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Late Ordovician And Early Silurian Graptolites, Cape Phillips Formation, Canadian Arctic Archipelago

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Late Ordovician and Early Silurian Graptolites, Cape Phillips Formation, Canadian Arctic Archipelago

Volume I

by

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ABSTRACT

Ashgill and Llandovery graptolites have been collected from a eleven sections in the Cape Phillips Formation of the Canadian Arctic Archipelago: from Melville, Bathurst, Truro, Cornwallis, Devon and Ellesmere islands.

A total of 179 graptolite species and a further 25 subspecies have been identified including 19 new species, 11 new subspecies, 2 new genera and 1 new subfamily. Their stratigraphic distribution has allowed the recognition of 13 graptolite zones. The two in the Ashgill are the fastigatus and pacificus zones while the acuminatus, atavus, acinaces, cyphus, curtus, convolutus, minor, turriculatus, crispus, griestoniensis and sakmaricus zones are found in the Llandovery. These zones can be correlated with graptolite sequences worldwide.

The Canadian Arctic faunas show strong affinities with those of Siberia and China as well as with the northern Canadian Cordillera although many European elements are also present. It may be possible to recognize a circum-equatorial faunal province in Northern Canada, Siberia and China based on the occurrence of several distinctive forms including Agetograptus and "Paramonoclimacis" in the Middle Llandovery and Cyrtograptus (especially C. sakmaricus) in the Upper Llandovery.

Study of the uncompressed diplograptids has revealed that several main proximal development patterns can be

recognized among these Llandovery forms and these patterns may be used to arrive at a more phylogenetically realistic classification scheme as has been recently accomplished for the Ordovician graptoloids. This new scheme shows that only *Hedrograptus* proceeds from Middle Ordovician times into the Llandovery and gives rise to the major Early Silurian graptolite radiation. This took place after the other Ordovician forms were entirely decimated by the Late Ordovician extinction event.

The evidence, from what is presently known of the proximal development patterns and their stratigraphic ranges, indicates that *Atavograptus*, the first monograptid genus, arose from either *Akidograptus* or *Dimorphograptus* rather than *Glyptograptus* as suggested previously. Within each of the main groups, the Hedrograptinae, the Petalograptinae (from which the Retiolitinae arose), the Dimorphograptinae and the Monograptidae, considerable diversification took place within the Llandovery although each of these groups had become established by the end of the *persculptus* Zone.

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Firstly, special thanks must go to my supervisor, Dr. A.C. Lenz who has been a continual source of support: intellectual, material and moral. Without his guidance this work would not have been possible.

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Field assistance was ably provided by C.C. Ryley, S.W. White, E.C. Prosh and Dr. A.C. Lenz. Dr. A.D. McCracken provided much useful information regarding the field area and sample localities as well as many stimulating discussions concerning Ordovician-Silurian things. He also generously provided samples collected by him in 1979 and 1980 and analyses of the conodont samples collected by myself. Other unpublished information regarding sample localities was provided by W. Stone and R. Thorsteinsson.

Assistance with the hard and soft aspects of computer use was given by Dr. A.C. Lenz, T. de Freitas, S. Talman, M. Mallamo, Dr. H.W. Nesbitt and Dr. J.A. Legault.

Mr. D. Yakobchuk showed me how to operate the SEM and was always there with assistance and advice. Mr. D. Geddes performed the TEM work.

Much has been gained by discussions with other graptolithologists, particularly Drs. C.E. Mitchell, M. Bjerreskov, D.E.B. Bates, N.H. Kirk, P.R. Crowther, and

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This thesis is dedicated to my sons, Gregory and Brendan, in the hope that they will grow with a curiosity and love for the world around them.

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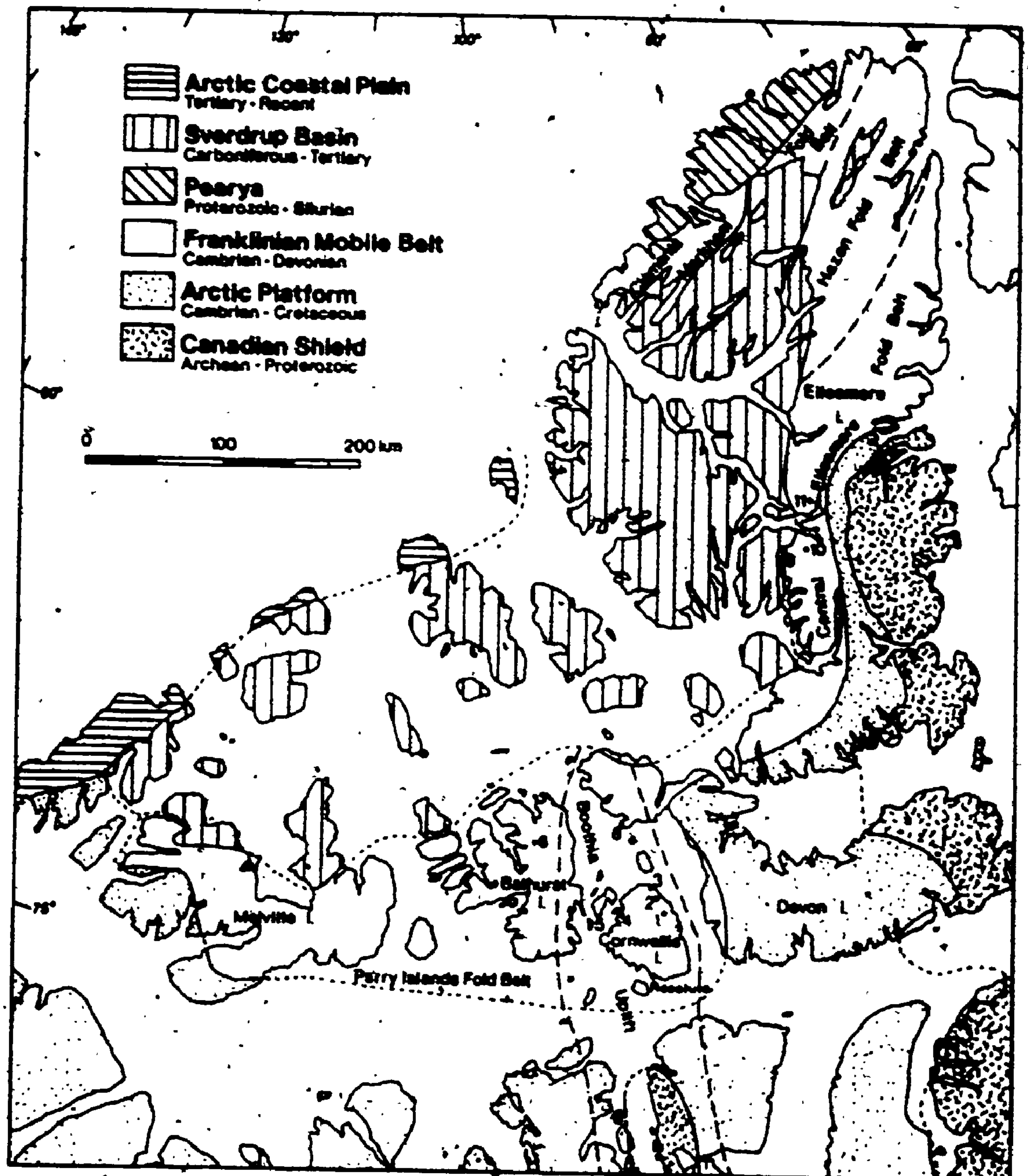
CHAPTER 1 - INTRODUCTION

The Cape Phillips Formation occurs in the Queen Elizabeth Island group of the Canadian Arctic Archipelago. The formation was originally defined and described by Thorsteinsson (1958) on Cornwallis Island and has since been mapped from Central Melville Island in the west to central Ellesmere Island in the northeast (figure 1). The Cape Phillips ranges in age from Late Ordovician to early Devonian across much of its outcrop area, although in some parts of the Bathurst Island Group (Kerr, 1974; Mayr, 1980) and Ellesmere Island (Kerr, 1976; Trettin, 1979) its age range is more restricted.

Probable Ordovician and Silurian graptolites were first reported from Ellesmere Island by Troelsen (1950) from what he called the Thorup Fjord Limestone, now considered the lower portion of the Cape Phillips Formation (Tozer, 1963). Thorsteinsson and Fortier (1954) first reported the well preserved graptolite faunas of Late Ordovician and Silurian age on Cornwallis and Little Cornwallis islands and these faunas were listed in some detail by Thorsteinsson (1958). In the latter report, twenty-two graptolite zones were recognized from Late Ordovician to Late Silurian in age. Two of these zones were considered to be Late Ordovician in age while five were from the Llandovery.

Aspects of these Ordovician and Llandovery faunas have since been found in the Bathurst Island Group (Thorsteinsson



Text-figure. 1. Tectonostratigraphic framework of the Canadian Arctic Islands and sample localities (refer to figures 4-9 for detailed location maps). Modified after Trettin (1987).

and Glenister, 1963; Kerr, 1974) on Melville Island (Tozer and Thorsteinsson, 1964) and Ellesmere Island (Tozer, 1963; Kerr, 1976; Trettin, 1979).

Several other papers have involved description or report of Cape Phillips graptolites (e.g. Thorsteinsson, 1955; Lenz, 1974a,b, 1978; Jackson et al., 1978; Riva in Ludvigsen, 1979; Lenz and Melchin, 1987) but of these, only Lenz (1978) has dealt with systematic description of Early Silurian faunas -- specifically, the cyrtograptids. Lenz (1982a) has also included a few referrals to Cape Phillips graptolite occurrences. Most recently, work related to the present study has been reported in Chen and Lenz (1984), Melchin and Lenz (1986), Lenz and Melchin (in press a,b) and Melchin (in press). The latter paper provides a systematic description of the Ashgill graptolites of the Cape Phillips Formation and a discussion of the Ordovician-Silurian boundary strata (see Appendix B). Melchin and Lenz (1986, see Appendix C) and Lenz and Melchin (in press a, see Appendix D) provide descriptions of uncompressed specimens of Monograptus turriculatus (Barrande) and the Retiolitinae of the Cape Phillips Formation respectively, and are based on material collected previously as well as part of this study.

The main purpose of this thesis is to provide a systematic account of the (primarily compressed) graptolites from the Ashgill and Llandovery portions of the Cape Phillips and to refine and expand the graptolite biozonation for the Canadian Arctic Islands. Attention has also been paid to the paleoecological and paleobiogeographic aspects of the graptolite faunas. In addition to this, study of the uncompressed Llandovery diplograptaceans, obtained from calcite concretions, has been undertaken in an effort to understand their morphology, early astogeny, classification and evolution. This has been done to help to place these forms within the new graptolite classification scheme recently proposed by Fortey and Cooper (1986) and Mitchell (1987) and to understand their relationships with their Ordovician predecessors as well as with the Monograptidae.

Field and Laboratory Methods

Graptolites were collected from ten sections across most of the Cape Phillips outcrop belt by the author during the summers of 1983 and 1984 (text-fig. 1). At most sections, samples were measured by staff, supplemented by pacing and dip or air photo measurements over longer covered intervals. Collections were measured to the nearest 0.5m in most circumstances. The Cape Manning section (section 2) was sampled very quickly in 1984 and again by A. C. Lenz in 1985 and was only divided into lower (0-2m), middle (2-5m) and upper (5-7m) collections. The Cape Becher section (section 8) was collected by B. D. E. Chatterton and D. G. Perry in 1978.

In addition to these samples, concretions used in this study have been collected from Snowblind Creek by A. C. Lenz in 1977, 1981 and 1985 and Rookery Creek in 1979 and 1980 and Marshall Peninsula (about 8.5km northeast of Rookery Creek) in 1979 by A. D. McCracken.

Concretions were dissolved in dilute hydrochloric or acetic acid, gently sieved to concentrate the graptolite fragments and washed in methanol to remove organic films. Scanning Electron Microscopy was done on a Hitachi HHS-2R at 20kV. Stereopairs were achieved by tilting the specimen stage between 8 and 4°, depending on the magnification and depth of field of the specimen.

CHAPTER 2 - STRATIGRAPHY AND REGIONAL GEOLOGY

The Cape Phillips Formation consists mainly of argillaceous limestones and dolostones and calcareous or dolomitic shales in its lower parts, with some chert, especially in the Upper Llandovery portion, changing gradually to shale and mudstone-dominated in the higher parts. Its type section is at Cape Phillips (section 3), which forms the northeast corner of Cornwallis Island. It represents the deeper-water or more basinal equivalent to the shallow-water carbonates of the Allen Bay Formation and the Read Bay Group to the south and east (text-fig. 2). The main areas of outcrop are on northern Cornwallis Island and Bathurst Island and on west-central Ellesmere Island with exposures also occurring on central Melville Island, the western rim of the Grinnell Peninsula as well as on several of the smaller islands which occur between the above-mentioned larger islands.

The Cape Phillips Formation occupies much of what is now exposed of the Franklinian Basin (Franklinian Mobile Belt, text-fig. 1). This major Lower and Middle Paleozoic basin is bounded to the south and east by the stable Arctic Platform. To the north it dips beneath the younger (Late Paleozoic through Cenozoic) Sverdrup Basin and is exposed again on northern Ellesmere Island where it flanks the southern margin of the once-uplifted Pearya. The Franklinian Basin has been called a geosyncline by many

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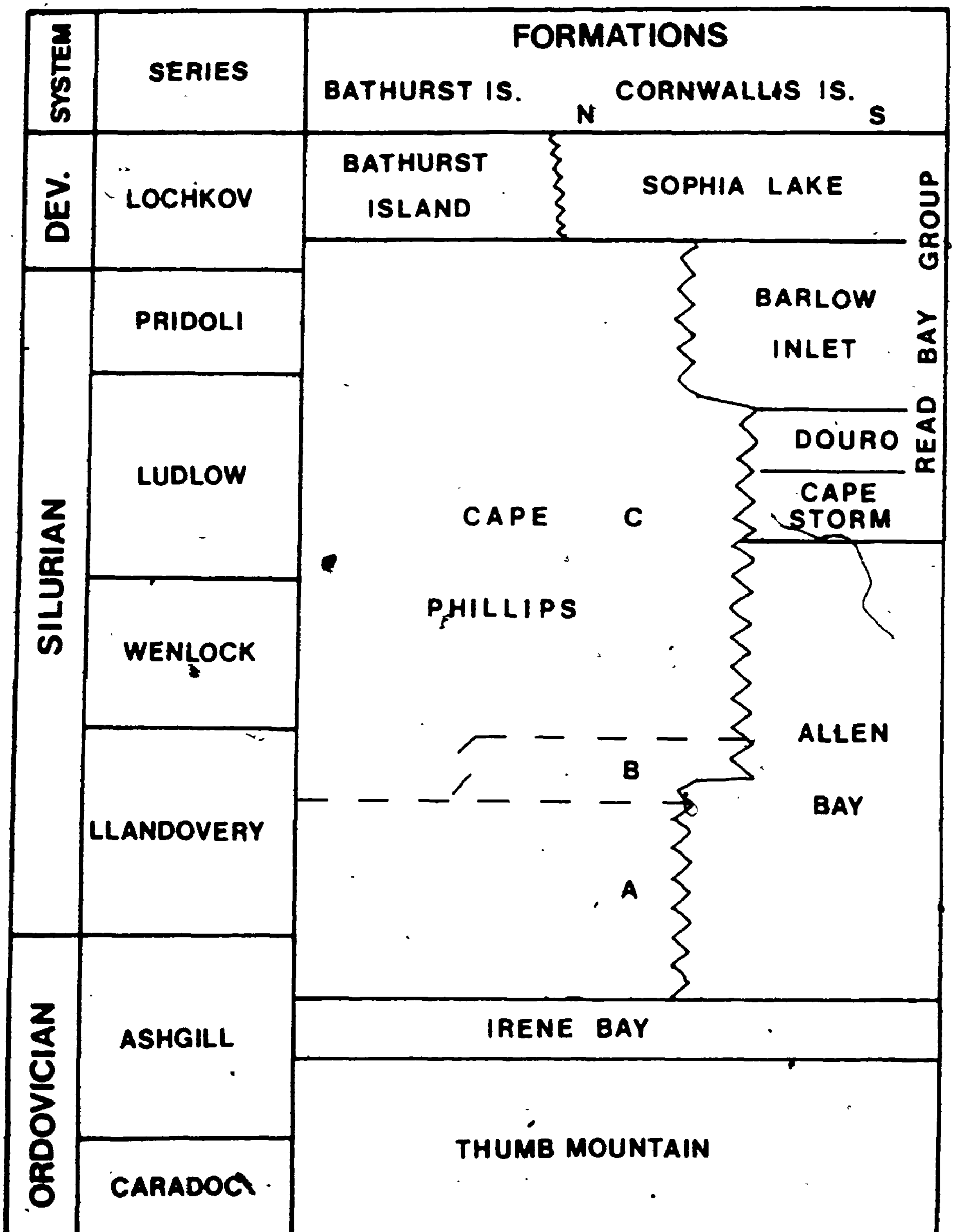
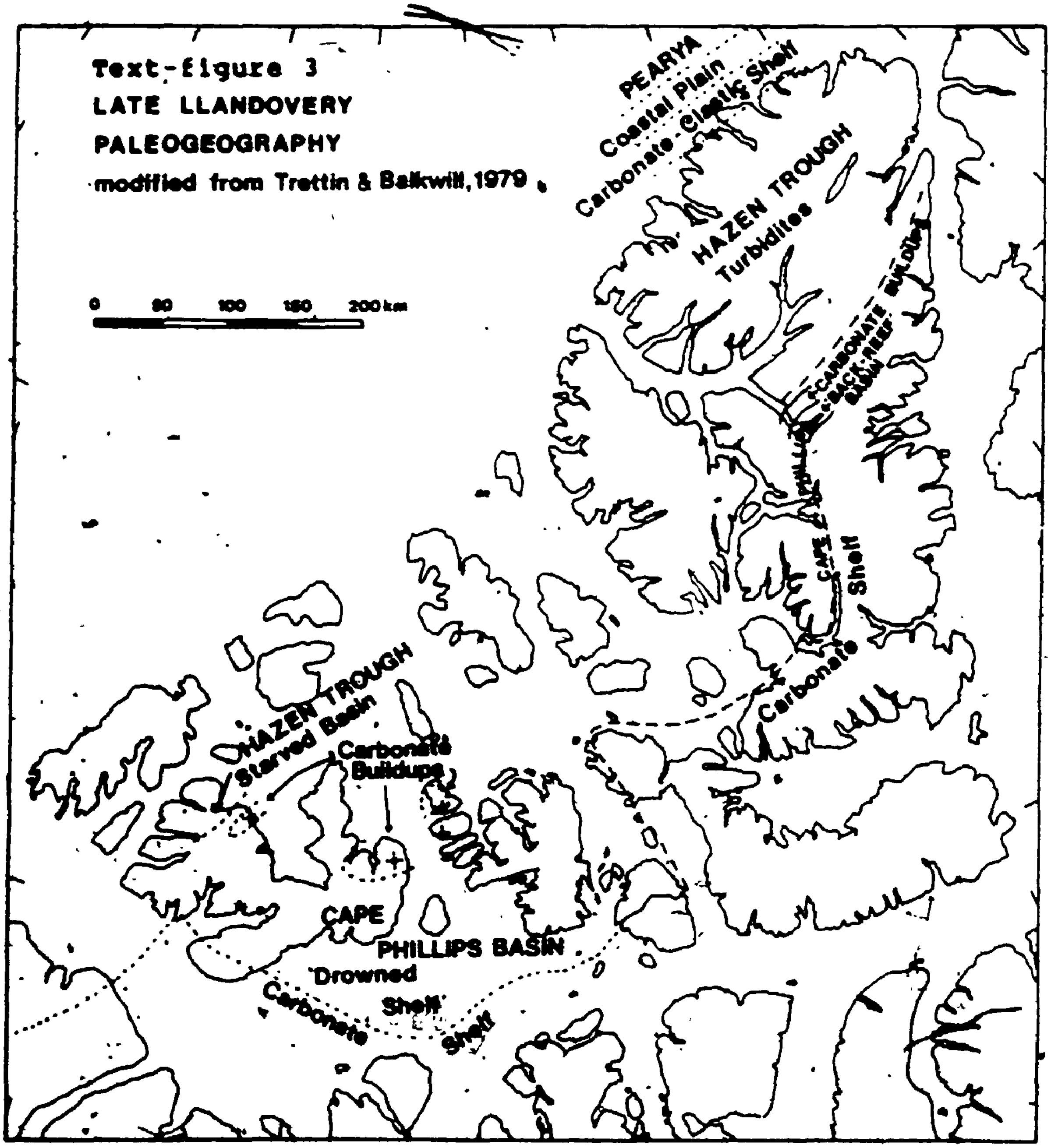


Text-figure 2. Correlation of the Cape Phillips Formation and the contiguous carbonate platformal units in the central part of the outcrop belt (Thorsteinsson, 1980).

workers although it has long been recognized that it is not a true geosyncline in the classical sense (Trettin and Balkwill, 1979). It appears to be a large intracratonic basin with a southeastern unstable shelf (the Franklin Miogeocline, Okulitch, et al., 1985) and axial basin (the Hazen Trough) and a northwestern belt (Pearya and its bordering shelf). The latter two were originally believed to represent the eugeosynclinal portion of the geosyncline. Most recently, Trettin (1987) has suggested that Pearya, with at least part of its flanking sedimentary sequence, was an allochthonous terrain of Caledonian origin accreted to the Franklinian Mobile Belt in Late Silurian time although the Pearya sedimentary sequence shows Franklinian affinities from latest Ordovician onward.

The Cape Phillips Formation occupies most of the southeastern unstable shelf from latest Ordovician to Early Devonian (in some areas Late Silurian) time. Since the Cape Phillips Formation seems to have occupied a distinct and apparently continuous subbasin on this unstable shelf, separated from the axial Hazen trough by (intermittent?) carbonate buildups (text-fig. 3) and has developed its own unique stratigraphic sequence, it is worthwhile to name this paleogeographic feature - here termed the Cape Phillips Basin.

Thorsteinsson (1958) divided the Cape Phillips Formation into three members, A, B and C respectively. The lithologic

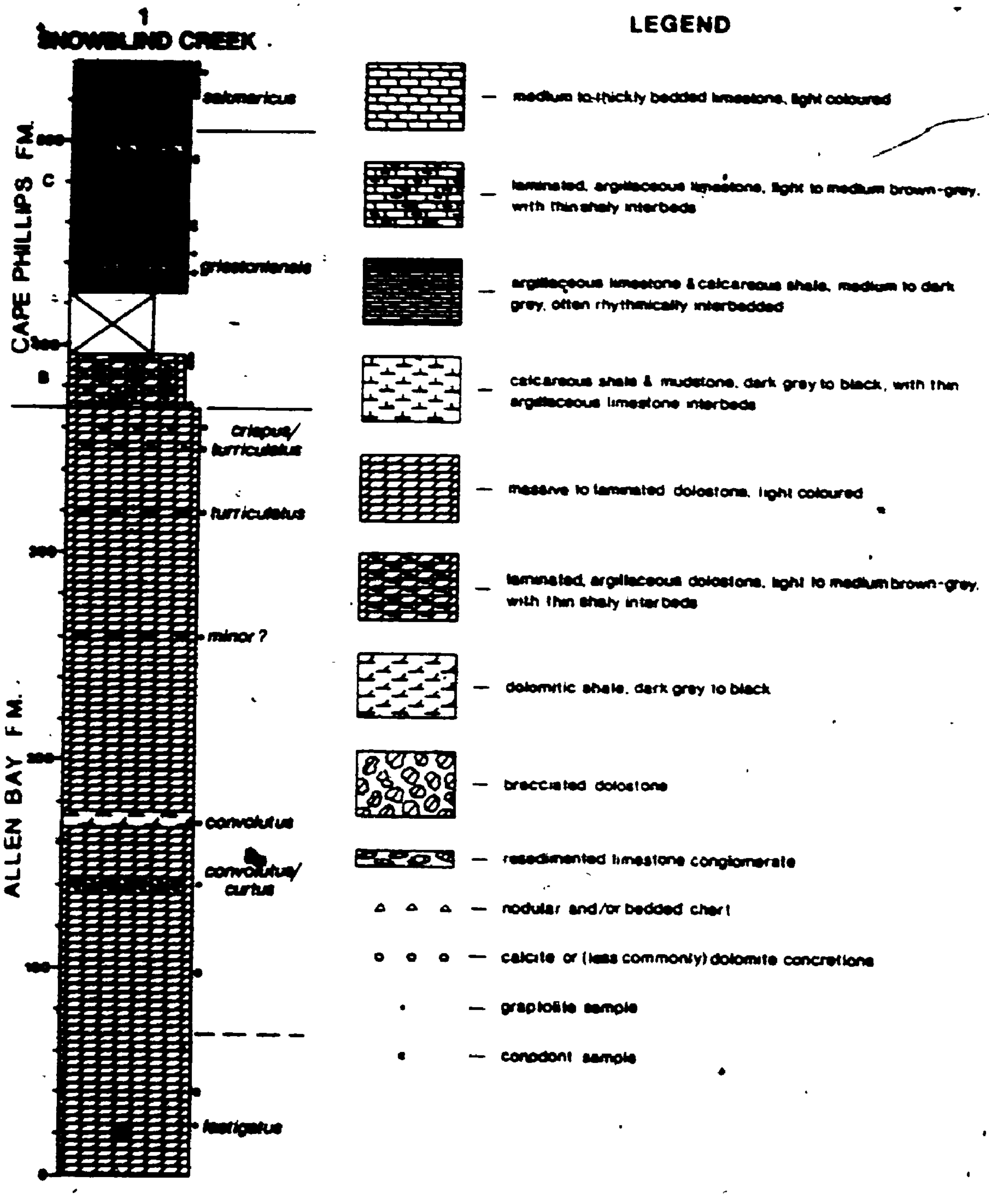

Text-figure 3
LATE LLANDOVERY
PALEOGEOGRAPHY
modified from Trettin & Balkwill,1979
0 50 100 150 200 km
PEARYA
Coastal Plain
Carbonate-Clastic Shelf
HAZEN TROUGH
Turbidites
CARBONATE BUILDUP
BACK-REEF BASIN
CAPE PHILLIPS
Shelf
Carbonate
HAZEN TROUGH
Starved Basin
Carbonate Buildups
CAPE
PHILLIPS BASIN
Drowned
Shelf
Carbonate
Shelf

and biostratigraphic sequence at each of the sections (except sections 2 and 8 which were not measured by the author) is shown graphically in figures 4 through 9, together with detailed location maps.

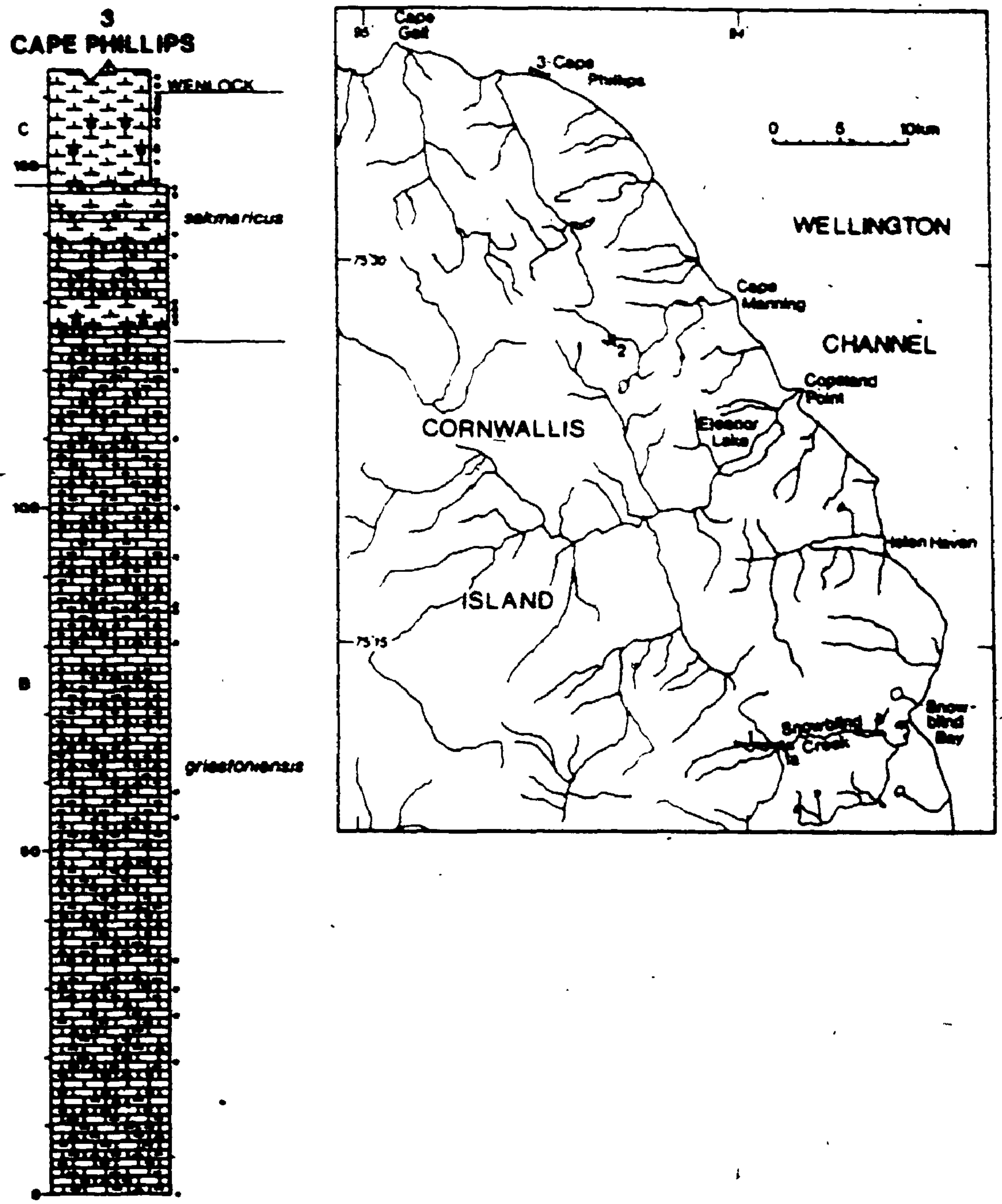
Member A. The base of the formation is consistently marked by a 10 to 15m bed of light to medium grey, mottled limestone or dolostone. Where original structures are preserved, this unit can be seen to be a bioturbated lime wackestone with small fossils such as ostracodes and crinoid fragments. This unit is continuous from the lowest Allen Bay Formation (Thorsteinsson, 1958; Sodero and Hobson, 1979) and conformably overlies the Irene Bay Formation which is a recessive unit characterized by soft, greenish-grey, argillaceous limestone with a diverse shelly macrofauna.

Above this, the beds gradually become darker grey and more argillaceous and the frequency and degree of bioturbation decreases giving way to laminated, argillaceous limestones or dolostones interbedded with varying amounts of calcareous or dolomitic shales. Some chert is also present in the higher parts of this unit in some areas. Calcite concretions of varying sizes up to as much as 0.5m or more are present in this unit, most commonly in the Middle Llandovery. In some areas, especially on Cornwallis Island, these concretions have yielded uncompressed graptolites.

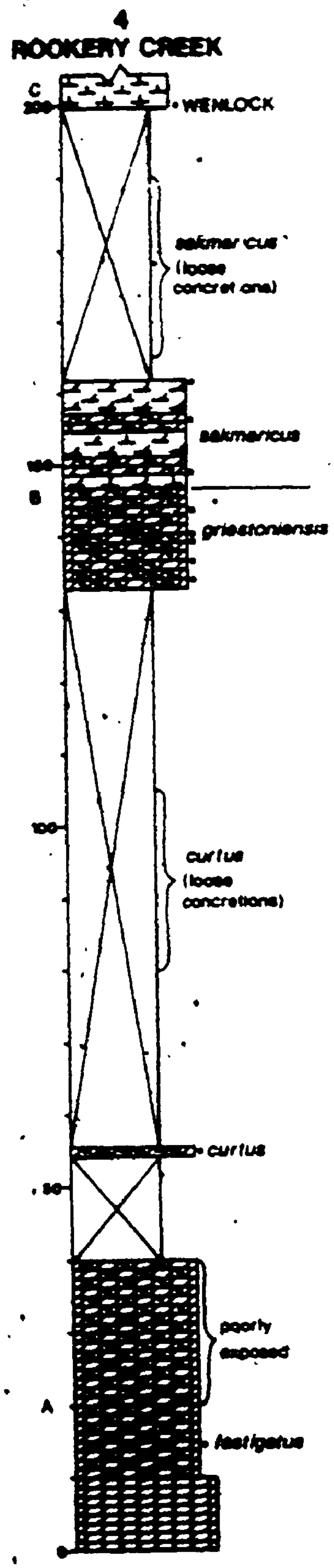
The laminae seen in some of the argillaceous carbonate beds are horizontal or discontinuous while in others, the

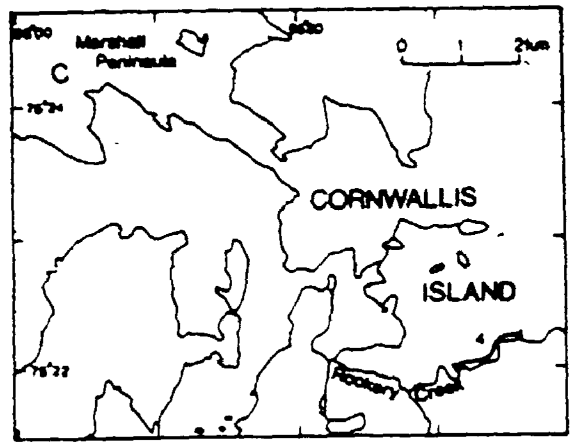


Text-figure 4. Lithologic log of section 1, Snowblind Creek with accompanying legend for figures 4 to 9. See figure 5 for locality map.

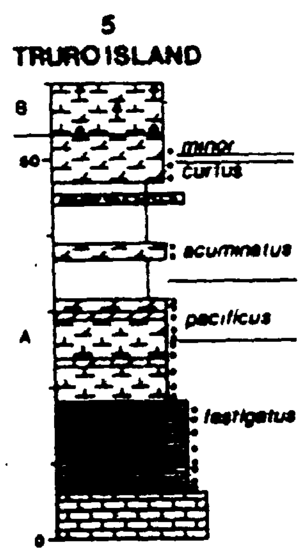


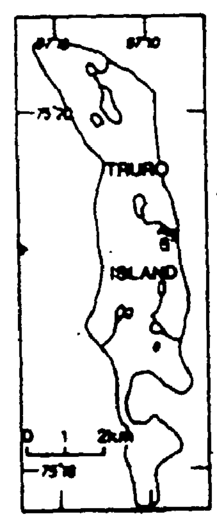
Text-figure 5. Lithologic log of section 3, Cape Phillips (the type section) and locality map of northeastern Cornwallis Island. Refer to text-figure 4 for legend.

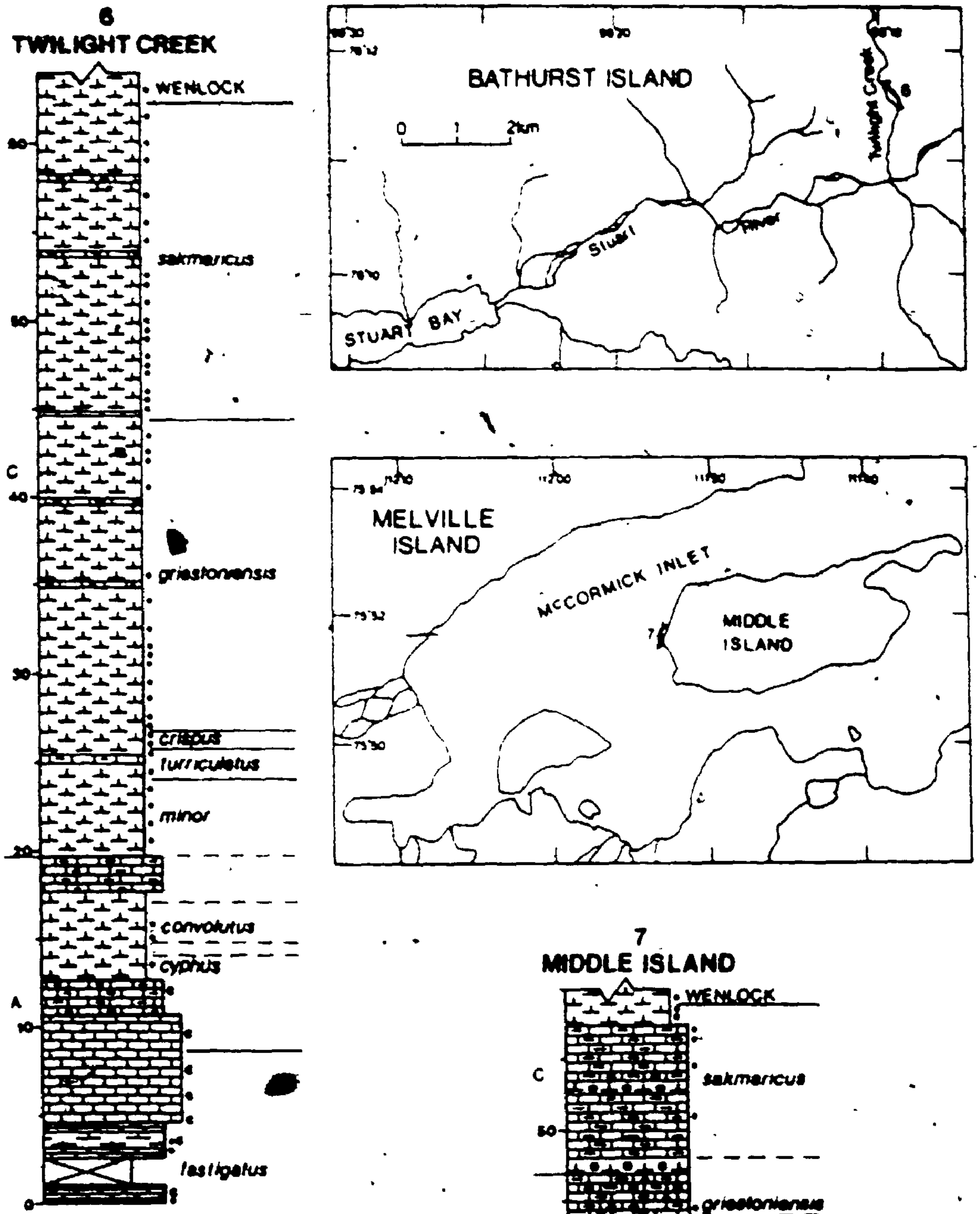


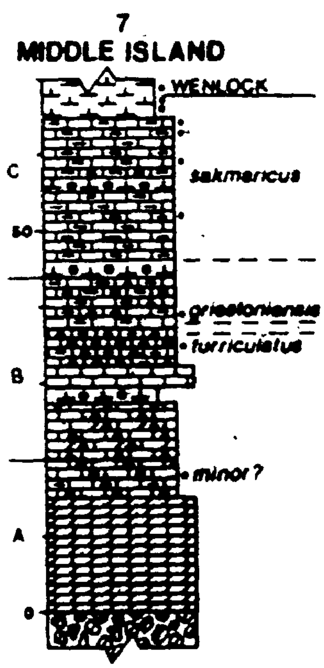


Text-figure 6. Lithologic logs and locality maps of sections 4 and 5 (Rookery Creek and Truro Island). Refer to text-figure 4 for legend.

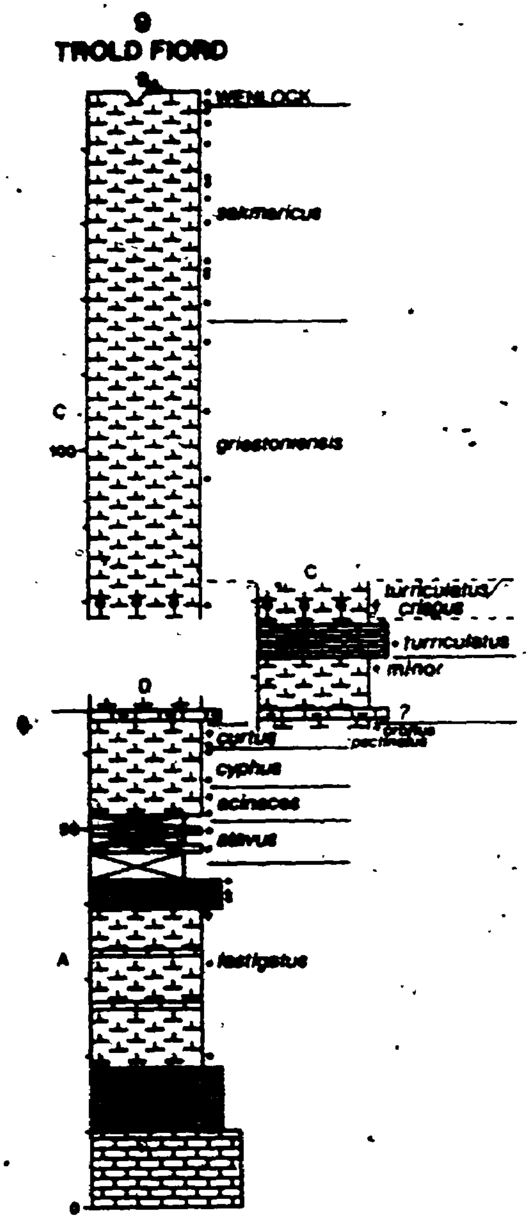


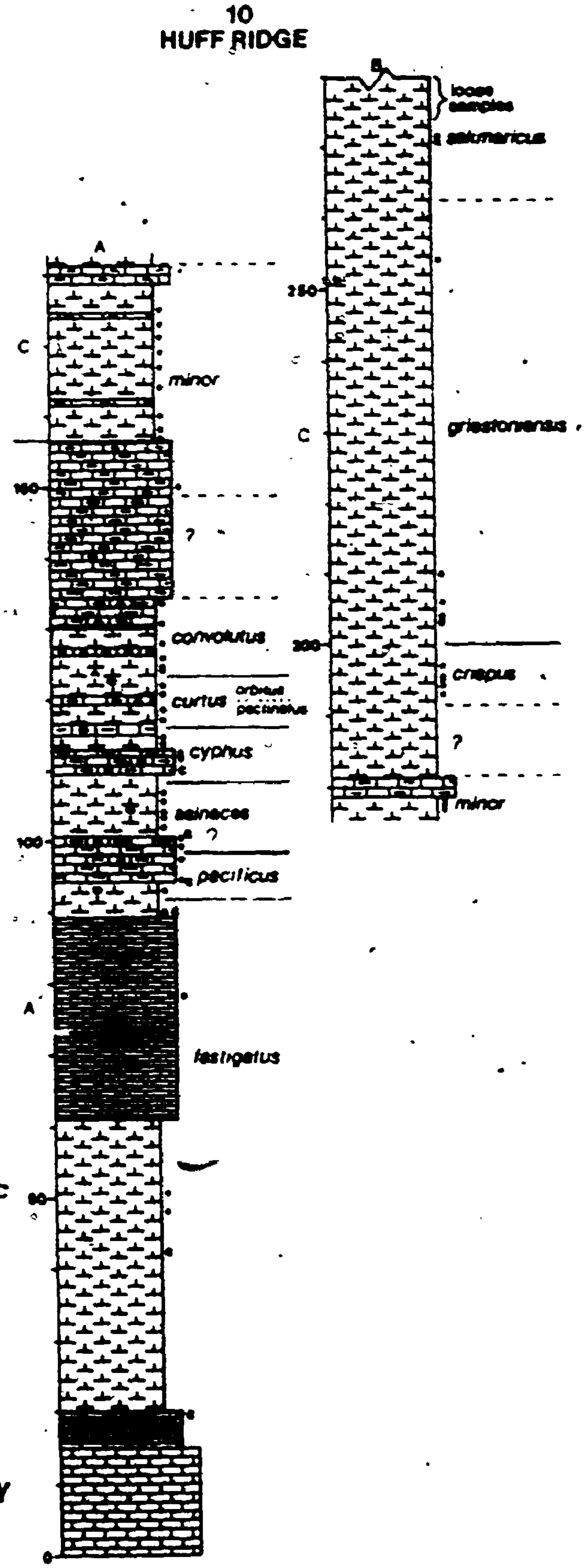




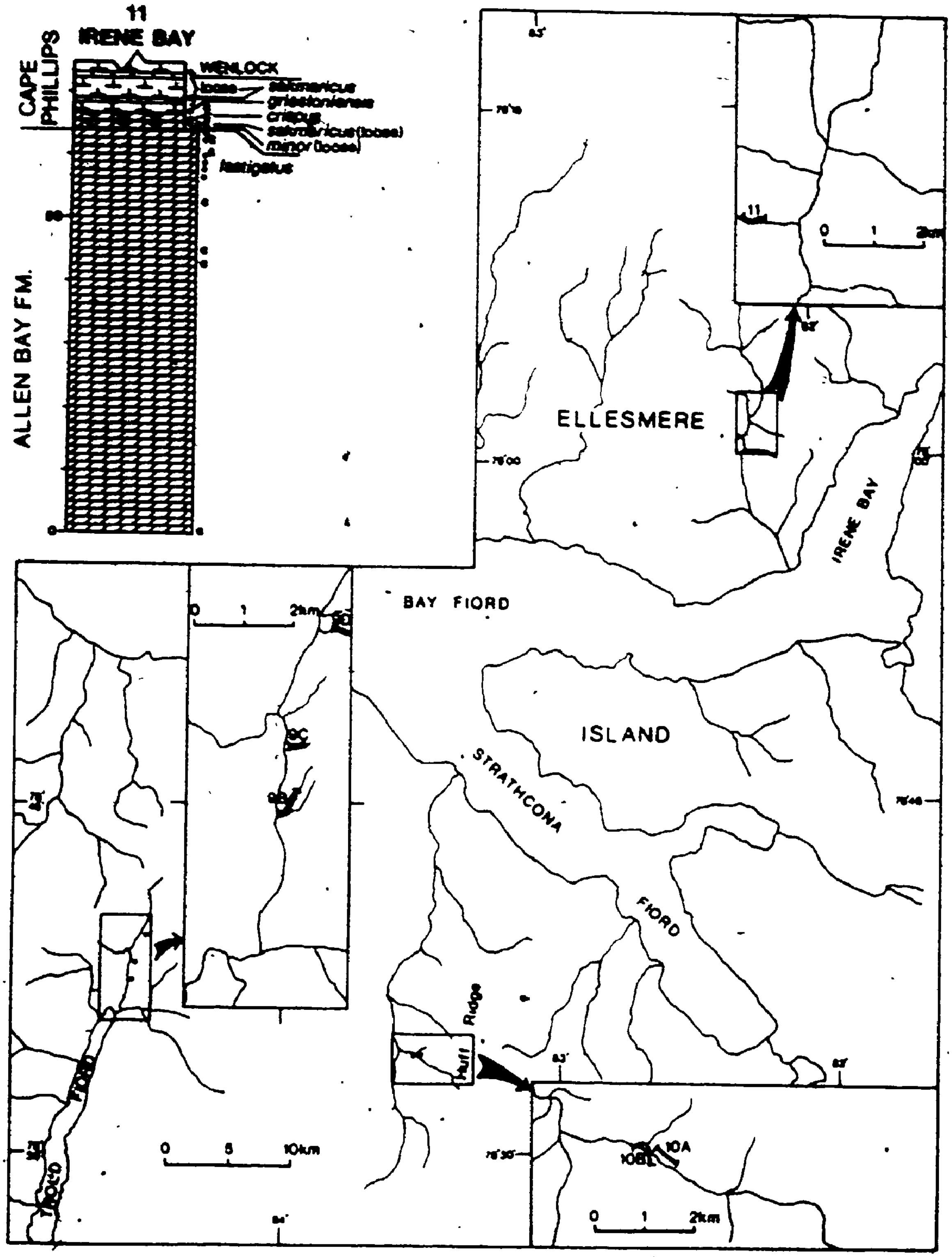


Text-figure 7. Lithologic logs and locality maps of sections 6 and 7 (Twilight Creek and Middle Island). Refer to text-figure 4 for legend.





Text-figure 8. Lithologic logs of sections 9 and 10 (Trold Fiord and Huff Ridge). Refer to text-figure 4 for legend and text-figure 9 for locality map.



Text-figure 9. Lithologic log of section 11 (Irene Bay) and locality map of west-central Ellesmere Island. Refer to text-figure 4 for legend.

laminae are wavy or may even form micro-ripples or lenticles of silt- to fine sand-sized carbonate. These wavy to micro-rippled laminae can be seen in carbonate beds throughout the Llandovery portion of the Cape Phillips and they may indicate that bottom currents were common and seem to have supplied and moved a large proportion of the carbonate in the Cape Phillips in addition to the hemipelagic input.

The dolostone and dolomitic shales are most common in areas closer to the line of facies change, especially in the central part of the outcrop belt on Cornwallis and neighbouring Truro Island (text-fig. 6) and, to a lesser extent, in the central part of Melville Island (Middle Island section, text-fig. 7). At Twilight Creek, Trold Fiord and Huff Ridge, member A consists almost entirely of limestone, argillaceous limestone and calcareous shale with some black chert (text-figs. 7,8).

The base of this unit is mid-Ashgill in age, the _Orthograptus fastigatus_ Zone being the lowest recognized zone, correlative with the lower part of the _Dicellograptus anceps_ Zone of Great Britain (Melchin, in press). The top of member A, as employed here is at the base of or within the _Monograptus turriculatus minor_ Zone, the lowest zone of the Upper Llandovery. The Ashgill portion of this unit and the nature of the Ordovician-Silurian boundary in the Cape Phillips have been described by Melchin (in press, see Appendix B) and they are also shown in text-figs. 4 to 9.

Some additional points need to be made concerning the boundary interval.

At Twilight Creek, where a massive carbonate unit spans the interval between the last Ordovician (fastigatus Zone) and first Silurian (Coronograptus cyphus Zone) strata, conodont evidence supplied by A. D. McCracken (pers. comm., 1987) indicates that the boundary occurs between 3.5 and 5.0m above the base of this carbonate unit. Unfortunately, none of the conodont collections is diagnostic enough to tell exactly what time span separates the two samples and further sampling of the critical interval of this interesting unit is necessary to see if a hiatus is present and how it may be manifest in the rocks.

On Ellesmere Island, the length of the hiatus seen at the boundary seems to become greater closer to the shelf margin. At Trold Fiord (text-fig. 8), the most distal of the three sections sampled, the missing interval is shortest despite the presence of a covered interval at the boundary. The Paraorthograptus pacificus Zone below the covered interval is followed by two samples assigned to the Atavograptus atavus Zone above, followed by the Lagarograptus acinaces Zone. At Huff Ridge (text-fig. 8), somewhat closer to the shelf edge facies transition, exposure is continuous across the boundary yet pacificus Zone strata are separated by only 1.5m from acinaces Zone strata. Irene Bay is very close to the facies transition and the uppermost Ordovician at this section is represented by a tongue of Allen Bay Formation, overlain by Cape Phillips beds (text-fig. 9). The uppermost dolostones of the Allen Bay have yielded fastigatus Zone graptolites at 62.5m and Ordovician conodonts at 64.0m. In Cape Phillips argillaceous limestones at 65.0m a loose slab has yielded minor Zone graptolites (Upper Llandovery) followed by Monograptus crispus Zone graptolites at 65.5m and Late Llandovery conodonts also at 65.0m (McCracken, pers. comm. 1987). It seems, therefore, that the entire interval from pacificus Zone to the base of the Upper Llandovery is missing at this locality.

At Snowblind Creek, which is also very close to the line of facies change, member A is replaced by a tongue of Allen Bay dolostones as at Irene Bay (text-fig. 3). The section at Snowblind Creek, however, is much thicker and contains a considerable thickness of Middle and possibly Lower Llandovery strata as dated by conodonts (Ryley, 1984) as well as graptolites found in some shaly and concretionary horizons.

At Middle Island, much of member A is not exposed and the lower part of what is exposed is a brecciated, dark grey dolostone with a white dolomite matrix. The brecciation is attributed to proximity to a major normal fault which occurs immediately to the south of the island (Fox, 1985). Above this, the upper part of member A consists of grey, massive limestone and mottled dolostone with some flaggy, laminated beds with shaly interbeds and calcite concretions near the top.

The passage from member A to member B is only exposed at two of the sampled sections, Truro Island and Middle Island. At both sections this interval is characterized by a significant increase in the amount of chert present, usually black, which occurs as replacements in small, often irregular nodules as well as 0.5 to 2cm beds. It is also characterized by a lack of preserved graptolites although rather poor collections made below in the upper parts of member A suggest that the transition takes place within the <u>minor</u> or <u>turriculatus</u> Zone.

At Twilight Creek, Trold Fiord and Huff Ridge, member B is absent and the boundary between members A and C is marked by a more massive, planar to wavy and micro-rippled laminated limestone. At Twilight Creek and Trold Fiord this bed is 1.5 to 2.0m thick while at Huff Ridge it is 23m thick and comprises several thick, massive beds with occasional thin shaly interbeds. Kerr (1976) considered this unit at Huff Ridge, together with 68.4m of the underlying member A to be a tongue of Allen Bay Formation within the Cape Phillips. The dark coloured, laminated nature of the limestone beds, the presence of many shaly beds, concretions and some chert as well as common graptolites, however, indicates that this is typical (albeit somewhat carbonate-rich) Cape Phillips Formation and compares closely with member A in the Cornwallis Island area.

Graptolites from immediately below this massive carbonate unit indicate upper Monograptus convolutus Zone at Twilight Creek and Huff Ridge while a sample 1.0m below this unit at Trold Fiord is of the Rastrites orbitus Subzone. The samples collected at the base of member C above this massive interval are all assigned to the minor Zone. The massive unit therefore seems to occupy the interval equivalent to Monograptus sedgwickii Zone seen in many other parts of the world including the northern Canadian Cordillera (Lenz, 1982a).

The widespread and apparently synchronous nature of this unit makes it a potentially useful marker horizon and this is enhanced by the fact that it is bounded by diverse and distinctive graptolite faunas above and below.

Member B. This member, as defined by Thorsteinsson (1958), is characterized by cherty, argillaceous limestones, calcareous shales and limestones. On Cornwallis Island, particularly at the type section and at Rookery Creek where only the upper parts of this member are exposed, the relatively resistant nature of this unit is due to the dominance of argillaceous limestones and chert and the scarcity of shales. Concretions, frequently graptolite-bearing, are present throughout this unit but are most common near the top. As noted above, the lower parts of this unit, as seen at Rookery Creek and Middle Island are more rich in calcareous shales and are marked by a significant increase in chert content. The limestone beds are mostly parallel to wavy laminated although some more massive limestones are present, some of which show a shelly fauna. It is clear that at least some of these shelly beds are derived from the adjacent platform and are resedimented. A few show scoured bases and upward grading typical of coarse, carbonate turbidites.

Although Thorsteinsson (1958) notes that this unit is also characterized by a lack of dolostones, some dolostones were found in this unit in the lower part of the exposed section at Rookery Creek. In addition, at Snowblind Creek, where this member seems to be stratigraphically more restricted, a significant proportion of the laminated, argillaceous limestones are replaced by dolomite.

Through most of northern Cornwallis Island, Truro Island (where the upper beds of member B are exposed on the hillside about 2km south of the main stream section) and the southeastern parts of Bathurst Island (Mayr, 1980) member B ranges through the Upper Llandovery from within the minor Zone to the top of the Cyrtograptus sakmaricus Zone. At Snowblind Creek, member B lithologies are found in a restricted interval above the Allen Bay tongue and below a thick succession of rhythmically interbedded argillaceous limestones and calcareous shales. Graptolites indicate that the top of the Allen Bay here is within the turriculatus-crispus zonal interval and that member B is restricted to the lower and possibly part of the middle Monograptus griestoniensis Zone. The interbedded argillaceous limestones and calcareous shales which occupy the remainder of the _griestoniensis_ Zone and the _sakmaricus_ Zone much more closely resemble the overlying member C as seen at this section and elsewhere and so are assigned to member C.

At Middle Island, member B also seems to be more restricted, the cherty, argillaceous limestones passing into interbedded, platy argillaceous limestones and interbedded calcareous shales somewhere within the _griestoniensis_ Zone.

Member C. In the more northerly parts of Bathurst Island (Mayr, 1980) including Twilight Creek, as well as on Ellesmere Island, member B is not recognizable. The Upper Llandovery part of the sequence, above the massive carbonate marker unit, is dominated by calcareous shales with interbedded, flaggy to platy, laminated, argillaceous limestones, all dark to medium grey. The lighter-coloured, more massive laminated limestones are rare to absent as are the chert and the concretions. Upward, into the Wenlock beds, the carbonate decreases and shales and calcareous shales dominate. The Upper Llandovery beds, at these localities, are therefore assigned to member C and member B is considered to be absent.

The remainder of member C, as described by Thorsteinsson (1958) and elsewhere, consists of a monotonous sequence of calcareous shales, shales, in some areas siltstones, and lesser amounts of argillaceous limestones and more massive limestones.

Resedimented carbonate beds are present through most of the Cape Phillips Formation with variable frequency. As noted above, the wavy to micro-ripple laminated limestone (and dolostone) beds appear to have been deposited by traction currents and may represent distal turbidites and/or other bottom currents such as contour currents. No paleocurrent analysis has yet been done on any of these units in the Cape Phillips. Also, as noted above, some shelly limestone beds, which are especially common in the sections close to the shelf edge - Snowblind Creek, Cape Phillips and Irene Bay - appear to be the more proximal portions of carbonate turbidites. These are most common in the uppermost Llandovery and higher parts of the sequence. Likewise, larger limestone debris flow beds one to several metres in thickness are occasionally present in the Upper Llandovery and Wenlock part of the sequence at the platform-edge sections but these become more common higher in the Ludlow part of the formation (Lenz, pers. comm. 1983; personal observation).

At Truro Island, a bed of lime mud chip conglomerate, probably resedimented deeper-water lime muds, occurs within a covered interval between Parakidograptus acuminatus Zone beds below and Monograptus millepeda curtus Zone beds above.

Depositional Environment

The continuity in lithology and distribution as well as fauna of the Irene Bay Formation and basal beds of the Cape Phillips over the entire Franklinian Basin suggests that the shelf was a stable extension of the Arctic platform during the early part of the Ashgill (as it was through much of the earlier part of the Ordovician). During the Richmondian (mid-Ashgill - fastigatus Zone), however, the Cape Phillips sediments began to differentiate from those of the Allen Bay. Darker, more argillaceous limestones with a deeper-shelf fauna of the trilobite Pseudogygites arcticus (Ludvigsen, 1979), diverse cephalopods (Sweet and Miller, 1957; pers. obs.) and ostracodes in addition to an abundant yet taxonomically restricted graptolite assemblage all indicate somewhat quieter, deeper, possibly cooler water conditions (Melchin, in press). Further up section in the Cape Phillips, into the pacificus Zone strata, the sediments become darker still, less commonly bioturbated with more diverse graptolites and a sparse to absent shelly fauna. This indicates that subsidence - differential with respect to the Arctic Platform and Allen Bay Formation - had effectively drowned most of the more distal regions of the shelf and formed the Cape Phillips Basin. Observation of the transition from shelf to basin both by myself and previous authors (Mayr, 1974; Mirza, 1976; Sodero and Hobson, 1979), including the apparent lack of a prominent shelf-edge facies and the lack of development of significant gravity flows in the proximal basin, suggests that, at least during the Ordovician and Early and probably Middle Llandovery the Cape Phillips Basin was deposited in the deeper portion of a carbonate ramp (Read, 1982). As noted by Melchin (in press), the absence of strata at many sections and a deposition of a massive carbonate unit at Twilight Creek at the Ordovician-Silurian boundary is interpreted to be due to the effects of the latest Ordovician glaciation (see section below "Late Ordovician Graptolite Extinction" for further discussion of this event). Submarine erosion and/or non-deposition as well as a change from calcareous shale to massive limestone deposition could both be accounted for by the combination of regression and increased oceanic circulation that are likely to be brought about by a major pulse of glaciation.

The first evidence of mass movement in the Cape Phillips is the mud-chip conglomerate bed found at Truro Island which underlies *curtus* Zone graptolites by a 1.5m covered interval.

The first evidence of incursion of more basinal conditions into the Allen Bay strata at Snowblind Creek (at the shelf edge) is the occurrence of thin, dark, shaly, graptolite- and concretion-bearing strata within the lighter-coloured dolostones. These incursions occur during *curtus*, *convolutus*, *minor* and *turriculatus* Zone times. The massive, carbonate marker unit seen at several of the sections, composed mainly of fine-grained, resedimented carbonate is the next indication of the possible buildup of some shelf-to-basin relief although coarser, more proximal turbidites or debris flows have not been found at the more proximal sections during this time interval.

During the lower griestoniensis Zone, the platform margin retreated rapidly to the south leaving the more basinal, Cape Phillips sediments at Snowblind Creek (this happened by the crispus Zone at Irene Bay). This also appears to be the time when a more significant shelf edge break developed, as suggested by the shelf edge and slope deposits south of Snowblind Creek (Sodero and Hobson, 1979), and the increased occurrence of small, carbonate turbidites and occasional larger debris-flow beds at Snowblind Creek and Irene Bay.

The increased thickness and more widespread occurrence of the Upper Llandovery sediments indicates a more stable shelf-basin system and more steady supply of fine, hemipelagic carbonate into the basin.

The shelf-to-basin differentiation appears, therefore, to have been gradual, beginning with the drowning of the distal shelf and then a gradual buildup of relief and retreat of the shelf edge in Late Llandovery times. Much more work needs to be done on the exact nature of the shelf-to-basin transition in Ashgill to Wenlock times before the details of this process can be elucidated. The establishment here of a detailed graptolite biostratigraphy for this interval will provide a necessary time framework for the understanding of the shelf-edge and basin development.

The timing of basin development in the Cape Phillips Basin appears to have proceeded somewhat ahead of that in the adjacent region of Washington Land, North Greenland (Hurst, 1980a,b; Bjerreskov, 1981). In that area, shelf sedimentation continued into the Middle Llandovery with the first incursions of graptolitic strata in the *argenteus* and *convolutus* zones (as at Snowblind Creek). By the early part of the Late Llandovery, basinal sedimentation had become firmly established and shelf-basin relief had become developed. Thus, although the initial phases of basin formation took place later in Washington Land, the main phase of shelf-basin differentiation appears to have been more-or-less synchronous. It is worth noting that north of the study area (in the Canon Fiord area of Ellesmere Island) the Cape Phillips Formation did not become established until late Middle Llandovery time (as in Washington Land) and overlies earlier Llandovery and Ashgill Allen Bay Formation (Trettin, 1979).

Structural Geology

The sampled area of the Cape Phillips outcrop belt lies within three structural provinces of the Franklinian Mobile Belt (figure 1): the Parry Islands Fold Belt in the west;

the Boothia Uplift in the central region; and Central Ellesmere Fold Belt extending to the northeast.

Parry Islands Fold Belt. This fold belt was first defined by Fortier and Thorsteinsson (1953) and described in some detail by Tozer and Thorsteinsson (1964) and Kerr (1974). Most recently, the structural geology of this belt has been synthesized by Fox (1985). The general trends of the folds and faults of the Parry Islands Fold Belt are east-west to east-southeast-west-northwest on Melville Island and east-northeast-west-southwest on Bathurst Island. Folding is concentric and generally consists of tight anticlines and open, U-shaped synclines. Normal and high angle reverse faults are also present but do not always penetrate the entire sequence. Deformation appears to have occurred at a Lower Ordovician or older detachment surface and involved the remaining Lower and Middle Paleozoic strata. The style and extent of deformation has been largely controlled by the presence of incompetent members within the sequence, particularly the evaporites of the Bay Fiord Formation and shales of the Cape Phillips Formation. In fact, the cratonward extent of the folding was strongly limited by the facies transitions into platformal carbonates of the Arctic Platform both in the Parry Islands and the Central Ellesmere fold belts.

Deformation took place during the Ellesmerian Orogeny (see, for example, Thorsteinsson and Tozer, 1970; Trettin, et al., 1972; Christie, 1979; Trettin and Balkwill, 1979; Kerr, 1981), a major orogenic event of the Arctic Islands area, whose main phase of deformation was in the Late Devonian and Early Carboniferous.

Boothia Uplift. The northward extension of Precambrian rocks of the Canadian Shield on the Boothia Peninsula was first recognized by Fortier, et al. (1954) who named the Boothia Arch, while Thorsteinsson (1958) reported the dominantly north-south structural trends of Cornwallis Island and named the Cornwallis Fold Belt. Kerr and Christie (1965) noticed the fault-bounded nature of these structures and renamed the Boothia Arch the Boothia Uplift and extended the Cornwallis Fold Belt onto the adjacent eastern Bathurst Island, Grinnell Peninsula to the north and part of the Paleozoic portion of the Boothia Peninsula to the south.

Kerr (1977) considered this major uplift trend to be a horst structure, forming a broad, steep-sided anticlinorium, formed during the Cornwallis Disturbance, an event of several phases lasting from Late Llandovery to Late Devonian. The initial (Late Llandovery) phase was the mildest involving uplift in the axial portion resulting in an unconformity beneath the Cape Storm Formation. Okulitch, et al. (1986) have reexamined this region and have abandoned the term "Cornwallis Fold Belt" referring to the entire uplifted region as the Boothia Uplift. They have concluded from stratigraphic and sedimentological studies that the initial phase of uplift in the Early Silurian was not related directly to the main deformation event of the uplift which appears to have been most active in Lower Devonian times.

The Cape Phillips Formation shows no direct evidence of late Llandovery uplift; in fact this appears to be a time of basin stabilization and foundering of marginal areas of the carbonate platform although the increased sedimentation rate and influx of more carbonate debris could be ascribed to uplift of the platformal areas. On the other hand these could equally be attributed to buildup of the platform margin and increased carbonate production at the shelf edge. Much more work remains to be done on the upper part of the Allen Bay Formation and the shelf-basin transition during this time.

Okulitch, et al. (1986) suggest that the deformation of the Boothia uplift was not a horsting event but westwardly directed compression resulting in uplift and some overthrusting. This is shown by the much higher angles and degrees of folding and faulting on the western edge of the uplift than on the eastern edge as well as by the sedimentologic patterns. Miall (1986) has attributed this westwardly directed compression to the effects of the Caledonian Orogeny.

The fold and fault structures of the Boothia uplift have been subsequently modified and reactivated by later events, including the Ellesmerian Orogeny whose main trend of deformation was at right angles to that of the Boothia Uplift. Along a zone where the Parry Islands Fold Belt and the Boothia Uplift meet on eastern Bathurst Island, the deformation is complex resulting from the overprinting of these two tectonic events.

Central Ellesmere Fold Belt. The Central Ellesmere Fold Belt is the southernmost and structurally simplest of three Franklinian Fold Belts on Ellesmere Island. It extends in a sinuous path, northwesterly from Grinnell Peninsula, diagonally across the central portion of Ellesmere Island (Thorsteinsson and Tozer, 1970; Trettin and Balkwill, 1979). Structurally, it can be traced into the North Greenland Fold Belt (Higgins, et al. 1982). The style of deformation is similar to that of the Parry Islands Fold Belt with tight synclines, broad anticlines and high angle normal and reverse faults. Like the Parry Islands belt, the extent of deformation has been controlled by the distribution of competent and incompetent units and deformation is restricted to the cover rocks, probably with a Late Proterozoic detachment surface. The structural trends parallel the borders of the fold belt itself. Deformation took place during the Ellesmerian Orogeny although some reactivation of Ellesmerian structures, particularly faults, appears to have taken place in subsequent orogenic events.

CHAPTER 3 - BIOSTRATIGRAPHY AND PALEOBIOGEOGRAPHY

The Ashgill graptolite zones encountered in this study are discussed at length in appendix B (Melchin, in press). Correlation of those zones with other areas around the world can be found in text-figure 15.

Eleven graptolite zones and two subzones are recognizable, from the present collections, in the Llandovery of the Cape Phillips Formation (text-fig. 10). This compares with the five zones recognized by Thorsteinsson (1958) for the same interval - although his work was based almost entirely on collections of uncompressed graptolites from concretions rather than flattened ones. Text-figure 10 provides a suggested correlation of the Cape Phillips graptolite zones with those of Thorsteinsson (1958) as well as with the standard zonal scheme of the British Isles. Text-figure 11 shows a suggested correlation with some other recently proposed schemes from other nearby, boreal regions as well as the standard zonal schemes of Bohemia and China. Text-figure 12 shows the composite ranges of the graptolite taxa encountered in this study. Stratigraphic ranges of the taxa at the individual sections is provided in Appendix A.

Lower Llandovery

Parakidograptus acuminatus Zone. This zone has been

		British Isles Standard (Rickards, 1976)	Canadian Arctic Islands (this paper)		Canadian Arctic Islands (Thorsteinsson, 1958)
		crenulata	sakmaricus		Cyrto. n. sp. A-grandis
		griestoniensis	griestoniensis		spiralis
	U	crispus	crispus		
		turriculatus	turriculatus		turriculatus
		maximus	minor		
		sedgwickii	?		
Llandovery	M	convolutus	convolutus		millepeda
		argenteus	curtus	orbitus	
		magnus		pectinatus	
		triangulatus			
		cyphus	cyphus		cyphus
	L	acinaces	acinaces		
		atavus	atavus		
		acuminatus	acuminatus		

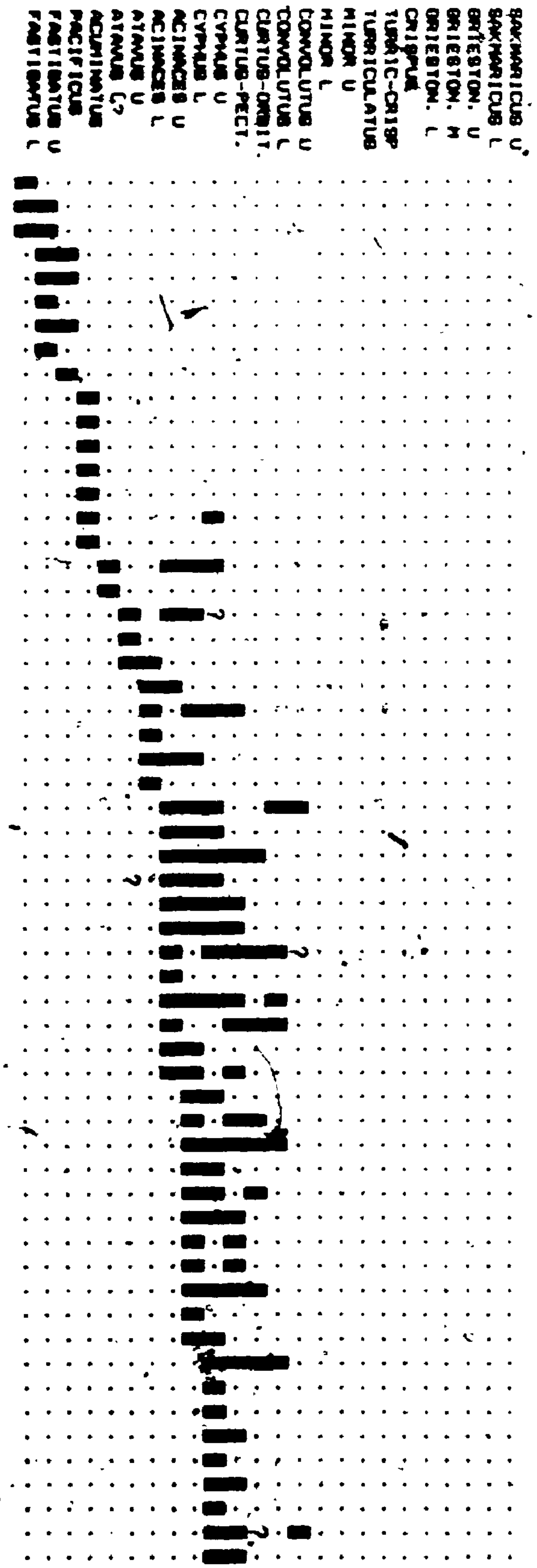
Text-figure 10. Correlation of the Cape Phillips Formation graptolite zones with the Llandovery standard sequence of the British Isles.

Text-figure 11. Correlation of the Llandovery graptolite zones with those of some other areas.

Canadian Arctic Islands (this paper)	North Greenland (Bjerreskov 1986)	Northern Cordillera (Lenz, 1982)	Siberia (Obut & Sennikov 1977, 1986)	China (Huo and Shu 1986)	Bohemia (Kříž, 1975)
sakmaricus	sakmaricus-laqueus	sakmaricus-laqueus	spiralis / grandis / griestoniensis	sakmaricus spiralis-grandis griestoniensis	grandis spiralis crenulata griestoniensis
griestoniensis	spiralis griestoniensis	spiralis			
crispus	turriculatus	turriculatus	crispus-turriculatus	crispus	crispus
turriculatus				turriculatus	turriculatus
minor			minor (linnaei)	linnaei	linnaei
		sedgwickii	sedgwickii	sedgwickii	sedgwickii
convolutus	convolutus?	convolutus	convolutus (cometa)	convolutus	convolutus
curtus: orbitus	argenteus	argenteus	gregarius-triangulatus	triangulatus-leei	pribyli
curtus: pectinatus		magnus?			pectinatus
		triangulatus			triangulatus
cyphus	atavus-cyphus	gregarius	cyphus	cyphus	cyphus
acinaces		acinaces	extenuatus-sibericus-vesiculosus		
atavus		atavus		vesiculosus	vesiculosus
acuminatus		acuminatus	acuminatus	acuminatus	acuminatus ascensus

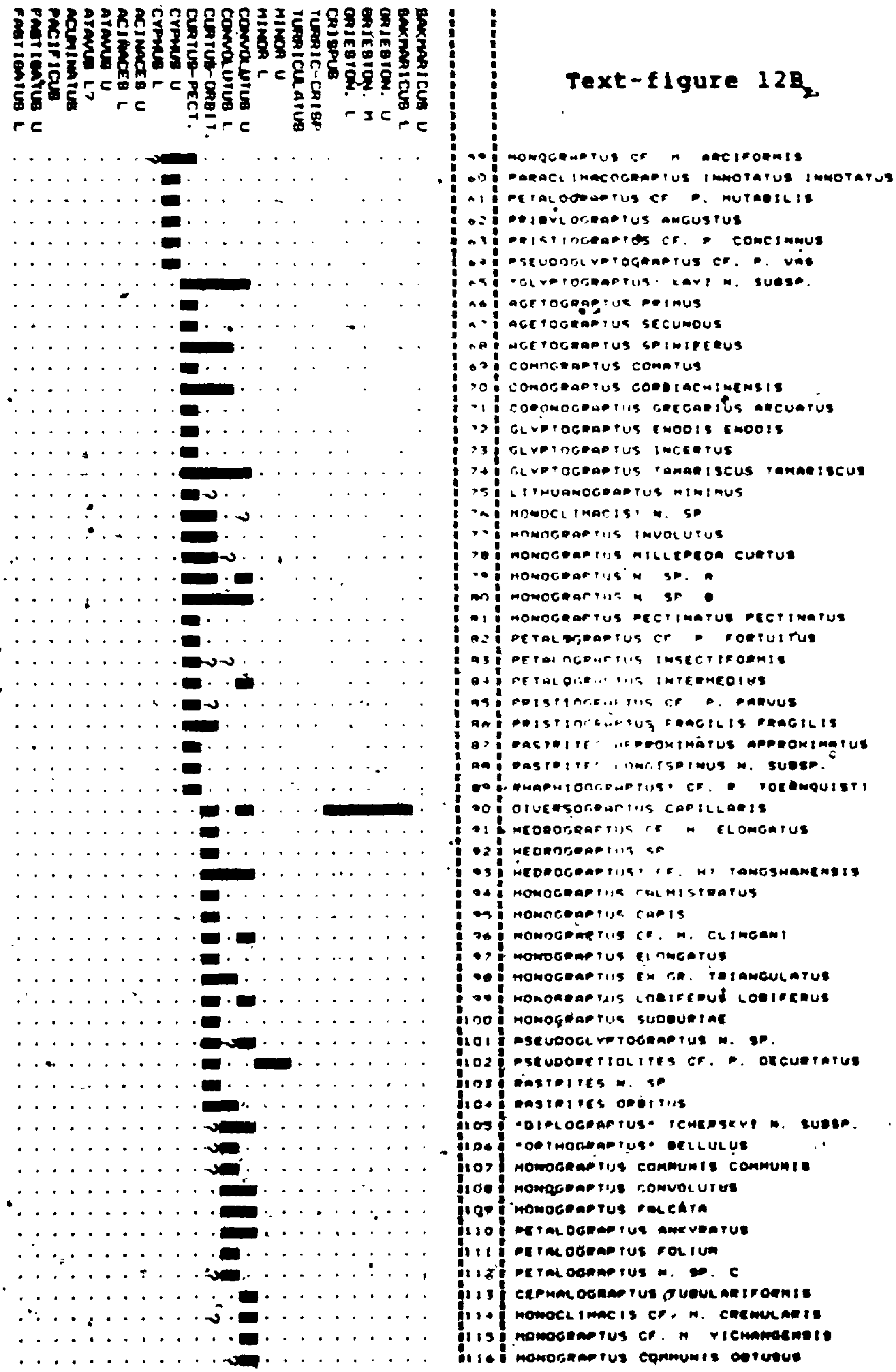
Text-figure 12A-D (following four pages). Composite range chart, by zones, of the Ashgill and Llandovery graptolites of the Cape Phillips Formation.

Text-figure 12A

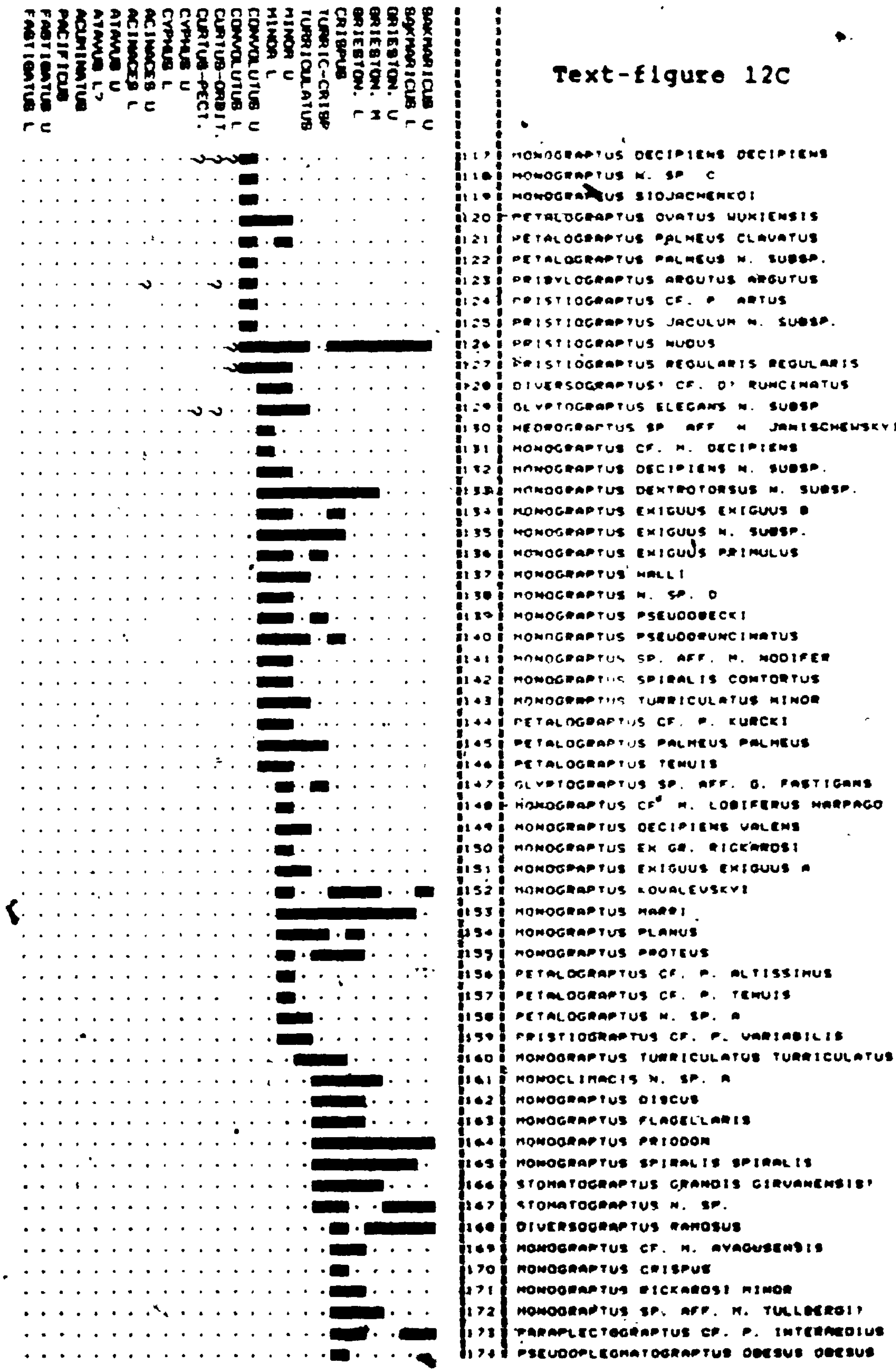


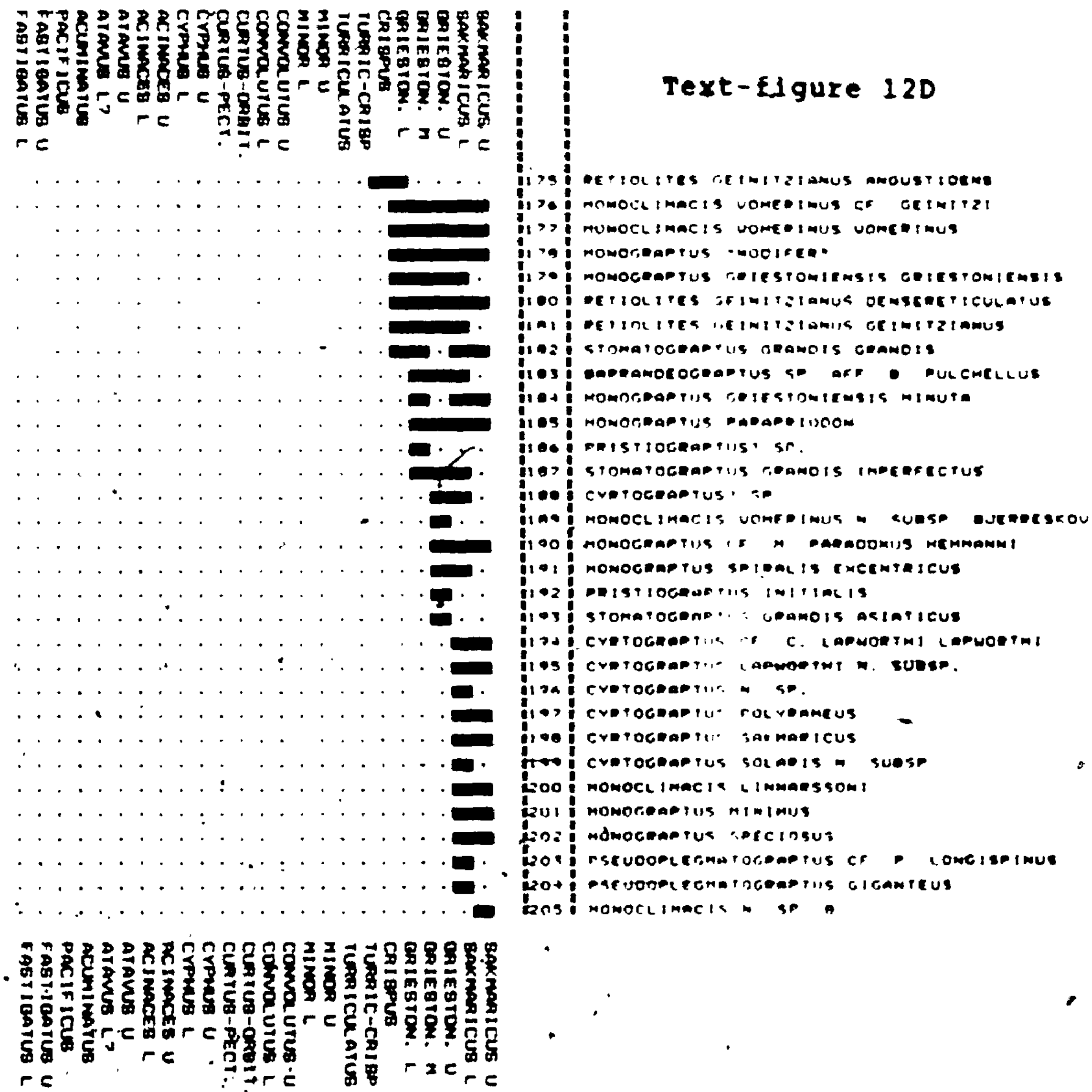
1 AMPLEXOGRAPTUS AFF A. PROMINENS
2 GLYPTOGRAPTUS CF G. LORRAINENSIS
3 ORTHOGRAPTUS FASTIGATUS
4 CLIMACOGRAPTUS LATUS
5 CLIMACOGRAPTUS LONGISPINUS SUPERNUS
6 CLIMACOGRAPTUS SP.
7 ORTHOGRAPTUS EX GR. AMPLEXICAULIS
8 ORTHOGRAPTUS THORSTEINSSONI
9 PARAORTHOGRAPTUS PACIFICUS
10 "DIPLOGRAPTUS" CF "D". ANGUSTIDENS
11 GLYPTOGRAPTUS? AFF. G NANUS
12 NEDROGRAPTUS ANGUSTUS
13 NEDROGRAPTUS MINUTUS
14 NEDROGRAPTUS N. SP. A
15 PARACLIMACOGRAPTUS INNOTATUS OBESUS
16 PARAKIDOGRAPTUS ACUMINATUS
17 GLYPTOGRAPTUS LACINIOSUS
18 PETALOGRAPTUS? N. SP. B
19 ATAVOGRAPTUS ATAVUS
20 GLYPTOGRAPTUS TENUIS
21 NEDROGRAPTUS MODESTUS MODESTUS
22 DIMORPHOGRAPTUS ERECTUS
23 GLYPTOGRAPTUS TAMARISCUS CF. VARIANS
24 NEDROGRAPTUS CF. N. LANPHEREI
25 NEDROGRAPTUS NORMALIS
26 PARACLIMACOGRAPTUS JINYANGENSIS
27 ATAVOGRAPTUS PRAESTRACHANI
28 DIMORPHOGRAPTUS MINUTUS
29 NEDROGRAPTUS JANISCHEWSKYI
30 NEDROGRAPTUS MAGNUS
31 NEDROGRAPTUS NIKOLAYEVI
32 NEDROGRAPTUS RECTANGULARIS
33 NEDROGRAPTUS SCALARIS FERGANENSIS
34 LAGAROGRAPTUS ACINACES
35 METACLIMACOGRAPTUS HUGHESI
36 METACLIMACOGRAPTUS ORIENTALIS
37 PRIBYLOGRAPTUS INCOMMODUS
38 PRISTIOGRAPTUS FRAGILIS PRISTINUS
39 AGETOGRAPTUS CF. A? SICHUANENSIS
40 AGETOGRAPTUS HUBEIENSIS
41 CLINOCLIMACOGRAPTUS SCULPTUS
42 CORONOGRAPTUS CYPHUS CYPHUS
43 CORONOGRAPTUS GREGARIUS CF. MINUSCULUS
44 CORONOGRAPTUS GREGARIUS GREGARIUS
45 NEDROGRAPTUS CF. N. MINUTUS
46 NEDROGRAPTUS ELONGATUS
47 NEDROGRAPTUS MEDIUS BREVICAUDATUS
48 NEDROGRAPTUS N. SP. C
49 PETALOGRAPTUS PHYSOPHORA ALASKENSIS
50 "DIPLOGRAPTUS" TCHERSKYI TCHERSKYI
51 AGETOGRAPTUS? SP.
52 CONOGRAPTUS? CF. C? TABUKENSIS
53 CORONOGRAPTUS CF. C. CIRRUS
54 CORONOGRAPTUS HIPPOSIDEROS
55 LAGAROGRAPTUS INEXPEDITUS
56 LAGAROGRAPTUS? N. SP.
57 METACLIMACOGRAPTUS UNDULATUS
58 MONOGRAPTUS AUSTERUS VULGARIS

Text-figure 12B



Text-figure 12C





Text-figure 12D

found in only two samples at Truro Island (the lower of which is only tentatively assigned to this zone) and is characterized by a typical, low diversity assemblage of *P. acuminatus* and several small hedrograptines, including the widespread *H. angustus* and *H. minutus* (= *H. mirnyensis*) and a possible *Glyptograptus* species. The only age-diagnostic species is *P. acuminatus* although the other forms are typical of this interval.

Atavograptus atavus Zone. This zone, like the *acuminatus* Zone, is restricted to two samples at a single section, Trold Fiord, which have yielded only five species. The lower sample is tentatively assigned to this zone and has yielded *Glyptograptus lacinosus* (found in the *atavus* Zone of the Northern Cordillera, Lenz, 1982a, and the *acuminatus* Zone of Alaska, Churkin and Carter, 1970) and a new species tentatively assigned to *Petalograptus*. This sample could equally belong to *acuminatus* Zone although the *Petalograptus*? n. sp. seems more indicative of the later interval. The co-occurrence of *Atavograptus atavus*, *Hedrograptus modestus modestus* and *Glyptograptus tenuis* in the suprajacent sample is diagnostic of the *atavus* Zone although the former two taxa range higher in the sequence. This is the first occurrence of monograptids in the sequence as is the case in many other parts of the world.

Lagarograptus acinaces Zone. This zone is recognizable at two sections, Trold Fiord and Huff Ridge, and it marks the incoming of a more morphologically diverse fauna to the region including Hedrograptus, Paraclimacograptus, Metaclimacograptus, Glyptograptus, Dimorphograptus, Atavograptus, Lagarograptus, Pribylograptus and slender Pristiograptus. The co-occurrence of H. m. modestus, Dimorphograptus erectus, L. acinaces and Pristiograptus fragilis pristinus strongly indicates the acinaces Zone of the British Isles. The lowest sample at Huff Ridge has yielded only Hedrograptus cf. H. lanpherei and Paraclimacograptus jinyangensis which, by themselves, are not age-diagnostic. Both of these forms, however, occur only in the acinaces Zone at Trold Fiord so this sample and those overlying it which have yielded only Hedrograptus normalis and H. janischewskyi are questionably considered to belong to this zone. This is the earliest known report of H. janischewskyi which is known only from the Middle Llandovery in the U.S.S.R.

Coronograptus cyphus Zone. This zone is recognizable at three sections, Twilight Creek, Trold Fiord and Huff Ridge. It is most strongly characterized by the incoming of species of Coronograptus, particularly C. cyphus cyphus (which appears to be restricted to this interval in the Arctic Islands) and C. gregarius ssp. which range upward into the curtus Zone. Agetograptus also makes its first appearance in this zone, particularly species such as A. hubeiensis and A. cf. A. sichuanensis which bear a close resemblance to Glyptograptus (as opposed to A. primus, A. secundus and A. spiniferus which appear in the curtus Zone and bear a closer resemblance to species of N. gen. B).

Clinoclimacograptus sculptus, Comograptus? cf. C? tabukensis and Pseudoglyptograptus cf. P. vas together with Petalograptus physophora alaskensis and P. cf. P. mutabilis all make their appearances in this zone and all but the first are restricted to this interval but represent early representatives of groups more common in the Middle Llandovery.

Of particular significance is the occurrence of Monograptus cf. M. arciformis, since it is, together with the report of the similar Monograptus cf. M. intermedius in the cyphus Zone of China (Chen and Lin, 1978) the earliest known occurrence of Monograptus s.s. (those monograptids with hooked thecae throughout). Previously, Monograptus s.s. was thought to be restricted to magnus Zone and later strata (Rickards, et al., 1977). These species bear a close resemblance to the coeval "pernerograptids" (e.g. Monograptus austerus vulgaris which occurs with M. cf. M. arciformis in the cyphus Zone in the Cape Phillips) except that the thecae do not become pristiograptid distally as in the latter group.

Middle Llandovery

Monograptus millepeda curtus Zone. The onset of the Middle Llandovery is marked by the incoming of the triangulate monograptids (e.g. *M. pectinatus*, *M. involutus*, *M. decipiens decipiens*, among others) as well as *Petalograptus* s.s. (e.g. *P. intermedius*) and *Rastrites* (*R. approximatus approximatus* and *R. longispinus* n. subsp.).

