

OBSERVATIONS ON GASTEROMYCETES—VIII

**Persoon's specimens of *Geastrum pectinatum* Pers. and a
reassessment of *Geastrum plicatum* Berk. and *G. tenuipes* Berk.**

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(With 26 Text-figures)

The authentic collections of *Geastrum pectinatum* Pers., *G. plicatum* Berk. and *G. tenuipes* Berk. are redescribed. Persoon's collection in the Rijksherbarium, Leiden, is designated as the Neotype of *G. pectinatum*. *Geastrum plicatum* and *G. tenuipes* are considered as probable synonyms, although observations on freshly expanded specimens are still required. Comparisons are made between freshly collected and dried material in the British Museum (Nat. Hist.), the Hartley Botanical Laboratories, the Rijksherbarium and Herb. Kew, and the literature is discussed.

INTRODUCTION.—The main purpose of this paper is to designate the Neotype of *Geastrum pectinatum* Pers. but the opportunity has also been taken to re-examine Berkeley's type specimens of *G. plicatum* and *G. tenuipes*, generally regarded as synonyms of *G. pectinatum*. Dried collections in the herbaria of the British Museum (Nat. Hist.), London; the Hartley Botanical Laboratories, Liverpool; the Rijksherbarium, Leiden; and the Royal Botanic Gardens, Kew, have been investigated and are compared with the types and freshly developed material studied by the author.

The fungi preserved in Persoon's Herbarium at Leiden were most probably acquired during the latter part of Persoon's life, whilst he was living in Paris, and it is doubtful, therefore, whether they can be considered to be the types of the species described in his 'Synopsis methodica fungorum' (1801), which was published whilst Persoon was living in Germany. However, the specimens indicate what Persoon had in mind and, in the absence of earlier authentic specimens, the author considers that neotypes should be selected from them in accordance with the International Code of Botanical Nomenclature.

In Persoon's Herbarium, the determination of some specimens is followed by a question mark whilst others, although often similar macroscopically, are found to have more than one species on the same sheet when examined microscopically, whilst some names were never published. With his classification being necessarily based on gross morphology, especially as microscopy was still in its infancy, we should not be too critical of Persoon, who could hardly be expected to anticipate

our decision to use his work (1801) as the starting point for the nomenclature of the Gasteromycetes just over one century later. Fortunately, no problem exists with *Geastrum pectinatum* as there is only a single sheet bearing this name and the two specimens glued to it are typical of the fungus which modern workers call *G. pectinatum* Pers.

Today, most European workers are agreed upon the limits of *Geastrum pectinatum* and can readily distinguish it from the related species with non-hygroscopic exoperidia, smooth endoperidia and sulcate mouths, i.e. *Geastrum badium* Pers., *G. bryantii* Berk. (= *G. striatum* DC.) and *G. nanum* Pers. Outside Europe, however, the situation is different and, particularly in Australasia, workers have experienced difficulty in separating *G. pectinatum* from its relatives. With the leathery peridia preserving so well, little critical observation seems to have been made on freshly expanded specimens and it is on such structures as the *Fleshy Layer*, which more readily succumb to attacks by insects and micro-organisms, that further information is required.

The author's examination of the type material of *G. plicatum* Berk. and *G. tenuipes* Berk. shows that, whilst both specimens deviate in some respects from the typical European form of *G. pectinatum*, the differences do not appear to warrant their separation as distinct species when taking into account the climatic conditions. However, the *Fleshy Layer* with the characteristic columnar structure around the *Pedicle* which, after its shrinkage to a ring-like appendage lying at the base, has often caused *G. pectinatum* to be confused with *G. bryantii* in Europe, is missing from the type specimens. Also, no record of this structure and little mention of the *Fleshy Layer* is found in the literature or herbarium specimens.

TECHNIQUE.—As in earlier papers in this series, microcharacters have been examined in Erythrosin Ammonia (Palmer 1955) and microscopic characters are camera-lucida drawn. The formulae show minimum, average and maximum measurements.

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GEASTRUM PECTINATUM PERS.

The single sheet bearing this name in Persoon's Herbarium in the Rijksherbarium, Leiden, is numbered H. L. B. 910.262-391 and bears two rather weathered specimens which, being similar in general appearance, probably belong to the same collection.

Overall dimensions: 7.5×8.5 cm. *Exoperidium* with 7 and 8 subdivided, broadly acuminate to narrowly wedge-shaped rays, divided about half-way to the centre and arched at the base. *Mycelial Layer* brown, lightly debris encrusted. Separated in one specimen from the rays. *Fibrillose Layer* varying from a thin, papery structure to a more tough consistency and yellow-ochraceous in colour. *Fleshy Layer* absent. *Endoperidium* 2×2.5 cm, smooth, globose, dark-brown to purplish, stipitate, lighter below with an inconspicuous, upwards tapering *Apophysis* varying from smooth to very faintly striate. *Pedicel* 5×3.5 mm, equal, circular or flattened in section. *Mouth* 6 mm tall, sulcate, conical, brown and merging with the surrounding *Endoperidium*. *Gleba* dark brown. *Capillitium* brown, thick-walled with the lumen indistinct, simple, sometimes very thin and sinuous, occasionally with abrupt bends and encrusted, between 4.4μ and 13.3μ maximum diameters, tapering to 1.2 to 3μ at the tips. *Spores* brown, globose to subglobose, 1-guttulate, thick-walled, 4.2 – 4.5 – 5.1×4.1 – 4.5 – 4.8μ , with flat-topped digitate verrucae, 5.8 – 6.1 – 7.0×5.5 – 5.9 – 6.4μ .

This collection is herewith formally designated as the Neotype.

GEASTRUM PECTINATUM IN BRITAIN

In Britain, the species is sparsely recorded and appears to be of local occurrence although tending to recur annually in established habitats. In the national herbaria, British material appears to be represented by only three collections at the British Museum (Nat. Hist.) and three at the Royal Botanic Gardens, Kew, whilst there are eight collections in the Mycological Herbarium of the Hartley Botanical Laboratories, two of which are also represented in the Kew Herbarium.

Most collections have been made under conifers (*Pinus*, *Picea*, *Taxus*, *Cupressus* and *Chamaecyparis*) whilst those without data usually have coniferous needles adhering to the *Mycelial Layer*. The species is not confined to conifers as the author has seen material from other habitats, i.e. in a hollow *Fraxinus* and from beneath *Crataegus*.

The following description is based on fresh and preserved British material examined by the author.

UNEXPANDED PERIDIA.—No specimens with immature glebae have been seen by the author and, as no account of the basidia appears to have been published, these structures are yet to be described. The eggs, approximately $1.5 \times 2.5 \times 2.5$ μ , although recorded about 5 μ broad by Staněk (1958), are depressed-globose structures, externally densely covered with debris and, being embedded in the substratum, are difficult to locate. Expansion is similar to that for other species and, on completion, the rays are typically recurved with the base arched and the fungus standing on the surface of the *Fleshy Layer*.

