TAXONOMY

Artificial Key to Arizona Earthstars (Geastraceae and *Astraeus*)

1a. Endoperidial body supported by several stalks, having multiple stomata; spores reticulate; exoperidium lustrous …… 22. ***Myriostoma coliforme***

1b. Endoperidial body sessile or supported by a single stalk, having a single stoma; spores not reticulate; exoperidium not lustrous ……. **2**

2a. Gleba containing numerous thin or thick-walled paracapillitia, eucapillitia lacking; spores echinate to verrucose; endoperidium reticulate, particularly on the lower portion of the endoperidial body …….. 23. ***Astraeus hygrometricus***

2b. Gleba containing numerous thick-walled eucapillitia; spores verrucose, but not echinate; endoperidium not reticulate …….. **3**

3a. Peristome fibrillose …….. **4**

3b. Peristome plicate …… **18**

4a. Gasterocarp fornicate ……... **5**

4b. Gasterocarp not fornicate ……. **6**

5a. Peristome disc-shaped, distinctly delimited by a raised rim; endoperidium lacking pigmented protruding hyphae; gasterocarp of small to medium stature (less than 35 mm in height); spores 5.6-6.4 µm in diameter (including ornamentation) ……..

……..……. 13. ***Geastrum quadrifidum***

5b. Peristome not disc-shaped, nor distinctly delimited or only faintly so, lacking a rim; endoperidium densely covered with thick, pigmented protruding hyphae; gasterocarp of medium to large stature (greater than 35 mm in height); spores 4.8-5.6 μm in diameter (including ornamentation) …… 8. ***Geastrum fornicatum***

6a. Endoperidial body sessile ……. **7**

6b. Endoperidial body stalked …….. **14**

7a. Mycelial layer present (membranaceous or encrusted); rays sub to non-hygroscopic ……. **9**

7b. Mycelial layer lacking; rays hygroscopic …… **8**

8a. Peristome distinctly delimited; spores 4.8-5.6 μm in diameter (including ornamentation) …….. 3. ***Geastrum corollinum***

8b. Peristome not distinctly delimited; spores 5.6-7.2 μm in diameter (including ornamentation) ……... 7. ***Geastrum floriforme***

9a. Peristome distinctly delimited …… **10**

9b. Peristome not distinctly delimited ……. **13**

10a. Endoperidial body ringed by a pseudoparenchymatous collar; gasterocarp saccate …… 20. ***Geastrum triplex***

10b. Endoperidial body not ringed by a pseudoparenchymatous collar; gasterocarp saccate or not …… **11**

11a. Gasterocarp not saccate; peristome darker than endoperidial body, lacking a rim; mycelial layer heavily encrusted with debris or particles of soil or sand, not splitting radially along rays; spores 3.2-4.0 µm in diameter (including ornamentation) …… …… 1. ***Geastrum arenarium***

11b. Gasterocarp saccate; peristome concolorous with endoperidial body, distinctly rimmed; mycelial layer membranaceous, not encrusted with debris or only lightly so, often splitting radially along rays; spores 4.0-5.6 µm in diameter (including ornamentation) ……..…… **12**

12a. Gasterocarp small to medium stature (less than 35 mm in width); spores 4.0-4.8 µm in diameter (including ornamentation); spore mass light brown; tips of rays narrow ……... 11. ***Geastrum lageniforme***

12b. Gasterocarp of medium to large stature (greater than 30 mm in width); spores 4.8-5.6 µm in diameter (including ornamentation); spore mass dark brown; tips of rays narrow or truncate …….. 15. ***Geastrum saccatum***

13a. Spores 3.2-4.0 µm in diameter (including ornamentation); gasterocarp of small to medium stature (less than 30 mm in height), often saccate; pseudoparenchymatous layer lacking reddish tints when fresh; fibrous layer papery to coriaceous ……... ……... 6. ***Geastrum fimbriatum***

13b. Spores 4.8-5.6 μm in diameter (including ornamentation); gasterocarp of medium to large stature (greater than 25 mm in height), never saccate; pseudoparenchymatous layer having reddish tints when fresh; fibrous layer coriaceous to rigid ……... …….. 14. ***Geastrum rufescens***

14b. Mycelial layer membranaceous, not encrusted with debris or only lightly so; gasterocarp often pseudofornicate ……...17. ***Geastrum smardae***

14a. Mycelial layer lacking or not membranaceous, if present then heavily encrusted with debris; gasterocarp never pseudofornicate …….. **15**

15a. Peristome distinctly delimited …….. **16**

15b. Peristome not distinctly delimited ……... **17**

16a. Endoperidial body having a dense pruinose layer of crystalline matter; spores 4.8-6.4 μm in diameter; peristome distinctly delimited but not ringed by a pale zone; gasterocarp of small to medium stature (less than 25 mm in height) …….. ……... 12. ***Geastrum minimum***

16b. Endoperidial body not having a dense pruinose layer of crystalline matter, or only finely so; spores 5.6-6.4 μm in diameter; peristome distinctly delimited and often ringed by a pale zone; gasterocarp of medium to large stature (greater than 20 mm in height) ……... 4. ***Geastrum coronatum***

17a. Endoperidium covered with dark, persistent, coarse, granular, irregular-shaped to spiny projections; pseudoparenchymatous layer not having reddish tints when fresh; spores 4.0-4.8 μm in diameter (including ornamentation) ……..... 9. ***Geastrum hieronymi***

17b. Endoperidium not covered with dark, persistent, coarse, granular, irregular-shaped to spiny projections; pseudoparenchymatous layer having reddish tints when fresh; spores 4.8-5.6 μm in diameter (including ornamentation) ……... 14. ***Geastrum rufescens***

18a. Endoperidial body sessile ……. **19**

18b. Endoperidial body stalked …… **21**

19a. Mycelial layer lacking; rays hygroscopic; endoperidium verrucose ……. ……. 10. ***Geastrum kotlabae***

19b. Mycelial layer present; rays sub- to non-hygroscopic; endoperidium not verrucose ……... **20**

20a. Endoperidial body having a dense pruinose layer of crystalline matter when fresh; endoperidium glabrous; rays not truncate or broken off at tips …….. ……. 5. ***Geastrum elegans***

20b. Endoperidial body not having a dense pruinose layer of crystalline matter when fresh; endoperidium minutely furfuraceous (hyphal protrusions visible only under magnification); rays often truncate or broken off at tips …… …… 21. ***Geastrum xerophilum***

21a. Exoperidium verrucose; rays hygroscopic, occasionally only weakly so; spores 6.4-8.0 μm in diameter (including ornamentation); fibrous layer coriaceous to rigid …… ……. 2. ***Geastrum campestre***

21b. Exoperidium not verrucose; rays sub to non-hygroscopic; spores 4.8-6.4 μm in diameter (including ornamentation); fibrous layer coriaceous …… **22**

22a. Endoperidial body not having a pruinose layer of matted hyphal elements and/or crystalline matter when fresh; rays often truncate or broken off at tips …… …… 21. ***Geastrum xerophilum***

22b. Endoperidial body having a pruinose layer of matted hyphal elements and/or crystalline matter when fresh; rays not truncate or broken off at tips ……. **23**

23a. Spores 5.6-6.4 μm in diameter (including ornamentation); apophysis not forming a ridged collar ……. 16. ***Geastrum schmidelii***

23b. Spores 4.8-5.6 μm in diameter (including ornamentation); apophysis forming a ridged collar or not ……... **24**

24a. Apophysis forming a ridged collar; peristome plicate, not delimited or only faintly so, conical and coming to a point at apex; gleba reddish brown ……... ……. 19. ***Geastrum striatum***

24b. Apophysis not forming a ridged collar; peristome deeply plicate, distinctly delimited and often recessed, applanate, often raised in central portion to a short, narrow point; gleba dark brown ……..……... 18. ***Geastrum smithii***

The Geastraceae

Geastraceae Corda (as 'Geastreae'), Anleitung zum Studium der Mycologie: 104 (1842).

Type genus: *Geastrum* Per.: Pers. (1801)

Geastrum Pers.: Pers., Synopsis Methodica Fungorum 1: 131 (1801).

Type species: *Geastrum coronatum* Pers. Syn. Meth. Fung.: 132 (1801, see Demoulin 1984).

1. ***Geastrum arenarium*** Lloyd, Mycological Writings, 'Geastraceae' 1: 28 (1902, as *Geaster*). (figs. 56a, 69a & 95a)

Type: The holotype is located in the National Fungus Collection (BPI 704841!) labeled "TYPE; *Geaster arenarius*, United States. Florida: Jupiter, Coll: Culbertson H.C. on 1895 FEB 00, Detr: Lloyd C.G. ". This collection is mixed with *Geastrum quadrifidum* and *Astreaus hygrometricus*, which F.D. Calogne separated and annotated on 08 January 2003.

Selected illustrations: Lloyd (1902: figs. 53 & 54, as *Geaster*); Long & Stouffer (1948: fig. 17, as *Geaster*); Sunhede (1989: fig. 145 b).

Expanded gastrocarp 15-25 (30) mm in width x 10-15 (20) mm in height. Exoperidium splitting to the middle or less, forming 5-11 rays, often splitting again at tips; rays arching and revolute, involute and extending upward around the endoperidial body, or often involute rolling up under the endoperidial body, subhygroscopic. Mycelial layer thin, persistent, heavily encrusted with debris or particles of sand. Pseudoparenchymatous layer pallid at first, becoming grayish orange (5B4), brownish orange (5C4) to brownish gray (5C2), or more pallid if covered with pruina, thin, glabrous at first, becoming rimulose with age, at times very sparsely covered with a fine pruina of crystalline matter left behind from the endoperidium, becoming less pruinose with age. Fibrous layer pallid, thin, papery to subcoriaceous. Endoperidial body 5-15 mm in diameter x 7-15 mm in height (including stalk & peristome), +/- sessile, globose to depressed globose. Apophysis present and reduced or absent. Stalk reduced to short (up to 2 mm), narrow, concolorous with the endoperidium. Endoperidium "Pallid Mouse Gray" to orange-gray (5B2), often sparsely covered with minute blackish speckles, glabrous, at times lightly pruinose with a fine layer of crystalline matter. Peristome fibrillose, normally distinctly delimited and darker in color than endoperidium, broadly conical, less than 2 mm in height. Gleba brown (8E5) to reddish brown (9E5), cottony. Columella columnar or absent in older specimens.

Basidiospores subglobose to globose, 3.2-4.0 µm X 3.2-4.0 µm [x = 3.8 ± 0.4 X 3.8 ± 0.4 µm, Q_m = 1.0, n = 20], verrucose with dense, short verrucae; small central oil drop; pedicel rudimentary, difficult to discern from verrucae; sterigmal remnants absent from mounts; spores yellow-brown in water mounts. Eucapillitium '*Geastrum*' type, 2.4-5.6 µm in diameter, thick-walled (up to 2.4 µm), glabrous to lightly encrusted,

unbranched or occasionally with knob-like projections, especially toward tips, straight to subundulate, attenuate to rounded at tips, lacking pores, elastic, aseptate, yellow-brown in water mounts. Endoperidium composed of thick-walled, tightly interwoven hyphal elements.

Habitat: Terrestrial and found in granitic soil or in leafy debris under cat claw acacia (*Acacia greggii*), mesquite (*Prosopis* spp.) or cactus species. This species occurs in the lower to mid elevations of the state within the Arizona Upland subdivision of the Sonoran desertscrub, interior chaparral, and semidesert grassland biotic communities.

Distribution: Known only from the southern regions of the United States, and previously reported from Arizona, Florida, New Mexico, and Texas (see fig. 5 for Arizona distribution). Also reported from Australia and South Africa.

Material examined: ARIZONA, Pima Co.: Near Sabino Canyon, 11 November 1933, W.H. Long & V.O. Sandberg (BPI, WHL8897); 30 min. North of Nogales on Tucson Hwy., 23 November 1933, W.H. Long & V.O. Sandberg (BPI, WHL7853); 3 mi. from Sabino Canyon, Coronado National Forest, 20 March 1935, W.H. Long & V.O. Sandberg (BPI, WHL7609); Near Tucson, 1 mi. from Mouth of Sabino Canyon, 04 June 1938, W.H. Long & D.J. Stouffer (BPI, WHL9263); Near Tucson, 2 mi. from mouth of Sabino Canyon, 10 August 1938, W.H. Long (BPI, WHL8256); Tucson, 4 mi. from Sabino Canyon, 28 September 1939, W.H. Long (BPI, WHL8392). Santa Cruz Co.: 7 mi. from Nogales, Hwy 84, 29 February 1934, W.H. Long & V.O. Sandberg (BPI,

WHL8768); 7 mi. North of Nogales, along Hwy 84, 13 November 1936, W.H. Long & V.O. Sandberg (BPI, WHL8846); 10 mi. from Nogales, Tucson-Nogales Hwy, 04 June 1938, W.H. Long (BPI, WHL8304); 7 mi. North of Nogales, along Hwy 84, 11 September 1941, W.H. Long & D.J. Stouffer (BPI, WHL9634); 9 mi. North of Nogales, Hwy 84, 11 September 1941, W.H. Long & D.J. Stouffer (BPI, WHL9696). Yavapai Co.: Mt. Mingus, Prescott NF, 18 May 1934, W.H. Long (BPI, WHL8813). FLORIDA: Jupiter, 00 February 1895, H.C. Culbertson (BPI, 704841, Type).

Geastrum arenarium is similar to *G. zerophilum*; however, that species has a plicate peristome, truncate rays and a minutely furfuraceous endoperidium. Another small earthstar with a delimited peristome is *G. minimum*. It can be distinguished from *G. arenarium* as *G. minimum* has a peristome that is concolorous or lighter than the endoperidium and the exoperidium is normally densely pruinose with a fine crystalline matter. The basidiospores of *G. minimum* are also considerably larger (5.0-6.4 µm in diam.) than *G. arenarium* (3.2-4.0 µm in diam.). Weathered specimens of *G. corollinum* can look very much like *G. arenarium*; however, that species has smaller spores (3.2-4.0 µm in diam.) and rays that are strongly hygroscopic. The delimited peristome of *G. arenarium* is also generally darker than the rest of the endoperidium, where as it is generally lighter or concolorous with the endoperidium in *G. corollinum* (see G. *corollinum* for further discussion). This species was previously reported from Arizona by Long and Stouffer (1948) as *Geaster*.

2. ***Geastrum campestre*** Morgan, American Naturalist 21: 1027 (1887, as *Geaster*).

(figs. 56b, 69b & 95b)

Reported synonyms

= *Geastrum pseudomammosum* Henn., Hedwigia 39 (Beibl.): 54-55 (1900).

= *Geastrum asperum* Lloyd, Mycol. Notes 7: 70 (1901).

Type: The holotype is located in the Ada Hayden Herbarium, Iowa State University, Ames (ISC 417500), and is labeled: "*Geaster campestris*, Morg. Type!, Hab- Earth by side of walk in city, Lincoln, Neb.- Sept 27, 1886, Coll. C.E. Bessey."

Selected illustrations: Calonge (1998: fig. 23); Morgan (1887: fig. 1, as *Geaster*); Pegler, Læssøe & Spooner (1995: figs. 54-55); Stanek in Pilát (1958: figs. 153 & 180); Sunhede (1989: figs. 37-42).

Expanded gastrocarp 10-36 mm in width x 10-30 mm in height. Exoperidium splitting to the middle or slightly more, forming 5-11 rays, occasionally splitting again at tips; rays arching and revolute, involute and extending upward around the endoperidial body or rolling up under the endoperidial body, hygroscopic. Mycelial layer thin, persistent, heavily encrusted with leafy debris or particles of soil. Pseudoparenchymatous layer pallid at first, becoming grayish orange (6B3), brownish orange (6C4), light brown (6D4-5), brown (6E4-6) to dark brown (6F5-6), or more pallid if covered with pruina, thin (up to 1.5 mm when fresh), glabrous, covered with a fine pruina of hyphal elements left behind from the endoperidium, persistent, occasionally

becoming rimose with age. Fibrous layer orange-white (6A2), thin, coriaceous to rigid. Endoperidial body 5-16 mm in diameter x 6-13 mm in height (including stalk & peristome), stalked, globose to depressed globose. Apophysis present and prominent or reduced. Stalk reduced to short (up to 2 mm), narrow to broad, concolorous, lighter or darker than the endoperidium. Endoperidium orange-gray (5B2), grayish brown (5D3, 6D3 to 6E3) to light brown (5D4-5 to 6D4), or more pallid due to the pruina, verruculose to verrucose with granular verrucae, covered with a fine pruinose layer of hyphal elements, becoming less pruinose and more glabrous with age. Peristome plicate, distinctly delimited and normally recessed, conical with a pointed or truncate apex, up to 3 mm in height, with 12-20 conspicuous folds. Gleba brown (6E5-7), cottony. Columella domed to subcolumnar.

Basidiospores globose, 6.4-8.0 X 6.4-8.0 µm [x = 7.7 ± 0.5 X 7.7 ± 0.5 µm, Q_m = 1.0, n = 20], verrucose with dense, long verrucae with rounded to truncate apices; oil drop difficult to discern; pedicel rudimentary, difficult to discern from verrucae; sterigmal remnants absent from mounts; spores yellowish brown in water mounts. Eucapillitium '*Geastrum*' type, 4.0-8.0 µm in diameter, thick-walled (up to 3.2 µm), glabrous to lightly encrusted, unbranched, mostly straight, often with long narrow attenuate, subundulate tips, lacking pores, elastic, aseptate, yellowish brown in water mounts. Endoperidium composed of thick-walled, tightly interwoven hyphal elements, protruding hyphae and granular components.

Habitat: Terrestrial and found in open areas or in leafy debris under cat claw acacia (*Acacia greggii*), mesquite (*Prosopis* spp.) or pines (*Pinus* spp.). This species is

found throughout Arizona and occurs in the lower to higher elevations of the state within the Arizona Upland subdivision of the Sonoran desertscrub, interior chaparral, Madrean evergreen woodland, Petran montane conifer forest, and the semidesert grassland biotic communities.

Distribution: Known throughout the United States, and previously reported from Arizona, Hawaii, Kansas, Michigan, Nebraska, New Mexico, North Dakota, Texas, Utah and Wyoming (see fig. 6 for Arizona distribution). Also reported from Australia, Europe, Great Britain, Mexico and South Africa.

Material examined: ARIZONA, Coconino Co.: Flagstaff, 06 February 1934, W.H. Long (BPI, WHL8979). Graham Co.: Cluff's pond near the Graham Mts., 15 March 1995, J.S. States (MICH, AEF1433). Greenlee Co.: Eagle District, Crook National Forest, 26 March 1947, W.H. Long & D.J. Stouffer (BPI, WHL7863). Pima Co.: 2 mi. from Sabino Canyon, 04 June 1938, W.H. Long (BPI, WHL8769). Santa Cruz Co.: Along Nogales-Tucson Road, 19 February 1934, W.H. Long & V.O. Sandberg (BPI, WHL7623); 7 mi. North of Nogales on Hwy. 84, 11 September 1941, W.H. Long & D.J. Stouffer (BPI, WHL9629); 7 mi. from Nogales on state Highway 84, 11 September 1945, W.H. Long & D.J. Stouffer (BPI, WHL9635). Yavapai Co.: Prescott, near Peterson area, 12 April 1934, W.H. Long & V.O. Sandberg (BPI, WHL7687); In old corral, along Copper Basin Rd., West of Prescott, 24 April 1934, W.H. Long & V.O. Sandberg (BPI, WHL7689).

The verrucose to verruculose endoperidium and large spore size (6.4-8.0 in µm diam.) distinguishes *G. campestre* from all other earthstars found in the state. The endoperidium of *G. kotlabae* also exhibits verrucae; however, besides having smaller spores (4.8-6.4 in µm diam.), that species is +/- sessile, has strongly hygroscopic rays and the mycelial layers is normally absent. *Geastrum berkeleyi* (not reported from Arizona) is a very similar taxon; however, that species can be distinguished from *G. campestre* as it generally has a larger stature, slightly smaller spores (5.5-7.0 µm in diam.), has non-hygroscopic rays and is found in more densely forested areas. *Geastrum smithii* is another similar species; however, that taxon does not have a verrucose endoperidium and the spores are smaller (4.8-5.6 µm in diam.). *Geastrum campestre* was previously reported from Arizona by Long and Stouffer (1948) as *Geaster*.

3. ***Geastrum corollinum*** (Batsch) Hollós, Magyarország Gasteromycetai: 57 (1903, as *Geaster*). (figs. 56c, 70a, 95c & 98f)

Basionym

Lycoperdon corollinum Batsch, Elench. Fung. 1: 151 (1783).

Reported synonyms

= *Lycoperdon recolligens* With., Bot. Arr. Brit. Pl. 3: 462 (1792).

= *Geastrum recolligens* (With.) Desv., J. Bot. 2: 102 (1809).

= *Geastrum mammosum* Chevall., Fl. Paris 1: 359 (1826).

Type: There is currently no holotype for this taxon as type material from Batsch has apparently not been preserved. Sunhede (1989) states, "As Batsch (1783) referred to

Micheli's tab. 100. fig. 3 (1729) this figure is a part of the protologue and can be selected as a lectotype. No doubt it [would have] been better if the ICBN had permitted a neotypification on real fruiting bodies in a case like this."

Selected illustrations: Long & Stouffer (1948: fig. 13, as *Geaster mammosus*); Pegler, Læssøe & Spooner (1995: figs. 78-79); Stanek in Pilát (1958: figs. 165 & 188, as *Geastrum recolligens*); Sunhede (1989: figs. 45-50).

Expanded gastrocarp 12-35 mm in width x 7-20 mm in height. Exoperidium splitting to the middle or more, forming 5-10 rays, occasionally splitting again at tips; rays involute, extending upward around the endoperidial body, or often rolling up over the endoperidial body, normally indented at the base, strongly hygroscopic. Mycelial layer normally absent, or very thin, membranaceous and not encrusted with debris. Pseudoparenchymatous layer pallid at first, becoming orange-gray (5B2), brown (6E5) to dark brown (8F4), thin (up to 1.5 mm when fresh), at first appearing pruinose, covered with fine matted hyphal elements, soon becoming glabrous, very persistent. Fibrous layer pallid on the inner parts, outer parts yellowish white (4A2) to orange white (5A2), thin, rigid. Endoperidial body 7-17 mm in diameter x 4-13 mm in height (including peristome), +/- sessile, subglobose, globose to depressed globose. Apophysis absent. Stalk absent or reduced, broad, not visible due to the persistent pseudoparenchymatous layer. Endoperidium orange-gray (5B2) to grayish orange (5B4), becoming pallid and sparsely covered with minute blackish speckles with age, appearing pruinose at first, covered with a fine layer of matted hyphal elements, then becoming more glabrous with

age. Peristome finely fibrillose, normally distinctly delimited, concolorous with the endoperidium or lighter, applanate, broadly conical to mammiform, up to 2 mm in height. Gleba dark brown (8F4-5), cottony to pulverulent. Columella domed to clavate, or absent.

Basidiospores globose, 4.8-5.6 (6.4) X 4.8-5.6 (6.4) µm [x = 5.3 ± 0.5 X 5.3 ± 0.5 µm, Q_m = 1.0, n = 20], verrucose with dense, thin, truncate verrucae; central oil drop; pedicel rudimentary, difficult to discern from verrucae; sterigmal remnants absent from mounts; spores yellow-brown in water mounts. Eucapillitium '*Geastrum*' type, 3.2-6.4 µm in diameter, thick-walled (up to 2.4 µm), lightly to heavily encrusted, unbranched, straight to subundulate, attenuate at tips, with occasional knob-like projections, lacking pores, elastic, aseptate, yellow-brown in water mounts. Endoperidium composed of thick-walled, tightly interwoven hyphal elements.

Habitat: Terrestrial and found in leafy debris under juniper (*Juniperus osteosperma*). This species is only known from northern Arizona and occurs in the higher elevations of the state within the Great Basin conifer woodland biotic community.

Distribution: Known throughout the United States, and previously reported form Arizona, Colorado, Hawaii, Iowa, New Jersey, New Mexico, North Carolina, North Dakota, Ohio, Texas and Wyoming (see fig. 7 for Arizona distribution). Also reported from Europe, Great Britain, and Mexico.

Material examined: ARIZONA, Mohave Co.: Near the N Rim of the Grand Canyon; Parashant Nat. Monument, 21 May 2003, S.T. Bates (STB 00485); Near the N Rim of the Grand Canyon; Parashant Nat. Monument, 21 May 2003, S.T. Bates (STB 00487). CZECH REPUBLIC, Moravia: Brno, 26 July 1943, Fr. Smarda (ASU, EXSCI. 109).

Geastrum corollinum is one of three species found in the state that are small, strongly hygroscopic and normally lack a mycelial layer. Macroscopically, these species can be distinguished by differences in the peristome. *Geastrum floriforme* has a fibrillose peristome that is not distinctly delimited, *G. corollinum* has a fibrillose peristome that is distinctly delimited and *G. kotlabae* has a plicate peristome (see *G. floriforme* and *G. kotlabae* for further discussion). *Geastrum corollinum*, especially aged or weathered specimens, could be confused with *G. arenarium*; however, that species has much smaller spores (see *G. arenarium* for further discussion). Pruinose specimens of *G. corollinum* could also be confused for *G. minimum*; however, that species is distinctly stalked and the pruina is composed of crystalline matter rather than fine, matted hyphal elements. Microscopically, the single capillitial units of *G. minimum* are shorter and less encrusted than *G. corollinum*. This species was previously reported from Arizona by Long and Stouffer (1948) as *Geaster mammosus*.

4. ***Geastrum coronatum*** Pers., Synopsis Methodica Fungorum: 132 (1801).

(figs. 56d, 70b & 95d)

Reported synonyms

= *Geastrum limbatum* Fr., Syst. Mycol. 3: 15-16 (1829).

= *Geastrum atratum* Smarda, Ceska Mykol. 1: 71-74 (1947).

Type: There is no valid type material left from Persoon's herbarium (Sunhede 1989) which is now housed at the National Herbarium Nederland (L). Sundhede states, "…Persoon (1801) reports no type material and no geographical site and information of the kind is not found in his earlier works (1794-1797). According to the ICBN Schmiedel's plate 46 (1793) is a part of the protologue … and can be selected as a lectotype."

Selected illustrations: Calonge (1998: fig. 24 a-c); Stanek in Pilát (1958: figs. 138 & 169); Sundhede (1989: figs. 54-60).

Expanded gastrocarp 22-43 mm in width x 20-38 mm in height. Exoperidium splitting to the middle or slightly more, forming 5-11 rays, often splitting again at tips; rays arching and revolute, often involute at ray tips, subhygroscopic. Mycelial layer thick, persistent, heavily encrusted with leafy debris. Pseudoparenchymatous layer pallid at first, becoming light brown (7D5-6), brown (7E4-6) to dark brown (6F4-6 to 7F4-7), or more pallid if covered with pruina, thick (up to 5 mm when fresh), rugose to rimose, often lightly encrusted with debris, occasionally covered with a fine pruina of crystalline

matter left behind from the endoperidium, gradually peeling away in patches and often devoid in aged or weathered specimens. Fibrous layer yellowish white (4A2) to orange-white (5A2), thin, papery to coriaceous. Endoperidial body 10-16 mm in diameter x 6-18 mm in height (including stalk & peristome), stalked, globose, subglobose, depressed globose to broadly ovate. Apophysis present and prominent or reduced. Stalk short to medium-sized (up to 4 mm), often laterally compressed, narrow to broad, darker than the endoperidium, fading concolorous or lighter. Endoperidium orange-white (5A2), orange-gray (5B2), grayish orange (5B3-4), brownish orange (5C3-6) to grayish brown (6F3), glabrous, at times lightly pruinose with a fine layer of crystalline matter that gradually wears away. Peristome fibrillose, distinctly delimited or not, normally ringed with a pale zone, applanate, broadly conical to mammiform, occasionally erect creating a large ostiole, up to 3 mm in height. Gleba brown (7E4) to grayish brown (7F3), cottony. Columella domed to columnar.

Basidiospores globose, 5.6-6.4 X 5.6-6.4 µm [x = 6.1 ± 0.4 X 6.1 ± 0.4 µm, Q_m = 1.0, n = 20], verrucose with irregular truncate verrucae; central oil drop; pedicel rudimentary, difficult to discern from verrucae; sterigmal remnants absent from mounts; spores yellowish brown in water mounts. Eucapillitium '*Geastrum*' type, 4.0-7.2 µm in diameter, thick-walled (up to 2.4 µm), glabrous to heavily encrusted, unbranched, straight to undulate, with long attenuate tips, lacking pores, elastic, aseptate, brownish yellow in water mounts. Endoperidium composed of thick-walled, tightly interwoven hyphal elements, occasionally intermixed with crystalline matter.

Habitat: Terrestrial and found in leafy debris under juniper (*Juniperus* spp.) and pinyon (*Pinus edulis*). This species occurs in the higher elevations of the state within the Great Basin conifer woodland and Petran montane conifer forest biotic communities.

Distribution: Distribution in the United States is difficult to discern due to synonymy with *G. limbatum* (see discussion); however, previous reports from New Mexico are confirmed (see fig. 8 for Arizona distribution). Also reported from Africa, Australia, Europe, Great Britain, and Mexico.

Material examined: ARIZONA, Coconino Co.: Walnut Canyon National Monument, 03 May 1995, J.S. States (MICH, AEF1443). Mohave Co.: Mt. Trumbell Loop Rd., Mt. Trumbell; Parashant Nat. Monument, 23 May 2003, S.T. Bates (STB00628).

Geastrum coronatum is very similar to *G. smardae*, and Lloyd (and subsequent American authors) included these two taxa, in addition to *G. pseudolimbatum*, under *Geaster limbatus* (Sunhede 1989). *Geastrum smardae* has a membranaceous mycelial layer, only lightly encrusted, that is often pseudofornicate; on the other hand, the mycelial layer in *G. coronatum* is persistent, heavily encrusted and not membranaceous. Microscopically, *G. coronatum* has slightly larger spores (5.6-6.4 μm in diam.) than *G. smardae* (4.8-5.6 μm in diam.). *Geastrum pseudolimbatum* (not reported from Arizona) has a verrucose endoperidium, a stalk that is normally lighter than the endoperidial body and hygroscopic rays. In contrast, *G. corontatum* has glabrous to pruinose endoperidium,

a stalk that is normally darker than the endoperidial body and subhygroscopic rays. *Geastrum coronatum* could also be confused with *G. smithii*; however, that species has plicate peristome, a darker spore mass and smaller spores (4.8-5.6 µm in diam.). This species was previously reported from Arizona by Long and Stouffer (1948) as *Geaster limbatus* the "dark European form".

5. ***Geastrum elegans*** Vittad., Monographia Lycoperdineorum: 15 (1842 as *Geaster*).

(figs. 57a, 71a &95e)

Reported synonyms

= *Geastrum badium* Pers., J. Bot. 2: 27 (1809), sensu Stanek in Pilát (1958).

Type: Sunhede (1989) neotypified this taxon, "Two specimens from herb. TO in an envelope marked '*Geaster elegans* Collez Mattirolo' are selected here." There is further discussion regarding the purported synonymy of *G. badium* Pers. and *G. umbilicatum* Fr. were Sunhede makes a strong case against synonymizing these taxa.

Selected illustrations: Pegler, Læssøe & Spooner (1995: figs. 52-53); Stanek in Pilát (1958: figs. 145 & 174, as *Geastrum badium*); Sunhede (1989: figs. 63-66).

Expanded gastrocarp 10-20 mm in width x 13-17 mm in height. Exoperidium splitting to the middle or more, forming 5-9 rays; rays saccate, arching and revolute, with revolute or occasionally involute ray tips, non-hygroscopic. Mycelial layer thin, persistent, encrusted with leafy debris or particles of soil. Pseudoparenchymatous layer

pallid at first, becoming grayish orange (5B3-5), light brown (6D4-5), brown (6E4), or more pallid if covered with pruina, thin (up to 2 mm when fresh), glabrous, rugulose to rimulose, persistent. Fibrous layer orange-white (5A2), grayish orange (5B3) to orange-gray (5B2), thin, papery to coriaceous. Endoperidial body 5-9 mm in diameter x 7-10 mm in height (including peristome), sessile, globose, subglobose to broadly ovate. Apophysis absent. Stalk absent. Endoperidium brownish orange (6C3-4) light brown (6D3-4), to brown (6E5-7), or more pallid due to the pruina, minutely furfuraceous (hyphal protrusions visible only under magnification), becoming more glabrous with age, when fresh heavily pruinose with a dense layer of crystalline matter that gradually wears away. Peristome plicate, distinctly delimited, narrowly to broadly conical with a pointed or truncate apex, up to 3 mm in height, with 11-18 conspicuous folds. Gleba brown (6E5-6), cottony. Columella domed to columnar.

Basidiospores globose, 4.8-6.4 (7.2) X 4.8-6.4 (7.2) µm [x = 5.9 ± 0.7 X 5.9 ± 0.7 µm, Q_m = 1.0, n = 20], verrucose with dense, truncate verrucae; central oil drop; pedicel rudimentary, difficult to discern from verrucae; sterigmal remnants absent from mounts; spores yellowish brown in water mounts. Eucapillitium '*Geastrum*' type, 3.2-6.4 µm in diameter, thick-walled (up to 2.4 µm), glabrous to heavily encrusted, unbranched or occasionally with knob-like projections, especially toward tips, straight to subundulate, attenuate at tips, lacking pores, elastic, aseptate, yellowish brown in water mounts. Endoperidium composed of thick-walled, tightly interwoven hyphal elements, intermixed with crystalline matter.

Habitat: Terrestrial and found in leafy debris under juniper (*Juniperus* spp.) and pine (*Pinus* spp.). This species occurs in the higher elevations of the state within the Petran montane conifer forest biotic community.

Distribution: Distribution in the United States poorly known, but previously reported from Arizona and New Mexico (see fig. 9 for Arizona distribution). Also reported from Europe and Great Britain.

Material examined: ARIZONA, Coconino Co.: Flagstaff, 06 February 1934, W.H. Long (BPI, WHL10030); Walnut Canyon National Monument, 12 October 1986, J.S. States (MICH, AEF528B).

This species is very similar to *G. schmidelii*; however, it can be distinguished by a few key features. *Geastrum elegans* is sessile, has a dense layer of pruina when fresh and the rays are often saccate; on the other hand, *G. schmidelii* is stalked, has only a light layer of pruina or is glabrous and the rays are arching. Smaller specimens of *G. fimbriatum* could be confused with *G. elegans* as they are both sessile with saccate rays; however, the former is not pruinose and has a fibrillose peristome and the later is normally pruinose and has a plicate peristome. The spores of *G. fimbriatum* are also smaller (+/- 3.2-4.0 μm in diam.) than those found in *G. elegans* (4.8-6.4 μm in diam.). This species was previously reported from Arizona by Long and Stouffer (1948) as *Geaster*.

6. ***Geastrum fimbriatum*** Fr., Systema Mycologicum 3: 16 (1829, as *Geaster*).

(figs. 57b, 71b & 95f)

Reported synonyms

= *Geastrum rufescens* var. *minor* Pers., Syn. Meth. Fung. 134 (1801).

= *Geastrum tunicatum* Vittad., Monogr. Lycoperd. 18-19 (1842).

= *Geastrum rufescens* Pers. em. Waveren, Meded. Ned. Mycol. Ver. 15: 118-121 (1926).

= *Geastrum sessile* (Sow.) Pouzar, Folia Geobot. Phytotax. Bohemoslov. 6: 93 (1971).

Type: There is apparently no type material left from Fries, and Sunhede (1989) discussed the reason why references to illustrations of other authors included in the protologue could not be selected as lectotypes in this case. Sunhede, therefore, neotypifies this taxon with, "…Coll. Sunhede 7592 (herb. GB). Among needles in *Pinus sylvestris* wood on calcareous sand. Gotland, Hangvar parish, Ihrevik, 4.XI.1970, leg. S. Sunhede."

Selected illustrations: Coker & Couch (1928: pl. 70, as *Geaster*); Pegler, Læssøe & Spooner (1995: figs. 66-67); Stanek in Pilát (1958: figs. 132 & 166); Sunhede (1989: figs. 68-75).

