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REVISION OF ZONAL AND RELATED GRAPTOLITES OF THE TOPMOST LANCEFIELDIAN AND BENDIGONIAN (EARLY FLOIAN) GRAPTOLITE SEQUENCE IN VICTORIA, AUSTRALIA

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ABSTRACT: The topmost Lancefieldian (La3, earliest Floian, Early Ordovician) *Paratetragraptus approximatus* Biozone of Victoria contains a previously undocumented graptolite fauna that includes, in addition to the nominative species, *Paratetragraptus cooperi* sp. nov., *P. thomassmithi* sp. nov., *P. acclinans*, *P.*? *henrywilliamsi* sp. nov., and *Tshallograptus cymulus* gen. et sp. nov., interpreted as the direct ancestor of *Tshallograptus fruticosus* (J. Hall). Taxa such as *Kinnegraptus*, *Laxograptus*, *Pseudobryograptus*, *Phyllograptus*, *Tetragraptus* and *Loganograptus* also make their first appearance in this zone. The succeeding Bendigonian stage, traditionally subdivided into four biozones using overlapping ranges of *P. approximatus* and the four- and three-stiped morphs of the *T. fruticosus* clade, is revised to accommodate the earlier than documented appearance of the 3-stiped morph, here renamed *Tshallograptus tridens* sp. nov., in the Be1 Biozone. The new subdivision consists of three biozones: Be1 *P. approximatus* + *T. fruticosus* Biozone, Be2+3 *T. fruticosus* + *T. tridens* Biozone, and Be4 *T. tridens* Biozone. *T. tridens* is vanishingly rare in Be1 and Be2 but appears in abundance in Be3 which is retained as a local subzone.

Keywords: Lancefieldian, Bendigonian, early Floian, *Paratetragraptus*, *Tshallograptus* gen. nov., Victorian graptolite zones

The early Floian (La3–Be4) graptolite succession of Victoria encompasses one of the most remarkable diversification events of graptolites, with the appearance of at least 70 new species (VandenBerg & Cooper 1992). For correlation purposes, the two most important of these are *Paratetragraptus approximatus* and two species of *Tshallograptus* gen. nov. that were formerly regarded as morphs of *Pendeograptus fruticosus.* These are the 4-stiped *T. fruticosus* (Hall) and the 3-stiped *T. tridens* sp. nov. They warrant full species rank, as they are easily distinguished and have different stratigraphic ranges. For convenience, they, together with the unnamed 2-stiped morph, are referred to as the '*T. fruticosus* clade'.

Victoria is unique in having used the overlapping ranges of *P. approximatus*, *T. fruticosus* and *T. tridens* to subdivide the sequence into five biozones, La3 and Be1–Be4 (see Appendix 1 for the use of the letter–number system). The most unusual aspect of this is that the subdivision has utilised not just the appearance but also the disappearance of particular zone fossils. The different stratigraphic distributions of *T. fruticosus* and *T. tridens* were first recorded by Harris (1916). In their introduction of the Bendigo 'series', Harris and Keble (1932) recognised five zones based on the overlap of the two morphs of the *T. fruticosus* clade, and with *Tetragraptus approximatus* below and *Didymograptus bifidus* above. Harris and Thomas (1938b) moved this topmost zone, then renamed the *Didymograptus protobifidus* Zone, into their new overlying Chewton 'series' but maintained the remaining four biozones of the Bendigonian, and introduced the letter–numbering shorthand system in current use (VandenBerg & Cooper 1992) (Figure 1A).

Elsewhere, investigations of early Floian sequences have found differences in the stratigraphic ranges of *T. fruticosus* and *T. tridens*. In the Valhallfonna Formation in Spitsbergen, Cooper and Fortey (1982) found an upward change in the frequency of the two species that is similar to that recorded in Victoria. Williams and Stevens (1988), however, found no such change in the Cow Head Group of western Newfoundland and suggested the subdivision of the *T. fruticosus* Biozone as used in Victoria should be abandoned.

In addition to the three members of the *T. fruticosus* clade (*T. fruticosus, T. tridens* and the unnamed 2-stiped morph), the early Floian in Victoria contains two other species of *Tshallograptus*: a small precursor of *T. fruticosus* here named *T. cymulus* sp. nov., and the two-stiped *T. furcillatus* sp. nov. The top of the Bendigonian is marked by the appearance of *Didymograptellus kremastus* (formerly *D. protobifidus*) (VandenBerg 2017).

DEFINITION OF THE LANCEFIELDIAN–BENDIGONIAN BOUNDARY

The Lancefieldian–Bendigonian transition in the lowermost Floian is poorly documented. It was first defined by Harris and Keble (1932) as an interval containing *Paratetragraptus approximatus*, accompanied by *Tshallograptus fruticosus* in the basal Bendigonian zone (Be1) but without

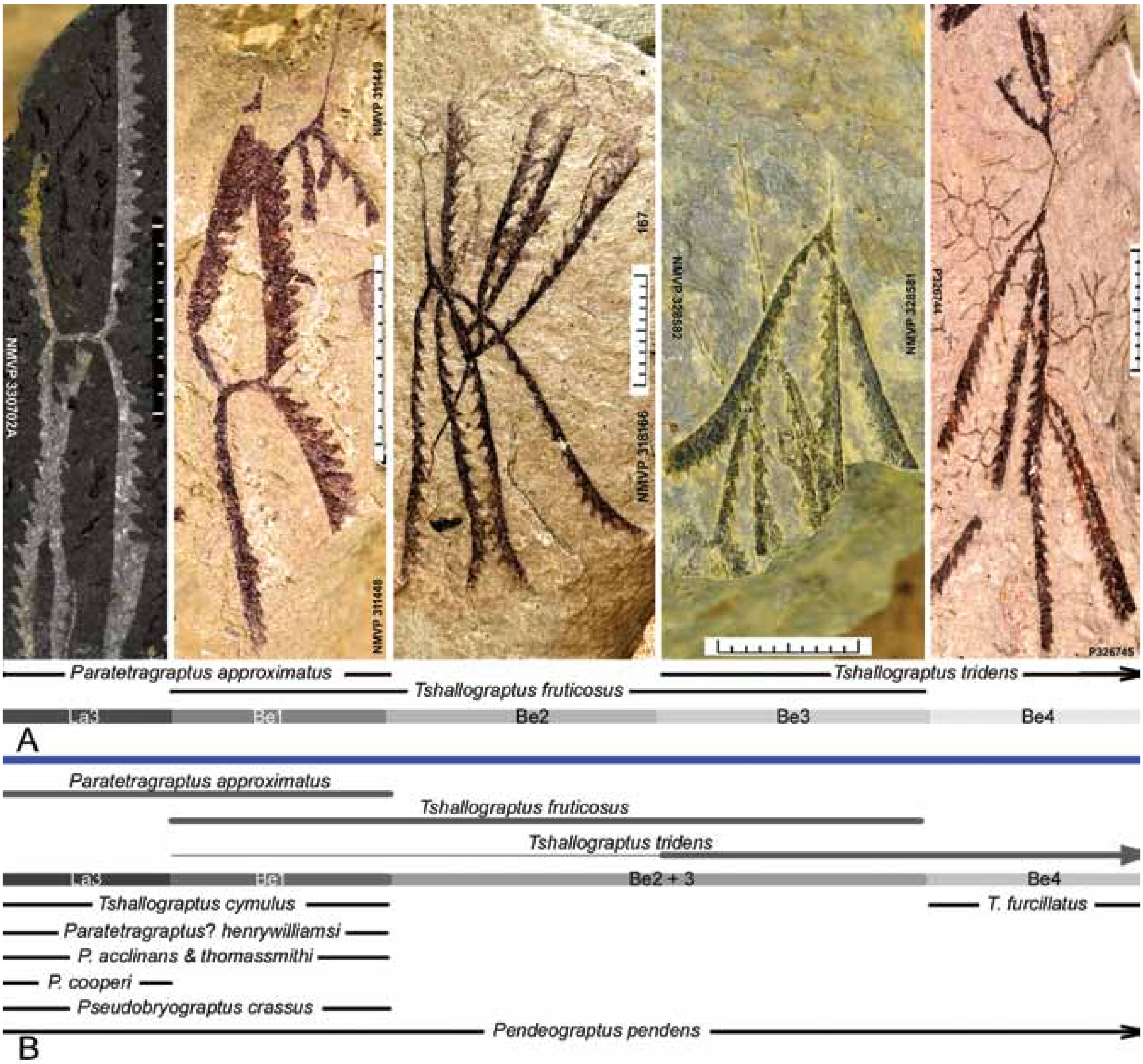


Figure 1: Subdivision of the early Floian. A shows the subdivision into five biozones (La3 and Be1-4) according to Harris and Thomas (1938b), Thomas (1960a) and Vandenberg and Cooper (1992), based on the overlapping stratigraphic ranges of *Paratetragraptus approximatus*, *Tshallograptus fruticosus* and *T. tridens*. B shows the revised subdivision that recognises the early appearance of *Tshallograptus tridens* in Be1 and also shows ranges of other species described.

T. fruticosus in the topmost Lancefieldian zone (La3). These authors provided the additional information that the uppermost Lancefieldian contains *Tetragraptus decipiens*, *T. quadribrachiatus*, *T. acclinans*, *Clonograptus tenellus* and rare '*Bryograptus*'. They further gave Bull Dog Creek on the Mornington Peninsula as its 'typical locality'.

There are several problems with this information. '*Bryograptus*', at the time of the Harris and Keble paper, referred to '*Bryograptus*' *victoriae* T.S. Hall and '*B.*' *clarki* T.S. Hall, now united as *Aorograptus victoriae* (T.S. Hall) (Williams & Stevens 1991). There is not a single locality in which *A. victoriae* occurs together with *Paratetragraptus approximatus*. The same holds for '*Tetragraptus*' *decipiens* T.S. Hall, which my work indicates is an early growth stage of *Paratemnograptus magnificus* (Pritchard) — it is only found in La2.

The collection from Bull Dog Creek is very small, with only seven identifiable specimens, all poorly preserved. One of these is an early growth stage of *Tshallograptus fruticosus*. This automatically rules out the collection, and its locality, being considered as representative of the La3 *Paratetragraptus approximatus* Biozone which, by definition, should not contain *Tshallograptus fruticosus*.

Later authors have added little detail. Harris and Thomas (1938b) revised the entire Ordovician graptolite succession of Victoria. They stated that 'in the highest

Lancefieldian [La3], the *Bryograpti* are not so abundant, but the incoming of *Tetragraptus approximatus* and variants between it and *T. acclinans* […] is very noticeable. Apart from these forms the general assemblage resembles that of [the preceding zone] La2'. Thomas (1960a) included a table that shows age ranges of virtually all graptolite species then recognised from Victoria. In the La3 column he showed the presence of *Araneograptus macgillivrayi*, *Aorograptus victoriae*, *Kiaerograptus pritchardi*, *Clonograptus flexilis*, *C. rigidus*, *C. tenellus*, *Paratemnograptus magnificus*, *Paratetragraptus approximatus*, *P. acclinans*, *Expansograptus vicinus*, *E. extensus* and *E. similis*. This list is much larger than those by earlier authors, but the accompanying description gives no information on any supposed La3 localities from which these forms were identified. VandenBerg and Cooper (1992) largely copied the information given by Thomas (1960a), but with a few differences: they showed the presence of *Araneograptus pulchellus* and *Paradelograptus antiquus* in La3, but not *Clonograptus tenellus* or *C. rigidus*.

Given that the 'typical' locality given for the La3 Zone is actually of Be1 age, and that the faunal lists for the zone seem to contain a mish-mash of La2 and Be1 forms, does the La3 interval exist or is it pure fiction? This paper investigates this question, and the validity of subdividing the Bendigonian stage using different species of *Tshallograptus*.

The uppermost Lancefieldian

A search through the large graptolite collection held by Museums Victoria has revealed six localities that fit the definition of La3 of Harris and Keble (1932). All of these were formerly part of the Geological Survey of Victoria fossil collection. Five are from the Campbelltown area southwest of Castlemaine, with the remaining one from near the Blackwood antimony mine (see Appendix 2). All contain *Paratetragraptus approximatus*, and none contain *Tshallograptus fruticosus* (although several contain *T. cymulus* sp. nov., which I regard as the ancestor to *T. fruticosus*). Of the species that Thomas (1960a) listed in the La3 column, *Araneograptus macgillivrayi*, *Aorograptus victoriae*, *Kiaerograptus pritchardi*, *Paratemnograptus magnificus*, *Expansograptus vicinus*, *E. extensus* and *E. similis* are all absent from these collections. They do, however, contain taxa not recognised from this level before, including *Paratetragraptus thomassmithi* sp. nov., *P.*? *henrywilliamsi* sp. nov., *P. cooperi* sp. nov., *Kinnegraptus*, *Expansograptus* (several new species), *Loganograptus*, *Laxograptus*, *Pseudobryograptus* and *Phyllograptus.*

THE SUBDIVISION OF THE BENDIGONIAN

The multi-zone subdivision of the Bendigonian stage first proposed by Harris and Keble (1932) was based on inference, piecing together the results of identifications from numerous graptolite localities, mainly in the Bendigo region, collected mostly by Geological Survey of Victoria geologists as a byproduct of mapping to aid gold exploration in the early twentieth century. In the Bendigo region, graptolites occur in the Castlemaine Group, a turbidite sequence estimated to be more than 3 km thick, with the Bendigonian portion accounting for approximately 600 m. With exception of the basal Lancefieldian portion, the lithology of the sequence is so monotonous that it can only be subdivided on the basis of graptolites that occur in sporadic black shale intervals. Exposures are small and scattered, and folds are tight and very closely spaced (VandenBerg et al. 2000).

Given these obstacles, Harris and Keble (1932) placed collections (identification lists) in an imaginary stratigraphic section, using overlapping species to determine the position of each list/collection. In this they followed the pioneering work of Hall (1895), who found that *Isograptus* ('*Didymograptus caduceus*') in the Castlemaine area became larger up the sequence — an observation that was subsequently used to subdivide the Castlemainian into four biozones (VandenBerg & Cooper 1992).

The results of Harris and Keble's work were summarised in 1932 (p. 30), in which they subdivided the Bendigonian (as defined by VandenBerg & Cooper 1992) into the four biozones shown in Figure 1A. Recognition of zonal boundaries depended not only on appearances (of *Tshallograptus fruticosus* in Be1, *T. tridens* in Be3, *Didymograptellus kremastus* at the upper boundary) but also absences (of *Paratetragraptus approximatus* in Be2, of *T. tridens* in the interval below Be3, and of *T. fruticosus* from Be4). Is this method valid?

REVISION OF THE BENDIGONIAN ZONAL SCHEME

The main danger with using the absence of a species to define a zone is that such an absence is very difficult to prove. In theory, one might need an infinitely large collection to prove it. And indeed this is the case with the current zonal scheme of the Bendigonian. What might be regarded as archetypal for the Be1 biozone is the collection from PL 2017, the 'Good bed', from Campbelltown (Appendix 2), from which Thomas Smith, W.J. Harris and D.E. Thomas collected several thousand slabs. A small part of the fauna was described by Harris (1933), Harris and Thomas (1938a, 1939, 1940) and Rickards and Chapman

(1991). The collection contains hundreds of tubaria of both *Paratetragraptus approximatus* and *Tshallograptus fruticosus*, the two species that together define the zone. However, a careful search has revealed about half a dozen specimens of *T. tridens* (Figure 2), which, in the current zonation scheme, is not supposed to enter until the Be3 biozone (Figure 1A).

The Museums Victoria graptolite repository contains numerous collections from Bendigonian localities. Most are small and therefore of no biostratigraphic use. Concentrating on the larger collections, in which most graptolites that lived at that time have a chance to be represented, gives seven that are Be1, seven that are Be2, two that are Be3 and nine that are Be4. Thus there are 14 large collections that contain *T. fruticosus* but not *T. tridens,* representing the Be1–Be2 interval. Yet we know from the occurrence of *T. tridens* in the PL 2017 collection (Be1) that it must have lived through this interval. My interpretation is that for the early period of its existence, *T. tridens* was very rare, and only very large collections have a chance of it being represented.

This means that the absence of *T. tridens* from Be2 is not real but a consequence of its rarity and that its appearance in abundance, which marks the base of Be3, is only of subzonal significance — its presence in any collection from the Be1–Be2 interval is a matter of chance. The difference between Be2 and Be3 is therefore a change in the abundance of *T. tridens*, and I suggest these two zones be merged into a single Biozone of *T. fruticosus* + *T. tridens* (Be2+3), maintaining Be3 as the upper subzone of the *T. fruticosus* + *T. tridens* Biozone. Its usefulness as a mappable unit has been demonstrated on detailed maps, for instance the 1:10 000 geological maps of the Bendigo goldfield, where it forms a biostratigraphic unit approximately 150 m thick (Byrne et al. 1992; Willman 1992, 1994). Be3 is therefore useful as a subzone that can be applied locally.

While it is possible that the Be4 biozone suffers from the same problem, work thus far suggests that the disappearance of *T. fruticosus* is real, so can be used as a biozone boundary. The revised zonation scheme arising from these observations is shown in Figure 1B. Revised zone names are: Be1 *P. approximatus* + *T. fruticosus* Biozone, Be2+3 *T. fruticosus* + *T. tridens* Biozone, and Be4 *T. tridens* Biozone. In view of their proved usefulness as mapping tools, Be2 and Be3 are retained as local subzones, with the same names as used by VandenBerg and Cooper (1992).

The upward change in the frequency of *T. fruticosus* and *T. tridens* found in the Bendigonian may be a localised phenomenon. Cooper and Fortey (1982) found a similar change in frequency in the Valhallfonna Formation in Spitsbergen, but Williams and Stevens (1988) found no such change in the Cow Head Group in Newfoundland, and, more remarkably, Cooper (1979a) did not find it in the Aorangi Mine succession in New Zealand.

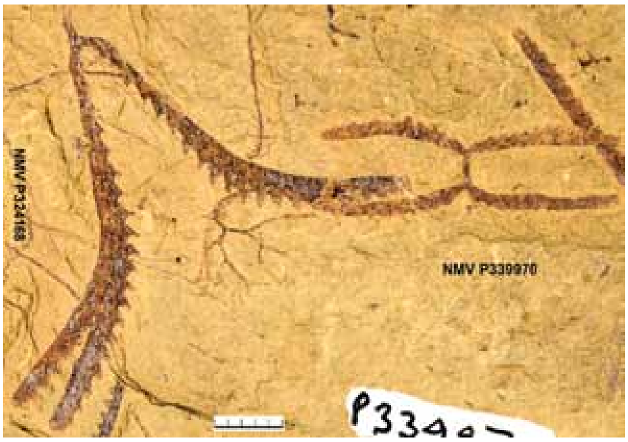


Figure 2: *Tshallograptus tridens* (NMV P324168) and *Paratetragraptus approximatus* (P339970) sharing a slab. The slab is from PL 2017, from the Be1 biozone, two zones lower than the supposed first appearance of *T. tridens* according to the Harris and Thomas (1938b) scheme.

SYSTEMATIC PALAEONTOLOGY

Suborder DICHOGRAPTINA Lapworth, 1873

Family PHYLLOGRAPTIDAE Lapworth, 1873

Diagnosis. Four- to two-stiped, pendent to horizontal, reclined, deflexed and scandent, biradiate graptoloids produced by one proximal dichotomy and with $th3^1$ and $th3^2$ as the only distal dicalycal thecae; sicula conical, widening distinctly towards the aperture, with rutellum and small prosicula; thecae simple, widening tubes often with distinct rutellum; proximal end with isograptid, dextral development (from Maletz et al. in prep.).

Paratetragraptus Obut, 1957

Type species. *Tetragrapsus approximatus* Nicholson, 1873 (OD), lectotype BM (NH) P1196 from Point Lévis, Quebec, designated Williams and Stevens 1988 p. 34.

Diagnosis. Tetragraptid with declined funicle and declined or deflexed stipes, tubarium H- or X-shaped in dorsoventral view.

Species included. *Tetragraptus approximatus* (and numerous junior synomyms, see below), *T. acclinans* Keble, 1920; *P. cooperi* sp. nov., *P. thomassmithi* sp. nov., ?*P. henrywilliamsi* sp. nov.

Discussion. Obut (1957, pp. 33, 38) introduced *Paratetragraptus* as a subgenus of *Tetragraptus*, nominating *T. approximatus* Nicholson, 1873 as type species. He gave no diagnosis or discussion, instead referring to a discussion of *T. approximatus* by Bouček and Přibyl (1952, p. 8), who placed the '*approximatus* group' in their new subgenus *T. (Eotetragraptus)*. They subdivided this subgenus into two groups, one with X-shaped tubaria and the other with H-shaped tubaria. As they relied entirely on published illustrations, chiefly by Ruedemann (1935, 1947), which only included tubaria preserved in the common H-shaped configuration, this gave an erroneous impression of the 3D shape. Surprisingly perhaps there is no previously published diagnosis of *Paratetragraptus*.

Paratetragraptus approximatus (Nicholson, 1873)
(Figures 2–4)

1873 *Tetragrapsus approximatus*, Nich.; Nicholson, pp. 136–137, figs 2a, b.

