CSIRO PUBLISHING
www.publish.csiro.au/journals/asb *Australian Systematic Botany*, **24**, 32–57

Australian species of *Elaphomyces* (Elaphomycetaceae, Eurotiales, Ascomycota)

Michael A. Castellano[A,D], *James M. Trappe*[B] *and Karl Vernes*[C]

[A]US Department of Agriculture, Forest Service, Northern Research Station, 3200 SW Jefferson Way, Corvallis, Oregon 97331, USA.
[B]Department of Forest Science, Oregon State University, Corvallis, Oregon 97331-5752, USA.
[C]Department of Ecosystem Management, The University of New England, Armidale, NSW 2351, Australia.
[D]Corresponding author. Email: mcastellano@fs.fed.us

Abstract. The sequestrate ascomycete genus *Elaphomyces* is described and illustrated from Australia. The following thirteen new species are described: *Elaphomyces aurantias*, *E. austrogranulatus*, *E. chlorocarpus*, *E. cooloolanus*, *E. coralloideus*, *E. laetiluteus*, *E. nothofagi*, *E. pedicellaris*, *E. queenslandicus*, *E. rugosisporus*, *E. suejoyceae*, *E. symeae*, and *E. timgroveii*. A key is provided to all *Elaphomyces* species from Australia.

Introduction

Elaphomyces is a sequestrate genus of hypogeous Ascomycota occurring across the northern hemisphere and Australasia. The first published report of *Elaphomyces* is as *Tubera cervina* (de L'Obel 1591). The genus name *Elaphomyces* was first proposed by Nees von Esenbeck (1820) and sanctioned by Fries (1825). Many authors contributed new species through the years, the only comprehensive work being by Dodge (1929), now outdated. *Elaphomyces* was first reported from the southern hemisphere by Cooke (1892), who listed *E. leveillei* Tul. (described originally from France) as occurring in Queensland, Australia. Later, Rodway (1918) listed *E. citrinus* Vittad. (described originally from Italy) from Tasmania. These reports have subsequently proven to be erroneous as both collections represent undescribed species that we treat below.

In the course of extensive collecting expeditions in forested regions of Australia over the past 25 years (Lebel and Castellano 1999), we have unearthed over 100 collections of *Elaphomyces*. In comparing Australian *Elaphomyces* specimens with previously described *Elaphomyces* species from the northern hemisphere, we found no overlap in distributions. All Australian *Elaphomyces* collections belong to endemic undescribed species. On the basis of peridial characteristics, the Australian *Elaphomyces* species can be separated into two broad groups, similar to those from the northern hemisphere. Most Australian species have a very dark brown or black, carbonaceous outer peridial layer, similar to that of many species in the northern hemisphere, i.e. *E. anthracinus* Vittad., *E. leveillei* Tul. or *E. viridiseptum* Trappe & Kimbrough. One species, *E. austrogranulatus* Castellano, Trappe & Vernes, has a thick, brown, leathery peridium, similar to that of *E. granulatus* Fries.

In the northern hemisphere, Vittadini (1831) divided *Elaphomyces* into the following two subgenera: *Malacoderma* typified by *E. papillatus* Vittad., characterised by species with small (<15 µm) spores and a more or less soft and thin peridium that is furrowed to wrinkled on drying, and subgenus *Scleroderma*, characterised by species with large (>14 µm) spores and a hard, brittle peridium unchanged when dried. Vittadini (1831) further divided subgenus *Scleroderma* into two unnamed groups, including (1) a group typified by *E. leucosporus* Vittad., possessing a smooth outer peridium, and (2) a group typified by *E. reticulates* Vittad., possessing a warty outer peridium. Fries (1849) named the section in subgenus *Scleroderma* that is represented by *E. leucosporus*, *Ceratogaster* (Corda) Fr. and the section represented by *E. reticulatus* as *Ceraunion* (Wall.) Fr. Subsequently, Dodge (1929) divided subgenus *Scleroderma* section *Ceraunion* into two subsections, mostly on the basis of the absence (subsection *Hypogeum* (Pers.) Dodge) or presence (*Phlyctospora* (Zobel) Dodge) of a rooting base to the ascoma.

The Australian *Elaphomyces* species have representatives that can be placed into all these groups except subgenus *Scleroderma* section *Ceraunion* subsection *Phlyctospora*, as none of the Australian *Elaphomyces* species possesses a rooting base. The use of spore size as a delimiting character among subgenera is not supportable when placing Australian *Elaphomyces* species into this scheme, because several small-spored species have a smooth, hard, carbonaceous peridium and spores <15 µm in diameter (i.e. *E. chlorocarpus*, *E. pedicellaris*, and *E. rugosisporus*). Vittadini's (1831) subgenus *Scleroderma*, if it were valid, would now be subgenus *Elaphomyces* typified by *E. granulatus* according to the International Code of Botanical Nomenclature. In any event, we prefer to await the results of future molecular analysis before recognising groups below the genus level.

The patterns of spore ornamentation vary markedly among Australian *Elaphomyces* species, as do those of the northern hemisphere species. Spore ornamentation ranges from individual rods or spines to a complete reticulum or labyrinth, or even an amorphous, plate-like structure. Scanning electron

 10.1071/SB10012 1030-1887/11/010032

microscopy (SEM) proved critical to elucidate the exact nature of spore ornamentation to help distinguish among some species. Correlating ornamentation structure that is observed with light microscopy with what is shown with SEM helped sort out taxa when observed with a light microscope at ×1000. Molecular information is presently lacking because extracting useable DNA for sequencing has been difficult for most *Elaphomyces* collections (Kerry O'Donnell, USDA, Agricultural Research Service, pers. comm.). Until comprehensive molecular work is accomplished, we hypothesise that the Australian *Elaphomyces* species form a distinct clade or clades within the genus, as has been demonstrated for many other sequestrate genera from Australia (Hosaka *et al*. 2006).

Elaphomyces does not so far overlap in species between western and eastern portions of Australia, although some have a broad latitudinal distribution. In all, 12 of the 13 *Elaphomyces* species described here occur with Myrtaceae or Casuarinaceae, whereas only one, *E. nothofagi*, is associated with *Nothofagus* (Nothofagaceae). *E. nothofagi* also possesses a spore ornamentation pattern unique within the genus, with an irregular reticulum beneath yarn-like hyphae.

Below we describe 13 new *Elaphomyces* species from Australia and provide a key to them for identification and classification purposes.

Materials and methods

Methods of collection and the macroscopic and microscopic study were generally as described in Castellano *et al*. (1989). Colours of fresh specimens are described in general terms. Hand-cut sections of both fresh and dried material were mounted in 5% KOH or water for standard light microscopy. Spore dimensions include ornamentation and are based on the measurement of 20 randomly selected spores, plus the largest and smallest seen. Measurements of sterile tissues and spores are from mature ascomata. Dried spores were mounted on 10-mm diameter aluminium support stubs using double-sided tape, rimmed with colloidal carbon and coated with ~15 nm gold in a Hummer 6.2 sputtering unit (Anatech, Springfield, VA). SEM performed by Jim Ehrman used a JEOL JSM-5600 SEM (JEOL USA, Peabody, MA) operating at 10 kV and 8–48 mm working distance at the Digital Microscopy Facility, Mount Allison University. SEM performed by Michael Castellano used an AmRay 3300 FE SEM (AmRay, Bedford, MA) under similar kV and working conditions as above. Holotype and paratype specimens are deposited in appropriate mycological herbaria in Australia depending on the origin of the collection (CANB, DAR, HO, MEL or PERTH) and in the mycological herbarium of Oregon State University (OSC) or Landcare Research, New Zealand (PDD). Abbreviations are according to Index Herbariorum (http://sciweb.nybg.org/science2/IndexHerbariorum.asp).

Taxonomy

Key to Australian *Elaphomyces* species (spore size includes ornamentation)

1. Spores >40 µm in diameter; associated with *Nothofagus* ..... ***E. nothofagi***
1. Spores <31 µm in diameter; associated with *Acacia* or Myrtaceae 2
2. Spores 8–17 µm in diameter 3
2. Spores 18 µm or larger in diamete 8
3. Spores 8–9 µm in diameter; Western Australia ..... ***E. timgroveii***
3. Spores 10–16 µm in diameter 4
4. Spores 14–16 µm in diameter; ornamentation of rods and spines ..... ***E. aurantius***
4. Spores 10–13 µm in diameter; with at least a partial reticulum 5
5. Ascoma enclosed in deep orange, orangy-red, or red mycelium 6
5. Ascoma enclosed in white or yellow or green mycelium 7
6. Spores 11–12 µm in diameter (mean 11.1 µm); ornamentation a pedicellate, fine reticulum; eastern Australia ..... ***E. rugosisporus***
6. Spores 12–13 µm in diameter (mean 12.8 µm); ornamentation a pedicellate, irregular reticulum; Western Australia ..... ***E. symeae***
7. Spores 10–11 µm in diameter (mean 10.9 µm); glebal spore mass dark greyish-blue; ascoma enclosed in bright yellow, yellowish-green to green mycelium; Western Australia ..... ***E. chlorocarpus***
7. Spores 11–13 µm in diameter; glebal spore mass black; ascoma enclosed in white or yellow mycelium; eastern Australia 8
8. Spore ornamentation of rods and spines to form a partial reticulum, ascomata enclosed in white mycelium, Queensland ..... ***E. cooloolanus***
8. Spore ornamentation of pedicellate, irregular plates forming a labyrinth, ascomata enclosed in yellow mycelium, Victoria ..... ***E. pedicellaris***
8. Spores 26–30 µm in diameter 9
8. Spores 18–25 µm in diameter 11
9. Peridium brown, leathery, with crowded pyramidal warts ..... ***E. austrogranulatus***
9. Peridium black, carbonaceous, smooth or wrinkled 10
10. Spores 26–30 µm in diameter (mean 27.5 µm), ornamentation of tall (2–5 µm) labyrinthine ridges; ascomata enclosed in brown mycelium ..... ***E. suejoyceae***
10. Spores 23–26 µm in diameter (mean 24.5 µm), ornamentation of dense rods that appear punctate when young, knobby and somewhat amorphous when mature; ascomata enclosed in yellow mycelium ..... ***E. laetiluteus***
11. Spores 24–25 µm in diameter (mean 24.5 µm), ornamentation of pedicellate, labyrinthine ridges, ±3 µm tall; glebal spore mass slate grey to bluish-black at maturity ..... ***E. queenslandicus***
11. Spores 18–20 µm in diameter (mean 19.1 µm), ornamentation a fine coral-like labyrinth of narrow ridges; glebal spore mass dark brown to black at maturity ..... ***E. coralloideus***

Elaphomyces aurantius Castellano, Trappe & Vernes, sp. nov. (Figs 1, 14*a*)

Ascomata in mycelio aurantio vel flavissimo omnino inclusa. Peridium strati duorum compositum: stratum exterius ±0.1 mm crassum, anthracinum, carbonaceum, pagina levis vel parum foveata; stratum interius 1.5–3 mm crassum, pallide griseum vel griseum maculosum, venis albis marmoratum, interdum erubescens. Gleba maturitate pulvereis griseo-caeruleis vel fuscis sporis repleta. Asci globosi, ±40 µm lati, parietibus 1–2 µm crassis, 8-spori. Sporae globosae, 14–16 µm latae virgasque spinas ornamenta 1–1.5 µm longas inclusae, in maturitate in KOH viridinigrae vel obscure porphyreae.

Holotypus: Australia: Tasmania, Cradle Mountain National Park, Waldheim, 13.v.1991, *M. Castellano H5045* (HO, isotypes PERTH, OSC).

Ascomata up to 10–22 × 11–30 mm, globose to subglobose or irregular, completely enclosed in bright orange to occasionally

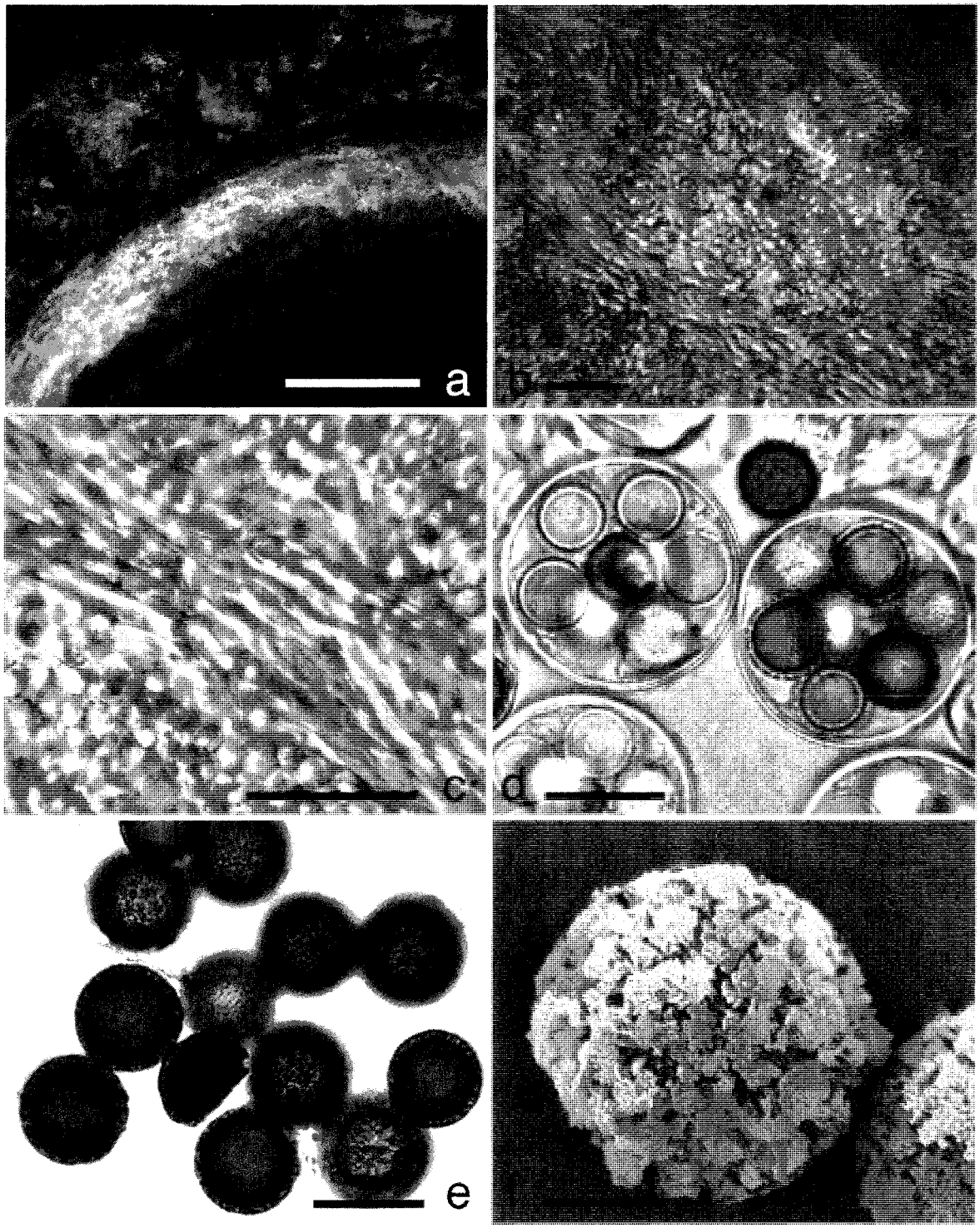

Fig. 1. *Elaphomyces aurantius*. (*a*) Ascoma in cross-section. (*b*) Structure of the inner peridial layer. (*c*) Bundled hyphae. (*d*) Asci with developing spores. (*e*) Spores viewed under light microscopy. (*f*) Scanning electron micrograph of a spore. Scale bars = 3 mm (*a*), 50 μm (*b*, *c*), 20 μm (*d*), 15 μm (*e*) and 5 μm (*f*).

bright yellow mycelium with much soil, roots and debris that form a crust, the fresh yellow hyphae sometimes turning orange over the course of the day after collection. *Peridium* 2-layered; outer layer dark brown–black, carbonaceous, smooth to somewhat pitted; inner layer pale grey mottled with grey and marbled with mostly periclinal white veins, occasionally

blushing faintly pink near gleba where cut. *Gleba* initially hollow, then filling with white, cottony-membranaceus, ascogenous tissue that blushes slightly pink where cut; spore mass powdery, greyish-blue in youth, becoming brownish-black when mature, mixed with arachnoid hyphae that are greyish-blue to olive, finally dark brown at maturity. *Odour* mild. *Taste* not recorded.

Outer layer of the *peridium* approximately 100 µm thick, of bundled hyphae 15–20 µm thick, arranged perpendicularly to each other and composed of numerous individual brownish-black, septate hyphae 3–4 µm in diameter, with walls approximately 1 µm thick; inner layer 1.6–3.1 mm thick at maturity, of bundled hyphae 40–70 µm thick arranged perpendicularly to each other and composed of numerous individual, interwoven to subparallel, hyaline hyphae up to ±7 µm broad and with walls ±1.5 µm thick. *Gleba* of spores and intermingling, hyaline, septate, acutely branched, sinuous to somewhat knobby, loosely interwoven hyphae 2–3 µm broad and with walls <0.5 µm thick. *Asci* globose, ±40 µm broad, pedicellate, hyaline, the walls 1–2 µm thick, 8-spored, arising from scattered, knot-like clusters of pale green (in KOH) ascogenous hyphae 5–6 µm broad. *Spores* globose, 14–16 µm broad (mean = 15.0 µm) including the ornamentation of rods and spines 1–1.5 µm tall, in clumps or bundles, giving the spore a somewhat coarse appearance under light microscopy; SEM reveals that single rods or spines often anastomose at their tips to form clumps; spore walls ±1 µm thick, in KOH hyaline singly and in mass in youth, at maturity greenish-black to dark reddish-brown both singly and in mass.