Expanded gastrocarp 15-35 mm in width x 15-30 mm in height. Exoperidium splitting to the middle or less, forming 5-10 rays, occasionally splitting again at tips; rays

saccate, or arching and revolute, rarely involute at ray tips (more common in larger, aged specimens), non-hygroscopic. Mycelial layer +/- thin, persistent, heavily encrusted with debris or occasionally only lightly encrusted. Pseudoparenchymatous layer pallid at first, becoming pale orange (5A3), grayish orange (5B4), brownish orange (6C5) to light brown (7D5), medium thickness (up to 3 mm when fresh), drying +/- thin, glabrous becoming rimose, particularly toward the ray tips, or in older specimens peeling away in patches and leaving only remnants, occasionally forming a pseudoparenchymatous collar. Fibrous layer pale orange (5A4) becoming more pallid with age, thin, papery to coriaceous. Endoperidial body 7-20 (35) mm in diameter x 9-15 (25) mm in height (including stalk & peristome), +/- sessile, subglobose, globose to depressed globose or broadly ovate. Apophysis reduced or absent. Stalk absent or short (up to 2 mm), broad, concolorous with the endoperidium. Endoperidium grayish orange (5D3) to light brown (6D4), becoming more pallid with age, minutely furfuraceous (hyphal protrusions visible only under magnification), becoming more glabrous with age. Peristome finely fibrillose, not delimited or only faintly so, applanate, broadly conical and truncate to mammiform, up to 3 mm in height. Gleba yellowish brown (5D6) to brown (6E6), cottony. Columella domed, subcolumnar to clavate.

Basidiospores globose, 3.2-4.0 (4.8) X 3.2-4.0 (4.8) µm [x = 3.8 ± 0.5 X 3.8 ± 0.5 µm, Q_m = 1.0, n = 20], verrucose with short, truncate verrucae; central oil drop; pedicel rudimentary, difficult to discern from verrucae; sterigmal remnants absent from mounts; spores pale brownish yellow in water mounts. Eucapillitium '*Geastrum*' type, 2.4-7.2 (9.0) µm in diameter, thick-walled (up to 3.2 µm), glabrous to lightly encrusted, unbranched, straight to subundulate, attenuate at tips, with occasional knob-like

projections, lacking pores, elastic, aseptate, pale brownish yellow in water mounts. Endoperidium composed of thick-walled, tightly interwoven hyphal elements.

Habitat: Terrestrial and found in leafy debris under conifers (e.g., *Abies concolor*, *Pinus edulis* or *Pinus ponderosa*), oak (*Quercus* spp.) or juniper (*Juniperus* spp.). This species is found throughout Arizona and occurs in the mid to higher elevations of the state within the Great Basin conifer woodland, Madrean montane conifer forest, Petran montane conifer forest, and the Plains and Great Basin grassland biotic communities.

Distribution: Known throughout the United States, and previously reported from Colorado, Michigan, New Hampshire, Ohio, Pennsylvania, South Carolina, Tennessee and Wisconsin (see fig. 10 for Arizona distribution). Also reported from Australia, Canada, Europe, Great Britain, Mexico and South Africa.

Material examined: ARIZONA, Cochise Co.: Pinery Canyon, 05 September 1994, J.S. States (MICH, AEF1161). Coconino Co.: Hwy 2 and Old Rim Rd., Coconino Nation Forest, 23 August 1981, J.S. States (MICH, AEF68); Walnut Canyon National Monument, 00 October 1986, J.S. States (MICH, AEF550); Walnut Canyon National Monument, 12 November 1986, J.S. States (MICH, AEF525); Mt. Elden, Coconino National Forest (FR 557, T22N R7E Sect. 36), 24 September 1994, J.S. States (MICH, AEF1246); Walnut Canyon National Monument, 03 May 1995, J.S. States (MICH, AEF1444). Navajo Co.: Near Heber Ranger District, Sitgreaves National Forest, 10 May 1955, W.H. Long & D.J. Stouffer (BPI, 731098); Holbrook, October 1958, D.J. Stouffer

(hb. STB, AZ100058-A1). Pima Co.: Santa Catalina Mts. near Tucson, 1911, W.H. Long (BPI, WHL8855); Mt. Lemmon, Santa Catalina Mts., Coronado Nat. Forest, 16 September 1969, R.L. Gilbertson (ARIZ, RLG9246B). CZECH REPUBLIC, Moravia: Brno, 28 August 1948, Fr. Smarda (ASU, EXSCI. 104).

Geastrum fimbriatum can be confused very easily with *G. rufescens*, and the most reliable character to distinguish the two species is the spore size. The spores of *G. fimbriatum* are much smaller (3.2-4.0 µm in diam.) than those found in *G. rufescens* (4.8-6.0 µm in diam.). In water mounts, the color of the spores and capillitium of *G. fimbriatum* is lighter than that of *G. rufescens*, which also tends to have more densely encrusted capillitia. Macroscopically, *G. fimbriatum* is generally smaller in stature than *G. rufescens* although some specimens can be larger, and *G. rufescens* normally displays reddish tints in the pseudoparenchymatous layer as it matures. In addition *G. fimbriatum* is normally sessile and saccate with a papery to coriaceous fibrous layer; where as, *G. rufescens* is stalked, rarely saccate and has a coriaceous to rigid fibrous layer. *Geastrum fimbriatum* occasionally displays a pseudoparenchymatous collar, and in this case should also be compared with *G. triplex* (see *G. rufescens* and *G. triplex* for further discussion). This species was previously reported from Arizona by Long and Stouffer (1948) as *Geaster*.

7. ***Geastrum floriforme*** Vittad., Monographia Lycoperdineorum: 23 (1842 as *Geaster*).

(figs. 57c, 72a & 96a)

Reported synonyms

= *Geastrum delicatum* Morgan, Amer. Naturalist 21: 1028 (1887).

= *Geastrum pazschkeanum* Henn., Hedwigia 29: 55 (1900).

= *Geastrum sibiricum* Pilát, Bull. Soc. Mycol. France 51: 423 (1935).

Type: Type material is apparently not available from Vittadini; however, collections said to have originated from him exist in the Royal Botanic Garden (K). Sunhede (1989) suggests, "A possible typification of *G. floriforme* should await a study of the complete Vittadinian collection at Kew."

Selected illustrations: Coker & Couch (1928: pl. 68, as *Geaster*); Long & Stouffer (1948: fig. 29, as *Geaster*); Pegler, Læssøe & Spooner (1995: figs. 64-65); Stanek in Pilát (1958: figs. 134 & 168); Sunhede (1989: figs. 77-81).

Expanded gastrocarp 10-23 mm in width x 7-14 mm in height. Exoperidium splitting to the middle or more, forming 5-15 rays, often splitting again at tips; rays involute, extending upward around the endoperidial body and revolute at ray tips, or rolling up over the endoperidial body, normally indented at the base, strongly hygroscopic. Mycelial layer normally absent, or present when +/- fresh, thin, membranaceous and lightly encrusted with fine pieces of leafy debris or particles of sand, soon peeling away from fibrous layer. Pseudoparenchymatous layer pallid at first,

becoming orange-gray (6B2), brownish orange (6C4) to grayish brown (6E3), or remaining pallid, thin (less than 1 mm), glabrous to rugulose, very persistent. Fibrous layer whitish, yellow-white (4A2), grayish orange (5B3) to brownish orange (5C4), thin, rigid, often striate on outer portions. Endoperidial body 8-20 mm in diameter x 5-12 mm in height (including peristome), sessile, subglobose, globose to ovate and laterally compressed. Apophysis absent. Stalk absent. Endoperidium "Pallid Mouse Gray", orange-gray (5B2) to grayish orange (5B3), minutely furfuraceous (hyphal protrusions visible only under magnification), becoming more glabrous with age. Peristome finely fibrillose, not delimited and often small, applanate to broadly conical and truncate, up to 1 mm in height. Gleba brown (6E4), cottony. Columella narrow and subcolumnar.

Basidiospores subglobose to globose, 5.6-7.2 X 5.6-7.2 μm [x = 6.3 ± 0.6 X 6.3 ± 0.6 μm, Q_m = 1.0, n = 20], verrucose with short, dense verrucae; central oil drop; pedicel rudimentary, difficult to discern from verrucae; sterigmal remnants absent from mounts; spores brownish yellow in water mounts. Eucapillitium '*Geastrum*' type, 4.8-7.2 μm in diameter, thick-walled (up to 3.2 μm), glabrous to lightly encrusted, unbranched, straight to subundulate, attenuate with occasional knob-like projections at tips, lacking pores, elastic, aseptate, brownish yellow in water mounts. Endoperidium composed of thick-walled, tightly interwoven hyphal elements and protruding hyphae.

Habitat: Terrestrial and found near old logs, in open areas or in leafy debris under mesquite (*Prosopis* spp.), Douglas fir (*Pseudotsuga menziesii*). This species is found throughout Arizona and occurs in the lower to higher elevations of the state within the Arizona Upland and Lower Colorado subdivision of the Sonoran desertscrub, Petran

montane conifer forest, Petran subalpine conifer forest, and the semidesert grassland biotic communities.

Distribution: Known from the southern and western regions of the United States, and previously reported from Arizona, California, Colorado, Florida, Nebraska, New Mexico, North Dakota, Texas and Washington (see fig. 11 for Arizona distribution). Also reported from Australia, China, Europe, Great Britain, Mexico and South Africa.

Material examined: ARIZONA, Apache Co.: W of (behind) corral, ~50 ft.; ~1 mi down FR 116 off of FR 273; Big Lake, 17 August 2003, S.T. Bates (STB00101). Coconino Co.: Flagstaff, 6 May 1934, W.H. Long (BPI, WHL8980). Gila Co.: Tonto National Forest, August 1934, W.H. Long & Noecker; Roberson (BPI, WHL10025). Greenlee Co.: Eagle Ranger District, Blue River area, Crook National Forest, 24 February 1947, W.H. Long & D.J. Stouffer (BPI, WHL11446). Pima Co.: Sabino Canyon, 04 January 1938, W.H. Long (BPI, WHL8771); Near Sabino Canyon, 28 September 1939, W.H. Long (BPI, WHL8775). Pinal Co.: Chiu Chu, on road to dam, Papago Indian Reservation, 30 November 1972, J.P. Lindsey (ARIZ, JPL109). Santa Cruz Co.: 7 mi. North of Nogales on Hwy. 87, 11 September 1941, W.H. Long & D.J. Stouffer (BPI, WHL9690).

Geastrum floriforme is among the small, strongly hygroscopic earthstars found in the state, which normally lack a mycelial layer. The small, fibrillose peristome that is not distinctly delimited distinguishes *G. floriforme* from *G. corollinum* and *G. kotlabae* (see

those species for further discussion). More pallid gastrocarps of *G. floriforme* could be confused with *G. arenarium*; however, that species has a distinctly delimited peristome and the spores are considerably smaller (3.2-4.0 μm in diam.). Specimens of *G. floriforme* with involute rays that are revolute at the tips look very much like small tan flowers, and the specific epithet was most likely derived from this feature. This species was previously reported from Arizona by Long and Stouffer (1948) as *Geaster*.

8. ***Geastrum fornicatum*** (Huds.) Hook., Flora Londinensis 4: 575 (1821).

(figs. 57d, 72b & 96b)

Basionym

Lycoperdon fornicatum Huds., Fl. Angl. 2: 502-503 (1762).

Reported synonyms

= *Lycoperdon fenestratum* Batsch., Elench. Fung.: 151 (1783).

= *Geastrum fenestratum* (Batsch) Lloyd, Mycol. Writings 1: 70 (1901).

= *Geastrum marchicum* Henn., Verh. Bot. Vereins Prov. Brandenburg 34: 4 (1893).

Type: Although there are several illustrations resembling *G. fornicatum* in the early literature, it is not clear if they represent this taxon, *G. quadrifidum* or *G. welwitschii*. In 1744 Watson illustrated this taxon, and in the opinion of some workers (Dörfelt & Berg 1983, Sunhede 1989) clearly represents *G. fornicatum*. However, Watson's name "*Geaster vulvae radiis et operculo elevates*" cannot be used as it was published before 1753 and it is not a binomial. As no type material from Hudson has

been preserved, Sunhede (1989) notes, "As Hudson (1762) refers to Watson's (1744) illustration, the latter is a part of the protologue and can be selected as lectotype of *L. fornicatum* according to the ICBN."

Selected illustrations: Calonge (1998: fig. 25); Coker & Couch (1928: pl. 70, as *Geaster*); Long & Stouffer (1948: fig. 26, as *Geaster*); Pegler, Læssøe & Spooner (1995: figs. 68-69); Stanek in Pilát (1958: figs. 144 & 173); Sunhede (1989: figs. 82-89).

Expanded gastrocarp 25-40 mm in width x 35-55 mm in height. Exoperidium splitting past the middle, often 3/4 of the way or more, forming 4-7 (normally 4) rays; rays fornicate, revolute with tips of rays attached to the mycelial layer, which forms a cup, non-hygroscopic. Mycelial layer thick, firm, persistent, membranaceous and densely encrusted with debris, forming a cup, often fused and joining 2 or more gastrocarps together. Pseudoparenchymatous layer pallid at first, becoming light brown (7D6), brown (7E7) to reddish brown (8E4), becoming dark brown (8F4) to brownish gray (8F2) with age, thick (up to 5 mm when fresh), drying +/- thin, covered with protruding hyphae, later becoming rimose and more glabrous, finally peeling away to expose the fibrous layer, small patches often remain. Fibrous layer orange-white (5A2), pale orange (5A3), grayish orange (5B3) to light brown (7D5), thin to medium thickness, rigid. Endoperidial body 8-15 (40) mm in diameter x 9-15 (38) mm in height (including stalk & peristome), stalked, subglobose, depressed globose to broadly ovate. Apophysis present and prominent or reduced. Stalk short (up to 3 mm), often laterally compressed, broad, concolorous or lighter than endoperidium. Endoperidium grayish brown (6D3),

light brown (6D6), brown (6E5-7E5) to dark brown (7F4), or more pallid due to the pruina, densely covered with thick, pigmented protruding hyphae, becoming more glabrous with age, often covered in a fine pruinose layer of crystalline matter, especially when fresh. Peristome fibrillose, not distinctly delimited but often lighter than endoperidial body, applanate to narrowly conical and truncate, less than 2 mm in height. Gleba dark brown (8F4-5), cottony to pulverulent, particularly toward center. Columella domed to columnar.

Basidiospores globose, 4.8-5.6 X 4.8-5.6 μm [x = 5.3 ± 0.4 X 5.3 ± 0.4 μm, Q_m = 1.0, n = 20], verrucose with narrow, truncate verrucae; central oil drop; pedicel rudimentary, difficult to discern from verrucae; sterigmal remnants absent from mounts; spores light brown in water mounts. Eucapillitium '*Geastrum*' type, 3.2-9.6 μm in diameter, thick-walled (up to 4.0 μm), glabrous to lightly encrusted, unbranched or occasionally with short branches or knob-like projections, especially toward tips, straight to undulate, attenuate and undulate at tips, lacking pores, elastic, aseptate, light brown in water mounts. Endoperidium composed of thick-walled, tightly interwoven hyphal elements and broad, pigmented protruding hyphae.

Habitat: Terrestrial and found in riparian areas, open areas or in leafy debris under cat claw acacia (*Acacia greggii*) and mesquite (*Prosopis* spp.). This species occurs in the mid to higher elevations of the state within the Madrean evergreen woodland and semidesert grassland biotic communities.

Distribution: Known only from the southern regions of the United States, and previously reported from Arizona, California, Hawaii, New Mexico, North Carolina and Texas (see fig. 12 for Arizona distribution). Also reported from Africa, Australia, Europe, Great Britain, Mexico and West Indies.

Material examined: ARIZONA, Gila Co.: Globe, AZ, date unknown, Mrs. C.N. Hagius (ARIZ, AN014649). Pima Co.: 2 mi. from the mouth of Sabino Canyon, 10 November 1938, W.H. Long (BPI, WHL8265); Lower Bear Canyon Picnic Area, Mt. Lemmon, Santa Catalina Mts., Coronado Nat. Forest, 16 November 1972, J.P. Lindsey (ARIZ, JPL106). Santa Cruz Co.: 10 mi. from Nogales, 04 June 1938, W.H. Long (BPI, WHL8266); About 8 mi. from Nogales, on banks of Santa Cruz river, 10 November 1938, W.H. Long (BPI, WHL8264).

The fornicate gastrocarp and fibrillose peristome, which is not distinctly delimited, distinguishes *G. fornicatum* from all other earthstars found in the state. *Geastrum quadrifidum* is the only species that could be confused with *G. fornicatum* as it also has a fornicate gastrocarp. However, *G. quadrifidum* is easily distinguished by the larger spores (5.6-6.4 μm in diam.) and distinctly delimited peristome (see *G. quadrifidum* for further discussion). This species was previously reported from Arizona by Long and Stouffer (1948) as *Geaster*.

9. ***Geastrum hieronymi*** Henn., Hedwigia 36: 211 (1903, as *Geaster*).

(figs. 58a, 73a & 96c)

Type: The type resides at the Botanical Museum Berlin-Dahlem (B) and is labeled "*Geastrum hieronymi* P. Henn., Argentina. Chacra de la Merced cerca de Cordoba. 18.X.1881. leg. C. Hieronymus. " The herbarium of the Department of Cryptogamic Botany at the Swedish Museum of Natural History houses a specimen (S F16380) labeled "*Geastrum hieronymi* P. Henn., South America, Argentina, Chacra de la Merced, Cordoba, Type, det.: *Geaster hieronymus*", which is likely to be a syntype or isotype.

Selected illustrations: Lloyd (1906: pl. 97, figs. 4 & 5, as *Geaster*); Long & Stouffer (1948: fig. 20, as *Geaster*).

Expanded gastrocarp 26-53 mm in width x 21-37 mm in height. Exoperidium splitting to the middle or more, forming 5-8 rays, occasionally splitting again at tips; rays arching and revolute, involute and extending upward around or rolling up over the endoperidial body, or occasionally irregular having some revolute rays and others involute, subhygroscopic. Mycelial layer thick, persistent, densely encrusted with debris. Pseudoparenchymatous layer pallid at first, becoming grayish brown (5D3), light brown (5D4) to brown (6D5-6E6 to 7E5), thin (up to 2 mm), glabrous, becoming rimulose with age, or completely lacking in very old specimens. Fibrous layer pale orange (6A3), grayish orange (6B3), becoming more pallid with age, thin, coriaceous. Endoperidial body 15-24 mm in diameter x 11-19 mm in height (including stalk & peristome), stalked,

globose, depressed globose to broadly ovate. Apophysis present and prominent or reduced. Stalk short (up to 3 mm), often laterally compressed, narrow to broad, concolorous or slightly lighter than endoperidium. Endoperidium grayish orange (5B3), light brown (5D5) to "Pallid Mouse Gray" or "Pale Olive Gray", covered with persistent coarse, granular, irregular-shaped to spiny projections that are grayish brown (7E3) to dark brown (7F4) in color. Peristome fibrillose, not distinctly delimited, applanate to broadly conical and truncate, less than 2 mm in height. Gleba brown (7E4-6), cottony. Columella domed to clavate.

Basidiospores globose, 4.0-4.8 X 4.0-4.8 μm [x = 4.4 ± 0.4 X 4.4 ± 0.4 μm, Q_m = 1.0, n = 20], verrucose with short, dense verrucae; central oil drop; pedicel rudimentary, difficult to discern from verrucae; sterigmal remnants absent from mounts; spores yellowish brown in water mounts. Eucapillitium '*Geastrum*' type, 4.0-7.2 μm in diameter, thick-walled (up to 2.4 μm), glabrous to heavily encrusted, unbranched or rarely with short branches at tips, straight to subundulate, often with long narrow attenuate tips, lacking pores, elastic, aseptate, yellowish brown in water mounts. Endoperidium composed of thick-walled, tightly interwoven hyphal element and darkly pigmented, irregular-shaped, thick-walled sphaerocysts.

Habitat: Terrestrial and found in leafy debris under juniper (*Juniperus* spp.). This species occurs in the mid to higher elevations of the state within the Madrean evergreen woodland biotic community.

Distribution: Known only from the southwestern United States, and previously reported from New Mexico (see fig. 13 for Arizona distribution). Also reported from Mexico, South America and South Africa.

Material examined: ARIZONA, Cochise Co.: Fort Huachuca military reservation, 15 January 1995, R. Hoskinson (MICH, AEF1426).

The darkly colored spicules that cover the endoperidium distinguish *G. hieronymi* from all other earthstars found in the state. This species could be confused with *G. pseudolimbatum* (not reported from Arizona) which has a roughened endoperidium; however, that species has hygroscopic rays, a distinctly delimited peristome and larger spores (5.5-7.0 µm in diam.). *Geastrum campestre* is another species with a roughened endoperidium that might be confused with *G. hieronymi*; however, that species is somewhat smaller in stature and has a distinctly delimited peristome and larger spores (6.4-8.0 µm in diam.). This species was previously reported from Arizona by Long and Stouffer (1948) as *Geaster*.

10. ***Geastrum kotlabae*** V.J. Stanek, In Pilát (ed.), Flora CSR B-1: 474-475 (1958).

(figs. 58b, 73b, 96d & 98e)

Reported synonyms

= *Geastrum ambiguum* Mont., Fl. Boliviensis: 47 (1839), sensu Hollós (1904).

= *Geastrum drummondii* Berk., J. Bot. 4: 63 (1845), sensu Hollós (1902).

Type: The holotype, which was designated by Stanek (1958), is located in the Czech Republic at the National Museum, Praha (PRM) labeled "Hungaria, VI.1953, leg. E. Nánay" (Sunhede 1989).

Selected illustrations: Long & Stouffer (1948: fig. 1, as *Geaster drummondii*); Stanek in Pilát (1958: fig. 157); Sunhede (1989: figs. 96-99).

Expanded gastrocarp 10-35 mm in width x 5-25 mm in height. Exoperidium splitting the middle or more, forming 5-11 rays, occasionally splitting again at tips; rays involute, extending upward around or rolling up over the endoperidial body, normally indented at the base, strongly hygroscopic. Mycelial layer normally absent, or present when +/- fresh, very thin, membranaceous and lightly encrusted with debris when fresh, soon peeling away from fibrous layer. Pseudoparenchymatous layer pallid at first, becoming orange-gray (5B3) to light brown (6D5) or darker with age, thin (up to 1 mm), glabrous to rimulose, very persistent. Fibrous layer yellow white (4A2) to orange white (5A2), thin, rigid. Endoperidial body 8-12 mm in diameter x 5-14 mm in height (including peristome), +/- sessile, subglobose, globose to depressed globose. Apophysis absent. Stalk absent or greatly reduced, broad, not visible due to the persistent pseudoparenchymatous layer. Endoperidium yellowish white (4A2), grayish brown (5D3-4) to light brown (6D4), conspicuously roughened with small rounded verrucae, becoming more glabrous with age. Peristome plicate, not delimited or only faintly so, broadly conical and truncate to mammiform, 1-2 mm in height, with 10-20 conspicuous folds. Gleba brown (7E4-6), cottony. Columella domed, subcolumnar to clavate.

Basidiospores globose, 4.8-6.4 X 4.8-6.4 µm [x = 5.7 ± 0.6 X 5.7 ± 0.6 µm, Q_m = 1.0, n = 20], strongly verrucose with truncate verrucae; central oil drop; pedicel rudimentary, difficult to discern from verrucae; sterigmal remnants absent from mounts; spores yellow-brown in water mounts. Eucapillitium '*Geastrum*' type, 4.8-6.4 (8.0) µm in diameter, thick-walled (up to 2.4 µm), lightly to heavily encrusted, unbranched, straight to subundulate, attenuate and undulate at tips, lacking pores, elastic, aseptate, yellow-brown in water mounts. Endoperidium composed of thick-walled, tightly interwoven hyphal elements.

Habitat: Terrestrial and found in open places, barren areas with granitic soil or in leafy debris under juniper (*Juniperus* spp.). This species occurs in the mid to higher elevations of the state within the Great Basin conifer woodland and interior chaparral biotic communities.

Distribution: Restricted to arid areas of the United States, and previously reported from Arizona, New Mexico and Texas (see fig. 14 for Arizona distribution). Also reported from Africa, Europe, Australia and Tasmania.

Material examined: ARIZONA, Gila Co.: S of Payson on Hwy. 87 (eastside), 21 February 2003, S.T. Bates (STB 00185). Greenlee Co.: Eagle Ranger District, Crook National Forest, 24 March 1947, W.H. Long & D.J. Stouffer (BPI, WHL11455); Eagle District, Crook National Forest, 28 March 1947, W.H. Long & D.J. Stouffer (BPI, WHL10104). Yavapai Co.: Copper Basin Area, Prescott, 15 September 1933, W.H.

Long (BPI, WHL7760); Prescott, 02 January 1934, W.H. Long (BPI, WHL7906); Prescott National Forest, Prescott, 16 February 1934, W.H. Long & V.O. Sandberg (BPI, WHL7615).

The roughened endoperidium and plicate peristome distinguish *G. kotlabae* from the other small, strongly hygroscopic earthstar species found in the state that normally lack a mycelial layer (see *G. corollinum* and *G. floriforme* for further discussion). This species could also be confused with *G. campestre* due to the roughened endoperidium; however, that species has a distinct stalk, encrusted mycelial layer and involute rays that normally roll up under the endoperidial body rather than over it (see *G. campestre* for further discussion). The spores of *G. campestre* are also larger (6.4-8.0 µm in diam.). *Geastrum xerophilum* is also very similar to *G. kotlabae*; however, that species has non-hygroscopic rays (see *G. xerophilum* for further discussion). This species was previously reported from Arizona by Long and Stouffer (1948) as *Geaster drummondii*.

11. ***Geastrum lageniforme*** Vittad., Monographia Lycoperdineorum: 16-17 (1842 as *Geaster*). (figs. 58c, 74a & 96e)

Type: Vittadini did not select type material, and illustrations referred to in the protologue are ambiguous. There are two collections in the herbarium of the Royal Botanic Gardens, Kew (K) marked "Type" which are believed to be authentic material from Vittadini. From these two collections Sunhede (1989) selected as a neotype the

collection labeled, “HERB. C.E. BROOME. - Bequeathed 1886; *Geaster lageniformis* Borghese Gardens. Rome. October 1845”.

Selected illustrations: Calonge (1998: fig. 26); Pegler, Læssøe & Spooner (1995: figs. 82-83); Stanek in Pilát (1958: fig. 161a); Sunhede (1989: figs. 100-106).

Expanded gastrocarp 27-35 mm in width x 5-10 mm in height. Exoperidium splitting to the middle or more, forming 5-8 rays, very narrow at tips; rays saccate, or revolute with rays rolling under gastrocarp, occasionally irregular having some revolute rays and others involute, rarely entirely involute, non-hygroscopic. Mycelial layer thin, persistent, membranaceous, not encrusted with debris or very lightly so, splitting radially along rays to reveal the fibrous layer, which is lighter in color. Pseudoparenchymatous layer pallid at first, becoming brown (7E4-6) to reddish brown (8D4-5 to 8E4-6), thin (less than 2 mm when fresh), glabrous to rimulose, often splitting radially along rays, very persistent. Fibrous layer orange-white (5A2-6A2), thin, papery. Endoperidial body 10-17 mm in diameter x 5-10 mm in height (including peristome), sessile, globose, depressed globose to broadly ovate. Apophysis absent. Stalk absent. Endoperidium “Pale Olive Buff”, “Cartridge Buff” to orange-white (5A2), glabrous to very minutely furfuraceous (hyphal protrusions visible only under high magnification). Peristome finely fibrillose, delimited by a distinct ridge, rarely only faintly delimited, concolorous with the endoperidial body, applanate, broadly conical and truncate to mammiform, up to 2 mm in height. Gleba light brown (5D5) to brown (6E5), cottony. Columella domed, subcolumnar to clavate.

Basidiospores globose, 4.0-4.8 X 4.0-4.8 μm [x = 4.5 ± 0.4 X 4.5 ± 0.4 μm, Q_m = 1.0, n = 20], verrucose with truncate verrucae; central oil drop; pedicel rudimentary, difficult to discern from verrucae; sterigmal remnants absent from mounts; spores yellowish to brownish yellow in water mounts. Eucapillitium '*Geastrum*' type, 4.0-9.6 μm in diameter, thick-walled (up to 2.0 μm), glabrous to lightly encrusted, unbranched or occasionally with short, rudimentary branches, straight to subundulate, attenuate at tips, lacking pores, elastic, aseptate, yellowish to brownish yellow in water mounts. Endoperidium composed of thick-walled, tightly interwoven hyphal elements.

Habitat: Terrestrial and found in leafy debris under juniper (*Juniperus* spp.) and pinyon (*Pinus edulis*). This species occurs in the higher elevations of the state within the Great Basin conifer woodland biotic community.

Distribution: Known from various parts of the United States and previously reported from Florida and Missouri (see fig. 15 for Arizona distribution). Also reported from Australia, Canada, Europe and Great Britain.

Material examined: ARIZONA, Navajo Co.: 3/4 mi S White River, Ft. Apache Ind. Res., 20 December 1971, G. Leach (ARIZ, no collection or accession number).

Geastrum lageniforme is superficially similar to *G. triplex*; however, that species normally lacks the radial cracking in the mycelial layer that is very apparent in *G. lageniforme*. *Geastrum triplex* also normally exhibits a pseudoparenchymatous collar,

which is not present in *G. lageniforme*. *Geastrum saccatum* is similar to *G. lageniforme*. *Geastrum saccatum* only occasionally exhibits radial cracking in the mycelial layer which is normally present in *G. lageniforme*. The endoperidium in *G. saccatum* is more strongly furfuraceous than *G. lageniforme* where the hyphal protrusions are visible only at the highest magnification under the dissecting microscope. Furthermore, *G. lageniforme* has lageniform basidia when mature, where as, *G. saccatum* exhibits bladder-like to clavate basidia at maturity. This species is reported for the first time from Arizona here.

12. ***Geastrum minimum*** Schwein., Schriften der Naturforschenden Gesellschaft zu Leipzig 1: 58 (1822, as *Geaster*). (figs. 58d, 74b & 96f)

Reported synonyms

= *Geastrum marginatum* Vittad., Monogr. Lycoperd.: 19-20 (1842).

= *Geastrum caesatii* Rabenh., Bot. Zeitung (Berlin) 9: 628-629 (1851).

= *Geastrum granulosum* Fuckel, Jahrb. Nassauischen Vereins Naturk. 15: 41 (1860).

= *Geastrum calceus* Lloyd, Mycol. Notes 2: 311 (1907).

= *Geastrum juniperinus* Macbride, Mycologia 4: 85 (1912).

Type: The poorly preserved holotype is in the herbarium of the Royal Botanic Garden, Kew (K) labeled, "*Geaster minimus* Schw. Ex herb. Schw., H.W. Ravenel's herbarium. – Recd. 1891" (Sunhede 1989).

Selected illustrations: Long & Stouffer (1948: figs. 15-16, as *Geaster*); Pegler, Læssøe & Spooner (1995: figs. 72-73); Stanek in Pilát (1958: figs. 140 & 171); Sunhede (1989: figs. 107-112).

Expanded gastrocarp 10-30 mm in width x 10-22 mm in height. Exoperidium splitting to the middle or less, forming 5-9 rays, often splitting again at tips; rays arching and revolute, or occasionally revolute with involute tips, subhygroscopic. Mycelial layer +/- thin, persistent, heavily encrusted with debris. Pseudoparenchymatous layer pallid at first, becoming orange-white (5A2), orange-gray (5B3) to brownish orange (6C4), or more pallid if covered with pruina, thin (up to 2 mm when fresh), glabrous and covered with a fine pruina of crystalline matter left behind from the endoperidium, becoming less pruinose and more rimose with age, often radially striate along rays. Fibrous layer orange-white (5A2), thin, papery to coriaceous. Endoperidial body 4-13 mm in diameter x 6-12 mm in height (including stalk & peristome), stalked, subglobose, depressed globose to broadly ovate. Apophysis present and prominent or occasionally reduced. Stalk short (up to 3 mm), often laterally compressed, narrow to broad, concolorous or lighter than endoperidium. Endoperidium orange-gray (5B2) to brownish orange (5C4), or more pallid due to the pruina, glabrous to minutely furfuraceous (hyphal protrusions visible only under magnification), covered in a fine, dense pruinose layer of crystalline matter, especially when fresh. Peristome finely fibrillose, distinctly delimited, concolorous, lighter or darker than endoperidium, applanate, broadly conical and truncate to mammiform, less than 2 mm in height. Gleba brownish orange (5C5) to brown (6E5), cottony. Columella subcolumnar to clavate, or absent.

Basidiospores subglobose to globose, 4.8-6.4 X 4.8-6.4 µm [x = 5.6 ± 0.7 X 5.6 ± 0.7 µm, Q_m = 1.0, n = 20], verrucose with short, truncate verrucae; central oil drop; pedicel rudimentary, difficult to discern from verrucae, or short (up to 2.0 µm); sterigmal remnants absent from mounts; spores yellowish brown in water mounts. Eucapillitium '*Geastrum*' type, 3.2-6.4 (8.0) µm in diameter, thick-walled (up to 2.4 µm), glabrous to lightly encrusted, unbranched or occasionally with short branches or knob-like projection, especially toward tips, straight to undulate, occasionally with swollen segments, attenuate and undulate at tips, units shorter than most *Geastrum* capillitia, lacking pores, elastic, aseptate, yellowish brown in water mounts. Endoperidium composed of thick-walled, tightly interwoven hyphal elements, intermixed with crystalline matter.

Habitat: Terrestrial and found in open places, wash areas or in leafy debris under conifers (e.g., *Pseudotsuga menziesii*, *Pinus edulis* or *Pinus ponderosa*), mesquite (*Prosopis* spp.) or juniper (*Juniperus* spp.). This species is wide-spread in northern Arizona and occurs in mid to higher elevations of the state within the Great Basin conifer woodland, interior chaparral, Petran montane conifer forest, and the Plains and Great Basin grassland biotic communities.

Distribution: Known throughout the United States, and previously reported from Arizona, Hawaii, Massachusetts, Michigan, New Mexico, Ohio, South Carolina, Texas and Wisconsin (see fig. 16 for Arizona distribution). Also reported from Australia, Europe, Great Britain, India, Japan, Mexico, New Zealand, South America and South Africa.

Material examined: ARIZONA, Coconino Co.: Grand Canyon, August 1930, W.H. Long & R.B. Stuet (BPI, WHL7889); 12 mi. from Flagstaff, 02 May 1933, W.H. Long (BPI, WHL8869); Flagstaff, 06 May 1934, W.H. Long (BPI, WHL7695); Flagstaff, 04 July 1941, W.H. Long (BPI, WHL9374); Paradise Rd., Flagstaff, 12 August 1986, J.S. States (MICH, AEF519); Walnut Canyon National Monument, 12 October 1986 (MICH, AEF528A); Walnut Canyon National Monument, 17 October 1986, J.S. States (MICH, AEF518); Walnut Canyon National Monument, 14 October 1990, J.S. States (MICH, AEF810). Gila Co.: Tonto National Forest, August 1936, W.H. Long & Noecker; Roberson (BPI, WHL8906); S side Hwy. 260 across from entrance to Quail Run Rd., ~10 mi NE of Payson, 10 August 2002, S.T. Bates (STB00067). Graham Co.: Near Safford, 09 September 1941, W.H. Long & D.J. Stouffer (BPI, WHL9703). Mohave Co.: Near the N Rim of the Grand Canyon; Parashant Nat. Monument, 21 May 2003, S.T. Bates (STB00488). Navajo Co.: Heber Ranger District, Sitgreaves National Forest near Heber, 05 October 1955, W.H. Long & D.J. Stouffer (BPI, 731389); Holbrook, October 1958, D.J. Stouffer (hb. STB, AZ100058-A2).

The small stature, often densely pruinose endoperidium, distinctly delimited peristome and short stalk distinguishes *G. minimum* from other smaller earthstars found in Arizona. Although it is not fornicate, *G. minimum* could be confused with specimens of *G. quadrifidum* that have lost the mycelial layer cup; however, that species normally has a distinct, disc-shaped peristome (see *G. quadrifidum* for further discussion). *Geastrum arenarium* is also superficially similar to *G. minimum*; however, that species has smaller spores (3.2-4.0 μm in diam.), it is +/- sessile and more pallid in color (see *G.*

arenarium for further discussion). *Geastrum minimum* could also be confused with *G. smithii*, which has a plicate peristome (see *G. smithii* for further discussion). Finally, *G. corollinum* is superficially similar to *G. minimum*; however, the former is +/- sessile and has strongly hygroscopic, rigid rays (see *G. corollinum* for further discussion). Cunningham (1944) included *G. minimum* and *G. quadrifidum* under *G. minus* (Pers.) Fischer. *Geastrum minimum* was previously reported from Arizona by Long and Stouffer (1948) as *Geaster*.

13. ***Geastrum quadrifidum*** Pers.: Pers., Synopsis Methodica Fungorum: 133 (1801).

(figs. 59a, 75a & 97a)

Reported synonyms

= *Lycoperdon coronatum* Scopoli, Fl. Carniol., ed. 2: 490 (1772).

