Llandoverian and Wenlockian graptolites from Bornholm

Merete Bjerreskov

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MERETE BJERRESKOV

Project
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Silurian (Llandovery and Lower Wenlock) graptolites from Bornholm, Denmark, are discussed. Hundred species and eleven subspecies are described of which five species and two subspecies are new. The ultrastructure of the graptolite rhabdosomes has been investigated and it is concluded that the carbon films show the original graptolite periderm structures. The total thickness of the Silurian sequence is measured to about 160 m. The biostratigraphic zonation of the Silurian on Bornholm is revised, and the sequence is now divided into twelve graptolite zones. The presence of the *persculptus* and *acuminatus* zones in the lowermost Llandovery is demonstrated together with the transition Llandovery–Wenlock. In the stratigraphic review the correlation with corresponding Silurian sequences, especially in Britain and Sweden, is discussed.

Merete Bjerreskov, Institute of Historical Geology and Palaeontology, University of Copenhagen, Øster Voldgade 10, DK-1350 Copenhagen K, Denmark, 11th April, 1975.

Contents

Introduction

On Bornholm the Silurian comprises the Llandovery and the lowermost part of the Wenlock Series. The deposits are preserved in fault-blocks and only exposed along the rivulets Læså and Øleå in the southern part of the island. The sequence is mainly developed as dark grey, graptolite shales interbedded with a few limestone bands.

The present work is a result of the author's studies of the graptolites and stratigraphy of the Llandovery and Wenlock Series. The investigations were initiated in 1967 as a revision of the stratigraphy of the *Rastrites* Shale (within the Llandovery Series). The shales are exposed in the valley of the rivulet Øleå on Southern Bornholm. Important preliminary results from the study of the *Rastrites* Shale were published by the author in 1969 under the name of Sjørring. Later Bjerreskov (1971) published a review of the stratigraphy of the Llandovery Series at Øleå and tabulated the graptolite fauna.

In the present study the graptolite fauna from the Llandovery and Wenlock Series is described and a detailed biostratigraphic zonation of the series is presented. On Bornholm the Silurian graptolites are occasionally well preserved and a description of the ultrastructures of the graptolite remains has been included in the section dealing with the state of preservation.

I am particularly indebted to Professor Valdemar Poulsen for discussion of all aspects of my work and for every kind of encouragement during the years I have been working on Silurian graptolites. Dr. Hermann Jaeger is sincerely thanked for invaluable help, discussions, and support with graptolite material. Special thanks are directed to Dr. Hans Jørgen Hansen for help and encouragements on the work on graptolite ultrastructures. Thanks are also due to Drs. Barrie Rickards, Jana Hutt, Isles Strachan, and Peter Toghill for assistance and discussions during study of type collections in England, and to Dr. Roland Skoglund during the investigation of collections in Stockholm. Director Ole Berthelsen, Geological Survey of Denmark, is thanked for the loan of graptolite material from the new well of Bavnegård. The excellent drawings of the Bornholm graptolites were prepared by Mrs. Erna Nordmann to whom I wish to express my sincere thanks. Mr. Henrik Egelund has kindly drawn the maps and the lithological columns. Many thanks are due to Mr. Jan Aagaard for photographing the graptolites. Mrs. Annelise Nørgaard Andersen has prepared many specimens for examination with the stereoscan microscope. Mrs. Inge Nyegaard has assisted in preparing the plates and Mrs. Else Møller-Hansen has typed the manuscript. Dr. John S. Peel has improved the English of the manuscript.

The project has been supported by grants from *Stipendier for unge Videnskabsmænd, Rask Ørsted Fondet, Statens naturvidenskabelige Forskningsråd* (including all the publication costs), and the University of Copenhagen, which are gratefully acknowledged.

Previous work

J. G. Forchhammer, L. Esmarck, and H. C. Ørsted were the first to make a detailed investigation of the geology of Bornholm in the years 1818–1819. The results were published in 1819 and 1820 and here the graptolite shales were mentioned. In a summary of the geology of Denmark, Forchhammer (1835) noted the graptolite shales from Bornholm and reported three graptolite species from the Copenhagen University collections. In 1874 Johnstrup distinguished the "Upper Graptolite Shales" (the Silurian) exposed at the outlet of Læså from the "Lower Graptolite Shales" (the Ordovician) found in the upper part of the rivulet. He

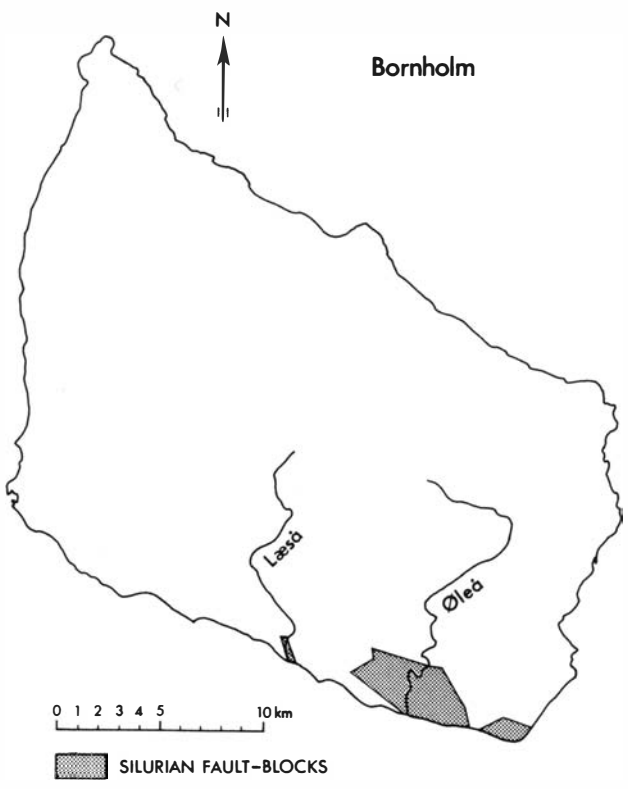


Fig. 1. Sketch-map showing the position of the Silurian fault-blocks on Bornholm.

reported eight different graptolite species from the "Upper Graptolite Shale". In a review from 1889 Johnstrup divided the Silurian shales into the *Rastrites* Shale and the *Retiolites* Shale. This division was equivalent to the stratigraphic division of the Silurian shales from Dalecarlia and Scania in Sweden which was carried out by Törnquist (1875), Linnarsson (1881), and Tullberg (1882b). The shales on Bornholm were described in some detail and the graptolite faunas listed by Grönwall (1899). He divided the *Rastrites* Shale into seven graptolite zones and the *Cyrtograptus* Shale, which was equivalent to the *Retiolites* Shale, into five zones. In a more complete description of the geology of Bornholm (Grönwall in Grönwall & Milthers, 1916) the zonal division was repeated and the thickness of the *Rastrites* Shales estimated to 30–40 m, the *Cyrtograptus* Shales were supposed to be slightly thicker.

In an unpublished prize dissertation Pedersen (1921) revised the *Rastrites* Shales in Øleå and presented a stratigraphic division of the shales and a detailed description of the graptolite fauna. In 1922 Pedersen divided the section into five graptolite zones: the zones of *Monograptus acinaces, Monograptus gregarius, Monograptus convolutus, Monograptus ?sedgwickii,* and *Monograptus turriculatus*. He listed the graptolite fauna and described three new graptolite species and two new subspecies. Laursen (1943) reported the *grayi, spiralis,* and *murchisoni* zones divided the shale into four zones: the zones of *Cyrtograptus grayi, Monograptus spiralis, Cyrtograptus lapworthi,* and *Cyrtograptus murchisoni*. He discarded the uppermost zone reported in Grönwall (1899), the *Monograptus riccartonensis* Zone. From Læså Laursen (1943) reported the *grayi, spiralis,* and *murchisoni* zones from the *Cyrtograptus* Shale, and here no exposures of the *Rastrites* Shale were observed.

In Sweden Wærn (1948 and 1960a) gave detailed descriptions of the *Rastrites* Shales from Kinnekulle in Västergötland and from Dalecarlia. In the latter paper he suggested that the designation *Rastrites* Shale should be abandoned and, on the basis of a revised zonation, he divided the shales into four stages. In a review of the Palaeozoic strata of Bornholm (V. Poulsen, 1966) the divisions introduced by Wærn (1960a) were applied to the local Silurian sequence.

Following an investigation of the Llandovery part of the Silurian shales of Bornholm, Bjerreskov (1971) arrived at a zonation which is close to the division of the Swedish shales mentioned by Wærn (1960a). The thickness of the Llandovery shales on Bornholm was measured to 110 m. During the latest investigation of the Øleå section the vertical extent of the Wenlock shales overlying the Llandovery layers has been measured to 30 m. Furthermore, a new well (see below) has added about 20 m of the basal Llandovery. The total thickness of the Silurian shales on Bornholm may then be 160 m. Only about half the sequence is exposed, implying that many details of the geological development are obscured.

In the present investigation the following graptolite zones have been recognized and defined in the Silurian shales (arranged in ascending order): *Glyptograptus persculptus, Akidograptus? acuminatus, acinaces, Monograptus revolutus, gregarius, convolutus, turriculatus, Monograptus crispus, Monograptus griestoniensis, spiralis,* and *lapworthi* in the Llandovery Series, and the *Cyrtograptus centrifugus* Zone in the Wenlock Series.

The Bavnegård Well

A cable-tool boring was carried out in 1973 by the Sømarken waterworks. The well is situated north-east of Bavnegård 1 km directly west of (Ø8) and attained a depth of 101 m. The pre-Quaternary surface here probably represents a level within the *gregarius* Zone which is exposed 1 km to the east of Øleå (Ø8). Figs. 1, 2, 4.

In the samples kindly placed to the author's disposal by the Geological Survey of Denmark lowermost Silurian shales were found to a depth of 34.5 m by the author. From the interval 34.5–34.6 m Valdemar Poulsen (pers. communication) is working on a shelly fauna belonging to the *Dalmanitina* beds, which constitute the uppermost part of the Ordovician sequence in Scania and other regions, and which have not hitherto been reported from Bornholm. Below this level Ordovician limestone and shales, occasionally with graptolites indicative of the *Dicellograptus* Shale, have been found to a depth of 70 m, underlain by Cambrian strata occurring down to the bottom of the well at 101 m.

The lowermost part of the Llandovery Series has not previously been reported from Bornholm and a possible hiatus between the Upper Ordovician *Tretaspis* Shale and the lowest exposed part of the Silurian, the *acinaces* Zone, has been suggested by V. Poulsen (1966) and Bjerreskov (1971). However, graptolite faunas representing the lowermost part of the *acinaces* Zone and the two lowermost zones according to the British standard zonation of the Silurian, the zones of *persculptus* and *acuminatus,* have now been found in the well sequence. Accordingly, the graptolite assemblages in the Silurian sequence of Bornholm would appear to be rather complete also in the lowermost parts.

Exposures

Øleå

The most complete part of the Silurian shales is exposed in the valley at the rivulet Øleå (Figs. 2 and 5). The shales are preserved in a fault-block, generally with an east-west strike and a dip of 3°–6° to the south. As the rivulet traverses the fault-block in a north-south direction the stratigraphically oldest exposures are found to the north, about 3 km north of the outlet of Øleå, and younger outcrops appear successively towards the outlet of the rivulet at the south coast of Bornholm. 200 m west of Køllergård the stratigraphically lowermost part of the Silurian of Bornholm is exposed (Ø3), the *acinaces* Zone from the Lower Llandovery. 200 m north of this outcrop a small exposure in the bed of the rivulet has

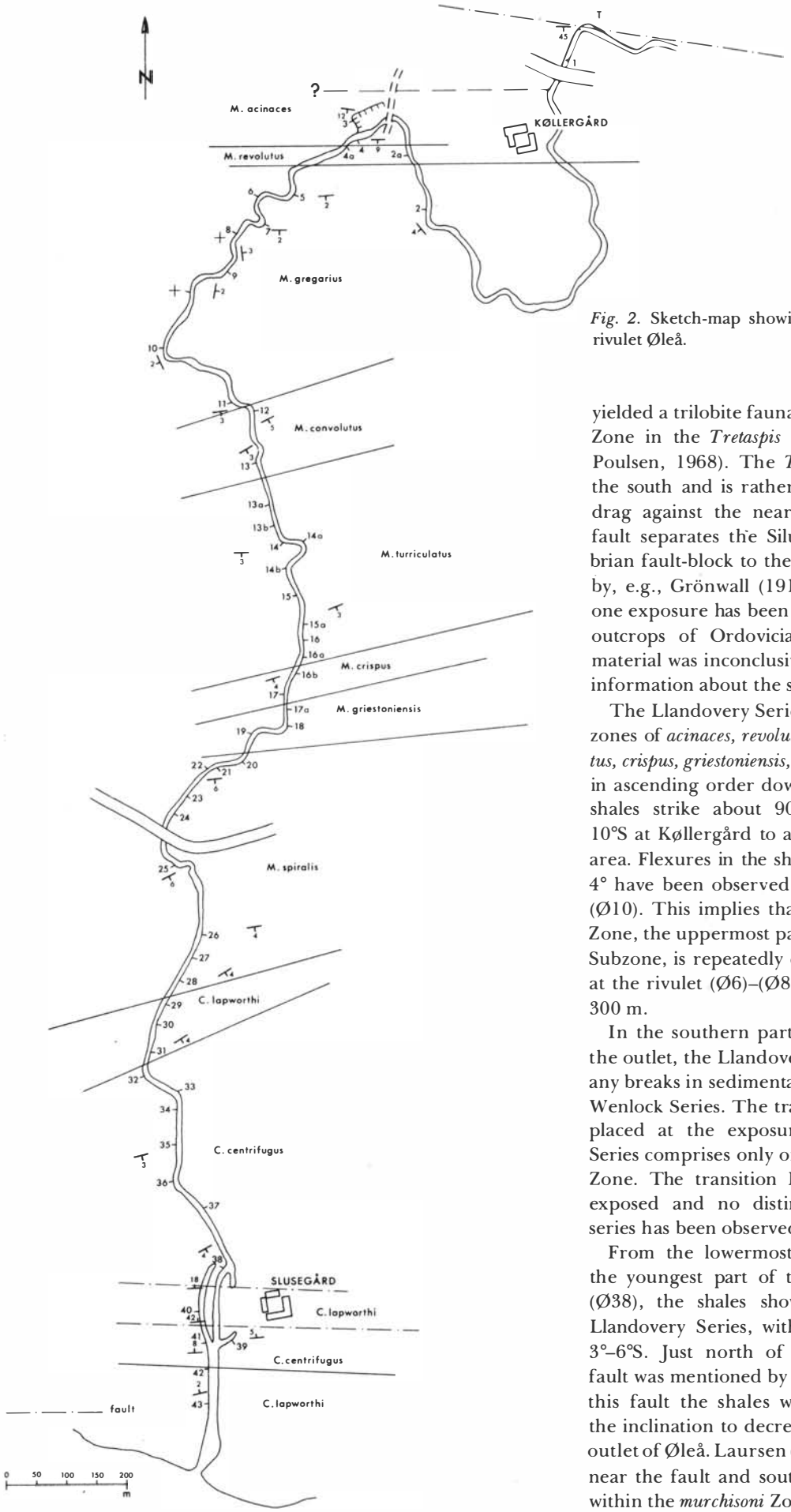


Fig. 2. Sketch-map showing the Silurian exposures along the rivulet Øleå.

yielded a trilobite fauna from the *Staurocephalus clavifrons* Zone in the *Tretaspis* Shale (Jerrestad Formation) (V. Poulsen, 1968). The *Tretaspis* Shale dips about 45° to the south and is rather sheared, probably as a result of drag against the nearby NW-SE trending fault. This fault separates the Silurian fault-block from the Cambrian fault-block to the north. The fault was mentioned by, e.g., Grönwall (1916) and V. Poulsen (1968). Only one exposure has been observed between the mentioned outcrops of Ordovician and Silurian strata, but the material was inconclusive and has not added any further information about the stratigraphy.

The Llandovery Series exposed in Øleå comprises the zones of *acinaces, revolutus, gregarius, convolutus, turriculatus, crispus, griestoniensis, spiralis,* and *lapworthi* which occur in ascending order downstream towards the south. The shales strike about 90° and the dip decreases from 10°S at Køllergård to about 4°S in the main part of the area. Flexures in the shales with inclinations of less than 4° have been observed within the *gregarius* Zone (Ø6)–(Ø10). This implies that the same level in the *gregarius* Zone, the uppermost part of the *Monograptus triangulatus* Subzone, is repeatedly exposed at intervals in the banks at the rivulet (Ø6)–(Ø8), (Ø10) over a distance of about 300 m.

In the southern part of Øleå, about 550 m north of the outlet, the Llandovery shales are apparently without any breaks in sedimentation conformably overlain by the Wenlock Series. The transition between the two series is placed at the exposures (Ø31)–(Ø32). The Wenlock Series comprises only one graptolite zone, the *centrifugus* Zone. The transition Llandovery–Wenlock is not well exposed and no distinct boundary between the two series has been observed.

From the lowermost stratigraphic level at (Ø32) to the youngest part of the Wenlock shales at Slusegård (Ø38), the shales show the same orientation as the Llandovery Series, with a 60°–90° strike and a dip of 3°–6°S. Just north of Slusegård an east-west striking fault was mentioned by Laursen (1940). Directly south of this fault the shales were reported to dip 25°N, and the inclination to decrease to 3°–4° in outcrops near the outlet of Øleå. Laursen (1940) claimed that the exposures near the fault and south of Slusegård were all situated within the *murchisoni* Zone.

At (Ø40), west of Slusegård, 10 m shale are exposed with a strike of 90° and a dip of 20°–40°N. In the southern part of the outcrop the shales are sheared and form an anticlinal flexure. In the exposures (Ø41)–(Ø43), south of (Ø40), the dip of the shale decreases from 8°N at (Ø41) to 3°N near the outlet of Øleå (Ø43). The strike is constantly about 90°.

The graptolites observed at (Ø40) indicate the transition from the *spiralis* Zone to the *lapworthi* Zone and just south of (Ø40), at (Ø41), the graptolites are from the *centrifugus* Zone. This stratigraphic arrangement implies two faults in the area at Slusegård. The northernmost fault is the fault reported by Laursen (1940). North of this fault, at (Ø38), the shales are from the *centrifugus* Zone, and here the uppermost stratigraphic level within the Silurian series of Bornholm is found. South of the fault the transition from the *spiralis* to the *lapworthi* Zone is recorded. The southernmost east-west trending fault must be placed just south of (Ø40), between (Ø40) and (Ø41). The anticlinal flexure at (Ø40) is evidently a drag against this fault.

The two fault-blocks are both inclined to the north. The northern fault-block is exposed at (Ø40) and comprises the transition from the *spiralis* Zone to the *lapworthi* Zone. In the southern fault-block, which is close to the outlet of Øleå, the top of the *lapworthi* Zone and the lower part of the *centrifugus* Zone are observed at (Ø39), (Ø41), (Ø43). The southern limit of this fault-block cannot be stated. Neither the eastern nor the western limits of the two fault-blocks are exposed.

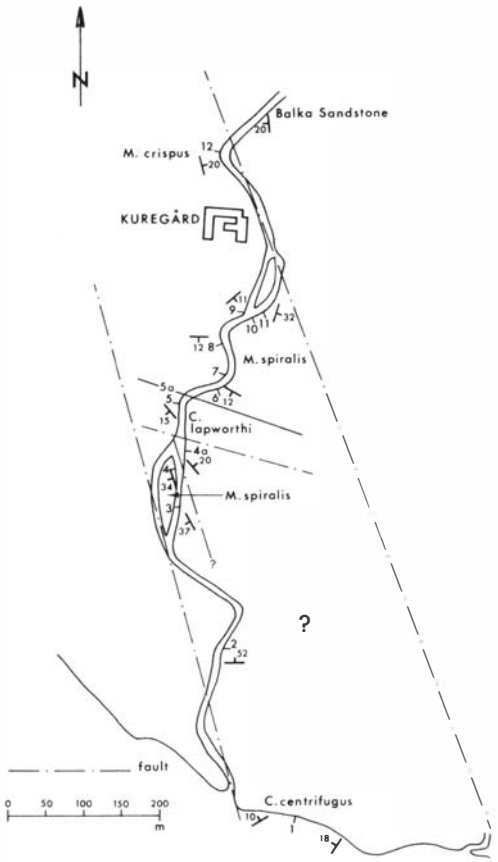


Fig. 3. Sketch-map showing the Silurian exposures along the rivulet Læså. Symbols as in Fig. 2.

Læså

In the area of Læså the exposures in the Silurian shales are preserved in an approximately 250 m wide east-west fault-block which is traversed by the southernmost 800 m of the rivulet (Figs. 3 and 6). Here the Silurian comprises the zones of *crispus, spiralis, lapworthi,* and *centrifugus.* The shales are cut off to the east and west by two faults situated close to the rivulet, both with a 160°–170° strike. The faults were earlier reported by Grönwall (1916) and Gry (1969). Below the Quaternary cover Lower Cambrian Balka Sandstone is found to the east of the fault-block and Keuper clay adjoins to the west. Within the fault-block the shales are rather disturbed tectonically due to the nearness of the faults. As at Øleå, the exposures generally become stratigraphically younger towards the south as the shales are mainly inclined to the south.

The northernmost exposure within the Silurian shales at Læså is observed 60 m north of Kuregård (L12) and the graptolite fauna here indicates the lower part of the *crispus* Zone. The outcrop is situated just south of the fault separating the Silurian from the Lower Cambrian Balka Sandstone which is exposed in the bottom of the rivulet 50 m north of (Ø12). The strike of the shale and the sandstone mirrors the trend of the fault.

In the central part of the Silurian fault-block, 100–300 m south of Kuregård, a large part of the *spiralis* Zone and the lower part of the *lapworthi* Zone are exposed in generally high profiles in the banks at the rivulet (L11)–(L5). The shales are mainly inclined at about 12° to the south, and the graptolite fauna can easily be correlated with that of the equivalent layers in the banks at Øleå (Ø23)–(Ø29).

South of the exposed *lapworthi* Zone (L5), parts of smaller fault-blocks with dips of up to 60° are found (L3)–(L4a). The graptolite fauna from these outcrops indicates the *spiralis* Zone, probably the middle part of the zone which is hardly exposed in Øleå. A concealed fault with a strike of about 120° must be situated between (L5), where shales from the *lapworthi* Zone are exposed, and (L4) within the *spiralis* Zone. Furthermore a north-south trending fault must be situated between exposures (L4) and (L4a), in the latter a non-graptolitiferous grey-greenish shale is recorded.

In the southernmost 500 m of the valley of Læså only one exposure is found, yielding a non-graptolitiferous grey shale (L2) which adds no further information about the stratigraphic relations.

In the cliff at the beach 50 m east of the outlet of Læså a 120 m long exposure comprising about 30 m of shale (L1) is seen. Here the graptolite fauna may be referred to the *centrifugus* Zone. This outcrop was reported by Laursen (1943) as belonging to the *murchisoni* Zone. The shales are overlain by a conglomerate with rounded blocks of local, partly kaolinised Palaeozoic rocks. The conglomerate passes upwards into sand and sandy clay from which megaspores indicate Dogger age (Gry, 1969). The orientation of the shales at the southern part of Læså and on the beach indicates that some

tectonic disturbance must have occurred between (L3) and (L1). The graptolite succession within (L1) is equivalent to the succession in Øleå from (Ø33) to (Ø38).

Stratigraphy

The Silurian shales of Bornholm appear to form an essentially continuous sequence and, with one exception, all graptolite zones from the *persculptus* Zone to the *centrifugus* Zone are present. The zonal division of the sequence and the stratigraphic range of the described graptolite species are shown in Fig. 7 and Fig. 8. The two lowermost graptolite zones of the Silurian, according to the British standard zonation, the zones of *persculptus* and *acuminatus*, have now been shown to be present on Bornholm by the new well, but otherwise the basal part of the Llandovery is nowhere exposed. In Øleå, 75 m south of the exposure in the *Tretaspis* Shale, a few fragments of grey shale were obtained from the bottom of the rivulet (Ø1). The sparse material includes badly preserved diplograptids. However, the resemblance of one of the diplograptids to *Glyptograptus persculptus* (Salter) is not here regarded as sufficient evidence for recognition of the exposure of the *persculptus* Zone.

The *Glyptograptus persculptus* Zone

The *persculptus* Zone is represented in the well sequence at a depth of 30.10–34.50 m. The shale here is grey to dark grey with well preserved pyritized graptolites.

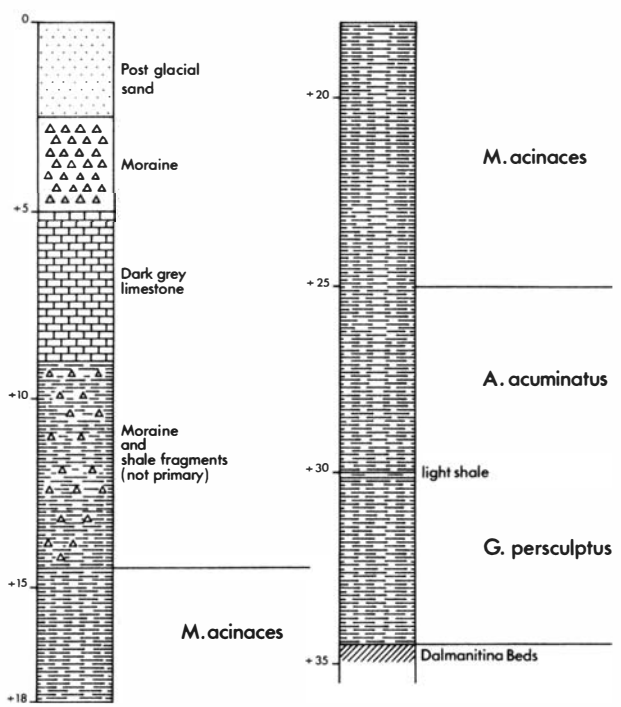


Fig. 4. Silurian sequence in the well at Bavnegård. Symbols as in Fig. 5.

The following graptolite species are recorded from this level: *Climacograptus angustus* (Perner) (synonymous with *Climacograptus miserabilis* (Elles & Wood)), *Orthograptus* sp., *G. persculptus, Glyptograptus* sp., and *?Monograptus* sp.

The most important species in this assemblage is the zone fossil *G. persculptus.* Following Davies (1929), the specimens can be referred to the lower part of the *persculptus* Zone. However, they are not identical to the oldest form of *G. persculptus.*

The presence of a fragment, possibly a *Monograptus,* at this level may indicate that the genus appeared in the lowermost part of the Llandovery. *Monograptus* was also reported by Rickards & Hutt (1970) from the *persculptus* Zone in the English Lake District.

In Scania *Climacograptus normalis* Lapworth has been reported from graptolite shales overlaying the *Dalmanitina* beds, but the presence of the *persculptus* Zone has not been ascertained (Regnéll, 1960). In Västergötland the *acuminatus* Zone has been observed (Wærn, 1948). Here graptolite shales with *C. normalis* were also observed below the *acuminatus* Zone, but without any record of the zone fossil, *G. persculptus.*

The *persculptus* Zone has also been reported from Frankenwald, Middle Europe by Stein (1965).

The *Akidograptus? acuminatus* Zone

The sequence from 25.0–30.0 m below ground level in the Bavnegård well is referred to the *acuminatus* Zone. Here the shale is homogeneous, dark grey, and most of the graptolites are flattened. The material is rather limited and the graptolite fauna in the well cuttings comprises only three species: *C. angustus, Climacograptus medius* Törnquist, and *Akidograptus ascensus* Davies.

The zone fossil *Akidograptus? acuminatus* (Nicholson) has not been found. However, *A. ascensus* has earlier been reported from the *acuminatus* Zone by Davies (1929) and later by Stein (1965), who indicated that this graptolite was more frequent in the *acuminatus* Zone than the zone fossil. Toghill (1968) has also demonstrated an equal range for the two species. Accordingly, the presence of *A. ascensus* is regarded as indicative of the *acuminatus* Zone.

The *acuminatus* Zone has not earlier been reported from Denmark, but has been proved in the nearby sequences in Scania (Törnquist, 1913) and in Kinnekulle, Västergötland (Wærn, 1948).

The *Monograptus acinaces* Zone

A graptolite assemblage possibly indicating the *acinaces* Zone has been recorded at the top of the pre-Quaternary sequence in the Bavnegård well at two depths: 14.5–15.0 m and 15–25 m below ground level. Above 14.5 m Quaternary deposits occur mixed with shalebits containing few non-identifiable graptolites and dark non-fossiliferous limestone.

The *acinaces* Zone is the stratigraphically lowest graptolite zone within the exposed part of the Llandovery Series on Bornholm, in outcrops occurring only at Øleå.

Here the thickness of the zone is more than 10 m; the top is not exposed.

The shales found in the well are homogeneous, dark grey, and with a flattened graptolite fauna. In the lower part of the exposed section of the zone grey, finely laminated and carbonate rich shale is found at (Ø3), an old limestone quarry. The shale is here interbedded with grey, non-graptolitiferous, concretionary limestone bands, up to 0.5 m in thickness. At least five bands are present. At this locality the graptolites occur sparsely. At higher levels in the zone (Ø4) the limestone is present in form of nodules, about 1 m in diameter and 0.5 m in thickness. The non-graptolitiferous, calcareous nodules occur in three layers almost in contact with each other. In the interbedded shales and in the shales overlying the limestone lenses the graptolites are frequent and occasionally preserved in low relief.

From the borehole level 14.5–15 m the graptolite assemblage includes *Climacograptus rectangularis* M'Coy, *C. angustus, C. medius, Diplograptus? rarus* Rickards, *Dimorphograptus erectus* s.l. Elles & Wood, *Monograptus* cf. *acinaces* Törnquist. In the few samples from the interval 15–25 m the graptolite fauna comprises *C. medius, D. erectus,* and *M.* cf. *acinaces.*

The particular assemblage from the well has not been observed in the material obtained from the exposed, higher levels of the *acinaces* Zone, and the species indicate an older fauna. Especially *C. angustus,* which is common in the lowermost Llandovery, has not been observed in the exposed parts of the *acinaces* Zone, and may here indicate the lowermost level of the zone. The assemblages are not as old as the true *acuminatus* fauna. The presence of *D. erectus* s.l. indicates that the graptolite fauna from these levels in the well should be placed in the *acinaces* Zone, if direct correlation with the British assemblages is accepted. Accordingly a distinction of an underlying *atavus* Zone has not been done even if the rather insufficient material bears some affinity to graptolite faunas from the *atavus* level.

The following graptolite assemblage has been collected from the exposures: *C. rectangularis, Climacograptus balticus* Pedersen, *Glyptograptus tamariscus* s.l. (Nicholson), *Cystograptus vesiculosus* (Nicholson), *Dimorphograptus confertus confertus* (Nicholson), *Rhaphidograptus toernquisti* (Elles & Wood), and *M. acinaces.*

The *acinaces* Zone was defined by Jones (1909) at Pont Erwyd, and the appearance of monograptids, other than *Monograptus atavus* Jones, is typical for the zone. From the *acinaces* Zone Jones (1909) reported *G. tamariscus, Climacograptus scalaris normalis* Lapworth, *Pseudoclimacograptus hughesi* (Nicholson), *Orthograptus mutabilis* Elles & Wood, *R. toernquisti, M. atavus,* and *Monograptus sandersoni* Lapworth. However *M. atavus,* which in Britain is quite common at this level, is not seen in the upper part of the *acinaces* Zone of Bornholm, but appears at higher levels, in the zones of *revolutus* and *gregarius.*

On Bornholm the *acinaces* Zone was initially identified by Pedersen (1922) and he correlated this zone with the *revolutus* and *vesiculosus* zones in Sweden. On Bornholm C. *vesiculosus* has only been found by the present author in an 0.5 m thick band in the upper part of the *acinaces* Zone, just above the layers of the limestone lenses (Ø4). Only juvenile specimens of *C. vesiculosus* were found, and no further change in the graptolite fauna has been observed. *C. vesiculosus* was reported by Pedersen (1922) from the *gregarius* Zone, but has not been collected from this level by the author. *Dimorphograptus extenuatus* Elles & Wood has not been found on Bornholm. This graptolite has given name to a zone at the level corresponding to the *acinaces* Zone in Sweden (Wærn, 1948 and 1960a).

The *Monograptus revolutus* Zone

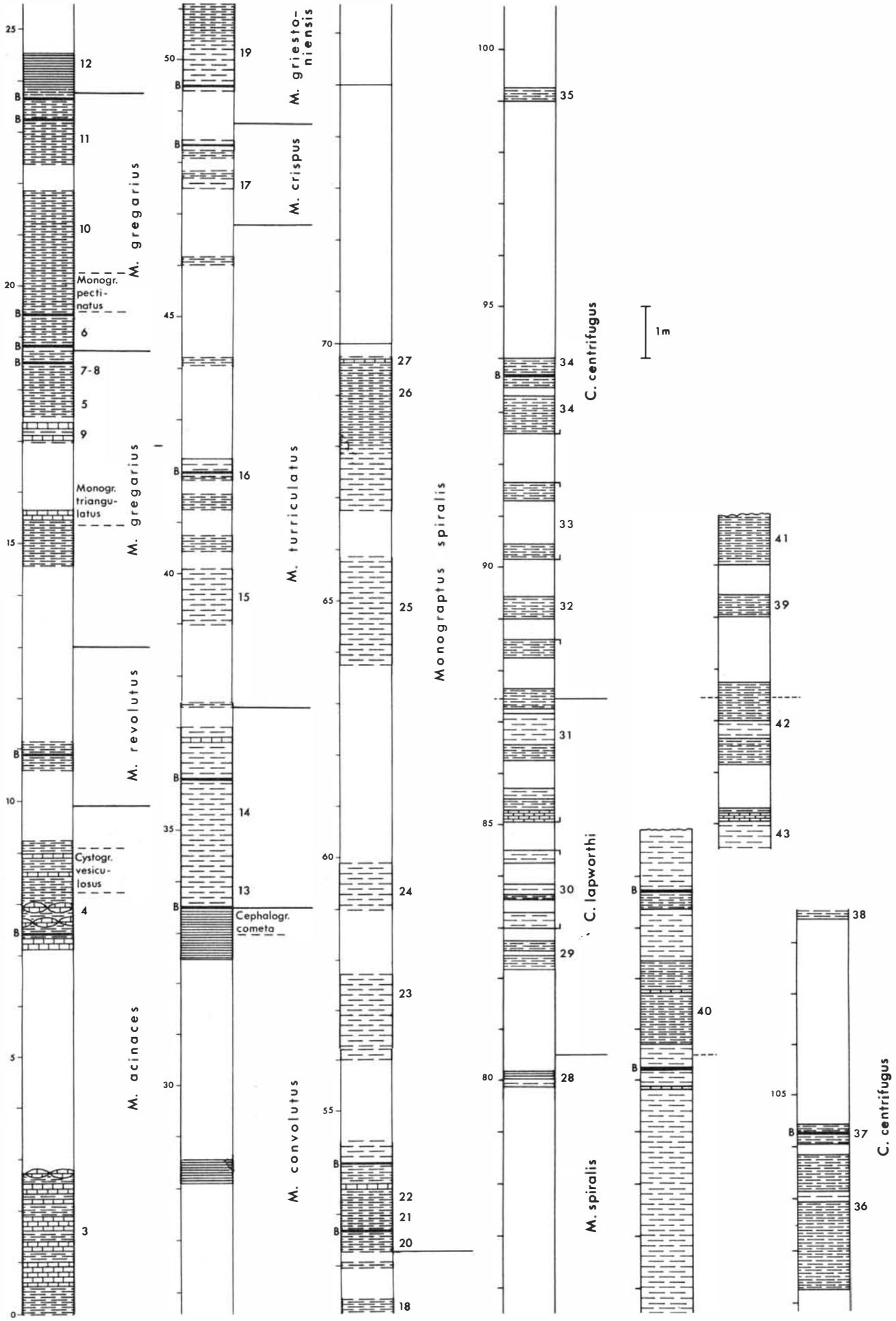
The *revolutus* Zone overlies the *acinaces* Zone, and the thickness is believed to be between 3 and 5 m, as the lower boundary is unknown. The *revolutus* Zone is only exposed in two small outcrops at Øleå (Ø2a) and (Ø4a).

The shales in this zone are like those of the preceding zone, grey to dark grey and with a small content of calcite. At the top of the zone a 15 cm thick band of dark grey limestone is seen. Graptolites are frequent throughout, and often well preserved in full relief infilled with pyrite. Near the top of the zone oriented graptolites occur in large numbers on many bedding planes. No predominant orientation of the rhabdosomes is evident.

The graptolite assemblage in the lower part of the zone (Ø4a) is: *C. rectangularis, C. scalaris?, Glyptograptus sinuatus sinuatus* (Nicholson), *R. toernquisti, Monograptus incommodus* Törnquist, *Monograptus revolutus* Törnquist, and *M. atavus.* In the upper part of the zone (Ø2a), *G. sinuatus sinuatus, C. rectangularis, R. toernquisti, Dimorphograptus physophora* (Nicholson) ?, *M. sandersoni, M. revolutus, M. atavus, M. incommodus,* and *Monograptus cyphus* Lapworth ? are found. At the top of the zone (Ø2a) *Monograptus gregarius* Lapworth and *Monograptus triangulatus triangulatus* Harkness appear contemporaneously and are here the only graptolites found. The two species indicate the basal part of the overlying *gregarius* Zone, and both species are rather small, when making their first appearance.

Characteristic of the *revolutus* Zone is the appearance of *M. revolutus* and the disappearance of *D. confertus confertus* and *C. vesiculosus.* Only a single specimen of *M. cyphus?,* which is the index fossil for the zone at the corresponding level in Britain (Rickards, 1970), has been found on Bornholm. *M. cyphus* is also rare in Sweden, and here a *revolutus* Zone was established (see Törnquist, 1913 and Wærn, 1960a). As the graptolite assemblage at this level on Bornholm corresponds closely to that in Sweden, the designation *revolutus* Zone is also used here. Pedersen (1922) did not distinguish the zone of *revolutus* between the *acinaces* Zone and the *gregarius*

Fig. 5. Section through the Llandovery and Wenlock series along Øleå, Bornholm. Full lines=black shale; broken lines= dark or light shale, gradation in intensity of symbol indicates gradation from dark to light coloured shale; rectangles=limestone; B=bentonite; solid black=unexposed parts of section. Numbers on right hand side of columns indicate localities.


M. acinaces
M. revolutus
M. gregarius
M. gregarius
M. convolutus
M. turriculatus
M. crispus
M. griesto-niensis
Monograptus spiralis
M. spiralis
C. lapworthi
C. centrifugus
C. centrifugus
Monogr. pecti-natus
Monogr. triangu-latus
Cystogr. vesicu-losus
Cephalogr. cometa
1m

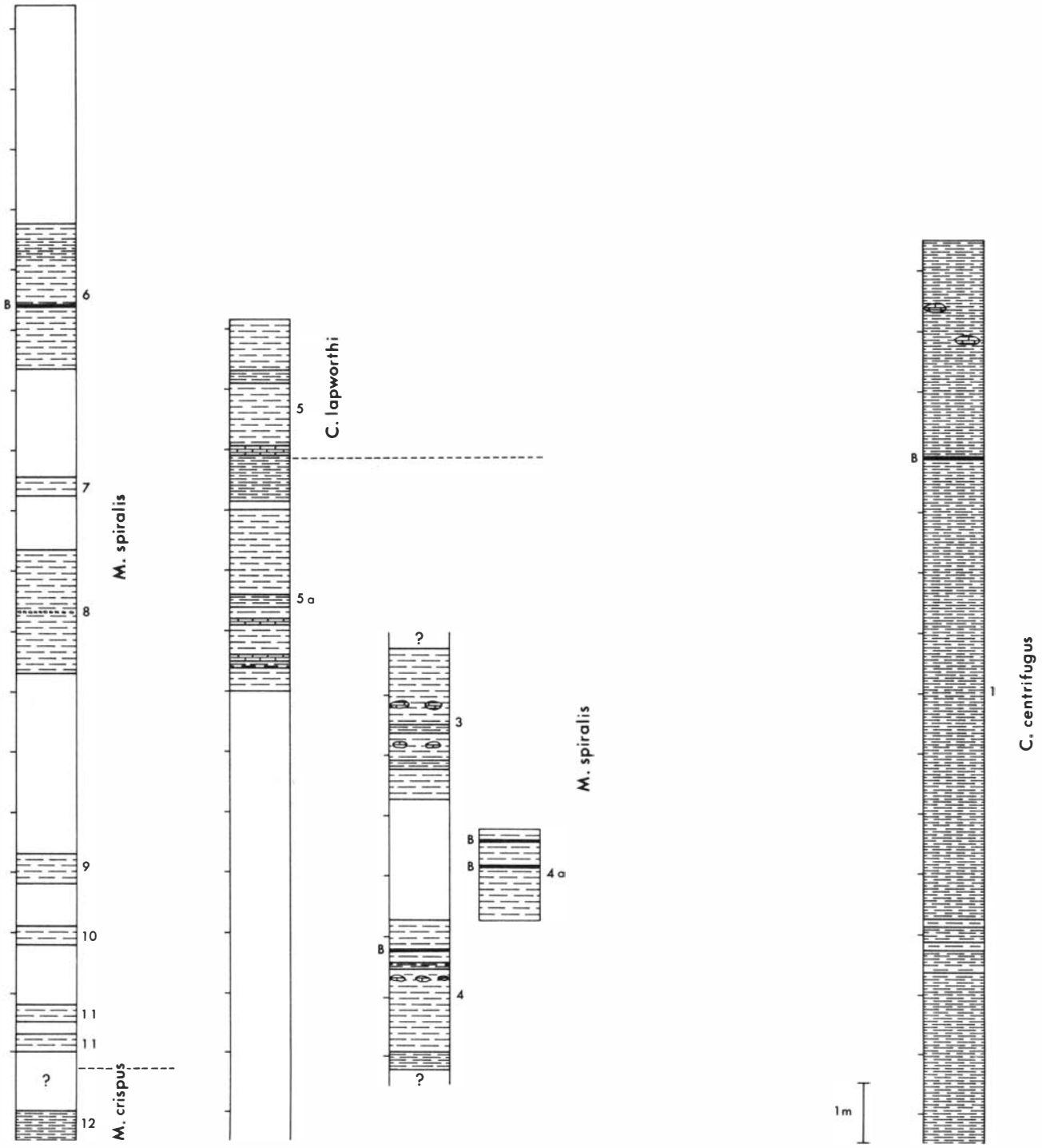


Fig. 6. Section through the exposed Llandovery and Wenlock Series along Læså. Symbols as in Fig. 5.

Zone, probably because the two exposures within the *revolutus* Zone seem to be of a later date.

The *Monograptus gregarius* Zone

The basal part of the *gregarius* Zone is indicated by the appearance of *M. gregarius* and *M. triangulatus triangulatus.* The basal part of the *gregarius* Zone is badly exposed. The thickness of the zone is about 8 m, the upper limit is placed at the level where *Monograptus convolutus* (Hisinger) and *Monograptus lobiferus lobiferus* M'Coy appear, and *M. gregarius* disappears.

The shales in the *gregarius* Zone are grey to dark grey. Three limestone bands, each about 10 cm thick, are seen in the lower part of the zone (Ø9). Occasionally horizons with well preserved pyritized graptolites occur (Ø6 and Ø10), the shales here having a small lime content. In the middle part of the zone an increase in the non-graptolitic fauna, comprising bivalves, brachiopods, and orthocone cephalopods is quite conspicuous. At this level a great number of orientated graptolites has been found (Ø2) and (Ø10), but with no

predominant trend of orientation of the rhabdosomes.

In the lower part of the *gregarius* Zone, (Ø9) and in the lower part of the sections at (Ø5), (Ø6), and (Ø8), the following graptolites are found: *Petalograptus ovatoelongatus* (Kurck), *R. toernquisti, Monograptus austerus sequens* Hutt, *Monograptus sudburiae* Hutt, *M. gregarius, M. atavus,* and *M. triangulatus triangulatus. Rastrites longispinus* Perner appears in the upper part.

The middle part of the zone, which is well exposed at (Ø2), (Ø6), and (Ø10), is characterized by the following graptolite fauna: *P. ovatoelongatus, Petalograptus minor* Elles ?, *R. toernquisti, M. sudburiae, Monograptus pectinatus* Richter, *Monograptus communis rostratus* Elles & Wood, *M. gregarius, R. longispinus.* Towards the upper part of the zone the graptolite assemblage is: *Diplograptus thuringiacus* Eisel, *Orthograptus cyperoides* (Törnquist), *P. ovatoelongatus, C. scalaris?, Pseudoclimacograptus retroversus* Bulman & Rickards, *Pseudoclimacograptus undulatus* (Kurck), *Monograptus simulans* Pedersen, *M. communis rostratus, Monograptus limatulus* Törnquist, *M. gregarius, Monograptus leptotheca* Lapworth, and *Monograptus argutus* Lapworth.

The *gregarius* Zone in Britain has been divided into three subzones, see Elles (1925); *M. fimbriatus* (synonym with *M. pectinatus*), *M. triangulatus,* and *M. argenteus.* Sudbury (1958) made a division into the subzones of *M. separatus, triangulatus-fimbriatus,* and *M. argenteus.* A division of the *gregarius* Zone is also possible on Bornholm. Here the *gregarius* Zone is divided into the *triangulatus* Subsone which is overlain by the *pectinatus* Subzone. The uppermost part of the *gregarius* Zone in Britain, the *argenteus* Subzone, cannot be distinguished on Bornholm. Here the graptolite fauna lacks important graptolites such as *Monograptus argenteus* (Nicholson) and *Diplograptus magnus* H. Lapworth. Furthermore the characteristic *M. leptotheca* is rare, and only one specimen of *M. argutus* has been found. On Bornholm *D. thuringiacus* is the most frequent graptolite at the uppermost level of the *gregarius* Zone. This species is possibly a geographic variant of *D. magnus.*

In Sweden the lowermost horizon in the *gregarius* Zone includes *M. triangulatus* and *M. pectinatus,* but no further division has been made. Here the *argenteus* or *magnus* Subzone cannot be distinguished (Wærn, 1960a). This is in agreement with the sequence on Bornholm.

The *Monograptus convolutus* Zone

The *gregarius* Zone passes into the *convolutus* Zone without any lithological change. Throughout the zone the shales become darker and in the uppermost part they are dark grey to nearly black. The limestone content in the shales disappears. The shales are rich in pyrite, especially in the lower and upper part of the zone, where well preserved graptolites with full relief infilled with pyrite are frequent. The thickness of the zone is about 9 m.

At the top of the *gregarius* Zone the major part of the "old" graptolite fauna disappears and in the overlying *convolutus* Zone many new species make their first appearance. The base of the zone is indicated by the disappearance of *M. gregarius* and the appearance of *M. lobiferus lobiferus, M. convolutus,* and *Petalograptus folium* (Hisinger). In the lowermost part of the zone exposed at (Ø11) and (Ø12) the graptolite assemblage comprises: *O. cyperoides, C. scalaris?, P. retroversus, P. undulatus, P. folium, M. convolutus, M. lobiferus lobiferus, M. limatulus, Monograptus jonesi* Rickards, and *Rastrites approximatus* Perner ?. In the middle part of the zone (Ø12) and (Ø12a) *M. lobiferus lobiferus* is frequent and occurs with *Orthograptus bellulus* (Törnquist), *Orthograptus insectiformis* (Nicholson), *Cephalograptus tubulariformis* (Nicholson), *M. leptotheca, Monograptus regularis regularis* Törnquist, *M. limatulus, Monograptus clingani* (Carruthers), *Monograptus decipiens* Törnquist, *Monograptus denticulatus* Törnquist, *M. convolutus,* and *Rastrites peregrinus peregrinus* Barrande. At the top of the zone, exposed in the lower part of the profile at (Ø13), *Cephalograptus cometa cometa* (Geinitz) is found in a 50 cm thick band and *Cephalograptus cometa extrema* Bouček & Přibyl occurs in the uppermost 10 cm. Furthermore, *O. bellulus, C. scalaris?, P. retroversus, M. convolutus, M. regularis regularis, M. limatulus, M. leptotheca, M. denticulatus, M. decipiens?,* and *Monograptus lobiferus harpago* Törnquist are found in the highest part of the *convolutus* Zone.

The *convolutus* Zone, which was also reported by Pedersen (1922), is retained here. The zone can be easily correlated with the corresponding *convolutus* Zone in Britain, as the graptolite fauna on Bornholm agrees with the fauna listed by e.g. Elles (1925) and Toghill (1968). *M. convolutus* is not common and, especially in the upper part of the zone, the index fossil is even rare. However, a further division into the zones of *P. folium* and *C. cometa* as in Sweden (see Wærn, 1960a) does not seem appropriate for the sequence on Bornholm. Here *P. folium* is rare and restricted to the lower third of the zone. In addition, the graptolite assemblage is rather constant throughout the zone. Only a single band with *C. cometa* can be separated in the uppermost part of the *convolutus* Zone.

The *Monograptus turriculatus* Zone

At the top of the *convolutus* beds, in the central part of the profile at (Ø13), a sudden change in the lithology is evident. Within a vertical distance of 1 cm the shales change to light grey, argillaceous and silty mudstone. The sediment is non-graptolitiferous but rich in pyritized fossil traces. In cross-section they are round, about 2 mm in diameter, and may be more than 5 cm long. They are mainly oriented parallel to the bedding-planes.

At 2 m above the top of the *convolutus* Zone at (Ø13a) graptolites reappear in a finely laminated, light grey, mainly argillaceous mudstone. Higher up in the sequence the mudstone becomes darker grey and towards the top of the zone dark grey shales alternate with 2–3 cm thick bands of non-fossiliferous green mudstone. The thickness of the *turriculatus* Zone is about 12 m. The lower and upper boundaries of the zone are defined by the range of *Monograptus turriculatus* (Barrande).

Nearly all graptolite species in the lower part of the

zone are new, and "old" groups, such as the triangulate monograptids and the cephalograptids, have disappeared. Only the extremely large species of the genus *Rastrites* are seen in this zone. The graptolite assemblage in the lower part (Ø13a)–(Ø15) comprises: *Glyptograptus auritus* n. sp., *Petalograptus palmeus* (Barrande), *Pseudoplegmatograptus obsesus* (Lapworth), *M. turriculatus* (mainly small specimens), *Monograptus halli* (Barrande), *Monograptus marri* Perner, *Monograptus* aff. *becki* (Barrande), *Monograptus planus* (Barrande), *Monograptus nudus* Lapworth, *Monograptus pseudoruncinatus* n. sp., *Rastrites maximus* Carruthers, and *Diversograptus runcinatus* (Lapworth). Near the middle of the zone *Petalograptus ovatus scopaecularus* Schauer and *Monograptus bjerringus* n. sp. are found. At the middle part of the zone (Ø15a) *R. maximus* disappears and is succeeded by *Rastrites linnaei* Barrande. At this level *Monograptus exiguus primulus* Bouček & Přibyl appears and is frequent together with an early form of *Monograptus priodon* (Bronn), *M. planus, M. turriculatus,* and *Monograptus* cf. *barrandei* sensu Elles & Wood. *Petalograptus altissimus* Elles & Wood is rare. At the top of the zone (Ø16)–(Ø16a) *Monograptus galaensis* Lapworth appears and is associated with *Monograptus pseudobecki* Bouček & Přibyl, *Monograptus proteus* (Barrande), *M. marri, M. priodon, M. turriculatus,* and *Monograptus exiguus* (Nicholson).

In the Llandovery sequence on Bornholm it is remarkable that all graptolite zones are present except the zone of *Monograptus sedgwickii.* This zone is well defined in Britain and has also been recorded in Scania (Törnquist, 1913) and Dalecarlia (Thorslund, 1935). The zone is not found at Kinnekulle, Västergötland (Wærn, 1948), where a non-graptolitic sequence has been correlated by bentonite layers with the *sedgwickii* Zone in Östergötland.

Pedersen (1922) observed a poor graptolite fauna at (Ø14) and he regarded the presence of the *sedgwickii* Zone on Bornholm as questionable. More material from (Ø14) has yielded a graptolite assemblage which clearly indicates the *turriculatus* Zone. Two new exposures (Ø13a) and (Ø13b), representing a lower level than (Ø14), have yielded a graptolite fauna which is clearly younger than the fauna characteristic for the *sedgwickii* Zone. Pedersen (1922) referred his "zone fossil" at (Ø14) to *Monograptus sedgwickii* (Portlock) but a restudy together with new additional material indicates a greater similarity to *M. halli* which succeeds *M. sedgwickii* in other sequences.

The non-graptolitiferous sequence between the top of the *convolutus* Zone and the appearance of the *turriculatus* fauna must at least comprise the entire *sedgwickii* Zone. At the level where the graptolite fauna reappears the faunal assemblage, including the small specimens of *M. turriculatus,* also recorded from this level by Jaeger (1959), indicates that the stratigraphic level is within the oldest part of the *turriculatus* Zone.

On Bornholm the *turriculatus* Zone corresponds to the *runcinatus* Zone reported from Sweden (Wærn, 1960a). In the present investigation *D. runcinatus* has only been found in the lower part of the *turriculatus* Zone.

In Britain a *Rastrites maximus* Subzone (Rickards, 1970) or a *maximus* Zone (Toghill, 1968) has been established below, or in the lower part of the *turriculatus* Zone. A separation of a *maximus* Zone or Subzone on Bornholm is not convenient, as *R. maximus* is only frequent in a thin horizon within the lower part of the *turriculatus* Zone. At higher levels the specimens are rare and may be mistaken for *R. linnaei.*

The *Monograptus crispus* Zone

No marked lithological change is evident between the *turriculatus* Zone and the overlying *crispus* Zone, although the lower part of the *crispus* Zone is probably not exposed. The *crispus* Zone is found at (Ø16) and (Ø17) and the thickness of the zone is estimated to be about 2.5 m. The upper boundary cannot be proved with certainty, but is defined by the appearance of *Monograptus griestoniensis* (Nicol). The shales in the *crispus* Zone are grey to dark grey, frequently interbedded with thin bands of light grey, non-graptolitiferous, argillaceous mudstone. In the middle part of the zone (Ø17) graptolites preserved in full relief infilled with pyrite are frequent.

The lower boundary of the *crispus* Zone is defined as the level where *M. turriculatus* disappears and a new graptolite fauna is introduced. *Monograptus veles* (Richter) and *M. proteus* are the most important graptolites throughout the zone. In the lowermost part *M. galaensis* and *M. pseudobecki* are frequent and throughout the middle and upper part of the zone *M. priodon, M. nudus, M. exiguus* s.l., and *M. marri* are fairly abundant. In the upper part *Petalograptus tenuis* (Barrande) is common together with *M. exiguus* s.l. The index fossil *Monograptus crispus* Lapworth is not observed in the extreme lower and upper parts of the zone and is rare in the middle part.

Pedersen (1922) and Laursen (1940) placed the transition between the *Rastrites* Shale and the *Cyrtograptus* Shale within the *crispus* Zone. Pedersen (1922) located the boundary above the *turriculatus* Zone, which he extended to a slightly higher level than in this investigation, i.e. to the middle of the present *crispus* Zone. Laursen (1940) placed the lowermost part of the *Cyrtograptus* Shale, the *grayi* Zone, just above the *turriculatus* Zone of Pedersen (1922).

In Sweden Wærn (1948) correlated the *veles* Zone at Kinnekulle, Västergötland, with the *crispus* Zone according to Elles & Wood (1918), and probably also with the *griestoniensis* Zone. However, in a diagram in Wærn (1960a), showing divisions of the Llandovery in Sweden, the *veles* Zone was dismissed and the *crispus* Zone was inserted between the *runcinatus* Zone and the *griestoniensis* Zone. This zonation is similar to the stratigraphy of the sequence on Bornholm, as presented here.

The *crispus* Zone on Bornholm has a fauna which corresponds to the *crispus* fauna reported from Britain, e.g. Elles (1925), and especially from Girvan (Cocks & Toghill, 1973).

The *Monograptus griestoniensis* Zone

The transition from the *crispus* to the *griestoniensis* Zone is not exposed. The *griestoniensis* Zone is exposed at (Ø17a), (Ø18), and (Ø19) and is about 3.5 m in thickness. The dark grey shales are mostly interbedded with about 1–5 cm thick bands of light green to grey, non-fossiliferous, argillaceous and silty mudstone. In the upper part of the zone, at (Ø19), graptolites are frequent and preserved in full relief infilled with pyrite. At the uppermost levels of the zone the graptolite fauna is impoverished and a 2 m non-graptolitiferous sequence forms the transition to the *spiralis* Zone.

The graptolite assemblage comprises *Glyptograptus? nebula* Toghill & Strachan, *Retiolites geinitzianus* (Barrande) ?, *Stomatograptus grandis girvanensis* Cocks & Toghill ?, *M. griestoniensis, Monograptus* aff. *crenulatus* sensu Elles & Wood, *M. priodon, Monograptus drepanoformis* Toghill & Strachan, *Monograptus tullbergi* Bouček ?, and *M. veles*. The lower boundary of the zone is defined by the appearance of *M. griestoniensis*. The upper boundary is indicated by the disappearance of *M. griestoniensis* and by the appearance of *Monograptus spiralis spiralis* Geinitz together with a new graptolite assemblage.

On Bornholm the section with the *griestoniensis* Zone was included in the lower part of the *Cyrtograptus* Shale, in the former *grayi* and *spiralis* zones, by Laursen (1940). The appearance of *R. geinitzianus?* indicates the basal part of the *Retiolites* Shale in Sweden (Törnquist, 1875). The *Retiolites* Shale was later applied on Bornholm by Johnstrup (1889) to the sequence corresponding to the *Cyrtograptus* Shale of Laursen (1940).

The graptolite assemblage on Bornholm is easily correlated with the fauna from Grieston Quarry (Toghill & Strachan, 1970), where the typical specimens of *M. griestoniensis* were obtained. In this zone *G.? nebula* is present. This species is possibly the latest biserial graptolite both in Britain (Toghill & Strachan, 1970) and on Bornholm.

Wærn (1948), with reservation, included the level of the British *griestoniensis* Zone in the *veles* Zone from Kinnekulle, but in 1960a he distinguished the zone of *griestoniensis* as a separate graptolite zone at the top of the Klubbudden Stage. This is in accordance with the zonation suggested for the sequence on Bornholm.

On Bornholm as well as in Sweden (Wærn, 1948 and 1960b) *M. veles* is never found associated with *M. spiralis* s.l., but is restricted to the two underlying zones of *crispus* and *griestoniensis*.

The *Monograptus spiralis* Zone

The non-graptolitiferous sequence between the upper boundary of the *griestoniensis* fauna and the appearance of the *spiralis* assemblage comprises light grey argillaceous and silty mudstone (Ø20). Three 1–3 cm thick bands of limestone were observed. In several places the mudstone is rich in pyrite, which is distributed along the bedding planes. Many burrows of different sizes occur mainly parallel to the bedding planes.

The upper boundary of the zone is defined by the disappearance of *M. spiralis* s.l. and the presence of *Cyrtograptus lapworthi* Tullberg. The *spiralis* Zone is about 25–30 m thick, but definite lower and upper boundaries are not exposed. Parts of the complete sequence are exposed in Øleå from (Ø21)–(Ø29) and at (Ø40). Outcrops from the middle and the upper half of the zone are recorded in Læså (L3)–(L4) and (L6)–(L8). In the lowermost graptolitiferous part of the zone the shales are grey and rich in well preserved graptolites. In a 1 m thick horizon at (Ø21) and (Ø22) the following assemblage was obtained: *M. spiralis spiralis, M. priodon, M. vomerinus* n. subsp., *M. vomerinus vomerinus* Nicholson, *Monograptus cultellus* Törnquist, *Monograptus anguinus* Přibyl, *Monograptus continens* Törnquist, *Monograptus denudatus* n. sp., and *M.* n. sp. ?.

Towards the middle of the zone the shales become grey-green, argillaceous to silty, and non-fossiliferous. Only a few bands of dark shales with sparse graptolites occur, mainly *M. vomerinus vomerinus*. In the middle part of the zone at (Ø26) and (L6) *Monograptus spiralis excentricus* n. subsp. is frequent, accompanied by *R. geinitzianus?, M. priodon, M. vomerinus vomerinus, M. exiguus?*, and *?Diversograptus* sp.

From the middle part of the zone to the uppermost level exposures are few and the dark grey graptolitiferous shales are interbedded with green to light grey non-fossiliferous mudstone. The graptolite fauna comprises mainly *M. vomerinus vomerinus* and *R. geinitzianus?*.

The *spiralis* Zone was reported from the same outcrops in Øleå by Laursen (1940), with the exception that (Ø19), which can now be referred to the *griestoniensis* Zone, was included in the *spiralis* Zone. In Læså the *spiralis* Zone was reported from (L4), (L5), and (L6) by Laursen (1943), but at (L5) he also included the *grayi* Zone. Here *C. lapworthi* has been found during the present investigation. The faunal assemblage at (L3) and (L4) comprises *M. priodon, M. vomerinus vomerinus, M. speciosus,* and *Barrandeograptus pulchellus* (Tullberg). This graptolite fauna may indicate strata corresponding to the rather poorly exposed section at Øleå between (Ø26) and (Ø29).

In Britain the *crenulatus* Zone is equivalent to the zone of *spiralis*. However, the *crenulatus* Zone is rather ill defined (Strachan, 1960). *Monograptus crenulatus* Törnquist needs a redefinition as this species is possibly synonymous with *M. vomerinus vomerinus. M. crenulatus* sensu Elles & Wood is different from the original species of Törnquist. On Bornholm vomerinid specimens, which bear resemblance to *M. crenulatus* sensu Elles & Wood, are found in the upper part of the *griestoniensis* Zone. Throughout the *spiralis* Zone *M. vomerinus* s.l. is common. *M. spiralis* s.l. is regarded as a more suitable index fossil than *M. crenulatus* for the zone, even if the shape of the rhabdosome shows some variation throughout the zone.

On Bornholm the zone of *spiralis* is easily correlated with the corresponding zone in Sweden, where it is developed in Scania, Västergötland, Dalecarlia (Wærn, 1948 and 1960a). In Sweden, *M. continens* and *M. cultellus* are also important in the basal part of the zone.

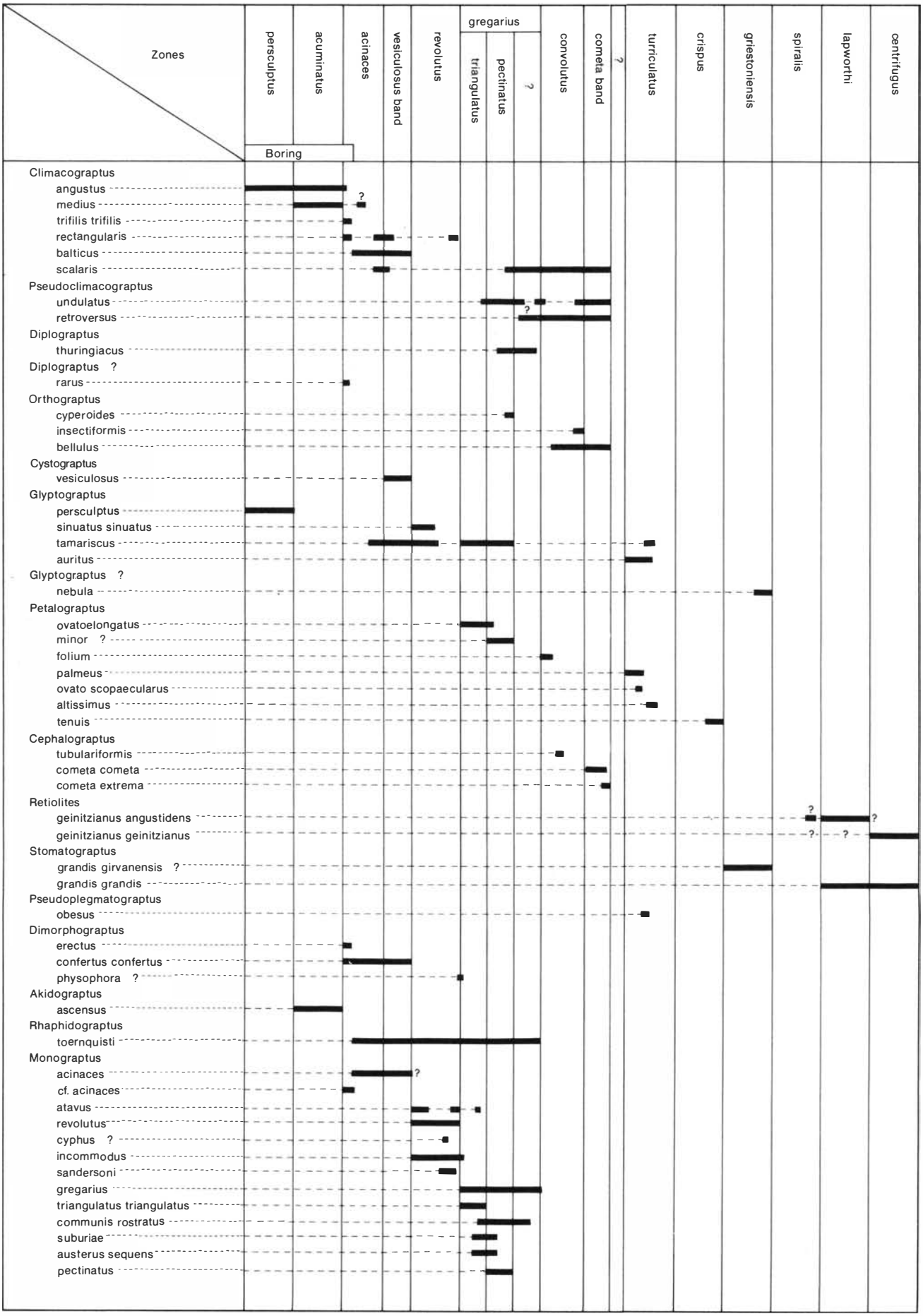


Fig. 7. Stratigraphic range of Llandovery and Wenlock graptolite species on Bornholm.

