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Four new genera of the fungal family *Boletaceae*

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Abstract Based on our previous molecular phylogenetic analyses, four new genera are described, namely *Baorangia*, *Lanmaoa*, *Parvixerocomus*, and *Rugiboletus*, and one known genus, *Neoboletus*, is re-delimitated. Four new species and nine new combinations are proposed. Morphological characters of each genus and related eleven species are described and illustrated. Most of species in the genera described from southwestern China are wild edible mushrooms and can be found in free markets.

Keywords *Boletaceae* · Boletes · New lineages · Taxonomy

Introduction

Boletaceae Chevall. has been studied intensively in past decades and molecular techniques have rapidly advanced the study of bolete evolution (Yang 2011, Wu et al. 2014). Recently, the molecular phylogenetic framework of the family *Boletaceae* has been reconstructed by the work of Nuhn et al. (2013) and Wu et al. (2014). In the latter study, seven major clades at the subfamily level and 59 lineages at the generic level including 22 new ones were inferred. Recently, several new genera, e.g., *Alessioporus* Gelardi et al., *Butyriboletus* D. Arora & J. L. Frank, *Caloboletus* Vizzini, *Crocinoboletus* N.K. Zeng et al., *Cyanoboletus* Gelardi et al., *Imleria* Vizzini, *Neoboletus* Gelardi et al., *Pseudoaustroboletus* Yan C. Li & Zhu L. Yang, *Pulchroboletus* Gelardi et al. and *Rubroboletus* Kuan Zhao et Zhu L. Yang have been described (Arora and Frank 2014; Gelardi et al. 2014a,b,c; Li et al. 2014a; Vizzini 2014a,b; Zeng et al. 2014; Zhao et al. 2014b). In large part, the new genera were proposed based on that comprehensive phylogeny of Wu et al (2014). Still, there are many new clades recognized in that work which need further examination. In this paper we provide the morphological documentation of clades 29, 37, 47, 49, and 51 in Wu et al. (2014). Most of these were previously placed in *Boletus* s.l.

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Materials and methods

Macro-morphological descriptions were derived from fresh basidiomata. Microscopic structures were revived in 5 % KOH, dyed with Congo Red when necessary. For those characters which may easily disappear in KOH, dH_2O was used as a mountant. Melzer's reagent was used for testing amyloidity of tissue fragments in the solution. Sections of the pileus surface were cut radially, vertically and halfway between center and margin of the pileus (Li et al. 2014b). All microscopic features were drawn by hand. Dimensions for basidiospores are given as (a) b–c (d). The range b–c contains a minimum of 90 % of the measured values. Extreme values (a and d) are indicated in parentheses. Other abbreviations are: Q (length/width of basidiospores) and Qm (average Q±standard deviation). The color-coding is in accordance with Kornerup and Wanscher (1981). The descriptions of genera and species appear in alphabetical order by genus and species under the genus. The images of fresh basidiomata of related species are shown in Figs. 1, 2 and 3. Voucher specimens were kept

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Fig. 1 Basidiomata of representative species in the studied genera–1. **a**–**b**: *Baorangia pseudocalopus* (HKAS 75739); **c**–**d**: *Lanmaoa angustispora* (HKAS 74752, holotype!); **e**–**f**: *Lanmaoa asiatica* (HKAS 82696, holotype!). a–f: Bars=5 cm

in the Cryptogamic Herbarium (KUN–HKAS) of the Kunming Institute of Botany, Chinese Academy of Sciences, New York Botanical Garden (NY), and Buffalo Museum of Science (BUF). Herbarium codes are according to Thiers (2014), except for HKAS.

Molecular evidence is based on the results of Wu et al. (2014). Additional sequences of nrLSU, *tef1*-α, *rpb1* and *rpb2* newly generated from specimens of the species described below were submitted to GenBank (see Table 1).

Results

Taxonomy

Baorangia G. Wu & Zhu L. Yang, **gen. nov.**

MycoBank: MB 810350

Etymology: "*Bao*" and "*rang*" mean "thin" and "hymenium" in Chinese, respectively, referring to the thin hymenophore.

Generic diagnosis: This genus differs from all other genera of *Boletaceae* by its thin hymenophore (thickness of hymenophore 1/3–1/5 times that of pileal context at the position halfway to the pileus center) with yellow tubes and pores which stain blue when bruised, a light yellow context which stains pale blue slowly when cut, and a trichodermium to an interwoven trichodermium pileipellis.

Generic description: *Basidiomata* stipitate-pileate with tubular hymenophore. *Pileus* hemispherical, convex or applanate, subtomentose, dry, usually incurved at the margin when young; context pale yellow to yellow, slowly staining pale blue when cut. *Hymenophore* relatively thin (thickness of hymenophore 1/3–1/5 times that of pileal context at the position halfway to the pileus center), usually decurrent; hymenophoral surface and

Fig. 2 Basidiomata of representative species in the studied genera–2. **g**–**h**: *Parvixerocomus pseudoaokii* (g HKAS 80480, holotype!, h HKAS 77032); **i**–**j**: *Parvixerocomus aokii* (HKAS 59812); **k**–**l**: *Rugiboletus brunneiporus* (k HKAS 83209, holotype!, l HKAS 83009); **m**–**n**: *Rugiboletus extremiorientalis* (m HKAS 74770, n HKAS 63523). g–j: Bars=2 cm, k–n: Bars=5 cm

tubes yellow, immediately staining light blue to greenish blue when injured; pores angular, or sometimes nearly round; tubes short. *Stipe* smooth or occasionally with reticulations at the upper part; context pale yellow to yellow, staining pale blue; basal mycelia white to pale yellow. *Pileipellis* a trichodermium to an interwoven trichodermium. *Pleuro-* and *cheilocystidia* present. *Basidiospores* smooth, subfusiform to elongated subfusiform, light yellow to brownish-yellowish. *Clamp connections* absent.

Type species: *Baorangia pseudocalopus* (Hongo) G. Wu & Zhu L. Yang

Fig. 3 Basidiomata of representative species in the studied genera–3. **o–p**: *Neoboletus thibetanus* (o HKAS 57093, p HKAS 82600); **q–r**: *Neoboletus venenatus* (q HKAS 51703, r HKAS 57489); **s–t**: *Neoboletus brunneissimus* (s HKAS 50450, t HKAS 74906); **u–v**: *Neoboletus magnificus* (HKAS 74939). o–p: Bars=2 cm, q–v: Bars=5 cm

Phylogenetic position: Clade 51 in Wu et al. (2014)

Baorangia pseudocalopus (Hongo) G. Wu & Zhu L. Yang, **comb. nov.** Figs. 1a, b and 4

Basionym: *Boletus pseudocalopus* Hongo, Memoirs of the Faculty of Education, Shiga University 22: 66, Fig. 37 (1972)

MycoBank: MB 810354

Pileus 5–13 cm in diam., grayish red (10C4–10C5), grayish rose (13A8), reddish gray (8B2–10B2), reddish brown (8E8–9E9), dry, subtomentose, incurved at the margin when young; context pale yellow (1A3–2A3) to light yellow (2A4–3A5), 13–18 mm thick, staining pale blue slowly when bruised. *Hymenophore* decurrent to free, surface pale yellow to light yellow (2A4–3A5), staining grayish blue

Table 1 Fungal names, specimen voucher, locations and GenBank accession numbers

Taxon	Specimen voucher	Location	GenBank accession number			
			nrLSU	*tef1-α*	*rpb1*	*rpb2*
Rugiboletus brunneiporus	HKAS 83209	Linzhi, Xizang, China	KM605134	KM605144	KM605158	KM605168
Rugiboletus brunneiporus	HAKS 83210	Shangri-La, Yunnan, China	KM605132	KM605145	KM605157	KM605171
Rugiboletus brunneiporus	HKAS 83009	Bomi, Xizang, China	KM605133	KM605146	KM605156	KM605168
Rugiboletus extremiorientalis	HKAS 76663	Neixiang, Henan, China	KM605147	KM605147	KM605159	KM605170
Rugiboletus extremiorientalis	HKAS 63591	Heqing, Yunnan, China	KM605148	KM605148	KM605160	—
Neoboletus brunneissimus	HKAS 57451	Jianchuan, Yunnan, China	KM605137	KM605149	KM605161	KM605172
Neoboletus brunneissimus	HKAS 50538	Shangri-La, Yunnan, China	KM605138	KM605150	KM605162	KM605173
Lanmaoa asiatica	HKAS 54095	Kunming, Yunnan, China	KM605141	KM605151	KM605164	KM605174
Lanmaoa asiatica	HKAS 63592	Heqing, Yunnan, China	KM605142	KM605152	KM605163	KM605175
Lanmaoa asiatica	HKAS 63603	Nanhua, Yunnan, China	KM605143	KM605153	KM605165	KM605176
Lanmaoa angustispora	HKAS 74752	Gongshan, Yunnan, China	KM605139	KM605154	KM605166	KM605177
Lanmaoa angustispora	HKAS 74759	Gongshan, Yunnan, China	KM605140	KM605155	KM605167	KM605178
Baorangia pseudocalopus	HKAS 75739	Shenlongjia, Yunnan, China	KJ184558	KJ184570	KJ184564	KM605179
Parvixerocomus pseudoaokii	HKAS 77032	Longnan, Jiangxi, China	KP658467	—	KP658471	KP658469
Parvixerocomus pseudoaokii	HKAS 80480	Guangzhou, Guangdong, China	KP658468	—	KP658472	KP658470

immediately; pores angular to nearly round, 1/mm, compound; tubes pale yellow to light yellow (2A4–3A5), 2–7 mm long (thickness of hymenophore 1/3–1/5 times that of pileal context at the position halfway to the pileus center), staining light blue to grayish blue slowly when bruised; *Stipe* subcylindrical to obclavate, 6–9×1.5–2.5 cm, pale yellow (1A3–2A3) to buttercup yellow (4A7) at the apex, and grayish red (12B4–12B6), sometimes with pale yellow background at other part, usually covered by reticulations at the upper part or only at the apex; context light yellow (2A4–2A6), yellow to canary yellow (2B7–2B8), staining pale blue when young; basal mycelia white. *Macrochemical reaction* not observed.

Basidia 22–50×8–14 μm, clavate to narrowly clavate, hyaline in KOH, 4–spored, sometimes 2–spored. *Basidiospores* 9–12.5 (14)×4–5 μm [Q=(1.88) 2.1–3 (3.2), Q_m=2.52± 0.23], subfusoid and inequilateral in side view with slightly suprahilar depression, ovate to subfusoid in ventral view, brownish-yellowish, smooth, inamyloid. *Hymenophoral trama* boletoid, hyphae cylindrical, 4–10.5 μm wide. *Cheilocystidia* 15–33×6–11 μm, ventricose-mucronate to clavate-ventricose with subacute apex, thin walled. *Pleurocystidia* 27–57×6.5–12.5 μm, fusoid-ventricose to ventricose-mucronate or clavate with subacute apex, thin walled. *Pileipellis* an interwoven trichodermium composed of brown to yellowish brown filamentous hyphae 5–11 μm in width with terminal cells 25–65×4.5–10 μm, which are almost subcylindrical, sometimes with subacute apex. *Pileal trama* composed of interwoven hyphae 4–7 μm wide. *Stipitipellis* hymeniform, 70–100 μm thick, composed of more or less vertically light brown to yellowish brown hyphae; terminal cells 19–42×10–20 μm. *Stipe trama* composed of parallel hyphae 5.5–9 μm wide. *Clamp connections* absent.

Habitat: solitary to scattered, in subtropical forests dominated by *Pinus* spp. or Fagaceae or in mixed forests.

Known distribution: Currently known from China and Japan.

Specimens examined: CHINA, YUNNAN PROVINCE: Nanhua County, bought from mushroom free market, 23 August 2010, alt. 2200 m, G. Wu 375 (HKAS 63607); same location, 18 August 2011, alt. 2200 m, G. Wu 766 (HKAS 75081); same location, 25 July 2013, alt. 2200 m, B. Feng 1378 (HKAS 82798); SICHUAN PROVINCE: Puge County, Luoji Mt., 12 September 2010, alt. 2000 m, X.F. Shi 678 (HKAS 76679); HUBEI PROVINCE: Shenlongjia District, Tianyanjing Scenic Region, 18 July 2012, alt. 1900 m, X.B. Liu 127 (HKAS 75739); same location and date, J. Qin 577 (HKAS 77979).

Commentary: *Baorangia pseudocalopus*, under the name of *Boletus pseudocalopus* by Hongo (1972), is surprisingly phenotypically very similar to *Caloboletus calopus* (Pers.) Vizzini, but the latter species has bitter taste of the context and distinct reticulations on the stipe (at least at the apex) (Zhao et al. 2014a; Hellwig et al. 2002). Phylogenetically, they appear in two different clades (Wu et al. 2014).

In Wu et al. (2014), *B. pseudocalopus* clusters together with *B. rubelloides* (≡ *Boletus bicolor* Peck, non Raddi, see below) and *Boletus rufomaculatus* Both. Morphologically, the latter two have darker pilei (red to purple-red, rusty brown to yellowish brown), and *B. rufomaculatus* has

narrower basidiospores (9.9–13.2×3.3–4.5 μm) (Bessette et al. 2000; Both 1998).

Baorangia rubelloides G. Wu, Halling & Zhu L. Yang, **nom. nov.**

Replaced synonym: *Boletus bicolor* Peck, Ann. Rep. N.Y. St. Mus. 24: 78 (1872) [1871]; *non Boletus bicolor* Raddi, Mém. Soc. Ital. Modena 13(2): 10, tab. 5, Fig. 4 (1806)

MycoBank: MB 810355

Habitat: solitary, scattered, or gregarious under broad-leaved trees.

Known distribution North America.

Specimen examined: USA, NEW YORK: North Collins Elementary School, 13 August 1977, collected by E.E. Both (BUF 2064).

Commentary: Because *Boletus bicolor* Peck (1872) is a latter homonym of *Boletus bicolor* Raddi (1806), a new name has been proposed. The epithet *rubelloides* was selected due to its morphological similarity to *Xerocomellus rubellus* (Krombh.) Šutara. Once, Singer (1947) even treated this species as a subspecies of *X. rubellus*.

