Lower Ordovician graptolites from Gausdal, central southern Norway: a reassessment of the fauna

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In 1889 and 1890 K. O. Bjørlykke collected graptolites from a phyllite in Gausdal, west of Lillehammer. His brief description of the fauna was the first article published in the *Norges geologiske Undersøkelse* series. The fossils were subsequently described in greater detail by C. Lapworth, but later thought to be lost. The collection has been rediscovered, as has the original locality at Bratland which has yielded additional material. Reassessment of the fauna suggests a middle Arenig to early Llanvirn age for the phyllite unit, which is bounded by the late Precambrian Hedmark Group and Lower Ordovician Gausdal Formation. A dominant first cleavage post-dates graptolite mineralisation and minor quartz veining; it is cut locally by a less well developed second cleavage and by minor folds and faults. The phyllite, which together with adjacent stratigraphical units appears to be part of the allochthonous Synfjell thrust sheet, has been subjected to greenschist facies metamorphism.

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Introduction

The graptolites from the parautochthonous Lower Palaeozoic succession of the Oslo Region, southern Norway are well known and have been studied thoroughly over the past century. The Ordovician graptolites range from Tremadoc (Bruton et al. 1982) through Arenig and Llanvirn to early Llandeilo (Monsen 1937, Berry 1964), and also occur locally in Caradoc and Ashgill strata (Williams & Bruton 1983). In contrast, very few graptolites have been recorded from the Lower Ordovician metasediments in the allochthonous Caledonides less than 150 km to the north. Although substantial research has been carried out in the area over the past twenty years on both the Lower Palaeozoic and underlying late Precambrian to early Cambrian Hedmark Group (e.g. Løberg 1970, Englund 1973a, b, Hossack et al. 1981, Nystuen 1982), this has concentrated largely on structural and lithostratigraphical problems. Few graptolites have been collected since Strand (1938), while none have been described since Lapworth (1905). The present study records the rediscovery of Bjørlykke's 'lost' collection, described by himself in 1891 and by Lapworth in 1905. In conjunction with small collections of comparative material, the fauna is here revised in the light of recent research elsewhere (e.g. Cooper & Fortey 1982) and its biostratigraphical implications reconsidered.

History of the collection

In the summer of 1889 K. O. Bjørlykke had virtually completed geological mapping for the 'Vestre Gausdal' Sheet, which was published by Norges geologiske undersøkelse (Norwegian Geological Survey) in 1893. He considered that the discovery of fossils in this 'palaeontologically barren' area would prove a great breakthrough and with this in mind set out on 10 July to

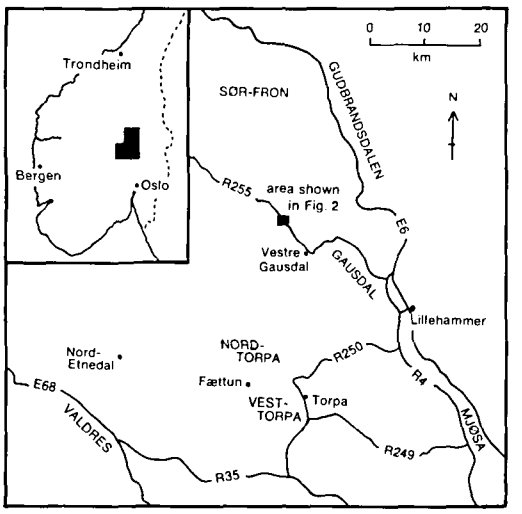

Fig. 1. Map showing the location of Gausdal, the area shown in Fig. 2, and neighbouring localities.

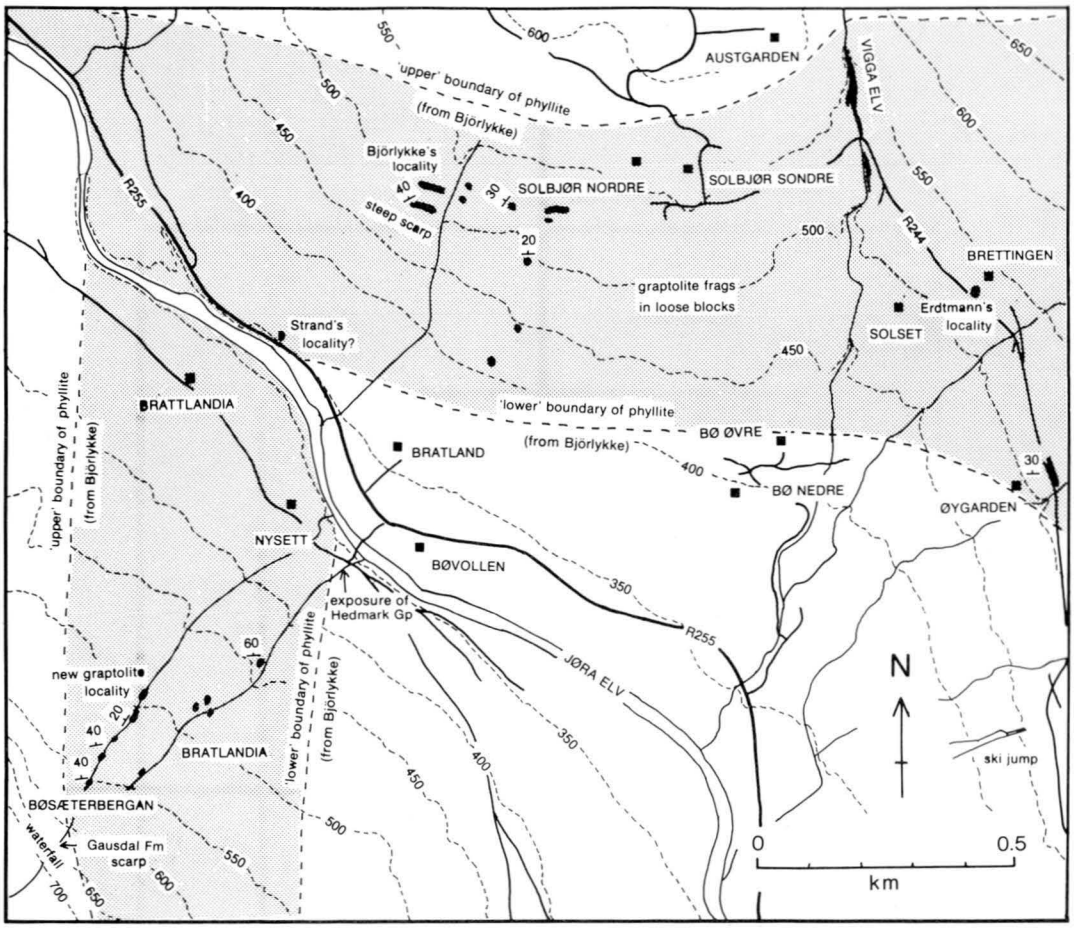

Fig. 2. Map of the area around Bratland, Gausdal, showing positions of the phyllite localities visited during the present study. The boundaries of the phyllite outcrop are taken from Bjørlykke's 1:50,000 geological map V, Gausdal, published by N.G.U. in 1893. Dip and strike symbols are of cleavage. Topography is adapted from the 1:5,000 geographical sheets Bøsætre CH 076–5–3 and Bødalen CH 076–5–4 published by Fylkeskartkontoret i Oppland.

investigate the potential of the sedimentary rocks north of Vestre Gausdal (Bjørlykke 1891, p. 1). After looking unsuccessfully at the limestone of the 'Sparagmite Group' (Hedmark Group of modern authors) he decided to visit an east-west striking exposure of shale/phyllite some 200 m above the houses at Bratland (Figs 1&2). On his way to the locality he found graptolites in loose blocks in a ditch, then found them *in situ* at the exposure. No further detail concerning the exact location of the exposure was given. Further collecting, both by himself and with Th. Münster who was working on the 'Lillehammer' Sheet to the south (published 1900), revealed a great number of graptolites at Bratland and rarer, but less weathered, specimens in the River Vigga 1 km to the east and at other smaller localities. In addition they found graptolites in the River Valaaen some 3 km to the south.

From the material collected in 1889, Bjørlykke (1891) published several identifications, together with brief remarks and somewhat idealised illustrations of the taxa. He concluded that while some of the fauna (e.g. *Didymograptus geminus* (Hisinger), *Diplograptus teretiusculus* (Hisinger) and *Pterograptus elegans* (Holm) were characteristic of 'etage 4a' (Llanvirn), others, such as *Tetragraptus bryonoides* Hall and uncertain *Phyllograptus* remains, indicated the middle of 'etage 3' (Arenig).

In late June or July 1890, Prof. C. Lapworth visited Oslo (then Kristiania) during a tour of Scandinavia. H. Reusch, Director of N.G.U., wrote a postcard to him on 11 July 1890, still

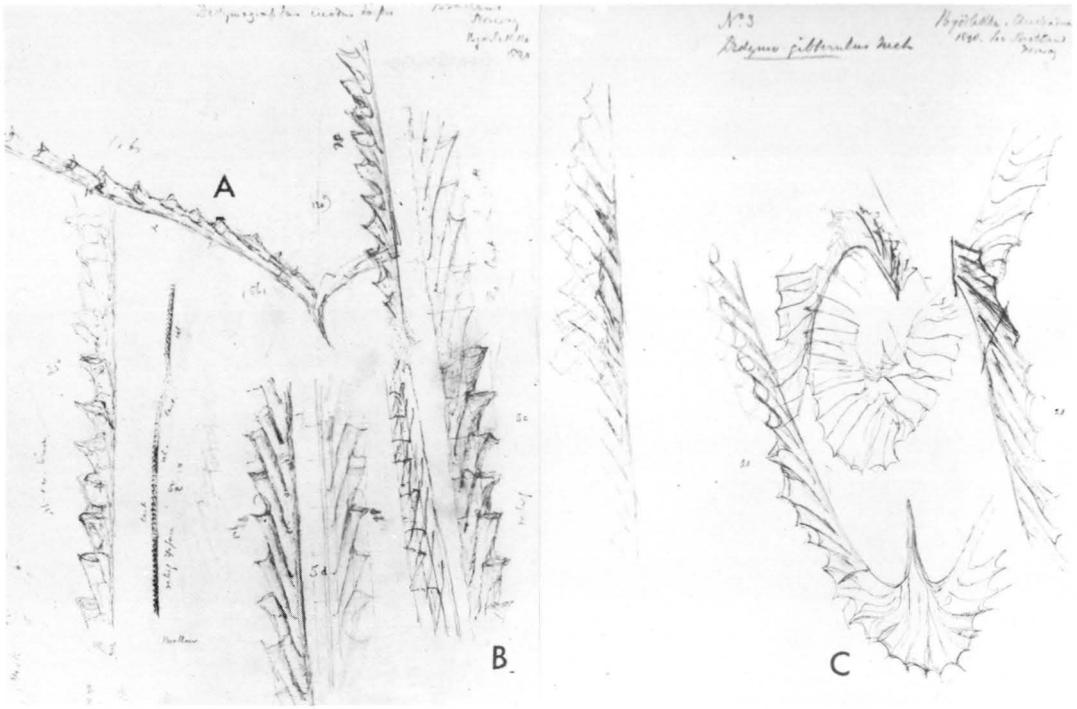

Fig. 3. Copies of Lapworth's original sketches (X1/3). Modern lettering refers to specimens located during the present study.
Left: *Didymograptus (Expansograptus) euodus bjoerlykki* Lapworth, 1905. Note construction grid used to facilitate accurate drawing. A. PMO 109.327. Lectotype, with enlargement (idealised?) of proximal end above. B. PMO 109.326.
Right: *Isograptus caduceus* cf. *gibberulus* (Nicholson 1875). C. PMO 109.329. Note that the other specimens are not on the same slab.

preserved in Birmingham University, where he informed Lapworth of Bjørlykke's discovery and invited him to look at the graptolites while in Oslo. Following Lapworth's visit to Scandinavia, which must have been relatively short as he had to be present for a meeting in Edinburgh in mid-August (I. Strachan, pers. comm.), Bjørlykke wrote a letter to him on 20 September 1890 which is also preserved in Birmingham University. He summarised the stratigraphical position of his findings, concluding that they were «older than the Zone of *Didymograptus geminus*.» The letter was sent together with the collection made in the summer of 1889, but it also includes reference to a second collection which Bjørlykke promised to send soon afterwards. Intriguingly there is a complete lack of reference to Bjørlykke's paper on the graptolites, which by that time must have been submitted and had possibly gone to proof to become the first article in the *Norges geologiske Undesøkelse* series. The only reference in this publication to Lapworth's visit and casual identifications is in the form of footnotes (Bjørlykke 1891, pp. 4,5). I conclude that the paper was submitted and had been sent to the printers before knowledge of Lapworth's proposed visit to Kristiania. When Lapworth looked at the collection and suggested a number of revised identifications it was too late to withdraw or substantially alter the paper and the only amendments possible to the proof were the insertion of simple footnotes.