1920 *Tetragraptus approximatus*, Nicholson; Keble, pp. 195–197, 201, text-figure 61, pl. 33, figs 1a–c.

1920 *Tetragraptus decipiens*, T.S. Hall; Keble, pl. 34, fig. 1d.

1932 *Tetragraptus approximatus*, Nich.; Harris & Keble, pp. 26, 30–31, 33, pl. 4, fig. 4.

1935 *Tetragraptus approximatus* Nicholson 1873; Benson & Keble, p. 275, pl. 33, fig. 22.

1935 *Tetragraptus (Etagraptus) laverdieri* nov.; Ruedemann, p. 11, pl. 1, fig. 4.

1935 *Tetragraptus (Etagraptus) quebecensis* nov.; Ruedemann, p. 12, pl. 1, fig. 5.

1935 *Tetragraptus (Etagraptus) lavalensis* nov.; Ruedemann, p. 12, pl. 1, fig. 6.

1938a *Tetragraptus approximatus* Nicholson; Harris & Thomas, p. 74, pl. 1, figs 17a–c, pl. 4, fig. 16.

1938a *Tetragraptus volitans* sp. nov.; Harris & Thomas, p. 74, pl. 2, figs 16a–d, pl. 4, fig. 15.

1938b *Tetragraptus approximatus* Nicholson; Harris & Thomas, p. 69, pl. 1, fig. 15.

1947 *Tetragraptus (Etagraptus) approximatus* (Nicholson); Ruedemann, pp. 312–313, pl. 52, figs 4–6, 17, 18.

1947 *Tetragraptus (Etagraptus) lavalensis* Ruedemann; Ruedemann, p. 313, pl. 52, figs 13–16.

1947 *Tetragraptus (Etagraptus) laverdieri* Ruedemann; Ruedemann, p. 313, pl. 52, figs 19–21.

1947 *Tetragraptus (Etagraptus) pacificus* n. sp.; Ruedemann, p. 314, pl. 52, figs 26–27.

1960 *Tetragraptus approximatus* (Nicholson); Berry, pp. 52–53, pl. 6, figs 1–3.

1960a *Tetragraptus approximatus*; Thomas, pl. 1, figs 18a, b.

1979a *Tetragraptus approximatus* Nicholson, 1873; Cooper, pp. 60–62, text-figs 29a–d, pl. 6, figs a, h.

1979b *Tetragraptus approximatus* Nicholson; Cooper, text-fig. 5H.

1983 *Tetragraptus (Etagraptus) approximatus* Nicholson 1873; Chen et al., p. 327 (in Chinese), text-fig. 3b, pl. 1, figs 3, 12.

1983 *Tetragraptus (Etagraptus) quebecensis* Ruedemann; Chen et al., pp. 327–328 (in Chinese), pl. 1, figs 1, 13.

1983 *Tetragraptus (Etagraptus) lavalensis* Ruedemann; Chen et al., p. 328 (in Chinese), pl. 1, fig. 2, text-fig. 3a.

1983 *Tetragraptus (Etagraptus) pacificus* Ruedemann; Chen et al., p. 328 (in Chinese), pl. 1, fig. 9, text-fig. 3d.

1983 *Tetragraptus approximatus* Nicholson 1873; Henderson, p. 159, figs 9A, B.

1984 *Paratetragraptus approximatus*; Obut & Sennikov, pp. 72–73, pl. 10, figs 2–4.

1988 *Tetragraptus approximatus* Nicholson 1873; Williams & Stevens, pp. 33–34, pl. 1, figs 5, ?6, pl. 5, figs 1–6, 8–11, pl. 7, figs 1–9, pl. 8, figs 1, 9, text-figs 20A–GG, 21 (with extensive synonymy).

1988 *Tetragraptus approximatus*; Cas & VandenBerg, text-fig. 3.3i.

1991 ?*Pendeograptus volitans* Harris and Thomas; Rickards & Chapman, p. 65, pl. 17, figs c, d, text-fig. 93.

1991 *Tetragraptus approximatus* Nicholson; Rickards & Chapman, pl. 2 fig. b (in part), pl. 18, fig. a.

1992 *T. approximatus*; VandenBerg & Cooper, text-fig. 3P.

1996 *Tetragraptus approximatus* Nicholson; Maletz et al., p. 156, fig. 13.1.

2001 *Tetragraptus approximatus* Nicholson; Maletz & Egenhoff, figs 8: 2, 3.

2002 *Tetragraptus (Etagraptus) laverdieri* Ruedemann; Mu et al., p. 180, pl. 53, fig. 12.

2002 *Tetragraptus approximatus* Nicholson; Mu et al., p. 179 (in Chinese), pl. 53 figs 1, 8.

2002 *Tetragraptus acclinans* Keble; Norford et al., pl. 4 fig. 3.

2002 *Tetragraptus approximatus* Nicholson; Norford et al., pl. 4 fig. 1.

2006 *Tetragraptus approximatus* Nicholson; Jackson & Lenz, fig. 5a–c.

2007 *Paratetragraptus approximatus* (Nicholson, 1873); Kim et al., pp. 63–64, pl. 111 fig. 2.

2009 *Tetragraptus approximatus* (Nicholson); Feng et al., fig. 5H, L.

Diagnosis. H-shaped tubarium with declined funicle and robust stipes that are proximally reclined, then horizontal and parallel.

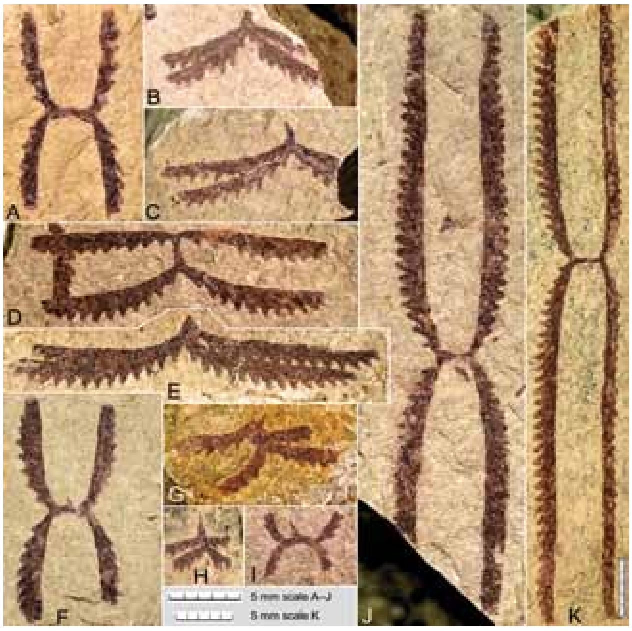


Figure 3: Photos of *Paratetragraptus approximatus* (Nicholson) showing the range of preservational aspects seen in the PL 2017 population. **A, F, I, J** and **K** are in dorsoventral view and **B**, **C, E** and **H** in lateral view, while **D** and **G** are intermediate between the two. Note that the proximal portions of stipes of 'H'-shaped tubaria, preserved in plan view, are gently curved in the same fashion as those seen in lateral view. **A**: NMV P331895; **B**: P331696; **C**: P324123; **D**: P323921; **E**: P323987; **F**: P331598; **G**: P331601; **H**: P327511; **I**: P323919B; **J**: P328617; **K**: P13094.

Lectotype. BM(NH) P1196, from Point Lévis, Quebec, Canada, designated Williams and Stevens (1988, p. 34).

Material and distribution. Twenty-nine measured specimens from PL 2017, Campbelltown (Be1), two from the Antimony mine, Blackwood (La3). *P. approximatus* occurs in six La3 localities in Victoria, and in numerous Be1 localities. It has a global distribution and its appearance is used to mark the base of the Floian stage.

Description. *P. approximatus* was comprehensively described by Williams and Stevens (1988) and observations herein are limited to the configuration of the proximal area. Specimens preserved in lateral view show that the two initial thecae that make up the funicle are not horizontal but declined, at an angle ranging from 90º–118º, measured along their dorsal margins (δ in Figure 6A). The four daughter thecae that make up the initial portions of the four secondary stipes are similarly declined, with the angle between them ranging from 86º–118º (β in Figure 6B). Beyond these four initial thecae, the stipes are gently dorsally curved. This curved portion is of variable length, ranging from 3 to 13 thecae long, after which the stipes are close to horizontal (or parallel, in the 'splayed' mode of preservation). This curvature is also seen in flattened H-shaped tubaria, not only in Victorian specimens (Figures 3A, F, I, J, K, 4B, E, H, K, L) but also those illustrated from elsewhere (e.g. Williams & Stevens 1988, figs 20, 21; Jackson & Lenz 2006, figs 5a, c). Apparent stipe width is variable, and in many H-shaped tubaria, stipes on opposite sides of the funicle have different apparent widths, with stipes on one side one-third to a quarter wider than those opposite (Figures 3F, K, 4H, L). Maximum stipe width is 2.0–2.1 mm and is reached by th7 in most tubaria (6 thecae from the funicle). Undamaged stipes have tapering growing tips that range from as little as 3 mm to as much as 14 mm long, with the length of the growing tip roughly proportional to the stipe length. In early growth stages, such stipes have the shape of a scimitar blade (Figures 3D–F, 4H–J).

Remarks. Hitherto, the tubarium of *P. approximatus* was interpreted as an essentially planar H-shape, much like their appearance on bedding planes (e.g. Williams & Stevens 1988, text-fig. 21). However, the lateral views show that the proximal area protruded above the horizontal portion of the stipes, like a small peak. In most specimens,

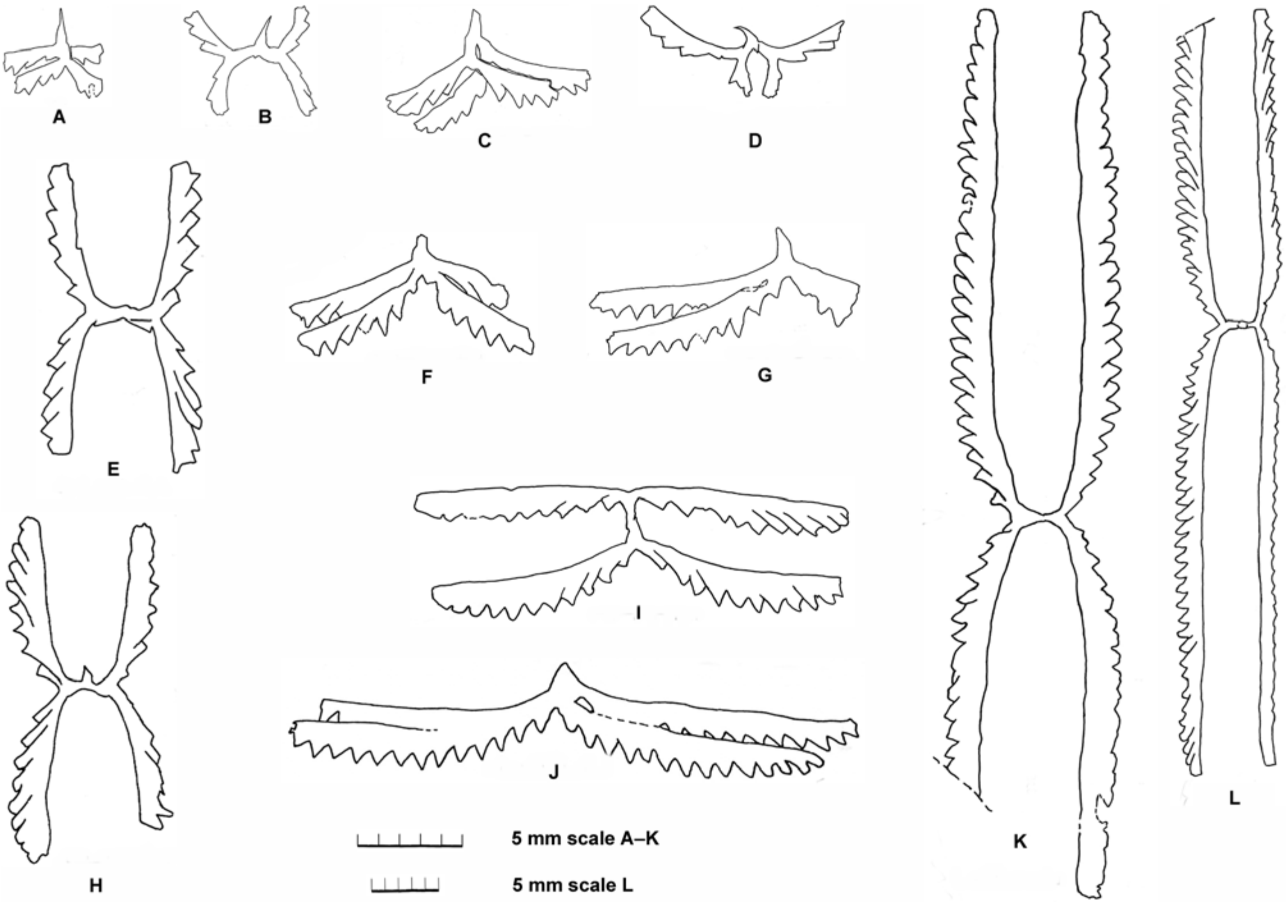


Figure 4: Drawings of *Paratetragraptus approximatus* specimens showing the range of preservational aspects seen in the PL 2017 population. Note that the proximal portions of stipes of 'H'-shaped tubaria, preserved in plan view, are gently curved in the same fashion as those seen in lateral view. **A**: NMV P327511; **B**: P323919A; **C**: P31995; **D**: P32008; **E**: P331895; **F**: P331696; **G**: P324123; **H**: P331598; **I**: P323921; **J**: P323987; **K**: P328617; **L**: P13094.

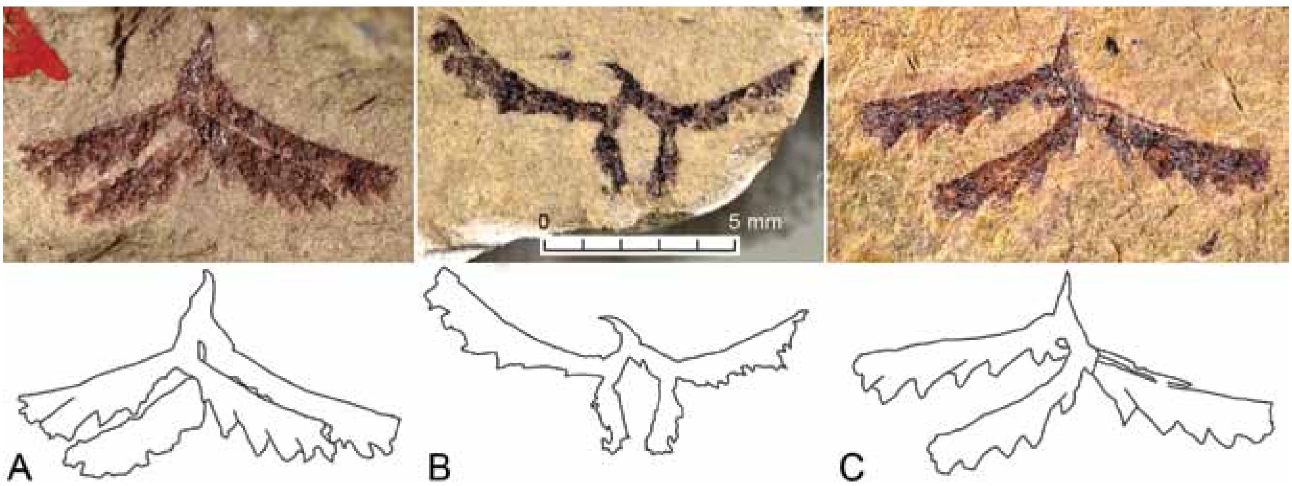


Figure 5: Early growth stages of *Paratetragraptus approximatus* presented in less commonly preserved aspects. All three are type specimens of '*Tetragraptus volitans*' Harris and Thomas 1938a. No doubt the resemblance of **B** to a flying eagle prompted the name — *volitans* is Latin for flying. It is a very unusual view, with the funicle in profile view — a similar view would be obtained if A were rotated by 90° through its vertical axis. **A**: NMV P31995 (holotype), **B**: P32008; **C**: P32006B, all from PL2017 (Be1).

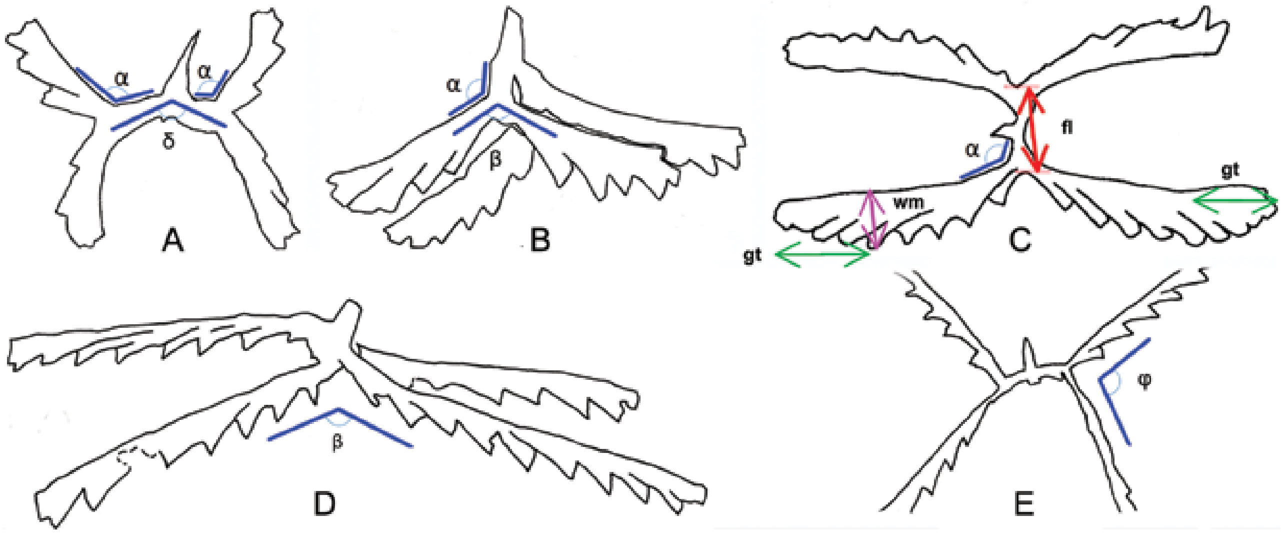


Figure 6: Useful biometrics of *Paratetragraptus*. The funicle length (fl) is quite variable, probably because of the variation in how the tubarium came to rest on the ocean floor. The angle between the dorsal margins of the stipe and the funicle (α) is obtuse in both "H"-shaped and ^-shaped specimens and shows that the stipes in the proximal area in this species are declined. Other useful angles are β, giving a measure of declination of the secondary stipes, and φ, which measures the angle between the stipes in plan view. The maximum stipe width is wm and gt is the growing tip.

this 'peak' consists of both the sicula and the foreshortened funicle. The sicula is rarely seen in full profile view, usually in very early growth stages where it has been forced sideways (Figures 3I, 4B, 5A). In larger tubaria it is not visible, pointing into the under- or overlying rock. In very unusual cases, it can be seen as a tiny circle within the funicle (Figure 3K). Tubaria showing stipes of different width on either side of the funicle (Figures 3F, K, 4H, L) are common and can be explained if the stipes are oval in cross-section, with the dorsoventral dimension being the greater. Stipes preserved in full profile view are wide and have prominent thecae whose free portions make up about half the stipe width, whereas stipes preserved in dorsoventral aspect appear relatively slender and their thecae have low profiles. A good example is the lectotype whose stipes are nearly smooth-sided (see Williams & Stevens 1988, pl. 1, fig. 5).

The declined habit of the first two thecae that form the funicle and the first few thecae of the secondary stipes can only be seen in rare specimens in which the entire tubarium is preserved in lateral aspect. Good examples are the tubaria of *Tetragraptus volitans* Harris and Thomas, particularly the paratype NMV P32008 (Figure 5B). I regard these as early growth stages of *P. approximatus* preserved in lateral view. Harris and Thomas (1938a) noted the similarity with *P. approximatus* and Rickards and Chapman (1991) remarked that the two might indeed be conspecific but nevertheless opted to redescribe Harris and Thomas's specimens under their original species name.

Paratetragraptus acclinans (Keble, 1920)
(Figures 7–10)

pars 1920 *Tetragraptus acclinans* sp. nov.; Keble, pp. 195–197, 201, text-fig. 61, pl. 33, fig. 2a, ?b, *non* fig. 2c.

1960 *Tetragraptus acclinans* Keble; Berry, p. 52, pl. 7, fig. 5.

1960a *Tetragraptus acclinans*; Thomas, pl. 1, fig. 12.

?1962 *Tetragraptus (Paratetragraptus) acclinans* (Keble); Obut & Sobolevskaya, pp. 81–82, pl. 4, figs 6, 7.

1974 *Tetragraptus acclinans,* Keble; Tsaj, pp. 56–57, pl. 4, figs 9, 10.

1979a *Tetragraptus acclinans* Keble, 1920; Cooper, pp. 59–60, text-fig. 27, pl. 7, fig. c.

