A revision of *Annularia* and *Asterophyllites* species from the lower Westphalian (Middle Pennsylvanian) of the Maritime Provinces of Canada

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Received 15 January 2016 ¶ accepted 28 November 2016

ABSTRACT

As part of a larger project to revise the systematics of lower Westphalian floras of Nova Scotia and New Brunswick, the sphenopsid taxa are presently reviewed. We recognize 15 species, of which one, *Annularia stopesiae*, is new. Detailed synonymy lists allow a refinement of the stratigraphic and geographic ranges of these species. Scant attention has been paid previously to Canadian species in the European literature. For example, *Annularia latifolia* was described later from Europe as *Annularia jongmansii*. The identical composition of Westphalian floras from Canada and western Europe is striking.

RÉSUMÉ

La révision de la flore du Westphalien inférieur de Nouvelle Écosse et Nouveau Brunswick a été continué à présent avec les sphénopsides. Nous avons reconnu quinze espèces, y compris une nouvelle, *Annularia stopesiae*. L'analyse des synonymies a permis établir l'extension stratigraphique ainsi que la répartition géographique de cettes espèces. On constate que les auteurs européens ignoraient souvent les espèces décrites au Canada. Un example à citer est *Annularia latifolia* qui est la même espèce qu'*Annularia jongmansii* décrite en Europe. On constate ausssi, une fois de plus, que la flore westphalienne est identique pour l'Europe occidentale et Canada.

[Traduit par la redaction]

ATLANTIC GEOLOGY 53, 17 - 62 (2017)
0843-5561|17|0017-62 $7.90|0

doi: 10.4138/atlgeol.2017.002

INTRODUCTION

While engaged in the taxonomic revision of upper Namurian to middle Westphalian floras of the Maritime Provinces of Canada, it became apparent that certain forms of the sphenopsid fossil-genera *Annularia* and *Asterophyllites* needed special attention in a broader context. Some of the species of these genera were first described from Canada, but have been referred to only rarely or not at all in the western European literature, despite the palaeogeographic proximity between the Maritime Provinces and Europe, the British Isles in particular. Conversely, some species described from Europe were used only sparingly in Canada and the United States. A more thorough comparison was clearly required. This has led to the recognition of several synonyms, thus leaving a smaller number of accepted species. The oft-quoted resemblance of the Westphalian floras of Canada with those of western Europe is reinforced by a thorough taxonomic revision. Several of Bell's (1944) and Matthew's (1906a, b) specimens are refigured from museum collections. Additional material from New Brunswick and Nova Scotia is also documented.

TAXONOMIC HISTORY

From the classic Fern Ledges locality at Saint John, New Brunswick, Dawson (1861) described as new *Asterophyllites parvulus* (corrected spelling by Jongmans 1914b; originally *Asterophyllites parvula*), which Stopes (1914) compared with *Asterophyllites grandis* and Bell (1944) synonymized with *Asterophyllites charaeformis*. Dawson (1862) introduced *Annularia acicularis* and *Annularia latifolia* (both initially attributed to *Asterophyllites*). Stopes (1914) compared *Annularia acicularis* with *Annularia radiata* and *Asterophyllites equisetiformis*, and *Annularia latifolia* with *Annularia stellata*. Another species introduced by Dawson in 1862 was *Asterophyllites*? *scutigerus* (corrected spelling) for what appear to be stems of *Calamites* (Dawson's pl. XIII, figs. 18, 20). He also recorded a strobilus (his pl. XIII, fig. 19) and *Annularia acuminata*, a species that Dawson refigured in 1871 as *Sporangites acuminata* and comprises sporangial clusters. Dawson (1871) additionally described *Asterophyllites lentus* (corrected spelling by Matthew 1906a). One of Dawson's specimens of *Asterophyllites lentus* was refigured by Stopes (1914) as *Asterophyllites* sp. and compared with *Annularia radiata*. Bell (1944) synonymized *Asterophyllites lentus* with *Annularia acicularis*.

Also from Fern Ledges, Matthew (1906a) described *Asterophyllites fasciculatus*. As Stopes (1914) pointed out, this name was preoccupied, having been used previously by Lesquereux (1879–1880) for a different species from Clinton, Missouri. Although fragmentary and poorly preserved, Matthew's material might be attributable to *Asterophyllites longifolius*. Matthew (1906a) described two additional specimens as *Asterophyllites*? *fissus* and *Annularia longifolia* mutation *leavittii*. The former is here referred to *Asterophyllites longifolius*. Stopes (1914) assigned *Annularia longifolia* mutation *leavittii* (figured photographically in Matthew 1906b, pl. IX) to *Annularia stellata*, but we regard it as belonging to *Annularia inflata* Lesquereux. Two specimens recorded as *Annularia recurva* by Matthew (1906a) were referred to *Annularia acicularis* by Bell (1944), albeit with doubt. Stopes (1914) regarded these two specimens and a more fragmentary one, described by Matthew (1906a) as *Annularia*? *ligata*, as indeterminable; we concur. *Annularia latifolia* var. *minor*, as described by Matthew (1906a), was compared by Stopes (1914) to *Annularia stellata*, but retained in *Annularia latifolia* because of a (slightly) greater width of leaves in the Canadian material. We regard *Annularia latifolia* var. *minor* as a synonym of *Annularia galioides*. We also assign to *Annularia galioides* a specimen from Fern Ledges figured by Bell (1966, pl. VII, fig. 3) as *Annularia latifolia*.

Among the sphenopsids from Fern Ledges, Stopes (1914, pl. V, fig. 7) figured a specimen as *Annularia sphenophylloides*. We agree with Bell (1944), that this specimen was misidentified and should be referred to *Annularia latifolia*.

Bell (1944) incorporated material from New Brunswick with his description of fossil plants from the Cumberland Basin in northern Nova Scotia. He discussed *Annularia latifolia* extensively, and regarded *Annularia latifolia* var. *minor* of Matthew (1906a) as falling within the range of variation of *Annularia latifolia* without necessitating a separate variety. As mentioned above, we regard *Annularia latifolia* var. *minor* as belonging to *Annularia galioides*. Bell (1944) introduced two new species, *Annularia aculeata* and *Annularia asteris*. The former was typified by material from Inverness County, Cape Breton Island, Nova Scotia, whereas the latter came from Tynemouth Creek, near Saint John, New Brunswick, from a level equivalent to that at Fern Ledges. *Annularia aculeata* is here regarded as founded on a mixture of *Annularia ramosa*, *Asterophyllites grandis* and *Asterophyllites charaeformis* (see below). Bell (1944, 1966) also figured two specimens from Springhill, Nova Scotia, as *Annularia stellata* forma *longifolia*. These specimens are refigured here and described as a new species, *Annularia stopesiae*.

The Canadian record contains fewer species than the publications suggest. Our critical revision emphasizes its similarity with the western European record.

REPOSITORY OF SPECIMENS, LOCALITY AND CATALOGUE NUMBERS

The specimens used for the current revision are in the collections of the Geological Survey of Canada, Ottawa (catalogue numbers preceded by GSC) and the New Brunswick Museum (NBMG). More complete information

about GSC localities can be found in the memoirs published by Bell (1938, pp. 108–115; 1940, pp. 133–139; 1944, pp. 111–118; 1962, pp. 63–64).

SYSTEMATIC PALAEOBOTANY

As in our previous revision of the Lycopsida (Álvarez-Vázquez and Wagner 2014), partial lists of synonymy are provided with special emphasis on types and listing all the illustrated records from Canada and the United States for the Middle Pennsylvanian time interval. European records are selective. However, all synonyms as accepted by the present authors are included. Descriptions, comparisons and remarks are included as well as stratigraphic and geographic distributions, and occurrence in Canada and the United States. Stratigraphic occurrences are given in accordance with the western European regional chronostratigraphic subdivisions of the Pennsylvanian Subsystem.

Annotations in the synonymy lists follow those of Cleal *et al.* (1996 — shortened/simplified): * = protologue; § = first publication of currently accepted combination; T = others' photographic illustrations of the type material; ? = references to doubtful specimens due to poor illustration or preservation; p (pars) = only part of the specimens published belong to the species; v (vide) = the authors have seen the specimen(s); cf. = comparable; k = reference includes cuticular evidence; acc. to = according to.

The various species recognized in the Maritime Provinces will be dealt with in alphabetical order within the adpression genera *Annularia* and *Asterophyllites*, which are based on leaves.

Class Equisetopsida Takhtajan ex Němejc 1963
Family Calamitaceae Unger 1840

Genus *Annularia* Sternberg 1821

1820 *Casuarinites* Schlotheim, p. 397 (illegitimate name).
1821 *Annularia* Sternberg, pp. 28, 32.
p 1825 *Bornia* Sternberg, p. 324.
1860 *Trochophyllum* Wood, p. 438 (see Abbott 1958).

TYPE: *Annularia spinulosa* Sternberg 1821

REMARKS: *Annularia* and *Asterophyllites* incorporate small *Calamites*-type articulate axes bearing leaf verticils at each articulation (node). Both genera have single-veined leaves which are more or less united at the base in each verticil. However, the leaves of *Annularia* are linear-lanceolate, lanceolate or spatulate, with the broadest part in the middle of the leaf or near the apex; *Asterophyllites* has narrower, almost parallel-sided leaves, with the broadest part in the lower third, and a pointed apex. Verticils of *Annularia* are usually found as dorsi-ventral adpressions spread out on the bedding plane; leaf whorls in *Annularia* are either isophyllous or markedly anisophyllous. In contrast, the leaves of *Asterophyllites* are usually preserved flattened sideways, parallel to the axis. However, in practice, it is not always possible to separate *Annularia* from *Asterophyllites* in view of the important role played by preservational characters.

Tables 1 and 2 summarize the morphological characters and numerical values of measurements for the different species of *Annularia* and *Asterophyllites*.

Annularia asteris Bell 1944
(Figs. 1a–e)

1869 *Annularia minuta*, Wood, pp. 347–348, pl. VIII, fig. 2 (acc. to Abbott 1958).
1884a *Annularia minuta*?, Lesquereux, pp. 725–726, pl. XCII, figs. 8–8a.
1917 *Annularia spicata*, Kidston *et al.*, pp. 1039–1041, pl. II, figs. 6–7a.
1934 *Annularia* sp., Arnold, p. 187, pl. I, figs. 2, 4 (acc. to Arnold 1949, p. 183).
*v 1944 *Annularia asteris* Bell, pp. 102–103, pl. LXVII, fig. 3 (holotype — partially refigured here as Figs. 1a–c); pl. LXVIII, fig. 5 (enlargement of holotype).
1949 *Annularia asteris*, Arnold, p. 183, pl. XVI, fig. 5 (same as Arnold 1934, pl. I, fig. 2).
* 1952–53 *Annularia subradiata* Stockmans and Willière, pp. 176–177, pl. XXVI, figs. 9–9a (only a brief diagnosis was provided by Stockmans and Willière, who compared with *Annularia radiata*).
p 1958 *Annularia asteris*, Abbott, pp. 310–311, pl. 49, figs. 88, 89 (same specimen as Wood 1869, pl. VIII, fig. 2); non pl. 35, fig. 7 (= *Annularia galioides*); non pl. 39, fig. 48 (= *Annularia galioides*); non pl. 40, fig. 54 (= *Annularia galioides*); non chart 2.
1969 *Annularia spicata*, Crookall, pp. 744–745, pl. CXXIV, fig. 3.
1988 *Annularia subradiata*, Tidwell *et al.*, p. 24, figs. 31–32.
p 1991 *Annularia ramosa*, Josten, Taf. 20, fig. 1; non pp. 75–77, Taf. 20, figs. 2–2a (= *Annularia ramosa*); Abb. 33 (= *Annularia ramosa* — drawing).
? 2000 *Annularia subradiata*, Purkyňová, p. 2, textfig. 1 (drawing).
? 2000 *Annularia asteris*, Purkyňová, pp. 2–3, textfig. 2 (drawing).

Excludenda:
1961 *Annularia asteris*, Leggewie and Schonefeld, pp. 29–30, Taf. 24, figs. 3–4 (= *Annularia galioides*); Taf. 26, figs. 7–8 (= *Annularia galioides*).
1963 *Annularia* cf. *asteris*, Cridland *et al.*, p. 70, pl. 18, fig. 22 (maybe *Annularia spicata*).
1977 *Annularia* cf. *asteris*, Leary and Pfefferkorn, p. 7, pl. 1, fig. 6 (= *Annularia* sp. — leaves with a

Table 1. Parameters used for the discrimination of the different species of *Annularia* in the Maritime Provinces.

	internode length	leaves per verticil	leaf form	apex	length	length/breadth ratio
A. asteris	2.25–3 mm	8–10	parallel-sided	acuminate	2–4.5 mm	10–18
A. fertilis	25 mm	14–16	oblong	acute, mucronate	9–17 mm	4.5–8.5
A. galioides	10–15 mm	10–12	oblanceolate	obtuse	4–6 mm	4–5
A. inflata	20–25 mm	22–24	oblanceolate	obtuse, mucronate	20–25/30-45 mm	8–10
A. latifolia	10–12 mm	12–16	oblanceolate	obtuse, mucronate	8–12 mm	~ 6
A. microphylla	4.5–5 mm	12	sickle-shaped	acute	5–6 mm	10
A. pseudostellata	9–14 mm	10–14	linear	–	20–25 mm (incomplete)	~ 50
A. radiata	10–25 mm	12–16	linear-lanceolate	acute	11–24 mm	11–16
A. ramosa	20 mm	8–12	linear-lanceolate	acute	3.5–8 mm	23–26
A. stopesiae	16–45 mm	20–24	linear-lanceolate	acute	up to 85 mm	50–56

Table 2. Parameters used for the discrimination of the different species of *Asterophyllites* in the Maritime Provinces.

	internode length	leaves per verticil	leaf form	apex	length	length/breadth ratio
A. charaeformis	2–3 mm	up to 10	reflexed	acute	2–3 mm	10
A. grandis	2.5–4 mm	–	curved	acute	4–6 mm	13–15
A. lindleyanus	5–10 mm	up to 16	linear-lanceolate	acute	10–14 mm	18–20
A. longifolius	8–14 mm	up to 20	filiform	acute	25–40 mm	25–40

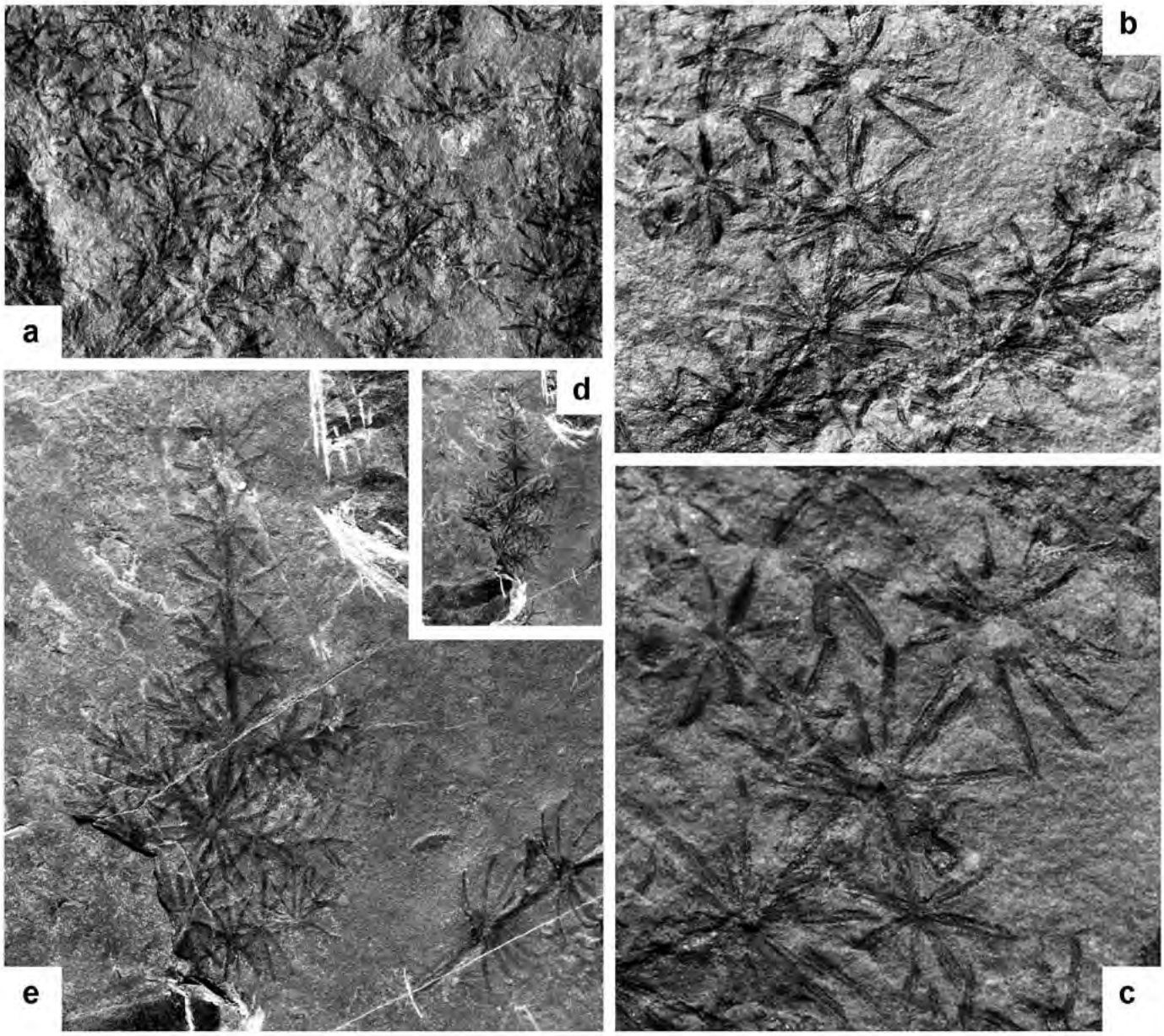


Figure 1. (a) *Annularia asteris* (x 3). GSC 9805. Detail of part of the holotype. Previously figured by Bell (1944, pl. LXVII, fig. 3; pl. LXVIII, fig. 5). Origin: east shore of Tynemouth Creek, Saint John, New Brunswick (locality 642). Repository: Geological Survey of Canada, Ottawa. (b) *Annularia asteris*. Enlargement (x 6) of specimen in Fig. 1a. (c) *Annularia asteris*. Another enlargement (x 9) of part of the same specimen. (d) *Annularia asteris* (x 1). NMBG 3436. Penultimate branch bearing verticils with the characteristic stiff, narrow, small leaves. Specimen on the same slab as that figured by Matthew (1906a, pl. VI, fig. 3) as *Asterophyllites parvulus*, here included in *Asterophyllites charaeformis* (see Fig. 13). Origin: Bed 2, Fern Ledges, Saint John, Lancaster, New Brunswick. Repository: New Brunswick Museum, Saint John. (e) *Annularia asteris*. Enlargement (x 3) of specimen in Fig. 1d.

more fleshy lamina than that of *Annularia asteris*, and of a size that is too small for *Annularia galioides*) (specimen mentioned previously by Leary 1976, p.

1978 *Annularia asteris*, Gillespie *et al.*, pp. 71, 74, 79, pl. 26, fig. 5 (= *Annularia galioides*).

1983 *Annularia asteris*, Winston, pp. 7, 8, 13, pl. II, fig. 4 (= *Annularia spicata*).

1985 *Annularia asteris*, Gillespie and Rheams, pp. 194, 196, pl. I, fig. 2 (= *Annularia ramosa*).

1985 *Annularia asteris*, Gillespie and Crawford, pp. 252, 255, pl. III, fig. 2 (= *Annularia ramosa*).

1987 *Annularia asteris*, Tenchov, p. 38, pl. XII, figs. 1–3 (more fleshy leaves; *Asterophyllites* sp. indet.?).
1991 *Annularia asteris*, Josten, pp. 86–87, Taf. 23, figs. 7–8a (fragmentary and poorly preserved lanceolate leaves resembling *Annularia galioides*); Abb. 41 (drawing).
1992 *Annularia* cf. *asteris*, Mamay and Mapes, Fig. 2.E (= *Annularia spicata* acc. to DiMichele *et al.* 2013, p. 290).
1996 *Annularia asteri*s, Cross *et al.*, pp. 406, 442, fig. 23–12.2 (= *Annularia* cf. *galioides*).

DESCRIPTION: Ultimate axes 0.2–0.3 mm wide, inserted subopposite at a wide angle (80–90°). Internodes 2.25–3 mm apart, bearing closely spaced verticils that overlap slightly in spread-out preservation. Verticils with 8 to 10 leaves of equal length and united at the base so as to form an annulus; they are stiff, narrow, with nearly parallel sides, though sometimes slightly wider across the middle; apex acuminate. Dimensions: 2–4.5 mm long at 0.20–0.25 mm width; length/breadth ratio = 10–18. Vein not visible.

REMARKS: Although widely reported, particularly in the United States, *Annularia asteris* has been generally misidentified. Bell (1944, pl. LXVII, fig. 3; pl. LXVIII, fig. 5) figured only one specimen (the holotype) from Tynemouth Creek, New Brunswick. Although well preserved, additional material is required to show the full range of morphological variation.

In addition to Bell's holotype, we figure as *Annularia asteris* a specimen from Fern Ledges at Saint John, New Brunswick, which is preserved on the same bedding plane as the type of *Asterophyllites parvulus* (= *Asterophyllites charaeformis*) (Matthew 1906a, pl. VI, fig. 3). At first, we considered that both specimens might belong to a single species (as Matthew may have thought). However, *Asterophyllites charaeformis* has small, reflexed, thread-like leaves that are preserved parallel to the axis, whereas *Annularia asteris* displays (equally small) leaves that are most commonly preserved in spread-out (dorsiventral) position (see Figs. 1a–c; parts of the holotype).

Annularia asteris was recorded from West Virginia as *Annularia minuta* by Wood (1869) and Lesquereux (1884a). However, this name had been used already by Brongniart (1828a, pp. 155, 175) as a nomen nudum referring to specimens from the Stephanian of Terrasson, Aquitaine, southwestern France. Brongniart's specimens were illustrated by Zeiller (1892, pl. XI, figs. 2, 3), who referred them to *Annularia spicata*, a late Stephanian species. We concur.

COMPARISONS: Bell (1944) compared *Annularia asteris* with *Annularia galioides* and its synonym *Annularia cuspidata*. The narrow, almost thread-like leaves of *Annularia asteris* are quite different to the more fleshy ones of *Annularia galioides*. Also, the leaves of the latter species are oblanceolate and possess a smaller length/breadth ratio. *Annularia minima* is another similar small-leaved species. However, its leaves are not as thread-like as those of *Annularia asteris*. Leggewie and Schonefeld (1961) observed that the leaves of *Annularia minima* are widest around the middle. *Annularia ramosa* possesses larger, linear-lanceolate leaves that have a length/breadth ratio between 23 and 26, and a more fleshy appearance.

STRATIGRAPHIC AND GEOGRAPHIC DISTRIBUTION: *Annularia asteris* has been rarely recorded. In Europe, the type material of the synonymous *Annularia subradiata* is from upper Namurian (Yeadonian) strata of the Assise d'Andenne, Belgium. The specimen (assigned to *Annularia ramosa*) by Josten (1991) came from the Langsettian of the Ruhr District, western Germany. Kidston *et al.* (1917) recorded this species (misidentified as *Annularia spicata*) from the lower Bolsovian of the Forest of Wyre in England. Crookall's (1969) specimen came from the Bolsovian of South Staffordshire, also in England. The material of Purkyňová (2000) originated from Kinderscoutian to Langsettian strata of the Upper Silesian Coal Basin, in the Moravian part of the Czech Republic.

OCCURRENCE IN THE MARITIME PROVINCES: Cumberland Basin (Nova Scotia): Bell (1944): locality 1087 (one piece without catalogue number); locality 1088 (GSC 10094 — together with *Asterophyllites charaeformis* + GSC 10099 + GSC 10100 — cf.; poorly preserved + GSC 10102 — cf.; together with *Calamites* sp. + GSC 10103 — cf. + GSC 10104 — cf. + GSC 10105 — cf.; together with *Calamites* sp. + GSC 10109). Tynemouth Creek (New Brunswick): Bell (1944): locality 642 (GSC 9805 — holotype; here Figs. 1a–c; together with *Laveineopteris polymorpha* on the same specimen). Fern Ledges (New Brunswick): New Brunswick Museum collection: NBMG 3435 + NBMG 3436 (see Figs. 1d–e; together with *Asterophyllites charaeformis* and *Alethopteris* sp. indet.).

