005): 4 km W of Carey Gully, along the Forest Range Road, 34°57'S, 138°43'E, alt. 456 m, on sandstone in dry sclerophyll forest, *J.A. Elix* 2813, 21 Dec 1976 [hypostictic and stictic acids] (CANB). **Victoria:** Midlands: Chiltern-Mount Pilot National Park, 2 km N of Chiltern, 36°07'47"S, 146°36'42"E, alt. 200 m, on sandstone in open *Eucalyptus* woodland, *J.A. Elix* 36952, 5 May 2006 [hypostictic and stictic acids] (CANB); Midlands: Pyalong–Seymour road, 3 km E of Pyalong, 37°08'S, 144°53'E, alt. 400 m, on rocky road cutting in grazing land, *H. Streimann* 36007, 24 Dec 1985 [stictic acid] (CANB); Midlands: Horan Track, Tallarook State Forest, 17 km S of Seymour, 37°11'S, 145°10'E, alt. 600 m, on boulder in dry sclerophyll forest, *H. Streimann* 36056, 25 Dec 1985 [hypostictic and stictic acids] (CANB); *H. Streimann* 36056, 25 Dec 1985, [stictic acid] (CANB). **Western Australia:** Swan Coastal Plain: Quinninup, 1 km W of Wetherall Road from South West Highway, 2 km N of Wheatley Coast Road, 33°26'S, 116°13'E, on sheltered, wet laterite stone in open *Eucalyptus* forest, *R.J. Cranfield* 13607, 8 Aug 1999 [stictic acid] (CANB, PERTH); Jarrah Forest: 55 km NW of Mount Barker along Muir Highway, 10.7 km S of Rocky Gully, 34°30'55"S, 117°07'35"E, on sheltered, wet stone in open sclerophyll forest, *R.J. Cranfield* 16666, 20 Jul 2001 [hypostictic and stictic acids] (CANB, PERTH); Jarrah Forest: Thornton Forest Block, 10.8 km W on Wagelup Road from Railway Crossing, 34°07'17"S, 116°03'26"E, on sheltered, wet stone in sclerophyll forest, *R.J. Cranfield* 18049 & *K. Knight*, 16 May 2002 [hypostictic and stictic acids] (CANB, PERTH); Jarrah Forest: Boundary Rock, 11 km E of Yornup, 34°04'22"S, 116°19'30"E, alt. 330 m, on sheltered granite ledge in open *Eucalyptus-Casuarina* woodland, *J.A. Elix* 43870, 9 Apr 2006 [hypostictic and stictic acids] (CANB).

#### 14. *Rhizocarpon superficiale* (Schaer.) Malme, *Svensk Botanisk Tidskrift* 8: 282 (1914)

Already known from New South Wales (McCarthy 2014), this lichen also occurs in Europe, Arctic Eurasia, Central and East Asia, the Himalayan region, East Africa, southern Africa, North and South America (Venezuela to Chile), Antarctica and New Zealand (Runemark 1956b; Hertel 1985; Timdal and Holtan-Hartwig 1988; Thomson, 1997; Øvstedal and Lewis Smith 2001; Calvelo and Liberatore 2002; Feuerer and Timdal 2004; Galloway 2007; Matwiejuk 2008; Fletcher et al. 2009). It is reported here as new to Victoria and Western Australia.

**Chemistry:** This species is known to produce several chemotypes: 1) rhizocarpic and stictic acids (Runemark 1956a; Timdal and Holtan-Hartwig 1988), 2) rhizocarpic, stictic and  $\pm$ psoromic acids (Runemark 1956a, Hertel 1985, Thomson 1997, Galloway 2007, Matwiejuk 2008), 3) rhizocarpic and norstictic acids (Runemark 1956a, Fletcher et al. 2009), or 4) rhizocarpic, hypostictic, norstictic and stictic acids (Feuerer and Timdal 2004). The Australian specimens contained rhizocarpic and stictic acids or a new chemotype with rhizocarpic and perlatolic acids (Table 1).