The *curtus* Zone is divisible into two subzones at three of the sampled sections, Trold Fiord, Huff Ridge and Cape Manning (although at the latter there is some overlap of the subzones owing to the broad and imprecise sampling intervals). At Snowblind Creek, Rookery Creek and Truro Island, the *curtus* Zone cannot be subdivided.

The lower of these is the *Monograptus pectinatus* Subzone, characterized by the presence of the nominate species, *Rastrites approximatus*, *R. longispinus* n. subsp., *Lagarograptus inexpeditus* (which is also uncommonly found in the upper part of the underlying *cyphus* Zone), *Agetograptus primus*, *A. secundus*, *Comograptus gorbiachinensis*, *Glyptograptus enodis enodis* and *G. incertus*.

The upper subzone, *Rastrites orbitus* is characterized by the nominate (which extends, less commonly into the *convolutus* Zone), *Rasttites* n. sp., the first retiolitid, *Pseudoretiolites* cf. *P. decurtatus*, a diversity of hooked, lobate and triangulate monograptids as well as the first occurrences of *Diversograptus capillaris*.

Monoclimacis has its beginnings in this zone and *Pristiograptus fragilis* ssp. and *Pristiograptus* cf. *P. parvus* are also found.

Other common *curtus* Zone species include the nominate species, species of N. gen. A and N. gen. B, *Glyptograptus tamariscus tamariscus*, *Monograptus* n. sp. A and *M.* n. sp. B, *Pseudoglyptograptus* n. sp. (all of which extend into the overlying *convolutus* Zone) as well as several *Hedrograptus* species which extend from the underlying zones.

The *curtus* Zone is the zone of highest species diversity, followed by the *convolutus* Zone. This is in accord with the diversity patterns seen in Great Britain (Rickards, 1977) and this appears to be the peak of the Llandovery radiation.

The condensed nature of this zone where it occurs at most sections and the lack of several of the distinctive index fossils such as *M. triangulatus* ssp. (except *M. pectinatus*), "*Diplograptus*" *magnus* or *Monograptus argenteus* or *M. leptotheca* prevents recognition of these zones in the Arctic Islands. It appears, however, that the *pectinatus* Subzone is approximately correlative with the *triangulatus* and *magnus* zones of Britain and the Northern Cordillera while the *orbitus* Subzone matches with the *leptotheca* and *argenteus* zones of those areas respectively. The presence of *Monograptus millepeda curtus* (= *Campograptus curtus*) among other species provides good correlation with the *triangulatus-gregarius* Zone of Siberia.

Monograptus convolutus Zone. This zone is recognizable at four of the sampled sections, Snowblind Creek, Cape Manning, Twilight Creek and Huff Ridge. Much of the diversity of the *convolutus* Zone is the result of continuation of forms from the *curtus* Zone. The distinctive elements of this zone, however, include *M. convolutus* itself, *M. communis* ssp., the "paramonoclimacids" *Monograptus sidjachenkoi* and *M. falcata*, several *Petalograptus* species including *P. folium*, *P. ankyratus*, *P.* n. sp. C, *P. palmeus* n. subsp., *P. insectiformis* (which extends from the underlying zone) and *P. ovatus wuxiensis* and *P. palmeus clavatus*. The latter two, together with the first of the typical pristiograptids, *P. regularis* and *P. nudus*, are among the few species which extend into the overlying *minor* Zone. *Cephalograptus* common in and diagnostic for this interval in many parts of the world is almost entirely absent except for a few, incomplete specimens of *C. tubulariformis*.

Evidence for the presence of the *Monograptus sedgwickii* Zone is lacking and this, as noted in a previous section, is considered to be due, at least in part, to sedimentological factors.

The almost cosmopolitan nature of *M. convolutus* as well as *M. communis* provide good correlation of this zone worldwide. In addition, the "paramonoclimacids" seem to be reliable zonal indicators through much of northern North

America, the U.S.S.R. and China.

Upper Llandovery

Monograptus turriculatus minor Zone. The *minor* Zone has been identified from Truro Island, Twilight Creek, Trold Fiord, Huff Ridge and a single, loose slab at Irene Bay. It has been questionably identified at Snowblind Creek and Middle Island. *Monograptus decipiens* n. subsp., *M. spiralis contortus* and *Petalograptus tenuis* (as well as several other less common petalograptids) are the most common species which are restricted to this zone, while *M. dextrorsus* n. subsp., *M. exiguus* ssp., *M. decipiens valens*, *M. pseudobecki*, *M. pseudoruncinatus*, *M. turriculatus minor* and *M. halli* are common in this zone but extend upward in to the following *turriculatus* Zone. The latter four species, in particular, are most abundant in the *minor* Zone. *Petalograptus palmeus palmeus*, *Glyptograptus* sp. aff. *G. fastigans* and *G. elegans* n. subsp. extend through this zone and are common in it. *Hedrograptus* appears to make its final appearance in this zone with a single occurrence of *H.* sp. aff. *H. janischewskyi*.

Monograptids of the *priodon*-group, *M. marri* and *M. kovalevskyi*, make their first appearance high in this zone, together with *M. proteus* and *M. planus*, and go on to become more common in the overlying zones.

The nominate subspecies and, to a lesser extent, *M.*

spiralis contortus, provide good correlation of this zone with the U.S.S.R. and the *linnaei* Zone of central Europe and China. This, in turn, provides correlation, at least in part, with the *maximus* Subzone of Britain and the lower part of the *turriculatus* Zone in the Northern Cordillera. Species of *Rastrites*, which are common in most parts of the world during this time interval, have not been found at all above the *convolutus* Zone in the Cape Phillips Formation.

Monograptus turriculatus turriculatus Zone. This zone has been found at four of the sampled sections, Snowblind Creek, Twilight Creek, Middle Island and Trold Fiord. There are no species confined to this zone, as defined here. The nominate subspecies extends into the overlying *crispus* Zone although it is most common in the *turriculatus* Zone. The zone is defined by the co-occurrence of *M. exiguus* ssp., *M. decipiens valens*, *M. pseudobecki* and *Petalograptus palmeus palmeus* as well as some other species from the preceding zone, and *M. turriculatus turriculatus*.

At Snowblind Creek, two samples which occur above *M. t. turriculatus* have a fauna belonging either to the *turriculatus* or *crispus* Zone but lack the diagnostic, nominate species. Another collection from Trold Fiord (TF:79.0) spans an interval of about one metre and seems to have elements of the *turriculatus* Zone (including the nominate) and the overlying *crispus* Zone (including the first occurrence of *M. priodon*, *M. s. spiralis*, *M. discus*,

M. *flagellaris* and *Stomatograptus* n. sp.). (*Monograptus discus* has recently been found in the *turriculatus* Zone in the South Nahanni region of Northwest Terretories, Lenz, pers. comm. 1987). Both of these occurrences are assigned to the undivided *turriculatus*-*crispus* Zone. The *turriculatus* Zone, as employed here, is much more restricted than that used by Lenz (1982a) in the Northern Cordillera where it spans the range of the *minor* and *turriculatus* zones and probably at least part of the *crispus* Zone as well. In the Arctic Islands, the *crispus* Zone encompasses the zone of overlap of *Monograptus spiralis spiralis* and *M. t. turriculatus*, which, in the Yukon, is included in the *turriculatus* Zone.

Monograptus crispus Zone. This zone can be certainly recognized at only three sections, Trold Fiord, Huff Ridge and Irene Bay. The only species restricted to this interval are the nominate and the uncommon *Pseudoplegmatograptus obesus obesus*. This zone is an interval of transition from early Late Llandovery (*turriculatus* Zone s.l.) to late Late Llandovery (*spiralis* Zone s.l.) faunas. *Monograptus exiguus* ssp., *M. pseudobecki*, *M. pseudoruncinatus*, *M. t. turriculatus*, *Glyptograptus* and *Petalograptus* all make their last Canadian Arctic appearances either in the *crispus* or the *turriculatus*-*crispus* zones.

In addition to the taxa noted above which appear in the *turriculatus*-*crispus* interval, *Diversograptus ramosus*, Monograptus rickardsi minor, Paraplectograptus cf. P. intermedius and Retiolites geinitzianus angustidens are common or significant taxa which first appear in the crispus Zone. Although it is not entirely cosmopolitan, the short-ranging M. crispus seems to be a very reliable zonal indicator when it is present.

Monograptus griestoniensis griestoniensis Zone. The two uppermost zones of the Llandovery are by far the thickest and most widely recognizable in the Cape Phillips Formation. The griestoniensis Zone is represented at eight of the sampled sections (at the other three this interval is not exposed). The dominant species of this interval are Monograptus priodon, M. s. spiralis, M. g. griestoniensis, M. marri, Monoclimacis vomerinus ssp., Pristiograptus nudus and Retiolites geinitzianus ssp. (especially R. g. densereticulatus). Only four taxa, all of which are uncommon, are restricted to the griestoniensis Zone. One of these, Pristiograptus initialis (= P. denemarkae), provides good correlation with the same horizons in Britain and central Europe, while another, Monoclimacis vomerinus n. subsp. Bjerreskov (1975) matches the upper part of the present griestoniensis Zone with the (restricted) spiralis Zone of Bornholm, Denmark. Another species linking the upper griestoniensis Zone (and lowest sakmaricus Zone) of the Arctic Islands with the spiralis Zone of Bornholm is M. spiralis excentricus.

The common presence of the nominate subspecies and M. s. spiralis, both of which become less common and terminate in the lower sakmaricus Zone, provides very good correlation of this zone with many areas worldwide.

Cyrtograptus sakmaricus Zone. This zone, like the preceding one, is recognizable wherever uppermost Llandovery strata are exposed - at nine of the sampled sections. Its base is taken at the first occurrence of unequivocal Cyrtograptus at each section. The diagnostic species of this zone include the six Cyrtograptus taxa, Monograptus speciosus, M. minimus and Monoclimacis linnarssoni and owing to these taxa, correlation with the sakmaricus-laqueus Zone of the Northern Cordillera and Greenland, the lapworthi Zone of Bornholm and the upper part of the spiralis and the grandis zones of central Europe is very good.

Correlation with the British standard section is somewhat more complex owing to the almost total lack of Llandovery cyrtograptids in that region. M. minimus and M. linnarssoni are only found in the lowest Wenlock beds in Britain (they also extend into the Wenlock in the Cape Phillips Formation) and none of the other age-diagnostic species of the crenulata Zone of Britain are found in the Arctic Islands. The lowest Wenlock of Britain, however, has several diagnostic Cyrtograptus species, including C. centrifugus, C. insectus and C. murchisoni, all of which have been tentatively identified from Cape Phillips samples overlying the last sakmaricus Zone samples. Since these Cyrtograptus species are taken to indicate the base of the Wenlock in the type area and sakmaricus completely predates these forms across northern Canada (Lenz, 1978), it can be concluded that the sakmaricus Zone, at least in Canada, is wholly Llandovery. This is supported by the partial overlap of the sakmaricus Zone with the range of M. s. spiralis and the total overlap of C. sakmaricus with the range of C. lapworthi-group forms (considered in Europe to be a Llandovery species) and Stomatograptus grandis esp.

In China, the sakmaricus Zone is considered to be Wenlock in age (Huo and Shu, 1986) and Fu (1985) has recognized a distinct lapworthi Zone (considered to be Llandovery) and sakmaricus Zone (considered to be lowest Wenlock). In both cases, the authors show the sakmaricus Zone predating insectiformis and/or centrifugus zones and infer that a gap exists in the lowest part of the Wenlock graptolite sequence in Britain between the crenulata and centrifugus Zones. The co-occurence of C. sakmaricus with other typical Llandovery species (including C. polyrameus, a species from the lapworthi Zone of Fu, 1985) and the other taxa noted above strongly indicates that it is not necessary to infer a gap in the British sequence and that C. sakmaricus is more likely a wholly Llandovery species.

In the eastern U.S.S.R., a murchisoni Zone has been identified containing several cyrtograptids, most of which are synonymous with, or closely related to C. sakmaricus and *C. laqueus* (Golikov, 1969, 1974). In addition, two new subspecies of *Stomatograptus grandis* have been reported, one of which, *S. g. asiaticus*, has been found in the upper part of the *griestoniensis* in the Cape Phillips Formation. The close affinities of these faunas with those in the latest Llandovery (pre-*insectus*, *centrifugus* or *murchisoni*) of northern North America suggests that they, too, may be Llandovery rather than Wenlock in age.

Paleobiogeographic Considerations

Llandovery graptolite faunas are considered to be among the most cosmopolitan of any throughout the graptolite sequence (Berry, 1979). As more information emerges from various parts of the world, however, some provincial patterns begin to emerge. Among the Ashgill graptolite faunas, most of the world shows assemblages of comparable diversity and generic and, at least in part, specific composition with the notable exception of China. Prior to the main extinction event (within the Chinese *bohemicus* Zone - see section below "Late Ordovician Graptolite Extinction") many endemic species existed as well as some endemic genera. In the late *bohemicus*, *persculptus* and *acuminatus* Zones, the species (although not generic) diversity is likewise much higher than in coeval faunas other parts of the world. Although it may be argued that some of this apparent diversity is the result of taxonomic splitting, the morphologic diversity seen in these faunas does indeed appear to be high as compared with other areas.

During this interval, the faunas of the Cape Phillips Formation are less diverse than most other regions and some of the most common Ashgill forms, notably Dicellograptus, are lacking entirely. As discussed by Melchin (in press, appendix B) this is considered to be a paleoecologic factor rather than a paleobiogeographic one. Likewise, the low diversities and sporadic occurrences seen through most of the Lower Llandovery part of the section are attributed to unstable and possibly restricted conditions within the Cape Phillips Basin.

By the cyphus Zone and into the Middle Llandovery, very diverse faunas had become established. As can be expected, the faunas show great similarities with the Northern Cordillera and Alaska. As noted previously, some of the diagnostic elements of the British sequence are absent. On the other hand, several elements absent in Britain and Europe but present in Siberia and China are found. Among these are Agetograptus, Comograptus and "Paramonoclimacis" as well as several species and subspecies (e.g. "Diplograptus" tcherskyi ssp., Lagarograptus inexpeditus, Monograptus cf. M. arciformis, Petalograptus ankyratus and M. millepeda curtus). The distribution of some of these forms can be used to show that close biogeographic affinities existed, during these times, between Arctic Canada and Siberia and, to a slightly lesser extent, China.

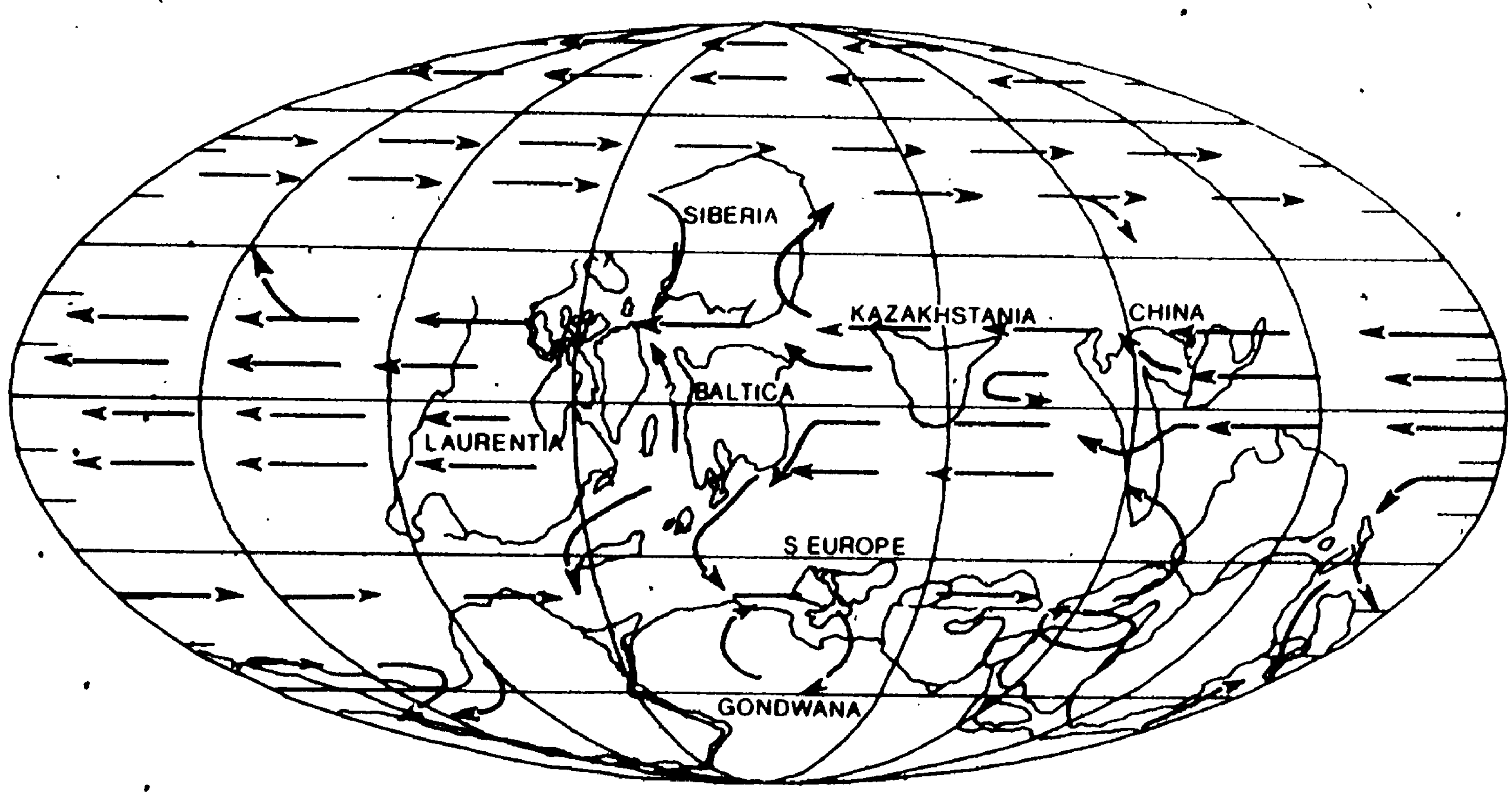
This is in accord with the paleogeographic reconstruction of Ziegler, et al. (1981) (text-fig. 13) which shows Siberia as two plates, both in close proximity to Arctic Canada and the Russian part of Baltica, Kazakstania and China all arranged along a circum-equatorial current system while the southern portion of the British Isles is further to the south, affected by a different current system.

In the Late Llandovery, the distribution of M. turriculatus minor defines a similar distribution pattern, being found in China, Siberia, eastern (and central) Europe and the Canadian Arctic Islands (although apparently not on the mainland of North America).

The influx of typically European Pristiograptus and Monoclimacis species in the late Middle and Late Llandovery, not seen further southeast in the Cordillera, may be the result of increased connection with Baltica, through its closer proximity as the Iapetus Ocean was closing, or through increased exchange of waters via North Greenland as basinal conditions became better established there.

In the uppermost Llandovery a distinct province is again established in northern North America, Siberia, China and, to a lesser extent, central Europe, defined by the diverse cyrtograptid fauna with C. sakmaricus, C. ex gr. lapworthi and others as well as a diverse retiolitid fauna.

The overall very high diversity of the Cape Phillips Llandovery graptolite fauna deserves some mention. Some 202 distinct taxa have been identified (including tentative



Text-figure 13. Late Llandovery paleogeographic reconstruction showing proposed surface ocean currents. Modified after Zeigler *et al.* (1981) and Scotese *et al.* (1985).

identifications). This is comparable to the 218 taxa found in the same interval in the British Isles (Rickards, 1976) where people have been collecting graptolites for well over 100 years. In the Northern Cordillera, where collecting has taken place for over 25 years, the comparable interval has yielded about 128 taxa (Lenz, 1979). Even by comparison with some Chinese reports, Chen and Lin (1978) have reported 109 taxa up to the top of the communis (=convolutus) Zone, while the Cape Phillips Formation has yielded 123 taxa from the Lower and Middle Llandovery. Chen (1984a) has reported 114 taxa up to the sinicus (=crispus?) Zone, while the comparable interval has yielded 167 taxa in Arctic Canada.

The reason for this unusually high diversity is not immediately apparent but several possible factors may be responsible. One consideration is surely the size of the study area - an outcrop belt approximately 1000km long has been sampled. This area is roughly comparable to the sampled area of Great Britain or the Northern Cordillera but much larger than the sampled areas of the Chinese studies. Still, only eleven sections were sampled across this area and large regional differences were not observed between the various sections. Furthermore, sampling was not at the intensive level undertaken in many other areas, the sampling interval being about 0.5 to 2.0m in productive intervals. It is reasonable to assume that more intensive sampling of more sections would yield still more taxa.

Another factor contributing slightly to the high diversity is the sampling of concretions which, on dissolution, yield the entire contained fauna rather than those found on single bedding planes. A few taxa have been found only in concretions (and not in compressed form) but this has contributed only slightly to the high diversity.

Obviously conditions in the Cape Phillips Basin were highly suited to graptolite proliferation, at least from late Early Llandovery time onward. Examination of the paleogeographic map (text-fig. 13) shows that the basin may have been a zone of confluence of the circum-equatorial current as well as one directed southward from Siberia. In addition, northward flow through the closing Iapetus Ocean would have met the equatorial current in Arctic North America. This confluence of currents from diverse areas, together with suitable conditions within the basin, may provide the explanation for the highly diverse faunas of the Cape Phillips Formation.

CHAPTER 4 - DIPLOGRAPTID MORPHOLOGY AND ULTRASTRUCTURE

Proximal Development Patterns

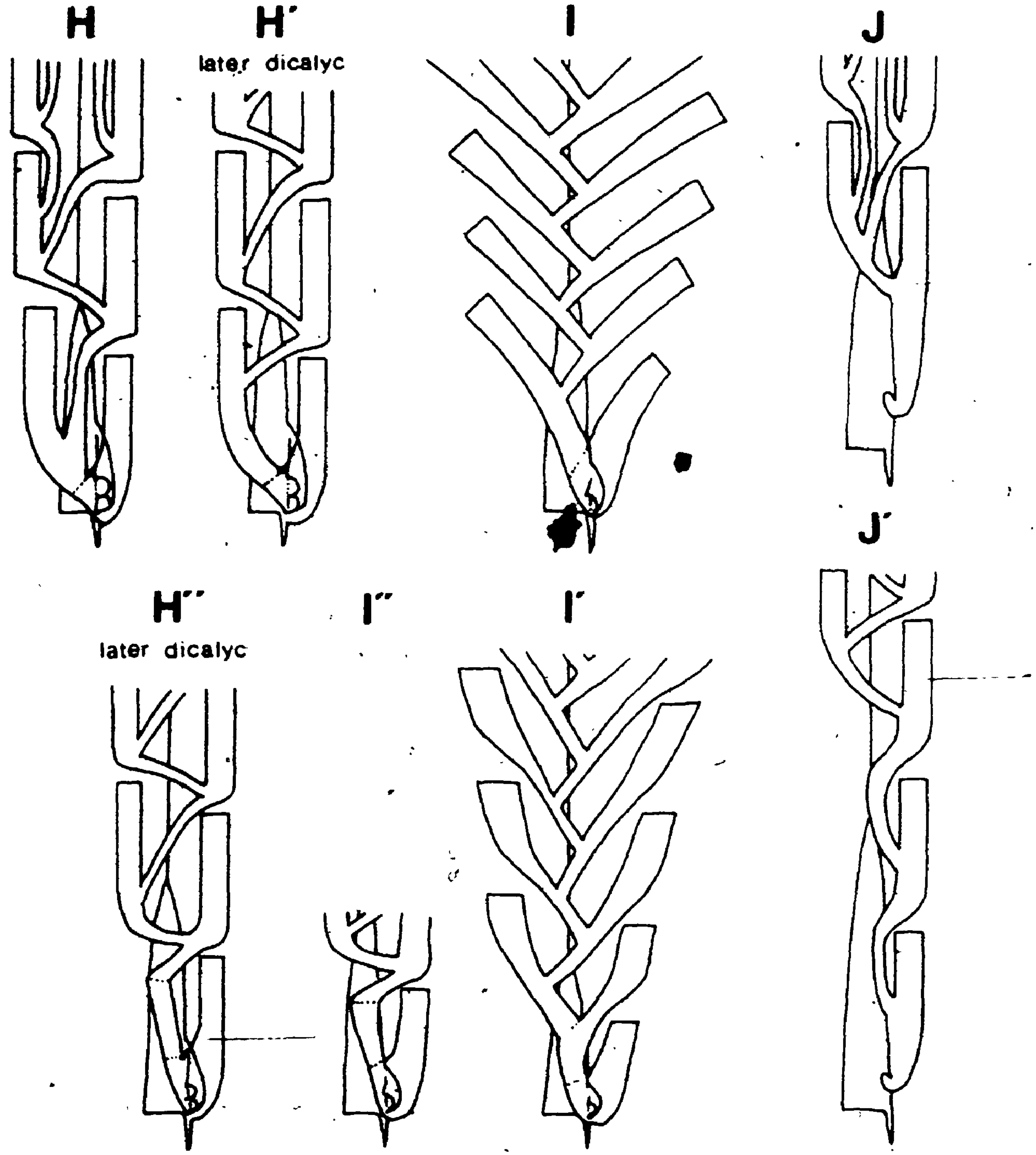
In the past few years, several attempts have been made by various authors to revise the generic and suprageneric classification schemes of the graptoloids. Some of these schemes have involved only a use of the traditional criteria of generic distinction such as stipe number and orientation, and thecal morphology (the latter especially among the diplograptids and monograptids - see, for example, Rigby, 1986). However, Fortey and Cooper (1986) and Mitchell (1987) have attempted to employ a new set of criteria based primarily on the ontogeny of the sicula and early astogeny of the rhabdosome to arrive at what they believe is a classification scheme which better reflects graptoloid phylogeny.

Among the diplograptids, which have been studied in detail by Mitchell, this new approach has shown that thecal morphology is a genetically highly "plastic" feature which is easily duplicated in different lineages and therefore can only be applied to taxa above the specific level with great discretion. The early growth stages and budding patterns, on the other hand, appear to have been more conservative features of graptolite evolution and therefore more reliable criteria for assignment of supraspecific taxa.

Mitchell recognized nine different proximal development types among the scandent, biserial graptolites which he designated the letters A through I. Of these, only H and I were recognized to occur in the Lower Silurian, the remainder being confined to the Ordovician. Type H forms were found in both Ordovician and Silurian strata while type I was considered to be restricted to the Silurian. Mitchell's conclusions concerning Silurian diplograptids, however, were based on the very scanty published information about the development of Silurian diplograptids and it is to his credit that he managed to correctly define the distinction between these two main early growth patterns.

The occurrence of an abundant and diverse Middle and Upper Llandovery fauna of isolated, uncompressed diplograptids in the Cape Phillips Formation enables me to examine the distribution of these growth patterns among some Silurian taxa, to illustrate some of the variations within each pattern and to show how the different patterns are manifest in both early growth stages and in mature rhabdosomes. This, in turn, can help to elucidate the phylogeny of latest Ordovician and Silurian diplograptids and monograptids.

The descriptions of the proximal development patterns are based in part on those given by Mitchell (1987) and partly on observations made by SEM on the present specimens. Text-figure 14 presents schematic illustrations of the basic proximal development patterns and their variations.



Text-figure 14. Schematic representations of proximal development patterns of Llandovery (non-retiolitid) diplograptids. Refer to text for explanation and discussion.

Pattern H. The sicula is commonly short and broad (usually 1mm or less in Ordovician species, and 0.9 to 1.7mm in Silurian forms) although is occasionally much longer (e.g. Cystograptus). The sicular aperture and first thecal pair are usually unornamented except for a virgella which can achieve great length and form multiple branches (exceptions can be seen in Hedrograptus n. sp. A, and the "spiny" forms of Hedrograptus rectangularis and H. janischewskyi seen in the present material and Hedrograptus serratus f. barbata (Elles and Wood) which show spines on both the sicular aperture and on the early thecal pairs).

The $th1^1$ protheca has a sinuous downward growth, turning to the left about halfway along its length and then downward again (e.g. pl. 2, fig. 13; pl. 8, fig. 6; pl. 11, fig. 5). Two foramina open at its end: one opening downward for the $th1^1$ metatheca; one opening to the right or reverse side for the bud of protheca 1^2. These foramina are separated by a list (list A) which extends from the edge of the descending protheca to the sicula. The metatheca 1^1 turns sharply upward just below the sicular aperture and partially encloses its protheca on the obverse side and the $th1^2$ foramen on the reverse side. In many type H species the reverse wall of metatheca 1^1 is free and not anchored against its protheca or the sicula during its growth except by another list (list B) which extends from the sicula to the free edge of the thecal wall (e.g. pl. 5, figs. 6,11; pl. 6, figs. 11, 12; pl. 7, fig. 4; pl. 8, fig. 7; pl. 11, figs. 8,9; pl. 12, fig. 8). An interthecal septum then forms at some later point and is generally not attached to the sicula at all. However, in some species (e.g. Hedrograptus kuckersianus (Wiman), Hedrograptus nikolayevi (Elles and Wood)) this wall is anchored against the sicula by an interthecal septum which grows from the point of differentiation of protheca 1^2 (pl.2, figs. 2,3,7). List B forms the point of origin of this septum.

The point at which protheca 1^2 differentiates is somewhat variable but appears to be to some extent governed by the position of list B. In the Ordovician species described by Mitchell, the line of unconformity between $th1^1$ and $th1^2$ begins at the very base of $th1^1$ (at the sicular aperture) and curves to the right and upward, meeting list B, and extending upward to the base of $th2^1$ (see Mitchell's text-fig. 3F,G). In the Silurian species observed here - and, apparently in "Climacograptus" aff. scalaris of Barrass (1954) - the line of unconformity between the first thecae extends at a variable angle downward and to the left from list B. In species of Metaclimacograptus, Lithuanograptus and probably Clinoclimacograptus, list B is 0.24mm from the sicular aperture and the unconformity extends nearly straight downward from this point, giving an appearance very similar to that of the Ordovician species (pl. 5, figs. 4,8,13; pl. 7, figs. 10,11). However, in many of the other species, such as Hedrograptus nikolayevi, Pseudoglyptograptus n. sp. B and species of n. gen.A, list B may be as much as 0.4mm above the sicular aperture and the line of unconformity extends downward and to the left at an angle of about 45° (pl. 2, figs. 2,3,7; pl. 4, fig. 2; pl. 8, figs. 2,8; pl. 11, fig. 6). The result is that the point of differentiation of the two thecae is between 0.2 and 0.4mm above the sicular aperture. The fusellae below this point are continuous with those of $th1^1$ extending in an arcuate path across part or all of the reverse side of the sicula. This results in an appearance similar to that seen in some pattern I species. It must be stressed, however, that in all of the pattern H species, the initial bud of $th1^2$ emerges from the descending portion of $th1^1$ at the sicular aperture and it is only the manifestation of $th1^2$ in the form of a fusellar differentiation that is delayed in these species (contrast this with the pattern I species described below). From the point of differentiation of $th1^2$ (i.e. the position of list B) the growth of theca 1^1 always proceeds ahead of that of $th1^2$ (pl. 2, fig. 3; pl. 5, figs. 4,8; pl. 7, fig. 10; pl. 11, fig. 3). The growth of $th1^2$ is first diagonally upward and across the remainder of the reverse side of the sicula and it later turns more-or-less straight upward. Theca 2^1 begins to differentiate very early in most type H species, often at, or just above the position of list B (pl. 2, fig. 4; pl. 4, fig. 2; pl. 5, fig. 9). In N. gen. A, however, the budding of $th2^1$ is delayed until just below or at the aperture of $th1^1$ and its differentiation is like that of $th2^2$ and of all later thecae (pl. 8, figs. 3,4; pl. 11, figs. 4,10). This slightly modified pattern with only two primordial thecae is here designated pattern H'.

The proximal development of *Rhaphidograptus toernquisti*, as illustrated by Hutt[illegible] al. (1970) bears a strong resemblance to that of N. gen. A, with a delayed differentiation of $th1^2$ as well as a delayed $th2^1$. Although, the delay of the first upconformity is slightly later than any observed here, the fusellar unconformity is more pronounced than is seen in most pattern I species and the rhabdosome shows other features which indicate associations with the other pattern H species, especially a complete median septum distally and the presence of small genicular hoods, neither of which have yet been found on any pattern I species. If *Rhaphidograptus* is indeed pattern H (if it proves to possess a descending protheca 1^1 with two terminal foramina) then this pattern, here desgnated H'', would be distinct from either *Agetograptus* (pattern I' and/or I'' - see text-fig. 15) or *Dimorphograptus* (pattern J') (see discussions of pattern I and J and the genus *Rhaphidograptus*).

Most type H species, then, have three primordial thecae with one, reduced crossing canal. N. gen. A (and possibly *Rhaphidograptus*) has a only two primordial thecae but is otherwise very similar and therefore included in the type H group.

Pattern H graptolites have a relatively slender, rounded, asymmetrical proximal end, generally posess a small portion of the sicula exposed below th1^2. On the obverse side the sicula is commonly exposed to about the level of the th1^1 aperture where it is enclosed by th1^2. Type H rhabdosomes usually have a complete median septum although in many Silurian species its formation is delayed until as late as the ninth thecal pair, a partial median septum being present before that point. Theca 2^1 is the earliest theca which may be dicalycal. The median septum may be straight or slightly undulose to angular. A notable probable exception is Hedrograptus? indivisus (Davies) which appears to be entirely aseptate (Waern, 1948). As Waern (p. 457) points out, however, and his excellent illustrations clearly show (especially pl. 27, fig. 6), the interthecal septa of the first three or four thecal pairs extend inward to the centre of the rhabdosome and those thecae are clearly alternate in origin. The interthecal septa of the following thecae run parallel to the outer walls and leave a significant central common canal. These more distal thecae give the distinct impression of having separated into two separately growing stipes at about the fourth thecal pair, despite the fact that no septum is present separating them.

Most type H graptolites exhibit climacograptid to glyptograptid thecae although pseudoclimacograptid to highly undulose thecae are also found in this group. Orthograptid thecae are found in the distal end of a few biform species in this group (e.g. "Diplograptus" tcherskyi n. subsp., *Hedrograptus* n. sp. B) and some of the *persculptus* Zone "orthograptids" reported from China may be pattern H species. Some species with geniculate thecae have genicular thickenings or outgrowths.

Pattern I. The sicula is commonly long in petalograptids but is shorter in glyptograptids and very short (0.4mm) in n. gen. B (e.g. "*Orthograptus*" *bellulus* (Törnquist), "*Glyptograptus*" *kayi* n. subsp., pl. 24, fig. 4; pl. 25, fig. 6) and reduced to absent in the retiolitids. Theca 1[1] has a short descending segment and only a single foramen at its end, opening downward and sometimes obliquely to the right (pl. 13, fig. 8; pl. 14, fig. 8; pl. 15, fig. 1; p. 17, fig. 12; pl. 18, fig. 8; pl. 19, fig. 4; pl. 21, figs. 2,9,10; pl. 23, fig. 5; pl. 24, fig. 6; pl. 26, fig. 11). The upward turn of th1[1] begins at or slightly below the sicular aperture and is sharp, with the obverse wall enclosing all or most of the descending portion. (Occasional specimens can be seen where th1[1] turns upward above the sicular aperture; e.g. Hutt, *et al*. 1970, pl. 1, fig. 10.) Observations on the present material, however, suggests that this is the exception rather than the rule. The reverse wall of th1[1] grows upward and diagonally across the reverse side of the sicula. At some point after this wall crosses the midline of the sicula, an interthecal septum appears differentiating the th1[1] metasicula from protheca 1[2] (pl. 15, figs. 2,7; pl. 18, fig. 14; pl. 21, figs. 2,8; pl. 22, figs. 2,6; pl. 23, fig. 6; pl. 25, figs. 4,5). The initial fusellae of $th1^2$ are usually conformable with those of $th1^1$ underlying although they may be more condensed or curve at a slightly different angle (pl. 15, fig. 10; pl. 17, fig. 2; pl. 18, fig. 15; pl. 19, fig. 12; pl. 20, fig. 4; pl. 23, fig. 8; pl. 25, figs. 1,4). The later growth of metatheca 1^1 and protheca 1^2 are more or less synchronous and the growth of $th1^2$ is strongly upward. The differentiation of $th1^2$ is often quite late and it follows a pattern similar to that of all later thecae. Therefore, $th1^1$ is the only primordial theca and no crossing canal is present.

The proximal end is usually sharply pointed and a variable length of the sicula is exposed below $th1^2$. On the obverse side, all or a considerable portion of the sicula is usually exposed (except in n. gen. B). In many of the species, especially the petalograptids, much of the upward growth of the first two thecae is concave outward.

Pattern I rhabdosomes may be aseptate or have a partial median septum (on the obverse side, pl. 13, fig. 5; pl. 15, fig. 8, pl. 16, fig. 7). In aseptate forms the virgula may be entirely free and central (e.g. Glyptograptus sp. aff. G. fastigans, pl. 18, fig. 9; "Orthograptus" bellulus pl. 24, fig. 8; and probably Petalograptus insectiformis, pl. 14, fig. 7; and P. n. sp. A, pl. 16, figs. 1,2), it may be attached at the bases of the interthecal septa (e.g. Glyptograptus elegans n. subsp, pl. 17, figs. 11,13; Conograptus gorbiachinensis, pl. 21, fig. 4;

"Glyptograptus" kayi n. subsp., pl. 26, fig. 1; and probably Agetograptus spiniferus pl. 23, figs. 1,4), or it may be incorporated in the obverse wall (e.g. Glyptograptus tamariscus ssp., pl. 19, figs. 2,3, 7-9; pl. 20, figs. 1-3,5,7). No species of the type I group are yet known to have a complete median septum with the possible exception of Rhaphidograptus toernquisti (see discussion of that genus).

Some species of this group have achieved what appears to be a dimorphograptid condition (e.g. species of Agetograptus). This has been achieved either through a redirection of $th1^2$ over top of $th1^1$ rather than away from it and resultant reversal of all subsequent thecae (see Bulman, 1970, fig. 61) or through suppression of metatheca 1^2 as in Rhaphidograptus toernquisti in which all of the subsequent theca grow normally (Hutt, et al., 1970, p. 8, pl. 1, fig. 22). Based on the illustration of Bulman (which is a specimen of Agetograptus from the Cape Phillips Formation) and the SEM work illustrated here, it is not entirely clear which of the above is actually the case and more work needs to be done on well preserved, translucent specimens. The "agetograptid" proximal development pattern is here designated as pattern I'. The alternative, in which metatheca 1^2 is suppressed (to which Rhaphidograptus belongs if it proves to be pattern I) is I'' (see text-figure 15).

All of the known pattern I species are Silurian in age (with the exception of Glyptograptus ex gr. tamariscus from the *persculptus* Zone of China and possibly other slender *Glyptograptus* species from that zone) and thecal forms ranging from climacograptid and pseudoglyptograptid to petalograptid are found.

Pattern J. Although Mitchell recognized only nine distinct proximal growth patterns, an examination of the available literature in addition to well preserved, compressed dimorphograptids from Yukon and Arctic Canada suggests that the proximal development of *Dimorphograptus* (*sensu stricto*), *Akidograptus* and *Parakidograptus* shows enough differences from pattern H or I to merit a separate designation. Davies (1929) and Stein (1965) have illustrated well preserved early growth stages of *Akidograptus* which show a long sicula and a $th1^1$ with an exceedingly short downward-growing portion which does not reach the sicular aperture, followed by a long, straight upward growth. The reverse wall of $th1^1$ does not grow obliquely across the sicula at the beginning of the upward growth as in type I species but grows straight upward for about one half of the thecal length before the $th1^2$ bud begins to diverge. *Parakidograptus* appears to share this early growth pattern. Well preserved, uncompressed specimens of akidograptids examined by Williams (1983) as well as the material studied by Li and Ge (1981) suggest that the metatheca 1^2 is not reduced as suggested by Bulman (1970) and others, but that the growth series is normal diplograptid.

Dimorphograptus does, however, share two important features of the proximal development with Akidograptus: the downward growth of th1[1] is reduced (to absent?) and does not reach down to the sicular aperture; the reverse wall of the upward growing-portion of th1 grows straight up rather than diagonally crossing the reverse side of the sicula. These features can be used to distinguish "true" dimorphograptids from type H? and I species (e.g. Agetograptus species, Petalograptus physophora and Rhaphidograptus) with a uniserial first theca. The uniserial portion of "true" dimorphograptids usually has more than one theca, often many, and appears to result from reorientation of the early thecae rather than loss or suppression of the second series thecae.

Elles and Wood (1908) and many subsequent authors (e.g. Bulman, 1970), in their generic diagnosis of Dimorphograptus say that the growth of th1 is upward from its origin although, to my knowledge, none presents evidence based on well preserved, early growth stages, to show that this is actually the case. Well preserved, compressed, mature rhabdosomes of Dimorphograptus confertus swanstoni from the collections of Lenz (1982a) from Yukon, Canada and D. minutus (Chen and Lin) from the present collections were examined by the author and show what appears to be a very short, downward-growing portion "pressed through" the base of th1 (text-fig. 25X). This has been subsequently overgrown by cortical tissue obscuring the rounded appearance of the base of this theca. A drawing of an early growth stage of Dimorphograptus cf. longissimus (Kurck) illustrated by Elles and Wood (1908, text-fig. 232a) also shows what appears to be a short downward-growing portion and a distinctly rounded base to th1. More well preserved species of Dimorphograptus will have to be examined in detail to determine if they do, indeed, lack a downward growth portion or if it is merely obscured by later cortical material.

It appears, therefore, that the "dimorphograptid condition" of a uniserial proximal end was achieved in at least two or three different lineages (possibly more) as suggested by Rickards et al. (1977) and Li (1985, and unpub. ms.) rather than one as suggested by Mitchell (1987). To derive the later occurring Agetograptus and Rhaphidograptus from Dimorphograptus would have required a reversal of the trends which resulted in the pattern J proximal end as described above, and this seems highly unlikely.

Pattern J rhabdosomes show a wide range of thecal forms, especially in the uniserial portions of Dimorphograptus, including monoclimacid or isolate thecae not found in other biserial graptolites. Akidograptids have a complete median septum while at least most dimorphograptids have a partial median septum in the biserial portion of the rhabdosome.

Recognizing Supraspecific Taxa in Non-isolated Graptolites

Mitchell recognized that his new (1987) classification scheme, based on early astogeny would be difficult to work with over the short term until more well preserved material was studied in detail and more species could be definitely assigned within this new scheme. He pointed out that although the study of isolated material was necessary to define the proximal growth patterns, it is not essential to place a species within the scheme once established. Another important point which he noted was that even if a species cannot be assigned with certainty to a genus within the new system, it does not diminish its utility. The species is the prime entity in biostratigraphic studies and this new classification scheme will not affect the stability of the species, only supraspecific taxa. In fact, the application of this new scheme will greatly enhance the usefulness of the generic and higher taxa since many have a much more limited range than the previously defined, thecal form-genera.

In his tables 1 and 2, Mitchell listed the species which could definitely be placed within his new classification scheme and pointed out some diagnostic features, recognizable in well preserved, non-isolated specimens, which could be used to distinguish the astogenetic patterns. I wish to emphasize some of those points here, particularly with respect to Ashgill and Llandovery faunas, and to add some new points of distinction between the Silurian genera based on the present findings.

Ashgill graptolite faunas are dominated by dicellograptids (pattern A') and pattern D, E, F and G diplograptids, all of which (with the possible exception of some Pattern D species) are characterized by the presence of a proximal end with ornamentation other than just a virgella, be it a pair of antivirgellar spines, mesial spines on the first theca(e) or both. Furthermore, in these forms the sicula, in profile view, tends to be obscured at its aperture. In this way, the pattern H species found in Ashgill strata (e.g. Hedrograptus normalis, H. miserabilis) can be easily recognized by their general lack of proximal ornamentation (except for an often elaborated virgella - see section below "Proximal Ornamentation"), the strong asymmetry of the proximal end, and by the fact that 0.2 to 0.3mm on the sicula is exposed below th1[2]. In addition, the passage from dominantly "Ordovician" faunas (those dominated by pattern A', D, E, F and G) to dominantly "Silurian" faunas (those dominated by pattern H, I, J and monograptids) can be easily recognized, both in samples in hand, or by close examination of illustrations in the published literature (see section below "Late Ordovician GRaptolite Extinction").

Distinction of pattern H from I species can be a more difficult matter since it was discovered in this study that Glyptograptus s.s. (including a few species with climacograptid thecae) have a pattern I proximal development. However, even these pattern I species tend to have a more pointed proximal end and the early growth of $th1^2$ is usually more strongly upward than outward. In specimens preserved in partial relief, a change in surface topography can often be seen at the origins of $th1^2$ and $th2^1$ in pattern H species but not seen in pattern I. If the primordial origin of $th2^1$ can be established (this can often be seen in compressed or partial relief specimens) then the species is pattern H, although not all pattern H species show this.

In most compressed specimens, however, the proximal details are not clear enough for positive assignment. The principal criterion employed here, and one which is applicable to reasonably well preserved, flattened specimens, is the presence or absence of a median septum. As far as can be determined from the present material and comparison with previous reports, there are no known pattern I species with a complete median septum although many possess a partial median septum (always on the obverse side). Partially septate pattern I species are mostly, if not exclusively, Petalograptus species with the typical petalograptid rhabdosomal form. Pattern H species, on the other hand, usually appear to have a complete median septum, although in many species it appears only distally. (The only encountered exceptions are N. gen. A? n. sp. which is partially septate but is only preserved to the fourth thecal pair - more complete specimens may reveal a complete septum distally - and Hedrograptus? indivisus which is aseptate and is discussed above.) It is on this basis that I have separated Glyptograptus from Hedrograptus in compressed specimens where otherwise proximal details are unclear. This method of distinction is one which can be employed on a variety preservational types including uncompressed specimens embedded in rock (especially internal moulds) or in compressed specimens where the septum can be seen "pressed through". In specimens where the distal end is complete, the median septum can sometimes be seen projecting beyond the distal thecae (e.g. text-figs. 19H; 20S,U,V; 22D,E). If, at the distal end, one stipe grows beyond the other by more than as one half a thecal length, then a median septum must be present (e.g. text-figs. 20D; 22C), because in aseptate species the two stipes must, by necessity, grow synchronously.

It must be admitted that still only a relatively small proportion of the Llandovery biserial fauna has been studied in enough detail and further work, especially with Ashgill and Early Llandovery species, may reveal fully septate petalograptines or aseptate hedrograptines. The distinction based on internal structure, however, seems intuitively reasonable if one assumes that rhabdosomal architecture, is, at least to some extent, a product of early astogeny.

Distinction of pattern J species from types H and I in non-isolated specimens is accomplished in most cases by

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recognition of fully exposed sicula below th1^1. In addition, there are, as yet, no known pattern H or I species with more than one uniserial theca whereas most *Dimorphograptus* species have at least two uniserial thecae. It is important to note that in many *Dimorphograptus* species, the space between the downward end of th1 and the sicular aperture is often overgrown with later cortical deposits although the original downward position can often be seen "pressed-through" in compressed specimens.

The occurrence of pattern I species in which th1^1 does not grow down to the sicula has already been noted, although it has not been seen, to my knowledge, in any *Agetograptus* or *Rhaphidograptus* species.

The growth of the reverse wall of metatheca 1^1 straight upward can easily be seen in well preserved akidograptids, even compressed. On the other hand, its growth across the reverse face of the sicula is difficult to see in slender *Agetograptus* species such as *A. hubeiensis* (Ni), although it can be clearly be seen in uncompressed examples. Distinction between *Rhaphidograptus* and some slender *Agetograptus* species is more difficult unless the fusellae can be seen over the first three thecae. For compressed material, the presence or absence of a median septum, or genicular hoods must be employed for their distinction.

Proximal Ornamentation

As noted above, pattern H and I species are generally characterized by a lack of ornamentation of their proximal end except for the virgella. However, examples of more elaborate ornamentation of the proximal end in these species are becoming more common and several of these variations can be seen in the uncompressed and compressed material from the Canadian Arctic.

The Virgella and its Modifications. Although the majority of pattern H and I species bear a simple virgella less than 1.0mm long, numerous modifications of this structure have developed. The most common modification is extreme lengthening, usually accompanied by thickening. Virgellae well in excess of 1cm long are not uncommon in some species (e.g. Hedrograptus? balticus (Pedersen), "Diplograptus" thuringiacus Eisel, "Orthograptus" bellulus, Rhaphidograptus toernquisti (Elles and Wood), (Bjerreskov, 1975). In most observed cases these long virgellae are circular in cross-section, but that of R. toernquisti was shown to be triangular in section and twisted clockwise along its length (Bjerreskov, 1975). In addition, Bjerreskov (1976) found a synrhabdosome of this species, apparently joined at the virgellae rather than the virgulae as is most common.

Transmission electron microscopic examination of the

long virgella of "*Glyptograptus*" *kayi* n. subsp. has shown that its structure consists of a hollow central area about 4um wide, surrounded by a layer of loose fusellar fabric material, surrounded by numerous concentric layers of cortical fabric. Scanning electron microscopy has revealed that the broken distal tip of the virgella sometimes shows a tiny central pore (pl. 26, fig. 3) but is often solid (pl. 26, fig. 12) and the unbroken distal tips of the virgellae of immature specimens are invariably solid. The possiblity exists that the internal portion is intermittantly solid and hollow, as observed in the virgulae described by Urbanek and Towe (1975). This is consistent with the notion of Bates and Kirk (1985) that such structures grew incrementally by the addition of sheath-like conical layers in much the same manner as normal fusellar increments. Externally, cortical bandages extend from the proximal portion of the rhabdosome onto the base of the virgella (pl. 26, fig. 2) and the cortical fibres then extend longitudinally along the length the the virgella. (Slight irregularities in the preservation of the virgellar surface do not permit the assessment of the longitudinal continuity of individual cortical fibres). The appearance of discrete bandages does not persist along the virgella and, when viewed in TEM section, the individual ~~co~~rtical layers only occasionally show lateral terminations.

The observation of many specimens of both "*G*. *kayi* n. subsp. and "*O*". *bellulus* in uncompressed form in various growth stages clearly shows that the virgella increases in both length and breadth (the latter especially at its base) during growth of the rhabdosome.

A single specimen of _Agetograptus hubeiensis_ from the present collections has developed a pair of blunt spines up to at least 0.13mm long emerging from the base of its virgella at right angles to it (pl. 22, figs. 1,5). Since these are only seen on one specimen they are interpreted to be an anomalous development. They may be a gerontic feature but the specimen does not appear to show the exceedingly thick cortical deposits typical of gerontic specimens.

In addition to being simple and straight, the virgella may be variously divided or branching. Branching patterns range from a simple distal bifurcation seen in _Hedrograptus_? _indivisus_ (Davies) to distal multiple branches (e.g. _Hedrograptus_? _radicatus_ (Chen and Lin)) as well as simple or complex branching at the base of the virgella (e.g. _Hedrograptus_? _trifilis_ (Manck), _Hedrograptus_ n. sp. A, this study, text-figure 19DD,EE,HH).

The most elegant form of virgellar division is the ancora seen in the Retiolinae and some _Petalograptus_ species. In _Petalograptus_ species the ancora ranges in form from a simple, four pronged structure seen in such species as _P._ _ankyratus_ and _P._ _intermedius_ (type 1 ancora of Bates and Kirk, 1984) to four prongs with a terminal loop and subsidary loops and an internal spiral seen in _P._ _insectiformis_ (type 3) and four prongs with long double spiral lists extending outward from the origin (type 2). The latter is probably the type seen in Petalograptus obuti (Rickards and Koren', 1974) and Petalograptus physophora and is also seen in Pseudoretiolites cf. P. decurtatus (Lenz and Melchin, in press a, pl. 1, figs. 5,8). Compressed specimens of P. obuti and P. physophora show that the more complex ancora types can enclose a considerable portion of the proximal end of the rhabdosome and may bear a sheet of continuous periderm between the ancora lists. Specimens of P. insectiformis found here also show the ragged edges of what may have been a fine tissue between the lists (pl. 14, fig. 3). Bates and Kirk have suggested that the Petalograptus ancorae and those of the Retiolitinae are homologous structures and studies of both types by Lenz and Melchin (in press a) and this paper suggest that this is indeed the case.

Ancora-like structures have also been observed on species of Akidograptus but it is not clear if these are homologous with those of Petalograptus and the Retiolitinae, or if they are independently derived, branching virgellae. Their less regular appearance and the greater distance between the sicular aperture and the first bifurcation and between the first and second bifurcations suggests that they may not be homologous.

Spinose Variants. Several examples have been found of otherwise "normal" Llandovery diplograptids with an unusually spinose proximal end. The best known of these is "*Glyptograptus*" *serratus barbata* Elles and Wood (1907) which shows numerous spines which appear to arise from the virgella and sicular area, as well as mesial spines from the proximal thecae. A variant of *Hedrograptus medius* (Tornquist) was also illustrated by Elles and Wood (1906, pl. 26, fig. 4f, text-fig. 122b) with two additional spines arising from the area of the sicular aperture.

The present collections have yielded similar spinose variants of *Hedrograptus rectangularis* (M'Coy) with an unusually long, robust virgella, an additional spine on the sicular aperture, mesial spines on one or both of the first thecae and genicular spines on some of the other proximal thecae, up to as high as the fourth or fifth thecal pair (text-fig. 19Q,Y,Z). In addition, a single specimen of *H. janischewskyi* also shows an extra pair of proximal spines, one arising from the dorsal side of the sicula, the other from the mesial portion of $th1^1$ (text-fig. 19E).

Another *Hedrograptus* species, *H.* n. sp. A, has a thick virgella with multiple branches (up to at least six) as well as one or possibly two mesial spines on the first thecal pair. This species is otherwise very similar to *Hedrograptus trifilis* (Manck) which has a similar dimensions and a single pair spines arising from the base of the virgella. The possibility exists that this is a more spinose variant of *H. trifilis* although that species has not been found in any of the present collections.

In addition, a single specimen each of H. scalaris ferganensis (text-fig. 1BB) and Pseudoglyptograptus n. sp. (pl. 3, figs. 8,9) have been found with an aberrent, extra proximal spine.

Sicular Spines. Rickards and Koren' (1974) first reported the presence of spines on the sicular rim of the Llandovery species Pseudoglyptograptus rhayaderensis and P. tabukensis (both species are here assigned to Comograptus - see discussion of that genus). Comograptus gorbiachinensis Obut and Sennikov and C. comatus Obut and Sobolevskaya have both been found uncompressed in the present material and both show a virgella as well as spines directed outward from the rim of the sicula (pl. 20, figs. 8,9,11; pl. 21, figs. 3,5,6,11). Comograptus gorbiachinensis has only three sicular spines, one opposite the virgella, two on either side and no other ornamentation. The single uncompressed specimen of C. comatus shows three prominent spines each bearing many smaller barbs as well as smaller spines between them. In addition, the sicula also has a spine emerging from its side, just below th1[2]. The compressed specimens (text-fig. 7F,I) show that genicular spines are also present on the thecae along a considerable length of the rhabdosome of mature specimens. These spines on the sicular rim, together with a distinctive proximal development are considered here to be diagnostic of the genus Comograptus.

Other Ultrastructural Observations.

Cortical Bandages. No systematic study of the ultrastructure of normal graptolite periderm has been undertaken here. It is worth noting, however, that cortical bandages of the type described by Crowther and Rickards (1977) and Crowther (1981) have been observed on at least some members of all of the subfamilies, and most of the genera studied (wherever, preservation has permitted their observation). Bandage widths are in the range 25 to 35um on the proximal thecae, 30 to 45um more distally, well within the normal range described by Crowther (1981). The bandages tend to be much more prominent on species of *Metaclimacograptus* (pl. 5, fig. 13; pl. 6, fig. 8), *Lithuanograptus* (pl. 7, fig. 12), *Agetograptus* (pl. 22, fig. 12) and N. gen. B (pl. 25, fig. 1; ~~pl.~~ 26; fig. 4), while it is often more subtle on most of the other taxa (pl. 10, fig. 7). Bandages appear to extend uninterrupted from the thecae onto "ornamental" structures such as apertural spines and, as noted above, virgellae.

The construction of retiolitid lists also shows that the subconcentric laminae which comprise the lists are built of bandages which overlap one another just as the bandages of other graptoloids do. This is especially evident at list junctions (appendix E, pl. 2, figs. 3-5).

<u>The Virgula</u>. The virgulae of a great many specimens of most of the species studied by SEM have been examined and the following observations have been made. With the exception of the <u>Paraplectograptus</u>, the majority of distal ends of virgulae of all species examined are solid (pl. 1, fig. 3; pl. 2, fig. 11; pl. 7, fig. 6; pl. 8, fig. 6; pl. 11, fig. 11; pl. 13, fig. 3; pl. 17, fig. 4), many show concentric laminae (pl. 4, fig. 7; pl. 19, fig. 6; pl. 20, fig. 10; pl. 24, fig. 9). A smaller number show what appears to be a tiny, axial pore (about 1um in diameter, pl. 20, fig. 10) although there is no correlation between the presence or absence of an axial pore and taxonomic group. The distal tips of the virgulae of immature specimens which are unbroken are invariable solid (pl. 18, fig. 3). Transmission electron microscopic examination of the virgula of "<u>Glyptograptus</u>" <u>kayi</u> n. subsp. shows an axial openning of about 5um surrounded by some loose, fusellar tissue, followed by a series of concentric laminae which are ultrastructurally like cortical tissue (pl. 27, figs. 5,6). In fact, the ultrastructure of the virgula of this species is almost identical to that of the virgella of the same species (pl. 27, figs. 1-5) including the axial pore.

These observations suggest that the virgula of the Retiolitidae do not possess a continuous axial canal but may be intermittently solid and hollow as observed for <u>Pristiograptus</u> <u>dubius</u> by Urbanek and Towe (1975) although they seem to be invariably solid at their distal, growing tip.

Other observations on the virgulae of retiolitine species show that the bandages observed on the list surfaces extend, uninterrupted onto the virgula where the two meet (appendix E, pl. 2, fig. 4). The surface texture, striated or pustulose, of the list surfaces (Lenz and Melchin, in press a, appendix D) is also seen on the virgula. In species where the sicula is absent, the virgula and the virgella have merged into a single, more-or-less continuous rod.

From the combination of these observations the following conclusions may be suggested regarding the secretion of the virgula in the Llandovery biserial graptolites (and probably uniserial as well). The virgula was probably not secreted from the inside as suggested for the nematularium of Pseudoclimacograptus scharnbergi by Mitchell and Carle (1986), or at its distal, growing tip (Crowther, 1981), unless the skeletal material was actually permeated with potential secretory tissue. Rather, in these taxa it appears to have been secreted by the same mechanism responsible for the virgella and the other rhabdosomal tissues. Whether, this secretion took place within an envelope of extrathecal tissue or was accomplished by the "rhabdopleuran mode" is still a matter of debate. It is, however, difficult to envisage how the zooids could have seceted structures many times their length away from their apertures unless they were freely wandering (Andres, 1977 -

an unlikely alternative owing to the morphologic unity and symmetry of the graptolite rhabdosome) or else possessed highly extensible secretory organs.

Aberrant Rhabdosomal Developments

In addition to the unusual development of spinose proximal ends described above, several types of aberrant development can be recognized in some of the Canadian Arctic specimens. These can be grouped into three categories:

1) Apparently congenital and gerontic developments which generally involve the addition of unusual or exaggerated features onto an otherwise normal rhabdosome. These appear to be the result of "plasticity" of the genotype. The above examples of spinose variants of Hedrograptus species appear to fit this category as well as some other examples discussed below.

2) Malformations caused by accidental, physical damage to the rhabdosome which have been subsequently compensated for by the growth of new tissue.

3) Pathogenic malformations caused by disease, infestation or death of individual zooids.

Congenital and Gerontic Developments. The ubiquitous process which affects the established thecae on a maturing rhabdosome is the addition of further (usually cortical) tissue. In retiolitids, this results in the thickening of established lists, the addition of smaller lists between the larger ones (see for example Lenz and Melchin, in press a) and, in some cases, the development of continuous peridermal tissue (Lenz and Melchin, in press b). In other graptolites this results in the thickening of the skeletal wall and often the extension of onamental features such as apertural spines or genicular hoods. In the case of Metaclimacograptus undulatus the progressive development of genicular hoods results in the increasing constriction of the aperture (pl. 6, fig. 1).

In a few species, however, the addition of tissue during the maturation process results in a change in apertural and thecal shape. The most dramatic example of this seen in the Canadian Arctic specimens is the development of Pseudoglyptograptus n. sp. The thecae of early stages of this species are climacograptid in appearance with a sharp geniculum, almost straight supragenicular wall and nearly horizontal aperture (pl. 4, figs. 5,6). As the rhabdosome matures, the proximal thecae, through the addition of cortical layers, develop more stongly flared and introverted apertures with development of a ventral apertural lip (pl. 4, figs. 1,12,15). With further growth, the lip becomes more pronounced and develops distinct corners and the lower half of the supragenicular wall becomes convex outward (pl. 4, figs. 9-11). In addition, the lip begins to develop on more distal thecae. In the most extreme examples, the aperture is strongly introverted, the thecae show a strongly sinous profile and the geniculum has been overgrown to the point where it appears rounded (pl. 4, fig. 13). In addition, the lip has become at least faintly recognizable as far along as the 13th or 14th thecal pair. Individual specimens, if found separately, depending on their growth stage, could be assigned to two different genera and at least three different species.

Another less striking example is seen in "Glyptograptus" kayi n. subsp. Immature specimens show a bluntly rounded proximal end with a relatively short, slender virgella, thecae whose apertures are only slightly everted and a small portion of the sicula exposed below $th1^2$ (pl. 25, fig. 7, pl. 26, figs. 6,8). As the rhabdosome matures, the virgella becomes longer and more robust and the addition of tissue obscures the sicula completely and the proximal end begins to take on a more pointed appearance (pl. 26, fig. 5). In extreme cases, the proximal end becomes very pointed, the walls merging gently into the very roboust virgella and the sicular aperture has become highly elongated downward. Furthermore, additon of material to the apertures of the first thecal pair has caused them to become strongly everted, adding to the pointed appearance of the proximal end (pl. 25, fig. 9; pl. 26, fig. 7).

"*Glyptograptus*" *sinuatus sinuatus* shows an example of the gerontic development of an entirely new feature, not seen at all in less mature rhabdosomes. Two specimens of this species have developed paired lateral hoods on the proximal thecae - a feature not seen on any other Llandovery diplograptids (pl. 12, figs. 2-4,7). That these hoods are progessively developed is evidenced by the fact that they are best developed on the first thecal pair and are more incipient on the second and third thecal pairs and also by the fact that they are less well developed on one specimen than on the other. That they are a gerontic feature is indicated by the fact that the same specimens otherwise show extreme overgrowth of tissue on the proximal end almost completely obscuring the sicula and forming a very robust, blunt virgella. Two otherwise normal specimens from the same collection shows some accretion of tissue on the lateral margins of some of the proximal thecae and this is interpreted to be incipient hood development (pl. 10, fig. 9; pl. 12, fig. 1).

Another species of n. gen. A, "*Diplograptus*" *tcherskyi tcherskyi*, has one specimen with a short, curved spine arising mesially from $th1^2$ (pl. 9, figs. 5,6) while another specimen shows a small, roughly triangular crest formed ventrally below the aperture of $th1^1$ (pl. 9, figs. 2,3). Such outgrowths appear to be congenital malformations although it is possible that they were secreted in response to the presence of a parasite or some other irritant occurring at that point.

The specimen of Pseudoglyptograptus n. sp. noted above which has been found with what appears to be two virgellae growing side-by side is almost certainly the result of congenital malformation.

A simpler form of congenital malformation is variation in the size of individual thecae. Stunted thecae may be the result of pathogenic causes but unusually large thecae such as those seen in a specimen of Hedrograptus n. sp. B (pl. 3, fig. 3) likely have a congenital cause.

Accidental Damage. Examples of regeneration of sicular or thecal tissue after damage has been well documented and several examples were illustrated by Bulman (1970). Although such examples probably exist in the present collections, examination by scanning electron microscopy, which tends to obscure fusellar growth lines, is not conducive to recognition of such features.

The most striking example of regeneration reported in the literature is that of the generation of pseudocladia, seen in several different types of monograptids (Urbanek, 1963, 1973; Palmer, 1971) which result from a complete severing of the proximal end of the rhabdosome and the generation of a new series of thecae growing from the broken proximal end of the stipe, away from the rest of the original portion of the rhabdosome. That the growth of these pseudocladia (and the remaining procladia) proceeds in the absence of the siculozooid is important, although Urbanek (1970) argues that the apolar growth of such pseudocladia is the result of the lack of influence of the sicula which normally provides morphogenetic substances which control polarity. No examples have, to my knowledge, been reported of any species other than a uniserial monograptid proceeding with growth and regeneration after loss of its sicula.

If growth after removal of the sicula were possible in diplograptids, specimens should occur which either show a biserial rhabdosome with thecae growing in both directions from a fracture point or (more likely) a mesial or distal portion of the rhabdosome with the the broken proximal end closed off with regenerative tissue. The former would be easy to recognize in compressed specimens and has not, so it is assumed that it does not occur. The latter, however, may be difficult to see in compressed specimens and these would probably be considered specimens broken at or after death. It would, howver, be easily recognized in isolated form and the examination of thousands of normal and retiolite diplograptids in uncompressed form in the present collections has failed to reveal a specimen which appears to have continued growth without its siculozooid. A single specimen of *Pseudoglyptograptus* n. sp. shows a proximal end which was damaged during life (pl. 3, figs. 7,10,11). Although the zooids inhabiting $th1^1$, $th1^2$ and 2^1 were killed in the event the presence of a small proximal aperture at the base of the virgella suggests that the siculozooid survived in a somewhat compressed, misshapen form. The zooids appear to have made a concerted effort to cover the apertures of the dead thecae as well as the opening produced in the rhabdosome below $th2^1$, possibly in an effort to protect the siculozooid from further damage.

Pathogenic Malformations. Malformations due to disease, parasite or death of a thecal zooid have been reported from collections of uncompressed graptolites rather commonly. The simplest type of malformation is the development of "blisters" or bulbous outgrowths on the thecal wall. Such bulbous outgrowths were reported by Jackson (1971, fig. 1A) and have been found on present specimens of *Hedrograptus* n. sp. B (pl. 3, fig. 6) and *H. nikolayevi* (pl. 2, fig. 10). The latter example is a more substantial outgrowth involving inflation of the entire $th2^1$. Such malformations are likely to be due to parasitic infestation although Urbanek (1958) considered that similar abnormalities found in *Monograptus haupti* were a gerontic development.

Another specimen of *H. nikolayevi* shows malformation of th12 in which that theca appears to be directed outward beyond its normal pathway with a large opening between that theca and the rest of the rhabdosome (pl. 3, fig. 1). The two subsequent thecae appear to have budded normally. This may have been due to the presence of a parasite or other obstruction, an extra thecal bud in the proximal end which did not develop fully or simply a malformation of th1^2 leaving empty space beside it.

A specimen of Metaclimacograptus orientalis shows termination of one of the stipes and normal development of the other (pl. 5, fig. 3). Stipe 1 has been terminated above th2^1 apparently through death of one of the two buds of th2^1, the dicalyc in this species. The other stipe developed normally to incipient growth of th4^2.

A specimen of Agetograptus spiniferus has the first theca in the second series stunted and the second in that series entirely lacking (pl. 22, figs. 7,9) although its protheca must have grown to give rise to the following theca on the other side. The killed and stunted thecae were almost certainly the result of disease or infestation in that region.

Finally, a specimen of Petalograptus intermedius? has the growth of its th1^2 stunted and the aperture covered over while the remaining thecae have budded normally (pl. 15, figs. 3,5). Again, this is likely due to a disease or parasite killing th1^2 before it reached maturity.

A consistent pattern seen among damaged and malformed graptolites is the tendency to attempt to repair the damaged skeletal tissue and, in the case of thecae which have died, to cover any apertures not occupied by living thecae. This is further illustrated by the blister-like growths which appear to be an attempt to enclose diseased or parasitic tissue. This tendency seems to highlight the protective nature of the graptolite periderm (which appears to have been abandoned by the retiolitids) in that any apertures not occupied by active tissue seem to, at least eventually, become closed off.

CHAPTER 5 - GRAPTOLITE EXTINCTION AND EVOLUTION

Late Ordovician Graptolite Extinction

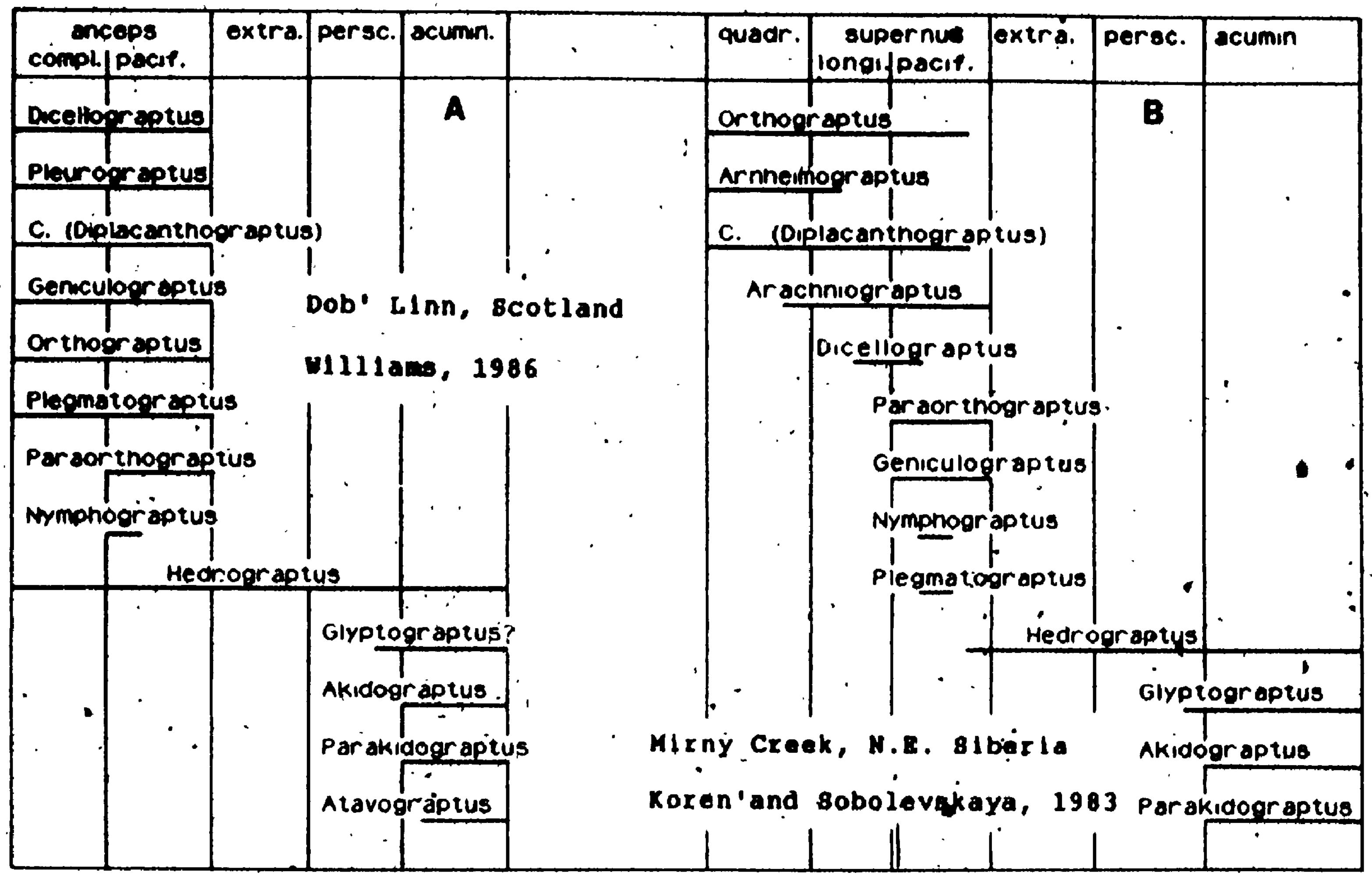
The new graptolite classification scheme advocated herein, and by Mitchell (1987) and Fortey and Cooper (1986), has a profound impact on the study of graptolite evolution and extinction events, especially the Late Ordovician extinction. The classification scheme of Bulman (1970) showed three graptolite families belonging to two suborders (including Neodicellograptus as a dicranograptid - see Discussion of the Subfamily Hedrograptinae for remarks on this unusual genus) with as many as seven genera (or even more depending on some individual generic assignments) passing through the Ashgill and well into the Llandovery. This new scheme, which I feel more accurately reflects actual graptolite phylogeny, shows the extinction to be an event of much greater magnitude involving the termination of all but one family (Mitchell, 1987; Kearsley, 1985).

An abundance of literature concerning the graptolite faunas of the Ordovician-Silurian boundary has recently been published in an effort to select a boundary stratotype (Cocks, 1985) and achieve accurate worldwide correlations with the stratotype. Close reexamination of these faunas from the literature shows a strong coincidence between the termination of the "Ordovician-style" faunas (those dominated by pattern A', D, E, F and G genera) and the rise of "Silurian-style" faunas (those dominated by pattern H, I, J and M genera - the Retiolitidae and Monograptidae). (See discussion above regarding distinction of these patterns in compressed material).

Obviously, any attempt to examine world-wide coincidence of an extinction event will rely heavily on the quality of the correlation of the various zonation schemes involved. Text-figure 15 shows a proposed correlation of the Ordovician-Silurian boundary zones from several key areas around the world. Examination of this and other published correlation charts shows that the end of the *pacificus* Zone in northwestern and arctic Canada, the *pacificus* Subzone of Scotland and northeastern Siberia, the *ornatus-latus* Zone of central Victoria and the *anceps* Zone of southeastern Alaska are closely coincident. (The correlation of the Chinese sections poses special problems which will be discussed separately below). The termination of these zones coincides with the nearly simultaneous disappearance of several key Ashgill genera including *Dicellograptus*, *Paraorthograptus*, *Climacograptus* (*Diplacanthograptus*) (the *C. longispinus* group), *Geniculograptus* ("*C*". *latus* and "*C.*" *inuiti*) *Orthograptus* s.s. (i.e. *O. amplexicaulis*, *O. truncatus*) and the "archiretiolitid" genera (text-figure 16A,B). Examination of the species occurrences in individual samples from some of these papers shows that these genera not only terminate within this final zone or subzone but, in some cases, are present up to the last sample (e.g. Williams, Text-figure 15. Correlation of Ordovician-Silurian boundary zonal schemes from several regions (modified after VandenBerg, *et al.*, 1984).

	Dob's Linn, Scotland (Williams 1986)	N. E. Siberia (Koren' *et al.* 1983)	Central China (Mu *et al.* 1984)	N. Cordillera (Lenz & McCracken 1982)	Arctic Islands (Melchin in press)
Llandovery	acuminatus	acuminatus	acuminatus	acuminatus	acuminatus
Ashgill	persculptus	persculptus	persculptus	persculptus?	
	extraordinarius	extraordinarius	Hirnantia / bohemicus		
	pacificus	pacificus	uniformis	pacificus	pacificus
	anceps	supernus	mirus typicus		
	complexus	longispinus	szechuanensis	ornatus	fastigatus

Text-figure 16A-E (following three pages). Ranges of graptolite genera at several key Ordovician-Silurian boundary sections. Note that the generic scheme used is that of Mitchell (1987) and this paper, not necessarily those of the authors of the boundary section descriptions.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extra.
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acumin.
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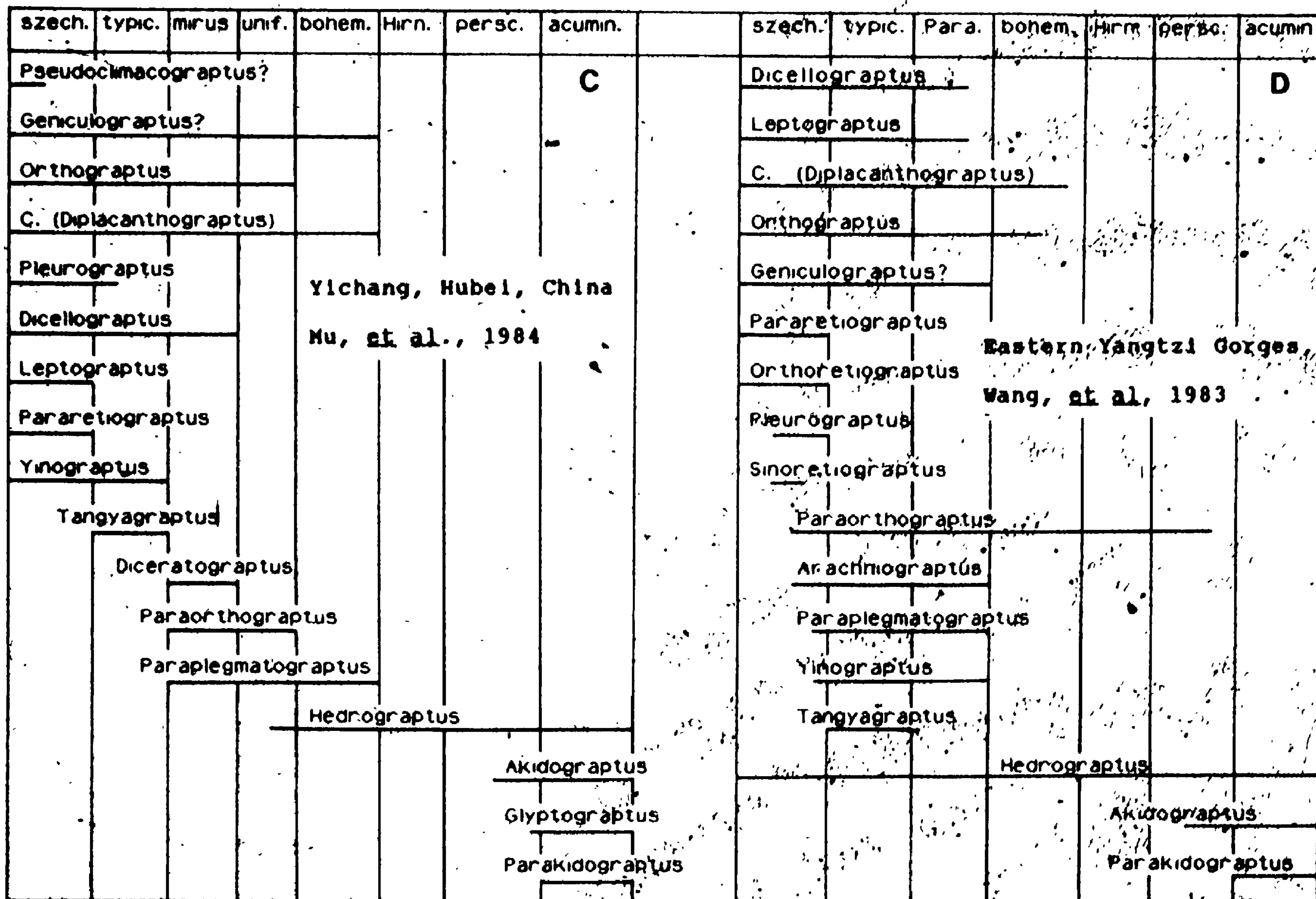
Dicellograptus
Pleurograptus
C. (Diplacanthograptus)
Geniculograptus
Orthograptus
Plegmatograptus
Paraorthograptus
Nymphograptus
Hedrograptus
Glyptograptus?
Akidograptus
Parakidograptus
Atavograptus
Dob' Linn, Scotland
Williams, 1986
quadr.
supernus
longi. pacif.
extra.
persc.
acumin
B
Orthograptus
Arnheimograptus
C. (Diplacanthograptus)
Arachniograptus
Dicellograptus
Paraorthograptus
Geniculograptus
Nymphograptus
Plegmatograptus
Hedrograptus
Glyptograptus
Akidograptus
Parakidograptus
Mirny Creek, N.E. Siberia
Koren' and Sobolevskaya, 1983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Pseudoclimacograptus?
Geniculograptus?
Orthograptus
C. (Diplacanthograptus)
Pleurograptus
Dicellograptus
Leptograptus
Pararetiograptus
Yinograptus
Tangyagraptus
Diceratograptus
Paraorthograptus
Paraplegmatograptus
Hedrograptus
Akidograptus
Glyptograptus
Parakidograptus
Yichang, Hubei, China
Mu, et al., 1984
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Leptograptus
C. (Diplacanthograptus)
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Geniculograptus?
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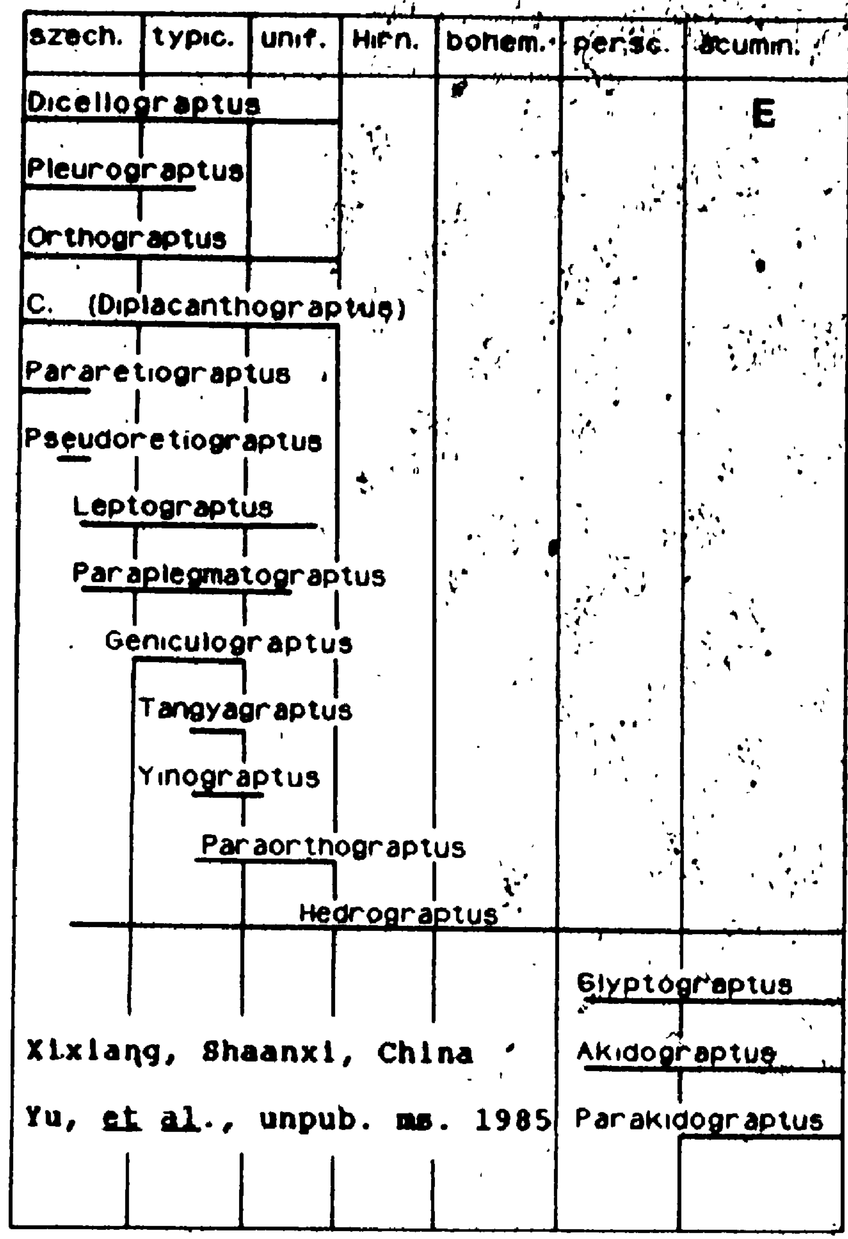
Pleurograptus
Sinoretiograptus
Paraorthograptus
Arachniograptus
Paraplegmatograptus
Yinograptus
Tangyagraptus
Hedrograptus
Akidograptus
Parakidograptus
Eastern Yangtzi Gorges,
Wang, et al, 1983



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Dicellograptus
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C. (Diplacanthograptus)
Pararetiograptus
Pseudoretiograptus
Leptograptus
Paraplegmatograptus
Geniculograptus
Tangyagraptus
Yinograptus
Paraorthograptus
Hedrograptus
Glyptograptus
Akidograptus
Parakidograptus
Xixiang, Shaanxi, China
Yu, et al., unpub. ms. 1985

1983). In north-eastern Siberia, however, where the sequence is complete and has yielded graptolites continuously across the transition, the terminations of key genera (e.g. Dicellograptus, C. (Diplacanthograptus) and Orthograptus) occur within the pacificus Subzone but prior to the termination of Paraorthograptus (Koren' et al., 1983 - text-figure 16B, herein). The succeeding zone in these areas, the extraordinarius Zone (where present), is a very low diversity fauna consisting of usually two to five species all of which can almost certainly be assigned to Hedrograptus as defined here. As pointed out by VandenBerg et al. (1984), the first occurrence of C? extraordinarius may show some overlap with the preceding fauna. In these areas, the base of the extraordinarius Zone is not recognized by the first occurrence of the nominate species but by the disappearance of the preceding fauna. Outside of China, only three species are known for certain to actually cross this extinction event: Hedrograptus normalis, H. angustus (=C. miserabilis) and H. extraordinarius (e.g. Williams, 1983). The latter species is restricted to the uppermost pacificus and the extraordinarius intervals although it is preceded by the very similar H. ojsuensis in the U.S.S.R. (Koren' et al., 1983).

Assessment of the boundary interval in China is somewhat more difficult owing to three factors: the use of different, usually endemic species as zonal indices; and some lack of taxonomic consistency with western workers especially with regard to "splitting"; and the apparent diachroneitiy of the *Hirnantia* fauna. Of particular interest is the position and range of the zone of "*Diplograptus*" *bohemicus* (a species here assigned to *Hedrograptus*). Mu *et al*. (1984) and Chen and Lenz (1984) considered the *bohemicus* Zone to be approximately equivalent to the *extraordinarius* Zone of U.S.S.R. and Scotland and the preceding *pacificus* Zone of the latter areas to be roughly equivalent to the *mirus* Zone or even the *typicus* Zone in China, with the succeeding *uniformis* Zone being equivalent to barren strata in Scotland. Chen and Lenz (1984) based this correlation in part on the occurrence of the distinctive, short-ranging Chinese genus *Diceratograptus* in Yukon, Canada in the *pacificus* Zone.

Williams (1983) and VandenBerg *et al*. (1984) present a slightly different picture which equates the *typicus*, *mirus*, *uniformis* and lower part of the *bohemicus* zones all with the *pacificus* (Sub)Zone (text-figure 15). This is based on the co-occurrence of *Paraorthograptus* and other distinctive, cosmopolitan species in all of these Chinese zones and the termination of the "Ordovician-style" lineages within the *bohemicus* Zone as it is broadly applied in various parts of China. In some of the Chinese studies where the *Hirnantia* fauna occurs between the *bohemicus* and *persculptus* Zone (e.g. Mu, 1979; Wang *et al*., 1983; Mu *et al*., 1984 - see text-figure 16C,D, herein) elements of the "Ordovician" lineages such as *Paraorthograptus*, *C*.

(*Diplacanthograptus*), and *Paraplegmatograptus* species proceed through the *bohemicus* Zone and are terminated at or below the base of the *Hirnantia* fauna. In other areas of China (Mu and Ni, 1983; Li *et al*., 1984, Yu, *et al*. 1985, unpub. ms. - see text-figure 16E) the *bohemicus* Zone consists entirely of species of the Retiolitidae (especially *Hedrograptus*) with no relics of the "Ordovician" lineages present. This strongly suggests that the *bohemicus* Zone does not represent a uniform entity as it is used in different parts of China (VandenBerg *et al*., 1984) and that the lower *bohemicus* Zone may be equivalent to the upper part of the *pacificus* (Sub)Zone, at least in some areas, while the upper part is equivalent to the *extraordinarius* Zone. It is noteworthy that *H. bohemicus* itself is the only species consistently reported to span the entire *bohemicus* Zone in its broadest sense and is therefore the only other species known for certain to pass through the extinction event. VandenBerg *et al* (1984), however, have questioned the taxonomic validity of this species, suggesting that, at least in its type area, this species is synonymous with *Hedrograptus persculptus*.

As in N.E. Siberia, the Chinese records of the passage from "Ordovician" to "Silurian" faunas do not always record an abrupt a termination of the Ordovician lineages and it is curious that from area to area it is not always the same taxa which persist a little longer than the others. (See text-fig. 16C-E for a summary of generic ranges at various boundary sections.) This may reflect the fact that different taxa persist longer in different areas. Indeed, the occurrence of *Paraorthograptus* in *persculptus* Zone strata at two localities (Wang *et al.*, 1983, fig. 3; Lin and Chen, 1984), involving several well preserved specimens indicates that this genus did persist longer than the others in a few refugia. On the other hand, the vagaries of preservation and sampling may account for some of the differential occurrences, especially since *uniformis* and *bohemicus* equivalent intervals are so thin, often 0.5m or less (Wang *et al.*, 1983; Mu *et al.*, 1984).

Occurrences of *Dicellograptus* have been reported from the *bohemicus* Zone by Ge (1984) and in the *Pristiograptus leei* Zone (Middle Llandovery) by Wang (1984), in both cases with an otherwise entirely retiolitid (s.l.)-monograptid fauna, and represented by single, incomplete specimens. In both of these cases the possibility of reworking must be considered, since in all other areas *Dicellograptus* disappears with or before the other "Ordovician" genera.

The reported occurrences of *Amplexograptus prominens*, *A. typicalis* and *A. typicalis crassimarginalis* in the *bohemicus* Zone by Ge (1984) must also be considered suspect since the illustrations, although poor, show a decidedly hedrograptid profile for these specimens with a pointed, asymmetrical proximal end and a pronounced virgella, apparent absence of other proximal ornamentation, and exposure of the dorsal side of the sicula below th1[2].

Likewise, the specimen of <u>Orthograptus</u> <u>abbreviatus</u> illstrated by Wang <u>et al</u>. (1983) from the <u>persculptus</u> Zone lacks a proximal end and may, therefore, be a hedrograptine or petalograptine of a rather than an orthograptid s.s.

Discussion of the Late Ordovician extinction event must involve a summary of the trends in the graptolite faunas and concommitant climates and oceanographic events leading up to the actual extinction. A general decrease in worldwide faunal diversity from Early to Late Ordovician is accompanied by a strong decrease in faunal provincialism, leaving an essentially cosmopolitan fauna during Ashgill times (Skevington, 1973; Berry, 1979). This trend toward decreasing provincialism through the Ordovician is also seen in several benthic groups including trilobites (Whittington and Hughes, 1973) and brachiopods (Williams, 1973). Species diversity, however, does not appear to have decreased steadily during the Ashgill but remained more-or-less constant or even increased slightly in some areas prior to the sudden decline at the end of the Rawthayan.

Cosmopolitanism may seem to be at odds with the inferred climatic history of the Ordovician which suggests formation of polar ice caps during this time and increasing latitudinal climatic gradients (Spjeldnaes, 1981). For example, the Cenozoic oceans show increasing provincialism with increasing climatic gradients culminating in the high degree of provincialism seen in the modern oceans (e.g. Valentine <u>et al</u>., 1978). However, the modern continental arrangement is highly longitudinal allowing a large number of individual latitudinal gradients to be established along the margins of each of the ocean basins. The Ordovician, on the other hand, shows an increasingly latitudinal arrangement of the continental land masses (Ziegler et al., 1981, fig. 7:2; see also text-fig. 13 herein) with Baltica moving northward from the south temperate or boreal into the south tropical to subtropical areas and the southward movement of China from the north temperate into the tropical realm. Recently published paleomagnetic data from the Yangzi Region of China (Ye, 1984) suggest a paleolatitude of about 20° N for that region around the time of the Ordovician-Silurian boundary. This arrangement, together with increased degree of oceanic circulation accompanying the climatic cooling would result in well-developed latitudinal tropical currents both north and south of these land masses homogenizing the tropical faunas. In addition, increased rate of circulation could bring about increased mixing of tropical and temperate/boreal faunas along the northern margins of Gondwana.

Although, the age of the glaciation event is poorly constrained (Spjeldnaes, 1981) it appears to range in age from Caradoc to Lower or Middle Llandovery as glacial centres shifted across the drifting landmass (Caputo and Crowell, 1985). The peak of glaciation is widely considered to have been Late Ashgill, however, partly due to the presence of well-dated Hirnantian glaciogenic strata in

Morocco (Destombes, 1968, 1981) and probable Ashgill glaciogenic strata in southwestern Europe (Dore, 1981; Robardet, 1981; Steiner and Falk, 1981) and to the pronounced regression seen in sea level curves during this interval (McKerrow, 1979; Leggett et al., 1981; Lenz, 1982b; Hallam, 1984) which is widely attributed to the glaciation event (e.g. Berry and Boucot, 1973; Lenz, 1976; Brenchley and Newall, 1980; Johnson et al., 1981; Petryk, 1981; Chen, 1984b). Although a certain amount of circular reasoning is involved here, the coincidence of the best-dated glaciogenic deposits with the maximum sea-level drop is taken as evidence that this period represented the time of maximum glacial expansion.