OCCURRENCE IN THE UNITED STATES: Michigan: Arnold (1934, 1949). Utah: Tidwell *et al.* (1988). West Virginia: Wood (1869); Lesquereux (1884a); Abbott (1958).

***Annularia fertilis* Sternberg 1825**
(Figs. 2a–e)

* 1825 *Annularia fertilis* Sternberg, p. 43, Taf. LI, fig. 2.
p 1862 *Asterophyllites latifolia* Dawson, pl. XIII, fig. 17c; non p. 311, pl. XIII, figs. 17a–b (= *Annularia latifolia*).
p 1868 *Asterophyllites latifolia* Dawson, Fig. 187D (same as Dawson 1862, pl. XIII, fig. 17c); non p. 538, Fig. 187A (*Annularia latifolia* — same as Dawson 1862, pl. XIII, figs. 17a–b); non Fig. 187B (?).
p 1886–88 *Annularia radiata*, Zeiller, pl. LXI, figs. 2, 2A;

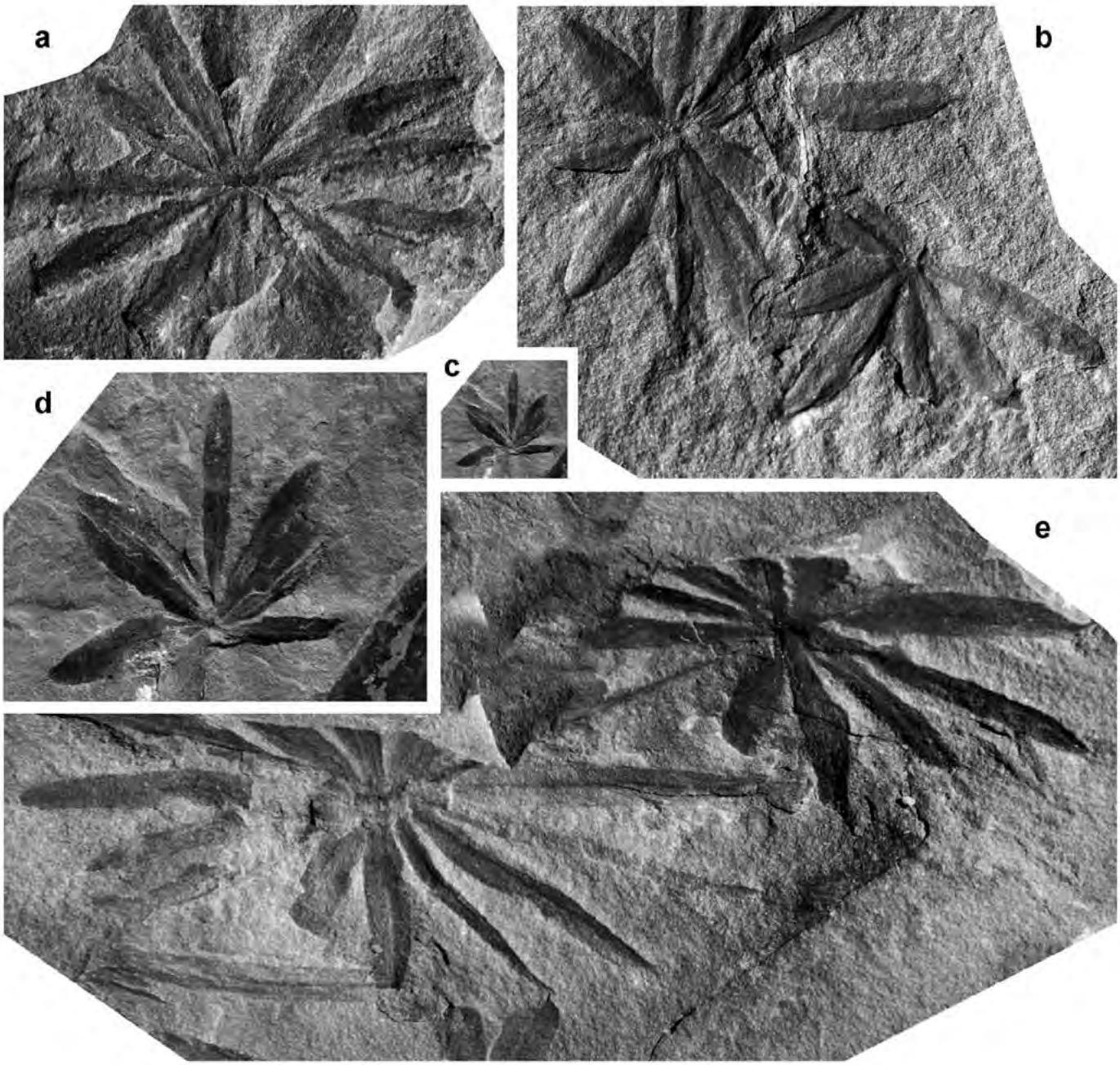


Figure 2. (a) *Annularia fertilis* (x 3). Verticil showing leaves with a strongly marked vein. Origin: east of Tynemouth Creek and east of anticline, Saint John, New Brunswick (locality 2577 = 1594). (b) *Annularia fertilis* (x 3). Specimen showing fleshy leaves (no locality stated; no locality number). (c) *Annularia fertilis* (x 1). Incomplete leaf verticil. Origin: same as for Fig. 2a (locality 1594). (d) *Annularia fertilis*. Enlargement (x 3) of specimen in Fig. 2c. (e) *Annularia fertilis* (x 3). Verticils slightly deformed tectonically. Origin: same as for Fig. 2a (locality 2577). Repository of all specimens: Geological Survey of Canada, Ottawa.

non pp. 394–398, pl. LIX, fig. 8 (= *Annularia radiata* and *Calamostachys*); non pl. LXI, figs. 1, 1A (= *Annularia radiata*).

p 1906a *Annularia latifolia*, Matthew, pp. 125–126, pl. VII, fig. 2; non pl. VII, fig. 3 (= *Annularia galioides*).

p 1914 *Annularia latifolia* [= A. *stellata*?], Stopes, pl. VI, fig. 11; non pp. 23–24, pl. VI, fig. 10 (= *Annularia latifolia* — photograph of Dawson 1871,

pl. V, fig. 51); non pl. VI, fig. 12 (= *Annularia latifolia*); non pl. VII, fig. 13 (= *Annularia latifolia*).

1949 *Annularia radiata*, Arnold, pp. 183–184, pl. XVII, fig. 3.

1959 *Annularia jongmansii*, Gothan *et al.*, pp. 44–45, Taf. 12, figs. 2–4.

p 1961 *Annularia fertilis*, Leggewie and Schonefeld, pp. 25–26, Taf. 15, figs. 5–6; Taf. 16, figs. 1–4; non Taf. 16, figs. 5–6 (diaphragm of *Calamites*).

1962 *Annularia radiata* var. *karvinensis*, Purkyňová, p. 45, Tab. X, fig. 3.

cf.1963 *Annularia radiata*, Wood, pp. 40–41, pl. 3, fig. 8 (leaf shape and size are similar to those of *Annularia fertilis*, but Wood's specimen possesses more leaves per verticil).

cf.1963 *Annularia stellata*, Wood, pp. 41–43, pl. 4, fig. 1 (more leaves per verticil).

p 1980 *Annularia radiata*, Zodrow and McCandlish, pl. 91, fig. 1; non pl. 91, fig. 2 (an *Annularia* with small, linear-lanceolate leaves); non pl. 91, fig. 3 (= *Asterophyllites* sp. indet.).

p 1980 *Annularia stellata*, Zodrow and McCandlish, pl. 94, figs. 1, 2 (longer leaves); non pl. 95, fig. 1 (= *Annularia stopesiae* sp. nov.); non pl. 95, fig. 2 (= *Annularia inflata*).

p 1987 *Annularia fertilis*, Tenchov, p. 39, pl. XII, figs. 9–12; pl. XIII, figs. 1, 2; non pl. XIII, fig. 6 (= *Annularia latifolia*).

p 1991 *Annularia jongmansi*, Josten, pp. 77–78, Taf. 21, figs. 1–1a; Abb. 35; non Taf. 20, figs. 3–3a (= *Annularia latifolia*); non Abb. 34 (= *Annularia latifolia*).

T 1997 *Annularia fertilis*, Kvaček and Straková, p. 75, pl. 23, fig. 1 (photograph of Sternberg's holotype).

? 2006 *Annularia*, Falcon-Lang, pp. 42, 43, Fig. 9G (too fragmentary for a proper identification).

DESCRIPTION: Ultimate axes apparently smooth, about 1 mm wide, with internodes 25 mm apart, bearing overlapping verticils with 14–16 isophyllous leaves, united at the base so as to form an annulus. Leaves oblong, tapering gradually in the upper quarter length into an acute, mucronate apex. Dimensions: 9–17 mm long and up to 2 mm broad; length/breadth ratio = 4.5–8.5. Vein straight and relatively broad, occupying about one fifth of the leaf width.

REMARKS: The holotype of Sternberg's *Annularia fertilis*, a species often included in the synonymy of *Annularia stellata* (e.g., by Zeiller 1888; Crookall 1969), is from Westphalian strata at Königsgruben, Upper Silesia, Poland. This specimen, reproduced photographically by Kvaček and Straková (1997, pl. 23, fig. 1), shows verticils composed of 14–16 isophyllous leaves, 7 to 14 mm long, with acute, mucronate apices. Canadian specimens assigned to *Annularia fertilis* fit this species perfectly, in particular those figured here in Figs. 2a and 2e (the latter slightly deformed tectonically).

COMPARISONS: *Annularia latifolia* possesses shorter, oblanceolate leaves, with maximum width in the upper third; it has a smaller length/breadth ratio than *Annularia fertilis*. In addition, *Annularia latifolia* shows a tendency towards anisophylly; this is not apparent in the leaf verticils of the holotype of *Annularia fertilis*. The late Stephanian *Annularia spinulosa* has longer, anisophyllous, lanceolate leaves (at 27–45 mm length, more than double the length of those of *Annularia fertilis*), with the greatest width just above the middle, and a sharply pointed apex. *Annularia spinulosa* has also more leaves (16 to 32) per verticil. *Annularia sphenophylloides* has smaller leaves than *Annularia fertilis*, and these are in anisophyllous verticils. Also, the leaves of *Annularia sphenophylloides* are spatulate and possess a markedly swollen, rounded, mucronate apex that is quite distinctive. The leaves of *Annularia asteropilosa* are also lanceolate, but are narrower, with a greater length/breadth ratio, and thus have a less pointed apex, apparently without a mucron.

STRATIGRAPHIC AND GEOGRAPHIC DISTRIBUTION: The holotype is from Westphalian strata of the Upper Silesian Basin, Poland. Gothan *et al.* (1959) recorded this species (misidentified as *Annularia jongmansii*) from Namurian C to Westphalian B of the Ruhr District, western Germany. Josten's (1991) specimen originated from Westphalian A (Langsettian) strata of the Ruhr District. Purkyňová (1962) figured specimens from upper Namurian B (Marsdenian) to Westphalian A (Langsettian) in the Ostrava-Karviná coalfield (Czech part of the Upper Silesian Basin). Tenchov (1987) figured this species from the Mogilište Formation, of Westphalian B (Duckmantian) age, in Bulgaria. *Annularia fertilis* is rarely recorded, but occurs widely.

OCCURRENCE IN THE MARITIME PROVINCES: Saint John (New Brunswick): Bell (1944): locality 788 (three pieces without catalogue number — fragmentary); locality 1594 = 2577 (GSC 5766 — one specimen in the same rock sample as that figured in Bell 1944, pl. LXXVII, fig. 1 as *Sporangites acuminata* + nineteen specimens without GSC catalogue number — eighteen numbered as locality 2577 and one as 1594; see Figs. 2a, c–e). Fern Ledges (New Brunswick): New Brunswick Museum collection: NBMG 1757/1. McGill University Collection: nº 3348 + one piece without catalogue number. Sydney Basin (Nova Scotia): Zodrow and McCandlish (1980).

OCCURRENCE IN THE UNITED STATES: Indiana: Wood (1963). Michigan: Arnold (1949).

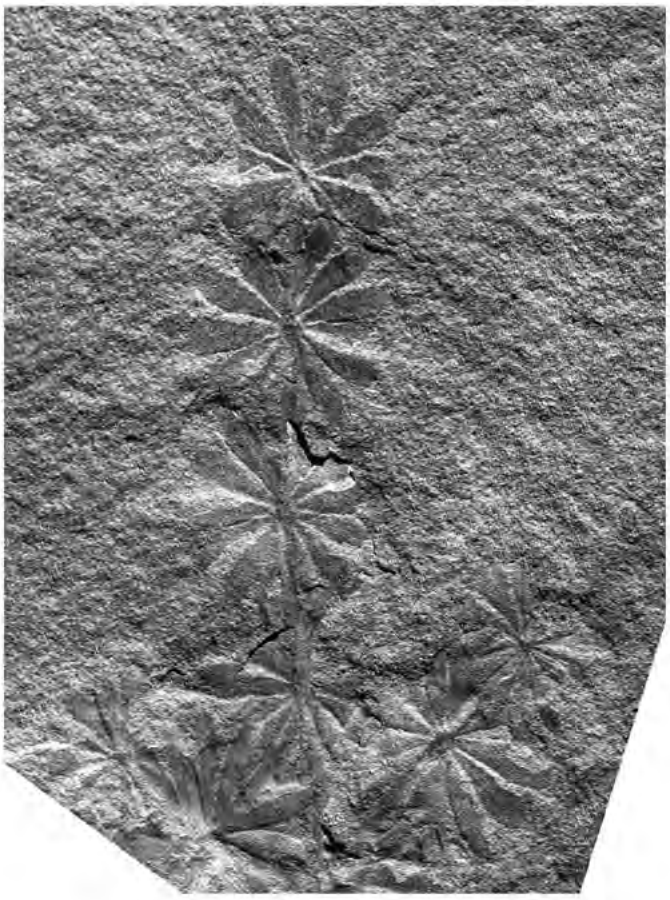


Figure 3. ***Annularia galioides*** **(x 3). GSC 14916. Specimen figured previously by Bell (1966, pl. VII, fig. 3). Origin: Duck Cove, near Fern Ledges, Saint John, New Brunswick (locality 804). Repository: Geological Survey of Canada, Ottawa.**

Annularia galioides **(Lindley and Hutton 1832) Kidston 1891**
(Fig. 3)

* 1832 *Asterophyllites galioides* Lindley and Hutton, pp. 79–80, pl. 25, fig. 2.
1868 *Annularia sphenophylloides*, Dawson, p. 444, Figs. 165B, B1.
* 1881–84a *Annularia Emersoni* Lesquereux, pp. 50–51 (1881 — description); p. 725, pl. XCII, figs. 6–6a (1884a — illustration) (acc. to Abbott 1958).
* 1884a *Annularia cuspidata* Lesquereux, p. 725, pl. XCII, figs. 7–7a (acc. to Kidston 1893).
1886–88 *Annularia microphylla*, Zeiller, p. 392, pl. LX, figs. 3–4A.
§ 1891 *Annularia galioides* (Lindley and Hutton) Kidston, p. 356.
1893 *Annularia galioides*, Kidston, pp. 317–318, pl. II, figs. 4–4a.
p? 1906a *Annularia latifolia*, Matthew, pl. VII, fig. 3 (difficult to judge from the illustration); non pp. 125–126, pl. VII, fig. 2 (= *Annularia fertilis*).
1906a *Annularia latifolia* var. *minor* Matthew, p. 126, pl. VII, figs. 4–5.
1907a *Annularia microphylla*, Zalessky, p. 429, Tab. XVIII, fig. 3.
k 1936 *Annularia galioides*, Walton, pp. 229–230, pl. 31, fig. 11.
1949 *Annularia sphenophylloides*, Arnold, pl. XVI, fig. 4.
p 1958 *Annularia asteris*, Abbott, pl. 35, fig. 7 (drawing); pl. 39, fig. 48; pl. 40, fig. 54; chart 2; non pp. 310–311, pl. 49, figs. 88–89 (= *Annularia asteris*).
1958 *Annularia galioides*, Abbott, pp. 311–312, pl. 40, fig. 52; chart 2.
1961 *Annularia asteris*, Leggewie and Schonefeld, pp. 29–30; Taf. 24, figs. 3–4; Taf. 26, figs. 7–8.
v 1966 *Annularia latifolia*, Bell, p. 16, pl. VII, fig. 3 (here as Fig. 3).
1966 *Annularia*, Gillespie *et al.*, pp. 64, 65, pl. 12, fig. 1.
1968 *Annularia galioides*, Basson, p. 57, pl. 5, fig. 1.
T 1969 *Annularia galioides*, Crookall, pp. 740–742, pl. CXXVII, fig. 6; text-fig. 216A (copy of Lindley and Hutton's figure of holotype); text-fig. 216B (same as Walton 1936, pl. 31, fig. 11).
1978 *Annularia asteris*, Gillespie *et al.*, pp. 71, 74, 79, pl. 26, fig. 5.
? 1991 *Annularia asteris*, Josten, p. 86–87, Taf. 23, figs. 7–8a (fragmentary and poorly preserved); Abb. 41.
cf. 1996 *Annularia asteris*, Cross *et al.*, pp. 406, 442, fig. 23–12.2.
cf. 1996 *Annularia* cf. *A. galioides*, Cross *et al.*, pp. 406, 442, fig. 23–12.6.
cf. 2002 *Annularia spicata*, Blake *et al.*, p. 292, pl. XVIII, fig. 6.

Excludenda:
1936 *Annularia galioides* (= *Annularia spicata*), Moore *et al.*, p. 11, fig. 6.7 (= *Annularia spicata*).
1957 *Annularia galioides*, Janssen, p. 87, Fig. 70 (here included, with doubt, in the synonymy of *Annularia latifolia*).
1963 *Annularia galioides*, Cridland *et al.*, p. 70, pl. 18, fig. 17 (fragmentary; resembles *Annularia spicata*).
2016 *Annularia galioides*, Cleal *et al.*, p. 3, Fig. 3g (= *Annularia spicata*).

DESCRIPTION: Axes longitudinally striate, 0.5–0.75 mm wide, with internodes 10–15 mm apart. Verticils on ultimate branches spaced at a little more than leaf length or slightly touching. Verticils with 10–12 leaves of approximately equal length, free, straight, oblanceolate, with maximum width above the middle and tapering basally and apically; blunt, obtuse apex. Dimensions: 4–6 mm long at 0.8–1.5 mm broad; length/breadth ratio = 4–5. Central vein not visible.

REMARKS: *Annularia galioides* was ascribed to *Asterophyllites* by Lindley and Hutton (1832), and recorded from lower Duckmantian strata at Barnsley, Yorkshire, England. Kidston (1891) transferred this species to *Annularia*. Lesquereux's *Annularia cuspidata* was placed in synonymy with *Annularia galioides* by Kidston (1893). Abbott (1958) did the same with Lesquereux's *Annularia emersonii*.

Here, we synonymize Matthew's *Annularia latifolia* var. *minor* with *Annularia galioides*. Matthew's variety was considered by Bell (1944) to fit the range of leaf length of *Annularia latifolia*; however, the verticils of the latter are anisophyllous and its leaves are widest in their upper third.

COMPARISONS: *Annularia sphenophylloides* has anisophyllous verticils with a larger number of leaves (12 to 18) that are spatulate, with a distinct mucron on the rounded apex. Although its leaves are also oblanceolate, *Annularia latifolia* has anisophyllous verticils with a larger number of leaves (12 to 16) that are longer and show a greater length/breadth ratio. *Annularia microphylla* has a similar number of leaves per verticil, but these are sickle-shaped and narrow gradually from a maximum width at mid-length to a pointed apex. Its leaves are of similar size to those of *Annularia galioides*, but have greater length/breadth ratio and are characterized by a rigid, slightly vaulted lamina. The upper Stephanian species *Annularia spicata* has smaller leaves (on average 2.5–3 mm long) that are stiffer, narrower, and have pointed apices.

STRATIGRAPHIC AND GEOGRAPHIC DISTRIBUTION: The holotype of *Annularia galioides* is from lower Duckmantian strata at Barnsley, Yorkshire, England. Crookall (1969) recorded this species from Westphalian B to Westphalian D (Duckmantian to Asturian) in Britain. Leggewie and Schonefeld (1961) recorded it from Westphalian A and lower Westphalian B (Langsettian and lower Duckmantian) of the Ruhr District, western Germany. According to Josten (1991), the species ranges from Langsettian to Bolsovian.

OCCURRENCE IN THE MARITIME PROVINCES: Cumberland Basin (Nova Scotia): Bell (1944): locality 1073 (GSC 9594 + GSC 9595 + GSC 9596 + GSC 9597 + GSC 9598 + GSC 9600 + GSC 9601 + one specimen with rubbed-out catalogue number — all specimens poorly preserved); locality 1088 (GSC 10995 + GSC 10996 — part and counterpart). Wilson Collection (GSC, Ottawa): locality 810 (two pieces without catalogue number). Fern Ledges (New Brunswick): Dawson (1868); Matthew (1906a); Bell (1944): locality 351 (one piece without catalogue number); Bell (1966): locality 804 (GSC 14916 — here Fig. 3).

OCCURRENCE IN THE UNITED STATES: Michigan: Arnold (1949). Missouri: Basson (1968). Ohio: Lesquereux (1881–1884a); Abbott (1958); Cross *et al.* (1996). West Virginia: Gillespie *et al.* (1966); Gillespie *et al.* (1978); Blake *et al.* (2002).

Annularia inflata **Lesquereux 1870**

(Fig. 4; Figs. 5a–b)

* 1870 *Annularia inflata* Lesquereux, p. 423, pl. XX, figs. 1–2, figs. 3–3b (drawings of leaf outline and cross section).
1870 *Annularia longifolia*, Lesquereux, pl. XX, figs. 4–4b (drawings of leaf and cross section).
p 1879–80 *Annularia inflata* Lesquereux, pp. 47–48, pl. II, fig. 2; pl. II, figs. 2bb (same as Lesquereux 1870, pl. XX, figs. 3–3b); non pl. II, fig. 1 (resembles *Annularia radiata*).
p 1880 *Annularia longifolia*, White, pp. 521–522, pl. XI, fig. 1; non pl. XI, fig. 2 (?).
p 1884b *Annularia longifolia*, Lesquereux, p. 44, pl. 7, fig. 1 (same as Lesquereux 1879, pl. II, fig. 2); non pl. 7, fig. 2 (*Annularia radiata* – same as Lesquereux 1879, pl. II, fig. 1).
v 1906a *Annularia longifolia* mutation *Leavitti* Matthew, pp. 124–125, pl. VII, fig. 1 (drawing) (assigned to *Annularia stellata* by Stopes 1914; here as Fig. 4).
v 1906b *Annularia longifolia* mutation *Leavitti* Matthew, pp. 396–397, pl. IX (upside down — photograph in Matthew 1906a, pl. VII, fig. 1; here as Fig. 4) (assigned to *Annularia stellata* by Stopes 1914).
1925 *Annularia stellata*, Noé, p. 13, pl. III, figs. 1–5.
p 1938 *Annularia stellata* forma *mucronata*, Bell, p. 85, pl. LXXXIX; pl. XCI, fig. 1; non pl. XC, fig. 1 (= *Annularia stopesiae* sp. nov.), non pl. XC, fig. 2 (difficult to judge from the illustration — *Annularia* sp. indet.).
T 1940 *Annularia stellata*, Janssen, pp. 9–12, pl. I, fig. 1 (photograph of the holotype of *Annularia inflata*).
1957 *Annularia stellata*, Janssen, p. 84, fig. 67.
1957 *Annularia radiata*, Janssen, pp. 85–86, fig. 68.
kp 1958 *Annularia stellata*, Abbott, pp. 321–326, pl. 35, fig. 1 (drawing); pl. 36, figs. 8–9 (drawings); pl. 41, fig. 58; pl. 43, figs. 62, 64 (cuticle); non pl. 49, fig. 87 (syntype of *Carpannularia americana*); chart 2.
? 1959 *Annularia longifolia*, Canright, pp. 21, 29, pl. 3, fig. 2 (figured at less than natural size and difficult to assess).
? 1959 *Annularia stellata*, Canright, pp. 21, 29, pl. 3, fig. 4 (at less than natural size).
1960 *Annularia*, Gillespie and Latimer, p. 42, pl. 6, fig. 4 (upside down).
1962 *Annularia stellata*, Gillespie and Clendening, p.