Etymology

Latin, *aurantius* (orange), in reference to the colour of the ascoma-enclosing mycelium.

Distribution, habitat and season

Queensland, south through New South Wales to Victoria and Tasmania; sandy, coastal lowlands to tablelands and mountains, hypogeous under various combinations of *Acacia longifolia*, *A. terminalis*, *A. verticillata*, *Allocasuarina littoralis*, *A. torulosa*, *Corymbia intermedia*, *C. maculata*, *Eucalyptus baxteri*, *E. botryoides*, *E. muelleriana*, *E. paniculata*, *E. pilularis*, *E. resinifera*, *E. sieberi*, *E. tenuiramis*, *E. umbra*, *Leptospermum* sp. and *Melaleuca linariifolia*; March through June.

Material examined

NEW SOUTH WALES: Mimosa Rocks NP, track leading to Gillards, 1.3 km E of junction with Tanja–Tathra road, 4.vi.1999, *G. Mires AWC3134* (DAR, OSC). QUEENSLAND: Atherton Tablelands, Mothar Mountain, 9.v.1988, *N. Malajczuk, M. Amaranthus & M. Castellano H4091* (PERTH, OSC, PDD); 12 km W of Mt Glorius, 4.v.1992, *J. Trappe H5971* (PERTH, OSC); Cooloola, 10.v.1988, *P. Reddell H4142* (PERTH, OSC); 10.v.1988, *M. Amaranthus, N. Malajczuk & M. Castellano H4147* (PERTH, OSC); 10.v.1988, *N. Malajczuk, M. Amaranthus & M. Castellano H4148* (PERTH, OSC, PDD); and 10.v.1988, *R. Young H4135* (PERTH, OSC). TASMANIA: Cradle Mountain NP, along creek, 13.v.1991, *N. Bougher H5030* (HO, PERTH, OSC); Waldheim, 13.v.1991, N. *Malajczuk H4884* (HO, PERTH, OSC) and 13.v.1991, *N. Malajczuk H4885* (HO, PERTH, OSC); Tasman Peninsula, vi.1916, *L. Rodway* (HO, OSC). Tasman Peninsula, Wedge Bay, vi.1916, *L. Rodway* (HO, OSC); near Colebrook, 30.ix.1991, *C. Johnson T31759* (HO, OSC, PERTH 07508042); VICTORIA: Cape Conran–Sydenham Inlet Coastal Park (all following collections): car park at ocean beach along Pearl Point Rd, 25.v.2001, *J. Trappe, A. Giachini & A. Jumpponen AWC4136* (MEL, OSC) and 1.vi.2003, *W. Colgan III & A. Claridge AWC5238* (MEL, OSC). Fletch's Stretch, 0.2 km N of Pearl Point Rd, 27.v.2001, *A. Jumpponen AWC4191* (MEL, OSC). Fletch's Stretch, 0.6 km N of Pearl Point Rd, 28.v.1999, *J. Trappe AWC2719* (MEL, OSC) and 28.v.2001, *A. Giachini AWC4140* (MEL, OSC); Yeerung River crossing, 29.v.1999, *J. Trappe AWC2780* (MEL, OSC) and *A. Jumpponen AWC2781* (MEL, OSC) and 27.v.2001, *A. Giachini AWC4116* (MEL, OSC); 0.6 km E of Yeerung River crossing, 29.v.1996, *W. Colgan III T18498* (MEL, OSC) and 27.v.2001, *A. Jumpponen AWC4124 & AWC4119* (MEL, OSC); Alpine NP, Benambraorryong Rd, 2 km S of junction with Sipthorp Track, 10.xi.1996, *D. Mills T20127* (OSC).

Discussion

Elaphomyces aurantius resembles *E. rugosisporus* in the colour of the mycelium enclosing the ascoma and the black, carbonaceous, smooth or somewhat smooth outer peridial surface. The spores of *E. auranticus* are larger (14–16 µm, mean = 15.0 µm) and more coarsely ornamented than those of *E. rugosisporus* ((10–)11–12 µm, mean = 11.1 µm). The spores of *E. aurantius* have spines and rods that are clumped to give a coarse appearance, whereas *E. rugosisporus* has a fine, low, complete reticulum that appears similar to the dimpling of a golf ball when observed under light microscopy. Both species occur in similar habit and have overlapping distributions from Queensland south to Tasmania. *E. aurantius* is also similar to *E. cooloolanus* in the appearance and size of their spores under light microscopy. The spores of *E. aurantius* are larger (14–16 µm, mean = 15.0 µm) and have a more clumped ornamentation than those of *E. cooloolanus* (11–13 µm, mean = 12.0 µm). *E. aurantius* is one of the more commonly encountered *Elaphomyces* species of eastern Australia.

Rodway (1918) erroneously cited his collections as *E. citrinus* Vittad.

Elaphomyces austrogranulatus Castellano, Trappe & Vernes, sp. nov. (Figs 2, 14*b*)

Ascomata in mycelio luteobrunneo vel aurantiobrunneo omnino inclusa. Peridium strati trium compositum: stratum externum verrucis pyramidalibus congestis usque ad 0.5 mm crassum,,; stratum medium angustum, obscurum; stratum intimum 1–3 mm crassum, griseum, pallide violaceobrunneum, rhodobrunneum vel fuscobrunneum. Gleba maturitate pulvereis nigris sporis repleta. Asci globosi, 20–25 µm lati, parietibus maturitate 1–2 µm crassis, 8-spori. Sporae globosae, (22–)24–28 (–32) µm latae verrucas applanatas 4–5 µm longas ornamentum inclusae, in maturitate in KOH fuscorufae.

Holotypus: Australia: Queensland, Atherton Tablelands, Davies Creek National Park, Davies Creek Road, 1.7 km from end of road, 6.iii.1994, *D. Arora, S. Joyce, & M. Castellano; T13487* (CANB, isotype OSC).

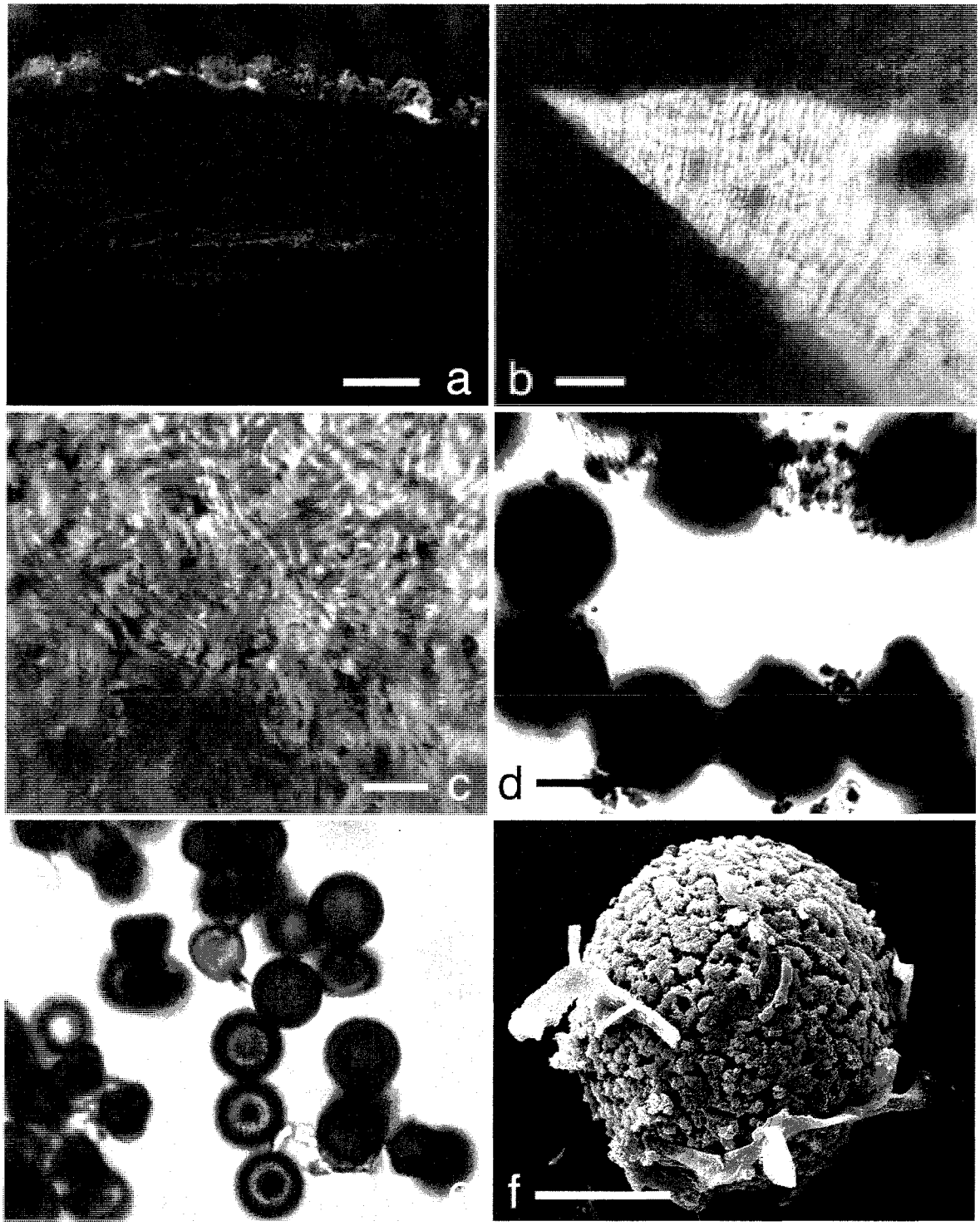

Fig. 2. *Elaphomyces austrogranulatus*. (*a*) Ascoma in cross-section. (*b*) Stacked hyphae found between peridial warts. (*c*) Thick-walled hyphae, with scattered crystals found in the middle peridial layer. (*d*) Opaque mature spores. (*e*) Maturing spores, showing surface ornamentation. (*f*) Scanning electron micrograph of a spore. Scale bars = 1 mm (*a*), 25 μm (*b*), 10 μm (*c*), 25 μm (*d*, *e*) and 10 μm (*f*).

Ascomata 8–25 mm in diameter, subglobose, slightly flattened to irregular, completely enclosed in golden brown, yellowish-brown to orangy-brown mycelium with much intermixed soil and debris, peridial surface yellowish-brown to brown, of crowded, pyramidal warts, 0.5 mm tall. *Peridium* 3-layered; warts of outer layer with a golden brown interior in cross-section and a thin brown outer surface; middle layer a more or less uniform dark-coloured line directly beneath the outer layer; innermost layer

grey to pale violet brown or rosy-brown to dark brown. *Gleba* initially hollow, filling with hyphae then spores at maturity, spore mass powdery, black, combination of hyphae and spores. *Odour* mildly pleasant or indistinct. *Taste* not recorded.

Outer layer of the *peridium* ±0.5 mm thick, warts composed of yellowish–reddish-brown, irregularly shaped cells, 3–4 µm thick, with walls 1–2 µm thick, and the hyphae between warts hyaline, periclinal, septate and compact, with walls ±2 µm thick; middle layer ±100 µm thick, of interwoven hyphal bundles composed of parallel, hyaline hyphae ±5 µm across, with walls ±1 µm thick; the layer has a high concentration of dark reddish-brown pigment dispersed across some hyphae, appearing at first as pigment particles but when closely examined, is shown to be coloration of parts of hyphal walls; inner layer up to 3 mm thick, of similar structure as middle layer but with a significantly lower concentration of the pigment across the hyphae. *Gleba* of spores and thin-walled, hyaline to reddish-brown, highly branched (90-degree angle), interwoven hyphae with cells ±35 µm long and 1.5–2.5 µm broad, the hyphae becoming dark reddish-brown and ornamented with knobby, coarse crystals in age. *Asci* globose 20–25 µm in diameter, pedicellate, hyaline, with walls 3–6 µm thick when spores start to develop, then thinner (1–2 µm) when spores mature, 8-spored; pedicel hyaline, 10 × 2–3 µm; asci enlarging as spores develop when mature; ascogenous hyphae not seen. *Spores* globose, (22–)24–28(–32) µm broad (mean = 25.8 µm) including the ornamentation of coarse, flattened, irregularly shaped warts, 4–5 µm tall under light microscopy; SEM reveals an absence of rods or spines; as spores mature, they become very dark and large and the ornamentation is difficult to distinguish because it becomes more dense with amorphous granules and hyphae adhering to the spore surface, making the spore outline subglobose to irregular in optical section; spore walls 1–2 µm thick, in KOH hyaline singly and in mass and unornamented or slightly ornamented when immature, soon darkening to finally dark reddish-brown to opaque when mature.

Etymology

Latin, *austro-* (southern) + *-granulatus* (granulate); hence, 'southern granulate' in reference to its similarity to the northern hemisphere *E. granulatus* complex.

Distribution, habitat and season

Northern Queensland, Victoria and Tasmania; tropical tablelands to mountains, hypogeous under various combinations of *Acacia flavescens*, *A. melanoxylon*, *Allocasuarina littoralis*, *Corymbia citriodora*, *C. clarksoniana*, *Eucalyptus dalrympleana*, *E. fastigata*, *E. phaeotricha*, and *E. radiata*; December through May.

Material examined

QUEENSLAND: Atherton Tablelands, Davies Ck NP, Davies Ck Rd, 3.v.1988, *C. Theodorou, J. Trappe & M. Castellano H4029* (CANB, PERTH, OSC); 3.ii.1992, *M. Castellano H5473* (OSC) and *H5471* (CANB, PERTH, OSC); 19.iv.1996, *K. Vernes T22544* (CANB, OSC); 10.xii.1996, *K. Vernes T22533* (CANB, OSC); Kennedy Rd, 5.v.1988, *C. Theodorou, J. Trappe & M. Castellano H4059* (CANB, PERTH, OSC); Mt Windsor Tablelands, 2.ii.1992, *M. Castellano & P. Reddell H5458* (CANB, PERTH, OSC); TASMANIA; Cascades, Old Fern Rd, 2.v.1990, *N. Malajczuk H1294* (HO, PERTH, OSC); VICTORIA, Errinundra NP, Gunmark Rd, 1.6 km SE of Survey Rd, 26.v.2001, *A. Jumpponen AWC4100* (MEL, OSC); 27.v.1999, *A. Jumpponen AWC2695* (MEL, OSC).

Discussion

Elaphomyces austrogranulatus resembles *E. granulatus* Fries from the northern hemisphere, particularly in macroscopic peridial characters. They both have a distinctly warty, brown, leathery outer peridium, with a non-marbled inner peridium. The mature spores of *E. granulatus* are usually 39–40 µm in diameter and coarsely ornamented with irregularly clumped rods as opposed to the much smaller (24–28 µm in diameter) spores of *E. austrogranulatus* that have coarse, flattened, irregularly shaped warts. Some collections are packed with dark tissue that becomes hard when dried and lacks spores. Whether this is a parasite or aberrant ascomatal development is unknown.

Elaphomyces austrogranulatus is widely distributed, although apparently uncommon. It is the only known *Elaphomyces* from the southern hemisphere with a brown, leathery peridium.

Elaphomyces chlorocarpus Castellano, Trappe & Lebel, sp. nov. (Figs 3, 14*c*)

Ascomata in mycelio laete luteo, luteo vel chlorino omnino inclusa. Peridium strati trium compositum: stratum externum tenue, anthracinum, carbonaceum, pagina verruculosa vel rugulosa; stratum medium griseum; stratum intimum album. Gleba maturitate pulvereis obscuris griseo-caeruleis sporis repleta. Sporae globosae, 10–11(–12) µm latae ornamentum clathratum punctatuminclusae, in maturitate in KOH viridinigrae vel obscurae porphyreae.

Holotypus: Australia, Western Australia, 10 km west of Albany, Howell Road, just off South Coast Highway, 25.vii.2001, *K. Syme, M. Hart & R. van der Waag KS1157/01* (MEL 2233805; isotypes OSC, PERTH).

Ascomata 8–30 mm in diameter, globose to subglobose, slightly flattened to irregularly lobed, completely enclosed in bright yellow, yellowish-green to green mycelium with soil and ectomycorrhizal roots that form a crust up to 5(–8) mm thick. *Peridium* 3-layered; surface black, carbonaceous, smooth and not wrinkled but with small, irregular bumps and folds, brittle and easily cracked and chipped, roots adhering to peridial surface forming a cross-hatched husk; interior 2–5 mm thick, 2-layered, with an outer pale grey layer and an inner white layer. *Gleba* initially hollow, then with white, cottony mycelium, at maturity filled with dark greyish-blue spore powder and scattered arachnoid hyphae. *Odour* indistinct to mild. *Taste* not recorded.