In the molecular phylogenetic analysis of Wu et al. (2014), *Baorangia rubelloides* clusters together with *Boletus rufomaculatus* and forms an independent clade as two independent species along with *B. pseudocalopus*.

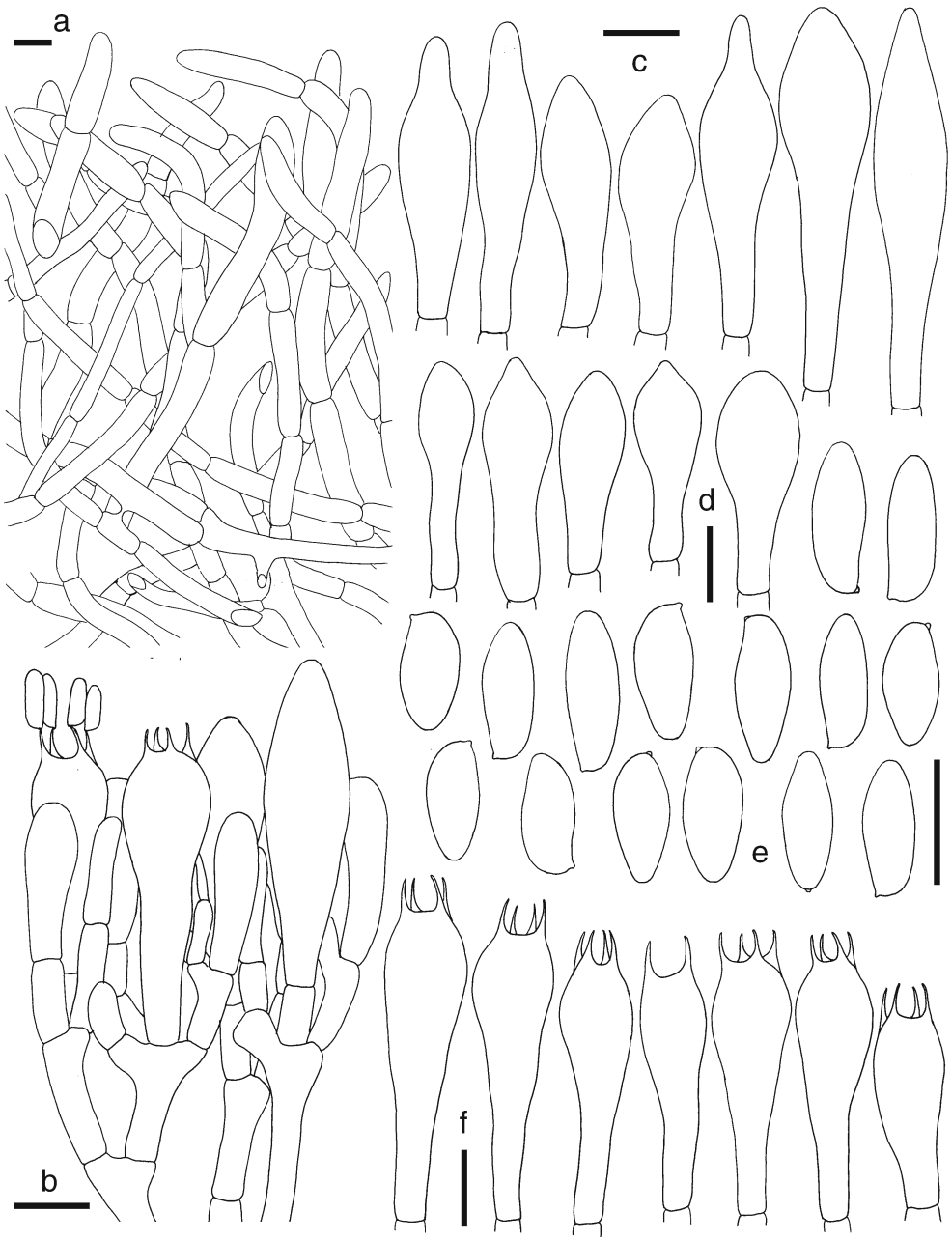


Fig. 4 *Baorangia pseudocalopus* (HKAS 75081) **a**. Pileipellis; **b**. Basidia and pleurocystidia; **c**. Pleurocystidia; **d**. Cheilocysitidia; **e**. Basidiospores; **f**. Basidia. Bars=10 μm

Morphologically, *B. rubelloides* has dark red to rose-red pilei (Bessette et al. 2000; Smith and Thiers 1971).

Lanmaoa G. Wu, Zhu L. Yang, Halling, **gen. nov.**

MycoBank: MB 810351

Etymology: *Lanmaoa* is named for Mr. Lan Mao (1397–1476, Ming Dynasty), an ancient Chinese botanist, who used the Chinese name "niuganjun" (cattle liver fungus) for boletes in the Chinese literature for the first time.

Generic diagnosis: This genus differs from all other genera of *Boletaceae* by its thin hymenophore (thickness of hymenophore 1/3–1/5 times that of pileal context at the position halfway to the pileus center) which stains blue when bruised, a light yellow context which stains pale blue slowly when cut, and an interwoven trichodermium to a subcutis pileipellis.

Generic description: *Basidiomata* stipitate-pileate with tubular hymenophore. *Pileus* hemispherical, convex or applanate, subtomentose, dry, slightly incurved at the margin when young; context off-white to cream yellow, slowly staining pale blue to light blue when injured. *Hymenophore* adnexed or sinuate, thickness of hymenophore 1/3–1/5 times that of pileal context at the position halfway to the pileus center; hymenophoral surface cream yellow to lemon yellow, staining dull blue when injured; pores angular or nearly round; tubes concolorous with hymenophoral surface or light red, staining dark blue when injured. *Stipe* central, cream yellow, light yellow to lemon yellow at the apex and light to dark purple red towards the base; basal mycelia yellowish white to white. *Pileipellis* often an interwoven trichodermium to subcutis, rarely ixosubcutis. *Pleuro-* and *cheilocystidia* subfusiform-ventricose or clavate. *Basidiospores* smooth, narrowly suboblong to subfusoid, light yellow to brownish yellow. *Clamp connections* absent.

Type species: *Lanmaoa asiatica* G. Wu & Zhu L. Yang

Phylogenetic position: Clade 49 in Wu et al. (2014)

Lanmaoa angustispora G. Wu & Zhu L. Yang, **sp. nov.** Figs. 1c, d and 5

MycoBank: MB 810364

Etymology: The epithet "*angustispora*" refers to the species with narrow spores.

Holotype: CHINA, YUNNAN PROVINCE: Gongshan County, Bingzhongluo Town, Shuangla Village, 30 July 2011, alt. 1500–1700 m, G. Wu 441 (HKAS 74752).

Pileus 4.5–12.5 cm in diam., hemispherical to convex, grayish red (7B4–7B5) to grayish orange (6B4–6B5), brownish orange (6D6–6D7) to brownish yellow (5C8–5D8), surface nearly smooth, and almost dry when young, becoming viscid when old, incurved at the margin, staining blue to dark blue immediately when touched; context cream to light yellow (1A3–1A5), 12–20 mm thick, staining pale blue to blue when cut. *Hymenophore* adnexed to sinuate, thickness of hymenophore 1/3–1/5 times that of pileal context at the position halfway to the pileus center; surface light yellow to yellow (2A5–2A7) when young and becoming grayish rose, geranium red (11B6–11B7) to grayish red (8B4–8B5) when old, staining blue to dark blue immediately when bruised; pores angular, 1.5–2/mm; tubes short, 2–7 mm long, light yellow to yellow (2A5–2A7), staining blue to dark blue immediately when bruised. *Stipe* cylindrical, 5.5–7.5×1.5–3 cm, straw yellow (3B3) to mustard yellow (3B6) at the upper part, and purplish red (13B6–13B7) to grayish Magenta (13B4–13B5) towards the base, sometimes with brownish orange tinge, often covered by purplish red dotted-elements, staining blue to dark blue immediately when touched; context almost concolorous with that of pileus, staining blue to dark blue when cut at the upper part, and staining pale blue at the lower part; basal mycelia white. *Taste* and *odor* mild. *Macrochemical reaction* not observed.

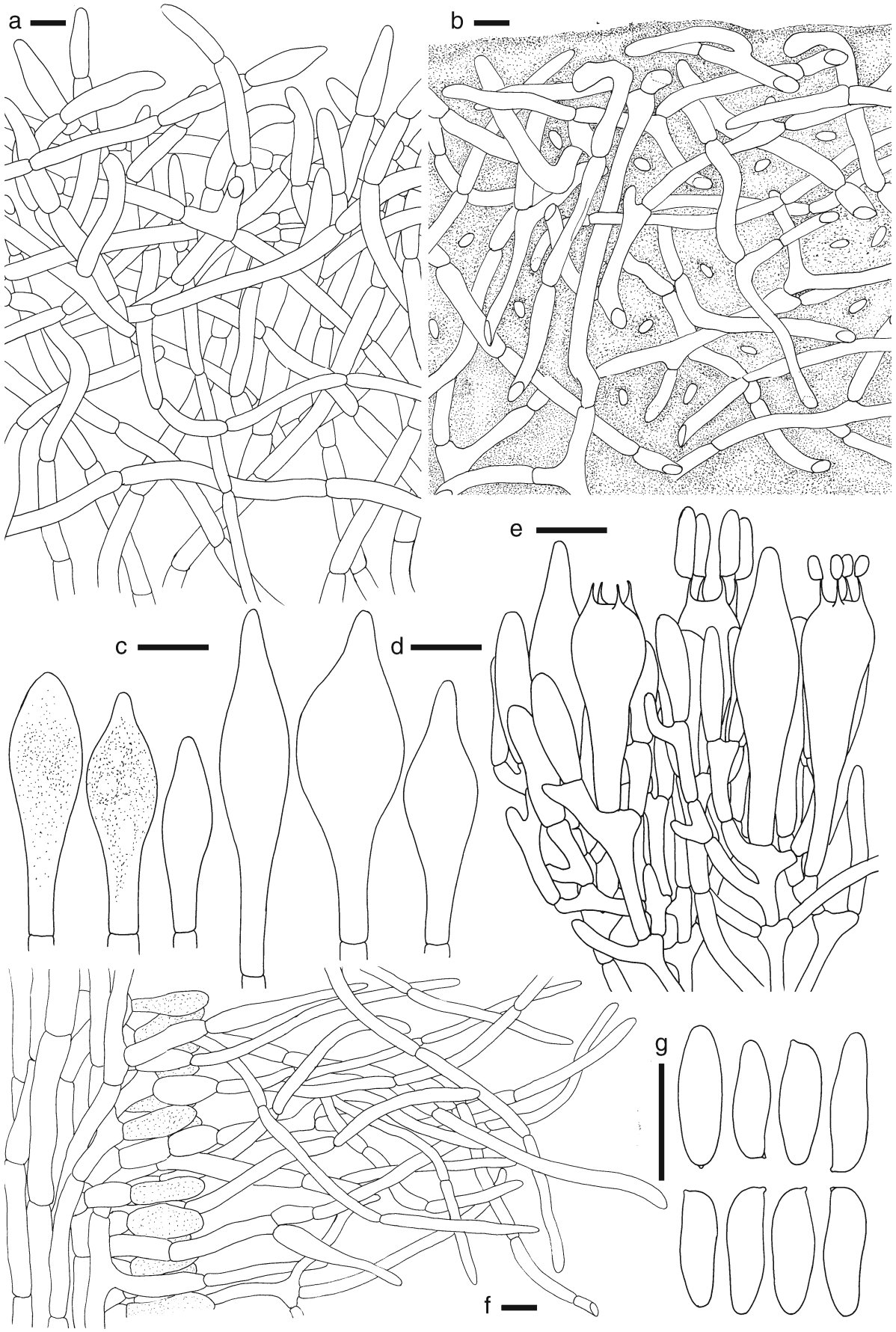
Basidia 25–49×7–13 μm, clavate to elongated clavate, hyaline in KOH, 4-spored, sometimes 2-spored. *Basidiospores* (9.5) 10–12×(3) 3.5–4 (5) μm [Q=(1.98) 2.5–3.43 (3.48), Q_m=2.95±0.25], narrowly suboblong to subfusoid and inequilateral in side view with slightly suprahilar depression, narrowly oblong to subfusoid in ventral view, brownish yellow, smooth, inamyloid. *Hymenophoral trama* boletoid; hyphae cylindrical, 6–9 μm wide. *Cheilocystidia* 19–49×5–13 μm, fusoid-ventricose to clavate with subacute apex, usually containing yellow to brownish yellow pigments, thin walled. *Pleurocystidia* 25–60×7–15 μm, fusoid-ventricose to broadly fusoid-ventricose, sometimes with subacute apex, thin walled. *Pileipellis* an interwoven trichodermium when young, and an interwoven ixotrichodermium to ixosubcutis when old, composed of light brown to yellowish brown interwoven filamentous hyphae 3–4.5 μm in width with terminal cells 20–80×4–8 μm, which are almost subcylindrical, sometimes with subacute apex or rarely cystidioid. *Pileal trama* composed of interwoven hyphae 3.5–7 μm wide. *Stipitipellis* 120–180 μm thick, composed of two layers, outer layer consisting of hyaline interwoven filamentous hyphae, terminal cells 40–82×2.5–4 μm; inner layer hymeniform, with terminal cells clavate (25–32×5–10 μm), often with brownish yellow intracellular pigments. *Stipe trama* composed of parallel hyphae 5–10 μm wide. *Clamp connections* absent.

Habitat: scattered, in subtropical forests of *Castanea mollissima* or mixed forests of *Castanea mollissima* and *Pinus yunnanensis*.

Known distribution: Currently only from southwestern China.

Additional specimens examined: CHINA, YUNNAN PROVINCE: Gongshan County, Bingzhongluo Town, Ridang village, alt. 1500–1700 m, G. Wu 448 (HKAS 74759); the same town and date, near Dala village, alt. 1500–1700 m, G. Wu 454 (HKAS 74765).