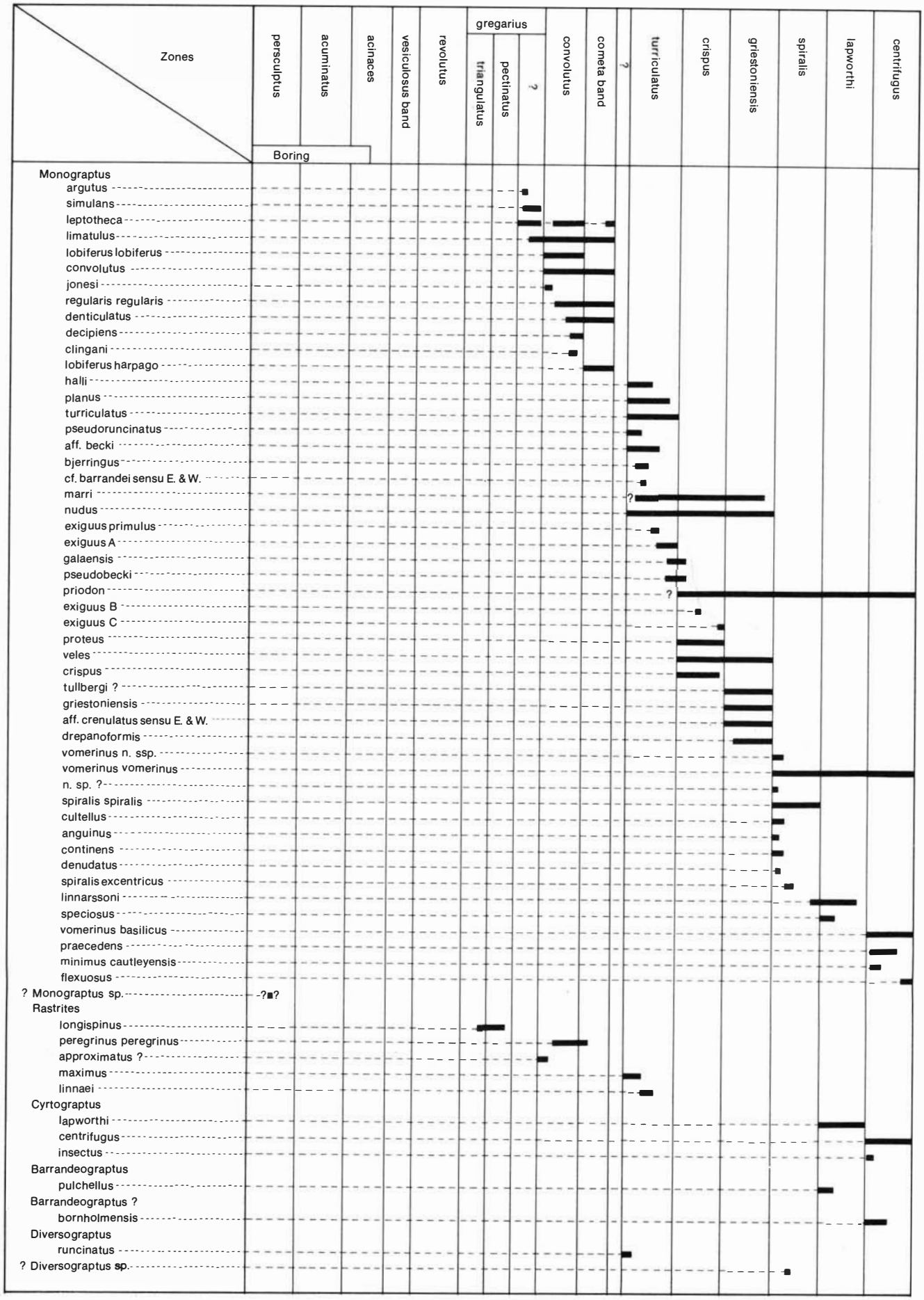


Fig. 8. Stratigraphic range of Llandovery and Wenlock graptolite species on Bornholm. Continued from Fig. 7.

The *Cyrtograptus lapworthi* Zone

The lower boundary of the *lapworthi* Zone is defined by the appearance of *C. lapworthi* and the upper boundary by the presence of *C. centrifugus* and the disappearance of *C. lapworthi.* The zone is well exposed at Øleå (Ø29)–(Ø31), (Ø40), and (Ø42), whereas only the lower part is exposed at Læså (L5) and (L5a). The thickness of the zone is about 5 m.

In the transition from the underlying *spiralis* Zone dark grey shale is seen (Ø29), (Ø40), and (L5a). The graptolite assemblage comprises *Retiolites geinitzianus angustidens* Elles & Wood, *Stomatograptus grandis grandis* (Suess), *M. spiralis spiralis, Monograptus linnarssoni* Tullberg, *Monograptus speciosus* Tullberg, *M. priodon, M. vomerinus vomerinus, C. lapworthi,* and *B. pulchellus.* This level is also very rich in orthocone cephalopods, *Aptychopsis,* and ceratiocarids.

In the middle part of the zone at (Ø30) grey-greenish mudstones are predominant, and burrows occur frequently. The mudstones are interbedded with a few layers of dark grey graptolitiferous shales. Here a small number of *R. geinitzianus angustidens, M. linnarssoni, M. priodon,* and *C. lapworthi* were obtained.

In the upper part of the zone the lithology is an alternation of dark grey to greenish bands (Ø31) and (Ø42), with a few 10 cm thick bands of recrystallized oolitic limestones. *R. geinitzianus angustidens* occurs in abundance, whereas the rest of the graptolite fauna is impoverished. *C. lapworthi* is only represented by small fragments associated with *M. priodon* and *M. vomerinus vomerinus.* The rich non-graptolitic fauna comprises ceratiocarids, pelecypods, and *Aptychopsis.*

Grönwall (1916) reported the zone of *lapworthi* from Øleå. The zone was retained by Laursen (1940) on the basis of the graptolite assemblage from a single outcrop at the level of (Ø29). At Læså Laursen (1943) did not find the *lapworthi* Zone. During the present investigation additional exposures from this level have been recorded. In the faulted area near the outlet of Øleå the graptolite assemblage from the *lapworthi* Zone has been found at (Ø40) and (Ø42), at the level where Laursen (1940) reported the *murchisoni* Zone. Laursen (1943) reported the *grayi* Zone from (L5) at Læså, but here the shales have yielded a graptolite fauna from the lower part of the *lapworthi* Zone.

Tullberg (1882b) was the first to describe the *lapworthi* Zone from Scania. The zone was included in the *Cyrtograptus* Shale and correlated with the uppermost Gala of England. Later Wærn (1948) reported a graptolite fauna from Kinnekulle showing resemblance to the fauna mentioned by Tullberg (1882b). In Wærn (1960a) the *lapworthi* Zone was retained as the youngest graptolite zone in the Llandovery Series.

The graptolite fauna from the *lapworthi* Zone is easily correlated with the fauna from Sweden, the zone being reported only from Sweden and Denmark. The zone is here retained on account of the very characteristic graptolite assemblage including *M. linnarssoni, M. speciosus, S. grandis grandis,* and *R. geinitzianus angustidens.* The graptolites in the *lapworthi* Zone are somewhat related to those from the uppermost *spiralis* Zone, but also new graptolite species appear in the *lapworthi* Zone. On Bornholm the *lapworthi* Zone is referred to the top of the Llandovery Series. This is due partly to the faunistic relationship with the *spiralis* Zone, and partly to the change in the graptolite assemblage in the transition from the *lapworthi* Zone to the *centrifugus* Zone in which the appearance of stout cyrtograptids takes place. Furthermore, the lithology (e.g. the oolitic limestone) and the impoverishment of the graptolite fauna in the upper part of the *lapworthi* Zone may indicate the transition to the Wenlock Series.

The *Cyrtograptus centrifugus* Zone

The *centrifugus* Zone is the youngest zone preserved in the Silurian of Bornholm. No clearly marked lithological change is evident in the transition from the *lapworthi* Zone to the *centrifugus* Zone, at the boundary the shales are grey to dark grey and alternate with bands of light green to grey mudstone. The upper boundary of the zone cannot be established. The index fossil *Cyrtograptus centrifugus* Bouček has not been observed in the uppermost layers. The *centrifugus* Zone is present at Øleå and Læså. The measured thickness of the zone at Øleå from (Ø31)–(Ø38) is 20–25 m, and from the long profile on the beach east of Læså (L1) nearly 30 m shale can be referred to this zone. Three outcrops in the southernmost fault-block at Øleå are from the lower part of the zone (Ø39) and (Ø41)–(Ø42). The shales in the *centrifugus* Zone are predominantly grey to dark grey and more homogeneous than the shales found in the *lapworthi* Zone. The shales are frequently finely laminated, and thin bands of grey-greenish mudstone without graptolites occur. Pyritized graptolites are observed in the lower third of the zone, but are rare in the upper part.

The index fossil *C. centrifugus* is not common. From the lower part of the zone at Øleå (Ø32) two specimens of *Cyrtograptus insectus* Bouček were obtained. Frequent graptolites throughout the zone are *R. geinitzianus geinitzianus, Monograptus vomerinus basilicus* Lapworth, and *M. priodon. S. grandis grandis, Monograptus minimus cautleyensis* Rickards ?, and *Barrandeograptus? bornholmensis* (Laursen) occur in the lower part of the zone. *Monograptus praecedens* Bouček is restricted to the middle part of the zone and is found at (Ø34)–(Ø35) and (L1). A slender, but widely branched species of *Barrandeograptus?* is observed at the top together with *Monograptus flexuosus* Tullberg, (Ø38).

Cyrtograptus murchisoni Carruthers was used as index fossil for the level corresponding to the present *centrifugus* Zone by Grönwall (1916) and Laursen (1940, 1943). The exposures in the southernmost part of Øleå (Ø40)–(Ø43) were included in the zone of *murchisoni* by Laursen (1940). They are here demonstrated to belong within the lower part of the *lapworthi* Zone and the lower part of the *centrifugus* Zone. During this investigation no specimens of the typical *C. murchisoni* with secondary cladia development have been obtained. Neither have specimens of *C. murchisoni* been met with in older

collections from Bornholm, now preserved in the Mineralogical Museum in Copenhagen.

The two specimens of *C. insectus* in the lower part of the *centrifugus* Zone (Ø32) do not warrant a separation of an *insectus* Zone, as recognized in Poland (Teller, 1969) and Middle Bohemia (Bouček, 1960). The graptolite fauna occurring together with *C. insectus* is equivalent to the fauna in the adjacent underlying and overlying horizons.

The graptolite fauna from the *centrifugus* Zone corresponds to the fauna observed in the same horizon in Britain (Rickards, 1965). On Bornholm the zone is also regarded as being the lowermost zone in the Wenlock Series. Earlier the zone of *murchisoni* was reported as the oldest zone in Wenlock, (e.g. Wærn, 1948 and 1960a), but later investigations by Rickards (1965), Cocks & Rickards (1969), and Bouček (1960) have shown that the *centrifugus* Zone indicates the basal part of the Wenlock Series and that the *murchisoni* Zone overlies the *centrifugus* Zone. The specimen of *C. murchisoni* figured as Pl. 4:9 in Tullberg (1883) shows a great similarity to *C. insectus*. Furthermore, *Cyrtograptus murchisoni crassiculus* Tullberg needs to be revised, as the subspecies appear to have a great resemblance to *C. centrifugus*. The two cyrtograptids were recorded by Tullberg (1882b) from the *murchisoni* Zone at Röstånga in Scania. New collections from this outcrop may possibly show that this part of the Röstånga section should be referred to the *centrifugus* Zone.

Correlation

The Silurian shales on Bornholm are primarily divided into the Llandovery and Wenlock Series, and this is in accordance with the common usage in Britain. For further subdivision of the Llandovery Series the terms Lower, Middle and Upper have been used by e.g. Jones (1925). Cocks et al. (1970) recommended elimination of the term Middle Llandovery and divided the Llandovery into "Lower" and "Upper", as originally defined by Murchison. However, Georg et al. (1967) suggested that a division into Lower, Middle and Upper was appropriate for informal usage only and, accordingly, Cocks et al. (1971) proposed that the division of Cocks et al. (1970) should be applied only informally.

In the type area of Wales four stages were erected within the Llandovery Series by Cocks et al. (1970): The Rhuddanian Stage comprising the *persculptus* Zone to the *cyphus* Zone, the Idwian Stage, including the *gregarius* Zone to the *convolutus* Zone, the Fronian Stage, with the *sedgwickii* Zone to the *turriculatus* Zone, and the Telychian Stage comprising the *crispus* Zone to the *crenulatus* Zone. The divisions were based on the shelly facies within the type area with firm correlation to fixed points in the graptolite zonation (Cocks et al., 1971). Within the Wenlock Series no formal stages have been erected in the type area, as the correlation of the shelly facies in this area with graptolitic sequences has not been completed. The base of the Wenlock Series is most likely situated at the lower boundary of the *centrifugus* Zone (Cocks & Rickards, 1969).

In Sweden the old terms *Rastrites* Shale and *Cyrtograptus* Shale have been used up to the year 1960. The *Rastrites* Shale was defined by Linnarsson (1881) as comprising the *lobiferus* Zone and the *turriculatus* Zone. In subsequent usage the *Rastrites* Shale has been extended far beyond the vertical extension of the genus *Rastrites* by e.g. Törnquist (1892) to include the Elles & Wood zones 16–24, all graptolite zones in the Llandovery except the uppermost one, zone no. 25. As a consequence Wærn (1960a) divided the Llandovery of Sweden into four stages: the Bollerup Stage, including the *persculptus* Zone to the *gregarius* Zone, the Silvberg Stage: the *folium* Zone to the *sedgwickii* Zone, the Klubbudden Stage with the *runcinatus* Zone to the *griestoniensis* Zone, and the Kullatorp Stage comprising the *spiralis* Zone to the *lapworthi* Zone.

In Sweden the *Retiolites* Beds (Regnéll, 1960) comprise the zones of *spiralis, lapworthi,* and *murchisoni.* The *Retiolites* Beds and the overlying *flemingii* Beds are included in the *Cyrtograptus* Shale, which is of Wenlock age, with the exception of the two lowermost zones (Regnéll, 1960). A division into stages of the Wenlock Series has not been completed in Sweden.

The Silurian sequence on Bornholm corresponds well to the Silurian in Sweden, especially in Scania. On Bornholm strata representing the *persculptus* Zone to the *gregarius* Zone appear to form a continuous sequence as in Scania, except that in Scania the *persculptus* Zone is probably missing. In Sweden the very top of the *gregarius* Zone, the subzone of *argenteus,* cannot be ascertained, and Wærn (1960a) claimed that *M. leptotheca,* the guide fossil for this subzone, has not been seen at this level.

The *argenteus* Subzone has not been recognized on Bornholm. *D. thuringiacus* is here characteristic of the uppermost part of the *gregarius* Zone. Only a very few specimens of *M. leptotheca* have been found in the upper part of the zone and, consequently, no formal name has been given to the uppermost part of the *gregarius* Zone. However, the *gregarius* Zone apparently passes continuously into the *convolutus* Zone.

In the zone of *convolutus* the shales reach their maximum darkness and become nearly black. This corresponds closely to the development in other areas in Fennoscandia where, especially in the *cometa* Zone being equivalent to the upper part of the *convolutus* Zone on Bornholm, the graptolite shales have their widest extension. In addition to its presence on Bornholm and in South and Central Sweden the zone has been reported from Bergen (Kolderup, 1934), below Gotland (Thorslund & Westergård, 1938), and from Västerbotten (Kulling, 1925).

On Bornholm the *sedgwickii* Zone is not represented by graptolite facies but is developed as non-fossiliferous light grey mudstone. In the sequence in Scania, which in other respects shows great similarity to Bornholm, as well as in Dalecarlia (Dalarna) and in Östergötland, the *sedgwickii* Zone is well developed. In Västergötland the *sedgwickii* Zone has not been identified. In Britain a

change in facies occurs between the former Middle and Upper Llandovery, now between the Idwian and the Fronian Stages. However, in Östergötland and Dalecarlia these two zones are monofacially developed. Here a change of facies is seen between the *sedgwickii* Zone and the *runcinatus* Zone, and this is also the case in Scania and Västergötland (Wærn, 1948 and 1960a). Further lithological changes at this level are recorded at Mjøsen in the Oslo area where a *turriculatus* fauna appears, and in Jämtland (Thorslund, 1948).

On Bornholm graptolites reappear in the *turriculatus* Zone but the great facial change happens at the top of the *convolutus* Zone. In this respect the sequence on Bornholm is closer to the British sequence than to the Swedish.

Between the *griestoniensis* Zone and the *spiralis* Zone Wærn (1960a) established the Klubbudden Stage in the sequence in Östergötland. The upper boundary was drawn at a light coloured, thick mudstone bed separating the *griestoniensis* fauna from the *spiralis* assemblage. On Bornholm the two zones are separated by a 1–2 m thick non-graptolitiferous mudstone bed, corresponding to the development in Scania, Västergötland, and Dalecarlia (Wærn, 1960a). Within the main part of the *spiralis* Zone the graptolite facies is not continuously developed on Bornholm, grey green mudstone predominates and alternates with a few graptolite rich beds. These sedimentation shifts are continued into the *lapworthi* Zone.

The transition Llandovery–Wenlock has not been worked out in Sweden. On Bornholm no marked boundary between the two series is evident. However, at the top of the *lapworthi* Zone the graptolite fauna becomes impoverished, and oolitic limestone indicates shallow water conditions. In the *centrifugus* Zone in the Wenlock Series the shales are more homogeneous and rich in graptolites than at the top of the preceding *lapworthi* Zone. This indicates that the transition from Llandovery to Wenlock Series worked out in the British type area is also reflected within the sequence on Bornholm.

On Bornholm a division of the Silurian into stages quite similar to those for Sweden (Wærn, 1960a) does not seem to be in complete agreement with the lithological and faunistic development throughout the sequence. The series on Bornholm seem to be continuously developed from the *acinaces* Zone to the top of the *convolutus* Zone, where an important change happens. At this level no distinction of stages has been done in Sweden. Between the *griestoniensis* Zone and the *spiralis* Zone an evident change in the sequence takes place. However, this change resembles what happens at the base of the Klubbudden Stage in Sweden, and there the stage seems to be equivalent to the sequence on Bornholm including the *spiralis* and *lapworthi* zones. Informally, a division of the Llandovery into the lower and upper Llandovery is proposed. The base of the upper Llandovery is placed at the transition *convolutus–turriculatus* Zone in agreement with the common British usage.

In Denmark corresponding strata to the Silurian sequence on Bornholm are only known from a boring at Slagelse, Zealand. Here Sorgenfrei & Buch (1964) and C. Poulsen (1974) have reported a graptolite assemblage from the *crispus* Zone at a depth of about 2800 m. The zone has a thickness of 150 m but appears to show the same lithological development as on Bornholm, with dark grey shales alternating with light grey siltstone (C. Poulsen, 1974).

The thickness of the Silurian shales at Øleå is about 160 m, including the "old" *Rastrites* Shale of about 100 m. These estimates correspond to the sequences reported from Scania. Here the *Rastrites* Shales were stated to be 120 m by Tullberg (1882b) and 40–120 m by Regnéll (1960). In Slagelse the entire Silurian sequence is less than 280 m (Sorgenfrei & Buch, 1964), but the only graptolitiferous zone, the *crispus* Zone, is about 150 m compared to 2.5 m of the corresponding zone on Bornholm.

The Silurian sequence on Bornholm and in Scania is situated within the intracratonic Oslo–Scanian–Baltic syneclise (Størmer, 1967). At Slagelse the sequence is probably situated outside the syneclise in a separate structure, which is bordered by the Ringkøbing–Funen gneiss ridge. This ridge is recorded only 830 m below the surface (Sorgenfrei & Buch, 1964), and no Silurian deposits have been found on the ridge. However, Silurian layers here may have been present and removed before the Triassic. The separate structural position of Slagelse appears to be reflected in the sedimentation rates. The Bornholm and Scania sequences from the lower Silurian are rather continuously developed, even shallow water conditions have been demonstrated, whereas only one graptolite zone has been recorded in Slagelse, here with a far greater thickness which may be related to the nearby land west of the basin.

The presence of the Silurian in Jutland has been proved in the borings Nos. 1 at Nøvling in central Jutland and possibly at Rønde (Christensen, 1971). In Nøvling the fossils recorded from claystones and siltstones are of Lower to Upper Ludlow Age.

The Silurian sequence on Bornholm was deposited in an intracratonic basin. However, throughout the series there is evidence of volcanic activity.

Bjerreskov (1971) reported 15 bentonite layers from the Llandovery Series at Øleå and about 10 rusty beds probably representing weathered bentonite beds (not figured). From the Wenlock Series four additional bentonite layers, all about 1–2 m thick have been observed at Øleå, and at Læså three beds were found in the Llandovery shales. In total there may be about 20 bentonite layers in the exposed part of the Silurian on Bornholm. The bentonite beds are scattered throughout the sequences at Øleå and Læså; but they seem to be most frequent in the *gregarius* Zone, possibly a function of the degree of exposure (Bjerreskov, 1971). From the Llandovery of Dalecarlia Wærn (1960b) distinguished 40 bentonite layers with the highest frequences in the *turriculatus* Zone. At the present no definite correlation of the bentonite layers from Sweden and Bornholm appears to be possible.

Systematic descriptions

Introduction

In the graptolite literature several discussions about the classification within the order Graptoloidea Lapworth, 1875 have been presented. No unified agreement with regard to the classification has yet been reached and many authors express their own views on the taxonomy, implying that a great deal of the graptolite literature is becoming rather inhomogeneous. In the present work the classification of the Graptoloidea into suborders Diplograptina Lapworth, 1880 and Monograptina Lapworth, 1880 (Bulman, 1963) is used. The Diplograptina and Monograptina have been widely discussed for many years, especially with regard to the criteria for dividing the suborders into families and genera. One of the problems is whether the basic classification should be based on the form of the rhabdosome and the growth of the thecae, or on the thecal morphology alone. The author regards a revision and an eventual new classification of the various genera to be beyond the scope of the present work. To avoid fundamental changes in well established generic names and complication in formulation of graptolite names the present author's use of generic names mostly follows the classification of Bulman (1970). The classification is regarded as practically workable, although not perfect.

Only genera represented in the Silurian on Bornholm have been treated in the systematic part. The author considers the gross structure of the rhabdosome with eventual cladial development and the thecal mode of growth to be the primary criteria for classification at the generic level and the thecal morphology principally of subordinate value with regard to the classification of Diplograptina. This agrees with the views of e.g. Jaeger (1959) and Stein (1965). However, from this very strict definition both authors make some exceptions in maintaining the genera *Climacograptus* Hall, 1865 and *Rhaphidograptus* Bulman, 1936. The two genera are based on thecal morphology only, but are maintained as both have been long established and are well known. Division of the genus *Diplograptus* M'Coy, 1850 into subgenera was suggested by Jaeger (1959), in dismissing the classification of Bulman (1955) who elevated the different groups and subgenera within the genus *Diplograptus* into independent genera.

For practical reasons the author follows Bulman (1955 and 1970) in the classifications of the Diplograptina. The genera *Diplograptus, Climacograptus, Glyptograptus* Lapworth, 1873, *Orthograptus* Lapworth, 1873, *Petalograptus* Suess, 1851, *Cephalograptus* Hopkinson, 1869, and *Pseudoclimacograptus* Přibyl, 1947, are mainly well defined genera. They have long been established in the literature and are of considerable importance, being widely used as stratigraphic indices. However, *Pseudoclimacograptus* and *Cephalograptus* have close relations respectively to the climacograptids and the petalograptids and should possibly be regarded as subgenera. The most remarkable difference between the pseudoclimacograptids and the climacograptids is the undulating median septum in the former which may take all shapes from zig-zag, to vaguely undulating, or nearly straight, and generally convex supragenicular walls. Among the petalograptids *P. tubulariformis* is evidently a transition from *P. folium* to *C. cometa,* and the difference between the petalograptids and the cephalograptids is restricted to the diversity of the thecal lengths.

Within the family Retiolitidae the division into genera from Bulman (1970) is retained as the rhabdosomes of *Retiolites* Barrande, 1850, *Stomatograptus* Tullberg, 1883, and *Pseudoplegmatograptus* Přibyl, 1948, are different. However, with more and better preserved material it may be possible to prove the closer relationship between the retiolitids and the stomatograptids, indicated by the discovery of the row of median pores in *R. geinitzianus angustidens.*

Long discussions have been presented concerning the suborder Monograptina and especially the Monograptidae. Many authors from Russia, China, Poland and Czechoslovakia have mainly during the last 30 years erected a large number of different genera within the monograptids, whereas the greatest part of the occasionally imperfectly defined genera has not been used by American, British, and some German authors. However, recently British authors, e.g. Bulman (1970), Hutt et al. (1972), and Rickards (1974) have accepted some of the numerous genera within the family Monograptidae.

The thecal form is the only valid criterion for classification of the widely distributed genus *Monograptus* Geinitz, 1852. However, a division of the monograptids based on the thecal morphology, including a distinction of the species with biform thecae, would imply a great number of genera, each represented by only very few species. The resulting classification would be of very limited value. Furthermore, the present knowledge of monograptid phylogeny is rather limited, even if some recent works have thrown new light on the thecal development and morphology within the monograptids, e.g. Rickards & Rushton (1968), Hutt et al. (1970), and Hutt (1974).

In the present work the genus *Rastrites* Barrande, 1850 is retained. This genus has long been established and is well characterized by the thecal form. Furthermore the genus *Rastrites* is of great stratigraphic importance.

The genus *Monoclimacis* Frech, 1897 is long ranging and quite inhomogeneous. The monoclimacograptids are distinguished by the geniculate thecae and suprageniculate walls which are parallel to the axis of the rhabdosome. However, included in the genus are graptolite species of variable appearance which may not be monophyletic. Some species, e.g. *M. vomerinus* n. ssp. described here, resemble the genotype, *M. vomerinus,* in many respects. However, *M. vomerinus* n. ssp. has biform thecae, the proximal 1–5 thecae are hooked, and in the specimens preserved with full relief the geniculum is flowing to nearly straight. Also *M. crenulatus* sensu Elles & Wood has biform thecae. *M. griestoniensis,* which was included in *Monoclimacis* (e.g. Toghill & Strachan, 1970), has retroflexed apertures throughout

the rhabdosome, and well preserved specimens show prothecal folds. This thecal morphology is quite different from the typical form of the monoclimacograptids. The Ludlow species, e.g. *Monograptus micropoma* (Jaekel), have well developed genicular flanges with outgrowth of microfussellar tissue, but *M. continens* from the upper Llandovery appears to have prolonged dorsal thecal walls. The walls seem to be rudiments from a retraction of a thecal hook formed by both the dorsal and ventral walls of the thecae. It appears to the author that with further investigation *Monoclimacis* may possibly be divided into different genera or subgenera, basically on criteria equal to those used for defining *Climacograptus* and *Glyptograptus*. The classification may be of stratigraphic importance. In this work the genus *Monoclimacis* is included in *Monograptus,* but species closely related to *M. vomerinus* s.l. are occasionally informally referred to as monoclimacograptids.

In the material from Bornholm some monograptids have thecae which superficially resemble the Ludlow genus *Cucullograptus* Urbanek, 1954. The thecae have laterally twisted apertural parts and possibly had two differently developed apertural lobes. Unfortunately the state of preservation does not allow any close comparison with *Cucullograptus* which is only defined from well preserved, isolated material.

The genus *Pristiograptus* Jaekel, 1889, distingushed as graptolites with simple straight tubes without apertural modifications, includes species with thecae of various morphologies. Some of the species in the *nudus* group, e.g. *M. nudus,* have thecae with sigmoidally curved ventral thecal walls and a slightly developed geniculum. These species seem to be rather different from the species within the *dubius* and *vulgaris* groups. Until relief specimens of the *nudus* group are better known, the author prefers not to separate the pristiograptids from the genus *Monograptus*.

In the family Cyrtograptidae the division into *Cyrtograptus* Carruthers, 1862 and *Barrandeograptus* Bouček, 1933 is rather dubious. The type species *B. pulchellus* has here been proved to have biform thecae with slender hooked proximal thecae and apparently rather simple distal thecae. The presence of biform thecae, which are proximally hooked, closely approaches the diagnostic features of the genus *Cyrtograptus*. No change of generic names has been made yet, as the exact nature of the thecal structures of *B. pulchellus* are still unknown.

The genus *Diversograptus* Manck, 1923 was recognized by Manck (1923) and Bulman (1971) as monograptids with one cladial development from the sicula and with or without thecal cladia. The thecae have retroflexed hooks and generally become simpler distally. Three species from Bornholm have a "diversograptid" ramification, but the cladial developments are rather different. As observed by Strachan (1952) a "sicula" cladium is found in *D. runcinatus*. In some of the diversograptid specimens of *M. speciosus* a somewhat sicula-like structure is found, but this is not a general feature. *M. sandersoni* has a thickened dorsal side of the stipe at the bipolar outgrowth and has prolonged initial thecae in the cladia. In the present material there is no evidence of sicular cladia in *M. sandersoni* and *M. speciosus,* and the bipolar outgrowth is merely regarded as a regeneration phenomenon, involving an outgrowth of pseudocladia (Bulman, 1970). For these reasons the two species are not referred to the diversograptids. *D. runcinatus* is discussed on p. 90.

In the present work all frequent and important graptolites from the Silurian sequence on Bornholm are described. However, two well known species, *C. scalaris* and *G. tamariscus* have not been treated. Both graptolites have been described and divided into well defined subspecies by e.g. Packham (1962) and Rickards (1972). The present material of the two species is rather poor, and it has not been possible to determine them at the subspecific level.

At least 20 graptolite specimens have been impossible to refer to presently known species, but in all cases the material is too small and insufficient for describing new species or subspecies.

Terminology and measurements

Most of the terms used in the systematic part to describe the morphology of the graptolites are in accordance with Bulman (1970). The length of the rhabdosome is here defined as the length of the thecae-bearing part of the rhabdosome, excluding virgella and virgula. The width of the rhabdosome is generally the total dorsoventral width including the thecal tubes, but excluding eventual thecal spines. The thecal width is measured as the dorso-ventral width in lateral view.

The thecal spacing is measured over intervals of 2.5 mm, 5 mm, or 10 mm, depending upon the curvature of the rhabdosome. Small intervals are used for strongly curved rhabdosomes to increase the accuracy of the measurements, and this also applies to short rhabdosomes with a large variation in the thecal spacing. If not otherwise specified, measurements have been made on thecae in the proximal and most distal 10 mm of the rhabdosome.

In Packham (1962) and Rickards (1965 and 1970) thecal spacing is calculated from a small number of thecae and then by extrapolation presented as number of thecae per 10 mm. This method, however, may result in strongly biased averages and is not used here.

With regard to the thecal height the terminology of Sudbury (1958) is used. The length of the thecae is measured from the proximal end of the interthecal septa to the thecal apertures along a line midway between the ventral and dorsal walls.

Preservation

In the present material the state of preservation of the graptolites ranges all the way from completely flattened to specimens in full relief, infilled with pyrite. None of the hitherto collected graptolites from the Llandovery and Wenlock Series on Bornholm have been subjected to tectonical deformations.

The organic remains of the graptolites are carbonized and preserved as thin, silvery to black carbon films, either enclosing the pyrite moulds or in flattened specimens appearing as brittle films. In the latter specimens the films may consist of one or two layers and are frequently broken into parallel sided fragments along lines which are mostly oblique to the axis of the rhabdosome and to growth lines, when these are present (Pl. 1:E).

The graptolites preserved in full relief have an internal mould of pyrite which must be syngenetic. The pyrite moulds are enclosed by the carbon films which occasionally show grooves, rarely ridges, from the junctions of the fusellar half rings. A cover of well developed pyrite crystals is not unusual on the external side of the carbon film. The thecal apertures are occasionally infilled with pyrite crystals which have enlarged the apertures by their growth.

Flattening during diagenesis has affected the rhabdosomes as described by Sudbury (1958). The thecal tubes and the common canal attain a greater width by lateral compression, while the junctions between the thecae and the common canal are more rigid and have a tendency to retain their form.

Depending on the morphology of the thecae the compression of the thecal apertures has rather varied effects. Occasionally the thecal apertural hooks have been flattened with a median groove in the dorsal wall of the hook, giving the impression that thecae seem to be composed of two lappets instead of one continuous hook. In the author's material this is observed in *M.* aff. *becki.* On the other hand the apertural parts of *M. galaensis,* which in obliquely flattened specimens show two lappets, appear in full relief specimens as simple rounded hooks.

During lateral compression the thecal apertures may be twisted resulting in a complete alteration of their original shape and orientation. In graptolites with a lateral apertural eversion, especially with a prolongation into a pair of lateral spines as in *M. spiralis* s.l., *M. turriculatus, M. halli,* and others, the effects of flattening imply that the apertures are twisted and only one spine is seen, appearing as one mesial apertural spine. The other spine will be broken off, or is hidden in the sediment.

In some species as *M. proteus, M. planus,* and *M. tullbergi?* the lateral twisting of the apertures is seen both in relief and in flattened specimens and the torsion is constantly to the reverse side of the rhabdosome, seen in dorsal view. In this case the torsion of the apertures is considered to be primary, as shown for isolated specimens of *M. proteus* (Hutt et al., 1970).

Ultrastructures

As the present graptolite material occasionally is well preserved with carbonized remains showing growth lines, the ultrastructures have been studied using a Cambridge stereoscan microscope (SEM). Wetzel (1958) was the first to make electron microscope studies of graptolites, and from the results of examinations in a transmission electron microscope he compared the graptolites with the bryozoans. Later on ultrastructures have been examined in transmission microscope by Kraatz (1962, 1968) and Berry and Tagaki (1970, 1971). In the latter two works the two peridermal layers from isolated graptolites were described.

Stereoscan microscopy on isolated specimens of *M. riccartonensis* was subsequently carried out by Rickards et al. (1971). The vertical tissue was described as successive layers built up by coalescing granules, the deepest and earliest deposited layers with the greatest coalescence. Laminated structures in the fusellar layer being normal to the peridermal walls and the lines of junctions between the peridermal half rings were noted. The structures appeared to cross the growth ridges without breaks.

Towe & Urbanek (1972) studied the periderm of isolated specimens of *Dictyonema,* and from transmission electron microscope investigations they found a well preserved morphology of a fibrous material in the periderm which they compared with collagen in association with polysaccharide. Virgula structure and thecal walls were described by Berry (1974) and ultrastructures of some retiolitids were studied by Urbanek & Rickards (1974).

In the present work, the carbonized remains of graptoloids have been examined, mainly from well preserved specimens which generally occur in relief with a mould of pyrite. The specimens have not been etched or prepared in other way; they were placed on aluminium stubs and coated with gold before examination in the SEM.

The external surfaces of the carbon films generally appear with irregularly placed holes and pores of different size and depth, giving the surface a corroded appearance (Pl. 1:B).

The internal surface of the periderm from a well preserved, pyrite infilled specimen of *Monograptus vomerinus vomerinus* was studied. The surface is rather smooth but is finely striated and with small irregularly situated pores, 0.3 μ in diameter (Pl. 1:C). Similar structures being normal to the growth lines were also demonstrated by Rickards et al. (1971), and they may represent the fibres on the inner margin, described by Berry (1974).

In a well preserved relief specimen of *M. vomerinus vomerinus* the carbonized films in cross-section are finely laminated parallel to the surface (Pl. 1:A). In specimens of diplograptids and other monograptids, in which the periderm has been further carbonized, the lamination has disappeared and the peridermal structures are compact and massive.

Generally the diplograptids appear somewhat better preserved than the monograptids, as growth lines are more frequently noted in the former. The junctions between the half rings of the fusellar layer are in all the present monograptids, and the greatest part of the diplograptids, preserved as grooves both on the outer surface of the periderm and on the surface of the pyrite moulds. However, in well preserved specimens of *Petalograptus minor?* and *Glyptograptus auritus* the growth

lines appear as ridges. At high magnification it is observed that the periderm is unbroken and continuous across the grooves and ridges (Pl. 2:A).

A cross-section of the growth ridges parallel to the direction of growth has been studied in a specimen of *G. auritus* (Pl. 2:A, B, C). The section is taken from the lateral thecal walls mesially in the rhabdosome which is well preserved with a low relief. Between the growth ridges the carbon films are laminated parallel to the outer surface and are composed of alternating compact and granulated laminae. In cross-section of the growth ridges the inner laminae form a tight, "recumbent" fold with the apex in the direction of growth. At the apex of the fold a new granular lamina seems to originate on the outer side of the apex. Only the inner laminae of the carbon films are folded, the outer laminae appear to continue into the succeeding fusellar half ring. The folded structure must have been formed before a new fusellar half ring was added. Identical structures of the fusellar layer were described by Berry (1974).

From these observations it may be concluded that the carbonized graptolite films, which are found in the dark shales, are remains of the periderm itself and, as shown by *G. auritus,* from the fusellar layer. However, exterior part of the fusellar layer may have disappeared during later corrosion processes. Remains from an outer cortical layer have not been detected.

In graptolites, which are not as well preserved as the present specimens of *G. auritus,* the growth lines appear as grooves. The granular laminae of the fold structures in the growth ridges here seem to occupy a proportionally larger space within the carbon film than in the periderm between the growth lines. Consequently the growth ridges may be more compressed and corroded by further diagenesis and decaying than the periderm between the ridges. This may explain the transformation of the growth ridges into grooves.

In a well preserved pyritized specimen of *Pseudoclimacograptus undulatus* the carbonized periderm was studied in the lateral wall of a mesial theca. The wall possesses a meshwork structure with dominating longitudinal plates situated perpendicular to the thecal surface, and also transverse laminae are well developed (Pl. 1:D). The thecal walls appear to be built up by laminae situated normal to each other. Larger deep pores, possibly penetrating the whole periderm, are present. Growth lines have not been observed in the examined specimen. It is possible that the periderm should be referred to the cortical tissue, when having a similar cross-hatch structure as the sublayers noted by Berry & Takagi (1970, Figs. 2, 5). However, the fusellar layer from an isolated specimen of a *Monograptus* has shown very similar structures (Rickards et al., 1971). No cortical layers have been found in the best preserved specimens in the present material, and the author tentatively regards the cross-hatch structures as being present in at least some of the laminae of the fusellar layers.

The outer surface of the carbonaceous periderm appears to be continuous across the interthecal septum in most of the graptolites investigated in the SEM. In *G. auritus* the fusellar ridges do not cross the interthecal septa. This shows that the cortical tissue is either extremely thin in the present specimens and has covered the whole rhabdosome or—which appears more likely to the author—the graptolite periderm has been enlarged during the carbonisation process to cover the interspaces of the rhabdosome.

The virgula has been observed in several specimens as in relief specimens of *M. vomerinus vomerinus* and *M. revolutus.* In *M. vomerinus* the virgula appears as a groove in the dorsal side of the rhabdosome and in *M. revolutus* as a ridge (Pl. 3:A–B). Cross-sections of the virgulae show an outer layer which is laminated parallel to the outer surface. In *M. revolutus* two pairs of thin granular laminae within the more compact layers are seen. The outer layers appear to be continued from the peridermal layers of the rhabdosome. Both virgulae are curved, with the convex surface facing the rhabdosome, and here no lamination has been noted; the carbon films are compact all through. The detailed structures of virgula were described from ultra thin sections by Berry (1974).

The reticulum of *Stomatograptus grandis girvanensis?* and *Retiolites geinitzianus* has been studied. The reticulum is composed of ridges and grooves, four to six are generally present, possibly originating from a bundle of fibres. At high magnification the ridges show longitudinal striae. The ridges continue uninterrupted into the neighbouring meshwork (Pl. 3:C–F). As in the diplograptids and the monograptids corrosion has left pores and holes of different sizes on the reticular surface. The fibrous structures have been further described by Urbanek & Rickards (1974), and based on their description it may be concluded that the present carbonized material has retained the original structures.

The fine structures of the graptolite periderm, composed of fibrils and dots resembling the structures shown in Towe & Urbanek (1972), cannot be demonstrated in the present heavily carbonized graptolite specimens. But the granular structures in the present peridermal remains may have been developed from finer granules in the original specimens.

The carbon films in the well preserved specimen of *G. auritus* are about 4 μ thick, and in *M. vomerinus vomerinus* (Pl. 1:A) about 10 μ. The latter measurement is the most common thickness of the carbonized periderms.

During the present study of the ultrastructure of the carbonized graptolites preserved in dark shales it has been demonstrated that the original structures of the fusellar layer are preserved. The fusellar mode of growth here reveals structures equivalent to those found by the author in thin sections of an isolated specimen of the Ordovician *Orthograptus gracilis* (Roemer) in transmission electron microscope. The symmetry of the fold structures in the fusellar ridges suggests that the lamination of the fusellar layer may possibly originate from both external and internal living tissue. The tissue supposedly has surrounded the fusellar layer and from its basal part secreted the laminae which constitute the fuselli.

Depository

The described and figured material is in the collections of the Mineralogical and Geological Museum of the University of Copenhagen (MMH).

Genus *Climacograptus* Hall, 1865

Type species (by original designation).—*Graptolithus bicornis* Hall (1848); from the Upper Ordovician, New York State, USA.

Diagnosis (from Bulman, 1970).—The rhabdosome is nearly circular in cross-section. The thecae are strongly geniculate with deep apertural excavations, the supragenicular wall is straight, parallel to the axis of the rhabdosome.

Climacograptus angustus (Perner, 1895)
Fig. 9A

Synonymy.—☐ *Diplograptus (Glyptograptus) euglyphus.* Lapworth. var. *angustus* mihi.—Perner: 27–28, Figs. 14a–b. ☐ 1895 *Diplograptus (Glyptograptus) lobatus* n. sp.—Perner: 28, Pl. 7:15, Pl. 8:15. ☐ 1906 *Climacograptus scalaris* (Hisinger) var. *miserabilis,* var. nov.—Elles & Wood: 186–187, Figs. 120a–b, Pl. 26:3a–h. ☐ 1949 *Climacograptus angustus* (Perner).—Přibyl: 7–10, Pl. 2: 2–9. ☐ 1963 *Climacograptus angustus* (Perner).—Skoglund: 40–42, Pl. 3:1–2, 4–6, Pl. 4:7, Pl. 5:6. ☐ 1970 *Climacograptus miserabilis* Elles & Wood.—Rickards: 28–29, Pl. 1:3, ?4, 5, 10. ☐ 1970 *Climacograptus scalaris miserabilis* Elles & Wood.—Toghill: 23, Pl. 12:1–11. ☐ 1971 *Climacograptus scalaris miserabilis* Elles & Wood.—Schauer: 29–30, Pl. 2:7–8, Pl. 5:15–16.

Lectotype.—Designated by Přibyl (1949:7), as the specimen figured by Perner (1895, Pl. 8:14a–b); from the Ordovician of Bohemia (Ashgillian).

Material.—About 20 specimens which are all flattened.

Horizon and locality.—The *persculptus* Zone, *acuminatus* Zone, and *acinaces* Zone; well at Bavnegård, from 30.1–34.5 m, 25.0–30.0 m, and 14.5–15.0 m below ground level.

Description.—The rhabdosome is straight and may attain a length of more than 1 cm. In a few specimens a median septum is observed. The rhabdosome increases in width from 0.7–0.8 mm at th1[1] to 0.95 mm at th10[1]. The maximum distal width in flattened specimens is 1.1 mm.

The apertural excavations of the climacograptid thecae are relatively small and occupy about one third to one fourth of the height of the free thecal parts, and one fourth of the width of the rhabdosome. The thecae number 11 per 10 mm throughout the rhabdosome. The length of th1[1] is 1.1 mm and of th2[1] 1.66 mm.

Sicula has not been observed with certainty, in one specimen a 2 mm long virgella has been measured.

Remarks.—Among the climacograptids *C. angustus* is recognized by the slender rhabdosome with a mesial width of 1.1 mm, by the thecal spacing, and by the thecal excavations which are rather small. Occasionally flattened specimens have a glyptograptid appearance with a rounded geniculum.

Previously *C. angustus* has been named *Climacograptus miserabilis* Elles & Wood by a majority of authors. As the measurements of the rhabdosome of *C. miserabilis* appear to be equal with those of *C. angustus* Perner, the species are considered to be synonymous with the latter name having priority.

C. angustus has a long stratigraphic range and has previously been reported from the uppermost Ordovician and the lowermost Silurian. In the Bavnegård well *C. angustus* is found at levels which are referred to the *persculptus* Zone, the *acuminatus* Zone, and the *acinaces* Zone.

Climacograptus trifilis trifilis Manck, 1923
Fig. 9B

Synonymy.—☐ 1906 *Climacogarptus medius* Törnq.—Elles & Wood: Pl. 26:4f. ☐ 1923 *Climacograptus trifilis* spec. nov.—Manck: 228, Fig. 32. ☐ 1952 *Climacograptus trifilis* Manck.—Münch: 51, (?Pl. 2:3). ☐ 1965 *Climacograptus trifilis* Manck.—Stein: 165–167, Fig. 17a–d, Pl. 14:d, e, Table 9, 10. ☐ 1971 *Climacograptus trifilis trifilis* Manck.—Schauer: 26, Pl. 3:1–3, Pl. 5:4–6, Fig. 8.

Holotype.—The specimen figured by Manck, 1923.

Material.—One flattened specimen.

Horizon and locality.—The *acuminatus Zone*: well at Bavnegård, from the interval 14.5–15.0 m below ground level.

Description.—The rhabdosome is very badly preserved. It is 2.5 mm long and prolonged with a 1 mm long virgula. Possibly only four thecal pairs are preserved. At th1[1] the rhabdosome is 0.75 mm wide, distally the width has increased to 1 mm.

The thecae are not clearly visible, however, they appear to be of climacograptid type. The apertures occupy apparently only about one fourth of the width of the rhabdosome. The thecae number 4 per 2.5 mm in the proximal end.

Proximally the rhabdosome is provided with a stout virgella and two basal spines. The two outer spines are situated perpendicular to each other. The spines are slightly curved and the length of each spine is about 1 mm. Due to the poor state of preservation further details at the proximal end cannot be seen.

Remarks.—On the basis of the presence of the three basal spines and on the measurements of the rhabdosome the graptolite is referred to *C. trifilis trifilis.* The species has been reported from the *acuminatus* Zone by Münch (1952), Stein (1965), and Schauer (1971).

Climacograptus medius Törnquist, 1897
Fig. 9C

Synonymy.—□ 1897 *Climacograptus medius* n. sp.—Törnquist: 7–8, Pl. 1:9–15. □ 1906 *Climacograptus medius* n. sp. Törnquist.—Elles & Wood, 189–190, Figs. 122 a–c, Pl. 26:4a–f. □ 1948 *Climacograptus medius* Törnquist.—Wærn: 449–452, Fig. 5, Pl. 26: 4. □ 1965 *Climacograptus medius* Törnquist.—Stein: 163, 165, Figs. 16a–g, Tables 7, 8. □ 1970 *Climacograptus medius* Törnquist.—Rickards: 30, Pl. 1:2. □ 1971 *Climacograptus medius* Törnquist subsp. indet.—Schauer: 31, Pl. 2:1–2, Pl. 4: 1–3.

Lectotype.—Subsequently designated by Přibyl (1948: 16) as the specimen figured by Törnquist (1897, Pl. 1: 9); from the *Rastrites* Beds of Nyhamn, Sweden.

Material.—Two flattened specimens.

Horizon and locality.—The *acuminatus* Zone; well at Bavnegård, from the interval 25.0–30.0 m below ground level.

Description.—The rhabdosome attains a length of more than 1 cm. The width of the stipe increases steadily from 0.9 mm at th1[1], 1.25 mm at th5[1], 1.66 mm at th10[1], to 2 mm at th15[1], which is the maximum width in the present specimens.

In the climacograptid thecae the apertures occupy one fourth of the width of the rhabdosome and about half the length of the free ventral walls. The thecal spacing is 7 per 5 mm in the most extreme proximal end and 5.5 per 5 mm most distally.

The proximal end is stout and rounded, and there is some indication of a virgella. The sicula has not been seen.

Remarks.—The present specimens of *C. medius* resemble Törnquist's original specimens in the shape of the rhabdosome and the origin of the median septum, but the long virgella described by Törnquist has not been observed.

The two specimens are distinguished from *Climacograptus praemedius* Wærn by the origin of the median septum, which in *C. praemedius* has been observed from the level of the third thecal pair. Furthermore, the proximal part of *C. praemedius* does not attain the same width as found in *C. medius*. *C. medius* is separated from *C. rectangularis* by the more stout proximal end. The present specimens have a somewhat closer proximal thecal spacing: 14–11 per 10 mm against the 12 thecae per 10 mm indicated for *C. medius* by Rickards (1970).

The species *medius* was reported by Törnquist (1897) from the *cyphus* Zone and by Wærn (1948) from the zones of *acuminatus, extenuatus,* and *cyphus*. In the Bavnegård well *C. medius* occurs in the *acuminatus* Zone and is associated with *A. ascensus* and *C. miserabilis*.

Climacograptus rectangularis (M'Coy, 1850)
Pl. 4:A

Synonymy.—□ 1850 *Diplograptus rectangularis* (M'Coy). —M'Coy: 271 (not figured). □ 1851 *Diplograptus rectangularis*.—M'Coy: 8, Pl. 1B:8. □ 1906 *Climacograptus rectangularis* (M'Coy).—Elles & Wood: 187–188, Figs. 112a–b, Pl. 26:5a–e. □ 1948 *Climacograptus rectangularis* M'Coy.—Wærn: 452, Fig. 5, Pl. 26:8. □ ?1965 *Climacograptus rectangularis* (M'Coy).—Stein: 160–163, Figs. 15a–c, Fig. 16h, Tables 5–6. □ 1970 *Climacograptus rectangularis* (M'Coy).—Rickards: 30–31, Pl. 3:1, Fig. 13: 15. □ ?1971 *Climacograptus rectangularis* (M'Coy).—Schauer: 30–31, Pl. 2:5–6, Pl. 5: 17–19. Further references in Stein (1965) and Rickards (1970).

Holotype (by monotypy).—M'Coy (1851, Pl. 1B:8). Refigured in Elles & Wood (1906, Pl. 26:5a), SM 200098a; from the Birkhill Shales, Scotland.

Material.—Three flattened specimens.

Horizon and localities.—The *acinaces* and *revolutus* zones; Øleå (Ø2a), (Ø4).

Description.—The rhabdosome is up to 1.5 cm long and has a maximum width of 2.5 mm at the distal end. The proximal part is characteristically slender, 0.7–0.8 mm in width, and from the level of th3[1] to th10[1] the width increases rapidly to 2.5 mm, which is practically constant in the distal portion. The median septum is complete and originates from the level of the aperture of th1[1].

The thecae are climacograptid, they overlap about half their length in the distal part. The apertural excavations occupy one fourth of the width of the rhabdosome. The thecae number 11 in the proximal 10 mm.

The sicula has not been observed. The virgella is straight, at least 6 mm long and is 0.15 mm in width.

Remarks.—The specimens from Bornholm are very characteristic of the species with the slender proximal ends and the rapid widening between th3[1] and th10[1]. They are not different from the British typical material.

The specimens described and figured by Stein (1965) and Schauer (1971) do not have the rapid increase in width in the proximal part, but the material is tectonically compressed and additional information is required.

Climacograptus balticus Pedersen, 1922
Pl. 4:B

Synonymy.—□ 1922 *Climacograptus balticus* n. sp.—Pedersen: 14–15, 18, Figs. 2a–e. □ ? 1966 *Rhaphidograptus toernquisti* (Elles & Wood).—Obut & Sobolevskaya: 23–24, Fig. 14, Pl. 4: 10.

Lectotype (designated herein).—Specimen figured in Pedersen (1922, Fig. 2a), MMH 1893; from the *acinaces* Zone, Øleå, Bornholm.

Material.—About 20 specimens, which are preserved flattened or with low relief.

Horizon and locality.—The *acinaces* Zone, Øleå (Ø4).

Diagnosis (new).—The rhabdosome is at least 5 cm long and the width increases from 0.9 mm proximally to 2.3 mm at the distal end. The thecae number 10–11 over 10 mm and are typically climacograptid. The most conspicuous feature is the robust virgella which is 0.33 mm wide at base and more than 1.5 cm long.

Description.—The rhabdosome is straight and the greatest fragment is 5 cm long. The proximal part is robust, 0.9 mm in width increasing to 2 mm before the tenth pair of thecae. Distal to that the width increases more slowly to a maximum of 2.3 mm.

The thecae are of climacograptid type and are situated alternately. The apertures are deep in lateral view, and occupy nearly half the width of the rhabdosome. The apertures have thickened rims. There are 11 thecae in the proximal 10 mm, distally they number 10 per 10 mm.

In the lectotype the virgula is prolonged into a 10 mm long, free part with a 0.5 mm wide, rounded vesicle-like structure at the distal end. The base of the free virgula is slightly thickened. In cross-section the free virgula is oval to rounded when it is preserved in relief, and it is approximately 0.2 mm wide.

The most conspicuous feature is the very stout virgella. The initial thecae seem to merge gradually with the virgella and the sicula is completely concealed by compact carbonaceous films. In sections the virgella is seen to be rounded and 0.33 mm wide in the initial part. It is straight and solid with compact carbonaceous material, and the length is more than 15 mm. Distally the width decreases to 0.2 mm and the extreme distal portion is cone-shaped in well preserved relief specimens. In some specimens a small ventral hollow is observed at the transition from the base of the initial thecae to the virgella.

Remarks.—The proximal end and virgella are very characteristic and cannot be confused with that of other climacograptids. The measured dimensions of the rhabdosome are very close to those of *R. toernquisti, C. medius,* and *C. rectangularis. C. balticus* is distinguished from *C. medius* by the more stout virgella, which merges with the proximal thecae, while *C. medius* has a pronounced rounded proximal end and a slender virgella. From *C. rectangularis, C. balticus* is separated by the wide proximal part and the slower increase in width throughout the rhabdosome.

C. balticus may be confused with *R. toernquisti,* as possibly done by Obut & Sobolevskaya (1966). However, *C. balticus* is distinguished by the wider proximal end and the wide proximal part of the virgella. In *R. toernquisti* the virgella is always twisted.

Genus *Pseudoclimacograptus* Přibyl, 1947

Type species (by original designation).—*Climacograptus Scharenbergi* Lapworth, 1876; from the Upper Ordovician, Scotland.

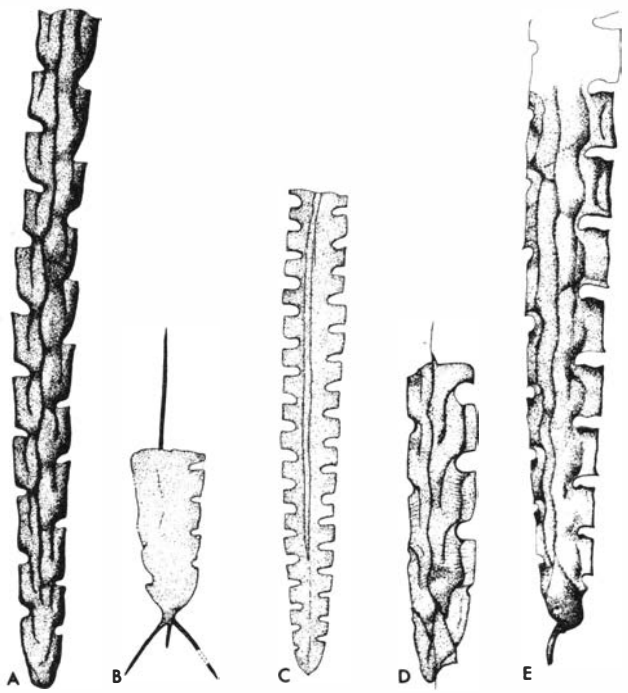


Fig. 9. ☐ A. *Climacograptus angustus* (Perner, 1895). Bavnegård well, 30.1–34.5 m below ground level. The *persculptus* Zone. MMH 13414. ×10. ☐ B. *Climacograptus trifilis trifilis* Manck, 1923. Bavnegård well, 14.5–15.0 m below ground level. The *acinaces* Zone. MMH 13415. ×10. ☐ C. *Climacograptus medius* Törnquist, 1887. Bavnegård well, 25–30 m below ground level. The *acuminates* Zone. MMH 13416. ×5. ☐ D–E. *Pseudoclimacograptus retroversus* Bulman & Rickards, 1968. The *convolutus* Zone, Øleå. ☐ D. Proximal part, obverse view, MMH 13417. ×10. ☐ E. Proximal part, reverse view. MMH 13418. ×10.

Diagnosis (emend. Bulman & Rickards, 1968).—Diplograptid with supragenicular walls which usually are distinctly convex, occasionally slightly convex, and rarely almost straight or concavo-convex. Median septum is zigzag, angular or undulating in the proximal region, sometimes becoming straighter distally. Apertural excavations are short and deep, often introverted. A genicular hood is present in some late representatives.

Pseudoclimacograptus retroversus (Bulman & Rickards, 1968)

Figs. 9D–E

Synonymy.—☐ 1893 *Climacograptus scalaris* Lin.—Törnquist: 2–6, Figs. 1–3, 5–8, 11–15, ? (4, 9, 10, 16–22). ☐ 1968 *P. (Clinoclimacograptus) retroversus* subgen. et sp. nov.—Bulman & Rickards: 8–9, 11–12, Figs. 3a–c, 4a–c, 5a–c. ☐ 1970 *Pseudoclimacograptus (Clinoclimacograptus) retroversus* Bulman & Rickards.—Rickards: 34–35, Fig. 14:1–4.

Holotype (by original designation).—Bulman & Rickards (1968, Fig. 4b), A52951; from the ? *sedgwickii* Zone, Tommarp, Sweden.

Material.—At least 30 specimens preserved from completely flattened to full relief.

Horizon and localities.—The *convolutus* Zone, and ? upper part of the *gregarius* Zone, Øleå (Ø11)–(Ø13).

Description.—The rhabdosome is straight and the longest specimen is at least 2.5 cm. The width, measured in a specimen preserved in partial relief, is 0.7 mm at the level of th1[1] and increases steadily to 1.75 mm in the extreme distal end. The median septum is complete in obverse view.

Specimens from the lower part of the occurrence have on the reverse side a slightly undulating median septum which originates from the level of the aperture th1[2] and becomes straight distally. In specimens from the upper part of the *convolutus* Zone the septum originates from the aperture of th1[1] in reverse view, and in the proximal part it is undulating to angular, distally only slightly undulating. The rhabdosome is prolongated into a 1 mm long and thread-like virgula.

The thecae are climacograptid with a well developed geniculum. The free ventral walls are straight to concave, and the apertures are everted and face ventrally. The thecae are alternating. The distal thecae are about 2 mm long and overlap slightly more than one third of their length. The thecae number 7 in the proximal 5 mm and 12 in the proximal 10 mm. Distally the thecal number is 9.5–10 per 10 mm.

In the specimens from the lower part of the *convolutus* Zone the sicula is visible for 0.5 mm of its length in obverse view, and in specimens from the upper part of the *convolutus* Zone the sicula is 0.2 mm long in obverse view. In both cases the sicula has a 0.5 mm long solid and slightly curved virgella.

Remarks.—From the description above it may be concluded that there is a tendency for differentiation in the form of the median septum, depending on the stratigraphic level at which the specimens occur.

The specimens from the lower part of the *convolutus* Zone with the slightly undulating septum are easily compared with the holotype, Fig. 4b in Bulman & Rickards (1968). The specimens from the uppermost part of the *convolutus* Zone display a larger visible part of sicula and a more strongly undulating septum, and the material may be compared to the specimen figured in Bulman & Rickards (1968, Fig. 4a). Thus if more and better preserved material may be obtained, two clearly defined forms of *P. retroversus* may possibly be separated, each of stratigraphic importance.

Pseudoclimacograptus undulatus (Kurck, 1882)
Pl. 4:E

Synonymy.—☐ 1882 *Climacograptus undulatus* n. sp.—Kurck: 303–304, Pl. 14:11 ☐ 1890 *Climacograptus internexus* n. sp.—Törnquist: 25, Pl. 2:8–9. ☐ 1893 *Climacograptus internexus,* Törnquist.—Törnquist: 6–9, Figs. 23–27. ☐ 1897 *Climacograptus undulatus* Kurck.—Törnquist: 9–10, Pl. 1:22–24. ☐ 1900 *Climacograptus extremus* sp. nov. —Lapworth: 134–135, Figs. 22A–B. ☐ 1906 *Climacograptus extremus,* H. Lapworth.—Elles & Wood: 210–211, Figs. 141a–c, Pl. 27: 13a–b. ☐ 1968 *Pseudoclimacograptus (Metaclimacograptus) undulatus* (Kurck).—Bulman & Rickards: 6–8, Figs. 1d–j, Fig. 3e. ☐ 1970 *Pseudoclimacograptus (Metaclimacograptus) undulatus* (Kurck).—Rickards: 33–34, Fig. 14:5, ? Pl. 8:5.

Holotype (by monotypy).—Kurck (1882, Pl. 14:11); from the *cyphus* Zone, Bollerup, Scania, Sweden.

Material.—About 50 specimens, mainly preserved in full relief, few specimens are flattened.

Horizon and localities.—The uppermost part of the *gregarius* Zone and in the lower part of the *convolutus* Zone, Øleå (Ø11)–(Ø12).

Description.—The rhabdosome is straight, the maximum length is 10 mm. The width increases from 0.5 mm proximally to a maximum of 1 mm distally (measured in a specimen almost in full relief). The median septum is complete and angular.

The thecae are of pseudoclimacograptid type and alternate. The thecae are slightly introverted and the overlap is about one fourth to one fifth of the thecal length. The apertures are deep and occupy one fourth of the width of the rhabdosome. In a few specimens small genicular hoods are preserved. The thecal number is 8.5 in the proximal 5 mm, and 8 per 5 mm at the distal end.

The sicula is 0.5 mm long and the apex is visible to the level of the aperture of th1[2].

Remarks.—The specimens from Bornholm are slightly larger than the British ones which reach a maximum of 7 mm in length and 0.6 mm in width (Bulman & Rickards, 1968).

The original specimens described by Kurck (1882) have a maximum length of 10 mm and a maximum width of 0.8 mm (measured in the original material from Scania). On Bornholm *P. undulatus* is frequent in the lower part of the *convolutus* Zone.

In the *gregarius* Zone three specimens were observed, having an angular median septum and more closely set thecae, numbering 18–20 in 10 mm, of pseudoclimacograptid type. The width never exceeds 0.6 mm. With additional material it may be possible to distinguish well defined forms which may be of stratigraphic importance.

Genus *Diplograptus* M'Coy, 1850

Type species (designated by Gurley, 1896).—*Prionotus pristis* Hisinger, 1837; from the Ordovician, Sweden.

Diagnosis (from Bulman, 1970).—The basal thecae are strongly sigmoidal, amplexograptid, with apertural semicircular excavations gradually becoming gently sigmoid (glyptograptid) and almost straight (orthograptid) distally, with apertural lists proximally. The cross-section is ovoid or nearly rectangular.

Table 1. Diplograptus thuringiacus. Dimensions (in mm).

Spec. No.	Flat or relief	Length	Width of the rhabdosome						Number of thecae	
			th1	th5	th10	th15	th20	th30	prox.	dist.
Lund spec.	F	13	0.75	1.8	3.0	2.8			9/10	9/10 (deformed)
MMH 13419	F	35	0.75	1.75	2.5	2.6	2.8		10.5/10	8/10
MMH 13499	F	14	0.75	1.75	2.5	2.5			10/10	
MMH 13500	F	7	0.75	1.75					5.5/5	
MMH 1897	F	40	0.6	1.70	2.3	2.7	2.9	2.7	11/10	8.5/10
German spec.		30	0.65	1.5	2.3	2.5	2.8	2.9	10/10	10/10

Diplograptus thuringiacus Eisel

Fig. 10A, Pl. 4:C, Table 1

Synonymy.—□ ? 1919 *Dipl. thuringiacus* Eisel.—Kirste: 135 (not figured), literature not seen. □ 1922 *Diplograptus (Glyptograptus?) bornholmiensis* n. sp.—Pedersen: 18–19, Fig. 3. □ ? 1952 *Climacograptus citorescens* Eisel.—Münch: 52, Pl. 2:4. □ 1952 *Diplograptus thuringiacus* Eisel.—Münch: 58, Pl. 4:10a–c. □ 1965 *Diplograptus (Diplograptus) thuringiacus* Eisel Ms in Münch.—Stein: 169–170, Figs. 18a–b. □ 1971 *Diplograptus thuringiacus* Eisel.—Schauer: 34–35, Pl. 6:9–10, Pl. 7:1. □ 1973 *Diplograptus thuringiacus* Münch.—Cocks & Toghill, Pl. 1: 6 (not described).

Type.—Not yet designated. The type material is from the collection of Eisel, Altmannsgrün, Germany.

Material.—About 70 specimens, preserved flattened or in very low relief.

Horizon and localities.—The upper part of the *gregarius* Zone, Øleå (Ø6), (Ø10)–(Ø12).

Diagnosis (new).—A large diplograptid with the proximal 5–8 thecae of the climacograptid amplexograptid type and the distal thecae glyptograptid. The maximum width is 3 mm, and the most rapid increase in width takes place within the proximal 10 mm. The thecal spacing is 11–8 per 10 mm. The virgula and virgella are long and conspicuous.

Description.—The rhabdosome is straight, normally 2–3 cm long and may attain a length of 4 cm. The width increases fairly rapidly from 0.75 mm at the level of th1[1] to 2.5 mm at th10[1]. Throughout the distal portion the width expands slowly to a maximum of 3.0 mm.

Distally the rhabdosome is prolonged with a long conspicuous virgula with a maximum length of 2.5 cm. The proximal base of the virgula is frequently enlarged, and the width is here about 1 mm. Distally the virgula becomes more slender and in the flattened virgula a median rim is developed; otherwise the structure is obscure.

The proximal 5–8 thecae are climacograptid, the apertural excavations are small and occupy less than one fourth of the width of the rhabdosome. From the level of th5[1]–th8[1] the thecae become glyptograptid and this form is maintained throughout the distal part of the rhabdosome. The ventral walls of the distal thecae are inclined at 25° to the rhabdosome and the apertures are 0.5 mm in width. The apertures are inclined at about 100° to the axis of the stipe. The thecal overlap is half to one third of the thecal length. The thecae number 11 in the proximal 10 mm and distally the number is 8 per 10 mm.

A median septum is present, in the main part of the specimens it originates from the level of th4[1], but in a few rhabdosomes it is seen from the level of the aperture of th1[1].

The sicula has not been observed, but it has a conspicuous virgella, the maximum length of which is measured to 1.2 cm.

Remarks.—*D. thuringiacus* described by Münch (1952) and Stein (1965) bears a great resemblance to the present specimens from Bornholm, earlier described as *Diplograptus (Glyptograptus) bornholmiensis* Pedersen. A bohemian specimen preserved in the Humboldt Museum in Berlin also seems to be identical with "*D. bornholmiensis*". The only difference is that the German specimens are generally shorter than the Bornholm specimens; the length was reported to be 2.5 cm (Stein, 1965) and (Schauer, 1971), in the present material the maximum length is 4 cm. Otherwise there are no differences between the two forms and *D. bornholmiensis* is regarded as a junior synonym of *D. thuringiacus.* In the present material the length of the rhabdosomes apparently increases with time. From the lowermost level, in the mesial part of the *gregarius* Zone, the rhabdosomes never exceed a length of 2.5 cm. At the highest levels just below the transition from the *gregarius* Zone to the *convolutus* Zone, most of the rhabdosomes are 2–4 cm long. However, the width of the rhabdosome and the thecal spacing are identical for the specimens from both levels. The original specimens of *D. bornholmiensis* were found in the upper part of the *gregarius* Zone.

D. thuringiacus is frequent in the upper part of the *gregarius* Zone. Earlier described forms from Germany are also reported from this level (Stein, 1965).

Diplograptus? rarus Rickards, 1970

Fig. 10B

Synonymy.—□ 1970 *Diplograptus? rarus* sp. nov.—Rickards: 36–37, Fig. 13:6, Pl. 2: 13.