130, pl. 4, fig. 6.
1966 *Annularia stellata*, Bell, p. 58, pl. XXVIII, fig. 6.
1966 *Annularia*, Gillespie *et al.*, pl. 12, fig. 4 (same as Gillespie and Latimer 1960, pl. 6, fig. 4).
1968 *Annularia stellata*, Basson, pp. 58–59, pl. 5, fig. 2; pl. 6, fig. 1.
1969 *Annularia stellata*, Darrah, p. 172, pl. 37, fig. 1.
1978 *Annularia stellata*, Gillespie *et al.*, pp. 70, 74, pl. 26, fig. 1.
p 1980 *Annularia stellata*, Zodrow and McCandlish, pl. 95, fig. 2; non pl. 94, fig. 1 (?), fig. 2 (resembles *Annularia fertilis*); non pl. 95, fig. 1 (= *Annularia stopesiae* sp. nov.).
1987 *Annularia longifolia leavitti*, Miller, p. 19, fig. 18 (upside down — same as Matthew 1906b, pl. IX).
p 2006 *Annularia stellata*, Wittry, fig. 1; non p. 92, fig. 2 (= *Annularia latifolia*).

DESCRIPTION: Ultimate axes up to 2.5 mm wide, with internodes 20–25 mm long, bearing slightly overlapping verticils. Verticils with 22–24 leaves, of unequal length, lying in the same plane as the axis and united at the base so as to form an annulus. Leaves oblanceolate, with convex margins and the greatest width in the upper third of leaf length; apex obtuse, with a mucron that is not always visible (frequently embedded in the matrix). Leaves are long and vary in size according to their position, the laterals (those placed perpendicular or subperpendicular to the axis) being longer than the lower and upper ones (more or less parallel to the axis); consequently, the verticils show an elliptical shape. Dimensions: varying between 20–25 mm and 30–45 mm length at 2.50–4.25 mm width; length/breadth ratio = 8–10. Vein clearly marked, straight, c. 0.3 mm wide.

REMARKS: Bell (1938) figured four specimens of this species from the Sydney Basin, Nova Scotia, as *Annularia stellata* forma *mucronata*. Two of these (Bell 1938, pl. XC, figs. 1–2) were included by Abbott (1958) in the synonymy of *Annularia stellata*; she attributed the other specimens (Bell 1938, pl. LXXXIX; pl. XCI, fig. 1) to *Annularia mucronata*. The holotype of the often-cited *Annularia stellata* (Schlotheim 1820, Taf. I, fig. 4 — possibly lost according to Kvaček and Straková 1997, p. 142) came from upper Stephanian strata of Kammerberg at Manebach, Thuringia, Germany. Barthel (2000) considered *Annularia spinulosa* (Sternberg 1821, Taf. 19, fig. 4 — photographically figured by Kvaček and Straková 1997, pl. 51, fig. 4, and Barthel 2000, Abb. 1a) as the correct name, with *Annularia stellata* as a synonym. Most authors now accept Barthel's point of view.

Annularia mucronata is a species introduced by Schenk (1883) from Permian strata in China. It is characterized by verticils with relatively long, spatulate, mucronate leaves. Most of the upper Westphalian and Stephanian specimens identified as *Annularia mucronata* from North America (e.g., Abbott 1958; Wood 1963) may be assigned to *Annularia sphenophylloides*.

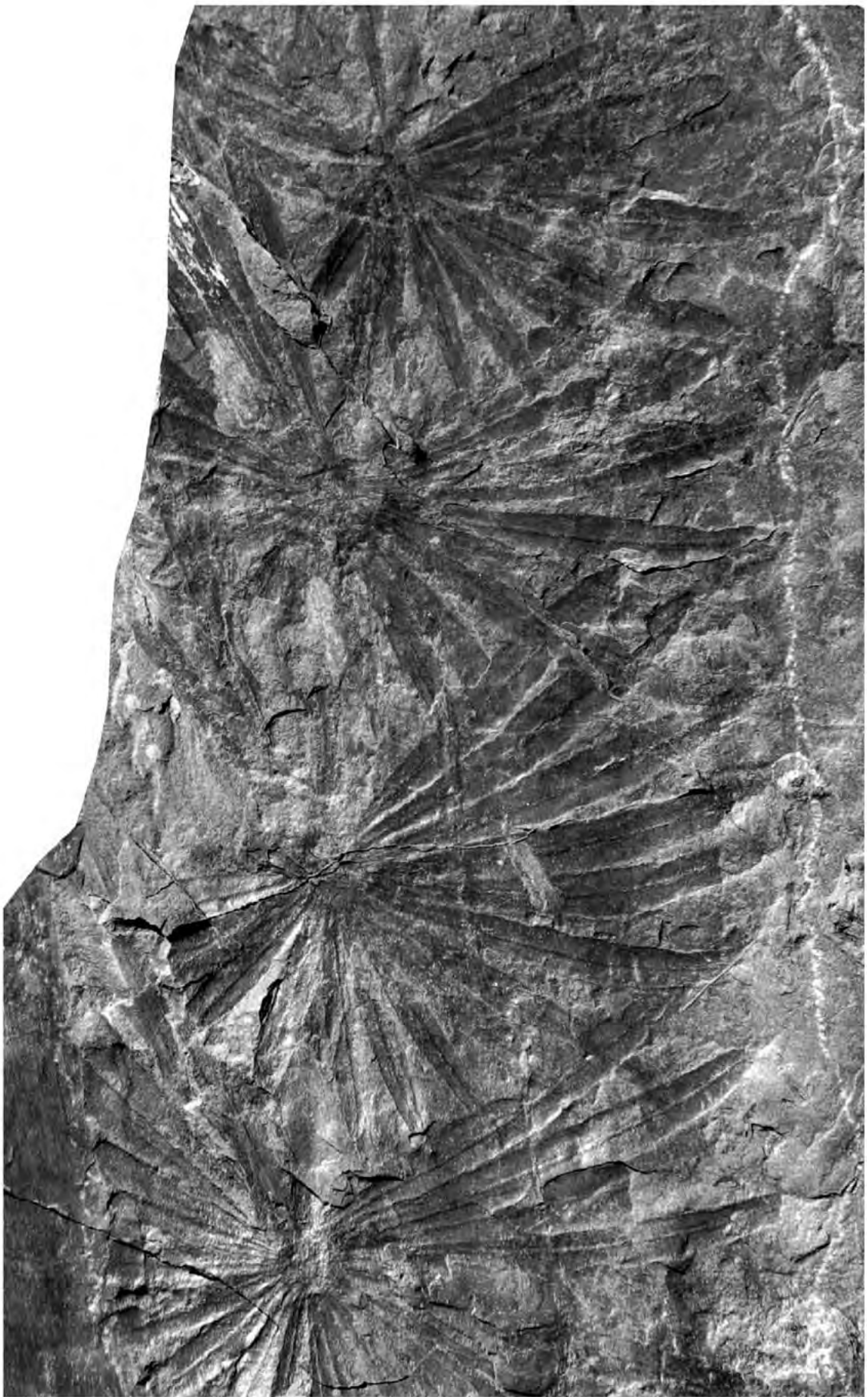
Most comparable to *Annularia mucronata* are the specimens described by Elias (1931) as *Carpannularia*, a genus based on the presence of some reproductive structures (which Elias assumed to be seeds) that are attached to *Annularia*-type verticils. Abbott (1958) accepted the connection between these "seeds" and the leaf verticils and synonymized Elias's *Carpannularia americana* with *Annularia stellata*. However, Cridland (1968), who re-examined Elias's specimens, noticed that the "seeds" are detached, and not connected to the *Annularia* verticils. He proposed the synonymy of *Carpannularia americana* with *Annularia mucronata*, noting a similar leaf size, spatulate shape and mucronate apices. He also regarded the leaves figured by Elias as completely covered with "hairs".

We agree with Abbott that more than one species is represented in Bell's (1938) material, assigning two of Bell's specimens (pl. LXXXIX; pl. XCI, fig. 1) to *Annularia inflata*. The specimen shown in Bell's pl. XC, fig. 1 is here included in *Annularia stopesiae* sp. nov.; the fourth specimen can only be assigned as *Annularia* sp. indet.

Annularia inflata, a rarely recorded species, has been introduced by Lesquereux (1870) on the basis of two specimens from Mazon Creek, Illinois. Rather than providing a proper description, he noted the differences between his material and *Annularia longifolia* Brongniart. Lesquereux (1870) mentioned that *Annularia inflata* has oblanceolate, obtuse leaves with a subcylindrical or inflated shape and without a clearly marked vein. *Annularia longifolia* has flatter leaves with convex margins and a well marked vein. Lesquereux admitted the possibility that these two kinds of leaf might belong to a single species, and considered that the dimorphism might be due to some leaves being subaerial (corresponding to *Annularia longifolia*) and others aquatic (*Annularia inflata*). However, this is speculation. Janssen (1940, pl. I, fig. 1) published a photograph of Lesquereux's holotype under the name *Annularia stellata*.

Annularia longifolia is an invalid name, introduced by Brongniart (1828a) without description or illustration. Brongniart (1828a, p. 153) noted only the differences in leaf length in a verticil, and (on p. 156) placed *Casuarinites stellatus* Schlotheim and *Bornia stellata* Sternberg in synonymy with *Annularia longifolia*.

COMPARISONS: *Annularia spinulosa* (= *Annularia stellata*) has 16 to 32 leaves per verticil with 25–45 mm length. As in *Annularia inflata*, the lateral leaves are longer than the lower and upper ones. *Annularia spinulosa* leaves are widest just above their middle, and the apices are bluntly pointed. *Annularia stopesiae* sp. nov. also displays anisophyllous verticils with similar number of leaves, but these are linear-lanceolate, much longer (up to 85 mm) and show a distinct cell pattern.



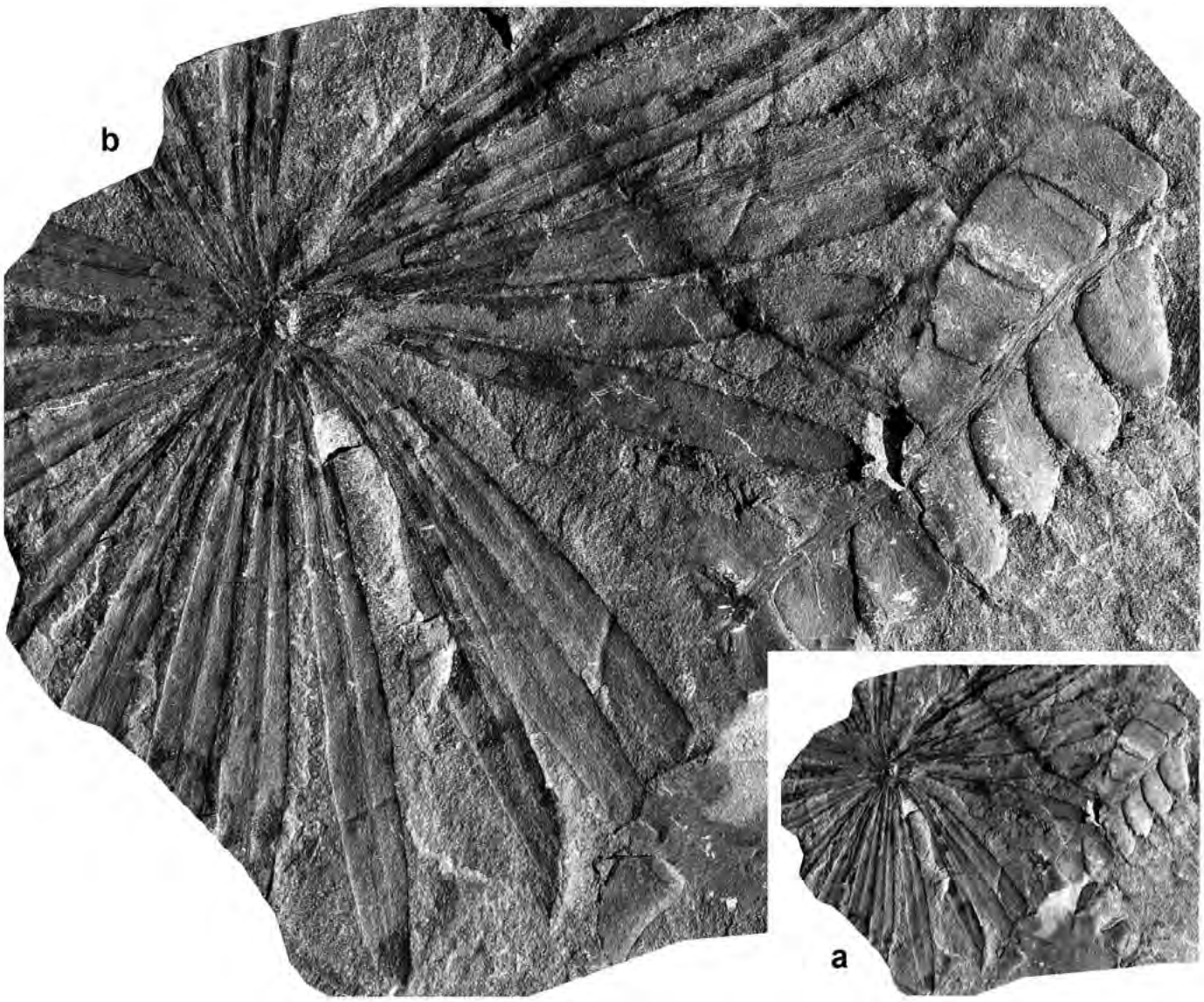


Figure 5. (a) *Annularia inflata* together with *Laveineopteris polymorpha* (x 1), NBMG 7649. Incomplete verticil showing the long, oblanceolate leaves characteristic of this species. Note the broad vein and small mucronate apex. Labelled as *Annularia longifolia*. Origin: Sunbury County, New Brunswick. Repository: New Brunswick Museum, Saint John. (b) *Annularia inflata*; enlargement (x 3) of specimen in Fig. 5a.

STRATIGRAPHIC AND GEOGRAPHIC DISTRIBUTION: Lesquereux's (1870) type material as well as that figured by Noé (1925) and Darrah (1969) are from uppermost Asturian and/or lowermost Cantabrian strata at Mazon Creek, Illinois, U.S.A. White (1880) figured material from Asturian strata of the Shelburn Formation, Indiana. Canright's (1959) specimens are also from Indiana; these are from the Lower Block Coal, lower Brazil Formation of late Bolsovian age according to Bashforth and Nelson (2015).

Figure 4. (previous page) *Annularia inflata* (x 2). NBMG 3423. Specimen figured by Matthew (1906a, pl. VII, fig. 1 — as a drawing, and 1906b, pl. IX — photographically) as *Annularia longifolia* mutation *leavittii*. Note the variation in leaf size according to their position. Origin: Duck Cove, near Fern Ledges, Saint John, Lancaster, New Brunswick. Repository: New Brunswick Museum, Saint John.

OCCURRENCE IN THE MARITIME PROVINCES: New Brunswick Museum collection: NBMG 3423 (Saint John — specimen described and figured as *Annularia longifolia* mutation *Leavittii* in Matthew 1906a and 1906b — see Fig. 4) + NBMG 7649 (Sunbury County — together with *Laveineopteris polymorpha* and labelled as *Annularia longifolia* and *Neuropteris* sp.; here as Figs. 5a–b). Sydney Basin (nova scotia): Bell (1938): locality 513 (GSC 2269); locality 556 (GSC 3107). Bell (1966): locality 1331 (GSC 14906). Zodrow and McCandlish (1980).

OCCURRENCE IN THE UNITED STATES: Illinois: Lesquereux (1870), Noé (1925), Janssen (1940), Janssen (1957), Darrah (1969), Wittry (2006). Indiana: White (1880), Canright (1959). Missouri: Basson (1968). Ohio: Abbott (1958). West Virginia: Gillespie *et al.* (1978).

Annularia latifolia (Dawson 1862) Kidston 1886
(Figs. 6a–b; Figs. 7a–k)

*p 1862 *Asterophyllites latifolia* Dawson, p. 311, pl. XIII, figs. 17a–b; non pl. XIII, fig. 17c (= *Annularia fertilis*).
p 1868 *Asterophyllites latifolia* Dawson, p. 538, Fig. 187A (same as Dawson 1862, pl. XIII, figs. 17a–b); non Fig. 187B (?); non Fig. 187D (= *Annularia fertilis* — same as Dawson 1862, pl. XIII, fig. 17c).
1869 *Annularia Dawsonii* Schimper, p. 350 (new name for *Asterophyllites latifolia* based on the reassignment to *Annularia* — see comments in Schimper 1874, p. 458).
p 1871 *Asterophyllites latifolia*, Dawson, p. 28, pl. V, figs. 50–51a; non fig. 52 (?); non fig. 53 (strobilus).
1884a *Calamites ramifer*?, Lesquereux, pp. 703–706, pl. XCI, figs. 4, 4a (acc. to White 1900, p. 898).
§ 1886 *Annularia latifolia* (Dawson) Kidston, p. 226.
p 1913 *Annularia radiata*, Jongmans and Kukuk, Taf. 16, fig. 5; non Taf. 16, figs. 1–4, 6 (= *Annularia radiata*).
p 1913 *Annularia stellata*, Jongmans and Kukuk, Taf. 22, fig. 4; non Taf. 21, figs. 1–2 (= *Annularia radiata*).
1914 *Annularia stellata*, Kidston, p. 121, pl. IX, figs. 1–1a.
1914 *Annularia sphenophylloides*, Stopes, pp. 21–22, pl. V, fig. 7 (acc. to Bell 1944).
p 1914 *Annularia latifolia* [= A. *stellata*?], Stopes, pp. 23–24, pl. VI, fig. 10 (photograph of Dawson 1871, pl. V, fig. 51), pl. VI, fig. 12 (fragmentary); pl. VII, fig. 13; non pl. VI, fig. 11 (= *Annularia fertilis*).
1934 *Annularia radiata*, Arnold, p. 187, pl. I, fig. 1.
*k1936 *Annularia Jongmansi* Walton, pp. 230–232, pl. 31, fig. 12 (holotype — here as Fig. 6a), fig. 13 (here Fig. 6b), figs. 14–15 (enlargements of holotype); text-fig. 6.

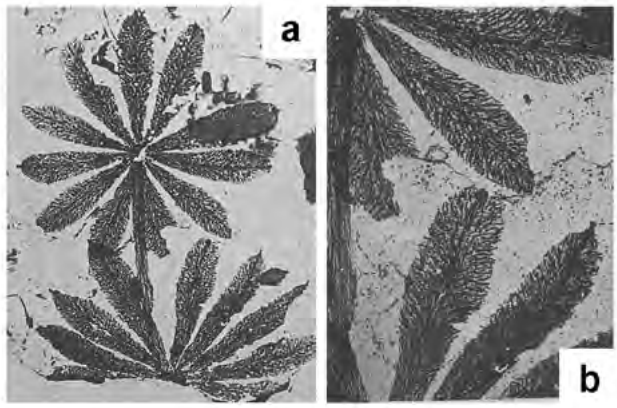
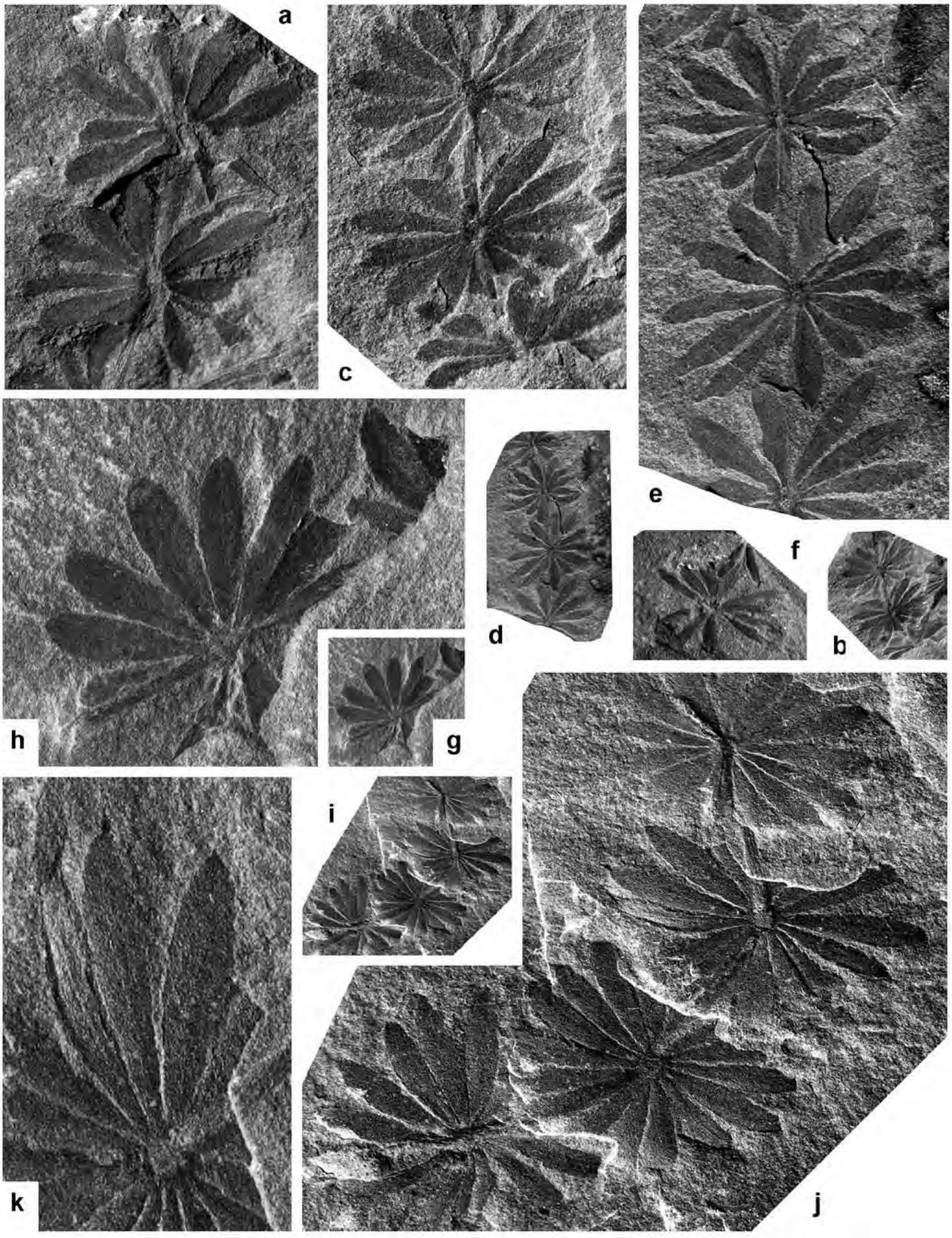


Figure 6. (a) ***Annularia latifolia*** (x 3). **Reproduction of the type of *Annularia jongmansii* as figured by Walton (1936, pl. 31, fig. 12) (so as to show the identity with Dawson's species). Origin: Devon Tower Colliery, southwest of Tillicoultry, Clackmannanshire, Scotland. (b) *Annularia latifolia*. Detail of specimen in Fig. 6a as figured by Walton (1936, pl. 31, fig. 13) showing the reticulate cell pattern of the lamina.**

Figure 7. (next page) (a) *Annularia latifolia* (x 3). Origin: Saint John, New Brunswick (locality 810). Repository: Geological Survey of Canada, Ottawa. (b) *Annularia latifolia* (x 1). Origin: same as for Fig. 7a (locality 810). (c) *Annularia latifolia*. Enlargement (x 3) of specimen in Fig. 7b. (d) *Annularia latifolia* (x 1). NBMG 3413. Origin: Bed 1, Fern Ledges, Saint John, New Brunswick. Repository: New Brunswick Museum, Saint John. (e) *Annularia latifolia*. Enlargement (x 3) of the same specimen. Note the great similarity with Walton's specimen as reproduced in Figs. 6a–b herein. (f) *Annularia latifolia* (x 1). Specimen on the counterpart of that figured as Fig. 6g. Origin: Fern Ledges, Saint John, New Brunswick (locality 139). Repository: Geological Survey of Canada, Ottawa. (g) *Annularia latifolia* (x 1). Here the mucron is embedded in the rock, thus emphasizing the rounded aspect of the leaf apex. Origin: Fern Ledges, Saint John, New Brunswick (locality 139). Repository: Geological Survey of Canada, Ottawa. (h) *Annularia latifolia*. Enlargement (x 3) of the same specimen showing the faintly marked vein. (i) *Annularia latifolia* (x 1). Thin axis bearing anisophyllous leaf verticils. Origin: McCoy Head, East of Dickson Point, Saint John, New Brunswick (locality 828). Repository: Geological Survey of Canada, Ottawa. (j) *Annularia latifolia*. Enlargement (x 3) of specimen in Fig. 7i. (k) *Annularia latifolia*. Detail (x 6) of leaves in Fig. 7i showing the tiny mucron as well as the reticulate cell pattern of the lamina.