1983 *Tetragraptus acclinans* Keble 1920; Henderson, pp. 158–159, fig. 9A.

?1984 *Paratetragraptus acclinans* (Keble), 1920; Obut & Sennikov, pp. 73–74 (in Russian), pl. 11, fig. 5.

?*pars* 1988 *Tetragraptus approximatus* Nicholson 1873; Williams & Stevens, ?pl. 1, figure 6 only.

1988 *Tetragraptus acclinans,* Keble; Williams & Stevens, pp. 35, pl. 1 figure 7, pl. 5, figs 1–3, text-figs 23A–D.

pars 1988 *Tetragraptus akzharensis* Tsaj; Williams & Stevens, pl. 2, fig. 1.

1991 *Tetragraptus acclinans* Keble; Rickards & Chapman, pl. 18, fig. b.

?2002 *Tetragraptus acclinans* Keble; Norford et al., pl. 4, fig. 3 (?= *P. approximatus*).

2006 *Tetragraptus acclinans* Keble; Jackson & Lenz, fig. 5d, e.

Diagnosis. Tubarium large, X-shaped in dorsoventral view but stipes deflexed with curvature extending for considerable lengths; funicle long, stipes reach maximum width of 1.8–2 mm by th8–th10; thecae prominent, inclined at ca 45º, spaced at 4 in 5 mm distally.

Holotype. NMV P31956, from Lightning Hill anticline, east of Great Extended Hustler's mine, Bendigo (OD) (Figures 7A, B).

Material and distribution. Measured material includes the holotype plus five specimens from the parish of Campbelltown, from the La3 and Be1 biozones. *P. acclinans* is rare in Victoria and has also been identified from North America and Kazakhstan.

Description. The funicle is unusually long, between 3.5 and 4.5 mm, but its detailed structure is obscured by secondary thickening; no specimen shows a sicula. The proximal stipe portions are also thickened but appear to be ca 1.5 mm wide at the aperture of th2. The stipe width increases gradually to a maximum of 2 mm; one exceptional specimen has stipes to 2.7 mm wide. Thecal inclination is quite high, with free ventral walls inclined at ca 45º (range 27º–45º) to the dorsal stipe margin. Distal thecal spacing is 4 in 5 mm. Stipes may grow to considerable lengths; the longest in the collection is 170 mm long (Figure 10). However, a fragment whose longest, distally broken stipe is 87 mm long (Figure 8E) is so heavily sclerotised that it suggests it is part of a much larger tubarium — the complete tubarium may have been considerably longer than the largest complete specimen.

Remarks. Of the three types designated by Keble (1920), only the holotype is sufficiently well preserved to determine the characters of the stipes and thecae. One paratype (P32149, Figure 7C top) is too faint to measure, and the third (P32150, Figure 7C bottom) may be an *Expansograptus*. Thus the only biometrical characters obtainable from the holotype are distal stipe width, thecal spacing and thecal inclination. Fortunately, a much better preserved specimen was illustrated by Harris and Thomas (1939b, pl. 1, fig. 16; Figure 8C herein).

The tightness of the curvature of the stipes and the length of the curved portion of the stipes both show considerable variation but this may be largely due to preservational aspects. This is most clearly shown in Figures 9 and 10 where the variation is shown in stipes of the same tubaria. The funicle is unusually long for *Paratetragraptus* (3.5–4.5 mm) but it is possible that the limited size of the Victorian population that is measurable is unusual. In populations of *P. acclinans* reported from elsewhere the funicle is considerably shorter — ranges given by other workers are 2.1 mm (Obut & Sennikov 1984) and 2.5–3 mm (Williams & Stevens 1988). Specimens illustrated by Jackson and Lenz (2006) have funicles 2.3 and 2.4 mm long, while a specimen illustrated by Norford et al. (2002) has a funicle 3.7 mm long. This suggests that funicle length may be too variable to be of taxonomic value.

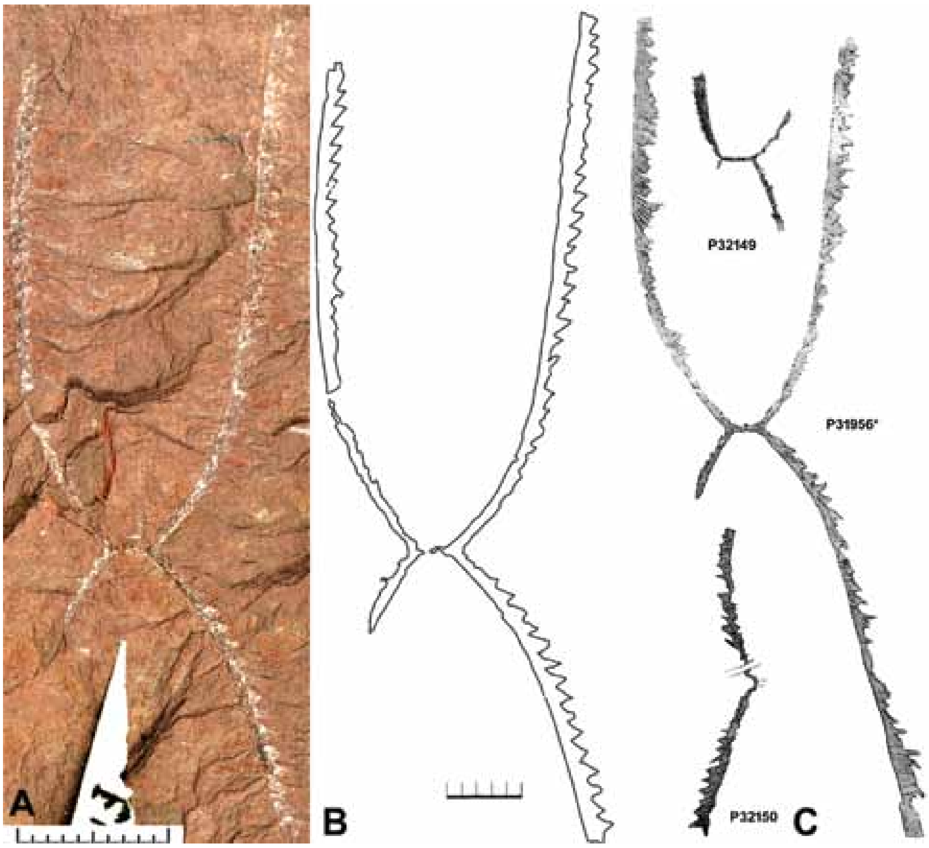


Figure 7: Holotype and paratypes of *Paratetragraptus acclinans* (Keble). **A, B**. Photograph and drawing of most of the holotype, NMV P31956. The distal portion of the lower right stipe is too faint to provide much information and is not shown, but is shown in **C**, Keble's original drawing. P32149 is a paratype that is too poorly preserved to photograph or draw; P32150, also a designated paratype, may be a specimen of *Expansograptus vicinus* (Harris & Thomas). Scales are 10 and 5 mm.

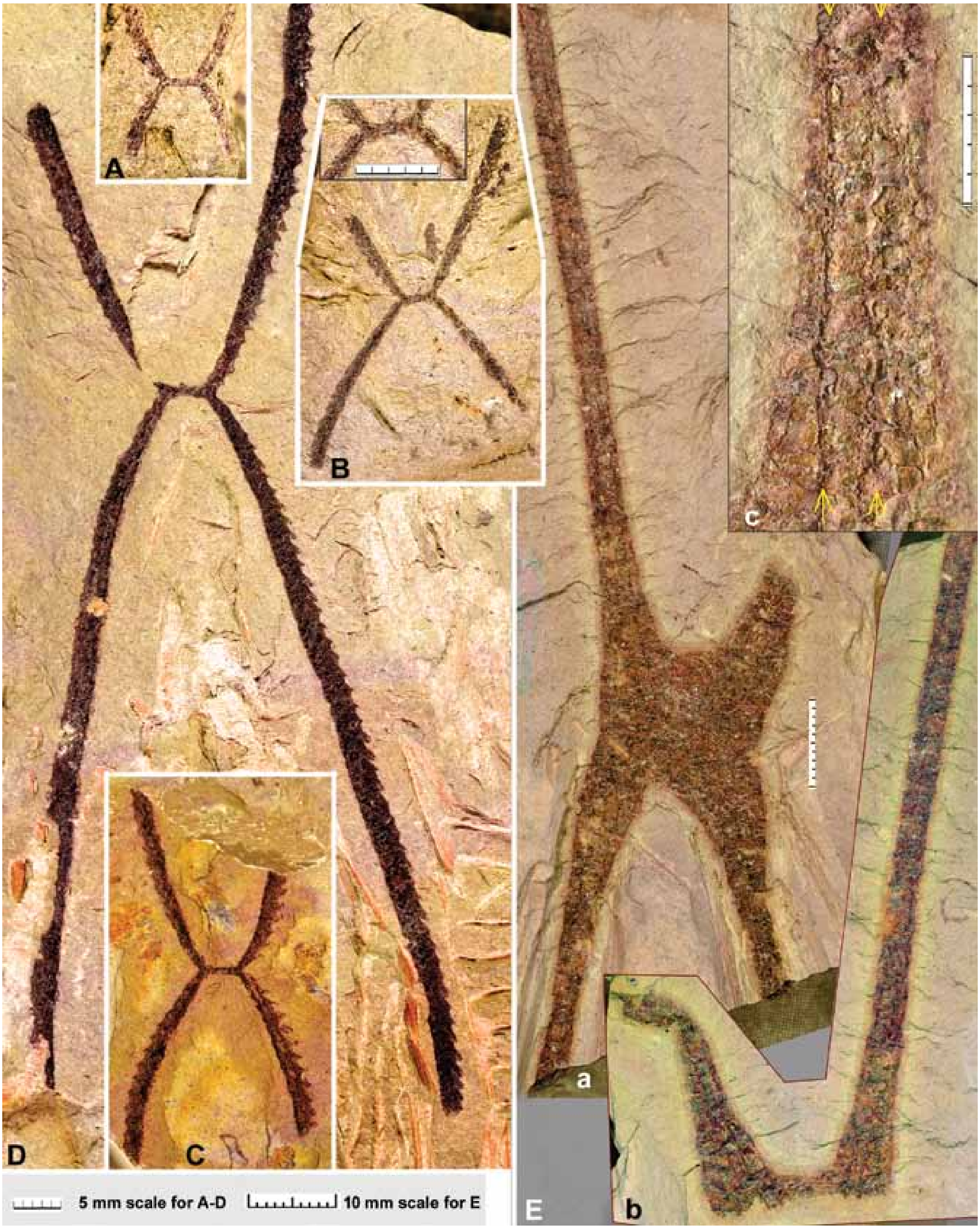


Figure 8: *Paratetragraptus acclinans*. **A–D** are arranged in a growth sequence. **A** shows the earliest growth stage that can be included in *P. acclinans* with confidence. **B** is the only specimen showing a sicula, magnified in the inset. **C** shows the specimen figured by Harris and Thomas (1938b) which forms the basis from which most other authors have interpreted the concept of the taxon. **E** shows a 'gerontic' specimen with extensive secondary overgrowth in the proximal region. The part and counterpart are shown in a and b, while c shows a magnified view of part of the right stipe of b which is preserved in low relief and shows the original stipe edges as faint ridges (arrowed). Several slit-like structures that lie across the stipe are interpreted to be thecal apertures. **A**: NMV P331898; **B**: P324207; **C**: P331899; **D**: P315067; **E**: P324208A & B. **A, C**: loc. S53 (La3); **B, E**: S50 (La3); **D**: 16A, all from Campbelltown (see Appendix 2 for locality details).

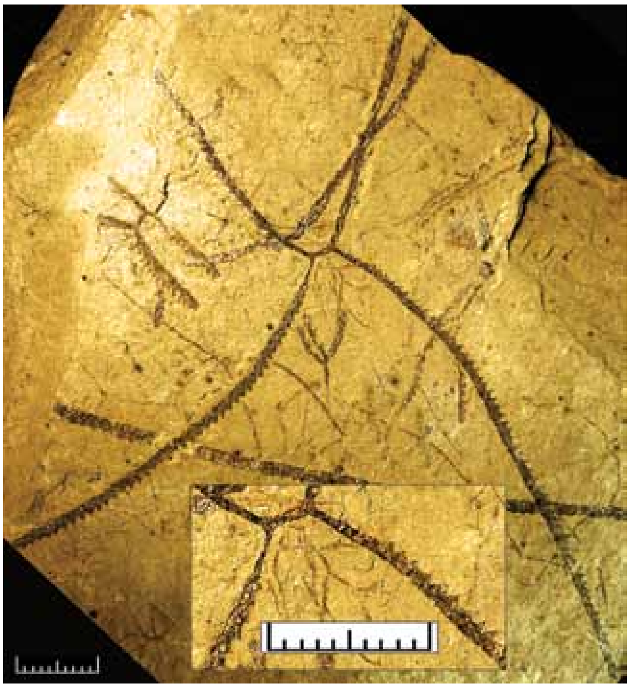


Figure 9: Moderately large tubarium of *Paratetragraptus acclinans* showing variation in stipe curvature. The magnified proximal area in the inset shows secondary thickening of the funicle, and unexplained attenuation of the proximal end of one of the stipes. NMV P318174, PL 2017.

The apparent thecal inclination is highly dependent on aspect of preservation and stipes are rarely preserved in full profile view, where the observed inclination is greatest. This is thought to be due to the inferred construction of the tubarium in which thecae point downwards as well as outwards, as in *P. approximatus*. Stipes therefore need to be twisted sideways after landing on the sea floor in order to be preserved in profile view. For this reason, specimens whose thecal inclination is considerably less than the maximum, such as those illustrated by Williams and Stevens (1988), should still be included in *P. acclinans*. One of their illustrations of *P. akzharensis* (pl. 2, fig. 1) does have less steeply inclined thecae. The same holds for specimens in which all stipes are preserved in dorsoventral view so that they are almost smooth-sided (e.g. in Cooper 1979a; and see Figure 8E). The Victorian population contains tubaria in which one or several stipes are preserved in dorsoventral view (Figures 8A, D) and one in which all stipes are preserved in perfect dorsoventral view (Figure 8E).

Paratetragraptus acclinans is very similar to *P. approximatus* and the two are considered to be closely related. The two have the same biostratigraphic ranges, from La3 to Be1. The main difference is the tubarium habit, with the stipes of *P. approximatus* running more or less parallel in dorsoventral view, whereas those of *P. acclinans* are more spread out, and gently curved when viewed in profile.

Figure 10: The largest known specimen of *Paratetragraptus acclinans*, showing considerable variation in stipe curvature. The insets show the proximal area and a small portion of the upper left stipe magnified. NMV P328351, from loc. S50.

Paratetragraptus cooperi sp. nov.
(Figures 11, 12)

pars 1988 *Pendeograptus fruticosus* (J. Hall, 1858); Williams & Stevens, pl. 9, fig. 8 only.

Etymology. Named for Roger Cooper, palaeontologist, mentor and friend.

Diagnosis. Large *Paratetragraptus* with three or four proximally declined, then deflexed stipes forming an X in dorsoventral view.

Type material. Holotype NMV P330705; paratypes NMV 331883, 330707.

Material and distribution. Nine measured specimens, from Blackwood and S53, additional specimens from S30; all from La3.

Description. Sicula large, 2.9 mm long, with prominent rutellum, and nema to 2.5 mm long. The two primary stipes that make up the funicle are declined, with the angle between them 90° or slightly less. The secondary stipes curve downwards so that the proximal area forms an arch. This ventral curvature is reversed between ca th3–th5, where stipes show a graceful dorsal curvature so that the distal stipe portions subtend an angle of approximately 90°. Stipe width increases rapidly from 1.1 mm at th1 to 1.3–1.5 mm at th3, then more gradually to a maximum of 1.6–2.0. Proximal thecae are long, with free ventral walls up to 1.6–2.2 mm long, twice as long as those of more distal thecae, and are inclined at 18°–25° proximally, increasing rapidly to 45–60° distally. Free ventral walls are straight to slightly ventrally curved, apertural margins are straight to slightly curved. Thecal spacing is 3–4 in 5 mm proximally, 4–5⅓ distally.

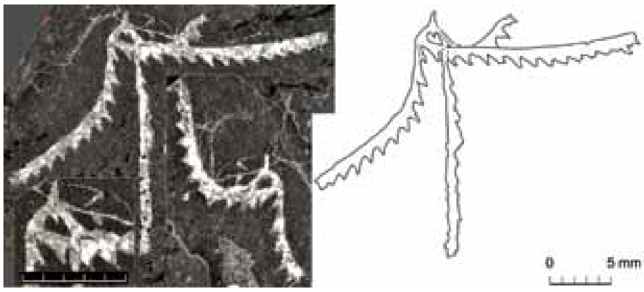


Figure 11: Holotype of *Paratetragraptus cooperi*. Inset shows counterpart. NMV P330705, from Blackwood (La3).

Remarks. *Paratetragraptus cooperi* is most similar to *P. approximatus* but its tubarium has a different habit, with an arched rather than 'peaked' proximal structure and spreading stipes. Both 3- and 4-stiped forms exist, whereas *P. approximatus* is only found as 4-stiped tubaria. Its biostratigraphic and geographic ranges are also more limited, having been found only in the *P. approximatus* Zone (La3), in Victoria. A single specimen illustrated as *Pendeograptus fruticosus* by Williams and Stevens (1988, pl. 9, fig. 8) is very similar to Victorian specimens of *Paratetragraptus cooperi*, particularly Figure 12H. Its proximal habit is 'peaked' rather than 'arched' as in *T. fruticosus*. Its presence in Newfoundland suggests that

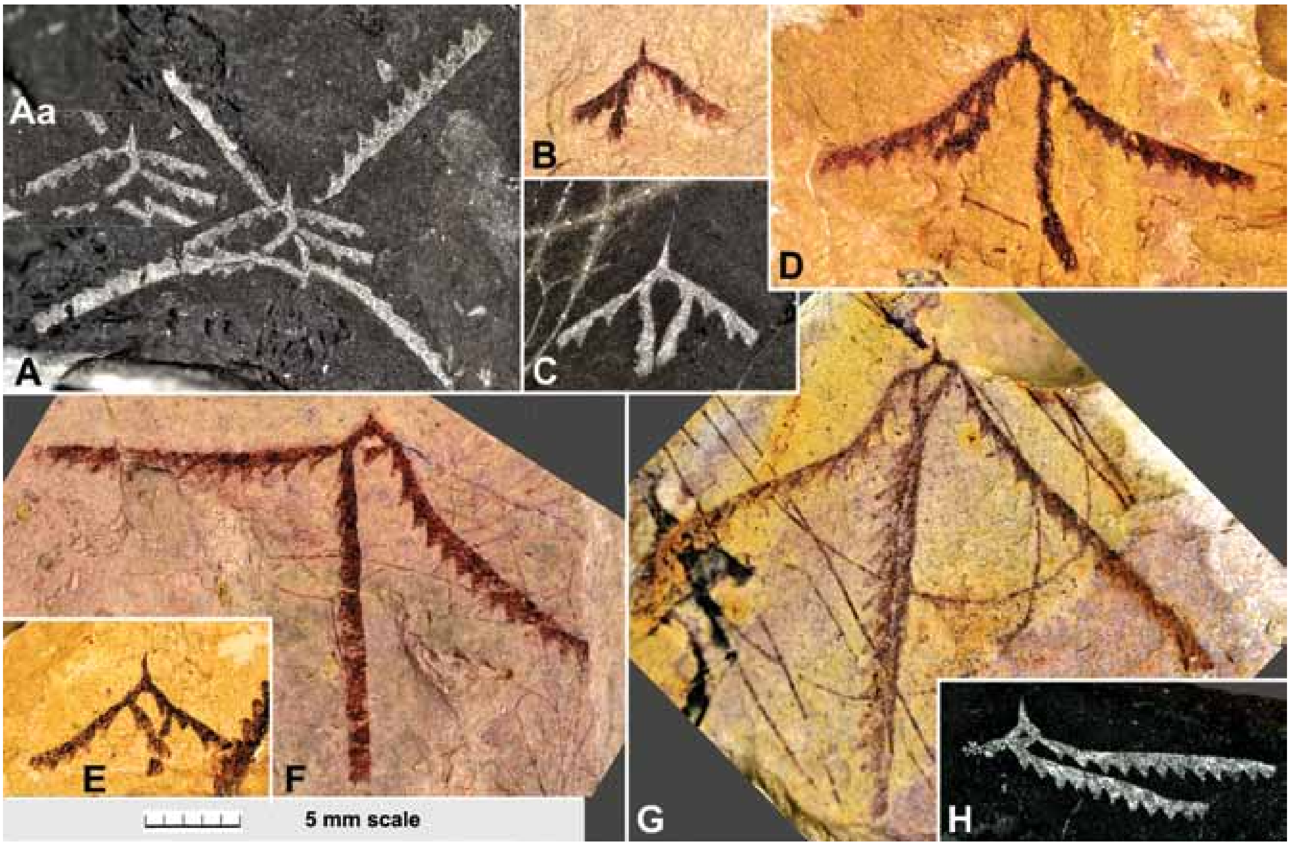


Figure 12: Various growth stages of *Paratetragraptus cooperi*. **A**: NMV P330722, two entangled tubaria; Aa shows the larger one digitally removed to clarify the appearance of the smaller one. **B**: P332095, a 3-stiped tubarium. **C**: P330707, an early growth stage with nema. **D**: P331886; **E**: P331887; **F**: P331930, mature tubarium with most of one stipe missing, probably a victim of predation. **G**: P331883A, fully grown tubarium; **H**: P330701A, left side broken off. **A, C, H** from Blackwood, others from S53 (La3).

it may occur elsewhere in the Pacific Province. There is some doubt about its stratigraphic position: Williams and Stevens give this as 'CHN 11.2D' but this cannot be matched with the numbering in the lithological log of the section (their text-fig. 4).