Wilde and Berry (1984) have developed a model which attributes extinction events to the onset of glacial activity, that resulted in oceanic turnover and the rise of inhospitable waters into the surface regions of maximum productivity. Briefly, their model depicts climatically warm, non-glacial periods as times of weak but stable stratification with two layers of anoxic (or at least strong oxygen-minimum) waters developing in the tropical areas (Wilde and Berry, 1984, fig. 2). During periods of transitional climate, the flood of cool, low-salinity waters would mix with the warmer, more saline waters of the same density in the deep and intermediate layers of the oceans causing a rise and merging of the anoxic/oxygen-minimum layers. With the appropriate rates of climatic change, this could result in a temporary condition of a neutral or reversed density gradient throughout the water column and overturn could result. Periods of glacial maximum would be characterized by a high stability of oceanic stratification based on strong temperature gradients from very cold bottom waters of polar origin and elimination of the anoxic layers by the movement of oxygenated waters into deep and intermediate depths.

The timing of the overturn and potential extinction in this model is related to the onset or decline of glacial activity although they suggest that variations in timing may result from the rate of development of the glacial centres. The Late Ordovician graptolite extinction, however, appears to coincide with the peak of glacial activity, while ice caps had apparently been present over the south polar areas at least since Caradoc (or earlier) time. It is possible that a slow rate of ice cap development may have delayed the overturn event until what may have been a maximum glacial advance during Hirnantian times.

The Wilde and Berry model predicts that the rise of anoxic waters during the overturn event should flood the deep shelf areas with inhospitable waters and result in the extinction of deep shelf faunas. Brenchley (1984) reviewed the faunal extinctions of the Late Ordovician and found that the deep shelf faunas suffered a significant extinction coincident with the graptolite extinction at the Rawthayan-

Hirnantian boundary while, the shallower-shelf faunas suffered fewer extinctions, spread over Hirnantian time. Brenchley attributed these extinctions to regression - the deep shelf faunas being displaced over the shelf edge onto the upper slope areas with a concommitant reduction in habitable area and the shallow shelf faunas migrating seaward with a gradual reduction in habitable area. He attributed the extinction of the pelagic faunas (especially graptolites) to contraction of the tropical plankton belts. However, Jablonski (1980, 1985) and Stanley (1984) have argued that reduction in habitable area by itself is not sufficient to cause large-scale extinction. Stanley argues that overall oceanic cooling is a more likely cause of the extinction of pelagic and shelf fauna adapted to tropical conditions.

Other plankton/nekton groups that appeared to have suffered from significant extinction were the acritarchs (Duffield and Legault, 1981; Culbath, 1986) and cephalopods (McKinney, 1985). Neither of these groups seems to have suffered as profound an extinction as the graptolites but this may be attributed to the fact both groups had a significant fauna in neritic waters which appear to have been less strongly affected than the pelagic realm.

The nature of the graptolite habitat is of crucial importance in the consideration of their extinction events. Many authors have considered that graptolite faunas may have been distributed with depth (Berry, 1962; Berry and Boucot, 1972; Erdtmann, 1976; Kaljo, 1978) while others have attributed regional faunal variations to lateral differentiation and association with specific water masses (Berry, 1974, 1977; Watkins and Berry, 1977; Finny, 1984). Analogy with modern zooplankters suggests that both of these factors may have been operative in graptolite ecology.

Koren' and Rickards (1979) have pointed out that although graptolites are found in aerated shelf environments, there is a very strong association between graptolites, especially diverse faunas, and dark carbonaceous mudstones and this led these authors to propose a model which links graptolite diversity patterns and their final extinction with the rise and fall of the "black shale environment" and its relation to climate and oceanic productivity (see also Leggett et al., 1981). Berry et al. (1985) have suggested that graptolites may have inhabited oxygen-poor, nitrate-rich waters which they believe may have overlain anoxic waters in the Paleozoic water column and underlain the oxygenated surface layers. This would explain the close, although not invariable association between graptolites and anaerobic and dysaerobic (Rhoads and Morse, 1971) sediments. Applying this to the Wilde and Berry (1984, fig. 2) model for extinction in the Ordovician, the Early Ordovician times of equitable climate could have resulted in several anoxic/dysaerobic interfaces within a tropical water column (see Wilde and Berry, 1984, fig. 2) especially in areas adjacent to continental shelves and epicratonic seas where warm, oxygenated, relatively high salinity waters would enter the oceanic water column, possibly at various depths. This would provide potential graptolite habitats at several levels within the water column. As the climate cooled into the later Ordovician the potential for low oxygen habitats would be reduced as the influx of cooler, oxygenated water would raise and merge the anoxic layers. This, together with constriction of the tropical plankton belts and increased circulation, resulted in the decrease in diversity and provincialism in the latter half of the Ordovician. With the onset of peak glaciation, the anoxic/dysaerobic layer system could have been completely disrupted with the upward and lateral movement of cool, oxygenated waters toward the surface in tropical areas. Not only would this temporarily destroy the main graptolite habitat, but these cooler waters would flood onto the deeper shelf areas putting the tropical, deep shelf faunas in jeopardy. Even in the absence of the overturn of toxic, anaerobic waters, this mechanism could therefore be responsible for the disruption of the tropical pelagic and deep shelf habitats, while the accompanying regression would drastically reduce the epicontinental and shallow shelf seas causing the more subdued levels of extinctions in those habitats.

Several observations may be enlisted in support of this hypothesis:

1) Although the final graptolite extinctions were

rather abrupt, the distribution of species and genus ranges discussed above suggests that the extinction was not an instantaneous event but that in some areas, some taxa (e.g. Paraorthograptus) persisted somewhat longer than others. This speaks against the occurrences of sudden extinction mechanisms such as bolide impact, or even sudden oceanic overturn.

2) Two of the species which persist across the extinction event, Hedrograptus angustus (=H. miserabilis) and H. normalis appear to have originated well down in the Ordovician and were highly cosmopolitan in latest Ashgill and Early Llandovery times - in fact, they are often the only, or among the only taxa found in the first Llandovery samples above the boundary, even in shelf areas such as Anticosti Island (Riva and Petryk, 1981). These two species are among the longest lived graptolite species known, with H. normalis persisting for about 7My (Rickards, 1977). These were obviously eurytopic species able to withstand disruption of the traditional graptolite habitat. The other main "crisis" species, H. extraordinarius and H. bohemicus, developed (probably from the H. normalis-angustus lineage) during the final decline of the "Ordovician" lineages at the end of "pacificus time" rather than after their disappearance suggesting that the onset of conditions unfavorable to the existing taxa and favorable to the crisis taxa was gradual. (One could equally argue that the "crisis taxa" evolved under normal graptolite-habitat conditions but

survived because they were somehow favorably preadapted to the crisis conditions.)

3) Finally, if the graptolite extinction event were the result of a sudden, temporary phenomenon, then many sequences should show a return to normal graptolitic sedimentation almost immediately, albeit with a reduced fauna. However, at almost all well-studied sections world-wide the pacificus fauna is followed by either a hiatus (probably indicative of increased oceanic circulation rates), light-coloured, barren strata (indicating higher degrees of oxygenation of the bottom waters) or an intervening Hirnantia shelly fauna.

Brenchley and Cullen (1984), after reviewing the distribution of the Hirnantia fauna have suggested that despite its occurrence in many tropical areas (except where shallow carbonate sedimentation is maintained) it is a cool-water fauna, originally derived from a south temperate to boreal area. Its incursion into many areas previously occupied by tropical shelf or planktonic faunas is strongly indicative of the spread of cool, oxygenated water at shallow and moderate depths throughout the worlds oceans. Only the carbonate shelf areas hydrographically isolated from the main oceanic water masses would be protected from the incursion of cooler waters and could have maintained their shallow, tropical shelf faunas.

Sheehan (1973, 1975, 1982) has suggested that following decline of the late Ordovician tropical shelf brachiopod communities, the recolonization process was largely accomplished by invaders from the cooler areas of the deeper waters and/or higher latitudes. A similar process of invasion of shallow shelf areas by previously cooler-water, deep shelf taxa was proposed by Chatterton and Perry (1983) for lower Silurian trilobites in northwestern Canada.

Comparison with the situation of Pleistocene glaciation brings out some important differences in the magnitude of extinctions which may be used against this model for the Late Ordovician extinctions. Three important differences between the Pleistocene and Ordovician may account for these differences:

1) The arrangement of the continents during the Late Ordovician, as noted above, was entirely different than at present and probably facilitated much more vigorous worldwide circulation and mixing of oceanic waters. In the Pleistocene, the ocean basins were strongly separated and the Pacific, in particular, was largely isolated from the influx of cold, polar waters.

2) The structure of the pelagic ecosystem was different and appears to have involved the development of dysaerobic/anoxic layer(s) which resulted from a long, relatively warm period of previous climatic history (Spjeldnaes, 1981), residual anoxicity of the oceans (Berry and Wilde, 1978) and/or a much higher rate of oceanic productivity due to the lack of terrestrial vegetation which, in later times has trapped nutrients on land (Tappan, 1986).

3) The lack of vegetation on land probably increased the effectiveness of the positive feedback of albedo (Frakes, 1979) in accelerating glaciation. This may have resulted in a higher rate of glacial advance as it approached its peak (at the beginning of the Hirnantian) resulting in more rapid climatic change and, therefore, change in the oceanic systems.

The Retiolitid-Monograptid Radiation

Following the extinction event, the rediversification of graptolites appears to have taken place entirely from the Hedrograptus and Akidograptus stock and does not appear to have taken place at the same rate around the world. In particular, the Yangzi Platform area appears to show the most rapid diversification of new forms with a greater number of species developing within the established lineages as well as more rapid development of new genera. Although the diversity levels seen in the late bohemicus, persculptus and acuminatus zones in China may be artificially high as a result of a propensity toward "splitting" on the part of many Chinese in relation to western workers, there can be no doubt that the Chinese faunas of this time period do, indeed show a higher diversity of morphologies.

In addition, some distinctive genera, especially Akidograptus, Dimorphograptus and Glyptograptus (i.e. G. tamariscus group) seem to appear earlier in China than elsewhere. Again, some difficulties arise in relation to the definition of the zones involved and the exact synchroneity of their bases. The Chinese workers define the base of their acuminatus Zone on the first occurrence of the nominate species. By their definition, Akidograptus ascensus consistently has its origin within the persculptus Zone because it consistently occurs before P. acuminatus. In Britain, P. acuminatus and A. ascensus occur simultaneously in the section and the base of the acuminatus Zone is drawn at the first occurrence of either of these species. Therefore, some western workers (e.g. S.H. Williams, pers. comm., 1985) would contend that the first occurrence of A. ascensus, by definition, marks the base of the acuminatus Zone despite the fact that it appears earlier in relation to the occurrences of P. acuminatus and H. persculptus. At Xixiang, Shaanxi (Yu et al., 1985, unpub. ms.), Akidograptus parallellus appears simultaneously in the section with H. persculptus and A. ascensus appears in the following sample while P. acuminatus does not appear until several samples later. This strongly indicates that Akidograptus appeared earlier in China than it did elsewhere and that the base of the Silurian, as defined by the base of the acuminatus Zone may be somewhat variable from place to place depending on what species is used to indicate its base.

A still earlier occurrence of Akidograptus has been reported by Li and Ge (1981) who found a new species, A.

antiquus, in the *typicus* Zone. This species is not known to be linked directly to any of the later species by occurrences in the intervening *mirus*, *uniformis* or *bohemicus* zones despite intensive sampling of this interval in many parts of the world. The possibility exists that *A. antiquus* represents a separate lineage from the later forms but it is equally possible that *Akidograptus* did indeed originate in the *typicus* Zone and survived in some as yet unsampled area until its widespread occurrence in the *persculptus*-*acuminatus* interval.

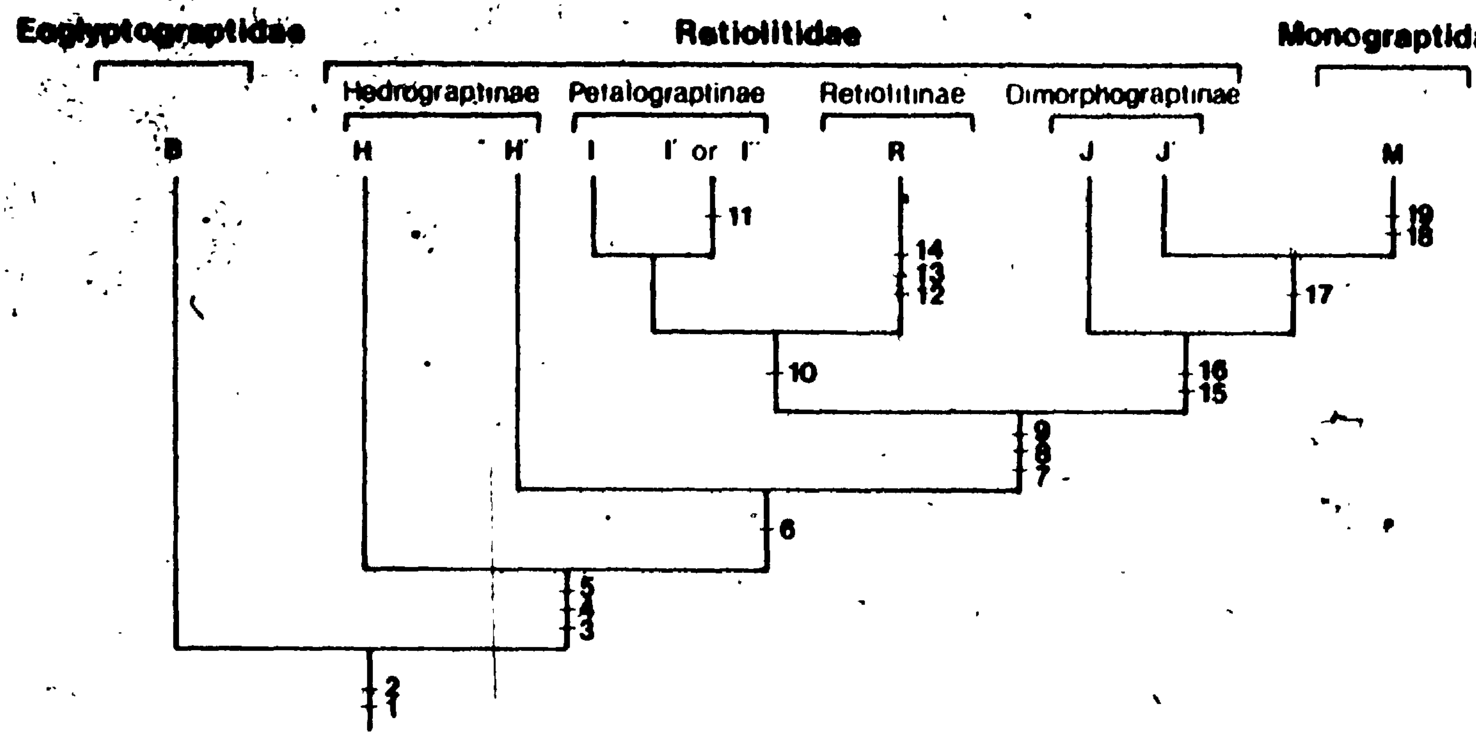
In a similar manner, it is not known if the Late Ordovician subspecies assigned to *Paraclimacograptus innotatus* (especially *P. innotatus nevadensis* - see Carter, 1972; Riva, 1974) are indeed of the same lineage as the Silurian representatives of this species and survived the Late Ashgill in some as-yet unsampled refugia or if they represent separate lineages. Further study of the Ordovician material, especially uncompressed specimens, would likely shed some light on this problem.

Koren, *et al*. (1983), Lin and Chen (1984), Li, *et al*. (1984), Ge (1984) and Yu, *et al*. (1985, unpub. ms.) have all reported what appear to be *G.* ex gr. *tamariscus* from the *persculptus* zone, in some instances from as early as its base. Lin and Chen (1984) reported *Dimorphograptus minutus* (= *Rhaphidograptus minutus* Chen and Lin, 1978) from the *persculptus* Zone of Yichang, Hubei. Rickards and Hutt (1970) reported *Atavograptus ceryx* from the *persculptus* Zone of the Lake District, Great Britain. All of these reports indicate that three of the four Silurian subfamilies of the Retiolitidae as defined herein (the Hedrograptinae, Petalograptinae and Dimorphograptinae) and the Monograptidae had developed by the end of the _persculptus_ Zone, prior to the beginning of the Silurian as it is now defined. Furthermore, most or all of this radiation event appears to have happened within the _persculptus_ Zone itself (although, as noted above _Akidograptus_ and _Paraclimacograptus_ may have originated somewhat earlier) a period dated by Carter _et al_. (1980), using sedimentation rates, as being only about 0.2My long.

The Yangzi Platform, which, as shown by Chen (1984b), was probably the site of a semi-enclosed tropical sea during latest Ashgill time, and may have seen reestablishment of appropriate graptolite habitats more rapidly following the disruption event than more open ocean areas (which may have taken longer to restabilize). This would have provided an ideal site for rapid proliferation of new forms, including some with modified proximal development patterns, which could then spread throughout the worlds oceans.

The lack of good morphologic data on the latest Ordovician and Early Llandovery biserials and monograptids makes delineation of precise lineages impossible, but some generalities and alternatives can be proposed. Text-figure 17 shows a cladistic analysis of the pertinent features of the astogeny and internal structure of the Retiolitidae and

Text-figure 17. Cladogram showing proposed relationships among the Eoglyptograptidae, Retiolitidae and Monograptidae. Terminal branches are identified according to astogenetic patterns identified by Mitchell (1987) and herein. Numbered synapomorphies are as follows: 1) asymmetrical proximal end; 2) delay in derivation of $th2^2$ to late in protheca 2^1 - $th2^2$ no longer primordial; 3) $th1^2$ crossing canal suppressed; 4) protheca 1^1 partly enclosed by metatheca 1^1; 5) protheca 1^2 begins growth upward and outward, unconformably on $th1^1$; 6) delay in derivation of $th2^1$ to late in $th1^2$ protheca - $th2^1$ no longer primordial; 7) short descending protheca 1^1 with only one terminal foramen - $th1^2$ derived later and is no longer primordial; 8) sicula usually extensively exposed on obverse side; 9) potential for ancora production; 10) loss of complete median septum and dicalycal theca; 11) $th1^2$ reoriented over $th1^1$ producing dimorphograptid appearance; 12) reduction or complete desclerotization of sicula; 13) replacement of primary thecal periderm with clathria and reticulum; 14) integration of ancora with framework of first thecal pair; 15) downward growth of protheca 1^1 reduced (to absent?) leaving sicula exposed for its full circumference near its aperture; 16) reverse wall of $th1^1$ grows straight upward for much of its length before budding of $th1^2$ (or $th2^1$); 17) reorientation of one or several thecae above $th1^1$ producing a uniserial proximal end; 18) sicula with porus and lacuna stages in budding of th1 - th1 no longer primordial; 19) rhabdosome uniserial throughout its length.


Eoglyptograptidae
Retiolitidae
Monograptidae
Hedrograptinae
Petalograptinae
Retiolitinae
Dimorphograptinae
B
H
H'
I
I' or I''
R
J
J'
M
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19

Monograptidae. It is not clear from the presently available information if all of the synapomorphies shared by the sister groups of the Petalograptinae and the Dimorphograptinae are, indeed homologous. As noted previously the ancora seen in the two groups may not be homologous structures. The short, descending protheca 1^1 and the delayed differentiation of $th1^2$ may also be independantly derived and convergent features of the two groups. Considerably more work needs to be done on the details of the early astogeny of the Dimorphograptinae and the earliest Petalograptinae, including the aquisition of new, isolated material, before the exact relationships between these two groups can be elucidated. It can be stated, however, that both have arisen from a Hedrograptine ancestry.

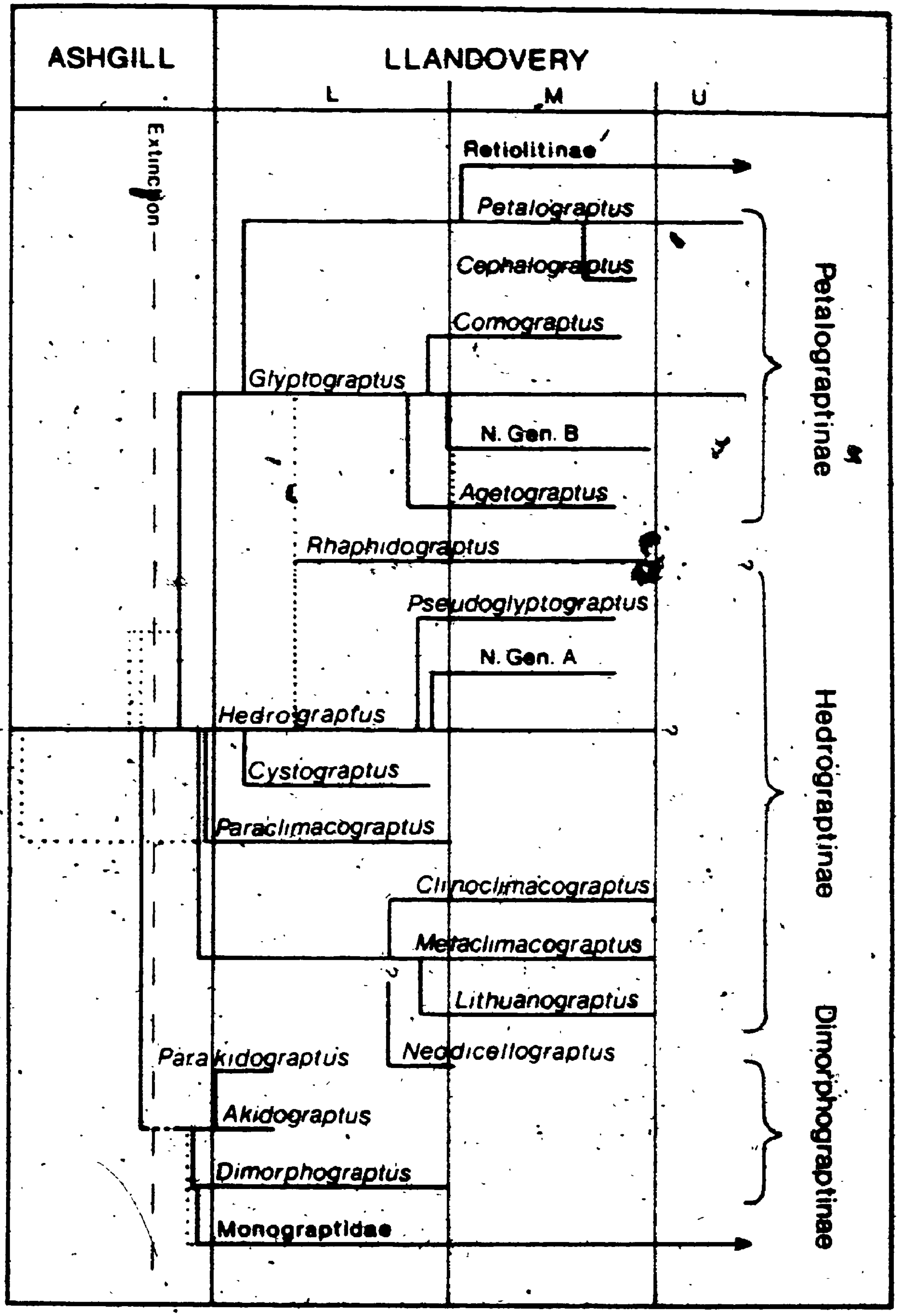
When Rickards and Hutt (1970) proposed that the first *Atavograptus* evolved directly from "*Glyptograptus*" their arguments were based primarily on the known stratigraphic ranges of the taxa involved and the similaries in thecal form. Both of these criteria have since proved to be notoriously misleading and new information about proximal development patterns as well as the new biostratigraphic information noted above (especially from China) suggests that a dimorphograptine ancestor to the monograptids may not, as noted by Mitchell (1987), be unreasonable. The "*Glyptograptus*" species illustrated by Rickards and Hutt (1970, figs. 2b-d) has a median septum and shows some exposure of the descending protheca 1^1 on the obverse side, both features typical of *Hedrograptus*. To jump directly from this form to *Atavograptus* would require a change from three primordial thecae to none (or possibly one if the earliest *Atavograptus* had not developed the sinus and lacuna stages) and a complete of almost complete or almost complete loss of the descending protheca 1^1 which, in *Hedrograptus*, gives rise to both of the two first thecae.

The proximal end of *Akidograptus*, on the other hand, (text-fig. 14J) shows almost identical growth of the first theca up to the point of development of $th1^2$. In fact, Williams (1983) notes the similarities in the proximal ends of *Akidograptus ascensus* and *Atavograptus ceryx*, as well as in the thecal form and spacing, but only goes so far as to suggest common ancestry. *Rhaphidograptus minutus* Chen and Lin (here referred to *Dimorphograptus*) which as been found in the *persculptus* Zone of China (see above) not only shares the common proximal development pattern and thecal form of *Akidograptus ascensus* and *Atavogrptus ceryx* (although it has a slightly longer sicula), but also has a uniserial proximal end. A transition from *Hedrograptus* - *Akidograptus* (like *A. ascensus*) - *Dimorphograptus* (like *D. minutus*) - *Atavograptus ceryx* is not in conflict with the known ranges of these taxa and requires very little morphologic change at each step. In fact, the biggest morphologic jump may be at the *Hedrograptus* - *Akidograptus* transition where the early growth of all three of the early thecae is redirected.

It is not known if the achievement of a uniserial rhabdosome is coincident with the development of the lacuna in the sicula for the budding of th1[1]. If *A. ceryx* does indeed show a slight downward growth of th1[1] then this seems unlikely, but only study of new, better preserved material will reveal the answer.

A possible scenario for the derivation of the Llandovery graptoloid groups is outlined in text-figure 18. As noted above, the exact the exact points of origin of the dimorphograptines relative to the petalograptines cannot be stated with any certainty. The two groups may have been independantly derived from a common hedrograptine ancestor and the shared features of the two groups would therefore be the result from convergence. On the other hand, the dimorphograptines may have been derived from an ancestral, septate petalograpine within the late Ashgill (as yet unidentified) in which case the pattern J astogeny would simply be a slightly more advanced state of the pattern I. The present biostratigraphic evidence favors the former alternative although undue reliance on known ranges has misled us before and cannot, therefore, be considered be a reliable criterion.

Text-figure 18. Proposed phylogenetic tree for the Retiolitidae and derivation of the Monograptidae showing approximate generic ranges as presently known. Dotted lines indicate possible alternative (or additional) routes of derivation. Dashed line indicates the late Ordovician graptolite extinction event, approximately coincident with the base of the Hirnantian.


ASHGILL
LLANDOVERY
L
M
U
Extinction
Retiolitinae
Petalograptus
Cephalograptus
Comograptus
Glyptograptus
N. Gen. B
Agetograptus
Rhaphidograptus
Pseudoglyptograptus
N. Gen. A
Hedrograptus
Cystograptus
Paraclimacograptus
Clinoclimacograptus
Metaclimacograptus
Lithuanograptus
Neodicellograptus
Parakidograptus
Akidograptus
Dimorphograptus
Monograptidae
Petalograptinae
Hedrograptinae
Dimorphograptinae

CHAPTER 6 - SYSTEMATIC PALEONTOLOGY

Wherever possible, the new classification scheme developed by Fortey and Cooper (1986) and Mitchell (1987) is used herein with modifications based on discoveries from the present material and reexamination of the literature. Since specimens are described both from uncompressed specimens and from compressed specimens in varying degrees of preservation, a positive identification at the genus level is not always possible since this may require knowledge of details of the proximal development or internal structure which is not discernable in most compressed specimens. In cases where the genus (as defined by the new phylogenetic scheme) is easily deduced from well preserved, specimens it is employed normally (e.g. <u>Glyptograptus tamariscus</u>). When this is not the case, the suggestions of Mitchell are followed: when the generic assignment is considered probable it is indicated as, for example, <u>Hedrograptus</u>? <u>lanpherei</u>; when the generic affinities of a species cannot be determined with any certainty at all it is assigned to a "form-genus", corresponding to the traditional diplograptid classification scheme, for example "<u>Diplograptus</u>" <u>angustidens</u>. This designation is also used for established species being assigned to new genera described herein, for example "<u>Orthograptus</u>" <u>bellulus</u> which is the type species of n. gen. B.

Although the convention of giving thecal spacing in terms of number in 10mm is well established, many authors have actually taken their spacing measurements over much fewer than 10mm and extrapolated to achieve this number (e.g. Packham, 1962; Rickards, 1965). In the proximal regions where thecal spacing is commonly changing (usually widening distally) this provides an unrealistic picture of proximal thecal spacing. On the other hand, quoting thecal spacings over very small lengths or few thecae are more difficult to compare and use at the practical level. In the present specimens, proximal thecal spacing was measured over two to five thecal pairs (depending on preservation and rate of change of spacing) and extrapolated to number in 5mm for the sake of consistency and ease of use. Distally, where the thecal spacing becomes more constant, measurements were made over 5mm (10mm wherever possible) and quoted as number in 10mm. Measurements made over one or two thecae were avoided wherever possible because it was observed that nonuniform variability sometimes occurred in individual thecal lengths along a stipe. Rhabdosomal width at thecal pair x was measured from the lip of thx^1 to that of thx^2, perpendicular to the axis of the rhabdosome (Packham, 1962).

The graptolite mophologic terminology used in this paper is defined by Bulman (1970).

Order GRAPTOLOIDEA Lapworth, 1875

Suborder VIRGELLINA Fortey and Cooper 1986

Superfamily DIPLOGRAPTACEA Lapworth 1873, emend.

Family RETIOLITIDAE Lapworth 1873, emend.

<u>Diagnosis</u> (emended herein). Rhabdosomes with narrow, asymmetrical proximal end showing pattern H, I or J development (see "Proximal Development Patterns", above) and (usually) simple or reduced sicula. Colonies may be biserial or uni-biserial. The first two thecae are closely pressed to the sicula and usually lack mesial spines. Rhabdosomes septate, partially septate or aseptate and may bear an ancora or become an ancora-based retiolitid. Septate forms rarely show distal divergence of stipes, giving a dicranograptid appearance. Thecae are primitively glyptograptid to climacograptid but are modified to petalograptid, pseudoclimacograptid or sinuous.

<u>Remarks</u>. Mitchell has grouped the pattern B, H and I (including the newly defined pattern J) forms together with the uniserial monograptids within an expanded Monograptidae. This procedure has not been followed here and the pattern B forms, the pattern H, I, J, and the Silurian "retiolitids", and the uniserial monograptids have been separated into three separate families: the Eoglyptograptidae, the Retiolitidae and the Monograptidae respectively (text-fig. 17). The relationships between these and the other

diplograptacean families has been outlined by Mitchell and are not discussed here. The points outlined below are a discussion of the ways in which this scheme differs from that of Mitchell.

Firstly, from a classification point of view, is the recognition that Glyptograptus tamariscus, the type species of Glyptograptus, shows a pattern I rather than pattern H proximal development. This, of course, means that the family name of the pattern H graptolites needs as to be changed from Glyptograptinae as does the generic name of the glyptograptid and climacograptid species within that group although the diagnosis, and essential characteristics of the group remain unchanged. For this purpose, the genus Hedrograptus proposed by Obut (1949) appears to suit rather well. Obut apparently intended the genus to include species with climacograptid thecae, a circular to elliptical cross-section, a median septum and a relatively narrow proximal end unornamented with spines except for a virgella. In the latter two points, Obut isolated two of the key manifestations of type H graptolites which differentiate them from other "climacograptids". Furthermore, the presence of a median septum is ubiquitous within this group while it is lacking in most or all of the known pattern I species. Hedrograptus is therefore chosen as the type genus of the subfamily Hedrograptinae, to include the type H graptolites, and the genus will be used in place of Glyptograptus, as employed by Mitchell, to include the type

H species, both Ordovician and Silurian, with climacograptid to glyptograptid thecae.

Secondly, is the recognition of the distinctness of the dimorphograptid proximal development found in the akidograptids and Dimorphograptus s.s. Although, this does not alter the essence of the subfamily Dimorphograptinae it has allowed me to recognize the distinction between the true dimorphograptids and those forms within the Hedrograptinae? and Petalograptinae which have independently achieved the "dimorphograptid condition". It also enhances what appears to be the close phylogenetic link between the Dimorphograptinae and the Monograptinae (see discussion of phylogeny).

Thirdly, is the recognition of the distinctness of the retiolitids from their presumed petalograptid ancestors. Mitchell discussed some of the profound differences between the normal diplograptid periderm and the retiolitid clathria and reticulum but chose to include both within the same subfamily (Retiolitinae). Recent work on the skeletal architecture of many retiolitid genera, however, by Bates and Kirk (1978, 1984), Crowther (1981), Obut and Zaslavskaya (1986) and Lenz and Melchin (in press a,b) as well as many observations made by myself on both retiolitids and ancora-bearing petalograptids shows that several profound differences exist both in the early growth stages and distal internal architecture between these two groups. The first is the partial to total desclerotization of the sicula, considered, by Mitchell and Fortey and Cooper (1986) to be the most phylogenetically conservative feature of the graptolite rhabdosome. Although some specimens of Pseudoretiolites preserve a portion of the metasicula, no retiolitids have yet been found in which a resorption foramen or initial bud of th1[1] is preserved. A second feature is the integration of the ancora with the basic thecal framework of the first thecal pair. This contrasts sharply with any of the known ancora-bearing petalograptids in which the ancora is not involved in the construction of the first thecae and suggests that fundamental differences may exist in the mode of development of the first thecae. Related to these two points is the third (and most obvious) distinction, the - total replacement of primary thecal periderm with clathria and reticulum as a supporting framework. As pointed out by Mitchell, the actual genetic relationship between thecal periderm and clathria and/or reticulum is ~~not clear.~~ While it is true that several retiolitid genera are known to produce continuous peridermal tissue such as "thecal floors" or subreticular membranes (e.g. Pseudoretiolites, Stomatograptus and Retiolites), ultrastructural studies on such tissue by Urbanek and Rickards (1974) and Lenz and Melchin (in press b) show that such tissue is ultrastructurally unlike normal fusellar or cortical tissue (although Bates and Kirk, 1978, pers. comm. 1987, have observed fusellar increments is these tissues). It appears to be superficial to the clathrial or reticular lists and it apparently develops as a late stage maturity or gerontic feature. It is therefore not considered to be a remnant of the normal periderm of the petalograptines. These points, together with some of the unique elements found in the internal architecture of many retiolitines which have no obvious equivalents in the petalograptines (e.g. the zig-zag list opposite the virgula, the structural spaces between the clathria and the reticulum and the raised stomata) strongly argues, in my opinion, for the separation of the retiolitids from the petalograptids at the subfamily level.

Although the question of the mono- or polyphyletic origin of the Silurian retiolitids has not been satisfactorily answered as yet (see appendix E), the fact that they all share the three derived characteristics (synapomorphies 15 to 17 on fig. 17), as described above, suggests that unless their polyphyletic origin can convincingly be demonstrated, they should be grouped together.

The subfamily Retiolitinae, as employed here is equivalent to the Family Retiolitidae as used by Lenz and Melchin (in press a) and the subfamilies Retiolitinae and Plectograptinae of Bulman (1970) and many other authors (see Rigby, 1986, for a historical review of classification schemes). It is not synonymous with the family Retiolitidae as used by Bulman, nor the Order Retiolitida of Obut and Zaslavskaya (1986) because the archiretiolitid genera were included in those groups. Mitchell has demonstrated that the archiretiolitids are not related to the Silurian retiolitids at the family level but were derived from a different diplograptid stock. The long-recognized genus groups characterized by Retiolites and Plectograptus previously designated as subfamilies as noted above, are here lowered to the little-used tribe level, the formal taxon intermediate between genus and subfamily. Since the distinctness of these genus groups is well established and has been been recently corraborated by detailed morphologic and ultrastructural observations (e.g. Lenz and Melchin, in press a) their formal separation above the genus level seems justified.

This leaves the remaining pattern I graptolites, consisting of tamariscus-group glyptograptids and the petalograptids as well as some other smaller species groups. Rather than use the subfamily name Glyptograptinae erected by Mitchell, which was intended by him to encompass the type H species, the name Petalograptinae is employed, which, in any event, has priority (it was first erected by Bulman, 1955).

Since the formation of this family involves the merging of the previously named Retiolitinae and Petalograptinae and the newly named Hedrograptinae the rules of priority stipulate that the senior family-group name be employed - in this case Retiolitidae.

Two alternative cladograms illustrating the proposed relationships between the subfamilies of the Eoglyptograptidae, Retiolitidae and Monograptidae are shown in figure 17, including the synapomorphies which characterize each branching event. Although they are based, to a large extent on figures 13A and 16 of Mitchell (1987) they incorporate the observations and modifications discussed above and in the following subfamily descriptions.

Subfamily HEDROGRAPTINAE n. subfam.

Diagnosis. Biserial monograptids with pattern H primordial astogeny. Thecae glyptograptid, climacograptid, pseudoclimacograptid or sinuous. Medial septum straight or undulose. Stipes may (rarely) diverge distally.

Genera Included. *Hedrograptus* Obut, *Clinoclimacograptus* Bulman and Rickards, *Cystograptus* Hundt, *Lithuanograptus* Paskevicius, *Metaclimacograptus* Bulman and Rickards, *Neodicellograptus* Mu and Wang, *Paraclimacograptus* Pribyl, *Pseudoglyptograptus* Bulman and Rickards and possibly *Rhaphidograptus* Bulman.

Discussion. It must be noted here that although the details of proximal development of *Hedrograptus janischewskyi* (the type species of *Hedrograptus*) are not known from uncompressed specimens, the very close similarities in both thecal and rhabdosomal morphology with other, better known *Hedrograptus* species (e.g. *H.* aff. *scalaris*, Barrass, 1954, here assigned to *H. scalaris ferganensis*; *H. medius brevicaudatus*, this study) strongly suggests that their proximal development pattern is also the same.

The recognition of the proximal development patterns enables one to distinguish the affinities of some otherwise puzzling taxa, in some cases even in compressed specimens, from the appearance of their proximal end. Such is the case with *Neodicellograptus* (Mu and Wang, 1977), a small group of stratigraphically isolated, apparently dicranograptid species found, to date, only in the Llandovery of China. The proximal end of these species, differs from Ordovician dicranograptids in that the ventral side of the sicula is slightly exposed below th1^2 and the first two thecae appear to be closely adpressed to the sicula, do not show a significant outward growth component and lack mesial spines. In fact, the proximal end shape as well as that of all later thecae strongly resembles that of *Metaclimacograptus* and none of the species of *Neodicellograptus* show divergence until at least the second thecal pair, the earliest dicalyic in hedrograptines. The fact that the two stipes of septate diplograptids are capable of growth independently of each other has long been known from observation of forms in which one of the stipes has "died" before the other (see pl. 5, fig. 3). Williams (1983) also illustrated a variant of *Hedrograptus normalis* in which the stipes have diverged distally. It therefore seems not unreasonable that such species may have secondarily adopted a "pseudoreclined" rhabdosomal form.

Genus Hedrograptus Obut, 1949, emend.

Type species. Hedrograptus janischewskyi Obut, 1949.

Diagnosis (emended herein). Pattern H species with (usually) unornamented glyptograptid to climacograptid thecae. Proximal end relatively narrow, rounded and asymmetrical with strongly alternating thecae. Median septum straight and complete, with $th2^1$ or some later theca dicalycal.

Remarks. As far as presently known, there seems to be a morphologic continuum between species with climacograptid thecae and those with glyptograptid thecae within both the Ordovician and Silurian lineages of this subfamily. This especially seems to be true in the Ordovician-Silurian boundary species of the persculptus-extraordinarius plexus. Until much more information is available concerning the boundary species and many of the other Early Llandovery type H species with glyptograptid thecae, it was deemed advisable here to include both, as well as some of the biform "Diplograptus" species (e.g. "D." modestus), within an expanded Hedrograptus.

In the following descriptions, then, Hedrograptus species are grouped into three informal species groups which may or may not have any phylogenetic significance: species with climacograptid thecae throughout; species with glyptograptid thecae throughout; those biform to polyform thecae.

Group 1, Hedrograptus species with climacograptid thecae throughout.

Hedrograptus angustus (Perner, 1895)

Text-figure 19A.

1895 Diplograptus (Glyptograptus) euglyphus Lapworth var. angustus Perner, pp. 27-28, pl. 8, fig. 14a,b.

1895 Diplograptus (Glyptograptus) lobatus Perner, p. 28, pl. 7, fig. 15; pl. 8, fig. 15.

1906 Climacograptus scalaris (Hisinger) var. miserabilis Elles and Wood, pp. 186-187, pl. 26, fig. 3a-h; text-fig. 120a-c.

1949 Climacograptus angustus (Perner); Příbyl, pp. 7-10, pl. 2, figs. 2-9.

1970 Climacograptus miserablis Elles and Wood; Rickards, pp. 28-29, pl. 1, figs. 3,4,5,10.

1971 Climacograptus scalaris miserabilis Elles and Wood; Schauer, pp. 29-30, pl. 2, figs. 7,8; pl. 5, figs. 15,16.

1974b Climacograptus miserabilis Elles and Wood; Hutt, p. 20,

Text-figure 19

All figures x5 unless otherwise stated.

A. *Hedrograptus angustus* (Perner), TI:37.0, x10.

B,R,S,U. *Hedrograptus normalis* (Lapworth): B) TF:52.0, x10; R) TF:52.0; S) two overlapping specimens, HR:111.0-112.0; U) TF:52.0.

C-F. *Hedrograptus janischewskyi* Obut: C) HR:111.0-112.0; D) HR:106.0; E) spinose variant, TI:47.0-48.0, x10; F) HR:111.0-112.0.

G-I. *Hedrograptus* sp. aff. *H. janischewskyi* Obut, all specimens from HR:156.5; H) x10.

J-M. *Hedrograptus medius brevicaudatus* (Churkin and Carter): J) CM:2-5; K) TF:61.0; L) CM:2-5, x10; M) TF:63.0.

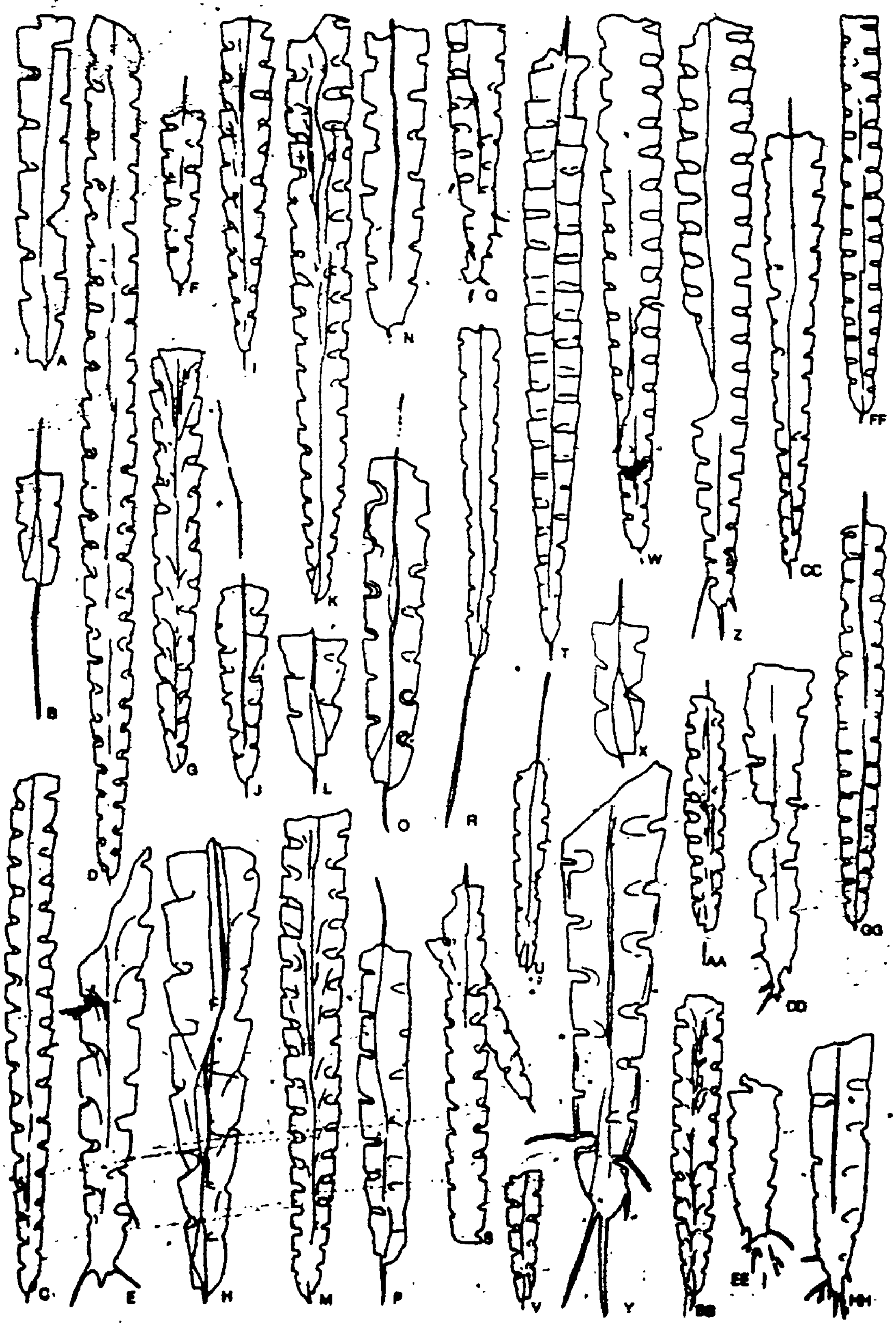
N,O. *Hedrograptus minutus* (Carruthers), both specimens from TI:38.5, both x10.

P. *Hedrograptus* cf. *H. minutus* (Carruthers), HR:117.0, x 10.

Q,T,V,W,Y,Z,CC. *Hedrograptus rectangularis* (M'Coy): Q) spinose variant, HR:111.0-112.0; T) HR:118.5; V) HR:112.5; W) HR:112.0-112.5; Y) spinose variant, TF:54.0, x10; Z) spinose variant, HR:112.0-112.5; CC) HR:111.0-112.0.

X,AA,BB,FF,GG. *Hedrograptus scalaris ferganensis* (Obut): X) TF:63.0, x10; AA) HR:111.0-112.0; BB) note aberrant spine on sicula, TF:61.0; FF) & GG) HR:107.0.

DD,EE,HH. *Hedrograptus* n. sp. A, all specimens from TI:37.0, all x10.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pl. 1, figs. 1,2; text-fig. 8, fig. 1.

1975 Climacograptus angustus (Perner); Bjerreskov, p. 23, fig. 9A.

1978 Climacogrgaptus miserabilis Elles and Wood; Chen and Lin, p. 29, pl. 4, figs. 9-13.

1978 Hedrograptus miserabilis (Elles and Wood); Sennikov, figs. c,d,e.

1978 Climacograptus angustus (Perner); Ye, p. 459, pl. 174, fig. 15.

1980 Climacograptus angustus (Perner); Koren', et al., pp. 131-132, pl. 37, figs. 2-7; text-fig. 34a-e.

?1983 Climacograptus miserabilis Elles and Wood; Huang and Lu, p. 134, pl. 2, fig. 19.

1983 Climacograptus angustus (Perner); Koren' and Sobolevskaya, pp. 106-108, pl. 27, figs. 1-5; text-fig. 34a-f.

1983 Climacograptus miserabilis Elles and Wood; Mu and Ni, pp. 167-168, pl. 4, figs. 6,7.

1983 Climacograptus miserabilis Elles and Wood; Williams, pp. 615-616, text-figs. 3f-i,?j; 4f-i; 5a,b.

1984a Climacograptus angustus (Perner); Chen, p. 38, pl. 2, figs. 9,10; text-fig. 3j.

1984a Climacograptus miserabilis Elles and Wood; Chen, p. 39, text-fig. 3l.

1984 Climacograptus miserabilis Elles and Wood; Ge, p. 428, pl. 8, figs. 1,9; pl. 9, fig. 4.

1984 Climacograptus miserabilis Elles and Wood; Li, p. 346, pl. 14, figs. 7,9,12.

1984 Climacograptus angustus (Perner); Li, p. 350, pl. 15, figs. 10,11.

1984 Climacograptus angustus (Perner); Vandenberg et al., fig. 4A.

1986 Climacograptus miserabilis Elles and Wood; Berry, fig. 5d,e.

Material. 10 compressed, rather poorly preserved specimens.

Occurrence. Acuminatus Zone. Truro Island at 37.0m.

Description. Rhabdosome up to 10.5mm long. Widens from 0.5 to 0.7mm at the first thecal pair to a maximum of 0.8 to 1.0mm, achieved between the fifth and tenth thecal pair. Thecae spaced at 11 to 12 in 10mm throughout, and are typically climacograptid in shape. Sicula indistinct but it bears a stout virgella up to at least 0.4mm long.

Remarks. Although the specimens are very poorly preserved they match well with those previously described in appearance and dimensions.

Bjerreskov (1975) has noted that although the name H. miserabilis is most commonly applied to this species, the two forms appear to be synonymous and H. angustus has priority. Williams (1983), however, has suggested that the

Ordovician forms referred to H. miserabilis may not be synonymous with H. angustus and further study of the type and topotype material is necessary.

Hedrograptus janischewskyi Obut, 1949

Text-figure 19C-F.

1949 Hedrograptus janischewskyi Obut, p. 14, pl. I, figs. 5a,b.

1968 Hedrograptus janischewskyi janischewskyi Obut; Obut and Sobolevskaya, pp. 57-58, pl. 1, figs. 1-11; p. 2, figs. 1-8.

1968 Hedrograptus janischewskyi serus Obut and Sobolevskaya, p. 59, pl. 3, figs. 1-3.

1970 Climacograptus cf. C. rectangularis (M'Coy); Churkin and Carter, pp. 17-18, pl. 1, figs. 7-9; text-fig. 7A,B.

1976 Hedrograptus janischewskyi janischewskyi Obut; Sennikov, pp. 130-131, pl. 4, figs. 6,7.

1976 Hedrograptus janischewskyi serus Obut and Sobolevskaya; Sennikov, pp. 131-132, pl. 4, figs. 8,9.

1978 Hedrograptus janischewskyi Obut; Ye, p. 461, pl. 175, fig. 4.

1980 Hedrograptus janischewskyi Obut; Obut and Sennikov, pp. 14-15, pl. I, fig. 1; pl. II, fig. 1.

1980 Hedrograptus janischewskyi janischewskyi Obut; Obut and Sennikov, pp. 15-16, pl. I, figs. 2-4, Ordovician forms referred to H. miserabilis may not be synonymous with H. angustus and further study of the type and topotype material is necessary.

Hedrograptus janischewskyi Obut, 1949

Text-figure 19C-F.

1949 Hedrograptus janischewskyi Obut, p. 14, pl. I, figs. 5a,b.

1968 Hedrograptus janischewskyi janischewskyi Obut; Obut and Sobolevskaya, pp. 57-58, pl. I, figs. 1-11; p. II, figs. 1-8.

1968 Hedrograptus janischewskyi serus Obut and Sobolevskaya, p. 59, p. III, figs. 1-3.

1970 Climacograptus cf. C. rectangularis (M'Coy); Churkin and Carter, pp. 17-18, pl. 1, figs. 7-9; text-fig. 7A,B.

1976 Hedrograptus janischewskyi janischewskyi Obut; Sennikov, pp. 130-131, pl. IV, figs. 6,7.

1976 Hedrograptus janischewskyi serus Obut and Sobolevskaya; Sennikov, pp. 131-132, pl. IV, figs. 8,9.

1978 Hedrograptus janischewskyi Obut; Ye, p. 461, pl. 175, fig. 4.

1980 Hedrograptus janischewskyi Obut; Obut and Sennikov, pp. 14-15, pl. I, fig. 1; pl. II, fig. 1.

1980 Hedrograptus janischewskyi janischewskyi Obut; Obut and Sennikov, pp. 15-16, pl. I, figs. 2-4.

1980 *Hedrograptus janischewskyi serus* Obut and Sobolevskaya; Obut and Sennikov, pp. 16-17, pl. I, fig. 5.

Material. Numerous compressed specimens, moderately well to poorly preserved.

Occurrence. Upper *acinaces* to *curtus* zones. Trold Fiord at 60.0, 61.0 and 63.0m and Huff Ridge at 103.0, 104.0, 106.0, 109.0, 110.5, 111.0-112.0 and 113.5m.

Description. Rhabdosome up to at least 30mm long. Widens gradually from 0.6 to 0.8mm at the first thecal pair to 1.1 to 1.3 at the fifth to a maximum of 1.6 to 2.2, achieved at about the fifteenth thecal pair. Thecae climacograptid, spaced at 5.5 to 6 in the first 5mm, 9.5 to 11 in 10mm distally. Virgella generally 0.5 to 0.9mm long, sicula is exposed for about 0.3mm below th1[2].

Remarks. The tapering rhabdosome and dimensions intermediate between those of *Hedrograptus normalis* and *H. rectangularis* characterize this species. Although two subspecies have been recognized, their distinction appears to based entirely on rhabdosome width (1.6 to 1.8mm for *H. j. serus* and 1.8 to 2.0mm for *H. j. janischewskyi*). In many of the present samples as in those of Churkin and Carter the two forms grade into one another suggesting a single population. In others, only the narrower or wider ones are present. Nevertheless, their common co-occurrence and intergradation suggests that they represent a single, variable species.

Hedrograptus sp. aff. H. janischewskyi Obut, 1949

Text-figure 19G-I.

Material. Ten moderately well preserved, and several more poorly preserved, compressed specimens.

Occurrence. Lower minor Zone. Huff Ridge at 156.5m.

Description. Rhabdosome up to at least 15mm long. Widens from 0.7 to 0.8mm at the first thecal pair, 1.25 to 1.4mm at the fifth, to a maximum of 1.65 to 1.85mm. Thecae spaced at 5 to 5.5 in the first 5mm and 9 to 9.5 in 10mm distally. Geniculum is abrupt and appears to be sharp on the proximal thecae, but rounded on the distal thecae. Supragenicular walls are straight and parallel to the rhabdosomal axis. Apertures are horizontal and excavations are shallow and asymmetrical. Sicula 1.1 to 1.2mm long and bears a virgella up to 0.8mm long. Median septum complete distally.

Remarks. This species, which occurs stratigraphically above H. janischewskyi, differs from it in only two respects. The proximal end of this species widens somewhat more rapidly and the distal thecae appear to possess a rounded, but abrupt geniculum and asymmetrical excavations rather than the typically climacograptid thecae of H. janischewskyi. It differs from Glyptograptus incertus Elles and Wood in that its thecal spacing is wider throughout, and its thecae are more nearly climacograptid, with shallower, shorter excavations. Hedrograptus magnus (Churkin and Carter) is also similar but it widens more gradually and has more flowing sigmoidal thecae.

Hedrograptus medius brevicaudatus

(Churkin and Carter, 1970)

Plate 1, figures 1-6; text-figure 19J-M.

1970 Climacograptus medius brevicaudatus Churkin and Carter, pp. 16-17, pl. 1, fig. 12.

1984 Climacograptus medius brevicaudatus Churkin and Carter; Lin and Chen, p. 212, pl. 4, figs. 1,2.

Material. Numerous compressed specimens, well to poorly preserved and several very well preserved, uncompressed specimens.

Occurrence. Cyphus and curtus zones. Cape Manning at 0-2 and 2-5m, Trold Fiord at 60.0, 61.0, 62.5 and 63.0m and Huff Ridge at 110.0 and 110.5m.

Description. Rhabdosome up to 23mm long with slightly ovate cross-section. Widens quickly from 0.8 to 1.1mm (0.7 to 0.8mm uncompressed) at the first thecal pair to 1.4 to 1.9mm (1.1 to 1.35mm) at the fifth to a maximum of 2.0 to 2.4mm (1.7 to 1.8mm) achieved by the fifteenth thecal pair. Thecae spaced at 6 to 6.5 in the first 5mm and 9.5 to 11.5 in 10mm distally. They are climacograptid in shape with a parallel to slightly inclined supragenicular wall, although it invariably appears parallel in compressed form. Apertures horizontal to weakly introverted with slightly asymmetrical excavations. Sicula about 1.1mm long and is exposed to the aperture of $th1^1$ on the reverse side. Virgella up to 0.9mm long. Median septum complete distally although its point of origin cannot be determined exactly.

Remarks. The present specimens match very well with those described by Churkin and Carter (1970) and differ from *H. medius medius* only in having a consistently short virgella. It differs from *H. rectangularis* (M'Coy) in having a wider, more blunt proximal end. In the absence of well preserved proximal parts, however, the two species can be easily confused.

Uncompressed specimens bear a strong resemblance to "immature" rhabdosomes of *Pseudoglyptograptus* n. sp., in which the apertural processes of the latter have not developed. They differ in that the supragenicular walls of this species are straight, the apertures are generally more nearly horizontal and the thecae are more widely spaced, especially proximally. "Mature" rhabdosomes of P. n. sp. are easily distinguished by the strongly concavo-convex supragenicular profile, the pronounced apertural process found on the more proximal thecae and the lesser distal width.

Hedrograptus minutus (Carruthers, 1868)

Text-figure 19N,O, cf. 19P.

1868 pars Climacograptus minutus Carruthers, p. 182, pl. 5, fig. 10a.

1906 ? Climacograptus minutus Carruthers; Elles and Wood, pp. 211-212, pl. 27, figs. 12a-c; text-fig. 142.

1934 Climacograptus minutus Carruthers; Hsü, p. 61, pl. 4, fig, 10.

1967 Hedrograptus mirnyensis Obut and Sobolevskaya, pp. 47-48, pl. 1, figs. 4-9.

1969 Climacograptus minutus Carruthers; Strachan, pp. 193-194, pl. 4, fig. 1; figs. 3b,4b.

1970 Climacograptus minutus? Carruthers; Churkin and Carter, p. 17, pl. 1, fig. 6; text-fig. 6C.

1975 Hedrograptus mirnyensis Obut and Sobolevskaya; Obut and Sobolevskaya, pp. 147-148, pl. 6, fig. 1.

1978 Climacograptus minutus Carruthers; Chen and Lin, pp. 28-29, pl. 4, figs. 4-8.

1978 ? Climacograptus minutus Carruthers; Ye, p. 459, pl.

174, fig. 16.

1980 Climacograptus mirnyensis (Obut and Sobolevskaya); Koren' et al., pp. 137-138, pl. 39, figs. 1,3; text-fig. 39.

1983 Climacograptus minutus Carruthers; Huang and Lu, p. 134, pl. 2, fig. 8; pl. 7, fig. 20.

1983 Climacograptus mirnyensis (Obut and Sobolevskaya); Koren' and Sobolevskaya, pp. 132-133; pl. 37, figs. 2-5; text-fig. 47k-n.

1984a Climacograptus mirnyensis (Obut and Sobolevskaya); Chen, pp. 38-39, pl. 2, figs. 12-14; text-fig. 3f,h.

1984 Climacograptus mirnyensis (Obut and Sobolevskaya); Ge, pp. 427-428, pl. 8, fig. 5.

1984 Climacograptus mirnyensis (Obut and Sobolevskaya); Li, p. 347, pl. 14, figs. 8,11.

1984 Climacograptus minutus Carruthers; Li, p. 348, pl. 15, fig. 12.

Material. About ten moderately well to poorly preserved, compressed specimens.

Occurrence. Acuminatus Zone. Truro Island at 38.5m and cf. Huff Ridge at 110.0, 117.0 and 118.5m (lower cyphus Zone and pectinatus Subzone.

Description. Rhabdosome up to 7mm long. Widens quickly from 0.7 to 0.8mm at the first thecal pair to a maximum of 1.0 to 1.2mm by the fifth thecal pair. Thecae spaced at 7 to 8 in 5mm at the proximal end to 13.5 to 14 in 10mm distally and have typical climacograptid form with a sharp geniculum and straight, parallel supragenicular walls. Sicula is 1.2mm long and exposed for 0.4mm below th1[2]. Virgella and free virgula are up to 0.8mm long.

Remarks. The Canadian Arctic specimens almost exactly match the previous descriptions of both H. minutus and H. mirnyensis (Obut and Sobolevskaya) in dimensions and thecal form and spacing and so the two species are considered synonymous. This species is distinguished from H. miserabilis by its slightly greater average width, but more importantly by its closer thecal spacing.

Several rather poorly preserved specimens which have a narrower proximal end (0.55 to 0.6mm) but are otherwise very similar to H. minutus have been found at Huff Ridge (see under "occurrence" above). These are assigned to H. cf. H. minutus (text-fig. 19P).

Hedrograptus normalis (Lapworth, 1877)

Text-figure 19B,R,S,U.

1877 Climacograptus scalaris var. normalis Lapworth, p. 138, pl. 6, fig. 31.

1906 Climacograptus scalaris (Hisinger) var. normalis Lapworth; Elles and Wood, p. 186, pl. 26, fig. 2a-g;

text-fig. 119a-d.

1970 Climacograptus normalis Lapworth; Rickards, p. 28, pl. 1, figs. 1,7,8; text-fig. 13, figs. 7,8.

1974b Climacograptus normalis Lapworth; Hutt, pp. 19-20, pl. 1, figs. 8,9; pl. 2, figs. 1,2,?3,4.

1974 Climacograptus normalis Lapworth; Mu, et al., p. 213, pl. 99, fig. 14.

1976 Hedrograptus normalis (Lapworth); Sennikov, pp. 133-135, pl. 4, figs. 12,13.

1978 Climacograptus normalis Lapworth; Chen and Lin, pp. 29-30, pl. 4, fig. 21.

1982 Climacograptus normalis Lapworth; Lenz and McCracken, fig. 4c,d.

1983 Climacograptus normalis Lapworth; Huang and Lu, pp. 134-135, pl. 2, fig. 9; pl. 7, fig. 21.

1983 Climacograptus normalis Lapworth; Koren' and Sobolevskaya, pp. 133-135, pl. 37, figs. 1,6-11; pl. 38, figs. 1-5; pl. 39, fig. 7; text-fig. 48a-m.

1983 Climacograptus normalis Lapworth; Mu and Ni, p. 168, pl. 2, fig. 5.

1983 Climacograptus normalis Lapworth; Williams, pp. 611-615, text-figs. 3a-e; 4a-e; 7g.

1984a Climacograptus normalis Lapworth; Chen, p. 40, pl. 2, figs. 15,16; pl. 3, fig. 1; text-fig. 31.

1984 Climacograptus normalis Lapworth; Vandenberg et al., fig. 10a,b.

Material. Numerous compressed specimens in varying states of preservation, mostly fragmentary and rather poorly preserved.

Occurrence. Acinaces and lower cyphus zones. Trold Fiord at 52.0m and Huff Ridge at 100.5, 102.0, 103.0, 106.0, 110.5 and 111.0 to 112.0m.

Description. Rhabdosome up to at least 11.5mm long (excluding virgella). Widens from 0.6 to 0.8mm at the first thecal pair to 0.9 to 1.3mm at the fifth to a maximum of 1.3 to 1.5mm. Thecae spaced at 9.5 to 11 in 10mm, occasionally somewhat higher proximally, and are climacograptid in shape. Virgella present, in some specimens very long, up to 5.8mm.

Remarks. Although the present specimens are rather poorly preserved, their dimensions and tapering rhabdosomal form are characteristic of this species.

Hedrograptus rectangularis (M'Coy, 1850)

Text-figure 19Q,T,V,W,Y,Z,CC.

1850 Diplograpsus rectangularis (M'Coy); M'Coy, p. 271.
1906 Climacograptus rectangularis (M'Coy); Elles and Wood, pp. 187-188, pl. 26, fig. 5a-c; text-fig. 121a,b.
1970 Climacograptus rectangularis (M'Coy); Rickards, pp. 30-31, pl. 3, fig. 1; text-fig. 13, fig. 5.

1974b *Climacograptus rectangularis* (M'Coy); Hutt, p. 19, pl. 1, figs. 4,5.

1975 *Climacograptus rectangularis* (M'Coy); Bjerreskov, p. 24, pl. 4A.

1975 *Hedrograptus rectangularis* (M'Coy); Obut and Sobolevskaya, pp. 148-149, pl. 8, fig. 2.

1976 *Hedrograptus rectangularis* (M'Coy); Sennikov, pp. 135-138, pl. 5, figs. 1-3.

1980 *Hedrograptus rectangularis* (M'Coy); Obut and Sennikov, pl. 1, fig. 6.

1982 *Climacograptus rectangularis* (M'Coy); Lenz and McCracken, fig. 5d.

1983 *Climacograptus rectangularis* (M'Coy); Huang and Lu, pp. 135-136, pl. 2, figs. 10,11.

Material. Numerous compressed specimens, well to poorly preserved.

Occurrence. Upper *acinaces* Zone to *pectinatus* Subzone. Trold Fiord at 54.0, 56.5, 60.0, 61.0 and 62.5m and Huff Ridge at 104.0, 106.0, 110.0, 111.0 to 112.0, 112.0-112.5, 112.5 and 117.0m.

Description. Rhabdosome up to at least 35mm long. Width at the first thecal pair is 0.7 to 0.9mm which increases only slightly over the first three of four thecal pairs. After this it increases to 1.1 to 1.4 at the fifth thecal pair to a maximum of 2.2 to 2.7mm, achieved between thecal pair 15 to 20. Thecae number 5 to 6 in first 5mm, 9 to 10 in 10mm distally and are climacograptid in shape. Subscalariform views are most common. Sicula length cannot be determined but is exposed for 0.2 to 0.3mm below th1[2]. Aperture bears a virgella up to 1.4mm long.

Remarks. The unique rhabdosomal form of the narrow, nearly parallel-sided proximal end, combined with the robust distal portion distinguishes this species.

A distinctive variant of this species has been found in two of the present samples (TF-54.0 and HR-112.5). The proximal end of this form is characterized by a long (up to 2.7mm), thick virgella as well as variable development of spines on the first few thecal pairs (text-fig. 19Q,Y,Z). Genicular spines are present up to as high as the fourth or fifth thecal pair and a mesial spine may be present on th1[1] or, rarely, on th1[2]. In addition the sicula may bear an apertural spine. The longest of these spines is 2.0mm. Other details of the sicula cannot be discerned.

The spinose forms resemble normal specimens of *H. rectangularis* in all other respects and they only occur in samples containing the latter. For this reason they are considered a variant of *H. rectangularis* rather than a new species or subspecies. A similar instance of a "spiny" variant of *Hedrograptus medius* was reported by Elles and Wood (1906).

Hedrograptus scalaris ferganensis Obut, 1949

Text-figure 19 X,AA,BB,FF,GG.

1949 *Climacograptus scalaris* var. *ferganensis* Obut, p. 12, pl. 1, fig. 1a,b.

1954 *Climacograptus* aff. *scalaris* (Hisinger); Barrass, pp. 66-71, figs. 9-11.

1966 *Hedrograptus ferganensis* (Obut); Obut and Sobolevskaya, pp. 9-10, pl. 3, fig. 2.

1970 *Climacograptus scalaris* (Hisinger); Churkin and Carter, p. 19, pl. 1, figs. 10-11; text-fig. 7G.

Material. Numerous compressed specimens, very well to poorly preserved.

Occurrence. Upper *acinaces*, upper *cyphus* to lower *convolutus* and upper *convolutus*? zones. Snowblind Creek at 170m, Trold Fiord at 61.0? and 63.0 and Huff Ridge at 107.0, 111.0-112.0, 112.0-112.5, 113.5 121.0, and 124.0.

Description. Rhabdosome up to 15.0mm long (excluding virgella and virgula). Width 0.7 to 0.9mm at the first thecal pair, 1.2 to 1.4 at the fifth thecal pair, maximum of 1.2 to 1.7mm (av. 1.5mm); in many specimens decreases distally by 0.1 to 0.2mm. Thecae spaced at 6.0 to 7.5 in the first 5mm and 10 to 13 in 10mm distally. Virgella up to

1.1mm long.

Remarks. The present material differs from the type subspecies redescribed by Rickards (1972) in that the thecae are, on average, more closely spaced, and many specimens show a distal narrowing. In both of these respects the present specimens resemble those of Churkin and Carter (1970) who illustrated a distally narrowing specimen (Pl. 1, fig. 10) and record thecal spacing of 11 to 14 in 10mm. The present material differs from *H. ferganensis* as described by Obut and Sobolevskaya (1966) only in that the present specimens show a wider range of variation in their dimensions and thecal spacing. For this reason, this material, that of Churkin and Carter (1970) and *H. ferganensis* are all considered synonymous. They are retained as a subspecies of *H. scalaris* (Hisinger) because of the very close similarities between them, especially in the rhabdosomal form.

The specimens assigned to *Climacograptus* aff. *scalaris* by Barrass (1954) resemble this subspecies in all respects including the wide proximal end, maximum width of 1.5mm (compressed) and close thecal spacing as well as in the thecal form. None of the specimens illustrated by Barrass is long enough to see if they taper distally.

Hedrograptus cf. H. simplex (Rickards, 1970)

Plate 1, figures 7-9.

Material. Four well preserved, uncompressed specimens.

Occurrence. Curtus Zone?. Rookery Creek at 80-105m (loose).

Description. Rhabdosome up to 3.2mm long, circular in cross-section. Width at the first thecal pair is 0.6mm and this may increase to 0.65 or 0.7mm distally. Thecae spaced at 7.5 to 9 in 5mm and are climacograptid but with the slightly introverted apertures extending into a weak lip in two of the specimens. Sicula length cannot be determined but is exposed for about 0.4mm on the obverse side and for 0.2mm below $th1^2$ and bears a virgella up to 0.2mm long. Median septum is complete.

Remarks. This species differs from Hedrograptus simplex (Rickards, 1970) in that it is somewhat narrower, has a slightly higher thecal spacing. The development of a weak apertural lip, however, allies the present specimens with Rickards' species. Although the lip is not seen in all of the present specimens, similar structures seen on specimens of Pseudoglyptograptus n. sp. are clearly progressively developed during astogeny and are not seen on the more "immature" specimens. These specimens differ from species of *Pseudoglyptograptus* in that the thecae show no signs of a concavoconvex supragenicular wall.

This species differs from *H. minutus* and *H. miserabilis* in the higher thecal spacing and introverted apertures.

Hedrograptus n. sp. A

Text-figure 19DD,EE,HH.

Material. Numerous compressed, rather poorly preserved specimens.

Occurrence. *Acuminatus* Zone. Truro Island at 37.0m.

Diagnosis. Small, slender climacograptid with a thick virgella which branches at its base and mesial spines on the first thecal pair.

Description. Rhabdosome up to 15mm (incomplete). Widens gradually from 0.6 to 0.7mm at the first thecal pair to 0.8mm at the fifth thecal pair to a maximum of 1.1mm achieved between the tenth and fifteenth thecal pair. Thecae spaced at 12 to 13 in 10mm throughout and appear to be typically climacograptid in shape. Proximal end bears a thick virgella which bifurcates at least once, often several times, within 0.5mm of its origin, producing up to at least four branches. In addition, the first pair of thecae each bear one (possibly two) mesial spines. In one specimen, one of the mesial spines appears to bifurcate. The maximum observed length of these basal appendages is 1.1mm, and the maximum number observed is seven, although six is common. Further details of the proximal development are unclear due to the poor state of preservation.

Remarks. The peculiar spinose proximal end distinguishes this species from all others. Aside from this it is similar to several other narrow species of Hedrograptus. From H. miserabilis (Elles and Wood) it differs in its slightly greater distal width and higher thecal spacing. From H. minutus (Carruthers) it differs in having a narrower proximal end. The species with which it may be most closely related is Hedrograptus trifilis (Manck) which has similar dimensions and also bears a pair (or trio) of proximal spines, apparently arising at the base of the virgella.

Comograptus comatus Obut and Sobolevskaya and C? tabukensis Rickards and Koren' possess a spinose proximal end but in these forms the spines arise from the sicular rim rather than from bifurcation of the virgella. In addition, both are much wider than this form.

Group 2, Hedrograptus species with glyptograptid thecae throughout.

previously reported occurrences. Churkin and Carter (1970) reported that the difference between "*Glyptograptus*" *gnomus* and *H. nikolayevi* was that the latter showed the aperture of th1[1] higher than that of th1[2], as seen in text-fig. 6 of Obut and Sobolevskaya (1966). However, many subsequent illustrations of this species by Obut and Sobolevskaya (1967, 1968, 1975) and Obut and Sennikov (1980) show that the positions of the first thecae is normal. "*Glyptograptus*" *gnomus*, which is otherwise very similar to the Russian and the Canadian specimens, is therefore considered synonymous with this species.

Hedrograptus nikolayevi differs from varieties of *G. tamariscus* in the inclination of the supragenicular walls, the strongly tapering shape and especially the presence of a median septum. Evidence of the septum can also be seen in the illustrations of the very well preserved specimens of Obut and Sobolevskaya (1968, pl. 5, figs. 4-10). *Glyptograptus laciniosus* has much less strongly sigmoidal thecae and no septum.

Glyptograptus incertus Elles and Wood has similar dimensions and proximal thecal form but *H. nikolayevi* does not show the distal decrease in degree of sigmoidal curvature seen in *G. incertus* and the latter appears to be aseptate.

Text-figure 20

All figures x5 unless othewise stated.

A,D. *Hedrograptus* cf. *H. lanpherei* (Churkin and Carter), both specimens from TF:52.0.

B. *Hedrograptus magnus* (Churkin and Carter)?, TF:47.0.

C,H. *Hedrograptus nikolayevi* (Obut), C) TF:60.0, x10; H) TF:54.0, x10.

E-G. *Hedrograptus magnus* (Churkin and Carter), all specimens from TF:56.5.

I. *Hedrograptus* cf. *H. tangshanensis* (Hsu), TC:15.0-15.5, x10.

J,L. *Hedrograptus* n. sp. B, both specimens from CM:2-5, J) x10.

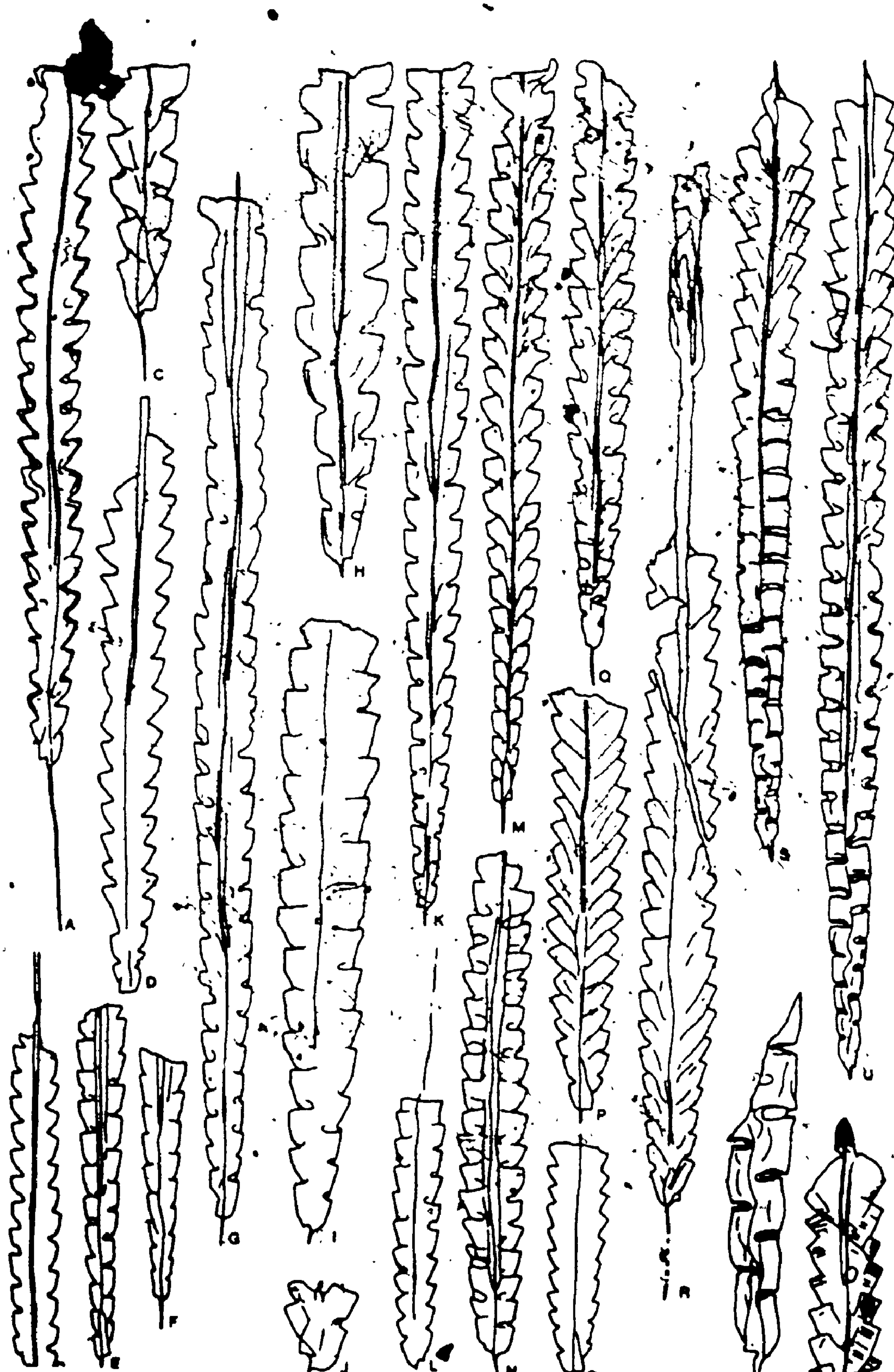
K,M. *Hedrograptus elongatus* (Churkin and Carter), both specimens from TC:13.5.

N. *Hedrograptus* sp., TF:63.0.

O. *Hedrograptus* cf. *H. elongatus* (Churkin and Carter), TF:63.0..

P-R. *Hedrograptus modestus modestus* (Lapworth); P) & Q) TF:49.0; R) TF:52.0.

S-V. *Hedrograptus* n. sp. C. all specimens from TC:13.5, T), x10.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Elles and Wood which is, on average, wider, and lacks the long, robust virgella.

<u>Hedrograptus magnus</u> (Churkin and Carter, 1970)

Text-figure 20B?,E-G.

1970 <u>Glyptograptus tamariscus magnus</u> Churkin and Carter, pp. 27-28, pl. 2, figs. 7-8; text-fig. 11A,B.

1984 non <u>Glyptograptus tamariscus magnus</u> Churkin and Carter; Lin and Chen, p. 211, pl. 1, fig. 7; pl. 2, figs. 1-7.

<u>Material</u>. About fifteen moderately well preserved, compressed specimens and several more poorly preserved fragments.

<u>Occurrence</u>. <u>Atavus</u>? and upper <u>acinaces</u> and <u>cyphus</u> zones. Twilight Creek at 13.5m, Trold Fiord at 47.0? and 56.5m and Huff Ridge at 107.0, 112.0-112.5? and 113.5m.

<u>Description</u>. Rhabdosome long, up to 36mm, and gently tapering. Widens slowly from 0.65 to 0.8mm at the first thecal pair to 0.9 to 1.25mm at the fifth thecal pair to a maximum of 1.4 to 2.0mm distally. Thecae spaced at 5 to 6.5 in the first 5mm and 9 to 11 in 10mm distally and show a strong sigmoidal curvature and a pronounced but rounded geniculum. Supragenicular walls straight to slightly convex and almost parallel to the rhabdosomal axis. Geniculum

sometimes partially obscured by subscalariform preservation. Length of sicula cannot be determined but is exposed for 0.3 to 0.4mm below th1[2]. Virgella commonly 0.5 to 0.7mm long. A complete median septum can be seen "pressed through", apparently beginning at about the sixth or seventh thecal pair.

Remarks. The present specimens match well with those of Churkin and Carter (1970) in all respects. The species is distinguished by its gently tapering proximal end and strongly sigmoidal thecae, nearly climacograptid in shape. It is distinguished from G. tamariscus by its greater overall width and the presence of a median septum. As result, it is not considered a subspecies of the latter and is raised to the species level.

Broken distal fragments resembling H. magnus have been found at TF-47.0 and HF-112.0-112.5. Lacking the characteristic tapering proximal end these are assigned questionably to H. magnus (text-fig. 2B).

The specimens assigned to G. tamariscus magnus by Lin and Chen (1984) have similar rhabdosomal form and dimensions but the thecae are much more weakly sigmoidal and have more highly inclined supragenicular walls and are therefore not considered here to belong to this species.

Nomenclatural difficulties may arise if "Diplograptus" magnus H. Lapworth, here tentatively assigned to n. gen. A, is found not to possess the proximal characteristics of that genus (see discussion of n. gen. A below). In those circumstances it, too, should be assigned to <u>Hedrograptus</u> and the Churkin and Carter species would become a junior homonym and need to be renamed.

<u>Hedrograptus nikolayevi</u> (Obut, 1965)

Plate 1, figures 10-12; plate 11, figures 1-16; plate 3, figure 1; text-figure 20C,H.

1965 <u>Glyptograptus nikolayevi</u> Obut, p. 36, pl. 1, fig. 5.

1966 <u>Glyptograptus tamariscus nikolayevi</u> Obut; Obut and Sobolevskaya, p. 14, pl. 3, figs. 8,9; text-fig. 6.

1967 <u>Glyptograptus tamariscus nikolayevi</u> Obut; Obut and Sobolevskaya, pp. 56-57, pl. 2, figs. 10-11.

1968 <u>Glyptograptus tamariscus nikolayevi</u> Obut; Obut and Sobolevskaya, pp. 67-68, pl. 5, figs. 4-10.

1970 <u>Glyptograptus gnomus</u> Churkin and Carter, pp. 24-25, pl. 2, fig. 16; text-fig. 11E.

1975 <u>Glyptograptus tamariscus nikolayevi</u> Obut; Obut and Sobolevskaya, p. 151, pl. 8, figs. 7,8.

1980 <u>Glyptograptus tamariscus nikolayevi</u> Obut; Obut and Sennikov, pp. 27-28, pl. 2, figs. 6-14.

1982 <u>Glyptograptus gnomus</u> Churkin and Carter; Lenz and McCracken, fig. 4g.

<u>Material</u>. About 20 moderately well preserved, compressed specimens and numerous very well preserved,

uncompressed ones.

Occurrence. Upper *acinaces* Zone to *pectinatus* Subzone. Cape Manning at 0-2m, Rookery Creek at 55m, Twilight Creek at 14.5m, Trold Fiord at 54.0, 60.0 and 62.5m and Huff Ridge at 109.0 and 111.0-112.0m.

Description. Rhabdosome short, up to 8.5mm long and tapering with ovate cross-section. Widens from 0.7 to 0.85mm (0.6 to 0.8mm uncompressed) at the first thecal pair to a maximum of 1.4 to 1.6mm (1.2 to 1.4mm). Thecae spaced at 6 to 7.5 in 5mm at the extreme proximal end decreasing quickly to 10.5 to 12.5 in 10mm, and show strong sigmoidal curvature and pronounced, rounded geniculum. Inclination of supragenicular wall variable from slight to about 30° depending, at least in part, on angle of compression. Apertures straight and even to slightly everted, excavations deep and relatively long. Sicula 0.9 to 1.1mm long and exposed for about 0.2 to 0.3mm below $th1^2$ and for about 0.6mm on the obverse side. Virgella up to about 1.0mm long. A partial median septum is present proximally, becomes complete distally at about the seventh thecal pair.

Remarks. The overall rhabdosomal and thecal shape of the present specimens matches well with that of the type material. The proximal width of the Canadian Arctic specimens is, on average, slightly greater than most previously-reported occurrences. Churkin and Carter (1970) reported that the difference between "*Glyptograptus*" *gnomus* and *H. nikolayevi* was that the latter showed the aperture of th1[1] higher than that of th1[2], as seen in text-fig. 6 of Obut and Sobolevskaya (1966). However, many subsequent illustrations of this species by Obut and Sobolevskaya (1967, 1968, 1975) and Obut and Sennikov (1980) show that the positions of the first thecae is normal. "*Glyptograptus*" *gnomus*, which is otherwise very similar to the Russian and the Canadian specimens, is therefore considered synonymous with this species.

Hedrograptus nikolayevi differs from varieties of *G. tamariscus* in the inclination of the supragenicular walls, the strongly tapering shape and especially the presence of a median septum. Evidence of the septum can also be seen in the illustrations of the very well preserved specimens of Obut and Sobolevskaya (1968, pl. 5, figs. 4-10). *Glyptograptus laciniosus* has much less strongly sigmoidal thecae and no septum.

Glyptograptus incertus Elles and Wood has similar dimensions and proximal thecal form but *H. nikolayevi* does not show the distal decrease in degree of sigmoidal curvature seen in *G. incertus* and the latter appears to be aseptate.

Hedrograptus? cf. H? tangshanensis (Hsu, 1934)

Text-figure 20I.

Material. Nine compressed specimens with fair preservation and several more poorly preserved ones.

Occurrence. Orbitus Subzone and convolutus Zone. Twilight Creek at 15.0 and 15.5-16.0m and Huff Ridge at 121.0, 124.0 and 126.0m.

Description. Rhabdosome up to 8mm long. Widens quickly from 0.55 to 0.7mm at the first thecal pair to a maximum of 1.45 to 1.6mm by about the seventh thecal pair. Thecae spaced at 9 to 8.5 in 5mm proximally, decreasing to 13.5 to 15 in 10mm distally. Thecae with pronounced sigmoidal curvature, decreasing slightly distally, rounded geniculum and inclined supragenicular walls. Apertures slightly introverted to horizontal, sometimes appearing slightly everted distally. Sicula indistinct but is exposed for 0.1 to 0.2mm below $th1^2$ and bears a virgella up to 0.6mm.

Remarks. Although the sicula and internal structure of this material are not discernable, the very close resemblance they bear to Hedrograptus? tangshanensis, in which Hsu (1934) observed a median septum on his uncompressed specimens, warrants their questionable assignment to the same genus. The present specimens differ from H? tangshanensis only in the higher thecal spacing found in the present material and the fact that some of the these specimens show slightly everted apertures distally (although this may be a compressional effect).

Hedrograptus n. sp. B

Plate 3, figures 2-6; text-figure 20J,L.

Material. Numerous very well preserved, uncompressed specimens in addition to well to poorly preserved compressed ones.

Occurrence. Orbitus Subzone?. Snowblind Creek at 140m and Cape Manning at 2-5m.

Diagnosis. Proximal end rather broad. Thecae glyptograptid with moderate sigmoidal curvature. Distally thecae become straight and reach a width of 1.7mm. Median septum becomes complete at about the tenth thecal pair.

Description. Rhabdosome up to 15mm long with ovate cross-section. Widens from 0.75 to 0.9mm (0.9 to 1.2mm compressed) at the first thecal pair to 1.25 to 1.5mm (1.5 to 1.7mm) at the fifth to a maximum of 1.5 to 1.7mm (1.65 to 1.8mm) achieved by about the eighth to tenth thecal pair. Thecae spaced at 6 to 7 in 5mm proximally, 11 in 10mm distally. Proximal thecae have a moderate sigmoidal curvature with slightly inclined supragenicular walls and slightly flared apertures. Distally thecae become gradually straighter until, by the eighth to tenth thecal pair, they are fully orthograptid, inclined at about 30°. Apertures are slightly everted, overlap is between 1/3 and 1/2. Sicula is 1.05 to 1.2mm long and virgella is 0.4mm long. Median septum is partial (obverse side) until the tenth thecal pair where it becomes complete.

Remarks. This species differs from other known *Hedrograptus* species by the wide proximal end with glyptograptid thecae proximally and orthograptid distally. Otherwise it is similar to *Hedrograptus nikolayevi*. It lacks the rapidly widening rhabdosome after a slender proximal portion seen in n. gen. A and also differs in possessing a possessing a primordial th2[1]. This species differs from *Glyptograptus* in having the pattern H proximal development and in having a complete median septum distally.

Hedrograptus sp.

Text-figure 20N.

Material. A single, moderately well preserved, compressed specimen.

Occurrence. *Orbitus* Subzone. Trold Fiord at 63.0m.

<u>Description</u>. Rhabdosome 18mm long. Widens from 1.3mm at the first thecal pair to a maximum of 2.2mm at the eighth thecal pair. The width slowly decreases thereafter to 2.1mm distally. Thecae spaced at 6 in the first 5mm and 10.5 in 10mm distally and are strongly sigmoidal with an abrupt but rounded geniculum. Supragenicular walls are inclined at 15 to 30° and apertures are horizontal. Details of proximal end cannot be discerned, virgella is 0.8mm long. Median septum appears to be complete, apparently arising near the aperture of $th2^2$.

<u>Remarks</u>. The rhabdosomal form of this specimen is unique with its very wide proximal end and the distal decrease in width. Otherwise it is very similar to ?<u>Glyptograptus</u> n. sp. as described by Churkin and Carter (1970) and the two may be conspecific. <u>Hedrograptus medius brevicaudatus</u> (Churkin and Carter) which occurs in the same sample has a narrower proximal end, does not taper distally, and has a sharp geniculum with vertical supragenicular walls.

Group 3, <u>Hedrograptus</u> species with biform to polyform thecae.

Hedrograptus elongatus (Churkin and Carter, 1970)

Text-figure 20K,M, cf. 20O.

1970 *Diplograptus elongatus* Churkin and Carter, p. 21, pl. 1, figs. 19-20; text-fig. 9C,D.

1984 non *Diplograptus elongatus* Churkin and Carter; Li, p. 341, pl. 12, figs. 14-17.

Material. Five well preserved, compressed specimens and numerous more poorly preserved fragments.

Occurrence. Lower *cyphus* Zone and *pectinatus* Subzone. Cape Manning at 0-2m, Twilight Creek at 13.5m and Trold Fiord at 56.5m.

Description. Rhabdosome up to at least 4cm long. Widens very gradually from 0.7 to 0.8mm at the first thecal pair to 1.1 to 1.3mm at the fifth thecal pair to 1.5 to 1.7mm at the tenth thecal pair to a maximum of 2.3 to 2.5mm, achieved by about the twentyfifth thecal pair. Thecal spacing widens from 6 in the first 5mm to 8 to 9 in 10mm distally. The first 6 to 9 thecal pairs are climacograptid in appearance after which point they become glyptograptid with flowing but pronounced sigmoidal curvature and deep apertural excavations. Sicula is 1.6mm long and is exposed for 0.4 to 0.5mm below $th1^2$. Virgella is up to 1.0mm long.

Remarks. The present specimens match well with those of Churkin and Carter (1970) although they are, on average, somewhat wider. Diplograptus aff. elongatus of Hutt (1974b) is very similar but has fully orthograptid thecae in the distal regions.

Specimens from TF-63.0 have been assigned to H. cf. H. elongatus (text-fig. 20O). These differ from H. elongatus in that they bear only 4 or 5 climacograptid thecal pairs proximally and they widen more rapidly achieving 1.4 to 1.55mm by the fifth thecal pair and 1.9 to 2.2mm by the first thecal pair. In the latter respect they resemble "Diplograptus" thuringiacus Eisel which attains a greater distal width and lower distal thecal spacing.

Hedrograptus modestus modestus (Lapworth, 1876)

Text-figure 20P-R.

1876 Diplograptus modestus Lapworth, pl. 2, fig. 33.

1907 Diplograptus (Mesograptus) modestus Lapworth; Elles and Wood, pp. 263-264, pl. 31, fig. 11a-e; text-fig. 180a-d.

1970 Diplograptus modestus modestus Lapworth; Rickards, pp. 35-36, text-fig. 13, fig. 4.

1974b Diplograptus modestus modestus Lapworth; Hutt, pp. 30-31, pl. 5, fig. 3; text-fig. 9, fig. 8.

1984 Diplograptus modestus Lapworth; [illegible], pp. 414-415, pl. 9, figs. 17,18; text-fig. 4.

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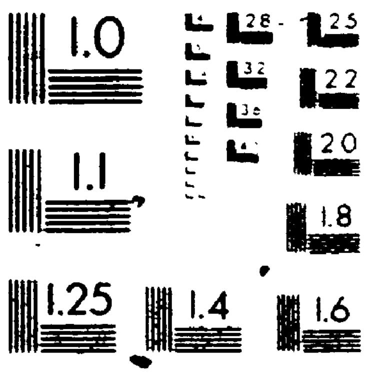


1984 Diplograptus modestus Lapworth; Li, pp. 342-343, pl. 5, fig. 9; pl. 12, figs. 7-9,13; pl. 13, figs. 1-4.

Material. Ten moderately well preserved, compressed specimens including two very early growth stages.