Outer layer of the *peridium* 50–75 µm thick at maturity, of compact, short, hyphal bundles 3–4 µm in diameter, with walls ±1 µm thick, somewhat branched, abruptly transitioning into the layer beneath; middle layer of irregularly interwoven hyphal bundles, sometimes these bundles are perpendicular to each other, composed of pale grey, slightly wavy, compact hyphae 5–7 µm across, with walls ±2 µm thick; innermost layer of similar structure as middle layer but hyphaè hyaline. *Gleba* of spores and intermingled, hyaline, somewhat twisted or curled, septate, elongate, interwoven hyphae ±2 µm in diameter, with walls <0.5 µm thick. *Asci* hyaline, globose with a tapered base,

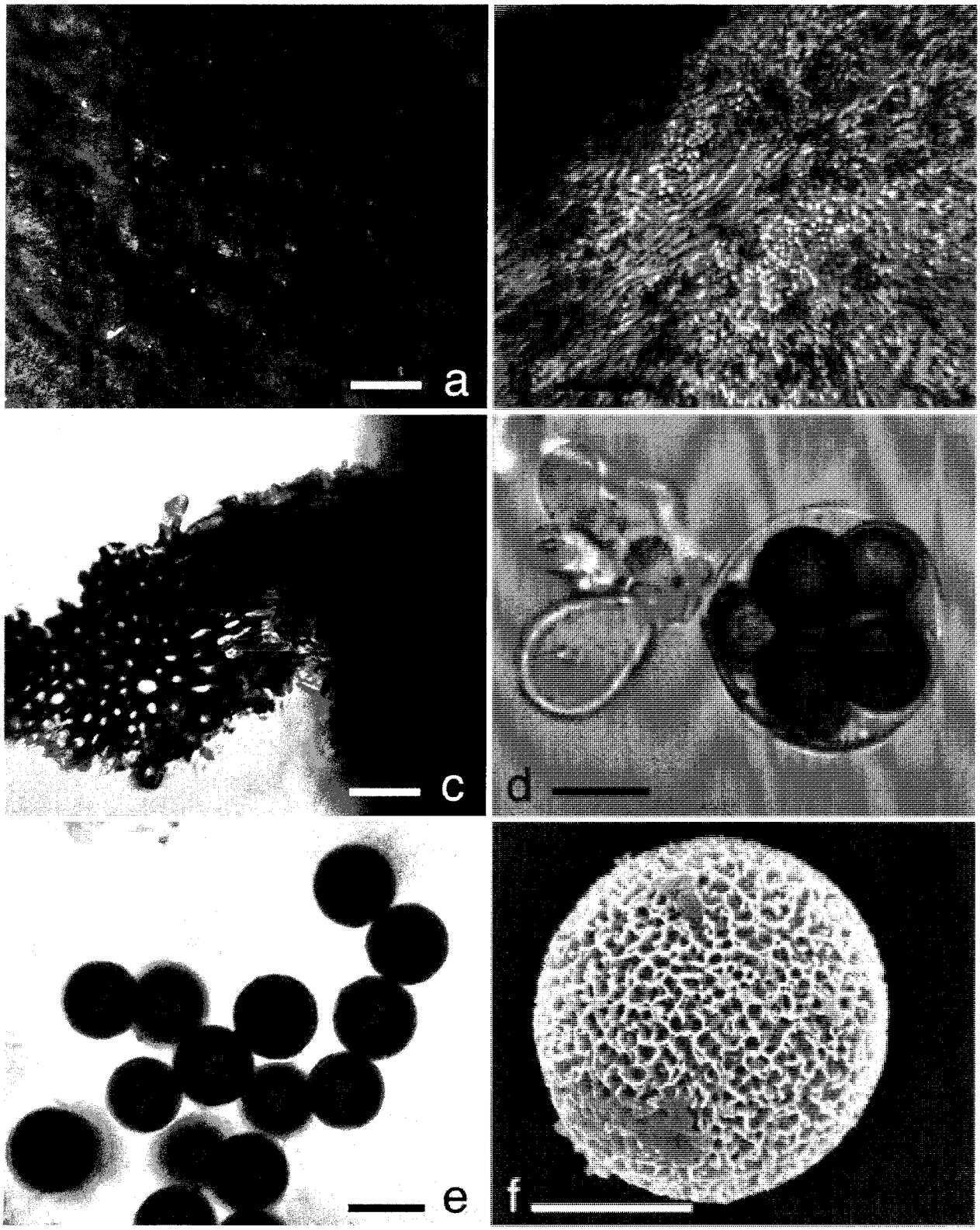

Fig. 3. *Elaphomyces chlorocarpus*. (*a*) Surface of ascoma, without adherent crust. (*b*) Inner peridium. (*c*) Short, dark, thick-walled hyphae of the outer peridial layer. (*d*) Asci arising from hyphal knot. (*e*) Maturing spores, showing surface ornamentation. (*f*) Scanning electron micrograph of a spore. Scale bars = 0.5 mm (*a*), 75 µm (*b*), 25 µm (*c*), 10 µm (*d*, *e*) and 5 µm (*f*).

25–26 µm in diameter, with walls ±1 µm thick, 8-spored; arising from hyphal knots composed of distorted, hyaline, short in length ascogenous hyphae ±7 µm in diameter, with walls up to 2 µm thick. *Spores* globose, 10–11(–12) µm broad (mean = 10.9 µm) including the ornamentation of an irregularly multidimensional lattice that appears punctate under light microscopy; SEM reveals an irregular reticulum-like structure that is several layers deep, with fine holes in the lattice; spore walls ±1 µm thick, in KOH yellowish-brown singly and dark yellowish-brown in mass when mature, with spores appearing nearly uniform in size and ornamentation.

Etymology

Latin, *chloro-* (yellowish-green) + *-carpus* (sporocarp), hence 'yellowish-green sporocarp', in reference to the colour of the enclosing mycelium completely encasing the ascoma.

Distribution, habitat and season

Western Australia; hypogeous, gregarious, usually in deep litter under various combinations of *Allocasuarina fraseriana*, *Corymbia ficifolia* or *Eucalyptus diversicolor*; July, October through December.

Material examined

WESTERN AUSTRALIA: E of Albany, Two Peoples Bay Nature Reserve, 12.xii.1998, *K. Syme, G. Evans, & M. Hart KS1040/98* (MEL 2105018, OSC); 15.xi.1998, *G. Evans & M. Barrett KS1038/98* (MEL 2105014); 22.x.1998, *K. Syme & G. Evans KS1030/98* (MEL 2105009); Manjimup, Scatter Rd, 1.xii.1981, *N. Malajczuk* (PERTH 07508093); Walpole–Nornalup NP, junction of Ficifolia Rd and Nut Rd, 22.vii.1993, *M. Castellano & J. Trappe T14919* (PERTH 07508123, OSC).

Discussion

Elaphomyces chlorocarpus has small spores similar to those of *E. cooloolanus*, *E. pedicellaris*, *E. rugosisporus* and *E. symeae*. *E. chlorocarpus* has the smallest spores of all Australian *Elaphomyces* species and the yellowish-green mycelium enclosing the ascoma easily distinguishes it from all other small-spored species except *E. pedicellaris*. *E. chlorocarpus* is restricted to Western Australia and possesses a fine, punctate spore ornamentation, whereas *E. pedicellaris* occurs in Victoria and has coarse spore ornamentation. The appearance of the spore ornamentation under light microscopy is closest to that of *E. rugosisporus*. The multi-dimensional lattice structure of the ornamentation of *E. chlorocarpus* is more complex than the fine reticulate ornamentation of *E. rugosisporus* spores. The spore structure is unusual in *Elaphomyces*, although it is somewhat similar to that found in *E. anthracinus* from Europe, except in *E. anthracinus* the fine reticulate spore ornamentation is overlain with irregularly shaped plates to form a widely spaced patchwork. This is one of three known *Elaphomyces* species from Western Australia. These species can be distinguished from each other in the field by the colour of the ascoma-enclosing mycelium, which is black for *E. timgroveii* and red for *E. symeae*.

Elaphomyces cooloolanus Castellano, Trappe & Vernes, sp. nov. (Fig. 4)

Ascomata in mycelio pallide albo vel brunneolo inclusa. Peridium strati duorum compositum: stratum externum tenue, nigrum, laeve; stratum intimum 1–1.2 mm crassum, in juventute lavandulum, in maturitate brunneolum. Gleba in maturitate pulvereis nigris sporis repleta. Sporae globosae, 11–13 µm latae ornamentum spinisque, virgisque cristiscongestis 1.0 µm altum labyrinthum irregularis facientibus inclusae, in maturitate in KOH fuscorufae.

Holotypus: Australia, Queensland, Cooloola, Rainbow Road, 10.v.1988, *M. Castellano H4139* (CANB, isotypes PERTH & OSC).

Ascomata 7–20 mm in diameter, globose to subglobose, completely enclosed in white to pale tan mycelium, ectomycorrhizal roots and sand that form a crust up to 7 mm thick. *Peridium* 2-layered; surface black, smooth, rubbery; inner layer rubbery, lavender when young, then pale brown at maturity. *Gleba* initially hollow, becoming filled with black spore powder at maturity. *Odour* not determined. *Taste* not determined.

Outer layer of the *peridium* 50–80 µm thick, of interwoven bundles of hyphae 20–30 µm in diameter, composed of dark brown to reddish-brown or nearly black, parallel at times, agglutinated, interwoven hyphae 2–3 µm in diameter with walls ±1 µm thick; subcutis 1–1.2 mm thick, of interwoven bundles of hyphae 12–15 µm in diameter, composed of pale brown, interwoven hyphae 4–5 µm in diameter with walls ±1 µm thick; peridial tissues much more disorganised than in other species. *Gleba* composed of spores and thin-walled, septate, hyaline, loosely interwoven hyphae 2–3 µm in diameter, some hyphae withered, some robust, some curly. *Asci* hyaline, globose with a tapered base, 28–30 µm in diameter, collapsing around the spores when mature to become irregular in outline, the walls 1.0–1.5 µm thick, 8-spored; tapered base hyaline, 4 µm wide by 4 µm long, somewhat tapered to 3 µm wide at base, arising from knots or clusters of hyaline, contorted ascogenous hyphae ±5 µm in diameter, scattered throughout the gleba. *Spores* globose, 11–13 µm (mean = 12.0 µm) including ornamentation that appears as coarse, crowded spines, rods and short ridges, ±1 µm tall, forming an irregular-looking labyrinth under light microscopy; SEM reveals the ornamentation as individual rods or spines that anastomose at their tips in irregular clumps, these clumps are crowded to form almost a complete covering at times; spore walls ±0.5 µm thick, in KOH initially hyaline soon dark green at maturity then reddish-brown singly and in mass.

Etymology

The place name, *cooloola* + *-anus* (relating to), hence relating to Cooloola, a sand dune area along the southern Queensland coast.

Distribution, habitat and season

Queensland, known only from the Cooloola coastal dune area in southern Queensland; hypogeous under various combinations of *Allocasuarina littoralis*, *Corymbia intermedia*, *Eucalyptus pilularis*, *E. resinifera*, *E. umbra*, *Leptospermum* spp. and *Melaleuca linariifolia*; May.

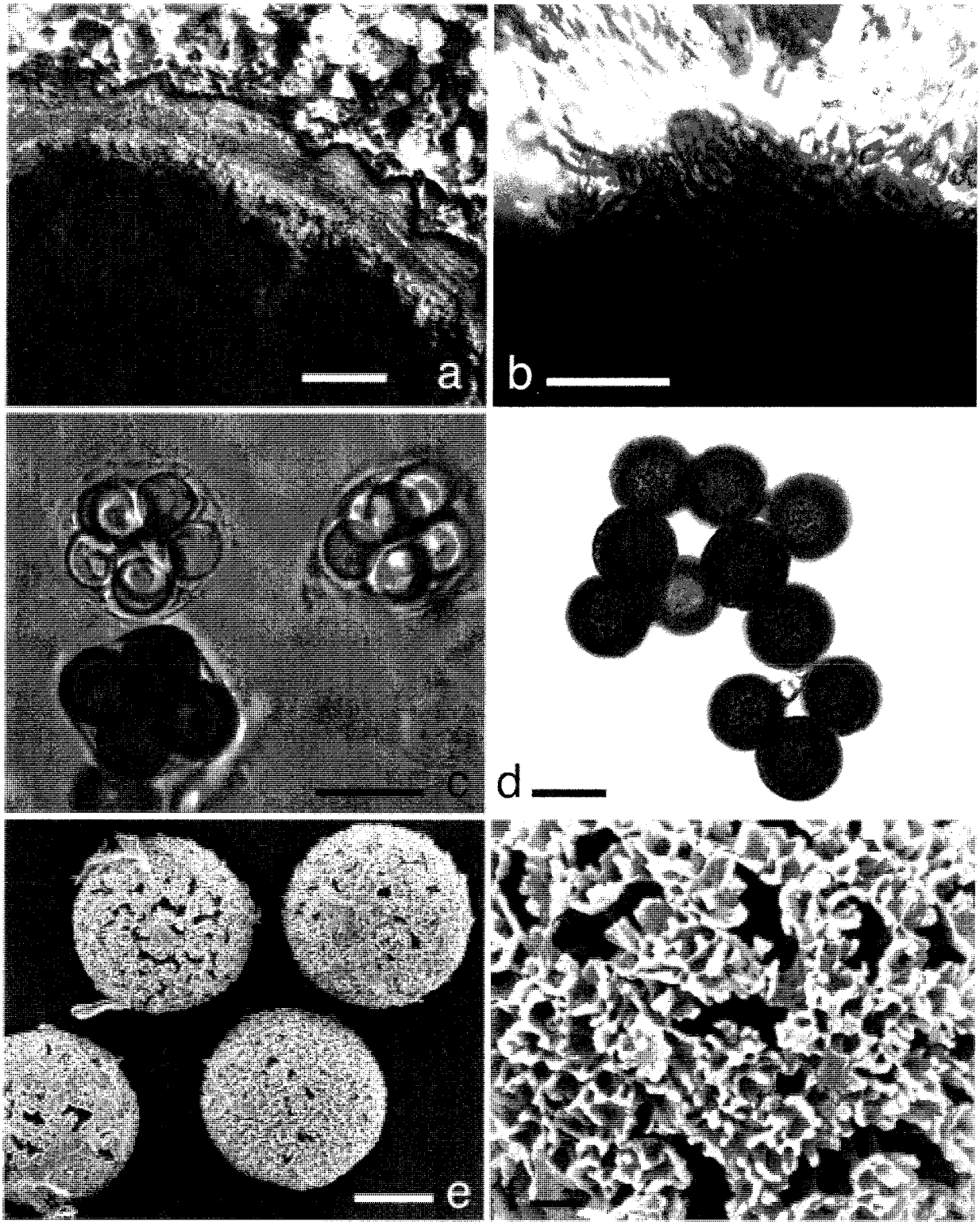

Fig. 4. *Elaphomyces cooloolanus*. (*a*) Ascoma in cross-section, with adherent crust. (*b*) Hyphal bundle of the outer peridial layer. (*c*) Asci with developing spores. (*d*) Spores viewed under light microscopy. (*e*) Scanning electron micrograph (SEM) of spores. (*f*) SEM of a spore, showing the spines and rods that anastomose at their tips. Scale bars = 1 mm (*a*), 20 µm (*b*, *c*), 10 µm (*d*), 5 µm (*e*) and 1 µm (*f*).

Material examined

Known only from the type collections.

Discussion

Elaphomyces cooloolanus has small spores, similar in size to those of *E. chlorocarpus*, *E. rugosisporus* and *E. timgroveii*. The deep orange to reddish-orange mycelium enclosing the ascoma of *E. rugosisporus* easily distinguishes it from *E. cooloolanus* which has white to pale tan mycelium on the ascoma surface and from *E. chlorocarpus* which has yellowish-green mycelium enclosing the ascoma. *E. timgroveii* has smaller and more finely ornamented spores (8–9 µm, mean = 8.7 µm) than those of *E. cooloolanus* (11–13 µm, mean = 12.0 µm).

The spore ornamentation appears to be ±1 µm tall when observed in cross-section under a light microscope and much lower than that observed at the surface view or by SEM. This is because the ornamentation of rods or spines anastomose at their tips to form a mostly intact outer shell. This also occurs in *E. pedicellaris*, *E. queenslandicus*, *E. symeae* and *E. timgroveii*.

Elaphomyces coralloideus Castellano, Trappe & Vernes, sp. nov. (Fig. 5)

Ascomata in mycelio fusco omnino inclusa. Peridium strati duorum compositum: stratum externum usque ad 0.5 mm crassum, anthracinum, carbonaceum, verruculosum; stratum intimum usque ad 1 mm crassum, albidum. Gleba in maturitate sporis pulvereis fuscis vel nigris repleta. Sporae globosae, 18–20(–23) µm latae ornamentum ± 2 µm altum cristis angustis, labyrinthum, coralloides facientibus inclusae, in maturitate in KOH atrocastaneae.

Holotypus: Australia, Queensland, Atherton Tablelands, Davies Creek National Park, Davies Creek Rd, 19.iv.1996, *K. Vernes T22547* (CANB, isotype OSC).

Ascomata up to 1.8 × 2.5 cm in diameter, subglobose, completely enclosed in dark brown mycelium with much soil, ectomycorrhizal roots and debris, when dried the ascoma collapses and forms a large reticulate pattern to the surface. *Peridium* 2-layered; surface black, carbonaceous, with low, rounded, circular warts ±0.4 mm in diam.; inner layer up off-white, more or less uniform. *Gleba* powdery, dark brown to black when mature. *Odour* not determined. *Taste* not determined.

