Graptolites at and below the Ordovician–Silurian boundary on Anticosti Island, Canada

J. Riva

Department of Geology, Laval University, Ste Foy, Québec, Canada, G1K 7P4

Synopsis

Graptolites in the lower and middle Vauréal Formation of Anticosti Island, Canada, form a discrete assemblage renamed the *Amplexograptus prominens* Zone, characterized by *Amplexograptus latus*, *Rectograptus abbreviatus*, *Amplexograptus prominens* and *Paraclimacograptus decipiens* sp. nov.: these suggest correlation with the *Dicellograptus anceps* Zone of Scotland, the *Climacograptus pacificus* Zone of north-eastern Siberia and Kazakhstan, and the Wufeng Shale of Central china. Graptolites are rare in the upper Vauréal Formation. A few have been collected from the upper members of the Ellis Bay Formation and the lower members of the Becscie Formation, but not in sufficient numbers to form a zonal assemblage. Most of them belong to the *normalis* group for which the new genus *Scalarigraptus* is proposed. The most common graptolite is *Scalarigraptus angustus*, which is known to range through the upper Ashgill and the lower Llandovery Series. Two fragmentary specimens identified as *Rectograptus abbreviatus* have been collected from the top (Member 6) of the Ellis Bay Formation. This species is only known from the Upper Ordovician and may be taken to indicate that the top members (6 and 7) of the formation belong to the Ordovician System.

Introduction

In an earlier paper Riva (Riva & Petryk 1981) reviewed and updated the work done by previous workers on graptolites from the Island of Anticosti, either as part of a general palaeontological study (Twenhofel 1928) or as detailed morphological studies of isolated graptolites (Barrass 1953; Strachan 1954). It also updated the study of subsurface collections which had been extracted by Riva (1969) from three drill cores during the summers of 1964 and 1965, and presented an evaluation of 33 new collections made by A. A. Petryk from 1975 to 1979 from the upper Vauréal to the Jupiter Formations. An accompanying range chart showed the stratigraphical position of all graptolites hitherto identified from surface collections. This chart will undergo further revisions and refinements as new morphological studies and revisions of type collections are made known. Part of this work is incorporated into this paper together with data on new collections made by Petryk from 1981 to 1983.

This paper is primarily concerned with the graptolites collected at or just above or below the Ordovician–Silurian boundary now located at the Ellis Bay–Becscie formational contact (Fig. 1) (Lespérance 1985). It also re-evaluates the fauna of the *Amplexograptus prominens* Zone of the lower and mid-Vauréal Formation and correlates it with the zonal successions of Scotland, the U.S.S.R., China and Australia. Figure 1 shows the range of all graptolites hitherto identified from the mid-Vauréal to the lower Becscie Formations plotted against the revised surface stratigraphy and nomenclature of Petryk (1979). The graptolites from below the mid-Vauréal Formation, which are known only from drill-cores, have been treated separately (Riva 1969).

A graptolite zone and other graptolites

The *Amplexograptus prominens* Zone. This is the youngest of the zones proposed by Riva (1969) from his study of drill cores and the only one recognized from surface exposures of the Vauréal Formation. In the N.A.C.P. well (Riva 1969: fig. 12) it spans much of the lower Vauréal between the 2047–1734 ft level (614–412 m), for a thickness of 202 m. In both the N.A.C.P. and the L.G.P.L. wells (Riva 1969: figs 11 and 12) it follows on the *Dicellograptus complanatus* Zone which spans most of the underlying 'English Head' Formation (to be renamed the Princeton Lake Formation) for a thickness of 193 m. Originally, Riva (1969) named the *A. prominens* Zone

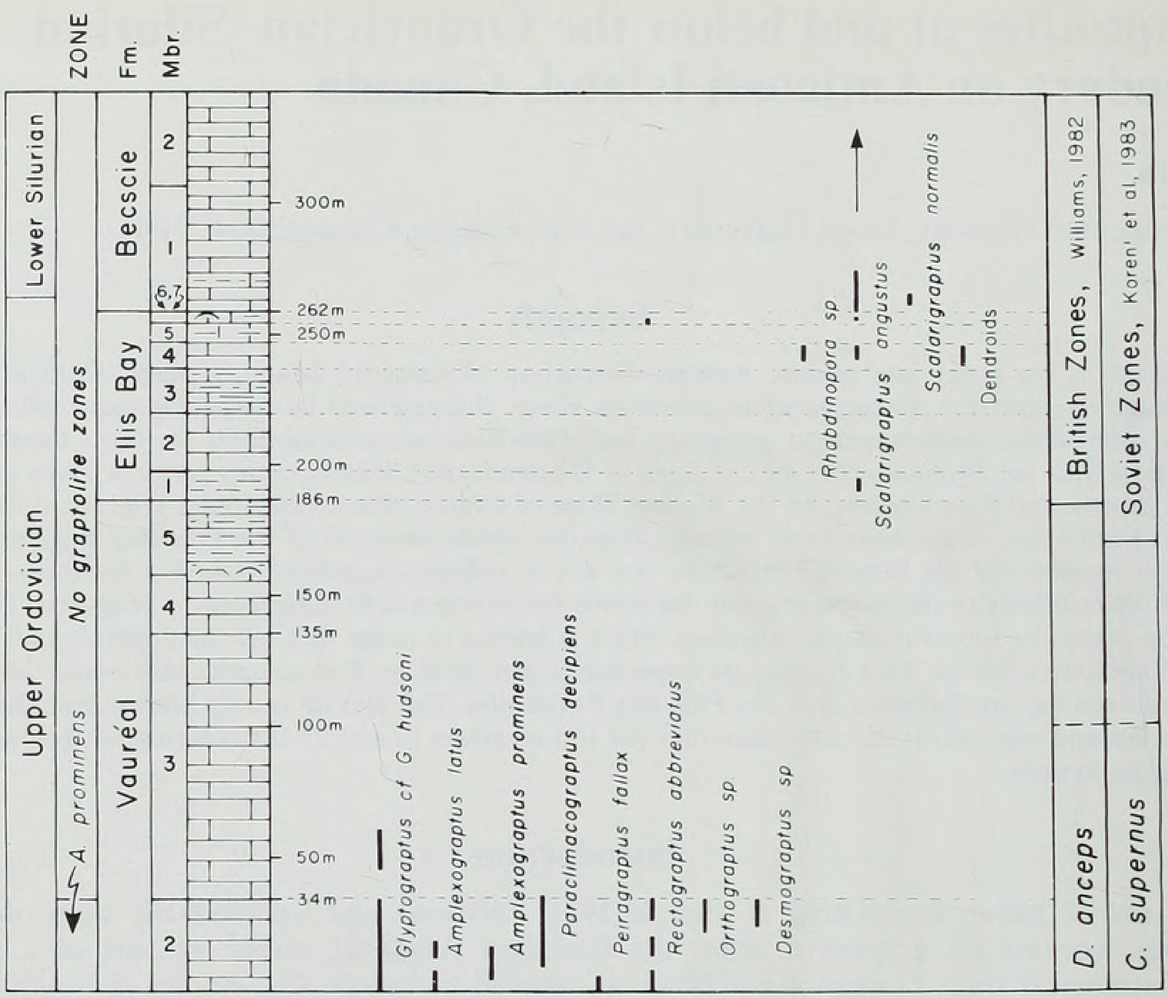


Fig. 1 Graptolite ranges in the upper Vauréal, Ellis Bay and lower Becscie Formations of Anticosti Island.

the *Climacograptus prominens–elongatus* Zone and interpreted its fauna (constituted primarily of biserial graptolites not easily related to those of other successions) as representing a level 'intermediate between ... the youngest Ordovician and the oldest Silurian' (1969: 551). He also referred the species used to name the zone to *Climacograptus* rather than *Amplexograptus*, as Barrass (1953) had done, because most specimens recovered from the core possessed climacograptid thecae with everted apertures rather than amplexograptid thecae. In 1981 he renamed the zone the *Amplexograptus inuiti* Zone on the recognition that *A. elongatus* Barrass was identical to *Amplexograptus inuiti* described by Cox (1933) and also its junior synonym. He also re-interpreted *Amplexograptus prominens* Barrass as a subspecies of *A. inuiti.*

In 1985, I studied and sorted out the type material of *Climacograptus latus* Elles & Wood and came to the conclusion that this species belongs to *Amplexograptus* rather than *Climacograptus, s.l.*, and is also identical to, and the senior synonym of, *A. inuiti. A. latus* was erected on flattened, fragmentary material and *A. inuiti* (Figs 4b–c) on excellent, isolated specimens from Akpatok Island in northeastern Canada. Cox (1933: 2) pointed out the similarity of *A. inuiti* to *A. latus*, but refrained from considering the two species identical because the thecal apertures of *A. latus* were 'more even' and lacked genicular flanges. In reviewing the type specimens of *A. latus*, I recognized apertural lappets in all specimens retained in the species and also residual genicular flanges (Figs 2a–h), but not in the specimens that I have excluded from it (Figs 2i–j), which belong to *Climacograptus tubuliferus* Lapworth. These features are even more pronounced in the topotype material recently identified as *C. latus* by Williams (1982: pl. 3, figs 12–18). The occurrence of *A. latus* in the *A. prominens* Zone of Anticosti is critical, for it allows us to correlate this zone with the *Dicellograptus anceps* Zone of Scotland and the *Cli-*

macograptus pacificus Zone of the U.S.S.R. and their equivalents in China, the Yukon, and elsewhere, something which had not hitherto been possible. I have, however, refrained from naming this zone after either *D. anceps* or *C. pacificus* because neither graptolite has been recovered from Anticosti.