When Lapworth received the collections he made notes and sketches and constructed a final plate. Copies of these were returned to Bjørlykke together with the collection early in 1891. Lapworth's identifications were listed by Bjørlykke (1893, p. 18) in his description of the Gausdal sheet, including a number of new 'manuscript' species. While Bjørlykke was preparing his major account on 'Det centrale Norges fjeldbygning' ('The mountain chain of central Norway') which was published in 1905, it was decided to incorporate Lapworth's note as an appendix. Lapworth was unable to reexamine the collection but revised his notes and identifications, which included descriptions of the named taxa. He concluded (1905, p. 6) that the fauna indicated a correlation with the 'Phyllograptus skiffer' (Lower Didymograptus Shale = Tøyen Shale For-

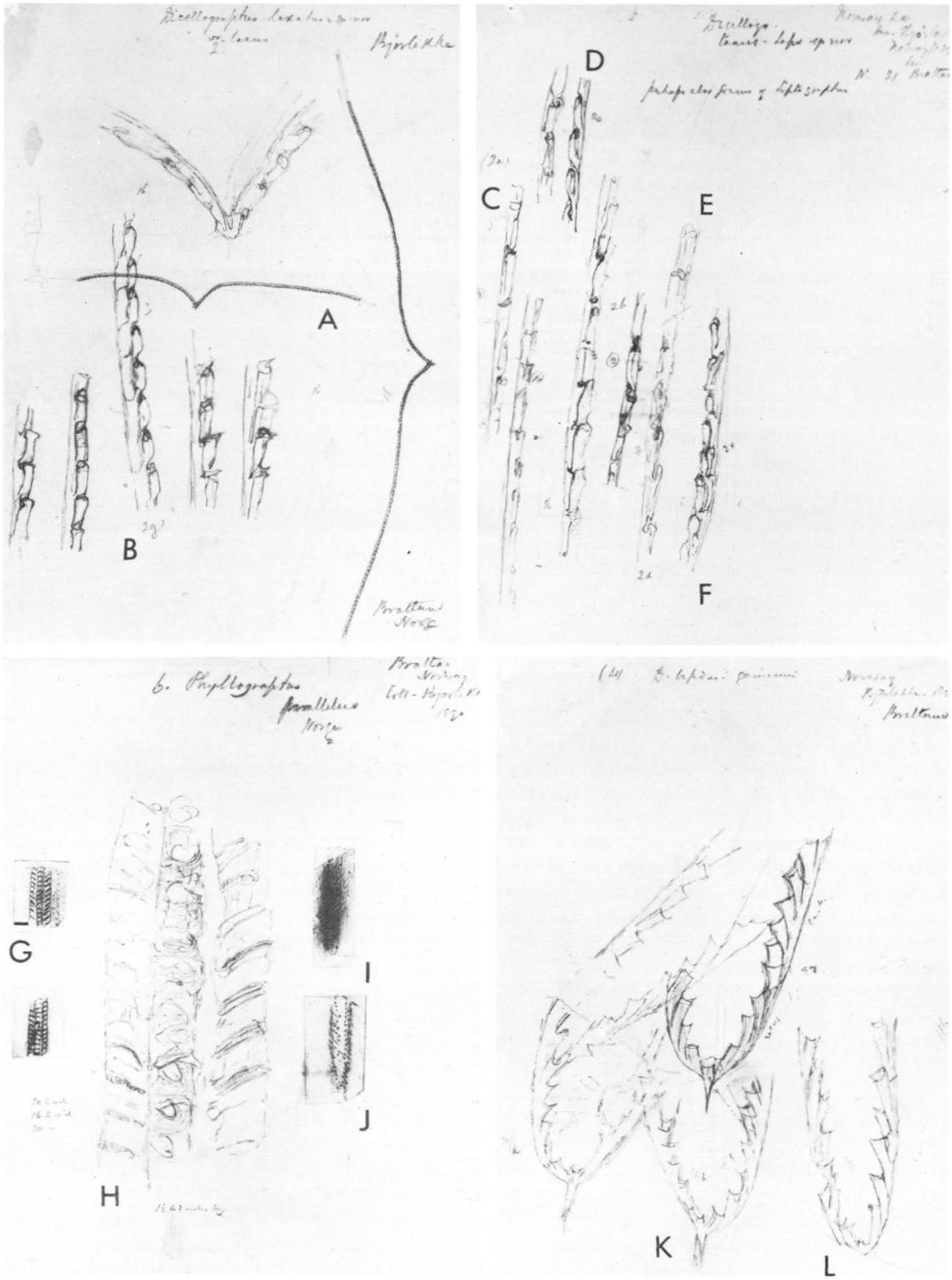

Fig. 4. Copies of Lapworth's original sketches (X1/3).
Top: *Holmograptus? laxatus* (Lapworth, 1905). A. PMO 109.317. Lectotype. B. PMO 109.322. Also figured Fig. 11D. C. PMO 109.326. D. PMO 109.221. E. PMO 109.325. F. PMO 109.323.
Bottom left: *Pseudophyllograptus angustifolius elongatus* (Bulman, 1931). G. PMO 109.333. H. PMO 109.334, 335. This specimen is now fragmented and the central thecal series missing. I. PMO 109.336. J. PMO 109.337?
Bottom right: *Didymograptus (Didymograptus?) geminus* (Hisinger 1840)? K. PMO 109.350. L. PMO 109.351.

mation of modern authors) of the Oslo Region, although the occurrence of *Diplograptus tereti-usculus* (Hisinger) and *Dicellograptus laxatus* sp. nov. suggested the occurrence of a second, later interval. In relation to the British succession he suggested (*op. cit.*, p. 7) a correlation with the higher Arenig (*D. extensus* and *D. hirundo* zones) and possibly the lowest 'Llandeilo' (*D. bifidus* and *D. murchisoni* zones). In Lapworth's publication there is oddly no reference to Bjørlykke's (1891) paper. He presumably must have known about it, although it was not apparently mentioned in their correspondance. Following Lapworth (1905) no further articles have been written on the graptolites, but they were referred to by Monsen (1937, pp. 65–67) and Erdtmann (1965, p. 530). Although Monsen included *'Didymograptus' gibberulus* Nicholson in her publication on Norwegian graptolites on the strength of Lapworth's description alone (1937, p. 155), she apparently did not examine the collection. Small collections have since been made by Strand, Seip, and Erdtmann but were seemingly not worked on. Meanwhile, the whereabouts of Bjørlykke's original collection became unknown, as did the exact position of the locality above Bratland. In 1977 a collection of graptolites from the Norges Landbrukshøgskole (Agricultural University of Norway) at Ås near Oslo (where Bjørlykke was Professor in Geology) was forwarded to the Paleontologisk Museum, Oslo by Dr. J. P. Nystuen. The collection included specimens from Bratland which had been numbered in white paint or ink. The numbers appeared to correspond with the figure numbers on Lapworth's published plate and it was concluded that the material must represent the figured type specimens and, indeed, the complete collection (Bruton 1977). They were consequently given PMO catalogue numbers and housed in the museum's type collection.

In 1982 Dr. D. L. Bruton drew my attention to the collection hoping that a modern reappraisal of the fauna would result in a more precise biostratigraphical identity. A search through the museum's non-type collection for comparative material revealed four draws of specimens from Gausdal in addition to those collected by Seip and Erdtmann. Two of these contained a few catalogued specimens collected by Strand and, interestingly enough, Bjørlykke, while the remaining two were crammed full of several hundred uncatalogued slabs in cardboard trays with handwritten labels. Many of the specimens also had the same white numbers as those in the collection from the Norges Landbrukshøgskole, which were clearly written with an old-fashioned 'mapping pen' due to the scratches left. Comparison with specimens of handwriting revealed that both the identification labels and white numbers were written by Bjørlykke. A number of slabs additionally had red pencil or crayon marks.

A check on the material housed in the type collection revealed that the vast majority of specimens were not the figured ones, while in several cases identifications deduced from the white numbers were clearly incorrect. At this stage in the investigation, Dr. I. Strachan fortuitously sent me copies of Lapworth's original sketches made in 1890 which are still preserved at Birmingham University (Figs. 3–5). Several points became immediately apparent; first, the sketches were far less idealised and contained more information about the positioning of specimens in relation to the edges of the slabs and other specimens than the final plate figures. Secondly, the numbers assigned to the taxa in the sketches were partly different from those used in the published plate, but agreed with the white numbers on the slabs. Third, several of the identifications included names, some of them new, which were not used in Lapworth's published article of 1905 but which were quoted by Bjørlykke in 1893. Some associated sketches were drawn with red pencil or crayon, suggesting that the red crayon marks on the slabs were Lapworth's.

It became evident that several, if not all, of the type specimens had to be present in the previously uncatalogued collection of several hundred slabs. Most of these have now been found by use of the original sketches. The locating of types was made slightly easier by the fact that Lapworth did not appear to have had a 'camera lucida' microscope at this time and drew a simple pencil grid (sometimes only a single line) on the slab to permit accurate drawing, normally at magnifications of X1 or X10. In addition, although most specimens were allotted an identification by a single number, those which were drawn were normally also given a letter which was indicated on the sketch. The mystery of why and how Bjørlykke, rather than Lapworth, wrote the white reference numbers on the slabs remains. Lapworth normally used identification labels on slabs rather than numbers (I. Stachan, pers. comm.) and these were possibly included loose in the (presumably) wrapped specimens.

Thus, the complete collection studied by Lapworth, including most of the figured material, has