Holotype.—HUR 1Bi/139, Rickards (1970, Pl. 2: 13); from the *atavus* Zone, Birks Beck (1Bi), Howgill Fells.

Material.—One flattened specimen.

Horizon and locality.—The *acinaces* Zone, well at Bavnegård, 14.5–15.0 m below ground level.

Description.—The rhabdosome is 1 cm long, straight, and the width increases from 0.5 mm at th1[1] to 1 mm at th10[1]. The rhabdosome has an attenuated periderm, and is prolonged with a conspicuous virgula.

The thecae alternate, proximally in the rhabdosome they have a glyptograptid form with a flowing geniculum, distally they have an orthograptid appearance. The thecal overlap is not observed in the proximal part of the rhabdosome, distally the overlap is one third of the length. The thecal count is 6 per 5 mm in the proximal part and 5 per 5 mm most distally.

The sicula has not been observed.

Remarks.—The present specimen shows a great similarity to the specimens described by Rickards (1970). *D.? rarus* was reported from the *atavus* and *acinaces* zones in the Howgill Fells.

Genus *Orthograptus* Lapworth, 1873

Type species (by original designation).—*Graptolithus quadrimucronatus* Hall, 1865; from the Middle Ordovician, Canada.

Diagnosis (from Bulman, 1970).—The rhabdosome is rectangular or ovoid in cross-section. The thecae are straight or with a very slight sigmoidal curvature. One group with paired apertural spines, large basal spines are not uncommon.

Orthograptus bellulus (Törnquist, 1890)
Pl. 4: F

Synonymy. — ☐ 1890 *Diplograptus bellulus* n. sp.—Törnquist: 28, Pl. 1:25–29. ☐ 1893 *Diplograptus bellulus* Törnq.—Törnquist: 10–11, Figs. 42–44. ☐ 1897 *Diplograptus bellulus* Törnquist.—Törnquist: 17, Pl. 2:20–25. ☐ 1907 *Diplograptus (Orthograptus) bellulus,* Törnquist.—Elles & Wood: 231–232, Figs. 152a–c, Pl. 29:2a–e. ☐ 1965 *Diplograptus (Orthograptus) bellulus* Törnquist.—Stein: 170–171, Figs. 19a–b. ☐ 1970 *Orthograptus bellulus* (Törnquist).—Rickards: 46, Pl. 3: 5. ☐ 1971 *Orthograptus bellulus* (Törnquist 1890).—Schauer: 36, Pl. 7:9–10, Pl. 16:6. For further references see Rickards (1970).

Lectotype.—Designated by Přibyl (1948: 11) as the specimen figured in Törnquist (1890, Pl. 1:25); from the *Rastrites* Shale, Kallholn, Sweden.

Material.—More than 25 specimens, mainly flattened, a few specimens are preserved in relief.

Horizon and locality.—Upper half of the *convolutus* Zone, Øleå (Ø13).

Description.—The rhabdosome is straight with a maximum length of 2 cm. The width at th1[1] is 0.5 mm, the maximum distal width is 2 mm in flattened specimens. The increase in width takes place within the five proximal pairs of thecae and is constant throughout the distal portion. No median septum has been observed.

The thecae are orthograptid and alternating. Relief specimens have slight sigmoidal ventral walls. The thecal tubes are inclined at about 30° to the rhabdosome and the apertures are situated at right angles to the thecal axis. They are slightly everted and have thickened rims.

The distal thecae are 1.3 mm long and 0.3 mm in width at the aperture. The overlap is less than half the thecal length in the proximal portion of the rhabdosome, and slightly more than half in the distal part. The thecae number 7.5 in the proximal 5 mm and 6.5 in the most distal 5 mm.

The visible part of the sicula is 0.5 mm long. The aperture of the sicula is provided with a conspicuous thread-like virgella up to 3 cm long.

Remarks.—The present material is not in any way different from earlier descriptions. *O. bellulus* is rather frequent in the upper part of the *convolutus* Zone and is here associated with *C. cometa cometa, C. cometa extrema, M. leptotheca,* and *M. limatulus.*

Orthograptus cyperoides (Törnquist, 1897)
Fig. 10D

Synonymy.— ☐ 1897 *Diplograptus cyperoides* n. sp.—Törnquist: 16, Pl. 2:30–32. ☐ 1907 *Diplograptus (Orthograptus) cyperoides,* Törnquist.—Elles & Wood: 238–239, Figs. 158a–b, Pl. 29:8a–c. ☐ 1970 *Orthograptus cyperoides* (Törnquist).—Rickards: 45–46, Fig. 14:12, ?17. ☐ *Orthograptus cyperoides* (Törnquist).—Sherwin: 150–152, Pl. 10: 1.

Holotype.—Not yet designated. Törnquist's material originates from the Llandovery of Scania, Sweden.

Material.—2 specimens, preserved in low relief.

Horizon and localities.—The upper part of the *gregarius* Zone (the subzone of *pectinatus*), Øleå (Ø2), (Ø10).

Description.—The length of the rhabdosome is about 5 mm. The width at th1[1] is 0.8 mm and increases to 1 mm in the most distal part. No median septum is observed.

The thecae are simple tubes of orthograptid type. They are inclined at about 30° to the axis of the rhabdosome and the overlap is one third to one half. The thecal apertures are perpendicular to the thecal axis, slightly ventrally everted, and occasionally with apparently paired lateral spines. Two of the apertural spines seem to be prolonged into a fine network. This network possibly connects the apertural spines with the virgella, which also appears to be prolonged into a network.

Th1[1] originates 0.75 mm above the aperture of sicula, the initial part grows downwards to the aperture of sicula and then recurves, the length of the theca is 2 mm. Th1[2] seems to originate 0.3 mm from the aperture of sicula. The thecae number 8 in the proximal 5 mm. The sicula is 1.5 mm long and the apex reaches to the aperture of th2[2].

Remarks.—The material from Bornholm fits with the description by Törnquist (1897), except for the sicula which in the Swedish specimens is 2 mm long compared to 1.5 mm in the Danish material.

The specimens described by Rickards (1970) have a complete median septum, whereas no median septum has been seen in the Danish and the Swedish material. Elles & Wood (1907) mentioned some degree of variation and further investigations are needed for distinction of possible stratigraphic and geographic variants.

Most striking is the delicate network which surrounds the graptolite. This feature has not been found before in *O. cyperoides,* but is known from well preserved specimens of other graptolite species, see Hutt et al. (1970).

Orthograptus insectiformis (Nicholson, 1869)
Fig. 10C

Synonymy.—☐ 1869 *Diplograptus insectiformis.*—Nicholson: 237, Pl. 11:13. ☐ 1907 *Diplograptus (Orthograptus) insectiformis,* Nicholson.—Elles & Wood: 228–229, Figs. 50a–c, Pl. 28:7a–c. ☐ 1970 *Orthograptus* cf. *insectiformis* (Nicholson).—Rickards: 46–47, Fig. 14:18. ☐ ?1971 *Orthograptus? inopinatus* Bouček.—Schauer: 37, Pl. 7:14. ☐ 1974 *Orthograptus insectiformis* (Nicholson).—Rickards & Koren: 200–201, Figs. 1–5.

Holotype (by monotypy).—Specimen figured as Pl. 11:13 in Nicholson (1869); from the Llandovery, The Lake District, Northern England.

Material.—2 specimens, both are flattened and badly preserved.

Horizon and localities.—The middle to upper part of the *convolutus* Zone, Øleå (Ø12)–(Ø13).

Description.—The rhabdosome is small, the maximum length being 1 cm. The width at the level of th1[1] is 0.5 mm and from th5[1] to the distal end of the rhabdosome the width is 1.3 mm.

The thecae are of orthograptid type. The ventral walls are inclined at about 30° to the rhabdosome and the overlap is one half to one third of the thecal length. The apertures are situated at right angles to the axis of the rhabdosome. They are ventrally everted and have a pair of long apertural spines, up to 1 mm in length. The exact position of the spines cannot be ascertained. The thecae number 7 in the proximal 5 mm.

The sicula and the most proximal thecae cannot be seen. An obscure network surrounds the proximal end and may be attached to the apertural spines. No virgula and virgella are seen.

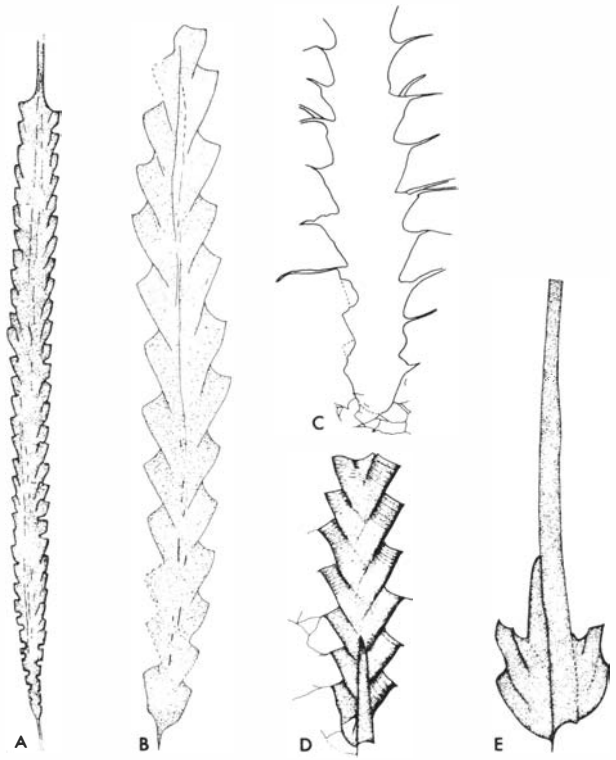


Fig. 10. ☐ A. *Diplograptus thuringiacus* Eise, 1919. The *gregarius* Zone, Øleå. MMH 13419. ×2.5. ☐ B. *Diplograptus? rarus* Rickards, 1970. Bavnegård well, 14.5–15.0 m below ground level. The *acinaces* Zone. MMH 13420. ×10. ☐ C. *Orthograptus insectiformis* (Nicholson, 1869). The *convolutus* Zone, Øleå. MMH 13421. ×10. ☐ D. *Orthograptus cyperoides* (Törnquist, 1897). The *gregarius* Zone, Øleå. MMH 13422. ×5. ☐ E. *Cystograptus vesiculosus* (Nicholson, 1868). The *acinaces* Zone, Øleå. MMH 13423. ×10.

Remarks.—*O. insectiformis* from Bornholm does not differ from earlier described specimens. *Orthograptus? inopinatus* Bouček described by Schauer (1971:37), seems to be closely related to *O. insectiformis,* but more information is required about the species. The virgellar meshwork described by Rickards & Koren (1974) is also present in the specimens from Bornholm.

Genus *Cystograptus* Hundt, 1942 emend. Rickards, 1970

Type species (subsequently designated by Jones & Rickards, 1967).—*Diplograptus vesiculosus* Nicholson, 1868; from the Llandovery of Dumfriesshire, Scotland.

Diagnosis (from Rickards, 1970).—Diplograptid with long, overlapping, doubly-sigmoidal thecae; thecal apertures everted, facing ventrally; sicula and th1[1] very long.

Cystograptus vesiculosus (Nicholson, 1868)
Fig. 10E

Synonymy.—☐ 1868 *Diplograptus vesiculosus.*—Nicholson, Pl. 3:11. ☐ 1907 *Diplograptus (Orthograptus) vesiculosus,*

Nich.—Elles & Wood; 229–231, Figs. 151a–f, Pl. 28: 8a–f. □ 1967 *Cystograptus vesiculosus* (Nicholson).—Jones & Rickards: 173–184 (partly described), Figs. 3d, 6, 8. □ 1969 *Orthograptus vesiculosus* (Nicholson).—Müller & Schauer, Figs. 12f–g, Figs. 13–18. □ 1970 *Cystograptus vesiculosus* (Nicholson).—Rickards: 44–45, Pl. 1: 11, Pl. 2: ?12, 14. □ 1971 *Orthograptus vesiculosus vesiculosus* (Nicholson).—Schauer: 35–36, Pl. 7: 5, 7–8, Pl. 16: 1–4, Pl. 45: 1. For further references see Rickards (1970).

Holotype (by monotypy).—Specimen figured by Nicholson (1868, Pl. 3: 11); from the Llandovery of Dumfriesshire, Scotland.

Material.—10 specimens, all of which are flattened and showing only the proximal parts.

Horizon and locality.—The uppermost part of the *acinaces* Zone, the *vesiculosus* band, Øleå (Ø4).

Description.—Only juvenile specimens with sicula and the proximal thecal pair are present. In the largest rhabdosome the sicula measures 1.5 mm and the apex is free. The aperture is 0.4 mm in width.

Th1[1] originates 2 mm from the aperture of sicula and grows downwards below the aperture and then recurves. The length of the recurved part is 1 mm and the free ventral wall is convex, the apertural part is obscure. In th1[2] the initial portion is not seen, but in obverse view the theca seems to grow out from the level of the sicular aperture. The ventral wall is slightly convex and the aperture faces towards the distal end of the rhabdosome. Th2[1] and th2[2] are not fully developed.

Remarks.—*C. vesiculosus* does not have the characteristic orthograptid thecae as described in Elles & Wood (1907), and Schauer (1971). The walls of the initial thecae are too curved, resembling those of *Cystograptus penna* (Hopkinson) in Jones & Rickards (1967).

The genus *Cystograptus* was established by Hundt, and subsequently *D. vesiculosus* was designated by Jones & Rickards (1967) as type species for the genus. The genus *Cystograptus* was based on the supposed presence of a distal "gas-bubble". Later Jones & Rickards (1967) demonstrated that the "vesicle" in the closely related species *C. penna* formed a three-vaned structure, and they supposed that the same structure is found in the fully developed specimens of *C. vesiculosus.* Unfortunately, the specimens from Bornholm are in a state of preservation which prevents any further information about the structures of the "vanes".

C. vesiculosus is frequent in a 1 m thick band in the upper part of the *acinaces* Zone.

Genus *Glyptograptus* Lapworth, 1873

Type species (by original designation).—*Diplograptus tamariscus* Nicholson, 1869; from Duffkinnel Burn, Southern Scotland.

Diagnosis (from Bulman, 1970).—The thecae with gentle sigmoidal curvature (glyptograptid), the supragenicular wall is almost straight, sloping outwards, or rarely with gentle double curvature and everted apertures. Apertural margin commonly undulate.

Glyptograptus persculptus (Salter, 1865)
Figs. 11A–C

Synonymy.—□ 1865 *Diplograptus persculptus* (Salter).—25. □ 1868 *Diplograptus persculptus.*—Carruthers: 30 (not seen). □ 1907 *Diplograptus (Glyptograptus) persculptus,* Salter.—Elles & Wood: 257–258, Figs. 176a–b, Pl. 31: 7a–c. □ 1929 *Glyptograptus* aff. *persculptus* Salter.—Davies: 10–14, Figs. 11–20. □ 1965 *Diplograptus (Glyptograptus)* cf. *persculptus* Salter.—Stein: 172, Fig. 20. □ 1971 *Glyptograptus* sp. aff. *persculptus Salter.*—Schauer: 38, Pl. 18: 1.

Type.—Presumably the Geological Survey specimens GSM 11781–11786 (Strachan, 1971).

Material.—About 20 specimens, ranging from completely flattened to full relief specimens showing growth lines.

Horizon and locality.—The *persculptus* Zone; well at Bavnegård, from 30.10–34.50 m below ground level.

Description.—The longest fragment is about 20 mm. The main increase in width occurs in the proximal part of the rhabdosome and is constant throughout the distal portion. The maximum width in flattened specimens is about 2 mm, and the maximum width in relief specimens is 1.6 mm. A median septum is present, and in the proximal part of the rhabdosome the septum is undulating. The septum originates at the level of the base of th3[1], and from the level of about the fifth thecal pair the median septum becomes straight.

The thecae are of glyptograptid type with flowing genicula. The distal thecae are 2 mm long and overlap for half their length. The extreme proximal thecae overlap for one third of their length. The apertures are mainly horizontal but slightly everted, and thickened rims surround the apertures. The thecae are inclined at about 20° to the axis of the rhabdosome. They number 5 in the proximal 5 mm, and distally the number is 9.5–10 in 10 mm.

The sicula is visible for about 1.25 mm of its length. Th1[1] originates 0.5 mm from the aperture of sicula, and both th1[1] and th2[1] are 1.25 mm high. The sicula is provided with a 2 mm long virgella. The width of the rhabdosome increases from 1 mm at th1[1] to 1.2 mm at th2[1], 1.3 mm at th3[1], and 1.5 mm at th5[1].

Remarks.—Davies (1929) demonstrated an evolution from earlier forms of *G. persculptus* with a more or less complete septum on the reverse side of the rhabdosome to forms with a progressive retardation of the origin of the septum, and to the latest mutations showing a complete loss of the septum. The specimens from Bornholm have a septum which is nearly complete, originating from the

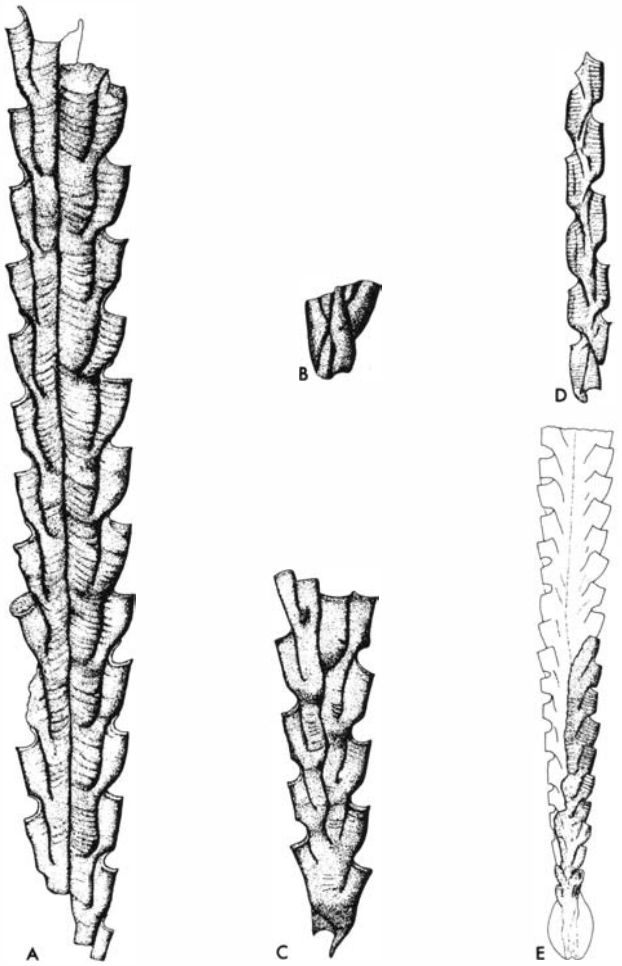


Fig. 11. ☐ A–C. *Glyptograptus persculptus* (Salter, 1868). Bavnegård well, 30.1–34.5 m below ground level. The *persculptus* Zone. ☐ A. Distal part in relief. MMH 13424. ×10. ☐ B. Proximal part, in relief, obverse view. MMH 13425. ×10. ☐ C. Proximal part in relief, reverse view. MMH 13426. ×10. ☐ D. *Glyptograptus? nebula* Toghill & Strachan, 1970. The *griestoniensis* Zone, Øleå. MMH 13427. ×10. ☐ E. *Glyptograptus auritus* n. sp. Holotype. The *turriculatus* Zone, Øleå. MMH 13428. ×5.

base of th3¹. These forms thus show resemblance to Davies' earlier forms, as they appear to be equivalent to the specimens figured in Davies (1929, Figs. 16 and 17). Following the stratigraphy of Davies the specimens from Bornholm are referred to the lower part of the *persculptus* Zone, but not to the lowermost forms. Rickards (pers. comm. (1972) in Lesperance (1974)) has suggested that *G. persculptus* probably includes several taxa, but the present limited material does not allow any revision.

Glyptograptus sinuatus sinuatus (Nicholson, 1869)
Pl. 4:D

Synonymy.—☐ 1869 *Diplograptus sinuatus* Nich.—Nicholson: 235, Pl. 11:11. ☐ 1897 *Diplograptus (Glyptograptus) sinuatus,* Nich.—Perner: 5, Fig. 3, Pl. 9:9–12. ☐ 1907 *Diplograptus (Glyptograptus) sinuatus,* Nicholson.—Elles & Wood: 255–257, Figs. 175a–b, Pl. 31:6a–c. ☐ 1970 *Glyptograptus sinuatus sinuatus* (Nicholson).—Rickards: 41–42, Pl. 4:1. For further references see Rickards (1970).

Holotype (by monotypy).—Specimen figured by Nicholson (1869, Pl. 11:11). Specimen not traced; from the Llandovery of the Lake District, Northern England.

Material.—10 specimens, mostly well preserved in full relief and infilled with pyrite.

Horizon and localities.—The *revolutus* Zone, Øleå (Ø2a), (Ø4a).

Description.—The rhabdosome is 1.5–2 cm long. The width is 0.5 mm at the level of th1¹ and increases rapidly from th3¹ (0.75 mm) to th4¹ (1.2 mm). Distally to that the rhabdosome gradually attains a maximum width of 2 mm (all measured dimensions are for relief specimens). The median septum is complete and gently undulating. The rhabdosome is prolonged with a slender more than 2 cm long virgella.

The thecae alternate and the overlap increases from one third proximally to half the length distally. The apertures have thickened rims and are slightly everted, situated at right angles to the axis of the rhabdosome. In the extreme proximal portion of the rhabdosome the thecae are inclined at 10° to the axis; the inclination in the distal part is 30°. The thecal spacing is 11.5–12 in the proximal 10 mm.

The sicula has not been seen.

Remarks.—*Glyptograptus sinuatus craterif ormis* Rickards differs from *G. sinuatus sinuatus* in having more widely spaced thecae, 10 per 10 mm in the proximal portion. In addition, the thecae are inclined to the axis at only 20°. *G. sinuatus sinuatus* occurs at a lower level on Bornholm than the British specimens which were reported from the zone of *gregarius* (Elles & Wood, 1907, and Rickards, 1970). In other respects the Danish specimens are similar to the British material.

Glyptograptus auritus n. sp.
Fig. 11E, Pl. 4:G

Holotype.—Specimen (MMH 13428), Pl. 4:G. The *turriculatus* Zone, lok. 13a, Øleå.

Derivation of name.—*auritus*=eared, referring to the ear-shaped vanes surrounding the proximal part.

Material.—About 50 mostly fragmentary specimens, preserved flattened or in low relief.

Horizon and locality.—The lower part of the *turriculatus* Zone, Øleå (Ø13a).

Diagnosis.—A rather large glyptograptid with a gradual increase in width from 0.5 mm at the level of th1¹ to 2.3 mm at th25¹, and then slightly decreasing to 2 mm throughout the distal portion. The thecae are glyptograptid, inclined at 20° to the rhabdosome and distally overlap half their length. They number 12–11 in 10 mm. In fully developed specimens rounded carbon films enclose the proximal four thecal pairs.

Description.—The rhabdosome has a length which may exceed 3 cm. The proximal end without a carbon film is 0.5 mm in width, within the proximal 2 cm the width increases to 2.3 mm at the level of about th25[1]. Distal to that the width decreases to 2 mm at the extreme distal end. In one specimen a median septum originates 1.5 cm from the proximal end.

The thecae alternate and are of the glyptograptid type. The supragenicular walls are almost straight, with only a slight geniculum, and are inclined at about 20° to the axis of the rhabdosome. The apertures are normal to the thecal axis and have a thickened rim. The dorsal walls in the apertures are slightly prolongated and in contact with the succeeding infragenicular wall. The distal thecal tubes are 1.75 mm long, 0.5 mm in dorso-ventral width, and overlap for about half their length. The thecae number 12 in the proximal 10 mm, distally they number 11 per 10 mm.

The sicula is clearly seen in juvenile specimens, before disc-like structures are developed. The sicula is 0.25 mm in width at the aperture and the visible part is about 0.9 mm long. The virgella is 0.5 mm long. Th1[1] grows out near the base of the sicula and appears to be 0.75 mm long. Th1[2] originates 0.3–0.4 mm above the aperture of the sicula and is 0.75–1.0 mm long.

In mature rhabdosomes the proximal portion is surrounded by an apparently disc-like structure, preserved as a carbon film. The "disc" increases in size corresponding to the growth of the rhabdosome. The "disc" seems to be composed of at least two semicircular vanes which maximally progress to the level of the fourth thecal pair. The greatest width including the vanes is 2.5 mm at a level between the aperures of th2[1] and th3[1]. In most of the well preserved specimens the fusellar structure is preserved in the carbon films, but in the vanes there are no signs of any fusellar half rings. The carbon films in the vanes are usually damaged, but well preserved specimens seem to have fine concentric structures parallel to the outer edges.

At least two vanes are seen but, in two specimens two longitudinal and parallel ridges are found in the ventral wall of the th1[1], probably resulting from the broken vane structure. It is possible that a pair of vanes has been situated on the ventral walls of the proximal thecae. However, in lateral view the exact structure and form of the initial thecae seem to be concealed by a cover of carbon film. Thus, there is no evidence as to whether or not the vanes were originally vesicular or simply flat.

Remarks.—*G. auritus* is easily separated from other glyptograptid graptolites by its size and the presence of the proximal vanes.

G. auritus is rather frequent in the basal part of the *turriculatus* Zone and is associated with *M. turriculatus, D. runcinatus,* and *R. maximus.*

Glyptograptus? nebula Toghill & Strachan, 1970
Fig. 11D

Synonymy.—☐ 1970 *Glyptograptus nebula* sp. nov.—Toghill & Strachan: 519–520, Figs. 3a–l, Pl. 105: 9–13.

Holotype.—BMNH Q3071b, figured by Toghill & Strachan (1970, Fig. 3b, Pl. 105: 12); from the Llandovery, Grieston Quarry, Peeblesshire.

Material.—Six specimens preserved flattened or in low relief.

Horizon and localities.—The *griestoniensis* Zone, Øleå (Ø18), (Ø19).

Description.—The rhabdosome is straight, 3 mm long, and the width is 0.5 mm throughout. The rhabdosome has a conspicuous 1 mm long virgula and a complete median septum.

The thecae are of glyptograptid-climacograptid type, and 3–5 pairs are present. The thecae alternate and the amount of overlap is small, about one fifth of the thecal length. The apertures face distally in the rhabdosome, and are slightly everted. The thecae number 2.5 in the proximal 2.5 mm.

The sicula is not clearly seen, the apex may reach to the level of the aperture of th1[2], the length is about 1 mm. In the figured specimen the apex is visible only to the aperture of th1[1].

Remarks.—The specimens from Bornholm fit the description of *G.? nebula* (Toghill & Strachan, 1970) except for the size of the sicula, which is longer in the British specimens, as Toghill & Strachan (1970) indicated 1.3–1.6 mm in the text, but on their Fig. 3: j, the sicula can be measured to be 2 mm.

In the present specimens the thecae are like those of *Climacograptus,* as the ventral wells are parallel to the axis of the rhabdosome. The rather flowing genicula, however, may suggest a reference of the material to *Glyptograptus.*

Genus *Petalograptus* Suess, 1851

Type species (designated by Lapworth, 1873).—*Prionotus folium* Hisinger, 1837; from the Llandovery, Sweden.

Diagnosis (from Bulman, 1970).—The rhabdosome is foliate, exaggeratedly rectangular in cross-section. The thecae long straight tubes with a gently ventral curvature, with a large thecal overlap. Th1[1] with pronounced upwards direction of growth, leaving sicula largely exposed.

Petalograptus ovatoelongatus (Kurck, 1882)
Pl. 4: H

Synonymy.—☐ 1882 *Cephalograptus ovato-elongatus* n. sp.—Kurck: 303, Pl. 14: 10. ☐ 1908 *Petalograptus palmeus* var. *ovato-elongatus,* Kurck.—Elles & Wood: 277–278, Figs. 191a–c, Pl. 32: 4a, ? 4b, (non 4c–d). ☐ 1941b *Petalolithus ovato-elongatus* (Kurck).—Bouček & Přibyl: 2, 4–5, Figs. 1a–e, Pl. 1: 1–2. ☐ 1969 *Petalolithus ovato-elongatus* (Kurck).—Müller & Schauer, Fig. 2a (not described). ☐ 1970 *Petalograptus ovatoelongatus* (Kurck).—Rickards: 47–48, Pl. 3: 4. ☐ 1971 *Petalolithus (Pet.)*

ovatoelongatus (Kurck).—Schauer: 40–41, Pl. 8:2–4, Pl. 11:2–3. For further references, see Rickards (1970).

Holotype (by monotypy).—Specimen figured in Kurck (1882, Pl. 4:10); from the *triangulatus* Zone, Bollerup, Scania, Sweden.

Material.—About 40 specimens, preserved flattened or in low relief. Many specimens with well preserved growth segments.

Horizon and localities.—The lower part of the *gregarius* Zone, in the subzone of *triangulatus,* Øleå (Ø2), (Ø5)–(Ø10).

Description.—The rhabdosome is ovate to elongate in lateral view, and the maximum length is about 2 cm. The proximal part of the rhabdosome is ovate, and the width at th1[1] is 3 mm increasing to a maximum width of 4–5 mm which is attained at the level of th6[1]–th7[1]. Distal to that the rhabdosome narrows and becomes elongated. The width is 3.5 mm at the distal end. In reverse view no median septum is observed, on the obverse side the septum originates from the apex of the sicula.

The thecae are alternating simple tubes. In the proximal end of the stipe they are ventrally curved and inclined at about 45° to the rhabdosome, distally the thecae become more straight and the inclination decreases to 25°. The apertures are perpendicular to the thecal axis and are slightly ventrally everted. The mesial tubes are 2 mm long and 0.5 mm wide in the apertural regions. The thecae number 7.5 in the proximal 5 mm, distally the number is 6 in 5 mm.

The sicula is 1.8 mm long and the apex reaches to the level of the aperture of th1[1]. Th1[1] originates at the base of the sicula and is 2 mm long. Proximally a 0.25 mm long virgella is seen.

Remarks.—The specimens from Bornholm are closely similar to those described by Kurck (1882). In the present work only rhabdosomes with an ovate-elongated appearance are referred to *P. ovatoelongatus,* contrary to Bouček & Přibyl (1941a) who also included elongated specimens in *P. ovatoelongatus.*

P. ovatoelongatus is different from *P. palmeus clavatus* in having longer proximal thecae and a larger dorsoventral width.

Petalograptus minor (Elles, 1897) ?
Pl. 4:I

Material.—About 5 specimens, preserved flattened or in relief with well preserved growth lines.

Horizon and localities.—The middle part of the *gregarius* Zone, in the subzone of *pectinatus,* Øleå (Ø2), (Ø6), and (Ø10).

Description.—The rhabdosome is oblong and the length is up to 1 cm. The initial width is about 2 mm and the maximum width is 3–5 mm, most commonly 3–4 mm. The greatest width is attained in the mesial part of the rhabdosome, at the level of th5[1], and distal to that the width decreases slightly towards the rounded distal portion. No median septum is present on the reverse side; on the obverse side a complete septum is developed.

The thecae alternate and are simple tubes like those of *P. ovatoelongatus.* The thecal tubes are throughout the rhabdosome inclined at 45°. The thecae number 7.5 in the proximal 5 mm.

The sicula is 2 mm long and the apex reaches halfway between the base of th2[1] and th3[1]. Th1[1] is 1.75 mm long and originates near the aperture of the sicula.

Remarks.—The rhabdosome is longer (1 cm) and has a greater width than the specimens described by Elles (1897) which are mainly 6 mm long and attain a width of 3 mm. In the specimens from Bornholm the sicula is somewhat shorter than stated in the original description, in which the sicula is measured to be 3 mm long with the apex between the base of th3[1] and th4[1].

P. minor? occurs at a higher level than *P. ovatoelongatus* and is restricted to the *pectinatus* Subzone.

Petalograptus palmeus (Barrande, 1850)
Pl. 4:J

Synonymy.—□ 1850 *Graptolithus palmeus* Barr. var. lata n. sp.—Barrande: 59–63 (pars), 3:3–4, non 1–2, 5–7. □ non 1897 *Diplograptus palmeus* Barrande.—Törnquist: 10, Pl. 1:25–26. □ 1908 *Petalograptus palmeus* s.s. (Barrande).—Elles & Wood: 274–275, Fig. 188a (non b), Pl. 32:1a–b, c–d?. □ 1941a *Petalolithus palmeus palmeus* Barrande.—Bouček & Přibyl: 3–4, Figs. 1–3, Pl. 1:1–3. □ 1971 *Petalolithus (Pet.) palmeus palmeus* (Barrande).—Schauer: 42–43, Pl. 10:5–6.

Lectotype.—Designated by Bouček & Přibyl (1941a:4), as the specimen figured in Barrande (1850, Pl. 3:3 (refigured Bouček & Přibyl, 1941a, Fig. 1:2); from the *linnaei* Zone, Želkowice, Bohemia.

Material.—About 15 specimens preserved flattened, or in low relief.

Horizon and localities.—The *turriculatus* Zone, Øleå (Ø13a)–(Ø14).

Description.—The rhabdosome is up to 3 cm long and the width at th[1] is 1 mm. The maximum width of 2.5 mm is attained at the level of th10. Towards the distal end the width remains constant, or decreases slightly to 2.3 mm. The rhabdosome has a prolonged thread-like virgula distally.

The thecae are simple alternating tubes, with the apertures situated normal to the thecal axis. Th1[1] and th1[2] are short, respectively 0.5 and 0.75 mm long, and the overlap in the proximal part of the rhabdosome is half the thecal length. The initial thecae are inclined at 60° to the rhabdosome. Towards the distal end the thecal overlap increases to two thirds and the degree of

inclination falls to 35°. The mesial and distal thecae are 1.8 mm long and 0.6 mm in width at their apertures. In the proximal 10 mm the thecae number 13–14, in the distal end they number 12 in 10 mm.

The sicula is not visible, but is provided with a short virgella.

Remarks.—The thecae in the specimens from Bornholm are slightly closer set (14–12) than in the specimens described by Barrande (1850), who indicated a thecal number of 10–12 per 10 mm. However, the refigured specimen, Fig. 1:3, in Bouček & Přibyl (1941a) shows 13 thecae in the proximal 10 mm.

P. palmeus resembles *P. tenuis* and *P. altissimus* but is distinguished from the former by a greater width and from the latter by a lesser distal width.

Petalograptus altissimus Elles & Wood, 1908
Pl. 4: K

Synonymy.—☐ 1908 *Petalograptus altissimus* sp. nov.—Elles & Wood: 281–282, Fig. 294a–c, Pl. 32: 7a, b, d, e, ?c. ☐ 1941a *Petalolithus altissimus* (Elles & Wood).—Bouček & Přibyl: 12, Fig. 3:4–7. ☐ ?1941a *Petalolithus giganteus* n. sp.—Bouček & Přibyl: 12–14, Fig. 3: 1–3. ☐ 1971 *Petalolithus (Pet.) altissimus* Elles & Wood.—Schauer: 47–48, Pl. 14: 1, 3, ?2, Pl. 15: 1–2, Pl. 44: 1a–c.

Lectotype.—Designated by Přibyl (1948: 12): Elles & Wood (1908, Pl. 32: 7a); from the Llandovery, Birkhill Shales, Scotland.

Material.—8 specimens, preserved flattened, or in low relief.

Horizon and localities.—The middle part of the *turriculatus* Zone, Øleå (Ø15)–(Ø15a).

Description.—The rhabdosome has a maximum length of 3 cm. The width is 0.5 mm at th1[1] and increases to a maximum width of 3.5–3.8 mm at the level of th15[1]. Towards the distal part the width decreases to about 2.5 mm. The median septum undulates and is complete on the obverse side. No septum is observed on the reverse side. The free virgula is thread-like and more than 1 cm long.

The thecae are simple, alternating tubes. They are proximally inclined at 70° to the rhabdosome, distally at about 30°. The thecal overlap increases from less than half the thecal length proximally to four fifths distally. The thecal apertures are slightly everted and at right angles to the thecal axis. The thecae number 13–16 in the proximal cm, distally the thecal count is about 12 in 10 mm. The sicula is about 1.5 mm long and the apex reaches to the base of th5[1]. The aperture of the sicula is 0.3 mm in width and provided with a 5 mm long virgella. In obverse view th1[1] seems to originate close to the aperture of the sicula and th2[1] 0.5 mm from the aperture.

Remarks.—Some of the *P. altissimus* specimens from Bornholm are different from those described earlier in having up to 16 thecae in the proximal 10 mm. In Elles & Wood (1908, Pl. 32: 7a, b, d, e) the thecal number is 12–13 in the proximal 10 mm. Otherwise their specimens are similar to the present material. Bouček & Přibyl (1941a) gave the thecal number of 10–11 in 1 mm in the text, but in Fig. 3: 5, the figured specimen shows 15 thecae in the proximal cm. In the tectonically compressed specimens figured in Schauer (1971) the exact thecal number cannot be measured. However, until more material has been obtained all the present specimens are included in *P. altissimus.*

Petalograptus tenuis (Barrande, 1850)
Fig. 12A

Synonymy.—☐ 1850 *Graptolithus palmeus* var. *tenuis,* Barr.—Barrande: 61, Pl. 3:2. ☐ 1897 *Diplograptus palmeus* Barr., var. tenuis.—Perner: 3, Pl. 9:3, 5, 7. ☐ 1908 *Diplograptus palmeus* var. *tenuis,* Barrande.—Elles & Wood: 276–277, Fig. 190, Pl. 32:3a–d. ☐ 1941a *Petalolithus tenuis* (Barrande).—Bouček & Přibyl: 7, Pl. 2:3, Fig. 2:8–11. ☐ 1971 *Petalolithus (Pet.) tenuis* (Barrande).—Schauer: 47, Pl. 14:4–7, Pl. 15:8–10, Pl. 43: 5a–b. For further references, see Bouček & Přibyl (1941a).

Holotype.—Barrande (1850, Pl. 3: 2); from the *turriculatus* Zone, Litholaver Mühle, Königshof, Bohemia.

Material.—5 specimens, all of which are flattened.

Horizon and locality.—The upper part of the *crispus* Zone, Øleå (Ø17).

Description.—The rhabdosome is elongated, the maximum length is 2 cm. The proximal part is slender and the width increases from 1.0 mm to 1.8 mm within the 7–8 proximal pairs of thecae. Distal to that the width decreases to 1.7 mm. The free part of the virgula is apparently band-formed, 1 mm in width, and may reach a length of 2 cm. The virgula is twisted clockwise two or three times, as seen from the proximal end.

The thecae are straight tubes, of which the maximum width is 0.5 mm and the greatest length is 1 mm. The overlap is nearly half the thecal length throughout the rhabdosome. The thecae are inclined at about 30° to the axis of the rhabdosome and the apertures are normal to the thecal axis. The thecae number 10–11 in the proximal 10 mm.

The sicula is 1 mm long and the aperture is 0.3 mm in width. Proximally the rhabdosome is prolonged into a 0.5 mm long virgella. Th1[1] is about 1.5 mm long and seems to originate close to the aperture of the sicula, th1[2] initiates 0.5 mm from the aperture.

Remarks.—The specimens from Bornholm are up to 2 cm long, earlier described specimens have a maximum length of 1.8 cm in tectonically compressed material (Schauer, 1971).

P. tenuis is closely related to *P. palmeus* and *P. elongatus.* From *P. palmeus, P. tenuis* is distinguished by the lesser

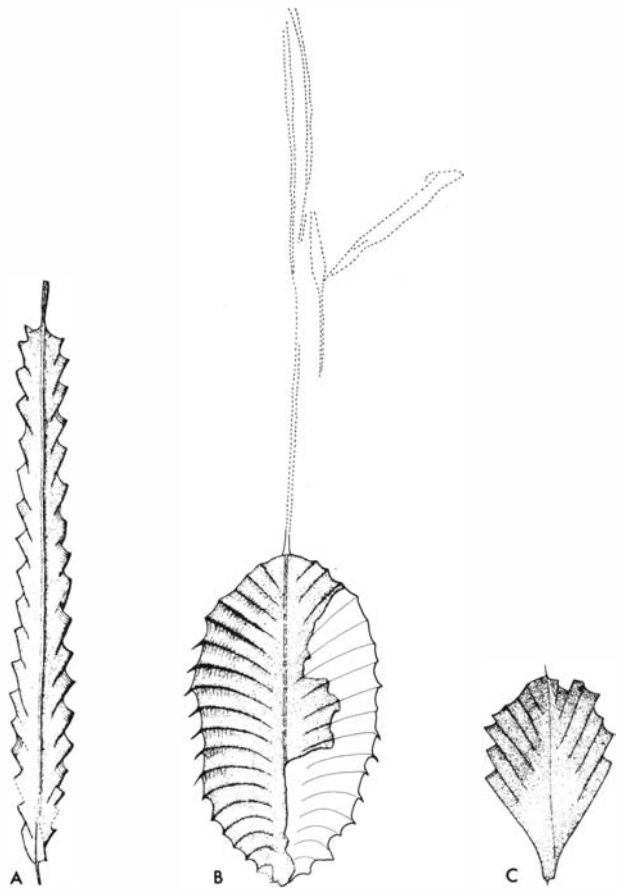


Fig. 12. ☐ A. *Petalograptus tenuis* (Barrande, 1850). The *crispus Zone*, Øleå. MMH 13429. ×5. ☐ B. *Petalograptus ovatus scopaecularis* Schauer, 1971. The *turriculatus* Zone, Øleå. MMH 13430. ×5. ☐ C. *Petalograptus folium* (Hisinger, 1837). The *convolutus* Zone, Øleå. MMH 13431. ×5.

width and from *P. elongatus* by the smaller sicula, but otherwise the latter species seems to be almost identical with *P. tenuis* and further investigation is needed.

The virgula observed in *P. tenuis,* was described as being of the "vinculare" type by Müller & Schauer (1969). Unfortunately, the virgula is flattened and rather badly preserved, thus it has not been possible to state whether the structure is three-vaned as observed for the thread-like outgrowths in other species, e.g. the structure of the virgella in *R. toernquisti.*

Petalograptus ovatus scopaecularus Schauer, 1971
Fig. 12B

Synonymy.—☐ 1952 *Petalolithus ovato-elongatus* Kurck.—Münch: 67, Pl. 9:4–6. ☐ 1969 *Petalolithus* n. sp. ? aff. *ovatoelongatus* Kurck.—Müller & Schauer, Figs. 19c–d. ☐ 1971 *Petalolithus (Pet.) ovatus scopaecularus* n. subsp.—Schauer: 45–46, Pl. 12:7–8, Pl. 13:8–10.

Holotype.—Specimen figured in Schauer (1971, Pl. 12: 8, Pl. 13:8); from the *linnaei* Zone, Johannisberg at Ronneburg, Thüringen.

Material.—Two flattened specimens.

Horizon and locality.—The lower part of the *turriculatus* Zone, Øleå (Ø14a).

Description.—The rhabdosome is ovate and short, about 1 cm long. The width at the level of th1[1] is 1.2 mm, the maximum width of 5.5 mm is reached at the level of the aperture of th12[1]. At the extreme distal end the width has decreased to 1 mm. The median septum is not observed with certainty. A 2 cm long free virgula seems to be divided into two or three branches, one of the branches has apparently a side-branch. The exact structures of the virgula cannot be stated.

The thecae are simple tubes. The initial parts of the proximal thecae are situated nearly perpendicular to the axis of the rhabdosome, and the thecae are ventrally curved. Towards the mesial part of the rhabdosome the inclination of the thecae has declined to 80° and the tubes become straight. Most distally the straight thecae are inclined at 45° to the rhabdosome. The thecal apertures are everted and normal to the thecal axis. The initial thecae are only 0.5 mm long. The maximum thecal length of 2.75 mm is reached in the mesial portion and distally the length decreases to 0.5 mm. The thecae overlap for nearly their entire length. The width of the thecal apertures is about 0.5–0.7 mm, and the mesial thecae are about 4–5 times as long as wide. The thecae are very closely set and number 19 in 10 mm. The sicula has not been observed.

Remarks.—The two specimens from Bornholm differ from those described by Schauer (1971) in the structure of the free part of virgula which, in the originally described specimens, is divided into many thread-like branches and seems to originate from a wedge-shaped structure in the distal end of the rhabdosome. This wedge structure is not apparent in the present material. Otherwise the measured dimensions of the rhabdosome are equal to those of the original described specimens.

P. ovatus scopaecularus differs from *P. ovatus ovatus* by attaining the greatest width of the rhabdosome and the maximum thecal length at the level of the thecal pairs Nos. 10–12, whereas the greatest width is reached at the level of th5[1] in *P. ovatus ovatus.*

Petalograptus folium (Hisinger, 1837)
Fig. 12C, Table 2

Synonymy.—☐ 1837 *Prionotus folium.*—Hisinger: 114, Pl. 35:8. ☐ 1881 *Diplograptus folium* His.—Törnquist: 442–443, Pl. 17:7. ☐ 1882 *Cephalograptus folium,* His.—Tullberg: 15–16, Pl. 1:15–19. ☐ 1897 *Diplograptus folium* Hisinger.—Törnquist: 12–14, Pl. 2:1–4. ☐ 1908 *Petalograptus folium* (Hisinger).—Elles & Wood: 282–284, Fig. 195, Pl. 32:8a–b, e, non c, d. ☐ ? 1941b *Petalolithus folium* toernquisti n. ssp.—Bouček & Přibyl: 8, Figs. 2d–e, Pl. 1:8. ☐ 1941b *Petalolithus folium* (Hisinger).—Bouček & Přibyl: 7–9, Figs. 2a–c, Pl. 1:6–7. ☐ 1969 *Petalolithus folium* His.—Müller & Schauer, Fig. 2c, ?b, Fig. 7c (not described). ☐ 1971 *Petalolithus (Pet.) folium* (Hisinger).—Schauer: 41, Pl. 9:1–2.

Lectotype.—Designated by Bouček & Přibyl (1941b: 7) as the specimen figured in Hisinger (1837, Pl. 35:8), refigured by Tullberg (1882, Pl. 1: 16); from the Llandovery of Dalecarlia, Sweden.

Material.—9 specimens, all flattened.

Horizon and localities.—The lower part of the *convolutus* Zone, Øleå (Ø11) and (Ø12).

Description.—The longest rhabdosome has a length of about 1.5 cm. The maximum width of 5 mm is attained at the level of th5[1]. The proximal end is wedge-shaped, and the initial thecae are very gently curved outwards, 3–4 mm long, with the apertures normal to the thecal axis. The thecae are inclined at 20°–30° to the rhabdosome, and the thecal length is 8 times the width of the tubes. The distal thecae are straight, and the slightly everted apertures have a thickened rim. The thecal overlap is large throughout the rhabdosome, about five sixths of the thecal length. The thecae number 12–10 in 10 mm.

The sicula has only been seen in one specimen, it is about 1 mm long. In a specimen from the lowermost parts of the occurrence the sicula is provided with a bifid virgella, each branch is at least 1.5 mm long and is recurved towards the distal end of the rhabdosome.

Remarks.—In some of the rhabdosomes a free virgula is present but the bifurcation described by Müller & Schauer (1969) and Schauer (1971) has not been found. The maximum width of Hisinger's original specimen is 5 mm at the level of th6[1]–7[1]. Törnquist (1897) described specimens from the *cometa* Zone in Dalecarlia with a greater width (5–6 mm), and more slender forms (3.5 mm) from Scania.

Bouček & Přibyl (1941b) described a new subspecies from Germany, *P. folium toernquisti,* but the description is rather insufficient and Schauer (1971) regarded the subspecies as a tectonically compressed specimen of *P. folium.*

There seems to be slight differentiation among the specimens from Bornholm. In the transition from the *gregarius* Zone to the *convolutus* Zone the rhabdosomes are shorter, less than 10 mm and the initial thecae are longer (4 mm) than in the specimens from the middle part of the *convolutus* Zone. Here the initial thecae are about 3 mm long. The dorso-ventral width is constant in all specimens throughout the occurrence, and the present material does not allow any further subdivision.

Genus *Cephalograptus* Hopkinson, 1869

Type species (by original designation).—*Diplograptus cometa* Geinitz, 1852; from the Llandovery, Germany.

Diagnosis (from Bulman, 1970, and Rickards, 1970).—An extreme development of *Petalograptus,* rhabdosome more or less triangular in lateral veiw, with few elongated thecae and exposed sicula.

Cephalograptus tubulariformis (Nicholson, 1867)
Pl. 5: A, Table 2

Synonymy.—☐ 1867 *Diplograptus tubulariformis* (n. sp.).—Nicholson: 111, Figs. 12–13 (non 14–15). ☐ 1908 *Cephalograptus tubulariformis* (Nicholson).—Elles & Wood: 287–288, Fig. 198, Pl. 32:9a–d. ☐ 1941b *Cephalograptus tubulariformis* (Nicholson).—Bouček & Přibyl: 12, Figs. 2f–h, Pl. 1:9. ☐ 1971 *Petalolithus (Ceph.) tubulariformis* (Nicholson).—Schauer: 49, Pl. 8:5–6, Pl. 9:3–5.

Lectotype.—Designated by Bouček & Přibyl (1941b: 12) as the specimen figured in Nicholson (1867, Pl. 7: 12); from the Llandovery, Scotland.

Material.—5 fragmentary, flattened specimens.

Horizon and localities.—The middle of the *convolutus* Zone, Øleå (Ø12)–(Ø13).

Description.—The rhabdosome is wedge-shaped with a very narrow proximal part. The longest fragment is 1.5 cm. The maximum dorso-ventral width of 4 mm is attained at the level of the apertures of th5[1–2]. The proximal end with sicula has not been seen but the width of the most proximal portion is 1 mm. The initial thecae may have been more than 7 mm long, they are gently ventrally curved and inclined at about 20° to the rhabdosome. The width of the thecal tubes is 0.5 mm and the apertures are normal to the axis of the thecae. Towards the distal portion of the rhabdosome the thecae become shorter and the inclination increases to 40°. The thecal overlap is obscured by the bad state of preservation, but may be about four fifths of the length of the thecae. From the level of the aperture th1[1] the thecae number 4–5 in 5 mm.

Remarks.—*C. tubulariformis* from Bornholm is in no way different from earlier described specimens, but the material at hand is small and incomplete. *C. tubulariformis* is an obvious transition form between *P. folium* and *C. cometa cometa,* having an intermediate length of the initial thecae (about 7 mm). The stratigraphic position also gives evidence of development from *P. folium* through *C. tubulariformis* to *C. cometa cometa.*

Cephalograptus cometa cometa (Geinitz, 1852)
Pl. 5: B, Table 2

Synonymy.—☐ 1852 *Diplograptus Cometa* Geinitz.—Geinitz: 26, Pl. 1:28. ☐ 1853 *Diplograptus cometa* Geinitz.—Richter: 457, Pl. 12:16–17. ☐ 1893 *Cephalograptus cometa* Gein.—Törnquist:11–12, Pl. 1:36–41. ☐ 1897 *Diplograptus cometa* Geinitz.—Törnquist: 14–15, Pl. 2: 9–14, ?8. ☐ 1908 *Cephalograptus cometa* (Geinitz).—Elles & Wood; 285–287 (pars), ? Fig. 197, Pl. 32: 10d. ☐ 1941b *Cephalograptus cometa cometa* (Geinitz).—Bouček & Přibyl: 13–14, Figs. 2i–k. ☐ 1971 *Petalolithus (Ceph.) cometa cometa* (Geinitz).—Schauer: 49–50, Pl. 8:7, Pl. 9:6–10, ?11.

Lectotype.—Designated by Bouček & Přibyl (1941b: 13):

Table 2. Dimensions (in mm).

Spec. No.	Flat or relief	Length	Length of th1[1]	Length of th2[1]	Max dist. width	No. of th prox.
P. folium						
MMH 13501	F	15	3.5	3.0	5.0	10/10
MMH 13502	F	7	4.0	4.0		5/5
C. tubulariformis						
MMH 13503	F	8	5.5	6.0	3.5	
MMH 13504	F	10	6.8	7.0	3.5	
C. cometa cometa						
MMH 13505	F	17	14	15	2.5	
MMH 13506	F	14	9	12	2.8	
C. cometa extrema						
MMH 13507	LR	20	20		1.2	
MMH 13508	LR	17	14		1.25	
MMH 13509	LR	15	15	15	1.0	
MMH 13510	LR	15	15		1.0	

LR=low reliet.

Geinitz (1852, Pl. 1:28); from the Llandovery of Germany.

Material.—About 15 specimens, all flattened.

Horizon and locality.—The upper part of the *convolutus* Zone, Øleå (Ø13).

Description.—The rhabdosome is elongated fusiform. The maximum length is about 2 cm and the greatest width of 3 mm is attained at the level of the apertures of th1[1]–th2[1]. Distal to that the width decreases rapidly.

The proximal part is long and slender, 0.5 in width at the sicula. The sicula itself is not seen. The first two thecae are 1.5 cm long tubes and the apertural width is 0.3 mm. They are inclined at 6°–7° to the rhabdosome. The distal thecae become shorter and the inclination increases to 10°–15°. The apertures are always normal to the thecal axis. The thecal overlap is distally four fifths to seven eighths of the thecal length, which implies that all the thecal apertures are situated at the distal end. This portion occupies one fifth of the total length of the rhabdosome. In the largest rhabdosomes about 10 thecae are observed.

In the author's material, which is badly preserved, no details can be observed at the extreme proximal end.

Remarks.—The specimens of *C. cometa cometa* from Bornholm perfectly match earlier descriptions. One specimen has the thecal apertures slightly separated in the distal end of the stipe and may be a transitional form between *C. tubulariformis* and *C. cometa cometa*; however, more material is needed for a thorough revision.

Cephalograptus cometa extrema Bouček & Přibyl, 1941
Pl. 5:C, Table 2

Synonymy.—☐ 1908 *Cephalograptus cometa* (Geinitz).—Elles & Wood: 285–287 (pars), Pl. 32:10a–c. ☐ 1941b *Cephalograptus cometa extrema* n. subsp.—Bouček & Přibyl: 14–15, Figs. 2 l–m, Pl. 1:10. ☐ 1971 *Petalolithus (Ceph.) cometa extrema* Bouček & Přibyl.—Schauer: 50, Pl. 8:8–9, Pl. 9:12–16, ?11.

Holotype.—Specimen figured Bouček & Přibyl (1941b, Fig. 21); from the *sedgwickii* Zone, Llandovery, Bohemia.

Material.—16 specimens preserved flattened or with low relief, frequently with well preserved fusellar structures. Complete rhabdosomes are rare.

Horizon and locality.—The uppermost part of the *convolutus* Zone, Øleå (Ø13).

Description.—The rhabdosome is very slender, slightly fusiform. The longest rhabdosome is about 2 cm, and the maximum width of 1.3 mm is attained at the level of the aperture of th1[2]. The extreme proximal end of the rhabdosome is 0.25 mm in width. The sicula is about 1 mm long, but no detailed structures can be observed, as proximal ends are rare and poorly preserved.

The initial thecae are up to 2 mm long and 0.25 mm in width. They are inclined at 2°–4° to the rhabdosome. The apertures are perpendicular to the thecal axis. The succeeding thecae are short and overlap for about their whole length, which implies that their apertures are situated close to the level of the apertures of the two first thecae. The maximum number of thecae is 6.

Remarks.—*C. cometa extrema* is closely related to *C. cometa cometa,* but is separated by the longer proximal thecae which are inclined at a lower angle to the rhabdosomes (2°–4°) than those of *C. cometa cometa* (6°–7°). The distal part of *C. cometa extrema* are more narrow than in *C. cometa cometa.*

Bouček & Přibyl (1941b) reported 6 thecae as a maximum, this is also seen in the specimens from Bornholm, but the specimen figured in Elles & Wood (1908, Pl. 32:10b) shows 8 thecae, but is certainly a *C. cometa extrema.* Fragments of *C. cometa cometa* and *C. cometa extrema* may be difficult to distinguish, but in the present material no fully developed transition forms between *C. cometa cometa* and *C. cometa extrema* have been found.

C. cometa extrema has a very restricted occurrence in the uppermost part of the *convolutus* Zone, but is also recorded from the *sedgwickii* Zone in other areas.

C. cometa extrema is the extreme offshot of the development-line *P. folium–C. tubulariformis–C. cometa cometa* and *C. cometa extrema.* The development is characterized by an increase in length of the initial thecae together with an increasing degree of thecal overlap, implying that the extremely developed *C. cometa extrema* has the thecal apertures nearly at the same level. Furthermore, the angle of inclination of the thecal tubes decreases throughout the development line. The oldest species *P. folium* shows some affinity to *P. ovatoelongatus* from the middle part of the *gregarius* Zone, and which also has rather long initial thecae.

Genus *Retiolites* Barrande, 1850

Type species (subsequently designated by Lapworth, 1873).—*Gladiolites Geinitzianus,* Barrande (1850); from the Silurian, Bohemia.

Diagnosis (from Bulman, 1970).—Reticulum on strongly developed clathria of parietal, pleural, apertural and aboral lists, with virgula rapidly incorporated in one side and a dorsal list ("zig-zag virgula") on the other.

Retiolites geinitzianus geinitzianus (Barrande, 1850)

Pl. 5:F, Table 3

Synonymy.— ☐ 1850 *Gladiolites Geinitzianus* Barr.—Barrande: 69–74, Pl. 4:16–33. ☐ 1885 *Retiolites Geinitzianus* Barr.—Tullberg: 41, Pl. 1:10–17. ☐ 1908 *Retiolites (Gladiograptus) Geinitzianus,* Barrande.—Elles & Wood: 336–338, Figs. 220a–f, Pl. 34:8a, c–d, ?8b. ☐ 1940 *Retiolites Geinitzianus* Barr.—Laursen: 32 (pars), Fig. 29, non Pl. 2:6–7. ☐ 1943 *Retiolites (Ret.) geinitzianus geinitzianus* Barr.—Bouček & Münch: 40–43: Figs. 13c–h, 14c–d, Pl. 3:2–5 (with a complete list of synonyms). ☐ 1971 *Retiolites (Ret.) geinitzianus geinitzianus* (Barrande).—Schauer: 83, Pl. 39:1–2, Pl. 40:1.

Lectotype.—Barrande (1850, Pl. 4:17), according to Bouček & Münch's designation (1943).

Material.—About 100 specimens, all are preserved flattened.

Horizon and localities.—The *centrifugus* Zone, Øleå (Ø31)–(Ø39), (Ø41), and Læså (L1).

Description.—The rhabdosome is straight and the maximum length is about 4 cm. The proximal portion is rounded, the width at th1[1] is 0.75 mm and increases to 3.75 mm at the level of th20[1]. This width is retained throughout the distal part of the rhabdosome. The greatest width measured is 3.9 mm. The reticulum and the clathria are well developed. From the proximal end to the distal part, the reticulum becomes more open; the meshes are 8–9 in 1 mm in the extreme proximal end and 4–5 per 1 mm in the distal part.

The thecae are straight tubes in contact for their whole length. They are inclined at about 60° throughout the rhabdosome. The apertures are straight and continuous in the greatest part of the specimens, but may have a slight concave form perpendicular to the thecal axis. The tubes are two to three times as long as wide. The thecae number 13 in the proximal 10 mm and 10–11 per 10 mm in the extreme distal portion. The sicula is not seen.

Remarks.—*R. geinitzianus geinitzianus* from Bornholm is not different from earlier described specimens. The graptolite is easily separated from *R. geinitzianus angustidens* by the wider rhabdosome and the rapid increase in width in the proximal end.

R. geinitzianus geinitzianus occurs in the *centrifugus* Zone, and may have developed from *R. geinitzianus angustidens.*

Retiolites geinitzianus angustidens Elles & Wood, 1908

Pl. 5: D–E, Table 3

Synonymy.— ☐ 1908 *Retiolites (Gladiograptus) Geinitzianus,* Barrande. Var. *angustidens,* nov.—Elles & Wood: 338, Pl. 34:9a–c. ☐ 1940 *Retiolites Geinitzianus* Barr.—Laursen: 32, pars, Pl. 2:7. ☐ 1943 *Retiolites (Ret.) geinitzianus angustidens* Elles & Wood.—Bouček & Münch: 37, Figs. 11a–e, 12b–e, Pl. 2:1–4. ☐ 1952 *Retiolites geinitzianus angustidens* E. u. W.—Münch: 78, Pl. 14:6a–c. ☐ 1971 *Retiolites (Ret.) geinitzianus angustidens* Elles & Wood.—Schauer: 83, Pl. 39:3, Pl. 40:2.

Lectotype.—Elles & Wood (1908, Pl. 34:9a), according to the designation of Bouček & Münch (1943).

Material.—About 500 specimens, preserved flattened or in low relief; most specimens are infilled with pyrite, and the reticulum is badly preserved.

Horizon and localities.—The *spiralis* Zone ?, the *lapworthi* Zone, and the *centrifugus* Zone ?, Øleå (Ø26), (Ø28)–(Ø31), (Ø40), (Ø42), (Ø43), and Læså (L3)–(L5).

Description.—The rhabdosome is straight, the maximum length is about 4 cm. The proximal end is rounded. The width of the rhabdosome increases gradually within the proximal 25 thecae from 0.8 mm at the level of th1[1] to 3.0 mm at th25[1]. The width is retained throughout the distal portion and never exceeds 3 mm. The reticulum is situated on a strongly developed clathria. In one specimen from the lower part of the *lapworthi* Zone, which is preserved in relief with an internal pyrite mould, a median row of pores is seen in the mesial part of the rhabdosome. The pores are not regularly spaced. They number about 7 in 10 mm and are rounded to ovate, about 0.25 mm in diameter and surrounded by a thickened rim (Pl. 5:E).

The thecae are parallel sided tubes in contact along their entire length. They are inclined at about 70° to the axis in the proximal part of the rhabdosome, and distally the inclination decreases to about 50°. In the majority of specimens the apertures have a straight and continuous appearance, specimens in oblique view show the apertural rims to be concave and normal to the thecal axis. The thecae are about twice as long as wide. The thecae number 14 in the proximal 10 mm and 11–12 per 10 mm in the distal end. The sicula has not been observed.

Remarks.—The reticulum and the clathria are generally poorly preserved, and in spite of a large material new information about these structures is rather limited.

The median row of pores has not been seen before, and as the internal mould is an impression of the inner surface of the reticulum the pores may not be distinguished in the outer surface of the reticulum. If the median row of pores is of systematic importance the

Table 3. Dimensions (in mm).

Spec. No.	Flat or relief	Length	Width of the rhabdosome						Number of th	
			th1	th5	th10	th15	th20	th30	dist.	Prox.	dist.
Stomatograptus grandis grandis											
MMH 13511	F	30	1.0	2.5	3.1	4.2	4.8	5.8		13/10	9/10
MMH 13512	F	60							6.75		8.5/10
Stomatograptus grandis girvanensis?											
MMH 13513	F	23	1.0	1.7	2.3	2.9	3.5			14/10	10/10
MMH 13514	F	37	0.9	1.6	2.3	3.0	3.5		4.0	13.5/10	11/10
MMH 13515	LR	15							4.5		10/10
Retiolites geinitzianus geinitzianus											
MMH 13516	F	40	1.0?	1.9	2.2	2.75	3.1	3.9	3.75	13/10	11/10
MMH 13517	F	30	0.75	1.8	2.5	3.3	3.75	3.75		13/10	10/10
Retiolites geinitzianus angustidens											
MMH 13518	F	32	0.8	1.5	2.3	2.5	2.75		3.0	14/10	12/10
MMH 13519	LR	29	0.9	1.5	2.0	2.3	2.5		2.8	14.5/10	12/10
MMH 13520	LR	33							3.0		11/10

discovery of the pores in *R. geinitzianus angustidens* makes the genera *Stomatograptus* and *Retiolites* more closely related. In other respects the material from Bornholm is not different from earlier described specimens.

A few very badly preserved specimens have been found in the upper part of the *spiralis* Zone. In the *lapworthi* Zone *R. geinitzianus angustidens* is the most frequent graptolite.

Genus *Stomatograptus* Tullberg, 1883

Type species (by original designation).—*Retiolites grandis* Suess, 1851.

Diagnosis (from Bulman, 1970).—Like *Retiolites* but with solid interthecal septa, less overlapping thecae, and a median row of large pores in reticulum.

Stomatograptus grandis grandis (Suess, 1851)

Pl. 5:1, Table 3

Synonymy.— ☐ 1851 *Retiolites grandis*.—Suess: 15, Pl. 7:2. ☐ 1893 *Stomatograptus Törnquisti* Tullb.—Tullberg: 42, Pl. 1:1–8. ☐ 1890 *Stomatograptus Törnquisti* Tullb.—Holm: 23–25, Pl. 2:6–11. ☐ 1892 *Stomatograptus grandis* Suess.—Törnquist: 8–9. Pl. 2:22–23. ☐ 1940 *Stomatograptus Törnquisti* Tull.—Laursen: 32 (not figured). ☐ 1940 *Retiolites Geinitzianus* Barr.—Laursen: Pl. 2:6. ☐ 1943 *Retiolites (Stomatograptus) grandis grandis* (Suess).—Bouček & Münch: 49, Fig. 15e, 16a–c. Pl. 3:78. ☐ 1952 *Stomatograptus grandis grandis* Suess.—Münch: 81, Pl. 16:3a–d. ☐ 1955 *Stomatograptus grandis* (Suess).—Bulman, Fig. 66, 6 (not described).

Holotype (by monotypy).—The specimen figured in Suess (1851, Pl. 7:2).

Material.—About 30 specimens, flattened or with low relief.

Horizon and localities.—The *lapworthi* and *centrifugus* zones Øleå (Ø29)–(Ø33), (Ø40)–(Ø42, Læså (L1), (L5).

Description.—The rhabdosome is straight and may have had an original length of more than 6 cm. The width increases rapidly in the proximal end from 1 mm at the level of th1[1] to 3 mm at th10[1]. Within the following 20 thecae width increases to 6.0 mm. The maximum width attained distally is about 7 mm (all measurements are from flattened specimens).

The network of the reticulum has about 3 interspaces in 1 mm. In well preserved specimens a median row of pores in the reticulum is seen. The spacing of the pores varies from specimen to specimen. In one well preserved specimen there are three pores in 5 mm. The pores are ovate and have a length of 0.5 mm and a lateral width of 0.3 mm. In other specimens the pores are irregularly shaped. The pores are surrounded by a thickened rim and in relief specimens they are elevated from the surrounding reticulum.

The thecae are inclined at about 50° in the proximal part and 60° in the distal end, where the thecal tubes are 1 mm in width and 3.5 mm long. The overlap of the distal thecae is about three fourths of the length. The ventral walls of the thecae are slightly convex and the apertures of the proximal thecae are mainly concave and situated perpendicular to the thecal axis. However, in the distal part of the rhabdosome the apertures seem to be approximately perpendicular to the axis of the rhabdosome. The interthecal septa are robust and the apertures have a thickened rim. The thecae number 13 in the proximal 10 mm, in the distal part the number is 9–8.5 per 10 mm.

Remarks.—*S. grandis grandis* is easily separated from other

species by the large rhabdosome, the solid interthecal septa, and the median row of pores.