Amplexograptus prominens itself is morphologically quite distinct from *Amplexograptus latus* and cannot be regarded as a mere subspecies or a morphological variant of it. The study of an original collection of *A. prominens* (made by Col. C. C. Grant) from the type strata at Observation Cliff on the north shore of Anticosti Island fully confirms Barrass' (1953) original diagnosis of this species. *A. prominens* is characterized by broad, short rhabdosomes which expand rapidly from a narrow proximal end (first pair of thecae), by prominent genicular flanges and the absence of a mesial spine on th 1^1. The long genicular flanges and the lack of a mesial spine on th 1^1 set *A. prominens* well apart from all other species of *Amplexograptus*, although it shares with them a similar type of proximal-end development (early prosoblastic) and thecal style (amplexograptid with well-developed lappets) (Riva 1987). *A. prominens* is a unique species, known up to now only from the upper Vauréal Formation of Anticosti. It is the last *Amplexograptus*. It could well be the immediate ancestor to *Paraclimacograptus decipiens* sp. nov. which has a long range through the upper Vauréal and with which it has been confused in the past. *P. decipens* differs from *A. prominens* both in thecal form and the nature of genicular ornaments (Fig. 2s) but otherwise it shares with it the same type of proximal development and general distal rhabdosome structure (Figs 2o–r). On the other hand, the isolated specimens from Manitoba referred to *A. prominens* by Jackson (1973: 2–4; text-figs 2B, E and F) are close to the topotypes of the older *Paraclimacogratus manitoulinensis* (Caley) shown here as Figs 5g, h and i. Occasional low or incipient lappets are present both on the everted thecal apertures of the Manitoba specimens and the topotype specimens of *P. manitoulinensis*, and the Manitoba specimens have also a keel-like appression on outer margin of th 1^1. One specimen referred to *Amplexograptus inuiti* by Jackson (1973: text-fig 2D) has also a mesial spine on th 1^1 in addition to the keel-like structure. This sort of structure has not been observed in topotype specimens of *P. manitoulinensis*, but a mesial spine has been reported and figured by Walters (1977) in specimens from the Lorraine Group of the St Lawrence Lowlands.

The name *Paraclimacograptus decipiens* is proposed below for the short, stubby biserial graptolites which stratigraphically follow on *A. latus* in the upper Vauréal Formation (Fig. 1). *P. decipiens* is morphologically close to *A. prominens* for which it may be easily mistaken (hence its specific name), but its thecae are of the paraclimacograptid type with clearly everted thecal apertures and reduced genicular flanges supported by two short genicular spines (Fig. 2s). The development of the proximal end is of the prosoblastic type and th 1^1 lacks a mesial spine, much as in *A. prominens*. The problem now arises as to the proper generic affiliation of the new species, which could be either in the genus *Paraclimacograptus* Přibyl, 1948 or *Paraorthograptus* Mu, 1974. *Paraclimacograptus* has *P. innotatus* (Nicholson) as type species. *P. innotatus* (Figs 5l–n) is a thin, short graptolite, restricted to the lower Llandovery, with an advanced prosoblastic type of proximal-end development, thecae slightly inclined to the axis of the rhabdosome with wide apertural excavations, everted thecal apertures and short genicular processes which turned out to be flanges in isolated Siberian specimens (Crowther 1981: pl. 13, fig. 4). It lacks a mesial spine on th 1^1. Rickards (1970: 32) has also noted a complete median septum on deformed specimens identified as *C. innotatus*, but it is probably the trace of the virgula. *Paraorthograptus* has *P. typicus* Mu from the Upper Ordovician *Paraorthograptus uniformis* Zone of the Wufeng Shale of central China as type species. This species was described as having '... thecae of the orthograptid type with paired ventral spines ... pointed obliquely downward at the proximal end, horizontal at the distal end ... Interthecal septa straight, slightly inclined, not curved; apertural margins everted, not horizontal ...' (Mu *et al.* 1974: 161; translated). No mention was made of the proximal end, which is not preserved in the holotype specimen (Fig. 5a); it is preserved, however, on a complete specimen on the type slab (Fig. 5b) and shows an apparently advanced type of proximal-end development, much as in *Paraorthograptus pacificus* (Ruedemann) (Figs 5c–f). The type species of *Paraclimacograptus* and *Paraorthogratus* share the same basic rhabdosome morphology, *i.e.* a prosoblastic type of proximal-end development, thecae inclined to the rhabdosome axis and wide thecal excavations with everted apertural margins. They differ, however, in the type and size of genicular processes which are flanges in species assigned to *Paraclimacograptus* (Fig. 5j) and genicular spines of various length in species included into *Paraorthograptus*. The latter also have a mesial spine on th 1^1, a virgella and antivirgellar spines, whereas the former generally lack a mesial spine on th 1^1 (except in some specimens of *P. manitoulinensis* figured by Walters 1977) and also, apparently, antivirgellar spines in the younger species such as *P. innotatus* (see Crowther 1981: pl. 13, fig. 4). The problem is whether two genera are needed to group species on the basis of external morphology, conspicuous as it may be. Lin & Chen (1984: 216), for instance, have tried to solve this problem by simply assigning *Climacograptus innotatus* Nicholson to *Paraorthograptus* in describing Chinese specimens identified and figured as *Paraorthograptus innotatus* (Nicholson). However, a study of the Chinese specimens has revealed that they are fragmentary growth or juvenile stages of *P. typicus*. One of them, complete with mesial spine on th 1^1 and long, paired genicular spines, is shown here as Fig. 5k. This deviation notwithstanding, I feel that the genus *Paraclimacograptus* should group species characterized by a prosoblastic proximal development (advanced as in the type species or more primitive as in *P. manitoulinensis*), thecae inclined to the rhabdosome axis, wide thecal excavations, everted apertures and genicular flanges. The genus *Paraorthograptus* should group all species which, in addition to the basic morphology of the paraclimacograptids, have genicular spines rather than flanges, a mesial spine on th 1^1 and antivirgellar spines. *Paraclimatograptus decipiens* has genicular processes consisting of reduced flanges supported by short, lateral spines (Fig. 2s). It may be regarded as a transitional form between species assigned to *Paraclimacograptus* and *Paraorthograptus*, but the fact that flanges are still present, genicular spines poorly developed and the rhabdosome lacks a mesial spine on th 1^1 support its inclusion in *Paraclimacograptus*, and it will be so described below.

The following graptolites have been identified from the *P. prominens* Zone from surface outcrops and the N.A.C.P. drill core (Fig. 1): *Amplexograptus latus* (Elles & Wood), *Amplexograptus prominens* Barrass, *Paraclimacograptus decipiens* n.sp., *Glyptograptus* cf. *G. hudsoni* Jackson, *Peiragraptus fallax* Strachan, *Rectograptus abbreviatus* (Elles & Wood), *Orthograptus*? and *Desmograptus* sp. In the N.A.C.P. well (Riva 1969), *Amplexograptus latus* has a short, 34 m long range at the base of the *P. prominens* Zone, from the 2047 to the 1933 ft level (614–579 m), whereas *P. decipiens* ranges through the middle and upper part of the zone, from the 1647 to the 1376 ft level (493–412 m), for a total of at least 80 m. *Glyptograptus* cf. *G. hudsoni* (Figs 2k–n) was described by Jackson (1971) from the Upper Ordovician of Southampton Island, north of Labrador and Akpatok Island; in the N.A.C.P. well it has a long range extending through both the *D. complanatus* and the *A. prominens* Zones to terminate somewhere in the upper Vauréal Formation (Fig. 1), for a total of at least 650 m; *P. fallax* is a rare graptolite and has been recognized in only one collection from the mouth of the Patate River in association with *A. latus*, *R. abbreviatus* and *G.* cf. *G. hudsoni* (Riva & Petryk 1981); *R. abbreviatus* occurs sporadically through both the *D. complanatus* and *A. prominens* Zones and two specimens were also collected by A. A. Petryk from member 6 of the Ellis Bay Formation, just below the Ordovician–Silurian boundary (Fig. 3i).

Correlation of the *A. prominens* Zone. *A. latus* is a cosmopolitan graptolite long recorded from the *D. anceps* Zone of southern Scotland and, especially, the *D. complexus* and *P. pacificus* Subzones (Williams 1982). This allows us definitely to correlate the *A. prominens* Zone of Anticosti Island with the uppermost British Ordovician. *A. latus* also occurs in the *C. supernus* Zone of Kazakhstan (Koren *et al.* 1980), where it has been described as *Amplexograptus stukalinae*, the *C. pacificus* Subzone of the Omulev Mountains of Siberia (Koren *et al.* 1983), where it is represented by *A. latus hekandaensis*, the *Amplexograptus yangtzensis* to the *Diplograptus bohemicus* Zones of the Wufeng Shale of central China (Mu & Lin 1984), where *A. latus* has been called *A. suni* and *A. yangtzensis* (Fig. 4a), and from the Bolindian *D. ornatus* and *C. latus* Zones of Victoria, Australia (VandenBerg 1981*a*). The *A. prominens* Zone of Anticosti is correlated with all the above-mentioned zonal levels (Fig. 1).