FRESHLY-EXPANDED PERIDIA.—On completion of expansion, peridia measure from 2.5 to 9.5 cm of the expanded rays. *Exoperidium* non-hygroscopic, fissuring into 5–10 broadly acuminate to narrow, wedge-shaped rays, often subdividing at the tips. The base is usually arched. *Mycelial Layer* densely coated with the substratum, usually coniferous needles, cream in colour and very persistent. *Fibrillose Layer* tough and leathery, whitish where exposed. *Fleshy Layer* whitish at first, becoming creamy-brown, often rimose, from 3 to 4.5 mm thick, continuous over the ray surface but frequently cracking or fissuring, although rarely flaking away, and forming a thick columnar structure which completely encloses the *Pedicel* and

flares out above where it is in close contact with the lower part of the *Endoperidium*, not infrequently corrugated where it has been in contact with the furrowed base of the *Endoperidium*. A slightly pungent or soapy odour and a somewhat bitter taste have been detected. *Endoperidium* 5–25 × 7–25 mm, depressed-globose to obturbinate, usually somewhat hemispherical in profile with the basal part lobed, smooth, purplish-brown to greyish-purple or very occasionally creamy-ochraceous, smooth to finely pubescent, often coated with whitish granules or a grey to buff farinaceous deposit. The base is obscured by the columnar structure of the *Fleshy Layer* but, on exposure, the upwards tapering *Apophysis* is found to vary from smooth through varying degrees of striae to plicate with such corrugations being partly decurrent down the upper part of the *Pedicel*. *Mouth* to 6 mm tall, conical, brown, sulcate, merging into the surrounding *Endoperidium*, rarely in a depressed area, typically acute but occasionally tubular and varying from typically conical to almost plain. *Gleba* dark-brown. *Columella* fusiform to broadly ellipsoid, about two-thirds of the endoperidial height.

DRIED OR WEATHERED EXPANDED PERIDIA.—Individuals which have dried under optimum conditions, either in the field or after collection, usually have the *Fleshy Layer* adhering to the rays as dried-up brown remnants with the columnar structure collapsed round the base of the *Pedicel* as a ring or collar.

Weathered specimens, often collected during the following Spring, have usually lost all traces of their *Fleshy Layer* and the persistent *Mycelial Layer* may also have disappeared. The exposed *Fibrillose Layer* varies from ochraceous to buff on the upper part, which is often green with algae, and the under part, after the *Mycelial Layer* has separated, is of a similar colour but, occasionally, silvery white. The *Pedicel* is now clearly apparent, 3–10 × 1.8–6 mm, varying in section from circular to elliptical, usually somewhat narrower at the middle but broadening out gradually above to form a thick base to the *Endoperidium* which becomes a somewhat inconspicuous, usually upwards tapering *Apophysis* when the *Endoperidium* shrinks. During damp conditions, or if the fungus is soaked, the *Endoperidium* resumes its original shape and size and the *Apophysis* virtually disappears.

MICROSCOPICAL CHARACTERS.—*Capillitium* brown, simple, rarely with narrow, usually short, side branches, nodular to rough, occasionally sinuous and sometimes with abrupt bends, thick-walled, with a prominent to an indistinct lumen, 1130–2570 μ long, with maximum diameters of the threads 6–17.5 μ, tapering to blunt ends ca. 2 μ thick. *Spores* brown, globose, typically with long, flat-topped warts, occasionally with a central guttule, but varying to rough or smooth, 3.6–4.7–6.2 × 3.6–4.6–5.5 μ, with the flat-topped, digitate verrucae 4.5–6.9–8.4 × 4.6–6.7–8.4 μ.

COLLECTIONS IN HERBARIA

Variations are to be found in all collections and only the most noteworthy are discussed.

BRITISH MUSEUM (NAT. HIST.), LONDON.—

(1) Without locality. November 1875. Det. as *Geaster striatus* DC. Leg. Rev. G. H. Sawyer (Herb. C. E. Broome). *Apophyses* with deeply decurrent sulcations. *Spores* with digitate verrucae 5.9–6.8–7.6 × 5.2–6.5–7.4 μ. Thick needle litter adhering to *Mycelial Layer*.

(2) Banner Down, Batheaston, Somerset, April 1869. Det. as *Geaster striatus* DC. Leg. Mr. Williams (Herb. C. E. Broome). *Mycelial Layer* absent. *Apophysis* with striations. *Spores* coarsely verrucosae, 6.3–6.7–7.6 × 5.2–6.2–6.8 μ.

(3) Dropmore, Berks., October 1867. Det. as *G. striatus* (Herb. C. E. Broome). *Mycelial Layer* with clayey soil and needles. *Endoperidium* prominently sulcate. *Spores* with digitate verrucae, $5.8-6.8-7.8 \times 5.8-6.6-7.7 \mu$.

THE HARTLEY BOTANICAL LABORATORIES, LIVERPOOL.—

LIVU 1000: Holkham Gap, Norfolk. 6 October 1958. In sand amongst short grass under *Pinus nigra*. Leg. *J. T. Palmer*. *Mycelial Layer* mainly coated with sand and debris but appearing light brown and split to show *Fibrillose Layer* where the adhering substrate is denuded. *Endoperidia* mainly purplish-brown but buff in one specimen. *Apophyses* slightly to moderately swollen, always upwards tapering and varying from smooth to sulcate. *Spores* with digitate verrucae, $6.4-7.7-8.4 \times 6.5-7.6-8.4 \mu$.

LIVU 1112: Coed Pwll-y-blawd, Denbighshire, Wales. 8 May 1952. Leg. *A. E. Willett*. On grassy bank beneath *Picea excelsa*, on limestone. *Mycelial Layer* with needle debris. *Endoperidium* with upwardly tapering *Apophyses* with striations. *Spores* with digitate verrucae, $5.6-6.6-7.6 \times 5.6-6.3-7.0 \mu$. Recorded by Palmer (1952).

LIVU 1114: As for above. 21 October and 1 November 1953. Leg. *J. T. Palmer*. *Apophyses* inconspicuous and varying from striate to sulcate. *Spores* with digitate verrucae, $6.3-7.4-8.2 \times 6.3-7.0-7.6 \mu$.

LIVU 1129: Under *Taxus* and *Fagus* on chalk downs, Mickleham, Surrey. 1 June 1953. Leg. *R. W. G. Dennis*. Weathered previous year's specimen with abundant needle debris clinging to the *Mycelial Layer*. *Endoperidium* shrunken into a rim-like *Apophysis* with plications beneath. *Spores* with digitate verrucae, $6.2-7.3-7.9 \times 5.7-6.9-7.8 \mu$.