**Specimens examined:** **New South Wales:** Southern Tablelands: 9 km ESE of Michelago, Tinderry Range, 35°44'32"S, 149°15'50"E, alt. 1220 m, on exposed granite in *Eucalyptus* woodland, *J.A. Elix* 45871, 3 Mar 2004 [rhizocarpic and stictic acids] (CANB). **Victoria:** Eastern Highlands: Basalt Hill, 20 km SE of Mount Beauty, Bogong High Plains, Alpine National Park, 36°53'S, 147°18'E, alt. 1650 m, on basalt in exposed, alpine grassland, *J.A. Elix* 40444 (part), 17 Feb 1994 [rhizocarpic and perlatolic acids] (CANB). **Western Australia:** Jarrah Forest: John Forrest National Park, Darling Range, 25 km E of Perth, 31°53'19"S, 116°05'14"E, alt. 250 m, on lateritic rock in *Eucalyptus* woodland, *J.A. Elix* 36067, 8 May 2004 [rhizocarpic and perlatolic acids] (CANB).

#### 15. *Rhizocarpon vigilans* P.M.McCarthy & Elix, *sp. nov.* Figs 1B, 2A, B

Mycobank No.: MB810878

Similar to *Rhizocarpon polycarpum* (Hepp) Th.Fr., but the apothecia become convex and immarginate, the epihymenium is K<sup>-</sup> rather than K<sup>+</sup> purple, and mature ascospores are dark greyish green to dark brown (not colourless).

Type: Australia. Australian Capital Territory, Namadgi National Park, summit of Sentry Box Mountain, 35°49'34"S, 148°54'11"E, alt. 1720 m, on sheltered granite, *P.M. McCarthy* 4121, 12 Dec 2013; holotype: CANB.

**Thallus** crustose, epilithic, effuse to determinate, areolate, pale to medium grey, rarely medium greyish green, (0.05–)0.10–0.15(–0.22) mm thick, forming colonies to c. 2 cm wide in a lichen mosaic; areoles contiguous and angular or scattered and somewhat rounded, 0.15–0.50(–0.85) mm wide, plane (and with the margins slightly raised) to moderately convex, smooth, dull, epruinose. **Cortex** poorly defined or distinct and 10–15  $\mu$ m thick, subtending a hyaline necral layer to 10–15(–20)  $\mu$ m thick; cells rounded, 5–8  $\mu$ m diam., thick-walled, with a dark olive-brown distal wall; inward-facing wall hyaline. **Algal layer** continuous, (20–)60–80(–150)  $\mu$ m deep, occupying much of the upper half of the thallus, with an uneven lower edge; cells green, globose, chlorococcoid, 6–15  $\mu$ m diam. **Medulla** white, I<sup>+</sup> deep blue; hyphae 3–6  $\mu$ m wide, larger, thin-walled and more compacted above, more irregular in shape and loosely arranged below. **Prothallus** black, well developed around

the thallus, to 0.3(–0.8) mm wide and minutely areolate, also visible as indistinct to 1 mm wide between areoles. *Apothecia* numerous, uniformly dull black, usually solitary, occasionally paired or in small clusters or short rows of 3 or 4, at first plane and innate between areoles, either remaining plane but usually becoming moderately to strongly convex and adnate between areoles, occasionally on areoles and more prominent, rarely becoming sessile, lecideine, round to angular due to mutual pressure or the effect of adjacent areoles, (0.30–)0.51(–0.77) mm diam. [ $n = 60$ ], not subtended by algae; disc smooth, epruinose, the black colour unchanged when wetted; margin concolorous with the disc, initially inconspicuous, entire and 30–60  $\mu\text{m}$  thick, epruinose, usually becoming excluded towards maturity in convex apothecia, occasionally remaining faintly visible in plane ones; in section the proper exciple is non-carbonized, 40–80  $\mu\text{m}$  thick, annular, not subtending the hypothecium, internally consisting of pale greenish brown, radiating hyphae, the outer layers of darker tightly packed rounded thick-walled cells 2–3  $\mu\text{m}$  wide, K–, N+ deep red-brown. *Epihymenium* medium to dark greenish brown, 15–20  $\mu\text{m}$  thick, non-amyloid, K–, N+ deep red-brown. *Hypothecium* dark reddish brown to olive-black, 80–150  $\mu\text{m}$  thick, not interspersed with granules or oil droplets, K–, N+ red-brown, I– (with or without pretreatment in K). *Hymenium* 80–120  $\mu\text{m}$  thick, not interspersed with oil droplets, granules or crystals, I+ blue (after pretreatment in K); *paraphyses* rather tightly conglutinate in water, loosening in K, anastomosing, long-celled, 1.5–2.5(–3.5)  $\mu\text{m}$  thick; apical cells apparently conglutinate, with thick dark brown walls, 3–4(–5)  $\mu\text{m}$  wide. *Asci* narrowly to broadly clavate, 70–88  $\times$  18–24  $\mu\text{m}$ , 8-spored, *Rhizocarpon*-type, the spores irregularly biseriate or massed. *Ascospores* dark greyish green to dark brown, 1-septate, elongate-ellipsoid to almost oblong, usually straight, occasionally a little bent, the distal cell sometimes shorter and more rounded than the proximal, with a thick, well-defined, hyaline, 5–8  $\mu\text{m}$  wide perispore when immature, often biguttulate, usually slightly constricted at the septum, (15–)20(–24)  $\times$  (6.5–)8.5(–10)  $\mu\text{m}$  [ $n = 50$ ]; apices rounded to subacute. *Pycnidia* not seen.