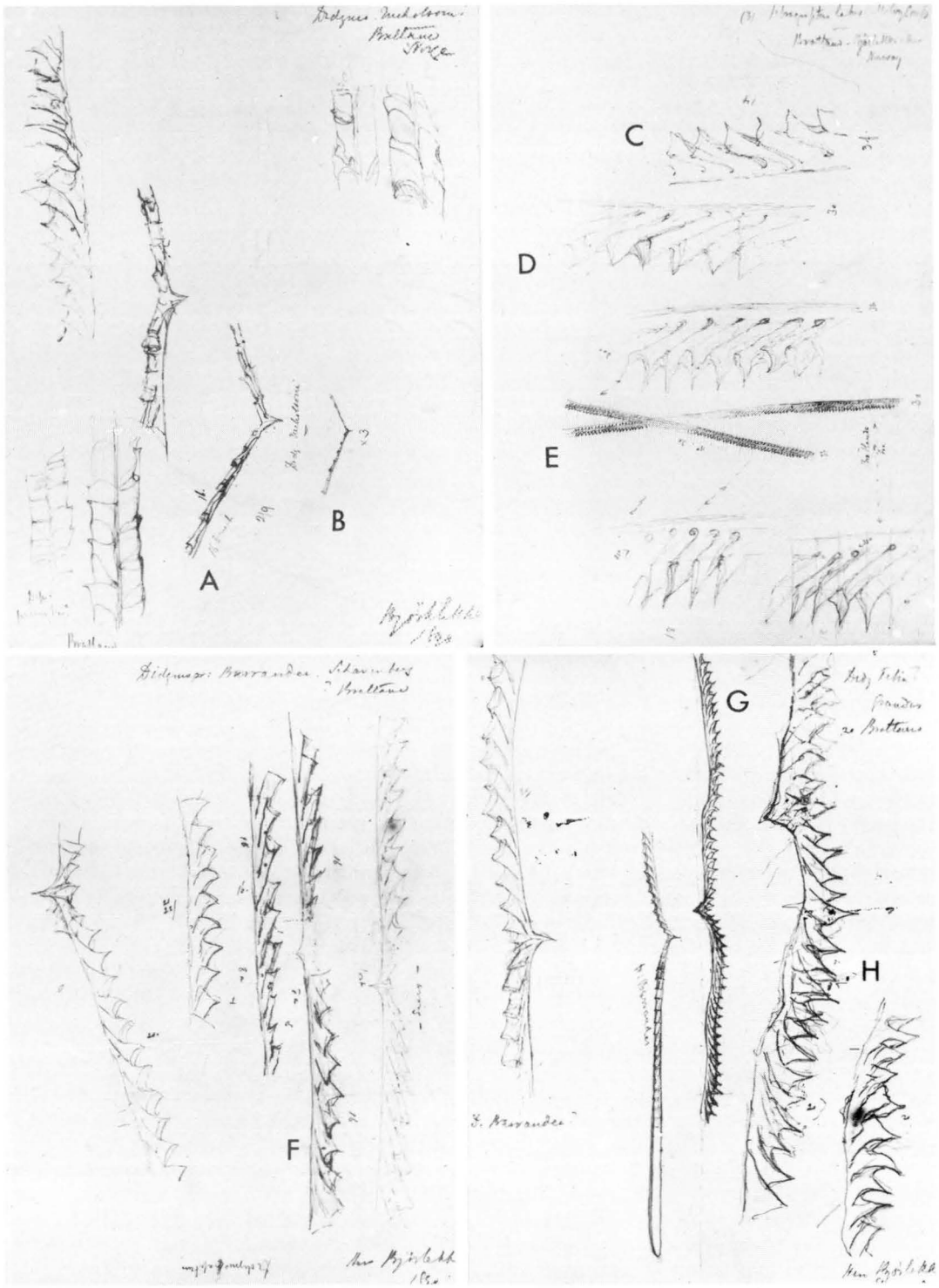

Fig. 5. Top left: *Acrograptus affinis* (Nicholson, 1869) and others. A. PMO 109.332. B. Enlargement of A.
Top right: *Didymograptus (Expansograptus) hirundo* Salter, 1863. C. PMO 109.338? D. PMO 109.318 (reverse of slab with PMO 109.317, *H? laxatus* lectotype). E. PMO 39851. Large part of slab now missing, counterpart of part of missing slab on PMO 109.328.
Bottom left: *Xiphograptus sp. cf. Didymograptus (Expansograptus) similis* (Hall, 1865). F. PMO 109.331.
Bottom right: *Didymograptus (Expansograptus) hirundo* Salter, 1863 and others. G. PMO 109.330. Also figured Fig. 11A. H. Enlargement of G.

now been located. Well preserved and distinctive specimens have been removed from their original crammed trays and catalogued, as have all the type figured specimens. Remaining slabs have been left in the drawers labelled 'Gausdal', housed in the regional non-type collection at the Paleontologisk Museum, together with amended notes.

The final problem concerning the whereabouts of the collection used by Bjørlykke in his 1891 publication was solved easily. This was represented by the catalogued specimens in an adjacent drawer. It was catalogued around 1920, although it was evidently not realised that this was Bjørlykke's type collection. Many of the specimens have deteriorated even more badly than those in the later Bjørlykke collection. Bjørlykke's handwritten labels are in several cases applicable only to single specimens and these must, therefore, represent the figured material. They have been separated as figured type material where they appear to correspond to Bjørlykke's somewhat idealised drawings. They show no white numbers or red pencil marks. One specimen was, however, figured by Lapworth as a 'dichograptid sp.' (1905, fig. 5a) and the slab shows some faint pencil marks. Lapworth must therefore have seen the collection and it is probably the first of the two collections referred to by Bjørlykke in his letter of September 1890.

SPECIMENS IDENTIFIED FROM LAPWORTH'S PLATE AND NOW CATALOGUED

2a. PMO 109.317. 2b. PMO 109.322. 4a. PMO 109.326? 4b. 109.327. 4c. PMO 109.326. 5a. PMO 39851. 5b. PMO 39851. 5c. PMO 109.318. 6. PMO 109.329. 8. PMO 109.330. 9. PMO 109.332. 10. PMO 109.334, 335/336? (could be reconstruction).

SPECIMENS IDENTIFIED FROM BJØRLYKKE'S FIGURE

4. PMO 39824. 5. PMO 109.339. 6. PMO 39852. 10. PMO 39851.

Stratigraphical setting

Bjørlykke originally recorded the graptolites of Gausdal from dark grey 'shales' lying above the 'sparagmites' and below a grey-blue quartzite. He stated that the shale was at least 150 m thick around Bratland, although it varied at other localities from 10 to 170 m. He described the lowermost part to have a paler, green colour, the graptolites coming from the upper, darker grey part of the unit. Münster (1900, p. 33) considered the measured section in the Vigga River 1 km east of Bratland (Bjørlykke 1891, pp. 7–10) to be unrealiable due to folding and faulting, but agreed with the two-fold lithological division. Besides the fauna from Bratland and neighbouring localities (Bjørlykke 1891, p. 2; 1893, pp. 17–19), graptolites were found in the Torpa region and elsewhere to the south (Münster 1900, pp. 31–34). Here a basal division, considered to be correlated with that in Gausdal, yielded Cambrian and early Ordovician trilobites (*op. cit.*, pp. 22–28). Graptolites were later recorded from the apparently equivalent 'Phyllite Division' of the Nord-Etnedal area to the south-west (Strand 1938, pp. 20–23). These were identified by A. Monsen (*in* Strand, *op. cit.*, p. 21) and proved similar to those described from Bratland.

The graptolitic unit has been referred to variously as a 'graptolitskiffer' (graptolitic shale) and 'fyllitformasjonen' (the phyllite formation). It is here considered to be a phyllite, owing to the apparently complete destruction of bedding by a heavy cleavage and to its appearance in hand specimen; it could, however, be referred equally well to a high grade slate. The underlying rocks are part of the late Precambrian and early Cambrian sedimentary sequence known to earlier workers as the 'Sparagmite Group.' Løberg (1970) used this term when she mapped the area of Gausdal to the south-west of Bratland, although following detailed studies by a number of authors in adjacent areas (see Nystuen 1981, 1982) it is now termed the Hedmark Group. The quartzite overlying the graptolitic phyllite has been named the Gausdal Formation (Englund 1973a, p. 6), but the phyllite itself at Bratland has yet to be named.

Løberg (1970, pp. 190–193, fig. 14) described a continuous sedimentary transition from the Ringsaker Quartzite of the Vangsås Formation (top Hedmark Group) into 'Cambrian shales' and dark grey-green phyllite at Bjørgebekken 2 km south-west of Bratland. Englund (1973b, p. 20, fig. 11) termed the phyllite the Kvitberg Phyllite in the area around Gudbrandsdalen to the west and north. Both he and Løberg (1970) confirmed the presence of a green basal division as recorded originally by Bjørlykke which they referred to the Cambrian ('etage 1a-b'), although no fossil evidence was found. Englund (1973b, fig. 11) recorded a total thickness of 150 m for the phyllite in Gausdal, the basal 20 m being pale grey-green. J. R. Hossack (pers. comm.) considers that the green slate is part of the succession

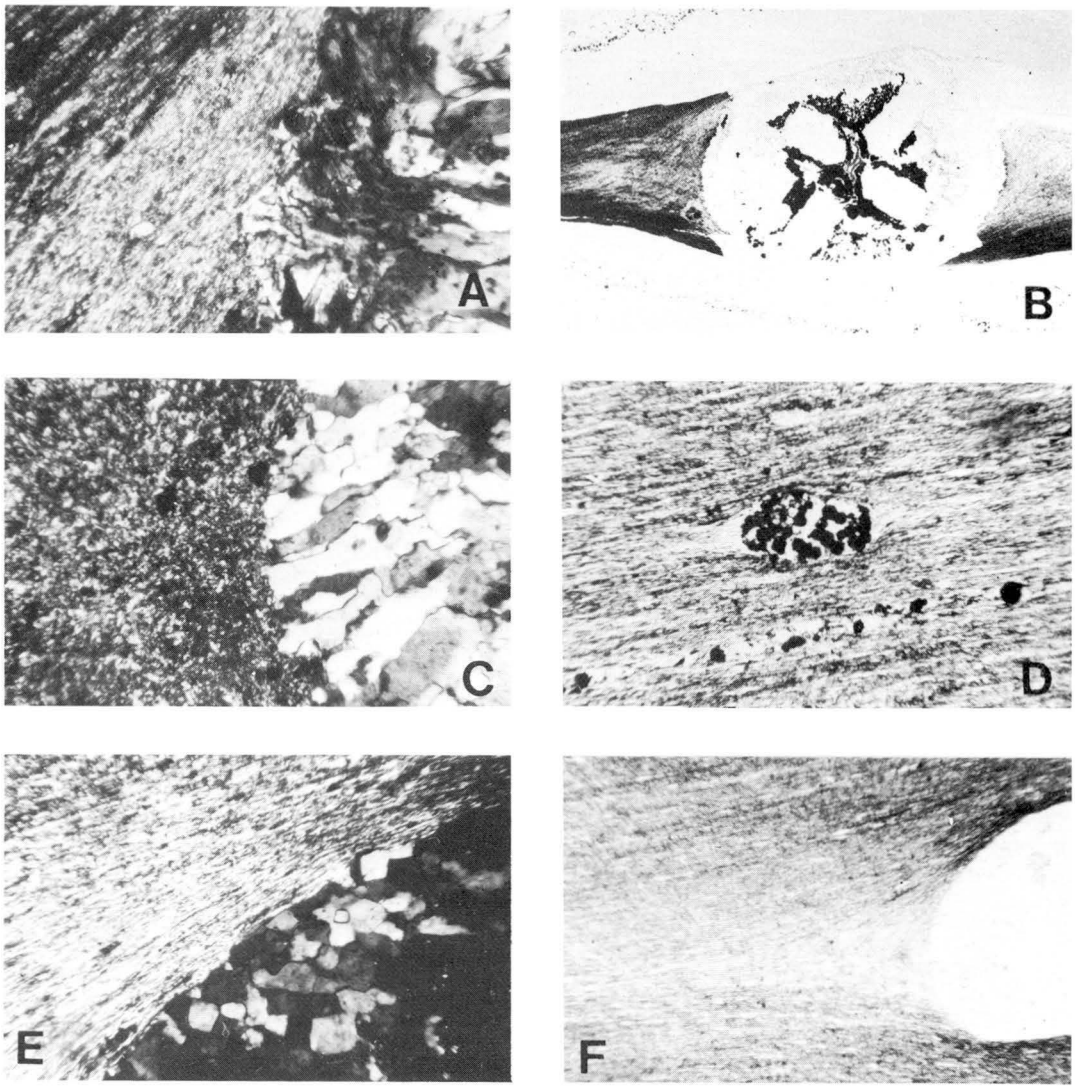

Fig. 6. Thin-section of the graptolitic phyllite near Bratland. A–C. Transverse section through a *Pseudophyllograptus*. A. Detail of cleavage in top left-hand part of the rhabdosome (crossed nicols, X100). B. General view showing bending of cleavage around rhabdosome (p.p.l., X4). C. Detail of randomly oriented sericite crystals in strain shadow to left, central part of the rhabdosome (crossed nicols, X100). D. Section through graptolite rhabdosome showing bending of cleavage (p.p.l., X150). E, F. Section through graptolite rhabdosome. E. Detail showing cleavage bending around top left hand part of rhabdosome (crossed nicols, X150). F. General view of left-hand side, showing strain shadow (p.p.l., X50).

associated with the Vangsås Formation but that the Kvitberg Phyllite above is equivalent to imbricated slates of the Ørnberget Formation, part of the succession associated with the structurally overlying Synnfjell thrust sheet (Nickelsen et al. in press). This thrust sheet has a different Eocambrian to Ordovician stratigraphy to that of the underlying thrust sheet containing the Vangsås Formation and the Cambrian slates. The two structural sucessions are separated by the Synnfjell thrust. Most of the Kvitberg Phyllite is considered to be structurally repeated stratigraphic equivalents of the Skrindsrud and Solheim Slate members of the Ørnberget Formation (Nickelsen et al., *op. cit.*). Hence, in the Bratland section the Synnfjell thrust carries Ørnberget Formation slates over Cambrian slates of the thrust sheet beneath and is consequently difficult to place exactly. The Bratland graptolite localities are within the Synnfjell thrust sheet and are