LIVU 1158: Under *Pinus* sp., Holkham Meols, Norfolk. 3 November 1954. Leg. *T. J. Wallace*. *Mycelial Layer* densely coated with sand and needle debris. *Apophysis* with faint striations but *Endoperidium* tending to collapse and to form a rim-like structure around the *Apophysis*. *Spores* with digitate verrucae, $5.6-6.3-7.2 \times 5.5-6.3-7.2 \mu$.

LIVU 1197: Under *Cupressus macrocarpa* in very large numbers, Friston Forest near Seaford, Sussex. 17 November 1956. Leg. *P. K. C. Austwick* and *P. D. Orton*. Very variable in size. *Apophyses* varying from inconspicuous to prominent with the surface from smooth to plicate, often with the *Endoperidium* tending to collapse around it and form a rim-like structure. *Spores* with digitate verrucae, often forming a halo, $5.9-7.0-7.7 \times 5.9-6.8-7.4 \mu$.

LIVU 1200: Amongst litter under *Chamaecyparis lawsoniana glauca*, Royal Horticultural Society's Gardens, Wisley, Ripley, Surrey. 20 November to 4 December 1956. Leg. *W. Sykes* and *R. P. Sease*. *Apophyses* inconspicuous to prominent and smooth to striate. *Spores* with digitate verrucae, $4.5-6.7-7.6 \times 4.6-6.4-7.5 \mu$.

LIVU 1223: Under *Picea excelsa*, on limestone, Fetcham Downs, Surrey. November 1956. Leg. *Winifred M. Parker*. *Apophyses* prominent, striate. *Spores* with digitate verrucae, $5.6-6.6-7.0 \times 5.6-6.4-7.0 \mu$.

THE HERBARIUM, THE ROYAL BOTANIC GARDENS, KEW.—

(1) In a hollow *Fraxinus excelsior*, Hereford. 6 October 1954. Leg. *M. Porter*. *Mycelial Layer* encrusted with humus. *Apophysis* slight and indistinctly striate. *Spores* with digitate verrucae, $4.9-6.9-7.9 \times 4.9-6.6-7.7 \mu$.

CONTINENTAL AND EXTRA-EUROPEAN COLLECTIONS

THE HARTLEY BOTANICAL LABORATORIES, LIVERPOOL.—

LIVU 1206: On coniferous needles, Strausberg near Berlin, Germany, 1952. Leg. *H. H. Handke*. *Apophyses* inconspicuous, striate. *Spores* with digitate verrucae, $6.2-6.8-7.7 \times 6.0-6.6-7.4 \mu$.

LIVU 1207: On coniferous needles, between Blankenheim and Unterharz, Germany. September 1952. Leg. H. H. Handke. *Apophysis* striate. Spores with digitate verrucae, 5.9-6.5-7.0 × 5.6-6.2-6.8 μ.

THE RIJKSHERBARIUM, LEIDEN.

L 939.334-8: Under *Pseudotsuga douglasii*, Bergen op Zoom, prov. Noord-Brabant. Leg. J. Schreinemakers. November 1923. *Apophysis* with faint striae. Spores with digitate verrucae, 6.0-6.6-7.9 × 5.7-6.3-7.7 μ.

L 939.334-15: Bergen op Zoom, prov. Noord-Brabant. Leg. J. Schreinemakers. 26 August 1924. *Apophyses* smooth to faintly striate or sulcate in one specimen. Spores with digitate verrucae, 6.5-7.2-7.8 × 6.4-7.0-7.8 μ.

L 939.334-16: Under *Picea*, Wapenvelde, prov. Gelderland. Leg. W. van der Meulen. October 1924. *Apophyses* with prominent basal striations. Spores with prominent verrucae, 5.1-6.2-7.3 × 5.1-6.1-6.7 μ.

L 949.204-137: Wapenvelde, prov. Gelderland. Leg. W. van der Meulen. October 1924. *Apophyses* striate to faintly sulcate. Spores with digitate verrucae, 5.5-6.6-7.8 × 5.0-6.3-7.1 μ.

L 939.334-17: Wapenvelde, prov. Gelderland. Leg. W. van der Meulen. *Apophyses* with basal striations. Spores with digitate verrucae, 4.7-6.8-7.9 × 4.7-6.5-7.7 μ.

L 939.334-18: In *Picea* wood, Wapenvelde, prov. Gelderland. 31 August 1920. Leg. W. van der Meulen. *Apophyses* striate to sulcate. Spores with a halo of digitate verrucae, 6.3-6.9-7.4 × 6.2-6.7-7.3 μ.

L 949.204-129: Wapenvelde, prov. Gelderland. October 1922. Leg. W. van der Meulen. *Apophysis* with basal sulcations. Spores with well spaced digitate verrucae, 5.4-7.4-8.5 × 5.4-7.2-8.1 μ.

L 939.334-19: Coniferous wood on the dunes. Oraniekom. Vogelenzang, prov. Noord-Holland. Leg. Duyvestein and Klein. December 1912. *Apophyses* varying from smooth to faintly striate. Spores with digitate verrucae, 5.4-7.0-8.1 × 5.4-6.9-7.8 μ.

L 939.334-20: Without data. Leg. C. Cool. *Apophyses* with strong striations. Spores with digitate verrucae, 6.2-6.8-7.8 × 6.2-6.5-7.6 μ.

L 939.334-21: "Naaldenveld", Aerdenhout, prov. Noord-Holland. Leg. E. Kits van Waveren. 28 April 1924. *Mycelial Layer* coated with sand and humus. *Apophysis* striate. Spores with digitate verrucae, 5.0-6.4-7.5 × 5.1-6.4-7.5 μ.

L 952.119-569: On the dunes northerly of Beverwijk, prov. Noord-Holland. 1951. Leg. H. J. van der Laan. *Mycelial Layer* debris encrusted. *Apophysis* prominently striate. Spores with digitate verrucae, 5.9-6.6-7.8 × 5.9-6.4-7.4 μ.

L 955.052-182: Previous year's specimen amongst moss on sand under *Pinus* sp. in the dunes, Vogelenzang, prov. Noord-Holland. Leg. R. A. Maas Geesteranus. 11 April 1955. *Mycelial Layer* missing. *Apophysis* with prominent striations. Spores with digitate verrucae, 5.4-6.6-7.8 × 5.1-6.1-7.0 μ.

L 955.118-113: Dunes, Oosterbeek, prov. Gelderland. Leg. B. K. Boom. 15 October 1924. *Mycelial Layer* debris and needle encrusted. *Apophyses* almost smooth to faintly striate. Spores with digitate verrucae, 5.9-7.1-8.2 × 5.9-6.8-7.7 μ.