Commentary: *Lanmaoa angustispora* is morphologically similar to *L. flavorubra* mentioned below and clustered together based on molecular data, but *L. flavorubra* has broader basidiospores (9.1–11.9×4.2–4.9 μm) and a darker (brownish


a
b
e
c
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◀ **Fig. 5** *Lanmaoa angustispora* (holotype) **a**. Pileipellis (young basidioma); **b**. Pileipellis (mature basidioma); **c**. Cheilocysitidia; **d**. Pleurocystidia; **e**. Basidia and pleurocystidia; **f**. Stipitipellis; **g**. Basidiospores. Bars=10 μm

red) stipe with fine reticula at the apex (Halling and Mata 2004).

Lanmaoa asiatica G. Wu & Zhu L. Yang, **sp. nov.** Figs. 1e, f and 6

MycoBank: MB 810365

Etymology: The epithet "*asiatica*" is proposed because this species is located in East Asia.

Holotype: CHINA, YUNNAN PROVINCE: Kunming City, bought from a mushroom free market, 8 June 2008, alt. 1900 m, Z.L. Yang 5058 (HKAS 54094).

Pileus 5–11 cm in diam., hemispherical to broadly convex, sometimes wrinkled, and slightly incurved at the margin, shell pink (8A3), dull red (9B3) to red (11A7–11A8), dry, staining brown to dark brown when touched; context pale yellow (2A4–2A5), 10–30 mm thick, staining pale blue to light blue slowly when bruised. *Hymenophore* sinuate, thickness of hymenophore 1/3–1/4 times that of pileal context at the position halfway to the pileus center; surface and tubes light yellow (2A5–2A7), staining light blue to blue immediately when bruised; pores irregular to nearly round, 1.5–3/mm; tubes short, 3–7 mm long, staining

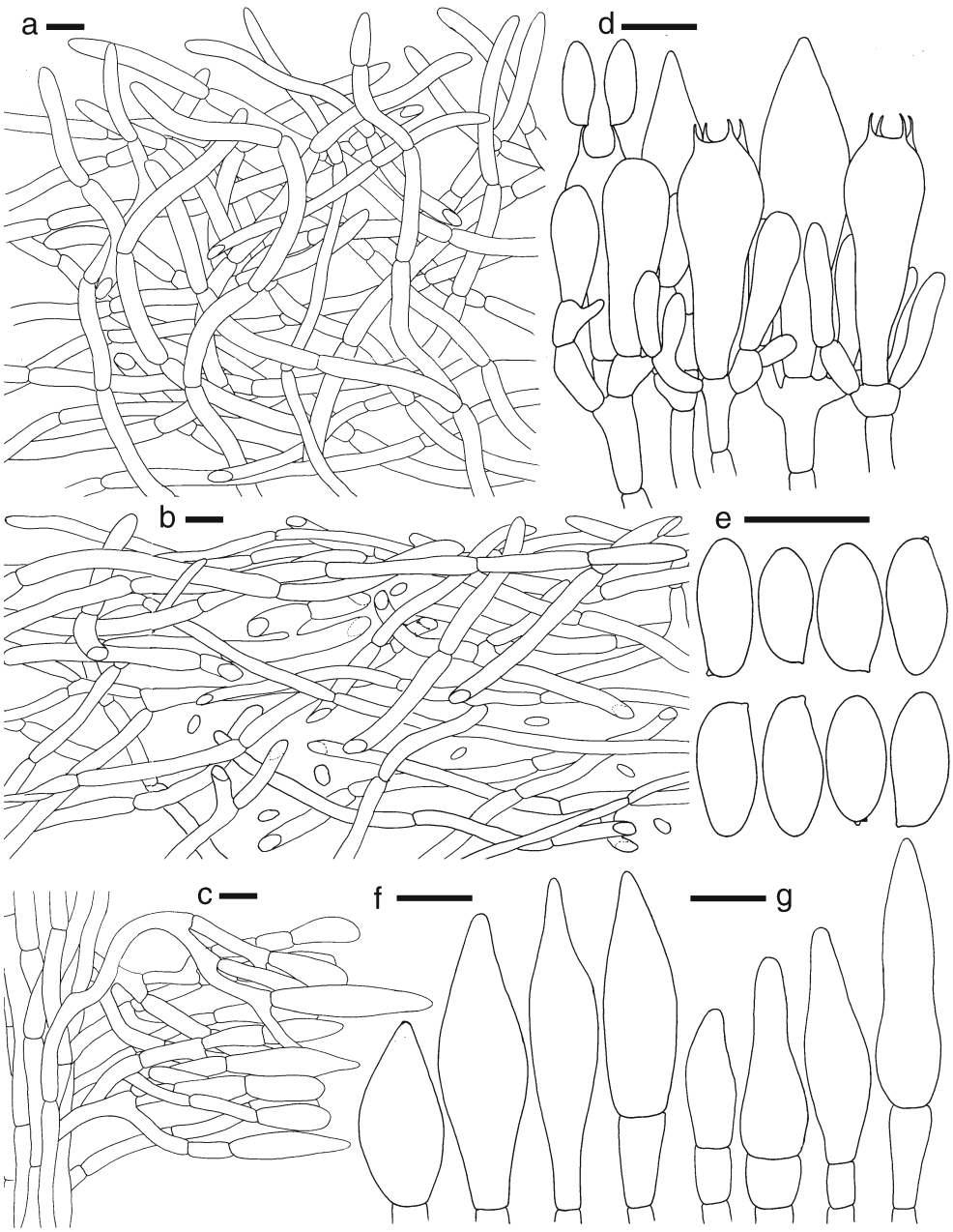

Fig. 6 *Lanmaoa asiatica* (holotype) **a**. Pileipellis (from the 1/2-radius part of the pileus); **b**. Pileipellis (from the submarginal part of the pileus) **c**. Stipitipellis; **d**. Basidia and pleurocystidia; **e**. Basidiospores; **f**. Pleurocystidia; **g**. Cheilocysitidia. Bars=10 μm

light blue to blue immediately when bruised. *Stipe* subcylindrical, obclavate, sometimes bulbous at base, 8–11× 1–3 cm, light yellow to chicken yellow (2A5–2A6) at the apex and grayish red to brownish red (6C5–6C6), grayish ruby (12C5–12C6) towards the base, sometimes with reticulations at the upper part; context chicken yellow to maize yellow (2A6–4A6), darker than that of pileus, staining pale blue to light blue slowly when bruised, especially at the place near outside; basal mycelia yellowish white. *Macrochemical reaction* the surface of the cap stains light yellow to yellow with KOH.

Basidia 24–52×6–12 μm, clavate, 4-spored, sometimes 1- or 2-spored. *Basidiospores* (8.5) 9–11.5 (13)×4–5.5 (6) μm [Q=(1.7) 1.86–2.63 (2.75), Q_m=2.20±0.18], subfusoid and inequilateral in side view with distinctly suprahilar depression, elliptic-subfusiform to oviform in ventral view, brownish yellow, smooth, inamyloid. *Hymenophoral trama* boletoid; hyphae cylindrical, 6–10.5 μm wide. *Cheilocystidia* 14–36×5–12 μm, fusoid-ventricose to obclavate, usually with subacute apex and always with a short cell adhered, thin-walled. *Pleurocystidia* 21–50×6–13 μm, broadly fusoid-ventricose to ventricose, with subacute apex, thin walled. *Pileipellis* an interwoven trichodermium to a subcutis composed of almost hyaline interwoven filamentous hyphae 2.5–5 μm in width with terminal cells 14–57×3–5 μm, which are almost subcylindrical with subacute apex. *Pileal trama* composed of interwoven hyphae 2–6 μm wide. *Stipitipellis* hymeniform, 65–90 μm thick, composed of more or less vertically light brown to yellowish brown hyphae, with terminal cells 17–43×6.5–9 μm. *Stipe trama* composed of parallel hyphae 4–6 μm wide. *Clamp connections* absent.

Habitat: solitary to scattered, in subtropical forests of *Pinus yunnanensis* or mixed forests of *Pinus yunnanensis* and *Quercus* spp.

Known distribution: Currently only known from southwestern China.

Additional Specimens examined: CHINA, YUNNAN PROVINCE: Shizong County, Danfeng Town, Shuzu village, 8 August 2010, alt. 2600 m, G. Wu 285 (HKAS 63516); Heqing County, Yanglongtan, 22 August 2010, alt. 2200 m, G. Wu 360 (HKAS 63592); Nanhua County, mushroom free market, 23 August 2010, alt. 2200 m, G. Wu 370 (HKAS 63602), and same location and date, G. Wu 371–374 (HKAS 63603–63606); Kunming City, bought from a mushroom free market, 8 June 2008, alt. 1900 m, Z.L. Yang 5059 (HKAS 54095); Nanhua County, bought from a mushroom free market, 23 August 2010, alt. 2200 m, G. Wu 1237a (HKAS 82696).

Commentary: *Lanmaoa asiatica* is very close to *L. carminipes* (see below) based on molecular data (Wu et al. 2014). However, *L. carminipes* has a quickly bluing reaction when its context is bruised and significantly narrower basidiospores (9–12×3–3.5 μm) (Bessette et al. 2000). *Baorangia rubelloides* (≡ *Boletus bicolor* Peck, non Raddi) is also similar to *L. asiatica*, but is negative with KOH on the cap and may form ectomycorrhizae with oaks (Bessette et al. 2000), while *L. asiatica* stains light yellow to yellow with KOH on the cap and is probably specific to pines due to its occurrence mainly in pines forests.

Lanmaoa carminipes (A.H. Sm. & Thiers) G. Wu, Halling & Zhu L. Yang, **comb. nov.**

Basionym: *Boletus carminipes* A.H. Sm. & Thiers, Boletes of Michigan (Ann Arbor): 282 (1971)

MycoBank: MB 810366

Habitat: solitary, scattered, or gregarious under trees of Fagaceae.

Known distribution: North America.

Specimens examined: USA, NEW YORK: Chestnut Ridge Road, Orchard Park, 4 August 1973, collected by E.E. Both (BUF 1730).

Commentary: This species is inferred to belong to *Lanmaoa* based on the molecular data of Nuhn et al. (2013) and Wu et al. (2014). Its short hymenophore and subcutis to cutis pileipellis meet the main characters of *Lanmaoa* (Smith and Thiers 1971).

Lanmaoa flavorubra (Halling & M. Mata) G. Wu, Halling & Zhu L. Yang, **comb. nov.**

Basionym: *Boletus flavoruber* Halling & M. Mata, Bull. Soc. mycol. Fr. 120(1–4): 258 (2005) [2004]

MycoBank: MB 810367

Habitat: scattered to gregarious in forests of Fagaceae (*Quercus seemanii*, *Q. rapurhuensis*, and *Q. copeyensis*).

Known distribution: Central America.

Specimens examined: COSTA RISCA, San José: Dota. Jardín, 5 June 2004, alt. 2220 m, RE Halling 8593 (NY 775777, isotype); same location, 01 July 1998, alt. 2220 m, RE Halling 7796 (NY 817328).

Commentary: *Lanmaoa flavorubra* is clustered in the *Lanmaoa* clade (Clade 49 of Wu et al. 2014) and is close to *L. angustispora* (HKAS 74765). For morphological comparisons between the two species, see the discussion under *L. angustispora*.

Lanmaoa pseudosensibilis (A.H. Smith & Thiers) G. Wu, Halling & Zhu L. Yang, **comb. nov.**

Basionym: *Boletus pseudosensibilis* A.H. Sm. & Thiers, Boletes of Michigan (Ann Arbor): 281 (1971)

MycoBank: MB 810368

Habitat: gregarious under broadleaf trees (Fagaceae).

Known distribution: North America.

Specimens examined: USA NEW YORK: Bronx, New York Botanical Garden, 15 August 1989, collected by R.E. Halling (NY, without herbarium number).

Commentary: Based on the results of Nuhn et al. (2013) and Wu et al. (2014), this species belongs to this genus. Its short tubes and subcutis pileipellis coincide with the main

morphological characters of this genus (Smith and Thiers 1971).

Parvixerocomus G. Wu & Zhu L. Yang, **gen. nov.**

MycoBank: MB 811420

Etymology: "*Parvixerocomus*" refers to the *Xerocomus*-like small basidioma.

Generic diagnosis: This genus differs from all other genera of *Boletaceae* by its small basidiomata (usually <4 cm in diam.) with yellow hymenophoral tubes and pores which stain blue when bruised, ovoid to ellipsoid smooth spores, and an epithelioid pileipellis.

Generic description: *Basidioma* stipitate-pileate with tubular hymenophore, small. *Pileus* convex to applanate, subtomentose, dry; context yellowish to yellow, staining blue immediately when injured. *Hymenophore* subdecurrent, often with teeth on the apex of stipe; hymenophoral surface yellowish to yellow, staining blue immediately when injured; pores irregular, angular to nearly round, often compound; tubes concolorous with hymenophoral surface, staining blue immediately when injured. *Stipe* central, light brown, brownish red to reddish brown, surface often pruinose; basal mycelia cream to grayish yellowish. *Pileipellis* an epithelium composed of submoniliform to moniliform hyphae with cystidioid terminal cells. *Pleuro-* and *cheilocystidia* subfusiform-ventricose or clavate, with subacute apex or with long beak. *Basidiospores* smooth, ovoid to ellipsoid, yellowish to brownish yellow. *Clamp connections* absent.

Type species: *Parvixerocomus pseudoaokii* G. Wu, K. Zhao & Zhu L. Yang

Phylogenetic position: Clade 29 in Wu et al. (2014)

Parvixerocomus pseudoaokii G. Wu, K. Zhao & Zhu L. Yang, **sp. nov.** Figs. 2g, h and 7

MycoBank: MB 811421

Etymology: "*pseudoaokii*" refers to the close relationship to *Parvixerocomus aokii* (Hongo) G Wu & Zhu L. Yang

Holotype: CHINA, GUANGDONG PROVINCE: Guangzhou City, Baiyun Mt. 28 May 2013, alt. 200 m, G. Wu 1106 (HKAS 80480).