1937 *Annularia radiata* forma *karwinensis*, Jongmans, p. 409, pl. 33, figs. 105–106.
1944 *Annularia latifolia*, Bell, p. 100.
? 1957 *Annularia galioides*, Janssen, p. 87, Fig. 70.
1958 *Annularia latifolia*, Abbott, pp. 313–314, pl. 35, fig. 3 (drawing); pl. 37, fig. 21 (drawing); chart 2.
1961 *Annularia jongmansii*, Leggewie and Schonefeld, pp. 28–29, Taf. 20, figs. 7–8; Taf. 26, figs. 4–6.
1968 *Annularia radiata*, Kotasowa, pp. 21–22 (excluding synonymy), Tab. III, fig. 5.
1987 *Annularia jongmansii*, Tenchov, p. 40, pl. XIII, figs. 3–4, fig. 5 (with doubt), figs. 7–9.
p 1987 *Annularia fertilis*, Tenchov, pl. XIII, fig. 6; non p. 39, non pl. XII, figs. 9–12 (= *Annularia fertilis*); non pl. XIII, figs. 1–2 (= *Annularia fertilis*).
p 1991 *Annularia jongmansi*, Josten, pp. 77–78, Taf. 20, figs. 3–3a, Abb. 34; non Taf. 21, figs. 1–1a (= *Annularia fertilis*); Abb. 35 (= *Annularia fertilis*).
v 1999 *Annularia jongmansii*, Álvarez-Vázquez, Figs. 2, 4 (name only).
p 2006 *Annularia stellata*, Wittry, p. 92, fig. 2; non fig. 1 (= *Annularia inflata*).
2007 *Annularia stellata*, Falcon-Lang and Miller, p. 240, Fig. 12 (same as Dawson 1871, pl. V, fig. 51, and Stopes 1914, pl. VI, fig. 10).
v 2010 *Annularia jongmansii*, Wagner and Álvarez-Vázquez, pp. 257, 266, 270.

Excludenda:

v 1966 *Annularia latifolia*, Bell, p. 16, pl. VII, fig. 3 (= *Annularia galioides*).

DESCRIPTION: Ultimate axes longitudinally striate, 0.8–1 mm wide, with internodes 10–12 mm apart, bearing verticils that touch or slightly overlap when spread out on the bedding plane. Verticils anisophyllous to a varying extent, with lateral leaves longer than those parallel to the axis. There are 12 to 16 leaves in a verticil, united at the base to constitute an annulus, oblanceolate, with maximum width in the upper third and gradually tapering to an obtuse, mucronate apex. Dimensions: 8–12 mm long at 1.25–1.9 mm (maximum) width; length/breadth ratio ≈ 6. Vein straight, relatively broad, c. 0.6 mm. In well-preserved adpressions an elongate, relatively coarse epidermal cell pattern, slightly oblique to the vein, is apparent.

REMARKS: *Asterophyllites latifolia* was introduced by Dawson in 1862 and transferred to *Annularia* by Schimper (1869), who renamed it (illegitimately) *Annularia dawsonii*. Kidston (1886) proposed the combination *Annularia latifolia*. Stopes (1914), who (incorrectly in our view) synonymized *Annularia latifolia* with the Stephanian species *Annularia stellata*, figured photographically the reasonably well-preserved specimens illustrated by Dawson in 1871. Abbott (1958) provided outline diagrams as well as a description and a brief history of what she regarded as *Annularia stellata* (but referring to specimens that in our view belong to *Annularia latifolia*).

Bell (1944) retained both *Annularia latifolia* and *Annularia stellata* as separate species. The Canadian species, *Annularia latifolia*, is identical to *Annularia jongmansii*, a species introduced and described more fully by Walton (1936) from lower Westphalian strata of the Midland Valley of Scotland. He seems to have been unaware of *Annularia latifolia*. *Annularia jongmansii* is characterized by anisophyllous verticils with lanceolate leaves showing a subrounded apex that includes a tiny mucron. Walton (1936) emphasized the presence of a relatively coarse, elongate epidermal cell pattern, which is also apparent in *Annularia latifolia* (Fig. 7k). These two species are identical in all respects and thus synonymous.

Bell (1944, p. 100) discussed *Annularia latifolia*, but did not provide an illustration. Practically all the localities cited by Bell (1944) are in New Brunswick, the only exception being locality 1362 at Joggins, Nova Scotia. However, the corresponding specimens (without catalogue number) are assigned here to *Annularia microphylla*. We note also that the specimen from New Brunswick figured by Bell (1966, pl. VII, fig. 3) as *Annularia latifolia* belongs to *Annularia galioides* (see Fig. 3).

COMPARISONS: *Annularia sphenophylloides* also has leaves with a prominent mucron, but these leaves are smaller, up to 12 mm long (6 to 8 mm on the average), spatulate and widest at the apex. *Annularia galioides* also has oblanceolate leaves, but these are smaller, up to 6 mm long, and have a smaller length/breadth ratio. In addition, leaves of *Annularia galioides* are of near-equal length in almost isophyllous verticils. *Annularia microphylla* has verticils with lanceolate and sickle-shaped leaves of equal length and stiffer aspect.

The leaves in *Annularia microphylla* are shorter than those of *Annularia latifolia* and have a smaller length/breadth ratio. Verticils of *Annularia fertilis* have isophyllous leaf whorls, with oblong, longer leaves, with a greater length/breadth ratio. Leaves of *Annularia asteropilosa* are less pointed and have a greater length/breadth ratio.

STRATIGRAPHIC AND GEOGRAPHIC DISTRIBUTION: The synonymous *Annularia jongmansii* has been reported in Europe from upper Langsettian to lower Asturian strata. Walton's type is from lower Westphalian strata in Clackmannanshire, Scotland. Kidston's (1914) specimen (which he determined as *Annularia stellata*) is from upper Duckmantian strata of Staffordshire, England. Jongmans and Kukuk (1913) recorded material from Asturian sediments at Piesberg, western Germany. Kotasowa (1968) documented the species (as *Annularia radiata*) from Westphalian A (Langsettian) in the northeastern part of the Upper Silesian Coal Basin, Poland. Tenchov's (1987) material came from several horizons in Westphalian A, B and C (Langsettian, Duckmantian and Bolsovian) strata

from the Dobrudža Basin, Bulgaria. Wagner and Álvarez-Vázquez (2010) recorded *Annularia jongmansii* from the upper Langsettian and the lower Bolsovian in the Peñarroya Basin, southwestern Spain, and from lower Asturian strata of the Sierra de la Demanda, Burgos province, northern Spain.

OCCURRENCE IN THE MARITIME PROVINCES: Saint John (New Brunswick): Dawson (1862), Dawson (1868), Dawson (1871), Stopes (1914), Bell (1944), Abbott (1958), Falcon-Lang and Miller (2007). Wilson collection (Geological Survey Canada, Ottawa): locality 136 (136B); locality 139 (139 — together with *Calamites* sp. + 139a — here Figs. 7f and Figs. 7g–h + 139b + 139c + 139d); locality 810 (three pieces without catalogue number — here Figs. 7a–c; together with *Annularia galioides*); locality 828 (198b — here Figs. 7i–k); locality 2254 (one piece without catalogue number). New Brunswick Museum collection: NBMG 3411 + 3412/1 + NBMG 3413 (here Figs. 7d–e) + NBMG 3416.

OCCURRENCE IN THE UNITED STATES: Illinois: Janssen (1957). Michigan: Arnold (1934). Ohio: Abbott (1958). Pennsylvania: Lesquereux (1884a), Wittry (2006). West Virginia: Jongmans (1937).

Annularia microphylla Sauveur 1848
(Fig. 8)

* 1848 *Annularia microphylla* Sauveur, pl. LXIX, fig. 6.
T 1913 *Annularia microphylla*, Jongmans and Kukuk, Taf. 21, fig. 10 (copy of Sauveur 1848).
1914 *Annularia microphylla*, Kidston, pp. 172–173, pl. X, figs. 1–3a.
* 1949 *Asterophyllites vernensis* Arnold, pp. 182–183, pl. XVI, figs. 6–9.
1957 *Annularia microphylla*, Gothan and Remy, p. 53, Abb. 43.
1958 *Annularia vernensis*, Abbott, pp. 326–327, pl. 37, fig. 24 (drawing — copy in Boureau 1964, text-fig. 166); chart 2.
1959 *Annularia microphylla*, Gothan *et al.*, p. 51, Taf. 16, fig. 1 (same as Gothan and Remy 1957, Abb. 43).
1961 *Annularia microphylla*, Leggewie and Schonefeld, p. 30, Taf. 24, figs. 6, 7.
T 1969 *Annularia microphylla*, Crookall, pp. 742–744, pl. CXVII, fig. 2; pl. CXXVIII, figs. 4–5a; text–fig. 217 copy of Sauveur 1848).
1969 *Annularia microphylla*, García-Loygorri and Ortuño Aznar, pp. 845, 859, Fotos 19–19a.
v ?1971 *Annularia microphylla*, Wagner in Moore *et al.*, p. 321, pl. 8, fig. 27 (fragmentary; Wagner and Álvarez-Vázquez 2010 compared with a sterile bract whorl of *Calamostachys*).
p 1978 *Annularia radiata*, Gillespie *et al.*, pl. 27, figs. 2, 6; non pp. 70, 74, 80, pl. 26, fig. 8 (= *Annularia ramosa*?); non pl. 27, fig. 1 (= *Annularia radiata*).
1991 *Annularia microphylla*, Josten, pp. 80–81, Taf. 22, figs. 3–5a; Abb. 37.
2010 *Annularia microphylla*, Wagner and Álvarez-Vázquez, p. 257.

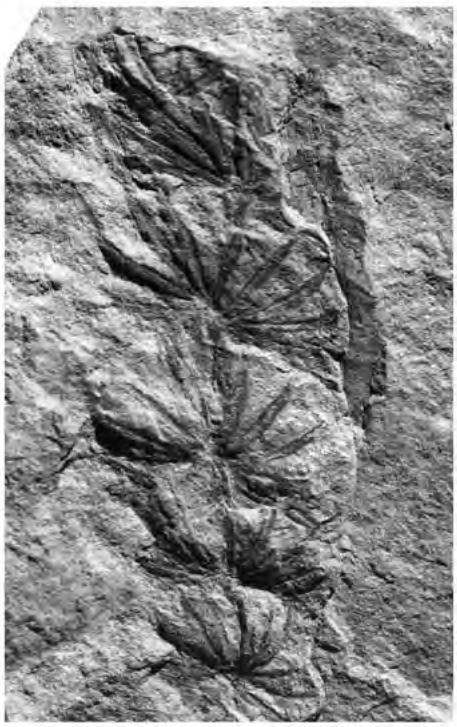


Figure 8. ***Annularia microphylla*** **(x 3). Very similar specimen to that figured by Crookall (1969, pl. CXXVIII, figs. 4–5a) from the lower Westphalian of England. Origin: East Apple River, Joggins (locality 1362; without catalogue number). Repository: Geological Survey of Canada, Ottawa.**

DESCRIPTION: Ultimate axis c. 0.75 mm wide, with internodes 4.5–5 mm long bearing verticils that touch or slightly overlap. Verticils with 12 leaves of equal length, lanceolate and sickle-shaped, gradually narrowing from maximum width at the middle to a pointed apex. Lamina relatively thick, slightly vaulted. Dimensions: 5–6 mm long at 0.5–0.6 mm width; length/breadth ratio = 10. Vein straight, immersed in the lamina, and occupying one third of leaf width.

REMARKS: The description given here is based on a single specimen from Joggins, Nova Scotia. It was not described by Bell, although part of his 1911 collection. Even though fragmentary (only 30 mm), it shows the sickle-shaped leaves, with a thick, vaulted lamina that is characteristic of *Annularia microphylla*. This species

has often been regarded as conspecific with either *Annularia galioides* (e.g., Kidston 1891; Jongmans 1911) or *Annularia spicata* (Potonié 1893), but these three species can be differentiated without too much difficulty (see under Comparison) and have quite different ranges.

We regard *Asterophyllites vernensis*, described by Arnold (1949) from Grand Ledge, Michigan, as a synonym of *Annularia microphylla*. Arnold pointed out that the leaves of *Asterophyllites vernensis* are curved and laterally imprinted, as in *Asterophyllites*. Indeed, he compared *Asterophyllites vernensis* with *Asterophyllites grandis*, noting broader leaves in *Asterophyllites vernensis*. Arnold's species was transferred to *Annularia* by Abbott (1958). Although Abbott maintained *Annularia vernensis* as a separate species, she noted its close resemblance to *Annularia galioides*.

COMPARISONS: *Annularia microphylla* is distinctive, easily identified by its leaf shape and a thick lamina. It shows a superficial resemblance to *Annularia galioides*, but the oblanceolate leaves of the latter are flat and straight.

Annularia spicata has smaller, oblong leaves, with pointed apices; there are also fewer leaves per verticil in *Annularia spicata*.

STRATIGRAPHIC AND GEOGRAPHIC DISTRIBUTION: *Annularia microphylla* is rarely cited. The holotype is from the lower Westphalian of Belgium. Kidston (1914) and Crookall (1969) recorded this species from the Westphalian A and lower Westphalian B (Langsettian and lower Duckmantian) in Britain. Gothan and Remy (1957), Gothan *et al.* (1959), Leggewie and Schonefeld (1961), and Josten (1991) record the same range for this species from the Ruhr District, western Germany. García-Loygorri and Ortuño Aznar (1969) figured *Annularia microphylla* from Langsettian strata of the Villanueva del Río y Minas coalfield, Sevilla province, southwestern Spain.

OCCURRENCE IN THE MARITIME PROVINCES: Cumberland Basin (Nova Scotia): Bell's collection 1911: locality 1362 (one piece without catalogue number).

OCCURRENCE IN THE UNITED STATES: Michigan: Arnold (1949); Abbott (1958). West Virginia: Gillespie *et al.* (1978).

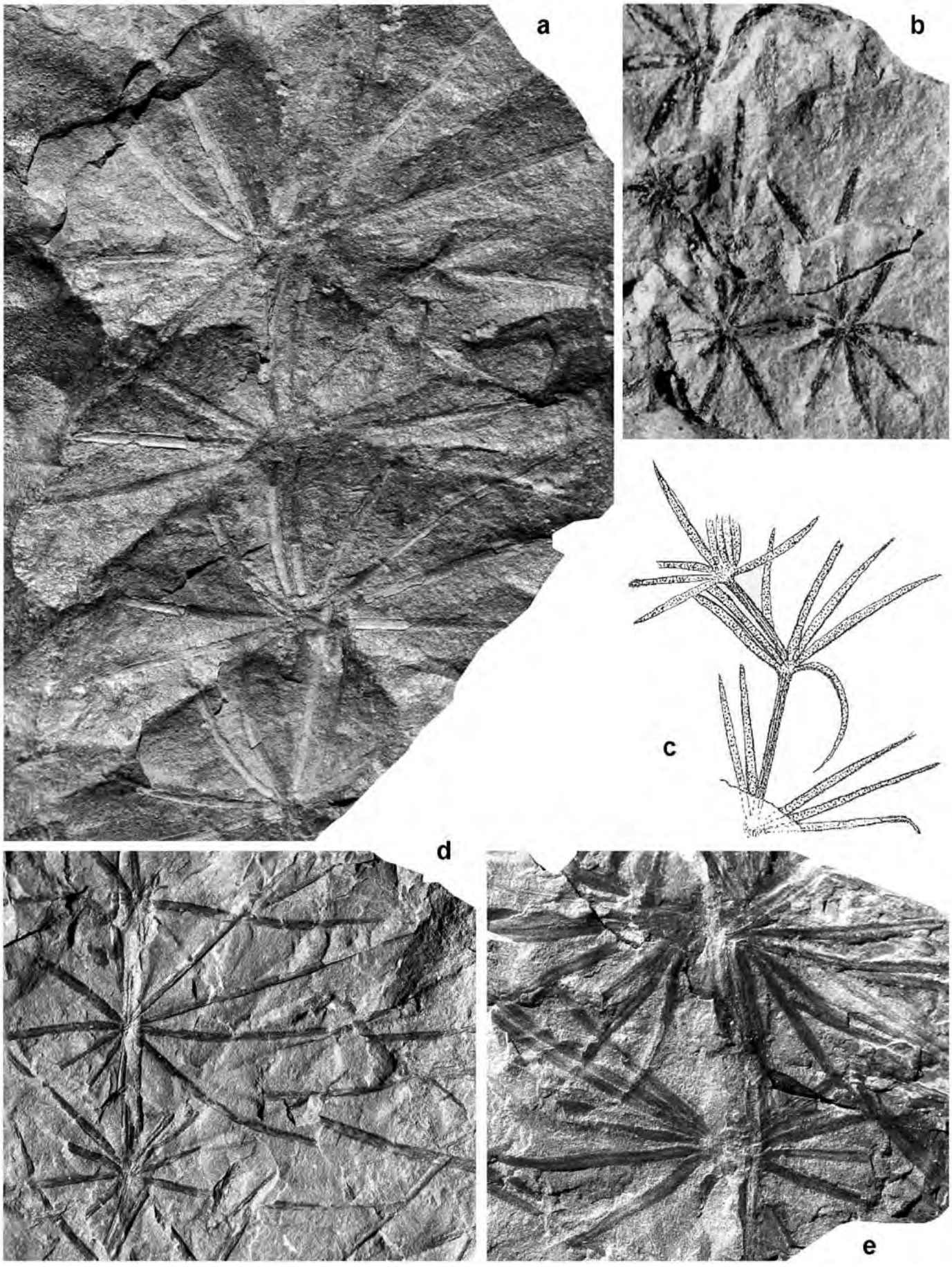
***Annularia pseudostellata* Potonié 1899**
(Figs. 9a, 9d–e)

* 1899 *Annularia pseudostellata* Potonié, pp. 200–201, Abb. 196 (copy in Jongmans 1911, p. 251, Fig. 204).
p 1906a *Annularia acicularis*, Matthew, p. 127, pl. V, fig. 1 (figured upside down — here as Fig. 9e); non pl. V, figs. 2–3 (= *Asterophyllites lindleyanus*).
1913 *Annularia pseudostellata*, Jongmans and Kukuk, Taf. 21, fig. 3, fig. 4 (upside down).
1934 *Sphenophyllum myriophyllum*, Arnold, p. 184, pl. VI, fig. 5; pl. VII, fig. 11 (cf.).
1957 *Annularia pseudostellata*, Guthörl, pp. 5, 7, Taf. 7, fig. 4; Taf. 8, fig. 9.
1959 *Annularia pseudo-stellata*, Remy and Remy, p. 79, Abb. 59.
v 1966 *Annularia acicularis*, Bell, p. 12, pl. V, fig. 14 (here Fig. 9d).
1966 *Annularia pseudostellata*, Bell, p. 40, pl. XIX, fig. 6.
1977 *Annularia pseudo-stellata*, Remy and Remy, p. 371, Bild 226a–b (same as Remy and Remy 1959).
1989 *Annularia pseudostellata*, Laveine, pp. 49–50, pl. 16, figs 4, 4a; text-figs 40A–B.

Excludenda:
1962 *Annularia pseudostellata*, Bell, pp. 50–51, pl. XLV, fig. 2 (= *Annularia ramosa*); pl. XLV, fig. 5 (= *Annularia radiata*); pl. XLVII, fig. 2 (= *Asterophyllites* sp.); pl. XLVII, fig. 3 (= *Asterophyllites* sp. indet.).
1978 *Annularia pseudostellata*, Gillespie *et al.*, p. 74, pl. 26, fig. 2 (here included, with doubt, in the synonymy of *Annularia stopesiae* sp. nov.).

DESCRIPTION: Ultimate axes longitudinally striate, 1–2 mm wide, with internodes 9–14 mm apart bearing verticils flattened in the same plane as the axis, each with 10–14 leaves that overlap slightly. Leaves linear, narrow, of uniform size, with 20–25 mm long (incomplete) at 0.4–0.5 mm width; length/breadth ratio ≈ 50. Lamina thick, vaulted. No vein. visible.

Figure 9. (next page) (a) *Annularia pseudostellata* (x3). GSC 283a. Origin: cutting east of Riversdale, Colchester County, Nova Scotia (locality 208). Repository: Geological Survey of Canada, Ottawa. (b) *Annularia ramosa* (x 6). GSC 9322. Specimen figured as *Annularia aculeata* by Bell (1944, pl. LX, figs. 3–4). Origin: Inverness County, Cape Breton Island, Chimney Corner area, shore about 1 km north of old coal mine (locality 1420). Repository: Geological Survey of Canada, Ottawa. (c) *Annularia radiata* (x 1). Copy of the synonymous *Asterophyllites lentus* as figured by Matthew (1906a, pl. V, fig. 7). Origin: Bed 2, Fern Ledges, Saint John, Lancaster, New Brunswick. (d) *Annularia pseudostellata* (x 3). GSC 14912. Figured as *Annularia acicularis* by Bell (1966, pl. V, fig. 14). Origin: unspecified location in a borehole in the Springhill area, Nova Scotia (locality 666). Repository: Geological Survey of Canada, Ottawa. (e) *Annularia pseudostellata* (x 3). NBMG 7008/1. Figured (upside down) as *Annularia acicularis* by Matthew (1906a, pl. V, fig. 1). Origin: Bed 1, Fern Ledges, Saint John, Lancaster, New Brunswick. Repository: New Brunswick Museum, Saint John.



COMPARISONS: *Annularia radiata* has shorter, linear-lanceolate leaves with a smaller length/breadth ratio than those of *Annularia pseudostellata*. *Annularia stopesiae* sp. nov. is anisophyllous, with longer lateral leaves. This species also has more leaves in a verticil (20–24); these are longer and wider than those of *Annularia pseudostellata.*

STRATIGRAPHIC AND GEOGRAPHIC DISTRIBUTION: *Annularia pseudostellata* has been rarely recorded, but is apparently widespread. It occurs in lower Bolsovian to Asturian strata.

OCCURRENCE IN THE MARITIME PROVINCES: Cumberland Basin (Nova Scotia): locality 208 (GSC 283a — unpublished specimen from Ami collection, 1897; here as Fig. 9a). Bell (1966): locality 666 (GSC 14912 — here Fig. 9d); locality 1039 (GSC 9061 + GSC 9063). New Brunswick: locality 650 (six unpublished specimens without catalogue numbers). Sydney Basin (Nova Scotia): Bell (1966): locality 1172 (GSC 14908). New Brunswick Museum collection: NBMG 7008/1 (here Fig. 9e).

OCCURRENCE IN THE UNITED STATES: Michigan: Arnold (1934).