Occurrence. Atavus and lower acinaces zones. Trold Fiord at 49.0 and 52.0m.

Description. Rhabdosome up to 22mm long. Widens quickly from 1.1 to 1.3mm at the first thecal pair to 1.7 to 2.0mm at the fifth thecal pair to a maximum of 2.0 to 2.6mm, achieved by the seventh or eighth thecal pair. Thecae spaced at 6 to 7 in the first 5mm, decreasing to 9 to 12 in 10mm distally. Proximal thecae sigmoidally curved with a sharp to abruptly rounded geniculum. By the fourth or fifth thecal pair thecae become orthograptid. Proximal thecae overlap for about one-half their length, distally, as their angle of inclination increases to as much as 35°, overlap increases to about two-thirds. Apertures everted and alternating. Theca 1^1 originates about 0.25mm above sicular aperture and grows downward to just below the aperture at which point it turns upward. Sicula is exposed for 0.4 to 0.5mm below th12 and is 1.4 to 1.6mm long. Sicular apex reaches to aperture of $th2^1$. Virgella up to at least 3.2mm. One specimen bears a free virgula 13mm long, the distal half of which bears what appear to be vanes, expanding its width to 1.1mm.

Remarks. The shape and dimensions of the present specimens match well with those previously reported for this taxon. The only difference with the present material is that the sicula is longer than that reported by Elles and Wood (1907).

This is the first report nemal vanes for this species.

Hedrograptus n. sp. C

Text-figure 20S-V.

Material. Twelve well preserved, compressed specimens and several more poorly preserved fragments.

Occurrence. Lower *cyphus* Zone. Twilight Creek at 13.5m.

Diagnosis. Rhabdosome possesses three to five pseudoclimacograptid thecal pairs proximally, changing to climacogrptid, then to glyptograptid at about the tenth thecal pair which distally become fully orthograptid.

Description. Rhabdosome up to 33mm long (excluding virgella and virgula). Widens gradually from 0.7 to 0.8mm at the first thecal pair to 1.2 to 1.4mm at the fifth to 1.8 to 1.9mm at the tenth to a maximum of 2.3 to 2.8mm. Thecal spacing is 5 in the first 5mm and 9 to 10 in 10mm distally. Thecal form changes throughout rhabdosome length. The first three to five thecal pairs are pseudoclimacograptid in appearance with convex supragenicular walls and a sinuous median septum. The succeeding thecae up to about the tenth thecal pair are climacograptid. Between the tenth and fifteenth thecal pair they gradually change from climacograptid to glyptograptid as the geniculum becomes rounded and the supragenicular walls become inclined. Toward the distal extremity thecae gradually become orthograptid in form. Sicula is approximately 1.8mm long and bears a stout virgella up to 0.5mm long. In some views the virgella appears to be notched at its base, the notch being an extension of the sicular aperture. Distally the median septum can be seen to extend to a point up to 1.0mm beyond the distal thecae. The virgella may extend at least another 2.5mm beyond this point.

Scalariform and subscalariform are common, implying a circular to subcircular cross section, particularly in the proximal portions. In specimens preserved in subscalariform view, differential compression creates a very different impression of thecal form (text-fig. 20S). The first fifteen thecae appear pseudoclimacograptid to climacograptid. In the more distal thecae compression of the apertural margins obscures the genicula of succeeding thecae giving the impression of an abrupt transition from climacograptid to orthograptid thecae in the mesial region.

Remarks. The presence of pseudoclimacograptid thecae at the proximal end and fully orthograptid thecae distally with the full range of thecal forms in between distinguishes this species from all others. The gradual change in thecal shapes when seen in lateral view (text-fig. 20U) contrasts sharply with the apparently abrupt change when seen in subscalariform view (text-fig. 20S).

In overall rhabdosomal form this new species resembles *Hedrograptus elongatus* (Churkin and Carter) and "*Diplograptus*" n. sp. A of Churkin and Carter (1970) (probably also a species of *Hedrograptus*). The former species has fewer climacograptid thecae and lacks orthograptid thecae distally and both species lack pseudoclimacograptid thecae proximally. Otherwise this new species closely resembles "*D*". n. sp. A.

Genus *Pseudoglyptograptus* Bulman and Rickards, 1968

Type species. *G*. (*Pseudoglyptograptus*) *vas* Bulman and Rickards, 1968.

Pseudoglyptograptus cf. *P*. *vas* Bulman and Rickards, 1968

Text-figure 21A-C.

Material. Eight moderately well preserved, compressed specimens and several poorly preserved fragments.

Text-figure 21

All figures x5 unless otherwise stated.

A-C. Pseudoglyptograptus cf. P. vas Bulman and Rickards, all specimens from HR:111.0-112.0

D-I. Pseudoglyptograptus n. sp. D) SC:170; E) CM:5-7m, x10; F) SC:170; G) CM:2-5; H) TC:15.5-16.0, I) CM:5-7.

J-L. Paraclimacograptus innotatus innotatus (Nicholson), all specimens x10, from HR:112.5.

M,P. Paraclimacograptus innotatus obesus (Churkin and Carter), both specimens x10, from TI:37.0.

N,O,Q,R. Paraclimacograptus jinyangensis (Ye), all specimens from TF:52.0, N),O) & Q) x10.

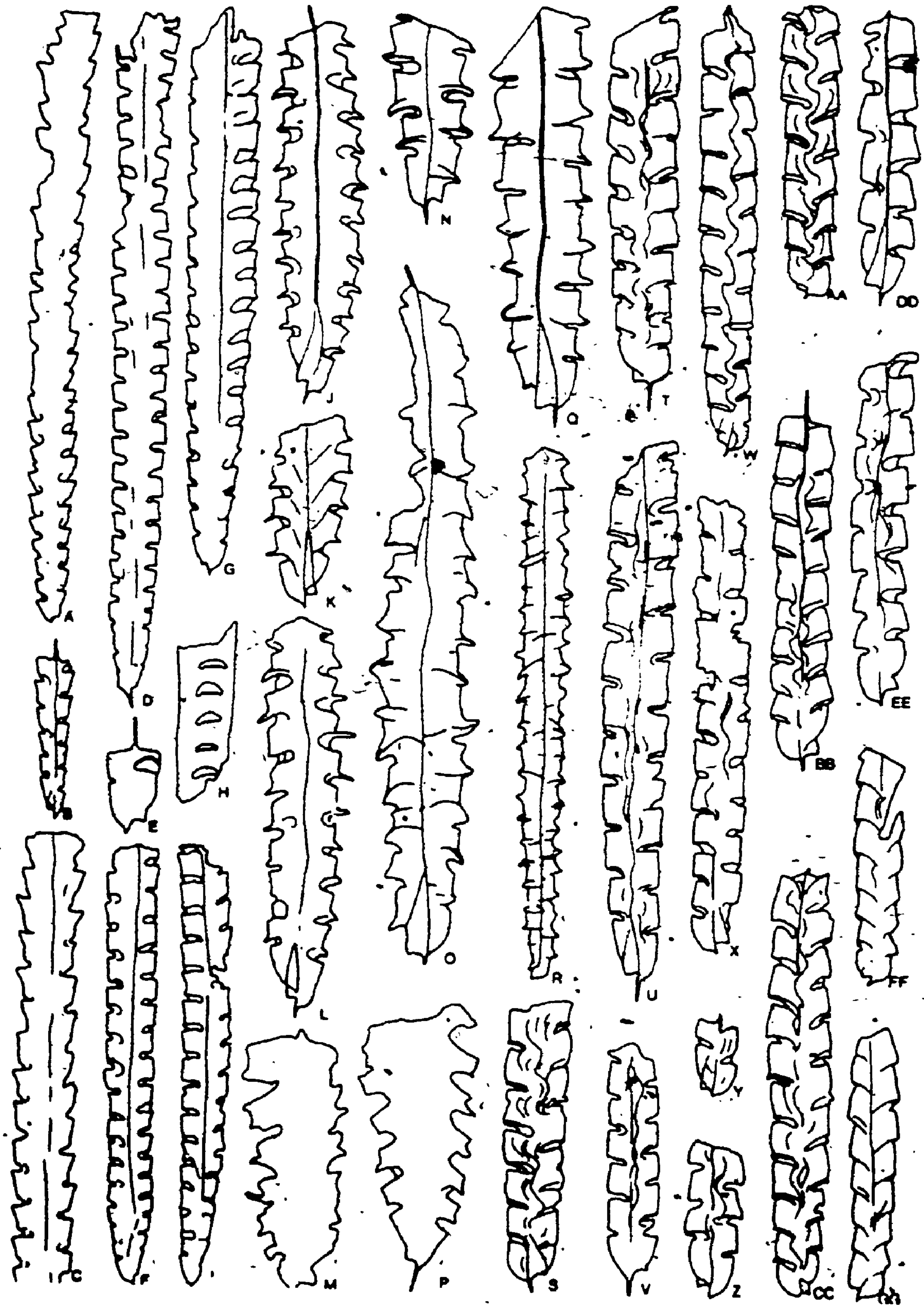
S-U. Metaclimacograptus hughesi (Nicholson): S) HR:107.0, x10; T) HR:111.0-112.0, x10; U) TF:60.0, x10.

V,X,Y. Metaclimacograptus orientalis (Obut and Sobolèvskaya): V) HR:104.0, x10; X) CM:5-7, x10; Y) TF:63.0, x10.

W,AA-CC. Metaclimacograptus undulatus (Kurck), all specimens x10, from TC:16.0 except BB) from HR:112.5.

Z,DD,EE. Clinoclimacograptus sculptus (Chen and Lin), all specimens x10 from TF:62.5.

FF,GG. Lithuanograptus minimus Paškevičius, both specimens x10, from CM:2-5.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<u>Occurrence</u>. Upper *cyphus* Zone. Huff Ridge at 111.0-112.0m.

<u>Description</u>. Rhabdosome up to at least 31mm long. Widens gradually form 0.8 to 1.0mm at the first thecal pair to 1.2 to 1.6mm at the fifth thecal pair to a maximum of 1.5 to 2.2mm. Thecae spaced at 6 to 7.5 in the first 5mm, 8.5 to 11 in 10mm distally. Thecal form is sinuous with abruptly rounded geniculum and concavoconvex supragenicular wall. Apertures straight to slightly introverted, depending on angle of compression. Sicula faintly visible on one specimen where it appears to be about 1.5mm long. Aperture bears a virgella up to 0.8mm long.

<u>Remarks</u>. The concavoconvex supragenicular wall with the aperture extending into a weak lip distinguishes this species form those of *Hedrograptus* or *Glyptograptus*. Unlike some pseudoglyptograptids, the undulose supragenicular wall is visible even in compressed specimens. This species differs from *P.* sp. 1 and *P.* sp. 2 of Rickards (1972) in that it apparently lacks the lateral apertural processes or "lappets" characteristic of these species (which otherwise appear as "climacograptids" in compressed form). *Pseudoglyptograptus vas* would probably have similar dimensions on compression although it is difficult to tell if the everted nature of the apertures of that species would be apparent. *Pseudoglyptograptus vas* has a wider thecal

spacing than most of the present specimens.

Clinoclimacograptus? washingtoni Bjerreskov (1981) also appears very similar to this species. It differs only in that the proximal end is narrower and has an undulose median septum, not visible on the present specimens. Bjerreskov reports that C. washingtoni appears climacograptid on compression. A case could be made for assignment of C. washingtoni to Pseudoglyptograptus based on both its rhabdosomal and thecal form. Despite the weakly undulose median septum (also seen in Pseudoglyptograptus n. sp.) it bears a much closer overall resemblance to P. vas and P. n. sp. than to typical specimens of Clinoclimacograptus retroversus Bulman and Rickards (1968) (the type species of that genus) or C. sculptus (Chen and Lin).

Pseudoglyptograptus n. sp.

Plate 3, figures 7-11; plate 4, figures 1-15;

text-figure 21D-I.

1890 Climacograptus scalaris (Hisinger); Törnquist, p. 23, pl. 11, figs. 12-15.

1972 G. (Pseudoglyptograptus) sp. 1 Rickards, pp. 277-279, text-fig. 1, figs. 1,4.

1972 G. (Pseudoglyptograptus) sp. 2 Rickards, p. 279, text-fig. 3, fig. 2.

1981 G. (Pseudoglyptograptus) sp. Bjerreskov, p. 18, pl. 1, figs. 6,7.

<u>Material</u>. Numerous compressed and partially compressed specimens, poorly to very well preserved as well as several very well preserved, uncompressed specimens.

<u>Occurrence</u>. <u>Orbitus</u> Subzone and lower? and upper <u>convolutus</u> Zone. Snowblind Creek at 140 and 170m, Cape Manning at 2-5 and 5-7m, Rookery Creek at 55.0m, Twilight Creek at 15.0, 15.5-16.0m and 20.5m and Huff Ridge at 128.0 and 131.0m.

<u>Description</u>. Rhabdosome appears bluntly tapering in compressed specimens, more sharp when uncompressed and may be up to 30mm long with circular cross-section. Widens rapidly from 0.7 to 1.1mm (ave. 0.8mm, 0.6 to 0.75mm uncompressed) at the first thecal pair, to 1.2 to 1.8mm (ave. 1.4mm, 0.9 to 1.15mm uncompressed) at the fifth thecal pair to a maximum of 1.4 to 2.3mm (ave. 1.8mm, 1.0 to 1.5mm uncompressed), with all or most of this width being achieved by the tenth thecal pair. Thecae spaced at 6 to 8 in 5mm (ave. 7) at the extreme proximal end to 9 to 12 in 10mm (ave. 10) distally. Thecae distinctive with a sharp geniculum, concavoconvex supragenicular wall (which appears nearly straight in many compressed specimens) and a ventral apertural lip or process marked on either side by sharp corners which appear in profile view as apertural lappets. This process is very pronounced on the proximal thecae,

especially of "mature" rhabdosomes, less so on the distal thecae although on many compressed specimens it is difficult to detect at all. Degree of apertural process development clearly dependent on maturity of rhabdosome, being almost totally absent on very "immature" specimens. Sicula is 1.0 to 1.3mm long and bears a virgella up to about 0.7mm long. Median septum complete from about the aperture of $th2^1$ and is gently undulating proximally, becoming straight distally.

Remarks. The Canadian Arctic specimens resemble *Pseudoglyptograptus* sp. 1 described by Rickards in every detail except that the present collections show a much wider range of variation in its dimensions and degree of development of the apertural processes. This variation is found, however, within several of the individual samples and so it is considered here to be intraspecific variation. The thecal form is distinctive and differs from most other species of *Pseudoglyptograptus* in that the geniculum is sharp, even in uncompressed specimens. Another species described by Rickards (1972), *P.* sp. 2, is very similar (it is wider but fits well within the range of variation described here) and has similar apertural processes which are more pronounced, further along the length of the rhabdosome and, like most other species of this genus, it has a slightly rounded geniculum. The present collection of uncompressed specimens has clearly shown, however, that the degree of development of the apertural processes along the rhabdosome as well as the degree of curvature of the supragenicular wall are dependant on the degree of maturity of the rhabdosome. Early growth stages with a few thecal pairs have only a very weak apertural lip, a slightly introverted aperture, a sharp geniculum and slightly concave supragenicular wall (pl. 4, figs. 5,6). Very mature rhabdosomes have very well developed apertural processes up to at least the tenth thecal pair and strongly concavoconvex supragenicular walls with a geniculum that appears slightly rounded (pl. 4, figs. 11,13). A complete range of intermediate forms has been found within the present collections. As a result, both of the Pseudoglyptograptus species described by Rickards are found to be within the range of variation of a single population and are considered to be conspecific.

Pseudoglyptograptus sp. described by Bjerreskov (1981) has very similar thecae to the present specimens and the dimensions and thecal spacings fit well within the range of variation found here. Bjerreskov considered that her form was too wide to be conspecific with P. sp. 1 of Rickards but it had fewer thecae with apertural processes than Rickards' P. sp. 2. Since both of Rickards' species are considered conspecific here the Greenland material also fits within the range of variation of this species.

This new species can be distinguished from P. vas and P. cf. P. vas, which have very similar dimensions and thecal spacings, by the shape of the thecae. The latter have a clearly rounded geniculum, their supragenicular curvature is more pronounced and their more flaring apertures are extended into a weak lip without the sharp corners seen on the apertural processes of *P*. n. sp.

This species resembles *Clinoclimacograptus*? *washingtoni* Bjerreskov in that the proximal portion of the median septum is undulose, and the species share similar thecal spacings and distal widths. They differ, however, in that *C*? *washingtoni* has a narrower proximal end and lacks the pronounced apertural processes.

Genus *Paraclimacograptus* Pribyl, 1947

Type species. *Climacograptus innotatus* Nicholson, 1869.

Remarks. Although no uncompressed specimens of *Paraclimacograptus* have been studied as part of this work, several lines of evidence suggest that it is of type H rather than type I proximal development. Firstly, the proximal end tends to be relatively wider and more rounded than is common for type I species. Secondly, compressed specimens in which the interthecal septa can be seen th2[1] appears to have a primordial origin (i.e. very early on the th1[2] protheca) which is not seen in type I species. Thirdly, a complete median septum is developed distally in at least some forms (e.g. *P. innotatus braziliensis*, see Stein, in Wolfart, *et al*., 1968; Jaeger, 1976) although the uncompressed specimen of *P. innotatus innotatus* illustrated by Crowther (1981) has only a partial median septum at the fourth thecal pair (Crowther, pers. comm., 1986).

Paraclimacograptus innotatus innotatus (Nicholson, 1869)

Text-figure 21J-L.

1869 Climacograptus innotatus Nicholson, p. 238, pl. 11, figs. 16,17.

1906 Climacograptus innotatus Nicholson; Elles and Wood, pp. 212-213, pl. 27, fig. 10a-e; teat-fig. 143a,?b.

1970 Climacograptus innotatus Nicholson; Churkin and Carter, pp. 14-16, pl. 1, fig. 2; text-fig. 6B.

1970 Climacograptus innotatus innotatus Nicholson; Rickards, pp. 31-32, pl. 2, fig 11.

1971 Climacograptus innotatus Nicholson; Churkin, Carter and Eberlein, p. 24, fig. D.

1974b Climacograptus innotatus innotatus Nicholson; Hutt, pp. 21-22, pl. 1, figs. 6,7,12; text-fig 8, fig. 7.

1976 Paraclimacograptus innotatus innotatus (Nicholson); Sennikov, pp. 122-123, pl. III, figs. 10-11.

1980 ? Paraclimacograptus ex gr. innotatus (Nicholson), Koren', et al., p. 140, pl. XL, figs. 1,2.

1981 Paraclimacograptus innotatus innotatus (Nicholson); Crowther, pp. 88-89, pl. 13, figs. 4-7.

1982 Climacograptus innotatus Nicholson; Lenz and McCracken, figs. 4e,k.

1984 non Paraorthograptus innotatus (Nicholson); Lin and

Chen, p. 216, pl. 4, fig. 7; pl. 6, figs. 12,13.

Material. About 20 compressed specimens, moderately well preserved.

Occurrence. Upper *cyphus* Zone. Huff Ridge at 111.0-112.0, 112.0-112.5, 112.5 and 113.5m.

Description. Rhabdosome up to at least 8mm. Widens quickly from 0.8 to 0.9mm at the first thecal pair to a maximum of 1.05 to 1.3mm by the fifth thecal pair, with a thecal spacing of 8 to 9 in 5mm. One specimen (from HR:113.5) has a maximum width of 1.4mm and 6.5 thecae in 5mm. Thecae have a thickened geniculum, expanded ventrally into a hood 0.2 to 0.3mm long. Supragenicular wall is concave and inclined slightly outward. Thecal overlap is about 1/3 proximally increasing to about 1/2 distally. Apertures are slightly everted and excavations are deep and long although often partly obscured by compression. Sicula 0.9 to 1.1mm long, exposed for about 0.2mm below $th1^2$. Aperture bears a short virgella.

Remarks. This widely occurring species shows considerable intraspecific variation in its width and thecal spacing. The Canadian Arctic collections as well as others from northwestern North America (Churkin and Carter, 1970; Lenz and McCracken, 1982) have yielded two distinct populations. The narrower population with closer thecal spacing as described above is closest to the material from Great Britain and known elsewhere as P. i. innotatus (see synonymy above). A second population is wider (1.5-2.0mm) with a more sharply tapering proximal end, named C. i. obesus by Churkin and Carter. Rickards et al. (1977) considered these two forms synonymous, but since they are easily separable and do not appear to be the result of differences in compression or deformation, they are retained here as separate subspecies. A third subspecies, P. i. braziliensis (Ruedemann)(=P. i. jordaniensis (Stein)) is consistently much longer and wider and has a more gently tapering proximal end (Jaeger, 1976).

The specimens assigned to Paraorthograptus innotatus by Lin and Chen (1984) have a different proximal end profile from typical examples of this species including antivirgellar spines on the sicular aperture and a mesial spine on $th1^1$. In addition, the rest of the thecae show paired genicular spines rather than genicular flanges. These specimens are therefore considered to be closer to Paraorthograptus pacificus (if not conspecific with it) and not a form of Paraclimacograptus.

Paraclimacograptus innotatus obesus (Churkin and Carter, 1970)

Text-figure 21M,P.

1970 Climacograptus innotatus obesus Churkin and Carter, p. 16, pl. 1, fig. 3; text-fig. 6D,E.

1982 Climacograptus innotatus obesus Churkin and Carter; Lenz and McCracken, fig. 4n.

Material. Six compressed specimens, moderately to poorly preserved.

Occurrence. Acuminatus and upper cyphus zones. Truro Island at 37.0m and Huff Ridge at 111.0-112.0m.

Description. Longest fragment 5.5mm long. Widens very quickly from 1.0 to 1.1mm at the first thecal pair to a maximum of 1.5 to 1.7mm, achieved by the fourth or fifth thecal pair. Thecae number 14 or 15 in 10mm. Geniculum expanded laterally into a hood. Supragenicular wall concave, slightly inclined outward, apertures everted. Proximal details obscure due to poor preservation.

Remarks. Despite poor preservation, these specimens are easily matched with those of Churkin and Carter (1970). Comparison with the type subspecies can be found in the remarks for that taxon.

Paraclimacograptus jinyangensis (Ye, 1978)

Text-figure 21N,O,Q,R.

1978 Climacograptus jinyangensis Ye, p. 459, pl. 174, figs. 17-18.

Material. Numerous compressed specimens, moderately well to poorly preserved.

Occurrence. Lower acinaces Zone. Trold Fiord at 52.0m and Huff Ridge at 99.0m

Description. Rhabdosome up to 19mm long. Widens from 0.7 to 0.9mm at the first thecal pair to 1.0 to 1.3mm at the fifth thecal pair to a maximum of 1.3 to 1.4mm (excluding hoods). Thecae number 7 in the first 5mm and 11.5 to 12.5 in 10mm distally. Thecae appear to be more-or-less climacograptid with a straight to slightly concave supragenicular wall. Geniculum is expanded ventrally and laterally into a hood with a thickened outer margin. Apertures straight to everted, excavations are commonly obscured by hood folded downward on compression. Sicula indistinct but appears to be 1.4mm long and bears a virgella up to 0.3mm long. Sicula is exposed below $th1^2$ for 0.4 to 0.5mm.

Remarks. The present specimens match exactly with those of Ye (1978) in rhabdosomal and thecal dimensions and spacing. In addition, the illustrations of Ye clearly show genicular flanges which appear to be of exactly the same nature as those of the present specimens.

This species of *Paraclimacograptus* differs from *P. innotatus* in being somewhat wider overall and having wider thecal spacing. *Paraclimacograptus innotatus obesus* achieves its maximum width more quickly, is consistently much shorter and has more closely spaced thecae. *Paraclimacograptus innotatus braziliensis* is considerably wider.

This species is easily distinguished from all of these, however, by the nature of its genicular hood which is expanded laterally as well as ventrally and has a thickened rim. The result, on compression, is that the hood folds over, either upward or downward, rather than flattening more simply as in *P. innotatus* ssp. Each geniculum, then, is represented by arcuate ridges, convex upward or downward or both, often obscuring the thecal apertures. They could not be confused with genicular spines as had commonly been done with *P. innotatus*.

These hoods impart a more nearly circular cross-section on the rhabdosome than in *P. innotatus* resulting in the more common occurrence of subscalariform views.

Finally, *P. jinyangensis* bears a genicular hood on th1[2] which is lacking on *P. innotatus* ssp.

Genus Metaclimacograptus Bulman and Rickards, 1968

Type species. Diplograptus hughesi Nicholson, 1869

Diagnosis (emended herein). Biserial rhabdosome, circular to ovate in cross-section. Thecae strongly geniculate with convex to straight supragenicular walls, introverted to straight apertures and deep, short excavations. Geniculum marked by a hood or, less commonly, a thickening which may partially obscure the thecal apertures. Median septum complete, beginning between the second thecal pair and showing distinct, rounded or angular undulations. Pattern H proximal development type. Proximal end profile is rounded with sicula exposed only slightly below $th1^2$ and for about 1/2 its length on the obverse side. Proximal ornamentation, other than a short virgella is lacking.

Remarks. The characteristic sinuous median septum and convex supragenicular walls are features shared by both the Ordovician and Silurian "pseudoclimacograptids" and have long been considered evidence for their close relationship. However, the proximal development types are distinctly different. The early growth stages of Metaclimacograptus very closely resemble those of other Silurian diplograptids and are much simpler than those of Pseudoclimacograptus scharenbergi as illustrated by Bulman (1947). As a result the Silurian forms must be considered as a separate genus, presumably having arisen from a separate stock, probably among the earliest Silurian hedrograptines such as H. miserabilis or H. normalis.

Metaclimacograptus orientalis (Obut and Sobolevskaya) was assigned by Rickards et al. (1977) to P. (Pseudoclimacograptus) since it lacks genicular hoods. Their illustration (fig. 3b) does show a slight thickening of the genicular rim and this can be clearly seen in the present material (e.g. pl. 5, fig. 10). In addition, the present specimens clearly show that the proximal development is of the same type as the more typical M. undulatus.

Based on the above considerations, then, Metaclimacograptus is raised to the genus level as suggested by Paškevičius (1976), Kearsley (1985) and Mitchell (1987). In compressed material, the Silurian species can be reasonably distinguished from their Ordovician counterparts in that the former lack any proximal ornamentation other than a virgella and the sicula is commonly at least a little exposed below $th1^2$. Based upon this, several new species of "Pseudoclimacograptus" described by Chen and Lin (1978) can be reassigned to Metaclimacograptus (or in a few cases Clinoclimacograptus).

The present collections have also yielded an abundance of a Lithuanograptus minimus Paškevičius and a detailed comparison can be made between this species and the uncompressed specimens of the similar Metaclimacograptus undulatus. The only appreciable differences occur in the development of the genicular hood. In M. undulatus the hood of theca x is first formed only as the flat infragenicular wall of theca x+1, with a thickened rim, which grows well in advance of the fusellae of the lateral walls of theca x+1 (pl. 6, figs. 1,3,5,6). The overhanging hood is later grown by the accretion of material onto the thickened rim. In L. minimus the infragenicular wall of theca x+1 grows at once as a concave upward surface, its edges overhanging the aperture of theca x (pl. 7, figs. 1,7-9). It too grows in advance of the fusellae of the lateral walls, apparently by about the same amount as in M. undulatus. This hood is later unconformably overgrown by the lateral thecal walls (pl. 7, figs. 7,12) but it appeared as an overhanging structure from its inception. The main distinction between these genera then is a matter of timing and degree of hood development, but the basic hood-forming structure (the infragenicular wall) and the timing of its development is the same. From a practical point of view, the distinction of these genera relies on knowledge of the details of hood development, information rarely available in compressed specimens and often not even discernible from uncompressed material. It is doubtful that these two genera could be distinguished in any but the most well preserved, compressed specimens unless the specimens could first be assigned to a species known to belong to one or the other genus.

Based on these considerations a case could be made either way for retention of Lithuanograptus as a separate genus or incorporating it into *Metaclimacograptus*. Since specimens of the type species of *Lithuanograptus* are not available for study, however, I have chosen to retain them as separate genera for the present.

Metaclimacograptus hughesi (Nicholson, 1869)

Text-figure 21S-U.

1869 *Diplograptus Hughesi* Nicholson, p. 235, pl. 11, figs. 9,10.

1906 *Climacograptus Hughesi* (Nicholson); Elles and Wood, pp. 208-210, pl. 27, fig. 11a-e; text-fig. 140a-d.

1966 *Pseudoclimacograptus hughesi* (Nicholson); Obut and Sobolevskaya, pp. 12-13, pl. 3, figs. 5,6; text-fig. 4.

1967 *Pseudoclimacograptus hughesi* (Nicholson); Obut and Sobolevskaya, pp. 52-53, pl. 2, fig. 4.

1968 *Pseudoclimacograptus* (*Metaclimacograptus*) *hughesi* (Nicholson); Bulman and Rickards, pp. 3-6, text-fig. 1a-c.

1970 *Pseudoclimacograptus* (*Metaclimacograptus*) *hughesi* (Nicholson); Hutt *et al*., p. 4, pl. 1, figs. 1-4.

1970 *Pseudoclimacograptus* (*Metaclimacograptus*) *hughesi* (Nicholson); Churkin and Carter, p. 20, pl. 1, figs. 16,17; text-fig. 8E.

1970 *Pseudoclimacograptus* (*Metaclimacograptus*) *hughesi* (Nicholson); Rickards, p. 33, text-fig. 14, fig. 6.

1971 *Climacograptus hughesi* (Nicholson); Schauer, p. 33, pl.

2, figs. 11,12; pl. 4, figs. 6,7.

1974b Pseudoclimacograptus (Metaclimacograptus) hughesi (Nicholson); Hutt, p. 22, pl. 2, figs. 6,7,13,14.

1975 Pseudoclimacograptus hughesi (Nicholson); Obut and Sobolevskaya, p. 149, pl. 8, figs. 3,4.

1976 Pseudoclimacograptus (Metaclimacograptus) hughesi (Nicholson); Sennikov, pp. 124-127, pl. 4, figs. 1-3.

1978 Pseudoclimacograptus hughesi (Nicholson); Chen and Lin, p. 36, pl. 6, figs. 3,4; text-fig. 8a-d.

1978 Pseudoclimacograptus hughesi (Nicholson); Ni, p. 379, pl. 1, figs. 12,17.

1981 Pseudoclimacograptus (Metaclimacograptus) hughesi (Nicholson); Bjerreskov, p. 16, pl. 1, fig. 9.

1982 Pseudoclimacograptus (Metaclimacograptus) hughesi (Nicholson); Lenz and McCracken, fig. 5c.

1983 Pseudoclimacograptus hughesi (Nicholson); Huang and Lu, pp. 132-133, pl. 7, figs. 13,14.

1986a Pseudoclimacograptus hughesi (Nicholson); Chen, pp. 233-234, pl. 1, fig. 12; pl. 2, figs. 1-3,5,11.

Material. Numerous compressed specimens, moderately well to poorly preserved.

Occurrence. Upper acinaces Zone to pectinatus Subzone and upper convolutus Zone. Truro Island at 49m, Trold Fiord at 54.0, 56.5, 60.0, 61.0 and 62.5m and Huff Ridge at 107.0, 110.0, 111.0-112.0 and 124.0m.

<u>Description</u>. Rhabdosome up to 10.5mm long. Widens quickly from 0.8mm to 0.9 to 1.1mm at the 2nd or 3rd thecal pair, parallel-sided thereafter. Thecae number 6 to 7 in 5mm at the extreme proximal end and 14 to 12 in 10mm distally. Supragenicular wall straight to slightly convex, apertures deep and slightly introverted. sometimes partly obscured by a weak genicular hood. Sicula exposed for 0.1 to 0.2mm below th1^2, aperture bears a virgella up to 0.3mm long. Median septum visible on many specimens, strongly undulose, angular near the proximal end on many of the stratigraphically lower specimens.

<u>Remarks</u>. The present specimens match well with previous reports of this species. The genicular hoods are clearly visible on many of the compressed specimens. Hutt (1974b) noted that early (<u>acinaces</u> and <u>cyphus</u> Zone) specimens show the more strongly undulating, sometimes angular median septum in the proximal end which is also seen in Canadian Arctic specimens of the same age. These specimens appear transitional between <u>M</u>. <u>hughesi</u> and <u>M</u>. <u>undulatus</u>.

<u>Metaclimacograptus</u> <u>orientalis</u> (Obut and Sobolevskaya, 1966)

Plate 5, figures 1-13; text-figure 21V,X,Y.

1966 <u>Pseudoclimacograptus</u> <u>orientalis</u> Obut and Sobolevskaya, p. 13, pl. 3, fig. 7, text-fig. 5.

1968 Pseudoclimacograptus orientalis Obut and Sobolevskaya; Obut and Sobolevskaya, pp. 64-65, pl. 4, figs. 12-18.

1976 Pseudoclimacograptus (Metaclimacograptus) orientalis Obut and Sobolevskaya; Sennikov, pp. 127-129, pl. 4, figs. 4,5.

1977 Pseudoclimacograptus (P.) orientalis Obut and Sobolevskaya; Rickards et al., p. 98. fig. 3b.

1978 Pseudoclimacograptus (Metaclimacograptus) orientalis Obut and Sobolevskaya; Sennikov, figs. A,B.

Material. About 25 compressed specimens, many of which are siculae or early growth stages, moderately well preserved, as well as numerous very well preserved uncompressed specimens.

Occurrence. Upper acinaces, curtus and lower convolutus zones. Cape Manning, a 0-2 and 2-5m, Trold Fiord at 63.0m and Huff Ridge at 104.0, 118.5, 124.0, 124.5 and 126.0m.

Description. Rhabdosome up to 6mm long, ovate in cross section. Width of 0.7 to 0.8mm (0.5 to 0.6mm) is usually achieved by the first thecal pair and is maintained or decreases slightly distally. Thecae number 15 to 20 in 10mm, usually higher over the first two or three thecal pairs. Thecae strongly sigmoidal with a sharp, slightly thickened geniculum. Supragenicular walls convex, sometimes appearing straight in compressed specimens. Apertures introverted and deep, occupying at least 1/3 of the rhabdosome width. Median septum originates near the aperture of $th1^1$ and shows angular undulations. Sicula 1.1 to 1.3mm long, is exposed for 0.1 to 0.2mm below $th1^2$ and bears a virgella 0.2 to 0.3mm long.

Remarks. Although no genicular hood is seen, the geniculum is clearly thickened as seen on the present uncompressed specimens and this is also seen in the illustration of Rickards et al. (1977, fig. 3b) and so this species is placed in an emended *Metaclimacograptus* as discussed in the remarks for the genus and done previously by Sennikov (1976).

The somewhat ovate rather than round cross-section results in less difference between uncompressed and compressed widths than in other metaclimacograptids. Its narrow width (especially on compression), high thecal count, angular median septum (frequently undetectable in compressed specimens) and deep, unobstructed apertures distinguish this species from others of this genus.

Metaclimacograptus fidus Koren' and Mikhaylova (1980) is very similar to *M. orientalis* but has a somewhat more slender proximal end, more widely spaced thecae and a more gently undulating septum while *M. pictus* Koren' and Mikhaylova is slightly wider with a very gently undulating septum.

Metaclimacograptus undulatus (Kurck, 1882)

Plate 6, figures 1-6; text-figure 21W,AA-CC.

1882 Climacograptus undulatus Kurck, p. 303, pl. 14, fig. 11.

1906 Climacograptus extremus Lapworth; Elles and Wood, pp. 210-211, pl. 27, figs. 13a,b; text-fig. 141a-c.

1968 Pseudoclimacograptus (Metaclimacograptus) undulatus (Kurck); Bulman and Rickards, pp. 6-8, text-figs. 1d-j,3e.

1970 Pseudoclimacograptus (Metaclimacograptus) undulatus (Kurck); Rickards, pp. 33-34, ?pl. 8, fig. 5; text-fig. 14, fig. 5.

1974b Pseudoclimacograptus (Metaclimacograptus) undulatus (Kurck); Hutt, p. 23, pl. 2, fig. 5.

1975 Pseudoclimacograptus undulatus (Kurck); Bjerreskov, p. 26, pl. 4E.

Material. Numerous compressed and partially compressed specimens, ~~moderately~~ to very well preserved and numerous very well preserved, uncompressed specimens.

Occurrence. Upper cyphus Zone, pectinatus and orbitus? subzones, and upper convolutus Zone. Snowblind Creek at 140 and 170m, Twilight Creek at 15.0m, Trold Fiord at 61.0m and Huff Ridge at 112.5m.

Description. Rhabdosome up to 8.5mm long, circular in cross-section. Widens from 0.6 to 0.85mm (0.5 to 0.55mm) at the first thecal pair to a maximum of 0.8 to 1.05mm (0.55 to 0.65mm) by the third or fourth thecal pair which is either maintained thereafter or decreases slightly distally. Thecae spaced at 8 to 9.5 in 5mm at the extreme proximal end to 14 to 17.5 in 10mm distally. Geniculum bears a well developed hood which partially obscures to thecal apertures. Supragenicular wall convex, apertures introverted and deep. Median septum strongly undulose and angular although the angularity is not always clear on compressed specimens. Sicula 0.95mm long, is exposed for 0.1 to 0.2mm below $th1^2$ and bears a virgella up to 0.6mm long.

Remarks. This species is distinguished from M. hughesi on the basis of its smaller size, closer thecal spacing, more angular median septum and more convex supragenicular walls. However, these criteria can either be altered or obscured on compression and distinguishing the two is not obvious without either a large population or else very well preserved material. In addition many of the present specimens, particularly in the convolutus Zone, have dimensions on the borderline between the two species. These specimens, however, show the strong genicular hood, strongly convex supragenicular wall and, where visible, an angular median septum (at least proximally) and these are features typical of M. undulatus.

This species is distinguished from _M. orientalis_, which has similar uncompressed dimensions, thecal spacing and an angular median septum, by the presence of the genicular hoods and a greater width on compression (owing to a circular rather than ovate cross-section).

Two, uncompressed, distal fragments recovered from Cape Manning (0-2m)(pl. 6, figures 7,8) are similar to _M. undulatus_ in the shape of the thecae, their spacing, and the angular median septum but differ in being somewhat wider (0.75mm) and have somewhat more developed genicular hoods at the growing, distal end. In addition, the apertural margins are raised into a slight lip or ventral process in their central regions. These specimens are assigned to _M._ cf. _M. undulatus_.

Genus _Clinoclimacograptus_ Bulman and Rickards, 1968

Type species. _Pseudoclimacograptus_ (_Clinoclimacograptus_) _retroversus_ Bulman and Rickards, 1968.

Remarks. Although the type species of this genus is not found in the present collections, it is clear from examination of previously published illustrations (e.g. Bulman and Rickards, 1968, text-figs. 3c,4a) that _Clinoclimacograptus_ shares the pattern H type of proximal development with _Metaclimacograptus_, distinguishing it from _Pseudoclimacograptus_ _sensu stricto_ (e.g. Bulman, 1947). Certainly, _Clinoclimacograptus sculptus_, found uncompressed here, shows all of the typical pattern H features and appears to be very similar in its internal details to *Metaclimacograptus*.

The thecal form, however, differs from that of *Metaclimacograptus* in the sinuous thecal form, weaker geniculum lacking a hood or thickening, and everted rather than introverted apertures. For these reasons, this author follows Paškevičius (1976), Kearsley (1985) and Mitchell (1987) in considering it a distinct genus.

Clinoclimacograptus sculptus (Chen and Lin, 1978)

Plate 6, figrues 9-14; text-figure 21Z,DD,EE.

1978 *Pseudoclimacograptus sculptus* Chen and Lin, p. 38, pl. 16 fig. 7; text-fig. 8g,h.

1978 *Pseudoclimacograptus sculptus* Chen and Lin; Ni, p. 397, p. 1, fig. 13.

Material. Numerous moderately well to poorly preserved, compressed specimens and numerous very well preserved, uncompressed specimens, most of which are very early growth stages.

Occurrence. *Cyphus* to lower *convolutus* zones. Cape Manning at 2-5 and 5-7m, Trold Fiord at 56.5 and 62.5m and Huff Ridge at 110.0-112.0, 112.5 and 126.0m.

Description. Rhabdosome up to 13mm long, circular in cross-section. Widens from 0.7 to 0.8mm (0.6mm) at the first thecal pair to a maximum of 0.9 to 1.1mm (0.8mm) by the third thecal pair; may decrease slightly distally. Thecae spaced at 7 to 7.5 in 5mm at the extreme proximal end, 12 in 10mm distally. Supragenicular wall convex, although often appearing straight in compressed specimens, and inclined inward. In compressed specimens apertural excavations are deep and geniculum is overhanging. In uncompressed specimens the aperture is wide in scalariform view but shallow in profile and retroverted. Median septum is strongly undulate and somewhat angular, apparently becoming more gently undulate distally although it is not visible on the majority of compressed specimens. Sicula 1.7mm long and is exposed for 0.3 to 0.4mm below th1^2. Virgella up to 0.6mm long and virgula is commonly extended beyond the distal thecae.

Remarks. The compressed specimens found here match those reported by Chen and Lin almost exactly in appearance and dimensions.

In compressed view this species does not strongly resemble *Clinoclimacograptus retroversus* Bulman and Rickards but uncompressed specimens clearly show the sigmoidal thecal profile ending in a slightly retroverted aperture. This species differs from *C. retroversus* in that the supragenicular wall is only concave, not becoming convex near the apertures. However, the thecae clearly follow the same concavoconvex pathway and this, together with the undulose median septum, suggests that this species should be assigned to Clinoclimacograptus.

Genus Lithuanograptus Paškevičius, 1976

Type species. Lithuanograptus fusiformis Paškevičius, 1976.

Remarks. A description of the mode of development of the genicular hoods and a comparison of Lithuanograptus and Metaclimacograptus is given above in the discussion of the latter genus.

Lithuanograptus minimus Paškevičius, 1976

Plate 7, figures 1-12; text-figure 21FF,GG.

1976 Lithuanograptus minimus Paškevičius, pp. 145-147, pl. 1, figs. 11-15; pl. 2, figs. 15-20; text-fig. 3.

Material. Numerous very well preserved, uncompressed specimens and five well preserved, compressed specimens and several more poorly preserved ones.

Occurrence. Pectinatus and orbitus? subzones. Cape Manning at 0-2 and 2-5m and Rookery Creek at 55.0 and 80-105m (loose).

Description. Rhabdosome up to 5.0mm long, ovate in cross-section at the proximal end, circular distally. Width at the first thecal pair is 0.5 to 0.6mm (0.6 to 0.65mm compressed) remaining constant or increasing by up to 0.1mm distally (0.75 to 0.9mm). Thecae spaced at 8.5 to 10 in 5mm at the proximal end, decreasing to 14 to 17.5 in 10mm distally. Geniculum marked by a pronounced hood, which is curved strongly upward toward the ventral axes, overhangs and completely obscures thecal apertures throughout the rhabdosome length. Apertures introverted and supragenicular walls convex. Thecal overlap is slight. Median septum strongly undulose and angular. Sicula 1.1mm long, exposed for about 0.5 to 0.6mm on the obverse side and for 0.1mm below $th1^2$. Virgella 0.4mm long and, with apertural region of sicula, is inclined at about 20° to rhabdosomal axis.

Remarks. The present species is differentiated from *Metaclimacograptus undulatus* (Kurck) by its more convex supragenicular walls and the arcuate genicular hoods which completely obscure the thecal apertures throughout the rhabdosome length. These features can, however, be difficult to distinguish in compressed specimens where the two species could be readily confused.

Metaclimacograptus hughesi (Nicholson) is somewhat wider, has more widely spaced thecae and its apertures tend to be less introverted, with weaker genicular hoods. In addition, *M. hughesi* has a more gently undulating median septum.

Genus *Diplograptus* M'Coy, 1850

Type species. *Prionotus pristis* Hisinger, 1837.

"*Diplograptus*" cf. "*D*". *angustidens* Ge, 1984

Text-figure 22F,I.

Material. About 15 compressed specimens, mostly poorly preserved.

Occurrence. *Acuminatus* Zone. Truro Island at 37.0m.

Description. Rhabdosome up to at least 18mm. Widens gradually from 0.7mm at the first thecal pair to 1.1mm at the fifth thecal pair to a maximum of 1.7 to 1.8mm, achieved by the fifteenth to twentieth thecal pair. Thecae spaced at 10 in 10mm throughout. Proximal thecae with sharp geniculum and straight supragenicular walls. Between the first and fifth thecal pair supragenicular walls change from parallel to rhabdosomal axis to inclined at about 20°. Beyond this, geniculum quickly disappears and thecae are orthograptid with slightly convex to slightly concave ventral walls and everted apertures. Sicula is not visible but it bears a virgella 0.3mm long.

Remarks. The long, narrow, gently tapering rhabdosome and low number of climacograptid thecae followed immediately by orthograptid thecae are all features which serve to distinguish this species. "Diplograptus" angustidens Ge (1984) matches fairly well with the present specimens but appears to show a more gradual transition from climacograptid to orthograptid thecae and shows introverted rather than everted thecal apertures. Both of these differences, however, could be considered the result of differential compression.

The present material is too poorly preserved to try to assign this taxon within the revised generic scheme and it is not morphologically similar to any better known taxa. As result, it is retained within the "Diplograptus" form-genus until better preserved material becomes available.

N. gen. A

Type species. Diplograptus (?) tcherskyi Obut and Sobolevskaya, 1967.

Diagnosis. Pattern H species with only two primordial thecae, a delayed $th2^1$ and weakly to strongly biform thecae. Proximal end thecae climacograptid or glyptograptid with an abrupt geniculum and straight, parallel supragenicular walls and relatively close spacing. Proximal end relatively narrow and widens rather abruptly as thecae become more gently sigmoidal to almost straight distally. Partial median septum in the proximal end becomes complete at or slightly beyond the point of thecal change, between the fourth and ninth thecal pair.

Species included. "Diplograptus" tcherskyi tcherskyi Obut and Sobolevskaya, "Diplograptus" tcherskyi n. subsp. and "Glyptograptus" sinuatus sinuatus have been observed in the present material to share the attributes noted above. The following taxa appear to have similar thecal and rhabdosomal characteristics and are therefore tentatively included in n. gen. A: "Diplograptus" tcherskyi sectilis Chen and Lin; "D". tcherskyi variatus Chen; "D". thuringiacus Eisel; "D". mucroterminatus Churkin and Carter; "Glyptograptus" sinuatus crateriformis Rickards; and possibly "Diplograptus" magnus.

Remarks. Among pattern H graptolites, the delayed differentiation of th2^1, as well as a slight delay in the differentiation of th1^2, has only been observed in n. gen. A and Rhaphidograptus toernquisti. This feature, together with the unique rhabdosomal form of a narrow proximal end with more-or-less geniculate, closely spaced thecae and a rather abrupt widening and change to more gently sigmoidal, widely spaced thecae distinguishes n. gen. A from other hedrograptines. Biform species of Hedrograptus (e.g. H.

modestus and *H. elongatus*) appear to have a primordial th2[1] and do not show the abrupt widening from a narrow proximal end as does n. gen. A.

"*Diplograptus*" *tcherskyi tcherskyi* Obut and Sobolevskaya, 1967

Plate 8, figures 1-14; plate 9, figures 1-8; text-figure 22A-C,G.

1967 *Diplograptus* (?) *tcherskyi* Obut and Sobolevskaya, pp. 59-60, pl. 3, figs. 1-5.

1975 *Diplograptus tcherskyi* Obut and Sobolevskaya; Obut and Sobolevskaya, pp. 152-153, pl. 8, fig. 10.

1978 *Diplograptus tcherskyi* Obut and Sobolevskaya; Chen and Lin, p. 20, pl. 1, figs. 12,14,15.

1983 *Diplograptus tcherskyi* Obut and Sobolevskaya; Huang and Lu. p. 139, pl. 3, figs, 2-4; pl. 8, figs 3-5.

1984a *Diplograptus tcherskyi* Obut and Sobolevskaya; Chen, p. 33, pl. 1, figs. 2,5,7,11.

Material. About 20 compressed specimens, moderately well preserved and numerous very well preserved, uncompressed specimens.

Occurrence. Upper *cyphus* to lower *convolutus* zones. Cape Manning at 0-2, 2-5 and 5-7m, Trold Fiord at 60.0, 61.0? and 63.0m and Huff Ridge at 112 to 112.5, 113.5 and

Text-figure 22

All figures x5 unless otherwise stated.

A-C,G. "*Diplograptus*" *tcherskyi tcherskyi* Obut and Sobolevskaya, A) TF:60.0; B) HR:133.5; C) HR:133.5; G) TF:60.0, x10.

D,E,H. "*Diplograptus*" *tcherskyi* n. subsp., D) CM:5-7; E) SC:170; H) SC:170, x10.

F,I. "*Diplograptus*" cf. "*D*". *angustidens* Ge, both specimens from TI:37.0.

J. *Rhaphidograptus*? cf. *R*. *toernquisti* (Elles and Wood), HR:117.0.

K. *Petalograptus* cf. *P*. *altissimus* Elles and Wood, TC:28.5.

L,M. *Petalograptus cyperoides* (Törnquist), both spcimens from CM:2-5, M) x10.

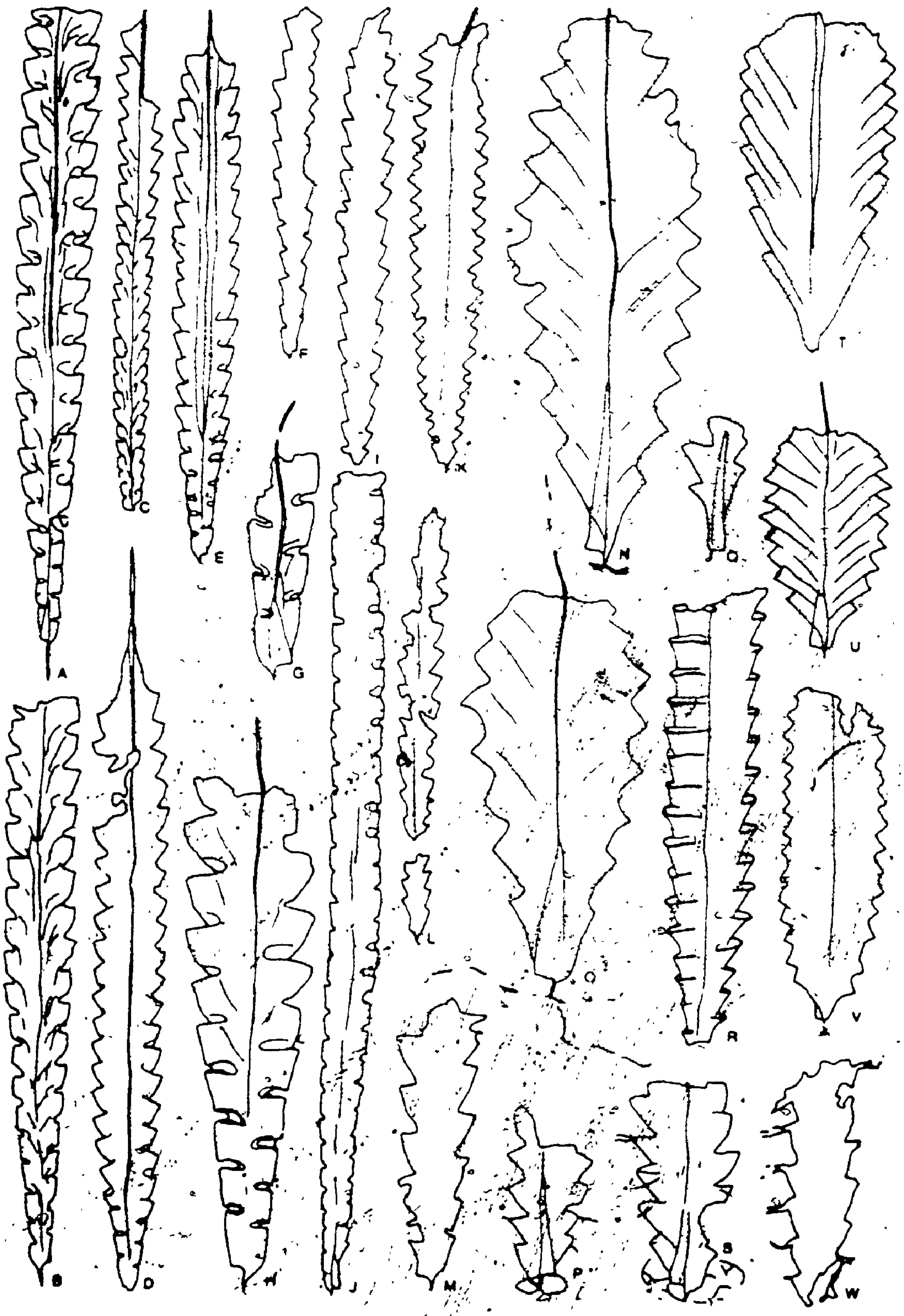
N,O. *Petalograptus ankyratus* (Mu, *et al*.), both specimens x10, from CM:5-7.

Q,R. *Petalograptus* cf. *P*. *fortuitus* (Obut and Sobolevskaya), Q) TF:61.0, x10; R) CM:2-5.

P,S,W. *Petalograptus insectiformis* (Nicholson), all specimens x10, P) TF:62.5; S) TF:61.0; W) SC:140.

T. *Petalograptus folium* (Hisinger), HR:126.0.

U,V. *Petalogratus intermedius* (Bouček and Přibyl), U) TF:61.0; V) SC:170.



A
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124.0m.

Description. Rhabdosome robust and long, longest specimen greater than 49mm, with an ovate cross-section. Widens rapidly from 0.65 to 0.75mm (0.55 to 0.65mm uncompressed) at the first thecal pair to 1.2 to 1.6mm (1.1 to 1.4mm) at the fifth to 1.7 to 2.3 at the tenth and then slowly to a maximum of 2.4 to 3.0mm (1.7 to 1.9mm). Thecae spaced at 5.5 to 6.5 in 5mm at the extreme proximal end to 8 to 10 in/10mm distally, the longest specimens showing the widest thecal spacing. Proximal 4 to 7 thecal pairs generally climacograptid although supragenicular walls may be slightly concave to slightly convex and are often somewhat inclined as the transition to glyptograptid thecae is approached. Thecae change gradually to glyptograptid and degree of sigmoidal curvature gradually decreases over the length of the rhabdosome as the supragenicular wall becomes more strongly inclined to the rhabdosomal axis. Sicula about 1.2 to 1.3mm long and it bears a virgella up to at least 1.3mm long. Median septum partial proximally (obverse side) becoming complete where the thecae change from climacograptid to glyptograptid.

Remarks. The fairly rapidly widening rhabdosome with closely-spaced proximal thecae and robust widely spaced distal thecae are characteristic of this species. These specimens differ from the type material only in that a wider variation in the number of climacograptid thecae. In this respect they resemble the Chinese populations (e.g. Chen and Lin, 1978). Generally speaking, the stratigraphically lower populations found here tend to have more climacograptid thecae in the proximal region. In addition, the proximal thecal spacing ranges to closer values; however, this may be due to the fact that for these diplograptids, proximal thecal spacing was measured over only the climacograptid thecae which are more closely spaced, whereas other authors may have included the first few glyptograptid thecae in a measurement of the first 5 or 10mm.

This species closely resembles "D". *thuringiacus* Eisel which has somewhat more widely spaced thecae proximally, widens somewhat more rapidly and has very long, robust virgella.

"*Diplograptus*" *tcherskyi* n. subsp.

Plate 10, figures 1-3; text-figure 22D,E,H.

Material. Numerous compressed, very well to poorly preserved specimens as well as several very well preserved, uncompressed specimens.

Occurrence. *Orbitus* Subzone? and *convolutus* Zone. Snowblind Creek at 140 and 170m, Cape Manning at 2-5 and 5-7m, Marshall Peninsula (loose A), Twilight Creek at 15.0 and 15.5-16.0m and Huff Ridge at 124.5, 126.0 and 131.0m.

Description. Rhabdosome up to 23mm long and tapers rapidly at the proximal end. Widens from 0.6 to 0.8mm (0.5 to 0.7mm) at the first thecal pair to 1.4 to 1.9mm (1.2 to 1.5mm) at the fifth, to a maximum of 2.1 to 2.6mm (1.75 to 2.0mm). Once the maximum width is achieved, it commonly narrows slightly at the distal end. Thecae spaced at 6.5 to 7.5 in 5mm at the extreme proximal end and decrease to 10 to 12 in 10mm distally. Proximal 4 to 5 thecal pairs are climacograptid to pseudoglyptograptid with a straight to slightly concave supragenicular wall and a sharp, thickened geniculum. Apertural excavations of these thecae are deep but narrow and often slightly introverted. Distally, the thecae quickly become glyptograptid, with a weakly sigmoidal profile, to orthograptid with highly inclined ventral walls and everted apertures. Sicula is 1.4 to 1.5mm long, with a virgella up to 1.2mm long. Median septum is partial (obverse side) proximally becoming complete where the thecae change to glyptograptid. Distally, the median septum may extend to a point up to 2.5mm beyond the last thecae, from which point the virgula may extend another 15mm. The virgella may be up to 1.5mm but is usually less than 1.0mm.

Remarks. This new subspecies differs from the type subspecies primarily in being narrower distally and having a more abrupt transition between climacograptid and glyptograptid thecae and, on average, closer thecal spacings. In addition, uncompressed specimens show that the proximal thecae of this subspecies have thickened geniculae and more constricted and slightly introverted apertures (the latter attributes are not always visible in compressed specimens). Forms transitional between these two subspecies occasionally occur (e.g. pl. 9, fig. 1).

The other named subspecies, "D". tcherskyi sectilis Chen and Lin and "N". tcherskyi variatus Chen have a greater number of thecae proximally although the latter form has similar widths to the present samples.

"Diplograptus" thuringiacus Eisel is much wider, has wider thecal spacing, reaches its maximum width more gradually (after initially widening very rapidly) and possesses a long, robust virgella (Bjerreskov, 1975).

"Glyptograptus" sinuatus sinuatus (Nicholson, 1869)
Plate 10 figures 4-10; pl. 11, figs. 1-13; plate 12, figures 1-4,7.

1869 Diplograpsus sinuatus Nicholson, p. 235, pl. 11, fig. 11.

1907 Diplograptus (Glyptograptus) sinuatus Nicholson; Elles and Wood, pp. 255-257, pl. 31, fig. 6a-c; text-fig. 175a,b.

1970 Glyptograptus sinuatus sinuatus (Nicholson); Rickards, pp. 41-42, pl. 4, fig. 1.

1974b Glyptograptus (G.) sinuatus sinuatus (Nicholson); Hutt,

p. 28, pl. 4, figs. 1-4,10.

1978 *Glyptograptus sinuatus* (Nicholson); Chen and Lin, p. 26, pl. 1, fig. 22, pl. 3, figs. 10-15.

1983 *Glyptograptus sinuatus* (Nicholson); Huang and Lu, p. 130, pl. 7, fig. 10.

Material. Numerous very well preserved, uncompressed specimens in all growth stages.

Occurrence. *Curtus* Zone?. Cape Manning at 2-5m and Rookery Creek at 55.0m.

Description. Rhabdosome up to 10mm long with ovate cross-section. Width at first thecal pair is 0.6 to 0.7mm, remaining narrow over first three or four thecal pairs, then widens quickly to 1.2 to 1.5 at the fifth thecal pair and to a maximum of 1.65 to 1.85mm. Thecae spaced at 6 to 7 in 5mm in the narrow portion of the proximal end, decreasing to 10 to 11 in 10mm distally. Proximal three or four thecal pairs have an abruptly rounded geniculum and a straight, parallel supragenicular wall. Distally, thecae become more gently sigmoidal and inclined. Apertures are slightly flared owing to a thickened margin and are horizontal to slightly introverted or everted and form shallow excavations proximally, much deeper distally. Thecal overlap is almost 1/2 distally, somewhat less proximally. Sicula is 1.1 to 1.3mm long and bears a virgella up to 0.5mm. Median septum partial (obverse side) over the proximal, narrow portion, becoming complete where the thecae change to less geniculate form and rhabdosome widens.

Remarks. The narrow proximal portion with geniculate thecae and a partial septum followed by an abrupt change to a wider, septate rhabdosome with more flowing thecae is characteristic of this species. In addition, the measurements and thecal spacing match well with those previously recorded except the maximum width, which is somewhat less in the present specimens. This is attributed to the fact that these specimens are uncompressed and most do not reach to a full distal extent where the greatest width is achieved. Thecae show no sign of torsion as reported by Elles and Wood (1907) although they do flare laterally as well as dorsoventrally and with a slight degree of compression, the apertures often appear to take a slight lateral turn. None of the present specimens show a long virgella as seen in some of the British material.

An abundance of well preserved early growth stages clearly shows that this species possesses the pattern H proximal development with foramina for both metatheca 1^1 and protheca 1^2 opening from protheca 1^1 (pl. 11, fig. 5).. The fusellar unconformity formed by the base of protheca 1^2 is pronounced but slightly delayed (pl. 11, fig. 6). The differentiation of $th2^1$ is clearly considerably delayed (pl. 11, figs. 4,10) and is not primordial. This early growth pattern, together with the slightly biform thecae and distinctive rhabdosomal form allies this species much more closely with the above mentioned n. gen. A species than with Glyptograptus or Hedrograptus.

Two specimens found in the Rookery Creek collection have developed a pair of curved lateral hoods or lappets on each of the first two or three thecal pairs (pl. 12, figs. 2-4,7). The hoods appear to have emerged largely from the lateral margins of the geniculae of the succeeding thecae and grown outward and toward the ventral margin, obscuring much of the aperture. On one of the specimens the hoods extend outward 0.3mm. Since the specimens appear to be otherwise similar to "D". sinuatus sinuatus and since the two specimens appear to be otherwise unusually thickly sclerotized, this is interpreted to be a gerontic development. This is supported by the fact that one of the other "normal" specimens shows incipient lateral hood development on the proximal thecae (pl. 10, fig. 9, pl. 12, fig. 1).

N. gen. A? n. sp.

Plate 12, figures 5,6,8-10.

Material. Four very well preserved, uncompressed specimens.

Occurrence. Orbitus Subzone? and lower convolutus

Zone?. Cape Manning at 2-5 and 5-7m.

Diagnosis. Slender species with nearly climacograptid thecae with shallow, long excavations and everted apertures. Widens from 0.55 to 0.6mm at the first thecal pair to 0.9mm at the fourth. Thecae spaced at 11.5 in 10mm and have a sharp to abruptly rounded geniculum and straight to very slightly inclined supragenicular walls. Partial median septum is present. Only two primordial thecae are present.

Description. Rhabdosome up to 3.5mm long, partially septate with an ovate cross-section. Widens from 0.55 to 0.6mm at the first thecal pair to 0.9mm measured at the fourth. Thecae spaced at 11.5 in 10mm. Infragenicular wall inclined at about 45° and geniculum is sharp in immature specimens, becoming more rounded in mature specimens with the addition of cortical tissue. Supragenicular wall parallel to very slightly inclined, apertures distinctly everted and concave in profile. Thecae overlap 2/5 their length. Sicula length is not known with certainty but is 1.1mm or less and bears a virgella up to 0.3mm long. Descending portion of protheca 1^1 is 0.35mm long and both $th1^1$ and $th1^2$ arise from foramina at its base. Theca 2^1 differentiates just below the aperture of $th1^1$ in the same manner as subsequent thecae. Virgula is roughly central and supported by a partial median septum (obverse side).

Remarks. This species differs from those of Hedrograptus in that only two primordial thecae are present. In this respect it resembles other species of n. gen. A. described above. It differs from other species of n. gen. A in that it does not show biform thecae or a complete median septum distally, but both of these may be the result of the fact that none of the specimens is preserved beyond the fourth thecal pair. It also differs from other known n. gen. A or Hedrograptus species in the strongly everted apertures. For these reasons it is only tentatively placed in this genus. In this respect it somewhat resembles Clinoclimacograptus from which it differs in the proximal end and internal structure and lesser sinuosity of the thecae. The possibility exists that this species may belong to a separate genus but such an assignment will have to await more complete material or description of other, similar species.

This species bears a very striking resemblance to Glyptograptus sp. aff. G. fastigans described herein and the proximal specimens are superficially almost indistinguishable. Internally, however, G. sp. aff. G. fastigans shows only a single foramen from the shorter descending protheca 1^1 rather than two, and the list formed at the differentiation of protheca 1^2 forms the base of the interthecal sept[illegible] whereas this list and the interthecal septum are not connected in this species. Furthermore, this new species has a partial median septum which is lacking in

G. sp. aff. G. fastigans.

Genus Rhaphidograptus Bulman, 1936

Type species. Climacograptus toernquisti Elles and Wood, 1906.

Diagnosis (emended herein). Pattern H (or possibly pattern I) graptolites with a uniserial first theca achieved by suppression of metatheca 1^2. Thecae climacograptid and may develop genicular hoods. Rhabdosome with complete median septum developed distally.

Remarks. Since Rhaphidograptus was first recognized as a genus it has been placed within the dimorphograptid genus group based on its uniserial first theca. Hutt, et al. (1970) have illustrated well preserved, isolated proximal specimens of R. toernquisti which clearly show the fusellar increments. The features seen in that material which distinguish it from the Dimorphograptinae, as defined here, are discussed above in the description of the Pattern J development type. Some additional points need to made here, however, which lead me to include Rhaphidograptus within the Hedrograptinae rather than the Petalograptinae with Agetograptus. Firstly, the dimorphograptid appearance in Rhaphidograptus is achieved by suppression of metatheca 1^2 rather than reorientation of that theca. This is not seen in any of the other known Pattern I species studied here and is unlikely to have occurred in any of the true dimorphograptids (including "*Rhaphidograptus*" *extenuatus*, here assigned to *Dimorphograptus*), most of which possess more than one uniserial theca. Secondly, there is an angular fusellar unconformity at the origin of protheca 1^2, a feature not seen in any of the studied petalograptines. Although, the origin of protheca 1^2 is later than is usual for hedrograptines, such a delay is also seen in n. gen. A species, where the fusellar unconformity is well above the sicular aperture. Like *Rhaphidograptus*, n. gen. A also has the differentiation of $th2^1$ delayed until the level of the aperture of $th1^1$. Distally, *Rhaphidograptus toernquisti* also shows features common to hedrograptines but not seen in any other known pattern I species: a complete median septum appears at the level of the fourth to eleventh thecal pair; and the thecae are strongly geniculate and have small genicular hoods (Hutt, 1974b; Bjerreskov, 1975).

As a result of these observations, *Rhaphidograptus* is tentatively placed within the Hedrograptinae and is restricted to include only *R. toernquisti* and any other allied species which can be shown to have a similar mode of proximal development and rhabdosomal form. The hedrograptine or petalograptine affinities could be certainly established if the descending portion of $th1^1$ could be seen to possess one or two foramina.

<u>Rhaphidograptus</u>? cf. <u>R</u>. <u>toernquisti</u> (Elles and Wood, 1906)

Text-figure 4J.

<u>Material</u>. One compressed specimen, with fair preservation.

<u>Occurrence</u>. <u>Pectinatus</u> Subzone. Huff Ridge at 117.0m.

<u>Description</u>. Rhabdosome 28mm long. Widens gradually from 0.5mm at the first theca to 1.0 at the fifth thecal pair. to a maximum of 1.8mm. Thecae spaced at 7 in 5mm at the proximal end to 10.5 in 10mm distally and are climacograptid in form with a sharp geniculum and vertical supragenicular walls. Details of the proximal end are not clear except that the first theca is uniserial and the sicula appears to be about 1.3mm long and reaches to the aperture of $th2^1$. The virgella is not preserved.

<u>Remarks</u>. Although this specimen closely resembles <u>R</u>. <u>toernquisti</u> a few differences can be seen. The sicula, although not entirely clear, appears to be somewhat shorter as are the first two thecae. The proximal thecal spacing is closer than previously reported and the maximum width is slightly less.

Subfamily Petalograptinae Bulman, 1955, emend.

Diagnosis (emended herein). Biserial graptolites with pattern I primordial astogeny and continuous thecal periderm. Thecae commonly glyptograptid to petalograptid, less commonly climacograptid or (possibly) pseudoglyptograptid. Proximal end commonly acicular or slender and rounded. Rhabdosome aseptate or with a partial median septum (obverse side).

Genera included. Petalograptus Suess, Cephalograptus Hopkinson, Comograptus Obut, Dischidograptus Ni, Glyptograptus Lapworth and n. gen. B.

Remarks. Description of the pattern I development type and comparisons with other subfamilies are discussed in preceding sections. However, some unique modifications of the petalograp ne rhabdosome should be pointed out here.

The normally unornamented proximal end of the Retiolitidae (apart from the virgella and its modifications) is departed from in Comograptus which is characterized by spines on the sicular rim. These spines are not considered homologous with the antivirgellar spines of the pattern F and G forms (within the Orthograptidae - see Mitchell, 1987) but are secondarily derived within this group.

Another apparent anomaly within this subfamily is

Dischidograptus Ni 1978 (type species, _D. mirabilis_ (Mu, _et al._, 1974) in which the stipes appear to diverge at the distal end. This would require that one of the distal thecae be dicalycal, which is not normally found within the petalograptines and would likely be a secondarily derived feature in this genus. The virgula also diverges at the same point and later ramifies into numerous smaller strands. Ni (1978) considered that _Petalograptus ovatus scopaecularus_ Schauer also belongs in this genus as it shows a similar distal divergence of stipes and virgula.

Genus _Petalograptus_ Suess, 1851

Type species. _Prionotus folium_ Hisinger, 1837 (=_Dittograptus_ Obut and Sobolevskaya, 1968).

Diagnosis (modified after Mitchell, 1987). Pattern I species with straight to ventrally concave thecae, disposed at moderate to high angles to the rhabdosome. Apertures usually everted. Rhabdosome ovate to tabular in cross-section with free virgula or partial median septum. May be elaborated by an ancora, thecal apertural spines or a variety of complex modifications of the virgula. Theca 1^2 may be redirected above rather than away from $th1^1$ resulting in a uniserial first theca.

Remarks. The definition of this genus was expanded by Mitchell to include Silurian species of _Orthograptus_ with the pattern I proximal end. The line of distinction between the Silurian orthograptids and petalograptids had been rather ill-defined in the past, with some Petalograptus species (e.g. P. tenuis (Barrande)) having straight thecae and a rhabdosome which is not particularly foliate and some Orthograptus species (e.g. O. mutabilis) with a relatively protracted proximal end and strongly upward-growing early thecae.

From the present specimens and records of uncompressed and partially compressed petalograptids previously published, it appears that those species previously assigned to Orthograptus tend to be aseptate with a central virgula (e.g. "O". insectiformis, "O". cyperoides; not however, "O". aff. mutabilis, Hutt, 1974b) while those previously assigned to Petalograptus tend to have a partial median septum (or possibly have the virgula embedded in the obverse wall - a condition which is difficult to distinguish from partially septate except in isolated specimens). A generic distinction could be made on this basis but I feel that this is not justified until information about the internal structure of more petalograptids is available. Elles and Wood (1908, p. 275) suggest that P. palmeus appears to have a complete septum, but the well preserved, uncompressed specimen illustrated by Rickards (in Paris, et al., 1980, pl. 1, fig. 13) clearly shows no septum is present in reverse view. Likewise, Hutt (1974b, p. 42) states that P. wilsoni appears to have a complete septum but admits that it could merely be the virgula "pressed through" the partially flattened specimen.

It should be noted that "Orthograptus" bellulus is here assigned as the type species of n. gen. B on the basis of some unique features of its proximal end not shared with other Petalograptus species.

Note also that Petalograptus physophora (Nicholson), previously assigned to Dimorphograptus, resembles Petalograptus in all respects of its proximal development and thecal and rhabdosomal form except that th1[2] appears to be redirected above th1[1] rather than away from it (or else terminated at the protheca stage as in Rhaphidograptus) giving it a dimorphograptid appearance (see under discussion of Pattern J). A case could be made for creating a new genus for P. physophora but here it is included within Petalograptus.

Petalograptus cf. P. altissimus Elles and Wood, 1908

Text-figure 22K.

Material. One moderately well preserved, compressed specimen (part and counterpart).

Occurrence. Upper minor Zone. Twilight Creek at 23.5m.

Description. Rhabdosome 15.5mm long. Widens gradually from 0.85mm at the first thecal pair to 1.8mm at the fifth thecal pair to a maximum of 2.7mm achieved at the fourteenth pair. Thecae spaced at 16 in the first 5mm to 14 in 10mm proximally. Thecae appear to be straight, simple tubes, inclined at about 45°, and with everted apertures. Virgella is about 0.3mm long - no other proximal details can be discerned.

Remarks. The characteristic narrow, tapering proximal end and close thecal spacing are both seen in the present specimen although the maximum width is somewhat less than the previously reported 3.0 to 3.5mm. This specimen closely resembles P. conicus Bouček (Bouček and Přibyl, 1941a) but Schauer (1971) and Lenz (1982a) considered the latter and P. altissimus to be synonymous, the narrower width of P. conicus being only the result of intraspecific variation. The specimen assigned to P. ?conicus by Bjerreskov (1981) has a substantially wider proximal end (1.5mm at th1[1]) and its width decreases distally (although this may be due to the fact that it is a less mature rhabdosome than that found here). In the absence of more material showing the range of variation of the Canadian Arctic population of this taxon, it is tentatively referred P. altissimus.

Petalograptus ankyratus (Mu et al., 1974)

Plate 13, figures 1-5,7,8; text-figure 22N,O.

1974 Petalolithus ankyratus Mu, et al., p. 213, pl. 98, fig.

7.

1977 Petalolithus ankyratus Mu, et al.; Wang et al., p. 340, pl. 103, fig. 12.

1978 Petalolithus ankyratus Mu, et al.; Ye, p. 468, pl. 176, fig. 9.

1982 Petalolithus ankyratus Mu, et al.; Ye and Zhao, pl. 19, figs. 1,2.

Material. About 25 well to poorly preserved, compressed specimens and several very well preserved, uncompressed specimens, most of which are early growth stages.

Occurrence. Convolutus Zone. Snowblind Creek at 170m, Cape Manning at 5-7m, Twilight Creek at 15.0, and 15.5-16.0m and Huff Ridge at 124.0, 126.0 and 131.0m.

Description. Rhabdosome tabular in cross section, up to 9mm long. Widens from 1.4 to 1.8mm at the first thecal pair to a maximum of 3.0 to 3.7mm achieved by the fifth thecal pair. Thecae spaced at 11.5 to 13.5 in 10mm. Thecae are simple tubes, 0.4 to 0.5mm wide with a slightly concave ventral wall. Overlap is about 1/2 at the proximal end increasing to 3/4 or more distally. Apertures everted and straight to slightly concave. Sicula 2.8 to 3.2mm long, about 0.25mm of which is prosicula. Virgella is divided into a simple, four-pronged ancora, the prongs of which may be as long as 1.5 to 2.0mm. The ancora is seen to be present on very early growth stages, even before any thecae have developed. Theca 1^1 begins to bud 0.45mm above the sicular aperture and grows downward for about 0.55mm before turning upward. Its total length varies from 1.45 to 1.9mm and is straight to only slightly ventrally curved. The ventral wall of $th1^2$ diverges from $th1^1$ slightly above the point where the latter turns upward and crosses the reverse side of the sicula at about 25° leaving the sicula exposed below it for 0.6 to 0.7mm. The sicula is exposed on the obverse side for 1.9 to 2.1mm. Virgula is supported by a narrow partial median septum on the obverse side and commonly extends beyond the distal thecae by as much as 2.5mm. At the growing end as many as six thecae can be seen to be incomplete and growing.

Remarks. The present specimens match very well with previous reports of this species which had only been known from southwest and south-central China. The relatively narrow, protracted proximal end and the well developed ancora are diagnostic of this species. *Petalograptus minor* (Elles, 1897) is very similar but its proximal end reaches a greater portion of its maximum width and it does not bear an ancora (although the latter may not be a safe taxonomic criterion).

Petalograptus intermedius, which has been found to occasionally bear an ancora in the present collections, differs in having a wider proximal end and generally more strongly curved proximal thecae. The distal thecae of P. ankyratus do not flare as do those of P. intermedius.

Petalograptus cyperoides (Tornquist, 1897)

Text-figure 22L,M.

1897 Diplograptus cyperoides Törnquist, p. 16, pl. 2, figs. 30-32.

1907 Diplograptus (Orthograptus) cyperoides Tornquist; Elles and Wood, pp. 238-239, pl. 29, figs. 6a-c; text-fig. 158a,b.

1970 Orthograptus cyperoides (Törnquist); Rickards, pp. 45-46, text-fig. 14, figs. 12,17.

1974b Orthograptus cyperoides (Tornquist); Hutt, p. 35, pl. 6, figs. 2-5; text-fig. p, figs. 6,7.

1974 Orthograptus cyperoides (Törnquist); Sherwin pp. 150-152, pl. 10, fig. 1,

1975 Orthograptus cyperoides (Tornquist); Bjerreskov, pp. 28-29, fig. 10D.

Material. Five rather poorly preserved, compressed specimens.

Occurrence. Orbitus Subzone?. Cape Manning at 2-5m.

Description. Rhabdosome up to 15mm long. Widens quickly from 0.8 to 0.9 mm at the first thecal pair to a maximum of 1.3 to 1.5mm. Thecae spaced at about 7 in the first 5mm decreasing to as low as 11.5 in 10mm distally. Thecae are orthograptid, inclined at about 30°, with everted apertures. Length of sicula cannot be determined but it is exposed for 0.3 to 0.4mm below th1².

Remarks. The present specimens match very well with previous reports of this species in dimensions and thecal form and spacing as well as the general form of the proximal end. The delicate thecal spines reported by Hutt (1974b) and Bjerreskov (1975) have not been seen in the present specimens but this is not suprising considering the poor state of preservation of the present specimens and the rarity of such structures in the collections in which they have been found.

Specimens of Petalograptus insectiformis (Nicholson) found in the same sample as these specimens clearly show the apertural spines and ancora, even in the most poorly preserved material.

Rickards (1970) showed that this species possesses a partial median septum (obverse side) although specimens illustrated by Hutt (1974b) and Bjerreskov (1975) are aseptate. Clearly, more work needs to be done on this species and its relationship to the similar P. insectiformis and other Petalograptus species.

Petalograptus folium (Hisinger, 1837)

Text-figure 22T.

1837 *Prionotus folium* Hisinger, p. 114, pl. 35, fig. 8.

1908 *Petalograptus folium* (Hisinger); Elles and Wood, pp. 282-284, pl. 32, fig. 8a-e; text-fig. 195.

1941b *Petalolithus folium* (Hisinger); Bouček and Přibyl, pp. 7-9, pl. 1, figs. 6,7; text-fig. 2a-c.

1971 *Petalolithus folium* (Hisinger); Schauer, p. 41, pl. 9, figs. 1,2.

1975 *Petalograptus folium* (Hisinger); Bjerreskov, pp. 35-36, fig. 12C.

1977 *Petalolithus folium* (Hisinger); Wang *et al*., p. 340, pl. 103, fig. 13.

1978 *Petalolithus folius* (Hisinger) sic; Chen and Lin, pp. 44-45, pl. 8, figs, 3-6; text-fig. 10a-e.

1978 *Petalolithus folium* (Hisinger); Ni, pl. 2, fig. 6.

1978 *Petalolithus folium* (Hisinger); Ye, p. 471, pl. 176, fig. 20.

1982a *Petalograptus folium* (Hisinger); Lenz, pp. 13-14, figs. 2C,D; 12D,E.

Material. One compressed, moderately well preserved specimen.

Occurrence. Lower *convolutus* Zone. Huff Ridge at 126.0m.

__Description__. Rhabdosome 12mm long with tapering appearance and conical proximal end. Widens from 3.5mm at the first thecal pair to a maximum of 5.3mm by the fifth thecal pair. Thecae spaced at 11 in 10mm and are long, relatively slender, straight tubes. Degree of overlap is very high, and thecae are inclined at about 30°. Apertures are slightly everted and straight. Sicula is not visible, th1[1] is 3.8mm long. Virgula becomes increasingly robust distally, reaching 0.35mm wide at the distal end.

__Remarks__. The present material matches well previous reports of this well known and distinctive taxon. The conical proximal end and long thecae with low inclination are diagnostic of this species.

__Petalograptus__ cf. __P__. __fortuitus__ (Obut and Sobolevskaya, 1968).

Plate 13, figure 6; text-figure 22Q,R.

__Material__. Eight compressed specimens, rather poorly preserved, and two well preserved, isolated but compressed fragments.

__Occurrence__. __Pectinatus__ Subzone. Cape Manning at 0-2 and 2-5m, Trold Fiord at 61.0m and Huff Ridge at 118.5m.

__Description__. Rhabdosome up to at least 15mm. Widens gradually from about 0.8mm at the first thecal pair to 1.6mm at the fifth thecal pair to a maximum of 3.2mm. Thecae spaced at 6 to 7 in 5mm at the proximal end to 9.5 in 10mm distally. Proximal end has a very tapered appearance, enhanced by the only slightly inclined, protracted first thecae. Thecae inclination increases somewhat distally although apertures remain near horizontal resulting in a pointed appearance to the thecae. Ventral walls are slightly curved outward. Sicula indistinct but appears to be 2.0mm long.

Remarks. The present fragmentary specimens clearly show the unique rhabdosomal form also seen in "*Dittograptus*" as described by Obut and Sobolevskaya. Rickards (1970) suggested that this genus could be incorporated into *Orthograptus* but is seen here as being more appropriately included in *Petalograptus* due to the protracted proximal thecae and ventral curvature of the distal ones. The present specimens differ from the type (and only) species of "*Dittograptus*", *P. fortuitus* in that the proximal end is somewhat narrower, and widens a little more gradually.

Petalograptus insectiformis (Nicholson, 1869)

Plate 14, figures 1-9; text-figure 22P,S,W.

1869 *Diplograptus insectiformis* Nicholson, p. 237, pl. 11, fig. 13.

1907 Diplograptus (Orthograptus) insectiformis Nicholson; Elles and Wood, pp. 228-229, pl. 28, fig. 7a-c; text-fig. 50a-c.

1943 Orthograptus? inopinatus Bouček, pp. 2-3, pl. 1, fig. 8; text-fig. 1a-c.

1968 Orthograptus insectiformis (Nicholson); Obut and Sobolevskaya, pp. 71-72, pl. 5, fig. 2.

1970 Orthograptus insectiformis minutus Churkin and Carter, p. 30, text-fig. 12C,H,I.

1970 Orthograptus? sp. Hutt, et al., p. 5, pl. 1, figs. 8-10.

1970 non Orthograptus cf. insectiformis (Nicholson); Rickards, pp. 46-47, text-fig. 14, fig. 18.

1971 Orthograptus? inopinatus Bouček; Schauer, p. 37, pl. 7, fig. 14.

1974b Orthograptus insectiformis (Nicholson); Hutt, pp. 34-35, text-fig. 9, figs. 1-3,13.

1974 Orthograptus insectiformis (Nicholson); Rickards and Koren', pp. 200-201, figs. 1-5.

1975 Orthograptus insectiformis (Nicholson); Bjerreskov, p. 29, fig. 10C

1978 pars Orthograptus insectiformis (Nicholson); Chen and Lin, p. 39, pl. 7, figs. 1,2 (non 3).

1984 unnamed species, Bates and Kirk, pl. 2, figs. 1-5; pl. 3, figs. 1-3; text-fig. 3a,b.

1985 Orthograptus sp. Bates and Kirk, fig. 28d.

Material. About 25 moderately well to poorly preserved, compressed specimens and numerous very well preserved, uncompressed specimens, mostly early growth stages.

Occurrence. *Curtus* and lower *convolutus*? zones. Snowblind Creek at 140m, Cape Manning at 2-5m, Trold Fiord at 61.0 and 62.5m and Huff Ridge at 126.0m?.

Description. Rhabdosome up to at least 4.5mm long and has a rectangular cross-section. Widens quickly from 0.95 to 1.3mm (0.7 to 0.8mm uncompressed) at the first thecal pair to a maximum of 1.3 to 1.65mm (1.1 to 1.2mm uncompressed). Thecae spaced at 15 to 21 in 10mm and are orthograptid in form. Thecal apertures, when viewed end on, have rectangular, rather than rounded, shape and the ventrolateral corners bear a pair of spines, each of which bifurcates near its base. One of each of the branches points ventrally, the other laterally and they may be up to 0.8mm long. Sicula is 2.3 to 2.4mm long and the virgella divides into an ancora within about 0.06mm of its origin. The ancora consists of four primary branches which curve outward and slightly upward (distally) where the end in a circular hoop about 0.6mm across. Along the four branches are what appear to be the vestiges of much finer lists which, from their arrangement, suggest that they formed a spiral around the centre of the ancora. From the outer hoop four subsidiary loops arise, each located over a main branch. These loops are curved upward and inward and partially enclose the first thecal pair. The lists forming the ancora have "seams" or grooves on one side similar to those seen on the lists of retiolitids. The seams on the main branches of the ancora are on the bottom side (away from the sicular aperture) whereas those on the outer hoop and loops are on the inner sides. These seams occasionally show ragged fringed edges suggesting that there may have been a web of very fine tissue between the lists. The virgula is central and unattached and is invariably missing in isolated distal fragments.

Remarks. This species which has been very widely reported, shows a fairly large range of variability in its dimensions but no one population appears distinct enough from another to merit its separation into subspecies. The exact nature of the apertural spines is confirmed here for the first time as being paired, each bifurcating. Since the spines are located opposite each other on the apertural margin and two of the prongs point laterally in opposite directions, it would be almost impossible to see all four prongs in compressed material and observations on the compressed specimens show that usually only one or two of the prongs (occasionally three, cf. Hutt, 1974b, text-fig. 9, fig. 2) is visible at a time on any one theca. The well preserved ancorae found in these collections are identical to those illustrated by Hutt, et al. (1970, pl. 1, figs.

8-10) except that the latter show additional small lists within the outer loops and the inner, spiral lists are more complete. For this reason the latter material is considered synonymous with the present specimens. Likewise, Bates and Kirk (1984, pl. 2, figs. 1-5, text-fig. 3a,b; 1985, fig. 28d) have illustrated an unidentified species of Orthograptus with an identical ancora and a few proximal thecae with a pair of bifurcating spines on the apertures. In their specimens the outer loops are incomplete and the outer loop branches bifurcate.

In fine structure, including the nature and location of the "seams", the ancora of this species is the same as the ancora in retiolitids and they are considered to be homologous structures (see also Bates and Kirk, 1984). Although the present specimens show jagged fringes indicative of possible fine tissue between the ancora lists no continuous films have been seen in any compressed or uncompressed specimens thus far reported.

Petalograptus intermedius (Bouček and Přibyl, 1941)

Plate 15, figs. 1-3?; text-figures 22U,V; 23A-C.

1941b Petalolithus intermedius Bouček and Přibyl, p. 10, pl. 1, fig. 5, text-fig. 1i.

1941b Petalolithus primulus Bouček and Přibyl, pp. 6-7, pl. 1, figs. 6-7; text-fig. 1h.

?1941b Petalolithus praecursor Bouček and Přibyl, pp.

Text-figure 23

All figures unless otherwise stated.

A-C. *Petalograptus intermedius* (Bouček and Přibyl), A) TC:15.0-15.5, A1, complete specimen, A2, proximal end, x10; B) TC:15.5-16.0; C) CM:2-5.

D. *Petalograptus* cf. *P. mutabilis* (Elles and Wood), x10, TF:60.0.

E,F. *Petalograptus* cf. *P. kurcki* Rickards, both specimens x10; E) TC:23.5; F) HR:156.5.

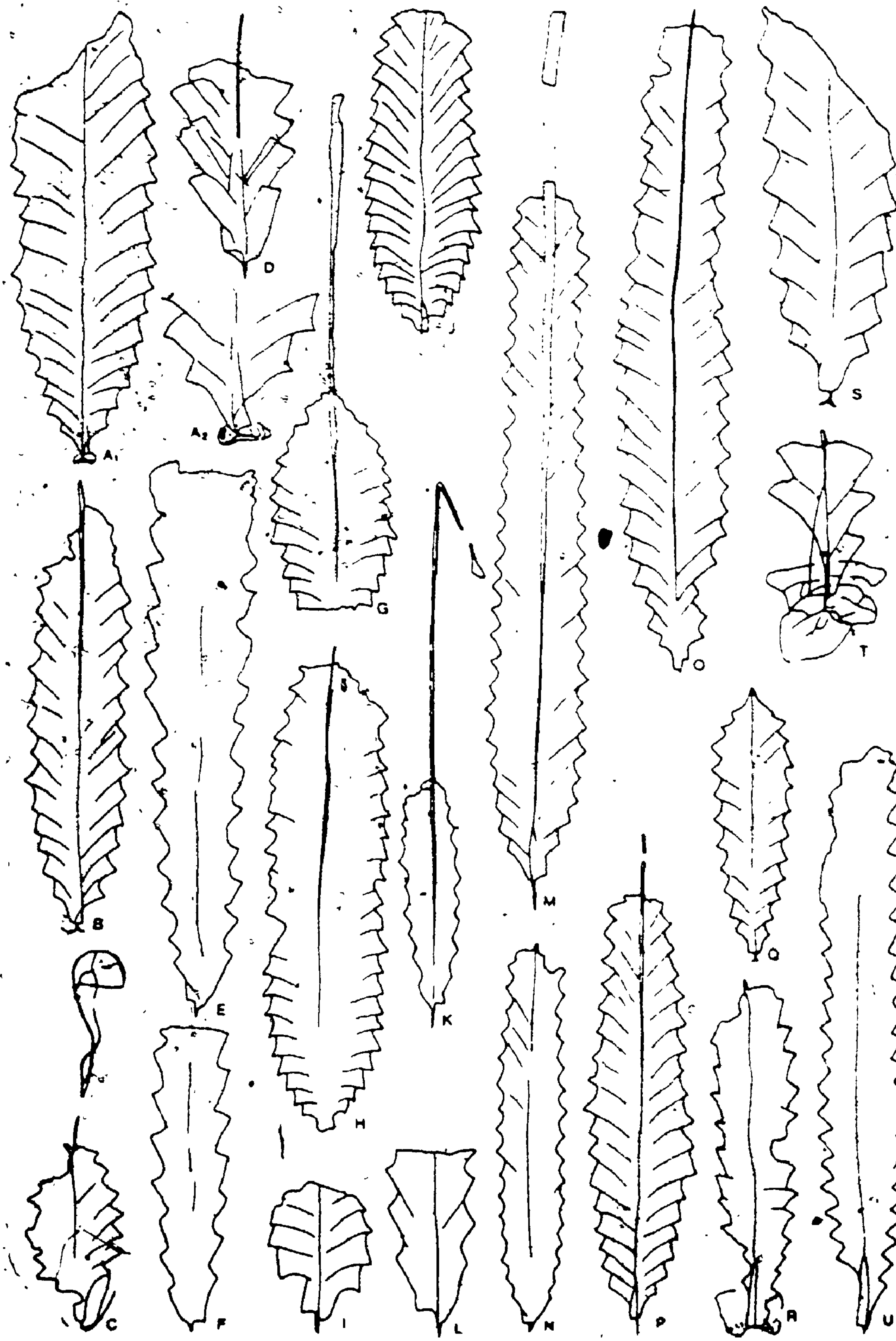
G-J. *Petalograptus ovatus wuxiensis* (Ye); G) TC:15.5-16.0; H) TC:22.5; I) TF:71.0, x10; J) TF:71.0.

K,L,N. *Petalograptus palmeus palmeus* (Barrande); K) TF:79.0; L) TF:79.0, x10; N) TF:74.0.

M,O,P. *Petalograptus palmeus clavatus* (Bouček and Přibyl); M) TC:16.0; O) TC:15.0-15.5; P) TC:15.5-16.0.

Q,S. *Petalograptus palmeus* n. subsp.; Q) HR:133.5; S) TC:15.0, x10.

R,T,U. *Petalograptus physophora alaskensis* (Churkin and Carter); R) TF:56.5; T) ~~HR:112~~.5, x10; U) HR: 113.5.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10-11, text-fig. 1j-k.

1967 Petalograptus duboyikovi Obut and Sobolevskaya, pp. 66-67, pl. 5, figs. 7,8.

1971 Petalolithus (P.) intermedius (Bouček and Přibyl); Schauer. pp. 41-42, pl. 10, figs. 1,2; pl. 11, figs. 7-9.

1975 Petalograptus dubovikovi Obut and Sobolevskaya; Obut and Sobolevskaya, p. 155, pl. 9, fig. 1.

?1976 Petalograptus praecursor (Bouček and Přibyl); Sennikov, pp. 150-151, pl. 6, figs. 6,7.