Pileus 0.8–3 cm in diam., convex to applanate; surface yellowish red, grayish red to rose red (8B6–8B7, 12A8–12B8), subtomentose, dry, sometimes incurved at the margin; context 2–4 mm thick, pale yellow to light yellow (2A3–2A4), staining light blue to blue when cut. *Hymenophore* subdecurrent; surface pale yellow to light yellow (3A3–3A5), staining blue when cut; pores irregular, angular to nearly, ca. 1–2/mm, tubes 0.7–2.5 mm long, concolorous with hymenophoral surface, staining light blue to blue when cut.

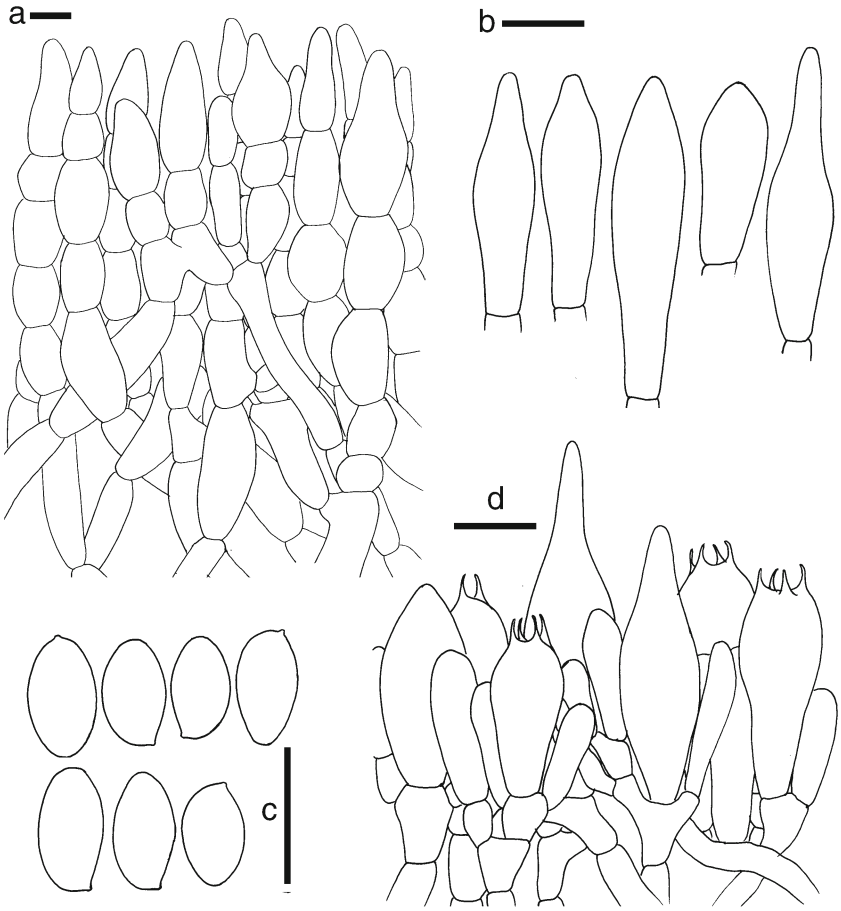

Fig. 7 *Parvixerocomus pseudoaokii* (holotype) **a**. pileipellis; **b**. Cheilocystidia; **c**: Basidiospores; **d**: Basidia and pleurocystidia. Bars=10 μm

Stipe central, cylindrical to subcylindrical, 1–2×0.15–0.2 cm, bluish red to grayish ruby (12B7–12C7) or reddish gold to brownish red (6C7–6C8); surface pruinose, staining blue when touched; context similar to that of pileus; basal mycelia cream to light yellow. *Macrochemical reaction* not observed.

Basidia 20–35×9–12 μm, clavate, 4-spored, rarely 2-spored. *Basidiospores* 7–8.5 (9)×4–5 (5.5) μm [Q=(1.4) 1.47–1.89 (2), Qm=1.66±0.11], ovoid and inequilateral in side view with indistinctly suprahilar depression, ovoid in ventral view, brownish yellow, smooth, inamyloid. *Hymenophoral trama* intermediate between boletoid and phylloporoid; hyphae cylindrical, 5–10 μm wide. *Cheilocystidia* 23–52×6–10 μm, fusoid-ventricose to clavate with subacute apex, rarely with a long beak, thin walled. *Pleurocystidia* 30–65×8–15 μm, fusoid-ventricose to broadly fusoid-ventricose, with a long beak, thin walled. *Pileipellis* an epithelium, up to 100 μm thick, composed of submoniliform to moniliform hyphae 7–16 μm wide, with cystidioid terminal cells 18–41×8–17 μm. *Pileal trama* composed of interwoven hyphae 7–15 μm wide. *Stipitipellis* thin, ca. 20–40 μm thick, hymeniform, with clavate terminal cells 33–44×6.5–20 μm. *Stipe trama* composed of parallel hyphae 9–15 μm wide. *Clamp connections* absent.

Habitat: scattered, in subtropical forests of Fagaceae (*Lithocarpus*, *Castanopsis*, *Quercus* etc.) or mixed forests of Fagaceae and *Pinus massoniana*.

Known distribution: Currently only from southwestern, southeastern and southern China.

Additional specimens examined: CHINA, JIANGXI PROVINCE: Longnan County, Jiulian Mt. 12 June 2012, alt. 450 m, G. Wu 860 (HKAS 77032); GUANGDONG PROVINCE: Guangzhou City, Baiyun Mt., 28 May 2013, alt. 200 m, K. Zhao 227 (HKAS 80652); same city, Huolu Mt., 30 May 2013, alt. 100 m, K. Zhao 237 (HKAS 80662); YUNNAN PROVINCE: Jinghong City, Dadugang town, 14 July 2006, alt. 1450 m, Y.C. Li 537 (HKAS 50291); same location, 23 July 2007, Y.C. Li 946 (HKAS 52633).

Commentary: *Parvixerocomus pseudoaokii* is characterized by its small basidioma staining blue when hurt and small basidiospores. Phylogenetically and morphologically, *Parvixerocomus aokii* is closely related to *P. pseudoaokii*, but *P. aokii* differs from the latter by its longer basidiospores (9–12.5×4–5 μm) (Hongo 1984). Morphologically, *Xerocomus parvulus* Hongo and *Boletus pseudoparvulus* Bi are similar to *P. pseudoaokii*. However, *X. parvulus* differs from *P. pseudoaokii* by its broader basidiospores (7.5–11×5–6.5 μm) and longer pleurocystidia (70–89×12–15 μm) (Hongo 1963); and *B. pseudoparvulus* differs from *P. pseudoaokii* by its narrower basidiospores 6.6–10×3–3.3 μm and different discoloration when hurt (staining purplish red) (Bi et al. 1982).

Parvixerocomus aokii (Hongo) G. Wu, N.K. Zeng & Zhu L. Yang, **comb. nov.** Figs. 2i, j and 8

MycoBank: MB 811422

Basionym: *Boletus aokii* Hongo, Trans. Mycol. Soc. Japan 25(3): 283 (1984)

Pileus 1.5–2 cm in diam., subhemispherical to applanate; surface orange red, vivid red to red (8A8–10B8), subtomentose, dry, rarely crackled on the surface; context 2–4 mm thick, pale yellow to light yellow (3A3–3A4), staining dark blue to blackish blue when cut. *Hymenophore* subdecurrent; surface light yellow to yellow (3A5–3A7), staining blue to dark blue immediately when hurt; pores nearly round to irregular, ca. 1–2/mm, tubes up to 2 mm long, concolorous with hymenophoral surface, staining blue when cut. *Stipe* central, cylindrical to subcylindrical, ca. 1.5×0.2 cm, orange red to carrot red (6B7–6B8), with yellow tinge at the base; surface indistinctly fibrillose, staining blue when touched; context similar to that of pileus; basal mycelia light yellow. *Macrochemical reaction* not observed.

Basidia 32–42×8–11 μm, clavate, 4-spored. *Basidiospores* 9–10 (11)×(4) 4.5–5 μm [Q=(1.20) 1.40–2.00, Q_m=1.67±0.18], ellipsoid and inequilateral in side view with indistinctly suprahilar depression, ellipsoid in ventral view, light yellow to brownish yellow, smooth, inamyloid. *Hymenophoral trama* boletoid; hyphae cylindrical, 3–8 μm wide. *Cheilocystidia* 35–57×7–12 μm, fusoid-ventricose to clavate with subacute apex, rarely with a long beak, thin walled. *Pleurocystidia* 50–62×9–11 μm, fusoid-ventricose to broadly fusoid-ventricose with subacute apex, thin walled. *Pileipellis* an epithelium, composed of submoniliform to moniliform hyphae with cystidioid terminal cells 23–50×7–10 μm. *Pileal trama* composed of interwoven hyphae 4–10 μm wide. *Clamp connections* absent.

Habitat: scattered, in subtropical to tropical forests of Fagaceae.

Known distribution: Currently only from south China and Japan.

Specimens examined: CHINA, HAINAN PROVINCE: Wanning City, Tongtieling, 6 May 2008, alt. 50 m, N.K. Zeng 3 (HKAS 59812).

Commentary: *Parvixerocomus aokii* was originally described as *Boletus aokii* by Hongo (1984) from Japan. Phylogenetically and morphologically, *P. pseudoaokii* is quite close to *P. aokii*. However, *P. pseudoaokii* differs from *P. aokii* by its shorter basidiospores.

Rugiboletus G. Wu & Zhu L. Yang, **gen. nov.**

MycoBank: MB 810352

Etymology: "*Rugi*-" refers to the wrinkled pileus.

Generic diagnosis: This genus differs from all other genera of *Boletaceae* by its distinctively wrinkled and gelatinized pileus with yellow hymenophoral tubes, a stipe surface covered with distinctively dotted squamules, and an ixotrichodermium pileipellis.

Generic description: *Basidiomata* stipitate-pileate with tubular hymenophore. *Pileus* hemispherical, convex or applanate, subtomentose, dry, strongly wrinkled (especially when young), usually with incurved or extended margin;

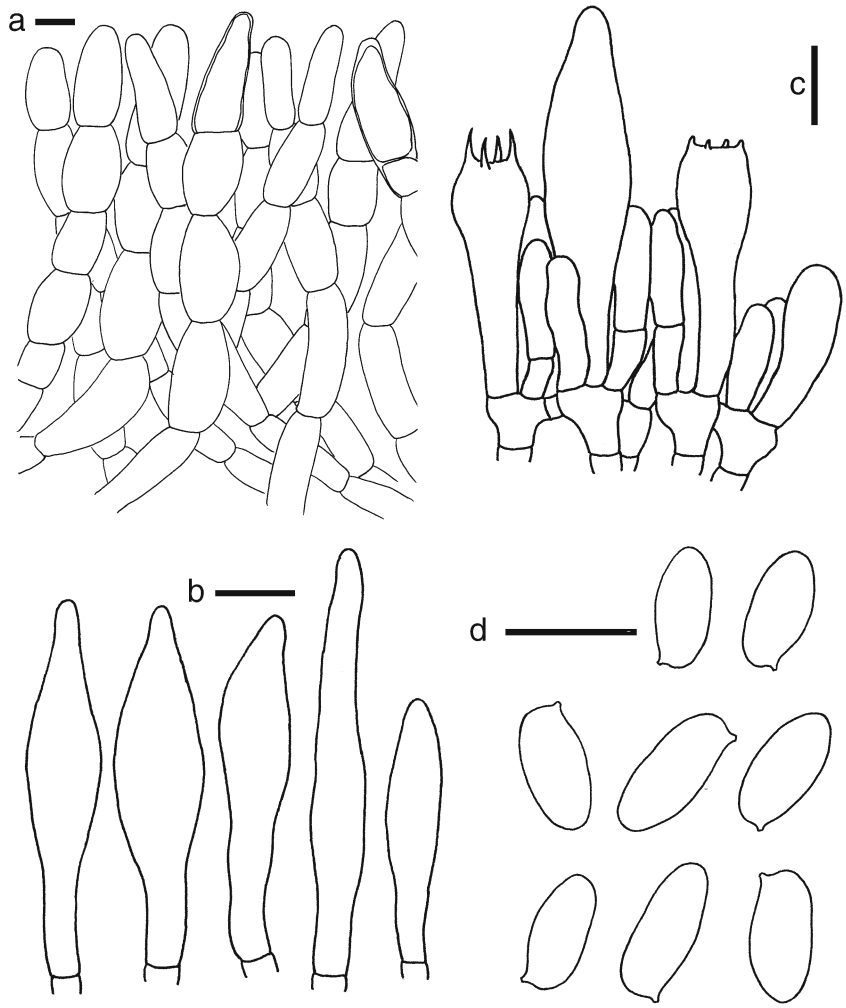

Fig. 8 *Parvixerocomus aokii* (HKAS 59812) **a**. Pileipellis; **b**. Pleurocystidia and cheilocystidia; **c**. Basidia and pleurocystidia; **d**. Basidiospores. Bars=10 μm

context cream, light yellow to yellow, unchanging or staining light blue slowly when bruised. *Hymenophore* adnexed; hymenophoral surface light yellow, yellow, or brown, reddish brown to yellowish brown, unchanging or staining blue to dark blue quickly when bruised; pores nearly round to round; tubes grayish-yellowish, brownish yellow, unchanging or staining blue, dark blue to greenish blue quickly when bruised, adnate. *Stipe* central, light yellow to yellow, covered by minute squamules; context cream to light yellow, unchanging or staining light blue slowly when bruised; basal mycelia off-white to light yellow. *Pileipellis* an ixotrichodermium to an interwoven ixotrichodermium. *Pleuro-* and *cheilocystidia* subfusiform-ventricose. *Basidiospores* smooth, subfusiform, brownish yellow. *Clamp connections* absent.