***Annularia radiata* (Brongniart 1822) Sternberg 1825**
(Figs. 9c; Fig. 10)

* 1822 *Asterophyllites radiatus* Brongniart, pp. 210, 235, 239, pl. II, figs. 7a–b.
§ 1825 *Annularia radiata* (Brongniart) Sternberg, p. 31.
* 1833 *Asterophyllites foliosa* Lindley and Hutton, pp. 77–78, pl. 25, fig. 1 (acc. to Kidston 1886, p. 44).
* 1848 *Annularia asterophylloïdes* Sauveur, pl. LXVII, fig. 1 (acc. to Zeiller 1888).
1848 *Annularia radiata*, Sauveur, pl. LXVII, fig. 2.
* 1862 *Asterophyllites acicularis* Dawson, p. 310, pl. XIII, figs. 16a–b (Dawson compared with Lindley and Hutton's *Asterophyllites foliosa*) (acc. to Lesquereux 1880).
1868 *Asterophyllites acicularis* Dawson, pp. 537–538, 555, Fig. 194H.
* 1871 *Asterophyllites lenta* Dawson, p. 29, pl. V, figs. 60–60a (acc. to Stopes 1914).
p 1886–88 *Annularia radiata*, Zeiller, pp. 394–398, pl. LIX, fig. 8 (together with *Calamostachys*); pl. LXI, figs. 1–1A; non pl. LXI, figs. 2–2A (= *Annularia fertilis*).
1906a *Asterophyllites lentus*, Matthew, p. 122, pl. V, fig. 5 (same as Dawson 1871, pl. V, fig. 60), fig. 6 (leaf), fig. 7 (copied here as Fig. 9c).
1907b *Annularia radiata*, Zalessky, p. 369, Tab. XIII, figs. 11A–B.
p 1910 *Annularia radiata*, Renier, pl. 51; non pl. 52 (= *Annularia galioides*).
Tp 1911 *Annularia radiata*, Jongmans, p. 252, text-figs. 206, 208 (copy of Brongniart's holotype figure); non text-fig. 207 (= *Annularia ramosa* and *Calamostachys* sp.); non text-fig. 209 (= *Annularia fertilis*).
p 1913 *Annularia radiata*, Jongmans and Kukuk, Taf. 16, figs. 1–4, 6; non Taf. 16, fig. 5 (= *Annularia latifolia*).
p 1913 *Annularia stellata*, Jongmans and Kukuk, Taf. 21,

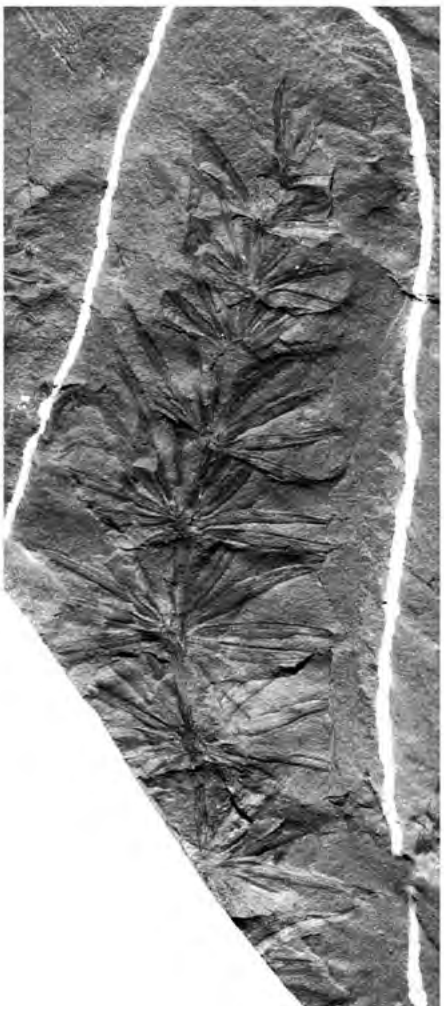


Figure 10. ***Annularia radiata*** **(x 3). GSC 9303. Figured by Bell (1944, pl. LXIII, fig. 3) as** ***Annularia acicularis*****. Origin: McCoy Head at Doctor Brook, near Saint John, New Brunswick (locality 628). Repository: Geological Survey of Canada, Ottawa.**

figs. 1, 2; non Taf. 22, fig. 4 (= *Annularia latifolia*).
1914 *Asterophyllites* sp. (= *Annularia radiata*?), Stopes, pp. 20–21, pl. IV, fig. 5 (photograph of Dawson 1871, pl. V, fig. 60).
1928 *Annularia radiata*, Jongmans, p. 19, pl. 10, fig. 3.
1925 *Annularia radiata*, Noé, p. 13, pl. IV, fig. 2; pl. V, fig. 1.
1932 *Annularia radiata*, Jongmans, p. 5, Fig. 9.
p 1937 *Annularia radiata*, Jongmans, pp. 406, 409, pl. 26, fig. 71 (fragmentary and poorly figured); pl. 33, fig. 104; non p. 405, pl. 25, fig. 68 (= *Annularia ramosa*).
? 1938 *Annularia radiata*, Bell, p. 85, pl. LXXXVIII, fig. 2.
vp 1944 *Annularia acicularis*, Bell, p. 101, pl. LVIII, fig. 5; pl. LX, fig. 6; pl. LXIII, fig. 3 (here as Fig. 10); pl. LXIV, fig. 5; pl. LXV, fig. 2; pl. LXIX, fig. 5; non pl. LVIII, fig. 2 (*Calamites* node).
1952 *Annularia radiata*, Novik, p. 148, Tab. XVI, figs. 3, 4.
? 1958 *Annularia radiata*, Abbott, pp. 317–319, pl. 41, fig. 56; chart 2.
? 1958 *Annularia radiata*, Langford, p. 40, fig. 41.
1959 *Annularia radiata*, Gothan *et al.*, pp. 45–47, Taf. 13, figs. 1–3.
1960 *Annularia*, Gillespie and Latimer, p. 28, pl. 6, fig. 2.
1961 *Annularia radiata* Brongniart forma, Leggewie and Schonefeld, p. 28, Taf. 24, figs. 1, 5.
1961 *Annularia radiata* f. *hirsuta*, Leggewie and Schonefeld, pp. 27–28, Taf. 23, figs. 1–4.
p 1962 *Annularia pseudostellata*, Bell, pl. XLV, fig. 5; non pp. 50–51, pl. XLV, fig. 2 (= *Annularia ramosa*); non pl. XLVII, fig. 2 (= *Asterophyllites* sp.); non pl. XLVII, fig. 3 (= *Asterophyllites* sp.).
? 1966 *Annularia radiata*, Bell, p. 56, pl. XXVII, fig. 6.
1966 *Annularia*, Gillespie *et al.*, p. 21, pl. 12, fig. 2 (same as Gillespie and Latimer 1960, pl. 6, fig. 2).
p 1978 *Annularia radiata*, Gillespie *et al.*, pp. 70, 74, 80, pl. 27, fig. 1 (same as Gillespie and Latimer 1960, pl. 6, fig. 2 and Gillespie *et al.* 1966, pl. 12, fig. 2); non pl. 26, fig. 8 (= *Annularia ramosa*?); non pl. 27, figs. 2, 6 (= *Annularia microphylla*).
1981 *Annularia radiata*, Cleal, p. 15, pl. 5, fig. 1.
1981 *Annularia radiata*, DiMichele and Dolph, pl. 2, fig. 18.
1982 *Annularia radiata*, Bassett and Edwards, p. 32 (right).
1982 *Annularia radiata*, DiMichele in Eggert and Phillips, pl. 2, fig. G (same as DiMichele and Dolph 1981, pl. 2, fig. 18).
p 1987 *Annularia fertilis*, Tenchov, pl. XII, figs. 9–12; pl. XIII, fig. 6 (?); non p. 39, pl. XIII, figs. 1–2 (= *Annularia fertilis*).
p 1987 *Annularia radiata*, Tenchov, p. 41, pl. XIV, fig. 5, 6 (?), figs. 7–8, figs. 11–14; non pl. XIV, fig. 9 (= *Asterophyllites* ?); non pl. XIV, fig. 10 (= *Annularia ramosa*).
1988 *Annularia radiata*, Cleal, p. 102, Fig. 1 (same as Cleal 1981).
1991 *Annularia radiata*, Josten, pp. 74–75, Taf. 18, figs. 2–3; Taf. 19; Abb. 32.
p 1991 *Annularia jongmansi*, Josten, Taf. 21, figs. 1, 1a; Abb. 35; non pp. 77–78, Taf. 20, figs. 3–3a (= *Annularia latifolia*); non Abb. 34 (= *Annularia latifolia*).
1994 *Annularia radiata*, Thomas and Cleal, p. 20, Fig. 2B.
2006 *Annularia radiata*, Wittry, p. 90, Figs. 1–4.
2009 *Annularia radiata*, Libertin *et al.*, pl. VI, fig. 1.
v 2010 *Annularia radiata*, Wagner and Álvarez-Vázquez, pp. 257, 266, 268, 270.
? 2014 *Annularia* sp. cf. *A. acicularis*, Bashforth *et al.*, pp. 243, 245, pl. 1, fig. 3 (fragmentary and poorly preserved).

Excludenda (including *Annularia acicularis*):
1871 *Asterophyllites acicularis* Dawson, pp. 28–29, pl. V, figs. 54 (= *Asterophyllites grandis*), figs. 54a–54c (leaves of *Annularia* sp. indet.); pl. V, figs. 55–56 (strobili); pl. V, fig. 57 (stem).
p 1906a *Annularia acicularis*, Matthew, p. 127, pl. V, fig. 1 (= *Annularia pseudostellata*); pl. V, figs. 2–3 (= *Asterophyllites lindleyanus*).
1914 *Asterophyllites acicularis* (= *A. equisetiformis*), Stopes, pp. 19–20, pl. IV, fig. 6 (= *Asterophyllites grandis* — same as Dawson 1871, pl. V, fig. 54).
1934 *Annularia radiata*, Arnold, p. 187, pl. I, fig. 1 (= *Annularia latifolia*).
1957 *Annularia radiata*, Janssen, p. 85, Fig. 68 (= *Annularia inflata*).
1962 *Annularia radiata*, Gillespie and Clendening, p. 125, pl. 4, fig. 4 (= *Annularia* sp., anisophyllous verticils with leaves showing a more acute apex than in *Annularia radiata*).
1963 *Annularia radiata*, Cridland *et al.*, p. 70, pl. 18, fig. 16 (= *Annularia carinata*).
1963 *Annularia radiata*, Wood, pp. 40–41, pl. 3, fig. 8 (= *Annularia* cf. *fertilis*).
1968 *Annularia acicularis*, Basson, p. 56, pl. 4, fig. 2 (to be compared with *Annularia ramosa* or *Asterophyllites* sp.).
1976 *Annularia acicularis*, Oleksyshyn, p. 156, Figs. 7B–7D (= *Asterophyllites* sp. indet. — too fragmentary for a specific identification).
1977 *Annularia radiata*, Gastaldo, pp. 137, 144, Fig. 29 (difficult to judge from an illustration at less than natural size, but apparently showing smaller, broader leaves with a more rounded apex).
1980 *Annularia radiata*, Zodrow and McCandlish, pl. 91, fig. 1 (= *Annularia fertilis*), pl. 91, figs. 2–3

(= *Asterophyllites*?).

1982 *Annularia radiata*, Ash and Tidwell, pp. 245–246, Fig. 2 (= *Asterophyllites* sp. indet. — fragmentary).

1996 *Annularia radiata*, Cross *et al.*, pp. 406, 442, Fig. 23–12.4 (difficult to judge from the illustration, but showing leaves with a broader lamina lamina and a subrounded apex).

DESCRIPTION: Ultimate axes longitudinally striate, c. 1–1.5 mm wide, with internodes 10–25 mm apart bearing verticils spread out on the bedding plane that touch but do not overlap. Verticils with 12 to 16 leaves, narrowly joint at the base, of almost equal length, linear-lanceolate, broadest about the middle and tapering to an acute apex. Dimensions: 11–24 mm long at 1–1.5 mm width; length/breadth ratio = 11–16. A longitudinal cell pattern is observed in some well-preserved leaves.

REMARKS: *Annularia acicularis*, here included in *Annularia radiata*, was introduced by Dawson (1862) as *Asterophyllites acicularis*; it was transferred to *Annularia* by White (1900). Bell (1944, p. 101) included *Annularia acicularis* in the synonymy of *Asterophyllites lentus* Dawson, a species that Stopes (1914, p. 20) regarded as a probable synonym of *Annularia radiata*. Abbott (1958) distinguished *Annularia acicularis* from *Annularia radiata* by the presence of linear leaves in *Annularia acicularis*, as against the linear-lanceolate leaves and a greater length/breadth ratio for *Annularia radiata*. She also noted that *Annularia acicularis* has anisophyllous leaf verticils, in contrast to the isophyllous verticils of *Annularia radiata*. However, these distinctions are blurred when Brongniart's and Dawson's original drawings are compared. *Annularia acicularis* has been ignored by European authors.

Most of the specimens that Bell (1944) assigned to *Annularia acicularis* have been available for reexamination. Six of these specimens (Bell 1944, pl. LVIII, fig. 5; pl. LX, fig. 6; pl. LXIII, fig. 3; pl. LXIV, fig. 5; pl. LXV, fig. 2; pl. LXIX, fig. 5) are included here in *Annularia radiata*. Another specimen (Bell 1944, pl. LVIII, fig. 2) represents a node of *Calamites* with stem leaves and thus cannot be assigned to *Annularia*. The specimen figured as *Asterophyllites* sp. (= *Annularia radiata*?) by Stopes (1914, pl. IV, fig. 5), after Dawson (1871), probably belongs also to *Annularia radiata*, but is too poorly preserved for a definitive identification. A specimen figured as *Asterophyllites acicularis* (= *Asterophyllites equisetiformis*?) by Stopes (1914, pl. IV, fig. 6), after Dawson (1871), is here assigned to *Asterophyllites grandis*.

COMPARISONS: *Annularia fertilis* possesses isophyllous verticils with a similar number of leaves to that in *Annularia radiata*; however, these are oblong, with an acute, mucronate apex. They are also a little longer, and possess a smaller length/breadth ratio. *Annularia latifolia* has anisophyllous leaf verticils with smaller, oblanceolate leaves topped by an obtuse, mucronate apex. Its leaves are smaller, with a smaller length/breadth ratio. In well-preserved adpressions of this species, the presence of an elongate, relatively coarse epidermal cell pattern, slightly oblique to the vein, is distinctive. *Annularia fimbriata* has more leaves in a verticil (15 to 20) than does *Annularia radiata*. The leaves are shorter and have a smaller length/breadth ratio. A transfer preparation by Walton (1936) shows a shallow median groove extending from the leaf base up to near the sharply pointed apex; he also recorded slightly oblique rows of hairs. *Annularia ramosa* has fewer leaves in a verticil (8 to 12) than *Annularia radiata*; they are also shorter and have a smaller length/breadth ratio. *Annularia isperichii*, described by Tenchov (1987), has fewer leaves (9 to 12) per verticil; they are of similar size to those of *Annularia radiata*, but are more markedly lanceolate, with a pointed, mucronate apex.

STRATIGRAPHIC AND GEOGRAPHIC DISTRIBUTION: *Annularia radiata* occurs most commonly in upper Langsettian and Duckmantian strata. Although the provenance of the holotype is unknown (Brongniart 1822), that of *Asterophyllites foliosa*, a synonym, is from the lower Duckmantian Bensham coal seam, Jarrow Colliery, near Newcastle, northern England. *Annularia asterophylloides*, another synonym, came from an unknown horizon in the lower Westphalian of Belgium (Sauveur 1848). Josten (1991) recorded *Annularia radiata* as ranging throughout Westphalian A–C (Langsettian to Bolsovian), and disappearing in the lower Westphalian D (Asturian). Tenchov (1987) figured this species from Westphalian B (Duckmantian) strata in Bulgaria. Wagner and Álvarez-Vázquez (2010) recorded *Annularia radiata* from Langsettian to lower Asturian strata in the Iberian Peninsula.

OCCURRENCE IN THE MARITIME PROVINCES: Cumberland Basin (Nova Scotia): Bell (1944): locality 999 (GSC 8607 + GSC 9120 + GSC 9580 + one piece without catalogue number — all specimens poorly preserved). Fern Ledges, New Brunswick: Dawson (1862). Dawson (1868). Dawson (1871). Matthew (1906a). Stopes (1914): locality 3340 of McGill University collection (holotype of *Asterophyllites lentus* — same as Dawson 1871 and Matthew 1906a). Bell (1944): locality 628 (GSC 9303 — here Fig. 10 + GSC 9314); locality 630 (GSC 9138 + GSC 9356 + 9373). Bashforth *et al.* (2014). Minto coalfield (New Brunswick): Bell (1962): locality 1019 (GSC 835). Minas Basin (Nova Scotia): Bell (1944): locality 3106 (GSC 10281). Sydney Basin (Nova Scotia): Bell (1966): locality 516 (GSC 14911).

OCCURRENCE IN THE UNITED STATES: Illinois: Noé (1925); Langford (1958); Wittry (2006). Ohio: Abbott (1958). West Virginia: Jongmans (1937); Gillespie and Latimer (1960).

***Annularia ramosa* Weiss 1884**
(Fig. 9b)

* 1884 *Annularia ramosa* Weiss (= *Ann. radiata* Brong. neque Auct.), pp. 184–197, Taf. V, fig. 1 (together with *Calamites ramosus* = *Calamites carinatus*); Taf. VI, figs. 1, 5 (with *Calamites ramosus*); Taf. VIII, fig. 4 (with *Calamites ramosus*); Taf. X, fig. 1 (with *Calamites ramosus*); Taf. XX, fig. 1 (together with *Calamites ramosus* and *Calamostachys ramosa*).

p 1937 *Annularia radiata*, Jongmans, p. 405, pl. 25, fig. 68; non pp. 406, 409, pl. 26, fig. 71 (= *Annularia radiata* — poorly figured); pl. 33, fig. 104 (= *Annularia radiata*).

*vp1944 *Annularia aculeata* Bell, pp. 101–102, pl. LX, figs. 3–4 (here Fig. 9b); pl. LXV, fig. 1 (cf.); pl. LXVIII, fig. 4 (holotype); pl. LXIX, figs. 1–2; non pl. LXII, fig.2 (= *Asterophyllites charaeformis*); non pl. LXIII, fig. 4 (= *Asterophyllites charaeformis*); non pl. LXV, fig. 4 (= *Asterophyllites charaeformis*?); non pl. LXVI, fig. 1(= *Annularia* sp. — poorly preserved); non pl. LXVI, fig. 3 (= *Asterophyllites grandis)*; non pl. LXVIII, fig. 1 (= *Asterophyllites charaeformis — figured as Annularia aculeata* and *Asterophyllites charaeformis*); non pl. LXIX, fig. 3 (poorly preserved, but resembling *Asterophyllites*);non pl. LXIX, fig. 6 (fragmentary — *Asterophyllites* sp.).

p 1962 *Annularia pseudostellata*, Bell, pl. XLV, fig. 2; non pp. 50–51, pl. XLV, fig. 5 (= *Annularia radiata*); pl. XLVII, fig. 2 (= *Asterophyllites* sp.); non pl. XLVII, fig. 3 (= *Asterophyllites* sp.).

1962 *Annularia radiata*, Purkyňová, p. 45, Tab. X, fig. 6.

1963 *Annularia radiata*, Němejc, p. 320, Tab. XXXV, fig. 2.

1965 *Annularia ramosa*, Stockmans and Willière, p. 16, pl. I, fig. 7.

? 1968 *Annularia acicularis*, Basson, p. 56, pl. 4, fig. 2 (poorly preserved).

? 1977 *Annularia* cf. *vernensis*, Leary and Pfefferkorn, p. 7, pl. 1, fig. 4 (might also be *Asterophyllites* sp.); text-figs. 4B–4C.

p 1978 *Annularia radiata*, Gillespie *et al.*, pp. 70, 74, 80, pl. 26, fig. 8; non pl. 27, fig. 1 (= *Annularia radiata);* non pl. 27, figs. 2, 6 (= *Annularia microphylla).*

1985 *Annularia asteris*, Gillespie and Rheams, pp. 194, 196, pl. I, fig. 2.

1985 *Annularia asteris*, Gillespie and Crawford, pp. 252, 255, pl. III, fig. 2.

1985 *Annularia* cf. *acicularis*, Lyons *et al.*, pp. 220, 222, 257, pl. VII, fig. c.

? 1987 *Annularia asteris*, Tenchov, p. 38, pl. XII, figs. 1–3.

p 1987 *Annularia radiata*, Tenchov, pl. XIV, fig. 10; non p. 41, pl. XIV, fig. 5 (= *Annularia radiata*), fig. 6 (?), figs. 7–8 (= *Annularia radiata*), figs. 11–14 (= *Annularia radiata*); non pl. XIV, fig. 9 (= *Asterophyllites*?).

p 1991 *Annularia ramosa*, Josten, pp. 75–77, Taf. 20, figs. 2–2a; Abb. 33 (drawing); non Taf. 20, fig. 1 (= *Annularia asteris*).

1991 *Annularia aculeata*, Josten, pp. 83–86, Taf. 23, figs. 4–6a; Abb. 40.

v 1995 *Annularia ramosa*, Álvarez-Vázquez, pp. 268–270, lám. 88, fig. 2; lám. 89, fig. 2; lám. 92, figs. 2–2a.

1996 *Annularia asteris*, Cross *et al.*, pp. 406, 442, fig. 23–12.2.

1997 *Annularia radiata*, Purkyňová, p. 194, Tab. I, fig. 2 (same as Purkyňová 1962, Tab. X, fig. 6).

v 2010 *Annularia ramosa*, Wagner and Álvarez-Vázquez, pp. 257, 266.

Excludenda:

1976 *Annularia aculeata*, Oleksyshyn, p. 156, Fig. 7B (fragmentary – *Asterophyllites* sp. indet.).

DESCRIPTION. Penultimate axes straight, 2–2.25 mm wide. Ultimate axes oppositely inserted at right angles, c. 0.5–0.75 mm wide; internodes 20 mm apart, bearing verticils with 8 to 12, widely spaced leaves all of similar length, linear-lanceolate, widely attached at the base and slightly pointed. Dimensions: 3.5–8 mm long at 0.15–0.3 mm wide; length/breadth ratio = 23–26. Vein not visible, obscured by a longitudinal cell pattern.

REMARKS: Bell (1944) included in *Annularia aculeata* specimens with verticils showing considerable variation in the number, size and shape of leaves. The holotype (Bell 1944, pl. LXVIII, fig. 4) shows second order branches with two fragmentary first order branches and one incomplete verticil that may be identified (a second is too poorly preserved), with 8 leaves, 3.5–4 mm long (three of these leaves show only the insertion). This specimen is a compression well enough preserved to show a longitudinal cell pattern. Very similar to the holotype is a well-preserved specimen from a locality (1420) in Inverness County, Cape Breton Island, Nova Scotia, showing widely spaced, small, slender, pointed leaves, fused at the base (Bell 1944, pl. LX, figs. 3–4; our Fig. 9b), all characters that accord with *Annularia ramosa*.

Several authors (e.g., Jongmans 1911; Abbott 1958; and Crookall 1969) regarded *Annularia ramosa* as a synonym of *Annularia radiata*. However, the holotype of *Annularia radiata* has a greater number of leaves per verticil (up to 16) than is the case for *Annularia ramosa*; they are also longer (20–22 mm), with a greater length/breadth ratio. These two species are clearly different.

COMPARISONS: *Annularia galioides* possesses oblanceolate leaves with an obtuse apex; maximum width occurs just above the middle, in contrast to the linear-lanceolate, fleshier leaves with pointed apices of *Annularia ramosa*. *Annularia radiata* has more leaves per verticil (12–16); although these leaves, like those of *Annularia ramosa*, are linear-lanceolate and in isophyllous verticils, they are longer. *Annularia asteris* has stiff, narrow leaves with acuminate apices; verticils are smaller (2–4.5 mm long and 0.20–0.25 mm width) than those of *Annularia ramosa*. Although *Annularia microphylla* has leaves similar in shape to those of *Annularia ramosa*, they are stiffer and curved, favouring adpression parallel to the axis.