= *Geastrum coronatum* (Scaeff.) Schroet. Krypt. Fl. Schlesiens 3: 702 (1889), sensu Lloyd (1902) and subsequent American authors.

= *Geastrum quadrifidum β minus* Pers., Syn. Meth. Fung. 133 (1801).

Type: Sunhede (1989) notes that the specimen selected by Eyndhoven in his 1937 publication, *Geastrologische Notizen* (Meded. Ned. Mycol. Ver. 24: 12-14), should be regarded as the neotype. The neotype resides in Persoon herbarium at the National Herbarium Nederland (L) and is labeled "*Geaster quadrifidum* var. Pers., HERB. LUGD. BAT. No 910.262-395 and No 79".

Selected illustrations: Coker & Couch (1928: pl. 71, as *Geaster coronatus*); Long & Stouffer (1948: fig. 19, as *Geaster coronatus*); Pegler, Læssøe & Spooner (1995: figs. 70-71); Stanek in Pilát (1958: figs. 142-143 & 172); Sunhede (1989: figs. 146-152).

Expanded gastrocarp 18-23 mm in width x 23-35 mm in height. Exoperidium splitting to the middle or more, forming 4-6 rays; rays fornicate, revolute with tips of rays attached to the mycelial layer, which forms a cup, non-hygroscopic. Mycelial layer thin, persistent, membranaceous and densely encrusted with debris, forming a cup. Pseudoparenchymatous layer pallid at first, becoming grayish orange (5B4-5), brownish orange (5C4-5) to brown (7E5), or more pallid if covered with pruina, thin (up to 2 mm when fresh), glabrous and covered with a fine to coarse pruina of crystalline matter left behind from the endoperidium, becoming less pruinose and more rimose with age, finally peeling away in patches to expose the fibrous layer. Fibrous layer orange-white (5A2), pale orange (5A3) to grayish orange (5B3), thin, papery to coriaceous. Endoperidial body 7-15 mm in diameter x 9-17 mm in height (including stalk & peristome), stalked, globose, broadly to narrowly ovate. Apophysis present and prominent. Stalk short (up to 3 mm), often laterally compressed, narrow to broad, concolorous or lighter than endoperidium. Endoperidium brownish orange (6C3), brown (6E4), grayish brown (6E3) to dark brown (8F4-5), or more pallid due to the pruina, glabrous, often covered in a fine to coarse, dense pruinose layer of crystalline matter, especially when fresh. Peristome fibrillose, distinctly delimited and normally rimmed, lighter than edoperidial body, conical to mammiform, up to 2 mm in height. Gleba dark brown (8F4-6), cottony. Columella domed to clavate.

Basidiospores globose, (4.8) 5.6-6.4 (7.2) X (4.8) 5.6-6.4 (7.2) μm [x = 6.1 ± 0.7 X 6.1 ± 0.7 μm, Q_m = 1.0, n = 20], verrucose with short, truncate verrucae; central oil drop; pedicel rudimentary, difficult to discern from verrucae; sterigmal remnants absent from mounts; spores light brown in water mounts. Eucapillitium '*Geastrum*' type, 4.0-7.2 μm in diameter, thick-walled (up to 3.2 μm), glabrous to lightly encrusted, unbranched, straight to subundulate, attenuate and often undulate at tips, lacking pores, elastic, aseptate, light brown in water mounts. Endoperidium composed of thick-walled, tightly interwoven hyphal elements, intermixed with crystalline matter.

Habitat: Terrestrial and found in leafy debris under fir (*Abies concolor*) or aspen (*Populus tremuloides*). This species occurs in the higher elevations of the state within the Petran montane conifer forest and Petran subalpine conifer forest biotic communities.

Distribution: Known throughout the United States, and previously reported from Arizona, California, Florida, Michigan, New Jersey, New York and Texas (see fig. 17 for Arizona distribution). Also reported from Canada, Caribbean, Europe, Great Britain, Japan, Mexico, New Zealand and South America.

Material examined: ARIZONA, Apache Co.: Phelps Botanical Area, Big Lake, October 1958, C.R. Leathers (hb. STB, AZ071958-A1). Cochise Co.: Tub Springs, Chiricahua Mts., Coronado Nat. Forest, 21 June 1969. R.L. Gilbertson (ARIZ, RLG9039). Graham Co.: Mt. Graham, Crook National Forest, 8 May 1947, W.H. Long & D.J. Stouffer (BPI, WHL11458). Pima Co.: Mt. Lemmon, Santa Catalina Mts., Coronado

Nat. Forest, 16 September 1969, R.L. Gilbertson (ARIZ, RLG9246A). CZECH REPUBLIC, Moravia: Brno, 26 Novemeber 1949, Fr. Smarda (ASU, EXSCI. 103).

The fornicate gastrocarp and fibrillose peristome, that is distinctly delimited, distinguishes *G. quadrifidum* from other earthstars found in the state. *Geastrum quadrifidum* could be confused with *G. fornicatum* as that species is also fornicate. *Geastrum fornicatum* has smaller spores (4.8-5.6 μm in diam.) and a peristome that is neither distinctly delimited nor rimmed (see *G. fornicatum* for further discussion). The mycelial layer cup of *G. quadrifidum* often becomes detached and, in this case, it could be confused with *G. minimum* as the endoperidial body is normally covered in crystalline matter. *Geastrum minimum*, however, has an peristome that is distinctly delimited but normally not rimmed. The endoperidial body of *G. minimum* is also generally lighter in color and the mycelial layer is persistent, heavily encrusted with debris and adheres tightly to the fibrous layer (see *G. minimum* for further discussion). Coker and Couch (1928) cite *Geastrum leptospermum* (not reported from Arizona), which is similar to *G. quadrifidum*. That species very small in stature, has smaller spores (3.0-4.0 μm in diam. - Sunhede 1989) and grows in mosses on tree trunks. *Geastrum quadrifidum* was previously reported from Arizona by Long and Stouffer (1948) as *Geaster coronatus*.

14. ***Geastrum rufescens*** Pers.: Pers., Synopsis Methodica Fungorum: 134 (1801).

(figs. 59b, 75b & 97b)

Reported synonyms

= *Geastrum schaefferi* Vittad., Monog. Lycoperd. 22-23 (1842).

= *Geastrum vulgatum* Vittad., Monog. Lycoperd. 20-21 (1842).

Type: Dörfelt & Müller-Uri (1984) selected as the lectotype Schaeffer's fig. 2, tab. 182 from the 1763 publication *Fungorum, qui in Bavaria et Palatinatu circa Ratisbonam nascuntur icons, natives coloribus expressa*.

Selected illustrations: Coker & Couch (1928: pl. 69, as *Geaster*); Long & Stouffer (1948: fig. 27, as *Geaster*); Pegler, Læssøe & Spooner (1995: figs. 74-75); Stanek in Pilát (1958: fig. 167); Sunhede (1989: figs. 155-161).

Expanded gastrocarp 25-55 mm in width x 25-35 mm in height. Exoperidium splitting to the middle or less, forming 5-8 rays, often splitting again at tips; rays arching and revolute, or occasionally revolute with involute tips, non-hygroscopic. Mycelial layer thin to medium thickness, persistent, lightly to heavily encrusted with debris. Pseudoparenchymatous layer pallid at first, displaying reddish tints as matures, becoming light brown (6D6), brown (7D6) to reddish brown (8E7), thick (up to 6 mm when fresh), drying +/- thin, glabrous at first, quickly becoming rimose and peeling away in irregular patches with age, occasionally forming a pseudoparenchymatous collar. Fibrous layer pale orange (5A3) to grayish orange (6B4), thin to medium thickness, coriaceous to rigid.

Endoperidial body 13-20 mm in diameter x 10-20 mm in height (including stalk & peristome), with short stalk or nearly sessile, subglobose, globose to broadly ovate. Apophysis reduced or absent. Stalk reduced, short (up to 3 mm), broad, concolorous with the endoperidium or slightly lighter. Endoperidium brownish orange (5C4) to light brown (6D5), minutely furfuraceous (hyphal protrusions visible only under magnification), often becoming glabrous with age. Peristome finely fibrillose, not delimited or only faintly so, applanate, broadly conical and truncate to mammiform, less than 3 mm in height. Gleba brown (7E7) to dark brown (7F7), cottony. Columella domed to clavate.

Basidiospores globose, 4.8-5.6 (6.0) X 4.8-5.6 (6.0) μm [x = 5.4 ± 0.4 X 5.4 ± 0.4 μm, Q_m = 1.0, n = 20], strongly verrucose with long, truncate verrucae; central oil drop; pedicel rudimentary, difficult to discern from verrucae; sterigmal remnants absent from mounts; spores pale brown in water mounts. Eucapillitium '*Geastrum*' type, 2.4-7.2 (12.0) μm in diameter, thick-walled (up to 3.2 μm), heavily encrusted, only occasionally glabrous, unbranched, straight to subundulate, attenuate at tips, lacking pores, elastic, aseptate, pale brown in water mounts. Endoperidium composed of thick-walled, tightly interwoven hyphal elements.

Habitat: Terrestrial and found in leafy debris under pinyon (*Pinus edulis*). This species occurs in the higher elevations of the state within the Great Basin conifer woodland biotic community.

Distribution: Known throughout the United States, and previously reported from Alabama, Michigan, Missouri, New Mexico, New York, Ohio, Texas and Wisconsin (see fig. 18 for Arizona distribution). Also reported from Canada, China, Europe, Great Britain, Japan and Mexico.

Material examined: ARIZONA, Coconino Co.: Navajo National Monument, 18 May 1983, J.S. States (MICH, AEF829); Walnut Canyon National Monument, 18 October 1986, J.S. States (MICH, AEF526B). Mohave Co.: Mt. Trumbell; Parashant Nat. Monument, 22 May 2003, S.T. Bates (STB00625).

Geastrum rufescens is very similar to *G. fimbriatum* and is best distinguished using spore size in conjunction with other characters discussed under that taxon. Like *G. fimbriatum*, *G. rufescens* can display a pseudoparenchymatous collar at times, which might cause confusion with *G. triplex*. However, *Geastrum triplex* normally has a more prominent collar. *Geastrum fimbriatum* can be distinguished from both *G. rufescens* and *G. triplex* by its having smaller spores (+/- 3.2 - 4.0 µm in diam.). *Geastrum triplex* is normally saccate, where as *G. rufescens* is not. In addition, the later has less defined peristome, while the former has a peristome that is distinctly delimited. This species was previously reported from Arizona by Long and Stouffer (1948) as *Geaster*.

15. ***Geastrum saccatum*** Fr., Systema Mycologicum 3: 16-17 (1828 as *Geaster*).

(figs. 59c, 76a & 97c)

Type: Fries concept of this species was based on material from Brazil. As no type material from Fries exists, Sunhede (1989) concluded that there was a need to have better knowledge of Brazilian *Geastrum* species before a judgment can be made regarding the identity of this species and its relationship to *G. lageniforme*. Therefore, Sunhede decided against neotypifying the species, but stated that he based his concept on material from Hollós housed in the herbarium at the University of Copenhagen (C 324).

Selected illustrations: Bottomley (1948: Pl. 56, fig. 2); Smith (1951: Pl. 30, figs. 1 & 2); Stanek in Pilát (1958: figs. 162-164 & 187); Sunhede (1989: figs. 165-174).

Expanded gastrocarp 30-60 mm in width x 15-25 mm in height. Exoperidium splitting to the middle or more, forming 6-8 rays, narrow to truncate and often splitting again at the tips; rays saccate, or revolute with rays rolling under gastrocarp, occasionally irregular having some revolute rays and others involute, non-hygroscopic. Mycelial layer thin, persistent, membranaceous, not encrusted with debris or very lightly so, occasionally splitting radially along rays to reveal the fibrous layer, which is lighter in color. Pseudoparenchymatous layer pallid at first, becoming grayish orange (5B3-5), brown (5E4-6 to 6E4-6), dark brown (6F4-6), grayish brown (6F3) to brownish gray (6F2), thin (less than 2 mm when fresh), glabrous to rimulose, occasionally splitting radially along rays, very persistent, rarely forming a fugacious pseudoparenchymatous

collar. Fibrous layer orange-white (5A2-6A2), thin, coriaceous. Endoperidial body 15-30 mm in diameter x 5-10 mm in height (including peristome), sessile, globose, depressed globose to broadly ovate. Apophysis absent. Stalk absent. Endoperidium brownish gray (5C2 to 5D2), grayish brown (5D3, 6C3 to 6D3), light brown (5D4 to 6D4) to yellowish brown (5E4) to brown (6E4), glabrous to minutely furfuraceous (hyphal protrusions visible only under high magnification). Peristome finely fibrillose, distinctly delimited and often with a distinct ridge, rarely only faintly delimited, concolorous with the endoperidial body, applanate, broadly conical and truncate to mammiform, up to 2 mm in height. Gleba brown (6E4-5) to dark brown (6F5-6), cottony. Columella domed, columnar to clavate.

Basidiospores globose, (4.0) 4.8-5.6 (6.4) X (4.0) 4.8-5.6 (6.4) µm [x = 5.4 ± 0.4 X 5.4 ± 0.4 µm, Q_m = 1.0, n = 20], verrucose with truncate verrucae; central oil drop; pedicel rudimentary, difficult to discern from verrucae; sterigmal remnants absent from mounts; spores pale in water mounts. Eucapillitium '*Geastrum*' type, 4.0-9.6 µm in diameter, thick-walled (up to 4.0 µm), glabrous to lightly encrusted, unbranched or occasionally with short, rudimentary branches, straight, occasionally subundulate, attenuate at tips, lacking pores, elastic, aseptate, hyaline to pale brown in water mounts. Endoperidium composed of thick-walled, tightly interwoven hyphal elements.

Habitat: Terrestrial and found in leafy debris under Douglas fir (*Pseudotsuga menziesii*). This species occurs in the higher elevations of the state within the Petran montane conifer forest biotic community.

Distribution: Known throughout the United States, and previously reported from Florida, Kansas, Maryland, Michigan, Missouri, Nebraska, North Carolina and Ohio (see fig. 19 for Arizona distribution). Also reported from Africa, Australia, Canada, Caribbean, Europe and Tasmania.

Material examined: ARIZONA, Gila Co.: Sierra Ancha Station, Tonto National Forest, 13 November 2004, F. Farruggia (herb. STB FF900).

Geastrum saccatum is very similar to *G. lageniforme*; however, that species normally has narrow ray tips, radial splitting in the mycelial layer along the rays, a lighter spore mass and is smaller. Microscopically, *G. saccatum* has slightly larger spores (4.8-5.6 μm in diam.), compared with (4.0-4.8 μm in diam.) *G. lageniforme*, and the capillitia are wider with thicker walls (see *G. lageniforme* for further discussion). Only rarely will *G. saccatum* form a pseudoparenchymatous collar, in which case it could be confused with *Geastrum triplex*. However, *G. triplex* is normally larger that *G. saccatum* and the endoperidium in the former is more glabrous than that found in the later when observed under magnification (see *G. triplex* for further discussion). Finally, *G. saccatum* could be confused with *G. fimbriatum* as that species is often saccate; however, *G. fimbriatum* normally does not have a delimited peristome and the spores are much smaller (3.2-4.0 μm in diam.). This species is reported for the first time from Arizona here.

16. ***Geastrum schmidelii*** Vittad., Monographia Lycoperdineorum: 16 (1842 as *Geaster*).

(figs. 59d, 76b & 97d)

Reported synonyms

= *Geastrum nanum* Pers., J. Bot. (Desvaux) 2: 27 (1809), sensu Stanek (1958).

= *Geastrum rabenhorstii* Kunze in Rabenh., Fungi Eur. Exsicc. Klotzsch. Herb. Vivi Mycol. (1875).

Type: Sunhede (1989) was of the opinion that *G. nanum* Pers. is conspecific with *G. schmidelii* Vittad., and he states, "…by citing in synonymy *G. striatum* DC., he (Persoon) included by implication the type of an earlier legitimate name (ICBN 63:1) and *G. nanum* thus becomes illegitimate. " Sunhede does not select a neotype or lectotype; however, we can infer that type material still might exists in the Royal Botanic Garden, Kew (K) among Vittadinian collections. Unfortunately, Pegler, Læssøe and Spooner (1998) make no mention of the Vittadinian material at Kew, and this taxon has yet to be typified.

Selected illustrations: Calonge (1998: fig. 25); Coker & Couch (1928: pl. 70, as *Geaster*); Long & Stouffer (1948: fig. 4, as *Geaster*); Pegler, Læssøe & Spooner (1995: figs. 58-59); Stanek in Pilát (1958: figs. 147 & 175-176, as *Geastrum nanum*); Sunhede (1989: figs. 177-186).

Expanded gastrocarp 12-23 mm in width x 11-22 mm in height. Exoperidium splitting to the middle or slightly more, forming 7-12 rays, occasionally splitting again at

tips; rays arching and revolute with involute or revolute tips, occasionally involute and rolling up under the endoperidial body, subhygroscopic. Mycelial layer thick, persistent, heavily encrusted with leafy debris. Pseudoparenchymatous layer pallid at first, becoming orange-white (5A2), grayish orange (5B4-5), brownish orange (5C4-5), light brown (5D4-6) to brown (5E5-6), or more pallid if covered with pruina, thin (up to 2 mm when fresh), glabrous, rugulose to rimose, occasionally peeling away at tips of rays, often covered with a fine to coarse pruina of crystalline matter left behind from the endoperidium, becoming less pruinose with age. Fibrous layer orange-white (5A2) to grayish orange (5B3), becoming more pallid with age, thin, papery to coriaceous. Endoperidial body 5-13 mm in diameter x 7-14 mm in height (including stalk & peristome), stalked, globose, subglobose to narrowly ovate. Apophysis present and prominent or reduced. Stalk short (up to 3 mm), often laterally compressed, narrow, concolorous or lighter than endoperidium. Endoperidium orange-white (5A2), orange-gray (5B2), grayish orange (5B3-5), purplish gray (13F2) to dark magenta (13F3), or more pallid due to the pruina, glabrous, covered with a fine pruinose layer of hyphal elements and/or crystalline matter that soon wears away. Peristome plicate, distinctly delimited and often recessed with a rim, narrowly to broadly conical with a pointed or truncate apex, up to 3 mm in height, with 12-20 conspicuous folds. Gleba brown (6D5-6), cottony. Columella domed to columnar.

Basidiospores globose, (4.8) 5.6-6.4 (7.0) X (4.8) 5.6-6.4 (7.0) µm [x = 6.1 ± 0.5 X 6.1 ± 0.5 µm, Q_m = 1.0, n = 20], verrucose with dense, truncate verrucae; central oil drop; pedicel rudimentary, difficult to discern from verrucae; sterigmal remnants absent from mounts; spores brownish yellow in water mounts. Eucapillitium '*Geastrum*' type,

4.0-7.2 μm in diameter, thick-walled (up to 2.4 μm), glabrous to lightly encrusted, unbranched or rarely with short branches at tips, straight to subundulate, attenuate to rounded tips, lacking pores, elastic, aseptate, brownish yellow in water mounts. Endoperidium composed of thick-walled, tightly interwoven hyphal elements, occasionally intermixed with crystalline matter.

Habitat: Terrestrial and found in leafy debris under juniper (*Juniperus* spp.) and pinyon (*Pinus edulis*). This species occurs in the mid to higher elevations of the state within the Great Basin conifer woodland and Madrean evergreen woodland biotic communities.

Distribution: Known throughout the United States, and previously reported from Arizona, Michigan, Nebraska, New Jersey, New Mexico, North Carolina, Texas and Virginia (see fig. 20 for Arizona distribution). Also reported from Australia, Europe, Great Britain and South Africa.

Material examined: ARIZONA, Mohave Co.: Mt. Trumbell Loop Rd., Mt. Trumbell; Parashant Nat. Monument, 23 March 2003, S.T. Bates (STB00626); Mt. Trumbell Loop Rd., Mt. Trumbell; Parashant Nat. Monument, 23 March 2003, S.T. Bates (STB00627). Pima Co.: Tucson, Sabino Canyon, 28 September 1939, W.H. Long (BPI, WHL8774). CZECH REPUBLIC, Moravia: Brno, 26 October 1951, Fr. Smarda (ASU, EXSCI. 108).

The small stature, plicate peristome and short stalk distinguishes *G. schmidelii*. *Geastrum elegans* is very similar; however, that species has a sessile endoperidial body (see *G. elegans* for further discussion). *Geastrum schmidelii* could be confused with smaller specimens of *G. pectinatum* (not reported from Arizona); however, that species normally has vertical striations on the basal portions of the endoperidial body. When fresh, *G. pectinatum* is densely pruinose with matted hyphal elements and often has pseudoparenchymatous collar ringing the stalk, where as, *G. schmidelii* is only finely pruinose with crystalline matter and never has a pseudoparenchymatous collar. Microscopically, *G. schmidelii* has spores with short, dense, truncate verrucae and in *G. pectinatum* the spores are more sparsely ornamented and have long, truncate to rounded verrucae. Smaller specimens of *G. smithii* could also be confused with *G. schmidelii*; however, that species has a unique peristome and spores that are smaller (4.8-5.6 μm in diam.) than those found in *G. schmidelii* (see *G. smithii* for further discussion). *Geastrum schmidelii* was previously reported from Arizona by Long and Stouffer (1948) as *Geaster*.

17. ***Geastrum smardae*** V.J. Stanek, Ceska Mykologie 10: 22-23 (1956).

(figs. 60a, 77a & 97e)

Reported synonyms

= *Geastrum coronatum* Pers., Syn. Meth. Fung. 132 (1801), sensu Kambly and Lee (1936).

= *Geastrum limbatum* Fr., Syst. Mycol. 3: 15-16 (1829), sensu Lloyd (1902) and subsequent American authors.

Type: According to Sunhede (1989), the holotype is located in the Mycological Department of the National Museum, Praha (PRM - Herb. Stanek) labeled "In a garden under *Picea pungens* and *Spiraea* x *vanhouttei*, Brno, Czechoslovakia, 19.X.1955, Leg. J. Vostrcil".

Selected illustrations: Coker & Couch (1928: pl. 64, as *Geaster limbatus*); Stanek in Pilát (1958: figs. 189-191); Sunhede (1989: figs. 187-191).

Expanded gastrocarp 20-45 mm in width x 15-50 mm in height. Exoperidium splitting to the middle or slightly more, forming 7-10 rays; rays arching and revolute, involute and rolling up under the endoperidial body, or irregular having some revolute rays and others involute, rarely entirely involute, non-hygroscopic. Mycelial layer thick, membranaceous, normally not encrusted with debris or occasionally only lightly encrusted, adhering to the fibrous layer or peeling away to become pseudofornicate. Pseudoparenchymatous layer pallid at first, becoming light brown (7D5), brown (7E5) to dark brown (7F5), thin (up to 5 mm when fresh), glabrous at first, becoming rimose and laterally or radially striate (particularly near stalk) or peeling away leaving only a scattered remnants. Fibrous layer orange-white (5A2) to brown (6E6), thin, coriaceous to rigid. Endoperidial body 15-35 mm in diameter x 7-18 mm in height (including stalk & peristome), stalked, subglobose, depressed globose to laterally compressed. Apophysis present and prominent or reduced. Stalk short to medium-sized (up to 5 mm), broad, concolorous or lighter than endoperidium. Endoperidium grayish orange (5B3) to light brown (5D4), or more pallid in weathered specimens, glabrous with occasional hyphal

protrusions (visible only under magnification). Peristome fibrillose, delimited or not, applanate to broadly conical and truncate to mammiform, less than 2 mm in height. Gleba reddish brown (8E5-8), cottony. Columella domed to subcolumnar.

Basidiospores globose, 4.8-5.6 (6.4) X (4.0) 4.8-5.6 (6.4) µm [x = 5.0 ± 0.6 X 5.1 ± 0.5 µm, Q_m = 1.0, n = 20], verrucose with dense, truncate verrucae; central oil drop; pedicel rudimentary, difficult to discern from verrucae; sterigmal remnants absent from mounts; spores yellowish brown in water mounts. Eucapillitium '*Geastrum*' type, 3.2-6.4 (12.0) µm in diameter, thick-walled (up to 2.4 µm), often heavily encrusted, unbranched, straight, attenuate and subundulate at tips, lacking pores, elastic, aseptate, yellowish brown in water mounts. Endoperidium composed of thick-walled, tightly interwoven hyphal elements.

Habitat: Terrestrial and found in leafy debris under juniper (*Juniperus* spp.) and pinyon (*Pinus edulis*). This species occurs in the mid to higher elevations of the state within the Great Basin conifer woodland and interior chaparral biotic communities.

Distribution: Known throughout the United States, and previously reported from Arizona, Colorado, Kansas, Massachusetts, Michigan, Minnesota, New Mexico, New York and Wisconsin (see fig. 21 for Arizona distribution). Also reported from Canada and Europe where it is considered a rare more species.

Material examined: ARIZONA, Navajo Co.: W of Cottonwood wash between Showlow and Heber, Hwy. 260 (S side Hwy.), Growing in sandy soil in Juniper/Pinyon

forest, 17 August 2002, S.T. Bates (STB00107). Yavapai Co.: 7 mi. from Prescott, in Pine & Juniper, 15 May 1933, W.H. Long (BPI, WHL8870); Prescott National Forest, 18 May 1934, W.H. Long (BPI, WHL8812).

The fibrillose peristome, stalked endoperidial body, pseudofornicate exoperidium and membranaceous mycelial layer, that is only very lightly encrusted, distinguishes *G. smardae* from other earthstars in the state. *Geastrum smardae* could easily be confused with *G. coronatum*; however, that species has a heavily encrusted mycelial layer and is not pseudofornicate (see *G. coronatum* for further discussion). *Geastrum pseudolimbatum* (not reported from Arizona) is also a very similar species, which can be distinguished from *G. smardae* as the former has a verrucose endoperidium (see *G. coronatum* for further discussion). This species was previously reported from Arizona by Long and Stouffer (1948) as *Geaster limbatus* in part.

18. ***Geastrum smithii*** Lloyd, Mycological Writings, 'Geastraceae' 1: 21 (1902, as *Geaster*). (figs. 60b, 77b & 97f)

Type: The holotype is located at the National Fungus Collection (BPI 705991!) labeled "*Geaster smithii*, New Smyrna, Florida, United States, Mrs. Sams, HOLOTYPE, C. G. Lloyd Mycological Collection Smithsonian Institution 22731". The collection was annotated by Moreno and Altes as *Geastrum smithii* in January of 1999.

Selected illustrations: Lloyd (1902: fig. 37, as *Geaster*); Long & Stouffer (1948: fig. 12, as *Geaster*).

Expanded gastrocarp 14-30 mm in width x 12-27 mm in height. Exoperidium splitting to the middle or slightly more, occasionally less, forming 7-12 rays; rays involute and extending upward around or rolling up under the endoperidial body, arching and revolute, often with involute tips, or irregular having some revolute rays and others involute, subhygroscopic. Mycelial layer thin, persistent, heavily encrusted with debris or particles of sand or soil. Pseudoparenchymatous layer pallid at first, becoming light brown (6D5-6) to brown (6E5-6 to 7E5-7), or more pallid if covered with pruina, thin (up to 2 mm), glabrous to rugulose, soon rimose, covered with a fine pruina of crystalline matter left behind from the endoperidium, becoming less pruinose and often peeling away in patches with age. Fibrous layer orange-white (5A2 to 6A2), pale orange (5A3) to grayish orange (5B3-4), thin, coriaceous. Endoperidial body 7-20 mm in diameter x 8-17 mm in height (including stalk & peristome), stalked, globose, subglobose to broadly ovate. Apophysis present and prominent or reduced. Stalk reduced to short (up to 2 mm), often laterally compressed, narrow, concolorous or lighter than endoperidium. Endoperidium orange-white (5A2), orange-gray (5B2), grayish orange to light brown (5D4-5 to 6D4-5), or more pallid due to the pruina, glabrous with occasional hyphal protrusions (visible only under high magnification), covered in a fine, occasionally dense, pruinose layer of crystalline matter, especially when fresh, soon wearing away and becoming more glabrous. Peristome deeply plicate, distinctly delimited and often recessed, darker than endoperidium or concolorous, applanate, often raised in central

portion to a short, narrow point, to broadly conical, less than 2 mm in height, with 16-30 conspicuous folds. Gleba dark brown (7F4-5), cottony to pulverulent. Columella domed to subcolumnar.

Basidiospores globose, 4.8-5.6 X 4.8-5.6 μm [x = 5.3 ± 0.4 X 5.3 ± 0.4 μm, Q_m = 1.0, n = 20], verrucose with short rounded or truncate verrucae; central oil drop; pedicel rudimentary, difficult to discern from verrucae; sterigmal remnants absent from mounts; spores yellowish brown in water mounts. Eucapillitium '*Geastrum*' type, 4.0-6.4 μm in diameter, thick-walled (up to 2.4 μm), glabrous to lightly encrusted, unbranched or occasionally with knob-like projection at tips, straight to undulate, attenuate to rounded at tips, lacking pores, elastic, aseptate, brownish yellow in water mounts. Endoperidium composed of thick-walled, tightly interwoven hyphal elements, occasionally intermixed with crystalline matter.

Habitat: Terrestrial and found in leafy debris under mesquite (*Prosopis* spp.). This species occurs in the lower to mid elevations of the state within the Arizona Upland subdivision of the Sonoran desertscrub and semidesert grassland biotic communities.

Distribution: Known only from the southern regions of the United States, and previously reported from Arizona, Florida and New Mexico (see fig. 22 for Arizona distribution). Also reported from Australia.

Material examined: ARIZONA, Gila Co.: Near Young in Tonto Nat. Forest, August 1944, N.F. Noecker & L.W. Roberson (BPI, WHL7970). Graham Co.: Near

Safford, 09 September 1941, W.H. Long & D.J. Stouffer (BPI, WHL9620); Near Safford, 09 September 1941, W.H. Long & D.J. Stouffer (BPI, WHL10024). Pima Co.: 4 mi. from Sabino Canyon, Tucson, 28 September 1939, W.H. Long (BPI, WHL9144).

Geastrum smithii is similar to other stalked, +/- pruinose earthstars found in Arizona; however, it can be distinguished by the unique peristome and dark spore mass. The peristome is deeply plicate, +/- applanate and often raised in the central portion to a narrow point, distinctly delimited and normally slightly darker than the endoperidium. Larger gastrocarps of *G. smithii* can be confused with *G. coronatum*; however, that species has a fibrillose peristome (see *G. coronatum* for further discussion). Smaller specimens of *G. smithii* are very similar to *G. minimum*; however, that species has a more pruinose endoperidium and a distinctly delimited fibrillose peristome that is normally lighter than the endoperidium (see *G. minimum* for further discussion). *Geastrum schmidelii* is another species that could be confused with smaller specimens of *G. smithii*; however, the former has a conical, plicate peristome and larger spores (see *G. schmidelii* for further discussion). *Geastrum campestre* is quite similar in outward appearance to *G. smithii*; however, closer inspection will reveal the verrucose endoperidium of *G. campestre*, which is not present in *G. smithii*. This species was previously reported from Arizona by Long and Stouffer (1948) as *Geaster*.

19. ***Geastrum striatum*** DC., Flora Francaise 2: 267 (1805). (figs. 60c, 78a & 98a)

Reported synonyms

= *Geastrum bryantii* Berk., Brit. Fungi 5: 300-301 (1836).

= *Geastrum orientale* Hazsl., Grevillea 6: 108-109 (1878).

Type: Sunhede (1989) selected as a lectotype fig. 19 in Bryant's 1782 work, *An Historical Account of Two Species of Lycoperdon*. He goes on to state that it is doubtful that any of the original type material from De Candolle exists. Arizona material of *G. striatum* housed at the National Fungus Collection (BPI, WHL7624) is not a typical form and was annotated by Pouzar, "*G. bryantii* Berk. f. *ovatum* Pouz., 21-II-44, Z. Pouzar" as the endoperidial body is narrowly ovate. The annotation also includes "Type material! "; however, it's likely that Pouzar was indicating that he had examined the type material of this form rather than actually selecting this specimen as the type.

Selected illustrations: Calonge (1998: fig. 29); Long & Stouffer (1948: fig. 3, as *Geaster bryantii*); Pegler, Læssøe & Spooner (1995: figs. 60-61); Stanek in Pilát (1958: figs. 150 & 178); Sunhede (1989: figs. 192-199).

Expanded gastrocarp 10-35 mm in width x 17-37 mm in height. Exoperidium splitting to the middle or less, forming 5-12 rays, occasionally splitting again at tips; rays arching and revolute, involute and extending upward around or rolling up under the endoperidial body, subhygroscopic. Mycelial layer thin, persistent, heavily encrusted with debris or peeling away to reveal the fibrous layer in aged specimens.

Pseudoparenchymatous layer pallid at first, becoming grayish orange (6B3), light brown (6D6) brown (6E5) to brownish gray (6C3), or more pallid if covered with pruina, thick (up to 5 mm when fresh), drying +/- thin, glabrous becoming rimose, often forming a collar that rings the stalk when fresh, often covered with a fine pruina of crystalline matter or hyphal elements left behind from the endoperidium, often striate along rays tips. Fibrous layer grayish orange (5B5), brownish gray (6C3) to brown (7E4), thin, coriaceous. Endoperidial body 5-15 mm in diameter x 7-20 mm in height (including stalk & peristome), stalked, subglobose, depressed globose to laterally compressed. Apophysis present and prominent, forming a ridged collar. Stalk short to medium-sized (up to 5 mm), narrow, concolorous or lighter than endoperidium. Endoperidium grayish orange (5B3), purple-gray (12E2-3) or dark magenta (13F3), or more pallid due to the pruina, glabrous, covered in a dense, fine pruinose layer of matted hyphal elements and/or crystalline matter, especially when fresh. Peristome plicate, not delimited or only faintly so, narrowly conical, coming to a point at apex, mammiform, or occasionally truncate, up to 4 mm in height, with 15-20 fine to conspicuous folds. Gleba reddish brown (8D85-8E5), cottony. Columella subcolumnar or lageniform.

Basidiospores subglobose to globose, (4.0) 4.8-5.6 X (4.0) 4.8-5.6 µm [x = 5.1 ± 0.5 X 5.1 ± 0.5 µm, Q_m = 1.0, n = 20], verrucose with large truncate verrucae, which are clearly visible in mounts; central oil drop; pedicel rudimentary, difficult to discern from verrucae; sterigmal remnants absent from mounts; spores yellow-brown in water mounts. Eucapillitium '*Geastrum*' type, 2.4-5.6 (8.0) µm in diameter, thick-walled (up to 1.6 µm), glabrous to lightly encrusted, unbranched, straight, attenuate and subundulate at tips, lacking pores, elastic, aseptate, yellow-brown in water mounts. Endoperidium composed

of thick-walled, tightly interwoven hyphal elements, intermixed with crystalline matter and protruding hyphae.

Habitat: Terrestrial and found in open areas, in leafy debris under mesquite (*Prosopis* spp.) or occasionally in urban areas. This species occurs in the lower to higher elevations of the state within the Lower Colorado subdivision of the Sonoran desertscrub, Madrean evergreen woodland, and the semidesert grassland biotic communities.

Distribution: Known from various parts of the United States and previously reported from Arizona, Maine, New Mexico, New York and Texas (see fig. 23 for Arizona distribution). Also reported from Australia, Europe, Great Britain Mexico and South Africa.

Material examined: ARIZONA, Greenlee Co.: Crook National Forest, Eagle Creek District, 24 February 1947, W.H. Long & D.J. Stouffer (BPI, WHL11443). Maricopa Co.: 1301 W. 7th St., Tempe, 23 February 2004, S.M. Standley (STB00773). Santa Cruz Co.: 10 mi. from Nogales, 19 February 1934, W.H. Long & V.O. Sandberg (BPI, WHL7624). CZECH REPUBLIC, Moravia: Brno, 08 October 1951, Fr. Smarda (ASU, EXSCI. 107).

The unique apophysis, which forms a ridged collar, distinguishes *G.striatum* from all other earthstars found in the state. *Geastrum pectinatum* (not reported from Arizona) is similar to *G. striatum*, particularly when fresh and the pseudoparenchymatous layer

rings the stalk; however, the apophysis in that species is often striate and does not form a ridged collar. It is possible that *G. striatum* could be confused with *G. quadrifidum* as it has similar coloration and has a pruinose endoperidium; however, that species is normally fornicate, does not form a ridged apophysis and the peristome is fibrillose rather than plicate. This species was previously reported from Arizona by Long and Stouffer (1948) as *Geaster bryantii*.

20. ***Geastrum triplex*** Jungh., Tijdschrift voor Natuurlijke Geschiedenis Physiologie 7: 287 (1840). (figs. 60d, 78b & 98b)

Reported synonyms

= *Geastrum michelianum* W.G. Sm., Gard. Chron. 18: 1275 (1873).