**Chemistry:** Medulla K–, C–, PD–, UV–; containing bourgeanic acid (major),  $\pm$ norstictic acid (trace),  $\pm$ protolichesterinic acid (trace) (Table 1).

*Rhizocarpon vigilans* is characterised by the grey thallus with comparatively large, plane to moderately convex areoles containing bourgeanic acid, an I+ blue medulla, convex apothecia that become immarginate, and asci containing 8 grey-green to dark brown, 1-septate ascospores. The bipolar *R. polycarpum* is similar, but the apothecia are persistently plane and marginate, the epihymenial region is K+ purple and the ascospores remain colourless until maturity (although post-mature propagules commonly darken as they collapse). *Rhizocarpon flavomedullosum* (see above) has smaller, plane to slightly concave areoles, more convex apothecia, and a yellowish non-amyloid medulla containing rhizocarpic acid. Furthermore, while dark 1-septate ascospores are also produced by the mainly boreal *R. copelandii* (Körb.) Th.Fr., the latter has a non-amyloid medulla and thalline chemistry dominated by norstictic acid or stictic acid (Timdal and Holtan-Hartwig 1988; Fryday 2000b; Galloway 2007; Fletcher et al. 2009). Finally, *R. simillimum* (Anzi) Lettau, a Northern Hemisphere species recently added to the lichen floras of the Falkland Islands and New Zealand (Fryday and Øvstedal 2012), has an amyloid medulla and brown 1-septate spores. However, the latter are only 12–16  $\times$  6–8  $\mu\text{m}$ , and the epihymenium and exciple are K+ purple-red.

**Etymology:** The epithet *vigilans* is the Latin for watchful or vigilant, in reference to the type locality, Sentry Box Mountain.

**Distribution and habitat:** The new species grows on granite boulders and outcrops on mountain tops in the southern A.C.T. Associated lichens included *Buellia aethalea* (Ach.) Th.Fr., *B. homophylia* (C.Knight) Zahlbr., *B. ocellata* (Flot.) Körb., *Fuscidea australis* Kantvilas, *Immersaria athrocarpa* (Ach.) Rambold & Pietschm., *Lecanora farinacea* Fée, *L. polytropa* (Ehrh.) Rabenh., *L. rupicola* (L.) Zahlbr., *Lecidea diducens* Nyl., *L. fuscoatrula* Nyl., *Protoparmelia badia* (Hoffm.) Hafellner, *Ramboldia petraeoides* (Nyl. ex C.Bab. & Mitt.) Kantvilas & Elix, *Rhizocarpon distinctum*, *R. geminatum*, *R. geographicum*, *R. lecanorinum*, *R. viridiatrum*, *Umbilicaria cylindrica* (L.) Delise ex Duby, *U. decussata* (Vill.) Zahlbr. and several species of *Xanthoparmelia*.