THE HERBARIUM, THE ROYAL BOTANIC GARDENS, KEW.—

Only two of the extra-European collections examined are dealt with here as they are typical of the European form of *Geastrum pectinatum*. The other collections can be found under *Geastrum plicatum* Berk. and *G. tenuipes* Berk.

(1) Union Department of Agriculture, Mycological Herbarium No. 1337. Under trees, Garstfontein, Pretoria Dist., South Africa. Leg. E. M. Doidge. 11 March 1911. Det. as *G. tenuipes*. *Mycelial Layer* whitish and heavily encrusted with deciduous leaf-mould. *Fleshy Layer*

creamy-brown (originally probably cream), thick, not fissuring, with remnants of a columnar structure around the *Pedicel*. *Apophysis* tapering upwards with deep plications partly filled by the fawn farinose deposit. *Spores* with very coarse, nodular verrucae, $6.8-7.5-8.5 \times 6.5-7.1-8.2 \mu$. This was cited under *G. pectinatum* by Bottomley, (1948).

(2) Phytologic Museum of Melbourne. Baron Ferd. von Mueller. Upper Hunter River, N.S. Wales, Australia. Leg. Miss Carter. *Mycelial Layer* thickly bound with soil. *Fleshy Layer* of dried-up, dark-brown remnants. *Apophysis* tapering upwards with prominent sulcations. *Spores* with digitate verrucae, $4.6-6.5-7.9 \times 4.6-6.3-7.6 \mu$.

GEASTRUM PECTINATUM IN LITERATURE

The diagnosis of Persoon (1801) reads:—

“Peridio pedicellato umbrino: ore acuto conico, radiis multifidis fornicatis pallidis . . . *Laciniae* s. radii, laxae, in- aut extrorsum reflexae. *Pedicelli* saepe sulcati. *Peridium* utrinque subattenuatum, punctatum, plicatum. Oris fimbriae longiores et crassiores quam in praecedente. Colore umbrinum.”

He cited the excellent figures of Schmidel (1776), i.e. Tab. 145 (*Lycoperdon volvam reflectens cre pectinato*), Figs. 11–14, and *Geastrum multifidum* var. *a* of his earlier work (1797). Later, Persoon (1809) wrote: “C’est une des plus grandes espèces, les rayons sont entièrement réfléchis, blanchâtres et minces. Le périдие est un peu brunâtre.” His illustration (Pl. II, Fig. 4), shows the *Exoperidium* divided into eight expanded rays tending to curl inwards, with an arched base, a tall, stout, \pm equal *Pedicel*, a globose *Endoperidium* and a sulcate *Mouth*. There are no indications of either striae, sulcations or an *Apophysis* at the base of the *Endoperidium* and the *Fleshy Layer* is missing.

Tab. XXXVII of Schmidel (1776) portrays both *Geastrum pectinatum* and *G. quadrifidum* Pers. as *Lycoperdon volvam reflectens ore pectinato*. Figs. 14 and 15 show very typical desiccated specimens of *G. pectinatum* with remnants of the *Fleshy Layer* persisting on the rays and the collapsed collar-like columnar structure round the *Pedicel*. The *Mouths* are sulcate and conical. Figs. 13 and 14 are less certain for *G. pectinatum* as they show a more flattened sulcate *Mouth*, upwards of ten rays and rather swollen, smooth *Apophyses*. Hollós (1904) referred them to *Geastrum limbatum* Fr. (= *G. coronatum* Pers.), although this species is admirably represented in Schmidel’s plate, Tab. XLVI, Figs. 1–6, as *Lycoperdon volvam explanans*.

Desvaux (1809) recombined the specific epithet as *Plecostoma pectinatum* but this name does not seem to have been taken up elsewhere.

Fries (1829) confused the issue by placing Persoon’s species under both *Geastrum fornicatum* and *G. striatum*, whilst Schmidel’s Tab. XXXVII is referred to *G. fornicatum*.

Tab. 5, fig. 3 of Fuckel (1870) for *Geastrum calyculatum* Fckl. n. sp. shows what appears to be the endoperidial basal collar of *G. bryantii* with the collapsed columnar structure of *G. pectinatum* at the base of the *Pedicel*. Fuckel stated ‘peridio supra annulo constricto, longitudinaliter plicato’ but this seems to refer to the constrictions shown on the side of the *Endoperidium* in his figure and not to the characteristic structure on the *Apophysis* in *G. pectinatum*.

In Britain, Smith (1873) illustrated *G. pectinatum* by his Fig. 95 as *G. limbatum* Fr. His figure shows a geaster with a long *Pedicel* and a tall, conical *Mouth* which,

being republished in Plowright (1873) and Ramsbottom (1923), has tended to confuse British mycologists to the present day. The species described and figured by Massee (1889) under *G. schmideli* is undoubtedly also *G. pectinatum*.

Scherffel (1896) described the species as new as *Geaster Bryantii* Berk. forma *fallax* on the grounds of the basal ring which, of course, is the dried-up remains of the columnar structure and remarking on the 'often beautiful radially grooved *Apophysis*'.

Hollós (1902) appears to have re-established the name *Geastrum pectinatum* Pers., subsequently taken up by Lloyd (1902), and the species has since appeared under this name in most European monographs.

Outside Europe, Cunningham (1926 & 1944) experienced difficulty in determining Australian specimens, and this problem is dealt with separately under *Geastrum plicatum*.

TAXONOMIC CRITERIA

Geastrum pectinatum belongs to the group of geasters with a non-hygroscopic *Exoperidium*, a smooth *Endoperidium* and a sulcate *Mouth*.

The taxonomic characters are (a) the depressed-globose form of the egg, which develops immersed in the substratum, (b) the arched form of the fully expanded *Exoperidium*, usually with the rays revolute, (c) the whitish colour of the *Fleshy Layer* (only apparent in freshly expanded specimens); (d) the characteristic columnar structure which completely surrounds the *Pedicel* and obscures the wrinkles or furrows of the base of the *Endoperidium* on expansion but later shrivels or completely disappears to reveal (e) the tall *Pedicel* and (f) the upwards tapering, somewhat inconspicuous *Apophysis* with (g) a surface varying from smooth through varying grades of striae to plicate, (h) the smooth *Endoperidium*, (i) the tall, conical to tubular, sulcate *Mouth*, rarely seated in a depressed area, (j) the thick *Capillitium* with maximum diameters varying from 6 μ to 17.5 μ , but usually rarely exceeding 10 μ , and (k) the typically digitate verrucae of the *Spores*, from 4.6 μ to 8.5 μ including the warts, with the verrucae often in the form of a halo.