= *Geastrum cryptorhynchum* Hazsl., Grevillea 3: 162 (1874).

= *Geastrum kalchbrenneri* Hazsl., Verh. Zool.-Bot. Ges. Wien 26: 220 (1876).

= *Geastrum pillotii* Roze, Bull. Soc. Mycol. France 4: 36 (1888).

Type: Palmer (1968) considered a collection in the National Herbarium Nederland, Leiden (L) to be the holotype and Sunhede (1989) agreed. The collection is in a glass vessel that is labeled "L. 4188 No. 1; Herb. F. Junghuhn in H.L.B. No 97 *Geaster triplex* Jungh.; TYPE".

Selected illustrations: Calonge (1998: fig. 30); Coker & Couch (1928: pl. 63, as *Geaster*); Long & Stouffer (1948: fig. 24, as *Geaster*); Pegler, Læssøe & Spooner (1995: figs. 80-81); Stanek in Pilát (1958: figs. 158 & 181-183); Sunhede (1989: figs. 202-207).

Expanded gastrocarp 30-70 mm in width x 15-35 mm in height. Exoperidium splitting to the middle or more, forming 2-8 rays, often splitting again at tips; rays saccate, or revolute with rays rolling under gastrocarp, occasionally irregular having some revolute rays and others involute, rarely entirely involute, non-hygroscopic. Mycelial layer thin, persistent, membranaceous, not encrusted with debris or very lightly so, splitting radially along rays to reveal the fibrous layer, which is lighter in color. Pseudoparenchymatous layer pallid at first, becoming grayish orange (6B3-4), brownish orange (6C3-4), light brown (7D4-6), brown (6E4-7), dark brown (6F4-7) to brownish gray (6D2), thick (up to 5 mm when fresh), drying ± thin, glabrous to rimose, often peeling away in patches with age, normally forming a prominent pseudoparenchymatous collar. Fibrous layer orange-white (6A2), grayish orange (6B4) to orange gray (6B2), thin, coriaceous. Endoperidial body 12-35 mm in diameter x 10-25 mm in height (including peristome), sessile, globose, subglobose, broadly ovate to pyriform. Apophysis absent. Stalk absent. Endoperidium orange gray (5B2), grayish orange (5B3-5) to brownish orange (6C4-5), glabrous, occasionally covered with a fine pruinose layer of crystalline matter that soon wears away. Peristome fibrillose, distinctly delimited, lighter or darker than endoperidial body, broadly conical to mammiform, up to 5 mm in height. Gleba brown (6E4-5), cottony. Columella domed to clavate.

Basidiospores globose, 4.8-5.6 (6.4) X 4.8-5.6 (6.4) µm [x = 5.4 ± 0.5 X 5.4 ± 0.5 µm, Q_m = 1.0, n = 20], verrucose with dense, truncate verrucae; central oil drop; pedicel rudimentary, difficult to discern from verrucae; sterigmal remnants absent from mounts; spores yellow-brown in water mounts. Eucapillitium '*Geastrum*' type, 4.0-12.0 µm in diameter, thick-walled (up to 4.0 µm), glabrous, or more frequently heavily encrusted,

unbranched, straight, with long attenuate, often subundulate, tips, lacking pores, elastic, aseptate, yellow-brown in water mounts. Endoperidium composed of thick-walled, tightly interwoven hyphal elements, occasionally intermixed with crystalline matter.

Habitat: Terrestrial and found in open places within conifer forests or in leafy debris under conifers. This species occurs in the higher elevations of the state within the Petran montane conifer forest and Petran subalpine conifer forest biotic communities.

Distribution: Known throughout the United States, and previously reported from Alabama, Arizona, Florida, Illinois, Maryland, Michigan, Missouri, New Jersey, New Mexico, Ohio, Pennsylvania, Texas Washington and Wisconsin (see fig. 24 for Arizona distribution). Also reported from Canada, China, Europe, Great Britain, New Zealand, Mexico and South America.

Material examined: ARIZONA, Pima Co.: Mt. Lemmon, Santa Catalina Mts., Coronado Nat. Forest, 15 October 1970, S. Thomson (ARIZ ST56). FLORIDA: On Hammock, 02 August 1938, E. West & W.A. Murrill (ARIZ, AN014574). MINNESOTA, Clearwater Co.: Lake Itasca State Park, 01 August 1970, R.L. Gilbertson (ARIZ, RLG9512).

Geastrum triplex is distinguished by having a prominent pseudoparenchymatous collar and a sessile endoperidial body with a distinctly delimited peristome. Both *G. rufescens* and *G. fimbriatum* are occasionally furnished with a pseudoparenchymatous

collar; however these species can be distinguish by other means. Unlike *G. triplex*, *G. rufescens* is never saccate, and *G. fimbriatum* has smaller spores (+/- 3.2 - 4.0 µm in diam.) than *G. triplex* (see *G. rufescens* for further discussion). *Geastrum lageniforme* and *G. saccatum* are also similar to *G. triplex*; however, these species rarely exhibit a pseudoparenchymatous collar (see *G. lageniforme* for further discussion). This species was previously reported from Arizona by Long and Stouffer (1948) as *Geaster*.

21. ***Geastrum xerophilum*** Long, Mycologia 34: 13-16 (1948, as *Geaster*).

(figs. 61a, 79a & 98c)

Type: The holotype is located in the National Fungus Collection (BPI 731707!) labeled "*Geaster xerophilus*, Jornada Exp. Range, Dona Ana Co., N. Mex., Nov. 12, 1938, coll. W.H. Long". The collection number "2858" listed on the label is crossed out and the number "8285" has been penciled in. Notes with the collection in Long's handwriting reads, "8258/ published as 8285 Type".

Selected illustrations: Long & Stouffer (1948: fig. 8, as *Geaster*).

Expanded gastrocarp 7-20 mm in width x 5-18 mm in height. Exoperidium splitting to the middle or slightly more, forming 7-11 rays, often truncate or broken off; rays involute, rolling up under the endoperidial body, non-hygroscopic. Mycelial layer thin, persistent, lightly encrusted with particles of sand or soil. Pseudoparenchymatous layer pallid at first, becoming grayish orange (5B3), light brown (5D4) to grayish brown

(5D3), thin (up to 2 mm), rugulose to rugose, occasionally splitting radially along rays, often covered with particles of sand or soil. Fibrous layer grayish brown (5D3), thin, coriaceous to rigid. Endoperidial body 5-18 mm in diameter x 5-16 mm in height (including stalk & peristome), stalked to subsessile, subglobose, globose to depressed globose. Apophysis reduced or absent, occasionally plicate at base. Stalk absent to short (up to 2 mm), narrow to broad, concolorous with endoperidium. Endoperidium orange-gray (5B2), grayish orange (5B3) to "Pallid Mouse Gray", densely to minutely furfuraceous (hyphal protrusions visible only under magnification), becoming more glabrous with age. Peristome plicate, not delimited, applanate to broadly conical and truncate, up to 2 mm in height, with 15-28 conspicuous folds. Gleba dark brown (6F4-6), cottony. Columella domed to clavate.

Basidiospores globose, 4.8-5.6 X 4.8-5.6 µm [x = 5.4 ± 0.4 X 5.4 ± 0.4 µm, Q_m = 1.0, n = 20], verrucose with dense, truncate verrucae; central oil drop; pedicel rudimentary, difficult to discern from verrucae; sterigmal remnants absent from mounts; spores brownish yellow in water mounts. Eucapillitium '*Geastrum*' type, 4.0-6.4 µm in diameter, thick-walled (up to 2.4 µm), glabrous to lightly encrusted, unbranched with occasional bulbous thickenings, attenuate at tips, lacking pores, elastic, aseptate, brownish yellow in water mounts with some hyaline elements. Endoperidium composed of thick-walled, tightly interwoven hyphal elements.

Habitat: Terrestrial and found in open, barren areas or in the partial shade of desert plants. This species occurs in the lower elevations of the state within the Arizona Upland subdivision of the Sonoran desertscrub biotic community.

Distribution: Restricted to arid areas of the United States, and previously reported from Hawaii and New Mexico (see fig. 25 for Arizona distribution). Not reported from other parts of the world.

Material examined: ARIZONA, Pima Co.: Near Sabino Canyon, 11 November 1936, W.H. Long & V.O. Sandberg (BPI, WHL8897B, mixed collection with *G. arenarium*). NEW MEXICO, Dona Ana Co.: Jornado Experimental Range, 12 November 1938, W.H. Long (BPI, WHL8258, Type).

Geastrum xerophilum is very similar to *G. kotlabae* as it has a plicate peristome and pallid endoperidium; however, there are several differences between these two species. *Geastrum kotlabae* has strongly hygroscopic rays which extending upward around or roll up over the endoperidial body, a verrucose endoperidium and a mycelial layer that is normally absent. On the other hand, *G. xerophilum* has non-hygroscopic, often truncate, rays which normally roll up under the endoperidial body, a furfuraceous endoperidium and a persistent mycelial layer that is encrusted with particles of sand or soil. This species is reported for the first time from Arizona here.

Myriostoma Desv., Journal de Botanique 2: 103-104 (1809).

Type species: *Myriostoma anglicum* Desv. J. Bot. 2: 103 (1809).

22. ***Myriostoma coliforme*** (With.: Pers.) Corda, Anleitung zum Studium der Mycologie: 131 (1842). (figs. 61b, 79b & 98d)

Basionym

Lycoperdon coliforme With., Bot. Arr. Veg. Gr. Brit., ed. 2: 783 (1776).

Reported synonyms

= *Myriostoma anglicum* Desv., J. Bot. 2: 104 (1809).

= *Geastrum columnatum* Lév., Ann. Sci. Nat., Bot. 5: 161 (1846).

Type: No type material of *M. coliforme* exists. Persoon in his sanctioning work *Synopsis Methodica Fungorum* (1801) referred to Dickson (1785). The protologue also mentions Woodward who, in turn, mentioned Withering's 1776 description of *Lycoperdon coliforme*, which is the earliest use of the binomial and has priority. Sunhede (1989) notes, "Dickson (1785, p. 24, tab III: 4a,b), without mentioning Withering, used the name *Lycoperdon coliforme*, beautifully illustrated the species and referred to Ray (l.c.). " As Dickson's illustration is part of the Persoon's protologue, it can be chosen to lectotypify this species.

Selected illustrations: Calonge (1998: fig. 25); Lloyd (1902: figs. 1-4, as *M. coliformis*); Long & Stouffer (1948: fig. 32); Pegler, Læssøe & Spooner (1995: figs. 84-85); Stanek in Pilát (1958: fig. 130); Sunhede (1989: figs. 213-219).

Expanded gastrocarp 42-105 mm in width x 38-63 mm in height. Exoperidium splitting to the middle or more, forming 5-12 rays, often splitting again at tips; rays arching and revolute, tips involute or rolling under the endoperidial body, occasionally irregular having some revolute tips and others involute, non-hygroscopic. Mycelial layer thin, persistent, membranaceous, lightly encrusted, often splitting radially along rays, often furnished with a umbilicus formed of interwoven mycelium, lightly encrusted with debris. Pseudoparenchymatous layer pallid at first, becoming grayish orange (5B3-5), light brown (5D4-5) to brown (6E5-7 to 7E5-6), thick (up to 5 mm when fresh), drying +/- thin, glabrous to rimulose, often peeling away in patches with age. Fibrous layer orange-white (5A2), grayish orange (5B3) to orange-gray (5B2), thin, coriaceous to rigid. Endoperidial body 23-45 mm in diameter x 17-28 mm in height (including stalks), stalked, globose, subglobose, depressed globose to broadly ovate. Apophysis absent. Stalk s numerous (7-24), short to medium-sized (up to 6 mm), often laterally compressed, narrow to broad, concolorous with endoperidium or slightly darker. Endoperidium “Pale Olive Buff”, “Olive Buff”, “Pallid Quaker Drab”, “Pallid Mouse Gray”, orange-white (5A2) to orange gray (5B2), verruculose to echinulate, often lustrous. Peristome lacking, 6-18 stomata, often slightly uplifted around rim, scattered across the surface of the endoperidial body. Gleba light brown (5D5-6) to yellowish brown (5E5-7), cottony. Columella numerous narrow, branching, subcolumnar units.

Basidiospores globose, 6.4-8.0 X 6.4-8.0 µm [x = 7.0 ± 0.5 X 7.0 ± 0.5 µm, Q_m = 1.0, n = 20], verrucose to reticulate with long, often fused verrucae or reticulae; central oil drop; pedicel rudimentary, difficult to discern from verrucae or reticulae; sterigmal remnants absent from mounts; spores brownish yellow in water mounts. Eucapillitium '*Myriostoma*' type, 3.2-4.6 µm in diameter, thick-walled (up to 1.6 µm), glabrous to lightly encrusted, short to long units, unbranched or occasionally with short branches or knob-like projections, particularly towards tips, straight to undulate, attenuate at tips, lacking pores, mostly elastic, occasionally with clamped septa, brownish yellow in water mounts. Endoperidium composed of thick-walled, tightly interwoven hyphal elements.

Habitat: Terrestrial and found in leafy debris under desert hackberry (*Celtis pallida*), juniper (*Juniperus* spp.), mesquite (*Prosopis* spp.) or cactus species. This species occurs in the lower to higher elevations of the state within the Arizona Upland subdivision of the Sonoran desertscrub and Madrean evergreen woodland biotic communities.

Distribution: Known throughout the United States, and previously reported from Arizona, Colorado, Florida, Hawaii, Michigan, New Mexico and Ohio (see fig. 26 for Arizona distribution). Also reported from Canada, Europe, Great Britain (possibly extinct) and South America.

Material examined: ARIZONA, Pima Co.: Sabino Canyon, Santa Catalina Mts., 20 February 1934, W.H. Long (BPI, WHL7621); 1 mi. from Sabino Canyon, Coronado

National Forest, 20 March 1934, W.H. Long & V.O. Sandberg (BPI, WHL7684); Sabino Canyon Road, 22 September 1934, W.H. Long & V.O. Sandberg (BPI, WHL8020); Sabino Canyon, Coronado National Forest, 10 November 1938, W.H. Long (BPI, WHL8309); Soldier Trail, Santa Catalina foothills, 21 March 1975, K.A. Butler (ARIZ, RLG11253). NEW MEXICO, Hidalgo Co.: Indian Creek, Animas Mts., 31 October 1972, R.L. Gilbertson (ARIZ, RLG10823).

The numerous stomata and multiple stalks distinguish *M. coliforme* from all other earthstars. Specimens of *M. coliforme* with a single stoma have been found; however, the large (6.4-8.0 μm in diam.) +/- reticulate spores are quite distinct from those found in *Geastrum* species. This species was previously reported from Arizona by Long and Stouffer (1948).

Sclerodermataceae Corda (as 'Sclerodermaceae'), Icones Fungorum hucque Cognitorum: 23 (1842).

Type genus: *Scleroderma* Pers.: Pers. (1801).

Type species: ***Scleroderma verrucosum*** (Bull.) Pers., Syn. Meth. Fung. (1801).

Astraeus Morgan, Journal of the Cincinnati Society of Natural History 12: 19 (1890).

Type species: *Astraeus hygrometricus* (Pers.) Morgan, J. Cincinnati Soc. Nat. Hist. 12: 20 (1890).

23. ***Astraeus hygrometricus*** (Pers.) Morgan, Journal of the Cincinnati Society of Natural History 12: 20 (1890). (figs. 61c &80a)

Basionym

Geastrum hygrometricum Pers., Syn. Meth. Fung. 1345 (1801).

Reported synonyms

= *Lycoperdon stellatum* Scop., Fl. Carniol., ed. 2: 489 (1772).

= *Astraeus stellatus* (Scop.) E. Fisch., Nat. Pflanzenfam. 1: 341 (1900).

= *Geastrum fibrillosum* Schwein., Schriften Naturf. Ges. Leipzig. 1: 59 (1822).

Type: It is not known whether the type material of *Geastrum hygrometricum* still exist among Persoon's herbarium which is now housed at the National Herbarium Nederland (L).

Selected illustrations: Coker & Couch (1928: pl. 77); Lloyd (1902: figs. 5-11, as *Geaster*); Pegler, Læssøe & Spooner (1995: figs. 20-21).

Expanded gastrocarp 25-75 mm in width x 14-28 mm in height. Exoperidium splitting to the middle or more, forming 5-16 rays, often splitting again at tips; rays applanate, involute and extending upward around or rolling up over the endoperidial body, irregular having some revolute rays and others involute, or slightly revolute, strongly hygroscopic. Mycelial layer normally absent, or present when +/- fresh, thin, membranaceous, later peeling away from fibrous layer, often covered with numerous dark rhizomorphs. Pseudoparenchymatous layer pallid at first, becoming reddish brown (8E4-6) to brownish gray (8D2-8F2 to 9D2-9F2), thick (up to 2 mm when dried), glabrous at first, soon rimose to rhagadiose. Fibrous layer orange-white (5A2), “Pallid Quaker Gray” to “Pallid Mouse Gray”, thick, rigid. Endoperidial body 13-30 mm in diameter x 5-17 mm in height (including ostiole rim), sessile, globose, subglobose, depressed globose to broadly ovate. Apophysis absent. Stalk absent. Endoperidium “Pale Olive Buff”, “Pallid Quaker Drab”, “Pallid Mouse Gray” to orange-white (5A2), verrucose to reticulate, particularly on lower portions, occasionally glabrous near the ostiole. Peristome lacking, ostiole present as an apical tear, occasionally with an

upturned rim, . Gleba light brown (7D6-7) to reddish brown (8D6-8E7), pulverulent. Columella lacking.

Basidiospores globose, 8.0-12.0 X 8.0-12.0 µm [x = 10.1 ± 1.3 X 10.1 ± 1.3 µm, Q_m = 1.0, n = 20], verrucose to echinate with dense verrucae or echinulae; central oil drop; pedicel rudimentary, difficult to discern from verrucae or echinulae; sterigmal remnants absent from mounts; spores yellow-brown in water mounts. Eucapillitium lacking. Paracapillitia present, 4.0-8.8 µm in diameter, thick-walled (up to 2.4 µm), glabrous with occasional membranous encrustations, occasionally branching or with knob-like projections, straight to undulate, often torulose, lacking pores, flexible but non-elastic, occasionally septate, hyaline in water mounts. Endoperidium composed of thick-walled, tightly interwoven hyphal elements.

Habitat: Terrestrial and found open areas, near washes or growing in needle or leaf debris under juniper (*Juniperus* spp.), mesquite (*Prosopis* spp.), oak (*Quercus* spp.) or ponderosa pine (*Pinus ponderosa*). This species occurs in the mid to higher elevations of the state within the Great Basin conifer woodland, interior chaparral, Madrean evergreen woodland, and Petran montane conifer forest biotic communities.

Distribution: Known throughout the United States, and previously reported from Arizona, California, Colorado, Connecticut, Florida, Georgia, Illinois, Maryland, Massachusetts, Michigan, Minnesota, New Mexico, New York, Pennsylvania, South Carolina, Tennessee, Texas and Washington (see fig. 27 for Arizona distribution). Also reported from Australia, Canada, Europe, India, Mexico and Great Britain.

Material examined: ARIZONA, Cochise Co.: Turkey Creek, Chiricahua Mts., Coronado Nat. Forest, 22 October 1970, E.R. Canfield (ARIZ, 137). Coconino Co.: East Allen Lake on W side of Hwy., 25 April 1957, P.D. Keener (ARIZ, PH-24); Right hand side of Mund's Park Rd., Oak Creek, 24 August 1958 (ARIZ, PH-2399); Powell Plateau, North Rim of the Grand Canyon Nat'l Park, 10 September 1963, N. Messenger (ARIZ, PH-538). Gila Co.: S side of Hwy. 260, across from entrance to Quail Run Rd., ~10 mi NE of Payson, 10 August 2002, S.T. Bates (STB00068). Maricopa Co.: 7 Springs area near Cave Creek, 25 January 2003, S.T. Bates (STB00125). Mohave Co.: Parashant Nat. Monument, 21 May 2003, S.T. Bates, K.G. Sweat & W.A. Iselin (STB00429). Pima Co.: Near Loma Linda, Santa Catalina Mts., 12 August 1960, K.J. Torgerson & P.D. Keener (ARIZ, PH-2395); Mt. Lemmon, Santa Catalina Mts., Coronado Nat. Forest, 16 August 1967, R.L. Gilbertson & J. McHenry (ARIZ, RLG7129). Yavapai Co.: Allen Spring Rd., Mingus Mt., 20 June 1957, P.D. Keener (ARIZ, PH-23).

The strongly hygroscopic rays, reticulate endoperidium and rimose to rhagadiose pseudoparenchymatous layer distinguishes *A. hygrometricus* from other earthstars found in the state. Although this species is very distinct, it is possible that it could be confused with other strongly hygroscopic *Geastrum* species, such as *G. floriforme*. However, these species can be easily separated microscopically as the gleba of *A. hygrometricus* contains paracapillitia, where as, *G. floriforme* and all other *Geastrum* species have eucapillitia. In addition, the spores of *A. hygrometricus* are larger (8.0-12.0 µm in diam.) than most *Geastrum* species. This species was previously reported from Arizona by Long and Stouffer (1948).

Artificial Key to Arizona Puffballs (Lycoperdaceae)

1a. At maturity gleba comprised of labyrinthiform, sinuous tramal plates; spore mass covering the surface of a true hymenium; spores subglobose to ovoid, smooth to asperulate (4.0-4.8 μm in diam. x 4.0-5.6 μm in length) …….. ……. 39. ***Holocotylon brandegeeanum***

1b. At maturity gleba not comprised of labyrinthiform, sinuous tramal plates; spore mass pulverulent and interwoven with paracapillitia or eucapillitia; spores variable ……... ……. **2**

2a. Paracapillitia present; gleba not containing eucapillitia …….. **3**

2b. Paracapillitia present or absent; gleba containing eucapillitia ……. **4**

3a. Exoperidium verrucose; verrucae broad, pyramidal, sloughing off of apical portions of the gasterocarp in small plates; spore globose to subglobose, asperate to echinulate (3.2-4.8 μm in diam. X 4.0-5.6 μm in length)…….. 49.***Vascellum intermedium***

3b. Exoperidium minutely verruculose, lower portions more noticabley verruculose to echinulate, not sloughing off in plates; spores globose, asperulate (4.0-5.6 μm in diam.) ……... 51 ***Vascellum texense***

4a. Eucapillitia highly branched …… **5**

4b. Eucapillitia lacking branches or with occasional dichotomous branches …… **6**

5a. Branches short with spinose tips; spores globose, verrucose to reticulate (8.0-12.0 μm in diam.), pedicel lacking; endoperidium rigid, thick (up to 4 mm) …… …… 48. ***Mycenastrum corium***

5b. Branches long with attenuate tips; spores ovoid, asperulate to asperate (4.0-5.6 μm in diam. x 5.6-6.4 μm in length); pedicel long (10.0-16.0 μm in length); endoperidium papery to rigid, thin (less than 2 mm) ……. 26. ***Bovista plumbea***

6a. Eucapillitia fragile, often breaking into shorter units …….. **7**

6b. Eucapillitia elastic to subelastic, occasionally breaking into shorter units ……... **18**

7a. Exoperidium comprised of a thick mycelial mat, heavily encrusted with particles of soil or sand, remaining attached and forming a cup around lower 1/5 to 1/2 of gasterocarp ….…… **8**

7b. Exoperidium not comprised of a thick mycelial mat, not heavily encrusted with particles of soil or sand, if attached then not forming a cup around lower 1/5 to 1/2 of gasterocarp ……... **11**

8a. Spores having long pedicels (5.6-18.0 μm in length) ……. …….. 38. ***Disciseda pedicellata***

8b. Spores having sort pedicels (less than 2.0 μm in length), or pedicels lacking ……. **9**

9a. Spores globose to subglobose, smooth to asperulate (4.0-5.0 μm in diam. X 4.0-5.6 μm in length) ……. 37. ***Disciseda cervina***

9b. Spores globose, verrucose (4.0-12.0 μm in diam.) …… **10**

10a. Endoperidium with reticulate pattern on basal portions, formed of felted to flocculent ridges; spores 4.0-5.6 (6.4) μm in diameter …… 36. ***Disciseda candida***

10b. Endoperidium lacking reticulate pattern; spores 8.8-12.0 μm in diameter ……... 35. ***Disciseda arida***

11a. Spore mass violaceous ……. **12**

11b. Spore mass brownish ……... **14**

12a. Spores globose, smooth (4.0-4.8 μm in diam.) ….. 32. ***Calvatia* cf. *leiospora***

12b. Spores globose, strongly verrucose …….. **13**

13a. Subgleba present and prominent, comprising lower 1/3 to 1/2 of gasterocarp, cellular and composed of medium- to large-sized cells; endoperidium having some sphaerocysts which containing pigments; spores 5.6-8.0 μm in diameter … 30. ***Calvatia cyathiformis***

13b. Subgleba absent or reduced, if present then composed of compacted or small-sized cells; endoperidium lacking pigments in sphaerocysts; spores 6.4-8.0 μm in diameter ….. …….. 31. ***Calvatia fragilis***

14a. Spores globose, strongly echinate (5.6-8.0 μm in diam.); endoperidium persistent in mature gasterocarps ……. 27. ***Calvatia bicolor***

14b. Spores globose to subglobose, smooth to asperate; endoperidium breaking apart in mature gasterocarps …… **15**

15a. Peridia staining yellow when fresh, developing an orange pigmentation with age; gasterocarp small- to medium-sized (20-60 mm in diam.); spores globose, asperate (3.2-4.8 μm in diam.) …… 34. ***Calvatia rugosa***

15b. Peridia not staining yellow when fresh, or only weakly so, not developing an orange pigmentation with age; gasterocarp medium- to large-sized (70-600 mm in diam.); spores globose, subglobose to ovoid, smooth to asperulate …… **16**

16a. Spores subglobose to ovoid, smooth (3.2-4.8 μm in diam. x 4.8-5.6 μm in length); endoperidium glabrous, thick (up to 4 mm) and persistent, developing vertical cracks on the apical portions of the gasterocarp ……..
…….. 33. ***Calvatia pachyderma***

16b. Spores globose to subglobose, smooth to asperulate; endoperidium glabrous to felted, thin and fragile, not developing vertical cracks on the apical portions of the gasterocarp ……. **17**

17a. Exoperidium thick (2-5 mm), breaking up into thick, polygonal or irregular-shaped patches; gasterocarp large-sized (160-600 mm in diam.); subgleba absent or reduced; spores globose to subglobose, smooth to asperulate (3.2-4.8 μm in diam. x 4.0-4.8 μm in length) …….. 28. ***Calvatia booniana***

17b. Exoperidium thin (up to 1 mm), breaking up into thin, irregular-shaped, flaky patches; gasterocarp medium- to large-sized (70-190 mm in diam.); subgleba present, comprising lower 1/3 to 1/2 of gasterocarp; spores globose, asperulate (3.2-4.0 μm in diam.) ……...……... 29. ***Calvatia craniiformis***

18a. Gasterocarp often growing directly on rotting wood; spores globose to subglobose, smooth (4.0-5.6 μm in diam.); eucapillitia lacking pores; subgleba present, white, composed of compact to small-sized cells; exoperidium rimulose to scurfy-granulose, composed of irregular-shaped, spinose sphaerocysts ……... 47. ***Morganella pyriformis***

18b. Gasterocarp terrestrial, not growing directly on rotting wood; spores variable; eucapillitia having pores; subgleba absent or present, tan, brown or lilaceous, cellular or with compact cells; exoperidium not composed of irregular-shaped, spinose sphaerocysts ……..…….. **19**

19a. Endoperidium of mature gasterocarp left with a reticulate or areolate pattern after exoperidium has sloughed off, composed of white, fugacious, long (up to 3 mm), stout, conical verrucae, encircled by shorter, persistent verrucae or echinae; spores globose, verrucose (3.2-4.8 μm in diam.); eucapillitia with small- to medium-sized pores, abundant or scarce …….. 43. ***Lycoperdon perlatum***

19b. Endoperidium of mature gasterocarp lacking a reticulate or areolate pattern after exoperidium has sloughed off, glabrous or ornamentation more or less equal in size; spores variable; eucapillitia pored ……... **20**

20a. Endoperidium covered with a fine granular matter; exoperidium sloughing off in plates, composed of numerous stout, conical, whitish echinae or verrucae, singular or fused at the tips; spores globose, smooth to asperulate (3.2-5.6 μm in diam.) …… 41. ***Lycoperdon marginatum***

20b. Endoperidium not covered with a fine granular matter; exoperidium not sloughing off in plates, ornamentation variable; spores variable …… **21**

21a. Exoperidium strongly echinate, echinae long (up to 3 mm), slender, whitish to tan, singular or fused at the tips, soon sloughing off of upper portions of the gasterocarp; spores globose, verrucose (5.6-6.4 μm in diam.) …….. 44. ***Lycoperdon pulcherrimum***

21b. Exoperidium glabrous to echinate, if echinate then echinae short (less than 2 mm), slender, tan to blackish brown; spores variable ……... **22**

22a. Exoperidium glabrous, rimulose to scurfy-granulose, or composed of minute to tightly appressed echinae ……. **23**

22b. Exoperidium echinulate to echinate ……. **26**

23a. Spores strongly verrucose (6.4-8.0 μm in diam.); exoperidium glabrous to rimulose; eucapillitia with abundant, small- to medium-sized pores … 45. ***Lycoperdon rimulatum***

23b. Spores smooth to asperate; exoperidium glabrous, rimulose to scurfy-granulose; eucapillitia pored …….. **24**

24a. Subgleba present, comprising lower 1/3 to 1/2 of gasterocarp, cellular; spores globose to subglobose, asperulate (3.2-4.8 μm in diam.); eucapillitia with abundant medium- to large-sized pores …… 40. ***Lycoperdon lividum***

24b. Subgleba absent or reduced and compact cellular; spores variable; eucapillitia with abundant small- to medium-sized pores …… **25**

25a. Spores globose, asperate (4.0-4.8 μm in diam.), mostly uniform in size; eucapillitia '*Lycoperdon*' type, elastic, abundant small- to medium-sized pores; gasterocarp globose, subglobose to depressed globose, occasionally plicate at base, often attached by a slender rhizomorph; subgleba reduced …… 25. ***Bovista dermoxantha***

25b. Spores globose to subglobose, smooth to asperulate (3.2-4.8 μm in diam. x 3.2-5.6 μm in length), varying in size; eucapillitia '*Lycoperdon*' type toward the apex of gleba, subelastic, abundant medium-sized pores, 'intermediate' type toward the center of the gleba, elastic, abundant small-sized pores; globose, subglobose, depressed globose to obpyriform, often attached by a thick rhizomorphs; subgleba absent to reduced …… ……..……... 24. ***Bovista aestivalis***

26a. Paracapillitia abundant in gleba, especially toward the periphery; echinae short (up to 1 mm), fugacious toward apical portions of gasterocarp; spores globose to subglobose, asperulate (4.0-4.8 μm in diam. X 4.0-5.6 μm in length); eucapillitia with occasional small- to medium-sized pores; apex of gasterocarp developing a large ostiole at maturity ……... 50. ***Vascellum lloydianum***

26b. Paracapillitia sparse or absent from gleba; echinae fragile to well formed, singular or fused at the tips, intermixed with granules or not; spores variable; eucapillitia pored; gasterocarp developing a small ostiole at maturity …… **27**

27a. Spore mounts containing numerous sterigmal remnants; spores globose, verrucose with large, dense, truncate verrucae (4.8-7.2 μm in diam.); eucapillitia with scattered small- to medium-sized pores; exoperidium entirely covering the endoperidium, echinae thin, short (up to 0.5 mm), occasionally intermixed with longer spicules (up to 1 mm); spore mass olive-brown to brown …… 42. ***Lycoperdon molle***

27b. Spore mounts mostly lacking sterigmal remnants; spores globose, asperate to echinulate (4.0-5.6 μm in diam.); eucapillitia with abundant medium- to large-sized pores; exoperidium not entirely covering the yellowish endoperidium, which is exposed between areas of ornamentation, echinae thin, short (up to 1 mm); spore mass olive-brown to light brown …….... 46. ***Lycoperdon umbrinum***

The Lycoperdaceae

Lycoperdaceae Chevall. [as 'Lycoperdoneae'], Flore Générale des Environs de Paris: 348 (1826).

Type Genus: *Lycoperdon* Pers.: Pers., Syn. Meth. Fung. 1: 146 (1801).

Bovista Pers.: Pers., Synopsis Methodica Fungorum 1: 146 (1801).

Type species: *Bovista plumbea* Pers.: Pers., Observ. Mycol. 1: 5 (1796).

24. ***Bovista aestivalis*** (Bonord.) Demoulin, Beihefte zur Sydowia 8: 143 (1979).

(figs. 61d, 80b, 99a & 104c)

Basionym

Lycopedon aestivale Bonord., Handb. Allg. Mykol.: 251 (1851).

Reported synonyms

= *Lycoperdon polymorphum* Vittad., Monogr. Lycoperd.: 183 (1843), nomen rej. (Art. 63, ICBN).

= *Lycoperdon coloratum* Peck, Rep. State Bot. of New York State Mus.: 29: 46 (1878).

= *Bovista colorata* (Peck) Kreisel, Feddes Repert. 69: 202 (1964).

= *Lycoperdon furfuracea* Schaeff., Icon. Fungorum Bav. 4: 131 (1774), non *Bovista furfuracea* (Gmelin: Pers.) Pers.

= *Bovista pusilliformis* (Kreisel) Kreisel, Feddes Repert. 69: 202 (1964).

Type: A lectotype from Germany is located in Nationaal Herbarium Nederland (L 910.262-767) according to Kreisel (1967b).

Selected illustrations: Calonge (1992: fig. 10b); Demoulin (1968: 55, as *B. polymorpha*); Demoulin (1996: fig. 25, photos 24-46); Kreisel (1967b: 108-115, as *B. polymorpha*); Pegler, Læssøe & Spooner (1995: figs. 97-98).

Gasterocarp 10-40 mm in diameter x 15-40 mm in height, globose, subglobose, depressed globose to obpyriform, slightly plicate at base, tapering to a single or branching thick rhizomorph (5-20 mm in length), composed of minute tightly woven mycelial strands, or a mycelial pad, encrusted with particles of soil; ostiole developing with the sloughing of the exoperidium, slit-like or irregularly torn, which is occasionally slightly upturned at the rim. Exoperidium whitish at first, becoming yellowish white (3A2), pale yellow (3A3), minutely verruculose, verrucuae thin, fragile, sub-flocculent, often appressed, sloughing off slowly, wearing away to reveal the endoperidium with weather and age. Endoperidium yellowish gray (3B2) to dull yellow (3B3-4), orange-gray (5B2), grayish orange (5B3-5) to brownish yellow (5C4-5C7), glabrous, papery and dull, persistent. Gleba grayish yellow (4B3-4 to 4C4-5), brownish orange (5C4-5) to yellowish brown (5D4-6), cottony. Subgleba brownish orange (5C3-5), cellular, composed of compact cells or absent, comprising only the lower portions of the gasterocarp, reduced or absent.

Basidiospores globose to subglobose, 3.2-5.6 X 3.2-4.8 µm [x = 4.4 ± 0.7 X 4.0 ± 0.7 µm, Q_m = 1.1, n = 20], smooth to asperulate, central oil drop; pedicle short (up to 0.8 µm in length); sterigmal remnants mostly absent from mounts; spores hyaline to yellowish in water mounts. Eucapillitium intermediate type, 3.2-8.0 µm in diameter, thick-walled (up to 0.8 µm), glabrous, sparse to frequent dichotomous branching with occasional knob-like projections, straight to subundulate, '*Lycoperdon*' type capillitia is commonly found near the ostiole, tips attenuate, narrow, often subundulate, abundant small-sized pores, subelastic to elastic, aseptate, yellowish to brownish yellow in water mounts. Paracapillitium absent. Exoperidium composed of thick-walled inflated hyphal elements with round to acute apices. Endoperidium composed of tightly interwoven septate, thick-walled hyphal elments.

Habitat: Terrestrial and found in open areas on the soil or growing amid leafy debris under aspen (*Populus tremuloides*), fir (*Abies* spp.), juniper (*Juniperus* spp.), pinyon (*Pinus edulis*), Ponderosa pine (*Pinus ponderosa*) or spruce (*Picea* spp.). This species occurs in the higher elevations of the state within the Great Basin conifer woodland, the Petran montane conifer forest, and Petran subalpine conifer forest biotic communities.

Distribution: Known from many parts of the United States, and previously reported from California, Colorado, Florida, Illinois, Massachusetts, Minnesota, Michigan, Missouri, New York, Nebraska, North Carolina, North Dakota, Ohio, Pennsylvania, Tennessee, Texas, Vermont, Washington, Wisconsin and Wyoming (see

fig. 28 for Arizona distribution). Also reported from Australia, Britain, Canada, China, Europe, New Zealand and South America.