**Table 1.** Secondary metabolites in *Rhizocarpon* species from mainland Australia. The satellite substances (constictic, cryptostictic, menegazziaic and peristictic acids) that can occur in minor or trace quantities with stictic acid are not included. ± = present or absent; t = trace amount.

	electronic acid	barbatic acid	bourgeanic acid	α-collatolic acid	confluent acid	connorstictic acid	demethylbarbatic acid	gyrophoric acid	hypostictic acid	2'-O-methylanziaic acid	2'-O-methylperlatolic ac.	norstictic acid	perlatolic acid	protolichesterinic acid	psoromic acid	rhizocarpic acid	stictic acid	NIL
<i>adarensis</i>	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	•	-	-
<i>badioatrum</i>	-	-	•	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
<i>disporum</i>	-	-	•	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
<i>disporum</i>	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	•	-
<i>disporum</i>	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	•
<i>distinctum</i>	-	-	-	-	-	±	-	-	-	-	-	•	-	-	-	-	-	-
<i>distinctum</i>	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	•	-
<i>distinctum</i>	-	-	•	-	-	-	-	-	-	-	-	-	-	-	-	-	•	-
<i>eupetraeoides</i>	-	-	±	-	-	-	-	-	-	-	-	-	-	-	-	•	-	-
<i>flavomedullosum</i>	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	•	-	-
<i>flavomedullosum</i>	-	-	•	-	-	-	-	-	-	-	-	-	-	-	-	•	-	-
<i>geminatum</i>	-	-	•	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
<i>geminatum</i>	-	-	•	-	-	±	-	-	-	-	-	•	-	-	-	-	•	-
<i>geminatum</i>	-	-	±	-	-	-	-	-	-	-	-	-	-	-	-	-	•	-
<i>geographicum</i>	-	•	-	-	-	-	•	±	-	-	-	-	-	-	-	•	-	-
<i>geographicum</i>	-	-	±	-	-	-	-	-	-	-	-	-	-	-	•	•	-	-
<i>geographicum</i>	-	-	±	-	-	-	-	-	-	-	-	-	-	-	•	•	-	-
<i>geographicum</i>	-	-	±	-	•	-	-	-	-	•	•	-	-	-	-	•	-	-
<i>geographicum</i>	•	-	-	•	-	-	-	±	-	-	-	-	-	-	•	•	-	-
<i>intersitum</i>	-	-	-	-	-	-	-	•	-	-	-	-	-	-	-	-	-	-
<i>lavatum</i>	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	•
<i>lecanorinum</i>	-	-	•	-	-	-	-	-	-	-	-	-	-	-	-	•	•	-
<i>lecanorinum</i>	-	-	•	-	-	-	-	•	-	-	-	-	-	-	-	•	•	-
<i>lecanorinum</i>	-	-	•	-	-	-	-	±	-	-	-	-	-	-	-	•	-	-
<i>polycarpum</i>	-	-	•	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
<i>polycarpum</i>	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	•	-
<i>polycarpum</i>	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	•
<i>reductum</i>	-	-	•	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
<i>reductum</i>	-	-	•	-	-	-	-	•	-	-	-	-	-	-	-	-	-	-
<i>reductum</i>	-	-	•	-	-	±	-	-	-	-	-	•	-	-	-	-	-	-
<i>reductum</i>	-	-	•	-	-	-	-	-	-	-	-	-	-	-	-	-	•	-
<i>reductum</i>	-	-	-	-	-	-	-	-	•	-	-	-	-	-	-	-	•	-
<i>superficiale</i>	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	•	•	-
<i>superficiale</i>	-	-	-	-	-	-	-	-	-	-	-	-	•	-	-	•	-	-
<i>vigilans</i>	-	-	•	-	-	-	-	-	-	-	-	±t	-	±t	-	-	-	-
<i>viridiatrum</i>	-	-	-	-	-	±	-	-	-	-	-	•	-	-	-	•	-	-
<i>viridiatrum</i>	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	•	-	-

**Additional specimens examined: Australian Capital Territory:** summit of Sentry Box Mountain, Namadgi National Park, 35°49'34"S, 148°54'11"E, alt. 1720 m, on sheltered granite, *P.M. McCarthy 4114* (part), 4312 (part), 12 Dec 2013 (CANB); summit of Mt Scabby, Namadgi National Park, 35°45'08"S, 148°54'35"E, alt. 1809 m, on exposed granite, *P.M. McCarthy 4190* (part), 9 Dec 2013 (CANB).