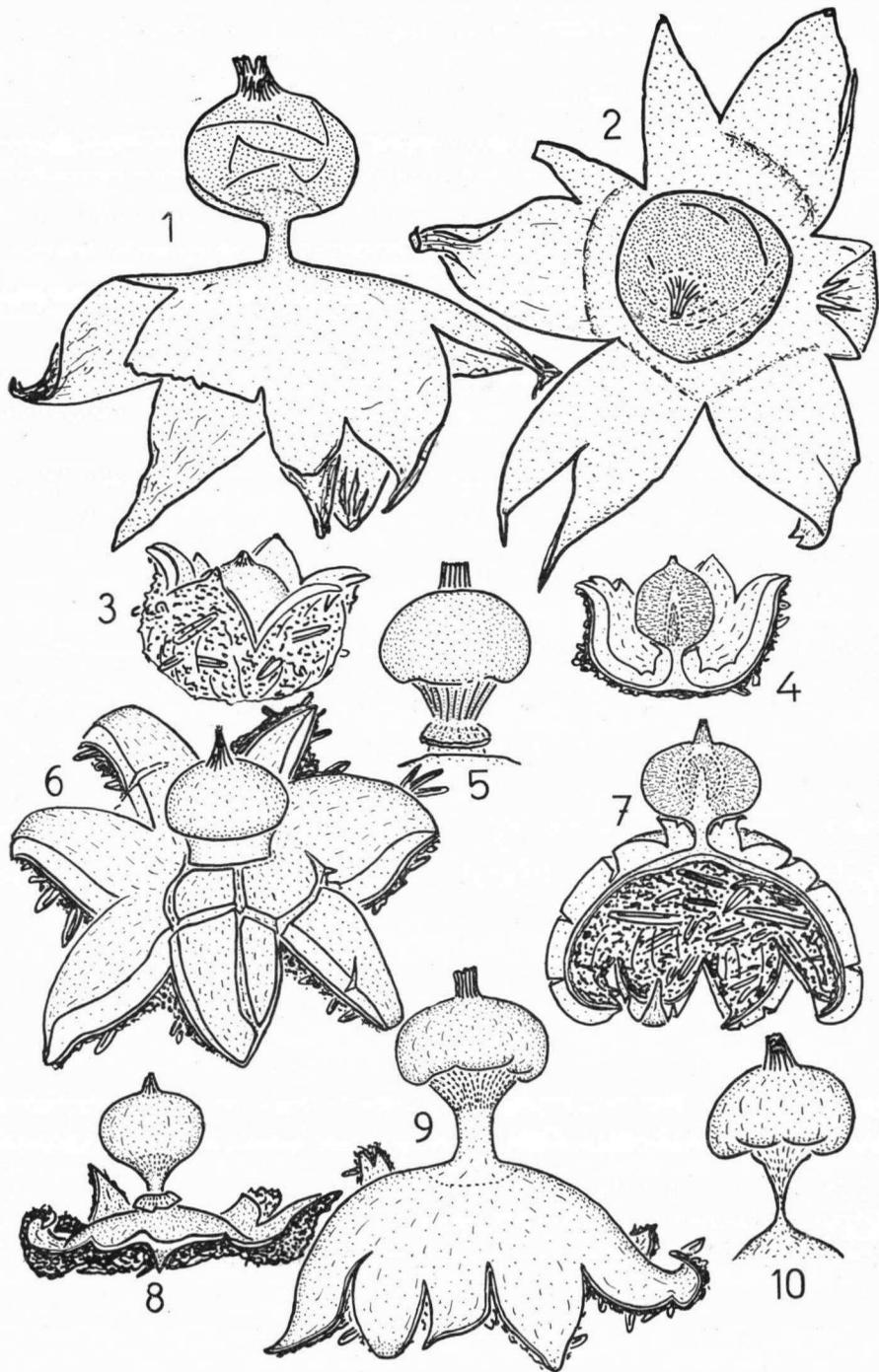
The *Peridium* develops hypogeously as a depressed-globose structure, hence the *Mycelial Layer* is densely coated with the substratum, and, on expansion, the base becomes arched with the rays typically revolute, although sometimes expanded to involute. Dried specimens in the latter condition have usually been collected before expansion has been completed or have been prevented from expanding fully by being deeply immersed in the substratum.

The *Fleshy Layer* has received little attention, mainly because, as with other species of *Geastrum*, specimens are so often collected in an old, weathered condition when this layer has completely disappeared. The columnar structure formed round the *Pedicel* is unrecorded in British literature but is shown in great detail by Eberle (1951a-b and 1956). Published photographs showing this layer, often with allusions in the text, are given by Lloyd (1902), Bottomley (1948) and Staněk (1958). *Geastrum nanum* Pers., which has a short *Pedicel* and a prominent *Apophysis*, has a *Fleshy Layer* plane with the base of the *Endoperidium* when freshly expanded. *Geastrum bryantii*, on the other hand, has a short columnar structure which fills the interior of the collar at the base of the *Endoperidium* and is well illustrated in the figures of Eberle

Figs. 1-10. *Geastrum pectinatum* Pers.—Macroscopic 1 \times .

Figs. 1-2. Neotype in L: Persoon's specimens.

Figs. 3-10. British *G. pectinatum* from LIVU 1114 except 5, which is from LIVU 1197: 3—expanding egg and 4—section; 5—dried specimen showing collapsed columnar structure and grooved *Apophysis*; 6—freshly expanded specimen and 7—section; 8—dried specimen showing collapsed columnar structure and finely striate *Apophysis*; 9—weathered specimen with a flattened *Pedicel* and 10—side view of *Endoperidium* and *Pedicel*.



(1951a-b) and in the photographs of Staněk (1958) as *Geastrum striatum* DC. f. *striatum*.

The *Pedicel* is typically long but varies from circular to elliptical or oblong in cross section, from slender to thick and from equal to narrower in the middle with considerable variation being found within the same collection. The upper part of the *Pedicel* gradually broadens to form an upwards tapering *Apophysis*, which is usually inconspicuous. The surface of the *Apophysis*, i.e. the lower part of the *Endoperidium*, typically varies from striate to plicate although occasional specimens are met with a smooth surface. These corrugations are present beneath the columnar structure in freshly expanded specimens and are, therefore, not the result of shrinkage. As was pointed out by the author (1958) for *Geastrum vulgatum* Vitt., the *Apophysis* is due to the thick layer formed by the upper part of the *Pedicel* where it becomes the lower part of the *Endoperidium*.

The shape of the *Endoperidium* is typically depressed globose and it is not unusual to find the lower part hanging in lobes over the rigid upwards tapering *Apophysis*, where they frequently form a rim-like structure.

The *Capillitium* is usually given as having a similar diameter as the *Spores*, i.e. 4-7 μ , but Eckblad (1955) gives measurements up to 9.5 μ , Staněk to 10.5 μ and the author finds that, whilst mainly under 10 μ , the threads may be as wide as 17.5 μ .