Material examined: ARIZONA, Apache Co.: ~50-100 ft to the W of corral by the side of 2 track dirt rd.; ~1 mi in on FR 116 off of Hwy. 273, Big Lake area, 16 August 2002, S.T. Bates (STB00088). Coconino Co.: Navajo Mountain 56 B, 22 October 1972, J.S. States (MICH AEF1422); Walnut Canyon National Monument, 18 October 1986, J.S. States (MICH AEF531); ~3/4 mi in on FR 34B, ~1 mi W on FR 34 from intersection w/ Rim Rd. (FR300) Woods Canyon Lake, Mogollon Rim, 10 August 2002, S.T. Bates (STB00074). Pima Co.: Mt. Bigelow, Santa Catalina Mts., Coronado Nat. Forest, 29 March 2003, S.T. Bates (STB00339).

Bovista aestivalis is easily confused with *B. dermoxantha*. In general, *B. aestivalis* has a endoperidium and gleba that is more brownish in tone than *B. dermoxantha* and the subgleba in the former is also less developed than in the later. However, these characters are not totally dependable as there is some overlap. The two species are most reliably distinguished using microscopic characters. *Bovista aestivalis* exhibits 'intermediate' type eucapillitia, when material is taken from the center of the gleba, with abundant small pores and smooth to asperulate spores, which are variable in size and shape (globose to subglobose). Alternatively, *B. dermoxantha* has '*Lycoperdon*' type eucapillitia with small to large pores and asperate, globose spores, which are more uniform in size (see B. *dermoxantha* for further discussion). *Bovista aestivalis* is reported for the first time from Arizona here.

25. ***Bovista dermoxantha*** (Vittad.) De Toni, Sylloge Fungorum 7: 100 (1888).

(figs. 62a, 81a & 99b)

Basionym

Lycopedon dermoxanthum Vittad., Monogr. Lycoperd.: 178 (1843).

Reported synonyms

≡ *Globaria dermoxantha* (Vittad.) P. Coutinho, Eubasid. Lusitan.: 166 (1919).

= *Lycoperdon pusillum* Batsch, Elench. Fung. 2: 123 (1789).

= *Bovista pusilla* (Batsch: Pers.) Pers., Syn. Meth. Fung.: 138 (1801).

= *Lycoperdon ericetorum* Pers., J. Bot. (Desvaux) 2: 17 (1809).

= *Lycoperdon hungaricum* Hollós, Math. Termeszettud. Ertes. 19: 510 (1901).

= *Lycoperdon pseudopusillum* Hollós., Növényt. Közlem. 2: 75 (1903).

Type: The holotype is located at Università degli Studi di Torino (TO) labeled '*Lycoperdon cepaeforme*' (Kreisel 1967b).

Selected illustrations: Calonge (1992: fig. 11a); Coker & Couch (1928: pl. 58 "below", as *L. pusillum*); Cunningham (1943: pl. 21, fig. 3); Demoulin (1996: fig. 26, photos 47-56); Pegler, Læssøe & Spooner (1995: figs. 99-100); Smith (1951: pl. 10, fig. 2, as *L. pusillum*).

Gasterocarp 10-35 mm in diameter x 10-40 mm in height, globose, subglobose to depressed globose, slightly plicate at base, tapering to a single or branching, thin rhizomorph encrusted with particles of soil; ostiole slow to develop, small- to medium-

sized, orbicular, irregular-shaped to torn. Exoperidium whitish at first, becoming yellowish white (3A2), pale yellow (3A3), yellowish gray (3B2) to dull yellow (3B3-4), minutely verruculose to verruculose, verrucuae thin, fragile, sub-flocculent, often raised, sloughing off slowly, wearing away to reveal the endoperidium with weather and age. Endoperidium pale yellow (3A3), yellowish gray (3B2) to dull yellow (3B3-4), glabrous, papery and dull, persistent. Gleba grayish yellow (4B3-4 to 4C4-5) to olive (3D4-5), cottony. Subgleba grayish yellow (4B3-4), cellular, composed of compact cells or absent, comprising only the lower portions of the gasterocarp, reduced or absent.

Basidiospores globose, 4.0-4.8 X 4.0-4.8 μm [x = 4.6 ± 0.4 X 4.4 ± 0.4 μm, Q_m = 1.1, n = 20], asperate, central oil drop; pedicle short (up to 0.8 μm in length); sterigmal remnants mostly absent from mounts; spores hyaline to yellowish in water mounts. Eucapillitium '*Lycoperdon*' type, 4.0-6.4 μm in diameter, thick-walled (up to 0.8 μm), glabrous, occasional dichotomous branching, straight to subundulate, tips attenuate, abundant small- to medium-sized pores, occasionally large, elastic, yellowish in water mounts. Paracapillitium absent. Exoperidium composed of orbicular sphaerocysts. Endoperidium composed of tightly interwoven, thick-walled hyphal elments.

Habitat: Terrestrial and found growing amid leafy debris under Gambel's oak (*Quercus gambelii*) or juniper (*Juniperus* spp.). This species occurs in the mid to higher elevations of the state within the Great Basin conifer woodland and interior chaparral biotic communities.

Distribution: Known from many parts of the United States, and previously reported from California, Connecticut, Florida, Georgia, Iowa, Louisiana, Massachusetts, New Jersey, Ohio, Texas, Washington and Wisconsin (see fig. 29 for Arizona distribution). Also reported from Africa, Australia, Britain, China and Europe.

Material examined: ARIZONA, Maricopa Co.: 7 Springs area near Cavecreek, 25 January 2003, S.T. Bates (STB00124). Mohave Co.: Mt. Trumbell; Parashant Nat. Monument, 22 March 2003, S.T. Bates (STB00624).

Superficially, *B. dermoxantha*, along with *B. aestivalis*, could be confused with other species of small puffballs found in the state (see *B. aesitivalis* for further discussion). Externally, *Holocotylon brandegeeanum* looks very much like *B. dermoxantha*; however, that species can be distinguished by cutting a cross-section through the gasterocarp to observe the gleba. *Bovista dermoxantha* will have a cottony gleba filled with eucapillitia, where as, *H. brandegeeanum* exhibits a gleba with labyrinthiform, sinuous tramal plates that form numerous locules (see *H. brandegeeanum* for further discussion). *Vascellum texense* could also be confused with *B. dermoxantha*; however, that species has fragile peridia and lacks eucapillitia, having only abundant paracapillitia (see *V. texense* for further discussion). *Bovista dermoxantha* is reported for the first time from Arizona here.

26. ***Bovista plumbea*** Pers.: Pers., Observationes Mycologicae 1: 5 (1796).

(figs. 62b, 81b & 99c-d)

Reported synonyms

≡ *Lycoperdon plumbeum* (Pers.) Vittad., Fung. Manger.: 257 (1835).

≡ *Sackea plumbea* (Pers.) Rostk., Deutschl. Fl. (Sturm), Abt. 3, Pilze Deutschl. 18: 35 (1839).

≡ *Globaria plumbea* (Pers.) Quél., Champ. Jura 2: 371 (1873).

= *Lycoperdon arrhizon* Batsch, Elench. Fung. 2: 239 (1786), nom. dev.

= *Bovista tunicata* Fr., Syst. Mycol. 3: 25 (1829).

= *Bovista pupurea* Lloyd, Mycol. Writings 6: 1201 (1923).

Type: Kreisel (1967b) selected as a lectotype the Friesian type of *Bovista tunicata*, which resides at the Herbarium at Uppsala University (UPS).

Selected illustrations: Calonge (1992: fig. 13b); Kreisel (1967b, ills. 68-70); Pegler, Læssøe & Spooner (1995: figs. 107-108); Smarda in Pilát (1958: figs. 112: 1-2 & 115-116); Smith (1951: pl. 24, fig. 2).

Gasterocarp 15-30 mm in diameter x 10-25 mm in height, globose, subglobose to depressed globose, normally becoming separated from the mycelium, although a small basal pad of thick mycelium often remains, encrusted with particles of soil; ostiole developing with the sloughing of the exoperidium, slit-like or irregularly torn to ovoid, up to 5 mm in length, older specimens sometimes developing radial splitting.

Exoperidium whitish at first, becoming grayish brown (6D5-8F3) or remaining whitish, glabrous or occasionally encrusted with particles of soil, thin and papery, sloughing off in large irregular sheets with remnants often remaining on the basal portions of the gasterocarp. Endoperidium lead gray (2D2) or grayish brown to brownish gray (6D3-8F2), glabrous, thin and flaccid to subcoriaceous, persistent. Gleba whitish and solid at first, becoming light brown (6D6), and finally dark brown (7F6), cottony. Subgleba , cellular, composed of compact cells, normally absent, comprising only the lower portions of the gasterocarp, reduced or absent.

Basidiospores ovoid, 5.6-6.4 X 4.8-5.6 μm [x = 6.0 ± 0.4 X 4.8 ± 0.6 μm, Q_m = 1.3, n = 20], asperulate to asperate, central oil drop; pedicel, long (10.0-16.0 μm in length), straight, with blunt or attenuate terminus; sterigmal remnants absent from mounts; spores brownish yellow in water mounts. Eucapillitium '*Bovista*' type, 4.0-16.0 (24) μm in diameter, thick-walled (up to 4.0 μm), glabrous, occasionally finely encrusted, singular units, highly branched with thick central strand, tips attenuate with acute apices, lacking pores, elastic, aseptate, yellowish brown in water mounts. Paracapillitium absent. Exoperidium translucent and plate-like, and it is difficult to readily discern the cellular composition. Endoperidium composed of tightly interwoven, thick-walled hyphal elments.

Habitat: Terrestrial and found in open areas, pastures, grassy areas within forests, cultivated lawns of urban areas, or along drainage sites, such as at the edge of roadways or trails. This species occurs in the higher elevations of the state within the Petran montane conifer forest and Petran subalpine conifer forest biotic communities.

Distribution: Know from many parts of the United States, and previously reported from Idaho, Illinois, Massachusetts, Michigan, Montana, New York, North Carolina, North Dakota, Ohio, South Carolina, Wisconsin and Wyoming (see fig. 30 for Arizona distribution). Also reported from Europe, Britain and Russia.

Material examined: ARIZONA, Apache Co.: ~50-100 ft to the W of corral by the side of 2 track dirt rd.; ~1 mi in on FR 116 off of Hwy. 273, Big Lake area, 16 August 2002, S.T. Bates (STB00087). Coconino Co.: East side Game Road, Kaibab Plateau, Kaibab Nat. Forest, 06 June 1968, R.L. Gilbertson (ARIZ RLG7874); 3919 N Paradise Road, 14 September 1983, J.S. States (MICH AEF1417); N Paradise Road 02 October 1983, J.S. States (MICH AEF104); 3919 N Paradise Road, 07 December 1991 (MICH AEF921).

This species is characterized by having a gasterocarp that separates from the mycelial pad at maturity, a grayish brown endoperidium, '*Bovista*' type capillitium, and ovoid spores with a long straight pedicel. Other *Bovista* species in Arizona exhibit the *Lycoperdon* or intermediate type capillitium. *Bovista graveolens*, *B. pila* and *B. nigrescens* should be compared with *B. plumbea* although none of these species have been reported from Arizona. *B. graveolens* is similar to *B. plumbea*, but it can be distinguished microscopically as it has a long pedicel with a 90^{o} or U-shaped bend. Darker specimens of *B. plumbea* could be confused with *B. nigrescens*; however, this species has spores with a shorter pedicel (4.0-10.0 μm) and the ornamentation is slightly more coarse. The smooth apedicellate spores and fragile capillitium with short branches

readily distinguish *B. pila*. *Bovista plumbea* is reported for the first time from Arizona here.

Calvatia Fr., Summa Vegetabilium Scandinaviae: 442 (1849).

Type species: *Calvatia craniiformis* (Schwein.) Fr., Summa Veg. Scand.: 442 (1849).

27. ***Calvatia bicolor*** (Lév.) Kreisel, Persoonia 14: 435 (1992).

(figs. 62c, 82a & 99e)

Basionym

Bovista bicolor Lév., Ann. Sci. Nat., Bot. Sér. 3, 5: 162 (1846).

Reported synonyms

≡ *Lanopila bicolor* (Lév.) Pat. Bull. Soc. Mycol. France 15: 203 (1899).

≡ *Langermannia bicolor* (Lév.) Demoulin & Dring, Bull. Jard. Bot. Belg. 45: 350 (1975).

= *Lanopila wahlbergii* Fr., Kongl. Vetensk. Acad. Handl.: 151 (1848).

= *Lasiosphaera fenzlii* Reich., Reise Austr. Freg. Nov. 1: 135 (1870).

= *Bovista tosa* Berk. & M.A. Curt., J. Bot. 26: 132 (1880).

= *Lanopila radloffiana* Verwoerd, Ann. Univ. Stellenbosch 3: 25 (1925).

= *Langermannia fenzlii* (Reich.) Kreisel, Feddes Repert.64: 120 (1962).

= *Langermannia wahlbergii* (Fr.) Dring, Mycol. Pap. 98: 46 (1964).

Type: Kreisel (1992) cites the type locality as being Bombay, India and indicates that type material is deposited at the Muséum National d'Histoire Naturelle (PC) and the Royal Botanic Garden (K).

Selected illustrations: Bottomley (1948: pl. 45 as *Lanopila wahlbergii*); Homrich & Wright (1973: fig. 3, B-D); Moreno, Kreisel & Altés (1996: fig. 14, SEM of spore).

Gasterocarp (30) 60-70 (100) mm in diameter x 50-60 (80) mm in height, globose, subglobose to depressed globose, attached at the base by a mycelial mat that soon becomes detatched from the gasterocarp; ostiole lacking, peridia slowly breaking apart at the apex of the gasterocarp to expose the gleba. Exoperidium light brown (7D5-7), brown (7D5-8) to reddish brown (8D5-6 to 8E4-8), glabrous, occasionally lightly encrusted with particles of soil, thin, persistent or breaking up into small-sized irregular-shaped, flaky patches, which soon slough off various parts of the gasterocarp, particularly toward the apex. Endoperidium grayish orange (6B3-5) to brownish orange (6C5-6), glabrous, thin, dull, papery to subcoriaceous, persistent, breaking apart at the apex of the gasterocarp with age to reveal the gleba. Gleba light brown (6D5-8 to 7D6-8), cottony, firm and persistent. Subgleba absent.

Basidiospores globose, 5.6-7.2 X 5.6-7.2 μm [x = 6.4 ± 0.7 X 6.4 ± 0.7 μm, Q_m = 1.0, n = 20], echinulate to echinate, central oil drop; pedicel absent or rudimentary; sterigmal remnants mostly absent from mounts; spores brownish yellow in water mounts. Eucapillitium '*Calvatia*' type, 3.2-6.4 μm in diameter, thick-walled (up to 0.8 μm), glabrous, sparsely branched (dichotomous when occuring), straight to subundulate,

abundant small- to medium-sized pores, fragile, septate, often breaking at septum, brownish yellow in water mounts. Paracapillitium absent. Exoperidium composed of thick-walled orbicular to ovoid sphaerocysts. Endoperidium composed tightly interwoven hyphal elements.

Habitat: Terrestrial and found in open areas or in soil and debris under ash trees (*Fraxinus* spp.). It is assumed that this species occurs in the higher elevations of the state within the Petran montane conifer forest biotic community (see comments).

Distribution: Not reported from the United States (see fig. 31 for Arizona distribution), although herbarium record (NY and BPI) cite collections from Arizona and Florida. Also reported from Africa, Asia, Indonesia, Caribbean, Central America and South America.

Material examined: ARIZONA, Coconino Co.?: "Pleasant Valley, Pima County", 05 November 1958, L.N. Goodding (ARIZ LNG756-58).

The glabrous, thin exoperidium, orangish endoperidium, echinulate to echinate spores, '*Calvatia*' type capillitium and manner of dehiscence distinguish *Calvatia bicolor* from all other puffball species found in Arizona. *Calvatia rugosa* also has echinate spores, but can be distinguished as fresh material of *C. bicolor* does not stain yellow, nor does it develop orange coloration when dry (see *C. rugosa*). Smaller, globose specimens of *C. craniiformis* could also be confused with *C. bicolor*; however, the former normally

has a well developed subgleba and the spores are not as coarsely ornamented as those found in the later.

There is some uncertainty regarding the collection locality of the *C. bicolor* specimen deposited in the Gilbertson Herbarium (ARIZ). Although the field label cites "Pleasant Valley, Pima Co.", it is clear if such a place exists. The vascular plant herbarium at the University of Arizona (ARIZ) has several records confirming that the collector, L.N. Goodding, frequented the Pleasant Valley in Coconino county. However, there is one 1934 record of Goodding collecting in the Pleasant Valley of Gila County. The New York Botanical Garden houses two specimens labeled *C. bicolor* (NY 123803 & 460667) from Santa Cruz County, which were collected by W.H. Long. *Calvatia bicolor* is reported for the first time from Arizona and the United States here.

28. ***Calvatia booniana*** A.H. Sm., Lloydia 27: 164 (1964). (figs. 62d, 82b, 99f & 105a)

Type: The holotype is located at the University of Michigan Fungus Collection (MICH Smith A.H. 65191) labeled "*Calvatia booniana* A.H. Sm., USA, Oregon, Cook Co., Prineville, Jul 1962" (Zeller & Smith 1964).

Selected illustrations: Zeller & Smith (1964: pls. VII & VIII).

Gasterocarp 160-600 mm in diameter x 70-300 mm in height, globose to depressed globose, sharply tapering at the base to a robust rhizomorph, encrusted with soil particles; ostiole lacking, peridia breaking apart in patches to expose the gleba.

Exoperidium whitish at first, becoming grayish yellow (4B4) with age; 2-5 mm thick, glabrous with some areas covered in a fine flocculence, breaking up into polygonal or irregular-shaped patches (reaching 20-50 mm in length) with a wrinkled surface; patches flat, concave or slightly raised often darkening toward the center, often sloughing off to reveal the endoperidium. Endoperidium white to grayish yellow (4B4), glabrous or felted, up to 2 mm thick, breaking up and sloughing off with the exoperidium. Gleba whitish and solid at first, becoming olive-yellow (3C8) and finally olive-brown (4E5-8), pulverulent. Subgleba whitish if present, absent or confined to the area of the rhizomorph, comprising only the lower portions of the gasterocarp, reduced or absent.

Basidiospores globose to subglobose, 4.0-4.8 X 3.2-4.8 µm [x = 4.3 ± 0.4 X 4.0 ± 0.5 µm, Q_m = 1.1, n = 20], smooth to asperulate, central oil drop; pedicel short; sterigmal remnants present in mounts; spores brownish yellow in water mounts. Eucapillitium '*Calvatia*' type, 4.0-7.2 µm in diameter, thick-walled (up to 1.6 µm), glabrous, dichotomously branched, straight to undulate, abundant small-sized pores, fragile, septate, often breaking at septum, yellow-brown in water mounts. Paracapillitium absent. Endoperidium composed of tightly interwoven, thick-walled hyphal elments.

Habitat: Terrestrial and found in open areas, meadows, grassy areas within forests, disturbed areas, drainage areas or even fruiting in dirt roadways. This species occurs in the higher elevations of the state within the Petran montane conifer forest and the Plains and Great Basin grassland biotic communities.

Distribution: Known only from the western United States, and previously reported from Colorado, Idaho, New Mexico, Oregon and Utah (see fig. 32 for Arizona distribution). Not reported from other parts of the world.

Material examined: ARIZONA, Coconino Co.: Parks, in Populus - Pinus ponderosa, 03 September 1986, J.S. States (MICH AEF406); Hart Prairie, San Francisco Peaks Natural Area, in dry open areas near old corrals, often near or under sagebrush, 28 August 1988, J.S. States (MICH AEF1323); Continental Country Club, Flagstaff, in dry open areas near old corrals, often near or under sagebrush, 17 June 1992, J.S. States (MICH AEF940).

Calvatia booniana is among the larger puffballs found in the United States. It is the only large puffball found in Arizona with a thick exoperidium that breaks up into polygonal or irregular-shaped patches. *Calvatia polygonia*, known only from Colorado, is a very similar species which can be distinguished by its strongly ornamented spores. Two other puffballs not reported from Arizona, *C. sculpta* and *Calbovista subsculpta*, could also be confused with *C. booniana*. *Calvatia sculpta* has polygonal patches with more prominent pyramidal warts, and *Calbovista subsculpta*, which also exhibits pyramidal warts, is easily distinguished by the presence of '*Bovista*' type capillitia. A medium-sized puffball found in Arizona, *C. pachyderma*, is distinguished by a glabrous exoperidium and a thick, hard endoperidium that develops large cracks in the apical portions of the gasterocarp (see *C. pachyderma* for further discussion). *Calvatia booniana* is reported for the first time from Arizona here.

29. ***Calvatia craniiformis*** (Schwein.) Fr., Summa Vegetabilium Scandinaviae.: 442 (1849). (figs. 63a, 83a, 100a 104e)

Basionym

Bovista craniiformis Schwein., Trans. Amer. Philos. Soc. II. 4: 256 (1832).

Reported synonyms

= *Lycoperdon delicatum* Berk. & M.A. Curtis, Grevillea 2: 51 (1873) , non *L. delicatum* Berk., J. Bot. (Hooker): 172 (1854).

= *Lycoperdon missouriense* Trelease, Trans. Acad. Sci. St. Louis 5: 240 (1891).

Type: The type material from Schweinitz, possibly a syntype, is housed at the Academy of Natural Sciences (PH) and was removed from the original packet and remounted by E. Michener. The specimen is labeled in Michener's hand and reads "2256 *Bovista craniiformis* Schw., Beth.". This cryptic notation most likely refers Bethel, NC as the locality. A fragment of the original Schweinitz type material is also housed at the National Fungus Collection (BPI 733283) and was originally a part of the herbarium of W.M. Trelease.

Selected illustrations: Coker & Couch (1928: pl. 39); Smith (1951:pl. 8); Zeller & Smith (1964: pls. 14 & 15).

Gasterocarp (50) 70-150 (190) mm in diameter x 60-120 (200) mm in height, obovoid, broadly obpyriform to turbinate, slightly tapering at the base to a broad pseudostipe which is rounded at the base, often attached by a thick branching

rhizomorph, encrusted with particles of soil; ostiole lacking, peridia breaking apart to expose the gleba. Exoperidium whitish at first, becoming dark yellow (4C8) to yellowish brown (5D8-5E6), glabrous to minutely floccose or sparsely encrusted with particles of dirt, thin and papery, breaking up into thin irregular-shaped, flaky patches, which soon slough off of the upper portions of the gasterocarp. Endoperidium often slightly paler than the exoperidium, glabrous or felted, thin and fragile, breaking up and sloughing off as does the exoperidium. Gleba whitish and solid at first, becoming olive-yellow (3C8), olive-brown (4D8) to light brown (5D7), cottony, firm and persisting for a long time after the peridial layers shed, pieces of the peridia often remain attached in random patches. Subgleba olive brown (4D8), cellular, composed of small-sized cells, comprising the lower 1/3 to 1/2 of the gasterocarp.

Basidiospores globose to subglobose, 3.2-4.0 X 3.2-4.0 μm [x = 3.8 ± 0.4 X 3.6 ± 0.4 μm, Q_m = 1.1, n = 20], smooth to asperulate, oil drop not apparent; pedicel absent or rudimentary; sterigmal remnants absent from mounts; spores brownish yellow in water mounts. Eucapillitium '*Calvatia*' type, to 4.8 μm in diameter, thick-walled (up to 1.0 μm), glabrous, occasionally finely encrusted, sparsely branched (dichotomous when occurring), straight to subundulate, abundant medium- to large-sized pores, fragile, septate, often inflated at septum (fig. 104e), yellowish brown in water mounts. Paracapillitium absent. Exoperidium composed of thick-walled (up to 1.0 μm), inflated irregular or flask-shaped sphaerocysts (yellowish in water mounts and deep brown in melzers). Endoperidium composed of tightly interwoven, thick-walled hyphal elments.

Habitat: Terrestrial and found in open areas, meadows, disturbed areas or under desert willow (*Chilopsis linearis*), mesquite (*Prosopis* spp.), oak (*Quercus* spp.), pinyon (*Pinus edulis*), juniper (*Juniperus* spp.) or sagebrush (*Artemesia* spp.). This species is widespread in Southern Arizona and occurs in the mid to higher elevations of the state within the Madrean evergreen woodland, Plains and Great Basin grassland, and semidesert grassland biotic communities.

Distribution: Known from various parts of the United States, particularly common in the southern states, and previously reported from Michigan, Oklahoma and Texas (see fig. 33 for Arizona distribution). Also reported from China and Japan.

Material examined: ARIZONA, Cochise Co.: Near John Hand's Lake, Chiricahua Mts., Coronado Nat. Forest, on ground, 10 October 1970, J.P. Lindsey (ARIZ AN014552); Pinery Canyon, Chiricahua Mts., Coronado Nat. Forest, on ground, 22 November 1974, B.G. Phillips (ARIZ AN014656); John Hands Park, Chiricahua Mts., Coronado Nat. Forest, on soil, 16 February 1975, C. Dennet (ARIZ no number); Scotia canyon, under Emory oak & pinyon, 21 September 1977, R.L. Gilbertson (ARIZ AN014711); Huachuca Mountains, on waste land often under sagebrush (*Artemesia*), 03 September 1994, J.S. States (MICH AEF1313). Santa Cruz Co.: Rd. between Patagonia and Lochiel, Patagonia Mts., on ground under mesquite and desert willow, 10 November 1967, R.L. Gilbertson (ARIZ AN014643); Canelo Road, on ground, 09 October 1970, R.L. Gilbertson (ARIZ AN014668); Sycamore Canyon, Atascosa Mts., Coronado Nat. Forest, on ground under oak-juniper, 23 September 1971, R.L. Gilbertson (ARIZ

RLG10490); Gardner Canyon, Santa Rita Mts., Coronado Nat. Forest, near base of *Juniperus deppeana* Steud., 06 September 1976, J.P. Lindsey (ARIZ JPL546); Washington Camp, Patagonia Mts., under oak and junipers, 02 September 1977, R.L. Gilbertson (ARIZ RLG11726).

The obpyriform to turbinate gasterocarp, persistent olive-brown gleba and flakey exoperidium distinguishes *Calvatia craniiformis* from other medium-sized puffballs in the field. Microscopically, the small spores (3.2-4.0 µm diam.) and capillitia with inflated septa are very characteristic of this species. *Calvatia craniiformis* often resembles *C. cyathiformis* externally, but is easily distinguished from that species which has a distinct violaceous gleba. Both of these species have gasterocarps that persist for long period of time (see *C. cyathiformis* for further discussion). *Calvatia rugosa* is also superficially similar; however, that species stains yellow when fresh and later develops an orangish coloration (see *C. rugosa* for further discussion). *Handkea utriformis* (not reported from Arizona) could also be confused with *C. craniiformis*; however, that species develops a crater-like opening, revealing a pulverulent olive-brown gleba and has distinct sinuous slits in the capillitia. In southern Arizona, *C. craniiformis* is one of the more common medium-sized puffballs. This species is reported for the first time from Arizona here.

30. ***Calvatia cyathiformis*** (Bosc) Morgan, Journal of the Cincinnati Society of Natural History 12: 168 (1890). (figs. 63b, 83b & 100b)

Basionym

Lycoperdon cyathiforme Bosc, Ges. Naturf. Freunde Berlin Mag. 5: 87 (1811).

Reported synonyms

= *Lycoperdon bovista* Vittad., Fung. Manger.: 264 (1835), non Pers., non Fr.

= *Bovista lilacina* Berk. & Mont., J. Bot. (Hooker) 4: 64 (1845).

= *Lycoperdon lilacinum* (Berk.) Massee, J. Roy. Microscop. Soc. London: 706 (1887).

= *Calvaitia lilacina* (Berk. & Mont.) Henn., Hedwigia 43: 205 (1904), sensu some authors see comments.

= *Hippoperdon crucibulum* Mont., Syll. Gen. Sp. Crypt. No. 1057 (1856).

= *Lycoperdon pseudo-lilacinum* Speg., Fungi Guaran.: 45 (1886).

Type: According to Calonge (1998) the holotype is located at the Naturhistorisches Museum Wien (W 25156). Kreisel (1992) states the type locality is "Carolina, USA".

Selected illustrations: Bottomley (1948: pl. 41, figs. 2-3, as *C. lilacina*); Coker & Couch (1928: pls. 35 & 36); Cunningham (1943: Pl. 23, fig. 1); Smarda in Pilát (1958: fig. 94, as *C. lilacina*); Smith (1951:pl. 6, fig. 1); Zeller & Smith (1964: pl. 1, as *C. cyathiformis* f. *cyathiformis*).

Gasterocarp 70-130 (160) mm in diameter x 80-130 (200) mm in height, obovoid, subglobose, depressed globose, broadly obpyriform to turbinate, gradually or sharply tapering at the base to a broad pseudostipe, rounded or slightly plicate at the base, often attached by a thick rhizomorph or a thick mycelial pad, encrusted with particles of soil; ostiole lacking, peridia breaking apart to expose the gleba. Exoperidium whitish at first, becoming light brown to brown (7D6-7E6) or remaining whitish, finally turning violet-brown (11E4) to dark magenta (13F4) as the peridia begin to disintegrate and violaceous spores begin to cover the gasterocarp, glabrous to minutely floccose or sparsely encrusted with particles of dirt, thin and papery, breaking up into small- to medium-sized irregular-shaped, flaky patches, which soon slough off of the upper portions of the gasterocarp. Endoperidium violet-brown (11E4) to dull violet (15E3) or purplish gray (14E2), felted, thin and fragile, breaking up and sloughing off as does the exoperidium. Gleba whitish and solid at first, becoming violet-brown (11E4) to dark magenta (13F4) or grayish magenta (13E4), cottony, rather firm and persisting for a long time after the peridial layers shed; pieces of the peridia often remain attached in random patches. Subgleba dark brown (8F5) to violet brown (10F5) in mature specimens, cellular, composed of small- to medium-sized cells (less than 3.0 mm in width), comprising the lower 1/3 to 1/2 of the gasterocarp.

Basidiospores globose, 5.6-8.0 X 5.6-8.0 µm [x = 6.9 ± 0.9 X 6.9 ± 0.9 µm, Q_m = 1.0, n = 20], strongly and densely verrucose, verrucae up to 1.0 µm in length, oil drop not apparent; pedicel rudimentary and difficult to discern due to the verrucae; sterigmal remnants mostly absent from mounts; spores pale brown in water mounts. Eucapillitium '*Calvatia*' type, 3.2-6.4 µm in diameter, thick-walled (up to 1.0 µm), glabrous,

occasionally finely encrusted, sparsely branched (dichotomous when occurring), straight to subundulate, occasionally with knob-like projections, abundant small- to medium-sized pores, extremely fragile, septate, often breaking at septum, pale brown to nearly hyaline in water mounts. Paracapillitium absent. Exoperidium composed of thick-walled, inflated, elongated, irregular-shaped or orbicular, pigmented (pale brown in water mounts) sphaerocysts and fragile hyaline hyphal elements with numerous pores. Endoperidium composed of tightly interwoven, thick-walled hyphal elments.

Habitat: Terrestrial and found in open areas, disturbed areas, cultivated lawns, meadows, along drainage ways or growing amid leafy debris under manzanita (*Arctostaphylos pungens*), mesquite (*Prosopis* spp.) or oak (*Quercus* spp.). This species occurs in the mid to higher elevations of the state within the Great Basin conifer woodland, Madrean evergreen woodland, and Petran montane conifer forest biotic communities.

Distribution: Common in many parts of the United States, and previously reported from California, Idaho, Michigan, North Dakota, Oklahoma, Pennsylvania, Texas, Washington and West Virginia (see fig. 34 for Arizona distribution). Also reported from Africa, China, Japan and South America.

Material examined: ARIZONA, Coconino Co.: Walnut Canyon National Monument, grass, prairie or desert communities, 10 September 1994, J.S. States (MICH AEF1176). Santa Cruz Co.: Near Canelo, Coronado Nat. Forest, on soil; oak/manzanita

scrub forest, 28 October 2003, S.T. Bates (STB00302). Yavapai Co.: Oak Creek Canyon Village, E Sedona, in *Prosopis*, at drainage to creek, 28 September 1988, J.S. States (MICH AEF780).

With the exception of two closely related species, the violaceous gleba of *C. cyathiformis* makes this a rather distinct species among puffballs (see comments under *C. fragilis* and *C.* cf. *leiospora*). *Calvatia fragilis* has a subgleba that is absent or composed of smaller, more compact cells, slightly less verrucose spores, and is often plicate at the base. *Calvatia* cf. *leiospora* can be distinguished by having smooth rather than verrucose spores. The gleba of *C. cyathiformis* can persist for weeks if not months. Once the gleba has worn away, the cup-shaped subgleba (from which the specific epithet was derived) can persist for a year if not longer. Herbaria collections of this species should be confirmed in comparison to *C. fragilis* as there has been some confusion regarding these taxa (see *C. fragilis* for further discussion). *Calvatia cyathiformis* is reported for the first time from Arizona here.

31. ***Calvatia fragilis*** (Vittad.) Morgan, Journal of the Cincinnati Society of Natural History 12: 168-169 (1890). (figs. 63c, 84a & 100c)

Basionym

Lycoperdon fragile Vittad., Monogr. Lycoperd.: 80 (1842).

Reported synonyms

≡ *Calvatia cyathiformis* f. *fragilis* (Vittad.) A.H. Sm., Lloydia 27: 150 (1964).

= *Calvatia lilacina* (Mont. & Berk.) Henn., Hedwigia 43: 205 (1845), sensu some authors.

= *Lycoperdon novae-zelandiae* Lév., Ann. Sci. Nat., Bot., Sér. 3, 5: 164 (1846).

= *Bovista cinerea* Ellis, Bull. Washburn Coll. Lab. Nat. Hist. 1: 40 (1885).

= *Lycoperdon violascens* Cooke & Massee, J. Roy. Microscop. Soc. London: 706 (1887).

= *Bovista amethystina* Cooke & Massee, Grevillea 16: 69 (1888).

= *Bovista dealbata* Berk. ex Massee, J. Bot. 26: 131 (1888).

= *Calvatia lilacina* var. *occidentalis* Lloyd, Mycol. Writings 6: 1097 (1921), nom. nud.

Type: Kreisel (1992) cites Italy as being type locality for this species, and it is possible that type material exist among the Vittadinian collection at the Royal Botanic Garden, Kew (K).

Selected illustrations: Coker & Couch (1928: pl. 37); Smith (1951: pl. 6, fig. 2); Zeller & Smith (1964: pl. I, as *C. cyathiformis* f. *fragilis*).

Gasterocarp 40-70 (95) mm in diameter x 35-60 mm in height, subglobose, depressed globose to turbinate, plicate at base, sharply tapering to a narrow pseudostipe, occasionally absent or greatly reduced, attached by a thick rhizomorph, encrusted with particles of soil; ostiole lacking, peridia breaking apart to expose the gleba. Exoperidium whitish at first, becoming pale yellow (4A3) or remaining whitish, finally turning violet-

brown (11E4) as the peridia begin to disintegrate and violaceous spores begin to cover the gasterocarp, glabrous to appressed floccose, thin and papery, breaking up into small-sized irregular-shaped, flaky patches, which soon slough off of the upper portions of the gasterocarp. Endoperidium grayish to violet-brown (11E4), felted, thin and fragile, breaking up and sloughing off as does the exoperidium. Gleba whitish and solid at first, becoming grayish magenta (13E3) to dull violet (15E3), cottony, rather firm and persisting for a long time after the peridial layers shed; pieces of the peridia often remain attached in random patches. Subgleba grayish yellow (4B5) to yellowish brown (5D6), cellular, composed of compact cells, or reduced to absent, comprising only the lower portions of the gasterocarp, reduced or absent.

Basidiospores globose, 6.4-7.2 (8.0) X 6.4-7.2 (8.0) μm [x = 6.8 ± 0.5 X 6.8 ± 0.5 μm, Q_m = 1.0, n = 20], verrucose, verrucae up to 0.8 μm in length, oil drop not apparent; pedicel rudimentary and difficult to discern due to the verrucae; sterigmal remnants mostly absent from mounts; spores pale brown in water mounts. Eucapillitium '*Calvatia*' type, 3.2-4.0 μm in diameter, thick-walled (up to 1.0 μm), glabrous, occasionally finely encrusted, sparsely branched (dichotomous when occurring), straight to subundulate, abundant small- (or occasionally medium-) sized pores, extremely fragile, septate, often breaking at septum, pale brown to nearly hyaline in water mounts. Paracapillitium absent. Exoperidium composed of thick-walled, inflated, elongated, irregular-shaped sphaerocysts and fragile hyaline hyphal elements with occasional pores. Endoperidium composed of tightly interwoven, thick-walled hyphal elments.