Graptolites from the Ellis Bay and lower Becscie Formations. Graptolites are scarce above the *A. prominens* Zone. Few graptolites have been collected above member 2 of the Vauréal Formation besides a few specimens of *G.* cf. *hudsoni* (Figs 2l–n). Graptolites are also scarce in the Ellis Bay and Becscie Formations: the few collected are either indicative of the uppermost Ordovician or are long-ranging species that straddle the Ordovician–Silurian boundary. Members 4 and 7 of the Ellis Bay Formation have yielded fragmental climacograptids which I have assigned to *Scalarigraptus angustus* (Elles & Wood); one of them is shown as Fig. 3i. In Scotland this graptolite ranges through the *D. anceps* Zone (Williams 1983: fig. 3) and may be taken to indicate that member 6 of the Ellis Bay is of uppermost Ordovician age. At Salmon River, the Becscie Formation has yielded fragments of *S. angustus* from its contact with the top of reef structures of the Ellis Bay upwards (Fig. 1). An excellent three-dimensional specimen of *S. angustus* was collected by A. A. Petryk a few metres above the base of the Becscie (Figs 3t, u); two small collections of this species were made 7 and 30 m above the base of the formation at pool 9 on Salmon River (Figs 3j–s) and one specimen (Fig 3v) was collected from the Gun River Formation, well above the Ordovician–Silurian boundary. This is the longest specimen of *S. angustus* collected on Anticosti Island. *S. angustus* ranges from the Ashgill to the lower Llandovery, and it is common in the *D. anceps*, *G. persculptus*, *A. acuminatus* and other Zones at or above the Ordovician–Silurian boundary and cannot be regarded as a good zonal indicator. In closing, it will be noted that a large climacograptid approaching *Scalarigraptus normalis* (Lapworth) in size (Fig. 3w) was collected by T. E. Bolton from the basal Becscie Formation on the east side of Ellis Bay at Cap-à-l'Aigle. *S. normalis* is only known from the *G. persculptus* Zone to the lower Llandovery.

The new genus *Scalarigraptus*. The occurrence of graptolites of the *normalis* (or *scalaris*) group in the Ellis Bay and Becscie Formations brings again to the fore the problem of their generic affiliation which cannot any longer be the traditional polyphyletic genus *Climacograptus* Hall. *Climacograptus* was created by Hall (1865: 111–112) for 'simple stipes with sub-parallel margins having a range of cellules (thecae) on each side', which were to be 'short and square'. *Graptolithus bicornis* was designated as the type species and the members of the *G. scalaris* group of Linné were 'conceived' as the 'veritable species of this genus'. (The generic name *Climacograptus* was obtained by adopting the Greek noun *klimax*, equivalent to the Latin *scala*, ladder, of which *scalaris* is the adjective). Since its creation, this genus has known enormous popularity, having been used as a generic umbrella for all sorts of biserial graptolites characterized by square or climacograptid thecae, at least in the mature or distal part of the rhabdosome. Elles & Wood (1906) attempted to deal with the large number of British graptolites assigned to *Climacograptus* by dividing them into five groups on the basic of thecal outline, type of apertural excavation or thecal ornaments such as spines, but did not propose new genera or subgenera. Přibyl (1947, 1948), on the other hand, went a step further and proposed the genus *Pseudoclimacograptus* for climacograptids characterized by a zig-zag median septum connected by transverse rods to the thecal septa and the genus *Paraclimacograptus* for climacograptids with genicular spines. The genus *Pseudoclimacograptus* has since been widely accepted by graptolite specialists, but the genus *Paraclimacograptus* has been overshadowed by the genus *Paraorthograptus* Mu, 1974. Riva (1974*b*, 1976) showed, on the basis of three-dimensional topotype material, that *C. bicornis* had a primitive diplograptid, or streptoblastic, type of proximal-end development and thus differs significantly from other climacograptids with a prosoblastic type of proximal-end development. The graptolites of the *scalaris* group, considered by Hall (1865: 112) as the 'veritable species' of *Climacograptus*, have an advanced prosoblastic type of proximal-end development and cannot be regarded as true climacograptids, although they share with *C. bicornis* a similar distal development. For this reason, I am proposing the new genus *Scalarigraptus* for all graptolites of the '*scalaris*' or *normalis* group and for all Ordovician climacograptids with an advanced prosoblastic type of proximal-end development and with a septate or partly septate rhabdosome. *C. normalis* will be designated as the type species of the new genus.

In 1949 Obut erected the genus *Hedrograptus* for early Silurian climacograptids with insignificant or incomplete apertural excavations on one side of the rhabdosome and complete on the other. The figures of the type species, *H. janischewskyi* Obut, show that it is also characterized by an advanced prosoblastic type of proximal-end development, just like *C. normalis*. In 1975, Obut extended *Hedrograptus* to include all climacograptids of the *scalaris* group. This would mean that *Hedrograptus* rather than the proposed *Scalarigraptus* is actually the genus intended for climacograptids of the *scalaris* group. I have, however, thanks to the cooperation of A. M. Obut, been able to examine a latex cast of the holotype of *H. janischewskyi* (Fig. 6a) and conclude that *Hedrograptus* is based on an incomplete and distorted specimen preserved in $\frac{3}{4}$-face view which does not allow us to ascertain whether the thecae are climacograptid or glyptograptid. Another specimen from the type locality, also preserved in $\frac{3}{4}$-face view (Fig. 6b), is much larger than the holotype of *H. janischewskyi* and probably not conspecific with it. For these reasons, I have been reluctant to adopt *Hedrogratus* and propose instead the genus *Scalarigraptus*.

Systematic palaeontology

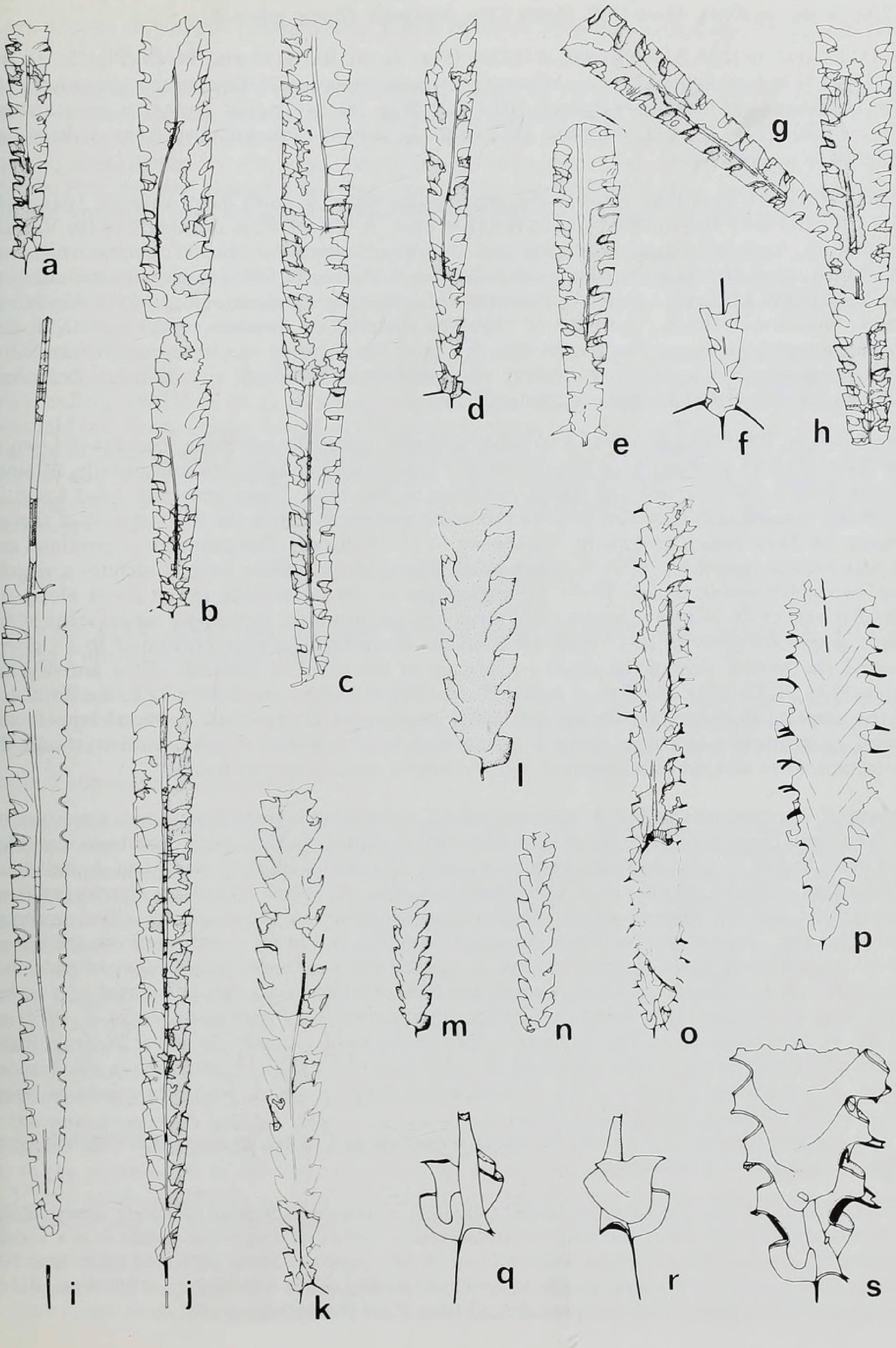
Family **DIPLOGRAPTIDAE** Lapworth, 1873