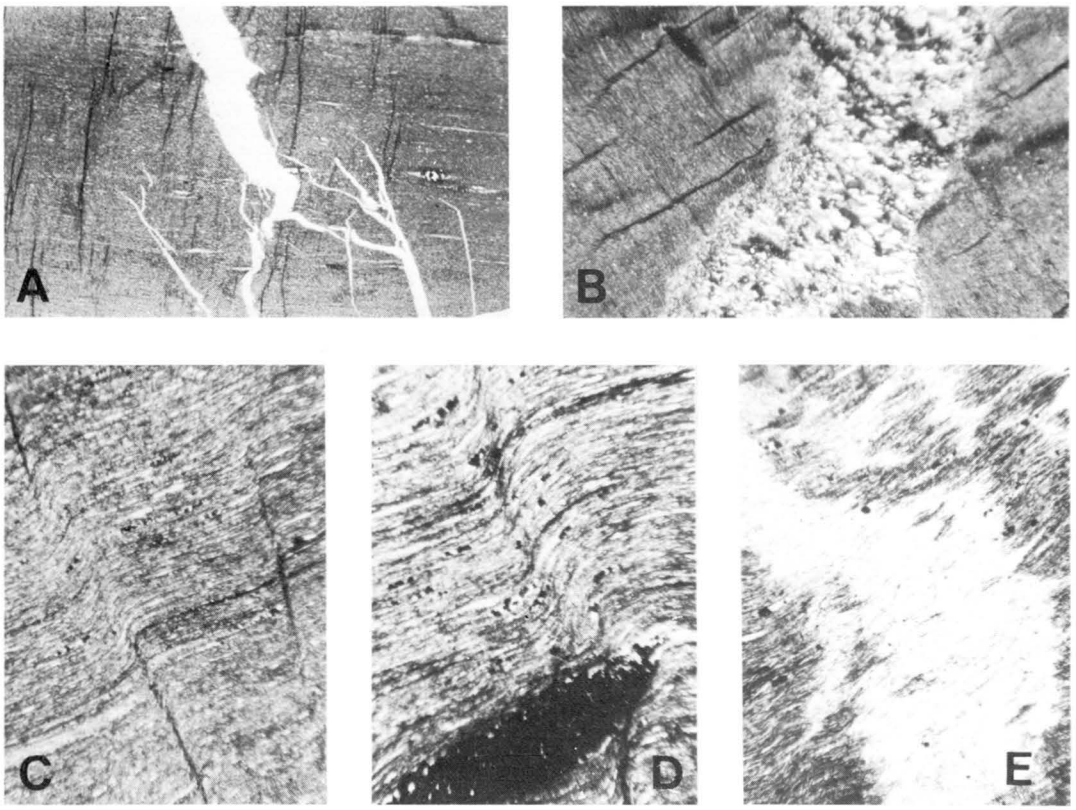

Fig. 7. Thin-section of the phyllite showing crenulation cleavage. A. General view of slab (p.p.l., X5). B. Detail of quartz vein and crenulation (crossed nicols, X20). C. Detail of crenulation (p.p.l, X50). D. Graptolite 'cutting' crenulation (p.p.l., X100). E. Detail of quartz vein; frayed edged and scattered cleavage traces indicate that vein injection predated cleavage formation (p.p.l., X100).

probably found within the Solheim Slate member (Nickelsen et al., *op. cit.*) of this sucession. Perhaps the graptolitic unit should be given this name in future works. With such tectonic complexities the logging of sections and estimating of thickness is not justifiable until marker horizons are found which permit the recognition of bedding, and allow identification of sedimentary, rather than structural contacts.

Lithology and structure

Bjørlykke (1891, 1983) evidently considered the foliation present in the phyllite unit to be bedding. On the basis of this he constructed a measured section at the Vigga River, although Münster (1900, p. 33) had misgivings about its validity, stating that the locality was clearly folded and faulted. In a geochemical study Englund (1973a) included a number of samples of the 'Cambro-Ordovician' phyllite and Gausdal Formation, most of which came from Vinstra some 35 km NNW from Bratland. He found them to yield relatively high contents of chlorite and organic material, but to contain lower percentages of albite and mica. He concluded that the pelites were derived from acid or intermediate rocks, most probably the Precambrian gneisses and sediments from the Hedmark Group.

The mineralogy of the phyllite is dominated by fine-grained quartz and sericite, with considerable quantities of chlorite, pyrite and organic material. The Gausdal Formation is composed predominantly of coarse-grained quartz with smaller amounts of chlorite, muscovite (apparently primary), sericite and pyrite, and rare alkali feldspar and plagioclase fragments. The quartz shows heavy strain-shadowing under crossed-nicols. The secondary sericite, and possibly the pyrite, was formed during cleavage formation which is marked by irregular stringers of these two minerals. All sedimentary clasts are fresh, angular and of low sphericity, implying rapid

deposition as suggested by Englund (1973b, p. 23).

The phyllite is heavily cleaved, no sign of bedding being visible. The cleavage bends around three-dimensionally preserved graptolites, resulting in drawn-out strain shadows in which cleavage is absent (Figs 6A–F). In the shadows, sericite is present but oriented haphazardly. Both this and the irregular cleaved margins of small quartz veins (Fig. 7E) demonstrate early, pre-cleavage mineralisation of both quartz and pyrite. Hossack et al. (1981, p. 24) considered that cleavage could already have been forming during the time of deposition of the Strondafjord Formation to the north-west (equivalent of the Gausdal Formation), implying extremely early onset of mineralisation. Larger scale quartz veining, commonly along faults, was observed in the field, indicating a second late period of quartz mineralisation.

One thin-section exhibits a crenulation cleavage (Figs. 7A–D); this occurs at a number of exposures, indicating a second, sporadically developed cleavage. It may, however, be a local feature related to minor late structures rather than in response to regional stress. Englund (1973b) considered the area to have undergone greenschist facies metamorphism. Although more detailed petrological study is required to confirm this, such a degree of metamorphism seems reasonable from the overall structure and mineralogy observed. It is, therefore, clear that the foliation measured by Bjørlykke as bedding was actually cleavage. The bedding may have been strongly folded, as is often the case with a soft, incompetent lithology in an otherwise competent, deformed sequence, and the discovery of marker horizons such as thin silt or sandstone laminae is needed to elucidate this problem. Dip and strike orientations reveal a sharp anomaly between orientation of cleavage and lithological boundaries on the valley side southwest of Bratland, although they are almost coincident on the northeastern valley slope. As stated in the previous section, the lower boundary has been observed to be a transitional, sedimentary one just south of the area studied (Løberg 1970), while the upper one with the Gausdal Formation is likely to be tectonic.

The preservation of graptolites in such a highly metamorphosed area is an enigma; although they were protected to an extent by early mineralisation, one normally expects graptolites to be 'sheared out' along planes of heavy cleavage and to be preserved only where they cut the cleavage direction in fold hinges (e.g. Jenkins et al. 1982). Although the majority of phyllite outcrops in Gausdal are apparently non-graptolitic, all thin-sections reveal probable graptolite rhabdosomes. Structural analysis and critical collecting of the graptolitic unit is clearly required, but is beyond the scope of the present study.

Biostratigraphical correlation

As noted by Lapworth (1905, p. 2) the graptolites from Bratland have suffered tectonic distortion and measurements are unreliable. In contrast to most deformed graptolites, the degree and effects of the deformation are, however, unclear and identifications are therefore somewhat tentative (see Systematic Section). Most of the taxa listed below are found at Bratland, although *Phyllograptus anna* and *Undulograptus* are found only at other localities, mostly Nordtorpa. The graptolites observed during the present study of Bjørlykke's collection of comparative material are considered to be assignable to the following taxa:

Tetragraptus (Tetragraptus) pseudobigsbyi Skevington
Tetragraptus (Pendeograptus) pendens Elles?
Didymograptus (Didymograptus?) geminus (Hisinger)?
Didymograptus (Expansograptus) euodus bjoerlykki Lapworth
Didymograptus (Expansograptus) hirundo Salter
Pseudophyllograptus angustifolius elongatus (Bulman)
Isograptus caduceus cf. *gibberulus* (Nicholson)
Acrograptus affinis (Nicholson)
Holmograptus? laxatus (Lapworth)
Phyllograptus anna Hall
Xiphograptus sp. cf. *Didymograptus (Expansograptus) similis* (Hall)
Glyptograptus cf. *dentatus* (Brongniart)
Undulograptus spp. indet.

Unfortunately, the stratigraphical usefulness of many of the taxa is limited by their long ranges. This problem is compounded by the general lack of published detailed range charts through continuously graptolitic successions elsewhere. Cooper (1979) and Cooper & Fortey (1982) provide such information, and by comparison with these and more generalised listings (e.g. Jackson 1962) an approximate age may be deduced. With the exception of *D. (D?) geminus?* which implies an upper Llanvirn age, the taxa may all be found in an interval lasting from middle Arenig to lower Llanvirn (*D. nitidus* or *I. gibberulus* Subzone to *'D. bifidus'* Zone of the British sequence). This is approximately equivalent to the *D. protobifidus* to *G. austrodentatus* zones of the Australasian sequence and the V1c to V4b of the Spitsbergen succession (Cooper & Fortey 1982, fig. 2).

Such a correlation is surprisingly similar to

that deduced by Lapworth (1905), when considering that most of the identifications listed here are different. By comparison with Monsen (1937) it would appear that the Bratland phyllite has both a younger base and top than the Lower Didymograptus Shale of the Oslo Region, which ranges from lowest Arenig (*T. approximatus* Zone) to a level below the first appearance of the diplograptids. A broadly equivalent fauna to that from the Bratland unit was found in the Bogo Shale of the Trondheim region by Blake (1962), implying at least a partial correlation.

If future structural analysis can permit elucidation of the tectonic structure a biostratigraphical subdivision of the phyllite may prove possible. More detailed taxonomic work will also, however, require a solution to the anomalous dimensions of the graptolites which currently limits the precision of taxonomic identifications.

Systematic section

All specimens are from Bjørlykke's collection, made above Bratland, Gausdal, from 1889 to 1890, unless otherwise strated. Although deformation is present, its effects are unknown; present surface lineations and apparent stretching directions are therefore meaningless and are not indicated on illustrations. The majority of specimens preserved in relief have suffered 'pyrite rot', both before and after collecting. Several of the types figured by Bjørlykke and Lapworth have deteriorated noticeably, some having lost all trace of detail originally present. Stippling on figures indicates presence of periderm or pyrite, heavy stippling shows presence of rotted pyrite. The synonomies given here are summaries only; fuller listings can be found in the references cited. Besides those in Bjørlykke's collection, specimens have been used which were collected by T. Strand in 1945 (from directly north of the fields at Bratland), by B.D. Erdtmann in 1965 (from the road leading to Brettingen farm) and by H.C. Seip (from loose blocks in the valley). All figured and well-preserved material is catalogued and housed in the Paleontologisk Museum, Oslo (PMO). Other specimens remain uncatalogued and are housed in the Gausdal section of the geographical collections of the Museum.

Order GRAPTOLOIDEA Lapworth, 1875
Family DICHOGRAPTIDAE Lapworth, 1873
Subfamily DICHOGRAPTINAE Lapworth, 1873
Form-genus *Tetragratus* Salter, 1863

Sub-genus *Tetragraptus (Tetragraptus)* Salter, 1863

Type species (by original designation). *Fucoides serra* Brongniart, 1828, p. 71, pl. 6, figs 7, 8.

***Tetragraptus (Tetragraptus) pseudobigsbyi* Skevington, 1965, Figs. 8A–E, 11E, F?, G?**

1865 *Graptolithus bigsbyi*, Hall; Hall *(pars)*, pp. 86–88, pl. 16, figs. 22–24, 27, 28 (*non* figs 25, 26, 29, 30 = *T. (T.) bigsbyi s.s.)*.
?1891 *Tetragraptus bryonoides* Hall; Bjørlykke, p. 5, fig. 3.
1965 *Tetragraptus pseudobigsbyi* sp. nov.; Skevington, pp. 8–9, fig. 2.
1982 *Tetragraptus (Tetragraptus) pseudobigsbyi* Skevington; Cooper & Fortey, pp. 202–203, pl. 5, fig. 7, text-figs 8a, 23a, b.

Holotype. GSC 923 b (Geol. Surv. Canada Coll., Ottawa). From Pt. Levis, Quebec. Figured Hall (1865, pl. 16, fig. 23) and Skevington (1965, fig. 2).

Diagnosis. Not yet given.

Material. Fifteen flattened specimens.

Description. Small rhabdosome with straight or slightly convex stipes up to 25 mm long (normally up to 15 mm long), measuring an almost constant 2–3 mm width throughout their length. The sicula is long, measuring up to 4 mm, with th1[1] budding high up from near the apex. Remaining proximal development is unclear. Following initial development, thecae are inclined at 30–45° to the dorsal wall, bending horizontal just before their apertures.