The subspecies *Stomatograptus grandis imperfectus* Bouček & Münch, *Stomatograptus grandis robustus* Bouček & Münch, and *Stomatograptus grandis major* Bouček & Münch are very close to *S. grandis grandis,* but until more information and material have been obtained of these subspecies, no further subdivisions will be carried out on the material from Bornholm.

Stomatograptus grandis girvanensis Cocks & Toghill, 1973?

Pl. 5:G–H, Table 3

Type.—Not yet designated. Specimen figured in Cocks & Toghill (1973, Pl. 2:2).

Horizon and localities.—The *griestoniensis* Zone, Øleå (Ø18) –(Ø19).

Material.—About 40 specimens, flattened or in low to medium relief.

Diagnosis.—A slender stomatograptid with gradually increasing width from 1.1 mm to a maximum of 4.5 mm distally. The thecae are of stomatograptid type with solid interthecal septa and an overlap of four fifths of the length. They number 14–10 in 10 mm. The rhabdosomes possess a median row of small closely situated pores which number 3–5 per 5 mm.

Description.—The rhabdosome is straight, and the maximum length is more than 4 cm. The greatest increase in width takes place along the proximal 2 cm, the width increasing from 1.1 mm to 3.5 mm. The maximum width observed is 4.5 mm, and the distal part is nearly parallel sided. No free virgula or virgella have been seen. The reticulum has rather small, irregularly formed interspaces, proximally numbering 5–6 per 5 mm, and distally 4 in 5 mm.

In well preserved specimens a median row of small pores is observed. The pores are irregularly spaced near the proximal end and number 3–5 in 5 mm, with a diameter of 0.2 mm. In the distal part the pores are rather regularly spaced, and they number 4–4.5 in 5 mm and have a diameter of 0.25 mm. The pores show a thickened rim and appear as holes in the surface, especially when seen in relief specimens.

The thecal tubes are straight with parallel walls and solid interthecal septa. Both proximally and distally the thecae are inclined at 55° to the axis of the rhabdosome. The distal thecae are 0.8 mm in width and 2.5 mm long. The overlap is four fifths of the thecal length. In relief specimens the apertures are apparently square and perpendicular to the thecal axis. In flattened specimens the apertures seem to be deeply convex and the ventral walls have a thickened rim, which, in flattened specimens, resembles a small process. The thecae number 14 in the proximal 10 mm and 10 in the distal 10 mm.

Remarks.—The specimen in Cocks & Toghill (1973, not described, but figured Pl. 2:2) seems to be identical to the present material with regard to width, thecal number, and the spacing of the median pores. This supports the tentative assignment of the present material to the subspecies *girvanensis.* The British specimen was also reported from the *griestoniensis* Zone.

S. grandis girvanensis? is separated from *S. grandis grandis* by the smaller size, a higher thecal number per 10 mm throughout the rhabdosome, and the reticulum is more finely interspaced. The median pores are smaller and more closely set than in *S. grandis grandis.* The pores in *S. grandis girvanensis?* appear as perforations in the surface of relief specimens in the present material. In *S. grandis grandis* the pores are elevated above the surface of the reticulum. However, the elevation of the pores may be related to the state of preservation.

S. grandis girvanensis? differs from *R. geinitzianus* s.l. by a more restricted thecal overlap, solid interthecal septa, and the distinct median row of pores. However, flattened specimens of *S. grandis girvanensis?* may easily be confused with *R. geinitzianus* s.l., as obliquely embedded specimens appear as if they have thecae which overlap along their entire length. The pores are not always evident in flattened specimens.

S. grandis girvanensis? is fairly frequent in the *griestoniensis* Zone and is here associated with *M. griestoniensis, M. priodon, M. nudus, M. tullbergi?,* and *M. vomerinus* s.l. *S. grandis girvanensis?* may be a forerunner to *S. grandis grandis,* which occurs in the *spiralis* and *lapworthi* zones.

Specimens of *S. grandis girvanensis?* have also been found in a material from the *spiralis* Zone in Dalecarlia.

Genus *Pseudoplegmatograptus* Přibyl, 1948

Type species (by original designation).—*Retiolites perlatus obesus* Lapworth (1877); from the Llandovery, Ireland.

Diagnosis (from Bulman, 1970).—Like *Retiolites* but with somewhat ill-defined clathria and well-developed lacinia.

Pseudoplagmatograptus obesus (Lapworth, 1877)

Synonymy.—☐ 1877 *Retiolites perlatus* var. *obesus.*— Lapworth: 137, Pl. 6: 29. ☐ 1890 *Retiolites obesus* Lapworth. —Törnquist: 10, Pl. 2: 24–25. ☐ 1908 *Retiolites (Plegmatograptus) obesus* (Lapworth).—Elles & Wood: 342–343, Figs. 223a–c, Pl. 34: 12a–c. ☐ 1970 *Pseudoplegmatograptus obesus* (Lapworth).—Rickards: 50, Fig. 13:20. ☐ 1971 *Retiolites (Pseudoplegmatograptus) obesus* Lapworth.— Schauer: 84, Pl. 39:5–8, Pl. 40: 5. For further referenses see Rickards (1970).

Holotype (by monotypy).—Specimen figured by Lapworth (1877, Pl. 6: 29); from the Llandovery of Down County, Ireland.

Material.—One flattened distal fragment.

Horizon and locality.—The lower part of the *turriculatus* Zone, Øleå (Ø13b).

Description.—The rhabdosome is 1 cm long, only the distal part is preserved. The dorso-ventral width including the thecal spines and the lacinia is 5 mm. The thecae number 5 in 5 mm. The lacinia is well developed, the clathria has not been identified with certainty.

Remarks.—The measurements of the fragment fit the earlier descriptions, especially when compared to the specimens described by Rickards (1970).

P. obesus is associated with *D. runcinatus, M. halli,* and *M. turriculatus.*

Genus *Dimorphograptus* Lapworth, 1876

Type species (subsequently designated by Bassler, 1915).—*D. elongatus* Bassler (1915); from the Llandovery of Scotland.

Diagnosis (from Rickards, 1970).—Proximal portion uniserial with loss of th1² and generally further thecae of secondary series, becoming biserial distally, biserial portion usually with partial septum, development more or less of monograptid type. Thecae orthograptid or glyptograptid with a tendency in some species towards isolation of the apertural region. The uniserial portion of varying length; initial bud upwardly directed at origin.

Dimorphograptus erectus s.l. Elles & Wood, 1908
Fig. 13A

Synonymy.—☐ 1908 *Dimorphograptus erectus* sp. nov.—Elles & Wood: 355–356, Figs. 233a–b, Pl. 35:9a–d.

Lectotype.—Specimen A 20779, figured in Elles & Wood (1908, Pl. 35:9a); from Dobb's Linn, Howgill Fells.

Material.—2 flattened specimens.

Horizon and locality.—The *acinaces* Zone, well at Bavnegård, at 14.5–15.0 m and 15.0–25.0 m below ground level.

Description.—The longest fragment is about 1 cm in length. The uniserial part contains three thecae, the width of th1 is 0.5 mm, and in the biserial portion at th1² the width is 1.2 mm, at th2² 1.5 mm, and at th5² 1.75 mm. The maximum distal width is about 1.8 mm.

The thecal tubes are apparently of orthograptid type, and distally the overlap increases to about half the thecal length. Occasionally the apertures are slightly everted. The thecae number 2.5 per 2.5 mm in the uniserial part and 6 per 5 mm in the biserial portion.

The sicula is 1.25 mm long and reaches approximately to the aperture of th2¹, which implies that the proximal portion appears to be rather robust. Th1¹ originates close to the aperture of the sicula.

Remarks.—In the present material the thecal count per cm is slightly higher, 12 per 10 cm, than in *Dimorphograptus erectus erectus* Elles & Wood, which has 10–11 per 10 mm. From *Dimorphograptus erectus nicholsoni* Rickards the present specimens are distinguished by the shorter sicula and by the greater width of the rhabdosome. The specimens from Bornholm appear to be transitional forms between the two subspecies and by correlation with the stratigraphic occurrence in Britain *D. erectus* s.l. may indicate the *acinaces* Zone.

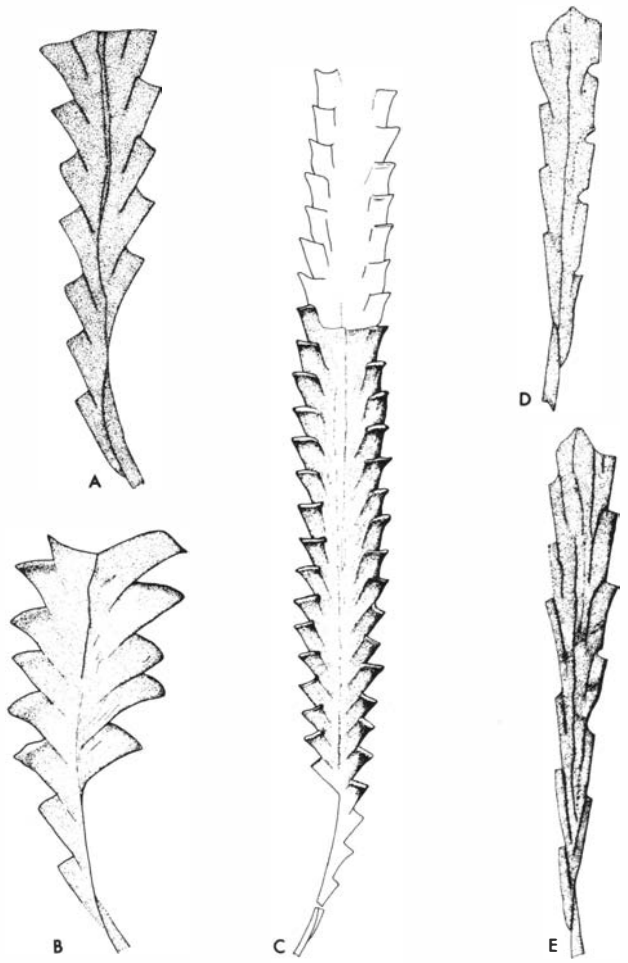


Fig. 13. ☐ A. *Dimorphograptus erectus* s.l. Elles & Wood, 1908. Bavnegård well, 14.5–15.0 m below ground level. The *acinaces* Zone. MMH 13432. ×10. ☐ B–C. *Dimorphograptus confertus confertus* (Nicholson, 1868). The *acinaces* Zone, Øleå. ☐ B. Proximal part. MMH 13433. ×10. ☐ C. More complete rhabdosome. MMH 13434. ×5. ☐ D–E. *Akidograptus ascensus* Davies, 1929. Bavnegård well, 25–30 m below ground level. The *acuminatus* Zone. ☐ D. Flattened specimen. MMH 13435. ×10. ☐ E. Specimen in low relief. MMH 13436. ×10.

Dimorphograptus confertus confertus (Nicholson, 1869)
Figs. 13B–C, Pl. 6: A

Synonymy.—☐ 1868 *Diplograptus confertus* Nich.—Nicholson: 256, Pl. 19:14–15. ☐ ? 1897 *Dimorphograptus* cf. *Swanstoni* Lapworth (var. *Kurcki*).—Törnquist: 19–20, Pl. 2:33–34. ☐ 1908 *Dimorphograptus confertus* (Nicholson).—Elles & Wood: 349–350, Figs. 227a–b, Pl. 35:3a–d. ☐ 1970 *Dimorphograptus confertus confertus* (Nicholson).—Rickards: 50–51, Pl. 3:11. ☐ 1971 *Dimorphograptus confertus confertus* (Nicholson).—Schauer: 52, Pl. 17:7–8, Pl. 18:15–17.

Holotype (by monotypy).—Nicholson (1868, Pl. 19: 14–15); from the "Coniston Flags", Lake District, Northern England.

Material.—Four specimens preserved with proximal parts and 25 fragments with only the distal portion. All the material is flattened.

Horizon and localities.—The *acinaces* Zone, Øleå (Ø3)–(Ø4).

Description.—The rhabdosome is straight, and may be up to 9 cm long. The uniserial portion is straight or dorsally curved, 3–4 mm long and with 3–4 thecae. The width of the thecae in the uniserial portion is 0.5 mm. In the biserial portion the proximal width of $th1^2$ is 1 mm increasing quickly to 2.5–2.7 mm at $th5^2$ which is maintained throughout the distal portion.

The thecae in the uniserial part are simple tubes with a slight overlap, inclined at about 20° to the rhabdosome. The inclination increases to 45° at the level of $th5^1$ in the biserial portion and, towards the distal part, the inclination falls to 20°. In the biserial portion the thecae are of orthograptid type with relatively simple tubes; the ventral walls are slightly concave. The apertures vary from being perpendicular to the thecal axis to perpendicular to the axis of the rhabdosome. The outher edge of the apertures is slightly ventrally everted or even. The thecal overlap increases from half the thecal length in the proximal end of the biserial portion to about two thirds in the distal end. In the biserial part the thecae number 11–12 in the proximal 10 mm; distally the number is 9 in 10 mm.

The apex of the sicula reaches between the apertures of $th1^1$ and $th2^1$ and the sicula is up to 2 mm long. $Th1^1$ is 0.5 mm in width and originates 1 mm from the aperture of the sicula.

Remarks.—All specimens with 3–4 thecae in the proximal uniserial portion are included in *D. confertus confertus.* Previous authors e.g. Elles & Wood (1908) and Schauer (1971), have mentioned only 3 thecae in the uniserial portion, but in their illustrations most specimens show 4 thecae in the uniserial portion, see Elles & Wood (Figs. 227a–b).

No specimens with 5 thecae in the proximal portion, which may be referred to *Dimorphograptus confertus swanstoni* (Lapworth), have been found on Bornholm.

D. confertus confertus is common throughout the *acinaces* Zone.

Dimorphograptus physophora (Nicholson, 1868) ?
Pl. 6: B

Material.—4 specimens, which all are flattened.

Horizon and localities.—The upper part of the *revolutus* Zone and the lower part of the *gregarius* Zone, Øleå (Ø2a), (Ø9).

Description.—The rhabdosome is straight, and the width increases from 1.25 mm in the proximal end to 3.5 mm in the distal part. The rhabdosome may attain a length of more than 6 cm.

The thecae are of orthograptid type. The ventral walls are inclined at about 25° to the axis of the rhabdosome. The apertures are situated normal to the axis of the rhabdosome. The free part of the ventral walls of the thecae is about 1 mm long. One specimen has 0.5 mm long apertural spines. Due to the imperfect state of preservation it has not been possible to observe the thecal length, the amount of overlap, and the apertural structures. The thecae number 11 in the proximal 10 mm, in the distal end the thecae number 7.5–8 per 10 mm.

The sicula and the proximal thecae are not visible. Two specimens have a circular disc or a vesicle structure proximally enclosing about the 3–4 proximal pairs of thecae. In one specimen the "disc" is circular and 4 mm in diameter. In the other specimen the "disc" has at least two crescent-shaped parts, each about 1 cm long and 0.5 mm in width (Pl. 6: B). The carbon films in the "discs" are very thin and do not show any conspicuous structures.

Remarks.—*D. physophora?* closely resembles *D. physophora* (Nicholson) but, in the specimens from Bornholm, no details of the proximal portion are disclosed. The present material has closer set thecae (11 in 10 mm) in the proximal part as compared to the English specimens (9 in 10 mm). In the distal portions the thecal number is the same in both materials.

Elles & Wood (1908) reported a maximum length of the rhabdosome of 3 cm with a largest width of 2 mm. However, the figured specimens on Pl. 35: 7a–d have a length of 5–6 cm and are 3 mm in maximum width, as also found in the specimens from Bornholm.

D. physophora? shows some affinity to *Orthograptus obuti* Rickards & Koren with regard to the distal width of the rhabdosome and the thecal morphology. However, the rhabdosome of *O. obuti* shows a more rapid increase in width, and the apertural processes are more pronounced than in *D. physophora?*

Genus *Akidograptus* Davies, 1929

Type species (by original designation).—*Akidograptus ascensus* Davies, 1929; from the Lower Llandovery of Dobb's Linn, Scotland.

Diagnosis (from Rickards, 1970).—Thecae climacograptid or ortograptid; proximal end characterized by loss or reduction of $th1^2$; but owing to shortening of $th2^2$ there is apparent uniserial portion; initial bud downwardly directed at origin.

Akidograptus ascensus Davies, 1929
Figs. 13D–E

Synonymy.—☐ 1929 *Diplograptus (Akidograptus) ascensus* sp. nov. —Davies: 9–10, Figs. 22–24. ☐ 1933 *Akidograptus*

ascensus Davies.—Bulman: 16–17, Fig. 5, Pl. 3:b. □ 1965 *Diplograptus (Akidograptus) ascensus* Davies.—Stein: 176–178, Figs. 22a, d, 25a–c, Pl. 14:f, Pl. 15:a, b. Tables 11–13. □ 1971 *Akidograptus ascensus* Davies.—Schauer: 53–54, Pl. 11:4–6, Pl. 12:6–10.

Holotype.—Specimen No. A10021, figured by Davies (1929, Fig. 23); from the Lower Birkhill Shales, South Scotland.

Material.—About 10 specimens which are flattened; a few specimens show a low relief.

Horizon and locality.—The *acuminatus* Zone; well at Bavnegård at 25–30 m below ground level.

Description.—The rhabdosome is straight or slightly curved, with a wedge-shaped proximal part. The maximum length is 1 cm. A complete median septum is present. The general width of the rhabdosome is 0.5 mm at the aperture of th1[1], and increases gradually to a maximum width of 1 mm at th5[1]. This width is retained throughout the distal part of the rhabdosome. Occasionally completely flattened specimens show a maximum distal width of only 0.8 mm.

The thecae are slender tubes of climacograptid?–glyptograptid? type with a flowing geniculum. They overlap for nearly half their length which is about 1.8 mm distally. The thecal tubes are parallel-sided with a width of 0.15 mm, and they are inclined at about 15° to the rhabdosome. The apertures are situated perpendicular to the thecal axis. The thecae number 4–5 per 5 mm in the proximal part distal to th2[1].

The length of the sicula is measured to be 0.75 mm and the distance from the aperture of the sicula to the aperture of th1[1] is 1.7–1.8 mm. Th1[1] originates 0.25 mm from the aperture of the sicula and is 1.5 mm long.

Remarks.—*A. ascensus* has a shorter sicula and shorter initial thecae than described in Stein (1965). However, when measured in the type specimen figured in Davies (1929, Fig. 23), the dimensions of the proximal parts appear to be identical. *A. ascensus* is easily separated from *Akidograptus? acuminatus acuminatus* (Nicholson) by the shorter sicula and initial thecae, and from *Akidograptus? acuminatus praematurus* Davies by the more slender rhabdosome.

A. ascensus was reported from the *acuminatus* Zone by Davies (1929) and mentioned by Stein (1965) as a common graptolite species in the *acuminatus* Zone. *A. ascensus* was reported by Schauer (1971) and others as guide fossil for a separate *ascensus* Zone. As a result of the small quantity of material available, without any specimens of *A? acuminatus,* a separate zone of *ascensus* cannot be distinguished on Bornholm. The sequence here is referred to the *acuminatus* Zone on basis of the associated fauna, following common practice in Britain and Sweden.

Genus *Rhaphidograptus* Bulman, 1936

Type species (by original designation).—*Climacograptus toernquisti* Elles & Wood, 1906; from the Birkhill Shales, Scotland.

Diagnosis (from Bulman, 1970).—Like *Dimorphograptus* but with thecae of climacograptid type; initial bud is downwardly directed at origin.

Rhaphidograptus toernquisti (Elles & Wood, 1906)

Pl. 6:C–D

Synonymy.—□ 1897 *Climacograptus rectangularis* M'Coy. —Törnquist: 8–9, Pl. 1:16–21. □ 1906 *Climacograptus Törnquisti,* sp. nov.—Elles & Wood: 190–191, Figs. 123a–b, Pl. 26:6a–f. □ 1965 *Rhaphidograptus toernquisti* (Elles & Wood).—Stein: 180–182, Fig. 16, Figs. 26a–d, Tables 14–16. □ ? 1966 *Rhaphidograptus toernquisti* (Elles & Wood).—Obut & Sobolevskaya: 23–24, Fig. 14, Pl. 4:10. □ 1970 *Rhaphidograptus toernquisti* (Elles & Wood).—Richards: 54, 56; Fig. 13:1–3. □ 1971 *Rhaphidograptus törnquisti* (Elles & Wood).—Schauer: 54–55, Pl. 4:14–17, Pl. 16:9–12. For further references see Stein (1965).

Lectotype.—Designated by Přibyl (1948:20): Elles & Wood (1906, Pl. 26:6f); from the Llandovery, Birkhill Shales, Scotland.

Material.—More than 200 specimens, the state of preservation varies from completely flattened to full relief.

Horizon and localities.—The *acinaces, revolutus,* and *gregarius* zones, Øleå (Ø3)–(Ø11).

Description.—The rhabdosome is straight. The width at the level at th1[1] is 0.5–0.7 mm, the maximum width of 2 mm is attained at the level of th10[1]. This width is maintained throughout the distal part of the rhabdosome. The maximum length of the rhabdosome is 3 cm.

In the obverse view (the sicula is on the left side of the rhabdosome) a median septum is observed from the level of th8[1], on the reverse side the septum originates immediately above the sicula. The septum on the reverse side is slightly undulating proximally in well preserved specimens.

The climacograptid thecae are distally 2 mm long and overlap half their length. In well preserved specimens the apertures have small genicular hoods, the excavations are deep. The thecae number 11–12 in the proximal 10 mm, in the distal part the number is 9.5–10 in 10 mm.

The sicula is 1.75 mm long and is visible for nearly the entire length. Th1[1] is 0.8 mm long, at first growing downwards, then recurving. Th2[1] is 1 mm long and the aperture is situated 2.1 mm from the aperture of the sicula.

The length of the rather robust virgella exceeds 1 cm, and the width in the rounded proximal part is 0.25 mm. The distal part is twisted two or three times, clockwise

in distal view. In low relief the twisted part of virgella is triangular in cross-section.

Remarks.—The present specimens of *R. toernquisti* in no way differ from earlier described material. *R. toernquisti* is frequent throughout its reported range, particularly in the *revolutus* Zone and in the lower part of the *gregarius* Zone.

Genus *Monograptus* Geinitz, 1852 emend.

Type species (subsequently designated) Bassler, 1915.—*Lomatoceras priodon* Bronn, 1835; from the Silurian of Germany.

Diagnosis (from Bulman, 1970).—Scandent uniserial rhabdosome without cladia, thecae and shape of rhabdosome variable.

Monograptus atavus Jones, 1909
Pl. 6:G–H

Synonymy.—☐ 1909 *Monograptus atavus* sp. nov.—Jones: 531, Figs. 18a–d. ☐ 1911 *Monograptus atavus,* Jones.—Elles & Wood: 403–404, Figs. 270a–e, Pl. 39:1a–d. ☐ 1922 *Monograptus revolutus* Kurck var. *enermis* n. var.—Pedersen: 20, Figs. 4a–b. ☐ 1970 *Monograptus atavus* Jones.—Churkin & Charter: 36, Fig. 14E. ☐ 1970 *Monograptus atavus* Jones.—Rickards: 65, Fig. 14:26, 30, Fig. 16:6, Fig. 18:6, Pl. 5:6, Pl. 6:1.

Lectotype.—Subsequently designated Přibyl & Spasov (1955:195): specimen No. GSM 23710, figured Jones (1909, Fig. 18b); from the Llandovery, Rheidol Gorge, Wales.

Material.—About 30 specimens preserved flattened or in relief. No complete specimens have been observed.

Horizon and localities.—In the *revolutus* Zone and the lowermost part of the *gregarius* Zone, in the *triangulatus* Subzone, Øleå (Ø2a)–(Ø10).

Description.—The length of the rhabdosome is more than 13 cm. The rhabdosome is straight or gently curved, mainly dorsally bent. The dorso-ventral width increases very gradually, the proximal part is slender, and the width at th1 is 0.25 mm, distally the width never exceeds 1 mm.

The thecae are slender tubes. The ventral walls are slightly sigmoidal, with a very flowing geniculum. The thecal apertures are situated perpendicular to the thecal axis which is inclined at 10°–15° to the stipe. The thecal overlap is proximally one fourth and less than one half distally. The proximal thecae are 1.25 mm long and the distal ones 1.75 mm. The thecae number 9.5 in the proximal 10 mm, distally 8–9 in 10 mm.

The sicula is 1 mm long, and the apex just about reaches the aperture of th1. Th1 originates 0.25 above the aperture of the sicula. Th1 is only 0.9 mm long.

Remarks.—*M. atavus* from Bornholm is not significantly different from specimens described from Britain. The usual thecal count given by Rickards (1970) is 7.5–9 in 10 mm for compressed material, whereas the specimens from Bornholm have 8–9.5 thecae per 10 mm.

Monograptus revolutus var. *enermis* (Pedersen, 1922:20, Figs. 4a–b) is identical to *M. atavus.* The width never exceeds 1 mm, and the thecae number 9.5 in 10 mm. The thecae are formed as those in the author's material of *M. atavus.* On Figs. 4a–b the mesial part of a flattened rhabdosome was shown; *M. revolutus* var. *enermis* was found by Pedersen in the lower part of the *gregarius* Zone.

Monograptus cf. *acinaces* Törnquist, 1899
Figs. 14A–B

Material.—About 20 specimens which all are fragmentary and flattened.

Horizon and locality.—The *acinaces* Zone, well at Bavnegård, at 14.5–15.0 m and 15.0–25.0 m below ground level.

Description.—The longest fragment is about 3 cm long. No proximal end with preserved sicula has been found. The most proximal fragments are slightly dorsally curved, and the most slender proximal part is 0.3 mm wide. The thecae appear to be straight tubes, and are inclined at only a few degrees to the rhabdosome. The thecal lengths are hardly discernible but appear to vary from 2.6 mm to 3.2 mm. The thecal number is about 4 per 5 mm.

Mesial fragments are about 0.66 mm wide, and are slightly dorsally curved. The thecae are 3.0–3.5 mm long tubes, and the overlap varies from half to one third. The thecal spacing is 4.5 per 5 mm. The distal fragments of the rhabdosome are straight, and attain a maximum width of 1.25 mm. The thecal tubes are straight, but widen slightly in their apertural regions. The thecae are inclined at about 20° to the axis of the rhabdosome, and the apertures are situated perpendicular to the thecal axis. The thecae overlap for about half their length and number 4 per 5 mm.

Remarks.—The state of preservation is too imperfect for detailed studies. In the present material the distal parts are not as wide as in *M. acinaces,* to which the present form shows a similarity with regard to the shape of the rhabdosome and the thecal morphology. Furthermore, the present specimens differ from *M. acinaces* by a shorter thecal length and less overlap.

M. cf. *acinaces* resembles *M.* aff. *acinaces* Rickards, 1970 except that the thecal spacing is approximately constant throughout the rhabdosome in *M.* cf. *acinaces*: 8–9 per 10 mm compared to *M.* aff. *acinaces* in which the thecal spacing varies from 5–7 per 10 mm proximally to 12 per 10 mm distally.

M. cf. *acinaces* has a superficial resemblance to *Monograptus strachani* Hutt & Rickards, but attains a greater distal width and a higher number of thecae per 10 mm.

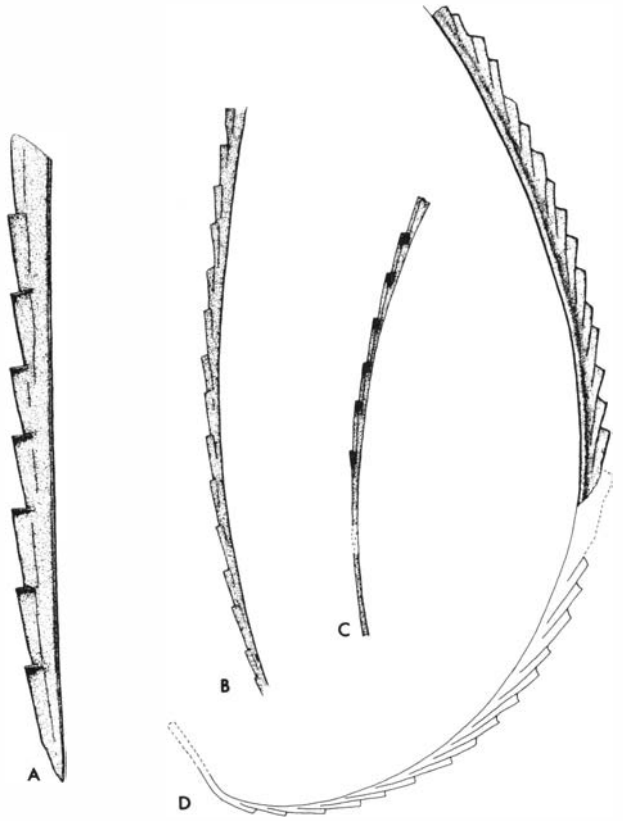


Fig. 14. ☐ A–B. *Monograptus* cf. *acinaces* Törnquist, 1899. Bavnegård well, 14.5–15.0 m below ground level. The *acinaces* Zone. ☐ A. Distal part. MMH 13437. ×10. ☐ B. proximal part. MMH 13438. ×5. ☐ C. *Monograptus acinaces* Törnquist, 1899. Proximal end. The *acinaces* Zone, Øleå. MMH 13439. ×5. ☐ D. *Monograptus cyphus* Lapworth, 1876? The *revolutus* Zone, Øleå. MMH 13440. ×5.

In *M. strachani* the spacing is 7 per 10 mm.

The present specimens differ from *M. atavus* by their straight and longer thecae which occasionally attain a greater overlap than in *M. atavus*.

M. cf. *acinaces* is the most frequent graptolite in the Bavnegård well at 14.5–15.0 m and 15.0–25.0 m below ground level.

Monograptus cyphus Lapworth, 1876 ?
Fig. 14D

Material.—3 fragments preserved flattened, or in low relief.

Horizon and locality.—The *revolutus* Zone (upper part), Øleå (Ø2a).

Description.—The proximal end and the sicula are not preserved. The rhabdosomes may have been more than 4 cm long, they are arcuate with a dorsal curvature throughout. The proximal width is 0.25 mm increasing gradually to a distal width of 1.1 mm.

The thecae are simple tubes, inclined at 10°–20° to the rhabdosome. The apertures are situated perpendicular to the thecal axis. The distal thecae are 0.3 mm wide and 2.5 mm long. The thecal overlap is two thirds in the mesial and distal part of the rhabdosome, proximally about half the thecal length. The thecae number 10 per 10 mm throughout the rhabdosome.

Remarks.—The distal fragments of *M. cyphus?* from Bornholm are close to specimens described earlier from Britain (see Rickards, 1970), but no proximal portions have yet been found on Bornholm. The distal parts may be confused with those of *M. revolutus* which are frequent in the same horizon.

However, the extreme proximal parts in *M. cyphus?* are only 0.25 mm wide, and the hooked proximal thecae characteristic of *M. revolutus* are not seen in the present material.

Monograptus acinaces Törnquist, 1899
Fig. 14C, Pl. 6:1

Synonymy.—☐ 1899 *Monograptus acinaces* n. sp.—Törnquist: 5, Pl. 1:7–8. ☐ 1909 *Monograptus rheidolensis* sp. nov.—Jones: 535, Figs. 19a–c. ☐ 1911 *Monograptus acinaces,* Törnquist.—Elles & Wood: 364–365, Figs. 237a–d, Pl. 36:2a–e. ☐ 1952 *Pristiograptus acinaces* Törnquist.—Münch: 83, Pl. 17:2a–b. ☐ 1971 *Monograptus (Pristiogr.) acinaces* Törnquist.—Schauer: 61, Pl. 21:1–2, Pl. 22:4–5.

Holotype.—Specimen figured by Törnquist (1899, Pl. 1: 7–8); from the Llandovery, Scania, Sweden.

Material.—About 50 specimens preserved, flattened and in relief. No complete rhabdosomes have been found, and proximal ends with sicula are rare.

Horizon and localities.—The *acinaces* Zone and *revolutus* Zone ?, Øleå (Ø3), (Ø4), (Ø2a)?.

Description.—The rhabdosomes are mostly dorsally curved throughout, arcuate in the proximal end with the distal portion more gently curved. The longest fragment is 11 cm. The width in flattened specimens increases slowly from 0.25 mm at th1 to a maximum of 1.25 mm distally.

The thecae are long straight tubes, slightly trumpet-shaped with enlarged apertures which are situated perpendicular to the thecal axis. The outer walls of the thecae are inclined at 10°–15° to the rhabdosome. Distally the thecae are 3.5 mm long and the overlap is two thirds of their length. The distal thecae in flattened specimens are 0.25 mm wide at the base, and 0.5 cm at the aperture. The proximal thecae number 5 per 10 mm and the distal thecae 7 in 10 mm.

The sicula is conspicuous and 3–?5 mm long. Th1 originates 2.2 mm from the aperture of the sicula and is 3 mm long. The sicula is 0.25 mm wide at the aperture. Th1 ia 0.25 mm and th5 is 0.35 mm in maximum width.

Remarks.—*M. acinaces* from Bornholm is not different from Törnquist's original described material. The state of preservation is far from perfect, and no ventral apertural processes as described by Hutt & Rickards (1970)

from *Monograptus rheidolensis* Jones (=*M. acinaces*) have been found.

M. acinaces is rather frequent throughout the *acinaces* Zone and a few sparse fragments are found in the lowest part of the *revolutus* Zone.

Monograptus gregarius Lapworth, 1876

Fig. 15A, Pl. 6:F

Synonymy.—☐ 1851 *Graptolithes Nilssoni* Barr.—Harkness: 61, Pl. 1:7a–d. ☐ 1876 *Monograptus gregarius* sp. nov.—Lapworth: 317, Pl. 10:12a–c. ☐ 1882 *Monograptus gregarius* Lapworth.—Törnquist: 8–9, Pl. 1:3–5. ☐ 1899 *Monograptus gregarius* Lapworth.—Törnquist: 4–5, Pl. 1: 1–6. ☐ 1911 *Monograptus gregarius,* Lapworth.—Elles & Wood: 365–366, Figs. 238a–b, Pl. 36:3a–d. ☐ 1943 *Procyrtograptus garboi* n. g. et n. sp.—C. Poulsen: 302–304. Fig. 2 (*partim*). ☐ 1970 *Monograptus gregarius* Lapworth.—Hutt et al.: 13–14, Pl. 3:63–68. ☐ 1970 *Monograptus gregarius* Lapworth.—Rickards: 61–62, Fig. 18:14 (see for further references). ☐ 1971 *Monograptus (Pristiogra.) gregarius* Lapworth.—Schauer: 60–61, Pl. 22:6–7.

Lectotype.—Designated by Přibyl (1948:71) as the specimen figured in Lapworth (1876, Pl. 10:12a), Bu. 1435; from the Birkhill Shales, Scotland.

Material.—More than 100 specimens preserved flattened or with low relief.

Horizon and loalitites.—The *gregarius* Zone, Øleå (Ø2), (Ø5)–(Ø12).

Description.—The rhabdosome is dorsally curved throughout, commonly not more than 3 cm long. The longest specimen is 5 cm. The rhabdosome widens gradually within the first 10 thecae from 0.5 mm proximally to 0.8–0.9 mm distally.

The thecae are simple tubes with slightly everted apertures which are situated perpendicular to the axis of the rhabdosome. Throughout the rhabdosome the overlap is nearly half the thecal length. The interthecal septum is inclined at a maximum of 5° to the rhabdosome, and the free ventral walls of the thecae at 10°–15°. The distal thecae are about 2.5 mm long. In some well preserved specimens a small geniculum is developed, slightly proximal to the aperture of the preceding theca. The thecal number is proximally 9–10 in 10 mm, distally 8.5 in 10 mm.

Characteristic for *M. gregarius* is the long sicula, varying in length from about 5 mm to 8–10 mm. The apex of the sicula is difficult to recognize, as it passes gradually into the dorsal margin, but the apex at least reaches the level of the aperture of th3. The width at the aperture of the sicula is 0.3 mm measured in a low relief specimen. Th1 originates 1.7 mm from the aperture of the sicula in the stratigraphically uppermost specimens and, in the oldest specimens from the lower part of the *gregarius* Zone, only 0.9 mm from the aperture. Th1 is 2 mm and th2 is 2.5 mm long.

In the transition from the *gregarius* to the *convolutus* Zone only juvenile specimens were found, with a maximum of two thecae developed. The sicula is 0.8–1.0 mm long, and th1 originates 0.9 mm from the sicular aperture.

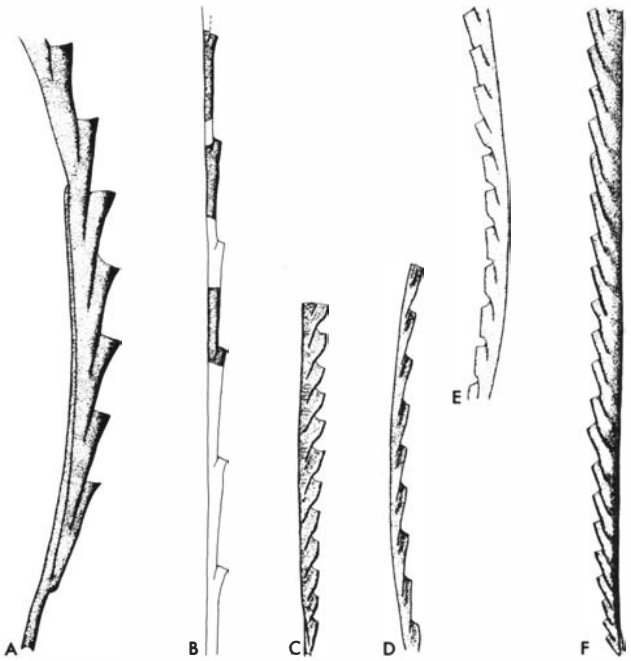


Fig. 15. ☐ A. *Monograptus gregarius* Lapworth. 1876. The *gregarius* Zone, upper part, Øleå. MMH 13441. ×10. ☐ B. *Monograptus jonesi* Rickards, 1970. The *convolutus* Zone, Øleå. MMH 13442. ×10. ☐ C. *Monograptus nudus* Lapworth, 1880. The *turriculatus* Zone, Øleå. MMH 13443. ×5. ☐ D–E. *Monograptus denudatus* n. sp. The *spiralis* Zone, Øleå. ☐ D. Holotype. Proximal part in low relief. MMH 13444. ×5. ☐ E. Distal part, flattened. MMH 13445. ×5. ☐ F. *Monograptus bjerringus* n. sp. The *turriculatus* Zone, Øleå. MMH 13446. ×5.

Remarks.—The presence of a geniculum was earlier described in Hutt et al. (1970). It appears that there is slight variation in *M. gregarius* throughout its range. The oldest forms have a shorter sicula, 5 mm long and an initial width of 0.4–0.5 mm, but these specimens are rather badly preserved. The specimens in the upper part of the *gregarius* Zone are well preserved with long rhabdosomes, maximum 5 cm, a longer sicula (6–8 mm), and a width of 0.6 mm at th1. The largest siculae are seen at the last occurrence of the species. *M. gregarius* shows a tendency to develop larger rhabdosomes and siculae throughout the range of the species. With better preserved material, especially of the early forms it may be possible to subdivide *M. gregarius* into stratigraphically useful subspecies.

Procyrtograptus garboi Poulsen, 1943

C. Poulsen (1943:302–304, Fig. 2) described *Procyrtograptus garboi* from the upper part of the *gregarius* Zone on Bornholm (Ø2). From a reexamination of the type specimen it may be concluded that "*P. garboi*" actually comprises the two graptolite species: *M. sudburiae* and two siculae of *M. gregarius*. The graptolites are embedded

in such a way that the apex of the two siculae are in contact with the thecal apertures of *M. sudburiae,* thereby resembling two extremely developed proximal thecae in the cladial development of a cyrtograptid.

The distal part of *M. sudburiae,* which is described as the "main stipe" of the "cyrtograptid", is dorsally curved, 0.75 mm in width, and the thecae number 5.5 in 5 mm. The thecae are simple tubes with sigmoidal slightly geniculate ventral walls due to the flattening. The apertures appear to be slightly introverted, but further details have not been revealed. The thecae overlap about two fifths of their length.

The two "side branches" are both siculae from *M. gregarius.* They are slightly curved, 6 mm and 7 mm long. The apex is 0.1–0.2 mm and the width of the aperture is 0.25 mm. In the "distal" sicula, the initial part of the first thecae originates 0.5 mm from the aperture of the sicula. The aperture of the initial theca faces the apex of the sicula.

As the type specimen of *"Procyrtograptus garboi"* comprises two different well known monograptid species, a retainment of the genus *Procyrtograptus* is no longer justified and the generic name *Procyrtograptus* must be suppressed.

Monograptus jonesi Rickards, 1970

Fig. 15B, Pl. 7:A

Synonymy.—☐ 1970 *Monograptus jonesi* n. sp.—Rickards: 68, Fig. 17:11.

Holotype (by original description).—Specimen figured by Rickards (1970, Fig. 17:11), HUR 6Bi/76; from the *argenteus* Zone, Birks Beck (6Bi), Howgill Fells.

Material.—8 specimens, all fragments, preserved flattened or in low relief.

Horizon and locality.—The lower part of the *convolutus* Zone, Øleå (Ø12).

Description.—The rhabdosome is slender, more than 7 cm long, dorsally curved or straight. The sicula has not been observed. The width of the rhabdosome varies from 0.25 mm in the most proximal part to 0.35 mm distally. In the proximal portion the thecae number 9 in 10 mm, in the distal part 10 in 10 mm.

The thecae are slender tubes, their outer walls are inclined at about 15° to the axis of the rhabdosome. The thecal apertures are situated perpendicular to the thecal axis. The ventral wall may be slightly sigmoidal, but is mainly straight. The overlap varies from less than one sixth to one fourth of the thecal length.

Remarks.—The typical *M. jonesi* agrees with the Bornholm specimens in size, number of thecae per cm, thecal form, and degree of overlap. The only difference is that the Bornholm specimens mainly have a nearly straight rhabdosome, and are not constantly dorsally curved as are the Howgill Fell specimens.

M. jonesi is rare on Bornholm and is only observed in a thin bed in the lower part of the *convolutus* Zone.

Monograptus regularis regularis Törnquist, 1899

Synonymy.—☐ 1899 *Monograptus regularis* n. sp.—Törnquist: 7, Pl. 1:9–14. ☐ 1911 *Monograptus regularis,* Törnquist.—Elles & Wood: 372–373, Figs. 243a–c, Pl. 37:3a–d. ☐ 1952 *Pristiograptus regularis regularis* Tq.—Münch: 93, Pl. 21:6a–b. ☐ 1970 *Pristiograptus regularis regularis* (Törnquist).—Rickards: 59–60, Fig. 16:16, Pl. 5:4. ☐ 1974 *Monograptus regularis* Törnquist.—Sherwin: 157–158, Fig. 2e, Pl. 11:10. For further references see Rickards (1970).

Lectotype.—Not yet designated.

Material.—20 specimens which all are flattened.

Horizon and localities.—The *convolutus* Zone, Øleå (Ø12)–(Ø13).

Description.—The rhabdosome is straight or gently curved, more than 10 cm long. The width is 0.3 mm at th1 and increases to 1.3 mm in the distal part.

The thecae are simple tubes, inclined at 30° to the axis proximally, and distally less than 20°. The free ventral wall of the first thecae seems in some specimens to be slightly convex. The thecal apertures are perpendicular to the thecal axis. There is no thecal overlap within the five proximal thecae, distally the thecal overlap increases to two thirds of the thecal length. In the proximal 10 mm the thecae number 13, in the fourth cm 11, and distally the thecae number 8.5 in 10 mm.

The sicula is hardly visible, but appears to be 0.9 mm long, and the apex reaches the aperture of th1. The aperture of the sicula is 0.25 mm wide.

Remarks.—The specimens from Bornholm bear a close resemblance to the specimens from Scania described by Törnquist (1899).

M. regularis regularis differs from *M. nudus* by the more slender proximal end and the greater thecal overlap distally. From *Monograptus regularis solidus* Přibyl it is distinguished by a lesser thecal number per cm and a greater dorso-ventral width.

As is the case with the Törnquist specimens from Scania the occurrence is restricted to the *convolutus* Zone, and *M. regularis regularis* is mostly found in the middle and upper parts of the zone.

Monograptus nudus Lapworth, 1880

Fig. 15C, Pl. 6:E, Table 4

Synonymy.—☐ 1876 *Monograptus Hisingeri,* Carruthers.—Lapworth: 350–351, Pl. 12:1a–c, ?1f. ☐ 1880 *Monograptus Hisingeri,* Carr. var. *nudus* var. nov.—Lapworth: 156, Pl. 4:7a–c. ☐ 1883 *Monograptus Hisingeri* Carr.—Tullberg: 18, Pl. 2:45–48. ☐ 1899 *Monograptus nudus* Lapworth.—Törnquist: 8–9, Pl. 1:18–20. ☐ 1911 *Monograptus nudus* Lapworth.—Elles & Wood: 375–376, Figs.

Table 4. M. nudus. Dimensions (in mm).

Spec. No.	Flat or relief	Length	Width of the rhabdosome						Number of thecae		Length of sicula
			th1	th5	th10	th15	th20	Dist.	prox.	dist.	
MMH 13443	LR	20	?0.3	0.75	0.8	0.9	1.0		11/10	10/10	1.0
MMH 13521	R	45	0.55	0.95	1.3	1.65	1.65	2.0	12.5/10	9/10	1.3
MMH 13522	LR	15	0.5	0.75	0.8				10.5/10		1.25
MMH 13523	F	70	0.5	0.75	1.1	1.25	1.33	1.7	13/10	9.5/10	1.0

246a–d, Pl. 36:6a–e. □ 1940 *Monograptus nudus* Lapworth.—Laursen: 22, Figs. 8a–b, Pl. 1:3. □ 1940a *Pristiograptus nudus nudus* (Lapworth).—Přibyl: 2, Pl. 1:6–9. □ 1970 *Pristiograptus nudus* (Lapworth).—Rickards: 59, Pl. 7:1 (see for further references). □ 1971 *Monograptus (Pristiogr.) nudus nudus* Lapworth.—Schauer: 62, Pl. 21:4–7, Pl. 22:12–13.

Lectotype.—Designated by Přibyl (1948:74) as the specimen figured by Lapworth (1876, Pl. 12:1a), Bu 1461; from the Llandovery of Grieston Quarry, Scotland.

Material.—About 150 specimens preserved flattened or with low relief.

Horizon and localities.—The *turriculatus* Zone to the *griestoniensis* Zone, Øleå (Ø13a)–(Ø19).

Description.—The rhabdosome is straight, occasionally slightly curved. The usual length is 3–5 cm, but specimens with more than 14 cm long rhabdosomes have been found. The initial width of the rhabdosome is 0.3–0.5 mm, the distal width may go up to 2 mm.

The thecae are simple tubes of pristiograptid type, the tubes are inclined at 40° to the rhabdosome. Th1 is 1 mm long and 0.25 mm wide at the aperture. The distal thecae are about 2 mm long and here the apertural width is 0.5 mm. The thecal overlap is less than half in the proximal portion of the rhabdosome, towards the distal part the overlap increases to half the thecal length. The thecal apertures are situated perpendicular to the thecal axis. The thecae number 10.5–13 in the proximal 10 mm, in the most distal end 9 in 10 mm.

The sicula is 1.0–1.23 mm long and the apex reaches the aperture of th1 or a little beyond, but never higher than half-way up the protheca of th2.

Remarks.—Through the reported range of *M. nudus* there is some variation in the measured dimensions of the graptolite. The specimens from the *griestoniensis* Zone have an initial width of 0.5 mm, and a sicula reaching beyond th1. In the specimens from the basal part of the *turriculatus* Zone the sicula reaches the aperture of th1 and the initial width is 0.3 mm.

M. nudus is close to *M. variabilis*, but has a greater distal width. The thecae are not so closely spaced as in *Monograptus artus* Bouček. The description of *Monograptus nudus pristinus* Přibyl is insufficient as basis for a division of *M. nudus* into subspecies.

Monograptus bjerringus n. sp.
Fig. 15F, Pl. 7:C

Synonymy.— □ 1881 *Monograptus jaculum* Lapw.—Linnarsson: 508, Pl. 22:1–2. □ 1921 *Monograptus* sp., n. sp.?.—Pedersen, Pl. 10:4 (MS).

Holotype.—Specimen No. MMH 13622, Pl. 7:C, the *turriculatus* Zone, loc. 16, Øleå.

Derivation of name.—*bjerringus*, in honour of the late Th. Bjerring Pedersen, who tentatively regarded the species as being new.

Material.—22 specimens preserved flattened or in relief, only fragments are observed.

Horizon and localities.—The middle part of the *turriculatus* Zone, Øleå (Ø14)–(Ø16).

Diagnosis.—The rhabdosome is straight and may be longer than 7 cm; with a steady increase in width from 0.5 mm to 3 mm distally. The thecae are long slender tubes of the pristiograptid type, with a great overlap distally. They number 11–9 in 10 mm.

Description.—The rhabdosome is straight. Only fragments of which the maximum length is 7 cm have been found. The width increases gradually from 0.5 mm at th1 to 1.25 mm in 10 mm distally from the proximal end. Flattened specimens may be up to 3 mm wide.

The thecae are simple tubes which are inclined at 20°–30° to the rhabdosome. The initial thecae overlap for about one third of their length, the overlap increases to three fourth of the thecal length in the distal part of the rhabdosome. The thecal tubes are 0.6 mm long proximally and the length increases to 4 mm distally. The dorso-ventral width of the distal thecal apertures is 0.5–0.7 mm. The apertures are situated perpendicular to the thecal axis. In well preserved, pyritized specimens the apertures are everted and have a thickened rim. The pyritized specimens have slightly undulating thecal walls. In the proximal end the thecal spacing is 11 over 10 mm, and in the distal end the number is 9 per 10 mm.

The sicula is seen in one specimen, but the aperture is broken. The rest is 1 mm long and the apex reaches the level of the aperture of th2. Th1 is 0.6 mm long and the dorso-ventral width of the aperture is 0.2 mm.

Remarks.—*M. bjerringus* was described and figured by Pedersen (1921, unpublished) under the name *Monograptus* sp., n. sp.?.

Specimens A20929–30 from the Sedgwick Museum can also be identified as *M. bjerringus*. The specimens were previously identified by G. L. Elles as *M. leptotheca* and *M. jaculum*. Among the British specimens proximal parts with the sicula preserved were found. The sicula is 1 mm long and the apex reaches to between th1 and th2. The thecae number 12 in the proximal 10 mm. The distal ends are identical with those of the specimens from Bornholm.

M. bjerringus has also been recognized in the Tullberg collection from Röstånga which is housed in Stockholm at the Geological Survey of Sweden. The specimens originate from the *runcinatus* Zone, and were identified by Tullberg as "*M. Hisingeri* Lapworth". The distal thecae count 8 in 10 mm, and the rhabdosome is 3.1 mm wide in flattened specimens. The distal thecae are 4 mm long and inclined at 30°–40° to the rhabdosome. The overlap is about three fourth of the thecal length.

M. bjerringus is separated from other representatives within the pristiograptid group by the greater width and longer thecae with a greater amount of overlap. The extreme proximal end is like that of *M. nudus,* but distally *M. bjerringus* attains a far greater width. *M. bjerringus* shows great resemblance to *Monograptus largus* Perner. However, the two graptolites are separated by the wider proximal end (1 mm) and the comparatively shorter thecae in *M. largus.* Here the apertural width is between half and one third of the thecal length, and in *M. bjerringus* the apertural width is one sixth to one eighth of the thecal length. In *M. largus* thecal overlap was reported to be two thirds, whereas the overlap in *M. bjerringus* is three fourths of the thecal length. Furthermore, *M. largus* has slightly wider spaced thecae, 9–7 per 10 mm, while the spacing in the new species varies from 11–9 per 10 mm. All measurements of *M. largus* have been taken from text and figures in Přibyl (1943).

M. bjerringus is restricted to the middle part of the *turriculatus* Zone and is here associated with *M. turriculatus, M. exiguus* s.l., *M. planus, M. halli,* and *R. linnaei.*

Monograptus denudatus n. sp.
Figs. 15D–E, Pl. 7:B

Holotype.—Specimen No. MMH 13444, Fig. 15:D, Pl. 7: B, the *spiralis* Zone, loc. 21, Øleå.

Derivation of name.—*denudatus*–denuded, alluding to the simple, unelaborated morphology.

Material.—8 fragmentary specimens preserved flattened or in low relief, the proximal end is unknown.

Horizon and localities.—The base of the *spiralis* Zone, Øleå (Ø21)–(Ø22).

Diagnosis.—Rhabdosome more than 10 cm long, slightly flexed, mainly ventrally curved, slender throughout, width increasing from 0.5–0.75 mm. Thecae simple tubes, with faintly developed geniculum, becoming more pronounced distally. Thecae numbering 7.5–8 in 10 mm. Sicula and proximal thecae unknown.

Description.—The rhabdosome is slender, slightly flexed or straight, mainly with a gently ventral curvature. The largest fragment is 10 cm; the sicula and the proximal thecae have not been seen. The width of most proximal part is 0.5 mm, increasing gradually throughout the rhabdosome to a maximum of 0.75 mm distally.

The thecae are simple tubes with an increasing "vomerinid" appearance towards the distal part of the rhabdosome. The proximal thecae have slightly sigmoidal ventral walls; towards the distal part the geniculum becomes more conspicuous. The overlap of the proximal thecae is one fifth of the length of the thecal tubes, distally the overlap increases to one third of the length. The thecal apertures are rounded with a thickened rim and are situated perpendicular to the thecal axis which is inclined at 5° to the rhabdosome. The thecal length is 1.75 mm throughout the rhabdosome and the width of the thecal tubes at the apertures is 0.3–0.4 mm. The common canal occupies slightly less than half the width of the rhabdosome. The most proximal thecae number 7.5 per 10 mm, distally the thecal count is 8 in 10 mm.

Remarks.—*M. denudatus* shows similarity to the monograptids from the Lower Llandovery having a rather simple thecal structure. The measurements of the rhabdosome and the proximal thecae are close to those of *M. atavus. M. denudatus* also bears some resemblance to *Monograptus concinnus* Lapworth but this species has a greater rhabdosomal width and a larger thecal overlap of the distal end.

Characteristic of *M. denudatus* is the vomerinid thecal appearance in the distal part, implying that the graptolite must be somewhat related to this group of monograptids.

M. denudatus, which is rare, occurs in a thin horizon in the lowermost part of the *spiralis* Zone and is associated with *M. anguinus, M. cultellus,* and *M. priodon.*

Monograptus sandersoni Lapworth, 1876
Fig. 16D

Synonymy.— ☐ 1876 *Monograptus Sandersoni,* sp. nov.—Lapworth: 310, Pl. 11:2a–e. ☐ 1910 *Monograptus Sandersoni,* Lapworth.—Elles & Wood: 404–405, Figs. 271a–d, Pl. 39:10a–e. ☐ 1952 *Pristiograptus sandersoni* Lapw. —Münch: 84, Pl. 17:7a–b. ☐ 1970 *Monograptus sandersoni* Lapworth.—Rickards: 66–67, Fig. 14:25. ☐ 1970 *Monograptus sandersoni* Lapworth.—Hutt & Rickards: 69, Fig. 2:b (not described).

Lectotype.—Designated by Přibyl (1948:79), as the specimen figured by Lapworth (1876, Pl. 11:2a); from the Birkhill Shales, Dobb's Linn, Scotland.

Material.—5 single specimens and an aggregate contain-

ing about 30 rhabdosomes; all are fragmentary and preserved flattened or with low relief.

Horizon and locality.—The *revolutus* Zone, Øleå (Ø2a).

Description.—The longest fragment is about 13 cm. The rhabdosomes are gently flexed, mainly slightly ventrally curved. The proximal minimum width is 0.5 mm and the maximum width in flattened specimens is 0.8 mm. No proximal ends with sicula have been found.

The thecae are long slender tubes, about 2 mm long. They are inclined at less than 5° to the rhabdosome and overlap for about half their length. Especially in flattened specimens the walls of the thecae are slightly sigmoidal. The apertures are somewhat introverted and face dorsally to distally in the rhabdosome. The apertural portion is laterally everted in some specimens, but not encompassing the succeeding theca, as the apertures of *M. incommodus* and *M. leptotheca.* In well preserved specimens a thickened apertural rim is present. The thecal number is 8 per 10 mm in relief specimens and 7 per 10 mm in flattened samples, all measurements being taken from distal parts.

In one of the specimens a bipolar outgrowth is present. The dorsal side of the rhabdosome is here slightly thickened, but no sicula or sicula-like structures are visible. The thecal apertures of the two "stipes" are situated on the same side of the rhabdosome. There is a difference in width of the initial thecae in the two branches from 0.5 mm to 0.6 mm. The intial thecae on each side of the outgrowth have free ventral walls which are longer than those of the succeeding thecae.

Remarks.—*M. sandersoni* from Bornholm is not morphologically different from earlier described specimens. The bipolar development was also reported by Rickards (1973). As no sicular cladia have been seen, the diversograptid development is here regarded as a possible regeneration phenomenon. *M. sandersoni* is restricted to a thin horizon near the uppermost part of the *revolutus* Zone.

Monograptus incommodus Törnquist, 1899
Fig. 16F, Pl. 7:D

Synonymy.—□ 1899 *Monograptus incommodus* n. sp.—Törnquist: 11. Pl. 2:1–5. □ *non* 1910 *Monograptus incommodus,* Törnquist.—Elles & Wood: 406, Figs. 272a–e, Pl. 40:1a–e. □ ? 1952 *Pristiograptus incommodus* Törnquist.—Münch: 84, Pl. 17:8. □ 1968 *Monograptus incommodus* Törnquist.—Rickards & Rushton: 272–273, Figs. 4a–d. □ 1970 *Monograptus incommodus* Törnquist.—Hutt & Rickards: 61–71 (only the relationship is described), Fig. 2:C. □ 1971 *Monograptus (Pristiogr.) incommodus* Törnquist.—Schauer: 61, Pl. 21:3, Pl. 22:1–2. For further references see Rickards & Rushton (1968).

Lectotype.—Designated by Přibyl (1948:79) as the specimen figured by Törnquist (1899, Pl. 2:1), refigured by Rickards & Rushton (1968, Fig. 4a); from the *cyphus* Zone, Scania, Sweden.

Material.—About 10 fragments, are mainly preserved in relief.

Horizon and localities.—The *revolutus* Zone and the lower part of the *gregarius* Zone, Øleå (Ø2a), (Ø4a), and (Ø9).

Description.—The rhabdosome is straight or gently curved, the longest fragment is 10 cm. The stipe is slender, and the width increases gradually from 0.2 mm in the most proximal end to 0.6 mm in the distal part (measured in relief specimens).

The thecae are uniform throughout the rhabdosome. The tubes are 3 mm long in the proximal part of the stipe and the overlap is one third of the length. The thecae are 2.5 mm long in the distal end of the rhabdosome, and the overlap increases to half the thecal length. The thecal apertures are introverted and laterally expanded into two horns, closely adpressed to the succeeding thecae. The apertures are obscure, apparently introverted and facing the dorsal side of the rhabdosome. The thecae have a gentle geniculum in most of the specimens, but in a well preserved fragment of a proximal part detailed thecal structures are disclosed. From each "geniculum" a large hood grows out; the hoods have rounded rims and are directed ventrally to proximally in the rhabdosome. The rounded rims are close to the apertural part of the preceding thecae. No growth lines are seen on the genicular hood. In other specimens the genicular hood may be broken off. Proximally the thecae number 6 per 10 mm, and in the distal part the thecal count is 8 in 10 mm. No sicula has been found.

Remarks.—The presence of the genicular hood in *M. incommodus* shows a far closer relationship to *M. leptotheca* and *M. argutus,* in which the genicular hoods were previously known, than suggested in earlier studies, e.g. Hutt & Rickards (1970). The thecal structures of *M. incommodus,* an old form in the development line *M. incommodus* to *M. leptotheca,* seem to be quite as complex as in the later *M. leptotheca.* The forerunner for *M. incommodus* may be *M.* cf. *incommodus* Törnquist as proposed by Hutt & Rickards (1970). This species has introverted thecal apertures but apparently without any genicular hoods. *M.* cf. *incommodus* Törnquist has not been found in the material collected for study.

Monograptus argutus Lapworth, 1876
Pl. 7:E

Synonymy.—□ 1876 *Monograptus argutus* sp. nov.—Lapworth: 318–319, Pl. 10:13a–c. □ 1970 *Monograptus argutus argutus* Lapworth.—Rickards: 67, Fig. 17:13 (also further references).

Lectotype.—Subsequently designated by Přibyl (1948:78) as the specimen figured in Lapworth (1876, Pl. 10:13b), BU 1538; from the Birkhill Shales, Dobb's Linn, Scotland.

Material.—One fragment, preserved in partial relief.

Horizon and locality.—The upper part of the *gregarius* Zone, Øleå (Ø10).

Description.—The specimen is 2 cm long and dorsally curved. The width is 0.5 mm throughout and the thecal count is 5.5 per 5 mm. The fragment may be referred to the mesial part of the rhabdosome.

The thecae are 1.7 mm long and 0.25 mm wide; they are inclined at 10°–20° to the rhabdosome. The thecal apertures are introverted, and slightly laterally everted. The degree of overlap is half the thecal length and there is a faintly developed geniculum.

Remarks.—Rickards & Rushton (1968) showed that the lateral margins of the thecal apertures are shaped as small horns, making impressions in the lateral walls of the succeeding thecae. The lateral horns are not well developed in the present single specimen. Genicular hoods have been observed by the author in specimens of *M. argutus* from the Lapworth collection, Bu 1540 and Bu 1541, and the hoods were also described by Hutt & Rickards (1970). In the present specimen no hoods are seen. In the *convolutus* Zone three specimens were found with thecal structures showing resemblance to those in *M. argutus,* but the state of preservation does not permit further comments.

Monograptus leptotheca Lapworth, 1876
Fig. 16C, Pl. 7: F–G

Synonymy.—☐ 1866 *Monograptus leptotheca,* sp. nov.—Lapworth: 352–353, Pl. 12:4a–e. ☐ 1882 *Monograptus leptotheca* Lapworth.—Tullberg: 12, Pl. 2:8–12. ☐ 1910 *Monograptus leptotheca* Lapworth.—Elles & Wood: 371–372, Figs. 242a–c, Pl. 37:2a–d. ☐ 1940a *Pristiograptus leptotheca* (Lapworth).—Přibyl: 4, Pl. 2:6–7. ☐ 1968 *Monograptus leptotheca* Lapworth.—Rickards & Rushton: 268–271, Figs. 2a–e, 3a–b. ☐ 1970 *Monograptus leptotheca* Lapworth.—Rickards: 68–69, Fig. 14:37, Fig. 16:2, Pl. 6: 3, 4 (see for further references).

Lectotype.—Selected by Přibyl (1948:73); as the specimen figured in Lapworth (1876, Pl. 12:4a); from the Birkhill Shales, Dobb's Linn, Scotland.

Material.—At least 50 fragmentary specimens from Bornholm, mainly preserved flattened; the proximal end with the sicula has not been found. In adddition, 5 specimens from Tommarp, Scania, herefrom as fragments preserved in relief.

Horizon and localities.—The upper part of the *gregarius* Zone and the *convolutus* Zone, Øleå (Ø10)–(Ø12).

Description.—The rhabdosome is straight, or occasionally gently curved. The longest fragment is 11 cm and the maximum width is 2 mm. The minimum width is 0.4 mm (measured in a specimen from Scania).

The distal thecae may attain a length of more than 4 mm, and are inclined at 10°–20° to the rhabdosome; the thecal tubes are 0.25 mm wide in flattened specimens. The thecal overlap is distally three fourths of the length. In the most proximal part of the rhabdosome the overlap is half the thecal length which is here about 2 mm. The thecal spacing is proximally 10 in 10 mm, measured in the Scanian specimens, and 8 in 10 mm distally.

The structure of the thecal apertures in the flattened specimens from Bornholm are identical to those described by Rickards & Rushton (1968) with paired lateral horns and a well-developed hood. It is not possible to state—based on the Danish material—whether the apertural hoods originate from the dorsal wall of the theca itself, or grows from the geniculum of the succeeding thecae. However, SEM photographs of thecal structures from well preserved relief specimens from Tommarp, Scania, show that a thickened rim laterally in the hoods is connected to the geniculum, possibly indicating that the hoods originate from the geniculum of the preceding thecae.

Unfortunately, in the SEM it has not been possible to detect any structures in the genicular hood, and it is not known if the hood is an outgrowth of microfusellar tissue, or built up by fusellar half-rings.

Remarks.—The specimens from Bornholm and Scania are similar to those described from Britain. Well preserved specimens of *M. leptotheca* are easily recognized by the long thecae with the low inclination, the paired lateral horns, and the genicular hoods.

M. leptotheca is closely related to *M. argutus* and *M. incommodus* by the similar thecal structures. All the species have paired lateral thecal horns. The genicular hood has earlier been observed in *M. argutus* and in the present work the hoods have also been demonstrated in well preserved fragments of *M. incommodus* from Bornholm.

Monograptus revolutus Kurck, 1882
Fig. $16A_{1-3}$, Pl. 8: B

Synonymy.—☐ 1882 *Monograptus revolutus* n. sp.—Kurck: 299–300, Pl. 14:2, 4. ☐ ? 1958 *Monograptus revolutus* Kurck A. —Sudbury: 533–534, Fig. 26: a. ☐ *Monograptus revolutus* Kurck.—Hutt: 197, Figs. 1a, 1b.

Lectotype.—Subsequently designated by Přibyl (1941a) as the specimen figured by Kurck (1882, Pl. 14:2, 4.); from the *cyphus* Zone, Bollerup, Sweden.

Material.—About 30 specimens, preserved in relief or flattened. The sicula and the proximal end are unknown. Also one specimen preserved in relief from Bollerup, Sweden.

Horizon and localities.—The *revolutus* Zone, Øleå (Ø2a), (Ø4a).

Description.—The rhabdosome is dorsally curved with an almost straight distal part and attains a length of about 10 cm. The most proximal end is 0.25 mm wide and the thecae are here axially elongated with small, apparently simple apertural hooks and rounded apertures. There is slight thecal overlap, and the thecae number

4 in 5 mm. Mesially in the rhabdosome, where the increasing overlap has reached the amount of half the thecal length, the hooks disappear, and the thecae become straight tubes. The change in thecal morphology takes place over about 4–6 thecae. The number of hooked thecae never exceeds 20 in the present material. Distally in the rhabdosome, the thecae become 3 mm long and overlap for about two thirds of their length. The interthecal septum is inclined at 10° to the rhabdosome and is occasionally slightly undulating in well preserved specimens. The thecae number here 8.5–9 per 10 mm. The width of the rhabdosome is distally 0.8 in flattened specimens.