Habitat: Terrestrial and found in open areas, meadows, grassy areas within forests or growing amid leafy debris under manzanita (*Arctostaphylos pungens*), pinyon (*Pinus edulis*) or juniper (*Juniperus* spp.). This species is found throughout Arizona and occurs in the mid to higher elevations of the state within the Great Basin conifer woodland, interior chaparral, Madrean evergreen woodland, and semidesert grassland biotic communities.

Distribution: Common in many parts of the United States, and previously reported from Idaho, Louisiana, Michigan, New Mexico, Oklahoma, Texas, Utah and Wyoming (see fig. 35 for Arizona distribution). Also reported from Africa, central Asia, Australia, Southern Europe, and New Zealand.

Material examined: ARIZONA, Coconino Co.: Red Mountain, Hwy 180 N, *Pinus edulis* & *Juniperus*, 16 December 1986, J.S. States (MICH AEF540); Encinosa Picnic Area, Oak Creek Canyon, in grass, prairie or desert communities, 18 September 1994, J.S. States (MICH AEF1180). Pima Co.: Pima Canyon, Santa Catalina Mts., Coronado Nat. Forest, on the ground, 05 September 1972, R. Halse (ARIZ no number); Santa Rita Exp. Range, Santa Rita Mts., Coronado Nat. Forest, on ground in a desert grass vegetation, 08 September 1975, R.L. Gilbertson (ARIZ RLG11300); Saguaro National Monument, East Unit, on ground in desert, 16 August 1982, A. Skarshaug (ARIZ AN014673). Santa Cruz Co.: 6 miles north of Lochiel, under *Arctostaphylos pungens*, 30 July 1977, J.P. Lindsey (ARIZ AN014655).

The smaller size and reduced subgleba with compact cells distinguish this species from *C. cyathiformis* in the field. Microscopically, there are also very slight differences in the capillitium, the degree of spore ornamentation and the composition of the exoperidial tissue. This species could also be confused with the poorly known *Calvatia* cf. *leiospora*; however that species can be easily distinguished as it has smooth spores that are smaller (4.0-4.8 μm in diam.). There continues to be disagreement as to whether *C. fragilis* represents a distinct species. Some authors prefer to considered *C. fragilis* as a form of *C. cyathiformis* (Smith & Zeller, 1964), while others prefer to synonymize *C. fragilis* under *C. cyathiformis* (Calonge, 1998). The Arizona material can clearly be separated into two distinct taxa with markedly different spores when observed at high magnification under SEM (figs. 100b and 100c); therefore, we agree with Kreisel (1992) and retain *C. fragilis* at the species level until more conclusive evidence can be cited. This species is reported for the first time from Arizona here.

32. ***Calvatia* cf. *leiospora*** Morgan, Journal of the Cincinnati Society of Natural History 18: 39 (1895). (figs. 63d, 84b, 100d & 104f)

Type: Morgan's holotype from South Dakota was deposited at the Iowa State Herbarium (ISC), Ames and is now apparently missing.

Selected illustrations: Morgan (1895: pl. II).

Gasterocarp 20-40 mm in diameter x 20-30 mm in height, obovoid, subglobose to depressed globose, sharply tapering toward a plicate base, pseudostipe absent or greatly reduced; ostiole lacking, peridia breaking apart to expose the gleba. Exoperidium whitish at first, becoming yellowish white (4A2), yellowish gray (4B2) to grayish orange (5B4), often having small brownish orange to light brown (6C7-6D7) patches, glabrous to rugulose, thin, papery and fragile, breaking up into small-sized irregular-shaped, flaky patches, which soon slough off of the upper portions of the gasterocarp. Endoperidium yellowish white (4A2), felted, thin and fragile, breaking up and sloughing off as does the exoperidium. Gleba whitish and solid at first, becoming grayish lilac (16B-C2), cottony and somewhat fragile. Subgleba cellular, composed of small-sized cells (less than 1.0 mm in width), or reduced to absent, comprising only the lower portions of the gasterocarp, reduced or absent.

Basidiospores globose, 4.0-4.8 X 4.0-4.8 μm [x = 4.3 ± 0.4 X 4.2 ± 0.3 μm, Q_m = 1.0, n = 20], smooth to minutely asperulate, central oil drop; pedicel absent or rudimentary; sterigmal remnants mostly absent from mounts; spores pale gray brown to nearly hyaline in water mounts. Eucapillitium '*Calvatia*' type, 2.4- 3.2 μm in diameter, glabrous, sparsely branched (dichotomous when occurring and often near septa), straight to subundulate, abundant small- to large-sized pores, fragile to subelastic, septate, often inflated at septum, pale smoky brown to nearly hyaline in water mounts. Paracapillitium absent. Exoperidium composed of thin-walled, occasionally branching hyphal elements, up to 5.6 μm in diameter. Endoperidium composed of tightly interwoven, thick-walled hyphal elments.

Habitat: Terrestrial and found growing amid leafy debris under mesquite (*Prosopis* spp.). This species is known from only one collection in Arizona and occurs in the lower elevations of the state within the Arizona Upland division of the Sonoran desertscrub biotic community.

Distribution: Rare, and previously reported from only one collection in South Dakota (see fig. 36 for Arizona distribution). Not reported from other parts of the world.

Material examined: ARIZONA, Pima Co.: C.T. Mason home, Tucson, under *Prosopis* sp., 16 August 1982, C.T. Mason (ARIZ AN014671).

This species is similar in size, stature and appearance to *C. fragilis*; however, that species can be easily distinguished by the verrucose spores. Zeller and Smith (1964) give a description of Morgan's *Calvatia leiospora* and mention that it has smooth spores (not mentioned in the protologue, though discernable in the illustration), although it is not clear if either author ever examined type material or any other specimens. The specimens described here fit this description in all aspects, except that the ARIZ material lacks a prominent sterile base. As Zeller and Smith suggest, more fresh material is needed to redefine this species. Confirmation that this specimen (ARIZ AN014671) is indeed conspecific with Morgan's species awaits examination of the holotype; however, it appears that the original type material from South Dakota is missing. In this case, it would be best to choose a neotype from specimens collected in that state. *Calvatia* cf. *leiospora* is reported for the first time from Arizona here.

33. ***Calvatia pachyderma*** (Peck) Morgan, Journal of the Cincinnati Society of Natural History 12: 167 (1890). (figs. 64a, 85a, 100e & 104d)

Basionym

Lycoperdon pachydermum Peck, Bot. Gaz. 7:54 (1882).

Reported synonyms

= *Calvatia primitiva* Lloyd, Mycol. Writings 1: 2 (1904), nom. nud.

= *Gastropila fragilis* (Lév.) Homrich & Wright, Mycologia 65: 790 (1973).

= *Langermannia pachyderma* (Peck) Kreisel, Feddes Repert. 64: 120 (1962).

Type: The holotype of Peck's species is located in the mycological collection at the New York State Museum (NYS) labeled "*Lycoperdon pachydermum* Peck, Arizona, Santa Catalina Mts, 22-6-1884, Pringle". There has been some confusion in the past related to the ornamentation of the spores present in the type material. Demoulin (1993) states that the verrucose spore described from the type by Calonge and Martin (1990) were a contamination and that the holotype definitely demonstrates smooth spores (see also Ponce De León 1976b, Wright 1990).

Selected illustrations: Bottomley (1948: pl. 44, fig. 2).

Gasterocarp (70) 100-170 (170) mm in diameter x 80-140 mm in height, obovoid, depressed globose to turbinate, tapering at the base to a robust rhizomorph, encrusted with particles of soil; ostiole lacking, peridia cracking apart at the apex of the gasterocarp to expose the gleba. Exoperidium whitish at first, becoming yellowish white (4A2) to

yellowish gray (4B5), glabrous to minutely floccose, developing horizontal cracks, splitting at the apical portions of the gasterocarp and then breaking off as large plates. Endoperidium grayish white (4B5) and often fading toward white and becoming shiny with age, glabrous, thick (up to 4 mm) and persistent, cracking apart and sloughing off in plates as does the exoperidium. Gleba whitish and solid at first, becoming olive-brown (4D7) to light brown (6D7), pulverulent and often breaking apart in clumps. Subgleba absent or confined to the area of the rhizomorph, comprising only the lower portions of the gasterocarp, reduced or absent.

Basidiospores subglobose to ovoid, (4.0) 4.8-5.6 X (3.2) 4.0-4.8 μm [x = 5.0 ± 0.4 X 4.4 ± 0.5 μm, Q_m = 1.1, n = 20], smooth, oil drop not apparent; pedicel short (up to 0.8 μm in length); sterigmal remnants mostly absent from mounts; spores yellowish in water mounts. Eucapillitium '*Calvatia*' type, 4.8-7.2 μm in diameter, thick-walled (up to 1.0 μm), glabrous, frequent dichotomous branching, straight to subundulate, abundant small-sized pores, extremely fragile, septate, often breaking at septum, yellowish in water mounts. Paracapillitium absent. Exoperidium composed of thick-walled collapsed hyphal elements. Endoperidium composed tightly interwoven hyphal elements and inflated hyphae resembling sphaerocysts.

Habitat: Terrestrial and found in open areas, meadows or at the forest's edge. This species occurs in the mid to higher elevations of the state within the Great Basin conifer woodland and Madrean evergreen woodland biotic communities.

Distribution: Known only from the western United States, and previously reported from Arizona, southern California, Colorado, Oregon and Utah (see fig. 37 for Arizona distribution). Also reported from Iran and Nepal.

Material examined: ARIZONA, Coconino Co.: Garland prairie, in open places, 28 September 1992, J.S. States (MICH AEF1322). Santa Cruz Co.: Canelo Hills, on ground, 01 February 1976, collector unknown (ARIZ AN014692).

Calvatia pachyderma is a very distinct medium to large size puffball found in Arizona. The glabrous exoperidium, thick endoperidium, smooth spores and manner of dehiscence distinguish this species from all others. More robust specimens of *C. craniiformis* could possibly be confused with *C. pachyderma*; however, the peridia in that species are much more thin and fragile. This species was previously reported from Arizona by Morgan (1890).

34. ***Calvatia rugosa*** (Berk. & M.A. Curt.) D.A. Reid, Kew Bulletin 31: 671 (1976).

(figs. 64b, 85b & 100f)

Basionym

Lycoperdon rugosum Berk. and M.A. Curtis, J. Linn. Soc., Bot. 10: 345 (1869).

Reported synonyms

= *Lycoperdon rubro-flavum* Cragin, Bull. Washburn Coll. Lab. Nat. Hist. 1: 36 (1885).

= *Calvatia rubroflava* (Cragin) Morgan., J. Cincinnati Soc. Nat. Hist. 12: 171 (1890).

= *Calvatia aurea* Lloyd, Mycol. Writings 1: 11 (1899).

= *Calvatia candida* var. *rubroflava* (Cragin) Cunningham, Proc. Linn. Soc. New South Wales 51: 368 (1926).

= *Bovista cisneroi* Speg., Hong. S.-Amer., Dec. Mycol. Argent. 4:100 (1881).

= *Bovista antarctica* Speg., Fungi Patagonici: 24 (1887).

Type: The holotype from Cuba is housed at the Royal Botanic Garden (K) under the original determination of *Lycoperdon rugosum* (Demoulin 1972a).

Selected illustrations: Coker & Couch (1928: pls. 33 & 34); Zeller & Smith (1964: pl. XIII).

Gasterocarp 20-60 (100) mm in diameter x 15-50 mm in height, subglobose, depressed globose to turbinate, sharply tapering to a pointed base with one or more rhizomorphs, encrusted with particles of soil; ostiole lacking, peridia breaking apart to expose the gleba. Exoperidium whitish at first or with a pinkish tinge and bruising yellow, becoming grayish orange (6B6) to orange (5A6-6A6) with age, glabrous to minutely floccose, thin and papery, breaking up into small-sized irregular-shaped, flaky patches which soon slough off of the upper portions of the gasterocarp. Endoperidium grayish orange (6B6), felted, thin and fragile, breaking up and sloughing off as does the exoperidium. Gleba whitish and solid at first, becoming brownish yellow (5C7), cottony,

rather firm and persisting for a long time after the peridial layers shed; pieces of the peridia often remain attached in random patches. Subgleba brownish yellow (5C7), composed of compact cells, or reduced to absent, comprising the lower 1/2 of the gasterocarp, reduced or nearly absent.

Basidiospores globose to subglobose, 4.0-4.8 X (3.2) 4.0-4.8 µm [x = 4.5 ± 0.4 X 4.3 ± 0.5 µm, Q_m = 1.1, n = 20], echinate, oil drop not apparent; pedicel short (up to 1.6 µm in length); sterigmal remnants mostly absent from mounts; spores nearly hyaline in water mounts, in KOH yellowish color pigments become soluble. Eucapillitium '*Calvatia*' type, 3.2-4.8 µm in diameter, thick-walled (up to 1.0 µm), glabrous, sparsely branched (dichotomous when occurring), straight to subundulate, abundant medium- to large-sized pores, extremely fragile, septate, slightly inflated at septum, nearly hyaline in water mounts. Paracapillitium absent. Exoperidium composed of thick-walled, inflated, elongated, irregular-shaped sphaerocysts, septate and branched. Endoperidium composed of thick-walled collapsed hyphal elements.

Habitat: Terrestrial and found in open areas, meadow or growing amid leafy debris under oak (*Quercus* spp.). This species occurs in the mid to higher elevations of the state within the Great Basin conifer woodland, Madrean evergreen woodland, and semidesert grassland biotic communities.

Distribution: Common in many parts of the United States, and previously reported from Iowa, Maryland, Ohio, Tennessee and Texas (see fig. 38 for Arizona distribution).

Also reported from Australia, Caribbean, Central America, China, Europe, Japan and South America.

Material examined: ARIZONA, Pima Co.: Above Sabino Canyon Dam, Santa Catalina Mts., Coronado Nat. Forest, on the ground, 07 September 1972, R. Halse (ARIZ AN014555). Santa Cruz Co.: Nature Conservancy Reserve, Patagonia, Sonoita Creek, on ground, 02 October 1970, R.L. Gilbertson (ARIZ AN014553); N.C.R. Patagonia, 15 October 1970, R.L. Gilbertson (ARIZ AN014651); Patagonia, on soil, 15 October 1970, D.C. Rhodes (ARIZ AN014554); Patagonia Highway, Sonoita Creek, on soil, 15 October 1970, E.R. Canfield (ARIZ AN014644).

Among the small- to medium-sized puffballs found in Arizona, this is the only species exhibiting yellow staining in fresh material and an orange coloration with age. These features distinguish *C. rugosa* in the field, and herbarium material can be differentiated by the orangish coloration that develops with age. Brownish specimens could be confused with *C. craniiformis*; however, that species has spores that are less ornamented and exoperidial tissue with a different composition. In addition, the capillitia and spores of *C. craniiformis* are brownish yellow in water mounts rather than +/- hyaline as is the case for *C. rugosa*. The name, *Calvatia rubro-flava* was commonly used in the U.S. and is perhaps more descriptive. However, Kreisel (1992) notes that *C. rugosa* has priority. This species is reported for the first time from Arizona here.

Disciseda Czern., Bulletin de la Société Imperiale des Naturalistes de Moscou 18: 153 (1845).

Type species: *Disciseda collabescens* Czern., Bull. Soc. Imp. Naturalistes Moscou 18: 153 (1845, as '*collabascens*').

35. ***Disciseda arida*** Velen., Novitates Mycologicae: 169 (1939).

(figs. 64c, 86a, 101a & 105b)

Type: The holotype is housed in the Mycological Collection of the National Museum in Prague (PRM 154108, X. 1934) and the type locality is given as "Střední Čechy – Stáncice (Pilát 1958)".

Selected illustrations: Moravec in Pilát (1958: fig. 124a).

Gasterocarp 8-20 mm in diameter x 9-17 mm in height, globose, subglobose, depressed globose to discoid, basal portions (once apical, see comments under *Disciseda*, pg. 29) covered by remnants of the exoperidium, which forms a thick mycelial pad, medium- to large-sized, heavily encrusted with vegetable matter and particles of sand or soil; ostiole formed as the gasterocarp detaches from the basal mycelial cord, rising to the apex once the gasterocarp rolls over, small- to medium-sized, often slightly upturned at the rim. Exoperidium color difficult to discern as the exoperidium is heavily encrusted,

mycelial mat whitish to grayish orange (5B3-4), roughened by encrusted debris, splitting apart tranversely, basal portions remaining in the ground, apical portions remaining attached to the gasterocarp to form the mycelial pad, later appearing to be the basal portions once the gasterocarp has rolled over. Endoperidium whitish, "Pale Mouse Gray", "Pale Mouse Gray", glabrous, minutely floccose to minutely verruculose, occasionally rimulose, coriaceous, persistent. Gleba brownish orange (6C4-5) to light brown (6D4-6), cottony at first, soon becoming pulverulent. Subgleba absent.

Basidiospores globose, (8.0) 8.8-12.0 (12.8) X (8.0) 8.8-12.0 (12.8) μm [x = 10.4 ± 1.4 X 10.4 ± 1.4 μm, Q_m = 1.0, n = 20], strongly verrucose, verrucae up to 1.6 μm in length, oil drop difficult to discern; pedicel short (up to 0.8 μm in length), often difficult to discern amid the verrucae; sterigmal remnants mostly absent from mounts; spores yellowish brown in water mounts. Eucapillitium '*Calvatia*' type, 2.4-5.6 μm in diameter, thick-walled (up to 0.8 μm), glabrous, occasionally finely encrusted, occasional dichotomous branching, straight to undulate, rounded tips, occasional small- to medium-sized pores, extremely fragile, septate, often breaking at septum, pale brown in water mounts. Paracapillitium absent. Exoperidium composed of hyphal elements interwoven with particles of vegetable matter or particles of sand or soil. Endoperidium composed of thick and thin-walled hyphal elements.

Habitat: Terrestrial and found in open areas, often in sandy or granitic soils, or growing amid the leafy debris under foothills palo verde (*Cercidium microphyllum*) juniper (*Juniperus* spp.), mesquite (*Prosopis* spp.) or pinyon (*Pinus edulis*). This species

occurs in the lower elevations of the state within the Arizona Upland and Lower Colorado River Valley subdivisions of the Sonoran desertscrub biotic communities.

Distribution: Not reported previously from the United States (see fig. 39 for Arizona distribution). Reported from Europe.

Material examined: ARIZONA, Coconino Co.: Navajo Mountain, 18 May 1983, J.S. States (MICH AEF828). Maricopa Co.: On flood planes leading down to Sycamore Creek, ~ 5 mi in FR 402 off of Hwy. 87; near Sugar Loaf Mountain, 15 August 2002, S.T. Bates (STB00085); Estrella Mountain Park near Goodyear, 20 January 2003, S.T. Bates (STB00120). Pima Co.: In desert 10 mi north of Three Points, Altar Valley, 19 April 1973, R.L. Gilbertson (ARIZ RLG10955).

Disciseda arida is very similar other *Disciseda* species with apedicellate spores; however, they can be sorted out fairly easily using microscopic combined with macroscopic characters. Species with strongly verrucose spores that are 8.8-12.0 μm in diameter with a grayish endoperidium are *D. arida*, while those with a brownish endoperidium are *D. muelleri* (not reported from Arizona). Species with verrucose spores that are under 9.0 μm in diameter that have a grayish endoperidium are *D. bovista*, and those that have a brownish endoperidium are *D. verrucosa*. Both of these species have not been reported as occuring in Arizona. *Disciseda arida* is reported for the first time from Arizona here.

36. ***Disciseda candida*** (Schwein.) Lloyd, Mycological Notes 1: 100 (1902).

(figs. 64d, 86b, 101b & 105c)

Basionym

Bovista candida Schwein., Syn. Fung. Car.: 126 (1822).

Reported synonyms

= *Bovista circumscissa* Berk. & M.A. Curtis, Grevillea 2: 50 (1873).

= *Catasoma circumscissa* (Berk. & M.A. Curtis) Morgan, J. Cincinnati Soc. Nat. Hist. 14: 143 (1892).

= *Disciseda circumscissa* (Berk. & M.A. Curtis) Hollós, Termes. Fuz. 25: 126 (1901).

Type: A type of *Bovista candida* Schwein. that had been housed at the Academy of Natural Sciences (PH) has apparently been misplaced. Kreisel (1967b) mentions an isotype of *B. candida* that is housed in the herbarium of the University of North Carolina (NCU) and cites "Carolina, U.S.A." as the type locality.

Selected illustrations: Bottomley (1948: pl. 64, figs. 1 & 2); Calonge (1992: fig. 20f); Smith (1951: pl. 21, fig. 1).

Gasterocarp 10-25 mm in diameter x 4-15 mm in height, globose, subglobose to depressed globose, basal portions (once apical, see comments under *Disciseda*, pg. 29) covered by remnants of the exoperidium, which forms a thick mycelial pad, large-sized, heavily encrusted with vegetable matter and particles of sand or soil; ostiole formed as

the gasterocarp detaches from the basal mycelial cord, rising to the apex once the gasterocarp rolls over, small- to medium-sized, orbicular to irregular-shaped and torn, fimbriate. Exoperidium color difficult to discern as the exoperidium is heavily encrusted, mycelial mat whitish to grayish orange (5B3-4), roughened by encrusted debris, splitting apart tranversely, basal portions remaining in the ground, apical portions remaining attached to the gasterocarp to form the mycelial pad, later appearing to be the basal portions once the gasterocarp has rolled over. Endoperidium whitish, "Pale Mouse Gray", "Pale Smoke Gray", apical portions glabrous, or occasionally rimulose, basal portions with prominent ridges, felted to flocculent, forming a reticulate pattern, which remains after the translucent watery layer becomes desiccated, coriaceous, persistent. Gleba light brown (6D4-5) to brown (6E5-6), cottony at first, soon becoming pulverulent. Subgleba absent.

Basidiospores globose, 4.0-5.6 (6.4) X 4.0-5.6 (6.4) µm [x = 5.0 ± 0.6 X 5.0 ± 0.6 µm, Q_m = 1.0, n = 20], asperate to verruculose, central oil drop; pedicel short (up to 0.8 µm in length), or absent; sterigmal remnants mostly absent from mounts; spores yellowish brown in water mounts. Eucapillitium '*Calvatia*' type, 4.0-10.4 µm in diameter, thick-walled (up to 1.0 µm), glabrous, occasionally finely encrusted, occasional dichotomous branching, straight to undulate, rounded tips, pores small- to medium-sized, extremely fragile, septate, often breaking at septum, pale brown in water mounts. Paracapillitium occasionally present, but not abundant. Exoperidium composed of hyphal elements interwoven with particles of vegetable matter or particles of sand or soil. Endoperidium composed of thick and thin-walled hyphal elements.

Habitat: Terrestrial and found in grassy areas or growing amid leafy debris under mesquite (*Prosopis* spp.), oak (*Quercus* spp.) or Ponderosa pine (*Pinus ponderosa*). This species occurs in the higher elevations of the state within the Great Basin conifer woodland and Petran montane conifer forest biotic communities.

Distribution: Know from many parts of the United States, and previously reported from Nebraska, New Jersey, North Carolina, Ohio, South Carolina and Virginia (see fig. 40 for Arizona distribution). Also reported from Australia, New Zealand, South Africa and South America.

Material examined: ARIZONA, Coconino Co.: Hochderffer Hill on FR 151 of off Hwy 180, near Flagstaff, 17 May 2003, S.T. Bates (STB00343). Gila Co.: S of Payson on Hwy. 87 (eastside), 21 February 2003, S.T. Bates (STB00186). Santa Cruz Co.: Near Canelo, Coronado Nat. Forest, 24 March 2003, S.T. Bates (STB00303); Near Canelo, Coronado Nat. Forest, 24 March 2003, S.T. Bates (STB00304).

Disciseda candida is easily distinguished macroscopically by the 'spongy layer' which forms a reticulate pattern at the 'base' of the gasterocarp. This character is noticable in previous illustrations with careful observation (see Bottomley 1948, Coker & Couch 1928, Smith 1951). All other *Disciseda* species lack the spongy layer. Microscopically this species has asperate to verrucose spores that are 4.0-5.6 (6.4) µm in diameter and typical '*Calvatia*' type capillitium. *Disciseda candida* is reported for the first time from Arizona here.

37. ***Disciseda cervina*** (Berk.) Hollós, Hedwigia 42: 22 (1903). (figs. 65a, 87a & 101c)

Basionym

Bovista cervina Berk., Ann. Nat. Hist. 9: 447 (1944).

Reported synonyms

= *Catastoma magnum* Lloyd, Mycol. Writings 5: 631 (1917).

Type: Kreisel (1967b) states that an isotype of *Bovista cervina* Berk. from Rio Negro, Argentina is housed at the Muséum National d'Histoire Naturelle, France (PC). The holotype possibly exists among the Berkeley collections at the Royal Botanic Garden (K).

Gasterocarp 10-18 mm in diameter x 10-14 mm in height, globose, subglobose to depressed globose, basal portions (once apical, see comments under *Disciseda*, pg. 29) covered by remnants of the exoperidium, which forms a thick mycelial pad, small- to medium-sized, covering only the basal most portions of the gasterocarp, heavily encrusted with vegetable; ostiole formed as the gasterocarp detaches from the basal mycelial cord, rising to the apex once the gasterocarp rolls over, small- to medium-sized, orbicular to irregular-shaped and torn, fimbriate. Exoperidium color difficult to discern as the exoperidium is heavily encrusted, mycelial mat whitish to grayish orange (5B3-4), roughened by encrusted debris, splitting apart tranversely, basal portions remaining in the ground, apical portions remaining attached to the gasterocarp to form the mycelial pad, later appearing to be the basal portions once the gasterocarp has rolled over. Endoperidium whitish, "Pale Smoke Gray", "Light Violet-Plumbeous", orange-gray (5B2

to 6B2), grayish orange (5B3), brownish orange (5C3-4) brownish gray (6C2), glabrous to minutely floccose, occasionally rimulose, coriaceous, persistent. Gleba brownish orange (5C4-5) to yellowish brown (5D5-6) to light brown (6D4-5), cottony at first, soon becoming pulverulent. Subgleba absent.

Basidiospores globose to subglobose, 4.0-5.6 X 4.0-5.6 µm [x = 4.7 ± 0.7 X 4.7 ± 0.7 µm, Q_m = 1.0, n = 20], smooth to asperulate, central oil drop; pedicel short (up to 0.8 µm in length); sterigmal remnants mostly absent from mounts; spores yellowish brown in water mounts. Eucapillitium '*Calvatia*' type, 4.0-5.6 µm in diameter, thick-walled (up to 0.8 µm), glabrous, occasionally finely encrusted, occasional dichotomous branching, straight to undulate, rounded tips, occasional small-sized pores, extremely fragile, septate, often breaking at septum, pale brown in water mounts. Paracapillitium absent. Exoperidium composed of hyphal elements interwoven with particles of vegetable matter or particles of sand or soil. Endoperidium composed of thick and thin-walled hyphal elements.

Habitat: Terrestrial and found in soil or growing amid needle debris under juniper (*Juniperus* spp.) or pinyon (*Pinus edulis*). This species occurs in the higher elevations of the state within the Great Basin conifer woodland biotic community.

Distribution: Reported previously from North America (see fig. 41 for Arizona distribution). Also reported from Australia, Europe, New Zealand and South Africa.

Material examined: ARIZONA, Coconino Co.: Navajo Mountain, site 56C, 22 October 1972, J.S. States (AEF1355b). Mohave Co.: Near the N Rim of the Grand Canyon; Parashant Nat. Monument, 21 May 2003, S.T. Bates (STB00484).

This species is similar to other small *Disciseda* species with gray endoperidia. *Disciseda candida* can easily be distinguished macroscopically as it exhibits a reticulate 'spongy layer' at the 'base' of the gasterocarp. Specimens with a grayish endoperidium smooth to asperate spores that lack pedicels are *D. anomola* if the gasterocarp exhibits a tubular ostiole, or are *D. cervina* if the ostiole is fimbriate. *Disciseda cervina* often has a purplish tint to the endoperidium. This species is reported for the first time from Arizona here.

38. ***Disciseda pedicellata*** (Morgan) Hollós, Termeszetrajzi Fuzetek 25: 103 (1902).

(figs. 65b, 87b & 101d)

Basionym

Catastoma pedicellata Morgan, J. Cincinnati Soc. Nat. Hist. 14: 143 (1892).

Type: According to Coker and Couch (1928), Morgan's concept of *D. pedicellata* is based on material from Ravenel labeled "*Bovista nigrescens*, No. 15" from South Carolina, which is housed at the Academy of Natural Sciences (PH).

Selected illustrations: Bottomley (1948: pl. 64, fig. 3); Coker & Couch (1928: pl. 80 "center"); Cunningham (1943: pl. 18, fig. 4).

Gasterocarp 10-34 mm in diameter x 7-20 mm in height, subglobose, depressed globose to discoid, basal portions (once apical, see comments under *Disciseda*, pg. 29) covered by remnants of the exoperidium, which forms a thick mycelial pad, medium- to large-sized, heavily encrusted with vegetable matter and particles of sand or soil; ostiole formed as the gasterocarp detaches from the basal mycelial cord, rising to the apex once the gasterocarp rolls over, small- to medium-sized, orbicular to irregular-shaped and torn, fimbriate. Exoperidium color difficult to discern as the exoperidium is heavily encrusted, mycelial mat whitish to grayish orange (5B3-4), roughened by encrusted debris, splitting apart tranversely, basal portions remaining in the ground, apical portions remaining attached to the gasterocarp to form the mycelial pad, later appearing to be the basal portions once the gasterocarp has rolled over. Endoperidium brownish gray (5C2), grayish brown (6D3 to 6E3), brown (6E4) to dark brown (6F4-8), glabrous to minutely floccose, occasionally partially covered with small, flaky patches lightly encrusted with particles of soil, subcoriaceous, persistent. Gleba yellowish brown (5E4-6), brown (6E4-5) to grayish brown (6E3), cottony at first, soon becoming pulverulent. Subgleba absent.

Basidiospores globose, (6.4) 8.0-10.4 X (6.4) 8.0-10.4 µm [x = 8.6 ± 1.1 X 8.6 ± 1.1 µm, Q_m = 1.0, n = 20], strongly verrucose, verrucae up to 1.6 µm in length, oil drop difficult to discern; pedicel long (5.6-16.8 µm in length); sterigmal remnants mostly absent from mounts; spores yellowish brown in water mounts. Eucapillitium '*Calvatia*' type, 2.4-4.8 µm in diameter, thick-walled (up to 0.8 µm), glabrous, occasionally finely encrusted, occasional dichotomous branching, straight to undulate, rounded tips, occasional small- to medium-sized pores, extremely fragile, septate, often breaking at septum, pale brown in water mounts. Paracapillitium absent. Exoperidium composed of

hyphal elements interwoven with particles of vegetable matter or particles of sand or soil. Endoperidium composed of thick and thin-walled hyphal elements.

Habitat: Terrestrial and found on cultivated grass lawns in urban areas. This species occurs in the lower elevations of the state within the Arizona Upland subdivision of the Sonoran desertscrub biotic community.

Distribution: Known from the southern United States, and previously reported from Alabama and South Carolina (see fig. 42 for Arizona distribution). Also reported from Australia, Europe and South Africa.

Material examined: ARIZONA, Coconino Co.: Tucson, 17 March 1971, R.L. Gilbertson (MICH AN014562).

The brownish, subcoriaceous endoperidium with fimbriate ostiole are characteristic of *D. pedicellata*. Microscopically the large spores (8.0-10.4 μm in diam.) and long pedicel (5.6-16.8 μm in length) readily distinguish this species. *Disciseda juglandiformis*, *D. castanea* and *D. hylothrix* are other species having spores with a long pedicel; however, none of these species has been reported from the United States. Known from South Africa, *D. juglandiformis* has coarsely verruculose spores with very long pedicels (60-70 μm in length), and a dark brown peridium. *Disciseda castanea*, also described from South Africa, has smooth spores with long pedicels and a blackish endoperidium. Described from Australia, *D. hyalothrix* has strongly verrucose, larger

spores (10.0-13.0 µm in diam.) and a umber to purplish endoperidium. All other *Disciseda* species know from Arizona and other parts of the the world have apedicellate spores. The genus *Disciseda*, as a whole, is in need of taxonomic revision due to variation in published description, the possibility of hybridization with the group (Calonge 1998), and the fact that sufficient material has not been collected for some species. *Disciseda pedicellata* is reported for the first time from Arizona here.

Holocotylon Lloyd, Mycological Notes 2: 254 (1906).

Type species: *Holocotylon brandegeeanum* Lloyd, Mycol. Writings 2: 254 (1906).

39. ***Holocotylon brandegeeanum*** Lloyd, Mycological Notes 2: 254 (1906).

(figs. 65c, 88a, 94e & 101e-f)

Reported synonyms

= *Holocotylon mexicanum* Lloyd, Mycol. Writings 2: 1-2 (1907).

Type: The holotype is located at the U.S. National Fungus Collection (BPI 711757!) and is labeled "*Holocotylon brandegeeanum*, Culican, Mexico, T.S. Brandegee, Type, det. C.G. Lloyd, Cat. No. 22748". Another collection (BPI 711757!) is labeled "*Holocotylon mexicanum*"; however, the three partially disintegrated gasterocarps are merely *H. brandegeeanum* specimens which have lost their peridia. A specimen has not

been selected to typify the genus. Considering that *H. brandegeeanum* is the first species to appear in Lloyd's (1906) original description of the genus, this species would serve well to lectotypify the genus. The holotype, mentioned above, is also one of the best preserved specimens among Lloyd's *Holocotylon* specimens housed in the U.S. National Fungus Collection.

Selected illustrations: Lloyd (1906: pl. 74, figs.5-7).

Gasterocarp 5-15 mm in diameter x 4-21 mm in height, globose, subglobose, depressed globose to broadly obpyriform, plicate at base, attached by a short, thin, white, branching rhizomorph, encrusted with particles of soil; ostiole lacking, peridia tearing open or breaking apart into many pieces, exposing the gleba. Exoperidium whitish, yellowish white (3A2), yellowish gray (3B2) to dull yellow (3B3-4), glabrous to rugulose; thin and fragile, composed of tighly appressed flocculence, which tightly adheres to the endoperidium, exoperidium persistent, only occasionally wearing away with age to reveal the endoperidium, more common in the basal portions of the gasterocarp. Endoperidium yellowish gray (4B2) to grayish yellow (4B3-4), felted, thin and fragile, breaking up into many pieces as does the exoperidium. Gleba grayish yellow (4B3-4 to 4C4-6) to olive-brown (4D5-6), composed of labyrinthiform, sinuous tramal plates, forming numerous locules, the interior being a hymenial surface, densely covered with spores and an exterior composed of grayish, membranaceous hyphal tissue, comprising the tramal plates. Subgleba whitish to yellowish white (3A2), cellular

composed of small- to medium-sized cells, normally reduced or absent, comprising only the lowest portions of the gasterocarp.

Basidiospores subglobose to ovoid, 4.0-5.6 X 4.0-4.8 μm [x = 5.0 ± 0.6 X 4.5 ± 0.4 μm, Q_m = 1.1, n = 20], smooth to minutely asperulate, central oil drop; pedicel (0.8-8.0 μm in length, occasionally longer, up to 16.0 μm); sterigmal remnants mostly absent from mounts; spores yellowish in water mounts. Eucapillitium absent. Paracapillitium absent. Exoperidium composed of thin-walled hyphal elements. Endoperidium composed of thin-walled hyphal elements.

Habitat: Terrestrial and found in grassy areas, pastures or rocky areas growing in the grass among the rocks. This species occurs in the lower to higher elevations of the state within the Arizona Upland subdivision of the Sonoran desertscrub, Madrean evergreen woodland, Petran montane conifer forest, Petran subalpine conifer forest, and semidesert grassland biotic communities.

Distribution: Know only from the southwestern United States (see fig. 43 for Arizona distribution). Also reported from Mexico.

Material examined: ARIZONA, Apache Co.: Hawley Lake; White Mountain Apache reservation, near McNary, 11 August 2002, L. Theriot (STB00111); ~35 ft. in on the N side of road leading to corral, off of FR 116, ~1 mi in from Hwy. 273, Big Lake area, 16 August 2002, S.T. Bates (STB00089); ~50 ft. N of parking lot (parallel to road) to trailhead of Tr. 627 off of FR 249E, Big Lake area, 16 August 2002, S.T. Bates

(STB00090). Greenlee Co.: Hennigan's meadow exact location unknown, 17 August 2002, S.T. Bates (STB00110). Pima Co.: Near C.T. Mason residence, Tucson, 26 August 1988 (ARIZ RLG16358). Pinal Co.: Oracle, 10 September 1917, W.H. Long (BPI WHL8915). MEXICO: Culican, T.S. Brandegee (BPI 711757, Type); Tacaupan, T.S. Brandegee (BPI 711758, Type of *H. mexicanum*).