Remarks. Cooper & Fortey (1982, p. 203) consider that *T. (T.) pseudobigsbyi* is separable from *T. (T.) serra* (Brongniart, 1828) only by its more strongly reclined stipes and more closely spaced thecae.

The overall form of the Gausdal specimens is similar to the type of *T. (T.) pseudobigsbyi* but the stipes narrower (2–3 mm as opposed to 3.5 mm of the holotype) and the thecal count lower (8–10 in 10 mm instead of 12–13 in 10 mm). These figures may, however, have been affected by tectonic distortion and the discrepancies are not considered important.

Subgenus *Tetragraptus (Pendeograptus)* Bouček & Přibyl, 1951.

Type species (by original designation). *Tetragraptus pendens* Elles, 1898, p. 491, text-fig. 13.

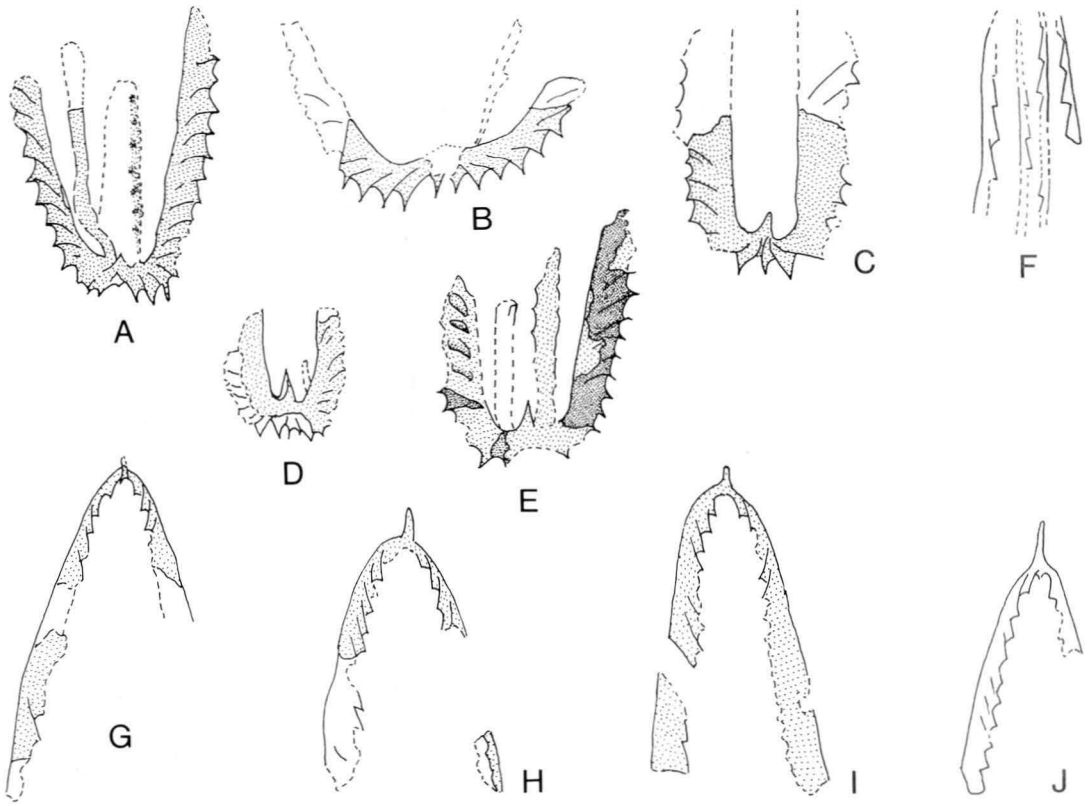

Fig. 8. *Tetragraptus (Tetragraptus) pseudobigsbyi* Skevington, 1965. (all X2 except D, X5). A. PMO 109.241. Erdtmann Coll. B. PMO 109.293. Bjørlykke Coll. C. PMO 109.233. Erdtmann Coll. D. PMO 65740. Strand Coll. E. PMO 65733. Strand Coll. F. *Tetragraptus (Pendeograptus) pendens* Elles, 1898? PMO 39824. Bjørlykke Coll. Figured Bjørlykke (1891, fig. 4) (X2). G–J. *Didymograptus (Didymograptus?) geminus* (Hisinger 1840)? Bjørlykke Coll. (x2). G. PMO 39834. H. PMO 109.272. I. PMO 39833. J. PMO 39840.

***Tetragraptus (Pendeograptus) pendens* Elles, 1898? Fig. 8F.**

1891 *Pterograptus elegans* Holm; Bjørlykke, p. 4, fig. 4.
?1898 *Tetragraptus pendens* sp. nov.; Elles, p. 491, text-fig. 13.
?1979 *Tetragraptus pendens* Elles; Cooper, p. 65, pl. 6, fig. f, text-fig. 34b.

Type specimen. Not yet designated. Elles' material is from the Skiddaw Group of the English Lake District.

Diagnosis. Not yet given.

Material. The one poor specimen figured by Bjørlykke.

Remarks. Positive identification of this specimen is impossible at both generic and specific level. It does, however, appear to belong to the subgenus *Tetragraptus (Pendeograptus)* and has a similar overall form to *T. (P.) pendens*. The stipe widths of 1 mm and (anomalous?) thecal density equivalent to 4 in 10 mm are, however, notably different. Although the thecal apertures do not appear denticulate, this may be due to poor preservation.

Genus *Didymograptus* M'Coy, 1851.

Type species (subsequently designated Miller 1889). *Graptolithes Murchisoni* Beck, 1839, pl. 26, fig. 4.

***Didymograptus (Didymograptus?) geminus* (Hisinger, 1840)? Figs. 4K–L, 8G–J.**

?1840 *Prionotus geminus;* Hisinger pl. 37, fig. 3.
?1882 *Didymograptus Murchisoni* Beck *geminus* His; Tullberg, pp. 16–17, pl. 3, figs. 5–10.
1891 *Didymograptus geminus* His = *Murchisoni* Beck; Bjørlykke, pp. 2–3, figs. 1, 2.
1905 *Didymograptus bifidus* Hall; Lapworth, p. 10, figs. 3a, b.

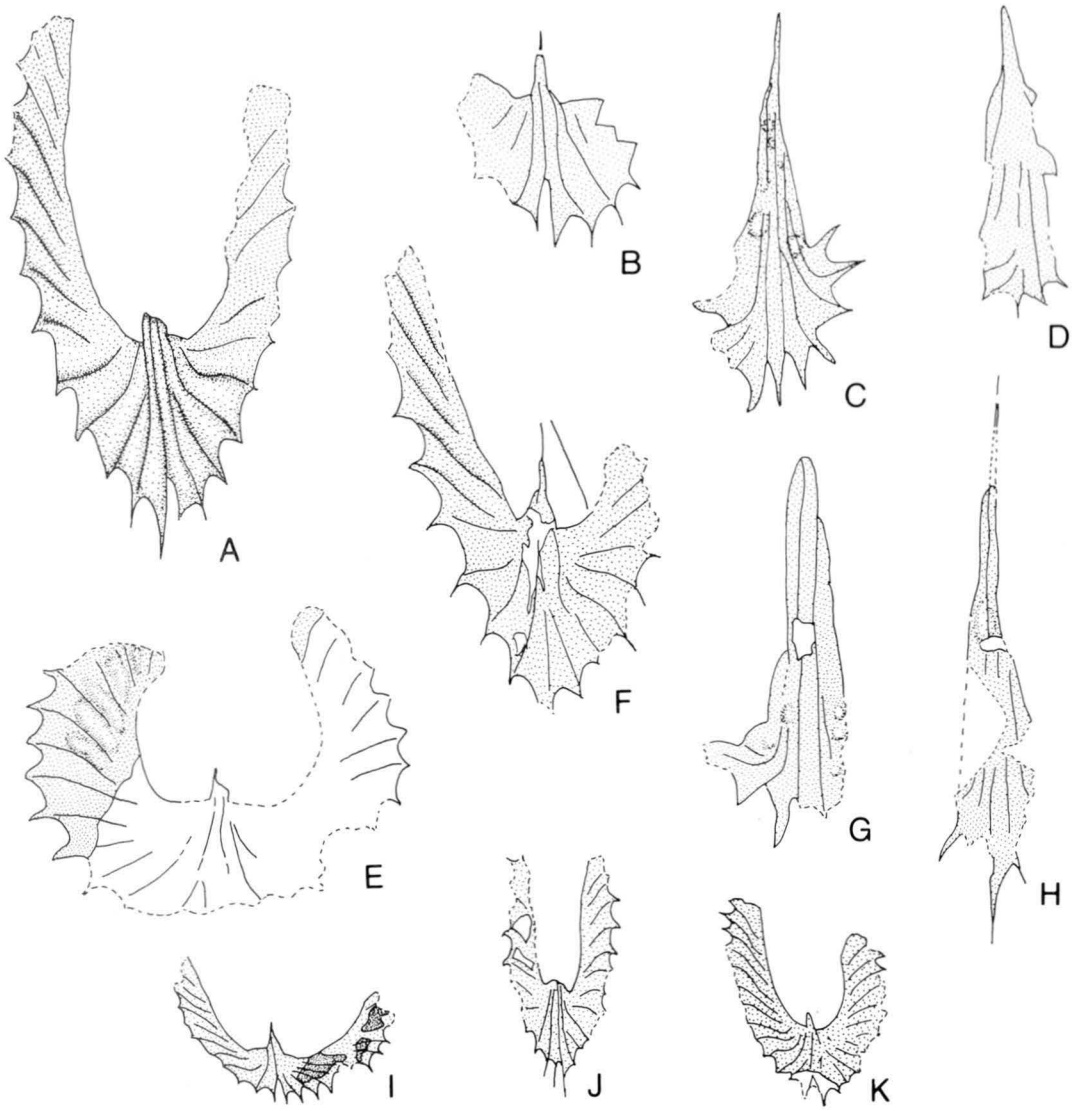

Fig. 9. *Isograptus caduseus* cf. *gibberulus* (Nicholson, 1875). Bjørlykke Coll. (A–H X5, I–K X2). A. PMO 109.373. B. PMO 109.268. C. PMO 109.300. D. PMO 109.355. E. PMO 109.288. F. PMO 109.297. G. PMO 109.275. Very large juvenile questionably assignable to *I.* cf. *gibberulus*. H. PMO 109.276. As G. I. PMO 109.353. J. PMO 109.345. K. PMO 109.312.

Material. Ten flattened specimens.

Remarks. The long, thin appearance of the sicula suggests a low origin for th1[1] (i.e. *artus* development), which would indicate *Didymograptus (Didymograptus) sensu* Cooper & Fortey (1982). The low thecal count of 7–9 in 10 mm and proximal width of 0.9–1.0 mm, widening to 1.5–1.7 mm by th5[1] and reaching a maximum of over 2.5 mm, do not agree strictly with any previous species descriptions. However, the specimen figured by Tullberg (1882, pl. 3, fig. 10) preserved in relief as '*D. murchisoni geminus*' appears almost identical, although the type (*op. cit.*, pl. 3, fig. 5) and his remaining figured specimens do not. Elles & Wood (1901) recorded '*D. murchisoni geminus*' from Abereiddy Bay, South Wales in association with *D. murchisoni* (Beck, 1839), but their specimens do not match closely with those from Bratland. *D. bifidus* (Hall, 1865) has isograptid development and is the type species of *Didymograptus (Didymograptellus)*. It

is concluded that the Bratland material is insufficient to allow a positive identification of *D. (D.) geminus,* which would have suggested a late Llanvirn age.

Subgenus *Didymograptus (Expansograptus)* Bouček & Přibyl, 1951.

Type species (by original designation). *Graptolithus extensus* Hall, 1858, p. 132.

***Didymograptus (Expansograptus) euodus bjoerlykki* Lapworth, 1905, Figs. 3A, B, 12L.**

1905 *Didymograptus euodus* Lapw. var. *Bjorlykki,* nov.; Lapworth, pp. 10–11, figs. 4a-d.

Lectotype. PMO 109.327, figured by Lapworth (1905, fig. 4b) is here selected as lectotype. The figure in the published plate is reversed (cf. the original sketch, this paper, Fig. 3A). This must have occurred during transfer of the sketch, when the tracing was inadvertently placed upside down when copying to give the final plate figure.

Change in spelling of name. Following ICZN ruling, article 11(b) the Norwegian letter 'ö' in 'Björlykki' is here changed to the Latin form 'oe'. Note that the spelling elsewhere in this paper conforms with modern Norwegian usage, viz. Bjørlykke.