1982a Petalograptus intermedius (Bouček and Přibyl); Lenz, pp. 16-17, figs. 2E-G,I,J,N; 12F,I-L.

Material. Numerous compressed specimens, poorly to well preserved and possibly two well preserved but broken uncompressed proximal specimens and several accompanying siculae.

Occurrence. Lower curtus and upper convolutus zones. Snowblind Creek at 170m, Cape Manning at 2-5m, Rookery Creek at 55m?, Twilight Creek at 15.0 and 15.5 to 16.0m, Trold Fiord at 61.0m and Huff Ridge at 118.5m.

Description. Rhabdosome up to 11.5mm long and has an elongate oval shape. Widens from 1.8 to 2.9mm at the first thecal pair to a maximum of 3.0 to 5.0mm achieved by the sixth to eighth thecal pair. Thecae number 6.5 to 8 in the first 5mm and this generally decreases to 10.5 to 14 in 10mm distally. Proximal thecae show a weak to moderate ventral curvature while the distal thecae are generally straight with a flaring, everted aperture. Sicula is 1.8 to 2.1mm long (although one of the uncompressed specimens has a sicula 2.9 mm long) and bears a short, slender virgella. Occasional specimens have a four-pronged ancora and one of these (from Cape Manning at 2-5m) also has a long (7mm) divided virgula which forms a terminal loop, apparently with two crossing branches.

Remarks. As previously shown by Schauer (1971) and Lenz (1982a) this species has a wide range of variation in widths and, as seen here, thecal spacing as well. Although, Schauer and Lenz considered P. praecursor to be synonymous with P. intermedius the specimens described by Boucek and Přibyl (1941b) and Sennikov (1976) are consistently narrower than any of those found here or by Lenz and they may indeed represent a separate taxon. Petalograptus dubovikovi Obut and Sobolevskaya (1967) has similar dimensions, thecal spacing and thecal form (although its proximal thecae are more strongly curved than is typical of P. intermedius). It differs primarily in being shorter and more ovate but this is attributed to lesser "maturity" of those rhabdosomes. As a result, P. dubovikovi is here considered to be synonymous with P. intermedius.

An ancora has not previously been reported on P.

intermedius but ancora-bearing forms occur in the same sample as non-ancora-bearing forms (TC:61.0m) and are otherwise identical so it is considered to be part of the range of morphologic variability. The single specimen with a long, looping virgula is also otherwise similar to typical specimens. A similar virgular structure was reported by Ni (1978) on a specimen assigned to P. ex gr. folium but this specimen is much wider than any of the present specimens.

The uncompressed proximal specimens from Rookery Creek questionably assigned to this species (pl. 15, figs. 1-5,7) have curved proximal thecae and a width (at the first thecal pair) of 1.9mm, more typical of P. intermedius than P. ankyratus or P. palmeus n. subsp. One of the specimens bears a four-pronged ancora and what appears to be an aborted th1^2, represented only by a bulge covered in cortical tissue. The subsequent two thecae appear to have budded normally. Siculae with an ancora and early bud of th1l also found in this collection clearly show the short, downward growing segment of th1^1 and its single foramen opening to the reverse side of the sicula. On one of these specimens, the downward growth does not reach the sicular aperture.

Petalograptus cf. P. kurcki Rickards, 1970

Text-figure 23E,F.

Material. Two rather poorly preserved, compressd specimens.

Occurrence. Minor Zone. Twilight Creek at 23.5m and Huff Ridge at 156.5m.

Description. Rhabdosome up to 9mm long. Widens from 0.8mm at the first thecal pair to a maximum of 1.25 to 1.7mm. Thecae spaced at 16.5 to 14 in 10mm and are short straight tubes inclined at about 30°. No details of the proximal end can be discerned.

Remarks. Petalograptus kurcki is characterized by its small, narrow rhabdosome and closely spaced, simple thecae. The present specimens have a thecal spacing within the range of variation described by Rickards (1970) but have a greater maximum width. The latter may be attributed to the fact that the present sample are compressed rather than uncompressed as in the type material. More better preserved material would be necessary to make a positive identification.

Petalograptus cf. P. mutabilis (Elles and Wood, 1907)

Text-figure 23D.

Material. Three moderately well preserved early growth stages.

Occurrence. Upper cyphus Zone. Trold Fiord at 60.0.

Description. Specimens widen from 1.5mm at the first thecal pair to 2.0mm at the third thecal pair and have a thecal spacing of 6.5 in 5mm. The sicula is about 1.8mm long and bears a virgella 0.3mm long. Thecae have a normal orthograptid form with straight ventral wall and everted apertures. They are inclined at 30 to 35°. Thecae 1^1 grows slightly below the thecal aperture before its upward growth of 1.3 to 1.5mm. Thecae 1^2 appears to be straight from its origin, growing diagonally across the sicula.

Remarks. The present proximal specimens bear a close resemblance to the type material (Elles and Wood, 1907) except that the thecae of the present specimens are straight rather than having a slight ventral curvature.

Petalograptus ovatus wuxiensis (Ye, 1978)

Text-figure 23G-J.

1978 Petalolithus wuxiensis Ye, pp. 469-470, pl. 176, figs. 15,16.

Material. Numerous compressed, poorly to well preserved specimens.

Occurrence. Upper convolutus and minor zones. Twilight

Creek at 15.5-16.0, 20.5 and 22.5m, Trold Fiord at 71.0m and Huff Ridge at 160.0m.

Description. Rhabdosome up to 17mm long with ovate to elongate-ovate profile. Widens quickly from 1.3 to 1.6mm at the first thecal pair to 2.8 to 4.1mm at the fifth thecal pair and then more gradually to a maximum of 3.4 to 4.6mm by the eighth to tenth thecal pair; this may be maintained for some distance, but more commonly the rhabdosome narrows distally to a rounded distal end. Thecae are spaced at 7.5 to 10 in 5mm proximally decreasing to 12.5 to 14.5 in 10mm distally. The proximal thecae are ventrally curved, the first one to three pairs turning to more than 90^{o} to the rhabdosomal axis. Distally the thecae become straight with a flared aperture and their inclination decreases to 45 to 50^{o}. Thecal overlap is almost total. Sicula is obscured except for 0.4 to 0.5mm exposed below $th1^{2}$. A single specimen bears a 10mm free virgula 0.3mm wide.

Remarks. This form, originally described as a separate species is here considered to be a subspecies of P. *ovatus* because of its close similarity to P. o. *ovatus* (Barrande) and P. o. *scopaecularus* (Schauer). It differs from the type subspecies in having a somewhat more tapered proximal end, wider thecal spacing and achieving a more elongate rhabdosomal form. From P. o. *scopaecularus* it differs in being slightly narrower, having a wider thecal spacing and lacking the complex virgular structures described by Schauer (1971) and Bjerreskov (1975).

Petalograptus ovatoelongatus (Kurck) has a much wider proximal end, reaches its greater maximum width more quickly and has a much lower thecal spacing. Petalograptus intermedius (Bouček and Příbyl) has less strongly inclined thecae, especially proximally and a greater width at the first thecal pair giving a much more conical rather than rounded appearance to the proximal end. It also generally has a wider thecal spacing.

Petalograptus palmeus palmeus (Barrande, 1850)

Text-figure 23K,L,N.

1850 pars Graptolithus palmeus var. lata Barrande, pp. 59-63, pl. 3, figs. 3,4 (non 1,2,5-7).

1908 pars Petalograptus palmeus s.s. (Barrande); Elles and Wood, pp. 274-275, pl. 32, figs. 1a,b, ?c,d; fig. 188a (non b).

1941a Petalolithus palmeus palmeus (Barrande); Bouček and Příbyl, pp. 3-4, pl. 1, figs. 1-3; text-fig. 1, figs. 1-3.

1970 Petalograptus palmeus (Barrande); Churkin and Carter, p. 32, pl. 3, fig. 6, text-fig. 13G.

1971 Petalograptus (Pet.) palmeus palmeus (Barrande); Schauer, pp. 42-43, pl. 10, figs. 5,6.

1975 Petalograptus palmeus (Barrande); Bjerreskov, pp.

33-34, pl. 4J.

1984a Petalolithus palmeus (Barrande); Chen, pp. 45-46, pl. 4, figs. 14,21.

Material. Numerous compressed, moderately to poorly preserved specimens.

Occurrence. Minor to turriculatus-crispus zones. Snowblind Creek at 210m, Twilight Creek at 21.5 and 23.5m, Trold Fiord at 71.0, 74.0 and 79.0m and Huff Ridge at 156.5, 171.5 and 178.5m.

Description. Rhabdosome up to 22mm long (excluding virgula). Widens from 1.0 to 1.25mm at the first thecal pair to a maximum of 2.0 to 2.5, usually attained by the seventh or eighth thecal pair. Thecae spaced at 6 to 7.5 in the first 5mm to 9 to 12.5 in 10mm distally. Thecae are straight, simple tubes, inclined at 40-50° proximally, 30-40° distally. Details of the proximal end cannot be discerned. A free virgula commonly extends as much as 13mm beyond the distal thecae.

Remarks. The present specimens match well with previous reports of this well known species despite the poor preservation of most of the Cape Phillips material. A greater range of variation is found in the thecal spacing than in any previously reported populations.

Petalograptus palmeus clavatus (Bouček and Příbyl, 1941)

Text-figure 23M,O,P.

1941a Petalolithus palmeus var. clavatus Bouček and Příbyl, pp. 4-6, pl. 1, figs. 4,5; pl. 2, fig. 2; text-fig. 1, figs. 4,5.

1971 Petalolithus (Pet.) palmeus clavatus Bouček and Příbyl; Schauer, pp. 43-44, pl. 10, figs. 9,10; pl. 13, figs. 4,5.

1974 Petalolithus clavatus Bouček and Příbyl; Mu, et al., p. 213, pl. 98, fig. 14.

1982a Petalograptus cf. palmeus clavatus (Bouček and Příbyl); Lenz, pp. 20-21, fig. 13E.

1984a Petalolithus clavatus Bouček and Příbyl; Chen, p. 46, pl. 5, figs. 3,8,12.

Material. Numerous compressed, moderately to very well preserved specimens.

Occurrence. Upper convolutus and upper minor zones. Twilight Creek at 15.0, 15.5-16.0, 22.5 and 23.5m, Trold Fiord at 71.0m and Huff Ridge at 133.5m.

Description. Rhabdosome up to at least 25mm with an elongate-ovate proximal portion and straight or slightly tapering distal portion. Widens from 1.35 to 1.75mm at the first thecal pair to 2.6 to 3.5mm at the fifth thecal pair to a maximum of 2.8 to 4.0mm achieved by the seventh to tenth thecal pair. Beyond this the width decreases somewhat. Long specimens commonly show a straight distal portion 2.4 to 3.2mm wide. Thecae spaced at 6.5 to 7.5 in 5mm proximally and 10 to 12 in 10mm distally and usually show a slight ventral curvature. Apertures everted very strongly proximally, less so distally. Degree of overlap is very high (3/4 to 7/8) and thecae are inclined at 40 to 50°. Proximal end is fairly sharp with strongly ventrally curved thecae. Sicula length cannot be determined but it appears to be exposed for about 1.2mm on the obverse side and it bears a virgella up to 1.0mm long. Virgula becomes robust distally (up to 0.5mm wide) and may extend as much as 9.0mm beyond the distal thecae.

Remarks. The distinctive club-shaped appearance with the narrow, tapering proximal end distinguishes this species from all others. Petalograptus ovatoelongatus (Kurck) is wider and has a much greater width at the first thecal pair. Petalograptus palmeus palmeus is somewhat narrower and, once achieved, maintains its maximum width distally.

The Canadian Arctic specimens show a somewhat wider range of variation in width than previously reported. This may be accounted for by the relatively large population size.

Petalograptus palmeus n. subsp.

Text-figure 23Q,S.

Material. Six well preserved, compressed specimens and several more poorly preserved, compressed and somewhat distorted specimens.

Occurrence. Upper convolutus Zone. Snowblind Creek at 170m, Twilight Creek at 15.0 and 15.5 to 16.0m and Huff Ridge at 133.5m.

Diagnosis. Moderately wide (up to 2.7 to 2.9mm) straight rhabdosome (except for tapering proximal end) with closely spaced, petalograptid thecae. Proximal end bears a small ancora.

Description. Rhabdosome up to at least 9mm. Widens from 1.1 to 1.45mm at the first thecal pair to 2.7 to 2.9mm (3.4mm in one distorted specimen) at about the seventh thecal pair. Thecae spaced at 12.5 to 15 in 10mm (20 in 10mm in one distorted specimen) and are straight to (more commonly) slightly ventrally curved tubes, inclined at about 45°. Proximal thecae show weak to moderate curvature. Sicular length cannot be determined but its aperture bears what appears to be a small ancora.

Remarks. This new subspecies differs from P. palmeus

palmeus only in that it is somewhat wider and has a small ancora. It differs from *P. palmeus clavatus* in being slightly narrower in the proximal half and in lacking the club-shaped appearance.

An ancora-bearing species, *P. lanceolatus* described by Huang and Lu (1983) is similar, but is somewhat wider, has a much wider thecal spacing and a more conical proximal end. *Petalograptus ankyratus* widens more rapidly to a greater distal width and has a wider thecal spacing. *P. intermedius* is wider throughout and has flared distal thecae.

Petalograptus physophora alaskensis

(Churkin and Carter, 1970)

Text-figure 23R,T,U.

1970 *Dimorphograptus physophora alaskensis* Churkin and Carter, pp. 33-34, pl. 3, fig. 7; text-fig. 13H,I.

1982a *Dimorphograptus physophora alaskensis* Churkin and Carter; Lenz, pp. 29-30, figs. 3L,M,O; 14F,I-K.

Material. Four well preserved, compressed specimens, including two mature and two immature rhabdosomes.

Occurrence. *Cyphus* Zone. Trold Fiord at 56.5m and Huff Ridge at 112.5 and 113.5m.

Description. Rhabdosome up to 20mm long. Uniserial portion straight consisting of only one theca. Widens rapidly from 0.8 to 1.2mm at th1 to 1.8 to 2.0mm at the first biserial pair to a maximum of 2.8 to 3.1mm at about the eighth thecal pair. Width decreases slightly thereafter. Thecae spaced at 11 to 12 in 10mm throughout and are more or less straight tubes usually showing some flaring at the apertures. Overlap is high, as much as 2/3 in distal regions. Sicula is 2.0 to 2.5mm long, its apex reaching to the level of the aperture of th2[1]. Virgella divides into a complex meshwork, traces of which can be seen in three of the four present specimens. This meshwork may bear a thin membrane.

Remarks. The present specimens differ from those of Churkin and Carter (1970) in being somewhat wider and bearing a virgellar network. In the latter respect they resemble the type subspecies. The present material, however, compares very favorably with that of Lenz (1982a) who described a much wider range of rhabdosomal widths and some specimens with a proximal, mesh-like structure. Lenz pointed out the similarity between this taxon and Petalograptus obuti (Rickards and Koren', 1974). The latter species is, however, wider, has a lower distal thecal spacing and lacks the uniserial first theca. The virgellar meshwork is very similar, though, as are the overall rhabdosomal and thecal profiles suggesting a close relationship between these species.

<u>Petalograptus</u> <u>tenuis</u> (Barrande, 1850)

Text-figure 24A,D.

1850 <u>Graptolithus</u> <u>palmeus</u> var. <u>tenuis</u> Barrande, p. 61, pl. 3, fig. 2.

1908 pars <u>Diplograptus</u> <u>palmeus</u> var. <u>tenuis</u> (Barrande); Elles and Wood, pp. 276-277, pl. 32, fig. 3a,c,d (non b); text-fig. 190.

1941a <u>Petalolithus</u> <u>tenuis</u> (Barrande); Bouček and Přibyl, p. 7, pl. 2, fig. 3; text-fig. 2, figs. 8-11.

1970 <u>Petalograptus</u> <u>palmeus</u> var. <u>tenuis</u> (Barrande); Churkin and Carter, pp. 32-33, pl. 3, fig. 3; text-fig. 13A.

1971 <u>Petalolithus</u> (<u>Pet</u>.) <u>tenuis</u> (Barrande); Schauer, p. 47, pl. 14, figs. 4-7; pl. 15, figs. 8-10; pl. 43, fig. 5a,b.

1975 <u>Petalograptus</u> <u>tenuis</u> (Barrande); Bjerreskov, pp. 34-35, fig. 12A.

?1982a <u>Petalograptus</u> <u>elongatus</u> (Bouček and Přibyl); Lenz, pp. 12-13, fig. 13b,d,g.

1984a <u>Petalolithus</u> <u>tenuis</u> (Barrande); Chen, p. 43, pl. 4, figs. 3,5-7,15,18.

<u>Material</u>. Five moderately to poorly preserved, compressed specimens.

Text-figure 24

All figures x5 unless otherwise stated.

A,D. _Petalograptus tenuis_ (Barrande); A) HR:156.5, x10; D) TC:22.5.

B,E. _Petalograptus_ n. sp. A, both specimens from TC:23.5; B) x10.

C,F,G. _Petalograptus_? n. sp. B, all specimens from TF:47.0.

H,I,K. _Cephalograptus tubulariformis_ (Nicholson), all speciemns from HR:128.0.

J,L-N. _Glyptograptus elegans_ n. subsp., all specimens from TF:71.0 except M from TC:23.5; n) x10.

O,R. _Glyptograptus enodis enodis_ Packham; O) TF:62.5, x10; R) HR:188.5; x10.

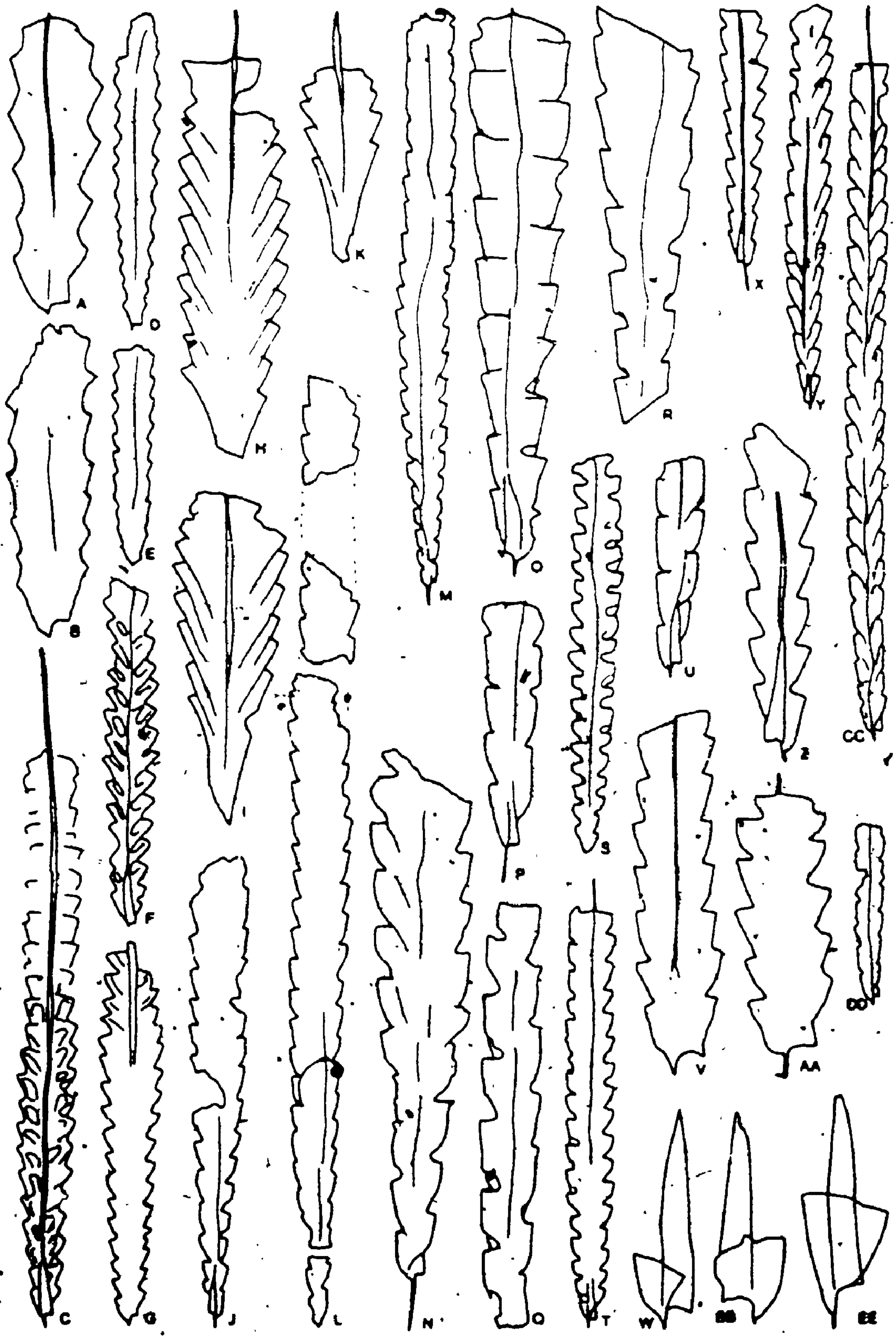
P,Q,U. _Glyptograptus_ sp. aff. _G. fastigans_ Haberfelner; P) TF:79.0, x10; Q) TF:71.0, x10; U) TF:71.0, x10.

S,T. _Glyptograptus incertus_ Elles and Wood; S) TI:47.0-48.0; T) HR:117.0.

X-Z. _Glyptograptus laciniosus_ Churkin and Carter; X) TF:47.0; Y) HR:107.0; Z) TF:47.0, x10.

V,AA. _Glyptograptus_? aff. _G_? _nanus_ Mu and Ni, both specimens x10, from TI:38.5.

W,BB-EE. _Glyptograptus tenuis_ (Rickards), all specimens from TF:49.0; W), BB) & EE) early growth stages showing simultaneous growth of first thecal pair, x20.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Occurrence. *Minor* Zone. Twilight Creek at 22.5 and 23.5m and Huff Ridge at 156.5m.

Description. Rhabdosome up to 11mm long and widens from 0.9 to 1.2mm at the first thecal pair to a maximum of 1.6 to 1.8mm at about the sixth thecal pair. Thecae spaced at 6 in the first 5mm and 11 in 10mm distally and are simple, straight tubes inclined at 30 to 40°. Apertures are everted, more strongly proximally than distally. Sicula somewhat obscure but appears to be about 1.4mm or less in length. Virgula extends 5.5mm beyond distal thecae in one specimen.

Remarks. Although the present specimens are few and rather poorly preserved, they match well with previous reports of this species. *Petalograptus elongatus* (Bouček and Příbyl) is similar but has a longer sicula (2mm) but Lenz (1982a) reported specimens which he identified as *P. elongatus* with siculae 1.5mm in length and considered that the two species may, in fact be synonymous. The specimens of *P. tenuis* reported by Chen (1984a) also have a sicula 1.5mm long. The sicula of the present specimens, although not entirely clear, appears to be 1.4mm or less and so is closer to the "typical" for *P. tenuis* than *P. elongatus*. It seems very likely that, as suggested by Lenz (1982a) and Bjerreskov (1975), the two are synonymous.

Petalograptus wilsoni Hutt (1974b) is distinguished by a long sicula as well as a complex, two-vaned virgula. However, Lenz also noted specimens bearing a complex, spiralling, vaned virgula within a population of otherwise normal specimens and so this, too, may be within the range of variation of this taxon.

This species is distinguished from P. palmeus and its subspecies by its consistently narrower width and also by the lower inclination of the proximal thecae.

Several uncompressed, early growth stage specimens have been found at Cape Manning (CM:5-7m, convolutus Zone), Snowblind Creek (SC:260m, minor Zone) and Marshall Peninsula (loose C, minor Zone?) which have been assigned as Petalograptus cf. P. tenuis (pl. 15, figs. 6,8-10). They show a sicula 1.3 to 1.5mm long and thecae with relatively low inclination. Width at the first thecal pair is 0.8 to 0.9mm, $th1^1$ is about 1.0mm long and the apertures are strongly everted. The virgula is supported by a very narrow partial median septum. The specimens differ from the uncompressed specimens of P. n. sp. in that $th1^1$ is much longer and is inclined at a somewhat lower angle. More complete material would be necessary to make a positive identification, but if the Cape Manning specimens are indeed P. tenuis then this is much earlier than the most reports of this species (see, however, Churkin and Carter, 1970).

Petalograptus n. sp. A

Plate 16, figs. 1-5; Text-figure 24, B,E.

?1970 *Orthograptus* sp. Hutt, *et al*., pp. 4-5, pl. 1, figs. 5-7.

Material. Four compressed specimens with fair preservation and possibly several more poorly preserved ones, as well as several well preserved, uncompressed specimens, most of which are early growth stages.

Occurrence. Upper *minor* and *turriculatus* zones. Snowblind Creek at 320m and Twilight Creek at 23.5m.

Diagnosis. Slender rhabdosome (up to 1.5 to 1.5mm) with straight, closely spaced thecae and very strongly everted apertures, especially proximally where they may be parallel to the rhabdosomal axis.

Description. Rhabdosome up to 7.5mm long with tabular cross-section. Widens from 0.8 to 1.1mm at the first thecal pair to a maximum of 1.4 to 1.5mm at the fifth thecal pair. Uncompressed widths are only slightly less. Thecae spaced at 15.5 to 14 in 10mm and are straight tubes inclined at 45° proximally, 35° distally. Apertures are strongly everted, especially proximally where they may parallel the rhabdosomal axis. It appears that the degree of apertural eversion increases with the age of the theca since proximal thecae on immature specimens are less strongly everted than those on mature specimens and distal thecae are less strongly everted than proximal ones on the same specimen. Sicula is about 1.0mm long and is exposed for about 0.4mm on the obverse side and 0.2 to 0.3mm below th1[2]. Median septum is lacking and the virgula appears to be entirely unattached (it is broken off at or near the sicula in most of the uncompressed specimens). Virgella is 0.15mm long.

Remarks. This new species is distinguished from other narrow species of *Petalograptus* by the higher thecal count, its narrower distal width, but most easily by the very high degree of apertural eversion, especially in the proximal thecae. A very similar form was described by Hutt, *et al.* (1970, pl. 1, figs 5,6) from Sweden with strongly everted thecae, in one specimen to the point of development of a weak hook, although this is not seen in the present specimens. The Swedish specimens appear to be slightly narrower and have a slightly wider thecal spacing. A small specimen from Eire was also reported by Hutt *et al.* (1970, pl. 1, fig. 7) which has slightly less everted thecae (similar to the more immature specimens found here) and dimension comparable to those found here. These forms are considered as probably belonging to the new species described here.

Petalograptus? n. sp. B

Text-figure 24C,F,G.

Material. About 20 compressed specimens, moderately well to poorly preserved.

Occurrence. Atavus Zone. Trold Fiord at 47.0m

Diagnosis. Rhabdosome widens from 0.8 to 1.0mm to a maximum of 1,7 tp 2.2mm. Thecae are orthograptid with everted apertures and a moderate inclination. Periderm is attenuated, especially distally where it gradually fades until only the robust virgula is visible.

Description. Rhabdosome up to 33mm long (incomplete). Widens from 0.8 to 1.0mm at the first thecal pair to 1.3 to 1.6mm at the fifth to a maximum of 1.7 to 2.2mm (average 1.9mm), achieved by the tenth to fifteenth thecal pair. Width commonly decreases distally by 0.2 to 0.4mm. Thecae number 6 to 7.5 in the first 5mm, decreasing slightly to 11 to 14 in 10mm distally. Thecae orthograptid with straight to slightly convex free ventral walls. Thecae inclined at 20 to 30° to rhabdosome axis proximally, increasing to as much as 40 to 50° distally. Apertural margins everted, straight to slightly concave and subopposite. Apertural excavations deep, occupying 1/5 to 1/3 total width. Apertural margin commonly appears rounded on distal thecae.

Thecae overlap 1/3 to 1/4 their length. Theca 1^1 grows downward to just below sicular aperture before it grows upward. Sicula 1.8 to 2.0mm long and is exposed for 0.2 to 0.4mm below $th1^2$. Virgella length variable, up to 0.6mm. Periderm becomes attenuated distally and distal thecae are very indistinct, often represented only by a trace of the free ventral wall. Virgula heavily sclerotized throughout, often extending well beyond the last visible theca.

Remarks. This new species closely resembles Petalograptus aff. mutabilis (Hutt, 1974b) but differs in that the thecae are inclined at somewhat higher angles and the periderm becomes attenuated distally until only the virgula is visible. Petalograptus? attenuatus (Rickards, 1970) is smaller, narrower and its thecae are inclined at lower angles to the rhabdosomal axis.

Glyptograptus laciniosus Churkin and Carter, found in the same samples as P? n. sp. B, shows some distal attenuation of the periderm (to a lesser extent) but the thecae are inclined at a much lower angle, are more widely spaced and show a weak sigmoidal curvature.

Petalograptus n. sp. C

Plate 16, figures 6-9.

Material. Two very well preserved, uncompressed specimens, both immature rhabdosomes.

Occurrence. Orbitus Subzone? and lower convolutus Zone. Cape Manning at 2-5 and 5-7m.

Diagnosis. Narrow rhabdosome with short, straight, closely spaced thecae with strongly everted apertures. Sicula 1.5mm long but is almost completely obscured on the reverse side by the curved growth of the first thecal pair. Virgella is long and robust.

Description. Rhabdosome up to 2.5mm long, excluding virgula, with rectangular cross-section. Widens from 0.7mm at first thecal pair to 0.85mm at the third. Thecae spaced at 8 in 5mm. First thecal pair almost completely enclose sicula on reverse side and thereafter curve almost straight upward. Subsequent thecae are straight, inclined at about 25°, and overlap about 1/2 their length. Apertures are strongly everted. Sicula is about 1.5mm long and is exposed for about 1/2 its length on th obverse side. Its aperture bears a very robust virgella 1.1 to 1.3mm long. Virgula supported by a very narrow partial median septum.

Remarks. This species is distinguished from all other known Petalograptus species by the blunt but narrow proximal end, and curved thecae which almost completely enclose the sicula (in reverse view). In this respect, and also in presence of a robust virgella, this species resembles species of n. gen. B, such as "O". *bellulus*, except that this species lacks the very short sicula characteristic of that genus. Other *Petalograptus* species tend to have straighter, more inclined proximal thecae and a more exposed sicula. Beyond the first thecal pair, this species resembles other, slender *Petalograptus* species such as *P.* n. sp. A (this study) with its strongly everted apertures, or *P. tenuis*.

Genus *Cephalograptus* Hopkinson, 1869

Type species. *Diplograptus cometa* Geinitz, 1852

Cephalograptus tubulariformis (Nicholson, 1867)

Text-figure 24H,I,K.

1867 *Diplograptus tubulariformis* Nicholson, p. 111, figs. 12,13 (non 14,15).

1908 *Cephalograptus tubulariformis* (Nicholson); Elles and Wood, pp. 287-288, pl. 32, fig. 9a-d; fig. 198.

1941b *Cephalograptus tubulariformis* (Nicholson); Bouček and Přibyl, p. 12, pl. 1, fig. 9; text-fig. 2f-h.

1965 *Cephalograptus tubulariformis* (Nicholson); Obut and Sobolevskaya, p. 37, pl. 2, figs. 7-10.

1967 *Cephalograptus tubulariformis* (Nicholson); Obut and Sobolevskaya, p. 71, pl. 6, fig. 1.

1971 *Petalolithus* (*Ceph*.) *tubulariformis* (Nicholson);

Schauer, p. 49, pl. 8, figs. 5,6; pl. 9, figs. 3-5.

1975 Cephalograptus tubulariformis (Nicholson); Bjerreskov, p. 36, pl. 5A.

1975 Cephalograptus tubulariformis (Nicholson); Obut and Sobolevskaya, pp. 156-157, pl. 9, figs. 3,4.

1978 Cephalograptus tubulariformis (Nicholson); Ye, p. 472, p. 177, figs. 4,5.

1982a Cephalograptus tubulariformis (Nicholson); Lenz, pp. 24-25, figs. 3E,F; 14E.

Material. Five moderately well preserved, compressed specimens and several more poorly preserved ones, none with a complete proximal end.

Occurrence. Upper convolutus Zone. Huff Ridge at 128.0m

Description. Rhabdosome at least 20mm long, of which at least 4 to 5mm is the first thecal pair. Widens from 2.2 to 2.9mm at the apertures of the first thecal pair to a maximum of 3.7 to 4.3mm achieved by about the fifth thecal pair. Thecae are spaced at 9.5 to 10 in 10mm. The long proximal thecae are slightly ventrally curved while the more distal thecae are straight and inclined at about 30°. Overlap is very high and the apertures are straight and normal to the thecal axis. Sicular details cannot be discerned, nor can the exact length of the initial thecae owing to poor preservation of the proximal portions. Virgula may extend up to 2.5mm beyond distal thecae.

Remarks. Despite the poorly preserved proximal ends of the present specimens, enough is present to identify this unique taxon. The proximal end is much more protracted than any species of Petalograptus while it possesses shorter proximal thecae and a much longer distal portion, consisting of many more thecae than Cephalograptus cometa cometa or C. c. extrema.

Genus Glyptograptus Lapworth, 1873, emend.

Type species. Diplograpsus tamariscus Nicholson, 1868.

Diagnosis (emended herein). Pattern I species with glyptograptid to, less commonly, climacograptid thecae. Proximal end rather slender, unornamented and usually tapering. Rhabdosome circular to ovate in cross-section, usually aseptate although a partial median septum may be present.

Remarks. There has long been difficulty in distinguishing species of Glyptograptus from Climacograptus in Llandovery collections and arbitrary criteria have been variously employed to distinguish these genera (e.g. Packham, 1962). This has resulted in what many authors have considered a phylogenetically unrealistic classification, even from the point of view of thecal morphology and rhabdosomal form alone (Rickards, et al., 1977). Mitchell (1987) felt that all of the Llandovery glyptograptids and climacograptids have the same proximal development pattern (pattern H) and he decided to include both within an expanded Glyptograptus until further information was available to distinguish more phylogenetically consistent subgroups. The present material has clearly shown, however, that some of the Llandovery glyptograptids are of the pattern I type, including G. tamariscus, the type species, while some (e.g. G. nikolayevi) possess the pattern H proximal growth form and are here grouped with the pattern H climacograptids in the genus Hedrograptus.

Glyptograptus elegans n. subsp.

Plate 17, figures 1-13; plate 18, figure 1?;

text-figure 24J,L-N.

Material. Numerous moderately well to poorly preserved, compressed specimens as well as numerous moderately to very well preserved uncompressed specimens, mostly early growth stages.

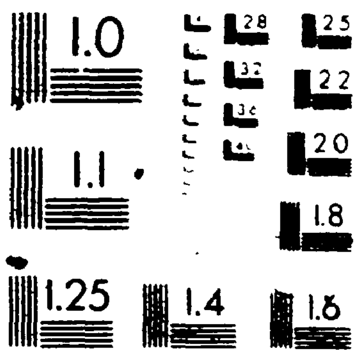
Occurrence. Curtus?, minor and turriculatus zones. Snowblind Creek at 260m, Cape Manning at 2-5m?, Rookery Creek at 55m, Marshall Peninsula (loose B, C, D), Twilight

Creek at 21.5, 22.5 and 23.5m, and Trold Fiord at 71.0 and 74.0m.

Diagnosis. Long, gradually tapering, aseptate glyptograptid. Thecae have flowing but pronounced sigmoidal curvature and horizontal apertures. Maximum width is up to 2.1mm (1.5mm uncompressed) and thecae are spaced at 9.5 to 11 in 10mm distally, more closely spaced proximally. Virgula central, attached to the bases of the interthecal septa.

Description. Rhabdosome up to 43mm long, aseptate with slightly ovate cross-section. Widens very gradually from 0.6 to 0.75mm at the first thecal pair (0.5 to 0.6mm uncompressed) to 1.0 to 1.3mm at the fifth thecal pair to a maximum of 1.6 to 2.1mm (1.55mm uncompressed). Thecae spaced at 5.5 to 7 in 5mm proximally, 9.5 to 11 in 10mm distally and have a pronounced, flowing sigmoidal curvature proximally becoming more gently sigmoidal distally. Apertures are horizontal and supragenicular walls are straight and slightly inclined. Thecae overlap about 1/3 their length proximally, closer to 1/2 distally. Sicula 1.0 to 1.2mm long and bears a virgella up to 0.8mm long. (One specimen questionably assigned to this species has a virgella 1.7mm long - pl. 18, fig. 1.). Virgula central, attached to the bases of the interthecal septa although it may become free distally.

4



Remarks. This subspecies differs from the type, described by Packham (1962), only in that the present specimens are slightly wider, especially distally, and that they reach their maximum width more gradually. They also tend to be much longer but this may be a preservational effect. The thecal shapes, their spacing and the gradual decrease in degree of curvature distally are all characteristic of this species as is the lack of a median septum. Packham found several specimens which he noted as showing a trace of a median septum. In compressed specimens, however, the supposed septum may only be the impression of the virgula. The single uncompressed specimen which he doubtfully assigned to this species (illustrated in his text-fig. 5i) which shows a median septum, visible on the reverse side, also has much longer first thecae and $th1^2$ of that specimen has a much more rounded base as compared with the other specimens illustrated by him. For this reason it is not considered here to belong to this species, but may be a slender species of Hedrograptus.

This taxon differs from G. tamariscus and its subspecies in that it reaches a greater maximum width and the virgula is central rather than embedded in the lateral wall. Early growth stages of this form are found together with early growth stages of G. sp. aff. G. fastigans, in some of the samples, but are distinguished from the latter by the horizontal rather than everted apertures and higher inclination of the supragenicular walls.

Glyptograptus enodis enodis Packham, 1962

Text-figure 240,R.

1962 Glyptograptus enodis enodis Packham, p. 517, pl. 71, figs. 18.19,21; pl. 72, figs. 1; text-fig. 4g-j.

?1984 Glyptograptus enodis Packham; Li pl. 3, figs. 4-8.

Material. Six moderately well preserved, compressed specimens and several more poorly preserved ones.

Occurrence. Pectinatus Subzone. Trold Fiord at 62.5m and Huff Ridge at 118.5.

Description. Rhabdosome up to 9.0mm long, aseptate. Widens from 0.8 to 0.9mm at the first thecal pair to a maximum of 1.6 to 1.7mm, achieved by about the seventh thecal pair. Thecae spaced at 10 to 11 in 10mm and have a weak sigmoidal curvature and slightly everted apertures. Sicula indistinct but appears to be about 1.5mm long with a virgella up to 0.5mm. Virgula appears to be embedded in obverse wall.

Remarks. The width of the present specimens is somewhat greater than most of those reported by Packham (1962) but this is accounted for by the fact that the study specimens are compressed. Although Packham reported the presence of a partial median septum, comparison of his figures with uncompressed specimens of G. tamariscus found here and in his study suggests that the appearance of a septum may also be achieved by having a laterally embedded virgula. Species with a partial septum found in the present material have the apex of the sicula obscured by the first thecal pair, whereas those with a lateral virgula have the sicula completely exposed on the obverse side as is the case in Packham's specimens of G. enodis enodis (cf. pl. 71, figs. 18,19; text-fig. 4g,h). Furthermore, in the present material, specimens preserved in scalariform view show the impression of the virgula extending along the side of the rhabdosome suggesting that it was indeed attached to the obverse wall.

This species differs from G. tamariscus primarily in the shape of the thecae which have a lower degree of sigmoidal curvature.

Glyptograptus sp. aff. G. fastigans Haberfelner, 1931

Plate 18, figures 2-15; text-figure 24P,Q,U.

?1962 Glyptograptus sp. cf. G. tamariscus fastigans Haberfelner; Packham, pp. 512-513, pl. 71, fig. 5; text-fig. 3f.

?1970 Glyptograptus aff. G. tamariscus fastigans Haberfelner; Hutt, et al., p. 6, pl. 1, fig. 14.

Material. Seventeen very well preserved uncompressed specimens, mostly early growth stages and several more poorly preserved, compressed specimens.

Occurrence. Upper *minor* and *turriculatus*-*crispus* zones. Marshall Peninsula B & C, Snowblind Creek at 260m, Truro Island at 51.0m, Twilight Creek at 23.5m and Trold Fiord at 71.0 and 79.0m.

Description. Rhabdosome up to at least 7.0mm, aseptate, with a roughly circular cross-section. Widens from 0.4 to 0.6mm at the first thecal pair (0.6 to 0.8mm compressed) to a maximum of 0.5 to 0.6mm (0.8 to 1.0mm). Thecae spaced at 6 to 6.5 in 5mm proximally, generally decreasing to 10 to 11 in 10mm distally. Geniculum is abrupt but rounded and supragenicular walls are straight and very slightly inclined. Apertures are slightly to moderately everted and excavations are shallow. Thecae overlap about 1/3 their length. Sicula is 0.9 to 1.2mm long and reaches to level of $th1^2$ aperture. It is exposed for most of its length on the obverse side. Virgella is up to 0.6mm long and virgula is central and free.

Remarks. This species resembles *G*. sp. cf. *G*. *tamariscus fastigans* of Packham (1962) in the shape of the thecae, their low degree of overlap and everted apertures in shallow excavations as well as the lack of a median septum or laterally embedded virgula. The latter feature distinguishes this species from G. *tamariscus* and its other subspecies which have the virgula embedded in the obverse wall. For this reason I have chosen to raise this form to the species level. The present specimens differ from that described by Packham and those of Hutt *et al*. (1970) in that these are narrower distally and have ~~a~~ shorter first theca and closer thecal spacing. Those originally described by Haberfelner (1931) also differ in that they have introverted rather than everted apertures.

There appear to be two populations present: one with slightly longer siculae (1.1 to 1.2mm), a slightly longer first theca (0.8mm) and a slightly greater proximal width (0.6mm); and one with a shorter sicula (0.9 to 1.0mm), shorter first theca (0.6 to 0.7mm) and a narrower first thecal pair (0.4 to 0.5mm). The two groups appear to be otherwise identical and since they consistently occur together in both compressed and uncompressed collections, they are included here together.

Glyptograptus incertus Elles and Wood, 1907

Text-figure 24S,T.

1907 *Diplograptus* (*Glyptograptus*) *tamariscus* Var. *incertus* Elles and Wood, p. 249, pl. 30, figs. 9a-d; text-fig. 168a,b.

1962 *Glyptograptus incertus* Elles and Wood; Packham, pp. 518-519, pl. 72, figs. 6,7; text-fig. 4a-d.

1970 Glyptograptus incertus Elles and Wood; Churkin and Carter, pp. 25-26, pl. 2, figs. 5,6; text-fig. 10D,E.

1974b Glyptograptus (G.) incertus (Elles and Wood); Hutt, p. 25, pl. 3, fig. 3; pl. 4, figs. 12,13; text-fig. 8, fig. 11.

1978 Glyptograptus incertus Elles and Wood; Chen and Lin, p. 25, pl. 3, figs. 6,7.

1984a Glyptograptus incertus Elles and Wood; Chen, pp. 35-36, pl. 1, figs. 8,8a; pl. 2, fig. 1.

?1984 Glyptograptus incertus Elles and Wood; Ge, p. 405, pl. 1, figs. 6-8,10.

?1984 Glyptograptus incertus Elles and Wood; Li, p. 327, pl. 4, figs. 2-4.

Material. About ten moderately well preserved, compressed specimens and several more poorly preserved fragments.

Occurrence. Pectinatus and orbitus? subzones. Truro Island at 47.0-48.0 and 49.0m and Huff Ridge at 117.0m.

Description. Rhabdosome up to 16mm long. Widens from 0.75 to 0.85mm at the first thecal pair to 1.3 to 1.4mm at the fifth to a maximum of 1.5 to 1.8mm achieved between the seventh and tenth thecal pair. Thecae spaced at 6.5 to 7 in 5mm proximally, 11 to 12 in 10mm distally and are strongly sigmoidally curved proximally, more moderately curved distally, but glyptograptid throughout. Apertures horizontal, in rather deep excavations. Sicula appears to be about 1.4mm long and virgella is up to 0.5mm long. No evidence of a median septum can be seen.

Remarks. The present specimens fit well within the range of variation previously reported for this species and the thecal form is characteristic. Although the present specimens are all compressed, none shows any sign of a median septum despite the fact some of them have a somewhat attenuated periderm distally and a flattened septum would be likely to "show through". This agrees with the findings of Hutt (1974b) who found no trace of a septum on the obverse side of her uncompressed specimens and only traces on the reverse side distally (the latter may be the result of impression of the virgula). This species differs from G. elegans n. subsp. in the more robust, less gently tapering proximal end and the more strongly sigmoidal thecae, especially proximally. Glyptograptus laciniosus Churkin and Carter has very weakly sigmoidal thecae throughout and more widely spaced thecae.

Hedrograptus nikolayevi (Obut) (="G". gnomus Churkin and Carter) is similar in overall form but its thecae do not become more gently sigmoidal distally and it possesses a median septum and a shorter sicula.

Glyptograptus laciniosus Churkin and Carter, 1970

Text-figure 24X-Z.

1970 *Glyptograptus laciniosus* Churkin and Carter, pp. 26-27, pl. 2, figs. 17-18; text-fig. 11D.

1984 *Glyptograptus laciniosus* Churkin and Carter; Li, p. 328, pl. 4, figs. 11, 13-15; pl. 17, fig. 4.

1986 *Glyptograptus laciniosus* Churkin and Carter; Berry, fig. 5f.

Material. About 20 compressed specimens, moderately well preserved.

Occurrence. *Atavus*, upper *acinaces* and *cyphus* zones. Trold Fiord at 47.0, 54.0, 56.5 and 60.0m and Huff Ridge at 107.0, 110.0, 113.5 and 114.5m?.

Description. Rhabdosome up to 16mm long (excluding virgula). Widens from 0.7 to 1.0mm at the first thecal pair to 1.1 to 1.4mm at the fifth to a maximum of 1.6 to 1.9mm achieved near the tenth thecal pair. Thecae spaced at 5.5 to 6.5 in the first 5mm and 10 to 12 in 10mm distally. Free ventral walls of thecae are nearly straight, showing only slight sigmoidal curvature, and are almost parallel to the rhabdosomal axis. Apertures are straight and slightly everted. Sicula 1.7 to 1.9mm long and is exposed for about 0.3mm below th1[2]. Aperture bears a virgella 0.2 to 0.3mm long.

Periderm is commonly somewhat attenuated at the distal extremities, although the virgula remains thick and commonly extends beyond the distal thecae. Subscalariform views are occasionally found.

Remarks. The characteristic thecal shape and rhabdosomal form, including subscalariform views are typical of this species. In addition, Churkin and Carter (1970, pl. 2, fig. 17) illustrate a specimen which appears to show a distally attenuated periderm, as seen in the present material. The only difference between these specimens and the Alaskan ones is that the present ones are, on average, somewhat wider, altnough there is overlap in their width ranges.

Hedrograptus nikolayevi Obut (1965) is similar, but the thecae are more strongly sigmoidally curved and are inclined at a greater angle to the rhabdosomal axis and it possesses a median septum.

Glyptograptus? aff. G? nanus Mu and Ni, 1983

Text-figure 24V,AA.

Material. Ten compressed specimens, moderately to poorly preserved.

Occurrence. Acuminatus Zone. Truro Island, 38.5m.

Description. Rhabdosome up to 6mm long (incomplete). Widens from 1.1 to 1.2mm at the first thecal pair to 1.4 to 1.5mm at the third. This width is either maintained thereafter or decreases slightly. Thecae spaced at 7 to 8 in 5mm and are gently sigmoidal with straight to slightly convex supragenicular walls. Apertures slightly everted. Sicula 1.6 to 1.8mm long and is exposed for 0.2 to 0.3mm below th1[2]. Virgella up to 0.4mm long and a free virgula is commonly present up to 1.5mm long.

Periderm appears to be very thin and virgula is conspicuous throughout the rhabdosome length.

Remarks. Glyptograptus? nanus Mu and Ni (1983) is the only taxon which the present specimens closely resemble. However, the study specimens differ from G? nanus in several respects. The maximum width is reached within 2mm of the proximal end rather than 5 and the thecal spacing is closer. Furthermore, the attenuated periderm (which is evident by comparison with other taxa preserved on the same slabs) does not appear to be characteristic of G? nanus.

Although no median septum can be seen in the present specimens, the poor preservation prevents positive assignment to this genus.

Glyptograptus? rarus (Rickards) and "Orthograptus" attenuatus Rickards are similar in the attenuated nature of the periderm, but both are thinner, more tapering and show a different thecal style.

Glyptograptus tamariscus tamariscus (Nicholson, 1868)

Plate 19, figures 1-12; text-figure 25A-C.

1868 pars Diplograpsus tamariscus Nicholson (sic), p. 526, pl. 10,11,?13 (non 12).

1907 pars Diplograptus (Glyptograptus) tamariscus Nicholson; Elles and Wood, pp. 247-248, pl. 30, fig. 8a (non b-d); text-fig. 167a-c (non d).

1962 Glyptograptus tamariscus tamariscus (Nicholson); Packham, pp. 504-506, pl. 71, figs. 1-4,11,13; text-fig. 1g-j,m-u.

?1965 Glyptograptus tamariscus (Nicholson); Obut and Sobolevskaya, pp. 31-32, pl. 1, fig. 13.

1967 Glyptograptus tamariscus tamariscus (Nicholson); Obut and Sobolevskaya, pp. 55-56, pl. 2, fig. 9.

1968 Glyptograptus tamariscus tamariscus (Nicholson); Obut and Sobolevskaya, pp. 65-67, pl. 5, figs. 1-3.

1970 Glyptograptus tamariscus tamariscus (Nicholson); Rickards, p. 38, pl. 2, fig. 9; text-fig. 14, figs. 8,13,15.

?1970 Glyptograptus tamariscus tamariscus (Nicholson); Hutt, et al., pp. 5-6, pl. 1, figs. 11-13.

?1971 Glyptograptus tamariscus (Nicholson); Schauer, p. 38, pl. 6, fig. 13; pl. 18, figs. 2,3.

1974b Glyptograptus (G.) tamariscus tamariscus (Nicholson);

Text-figure 25

All specimens x5 unless otherwise noted.

A-C. Glyptograptus tamariscus tamariscus (Nicholson), all specimens x10: A) HR:128.0; B) HR:118.5; C) HR:128.0.

D,E,G. Glyptograptus tamariscus cf. varians Packham, all specimens x10: D) TF:56.5; E) TF:52.0; G) TF:56.5.

F,I. Comograptus comatus Obut and Sobolevskaya, both specimens from HR:188.5; F) x10.

H,J,K. Comograptus? cf. C? tabukensis (Rickards and Koren'), all specimens from TF:60.0; J) x10.

L,P. Agetograptus hubeiensis (Ni); L) TF:63.0; P) HR:109, x10.

M,Q. Agetograptus secundus Obut and Sobolevskaya, both specimens from TF:61.0; M) x10.

N,R. Agetograptus primus Obut and Sobolevskaya, both specimens from TF:62.5; N) x10.

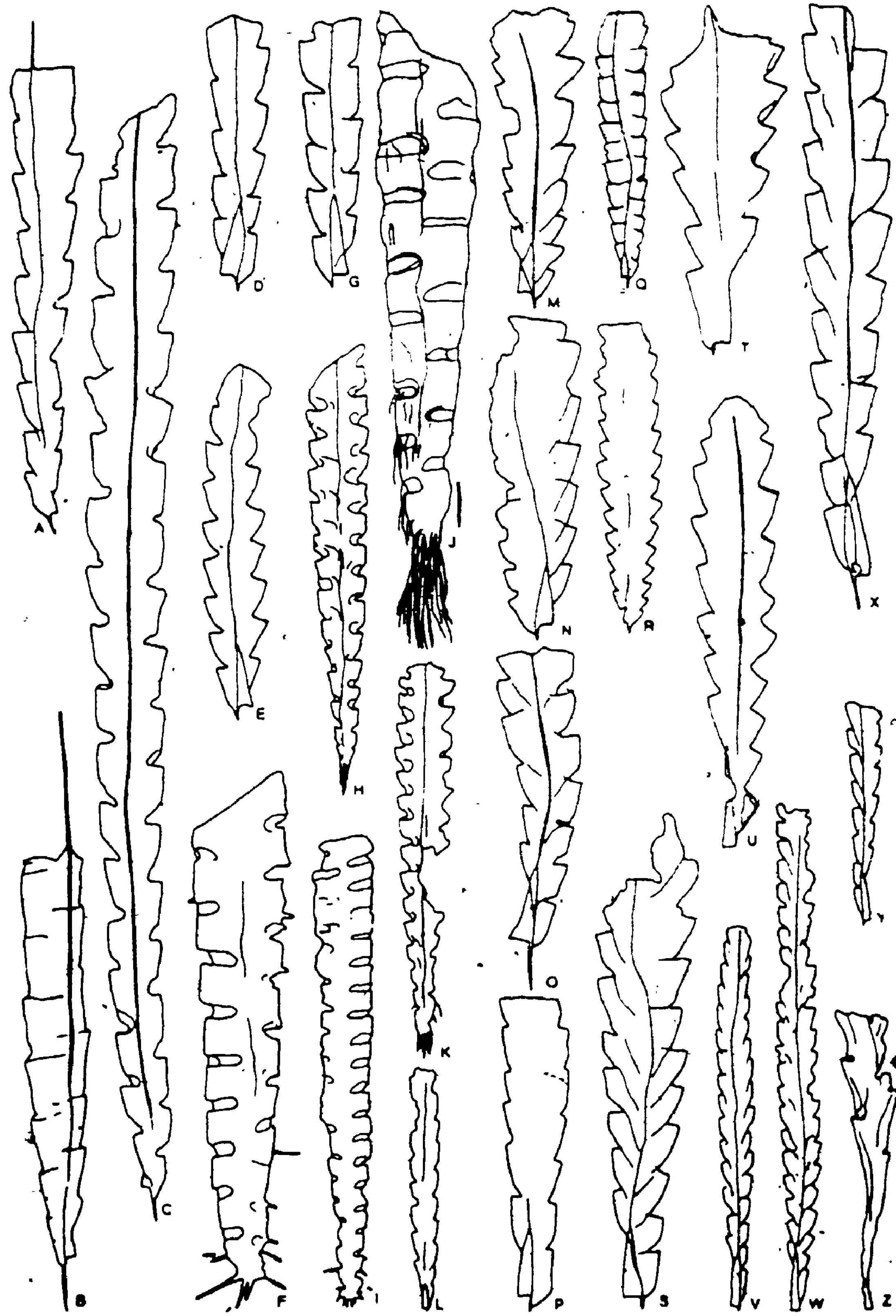
O,S. Agetograptus cf. A? sichuanensis (Ye), both specimens x10, from TF:60.0.

T. Agetograptus? sp., HR:144.5, x10.

U. Dimorphograptus erectus Elles and Wood, TF:52.0, x10.

V-Y. Dimorphograptus minutus (Chen and Lin): V) & W) TC:13.5; X) note apparent short downward growth of thl "pressed through", TF:56.5, x10; Y) HR:112.5.

Z. Parakidograptus acuminatus (Nicholson), TI:38.5, x10.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Hutt, p, 24, pl. 2, figs. 18-21; pl. 7, fig. 8.

1975 *Glyptograptus tamariscus tamariscus* (Nicholson); Obut and Sobolevskaya, pl. 8, fig. 6.

?1976 *Glyptograptus tamariscus tamariscus* (Nicholson); Sennikov, pp. 140-143, pl. 5, figs. 7-9.

1978 *Glyptograptus tamariscus* (Nicholson); Chen and Lin, pp., 23-24, pl. 1, fig. 19, text-fig. 4c.

1978 *Glyptograptus tamariscus* (Nicholson); Ni, pl. 1, fig. 11; text-fig. 1, fig. 3.

1978 non *Glyptograptus tamariscus* (Nicholson); Ye, p. 454, pl. 174, fig. 5.

1980 *Glyptograptus tamariscus tamariscus* (Nicholson); Obut and Sennikov, pp. 24-26, pl. 2, figs. 2-5.

1984a *Glyptograptus tamariscus* Form C Packham; Chen, pp. 33-34, pl. 1, fig. 13.

1984 *Glyptograptus tamariscus* (Nicholson); Ge, pp. 406-407, pl. 2, figs. 6-[illegible].

1984 *Glyptograptus tamariscus* (Nicholson); Li, pp. 329-330, pl. 5, figs. 14-15; pl. 6, fig. 1.

1986a *Glyptograptus tamariscus tamariscus* (Nicholson); Chen, p. 233, pl. 1, figs. 1-4,7,8,10,11; pl. 2, fig. 7.

Material. Numerous compressed specimens, fairly to poorly preserved and several very well preserved, uncompressed specimens.

Occurrence. *Curtus* and *convolutus* zones; Snowblind

Creek at 140 and 170m, Cape Manning at 2-5 and 5-7m, Twilight Creek at 15.5-16.0m, Trold Fiord at 62.5m and Huff Ridge at 118.5, 121.0, 124.0 and 128.0m.

<u>Description</u>. Rhabdosome up to 19mm long with circular cross-section. Widens from 0.5 to 0.6mm (0.4 to 0.55mm uncompressed) at the first thecal pair to 0.8 to 1.1mm at the fifth thecal pair, to a maximum of 1.0 to 1.4mm (0.7 to 0.9mm uncompressed). Thecae spaced at 10.5 to 13 in 5mm proximally to 9 to 11 in 10mm distally and have a flowing sigmoidal curvature with a distinct, but rounded geniculum. Supragenicular walls are usually slightly inclined although sometimes appear parallel in compressed specimens. Apertures horizontal to slightly everted, excavations are deep and long. Thecal overlap is small, about 1/4. Sicula is 0.9 to 1.0mm long, reaching to just below the aperture of $th1^2$. Descending portion of protheca 1^1 is 0.15 to 0.2mm long and grows first to the left and turns and opens downward. Median septum is absent and virgula is embedded in the obverse wall. Fusellae on the obverse wall curve distally to meet the virgula. This results in a pointed appearance to the distal end when it is found unbroken.

<u>Remarks</u>. The present specimens match previous reports of this widely known species in all respects. Most of the present specimens fall roughly into the Form C as described by Packham (1962). Although Packham and many other previous

workers considered there to be a partial median septum (complete on the obverse side), isolated, uncompressed specimens clearly show that no median septum is present, but that the virgula in actually embedded in the obverse wall. In uncompressed or partially compressed specimens embedded in rock (such as pyrite moulds) this would appear indistinguishable from a partial medial septum (as a depression down the obverse wall). A characteristic feature of (at least some) species with the embedded virgula, however, is that an unbroken distal end appears pointed owing to the curvature of the fusellae distally, effectively becoming tangential with the virgula. This feature can be seen in the (probable) holotype as illustrated by Packham (1962, pl. 71, fig. 13). It can also be seen in the isolated specimens illustrated by Obut and Sennikov (1980, pl. 2, fig. 3) and Chen (1986, pl. 1, fig. 2).

<u>Glyptograptus</u> <u>tamariscus</u> <u>acutus</u> Packham, 1962

Plate 20, figures 1-7.

1962 <u>Glyptograptus</u> <u>tamariscus</u> <u>acutus</u> Packham, pp. 511-512, pl. 71, fig. 12; text-fig. 3d.

<u>Material</u>. Seven well to very well preserved, uncompressed specimens and two compressed, well preserved fragments.

Occurrence. *Curtus* Zone?. Snowblind Creek at 140m and Rookery Creek at 55.0 and 80-105m (loose).

Description. Rhabdosome up to at least 5mm long and is circular in cross-section. Widens from 0.4 to 0.45mm uncompressed (0.6mm compressed) at the first thecal pair to a maximum of 0.45 to 0.6mm (0.7mm compressed). Thecae spaced at 6 to 6.5 in 5mm at the extreme proximal end to 9 to 10 in 10mm distally and have an abrupt but rounded geniculum and straight, parallel supragenicular walls. Overlap is very low, about 1/5. Apertures are everted and have concave lateral margins. Sicula is 0.95mm long and is completely exposed on the obverse side. Virgella is up to 0.5mm long. Virgula is embedded in the obverse wall and the fusellae of the obverse side curve distally, resulting in a pointed appearance to the distal end of the obverse wall.

Remarks. This subspecies differs from the type in that the geniculum is more abrupt and the supragenicular walls are parallel rather than inclined. In addition, it is more slender distally. It differs from *G*. *t*. *angulatus* Packham primarily in the shorter, more closely spaced proximal thecae. *Glyptograptus tamariscus tamariscoides* (Packham) n. comb., as seen in Packham's illustrations (pl. 71, fig. 6; text-fig. 3e) appears to have the same rhabdosomal form (including a laterally embedded virgula and fully exposed sicula) and probably proximal development and is therefore, considered as simply another subspecies of *G. tamariscus*. It differs from *G. t. acutus* in its slightly greater width and the fact that the geniculum is sharper and the infragenicular wall more highly inclined.

Glyptograptus tamariscus cf. *varians* Packham, 1962

Text-figure 25D,E,G.

Material. Numerous compressed specimens, well to poorly preserved.

Occurrence. Lower *acinaces* and *cyphus* zones and *pectinatus* Subzone. Trold Fiord at 52.0, 56.5, 60.0, 61.0 and 62.5m and Huff Ridge at 110.0m.

Description. Rhabdosome up to 9mm long. Widens from 0.7 to 0.9mm at the first thecal pair to a maximum of 0.85 to 1.2mm, achieved by the third to fifth thecal pair. The width is thereafter maintained or narrows slightly. Thecae number 6 to 7.5 in 5mm and have flowing sigmoidal curvature with even or slightly everted apertures. Most specimens show a decrease in degree of curvature distally, from strongly to more moderately curved. Sicula 1.2 to 1.4mm long and is exposed below $th1^2$ for 0.3mm. Aperture bears a virgella up to 0.8mm long although one specimen has a virgella 3.0mm long. Rhabdosome appears to be aseptate.

Remarks. The rhabdosomal and thecal form match closely with those of G. tamariscus varians Packham (1962) but the present specimens differ in several respects. The thecal spacing is closer than seen by Packham, and most of these specimens are wider throughout their length although this may be due to the degree of compression. The stratigraphically lowest specimens are somewhat narrower but do not show the change in thecal form proximally to distally.

Glyptograptus tenuis (Rickards, 1970)

Text-figure 24W,BB-EE.

1970 Diplograptus modestus tenuis Rickards, p. 36, pl. 1, fig. 6; ?pl. 2, fig. 2.

1974b Glyptograptus (G.)? tenuis (Rickards); Hutt, pp. 27-28, pl. 3 fig. 4; text-fig. 8, fig. 8.

Material. Five "mature" rhabdosomes and numerous siculae and early growth stages, all compressed and moderately to well preserved.

Occurrence. Atavus Zone. Trold Fiord at 49.0m.

Description. A single rhabdosome 23mm long, the remainder 8mm or less. Widens from 0.7 to 0.8mm at the first thecal pair to 1.0 at the fifth to a maximum of 1.2 to

1.3mm. Thecae spaced at 5.5 to 6.5 in the first 5mm and 10 to 12 in 10mm distally and show strong sigmoidal curvature with a distinct but rounded geniculum. Supragenicular walls straight and parallel to rhabdosome axis or slightly inclined. Apertures slightly everted. Sicula 1.7 to 2.0mm long and is exposed below $th1^2$ for 0.3 to 0.6mm. Theca 1^1 originates 0.3 to 0.4mm above the sicular aperture and grows downward to just beyond the aperture where it turns upward for 0.9 to 1.1mm. Theca 1^2 originates 0.2 to 0.3mm above the sicular aperture and grows diagonally across the reverse side of the sicula. Sicular aperture is 0.2 to 0.25mm wide and bears a thin virgella up to 0.6mm long. Virgula is observed extending up to 2mm beyond the distal thecae.

Remarks. The present specimens differ from those of Hutt (1974b) only in having slightly more widely spaced thecae in the proximal end. The specimens of Rickards (1970) have a somewhat narrower proximal end. The diplograptid appearance originally described by Rickards was apparently the result of compression of the rather poorly preserved type specimen.

No median septum can be seen in any of the rather well preserved material. Furthermore, a range of early growth stages can be seen which indicate that the growth of $th1^1$ is synchronous with the early growth of $th1^2$ rather than ahead of it (text-figure 24W,BB,EE). This is typical of the petalograptine (pattern I) astogeny and supports the affinities of this species to Glyptograptus rather than to H. modestus as originally suggested by Rickards (1970).

Genus Comograptus Obut and Sobolevskaya, 1968, emend.

Type species. Comograptus comatus Obut and Sobolevskaya, 1968.

Diagnosis (emended herein). Pattern I species with at least three spines (often many) projecting outward from the sicular rim. Thecae climacograptid to pseudoglyptograptid, possibly glyptograptid and may bear mesial and/or genicular spines, especially proximally. Rhabdosome aseptate.

Remarks. This genus remains largely unchanged from the definition of Obut and Sobolevskaya, except that it has been found here to include only pattern I species (not Hedrograptus? serratus barbatus which appears to be a spinose variant of an otherwise normal pattern H species). The proximal development, as seen clearly in present isolated specimens of C. gorbiachinensis and the single isolated specimen of C. comatus is typical of the petalograptines and this type of proximal end can also be seen in the uncompressed specimen of "Pseudoglyptograptus" rhayaderensis illustrated by Rickards and Koren'' (1974). The sicula which is long and exposed for a considerable length on the obverse side, the presence of spines on the sicular rim and the absence of a median septum, even on the obverse side, are all characteristic of this genus. "*Pseudoglyptograptus*" *tabukensis* 'Rickards and Koren' is less well preserved but also shows the sicular spines and in other ways is similar to *C. rhayaderensis* and is therefore questionably included in *Comograptus*.

Comograptus comatus Obut and Sobolevskaya, 1968

Pl. 20, figs. 8-11; text-figure 25F,I.

1968 *Comograptus comatus* Obut and Sobolevskaya, pp. 61-62, pl. 3, figs. 8-10; pl. 4, fig. 1.

1977 "*Comograptus*" *comatus* Obut and Sobolevskaya; Rickards, *et al*., p. 100, fig. 54.

Material. One uncompressed, isolated specimen, very well preserved, as well as two moderately well preserved, and several more poorly preserved, compressed specimens.

Occurrence. *Pectinatus* Subzone. Cape Manning at 0-2m, and Huff Ridge at 118.5m.

Description. Rhabdosome up to 23mm long. Widens from 0.7 to 0.75mm at the first thecal pair (0.6mm uncompressed) to 1.0 to 1.2mm at the fifth to a maximum of 1.7 to 1.9mm. Thecae number 6 to 6.5 in the first 5mm, 11.5 to 12 in 10mm distally. Thecae climacograptid in shape with a strong genicular spine found on the proximal thecae, less commonly on the distal thecae. Rim of sicula is ornamented with numerous spines of varying lengths (up to 0.8mm) and degrees of robustness, some of which appear to branch. The single uncompressed specimen shows three very prominent, barbed spines with many smaller ones between them. All of these spines point outward and curve slightly downward. A virgella is also present which points downward. The spines coalesce at their bases to form an apron or skirt around the sicular rim which, on compression, folds downward, pointing most of the spines downward. Sicula is 1.3mm long and also bears a blunt spine on its exposed side between its rim and the base of $th1^2$. Most compressed specimens are preserved in subscalariform view.

Remarks. The overall dimensions as well as the unique nature of the ornamentation match those described by Obut and Sobolevskaya (1968) for this species. Those authors described the thecal form as glyptograptid to climacograptid, but their illustrations as well as those of Rickards et al. (1977) clearly show climacograptid thecae. Compression may impart a glyptograptid appearance on some specimens but the sharp geniculum is still apparent.

Rickards, et al., considered that this species might be conspecific with Glyptograptus serratus var. barbatus Elles and Wood. The latter species is, however, considerably wider, even than the widest compressed specimens of C.

comatus, its thecae are glyptograptid, lacking a sharp geniculum and the sicular spines grow downward rather than outward and do not appear to coalesce at their bases.

Comograptus gorbiachinensis Obut and Sennikov, 1980

Plate 21, figures 1-11.

1980 *Comograptus gorbiachinensis* Obut and Sennikov, pp. 21-22, pl. 1, figs. 8,9.

Material. About 20 compressed specimens, moderately to very well preserved and several uncompressed, very well preserved specimens. Most specimens are early growth stages.

Occurrence. *Curtus* and lower *convolutus* zones. Cape Manning at 0-2, 2-5 and 5-7m.

Description. Longest specimen found is 6mm and tapers throughout its length. Widens from 0.6 to 0.75mm (0.55mm) at the first thecal pair to a maximum of 1.2mm, observed at the sixth. Thecae spaced at 6 to 7.5 in 5mm, and is highest measured over the first few thecal pairs. Thecae climacograptid with a sharp geniculum and straight, although slightly inclined supragenicular wall. Theca 1^1 does not extend below the level of the thecal aperture and $th1^2$ appears to arise from the base of $th1^1$ and grows in a straight line upward, at a low angle to the sicula to its aperture 1.1 to 1.2mm from the sicular aperture. As a result, 0.4 to 0.5mm of the sicula is exposed below th1[2] and the proximal end has a very tapered appearance. The sicula is 1.1 to 1.3mm long and bears a virgella 0.21 to 0.45mm long as well as three spines arising from its apertural rim, one each on either side of the virgella and one opposite. The spine opposite the virgella develops first, prior to growth of the first theca, while the other two spines grow along with the first theca. Descending portion of protheca 1[1] is about 0.2mm long and grows obliquely to the left but opens straight downward.

Remarks. The present specimens match very well with those described by Obut and Sennikov (1980) in the narrow tapering rhabdosome, the closely spaced, climacograptid thecae and the spines on the sicular rim.

In the presence of three basal spines plus the virgella as well as the overall small rhabdosomal size this new species resembles *Hedrograptus trifilis lubricus* (Chen and Lin, 1978) but it differs in that this species has a more gradually tapering, more pointed proximal end. This is the result of the straight, low angle growth of th1[2] in contrast to that of hedrograptines in which th1[2] grows across the sicula at a higher angle and turns upward. A consequence of this is that more of the sicula is exposed than in typical hedrograptines. In addition, the spines of *H. t. lubricus* appear to emanate from the base of the virgella rather than the sicular rim. In these respects, this species is very similar to Comograptus comatus Obut and Sobolevskaya, also found at Cape Manning, and it is clear from examination of the uncompressed specimens that these two species are very closely related.

Comograptus? cf. C? tabukensis (Rickards and Koren', 1974)

Text-figure 25H,J,K.

Material. Three moderately well preserved, compressed specimens.

Occurrence. Upper cyphus Zone. Trold Fiord at 60.0m.

Description. Rhabdosome 24.5mm long. Widens from 0.6 to 0.8mm at the first thecal pair to 1.1 to 1.3mm at the fifth to a maximum of 1.9mm, achieved between the tenth and fifteenth thecal pairs. Thecae spaced at 6 to 6.5 in the first 5mm, 10 in 10mm distally and have an abrupt but rounded geniculum and parallel to slightly inclined supragenicular walls which are straight to slightly concave. Proximal end bears a multitude of long (up to at least 2mm) fine spines, apparently arising from the sicular rim and growing straight downward. The proximal few thecal pairs also bear many fine, proximally directed spines, some arising from the genicula, others appear to be mesial.

Remarks. These specimens resemble *C*? *tabukensis* in all respects except that the proximal spines of the latter are restricted to the sicular rim and appear to point outward before turning downward.

Comograptus comatus Obut and Sobolevskaya also has similar dimensions, but shows more nearly climacograptid thecae and has fewer, more robust, outwardly pointing basal spines, and genicular spines on the mesial and distal thecae as well as on the proximal ones.

The presence of numerous spines on the sicular rim is known among Llandovery species in the genus *Comograptus* but not in any genera of the Hedrograptinae. Although the proximal development of *C*? *tabukensis* is not visible in any of the known material, the presence of the sicular spines as well as the close similarities to *C*. *rhayaderensis*, which shows a typical *Comograptus* proximal end, and to *C*. *comatus* strongly suggests that this species belongs in *Comograptus* rather than *Pseudoglyptograptus*.

Genus *Agetograptus* Obut and Sobolevskaya, 1968, emend.

Type species. *Agetograptus secundus* Obut and Sobolevskaya, 1968.

Diagnosis (emended herein). Pattern I species in which a dimorphograptid appearance has been achieved either by has been redirection of $th1^2$ above $th1^1$ or suppression of the $th1^2$ metathecae and all of the following thecae are in a normal biserial pattern. Thecae orthograptid to glyptograptid, possibly climacograptid and may bear apertural spines. Sicula relatively short, often with a long virgella. Rhabdosome aseptate.

Remarks. Obut and Sobolevskaya (1968) recognized that the difference between *Agetograptus* species and *Dimorphograptus* was the short sicula, not fully exposed below $th1^1$ and the short first theca, and recognized the similarities with other pattern I species such as "*Orthograptus*" *bellulus*. The genus is expanded here to include all pattern I species with a uniserial first theca, except for *Petalograptus physophora* and its subspecies which show stronger affinities with other *Petalograptus* species owing to its ventrally curved thecae and the presence of an ancora, not seen in any other *Agetograptus* species.

Many of the "dimorphograptid" species described from China with a single uniserial thecae are included in this genus, such as *A. hubeiensis* (Ni) and *A.* cf. *A? sichuanensis* (Ye), which have been found in the present collections and *A. anhuiensis* (Li) and *A. brevis* (Li) both illustrated by Li (unpub. ms., 1985). In addition, some have been synonymized with *Agetograptus* species of Obut and Sobolevskaya (see descriptions below). Although Li suggested diverse origins for several of these species, his conclusions were based on thecal form and overall rhabdosomal profile. More information is necessary regarding the details of the proximal end and internal structure before the mono- or polyphyletic origin of this genus can be determined. For the present, the apparent similarity in early thecal growth patterns justifies including them in a single genus.

Agetograptus hubeiensis (Ni, 1978)

Plate 22, figures 1-6,8; text-figure 25L,P.

1978 *Dimorphograptus hubeiensis* Ni, p. 404, pl. 1, fig. 24; text-fig. 1, fig. 6.

Material. Five moderately well preserved, compressed specimens and several more poorly preserved ones, as well as several very well preserved, uncompressed specimens.

Occurrence. Lower *cyphus* and *curtus* zones. Cape Manning at 0-2m, Rookery Creek at 80-105m (loose), Troid Fiord at 62.5 and 63.0m and Huff Ridge at 109.0 and possibly 110.0m.

Description. Rhabdosome up to 8.5mm long. One uniserial theca present, 0.5mm wide at its aperture (0.4mm uncompressed). Biserial portion widens from 0.7 to 0.8mm (0.55 to 0.65mm) to a maximum of 1.0 to 1.1mm (0.7 to

0.9mm). Thecae spaced at 6.5 to 7 in the first 5mm, 11 in 10mm distally with smoothly rounded geniculum and straight supragenicular walls, slightly inclined although may become parallel distally. Apertures even, with shallow excavations. Sicula short, about 0.8 to 1.0mm, reaching to just beyond the aperture of th1. Virgella may be very long, up to 1.8mm and one specimen shows spinose outgrowths from the virgella near its base. Virgula central and free.

Remarks. This species, although more slender than typical *Agetograptus* species, shows the short sicula, the first theca which grows down to the sicular aperture and the reverse lateral wall of $th1^1$ which begins to grow across the reverse side of the sicula before turning upward and forming the redirected (or aborted) $th1^2$. Bulman (1970, fig. 61) illustrated a specimen of this species provided him by R. Thorsteinsson from the Cape Phillips Formation. His figure clearly shows the fusellar increments and how they define the early thecal growth patterns. Bulman did not, however, observe the downward-growing protheca 1^1 seen in the present material because his specimen had an unbroken proximal end. As a result, he believed that $th1^1$ began its growth directly outward and upward.

Li (unpub. ms. 1985) pointed out close similarities between this species and *Glyptograptus tamariscus* and suggested that it was directly derived from the latter. Although the thecae and overall dimensions are similar, A.

hubeiensis has a shorter sicula and a free, central virgula rather than one embedded in the obverse wall as in *G. tamariscus* so a direct descendancy seems unlikely. In the latter respects, *A. hubeiensis* more strongly resembles the other *Agetograptus* species.

Agetograptus primus Obut and Sobolevskaya, 1968

Text-figure 25N,R.

1968 *Agetograptus primus* Obut and Sobolevskaya, pp. 80-81, p. 10, figs. 6-12.

1978 *Dimorphograptus longicaudatus fusiformis* Chen and Lin, p. 50, pl. 9, figs. 6,7; text-fig. 12b.

Material. Three compressed, moderately well preserved specimens.

Occurrence. *Pectinatus* Subzone. Trold Fiord at 62.5m.

Description. Rhabdosome up to 12mm long. Widens from 0.75mm at $th1^1$ to 1.2mm at $th2^1$ to a maximum of 2.3mm. Thecal spacing widens rapidly from 9 in 5mm over the first four thecae to 12 in 10mm distally. Thecae with gentle sigmoidal curvature, apertures slightly everted, overlap about 1/3 proximally, up to about 2/3 distally. Sicula 0.8 to 1.0mm long bearing a short, stout virgella.

Remarks. The width of the proximal ends of the present specimens is slightly lower than that described by Obut and Sobolevskaya (1968) and the distal thecal spacing is slightly wider but otherwise, the present specimens match well with the type material. This species differs from *Agetograptus secundus* Obut and Sobolevskaya only in the rhabdosomal width and, with a much larger population, the two could be found to be conspecific.

"*Dimorphograptus*" *longicaudatus fusiformis* Chen and Lin (1978) fits within the genus *Agetograptus* as here defined and differs from the present material only in having a longer virgella a feature also seen in some of the type specimens of this species.

Agetograptus secundus Obut and Sobolevskaya, 1968

Text-figure 25M,Q.

1968 *Agetograptus secundus* Obut and Sobolevskaya, pp. 79-80, pl. 8, figs. 9-12; pl. 9, figs 1-13; pl. 10, figs. 1-5.

1978 *Dimorphograptus longicaudatus* Chen and Lin, pp. 49-50, pl. 8, figs. 13-20; text-fig. 12a.

1978 *Bulmanograptus deminutus* Ni, p. 404, pl. 1, fig. 15; text-fig. 1, fig. 2.

1978 *Dimorphograptus sichuanensis* Ye, p. 475, p. 177, fig. 7.

Material. About eight compressed specimens moderately well preserved.

Occurrence. *Pectinatus* Subzone. Trold Fiord at 61.0 and 62.5m.

Description. Rhabdosome up to 9.5mm long. Widens rapidly form 0.6 to 0.7mm at $th1^{1}$ to 0.9 to 1.0 at $th1^{2}$ to a maximum of 1.6 to 1.7mm. Thecal spacing widens rapidly from about 9 to 10 in 5mm at the extreme proximal end to 13 to 14 in 10mm distally. Thecae show gentle sigmoidal curvature. Apertures slightly everted proximally, horizontal distally. Theca 1^{2} appears to arise near the base of $th1^{1}$ and extends beyond the aperture of $th2^{1}$ giving a dimorphograptid appearance. Sicula about 0.8 to 1.0mm long reaching to aperture of $th2^{1}$, and bears a virgella up to 0.4mm.

Remarks. The present specimens match closely with those of Obut and Sobolevskaya (1968). The lack of a long virgella in the present material may be a preservational feature or it may be due to intraspecific variation. *Agetograptus primus* Obut and Sobolevskaya, also found here can only be reliably distinguished on the basis of width, the latter being the wider, especially distally.

"*Dimorphograptus*" *longicaudatus* Chen and Lin (1978) "*Bulmanograptus*" *deminutus* Ni (1978) and "*Dimorphograptus*" *sichuanensis* Ye (1978) all have proximal end, rhabdosomal and thecal form and dimensions within the range of variation of this species and all three show a long virgella, also seen in the type material of A. *secundus*. As a result, they are all considered synonymous with the latter species.

Agetograptus cf. A? *sichuanensis* (Ye, 1982)

Text-figure 250,S.

Material. Three moderately well preserved and several more poorly preserved, compressed specimens.

Occurrence. *Cyphus* Zone. Trold Fiord at 56.5 and 60.0m.

Description. Rhabdosome up to 8.5mm long, with uniserial first theca. Widens from 0.5 to 0.7mm at the first theca to a maximum of 1.4 to 1.6mm. Thecae spaced at 7 in 5mm proximally, 12 in 10mm distally. Thecae strongly sigmoidal proximally, with an abrupt geniculum, becoming somewhat more gentle sigmoidal distally. Sicula 1.2 to 1.3mm long, exposed for most of its length on its dorsal side. Virgella up to 0.7mm long.

Remarks. This species shows a proximal development typical of *Agetograptus* species, even in compressed form, including the growth of $th1^1$ down to, or just below the sicular aperture and the growth of the reverse wall of $th1^1$ part way across the reverse side of the sicula. In addition, the virgula appears to "wander" within the central portion of the rhabdosome, indicating that it is unattached.

The present specimens differ from those of *A*? *sichuanensis* (Ye, in Jin, *et al*., 1982 - originally assigned to *Rhaaphidograptus*) in that the thecal spacing is closer, especially in the proximal end and the thecae of *A*? *sichuanensis* appear to be more nearly climacograptid throughout. Although it is difficult to see in Ye's illustrations of *A*? *sichuanensis*, the first theca appears to be longer and its aperture appears to be at or slightly beyond the apex of the sicula, in contrast to the present specimens. Since the proximal details are not clearly discernible in Ye's figures, that species is only questionably assigned to *Agetograptus* although the generic assignment of the Canadian Arctic specimens is not in doubt.

Agetograptus spiniferus Obut and Sobolevskaya, 1968

Plate 22, figures 7,9-13; plate 23, figures 1-8.

1968 *Agetograptus spiniferus* Obut and Sobolevskaya, pp. 82-83, pl. 10, figs. 18-22.

Material. Numerous very well preserved, uncompressed specimens.

Occurrence. *Curtus* and lower *convolutus* zones. Snowblind Creek at 140m and Cape Manning at 0-2, 2-5 and

5-7m.

Description. Rhabdosome up to at least 9mm long with near circular cross-section. Widens from 0.45 to 0.65mm at uniserial first theca, to a maximum of 1.7 to 1.8mm by about the tenth thecal pair after which point it may decrease somewhat. Thecae spaced at 10 to 11 in 5mm at the extreme proximal end, decreasing to 14 to 15 in 10mm distally. Thecae show a weak to moderate sigmoidal curvature proximally, becoming straighter and more highly inclined distally. Apertures everted, rather strongly so distally, and each bears a pair of lateral spines generally 0.2 to 0.3mm long. The lateral margins of the apertures tend to rise to a point, forming distinct lappets where the spines project, especially on the distal thecae. Sicula is 0.65 to 0.8mm long with a prominent virgella up to 3.0mm long. Downward-growing portion of protheca 1^1 is 0.1mm long and is directed first to the left and turns and opens downward. Theca 1^1 reverse wall almost completely crosses the reverse side of the sicula before th 2 differentiates. The virgula is free and central.

Remarks. The rhabdosomal form and dimensions, and the shape of the thecae with apertural spines (and lappets on the distal thecae) all match with the descriptions and illustrations of the type material by Obut and Sobolevskaya (1968). The only differences are that the present specimens tend to have longer virgellae and that the thecal spacing in the proximal end is closer in the present specimens. The latter point may be accounted for by the fact that the thecal spacing in the specimens of this study were measured over only the first two to four thecal pairs, where the spacing is closest. The lesser maximum width of the Canadian specimens is easily accounted for by the fact that they are uncompressed as compared with the compressed Russian specimens.

This species is distinguished from other _Agetograptus_ species (or any other "dimorphograptids") by the presence of apertural spines. This species was most likely the one studied by Crowther (1981, listed as _Dimorphograptus_? sp.) from the Cape Phillips Formation, although Crowther described thll as being upwardly directed from its origin. Unfortunately, he provided no illustrations of this specimen.

A single specimen has been found in which the first metatheca of the second series has been "stunted" and the second metatheca of that series entirely suppressed (pl. 22, figs. 7,9). This is interpreted to be a pathological malformation. It is interesting to note that although the aperture of the stunted theca is quite constricted, the lateral spines have been secreted where the lateral margin of the aperture would have been had it grown normally.

Agetograptus? sp.

Text-figure 25T.

Material. A single, compressed specimen with fair preservation.

Occurrence. Upper *cyphus* Zone. Huff Ridge at 114.5m.

Description. Rhabdosome 5.5mm long with uniserail first theca. Widens from 0.75 at th1 to a maximum of 2.1mm at the fifth thecal pair. Thecal spacing at 7 in 5mm although th1 is 1.3mm long. Orthograptid thecae are inclined at about 35o. Sicula length cannot be determined, th1[1] grows down slightly below the sicular aperture.

Remarks. This specimen does not bear a close resemblence to any other described *Agetograptus*, particularly in that the first theca is longer than the subsequent ones. However, the downward growth of th1[1] to a point slightly below the sicular aperture together with the orthograptid thecae suggests that it be included in that genus. "*Bulmanograptus*" *anhuiensis* (Li, unpub. ms.) bears some similarities to the present specimen but the first theca of the former does not appear to be as long as the one found here. Lack of accompanying description or scale on illustration provided by Li prevent a more complete comparison. In any event, until that species in published, it remains a *nomen nudum*.

N. gen. B

Type species. *Diplograptus bellulus* Tornquist, 1890.

Diagnosis. Pattern I species with very short sicula, almost completely obscured by growth first thecal pair. Downward growth of $th1^1$ also short. Thecae glyptograptid to orthograptid and may bear apertural spines. Rhabdosome aseptate and roughly circular in cross-section. Virgella commonly long and robust.

Description. Proximal development pattern is type I but it differs in having a very short sicula (0.4 to 0.5mm long) and a short downward-growing portion of $th1^1$ near the sicular aperture. Upward growth of $th1^1$ crosses both obverse and reverse side of the sicula at a rather high angle. Reverse wall almost completely obscures the sicula, leaving less than 0.1mm exposed before turning upward and differentiating into theca 1^2. About 0.1 to 0.2mm is left exposed on the obverse side. Thecae glyptograptid to orthograptid and may bear paired apertural spines. Virgula is commonly long and robust. Rhabdosome has a more-or-less circular cross-section and is aseptate. Virgula is central and may be free or attached to the bases of the interthecal septa.

Remarks. Although species of this genus show the key pattern I characteristics (only one primordial theca and normal differentiation of all subsequent thecae), they have acquired a proximal appearance quite unlike other petalograptines with their extremely short, obscured sicula. This unique proximal end is shared by only three known taxa to date ("Orthograptus" bellulus (Tornquist), "G". kayi kayi (Churkin and Carter) and "G". kayi n. subsp.) and is here considered distinct enough to merit separate generic status. Even in compressed form, the short, obscured sicula is evident, differentiating species of this genus from other Llandovery genera.

Although the details of the proximal development of "G". kayi kayi have not been observed, it shows the characteristic obscured sicula and aseptate rhabdosome, and its otherwise close similarity to "G". kayi n. subsp., found in uncompressed form here, strongly suggests that it should be included in this new genus.

"Orthograptus" bellulus (Törnquist, 1890)

Plate 24, figures 1-9; plate 25, figures 1-5.

1890 Diplograptus bellulus Törnquist, p. 28, pl. 1, figs. 25-29.

1907 Diplograptus (Orthograptus) bellulus Törnquist; Elles and Wood, pp. 231-232, pl. 29, fig. 2a-e; text-fig.

152a-c.

1967 Rectograptus bellulus (Törnquist); Obut and Sobolevskaya, pp. 62-63, pl. 3, fig. 6.

1970 Orthograptus bellulus (Törnquist); Churkin and Carter, p. 29, pl. 3, fig. 1; text-fig. 12G.

1970 Orthograptus bellulus (Tornquist); Rickards, p. 46, pl. 3, fig. 5.

1971 Orthograptus bellulus (Tornquist); Schauer, p. 36, pl. 7, figs. 9,10; pl. 16, fig. 6.

1974b Orthograptus bellulus (Törnquist); Hutt, p. 37, pl. 3, figs. 1,2; pl. 6, fig. 13?; text-fig. 8, figs. 2-4.

1975 Orthograptus bellulus (Tornquist); Bjerreskov, p. 28, pl. 4F.

1978 Orthograptus bellulus (Törnquist); Chen and Lin, p. 38, pl. 6, figs. 18-23.

1984a Orthograptus bellulus (Tornquist); Chen, p. 41, pl. 3, fig. 6.

1984 non Rectograptus bellulus (Törnquist); Li, p. 17, pl. 17, figs. 1,2.

Material. About twenty very well preserved, uncompressed specimens.

Occurrence. Orbitus Subzone? and lower convolutus Zone. Cape Manning at 2-5 and 5-7m.

Description. Rhabdosomes up to 5mm long, aseptate, with a circular cross-section. Widens from 0.7 to 0.8mm at the first thecal pair to 1.2 to 1.25mm at the fifth. The maximum observed width is 1.3mm at the seventh thecal pair. Thecae spaced at 8 to 10 in 5mm at the extreme proximal end, decreasing to 14 to 15.5 in 10mm distally and are very slightly sigmoidally curved throughout. Apertures are everted and bear a pair of lateral spines up to 0.3mm long. Spines are best developed on proximal thecae, often being reduced to slight points on the apertural margins of the distal thecae. Thecae are inclined at 30 to 40° and overlap 1/4 to 1/3 of their length proximally, increasing to 1/2 distally. Sicula is 0.4 to 0.5mm long and is exposed for 0.15 to 0.2mm on the obverse side and for less than 0.1mm below th1². In more mature specimens, it is completely overgrown with cortical deposits. Downward-growing portion of protheca 1¹ is about 0.2mm long and grows almost straight downward. Virgella is robust and up to at least 4.5mm long. The virgula is central and unattached.

<u>Remarks</u>. The more-or-less orthograptid, closely spaced thecae with short apertural spines and the blunt, rounded proximal end with a very short sicula and long virgella are all features characteristic of this species. The present specimens do not reach a maximum width comparable to those previously reported but this is attributed to the fact that the present specimens are uncompressed and have a circular cross-section (the maximum width of 1.3mm found here, if

compressed, would measure up to 1.9 to 2.0mm) and that none of these specimens reaches beyond the seventh thecal pair.

The apertural spines are lateral in position, relatively short, and often reduced or absent on the more distal thecae. This accounts for the fact they have frequently not been observed in compressed or partially compressed specimens in rock. Their position is such that in a normal, profile compression the spines would be pressed against the sides of the succeeding thecae. It is only in subscalariform view that the spines would be visible (e.g. Hutt, 1974b, text-fig. 8, figs. 2-4). The possibility exists, of course, that some populations of this species are lacking in apertural spines.

"Glyptograptus" kayi n. subsp.

Plate 25, figures 6-9; plate 26, figures 1-12; plate 13, figures 1-6.

Material. Hundreds of well to very well preserved, uncompressed specimens and several moderately to poorly preserved, compressed specimens.

Occurrence. Curtus and convolutus zones. Snowblind Creek at 140m, Cape Manning at 0-2, 0-5 and 5-7m and Twilight Creek at 15.0m.

Diagnosis. Slender, aseptate rhabdosome with closely spaced, glyptograptid thecae and a near circular cross-section. Sicula very short and obscured by growth of first thecae. Virgella very long and robust in mature specimens.

Description. Rhabdosome up to 11mm long (excluding virgella) and is nearly circular in cross-section. Widens from 0.6 to 0.8mm at the first thecal pair (0.5 to 0.6mm uncompressed) to 1.2 to 1.4mm at the fifth thecal pair (0.8 to 1.15) to a maximum of 1.4 to 1.8mm (1.0 to 1.2mm). Thecae are spaced at 7 to 9 in 5mm proximally and 12 to 14.5 in 10mm distally. Thecae have a flowing sigmoidal curvature and horizontal to slightly introverted apertures distally and slightly everted proximally. In some very mature rhabdosomes the apertures of the first thecal pair are strongly everted due to the addition of (cortical) tissue onto the apertural lip. Thecal overlap is about 1/3. The sicula is 0.4 to 0.5mm long and is almost completely obscured on the reverse side by the early growth of $th1^2$. With the addition of cortical tissue in mature specimens, the sicula is completely overgrown and obscured. The sicular aperture bears a virgella which is very long (up to at least 5.5mm) and robust on mature specimens although shorter and more slender in more immature specimens. The downward-growing portion of protheca 1^1 is almost straight and about 0.2mm long. A median septum is absent and the virgula is central and alternately attached to the bases of the intertheca1 septa. The virgula occasionally extends well beyond the distal thecae.

Remarks. This new subspecies, together with "*G*". *kayi kayi* (Churkin and Carter) are unique among Llandovery "glyptograptids" in that the sicula is obscured on the reverse side by the first thecal pair. It is not unique in lacking a median septum as suggested by Churkin and Carter (1970).