Holocotylon brandegeeanum is a lesser known puffball first described by C.G. Lloyd in 1906, which can be encountered in grassy areas in the Southwest. This species is small, rather fragile, and has a whitish endoperidium. The gleba is quite distinct having labyrinthiform, sinuous tramal plates, which form numerous locules (fig. 94e). In this aspect it is reminiscent of the gleba of a *Lycoperdon* species early in its ontogeny. Microscopically, *H. brandegeeanum* lacks eucapillitia and has subglobose to ovoid, nearly smooth spores, often having attached pedicels of varying lengths. Superficially, this species strongly resembles *Arachnion album* (not reported from Arizona); however, that species is unmistakable with its numerous small peridioles which comprise the gleba (fig. 94d). *Holocotylon brandegeeanum* might also be mistaken for *Bovista aestivalis* or *B. dermoxantha*; however, those species exhibit capillitium that impart a 'cottony' appearance to the gleba. *Holocotylon brandegeeanum* is reported for the first time from Arizona here.

Lycoperdon Pers.: Pers., Synopsis Methodica Fungorum 1: 140 (1801).

Type species: *Lycoperdon perlatum* Pers.: Pers. Syn. Meth. Fung.: 145 (1801) .

40. ***Lycoperdon lividum*** Pers., Journal de Botanique 2: 18 (1809).

(figs. 65d, 88b & 102a)

Reported synonyms

= *Lycoperdon spadiceum* Pers., J. Bot. (Desvaux) 2: 20 (1809), non *L. spadiceum* (Schaeff.: Pers.) Poiret (1808).

Type: According to Demoulin (1973a), Poiret's 1808 combination of *Scleroderma spadiceum* Schaff.: Pers. under *Lycoperdon spadiceum* (Schaeff.: Pers.) Poiret makes *Lycoperdon spadiceum* Pers. a later homonym. Therefore, *Lycoperdon lividum* Pers. should be used for this species in favor of *L. spadiceum* Pers. even though that name had been commonly used in Europe. Modern authors (Pegler et al. 1995, Calonge 1998) appear to agree with this position. After mentioning that original material from Persoon of *L. lividum* does not exist, Demoulin (1970) states that this species "est identique à *L. spadiceum*." Demoulin goes on to declare that *L. spadiceum* Pers. is typified by Persoon's published description and illustration (1809, J. Bot. [Desvaux] 2: 20, tab. I, fig. 5). This would suggest that *L. lividum* Pers. is also typified by Persoon's description and illustration of this species in the same publication (2: 18, tab. I, fig. 4); however, it is not clear whether a proposal for lectotypification has been put forward.

Selected illustrations: Pegler, Læssøe & Spooner (1995: figs. 121-122).

Gasterocarp 10-45 mm in diameter x 10-40 mm in height, globose, subglobose, depressed globose to obpyriform, occasionally plicate at base, attached by thick, branching rhizomorph, heavily encrusted with particles of soil; ostiole slow to develop, small- to medium-sized, orbicular, irregular-shaped to torn. Exoperidium whitish at first, becoming light yellow (4A4-5), grayish yellow (4A3-5), grayish orange (5B3-5) to brownish orange (5C5-6), occasionally with orangish brown patches or patchy water stains, glabrous, to granulose; composed of tightly appressed flocculence, minute echinae, or appressed granular verrucae, sloughing off slowly, exposing more of the endoperidium and becoming more glabrous with age and weathering. Endoperidium pale yellow (4A3) to yellowish gray (4B2), glabrous, papery and dull, persistent. Gleba grayish yellow (4B4-6) to olive-brown (4D5-7), cottony. Subgleba yellowish gray (4B2) to grayish yellow (4B3-5), cellular, composed of medium-sized cells, or reduced, comprising the lower 1/4 to 1/3 of gasterocarp, or reduced.

Basidiospores globose to subglobose, (3.2) 4.0-4.8 X (3.2) 4.0-4.8 μm [x = 4.4 ± 0.5 X 4.4 ± 0.5 μm, Q_m = 1.0, n = 20], asperulate, central oil drop; pedicel minute; sterigmal remnants absent from mounts; spores yellowish to brownish yellow in water mounts. Eucapillitium '*Lycoperdon*' type , 4.0-7.2 μm In diameter, thick-walled (up to 0.8 μm), glabrous, numerous dichotomous branches, straight to undulate, tips attenuate, long and narrow, often subundulate, abundant medium- to large-sized pores, subelastic, aseptate, yellowish to brownish yellow in water mounts. Paracapillitium occasionally

present and septate, but not abundant. Exoperidium composed of thick-walled, orbicular to irregular-shaped sphaerocysts, intermixed with hyphal elements. Endoperidium composed of tightly interwoven hyphal elements.

Habitat: Terrestrial and found in grassy areas. This species occurs in the mid to higher elevations of the state within the Petran montane conifer forest and semidesert biotic communities.

Distribution: Known only from the western United States, previously reported from California, Colorado and Idaho (see fig. 44 for Arizona distribution). Also reported from Australia, Europe, Great Britain and New Zealand.

Material examined: ARIZONA, Coconino Co.: Near V.T. Ranch, Kaibab Nat. Forest, 22 October 1933, W.H. Long (BPI WHL7871). Gila Co.: Tonto Nat. Forest, near Young, 01 October 1934, N.F. Noecker & L.W. Roberson (BPI WHL7964).

Lycoperdon lividium and *L. rimulatum* are two *Lycoperdon* species found in Arizona with a nearly glabrous exoperidia, which often develop water stains. The two species are very difficult to distinguish macroscopically; however, microscopically these species are easily distinguishable. *Lycoperdon lividum* has asperulate spores, while *L. rimulatum* has strongly verrucose spores that are larger (6.4-8.0 μm in diam.) than those found in *L. lividum* (4.0-4.8 μm in diam.). All other *Lycoperdon* species found in the state have ornamented exoperidia and should not be confused with these species. It is

unlikely that *L. lividum* would be confused with a *Calvatia* as those species have a very different mechanism of spore dispersial and thus have exoperidia that crack apart or disintegrate to some degree. Microscopically, *Calvatia* species are also easily distinguished as they have fragile eucapillitia, which break into many smaller units, rather than the subelastic eucapillitia that are found in *L. lividum*, which only occasionally break into smaller units. *Lycoperdon lividum* is reported for the first time from Arizona here.

41. ***Lycoperdon marginatum*** Vittad., Monographia Lycoperdineorum: 41 (1842).

(figs. 66a, 89a & 102b)

Reported synonyms

= *Lycoperdon cruciatum* Rostk., Deutschl. Fl. (Sturm), Abt. 3, Pilze Deutschl.: 19 (1839).

= *Lycoperdon muricatum* Bonord., Bot. Zeitung (Berlin) 15: 596 (1857).

= *Lycoperdon separans* Peck, Rep. State Bot. of New York State Mus. 26: 73 (1874).

= *Lycoperdon wrightii* var. *atropunctum* Peck, Rep. State Bot. of New York State Mus. 32: 67 (1879).

= *Lycoperdon wrightii* var. *separans* Peck, Rep. State Bot. of New York State Mus. 32: 67 (1879).

= *Vascellum cruciatum* (Rostk.) De León Fieldiana, Bot. 82: 118 (1970).

Type: The type locality for this species from Italy is as Vittadini (1842) states, "In locis sterilibus sabulosis circa Papiam et Mediolanum frequens", and it is possible that

type material exist among the Vittadinian collection at the Royal Botanic Garden, Kew (K).

Selected illustrations: Calonge (1992: fig. 40); Coker & Couch (1928: pls. 55-56); Smarda in Pilát (1958: figs. 79 & 99, as *L. candidum*); Smith (1951: pl. 11, figs. 1-2).

Gasterocarp 10-45 (65) mm in diameter x 10-35 (55) mm in height, obovoid, depressed globose to obpyriform, occasionally plicate at base, particularly on larger specimens; attached by fine, branching rhizomorphs, heavily encrusted with particles of soil; ostiole developing with the sloughing of the exoperidium, medium to very large, slit-like, irregular-shaped and torn. Exoperidium whitish at first, remaining whitish or becoming yellowish white (4A2), pale yellow (4A3) to grayish yellow (4B3-4) to grayish orange (5B3-5) with age, strongly verrucose; verrucae medium length (up to 2.0 mm), broad, pyramidal, often darker, fused and/or recurved at tips, or occasionally somewhat appressed, sloughing off the apical portions of the gasterocarp in plates. Endoperidium yellowish white (4A2) to pale orange (5A3), appearing darker due to covering of pigmented sphaerocysts, brownish orange (5C3-4) to light brown (5D4-5), covered in a granular layer of pigmented sphaerocysts, papery and dull, persistent. Gleba grayish orange (5B3-4) to yellowish brown (5D4-6), cottony. Subgleba yellowish gray (4B2) to grayish orange (5B3), cellular, composed of medium-sized cells, or reduced to absent, comprising the lower 1/3 of gasterocarp, reduced or nearly absent.

Basidiospores globose, (3.2) 4.0-4.8 (5.6) X (3.2) 4.0-4.8 (5.6) µm [x = 4.4 ± 0.6 X 4.4 ± 0.6 X µm, Q_m = 1.0, n = 20], smooth to asperulate, central oil drop; pedicel short

(up to 0.8 μm in length), or occasionally longer (up to 1.6 μm in length); sterigmal remnants mostly absent from mounts; spores pale yellowish brown in water mounts. Eucapillitium '*Lycoperdon*' type, 3.2-5.6 μm in diameter, thick-walled (up to 0.8 μm), glabrous, occasionally finely encrusted, occasional dichotomous branching, straight to subundulate, tips attenuate, abundant small- to medium-sized pores, subelastic to elastic, aseptate, yellowish brown in water mounts. Paracapillitium occasionally present and septate, but not abundant. Exoperidium composed of thick-walled, orbicular to irregular-shaped sphaerocysts. Endoperidium composed of tightly interwoven hyphal elements covered in pigmented, orbicular to irregular-shaped sphaerocysts.

Habitat: Terrestrial and found in open areas on granitic soils, in grassy area or growing amid needle debris under Ponderosa pine (*Pinus ponderosa*). This species is found throughout Arizona and occurs in the mid to higher elevations of the state within the Great Basin conifer woodland, interior chaparral, Madrean evergreen woodland, Petran montane conifer forest, and semidesert grassland biotic communities.

Distribution: Known from throughout the United States, and previously reported from Alabama, Arizona, Arkansas, Colorado, Connecticut, Florida, Georgia, Illinois, Indiana, Iowa, Kansas, Louisiana, Maine, Maryland, Massachusetts, Michigan, Minnesota, Mississipi, Missouri, Nebraska, New Hampshire, New Jersey, New Mexico, New York, North Carolina, Ohio, Oklahoma, Pennsylvania, Rhode Island, South Carolina, South Dakota, Tennessee, Texas, Vermont, Virginia, West Virginia and Wisconsin (see fig. 45 for Arizona distribution). Also reported from Canada and Europe.

Material examined: ARIZONA, Cochise Co.: Chiricahua, 21 August 1990, J.S. States (MICH AEF670). Coconino Co.: Ft. Valley Experimental Station, 19 August 1916, W.H. Long (BPI 734384); Base of San Francisco Peaks, 07 August 1917, L.N. Goodding (BPI WHL8919); Grand Canyon, 01 August 1930, R.B. Street (BPI WHL7892a); Grand Canyon, 01 August 1930, R.B. Street (BPI WHL7893); ~1/2 mi in on FR 237, N off of Hwy. 260, near Forest Lake Campground, Mogollon Rim, 10 August 2002, S.T. Bates (STB00070); ~1/2 mi in on FR 237, N off of Hwy. 260, near Forest Lake Campground, Mogollon Rim, 10 August 2002, S.T. Bates (STB00072). Gila Co.: Tonto Nat. Forest, Young, 01 August 1934, N.F. Noecker (BPI WHL8880). Pima Co.: Bear Wallow, Santa Catalina Mts., Coronado National Forest, 15 October 1970, T. Burr (ARIZ AN014592). Yavapai Co.: Copper Basin Area, Prescott, 15 September 1933, W.H. Long (BPI WHL7790); Prescott Nat. Forest, 01 August 1934, W.H. Long, V.O. Sandberg & K.D. Butler (BPI WHL7957); Wolf Creek Area, Prescott Nat. Forest, 20 August 1934, K.D. Butler (BPI WHL7978); Wolf Creek Area, Prescott Nat. Forest, 20 August 1934, K.D. Butler (BPI WHL7982)

Lycoperdon marginatum is a very distinct species in having a relatively thick, strongly verrucose exoperidium, which sloughs off in plates to expose the endoperidium that is covered in a granular matter. A very similar species, *Vascellum intermedium*, is smaller in stature, has a glabrous endoperidium, and lacks eucapillitium but has abundant paracapillitium (see *V. intermedium* for further discussion). *Lyoperdon calvescens* (not reported from Arizona) is another similar species, which is distinguished from *L. marginatum* by the brownish, slender echinae that slough off individually and are

composed of large sphaerocysts (55.0 μm in diam.) with intracellular pigments. Finally, *L. pulcherrimum* could be confused with *L. marginatum*; however, the former has an echinate exoperidium with long, slender echinae and verrucose spores. *Lycoperdon marginatum* was previously reported from Arizona by Demoulin (1972a).

42. ***Lycoperdon molle*** Pers.: Pers., Synopsis Methodica Fungorum: 150 (1801).

(figs. 66b, 89b & 102c)

Reported synonyms

= *Lycoperdon turbinatum* Pers., J. Bot. (Desvaux) 2: 18 (1809).

= *Lycoperdon hirtum* var. *fuscescens* Pers., J. Bot. (Desvaux) 2: 20 (1809).

= *Lycoperdon cupricum* Bonord., Handb. Mykol.: 252 (1851).

= *Lycoperdon glabellum* Peck, Rep. State Bot. of New York State Mus. 31: 39 (1879).

= *Lycoperdon umbrinum* var. *pedicellatum* Velen. Ceske Houby 821: (1922).

Type: Demoulin (1970) gives a detailed explanation of the problems related to the typification of *L. molle*. For clarification he gives a brief description of his concept for the species and states, "l'espèce étant typifiée par la description de 1799 complétée par celle de 1801." Persoon's 1799 description with illustration was published in Observationes Mycologicae (2: 106, tab. VI), while the 1801 description is found in Synopsis Methodica Fungorum. Furthermore, the database for the Nationaal Herbarium Nederland (http://145.18.162.53:81/c8) cites two specimens (L 0054569 and L 0054570) as the being the "type" of *L. molle*.

Selected illustrations: Calonge (1992: fig. 41); Pegler, Læssøe & Spooner (1995: figs. 125-126); Smarda in Pilát (1958: figs. 86 & 110).

Gasterocarp 20-55 (70) mm in diameter x 25-65 (95) mm in height, subglobose, obpyriform, turbinate to pseudostipitate, often plicate, occasionally puncticulate at base, attached by fine branching rhizomorphs, or mycelial mat, encrusted with particles of soil; ostiole slow to develop, medium- to large-sized, orbicular to irregular-shaped and torn. Exoperidium whitish at first, becoming grayish yellow (4C3-5), grayish orange (5B3-4), brownish orange (5C4-6) to yellowish brown (5E5-7), scrurfy to echinulate, echinae thin, short (up to 0.5 mm in length), occasionally appressed or with scattered, longer spicules (up to 1.0 mm in length), intermixed with scurfy or granulose matter, completely covering the endoperidium, sloughing off the apical portions of the gasterocarp with weather and age. Endoperidium grayish yellow (4B4-6 to 4C3-5) to brownish orange (5C3-5), glabrous, papery and dull, persistent. Gleba olive-brown (4D3-5) to brownish orange (5C4-5), cottony. Subgleba grayish yellow (4B4-5 to 4C4-5), light brown (5D4) to yellowish brown (5D5 to 5E6), occasionally with lilac tones, cellular, composed of medium- to large-sized cells, comprising the lower 1/4 to 1/2 of gasterocarp, or reduced.

Basidiospores globose, 5.6-7.2 X 5.6-7.2 µm [x = 6.3 ± 0.7 X 6.3 ± 0.7 µm, Q_m = 1.0, n = 20], verrucose, verrucae up to 0.8 µm in length, central oil drop; pedicel short (up to 1.0 µm in length); sterigmal remnants abundant in mounts; spores yellow-brown in water mounts. Eucapillitium '*Lycoperdon*' type, 4.0-8.0 µm in diameter, thick-walled (up to 1.0 µm), glabrous, frequent dichotomous branching with occasional infated areas or knob-like projections, straight, occasionally subundulate, tips attenuate, long and

narrow, occasionally subundulate, scattered medium- to large-sized pores, elastic, aseptate, yellow-brown to light brown in water mounts. Paracapillitium scarce to absent. Exoperidium composed of orbicular sphaerocysts, apical sphaerocysts dextrinoid in Melzer's. Endoperidium composed of tightly interwoven hyphal elements, with frequent septa.

Habitat: Terrestrial and found in open areas on granitic soils, in grassy areas or growing amid needle debris under fir (*Abies* spp.) or spruce (*Picea* spp.). This species is found throughout the Arizona and occurs in the mid to higher elevations of the state within the Petran montane conifer forest, Petran subalpine conifer forest, Plains and Great Basin grassland, and semidesert grassland biotic communities.

Distribution: Known from throughout the United States, and previously reported from Alabama, California, Colorado, Connecticut, Delaware, Idaho, Illinois, Indiana, Iowa, Kansas, Maine, Massachusetts, Michigan, Minnesota, Missouri, Montana, Nebraska, New Hampshire, New Jersey, New Mexico, New York, North Carolina, Ohio, Oregon, Pennsylvania, South Dakota, Tennessee, Utah, Vermont, Virginia, Washington, West Virginia, Wisconsin and Wyoming (see fig. 46 for Arizona distribution). Also reported from Canada, Europe and Great Britain.

Material examined: ARIZONA, Cochise Co.: Rustlers Park, Chiricahua Mountains, 11 September 1988, J.S. States (MICH AEF771). Coconino Co.: Grand Canyon, 01 August 1930, R.B. Street (BPI WHL7892c); San Francisco Mountains, 06

August 1938, I. Hatfield (BPI WHL7818); San Francisco Mountains, 06 August 1938, I. Hatfield (BPI WHL7815); Paradise Road, Flagstaff, 16 August 1986, J.S. States (MICH AEF362). Gila Co.: Tonto Nat. Forest, 01 August 1934, N.F. Noecker & W.H. Long (BPI WHL8878); Tonto Nat. Forest, 01 August 1934, W.H. Long (BPI WHL8884); Tonto Nat. Forest, 01 August 1934, N.F. Noecker & L.W. Roberson (BPI WHL8000). Pima Co.: Mt. Bigelow, Santa Catalina Mts., Coronado Nat. Forest, 22 August 1970, D.C. Rhodes (ARIZ ML-2). Pinal Co.: Near Oracle, 1912, W.H. Long (BPI WHL8932). Yavapai Co.: Prescott Nat. Forest, 1930, W.H. Long & V.O. Sandberg (BPI WHL7870); Lynx Creek area, Prescott National Forest, 22 August 1934, W.H. Long, V.O. Sandberg & K.D. Butler (BPIWHL7981). CALIFORNIA, San Mateo Co.: San Francisco Watershed, 24 February 1970, H.D. Thiers (SFSU HDT24809); Skyline Blvd., 02 August 2002, F. Stevens (STB00690).

The scurfy to echinulate exoperidium that entirely covers the endoperidium, verrucose spores and abundant sterigmal remnants present in mounts distinguishes *L. molle* from other medium-sized puffballs found in the state. *Lycoperdon atropurpureum* and the North American equivelent, *L. mauryanum* (not reported from Arizona), are very similar to *L. molle* and can be distinguished as these species have erect, brownish spicules, a thick radicating rhizomorph, and very thick-walled (1.5 µm) eucapillitium (Demoulin 1972a, Pegler et al. 1995). *Lycoperdon molle*, on the other hand, has fewer spicules, a finer rhizomorph, and exhibits thinner walls in the eucapillitium (up to 1.0 µm thick). Scanning electron images of the spores in *L. atropurpureum* apparently reveal conical verrucae (Calonge 1998), as opposed to the cylindrical, truncate verrucae found

in *L. molle* (see fig. 102c). Another similar species, *L. decipiens*, has verrucose spores with dense verrucae, a more reduced subgleba, and is more densely spiculose with the apical spicules being stellate; however, some authors (Calonge 1998) synonymise this taxon with *L. atropurpureum*. *Lycoperdon umbrinum* superficially resembles *L. molle*, but can be distinguished from the later because the ornamentation on the exoperidium of *L. umbrinum* is less dense, which leaves areas of the endoperidium exposed. Microsopically, *L. umbrinum* is easily distinguished as it has asperate to echinulate spores that are smaller (4.0-5.6 μm in diam.) and lacks sterigmal remnants in the mounts. *Lyocoperdon molle* is reported for the first time from Arizona here.

43. ***Lycoperdon perlatum*** Pers.: Pers., Synopsis Methodica Fungorum: 145 (1801).

(figs. 66c, 90a & 102d)

Basionym

Lycoperdon gemmatum var. *perlatum* (Pers.) Fr., Syst. Mycol. 3: 36-37 (1829).

Reported synonyms

= *Lycoperdon gemmatum* Batsch, Enum. Pl. (Schumacher) 2: 190 (1803).

= *Lycoperdon hirtum* Bull., Essai Chloris: 498 (1803).

= *Lycoperdon lacunosum* Bull.: Pers., Essai Chloris: 497 (1803).

= *Lycoperdon bonordenii* Massee, J. Roy. Microscop. Soc. London: 713 (1887).

= *Lycoperdon excoriatum* Lloyd, Mycol. Writings 2: 229 (1905).

= *Lycoperdon macrogemmatum* Lloyd, Mycol. Writings 2: 265 (1906).

= *Lycoperdon globoso-piriforme* Lloyd, Mycol. Writings 6: 1058 (1921).

= *Lycoperdon albidum* Velen., Ceske Houby: 827 (1922).

Type: Demoulin (1973a) presents a convincing case to retain *Lycoperdon perlatum* Pers.: Pers. as the type for the genus *Lycoperdon*. The typification of the species was considered by Demoulin (1970), who did not select a lectotype from the material available at Nationaal Herbarium Nederland, Leiden (L 910.258-671, L 910.258-676, L 910.678, L 910.258-681, L 910.258-761). He did, however, go on to state, "Cette espèce bien connue, la plus fréquente du genre en Europe, nous paraît d'ailleurs suffisamment caractérisée par les descriptions qu'en donne PERSOON et la première de celles-ci [Obs. Mycol., I : 4 (1796)] nous paraît un type suffisant."

Selected illustrations: Bottomley (1948; pl. 35, fig. 1); Calonge (1992: fig. 42); Coker & Couch (1928: pls. 52 & 53 "plant on left", as *L. gemmatum);* Cunningham (1943: pl. 19, fig. 5 & pl. 21, fig. 5); Pegler, Læssøe & Spooner (1995: figs. 117-118); Smarda in Pilát (1958: figs. 73-74 & 101-103); Smith (1951: pls. 13-14 & pl. 15, fig. 1).

Gasterocarp 15-55 mm in diameter x 18-67 (100) mm in height, subglobose, obovoid, obpyriform to pseudostipitate, often developing a medium- to large-sized pseudostipe (up to 70 mm in length), attached at base attached by fine, branching rhizomorphs, heavily encrusted with particles of soil; ostiole slow to develop, small- to medium-sized, orbicular to irregular-shaped and torn. Exoperidium whitish at first, becoming yellowish white (4A2), pale yellow (4A3) to grayish yellow (4B3-4), grayish orange (5B3-5) to brownish orange (5C4-6), verrucose/echinulate; larger verrucae (up to 2.0 mm in length) conical, singular or composed of several units fused at the tips, encircled by numerous smaller echinae or verrucae (up to 0.5 mm in length), larger

verrucae fugacious, especially on apical portions of gasterocarp, smaller echinae or verrucae more persistent, particularly on basal portions of gasterocarp and remaining on the apical portions to form characteristic reticulate pattern around the s. Endoperidium yellowish white (4A2), covered with reticulate pattern of formed around persistent ornamentation, papery and dull, smaller ornamentation persistent. Gleba olive-brown (4D4-6 to 4E5-6) to yellowish brown (5D5-6), cottony. Subgleba grayish yellow (4B3-5) to grayish orange (5B3-4), cellular, composed of medium- to large-sized cells, comprising lower 1/2 of gasterocarp or more if pseudostipe is present.

Basidiospores globose to subglobose, (3.2) 4.0-4.8 X (3.2) 4.0-4.8 μm [x = 4.4 ± 0.5 X 4.4 ± 0.5 μm, Q_m = 1.0, n = 20], asperate to echinulate, central oil drop; pedicel short (up to 0.8 μm in length); sterigmal remnants often present in mounts; spores hyaline to yellowish in water mounts. Eucapillitium '*Lycoperdon*' type, 3.2-5.6 μm in diameter, thick-walled (up to 1.0 μm), glabrous, occasionally finely encrusted, occasional dichotomous branching, straight, tips attenuate, often subundulate, abundant to sparse, small- to medium-sized pores, elastic, aseptate, yellowish to brownish yellow in water mounts. Paracapillitium present, often abundant, septate. Exoperidium composed of orbicular to ovoid sphaerocysts, occasionally containing contents staining yellow in Melzer's. Endoperidium composed of tightly interwoven hyphal elements, containing inflated elements resembling sphaerocysts, some of which contain contents staining yellow in Melzer's.

Habitat: Terrestrial and found in open areas with granitic soil, open grassy areas, or growing amid leaf or needle debris under fir (*Abies* spp.), oak (*Quercus* spp.),

Ponderosa pine (*Pinus ponderosa*) or spruce (*Picea* spp.). This species is found throughout the Arizona and occurs in the mid to higher elevations of the state within the Great Basin conifer woodland, interior chaparral, Madrean evergreen woodland, Petran montane conifer forest, and Petran subalpine conifer forest biotic communities.

Distribution: Known from throughout the United States, and previously reported from Alabama, Arizona, California, Colorado, Connecticut, Florida, Georgia, Idaho, Illinois, Indiana, Iowa, Kansas, Kentucky, Louisiana, Maine, Maryland, Massachusetts, Michigan, Minnesota, Missouri, Montana, New Hampshire, New Jersey, New Mexico, New York, North Carolina, Ohio, Oklahoma, Oregon, Pennsylvania, South Carolina, Tennessee, Texas, Utah, Vermont, Virginia, Washington, West Virginia, Wisconsin and Wyoming (see fig. 47 for Arizona distribution). Also reported from Africa, Australia, Britain, China, Europe, India, New Zealand, South America and Tasmania.

Material examined: ARIZONA, Cochise Co.: Rustlers Park, Chiricahua Mountains, August 1958, J.Lowe & R.L. Gilbertson, (MICH 00017652); Rustlers Park, Chiricahua Mountains, 05 September 1986, J.S. States (MICH AEF425); Rustlers Park, Chiricahua Mountains, 21 August 1990, J.S. States (MICH AEF684); Pinery Canyon Road and Forest Service boundary, 04 September 1993, J.S. States (MICH AEF1041). Coconino Co.: Oak Creek Canyon, Sedona, October 1972, C. Barrows (MICH CB#14); San Francisco Mountain near Flagstaff, September 1973, C. Barrows (MICH CB#2-1973); Paradise Rd., Flagstaff, 01 September 1992, J.S. States (MICH AEF979); Sitgreaves NF, near Mogollon Rim, off of Rim Road (FR 300), on road to Bear Canyon

Lake, 02 September 2003, S.T. Bates (STB00723); Coconino NF, Lamar Haines Memorial Wildlife area, near enterance, off of Snowbowl Road (FR516), 20 September 2003, S.T. Bates (STB00727); San Francisco Peaks area, Snowbowl ski area, off of Snowbowl Road (FR516), 24 September 2003, S.T. Bates (STB00712). Gila Co.: Tonto National Forest - mailed from Young, August 1934, N.F. Noecker & L.W. Roberson (BPI WHL8001a). Greenlee Co.: ~1/8 mi north of Hennigan's meadow lodge, W side of Hwy. 191, 16 August 2002, S.T. Bates ~1.5 mi S of Hennigan's meadow campground entrance, W side of Hwy. 191, 16 September 2002, S.T. Bates (STB00097). Pima Co.: Bear Wallow, Santa Catalina Mts., Coronado National Forest, 22 September 1970, F. Gray (ARIZ no number); Mt. Lemmon, Santa Catalina Mts., Coronado Nat. Forest, 22 September 1970, D.C. Rhodes (ARIZ DCR41); Bear Canyon, Santa Catalina Mts., Coronado National Forest, 22 September 1974, C. Dennet (ARIZ CD43). Yavapai Co.: Prescott, 19 September 1934, W.H. Long (BPI WHL8024); Copper Basin Area, Prescott, 15 September 1937, W.H. Long (BPI WHL7791).

Lycoperdon perlatum is one of the more distinct puffball species and is easily recognized as it has an exoperidium with large, conical verrucae surrounded by smaller, thinner verrucae or echinae, which leave a reticulate pattern on the endoperidium once the exoperidium sheds. Microscopically this species has small (4.0-4.8 μm in diam.), asperate to echinulate spores, mostly straight eucapillitium with scattered small- to medium-sized pores, an exoperidium composed of sphaerocysts and an endoperidium that contains inflated hyphae, which resemble sphaerocysts. This species could be confused with *L. nigrescens* (not reported from Arizona) which is almost identical;

however, that species has an exoperidium composed of more uniformed brownish to blackish echinae, which are often fused at the tips and leave a reticulate pattern on the endoperidium once they have sloughed off. The spores of *L. nigrescens* have punctate rather than the distinctly conical ornamentation, which is present in *L. perlatum*. This character is very apparent when observed at higher magnification under the scanning electron microsope (Demoulin 1972a). *Lycoperdon perlatum* was previously reported from Arizona by Demoulin (1972a).

44. ***Lycoperdon pulcherrimum*** Berk. & M. A. Curtis, Grevillea 2: 51 (1873).

(figs. 66d, 90b & 102e)

Reported synonyms

= *Lycoperdon frostii* Peck, Bot. Gaz. 4: 139 (1879).

Type: According to Demoulin (1972a), the holotype is located in the Royal Botanic Garden (K) labeled "Pennsylvania, 1852, Michener 3933" and an isotype is housed at the Farlow Herbarium of Cryptogamic Botany (FH).

Selected illustrations: Coker & Couch (1928: pls. 43-44); Smith (1951: pl. 19, fig. 2).

Gasterocarp 20-50 mm in diameter x 15-50 mm in height, subglobose, obovoid to obpyriform, occasionally plicate at base, tapering to a thick radicating rhizomorph, often highly branched to form a dense mycelial mat, encrusted with particles of soil; ostiole

developing with the sloughing of the exoperidium, medium- to large-sized, irregular-shaped and torn. Exoperidium whitish at first, becoming pale yellow (4A3), grayish yellow (4B3), grayish orange (5B3-5) to brownish orange (5C5-6), echinate; echinae long (up to 5.0 mm in length), slender, singular or often fused and occasionally recurved at tips, echinae fugacious, sloughing off individually or in small groups from the apical portions of the gasterocarp, echinae becoming shorter and more persistent toward the basal portions. Endoperidium brownish orange (5C4-6), light brown (5D5-6) to yellowish brown (5E5-7), glabrous to minutely furfuraceous, papery and dull, persistent. Gleba whitish and solid at first, becoming brown (6E4-6 to 7E5-6) to reddish brown (8F5-6), cottony. Subgleba grayish yellow (4C4-5) to brownish orange (5C4-5), cellular, composed of small cells, comprising the lower 1/5 to 2/3 of the gasterocarp.

Basidiospores globose, 5.6-6.4 X 5.6-6.4 μm [x = 5.8 ± 0.4 X 5.8 ± 0.4 μm, Q_m = 1.0, n = 20], verrucose, verrucae up to 1.0 μm in length, central oil drop; pedicel (up to 2.4 μm in length); sterigmal remnants abundant in mounts; spores brownish yellow in water mounts. Eucapillitium '*Lycoperdon*' type, 3.2-6.4 μm in diameter, thick-walled (up to 1.0 μm), glabrous, occasionally finely encrusted, occasional dichotomous branching or knob-like projections, straight, tips attenuate, scattered small-sized pores, subelastic, aseptate, yellowish brown in water mounts. Paracapillitium not present. Exoperidium composed of thick-walled, orbicular sphaerocysts, which become more elongated toward the apex. Endoperidium composed of tightly interwoven hyphal elements.

Habitat: Terrestrial and found growing amid leaf or needle debris under oak (*Quercus* spp.), juniper (*Juniperus* spp.), mesquite (*Prosopis* spp.) or pinyon (*Pinus edulis*). This species is found throughout the Arizona and occurs in the mid to higher elevations of the state within the interior chaparral, Madrean evergreen woodland, Petran montane conifer forest, and the Plains and Great Basin grassland biotic communities.

Distribution: Known from throughout the United States, and previously reported from Arizona, Arkansas, Illinois, Indiana, Iowa, Kansas, Maine, Maryland, Massachusetts, Michigan, Minnesota, Missouri, Nebraska, New Jersey, New Mexico, New York, North Carolina, Ohio, Pennsylvania, Tennessee, Texas, Vermont, Virginia and Wisconsin (see fig. 48 for Arizona distribution). Also reported from Canada.

Material examined: ARIZONA, Cochise Co.: Pinery Canyon Road and intersection with Methodist Camp, Chiricahua Mountains, 04 September 1993, J.S. States (MICH AEF1020). Coconino Co.: Mount Elden (Coconino National Forest, Forest Service Road 557, T22N R7E Sect. 36), 01 October 1994, J.S. States (MICH AEF1264). Gila Co.: SW side of Hwy. 260, across from entrance to Quail Run Rd., ~10 mi NE of Payson, 10 August 2002, S.T. Bates (STB00066). Yavapai Co.: Lynx Club, Prescott Nat. Forest, 22 August 1934, W.H. Long, V.O. Sandberg & K.D. Butler (BPI WHL7980).

Lycoperdon pulcherrimum is a distinct puffball exhibiting an echinate exoperidium with long, slender echinae (up to 5.0 mm in length), which slough off the apical portions of the gasterocarp to expose a glabrous, brownish endoperidium.

Lycoperdon echinatum and the North American equivalent, *L. americanum* (Demoulin 1972a and Pegler et al. 1995), are very similar to *L. pulcherrimum*; however, they are not encountered in Arizona. Those species slough off the exoperidium leaving a prominent reticulate pattern on the endoperidium, as opposed to the glabrous endoperidium that becomes exposed in *L. pulcherimum*. *Lycoperdon pulcherrimum* could also be confused with *L. marginatum* or *L. calvescens*. The verrucose exoperidium with pyramidal verrucae in *L. marginatum* and way in which it sheds in plates is markedly different from the exoperidium of *L. pulcherrimum*, which sheds its echinae individually. *Lycoperdon calvescens* can be distinguished from *L. pulcherrimum* as that species has considerably shorter echinae, asperate to echinulate spores and has an exoperidium is composed of large sphaerocysts (55.0 µm in diam.) with intracellular pigments. *Lycoperdon pulcherrimum* was previously reported from Arizona by Demoulin (1972a).

45. ***Lycoperdon rimulatum*** Peck ex Trelease, Transactions of the Wisconsin Academy of Science, Arts and Letter 7: 117 (1889). (figs. 67a, 91a & 102f)

Reported synonyms

≡ *Lycoperdon decipiens* var. *rimulatum* (Peck ex Trelease) F. Smarda in Pilat, Fl. CSR; Gasteromycetes: 354 (1958).

= *Bovistella atrobrunnea* Zeller, Mycologia 40: 642 (1948).

Type: The syntypes of this species from the type locality of River Falls, WI were lost along with the Trelease herbarium. Demoulin (1972a) states, “Nous proposons comme lectotype de cette espèce américane bien connue la récolte (Lyndonville, C.F.

Fairman) de l'herbier de Peck (NYS)." However, Demoulin (1979) fails to bring up the above mentioned collection and instead states, "Since this species is unproblematic, I prefer at the moment to leave it typified by the description." The description and illustration can be found Trelease (1887: 117, pl. IX, fig. 3).

Selected illustrations: Coker & Couch (1928: pl. 41 "below" & pls. 46-47); Smith (1951: pl. 19, fig. 1).