Revised diagnosis. Stipes slightly declined widening from 1 mm to a maximum 25 mm. Thecae straight, inclined at about 20°

Material. Several proximal and distal fragments, preserved flattened and in partial relief.

Description. The stipes are over 120 mm long, initially slightly declined but becoming horizontal. They initially widen fairly rapidly from 1.0 mm proximally to about 1.5 mm by th5[1], then gradually reach a maximum 2.5 mm. Proximally the thecae number 7 in 10 mm, reducing distally to 4–5 in 10 mm. The sicula is 2–3 mm long with a short nema. Th1[1] buds from high up the metasicula and initially runs parallel with the sicula wall, giving a somewhat slimmer appearance to the sicula than found in associated *Xiphograptus* and *Didymograptus (Expansograptus)* species. The remaining thecae are consistently inclined at about 20° to the dorsal wall with somewhat denticulate apertures.

Remarks. D. (E.) euodus bjoerlykki has a similar form and maximum width to *D. (E.) euodus* Lapworth, 1875, but widens more rapidly and has a lower distal thecal count. No other *Didymograptus (Expansograptus)* with similar form possess such low thecal counts or similar stipe widths. Distal fragments are similar to those of *Xiphograptus* sp. cf. *Didymograptus (Expansograptus) similis* (Hall, 1865), but are slightly wider with a lower thecal count.

***Didymograptus (Expansograptus) hirundo* Salter, 1863, Figs. 5C, D, E, G, H, 11A, 12J, K.**

1863 *Didymograptus hirundo* (M.S.); Salter, p. 138, fig. 13f.
1901 *Didymograptus hirundo* Salter; Elles & Wood, pp. 15–17, pl. 1, figs. 5a–c.
1905 Dichograptid sp.; Lapworth, pp. 11–12, figs. 5a–c.
1905 *Didymograptus hirundo* Salter; Lapworth, p. 13, fig. 8.

Holotype. GSM 6803 (I.G.S. collections, London). Figured Salter (1863, fig. 13f) and Elles & Wood (1901, pl. 1, fig. 5c). From the Skiddaw Group of Ellergill, English Lake District.

Diagnosis. Not yet given.

Material. Two proximal and several distal fragments, mostly flattened.

Remarks. Insufficient material is present to allow a full description. Overall form, stipe widths and thecal count agree with Elles and Wood's description, although the thecal inclination is commonly rather lower and thecal density less in distal fragments. This could be due to tectonic deformation. Assignment of the distal fragments is necessarily rather tentative, although they appear to match the proximal ends. Elles & Wood (1901, p. 15) recorded stipe widths up to 305 mm long; a distal fragment 160 mm long and about 4 mm wide is present in the Strand collection. The length of the stipes explains why distal fragments are common in proportion to proximal ones. Although the specimens could possibly be assigned to one of a number of *Didymograptus (Expansograptus)* taxa, more material would be required before justifying a revision of Lapworth's original identification.

***Didymograptus (Expansograptus)* sp. A. Fig. 12I.**

Material. One flattened specimen.

Description. The specimen has a proximal width of 2.0 mm which remains uniform throughout the ten thecae present; thecae number 7 in 10

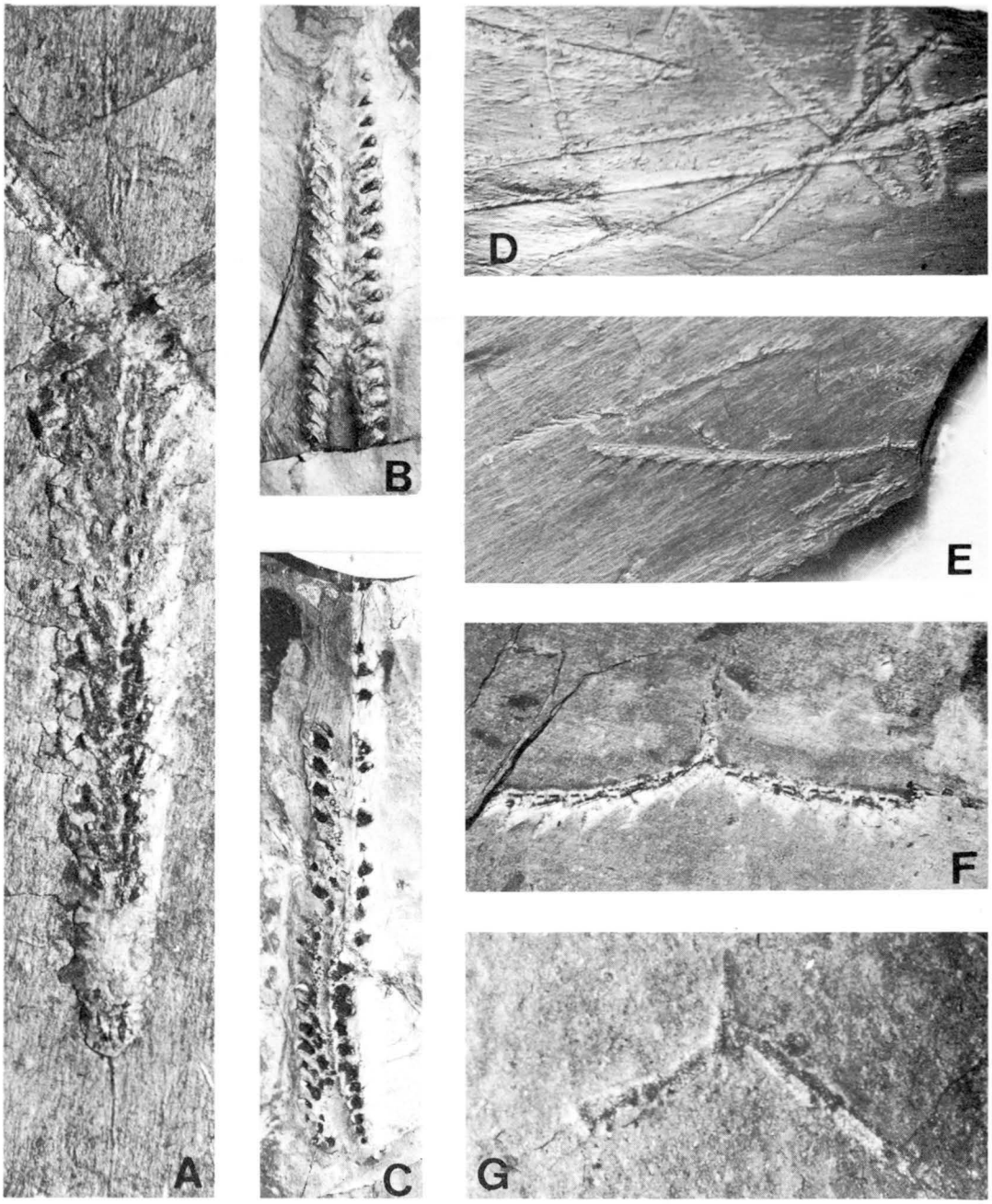

Fig. 10. A. *Glyptograptus* cf. *dentatus* (Brongniart, 1828). PMO 39850. Note long virgella and nema. Bjørlykke Col. (X5).
B. C. *Pseudophyllograptus angustifolius elongatus* (Bulman, 1931). Bjørlykke Coll. (X2). B. PMO 109.253. C. PMO 109.386.
D. *Didymograptus (Expansograptus)* sp. indet. PMO 109.387. Author's coll. from new locality on valley side southwest from Bratland (X1).
E. F. *Xiphograptus* sp. cf. *Didymograptus (Expansograptus) similis* (Hall, 1865). E. PMO 109.223. Also figured Fig. 12G. Seip Coll. (X2). F. PMO 109.242. Also figured Fig. 12B. Erdtmann Coll. (X5). G. *Acrograptus affinis* (Nicholson, 1869). PMO 109.247. Bjørlykke Coll. (X10).

mm. The thecae are inclined at a low angle in their inital portions, but increase to about 30° towards their apertures.

Remarks. The single example apparently does not agree with any previously described specimens of this subgenus. Additional material may, however, reveal an affinity with a previously defined taxon.

Genus *Pseudophyllograptus* Cooper & Fortey, 1982.

Type species (by original designation). *Phyllograptus angustifolius* Hall, 1858, p. 139.

***Pseudophyllograptus angustifolius elongatus* (Bulman, 1931).**
Figs. 4G–J, 10B, C.

1905 *Phyllograptus angustifolius*, Hall; Lapworth, pp. 13–14. fig. 10.
1931 *Phyllograptus angustifolius* var. *elongatus* nov.; Bulman, pp. 46–47, pl. 3, figs. 1, 2.

Holotype. No. 238b in the Nordenskiöld Collection. Figured Bulman (1931, pl. 3, fig. 2). From the Llanvirn of Korpa, Boliva.

Diagnosis. Not yet given.

Material. Many poor fragments preserved in full relief.

Remarks. Although most fragments are preserved in relief, removal of the surrounding lithology is impossible due to 'cleavage drape' (Figs. 6A–C) and they are commonly seen only as rounded ridges in the phyllite. Many are several centimetres long and the overall form agrees with *P. angustifolius elongatus.*

Subfamily ISOGRAPTINAE Harris, 1933
Genus *Isograptus* Moberg, 1892.

Type species (by original designation). *Didymograptus gibberulus* Nicholson, 1875, p. 271, pl. 7, figs. 3, 3a, b.

***Isograptus* cf. *gibberulus* (Nicholson, 1875)**
Figs. 3C, 9A–F, G?, H?, I–K, 11F.

cf.1875 *Didymograptus gibberulus* sp. nov.; Nicholson *(pars)*, p. 271, pl. 7, fig. 3 (*non* figs 3a, b = *P. angel* Jenkins, 1982).
cf.1892 *Isograptus gibberulus* Nicholson sp.; Moberg, pp. 346–348, pl. 8, figs. 3–7.
cf.1901 *Didymograptus gibberulus* Nicholson (=gen. *Isograptus*, Moberg); Elles & Wood, pp. 52–54, pl. 2, figs. 9a–e, text-figs 33a, b.
1901 *Isograptus gibberulus* Moberg; Törnquist, pp. 23–24, pl. 3, figs 16–19.
1905 *Didymograptus gibberulus*, Nich.; Lapworth, p. 12, fig. 6.
1932 *Isograptus gibberulus* (Nicholson); Bulman, pp. 23–25, pl. 1, figs. 1–5, text-fig. 1.
cf.1982 *Isograptus caduceus gibberulus* (Nicholson); Jenkins, pp. 224–228, pl. 16, fig. 1, figs 1a–e, 2a–e, g, k.

Material. Over twenty specimens preserved flattened and in partial relief.

Description. Most of the material consists of small proximal fragments, although one specimen has stipes 25 mm long. The overall axial angle is variable from 20° to convergent. The stipes measure 3.0–5.5 mm wide at th1[1] (commonly 5.0 mm), decreasing to 2.0–3.0 mm (commonly 3.0 mm) at th5[1] and normally narrowing somewhat distally. Proximally the thecae number 4–5 in 5 mm (commonly 4 in 5 mm), reducing only slightly distally. The sicula is large, varying from 5 to 10 mm long (normally 5–8 mm) and measuring 0.9 mm wide at its aperture. Proximally the prosicula merges indistinguishably with the virgella, which is only rarely preserved.

The first two thecae grow straight down throughout their length, while the folllowing four or five pairs bend out horizontal or sub-horizontal after an initial downward growth. Remaining thecae grow upward throughout their length. Their initial angle with the dorsal wall is 20–30°; in some specimens this apparently remains constant throughout growth, while in others the thecae bend to become inclined at a high angle to the dorsal wall aperturally. Thecal apertures are concave and denticulate, although not commonly preserved in their entirety.