#### 16. *Rhizocarpon viridiatrum* (Wulfen) Körb., *Systema Lichenum Germaniae* 262 (1855)

Previously known from Victoria (McCarthy 2014) and recorded here for the first time from the Australian Capital Territory, New South Wales and Western Australia, this lichen also occurs in Europe, Macaronesia, Morocco, Turkey, South Africa, Central Asia, China, North America, Chile and New Zealand (Runemark 1956b; Hertel 1985; Timdal and Holtan-Hartwig 1988; Galloway 2007; Fletcher et al. 2009; Golubkov and Matwiejuk 2009, 2011).

**Chemistry:** This species was previously reported to contain 1) rhizocarpic and stictic acids (Runemark 1956a; Timdal and Holtan-Hartwig 1988), 2) rhizocarpic and norstictic acids (Hertel 1985; Galloway 2007), 3) rhizocarpic, norstictic and stictic acids (Feuerer and Timdal 2004), 4) rhizocarpic and gyrophoric acid (Runemark 1956a), 5) rhizocarpic and unidentified fatty acids (Fletcher et al. 2009), and 6) rhizocarpic acid only (Runemark 1956a). The Australian specimens produced only rhizocarpic acid or that compound together with norstictic acid (Table 1).

**Selected specimens examined: Australian Capital Territory:** summit of Mt Aggie, 43 km WSW of Canberra, 35°28'S, 148°46'E, alt. 1490 m, on sheltered schist ledges on exposed summit, *J.A. Elix 11628 & P.W. James*, 21 Jan 1984 [norstictic and rhizocarpic acids] (CANB); summit of Sentry Box Mountain, Namadgi National Park, 35°49'34"S, 148°54'11"E, alt. 1720 m, on sheltered granite, *P.M. McCarthy 4114* (part), 4121, 12 Dec 2013 [norstictic and rhizocarpic acids] (CANB). **New South Wales:** Central Tablelands: NW slopes of Mt Canobolas, 13 km SW of Orange, 33°21'S, 148°59'E, alt. 1300 m, on weathered volcanic rocks in *Eucalyptus* woodland, *J.A. Elix 23428*, 6 Dec 1989 [rhizocarpic acid] (CANB); Southern Tablelands: New Chums Hill, above old Kiandra cemetery, Mount Kosciuszko National Park, 35°52'S, 148°30'E, alt. 1460 m, on exposed rocks in subalpine grassland, *J.A. Elix 19126 & H. Streimann*, 10 Apr 1985 [rhizocarpic acid] (CANB); Southern Tablelands: Umaralla Parish, property of J.D.Wood, portion 113 on Monaro Shire map, along Numeralla road E of Cooma, on sandstone rock in open *Eucalyptus macrorrhynca-E. rossii* woodland, *D. Verdon 3681*, 28 Sep 1978 [rhizocarpic acid] (CANB); South Western Slopes: Great Yambla Ridge, 17 km SSE of Culcairn, 35°50'S, 147°04'E, alt. 580 m, on exposed rocks in grassland, *J.A. Elix 23135*, 16 Nov 1989 [norstictic and rhizocarpic acids] (CANB). **Western Australia:** Jarrah Forest: Koodiwoodle Range, near Bidgerabbie Hill, 19 km N along Scenic Drive off Rowes Road, 30°48'14"S, 115°48'34"E, alt. 200 m, on lateritic rock in *Eucalyptus ficifolia* woodland, *J.A. Elix 28955*, 6 May 2004 [rhizocarpic acid] (CANB); *J.A. Elix 28981*, 6 May 2004 [norstictic and rhizocarpic acids] (CANB); Jarrah Forest: Caernarvon Hills, Dryandra Woodland, 17 km NW of Narrogin, 32°48'21"S, 117°03'21"E, alt. 325 m, on lateritic rock in *Eucalyptus salmonophloia* woodland, *J.A. Elix 39855*, 6 Apr 2006 [norstictic and rhizocarpic acids] (CANB); Esperance Plains: Ravensthorpe Range, South Coast Highway, 9 km E of Ravensthorpe, 33°35'S, 120°08'E, alt. 160 m, on siliceous rock in dry sclerophyll forest with scattered *Callitris*, *H.T. Lumbsch 10839c*, 18 Sep 1994 [rhizocarpic acid] (CANB).