In the straight distal thecae an introversion of the apertural region is apparently introduced. However, a few specimens give a more precise information about the "introverted" apertures. In well preserved relief specimens, in the mesial part of the rhabdosome, the thecae have retained a hooked appearance, and the apertures appear to be divided into small, rounded lateral lappets or flanges. Each lappet has a dorsal open "horn" structure similar to that seen in *M. leptotheca.* The shape of the lappet is clearly seen in a flattened specimen (Fig. $16A_2$). In two specimens a dorsal hood covering most of the thecal aperture has been found. The rims of the hoods are in close contact with the rims of the lateral flanges. It has not been possible to see whether the hood is the dorsal wall of the thecae, or if it is a genicular hood as appears to be the case in *M. leptotheca.* Distally in the rhabdosome of *M. revolutus* the lateral horns and the hooked parts of the lateral flanges are retracted, and only the lateral, rounded apertural rims are seen. Further development of the hood cannot be recognized.

In most rhabdosomes, which are preserved in relief, the horned, lappet-like thecal structures are obscured; the apertures appear introverted, and continuous carbon films cover the apertural region. However, this phenomenon is also known in *M. galaensis,* where the lappet structures of the apertures have not been seen in specimens in full relief.

Remarks.—Hutt (1974) separated the *revolutus* group described by Sudbury (1958) into different species. *M. revolutus* and *M. sudburiae* (earlier *M. revolutus* C. Sudbury) were described with introverted thecae and lateral open apertural horns, and the relationship of the two species to *Pribylograptus* was suggested. The remaining *revolutus* forms with more simple apertures of Sudbury (1958) were included in the *Monograptus austerus* group.

However, the present well preserved material of *M. revolutus* has shown that the dorsal wall of the theca, or a genicular outgrowth of the succeeding theca, constitutes the main part of the cover of the *revolutus* aperture in the mesial thecae, and introversion is only apparent. The presence of thecal hoods confirms the suggested relationship to *Pribylograptus,* where *M. leptotheca, M. argutus,* and *M. incommodus* have identical thecal structures.

The apparent introversion of the thecae may be recognized in all the present biform specimens of *revolutus* type in the *revolutus* Zone, but is mostly not clearly visible. *M. revolutus* has exactly the same dimensions and shape of the stipe, as described for *Monograptus austerus vulgaris* Hutt which occurs at the same horizon. The latter graptolite has not been found in the present material. *M. revolutus* is separated from *M. sudburiae* by its wider rhabdosome and the more pronounced distal thecal overlap. *M. revolutus* occurs rather frequently throughout the *revolutus* Zone.

Monograptus sudburiae Hutt, 1974
Pl. 8:A

Synonymy.—□ 1943 *Procyrtograptus garboi* n. g. et n. sp.—C. Poulsen. 302–304. Fig. 2 (*partim*). □ 1958 *Monograptus revolutus* C.—Sudbury: 536, Fig. 26c. □ 1974 *Monograptus sudburiae* sp. nov.—Hutt: 198, Fig. 1d.

Holotype.—Specimen No. LO 44541, Hutt (1974, Fig. 1d); from the *gregarius* Zone, Tommarp, Scania.

Material.—About 20 specimens preserved in relief, or flattened.

Horizon and localities.—The middle of the *gregarius* Zone, Øleå (Ø6), (Ø10).

Description.—The rhabdosome is dorsally curved with the curvature accentuated in the mesial part. The stipe may be more than 4 cm long. The sicula and the most proximal end have not been found, the smallest width measured is 0.25 mm. The most proximal thecae are axially elongated with small hooks. Thecal overlap begins about the level of at least th10. A maximum of about 15 hooked thecae are observed, and in well preserved specimens prothecal folds of the elongated thecae have been seen. The proximal thecae number 9 in 10 mm.

At the level of at least th15 the hooks disappear and, through a phase comprising 3–4 thecae, the hooks are gradually retracted with the thecae becoming straight tubes inclined at 15° to the rhabdosome. The thecal overlap never exceeds half the thecal length which is 1.8 mm distally. The maximum width of the rhabdosome is 0.7 mm in nearly flattened specimens, and the distal thecal tubes number 11 in 10 mm.

The proximal hooked thecae appear to have simple rounded apertures. The mesial thecae have apertures resembling those of *M. revolutus* in having an apparently introverted shape and an indication of small lateral open horns. No apertural hoods have been seen. However, the apertural morphology of the distal thecae cannot be worked out in detail.

Remarks.—*M. sudburiae* from Bornholm is in no way different from the specimens described by Hutt (1974) in terms of the dimensions of the rhabdosome and the apertural form. However, with the material at hand it has not been possible to determine, whether the apertures are similar to those of *M. revolutus,* with only an apparent introversion formed by the lateral flanges and the hood,

or whether the introversion is "true" as in *M. argutus*. *M. sudburiae* is distinguished from *M. revolutus* by the more slender rhabdosome and the lesser distal overlap. A fragment of *M. sudburiae* was described by C. Poulsen (1943) as belonging to a new genus and species, *Procyrtograptus garboi,* but this species has turned out to be invalid—see discussion on pp. 46–47.

M. sudburiae is rather common in the middle part of the *gregarius* Zone, in the transition *triangulatus–pectinatus* subzones.

Monograptus austerus sequens Hutt, 1974
Pl. 7:H

Synonymy.—☐ 1958 *Monograptus revolutus* D.—Sudbury: 536, Figs. 27a, 28. ☐ 1974 *Monograptus austerus sequens* subsp. nov.—Hutt: 201, Fig. 6c.

Holotype.—Specimen No. SMA24508 figured in Sudbury (1958, Fig. 27a); from the *triangulatus* var. band, Rheidol Gorge (Cardiganshire).

Material.—About 100 specimens preserved flattened or in low relief. The proximal end with sicula has not been found.

Horizon and localities.—The *gregarius* Zone, frequent in the upper part of the *triangulatus* Subzone, Øleå (Ø5)–(Ø8), (Ø10).

Description.—The rhabdosome has biform thecae and a dorsal curvature which is accentuated mesially. The stipe may attain a length of more than 10 cm. The most proximal portion is 0.35 mm wide, the proximal thecae are axially elongated and number 7 in 10 mm. At the level of th11–17 the width has increased to 0.5 mm, and the thecae begin to overlap. About 40 hooked proximal thecae have been seen. The apertures of the hooked thecae appear to be rounded without any lateral eversions. At a width of about 0.75 mm the thecal hooks are retracted and, in the distal part of the rhabdosome, the thecae are straight tubes with a length of up to 3.1 mm. The thecal overlap increases distally to two thirds of the length of the tubes, and the thecae are inclined at 15° to the rhabdosome. Distal fragments may attain a width of 1.2 mm (in relief specimens). The distal thecae number 8.5 in 10 mm.

The apertures in the distal part of the rhabdosome are rounded, but in many specimens the walls of the apertures apparently grow up along the ventral wall of the succeeding theca, leaving the impression that the apertures are inclined at up to 160° to the axis of the rhabdosome.

Remarks.—*M. austerus sequens* is characterized by the large number (40) of hooked thecae with rounded apertures.

M. austerus sequens occurs in the *triangulatus* Subzone and is most frequent near the top where it is associated with *P. ovatoelongatus, M. sudburiae, M. triangulatus triangulatus,* and *R. longispinus.*

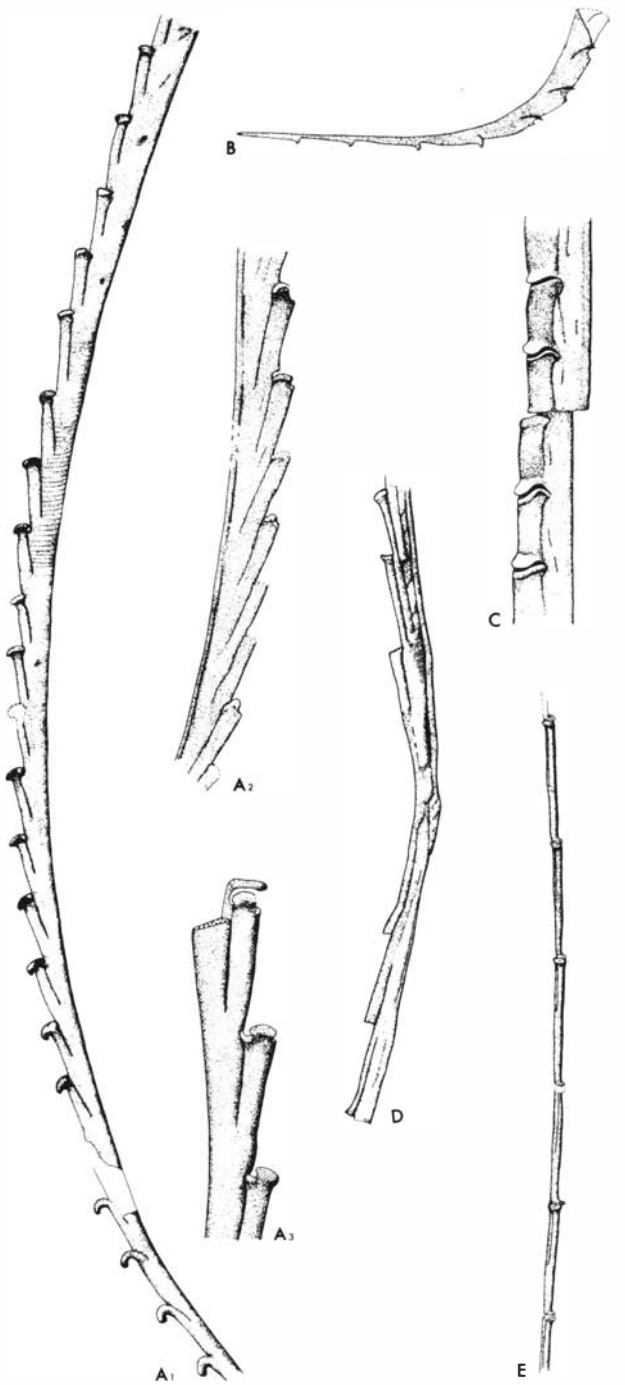


Fig. 16. ☐ A. *Monograptus revolutus* Kurck, 1882. ☐ A_1. Mesial part of a rhabdosome, Tommarp, Scania. Lund spec. × 10. ☐ A_2. Section from a mesial part. The *revolutus* Zone. Øleå. MMH 13447. × 20. ☐ A_3. Section from a distal part. The *revolutus* Zone, Øleå. MMH 13448. × 20. ☐ B. *Monograptus limatulus* Törnquist, 1892. The *gregarius* Zone, Øleå. MMH 13449. × 10. ☐ C. *Monograptus leptotheca* Lapworth, 1876. The *convolutus* Zone, Øleå. MMH 13450. ×10. ☐ D. *Monograptus sandersoni* Lapworth, 1876. The *revolutus* Zone, Øleå. MMH 13451. ×10. ☐ E. *Monograptus incommodus* Törnquist, 1899. The *revolutus* Zone, Øleå. MMH 13452. ×10.

Monograptus limatulus Törnquist, 1892
Fig. 16B, Pl. 7:I

Synonymy.—☐ 1892 *Monograptus limatulus* n. sp.—Törnquist: 9–10, Pl. 1:6–8. ☐ ? 1897 *Monograptus limatulus,* Törnquist.—Perner: 10, Pl. 13:9. ☐ 1899 *Monograptus*

limatulus Törnquist.—Törnquist: 14, Pl. 2: 18–20. □ 1911 *Monograptus limatulus,* Törnquist.—Elles & Wood: 390–391, Figs. 259a–c, Pl. 38: 7a–d. □ 1952 *Pernerograptus limatulus* Törnquist.—Münch: 99, Pl. 25: 4. □ 1970 *Monograptus limatulus* Törnquist.—Rickards: 70, Fig. 16: 10, Fig. 18: 11. □ 1971 *Monograptus (Pernerogr.) limatulus* Törnquist.—Schauer: 69–70, Pl. 25: 20–22.

Lectotype.—Designated by Přibyl (1948: 65) as the specimen figured by Törnquist (1892, Pl. 1: 6); from the Llandovery of Sweden.

Material.—More than 60 specimens preserved flattened or in partial relief. No complete specimen has been found.

Horizon and localities.—The upper part of the *gregarius* Zone and the *convolutus* Zone, Øleå (Ø10)–(Ø13).

Description.—The rhabdosome has a thread-like straight proximal end, the mesial part is strongly dorsally curved, and the distal end is dorsally bent with a tendency to become straight. The sicula has not been seen. The longest proximal portion found is 1.4 cm long and the initial width is 0.15 mm. The width of this portion increases only slightly until the strongly curved mesial part of the rhabdosome is reached. Here the width increases to 0.8–0.9 mm within the distance of three thecae and this width remains constant throughout the distal portion. This part may have been more than 3 cm long, implying that the length of a complete rhabdosome may conceivably exceed 5 cm.

The proximal thecae are elongated without any overlap, and some well preserved specimens have prothecal folds. The apertural regions have a "hooked" appearance, the retroverted part of the hook occupies about one fifth of the thecal height. The thecae number 8 in 10 mm. In the mesial part of the rhabdosome the "hooks" are rapidly reduced; in some specimens the thecal apertures seem to have dorsal genicular hoods. The distal thecae are simple tubes with a small geniculum. The interthecal walls are inclined at about 30° to the rhabdosome and the apertures are perpendicular to the thecal axis. The distal thecae overlap about half their length and they number 11 in 10 mm.

Remarks.—In 1892 Törnquist described *M. limatulus* as a new species with three prominent hooks in the transition from the proximal to the distal portion, figured on his Plate 1, Figs. 6, 8. Fig. 6 was subsequently designated as the lectotype by Přibyl (1948). This choice was rather unfortunate, as Törnquist in 1899 redescribed *M. limatulus* based on a better preserved material, and the additional specimens only showed small mesial thecal hooks. The material from Bornholm resembles the specimens described in 1899 by Törnquist, and no rhabdosome with prominent hooks are observed in the present material. The form described in 1892 may be a variant of *M. limatulus.*

The prothecal folds in the proximal thecae have not previously been reported from *M. limatulus.* The presence of prothecal folds in *M. limatulus* supports the fact that these structures are common in otherwise quite different graptolite species.

M. limatulus is rather frequent in the upper part of the *gregarius* Zone and the lower part of the *convolutus* Zone.

Monograptus aff. *crenulatus* sensu Elles & Wood, 1911

Pl. 8: D, Table 5

Material.—About 100 specimens, preserved flattened or in relief.

Horizon and localities.—The *griestoniensis* Zone, Øleå (Ø17b)–(Ø19).

Description.—The rhabdosome is straight and may attain a length of more than 10 cm. The width increases gradually from 0.5 mm at the level of th1 to 2 mm in the distal part (in flattened specimens).

The thecae are of vomerinid type, the two proximal thecae are hooked. All other thecae have apertures which face ventrally to distally. The apertural excavations occupy distally one third of the width of the rhabdosome in flattened specimens. The interthecal septum is slightly curved, and inclined at about 40° to the rhabdosome. The thecal overlap is about half the thecal length. The thecae number 11 in the proximal 10 mm, distally the number is 7–8 per 10 mm.

The sicula is 1.8 mm long and the apex reaches just below the aperture of th2.

Remarks.—The present specimens have proportions close to the observed specimens of *M. vomerinus vomerinus,* but are separated by the distinctly hooked proximal thecae.

The similarities to *M. crenulatus* sensu Elles & Wood comprise the hooked proximal thecae and the size of the rhabdosome. However, the Elles & Wood (1911) specimens have a higher thecal number (12–13) in the proximal 10 mm, and a shorter sicula, 1.5 mm as compared to 1.8 mm in the specimens from Bornholm. In the Elles & Wood specimens the apex of the sicula reaches the base of th3. *M.* aff. *crenulatus* sensu Elles & Wood occurs in the *griestoniensis* Zone and is associated with the index fossil, *M. priodon,* and *M. tullbergi*?.

Monograptus linnarssoni Tullberg, 1883

Fig. 17B, Pl. 8: F

Synonymy.—□ 1883 *Monograptus Linnarssoni* n. sp.—Tullberg: 20, Pl. 2: 5–9. □ 1940b *Monoclimacis linnarssoni* (Tullberg).—Přibyl: 7, Pl. 3: 11–13. □ 1940 *Monograptus Linnarssoni* Tull.—Laursen: 25, Figs. 14a–b. □ 1965 *Monoclimacis linnarssoni* (Tullberg).—Rickards: 250, 252, Figs. 2a–b, Pl. 30: 5. □ 1971 *Monograptus (Monoclim.) linnarssoni* Tullberg.—Schauer: 67, Pl. 28: 9, Pl. 29: 11.

Lectotype.—Designated by Přibyl (1940b: 7) as the speci-

men figured in Tullberg (1883, Pl. 2:5); from the "*Cyrtograptus* Shale", Scania, Sweden.

Material.—About 130 specimens preserved flattened or in relief.

Horizon and localities.—The upper part of the *spiralis* Zone and the *lapworthi* Zone, Øleå (Ø29), (Ø30)–(Ø40), and Læså (L5).

Description.—The rhabdosome is mainly straight, occasionally with a gently ventrally curved proximal part. The longest specimen is about 10 cm. The width increases steadily from 0.3 mm at the level at th1 to 1.1 mm in the distal end (in flattened specimens); in relief specimens the maximum distal width is 0.8 mm.

The thecae are of *Monoclimacis* type. The thecal overlap increases from one quarter of the thecal length proximally to two fifths in the distal end. The interthecal septum is sigmoidal, and the main part of the septum is parallel to the axis of the rhabdosome. Both the dorsal and the ventral walls of the apertural part of the thecae are curved towards the ventral side of the rhabdosome and the apertures face ventrally. The height of the apertures is about one sixth of the thecal height, and in flattened specimens the excavations occupy about one fifth of the width of the rhabdosome. The thecae number 9.5 in the proximal 10 mm, distally the thecal count is 9 in 10 mm.

The sicula is conspicuous, 1.8–1.9 mm long, and the apex reaches the aperture of th1. Th1 is 1.3 mm long and originates 0.6 mm from the aperture of the sicula.

Remarks.—In the collection at S. G. U. of type-specimens from Tullberg (1883) the author found one fragmentary specimen being referred to Tullberg's Pl. 2:5 which was subsequently designated as lectotype by Přibyl (1940b). The fragment is 2.8 cm long and without any sicula. The most proximal width is 0.25 mm increasing to 0.6 mm distally. The thecal number is proximally 9.5 per 10 mm, the distal number is 8.5 in 10 mm. None of the specimens in the collection demonstrate the thecal number of 7–8 mm per 10 mm stated by Tullberg (1883:20).

M. linnarssoni is separated from *M. vomerinus* n. ssp. by the proximal thecae since no prominently hooked apertures are seen in the two proximal thecae of *M. linnarssoni*. *M. linnarssoni* has characteristic sigmoidal interthecal septa and the apertures face ventrally, whereas *M. vomerinus* n. ssp. has nearly straight septa, and apertures facing distally.

From the very short description in Přibyl (1940b) it is not possible to decide whether *M. sublinnarssoni* is to be included in *M. linnarssoni* (as done by Schauer, 1971) or may be retained as a separate species.

M. linnarssoni is frequent in the transition from the *spiralis* Zone to the *lapworthi* Zone and is associated with *M. priodon, M. vomerinus vomerinus, B. pulchellus,* and the index fossils.

Monograptus continens Törnquist, 1881
Fig. 17C

Synonymy.—☐ 1881 *Monograptus continens* n. sp.—Törnquist: 440–441. Pl. 17:5a–c. ☐ 1883 *Monograptus spinulosus* n. sp.—Tullberg: 21, Pl. 2:12–15. ☐ 1892 *Monograptus continens* Törnq.—Törnquist: 12–13, Pl. 1:17–21. ☐ 1940 *Monograptus spinulosus* Tullb.—Laursen: 23, Figs. 9a–b. ☐ 1940b *Monoclimacis continens* (Törnquist).—Přibyl: 11, not figured.

Lectotype.—Subsequently designated by Přibyl (1940b: 11) as the specimen figured in Törnquist (1881, Pl. 17:5); from the *Retiolites* Shale, Stygforsen, Dalecarlia, Sweden.

Material.—More than 250 specimens preserved flattened or with low relief.

Horizon and localities.—The lowermost part of the *spiralis* Zone, Øleå (Ø21)–Ø22).

Description.—The rhabdosome may be more than 12 cm long and shows a constant gentle ventral curvature; small fragments seem to be straight. The width increases steadily throughout the rhabdosome from a proximal width of 0.5 mm to maximum 1.25 mm distally.

The thecae are of *Monoclimacis* type. The overlap is distally half the thecal length and the interthecal septum is inclined at 10°–20° to the rhabdosome. The apertures are rounded, in the distal thecae about 0.25 mm high and occupy one fourth of the width of the rhabdosome. The proximal thecae have strongly everted apertures, both the dorsal and the ventral walls are involved in the small apertural hooks. Towards the distal part of the rhabdosome the apertural hooks withdraw and only the dorsal walls appear elongated, forming a small rounded "flange" perpendicular to the axis of the rhabdosome. The apertures face ventrally throughout the rhabdosome and are surrounded by a thickened rim. The thecal count is 10 in the proximal 10 mm, and there are 9 per 10 mm distally.

The sicula is 1.5 mm long and reaches just above the aperture of th1. The aperture of sicula is 0.5 mm wide and th1 originates 0.3 mm from the aperture of the sicula.

Remarks.—The specimens from Bornholm are in no way different from the Swedish specimens described by Törnquist (1881). *M. continens* is easily distinguished from the other species of the *Monoclimacis* group by the constant ventral curvature of the rhabdosomes and the apparent prolongation of the dorsal walls of the thecae. *M. continens* is frequent in the lowermost part of the *spiralis* Zone and is associated with *M. priodon, M. cultellus, M. vomerinus* n. ssp., *M. anguinus,* and *M. spiralis spiralis.*

Monograptus vomerinus vomerinus (Nicholson, 1872)
Fig. 17E, Pl. 8:E–G, Table 5

Synonymy.—☐ 1850 *Graptolithus colonus* Barr.—Bar-

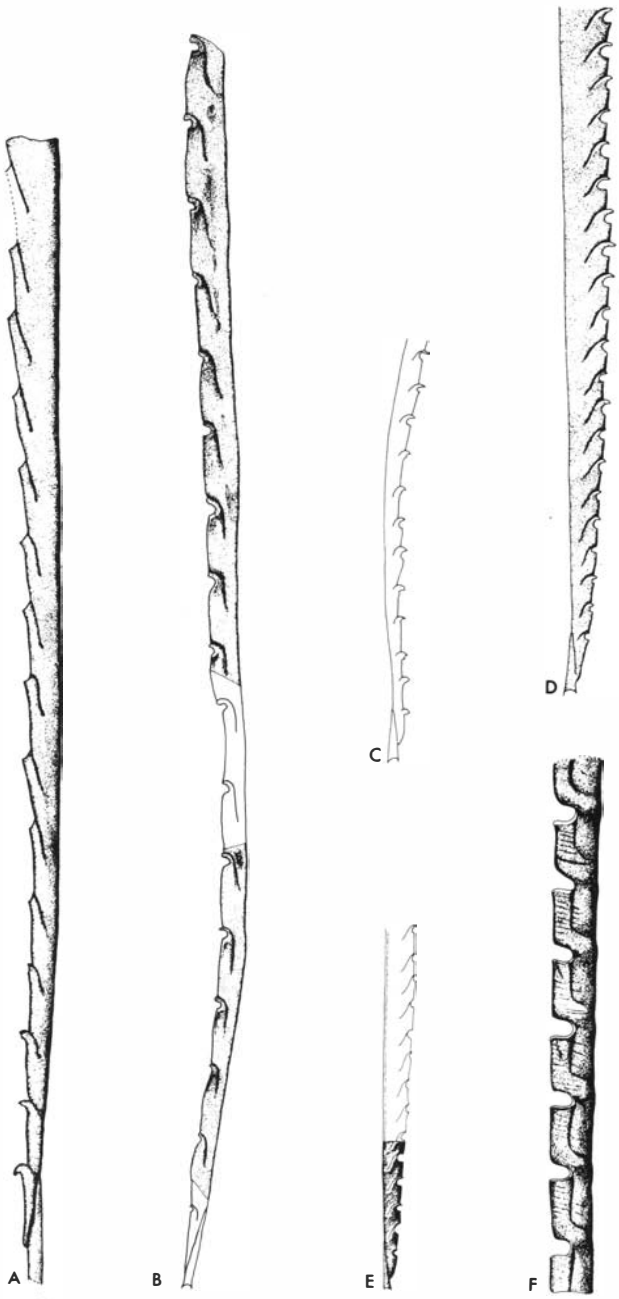


Fig. 17. □ A. *Monograptus vomerinus* n. subsp. The *spiralis* Zone, lower part, Øleå. MMH 13453. ×10. □ B. *Monograptus linnarssoni* Tullberg, 1883. The *lapworthi* Zone, Øleå, MMH 13454. ×10. □ C. *Monograptus continens* Törnquist, 1881. The *spiralis* Zone, Øleå. MMH 13455. ×5. □ D. *Monograptus vomerinus basilicus* Lapworth, 1880. The *centrifugus* Zone, Øleå. MMH 13456. ×5. □ E. *Monograptus vomerinus vomerinus* (Nicholson, 1872). The *spiralis* Zone, Øleå. MMH 13457. ×5. □ F. *Monograptus?* sp. Bavnegård well, 30.1–34.5 m below ground level. The *persculptus* Zone. MMH 13458. ×10.

rande: Pl. 2, 4. □ 1872 *Graptolithus vomerinus.*—Nicholson: 53, Figs. 21a–c. □ 1876 *Monograptus vomerinus,* Nich.—Lapworth: 353–354, Pl. 12:6a–e. □ 1910 *Monograptus vomerinus* (Nicholson).—Elles & Wood: 409–411, Figs. 275a–f, Pl. 41:1a–e. □ 1940b *Monoclimacis vomerina vomerina* Nicholson.—Přibyl: 2–3, Pl. 1:1–4. □ 1940 *Monograptus vomerinus* Nich.—Laursen: 23, Figs. 10a–c, Pl. 1:4–6. □ 1971 *Monograptus (Monoclim.) vomerina vomerina* (Nicholson).—Schauer: 67, Pl. 28:10–11, Pl. 29:7–8.

Type.—Lectotype designated by Přibyl (1940b:2) as Nicholson (1872:53, Fig. 21). The specimen in this figure has not been identified and a neotype from Lapworth's material, Bu 1542, figured in Elles & Wood (1910, Pl. 41:1a), was selected by Strachan (1971:65); from the Riccarton Beds, South of Scotland.

Material.—About 600 specimens which are preserved in all states from flattened to full relief.

Horizon and localities.—The *spiralis* Zone, the *lapworthi* Zone, the *centrifugus* Zone, Øleå (Ø21)–(Ø31), (Ø39)–(Ø42), and Læså (L1)–(L8).

Description.—The rhabdosome is straight, occasionally slightly dorsally curved in the proximal end. The longest specimen has a length of 20 cm. The width increases gradually from 0.4 mm at the level at th1 to 2.5 mm distally, with the maximum about 7 cm from the sicula.

The thecae are of *Monoclimacis* type. Thecal overlap increases from one third proximally to two thirds distally. The interthecal septum is inclined at 30°–40° to the rhabdosome. The apertures face ventrally in the rhabdosome and the height occupies about one third of the height of the free part of the thecae. In flattened specimens the apertures occupy one quarter of the width distally. In the proximal 10 mm the thecal count is 10–11, distally 7–8 per 10 mm.

The sicula is 1.5–1.75 mm long, and the apex reaches to a level between the apertures of th1 and th2. Th1 mostly originates 0.3 mm from the aperture of the sicula. Th1 is 1.0–1.3 mm long.

Remarks.—During the current study specimens have been included in *M. vomerinus vomerinus* when having a distal width of 2.0–2.5 mm, a thecal number of 11–8 per 10 mm, and a 1.5–1.75 mm long sicula, with the apex reaching between the apertures of th1 and th2. The measurements correspond to those given by Elles & Wood (1910) and the size of the sicula with Bassett & Rickards (1971). However, within the great vertical range of *M. vomerinus vomerinus* the species shows small variations in thecal number as well as length of the sicula, and the width of the rhabdosome. In the transition from the *lapworthi* Zone to the *centrifugus* Zone *M. vomerinus basilicus,* which attains a greater width of the rhabdosome and where the apex of the sicula reaches only the level of the aperture of th1, develops from *M. vomerinus vomerinus.*

Specimens of *Monograptus crenulatus* Törnquist from the type areas, Stygforsen and Nittsjö, Dalecarlia, Sweden, have been measured. The sicula is 1.5 mm long and the apex is midway between the apertures of th1 and th2. The thecae number 11 in the proximal 10 mm, th1 is 1.25 long and 0.4 mm in width. Maximum width is 2.2 mm in flattened specimens. These specimens have measurements so close to those of *M. vomerinus vomerinus* and a revision will probably show that they have to be

Table 5. Dimensions (in mm).

Spec. No.	Flat or relief	Length	Width of the rhabdosome							Number of thecae		Length of sicula
			th1	th5	th10	th15	th20	th30	dist.	Prox.	dist	
M. vomerinus n. ssp												
MMH 13524	R	35	0.25	0.4	0.5	0.75	0.75	0.9?		9.5/10	9/10	>1.3
MMH 13453	R	17	0.4	0.45	0.55	0.6				9.5/10		1.8
MMH 13525	R	120							1.3		8.5/10	
M. aff. *crenulatus* sensu E. & W.												
MMH 13526	LR	25	0.5	0.75	0.75	1.0			1.2	11/10	9/10	1.8
MMH 13527	LR	50							2.0		7.5/10	
BU 1555	F	10	0.3		0.65					12/10		1.5
M. vomerinus vomerinus												
MMH 13528	F	25	0.5	0.75	1.2	1.5	1.5			11.5/10		1.5
MMH 13529	LR	55	0.5	0.66	0.8	1.1	1.25	1.5	1.75	11.5/10		1.5
MMH 13530	F	160							2.2		8/10	
MMH 13531	R	20							1.8		8/10	
MMH 13532	F	10	0.5	0.6	1.0					10.5/10		
MMH 13533	F	120	0.4	0.75	1.0	1.2	1.3	1.75	2.3	10/10	8/10	1.5
MMH 13534	F	80	0.5	0.75	1.2	1.4	1.4		1.85	10/10	7.5/10	1.3
MMH 13535	F	15	0.4	0.9	1.3	1.45				10/10	9/10	1.25
MMH 13536	LR	150							2.5		7/10	
MMH 13537	LR	40	0.5	0.8	1.25	1.5				10/10		1.75
MMH 13538	R	15							2.0		7/10	
M. vomerinus basilicus												
MMH 13539	F	200							3.25		7/10	
MMH 13540	F	40	0.5	0.8	1.1	1.2	1.3	1.75		10/10		1.3
MMH 13541	F	9	0.4	0.8						5/5		1.4
MMH 13542	F	5	0.5	0.75						5/5		1.5
MMH 13543	F	8	0.5	1.0						5.5/5		1.5
MMH 13544	F	60	0.5	0.8	1.1	1.3	1.5	1.85	2.0	10.5/10	8/10	1.5
MMH 13545	F	23	0.5	1.0	1.3	1.5				11/10		

included in this species. However, *M. crenulatus* sensu Elles & Wood is quite different from *M. vomerinus vomerinus,* and this form should be maintained as a separate species or subspecies.

Monograptus vomerinus basilicus Lapworth, 1880

Fig. 17D, Table 5

Synonymy.—□ 1880 *Monograptus galaensis* var. *basilicus* var. nov.—Lapworth: 152–153, Pl. 4:6a–b. □ 1910 *Monograptus vomerina* var. *basilicus,* Lapworth.—Elles & Wood: 411, Figs. 276a–b, Pl. 41:2a–d. □ ? 1931 *Monograptus vomerinus robustus* n. var.—Bouček: 3, Figs. 2f–g. □ ? 1940b *Monoclimacis vomerina robusta* (Bouček).—Přibyl: 3, Pl. 1:5–6. □ 1940 *Monograptus vomerina* Nich. —Laursen: Pl. 1:6. □ 1940 *Monograptus vomerinus* var. *basilicus* Lapw.—Laursen: 24, Fig. 11. □ 1940 *Monograptus dubius* Suess.—Laursen, Pl. 1:1–2. □ 1971 *Monograptus (Monoclim.) vomerinus hemipristis* (Meneghini).—Schauer: 67–68, Pl. 29:9. □ 1971 *Monoclimacis vomerina basilica* (Lapworth).—Bassett & Rickards: 257 (partly described, not figured).

Lectotype.—Designated by Strachan (1971:65): Bu 1548, refigured in Elles & Wood (1910, Pl. 41:2c) as "type specimen"; from the *Cyrtograptus linnarssoni* Zone, Wenlock Shales, Builth.

Material.—About 250 specimens, preserved flattened or in low relief.

Horizon and localities.—In the *centrifugus* Zone, Øleå (Ø32)–(Ø39), (Ø41), and Læså (L1).

Description.—The rhabdosome is straight, rarely gently curved. The proximal end is occasionally slightly dorsally bent. The stipe widens gradually from 0.4–0.5 mm at the level of th1 to a maximum of 3.75 mm in the distal part. The longest fragment is 35 cm.

The thecae are of *Monoclimacis* type, the apertures face ventrally and the interthecal septum is inclined at about 30°–45° to the rhabdosome. The geniculum becomes less pronounced distally, and the ventral thecal walls become nearly straight. The distal thecae are 3.5 mm long and they overlap two thirds of their length. The thecae number 10–11 in the proximal 10 mm and distally 7–7.5 per 10 mm.

The sicula is 1.25–1.5 mm long and the apex reaches the aperture of th1 or slightly above. Th1 originates from 0.1 mm to 0.3 mm above the aperture of the sicula and is 1.0–1.3 mm long.

Remarks.—The measurements of the specimens from Bornholm are like those given for *M. vomerinus basilicus* by Bassett & Rickards (1971). *M. vomerinus basilicus* is

closely related to *Monoclimacis vomerina vikensis* Bassett & Rickards, but is safely separated by the shorter sicula. The sicula of *M. vomerinus vikensis* is 2 mm long. *M. vomerinus basilicus* is distinguished from *M. vomerinus vomerinus* by the greater distal width and the position of the apex of the sicula. In *M. vomerinus basilicus* the sicula reaches the aperture of th1 whereas the apex of the sicula in *M. vomerinus vomerinus* is midway between the apertures of th1 and th2.

M. vomerinus basilicus was regarded by Přibyl (1940b) and Schauer (1971) as a junior synonym of *Monograptus hemipristis* Meneghini. The measurements of *M. hemipristis* (Meneghini, 1857) correspond to those of Lapworth's specimens, the distal width is 3.0–3.2 mm and the thecae number distally 6–7 per 10 mm. However, both *M. vomerinus basilicus* and *M. hemipristis* are in need of a revision and here Lapworth's name is retained.

M. vomerinus basilicus is frequent in the *centrifugus* Zone.

Monograptus vomerinus n. subsp.
Fig. 17A, Table 5

Material.—More than 100 specimens, preserved in relief or flattened. Many specimens are well preserved with full relief.

Horizon and localities.—The lower part of the *spiralis* Zone, Øleå (Ø21)–(Ø22).

Diagnosis.—The rhabdosome is slender, straight or gently curved, with a gradual increase in width from 0.4 mm to 1.3 mm distally in relief specimens. Thecae of *Monoclimacis* type with the two or three proximal thecae hooked. The sicula is comparatively long.

Description.—The rhabdosome is straight or may be gently curved. The longest fragment is 12 cm. The width increases gradually throughout the rhabdosome from 0.4 mm proximally to a maximum of 1.3 mm distally in relief specimens.

The thecae are of *Monoclimacis* type, the proximal two or three thecae have small apertural hooks, distally to that the hooks disappear, and the thecal apertures face distally in the rhabdosome. In flattened specimens the distal apertures occupy about one third of the width of the rhabdosome. The proximal thecae have only a slight overlap and the overlap increases distally to nearly half the thecal length. In the proximal end of the rhabdosome the interthecal septum is inclined at 45° to the rhabdosome. Towards the distal part the inclination diminishes and the septum becomes approximately parallel to the stipe. The proximal thecae number 9.5 per 10 mm, the distal number is 8.5 mm in 10 mm.

The sicula is 1.8 mm long and the apex reaches the level of the aperture of th1. Th1 is 1 mm long and originates 0.6 mm from the aperture of the sicula.

Remarks.—*M. vomerinus* n. ssp. has measurements very close to those of *M. linnarssoni*; from *M. vomerinus vomerinus* and other vomerinids it is separated by the slender rhabdosome, the gradual increase in width, and the long sicula. *M. vomerinus* n. ssp. is distinguished from *M. linnarssoni* by the presence of the two proximal prominently hooked thecae and the distal thecal apertures which face distally in the rhabdosome.

M. vomerinus n. ssp. has a restricted occurrence in the lowermost part of the *spiralis* Zone, but is frequent here and is associated with *M. spiralis spiralis, M. priodon, M. cultellus, M. anguinus,* and *M. continens.*

Monograptus galaensis Lapworth, 1876
Fig. 18A

Synonymy.—☐ 1876 *Monograptus Galaensis* sp. nov.—Lapworth: 356, Pl. 12:5a–d. ☐ 1912 *Monograptus galaensis* Lapworth.—Elles & Wood: 415–416, Figs. 281a–d, Pl. 42: 1a–c. ☐ 1968 *Monoclimacis? galaensis* (Lapworth).—Rickards: 304–307, Figs. 1–3.

Lectotype.—The specimen figured in Lapworth (1876, Pl. 12: 5b), refigured in Elles & Wood (1912, Pl. 42: 1a); from the Gala Beds, Scotland.

Material.—About 140 specimens preserved flattened or in relief.

Horizon and localities.—The top of the *turriculatus* Zone and the basal part of the *crispus* Zone, Øleå (Ø16a)–(Ø16b).

Description.—The rhabdosome is stiff or gently curved, the width increases steadily from 0.4 mm proximally to 1.5 mm at the level of th20. This width is maintained throughout the distal part (in flattened specimens). The rhabdosomes may reach a length of more than 20 cm.

The thecae are biform. The proximal thecae are hooked; from the level of th4 the hooks gradually withdraw, and distally the thecae become almost straight tubes. In the proximal part of the rhabdosome the thecal overlap is one third and distally two thirds of the length. The interthecal septum is inclined at 45° proximally and towards the distal part at about 30°. The mesial thecae observed in relief specimens are similar to those of the *Monoclimacis* group in having a flowing geniculum. However, the geniculum diminishes distally in the rhabdosome. In well preserved specimens, which are found with partial relief and obliquely flattened, the apertural structures of the thecae are seen. Instead of an apparently simple rounded aperture the thecae have two lateral apertural lappets. The ventral apertural margin is thickened. In the mesial part of laterally flattened specimens the lappets appear like small hooks, but in relief specimens there is no sign of apertural lappets. The lappets are only seen in the mesial to distal part of the rhabdosome. It is not possible to state whether the hooks in the proximal end are "closed", or composed of paired lappets. The thecal count is 11 per 10 mm proximally and 8 in 10 mm distally.

The sicula is 1.2 mm long and the apex reaches the middle of th2. In low relief specimens the width of the aperture of the sicula is 0.25 mm. Th1 is 0.75 mm long and originates just above the aperture of the sicula.

Remarks.—The thecal structures of *M. galaensis* were described by Rickards (1968), and the lappet structure is clearly seen also in the specimens from Bornholm. However, in the present material the dorsal part of the thecal aperture is always covered by a thin coating of sediment, and it has not been possible to observe the entire apertural portion. The lappet appearance, "false lappets", are known from other graptolite species with hooked thecae in subventral view. However, in *M. galaensis* the lappets are very regular and are bordered by slightly thickened rims. This implies that the lappets are regarded as "true" lappets.

Among the Llandovery monograptids the lappet thecal structures are also present in *M. revolutus* from the Lower Llandovery. However, the distal thecae of *M. galaensis* are more simple, without any lateral "horns". Common for the two graptolite species are the biform thecae in which the detailed structures of the hooked proximal thecae are unknown.

The presence of the paired lappet thecal structures in *M. galaensis* excludes the earlier supposed close relationship between the *Monoclimacis* group and *M. galaensis* (Elles & Wood, 1912), although *M. galaensis* has an apparent geniculum.

M. galaensis is fairly frequent in the transition from the *turriculatus* to the *crispus* zones and is observed with *M. turriculatus, M. marri, M. nudus, M. pseudobecki, M. proteus,* and *P. palmeus.*

Monograptus griestoniensis (Nicol, 1850)

Fig. 18B, Pl. 8:H–J, Table 6

Synonymy.—□ 1850 *Graptolites griestoniensis.*—Nicol: 63, Figs. 2a–b. □ 1910 *Monograptus griestoniensis* (Nicol).—Elles & Wood: 413–414, Figs. 279a–f, Pl. 41:5a–d. □ 1940b *Monoclimacis griestoniensis griestoniensis* (Nicol).—Přibyl: 8, Pl. 3:1–3. □ ? 1940b *Monoclimacis griestoniensis minuta* n. var.—Přibyl: 8–9, Pl. 3:4–5. □ 1970 *Monoclimacis griestoniensis* (Nicol).—Toghill & Strachan: 514–517, Figs. 1a–h, Pl. 103:1–5. □ ? 1971 *Monograptus (Monoclim.) griestoniensis griestoniensis* (Nich.)—Schauer: 66, Pl. 28:1–3, Pl. 29:3–4.

Lectotype.—GSM 11800 figured Elles & Wood (1910, Pl. 41:5a); from the Llandovery, Grieston Quarry, South of Scotland.

Material.—About 80 specimens preserved flattened or in relief. Samples from the Grieston Quarry, including the lectotype, and specimens from Tarannon, Montgomeryshire, have also been examined.

Horizon and localities.—The *griestoniensis* Zone, Øleå (Ø17a), (Ø18)–(Ø19).

Description.—The rhabdosome is slender, straight or slightly arcuate with a gradual increase in width throughout the rhabdosome from 0.2 mm at th1 to 0.5 mm at th20, and a maximum width of 0.8–0.9 mm in the most distal parts. The longest fragment measures 7 cm.

The thecae are slender with a parallel-sided protheca; in relief specimens prothecal folds can be observed. Proximally the thecal overlap is one sixth of the thecal length, distally the overlap has increased to nearly half the thecal length. The interthecal septum is for the main part parallel to the axis of the stipe.

In well preserved specimens the apertural portions of the thecae are retroverted, forming small closely adpressed hooks, and the apertures face the proximal end of the rhabdosome. Both the dorsal and the ventral walls of the thecal apertural regions apparently take part in forming the hook. Close to the hook the succeeding theca has a pronounced geniculum. However, in most specimens the retroverted apertural parts are broken off, leaving a vomerinid appearance with a rounded "aperture" and a well developed geniculum. The thecae number 11 in the proximal 10 mm and distally the count is 10 in 10 mm.

The sicula is 1 mm long and the apex reaches the base of th2. Th1 is about 1 mm long and originates 0.25 mm above the aperture of the sicula.

Remarks.—The prothecal folds have not previously been found in *M. griestoniensis.* The small apertural hooks have been interpreted as genicular hoods (Toghill & Strachan, 1970). The specimens from the type locality, Grieston Quarry, are not well preserved, but in specimen GSM Geol. Soc. Coll. 6957 figured in Toghill & Strachan (1970, Pl. 103:4), the retroverted dorsal walls can be seen. In most other specimens the wall is broken. In the collections of the Sedgwick Museum a slab was found originating from the *griestoniensis* Zone, Tarannon District, Montgomeryshire, and with specimens recorded as *M. griestoniensis* by Elles & Wood (1910:413–414). On this slab the impression of a proximal portion in relief was found, having prothecal folds and small hooks. Also the distal fragments, specimen nos. 21674–21676, have hooked apertures.

The measurements of the specimens of *M. griestoniensis* from Bornholm are identical to those of the specimens from the Grieston Quarry.

Many authors regard *M. griestoniensis* as a monoclimacograptid, but the thecal structures seem to be rather different from this group since the apertural hooks, which are present throughout the rhabdosome, have not been recorded in other "monoclimacograptids". Only the pronounced geniculum is common for *M. griestoniensis* and members of the *Monoclimacis* group, but a geniculum also exists in many other groups of monograptids.

The description of *M. griestoniensis minuta* (Přibyl, 1940b) is rather short. The specimens from Bornholm have very slender proximal ends and, at a distance of 2 cm from the sicula, the width is 0.5 mm as also seen in the British specimens. It has not been possible to separate the subspecies on Bornholm, and *M. griestoniensis minuta* may be proximal parts of *M. griestoniensis,* sensu strictu.

M. griestoniensis is associated with *S. grandis girvanensis?, M. marri, M. veles,* and *M. priodon.* The occurrence is restricted to the *griestoniensis* Zone.

Table 6. M. griestoniensis. Dimensions (in mm).

Spec. No.	Flat or relief	Length	Width of the rhabdosome:						Number of thecae		Length of sicula
			th1	th5	th10	th20	th30	dist.	prox.	dist.	
MMH 13460	LR	25	0.2	0.25	0.3	0.4	0.4				
MMH 13546	F	30	0.2	0.25	0.3	0.4	0.45	0.6	11/10	10/10	1.0
MMH 13547	F	20	0.2	0.25	0.3	0.45	0.5		10/10	10/10	
MMH 13548	LR	20	0.25	0.25	0.3	0.45			11/10		0.9
MMH 13549	F	25	0.2	0.3	0.4	0.4	0.5		11/10	10/10	0.9
MMH 13550	F	dist						0.9		10/10	

Monograptus pseudoruncinatus n. sp.
Fig. 18C, Pl. 9:C

Synonymy.—☐ ? 1881 *Monograptus runcinatus.*—Linnarsson: 503, Pl. 23:8–12. ☐ ? 1912 *Monograptus runcinatus* Lapworth.—Elles & Wood: 450–451 (pars), Figs. 309a–b, Pl. 45:2a–b.

Holotype.—Specimen No. MMH 13461, Fig. 18:C, the *turriculatus* Zone, loc. 13a, Øleå.

Derivation of name.—*pseudoruncinatus,* referring to the resemblance to *D. runcinatus.*

Material.—About 20 specimens preserved flattened or with low relief.

Horizon and localities.—The lower part of the *turriculatus* Zone, Øleå (Ø13a)–(Ø13b).

Diagnosis.—Small slender monograptid with a slight dorsal proximal curvature, distally the rhabdosome is ventrally curved to nearly straight. The thecae are enrolled, of *exiguus* type, with prothecal folds, numbering 16–12 per 10 mm. The sicula is small.

Description.—The length of the rhabdosome may exceed 3 cm, but is commonly about 1 cm. The proximal portion is dorsally curved, and the distal part is mainly ventrally flexed, only few specimens are straight. The width increases gradually from 0.25 mm in the initial part to 0.45 mm at th10. The maximum distal width is 0.65 mm.

The thecae are of *exiguus* type with the apertural parts enrolled. The prothecal portions are parallel-sided with well developed prothecal folds, distally in flattened specimens the base of the prothecae is enlarged. In the proximal thecae the retroverted part occupies one third of the thecal height, distally about half the height. The width of the enrolled part is proximally one third of the width of the rhabdosome, distally about half the width. The thecal apertures face the dorsal part of the rhabdosome and are in close contact with the prothecal portions. No lateral spines are seen. The thecae number 8 in the proximal 5 mm, distally 12 in 10 mm.

The sicula is 0.7 mm long and 0.15 mm wide at the aperture. The apex of the sicula reaches the base of th2. Th1 originates 0.15 mm from the aperture of the sicula and is 0.75 mm high.

Remarks.—*M. pseudoruncinatus* is closely related to *M. pseudobecki,* but has a higher thecal number per 10 mm. *M. pseudoruncinatus* is separated from *M. exiguus* s.l. by the curvature of the rhabdosome and the thecal number per 10 mm. From *D. runcinatus* it is distinguished by the different thecal morphology, the shorter sicula, and the closer set thecae.

M. pseudoruncinatus is the earliest species on Bornholm with enrolled *exiguus* type thecae. The proximal part of *M. pseudoruncinatus* shows great resemblance to *M.* cf. *barrandei* sensu Elles & Wood described by Hutt et al. (1970). However, the distal part of *M.* cf. *barrandei* was not described in 1970, and the distal portion of *M. barrandei* described in Elles & Wood (1912) is quite different from the distal part in *M. pseudoruncinatus. M. pseudoruncinatus* occurs in the lower part of the *turriculatus* Zone and is associated with *M. turriculatus, M. halli, D. runcinatus, R. maximus,* and *G. auritus.*

Monograptus exiguus s.l. (Nicholson, 1868)

Synonymy.—☐ 1868 *Graptolites lobiferus* var. *exiguus,* Nich.—Nicholson: 533, Pl. 19:27–28. ☐ 1876 *Monograptus exiguus* Nicholson sp.—Lapworth: 503: Pl. 20:6. ☐ 1892 *Monograptus exiguus* Nich.—Törnquist: 25–26, Pl. 2:22. ☐ 1899 *Monograptus exiguus* Nicholson.—Törnquist: 24–25, Pl. 4:26–28. ☐ 1912 *Monograptus exiguus* (Nicholson).—Elles & Wood: 453–454, Figs. 312a–c, Pl. 46:1a–d. ☐ 1942 *Monograptus (Streptograptus) exiguus* (Nicholson).—Bouček & Přibyl; 566, Figs. 3a–d, Pl. 16:1–3. ☐ 1952 *Streptograptus exiguus* Nich.—Münch: 111, Pl. 35:1a–b. ☐ 1970 *Monograptus exiguus* (Nicholson).—Rickards: 78, Pl. 8:3, 8. ☐ 1970 *Monograptus exiguus* (Nicholson).—Hutt et al.: 11–12, Pl. 2:43–46 (see for further references). ☐ 1971 *Monograptus (Streptogr.) exiguus exiguus* (Nicholson).—Schauer: 71, Pl. 24:7–8, Pl. 25:8–10.

Holotype.—Specimen figured Nicholson (1868, Pl. 19:27–28); from the "Coniston Flags" of Skelgill, Northern England.

Material.—About a hundred specimens mainly preserved flattened, a few specimens in relief.

Horizon and localities.—From the middle of the *turriculatus* Zone to the upper part of the *crispus* Zone, Øleå (Ø16)–(Ø17a).

General description.—The rhabdosome is short, slender and hook-shaped. The extreme proximal end has a slight dorsal curvature, and the mesial part of the rhabdosome is strongly ventrally curved. The curvature diminishes gradually towards the distal end. The width does not exceed 0.5 mm. The thecal count is 12–20? per 10 mm, mainly 14–16 per 10 mm. The apertural portions of the thecae are retroverted and enrolled, the apertures facing dorsally in the rhabdosome.

Remarks.—It has not been possible to identify the holotype. It appears that various authors have included all small hook-shaped rhabdosomes with enrolled thecae in *M. exiguus,* and the whole group needs redefinition. On Bornholm many specimens from various stratigraphic levels and with slightly different proportions fit the general description. Consequently the author has chosen to describe three different forms of *M. exiguus* s.l. and one subspecies, *M. exiguus primulus* which is easily separated from the other forms by the greater width.

Monograptus exiguus A
Fig. 18F

Material, horizon, and locality.—About 50 specimens which all are preserved flattened; from the middle to upper part of the *turriculatus* Zone, Øleå (Ø16).

Description.—The rhabdosomes are of typical *exiguus* shape, the maximum length is 1.5 cm. The width increases slightly throughout the rhabdosome, from 0.3 mm proximally to 0.4 mm distally.

The thecae are enrolled, the free part of the lobes occupies one third of the width of the rhabdosome and about one third of the thecal height. The apertures face the dorsal part of the rhabdosome and are strongly everted. The thecal count is 6–7 per 5 mm distally.

The sicula is 0.9 mm long and the apex reaches the base of th2. Th1 originates 0.15 mm from the aperture of the sicula, the width of the sicular aperture is 0.15 mm.

Remarks.—*M. exiguus* A is slightly more slender than *M. exiguus* described by Lapworth (1876) and Elles & Wood (1912), and the enrolled part occupies a smaller portion of the dorso-ventral width of the rhabdosome.

M. exiguus A occurs in the middle to upper part of the *turriculatus* Zone and is associated with *M. turriculatus.*

Monograptus exiguus B
Fig. 18G

Material, horizon, and locality.—Two proximal parts preserved in relief, without sicula; from the middle part of the *crispus* Zone, Øleå (Ø17).

Description.—The two rhabdosomes have a prominent ventral curvature. The distal width is 0.4 mm, and the length of the largest rhabdosome is 5 mm.

The thecae are enrolled. The coiled part occupies about half the width of the rhabdosome, and one half to one third of the thecal height. The prothecal parts are mainly parallel-sided, and there are faintly developed prothecal folds. The thecal apertures face the dorsal part of the rhabdosome and do not appear to be everted. The thecal count is 3 per 2.5 mm (in the largest fragment only 7 thecae are preserved in the strongly curved fragment).

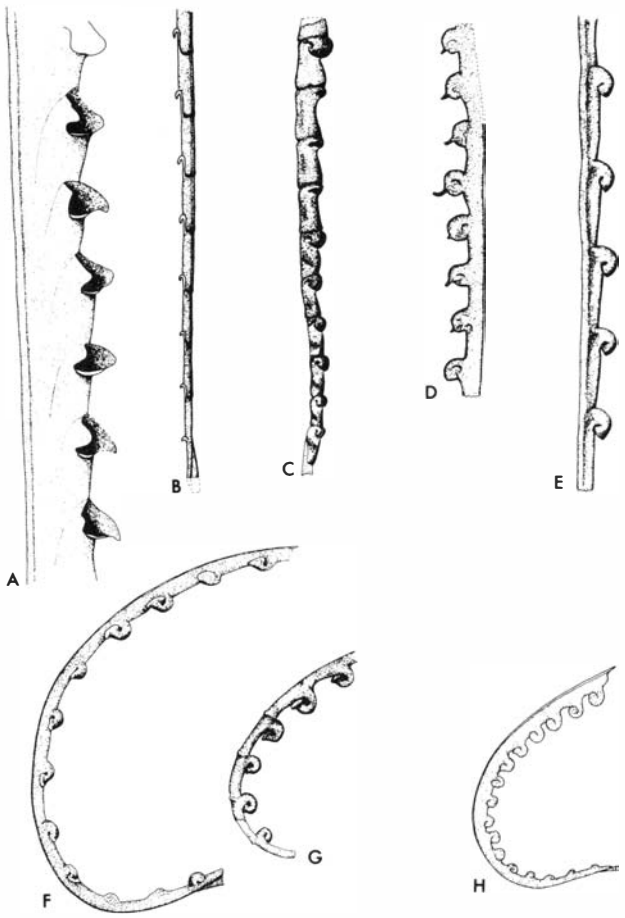


Fig. 18. □ A. *Monograptus galaensis* Lapworth, 1876. The *turriculatus* Zone, Øleå. MMH 13459. ×10. □ B. *Monograptus griestoniensis* (Nicol, 1850). The *griestoniensis* Zone, Øleå. MMH 13460. ×10. □ C. *Monograptus pseudoruncinatus* n. sp. Holotype. The *turriculatus* Zone, Øleå. MMH 13461. ×10. □ D. *Monograptus exiguus* (Nicholson, 1868) C. The *crispus* Zone, Øleå. MMH 13462. ×10. □ E. *Monograptus* cf. *barrandei* sensu Elles & Wood, 1912. The *turriculatus* Zone, Øleå. MMH 13463. ×10. □ F. *Monograptus exiguus* (Nicholson, 1868) A. The *turriculatus* Zone, Øleå. MMH 13464. ×10. □ G. *Monograptus exiguus* (Nicholson, 1868) B. The *crispus* Zone, Øleå. MMH 13465. ×10. □ H. *Monograptus exiguus primulus* Bouček & Přibyl, 1942. The *turriculatus* Zone, Øleå. MMH 13466. ×5.

Remarks.—Form B has a slightly lower thecal count per 10 mm than other forms of *M. exiguus.* The apertures are not everted and no thecal spines are observed. The form may possibly be excluded from the *exiguus* group.

Monograptus exiguus C
Fig. 18D

Material, horizon, and locality.—One flattened distal frag-

ment; from the upper part of the *crispus* Zone, Øleå (Ø17).

Description.—The 2 cm long specimen is flattened, ventrally curved, and only the distal portion is preserved. The width is constantly 0.5 mm.

The apertural portions of the thecae are coiled into a lobe which occupies about half the width of the rhabdosome and about half the height of the thecae. The ventral prothecal walls are more or less parallel to the rhabdosome, and there are no signs of prothecal folds. The thecae are provided with 0.2 mm long lateral spines. It is not possible to disclose the precise structure of the thecal aperture, no apertural eversion has been observed. The thecal structure with paired lateral spines may be similar to that of *M. exiguus* described by Hutt et al. (1970). The thecae number 7.5 in 5 mm.

The single specimen shows a great resemblance to the specimens of *M. exiguus* described by Lapworth (1876).

Monograptus exiguus primulus Bouček & Přibyl, 1942
Fig. 18H, Pl. 9: D

Synonymy.—☐ 1942 *Monograptus (Streptograptus) exiguus primulus* n. subspec.—Bouček & Přibyl: 7, Figs. 3e–f, Pl. 1:4. ☐ 1952 *Streptograptus exiguus primulus* Bouček & Přibyl.—Münch: 111, Pl. 35:2. ☐ 1971 *Monograptus (Streptogr.) exiguus primulus* Bouček & Přibyl.—Schauer: 71, Pl. 24:9, Pl. 25:4–5.

Holotype.—Bouček & Přibyl (1942, Pl. 1:4); from the *linnaei* Zone, Želkovice, Bohemia.

Material.—15 specimens which all are flattened.

Horizon and localities.—The middle part of the *turriculatus* Zone, Øleå (Ø15a)–(Ø16).

Description.—The rhabdosome is shaped like a hook. The extreme proximal portion is straight to dorsally curved. At the level of th6–th10 the rhabdosome is strongly ventrally curved. The curvature decreases towards the distal part, but is constantly ventral. The maximum length of the rhabdosome is 5 cm. The main increase in width from 0.3 mm to 0.85 mm takes place from the proximal end up to the th20. The extreme distal width is 1.1 mm, but commonly the maximum width is 0.9 mm.

The thecae are of *exiguus* type. They have closely enrolled distal portions which occupy half the width of the rhabdosome. In the proximal part of the rhabdosome the enrolled part occupies half the thecal height, distally two thirds of the height. The prothecal ventral walls are parallel to the axis of the rhabdosome, and there are traces of prothecal folds in some well preserved specimens. The apertures are almost in contact with the prothecal parts; they are enlarged and face dorsally in the rhabdosome. The thecal count is 6 per 5 mm proximally and distally 11–12 in 10 mm.

The sicula is 1 mm long and the apex reaches the base of th2. Th1 commences just above the aperture of the sicula.

Remarks.—The original description of *M. exiguus primulus* (Bouček & Přibyl, 1942) is rather brief. The subspecies is above all characterized by a rhabdosome wider than that of other *M. exiguus* forms. The specimens from Bornholm and those described by Schauer (1971) are both longer than indicated in the original description and figures.

Strachan (1971) included *Monograptus nodifer* Törnquist as described by Elles & Wood (1912) in *M. exiguus primulus.* However, the author has studied the specimens in Elles & Wood, Figs. 313a and 313c; these have a distal width of only 0.5 mm, and cannot be referred to this subspecies.

M. exiguus primulus occurs within a range of one metre in the middle part of the *turriculatus* Zone and is associated with *M. turriculatus, M. planus, M. nudus,* early *priodon* forms, and *R. linnaei.*

Monograptus cf. *barrandei* sensu Elles & Wood, 1912
Fig. 18E

Material.—One distal fragment and one proximal end which may possibly be referred to this species. Both specimens are preserved partly in relief.

Horizon and locality.—The middle part of the *turriculatus* Zone, Øleå (Ø15a).

Description.—The distal fragment is straight, slender, and about 6 cm long. The width increases from 0.4 mm to 0.5 mm from the proximal to the distal end.

The apertural part of the thecae is coiled to form a lobe which occupies between one half and one third of the width of the stipe; the height of the lobe is one third of the thecal height. The prothecal portions are parallel-sided. The thecal apertures are slightly everted, adpressed to the ventral walls of the prothecae and face dorsally-proximally in the rhabdosome. The thecal count is 8 per 10 mm throughout the distal fragment.

The sicula is 0.75 cm long and its apex is at the level of the base of th2. Th1 is 0.65 mm in height, and th2 is 0.8 mm. The proximal thecal count in this specimen may be more than 10 per 10 mm. The proximal thecae have prothecal folds. The thecae in the small proximal fragment have the same structure as the thecae in the distal fragment. However, it is possible that the fragments are not conspecific.

Remarks.—The measurements of the distal fragment from Bornholm agree with those of *M. barrandei* as recorded by Elles & Wood (1912:462), but the thecal structures may be different.

Monograptus cf. *M. barrandei* described by Hutt et al. (1970) has a slightly shorter sicula which does not reach the base of th2, but the specimens from Dalecarlia are here regarded as possibly belonging to *M. pseudoruncinatus. M.* cf. *barrandei* from Bornholm is associated with *M. planus, M. turriculatus,* and *M. exiguus primulus.*

Monograptus pseudobecki Bouček & Přibyl, 1942
Pl. 9: A–B

Synonymy.—☐ 1876 *Monograptus Becki,* Barrande sp.—Lapworth: 500–501, Pl. 20:2a, b ?. ☐ 1912 *Monograptus Becki* (Barrande).—Elles & Wood: 452–453, Figs. 311a–b, Pl. 45:4a–f. ☐ 1942 *Monograptus (Streptograptus) pseudobecki* n. sp.—Bouček & Přibyl: 17–18, Figs. 4a–b. ☐ 1952 *Streptograptus pseudobecki* Bouček & Přibyl.—Münch: 113, Pl. 35:14a–b. ☐ 1970 *Monograptus pseudobecki* Bouček & Přibyl.—Rickards: 78–79, Fig. 17:23, Pl. 8:7. ☐ 1971 *Monograptus (Streptograptus) runcinatus pseudobecki* Bouček & Přibyl.—Schauer: 71, Pl. 25:13–14.

Lectotype.—Designated by Bouček & Přibyl (1942:17) as the specimen figured in Lapworth (1876, Pl. 20:2a). BU 1644; from the Gala Beds, Gala Shield, Scotland.

Material.—About 30 specimens mostly preserved flattened; a few proximal parts are preserved in low relief, no complete rhabdosome has been found.

Horizon and localities.—The upper part of the *turriculatus* Zone and the lower part of the *crispus* Zone, Øleå (Ø16a)–(Ø16b).

Description.—The rhabdosome is S-shaped, dorsally curved in the proximal portion and ventrally flexed in the distal part. The length may have exceeded 10 cm. The width increases gradually from 0.25 mm at th1 to 0.9 mm distally in flattened specimens.

The thecae are of *exiguus* type with parallel prothecal parts and the distal portions are tightly coiled. The initial portions of the thecae have prothecal folds and the thecae have a small overlap. The thecal apertures are slightly everted and they face oblique dorsally-proximally in the rhabdosome. Proximally the height of the enrolled part of the thecae occupies one fourth of the thecal height, increasing to about half the thecal height in the distal part of the rhabdosome. The coiled part of the thecae occupies one third of the width of the rhabdosome proximally as well as distally. The thecal count is 14 in the proximal 10 mm, distally 9 per 10 mm.

The sicula is about 8 mm long and the apex reaches the base of th2. The length of th1 and the width of the sicular aperture cannot be stated.

Remarks.—The double curvature and the proportions of the rhabdosome agree with previous descriptions of *M. pseudobecki.* The presence of prothecal folds has not previously been reported from this species. *M. pseudobecki* is quite frequent in the transition *turriculatus–crispus* zones, and is associated with *M. galaensis, M. proteus,* and *M. marri.*

Monograptus anguinus Přibyl, 1941
Pl. 9: E–G

Synonymy.—☐ 1941b *Monograptus (Streptograptus) anguinus* n. sp.—Přibyl: 4–5, Pl. 2:2–4. ☐ 1942 *Monograptus (Streptograptus) anguinus* Přibyl.—Bouček & Přibyl: 8, Figs. 3k–n, Pl. 1:7. ☐ ?1971 *Monograptus (Streptogr.)* cf. *exiguus anguinus* Přibyl.—Schauer: 72, Pl. 25:6–7.

Holotype.—The specimen figured in Přibyl (1941b, Pl. 2:3); from the *spiralis* Zone, Kuchelbad, Bohemia.

Material.—More than 30 specimens, preserved in relief or flattened. Some specimens are very well preserved.

Horizon and localities.—The lower part of the *spiralis* Zone, Øleå (Ø21)–(Ø22).

Description.—The rhabdosome is slender and hook-shaped, like the *exiguus* forms. The extreme proximal end is straight, the ventral curvature is strongest between th5–th10, and decreases distally. The maximum length of the rhabdosome is about 5 cm. The width of the stipe increases steadily from an initial width of 0.2 mm at th1 to 0.6 mm at the level of th15. This width is maintained throughout the distal part, never exceeding 0.6 mm.

The thecae are uniform throughout the rhabdosome. In the initial portions of the prothecae prothecal folds are developed. The main part of the prothecae has parallel dorsal and ventral walls. The metathecal part is involved in a complex thecal "hook", comprising retroversion of both the dorsal and the ventral walls of the thecae. The apertural portion is initially enrolled 360°, and then the extreme apertural part is refolded 90°, so that the thecal apertures face proximally in the rhabdosome. The enrolled part of the thecae is transversely expanded and pointed in well preserved relief specimens, but no lateral spines have been observed. The coiled part of the thecae occupies about half the width of the prothecae. In flattened specimens the thecal "hook" occupies less than one third of the width of the rhabdosome. Within the four proximal thecae the thecae number 3.5 per 2.5 mm, distally the thecal count is 4.5 in 5 mm.

The sicula is 0.75 mm long and its apex reaches the base of th2. The aperture of the sicula is 0.1 mm in width and th1 originates 0.1 mm from the aperture. Th1 is 0.6 mm high.