Remarks. The material is unusual in its large overall size, the length of the sicula, the proximal widths and the low thecal counts. Such large dimensions are in common with other Bratland taxa and may be due partly to tectonic deformation. They agree in overall form with the specimens from Sweden described as *I. gibberulus* by Törnquist (1901) and Bulman (1932), although the Bratland material has slightly larger maximum dimensions and lower thecal counts. The type and other British material described by Jenkins (1982), is, however, much smaller, as are the Swedish specimens described by Moberg (1892). The overall form of some specimens agrees closely with that of *I. forcipiformis* (Ruedemann, 1904), but this species is much smaller

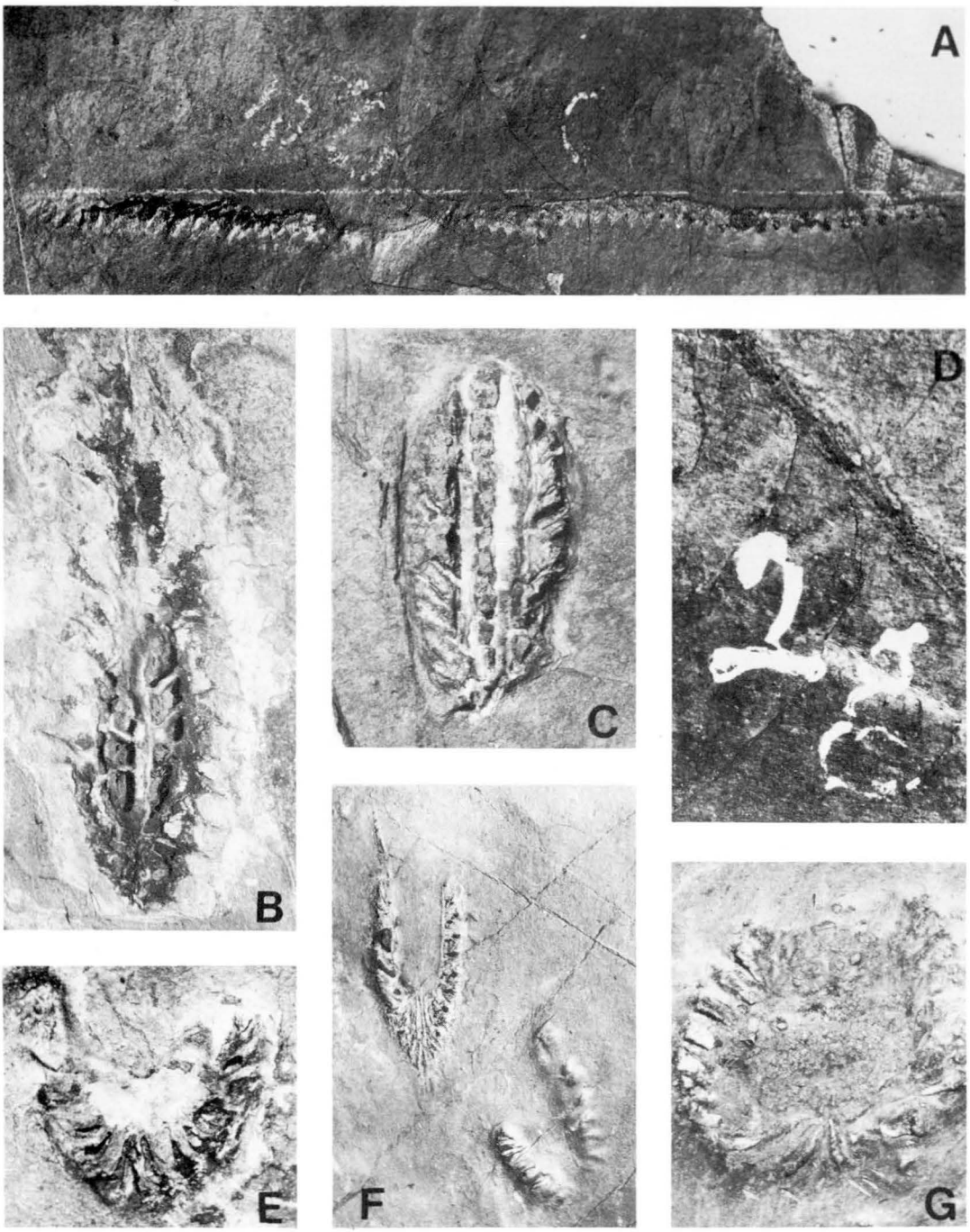

Fig. 11. A. *Didymograptus (Expansograptus) hirundo* Salter, 1863. PMO 109.330. Figured Lapworth (1905, fig. 8). Note Lapworth's pencil line (used to facilitate drawing) and red crayon number '2a' (upside down) which was written by Lapworth. Bjørlykke Coll. (X2). B, C. *Phyllograptus anna* Hall, 1865. Specimens have suffered badly from 'pyrite rot' to reveal the internal structure. Münster Coll. Faettun, Nord-Torpa (X5). B. PMO 109.384. C. PMO 109.383. D. *Holmograptus? laxatus* (Lapworth, 1905). PMO 109.322. Figured Lapworth sketch (Fig. 4B). Clear example of the white numbering system used by Bjørlykke. Bjørlykke Coll. (X5). E. *Tetragraptus (Tetragraptus) pseudobigsbyi* Skevington, 1965. PMO 109.294. Showing normal appearance of specimens from Bratland suffering 'pyrite rot'. Bjørlykke Coll. (X5). F. *Isograptus caduceus* cf. *gibberulus* (Nicholson, 1875). With poor specimen of *T. (T). pseudobigsbyi?* PMO 109.345. Note cleavage draping over the lower specimen. Bjørlykke Coll. (X2). G. *Tetragraptus (Tetragraptus) pseudobigsbyi* Skevington, 1965? PMO 109.298. The converging stipes are reminiscent of *T. (T). bigsbyi* (Hall, 1865), but the wide axil more characteristic of *T. (T.) pseudobigsbyi.* Bjørlykke Coll. (X5).

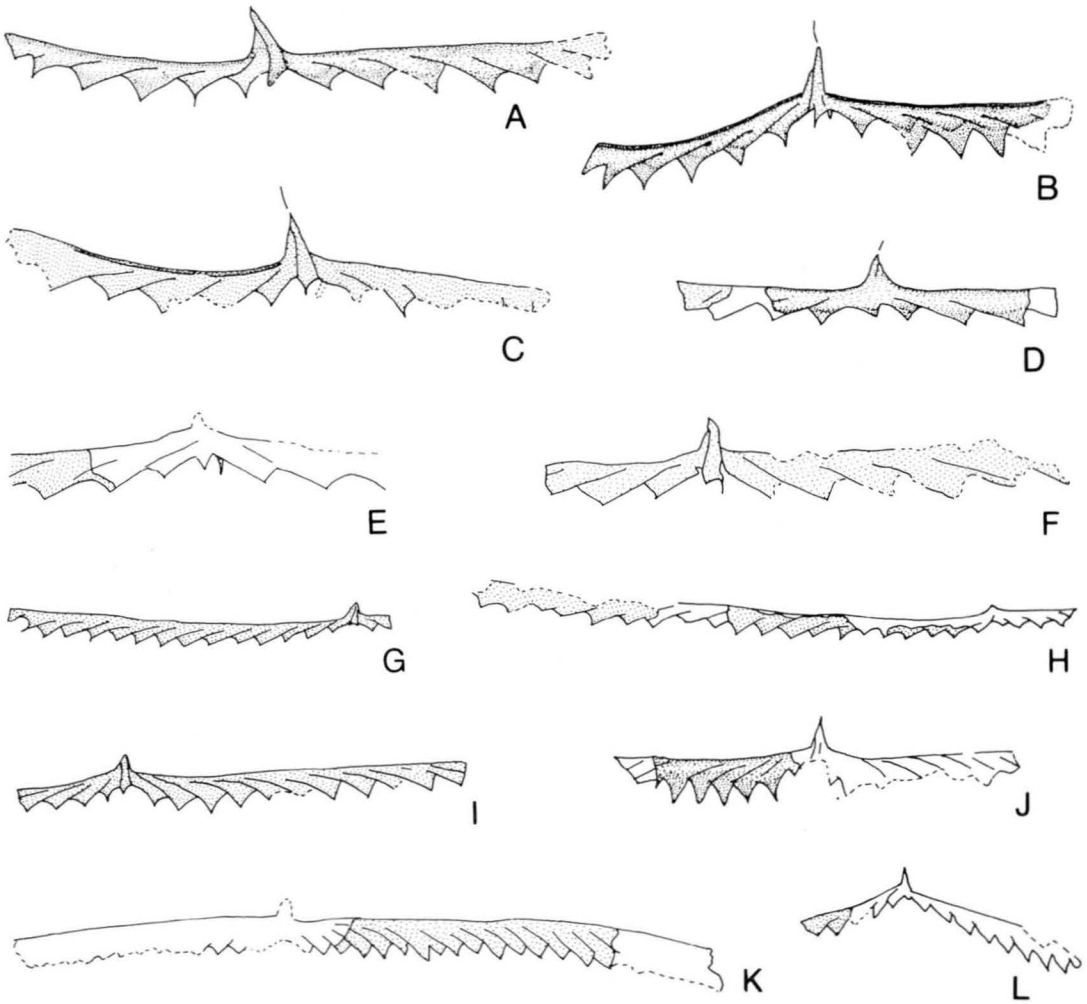

Fig. 12. A–H *Xiphograptus* sp. cf. *Didymograptus (Expansograptus) similis* (Hall, 1865). (A–F X5, G, H X2). A. PMO 109.236. Erdtmann Coll. B. PMO 109.242. Specimen with slightly declined stipes and thickened interthecal septal nodes. Also figured Fig. 10F. Erdtmann Coll. C. PMO 109.231. Poorly preserved virgella possibly present. Erdtmann Coll. D. PMO 109.245. Bjørlykke Coll. E. PMO 109.224. Virgella visible. Seip Coll. G. PMO 109.223. Also figured Fig. 10E. Seip Coll. H. PMO 65731. Strand. Coll. I. *Didymograptus (Expansograptus) sp. A. PMO 109.237. Erdtmann Coll. (X2). J.K. Didymograptus (Expansograptus) hirundo* Salter, 1863. (X2). J. PMO 109.239. Erdtmann Coll. K. PMO 109.260. Bjørlykke Coll. L. *Didymograptus (Expansograptus) euodus bjoerlykki* Lapworth, 1905. PMO 109.238. Erdtmann Coll. (X2).

with narrower stipes. Owing to recent statistical revision of *Isograptus* by Cooper (1973), positive identification requires numerically viable numbers of undeformed specimens. Reliable identification of the Bratland material is therefore impossible.

Subfamily SIGMAGRAPTINAE Cooper & Fortey, 1982

Genus *Acrograptus* Tzaj, 1969.

Type species (by original designation). *Didymograptus affinis* (Nicholson, 1869, p. 240, pl. 11, fig. 20.

***Acrograptus affinis* (Nicholson, 1869)**
Figs. 5A, B, 10G.

1869 *Didymograptus affinis* sp. nov.; Nicholson, p. 240, pl. 11, fig. 20.
1905 *Didymograptus Nicholsoni* Lapw.; Lapworth, p. 13, fig. 9.
(non 1875 *Didymograptus Nicholsoni* Lapw. sp. nov.; Lapworth, pp. 644–645, pl. 33, figs 5a–d).

Neotype (selected Elles & Wood 1901, p. 24). BM Q3108 (British Museum, Nat. Hist. collections). From the Skiddaw Group of Outerside, English

Lake District. Figured Elles & Wood (*op.cit.*, pl. fig. 1b).

Diagnosis. Not yet given.

Material. Two flattened specimens with proximal ends.

Remarks. Although the proximal stipe width of 0.4 mm is similar to *A. nicholsoni*, the low thecal count of 7 in 10 mm and overall form are closer to those of *A. affinis*. Lapworth's figured specimen has deteriorated since being drawn and few details are now visible. The thecal style is reminiscent of *Didymograptus leptograptoides* Monsen, 1937 and the specimens could prove to be proximal ends of *Holmograptus? laxatus* (Lapworth, 1905) which is currently known only from distal fragments.

Genus *Holmograptus* Kozlowski, 1954.

Type species (by original designation). *Didymograptus callotheca* Bulman, 1932, p. 16, text-figs 2–5.

Holmograptus? laxatus (Lapworth, 1905) Figs. 4A–F, 11D, 13J.

1905 *Dicellograptus laxatus* sp. nov.; Lapworth, pp. 9–10, figs. 2a–c.

Lectotype. PMO 109.317, figured by Lapworth (1905, fig. 2a) is here selected as lectotype. The specimen has deteriorated badly since being drawn; the proximal end has now almost completely disintegrated (cf. Fig. 4A) and few other thecae are visible. It is, however, the only example with a possible proximal end and must therefore be designated lectotype.

Revised diagnosis. Large sigmagraptine lacking secondary stipes, about 1 mm uniform width. Thecae gently sigmoidal with almost straight supragenicular walls parallel to stipe axis, opening into simple, slightly introverted apertures, numbering 4–7 in 10 mm. Proximal end unknown.