Type species: *Rugiboletus extremiorientalis* (Lar.N. Vassiljeva) G. Wu & Zhu L. Yang

Phylogenetic position: Clade 47 in Wu et al. (2014)

Rugiboletus brunneiporus G. Wu & Zhu L. Yang **sp. nov.** Figs. 2k, l and 9

MycoBank: MB 810362

Holotype: CHINA, XIZANG Autonomous Region: Linzhi County, Lulang Town, Zhaxigang Village, 1 August 2014, alt. 3300 m, B. Feng 1676 (HKAS 83209).

Pileus 10–20 cm in diam., hemispherical to broadly convex, earthy yellow, brownish yellow, yellowish brown (4C8–5C8), reddish brown (8E7–8E8), usually viscid to heavily viscid, incurved or suspended at the margin, usually wrinkled on the surface; context light yellow to yellow (4A4–4A7), ca. 2.5 cm thick, staining dark blue when bruised at some place, especially close to the hymenophore. *Hymenophore* adnexed; surface brownish yellow (5C6–5C8), reddish brown (8E8–9E8), brownish violet to violet-brown (11D7–11E7), staining dark blue immediately when bruised; pores nearly round, minute, ca. 2.5/mm; tubes yellow (2B8–3B8) to olive yellow (2C6–3C6), 1–1.5 cm long, adnexed to free, staining dark blue immediately when bruised. *Stipe* 12–22×2–4 cm, subcylindrical to obclavate, yellow to orange yellow (3A8–5A8), with nearly black dotted squamules on the stipe; context pale yellow, light yellow to yellow (2A5–4A5) mixed with brown tinge, staining dark blue immediately at some place; basal mycelia cream to light yellow. *Macrochemical reaction* not observed.

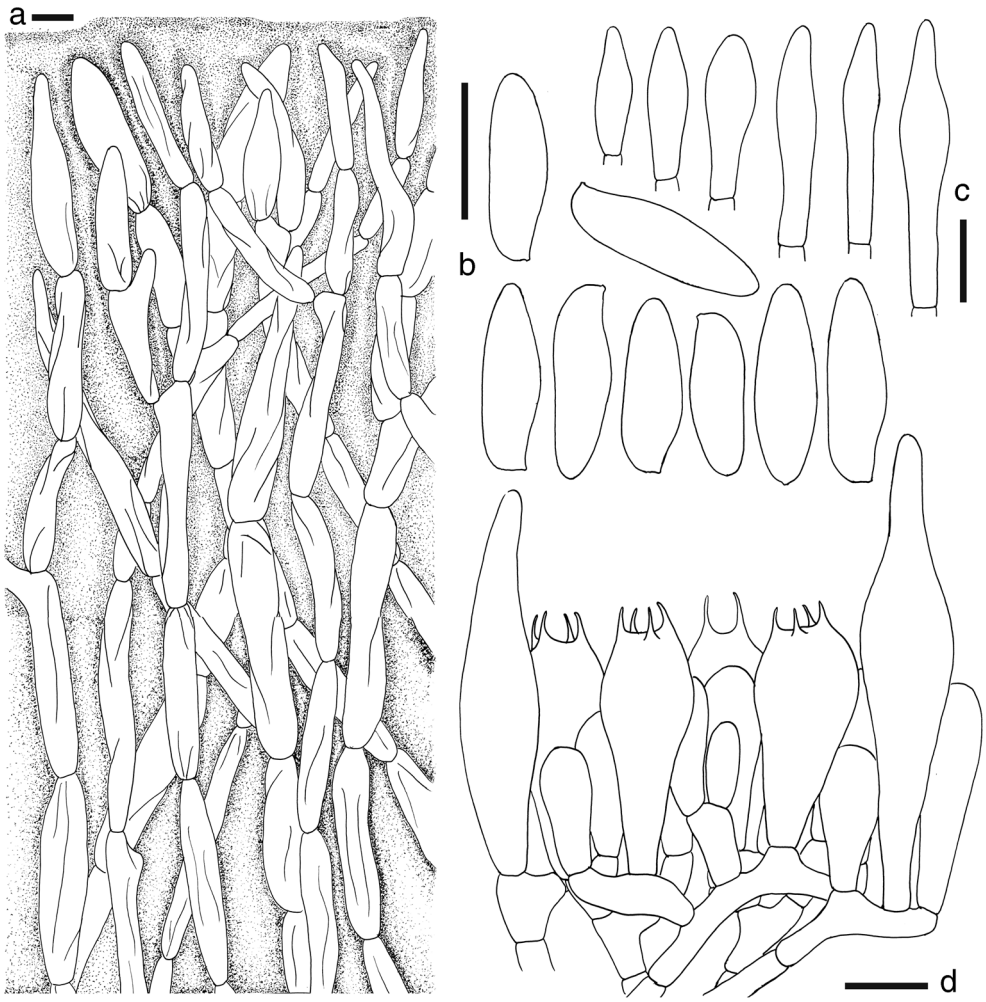

Fig. 9 *Rugiboletus brunneiporus* (holotype) **a**. Pileipellis; **b**. Basidiospores; **c**. Cheilocysitidia; **d**. Basidia and pleurocystidia. Bars=10 μm

Basidia 20–42×8–13 μm, elongate-clavate, clavate to broad-clavate, 4-spored, sometimes 2-spored. *Basidiospores* 12–15×4–5.5 (6) μm, [Q=(2.18) 2.60–3.33 (3.75), Q_m= 2.96±0.19], subfusoid and inequilateral in side view with distinct suprahilar depression, narrow subfusiform to elongated oviform in ventral view, light yellow, smooth, inamyloid. *Hymenophoral trama* boletoid, hyphae cylindrical, 4–11 μm wide. *Cheilocystidia* 16–35×4–7 μm, fusoid-ventricose to subfusoid-mucronate with subacute apex, or clavate, thin walled. *Pleurocystidia* 30–50×6–12 μm, broadly fusoid-ventricose to ventricose, always with long beak, thin walled. *Pileipellis* an ixotrichodermium to an interwoven ixotrichodermium, composed of brownish yellow to yellowish brown filamentous hyphae 4–9 μm in width (sometimes branched) with terminal cells 18–82×3–13 μm, which are subcylindrical, often with subacute apex to cystidioid, sometimes inflated. *Pileal trama* composed of interwoven hyphae 6–12 μm wide. *Stipitipellis* hymeniform, 80–100 μm thick, composed of more or less vertically brownish yellowish to light brown hyphae; caulocystidia 18–37.5×6–11 μm, caulobasidia 19–38×6–8 μm. *Stipe trama* composed of distinctly thick-walled (ca. 1 μm) parallel hyphae 5–7.5 μm wide. *Clamp connections* absent.

Habitat: solitary or scattered, under *Abies* spp. or *Picea* spp., or in subalpine mixed forests of *Picea/Abies* and Fagaceae (*Quercus* spp.).

Known distribution: Currently known from southwestern China.

Specimens examined: CHINA, XIZANG Autonomous Region: Bomi County, 3 July 2014, alt. 2700 m, Y.J. Hao 1218 (HKAS 83009); YUNNAN PROVINCE: Shangri-La County, bought from mushroom market, 25 July 2011, alt. 3300 m, G. Wu 419 (HKAS 74730); same county, Xiaoxueshan Mt., 9 August 2014, alt. 3900 m, B. Feng 1719 (HAKS 83210); Dali city, Cangshan Mt., 12 August 2010, alt. 3500 m, B. Feng 805 (HKAS 68586); Deqin County, Benzilan Town, Baima Mt., 18 August 2008, alt. 4200 m, Y.C. Li 1519 (HKAS 56359).

Commentary: Phylogenetically, *Rugiboletus brunneiporus* is a sister species of *R. extremiorientalis*, and they share many morphologically similarities so that misidentification often occurs. However, the former is located in subalpine regions

which are dominated by *Picea* spp. or *Abies* spp. and has a brown to reddish brown hymenophore surface.

Morphologically, *R. brunneiporus* is also similar to *Boletus hortonii* A.H. Sm. & Thiers and *Leccinum rugosiceps* (Peck) Singer, both of which have rugose caps and terminal inflated cells of the pileipellis (Smith and Thiers 1971). However, both *B. hortonii* and *L. rugosiceps* lack a brown hymenophoral surface. Moreover, *B. hortonii* has narrower basidiospores (12–15×3.5–4.5 μm) and the oxidation reaction of *L. rugosiceps* when bruised is non-blue stain (Smith and Thiers 1971). Phylogenetically, these two species have been proven to belong to different subfamilies. *Boletus hortonii* was clustered in the "xerocomoid boletes (Binder and Besl 2000)" group, namely, the subfamily *Xerocomoideae* (Wu et al. 2014). Therefore, it was transferred to the genus *Xerocomus* by Binder and Besl (2000). *Leccinum rugosiceps* was grouped in *Leccinum* s. s. by Drehmel et al. (2008), which belongs to the subfamily *Leccinoideae* (Wu et al. 2014).

Rugiboletus extremiorientalis (Lj.N. Vassiljeva) G. Wu & Zhu L. Yang, **comb. nov.** Figs. 2m, n and 10

Basionym: *Krombholzia extremiorientalis* Lj.N. Vassiljeva, Notul. Syst. Sect. Cryptog. Inst. Bot. Acad. Sci. USSR. 6: 191 (1950) (nom. invalid).

Leccinum extremiorientale (Lar. N. Vassiljeva) Singer, Agaric. Mod. Tax., Edn 2 (Weinheim): 744 (1962).

MycoBank: MB 810363

Pileus 8–11 cm in diam., hemispherical to broadly convex, subtomentose, brownish yellow, yellowish brown to brown (5C8–5E8), often viscid when wet, incurved or suspended at the margin, usually wrinkled when young and crackled when old; context pale yellow to light yellow (2A2–2A4), ca. 2 cm thick, unchanging when bruised. *Hymenophore* adnexed; surface cream yellow, light yellow (3A7–3A8), almost concolorous with tubes, unchanging when bruised; pores nearly round, minute, ca. 2.5/mm, unchanging when bruised; tubes grayish yellowish (2B3–2B4), 1.5–2 cm long, free, unchanging when bruised. *Stipe* 9×2 cm, cylindrical to subcylindrical, light yellow to canary yellow (2A5–2B8), with concolorous or darker (brownish yellow) dotted squamules on the stipe, sometimes streaked with fibrils at the lower part; context pale yellow to light yellow (2A2–2A4) mixed with brown tinge, unchanging when bruised; basal mycelia off-white. *Macrochemical reaction* not observed.

Basidia 21–36×8.5–14 μm, clavate to broadly clavate, 4-spored, sometimes 1 or 2-spored. *Basidiospores* 11–13×4–5 (5.5) μm, [Q=(2.18) 2.45–3.17 (3.25), Q_m=2.81±0.19], subfusoid and inequilateral in side view with distinct suprahilar depression, narrow subfusiform to elongated oviform in ventral view, light yellow, smooth, inamyloid. *Hymenophoral trama* boletoid, hyphae cylindrical, 4–8 μm wide. *Cheilocystidia* 22–35×5–8 μm, fusoid-ventricose to subfusoid-mucronate with subacute apex, or clavate, thin walled. *Pleurocystidia* 20–60×7–13 μm, broadly fusoid-ventricose to ventricose, sometimes with subacute apex, thin walled. *Pileipellis* an ixotrichodermium to an interwoven ixotrichodermium composed of brown to yellowish brown branched filamentous hyphae 3–6 μm in width with terminal cells 26–64×3–11 μm, which are almost subcylindrical with subacute apex to cystidioid, rarely inflated. *Pileal trama* composed of interwoven hyphae 3–6 μm wide. *Stipitipellis* hymeniform, 60–90 thick, composed of more or less vertically light brown to yellowish brown hyphae, terminal cells 20–40×8–16 μm. *Stipe trama* composed of slightly thick-walled (<1 μm) parallel hyphae 5–10 μm wide. *Clamp connections* absent.

Habitat: solitary or scattered, in mixed forests of *Pinus* spp. (*P. yunnanensis* and *P. densiflora*, etc.) and Fagaceae (*Quercus* spp., *Castanopsis* spp., and *Lithocarpus* spp.) or the forests dominated by Fagaceae.

Known distribution: China: Currently known from southwestern, central, and northeastern China (Li and Bau 2003); Far East Russia (Vassiljeva 1950); Korea (Kim et al. 1975); Japan (Hongo and Izawa 1994); Nepal (Christensen 2009); Thailand (Chantorn et al. 2007).

Specimens examined: CHINA, YUNNAN PROVINCE: Gongshan County, Bingzhongluo Natural Reserve, 2 August 2010, alt. 1600 m, Q. Cai 252 (HKAS 67814); Gongshan County, Dandang Park, 31 July 2011, alt. 1900 m, G. Wu 459 (HKAS 74770); Heqing County, Yanglongtan, 22 August 2010, alt. 2200 m, G. Wu 359 (HKAS 63591); Nanhua County, mushroom free market, 25 August 2010, alt. 2200 m, G. Wu 402 (HKAS 63635); Kunming City, mushroom free market, 10 August 2010, alt. 1900 m, G. Wu 292 (HKAS 63523); HENA N PROVINCE: Neixiang County, Taohuayuan, 31 July 2010, alt. 350 m, X.F. Shi 412 (HKAS 76663).

Commentary: *Rugiboletus extremiorientalis* was originally considered as a *Krombholzia*, and then transferred to *Leccinum* Gray sect. *Luteoscabra* Singer by Singer (1962). Binder and Besl (2000) and Zang (2013) also treated it in *Leccinum*. However, it never stains brown when bruised or cut, a feature that could be used to distinguish this genus from *Leccinum* species.