Genus ***AMPLEXOGRAPTUS*** Elles & Wood, 1907

Amplexograptus latus (Elles & Wood)
Figs 2a–h, 4

1906 *Climacograptus latus* Elles & Wood: 204–205; pl. 27, figs 3a–e and g, *non* figs 3f–h; text-figs 135a–d.
1933 *Climacograptus inuiti* Cox: 1–19, pls 1, 2.
1953 *Amplexograptus elongatus* Barrass: 62–66; figs 6–8.
non 1970 *Climacograptus latus* Elles & Wood; Toghill: 22; pl. 15, figs 1, 2.
1974 *Amplexograptus disjunctus yangtzensis* Mu & Lin; Mu *et al.*: 162; pl. 70, fig. 6.
1980 *Amplexograptus stukalinae* Mikhailova; Koren *et al.*: 125–126; pl. 4, figs 1, 2.
1982 *Climacograptus latus* Elles & Wood; Williams: 39–40; pl. 3, figs 12–18. [See also for other synonyms.]
1983 *Climacograptus latus hekandaensis* subsp. nov.; Koren & Sobolevskaya: 116–117; pl. 30, figs 2–6; pl. 31, figs 1–3.
1983 *Climacograptus latus* Elles & Wood; Wang *et al.*: pl. 3, fig. 1.
1984 *Amplexograptus suni* (Mu); Mu & Lin: 56; pl. 5, figs 4–6.

Fig. 2 Type specimens of *Amplexograptus latus* (Elles & Wood, 1906) and graptolites from the Vauréal Formation. a–h, Type specimens of *A. latus* from the upper Hartfell Shale, Main Cliff, Dob's Linn; a, SM 19683b (Elles & Wood 1906: text-fig. 135a), paralectotype, × 5; b, SM A19680 (Elles & Wood 1906: pl. 27, fig. 3a), proposed **lectotype**, × 5; c, BU 1195 (Elles & Wood 1906: pl. 27, fig. 36), paralectotype, × 5; d, SM 19682a (Elles & Wood 1906: pl. 27, fig. 3g, text-fig. 135c), paralectotype, × 5; e, BU 1412b, unfigured paralectotype (on the same slab as BU 1412a of Fig. 2j), × 5; f, SM A19683c, unfigured growth stage, × 10; g, BU 1411a (Elles & Wood: pl. 27, fig. 3e), paralectotype, × 5; h, BU 1411b, unfigured paralectotype, × 5; i–j, *Scalarigraptus tubuliferus* (Lapworth) originally included in the type material of *A. latus*; i, BU 1413 (Elles & Wood: pl. 27, fig. 3h) doubtfully included, × 5; j, BU 1412a (Elles & Wood 1906: pl. 27, fig. 3f), × 5; k–n, *Glyptograptus* cf. *G. hudsoni* Jackson; k, G.S.C. 82880, from the 2739 ft (822 m) level in the N.A.C.P. core, × 5; l, m, G.S.C. 82881, from member 2 of the Vauréal Formation at Cap Crotté, Anticosti Island (A. A. Petryk's coll. 76 AP29-1), respectively × 10 and × 5; n, G.S.C. 82882, same locality and collection, × 5; o–s, *Paraclimacograptus decipiens* sp. nov.; o, G.S.C. 82883, **holotype**, longest specimen recovered from the 1376 ft (413 m) level in the N.A.C.P. core × 5; p, G.S.C. 82884, paratype, a large macerated specimen (A. A. Petryk's coll. 83 AP6-5), from 90 m above the mouth of Patate River, member 2, Vauréal Formation, × 5; q–s, G.S.C. 82885, 82886, paratypes, isolated specimens from the 1381 ft (414 m) level in the N.A.C.P. core showing the development of the proximal-end thecal structure, × 15. Note the development of vertical cortex filaments in the apertural excavations of th 2^2 and 3^2.


a
b
c
d
e
f
g
h
i
j
k
l
m
n
o
p
q
r
s

LECTOTYPE. SM A19680 (Fig. 2b) (Elles & Wood 1906: pl. 27, fig. 3a) from the upper Hartfell Shale, *D. anceps* Zone, Main Cliff, Dob's Linn, Scotland. Herein selected.

PARALECTOTYPES. SM A19683b and A19682a (Figs 2a, b), BU 1195 and 1411a (Figs 2c, g), BU 1414 and 1196 (not figured because of poor preservation) and the following specimens from the type collection, not previously figured: BU 1412b (Fig. 2e), 1411b (Fig. 2h) and a growth stage, SM A19683c (Fig. 2f). BU 1413 and 1412 (Figs 2i, j) have been excluded from *A. latus* and assigned to *C. tubuliferus*.

OTHER MATERIAL EXAMINED. Several topotype specimens of *A. inuiti* from Akpatok Island, the N.A.C.P. drill core and surface collections made by A. A. Petryk from member 2 of the Vauréal Formation, Anticosti Island. The type and topotype material of *Amplexograptus stukalinae* Mikhailova and of *Climacograptus latus hekandaensis* Koren & Sobolevskaya stored either at the VSEGEI in Leningrad or at the Institute of Geology and Palaeontology of the Akademya Nauk, Moscow, U.S.S.R.; the type or topotype material of *Amplexograptus suni* (Mu) and *Amplexograptus disjunctus yangtzensis* Mu & Lin at the Institute of Geology and Palaeontology, Academia Sinica, Nanjing, and at the Institute of Geology and Mineral Resources, Academy of Geological Sciences, Yichang, China.

DESCRIPTION. Rhabdosome up to 5 to 6 cm in length, gradually widening from 0·8–1·1 mm at the level of th 1^2 aperture to a maximum of 2·2–2·4 (exceptionally 2·6) mm distally, attained within 2 or 3 cm. The average width, however, is less than 2 mm, generally 1·6–1·8 mm. A waist-like constriction may also be noted in some specimens above the the first pair of thecae. Thecae 14–12 in 10 mm proximally, decreasing to 11–12 distally. Development of proximal end of prosoblastic type (Cox 1933: 6, 7; figs 1–21). The sicula is 1·5 mm long; it secretes a virgella and two antivirgellar spines. Th 1^1 originates low in the metasicula, grows down along the virgellar side to the sicular aperture, then turns out and upwards, secreting a mesial spine at the point of upward growth; th 1^2 buds off from the downward-growing portion of th 1^1, grows around the reverse side of the sicula to turn up at the point of issuance of the antivirgellar spines (Fig. 4). Th 2^1 buds off th 1^1 and th 2^2 from th 1^2 and so on alternately to the distal end of the aseptate rhabdosome. Thecae are of the amplexogratid type with apertural lappets and thecal excavations occupying about $\frac{1}{4}$ of the rhabdosome width. A selvage runs around the thecal apertures and the infragenicular walls to form a short genicular flange.

REMARKS. The type material of *A. latus* was mixed, containing two specimens herein assigned to *C. tubuliferus* (Figs 2i, j). Because of its world-wide distribution, this species has been identified and described as *C. latus* and also under a number of names such as *C. inuiti* and *A. stukalinae* Mikhailova, *Climacograptus latus hekandaensis* Koren & Sobolevskaya for specimens from Kazakhstan and NE Siberia, and as *Amplexograptus disjunctus* Mu & Zhang, *Climacograptus suni* (Mu) and *Amplexograptus disjunctus yangtzensis* Mu & Lin for specimens from the Upper Ordovician Wufeng Shale of central China. *A. yangtzensis* is a species in its own right and not a subspecies of *A. disjunctus*, a *nomen nudum*, the type of which could not be located in a recent study visit to Nanjing. It is based on a single three-dimensional specimen (Mu *et al.* 1974: pl. 70, fig. 4), here refigured as Fig. 4a, from a zone of the same name in the lower Wufeng Shale, where graptolites are generally preserved in relief in a black shale. Farther up in the Wufeng Shale, *A. yangtzensis* is replaced by *A. suni*, which differs from *A. yangtzensis* only in being preserved as flattened, brown, flaky films.

The specimens from Dob's Linn, Scotland, identified as *C. latus* by Toghill (1970) belong to either *S. normalis* or *S. tubuliferus*.