This new subspecies differs from *C*. *k*. *kayi* in that it has a closer thecal spacing (especially proximally), is somewhat narrower distally and has a long, robust virgella.

Hedrograptus? *tangshanensis* (Hsu) has similar thecal form, dimensions and thecal spacing, and Chen and Lin (1978) reported a long virgella on some examples of that species. Hsu (1934), however, observed a median septum on his uncompressed specimens and a portion of the sicula appears to be visible below thl[2] on Chen and Lin's specimens.

Subfamily RETIOLITINAE Lapworth, 1873

Diagnosis. Sicula reduced to absent. Thecal framework represented by clathria and/or reticulum which may show some development continuous periderm. Ancora always present and incorporated in framework of first thecal pair.

Remarks. This subfamily comprises the groups previously regarded as the Retiolitinae and the Plectograptinae, which comprises, as far as presently known, all of the Silurian retiolitids. The Ordovician forms previously included in the Retiolitidae (sensu Bulman, 1970), the "archiretiolitids", are regarded as having a different proximal development pattern not involving an ancora and have been included by Mitchell (1987) within the Orthograptidae.

The "retiolitid" and "plectograptid" genus groups which have been long recognized at the subfamily level (although raised to the family level by Obut and Zaslavskaya, 1986) have stood up well under study of flatten material, as well as morphologic and ultrastructural study of uncompressed specimens and so are here formally retained at the tribe level, the Retiolitini and the Plectograptini respectively.

Discussions of the skeletal structure and morphology of most of the genera recovered in this study, as well as diagnoses and remarks concerning the Retiolitini and Plectograptini are presented in Lenz and Melchin (in press a, see appendix D).

Tribe RETIOLITINI Lapworth, 1876

Genus Pseudoplegmatograptus Přibyl, 1948

Type species. Retiolites perlatus var. obesus Lapworth, 1877.

<u>Pseudoplegmatograptus giganteus</u> Bouček and Münch, 1943

Text-figure 26A.

1943 <u>Plegmatograptus giganteus</u> Bouček and Münch, pp. 17-18, text-figs. 5b,c; 6a-c.

1982a <u>Pseudoplegmatograptus giganteus</u> (Bouček and Münch); Lenz, p. 41, fig. 17C,D.

<u>Material</u>. Two distal fragments, one very well preserved, one rather poorly preserved.

<u>Occurrence</u>. Lower <u>sakmaricus</u> Zone - Snowblind Creek at 528.0m and Irene Bay at 68-72m.

<u>Description</u>. Width is up to 7.6mm, 11.5mm including lacinia and thecae are spaced at 8 in 10mm. Clathria indistinct except for virgula and looping apertural lists each of which gives rise to a pair of spines. Distally, apertural spines merge into a 1.0 to 1.2mm wide band of continuous tissue which extends the length of the preserved rhabdosome. Thin peridermal tissue also appears to be present in the central portion of the rhabdosome. Reticular meshes coarse (1.0 to 2.0mm across) and roughly arranged in five rows along the rhabdosome.

Text-figure 26

All specimens x5 unless otherwise stated.

A. *Pseudoplegmatograptus giganteus* Bouček and Munch,
SC:528.0, x2.5.

B. *Pseudoplegmatograptus* cf. *P. longispinus* Bouček and Münch, SC:534.7.

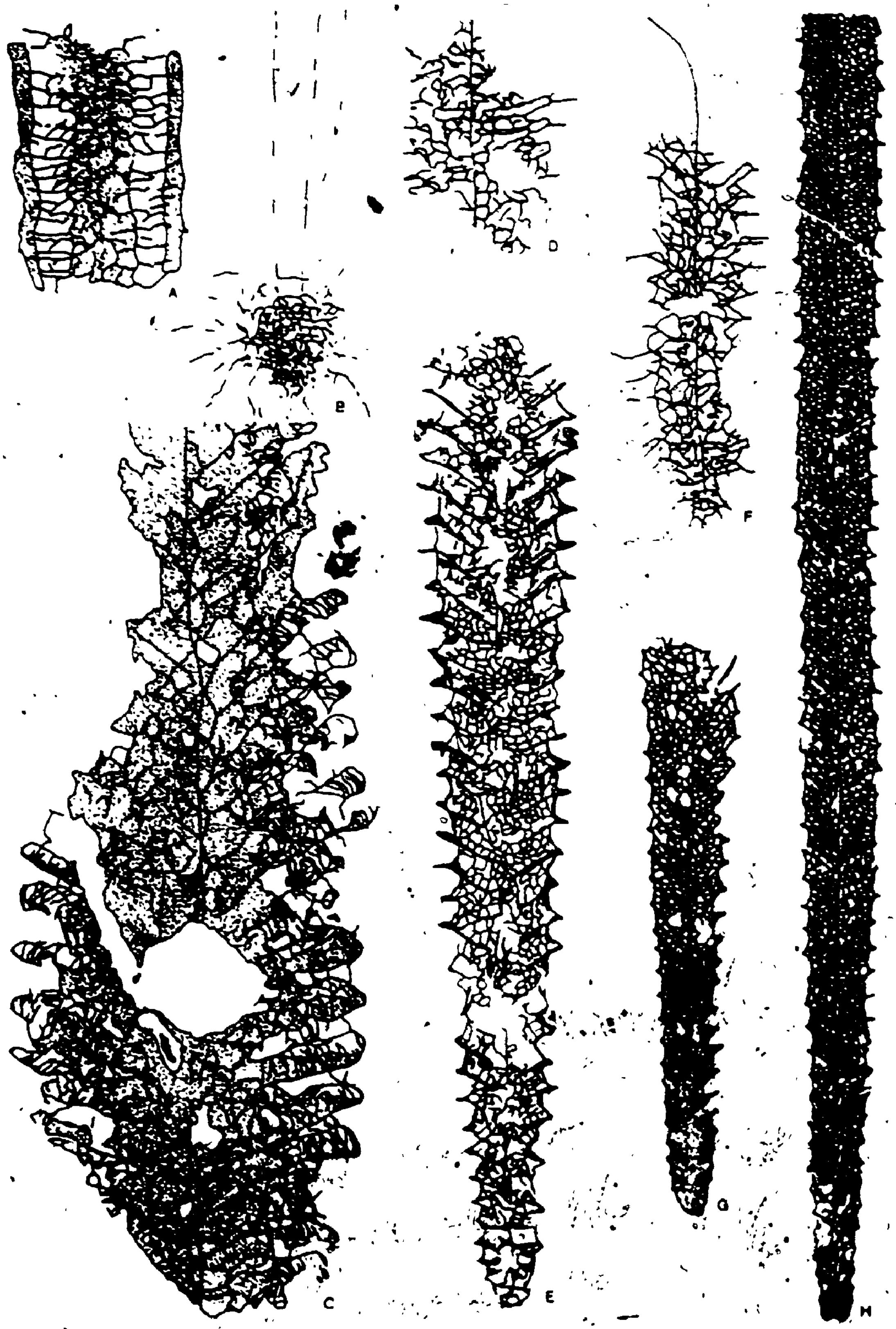
C. *Pseudoretiolites* cf. *P. decurtatus* Bouček and Munch,
CM:2-5, x10.

D,F. *Pseudoplegmtograptus obesus obesus* (Lapworth), both specimens from TC:26.0.

E. *Retiolites geinitzianus geinitzianus* (Barrande),
SC:393.0.

G. *Retiolites geinitzianus angustidens* Elles and Wood,
TC:26.0.

H. *Retiolites geinitzianus densereticulatus* Bouček, TC:57.0.


A
B
C
D
E
F
G
H

Remarks. The present specimens do not differ from the type material (Bouček and Munch, 1943) or that of Lenz (1982a). The very large size, the coarse meshwork and the presence of the bands of apparently continuous periderm along the margins of the lacinia are all diagnostic of this species.

Pseudoplegmatograptus obesus obesus (Lapworth, 1877)

Text-figure 26D,F.

1877 Retiolites perlatus var. obesus Lapworth, p. 137, pl. 6, fig. 29.

1908 Retiolites (Plegmatograptus) obesus (Lapworth); Elles and Wood, 342-343, pl. 34, fig. 12a-c; text-fig. 223a-c.

1943 Plegmatograptus obesus obesus (Lapworth); Bouček and Munch, pp. 6-9, pl. 1, figs. 1,2; text-figs. 1a-g, 2a,b.

1970 Pseudoplegmatograptus obesus obesus (Lapworth); Rickards, p. 50, text-fig. 13, fig. 20.

1971 Retiolites (Pseudoplegmatograptus) obesus Lapworth; Schauer, p. 84, pl. 39, figs. 5-8; pl. 40, fig. 5.

1974 Pseudoplegmatograptus obesus obesus (Lapworth); Hutt, pp. 47-48, text-fig. 12, fig. 1.

1976 Pseudoplegmatograptus obesus obesus (Lapworth); Sennikov, pp. 158-160, pl. 7, figs. 6,7.

1978 Pseudoplegmatograptus obesus obesus (Lapworth); Wang,

pp. 305-308, pl. 1, fig. 4.

1982a Pseudoplegmatograptus obesus obesus (Lapworth); Lenz, pp. 41-42, figs. 16E; 17A,B.

1984a Pseudoplegmatograptus obesus (Lapworth); Chen, pp. 50-51, pl. 7, figs. 5,8; pl. 8, figs. 1,2.

1984 Sinostomatograptus sp. Bates and Kirk, text-fig. 4b-d.

1985 Pseudoplegmatograptus obesus (Lapworth); Liu, p. 44, pl. 2, fig. 8.

in press a Pseudoplegmatograptus obesus obesus (Lapworth); Lenz and Melchin, pl. 1, fig. 1.

Material. Two moderately well preserved compressed specimens and several more poorly preserved fragments.

Occurrence. Crispus Zone. Twilight Creek at 26.0m and Huff Ridge at 195.0m.

Description. Rhabdosomes fragmentary, up to 18mm long. Widens from a minimum of 1.4 to a maximum of 5.0mm, plus apertural spines which may be up to 1.2mm long. Thecae spaced at 12 in 10mm, reticulum meshes spaced at about 4 to 6 in 2mm. Clathria indistinct except for virgula and looping apertural lists. Lacinia consists only of simple, unconnected apertural spines.

Remarks. The details of the skeletal architecture of this species has been outlined by Lenz and Melchin (in press a).

The present specimens match well with those previously described in dimensions and rhabdosomal form as well as the nature of the reticulum. The fact that the apertural spines do not appear to be connected to form a lacinia may be the result of intraspecific variation or preservation. Study of the uncompressed specimens shows that the outer apertural loop, on flattening, may give the appearance of a lacinia.

The specimens illustrated as Sinostomatograptus sp. by Bates and Kirk (1984) compare very closely with the uncompressed specimens from the Cape Phillips Formation and were identified as Sinostomatograptus due to the presence of stomata. The Canadian specimens, which involve more distal specimens, are identical to previously described P. obesus obesus and the presence of stomata, not previously seen in this genus, were attributed to the fact that they are not thickly rimmed as in Stomatograptus and would, therefore, not be detected in flattened material. Indeed, the stomata can not be seen on the present, flattened specimens.

Bates and Kirk (pers. comm., 1985, 1986) have also found uncompressed specimens of this species in which the apertural spines merge distally and form a lateral lacinia.

Pseudoplegmatograptus cf. P. longispinus

Bouček and Munch, 1943

Text-figure 26B.

Material. A single, moderately well preserved, compressed specimen.

Occurrence. Lower sakmaricus Zone. Snowblind Creek at 534.7m.

Description. Rhabdosome about 5mm long, plus a 12mm long free virgula. Width is up to 3.3mm and thecae are spaced at 15 in 10mm. Clathria indistinct, reticulum dense, 8 polygonal cells in 1mm. Apertures bear spines up to 2.3mm long.

Remarks. This single specimen differs from other species of Pseudoplegmatograptus in the narrow width, more dense reticulum and very close thecal spacing. The width and thecal spacing could be due to immaturity of the specimen. If it is an immature specimen then the long apertural spines suggest a close affinity with Pseudoplegmatograptus longispinus which has been found uncompressed in the Cape Phillips Formation (Lenz and Melchin, in press a). The latter specimen has a more widely spaced reticular mesh.

Genus __Pseudoretiolites__ Bouček and Munch, 1943

__Type species__. __Retiolites perlatus__ Nicholson, 1868.

__Pseudoretiolites__ cf. __P. decurtatus__ Bouček and Munch, 1943

Text-figure 26C.

in press a __Pseudoretiolites__ cf. __decurtatus__ Bouček and Munch; Lenz and Melchin, pl. 1, figs. 2-8.

__Material__. About ten well to poorly preserved, compressed specimens.

__Occurrence__. __Orbitus__ Subzone and __minor__ Zone. Cape Manning at 2-5m, Twilight Creek at 22.5 and 23.5m, Trold Fiord at 62.5 and 63.0m and Huff Ridge at 156.5m.

__Description__. Rhabdosome up to at least 20mm long. Widens rapidly from about 1.5mm (1.1mm uncompressed) at the ancora to a maximum of 5.8 to 6.6mm. Thecae spaced at 11 to 12.5 in 10mm (about 7 in 5mm proximally) and appear to have a petalograptid profile. Reticular meshwork has about 6 to 7 polygonal openings in 2mm. Clathria indistinct in compressed specimens. One specimen shows well developed continuous periderm occupying the central portion of the rhabdosome as well as forming interthecal septa.

Remarks.--The nature of the basket-like ancora and the clathrial framework have been outlined by Lenz and Melchin (in press a) and the presence of continuous periderm on uncompressed specimens has been reported by Lenz and Melchin (in press b). The similarity of the clathria with those of the other Retiolitini and the newly reported presence of raised stomata (Lenz and Melchin, in press a) indicates the close relationship between _Pseudoretiolites_ and _Stomatograptus_ and _Pseudoplegmatograptus_ indicates that there is no justification for raising this genus to a separate suprageneric taxon (i.e. the Pseudoretiolitidae of Obut and Zaslavskaya, 1986).

This species is, in some ways, intermediate in form between _P. decurtatus_ and _P. perlatus_. The maximum width is greater than that typical of the former species (5-6mm) but generally less that of the latter (7-8mm). The distal thecal spacing is likewise in between typical values of the two species. The thecal form of the two species appears to be very similar. The overall rhabdosomal form of the Canadian Arctic specimens, however, more closely resemble that of _P. decurtatus_ with the rapid widening from a relatively narrow ancora giving an ovate outline to the rhabdosome. A larger population of more complete specimens would be necessary before these specimens could be formally assigned although they may represent a new subspecies of _P. decurtatus_.

Genus *Retiolites* Barrande, 1850

Type species. *Gladiolites Geinitzianus* Barrande, 1850.

Retiolites geinitzianus geinitzianus (Barrande, 1850)

Text-figure 26E.

1850 *Gladiolites Geinitzianus* Barrande, pp. 69-74, pl. 4, figs. 16-33.

1908 *Retiolites* (*Gladiograptus*) *Geinitzianus* Barrande; Elles and Wood, pp. 336-338, pl. 34, fig. 8a-d; text-fig. 220a-f.

1943 *Retiolites* (*Retiolites*) *geinitzianus geinitzianus* Barrande; Bouček and Münch, pp. 40-43, pl. 3, figs. 2-5; text-figs. 13c-h; 14c,d.

1966 *Retiolites geinitzianus* Barrande; Obut and Sobolevskaya, pp. 15-16, pl. 3, figs. 10-13; text-fig. 7.

1967 *Retiolites geinitzianus* Barrande; Obut and Sobolevskaya, pp. 79-80, pl. 7, figs. 7,8.

1971 *Retiolites* (*Ret.*) *geinitzianus geinitzianus* (Barrande); Schauer, p. 83, pl. 39, figs. 1,2; pl. 40, fig. 1.

1975 *Retiolites geinitzianus geinitzianus* (Barrande); Bjerreskov, p. 38, pl. 5F.

1975 *Retiolites geinitzianus geinitzianus* Barrande; Berry and Murphy, pp. 98-99, pl. 14, fig. 1.

1975 *Retiolites geinitzianus* Barrande; Obut and

Sobolevskaya, pp. 159-160, pl. 32, fig. 2.

1979 <u>Retiolites geinitzianus geinitzianus</u> Barrande; Paškevičius, pp. 143-145, pl. 6, fig. 7; pl. 7, fig. 1; pl. 22, figs. 10,11.

1985 <u>Retiolites geinitzianus</u> Barrande; Liu, pp. 41-42, pl. 1, figs. 11,12.

<u>Material</u>. About ten moderately well preserved, compressed specimens.

<u>Occurrence</u>. Lower <u>griestoniensis</u> to lower <u>sakmaricus</u> Zone. Snowblind Creek at 393.8m, Twilight Creek at 29.5, 42.0, 45.0 and 52.5m and Huff Ridge at 203.0m.

<u>Description</u>. Rhabdosome up to 35mm long. Widens gradually from 1.7 to 2.1mm at the first thecal pair to a distal maximum of 5.0 to 5.5mm. Thecae spaced at 6.5 to 7 in the first 5mm, 8.5 to 11 in 10mm distally. Thecae are nearly straight tubes, inclined at 60 to 65° proximally, 45 to 55° distally, with strongly everted apertures which are often parallel the rhabdosomal axis, except for the ventral margin which is usually extended into a thick lip. Clathria is distinct and reticulum is moderately dense, usually with about 3 1/2 to 4 1/2 meshwork cells per millimetre (often more dense proximally).

<u>Remarks</u>. The present specimens do not differ from

previous reports of this well known and widely reported taxon. This form is much less common than R. geinitzianus densereticulatus from which it is easily separated by its greater width and, to a lesser extent, by the less dense reticulum. It is separated from species of Stomatograptus by the lack of interthecal septa (although see Lenz and Melchin, in press b, where interthecal septa have been found on uncompressed specimens of Retiolites sp.), the lack of stomata and the strongly everted apertures providing a nearly parallel-walled appearance to many of the specimens.

Retiolites geinitzianus angustidens Elles and Wood, 1908

Text-figure 26G.

1908 Retiolites (Gladiograptus) Geinitzianus var. angustidens Elles and Wood, p. 338, pl. 34, fig. 9a-c.

1943 Retiolites (Retiolites) geinitzianus angustidens Elles and Wood; Bouček and Münch, pp. 37-40, pl. 2, figs. 1-4; text-figs. 11a-e; 12b-e.

1971 Retiolites (Ret.) geinitzianus angustidens Elles and Wood; Schauer, p. 83, pl. 39, fig. 3, pl. 40, fig. 2.

1975 Retiolites geinitzianus angustidens Elles and Wood; Berry and Murphy, pl. 14, fig. 2.

1975 Retiolites geinitzianus angustidens Elles and Wood; Bjerreskov, pp. 38-39, pl. 5D,E.

1978 Retiolites geinitzianus angustidens Elles and Wood; Wang, p. 305, pl. 1, fig. 1.

1979 Retiolites angustidens Elles and Wood; Paškevičius, pp. 142-143, pl. 6, figs. 5,6; pl. 22, figs. 8,9.

1985 Retiolites geinitzianus angustidens Elles and Wood; Liu, p. 40, pl. 1, figs. 1-3.

Material. Seven moderately to very well preserved and several more poorly preserved compressed specimens.

Occurrence. Crispus and lower griestoniensis zones. Snowblind Creek at 350, 360, 394.0 and 396.0m and Twilight Creek at 26.0m.

Description. Rhabdosome up to at least 22mm long. Widens from 1.2 to 1.4mm at th1 to a maximum of 3.3mm. Thecae spaced at about 8 in the first 5mm, 9.5 to 11 in 10mm distally and are simple tubes inclined at about 50 to 55° proximally and about 45° distally. Apertures strongly everted, parallel to rhabdosomal axis. Clathria well defined, reticulum meshes spaced at 3 to 4 in 1mm although they may be closer proximally. Meshwork cells are roughly arranged in three rows along each thecae although these may be subdivided by later generation lists as the specimen matures.

Remarks. This subspecies is not common in the Cape Phillips Formation and seems to be largely replaced in the griestoniensis and sakmaricus zones by R. geinitzianus densereticulatus. It is separated from the latter by its less dense reticulum (see discussion of R. g. densereticulatus below) and from R. g. geinitzianus by its significantly lesser width. As noted below, some previously reported occurrences of this subspecies (e.g. Obut and Sobolevskaya, 1966; Lenz, 1982a) have been here referred to R. g. densereticulatus owing to their dense reticulum.

The assignment of this form to a separate species by Obut and Sobolevskaya (1966) and Paškevičius (1979) has not been followed here due to the very close similarities within the Retiolites geinitzianus group. If they were to be separated, however, R. g. densereticulatus should be included as a subspecies of R. angustidens rather than R. geinitzianus since the two are separated only by the density of the reticulum.

Retiolites geinitzianus densereticulatus Bouček, 1931

Text-figure 26H.

1931 Retiolites geinitzianus densereticulatus Bouček, p. 306, text-fig. 16.

1943 Retiolites geinitzianus densereticulatus Bouček; Bouček and Münch, pp. 43-45, pl. 2, figs. 5-9; text-figs. 13i-k; 14e.

1966 Retiolites angustidens (Elles and Wood); Obut and Sobolevskaya, pp. 16-18, pl. 3, figs. 14-16; text-fig. 8.

1979 Retiolites geinitzianus densereticulatus Bouček; Paškevičius, p. 145, pl. 7, fig. 2; pl. 22, fig. 12.

1981 ? Retiolites geinitzianus angustidens Elles and Wood; Bjerreskov, p. 20, pl. 6, fig. 1.

1981 Retiolites geinitzianus densereticulatus Bouček; Crowther, pp. 89-96, pl. 15, figs. 1-5; text-fig, 29A.

1982a Retiolites geinitzianus angustidens Elles and Wood; Lenz, pp. 33-36, fig. 15C,H.

Material. Hundreds of very well to poorly preserved, compressed, partial relief and uncompressed specimens.

Occurrence. Lower griestoniensis to upper sakmaricus Zone. Snowblind Creek at 457.0, 460.0, 492.0, 522.5, 524.5, 525.0, 526.0, 528.0, 536.5, 538.5, A2.0 and A16.0m, Cape Phillips at 58.5, 120.0, 127.0, 128.0, 146.0, 148.0, 151.0, 152.5, 156.0 and 157.0m, Rookery Creek at 140.5 and 156.5m, Twilight Creek at 21.0, 27.5, 29.5, 42.0, 42.5, 48.0, 49.0, 49.5, 50.0, 52.5, 54.5, 55.5, 57.0, 59.0, 60.0 and 61.5m, Middle Island at 52.0, 63.0 and 64.0m, Cape Becher at 2.0, 5.0, 7.0, 10.0, 20.0, 22.0, 26.0 and 32.0m, Trold Fiord at 105.0, 135.0, 136.0, 140.5 and 143.0m, Huff Ridge at 204.0 and 274-280m and Irene Bay at 67.0, 68-72 and 69.0m.

Description. Rhabdosome up to at least 55mm long. Widens gradually from 0.9 to 1.1mm at the first thecal pair to a distal maximum of 2.9 to 4.0mm although a few specimens reach a distal width of only 2.2 to 2.4mm. Thecae spaced at 7 to 8.5 in the first 5mm, 9 to 12 in 10mm distally. Thecae are essentially straight tubes with variable inclination, generally 45 to 55°, somewhat higher proximally. Apertures are strongly everted, usually parallel to rhabdosomal axis (except for the ventral margin which often extends into a thick lip), possibly retroverted on the proximal thecae of some specimens and thecal overlap is virtually complete. Clathria is distinct and reticulum is rather dense, with meshwork cells usually 4 to 5 in 1mm, often more dense proximally to mesially, and not arranged in rows but usually 4 to 6 across the width of one theca. One compressed specimen observed with a possible prosicula.

Remarks. This subspecies is by far the most common retiolitid found in the Llandovery portion of the Cape Phillips Formation. Its separation from R. geinitzianus angustidens is very subtle and due to the ranges of variation seen in width, thecal spacing and thecal inclination within these forms, density of the reticulum is the only reliable criterion for their separation. In fact, a case could be made to consider the two forms synonymous although a restudy of the type material should be done before such a move is made.

In these collections, the criteria defined by Bouček and Münch (1943) are used to separate these two taxa: if the reticulum shows three to four meshwork cells in 1mm and the thecae show only three crudely defined rows of cells then the specimens are assigned to R. g. angustidens; if there are four or more cells in 1mm (occasionally as few as 3 1/2 in the distalmost thecae) and the thecae have four or more cells across their width, then they are assigned to R. g. densereticulatus. Unfortunately, the density of meshwork cells varies along the length of the rhabdosome and is commonly more dense proximally as later generations of fine lists are added to the reticulum and well preserved, distal thecae are necessary to reliably distinguish the two forms.

The specimens assigned to R. g. angustidens by Obut and Sobolevskaya (1966) and Lenz (1982a) explicitly state that the meshwork density is four or more in 1mm and this is borne out by their illustrations so these occurrences are here assigned to R. g. densereticulatus. The specimens reported by Bjerreskov (1981) have seven to nine meshes in 1mm, more than is found in most of the present specimens, except proximally, and they are slender, not exceeding 2.5mm. These specimens may be synonymous with R. angustissimus Obut and Sobolevskaya (1967) which is consistently narrower than R. geinitzianus densereticulatus and has a very dense reticulum. A few of the present specimens found in the upper part of the sakmaricus Zone resemble this slender, densely meshed form, but do not show such a high mesh density (only 6 to 7 in 1mm) and have more closely spaced thecae than the Russian specimens. For this reason they are considered within the range of variation of

R. g. densereticulatus rather than being assigned to the separate, Russian taxon.

Genus *Stomatograptus* Tullberg, 1883

Type species. *Retiolites granlis* Suess, 1851.

Stomatograptus grandis grandis (Suess, 1851)

Text-figure 27A.

1851 *Retiolites grandis* Suess, p. 15, pl. 7, fig. 2.

1943 *Retiolites* (*Stomatograptus*) *grandis grandis* Suess; Bouček and Munch, pp. 49-50, pl. 3, figs. 7,8; text-figs. 15e; 16a-c; 17a-c.

1965 *Stomatograptus grandis* (Suess); Obut and Sobolevskaya, pp. 39-40, pl. 2, figs. 12,13.

1967 *Stomatograptus grandis* (Suess); Obut and Sobolevskaya, pp. 84-85, pl. 8, figs. 1-4.

1975 *Stomatograptus grandis grandis* (Suess); Bjerreskov, pp. 39-40, pl. 5I.

1975 *Stomatograptus grandis* (Suess); Obut and Sobolevskaya, pp. 160-161, pl. 32, figs. 4,5.

1976 *Stomatograptus grandis* (Suess); Sennikov, pp. 155-158; pl. 7, figs. 4,5.

1977 *Stomatograptus grandis grandis* (Suess); Obut and Sennikov, pp. 109-110, pl. 1, fig. 1.

1978 *Stomatograptus grandis* (Suess); Wang, p. 309, pl. 3,

Text-figure 27

All specimens x5 unless otherwise stated.

A. *Stomatograptus grandis grandis* (Suess), TC:31.5.

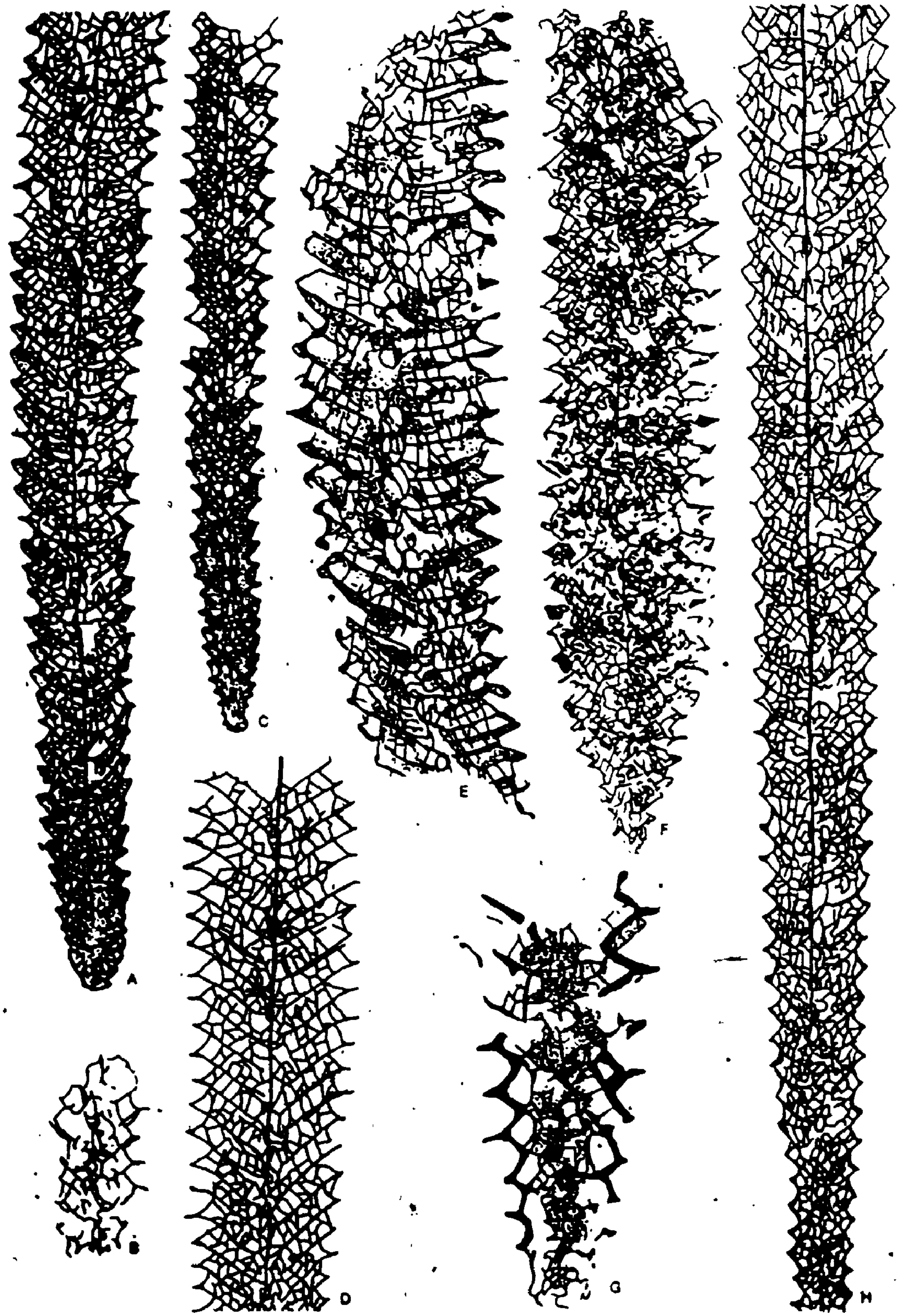
B. *Paraplectogrptus* cf. *P. intermedius* (Bjerrekov), IB:65.5.

C. *Stomatograptus grandis girvanensis* Cocks and Toghill?, TC:27.5.

D,G,H. *Stomatograptus* n. sp.: D) TC:57.0; G) CP:30.0, x10; H) TC:29.5.

E. *Stomatograptus grandis imperfectus* Bouček and Münch, SC:A16.0.

F. *Stomatograptus grandis asiaticus* Golikov, RC:149.0.


A
B
C
D
E
F
G
H

figs. 3,4.

1981 Stomatograptus grandis grandis (Suess); Bjerreskov, p. 21, pl. 5, fig. 7.

1982a Stomatograptus grandis grandis (Suess); Lenz, pp. 36-37, fig. 16A-C.

1985 Stomatograptus grandis (Suess); Liu, pp. 42-43, pl. 2, figs. 2,3.

in press a Stomatograptus grandis grandis (Suess); Lenz and Melchin, pl. 2, fig. 2.

Material. About fifteen very well to poorly preserved, compressed specimens.

Occurrence. Lower and middle griestoniensis Zone and sakmaricus Zone. Snowblind Creek at 393-396m, Cape Phillips at 152.5m, Twilight Creek at 31.5m and Middle Island at 64.0m.

Description. Rhabdosome up to 52mm long. Widens gradually from 1.3 to 1.7mm at th1 to a maximum of 5.1 to 5.8mm and thecae spaced at 6 to 7 in the first 5mm, 9 to 10.5 in 10mm distally. Thecae are inclined at 45 to 50^{o} and curved slightly upward with weakly everted apertures. Links: Interthecal septa are almost invariably present (except possibly at the distal ends) and some rhabdosomes are completely sclerotized at the proximal end. Stomata commonly well defined although may not be visible depending on mode of preservation.

Remarks. The moderate width of this subspecies, together with the well sclerotized septa and pronounced stomata make it easy to distinguish from other retiolitids. The most similar form is *S. grandis imperfectus* from which it is distinguished by the lesser maximum width and the thecal profiles which are slightly convex downward.

Stomatograptus grandis asiaticus Golikov, 1974

Text-figure 27F.

1974 *Stomatograptus grandis asiaticus* Golikov, pp. 92-93, pl. 4, figs. 2,3.

Material. Two well preserved, compressed specimens.

Occurrence. Upper *griestoniensis* and loer *sakmaricus* zones. Cape Phillips at 100.0m and Rookery Creek at 149.0m.

Description. Rhabdosome about 30mm long. Widens from 1.6mm to its maximum of 6.1mm within about 10mm of the proximal end. Thecae spaced at 14 in the first 5mm, 8.5 in 10mm distally and are straight, inclined at about 50o with weakly everted apertures. Reticulum moderately dense proximally (4 to 5 meshes/mm) becoming more open distally (3/mm) and two rows of mesh cells per theca. Interthecal septa visible proximally, apparently not present mesially to distally. A few possible stomata visible but do not show thickened rims.

Remarks. These specimens resemble those of Golikov (1974) in all respects except that the thecae are somewhat more highly inclined. This subspecies is distinguished by its rapidly widening proximal end and relatively open reticulum with indistinct stomata. Stomatograptus grandis imperfectus, which it most closely resembles, widens somewhat more gradually and has more prominent interthecal septa (especially at the distal ends of the theca), more prominent, thickened ventral lips on the thecal apertures and more strongly everted apertures. In addition, the reticulum and stomata of S. g. imperfectus tend to ~~be more~~ regular and better defined. The possibility exists that some of these differences could be accounted for by lack of "maturity" of this specimen. Since they bear such a striking resemblance to the Russian specimens, however, it is assigned to that subspecies. Future work on larger collections may reveal that the two subspecies are synonymous.

Stomatograptus grandis girvanensis Cocks and Toghill, 1973?

Text-figure 27C.

?1973 Stomatograptus grandis girvanensis Cocks and Toghill, pl. 2, fig. 2 (not described).

1975 Stomatograptus grandis girvanensis Cocks and Toghill?; Bjerreskov, p. 40, pl. 5G,H.

Material. Ten moderately well preserved, compressed specimens and several more poorly preserved fragments.

Occurrence. Turriculatus-crispus to middle griestoniensis Zone. Snowblind Creek at 393-396m, Twilight Creek at 25.5, 27.5 and 29.5m and Huff Ridge at 195.5 and 206.5m.

Description. Rhabdosome up to 40mm long. Widens gradually from 1.1 to 1.3mm at th1 to a maximum of 3.8 to 4.4mm. Thecae spaced at 7 to 8 in the first 5mm, 9.5 to 11 in 10mm distally. Thecae are more or less straight tubes, inclined at 40 to 45° with moderately everted apertures. Ventral margin of aperture extended into a thick lip. Interthecal septa commonly well sclerotized especially proximally where entire reticulum may be fully sclerotized as well. Reticular mesh fairly dense (about 4 to 5 in 1mm) and stomata are small and closely spaced, about 4 1/2 to 5 1/2 in 5mm, and are pronounced with thickened rims.

Remarks. The present specimens match well in all respects with those of Bjerreskov (1975). The original material is undescribed and only one distal fragment is illustrated but that specimen is similar to the Cape Phillips specimens. This subspecies differs from S. grandis grandis primarily in that is more slender and has smaller, more closely spaced stomata. Otherwise the two subspecies are very similar. These specimens, which are from the crispus and lower griestoniensis zones, extend the known range of this taxon earlier than it has been previously reported.

Stomatograptus grandis imperfectus Bouček and Münch, 1943

Text-figure 27E.

1943 Retiolites (Stomatograptus) grandis imperfectus Bouček and Münch, pp. 51-52, pl. 3, fig. ~; text-figs. 15a-d; 17e,f.

1982a Stomatograptus grandis imperfectus (Bouček and Münch); Lenz, pp. 37-39, fig. 16D,F,G.

in press a Stomatograptus grandis imperfectus Bouček and Münch; Lenz and Melchin, pl. 2, figs. 1,4.

Material. About thirty well to poorly preserved, compressed specimens.

Occurrence. Middle griestoniensis to lower sakmaricus Zone. Snowblind Creek at 492.0 and A16.0m, Cape Phillips at 30.0, 85.0, 93.5, 128.0 and 148.0m, Twilight Creek at 42.0m, Middle Island at 52.0m, Cape Becher at 6.0, 7.0, 20.0, 22.0

and 30.0m and Irene Bay at 67.0m.

Description. Rhabdosome up to 75mm wide. Widens fairly rapidly from 1.3 to 1.5mm at th1 to a maximum of 6.3 to 9.0mm (although one long distal fragment which otherwise resembles this subspecies in only 5.2mm wide). Thecae spaced at 8 to 9 in 10mm and are straight to slightly sigmoidally curved and inclined at 55 to 60°. Interthecal septa are commonly visible, although they tend to disappear distally. Apertures are rather strongly everted and show a very pronounced, thickened ventral lip. Reticular meshes spaced at about 3 in 5mm and stomata are sometimes visible (depending on state and mode of preservation) and spaced at 3 1/2 in 5mm.

Remarks. This subspecies is the widest of the retiolitids found in the Cape Phillips, except for Pseudoplegmatograptus giganteus, and is also distinguished by having the combination of strongly everted apertures, interthecal septa and stomata. In addition, the reticulum tends to be less dense than in other S. grandis subspecies.

Stomatograptus n. sp.

Text-figure 27D,G,H.

1984 Stomatograptus sp. Bates and Kirk, text-fig. 4d,e.

in press = Stomatograptus sp, Lenz and Melchin, pl. 2, figs.

6-10.

Material. Numerous very well to poorly preserved, compressed specimens.

Occurrence. Turriculatus-crispus, crispus and upper griestoniensis to upper sakmaricus zones. Snowblind Creek at 497.0 and [illegible]42.0m, Cape Phillips at 30.0 and 34.0m, Twilight Creek at 28.5, 29.5, 46.0, 49.0, 57.0, 59.0, 60.0 and 61.5m, Cape Becher at 6.0, 7.0, 12.0, 14.0 and 17.0m, Trold Fiord at 79.0 and 143.0m and Huff Ridge at 195.0 and 254.0m.

Description. Rhabdosome up to at least 50mm long. Widens gradually from 1.3 to 1.7mm at th1 to a maximum of 4.3 to 6.2mm. Thecae spaced at 7 in 5mm proximally, 8 to 11 in 10mm distally. Thecae straight, simple tubes inclined at 45 to 55° with straight, moderately everted apertures, ventral margins slightly extended into weak lips. Interthecal septa not commonly present except proximally on mature specimens. Occasional specimens are found where central axis of rhabdosome is sclerotized internally, extending laterally into interthecal septa. Reticulum generally loose, quadrate, with 2 1/2 to 3 meshwork cells in 1mm distally, up to 4 in 1mm proximally. Cells form 2 to 3 rows per theca. Reticulum is commonly somewhat more dense axially than along the lateral margins where cells tend to be larger. Pleural and apertural lists usually not strongly thickened. Stomata indistinct, usually not visible, not marked by a thickened rim.

Remarks. This new species is the most common Stomatograptus in the Cape Phillips Formation and has been recovered in uncompressed form (Stomatograptus sp. of Lenz and Melchin, in press a) and is distinguished from other Stomatograptus species by its indistinct stomata, lack of interthecal septa except on very mature rhabdosomes and open reticulum, especially along the lateral margins. While S. grandis ssp. tend to have the most pronounced interthecal septal tissue as well as thickened lists along the lateral margins, near the thecal apertures, this new species tends to be most open along the margins and shows more dense reticulum as well as continuous periderm (where present on mature specimens) most concentrated axially. Uncompressed specimens show that the stomata are always present and raised as in other Stomatograptus species, but that they are not marked by pronounced, thickened rims and so are only rarely visible in compressed specimens.

The open reticulum and the only moderately everted apertures serve to distinguish this species from Retiolites geinitzianus geinitzianus when the stomata or interthecal tissue are not visible.

Stomatograptus n. sp. shows a wide range of variation in dimensions and thecal spacing but no trends, or distinct populations were noted within these samples which could be used to subdivide it into subspecies.

Tribe PLECTOGRAPTINI Bouček and Munch, 1952

Genus Paraplectograptus Příbyl, 1948

Type species. Retiolites eiseli Manck, 1917.

Paraplectograptus cf. P. intermedius (Bjerreskov, 1981)
Text-figure 27B.

Material. Five moderately preserved and several more poorly preserved, compressed specimens.

Occurrence. Crispus, lower griestoniensis and sakmaricus zones. Cape Phillips at 19.5, 159.5 and 160.0m, Twilight Creek at 52.5m and Irene Bay at 65.5, 67.0 and 69.0m.

Description. Rhabdosome up to at least 7mm long. Widens from about 0.9mm to a maximum of 2.6 to 3.6mm and thecae spaced at 11 to 12.5 in 10mm. Clathria distinct on most specimens, especially along the margins where the zig-zag pleural lists and the looping apertural lists are seen. The reticulum is variably developed, rather open in some specimens, more dense in others.

Remarks. These compressed specimens resemble the uncompressed specimens of Paraplectograptus praemacilentus and P. sp. A reported by Lenz and Melchin (in press a) in the nature of the clathria and seem to show a comparable range of variation in development of the reticulum. These compressed specimens differ, however, in that they are substantially wider distally (2.6 to 3.6mm as opposed to 1.4mm in the uncompressed specimens and 2.0mm for the compressed specimens reported by Bouček and Münch, 1952), more than would normally be accounted for by compression.

Paraplectograptus intermedius was originally assigned questionably to Plectograptus by Bjerreskov (1981) due to its resemblance to P. praemacilentus. Since the latter species has been reassigned to Paraplectograptus by Lenz and Melchin (in press a) by virtue of its laterally incorporated virgula and P. intermedius also has a laterally incorporated virgula, that species should be assigned to Paraplectograptus as well. This contrasts with Plectograptus s.s. which has a free, central virgula.

Paraplectograptus intermedius differs from P. praemacilentus in that it is somewhat wider (2.5mm distally, closer the width of the present specimens) and has a variably developed reticulum, more dense and chaotic proximally, wider and more nearly orderly distally. In the latter respect, it fits within the plexus of P. praemacilentus and P. n. sp. A as observed by Lenz and

Melchin. Due to the somewhat greater width of the present flattened specimens and the lack of more complete material, they are tentatively referred to P. intermedius a species previously known only from the mid-Wenlock.

Subfamily DIMORPHOGRAPTINAE Elles and Wood, 1906, emend.

Diagnosis (emended herein). Pattern J graptolites which may be uni-biserial or fully biserial. Sicula long (usually 1.7 to 2.0mm) fully exposed on its dorsal side. Downward growing portion of $th1^1$ strongly reduced (or absent?) and does not reach down to sicular aperture, leaving a portion of sicula exposed for its full circumference. Obverse and reverse walls of $th1^1$ both grow straight upward for all or much their length. Rhabdosome fully or partially septate or possibly aseptate. Thecae commonly orthograptid to climacograptid but may be isolate or slightly hooked, especially in uniserial portions.

Genera included. Dimorphograptus Lapworth (= Bulmanograptus Pribyl and Metadimorphograptus Pribyl), Akidograptus Davies and Parakidograptus Li and Ge.

Remarks. The description of the pattern J astogeny and distinction of the "true" dimorphograptines from Rhaphidograptus and Agetograptus is discussed above in the description of Proximal Development Patterns and subsequent discussion of their recognition in non-isolated graptolites.

Several authors have recently recognized that *Akidograptus* and *Parakidograptus* do not possess a uniserial first theca (e.g. Williams, 1983; Li and Ge, 1981) and this led them to include these genera within the Diplograptidae rather than the Dimorphograptidae. Despite the fact that they have a fully biserial rhabdosome, the early growth of their first theca is more like that of the dimorphograptids than the other diplograptid groups and they are therefore included within the Dimorphograptinae here.

Genus *Dimorphograptus* Lapworth, 1876

Type species. *Dimorphograptus elongatus* Lapworth, 1876.

Diagnosis. Pattern J species with a uni-biserial rhabdosome. Uniserial portion, consisting of one or several thecae, apparently achieved by redirection of theca(e) following th1. Thecae orthograptid to climacograptid although may be isolate or slightly hooked, especially in the uniserial portion. Biserial portion usually with partial median septum.

Remarks. This genus, as employed here, includes all pattern J species with a uniserial proximal portion. Although other genera have been introduced to subdivide this group according to thecal shape (e.g. *Bulmanograptus*, Metadimorphograptus) many authors have not accepted these genera because their morphologic or phylogenetic basis was considered questionable. A great deal more work needs to be done, especially to define the details of thecal form of some of the dimorphograptids, many of which appear to be rather complex.

Dimorphograptus erectus Elles and Wood, 1908

Text-figure 25U.

1908 Dimorphograptus erectus Elles and Wood, pp. 355-356, pl. 35, fig. 9a-d; text-fig. 233a,b.

1970 Dimorphograptus erectus erectus Elles and Wood; Rickards, text-fig. 13, fig. 10.

1970 Dimorphograptus erectus nicholsoni Rickards, p. 52, pl. 3, fig. 13; text-fig. 13, fig. 6.

1974b Dimorphograptus erectus Elles and Wood; Hutt, p. 52, pl. 7, fig. 11; text-fig. 13, fig. 6.

1975 Dimorphograptus erectus s.l. Elles and Wood; Bjerreskov, p. 41, text-fig. 13A.

?1983 Dimorphograptus minutus Huang and Lu, p. 149, pl. 4, fig. 19; pl. 9, fig. 16.

Material. Three compressed, moderately well preserved specimens.

Occurrence. acinaces Zone. Trold Fiord at 52.0m and

Huff Ridge at 107.0m.

Description. Rhabdosome up to 7.5mm long. Uniserial portion has a slight dorsal curvature and is about 1.7mm long and 0.5 to 0.6mm wide, consisting of two thecae. Biserial portion widens from 0.8 to 1.0mm to a maximum of 1.3 to 1.6mm. Thecae spaced at 11 to 13 in 10mm throughout. Distal thecae straight and inclined at about 30°. Distal thecae show a somewhat lower inclination and a slight sigmoidal curvature. Sicula 1.6 to 1.9mm long and reaches almost to the end of the uniserial portion.

Remarks. The thecal form and overall dimensions match well with those previously reported for this species. The uniserial portion is shorter than in typical specimens of D. erectus, having only two uniserial thecae, and in this respect they resemble D. e. nicholsoni. Hutt (1974b), however, considered these two subspecies to be morphologic variants of the same taxon.

Although the uniserial portions of the present specimens are almost straight, Elles and Wood (1908, pl. 35, fig. 9d) and Rickards (1970, text-fig. 13, fig. 10) both illustrate specimens with virtually straight uniserial portions.

Dimorphograptus erectus is the only dimorphograptid found in any of the present collections bearing more than one uniserial theca.

Dimorphograptus minutus Huang and Lu (1983) differs from the present specimens only in having a slightly longer sicula and a lower distal width. The latter may be accounted for by the fact that the specimens described by Huang and Lu are shorter and have not reached their maximum width. That species is therefore questionably considered synonymous with D. erectus. If it is, indeed, a separate species its name is a junior homonym of D. minutus (Chen and Lin) and would need to be changed.

Dimorphograptus minutus (Chen and Lin, 1978)

Text-figure 25V-Y.

1978 Rhaphidograptus minutus Chen and Lin, pp. 51 -52, pl. 9, figs. 15-22; text-fig. 12g.

1984 Rhaphidograptus minutus Chen and Lin; Lin and Chen, 219-220, pl. 6, fig. 5.

Material. Numerous compressed specimens, very well to poorly preserved.

Occurrence. Upper acinaces and cyphus zones. Twilight Creek at 13.5m, Trold Fiord at 54.0 and 56.5m and Huff Ridge at 111.0 to 112.0, 112.5 and 113.5m.

Description. Rhabdosome straight, up to 18mm long. Only one uniserial theca present, 0.4 to 0.6mm wide at its aperture. Biserial portion widens from 0.7 to 1.0mm to a maximum of 1.1 to 1.8mm (average 1.4mm). In long specimens width may decrease slightly distally. Thecal spacing varies from 10 to 14 in 10mm and remains more or less constant throughout rhabdosome length. Thecae show strong sigmoidal curvature with a rounded but distinct geniculum, overlap 1/3 to 1/2 their length. First theca in second series appears to arise 1/3 to 1/2 way up the length of th1[1], apparently at about the same level as th21. The former is, however, somewhat longer than the latter. Sicula 1.6 to 2.3mm long, its apex reaching to the aperture of th2[1]. It is exposed for most of its length along the biserial portion.

Remarks. The present specimens are, on average, wider than those described by Chen and Lin (1978) but the latter fall within the range of variation of this population. In general, the stratigraphically higher specimens found here tend to be narrower and have a closer thecal spacing (more similar to the type material).

Although this species shows some similarities to species of Rhaphidograptus and Agetograptus the fact that the sicula is consistently exposed below th1, and the protracted, straight upward growth of th1 identify this species as Dimorphograptus.

This species differs from the similar Dimorphograptus macilentus (Mu, et al., 1974) in that it is, on average, narrower, has closer thecal spacing and its thecae have a pronounced sigmoidal curvature in contrast to the orthograptid thecae of D. macilentus.

This species in not synonymous with Dimorphograptus minutus Huang and Lu, 1983. The Huang and Lu species is here considered to be questionably synonymous with D. erectus (see remarks for that species above).

Genus Parakidograptus Li and Ge, 1981

Type species. Diplograptus acuminatus Nicholson, 1867.

Parakidograptus acuminatus acuminatus (Nicholson, 1867)

Text-figure 252.

1867 Diplograpsus acuminatus Nicholson (sic), p. 109, pl. 7, figs. 16,17.

1908 Cephalograptus(?) acuminatus (Nicholson); Elles and Wood, pp. 289, 295, pl. 32, fig. 11a-d; text-fig. 199.

1970 Akidograptus acuminatus acuminatus (Nicholson); Rickards, p. 53, pl. 6, fig. 5; text-fig. 14, fig. 27.

1970 Akidograptus acuminatus (Nicholson); Churkin and Carter, p. 34, pl. 3, figs. 16,17; text-fig. 13B,C.

1971 Akidograptus acuminatus (Nicholson); Churkin, Carter and Eberlein, pl. 24J.

1971 Akidograptus acuminatus (Nicholson); Schauer, p. 54, pl. 17, figs. 1-3; pl. 18, figs. 11-14.

1974b Orthograptus? acuminatus acuminatus (Nicholson); Hutt, pp. 37-38, pl. 7, fig. 9; text-fig. 9, fig. 11;

text-fig. 10, fig. 4.

1975 Akidograptus acuminatus (Nicholson); Obut and Sobolevskaya, p. 158, pl. 7, figs. 2,3.

1981 Parakidograptus acuminatus (Nicholson); Li and Ge, pp. 229-230, pl. 1, figs. 8-10.

1982 Orthograptus acuminatus (Nicholson); Lenz and McCracken, fig. 41,l,m.

1983 pars Parakidograptus acuminatus (Nicholson) sensu lato; Williams, pp. 632-633, text-fig. 10d-f,h,i (non g).

?1983 Parakidograptus acuminatus (Nicholson); Wang et al., pl. 10, fig. 2.

1984 Parakidograptus acuminatus (Nicholson); Mu and Lin, p. 63, pl. 6, fig. 10.

1984 Parakidograptus acuminatus (Nicholson); Lin and Chen, p. 219, pl. 6, figs 7,8.

Material. A single compressed, moderately well preserved, proximal-portion specimen.

Occurrence. acuminatus Zone. Truro Island at 38.5m.

Description. Rhabdosome 4.6mm long (broken). Widens from about 0.2mm at the aperture of the sicula to 0.5mm at the aperture of $th1^1$ to a maximum preserved width of 0.9mm (across the second thecal pair) Thecae with a slight geniculum and straight to slightly concave supragenicular wall. Sicula about 1.6mm long, $th1^1$ about 1.5mm long originating 1.1mm above sicular aperture (although it could be longer owing to poor preservation of the sicular region). Thecae spaced at about 1.0mm and are alternate.

<u>Remarks</u>. Although the first thecae is shorter than reported by most previous workers, it appears to fit well within the known range of variation of this distinctive taxon.

Late Ordovician and Early Silurian Graptolites, Cape Phillips Formation, Canadian Arctic Archipelago

Volume II

by

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Faculty of Graduate Studies
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Family MONOGRAPTIDAE Lapworth, 1873

Diagnosis (after Bulman, 1970). Scandent uniserial rhabdosomes with th1 arising from a sinus, upwardly directed from its origin.

Remarks. Previously, this family has included only the monograptids without cladia, those with cladia being included in the Cyrtograptidae and both being in the Suborder Monograptina. Fortey and Cooper (1986) and Mitchell (1987), however, have shown that the monograptid condition is not a "grade of organization" different from the related diplograptids and those authors have lowered the monograptids to the family level. Mitchell has proposed that all of the monograptids, plus the pattern B, H and I diplograptids as well as the dimorphograptids be included in the Monograptidae. Here, however, this proposal is not adopted and the latter groups are included in the Eoglyptograptidae and Retiolitidae (see discussions above) and the monograptids are retained as a separate family, including the cyrtograptids.

The various cladia-bearing genera of the Monograptidae are not considered by many workers to be a monophyletic group (Rickards et al., 1977) and as many as four, or even more separately derived lineages may be involved. For this reason, the cyrtograptids are not separated at the subfamily level here until more is known about the relationships within and between the various cladia-bearing groups.

Within the non-cladia bearing monograptids, a large number of genera have been erected to encompass their wide range of morphologic variation in thecal form. Many of these genera have been erected on the basis of variably preserved, compressed material in which the true nature of the thecal morphology cannot be accurately discerned. As a result, the status of many of these genera as morphologically and phylogenetically unique entities is questionable and they are not employed here.

Genus Atavograptus Rickards, 1974

Type species. Monograptus atavus Jones, 1909

Remarks. Many of the samples collected in the Cape Phillips Formation from the acinaces and cyphus zones contain a large number of long, slender (0.2 to 0.5mm), straight to slightly curved rhabdosome fragments. The vast majority of these fragments are too poorly preserved to discern thecal structures and could be assigned to any one of several Atavograptus species: A. atavus; A. praestrachani; A. strachani; or A. gracilis. Since no specimens definitely assignable to either of the two latter species are found it is assumed that they are not represented here. The best preserved specimens are assignable to A. praestrachani and clearly show the sharply geniculate proximal thecae and nearly straight distal thecae. Distally, *A. atavus* is wider than *A. praestrachani* and its thecae are more strongly sigmoidal with greater overlap. Some proximal fragments with a flowing rather than sharp geniculum have been found and these are assumed to be *A. atavus*.

Atavograptus atavus (Jones, 1909)

Text-figure 28A-C.

1909 *Monograptus atavus* Jones; p. 531; text-fig. 18a-d.

1911 *Monograptus atavus* Jones; Elles and Wood, pp. 403-404, pl. 39, fig. 1a-d; text-fig. 270a-e.

1970 *Monograptus atavus* Jones; Churkin and Carter, p. 36, pl. 3, fig. 11; text-fig. 14E.

1970 *Monograptus atavus* Jones; Rickards, p. 65, pl. 5, fig. 6; pl. 6, fig. 1; text-fig. 14, figs. 26,30; text-fig. 16, fig. 6; text-fig. 18, fig. 6.

1974 *Atavograptus atavus* (Jones); Rickards, pl. 9, figs. 1,2.

1975 *Monograptus atavus* Jones, Bjerreskov, p. 44, pl. 6G,H.

1975 *Atavograptus atavus* (Jones); Hutt, pp. 62-63. p. 11, fig. 1; pl. 12, figs. 5,9,10.

1978 *Pristiograptus atavus* (Jones); Chen and Lin, p. 53, pl. 9, fig. 27.

Material. At least 20 fairly well preserved distal fragments and numerous moderately to poorly preserved

Text-figure 28

All figures x7.5 unless otherwise stated.

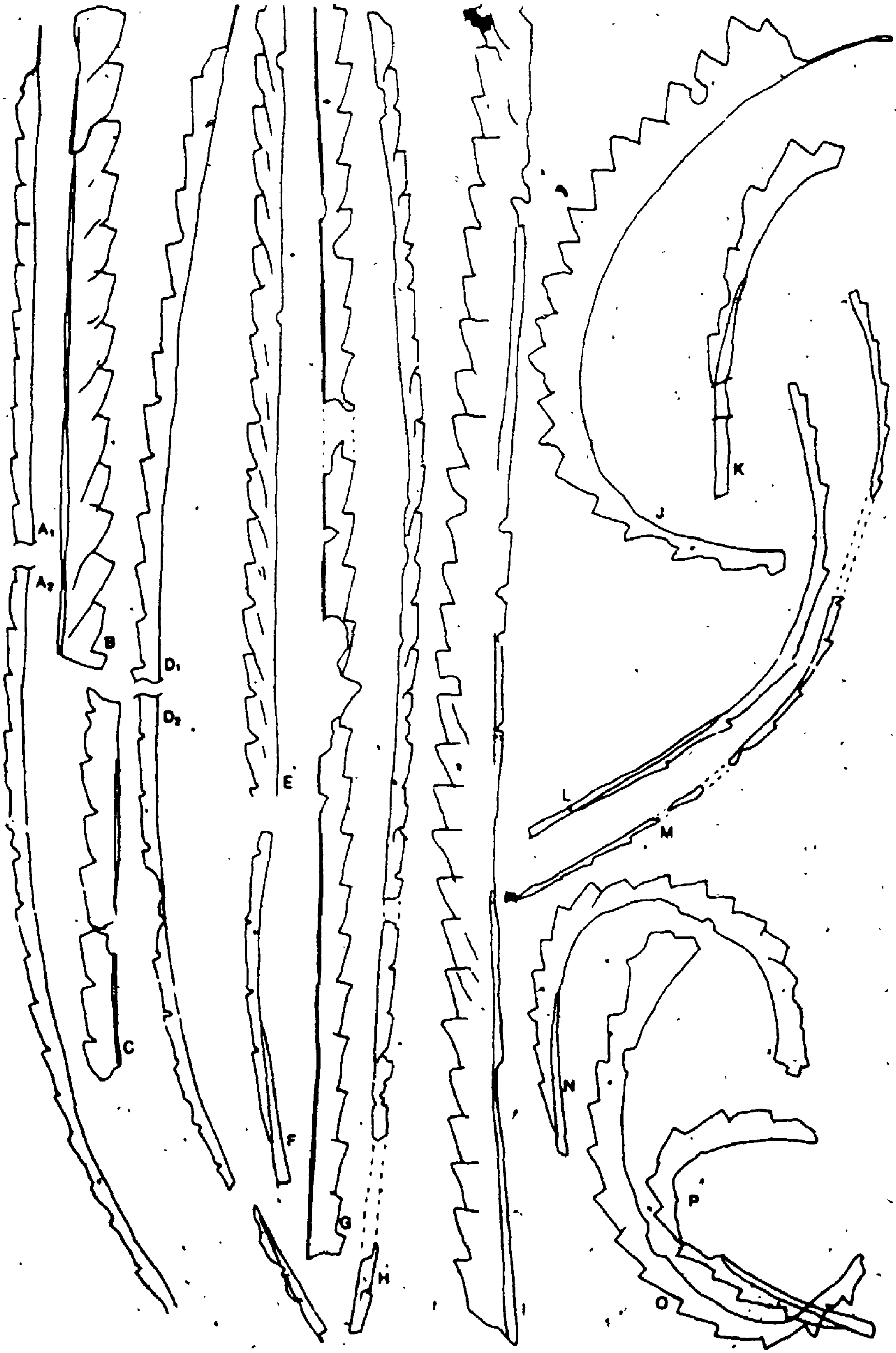
A-C. _Atavograptus atavus_ (Jones): A) A1 and A2 are proximal and distal portions of same specimen, HR:107; B) TF:56.5; C) TC:13.5.

D-H. _Atavograptus praestrachani_ Rickards, _et al_.: D) D1 and D2 are proximal and distal portions of same specimen, HR:112.0-112.5; E) SC:170; F) HR:107.0, x10; G) HR:107.0.

I-K. _Coronograptus cyphus_ (Lapworth); I) TF:60.0; J) HR:112.5; K) TF:60.0, x10.

L-M. _Coronograptus_ cf. _C_. _cirrus_ Hutt; L) HR:113.5, x10; M) TF:62.5.

N-P. _Coronograptus hipposideros_ Toghill, all specimens from TF:60.0.



A_1
A_2
B
C
D_1
D_2
E
F
G
H
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near-proximal to distal fragments, all compressed.

Occurrence. *Atavus* and upper *acinaces* zones and *pectinatus* and *orbitus*? subzones. Twilight Creek at 13.5m, Trold Fiord at 49.0, 54.0 and 56.5m and Huff Ridge at 107.0, 110.0 and 113.5m?.

Description. Rhabdosome very long and invariably fragmentary, straight or weakly dorsally curved. No proximal ends found. Narrowest identifiable fragments 0.35 to 0.4mm, maximum width 1.1 to 1.3mm. Thecae number 8 to 9.5 in 10mm. Thecae have flowing sigmoidal curvature and rounded geniculum. Thecal overlap about 1/2 distally and cannot be discerned more proximally but is less than 1/2. Apertures everted distally, horizontal proximally.

Remarks. The present specimens match very well with previous reports of this well known and widespread species. For further discussion see under remarks of the genus *Atavograptus*.

Atavograptus praestrachani Rickards, *et al*., 1977

Text-figure 28D-H.

1970 *Monograptus* sp. 1, Hutt and Rickards, p. 75, fig. 3c,d.

1974 *Atavograptus* sp. 1, Rickards, text-fig. 1j.

1977 *Atavograptus praestrachani* Rickards, *et al*., pp.

102-103, fig. 17.

Material. Hundreds of compressed specimens, most moderately to poorly preserved, occasionally well preserved.

Occurrence. Upper *acinaces*, *cyphus* and *convolutus* zones. Snowblind Creek at 140 and 170m, Cape Manning at 5-7m, Twilight Creek at 13.5m, Trold Fiord at 54.0, 56.5, 61.0, 62.5 and 63.0m and Huff Ridge at 106.0, 107.0, 111.0-112.0, 112.0-112.5, 114.5, 124.0, 126.0 and 128.0m.

Description. Rhabdosome very long and invariably fragmentary, weak dorsal curvature proximally and straight to slightly dorsally or ventrally curved distally. Widens from 0.2 to 0.25mm at th2 very gradually to a maximum of 0.7 to 0.9mm. Width increase is often less than 0.1mm over a length of 10mm. Thecae spaced at about 9 to 10 in 10mm proximally to 7.5 to 8.5 in 10mm distally. First 15 to 20 thecae sharply geniculate with straight supragenicular wall roughly parallel to rhabdosomal axis. Apertural excavations semicircular. Distally, geniculum weakens and becomes, in many specimens, imperceptible and thecae become inclined up to 10^{o}. Thecal overlap about 1/3 distally, much less proximally. Sicula 2.7 to 3.0mm long reaching to about halfway along th2.

Remarks. In addition to the remarks made above in the discussion of Atavograptus it is worth pointing out that the present specimens match almost exactly with the type material despite the fact that most of the present material is stratigraphically younger. In fact, the convolutus Zone occurrences are the youngest known record of an Atavograptus species. Although Hutt and Rickards (1970) describe the distal thecae as "atavus-like" the fact that distal thecae are straighter and overlap less than those of A. atavus is very important for their distinction. This can be seen both in the present material and the illustrations of the type specimens.

Genus Coronograptus Obut and Sobolevskaya, 1968

Type species. Monograptus gregarius Lapworth, 1876

Coronograptus cf. C. cirrus Hutt, 1975
Text-figure 28L,M.

Material. Two moderately well preserved specimens and two poorly preserved fragments, all compressed.

Occurrence. Upper cyphus Zone and pectinatus Subzone. Trold Fiord at 62.5m and Huff Ridge at 113.5m.

Description. Rhabdosome 10.5mm long with moderate dorsal curvature. Widens from 0.25mm at the aperture of th1

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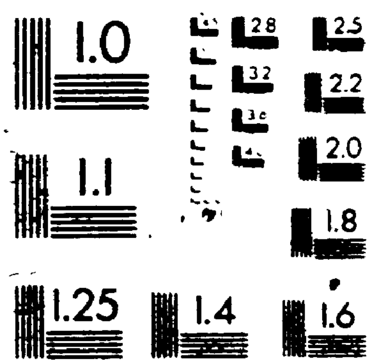


to 0.3mm at th6. Thecae spaced at 6.5 in 10mm and consist of straight tubes with a geniculum which is apparent in the proximal two thecae and is obscured distally. Apertures slightly flared, overlap cannot be determined. Sicula 3.8mm long, extending to the aperture of th2. Theca 1 begins 1.0mm above sicular aperture and is 1.7mm long.

Remarks. The present specimens match well in proximal detail and overall rhabdosomal form with Coronograptus cirrus. They differ from the latter in that they are slightly wider and the thecae flare slightly at their apertures. Both of these features could be accounted for by compression. The present specimens also have a somewhat wider thecal spacing. More material would be needed, however, before a definite comparison could be made.

Coronograptus cyphus cyphus (Lapworth, 1876)

Text-figure 28I-K.

1876 Monograptus cyphus Lapworth, p. 352, pl. 12, figs. 3a,c (non b,d)

1911 Monograptus cyphus Lapworth; Elles and Wood, pp. 362-364, pl. 36, figs. 1a-e; text-fig. 236a-e.

1970 Monograptus cyphus Lapworth; Churkin and Carter, p. 38, pl. 4, figs. 5,6; text-fig. 16F.

1970 Monograptus cyphus Lapworth; Rickards, pp. 62-63, pl. 4, fig. 11; pl. 5, figs. 1,2; text-fig. 14, fig. 31;

text-fig. 16, fig. 17.

1974 _Coronograptus cyphus_ (Lapworth); Rickards, pl. 9, fig. 8.

1975 _Coronograptus cyphus_ (Lapworth); Hutt, pp. 67-68, pl. 12, figs. 6,11; pl. 14, figs. 6,7.

1978 _Pristiograptus cyphus_ (Lapworth); Chen and Lin, p. 53, pl. 10, figs. 1,2.

Material. About 20 compressed specimens, moderately well to poorly preserved.

Occurrence. _Cyphus_ Zone. Twilight Creek at 13.5m, Trold Fiord at 60.0m and Huff Ridge at 110.0 and 112.0-112.5m.

Description. Rhabdosome long and invariably fragmentary, ~~moderately~~ dorsally curved proximally, weakly so to straight distally. Widens from about 0.4mm at th1 to a distal maximum of about 1.4 to 1.8mm. Thecae spaced at 8 to 10 in 10mm and are nearly straight tubes with a slight geniculum sometimes visible. Thecal overlap increases from about 1/4 proximally to 2/3 to 3/4 distally. Sicula 3.7mm long reaching to between apertures of th1 and 2.

Remarks. _Coronograptus cyphus cyphus_ is distinguished from other species of _Coronograptus_ found here by its greater maximum width, by a lack of flaring apertures and by a sicula which reaches only to between th1 and 2. Distally, Atavograptus atavus is similar but not as wide and thecae show less overlap and more pronounced curvature.

Species of Pristiograptus have a less strongly curved proximal end, a shorter sicula and their thecae are usually not geniculate.

Coronograptus gregarius (Lapworth, 1876)

Remarks. The present collections contain a widely variable group of forms assignable to C. gregarius s. l. and no single criterion such as rhabdosomal width or degree of curvature could be used to subdivide them adequately. However, when rhabdosomal width and thecal spacing are both taken into account, three more-or-less distinct groups emerge. These three groups correspond roughly to C. g. gregarius, C. g. arcuatus and C. g. minusculus as defined by Obut and Sobolevskaya, (1968). It is worth noting that within any given sample only one of these three forms can be found which suggests that they may indeed represent separate populations (except in the case of the Cape Manning sample which covers a 3m sample interval and cannot be considered to represent a single population). Within any three of these groups specimens exist which are close in dimensions to the holotypical form and it could well be argued that a single taxon is represented here. However, they have been subdivided here in the hope that their usefulness, stratigraphic or biogeographic, may be enhanced. Future work on similar large and varied collections will undoubtedly prove or disprove the validity of these subspecies.

Coronograptus gregarius gregarius (Lapworth, 1876)

Text-figure 29C-G.

1876 *Monograptus gregarius* Lapworth; p. 317, pl. 10, fig. 12a-c.

1911 *Monograptus gregarius* Lapworth; Elles and Wood, pp. 365-366, pl. 36, fig. 3a-d; text-fig. 238a,b.

1968 *Coronograptus gregarius gregarius* (Lapworth); Obut and Sobolevskaya pp. 92-94, pl. 20, figs. 1-6; pl. 21, fig. 1.

1970 non *Monograptus gregarius* Lapworth; Churkin and Carter, p. 39, pl. 4, fig. 1; text-fig. 16C.

1970 *Monograptus gregarius* Lapworth; Rickards, pp. 61-62, text-fig. 14, fig. 35; text-fig. 18, fig. 14.

1975 *Monograptus gregarius* Lapworth; Bjerreskov, p. 46, pl. 6, fig. F; text-fig. 15A.

1975 *Coronograptus gregarius gregarius* (Lapworth); Hutt, pp. 64-67, pl. 13, fig. 2; pl. 14, figs. 1-3; text-fig. 15, figs. 1-4.

1978 *Pristiograptus gregarius* (Lapworth); Chen and Lin, pp. 53-54, pl. 10, figs. 7-10; text-fig. 13f,g.

1982a *Coronograptus gregarius gregarius* (Lapworth); Lenz, pp.

Text Figure 29

All specimens x7.5 unless otherwise stated.

A,B. *Coronograptus gregarius arcuatus* Obut and Sobolevskaya, both specimens from HR:118.5.

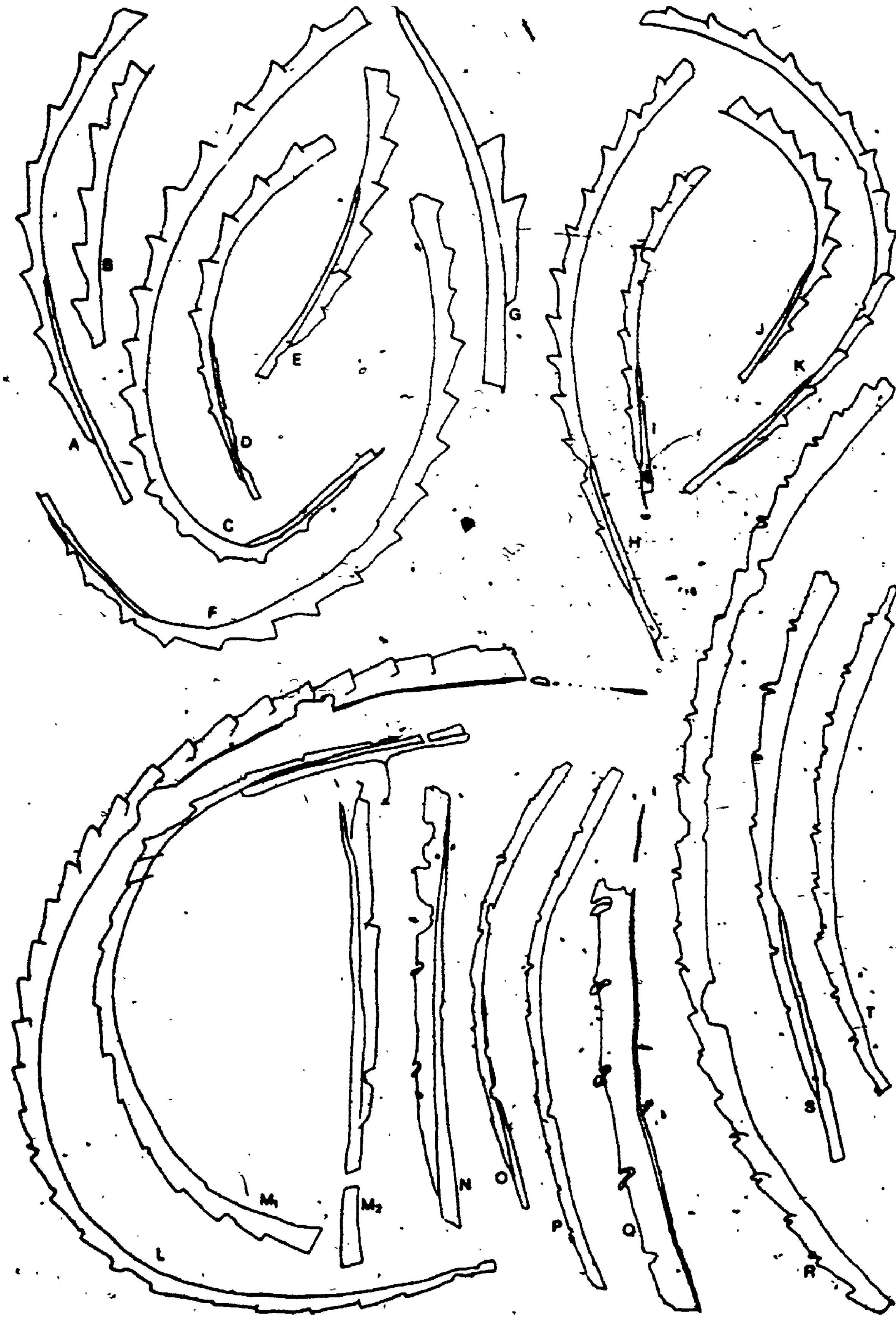
C-G. *Coronograptus gregarius gregarius* (Lapworth): C) & D) TF:60.0; E) TF:62.5; F) HR:110.0, G) TF:62.5, x15.

H-K. *Coronograptus gregarius* cf. *minusculus* Obut and Sobolevskaya, all specimens from TF:56.5.

L,M. *Lagarograptus acinaces* (Törnquist): L) HR:107.0; M) M1 is the proximal end of M1, x15, TF:54.0.

N-Q. *Lagarograptus inexpeditus* Obut and Sobolevskaya: N) & Q) CM:2-5, x15; O) & P) TF:61.0.

R-T. *Lagarograptus*? n. sp., all specimens from HR:112.5; S) x10.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52-53, figs. 4D,E,O,Q; 20B-D.

1984a Pristiograptus gregarius (Lapworth); Chen, p. 61, pl. 11, figs. 2,3.

Material. Numerous compressed specimens, very well to poorly preserved.

Occurrence. Cyphus Zone and pectinatus Subzone. Cape Manning at 2-5m, Trold Fiord at 60.0, 61.0 and 62.5m and Huff Ridge at 110.0m

Description. Rhabdosome up to at least 30mm long, commonly 20mm or less, almost straight over first two or three thecae, moderately dorsally curved mesially, weakly so distally. Widens from 0.4 to 0.65mm at th1 to a maximum of 0.7 to 0.9mm. Thecae spaced at 7.5 to 9 in 10mm, often slightly higher proximally than distally. Thecae show gentle sigmoidal curvature, geniculum rounded but often obscured on compression. Apertures distinctly flared. Thecal overlap cannot be discerned. Sicula 3.5 to 5.5mm (to 8.5mm?) long reaching to between the apertures of th2 and 4. Theca 1 originates 0.7 to 0.9mm (to 2.5mm?) from sicular aperture.

Remarks. The present specimens match well with previously described occurrences of this subspecies (e.g. Bjerreskov, 1975; Lenz, 1982a) although they are, on average, somewhat wider with slightly more widely spaced thecae than the holotypical material.

The siculae are, on average, shorter than those previously reported, but this may be due to the fact that many of the Canadian Arctic occurrences are at the early end of the species age range where the siculae tend to be shorter (Hutt, 1975, p. 65). A group of specimens have been found in sample TF:62.5 in which large numbers of early growth stages are found with very long siculae (up to at least 8.5mm) on several single bedding planes. This is very similar to an occurrence described from the argenteus Zone of the English Lake District (Hutt, 1975, p. 65, text-fig. 15, figs. 1,2; pl. 14, fig. 2). The present specimens differ from those, however, in that a longer distance exists between the sicular aperture and the first theca (up to 2.5mm) and the thecal apertures do not flare as strongly as in typical specimens of this species.

Coronograptus gregarius arcuatus Obut and Sobolevskaya, 1986

Text-figure 29A,B.

1968 Coronograptus gregarius arcuatus Obut and Sobolevskaya, pp. 94-95, pl. 21, figs. 2-11; pl. 22, figs. 1,2.

1982a Coronograptus gregarius arcuatus Obut and Sobolevskaya; Lenz, p. 53, figs. 5C,D,R; 20F,G,H,J.

?1985 Monograptus gregarius arcuatus (Obut and Sobolevskaya); Norford (in Norford and Orchard), p. 8, pl. 4, figs. 16-18.

Material. Five recognizable specimens, two well preserved with proximal ends.

Occurrence. *Pectinatus* Subzone. Huff Ridge at 118.5m.

Description. Rhabdosome up to at least 13mm long with gentle dorsal curvature. Widens from 0.55 to 0.6mm at th1 to a maximum of 0.65 to 0.7mm. Thecae spaced at 7.0 to 8.5 in 10mm and show gentle sigmoidal curvature with distinctly flaring apertures. Sicula 5.7 to 6.5mm long.

Remarks. The present specimens match almost exactly with the type material. They tend to be somewhat wider with a wider thecal spacing than those of Lenz (1982a). The specimens of Norford (in Norford and Orchard, 1985) are narrower still (0.4mm) with a closer thecal spacing (10 in 10mm) and have a shorter sicular region (3 to 4mm). In all of these respects Norford's specimens more closely resemble *C. gregarius minusculus* and they may belong to that subspecies.

The separation of this subspecies from *C. g. gregarius* is not an obvious one based on the present material and a case could be made for lumping these two subspecies. Only the fact that they do not occur in the same samples allows a clear distinction. The amount of dorsal curvature, although generally weaker in _C. g. arcuatus_ than in _C. g. gregarius_ does not appear to be a consistently reliable mode of distinction as suggested by Lenz (1982a).

Coronograptus gregarius cf. _minusculus_
Obut and Sobolevskaya, 1968
Text-figure 29H-K.

1968 cf. _Coronograptus gregarius minusculus_ Obut and Sobolevskaya, pp. 95-96, pl. 22, figs. 3-6.

1970 _Monograptus gregarius_ Lapworth; Churkin and Carter, p. 39, pl. 4, fig. 1; text-fig. 16C.

?1985 _Monograptus gregarius arcuatus_ Obut and Sobolevskaya; Norford (in Norford and Orchard), p. 8, pl. 4, figs. 16-18.

Material. Numerous compressed specimens, very well to poorly preserved.

Occurrence. _Cyphus_ Zone and _orbitus_ Subzone. Cape Manning at 2-5m, Twilight Creek at 13.5m, Trold Fiord at 56.5 and 63.0m and Huff Ridge at 122.0 to 112.5, 133.5 and 114.5m.

Description. Rhabdosome up to 21mm long with gentle to moderate dorsal curvature. Widens from 0.35 to 0.5mm at th1 to a maximum of 0.5 to 0.7mm. Thecae spaced at 10 to 14 in

10mm (ave. 11.5). Thecae with gentle sigmoidal curvature, distinctly flaring apertures and 1/4 to 1/3 overlap proximally, to 1/2 distally. Sicula 3.2 to 4.5mm long reaching to the aperture of th2 to th3. Aperture bears a virgella up to at least 8.4mm long.

Remarks. The present specimens are, on average wider than the type specimens of Obut and Sobolevskaya (1968) and show a wider range of thecal spacing. For this reason the present material is only tentatively assigned to this taxon. A few of the specimens within this group fall very near the range of typical *C. g. gregarius* but they are, on average, narrower than the type subspecies with more closely spaced thecae. The present specimens match very well with the specimens of *M. gregarius* of Churkin and Carter (1970) and the latter is here considered to belong to this subspecies.

Hutt (1975) suggested that *C. g. minusculus* and *C. hipposideros* (Toghill) were conspecific but the latter is wider, has more widely spaced thecae, a stronger dorsal curvature and distal thecae which are not flared at the apertures. *Coronograptus* ex gr. *gregarius* of Hutt (1975) may be referable to "*Monograptus*" *leei* Hs which is much narrower with more closely spaced thecae and a very short sicula (approx. 2mm) (Hs, 1934).

Coronograptus hipposideros (Toghill, 1968)

Text-figure 28N,P.

1968 Monograptus hipposideros Toghill, pp. 384-386,

1982a Coronograptus hipposideros (Toghill); Lenz, pp. 53-55, figs. 5A,B,E; 20E,I.

Material. About ten compressed specimens, moderately to poorly preserved.

Occurrence. Upper cyphus Zone. Trold Fiord at 60.0m.

Description. Rhabdosome up to at least 15mm with moderate to strong dorsal curvature, especially pronounced around th3 to 6. Complete rhabdosomes have gone through 180o of curvature by th10 to 15. Widens from 0.5 to 0.6mm at th1 to a maximum of 0.7 to 0.9mm. Thecae spaced at 9,5 to 11.5 in 10mm. Thecae show a weak geniculum which is usually obscured on compression. Proximal thecae flare at the apertures while distal thecae are almost completely to completely straight. Sicula 3.6 to 4.2mm long reaching to aperture of th3.

Remarks. Although Hutt considered that this species may be synonymous with Coronograptus gregarius minusculus Obut and Sobolevskaya, it differs from the latter in that it has much stronger dorsal curvature, the thecae (especially the distal thecae) are less strongly flared and it is relatively wide compared to its fairly close thecal spacing. In contrast with the type specimens of Toghill (1968), the present specimens are not tectonically distorted and the importance of the horseshoe-shaped rhabdosome as a distinguishing feature is clearing seen.

Genus Lagarograptus Obut and Sobolevskaya, 1968

Type species. Lagarograptus inexpeditus Obut and Sobolevskaya, 1968.

Lagarograptus acinaces (Tornquist, 1899).

Text-figure 29L,M.

1899 Monograptus acinaces Törnquist, p. 5. pl. 1, figs, 7,8.

1911 Monograptus acinaces Tornquist; Elles and Wood, pp. 364-365, pl. 36, fig. 2a-e; text-fig. 237a-d.

1970 Monograptus acinaces Törnquist; Churkin and Carter, p. 35, pl. 3, figs. 13-15; text-fig. 14A.

1970 Monograptus acinaces Törnquist; Hutt and Rickards, text-fig. 3I,J.

1971 Monograptus acinaces Törnquist; Churkin et al., pl. 24C.

1975 Lagarograptus acinaces (Törnquist); Hutt, p. 69, pl. 13, figs. 5,6; text-fig. 16, figs. 1-3.

1982a Lagarograptus cf. acinaces (Törnquist); Lenz, pp.

45-47, figs. 4G,H,P; 19A,C,D.

Material. Numerous compressed specimens, two of which show proximal and mesial portions, moderately well preserved.

Occurrence. Upper *acinaces* Zone. Trold Fiord at 54.0m and Huff Ridge at 107.0m.

Description. Rhabdosome up to at least 21mm long, and is straight to the apex of the sicula at which point it begins a moderate dorsal curvature, decreasing distally. Widens gradually from 0.35mm at the aperture of th1 to 0.65 at th10. The maximum observed width in the present material is 0.8mm, from a broken mesial to distal fragment. Thecal spacing 7 in 10mm proximally, 9 to 10 in 10mm distally. Thecae long tubes with a more or less pronounced geniculum and a slightly flaring aperture. Overlap is about 1/3 proximally, up to about 2/3 distally. Sicula about 5mm long reaching to near aperture of th2. Theca 1 originates about 1.5mm above sicular aperture and is about 2.3mm long.

Remarks. The present specimens match well with those previously reported except that th1 is shorter than those reported from Great Britain (Hutt, 1975). As result the sicular apex reaches to near the aperture of th2 rather than th1 as in the British specimens. In this respect the present material more closely resembles other North American reports of this species (Churkin and Carter, 1970; Lenz, 1982a). In addition, no distal fragments are found in these collections exceeding 0.8mm in width, but this may be due to a lack of "mature" rhabdosomes.

Lagarograptus _inexpeditus_ Obut and Sobolevskaya, 1968

Text-figure 29N-Q.

1968 _Lagarograptus_ _inexpeditus_ Obut and Sobolevskaya, pp. 91-92, pl. 18, figs. 4-6; pl. 19, figs. 1-6.

1982a _Lagarograptus_ _inexpeditus_ Obut and Sobolevskaya; Lenz, pp. 47-48, figs. 4C,M,N; 19E.

Material. Hundreds of compressed specimens, mostly rather poorly preserved.

Occurrence. Upper _cyphus_ Zone and _pectinatus_ Subzone. Cape Manning at 0-2 and 2-5m, Truro Island at 47.0-48.0m, Trold Fiord at 60.0 and 61.0m and Huff Ridge at 117.0 and 118.5m.

Description. Rhabdosome long but invariably fragmentary with uniform, moderate dorsal curvature. Width is 0.3mm at th1 increasing to 0.4 to 0.5mm distally. Thecae number 8 to 10 in 10mm (a single specimen has 12 in 10mm). Free ventral wall is parallel to rhabdosomal axis with a pronounced geniculum expanded into a small, proximo-ventrally directed hood giving the appearance of a slight hook. From beneath this hood, the thecal aperture gives rise to a short (up to 0.2mm) apertural process which is also proximo-ventrally directed although this is commonly not preserved or visible. Sicula 3.5 to 5.0mm long reaching to between th2 and 4.

Remarks. The present specimens differ from the type material (Obut and Sobolevskaya, 1968) and that of Lenz (1982a) only in that the sicula reaches a greater maximum length.

Although several well preserved fragments clearly illustrate the distinctive apertural structures (e.g. text-fig. 29Q), in the majority of specimens thecal structures are obscure and the rhabdosome appears as a nearly uniform, curved ribbon about 0.4mm wide.

Lagarograptus? n. sp.

Text-figure 29R-T.

Material. About 20 compressed specimens, moderately to poorly preserved.

Occurrence. Upper *cyphus* Zone. Huff Ridge at 112.0-112.5m.

Description. Rhabdosome up to at least 25mm long, with weak to moderate dorsal curvature. Widens from 0.3 to 0.35mm at th1 to a maximum of 0.6 to 0.7mm. Thecae number 8 to 9 in 10mm and are nearly straight tubes. Overlap cannot be determined accurately but is probably about 1/3 proximally to 1/2 distally. Proximal thecae are nearly parallel to the rhabdosome axis, distally they become inclined up to about 15°. Thecal apertures distinctly hooded, with hood arising from position of the geniculum of the succeeding theca. Hood is more pronounced proximally than distally and is rather difficult to see on more poorly preserved distal fragments. A few thecae show what may be ventral apertural processes although none of these is unequivocal. Sicula 4.5 to 5.5mm long reaching to near the aperture of th3.

Remarks. The moderate dorsal curvature, slightly inclined, overlapping thecae and long sicula give this new species strong similarities to L. acinaces (Tornquist). However, it differs in being narrower distally, and, more importantly, in having distinctly hooded thecae with a monoclimacid appearance. Lagarograptus inexpeditus Obut and Sobolevskaya has monoclimacid thecal apertures but its thecae are narrower and parallel-sided throughout and it possesses more pronounced apertural processes.

Although no unequivocal apertural processes can be seen on the present specimens, the long sicula and similarity in rhabdosomal and thecal form to other species of

Lagarograptus suggest that it is probably a representative of that genus.

Genus *Pribylograptus* Obut and Sobolevskaya, 1966

Type species. *Monograptus incommodus* Törnquist, 1899.

Pribylograptus angustus (Rickards, 1970)

Text-figure 30A.

1970 *Monograptus angustus* Rickards, p. 89, text-fig. 17, figs. 15,16.

1982a *Pribylograptus angustus* Rickards; Lenz, p. 56, figs. 5Q; 20A.

Material. A single, moderately well preserved distal fragment and several poorly preserved fragments.

Occurrence. Upper *cyphus* Zone. Trold Fiord at 60.0m.

Description. Rhabdosome up to at least 19mm long (incomplete distal fragment). Width is 0.2mm and thecae are spaced at 8.5 in 10mm. Thecae are straight tubes inclined only very slightly to rhabdosomal axis. Apertures are introverted and thecae flare slightly at the aperture. There is no apparent thecal overlap. No proximal portions are recognized.

Text-figure 30

All figures x7.5 unless otherwise stated.

A. *Pribylograptus angustus* (Rickards), TF:60.0.

B. *Pribylograptus argutus argutus* (Lapworth)?, TF:54.0, x10.

C,D. *Pribylograptus argutus argutus* (Lapworth): C) C2 is an enlargement of the seventh preserved theca of C1, x20, TC:15.0; D) TC:15.5-16.0.

E-G. *Pribylograptus incommodus* (Tornquist): E) TF:54.0; F) SC:170; G) G2 is an enlargement of the mesial thecae of G1, x15, TF:56.5.

H. *Pristiograptus* cf. *P. artus* Bouček, TC:15.5-16.0.

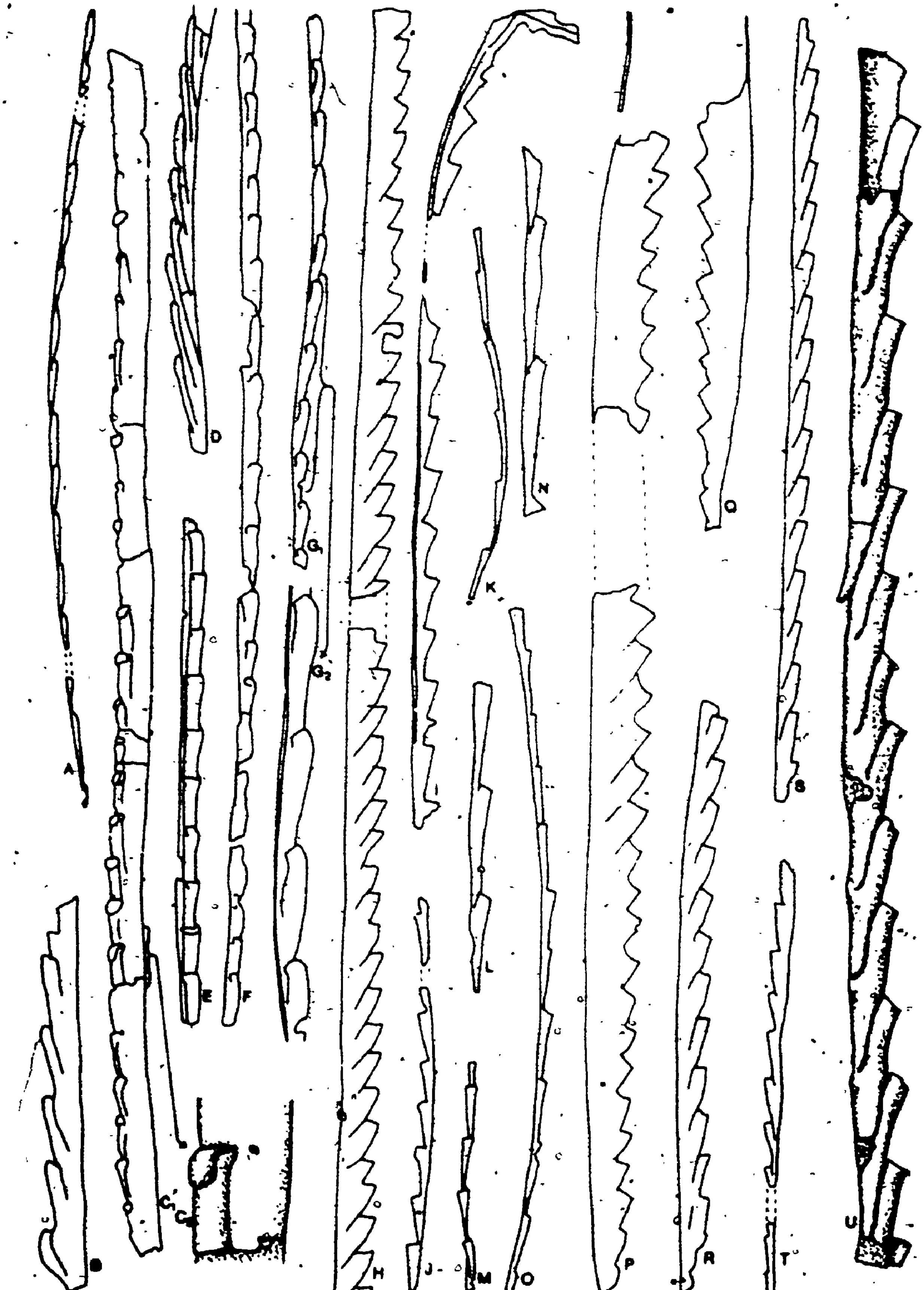
I. *Pristiograptus* cf. *P. concinnus* (Lapworth), TF:60.0.