Spore dimensions are usually given as being within the range 4-7 μ but Bottomley (1948) records the dimensions 3.5-5.1 μ and Staněk (1958) 6-7.5 μ . The author's measurements are 3.6-4.5-6.2 \times 3.6-4.5-5.5 μ without verrucae and 4.5-7.0-8.5 \times 4.6-6.5-8.4 μ when the verrucae are included. Whilst most authors refer to the very coarse verrucae, their characteristic digitate structure appears to have been first remarked upon by Nečásek (1947). However, in all collections, many *Spores* have been observed collapsed, smooth or with part of their ornamentation missing. It would appear that the coarse verrucae are readily abraded and only *Spores* showing normal verrucae have been measured and the smooth or collapsed *Spores* have been omitted as being atypical.

In Europe, like most species of *Geastrum*, *G. pectinatum* is autumnal in occurrence, and freshly expanding peridia have been observed by the author from September to November. The species is typically found beneath conifers, especially *Picea excelsa*, but occasional collections have been made in other associations. *G. pectinatum* is not a frequent fungus in Europe, although Fries (1922) reported it to be not uncommon in Sweden, where it appears to have the most northerly distribution of the genus. The records indicate a calcareous habitat and Sandberg (1940) reported a collection under *P. excelsa* in Sweden with pH indices of 5.92 for the needle litter and 6.94 for the raw humus layer beneath.

GEASTRUM PLICATUM BERK.

BERKELEY'S SPECIMEN.—The type sheet in Herb. Kew bears a single specimen marked "*Geastrum plicatum* Berk. TYPE" followed by "*Geaster striatum* γ *plicatus* Klotzsch Madras Dr. Wight" and a long Latin description. The sheet is stamped "Herbarium Hookerianum 1867."

The single specimen has a non-hygroscopic *Exoperidium* measuring approximately 5.2 \times 4.3 cm of the expanded rays, divided for almost half the radius into 7 broadly to narrowly acuminate rays, subdividing and often ragged at the tips, with the base arched. *Mycelial Layer* absent except for a few encrusted soil fragments. *Fibrillose*

Layer completely absent. *Pedicel* 6.5 mm tall, equal, circular in section. *Endoperidium* $8 \times 14 \times 12$ mm, depressed globose, smooth, purplish-grey and coated with a fine buff farina. Base plane, with a rim-like *Apophysis* on the underside of which are deep, broad plications radiating outwards from the apex of the *Pedicel* and densely coated with the buff farinose deposit. *Mouth* sulcate, brown, heavily coated with the buff farina, seated in a depressed area but not clearly demarcated from the remainder of the *Endoperidium*, conical and up to 4.3 mm tall. *Columella* not examined as there was only a single specimen. *Gleba* dark brown. *Capillitium* brown, formed of simple threads about 1500μ long with occasional thin side branches, particularly towards the tips, with maximum breadth varying from 4.9μ to 10.5μ and tapering to ca. 2μ at the tips, thick-walled, encrusted and occasionally rather irregular. *Spores* brown, globose, contents obscured, $4.5-4.9-5.4 \times 4.5-4.8-5.4 \mu$, with digitate, flat-topped verrucae, $5.9-6.7-7.3 \times 6.3-6.6-7.1 \mu$.

Type locality: Madras, India.

BERKELEY'S DESCRIPTION OF *GEASTRUM PLICATUM*.—The original description of Berkeley (1839) reads:—

"*Geaster plicatus* Berk. *Geaster striatus*, γ *plicatus*, Kl. Mss. in Hook. Herb. Outer peridium soft, papyraceous, pale umber, smooth; laciniae about 7, acute; inner peridium seated on a long peduncle, globose, dark umber, smooth, strongly plicate at the base; orifice seated in a circular depression, conical, plicato-sulcate. Sporidia brown.

Madras. Dr. Wight. Nearly allied to *G. striatus*, β . *minimum*, but certainly distinct. The folds at the base of the inner peridium are very remarkable."

MATERIAL IN HERB. KEW UNDER *GEASTRUM PLICATUM*.—Besides the type specimen, there are three Ceylonese collections and one Australian collection determined as *G. plicatum* and there is also a Sudanese collection determined as *G. pectinatum* which requires treatment under this species.

(1) Labelled: "4593. *Geaster plicatus* Berk. Hakgala, May, 1913." Three weathered specimens with expanded *Exoperidia* up to 4.5 cm. *Fleshy Layer* completely absent and *Pedicel* up to 5 mm tall with the *Endoperidium* purplish-brown to grey, finely coated with white farina and a somewhat tubular *Mouth* merging with the surrounding *Endoperidium*. *Capillitium* $5.4-6.8 \mu$ and *Spores* $4.9-5.3-5.7 \times 4.9-5.1-5.7 \mu$, with broad, blunt verrucae, $6.5-7.1-8.2 \times 6.2-7.0-7.5 \mu$.

(2) Labelled: "4471. *Geaster plicatus* Berk. Peradeniya, Dec. 1914." Two loose specimens with a maximum diameter of 6.5 cm for the expanded rays. *Fleshy Layer* absent and *Pedicels* tall (4 mm and 6 mm). *Endoperidium* purplish-brown with a fawn farinaceous deposit and a tall, conical *Mouth* which merges with the surrounding *Endoperidium*. *Capillitium* with a maximum diameter of $5.5-9.8 \mu$ and *Spores* $3.8-4.2-4.6 \times 3.6-4.1-4.6 \mu$, very coarsely verrucose, typically with a halo of digitate verrucae, $5.2-6.0-6.7 \times 4.9-5.8-6.5 \mu$.

(3) Labelled: "*Geaster plicatus* Berk. No. 218. Hakgala. March, 1922." Four loose, rather small specimens with soil debris adhering to the *Mycelial Layer*. *Fleshy Layer* persisting in only one specimen as a dried-up creamy remnant with fragments around the *Pedicel* indicating that a columnar structure had originally been present. *Pedicel* up to 3.5 mm tall and tapering upwards into the *Endoperidium*. *Endoperidium* buffy-brown with a farinose deposit on the surface. *Capillitium* with a maximum diameter of $4.2-6 \mu$. *Spores* $3.6-4.4-5.2 \times 3.6-4.3-4.9 \mu$, coarsely warted, often close and halo-like, $5.7-6.3-6.7 \times 5.2-6.0-6.7 \mu$.