Outer layer of the *peridium* up to 0.5 mm thick, of dark reddish-brown to black near the surface to dark reddish-brown to reddish-brown as it nears the inner layer, thick-walled, short segmented or bead-like, parallel hyphae ±3 µm in diameter; a distinct demarcation between layers in colour but not in structure; inner layer up to 1 mm thick, of hyaline to pale reddish-brown, thick-walled (±3 µm thick), interwoven hyphae with enlarged ends, hyphae 8–11 µm in diameter, ends enlarged up to 10–20 µm in diameter. *Gleba* composed of spores and thin-walled, hyaline, somewhat encrusted, sinuous, loosely interwoven hyphae, ±2 µm in diameter. *Asci* subglobose and shortly pedicellate, up to 37 × 42 µm, the walls ±2 µm thick, hyaline at first then pale greenish-black from maturing spores, 8-spored; ascogenous hyphae not seen. *Spores* globose, 18–20(–23) µm (mean = 19.1 µm) including ornamentation of anastomosed rods that form a fine, coral-like labyrinth of narrow ridges, ±2 µm tall; SEM reveals the ridges to be composed of anastomosed rods that form sinuous, undulating lines; spore walls 1–2 µm thick, in KOH initially hyaline singly and in mass, soon pale reddish-brown then finally dark reddish-brown when mature.

Etymology

Latin, *coralloideus* (coral-like), in reference to the coral-like spore ornamentation as observed by SEM.

Distribution, habitat and season

Known only from northern Queensland; hypogeous under various combinations of *Acacia flavescens*, *Allocasuarina littoralis*, *Corymbia citriodora*, *C. clarksoniana* or *Eucalyptus phaeotricha*; September and December.

Material examined

QUEENSLAND: Atherton Tablelands, Davies Creek NP, Davies Ck Rd, 10.xii.1995, *K. Vernes T22565* (CANB, OSC); 29.ix.1996, *K. Vernes T22567* (CANB, OSC).

Discussion

Elaphomyces coralloideus resembles *E. cooloolanus*, *E. queenslandicus* and *E. suejoyceae* in the black, carbonaceous outer peridium enclosed by tan to brown mycelium. The spores of *E. coralloideus* (18–20(–23) µm, mean = 19.1 µm) are much larger than those of *E. cooloolanus* (11–13 µm, mean = 12 µm) and have a distinctly different ornamentation. The spores of *E. suejoyceae* are larger ((24–)26–30(–31) µm, mean = 27.6 µm) than the spores of *E. coralloideus* and the labyrinthine ornamentation is much finer in appearance. The spores of *E. queenslandicus* and *E. coralloideus* nearly overlap in size; however, the ornamentation of *E. queenslandicus* is much coarser in appearance.

Elaphomyces coralloideus is restricted to northern Queensland and seems to fruit irregularly, but this may be an artefact of its being underrepresented in herbaria.

Elaphomyces laetiluteus Castellano, Trappe & Vernes, sp. nov. (Figs 6, 14*d*)

Ascomata in mycelio laete luteo omnino inclusa. Peridium strati duorum compositum: stratum externum 50–65 µm crassum, brunneonigrum vel anthracinum, carbonaceum, laeve; stratum intimum ± 1 mm crassum, in juventute laete flavovirens, in maturitate fumeum vel zonatum. Gleba in maturitate sporis pulvereis nigris repleta. Sporae subglobosae vel globosae, (22–)23–26(–28) µm latae ornamentum virgas dispersas vel congestas inclusae, in maturitate in KOH purpureonigrae.

Holotypus: Australia, Queensland, Atherton Tablelands, Davies Creek National Park, Davies Creek Road, 5.iii.1994, *D. Arora & M. Castellano T13452* (CANB, isotype OSC).

Ascomata up to 18 × 25 mm, subglobose to irregular, completely enclosed in bright yellow mycelium with much soil, ectomycorrhizal roots and debris forming a distinct

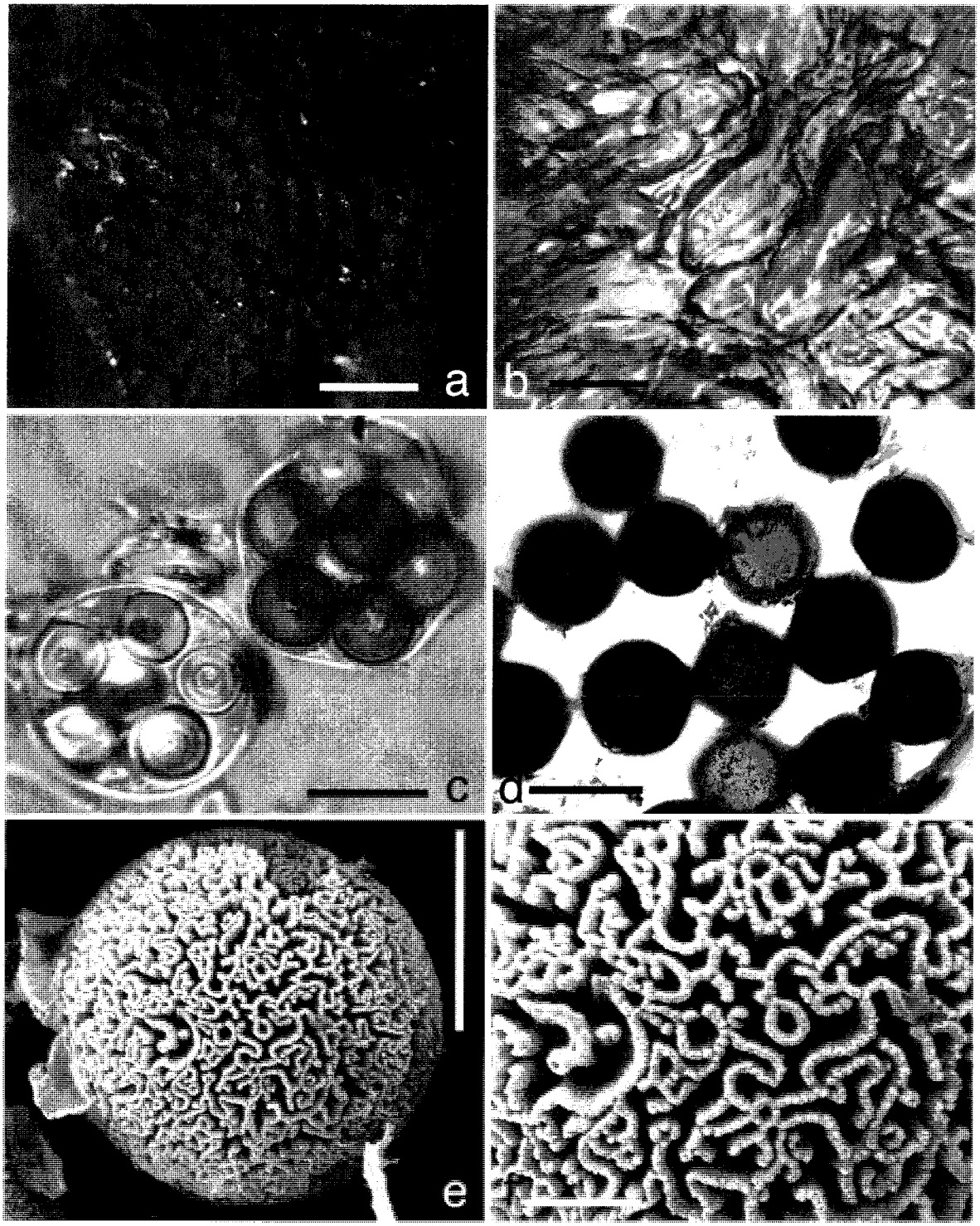

Fig. 5. *Elaphomyces coralloideus.* (*a*) Surface view of the ascoma, with crust removed. (*b*) Large ends cells within the inner peridial layer. (*c*) Asci with developing spores. (*d*) Spores viewed under light microscopy. (*e*) Scanning electron micrograph (SEM) of a spore. (*f*) SEM of a spore, showing the construction of the narrow ridges. Scale bars = 1 mm (*a*), 20 µm (*b–d*), 10 µm (*e*) and 2.5 µm (*f*).

crust. *Peridium* 2-layered; surface brownish-black to black, carbonaceous, smooth, somewhat wrinkled when dried; inner layer bright yellowish-green when young, then evenly smoky or zonate with a pale zone near the surface layer, very dark when dried. *Gleba* powdery, black when mature. *Odour* indistinct. *Taste* (of peridium) nutty.

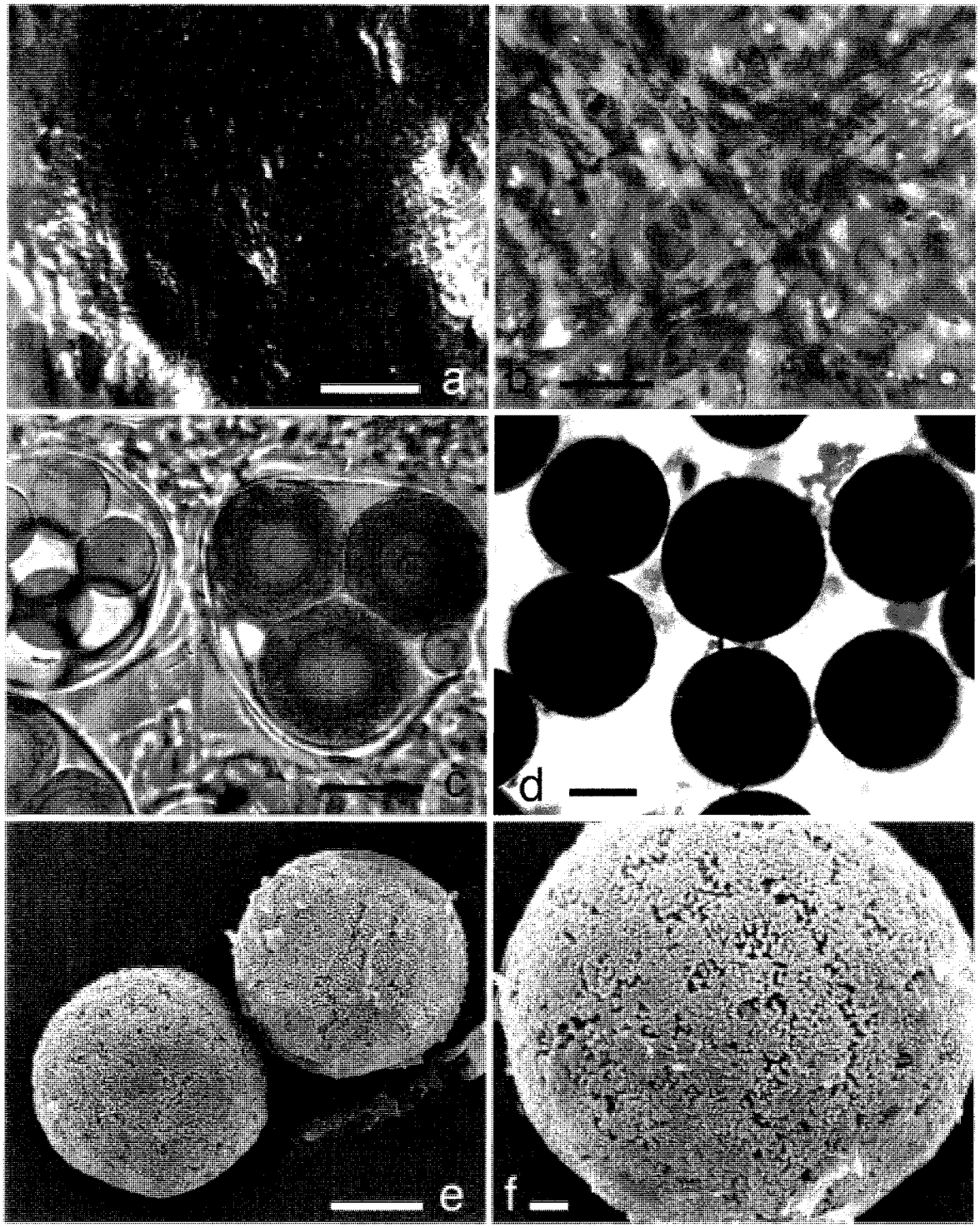

Fig. 6. *Elaphomyces laetiluteus.* (*a*) Surface view of the ascoma, with crust removed. (*b*) Capitate cells found with the inner peridial layer. (*c*) Asci with developing spores. (*d*) Spores viewed under light microscopy. (*e*) Scanning electron micrograph (SEM) of spores. (*f*) SEM of a spore, showing individual rods and clumps of rods. Scale bars = 3 mm (*a*), = 20 μm (*b*, *c*), = 10 μm (*d*, *e*) and 2 μm (*f*).

Peridial tissues leaching a dark greenish-black pigment when mounted in 5% KOH, outer layer of the *peridium* 50–65 μm thick, of subhyaline to pale green, thick-walled (1–2 μm thick) and thin-walled hyphal elements 4–6 μm in diameter; inner layer ±1 mm thick, of hyaline, thick-walled, septate, capitate, interwoven hyphae, up to 10 μm in diameter, with the hyphae spotted with

numerous tiny to medium-sized occlusions. *Gleba* composed of spores and thick-walled (0.5–1.0 µm diameter), hyaline, loosely interwoven, septate, thread-like hyphae, ±3µm in diameter. *Asci* globose with a tapered base, 50–52 µm in diameter, the walls ±2 µm thick, hyaline at first, then smoky grey from maturing spores, 8-spored arising from knots or clusters of pale green, ascogenous hyphae ±5 µm broad, scattered throughout the gleba. *Spores* subglobose to appearing globose, (22–)23–26(–28) µm (mean = 24.6 µm) including ornamentation of scattered and irregularly clustered spines or rods, ±2 µm tall, that give a punctate appearance under light microscopy; SEM reveals the clustered spines anastomose to form a mosaic pattern of clumps and individual spines; spore walls ±5 µm thick when young, thinning at maturity, in KOH initially hyaline singly and in mass then dark greenish-black to pale violet to finally dark purplish-black when mature.

Etymology

Latin, *laeti-* (bright) + *-luteus* (yellow), in reference to the bright yellow enclosing mycelium.

Distribution, habitat and season

Northern Queensland, New South Wales and Victoria; hypogeous under various combinations of *Allocasuarina littoralis*, *Eucalyptus cypellocarpa*, *E. dalrympleana*, *E. fastigata*, *E. pauciflora*, *E. stellulata* or *E. tereticornis*; March, May, June and September.

Material examined

NEW SOUTH WALES, Coolangubra State Forest, Coolangubra Forest Way, 1 km N of the junction with Wog Way, vi.1992, *A. Claridge T17601* (DAR, OSC); QUEENSLAND, Davies Ck NP, Davies Ck Rd, 28.ix.1996, *K. Vernes T22562* (CANB, OSC); VICTORIA, Alpine NP, Native Cat Track, 0.3 km S of the junction with Black Mountain Rd, 16.v.2001, *A. Claridge AWC3476* (MEL, OSC).

Discussion

Elaphomyces laetiluteus can resemble *E. aurantius* in the colour of the mycelium enclosing the ascoma. Usually, the enclosing mycelium on *E. aurantius* ascomata is bright orange but sometimes it is bright yellow when fresh and turns orange over time after collection. The spores of *E. aurantius* are distinctly smaller (14–16 µm, mean = 15.0 µm) and differ in colour (dark reddish-brown) from the dark purplish-black spores of *E. laetiluteus* ((22–)23–26(–28) µm, mean = 24.6 µm).

Elaphomyces laetiluteus is widely distributed in eastern Australia, although rather infrequently encountered.

Elaphomyces nothofagi Castellano, Trappe & Vernes, sp. nov. (Figs 7, 14*e*)

Ascomata in mycelio cremeo omnino inclusa. Peridium strati duorum compositum: stratum externum 70–80 µm crassum, nigrum, carbonaceum, laeve; stratum intimum 1–2 mm crassum, in juventute viridoluteum, in maturitate olivaceum vel prasinum. Gleba in maturitate sporis pulvereis nigris repleta. Sporae globosae, 43–55 µm latae ornamentum cristis implicatis, labyrinthinis inclusae, in maturitate in KOH atroporphyreae.

Holotypus: Australia, Victoria, Tarra-Bulga National Park, Tarra Valley picnic area, 17.vi.1994, *J. Trappe H6811* (MEL, isotypes PERTH, OSC).

Ascomata up to 12 × 18 mm, irregularly flattened, completely enclosed in cream-coloured mycelium, ectomycorrhizal roots and soil that form a crust. *Peridium* 2-layered; surface black, carbonaceous, smooth; inner layer olive green near outer layer and pale to bright green underneath when mature, greenish-yellow when young. *Gleba* initially hollow, lined with brown, wet hyphae, at maturity with a wet, black spore mass. *Odour* not recorded. *Taste* not recorded.