Paratetragraptus thomassmithi sp. nov.
(Figures 13–16)

Etymology. Named for Thomas Smith, resident of Campbelltown in the early twentieth century, who collected most of the specimens from the Campbelltown area illustrated in this paper (see also Harris & Thomas 1948).

Diagnosis. Large tubarium with slender funicle; curved secondary stipes remain slender and diverge at variable angles; thecae relatively steeply inclined.

Type material. Holotype NMV P330685, from Blackwood; paratypes: NMV P330779, P330723 and P330585 from the same locality, and P324227, from loc. S50.

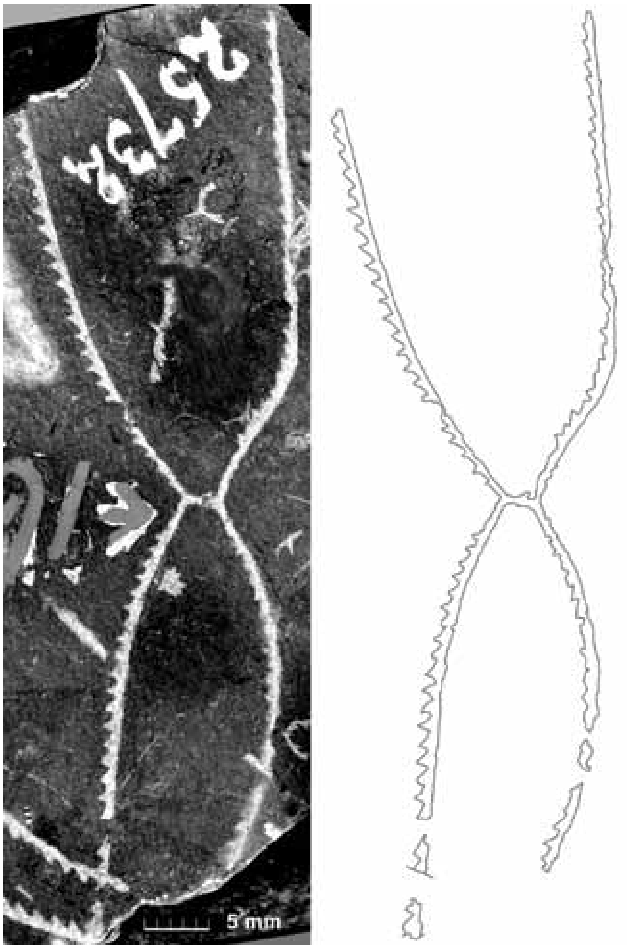


Figure 13: *Paratetragraptus thomassmithi*, photo and drawing of the holotype, NMV P330688B, from Blackwood (La3).

Material and distribution. Twenty measured specimens: eight from the Blackwood locality (La3) and 12 from localities from the Campbelltown area. The taxon is rare and only known from these localities, and limited to the topmost Lancefieldian (La3) and basal Bendigonian (Be1) — its range is therefore the same as that of *P. approximatus*.

Description. None of the specimens are sufficiently well preserved to show proximal details. Only three show a sicula, in foreshortened view, with the best-preserved one at least 2.8 mm long. Funicle length is highly variable, ranging from 1.8–3.2 mm. It is slender, 0.7 mm wide at the apertures of th1. The angle of stipe divergence is highly variable so that the appearance of the proximal area ranges from H-shaped to X-shaped, with the stipes diverging from the funicle at variably obtuse angles. Stipes are slender throughout, ranging from 0.5–0.9 (rarely >1) mm wide at th2 to a maximum of 1.3–1.6 mm, reached at 5–8 mm from the funicle. Thecae are prominent, with the free portions making up approx. half of the stipe width. The inclination of the free ventral walls is relatively steep, 40º–55º. These characters are, however, only shown clearly in stipe portions that are preserved in true profile view — most specimens are not, so that the apparent steepness of the free ventral wall and stipe width are considerably less. Tubaria can reach considerable size, with stipes reaching lengths of 70 mm (Figure 16). The proximal portions of stipes are gently curved for lengths that range from 15 to 40 mm. In the majority, the curvature is dorsal but some are ventrally curved. This appears to be a preservational effect — ventrally curved stipes occur in tubaria where the other three stipes are dorsally curved (e.g. in the holotype, Figure 13). Thecal spacing is 4–4½ (rarely 3½) in 5 mm proximally, 3–5 in 5 mm distally.

Remarks. *P. thomassmithi* is close to *P. acclinans* in shape but has more slender stipes that are more strongly and more persistently curved. While no early growth stages are preserved in lateral aspect, the stipes are inferred to have been gently declined and the colony may have had a similar habit to *P. acclinans*.

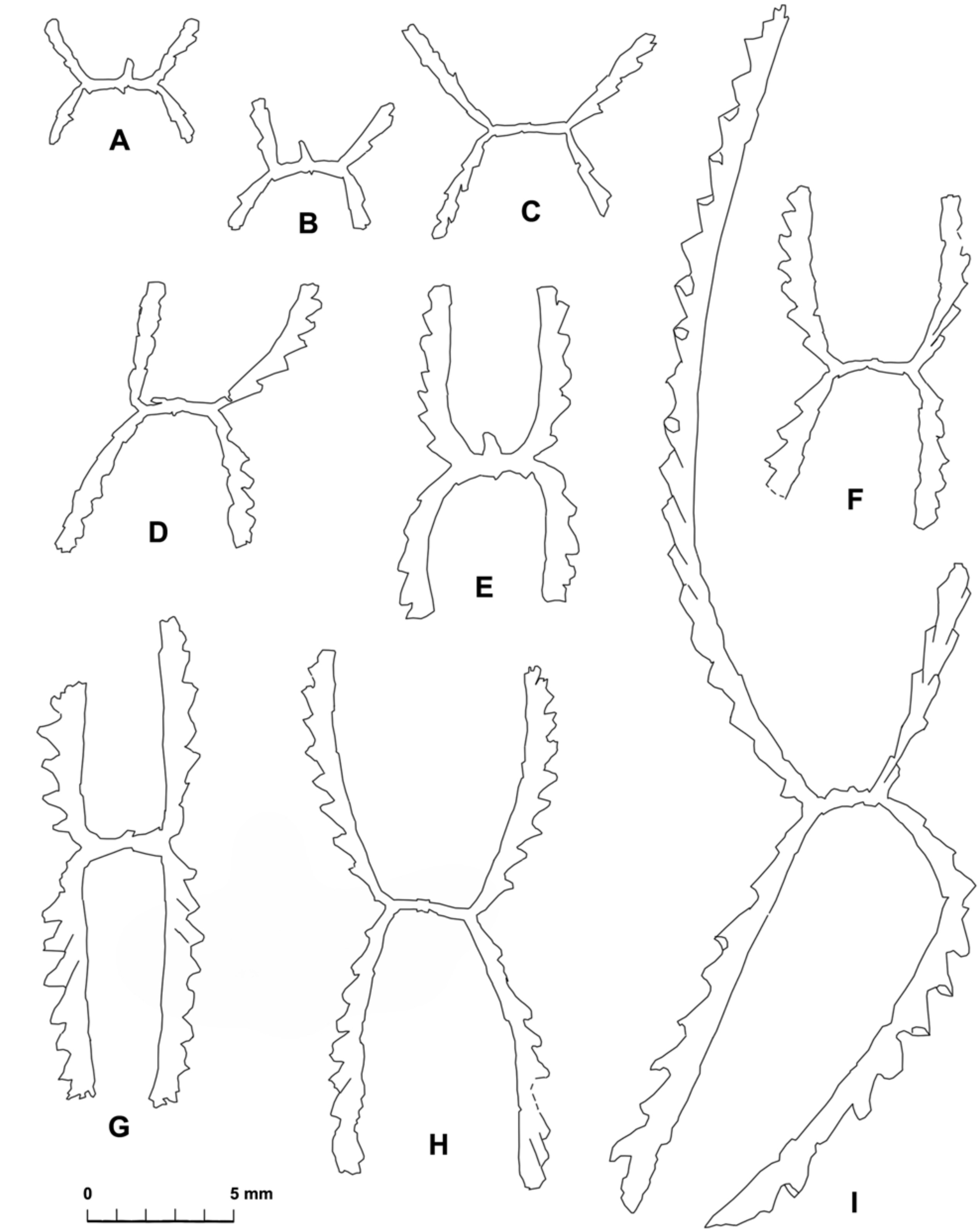


Figure 14: *Paratetragraptus thomassmithi*. Growth series of early growth stages showing the variation in appearance caused by differences in preservational aspect. **A**: NMV P332251; **B**: P330686; **C**: P332227; **D**: P330709; **E**: P324218; **F**: P330723; **G**: P331894; **H**: P330685; **I**: P319267; **A, C, G**: PL 2017; **B, D, F, H**: Blackwood; **E**: S50; **I**: 18B (see Appendix 2 for locality details).

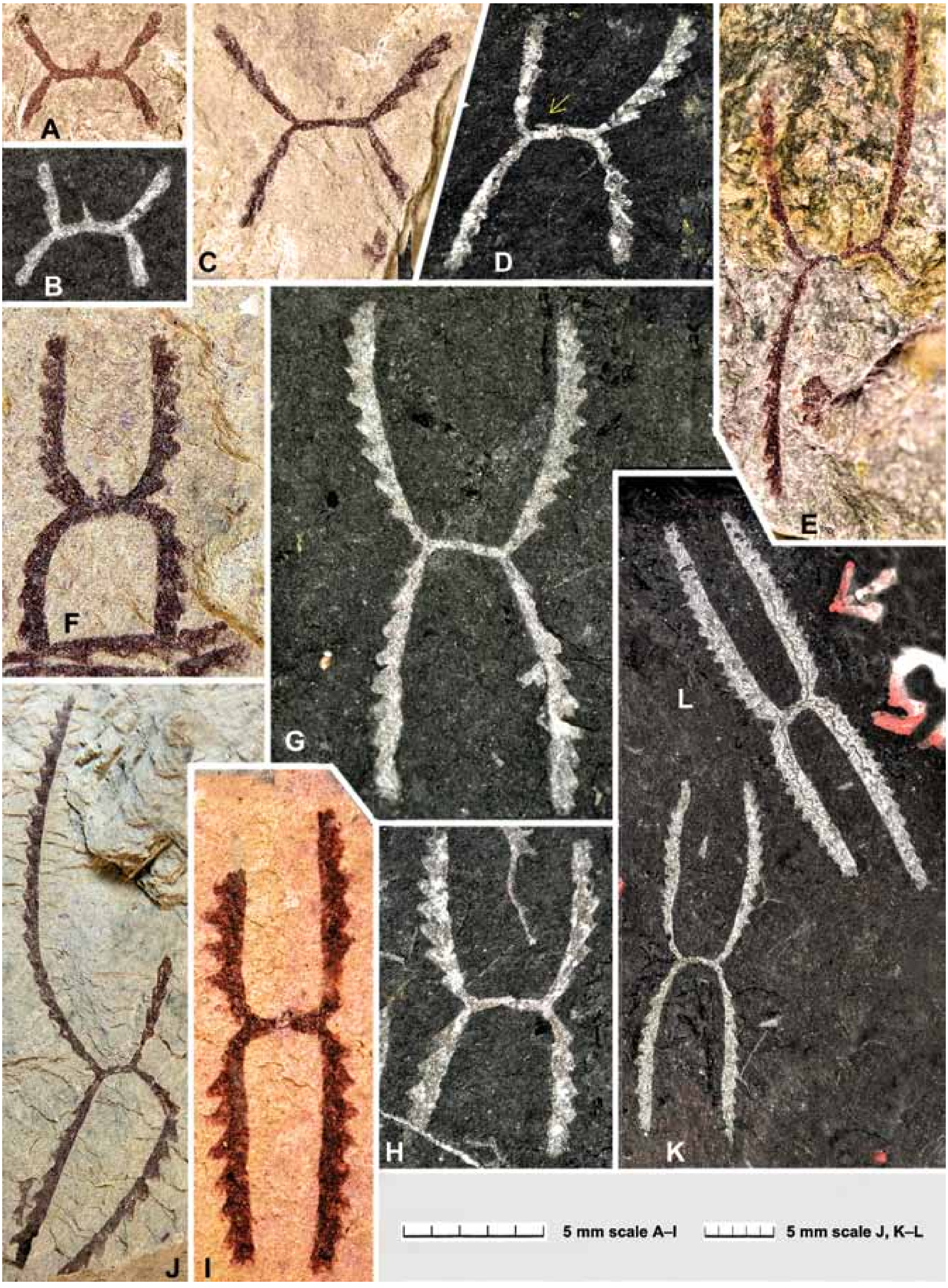


Figure 15: *Paratetragraptus thomassmithi*, photos of early growth stages showing the variation in appearance of tubaria preserved in different aspects. Arrow in D points to sicula. **A**: NMV P332251; **B**: P330686; **C**: P332227; **D**: P330709; **E**: P328148; **F**: P324218; **G**: P330685; **H**: P330723; **I**: P331894; **J**: P319267; **K**: P330715; **L**: *Paratetragraptus approximatus* (same slab), P330714. **A, C, I**: PL 2017; **B, D, G, H, K, L**: Blackwood; **E**: 18B; **F, J**: S50.

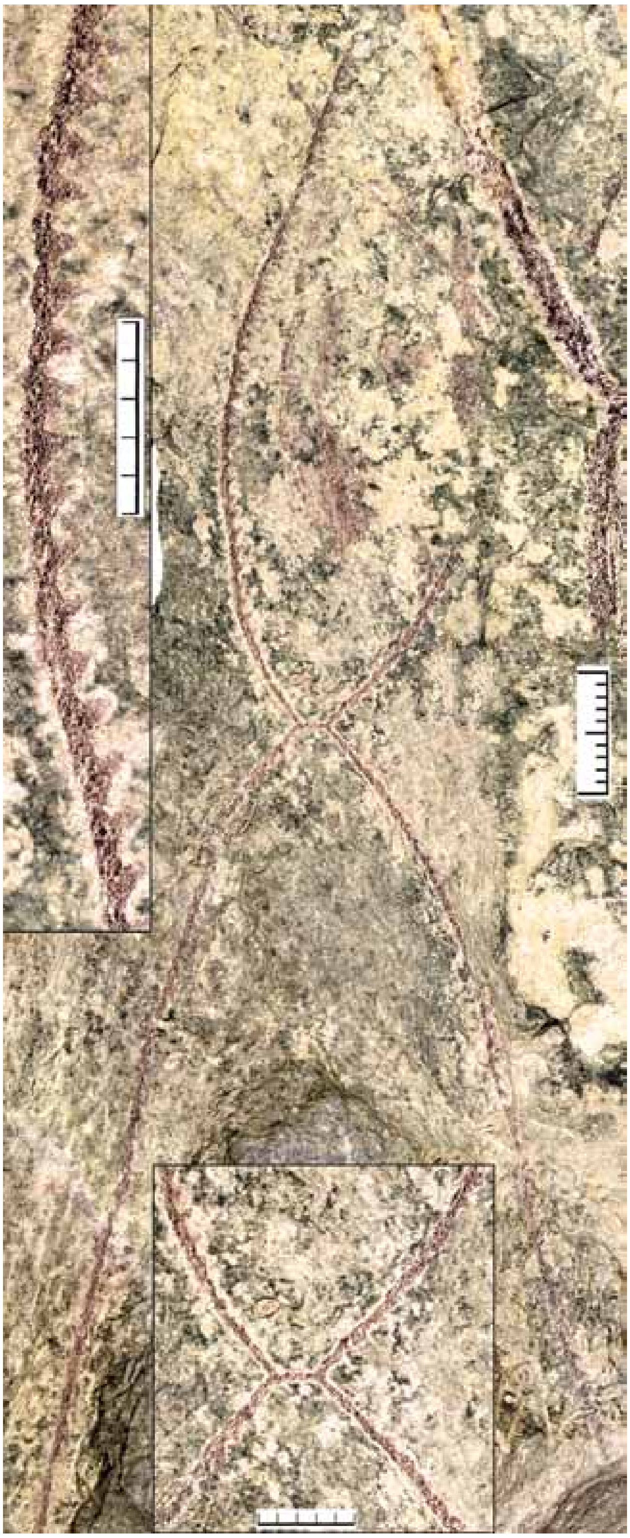


Figure 16: The largest tubarium of *Paratetragraptus thomassmithi*, with insets showing the funicle and portion of the best preserved stipe at higher magnifications. Scales are 5 mm (insets) and 10 mm (main). NMV P324227, from S50.

Paratetragraptus*? *henrywilliamsi sp. nov.
(Figures 17–19)

?*pars* 1988 *Tetragraptus akzharensis* Tzaj, 1968; Williams & Stevens, text-figs 24C, G, ?D.

Etymology. Named after S. Henry Williams, with whom I spent some memorable times at Dob's Lin, Enoch's Point, Bendigo and in the Great Basin.

Diagnosis: X-shaped tubarium with slender, straight to slightly flexuous gently declined stipes.

Type material. Holotype NMV P324113 from PL2017; paratypes P337911 and P331915, both from S53.

Material and distribution. Nine measured specimens from the La3 biozone from the Blackwood antimony mine and from several localities in the Campbelltown area, and seven from Be1 localities in the Campbelltown area.

Description. The sicula is slender, 1.6–1.7 mm long and straight in some aspects, but with distinct bend in others (Figures 18A–C, E), provided with short thin nema and short rutellum. The funicle is 2.6–3 mm long. The tubarium is quite large, with slender stipes of 60+ mm long, widening rapidly from 0.8–1.0 mm wide proximally to 1.1–1.3 mm distally. Thecae prominent, with free ventral walls inclined at 35–40º. Stipes are gently declined, with inter-stipe angle ranging from 120–180º.

Remarks. The X-shape of the tubarium and slightly declined, straight, uniformly slender stipes serve to distinguish *P. henrywilliamsi* from all other taxa. Early growth stages preserved in lateral view indicate its habit was similar to that of *P. cooperi* although it lacks the proximal 'arch', with stipes being straight for their entire length. Tubaria are found in great abundance on bedding planes, usually to the exclusion of other taxa, which suggests they may have formed 'swarms' (Figure 19). In their illustration of *Tetragraptus akzharensis*, Williams and Stevens (1988, figs 24C, G, ?D) included several X-shaped specimens from their *T. akzharensis* Zone that have straight, slender stipes and fit the morphology of *P. henrywilliamsi*. This suggests that *P. henrywilliamsi* may yet be found in other Pacific Province localities.

Tshallograptus gen. nov.

Etymology. Named for T.S. (Thomas Sergeant) Hall, pioneer graptolite researcher in south-eastern Australia. The recommended pronunciation rhymes with shallow.

Type species. *Graptolithus fruticosus* J. Hall, 1858.

Diagnosis. Pendent to deflexed phyllograptid; proximal development isograptid, dextral; low prosicular origin of

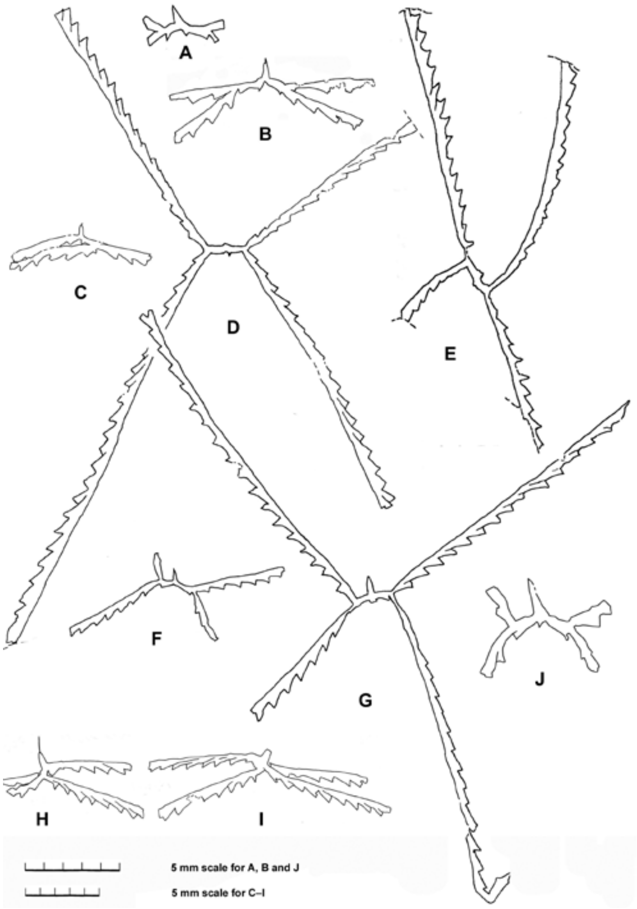


Figure 17: *Paratetragraptus*? *henrywilliamsi*. Early growth stages have the proximal area preserved either in lateral (**A–C, H, I**) or plan view (**D–F, J**). The sicula is evidently twisted sideways in several of the latter. **A**: NMV P332170; **B**: P332113; **C**: P332254; **D**: P331944A; **E**: P328444; **F**: P331991B; **G**: P324231B; **H, I**: P337911B & A; **J**: P331901. **A**: Blackwood; **B, C, E**: PL 2017; **D, H–J**: S53; **F**: Molloy's; **G**: S50 (see Appendix 2 for locality details).

th1[1]; crossing canals low on sicula; sicula long and slender, with mitre-shaped prosicula.