Remarks.—The material from Bornholm only differs from the originally described specimens of *M. anguinus* in having a slightly higher thecal count, 9–10 per mm compared to the Bohemian specimens with 8–9 thecae in 10 mm. Only flattened specimens were described from Bohemia, and no detailed thecal structures were seen. The thecal structures of *M. anguinus* bear great similarity to those of *M. nodifer,* but in *M. nodifer* the refolded part of the thecae is coiled in such a manner that the thecal apertures face ventrally to distally in the rhabdosome, and not proximally as in *M. anguinus. M. nodifer* can also be separated from *M. anguinus* by the greater distal width which is 1 mm in *M. nodifer.*

The shape of the rhabdosome of *M. anguinus* recalls that of *M. exiguus* s.l., but the thecal spacing is greater in *M. anguinus.* Furthermore, the thecal structures of *M. anguinus* are more complex than those of *M. exiguus* s.l. Together with *M. nodifer, M. anguinus* represents

an extreme development of the *M. exiguus* group, as the distal parts of the thecae are enrolled and further refolded, including both the dorsal and ventral walls. *M. anguinus* has retained the transverse expansion of the enrolled part of the thecae from *M. exiguus* s.l. *M. anguinus* occurs in a thin horizon in the lowermost part of the *spiralis* Zone and is associated with *M. vomerinus* n. ssp., *M. spiralis spiralis, M. priodon, M. continens,* and *M. cultellus.*

Monograptus communis rostratus Elles & Wood, 1913
Fig. 19A, Pl. 10:B

Synonymy.—□ 1913 *Monograptus communis* (Lapworth) var. *rostratus* var. nov.—Elles & Wood: 481–482 (pars), Fig. 337, Pl. 49:2b (non a, c). □ 1913 *Monograptus communis* (Lapworth).—Elles & Wood: 480–481 (pars), Pl. 49:1b, (non Figs. 336a–b, Pl. 49:1a, c–e). □ ?1944 *Spirograptus communis rostratus* (Elles & Wood).—Přibyl: 31, not figured, not described. □ 1958 *Monograptus communis rostratus* Elles & Wood.—Sudbury: 522–523, Fig. 21, Pl. 23:102–105. □ 1970 *Monograptus communis rostratus* Elles & Wood.—Rickards: 85, Fig. 13:18.

Lectotype.—Subsequently designated by Přibyl (1944), redesignated by Sudbury (1958). Specimen figured by Elles & Wood (1912; Fig. 337, Pl. 49:2b); from the Lower Birkhill Shales, Dobb's Linn, Scotland.

Material.—More than 80 specimens which all are fragmentary and preserved flattened or in relief.

Horizon and localities.—The middle to upper part of the *gregarius* Zone, Øleå (Ø2), (Ø10), and (Ø11).

Description.—The rhabdosome may attain a length of more than 10 cm. The stipe is dorsally curved, with the strongest curvature in the proximal part. The width increases gradually from 0.35 mm at th1 to a maximum of 1.5 mm distally.

The thecae are isolated triangular, with an apertural hook. The apertures face sub-ventrally or proximally. The recurved part occupies one fourth of the width of the stipe. The flattened specimens have slightly transverse expanded apertures, and small lateral spines have been observed in few well preserved specimens. In relief specimens the apertures seem to be simply rounded. The thecal count is 9 per 10 mm distally.

The sicula is 0.9 mm long and 0.2 mm wide at the aperture. Th1 originates 0.25 mm from the aperture of the sicula and is axially elongated with a small hook. The height of th1 is 1.2 mm. Th2 is 0.8 mm high. The apex of the sicula reaches 0.25 mm below the aperture of th1.

Remarks.—Only a few proximal parts have been found, all with only the first thecae elongated. This feature is characteristic of *M. communis rostratus,* and separates this subspecies from *M. communis communis* which has two to three elongated proximal thecae. The distal fragments of the two subspecies are difficult to distinguish, and *M. communis communis* may be represented by some of the distal fragments from Bornholm.

In the uppermost part of the *gregarius* Zone some specimens were found in which the ventral walls of the thecae have a lower angle of inclination to the rhabdosome (30°) than in *M. communis rostratus* (45°). These specimens may be related to *M. communis obtusus* Rickards which occurs in the *sedgwickii* Zone in Spengill. No proximal part has been found among these specimens.

M. communis rostratus is frequent in the middle and upper part of the *gregarius* Zone and is mostly associated with *M. pectinatus* and *M. limatulus.*

Monograptus planus (Barrande, 1850)
Pl. 10:A

Synonymy.—□ 1850 *Graptolithus proteus* var. *plana,* Barr.—Barrande: 58–59, Pl. 4:15. □ 1881 *Monograptus resurgens* n. sp.—Linnarsson: 515, Pl. 23:13–21. □ 1913 *Monograptus planus* (Barrande).—Elles & Wood: 484–485, Fig. 340, Pl. 48:6a–d. □ 1944 *Spirograptus planus* (Barrande).—Přibyl: 33–35, Pl. 4:1, 8, Pl. 8:6–8, Pl. 11:5–6. □ 1958 *Monograptus planus* (Barrande).—Sudbury: 524–525, Fig. 22b, Pl. 22:92–93. □ 1970 *Monograptus planus* (Barrande).—Rickards: 86, Fig. 11:7. □ 1971 *Monograptus (Spirogr.). planus planus* (Barr. 1850).—Schauer: 73–74, Pl. 27:6–9, Pl. 33:5–7. □ 1974 *Monograptus planus* (Barrande).—Sherwin: 168–170, Figs. 2c–d, Pl. 10:7, 10, 11.

Holotype (by monotypy).—Specimen figured in Barrande (1850, Pl. 4:15); from the *linnaei* Zone of Želkovice, Bohemia.

Material.—About 65 specimens which are preserved flattened or in partial relief.

Horizon and localities.—The *turriculatus* Zone, Øleå (Ø13a) –(Ø15a).

Description.—The rhabdosome is dorsally curved with the strongest curvature at the middle, the proximal and distal ends are only slightly curved. Occasionally the rhabdosome is twisted 180° distally, and then has a ventral curvature. No rhabdosomes with a length exceeding 8 cm have been found. The proximal width at th1 is 0.15 mm and the maximum distal width 1.5 mm.

The proximal thecae have very slender, axially elongated prothecal parts and, with only about one eighth of the thecal length involved in a small apertural hook which occupies one third of the width of the rhabdosome. At the level of about th5–th10 the width increases rapidly from 0.4 mm to 0.9 mm, and the thecae become more triangular with the hooks occupying half the thecal height and half the width of the rhabdosome. In well preserved specimens, either flattened or with low relief, the distal apertural parts of the hooks seem to be twisted, the apertures face laterally, always to the reverse side of the rhabdosome. In the present material the twisting is not seen in the proximal elongated thecae, but these portions are not well preserved. The apertures

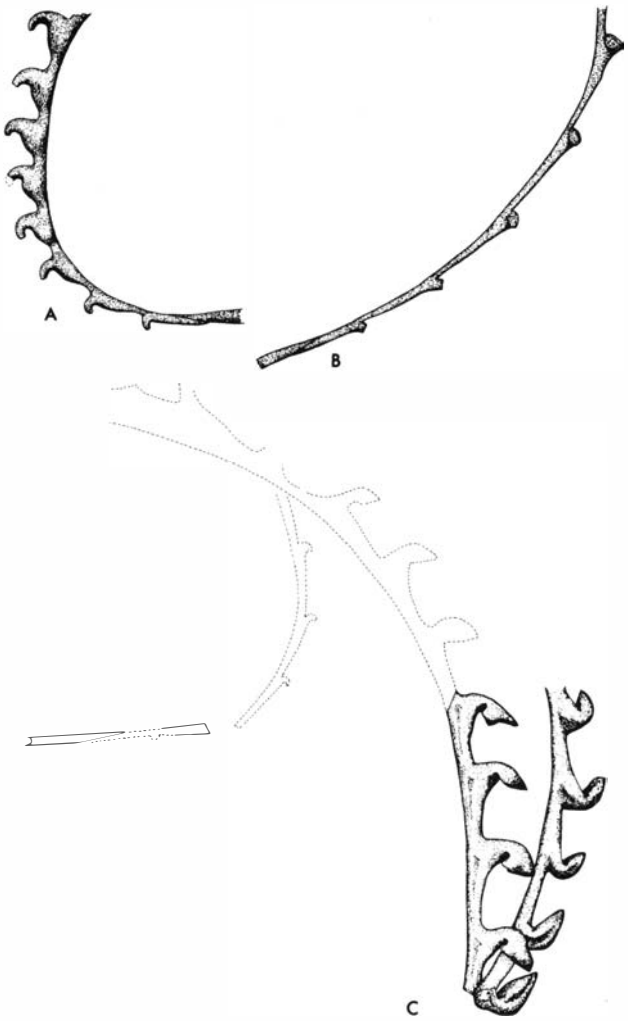


Fig. 19. □ A. *Monograptus communis rostratus* Elles & Wood, 1913. The *gregarius* Zone, Øleå. MMH 13467. ×10. □ B. *Monograptus proteus* (Barrande, 1850). The *crispus* Zone, Øleå. MMH 13468. ×10. □ C. *Monograptus tullbergi* Bouček, 1931?. The *griestoniensis* Zone, Øleå. MMH 13469. ×10.

of the thecae are slightly expanded transversely.

The thecal count is 4 in 5 mm proximally, in the middle part of the stipe 5 in 5 mm, and at the distal end 5.5 in 5 mm.

The sicula is 1 mm long, and the apex is just below the aperture of th1. The width of the aperture is 0.15 mm and the virgella is 0.3 mm long. Th1 originates 0.25 mm from the aperture of the sicula.

Remarks.—About 12 fragmentary specimens up to 2.5 cm long and with a width increasing from 0.9 mm proximally to 1.9 mm distally were found at the base of the *turriculatus* Zone. The thecal spacing varies from 4 per 5 mm proximally to 5 per 5 mm distally. These specimens have a greater dorsoventral width than the specimens from the upper part of the *turriculatus* (where the maximum width is 1.5 mm). The proximal end with sicula has not been found among the early specimens. The early specimens may be compared with the *M. planus obtusus* Schauer which has been recorded from the *linnaei* Zone, at a level roughly corresponding to the lower part of the *turriculatus* Zone on Bornholm. However, the specimens from Bornholm are longer and have longer proximal slender portions than *M. planus obtusus.*

The lateral twisting of the thecal apertural parts is not previously reported from *M. planus,* but has been described by Hutt et al. (1970) from the rather similar *M. proteus,* and is also noted in that species by the author, see below. The torsion of the thecae is also evident in well preserved specimens from the collection of Linnarsson's types of *M. resurgens (=M. planus)* studied by the author at The Geological Survey of Sweden, Stockholm.

M. planus shows a great resemblance to *M. proteus* in the proportions of the rhabdosome and in the twisting of the thecae as well. There probably is an evolution from *M. planus* to *M. proteus,* resulting in increasing coiling of the rhabdosome. *M. planus* is rather frequent throughout the *turriculatus* Zone.

Monograptus proteus (Barrande, 1850)

Fig. 19B, Pl. 10:C

Synonymy.—□ 1850 *Graptolithus proteus* Barr.—Barrande: 58, Pl. 4:12–14. □ 1892 *Monograptus proteus* Barrande.—Törnquist: 40–42, Pl. 3:29–30. □ 1912 *Monograptus proteus* (Barrande).—Elles & Wood: 477–478, Figs. 332a–c, Pl. 48:8a–c. □ 1944 *Spirograptus proteus* (Barrande).—Přibyl: 11–14, Fig. 2a–f, Pl. 3:3–8, Pl. 5:7, Pl. 9:1–3. □ 1970 *Monograptus proteus* (Barrande).—Rickards: 87–88, Fig. 13:13, Fig. 17:14. □ 1970 *Monograptus proteus* (Barrande).—Hutt et al.: 12–13, Pl. 3:51–55. □ 1971 *Monograptus (Spirogr.) proteus proteus* (Barrande).—Schauer: 75, Pl. 30:9, Pl. 31:1–3, Pl. 34:1–2. For further references see Přibyl (1944) and Hutt et al. (1970).

Lectotype.—Designated by Přibyl (1948:50); the specimen figured in Barrande (1850, Pl. 4:12); from the Upper Llandovery of Bohemia.

Material.—30 specimens which are preserved in relief or flattened; no complete specimen has been recorded.

Horizon and localities.—The *crispus* Zone, Øleå (Ø16b)–(Ø17).

Description.—The rhabdosome is coiled in an open spiral. Incomplete fragments up to 15 cm in length have been found. The proximal width is 0.2 mm, distally increasing to a maximum width of 2 mm.

The proximal thecae are slender and axially elongated with apertural hooks occupying one seventh to one eight of the thecal length. The apertures are twisted and face laterally, always to the reverse side of the rhabdosome. The thecae become more triangular distally, and develop prominent hooks which occupy half the thecal length. The apertural parts continue to twist towards the right. The apertures themselves are transversely everted, and the metathecal parts are very slender. The thecae number about 7–8 in the proximal 10 mm while the thecal count is 10 in 10 mm distally.

The sicula is about 1 mm long and 0.2 mm wide at the

aperture. The apex reaches the middle of th1 which is 1.4 mm long.

Remarks.—The torsion of the thecae was described by Hutt et al. (1970) from isolated specimens from Dalecarlia, Sweden. However, the specimens from Bornholm are occasionally very well preserved in full relief and reveal the same torsion of the tecal axis, but the dorsal zig-zag suture is not preserved. No specimens with a sinistral twisting of the apertural parts have been found.

The thecal count of 10 in 10 mm in Bornholm specimens is slightly less than the number (11–12) given by Barrande (1850).

M. proteus occurs in the upper part of the *turriculatus* Zone and the lower part of the *crispus* Zone and is associated with *M. galaensis, M. veles, M. priodon, M. nudus,* and *M. crispus.*

Monograptus tullbergi Bouček, 1931 ?

Fig. 19C

Material.—14 specimens preserved in low relief or flattened.

Hoizon and localities.—The *griestoniensis* Zone, Øleå (Ø18)–(Ø19).

Description.—The rhabdosome is coiled two to three times spirally or irregularly. The maximum length is 5–8 cm. The proximal part is 0.2 mm in width, towards the distal end increasing to 1 mm.

At least five proximal thecae are elongated with slender prothecal parts and reflexed apertural regions, occupying one sixth of the thecal length. Towards the distal part of the rhabdosome the prothecae become triangular; the base of the prothecal parts are 0.4 mm in width. The apertural hooks occupy nearly half the thecal length, they are twisted constantly to the reverse side of the rhabdosome. The apertures face laterally in the rhabdosome and are somewhat transversely expanded. The thecal count is 5 in the proximal 5 mm and distally the number is 8–9 in 10 mm.

The sicula is 1.1 mm long and the apex reaches to 0.4 mm below the aperture of th1 which is 1 mm long. The sicula is 0.15 mm wide at the aperture.

Remarks.—The available specimens of *M. tullbergi?* are more strongly curved than *Monograptus tullbergi tullbergi* Bouček and have a smaller distal width, 1 mm as compared to 1.4 mm in the Bohemian specimens. The shape of the rhabdosome is like that of *Monograptus tullbergi spiraloides* (Přibyl). However, *M. tullbergi?* is separated from this subspecies by the longer and more slender proximal part and the lesser distal width.

The constant torsion of the thecal apertures to the right side of the rhabdosome has not been seen previously in *M. tullbergi* like specimens. However, the present specimens are referable to the *tullbergi* group by the proximal part, which is different from other species of the coiled monograptids, and by the thecal form which in flattened specimens bears resemblance to that in the figure of the lectotype of *M. tullbergi.*

M. tullbergi? resembles *M. proteus,* but has a lesser distal width, in *M. proteus* the distal width is 2 mm.

A specimen of *M. tullbergi* from Bornholm has been figured by Laursen (1940, Pl. 2:8) as *C. grayi* and is possibly included in his description p. 29.

It is probable that the specimens from Bornholm belong to a new subspecies of *M. tullbergi,* but the present material is insufficient for any further separation.

M. tullbergi? appears to be the youngest member in the line *M. planus–M. proteus–M. tullbergi?,* and in which all species have slender proximal parts, more or less coiled rhabdosomes, and torsion of the apertural portion of the thecae.

M. tullbergi? occurs in the upper part of the *griestoniensis* Zone associated with *M. griestoniensis* and *M. veles.*

Monograptus lobiferus lobiferus (M'Coy, 1850)

Fig. 20C, Pl. 10: D

Synonymy.— ☐ 1850 *Graptolites lobiferus.*—M'Coy: 270. ☐ 1876 *Monograptus lobiferus* M'Coy.—Lapworth: 499–500, Pl. 20: 1a–d. ☐ 1892 *Monograptus lobiferus* M'Coy.—Törnquist: 18–20, Pl. 1:37, Pl. 2: 1–3. ☐ ? 1899 *Monograptus harpago* n. sp.—Törnquist: 16–17 (pars), Pl. 3:4–6?, 8–11?. ☐ 1913 *Monograptus lobiferus* (M'Coy).—Elles & Wood: 448–450, Figs. 308a–e, Pl. 45:1a–f. ☐ 1922 *Monograptus lobiferus* M'Coy.—Pedersen: 21–24, Figs. 6a–f. ☐ 1952 *Monograptus lobiferus* M'Coy.—Münch: 106, Pl. 31: 1a–f. ☐ 1971 *Monograptus (Monogra.) lobiferus* (M'Coy).—Schauer: 58, Pl. 36:6–7.

Holotype.—Specimen No. A. 21182, figured in M'Coy (1855, Pl. 1B:3); refigured Elles & Wood (1913, Pl. 45: 1a); from Moffat.

Material.—About 35 specimens, preserved in relief or flattened; all specimens are fragmentary.

Horizon and localities.—The *convolutus* Zone, mainly the lower part, Øleå (Ø11)–(Ø12).

Description.—The rhabdosome is straight or slightly curved, the proximal part is always dorsally curved. The largest fragment is 8 cm long. The width of th1 is 0.5 mm, 0.8 mm at th10, and 1.0 mm at th20 in relief specimens. The maximum width in the distal part is 2.0 mm in relief specimens, and 2.1 mm in flattened specimens.

The thecae show no overlap, and have slender prothecal parts. The metathecae grow away from the axis at about 70°–80°, and for about three quarters of the thecal length are recurved to form a lobe with the aperture facing the proximal part of the rhabdosome. The lobe distally occupies three quarters of the width of the rhabdosome. A few specimens, which are dorsally compressed, show 0.5 mm long paired apertural spines. The lateral apertural spines have also been seen in laterally compressed specimens, especially in proximal portions. The spines were described by Pedersen (1922). The thecal count is 10 per 10 mm in the proximal part

and 7.5 in 10 mm in the exteme distal part of the rhabdosome.

The sicula is 1 mm long and the apex reaches the aperture of th1. Th1 originates 0.25 mm from the aperture of the sicula and is 0.65 mm high.

Remarks.—*M. lobiferus lobiferus* occurs frequently in the lower to middle part of the *convolutus* Zone. Towards the upper part of the *convolutus* Zone *M. lobiferus lobiferus* is succeeded by *M. lobiferus harpago.*

Monograptus lobiferus harpago Törnquist, 1899
Fig. 20A, Pl. 10:E

Synonymy.—□ 1899 *Monograptus harpago* n. sp.—Törnquist: 16–17 (pars), 3:3, 7 (4–6, 8–11 ?). □ ? 1915 *Monograptus knockensis* sp. nov.—Elles & Wood: 462–463, Figs. 321a–b, Pl. 46:8a–b. □ ? 1970 *Monograptus knockensis?* Elles & Wood.—Rickards: 72–73, Pl. 6:6.

Lectotype (here designated).—Specimen figured in Törnquist (1899, Pl. 3:7); from the *cometa* Zone, Tommarp, Scania.

Material.—10 fragmentary specimens which are preserved in relief, or flattened.

Horizon and locality.—The upper part of the *convolutus* Zone, Øleå (Ø13).

Diagnosis (new).—The extreme proximal end is unknown but the most proximal portion is dorsally curved. The distal part of the rhabdosome is slightly flexed. The width increases from 0.3 mm proximally to 1.5 mm distally. The thecae are characteristically lobate, the recurved part is adpressed to the projected portion. The thecae number 11–8 in 10 mm throughout.

Description.—The rhabdosome is straight or gently curved, the longest fragment is 7 cm. The proximal portion is dorsally curved, the main part of the stipe is flexed, commonly slightly ventrally curved. The most proximal width is 0.3 mm, and the width gradually increases to 1.5 mm at the extreme distal end measured in specimens preserved in partial relief.

The thecae are isolated all along the rhabdosome. The proximal thecae are hooked and the hooks occupy one quarter of the thecal height. Towards the distal end of the rhabdosome the recurvature of the hooks gradually increases in such a way that the recurved part becomes closely adpressed to the proximal part of the metatheca. The apertures of the initial thecae face proximally in the rhabdosome, and in the distal portion the increasing recurvature implies that the apertures face dorsally in the rhabdosome. The hooks occupy one fourth of the height of the thecae proximally, increasing to three fourths of the thecal height distally. In well preserved specimens the apertures have a pair of 0.4 mm long lateral spines which are mainly found in the proximal part of the rhabdosome. The sicula has not been observed.

Remarks.—*M. lobiferus harpago* is separated from *M. lobiferus lobiferus* by its lesser width and the more tightly lobed thecae. *M. lobiferus harpago* agrees with the description of *Monograptus harpago* Törnquist given by Törnquist (1899). However, *M. harpago* was erected as a new species, as Törnquist believed that the proximal part of *M. lobiferus* formed a complete involution, although this is not accepted here. However, Törnquist's description of the distal thecae of *M. harpago* and especially the specimen figured on his Pl. 3:7, also shows characters undoubtedly different from those of *M. lobiferus lobiferus.* As the extreme proximal part with sicula of *M. lobiferus harpago* is presently unknown, only the distal parts of the two subspecies can be separated presently.

M. knockensis? in Rickards (1970) will most likely have to be included in *M. lobiferus harpago.* The description of the former perfectly fits Törnquist's old description and the present specimens from the *cometa* band in the *convolutus Zone. M. harpago* was also reported from the *cometa* band by Törnquist (1899). *Monograptus knockensis* Elles & Wood appears to have more isolated thecae and may be somewhat related to *Monograptus singularis* Törnqust. *M. knockensis* occurs in the *crispus* Zone.

In the line *M. lobiferus lobiferus–M. lobiferus harpago,* and possibly further to *M. knockensis* in the *crispus* Zone the lobate thecal type tends to become more isolated. This tendency was also suggested by Törnquist (1899) and Rickards (1970). *M. lobiferus harpago* is recorded from the uppermost part of the *convolutus* Zone and is mainly associated with *O. bellulus, C. cometa extrema,* and *M. convolutus.*

Monograptus clingani (Carruthers, 1867)
Fig. 20E

Synonymy.—□ 1867 *Graptolithus Clingani.*—Carruthers: 369, Pl. 2:8 (not available). □ 1868 *Graptolithus Clingani* Carruthers.—Carruthers: 127, Pl. 5:19a–b (not available). □ 1876 *Monograptus Clingani* Carr.—Lapworth: 501, Pl. 20:3a–c. □ *non* 1897 *Monograptus Clingani,* Carr.—Perner, Pl. 11:15–17. □ 1912 *Monograptus Clingani* (Carruthers).—Elles & Wood: 463–465, Figs. 322a–b, Pl. 46:11a–f. □ 1969 *Monograptus clingani* (Carruthers).—Strachan: 195–196, Pl. 5:1–5.

Lectotype.—Selected by Přibyl (1948:28), as the specimen figured in Carruthers (1868, Pl. 5:19a) (=Elles & Wood (1912, Pl. 46:11a)); from the Birkhill Shales, Britain.

Material.—Two small flattened proximal specimens.

Horizon and locality.—The middle of the *convolutus* Zone, Øleå (Ø12).

Description.—The largest rhabdosome is 1.3 cm long. The two specimens are strongly dorsally curved. The width at th1 is 0.5 mm, increasing to 0.8 mm at th5, 1.0 mm at th10, and distally the maximum width is 1.5 mm at th15.

The thecae are hooked, and the common canal is

rather broad. The hooks distally occupy one third of the width of the rhabdosome, and the thecal apertures face proximally. There may be a slight thecal overlap. The state of preservation is too poor to yield further information about the detailed structures of the thecae. The thecal count is 5 per 5 mm distally.

The sicula is seen in one of the specimens, it is 1.1 mm long and the apex reaches between the apertures of th1 and th2.

Remarks.—The specimens from Bornholm have a common canal like the Elles & Wood (1912) specimen figured Pl. 46:11b. The common canal in the lectotype selected by Přibyl (1948) is wider, a feature which seems to be uncharacteristic for *M. clingani* in Britain (Strachan, 1969).

The two rhabdosomes of *M. clingani* were found on the same slab associated with *M. decipiens* and *P. palmeus.*

Monograptus aff. *becki* (Barrande, 1850)
Fig. 20D

Material.—60 specimens preserved flattened or in low relief. Specimens from Želkovice, Bohemia, and the original specimens of Linnarsson's *M.* cfr. *lobifer* have also been examined.

Horizon and localities.—The lower to middle part of the *turriculatus* Zone, Øleå (Ø13b)–(Ø15).

Description.—The rhabdosome is mainly straight and may attain a length of more than 8 cm. The width increases within the proximal 2 cm from the initial width of 0.35 mm to a distal width of 1.2 mm which is maintained throughout the distal part of the rhabdosome.

The prothecae have parallel walls, and the metathecae are hooked. The overlap is one third of the thecal height and the interthecal septum is inclined at 15° to the axis of the rhabdosome. The retroverted part of the thecal hook occupies one third to half the thecal height. The apertures face proximally in the rhabdosome, they appear wide and have paired, blunt, lateral processes 0.25 mm long (only observed in a few well preserved specimens). The free part of the thecae occupies half the width of the rhabdosome. The thecal spacing is 12 in the proximal 10 mm and distally about 9.5 in 10 mm.

The sicula is 1.3 mm long, and the apex reaches the aperture of th1 which originates 0.25 mm above the aperture of the sicula.

Remarks.—*M.* aff. *becki* resembles *M. becki,* as described by Barrande (1850), in the general form of the rhabdosome and the thecae. However, the specimens from Bornholm have a somewhat straighter rhabdosome, greater initial width, and a slightly more rapid increase in width than the Bohemian specimens.

The specimens from Bornholm are identical to *M.* cfr. *lobifer* described by Linnarsson (1881, Pl. 1:9–16).

M. aff. *becki* is closely related to *M. marri,* but in the former the proximal end is more slender and has more closely set thecae.

M. aff. *becki* is frequent in the middle part of the *turriculatus* Zone and is mainly associated with the zone fossil, *M. halli,* and *R. linnaei.*

Monograptus halli (Barrande, 1850)
Fig. 20B

Synonymy.—☐ 1850 *Graptolithus Halli* Barr.—Barrande: 48–50, Pl. 2:12–13. ☐ 1876 *Monograptus Halli,* Barr.—Lapworth: 354–355, Pl. 13:1a–d. ☐ 1897 *Monograptus Halli,* Barr.—Perner: 13, Pl. 13:19–20. ☐ *Monograptus Halli* (Barrande).—Elles & Wood: 443–445, Figs. 305a–e, Pl. 44:8a–f. ☐ 1952 *Monograptus halli* Barr.—Münch: 105, Pl. 30:3a–b. ☐ 1970 *Monograptus halli* (Barrande).—Rickards: 73, Fig. 13:21, Fig. 16:1. ☐ 1970 *Monograptus halli* (Barrande).—Hutt et al.: 8–9, Pl. 2:23–25. ☐ 1971 *Monograptus (Monograptus) halli* (Barrande).—Schauer: 56, Pl. 36:2–3. ☐ 1974 *Monograptus halli* (Barrande).—Sherwin: 163, Pl. 11:9, 12. For further references see Rickards (1970).

Lectotype.—Designated by Přibyl (1948:29), as the specimen figured in Barrande (1850, Pl. 2:12); from the Llandovery of Bohemia.

Material.—About 50 distal fragments, preserved flattened or with low relief, and one flattened proximal end possibly referable to this species.

Horizon and localities.—The lower to middle part of the *turriculatus* Zone, Øleå (Ø13a)–(Ø15).

Description.—The rhabdosome is straight or slightly flexed. The most distal fragment is 2.5 mm in width. The fragments attain a length of 13 cm.

The thecae have slightly hooked apertural parts with the apertures facing ventrally in the rhabdosome. The thecal overlap depends on the state of preservation, in flattened specimens the overlap is slightly more than half the thecal length. The interthecal septum is inclined at about 45° to the rhabdosome. The distal thecae are about 2 mm long. In well preserved specimens a pair of lateral spines are observed, the spines being 0.5 mm long and ventrally directed. Distally the thecae number 7.5–8 in 10 mm.

One flattened fragment with sicula, possibly referable to *M. halli,* has been found. The sicula is 1.65 mm long and the apex reaches the aperture of th1. The proximal thecae are hooked, the hooks occupy half the width of the stipe. They have no thecal overlap, and the apertures face proximally. The width at th1 is 0.4 mm and at th2 0.6 mm. Only the first 5 thecae, which number 4–5 in 5 mm, are preserved.

Remarks.—*M. halli* may be confused with *M. sedgwickii* and the two graptolites need redefinition. On the basis of the original figure of *M. halli* (Barrande, 1850, Pl. 2:12) and *M. sedgwickii* (Portlock, 1843, Pl. 19:7) it would appear that *M. halli* is characterized by a greater thecal overlap and shorter spines than *M. sedgwickii.* However,

Table 7. Dimensions (in mm).

Spec. No.	Flat or relief	Length	Width of the rhabdosome							Number of thecae		Length of sicula
			th1	th5	th10	th15	th20	th30	dist.	Prox.	dist.	
M. marri												
MMH 13551	F	75	0.5	0.8	0.95	1.0	1.20	1.3	1.66	11/10	9/10	1.4
MMH 13552	R	15							1.8		10/10	
MMH 13553	LR	20	0.5	1.0	1.4	1.8				10/10		
M. priodon?; turriculatus Zone												
MMH 13554	F	55	1.0	1.25	1.5	1.8	2.0	2.25	2.2	12/10	9.5/10	1.4
MMH 13555	R	15	0.75	1.1	1.25					11/10		1.4
MMH 13556	R	7	0.75	1.0						6.5/5		2
MMH 13557	F	18	0.8	1.3	1.8					12.5/10		1.3
M. priodon												
MMH 13558	F	12	0.7	0.9	1.3					14/10		1.25
MMH 13559	LR	230							2.5		8/10	
MMH 13560	F	25	0.75	0.9	1.25					13/10		1.3
MMH 13561	R	6	0.7							6/5		
MMH 13562	F	17	0.75	1.0	1.4	1.75				12.5/10		
MMH 13563	F	25	0.75	0.9	1.33	1.5		1.8		13/10		1.5
MMH 13564	F	140							2.0		7.5/10	
MMH 13565	LR	15	0.67	0.9	1.3	1.8				13/10		1.5
MMH 13566	LR	23	0.66	1.1	1.25	1.75				11.5/10		1.4
MMH 13567	R	28							2.0		10/10	
MMH 13568	R	50	0.66	0.8	1.33	1.6	1.8		2.2	11.5/10	8.5/10	1.5
MMH 13569	F	12							2.6		8/10	
MMH 13570	LR	50	0.75	1.0	1.5	1.8			2.5	12/10	9/10	1.7
MMH 13571	R	11	0.5	0.8	1.4					12/10		1.5
MMH 13572	R	52							2.7		9/10	
MMH 13573	R	50	0.6	0.9	1.25	1.33	1.5	2.0	2.25	12/10	9.5/10	1.7
MMH 13574	F	50	0.66	1.2	1.5				2.5	13/10	10/10	
MMH 13575	F	12	0.7	1.1	1.6	1.7				13/10		1.5
MMH 13576	F	60	0.66	1.0	1.5	1.6			2.5	13/10	9–10/10	1.5
MMH 13577	F	60	0.66	1.0	1.4	1.5			2.4	13/10	10/10	1.5
MMH 13578	F	10	0.66	1.1	1.4					6.5/5		1.5
MMH 13579	F	140							2.85		9/10	
MMH 13580	F	12							2.5		10/10	
MMH 13581	F	42	0.75	0.9	1.3		1.7		2.0	13/10	9.5/10	

Hutt et al. (1970) described isolated specimens of *M. halli* from Dalecarlia with very small, or no, overlap.

The specimens from Bornholm, which have a rather great overlap in flattened distal fragments and short lateral spines, are at the present time regarded as *M. halli.*

Monograptus marri Perner, 1897

Pl. 10:F, Table 7

Synonymy.—☐ 1897 *Monograptus Marri,* n. sp. Perner: 21, Figs. 23–25, Pl. 11:5, 6, 10, 11. ☐ 1912 *Monograptus Marri* Perner.—Elles & Wood: 422–423, Figs. 284a–b, Pl. 42:4a–d. ☐ 1952 *Monograptus priodon marri* Perner.—Münch: 100, Pl. 26:2a–b. ☐ 1970 *Monograptus marri* Perner.—Hutt et al.: 9–10, Pl. 2:26–29. ☐ 1970 *Monograptus marri* Perner.—Rickards: 71–72, Fig. 16:19, Pl. 4:10, Pl. 5:7.

Lectotype.—Designated by Přibyl (1948:30), as the specimen figured in Perner (1897, Pl. 11:11); from Litholav, Bohemia.

Material.—60 specimens which are mainly flattened; a few specimens are preserved with low relief.

Horizon and localities.—The *turriculatus* Zone to the *griestoniensis* Zone, Øleå (Ø13a)?, (Ø13b)–(Ø19).

Description.—The rhabdosome is mainly straight or may be gently curved. The longest fragment is about 8 cm long. Width increases steadily throughout the rhabdosome, but mainly within the proximal 2 cm, from an initial width of 0.5 mm to 1.8 mm in flattened specimens. The maximum distal width is 2.0 mm.

The thecae have a small degree of overlap. They are hooked, of *priodon* type. The hook in the distal thecae occupies half the width of the rhabdosome, and in the proximal part of the stipe, about one third of the width. The apertures face proximally in the rhabdosome and are slightly transversely expanded with small, blunt, lateral processes in some well preserved specimens. The thecal spacing is 10–11 in the proximal 10 mm and distally 9–10 in 10 mm.

The sicula is 1.4 mm long and the apex reaches half

way between th1 and th2. Th1 originates close to the aperture of the sicula which is 0.2 mm in width.

Remarks.—The specimens from Bornholm resemble previously described material (Perner, 1897; Elles & Wood, 1912), except for the thecal spacing which in the present material shows a slightly greater variation, 9–11 in 10 mm compared to the constant 10 thecae in 10 mm given in earlier descriptions.

With regard to thecal structures *M. marri* is closely related to *M. priodon* and *M. parapriodon. M. marri* is distinguished from *M. priodon* by a lesser degree of overlap, a higher thecal number distally, and a smaller distal width. From *M. parapriodon M. marri* differs in having a more slender rhabdosome.

M. marri is rather common in the *turriculatus,* the *crispus,* and the *griestoniensis* zones.

Monograptus priodon (Bronn, 1835)

Pl. 10:B, Table 7

Synonymy.— ☐ 1935 *Lomatoceras Priodon.*—Bronn: 55–56, Pl. 1:13. ☐ 1940 *Monograptus priodon* Bronn.—Laursen: 25, Fig. 15, Pl. 2:1–2. ☐ 1958 *Monograptus (Monograptus) priodon* (Bronn).—Urbanek: 43–47, Figs. 17–20, Pl. 1c: 1–2. ☐ 1971 *Monograptus (Monograptus) priodon priodon* (Bronn).—Schauer: 56–57, Pl. 35:6–8, Pl. 36:8–11, Pl. 37:1–2. Fur further references see e.g. Elles & Wood (1912:418).

Holotype.—Bronn (1835, Pl. 1:13); from the Silurian of Bohemia.

Material.—About 400 specimens, the state of preservation varying from flattened to full relief.

Horizon and localities.—The upper part of the *turriculatus* Zone?, the *crispus* to the *centrifugus* zones. Øleå (Ø16)–(Ø43) and Læså (L1)–(L8).

Description.—The rhabdosome is long, straight or gently curved. The longest distal fragment is 23 cm. The proximal end of the rhabdosome is occasionally gently dorsally curved. The width of the rhabdosome at th1 is about 0.6–0.75 mm, increasing to about 1 mm at the level af th5, and 1.25–1.5 mm at th10. Specimens from the *centrifugus* Zone attain a width of 3 mm (flattened). In flattened specimens from subjacent zones the distal width is generally 2.5 mm.

The thecae are hooked, and overlap for about one third of their length. In relief specimens the inclination of the interthecal septum decreases from 60° in the proximal part of the rhabdosome to 45° in the distal part. The thecal apertures face proximally in the rhabdosome. They are slightly laterally everted, and in the proximal thecae lateral spines about 0.25 mm long are occasionally seen. The thecae number 11.5–14 in the proximal 10 mm; in the distal part the thecal count is 7.5–10 in 10 mm. Generally the thecal spacing varies from 13–9 per 10 mm throughout the rhabdosome.

The sicula is 1.3–1.7 mm long, generally 1.5 mm, and the apex reaches the level of the aperture of th2. Th1 originates 0.25 mm from the aperture of the sicula.

The earliest representatives of *M. priodon* in the upper part of the *turriculatus* Zone are slightly different. The material includes about 50 specimens. In flattened specimens the proximal ends have a greater width than that of the younger representatives of *M. priodon.* The width at the level of th1 is 0.8–1.0 mm, and 1.3 mm at th5; at th5 the maximum width in the specimens from the overlying zones is 1.1 mm. The thecal spacing, the size, and position of the sicula are the same in the two forms. The thecal morphology is slightly different, as the hooks of the proximal thecae in the oldest specimens are more recurved, implying that the apertures face almost dorsally in the rhabdosome.

Remarks.—The author's specimens of *M. priodon* are not different from earlier described material from outside Bornholm. Only the oldest representatives of *M. priodon* may, based on their greater proximal width and the more pronounced hooked proximal thecae, possibly be regarded as a separate early form of *M. priodon.* Otherwise *M. priodon* is, morphologically, an extremely homogeneous species during its vertical range, except for the uppermost specimens from the *centrifugus* Zone which attain a greater distal width. An increase in size (sicula length and the width at th5) throughout the range was also reported by Lenz (1974).

M. priodon is distingushed from *M. marri* by greater diversity in the thecal spacing and the greater distal width. *Monograptus pandus* (Lapworth), which seems to be very close to *M. priodon,* needs redescription, as the lectotype appears to be unrecognizable (Strachan, 1971). Dimensions of the specimen figured by Elles & Wood (1912, Pl. 42:3a, BU 1576), probably the original of Lapworth, are referable to a proximal end of *M. marri,* as also suggested by Přibyl (1948). However, the distal part of *M. pandus* appears to be too insufficiently known to enable separation from *M. priodon.*

Monograptus turriculatus (Barrande, 1850)

Pl. 10:4

Synonymy.— ☐ 1850 *Graptolithus turriculatus* Barr.—Barrande: 56–57, Pl. 4:7–11. ☐ 1944 *Spirograptus turticulatus turriculatus* (Barrande).—Přibyl: 27–28, Pl. 10:1–2. ☐ 1970 *Monograptus turriculatus* (Barrande).—Rickards: 77, not figured. ☐ 1971 *Monograptus (Spirogr.) turriculatus turriculatus* (Barr.).—Schauer: 74, Pl. 30:1–5, Pl. 31:11–13, Pl. 45:1–3. ☐ ?1974 *Monograptus turriculatus* (Barrande)?.—Sherwin: 172–173, Pl. 12:6. For further references see Přibyl (1944).

Lectotype.—Subsequently designated by Přibyl (1944:28); the specimen figured in Barrande (1850, Pl. 4:10); from the Llandovery of Bohemia.

Material.—About 75 specimens which are flattened or preserved with low relief.

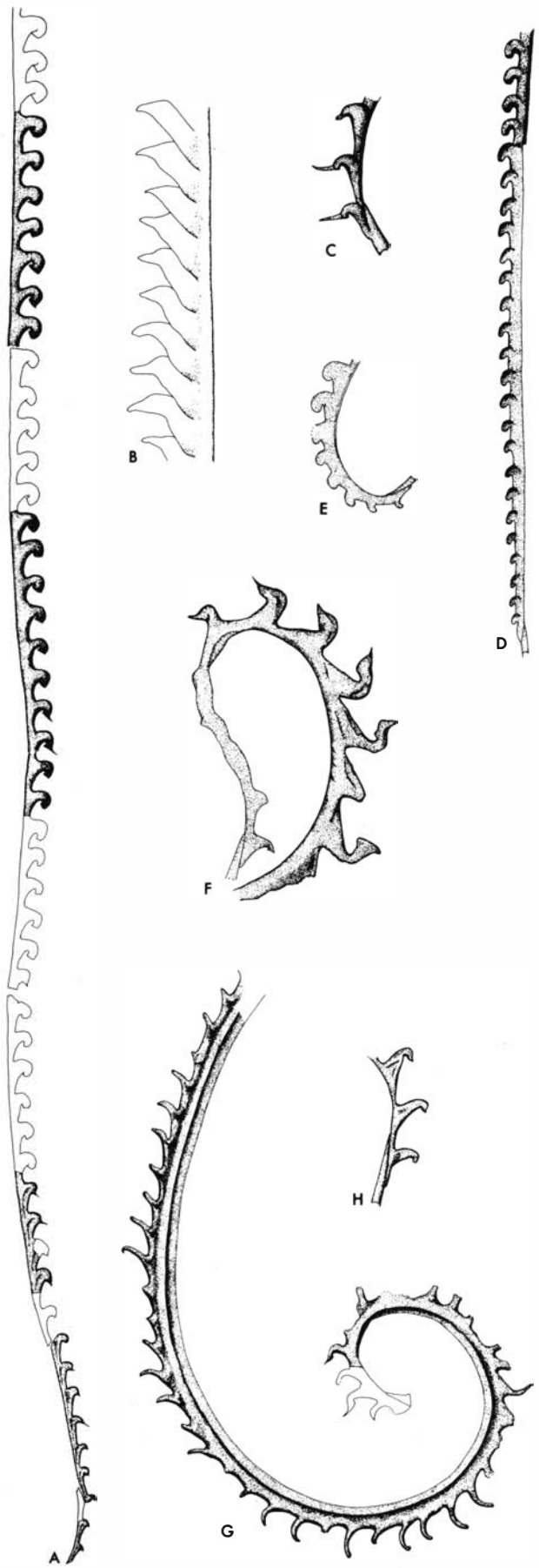


Fig. 20. □ A. *Monograptus lobiferus harpago* Törnquist, 1899. The *convolutus* Zone, Øleå. MMH 13470. ×5. □ B. *Monograptus halli* (Barrande, 1850). The *turriculatus* Zone, Øleå. MMH 13471. ×5. □ C. *Monograptus lobiferus lobiferus* (M'Coy, 1850). Proximal part. The *convolutus* Zone, Øleå. MMH 13472. ×10. □ D. *Monograptus* aff. *becki.* (Barrande, 1850). The *turriculatus* Zone, Øleå. MMH 13473. ×5. □ E. *Monograptus clingani* (Carruthers, 1867). The *convolutus* Zone, Øleå. MMH 13474. ×5. □ F. *Monograptus spiralis spiralis* (Geinitz, 1842). Proximal part. The *spiralis* Zone, lower part, Øleå. MMH 13475. ×10. G–H. *Monograptus spiralis excentricus* n. ssp. Middle part of the *spiralis* Zone, Øleå. □ G. Holotype. Rhabdosome without the proximal end. MMH 13476. ×5. □ H. Proximal end. MMH 13477. ×10.

Horizon and localities.—The *turriculatus* Zone, Øleå (Ø13a) –(Ø16a).

Description.—The rhabdosome is coiled in a conical spiral with up to 8 whorls. The stipe may attain a length of more than 5 cm. The width at th1 is 0.5 mm and this increases steadily to a distal width of 1.5 mm (measured in flattened specimens excluding the thecal spines).

The thecae are isolated triangular with small apertural hooks. The common canal occupies about half the width of the rhabdosome. The thecal apertures are provided with two lateral spines with a maximum length of 2.5 mm. The true nature of the apertures has not been revealed as all the specimens are too flattened. The thecal count is 7 in 5 mm distally in the rhabdosome.

The sicula is 1 mm long and the apex reaches between th1 and th2.

Remarks.—The thecal structures of *M. turriculatus* resemble those of *M. spiralis* s.l., especially the structures of the thecae in the distal part of the *spiralis* rhabdosome.

The specimens from Bornholm are not different from specimens previously described from Bohemia (Barrande, 1850), Sweden (Törnquist, 1892), and Britain (Elles & Wood, 1912).

The greater part of small specimens of *M. turriculatus* are found in the lower part of the *turriculatus* Zone, the level from which *Monograptus turriculatus minor* has been reported (Bouček, 1932). However, is is not possible to recognize the subspecies of *M. turriculatus* on Bornholm, as the specimens of *M. turriculatus minor,* which were described by Bouček (1932), appear to be identical to juveniles of *M. turriculatus* s.l.

Monograptus veles (Richter, 1871)

Pl. 11: D

Synonymy.— □ 1871 *Nautilus veles* n. sp.—Richter: 243, Fig. p. 243. □ 1883 *Monograptus discus* Törnquist.—Törnquist: 24–25. □ 1892 *Monograptus discus* Törnq.—Törnquist: 39–40, Pl. 3: 27–28. □ 1913 *Monograptus discus* Törnquist.—Elles & Wood: 439–440, Figs. 302a–c, Pl. 44: 5a–d. □ 1940 *Monograptus discus* Tqu.—Laursen: 26, Fig. 18, Pl. 1: 9. □ 1952 *Monograptus veles* Richt.—Münch: 106, Pl. 30: 10a–c. □ 1970 *Monograptus discus* Törnquist.—Rickards: 76–77, Pl. 6: 8. □ 1971 *Monograptus (Monogr.) veles* (Reinh. Richter).—Schauer: 59, Fig. 5, Pl. 35: 1–3, Pl. 36: 16–18. For further references see Rickards (1970).

Holotype.—The specimen figured in Richter (1871, Fig. p. 243); from the Silurian of Thüringia.

Material.—About 50 specimens which are mainly preserved flattened or with low relief.

Horizon and localities.—The *crispus* to the *griestoniensis* zones, Øleå (Ø17)–(Ø19).

Description.—The rhabdosome is small, ventrally coiled into a tight, apparently plane spiral. The spiral is subellipsoidal with the longest axis up to 6 mm. The rhabdosome attains a maximum length of 2 cm. The width increases from 0.5 mm at th1 to 1.0 mm at th8 and to a maximum of 1.5 mm at the level of th20 (measured in relief specimens).

The thecae are hooked and *priodon* like. The prothecal part is rather thick and the apertural region slender compared to typical *priodon* thecae. The thecal overlap is small, increasing with the degree of flattening. The interthecal septum is inclined mainly at about 70° to the axis of the rhabdosome. All the structures of the apertures are not clearly visible, but the apertures are elliptical, lateral everted, and with paired apertural spines. The apertures face subventrally to proximally in the rhabdosome. In dorso-ventrally flattened specimens the two apertural spines point to either side of the rhabdosome, and here the maximum length of the spines has been measured as 1.5 mm.

The sicula is 1 mm long and the apex reaches just below the base of th3. The width of the sicula at the aperture is 0.2 mm. A small virgella is seen in one specimen. Th1 grows out very close to the base of the sicula.

Remarks.—*M. veles* is easily separated from all other monograptids, and the present material from Bornholm does not deviate from earlier descriptions. No stratigraphic variation in size has been found within the range of the species on Bornholm.

M. veles was originally described as a nautiloid, *Nautilus veles,* by Richter (1871). Later Törnquist (1883) described the graptolite from Dalecarlia and named the species *Monograptus discus.* Here the original name is retained.

Monograptus spiralis spiralis (Geinitz, 1842)

Fig. 20F, Pl. 11:C

Synonymy.—☐ 1842 *Graptolithus spiralis.*—Geinitz: 700, Pl. 10:26–27. ☐ 1883 *Cyrtograptus dubius* n. sp.—Tullberg: 33–34, Pl. 4: 19–24. ☐ 1883 *Cyrtograptus spiralis* Gein. sp.—Tullberg: 34–35, Pl. 4: 1–3. ☐ 1932a *Monograptus spiralis* Geinitz.—Bulman: 13–14, Figs. 2a–d, Pl. 6: 15–16. ☐ 1940 *Monograptus spiralis* Gein.—Laursen: 28, Fig. 23, Pl. 2:5. ☐ 1944 *Spirograptus spiralis spiralis* (Geinitz).—Přibyl: 6–9, Fig. 1:3–4, Pl. 1: 1–4, Pl. 5: 1–3. ☐ 1958 *Monograptus spiralis* (Geinitz).—Sudbury: 513–514, Pl. 21:79–82. ☐ 1970 *Monograptus spiralis* (Geinitz) sensu lato.—Rickards: 88–89, not figured. ☐ 1971 *Monograptus (Spirogr.) spiralis spiralis* (Geinitz).—Schauer: 76–77, Pl. 32: 1–5, Pl. 33: 1–2. Further references in Přibyl (1944).

Lectotype.—Designated by Přibyl (1944:7), as the specimen figured by Geinitz (1842, Pl. 10:26); from the Llandovery of Germany.

Material.—About 20 specimens which are preserved with relief or flattened.

Horizon and localities.—The *spiralis* Zone and the lowermost part of the *lapworthi* Zone, Øleå (Ø21)–(Ø29), Læså (L3)–(L8).

Description.—The rhabdosome is coiled in a low spiral, generally with 4–5 whorls, but large specimens have 7–8 whorls. The extreme proximal end is always dorsally curved. Laterally compressed specimens may appear as low cones. The maximum length of the rhabdosome is 10 cm in most specimens, but an extreme length of 50 cm has been found in one specimen (Pl. 11:C). The rhabdosome is 0.6–0.7 mm in width at th1, and the width increases steadily to 3 mm at the distal end.

The thecae are isolated triangular and hooked. The common canal occupies an increasingly greater part of the width of the rhabdosome during growth, from about one quarter proximally to one half distally. The thecal apertures have lateral projections as described in Bulman (1932a), but all specimens from Bornholm show a twisting of the thecal apertures produced by later compression. In general only one of the lateral projections is seen, as the other is broken off or concealed in the sediment. The thecae number 6 per 5 mm proximally, in the distal part 8 per 10 mm.

The sicula has only been observed in a few badly preserved specimens. The length of the sicula is about 1.1 mm and the apex reaches the base of the protheca of th2.

Remarks.—*M. spiralis spiralis* is easily distinguished from other monograptids by the general form of the rhabdosome and the thecal structure. The sicula in the specimens from Bornholm is shorter than described by Sudbury (1958) who found the sicula to be 1.4 mm long, with the apex situated between th2 and th3.

On Bornholm one extremely long specimen was found in the lower part of the *spiralis* Zone. The length of the rhabdosome is about 50 cm which is twice the maximum length mentioned by Přibyl (1944).

M. spiralis spiralis is absent in the middle part of the *spiralis* Zone and is probably here replaced by *M. spiralis excentricus.* However, there is no difference in the proportions of the rhabdosomes between specimens of *M. spiralis spiralis* found in the lowermost part of the *spiralis* Zone and in the lower part of the *lapworthi* Zone.

Throughout its range *M. spiralis spiralis* is associated with *M. priodon,* in the lower part of the zone with *M. cultellus, M. vomerinus* n. ssp., *M. anguinus,* and in the upper part with *M. linnarssoni, C. lapworthi,* and *B. pulchellus.*

Monograptus spiralis excentricus n. subsp.
Figs. 20G–H

Synonymy.— ☐ 1940 *Monograptus spiralis* Gein.—Laursen: 28 (pars.), Pl. 2:5.

Holotype.—Specimen No. MMH 13476, Fig. 20:G, the middle part of the *spiralis* Zone, loc. 26, Øleå.

Derivation of name.—excentricus, alluding to the excentrical coiling of the rhabdosome.

Material.—About 40 specimens which are preserved with low relief or flattened.

Horizon and localities.—The middle of the *spiralis* Zone, Øleå (Ø26) and Læså (L6).

Diagnosis.—The rhabdosome is excentrically coiled with a maximum of two whorls. The extreme distal portion is slightly ventrally curved. The width increases from 0.65 mm proximally to about 2 mm distally. The thecae are of *spiralis* type, numbering 9–10 per 10 mm.

Description.—The rhabdosome may be more than 15 cm long and is dorsally curved in the proximal end. The main part of the rhabdosome is coiled into one or two excentric whorls. The extreme distal part is commonly ventrally curved. Width increases steadily within the proximal 20 thecae from 0.65 mm at th1–th3 to 2 mm at th20, and this width is maintained throughout the distal part (measured in flattened specimens).

The thecae are of *spiralis* type, isolated, somewhat triangular, hooked, and the apertures have paired lateral projections as those of *M. spiralis spiralis.* Proximally the common canal is 0.2 mm wide, increasing to 0.7 mm distally. The thecal number is 5 per 5 mm proximally and distally 9 in 10 mm.

The sicula is 1.4 mm long and 0.2 mm wide at the aperture. The apex reaches the middle of the protheca of th2. Th1 originates 0.3 mm from the aperture of the sicula.

Remarks.—M. spiralis excentricus agrees with *M. spiralis spiralis* with regard to the thecal number per 10 mm, and the thecal morphology. However, the maximum distal width, 2 mm, of *M. spiralis excentricus* is less than that of *M. spiralis spiralis* (2 mm to 3 mm) and the shape of the rhabdosomes is different. *M. spiralis excentricus* is only coiled twice and has a conspicuously excentric mode of coiling, whereas *M. spiralis spiralis* is enrolled in a more concentrical spiral.

The new subspecies is distinguished from *Monograptus spiralis contortus* (Perner) by its greater width, lesser thecal number per 10 mm, and more coiled rhabdosome. *M. spiralis excentricus* differs from *Monograptus grobsdorfiensis* (Hemman) by the greater width and by the thecal morphology.

M. spiralis excentricus is restricted to one horizon in the middle of the *spiralis* Zone, where it occurs frequently and is associated with *M. vomerinus vomerinus, M. cultellus,* and *M. priodon.*

Monograptus cultellus Törnquist, 1881
Pl. 11:B

Synonymy.— ☐ 1881 *Monograptus cultellus* n. sp.—Törnquist: 434–436, Pl. 17:1a–b. ☐ 1883 *Monograptus cultellus* Törnqu.—Tullberg: 30, Pl. 1:26–27. ☐ 1892 *Monograptus cultellus* Törnq.—Törnquist: 17–18, Pl. 1: 32–35. ☐ 1912 *Monograpltus cultellus* Törnquist.—Elles & Wood: 423–424, Fig. 285, Pl. 42:9a–b. ☐ 1940 *Monograptus cultellus* Tqt.—Laursen: 25–26, Figs. 16a–b. ☐ 1952 *Monograptus cultellus* Tq.—Münch: 100, Pl. 26: 8a–c.

Types.—The original specimens of Törnquist (1881); from the Silurian of Dalecarlia, Sweden.

Material.—About 50 specimens which are preserved in full relief to completely flattened.

Horizon and localities.—The lower part of the *spiralis* Zone, Øleå (Ø21)–(Ø22).

Description.—The rhabdosome is small, straight or with a slight ventral curvature. The maximum length is 1 cm. The width increases quickly from 0.65 mm at th1 to 1 mm at th3. At th6 the width is 1.4 mm; therefrom remaining constant to the distal end of the rhabdosome (measured in a relief specimen). The stipe is distally prolonged with an up to 4 mm long virgula.

The thecae are hooked, similar to those of *M. priodon.* However, the prothecal part in *priodon* forms grows upwards, whereas the initial parts of the prothecae of *M. cultellus* grow downwards towards the proximal portion of the rhabdosome. This implies that the proximal part of the interthecal septum is inclined at about 135° to the axis of the rhabdosome. The metathecal part changes direction and grows slightly upwards, the dorsal walls of this part are perpendicular to the axis of the rhabdosome. In well preserved relief specimens there is only a very small overlap of the thecae. In flattened specimens the sutures between successive thecae are mostly situated perpendicular to the stipe.

In the proximal thecae the retroverted part of the thecal hook occupies about one third of the width of the rhabdosome. Distally this part is comparatively smaller, only one fifth of the width. The apertures face subdorsally in the rhabdosome but appears to be similar to those of *M. priodon.* Two small lateral spines are observed on each aperture. From the level of th2 the thecae number 8 per 5 mm.

The sicula is conspicuous, 1.3 mm long, and the apex reaches the base of th3. The aperture of the sicula is 0.15 mm in width. Th1 originates 0.15 mm from the aperture of the sicula.

Remarks.—The present specimens of *M. cultellus* are not different from specimens described from Sweden and Germany. *M. cultellus* is restricted to a thin horizon in the lower part of the *spiralis* Zone and is associated with *M. spiralis spiralis, M. priodon, M. anguinus, M. continens,* and *M. vomerinus* n. spp.

Monograptus praecedens Bouček, 1931
Pl. 11:A

Synonymy.—□ 1931 *Monograptus praecedens* n. sp.—Bouček: 6, 17, Figs. 3a–b. □ 1952 *Monograptus praecedens* Bouček.—Münch: 100, Pl. 26:6a–b. □ ? 1971 *Monograptus (Monograptus) priodon praecedens* Bouček.—Schauer: 57, Pl. 36:14–15, Pl. 37:3.

Lectotype.—Designated by Přibyl (1948:32), as the specimen figured in Bouček (1931, Fig. 3a); from the *spiralis* Zone, Bohemia.

Material.—About 30 specimens which are preserved flattened or in very low relief.

Horizon and localities.—The lower part of the *centrifugus* Zone, Øleå (Ø34)–(Ø35), Læså (L1).

Description.—The rhabdosome is straight, frequently with a slightly dorsally curved proximal portion. The maximum length of the rhabdosome is 4 cm. An expansion takes place within the proximal 10 mm from an initial width of 0.8 mm to 2.5 mm which is maintained throughout the distal part of the rhabdosome.

The thecae are hooked and of the *priodon* type, with a larger overlap. Throughout the stipe the interthecal septum is inclined at 45° to the rhabdosome, and the common canal occupies about one third of the width of the stipe. The retroverted hooked part of the thecae occupies proximally about one third of the width of the rhabdosome and distally one quarter of the width. The apertures face proximally and appear to be of the *priodon* type with small lateral eversions. The apertures are generally at the same level as the top point of the hooks from the preceding thecae. The thecal count is 15 in the proximal 10 mm and in the most distal portion of the rhabdosome 11 in 10 mm.

The sicula is 1.5 mm long and the apex reaches almost to the level of the aperture of th3. Th1 originates very close to the aperture of the sicula.

Remarks.—The shape of the rhabdosome of *M. praecedens* may be compared to the *flemingii* forms in late Wenlock, but the thecae have apertures facing proximally, and which are rather similar to those of *M. marri* and *M. priodon*. *M. praecedens* is distinguished from *M. priodon* by its greater proximal width, the rapid increase in width over the first 10 mm, and by the more closely set thecae. *M. praecedens* is distinguished from *M. flemingii flemingii* by the more closely set thecae. *M. praecedens* differs from *Monograptus flemingii primus* Elles by the more slow widening of the rhabdosome, and from *Monograptus flemingii compactus* Elles & Wood by the thecal spacing.

Schauer (1971) reported *Monograptus priodon praecedens* from the *testis* Zone, but his material shows a greater width and more closely spaced thecae than *M. praecedens* from Bornholm. In Schauer (1971, Pl. 36:15) a thecal number of 16 in 10 mm in the proximal part of the specimen is evident, although the specimen is dorsoventrally compressed.

Tullberg's collection from Röstånga in Scania contains specimens with a *praecedens* appearance. They have a rhabdosome length of up to 6 cm and a maximum width of 3 mm. The thecal count is 12 in the proximal 10 mm and 9–11 in the distal 10 mm. These specimens were reported by Tullberg from the *murchisoni* Zone.

M. praecedens occurs in a 3 m thick sequence in the middle part of the *centrifugus* Zone on Bornholm. The originally described material was reported from the *spiralis* Zone in Bohemia.

Monograptus crispus Lapworth, 1876
Fig. 21B

Synonymy.—□ 1876 *Monograptus crispus* sp. nov.—Lapworth: 503–504, Pl. 20:7a–c. □ 1907 *Monograptus gemmatus* Barrande.—Törnquist: 21, Pl. 3:26–27. □ 1912 *Monograptus crispus* Lapworth.—Elles & Wood: 456–457, Figs. 314a–c, Pl. 45:6a–f. □ 1951 *Monograptus (Globosograptus) crispus* Lapworth.—Bouček & Přibyl: 8–10, Pl. 1:1–7, Pl. 2:1–3. □ 1970 *Monograpus crispus* Lapworth.—Rickards: 77–78, Fig. 16:12. □ 1971 *Monograptus (Streptogr.) crispus* Lapworth.—Schauer: 72, Pl. 24:4–6, Pl. 25:1–2.

Lectotype.—Subsequently designated by Elles & Wood (1912, Pl. 45:6a). The specimen was figured by Lapworth (1876, Pl. 20:7a); from Gala Beds, Galashield, Scotland.

Material.—About 10 specimens which are all fragmentary and flattened.

Horizon and locality.—The *crispus* Zone, Øleå (Ø17).

Description.—The rhabdosome is s-shaped. The extreme proximal end is dorsally curved, the mesial part is straight, and the distal portion ventrally curved. The largest specimen has a length of 1.5 cm. The width of the dorsally curved proximal portion is less than 0.2 mm; the width of th1? is 0.15 mm. The width increases slightly in the straight mesial part. From the mesial to the ventrally curved distal portion, at the level of th6–th8, the width quickly increases to a maximum of 1 mm which is maintained all the way to the distal end.

The thecae are isolated and somewhat enrolled throughout the rhabdosome. The prothecal parts are parallel sided proximally in the stipe and somewhat triangular distally. The apertural region is coiled. The recurved part of the proximal thecae is about one tenth of the thecal length, and is tightly adpressed to the prothecal part. Distally the coiled part has increased in size and constitutes about half the thecal length. The retroverted portion is slightly removed from the protheca. Proximally the thecal count is 4.5 in 5 mm, distally the number is 10 in 10 mm.

The author's material of *M. crispus* has not revealed the sicula.

Remarks.—The few specimens described here appear to

Fig. 21. □ A. *Monograptus praecedens* Bouček, 1931. The *centrifugus* Zone, Øleå. MMH 13478. ×5. □ B. *Monograptus crispus* Lapworth, 1876. The *crispus* Zone, Øleå. MMH 13479. ×10. □ C. *Monograptus drepanoformis* Toghill & Strachan, 1970. The *griestoniensis* Zone, Øleå. MMH 13480. ×5. □ D–E. *Monograptus* n. sp.?. The lower part of the *spiralis* Zone, Øleå. □ D. Proximal end, flattened specimen. MMH 13481. ×10. □ E. Distal fragments in full relief. MMH 13482. ×10.

be identical to the Lapworth (1876) specimens.

In the horizon, where *M. crispus* occurs, long slender fragments with a nearly uniform width of 0.33–0.5 mm are found. The fragments are more than 2 cm long, possibly too long to represent proximal parts of *M. crispus*. The apertural parts of the thecae are coiled, closely adpressed to the rhabdosome. The thecae number 6–7 in 10 mm. Some specimens have a sicula which is 1 mm long and with an 0.5 mm long virgella. The apex reaches 0.6 mm below the aperture of th1. Th1 is 1.1 mm long, 0.15 mm in width, and originates 0.6 mm from the aperture of the sicula.

M. crispus is here recorded for the first time on Bornholm, but has earlier been reported from the Slagelse Boring on Sealand (Sorgenfrei & Buch, 1964, and C. Poulsen, 1974). *M. crispus* is rare on Bornholm and only fragments have been recorded.

Monograptus drepanoformis Toghill & Strachan, 1970
Fig. 21C

Synonymy.—□ 1970 *Monograptus drepanoformis* n. sp.—Toghill & Strachan: 517–518, Figs. 2a–f, Pl. 104:1–4.

Holotype.—BMNH Q3072b. The specimen is figured in Toghill & Strachan (1970, Fig. 2a, Pl. 104:1); from Grieston Quarry, Peeblesshire, Llandovery Series, Scotland.

Material.—4 flattened specimens.

Horizon and localities.—The *griestoniensis* Zone, Øleå (Ø18)–(Ø19).

Description.—The short rhabdosome is shaped as a question-mark. The maximum length is about 1 cm. The proximal part is slightly dorsally curved and the distal portion is ventrally curved. The width increases rapidly from 0.25 mm at th1 to 1.2 mm distally.

The longest specimen has 8 thecae preserved. The prothecae of the proximal thecae have nearly parallel walls, and the retroverted part of the apertural hooks occupy about one quarter of the thecal height. Distally the thecae become triangular, and the open apertural hooks occupy two thirds of the height of the thecae. The apertures face proximally and seem to be slightly enlarged. The proximal thecae number 3 per 2.5 mm and distally in the rhabdosome the spacing is 2.5 per 2.5 mm.

The sicula is 1.2 mm and the apex reaches the base of th2.

Remarks.—The specimens from Bornholm are identical to the original specimens described by Toghill & Strachan (1970). *M. drepanoformis* appears to be related to *M. crispus*, but is easily recognized by the shape of the rhabdosome and the thecal structure. *M. drepanoformis* is rare in the *griestoniensis* Zone and occurs associated with *M. griestoniensis, M. priodon, M. nudus,* and *M. tullbergi?*.

Monograptus n. sp. ?
Figs. 21D–E

Material.—15 fragmentary specimens, preserved with relief or flattened.

Horizon and localities.—The lowermost part of the *spiralis* Zone, Øleå (Ø21)–(Ø22).

Description.—The rhabdosome fragments are irregularly curved, with the thecae situated mostly on the concave side of the rhabdosome. The length of the largest fragment is 3 cm. The width at the level of th1 is 0.4 mm, the distal width is 0.8 mm in relief specimens.

The thecae are all isolated. They are slightly triangular, with long slender prothecal parts. The metathecal part is laterally coiled in a circle, the plane of which is perpendicular to the axis of the rhabdosome, and constantly

with the apertural parts to the obverse side of the stipe. The thecal apertures themselves are not clearly seen, but must face inwards, towards the initial part of the metathecae. The coiled part of the thecae occupies at least two thirds of the width of the rhabdosome, and the recurved apertural region about one third of the width. The height of the metathecae is about one quarter of the thecal height. In relief specimens the base of the prothecal parts is 0.2 mm in width. The thecae number distally 4 per 5 mm.

A single specimen showing the sicula was found. The length of sicula is 1.25 mm and the apex reaches the base of the protheca of th2. Th1 is 0.75 mm high and originates 0.25 mm from the aperture of the sicula. Th2 is 1 mm high.

Remarks.—*M.* n. sp. ? is similar to *M. singularis,* but deviates from this species through its lesser distal width. Furthermore, the thecae of *M. singularis* have the apertural portions retroverted towards the proximal part of the rhabdosome. *M.* n. sp. ? is distinguished from *Monograptus wimani* Bouček by its greater width and the more closely set thecae in the distal part. The exact structures of the thecae of *M. wimani* are unknown. *M.* n. sp. ? is separated from *Monograptus sartorius* Törnquist by its greater width.

M. n. sp. ? bears some resemblance to *Cyrtograptus grayi* Tullberg (1883, Pl. 3:6–7). The types of *C. grayi* cannot be traced. However, in the Tullberg collection at S.G.U., Stockholm, flattened specimens, labelled *Cyrtograptus Grayi,* show resemblance to *M.* n. sp. ?. The thecal number in these specimens is 8–9 in 10 mm distally, and the distal width is 1 mm. The rhabdosomes are irregularly coiled, but the detailed thecal structures were not visible.

M. n. sp. ? is found together with *M. spiralis spiralis, M. anguinus, M. vomerinus* n. ssp., *M. priodon, M. continens,* and *M. cultellus* in a thin horizon in the lower part of the *spiralis* Zone.