Outer layer of the *peridium* 70–80 µm thick, of green to olive, compact, interwoven hyphae up to 10 µm in diameter, with walls 0.5–1.0 µm thick, encrusted with debris and fine crystals, particularly the outer hyphae; inner layer 1–2 mm thick, rehydrated, of hyaline, compact, interwoven to parallel hyphae 4–5 µm in diameter; the demarcation between layers distinct. *Gleba* composed of spores and septate, thread-like, curly, hyaline, loosely interwoven hyphae ±3 µm in diameter, with walls ±0.5 µm thick. *Asci* not seen but knots or clusters of pale green, contorted, ascogenous hyphae 5–6 µm in diameter scattered throughout the gleba. *Spores* globose, 43–55 µm (mean = 47.9 µm) including ornamentation of infolded labyrinthine ridges 5–7 µm tall under light microscopy; SEM reveals the folds to be entangled hyphae emanating from the spore surface and these hyphae are sometimes flask-shaped and appear yarn-like; walls 5–6 µm thick, in KOH dark reddish-brown singly and in mass.

Etymology

Latin, *nothofagi*, in reference to the association of this species with the tree genus *Nothofagus* (Nothofagaceae).

Distribution, habitat and season

Victoria; hypogeous under *Nothofagus cunninghamii*; June.

Material examined

Known only from the type collections.

Discussion

Elaphomyces nothofagi is the only Australian *Elaphomyces* species discovered to be associated with *Nothofagus*. It is also unique amongst Australian *Elaphomyces* species in that it has very large spores (43–55 µm, mean = 47.9 µm) and is covered by entangled hyphae, similar to nurse hyphae of some *Scleroderma* spp. It is known only from the holotype collection.

Elaphomyces pedicellaris Castellano, Trappe & Vernes, sp. nov. (Fig. 8)

Ascomata in mycelio luteolo omnino inclusa. Peridium strati trium compositum: stratum externum 100–125 µm crassum, nigrum, carbonaceum, laeve vel prope laeve; stratum medium ± 2 mm crassum, album, succulentum; stratum intimum 0.7–1 mm crassum, albidum, cavitatibus irregularibus. Gleba in maturitate sporis pulvereis nigris repleta. Sporae globosae, 11–13(–14) µm latae ornamentum catillis irregularibus, pedicellatis inclusae, in maturitate in KOH luteobrunneae.

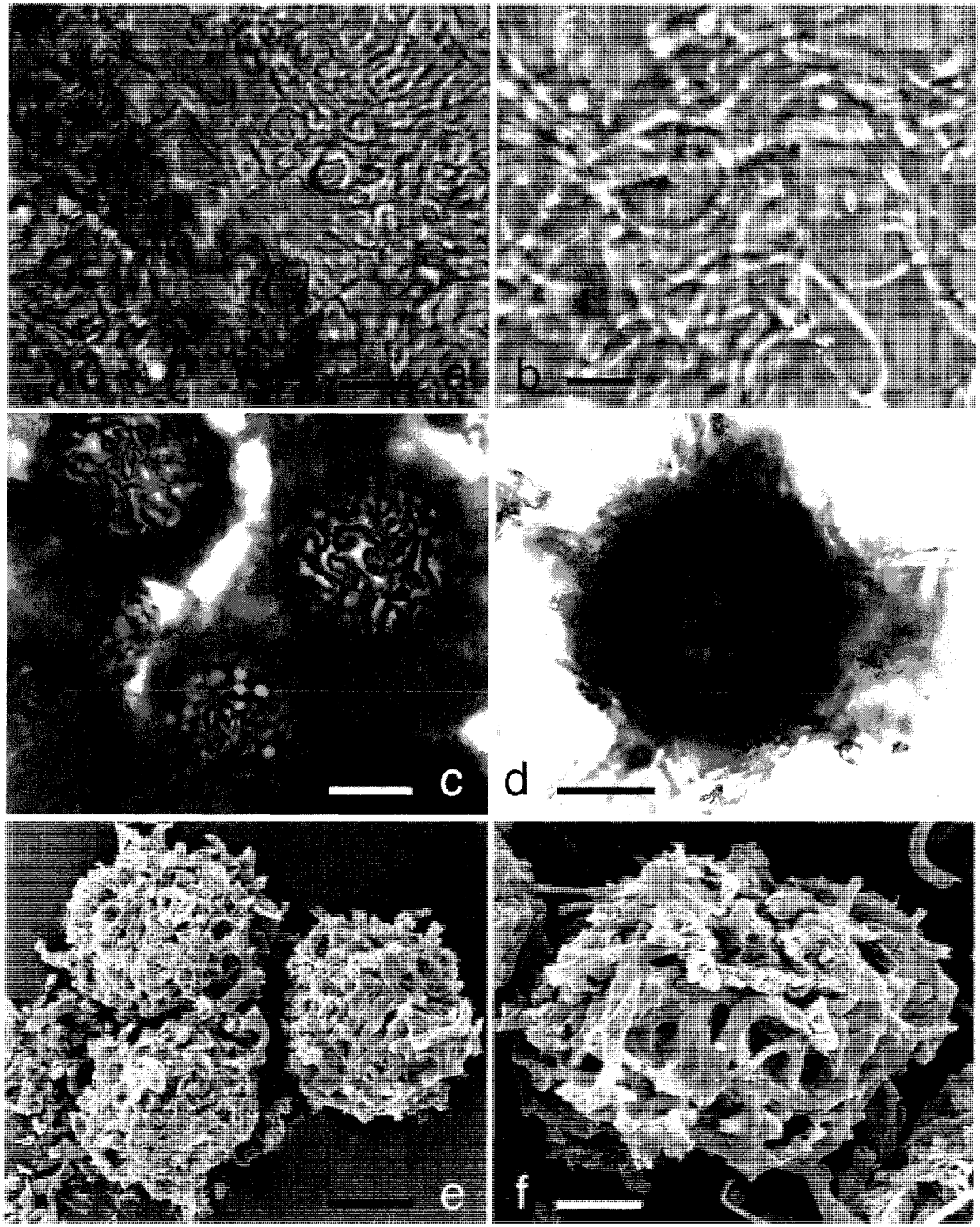

Fig. 7. *Elaphomyces nothofagi*. (*a*) Interface between the outer and inner peridial layers. (*b*) Sinuous hyphae within the gleba. (*c*) Surface view of spores under light microscopy. (*d*) Cross-sectional view of spores under light microscopy, showing enclosing hyphae. (*e*) Scanning electron micrograph (SEM) of spores. (*f*) SEM of a spore, showing the entangled hyphal cells. Scale bars = 10 μm (*a*, *b*), 20 μm (*c*–*e*) and 10 μm (*f*).

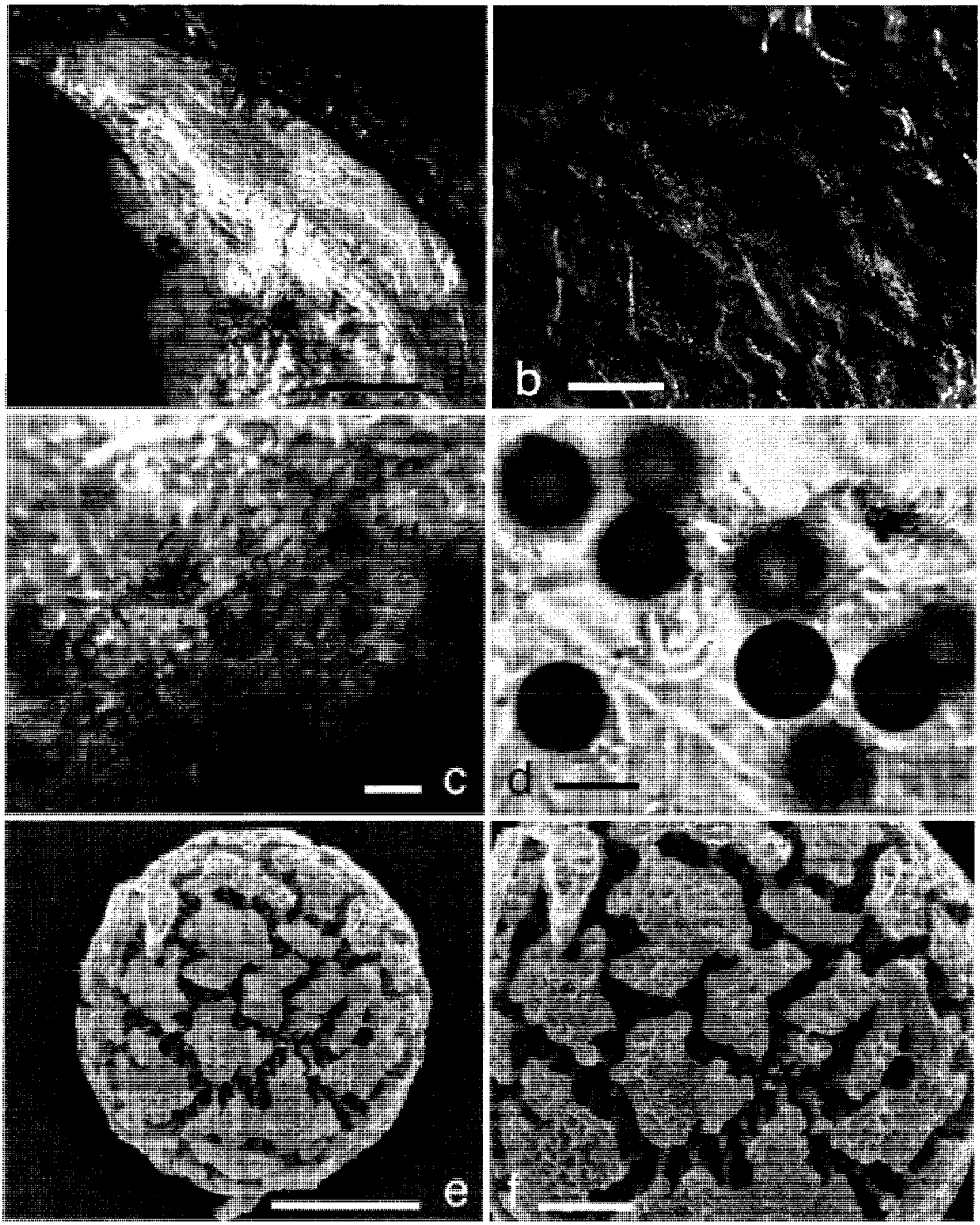

Fig. 8. *Elaphomyces pedicellaris.* (*a*) Ascoma in cross-section. (*b*) Surface view of the ascoma, with crust removed. (*c*) Interface of outer and middle peridial layers. (*d*) Spores viewed under light microscopy. (*e*) Scanning electron micrograph (SEM) of a spore. (*f*) SEM of spore surface, showing the pedicellate plates with rugose surface. Scale bars = 3 mm (*a*), 2 mm (*b*, *c*), 10 μm (*d*), 5 μm (*e*) and 2 μm (*f*).

Holotypus: Australia, Victoria, Gippsland Plain, Cranbourne, Royal Botanic Gardens, near works department on hill above woodlands near boundary fence, 11 Aug. 2000, *T. Lebel TL233* (MEL 2063443, isotype OSC).

Ascomata 8–28 × 8–25 mm in diameter, globose to subglobose, completely enclosed in pale yellow to yellow mycelium, sand and ectomycorrhizae that forms a tightly adherent mesh enclosing the ascoma. *Peridium* 3-layered; surface black, carbonaceous, smooth or nearly so, becoming somewhat irregularly wrinkled when dried, firm; inner peridium white and fleshy towards the surface, with a thin, off-white layer of small, irregular cavities. *Gleba* at maturity filled with black, powdery spore mass. *Odour* disagreeable. *Taste* not recorded.

Peridium is overlain by cottony, hyaline, somewhat encrusted hyphae. Outer layer 100–125 µm thick, of compact, smooth, dark brown, shortly segmented, highly branched (90-degree angle) interwoven hyphae ±5 µm in diameter and with walls ±1 µm thick, outer 50 µm dark then gradually paler towards middle layer; middle layer ±2000 µm thick, of hyaline, compact interwoven hyphae ±4 µm in diameter and with walls ±2 µm thick, occasional hyphae bundled in 2's, 3's or 4's; inner layer 700–1000 µm in diameter, hyaline, interwoven hyphae 5–6 µm in diameter and with walls ±2 µm thick, mostly in bundles of many hyphae, with the bundles loosely interwoven in a cris-cross pattern. *Gleba* of spores and septate, elongate, curly, hyaline, loosely interwoven hyphae, 2–3 µm in diameter and with walls ±0.5 µm thick, mostly smooth but some bumpy or kinked. *Asci* and ascogenous hyphae not seen. *Spores* globose, 11–13(–14) µm broad (mean = 12.2 µm) including the ornamentation of irregularly shaped, pedicellate plates that appear somewhat warty under light microscopy; SEM reveals that the plates are supported by rods and spines 1–2 µm tall, and the surface of the plates is finely rugose; spore walls ±1 µm thick, in KOH pale yellowish-brown to yellowish-brown singly and in mass when mature.

Etymology

Latin, *pedicellaris* (pedicellate), in reference to the pedicellate spore ornamentation.

Distribution, habitat and season

Victoria; hypogeous under trees in open woodland; August.

Material examined

Known only from the type collections..

Discussion

Elaphomyces pedicellaris is similar to *E. cooloolanus* and *E. rugosisporus* in spore size, but differs in spore ornamentation, as revealed by SEM, in the colour of the enclosing mycelium and distribution. The type collection of *E. pedicellaris* was associated with wombat diggings.

Elaphomyces queenslandicus Castellano, Trappe & Vernes, sp. nov. (Figs 9, 14*f*)

Ascomata in mycelio fusco omnino inclusa. Peridium strati duorum compositum: stratum externum 100–200 µm crassum, nigrum, carbonaceum, verrucis irregularibus, applanatis; stratum intimum 1–2 mm crassum, plus minusve pallide luteobrunneum vel brunneum, columbrinum. Gleba in maturitate sporis pulvereis schistaceis vel atramentariis repleta. Sporae globosae, (23–)24–25(–26) µm latae ornamentum 1–3 µm altum cristis labyrinthinis, pedicellatis inclusae, maturitate in KOH atrovirides vel brunneae.

Holotypus: Australia, Queensland, Atherton Tablelands, Davies Creek National Park, Davies Creek Road, 5.iii.1994, *D. Arora & M. Castellano T13457* (CANB, isotype OSC).

Ascomata up to 22 mm in diameter, subglobose, completely enclosed in dark brown mycelium, soil and ectomycorrhizae. *Peridium* 1–1.5 mm thick, 2-layered; surface black, carbonaceous, of irregularly sided, flattened warts up to 0.5 mm in diameter; inner layer rose-tinged directly beneath the carbonaceous layer, then mottled pale tan and off-white but basically pale tan towards the surface, grading to more brown toned near the gleba; when dried, ascoma collapses to form large wrinkles on the surface. *Gleba* initially stuffed with white cottony mycelium, at maturity becoming powdery with slate grey to dark bluish-black spores. *Odour* indistinct. *Taste* not determined.

Peridium overlain by a layer of bristly, dark reddish-brown, thin-walled, septate, somewhat knobby, extended hyphae that are slightly encrusted; outer layer 100–200 µm thick, dark reddish-brown to black textura angularis near the surface to dark reddish-brown to reddish-brown to red near the subcutis, the cells 10–18 µm in diameter; inner layer 1.0–1.4 mm thick, of hyaline to pale tan, septate, compact, interwoven hyphae 2–5 µm in diameter and with walls 0.5 µm thick. *Gleba* composed of spores and hyaline to pale green, sinuous, loosely interwoven hyphae 4–5 µm in diameter and walls 0.5 µm thick. *Asci* subglobose to globose, with a short tapered base, 45–55(–70) µm in diameter and walls 1–1.5 µm thick, hyaline at first, then greenish-black from maturing spores, 8-spored, the tapered base ±5 µm long × 4 µm wide, arising from knots or clusters of pale green, short-segmented, contorted, ascogenous hyphae ±5 µm in diameter scattered throughout the gleba. *Spores* globose, (23–)24–25(–26) µm (mean = 24.5 µm) including ornamentation of pedicellate, labyrinthine, rounded ridges ±3 µm tall under light microscopy, smaller when immature; SEM reveals that the labyrinthine ridges are supported by spines or rods and the surface of the plate-like structures is finely pitted or scored; occasional irregular patches of reddish-brown amorphous tissue on many mature spores; spore walls 1.5–2 µm thick, in KOH in youth hyaline singly and in mass, then dark green, by maturity reddish-brown to brown.

Etymology

In reference to its occurrence in Queensland, Australia.

Distribution, habitat and season

Northern Queensland; hypogeous under various combinations of *Acacia flavescens*, *Allocasuarina littoralis*, *A. torulosa*, *Corymbia citriodora*, *C. clarksoniana*, *Eucalyptus grandis*, *E. phaeotricha* or *Syncarpia hillii*; September through March.