Material. Many poorly preserved distal fragments in partial relief.

Description. No certain proximal region has been observed; that figured by Lapworth has not deteriorated and no detail is visible. I believe that Lapworth's illustration may have been idealised and should not be relied upon. Distal fragments reach over 100 mm long and are of uniform width, commonly a little over 1 mm. The thecae number 4–7 in 10 mm; they are gently sigmoidal with almost straight supragenicular walls parallel to stipe axis and straight, interthecal septa subparallel to stipe axis which reach down to the preceeding aperture. The apertures are slightly introverted, opening into short excavations which occupy 1/5 of the total ventral wall and upon to 1/2 of the total stipe width. Prothecal folds are visible occasionally and were probably present throughout.

Remarks. Lapworth's original assignment of *H. laxatus* to *Dicellograptus* seems reasonable in view of the quality of the material. When poorly preserved, the thecal style is not unlike that of a simple *Dicellograptus* and it is only the associated Arenig/Llanvirn fauna that demonstrates the unlikely occurrence of this genus. Bjørlykke (1891, p. 5) referred to fragments of 'monopriodon type' graptolites, a clear reference to *H.? laxatus*, and in a footnote on the same page stated that Lapworth referred them to a new species of *Pleurograptus*. Later (Bjørlykke 1893, p. 18) it is clear that Lapworth at one time also considered the specimens to belong to *Dicellograptus moffatensis* (Carruthers, 1858).

The lack of any certain proximal fragments is strange when so many distal fragments are present and more critical taxonomic discussion must await their discovery. The assignment of *H? laxatus* to *Holmograptus* is tentative not only because of the lack of a proximal end, but because of the rather simple thecal style which does not normally show the flared apertures of *H. callotheca*. The problem concerning the relation of *Holmograptus* to other sigmagraptine genera was discussed by Skevington (1965) but remains in need of a full revision.

Family PHYLLOGRAPTIDAE Lapworth, 1873 (emend. Cooper & Fortey, 1982)

Genus *Phyllograptus* Hall, 1858.

Type species (by original designation). *Phyllograptus typus* Hall, 1858, p. 137.

Phyllograptus anna Hall, 1865 Figs. 11 B, C.

1865 *Phyllograptus Anna*, Hall (n.s.); Hall, p. 124, pl. 16, figs. 11–16.

1982 *Phyllograptus anna* Hall; Cooper & Fortey, pp. 285–286, figs. 79a–d.

Lectotype (selected Cooper & Fortey 1982, p.

285). GSC 938a (Geol. Surv. Canada Coll., Ottawa). From the Levis Shale of Levis, Quebec, Canada. Figured Hall (1865, pl. 16, fig. 15) and Cooper & Fortey (1982, fig. 79a).

Diagnosis. Not yet given.

Material. Four rotted specimens preserved in partial relief from Fættun, Nordtorpa (Münster collection).

Remarks. Fornices have been observed between the thecal series of rotted specimens, indicating the occurrence of true *Phyllograptus* in Scandinavia, while the overall form agrees with *P. anna.* Unfortunately it is impossible to illustrate these structures. *P. anna* has not been observed from Bratland.

Genus *Xiphograptus* Cooper & Fortey, 1982.

Type species (by original designation). *Didymograptus formosus* Bulman, 1936, pp. 24–26, pl. 1, figs. 5–7, text-figs 6a–d.

Xiphograptus sp. cf. *Didymograptus (Expansograptus) similis* (Hall, 1865).
Figs 5F, 10E, F, 12A–H.

cf.1865 *Graptolithus similis.* Hall (n.s.); Hall, pp. 78–79, pl. 2, figs 1–5.
cf.1880 *Didymograptus suecicus* n.sp.; Tullberg, p. 43, pl. 2, figs 15, 16.
cf.1901 *Didymograptus decens* n. sp.; Törnquist, p. 18, pl. 1, figs. 13, 14.
1905 *Didymograptus* cfr. *extensus* Hall; Lapworth, p. 12, fig. 7.
cf.1982 *Didymograptus (Expansograptus) similis* (Hall); Cooper & Fortey, pp. 238–239, figs 45a–c.

Material. Over fifty specimens preserved flattened and in partial relief.

Description. The stipes are over 30 mm long and normally horizontal; they are occasionally, however, slightly declined proximally and slightly reclined distally. Stipe increase is gradual from 0.9–1.3 mm (commonly 1.0 mm) wide at th1[1] to 1.3–1.4 mm wide at th5[1] and reaching 1.7 mm at th10[1] The maximum width is 2.0 mm, although this may have been subject to tectonic stretching. The thecae usually number 3–4 in 5 mm (i.e. 6–8 in 10 mm) throughout the rhabdosome, although thecal counts are low as 5 in 10 mm have been observed. The sicula is 1.7–2.0 mm long, 0.5 mm wide at its aperture and bears a nema up to 7 mm long. In two (and possibly a third) specimens a virgella is present, indicating the genus *Xiphograptus.* Th1[1] buds from towards the top of the sicula and grows down at an inclination of about 20° to the sicula axis, resulting in a broad, triangular projection. Proximal development agrees with that described by Cooper & Fortey (1982). The thecae are inclined at about 20° throughout the rhabdosome, although they sometimes turn downwards aperturally, giving a final angle up to 30° One specimen (Fig. 12B) shows thickened interthecal septal nodes, but no certain prothecal folds, as observed in *X. formosus svalbardensis* (Archer & Fortey, 1974) by Cooper & Fortey (1982, p. 291), are present.

Remarks. The genus *Xiphograptus* is distinguished from *Didymograptus (Expansograptus)* by the presence of a virgella. Although this is a clear indication of separate phyllogenetic origins, the virgella is rarely visible and many specimens assigned previously to *Didymograptus (Expansograptus)* might actually belong to *Xiphograptus.* The problem is highlighted by the present material, where although at least fifty specimens have been identified, only two (and possibly a third) exhibit virgellae.

Cooper & Fortey (1982, p. 289) did not include any species in their genus identical to the specimens described here. The only *Didymograptus (Expansograptus)* taxa which agree broadly in form and thecal inclination are those listed in the synonymy. They differ, however, in having slightly higher thecal counts and not possessing virgellae. Törnquist (1901) separated *D. (E.) decens* from *D. (E.) suecicus* by its thecal style, the overall form and dimensions being identical. His type specimens of *D. (E.) decens* are, however, flattened while those of *D. (E.) suecicus* are preserved in partial relief. This accounts for the apparent difference in thecal style and the two taxa are, therefore, probably synonymous. Tzaj (1974, pp. 73–74) listed 43 previously described *Didymograptus (Expansograptus)* taxa, excluding subspecies. This number appears excessive when considering the few possible variations in such a simple rhabdosome; it is likely that a thorough revision would prove many synonyms and require a number of generic reassignments.

Family DIPLOGRAPTIDAE Lapworth, 1873
Genus *Glyptograptus* Lapworth, 1873

Type species (by original designation). *Diplograptus tamariscus* Nicholson, 1868, p. 526, pl. 19, figs 10–13.

Remarks. Typical *Glyptograptus* occur in the Lower Silurian (see Packham 1962). Although

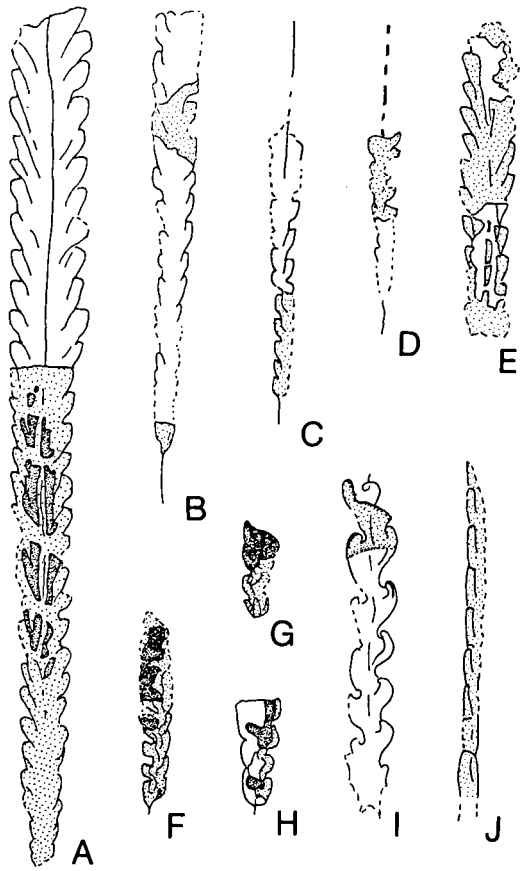

Fig. 13. A. *Glyptograptus* cf. *dentatus* (Brongniart, 1828)? PMO 109.339. Figured Bjørlykke (1891, fig. 5). Bjørlykke Coll. (X2). B–E. *Glyptograptus* cf. *dentatus* (Brongniart, 1828). Bjørlykke Coll. (X2). B. PMO 109.255. C. PMO 109.273. D. PMO 109.256. E. PMO 109.341. F–H. *Undulograptus* sp. A. Fætunn, Nord-Torpa? Münster Coll.? (X5). F. PMO 109.378. G. PMO 109.377. H. PMO 109.377. I. *Undulograptus* sp. B. PMO 109.316. Vigga River? Bjørlykke Coll. (X5). J. *Holmograptus? laxatus* (Lapworth, 1905). PMO 109.243. Bjørlykke Coll. (X2).

the thecal style of Lower and Middle Ordovician diplograptids attributed to this genus is similar, proximal development is noticeably different and their assignment to *Glyptograptus* has no phyllogenetic significance. A new genus should be erected to incorporate these taxa, but this is outside the scope of the present study.

Glyptograptus cf. dentatus (Brongniart, 1828) N/L Figs. 10A, 13A?, B–E.

cf.1828 *Fucoides dentatus;* Brongniart, p. 70, pl. 6, figs. 9–12.
1891 *Diplograptus teretiusculus* His.; Bjørlykke, p. 4, figs. 5, 6.
1905 *Diplograptus teretiusculus,* His.; Lapworth, pp. 7–9, figs 1a–e.
cf.1907 *Diplograptus (Glyptograptus) dentatus* (Brongniart); Elles & Wood, pp. 253–255, pl. 31, figs. 4a–d, text-figs. 174a–c.
cf.1963 *Glyptograptus dentatus* (Brongniart); Bulman, pp. 673–675, pl. 96, figs 1–5, text-figs. 1a–c, 4a–d.

Material. Many poor fragments, including four with proximal ends.

Description. Rhabdosome of unknown length, normally widening from 1 mm proximally to a maximum 3.5 mm. The sicula bears a prominent virgella up to 3 mm long; the first two thecae probably possessed spines, although these have not been observed. The thecae number 6–8 in 10 mm and are broadly *Glyptograptus* in style. A nema is occasionally present, reaching up to 7 mm long.

Remarks. The overall form of the proximal fragments agrees with Bulman's (1963) revised type description, with the exception of a much lower thecal count (8 in 10 mm instead of 14–18 in 10 mm). The distal fragments are both broader and with lower thecal counts than the type material, which has a maximum width of 2.0–2.2 mm and thecal count of 10–13 in 10 mm. Jenkins (1980) revised many of Bulman's (1963) generic assignments, transferring several of his species to *Undulograptus* Bouček, 1973. The Bratland material does not appear to be similar to any otherpreviously described taxa because of the large dimensions. The specimen figured by Bjørlykke (1891, fig. 5) and refigured here (Fig. 13A) is of enormous proportions and it is uncertain whether it should be included in *G.* cf. *dentatus.*

Genus *Undulograptus* Bouček, 1973.

Type species (by original designation). *Pseudoclimacograptus formosus* Mu & Lee, 1958, pp. 406–407, pl. 5, figs 6–13, text-figs 10–12.

Undulograptus spp. indet. Figs 13F–I.

Material. Three proximal fragments possibly from Nordtorpa (Münster Coll.) and one from the Vigga River(?), Gausdal.

Remarks. All four specimens show the characteristic thecal form of *Undulograptus.* The three from Nordtorpa(?) are a smaller form, not unlike *U. formosus,* and are here referred to *Undulograptus* sp. A. The remaining specimen (Fig. 131) from the Vigga River(?) is larger with a lower thecal count and is here referred to *Undulograp-*

tus sp. B. Although specific identification is not possible, the specimens are stratigraphically useful as *Undulograptus* is restricted to the upper Arenig and lower Llanvirn.

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