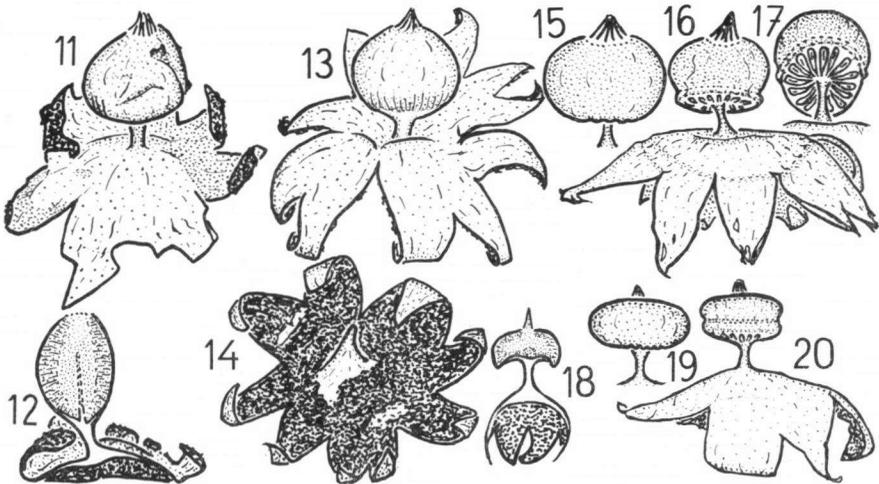
(4) Labelled: "*Geaster plicatus* Berk. Eidsvold, near Brisbane, Australia. Aug., 1913. Leg. T. L. Bancroft." Single specimen measuring approximately 5 cm of the expanded rays. *Fleshy Layer* persisting as a fissured brown layer with the remains of a columnar structure at the

base of the *Pedicel* (5 mm tall) with the surface coated with a white, woolly or farinose deposit. *Endoperidium* purplish-brown, densely coated with the white deposit which also fills the plications of both the plane rim-like *Apophysis* and the tall, conical *Mouth*. *Capillitium* 6.8–10.1 μ and *Spores* 4.4–4.7–5.1 \times 4.2–4.6–4.9 μ , typically with a halo of digitate verrucae, 5.1–6.6–7.1 \times 5.1–6.4–6.7 μ .

(5) The following collection, whilst determined as *Geastrum pectinatum*, requires treatment under *G. plicatum*. J.T. 1972. Sudan Mycological Herbarium. On the ground, Kagelu. Leg. J. K. Jackson. 21 August 1951.

A loose, weathered *Peridium* with the *Fleshy Layer* absent. *Pedicel* 11 mm tall with a broadly upwards tapering *Apophysis* bearing deep, prominent plications up to 8 mm long. *Spores* with irregular digitate verrucae, 5.5–6.5–7.6 \times 5.5–6.2–7.0 μ .

GEASTRUM PLICATUM BERK. IN LITERATURE.—In Australasia, Cunningham (1926) experienced difficulty in separating *Geastrum pectinatum*, *G. plicatum* and *G. bryantii*. He considered that they were better treated as subspecies distinguished by the base of the *Endoperidium* being smooth or slightly striate in *G. pectinatum*, plicate in *G. plicatum* and having a well-defined collar or ring in *G. bryantii*. Later (1944), he



Figs. 11–14. *Geastrum tenuipes* Berk.—Macroscopic 1 \times .

Figs. 11–12. Berkeley's specimens: 11—the only specimen still showing the *Mouth* characters; 12—section of a specimen.

Figs. 13–14. Cooke's specimen; 14—showing the peculiarly pointed base.

Figs. 15–20. *Geastrum plicatum* Berk.—Macroscopic 1 \times .

Figs. 15–17. Berkeley's specimen: 16—showing the *Endoperidium* contracted when desiccated; 15—“plumped out” after soaking; 17—the plicate base of the *Endoperidium*, i.e. the plane *Apophysis*.

Figs. 18–20. Hakgala collection in K (No. 218): 20—dried, weathered specimen showing *Endoperidium* contracted and 19—“plumped out” after soaking; 18—section of an expanded specimen.

referred to a collection of *G. plicatum* exhibiting both the collar of *G. bryantii* and the plicate base. Most authors regard *G. plicatum* as a synonym of *G. pectinatum*.

DISCUSSION.—The material examined differs from typical specimens of *G. pectinatum* by the plane base to the *Endoperidium* with the rim-like *Apophysis* bearing deep, broad plications beneath which radiate outwards from the apex of the *Pedicel* and are not decurrent. Otherwise the characters of these collections can be matched with those in various forms of European *G. pectinatum* and even the plane plicate *Apophysis* is similar to the structure found in the specimen of *G. pectinatum* collected at Mickleham, Surrey (LIVU 1129). Unless further evidence is forthcoming regarding the freshly expanded condition of this form, the author prefers to treat it as a synonym of *G. pectinatum*.

GEASTRUM TENUIPES BERK.

THE TYPE FOLDER IN HERB. KEW.—The sheet in the type folder bears five collections but only one of these can be considered to be authentic material. There is, however, a collection from Tasmania which may have been part of the original collection, and there is also a collection from Cuba which resembles the *G. tenuipes* type specimens. The remaining two collections are typical *G. pectinatum* and have been dealt with under that species.

BERKELEY'S SPECIMENS.—There are three specimens labelled: "*Geaster tenuipes* Berk. 1778. Tasmania. Gunn."

They are all damaged to some extent and only one specimen has a recognizable *Mouth*. *Exoperidium* non-hygroscopic, divided into six (two specimens) and seven broadly acuminate, ragged rays which tend to subdivide, extending halfway to the centre, recurved, with an arched base. Ray diameters varying from 3.5 cm to 4.3 cm. *Mycelial Layer* soil encrusted but absent in parts. *Fibrillose Layer* varying from flaccid to papery, buffy-ochraceous. *Fleshy Layer* consisting of a dried-up brownish layer, missing in parts, with no evidence of a columnar structure. *Pedicel* $3 \times 1-1.6$ mm, circular to elliptical in section. *Endoperidium* globose to obovate, buffy-ochraceous to brown with a slight purplish cast, $1.2-1.3 \times 1.2-1.4 \times 1-1.2$ cm. Base gradually tapering upwards from the apex of the *Pedicel* and forming an inconspicuous *Apophysis* with the surface varying from faintly wrinkled to inconspicuously sulcate. *Mouth* (destroyed in two specimens) sulcate, conical, concolorous with the surrounding *Endoperidium*, with which it merges, and seated within a depressed area. *Columella* appearing to comprise a tall, thin, plate-like structure. *Capillitium* brown, simple, but with mainly short narrow side branches, mostly at the tips, 820-1850 μ long, with maximum diameters of 5.7-7.6 μ , tapering to ca. 2 μ blunt tips, with the lumen indistinct. *Spores* brown, globose to subglobose, occasionally a single guttule seen, $4.1-4.6-5.0 \times 3.6-4.5-4.9$ μ , with close, irregular verrucae, $5.7-6.1-6.7 \times 4.6-5.9-6.5$ μ .

Type locality: Tasmania.

BERKELEY'S DESCRIPTION OF GEASTRUM TENUIPES.—The original description of *Geastrum tenuipes* Berk. in Berkeley (1848) reads:—

"*Geaster tenuipes* n.s.; peridio exteriore simplici multifido reflexo; interiore longe pedicellato ovato subtus leviter plicato; ore prominente conico plicato sulcato. Gunn. No. 1778. HAB. On the ground."