Species assigned. *Graptolithus fruticosus* J. Hall, 1858; *Tshallograptus cymulus* sp. nov.; *T. tridens* sp. nov., *T. furcillatus* sp. nov. Etheridge (1874) illustrated what appears to be the 2-stiped morph under the name *Didymograptus*? *pantoni* but the illustrated specimens have not been found. The 2-stiped morph is very rare in Victoria and has no biostratigraphic significance so is not formally named here.

Discussion. Bouček & Příbyl (1952) included *Tetragraptus fruticosus* (Hall) in their new genus *Pendeograptus*, with *Tetragraptus pendens* Elles as type species, and subsequent authors have followed suit. Differences between *P. pendens* and *T. fruticosus* include tubarium size and habit, and the size and shape of the stipes. Previously published diagnoses of *Pendeograptus* have largely ignored the poorly known type species and are based on the *T. fruticosus* clade, of which good 3D early growth stages have been described (Williams & Stevens 1988). *P. pendens* also appears to be significantly younger than *T. fruticosus* (Williams & Stevens 1988, p. 38). I regard these differences as sufficiently marked to separate *T. fruticosus* and allied taxa, all of which are early Floian, into the new genus *Tshallograptus*.

Tshallograptus fruticosus (J. Hall, 1858)
(Figures 18I, 20–22, 25I–N)

1858 *Graptolithus fruticosus*; J. Hall, p. 128.

pars 1865 *Graptolithus fruticosus*, Hall; J. Hall, pp. 90–91, pl. 5, figs 6–8, pl. 6, figs 1, 2.

pars 1874 *Graptolites (Didymograptus) fruticosus* (Hall sp.); McCoy, pp. 13–14, pl. 1, figs 9–12, 14.

pars 1904 *Tetragraptus fruticosus* Hall sp.; Ruedemann, pp. 649–652, pl. 10, figs 4, 6.

pars 1904 *Tetragraptus fruticosus* var. *campanulatus*; Ruedemann, p. 652, pl. 10, fig. 8 only.

pars 1904 *Tetragraptus fruticosus* var. *tubiformis*; Ruedemann, p. 652, pl. 10, figs 3, 5.

pars 1932 *Tetragraptus fruticosus* (J. Hall); Harris & Keble, pp. 32–33, 35–36, pl. 4, fig. 1.

pars 1935 *Tetragraptus fruticosus* (J. Hall) 1857; Benson & Keble, pp. 275–276, pl. 30, figure 41, pl. 33, fig. 25.

1935 *Tetragraptus fruticosus* var. *conferticosus* var. nov.; Benson & Keble, pp. 275–276, pl. 33, figs 23, 24.

pars 1938a *Bryograptus crassus*, sp. nov.; Harris & Thomas, pp. 72–73, pl. 1, fig. 7d only.

pars 1938b *Tetragraptus fruticosus* (J. Hall); Harris & Thomas, pl. 1, fig. 18.

pars 1947 *Tetragraptus fruticosus* (Hall); Ruedemann, pp. 304–305, pl. 51, fig. 26.

pars 1947 *Tetragraptus fruticosus* Hall var. *campanulatus* Ruedemann; Ruedemann, p. 305, pl. 51, fig. 32.

1947 *Tetragraptus fruticosus* Hall var. *tubiformis* Ruedemann; Ruedemann, p. 305, pl. 51, figs 27, 29.

pars 1960 *Tetragraptus fruticosus* (Hall); Berry, pp. 54–55, pl. 6, figs 11, 12, pl. 7, fig. 14, pl. 8, fig. 1, pl. 9, fig. 3.

pars 1960a *Tetragraptus fruticosus*; Thomas, pl. 3, fig. 26.

1976 *Tetragraptus fruticosus* (Hall, 1858); Legg, p. 26, pl. 8, figs 27, 28.

pars 1979a *Tetragraptus fruticosus* (J. Hall, 1858); Cooper, pp. 64–65, text-fig. 32a, pl. 6, fig. e.

1980 *Tetragraptus fruticosus* 4 br; Kilpatrick & Fleming, text-figs 3, 4.

pars 1982 *Tetragraptus (Pendeograptus) fruticosus* (J. Hall 1858); Cooper & Fortey, pp. 210–213, text-fig. 30f only.

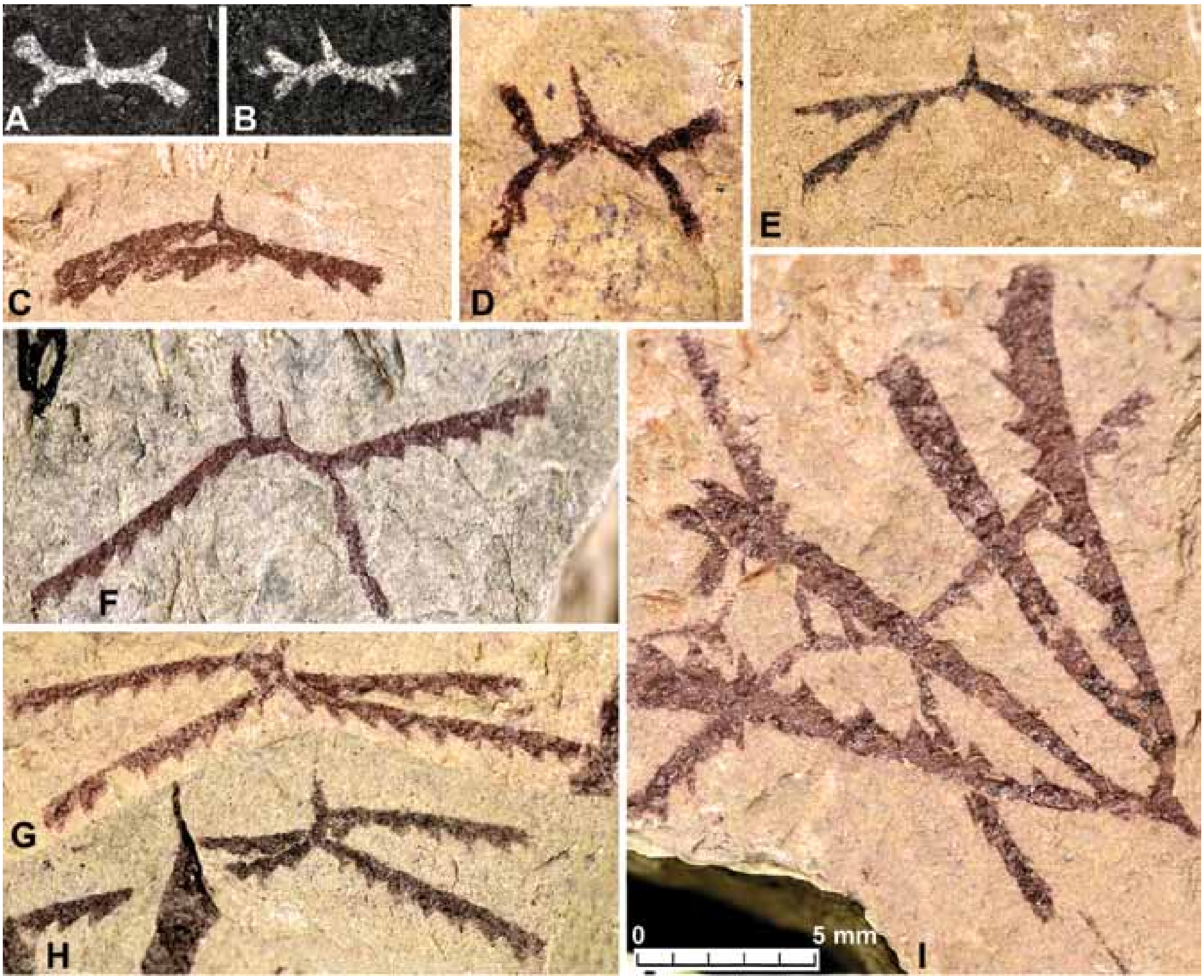


Figure 18: *Paratetragraptus*? *henrywilliamsi* and *Tshallograptus fruticosus* (J. Hall), early growth stages preserved in lateral and plan view. **A**: NMV P332169; **B**: P332170; **C**: P332254; **D**: P331901; **E**: P324113; **F**: P331991B; **G, H**: P33191A & B; **I**: P332261, *T. fruticosus* P332262. **A, B**: Blackwood; **C, E, I**: PL 2017; **D, G**, **H**: S53; **F**: S16A (see Appendix 2 for locality details).

pars 1983 *Tetragraptus fruticosus* (J. Hall 1858); Henderson, pp. 159, 161, fig. 7K.

pars 1988 *Pendeograptus fruticosus* (J. Hall, 1858); Williams & Stevens, pp. 39–41, text-figs 27G, H, J, M only.

pars 1988 *Tetragraptus (Pendeograptus) fruticosus*; Cas & VandenBerg, fig. 3.3m.

pars 1991 *Pendeograptus fruticosus* (J. Hall); Rickards & Chapman, pp. 63–65, pl. 16, figs a, b, pl. 17, fig. e.

pars 1992 *Pendeograptus fruticosus*; VandenBerg & Cooper, text-fig. 4A.

2002 *Pendeograptus fruticosus* (Hall); Mu et al., p. 200 (in Chinese), pl. 60, figs 4, 7.

pars 2006 *Pendeograptus fruticosus* (J. Hall); Jackson & Lenz, fig. 6d.

Type specimen. Lectotype GSC 926, figured J. Hall (1865, pl. 5, figure 6) designated by Williams and Stevens (1988), from Orleans Island, three miles above River St. Anne, Quebec, Canada.

Diagnosis. Large tubarium composed of four, rarely five stipes by consecutive dichotomy, proximally pendent, then deflexed, stipe width increasing from 0.8–1.0 mm to a maximum 3.0–4.0 mm in 25 mm. Sicula 2.5–3.5 mm long, nema usually thickened. Thecae number a uniform 7 in 10 mm, inclination increasing ventrally from 10º to as much as 50º in distal parts of mature tubaria.

Material and distribution. Twenty-one specimens mostly from two localities, PL 2017 and S16A, both from Be1, with additional specimens from 'Dam 17', 'Allotment 17' and S83 (see Appendix 2). Although most of the material is moderately cleaved, there is no evidence of tectonic distortion. All localities are in the Be1 *P. approximatus* + *T.*

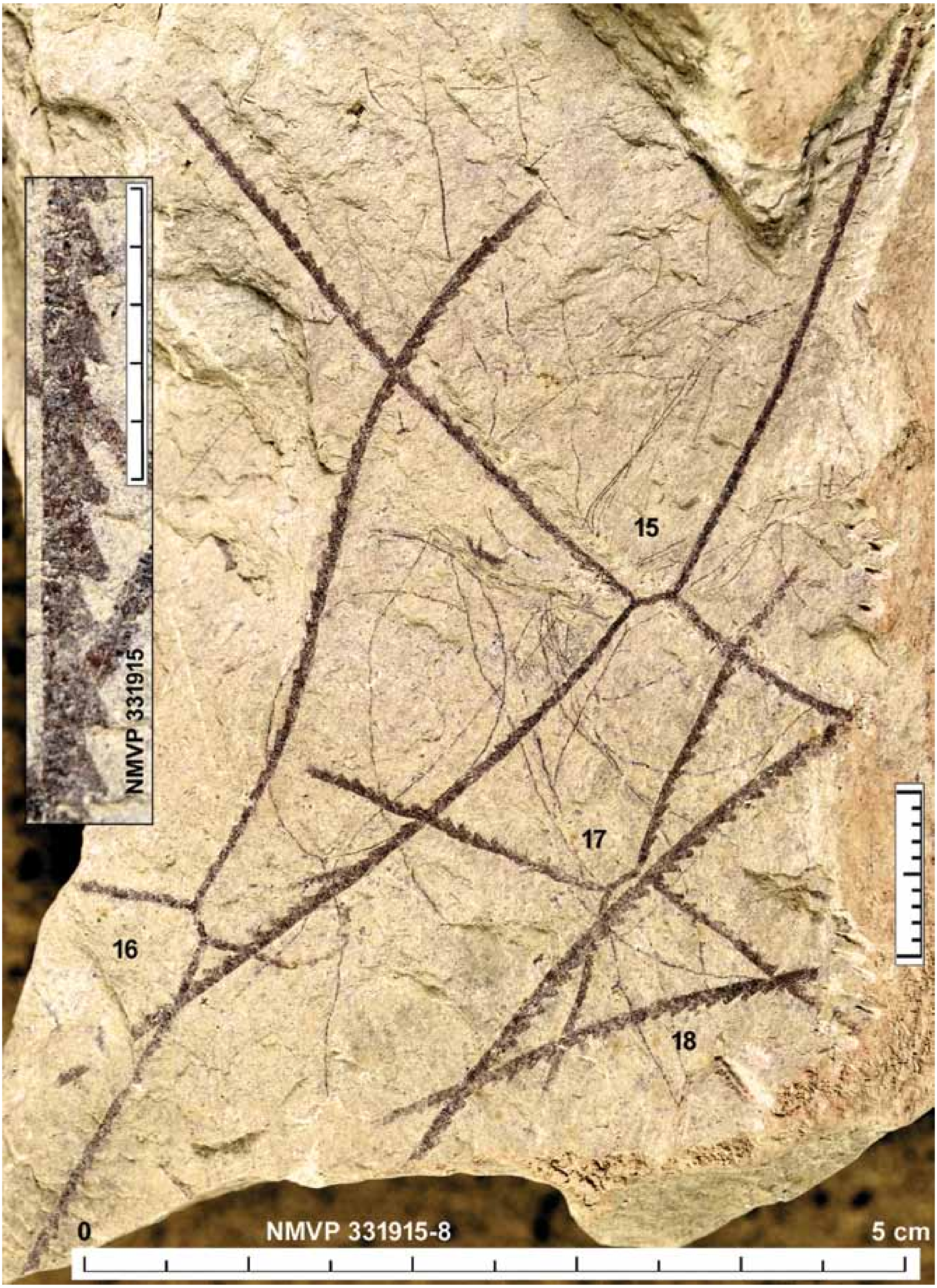


Figure 19: *Paratetragraptus*? *henrywilliamsi*. Group of large and medium-sized tubaria showing the most common aspect of the taxon. The inset shows portion of the lower left stipe of P331915 at higher magnification. NMV P331915–918, from S53 (La3).

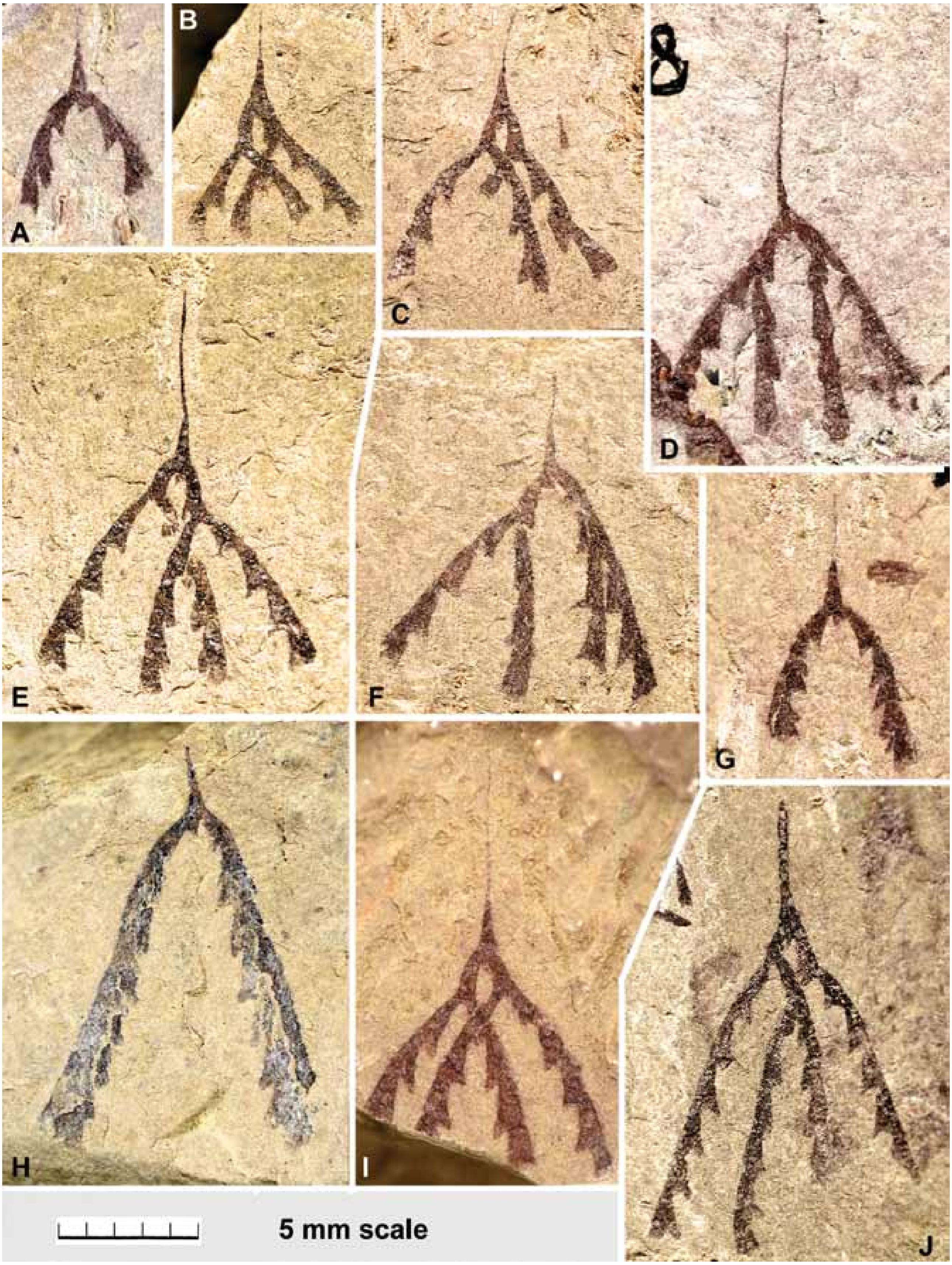


Figure 20: *Tshallograptus fruticosus* — early growth stages. Variation in stipe width is largely a preservational phenomenon, with the broadest stipes preserved in full lateral view and a few in dorsoventral view (**B** and **F**), others are in between. Note also the variation in the width and length of the nema. **A, G** and **H** have stipes superimposed giving the appearance of 2- and 3-stiped morphs. **A**: NMV P331452; **B**: P332450; **C**: P332424; **D**: P332386; **E**: P332374; **F**: P332326; **G**: P332378; **H**: P331528; **I**: P332429; **J**: P332404; all from PL 2017, Be1.

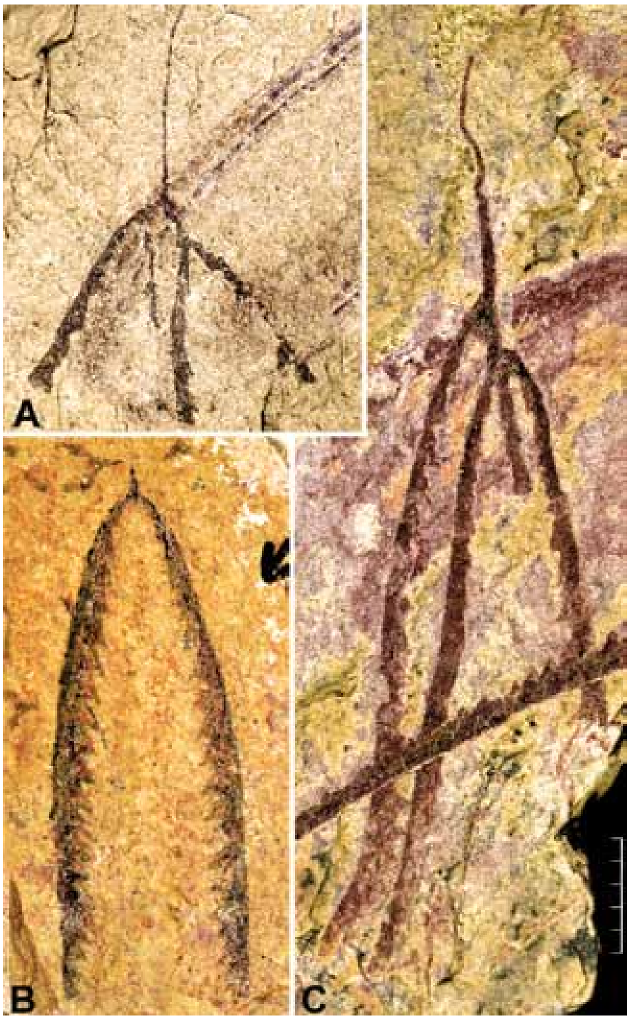


Figure 21: *Tshallograptus fruticosus.* **A**, slab showing three 4-stiped and one 5-stiped morph. NMV P332224, P332225, P324026B; **B**, two specimens are preserved in the usual lateral view, with two others shown in an unusual plan view; NMV P317715–17; both from PL 2017, Be1. Scales are 10 mm long.