### Key to *Rhizocarpon* in Australia

- |    |   |                         |
|----|---|-------------------------|
| 1  | Upper surface of thallus yellow-green; cortex containing rhizocarpic acid .....   | 2                       |
| 1: | Upper surface of thallus whitish, brown, green or grey; cortex lacking rhizocarpic acid .....   | 7                       |
| 2  | Ascospores 1-septate .....  | 3                       |
| 2: | Ascospores submuriform to muriform .....  | 5                       |
| 3  | Ascospores 25–35 × 12–17 µm .....   | <i>R. eupetraeoides</i> |
| 3: | Ascospores 12–23 × 6–10 µm .....  | 4                       |
| 4  | Medulla yellow; containing only rhizocarpic acid .....  | <i>R. adarense</i>      |
| 4: | Medulla white; containing rhizocarpic and stictic or perlatolic acids .....   | <i>R. superficiale</i>  |
| 5  | Thallus forming a pseudolecanorine margin around apothecia .....  | <i>R. lecanorinum</i>   |
| 5: | Thallus not forming a pseudolecanorine margin around apothecia .....  | 6                       |
| 6  | Thallus initially parasitic on the lichen <i>Aspicilia sens. lat.</i> ; upper surface usually pale green; containing rhizocarpic and ±norstictic acids .....            | <i>R. viridiatrum</i>   |
| 6: | Thallus not parasitic on other lichens; upper surface predominantly yellow; containing rhizocarpic and psoromic, barbatic or 2'- <i>O</i> -methylperlatolic acids ..... | <i>R. geographicum</i>  |

7	Ascospores 1-septate .....	8
7:	Ascospores 3-septate to submuriform or muriform .....	11
8	Mature ascospores hyaline, 17–22 × 8–11 µm; medulla I+ blue (Fig. 2G) .....	<b>R. polycarpum</b>
8:	Mature ascospores dark grey-green to dark brown; medulla I+ blue or I– .....	9
9	Medulla white, I+ blue (Fig. 2B) .....	<b>R. vigilans</b>
9:	Medulla yellow or white, I– .....	10
10	Medulla yellow above [rhizocarpic acid]; ascospores 12–22 × 6–10 µm (Fig. 2C) .....	<b>R. flavomedullosum</b>
10:	Medulla uniformly white; ascospores 24–40 × 13–20 µm (Fig. 2D) .....	<b>R. badioatrum</b>
11	Mature ascospores predominantly 3-septate, rarely 1-septate, occasionally with 1 or 2 longitudinal or diagonal septa, colourless (collapsed post-mature ascospores can be dark brown); medulla I+ blue (Fig. 2E) .....	<b>R. distinctum</b>
11:	Mature ascospores submuriform to muriform, with 8–50 cells in optical section, colourless to dark brown; medulla I– .....	12
12	Mature ascospores colourless .....	13
12:	Mature ascospores dark grey-green to dark brown .....	15
13	Ascospores 22–35 µm long (Fig. 2H).....	<b>R. reductum</b>
13:	Ascospores 33–50 µm long .....	14
14	Upper surface pale brown; proper margin thick, swollen; thallus lacking lichen substances; on siliceous rocks.....	<b>R. lavatum</b>
14:	Upper surface white to grey; proper margin not swollen; thallus with stictic acid; usually on calcareous rocks [Tasmania] .....	<b>R. petraeum</b>
15	Asci 1-spored; ascospores 50–75 × 20–30 µm .....	<b>R. disporum</b>
15:	Asci 2–8-spored; ascospores smaller .....	16
16	Ascospores 24–34 × 10–16 µm, (4–)8 per ascus (Fig. 2F) .....	<b>R. intersitum</b>
16:	Ascospores 30–55 × 17–25 µm, 2–6 per ascus.....	17
17	Paraphyses anastomosing; ascospores (1–)2(–4) per ascus; apothecia ±elevated, uniformly black; on comparatively dry montane rocks, not associated with water bodies .....	<b>R. geminatum</b>
17:	Paraphyses ±simple; ascospores 2–4(–6) per ascus; apothecia immersed, with a white rim; on rocks in and around Tasmanian alpine lakes .....	<b>R. austroamphibium</b>

### Acknowledgments

Many of the specimens listed above were collected during the Bush Blitz survey of the southern Australian Capital Territory and nearby alpine areas of New South Wales, co-funded by the Australian Government and BHP Billiton. We thank Dr Christine Cargill and Ms Judith Curnow (CANB) for their kind assistance.