The species is frequently cited as having been published in the *Flora Tasmaniae* II (1860), which gives a figure.

FURTHER SPECIMENS IN HERB. KEW UNDER *G. TENUIPES*.—There are only two collections worthy of consideration.

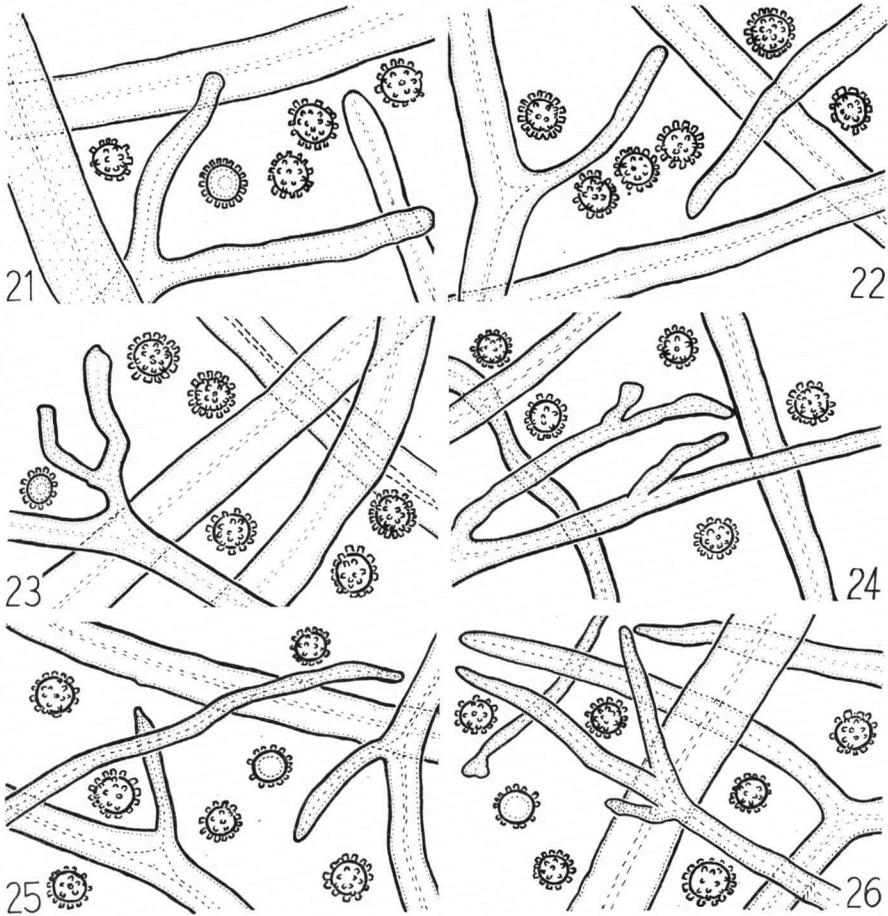
(1) A single specimen from Herb. Mycol. M. C. Cooke labelled: "*Geaster tenuipes*, B. Tasmania." The fungus is in very good condition but is somewhat weathered with only a few brownish remnants of the *Fleshy Layer* persisting on the ray surfaces. *Exoperidium* somewhat saccate, divided into 8 broadly to narrowly acuminate rays, 5 cm diameter of the expanded rays, with the base forming a thick, pointed, rooted structure. *Mycelial Layer* cream and heavily soil encrusted. *Fibrillose Layer* tough, creamy-ochraceous. *Fleshy Layer* comprising only a few brownish remnants persisting on the ray surfaces. *Pedice*l 3 × 1.2 mm, elliptical in section. *Endoperidium* 1.3 × 1.2 × 0.8 cm, obovate, buff above and purple to greyish below, where it is somewhat swollen into an *Apophysis* with a wrinkled to sulcate surface. *Mouth* sulcate, 2.5 mm tall, conical and merging with the surrounding *Endoperidium*, buff. *Gleba* brown. *Capillitium* brown, mainly simple, 1310–1950 μ , with very occasional narrow side branches, with maximum diameters varying from 5.2–7.8 μ , tapering to about 2 μ . *Spores* brown, globose, occasionally with a single guttule, 4.1–4.8–5.2 × 3.9–4.8–5.2 μ , with prominent but often irregular verrucae, 5.4–6.3–7.5 × 5.2–6.0–6.8 μ .

Whilst this specimen may possibly be part of the type collection, in view of the peculiar base, it seems preferable to regard it as being distinct. However, Plate 183, fig. 9 in Berkeley (1860) depicts a geaster closely resembling this specimen.

(2) Labelled: "694. *Geaster tenuipes* B. Cuba Wright (Curtis)". The fungus resembles the type collection of *G. tenuipes* but the *Endoperidium* is purplish-brown and the *Mouth* dark brown. *Pedice*l 5 mm tall. *Endoperidium* with a wrinkled sulcate base. *Mouth*, which is damaged, sulcate and merging with the surrounding *Endoperidium*. *Capillitium* maximum diameters 5.5–8.3 μ . *Spores* brown, globose, 4.6–4.9–5.6 × 4.2–4.8–5.4 μ , varying from regularly to irregularly verrucose with rounded, projecting verrucae, 5.6–6.5–7.7 × 5.6–6.3–7.5 μ .

GEASTRUM TENUIPES BERK. IN LITERATURE.—Lloyd (1905) referred *G. tenuipes* to *G. pectinatum*, and considered it to be smaller and intermediate between *G. pectinatum* and *G. plicatum*. Cunningham (1944) considered *G. tenuipes* to be a synonym of *G. plicatum*. Dennis (1953) referred Wright's collection from Cuba to *G. pectinatum*. In the most recent work on the Gasteromycetes, Staněk (1958) places *G. tenuipes* under *G. pectinatum* as a synonym.

DISCUSSION OF GEASTRUM TENUIPES.—The three collections can probably be referred to *Geastrum pectinatum* although they all differ from each other and from typical *G. pectinatum* in minor respects. The pale *Mouth* in the Tasmanian collections is unusual in *G. pectinatum* and more closely resembles that of *Geastrum nanum*, whose *Mouth* is typically dark brown, and the basal ridges and wrinkles of the *Endoperidium* differ from those normally found in *G. pectinatum* or the form called *G. plicatum*.



Figs. 21-26. Spores and *Capillitium*. Microscopic—1000 \times .

Figs. 21-23. *Geastrum pectinatum*: 21—Neotype in L; 22—L 939.334-18; 23—LIVU 1197.

Figs. 24-25. *Geastrum plicatum*: 24—Hakgala No. 218 in K; 25—Type in K.

Fig. 26. *Geastrum tenuipes*: Type in K.

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