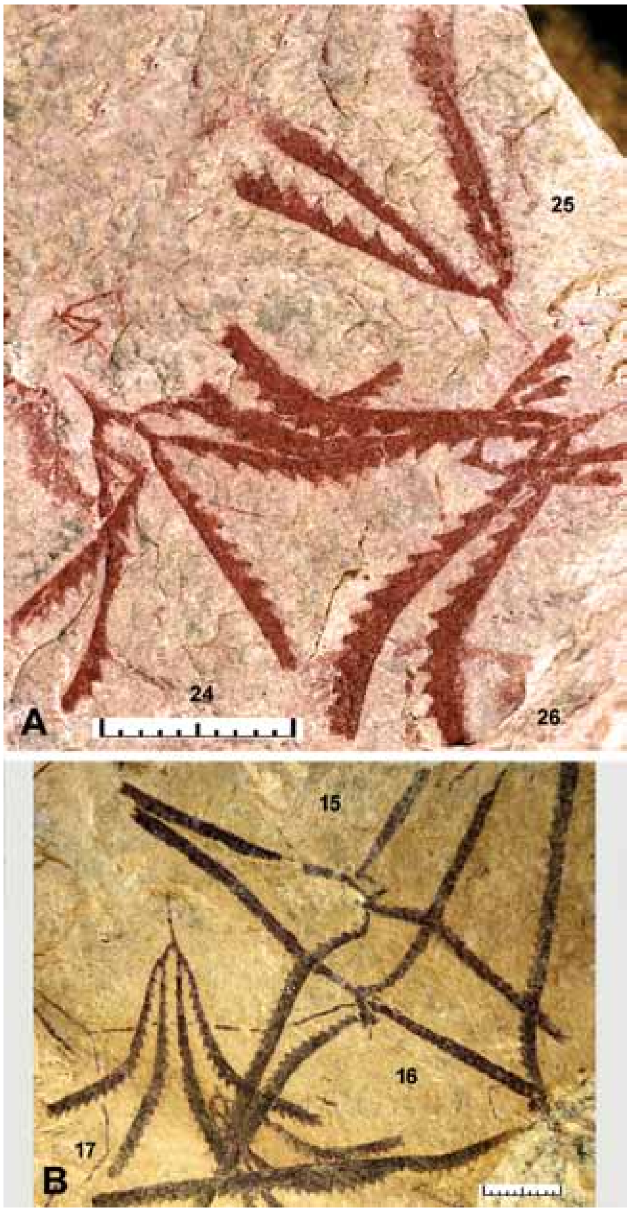


Figure 22: *Tshallograptus fruticosus*. **A**, early growth stage with long nema; fourth stipe is partly shown; NMV P332237; **B**, stipes are fully pendent, with no deflexed portion; P331882; **C**, tubarium showing variably thickened nema; the truncated stipe is thought to be due to predation; P332283. All are from PL 2017 (Be1).

fruticosus Biozone (VandenBerg & Cooper 1992) which in the Victorian succession is lowest in the stratigraphic range of the *T. fruticosus* clade. *T. fruticosus* is widely distributed in Victoria and its stratigraphic range encompasses the lowest three biozones of the Bendigonian (Figure 1). In many collections it is the most abundant species. *T. fruticosus* is one of the most widely distributed taxa in the world and its appearance is used to mark the base of the *T. fruticosus* Biozone.

Remarks. The Victorian material matches that from the Cow Head Group described by Williams and Stevens (1988), which is much better preserved and includes isolated 3D specimens. Because of its bell-like shape, the preservational aspect of *T. fruticosus* is quite variable, particularly of large tubaria (e.g. Figures 20, 21). However, its thecal shape and rapidly widening (to 3.0–4.0 mm wide) deflexed stipes make it distinctive (although in rare specimens the stipes are not deflexed; Figure 21B). The long nema, which in relatively early growth stages may be more than half the tubarium length (5–10 mm; Figures 19D, E, 21A, C), is also characteristic but may need careful preparation to reveal its full length. Thecae are long, with spacing ranging from 2½ to 3 in the first 5 mm and 7 in 10 mm distally.

Tshallograptus tridens sp. nov.
(Figures 2, 23, 24, 27L, 29B1)

pars 1858 *Graptolithus fruticosus*. J. Hall, p. 128.

pars 1865 *Graptolithus fruticosus*, Hall; J. Hall, pp. 90–91, pl. 6, fig. 3 only.

pars 1874 *Graptolites (Didymograptus) fruticosus* (Hall sp.); McCoy, pp. 13–14, pl. 1, fig. 13 only.

1874 *Didymograptus*? *fruticosus*, Hall. Etheridge, p. 8, pl. 3, fig. 19.

1902 *Tetragraptus fruticosus* (Hall); Elles & Wood, pp. 61–63, text-fig. 37, pl. 6, figs. 2a, b.

pars 1904 *Tetragraptus fruticosus* Hall sp.; Ruedemann, pl. 10, fig. 7 only.

pars 1904 *Tetragraptus fruticosus* var. *campanulatus*; Ruedemann, p. 652, pl. 10, figs 9, 10.

pars 1904 *Tetragraptus fruticosus* var. *tubiformis*; Ruedemann, pp. 652, pl. 10, fig. 2 only.

pars 1932 *Tetragraptus fruticosus* (J. Hall); Harris & Keble, pp. 32–33, 35–36, pl. 4, fig. 5 only.

pars 1935 *Tetragraptus fruticosus* (J. Hall); Benson & Keble, pp. 275–276, pl. 33, fig. 27 only.

pars 1938b *Tetragraptus fruticosus* (J. Hall); Harris & Thomas, pl. 1, fig. 19.

pars 1947 *Tetragraptus fruticosus* var. *tubiformis* Ruedemann; Ruedemann, pp. 304–305, pl. 51, fig. 28 only.

pars 1947 *Tetragraptus fruticosus* var. *campanulatus* Ruedemann; Ruedemann, pp. 304–305, pl. 51, figs 30, 31.

pars 1960 *Tetragraptus fruticosus* (Hall); Berry, pp. 54–55, pl. 6, fig. 7, pl. 8, fig. 3.

pars 1960a *Tetragraptus fruticosus*; Thomas, pl. 3, figs 27, 28a, b.

pars 1979a *Tetragraptus fruticosus* (J. Hall, 1858); Cooper, pp. 64–65, text-figs 32b, c, pl. 6, figs b, g.

pars 1982 *Tetragraptus (Pendeograptus) fruticosus* (J. Hall 1858); Cooper & Fortey, pp. 210–213, text-fig. 30c only, pl. 4, fig. 2.

pars 1983 *Tetragraptus fruticosus* (J. Hall 1858); Henderson, pp. 159, 161, figs 7C, F.

1983 *Tetragraptus (Pendeograptus) fruticosus*; VandenBerg & Stewart, text-fig. 2.

pars 1988 *Tetragraptus (Pendeograptus) fruticosus*; Cas & VandenBerg fig. 3.3l.

pars 1988 *Pendeograptus fruticosus* (J. Hall, 1858); Williams & Stevens, pp. 39–41, text-figures 27I, K, R, S, U, pl. 9, figures 3, 8–12; pl. 9, figure 13.

pars 1991 *Pendeograptus fruticosus* (J. Hall); Rickards & Chapman, pp. 63–65, text-fig. 91, pl. 16, figs a, c.

pars 1992 *Pendeograptus fruticosus*; VandenBerg & Cooper, text-fig. 4B.

2002 *Pendeograptus fruticosus* (J. Hall); Norford et al., pl. 4, fig. 4.

pars 2006 *Pendeograptus fruticosus* (J. Hall); Jackson & Lenz, fig 6h.

Etymology. From L. *tridens*= trident, three-tined fork.

Diagnosis. As *T. fruticosus* but tubarium composed of three stipes by suppression of branching of th2^1.

Type material. Holotype NMV P324168 from PL 2017 (Be1); paratypes P326839, from Bo75 (Be4), and P76752 and P76753 (same slab), Devilbend Quarry (Ch1).

Material and distribution. The distribution of *T. tridens* is similar to that of *T. fruticosus* but the stratigraphic distribution is different — in that it persists into the Chewtonian Ch1 *Didymograptellus kremastus* Biozone.

Discussion. Other than the number of stipes, *T. tridens* has the same biometric characteristics as *T. fruticosus*. In Victoria, *T. tridens* is so rare in the Be1 and Be2 interval that it is only represented in the largest collections, and only in the Be3 subzone does it become abundant. Most of the material in the MV collection is of early to medium growth stages but this is strongly biased by slab size which, in the cleaved rocks of the Castlemaine Group, is generally small. Stipe fragments of large dichograptids are usually not determinable to genus, let along species level. However, one slab in the collection shows a fragment of a tubarium whose stipes must have been at least 18 cm long (Figure 24). Large tubaria are also known from the Cow Head Group in Newfoundland, Canada (Williams & Stevens 1988, text-fig. 27R, S, U).

Tshallograptus cymulus sp. nov.
Figures 25A–H, 26

1988 *Pendeograptus* cf. *pendens* Williams & Stevens, pp. 38–39, text-figs 26A–M, pl. 7, figs 10–14, pl. 8, figs 3? 4? pl. 9, figs 6, 7.

Etymology. From L. *cymula* = small young shoot, an indirect reference to its larger descendant *fruticosus* (L. = bushy).

Type material. Holotype NMV P332154, from Blackwood (La3); paratypes P330713, P330704, from the same locality; P331888, from S53.

Diagnosis. Small tubarium with four, less commonly three pendent stipes that widen from 0.7–0.8 mm wide proximally to a maximum width of 1.3 mm; sicula long

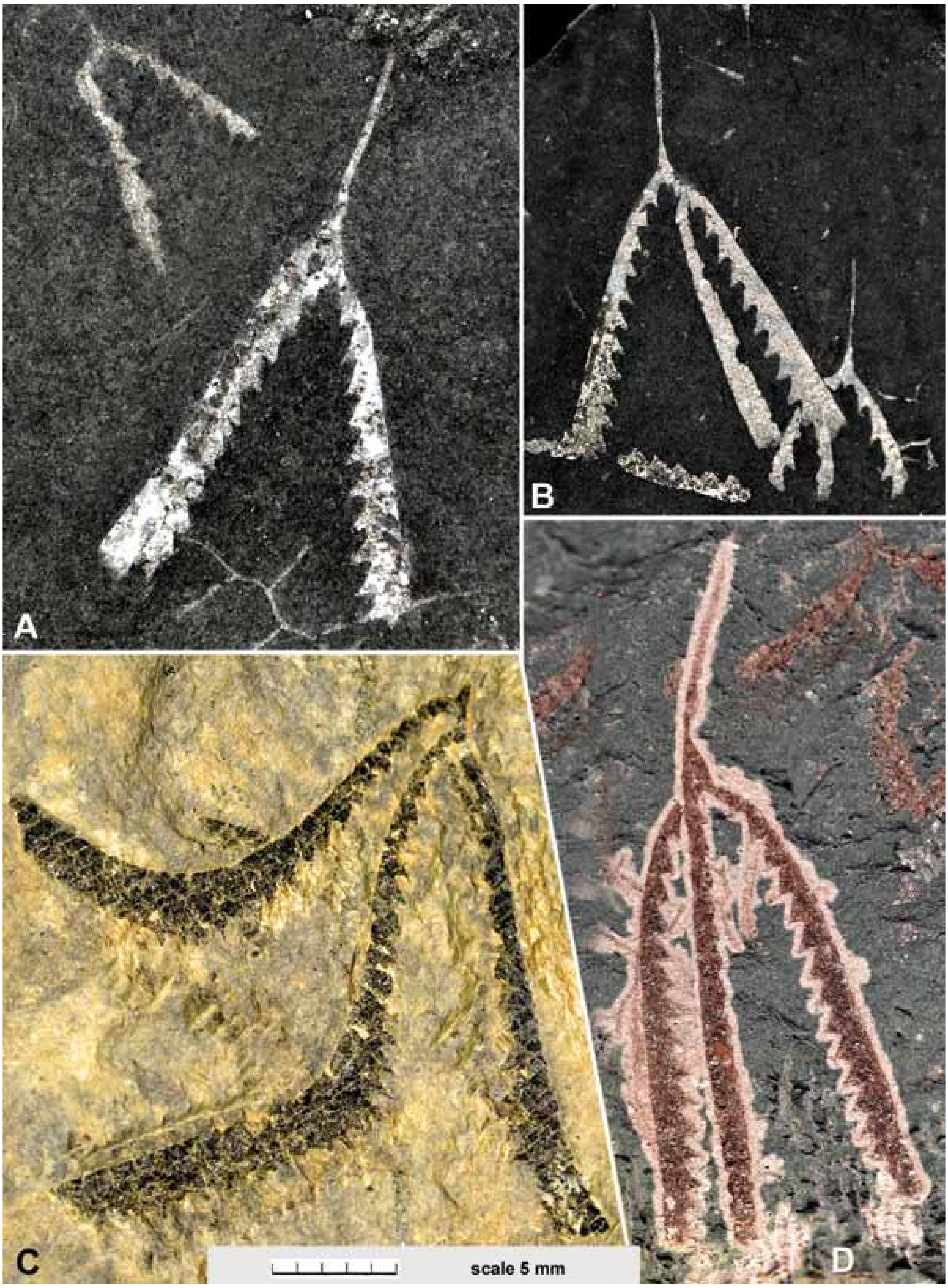


Figure 23: *Tshallograptus tridens*. **A, B** and **D** are early growth stages with fully pendent stipes preserved in lateral and dorsoventral aspects and with prominent nematularia; **C** is a later growth stage with deflexed stipes. **A**: NMV P325833 (with *Didymograptellus kremastus* VandenBerg, P325832); **B**: P76752 (left) and P76753; **C**: P326839; **D**: P326886. **A** and **B**: Devilbend Quarry (Ch1); **C**: Bo75, Be4; **D**: Bo177, Be4.

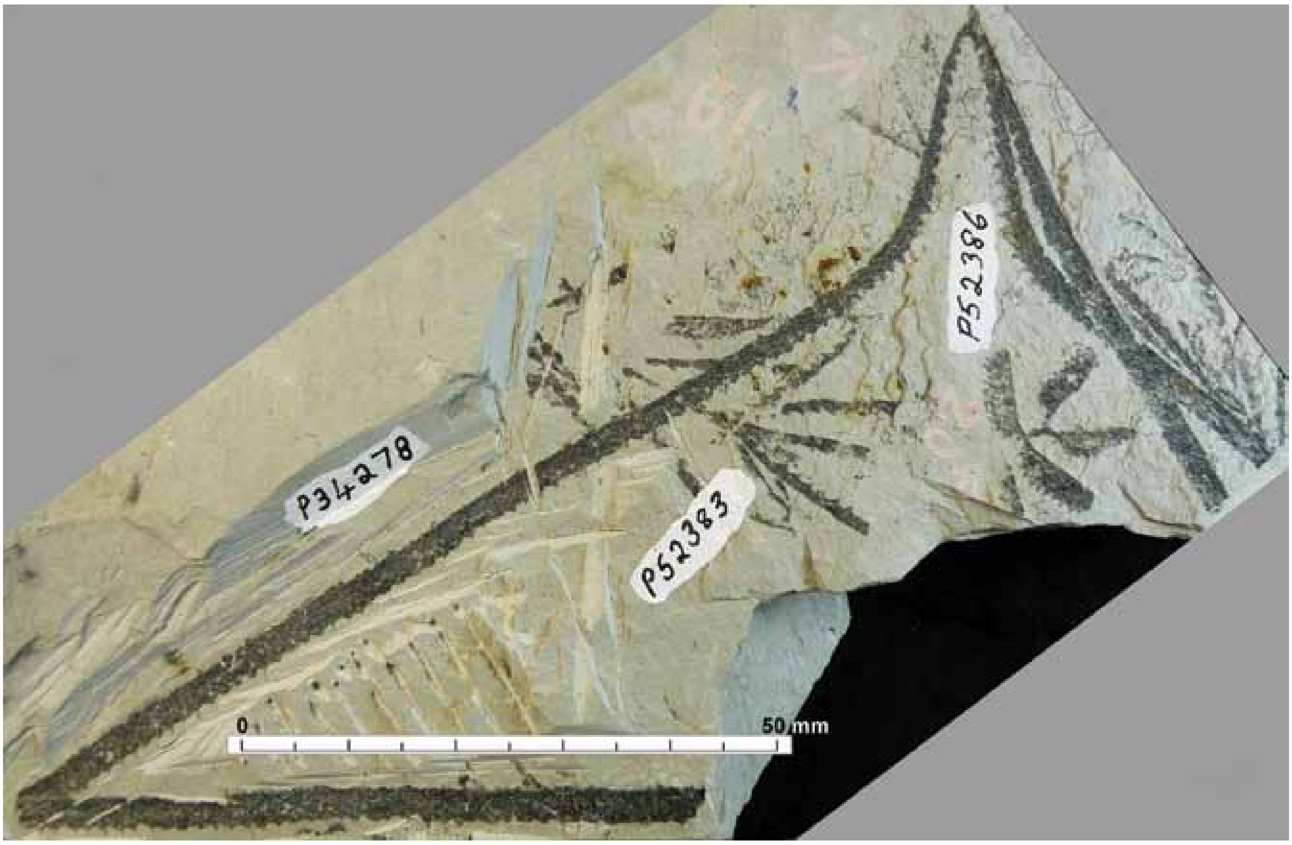


Figure 24: The largest specimen of *Tshallograptus tridens* in the NMV collection. As in other large dichograptids, the maximum size is almost always determined by the size of the slab it is preserved on. In this case, the fortuitous kink in the longer stipe of NMV P34278 means that its preserved length is considerably more than the size of the slab, and that it must have been more than 18 cm long and quite rigid. Two other specimens are of early growth stages of *T. tridens* (P52383) and *Tetragraptus serra* (Brongniart, 1828) (P52386). There is no record of the locality this slab came from.

and slender, ca 0.4–0.5 mm wide at aperture which bears a small rutellum; thecae long, with spacing of 3 to 4½ in 5 mm proximally, 4½ to 5 distally; nema short, slender.

Material and distribution. Twenty-two measured and a smaller number of additional poorly preserved specimens, from Blackwood and S53 (both La3), and from Molloy's (Be1).

Description. None of the specimens are preserved sufficiently well to show details of the proximal structure. The sicula is approximately 3.5 mm long, with a rutellum 0.25 mm long at its aperture. A thin nema is up to 2 mm long; in one exceptional case it is 3.2 mm long and somewhat thicker (P330713A; Figures 25E, 26G). Thecae have ventrally curved free ventral walls and apertural margins so that their tips are acute. Free ventral walls of distal thecae are inclined at ca 45° although in most specimens the stipes are not preserved in true profile view so that the angle appears less. Thecal spacing is 3 to 4½ in 5 mm proximally, 4½ to 5 distally, although very few tubaria have stipes long enough for this to be measured—the longest stipe in the collection is 9.8 mm long.

Remarks. Earlier Victorian workers mistook *T. cymulus* for *T. fruticosus* and similarities include the pendent habit, shape of the thecae, and long sicula. However, *T. cymulus* is altogether smaller, with a maximum stipe width of 1.3 mm; in *T. fruticosus*, this width is usually reached at th4 in stipes whose width increases steadily to a maximum of 3–4 mm. Thecae in *T. cymulus* are more closely spaced at an average of 4 in 5 mm, versus 2.5–3 in the first 5 mm in *T. fruticosus*. Thecae also have more steeply inclined free ventral walls, and the nema is much shorter (Figures 25A, C, E–G). I therefore regard *T. cymulus* as distinct from *T. fruticosus* and probably its direct ancestor.

Specimens illustrated as *Pendeograptus* cf. *pendens* (Elles, 1898) by Williams & Stevens (1988) are very similar to *T. cymulus*, and occur at a similar biostratigraphic level, although in Victoria *T. cymulus* ranges to a slightly higher level. I regard them as conspecific with *T. cymulus.* However, I disagree with these authors' opinion that the Victorian specimens illustrated as *P. pendens* (e.g. by Harris & Thomas 1938a) belong to their *P.* cf. *pendens* (and hence are conspecific with *T. cymulus*) — thecae of *P. pendens* have attenuated wall material, a character not seen in *T. cymulus* (and not visible in drawings).