J,L,M. *Pristiograptus fragilis fragilis* (Rickards): J) & L) TF:61.5; M) TF:62.5.

K,N,O. *Pristiograptus fragilis pristinus* Hutt: K) TF:62.5; N) TF:54.0, x15; O) TF:54.0.

P,Q. *Pristiograptus initialis* (Eisel): P) TC:40.5; Q) TC:42.5.

R-U. *Pristiograptus jaculum* n. subsp.: R) TC:15.5-16.0; S) HR:133.5; T) TC:15.0; U) TC:15.5-16.0, x15.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Remarks. The straight thecae with introverted apertures and overall very slender rhabdosome characterize this species. Although the thecal spacing is slightly higher than that of the type specimen, Rickards (1970) found distal fragments with similar spacing. In the present material, this species can be separated from P. incommodus (Törnquist) on the basis of rhabdosomal width and the fact that the thecae of the latter show a gentle sigmoidal curvature rather than being straight.

Pribylograptus argutus argutus (Lapworth, 1876)

Text-figure 30B?,C,D.

1876 Monograptus argutus Lapworth, pp. 318-319, pl. 10, fig. 13a-c.

1911 Monograptus argutus Lapworth; Elles and Wood, pp. 408-409, pl. 40, fig. 3a-c; text-fig. 274a-f.

1968 Monograptus argutus Lapworth; Rickards and Rushton, pp. 266-268, fig. 1.

1970 Monograptus argutus Lapworth; Hutt and Rickards, p. 69, text-fig. 2d.

1970 Monograptus argutus argutus Lapworth; Rickards, p. 67, text-fig. 17, fig. 13.

1975 Monograptus argutus Lapworth; Bjerreskov, pp. 50-51, pl. 7E.

1975 Pribylograptus argutus argutus (Lapworth); Hutt, pp.

72-73, pl. 16, figs. 4?,9?; text-fig. 15, fig. 6.

1982 _Pribylograptus sichuanensis_ Zhao (in Jin _et al_.), p. 58, pl. 23, figs. 1,2; text-fig. 19a-c.

1982 _Pribylograptus sichuanensis curvithecatus_ Zhao (in Jin _et al_.), p. 58, pl. 23. fig. 5; text-fig. 20a,b.

1982 _Pribylograptus formosus_ Zhao (in Jin _et al_.), pp. 58-59, pl. 23, figs. 3,4; text-fig. 21a-c.

Material. Five moderately to poorly preserved, compressed specimens and one in partial relief.

Occurrence. Upper _acinaces_ Zone?, _orbitus_ Subzone? and upper _convolutus_ Zone. Cape Manning at 2-5m?, Twilight Creek at 15.0 and 15.5-16.0m and Tròld Fiord at 54.0m?.

Description. Rhabdosomes fragmentary, up to at least 35mm long, weakly dorsally curved becoming straight distally. No proximal ends are preserved, widens from 0.4mm gradually to a maximum of 0.9 to 1.0mm. Thecae spaced at 10 in 10mm and are weakly geniculate with introverted apertures. The low relief specimen shows some lateral expansion of the apertural margin and a small hood overhanging the aperture. Overlap appears to be about 1/2 and supragenicular walls are near parallel to the rhabdosomal axis.

Remarks. The present specimens fit well within the somewhat variable range of previously reported dimensions and thecal spacings and the low relief specimen clearly shows the diagnostic, pribylograptid thecal form. The species of Pribylograptus reported by Zhao (in Jin et al., 1982, see synonymy above) appear to differ from one another only by slight variations in dimensions and thecal spacing and all fit within the range of variation of this species.

Two small, distal fragments which may be referable to this species have been found at TF:54.0 and Cape Manning but the lack of proximal or mesial fragments prevents positive assignment. They could equally be assigned to Monograptus sudburiae Hutt which occurs somewhat higher in the same section, which differs in having hooked proximal thecae and a more strongly curved mesial portion.

Pribylograptus incommodus (Törnquist, 1899)

Text-figure 30E-G.

1899 Monograptus incommodus Tornquist, p. 11, pl. 2, figs. 1-5.

1968 Monograptus incommodus Törnquist; Rickards and Rushton, pp. 272-273, fig. 4a-d.

1970 Monograptus incommodus Törnquist; Hutt and Rickards, p. 69, text-fig. 2c.

1975 Monograptus incommodus Törnquist; Bjerreskov, p. 50, pl. 7D; text-fig. 16E.

1975 Pribylograptus incommodus (Törnquist); Hutt, pp. 71-72,

p. 16, figs. 6,8,10; text-fig. 16, fig. 6.

1980 *Pribylograptus incommodus* (Törnquist): Obut and Sennikov, pp. 38-40, pl. 4, figs. 2,7-10.

Material. Ten moderately well preserved, compressed specimens and several other doubtful, poorly preserved ones.

Occurrence. Upper *acinaces* and lower *cyphus* zones. Trold Fiord at 54.0 and 56.5m, Huff Ridge at 110.0 and 111.0-112.0m and possibly Snowblind Creek at 170m.

Description. Rhabdosome long, straight and invariably fragmentary. Near proximal fragments 0.3mm wide, increasing to 0.4 to 0.55mm. Thecae spaced at 8 to 9 in 10mm. Thecae show very slight sigmoidal curvature (although this is sometimes obscured on an oblique compression), with a weak geniculum and introverted apertures, apparently somewhat expanded laterally. Free ventral walls inclined slightly to rhabdosomal axis and thecal overlap is slight. No proximal ends are preserved.

Remarks. Although the present specimens are incomplete the thecal structures and dimensions are distinctive for this species. Due to compression and the variable state of preservation, the geniculum is commonly not visible, nor can thecal overlap be precisely determined.

Genus Pristiograptus Jaekel, 1889

Type species. Pristiograptus frequens Jaekel, 1889.

Pristiograptus cf. P. artus Bouček, 1931

Text-figure 30H.

Material. Four moderately well preserved and several more poorly preserved compressed fragments.

Occurrence. Upper convolutus Zone. Twilight Creek at 15.0 and 15.5-16.0m and Huff Ridge at 133.5m.

Description. Rhabdosome up to 40mm long, straight or slightly dorsally curved. No proximal end is preserved, width is 0.7 to 1.0mm. Thecae spaced at 15 to 12 in 10mm and show a slight sigmoidal curvature. Overlap is about 1/2 and apertures are perpendicular to rhabdosomal axis.

Remarks. The high thecal spacing and slightly sigmoidal thecae seen in this material are characteristic of P. artus but that species does not show a dorsally curved rhabdosome seen in some of the present specimens. This together with the lack of any preserved proximal portions prevents more positive assignment. The Canadian material is older than the European specimens of P. artus which are known from the younger turriculatus and crispus zones (Münch 1952).

Pristiograptus cf. P. concinnus (Lapworth, 1876)

Text-figure 30I.

Material. Two moderately well preserved, though fragmentary compressed specimens.

Occurrence. Upper cyphus Zone. Snowblind Creek at 140m and Trold Fiord at 60.0m.

Description. Rhabdosome up to 25mm long, incomplete and bent, but shows a slight ventral curvature. Widens from 0.5 to 0.7mm but neither proximal nor distal ends are complete. Thecae number 8 in 10mm and are straight although the ventral wall is slightly concave to convex. Overlap slight, about 1/4 and apertures slightly everted.

Remarks. The two incomplete specimens resemble Pristiograptus concinnus in all respects except that the degree of thecal overlap is lower. This could, however, be due to the fact that they are from a proximal to mesial portion of the rhabdosome where thecal overlap is lower. Pristiograptus sp. 1 of Rickards et al. (1977) is narrower, dorsally curved, and its thecae are more closely spaced and have straight to introverted apertures.

Pristiograptus fragilis fragilis (Rickards, 1970)

Text-figure 30J,L,M.

1970 Monograptus fragilis Rickards, pp. 89-90, text-fig. 17, fig. 17.

1975 Pristiograptus fragilis fragilis (Rickards); Hutt, p. 60, text-fig. 14, fig. 6.

Material. Six moderately well preserved, compressed specimens.

Occurrence. Curtus Zone. Trold Fiord at 61.0, 62.5 and 63.0m.

Description. Longest fragment 5.5mm, rhabdosome straight or dorsally or ventrally curved. Widens gradually from 0.15 to 0.2mm at th1 to a maximum of 0.25 to 0.3mm. Thecae spaced at 7.5 to 8.5 in 10mm and are axially elongate, widening gradually toward the slightly everted aperture. Sicula is 0.8mm long, extending about 2/3 along the length of th1 which originates 0.15mm above the sicular aperture.

Remarks. This species is more slender than other known pristiograptids and differs from other slender monograptids by the straight, simple thecae. Pristiograptus fragilis pristinus differs from this subspecies only in that its thecae are more widely spaced.

As is the case in Great Britain (Hutt, 1975), this subspecies ranges somewhat higher in the section than *P. f. pristinus*, although their ranges do overlap.

Pristiograptus fragilis pristinus Hutt, 1975

Text-figure 30K,N,O.

1975 *Pristiograptus fragilis pristinus* Hutt, p. 60, text-fig. 14, figs. 8,9.

Material. Three moderately preserved and several poorly preserved, compressed fragments.

Occurrence. Upper *acinaces* and lower *cyphus* zones and *pectinatus* Subzone. Trold Fiord at 54.0, 56.5 and 62.5m.

Description. Longest rhabdosomal fragment 16mm, which widens very gradually from 0.2 to 0.28mm. Thecae number 6.5 to 5.5 in 10mm and overlap only very slightly. Thecae straight, widening toward a slightly flaring, everted aperture. Rhabdosome straight to slightly dorsally curved.

Remarks. The present specimens match very closely with those described by Hutt (1975). This subspecies differs from *P. f. fragilis* (Rickards) only in its wider thecal spacing, the latter having thecae spaced at about 7 to 7.5

in 10mm distally (Rickards, 1970; Hutt, 1975).

Pristiograptus initialis (Eisel Ms.)

Text-figure 30P,Q.

1943 *Pristiograptus initialis* (Eisel); Přibyl, pp. 9-10, pl. 2, figs. 1-4.

1952 *Pristiograptus initialis* (Eisel); Münch, p. 85, pl. 18, fig. 4a,b.

Material. Three moderately preserved, compressed specimens and a few more poorly preserved fragments.

Occurrence. Upper *griestoniensis* Zone. Twilight Creek at 40.5, 42.0 and 42.5m.

Description. Rhabdosome up to 7cm long, straight except for slight ventral curvature at the proximal end. Widens from about 0.5mm at th1 to a maximum of 1.3 to 1.4mm. Thecae spaced at 11 to 9.5 in 10mm and are simple tubes with about 1/2 overlap and slightly everted apertures. Sicula length cannot be ascertained.

Remarks. Although the present specimens are somewhat wider than those previously reported (1.2mm - Münch, 1952), this may accounted for by the greater length of the Canadian Arctic material. The relatively close thecal spacing and the slight ventral curvature of the proximal end distinguish this species, especially from other Llandovery pristiograptids.

Pristiograptus jaculum n. subsp.

Text-figure 30R-U.

Material. Numerous uncompressed (pyritized), partially compressed and flattened specimens.

Occurrence. Upper convolutus Zone. Twilight Creek at 15.0 and 15.5-16.0m and Huff Ridge at 133.5m.

Description. Rhabdosome up to at least 44mm long, straight throughout although no proximal ends have been identified. Widens from a minimum of 0.25mm gradually to a maximum of 0.7 to 0.9mm (0.6 to 0.7mm uncompressed). Thecae spaced at 9 to 11 in 10mm and show a slight sigmoidal curvature. Thecal inclination is low and overlap is up to 1/2 distally, much less in the more proximal portions. Apertures are slightly everted.

Remarks. This new subspecies differs from P. jaculum jaculum (Lapworth) only in that its maximum width is less (0.7-0.9mm as opposed to about 1.5mm). The slightly sigmoidal thecae with about 1/2 overlap are characteristic of this species as is the very slender proximal end (not complete in any of these specimens). Pristiograptus artus has sigmoidal thecae with about 1/2 overlap but they are more highly inclined and more closely spaced and do not have everted apertures. Pristiograptus variabilis has similar dimensions but the thecae are straight and have lower overlap throughout.

Pristiograptus nudus (Lapworth, 1880)

Text-figure 31A-E.

1880 Monograptus Hisingeri var. nudus Lapworth, p. 356, pl. 4, figs. 7a-c.

1911 Monograptus nudus (Lapworth); Elles and Wood, pp. 375-376, pl. 37, fig. 6a-e.

1965 Pristiograptus nudus (Lapworth); Obut and Sobolevskaya, p. 71, pl. 13, fig. 1.

1970 Pristiograptus nudus (Lapworth); Rickards, p. 59, pl. 7, fig. 1.

1971 Monograptus (Pristiograptus) nudus nudus Lapworth; Schauer, p. 62, pl. 21, figs. 4-7; pl. 22, figs. 12-13.

1975 Monograptus nudus Lapworth; Bjerreskov, pp. 47-48, pl. 6E; text-fig. 15C.

1975 Pristiograptus nudus (Lapworth); Hutt, p. 59, pl. 11, figs. 5,6.

1982a Pristiograptus nudus (Lapworth); Lenz, pp. 58-60, figs. 5L,M,P; 21D.

1984a Pristiograptus nudus (Lapworth); Chen, p. 61, pl. 10,

Text-figure 31

All figures x7.5 unless otherwise stated.

A-E. Pristiograptus nudus (Lapworth): A) TC:55.5; B) TC:57.0; C)TC:55.5, x15; D) TC:13.5; E) TC:23.5.

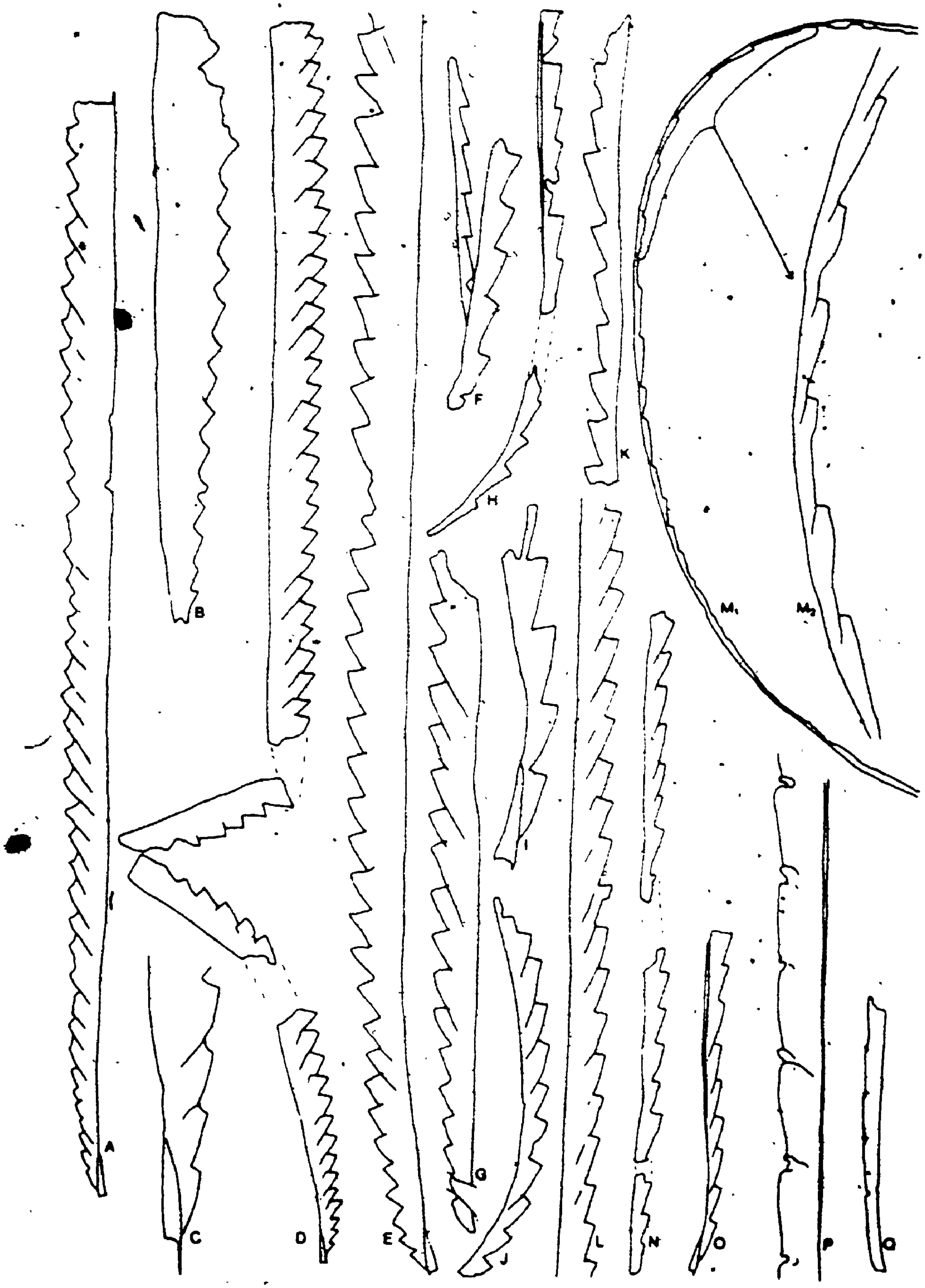
F,H,K. Pristiograptus cf. P. parvus Huang and Lu, all specimens from TF:61.0.

G,I,J,L. Pristiograptus regularis regularis (Törnquist): G) HR:171.5; I) HR:156.5, x15; J) HR:133.5; L) TC:22.5.

M. Pristiograptus? sp., M2 is and enlargement of the mesial thecae of M1, x15; M1 is x3.3.

N,O. Pristiograptus cf. P. variabilis (Perner), both specimens from TF:71.0.

P,Q. Monoclimacis cf. M. crenularis (Lapworth), both specimens from TC:15.0; P) x15.


A
B
C
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M_1
M_2
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O
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Q

figs. 13,14; pl. 11, fig. 4.

Material. Numerous very well to poorly preserved, compressed specimens.

Occurrence. Lower *convolutus*? and upper *convolutus* to upper *sakmaricus*. Snowblind Creek at 457.0, 528.0 and 538.5m, Cape Phillips at 34.0, 151.0, 152.5, 153.0, 156.0 and 158.0m, Cape Manning at 5-7m, Rookery Creek at 139.5 and 162.0m, Truro Island at 51.0m, Twilight Creek at 15.0, 15.5-16.0, 20.5, 22.5, 23.5, 24.5, 27.5m, 31.0, 31.5, 32.5, 40.5, 55.5, 57.0, 50.0, 60.0 and 61.5m, Middle Island at 59.0, 63.0 and 64.0m, Trold Fiord at 71.0, 74.0 and 143.0m and Huff Ridge at 158.0, 160.0, 164.0, 171.5, 173.0, 175.0, 195.0 and 195.5m.

Description. Rhabdosome up to 65mm long and straight although may show a slight dorsal or ventral curvature proximally. Widens gradually from 0.4 to 0.6mm at th1 to a maximum of 1.5 to 2.5mm. Thecae spaced at 6.5 to 8.5 in 5mm proximally to 7.5 to 11 in 10mm distally and are simple tubes with slightly to strongly everted apertures. Thecal overlap about 1/2 distally, decreasing proximally. Sicula 0.9 to 1.3mm long reaching to aperture of th2.

Remarks. The Canadian Arctic collections show a wide range of variation in dimensions and thecal spacings and it covers much of the known range of variation for this widely reported species. The proximal thecal spacing tends to be higher than previously reported and the sicula tends to show a greater length like those reported by Lenz (1982a) and Bjerreskov (1975) rather than the shorter ones seen by Hutt (1975).

The stratigraphically lower populations (convolutus to crispus Zone) tend to show shorter siculae and more highly inclined, more closely spaced proximal thecae while the later populations tend to reach greater maximum widths and often have more strongly everted apertures. In addition, the earlier populations tend to show only straight or slightly dorsally curved proximal ends while the later collections have slightly dorsally or ventrally curved or straight proximal ends.

Pristiograptus cf. *P. parvus* Huang and Lu, 1983

Text-figure 31F,H,K.

Material. About twenty moderately to poorly preserved compressed specimens.

Occurrence. Pectinatus and orbitus? subzones. Snowblind Creek at 140m, Cape Manning at 0-2 and 2-5m, Truro Island at 49.0m, Trold Fiord at 61.0 and 62.5m and Huff Ridge at 117.0m.

<u>Description</u>. Rhabdosome up to at least 40mm long, weakly dorsally curved proximally usually becoming straight distally. No proximal ends preserved. Widens gradually from 0.35mm proximally to 0.6 to 0.8mm distally. Thecae spaced at 8 to 10.5 in 10mm and are straight, simple tubes overlapping 1/4 to 1/3 their length. Apertures are horizontal.

<u>Remarks</u>. The present specimens match those of Huang and Lu in the dimensions and rhabdosomal and thecal form but the distinctive sicula with its long, outwardly-directed virgella are not seen due, probably, to the rather poor state of preservation. A provisional assignment is therefore made to <u>P</u>. <u>parvus</u>. <u>Pristiograptus</u> sp. 1 of Hutt (1975) is similar to this material but is narrower and tends to have more closely spaced distal thecae. Again, poor preservation of the present material prevents more complete comparison.

This species is very similar to the later occurring <u>P</u>. cf. <u>P</u>. <u>variabilis</u> but the latter shows much less dorsal curvature of the rhabdosome.

<u>Pristiograptus</u> <u>regularis</u> <u>regularis</u> (Törnquist, 1899)

Text-figure 31G,I,J,L.

1899 <u>Monograptus</u> <u>regularis</u> Törnquist, p. 7, pl. 1, figs. 9-14.

1911 Monograptus regularis Törnquist; Elles and Wood, pp. 372-373, pl. 37, fig. 3a-d; text-fig. 243a-c.

1970 Pristiograptus regularis regularis (Törnquist); Rickards, pp. 59-60, pl. 7, fig. 1.

1974 Monograptus regularis Törnquist; Sherwin, pp. 157-158, pl. 11, fig. 10; text-fig. 2e.

1975 Monograptus regularis regularis Törnquist; Bjerreskov, p. 47.

1975 Pristiograptus regularis regularis (Törnquist); Hutt, pp. 58-59, pl. 11, fig. 10; pl. 12, fig. 4; text-fig. 14, fig. 7.

1978 Pristiograptus regularis (Törnquist); Chen and Lin, p. 56, pl. 11, figs. 2,11,12.

1982a Pristiograptus regularis (Törnquist); Lenz, pp. 60-61, figs. 5H-J; 21A-C.

1984a Pristiograptus regularis (Törnquist); Chen, pp. 60-61, pl. 10, fig. 10.

Material. Numerous well to poorly preserved, compressed specimens.

Occurrence. Lower convolutus?, upper convolutus and minor zones. Cape Manning at 5-7m, Twilight Creek at 15.0, 21.5, 22.5, 23.5 and 27.5m, and Huff Ridge at 131.0, 133.5, 156.5, 158.0 and 171.5m.

Description. Rhabdosome up to at least 30mm and is straight, may be slightly dorsally curved proximally. Widens very gradually from 0.3 to 0.45mm at th1 to a maximum of 1.0 to 1.4mm. Thecae spaced at 5.5 to 7 in 5mm proximally to 9 to 11.5 in 10mm distally and are straight, simple tubes with slightly everted apertures. Thecae overlap 1/2 to 2/3 distally, decreasing proximally. Sicula 1.1 to 1.4mm long reaching about half way along th2.

Remarks. The present material shows a wide range of variation in dimensions but fits well with the previously reported values for this species. *Pristiograptus regularis regularis* differs from *P. nudus* in being more slender and generally has less highly inclined thecae, more closely spaced distally. *Pristiograptus variabilis* is more slender and has much lower distal thecal overlap while *P. jaculum* has thecae with a slight sigmoidal curvature.

Pristiograptus cf. *P. variabilis* (Perner, 1897)

Text-figure 31N,O.

Material. Four moderately well preserved, compressed specimens.

Occurrence. Upper *minor* and *turriculatus* zones. Trold Fiord at 71.0 and 79.0m.

Description. Rhabdosome up to at least 16mm long, with slight dorsal curvature proximally, straight distally. Widens from 0.35mm at th1 to a maximum of 0.6 to 0.75mm. Thecae spaced at 10 to 11.5 in 10mm and are simple tubes with horizontal apertures and about 1/3 overlap. Sicula 0.9mm long reaching about 2/3 along the length of th1.

Remarks. The Canadian Arctic specimens differ from typical P. *variabilis* in that they are somewhat narrower and possess a shorter sicula. Otherwise the thecal and rhabdosomal characteristics match well with previously described material.

Pristiograptus? sp.

Text-figure 31M.

Material. A single, rather porly preserved, compressed specimen.

Occurrence. Middle *griestoniensis* Zone. Twilight Creek at 34.0m.

Description. Rhabdosome 65mm long (incomplete) and moderately ventrally curved. Width is about 0.3mm and thecae spaced at 8 in 10mm. Thecae are simple, very wealy sigmoidally curved tubes with about 1/6 overlap and slightly everted apertures. Proximal end is not preserved.

Remarks. The thecae of this species resemble those of the much earlier occurring *Pristiograptus fragilis fragilis*. The degree of overlap is slightly greater and the degree of sigmoidal curvature is slightly more pronounced. *Monograptus jonesi* is also similar but shows less overlap and has more closely spaced thecae. Neither of the above species shows such pronounced ventral curvature as this form but this may be a preservational feature.

The lack of more complete or well preserved material prevents a more complete description or positive assignment of this apparently unique species.

Genus *Monoclimacis* Frech, 1897

Type species. *Graptolithus vomerinus* Nicholson, 1872.

Monoclimacis cf. *M. crenularis* (Lapworth, 1880)

Text-figures 31P,Q; 32A.

Material. About ten moderately to poorly preserved, compressed fragments.

Occurrence. *Orbitus* Subzone? and upper *convolutus* Zone. Cape Manning at 2-5m, Truro Island at 47.0-48.0m and Twilight Creek at 15.0m.

Description. Rhabdosomal fragments short, some with weak ventral curvature, others straight. Width ranges from

Text-figure 32

All figures X7.5 unless otherwise stated.

A. *Monoclimacis* cf. *M. crenularis* (Lapworth), TI:47.0-48.0.

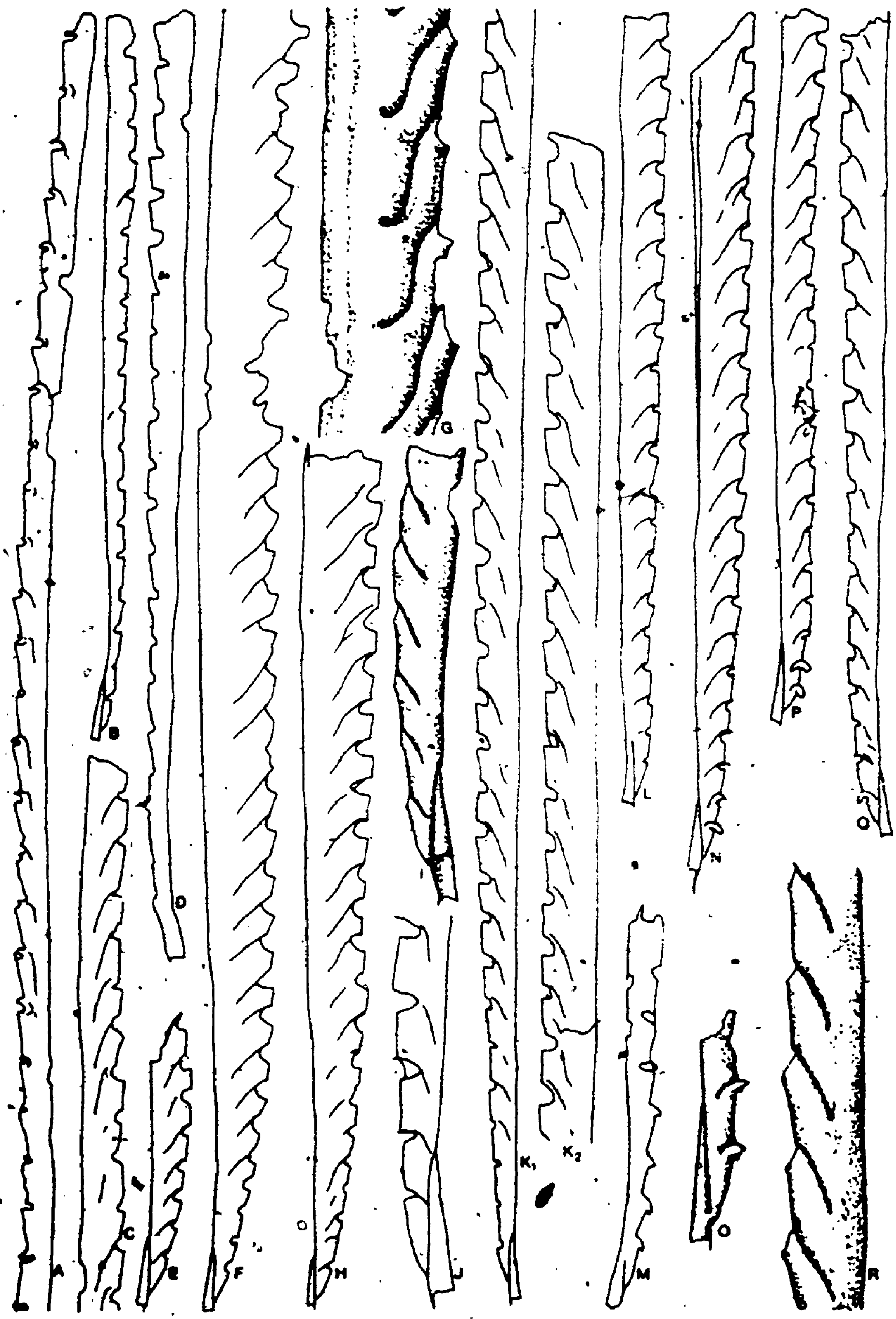
B-D. *Monoclimacis linnarssoni* (Tullberg): B) TC:61.5; C) TC:49.0; D) TF:143.0.

E-I. *Monoclimacis vomerinus vomerinus* (Nicholson): E) TC:32.5; F) TC:61.5; G) TC:29.5, x15; H) TC:57.0; I) TC:34.0, x15.

J-L. *Monoclimacis vomerinus* cf. *geinitzi* (Bouček): J) TC:43.5, x15; K) K1 and K2 are proximal and distal halves of the same specimen, TC:32.5; L) TC:43.5.

M. *Monoclimacis vomerinus* n. subsp. *sensu* Bjerreskov, 1975, CP:81.0.

N-R. *Monoclimacis* n. sp. A; N) TC:41.5; O) TC:25.5, x15; P) TC:29.5; Q) TC:29.5; R) TC:29.5, x15.


A
B
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K1
K2
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0.3 to 0.8mm, although most specimens are 0.5 to 0.6mm wide. Thecae spaced at 9 to 11 in 10mm. Thecae geniculate with a straight, parallel to slightly inclined supragenicular wall and everted apertures. The geniculum is marked a small hood, apparently formed as an extension of the dorsal thecal wall, which is more pronounced on the more proximal thecae. No proximal ends are preserved.

Remarks. The general thecal form and dorsally curved to straight rhabdosome are characteristic features of M. crenularis but the poor state of preservation and lack of proximal ends prevents positive identification. None of the present specimens appear to reach the width of 1.0mm previously cited for this species. Many of the present specimens occur in earlier strata than is typical for M. crenularis and, as a result, may be transitional in nature between that species and the more slender M. n. sp. which also occurs in the curtus Zone.

Monoclimacis linnarssoni (Tullberg, 1883)

Text-figure 32B-D.

1883 Monograptus Linnarssoni Tullberg, p. 20, pl. 2, figs. 5-9.

1965 Monoclimacis linnarssoni (Tullberg); Rickards, pp. 250-252, pl. 30, fig. 5; text-fig. 2a,b.

1967 Monoclimacis linnarssoni (Tullberg); Obut and

Sobolevskaya, pp. 107-108, pl. 13, figs. 8,9.

1971 Monograptus (Monoclim.) linnarssoni Tullberg; Schauer, p. 67, pl. 28, fig. 9; pl. 29, fig. 11.

1975 Monograptus linnarssoni Tullberg; Bjerreskov, pp. 54-55, pl. 8F; text-fig. 17B.

1975 Monoclimacis linnarssoni (Tullberg); Obut and Sobolevskaya, p. 171, pl. 33, fig. 8.

1976 Monoclimacis linnarssoni linnarssoni (Tullberg); Sennikov, pp. 190-192, pl. 13, fig. 1.

1978 Monoclimacis linnasoni (Tullberg) (sic); Wang, p. 510, pl. 1, fig. 9.

1982a Monoclimacis linnarssoni (Tullberg); Lenz, pp. 63-64, fig. 8F,G.

Material. Numerous very well to poorly preserved, compressed and partial to full relief specimens.

Occurrence. Sakmaricus Zone. Snowblind Creek at 522.5m and A2.0m, Cape Phillips at 156.0m, Twilight Creek at 49.0, 49.5, 51.0 and 61.5m, Middle Island at 66.0m, Cape Becher at 20.0, 20.5 and possibly 2.0m, Trold Fiord at 143.0 and 145.0m and Huff Ridge at 274-280m. Extends in to Lower Wenlock at some sections.

Description. Rhabdosome up to at least 90mm long, straight although may be slightly dorsally curved proximally. Widens from 0.3 to 0.4mm at th1 to a maximum of

0.9 to 1.1mm. Thecae spaced at 6 in the first 5mm, 9 to 10 in 10mm distally and are strongly sigmoidally curved with a sharp geniculum and straight to slightly convex supragenicular wall. Interthecal septa are S-shaped and thecae overlap slightly proximally, up to 1/2 distally. Apertures everted.. Sicula 1.5 to 1.7mm long reaching to or just below the aperture of th2.

Remarks. The present specimens match well with previous reports of this species in the width and thecal and rhabdosomal form but the thecal spacing tends to be slightly higher than is typical of this species. It is distinguished by its lack of hooked proximal thecae and slender width. *Monograptus griestoniensis* has slightly hooked thecae throughout which are not visible on the less well preserved specimens and the two could be confused except that the latter is consistently slightly narrower and reaches its maximum width much more gradually.

Monoclimacis vomerinus vomerinus (Nicholson, 1872)

Text-figure 32E-I.

1872 *Graptolithus vomerinus* Nicholson, p. 53, fig. 21a-c.

1910 *Monograptus vomerinus* (Nicholson); Elles and Wood, pp. 409-411, pl. 41, fig. 1a-e; text-fig. 275a-f.

1971 *Monograptus* (*Monoclim.*) *vomerina vomerina* (Nicholson) (sic); Schauer, p. 67, pl. 28, figs. 10,11; pl. 29, figs. 7,8.

1975 Monograptus vomerinus vomerinus (Nicholson); Bjerreskov, pp. 55-57, pl. 8E-G; text-fig. 17E.

Material. Hundreds of very well to poorly preserved, compressed and partial to full relief specimens.

Occurrence. Griestoniensis to sakmaricus Zone. Snowblind Creek at 375.0, 393.0, 394.0, 396.0, 457.0, 460.0, 491.0, 491.5, 492.0, 524.0, 524.5, 526.0, 527.5, 528.0, 530.0, 534.2, 534.7, 536.5, 537.5, 538.5m, A0.0, A2.0, A5.0 and A24.0m, Cape Phillips at 19.5, 30.0, 34.0, 100.0, 110.0, 120.0, 127.0, 128.0, 129.0, 140.0, 146.0, 147.0, 148.0, 152.5 and 158.0m, Rookery Creek at 137.0, 139.5, 144.0, 149.0, 156.5 and 162.0m, Twilight Creek at 29.5, 30.5, 31.5, 32.5, 34.0, 40.5, 42.0, 42.5, 43.5, 45.0, 45.5, 46.0, 48.0, 49.0, 49.5, 52.0, 54.5, 57.0, 59.0 and 61.5m, Middle Island at 52.0, 59.0, 63.0, 64.0 and 67.0m, Cape Becher at 5.0, 6.0, 7.0, 10.0, 12.0, 20.0, 27.0, 30.0 and 32.0m, Trold Fiord at 105.0, 123.5, 125.0, 133.0, 136.0, 140.5 and 143,0m, Huff Ridge at 274-280m and Irene Bay at 67.0, 68-72 and 69.0m.

Description. Rhabdosome with slight dorsal curvature proximally, straight distally, up to 360mm long. Widens rather rapidly from 0.45 to 0.55mm at th1, to 0.8 to 1.0 at th5 to a distal maximum of 1.8 to 2.5mm. Thecae spaced at 6 to 7 in the first 5mm, 8 to 9.5 in 10mm distally and are monoclimacid throughout with parallel to slightly inclined supragenicular walls, sharp to slightly rounded geniculae and everted apertures. Thecae overlap about 1/6 proximally, increasing to as much as 2/3 distally. Sicula is 1.2 to 1.6mm long and generally reaches about midway along th2.

Remarks. This species shows a range of variation in maximum width, sicular length similar to that seen by Bjerreskov (1975) and the presence of no strongly hooked thecae at the proximal end, which together with these dimensions, are characteristic of M. vomerinus vomerinus. As pointed out by Bjerreskov, this form may be synonymous with M. crenulatus (Törnquist) s.s. (not, however, with M. crenulatus sensu Elles and Wood, 1911).

In many of the present collections, a more slender form of M. vomerinus has been found, which widens more gradually to a maximum width of 1.3 to 1.6mm. This form is otherwise very similar to M. v. vomerinus and when only small or poorly preserved fragments are found, the two can be very difficult to distinguish. The slender from is described below as M. vomerinus cf. geinitzi (Bouček).

Monoclimacis vomerinus cf. geinitzi (Bouček, 1932)

Text-figure 32J-L.

?1975 Monoclimacis cf. crenulatus (Törnquist); Berry and

Murphy, pp. 66-68, text-fig. 20a.

Material. Hundreds of very well to poorly preserved compressed and low relief specimens.

Occurrence. Griestoniensis to sakmaricus Zone. Snowblind Creek at 390.0, 393.0, 396.0, 445.0, 460.0, 491.5, 492.0, A2.0 and A16.0m, Cape Phillips at 0.0, 19.5, 26.5, 34.0, 93.5 and 157.0m, Twilight Creek at 30.5, 32.5, 43.5, 45.0, 46.0, 49.0, 50.0 and 52.5, Middle Island at 39.0, Trold Fiord at 119.0, 123.0, 135.0 and 140.5 and Irene Bay at 67.0 and 69.0m.

Description. Rhabdosome up to at least 70mm, straight throughout. Widens slowly from 0.4 to 0.45mm at th1 to 0.55 to 0.65mm at th5 to a distal maximum of 1.3 to 1.6mm. Thecae spaced at 5.5 to 6.5 in the first 5mm, 8 to 10 in 10mm distally and are typically monoclimacid with sharp geniculae, parallel supragenicular walls and slightly everted apertures. Thecae overlap less than 1/3 proximally, somewhat more than 1/2 distally. Sicula is 1.5 to 1.7mm long reaching to, or just below the aperture of th2.

Remarks. This form closely resembles Monoclimacis vomerinus vomerinus from which it is distinguished by lesser width throughout its length. This form resembles Monoclimacis geinitzi (Bouček, 1932), here considered a subspecies of M. vomerinus, except that it may reach a slightly greater maximum width and the distal thecal spacing is, on average, somewhat wider. These may be the result of larger specimens in the Canadian collections and/or wider variation within a larger population size.

This form is distinguished from Monoclimacis vomerinus gracilis (Elles and Wood, 1911) by the wider thecal spacing and the straight proximal end and from M. vomerinus subgracilis by the straight proximal end. Both of the latter are Lower Wenlock forms.

The specimens assigned to Monoclimacis cf. crenulatus by Berry and Murphy (1975) are almost identical to the present material except that they widen more quickly at the proximal end, and reach their maximum width sooner.

Monoclimacis vomerinus n. subsp. sensu Bjerreskov, 1975

Text-figure 12M.

1975 Monograptus vomerinus n. subsp. Bjerreskov, p. 58, text-fig. 17A.

Material. A single, moderately well preserved, compressed specimen.

Occurrence. Upper griestoniensis Zone. Cape Phillips at 81.0m.

Description. Rhabdosome slightly dorsally curved, 9.5mm long. Widens from 0.5mm at th1 to 0.7mm at th7 and thecae spaced at 4.75 in 5mm. First four thecae are moderately to weakly hooked, distally they are monoclimacid. Sicula indistinct.

Remarks. Despite the presence of only one proximal specimen, it matches very well with the subspecies described by Bjerreskov (1975). The distinctive features are the presence of the few, hooked proximal thecae and the slender, very gradually widening proximal end and the wide thecal spacing. Monoclimacis n. sp. A is similar but widens more quickly and has more closely spaced proximal thecae while Monoclimacis n. sp. B has 8 to 12 hooked thecae.

This specimen differs from Bjerreskov's in that there are four hooked thecae rather than two or three (although the fourth is only weakly hooked) and a slightly greater width which is accounted for by the fact that the Danish material is uncompressed while the Canadian specimen is flattened.

Monoclimacis vomerina ssp. 1 of Bjerreskov (1981) is similar but has more closely set proximal thecae.

Monoclimacis n. sp. A

Text-figure 32N-R.

?1911 Monograptus vomerinus var. crenulatus (Törnquist);

Elles and Wood, pp. 412-413, pl. 41, fig. 4a-d; text-fig. 278a-e.

1975 *Monograptus* aff. *crenulatus* sensu Elles and Wood, 1911; Bjerreskov, p. 54, pl. 8D.

?1981 *Monoclimacis crenulata sensu* Elles and Wood, 1911; Bjerreskov, pp. 24-25, pl. 2, fig. 3.

Material. Hundreds of very well to poorly preserved, compressed, low relief and uncompressed, pyritized specimens.

Occurrence. *Turriculatus*-*crispus* to middle *griestoniensis* Zone. Twilight Creek at 25.5, 26.0, 27.0, 27.5, 28.5, 29.5 and 30.5m and Huff Ridge at 195.5, 203.0, 203.5, 204.0 and 206.5.

Description. Rhabdosome up to 85mm long and is straight with very slight dorsal curvature proximally. Widens quickly from 0.5 to 0.7mm at th1 (including metathecal hooks) rather quickly to 0.9 to 1.1mm and slowly thereafter to a maximum of 1.3 to 1.8mm. Thecae spaced at 5 to 6.5 in the first 5mm, 8 to 9.5 in 10mm distally. First one to three thecae (usually two or three) geniculate with parallel ventral walls and an aperture which forms a closely adpressed, moderately to strongly recurved hook. The hook is commonly strongest on th1 and weakens on th2 and 3. All subsequent thecae are monoclimacid, like those of *M*.

vomerinus with everted apertures set in a shallow excavation. Overlap is slight proximally, increasing to almost 1/2 distally. Sicula is 1.4 to 1.8mm long usually reaching to the base of th3, occasionally as far as the base of th4.

Remarks. This species resembles the *Monoclimacis vomerinus* group but is distinguished by the presence of a relatively wide proximal end with two or three (rarely one) moderately to strongly hooked thecae. *Monoclimacis vomerinus* var. *crenulatus* of Elles and Wood (1911) and *Monoclimacis crenulatus sensu* Elles and Wood of Bjerreskov (1981) are similar to the present specimens but have only one hooked proximal theca and seem to widen somewhat more gradually. These occur in a stratigraphically higher zone, equivalent of the *sakmaricus* Zone of this report and are considered possibly synonymous with this new species. *Monograptus* aff. *crenulatus sensu* Elles and Wood of Bjerreskov (1975) shows two hooked proximal thecae and otherwise resembles the present specimens (except for a slightly greater maximum width) and those specimens, from the *griestoniensis* Zone, are considered to belong to this new species. Future work may show this species and the latest Llandovery forms to be temporal subspecies.

The original material of *Monoclimacis crenulatus* (Törnquist, 1881) lacks any hooked proximal thecae and may be synonymous with *M. vomerinus vomerinus* (Bjerreskov, 1975).

Monoclimacis n. sp. B

Text-figure 33A-C.

Material. Numerous moderately to very well preserved compressed and partial relief specimens.

Occurrence. Upper sakmaricus Zone. Cape Phillips at 156.0m, Twilight Creek at 61.5m and Cape Becher at 32.0m.

Diagnosis. Straight rhabdosome with proximal 8 to 12 thecae hooked, becoming monoclimacid distally. Widens quickly to a maximum width of 1.6mm.

Description. Rhabdosome up to at least 24mm long and straight although may be slightly dorsally curved proximally. Widens quickly from 0.4 to 0.5mm at th1 to a maximum of 1.3 to 1.6mm. Thecae spaced at 6.5 to 7 in the first 5mm, 8 to 10 in 10mm distally. Proximal thecae have parallel prothecae and tightly hooked metathecae. The amount of thecal involvment in the hook gradually decreases until, by the ninth to thirteenth theca, the hook has retreated and the thecae are monoclimacid with everted apertures. Thecal overlap is slight proximally, up to over one half distally. Sicula is 1.3 to 1.5mm long, reaching midway along th2.

Text-figure 33

All figures x7.5 unless otherwise stated.

A-C. _Monoclimacis_ n. sp. B: A) CP:156.0; B) & C) TC:61.5.

D,G-I. _Monoclimacis_? n. sp., all specimens from TF:63.0 except H TF:62.5, x15.

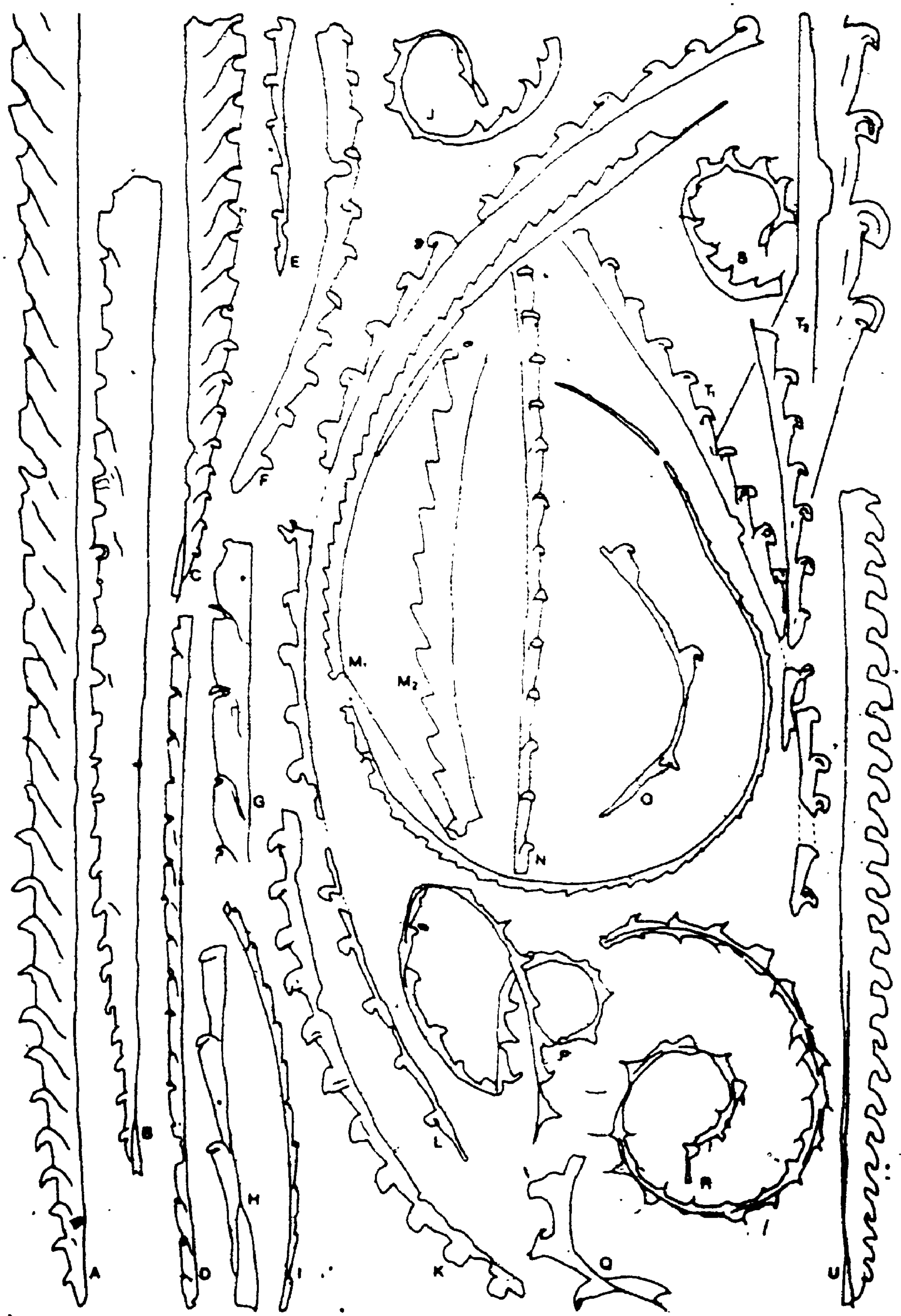
E,F,K,L,T. _Monograptus_ cf. _M_. _arciformis_ Chen and Lin: E) & F) TF:61.5; K) HR:110.0; L) CM:2-5; T) TI:47.0-48.0.

J,P-S. _Monograptus_ _calamistratus_ Churkin and Carter, all specimens from TF:63.0; Q) x15.

M,N. _Monograptus_ _austerus_ _vulgaris_ Hutt, both specimens from HR:113.5, M2 is an enlargement of M1 mesial thecae, M1 x3.5.

O. _Monograptus_ _capis_ Hutt, TF:63.0.

U. _Monograptus_ cf. _M_ _ayagusensis_ Obut and Sobolevskaya, TC:27.5.


A
B
C
D
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M_1
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T_1
T_2
U

Remarks. The rapidly widening proximal end with eight to twelve hooked thecae and monoclimacid distal thecae make this new species unlike any previously reported forms. All of the previously found monoclimacids with hooked proximal thecae (e.g. _Monoclimacis_ n. sp. A, _M. crenulatus_, _sensu_ Elles and Wood, 1911, _M. continens_ (Törnquist), _M. vomerinus_ n. subsp. (Bjerreskov, 1975), _M. crenularis_) have fewer hooked thecae and widen more slowly.

Incomplete proximal fragments of this species could be easily mistaken for those of _Monograptus parapriodon_ while distal fragments look like those of the _Monoclimacis vomerinus_ group. As a result, fairly complete specimens are necessary for correct identification of this new species.

Monoclimacis? n. sp.

Text-figure 33D,G-I.

1975 _Monoclimacis_? sp. Hutt, 1975, pl. 13, fig. 1; text-fig. 13, figs. 1,2.

?1981 _Monoclimacis_ sp. Bjerreskov, p. 29, pl. 2, figs. 9, 15.

Material. About 20 moderately to very well preserved, compressed specimens and several more poorly preserved fragments.

Occurrence. Curtus and upper? convolutus zones. Snowblind Creek at 170m, Troid Fiord at 62.5 and 63.0m and Huff Ridge at 118.5 and 122.0m.

Description. Rhabdosome up to at least 28mm (distal fragment) and is weakly dorsally curved proximally and mesially, becoming straight distally. Widens gradually from 0.25 to 0.3mm at th1 to a distal maximum of 0.35 to 0.45mm. Thecae spaced at 4 to 5 in 5mm proximally to 10 to 11 in 10mm distally. Proximal thecae slender, axially elongate and weakly hooked, the hook being entirely formed by the dorsal thecal wall. After about th6, the hook gradually retreats to form a small hood at the geniculum of the succeeding theca and the prothecae broaden giving the distal thecae a strongly monoclimacid appearance. Overlap is slight proximally, increasing to about 1/3 distally. Sicula is 1.2mm long and extends about half way along the length of th1 which originates 0.35mm above the sicular aperture.

Remarks. As pointed out by Hutt (1975) this species resembles Monoclimacis? crenularis in the hooked nature of the proximal thecae. Since the "genicular" hoods appear to actually be extensions of the dorsal thecal wall (they are, fact, weak hooks) assignment to this genus is questionable. More work needs to be done on the nature of the geniculae and genicular structures of Llandovery "monoclimacids" to determine the nature of these structures and whether they are, indeed homologous with the genicular structures of later Monclimacis species.

The specimens assigned to Monoclimacis sp. by Bjerreskov appear to be similar to these but in the absence of any proximal ends, more positive comparison is difficult.

Monclimacis lunata Chen and Lin (1978) is similar to this species in dimensions and rhabdosomal form but lacks the hooked proximal thecae and has a much longer sicula.

Genus Monograptus Geinitz, 1852 emend.

Type species. Lomatoceras priodon Bronn, 1835.

Monograptus cf. M. arciformis Chen and Lin, 1978

Text-figure 33E,F,K,L,T.

Material. About twenty compressed, moderately to poorly preserved specimens.

Occurrence. Lower? and upper cyphus Zone and pectinatus Subzone. Cape Manning at 2-5m, Truro Island at 47.0-48.0m, Trold Fiord at 60.0 and 61.0m and Huff Ridge at 110.0? and 117.0m.

Description. Rhabdosome at least 32mm long, weakly dorsally curved throughout. Widens very gradually from 0.35

to 0.45mm proximally, to a maximum of 0.8 to 0.9mm. Thecae spaced at 3.5 to 4.5 in 5mm proximally to 8.5 to 9.5 in 10mm distally. Proximal thecae strongly axially elongate with slender protheca and hooked metatheca each occupying about 1/2 the width. Distally the protheca becomes shorter and broader, its ventral wall slightly inclined and the hooked metatheca occupying less than 1/2 the width. Proximal end is not preserved.

Remarks. The present material closely resembles *Monograptus arciformis* Chen and Lin (1978) except that they did not report a variation in thecal spacing throughout the rhabdosome length and none of the present specimens show proximal portions as narrow as the Chinese specimens. This together with the rather poor state of preservation of this material prevents a more positive assignment. *Monograptus arciformis nanzhangensis* Chen (1984a) has a wider proximal end and appears to reach its maximum width much more quickly.

Monograptus cf. *intermedius* of Chen and Lin (1978) also appears to be very similar, although it reaches a greater maximum width, and may be conspecific with this material.

Subspecies of the *Monograptus austerus* group appear somewhat similar proximally but do not have hooked distal thecae. The distal region somewhat resembles that of *M. clingani* (Carruthers) but the latter is much wider and reaches its distal width much more quickly.

The early occurrences of these specimens at Huff Ridge and Trold Fiord, together with the report of *M.* cf. *intermedius* from the *cyphus*-*lunata* Zone of China (Chen and Lin, 1978) are significant because they are among the earliest known occurrences of monograptid species with hooked thecae throughout their length.

Monograptus austerus vulgaris Hutt, 1974

Text-figure 33M,N.

1911 *Monograptus revolutus* Kurck; Elles and Wood, pp. 384-385, pl. 38, figs. 1a-d,?e; text-fig. 254a (*non* b).

1974a *Monograptus austerus vulgaris* Hutt, p. 199, text-fig. 6b.

Material. Two moderately well preserved, compressed specimens and several rather poorly preserved specimens possibly assignable to this species.

Occurrence. Upper *cyphus* Zone and *pectinatus* Subzone. Trold Fiord at 60.0? and 61.0m and Huff Ridge at 113.5m.

Description. Rhabdosome up to 90mm long, moderately dorsally curved mesially, weakly so proximally and distally. Widens slowly from 0.2 to 0.3mm proximally to a maximum of 1.0mm. Thecae spaced at 8 to 9 in 10mm throughout. Proximal

20 to 25 thecae hooked with axially elongate prothecae. Overlap is negligible proximally increasing to 1/2 distally. Distal thecae are straight tubes inclined at 15 to 25° with even apertures. Change from hooked to straight thecae takes place gradually within the more strongly curved mesial region. Sicula is not observed.

Remarks. Hutt (1974a) pointed out that this subspecies is distinguished from others of Monograptus austerus by its tighter dorsal curvature, clearly seen here. Also clearly seen in the present specimens is the hooked nature of the proximal thecae and the simple distal ones. The single specimen from TF:60.0 is an incomplete proximal fragment and could equally be assigned to any subspecies of M. austerus or to M. revolutus Kurck.

Monograptus cf. M. ayagusensis Obut and Sobolevskaya, 1966

Text-figure 33U.

Material. Three moderately to poorly preserved, compressed distal specimens.

Occurrence. Crispus and lower griestoniensis zones. Twilight Creek at 27.5m and Huff Ridge at 195.5m.

Description. Rhabdosomal fragments up to 20mm long, straight, 0.9 to 1.3mm wide. Thecae spaced at 16 to 13 in 10mm and have a prominent, open metathecal hook with a relatively long downward-growing portion and proximally pointing apertures. Overlap appears to be very low. Sicula 1.2mm long reaching midway along th2.

Remarks. The metathecae seem to grow "downward" almost immediately and this gives them a "hanging' appearance which they seem to share with M. ayagusensis. This, together with the very close thecal spacing distinguishes this species from all others. The relatively poor state of preservation prevents more positive specific assignment.

Monograptus caldmistratus Churkin and Carter, 1970

Text-figure 33J,P-S.

1970 Monograptus calamistratus Churkin and Carter, p. 37, pl. 4, fig. 12; text-fig. 15a-c.

Material. About 20 compressed specimens, well to poorly preserved.

Occurrence. Orbitus Subzone. Trold Fiord at 63.0m.

Description. Rhabdosome spirally coiled probably in a low cone, through at least two volutions, up to at least 23mm long. Thecae apparently oriented more or less axially although it is not clear if they are pointed toward or away from the apex. Widens from 0.45mm at th1 to a maximum of 0.6 to 0.7mm. Thecae spaced at 14 to 16 in 10mm proximally to 10 to 12 in 10mm distally. Prothecae axially elongate, occupying up to 1/2 to 2/3 rhabdosome width. Metathecae short, stout and hooked. The aperture is covered by a small hood which is expanded laterally into spines up to 0.5mm long. Apertures face proximally. Sicula 0.7 to 0.75mm long with a notched aperture and a virgella up to 0.15mm long. Theca 1 appears to originate about halfway along the sicula and extends to just beyond its apex.

Remarks. The present specimens match very closely with the type material in rhabdosomal form and thecal shape and orientation. The Canadian specimens reach a somewhat greater maximum width and have a somewhat wider thecal spacing but this is probably due to the presence of better preserved, more distal material. In addition, details of the thecal apertures are shown clearly by these well preserved specimens. Although Churkin and Carter (1970) stated that the rhabdosome was planispirally coiled, the presence of occasional, more irregularly compressed forms (pl., fig.) suggests that it was coiled in a low cone rather than a plane. The very common occurrence of dorsoventrally compressed thecae (text-fig. 33R; see also Churkin and Carter, 1970, fig. 15A) shows that they were oriented more nearly axially rather than outward (or inward).

This species is very similar to Monograptus involutus Lapworth (= M. changyangensis Sun) but differs in the lower maximum width, closer thecal spacing and more strongly hooked and hooded thecae with laterally directed spines.

Monograptus capis Hutt, 1975

Text-figure 330.

1970 Monograptus ex gr. elongatus Törnquist; Rickards, p. 76, text-fig. 17, fig. 21.

1975 Monograptus capis Hutt, pp. 79-81, pl. 19, fig. 7; text-fig. 19, figs. 1-3.

Material. A single moderately well preserved, compressed fragment.

Occurrence. Orbitus Subzone. Trold Fiord at 63.0m.

Description. Fragment is 3.7mm long and dorsally curved although this may be partly due to bending of the slender prothecal portion. Thecae 0.35mm wide and spaced at about 7 in 10mm. Prothecal portion consists of a slender thread which makes up about 2/3 the thecal length. Theca then swells to a convex wall terminating a small metathecal hook.

Remarks. Despite the presence of only a single, very short fragment, the thecal characteristics match those of the type material of this distinctive species. Although Hutt describes the rhabdosome as being straight, the holotype, like the present specimen, shows some dorsal curvature and this is likely due to flexure of the very slender prothecal portion.

Monograptus cf. M. clingani (Carruthers, 1867)

Text-figure 34E,G.

Material. About ten compresssed, moderatly to poorly preserved specimens.

Occurrence. Orbitus Subzone and upper convolutus Zone. Snowblind Creek at 140m, Trold Fiord at 62.5m and Huff Ridge at 128.0 and 131.0m

Description. Rhabdosome up to at least 34mm long, moderate dorsal curvature proximally, weaker distally. Widens from about 0.6mm to a maximum of 1.2 to 1.5mm. Thecae spaced at about 5.5 to 6.5 in 5mm proximally, 8 to 9 in 10mm distally. Thecae form open, fairly weak hooks proximally becoming more strongly hooked distally. Prothecae proportionately broad throughout, with ventral wall only slightly to moderately inclined. Sicula is not preserved.

Remarks. The present specimens tend to be more weakly curved proximally than most previously reported examples of

Text-figure 34

All specimens x7.5 unless stated otherwise.

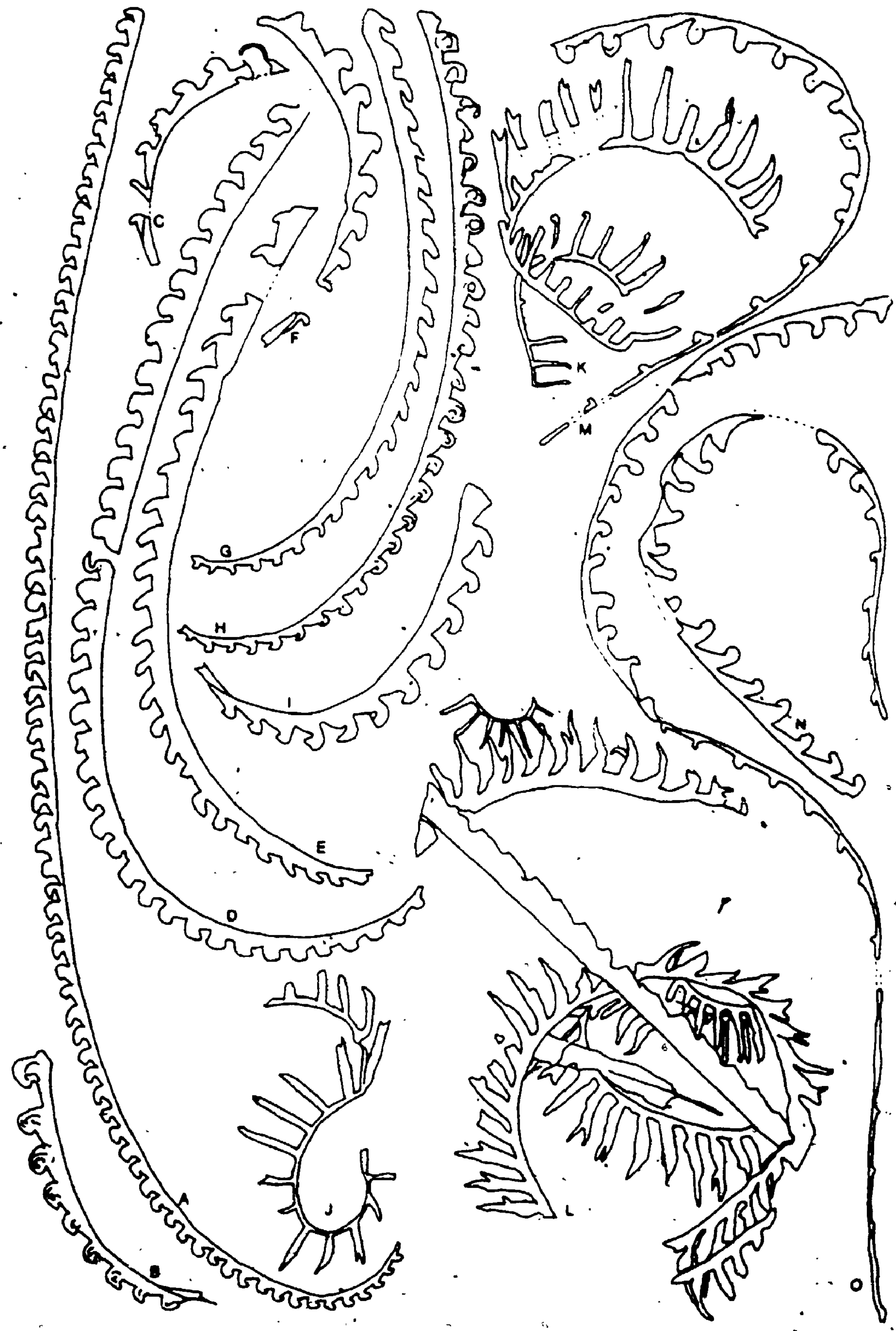
A,B,H<I. Monograptus communis obtusus Rickards: A) TC:15.5-16.0, x3.5; B) TC:15.0; H) TC:15.0, x5.0; I) HR:133.5.

C,D,F. Monograptus communis communis Lapworth: C) CM:5-7; D) CM:5-7, x5; F) HR:124.0.

E,G. Monograptus clingani (Carruthers), both specimens HR:131.0, x5.

J,K,L. Monograptus convolutus (Hisinger): J) TC:15.0; K) CM:5-7; L) TC:15.5-16.0, x5.0.

M-O. Monograptus crispus Lapworth: M) TC:27.0; N) TC:26.0; O) HR:193.0.


A
B
C
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O

Monograptus clingani but the thecal form with the relatively broad prothecae is characteristic of this species. Another characteristic feature, the increasing degree of metathecal hook distally is only evident on two of the specimens. In the absence of better preserved material, particulaly in the proximal end, a positive identification cannot be made.

The possibility exists that these specimens represent poor specimens of M. communis ssp. indet. which have undergone distortion on compression, but the difference in the shape of the prothecae makes this seem unlikely.

Monograptus communis communis Lapworth, 1876

Text-figure 34C,D,F.

1876 Monograptus convolutus Hisinger, sp. Var. (a) communis Lapworth, p. 358, pl. 13, fig 4a (non 4b).

1913 pars Monograptus communis Lapworth; Elles and Wood, pp. 480-481, pl. 49, fig. 1a,c (non b,d,e); text-fig. 336a (non b).

1958 Monograptus communis communis Lapworth; Sudbury, pp. 520-522, pl. 23, figs. 97-101.

1967 Campograptus communis communis (Lapworth); Obut and Sobolevskaya, pp. 123-124, pl. 27, figs. 1-7.

1968 Campograptus communis communis (Lapworth); Obut and Sobolevskaya, pp. 103-104, pl. 26, figs. 1-4.

1970 Monograptus communis communis Lapworth; Rickards, pp. 84-85, pl. 6, fig. 7; text-fig. 17, figs. 1,9,19.

1975 *Campograptus communis communis* (Lapworth); Obut and Sobolevskaya, p. 176, pl. 10, fig. 3.

1976 *Campograptus communis* (Lapworth); Sennikov, pp. 204-207, pl. 14, figs. 6,7.

?1977 *Oktavites communis* (Lapworth); Wang and Ma, p. 366, pl. 115, fig. 4.

1978 non *Oktavites communis* (Lapworth); Chen and Lin, pp. 66-67, pl. 16, figs. 1-5; text-fig. 18c,d.

?1978 *Oktavites communis* (Lapworth); Wang and Zhao, p. 657, pl. 212, fig. 14.

1978 non *Oktavites communis* (Lapworth); Ye, p. 482, pl. 180, fig. 8.

1982a *Monograptus communis* Lapworth; Lenz, pp. 67-69, figs. 5F,G,T; 21G,H,J,L.

1984a non *Oktavites communis* (Lapworth); Chen, p. 68, pl. 13, fig. 12; text-fig. 2a.

Material. About ten moderately preserved compressed, specimens and several more poorly preserved fragments.

Occurrence. *Orbitus* Subzone? and lower *convolutus* Zone. Snowblind Creek at 140m, Cape Manning at 5-7m, Huff Ridge at 124.0 and 126.0m and possibly Trold Fiord at 62.5m.

Description. Rhabdosomes mostly fragmentary, up to at least 48mm long, with moderate dorsal curvature proximally, weakening distally. Widens gradually from 0.45mm at th1 to a maximum of 1.4mm. Thecae spaced at 5 to 5.5 in the first 5mm to 7.5 to 9.5 in 10mm distally. First three of four thecal pairs axially elongate with low, moderately hooked metathecae. Distally thecae become more bluntly triangular, higher, and more strongly hooked. Sicula appears to be about 1.1mm long.

Remarks. The present specimens match well with the previously reported descriptions of this well known and widely dispersed species. The proximal end with 3 or 4 axially thecae and more blunt, hooked distal thecae on a "J"-shaped rhabdosome are characteristic of this species.

Monograptus communis obtusus Rickards, 1970

Text-figure 34A,B,H,I.

1970 *Monograptus communis obtusus* Rickards, pp. 85-86, pl. 8, fig. 4; text-fig. 18, fig. 12.

1978 *Oktavites communis* (Lapworth); Chen and Lin, pp. 66-67, p. 16, figs. 1-5; text-fig. 18c,d.

1984a *Oktavites communis* (Lapworth); Chen, p. 68, pl. 13, fig. 12; text-fig. 2a.

Material. Hundreds of compressed and partially compressed specimens, very well to poorly preserved.

Occurrence. Lower? and upper *convolutus* Zone.

Snowblind Creek at 170m, Cape Manning at 5-7m, Twilight Creek at 15.0 and 15.5 to 16.0m and Huff Ridge at 128.0 and 133.5m

Description. Rhabdosome up to 70mm long, with moderate to weak dorsal curvature proximally, weak to straight distally. Widens from 0.4 to 0.55mm at th1 to a maximum of 1.0 to 1.3mm achieved by th10 to 15. Thecae spaced at 6 to 7.5 in 5mm proximally, 7.5 to 9.5 in 10mm distally. Proximal thecae are not axially elongate, but have a relatively short, nearly parallel-sided protheca and a small metathecal hook. Distally, the protheca widens as its ventral wall becomes more inclined and the metathecal hook becomes higher. Apertures directed proximally as is characteristic of this species. Sicula 0.9 to 1.2mm long and reaches to or just beyond the tip of th1.

Remarks. The lack of axially elongate thecae at the proximal end and the lower distal width distinguishes this subspecies from others of M. communis. Monograptus millepeda curtus (Obut and Sobolevskaya) is similar but its proximal end of has a stronger dorsal curvature, is somewhat wider and the ventral walls of the proximal thecae are more inclined.

Campograptus elegans Koren' (Obut and Sobolevskaya, 1968) is very similar but is somewhat narrower, on average, and appears to have somewhat more widely spaced proximal thecae. The two could, however, be conspecific.

Monograptus convolutus (Hisinger, 1837)

Text-figure 34J-L.

1837 *Prionotus convolutus* Hisinger, p. 114, pl. 35, fig. 7.

1913 *Monograptus convolutus* (Hisinger); Elles and Wood, pp. 467-469, pl. 47, fig. 1a-d; text-fig. 324a,b.

1965 *Demirastrites convolutus* (Hisinger); Obut and Sobolevskaya, pp. 84-85, pl. 16, fig. 6.

1967 *Demirastrites convolutus* (Hisinger); Obut and Sobolevskaya, pp. 126-127, pl. 13, fig. 1.

1970 *Demirastrites convolutus* (Hisinger); Rickards, pp. 82-83, text-fig. 13, fig. 15.

1971 *Monograptus* (*Demirastrites*) *convolutus* (Hisinger); Schauer, pp. 78-79, pl. 26, figs. 5,6.

1975 *Monograptus convolutus* (Hisinger); Bjerreskov, p. 81, pl. 12D; text-fig. 23F.

1975 *Monograptus convolutus* (Hisinger); Hutt, pp. 83-84, pl. 19, fig. 3, pl. 25, fig. 3, text-fig. 22, figs. 2,6.

1975 *Demirastrites convolutus* (Hisinger); Obut and Sobolevskaya, p. 1777, pl. 2, fig. 1.

1976 *Demirastrites convolutus convolutus* (Hisinger); Sennikov, pp. 211-213, pl. 15, fig. 3.

1979 *Demirastrites convolutus* (Hisinger); Paškevičius, pp. 184-186, pl. 15, fig. 6; pl. 16, figs. 6-8; pl. 32, figs. 1,2.

1982a Monograptus convolutus (Hisinger); Lenz, pp. 69-71, figs. 6B; 22A,F.

1984a Demirastrites convolutus (Hisinger); Chen, p. 64, pl. 12, fig. 6.

Material. Numerous compressed specimens, all incomplete, moderately well to poorly preserved.

Occurrence. Convolutus Zone. Snowblind Creek at 170m, Cape Manning at 5-7m, Twilight Creek at 15.0 and 15.5 to 16.0m and Huff Ridge at 124.0, 124.5, 126.0 and 128.0m.

Description. Rhabdosomes very long but all specimens are fragmentary. Coiling appears to be in a conical spiral but long distal fragments appear to be nearly straight with either dorsal or ventral curvature and compression produces a variety of irregular patterns on proximal and mesial specimens. The longest specimen shows at least five complete volutions. Widens from 0.75 at th1 to a distal width of about 2.2 to 3.1mm. Thecae spaced at 12 to 18 in 10mm in the proximal regions to 8 to 12 in 10mm distally. The fist few thecae appear to have a normal rastritid appearance with two small apertural spines. The mesial thecae are like those of Rastrites phleoides Törnquist which widen at their apertures, and split into two pronounced, tapering spines, giving a "Y"-shaped appearance to the thecae. Some of the more complete specimens show at least 1

1/2 to 2 complete volutions of rastritid thecae. Distally, (between th25 and 30 on one specimen) the thecae become slender and triangular in form slightly inclined toward the distal end. Most of these distal thecae appear to come to a simple point distally but some of the specimens clearly show a pair of robust, tapering spines which were presumably pointed ventrolaterally. The sicula, seen on one specimen, is 0.6mm long.

Remarks. The present specimens match well with *Monograptus convolutus* although many also bear a close resemblance to *Rastrites phleoides* and the possibility exists that both species are represented here. All of the specimens which can be considered as truly distal fragments, however, have triangulate rather than rastritid thecae. Furthermore, all of the specimens which look most like *R. phleoides*, that is with rastritid thecae through up to two volutions, also have specimens with triangulate thecae in the same sample, often on the same slab. The appearance of two spines on otherwise *convolutus*-like thecae comes as no surprise and was suggested as being likely by Hutt (1975). The fact that they are not seen more commonly may be accounted for by the fact that they originally pointed dorsolaterally and as a result are not likely to be seen preserved in the same plane. (Although if this is the case, why are the two spines commonly seen on other specimens of *R. phleoides*?) Hutt suggested the possibility that M.

convolutus and R. phleoides were part of a highly variable, single species and the present material is consistent with that suggestion although it is too incomplete to prove (or disprove) it. The two forms are undoubtedly closely related as first suggested by Přibyl and Münch (1942).

Monograptus crispus Lapworth, 1876

Text-figure 34M-O.

1876 Monograptus crispus Lapworth, pp. 503-504, pl. 20, fig. 7a-c.

1913 Monograptus crispus Lapworth; Elles and Wood, pp. 456-457, pl. 45, figs. 6a-f; text-fig. 314a-c.

1951 Monograptus (Globosograptus) crispus Lapworth; Bouček and Přibyl, pp. 192-194, pl. 1, figs. 1-7; pl. 2, figs. 1-3.

1970 Monograptus crispus Lapworth; Rickards, pp. 77-78, text-fig. 16, fig. 12.

1971 Monograptus (Streptogr.) crispus Lapworth; Schauer, p. 72, pl. 24, figs. 4-6; pl. 25, figs. 1,2.

1975 Monograptus crispus Lapworth; Bjerreskov, pp. 74-75, text-fig. 21B.

1975 Monograptus crispus Lapworth; Hutt, pp. 84-85, pl. 11, figs. 8,9; text-fig. 25, fig. 5.

1979 Monograptus (Globosograptus) crispus Lapworth; Paškevičius, pp. 169-170, pl. 12, fig. 9; pl. 13, figs. 1-3, 5-7; pl. 28, figs. 13-15.

1982a *Monograptus crispus* Lapworth; Lenz, pp. 71-73, fig. 6M,P.

1985 *Prochnygraptus crispus* (Lapworth); Přibyl and Storch, pp. 162-163, pl. 1, figs. 1,2; pl. 2, fig. 4, cf. 1.

Material. Five moderately well preserved, compressed specimens.

Occurrence. *Crispus* Zone. Twilight Creek at 26.0 and 26.5m, Huff Ridge at 193.0m and Irene Bay at 65.5m.

Description. Rhabdosome up to about 32mm long with weak dorsal curvature proximally, moderate ventral curvature mesially to distally. May be a simple "U" shape or else undergo torsion and form an elongate "S" shape. Widens from 0.25mm to a maximum of 0.7 to 0.85mm. Thecae spaced at 3.5 to 4 in 5mm proximally, 9 to 11 in 10mm distally. Proximal thecae elongate with a small apertural lobe, distally the prothecae are slightly more broad with a slightly inclined ventral wall and metathecae are lobate. No proximal ends are preserved.

Remarks. The present specimens are similar to those previously reported. The distal thecal spacing reaches higher values in two of these specimens than is typically seen in this species (11 in 10mm) although Bouček and Přibyl (1951) also reported rare specimens with such closely spaced thecae. It is observed that those specimens with the more closely spaced distal thecae also tend to show somewhat more triangular metathecae (text-fig. 34N) and in this respect approach "_Prochnygraptus_" _germanicus_ Přibyl and Storch (1985) in appearance.

The specimens reported by Lenz (1982a) were also from the Cape Phillips Formation from an unknown locality on Ellesmere Island.

Monograptus decipiens decipiens Törnquist, 1899

Text-figure 35J-M.

1899 _Monograptus decipiens_ Törnquist, pp. 20-21, pl. 14, figs. 9-14.

1912 pars _Monograptus decipiens_ Törnquist; Elles and Wood, pp. 469-470, pl. 47, figs. 3a,b,e (non c,d); text-fig. 325a (non b,c).

1975 _Monograptus decipiens_ Törnquist; Bjerreskov, pp. 80-81, pl. 12, fig. E.

1975 _Monograptus decipiens decipiens_ Törnquist; Hutt, pp. 85-87, pl. 21, figs. 2-4; text-fig. 17, fig. 5; text-fig. 20.

1982a _Monograptus decipiens decipiens_ Törnquist; Lenz, pp. 74-75, figs. 6F,N; 23A,C,F.

1985 _Monograptus decipiens decipiens_ Törnquist; El-Khayal, pp. 18-20, pl. 1, figs. 1-3,8.

Text-figure 35

All figures x7.5 unless otherwise stated.

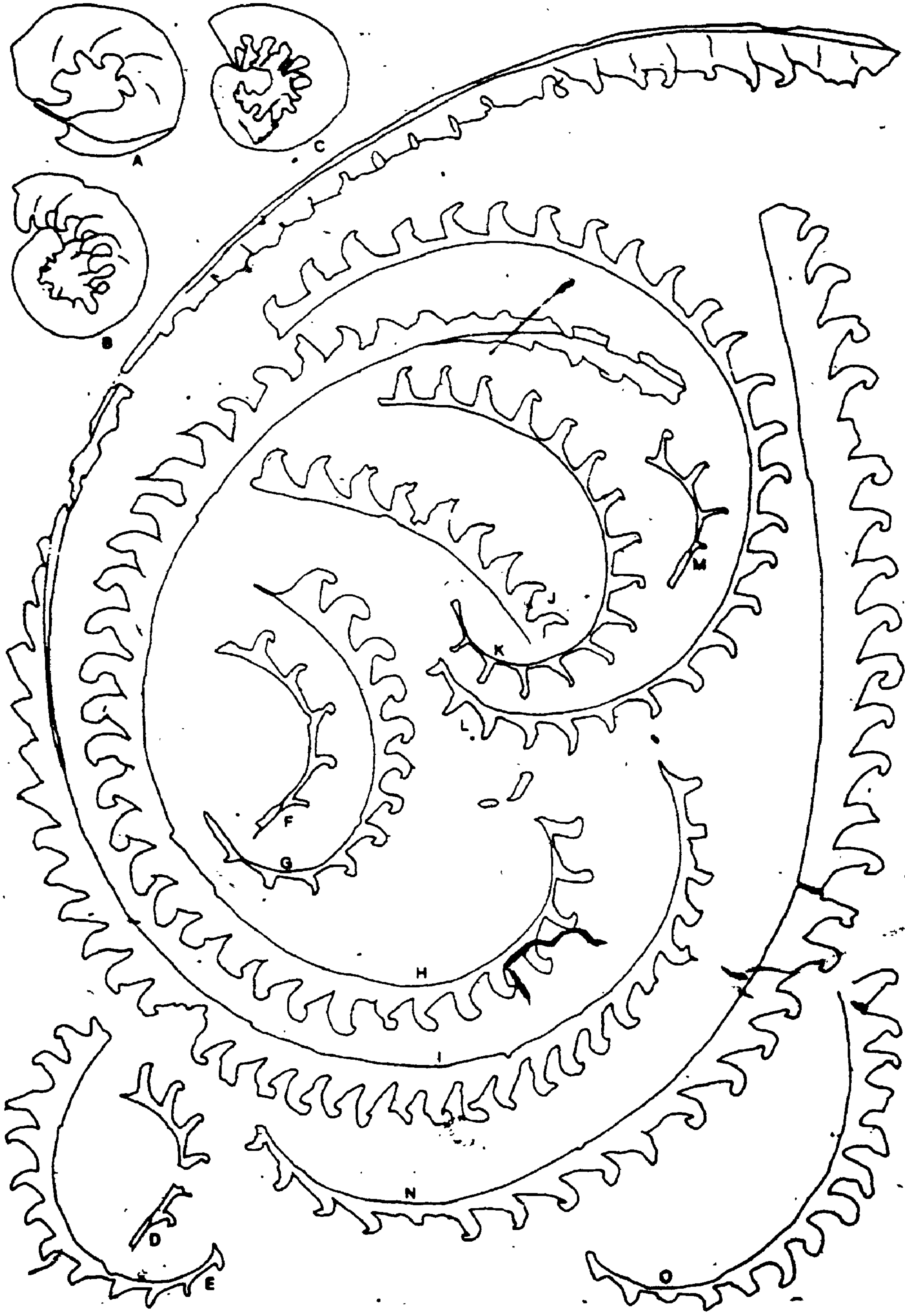
A-C. *Monograptus discus* Törnquist: A) TC:26.0, x20; B) TC:27.0, x10; C) TC:31.0, x10.

D,E. *Monograptus* cf. *M. decipiens* Törnquist, both specimens from HR:150.0.

F-H. *Monograptus decipiens* n. subsp.: F) HR:160.0; G) TC:23.5; H) HR:156.5.

I,N,O. *Monograptus decipiens valens* (Přibyl and Münch), all specimens from TC:22.5.

J-M. *Monograptus decipiens decipiens* Törnquist: J) CM:2-5; K), L) and M) TC:15.5-16.0.



A
B
C
D
E
F
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H
I
J
K
L
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O

Material. About 30 compressed specimens moderately well to poorly preserved.

Occurrence. *Curtus* Zone? and lower? and upper *convolutus* Zone Snowblind Creek at 140 and 170m, Cape Manning at 2-5m, Twilight Creek at 15.5 to 16.0m, Trold Fiord at 61.0m? and Huff Ridge at 128.0, 131.0 and 133.5m.

Description. Rhabdosome up to about 26mm long with moderate dorsal curvature through about 180°. Widens from 0.5 to 0.65mm at th1 to a maximum of 1.0 to 1.3mm. Thecae spaced at 12 to 13 in 10mm proximally, 7.5 to 10 in 10mm distally. Proximal 6 to 9 thecae rastritiform, slightly distally inclined with a hooked aperture. Distal thecae become increasingly triangulate with gradually broadening prothecal and metathecal portions. Single preserved sicula is 0.95mm long.

Remarks. Most of the present specimens are broken mesial fragments, but the low, hooked rastritiform proximal thecae passing gradually to low triangulate thecae are characteristic of this species. Dimensions and thecal spacing match closely with those previously reported for this species (e.g. Bjerreskov, 1975).

A form identified as *Monograptus triangulatus* cf. *M.? triangulatus? orbitus* (Churkin and Carter) was reported by Norford (in Norford and Orchard, 1985) which, although it is incomplete and twisted, strongly resembles the present specimens in thecal form and dimensions and may belong to this species. Rastrites orbitus as identified here, and by Churkin and Carter (1970) and Lenz (1982a) does not show a change to triangulate thecae distally as suggested by Norford.

Monograptus decipiens valens (Přibyl and Münch, 1942)

Text-figure 35I,N,O.

1912 pars Monograptus decipiens Törnquist; Elles and Wood, pp. 469-470, pl. 47, fig. 3c,d (non fig. 3a,b,e); text-fig. 325b,c (non 325a).

1942 Demirastrites decipiens valens Přibyl and Münch, p. 13, pl. 1, fig. 11; text-fig. 1, fig. 8.

1982a Monograptus decipiens valens (Přibyl and Münch); Lenz, pp. 75-76, figs. 6G,J,L; 23B,D,E,G.

1984a Demirastrites valens Přibyl and Münch; Chen, p. 64, pl. 12, figs. 4,11.

Material. Hundreds of very well to poorly preserved, compressed specimens.

Occurrence. Upper minor and turriculatus zones. Twilight Creek at 22.5 and 23.5m, Trold Fiord at 71.0 and 74.0m and Huff Ridge at 167.0, 171.5 and 173.0m.

Description. Rhabdosome up to 50mm long, spiralling dorsally although it may undergo torsion and curve ventrally distally, completing one full volution. Widens from 0.4 to 0.5mm at th1 to a distal maximum of 1.5 to 1.8mm. Thecae spaced 9 to 11 in 10mm. Proximal three thecae rastritiform, thereafter broadening and becoming more triangular. Apertural hook pronounced with retroverted apertures. Distal thecae overlap 1/4 to 1/3. Sicula 0.9 to 1.0mm long reaching to base of th1 metatheca.

Remarks. This subspecies matches very closely with the type material and that described by Lenz (1982a) except that the thecae are, on average, slightly more closely spaced. This subspecies is wider distally and has fewer proximal rastritiform thecae than M. decipiens decipiens or M. decipiens n. subsp. In addition, the distal thecae are broader and show more overlap than those of the type subspecies.

Monograptus decipiens n. subsp.

Text-figure 35F-H.

Material. Hundreds of very well to poorly preserved, compressed specimens.

Occurrence. Minor Zone. Twilight Creek at 20.5, 21.5, 22.5 and 23.5m and Huff Ridge at 156.5, 158.0, 160.0 and

164.0m.

Diagnosis. Spiral rhabdosome with thecae on dorsal side although may undergo torsion distally. Proximal 5-6 thecae rastritiform, rapidly becoming more broadly triangular and overlapping up to 1/4 distally. Apertures hooked and strongly retroverted throughout. Width is 0.5mm to 1.25 to 1.4mm distally and thecae spaced at 10-12 in 10mm. Sicula is 0.8-1.0mm long.

Remarks. This form appears to be intermediate in some respects between *M. decipiens decipiens* and *M. decipiens valens*. The number of rastritiform thecae is greater than in the latter but fewer than the former. The maximum width is more like that of the type subspecies, less than in *M. d. valens*, but the thecal spacing is higher than is typical of either form. The distal thecae show a greater resemblance to those of *M. d. valens* in their broader shape and degree of overlap and the rhabdosome shows the distal torsion seen commonly in that subspecies.

A few fragments of a form very similar to this were found at HR:150.0 but they differ in that the thecal spacing is higher still, 12 to 14.5 in 10mm, and the distal thecae seem to be less strongly hooked (text-fig. 35D,E). This form is referred to *M.* cf. *M. decipiens*.

Monograptus dextrorsus n. subsp.

Text-figure 36H-J.

Material. Numerous very well to poorly preserved, compressed and low relief specimens and several very well preserved, uncompressed, pyritized specimens.

Occurrence. *Minor* to middle *griestoniensis* zones. Snowblind Creek at 350m, Twilight Creek at 20.5, 23.5, 24.5, 26.0, 26.5, 27.0, 27.5, 29.5 and 35.5m?, Trold Fiord at 79.0m and Huff Ridge at 173.0 and 194.0m.

Description. Rhabdosome long and slender, generally with weak dorsal curvature although may undergo torsion and continue for a portion with slight ventral curvature. Widens gradually from 0.3 to 0.4mm in the proximal regions to a maximum of 0.8 to 0.9mm. Thecae usually spaced at 10 to 12 in 10mm although spacings of 8.5 to 9 in 10mm may be found, especially in the slender, more proximal portions. Prothecae axially elongate with the ventral wall inclined at 5 to 10° and may be slightly concave outward. Metathecae are somewhat isolate, especially distally and show a strong dextral torsion, with asymmetrical apertures pointing laterally and slightly proximally. Metathecae seem to constrict slightly as they emerge from the prothecae before expanding at the aperture. On compression, the appearance of the metathecae is variable depending on the nature of flattening. They may appear as simple hooks, as small, lobate apertures, or the metathecae may be partially or completely buried in sediment giving a blunt, rounded termination to the thecae. No proximal ends have been found which can be definitely assigned to this species but several specimens have been found which are bipolar, apparently the result of regeneration since no evidence of a sicula is present.

Remarks. The present specimens match with M. dextrorsus Linnarssón in the unique, dextral asymmetrical thecae and the long, arcuate rhabdosome but differ in that the curvature is almost always dorsal rather than ventral as is most common for the type subspecies, and the thecae are more closely spaced. The specimens of M. cf. M. dextrorsus reported by Bjerreskov (1981) have the same, closer thecal spacing as the present specimens, but are straight (although the fragments are relatively short) and the exact nature of the thecae is somewhat obscure. Better preserved material from Greenland may show that material to belong to this new subspecies.

Although several of the specimens show bipolar growth, this appears to be the result of regeneration in each case (the appearance of a sicula in text-figure 36I2 is produced by the virgula crossing the specimen as it undergoes torsion). The branches are, therefore, pseudocladia rather than true cladia. None of the specimens shows any evidence of the development of thecal cladia.

Monograptus discus Törnquist 1883

Text-figure 35A-C.

?1871 *Nautilus veles* Richter, p. 243, fig. p. 243.

1883 *Monograptus discus* Törnquist, pp. 24-25.

1913 *Monograptus discus* Törnquist; Elles and Wood, pp. 439-440, pl. 44, fig. 5a-d; text-fig. 302a-c.

1965 *Monograptus veles* (Richter); Obut and Sobolevskaya, p. 52, pl. 7, figs. 2-4.

1967 *Monograptus veles* (Richter); Obut and Sobolevskaya, pp. 99-100, pl. 11, figs. 5,6.

1970 *Monograptus discus* Törnquist; Rickards, pp. 76-77, pl. 6, fig. 8.

1971 *Monograptus* (*Monogr.*) *veles* (Richter); Schauer, p. 59, pl. 35, figs. 1-3; pl. 36, figs. 16-18; text-fig. 5.

1975 *Monograptus veles* (Richter); Bjerreskov, pp. 71-72, pl. 11D.

1975 *Monograptus discus* Törnquist; Hutt, pp. 89-91, text-fig. 22, figs. 1,3-5.

1975 *Monograptus veles* (Perner); Obut and Sobolevskaya, pp. 168-169, pl. 33, figs. 3,4.

Material. One very well preserved, low relief specimen and numerous well to poorly preserved, compressed specimens.

Occurrence. *Turriculatus-crispus* to lower *griestoniensis* zones. Snowblind Creek at 360m, Twilight Creek at 26.0, 26.5 and 27.5m, Trold Fiord at 79.0m and Huff Ridge at 194.0, 195.0, 195.5, 197.0 and 204.0m.

Description. Rhabdosome tightly ventrally coiled through up to almost 1 1/2 volutions, up to 2.6 to 3.0mm across. Widens from about 0.5 to 0.6mm at th1 to a maximum of about 0.9mm. Thecal spacing difficult to measure but is in excess of 20 in 10mm. Thecae form open hooks with apertures pointing proximoventrally. A pair of apertural spines is present although not commonly visible. Sicula 0.9 to 1.0mm long with a virgella up to 0.6mm long.