Neoboletus Gelardi et al., Index Fungorum 192: 1 (2014)

Basidiomata stipitate-pileate, sometimes sequestrate. When basidiomata stipitate-pileate, pileus hemispherical, convex or applanate, subtomentose to tomentose, dry, usually staining blue when touched; context cream-yellow to light yellow, always staining blue immediately when injured. *Hymenophore* adnate, adnexed, sinuate to free; hymenophoral surface brown, dark brown, reddish brown when young, and becoming yellowish brown when mature, staining blue to dark blue immediately when injured; pores nearly round to round; tubes yellow to bright yellow when young, becoming ochraceous to olive when mature, always staining blue to dark blue immediately when injured. *Stipe* central, pale yellow, light yellow to brownish-yellowish at the upper part and brown, reddish brown at the lower part, with finely dotted

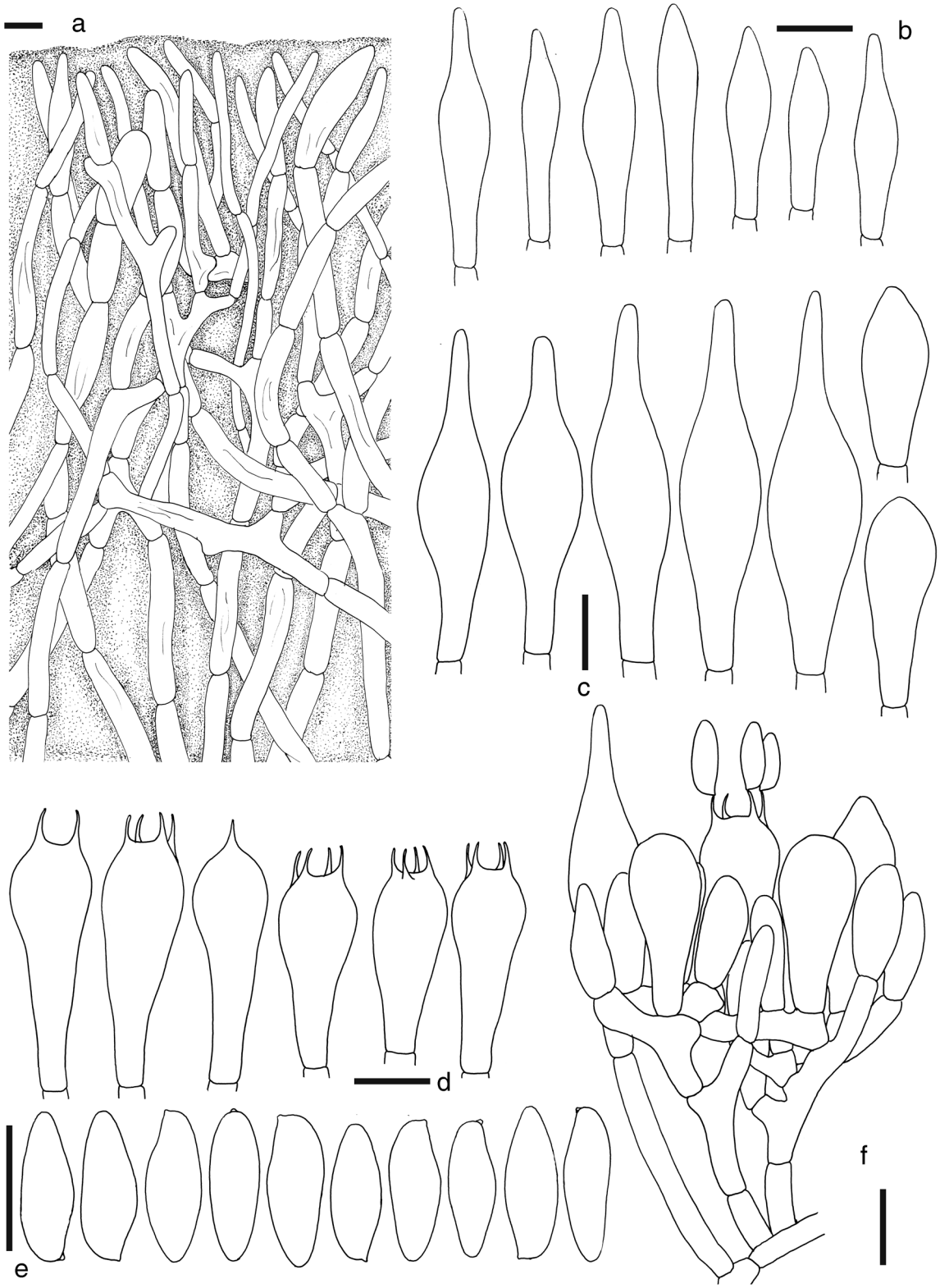

Fig. 10 *Rugiboletus extremiorientalis* (HKAS 67814) **a**. Pileipellis; **b**. Cheilocysitidia; **c**. Pleurocystidia; **d**. Basidia; **e**. Basidiospores; **f**. Basidia and pleurocystidia. Bars=10 μm

scales but always no reticulations, often staining blue when touched; context cream yellow to light lemon-yellow at whole part when young, becoming brown to reddish brown at the lower part when mature or old, always staining blue immediately when injured; basal mycelia white to cream yellow or brown. *Pileipellis* an interwoven trichodermium with long

terminal cells. *Pleuro-* and *cheilocystidia* subfusiform-ventricose or sometimes clavate. *Basidiospores* smooth, subfusiform, brownish yellow. When basidiomata sequestrate, *gleba* loculate, always exposed, and context yellow, always staining blue immediately when bruised. *Basidiospores* yellow-brown, brown to cinnamon brown. *Clamp connections* absent.

Type species: *Neoboletus luridiformis* (Rostk.) Gelardi et al.

Phylogenetic position: Clade 37 in Wu et al. (2014)

Neoboletus thibetanus (Shu R. Wang & Yu Li) Zhu L. Yang, B. Feng & G. Wu, **comb. nov.** Figs. 3o, p and 11

Basionym: *Gastroboletus thibetanus* Shu R. Wang & Yu Li Mycotaxon 129: 80 (2014)

MycoBank: MB 810356

Basidiomata hypogeous to emergent, sequestrate, subglobose, ca. 2 cm in diam., stipitate, surface yellow (2A8) but becoming pale gray (25A3) to olivaceous (4 F6–4 F8) when bruised, finely rugose, with small holes. *Peridium* practically absent. *Gleba* yellow (2A8) to sulphureous (1A5), staining blue immediately when cut, then to light yellow to green-yellow slowly, irregularly to angularly loculate; loculi 0.5–1 mm broad; columella present, yellow to sulphureous, staining blue immediately when cut. *Stipe* 1.2×0.2–0.3 cm, attenuate downwards, pale gray (25A3) to olivaceous (4 F6–4 F8), yellow (2A8) at the upper part, yellow (2A8) to reddish brown (8E8) at base; nearly smooth, but apical part with indistinct reticulations; context yellow (2A8) to brownish yellow (5C5) but yellowish brown (5E5) with reddish tinge at base, staining blue immediately when injured. *Macrochemical reaction* not observed.

Basidiospores 16–19 (20)×(9) 9.5–11(11.5) μm [Q=1.6–2.0, Q_m=1.78±0.13], statismosporic, amygdaliform, yellow-brown, brown to cinnamon brown, slightly thick-walled (≤2 μm thick), smooth; sterigmal appendage short, occasionally present. *Basidia* 25–40×11.5–15 μm, clavate to broadly clavate, 4-spored, occasionally 2- or 3-spored; sterigmata 3–4 μm long. *Cystidia*-like cells locally present, 25–45×17–

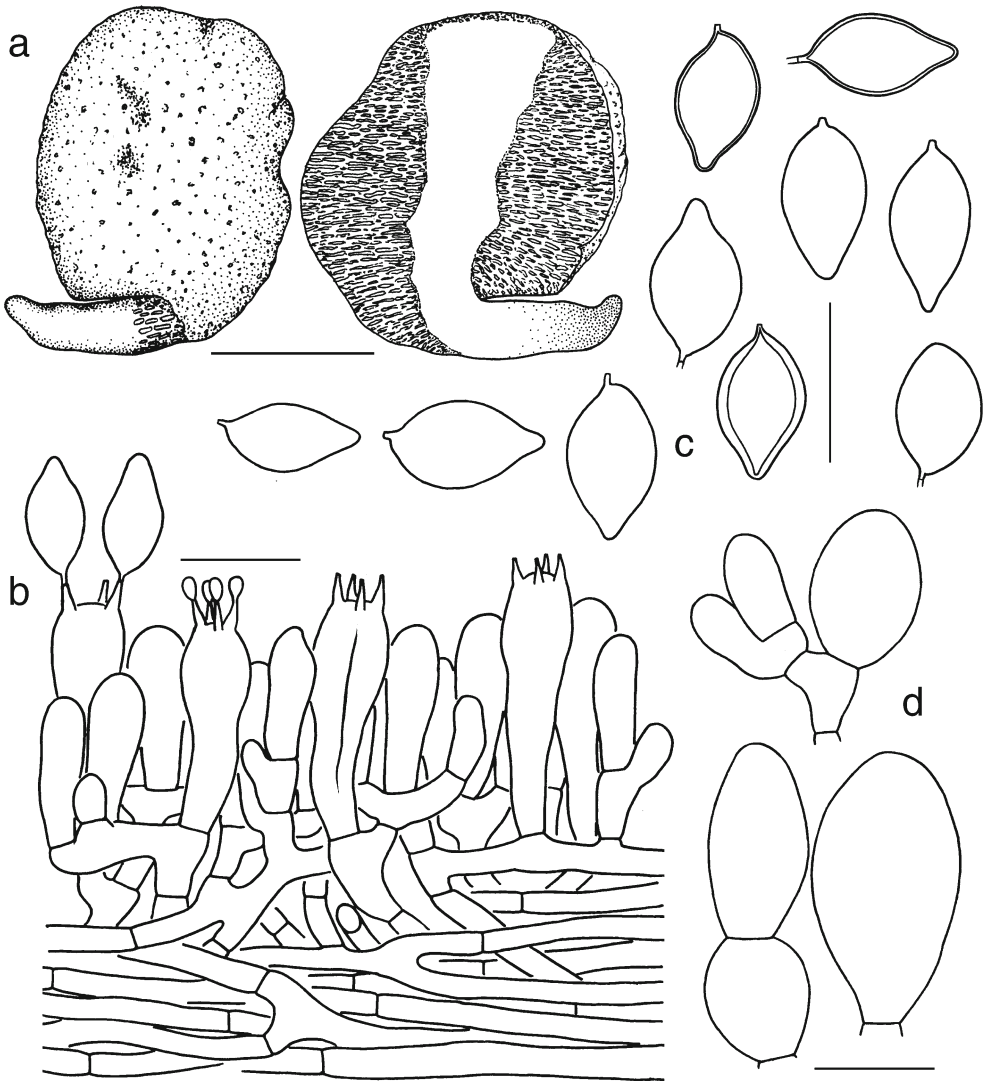

Fig. 11 *Neoboletus thibetanus* (HKAS 57093) **a**. Habitus of a basidioma and its vertical section; **b**. Hymenium, subhymnium and trama of tramal plate with basidia and basidiospores at different stages of development; **c**. Basidiospores; **d**. Cystidia-like cells in the hymenium. Bars a=1 cm, b–d=20 μm

25 μm, broadly ellipsoid, thin-walled, colorless. *Tramal plates* composed of thin-walled, non-gelatinized to gelatinized, colorless and hyaline (in interior) or ochraceous yellow intracellularly pigmented (on the surface of the peridium) filamentous hyphae 3–5 (7) μm broad. *Peridiopellis* poorly developed, very thin to absent, in some areas with a hymenoderm (like the hymenium) composed of yellow-brown intracellularly pigmented clavate to broadly clavate cells 8–15 μm broad, in other areas with a cutis (like the trama of tramal plates) composed of yellow-brown intracellularly pigmented filamentous hyphae 3–7 μm broad. *Stipe trama* composed primarily of longitudinally arranged, branching, thin-walled, colorless and hyaline or brown-yellow intracellularly pigmented filamentous hyphae 3–7 μm broad. *Clamp connections* absent.

Habitat: solitary, under ground in a forest dominated by *Abies, Betula*, and *Larix*.

Known distribution: Currently only from subalpine forests in southwestern China.

Specimens examined: CHINA, YUNNAN: Shangri-La County, 2 September 2013, alt. 3700 m, B. Feng 1494 (HKAS 82600); XIZANG Autonomous Region: Bomi County, 22.VI 2009, alt. 3400–3500 m, B. Feng 364 (HKAS 57093).

Commentary: *Neoboletus thibetanus*, under the name of *Gastroboletus thibetanus* by Wang et al. (2014), is characterized by its subglobose light yellow basidioma practically without a peridium, a stipe with a yellow to purplish base, a yellow to sulphureous context (including the gleba, the stipe-columella and the stipe trama) which becomes blue immediately upon exposure, and amygdaliform basidiospores 16–20×9–11 μm.

Neoboletus thibetanus looks like *Gymnogaster boletoides* J.W. Cribb from Australia. However, the latter has a characteristic red area at the top of the basidioma and much smaller ellipsoid to ovoid basidiospores (9.5–13×5.6–7.0 μm) (Cribb 1956). Phylogenetically, they belong to two independent lineages [Clade 37 and 50 of Wu et al. (2014)].

Neoboletus thibetanus is also somewhat similar to *Gastroboletus turbinatus* (Snell) A.H. Sm. & Singer, originally described from North America, in the yellow to sulphureous context that blues instantly when exposed. However, *N. thibetanus* differs by its enclosed hymenophore and wider amygdaliform basidiospores.

The subglobose basidioma of *Neoboletus thibetanus* is somewhat similar to that of *Gastroboletus ruber* (Zeller) Cázares & Trappe, originally described from western North America as *Truncocolumella rubra* by Zeller (1939). However, the latter has a rose, brownish red to reddish brown basidioma, a pale yellow stipe with concolorous context, and narrower subfusiform basidiospores measuring 9–15×4–6 μm (Zeller 1939; Cázares and Trappe 1991; Bessette et al. 2000).