STRATIGRAPHIC AND GEOGRAPHIC DISTRIBUTION: *Annularia ramosa* is fairly widespread and ranges from Namurian B to lower Bolsovian. The type material (Weiss 1884) is from lower Westphalian strata in Neurode (Nowa Ruda), Lower Silesia, Intrasudetic Basin, southwestern Poland. Josten (1991) records this species (as *Annularia ramosa* and *Annularia aculeata*) from upper Langsettian and lower Duckmantian strata in the Ruhr District in western Germany. Specimens figured by Tenchov (1978) from Bulgaria as *Annularia asteris* and *Annularia radiata* are from Namurian C (Yeadonian) and Westphalian A (Langsettian) strata. Stockmans and Willière (1965) recorded *Annularia ramosa* from Langsettian deposits at San Emiliano, León province, northwestern Spain. Wagner and Álvarez-Vázquez (2010) added a record from the Langsettian of La Camocha coal mine, near Gijón (Asturias province), northwestern Spain; they also recorded this species from upper Langsettian and lower Bolsovian strata of the Peñarroya Basin (Córdoba province), southwestern Spain.

OCCURRENCE IN THE MARITIME PROVINCES: Cumberland Basin (Nova Scotia): Bell (1944): locality 162 (nine pieces without catalogue number); locality 999 (GSC 9578 + GSC 9579 — both poorly preserved); locality 1080 (two pieces without catalogue number); locality 1406 (GSC 9318 — with doubt + GSC 9321 + GSC 9324 + four pieces without catalogue number — together with *Karinopteris acuta* and *Asterophyllites* sp. indet.); locality 1412 (GSC 9325 — holotype of *Annularia aculeata*); locality 1420 (GSC 9322 — here refigured, as part, in Fig. 9b); locality 1435 = 1406 (four pieces without catalogue number — together with *Alethopteris decurrens* and *Bergeria dilatata*); locality 1728 (cf. — four pieces without catalogue numbers). Minto coalfield (New Brunswick): Bell (1962): locality 1000 (GSC 837).

OCCURRENCE IN THE UNITED STATES: Alabama: Gillespie and Rheams (1985); Lyons *et al.* (1985). Georgia: Gillespie and Crawford (1985). Missouri: Basson (1968). West Virginia: Jongmans (1937); Gillespie *et al.* (1966); Gillespie *et al. (*1978).

***Annularia stopesiae* sp. nov.**
(Figs. 11–12)

p 1938 *Annularia stellata* forma *mucronata*, Bell, pl. XC, fig. 1; non p. 85, pl. LXXXIX (= *Annularia inflata*); non pl. XC, fig. 2 (= *Annularia* sp.); pl. XCI, fig. 1 (= *Annularia inflata*).
*v 1944 *Annularia stellata* forma *longifolia*, Bell, p. 102, pl. LXX, fig. 5 (holotype of the new species; see Fig. 11).
? 1949 *Annularia stellata*, Arnold, p. 184, pl. XVII, fig. 1 (incomplete leaves).
v 1966 *Annularia stellata* forma *longifolia*, Bell, p. 22, pl. X, fig. 4 (here Fig. 12).
? 1978 *Annularia pseudostellata*, Gillespie *et al.*, p. 74, pl. 26, fig. 2 (fragmentary; showing epidermal cell pattern).
v 1995 *Annularia* cf. *stellata*, Álvarez-Vázquez, pp. 270 –271, lám. 90, figs. 1–2.
p 1980 *Annularia stellata*, Zodrow and McCandlish, pl. 95, fig. 1; non pl. 94, fig. 1 (?), fig. 2 (= *Annularia* cf. *fertilis*); non pl. 95, fig. 2 (= *Annularia inflata*).
vp 2010 *Annularia stellata*, Wagner and Álvarez-Vázquez, p. 266; non pp. 270, 273, 274, 276, 282, 284, 291, 301 (= *Annularia stellata*).

HOLOTYPE: GSC 9876, a specimen described and figured by Bell 1944 (pl. LXX, fig. 5) as *Annularia stellata* forma *longifolia* (Fig. 11 of the present paper).

DERIVATION OF NAME: Named after Marie C. Stopes in recognition of her significant contribution to Canadian palaeobotany through her work at Fern Ledges, Saint John.

TYPE LOCALITY AND HORIZON: Mapleton Brook, Springhill area, 300 feet below driving dam (GSC locality 3116).

DIAGNOSIS: Anisophyllous verticils flattened in spread out condition; 20–24 linear-lanceolate leaves, up to 85 mm long and 1.5–2 mm broad. Vein straight, broad and well marked.

DESCRIPTION: Ultimate axes 2–5 mm wide, with internodes 16–45 mm apart bearing slightly overlapping verticils which are flattened in spread-out condition; anisophyllous (slightly elliptical), with the lateral leaves longer than those situated in lower and upper parts. Each verticil consists of 20–24 large, linear-lanceolate leaves, united at the base so as to form an annulus. Dimensions: 40 (incomplete) – 85 mm length at 1.5–2 mm width; length/breadth ratio = 50–56. Vein straight, broad and well marked in the central part of a thick leaf lamina.

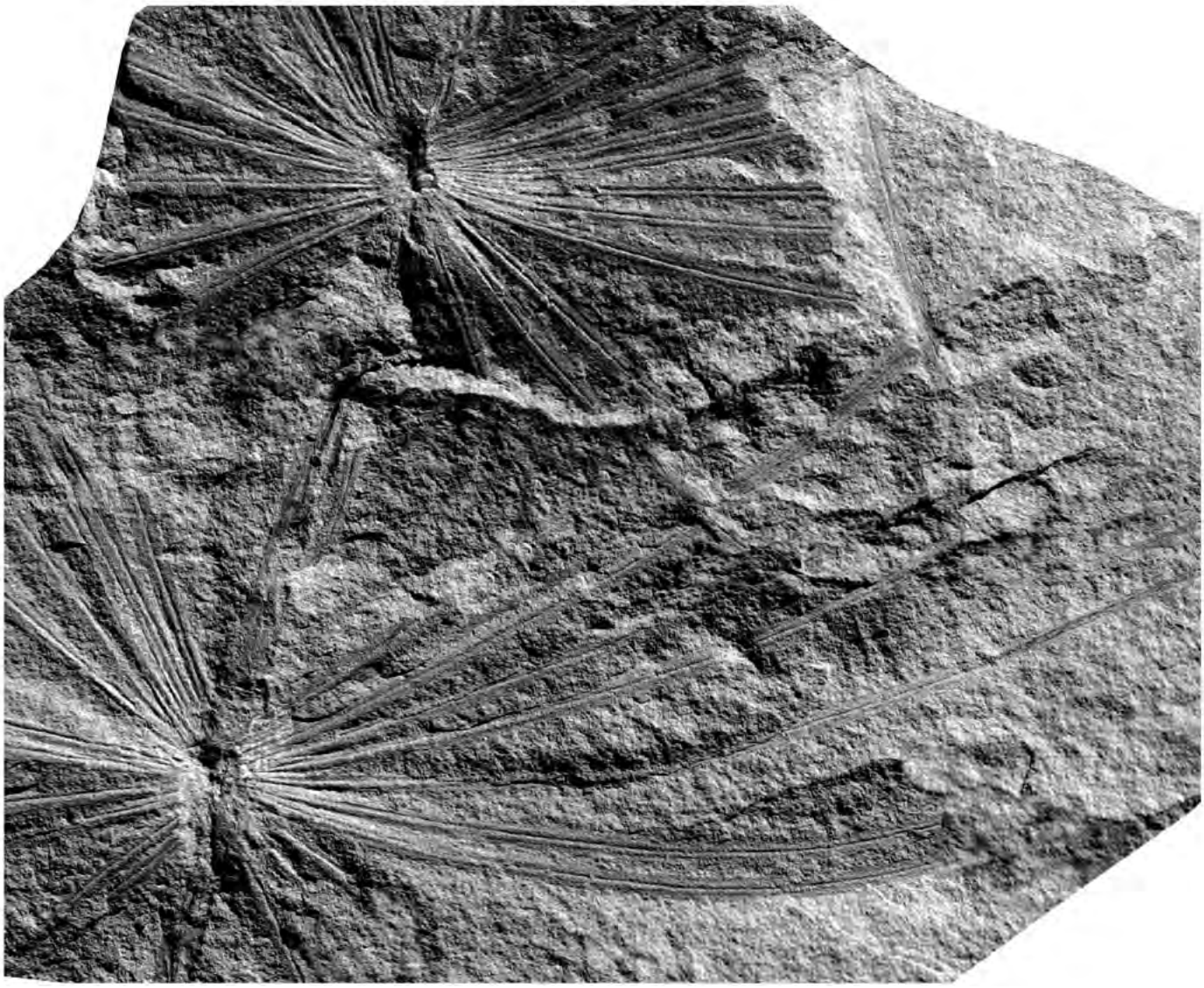


Figure 11. ***Annularia stopesiae*** **(x 2). Holotype. GSC 9876. Note the long, linear-lanceolate leaves in anisophyllous whorls. Specimen figured by Bell (1944, pl. LXX, fig. 5) as** ***Annularia stellata*** **forma** ***longifolia*****. Origin: Mapleton Brook, Springhill area, Nova Scotia, 300 feet below driving dam (locality 3116). Repository: Geological Survey of Canada, Ottawa.**

REMARKS: Bell (1944, pl. LXX, fig. 5; 1966, pl. X, fig. 4) figured two specimens of *Annularia* with very long, thin leaves, more than 20 per verticil, from two different localities at Springhill, Cumberland Basin, Nova Scotia. Bell (1944, p. 102) also recorded another (unfigured) specimen, from the Joggins section. All these specimens are preserved in a similar lithology. Bell applied the name *Annularia stellata* forma *longifolia*. However, this is based on the invalid species name *Annularia longifolia* (see Remarks on *Annularia inflata*). Leaf size in Bell's specimens is comparable to that known for *Annularia inflata*, but its leaves are narrower and linear-lanceolate. Bell (1944) observed a transverse epidermal cell pattern that he described as "… short hair-like fibres that run generally transverse to the midrib…"; this is characteristic for *Annularia spinulosa* (= *Annularia stellata*).

Specimens similar to those recorded by Bell from Canada, also showing the transverse epidermal cell pattern, have been recovered from five different localities in lower Bolsovian strata at the eastern end of the Peñarroya–Belmez–Espiel coalfield, southwestern Spain (Álvarez-Vázquez 1995, pp. 270–271, lám. 90, figs. 1–2, labelled *Annularia* cf. *stellata*).

COMPARISONS: *Annularia inflata* has shorter and broader oblanceolate leaves with an obtuse apex. Length/breadth ratio is much lower, between 8–10. *Annularia spinulosa* also possesses slightly anisophyllous verticils

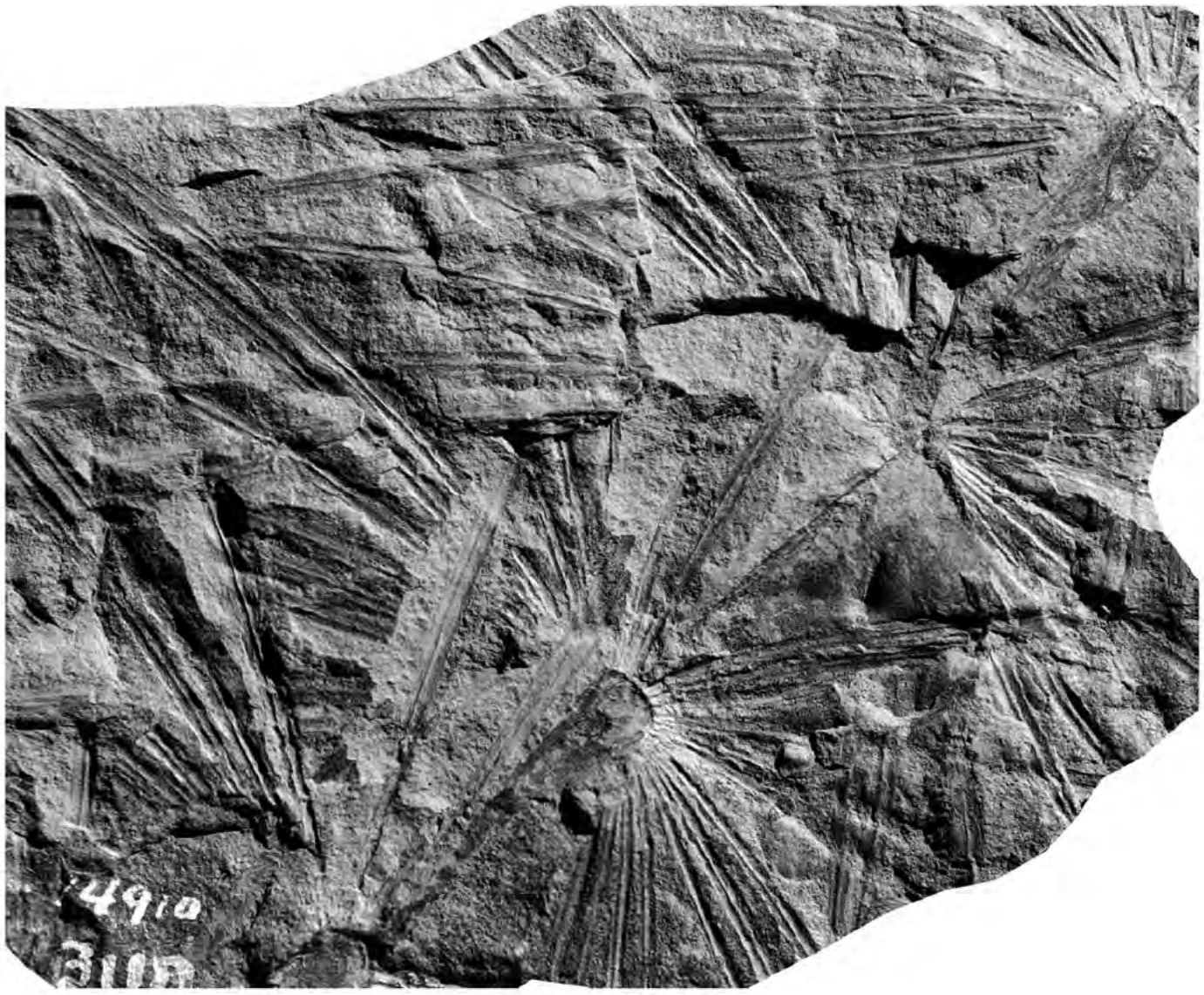


Figure 12. ***Annularia stopesiae*** (x 2). **GSC 14910. Note the broad vein, strongly marked in a thick lamina. Figured as *Annularia stellata* forma *longifolia* by Bell (1966, pl. X, fig. 4). Origin: Captain Henry Mill's Brook, tributary to Maccan River, Springhill area, Nova Scotia (locality 3110). Repository: Geological Survey of Canada, Ottawa.**

with a similar number of leaves, but these are shorter (around 30 mm), lanceolate, with bluntly pointed apices; length/breadth ratio is lower. *Asterophyllites longifolius* has a similar number of long, narrow leaves, but these are shorter and joined in isophyllous verticils. In addition, *Asterophyllites longifolius* leaves are normally flattened sideways, close to the axis, at an angle of less than 45°.

STRATIGRAPHIC AND GEOGRAPHIC DISTRIBUTION: Spanish material included in the synonymy comes from lower Bolsovian strata of the Peñarroya–Belmez–Espiel coalfield, Córdoba province, southwestern Spain.

OCCURRENCE IN THE MARITIME PROVINCES: Cumberland Basin (Nova Scotia): Bell (1944): locality 3116 (GSC 9876 — holotype; refigured in Fig. 11). Bell (1966): locality 3110 (GSC 14910 — Fig. 12 + one piece without catalogue number). Minto coalfield (New Brunswick): Bell (1966): locality 1172 (GSC 14908 — with doubt).

OCCURRENCE IN THE UNITED STATES: Michigan: Arnold (1949). West Virginia: Gillespie *et al.* (1978).

Figure 13. ***Asterophyllites charaeformis*** **(x 3). NMMG 3435. Counterpart of the specimen figured by Matthew (1906a, pl. VI, fig. 3) as** ***Asterophyllites parvulus*** **var. Origin: Bed 2, Fern Ledges, Lancaster, New Brunswick. Repository: New Brunswick Museum, Saint John.**

Genus *Asterophyllites* Brongniart 1822

p 1820 *Casuarinites* Schlotheim, p. 397 (illegitimate name; included by Brongniart 1822 in *Asterophyllites*).
1821 *Schlotheimia* Sternberg, p. 28 (illegitimate name; used previously for certain bryophytes).
1822 *Asterophyllites* Brongniart, p. 210 (nomen conservandum).
p 1825 *Bornia* Sternberg, p. 28 (nomen rejiciendum).
1825 *Bruckmannia* Sternberg, p. 29 (nomen rejiciendum).
1836 *Hippurites* Lindley and Hutton, p.105.
1869 *Calamocladus* Schimper, p. 323 (acc. to Zeiller 1888).
1880 *Asterophyllum* Schimper, p. 175 (acc. to Zeiller 1888).

TYPE: *Asterophyllites radiatus* Brongniart (= *Annularia radiata* Brongniart).

Asterophyllites charaeformis (Sternberg 1825) Göppert 1844
(Fig. 13)

* 1825 *Bechera charaeformis* Sternberg, p. 30, Taf. LV, figs. 3, 5.
§ 1844 *Asterophyllites charaeformis*, Göppert, p. 198.
* 1860 *Asterophyllites gracilis* Lesquereux, p. 310, pl. II, figs. 4–4a (acc. to Kidston 1911).
* 1861 *Asterophyllites parvula* Dawson, p. 168, Fig. 6 (acc. to Bell 1944).
1862 *Asterophyllites parvula* Dawson, p. 311.
1868 *Asterophyllites parvula* Dawson, p. 539, Fig. 188Aa–c (same as Dawson 1861).
* 1875 *Asterophyllites*? *minutus* Andrews, pp. 424–425, pl. 51, figs. 4–4a (Andrews noted the resemblance with *Asterophyllites parvula* and *Asterophyllites gracilis*, both synonyms of *Asterophyllites charaeformis*).
p 1879–80 *Asterophyllites gracilis* Lesquereux, pp. 42–43, pl. II, figs. 4–4c; non pl. II, figs. 5–5a (= *Calamostachys charaeformis*).
p 1884a *Asterophyllites gracilis* Lesquereux, pp. 714–715, pl. XCIII, fig. 3; non pl. XCIII, fig. 4 (= *Calamostachys charaeformis*); non pl. XCIII, figs. 5–6 (strobilus); non pl. XCIII, fig. 7 (*Calamites* stem).
p 1884b *Asterophyllites gracilis* Lesquereux, pp. 43–44, pl. 6, figs. 4–4a (same as Lesquereux 1884a, pl. XCIII, fig. 3); non pl. 6, figs. 5–5a (= *Calamostachys charaeformis* — same as Lesquereux 1884a, pl. XCIII, fig. 4); non pl. 6, fig. 6 (= strobilus — same as Lesquereux 1884a, pl. XCIII, fig. 5).
* 1887 *Asterophyllites Roehli* Stur, pp. 209–211, Taf. XIV, figs. 10–13a, 13b–c (= *Calamostachys*); Taf. XVb, fig. 3 (acc. to Kidston 1911).
1900 *Asterophyllites arkansanus* White, p. 897 (new name for Lesquereux's *Asterophyllites gracilis*).
v 1906a *Asterophyllites parvulus*, Matthew, pp. 122–123, pl. VI, figs. 1–2, fig. 3 (here Fig. 13).
1911 *Asterophyllites charaeformis*, Jongmans, pp. 232–234, figs. 190–191.
1914 *Asterophyllites parvulus* (= *A. grandis*?), Stopes, p. 20 (Stopes noted the similarity of Dawson's species with *Asterophyllites grandis*, as pointed out already by White 1900).
1937 *Asterophyllites grandis*, Jongmans, p. 409, pl. 32, fig. 102.
1940 *Asterophyllites charaeformis*, Bell, p. 129, pl. X, fig. 3.
v 1944 *Asterophyllites charaeformis*, Bell, p. 103, pl. LXIII, fig. 2; pl. LXVIII, fig. 1 (together with *Annularia aculeata*).

vp 1944 *Annularia aculeata* Bell, pl. LXII, fig. 2; pl. LXIII, fig. 4; non pl. LXV, fig. 4 (? — poorly preserved); pl. LXVIII, fig. 1; non pp. 101–102, pl. LX, figs. 3–4 (= *Annularia ramosa*); non pl. LXV, fig. 1 (?); non pl. LXVIII, fig. 4 (= *Annularia ramosa*); non pl. LXIX, figs. 1–2 (= *Annularia ramosa*); non pl. LXVI, fig. 1 (= *Annularia* sp. indet.); non pl. LXVI, fig. 3 (= *Asterophyllites grandis*); non pl. LXIX, fig. 3 (= *Asterophyllites* sp. indet.); non pl. LXIX, fig. 6 (fragmentary — *Asterophyllites* sp. indet.).
1958 *Asterophyllites charaeformis*, Abbott, pp. 296, 298, pl. 35, fig. 2 (drawing); pl. 48, fig. 85 (holotype of *Asterophyllites gracilis*), fig. 86; chart 1.
1959 *Asterophylllites charaeformis*, Gothan *et al.*, p. 55, Taf. 17, figs. 2–5.
1961 *Asterophyllites charaeformis*, Leggewie and Schonefeld, pp. 32–33; Taf. 26, figs. 1–2.
1966 *Asterophyllites*, Gillespie *et al.*, pl. 12, fig. 7.
1977 *Asterophyllites charaeformis*, Pfefferkorn and Gillespie, pl. 2, fig. D.
1978 *Asterophyllites charaeformis*, Gillespie *et al.*, p. 70, pl. 25, figs. 1, 4.
1979 *Asterophyllites charaeformis*, Gillespie and Pfefferkorn, pp. 90, 92, pl. 2, fig. 6.
1981 *Asterophyllites charaeformis*, Leary, pp. 59, 78, pl. 6, fig. 7.
1981 *Asterophyllites charaeformis*, Pfefferkorn and Gillespie, pl. 2, fig. 10.
1985 *Asterophyllites charaeformis*, Gillespie and Rheams, pp. 194, 199, pl. II, fig. 5.
1985 *Asterophyllites charaeformis*, Lyons *et al.*, pp. 216, 220, 237, pl. V, figs. f–g; pl. XI, fig. c.
1985 *Asterophyllites grandis*, Gillespie and Crawford, pp. 252, 255, pl. III, fig. 3.
1986 *Asterophyllites charaeformis*, Gillespie and Pfefferkorn, p. 128, pl. 3, figs. 5–6.
1989 *Asterophyllites charaeformis*, Gillespie *et al.*, p. 5, pl. 1, fig. 8.
1996 *Asterophyllites charaeformis*, Cross *et al.*, p. 444, fig. 23–13.2 (or *Calamostachys*?), fig. 23–13.3.
1997 *Asterophyllites charaeformis*, Blake, p. 83, pl. 4, fig. 3.
T 1997 *Asterophyllites charaeformis*, Kvaček and Straková, p. 48, pl. 13, fig. 1 (same as Sternberg 1825, Taf. LV, fig. 5).
2002 *Asterophyllites charaeformis*, Blake *et al.*, pp. 268, 291, pl. XVI, fig. 5.
2005 *Asterophyllites charaeformis*, Bashforth, pp. 45–46, pl. 4, figs. 10–11.
2005 *Asterophyllites charaeformis*, Dilcher *et al.*, p. 159, Figs. 3.8, 3.10.
2005 *Asterophyllites charaeformis*, Dilcher and Lott, pl. 126, figs. 1–2 (same as Dilcher *et al.* 2005, Figs. 3.8, 3.10), figs. 3–4.
v 2010 *Asterophyllites charaeformis*, Wagner and Álvarez-Vázquez, pp. 257, 266.

Excludenda:

1941 *Asterophyllites charaeformis*, Arnold, pl. I, fig. 2 (difficult to judge from the illustration, but possibly a conifer branchlet).
1967 *Asterophyllites charaeformis*, Tidwell, p. 27, pl. 9, fig. 1 (resembles *Asterophyllites grandis*).