### References

- Anonymous (1975) [untitled map] *Contributions of the Queensland Herbarium* 19: end paper
- Barker WR, Barker R, Jessop J, Vonow H (eds) (2005) *Census of South Australian Vascular Plants*, Edition 5.00. (Botanic Gardens and State Herbarium, Adelaide)
- Brodo IM, Duran Sharnoff S, Sharnoff S (2001) *Lichens of North America*. (Yale University Press, New Haven and London)
- Calvelo S, Liberatore S (2002) Catálogo de los líquenes de la Argentina. *Kurtziana* 29: 7–170.
- Clauzade G, Roux C (1985) Likenoj de Okcidenta Eŭropo. Ilustrita Determinlibro. *Bulletin de la Société Botanique du Centre-Ouest*, Nouvelle Série, Numéro Spécial 7: 1–893.

- Conn BJ (1993) Natural regions and vegetation of Victoria, Pp. 79–158. In Foreman DB and Walsh NG (eds). *Flora of Victoria*, Vol. 1. (Inkata Press, Melbourne)
- Darbishire OV (1923) Lichens. *British Antarctic (“Terra Nova”) Expedition, 1910, Natural History Report, Botany*, Part III, pp. 29–76.
- Elix JA (2014) *A Catalogue of Standardized Thin-Layer Chromatographic Data and Biosynthetic Relationships for Lichen Substances*, 3rd edn. (Published by the author, Canberra)
- Elix JA, Giralto M, Wardlaw JH (2003) New chloro-depsides from the lichen *Dimelaena radiata*. *Bibliotheca Lichenologica* 86: 1–7.
- Feurerer T (1991) Revision der europäischen Arten der Flechtengattung *Rhizocarpon* mit nichtgelbem Lager und veiltelligen Sporen. *Bibliotheca Lichenologica* 39: 1–218.
- Feurerer T, Timdal E (2004) *Rhizocarpon*. Pp. 456–466 in Nash III TH, Ryan BD, Gries C and Bungartz F (eds), *Lichen Flora of the Greater Sonoran Desert Region 2*. (Lichens Unlimited, Tempe, Arizona)
- Fletcher A, Gilbert OL, Clayden S, Fryday AM (2009) *Rhizocarpon* Ramond ex DC. (1805). Pp. 792–808 in Smith CW, Aptroot A, Coppins BJ, Fletcher A, Gilbert OL, James PW and Wolseley PA (eds), *The Lichens of Great Britain and Ireland*. (British Lichen Society, London)
- Fryday AM (2000a) On *Rhizocarpon obscuratum* (Ach.) Massal., with notes on some related species in the British Isles. *Lichenologist* 32: 207–224. <http://dx.doi.org/10.1006/lich.2000.0269>
- Fryday AM (2000b) Additional lichen records from New Zealand 31. *Australasian Lichenology* 46: 36–39.
- Fryday AM (2002) A revision of the species of the *Rhizocarpon hochstetteri* group occurring in the British Isles. *Lichenologist* 34: 451–477. <http://dx.doi.org/10.1006/lich.2002.0416>
- Fryday AM (2004) New species and records of lichenized fungi from Campbell Island and the Auckland Islands, New Zealand. *Bibliotheca Lichenologica* 88: 127–146.
- Fryday AM (2010) A brief lichen foray in the Mount Washington alpine zone—including *Claurouxia chalybeoides*, *Porina norrlinii* and *Stereocaulon leucophaeopsis* new to North America. *Opuscula Philolichenum* 8: 1–10.
- Fryday AM, Kantvilas G (2012) *Rhizocarpon austroamphibium* (Rhizocarpaceae, lichenized Ascomycota), a new species from Tasmania. *Australasian Lichenology* 71: 12–17.
- Fryday AM, Øvstedal DO (2012) New species, combinations and records of lichenized fungi from the Falkland Islands (Islas Malvinas). *Lichenologist* 44: 483–500. <http://dx.doi.org/10.1017/S0024282912000163>