STRATIGRAPHICAL AND GEOGRAPHICAL OCCURRENCE. *A. latus* is restricted to the *D. anceps* Zone of Scotland (Williams 1982) and may be considered as one of its diagnostic fossils. It is a widely distributed, cosmopolitan species, known from the *C. supernus* Zone of Kazakhstan and NE Siberia, the Upper Ordovician of China and correlative strata elsewhere. In SE Australia it helps name the upper Bolindian *D. ornatus–C. latus* Zone (VandenBerg 1981*a*).

Genus *PARACLIMACOGRAPTUS* Přibyl, 1948

TYPE SPECIES (by original designation). *Climacograptus innotatus* Nicholson (Nicholson 1869: 238; pl. 11, figs 16, 17).

DIAGNOSIS (amended from Přibyl 1948: 40–41, 47–48, fig. 6). Rhabdsome aseptate, apparently ovoid in cross-section; thecae of the paraclimacograptid type, inclined to the axis of the rhabdosome; apertural excavations wide and deep with everted thecal apertures and genicular flanges, strengthened by a selvage (list) split into two short spines at the geniculum in some species. Proximal end characterized by a prosoblastic type of development, and provided with a virgella, antivirgellar spines and, exceptionally, a mesial spine on th 1^1 (in older species).

INCLUDED SPECIES. The following species may be included in *Paraclimacograptus: Paraclimacograptus innotatus* (Nicholson), *Paraclimacograptus manitoulinensis* (Caley), *Paraclimacograptus decipiens* sp. nov., *Paraclimacograptus* sp., an undescribed species from the *Climacograptus wilsoni* Zone of Gaspé, Canada.

Climacograptus innotatus nevadensis Carter (Riva 1974*a*: figs 2k–m) from the late mid-Ordovician of Nevada, Texas (Marathon region), Oklahoma (unpubl. data) and Australia (VandenBerg 1981*b*) is close to *Scalarigraptus.* This species has an advanced prosoblastic proximal-end development, thecae of the climacograptid type with stiff genicular spines in the first six to twelve pairs, a long virgella accompanied by a sicular downgrowth, a long inflated virgula and a sicula lacking the prosicula. These characteristics brings it closer to the scalarigraptids of the *tubuliferus* group of the Upper Ordovician rather than to the paraclimacograptids.

Paraclimacograptus decipiens sp. nov.
Figs 2o–s

HOLOTYPE. G.S.C. 82883 (Fig. 2o), from the 1376 ft (413 m) level in the N.A.C.P. core, upper Vauréal Formation, Anticosti Island.

PARATYPES. G.S.C. 82884 (Fig. 2p), from 90 m above the mouth of Patate River, Anticosti Island, member 2 of the Vauréal Formation; G.S.C. 82885 and 82886 (Figs 2q–s), isolated growth stages from the 1381 ft (414 m) level of the N.A.C.P. core, upper Vauréal Formation.

NAME. Latin *decipiens*, deceiving.

DESCRIPTION. Rhabdosome of moderate length, usually not exceeding 2 to 3 cm, maximum observed 4 cm (Fig. 2o), widening rapidly from 0·8–1·0 mm at the level of the aperture of th 1^2 to 1·6–2·0 mm (maximum observed 2·4 mm) at the level of the 4th to 5th pair of thecae. Thecae numbering 8 in 5 mm, or 15 in 10 mm, proximally, decreasing to 12–13 in 10 mm distally, of the paraclimacograptid type with everted thecal apertures, except for the first two which have low lappets (faintly visible also on the second pair of thecae in Fig. 2s). Interthecal septa inclined at 20° to 40° to the rhabdosome axis; supragenicular walls parallel or slightly inclined to it. Thecal excavations wide, occupying $\frac{1}{4}$ of the rhabdosome width, reinforced by a selvage running around the thecal aperture and the infragenicular wall and terminating as two short, stiff genicular spines supporting a reduced hood (Fig. 2s). Development of the proximal end of the prosoblastic type. Sicula about 1·5 mm long, partly exposed on the obverse side of the rhabdosome (Figs 2o, s). Th 1^1 originates low in the metasicula, grows down the virgellar side to the sicular aperture before turning out and upwards to terminate about level with its point of origin. Th 1^2 buds off the downward-growing portion of th 1^1, grows diagonally around and up on the obverse side of the rhabodosome (Fig. 2r); th 2^1 buds off from th 1^2 and th 2^2 from th 1^2 and so on alternately to the distal end of the rhabdosome. A thin nema passes through the rhabdosome and extends a short distance beyond it. The rhabdosome is aseptate.

REMARKS. The development of the proximal end of *P. decipiens* is identical to that of *A. latus* and *A. prominens*, suggesting a close genetic relationship between the three species. *P. decipiens* is much larger than *P. innotatus* which has a proximal development of the advanced prosoblastic type. *P. decipiens* is much closer to *P. manitoulinensis* from the lower Upper Ordovician of NE North America (Riva 1969) (Figs 5g, h and i), but this species is thinner, of uniform width and has genicular flanges strengthened by a thickened selvage (Fig. 5j). A mesial spine on th 1^1 may occur sporadically in some rhabdosomes (Walters 1977).

STRATIGRAPHICAL AND GEOGRAPHICAL OCCURRENCE. *P. decipiens* is only known from the *A. prominens* Zone of Anticosti, where it has a stratigraphical range of at least 80 m in the upper Vauréal Formation (Riva 1969). It has been found also sporadically in recent surface collections made by A. A. Petryk and in an older collection (Y.P.M. 3036/4) made by W. H. Twenhofel and stored at the Peabody Museum of Yale University (Riva & Petryk 1981: 160).

Genus *SCALARIGRAPTUS* nov.

TYPE SPECIES. *Climacograptus normalis* Lapworth (Lapworth 1877: 138; pl. 6, fig. 31; Elles & Wood 1906: pl. 26, fig. 2a; Williams 1983: text-fig. 4a).

NAME. From the Latin *scalaris*, ladder-like.

DIAGNOSIS. Rhabdosome septate or partly septate, ovoid to subrectangular in cross-section; thecae of the climacograptid type with definite genicula, deep horizontal apertural excavations and straight supragenicular walls, usually parallel to the axis of the rhabdosome. Proximal-end development of the advanced prosoblastic type with only th 1^1 initially growing down along the sicula. The virgella is the only proximal spine.

INCLUDED SPECIES. The following species, among others, fall within the limits of the diagnosis of *Scalarigraptus*: *C. normalis*, *C. angustus* (Perner), *C. transgrediens* Waern, *C. medius* Törnquist, *C. praemedius* Waern, *C. rectangularis* M'Coy, *C. brevis* Elles & Wood, *C. putillus* (Hall), *C. tubuliferus* Lapworth, *C. nevadensis* Carter, *C. yumenensis* Mu and *C. biformis* (Mu & Lee).

Fig. 3 Syntypes of *Climacograptus miserabilis* Elles & Wood, 1906 and graptolites from the Ellis Bay and the lower Becscie Formations. a–c, Syntypes of *C. miserabilis*; a, BU 1148b (Elles & Wood 1906: text-fig. 120b), proximal end with long virgella (freed from matrix), × 5; b, BU 1150 (Elles & Wood 1906: text-fig. 120a), typical specimen with long virgella (freed from matrix), × 5; c, BU 1146a (Elles & Wood 1906: pl. 26, fig. 3b and text-fig. 120c), distal fragment showing thread-like virgula passing through the thin rhabdosome, × 5. d–h, *Scalarigraptus angustus* (Perner) from the Ellis Bay Formation; d, G.S.C. 82887, obverse view of growth stage preserved in relief, showing climacograptid thecae and wavy median septum, from the oncolite platform bed, basal member 7 (A. A. Petryk's collection 84AP8-2-1F), Pointe Laframboise, Cape Henry, × 10; e–h, G.S.C. 82888–82891, large distorted or fragmentary rhabdosomes from upper member 4 (A. A. Petryk's collection 81AP3-2), Baie des Navots, Ellis Bay, × 5. i, G.S.C. 82892, *Rectograptus abbreviatus* (Elles & Wood), macerated specimen from member 5, Ellis Bay Formation, immediately below reef bioherms, 7 km upriver from mouth of Salmon River, right bank (A. A. Petryk's collection 75APt3-3), × 5. j–m, *S. angustus* (Perner) from the basal beds of the Becscie Formation; j, k, G.S.C. 82893, 82894, a growth stage and an adult individual showing a thin virgella distally prolonged (A. A. Petryk's collection 81AP13-1-1F), from pool 9, Salmon River, 13 m above the base of the formation, × 5; l–m, G.S.C. 82895, 82896, from the basal Becscie at pool 9 on Salmon River (collected by J. Riva 1981), × 5. n–s, G.S.C. 82897–82902, growth series of *S. angustus* (A. A. Petryk's collection 79AP48-4), 7 m above base of the Becscie, base of pool 9 on Salmon River, × 5. t, u, G.S.C. 82903, observe view of *S. angustus* preserved in excellent relief, showing wavy median septum in proximal part of rhabdosome (A. A. Petryk's collection 76AP22-30-6′), 2–3 m above base of Becscie Formation on Salmon River, respectively × 10 and × 5. v, G.S.C. 82904, longest specimen of *S. angustus* recovered from the mid-part of the Gun River Formation, 3·5 km from mouth of Chute Creek, eastern Anticosti (A. A. Petryk's collection 75MPt18-L8C-1F), × 5. w, G.S.C. 69157, *Scalarigraptus normalis* (Lapworth), collected by T. E. Bolton in 1981 from the basal Becscie Formation on the east shore of Ellis Bay near Cap-à-l'Aigle, Anticosti Island, × 5.