Gasterocarp 12-57 mm in diameter x 30-45 mm in height, globose, subglobose, depressed globose to obpyriform, occasionally plicate at base, attached by branching rhizomorph, encrusted with particles of soil; ostiole slow to develop, small- to medium-sized, irregular-shaped and torn. Exoperidium whitish at first, becoming yellowish gray (4B2), grayish orange (5B3-4) to light brown (5D4-5), or brown (6D4-6) with age, occasionally with orangish brown patches or patchy water stains, glabrous; composed of a minute flocculence, entirely covering the gasterocarp, often with minute echinae, tightly appressed to the surface, sloughing off slowly, exposing more of the endoperidium and becoming more glabrous with age and weathering. Endoperidium grayish yellow (3B4-5) to yellowish gray (4B2), glabrous, papery and shinny, persistent. Gleba grayish brown (8D3), reddish brown (5D4) to purplish gray (4D2), cottony. Subgleba brownish gray (7D2), cellular, composed of small- to medium-sized cells, comprising the lower 1/5 to 1/4 of the gasterocarp, or reduced.

Basidiospores globose, 6.4-8.0 X 6.4-8.0 μm [$x = 7.4 \pm 0.6$ X 7.4 ± 0.6 μm, $Q_m = 1.0$, $n = 20$], strongly verrucose, verrucae up to 1.6 μm in length, central oil drop; pedicel

short to long (1.6-24.0 μm in length); sterigmal remnants abundant in mounts; spores pale gray-brown in water mounts. Eucapillitium '*Lycoperdon*' type, 3.2-5.6 μm in diameter, thick-walled (up to 1.0 μm), glabrous, occasional dichotomous branching or knob-like projections, straight, tips attenuate, long and narrow, occasionally subundulate, abundant small- to medium-sized pores, subelastic to elastic, aseptate, hyaline to pale gray-brown in water mounts. Paracapillitium occasionally present but not abundant, septate. Exoperidium composed of thick-walled hyphal elements, inflated at tips to form orbicular, broadly fusiform to irregular-shaped sphaerocysts, dextrinoid in Melzer's, reaction soon fading. Endoperidium composed of tightly interwoven hyphal elements, occasionally inflated some portions, dextrinoid in Melzer's, reaction soon fading.

Habitat: Terrestrial and found growing in grassy open areas or amid leaf or needle debris under fir (*Abies* spp.), oak (*Quercus* spp.) or Ponderosa pine (*Pinus ponderosa*). This species is found throughout the Arizona and occurs in the mid to higher elevations of the state within the Madrean evergreen woodland, Petran montane conifer forest, Petran subalpine conifer forest, and the Plains and Great Basin grassland biotic communities.

Distribution: Known from throughout the United States, and previously reported from Florida, Indiana, Iowa, Kansas, Maine, Michigan, Minnesota, Missouri, Nebraska, New Jersey, New York, North Carolina, North Dakota, Ohio, Oregon, Pennsylvania, South Carolina, South Dakota, Texas and Wisconsin (see fig. 49 for Arizona distribution). Also reported from Canada.

Material examined: ARIZONA, Apache Co.: Hawley Lake; White Mountain Apache reservation, near McNary, 11 August 2002, L. Theriot (STB00112). Cochise Co.: Tex Canyon, Chiricahua Mountains, 03 September 1994, J.S. States (MICH AEF1281). Coconino Co.: Grand Canyon, 01 August 1930, R.B. Street (BPI WHL7892b); Flagstaff, 06 August 1933, I. Hatfield (BPI WHL7814); ~1/2 mi in on FR 237, N off of Hwy. 260, near Forest Lake Campground, Mogollon Rim, 10 August 2002, S.T. Bates (STB00071); ~3/4 mi in on FR 34B, ~1 mi W on FR 34 from intersection w/ Rim Rd. (FR300) Woods Canyon Lake, Mogollon Rim, 10 August 2002, S.T. Bates (STB00077); Near parking lot to Willow Springs Lake, N of Hwy. 260, Mogollon Rim, 10 August 2002, S.T. Bates (STB00069); ~1/4 mi in on FR 237, N off of Hwy. 260 near Forest Lakes, Mogollon Rim, 10 August 2002, S.T. Bates (STB00073). Gila Co.: Tonto Nat. Forest, near Young, 01 August 1934, W.H. Long (BPI WHL8006). Pima Co.: Summer Haven, Santa Catalina Mts., Coronado Nat. Forest, 19 October 1970, T. Burr (ARIZ TB35). Yavapai Co.: Lynx Creek area, Prescott National Forest, 22 August 1934, W.H. Long, V.O. Sandberg & K.D. Butler (BPI WHL7981).

This species is common in some areas of the state, but is often overlooked because of its small stature and inconspicuous coloration. *Lycoperdon lividium* is a superficially identical species with a glabrous exoperidium, and in order to reliably distinguish between this species and *L. rimulatum* one should examine the basidiospores under the light microscope. Verrucose spores are found in *L. rimulatum* and asperululate spores are present in *L. lividum* (see *L. lividum* for further discussion). *Lycoperdon rimulatum* is reported for the first time from Arizona here.

46. ***Lycoperdon umbrinum*** Pers.: Pers., Synopsis Methodica Fungorum: 147 (1801).

(figs. 67b, 91b &103a)

Reported synonyms

= *Lycoperdon gemmatum* var. *hirtum* (Pers.) Fr., Syst. Mycol. 3: 38 (1829).

= *Lycoperdon umbrinum* var. *fissispinum* Kreisel, Feddes Repert. 64: 141 (1962).

Type: Demoulin (1970) mentions that the description in the protologue (Persoon 1801: 147) along with the illustration in Icones Pictae Rariorum Fungorum (1806, pl. XVII, fig. 3) typify this species well. He goes on to agree with Perdeck's (1950) neotypification of a specimen in the Nationaal Herbarium Nederland (L 0116502, Acc. No. 911.81-14), which includes on the labeled "Hab. Gottingae".

Selected illustrations: Calonge (1992: fig. 44); Coker & Couch (1928: pl. 48); Pegler, Læssøe & Spooner (1995: figs. 129-130); Smarda in Pilát (1958: fig. 106); Smith (1951: pl. 16, fig. 1).

Gasterocarp 18-45 mm in diameter x 20-30 mm in height, globose, subglobose, depressed globose to obpyriform, occasionally plicate at base, attached by a whitish branching rhizomorph, encrusted with particles of soil; ostiole slow to develop, small- to medium-sized, irregular-shaped and torn. Exoperidium whitish at first, becoming grayish orange (5B3-4), brownish orange (5C4-5) to yellowish brown, often darker, particularly at tips brown (6E4), dark brown (6F4) to blackish, echinate; echinae short (up to 1.0 mm in length), slender, often fused at tips, ornamentation persistent, more fugaceous toward

the apex, endoperidium exposed between groups of echinae. Endoperidium pale yellow (4A3), light yellow (4A4-5) to grayish yellow (4D5-6), glabrous, papery and dull, persistent. Gleba olive-brown (4D3-5) to light brown (5D4), cottony. Subgleba grayish yellow (4B3-4 to 4C3-4), cellular, composed of small- to medium-sized cells, comprising the lower 1/3 to 1/2 of gasterocarp.

Basidiospores globose, 4.0-5.6 X 4.0-5.6 μm [x = 4.8 ± 0.6 X 4.8 ± 0.6 μm, Q_m = 1.0, n = 20], asperate to echinulate, central oil drop; pedicel short (up to 0.8 μm in length); sterigmal remnants absent from mounts; spores yellowish in water mounts. Eucapillitium '*Lycoperdon*' type, 4.0-8.0 μm in diameter, thick-walled (up to 0.8 μm), glabrous, dichotomously branched, straight to subundulate, tips attenuate, long and narrow, abundant medium- to large-sized pores, elastic, aseptate, yellowish in water mounts. Paracapillitium occasionally present but not abundant, septate. Exoperidium composed of orbicular sphaerocysts. Endoperidium composed of tightly interwoven hyphal elements.

Habitat: Terrestrial and found in granitic soil or growing amid leaf or needle debris under aspen (*Populus tremuloides*), oak (*Quercus* spp.) or mixed conifers. This species occurs in the higher elevations of the state within the Petran montane conifer forest and Petran subalpine conifer forest biotic communities.

Distribution: Known from throughout the United States, and previously reported from Alabama, California, Colorado, Florida, Idaho,Illinois, Maine, Michigan, New Hampshire, New York, North Carolina, North Dakota, Ohio, Oregon, Pennsylvania,

Texas, Utah, Virginia, Washington, West Virginia and Wyoming (see fig. 50 for Arizona distribution). Also reported from China, Europe and South Africa.

Material examined: ARIZONA, Apache Co.: Greens Peak, on FR 61, off of FR 117, 18 August 2003, S.T. Bates (STB00704). Coconino Co.: Conconino NF, Snowbowl ski area, off of Snowbowl road (FR 516), 20 September 2003, S.T. Bates (STB00730). Greenlee Co.: East side of Hwy. 191 (roadside), ~1.5 mi. south of Hennigan's Meadow campground entrance, 16 September 2002, S.T. Bates (STB00098). CALIFORNIA, Santa Cruz Co.: Felton, 18, January 1967, H.D. Thiers (SFSU HDT18538).

The minutely echinate puffball species require careful observation in order to arrive at a proper identification, and *L. umbrinum* is no exception. The best way to reliably distinguish *Lycoperdon molle* and closely related species from *L. umbrinum* is to examine spores mounts under the light microscope. Asperate to echinulate spores that lack sterigmal remnants in the mount are characteristic of *L. umbrinum*, while verrucose spores with abundant sterigmal remnants in the mounts distinguish *L. molle* and its allies (see *L. molle* for further discussion). *Lycoperdon lambinonii* and *L. ericeaum* could also be confused with *L. umbrinum*, and these species are like wise best distinguished using microscopic characters. Asperulate spores with sterigmal remnants present in the mount and eucapillitium that mostly lack pores distinguish *L. lambinonii* from *L. umbrinum*, which lacks sterigmal remnants in the mounts and has noticably pored eucapillitium. *Lycoperdon ericaeum* is very similar to *L. umbrinum* and is distinguished by having subelastic eucapillitium with abundant medium- to large-sized pores and spores that are

more densely ornamented. *Lycoperdon umbrinum* is reported for the first time from Arizona here.

Morganella Zeller, Mycologia 40: 650 (1948).

Type species: *Morganella mexicana* Zeller, Mycologia 40: 650 (1948).

47. ***Morganella pyriformis*** (Schaef.: Pers.) Kreisel & D. Krüger, Mycotaxon 86: 175 (2003). (figs. 67c, 92a & 103b)

Basionym

Lycoperdon pyriforme Schaef.: Pers., Syn. Meth. Fung. :148 (1801).

Reported synonyms

≡ *Lycoperdon proteus* var. *pyriforme* (Scaeff.: Pers.) Rehlan, Fl. Cantab., ed. 2: 535 (1802).

= *Lycoperdon ovoideum* Bull., Hist. Nat. Veg. (Lam. & Mirbel) 4: 60 (1803).

= *Lycoperdon tessellatum* (Pers.) Schumach., Enum. Pl. (Schumacher) 2: 191 (1803).

= *Lycoperdon saccatum* Pers., J. Bot. (Desvaux) 2: 19 (1809).

= *Lycoperdon desmazieri* Lloyd, Mycol. Writings 2: 213 (1905).

= *Lycoperdon faveolum* Lloyd, Mycol. Writings 2: 230 (1905), nom. reg.

= *Lycoperdon cupricolor* Lloyd, Mycol. Writings 2: 265 (1906).

= *Lycoperdon betulinum* Velen., Ceske Houby: 830 (1922).

Type: Demoulin (1970) contests Perdeck's (1950) neotypification of a specimen in the Nationaal Herbarium Nederland (L Acc. No. 910.258-341) as this specimen is apparently not a typical form and is labeled in Persoon's hand "var. umbone nullo aut obsolete". He did, however, state, "Les spécimens désignés par PERDECK correspondent cependant indiscutablement au *L. pyriforme* (spores lisses, capillitium sans pores, paracapillitium abundant)…." He goes on to suggests that more typical specimens in the Royal Botanic Garden (K) determined by Persoon might be better suited for neotypification and that the description in the protologue (Persoon 1801: 148) should presently serve to typify the species.

Selected illustrations: Calonge (1992: fig. 43, as *L. pyriforme*); Coker & Couch (1928: pls. 49 "below" & 50, as *L. pyriforme*); Cunningham (1943: pl. 20, fig. 6, as *L. pyriforme*); Pegler, Læssøe & Spooner (1995: figs. 109-110, as *L. pyriforme*); Smarda in Pilát (1958: figs. 80, 82-83 & 107, as *L. pyriforme*); Smith (1951: pl. 12, figs. 1-2, as *L. pyriforme*).

Gasterocarp 10-45 mm in diameter x 15-60 (90) mm in height, subglobose, obovoid to obpyriform, often echinulate on the basal portions, occasionally pseudostipitate (up to 60 mm in length), with or without a slightly bulbous base, normally attached by a thick, whitish, branching rhizomorph, encrusted with particles of soil; ostiole slow to develop, small- to medium-sized, orbicular to irregular-shaped and torn, often uplifted at rim. Exoperidium whitish at first, becoming grayish orange (5B3-4), brownish orange (5C4-6), occasionally darker toward the tips of ornamentation, light

brown (6D4-6) to brown (6E5-6), rimulose to rimose, verruculose, verrucae appressed, often granular, ornamentation persistent, wearing away and becoming more glabrous with age and weather, particularly on the apical portions, often forming a reticulate pattern as the exoperidium sloughs off. Endoperidium grayish orange (5B3-6), glabrous, papery and dull, persistent. Gleba whitish and solid at first, becoming grayish yellow (3B5-6), later olive-brown (4D3-4) to light brown (5D4-6 to 6D5), cottony. Subgleba white (1A1), somewhat compact, becoming cellular, composed of small cells (less than 1.0 mm in width), reduced or comprising lower 1/4 to 3/4 of gasterocarp, occasionally more.

Basidiospores globose to subglobose, 4.0-5.6 X 4.0-5.6 µm [x = 5.0 ± 0.7 X 4.9 ± 0.7 µm, Q_m = 1.0, n = 20], smooth, large central oil drop; pedicel absent or rudimentary; sterigmal remnants mostly absent from mounts; spores yellowish in water mounts. Eucapillitium '*Lycoperdon*' type, 4.0-8.0 µm in diameter, thick-walled (up to 0.8 µm), glabrous, dichotomously branched, straight to subundulate, tips attenuate, long and narrow, lacking pores, subelastic, aseptate, brownish yellow in water mounts. Paracapillitium present, often abundant, septate. Exoperidium composed of thick-walled (up to 2.4 µm), inflated, spinose to irregular-shaped sphaerocysts. Endoperidium composed of tightly interwoven hyphal elements.

Habitat: Lignicolous and found on rotting conifer wood or occasionally terrestrial and found in soil or moss in mixed conifer forests. This species is found throughout Arizona and occurs in the higher elevations of the state within the Petran montane conifer forest and Petran subalpine conifer forest biotic communities.

Distribution: Known from throughout the United States, and previously reported from Alabama, Arizona, Arkansas, California, Colorado, Connecticut, Delaware, Florida, Georgia, Idaho, Illinois, Indiana, Iowa, Kansas, Kentucky, Louisiana, Maine, Maryland, Massachusetts, Michigan, Minnesota, Mississippi, Missouri, Montana, Nebraska, New Hampshire, New Jersey, New Mexico, New York, North Carolina, North Dakota, Ohio, Oklahoma, Oregon, Pennsylvania, South Carolina, South Dakota, Tennessee, Texas, Utah, Vermont, Virginia, Washington, West Virginia, Wisconsin and Wyoming (see fig. 51 for Arizona distribution). Also reported from China, Europe, Great Britain, India, Japan, South America, Australia, Tasmania and New Zealand.

Material examined: ARIZONA, Apache Co.: ~25 mi on beyond the start of the Terry Flat's Loop Rd.; Terry Flats, East off of Hwy. 191/180 (FR 56); N of Alpine, 17 August 2002, S.T. Bates (STB00106). Cochise Co.: Rustlers Park, Chiricahua Mountains, 11 September 1988, J.S. States (MICH AEF765); Rustlers Park, Chiricahua Mountains (UTM XL 630 308), 21 August 1990, J.S. States (MICH AEF679). Coconino Co. : Vicinity of Flagstaff, not date given, Quinby (MICH 110a), Vicinity of Flagstaff, not date given, Quinby (MICH 130c), Vicinity of Flagstaff, not date given, Quinby (MICH 135); San Francisco Peaks Natural area, 25 September 1985, J.S. States (MICH AEF345); Bismar Lake, San Francisco Peaks, Coconino N.F., 26 August 1992, J.S. States (MICH AEF978); Greenlee Co.: ~8 mi S of Hannigan's meadow campground entrance; on the E side of Hwy. 191, 16 August 2002, S.T. Bates (STB00092); S of (~1.5 mi) Hannigan's meadow campground entrance, W side of Hwy. 191, 16 August 2002, S.T. Bates (STB00096); ~100 yards in and just N of parking lot, lot for Trail 76, off of Hwy. 191,

Hannigan's meadow, 17 August 2002, S.T. Bates (STB00102);W off of Hwy. 191, Hannigan's meadow, 17 August 2002, S.T. Bates (STB00103); E side of Hwy. 191, ~2 mi N from Hannigan's Meadow Lodge, 17 August 2002, S.T. Bates (STB00105). Navajo Co.: Reservation Lake, 03 September 1970, D.C. Rhodes (MICH RL-13). Pima Co.: Santa Catalina Mts., 03 September 1934, N.F. Noecker & Carlson (BPI WHL8791).

The lignicolous habit, verruculose, rimulose to glabrous exoperidium, whitish subgleba, smooth spores, eucapillitium lacking pores, and exoperidium that is composed of spinose to irregular-shaped sphaerocysts distinguishes this common puffball, formerly know as *Lycoperdon pyriforme*. *Morganella subincarnatum* (not recorded from Arizona) also assumes the lignicolous habit; however, that species has an echinulate to verruculose exoperidium, which sloughs off to reveal the punctate endoperidium and lacks eucapillitium but has abundant paracapillitium. *Morganella pyriformis* is occasionally terrestrial and could possibly be confused with other more glabrous species such as *L. rimulatum* or *L. lividum*. These species, however, are easily distinguished microscopically as they have ornamented spores, pored eucapillitium, and smaller non-spinose shaerocysts in the exoperidium. The recombination of *Lycoperdon pyriforme* under the genus *Morganella* by Krüger and Kreisel (2003) is based on molecular sequence data as well as morphological and ecological characters (see comments under *Morganella*, pg. 73). This species was previously reported from Arizona by Demoulin (1972a, as *Lycoperdon pyriforme*).

Mycenastrum Desv., Annales des Sciences Naturelles; Botanique, Sér. 2, 17: 147 (1842).

Type species: *Mycenastrum corium* (Guers.ex DC. & Lam.) Desv., Ann. Sci. Nat.; Bot., Sér. 2, 17: 147 (1842).

48. ***Mycenastrum corium*** (Guers.ex DC. & Lam.) Desv., Annales des Sciences Naturelles; Botanique, Sér. 2, 17: 147 (1842). (figs. 67d, 92b & 103c-d)

Basionym

Lycoperdon corium Guers. ex DC. & Lam., Fl. Franc. (DC. & Lamarck), suppl. 2: 598 (1815).

Reported synonyms

≡ *Scleroderma corium* (Guers.ex DC. & Lam.) A.H. Graves, Bot. Gall. 2: 892 (1830).

= *Bovista suberosa* Fr., Syst. Mycol. 3: 26 (1829).

= *Mycenastrum phaeotrichum* Berk., J. Bot. (Hooker) 2: 418 (1843).

= *Mycenastrum chilense* Mont., Ann. Sci. Nat., Bot., Sér. 2, 20: 375 (1843).

= *Mycenastrum leptodermeum* Durieu & Mont., Expl. Sci. Algerie: 386 (1849).

= *Bovista spinulosa* Peck, Bot. Gaz. 3: 170 (1879).

= *Mycenastrum spinulosum* Peck, Bot. Gaz. 6: 240 (1883).

= *Scleroderma spinulosum* (Peck) De Toni, Syll. Fung. 7: 141 (1888).

Type: Type material of *Mycenastrum corium* is apparently not extant. Calonge (1998) cites the type locality as "France… dans les champs de Luzerne entre Sotteville et Rouen: elle y etoit en fruit au milieu de l'été."

Selected illustrations: Bottomley (1948: pl. 65); Calonge (1992: fig. 45); Coker & Couch (1928: pl. 62); Guzmán (1969: fig. 29); Smarda in Pilát (1958: figs. 125-129); Smith (1951: pl. 25, figs. 1-2 & pl. 26, fig. 1).

Gasterocarp 60-95 mm in diameter x 50-90 mm in height, globose, subglobose, obovate to irregular-shaped, occasionally plicate at base, forming irregular lobes, attached by a mycelial mat, encrusted with particles of soil; ostiole lacking, peridia cracking apart at the apex of the gasterocarp to expose the gleba. Exoperidium whitish at first, remaining whitish or becoming yellowish white (3A2 to 4A2) to orange-white (5A2), glabrous to minutely floccose, thin, breaking up into small-sized irregular-shaped, flaky patches, which soon slough off of the gasterocarp. Endoperidium brownish gray (7C2 to 7E2), greyish brown (7D3 to 7E3), light brown (7D4-5) to brown (7E4-5), glabrous, occasionally pitted, thick (up to 3 mm), coriaceous to corky, persistent, developing horizontal cracks at the apical portions of the gasterocarp, eventually splitting open entirely. Gleba yellowish brown (5D5-7), brown (6E6-7 to 7E6-8), reddish brown (8E6-8 to 9E6-8) to dark brown (8F4-7 to E4-7), cottony at first, soon becoming pulverulent. Subgleba absent.

Basidiospores globose, (8.8) 10.4-12.8 X (8.8) 10.4-12.8 μm [x = 11.9 ± 1.0 X 11.9 ± 1.0 μm, Q_m = 1.0, n = 20], echinate, verrucose to reticulate, oil drop not apparent;

pedicel rudimentary and difficult to discern due to the ornamentation; sterigmal remnants absent from mounts; spores brownish in water mounts. Eucapillitium '*Mycenastrum*' type, 9.6-16.0 μm in diameter, thick-walled (up to 2.4 μm), glabrous, occasional dichotomous braching, with numerous spinose projections, subundulate, sharply attenuate or rounded at tips, lacking pores, elastic, aseptate, pale brown in water mounts. Paracapillitium absent. Exoperidium composed of thick-walled hyphal elements. Endoperidium composed of tightly interwoven hyphal elements.

Habitat: Terrestrial and found in grassy areas, pastures or in leafy debris under juniper (*Jumiperus* spp.) and mesquite (*Prosopis* spp.) This species occurs in the lower to mid elevations of the state within the Lower Colorado River Valley subdivision of the Sonoran desertscrub and semidesert grassland biotic communities.

Distribution: Common in many parts of the United States, abundant in the west, and previously reported from California, Colorado, Florida, Idaho, Illinois, Michigan, Montana and Wyoming (see fig. 52 for Arizona distribution). Also reported from Asia, Australia, Europe, India, Mexico, New Zealand, South Africa and South America.

Material examined: ARIZONA, Coconino Co.: Baderville, 15 November 1994, G. Poiŕer (MICH AEF1320). Cochise Co.: Pinery Canyon, Chiricahua Mts., 01 September 1984, R.L. Gilbertson (ARIZ RLG15210); Pinery Canyon, Chiricahua Mts., 01 September 1984, R.L. Gilbertson (ARIZ RLG15211). Maricopa Co.: M. Wert residence, 1233 E. Yucca, Phoenix, 24 November 2002, S.T. Bates (STB00113). Pinal Co.:

Freedman Rd., south of Florence (near corral), 01 August 1979, M. Olsen (ARIZ AN014721). COLORADO, La Plata Co.: Durango, 23 October 1997, J.P. Lindsey (ARIZ AN030154).

Mycenastrum corium is unique among the medium-sized puffballs found in Arizona and is distinguished by the globose or irregular-shaped gasterocarp with a thick, brownish endoperidium and a pulverulent gleba. The manner in which the endoperidium splits apart as horizontal cracks develop in the apical portion of the gasterocarp is reminicent of *Calvatia pachyderma*; however, that species has a whitish endoperidium and the spore mass in mature specimens is normally yellowish to olive-brown rather than reddish to dark brown, which is commonly found in *M. corium*. *Calvatia bicolor* is also somewhat similar; however, that species has a thinner endoperidium and the spore mass that is normally a lighter shade of brown. However, these species are easily distinguished microscopicallyas *M. corium* has conspicuous spinose eucapillitia, which are not encountered in any other puffball species. Another unique character is the pitting that can be observed in the spores under high magnification in the scanning electron microscope (see figs. 103c & 103d). A wide range of variation in the shape of the gasterocarp and the color of the spore mass has caused *M. corium* to be described under numerous different species, which are now commonly accepted as synonyms (see Appendix II). *Mycenastrum corium* is reported for the first time from Arizona here.

Vascellum F. Smarda, in Pilát, Bulletin International de l'Academie Polonaise de Sciences et des Lettres 1: 760 (1958).

Type species: *Vascellum depressum* (Bonord.) F. Smarda, Bull. Int. Acad. Polon. Sci. 1: 760 (1958).

49. ***Vascellum intermedium*** A.H. Sm., Numéro Spécial du Bulletin de la Société Linnéenne de Lyon 43: 417-419 (1974). (figs. 68a, 93a & 103e)

Type: The holotype is located in the University of Michigan Fungus Collection (MICH) and is from Cisco, Texas, labeled "E.A. Smith, 1225b, on soil in fields. "

Selected illustrations: Smith (1974: fig. 5).

Gasterocarp 10-25 (35) mm in diameter x 10-20 mm in height, globose, subglobose to depressed globose, sharply tapering at the base, attached by a thin rhizomorph or mycelial patch, encrusted with particles of soil; ostiole developing with the sloughing of the exoperidium, small- to medium-sized orbicular or irregular-shaped. Exoperidium whitish at first, remaining whitish or becoming yellowish white (3A2 to 4A2) to pale yellow (4A3), echinate; echinae medium length (up to 1.5 mm in length), broad, pyramidal, often fused and/or recurved at tips, sloughing off of apical portions of the gastercarp in small plates. Endoperidium yellowish gray (4B2) to grayish yellow

(4B3), minutely furfuraceous, papery and dull, persitent or occasionally fragile. Gleba grayish yellow (4B4 to 4C4-5) to olive-brown (4D5-6), cottony at first, soon becoming pulverulent. Subgleba grayish yellow (4B3) to grayish yellow (4B3-4), cellular, composed of small- to medium-sized cells, diaphragm well deliniated, comprising only the lower portions of the gasterocarp, reduced or absent.

Basidiospores globose to subglobose, 4.0-5.6 X (3.2) 4.0-4.8 μm [x = 4.8 ± 0.4 X 4.4 ± 0.5 μm, Q_m = 1.1, n = 20], asperate to echinulate, central oil drop; pedicel short (up to 0.8 μm in length); sterigmal remnants absent from mounts; spores hyaline to yellowish in water mounts. Eucapillitium absent. Paracapillitium straight to subundulate with occasional knob-like projections or dichotomous branches, septate. Exoperidium composed of orbicular, lanceolate to irregular-shaped sphaerocysts, interwoven with inflated hyphal elements. Endoperidium composed of tightly interwoven hyphal elements.

Habitat: Terrestrial and found on soil or in grass under pinyon (*Pinus edulis*) or juniper (*Juniperus* spp.). This species occurs in the higher elevations of the state within the Petran montane conifer forest biotic community.

Distribution: Known only from the southwestern United States, and previously reported from Texas (see fig. 53 for Arizona distribution). Not reported from other parts of the world.

Material examined: ARIZONA, Apache Co.: 1.5 mi in on the road to the ranch at South Fork (FR 560) off of Hwy. 260, N side of road, E of Springerville, 16 August 2002, S.T. Bates (STB00091).

Superficially, *Vascellum intermedium* strongly resembles *Lycoperdon marginatum*. These two species can be easily separated microscopically as the gleba of the former contains only paracapillitium, while the later contains eucapillitum and few paracapillitium. Macroscopically, *V. intermedium* is normally slightly smaller in stature than *L. marginatum*, in addition the former lacks a granular endoperidium and sheds its exoperidium in slightly smaller patches than the later. *Vascellum texense* is also very similar to *V. intermedium*; however, the exoperidium of that species is not coasely ornamented nor does it shed in plates. *Vascellum texense* is also generally smaller in stature and more fragile than *V. intermedium*, which is reported for the first time from Arizona here.

50. ***Vascellum lloydianum*** A.H. Sm., Numéro Spécial du Bulletin de la Société Linnéenne de Lyon 43: 410-414 (1974). (figs. 68b, 93b & 103f)

Reported synonyms

= *Lycoperdon subpratense* (Lloyd) Ponce De León, Fieldiana, Bot. 82: 113 (1970), nom. rej.

Type: The holotype is housed at the University of Michigan Fungus Collection (MICH Smith, A.H. 83267) labeled "*Vascellum lloydianum* A.H. Sm. USA, Washington, Lewis Co., Randle, Crispus Environmental Center, in lawn, 29 Oct. 1972."

Selected illustrations: Smith (1974: figs. 2-3).

Gasterocarp 15-40 mm in diameter x 10-37 mm in height, subglobose, depressed globose, broadly obpyriform to turbinate, basal portions broad, bowl-shaped, occasionally plicate, attached at base by fine branching rhizomorphs or small mycelial mat, encrusted with particles of soil; ostiole developing with the sloughing of the exoperidium, medium- to large-sized, irregular-shaped and torn, often expanding with age and weather until the entire apical portion of the gasterocarp has worn away. Exoperidium whitish at first, becoming pale yellow (4A3), yellowish gray (4B2), grayish yellow (4B3-4), orange-white (5A2), orange gray (5B2) to grayish orange (5B3-4), echinulate to echinate; echinae short (up to 1.0 mm in length), erect at first, often becoming more appressed with age, sloughing off slowly, echinae more fugacious toward the apical portions of the gasterocarp, falling individually, more persistent toward the basal portions. Endoperidium yellowish white (4A2) to grayish yellow (4B3-5), glabrous, occasionally puncticulate, papery and dull, becoming more fragile and disintegrating with age. Gleba grayish yellow (4C3-5) to olive-brown (4D4-6 to 4E6), cottony at first, soon becoming pulverulent. Subgleba pale yellow (4A3) to grayish yellow (4B3-5), cellular, composed of medium-sized cells, diaphragm not well deliniated, comprising the lower 1/3 to 1/2 of gasterocarp or reduced.

Basidiospores globose to subglobose, 4.0-5.6 X 4.0-4.8 μm [x = 4.7 ± 0.5 X 4.3 ± 0.4 μm, Q_m = 1.1, n = 20], asperulate, central oil drop; pedicel short (up to 0.8 μm in length), or occasionally longer (up to 2.4 μm in length); sterigmal remnants scarce to abundant in mounts; spores hyaline to yellowish in water mounts. Eucapillitium '*Lycoperdon*' type, 3.2-8.0 μm in diameter, thick-walled (up to 0.8 μm), glabrous, occasionally finely encrusted, scarce or present, but not abundant throughout the gleba, occasional dichotomous branching or knob-like projections, straight to subundulate, tips attenuate, narrow, often subundulate, occasional small- to medium-sized pores, elastic, aseptate, yellowish to in water mounts. Paracapillitium more abundant toward the perifery of gleba. Exoperidium composed of orbicular sphaerocysts, occasionally filled with pigment. Endoperidium composed of tightly interwoven hyphal elements, occasionally inflated.

Habitat: Terrestrial and found in grassy areas in or near mixed conifer forest. This species occurs in the higher elevations of the state within the Petran subalpine conifer forest biotic community.

Distribution: Known mainly from the western United States, and previously reported from California, Oregon and Washington (see fig. 54 for Arizona distribution). Also reported from Brazil.

Material examined: ARIZONA, Coconino Co.: San Francisco Peaks area, Coconino National Forest, off of Snowbowl Road (FR516), 24 August 2003, S.T. Bates (STB00713).

Vascellum lloydianum superficially resembles *V. pratense* (not been reported from Arizona); however, the later has a more developed diaphragm and sparse eucapillitium, where as former has a poorly developed diaphragm and abundant eucapillitium. Smith (1974) suggest that *L. pratense* occurs only rarely in the United States, if at all. This species could be confused with *Lycoperdon calvescens*; however, that species has an exoperidium that is more strongly ornamented and composed of large sphaerocysts (55.0 µm in diam.) with intracellular pigments. Smith (1974) discusses the taxon *Vascellum subpratense* (Lloyd) Ponce De León, which is apparently conspecific with *V. lloydianum* A.H. Sm. However, Ponce De León (1970) apparently typified his taxon with an immature specimen of *L. calvescens* and is, therefore, a nomen rejiciendum as proposed by Demoulin (1971a). *Vascellum lloydianum* is reported for the first time from Arizona here.

51. ***Vascellum texense*** A.H. Sm., Numéro Spécial du Bulletin de la Société Linnéenne de Lyon 43: 416-417 (1974). (figs. 68c, 94a & 104a)

Type: The holotype is housed at the University of Michigan Fungus Collection (MICH Smith, E.A. 1208) labeled "*Vascellum texense* A.H. Sm. USA, Texas, Eastland Co., Cisco, on wet soil in woods, Jul. 1938."

Selected illustrations: Homrich & Wright (1988: figs. 19-20, 79-83 & 91); Smith (1974: fig. 4).

Gasterocarp 5-20 (30) mm in diameter x 5-20 mm in height, globose, subglobose to depressed globose, occasionally plicate at base, attached by a small mycelial pad, encrusted with particles of soil; ostiole developing with the sloughing of the exoperidium, at first small becoming large, irregular-shaped and torn with age and weather. Exoperidium whitish at first, becoming yellowish white (4A2), pale yellow (4A3), light yellow (4A4), yellowish gray (4B2) to grayish orange (5B3-4), minutely verruculose, verrucuae sub-flocculent, often appressed, lower portions more noticabley verruculose to echinulate, fragile, breaking apart, often toward the apex, or sloughing off in small plates from the apical portions of the gasterocarp. Endoperidium yellowish white (4A2), grayish yellow (4B3-4) to grayish orange (5B3), glabrous, occasionally puncticulate, papery and dull, breaking up and/or sloughing off as does the exoperidium. Gleba yellowish gray (4B2) to grayish yellow (4B3-4 to 4C3-4), cottony at first, soon becoming pulverulent. Subgleba yellowish white (4A2) to yellowish gray (4B2), cellular, composed of medium-sized cells, diaphragm not well deliniated, comprising the lower 1/5 of the gasterocarp, reduced or absent.

Basidiospores globose, 4.0-4.8 (5.6) X 4.0-4.8 (5.6) µm [x = 4.6 ± 0.4 X 4.6 ± 0.4 µm, Q_m = 1.0, n = 20], asperulate, central oil drop; pedicel short (up to 0.8 µm in length), or absent; sterigmal remnants mostly absent from mounts; spores hyaline to yellowish in water mounts. Eucapillitium absent. Paracapillitium straight to subundulate with occasional knob-like projections or dichotomous branches, septate. Exoperidium

composed of ovoid or irregular-shaped sphaerocysts. Endoperidium composed of tightly interwoven septate, thick-walled hyphal elments.

Habitat: Terrestrial and found on soil in open areas or woodlands. This species occurs in the mid to higher elevations of the state within the Great Basin conifer woodland and interior chaparral biotic communities.

Distribution: Known only from the southwestern United States, and previously reported from Arizona and Texas (see fig. 55 for Arizona distribution). Not reported from other parts of the world.

Material examined: ARIZONA, Cochise Co.: S. W. Research Station grounds, 10 October 1970, J.P. Lindsey (ARIZ JPL36). Gila Co.: Tonto Nat. Forest, 01 August 1934, W.H. Long (BPI WHL8884). Yavapai Co.: Wolf Creek, Prescott Nat. Forest, 20 August 1934, K.D. Butler (BPI WHL7982).

The small stature, fragile nature, minutely verruculose exoperidium, and gleba exhibiting only paracapillitium distinguishes this small puffballs from all others. *Bovista aestivalis* and *B. dermoxantha* are simular in size and stature; however, these species have a more persistent peridia and eucapillitia are found in abundance within the gleba. This species could also superficially be confused with *Holocotylon brandegeeanum*; however, the gleba found within that species is very distinct having labyrinthiform,

sinuous tramal plates, which form numerous locules. *Vascellum texense* was previously reported from Arizona by Smith (1974).

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