Neoboletus venenatus (Nagas.) G. Wu & Zhu L. Yang, **comb. nov.** Figs. 3q, r and 12

Basionym: *Boletus venenatus* Nagas., Rep. Tottori Mycol. Inst. 33: 2, Figs. 1, 2, 3, 4, 5, 6, 7 and 8 (1996) [1995]

MycoBank: MB 810361

Pileus 7–26 cm in diam., hemispheric then convex, incurved at the margin when young, dry, subtomentose, grayish yellow (4C5), yellowish brown (3E7–3E8) or olive brown (5E8–5 F8); context pale yellow to light yellow (2A3–2A5), 2–3 cm thick, staining pale blue to light blue slowly when bruised. *Hymenophore* emarginate, surface light yellow (2A4–2A5) to yellowish brown (5E6), staining blue quickly when bruised; pores nearly round, 1–2/mm; tubes pastel yellow to light yellow (3A4–3A5) when young, becoming yellowish brown (5E6) to olive brown (4E6), 8–20 mm long, staining light blue to dull blue slowly when bruised; *Stipe* nearly equal to subventricose, 10–15×2–4.5 cm, cream to light yellow at the apex, and yellowish brown to brown towards the stipe, covered by finely furfuraceous scales, sometimes with reticulations at the apex; context pale yellow to light yellow (2A3–2A5), staining pale blue slowly when bruised; basal mycelia yellowish white to pale yellow. *Macrochemical reaction* not observed.

Basidia 30–65×8–15 μm, clavate, 4-spored, sometimes 2-spored. *Basidiospores* (12) 12.5–17 (18)×(4.8) 5–6.5 (7) μm [Q=(1.9) 2.17–2.98 (3.4), Q_m=2.53±0.24], subfusoid and inequilateral in side view with suprahilar depression, ovate to subfusoid in ventral view, brownish-yellowish, smooth, inamyloid. *Hymenophoral trama* boletoid, hyphae cylindrical, 4.5–9 μm wide. *Cheilocystidia* 20–51×4–7.5 μm, elongated fusoid-ventricose, thin walled. *Pleurocystidia* 37–72×6–12 μm, fusoid-ventricose to elongated fusoid-ventricose, thin walled. *Pileipellis* a trichodermium to an interwoven trichodermium, up to 200 μm thick, composed of brown to yellowish brown filamentous hyphae 5–8 μm in width with comparatively long terminal cells 40–85×5–9 μm, which are almost subcylindrical, sometimes with subacute apex or clavate. *Pileal trama* composed of interwoven hyphae 4–8 μm wide. *Stipitipellis* 90–110 μm thick, composed of two layers, the outer layer composed of loose and interwoven hyphae 3–4 μm wide, the inner layer hymeniform, composed of clavate to broad clavate cells 20–35 μm wide. *Stipe trama* composed of parallel hyphae 3.5–7 μm wide. *Clamp connections* absent.

Habitat: solitary, scattered, or gregarious in forests dominated by *Picea* spp. or *Abies* spp. or in mixed forests.

Known distribution: Currently only known from Japan and subalpine regions in southwestern China.

Specimens examined: CHINA, YUNNAN PROVINCE: Yulong County, Shitou Town, Laojun Mt., 2 September 2009, alt. 3100 m, B. Feng 760 (HKAS 57489); SICHUAN PROVINCE: Kangding County, 18 August 2010, alt. 2500 m,

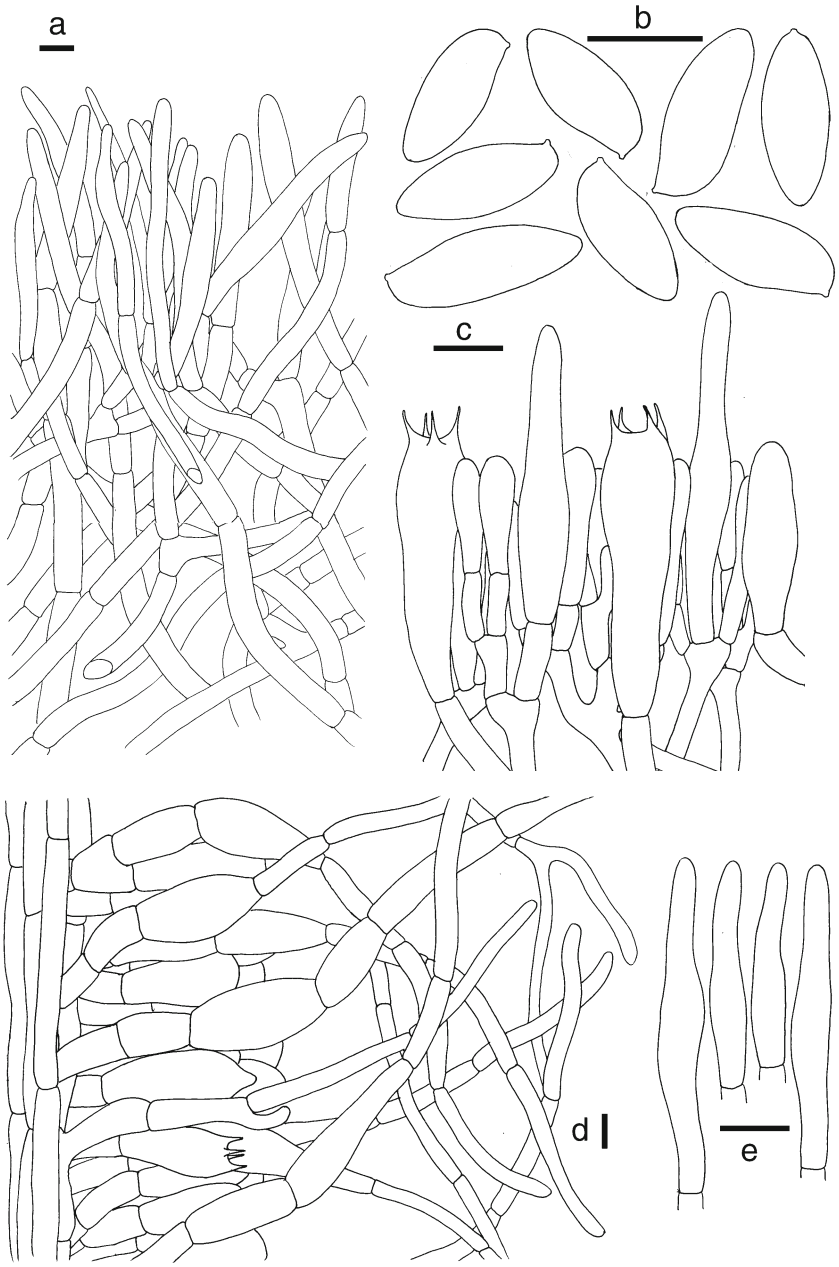

Fig. 12 *Neoboletus venenatus* **a**. Pileipellis; **b**. Basidiospores; **c**. Basidia and pleurocystidia; **d**. Stipipellis; **e**. Cheilocysitidia. a-b drawn from HKAS 57489, c-e drawn from HKAS 51703. Bars= 10 μm

G. Wu 304-306 (HKAS63535-63537); same location, 26 August 2006, Z.L. Yang 4892 (HKAS 51703)

Commentary: *Neoboletus venenatus* was originally described as *Boletus venenatus* from Japan in the forests of *Abies* and *Picea* by E. Nagasawa (Nagasawa 1996). It was reported as a poisonous species which could cause a severe gastrointestinal syndrome, such as nausea, repetitive vomiting, diarrhea, and stomachache (Nagasawa 1996; Matsuura et al. 2007).

Neoboletus brunneissimus (W.F. Chiu) Gelardi et al., Index Fungorum 192: 1 (2014). Figs. 3s, t and 13

Basionym: *Boletus brunneissimus* W.F. Chiu, Mycologia 40(2): 228 (1948)

Pileus 2–8 cm in diam., hemispherical to convex, dry, subtomentose to tomentose, brownish yellow, yellowish brown, light brown to brown (5C8–5E8); context 6–12 mm thick, pale yellow to light yellow (3A4–3A5), staining light blue, blue to dark blue immediately when injured. *Hymenophore* adnate to sinuate; surface brownish yellow, yellowish brown, light brown to brown (5C8–5E8), sometimes with reddish tinge, staining blue to dark blue immediately when bruised; pores nearly round, minute, 1.5–2/mm; tubes 4–18 mm long, butter yellow to maize yellow (4A4–4A6) when young, becoming olivaceous (4E6–4E8) when old, sinuate to free, staining blue to dark blue immediately when bruised; *Stipe* 4–9 cm long, 5–13 mm in diam., cylindrical to subcylindrical, or slightly obclavate, brownish yellow

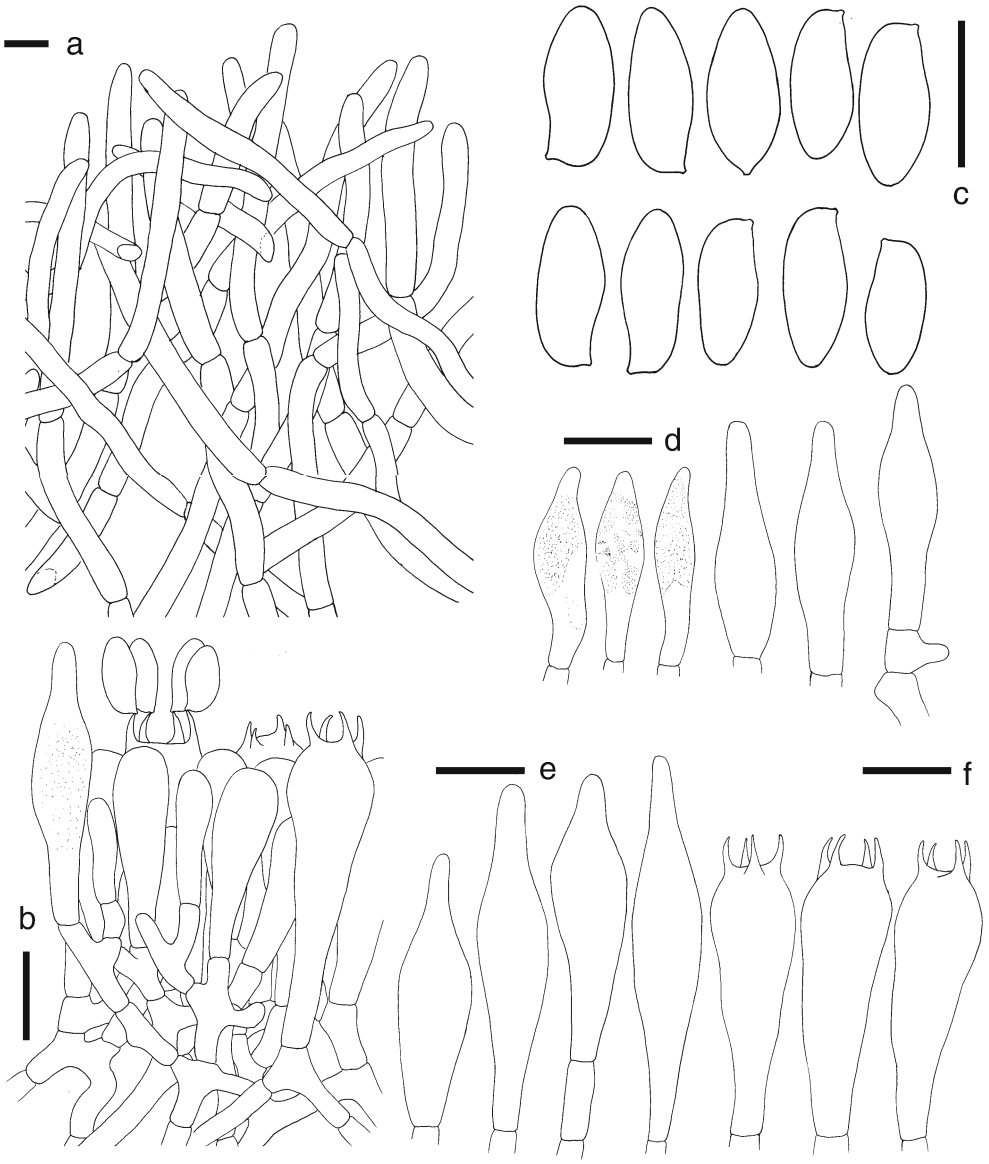

Fig. 13 *Neoboletus brunneissimus* (HKAS 50450) **a**. Pileipellis; **b**. Basidia and pleurocystidia; **c**. Basidiospores; **d**. Cheilocysitidia; **e**. Pleurocystidia; **f**. Basidia. Bars= 10 μm

(5C7–5C8) with yellow background to brown (5E7–5E8) at the upper part (occasionally with indistinctive nets or fibrils) and brown to umber (5E7–5E8) towards the base, covered by densely dotted scales at the surface and with cream, brown to yellowish brown mycelia or pseudo-roots around the stipe base, always staining blue to dark blue when touched; context light yellow to yellow (3A5–3A7) at the apex and light yellow (3A5), brownish yellow to brown (5C8–5E8) towards the base, staining blue when bruised. *Macrochemical reaction* not observed.

Basidia 25–40×9–11.5 μm, clavate, hyaline in KOH, sometimes containing light yellow pigments, 4-spored. *Basidiospores* (9) 10–14 (18)×(4) 4.5–5 (6) μm, [Q=(1.86) 2.04–2.8 (3), Q_m=2.41±0.20], subfusoid and inequilateral in side view with a suprahilar depression, subfusiform in ventral view, yellowish brown, smooth, inamyloid. *Hymenophoral trama* boletoid; hyphae cylindrical, 4–8 μm wide. *Cheilocystidia* 20–43×4–9 μm, fusoid-ventricose to ventricose-mucronate, or obclavate, thin walled, mostly containing yellow to brownish yellow pigments which can be slowly dissolved in 5 % KOH; *Pleurocystidia* 27–49×6–10 μm, similar to cheilocystidia in form, thin walled, and very few with yellow to brownish yellow pigments. *Pileipellis* a trichodermium to an interwoven trichodermium composed of brown to yellowish brown filamentous hyphae 3–5.5 μm in width with terminal cells 23–58×3.5–5 μm, which are almost subcylindrical, rarely with subacute apex. *Pileal trama* composed of interwoven hyphae 6.5–11 μm wide. *Stipitipellis* hymeniform, 55–65 μm thick, composed of more or less vertically brownish yellow hyphae; terminal cells 20–27×3–8 μm. *Stipe trama* composed of parallel hyphae 3–5.5 μm wide. *Clamp connections* absent.