a
b
c
d
e
f
g
h
i
j
k
l
m
w
n
o
p
q
r
s
t
u
v

Scalarigraptus angustus (Perner, 1895)
Figs 3a–u

1895 *Diplograptus* (*Glyptograptus*) *euglyphus* Lapworth var. *angustus* Perner: 48; pl. 8, figs 14a, b.
1906 *Climacograptus scalaris* (Hisinger) var. *miserabilis* Elles & Wood: 186; pl. 26, figs 3a, b, d, e, g, h, *non* figs 3c, f; text-figs a–c.
1951 *Climacograptus angustus* (Perner) Přibyl: 7; pl. 2, figs 2–9.
1975 *Climacograptus angustus* (Perner); Bjerreskov: 23; fig. 9A.
1980 *Climacograptus angustus* (Perner); Koren *et al.*: 131; pl. 37, figs 2–7; text-figs 34a–e.
1983 *Climacograptus angustus* (Perner); Koren & Sobolevskaya: 106–108; pl. 27, figs 1–5; text-fig. 34.
?1983 *Climacograptus mirnyensis* (Obut & Sobolevskaya); Koren & Sobolevskaya: 132–133; pl. 37, figs 2–5; text-figs 47K–H.
1983 *Climacograptus miserabilis* Elles & Wood; Williams: 615–616; text-figs 3f–i, ?j, 4f–i, 5a–b. [See also for a more extended pre-1983 synonymy.]

HOLOTYPE. National Museum of Prague CD 1835, partly figured by Perner (1895: pl. 8, figs 14a–b) and refigured in full by Přibyl (1951: pl. 2, fig. 8).

MATERIAL STUDIED. The type collection of *C. miserabilis* in the Lapworth collection of Birmingham; part of the collections made by P. Toghill at Dob's Linn; the type and topotype material of *C. angustus* in Prague; the collections of *C. angustus* and *C. mirnyensis* at VSEGEI, Leningrad, several collections made by A. A. Petryk from the Ellis Bay, Becscie and Gun River Formations of Anticosti Island.

DESCRIPTION. Rhabdosome up to 2 cm in length, widening imperceptibly from 0·8–0·9 mm at the level of th 1^2 aperture to a maximum of 1·0–1·1 mm (exceptionally 1·2 mm) within one pair of thecae. Thecae of the climacograptid type, numbering 11–12 in the first 10 mm, decreasing to 10–11 distally, with sharp genicula and supragenicular walls parallel to slightly inclined to the rhabdosome axis. Thecal apertures horizontal to slightly everted; thecal excavations wide and semicircular, occupying about $\frac{1}{4}$ of the rhabdosome width and reinforced by a thin selvage around the aperture and the infragenicular walls, terminating as a slight genicular flange (Figs 3d, t). Development of the proximal end of the advanced prosoblastic type. Sicula from 1·2 to 1·6 mm long, secreting a long virgella; it is mostly exposed on the obverse side of the rhabdosome (Williams 1983: text-fig. 3h). Th 1^1 first grows down along the sicula and then turns out and upwards at the sicular aperture (Figs 3d, t); th 1^2 grows up from th 1^1 and th 2^1 from th 1^2. Th 2^1 is also the dycalical thecae which gives rise to two independent linear series separated by a median septum. The median septum begins on the obverse side of the rhabdosome at about the level of th 1^2 aperture (its point of origin is marked by a notch in some specimens, Fig. 3t) and follows a wavy pattern through the first 5 or 6 pairs of thecae before straightening out (Figs 3d and t). A thin, thread-like nema passes through the rhabdosome and extends for some distance beyond.

REMARKS. In 1951 Přibyl pointed out that *C. miserabilis* Elles & Wood 1906 was identical to, and the junior synonym of, *C. angustus* (Perner 1895). This synonymy was accepted by some workers (for instance Bjerreskov 1975: 23) but not by British workers for a number of reasons best summarized by Williams (1983: 616). Recently, I have been able to study the type material of both *C. miserabilis* and of *S. angustus*. *C. miserabilis* is based on seven specimens from the *D. complanatus* Zone and two from the *D. anceps* Zone of Dob's Linn, Scotland. The two specimens from the *D. anceps* Zone do not belong to *C. miserabilis*: one, BU 1145b (Elles & Wood 1906: pl. 26, fig. 3c), is a distal fragment of *tubuliferus*, and the other, BU 1149 (Elles & Wood: pl. 26, fig. 3f), is of uncertain affiliation. The specimens from the *D. complanatus* Zone (three of which are shown here as Figs 3a–c) are preserved as thin, flaky, abraded films. They all belong to *C. miserabilis*. They are from 0·8 to 1·1 mm wide and have 12–11 thecae per 10 mm proximally and 11 distally. The proximal end bears a long virgella, and a thin nema passes through the rhabdosome. This is all that can be learned from the type material of *C. miserabilis*. The type and topotype material of *S. angustus* is more diversified and contains several specimens in partial relief. (I was unable to draw any specimens, but was assisted in my work by Dr A.

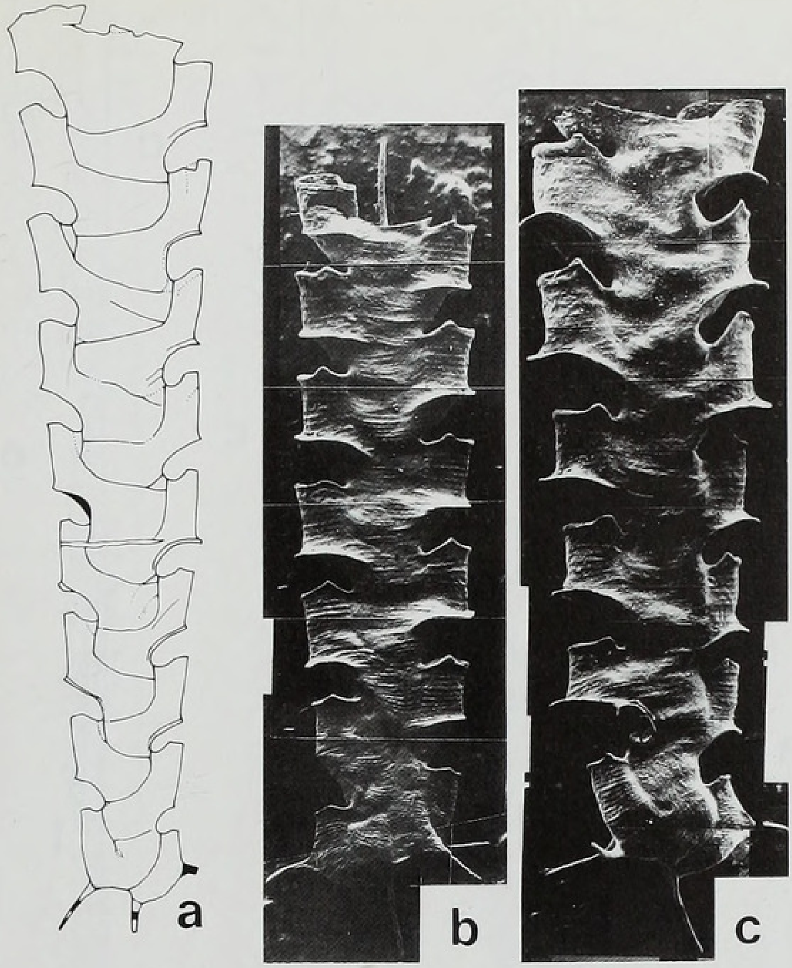


Fig. 4 a, N.I.G.P. Catalogue Number 21410, holotype of *Amplexograptus yangtzensis* Mu & Lin (= *A. latus*), × 20; b and c, SEM montages of *Amplexograptus inuiti* (Cox) (= *A. latus*) from Akpatok Island, Canada: b, SM A102524, obverse view; c, SM A102521, reverse view, both × 20 (courtesy of Peter Crowther).

Přibyl). The specimens attain a width of 1·0–1·1 mm, have 12–11 thecae per 10 mm proximally and 10 distally. The thecae are all of the climacograptid type with strong genicula. The proximal end bears a long virgella and a thin virgula passes through the rhabdosome. The holotype is a complete, not partial, specimen as claimed by Strachan (1971: 34); it has been refigured in full by Přibyl (1951: pl. 2, fig. 8). With the aforesaid in mind, I do not see any morphological differences between the types of *C. miserabilis* and *S. angustus* and do not hesitate to place the former in synonymy with the latter.

The specimens from the basal Becscie Formation (Figs 3j–u) are all practically identical to the type of *S. angustus* and so are those from the Gun River Formation. The specimens from member 4 of the Ellis Bay Formation (Figs 3e–h) are wider (from 1·1 to 1·3 mm) because of poor preservation and distortion; that from the base of member 7 (Fig. 3d) has the same dimensions as the holotype in Prague.