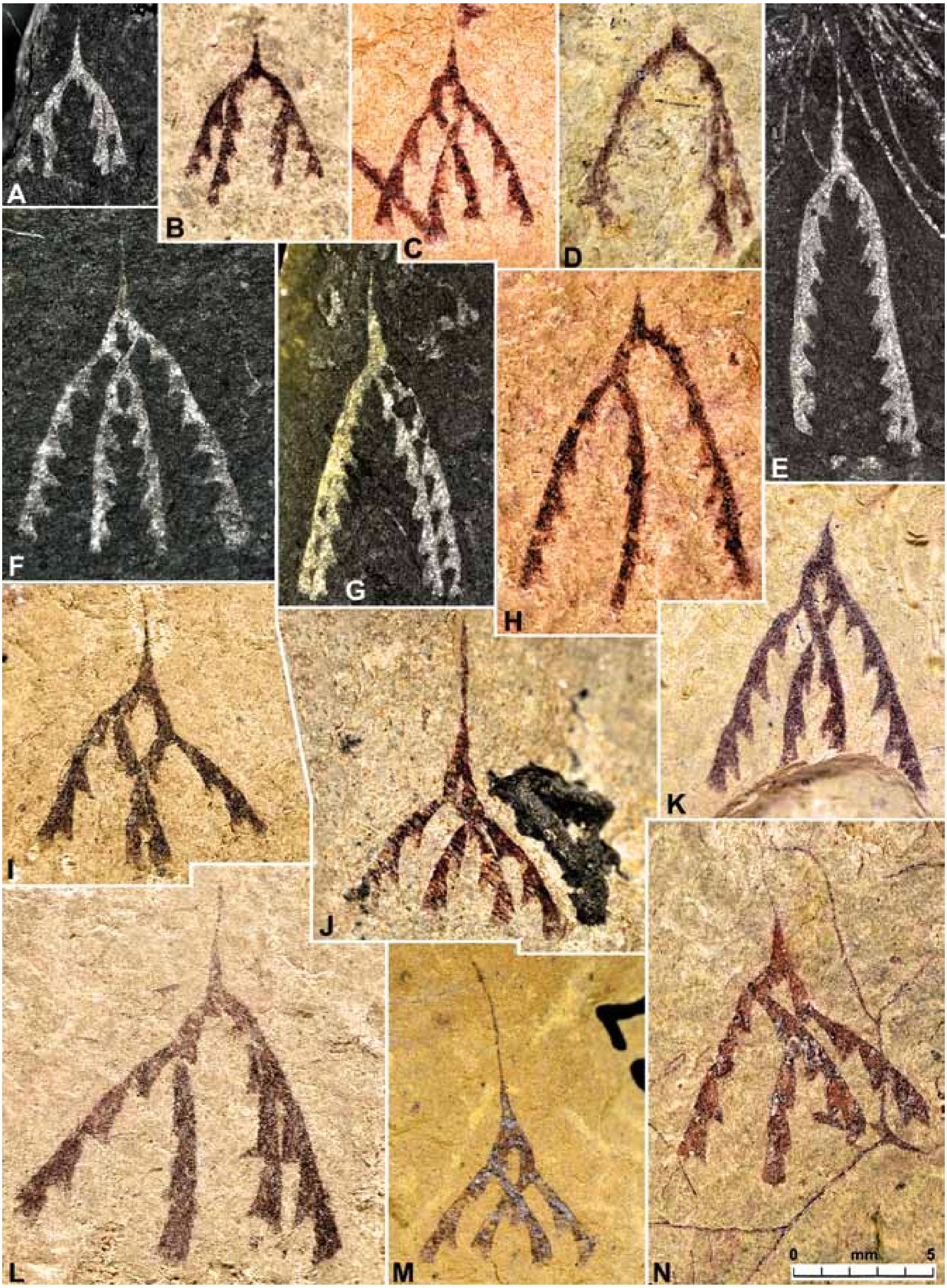


Figure 25: Tubaria of *Tshallograptus cymulus* (**A–H**) and *T. fruticosus* (**I–N**). The latter are early growth stages shown for comparison. **A**: NMV P332154; **B**: P332016; **C**: P331891; **D**: P331884; **E**: P330713A; **F**: P330704; **G**: P332182; **H**: P331888; **I**: P332434; **J**: P327539; **K**: P331938; **L**: P332326; **M**: P331527; **N**: P332403 (also shows proximal area of *Kinnegraptus sedecimus* (Harris & Thomas, 1938a), P332402). **A, E–G**: Blackwood (La3); **B**: 18B (Be1); **C, D, H, J, K**: S53 (La3); **I, L–N**: PL 2017 (Be1).

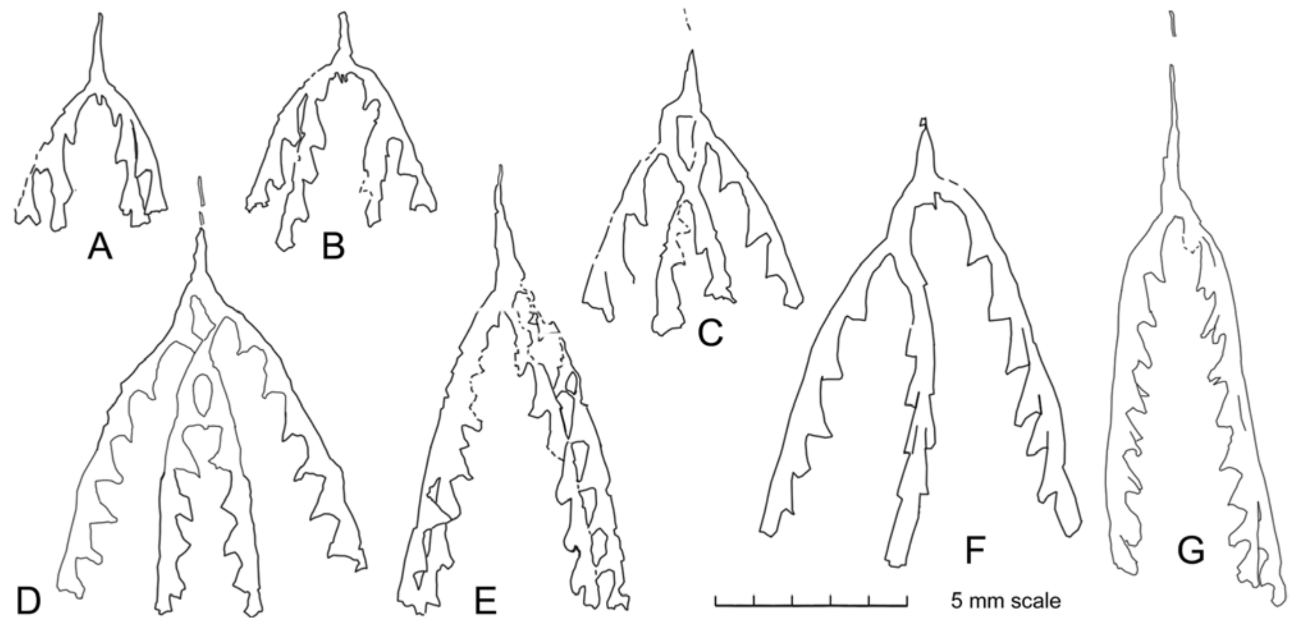


Figure 26: *Tshallograptus cymulus* tubaria arranged approximately in order of growth stage. Note that F is a 3-stiped morph; in **G**, stipes overlap almost perfectly but the lower stipes are shown up by the multiple thecal apertures. **A**: NMV P332154; **B**: P332016; **C**: P331891; **D**: P330704; **E**: P332182; **F**: P331888; **G**: P330713A. **A, E–G**: Blackwood (La3); **B**: 18B (Be1); **C, F**: S53 (La3).

Tshallograptus furcillatus sp. nov.
(Figures 27, 28)

?*pars* 2002 *Didymograptus* cf. *bidens*; Mu et al., pp. 234, pl. 73, fig. 10 (*non* pl. 72, fig. 12).

Etymology: From the Latin *furcillatus*, forked.

Type material. Holotype NMV P318296, from Devilbend; paratypes NMV P320950, P321190 and P321095, from loc. SCR.

Diagnosis: *Tshallograptus* with medium-sized tubarium, large sicula bearing a slender nema, two almost straight declined stipes with slender proximal thecae widening rapidly to a maximum width of ca 2 mm.

Material and distribution. The holotype and three other specimens from the Devilbend Quarry show no tectonic deformation. Several dozen specimens from loc. SCR all show significant tectonic distortion. All are from Be4 (*T. tridens* Biozone).

Description. The sicula is large, 1.8–2.2 mm long, approx. 0.4 mm wide at aperture, bearing a short rutellum and a slender nema up to 3 mm long. Stipes widen rapidly from 0.6–0.7 mm at th1^1 to 1.0–1.2 mm at th5^1, after which they are almost parallel-sided. The tubarium is of moderate size, with the largest having stipes approximately 20 mm long. Stipes have very gentle dorsal curvature, some are straight; angle of divergence is 30º–45º in undistorted specimens. Ventral margins of proximal thecae have ventral curvature with flaring apertures, more distal thecae have almost straight ventral walls. Apertures are inwardly inclined giving a denticulate appearance to the ventral margin. The first few thecae are considerably longer than those of the remainder of the stipes, and this is reflected by the thecal spacing which, unusual for dichograptids, increases from 4.5 proximally to 5.5 in 5 mm distally in the only specimen without tectonic distortion large enough for this to be measured. The same trend, however, is shown in distorted specimens, where distal spacing is slightly closer than in the first 5 mm. Most specimens show growing tips 2–4 thecae long.

Remarks. The relatively narrow and nearly straight stipes set *P. furcillatus* apart from other species of *Tshallograptus*. While it is unfortunate that the population from Devilbend Quarry, where tectonic deformation is absent, is so small and represented by relatively early growth stages, the characters of the proximal region are sufficiently well shown in the deformed SCR specimens to link the two populations. This is strengthened when the SCR specimens are retro-deformed (Figure 28).

Pendeograptus Bouček & Přibyl, 1952

Type species. *Tetragraptus pendens* Elles, 1898, designated Bouček & Přibyl (1952, p. 12).

Amended diagnosis. Small tetragraptid with slender pendent stipes; sicula long and conspicuous, thecae long, slender.

Discussion. Previous diagnoses of *Pendeograptus* gave undue emphasis to the biometric characters of *Tshallograptus fruticosus* (Cooper & Fortey 1982; Williams & Stevens 1988). With this species and its relatives removed from *Pendeograptus*, the amended diagnosis is mostly that of the type species, *P. pendens*, given in Williams & Stevens (1988, p. 38).

Pendeograptus pendens (Elles, 1898)
Figure 29

1898 *Tetragraptus pendens*, sp. nov.; Elles, pp. 491–492, fig. 13.

pars 1902 *Tetragraptus pendens* Elles; Elles & Wood, pp. 63–64, pl. 6, figs 3a–c (*non* fig. 3d & text-fig. 38).

1904 *Tetragraptus pendens* Elles; Ruedemann, pp. 653–655, text-fig. 55, pl. 2, figs 17–20.

1935 *Tetragraptus pendens* Elles, 1898; Benson & Keble, pp. 276–277, pl. 33, fig. 26.

1938a *Tetragraptus pendens* Elles; Harris & Thomas, p. 74, pl. 1, figs 13a–d, pl. 4, fig. 12.

1960 *Tetragraptus pendens* Elles; Berry, p. 55, pl. 7, fig. 7.

1976 *Tetragraptus pendens* Elles, 1898; Legg, p. 26, pl. 8, fig. 30.

1979a *Tetragraptus pendens* Elles, 1898; Cooper, p. 65, text-fig. 34b, pl. 6, fig. f.

1979a *Tetragraptus* cf. *pendens* Elles, 1898; Cooper, p. 66, text-fig. 34a, pl. 6, fig. c.

1983 *Tetragraptus pendens* Elles 1898; Henderson, p. 161, figs 8E, F.

1988 *Tetragraptus (P.) pendens*; Cas & VandenBerg, fig. 3.3n.

1988 *Pendeograptus pendens* (Elles, 1898); Williams & Stevens, p. 38, pl. 6, fig. 4.

1991 *Pendeograptus pendens* Elles; Rickards & Chapman, pp. 59, 61, text-figs 92, 96, pl. 15, figs c–e.

1992 *Pendeograptus pendens*; VandenBerg & Cooper 1992, fig. 4E.

2002 *Pendeograptus pendens* (Elles); Mu et al., p. 201, pl. 59, fig. 7, pl. 60, fig. 6.

2006 *Pendeograptus pendens* (Elles); Jackson & Lenz, figs 6a–c.

Type material. Lectotype NHMUK PM Q37, selected by Williams & Stevens (1988, p. 38), Skiddaw Slates, Loweswater Formation, Barf, England.

Diagnosis. Tubarium small, with slender pendent stipes a uniform 0.5–0.6 mm wide; sicula long and conspicuous, thecae long, slender, with thin walls, gently inclined, numbering 9–12 in 10 mm (from Williams & Stevens 1988, p. 38).

Material and distribution. Several dozen measured specimens from Be4 and Ch1 localities. It is uncommon, with a considerable biostratigraphic range in Victoria, ranging from Be1 to Ch1, i.e. through most of the Floian.

Discussion. The illustrations and revised diagnosis of *P. pendens* are included to emphasise the differences between it and the new genus *Tshallograptus*, which was formerly included in *Pendeograptus*. The long sicula, slender stipes and thin wall material make this species distinctive. It has been identified from North America, New Zealand, Victoria, Western Australia and Queensland. The Victorian material shows a greater range in biometric characters than the type material, probably because of tectonic distortion.

The biostratigraphic range recorded here is somewhat longer than that indicated by some earlier authors — Rickards and Chapman (1991) showed it ranging from Be2 to Be4 whereas Thomas (1960a) gave it a slightly longer range, from Be1 to Ch1 and VandenBerg and Cooper (1992) showed it ranging to Ch2. The long range may resolve a problem that Williams and Stevens (1988) perceived. They redescribed the type specimen, for which they estimated a 'middle Arenig' age. They suggested that specimens referred to *P. pendens* from North America, China, Australia and New Zealand (see synonymy list) could not belong to *P. pendens* because they came from older rocks, mainly 'early Arenig'. However, the upper end of its Victorian range is 'middle Arenig', correlating with the base of the British *Expansograptus simulans* Biozone.

Family **PTEROGRAPTIDAE** Mu, 1974

Diagnosis. Two-stiped, pendent to deflexed and horizontal graptoloids; cladial branching in some taxa form secondarily multiramous tubaria; sicula conical, widening distinctly towards the aperture and with small prosicula, or parallel-sided with wide prosicula; sicula with distinct dorsal virgellar spine and antivirgellar origin of $th1^1$; thecae simple, widening tubes with moderate development of rutella; proximal development isograptid or artus type, dextral (from Maletz et al., in prep.).

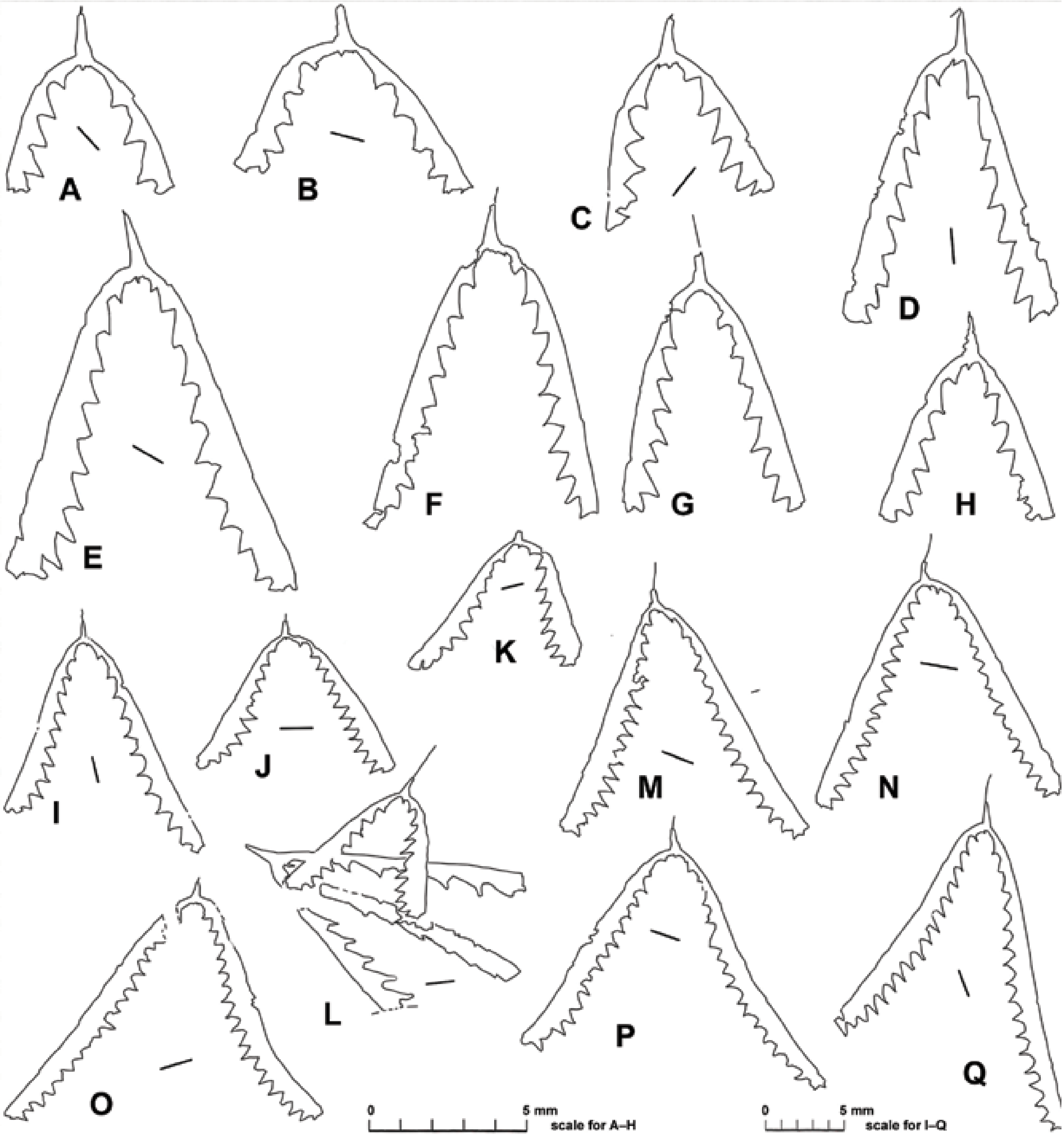
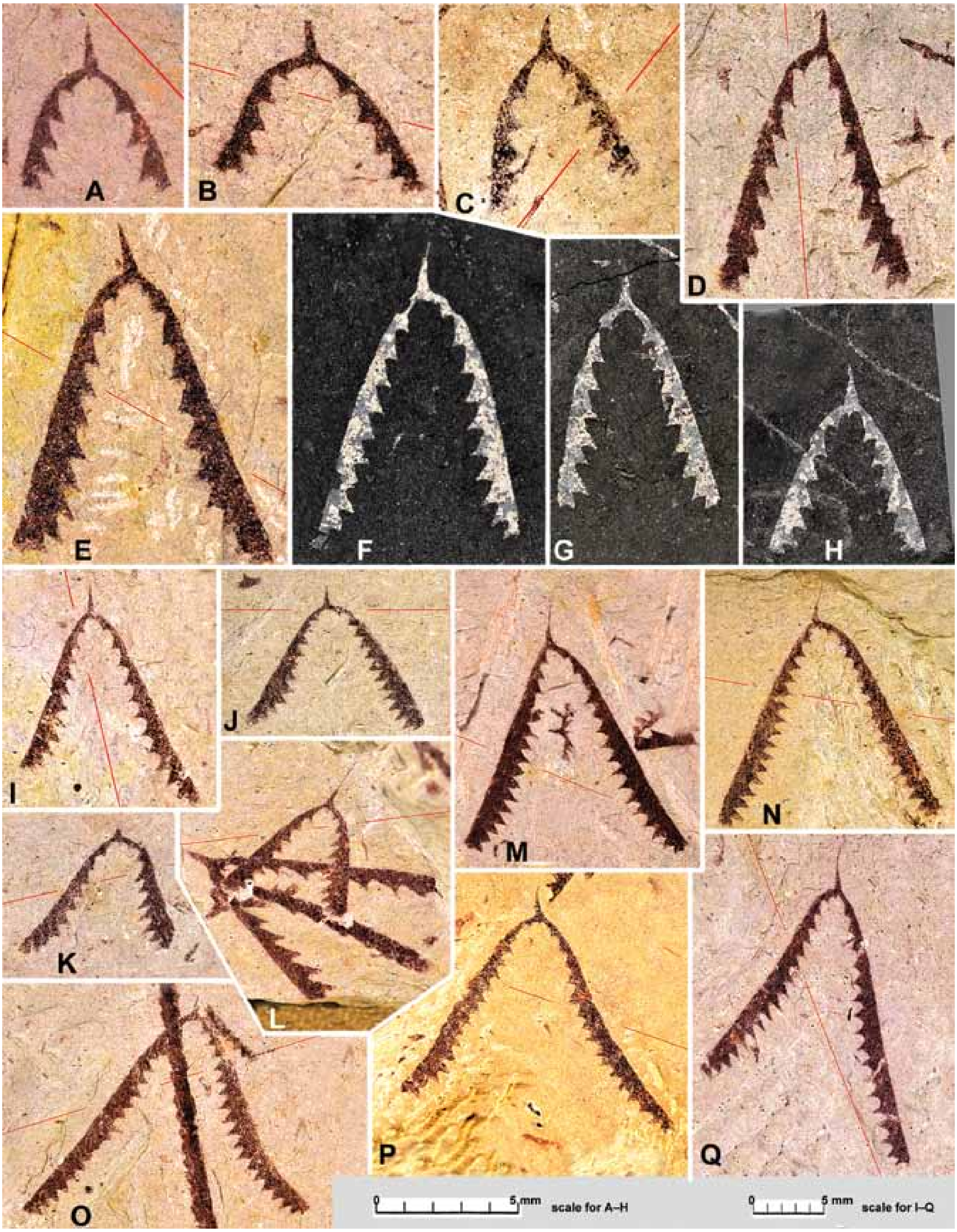