Monograptus speciosus Tullberg, 1883

Fig. 22A$_{1-2}$, Pl. 12: A

Synonymy.—□ 1883 *Monograptus speciosus* n. sp.—Tullberg: 21, Pl. 2: 16–19. □ 1940 *Monograptus speciosus* Tull.—Laursen: 27, Fig. 20, Pl. 2:3. □ 1942 *Monograptus (Streptograptus) speciosus* (Tullberg).—Bouček & Přibyl: 8–9, Figs. 3o–s, Pl. 2: 7–9. □ 1952 *Streptograptus speciosus* Tullb.—Münch: 111, Pl. 35: 5.

Lectotype.—Designated by Bouček & Přibyl (1942: 8) as the specimen figured in Tullberg (1883, Pl. 2: 19); from the *Cyrtograptus* Shale, Scania.

Material.—25 specimens preserved flattened or width partial relief.

Horizon and localities.—The lower part of the *lapworthi* Zone, Øleå (Ø29), (Ø40), and Læså (L5).

Description.—The rhabdosome is slender and mainly slightly curved, generally with the thecae on the concave side of the rhabdosome. The longest fragment has a length of 10 cm. The width increases gradually from 0.3 mm proximally to 1.25 mm distally.

All the thecae are hooked, and the hook occupies one third of the width of the rhabdosome. The thecal overlap increases from one fifth proximally to one third in the distal portion of the rhabdosome. The angle of inclination of the interthecal septum decreases throughout the rhabdosome from 45° proximally to 20° distally. In the proximal thecae the retroverted part of the thecal hook occupies one third of the thecal height and, in the distal thecae, only about one sixth of the height. The thecae number 9.5 per 10 mm throughout the rhabdosome.

No specimens have been found width the proximal end and sicula preserved. Some specimens are bipolar, and occasionally a sicula like structure is developed at the junction between the original stipe and the pseudocladium.

Remarks.—In the "diversograptid" specimens no transverse rim indicating the aperture of the sicula has been found. The bipolar outgrow is different from specimen to specimen and is regarded as a regeneration phenomenon. The sicula like structure is possibly an outgrowth to strengthen the rhabdosome.

The thecae of *M. speciosus* are hooked and not of the "streptograptid" type as described by Bouček & Přibyl (1942). However, the exact thecal structures, especially the form of the apertures, are obscure in the present material.

M. speciosus is characteristic of the lower part of the *lapworthi* Zone and is associated with *R. geinitzianus angustidens, S. grandis grandis, M. linnarssoni, M. priodon, M. vomerinus vomerinus,* and *C. lapworthi.*

Monograptus minimus cautleyensis Rickards, 1965

Fig. 22B

Synonymy.—□ 1965 *Monograptus minimus cautleyensis* subsp. nov.—Rickards: 226, Figs. 3c–d, Pl. 30: 1.

Holotype.—HUR/IM/50, figured in Rickards (1965, Fig. 3d); from the *centrifugus* Zone, Howgill Fells, Northern England.

Material.—25 specimens mostly flattened; some are infilled with pyrite.

Horizon and localities.—The *centrifugus* Zone, Øleå (Ø34)–(Ø36), and Læså (L1).

Description.—The rhabdosome may attain a length of 3 cm, the proximal portion is dorsally curved. Distally the rhabdosome is gently flexed, or occasionally ventrally curved. The width at the level at th1 is 0.25 mm and it increases distally to 0.5–0.6 mm.

The thecae have parallel-sided prothecal parts. Overlap is up to one third of the prothecal length, and the interthecal septum is inclined at 20° to the rhabdosome.

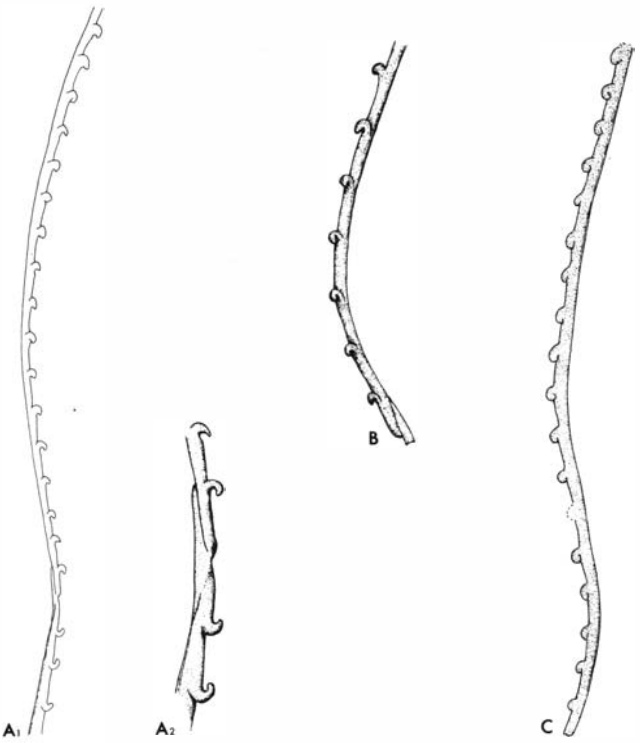


Fig. 22. □ A. *Monograptus speciosus* Tullberg. The *lapworthi* Zone, Øleå. MMN 13483. □ A_1. Section of a long rhabdosome. ×5. □ A_2. Enlargement of the bipolar outgrowth. ×10. □ B. *Monograptus minimus cautleyensis* Rickards, 1965. The *centrifugus* Zone, Øleå. MMH 13484. ×10. □ C. *Monograptus flexuosus* Tullberg, 1883. The *centrifugus* Zone, Øleå. MMH 13485. ×5.

The apertural region is coiled to form a lobe, which is closely adpressed to the rhabdosome, and occupies one third of the dorso-ventral width. The retroverted part occupies one fifth of the thecal height. The apertural parts are obscure but seem to be somewhat enrolled. Proximally the thecal number is 6 per 5 mm, towards the distal portion the number is 10 in 10 mm.

The sicula is 0.9 mm long and the apex reaches just below the apertural lobe of th1. Th1 originates slightly above the aperture of the sicula.

Remarks.—The specimens from Bornholm come closest to *M. minimus cautleyensis,* and have the same distal width and thecal number per 10 mm. In the author's material the coiled apertural part occupies one third to one quarter of the width of the rhabdosome compared to one quarter to one fifth in the British specimens. *M. minimus cautleyensis* is closely related to *M. flexuosus,* but the latter has a lower thecal number of 8.5–9 per 10 mm.

M. minimus cautleyensis occurs in the lower part of the *centrifugus Zone* and is associated with *S. grandis grandis, M. vomerinus basilicus, M. priodon,* and *C. centrifugus.*

Monograptus flexuosus Tullberg, 1883
Fig. 22C

Synonymy.—□ 1883 *Monograptus flexuosus* n. sp.—Tullberg: 24–25, Pl. 2:33–34. □ 1940 *Monograptus flexuosus* Tull.—Laursen: 27, Fig. 21. □ 1942 *Monograptus (Streptograptus) flexuosus* (Tullberg).—Bouček & Přibyl: 12, Figs. 5h–i, Pl. 3:1–4.

Lectotype.—Designated by Bouček & Přibyl (1942:12) as the specimen figured in Tullberg (1883, Pl. 2:34); from the *murchisoni* Zone in Scania, Sweden.

Material.—About 15 flattened specimens.

Horizon and localities.—The upper part of the *centrifugus* Zone, Øleå (Ø36)–(Ø38), and Læså (L1).

Description.—The rhabdosome is flexed, generally with a proximal dorsal curvature. The maximum length is about 4 cm. The rhabdosome is 0.25 mm wide at the level of th1, increasing to a distal maximum of 0.7 mm.

The thecae have parallel sided prothecal parts, the apertural portions being coiled into a lobe which is adpressed to the rhabdosome. The retroverted part occupies one fifth of the height of the theca and one third of the width of the rhabdosome. The thecal apertures face proximally in the rhabdosome. The thecae number proximally 5 per 5 mm, distally 8.5 per 10 mm.

The sicula is 1 mm long and the apex is situated just below the aperture of th1. Th1 originates 0.2 mm from the aperture of the sicula.

Remarks.—The present specimens of *M. flexuosus* are not different from the original specimens from Scania. Tullberg (1883) gives a thecal number of 6 per 10 mm, but specimens in collections from Röstånga, Scania, have a distal thecal number of 9 in 10 mm. The specimens figured in Tullberg (1883, Pl. 2:33), also show a thecal spacing of 9 in 10 mm. The thecae of *M. flexuosus* do not show the "streptograptid" coiling as described by Bouček & Přibyl (1942). The apertural parts are more simply lobed, but the exact structures cannot be observed.

M. flexuosus occurs in the middle to upper part of the *centrifugus* Zone and is associated with the index fossil, *M. vomerinus basilicus, M. priodon,* and *R. geinitzianus geinitzianus.*

Monograptus triangulatus triangulatus (Harkness, 1851)
Fig. 23A, Pl. 11:E

Synonymy.—□ 1851 *Rastrites triangulatus* Harkness.—Harkness: 59–60 (pars), Pl. 1:3a–b (non 3c–d). □ 1942 *Demirastrites triangulatus triangulatus* (Harkness).—Přibyl & Münch: 3–6, Figs. 1:1a–b, 2a–b, 3a–b, Pl. 1:1–5. □ 1958 *Monograptus separatus triangulatus* (Harkness).—Sudbury: 503–506, Pl. 20:52–63. □ 1970 *Monograptus triangulatus triangulatus* (Harkness).—Rickards: 80–81, Fig. 18:1. □ 1971 *Monograptus (Demirastrites) triangulatus* (Harkness).—Schauer: 78, Pl. 26:9–11, Pl. 27:3. For further references see Sudbury (1958) and Rickards (1970).

Lectotype.—Selected by Přibyl & Münch (1942:4), as the specimen figured in Harkness (1851, Pl. 1:3a), GSM 6941; from Dumfriesshire, Scotland.

Material.—About 200 specimens which are preserved flattened or in relief. No complete rhabdosomes have been found.

Horizon and localities.—The lower part of the *gregarius* Zone, indicating the lowermost subzone, the subzone of *triangulatus,* Øleå (Ø2a), (Ø5)–(Ø10).

Description.—The rhabdosome is dorsally curved. The proximal part is hook-shaped and the distal portion is gently curved. The longest fragment is about 8 cm. The initial width is 0.3 mm, the maximum distal width is 1.9 mm.

The proximal thecae are rastritiform, except the first one which is triangular. From a level of about th10, the thecae become triangular. All the thecae are isolated. The apertures of the thecae are situated on small recurved hooks. In well preserved fragments the recurved part is one ninth of the thecal height and adpressed to the metathecal part. In the best preserved specimens the thecal apertures seem to be laterally everted, and they may have carried a pair of lateral horns. The thecal count is 5.5 in 5 mm proximally, and generally 4.5 per 5 mm distally. Values of 10 in 10 mm have been found distally in the oldest representatives. In a few specimens from the uppermost level the distal thecal count is 7.5 in 10 mm.

In spite of the rather large material the sicula and the proximal thecae are rarely preserved. The sicula is 0.7 mm long and the apex reaches one third of th1 which originates 0.3 mm from the aperture of the sicula. Th1 is 1 mm long and 0.3 mm high, with a small hook.

Remarks.—The specimens from the basal part of the *triangulatus* Subzone have slightly closer set distal thecae, 10 per 10 mm, when compared to the 9 per 10 mm in specimens from the main part of the subzone. However, throughout the range of *M. triangulatus triangulatus* the maximum distal width is 1.9 mm. All the proximal parts seem to be of identical proportions all through the range of the species.

It has not been possible to identify *M. triangulatus separatus* Sudbury in the material from Bornholm. All the present specimens appear to have more than 8 rastritiform thecae, but the thecae about the level of th8 become slightly wider at the base of the metatheca in the transition to the triangular form. *M. triangulatus triangulatus* is narrower than *Monograptus triangulatus major* Elles & Wood which has not been recorded from Bornholm.

Monograptus pectinatus Richter, 1853

Fig. 23D, Pl. 11:F

Synonymy.—□ 1853 *Monograptus pectinatus?* n. sp.—Richter: 461, Pl. 12:26, non 27. □ 1868 *Graptolithes fimbriatus,* Nich.—Nicholson: 536–537, Pl. 20:5, ?3–4. □ 1912 *Monograptus fimbriatus* (Nicholson).—Elles & Wood: 482–483 (pars), Figs. 338a–c, ?d, Pl. 48:4a, d, (non b), ?c. □ 1942 *Demirastrites pectinatus* (Richter).—Přibyl & Münch: 7–8, Fig. 1:4–5, Pl. 1:6. □ 1958 *Monograptus separatus fimbriatus* Nicholson).—Sudbury: 499–501, Fig. 5, Pl. 19:40–51. □ 1970 *Monograptus triangulatus fimbriatus* (Nicholson).—Rickards: 82, Fig. 17:2, Pl. 7:4. □ 1971 *Monograptus (Demirastrites) pectinatus* (Richter).—Schauer: 77–78, Pl. 26:1, Pl. 27:1. For further references see Přibyl & Münch (1942), Sudbury (1958), and Rickards (1970).

Holotype.—The specimen figured in Richter (1853, Pl. 12:26).

Material.—About 70 specimens which are preserved in relief or flattened.

Horizon and localities.—The middle part of the *gregarius* Zone, throughout the *pectinatus* Subzone, Øleå (Ø2), (Ø6)–(Ø8), (Ø10)–(Ø11).

Description.—The rhabdosome is dorsally curved, with the proximal part recurved to form a hook and the distal portion more gently curved. The longest specimen measures 8 cm. The width increases steadily from 0.5 mm at th1 to 1 mm at th6, and the maximum distal width is 1.8 mm.

The thecae are triangular throughout the rhabdosome. The proximal thecae are isolated and slender, each with a small apertural hook occupying one fifth of the width of the rhabdosome. The apertures face proximally in the rhabdosome. The apertural regions of the proximal thecae are laterally everted in relief specimens and may have formed "horns" as described by Sudbury (1958). The distal thecae are also isolated. The initial prothecal parts are short and occupy one quarter of the width. The thecae preserved in relief lack lateral "horns", and the apertures appear blunt both in flattened and relief specimens. The state of preservation obscures details of the apertural structures. In the proximal end the thecae number 6 per 5 mm, in the most distal parts the number is 10 per 10 mm.

The sicula is 0.8 mm long and the apex reaches the base of th2. Th1 originates 0.15 mm from the aperture of the sicula.

Remarks.—The presence of the triangular thecae throughout the rhabdosome separates *M. pectinatus* from other triangular monograptids which are characterized by rastritiform thecae in the proximal portion. The maximum distal width of 1.8 mm in the specimens from Bornholm is slightly more than reported for Bohemian and German specimens. Here the maximum width is 1.5 mm (Přibyl & Münch, 1942). The distal thecal number per 10 mm in the specimens from Bornholm is equal to the thecal spacing in the Bohemian samples, namely 9–11 per 10 mm.

A redescription of the type specimen of *M. pectinatus* (Richter, 1853, Pl. 12:26) is highly desirable.

M. pectinatus is frequent throughout the subzone of

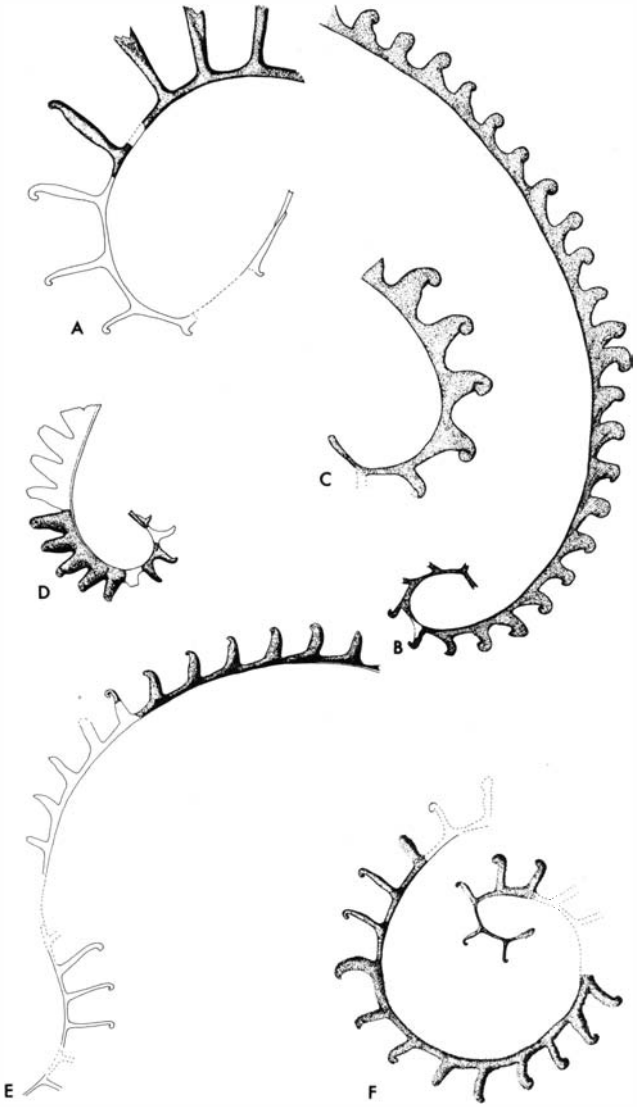


Fig. 23. ☐ A. *Monograptus triangulatus triangulatus* (Harkness, 1851). The *gregarius* Zone, the *triangulatus* Subzone, Øleå. MMH 13486. ×10. ☐ B–C. *Monograptus denticulatus* Törnquist, 1899. The *convolutus* Zone, Øleå. ☐ B. Complete rhabdosome. MMH 13487. ×5. ☐ C. Proximal end with sicula. MMH 13488. ×10. ☐ D. *Monograptus pectinatus* Richter, 1853. Proximal portion. The *gregarius* Zone, *pectinatus* Subzone, Øleå. MMH 13489. ×5. ☐ E. *Monograptus simulans* Pedersen, 1922. The *gregarius* Zone, Øleå. MMH 1902. ×5. ☐F. *Monograptus convolutus* (Hisinger, 1837). The *convolutus* Zone, Øleå. MMH 13490. ×5.

pectinatus and is associated with *P. minor?, M. communis rostratus, M. gregarius,* and *R. longispinus.*

Monograptus simulans Pedersen, 1922
Fig. 23E

Synonymy.—☐ 1922 *Monograptus simulans* n. sp.—Pedersen: 21, Figs. 5a–e.

Lectotype (here designated).—The specimen figured in Pedersen (1922:20, Fig. 5c). MMH 1902; from the "*Rastrites* Shale", Llandovery, Øleå, Bornholm.

Material.—20 specimens including the type material of Pedersen. The specimens are preserved flattened or in relief. No complete rhabdosome has been found, and the sicula is unknown.

Horizon and localities.—The upper part of the *gregarius* Zone, Øleå (Ø2) and (Ø10).

Diagnosis (emended herein).—The proximal part of the rhabdosome forms a nearly circular coil, the distal portion is dorsally curved. The thecae are rastritiform proximally in the rhabdosome, slightly triangular distally. All thecae have apertural hooks which are most fully developed in the proximal part of the rhabdosome. The rhabdosome attains a length of 8 cm, and the maximum width distally is 1.8 mm. The thecae number 11–7.5 per 10 mm.

Description.—The rhabdosome may have been coiled in an open spiral, the proximal end constantly being almost circular. The curvature is mainly dorsal. At least the eight proximal thecae are rastritiform. The width of the most proximal thecae is 0.8 mm and within the rastritiform thecae width increases to 1.9 mm distally. The metathecae are situated perpendicular to the axis of the rhabdosome. The slightly enrolled apertural hooks occupy one sixth of the width of the rhabdosome. In well preserved specimens the apertures are laterally expanded, possibly forming paired "horns". The thecal apertures face dorsally in the rhabdosome. The proximal rastritiform thecae number 5.5 in 5 mm.

Along the strech where the transition to the triangular thecae takes place the width of the rhabdosome decreases to 1.4 mm. The dorsal walls of the metathecae are situated perpendicular to the axis of the rhabdosome, the ventral walls are slightly curved and inclined at 70°–80° to the rhabdosome. Distally the thecal hooks become less pronounced. The distal width increases to a maximum of 1.8 mm, and the distal thecae number 7.5–8 in 10 mm.

Remarks.—Pedersen (1922) did not notice the rastritiform proximal part of *M. simulans,* but further preparation of the lectotype revealed the characteristic proximal end and the thecal hooks.

Fragments of the proximal portion of *M. simulans* may be confused with those of the *Rastrites* species. However, the distal part shows clear affinities to the triangular monograptids. *M. simulans* is closely related to *M. triangulatus* and *M. convolutus* and may be a transition form. *M. simulans* is separated from *M. convolutus* by the smaller distal width and the lesser degree of coiling of the rhabdosome. *M. simulans* is distinguished from *M. triangulatus* by the more coiled rhabdosome, the higher number of proximal rastritiform thecae, and the less triangulate thecae in the distal portion.

Monograptus denticulatus Törnquist, 1899
Figs. 23B–C

Synonymy.—☐ 1899 *Monograptus denticulatus* n. sp.—Törnquist: 18, Pl. 3: 19–23. ☐ 1912 *Monograptus denticula-*

tus Törnquist.—Elles & Wood: 474–475, Fig. 330, Pl. 48:2a–f. □ 1936 *Monograptus pseudodenticulatus* n. sp.—Haberfelner: 91–92, Figs. 4a–b. □ ? 1942 *Demirastrites pseudodenticulatus* (Haberfelner).—Přibyl & Münch: 9–10, Fig. 2:1–4, Pl. 3:1–4. □ 1942 *Demirastrites denticulatus denticulatus* (Törnquist).—Přibyl & Münch: 8–10 (not figured). □ 1958 *Monograptus denticulatus* Törnquist.—Sudbury: 509–510, Pl. 21:72–73. □ 1970 *Monograptus denticulatus* Törnquist.—Rickards: 83–84, Fig. 17:5–6, Pl. 7:3. □ 1971 *Monograptus (Demirastrites) denticulatus* Törnquist.—Schauer: 79, Pl. 26:4. For further references see Rickards (1970).

Lectotype.—Designated by Přibyl & Münch (1942:8), as the specimen figured in Törnquist (1899, Pl. 3:19); from the *convolutus* Zone, Scania, Sweden.

Material.—About 70 specimens which all are flattened. Törnquist's specimens from the type locality, Tommarp, have also been examined.

Horizon and localities.—The *convolutus* Zone, Øleå (Ø12)–(Ø13).

Description.—The rhabdosome is dorsally curved. The proximal end is recurved, hook-shaped, and the distal portion is gently curved. The maximum length is 4–5 cm, but most rhabdosomes are 1–2 cm long. The width is 0.5 mm at the level of th1, gradually increasing to 0.8 mm at th5, and 1 mm at th10. Distally the maximum width is 1.3 mm.

The thecae are biform, but isolated and hooked all through the rhabdosome. The proximal four thecae are rastritiform and situated perpendicular to the axis of the stipe. Towards the distal part of the rhabdosome the thecae become triangular. Here the prothecal parts have ventral walls parallel to the axis of the rhabdosome, and their height is one third of the height of the thecae. In the distal thecae the dorsal wall of the metathecal part is perpendicular to the rhabdosome, and the hooked part is prominent. In the best preserved specimens the apertural regions of the thecal hooks are recurved and twisted laterally, always to the reverse side of the rhabdosome. As seen from the obverse side the thecae show a blunt apertural part with concealed apertures. The lateral twisting of the thecal apertures is only seen in the triangular thecae, from the level of th5. The proximal rastritiform thecae have small hooks, and the apertures face proximally in the rhabdosome. In the twisted apertures only the outer walls have been seen. They are rounded, and there is no indication of a transverse expansion of the thecal apertures. The apertures may face in towards the coiled metathecae. The thecae number proximally 5.5 in 5 mm, distally 9 in 10 mm.

The sicula is 0.65 mm long and the apex reaches the aperture of th1.

Remarks.—The laterally twisted apertural part of the thecae in *M. denticulatus* was described by Törnquist in 1899 and figured on his Pl. 3:22 and 23. Unfortunately, Törnquist's material only includes specimens in obverse view. *M. denticulatus* is presently the oldest graptolite in which lateral twisting of the apertural parts occurs. This apparently new character appears to be introduced distally. In the younger species *M. planus, M. proteus,* and *M. tullbergi?* lateral torsion of the thecal apertures is also present, and *M. denticulatus* is probably related to those species.

M. denticulatus is easily separated from *M. decipiens* and *M. triangulatus* s.l. by its distal thecal characters and the few proximal rastritiform thecae.

Monograptus pseudodenticulatus Haberfelner was separated from *M. denticulatus* by a shorter rhabdosome, which is 1–2 cm long, a lesser width, 1.0 mm, and a higher thecal count, 11 per 10 mm. *M. pseudodenticulatus* has the same proportions as the proximal parts of *M. denticulatus,* described by the author, and in which the proximal cm is only 1 mm wide, and the thecal number is 11 per 10 mm. This implies that a division of *M. denticulatus* into two species is questionable.

Monograptus decipiens Törnquist, 1899
Pl. 12:E

Synonymy.—□ 1899 *Monograptus decipiens* n. sp.—Törnquist: 20–21, Pl. 4:9–14. □ 1912 *Monograptus decipiens,* Törnquist.—Elles & Wood: 469–470, Fig. 325a, b–c ?, Pl. 47:3a, b, e (non c–d). □ 1942 *Demirastrites decipiens decipiens* (Törnquist).—Přibyl & Münch: 12–13, Fig. 1:6. □ 1952 *Demirastrites decipiens decipiens,* Törnquist.—Münch: 127, Pl. 42:3 (Přibyl's Fig.). □ 1970 *Monograptus decipiens* Törnquist.—Rickards: 83, Fig. 13:16, Fig. 17:8, Fig. 18:3, 13. □ 1971 *Monograptus (Demirastrites) decipiens* Törnquist.—Schauer: 79, Pl. 26:2–3, Pl. 27:2.

Lectotype.—Designated by Přibyl & Münch (1942:12), as the specimen figured in Törnquist (1899, Pl. 4:10); from the *convolutus* Zone, Tommarp, Sweden.

Material.—20 specimens which are all preserved flattened.

Horizon and localities.—The middle part of the *convolutus* Zone, Øleå (Ø12)–(Ø13).

Description.—The rhabdosome is coiled in an open spiral, generally with dorsal curvature. The longest rhabdosome is about 4 cm, but no complete rhabdosomes have been observed. The width at th1 is 0.65 mm, gradually increasing to a distal maximum of 1.4 mm. The extreme distal parts of the thecae are often concealed by the sediment.

The thecae are isolated all along the stipe. The proximal thecae have very slender prothecal and metathecal parts, the latter being situated perpendicular to the rhabdosome, in similar way as the *Rastrites* thecal type. Towards the distal end the thecae become somewhat triangular, but are still very slender. All the thecae have apertural hooks, the retroverted part occupying about one third to one quarter of the width of the rhabdosome. The apertures face proximally in the

rhabdosome. However, the distal portions of the thecae are mostly blunt, and no evident thecal hooks are seen. The protheca is 0.2 mm in width in the distal part of the rhabdosome, and the base of the metathecal part is 0.4 mm wide, diminishing towards the aperture of the thecae. The thecal spacing is 4 in 5 mm proximally and 8 per 10 mm distally.

The sicula is 0.8 mm long, and the apex reaches the aperture of th1. Th1 originates close to the aperture of the sicula.

Remarks.—In the author's material the number of thecae in the distal part is 8 in 10 mm. In Törnquist's original description the spacing is indicated to be 10 in 10 mm. Otherwise the measurements of the present specimens match those described by Törnquist (1899).

M. decipiens is mainly restricted to the middle part of the *convolutus* Zone and is associated with *P. folium, M. lobiferus lobiferus, M. leptotheca,* and the index fossil.

Monograptus convolutus (Hisinger, 1837)
Fig. 23F, Pl. 12: D

Synonymy.—☐ 1828 Krotka graptolites from Furudal.—Hisinger: 169, Pl. 4:10. ☐ 1837 *Prionotus convolutus.*—Hisinger: 114, Pl. 35:7. ☐ 1882a *Monograptus convolutus.*—Tullberg: 14–15, Pl. 2:13–16. ☐ 1892 *Monograptus convolutus* His.—Törnquist: 30–34, Pl. 1:5–11. ☐ 1912 *Monograptus convolutus* (Hisinger).—Elles & Wood: 467–469, Figs. 324a–b, Pl. 47:1a–d. ☐ 1942 *Demirastrites convolutus* (Hisinger).—Přibyl & Münch: 13–15, Fig. 1, Pl. 1:9–10, Pl. 3:7–9. ☐ 1958 *Monograptus convolutus* (Hisinger).—Sudbury: 511–513, Fig. 13, Pl. 21:76–78. ☐ 1970 *Monograptus convolutus* (Hisinger).—Rickards: 82–83, Fig. 13:15. ☐ 1971 *Monograptus (Demirastrites) convolutus* (Hisinger).—Schauer: 78–79, Pl. 26:5–6.

Holotype (by monotypy).–Specimen figured by Hisinger (1837, Pl. 35:7) refigured by Tullberg (1882, Pl. 2:13); from the *convolutus* Zone, Furudal, Dalecarlia, Sweden (specimen seen).

Material.–About 45 specimens, which are preserved flattened or in full relief. No complete specimens have been found. Hisinger's type specimen and the specimen figured in Sudbury (1958, Pl. 21:76) have been studied.

Horizon and localities.—The *convolutus* Zone, Øleå (Ø11)–(Ø13).

Description.—The main part of the rhabdosome is more or less spirally coiled with the thecae on the convex side. The distal portion is usually only gently curved, occasionally with the thecae on the concave side of the rhabdosome. The length of the largest fragment is about 20 cm and up to four whorls are present in the spiral. The width of the rhabdosome increases gradually from 0.75 mm at the extreme proximal thecae to 3 mm distally.

The thecae are isolated and biform. About 20 thecae are rastritiform and mainly situated perpendicular to the proximal stipe. Younger thecae become gradually slender and triangular, still with the dorsal walls normal to the rhabdosome. Proximally to mesially in the rhabdosome the thecae are hooked, in the well preserved relief specimens the retroverted parts of the thecal hooks occupying one third to one quarter of the width of the stipe. The apertures face dorsally in the rhabdosome. Towards the distal end of the rhabdosome the hooks are retracted, the metathecal part is gently curved, and the apertures point proximally in the rhabdosome. In full relief specimens the metathecal parts are transversely flattened, but a lateral apertural eversion has not been seen.

In the proximal portion the thecae number 5 per 5 mm, and distally 9 per 10 mm. The sicula has not been recorded.

Remarks.—Hisinger's type specimens of *M. convolutus* have been restudied. An obscure sicula was observed, 0.5 mm in length and the apex reaches possibly the level of the aperture of th1. The width of the flattened rhabdosome is at th1 0.75 mm, at the level of th15 it is 1.5 mm, and distally 2.5 mm. The thecae are rastritiform in the proximal portion of the rhabdosome, and distally they gradually become slender and triangular. In some of the thecae small apertural hooks were seen. The thecae number 5–6 in 5 mm in the proximal portion and distally 4.5 in 5 mm.

The specimens from Bornholm agree with the description of the holotype. However, the form of the rhabdosome is highly variable in the present material. Furthermore, in well preserved specimens with full relief the hooks seem to occupy a greater part of the length of the metathecae than in the type specimen. However, this appearance may be due to the state of preservation, as the hooks often seem to "disappear" in flattened specimens, and the apertural portions of the thecae are tapering, and only slightly recurved.

The lateral eversion of the thecal apertures described by Sudbury (1958) has not been seen even in well preserved specimens. In the proximal end of the rhabdosome the apertural hooks are simple. Distally a transverse eversion of the metathecae is observed, but not of the apertural portions.

As the form of the rhabdosomes is highly variable, an investigation of a large and more complete collection of material may reveal stratigraphically important forms within the species.

?Monograptus sp.
Fig. 17F

Material.—One fragment which is preserved in full relief.

Horizon and locality.—The *persculptus* Zone; well at Bavnegård, 30.10–34.50 m below ground level.

Description.—The straight fragment is 8 mm long, without proximal end and sicula. The width of the rhabdosome is 0.75 mm.

The thecae are of climacograptid type. They are 1.9

mm long, and overlap for about half their length. The geniculum is pronounced, and the free ventral walls are parallel with the stipe. The apertures are horizontal to slightly everted, and occupy three eigths of the width of the rhabdosome. The interthecal septa are for the main part of their length parallel to the axis of the rhabdosome, with a characteristic curvature in their proximal end. The thecal spacing is 5 per 5 mm throughout the stipe.

Remarks.—The specimen cannot be mistaken for being an uniserial part of *Dicellograptus* or *Dicranograptus,* as the present climacograptid thecae are quite different from the introverted thecae in those genera.

The fragment is only tentatively assigned to *Monograptus,* as one cannot exclude the faint possibility that it represents a part of the uniserial portion of a member of the family Dimorphograptidae, possibly of the "*Metadimorphograptus*" type with climacograptid thecae. In this case the graptolite ought to have an uniformly long uniserial portion not hitherto known.

?Monograptus sp. is regarded as belonging to the *persculptus* Zone, and not as contamination in the bore hole from the overlying graptolite zones, as both the state of preservation of the graptolite and the shale, in which it occurs, are identical to the samples with *G. persculptus.*

Only one monograptid, *Monograptus ceryx* Rickards & Hutt, has previously been described from the *persculptus* Zone. From the thecal form *M. ceryx* was regarded as a possible link between *Glyptograptus* and the *Monograptus atavus* group (Rickards & Hutt, 1970), and later included to the *atavus* group by Rickards (1974). *?Monograptus* sp. appears to occur at approximately the same level as *M. ceryx.* However, *?Monograptus* sp. has thecae of climacograptid type and may be related to the climacograptids. Accordingly, the presence of *?Monograptus* sp., which bears resemblance to the later representatives of the *Monoclimacis* group, such as *M. vomerinus* s.l., may indicate that the well developed geniculum is an early phenomenon in the development of the monograptids.

Rickards (1974) contended that the *atavus* group makes the foundation of the Silurian monograptid evolution, as there is no evidence of uniserial graptolites being derived from other sources. However, *?Monograptus* sp. has characteristic climacograptid thecae with a pronounced geniculum, a structure which makes inclusion in the *atavus* group highly questionable. The evidence of a single fragment is not conclusive, but it seems to support the suggestion of Rickards and Hutt (1970) that the origin of uniserial graptolites was achieved polyphyletically.

Genus *Rastrites* Barrande, 1850

Type species (subsequently designated by Miller, 1889).—*Rastrites peregrinus* Barrande, 1850; from the Llandovery of Bohemia.

Diagnosis (from Bulman, 1970).—Rhabdosome dorsally curved. The thecae straight, isolate and tubular, with retroflexed hooked apertures and lateral spines in some, at high angles arising widely spaced from a threadlike "common canal".

Rastrites longispinus Perner, 1897

Pl. 12:C,

Synonymy.—☐ 1897 *Rastrites peregrinus* var. *longispinus.* —Perner: 9, Fig. 7, Pl. 13:32, 35. ☐ 1907 *Rastrites longispinus* Perner.—Törnquist: 10 (not figured). ☐ 1913 *Monograptus (Rastrites) longispinus* (Perner).—Elles & Wood: 489–490, Figs. 344a–b, Pl. 50:2a–g (? Fig. 1d). ☐ 1941c *Rastrites longispinus* Perner.—Přibyl: 6–7, Figs. 1, 4, Pl. 1:1–3, Pl. 2:3. ☐ 1958 *Rastrites longispinus* (Perner).—Sudbury: 525–526, Fig. 23, Pl. 21:71. ☐ 1967 *Rastrites longispinus* Perner.—Schauer: 176, Pl. 2:1–2. ☐ 1970 *Rastrites longispinus* Perner.—Rickards: 97, Fig. 18: 9, Pl. 8:2, ?6.

Lectotype.—Designated by Přibyl (1941c:7), as the specimen figured in Perner (1897, Fig. 7); from the Llandovery of Kosov, Bohemia.

Material.—About 100 specimens preserved flattened or with partial relief.

Horizon and localities.—The *gregarius* Zone; in the upper part of the *triangulatus* Subzone and in the lower part of the *pectinatus* Subzone, Øleå (Ø1)–(Ø2), (Ø5)–(Ø8), (Ø10).

Description.—The rhabdosome is 3–4 cm long and dorsally curved throughout, with a hooked proximal part and gently curved distal portion. The width increases gradually from about 1 mm at the level of th2, to 2 mm at th7, and to a maximum of 4 mm in the distal part. The greatest width attained is commonly 3 mm.

The metathecal parts are mainly perpendicular to the axis of the rhabdosome, and have small retroflexed apertural hooks which occupy only about 1/14 of the rhabdosomal width. The hooks face dorsally. In well preserved specimens the apertures are slightly expanded transversely. In the extreme proximal end the thecae number 6 in 5 mm, distally the number is mainly 10 in 10 mm, occasionally 8 in 10 mm.

The sicula is about 0.75 mm long and th1 originates 0.4 mm above the aperture of the sicula. The apex of the sicula reaches 0.25 mm below the base of the metatheca of th1. The apertural part of th1 has not been seen, as the extreme proximal end, in spite of the large quantity of material available, has only been seen in very few specimens.

Remarks.—The available material agrees with the earlier descriptions, except for the slightly higher thecal count (8–10 per 10 mm) in the specimens from Bornholm and Bohemia (Přibyl, 1941c) than in the specimens from Britain, (7–8 thecae per 10 mm), see Elles & Wood (1913), and Rickards (1970).

R. longispinus is the oldest species of the genus *Rastrites* on Bornholm. No specimens have been found which could be compared to *Monograptus separatus extremus* Sudbury which was regarded by Sudbury (1958) as an ancestor to *R. longispinus*.

Rastrites peregrinus peregrinus Barrande, 1850
Pl. 13:A

Synonymy.—☐ 1850 *Rastrites peregrinus.* Barr.—Barrande: 67, Pl. 4:6. ☐ 1907 *Rastrites peregrinus* Barrande.—Törnquist: 6–7, Pl. 1:1–22 (19 ?). ☐ 1913 *Monograptus (Rastrites) peregrinus* (Barrande).—Elles & Wood: 488–489, Fig. 343, Pl. 50:1b, 1c, 1e (not 1a, 1d). ☐ 1941c *Rastrites peregrinus peregrinus* Barrande.—Přibyl: 3–6, Fig. 1:5–6, Pl. 1:8–9, Pl. 2:8, Pl. 3:13. ☐ 1967 *Rastrites peregrinus peregrinus* Barrande.—Schauer: 176, Pl. 2:5–7. Also further references.

Lectotype.—Designated by Přibyl (1941c:3), as the specimen figured in Barrande (1850, Pl. 4:6); from the Llandovery of Bykoš, Bohemia.

Material.—12 specimens which are all fragmentary and flattened. No siculae have been found.

Horizon and localities.—The middle part of the *convolutus* Zone, Øleå (Ø12)–(Ø13).

Description.—The rhabdosome is about 3 cm in maximum length, and dorsally curved. The proximal part is hook-shaped and the curvature diminishes towards the distal end, the rhabdosome becoming nearly straight. The width is 2.0–2.2 mm all way through the rhabdosome.

The thecae are rastritiform, no apertural hooks have been observed. In the proximal hooked region of the rhabdosome the metathecal parts are perpendicular to the axis of the stipe, and in the distal part the thecae are inclined at about 120° to the rhabdosome. The thecae number 10 in 10 mm in the mesial and the distal parts of the rhabdosome.

The sicula and the initial thecae have not been found.

Remarks.—The specimens from Bornholm are few and poorly preserved, but not different from earlier described material. *R. peregrinus peregrinus* is separated from other rastritiform graptolites by the width, the number of thecae per 10 mm, and the inclination of the distal thecae.

Rastrites peregrinus socialis Törnquist was described by Törnquist (1907) as having a maximum width of 1.5 mm, which is less than that of *R. peregrinus peregrinus.*

R. peregrinus peregrinus occurs only in the middle part of the *convolutus* Zone and is associated with *P. folium, M. leptotheca, M. decipiens,* and *M. regularis.*

Rastrites linnaei Barrande, 1850
Fig. 24A, Table 8

Synonymy.—☐ 1850 *Rastrites Linnaei.* Barr.—Barrande: 65–66, Pl. 4:1–2. ☐ 1897 *Rastrites Linnaei.* Barr.—Perner: 7–8, Figs. 4–5, Pl. 13:29–31 (non 27–28). ☐ 1907 *Rastrites Linnæi* Barrande.—Törnquist: 14–15, Pl. 2:21–26. ☐ 1913 *Monograptus (Rastrites) Linnæi* (Barrande).—Elles & Wood: 493–494, Figs. 349a–b, Pl. 51:1a–c. ☐ 1941c *Rastrites linnaei* Barrande.—Přibyl: 11–12, Figs. 1–3, Pl. 2:1–2, Pl. 3:1–8. ☐ 1967 *Rastrites linnaei* Barrande.—Schauer: 180–182, Pl. 5:1–8. ☐ 1970 *Rastrites linnaei* Barrande.—Rickards: 94, 96, Fig. 16:13. ☐ 1970 *Rastrites linnaei* Barrande.—Hutt et al.: 14–15, Pl. 3:69–72. ☐ 1974 *Rastrites linnaei* Barrande.—Sherwin: 173, Fig. 2f, Pl. 11:13, Pl. 12:7. Further references in Hutt et al. (1970).

Lectotype.—Designated by Přibyl (1941c:11), as the specimen figured in Barrande (1850, Pl. 4:2); from Želkovice, Bohemia.

Material.—6 flattened and fragmentary specimens.

Horizon and localities.—The *turriculatus* Zone, Øleå (Ø15)–(Ø16).

Description.—The longest fragment recorded is about 6 cm long. The proximal end of the rhabdosome is gently curved dorsally, the distal part being nearly straight. The rhabdosome widens rapidly from an initial width of 1.2 mm at th1 to 8 mm at the level of th5.

The rastritiform thecae are completely isolated. The extreme base of the metathecae is triangular, and the distal portions of the thecae have small hooks. However, no specimens are found with well preserved apertures and no apertural spines or eversions have been observed.

The two proximal thecae are comparatively short. The metathecal part of th1 originates close to the aperture of the sicula and is 1.25–1.5 mm long, that of th2 being 3 mm long. The metathecal spacing of th1 and th2 is 0.4–0.5 mm, and that of th2 and th3 about 1.4 mm. The metathecal portion of th3 is 4–6 mm long. The maximum length of the distal metathecal parts is 8 mm. The base of the metathecae is triangularly enlarged both proximally and distally, implying that the major part of the prothecae is extended distally beyond the origin of the metathecae. The metathecae are inclined at about 100°–135° to their prothecal parts. The distal thecae are more widely spaced than the extreme proximal thecae, the former numbering 3–4 per 10 mm.

The sicula is mainly indistinct, but in a few specimens the length may be shown to be 1 to 2 mm. The position of the apex of the sicula varies from the base of the protheca of th3 to the origin of the metatheca of th3.

Remarks.—The specimens of *R. linnaei* from Bornholm are not different from earlier described material. *R. linnaei* is closely related to *R. maximus,* but is separated by the shorter and more closely set thecae. *R. linnaei* is mainly found in the middle part of the *turriculatus* Zone, where it is infrequent and occurs associated with *M. turriculatus, M. exiguus primulus,* and *M. planus.*

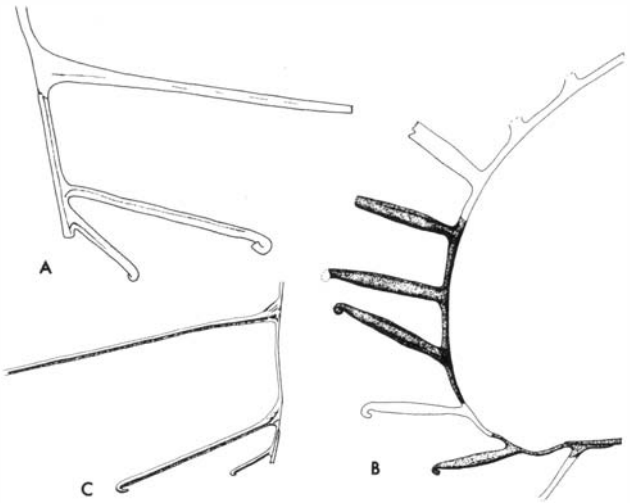


Fig. 24. ☐ A. *Rastrites linnaei* Barrande, 1850. The *turriculatus* Zone, Øleå. MMH 13491. ×10. ☐ B. *Rastrites approximatus* Perner, 1897?. The *convolutus* Zone, Øleå. MMH 13492. ×10. ☐ C. *Rastrites maximus* Carruthers, 1867. The *turriculatus* Zone, Øleå. MMH 13493. ×5.

Rastrites maximus Carruthers, 1867

Fig. 24C, Pl. 12: F, Pl. 13: B, Table 8

Synonymy.—☐ 1867 *Rastrites maximus* Carruthers.—Carruthers: 540, Fig. 90 (6) (not seen). ☐ 1876 *Rastrites maximus* Carruthers.—Lapworth: 313 (not figured). ☐ 1907 *Rastrites maximus* Carruthers.—Törnquist: 15, Pl. 2:27–33, Pl. 3:1. ☐ 1913 *Monograptus (Rastrites) maximus* (Carruthers).—Elles & Wood: 494–495, 500, Figs. 350a–c, Pl. 50:6a–d, ?6e. ☐ 1941 *Rastrites maximus* (Carruthers).—Přibyl: 15 (not figured). ☐ 1967 *Rastrites maximus* Carruthers.—Schauer: 184–185, Pl. 6:1. ☐ 1969 *Rastrites maximus* Carruthers.—Strachan: 200–202, Fig. 7a, Pl. 5:7. ☐ 1970 *Rastrites maximus* Carruthers.—Rickards: 92, 94, Fig. 16:7, 11, Pl. 8:1.

Neotype.—Designated by Strachan (1969:201): Specimen figured in Elles & Wood (1913, Pl. 50:6b); from the Upper Birkhill Shales, Peeblesshire, Scotland.

Material.—40 specimens which are preserved flattened or with low relief. No complete specimens have been found.

Horizon and localities.—The lower part of the *turriculatus* Zone, Øleå (Ø13a)–(Ø15).

Description.—The rhabdosome is irregularly curved, the longest fragment being 3–4 cm in length. The width of the rhabdosome (=the length of the metathecal parts) increases rapidly within a few proximal thecae from 1.5 mm at th1, to 5 mm at th2, 10 mm at th3, and a maximum of 18 mm distally. The common canal is extremely slender, about 0.1 mm in width.

The thecae are triangular at their metathecal base with the prothecae enlarged in similar fashion to those of *R. linnaei.* The metathecal parts are situated perpendicular to, or inclined at about 110° to the common canal. The distal portion of the thecae has small hooks with transversely enlarged apertures forming a pair of short lateral projections. The metathecae of th1 and th2 have an interspace of about 1 mm and between th2 and th3 the interspace is 2–4 mm. The thecae number 5–6 in the proximal 10 mm; in the extreme distal portion the number has fallen to 1–2 in 10 mm.

The sicula is 1.2–1.75 mm long and the apex reaches the base of the metatheca of th2. The metatheca of th1 originates very close to the aperture of the sicula.

Remarks.—In the Danish material it is possible to distinguish *R. maximus* from *R. linnaei* only by the properties of the proximal portions. The distance between the metathecae of th1 and th2 in *R. maximus* is 0.8–1.0 mm and in *R. linnaei* the distance is 0.4–0.5 mm. The second theca is generally longer in *R. maximus* (about 5 mm) than in *R. linnaei* (3 mm).

R. maximus is easily separated from other rastritiform graptolites by its long and more widely spaced thecae.

R. maximus is frequent in the lower part of the *turriculatus* Zone and is associated with *G. auritus, M. planus, D. runcinatus, M. pseudoruncinatus,* and *M. turriculatus.*

Rastrites approximatus Perner, 1897 ?

Fig. 24B

Material.—16 specimens which are preserved flattened or with relief.

Horizon and localities.—The lower part of the *convolutus* Zone, Øleå (Ø11)–(Ø12).

Description.—The rhabdosome is up to 2 cm long and is dorsally curved, with an open hooked proximal portion. The width increases from 0.75 mm at th1 to 1 mm at th2, 1.7 mm at th5, 2 mm at th9, and a maximum of 2.4 mm in the distal portion.

The two to three proximal thecae are inclined at 45° to the rhabdosome. The inclination increases to 90° at th5 and this angle is maintained distally. The thecae have small apertural hooks which are transversely expanded in well preserved specimens, having a pair of short lateral horns. The retroverted part of the hooks occupies less than one sixth of the width of the rhabdosome. The apertures face dorsally to proximally in the stipe. The thecae number 5.5 per 5 mm throughout the rhabdosome.

The sicula is 0.8–0.9 mm long and the apex reaches one third of the distance between the metathecae of th1 and th2. Th1 origintes 0.2 mm from the aperture of the sicula.

Remarks.—*R. approximatus?* is very closely related to, but not identical with *R. approximatus* Perner from Bohemia. The latter has a thecal number of 12–16 in 10 mm (Přibyl, 1941c) compared to 11 in 10 mm in the author's material. The proximal portions of the original specimens (Perner, 1897) seem to be more tightly coiled than the specimens from Bornholm. *R. approximatus?* is separated from *Rastrites approximatus geinitzi* Törnquist by its

Table 8. R. maximus and *R. linnaei.* Dimensions (in mm).

Spec. No.	Length			Distance between			Length of sicula
	th1	th2	th3	th1–th2	th2–th3	th3–th4	
R. maximus							
MMH 13582	1.25	3.5*		1.0	4.0		1.75
MMH 13583	1.3	3*		0.8	2.0		1.75
MMH 13584	1.2	6		1.2	4.0		1.4
MMH 13585	1.0	4		1.1			1.5
MMH 13493	1.3	5	10	0.8	3.0		1.75
MMH 13586	1.5	2*	2*	1.0	2.0		1.0
MMH 13587	1.7	4		1.0	2.0		1.75
MMH 13588	1.25	2*	5*	0.9	1.75	2.7	1.2
R. linnaei							
MMH 13589	1.3	3	6	0.5	1.4		1.0
MMH 13590	1.5	3	5	0.5	1.4	1.4	
MMH 13591	1.25	3	4	0.4	1.2	1.2	
MMH 13491	1.3	3.1	5	0.4	1.75		1.75

* The distal parts are broken off.

lesser width, in *R. approximatus geinitzi,* the maximum width being 3–4 mm.

R. approximatus? is restricted to the lower part of the *convolutus* Zone and is associated with *M. lobiferus lobiferus* and *M. limatulus.*

Genus *Cyrtograptus* Carruthers, 1867

Type species.—Cyrtograptus murchisoni Carruthers, 1867.

Diagnosis (from Bulman, 1970).—Thecae biform, hooked or triangulate proximally with retroflexed apertures, becoming simpler distally.

Cyrtograptus lapworthi Tullberg, 1883

Pl. 13:C

Synonymy.—☐ 1883 *Cyrtograptus Lapworthi* n. sp.—Tullberg: 36, Pl. 3:8–11. ☐ 1931 *Cyrtograptus evolvens* n. sp.—Bouček: 11, 19, Figs. 11a–b. ☐ 1933 *Cyrtograptus lapworthi,* Tullb.—Bouček: 24–27, Fig. 2, Pl. 3:6, Pl. 4:1–3. ☐ 1940 *Cyrtograptus lapworthi* Tull.—Laursen: 31, Fig. 28, Pl. 4:2. ☐ 1952 *Cyrtograptus lapworthi* Tullb.—Münch: 135, Pl. 48:3a–d. ☐ 1968 *Cyrtograptus (Cyrtograptus) lapworthi* Tullberg.—Schauer: 56, Pl. 1:1–2, Pl. 4:1–2.

Lectotype.—A neotype was selected by Bouček (1933: 25, Pl. 3:6) from Vyskočilka, Bohemia. This choice of neotype was based on the supposition that the original material was missing. However, during the present author's studies of Tullberg's types in the collections at the Geological Survey of Sweden, Stockholm, a well preserved specimen, which is pictured in Tullberg (1883, Pl. 3:8) was found, and this specimen is here proposed as lectotype. The specimen is from Röstånga, Scania.

Material.—About 20 specimens, preserved flattened or with a low relief. Also specimens from Tullberg's original collection have also been examined.

Horizon and localities.—The *lapworthi* Zone, Øleå (Ø29)–(Ø30), (Ø40), (Ø42), Læså (L5).

Description.—The main stipe is more than 12 cm long and slightly curved. The proximal portion is circularly curved dorsally; at the utmost forming one volution. The cladia are only of first order, are slightly curved or straight. The proximal cladium originates at a distance of about 6–14 thecae from the sicula; the second cladium at 7–14 thecae distally to the first one. The rhabdosomes have up to five cladia and the intervals between the distal ones vary from 15 mm to 30 mm. The length of the cladia may exceed 6 cm. The width of the rhabdosome grows steadily from 0.6 mm proximally to 1 mm distally.

The thecae are subtriangular and hooked. No thecal overlap has been seen. The common canal occupies about half the width of the rhabdosome. The thecal apertures face proximally to dorsally in the rhabdosome. Towards the distal end of the main stipe the thecal hooks seem to be less conspicuous, but the true form is concealed by a twisting of the main stipe. The torsion occurs generally between cladium 1 and cladium 2. In well preserved specimens a pair of long lateral thecal apertural spines up to 0.5 mm in length is observed.

The thecae of the cladia correspond to the thecae in the distal part of the main stipe. However, the structure is also here concealed by torsion of the cladia. Most proximally the thecae number 6 per 5 mm. Between cladium 1 and cladium 2 the number is 5 per 5 mm, while in the extreme distal portion of the main stipe the thecae number 8 per 10 mm.

The sicula is 1.25 mm long and 0.25 mm in width at the aperture. The apex reaches the level of the aper-

ture of th1, or mesial in th2. Th1 originates 0.25 mm from the aperture of the sicula.

Remarks.—The material from Bornholm is not different from the specimens described originally from Scania. The development described by Schauer (1968) characterized by the presence of only one cladium in the oldest representatives and an increasing number of cladia in the younger has not been found in the author's material from Bornholm.

On Bornholm and in Scania the characteristic graptolite assemblage in the *lapworthi* Zone is *C. lapworthi, S. grandis grandis, M. linnarssoni, M. speciosus,* and *B. pulchellus.*

Cyrtograptus centrifugus Bouček, 1931

Fig. 25

Synonymy.—□ 1931 *Cyrtograptus centrifugus* n. sp.—Bouček: 13, Figs. 14a–d. □ 1933 *Cyrtograptus centrifugus,* Bouček.—Bouček: 27–28, Figs. 3a–d, Pl. 3:1–4. □ ? 1933 *Cyrtograptus insectus* Bouček.—Bouček, Pl. 2:8. □ 1940 *Cyrtograptus Murchisoni* Carr.—Laursen, Pl. 4:1. □ 1952 *Cyrtograptus centrifugus* Bouč.—Münch: 135, Pl. 49: a–e. □ 1968 *Cyrtograptus (Cyrtograptus) centrifugus* Bouček.— Schauer: 36–37, Pl. 1:3, Pl. 3:3–4.

Lectotype.—Designated by Bouček (1933:27) as the specimen figured in Bouček (1931, Figs. 14a–b), refigured in Bouček (1933, Figs. 3a–b, Pl. 3:2).

Material.—About 40 specimens which all are preserved flattened. No complete specimens have been found.

Horizon and localities.—The basal part of Wenlock, the *centrifugus* Zone, Øleå (Ø31)–(Ø39), (Ø41), and Læså (L1).

Description.—The rhabdosome is cyrtograptid with the proximal portion of the main stipe forming a helical spiral with up to three more or less tightly enrolled evolutions. The main stipe is more than 20 cm long, and only slightly curved distally. The rhabdosome has cladia of first order, the maximum number being four cladia, which are curved to nearly straight. The length of the cladia may exceed 20 cm. The distance from the sicula to cladium 1 varies from 20–28 thecae, from cladium 1 to cladium 2 it is about 5 thecae, cladium 2 to cladium 3 from 5–9 thecae, and cladium 3 to cladium 4 also 5–9 thecae. The width of the main stipe increases gradually from 0.5 mm at th1 to 0.8 mm at th5, and to a distal maximum of 2 mm.

The thecae are triangular with hooked apertures, the hooks occupying about one third of the width of the rhabdosome. The best preserved specimens show a pair of small lateral apertural spines. The proximal thecae number 10 per 10 mm, the distal thecae number 9 per 10 mm.

The sicula is 1 mm long and the apex reaches the aperture of th1. The width of th1 is 0.5 mm and of th2 0.8 mm.

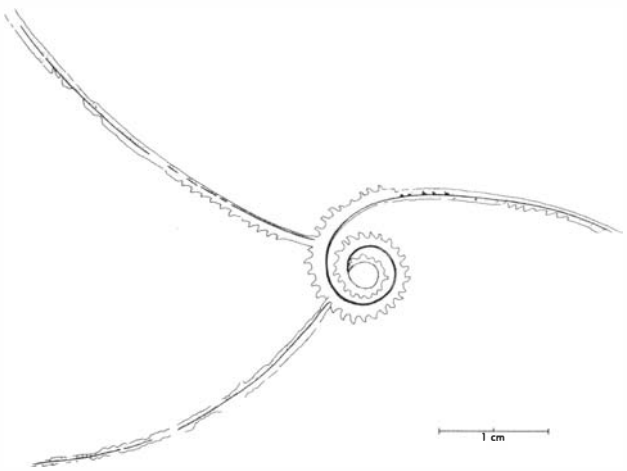


Fig. 25. Cyrtograptus centrifugus Bouček, 1931. The *centrifugus* Zone, Øleå. MMH 13494.

Remarks.—Strachan (1969) and others have discussed the taxonomically valuable features among the cyrtograptids, but a thorough revision of the group has not yet been done. Here, the following characters are believed relevant for discussions of the cyrtograptid taxonomy.

When differentiation at the specific level is required, one of the most characteristic features within the cyrtograptids is the cladial development—whether it is primary or of higher orders. Also the distances between the cladial outgrowths are regarded as significant.

In this work a distinction is made between forms with different degrees of coiling of the proximal portion of the main stipe, but this character is regarded as valuable only for the differentiation of the subspecies level, when other characters of the rhabdosomes are identical. Otherwise the degree of the main stipe curvature and of the cladia is here considered to be less important. This implies that it is possible to separate *Cyrtograptus murchisoni bohemicus* Bouček from *C. centrifugus* at the subspecific level, as the only difference between the two graptolites is the degree of enrolling of the proximal end. *C. murchisoni bohemicus* is coiled to a maximum of 450°, according to the revised description of Bouček (1933), whereas *C. centrifugus* has a proximal part which shows two or three complete volutions.

As the mode of cladial development and position is regarded as much more important than the curvature of the rhabdosome, the taxonomic position of *C. murchisoni bohemicus,* which only has cladia of primary order different from *C. murchisoni murchisoni,* will have to be changed accordingly. *C. centrifugus* and *C. murchisoni bohemicus* may be regarded as being conspecific, but belonging to different subspecies. However, a restudy of the type specimen of *C. murchisoni bohemicus* is necessary before a formal decision about the suggested change can be made.

Cyrtograptus murchisoni crassiculus Tullberg, which is primarily figured in Tullberg (1883, Pl. 4:6) and deposited in the collections of the Geological Survey, Stockholm, is very close to *C. centrifugus,* but the lack of the proximal end implies that it is not, based upon the

available material, possible to make further comparisions of these specimens to *C. centrifugus*. Otherwise, the measured dimensions of the material preserved in S.G.U. agree with those of *C. centrifugus*. In the Swedish specimens the width of the proximal end (sicula and the proximal thecae are missing) is 1.4 mm, and the width of the distal part of the rhabdosome is 2 mm. The thecae number 4 in 5 mm in the mesial part of the rhabdosome. Additional material from the type locality in Sweden may show that *C. centrifugus* and *C. murchisoni crassiculus* are identical, and that *C. centrifugus* accordingly, must be regarded as a junior synonym.

On Bornholm all known specimens with well preserved proximal parts are enrolled more than 450°, and they are presently referred to *C. centrifugus*. However, the material shows some variation. Some specimens occur with dimensions equal to those of the typical *C. centrifugus* (thecal number per 10 mm, width of the rhabdosome, and distances between cladia), but the proximal parts are coiled in a more open spiral, about 2–3 cm in diameter, and the cladia are more strongly curved. With more material and better definition of the curvature of the proximal portions, which may be possibly valid for the determination of taxonomic position, a separation of the apparently different forms now included in *C. centrifugus* may be possible.

In the present material the proximal spiral of *C. centrifugus* is more or less excentrically enrolled, but this feature is supposed to depend mainly upon post-mortem bedding of the rhabdosome, and is not regarded as taxonomically important, contrary to Bouček (1933).

All specimens previously found on Bornholm were referred to *C. murchisoni* by Laursen (1940 and 1943). However, specimens of *C. murchisoni* are easily distinguished from the earlier collected specimens which have only developed cladia of first-order. A preparation of the counterpart of the specimens described and figured by Laursen (1940, Pl. 4: 1) as *C. murchisoni* shows that the proximal portion is coiled more than twice. Furthermore, no secondary cladia have been observed, and the specimen can now safely be referred to *C. centrifugus*.

In Britain and in Bohemia *C. centrifugus* indicates the basal part of Wenlock (Strachan, 1960; Cocks & Rickards, 1969; Bouček, 1960). On Bornholm *C. centrifugus* is also regarded as indicative for the lowermost Wenlock, and the most important associates are here *R. geinitzianus geinitzianus, M. vomerinus basilicus,* and *M. priodon.*

Cyrtograptus insectus Bouček, 1931
Fig. 26

Synonymy.—☐ (?) 1883 *Cyrtograptus Murchisoni* Carr. —Tullberg: 35 (pars), Pl. 4:9. ☐ 1931 *Cyrtograptus insectus* n. sp.—Bouček: 12, Figs. 12a–b. ☐ 1933 *Cyrtograptus insectus,* Bouček.—Bouček: 37–39, Figs. 7a–b, Pl. 2:4–7, ?8, Pl. 6: 1. ☐ 1952 *Cyrtograptus insectus* Bouč.—Münch: 136, Pl. 50:a–c, ?d.

Holotype.—The specimen figured by Bouček (1931, Fig. 12); from the lower Wenlock, Vyskočilka, Bohemia.

Fig. 26. Cyrtograptus insectus Bouček, 1931. The *centrifugus* Zone, Øleå. MMH 13495.

Material.—2 specimens which both are flattened.

Horizon and locality.—The lower part of the *centrifugus* Zone, Øleå (Ø32).

Description.—The rhabdosome is large, the main stipe is curved, but not seen in its full development. Cladial development goes up to at least third-order. The main stipe is proximally coiled to a maximum of about 450°, the extreme proximal end with sicula not being found. The cladia may attain a length of at least 30 cm. The first cladium of primary-order originates about 180° from the proximal end of the main stipe, the second primary-order cladium 2.5 cm from the first one, and the third cladium 4.5 cm from the second. The first cladium of second-order originates on the first primary cladium 2.5 cm from its outgrowth, and the first second-order cladium of the second primary cladium originates 7 cm from its origin. The interval is 6–8 cm between later cladia. The width of the proximal part of the rhabdosome is 1.0 mm increasing to 2 mm in the distal part.

The thecal structures have not been seen in detail. The thecae appear to be triangular with small apertural hooks, as figured in Bouček (1931), but no apertural spines can be seen in the present specimens. The thecal spacing is 10 in 10 mm in the proximal part of the rhabdosome. The sicula and the initial thecae are not seen.

Remarks.—The two specimens show a great resemblance to *C. insectus,* figured in Bouček (1933, Pl. 6: 1), with regard to the curvature of the rhabdosome, the degree of enrolling of the proximal end, and the distances between the points of origin of the cladia.

The two original specimens figured by Tullberg (1883, Pl. 4: 9) as *C. murchisoni* have been restudied by the

author. They are initially 0.8 mm in width. The rhabdosome has cladia of second-order, and the degree of enrolling of the proximal end corresponds to that of the present specimens. The thecae number 9–10 per 10 mm and are similar to those in Bouček (1931) with very small apertural spines. The two specimens may possibly be referred to *C. insectus*.

In Bohemia *C. insectus* is an index fossil of the corresponding graptolite zone in the lowermost Wenlock (Bouček, 1960). On Bornholm the poor material does not indicate the zone itself. However, the level of the occurrence on Bornholm corresponds to that of the Bohemian specimens.

Genus *Barrandeograptus* Bouček, 1933

Type species (subsequently designated by Bouček, 1933). —*Cyrtograptus pulchellus*; from the Silurian, Sweden.

Diagnosis (emended herein).—The stipe is slender, generally not spirally coiled. The thecae are slender, axially elongated, triangular tubes. They may be biform, with or without apertural modifications.

Barrandeograptus pulchellus (Tullberg, 1883)
Figs. 27C–D, Pl. 13: E

Synonymy.—□ 1883 *Cyrtograptus pulchellus* n. sp.—Tullberg: 36–37, Pl. 3: 12–13. □ ? 1933 *Cyrtograptus (Barrandeograptus) pulchellus,* Tullberg.—Bouček: 64–65, Figs. 15a–b ?, Pl. 7: 1–6. □ 1940 *Cyrtograptus (Barrandeograptus) pulchellus* Tullb.—Laursen: 30, Fig. 27. □ 1952 *Cyrtograptus (Barrandeograptus) pulchellus* Tullb.—Münch: 141, Pl. 56: 1a–c. □ 1952 *Barrandeograptus pulchellus* (Tullberg).—Bouček & Přibyl: 19–20 (pars), Figs. 5a–b?, Pl. 3: 3, Pl. 4: 1, 2–3 ?. □ 1968 *Cyrtograptus (Barrandeograptus pulchellus)* Tullberg.—Schauer: 40, Pl. 2: 7–8 (the text is from Bouček (1933)).

Lectotype.—Bouček (1933) designated the specimen figured Pl. 7: 3–4, from the *insectus* Zone, Vyskočilka, Bohemia, as "neo-holotype". This choice is unfortunate, as the specimen seems to be considerably different from the original specimens described by Tullberg (1883). Instead, the specimen figured by Tullberg (1883, Pl. 3: 12–13) is here proposed as lectotype. The specimen is preserved in SGU, Stockholm, Sweden; from the *lapworthi* Zone in Röstånga, Scania.

Material.—About 20 specimens which are preserved flattened or with low relief. From Bornholm no proximal end with the sicula are known. In addition, the original material described by Tullberg (1883) has been reexamined.

Horizon and localities.—The lower part of the *lapworthi* Zone, Øleå (Ø29), (Ø40), Læså (L5).