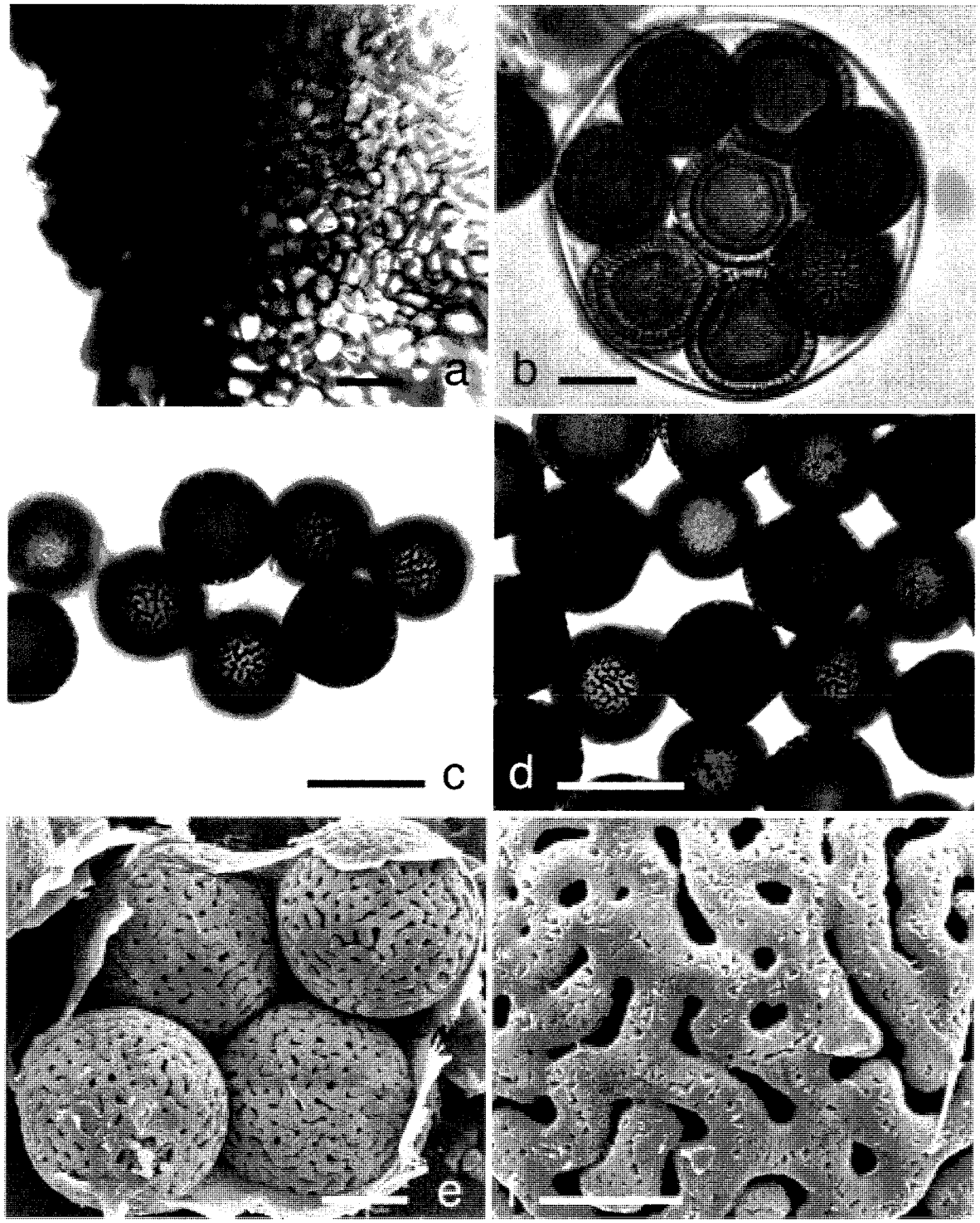

Fig. 9. *Elaphomyces queenslandicus.* (*a*) Cell structure of the outer peridial layer. (*b*) Ascus with developing spores. (*c*, *d*) Spores viewed under light microscopy. (*e*) Spores in ascus, a scanning electron micrograph (SEM) . (*f*) SEM of a spore surface, showing the etchings of the labyrinth. Scale bars = 20 μm (*a*), 10 μm (*b*), 25 μm (*c*, *d*), 10 μm (*e*) and 5 μm (*f*).

Material examined

QUEENSLAND: type locality, 30.i.1997, *K. Vernes T22577* (OSC); 5.iii.1994, *D. Arora & M. Castellano T13453* (OSC); 5.iii.1994, *M. Castellano T13448* (OSC); 9.xii.1996, *K. Vernes T22525* (OSC); 21.xi.1996, *K. Vernes T22529* (OSC); 27.ix.1996, *K. Vernes T22585* (OSC); 27.ix.1996, *K. Vernes T22588* (OSC); near Paluma, 17.ii.1992, *R. Halling H5663* (OSC).

Discussion

The black, carbonaceous peridium with dark brown enclosing mycelium of *E. queenslandicus* resembles *E. cooloolanus*, *E. coralloideus* and *E. suejoyceae* in appearance. The spores of *E. cooloolanus* (11–13 µm, mean = 12.0 µm) and *E. coralloideus* (18–20 µm, mean = 19.1 µm) are significantly smaller. Both *E. cooloolanus* and *E. coralloideus* spores differ distinctly in ornamentation from *E. queenslandicus*. The spores of *E. suejoyceae* ((24–)26–30(–31) µm, mean = 27.6 µm) are in size similar to those of *E. queenslandicus* ((23–)24–25(–26) µm, mean = 24.5 µm); however, the ornamentation is distinctly different.

In a surface view under a light microscope, the spores of *E. queenslandicus* appear to have shallow ornamentation. SEM and cross-sectional viewing under light microscopy reveal the spines or rods beneath the rounded pitted plate-like structures and a total height to the ornamentation of ±3 µm.

Elaphomyces rugosisporus Castellano, Trappe & Vernes, sp. nov. (Figs 10, 15*a*)

Ascomata in mycelio flammeo, miniato vel puniceo omnino inclusa. Peridium strati trium compositum: stratum externum ±60 µm crassum, nigrum, carbonaceum, laeve; stratum medium 170–180(–500) µm crassum; strato interiore ≠1 mm crasso aliquantum transienti, uterque albo vel albido, saepe areo carneo, rubro vel magenteo. Gleba in maturitate sporis pulvereis atrocaesiis vel atramentariis repleta. Sporae globosae, (10–)11–12 µm latae ornamentum reticulo tenui, punctato vel rugoso inclusae, in maturitate in KOH pallide olivaceae.

Holotypus: Australia, Queensland, Atherton Tablelands, Russell Pocket Road, 7.1 km from Gilles Highway, 8.iii.1995, *M. Castellano & J. Trappe T15300* (CANB, isotype OSC).

Ascomata 6–20 × 8–28 mm, ellipsoid to subglobose, completely enclosed in deep orange to reddish-orange to red mycelium, ectomycorrhizae and soil that form a crust 3–10 mm thick or thicker. *Peridium* 3-layered; surface black, carbonaceous, smooth, brittle; inner layers somewhat merged, white to off-white, often developing erratic areas of pink to deep red to magenta, especially on well matured specimens; these layers are shrinking significantly on drying. *Gleba* initially stuffed with white cottony mycelium, becoming filled with dark greyish-blue to greyish-black to bluish-black spore powder, the adjacent peridial tissue pink. *Odour* mild or indistinct. *Taste* not determined.

Peridium in youth 2–5 mm thick, narrowing to as little as 1–3 mm by maturity, in KOH with a distinct rose blush to the extreme outer surface of the carbonaceous layer, with outer layer ±60 µm thick, of dense, dark brown, grading into pale brown textura epidermoidea that grades into hyaline, more or less periclinal hyphae 170–180 µm thick, occasionally up to 500 µm thick; middle (transitional) layer of perpendicularly stacked bundles of hyaline hyphae 5 µm in diameter, inner layer ±1.5 mm thick, of pale rose-tinted, inflated cells, 15 µm in diameter. *Gleba* composed of spores and thin-walled, hyaline, highly branched (±90-degree angle), septate, loosely interwoven hyphae ±2 µm in diameter. *Asci* globose and with a short tapered base, 22–25 µm in diameter, the walls ±2 µm thick when young and thinning down to ±0.5 µm thick at maturity, hyaline, 8-spored; tapered base hyaline, ±5 µm broad; asci enlarging as spores develop and the walls thinning by maturity, arising from knots or clusters of pale green, contorted, ascogenous hyphae ±5 µm in diameter scattered throughout the gleba. *Spores* globose, (10–)11–12 µm (mean = 11.1 µm) including ornamentation of a fine reticulum ±2 µm tall that appears somewhat rugose to punctate under light microscopy; SEM reveals a fine lattice work; spore walls ±1 µm thick, in KOH pale greenish-brown singly and in mass.

Etymology

Latin, *rugose* (wrinkled) + *sporus* (spore), in reference to the wrinkled appearance of the spore surface.

Distribution, habitat and season

Northern Queensland, New South Wales and Tasmania; hypogeous under various combinations of *Acacia flavescens*, *A. falciformis*, *A. longifolia*, *A. mearnsii*, *Allocasuarina littoralis*, *Corymbia citriodora*, *C. clarksoniana*, *C. gummifera*, *Eucalyptus cypellocarpa*, *E. dalrympleana*, *E. globulus*, *E. grandis*, *E. obliqua*, *E. phaeotricha* or *E. sieberi*; November through June.

Material examined

NEW SOUTH WALES: Tantawangalo NP, New Line Rd, 0.7 km N of the junction with Postman's Track, 1.vi.1999, *S. Cork AWC2953* (DAR, OSC); QUEENSLAND: Atherton Tablelands, Davies Ck NP, Davies Ck Rd, 18.iv.1996, *K Vernes, T22523* (CANB, OSC); 23.v.1996, *K. Vernes, T22522* (CANB, OSC); 12.vi.1996, *K. Vernes, T22546* (CANB, OSC); 7.xii.1996, *K. Vernes, T22548* (CANB, OSC); 4.ii.1997, *K. Vernes, T22566* (CANB, OSC); 16.iv.1996, *K. Vernes, T22564* (CANB, OSC); 5.ii.1992, *M. Castellano & R. Young H5534* (PERTH, OSC); 6.iii.1994, *M. Castellano, T13485 & T13486* (CANB, OSC); Kirrama, 9.v.1991, *N. Malajczuk & M. Castellano H4736* (PERTH, OSC); Kenilworth, 12.v.1988, *R. Young H4165* (PERTH, OSC); near Atherton, Rifle Range Rd, 7.v.1991, *P. Reddell & M. Castellano H4671* (PERTH, OSC); Paluma, 9.iii.1990, *P. Reddell NQ7* (CANB, OSC); SOUTH AUSTRALIA: Kuitpo Forest, 25.xi.1971, *J. Warcup* (MEL 2024731); TASMANIA: S of Geeveston, Huon Valley, Hermons Rd, 7.v.1990, *J. Trappe & N. Malajczuk H1563* (HO, PERTH, OSC); VICTORIA: Croajingalong NP, Genoa Park Rd, 3.3 km N of the junction with Hard-to-Seek Track, 29.v.2001, *A. Jumpponen AWC4275* (MEL, OSC).

Discussion

Elaphomyces rugosisporus resembles *E. auranticus* in having a black, carbonaceous peridium with orange-coloured mycelium enclosing the ascoma. See the discussion under *E. auranticus* for differences.

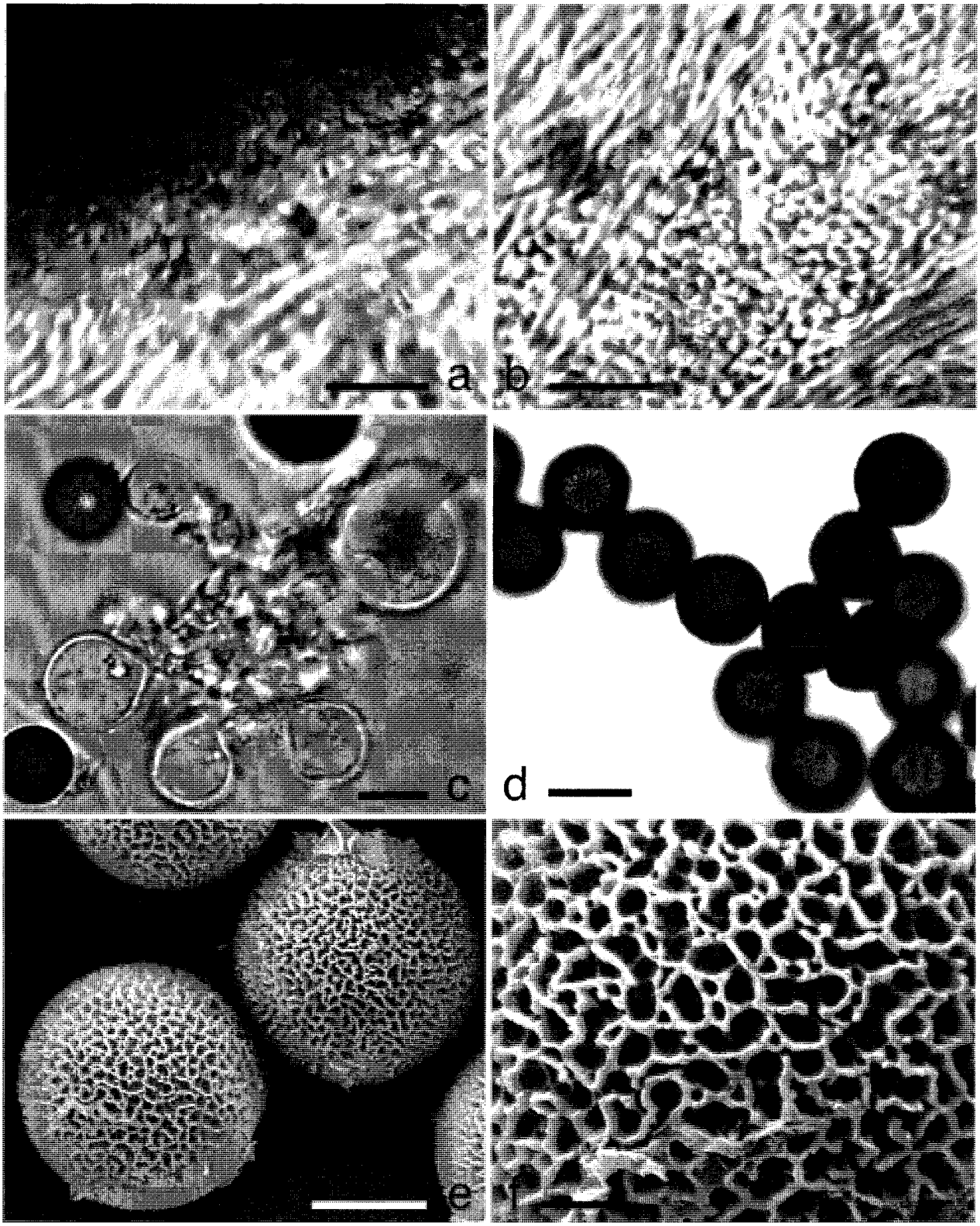

Fig. 10. *Elaphomyces rugosisporus.* (*a*) Interface between outer and middle peridial layers. (*b*) Bundled hyphae of the middle peridial layer. (*c*) Hyphal cluster, giving rise to asci. (*d*) Spores viewed under light microscopy. (*e*) Scanning electron micrograph (SEM) of spores. (*f*) SEM of a spore surface, showing the complex lattice structure of the ornamentation. Scale bars = 25 μm (*a*, *b*), 10 μm (*c*, *d*), 5 μm (*e*) and 2 μm (*f*).

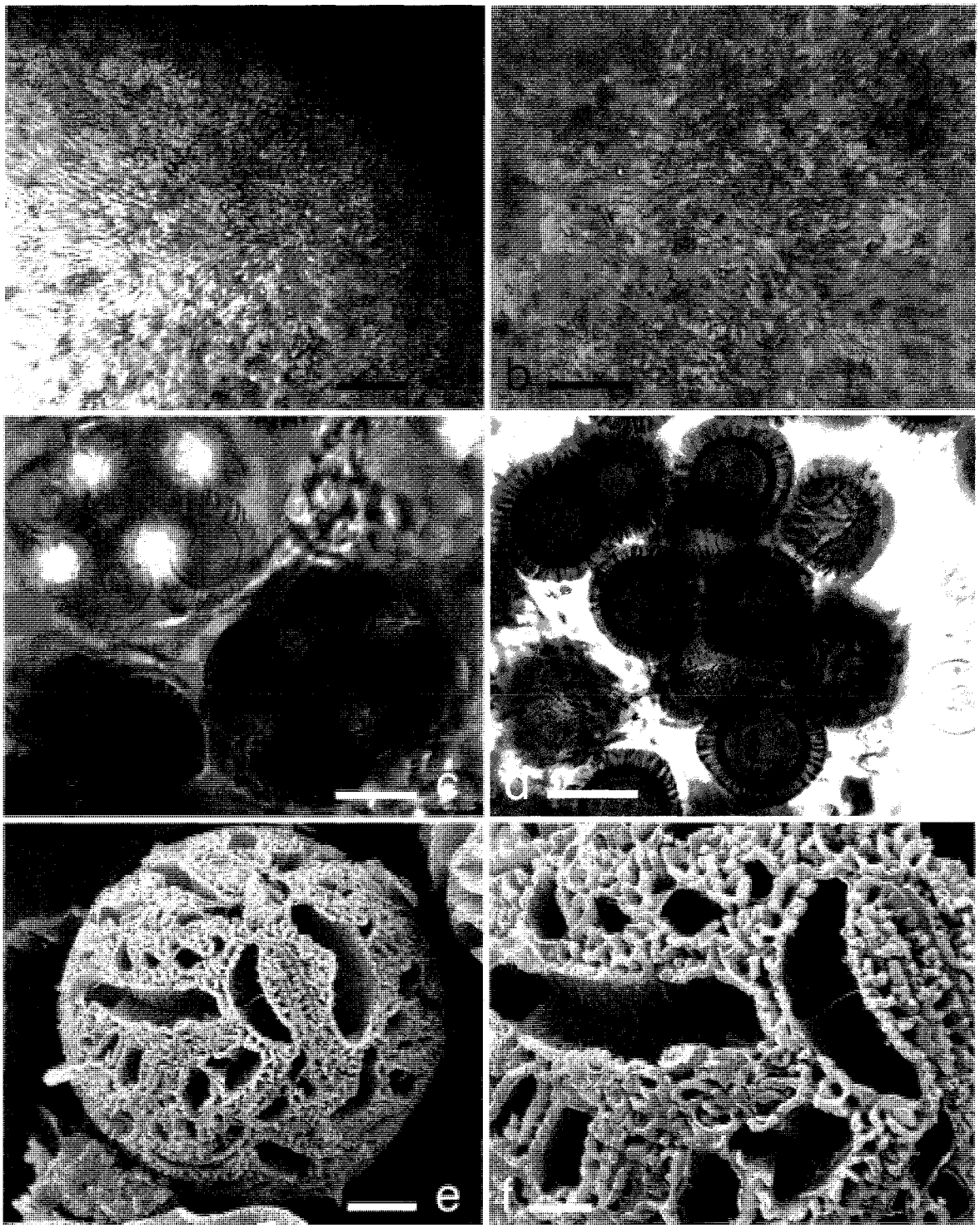

Fig. 11. *Elaphomyces suejoyceae*. (*a*) Interface between outer and inner peridial layers. (*b*) Inner peridial layer, showing the scattered, small crystals. (*c*) Asci with developing spores. (*d*) Spores viewed under light microscopy. (*e*) Scanning electron micrograph (SEM) of a spore. (*f*) SEM of spore ornamentation, showing the complex construction of anastomosed rods. Scale bars = 30 μm (*a*, *b*), 20 μm (*c*, *d*), 5 μm (*e*) and 2 μm (*f*).