Figure 27: Drawings (above) and photos (opposite page) of *Tshallograptus furcillatus*. Images are arranged in approximate order of growth stage. **A–E, I–Q** are from SCR and show considerable tectonic distortion; red lines (bars in drawn figures) are drawn along the cleavage trace. **F–H** are from Devilbend Quarry and are flattened but not distorted. **A**: NMV P321099A; **B**: P321100: **C**: P321050; **D**: P332761; **E**: P320950; **F**: P318409; **G**: P318429; **H**: P318296B; **I**: P321097; **J**: P321106; **K**: P321107; **L**: P321104; P332762 (*Tshallograptus tridens*); **M**: P321192 (with P321191, early growth stage of the sigmagraptid "*Tetragraptus*" *taraxacum* Ruedemann); **N**: P321096; **O**: P321105; **P**: P320968; **Q**: P321095.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0 5 mm scale for A–H
0 5 mm scale for I–Q

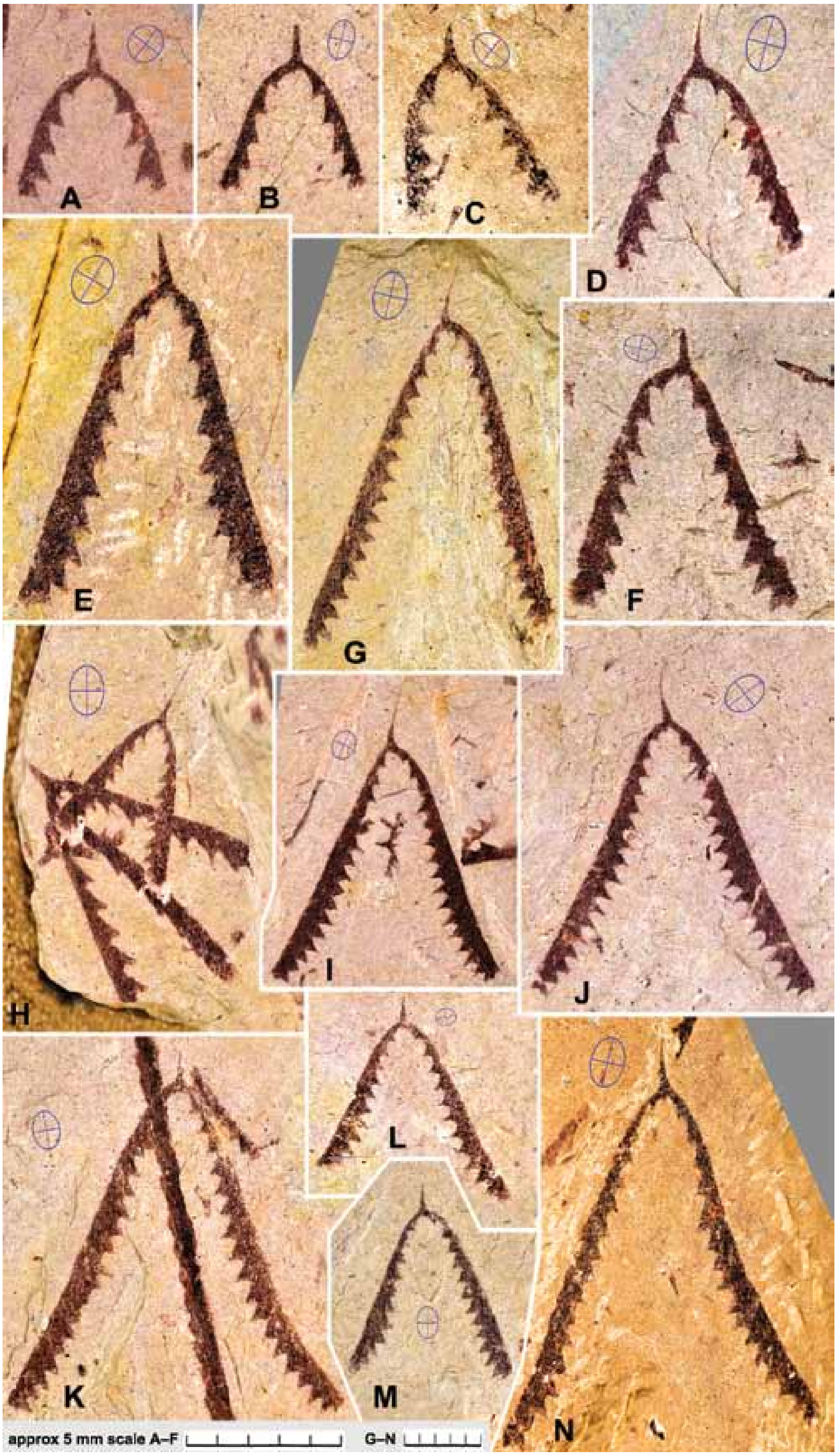

Figure 28: *Tshallograptus furcillatus*. Tectonically deformed specimens from the SCR locality shown in Figure 27 have been retro-deformed by simple shortening of the image parallel to the cleavage trace, and lengthening it in the opposite direction. The amount and direction of retro-deformation are indicated by the strain ellipses. Scales are approximate only. **A**: NMV P321099A; **B**: P321100; **C**: P321050; **D**: P332761; **E**: P320950; **F**: P332761; **G**: P321096; **H**: P321104; P332762 (*Tshallograptus fruticosus*); **I**: P321192 (with P321191, early growth stage of "*Tetragraptus*" *taraxacum*); **J**: P321095; **K**: P321105; **L**: P321097; **M**: P321106; **N**: P320968.

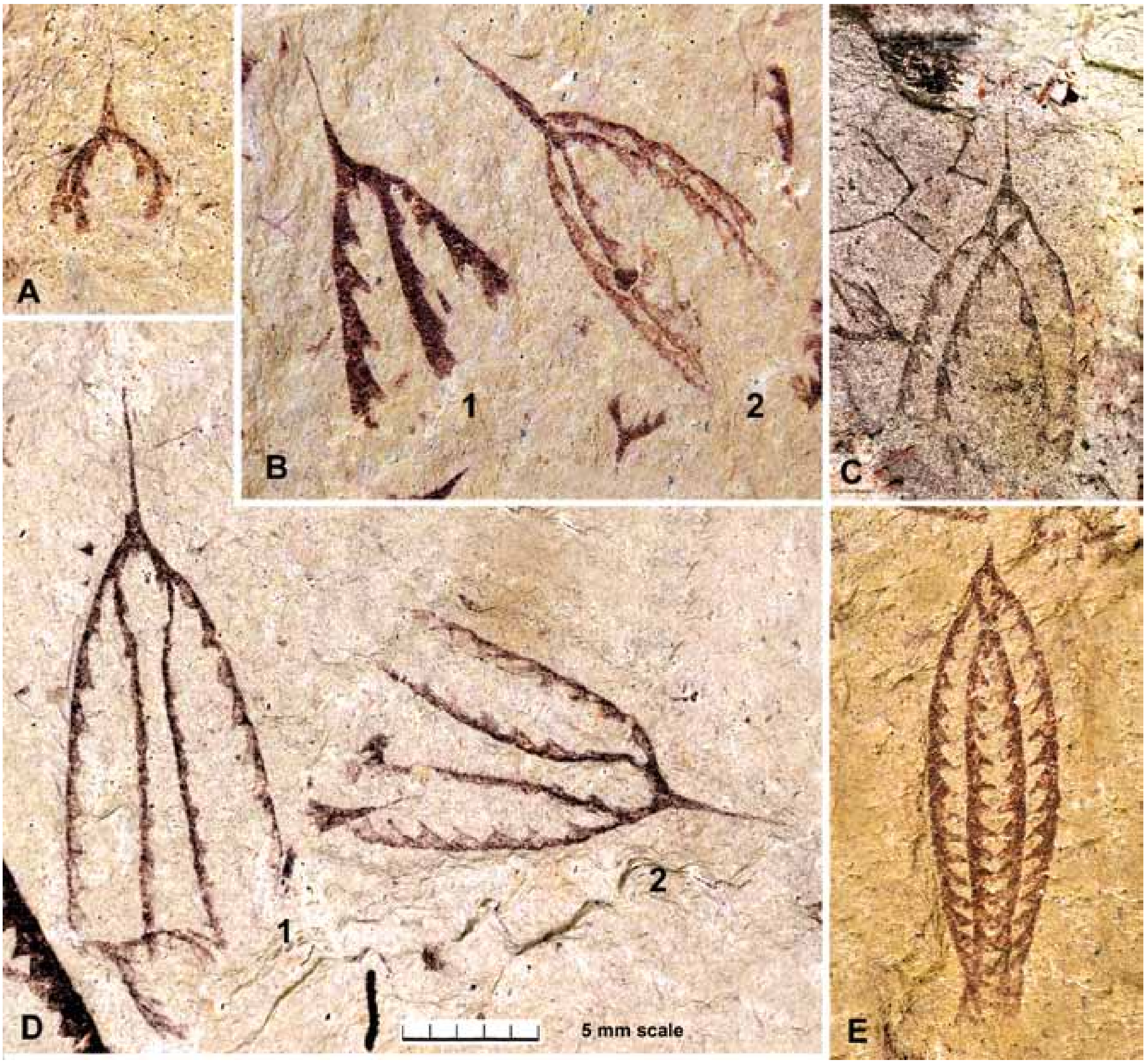

Figure 29: *Pendeograptus pendens* (Elles, 1898) — specimens showing the attenuated thecal walls typical of Victorian specimens. **A**: early growth stage in full profile view. **B1**: early growth stage of *Tshallograptus tridens*; **B2**: *P. pendens* in lateral view so that the first two stipes overlap and appear as an extension of the sicula. Note the difference in appearance of the 'normal' thick-walled thecae of *T. tridens* and the thin walls of *P. pendens*. **C, D**: medium growth stages preserved in semiprofile view. **E**: mature tubarium with stipes mostly in full profile view. **A**: P324363; **B1**: P318141; **B2**: P318142; **C**: P326288; **D1**: P321164, **D2**: P321163; **E**: P13067; **A, B, D**: SCR (Be4); **C**: Diamond Hill, Ch1; **E**: "Campbelltown".

Pseudobryograptus Mu, 1957

Type species. *Pseudobryograptus parallelus* Mu, 1957 (OD).

Holotype. NIGP 8863, Changshan, western Chekiang, China (OD).

Diagnosis. Small, pendent tubarium with 5–8 stipes; thecae simple with low inclination and overlap; branching after the initial dichotomy is by cladia generation (?); proximal development probably of artus type. (from Maletz et al., in prep.).

Pseudobryograptus crassus (Harris & Thomas, 1938)
Figure 30

pars 1938a *Bryograptus crassus*, sp. nov.; Harris & Thomas, pp. 72–73, pl. 1, figs 7a–c (*non* d = *T. fruticosus*); pl. 4, fig. 6.

1938b *Bryograptus crassus* H. and T.; Harris & Thomas, pl. 1, fig. 24.

pars 1960a *Bryograptus crassus*; Thomas, pl. 2, fig. 16a (*non* b = *T. fruticosus*).

?1960 *Bryograptus crassus* Harris & Thomas?; Berry, p. 47, pl. 5, fig. 9.

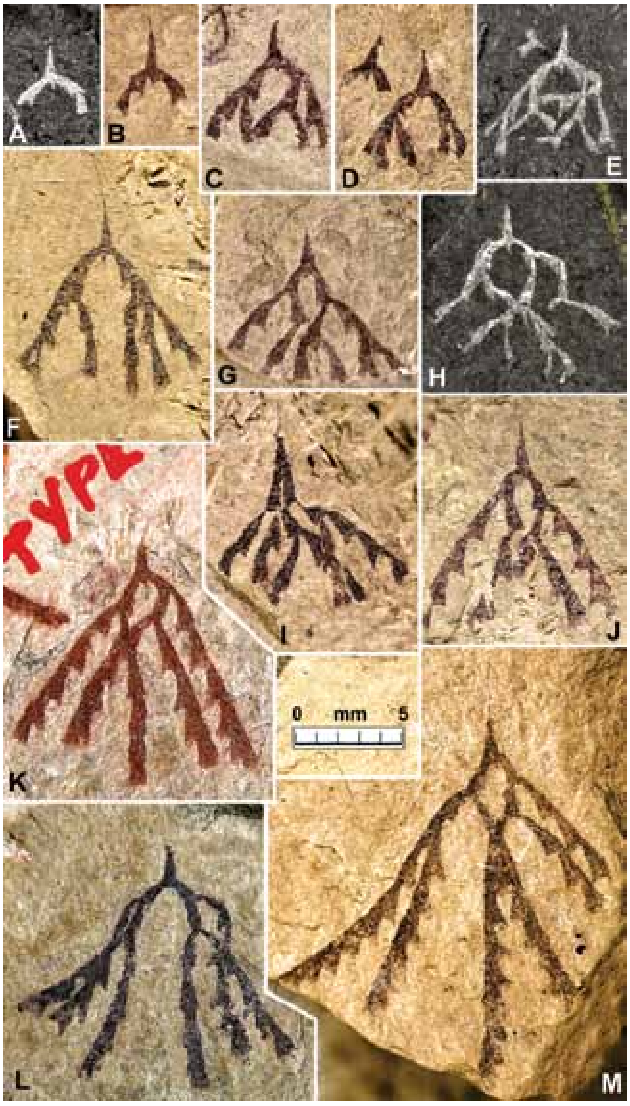

Figure 30: *Pseudobryograptus crassus* (Harris & Thomas, 1938a). Photos are arranged in approximate growth order. **A**: NMV P330693B; **B**: P324128; **C**: P331553; **D**: P332213 (larger); **E**: P330696; **F**: P323433; **G**: P327518; **H**: P330703; **I**: P324024; **J**: 332409; **K**: P32009 (holotype); **L**: P34874; **M**: P323966. **A, E, H** are from Blackwood (La3), all others are from the parish of Campbelltown: **B–D, F, I–M** are from PL 2017 (Be1), **G** is from S13 (Be1).

1991 *Pseudobryograptus crassus* (Harris and Thomas); Rickards & Chapman, pp. 65–67, text-figures 94, 95, pl. 17, figures a, b.

Type material. Holotype NMV P32009 (GSV 41365); paratypes P34974, P32047.

Diagnosis. Small tubarium with large sicula and slender stipes; two orders of monoprogressive branching gives rise to 5–8 ternary branches. Thecae large, with spacing of 2⅓–3½ in 5 mm proximally, 4–4½ distally.

Material and distribution. Sixteen measured specimens, mostly from PL 2017, one specimen from S13 (both Be1), and three from Blackwood (La3). *Pseudobryograptus crassus* is rare, only occurring in these three localities, and restricted to the La3–Be1 interval. It has only been reported from Victoria—the illustration of a specimen from west Texas questionably referred to *P. crassus* by Berry (1960) is very poor and the specimen is dissimilar to the Victorian specimens.

Description. The sicula is large and straight, 2.3–2.6 (outliers to 1.8 and 2.8) mm long, furnished with a prominent rutellum. The aperture is poorly defined and is approximately 0.4–0.5 mm wide. A very slender nema, up to 2.5 mm long, is present in most specimens. Three orders of monoprogressive branching occur, but the third order may be present in only one, two, three or all four second-order stipes, thus resulting in between 5 and 8 terminal branches; 6 terminal branches are most common. Proximal thecae are long, with a spacing of 2⅓ to 3½ in 5 mm. Unusually for dichograptids, distal thecae are smaller and more closely spaced, at 4–4½ per 5 mm. However, this is based on a sample size of one, there being only one specimen (Figure 30M) in the entire Museums Victoria collection with stipes longer than 10 mm that is sufficiently well preserved to give a reliable thecal count. In this largest specimen, stipes are > 14 mm long (the tubarium is larger than the slab). Stipes are slender and only show very slight widening, from 0.9–1.1 mm at th1 to a maximum of 1.5 mm distally.

Remarks. In their original description, Harris and Thomas (1938a) included a specimen subsequently placed in *T. fruticosus* and this seems to have skewed the view of these authors that, apart from the more abundant stipes, *Pseudobryograptus crassus* is very similar to *T. fruticosus*. This error was pointed out by Rickards and Chapman (1991) who remarked on the significantly more slender stipes of *Pseudobryograptus crassus*. A puzzling observation made by the latter authors is that *Pseudobryograptus crassus* is more declined than pendent and that this explains the frequency with which *Pseudobryograptus crassus* occurs in plan view. Rickards and Chapman did not illustrate any such specimen, and I have not seen a single specimen in the Museums Victoria collection preserved in plan view—thus the term pendent is apt. A more important point not mentioned by any of these earlier authors is the variation in branching pattern.

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APPENDIX 1: ZONE SYMBOLS

For purely practical reasons, the graptolite zones are given 3-symbol codes consisting of the two initial letters of the stage name plus a numeral indicating its level within the stage (e.g. Be1 for the lowest zone in the Bendigonian) (VandenBerg & Cooper 1992). The practice grew out of the need to indicate the age of a great many localities crowded together on geological maps (e.g. Figure 31). One benefit is that, while the names of zone index fossils have changed, there has been no need to change the shorthand labels—making it easy to read the ages of localities on maps published over half a century ago.

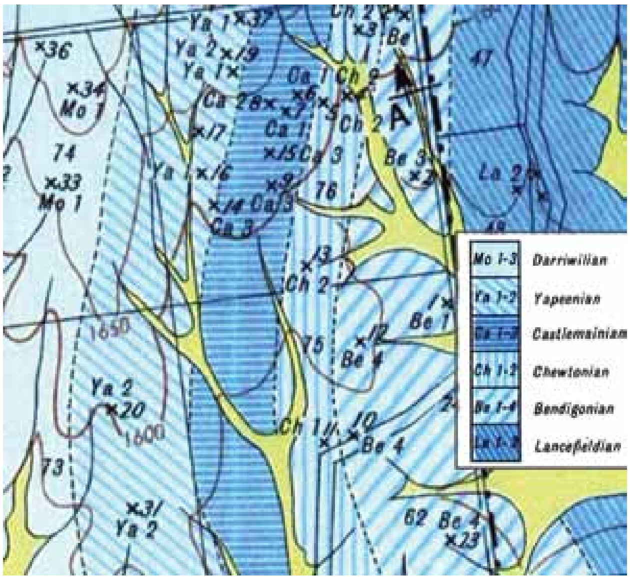

Figure 31: Small portion of the Lancefield geological map showing graptolite stages with localities and their zonal notation. From Thomas (1960b). At the time of printing, the lettercode Mo was used to denote Darriwilian.

APPENDIX 2: LOCALITY DETAILS

Bull Dog Creek	Be1	near Merricks North, Mornington Peninsula	38°20’6.25”S, 145°3’42.4”E
Blackwood	La3	antimony mine near Blackwood	37°25’56.3”S, 144°20’3.6”E
PL 2017	Be1	S16, ‘Good bed’, ph. of Campbelltown	37°13’57.28S 144°02’22.80”E
S13	Be1	Oliver’s common	
S16A	La3 or Be1	Molloy’s, Allotment 11 parish of Sandon	
S50	La3	?allotment 25B Section III, parish of Sandon	
S53	La3	North of Providence Gully, parish of Sandon	
18B	Be1	near E boundary of allotment 18B, parish of Campbelltown	
16Bo	Be4	GSV locality 16Bo, Bendigo	36°44’53.24”S 144°16’9.17”E
75Bo	Be4	GSV locality 75Bo, Bendigo	
177Bo	Be4	GSV locality 177Bo, Bendigo	36°46’53.02”S 144°16’09”E
B351	Be–Ch	GSV locality 351, Bendigo	36°45’13.66”S 144°14’59.26E
“Bendigo”	Be–Ch	locality details unknown, Bendigo area	
Mt Carmel 10	Be–Ch	GSV loc. 10, Mt Carmel near Heathcote	
SCR	Be4	Spring Creek Reservoir, Bendigo	36°48’26.37”S, 144°16’56.35”E
S103	Be2	parish of Campbelltown	
Diamond Hill	Ch1	Diamond Hill, Bendigo	36°48’15” S, 144°15’55”E