Habitat: gregarious, solitary, or scattered, in subtropical forests of *Pinus* spp. (*Pinus yunnanensis*, *P. armandii*, etc.) or Fagaceae (*Castanopsis* spp., etc.), or mixed forests.

Known distribution: CHINA: Currently known from southwestern China.

Specimens examined: CHINA, YUNNAN PROVINCE: Kunming City, QiongZhu Temple, 8 August 2007, alt. 2100 m, Y.C. Li 973 (HKAS 50450, near type location!); Jianchuan County, 29 August 2009, alt. 2300 m, B. Feng 722 (HKAS 57451); Lanping County, Jinding County, Xinshengqiao National Forest Park, 14 August 2010, alt. 2400 m, B. Feng 834 (HKAS 68615); Tengchong County, Houqiao Town, 10 August 2011, alt. 1700 m, G. Wu 592 (HKAS 74906); Lijiang Gucheng District, Qihe Town, Longtan Village, 19 August 2010, alt. 2780 m, B. Feng 919 (HKAS 68700); Jingdong County, Ailaoshan Natural Reserve, 10 July 2008, alt. 2500 m, L.P. Tang 387 (HKAS 54618); Jianchuan County, Laojunshan Town, Xinhe Village, 31 August 2009, alt. 2900 m, G. Wu 202 (HKAS 57734); Shangri-La County, 26 July 2006, alt. 3400 m, Z.L. Yang 4741 (HKAS 50538).

Commentary: *Neoboletus brunneissimus*, under the name of *Boletus brunneissimus* by Chiu (1948), is morphologically similar to *N. luridiformis* and *Boletus vermiculosus* Peck, described from Europe and North America, respectively. However, *N. luridiformis* has red hymenophoral pores and red dotted scales on the stipe and usually forms ectomycorrhizae with temperate deciduous and coniferous trees, e.g., *Picea* or *Fagus* or *Quercus* spp. (Rauschert 1987; Hansen and Knudsen 1992), and *B. vermiculosus* has narrower basidia (24–32×7–9 μm) and occurs in North and Central America (Smith and Thiers 1971; Bessette et al. 2000; Halling and Mueller 2005).

Neoboletus magnificus (W.F. Chiu) Gelardi et al., Index Fungorum 192: 1 (2014). Figs. 3u, v and 14

Basionym: *Boletus magnificus* W.F. Chiu, Mycologia 40(2): 221 (1948)

Pileus 5–8 cm in diam., hemispherical to broadly convex, rose red to light red (12A8–12B8) to coffee brown to umber (5 F7–5 F8), dry, subtomentose, staining dark blue immediately when touched, margin incurved when young; context light yellow (2A5–3A5), 1.5–2 cm thick, staining dark blue immediately when bruised. *Hymenophore* adnate to sinuate; surface reddish brown, brownish red, laker red (9C8–9E8), sometimes pale yellowish red (8A8), light yellow to yellow (2A5–2A6) at the margin, staining dark blue immediately when bruised; pores nearly round, minute, 2–3/mm; *tubes* 6–10 mm long, light yellow to maize yellow (4A4–4A6) to ochraceous (4D7–4D8), sinuate to free, staining dark blue immediately when bruised. *Stipe* 7.5–10×1.5–5 cm, obclavate, sometimes slightly bulbous at the base, buttercup yellow to maize yellow (4A6–4A7) at the apex, cock's-comb red (10B7–11B7) to dark red (11C8) with scattered areas dark yellow tinged towards the base, smooth, or with red dotted scales or indistinctive striations at the upper part and sometimes with hairy scales at the base, staining dark blue immediately when touched; context similar to that of the pileus; basal mycelia pale yellow to light yellow. *Macrochemical reaction* not observed.

Basidia 24–42×8.5–13 μm, clavate to broadly clavate, 4-spored, sometimes 2-spored. *Basidiospores* (9) 10–13 (15)×(4) 4–5 (5.5) μm, [Q=(1.84) 2.27–3 (3.7), Q_m=2.61±0.19], subfusoid and inequilateral in side view with mostly distinct suprahilar depression, fusiform to subfusiform in ventral view, brownish-yellowish, smooth, inamyloid. *Hymenophoral trama* boletoid; hyphae cylindrical, 7–12 μm wide. *Cheilocystidia* 25–45×5–7.5 μm, lanceolate to narrowly fusoid, or clavate, or irregular-elongate, thin walled, with yellow to brownish yellow pigments which can be slowly dissolved in 5 % KOH. *Pleurocystidia* 28–58×6–11 μm, fusoid-ventricose, thin walled. *Pileipellis* a trichodermium to an interwoven trichodermium composed of brown to yellowish brown filamentous hyphae 5–7 μm in width with terminal cells 38–92×5–16 μm, which are almost subcylindrical with subacute apex to sometimes cystidia-like. *Pileal trama* composed of interwoven hyphae 5–11 μm wide. *Stipitipellis* hymeniform, 80–100 μm thick, composed of more or less vertically light yellow to yellowish brown hyphae; terminal cells 23–60×8–15 μm. *Stipe trama* composed of parallel hyphae 4.5–8 μm wide. *Clamp connections* absent.

Habitat: solitary, in subtropical mixed forests dominated by *Pinus yunnanensis* or *P. armandii* with Fagaceae (*Quercus* spp., *Castanopsis* spp. and *Lithocarpus* spp.).

Known distribution: CHINA: Currently known from southwestern China.

Specimens examined: CHINA, YUNNAN PROVINCE: Tengchong County, 11 August 2011, alt. 1600 m, G. Wu 625 (HKAS 74939); Kunming City, Miaogao Temple, 6 August 2006, alt. 2100 m, Y.C. Li 696 (HKAS 50450, from type location); Nanhua County, mushroom free market, 23 August 2010, alt. 2200 m, G. Wu 369 (HKAS 63601); Kunming City, mushroom free market, 7 June 2008, alt. 1900 m, Z.L. Yang 5060 (HKAS 54096).

Commentary: *Neoboletus magnificus*, under the name of *Boletus magnificus* by Chiu (1948), is morphologically similar to *Rubroboletus sinicus* (W.F. Chiu) Kuan Zhao & Zhu L. Yang and *Neoboletus luridiformis*. However, *R. sinicus* has distinctive reticulations on the whole stipe and a paler color change when bruised. *Neoboletus luridiformis* has slightly larger basidiospores (12–17×4–6 μm) and can form ectomycorrhizae with temperate deciduous and coniferous trees (Alessio 1985; Bessette et al. 2000; Hansen and Knudsen 1992).

Discussion

The documentation of new genera of *Boletaceae* has been accelerated since the work of Nuhn et al. (2013) and Wu

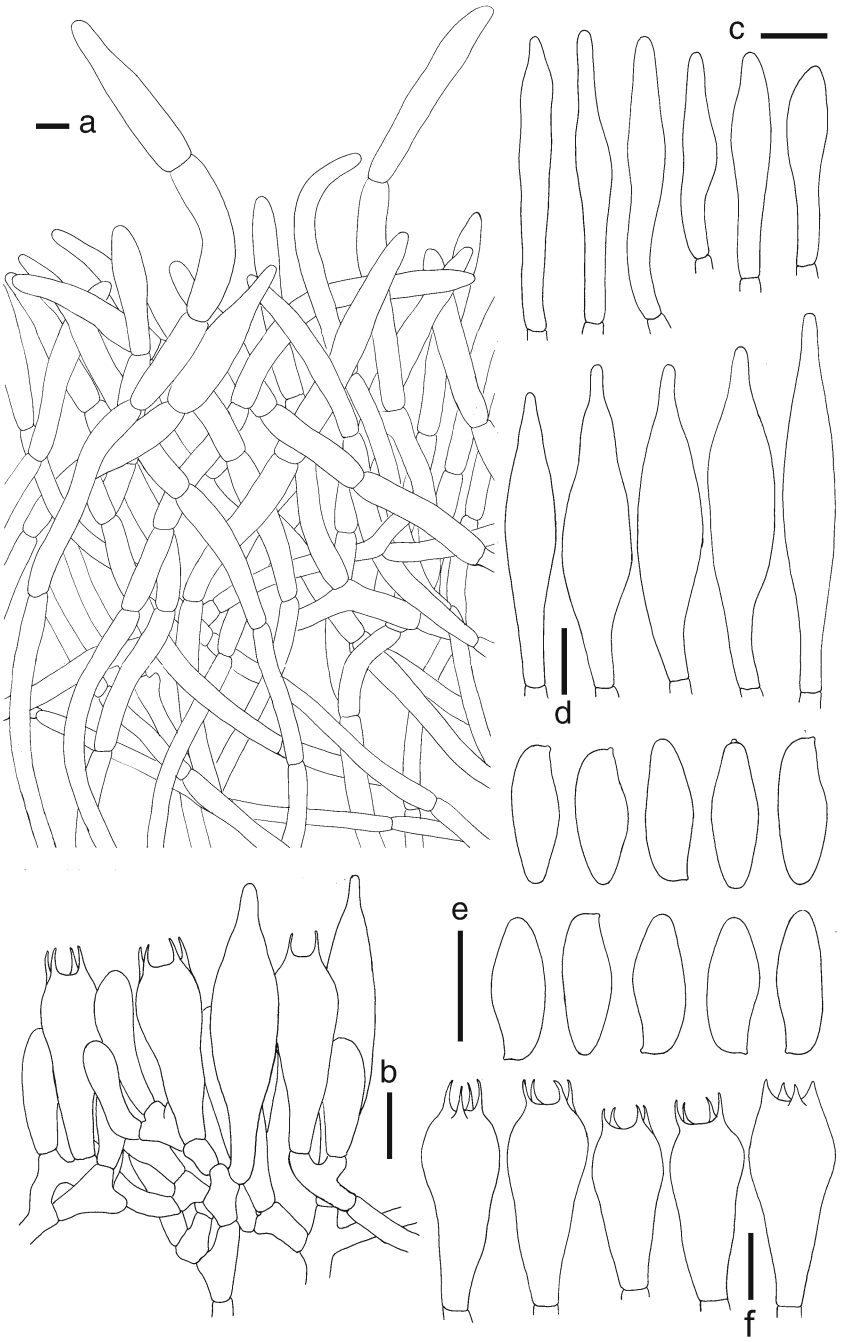

Fig. 14 *Neoboletus magnificus* (HKAS 74939) **a**. Pileipellis; **b**. Basidia and pleurocystidia; **c**. Cheilocysitidia; **d**: Pleurocystidia; **e**. Basidiospores; **f**: Basidia. Bars=10 μm

et al. (2014). About ten new genera were published in year 2014. We have described and illustrated here *Baorangia*, *Lanmaoa*, *Parvixerocomus*, *Rugiboletus*, and *Neoboletus* corresponding to five clades in Wu et al. (2014).

Baorangia is characterized by a thin hymenophore (thickness of hymenophore 1/3–1/5 times that of pileal context at the position halfway to the pileus center) and staining light blue when bruised. This genus is extremely similar to *Lanmaoa* in macro-morphology such that confusion is possible. Micro-morphologically, the pileipellis of *Baorangia* is usually a trichodermium or an interwoven trichodermium, while that of *Lanmaoa* is often an interwoven trichodermium to a subcutis. Molecular data infer that they belong to two separate clades (Wu et al. 2014; Nuhn et al. 2013). Chemical differences between the two genera are still unknown.

Lanmaoa is phylogenetically inferred as a sister group of *Cyanoboletus*, a genus recently proposed by Gelardi et al. (2014c). However, species of *Lanmaoa* have short hymenophoral tubes (thickness of hymenophore 1/3–1/5 times that of pileal context at the position halfway to the pileus center) and a slow color change when injured, while *Cyanoboletus* is characterized by dark basidioma and quick

bluing when injured and always gelatinized pileus (personal observations).

Parvixerocomus is the basal group of the subfamily *Boletoideae* inferred in Wu et al. (2014) and is characterized by its small basidiomata, staining light blue to blue when bruised, an epithelioid pileipellis, and ovoid to ellipsoid basidospores. Geographically, the genus is distributed in subtropical to tropical regions.

Rugiboletus has so far been only known from eastern Asia and based on molecular phylogenetic evidence (Wu et al. 2014) includes at least three species, one of which is not formally described because of the lack of adequate materials. Species in this genus were previously treated in the genus *Leccinum* due to similar scaly stipe (Singer 1962, 1986). However, *Rugiboletus* species have non-browning reaction when bruised, while *Leccinum* species often stain brown when bruised or cut. Moreover, the scales on the stipe of *Rugiboletus* species are comparatively tiny and do not become darker with age. It should be emphasized that the genus *Leccinum* should be studied and delimited further as suggested in the elegant work of den Bakker et al. (2004, 2007) and den Bakker and Noordeloos (2005).

Neoboletus is characterized by the brown or reddish brown hymenophoral surface, the lack of reticulations on the stipe and an quick blue stain when bruised. Phylogenetically, it is nested closely to *Sutorius* described by Halling et al. (2012). However, the basidiomata of *Sutorius* are distinctively purple in color and have no distinctive oxidation reaction. Geographically, *Neoboletus* is holarctic.

On the basis of nrLSU data of Nuhn et al. (2013) and Wu et al. (2014), *Boletus subvelutipes* Peck and *B. vermiculosus* Peck could belong to *Neoboletus*; *Boletus bicolor* var. *borealis* Smith & Thiers and *B. pallidoroseus* Both could be members of *Lanmaoa*; *Boletus bicolor var. subreticulatus* A.H. Sm. & Thiers, *B. rufomaculatus* Both and *B. subluridellus* A.H. Sm. & Thiers should be moved to *Baorangia*. Due to lack of related materials, the species mentioned above were not recombined to their relevant genus for the time being.

It is interesting to mention that most of the East Asian species studied in the present paper can be found in free markets in summer in southwestern China, and, thus, are considered edible. However, *N. venenatus*, sporadically mixed with other boletes in the free markets, is poisonous and must be avoided (Nagasawa 1996).

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