Elaphomyces suejoyceae Castellano, Trappe & Vernes, sp. nov. (Figs 11, 15*b*)

Ascomata in mycelio albo, brunneolo vel fusco omnino inclusa. Peridium strati duorum compositum: stratum externum 170–180 µm crassum, fuligineum vel nigrum, carbonaceum, laeve; stratum intimum 1–4 mm crassum, album vel prope glebam brunneum. Gleba in maturitate sporis pulvereis brunneonigris, fuscis, atroporphyreis vel atroferrugineis repleta. Sporae globosae, (24–)26–30(–31) µm latae ornamentum 2–4(–5) µm altum cristis labyrinthinis inclusae, in maturitate in KOH porphyreae.

Holotypus: Australia, Queensland, Atherton Tablelands, Davies Creek National Park, Davies Creek Road, 3.v.1988, *M. Trappe & N. Malajczuk H4031* (CANB, isotypes PERTH, OSC).

Ascomata 12–35 × 23–50 mm, subglobose, with scant to abundant, white or near white to pale brown to dark brown mycelium enclosing the ascoma. *Peridium* 2-layered; surface brownish-black to black, carbonaceous, smooth; inner layer white and grading to brown near gleba, then with brown areas marbled pale brown and dark brown clear in some places, obscure in others, fleshy leathery. *Gleba* at maturity powdery or sometimes wet, brownish-black to rich blackish-brown or dark reddish-brown or even rusty dark brown. *Odour* mild or indistinct. *Taste* not determined.

Outer layer of the *peridium* 170–180 µm thick, of dark brown to reddish-brown textura epidermoidea, hyphae 4–5 µm in diameter, with walls ±0.5 µm thick: inner layer 1–4 mm thick, of thin-walled, hyaline to pale tan (in patches), closely interwoven hyphae, some patches pale brown with small brown crystals scattered across the layer; hyphae with walls up to 3 µm thick near the gleba and inflated up to 10 µm in diameter, thin-walled hyphal layer thin and only adjacent to dark-coloured outer hyphae. *Gleba* composed of spores and thin-walled, hyaline, slightly encrusted, branched, septate, loosely interwoven hyphae, 3–4 µm in diameter. *Asci* globose with a short tapered base, ±50 µm in diameter, with walls 2–4 µm thick, hyaline, 8-spored; tapered base hyaline, 4 µm wide by 3 µm long, arising from knots or clusters of pale green (in KOH), contorted, ascogenous hyphae ±5 µm in diameter scattered throughout the gleba. *Spores* globose, (24–)26–30(–31) µm (mean = 27.6 µm) including ornamentation of labyrinthine ridges 2–4(–5) µm tall, ridges irregular in thickness under light microscopy; SEM reveals the ridges to be composed of anastomosed spines or rods, sometimes in ranks of 2 or 3 or more; walls 1–2 µm thick, in KOH initially hyaline, soon golden reddish-brown to reddish-brown singly and in mass, typically when mature the ridges are dark against the paler valleys between them.

Etymology

In honour of Ms Sue Joyce, an accomplished collector of sequestrate fungi in Queensland and a gracious hostess to numerous mycological expeditions.

Distribution, habitat and season

Northern Queensland and New South Wales; hypogeous under various combinations of *Acacia flavescens*, *Allocasuarina littoralis*, *A. torulosa*, *Corymbia citriodora*, *C. clarksoniana*, *C. intermedia*, *Eucalyptus grandis*, *E. phaeotricha*, *E. pilularis*, *E. propinqua*, *E. tereticornis* or *Syncarpia hillii*; November through July.

Material examined

QUEENSLAND: Atherton Tablelands, Davies Ck NP, Davies Ck Rd, 5.iii.1994, *M. Castellano, T13437, T13446, T13455, T13456* (all CANB & OSC); 18.ii.1996, *K. Vernes, T22524* (CANB & OSC); 1.ii.1997, *T22528* (CANB & OSC); 27.ix.1996, *T22530* (CANB & OSC); 7.xii.1995, *T22572* (CANB & OSC); 30.i.1997, *T22574* (CANB & OSC); 31.i.1997, *T22581* (CANB & OSC); 19.xi.1996, *T22582* (CANB & OSC); 9.xii.1996, *T22583* (CANB & OSC); 1.ii.1997, *T22584* (CANB & OSC); 27.vii.1996, *T22586* (CANB & OSC); 5.iv.1989, *N. Malajczuk H4379* (PERTH & OSC); near Atherton, Rifle Range Rd, 3.iv.1989, *M. Castellano H4321* (PERTH & OSC); Mt Glorius, 16.v.1988, *M. Amaranthus H4268* (PERTH & OSC); Mothar Mountain, 9.v.1988, *R. Young H4086* (PERTH & OSC); Tully Falls NP, Red Rd, 4.v.1988, *J. Trappe H4047* (CANB & OSC); near Paluma, 26.iv.1990, *N. Malajczuk H4524* (PERTH & OSC); 9 km W of Mt Glorius, 4.v.1992, *R. Schaefer H5990* (PERTH & OSC); Mt Windsor Tablelands, 2.ii.1992, *M. Castellano H5460* (PERTH & OSC); VICTORIA: East Gippsland, Kuark Forest Management Block, Fred's Track, 0.7 km NW of junction with Little Arte Trail, 28.vii.1996, *A. Claridge, T19845* (MEL & OSC); 0.3 km off Omeo Hwy, 2.1 km S of junction with Ash Range Rd, 11.xi.1996, *E. Cázares, T20145* (MEL & OSC).

Discussion

The black, carbonaceous peridium and the brown enclosing mycelium of *E. suejoyceae* resembles that of *E. queenslandicus*, *E. cooloolanus* and *E. coralloideus*. The spores of *E. cooloolanus* (11–13 µm, mean = 12.0 µm) and *E. coralloideus* (18–20 µm, mean = 19.1 µm) are significantly smaller than and both have ornamentation that differs distinctly from those of *E. suejoyceae*. The spores of *E. suejoyceae* ((24–)26–30(–31) µm, mean = 27.6 µm) are similar in size to those of *E. queenslandicus* ((23–)24–25(–26) µm, mean = 24.5 µm); however, the ornamentation is distinctly different.

Elaphomyces symeae Castellano, Trappe & Lebel, sp. nov. (Figs 12, 15*c*)

Ascomata in mycelio saturate mineato, saturate cinnamomeo vel ferrugineo omnino inclusa. Peridium strati duorum compositum: stratum externum 120–160 µm crassum, nigrum, carbonaceum, irregulariter asprum; stratum intimum ± 1 mm crassum, album, interdum caerulescens. Gleba in maturitate sporis pulvereis viridigriseis vel carboneis repleta. Sporae globosae, 12–13(–14) µm latae ornamentum ± 1 µm altum reticulo pedicellato inclusae, in maturitate in KOH auratobrunneae.

Holotypus: Australia, Western Australia, east of Albany, Two Peoples Bay Nature Reserve, opposite the track to heath site, 30.vi.1998, *K. Syme KS1005/98* (MEL 2104387, isotype OSC).

Ascomata 7–17 mm in diameter, globose, completely enclosed in deep orangy-red, deep orangy-brown to rusty red mycelium, ectomycorrhizal roots and sand that form a crust. *Peridium* 2-layered; surface black, carbonaceous with some incorporated sand granules, irregularly roughened, brittle; inner layer white to off-white, sometimes bruising blue, firm.

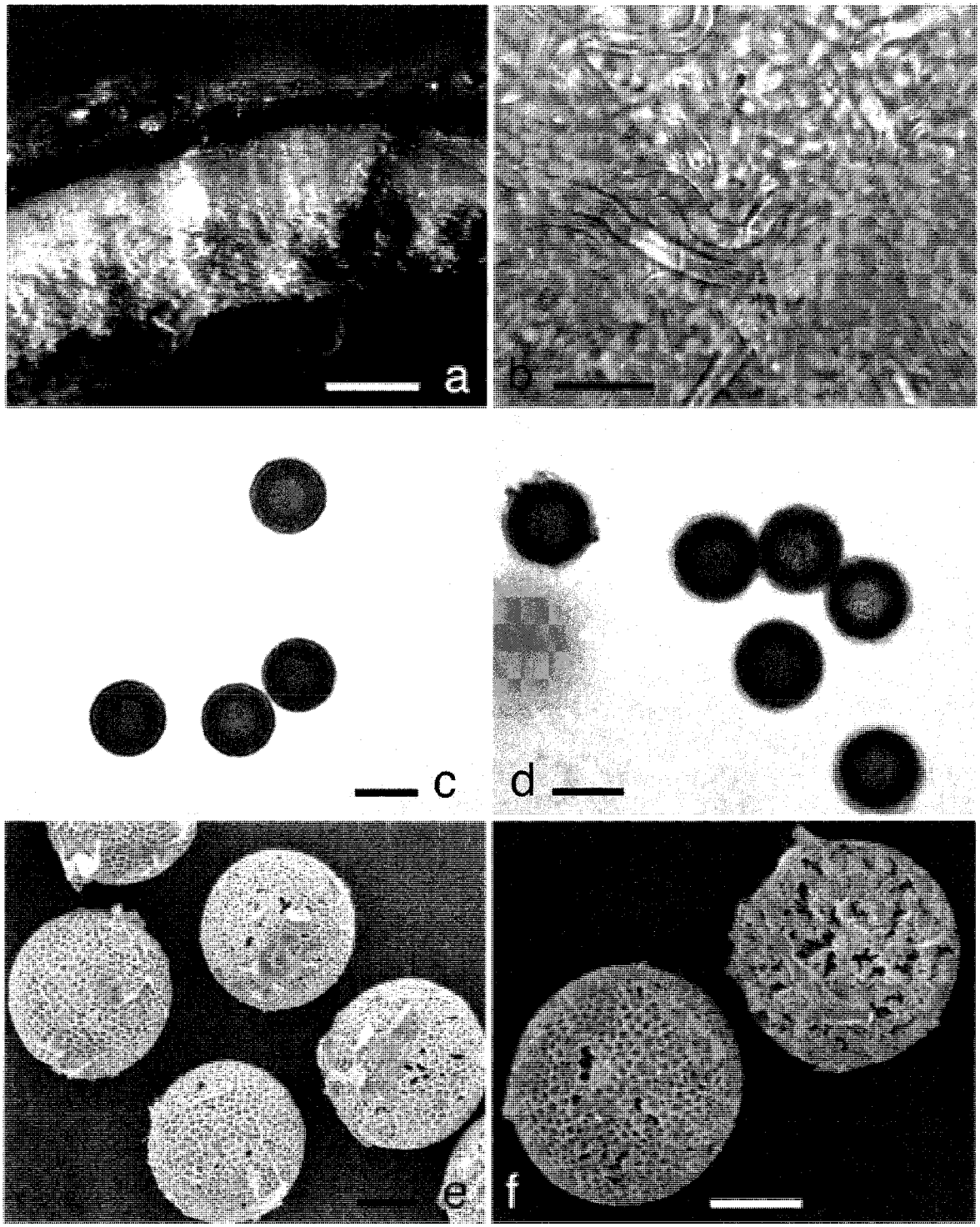

Fig. 12. *Elaphomyces symeae*. (*a*) Ascoma in cross-section. (*b*) Hyphal structure of the inner peridial layer. (*c*) Cross-section view of spores viewed under light microscopy. (*d*) Surface view of spores under light microscopy. (*e*) Scanning electron micrograph (SEM) of spores. (*f*) SEM of spore ornamentation, showing the supporting rods to the honey-comb spore surface. Scale bars = 0.5 mm (*a*), 20 μm (*b*), 10 μm (*c*, *d*) and 5 μm (*e*, *f*).

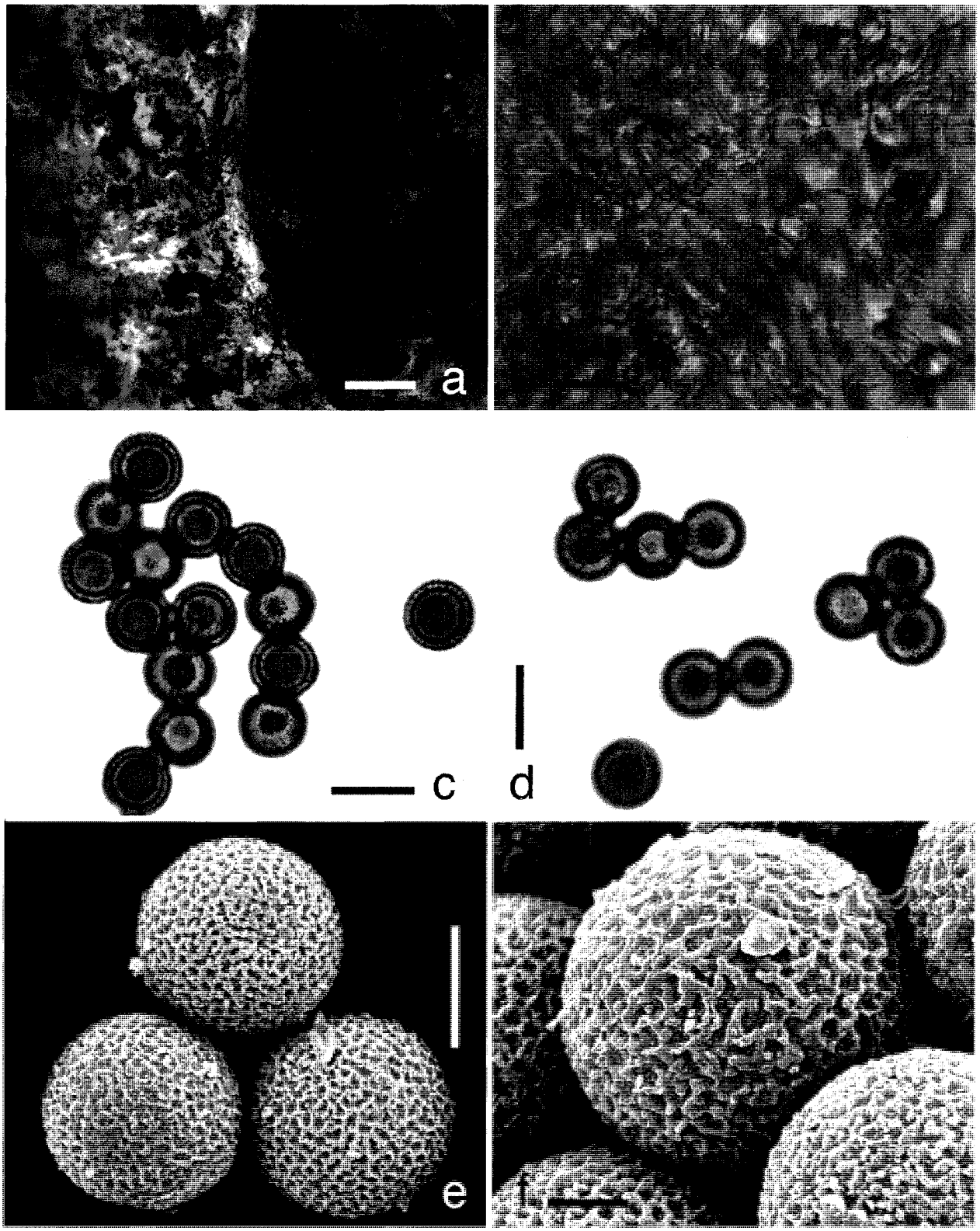

Fig. 13. *Elaphomyces timgroveii.* (*a*) Ascoma in cross-section. (*b*) Hyphae of the inner peridial layer. (*c*) Cross-section view of spores under light microscopy. (*d*) Surface view of spores under light microscopy. (*e*) Scanning electron micrograph (SEM) of spores. (*f*) SEM of spores, showing the low irregular reticulum. Scale bars = 0.5 mm (*a*), 15 µm (*b*), 10 µm (*c*, *d*), 5 µm (*e*) and 2 µm (*f*).