Stratigraphical and geographical occurrence. *S. angustus* is a cosmopolitan graptolite ranging through the Upper Ordovician and part of the Lower Silurian. In NE Siberia (Omulev Mountains) it is common from the base of the *C. extraordinarius* Zone to the top of the *A. acuminatus* Zone (Koren *et al.* 1983: figs 62, 64). On Anticosti Island it first occurs at the top of the *P. manitoulinensis* Zone (Riva 1969: figs 11, 13), below the base of the *D. complanatus* Zone, and extends all the way up into the Gun River Formation of mid-Llandovery age.

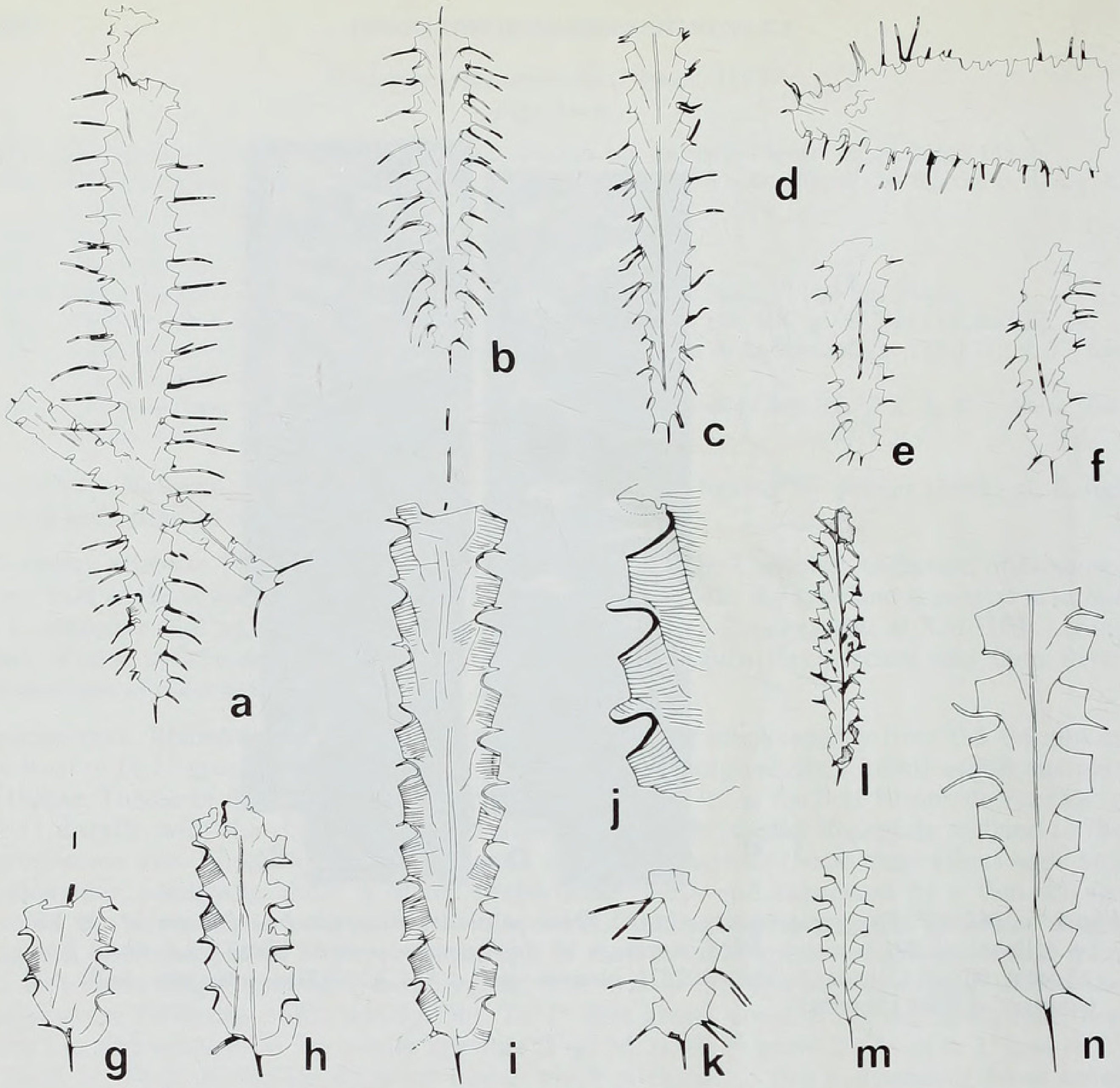
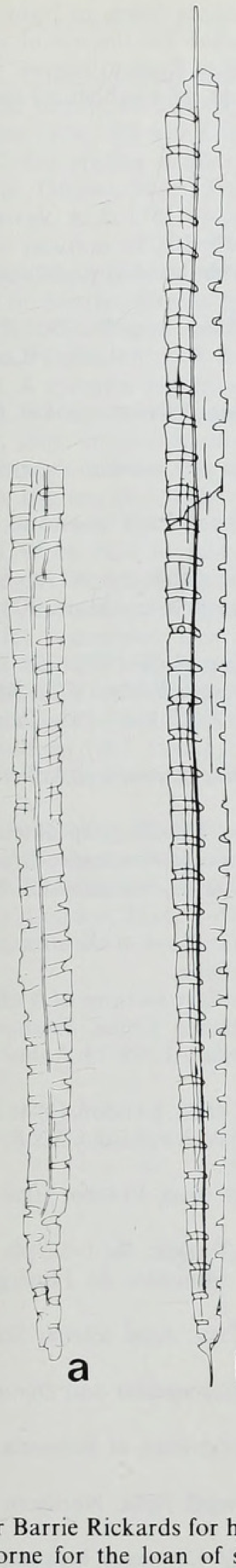


Fig. 5 a, b, *Paraorthograptus typicus* Mu; a, N.I.G.P. Cat. No. 21418a, counterpart of the holotype (better preserved than the part) from the Wufeng Shale north of Yichang, central China, showing the characteristic long, paired genicular spines of the species but with the proximal end missing (a rhabdosome of *Climacograptus longispinus supernus* Elles & Wood lies diagonally across its proximal end), × 5; b, unfigured specimen of *P. typicus*, with a complete proximal end, occurring on the same slab as the holotype, × 5. c–f, U.S.N.M. 415038–415401, rhabdosomes of *Paraorthograptus pacificus* (Ruedemann) from the Phi Kappa Formation at Trail Creek, Idaho, U.S.A., near the type locality of the species, showing their characteristic short genicular spines, both paired and triple, and stubby form; note the tectonic deformation undergone by specimens of Figs 5c and d lying normal to each other, × 5. g–j, G.S.C. 56899, 56895, 56900 and 56901, respectively, topotypes of *Pseudoclimacograptus manitoulinensis* (Caley) from the upper Whitby Formation, 5 km south of Little Current west side of Rt 68, Manitoulin Island, Ontario, Canada; g–i, growth series showing distinct fusellar rings, × 10; j, detail of thecal excavations showing everted thecal apertures and well-developed genicular lappets strengthened by a selvage, × 20. k, N.I.G.P. Cat. No. 82816, proximal end of *P. typicus* figured as *Paraorthograptus innotatus* (Nicholson) by Lin & Chen (1984: pl. 4, fig. 7), showing the spinose processes typical of the species: virgella, antivirgellar spines, mesial spine on th 1^1 and genicular spines, × 10. l–n, *Paraclimacograptus innotatus* (Nicholson), topotypes from the lower Birkhill Shale (Lower Silurian) at Dob's Linn, southern Scotland; l, SM A20222, specimen figured by Elles & Wood (1906: pl. 27, fig. 10a) as a 'typical specimen' (but not the 'type' of Nicholson), × 5; m, n, SM A20232 (*op. cit.*: pl. 27, fig. 106), specimen showing advanced prosoblastic development of proximal end and a partly uncovered sicula below th 1^2, × 5 and × 10, respectively.



a b

Fig. 6 a, I.G.G.–COAH-SSSP No. 278/5, 1945, a camera lucida drawing of latex cast of the holotype of *Hedrograptus janischewskyi* Obut from the Lower Silurian (Llandovery) of the southern Ural Mountains, U.S.S.R., preserved as a $\frac{3}{4}$-face view impression, × 4; b, I.G.G.–COAH-SSSP No. 278/6, 1945, a 'topotypic specimen' of *H. janischewskyi* 'from the same locality as the holotype and the closest to the type' (Obut, *in litt.* 1984), preserved as a $\frac{3}{4}$-face impression in a light-grey aphanitic limestone with most of the periderm missing, × 4.

Acknowledgements

I thank Dr Barrie Rickards for hospitality and facilities during several visits to the Sedgwick Museum, Mr P. J. Osborne for the loan of specimens from the Lapworth Collection, Birmingham, Dr Tatyana N. Koren, VSEGEI, Leningrad, for permission to study the collections from the Omulev Mountains and Kazakhstan; Dr A. Přibyl for his help in studying graptolites at the National Museum of Prague, Dr A. A. Petryk for permission to study his Anticosti collections, Miss Claire Carter, U.S.G.S., for the loan of topotype specimens of *P. pacificus*, Li Ji-jin for his assistance at the Academia Sinica in Nanjing, Wang Xiao-feng for organizing a field excursion near Yichang, Mme Aïcha Achab for the use of the INRS-Géoressources photolaboratory and my daughter Patricia for translations of Russian papers. This work was supported in part by a research grant from the N.R.C. of Canada and by a sabbatical travel grant from Université Laval.