- Galloway DJ (2007) *Flora of New Zealand Lichens*. Revised second edition. Volume 2. (Manaaki Whenua Press, Lincoln)
- Geyer M, Feuerer T, Feige GB (1984) Chemie und Systematik in der Flechtengattung *Rhizocarpon*: Hochdruckflussigkeitschromatographie (HPLC) der Flechten-Sekundarstoffe der *Rhizocarpon superficiale*-Gruppe. *Plant Systematics and Evolution* 145: 41–54. <http://dx.doi.org/10.1007/BF00984030>
- Golubkov V, Matwiejuk A (2009) Some new records of *Rhizocarpon* from north-eastern Poland and north-western Belarus. *Acta Mycologica* 44: 201–210. <http://dx.doi.org/10.5586/am.2009.018>
- Golubkov V, Matwiejuk A (2011) *Rhizocarpon distinctum* and *R. superficiale* new to the Yamal Peninsula, Russia. *Graphis Scripta* 23: 39–41.
- Hertel H (1985) New, or little-known New Zealand lecideoid lichens. *Mitteilungen der Botanischen Staatssammlung München* 21: 301–337.
- Ihlen PG (2004) Taxonomy of the non-yellow species of *Rhizocarpon* (Rhizocarpaceae, lichenized Ascomycota) in the Nordic countries, with hyaline and muriform ascospores. *Mycological Research* 108: 533–570. <http://dx.doi.org/10.1017/S0953756204009803>
- Jacobs SWL, Pickard J (1981) *Plants of New South Wales*. (D. West, Government Printer, Sydney)
- Joshi Y, Koh YJ, Hur J-S (2010) Three new records of lichen genus *Rhizocarpon* from South Korea. *Mycobiology* 38: 219–221. <http://dx.doi.org/10.4489/MYCO.2010.38.3.219>
- Lendemer JC, Knudsen K, Fryday AM (2010) New and interesting lichens, lichenicolous and allied fungi from Yosemite National Park, California, U.S.A. *Opuscula Philolichenum* 8: 107–120.
- Matwiejuk A (2008) Noteworthy species of the genus *Rhizocarpon* Ramond ex DC. (Rhizocarpaceae, lichenized Ascomycota) in the LBL herbarium. *Annales Universitatis Mariae Curie-Skłodowska, Sec. C*, 68: 79–92.
- McCarthy PM (2014) *Checklist of the Lichens of Australia and its Island Territories*. (Australian Biological Resources Study, Canberra; <http://www.anbg.gov.au/abrs/lichenlist/introduction.html>; Version 9 Sep 2014)
- Øvstedal DO, Lewis Smith RI (2001) *Lichens of Antarctica and South Georgia: A Guide to their Identification and Ecology*. (Cambridge University Press, Cambridge)
- Runemark H (1956a) Studies in *Rhizocarpon*. I. Taxonomy of the yellow species in Europe, *Opera Botanica* 2(1): 1–152.
- Runemark H (1956b) Studies in *Rhizocarpon*. II. Distribution and ecology of the yellow species in Europe, *Opera Botanica* 2(2): 1–150.

- Thackway R, Cresswell ID (1995) *An Interim Biogeographic Regionalisation for Australia : a framework for setting priorities in the National Reserves System Cooperative Program Version 4.0*. (Australian Nature Conservation Agency, Reserve Systems Unit, Canberra)
- Thomson JW (1997) *American Arctic Lichens: The Microlichens*. (University of Wisconsin Press, Madison)
- Timdal E, Holtan-Hartwig J (1988) A preliminary key to *Rhizocarpon* in Scandinavia. *Graphis Scripta* 2: 41–54.
- Wirth V (1995) *Die Flechten Baden-Württembergs*. Volume 2. (Ulmer-Verlag, Stuttgart)

Manuscript received 13 October 2014, accepted 25 November 2014