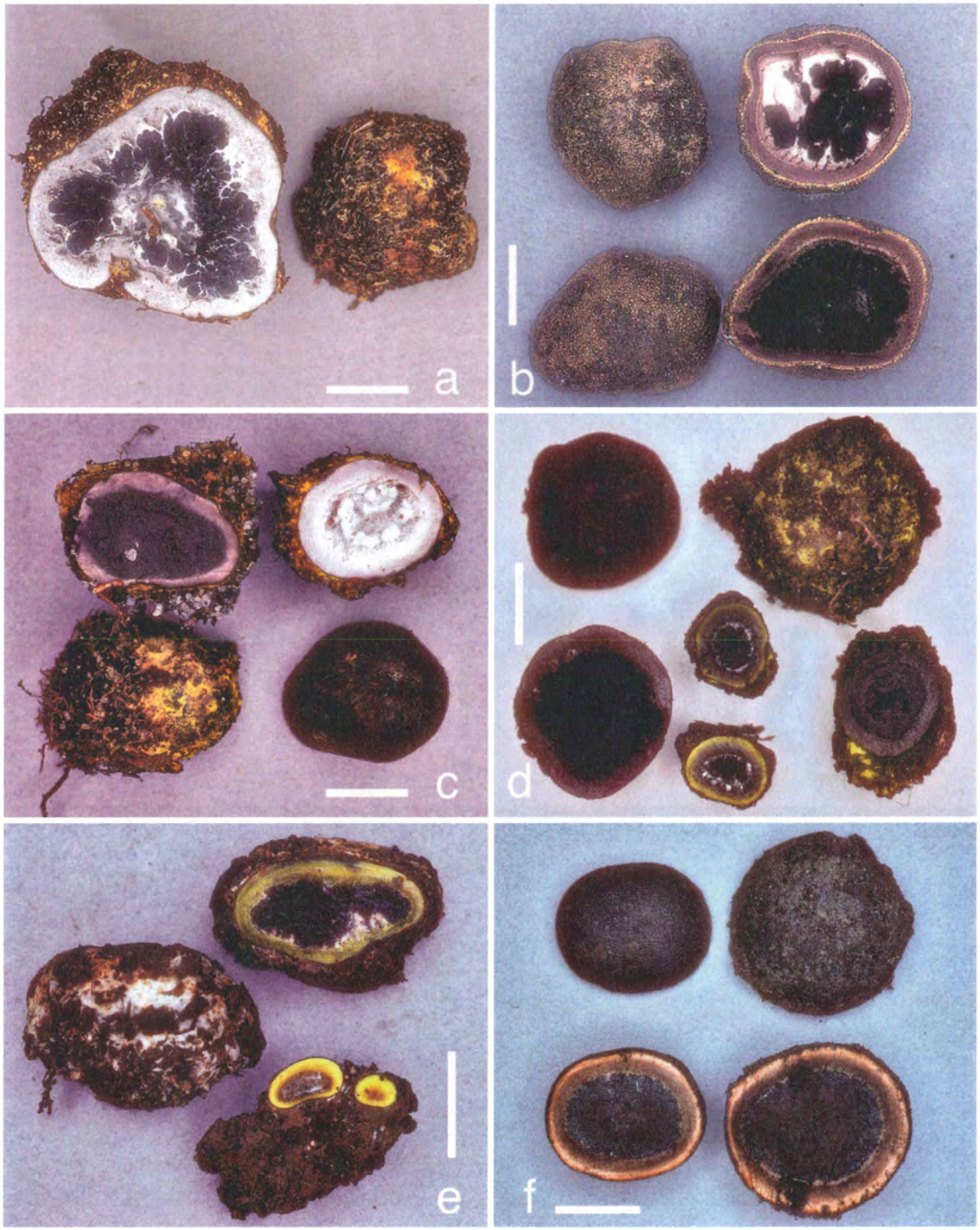

Fig. 14. *Elaphomyces* ascomata. (*a*) *E. aurantius*. (*b*) *E. austrogranulatus*. (*c*) *E. chlorocarpus*. (*d*) *E. laetiluteus*. (*e*) *E. nothofagi*. (*f*) *E. queenslandicus*. Scale bars = 10 mm.

Gleba initially hollow, then with white, cottony mycelium that sometimes bruises pink or blue, at maturity filled with dark greenish-grey to charcoal-coloured spore powder and scattered thread-like hyphae. *Odour* indistinct. *Taste* not recorded.

Outer layer of the *peridium* 120–160 µm thick at maturity, of compact, smooth, dark reddish-brown to nearly black, agglutinated, short hyphae of 2–3 µm in diameter and with walls ±1 µm thick; inner layer ±1 mm thick, somewhat off-white to pale brown but hyaline as it nears gleba, of irregularly interwoven (perpendicular at times) hyphal bundles composed of hyaline, agglutinated, compact hyphae up to 6 µm in diameter and with walls ±2 µm thick. *Gleba* composed of spores and thin-walled, hyaline, septate, smooth, sinuous hyphae 2–5 µm in diameter. *Asci* globose, 20–22 µm in diameter, hyaline, the walls ±1 µm thick, 8-spored; arising from knots of hyaline, short-celled, contorted, hyaline, ascogenous hyphae 5–10 µm in diameter, with walls up to 2 µm thick. *Spores* globose, 12–13(–14) µm broad (mean = 12.8 µm) including the ornamentation of an irregular, pedicellate reticulum ±1 µm tall that appears as a fine to coarse punctation or honey-comb under light microscopy; SEM reveals an irregular honey-comb surface that is supported by individual rods or spines; spore walls ±1 µm thick, in KOH golden yellowish-brown singly and dark golden yellowish-brown in mass when mature; spores appearing nearly uniform in size and ornamentation at maturity.

Etymology

In honour of Ms Karen Syme, accomplished mycological artist and collector of sequestrate fungi in Western Australia.

Distribution, habitat and season

Western Australia; hypogeous, usually in deep litter under various combinations of *Allocasuarina fraseriana*, *Eucalyptus conferruminata*, *E. marginata*, *E. megacarpa* or *Gastrolobium bilobum*; June, August or October.

Materials examined

WESTERN AUSTRALIA: E of Albany, Two Peoples Bay Nature Reserve, west of Firebreak Valley Track, 21.x.1998, *K. Syme & G. Evans KS1029/98* (MEL 2104377); 22.x.1998, *KS1031/98* (MEL 2105010); Bold Island Nature Reserve, 15.viii.2007, *L. Bell, T. Friend & N. Bougher 387* (PERTH).

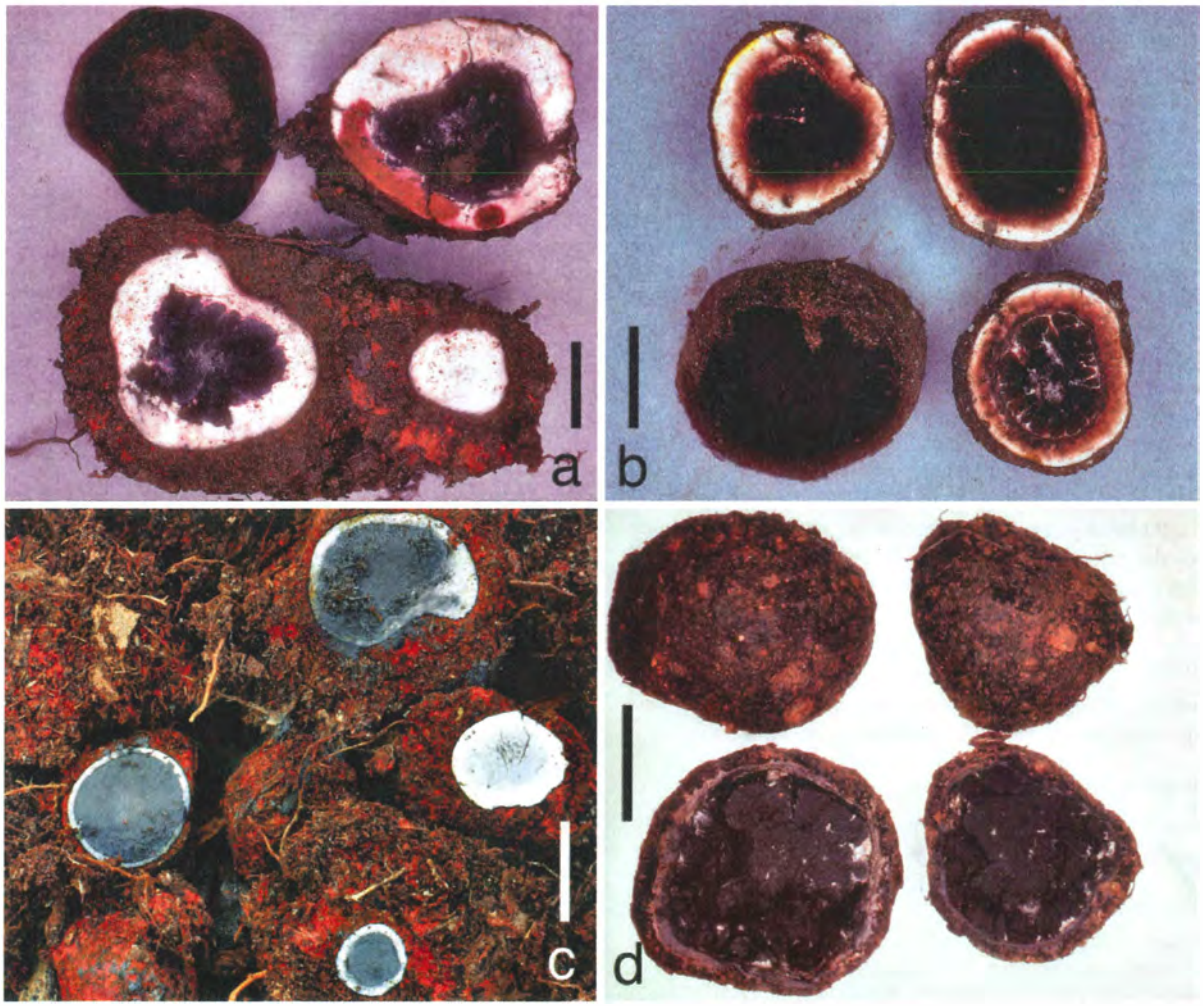

Fig. 15. *Elaphomyces* ascomata. (*a*) *E. rugosisporus*. (*b*) *E. suejoyceae*. (*c*) *E. symeae*. (*d*) *E. timgroveii*. Scale bars = 10 mm (*a*, *c*, *d*) and 20 mm (*b*).

Discussion

Elaphomyces symeae resembles *E. rugosisporus* with its small spores and orange–red mycelium enclosing the ascoma. *E. symeae* is known only from Western Australia and has slightly larger spores than does *E. rugosisporus* which is found in eastern Australia. *E. timgroveii* also occurs in Western Australia and has black mycelium enclosing the sporocarp surface and spore ornamentation constructed differently from that of *E. symeae*, as revealed by SEM (however, they may appear similar under light microscopy).

Elaphomyces symeae is sometimes found in pink-stained sand that turns orange near the ascoma surface.

Elaphomyces timgroveii Castellano, Trappe & Vernes, sp. nov. (Figs 13, 15*d*)

Ascomata in mycelio atro omnino inclusa. Peridium strati duorum compositum: stratum externum 35–50 µm crassum, fumosum, laeve; stratum intimum ±1 mm pallide olivaceum. Gleba in maturitate sporis pulvereis pallide viridis vel nigris repleta. Sporae globosae, 8–9 µm latae ornamentum ±1 µm altum reticulo pedicellato, irregulari, tenui inclusae, in maturitate in KOH olivaceae.

Holotypus: Australia, Western Australia, no locality, xi.1978, *T5550* (PERTH, isotype OSC).

Ascomata 8–20 × 12–23 mm, subglobose, completely enclosed in black mycelium, ectomycorrhizal roots and sand that form a thick crust. *Peridium* 2-layered; surface greyish-brown, smooth; inner layer pale olive, rubbery. *Gleba* of a pale green to black spore powder when mature. *Odour* musty. *Taste* not recorded.

Outer layer of the *peridium* 35–50 µm thick, of hyaline to pale green, thin-walled, septate, compact, interwoven hyphae 2–3 µm in diameter, with much amorphous material incorporated throughout the layer; inner layer ±1 mm thick, of pale yellowish-green, coarse, granulate-encrusted, compact, interwoven hyphae 7–9 µm in diameter and with walls ±2 µm thick. *Gleba* of spores, no hyphae seen. *Asci* and ascogenous hyphae not seen. *Spores* globose, 8–9 µm (mean = 8.7 µm) including ornamentation of shallow, short, meandering ridges in an irregular, fine reticulum ±1 µm tall, that appears punctate under light microscopy; SEM reveals the ornamentation to be an irregular reticulum, with some patchy amorphous material adhering at various spots on the spore; walls ±1 µm thick, in KOH olive singly and in mass.

Etymology

In honour of Dr Tim Grove, esteemed colleague and accomplished collector of sequestrate taxa in Australia.

Distribution, habitat and season

Western Australia; hypogeous under *Eucalyptus* spp.; July, November or December.

Material examined

WESTERN AUSTRALIA: no locality, xi.1978, *T5534* (PERTH & OSC); Pemberton, vii.1982, *N. Malajczuk* (PERTH 00746169); Manjimup, Pine Ck Rd, 1.xii.1981, *N. Malajczuk* (PERTH 07507992).

Discussion

The very small spores of *E. timgroveii* are similar in size to those of *E. cooloolanus*, *E. rugosisporus* and *E. symeae*. The spore ornamentation of *E. cooloolanus* is made up of close rods or spines that form short ridges, the spore ornamentation of *E. rugosisporus* is a tall (±2 µm) fine reticulum, the ornamentation of *E. timgroveii* is also a fine reticulum but not as tall in stature (±1 µm). The spore size of *E. timgroveii* (8–9 µm, mean = 8.7 µm) does not overlap with the that of the other three species (*E. cooloolanus* spores 11–13 µm, mean = 12.0 µm; *E. rugosisporus* spores (10–)11–12 µm, mean = 11.1 µm; *E. symeae* spores 12–12(–14) µm, mean = 12.8 µm).

SEM confirms that an outer shell of fine ornamentation is supported underneath by rods or spines.

Acknowledgements

This research was supported in part by Australian Biological Resources Study (ABRS) Grant No. 95130, by Australian Centre for International Agricultural Research Grant No. 8736, by National Science Foundation Grants DEB 9007186 and 9400545, and by CSIRO, Forestry/Forest Products and Sustainable Ecosystems. We appreciate the review of this manuscript by A. Claridge and D. Luoma. We appreciate the expert assistance in the field by M. Amaranthus, D. Arora, N. Bougher, E. Cázares, A. Claridge, W. Colgan III, S. Cork, A. Giachini, Dr T. Grove, R. Halling, S. Joyce, A. Jumpponen, T. Lebel, N. Malajczuk, D. Mills, G. Mires, P. Reddell, R. Schaefer, K. Syme, C. Theodorou and R. Young. We appreciate the contribution of some of the SEM images by Jim Ehrman of Mount Allison University, Canada. We also appreciate the loan of specimens from CANB, HO, MEL, OSC, PDD, and PERTH.

References

Castellano MA, Trappe JM, Maser Z, Maser C (1989) 'Keys to spores of the genera of hypogeous fungi of North Temperate forests with special reference to animal mycophagy.' (Mad River Press: Eureka, CA)

Cooke MC (1892) 'Handbook of Australian fungi.' (Williams and Norgate: London)

de L'Obel M (1591) Icones stirpium. Vol. 2, 276. (Antwerp)

Dodge CW (1929) The higher Plectascales. *Annales Mycologici* **27**, 145–184.

Fries EM (1825) 'Systema orbis vegetabilis.' (Lund)

Fries E (1849) 'Summa Vegetabilium Scandinaviae.' 2: 445. (Leipzig)

Hosaka K, Bates ST, Beever RE, Castellano MA, Colgan W III, Dominguez LS, Nouhra ER, Geml J, Giachini AJ, Kenney SR, Simpson NB, Spatafora JW, Trappe JM (2006) Molecular phylogenetics of the gomphoid-phalloid fungi with an establishment of the new subclass Phallomycetidae and two new orders. *Mycologia* **98**, 949–959. doi:10.3852/mycologia.98.6.949

Lebel T, Castellano M (1999) Australasian truffle-like Fungi. IX. History and current trends in the study of the taxonomy of sequestrate macrofungi from Australia and New Zealand. *Australian Systematic Botany* **12**, 803–817. doi:10.1071/SB97039

Nees von Esenbeck CG (1820) Synopsis generum plantarum mycetoidearum. In 'Beschreibung der um Halifax wachsenden Pilze von J Bolton 4, LXIX'. (Bey G. Reimer Publisher: Berlin)

Rodway L (1918) Botanical notes. *Papers and Proceedings of the Royal Society of Tasmania* **1917**, 105–110.

Vittadini C (1831) 'Monographia Tuberacearum.' (Torino)

Manuscript received 11 March 2010, accepted 21 October 2010