DESCRIPTION: Penultimate axes striate longitudinally (not always discernible), c. 1 mm wide; internodes 7–12 mm long, showing two oppositely inserted, small (10–20 mm long), smooth ultimate branches, with internodes 2–3 mm long.Verticils composed of up to 10 acicular leaves, as long as or slightly longer than the internodes, attached at right angles and reflexed sharply upwards to a position parallel to the next internode, with the acute apex often incurved towards the axis. Dimensions: 2–3 mm long and 0.2–0.3 mm wide at the base; length/breadth ratio = 10.

REMARKS: Bell (1944, pl. LXIII, fig. 2; pl. LXVIII, fig. 1) figured two distinctive specimens of *Asterophyllites charaeformis*. We also include in this species two specimens described by Bell (1944) as *Annularia aculeata* (Bell 1944, pl. LXII, fig. 2; pl. LXIII, fig. 4). An incomplete strobilus was figured as *Calamostachys charaeformis* by Bell (1944, pl. LXX, fig. 1).

The vegetative leaves of *Calamostachys charaeformis* are distinctive. Two specimens that Bell (1944, pl. LXVII, fig. 5; pl. LXXIV, fig. 5) identified as "*Calamostachys* of *Asterophyllites grandis*", are included here in *Calamostachys charaeformis*; also the specimens figured by Bell (1944, pl. LXXIV, figs. 4, 7) as "*Calamostachys* of *Annularia aculeata*". We also include in *Calamostachys charaeformis* the specimen figured by Stopes (1914, pl. III, fig. 4) as *Calamostachys* sp.

COMPARISONS: The hooked shape of leaves of *Asterophyllites charaeformis* is distinctive. The slightly larger, sickle-shaped leaves of *Asterophyllites grandis* distinguish that species from *Asterophyllites charaeformis*. The same difference in bract shape separates *Calamostachys charaeformis* and *Calamostachys grandis*. *Asterophyllites lycopodioides* has 4–6 acicular leaves of similar size, but these are closely adpressed to the axis and only slightly curved. In addition, each verticil reaches the next one.

STRATIGRAPHIC AND GEOGRAPHIC DISTRIBUTION: *Asterophyllites charaeformis* is a fairly common species. In Europe, it occurs usually in lower Langsettian to upper Bolsovian strata, but Kotasowa (1968) also recorded (but did not illustrate) it from the upper Namurian (Yeadonian) of the Upper Silesian Basin. The type material is from the Bolsovian strata of the Radnice Member, Kladno Formation, Bohemia, Czech Republic.

OCCURRENCE IN THE MARITIME PROVINCES: Cumberland Basin (Nova Scotia): Bell (1944): locality 162 (three pieces without catalogue number); locality 881 (GSC 5984 — *Calamostachys charaeformis*); locality 1070 (GSC 10187 + GSC 10185); locality 1086 (GSC 9994 — together with *Sphenophyllum cuneifolium* and *Karinopteris acuta*); locality 1125 (one piece without catalogue number); locality 1190 (GSC 9019); locality 1374 (GSC 10990 — with cf.); locality 1686 (GSC 8238); locality 2253 = locality 1386 (one piece without catalogue number — together with *Laveineopteris polymorpha*); locality 3995 (two pieces without catalogue number). Albert County (New Brunswick): Bell (1944): locality 621 (GSC 8565 — *Calamostachys charaeformis* + GSC 9135); locality 647 (GSC 10869 — *Calamostachys charaeformis*). Fern Ledges (New Brunswick): New Brunswick Museum collection: NBMG 3435 (here Fig. 13) + NBMG 3436 (together with *Annularia asteris* and *Alethopteris* sp. indet.). Pictou coalfield (Stellarton Basin), Nova Scotia: Bell (1940): locality 1153 (GSC 10409).

OCCURRENCE IN THE UNITED STATES: Alabama: Lesquereux (1879–1880), Lesquereux (1884a, 1884b), Gillespie and Rheams (1985), Lyons *et al.* (1985), Dilcher and Lott (2005), Dilcher *et al.* (2005). Arkansas: Lesquereux (1860), Lesquereux (1879–1880), Lesquereux (1884b), Abbott (1958). Georgia: Lesquereux (1884a, 1884b). Ohio: Andrews (1875), Abbott (1958). West Virginia: Jongmans (1937); Gillespie *et al.* (1966), Pfefferkorn and Gillespie **(1977)**; Pfefferkorn and Gillespie (1981); Gillespie *et al.* (1978).

Asterophyllites grandis **(Sternberg 1825) Geinitz 1855**
(Fig. 14)

* 1825 *Bechera grandis* Sternberg, p. 42, Taf. XLIX, fig. 1.
* 1825 *Bechera delicatula* Sternberg, p. 42, Taf. XLIX, fig. 2 (acc. to Kidston 1886).
* 1828a *Asterophyllites pygmaeus* Brongniart, p. 150 (nomen nudum) (acc. to Schimper 1869 who re-examined Brongniart's specimen).
§ 1855 *Asterophyllites grandis*, Geinitz, p. 8, Taf. XVII, fig. 4.
p 1871 *Asterophyllites acicularis* Dawson, pp. 28–29, pl. V, figs. 54; non pl. V, figs. 54a–54c (indeterminate *Annularia* leaves); non pl. V, figs. 55–56 (strobili); non pl. V, fig. 57 (stem).
1884b *Asterophyllites fasciculatus*, Lesquereux, p. 43, pl. 6, fig. 7.
1886–88 *Asterophyllites grandis*, Zeiller, p. 376, pl. LIX, figs. 4, 7; non pl. LIX, figs. 5–6A (= *Calamostachys*).
vp1944 *Asterophyllites grandis*, Bell, p. 104, pl. LXIX, fig. 4; pl. LXXII, figs. 1, 4; pl. LXXV, fig. 1; non pl. LXVII, fig. 5 (= *Calamostachys charaeformis*); non pl. LXX, figs. 3–4 (= *Calamostachys grandis*); non pl. LXXII, figs. 2–3 (= *Calamostachys grandis*); non pl. LXXIV, fig. 5 (= *Calamostachys charaeformis*).
vp 1944 *Annularia aculeata* Bell, pl. LXVI, fig. 3 (here Fig. 14); non pp. 101–102, non pl. LX, figs. 3, 4 (= *Annularia ramosa*); non pl. LXII, fig. 2 (= *Asterophyllites charaeformis*); non pl. LXIII, fig. 4 (= *Asterophyllites charaeformis*); non pl. LXV, fig. 1 (= *Asterophyllites* cf. *charaeformis*); non pl. LXV, fig. 4 (poorly preserved — maybe *Asterophyllites charaeformis*); non pl. LXVIII, fig. 1 (= *Asterophyllites charaeformis*); non pl. LXVIII, fig. 4 (= *Annularia ramosa*); non pl. LXIX, figs. 1–2 (= *Annularia ramosa*); non pl. LXVI, fig. 1 (= *Annullaria* sp. indet.); non pl. LXIX, fig. 3 (= *Astero-Asterophyllites* sp.); non pl. LXIX, fig. 6 (= *Asterophyllites* sp. indet.).
1958 *Asterophyllites grandis*, Abbott, pp. 302–303; chart 1.
1962 *Asterophyllites grandis*, Bell, p. 49, pl. XLV, fig. 3; pl. XLVII, fig. 4.
1966 *Asterophyllites*, Gillespie *et al.*, pl. 12, fig. 5.
?p 1967 *Asterophyllites equisetiformis*, Tidwell, p. 27, pl. 4, fig. 1 (difficult to judge from the illustration); pl. 5, fig. 1 (difficult to judge from the illustration

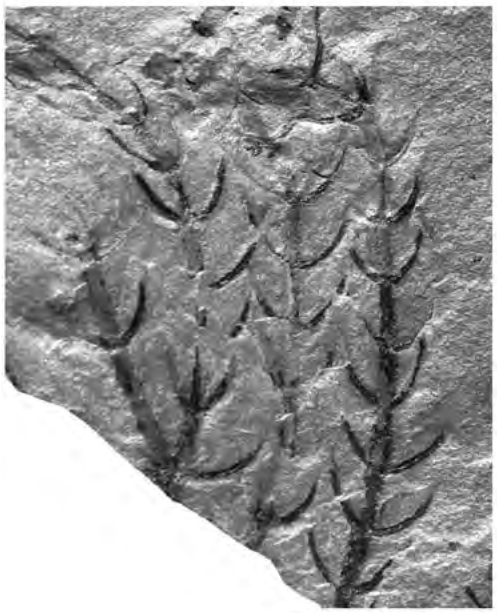


Figure 14. ***Asterophyllites grandis*** (x 3). **GSC 9931. Specimen figured as *Annularia aculeata* by Bell (1944, pl. LXVI, fig. 3). Origin: South Brook, Leamington, Cumberland County, Nova Scotia (locality 1162). Repository: Geological Survey of Canada, Ottawa.**

— together with *Sphenopteris* sp. indet.); non pl. 9, fig. 2 (difficult to judge, but probably *Annularia* sp.).

? 1967 *Asterophyllites charaeformis*, Tidwell, p. 27, pl. 9, fig. 1 (fragmentary verticil associated with *Calamostachys* sp. indet.).

1978 *Asterophyllites grandis*, Gillespie *et al.*, p. 70, pl. 25, fig. 2 (same as Gillespie *et al.* 1966, pl. 12, fig. 5), pl. 25, fig. 4.

T 1997 *Asterophyllites grandis*, Kvaček and Straková, pp. 62, 82, pl. 18, fig. 4 (holotype of *Bechera delicatula*); pl. 25, fig. 4 (holotype of *Bechera grandis*).

2014 *Asterophyllites grandis*, Bashforth *et al.*, pp. 243, 245, pl. 1, fig. 2.

Excludenda:

1937 *Asterophyllites grandis*, Jongmans, p. 409, pl. 32, fig. 102 (= *Asterophyllites charaeformis*).

DESCRIPTION: Ultimate axis 0.30–0.50 mm wide, longitudinally striate, with internodes 2.5–4 mm long that become shorter and thinner towards the apex. Leaves slightly shorter than the internodes, thread-like, inserted at acute angles and curving slightly towards the axis in the upper half. Dimensions: 4–6 mm long and 0.3–0.4 mm broad; length/breadth ratio = 13–15. Vein not visible.

REMARKS: Bell (1944) figured two specimens of *Asterophyllites grandis* that are easily recognized by their sickle-shaped leaves, which overlap slightly at successive whorls. Bell also attributed four specimens of *Calamostachys* to *Asterophyllites grandis*, two of which are reassigned here to *Calamostachys charaeformis*. The cylindrical strobili of *Asterophyllites grandis* possess bracts similar to the vegetative leaves, and sporangiophores situated at about middle distance between verticils.

The similar species *Asterophyllites tayloriorum*, described from South Wales, is indistinguishable from *Asterophyllites grandis* in the vegetative state, but differs with regard to its associated fertile remains, assigned to *Palaeostachya wagneri* (Cleal and Shute 2016).

COMPARISONS: *Asterophyllites charaeformis* has smaller, distinctively reflexed leaves placed at right angles. Leaves of *Asterophyllites lycopodioides* are less curved and pass beyond the internode to touch the base of the next verticil.

STRATIGRAPHIC AND GEOGRAPHIC DISTRIBUTION: *Asterophyllites grandis* occurs in Yeadonian to upper Bolsovian strata. Type material of *Bechera grandis* and *Bechera delicatula* are both from Bolsovian strata of the Radnice Member, Kladno Formation, Bohemia, Czech Republic.

OCCURRENCE IN THE MARITIME PROVINCES: Cumberland Basin (Nova Scotia): Bell (1944): locality 1039 (GSC 9054 + GSC 9067a — together with *Sphenopteris* sp., *Calamites suckowii* and *Cyperites*); locality 1052 (two pieces, part and counterpart, with catalogue numbers unclear as a result of damage to the specimen — together with *Renaultia* sp. and *Cordaites* sp.); locality 1162 (GSC 9931 — together with *Calamites* sp.; here Fig. 14); locality 1362 (GSC 10989); locality 1406 (GSC 9134); locality 1675 (one piece without catalogue number — *Calamostachys grandis*). Albert County (New Brunswick): Bell (1944): locality 621 (GSC 9135 + GSC 9376 — *Calamostachys grandis*); locality 1401 (GSC 6554 — *Calamostachys grandis*). Minto coalfield (New Brunswick): Bell (1962): locality 5430 (GSC 937 + GSC 938).

OCCURRENCE IN THE UNITED STATES: Ohio: Abbott (1958). Utah: Tidwell (1967). West Virginia: Gillespie *et al.* (1966), Gillespie *et al.* (1978).

***Asterophyllites lindleyanus* Göppert 1848**

(Fig. 15; Figs. 16a–c)

*p 1835 *Hippurites longifolia* Lindley and Hutton, p. 106, pl. 191 (copied here as Fig. 15); non pl. 190 (= *Calamites stems*).

§ 1848 *Asterophyllites lindleyanus* Göppert, p. 122 (substitute name for Lindley and Hutton's *Hippurites longifolia*).

* ? 1848 *Asterophyllites arcuata* Sauveur, pl. LXVIII, fig. 2 (fragmentary).

* 1848 *Asterophyllites subulata* Sauveur, pl. LXIX, fig. 5 (synonym of *Asterophyllites equisetiformis* acc. to Jongmans 1914b).

* 1868 *Asterophyllites trinervis* Dawson, p. 479, Fig. 165A (synonym of *Calamocladus equisetiformis* acc. to Kidston 1886).

* 1875 *Asterophyllites erectifolius* Andrews, p. 425, pl. XLIX, fig. 3.

* 1876 *Calamocladus binervis* Boulay, p. 22, pl. II, fig. 1 (probable synonym of *Calamocladus equisetiformis* acc. to Kidston 1886).

p 1884b *Asterophyllites equisetiformis*, Lesquereux, p. 42, pl. 6, fig. 1; non pl. 6, fig. 2 (strobilus).

p 1886–88 *Asterophyllites equisetiformis*, Zeiller, pp. 368–374, pl. LVIII, figs. 3–7; non pl. LVIII, figs. 1–1B (strobilus), fig. 2 (nodal leaves).

1901 *Calamocladus equisetiformis*, Kidston, p. 202, pl. XXX, fig. 3.

p 1906a *Annularia acicularis*, Matthew, pl. V, figs. 2–3; non p. 127, pl. V, fig. 1 (= *Annularia pseudostellata*).

1913 *Asterophyllites equisetiformis* forma *Schlotheimii*, Jongmans and Kukuk, Taf. 17, figs. 2–5.

p 1934 *Asterophyllites equisetiformis*, Arnold, p. 186, pl.

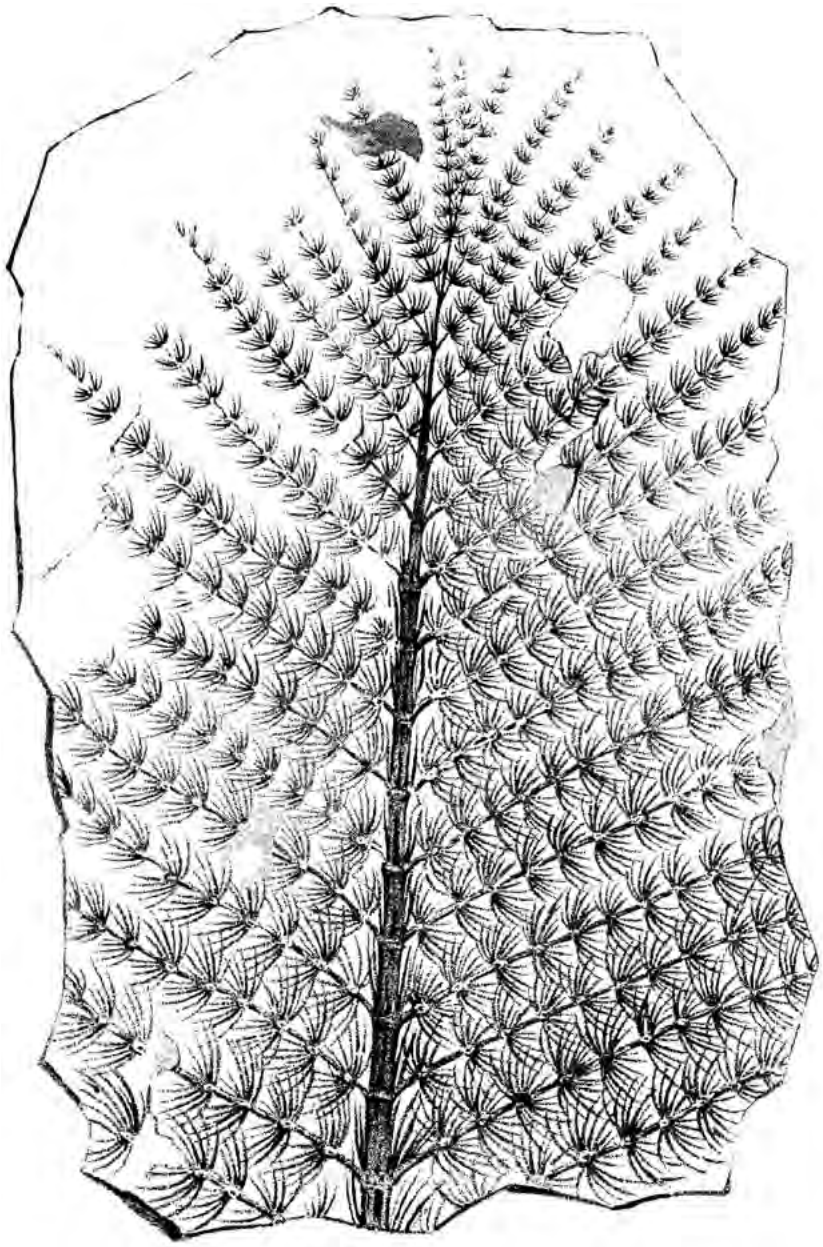


Figure 15. ***Asterophyllites lindleyanus*** **(× 1). Copy of** ***Hippurites longifolia*** **as figured by Lindley and Hutton (1835, pl. 191); here designated as the lectotype of** ***Asterophyllites lindleyanus*****.**

I, fig. 3; non pl. III, fig. 3 (? — calamitean axis with stem leaves).

1937 *Asterophyllites equisetiformis*, Jongmans, p. 409, pl. 32, fig. 103.

1938 *Asterophyllites equisetiformis*, Bell, p. 86, pl. LXXXVII, figs. 3–4; pl. LXXXVIII, fig. 1.

1938 *Asterophyllites equisetiformis*, Renier and Stockmans *in* Renier *et al.*, p. 71, pl. 45.

vp 1944 *Asterophyllites equisetiformis*, Bell, p. 103, pl. LXX, fig. 2 (cf. — fragmentary); pl. LXXI, fig. 3 (here Fig. 16c); non pl. LXXI, fig. 1 (= *Acrobulbillites* — here as Fig. 17; name introduced by Amerom 1973 and interpreted as galls at the end of calamitean branchlets).

1949 *Asterophyllites equisetiformis*, Arnold, p. 183, pl. XVII, figs. 2, 4, 5.

1952–53 *Asterophyllites equisetiformis*, Stockmans and Willière, p. 185, pl. XLVI, fig. 3.

k 1958 *Asterophyllites equisetiformis*, Abbott, pp. 299–302, pl. 35, fig. 4; pl. 36, figs. 12, 15, 19, 20 (cuticles); pl. 39, figs. 46–47, 49–51; pl. 43, fig. 63; pl. 47, fig. 78 (cuticle); chart 1.

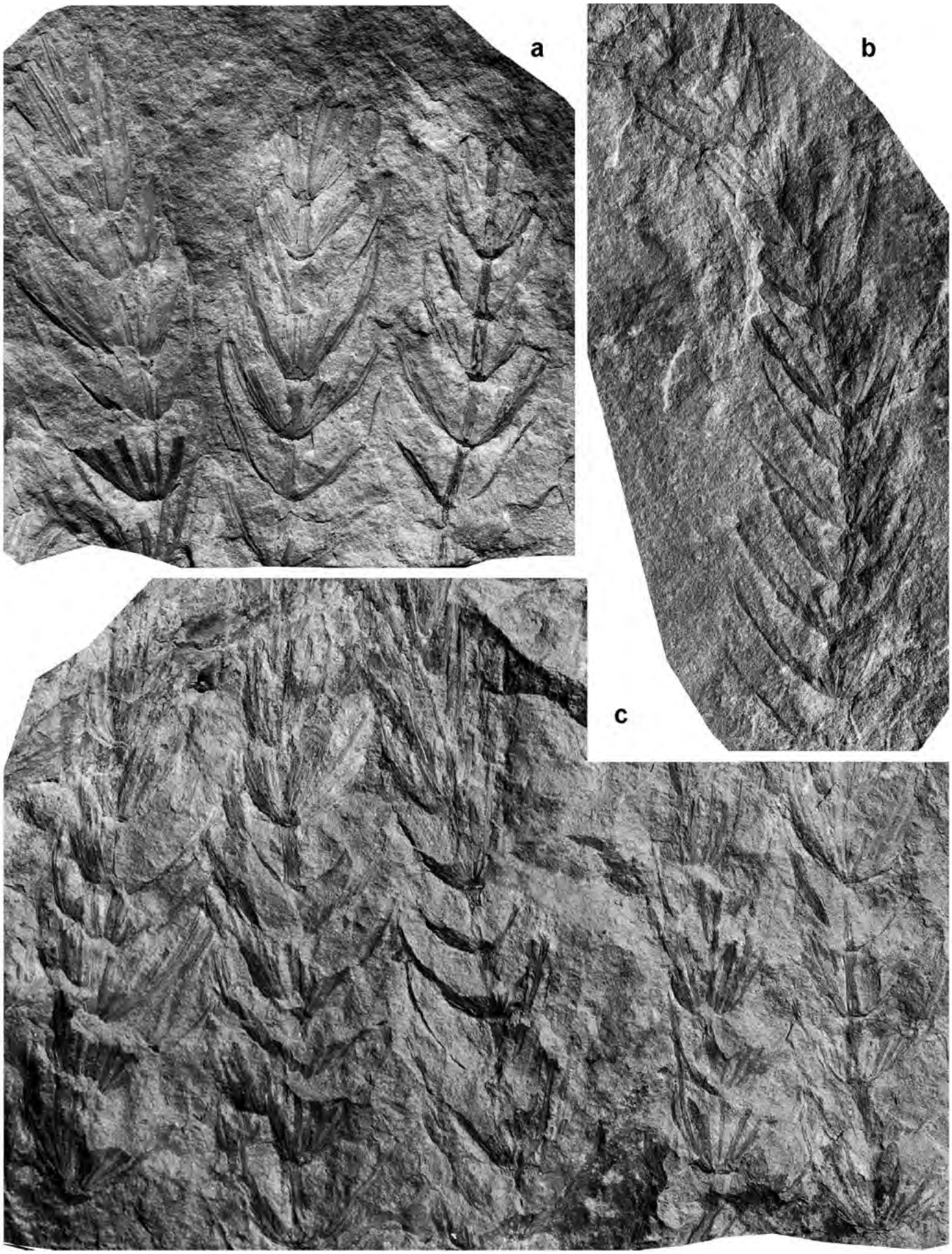


Figure 16. (previous page) (a) *Asterophyllites lindleyanus* (x 3). GSC 10133. Origin: South Brook, tributary of Maccan River, below South Brook settlement, Nova Scotia (locality 1087). (b) *Asterophyllites lindleyanus* (x 2). Origin: Leamington, South Brook, Nova Scotia (locality 156). (c) *Asterophyllites lindleyanus* (x 2). GSC 10132. Specimen figured as *Asterophyllites equisetiformis* by Bell (1944, pl. LXXI, fig. 3). Origin: as for Fig. 16a (locality 1087). Repository: Geological Survey of Canada, Ottawa.