Description.—The rhabdosome is cyrtograptid with primary and secondary cladia. The main stipe of the rhabdosome is commonly irregularly curved, but the proximal end is somewhat rounded and dorsally curved. The longest fragment is about 10 cm. The first cladium of first-order originates about 8 mm from the extreme proximal end, the second cladium of first-order originating 3 cm from the first cladium. The second-order cladium grows out some 2.5 cm from the proximal end of the first cladium. The width of the rhabdosome increases from 0.25 in the proximal part to 1.0 mm distally.

The thecae appear as rather simple tubes. In the distal thecae the ventral wall is inclined at 35° to the axis of the rhabdosome, and the apertural part is perpendicular to the thecal axis. The distal thecae are 2 mm long, and the common canal is about 0.5 mm wide. In flattened specimens the thecae appear to overlap by one third of their length, but in well preserved specimens it is seen that the thecae are not in contact with each other, the distal third of the thecal length being free. In well preserved specimens the dorsal wall of the free part of the thecae seems to have a median furrow situated perpendicular to the aperture, parallel to the thecal axis. Furthermore, some of the apertures show rounded thickened rims, and somewhat approach an apertural structure with two lateral lappets. Fusellar half rings on well preserved specimens are parallel to the apertural rims. Other apertures appear to be simple and rounded (Fig. 27: C). The state of preservation does not reveal additional details of the thecal apertures. The thecae number proximally 8 per 10 mm, and distally 7.5 in 10 mm. The sicula has not been seen in the specimens from Bornholm.

A sicula is present in the specimen figured in Tullberg (1883, Pl. 3: 12–13). It is 1.5 mm long and the apex reaches the middle of the protheca of th1. The width of th1 is 0.15 mm. The proximal thecae are axially elongated with very slender proximal parts, and the apertural regions are apparently hooked. The recurved part of the small hooks occupies half the width of the rhabdosome, and the height of the hook is only one tenth of the thecal height. The most proximal thecae are about 1.5 mm in height and number 6–7 in 10 mm.

Remarks.—The genus *Barrandeograptus* has hitherto been deliniated by the uniform thecae throughout the rhabdosome, but after a restudy of Tullberg's specimen, showing hooked initial thecae, the diagnosis for the genus is emended accordingly.

Bouček (1933) and Bouček & Přibyl (1952) included in *B. pulchellus* a specimen which is different from that originally described. Bouček (1933) described the "neo-holotype" with a main branch and sidebranches of up to 3–4th order, and with a slow increase in width throughout the rhabdosome. The specimens from Sweden and Bornholm show a rapid increase in width from 0.15–0.25 mm in the proximal end to 0.8 mm at the level of th15. Furthermore, the thecae in the Scandinavian specimens apparently do not have simple apertural parts, as those described by Bouček (1933).

The specimens figured in Bouček & Přibyl (1952, Pl.

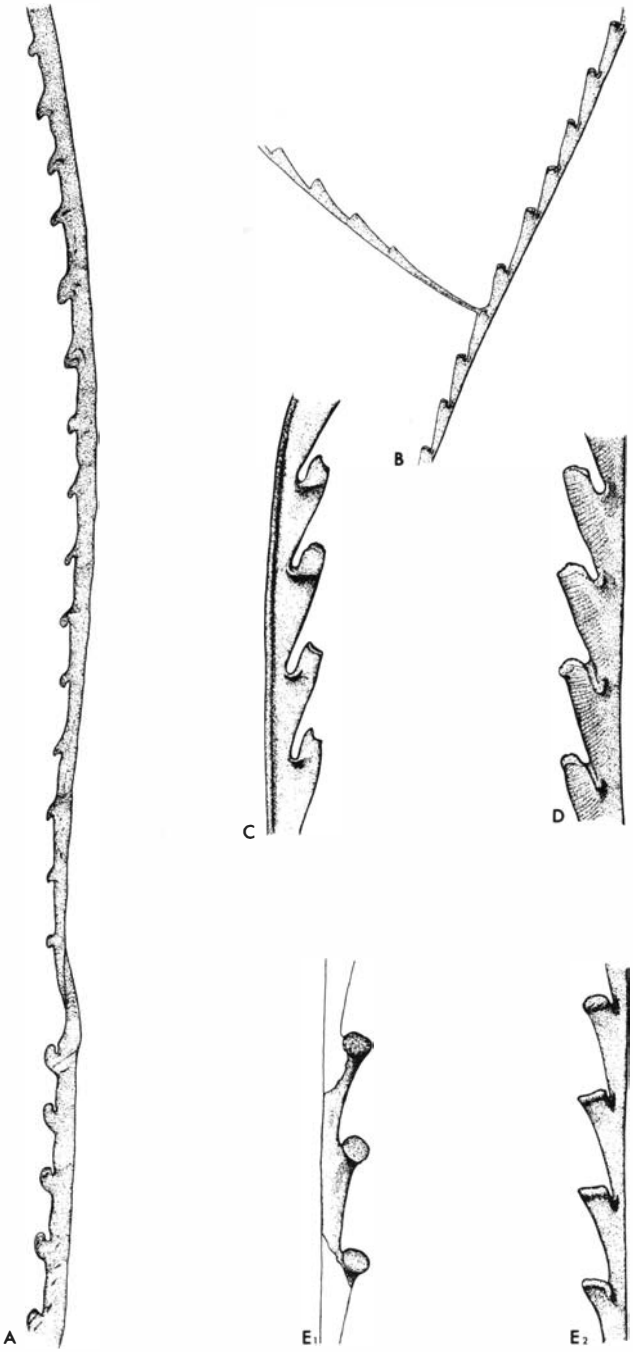


Fig. 27. □ A. *Diversograptus runcinatus* (Lapworth, 1876). The *turriculatus* Zone, Øleå. MMH 13496. ×10. □ B. *Barrandeograptus? bornholmensis* (Laursen, 1940). The *centrifugus* Zone, Øleå. MMH 3843. ×5. □ C–D. *Barrandeograptus pulchellus* (Tullberg, 1883). Sections of mesial parts of a rhabdosome. The *lapworthi* Zone, Øleå. MMH 13497. ×10. □ E. *?Diversograptus* sp. The *spiralis* Zone, middle part, Øleå. MMH 13498. ×10. E_1 Section from 1. in Fig. 28. E_2. Section from 2 in Fig. 28.

4: 2–3) have elongated thecae which resemble the thecae of the specimens of *B.? bornholmensis* from the middle part of the *centrifugus* Zone on Bornholm.

Barrandeograptus? bornholmensis (Laursen, 1940)
Fig. 27B

Synonymy.—□ 1940 *Cyrtograptus bornholmensis* n. sp.—Laursen: 30, 35–36, Pl. 3: 1–4. □ 1952 *Barrandeograptus pulchellus* (Tullberg).—Bouček & Přibyl: 18–20 (pars).

Lectotype (designated herein).—The specimen figured by Laursen (1940, Pl. 3: 1–4), MMH 3843; from the *centrifugus* Zone, Lower Wenlock, Bornholm.

Material.—About 30 specimens which all are flattened and fragmentary, the sicula is not seen. The original specimen figured by Laursen (1940) has also been examined.

Horizon and localities.—The *centrifugus* Zone, Øleå (Ø32)–(Ø38) and Læså (L1).

New diagnosis.–The rhabdosome is slender throughout. The width does not exceed 0.75 mm and is in average about 0.5 mm. The cladia may be of up to third-order. The thecae are axially elongated and isolated. The apertures are rounded. The thecal spacing is 6–7 per 10 mm.

Description.—The rhabdosome is only known in a fragmentary state and may be more or less irregularly curved. The longest main stipe is more than 20 cm in length and the cladia may exceed 14 cm. The width increases slowly throughout the rhabdosome from 0.1–0.2 mm proximally to a maximum of 0.75 mm measured distally in one specimen. The distal width is 0.5 mm in most of the specimens.

The thecae are axially elongated and they number 6–7 in 10 mm throughout the rhabdosome. The straight ventral walls are inclined at 15°–20° to the axis of the rhabdosome, and there is no thecal overlap. The extreme distal portions of the thecae are free. The apertures are rounded and face the distal part of the rhabdosome. In well preserved fragments is seen a small dorso-ventral apertural eversion which is somewhat similar to the profile of the apertural parts of *Lobograptus*. However, the details of the thecal apertures are obscured.

The sicula has not been found, but the most proximal end of the main stipe has a more pronounced curvature than the distal parts of the rhabdosome.

Remarks.—*B.? bornholmensis* was included into *B. pulchellus* by Bouček & Přibyl (1952), but must be regarded as a separate species. *B.? bornholmensis* is distinguished from *B. pulchellus* by the lesser width which increases very slowly throughout the rhabdosome to a general maximum of 0.5 mm.

The enrolled thecae described and drawn by Laursen (1940) have not been found, not even in the lectotype, and the structures of the apertures are in fact more simple. However, the apertures are somewhat similar to those of *B. pulchellus*. The species is tentatively referred to *Barrandeograptus* by the shape of the rhabdosome end of the thecae, but the proximal end is unknown.

B.? bornholmensis is rather frequent throughout the *centrifugus* Zone. It is associated with *S. grandis grandis, R. geinitzianus geinitzianus, M. vomerinus basilicus, M. priodon,* and the index fossil.

Genus *Diversograptus* Manck, 1923

Type species.—*Diversograptus ramosus* Manck, 1923; from the Silurian, Germany.

Diagnosis (from Bulman, 1970).—Rhabdosome comprising one sicular cladium, with or without thecal cladia; thecae hooked, with retroflexed apertures generally becoming simpler distally.

Diversograptus runcinatus (Lapworth, 1876)

Fig. 27A, Pl. 13:D

Synonymy.—□ 1876 *Monograptus runcinatus* sp. nov.—Lapworth: 501–502, Pl. 20:4a–g. □ non 1891 *Monograptus runcinatus.*—Linnarsson: 503, Pl. 23:8–12. □ 1892 *Monograptus runcinatus* Lapworth.—Törnquist: 27–28, Pl. 2:29–30. □ 1897 *Monograptus runcinatus,* Lapworth.—Perner: 19, Figs. 19a–b. □ 1912 *Monograptus runcinatus,* Lapworth.—Elles & Wood: 450–451 (pars), Figs. 309e–f (non 309a–d), Pl. 45:2c–g (non 2a–b). □ non 1942 *Monograptus (Streptograptus) runcinatus* (Lapworth).—Bouček & Přibyl: 11–12, Figs. 5a–d, Pl. 2:1–3. □ non 1952 *Streptograptus runcinatus* Lapworth.—Münch: 112, Pl. 35:8. □ 1952 *Diversograptus runcinatus* (Lapworth).—Strachan: 365–368, Fig. 1a–c. □ ? 1970 *Monograptus* ex gr. *runcinatus* Lapworth.—Rickards: 79–80, Fig. 17:22, Pl. 6:2. □ ? 1971 *Monograptus (Streptograptus) runcinatus runcinatus* Lapworth.—Schauer: 70–71, Pl. 25:11–12.

Lectotype.—Designated by Bouček & Přibyl (1942:11); as the specimen figured in Lapworth (1876, Pl. 2:4c), refigured Elles & Wood (1912, Pl. 45:2e), BU 1639; from Glenkin Burn, Scotland.

Material.—About 25 specimens which are preserved flattened or with partial relief.

Horizon and localities.—The lower part of the *turriculatus* Zone, Øleå (Ø13a)—(Ø13b).

Description.—The rhabdosome is more than 5 cm long, straight or slightly curved. The width increases steadily throughout the rhabdosome from an initial width of 0.25 mm at th1 to 0.9 mm in the distal portion.

The thecae are of the same structure all through the rhabdosome. The free ventral walls are parallel to the axis of the rhabdosome and the apertural portions are reflexed. The apertures in flattened specimens are inclined at 150° to the axis of the rhabdosome and face dorsally to proximally. In the proximal thecae the reflexed part occupies one third of the thecal height, distally nearly half the height. All along the rhabdosome the reflexed part occupies one third of the width of the stipe. The thecal count is proximally 6 in 5 mm, distally 8.5 per 10 mm.

The sicula is 1.2 mm long and the apex reaches the base of th2. Th1 originates 0.3 mm from the aperture of the sicula.

In the author's material a diversograptid development, as described by Strachan (1952), is seen in a single specimen. Here a sicula-like structure is developed. One of the stipes shows a "normal" monograptid development, the sicula being of the same size as in the single-stiped specimens. The width of the initial theca is 0.25 mm. The "normal" monograptid stipe is 2 cm long and the thecal count is 6 in the proximal 5 mm.

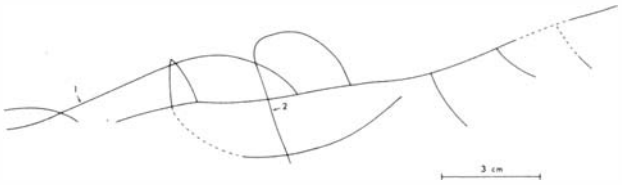


Fig. 28. ?*Diversograptus* sp. The *spiralis* Zone, Øleå. MMH 13498.

In the sicular cladium the protheca of the first theca seems to grow directly out from the aperture of the sicula, the height being only half the height of the succeeding thecae. The width of the theca is 0.5 mm corresponding to th15 in the main stipe. The length of the sicular cladium is 5 mm, and the thecae number 2.5 per 2.5 mm.

Remarks.—*D. runcinatus* from Bornholm is similar to the specimens described by Lapworth (1876). Linnarsson (1881), Elles & Wood (1912), Bouček & Přibyl (1942), and Schauer (1971) referred specimens with lobate "streptograptid" thecae to *M. runcinatus,* but they are not like the originally described samples, implying that the specimens with "streptograptid" thecae must be referred to other species, as for instance *M. pseudoruncinatus.*

Among the specimens with a "diversograptid" mode of growth observed on Bornholm *D. runcinatus* is the only one which has developed a sicular cladium with transversal septation (rounded like the aperture of the sicula). In all other "diversograptids" only oblique septa or direct outgrowths from the opposite thecae appear to be present.

D. runcinatus is still included in the genus *Diversograptus* by the sicular cladium, the hooked thecae with retroflexed apertures, and the rather slender rhabdosome. However, the sicular cladium is not frequent, and no thecal cladia have been observed. It is possible that the species, with a better understanding of the thecal structures, may be excluded from the genus *Diversograptus,* as done by Rickards (1973).

It is impossible to state on the basis of examination the present small quantity of material whether the diversograptid development is a regeneration phenomen with a sicular cladium outgrowth from a broken prothecal part, or a cladial outgrowth of the aperture of the sicula with the width of the initial thecae equal to that of the distal thecae in the original stipe. The latter development is comparable to a cladial outgrowth in *Cyrtograptus* but in the diversograptids the initial theca is different from the theca in *Cyrtograptus* in having a short prothecal part.

D. runcinatus is common in the basal part of the *turriculatus* Zone, and is associated with *G. auritus, M.*

turriculatus, M. planus, M. pseudoruncinatus, and *R. maximus.*

?Diversograptus sp.
Fig. 27E, Fig. 28

Material.—6 specimens which are preserved almost flattened.

Horizon and localities.—The middle of the *spiralis* Zone, Øleå (Ø26) and Læså (L6).

Description.—The rhabdosome is cyrtograptid, slightly curved, with a slender main stipe and slender cladia. The main stipe is at least 25 cm long and the longest cladium is 12 cm. Only cladia of first-order have been seen, and they are situated at a distance from each other of 2.5–3.5 cm. The main stipe is bipolar, but the outgrowth is concealed by torsion of the slender rhabdosome.

The thecae are axially elongated with a very small overlap. The width of the thecae at their base is 0.25 mm and the maximum width at the apertures is 0.75 mm. The distal fifth of the thecal length is retroflexed and twisted, always to the right side of the rhabdosome, in dorsal view. The apertural rims are rounded, and the apertures must face laterally, proximally to dorsally in the rhabdosome. However, the exact structures of the apertural region have not been observed. The thecae number 7 per 10 mm distally. No sicula has been observed.

Remarks.—The thecal structures of the specimens have a superficial resemblance to *B. pulchellus* figured in Přibyl & Bouček (1952, Pl. 4:2–3). In the description of *B. pulchellus* (p. 17) they mentioned that the apertures of the thecae were turned somewhat sidewards.

The thecal structures are quite different from the original *B. pulchellus* and, furthermore, a bipolar outgrowth is present. However, more material is required for a detailed description of this form.

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Plates

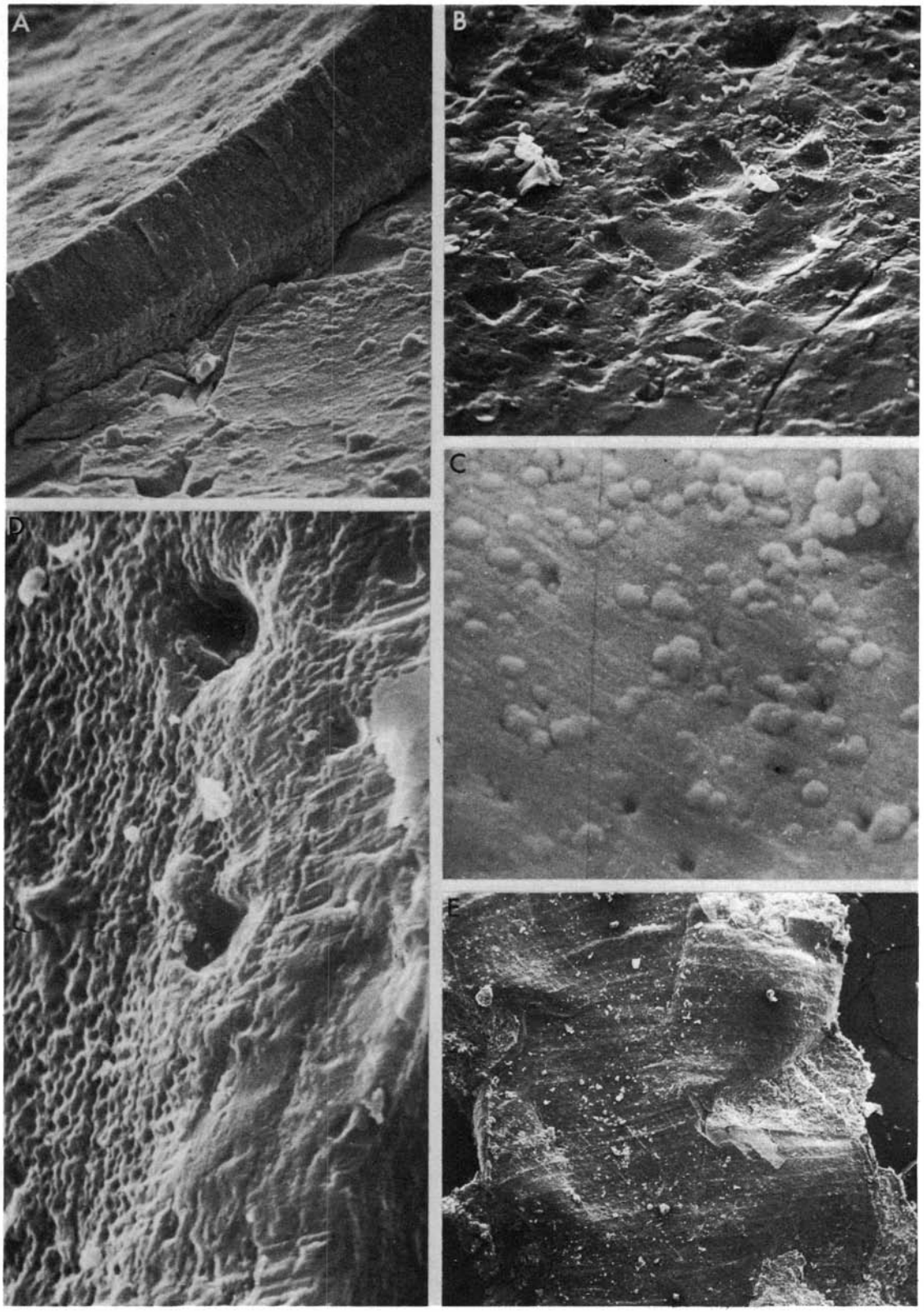


Plate 1. ☐ A. *Monograptus vomerinus vomerinus* (Nicholson, 1872). Cross section of a carbon film from a relief specimen, mesial in the rhabdosome. MMH 13592. × 1680. ☐ B. *Monograptus griestoniensis* (Nicol, 1850). Carbon film from the mesial part of the rhabdosome. MMH 13593. ×1920. ☐ C. *Monograptus vomerinus vomerinus* (Nicholson, 1872). Innerside of a carbon film from a pyritized specimen. MMH 13594. ×8000. ☐ D. *Pseudoclimacograptus undulatus* (Kurck, 1882). Lateral wall of a mesial theca. MMH 13595. ×4200. ☐ E. *Glyptograptus auritus* n. sp. Mesial part of the rhabdosome. MMH 13696. ×46.

Plate 2. ☐ A. *Glyptograptus auritus* n. sp. Cross section of the carbon film perpendicular to the growth ridges. From the mesial part of the rhabdosome figured on Pl. 1:E. The arrow indicates the direction of growth. ×480. ☐ B. *Glyptograptus auritus.* Enlargement of Pl. 1:A, 1. ×4800. ☐ C. *Glyptograptus auritus.* Enlargement of Pl. 1:A, 2. ×4800.

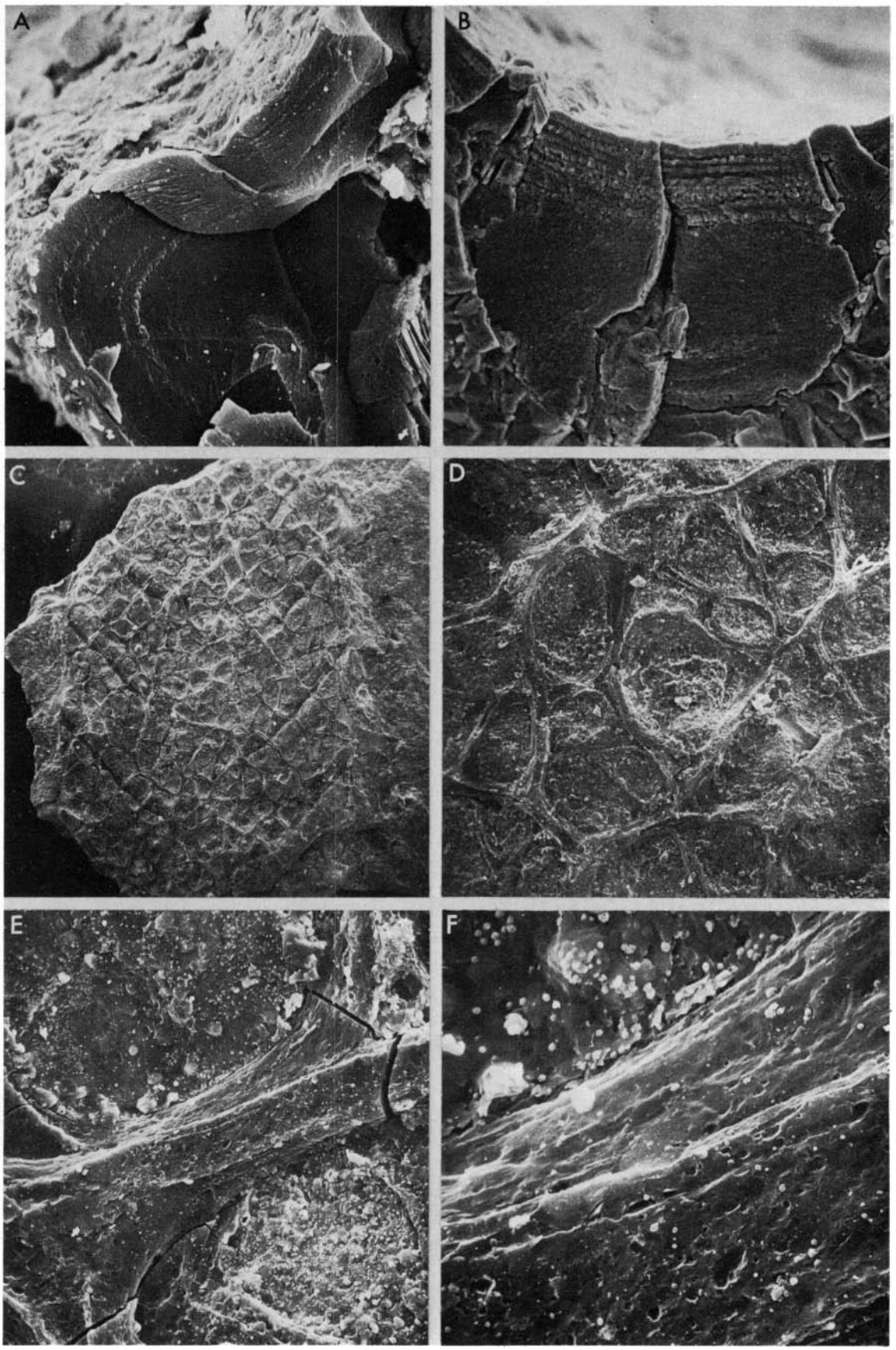


Plate 3. □ A. *Monograptus revolutus* Kurck, 1882. Cross section of virgula. MMH 13597. ×2000. □ B. *Monograptus vomerinus vomerinus.* (Nicholson, 1872). Cross section of virgula. MMH 13592. ×1330. □ C. *Stomatograptus grandis girvanensis* Cocks & Toghill, 1973 ?, mesial part of the rhabdosome. MMH 13598. ×19. □ D. Enlargement of the reticulum of *Stomatograptus grandis girvanensis?*, Fig. C. ×72. □ E. Enlargement of Fig. D. ×480. □ F. Enlargement of Fig. E. ×1920.

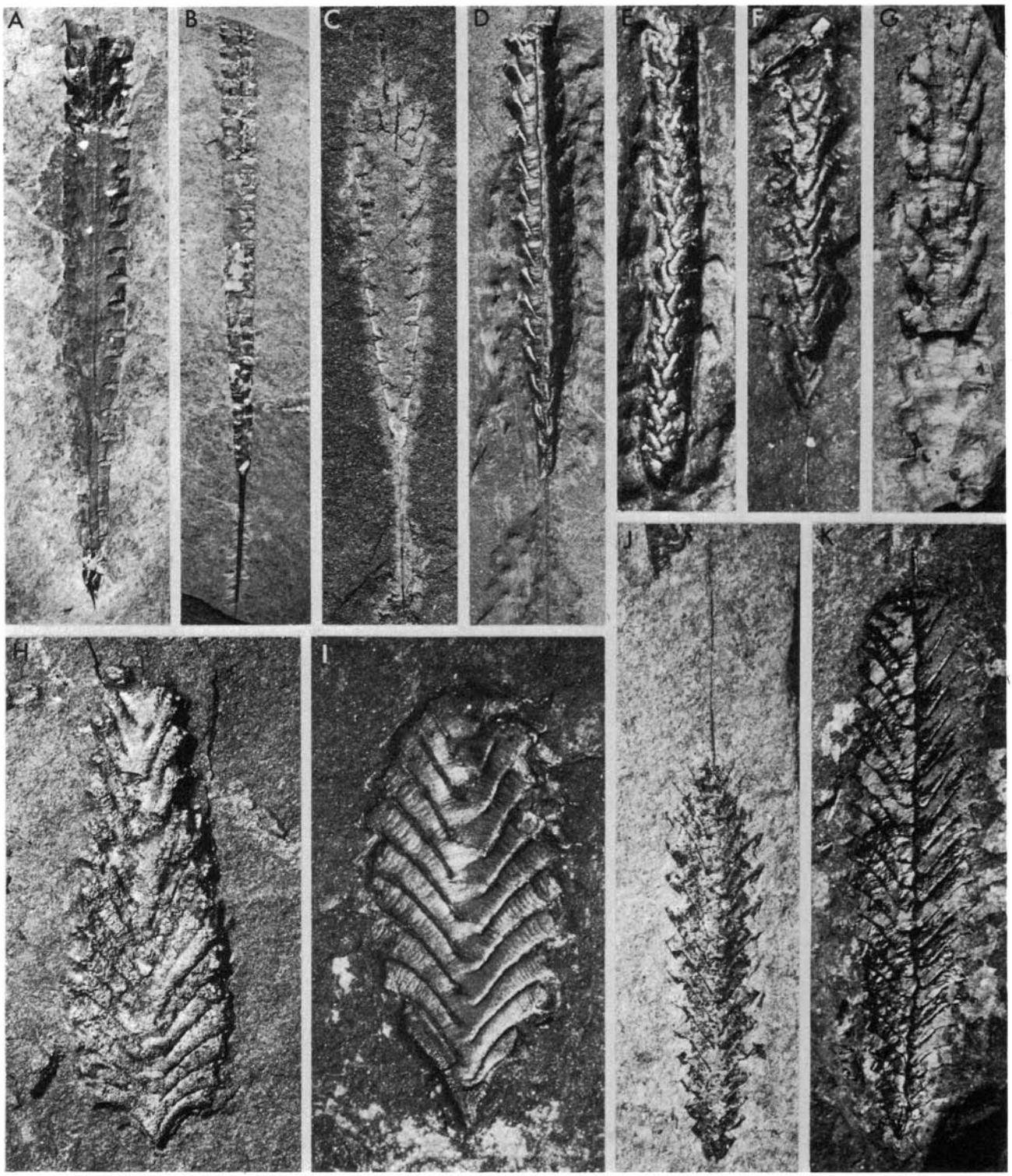
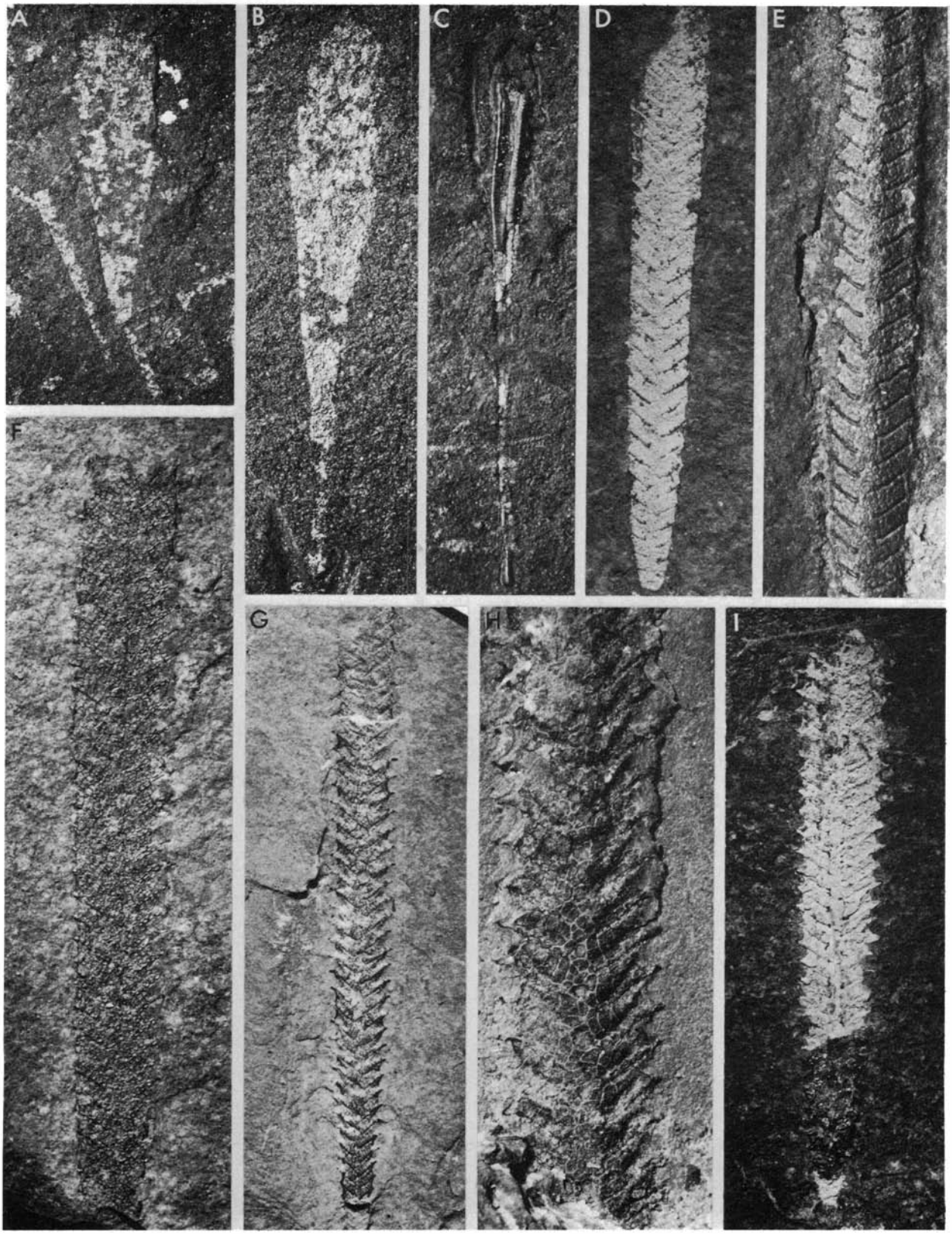


Plate 4. ☐ A. *Climacograptus rectangularis* (M'Coy, 1850). The *acinaces* Zone, Øleå. MMH 13599. ×5. ☐ B. *Climacograptus balticus* Pedersen, 1922. The *acinaces* Zone, Øleå. MMH 13600. ×3. ☐ C. *Diplograptus thuringiacus* Eisel. The *gregarius* Zone, Øleå. MMH 13499. ×5. ☐ D. *Glyptograptus sinuatus sinuatus* (Nicholson, 1869). The *revolutus* Zone, Øleå. MMH 13601. ×5. ☐ E. *Pseudoclimacograptus undulatus* (Kurck, 1882). The *convolutus* Zone, Øleå. MMH 13602. ×8. ☐ F. *Orthograptus bellulus* (Törnquist, 1890). The *convolutus* Zone, Øleå. MMH 13603. ×7.5. ☐ G. *Glyptograptus auritus* n. sp. The *turriculatus* Zone, Øleå. MMH 13604. ×7.5. ☐ H. *Petalograptus ovatoelongatus* (Kurck, 1882). The *gregarius* Zone, Øleå. MMH 13605. ×6.5. ☐ I. *Petalograptus minor* (Elles, 1897) ?. The *gregarius* Zone, Øleå. MMH 13606. ×9. ☐ J. *Petalograptus palmeus* (Barrande, 1850). The *turriculatus* Zone, Øleå. MMH 13607. ×7. ☐ K. *Petalograptus altissimus* Elles & Wood, 1908. The *turriculatus* Zone, Øleå. MMH 13608. ×6.



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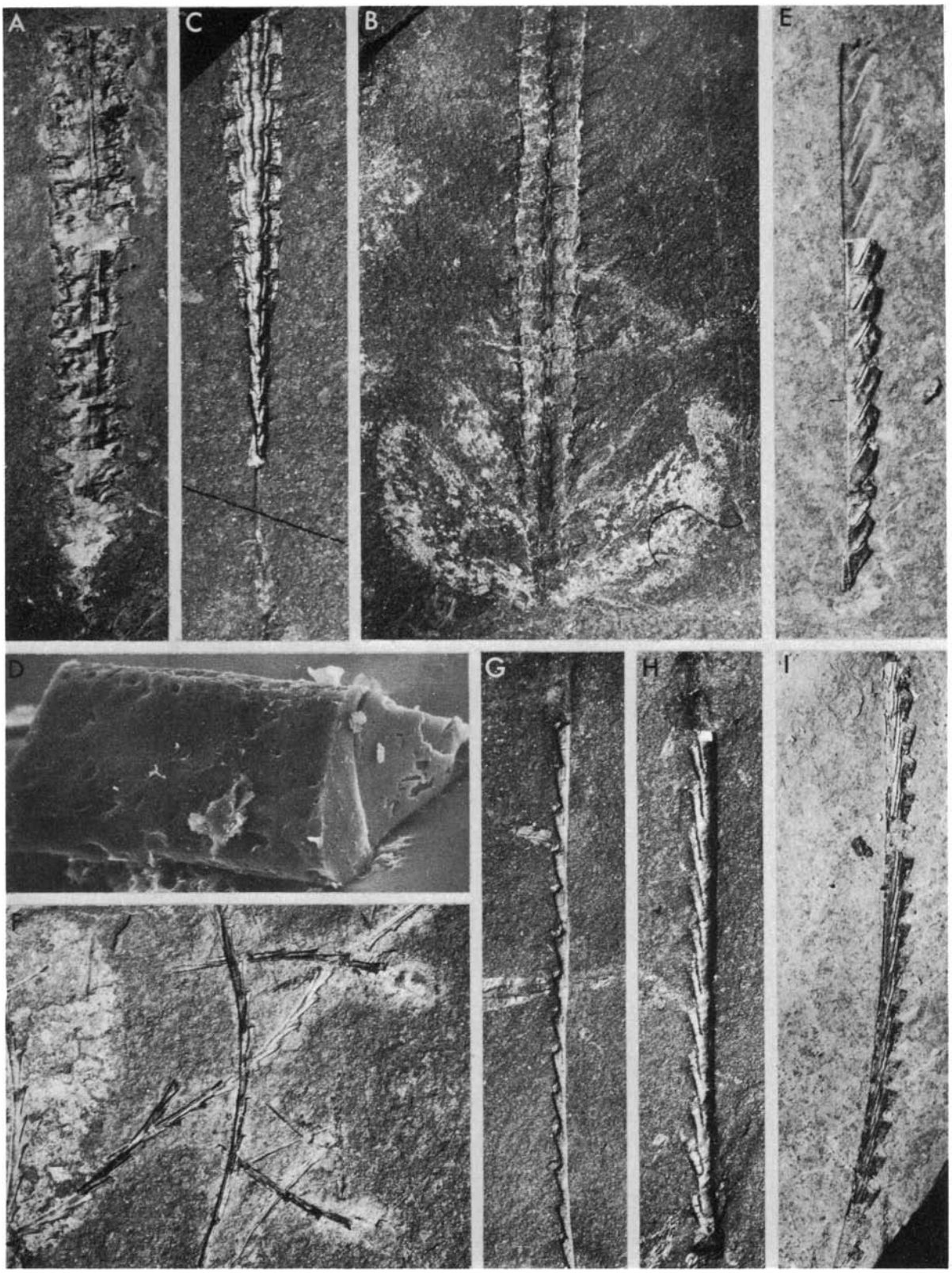
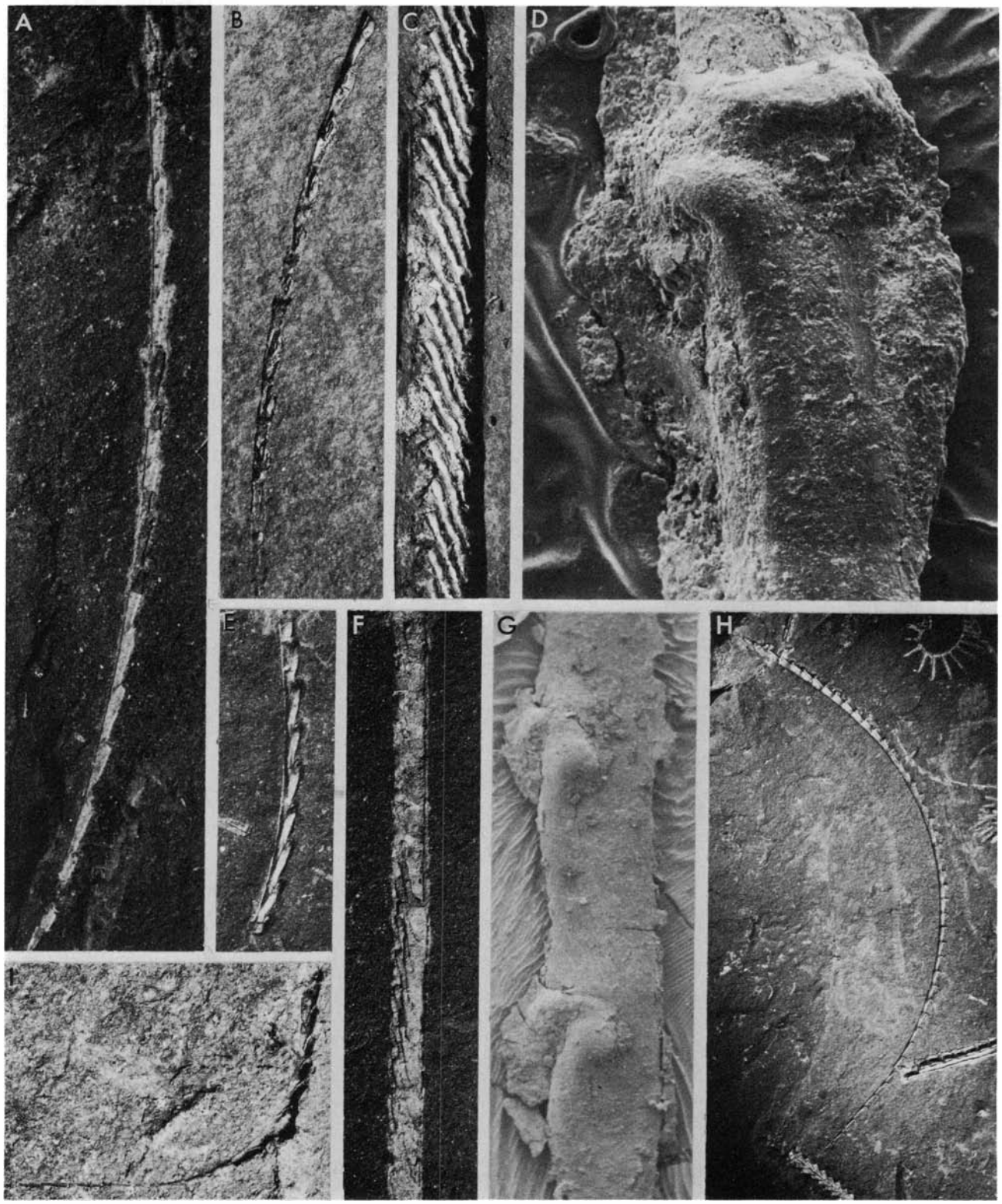


Plate 6. ☐ A. *Dimorphograptus confertus confertus* (Nicholson, 1868). The *acinaces* Zone, Øleå. MMH 13612. ×5. ☐ B. *Dimorphograptus physophora* (Nicholson, 1868). The *revolutus* Zone, Øleå. MMH 13613. ×4. ☐ C. *Rhaphidograptus toernquisti* (Elles & Wood, 1906). The *revolutus* Zone, Øleå. MMH 13614. ×5.5. ☐ D. *Rhaphidograptus toernquisti* (Elles & Wood, 1906). Virgella. The *revolutus* Zone, Øleå. MMH 13615. ×160. ☐ E. *Monograptus nudus* Lapworth, 1880. The *turriculatus* Zone, Øleå. MMH 13616. ×6. ☐ F. *Monograptus gregarius* Lapworth, 1876. The gregarius Zone, Øleå. MMH 13617. ×4.5. ☐ G. *Monograptus atavus* Jones, 1909. Proximal part. The *revolutus* Zone, Øleå. MMH 13618. ×5. ☐ H. *Monograptus atavus* Jones, 1909. Distal part. The *revolutus* Zone, Øleå. MMH 13619. ×5. ☐ I. *Monograptus acinaces* Törnquist, 1899. The *acinaces* Zone, Øleå. MMH 13620. ×4.



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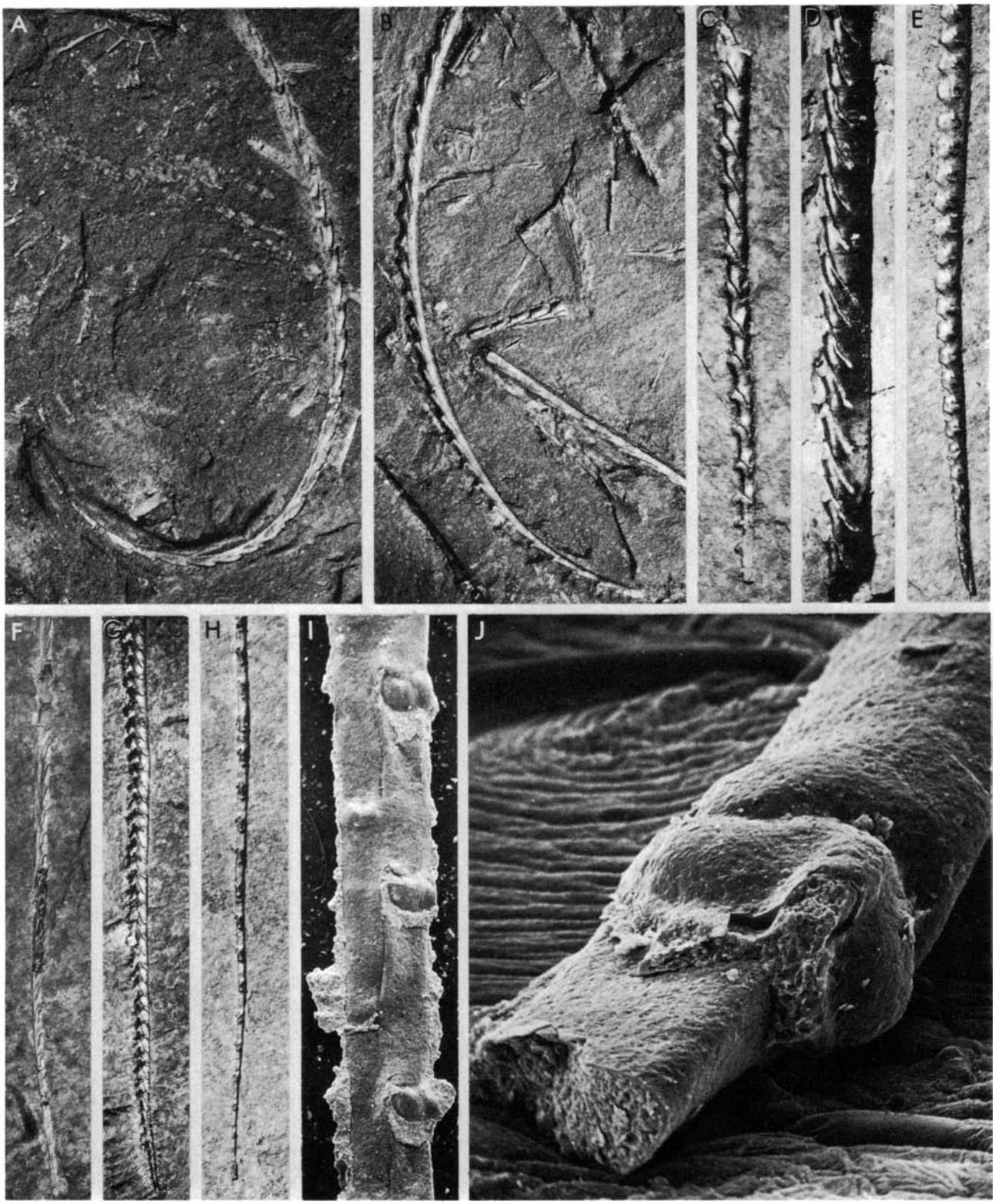
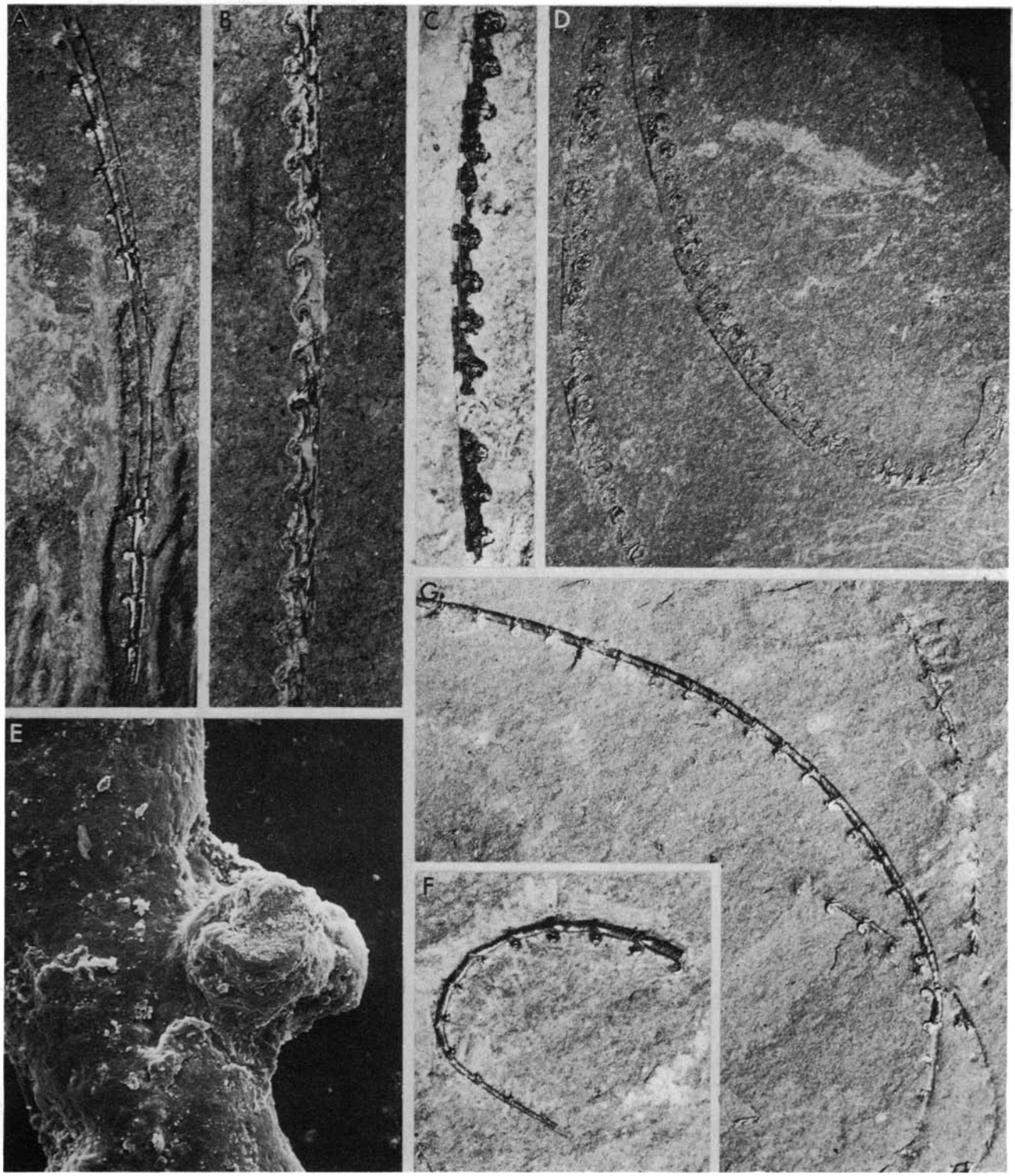


Plate 8. □ A. *Monograptus sudburiae* Hutt, 1974. The *gregarius* Zone, Øleå. MMH 13629. ×6. □ B. *Monograptus revolutus* Kurck, 1882. The *revolutus* Zone, Øleå. MMH 13630. ×5. □ C. *Monograptus galaensis* Lapworth, 1876. The *turriculatus* Zone, Øleå. MMH 13631. ×6. □ D. *Monograptus* aff. *crenulatus* sensu Elles & Wood, 1911. The *griestoniensis* Zone, Øleå. MMH 13632. ×5. □ E. *Monograptus vomerinus vomerinus* (Nicholson, 1872). The *spiralis* Zone, Øleå. MMH 13633. ×2. □ F. *Monograptus linnarssoni* Tullberg, 1883. The *lapworthi* Zone, Øleå. MMH 13634. ×3.9. □ G. *Monograptus vomerinus vomerinus* (Nicholson, 1872). The *centrifugus* Zone, Øleå. MMH 13635. ×4.5. □ H. *Monograptus griestoniensis* (Nicol, 1850). The *griestoniensis* Zone, Øleå. MMH 13460. ×6. □ I. *Monograptus griestoniensis* (Nicol, 1850). The *griestoniensis* Zone, Øleå. MMH 13636. ×32. □ J. *Monograptus griestoniensis* (Nicol, 1850). Mesial thecae. The *griestoniensis* Zone, Øleå. MMH 13593. ×250.



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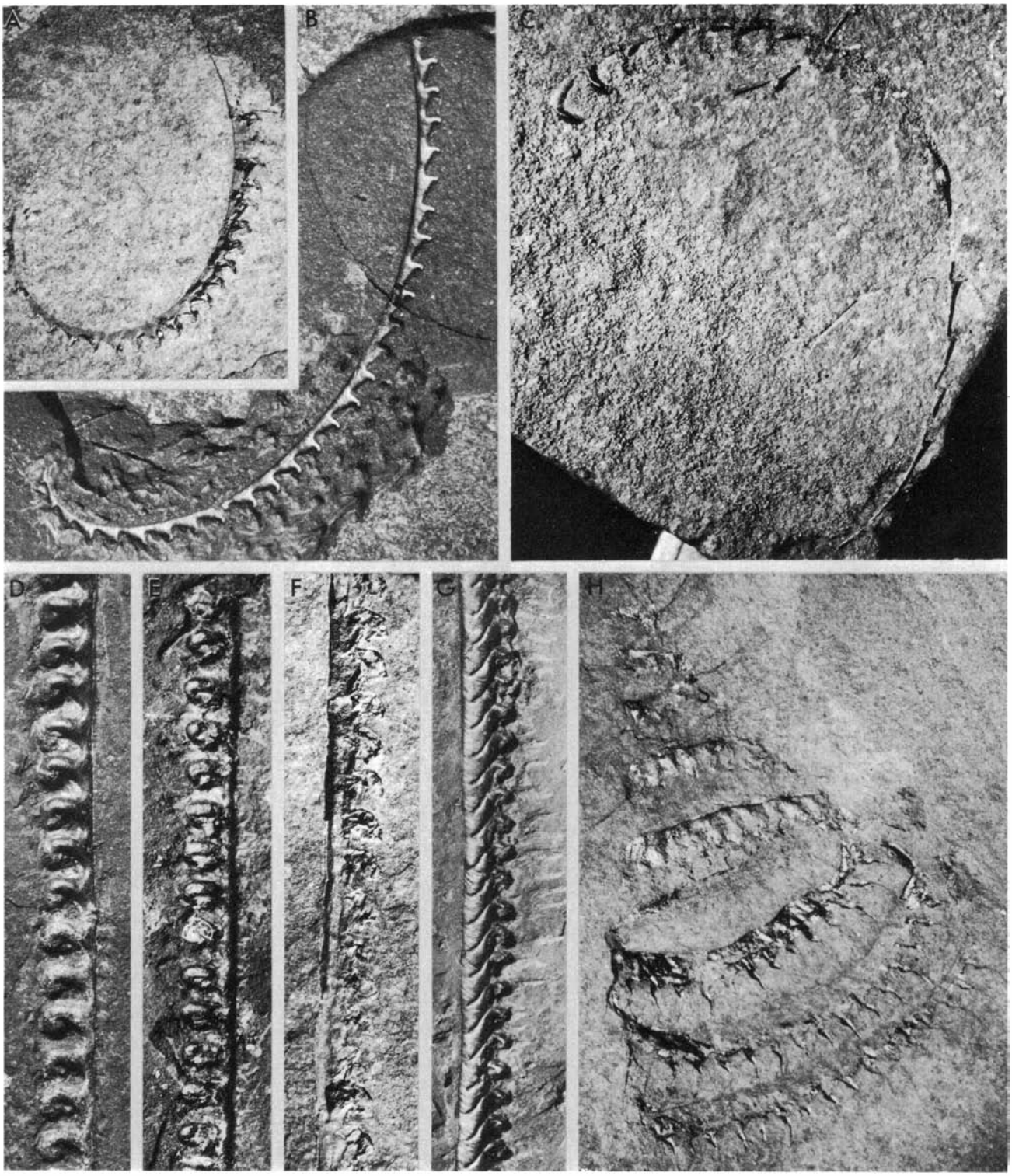

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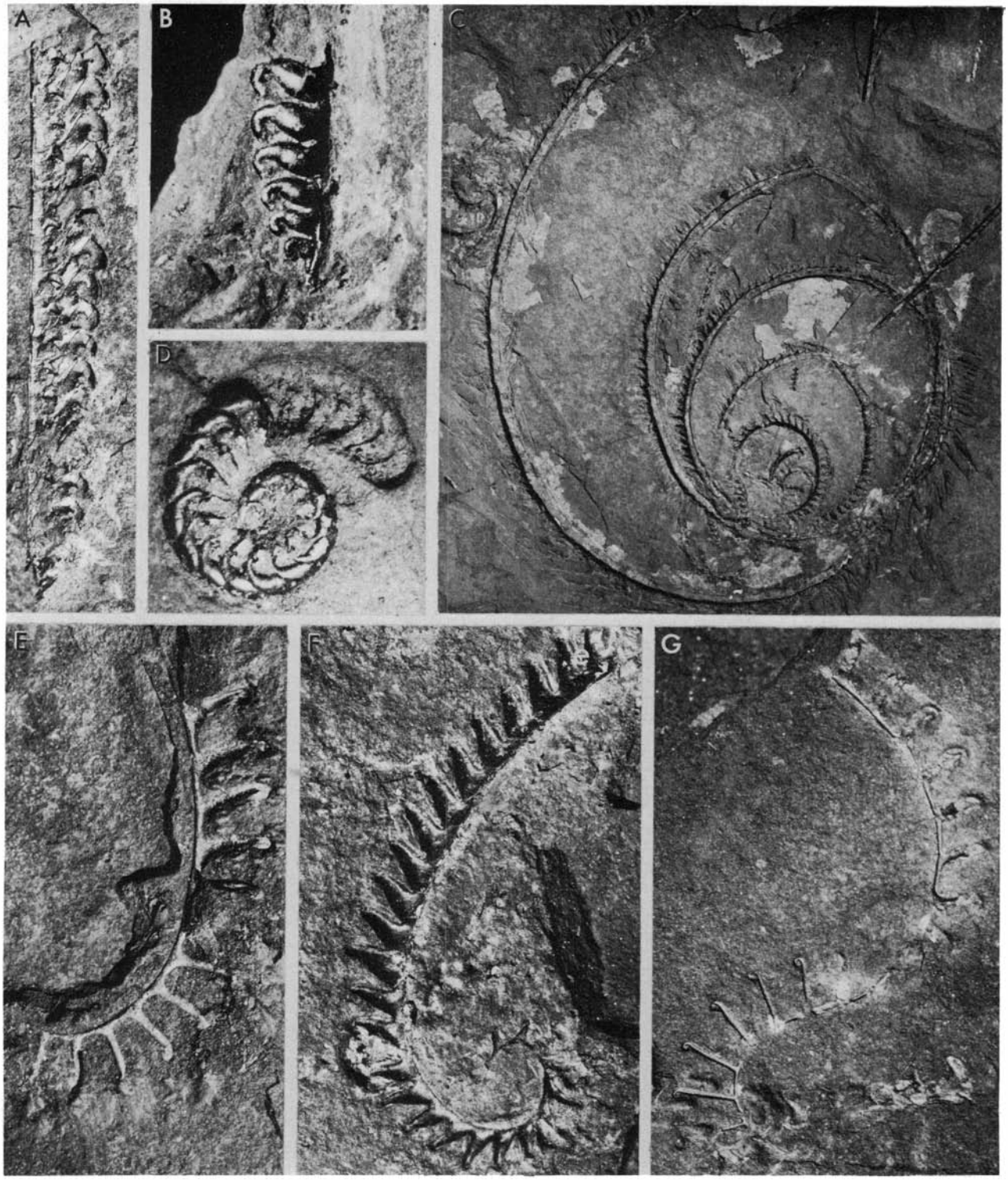

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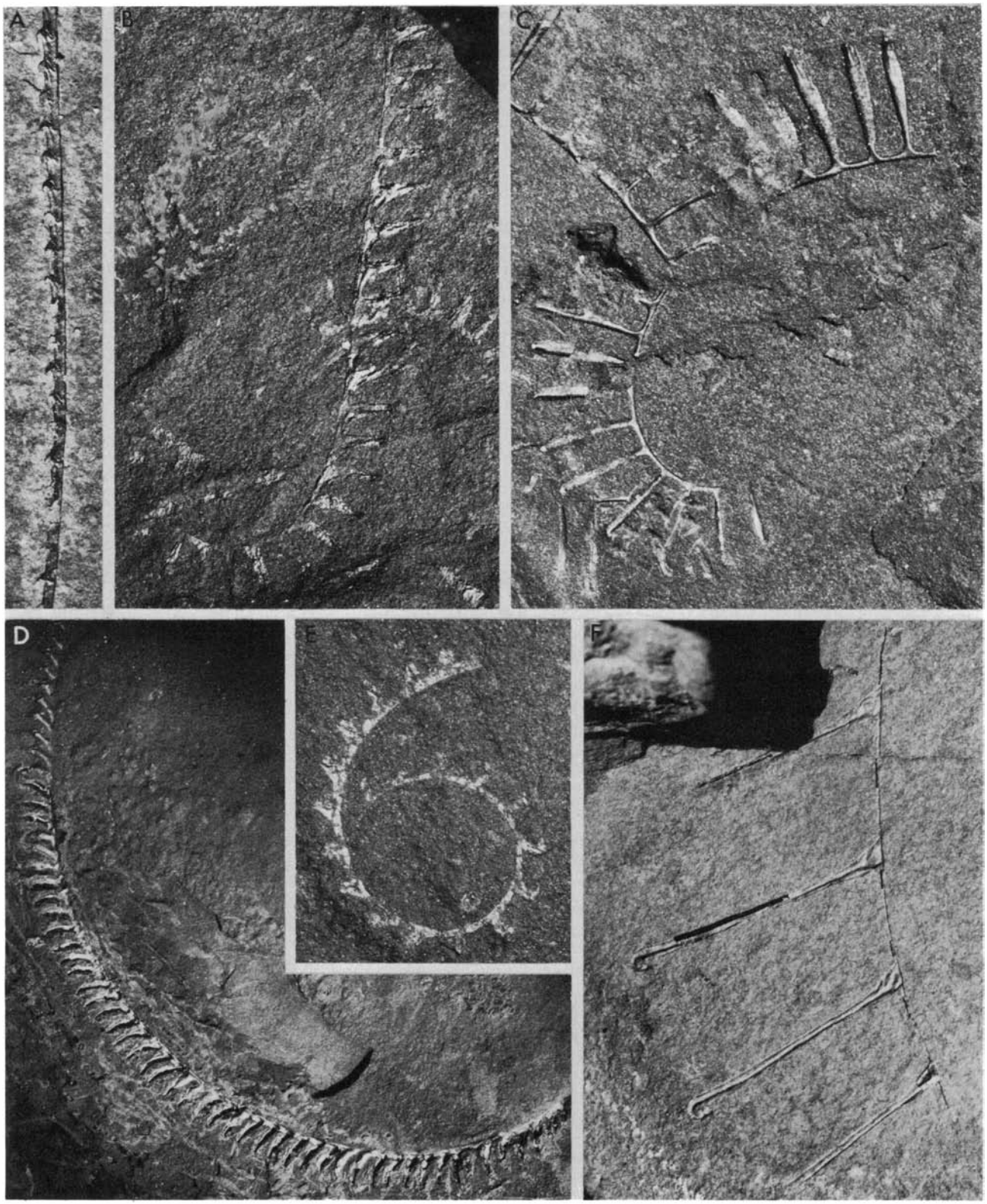

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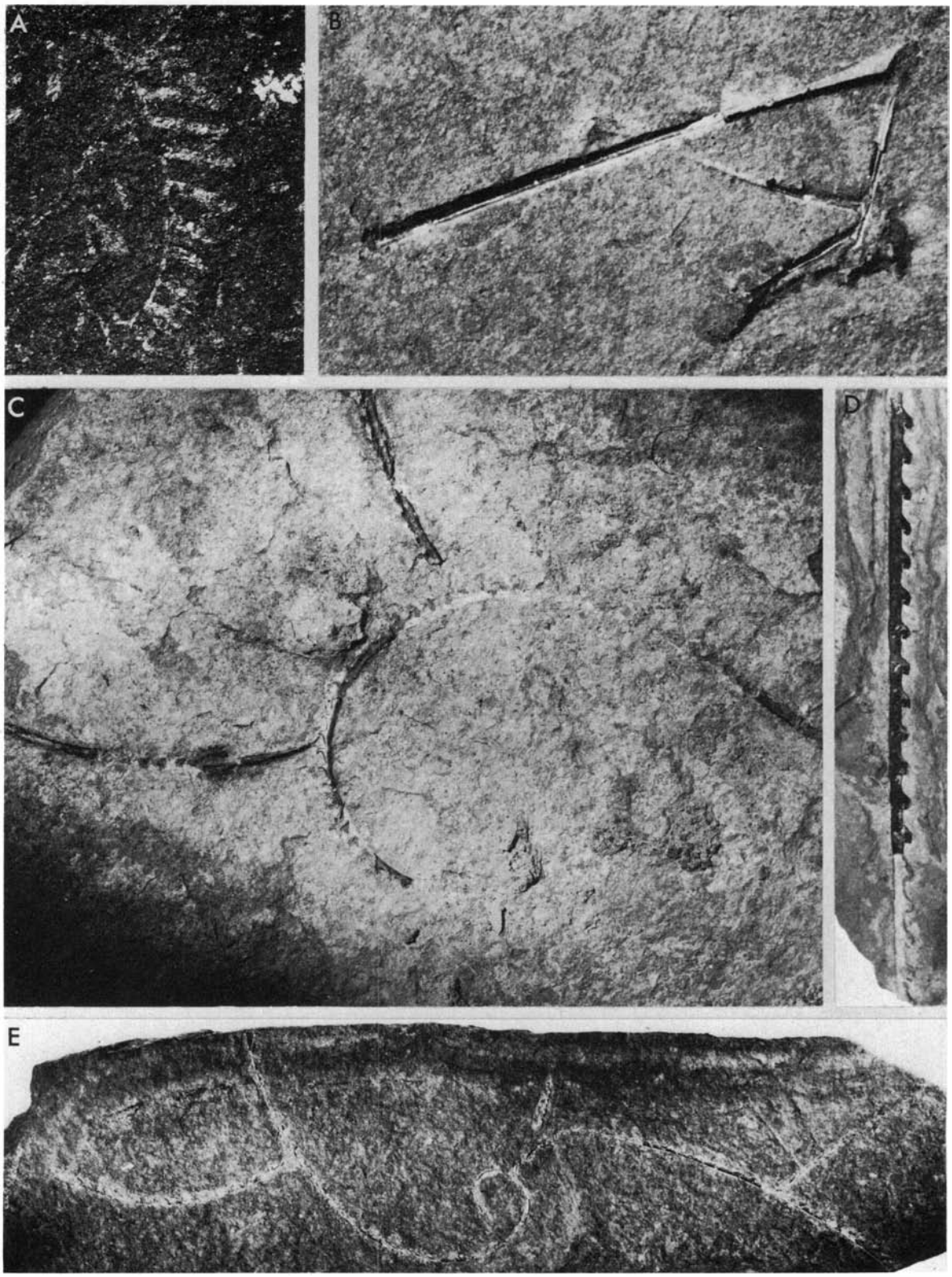

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