References

Barrass, R. 1953. Graptolites from Anticosti Island. *Q. Jl geol. Soc. Lond.* **110:** 55–75.

Bjerreskov, M. 1975. Llandoverian and Wenlockian graptolites from Bornholm. *Fossils Strata*, Oslo, **8:** 1–94, pls 1–13.

Cox, I. 1933. On *Climacograptus inuiti* sp. nov. and its development. *Geol. Mag.*, London, **70:** 1–19.

Crowther, P. R. 1981. The fine structure of the graptolite periderm. *Spec. Pap. Palaeont.*, London, **26:** 1–119.

Elles, G. L. & Wood, E. M. R. 1901–18. A monograph of British Graptolites. *Palaeontogr. Soc.* (*Monogr.*), London. *m* + clxxi + 539 pp., 52 pls.

Hall, J. 1865. Graptolites of the Quebec Group. *Figures and Descriptions of Canadian organic-remains*, Dec. **II**. 151 pp. Montreal, Canada geol. Surv.

Jackson, D. E. 1973. *Amplexograptus* and *Glyptograptus* isolated from Ordovician limestones in Manitoba. *Bull. geol. Surv. Can.*, Ottawa, **222:** 1–8.

Koren, T. N., Mikhailova, N. F. & Tsai, D. T. 1980. Class Graptolithina. Graptolity. *In* M. K. Apollonov, S. M. Bandaletov & I. F. Nikitin (eds), *The Ordovician–Silurian boundary in Kazakhstan.* 300 pp. Alma Ata, Nauka Kazakh S.S.R. Publ. Ho.

——, **Oradovskaya, M. M., Pylma, L. J., Sobolevskaya, R. F. & Chugaeva, M. N.** 1983. *The Ordovician and Silurian boundary in the Northeast of the U.S.S.R.* 208 pp., 48 pls. Leningrad, Nauka [In Russian].

Lapworth, C. 1877. On the graptolites of County Down. *Rep. Proc. Belf. Nat. Fld Club* **1876–77** (Appendix): 125–144, pls 5–7.

Lespérance, P. J. 1985. Faunal distributions across the Ordovician–Silurian boundary, Anticosti Island and Percé, Québec, Canada. *Can. J. Earth Sci.*, Ottawa, **22:** 838–849.

Lin Yao-kun & Chen Xu 1984. *Glyptograptus persculptus* Zone—the earliest Silurian graptolite zone from Yangzi Gorges, China. *In* Nanjing Institute of Geology and Palaeontology, Academia Sinica, *Stratigraphy and Palaeontology of Systemic Boundaries in China. Ordovician–Silurian Boundary* **1:** 199–223, pls 1–6. Anhui Sci. Tech. Publ. House.

Mu En-zhi, Ge Mei-yu, Chen Xu, Ni Yu-nan & Lin Yao-kun 1974. *In*: *A Handbook of the stratigraphy and palaeontology of Southwest China*: 154–221. China Publishing House, Nanjing.

—— **& Lin Yao-kun** 1984. Graptolites from the Ordovician–Silurian boundary sections of Yichang area, W. Hubei. *In* Nanjing Institute of Geology and Palaeontology, Academia Sinica, *Stratigraphy and Palaeontology of Systemic Boundaries in China. Ordovician–Silurian Boundary* **1:** 45–73. Anhui Sci. Tech. Publ. House.

Nicholson, H. A. 1869. On some new Species of Graptolites. *Ann. Mag. nat. Hist.*, London, (4) **4:** 231–242.

Obut, A. M. 1949. *Polievoj atlas rukovodyashchikh graptolitov verkhnego silura Kirghizskoj S.S.R.*: 1–57, pls 1–7. Publishing House of the Academy of Science of the U.S.S.R., Frunze.

—— 1975. Tip *Hemichordata*–Klass *Graptoloidea*. *In* A. A. Nikolaev *et al.* (eds), *Polievoj atlas silurijskoj fauny severo-vostoka S.S.S.R.*: 145–183. Magadan.

Perner, J. 1895. Studie o ceskych graptolitech, cast II. *Palaeontogr. Bohem.*, Prague, **3b:** 1–52, pls 1–8.

Petryk, A. A. 1979. *Stratigraphie revisée de l'Île d'Anticosti.* Québec Ministère de l'Energie et des Ressourses, **DPV-711:** 1–24.

Přibyl, A. 1947. Classification of the genus *Climacograptus* Hall, 1865. *Bull. int. Acad. tchéque Sci.*, Prague, An. **48** (2): 1–12, pls 1–2.

—— 1948. Some new subgenera of graptolites from the Families *Dimorphograptidae* and *Diplograptidae*. *Věst. st. geol. Ust. čsl. Repub.*, Prague, **23:** 37–48.

—— 1951. Revision of the *Diplograptidae* and *Glossograptidae* of the Ordovician of Bohemia. *Bull. int. Acad. tchéque Sci.*, Prague, **50** (1949): 1–51, pls 1–5.

Rickards, R. B. 1970. The Llandovery (Silurian) graptolites of the Howgill Fells, Northern England. *Palaeontogr. Soc.* (*Monogr.*), London. 108 pp., 8 pls.

Riva, J. 1969. Middle and Upper Ordovician graptolite faunas of the St Lawrence Lowlands, and of Anticosti Island. *Mem. Am. Ass. Petrol. Geol.*, Tulsa, **12:** 513–556.

—— 1974*a*. Graptolites with multiple genicular spines from the Upper Ordovician of Western North America. *Can. J. Earth Sci.*, Ottawa, **11:** 1455–1460.

—— 1974*b*. A revision of some Ordovician graptolites of eastern North America. *Palaeontology*, London, **17**: 1–40.

—— 1976. *Climacograptus bicornis bicornis* (Hall), its ancestor and likely descendants. *In* M. G. Bassett (ed.), *The Ordovician System: Proceedings of a Palaeontological Association symposium, Birmingham, September 1974*: 589–619. Cardiff, Univ. Wales Press & Natl Mus. Wales.

—— 1987. The species *Amplexograptus praetypicalis* n. sp. and the origin of the *typicalis* group. *Can. J. Earth Sci.*, Ottawa, **24** (5): 924–933.

—— **& Petryk, A. A.** 1981. Graptolites from the Upper Ordovician and Lower Silurian of Anticosti Island and the position of the Ordovician–Silurian Boundary. *In* P. J. Lespérance (ed.), *Field Meeting, Anticosti–Gaspé, Quebec, 1981* **2** (Stratigraphy and paleontology): 159–164. Montréal (I.U.G.S Subcommission on Silurian Stratigraphy Ordovician–Silurian Boundary Working Group).

Strachan, I. 1954. The structure and development of *Peiragraptus fallax* gen. and sp. nov. *Geol. Mag.*, Hertford, **91**: 509–513.

—— 1971. A synoptic supplement to 'A Monograph of British Graptolites by Miss G. L. Elles and Miss E. M. R. Wood'. *Palaeontogr. Soc.* (*Monogr.*), London. 130 pp.

Toghill, P. 1968. Graptolite assemblages and zones of the Birkhill shales (Lower Silurian) at Dobb's Linn. *Palaeontology*, London, **11**: 654–668.

—— 1970. Highest Ordovician (Hartfell Shales) graptolite faunas from the Moffat area, South Scotland. *Bull. Br. Mus. nat. Hist.*, London, (Geol.) **19**: 1–26, pls 1–16.

Twenhofel, W. H. 1928. Geology of Anticosti Island. *Mem. geol. Surv. Brch Canada*, Ottawa, **154**: 1–481.

VandenBerg, A. H. M. 1981*a*. Victorian stages and graptolite zones. *In* B. D. Webby (ed.), *The Ordovician System in Australia, New Zealand and Antarctica*: 2–6. I.U.G.S. Publication 6.

—— (1981*b*). A complete Late Ordovician graptolite sequence at Mountain Creek near Deddick, eastern Victoria. Unpubl. report, geol. Surv. Victoria 1981/81.

Walters, M. 1977. Middle and Upper Ordovician graptolites from the St Lawrence Lowlands, Québec, Canada. *Can. J. Earth Sci.*, Ottawa, **14**: 932–952.

Wang Xiao-feng 1983. Latest Ordovician and earliest Silurian faunas from the eastern Yangtze Gorges, China, with comments on Ordovician–Silurian boundary. *Bull. Yichang Inst. Geol. Min. Res.* **6**: 129–163.

Williams, S. H. 1982. The Late Ordovician graptolite fauna of the Anceps Bands at Dob's Linn, southern Scotland. *Geologica Palaeont.*, Marburg, **16**: 29–56, 4 pls.

—— 1983. The Ordovician–Silurian boundary graptolite fauna at Dob's Linn, southern Scotland. *Palaeontology*, London, **26**: 605–639.