1959 *Asterophylllites equisetiformis*, Gothan *et al.*, pp. 53–54, Taf. 16, figs. 2–4; Taf. 17, fig. 1.
1961 *Asterophyllites equisetiformis* f. *typica*, Leggewie and Schonefeld, pp. 34–35, Taf. 28, figs. 1, 5–6.
1963 *Asterophyllites equisetiformis*, Wood, pp. 42–43, pl. 4, fig. 2.
p 1966 *Asterophyllites equisetiformis*, Bell, pp. 58, 60, pl. XXVIII, fig. 7; pl. XXIX, fig. 4; non p. 74, pl. XXXVI, fig. 3 (difficult to judge from the the illustration).
p 1969 *Asterophyllites equisetiformis* forma *typica*, Crookall, pp. 695–700, pl. CXLII, fig. 3 (same as Kidston 1901, pl. XXX, fig. 3); non text-fig. 203 (copy of Geinitz 1855, Taf. XVII, fig. 1, topotopotype of Schlotheim's species).
? 1989 *Asterophyllites equisetiformis*, Gillespie *et al.*, p. 5, pl. 1, fig. 6.
v 1995 *Asterophyllites* cf. *equisetiformis*, Álvarez-Vázquez, pp. 275–276, lám. 88, figs. 3–4.
2005 *Asterophyllites equisetiformis*, Bashforth, p. 46, pl. 6, figs. 2, 5.
v 2010 *Asterophyllites* cf. *equisetiformis*, Wagner and Álvarez-Vázquez, pp. 257, 266, 268.

Excludenda:

1967 *Asterophyllites equisetiformis*, Tidwell, p. 27, pl. 4, fig. 1 (cf. *Asterophyllites grandis)*; pl. 5, fig. 1 (= *Asterophyllites grandis*); pl. 9, fig. 2 (difficult to judge, but possibly a species of *Annularia*).

LECTOTYPE (DESIGNATED HEREIN): The specimen figured by Lindley and Hutton (1835, pl. 191) as *Hippurites longifolia*. Lindley and Hutton's drawing is refigured here as Fig. 15.

DESCRIPTION: Ultimate axes with fine longitudinal striae, straight, 1–1.5 mm wide, with internodes 5–10 mm long, becoming shorter and narrower upwards. Verticils with up to 16 closely placed, linear-lanceolate leaves, showing nearly parallel margins and an acute apex; lower leaves attached at approximate right angles and curved at about mid-length; higher leaves are more or less straight and attached at acute angles. Dimensions; 10–14 mm long and 0.5–0.75 mm broad; length/breadth ratio = 18–20.

REMARKS: The (missing) type material of Schlotheim's *Asterophyllites equisetiformis* (originally *Casuarinites equisetiformis*) originated from upper Stephanian strata of Wettin and Manebach, eastern Germany. Most authors acknowledge that a varied group of similar taxa has been figured under this name in the literature. Jongmans and Kukuk (1913) recorded as *Asterophyllites equisetiformis* forma *schlotheimii* the form introduced by Schlotheim (1820) for uppermost Stephanian (lower Permian?) material characterized by leaves that are relatively broad, are broadest at about one third above the base, and possess a sharply pointed apex. The taxon with more thread-like, narrow and parallel-sided leaves that occurs throughout the Westphalian Stage (up to the lower Asturian) was named *Asterophyllites equisetiformis* forma *jongmansii* by Josten (1991), who applied the name *Asterophyllites equisetiformis* forma *equisetiformis* to the Stephanian (including the upper Asturian) taxon. Josten's *Asterophyllites equisetiformis* forma *jongmansii* includes both *Asterophyllites equisetiformis* forma *typica* of Jongmans (1914b) and *Asterophyllites gothanii* (Leggewie and Schonefeld in Gothan *et al.* 1959); both were poorly defined and inadequately figured. The fragmentary Canadian specimens do not warrant a detailed discussion. Lindley and Hutton's specimen (lectotype) still needs to be reproduced photographically; however, we suggest for the time being that most of the Westphalian specimens recorded in the literature as *Asterophyllites equisetiformis* may be attributable to *Asterophyllites lindleyanus*.

Bell (1944) reported *Asterophyllites equisetiformis* as uncommon in the Cumberland Basin. Bell's specimens (plus additional ones from the same localities) have been available for reexamination. His pl. LXX, fig. 2, representing only a fragment of leaf verticil, and pl. LXXI, fig. 3 (our Fig. 16c), which is a more complete specimen with several ultimate axes showing thin-leaved verticils, fit Josten's *Asterophyllites equisetiformis* forma *jongmansii*, from the Westphalian. Bell's pl. LXXI, fig. 1 (our Fig. 17) represents the swollen tip of a branch that may be interpreted as a response to a fungal infection, and attributed to *Acrobulbillites* (as described by Amerom 1973).

COMPARISONS: *Asterophyllites equisetiformis*, as found in the higher Stephanian, shows broader leaves with the maximum width at about one third from the base, and a sharply pointed apex. Leaves of *Asterophyllites grandis* are smaller, more falcate, and less broad than those of *Asterophyllites lindleyanus*, with a smaller length/breadth ratio. Leaves of *Asterophyllites lycopodioides* are shorter and less arched; they pass beyond the node above to touch the base of the next verticil.

Figure 17. ***Acrobulbillites*** **sp. (x 2). GSC 9017. Specimen figured by Bell (1944, pl. LXXI, fig. 1) as** ***Asterophyllites equisetiformis*****. Origin: Springhill, No. 2 mine, from roof shales in waste dump (locality 1039), Nova Scotia. Repository: Geological Survey of Canada, Ottawa.**

STRATIGRAPHIC AND GEOGRAPHIC DISTRIBUTION: The species occurs rarely in the Yeadonian, but is relatively common and widespread in Westphalian strata (up to and including the lower Asturian).

OCCURRENCE IN THE MARITIME PROVINCES: Cumberland Basin (Nova Scotia): Bell (1944): locality 136 (poorly preserved — one piece without catalogue number); locality 156 (one piece without catalogue number — here Fig. 16b; together with *Zeilleria avoldensis* and *Sphenophyllum cuneifolium*); locality 173b (poorly preserved — one piece without catalogue number); locality 1063 (GSC 9401); locality 1087 (GSC 10132 — Fig. 16c + GSC 10133 — Fig. 16a; together with *Dorycordaites palmaeformis* + GSC 10134 — with *Dorycordaites palmaeformis* and *Samaropsis* sp. + one piece without catalogue number, together with *Asterophyllites charaeformis* and *Samaropsis* sp.); locality 2984 (one piece without catalogue number); locality 3001 (GSC 5993 — recorded with cf.; together with *Paripteris* sp.). Fern Ledges (New Brunswick): New Brunswick Museum collection: NBMG 7030 + NBMG 7043. Sydney Basin (Nova Scotia): locality 518 (GSC 14922).

OCCURRENCE IN THE UNITED STATES: Indiana: Wood (1963). Ohio: Andrews (1875); Abbott (1958). West Virginia: Jongmans (1937).

Asterophyllites longifolius (Sternberg 1825) Brongniart 1828

(Figs. 18, 19)

* 1825 *Bruckmannia longifolia* Sternberg, p. 45, Taf. LVIII, figs. 1A–B.

* 1825 *Bruckmannia rigida* Sternberg, p. 29, Taf. XIX, fig. 1 (acc. to Kidston 1886).

§ 1828a *Asterophyllites longifolius*, Brongniart, p. 159.

* 1834 *Asterophyllites comosus* Lindley and Hutton, pp. 73–74, pl. 108 (acc. to Kidston 1886).

*? 1848 *Asterophyllites arcuata* Sauveur, pl. LXVIII, fig. 2 (fragmentary).

* 1848 *Asterophyllites elegans* Sauveur, pl. LXVIII, fig. 1 (acc. to Zeiller 1888).

1870 *Asterophyllites rigidus*, Lesquereux, p. 424, pl. XXI, figs. 4–4a.

*p 1884 *Asterophyllites striatus* Weiss, pp. 192–193 [278–279], Taf. XX, fig. 3; non Taf. XX, figs. 4–5 (= *Palaeostachya striata*) (acc. to Jongmans 1911).

1886–88 *Asterophyllites longifolius*, Zeiller, p. 374, pl. LIX, fig. 3.

*? 1887 *Asterophyllites germarianus* Stur, p. 71, Taf. XVb, fig. 1 (acc. to Jongmans 1911).

1899 *Asterophyllites longifolius*, White, pp. 153–156, pl. XLIX, figs. 2–4.

1906a *Asterophyllites longifolius*, Matthew, p. 120, pl. I, fig. 3.

*? 1906a *Asterophyllites fasciculatus* Matthew (non Lesquereux 1879 — who already used the same specific name), p. 121, pl. I, fig. 2 (Fig. 19 — although based on a fragmentary and poorly preserved holotype, Matthew's species is here tentatively identified with *Asterophyllites longifolius*).

*p 1906a *Asterophyllites* (?) *fissus* Matthew, pp. 121–122, pl. VI, figs. 4, 6; non pl. VI, fig. 5 (too fragmentary for a specific determination).

Figure 18. ***Asterophyllites longifolius*** **(x 3). Origin: Squaw Point, Cape Enragé, Albert County, New Brunswick (locality 626). Repository: Geological Survey of Canada, Ottawa.**

*p 1906a *Ramicalamus dumosus* Matthew, pl. VIII, fig. 5; non pp. 115–116, pl. VIII, figs. 2–3 (= *Calamites* stems); non pl. VIII, fig. 4 (= node).
1940 *Asterophyllites longifolius* forma *striata*, Bell, pp. 128–129, pl. III, fig. 5.
1957 *Asterophyllites longifolius*, Janssen, p. 88, Fig. 72.
1958 *Asterophyllites longifolius*, Abbott, pp. 303–304, pl. 40, fig. 53; pl. 42, fig. 60; chart 1.
1958 *Asterophyllites longifolius*, Langford, p. 43, figs. 51–52.
* 1961 *Asterophyllites discifer* Leggewie and Schonefeld, pp. 8–11, Taf. 3, figs. 3–6; Taf. 4, figs. 1–3, 5.
1962 *Asterophyllites longifolius*, Bell, pp. 49–50, pl. XI, figs. 3–4 (together with *Palmatopteris furcata*); pl. XLV, fig. 1.
1963 *Asterophyllites longifolius*, Cridland *et al.*, p. 71, pl. 19, fig. 32.

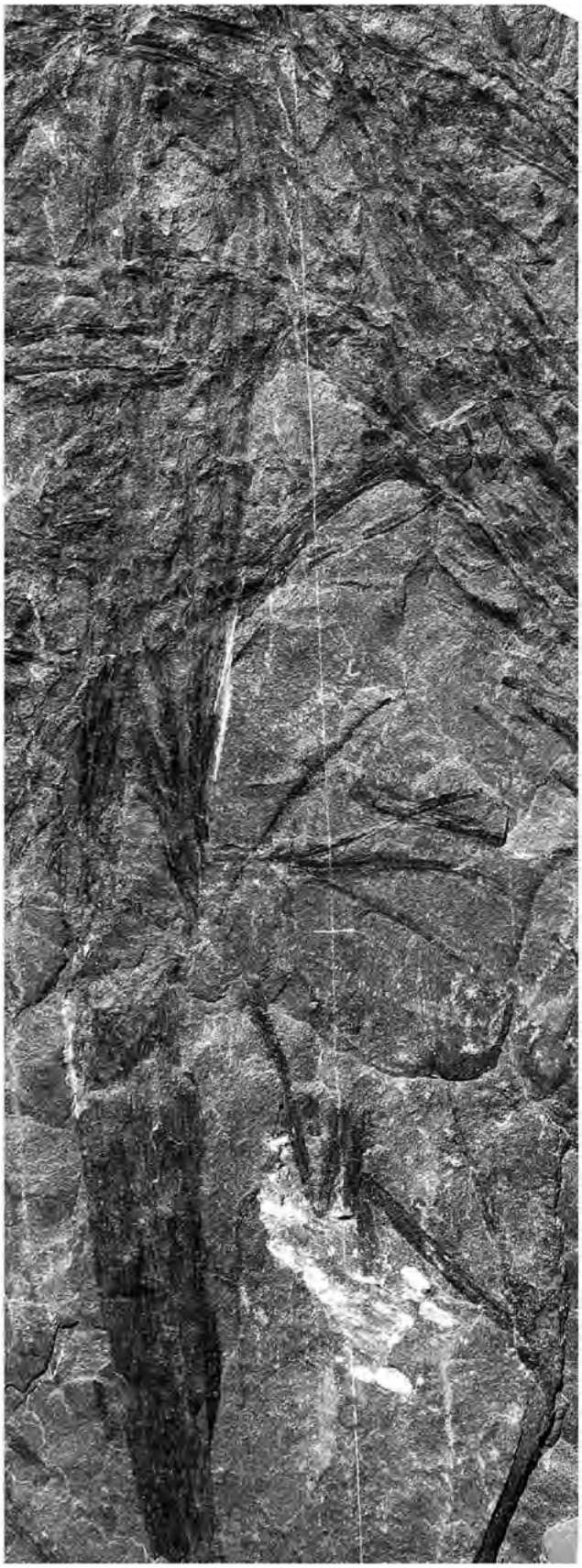


Figure 19. (right) ***Asterophyllites longifolius*****? (x3). Holotype of** ***Asterophyllites fasciculatus*** **Matthew (1906a, pl. I, fig. 2). Origin: Bed 7, Fern Ledges, Saint John, Lancaster, New Brunswick. Repository: New Brunswick Museum, Saint John.**

1966 *Asterophyllites longifolius*, Bell, p. 62, pl. XXX, fig. 2 (fragmentary).
? 1967 *Asterophyllites longifolius*, Tidwell, pp. 27–28, pl. 4, fig. 6.
? 1967 *Archaeocalamites radiatus*, Tidwell, pp. 23–24, pl. 8, fig. 9 (small stem with verticils of long, overlapping, narrow leaves).
1969 *Asterophyllites longifolius* forma *typica*, Crookall, pp. 704–707 (including synonymy), pl. CL, fig. 2; text-fig. 205 (same as Sternberg 1825, Taf. LVIII, figs. 1A–B).
? 1975 *Archaeocalamites* foliage, Tidwell, pl. 23, fig. 5 (same as Tidwell 1967, pl. 8, fig. 9).
1987 *Asterophyllites longifolius* forma *striata*, Tenchov, p. 46, pl. XVI, figs. 1–2, 12.
1987 *Asterophyllites tenuifolius*, Tenchov, p. 47, pl. XVI, figs. 3–4, 6.
1991 *Asterophyllites longifolius*, Josten, pp. 87–89, Taf. 24, figs. 1–1a; Taf. 25.
T 1997 *Asterophyllites longifolius*, Kvaček and Straková, p. 98, pl. 35, fig. 1 (holotype of *Bruckmannia longifolia*).
1997 *Asterophyllites longifolius*, Kvaček and Straková, p. 130, pl. 45, fig. 2 (holotype of *Bruckmannia rigida*).
2006 *Asterophyllites longifolius*, Wittry, p. 94, fig. 1.
2011 *Asterophyllites longifolius*, Pšenička and Opluštil, p. 72, pl. V, figs. 5–6, 8–9; pl. VI, fig. 4; text-fig. 4 (drawing).

Excludenda:

1934 *Asterophyllites longifolius*?, Read, pp. 81, 83, pl. 16, fig. 8 (incomplete verticils which cannot be assigned specifically, but clearly not belonging to this species).
1938 *Asterophyllites longifolius*, Bell, p. 86, pl. XCII, fig. 5 (broad leaves which can only be assigned as *Annularia* sp. indet.).

DESCRIPTION: Ultimate axis 3–4 mm wide, with ribbed internodes 8–14 mm long. Verticils with up to 20 filiform leaves with acute apices, adpressed in the axial plane, inserted at an acute angle (30–45°), and overlapping 2–4 internodes. Dimensions: 25–40 mm long and ~ 1 mm width. Vein not visible.

REMARKS: Although Bell (1944) did not report *Asterophyllites longifolius*, he figured a moderately well-preserved specimen of *Palaeostachya striata* (Bell 1944, pl. LXXIII, fig. 6) from the Springhill area, Nova Scotia. *Palaeostachya striata*, a species that we consider synonymous with *Palaeostachya elongata*, is often regarded as the strobilus of *Asterophyllites longifolius*.

COMPARISONS: *Asterophyllites longifolius* is easily recognized by its long, filiform leaves that overlap several verticils.

STRATIGRAPHIC AND GEOGRAPHIC DISTRIBUTION: *Asterophyllites longifolius* is a long-ranging species, from upper Namurian to the lower Stephanian. The holotype is from Westphalian strata at Eschweiler, Aachen coalfield, western Germany. The holotype of its synonym, *Asterophyllites rigidus*, is from Bolsovian strata of the Radnice beds, Bohemia, Czech Republic. Sauveur's *Asterophyllites elegans*, another synonym, came from the lower Westphalian of Belgium. Leggewie and Schonefeld's *Asterophyllites discifer*, also a synonym, came from the Westphalian A (Langsettian) of the Ruhr District, western Germany. Crookall (1969) mentioned that *Asterophyllites longifolius* is fairly rare, occurring in Langsettian to Bolsovian strata in Great Britain.

OCCURRENCE IN THE MARITIME PROVINCES: New Brunswick: locality 626: unpublished specimen, without catalogue number (here as Fig. 18). Fern Ledges (New Brunswick): Wilson collection from 1884 (one specimen from locality 352, without catalogue number, here Fig. 19) + New Brunswick Museum collection: NBMG 7721 (labelled as *Ramicalamus dumosus*); NBMG 3429 (holotype of *Asterophyllites fasciculatus* — here Fig. 19). Minto coalfield (New Brunswick): Bell (1962): locality 856 (GSC 839); locality 5074 (GSC 943 — together with *Palmatopteris furcata*). Pictou coalfield (Nova Scotia): Bell (1940): locality 2488 (GSC 10309). Sydney coalfield (Nova Scotia): Bell (1938): locality 537 (GSC 2942); locality 1146 (GSC 14909).

OCCURRENCE IN THE UNITED STATES: Illinois: Lesquereux (1870); Janssen (1957); Langford (1958). Kansas: Cridland *et al.* (1963). Missouri: White (1899), Abbott (1958). Ohio: Abbott (1958). Utah: Tidwell (1967, 1975).

SUMMARY AND CONCLUSIONS

We have updated the taxonomy of *Annularia* and *Asterophyllites* species from lower Westphalian strata of the Maritime Provinces after re-examination of material in the Geological Survey of Canada (GSC) collections in Ottawa, and in the New Brunswick Museum (NBMG) at Saint John.

As with the lycopsid taxa revised in an earlier paper (Álvarez-Vázquez and Wagner 2014), the published record of Canadian sphenopsids from lower Westphalian strata is only sporadic and may be regarded as incomplete. Further collecting might well increase the number of species recognized, but our current revision shows already that

the species composition of *Annularia* and *Asterophyllites* in the Maritime Provinces is identical to that found in western Europe. Both areas obviously represent a single palaeogeographic region.

The profusion of names used by Dawson, Matthew and Bell needed to be scaled down considerably. We have reduced the number of species from 19 to 6. The following taxa have been maintained: *Annularia asteris, Annularia latifolia, Annularia radiata, Asterophyllites charaeformis, Asterophyllites grandis* and *Asterophyllites longifolius*. We have introduced one new species, *Annularia stopesiae*, based on Canadian specimens but including also material from western Europe that was attributed originally to *Annularia stellata*. Lesquereux's *Annularia inflata* is reinstated herein. We make the case for using Göppert's specific name *Asterophyllites lindleyanus* for Westphalian material commonly referred to as *Asterophyllites equisetiformis* and, more particularly, as *Asterophyllites equisetiformis* forma *jongmansii*.

The parameters used for species discrimination are set out in Tables 1 and 2, for *Annularia* and *Asterophyllites*, respectively. Table 3 shows the identifications accepted in the present paper, as compared with those made by Dawson (1862, 1868, 1871), Matthew (1906a, b) and Bell (1944, 1966).

ACKNOWLEDGEMENTS

We express our gratitude to John Utting for providing the stimulus for a general revision of lower Westphalian floras in the Maritime Provinces, and accompanying the second author on several visits for which he provided logistic support. Jean Dougherty was most helpful in providing access to material and data regarding the fossil collections of the Geological Survey of Canada in Ottawa. Randall Miller did the same in the New Brunswick Museum at Saint John, providing geological information. Robert Wagner gratefully acknowledges a G.F. Matthew Grant from the New Brunswick Museum. Access to the Dawson Collection at the Redpath Museum, McGill's University, Montreal is also acknowledged. The paper benefited from constructive comments and suggestions by Arden Bashforth and Chris Cleal. Various suggestions by the Editor, Rob Fensome have been well received.

Table 3. List of the various species figured and described in the present paper in comparison with identifications in Bell (1944,1966), Matthew (1906a, b) and Dawson (1862,1868,1871)

Present paper	Bell (1944/1966)	Matthew (1906a/1906b)	Dawson (1862/1868/1871)
Annularia asteris	*Annularia asteris*		
Annularia fertilis		*Annularia latifolia* pars	*Asterophyllites latifolia* pars
Annularia galioides	*Annularia latifolia*	*Annularia latifolia* pars + *Annularia latifolia* var. *minor*	*Annularia sphenophylloides*
Annularia inflata	*Annularia stellata*	*Annularia longifolia* mutation *leavitti*	
Annularia latifolia	*Annularia latifolia*		*Annularia latifolia* pars
Annularia microphylla			
Annularia pseudostellata	*Annularia acicularis*		
Annularia radiata	*Annularia acicularis* pars + *Annularia radiata*	*Annularia acicularis* + *Asterophyllites lentus*	*Asterophyllites acicularis* pars + *Asterophyllites lenta*
Annularia ramosa	*Annularia aculeata* pars + *Annularia acicularis* pars		
Annularia stopesiae	*Annlaria stellata* forma *longifolia* + *Annularia pseudostellata*		
Asterophyllites charaeformis	*Asterophyllites charaeformis* + *Annularia aculeata* pars + *Asterophyllites grandis* pars	*Asterophyllites parvulus*	*Asterophyllites parvula*
Asterophyllites grandis	*Asterophyllites grandis* pars + *Annularia aculeata* pars		*Asterophyllites acicularis* pars
Asterophyllites lindleyanus	*Asterophyllites equisetiformis* pars		*Asterophyllites trinervis*
Asterophyllites longifolius	*Asterophyllites longifolius*	*Asterophyllites longifolius* + *Asterophyllites fasciculatus* + *Asterophyllites ? fissus*	

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APPENDIX: LIST OF NAMES OF SPECIES AND INFRASPECIFIC TAXA CITED HEREIN, WITH AUTHORSHIPS

Acrobulbillites Amerom 1973
Alethopteris Sternberg 1825
Annularia Sternberg 1821
Annularia acicularis (Dawson 1862) White 1900
Annularia aculeata Bell 1944
Annularia acuminata Dawson 1862
Annularia asteris Bell 1944
Annularia asterophylloides Sauveur 1848
Annularia asteropilosa Remy and Remy 1975
Annularia calamitoides Schimper 1869
Annularia carinata Gutbier 1849
Annularia cuspidata Lesquereux 1884a
Annularia dawsonii Schimper 1869
Annularia dubia (Sternberg 1825) Wood 1860
Annularia emersonii Lesquereux 1881
Annularia fertilis Sternberg 1825
Annularia fimbriata Walton 1936
Annularia galioides (Lindley and Hutton 1832) Kidston 1891
Annularia inflata Lesquereux 1870
Annularia isperichii Tenchov 1987
Annularia jongmansii Walton 1936
Annularia latifolia (Dawson 1862) Kidston 1886
Annularia latifolia var. *minor* Matthew 1906a
Annularia ligata Matthew 1906a
Annularia longifolia Brongniart 1828
Annularia longifolia mutation *leavittii* Matthew 1906a
Annularia microphylla Sauveur 1848
Annularia minima Leggewie and Schonefeld 1961
Annularia minuta Brongniart 1828
Annularia mucronata Schenk 1883
Annularia mucronata forma *stellata* Bell 1938
Annularia patens (Sauveur 1848) Kidston 1886
Annularia pseudostellata Potonié 1899
Annularia radiata (Brongniart 1822) Sternberg 1825
Annularia radiata forma *hirsuta* Jongmans and Gothan 1934
Annularia radiata forma *karwinensis* Jongmans 1937
Annularia ramosa Weiss 1884
Annularia recurva Matthew 1906a
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