Remarks. The Canadian Arctic specimens of this species do not differ significantly from previous descriptions. The tightness of coiling is somewhat variable and may depend, in part on the mode of compression. The distal portions commonly overlap the proximal end indicating that the spiral was somewhat conical rather than planar.

As currently employed, *Monograptus discus* and *M. veles* are synonymous. Although the latter name has priority, Tornquist (1912), Strachan (1971) and Hutt (1975) have suggested that the original specimen illustrated by Richter (1871) is not recognizable as a graptolite and that the name should not be applied to this species.

<u>Monograptus elongatus</u> Törnquist, 1899

Text-figure 36K,L.

1899 <u>Monograptus elongatus</u> Törnquist, pp. 17-18, pl. 3, figs. 12-18.

1985 <u>Monograptus elongatus</u> Tornquist; El-Khayal, pp. 20-21, pl. 1, figs. 4-6.

<u>Material</u>. Four fragmentary, compressed specimens, moderately well preserved, and possibly several more poorly preserved fragments.

<u>Occurrence</u>. <u>Orbitus</u> Subzone. Cape Manning at 2-5m, Trold Fiord at 62.5m and possibly Snowblind Creek at 140m.

<u>Description</u>. Rhabdosomes very fragmentary, up to 10mm long, straight or slightly dorsally curved. More proximal fragments 0.35 to 0.5mm wide with 6.5 to 7.5 thecae in 10mm. More distal fragments 0.65 to 0.75mm wide with 9 thecae in 10mm. Prothecal portions are very narrow, axially elongate triangles with a concave ventral wall. Metathecae form open hooks with apertures apparently pointing proximodorsally. No proximal ends are preserved.

<u>Remarks</u>. Although the present specimens are very fragmentary enough of the characteristic features are present for positive identification: the narrow, widely

spaced proximal thecae; the more closely spaced, higher distal thecae; the long, slender prothecae with concave ventral walls; and the openly hooked metathecae. Monograptus cf. elongatus of Chen and Lin is very similar but not as wide and apparently does not show the more widely spaced proximal thecae. Globosograptus tenuissimus Obut and Sobolevskaya (1968) has very similar thecae which are more closely spaced throughout and lower distally, and a more strongly curved rhabdosome.

Monograptus exiguus exiguus (Nicholson, 1868)

1868 Graptolites lobiferus var. exiguus Nicholson, p. 533, pl. 19, figs. 27,28.

1912 Monograptus exiguus (Nicholson); Elles and Wood, pp. 453-454, pl. 46, fig. 1a-d; text-fig. 312a-c.

1942 Monograptus (Streptograptus) exiguus (Nicholson); Bouček and Přibyl, pp. 5-6, pl. 1, figs. 1-3; text-fig. 3a-d.

1967 Streptograptus exiguus exiguus (Nicholson); Obut and Sobolevskaya, pp. 102-103, pl. 12, figs. 5-11.

1968 pars Streptograptus exiguus exiguus (Nicholson); Obut and Sobolevskaya, pp. 100-101, pl. 24, fig. 12 (non pl. 25, fig. 1).

1970 Monograptus exiguus (Nicholson); Hutt et al., pp. 11-12, p. 2, figs. 43-46.

1970 Monograptus exiguus (Nicholson); Rickards, p. 78, pl.

Text-figure 36

All figures x7.5 unless otherwise stated.

A-C *Monograptus exiguus exiguus* A: A) TC:23.5; B) uncompressed fragment, TF:74.0, x20; C) TF:74.0.

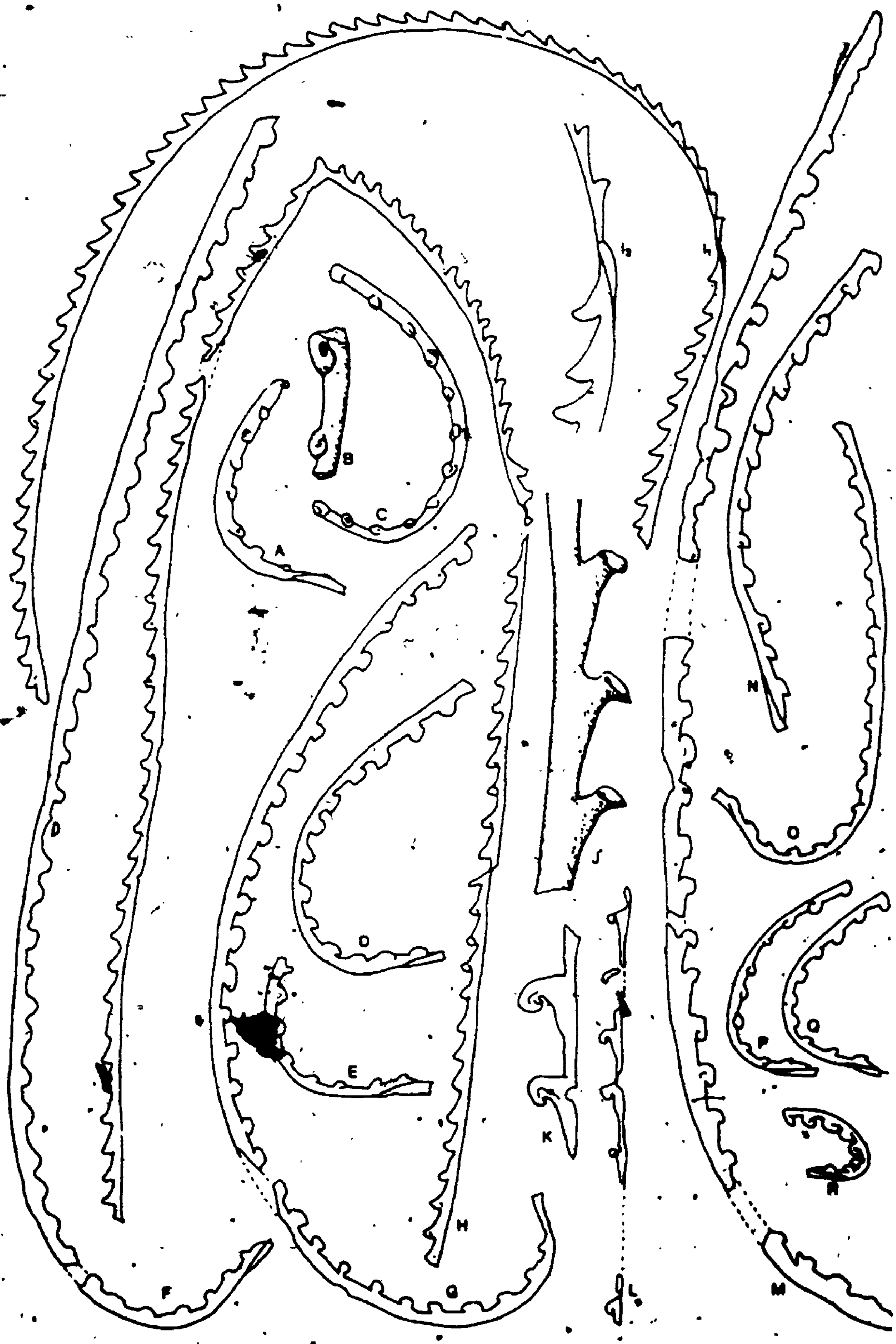
D-G. *Monograptus exiguus* n. subsp.: D) SC:360; E) HR:195.0; F) HR:173.0; G) TC:29.5.

H-J. *Monograptus dextrorsus* n. subsp.: H) TC:27.0; I) I2 is an enlargement of the region of pseudocladium generation; note that the appearance of a sicula is caused by the virgula crossing the rhabdosome as it undergoes torsion, x10; I1 is x5, TC:26.0; J) distal portion of long, partial relief specimen, TC:27.0, x20.

K,L. *Monograptus elongatus* Törnquist, both specimens from CM:2-5; K) x15.

M,N. *Monograptus exiguus primulus* Bouček and Přibyl: M) TF:71.0; N) HR:156.5.

O-R. *Monograptus exiguus exiguus* B: O) TC:26.0; P) TC:27.0; Q) TC:26.0; R) HR:197.0.


A
B
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8, figs. 3,8.

1971 Monograptus (Streptogr.) exiguus exiguus (Nicholson); Schauer, p. 71, pl. 24, figs. 7,8; pl. 25, figs. 8-10.

1975 Monograptus exiguus ~~A~~ Bjerreskov, p. 61, text-fig. 18F.

1975 non? Monograptus exiguus B Bjerreskov, p. 61, text-fig. 18G.

1975 Monograptus exiguus C Bjerreskov, pp. 61-62, text-fig. 18D.

1975 Monograptus exiguus exiguus (Nicholson); Hutt, p. 91, pl. 24, fig. 5; text-fig. 22, figs. 7,8.

1975 non Streptograptus exiguus exiguus (Nicholson); Obut and Sobolevskaya, p. 173, pl. 34, figs. 1,2.

1978 non Streptograptus exiguus exiguus (Nicholson) (sic); Wang, p. 314, pl. 4, fig. 7.

1981 non Monograptus exiguus (Nicholson) s.l.; Bjerreskov, p. 38, pl. 3, fig. 9.

1984a Streptograptus exiguus (Nicholson); Chen, pp. 72-73, pl. 17, figs. 4,6,11.

Remarks. Specimens assignable to Monograptus exiguus from Arctic Canada appear to fall into several distinct populations based on their width and thecal spacing and, as noted by Bjerreskov (1975), the exact nature of the holotype is unclear and the group is in need of revision. The present collections fall into four groups one of which is intermediate in dimensions and thecal spacing between M. exiguus primulus and M. exiguus exiguus as it is most commonly used. This form is here assigned to a new subspecies - this is the most common variety of *M. exiguus* in the Canadian Arctic collections. Two of the other groups are slender with relatively high thecal spacings and are most consistent with *M. exiguus exiguus* as it is currently employed and they are therefore assigned as *M. exiguus exiguus* form A and B. The fourth matches with *M. exiguus primulus*. All of the four groups share a common rhabdosomal form with the extreme proximal end being straight to slightly dorsally curved, followed by moderately to tightly ventrally curved mesial region and a weakly ventrally curved to straight distal portion. The thecae are strongly hooked with ventrally facing apertures as shown by Hutt *et al.* (1970) but the metathecae occupy a variable proportion of the total width.

Monograptus exiguus exiguus A

Text-figure 36A-C.

Material. Five moderately well preserved, compressed specimens, one uncompressed, pyritized fragment and several more poorly preserved compressed specimens.

Occurrence. Upper *minor* and *turriculatus* zones. Twilight Creek at 23.5m and Trold Fiord at 74.0m.

Remarks. This form has a width of 0.35 to 0.45mm and thecal spacings of 13.5 to 11.5 in 10mm. The metathecae are very low occupying 1/3 or less of the total rhabdosomal width. The single uncompressed specimen shows some tendency toward lateral spread of the apertural margin but spinose structures are not preserved.

This form corresponds very closely with M. exiguus A of Bjerreskov (1975) in the dimensions and thecal spacing as well as the very low profile metathecae.

Monograptus exiguus exiguus B

Text-figure 360-R.

Material. Numerous moderately well to poorly preserved, compressed specimens.

Occurrence. Minor and crispus zones. Snowblind Creek at 360m, Twilight Creek at 21.5?, 26.0 and 27.0m and Huff Ridge at 175.0, 193.0 and 197.0m.

Remarks. This variety widens from 0.3mm proximally to 0.4 to 0.5mm and has thecae spaced as closely as 8 to 10 in 5mm proximally, 16 to 13 in 10mm distally. Metathecae are somewhat more prominent occupying 1/3 to 1/2 of the total width.

This from corresponds very closely with M. exiguus C of Bjerreskov (1975) and, as pointed out by her, most closely resemble the specimens of M. exiguus described by Lapworth

(1876).

Monograptus exiguus primulus Bouček and Přibyl, 1942

Text-figure 36M,N.

1942 Monograptus (Streptograptus) exiguus primulus Bouček and Přibyl, p. 7, pl. 1, fig. 4; text-fig. 3e,f.

1971 Monograptus (Streptogr.) exiguus primulus Bouček and Přibyl; Schauer, p. 71, pl. 24, fig. 9; pl. 25, figs. 4,5.

1975 Monograptus exiguus primulus Bouček and Přibyl; Bjerreskov, p. 62, pl. 9D; text-fig. 18H.

1982a Monograptus exiguus primulus Bouček and Přibyl; Lenz, pp. 79-80, figs. 7A,D,F,G; 24C-F,K.

Material. Numerous moderately well to poorly preserved, compressed and low relief specimens.

Occurrence. Minor and turriculatus-crispus zones. Twilight Creek at 21.5 and 22.5m, Trold Fiord at 71.0m and Huff Ridge at 150.0, 156.5 and 160.0m.

Remarks. This subspecies widens from 0.4 to 0.5mm at th1 to a maximum of 0.7 to 0.9mm. Thecae are spaced at 5.5 in 5mm proximally, 8 to 9 in 10mm distally. Prothecae are parallel and metathecae are strongly hooked with proximodorsally directed apertures. Metathecal hook occupies about 1/3 the total width. Sicula seen in only one specimens where it appears to be about 1.3mm long.

The present specimens match well with those previously described in possessing a relatively wide distal end and the most widely spaced thecae within the _M. exiguus_ group.

Monograptus exiguus n. subsp.

Text-figure 36D-G.

1968 pars _Streptograptus exiguus exiguus_ (Nicholson); Obut and Sobolevskaya, pp. 100-101, pl. 25, fig. 1 (non pl. 24, fig. 12).

?1975 _Monograptus exiguus_ B Bjerreskov, p. 61, text-fig. 18F.

1975 _Streptograptus exiguus exiguus_ (Nicholson); Obut and Sobolevskaya, p. 173, pl. 34, figs. 1,2.

1978 _Streptograptus exiguus exiguus_ (Nicholson) (sic); Wang, p. 314, pl. 4, fig. 7.

1981 _Monograptus exiguus_ (Nicholson) s.l.; Bjerreskov, p. 38, pl. 3, fig. 9.

Material. Hundreds of well to poorly preserved, compressed specimens.

Occurrence. _Minor_ to _crispus_ zones. Snowblind Creek at 360m, Twilight Creek at 23.5m, Middle Island at 35.0m, Trold Fiord at 71.0, 74.0 and 79.0m and Huff Ridge at 156.5, 171.5, 173.0, 178.5, 194.0, 195.0 and 195.5m.

Diagnosis. Relatively long (up to 42mm), fish-hook shaped rhabdosome widens from 0.35 to 0.4mm at th1 to a maximum of 0.6 to 0.75mm distally. Thecae spaced at 5.5 to 7 in 5mm proximally to 9 to 12 in 10mm distally and have tightly hooked metathecae which occupy 1/3 to 1/2 the total width.

Remarks. This form is consistently wider with more widely spaced thecae than is typical of M. exiguus s.s. but is more narrow than M. exiguus primulus. The suggestion of Bjerreskov (1981) is therefore followed here and this form is raised to a new subspecies. Comparison with other previously published descriptions and illustrations shows that this form also occurs in the Soviet Union (Obut and Sobolevskaya 1968, 1975) and China (Wang, 1978). Monograptus exiguus B on Bjerreskov (1975) is only represented by two short proximal fragments which do not reach the widths seen in this subspecies but show the typically low thecal spacing and relatively high thecae and are therefore questionably included here.

Monograptus falcata (Chen and Lin, 1978)

Text-figure 37A-F,I.

?1967 Pernerograptus aff. cygneus (Törnquist) Obut and

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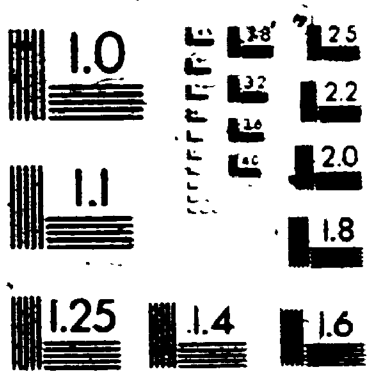


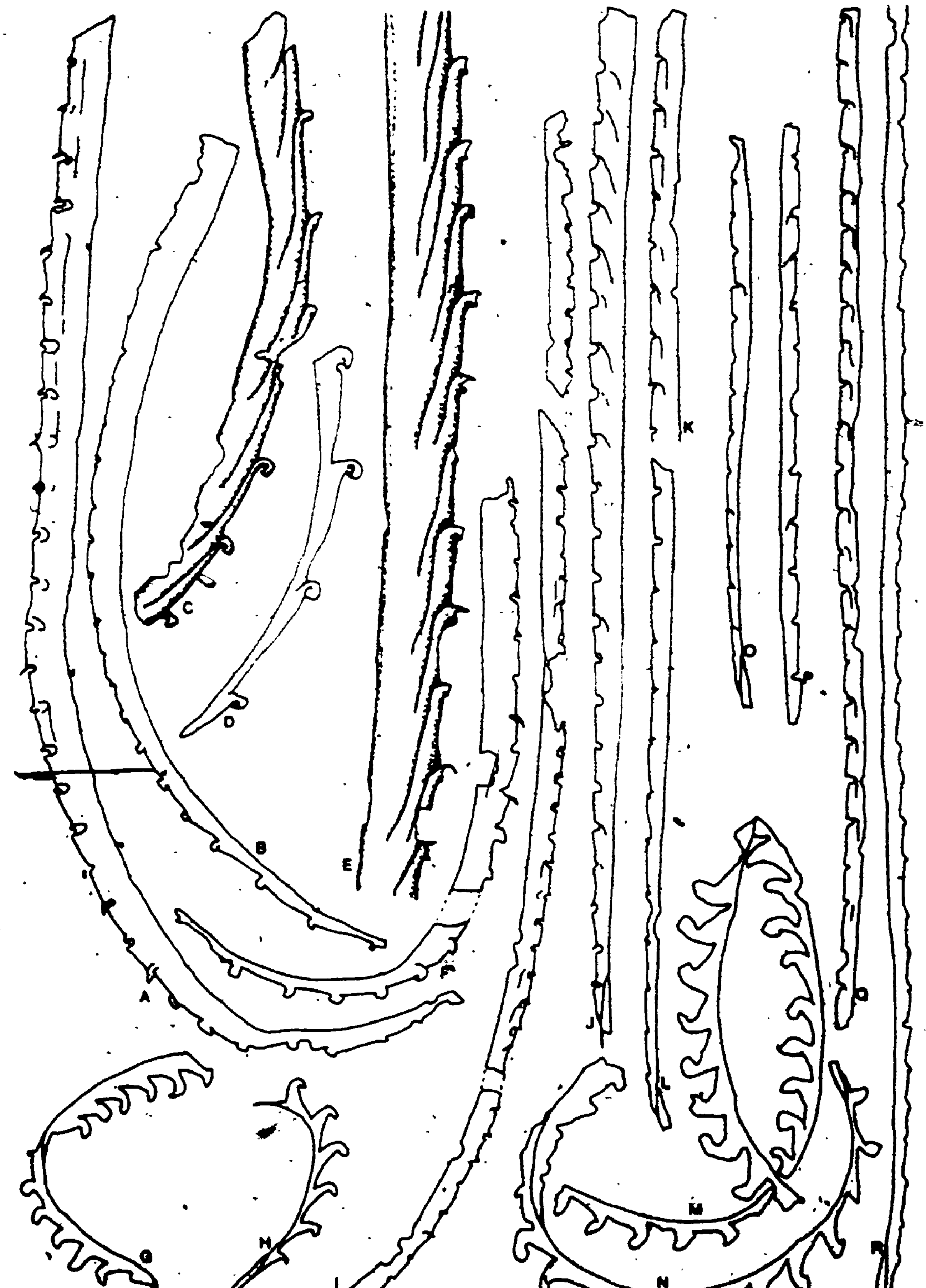
Text-figure 37

A-F,I. *Monograptus falcata* (Chen and Lin): A) SC:170; B) TC:15.0; C) uncompressed specimen, mesial thecae, TC:15.0, x15; D) proximal thecae, TC:15.0, x15; E) uncompressed distal thecae, TC:15.0; F) SC:170; I) SC:170.

G,H,M,N. *Monograptus flagellaris* Tornquist; G) TC.26.0; H) TC:26.5; M) TF:79.0; HR:203.5.

J-L. *Monograptus griestoniensis griestoniensis* Nicol: J) TC:33.5; K) RC:162.5; L) TC:29.5.

O-R. *Monograptus griestoniensis minuta* (Přibyl): O) TC:32.5; P) TC:61.5, Q) TC:52.5; R) TF:133.0.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Sobolevskaya, p. 110, pl. 14, figs. 8-10.

1978 Monoclimacis falcata Chen and Lin, p. 60, pl. 12, fig. 10; text-fig. 15e.

?1982a Monograptus aff. cygneus Tornquist; Lenz, p. 70, figs. 6D,E; 22B,E.

Material. Hundreds of well to poorly preserved, compressed and low relief specimens (invariably incomplete).

Occurrence. Convolutus Zone. Snowblind Creek at 140 and 170m, Cape Manning at 5-7m, Twilight Creek at 15.0 and 15.5 to 16.0m and Huff Ridge at 124.0, 124.5, 126.0 and 128.0m.

Description. Rhabdosome up to at least 67mm long (distal fragment), moderately dorsally curved in the mesial region, weakly so proximally, becoming straight distally. Widens gradually from 0.3 to 0.4mm at th1 to a distal maximum of 0.9 to 1.2mm. Thecae spaced at 3.5 to 4.5 in five mm proximally, 9 to 11 in 10mm distally. Proximal 7 to 10 thecae are axially elongate with slender prothecae with slightly inclined ventral walls and a small, moderately to strongly hooked metatheca. Mesially, the protheca broadens and the hook retreats so that by about th15 the metathecal hook gives way to what appears to be a narrow, short hood about 0.3mm long (not visible on all specimens), apparently arising from the dorsal wall of the thecae whose aperture it covers, although its base forms the geniculum of the succeeding theca. Distally, this tends to retreat leaving what appears to be unornamented, parallel to slightly inclined monoclimacid thecae with ventrally facing apertures. Thecal overlap is slight proximally, increasing to about 1/2 distally. Sicula 0.6mm long, reaching about halfway along the length of th1.

Remarks. The present specimens match very well in both appearance and dimensions with the type material of Chen and Lin (1978) although these collections have yielded much longer specimens which show that the hoods present on the mesial thecae tend to disappear and the rhabdosome becomes staight distally. In addition, this material shows a wider range of variation in dimensions, number of proximal, hooked thecae and degree of rhabdosomal curvature.

The specimens assigned to Monograptus (or Pernerograptus) aff. cygneus by Lenz (1982a) and Obut and Sobolevskaya (1967) may be conspecific with this taxon. They differ only in that the sicula is somewhat longer (about 1.0mm), the proximal thecae appear to be less strongly hooked (although in many of the compressed specimens found here the proximal thecae appear to be only moderately hooked - this may be an artifact of compression) and the proximal end tends to be shorter and broader although it may be within the range of variation of this species.

This species differs from the similar Monograptus sidiachenkoi (Obut and Sobolevskaya) in that the proximal end is more slender and protracted as well as less tightly coiled.

Although Chen and Lin (1978) placed this species in the genus Monoclimacis, the proximal and mesial thecae clearly show a monograptid (s.s.) hook, with the dorsal wall extending beyond the geniculum of the succeeding theca. Even on the distal thecae, the pyritized specimen shows that the dorsal wall extends at least to the geniculum of the next thecae forming a ventrally facing aperture. It is on compression that the thecae take on a monclimacid appearance.

Monograptus flagellaris Törnquist, 1892

Text-figure 37G,H,M,N.

1892 Monograptus flagellaris Törnquist, pp. 42-43, pl. 3, figs. 31-33.

1912 Monograptus flagellaris Törnquist; Elles and Wood, pp. 457-458, pl. 46, fig. 5, text-fig. 315.

1952 Spirograptus flagellaris (Törnquist); Münch, p. 116, pl. 37a, fig. 8.

?1981 Monograptus aff. M. proteus (Barrande); Bjerreskov, pp. 44-45, pl. 4, fig. 4.

1982a Monograptus flagellaris Törnquist; Lenz, pp. 81-82, fig. 7E.

<u>Material</u>. Hundreds of well to poorly preserved, compressed specimens.

<u>Occurrence</u>. <u>Turriculatus-crispus</u> to lower <u>griestoniensis</u> zones. Twilight Creek at 26.0, 27.0 and 27.5m, Trold Fiord at 79.0m and Huff Ridge at 194.0, 195.0, 195.5, 203.0, 203.5 and 204.0m.

<u>Description</u>. Rhabdosome characteristically dorsally curved proximally, undergoing torsion mesially, and ventrally curved distally. Occasional specimens up to 23mm long and curve again distally to form an "S" shape. Widens from 0.5 to 0.65mm at th1 to a maximum of 1.0 to 1.2mm. Thecae generally spaced at 9 to 12 in 10mm although closer spacings may be achieved, especially mesially. Thecae triangular, slender proximally becoming more broad distally. Apertures form a rather tight hook and point proximoventrally. Sicula 1.2 to 1.4mm long and reach to the apex of th1.

<u>Remarks</u>. The small width, relatively tall proximal thecae and characteristic rhabdosomal shape serve to separate this from other similar species. <u>Monograptus drepanoformis</u> Toghill and Strachan has more slender, axially elongate proximal thecae and the apertures of the distal thecae form a more open hook. <u>Monograptus proteus</u> is wider,

larger and has more slender proximal thecae.

The specimens described by Bjerreskov (1981) as M. aff. M. proteus have similar width, thecal spacing and rhabdosomal form but the thecae do not appear to be sufficiently well preserved to provide to more complete comparison.

Monograptus griestoniensis griestoniensis (Nicol, 1850)

Text-figure 37J-L.

1850 Graptolites griestoniensis Nicol, p. 63, fig. 2a,b.

1911 Monograptus griestoniensis (Nicol); Elles and Wood, pp. 413-414, pl. 41, fig. 5a-d; text-fig. 279a-f.

1966 Monoclimacis griestonensis (Nicol) (sic); Obut and Sobolevskaya, pp. 39-40, pl. 7, fig. 6; text-fig. 29.

1970 Monoclimacis griestoniensis (Nicol); Toghill and Strachan, pp. 514-517, pl. 103, figs. 1-5; text-fig. 1a-h.

1971 Monograptus (Monoclim.) griestoniensis griestoniensis (Nicol); Schauer, p. 66, pl. 28, figs. 1-3; pl. 29, figs. 3,4.

1975 Monograptus griestoniensis (Nicol); Bjerreskov, p. 59, pl. 8H-J; text-fig. 18B.

1976 Monoclimacis griestonensis griestonensis (Nicol) (sic); Sennikov, pp. 187-188, pl. 12, figs. 4-6.

Material. Hundreds of very well to poorly preserved, compressed and partial relief specimens.

Occurrence. *Griestoniensis* to lower *sakmaricus* zones. Snowblind Creek at 375.0, 396.0, 457.0, 460.0, 491.0, 491.5, 524.0, 527.5 and 528.0m, Cape Phillips at 34.0; 58.5, 63.0, 85.0, 128.0, 129.0, 130.0, 137.0, 146.0 and 152.5m, Rookery Creek at 144.0, 162.0 and possibly 134.5m, Twilight Creek at 27.0, 27.5, 28.5, 29.5, 31.0, 32.5, 34.0, 42.0 and possibly 41.5m, Trold Fiord at 96.0, 123.0, 123.5, 125.0, 133.0 and 136.0m, Huff Ridge at 203.0, 203.5 and 204.0m and Irene Bay at 68-72m.

Description. Rhabdosome up to at least 7cm long, slender and usually straight although may show weak dorsal or ventral curvature. Widens very gradually from 0.2 to 0.35mm at th1 to a maximum of 0.7 to 1.0mm. Thecae spaced at 5 to 6 in the first 5mm, 8 to 10.5 in 10mm distally. Thecae are strongly geniculate with a parallel (although sometimes slightly convex) supragenicular wall. Apertures are everted to slightly retroverted and hooded by an extension of the dorsal thecal wall forming a slight hook. This is more pronounced proximally than distally and is often not visible on flattened distal specimens. Thecal overlap is slight proximally, increasing to about 1/2 distally. Sicula is 1.1 to 1.4mm long and reaches to just above the aperture of th1.

<u>Remarks</u>. The present specimens match well with previous reports of this species. The slight apertural hooks observed by Bjerreskov (1975) can be seen in some more well preserved specimens found here although the prothecal folds usually cannot (except faintly on a few specimens). For this reason, the species does not appear to belong to *Monoclimacis* as assigned by many previous authors but seems to be more closely allied to *Monograptus* s.s. Study of uncompressed, isolated specimens of this species, as well as other *Monograptus* and *Monoclimacis* species may more completely clarify the relationship of *M. griestoniensis* to these two genera.

Monograptus griestoniensis minuta (Přibyl, 1940)

Text-figure 370-R.

1940 *Monoclimacis griestoniensis minuta* Přibyl, pp. 8-9, pl. 3, figs. 4,5.

1971 *Monograptus* (*Monoclim*.) *griestoniensis minuta* Přibyl; Schauer, p. 66, pl. 28, figs. 4-6; pl. 29, figs. 5,6.

1984a *Monoclimacis griestoniensis minuta* Přibyl; Chen, p. 59, pl. 10, figs. 4,8,9.

<u>Material</u>. Numerous moderately well to poorly preserved, compressed specimens.

Occurrence. Middle griestoniensis and sakmaricus zones. Snowblind Creek at 536.5 and A2.0m, Cape Phillips at 159.5 and 160.0m, Twilight Creek at 31.0, 46.0, 52.5, 54.5, 59.0m and 61.5, Middle Island at 63.0 and 64.0m, Trold Fiord at 119.0 and 133.0 and Irene Bay at 69.0m.

Remarks. This form is, in all respects, similar to M. griestoniensis griestoniensis except that it widens more gradually to a maximum width of only 0.4 to 0.6mm. Bjerreskov (1975) has suggested that these forms may represent proximal specimens of the type subspecies, but the present collections show many long distal fragments of this form (10mm and more) at this narrow width with no perceptible increase through the length and no wider specimens in the same collections. It therefore appears to be a distinct subspecies. In addition, while M. griestoniensis griestoniensis is most common in the griestoniensis and lower sakmaricus zones, M. g. minuta is most common in the higher parts of the sakmaricus Zone.

Monograptus halli (Barrande, 1850)

Text-figure 38A-F.

1850 Graptolithus Halli Barrande, p. 48, pl. 2, figs. 12,13.

1913 Monograptus Halli (Barrande): Elles and Wood, pp. 443-445, pl. 44, fig. 8a-f; text-fig. 305a,b.

1967 Monograptus halli (Barrande); Obut and Sobolevskaya,

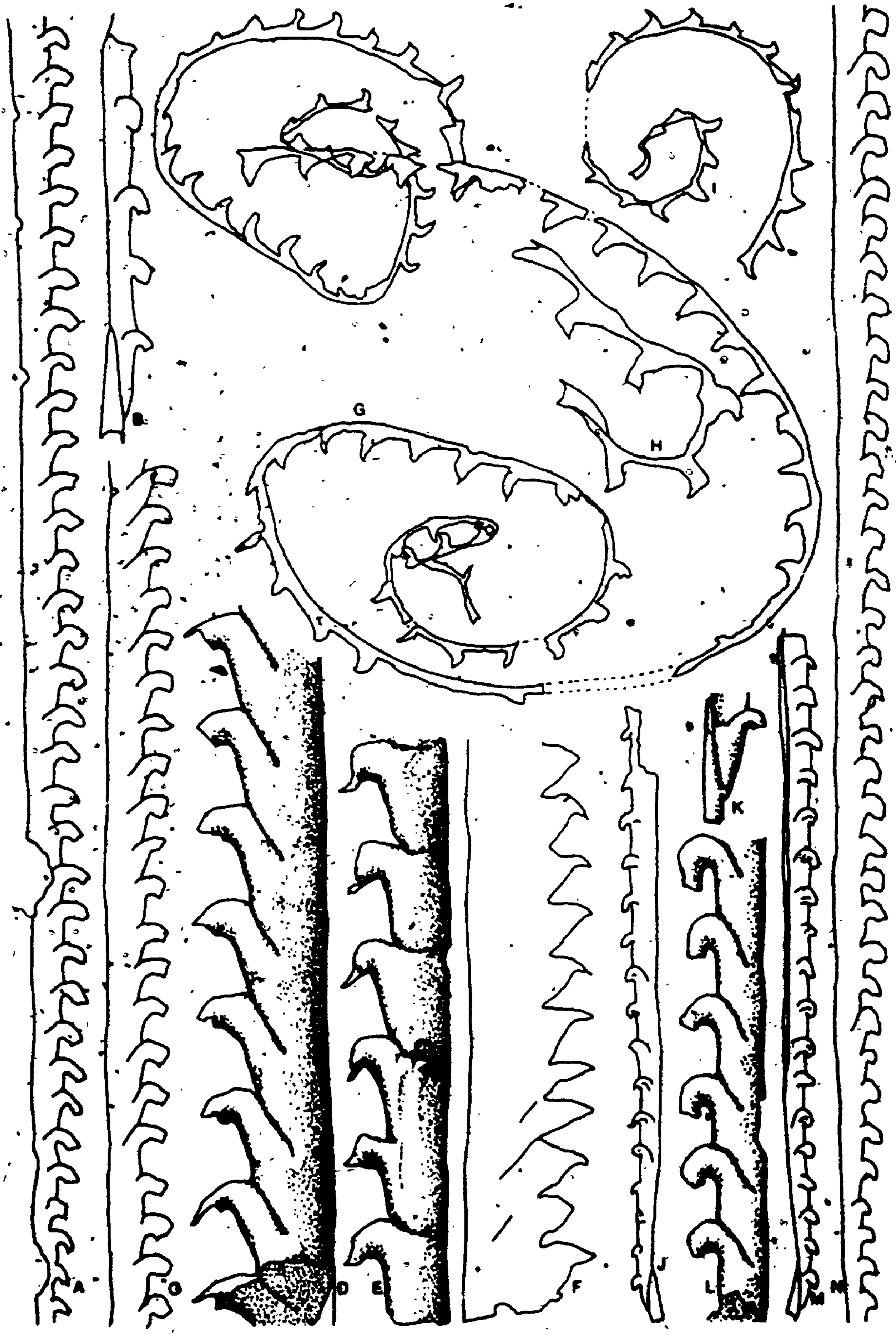
Text-figure 38

All specimens x7.5 unless otherwise stated.

A-F. Monograptus halli (Barrande): A) TG:22.5; B) proximal end specimen, HR: 156.5, x15; C) TC:22.5; D) uncompressed distal fragment, TC:22.5, x15; E) uncompressed mesial specimen, TF:74.0; F) TF:71.0.

G-I. Monograptus involutus Lapworth, all specimens from TF:62.5: G) two superimposed specimens; H) x15.

J-N. Monograptus kovalevskyi Obut and Sobolevskaya: J) TC:41.5; K) uncompressed proximal end, TC: 41.5, x15; L) TC:29.5, x15, M) TC:26.5; N) TC:23.5.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pp. 92-93, pl. 10, fig. 2.

1970 Monograptus halli (Barrande): Rickards, p. 73, text-fig. 13, fig. 21; text-fig. 16, fig. 1.

1970 Monograptus halli (Barrande); Hutt et al., pp. 8-9, pl. 2, figs. 23-25.

1971 Monograptus halli (Barrande); Schauer, p. 56, pl. 36, figs. 2,3.

1974 Monograptus halli (Barrande); Sherwin, p. 163, pl. 11, figs. 9,12.

1975 Monograptus halli (Barrande); Bjerreskov, pp. 68-69, fig. 20B.

1976 Monograptus halli (Barrande); Sennikov, pp. 173-175, pl. 9, figs. 14-16.

1983 Monograptus (Stimulograptus) halli (Barrande); Pribyl and Storch, pp. 222-223, pl. 1, figs. 1,3,5,6; pl. 2, fig. 1; text-figs. 1A-C; 2A,B.

1984a Monograptus halli (Barrande); Chen, pp. 52-53, pl. 9, fig. 5.

Material: Numerous very well to poorly preserved, uncompressed (pyritized), low relief and flattened specimens.

Occurrence. Minor and turriculatus zones. Snowblind Creek at 210m, Truro Island at 51.0m, Twilight Creek at 20.5, 21.5, 22.5 and 23.5m, Middle Island at 18.0m?, Trold Fiord at 71.0 and 74.0m, Huff Ridge at 150.0, 156.5, 158.0

and 164.0m and Irene Bay at 65m (loose).

<u>Description</u>. Rhabdosome straight, up to at least 72mm long. Widens very gradually from 0.45 to 0.5mm at th1 to a maximum of up to 3.0mm although many distal fragments reach only 2.0 to 2.3mm. Thecae spaced at 5.5 to 7.5 in 5mm proximally to 7 to 10 in 10mm distally. Proximal thecae show a somewhat elongate triangulate form with a slightly inclined ventral wall and the dorsal wall forming a pronounced hook. Apertures are retroverted with a pair of lateral spines. Thecal overlap is almost nil. Mesially, thecae become more broad, ventral wall becomes more highly inclined although overlap is still only slight and apertural hook begins to retreat. Distal thecae are very broad with the ventral wall inclined at about 45° and overlap increases to 1/3 to almost 1/2. Dorsal wall retreats further so that apertures point more ventrally than proximally. Apertural spines up to 0.5mm long are still present although often not visible depending on mode of preservation. Sicula is 1.2 to 1.25mm long and reaches to the apex of th1.

<u>Remarks</u>. The proximal hooked thecae with almost no overlap changing gradually to overlapping distal thecae with only a slight hook, together with the presence of apertural spines distinguishes this species from all others. <u>Monograptus sedgwickii</u> is similar but has more strongly hooked thecae throughout and appears to show greater thecal

overlap.

The uncompressed specimens of this species illustrated by Hutt *et al.* (1970) compare very closely with the uncompressed and low relief specimens of proximal and mesial portions seen here. It is clear from the present material that significant thecal overlap does not begin until the distal portions, where the ventral wall becomes more highly inclined. It can also be seen that compression can impart the impression of greater overlap than actually exists by folding the free portions of the dorsal metathecal wall and the ventral prothecal wall of the succeeding theca toward each other, causing them to overlap.

Monograptus involutus Lapworth, 1876

Text-figure 38G-I.

1876 *Monograptus intermedius* var. *involutus* Lapworth, p. 317, pl. 10, fig. 11.

1913 *Monograptus involutus* Lapworth; Elles and Wood, p. 478, pl. 49, fig. 4a-c; text-fig. 334a-c.

1933 *Monograptus changyangensis* Sun, p. 34, pl. 6, fig. 8a,b.

1975 *Monograptus involutus* Lapworth; Hutt, pp. 91-92, pl. 24, figs. 3,4; text-fig, 19, figs. 10-12.

1978 *Monograptus changyangensis* Sun; Chen and Lin, p. 61, pl. 14, figs. 14-18; text-fig. 16a.

1982a *Monograptus involutus* Lapworth; Lenz, pp. 82-85, figs.

7B,C; 25A,B,E.

Material. About 15 compressed moderately to very well preserved specimens.

Occurrence. Curtus Zone. Trold Fiord at 61.0 and 62.5m and Huff Ridge at 122.0m.

Description. Rhabdosome spirally coiled, sometimes regularly, sometimes irregularly depending on nature of compression. Coiling is likely in a low cone and thecae appear to point more-or-less abapically. The largest specimen (complete) goes through about 3 1/2 complete whorls and is about 60mm long. On distal portions curvature may appear "dorsal" or "ventral" depending on angle of compression. Thecae widen from 0.45 to 0.5mm at th1 to a maximum of up to 0.9mm and are spaced at 12 to 13.5 in 10mm proximally and 7.5 to 10 in 10mm distally. Thecae are characterized by a long, slender, triangular protheca and a slim, weakly hooked, pointed metatheca. Apertures face proximally and apparently bear very fine spines. Sicula 0.65mm long and is slightly ventrally curved while the proximal portion of the stipe is dorsally curved. Theca 1 arises near the sicular aperture and extends to slightly beyond the sicular apex.

Remarks. This species appears to show a high degree of morphologic variability throughout its geographic range both in the rhabdosomal coiling and thecal height, although the characteristic thecal shape remains constant. Several authors (e.g. Lenz, 1982a) have illustrated specimens with dorsal curvature throughout giving it a distinctly planispiral appearance while others (e.g. Hutt, 1975) show more irregular rhabdosomes with apparent dorsal and ventral curvature. This may be accounted for by the vagaries of post-mortem settlement and compression and possibly by some variability in the height of the spiral cone (and concomitant thecal orientation) in different areas.

Hutt (1975) and Lenz (1982a) considered M. involutus and M. changyangensis Sun conspecific and since forms assignable to both taxa are found here in a single sample apparently as part of a single, variable population, this procedure is followed.

Monograptus kovalevskyi Obut and Sobolevskaya, 1966

Text-figure 38J-N.

1966 Monograptus kovalevskyi Obut and Sobolevskaya, pp. 28-29; pl. 5, figs. 11-13; text-figs. 19,20.

1976 Monograptus kovalevskyi Obut and Sobolevskaya; Sennikov, pp. 175-176, pl. 10, figs. 1,2.

Material. Over one hundred very well to poorly preserved compressed, low relief and uncompressed, pyritized specimens.

Occurrence. Upper minor, crispus to middle griestoniensis and upper sakmaricus zones. Snowblind Creek at 360 and 375m, Twilight Creek at 23.5, 26.0, 26.5, 27.0 and 29.5m, Cape Becher at 20.0, 27.0 and 30.0m and Huff Ridge at 171.5m.

Description. Rhabdosome up to at least 10cm long and is straight through most of its length although commonly shows weak dorsal curvature near the sicula followed by weak ventral curvature. Widens very gradually from 0.55 to 0.7mm at th1 to a maximum of 1.1 to 1.3mm. Thecae spaced at 5.5 to 6.5 in 5mm proximally, 9 to 11 in 10mm distally. Metathecae form and open hook with proximoventrally facing apertures, the hook occupying about 1/3 the total width. Thecae overlap about 1/4 proximally, 1/3 to almost 1/2 distally. Sicula 1.2 to 1.4mm long extending to just beyond the apex of th1.

Remarks. The Canadian Arctic specimens match in all respects with the type material of Obut and Sobolevskaya (1966). The thecae are typical of the priodon-group but this species is distinguished from most other members of that group by its narrow distal width and dorsoventrally curved, more gently widening proximal end.

Monograptus becki (Barrande) has similar rhabdosomal form and distal dimensions but is much more narrow proximally and has less overlapping, more strongly hooked thecae.

Most of the Canadian specimens occur somewhat earlier than the Russian ones which were found in the griestonensis, grandis and murchisoni zones.

Monograptus lobiferus lobiferus (M'Coy, 1850)

Text-figure 39A,C.

1850 Graptolites lobiferus (M'Coy); M'Coy, p. 270.

1913 Monograptus lobiferus (M'Coy); Elles and Wood, pp. 448-450, pl. 45, figs. 1a-f; text-fig. 308a-e.

1970 Monograptus lobiferus (M'Coy); Churkin and Carter, p. 42, pl. 3, figs. 12,21.

1975 Monograptus lobiferus (M'Coy); Hutt, pp. 94-95, pl. 18, figs. 1,3; pl. 19, fig. 6; text-fig. 24, fig. 4a,b.

1975 Monograptus lobiferus lobiferus (M'Coy); Bjerreskov, pp. 66-67, pl. 10D; fig. 20C.

1981 Monograptus lobiferus lobiferus (M'Coy); Bjerreskov, p. 41, pl. 4, fig. 1.

Material. Eight moderately well preserved, compressed specimens and a few more poorly preserved fragments.

Occurrence. Orbitus Subzone and upper convolutus Zone. Twilight Creek at 15.5 to 16.0m and Huff Ridge at 121.0 and

Text-figure 39

All specimens x7.5 unless othewise stated.

A,C. _Monograptus_ _lobiferus_ (M'Coy): A) TC: 15.5-16.0; C HR.121.0.

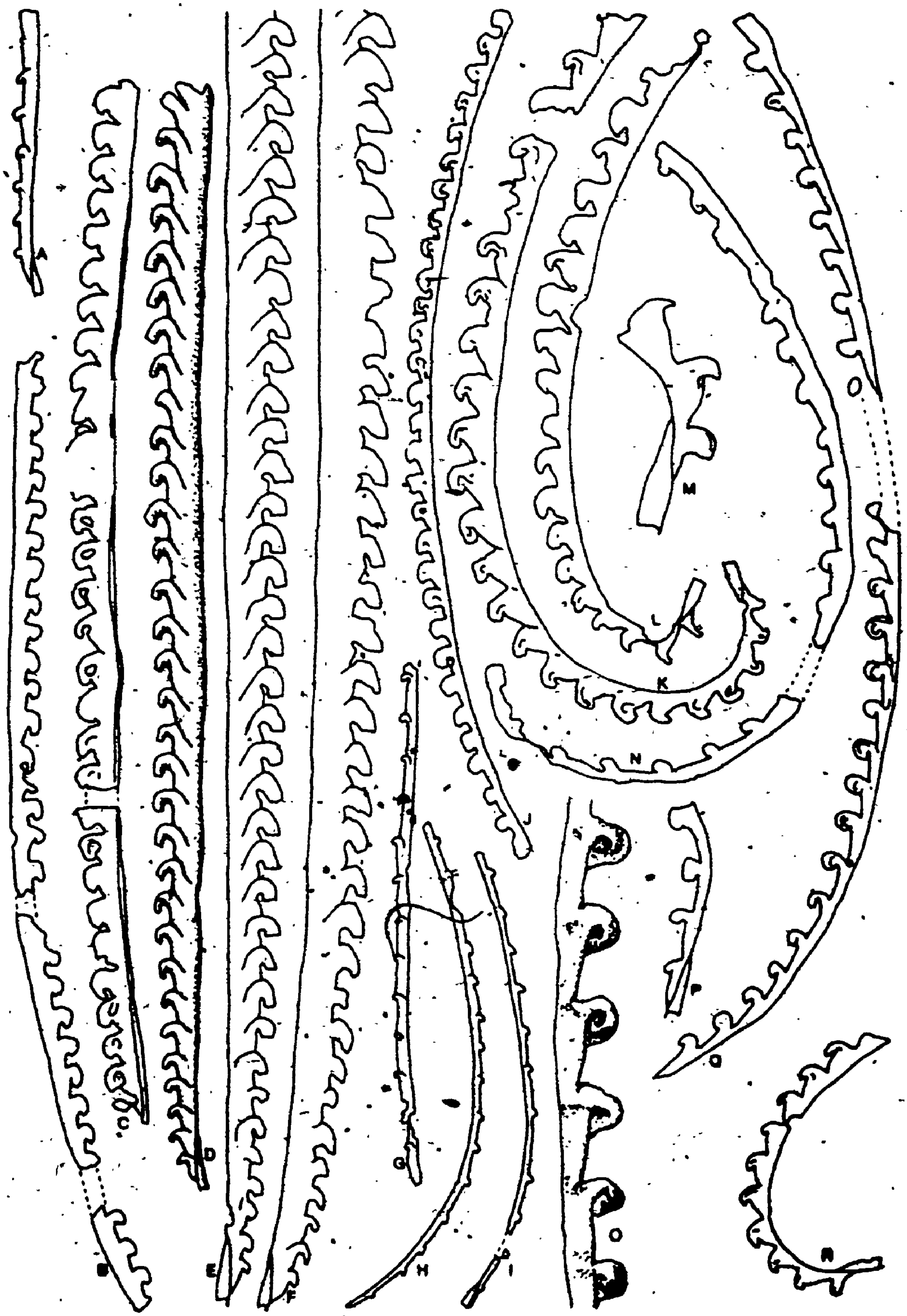
B. _Monograptus_ _lobiferus_ _harpago_ Törnquist, TF:71.0.

D-F. _Monograptus_ _marri_ Perner: D) TC:34.0; E) TC:32.5; F) SC:492.0.

G-I. _Monograptus_ _minimus_ Bouček and Přibyl: G) CP:146.0; H) TC:55.5; I) TC:61.5.

J-M,R. _Monograptus_ _millepeda_ _curtus_ (Obut and Sobolevskaya): J) HR:124.5, x5; K) CM:2-5; L) TF:62.5; M) TF:62.5, x15; R) TF:62.5.

N-Q. _Monograptus_ "_nodifer_" Törnquist: N) CP:158.5; O) TF:74.0, x15; P) TF:105.0; Q) TF:74.0.



128.0m.

Description. Rhabdosome up to at least 53mm long (distal fragment) with weak dorsal curvature proximally, straight or weak ventral curvature distally. Widens from 0.4 to 0.5mm at th1 to 1.6 to 1.9mm distally. Thecae spaced at 4.5 to 5 in the first 5mm, 7.5 to 8.5 in 10mm distally. Proximal thecae slightly elongate, prothecae widening slightly, metathecae forming strong hooks. Distally, the prothecae become relatively much shorter and wider, with their dorsal wall highly inclined. Metathecal hook or lobe robust, apertures face proximodorsally. Sicula 1.1mm long.

Remarks. The present specimens fit well within the previously described range of variation of this common and widely distributed species. The lateral thecal spines reported by Bjerreskov (1975) and Hutt (1975) have not been seen in any of the present specimens.

Monograptus cf. *M. lobiferus harpago* Törnquist, 1899

Text-figure 39B.

Material. A single, moderately well preserved, mesial or distal fragment.

Occurrence. Upper *minor* Zone. Trold Fiord at 71.0m.

Description. Rhabdosome 40mm long with weak ventral curvature throughout. Width is 1.1 to 1.2mm and thecae spaced at 8.5 to 9 in 10mm. Thecae strongly hooked with proximodorsally directed apertures. Ventral prothecal walls inclined at about 15°, metathecal hook occupies about 1/2 the total width.

Remarks. The thecal shape of the present specimen matches exactly with that of *M. lobiferus harpago* as illustrated by Bjerreskov (1975) and Lenz (1982a) and the thecal spacing and weak ventral curvature are in keeping with this species. The maximum width seen here is less than is typical of this species but this specimen may be a mesial fragment which has not achieved the maximum width. In the absence of more complete specimens, a tentative assignment is made to this species.

Monograptus marri Perner, 1897

Text-figure 39D-F.

1897 *Monograptus Marri* Perner, p. 21, pl. 2, figs. 5,6,10,11; text-figs. 23-25.

1912 *Monograptus Marri* Perner; Elles and Wood, pp. 422-423, pl. 42, fig. 4a-d; text-fig. 284a,b.

1965 *Monograptus marri* Perner; Obut and Sobolevskaya, pp. 46-47, pl. 4, figs. 6-8.

1970 *Monograptus marri* Perner; Hutt *et al*., pp. 9-10, pl. 2, figs. 26-29.

1970 _Monograptus marri_ Perner, Rickards, pp. 71-72, pl. 4, fig. 10; pl. 5, fig. 7, text-fig. 16, fig. 19.

1975 _Monograptus marri_ Perner; Bjerreskov, pp. 69-70, pl. 10F.

1975 _Monograptus marri_ Perner; Hutt, pp. 95-96, pl. 15, fig. 6; text-fig. 26, fig. 4.

1982a _Monograptus marri_ Perner; Lenz, pp. 87-88, figs. 8D,E; 26A-D.

1984a _Monograptus marri_ Perner; Chen, p. 52, pl. 8, figs. 9-11,16; pl. 9, figs. 1,2.

Material. Numerous well to poorly preserved, compressed to low relief specimens.

Occurrence. Upper _minor_ to lower _sakmaricus_ zones. Snowblind Creek at 491.5, 492.0, A0.0 and A2.0m, Cape Phillips at 85.0 and 93.5m, Twilight Creek at 23.5, 25.5, 29.5, 31.5, 32.5, 34.0, 35.5, 40.5, 42.5 and 43.5m, Trold Fiord at 74.0 and 79.0m, Huff Ridge at 177.5, 178.5, 194.0, 195.5 and 203.0m, Middle Island at 35.0? and 52.0 and Irene Bay at 65.5m.

Description. Rhabdosome up to at least 65mm long, straight although may show a slight dorsal curvature proximally. Widens from 0.5 to 0.7m at th1 to a maximum of 1.5 to 1.9mm. Thecae spaced at 5.5 to 8 in the first 5mm to a maximum of 9 to 12 in 10mm distally. Thecae have a pronounced metathecal hook which occupies 1/3 to 1/2 the total width with proximally directed apertures. Sicula 1.25 to 1.5mm long reaching just beyond the aperture of th1.

Remarks. This species is characterized by its pronounced metathecal hooks and relatively slender width as compared with other priodon-group species. Monograptus rickardsi minor has apertural spines on the proximal thecae and less of the thecae is involved in the hook.

The stratigraphically higher populations of this species (griestoniensis Zone) tend to have closer proximal thecal spacings (7 to 8 in the first 5mm) than the earlier forms but they are otherwise very similar.

Monograptus millepeda curtus (Obut and Sobolevskaya, 1968)

Text-figure 39J-M,R.

1968 Campograptus curtus Obut and Sobolevskaya, pp. 104-105, pl. 25, figs. 7,8.

Material. Numerous compressed and partially compressed specimens, very well to poorly preserved.

Occurrence. Curtus Zone and lower convolutus Zone?. Snowblind Creek at 140m, Cape Manning at 2-5m, Trold Fiord at 62.5 and 63.0m and Huff Ridge at 118.5, 122.0 and

124.0m?.

Description. Rhabdosome commonly less than 25mm long although distal fragments up to 40mm are present, moderately to tightly dorsally curved proximally, weakly curved to straight distally. Widens gradually from 0.5 to 0.7mm at th1 to a maximum of 0.9 to 1.3mm. Thecae spaced at 6.5 to 8 in 5mm at the extreme proximal end to 9 to 11 in 10mm distally. Thecae triangular with large hooked metathecae and retroverted apertures. Ventral wall inclined with angle of inclination increasing distally. Sicula 0.9 to 1.2mm long, reaching to, or just beyond the tip of th1.

Remarks. Hutt (1975) and Lenz (1982a) placed *Campograptus curtus* in synonymy with *Monograptus millepeda* (M'Coy) despite the fact that the former had a maximum reported width of 1.0mm and the latter was commonly 1.4 to 1.5mm wide. In all other respects the two species are identical. The present collections fall into the width range of *C. curtus* (as well as somewhat wider), but none fall into the typical width range of *M. millepeda* s.s., despite the fact that most are flattened (although otherwise undeformed). For this reason, *C. curtus* is considered a subspecies of *M. millepeda*, distinguished from the latter on the basis of its consistently narrower width, and the present material is all assigned to this subspecies.

Monograptus minimus Bouček and Příbyl, 1951

Text-figure 39G-I.

1951 Monograptus (Mediograptus) minimus Bouček and Příbyl, pp. 200-201, pl. 3, figs. 9,10; text-fig. 3a,b.

?1965 Monograptus minimus cautleyensis Rickards, p. 226, pl. 30, fig. 1; text-fig. 3c,d.

?1975 Monograptus minimus cautleyensis Rickards; Bjerreskov, pp. 76-77, fig. 22B.

1982a Monograptus minimus Bouček and Příbyl; Lenz, p. 91, figs. 8A; 26H.

Material. Hundreds of well to poorly preserved, compressed specimens.

Occurrence. Sakmaricus Zone. Snowblind Creek at 536.5 and 537.5m, Cape Phillips at 127.0, 146.0, 147.0, 152.5, 153.0, 156.0, 157.0 and 158.5m, Twilight Creek at 59.0, 60.0 and 61.5m, Middle Island at 63.0 and 64.0m, Cape Becher at 5.0, 7.0, 10.0, 12.0, 20.0, 20.5, 22.0 and 29.0m and Trold Fiord at 140.5, 143.0 and 145.0m. Also in the Lower Wenlock at several sections.

Description. Rhabdosome invariable fragmentary, straight of with weak dorsal curvature. Widens gradually from 0.2 to 0.25 proximally to 0.4 to 0.45 distally. Thecae usually spaced at 10 to 11 in 10mm but occasionally as closely as 12 or as widely as 8.5 to 9.5 in 10mm. Thecae have long, parallel prothecae and small, lobate metathecae which occupy about 1/3 the stipe width. No well preserved, complete proximal ends have been found in these collections.

Remarks. As with the Yukon specimens reported by Lenz (1982a) the Arctic Islands material has thecal spacings which are intermediate between those typical of M. minimus minimus (11 to 12 in 10mm, Bouček and Přibyl, 1951) and M. minimus cautleyensis (9 to 10 in 10mm, Rickards, 1965, Bjerreskov, 1975). In fact, the full range of thecal spacings can be seen in some of the present specimens, even within some individual collections. For this reason, two subspecies may be synonymous.

Monograptus "nodifer" Törnquist, 1881

Text-figure 39N-.

?1881 Monograptus nodifer Törnquist, p. 436, pl. 17, fig. 2a-c.

1913 Monograptus nodifer Törnquist; Elles and Wood, pp. 454-456, pl. 46, fig. 2a-d; text-fig. 213a-d.

1942 Monograptus (Streptograptus) nodifer (Törnquist); Boucek and Pribyl, pp. 3-5, pl. 1, figs. 5,6; text-fig. 3h-j.

1967 Streptograptus nodifer (Törnquist); Obut and Sobolevskaya, pp. 101-102, pl. 12, figs. 1-4.

1968 *Streptograptus nodifer* (Törnquist); Obut and Sobolevskaya, pp. 99-100, pl. 14, figs. 8-11.

?1975 *Monograptus* ?*nodifer* Törnquist; Hutt, pp. 97-98, text-fig. 24, figs. 6,7.

1975 *Streptograptus nodifer* (Törnquist); Obut and Sobolevskaya, pp. 172-173, pl. 33, fig. 9.

1976 *Streptograptus nodifer* (Törnquist); Sennikov, pp. 185-186, pl. 12, figs. 1-3.

1984a *Streptograptus nodifer* (Törnquist); Chen, pp. 71-72, pl. 16, figs. 5,8,13.

1986b *Streptograptus nodifer* (Törnquist); Chen, pp. 134-135, pl. 1, figs. 1-12; pl. 2, figs. 1-12; pl. 3, figs. 1-12.

Material. Numerous very well to poorly preserved compressed and low relief specimens.

Occurrence. *Griestoniensis* and *sakmaricus* zones. Snowblind Creek at 393-396m, Cape Phillips at 158.5m, Rookery Creek at 144.0m, Twilight Creek at 27.0, 28.5, 29.5, 42.0, 43.5, 45.5 and ?61.5m.

Description. Rhabdosome up to 53mm long, straight at the extreme proximal end, moderately dorsally curved mesially, weakly so to straight distally. Widens from 0.45 to 0.55mm at th1 to a maximum of 0.7 to 0.9mm. Thecae spaced at 8 to 11 in 10mm. Prothecae parallel to slightly inclined, metathecae strongly lobate with dorsally directed apertures. Apertural margin of ventral wall can be seen to flare slightly in low relief specimens. Metathecal lobe occupies about 1/2 the total width. Sicula seen in only one specimen where it appears to be about 1.3mm long.

Remarks. The ventrally curved rhabdosome and tightly coiled thecae seem to be characteristic of this species as it is most commonly applied although distinction of this form from M. exiguus primulus is extremely difficult unless very well preserved material is available. The two are distinguished by the thecae which are tightly hooked in the case of M. exiguus primulus and coiled in M. nodifer, the coil involving complete 180° curvature (or more) of both the dorsal and ventral walls of the metathecae. In addition, the apertural margins of the thecae seem to flare slightly as they curve down upon the ventral wall of the protheca. The details of the thecae have been illustrated from isolated, uncompressed specimens by Chen (1986).

These specimens do not appear to be synonymous with M. nodifer sensu Törnquist, 1892 whose thecal profile is somewhat more complex (see Hutt, 1975 and Rickards et al. 1977) but the nature of the original specimens of Tornquist (1881) is somewhat less clear.

Monograptus sp. aff. M. nodifer Törnquist, 1881

Text-figure 40A.

Material. About ten moderately to poorly preserved, compresses mesial to distal fragments.

Occurrence. Minor Zone. Twilight Creek at 21.5 and 23.5m and Huff Ridge at 171.5m.

Description. Rhabdosome up to at least 45mm long, moderately to weakly ventrally curved throughout. Width is 0.4 to 0.8mm and thecae spaced at 12 to 14 in 10mm. Metathecae lobate with apparently dorsally facing apertures.

Remarks. These specimens differ from M. nodifer, as described above, principally in the closer thecal spacing. The relatively poor state of preservation prevents elucidation of thecal details and this, together with the lack of preserved proximal parts, prevents a more complete description and identification.

Monograptus cf. M. paradoxus hemmanni Přibyl, 1941

Text-figure 40B-D.

Material. Numerous moderately well to poorly preserved, compressed and partial relief specimens.

Text-figure 40

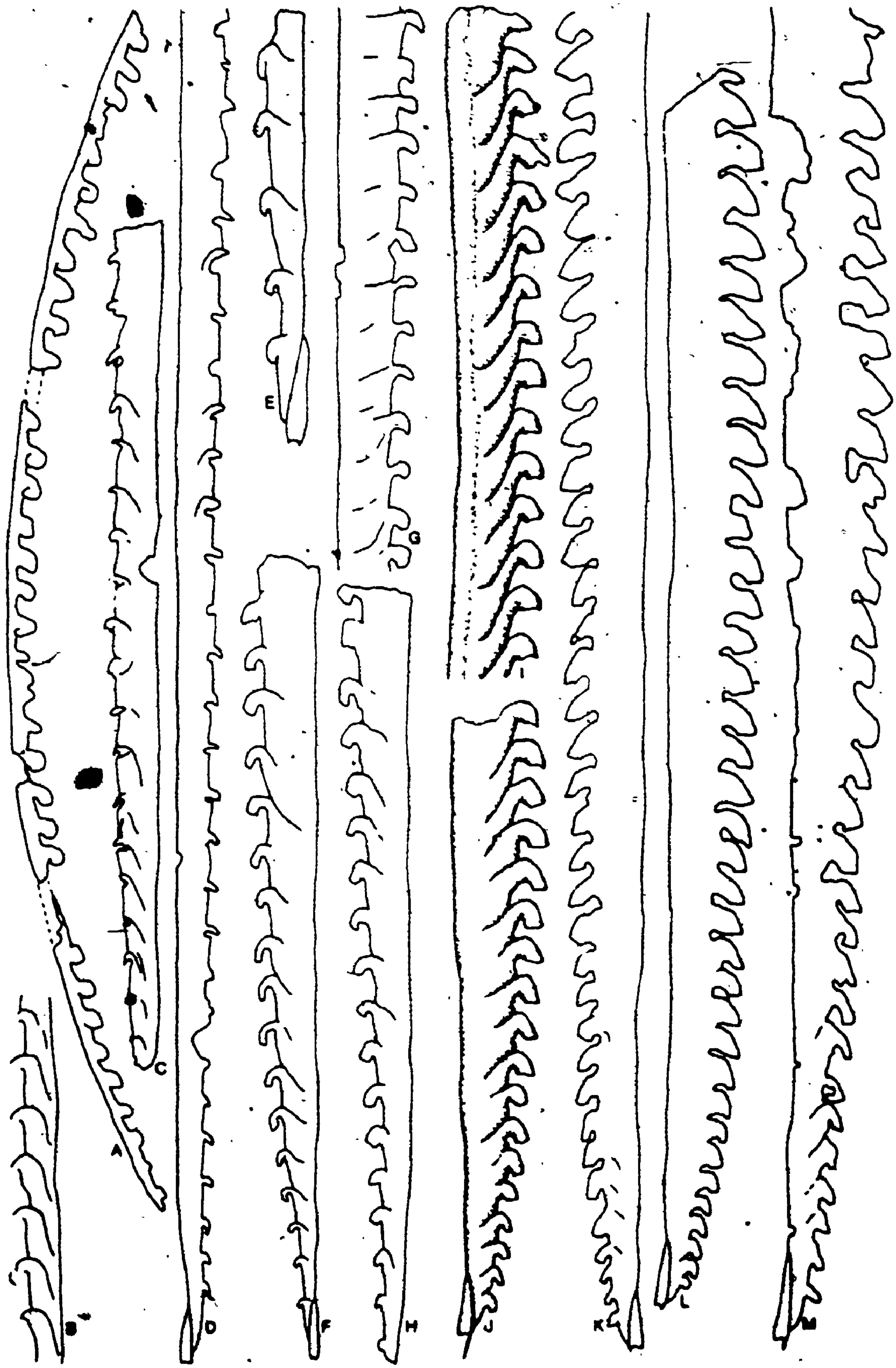
All specimens x7.5 unless otherwise stated.

A. _Monograptus_ sp. aff. _M. nodifer_ Tornquist, TC:23.5.

B-D. _Monograptus_ cf. _M. paradoxus hemmanni_ Přibyl: B) CP:128.0; C) TC:57.0; D) TF:125.0.

E-H. _Monograptus parapriodon_ Bouček: E) TC:55.5, x15; F) TF:140.5; G) TC:55.5; H) TC:60.0.

I-M. _Monograptus priodon_ (Bronn): I) TC:29.5; J) SC:360; K) TC:49.0; L) TC:61.5; M) CP:160.0.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Occurrence. Upper griestoniensis and sakmaricus zones. Snowblind Creek at 457.0 and 536.5m, Cape Phillips at 128.0m, Twilight Creek at 46.0, 49.0, 49.5, 54.5 and 57.0m and Trold Fiord at 125.0m.

Description. Rhabdosome up to at least 75mm long, straight or slightly ventrally curved. Widens gradually from 0.5mm at th1 to a maximum of 1.0 to 1.4mm distally. Thecae spaced at 6 in the first 5mm 8 to 10 in 10mm distally. Thecae have relatively wide prothecae with parallel to slightly inclined ventral walls. Metathecae form a rather weak hook by overgrowth of the dorsal wall to form a pronounced hood. Apertures appear to point ventrally to proximoventrally and often appear to lie within shallow excavations beneath the hood. Sicula is 1.2mm long (only seen in one specimen) and reaches to just below the aperture of th1.

Remarks. The present specimens match with Monograptus paradoxus hemmanni Příbyl (1941a) in the rhabdosomal form, dimensions, thecal spacing and weakly hooked thecae with broad prothecae but appear to differ in that the apertures seen to form shallow excavations under a hood rather than in a simple hook. This may, however, be a function of preservation (especially angle of compression) since some of the present specimens do not show excavations and the thecae appear more as simple hooks, like those of M. parapriodon.

They are, therefore, tentatively referred to *M. paradoxus hemmanni*.

Monograptus parapriodon Bouček, 1931

Text-figure 40E-H.

1931 *Monograptus parapriodon* Bouček, p. 6, text-fig. 4a-b.

1971 *Monograptus* (*Monogr.*) *priodon parapriodon* Bouček; Schauer, p. 57, pl. 36, figs. 12,13.

1982a *Monograptus parapriodon* Bouček; Lenz, p. 93, figs. 8h,i; 26G,I.

Material. Numerous very well to poorly preserved, compressed and low relief specimens.

Occurrence. Middle *griestoniensis* to *sakmaricus* zones. Snowblind Creek at 528.0m, Cape Phillips at 127.0, 128.0, 129.0, 137.0, 148.0, 152.5 and 153.0m, Twilight Creek at 30.5, 35.5, 45.5, 49.0, 51.0, 57.0, 59.0, 60.0 and 61.5m, Middle Island at 64.0, 66.0 and 67.0m, Cape Becher at 7.0, 12.0, 14.0 and 27.0m and Trold Fiord at 105.0, 123.0, 123.5m, 133.0, 140.5 and 143.0m.

Description. Rhabdosome up to at least 80mm long, straight throughout. Widens gradually from 0.45 to 0.5mm at th1 to a distal maximum of 1.4 to 1.8mm. Thecae spaced at 5 to 6 in the first 5mm, 8 to 10 in 10mm distally and have a slightly inclined prothecal ventral wall and a relatively short, open metathecal hook which occupies 1/4 to 1/3 the total width. Thecae overlap about 1/2 distally, less so proximally. Sicula about 1.2mm long, reaching to the top of th1.

Remarks. In Europe this species ranges from crispus Zone through to the top of the Llandovery (Münch, 1952; Schauer, 1972) and tends to be rather slender (generally about 1.5mm) while in northwestern Canada it is found in the sakmaricus Zone and lowest Wenlock and is as much as 1.8 to 1.9mm wide. The Arctic Islands specimens are rather uncommon in the lower part of this range (griestoniensis Zone) where they are more slender and more robust and most abundant in the sakmaricus Zone. As in Yukon, it appears to range into the lowest Wenlock as well.

Monograptus pectinatus pectinatus Richter, 1853

Text-figure 41A-D.

1853 pars Monograptus pectinatus Richter, 461, pl. 12, fig. 26 (non fig. 27).

1868 Graptolites fimbriatus Nicholson, p. 536, pl. 20, figs. 5,?3,4.

1913 pars Monograptus fimbriatus (Nicholson); Elles and Wood, p. 482-483, pl. 48, figs. 4a,d,?c (non b); text-fig. 338a-c,?d.

Text-figure 41

All specimens x7.5 unless otherwise stated.

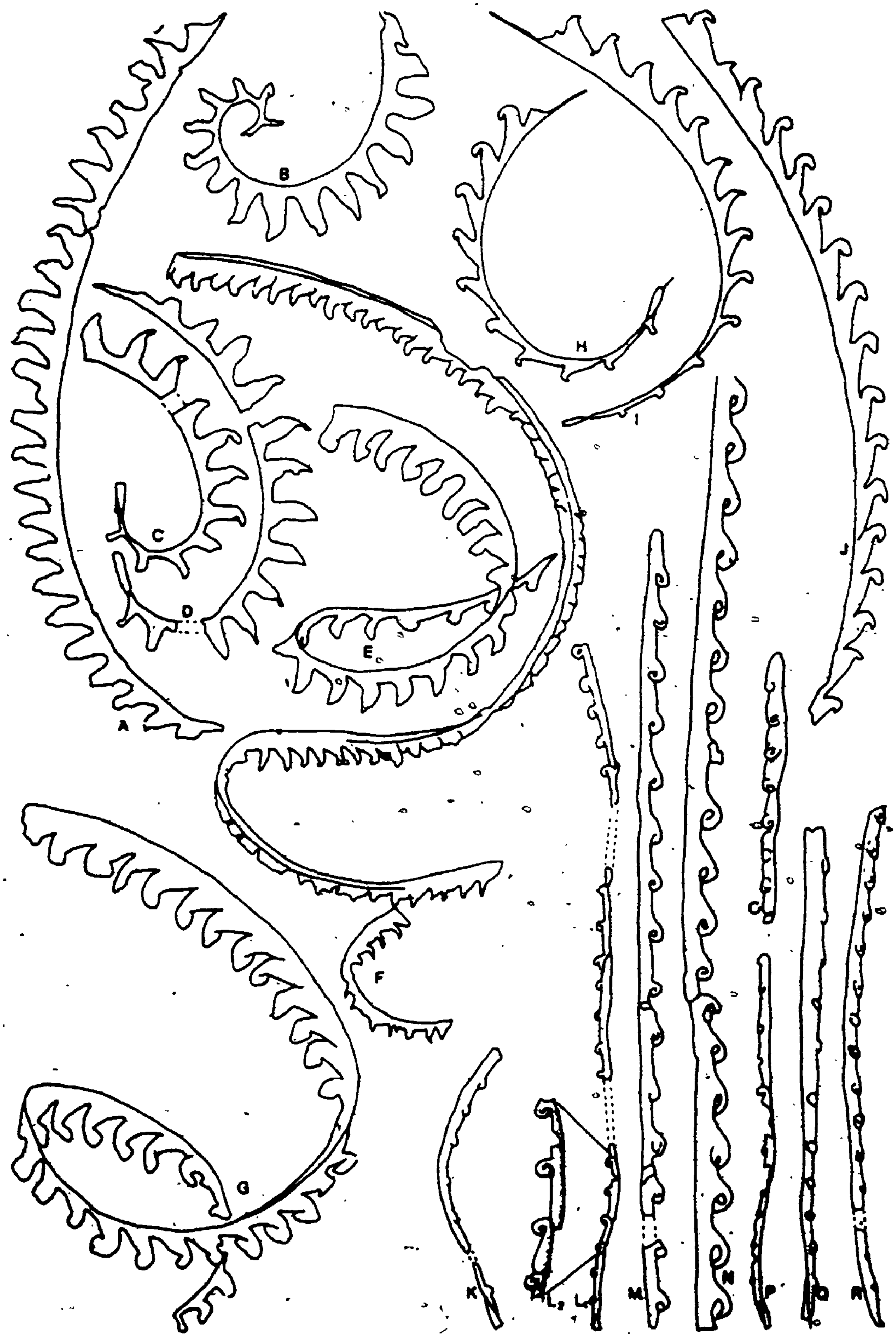
A-D. *Monograptus pectinatus pectinatus* Richter: A) CM:2-5; B) CM:0-2; C) TF:62.5; D) CM:0-2.

E-G. *Monograptus proteus* (Barrande): E) HR:175.0; F) TC:26.0, x3.7; G) HR:175.0.

H-J. *Monograptus planus* (Barrande): H) TF:79.0; I) TC:26.0; J) HR:173.0.

K-N. *Monograptus pseudobecki* Bouček and Přibyl: K) TC:23.5; L) L2, enlargement of near-proximal thecae of L1, x15, TC:22.5; M) TC:22.5; N) TC:22.5.

O-R. *Monograptus pseudoruncinatus* Bjerreskov: O) TF:71.0; P) HR:164.0; Q) TF:74.0; R) TF:71.0.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1958 Monograptus separatus fimbriatus (Nicholson); Sudbury, pp. 499-501, pl. 19, figs. 40-51; text-fig. 5.

1968 Demirastrites pectinatus pectinatus (Richter); Obut and Sobolevskaya, pp. pp. 108-109, pl. 29, figs. 4-6; pl. 30, figs. 1,2.

1970 Monograptus triangulatus fimbriatus (Nicholson); Rickards, p. 82, pl. 7, fig. 4; text. fig. 17, fig. 2.

1975 Monograptus pectinatus Richter; Bjerreskov, pp. 78-79, pl. 11F; text-fig. 23D.

1975 Monograptus triangulatus fimbriatus (Nicholson); Hutt, p. 110, pl. 20, fig. 5; pl. 21, figs. 5,6; pl. 22, figs. 3,4,6,7; text-fig. 17, fig. 6.

1976 Demirastrites pectinatus pectinatus (Nicholson); Sennikov, p. 216-218, pl. 16, figs. 1-3.

1982a Monograptus triangulatus fimbriatus (Nicholson); Lenz, p. 116, figs. 9L,M,Q; 30B,G.

Material. Numerous compressed specimens, moderately well to poorly preserved.

Occurrence. Pectinatus Subzone. Cape Manning at 0-5m, Trold Fiord at 61.0 and 62.5m and Huff Ridge at 118.5.

Description. Rhabdosome hook-shaped with moderate to strong dorsally curvature proximally, becoming weaker distally. Longest fragment (incomplete) is 30mm. Widens from 0.45 to 0.6mm at th1 to a maximum of 1.3 to 1.7mm.

Thecae spaced at 13 to 16.5 in 10mm proximally, 10 to 13 in 10mm distally and are triangulate throughout. Theca 1 is somewhat elongate, theca 2 in some specimens is nearly rastritiform, the remainder are relatively broad with hooked proximally-facing apertures. Sicula is 0.75 to 0.9mm long.

Remarks. The triangulate thecal form throughout with a hook-shaped rhabdosome are characteristic of this species. The thecal spacing is somewhat closer than in most previously reported occurrences, especially proximally, but it is considered to be within the range of variation of this wide-ranging species.

The total lack rastritiform thecae at the proximal end suggests that it is not a subspecies of M. triangulatus (Nicholson) as assigned by many previous workers (see synonymy). Since the name M. pectinatus was assigned prior to M. fimbriatus the former is considered here to be the senior synonym.

Monograptus planus (Barrande, 1850)

Text-figure 41H-J.

1850 Graptolithus proteus var. plana Barrande, p. 58-59, pl. 4, fig. 15.

1913 Monograptus planus (Barrande); Elles and Wood, pp. 484-485, pl. 48, fig. 6a,b,c?,d; text-fig. 340.

1967 Oktavites planus (Barrande); Obut and Sobolevskaya, pp.

120-121, pl. 16, figs. 12,13.

1970 Monograptus planus (Barrande); Rickards, p. 86, text-fig. 17, fig. 7.

1971 Monograptus (Spirogr.) planus planus (Barrande); Schauer, p. 73, pl. 27, figs. 6-9; pl. 33, figs. 5-7.

1974 Monograptus planus (Barrande); Sherwin, pp. 168-169, pl. 10, figs. 7,10,11; text-fig. 2c,d.

1975 non Monograptus planus (Barrande); Bjerreskov, pp. 64-65, pl. 10A.

1975 Monograptus planus (Barrande); Hutt, pp. 99-101, text-fig. 22, figs. 11,12.

1975 Oktavites planus (Barrande); Obut and Sobolevskaya, p. 175, pl. 35, figs. 3,4.

1976 Oktavites planus (Barrande); Sennikov, pp. 201-203, pl. 14, figs. 3-5.

1981 Monograptus planus (Barrande); Bjerreskov, pp. 42-43, pl. 4, fig. 3.

1982a Monograptus planus planus (Barrande); Lenz, p. 94, figs. 7H,L; 26E,F,K.

1984a Oktavites planus (Barrande); Chen, p. 68, pl. 13, fig. 14; pl. 14, figs. 1,4; pl. 18, fig. 7.

Material. Seven moderately to very well preserved, compressed specimens and several more poorly preserved fragments.

Occurrence. Upper minor to crispus zones. Twilight

Creek at 23.5 and 26.0m, Trold Fiord at 71.0, 74.0 and 79.0m and Huff Ridge at 173.0m.

Description. Rhabdosome up to at least 18mm long, moderately dorsally curved mesially, weakly so at the proximal end and distally. Widens from about 0.3mm at th1 to a maximum of 1.2mm. Thecae spaced at 4.5 in 5mm proximally, 9 to 10.5 in 10mm distally. Proximal five thecae axially elongate with near parallel prothecal portions and small metathecal hooks. Distally the thecae broaden, becoming triangular with slight overlap and retroverted apertures. Sicula seen in one specimen is 0.85mm long and reaches to apex of th1.

Remarks. The slender, elongate proximal thecae changing to triangular distally are characteristic of this species. The Canadian Arctic specimens, like those reported from Australia by Sherwin (1974) tend to be narrower than in many previous reports but still seem to be within the range of variation of this species. Distal specimens can be easily confused with those of *M. decipiens* n. subsp., found at some of the same horizons.

Bjerreskov (1981) noted that this species does not show lateral torsion of the metathecae and that the specimens described by her from Bornholm (Bjerreskov, 1975) do not belong to this species, but may be synonymous with *M. resurgens* Linnarsson, previously considered to be a junior synonym of *M. planus*. The specimens of *M. planus obtusus* Schauer reported by Lenz (1982a) also show thecal torsion and may, therefore, be best considered a separate species.

Monograptus priodon (Bronn, 1835)

Text-figure 40I-M.

1835 *Lomatoceras priodon* Bronn, pp. 55-56, pl. 1, fig. 13.

1913 *Monograptus priodon* (Bronn); Elles and Wood, pp. 418-420, pl. 42, fig. 2a-e; text-fig. 282a-d.

1966 *Monograptus priodon* (Bronn); Obut and Sobolevskaya, pp. 24-26, pl. 5, figs. 1-6; text-figs. 15,16.

1967 *Monograptus priodon* (Bronn); Obut and Sobolevskaya, pp. 86-87, pl. 8, figs. 9,10; pl. 9, fig. 1.

1971 *Monograptus* (*Monogr.*) *priodon priodon* (Bronn); Schauer, pp. 56-57, pl. 35, figs. 6-8; pl. 36, figs. 8-11; pl. 37, figs. 1,2.

1974a *Monograptus priodon* (Bronn); Lenz, text-fig. 1A-E.

1974 *Monograptus priodon* (Bronn); Mu *et al.*, p. 216, pl. 99, fig. 12.

1975 *Monograptus priodon* (Bronn); Berry and Murphy, pp. 56-57, pl. 4, figs. 1,4,5; pl. 8, fig. 3.

1975 *Monograptus priodon* (Bronn); Bjerreskov, p. 70, pl. 10G.

1975 *Monograptus priodon* (Bronn); Obut and Sobolevskaya, p. 164, pl. 32, fig. 6.

1976 *Monograptus priodon* (Bronn); Sennikov, pp. 169-172, pl.

9, figs. 7-10.

1977 *Monograptus priodon* (Bronn); Obut and Sennikov, pp. 111-112, pl. 1, fig. 2.

1977 *Monograptus priodon* (Bronn); Wang *et al*., p. 360, pl. 110, fig. 3; pl. 115, fig. 7.

1978 *Monograptus priodon* (Bronn); Wang, p. 311, pl. 2, fig. 2.

1981 *Monograptus priodon* (Bronn); Bjerreskov, p. 44, pl. 6, fig. 3.

1982a *Monograptus priodon* (Bronn); Lenz, pp. 97-98, fig. 28A.

1983 *Monograptus priodon* (Bronn); Huang and Lu, p. 158, pl. 5, figs. 16,17; pl. 10, fig. 11.

Material. Hundreds of very well to poorly preserved, compressed, low relief and uncompressed, pyritized specimens.

Occurrence. *Turriculatus*-*crispus* to *sakmaricus* zones. Snowblind Creek at 350, 360, 390.0, 393.0, 396.0, 437.0, 457.0, 460.0, 491.0, 491.5, 492.0, 522.5, 525.0, 526.0, 528.0, 530.0, 536.5, 538.5, A0.0, A2.0 and A16.0, Cape Phillips at 30.0, 34.0, 58.5, 81.0, 85.0, 100.0, 128.0, 129.0, 137.0, 147.0, 148.0, 152.5, 156.0, 157.0, 158.5 and 159.5m, Rookery Creek at 134.5, 144.0 and 149.0m, Twilight Creek at 26.0, 26.5, 27.0, 27.5, 28.5, 29.5, 30.5, 31.0, 34.0, 35.5, 42.0, 42.5, 43.5, 45.0, 45.5, 46.0, 47.0, 47.5, 49.0, 49.5, 50.0, 51.0, 52.0, 52.5, 54.5, 55.5, 57.0, 59.0, 60.0 and 61.5m, Middle Island at 35.0?, 39.0, 59.0, 63.0, 64.0 and 67.0, Cape Becher at 2.0, 7.0, 20.0, 27.0 and 29.0m, Trold Fiord at 79.0, 105.0, 123.0, 123.5, 125.0, 133.0, 135.0, 136.0, 140.5, 143.0 and 145.0m, Huff Ridge at 195.5, 203.0 and 271.0m and Irene Bay at 65.5, 67.0, 68-72 and 69.0m.

Description. Rhabdosome up to at least 200mm long, straight except for proximal end which may be slighty dorsally curved. Widens from 0.6 to 0.85mm at th1 to a maximum of 2.2 to 3.3mm. Thecae spaced at 6 to 8 in the first 5mm, 8 to 10.5 in 10mm distally and form an open hook with retroverted apertures and 1/3 to 1/2 overlap. Sicula 1.25 to 1.6mm long, reaching to or just above base of th3.

Remarks. The present collections of this abundant and ubiquitous species show a wide range of variation in width, thecal spacing and rate of widening at the proximal end. The majority of specimens, from the griestoniensis and lower sakmaricus zones show the typical, rather gradual rate of proximal widening and tend to show proximal thecal spacings of about 6 to 7 in the first 5mm. Some collections in the turriculatus and crispus zones and in the higher part of the sakmaricus Zone (e.g. text-fig. 40L) tend have specimens which have a more rapid rate of proximal widening and somewhat closer proximal thecal spacing (7 to 8 in 10mm). In addition, these latter specimens tend to reach somewhat greater distal widths, 2.9 to 3.3mm. The higher sakmaricus Zone specimens, in particular, are approaching M. praecedens Bouček in appearance. The latter species, however, reaches its maximum width very early, often within the first 10mm (Bjerreskov, 1975) and may reach greater maximum widths (up to 4.0mm, Münch, 1952). Forms probably referable to M. praecedens are present in the Lower Wenlock of some of the sampled sections.

Lenz (1974a) illustrated uncompressed, isolated specimens of M. priodon from the Cape Phillips type section and showed a trend toward increased sicula length and increase width at th5 upward from the Upper Llandovery through the Upper Wenlock. The present collections, from a variety of sections throughout the Cape Phillips Basin all show the shorter sicula lengths typical of Lenz's Llandovery samples although the width at th5 is somewhat more variable owing, in part, to varying degrees and angles of compression.

Monograptus proteus (Barrande, 1850)

Text-figure 41E-G.

1850 Graptolithus proteus Barrande, p. 58, pl. 55, figs. 12-14.

1913 Monograptus proteus (Barrande); Elles and Wood, pp. 477-478, pl. 48, fig. 8a-c; text-fig. 332a-e.

?1967 Oktavites proteus (Barrande); Obut and Sobolevskaya,

pp. 121-122, pl. 16, fig. 11.

1970 *Monograptus proteus* (Barrande); Hutt *et al.*, pp. 12-13, pl. 3, figs. 51-55.

1970 *Monograptus proteus* (Barrande); Rickards, pp. 87-88, text-fig. 13, fig. 13; text-fig. 17, fig. 14.

1971 *Monograptus* (*Spirogr.*) *proteus proteus* (Barrande); Schauer, p. 75, pl. 30, fig. 9; pl. 31, figs. 1-3; pl. 34, figs. 1,2.

1975 *Monograptus proteus* (Barrande); Bjerreskov, pp. 65-66, pl. 10C; text-fig. 19B.

1975 *Monograptus proteus* (Barrande); Hutt, p. 102, pl. 26, fig. 4; text-fig. 25, figs. 2,3.

1975 *Oktavites proteus* (Barrande); Obut and Sobolevskaya, p. 176, pl. 35, fig. 5.

?1978 *Spirograptus proteus* (Barrande); Wang, p. 312, pl. 2, fig. 6.

1982a *Monograptus proteus* (Barrande); Lenz, pp. 98-99, figs. 8S,T; 27C,H,I.

Material. Numerous compressed, well to poorly preserved specimens.

Occurrence. Upper *minor* and *turriculatus*-*crispus* to lower *griestoniensis* zones. Twilight Creek at 26.0, 26.5 and 27.5m, Trold Fiord at 79.0m and Huff Ridge at 175.0 and 203.0m.

Description. Rhabdosome forms an open conical spiral which, on compression may appear as an open, loose spiral or as an S-shape. Rhabdosome widens from about 0.3mm proximally to 1.5 to 1.6mm distally. Thecae spaced at 4.5 in 5mm proximally, 11 to 12 in 10mm distally. Proximal thecae are axially elongate with short metathecal hooks. Distal thecae triangular with about 1/4 to 1/3 overlap and asymmetrically hooked apertures. Distal metathecae occupy about 2/3 the total width. No well preserved proximal parts have been found.

Remarks. The torsion of the metathecae described for this species by Hutt et al. (1970) and Bjerreskov (1975) cannot be clearly seen on most of the present material but the rhabdosomal form and rather close distal thecal spacing are characteristic of this species.

Monograptus pseudobecki Bouček and Příbyl, 1942

Text-figure 41K-N.

1912 Monograptus Becki (Barrande); Elles and Wood, pp. 452-453, pl. 45, figs. 4a-f; text-fig. 311a,b.

1942 Monograptus (Streptograptus) pseudobecki Bouček and Příbyl, pp. 17-18, text-fig. 4a,b.

1965 Streptograptus pseudobecki (Bouček and Příbyl); Obut and Sobolevskaya, p. 54, pl. 7, fig. 8.

1970 Monograptus pseudobecki Bouček and Příbyl; Rickards, pp. 78-79, pl. 8, fig. 7; text-fig. 17, fig. 23.

1971 Monograptus (Streptograptus) runcinatus pseudobecki Bouček and Přibyl; Schauer, p. 71, pl. 25, figs. 13-14.

1975 Monograptus pseudobecki Bouček and Přibyl; Bjerreskov, p. 63, pl. 9A,B.

1982a Monograptus pseudobecki Bouček and Přibyl; Lenz, pp. 99-100, figs. 8J-L; 28C,E.

Material. Numerous very well to poorly preserved compressed, low relief and uncompressed, pyritized distal and mesial fragments, and two moderately well preserved, compressed proximal specimens.

Occurrence. Minor and turriculatus-crispus zones. Twilight Creek at 20.5, 21.5, 22.5 and 23.5m, Trold Fiord at 79.0m and Huff Ridge at 171.5m.

Description. Rhabdosome up to at least 54mm long, with slight dorsal curvature proximally, followed by weak ventral curvature, may become straight distally. Widens from 0.25mm at th1 to a maximum of 0.6 to 0.9mm distally. Thecae spaced at 6 to 7 in 5mm proximally, 8 to 10.5 in 10mm distally. Thecae lobate with dorsally facing apertures. Prothecal walls parallel. On proximal thecae, the prothecae is sharply delineated from the preceding metatheca while distally, the dorsal wall of the metathecal lobe flows more smoothly into the ventral wall of the succeeding protheca.

Metathecal lobe occupies 1/3 to 1/2 the total width. Sicula 0.8mm long.

Remarks. The rhabdosomal shape, dimensions and thecal spacings all match well with previous reports of this species. The vast majority of the present specimens are distal fragments and the thecal profile seen in the uncompressed and low relief specimens matches well with the distal thecae illustrated by Bjerreskov (1975, pl. 9B).

The thecae differ from those of Diversograptus runcinatus in that the apertures are more tightly coiled and face dorsally rather than the more nearly proximally facing apertures of the latter species. In addition, D. runcinatus in wider distally, while D? runcinatus richardsonensis (Lenz) has a more strongly flexed proximal region.

Monograptus pseudoruncinatus Bjerreskov, 1975

Text-figure 410,R.

1975 Monograptus psuedoruncinatus Bjerreskov, p. 60, pl. 9C; text-fig. 18C.

Material. Hundreds of moderately well to poorly preserved, compressed specimens.

Occurrence. Minor to crispus zones. Snowblind Creek at 210m, Twilight Creek at 21.5 and 23.5m, Trold Fiord at 71.0

and 74.0m and Huff Ridge at 160.0, 164.0, 175.0, 177.0, 178.5 and 197.0m.

Description. Rhabdosomes fragmentary, up to 12mm long, with slight dorsal curvature proximally, ventrally curved to straight distally. Widens from 0.2 to 0.3mm at th1 to a maximum of 0.4 to 0.6mm. Thecae spaced at 6.5 to 7.5 in 5mm proximally, 11.5 to 14 in 10mm distally. Ventral prothecal wall is parallel although may be wider at its base and metathecae are tightly enrolled and appear to be "sunken" into the prothecal walls giving a very low profile appearance, especially proximally. Sicula is 0.75 to 1.0mm long.

Remarks. The rhabdosomal shape and narrow, low relief, closely spaced thecae are distinctive fro this species. The lesser distal width and closer thecal spacing distinguishes it from M. pseudobecki. Diversograptus runcinatus, as pointed out by Bjerreskov (1975), does not show the tightly coiled thecae ("streptograptid") thecae but has strongly hooked thecae with more proximally facing apertures. Bjerreskov has suggested that some of the specimens previously assigned to D. runcinatus which show tightly coiled thecae may belong to this species.

The low profile, "sunken" appearance of the metathecae appears to have been enhanced by compression and in many of the more poorly preserved specimens, which occur in great abundance on some slabs, appear almost featureless and parallel-sided.

Monograptus rickardsi minor Hutt, 1975

Text-figure 42A-D.

1975 Monograptus rickardsi minor Hutt, pp. 103-105, pl. 15, fig. 3; text-fig. 26, figs. 1,2,5.

1982a Monograptus rickardsi minor Hutt; Lenz, p. 104, figs. 9F,G; 29A,B.

Material. Numerous very well to poorly preserved compressed and low relief specimens.

Occurrence. Crispus and lower griestoniensis zones. Snowblind Creek at 360m, Cape Phillips at 19.5m and Twilight Creek at 26.0, 26.5, 27.0 and 27.5m.

Description. Rhabdosome long and straight with slight dorsal curvature proximally. Widens from 0.6 to 0.8mm at th1 to a maximum of 1.7 to 2.3mm. Thecae spaced at 6.5 to 8 in the first 5mm, decreasing to 9 to 10.5 in 10mm distally. Thecae with strongly hooked, retroverted apertures, somewhat less so distally with thecal hook occupying 1/4 to 1/3 of the total width distally. Proximal thecae bear lateral apertural spines up to 0.5mm long which are not always visible, depending on mode of compression. Thecal overlap

Text-figure 42

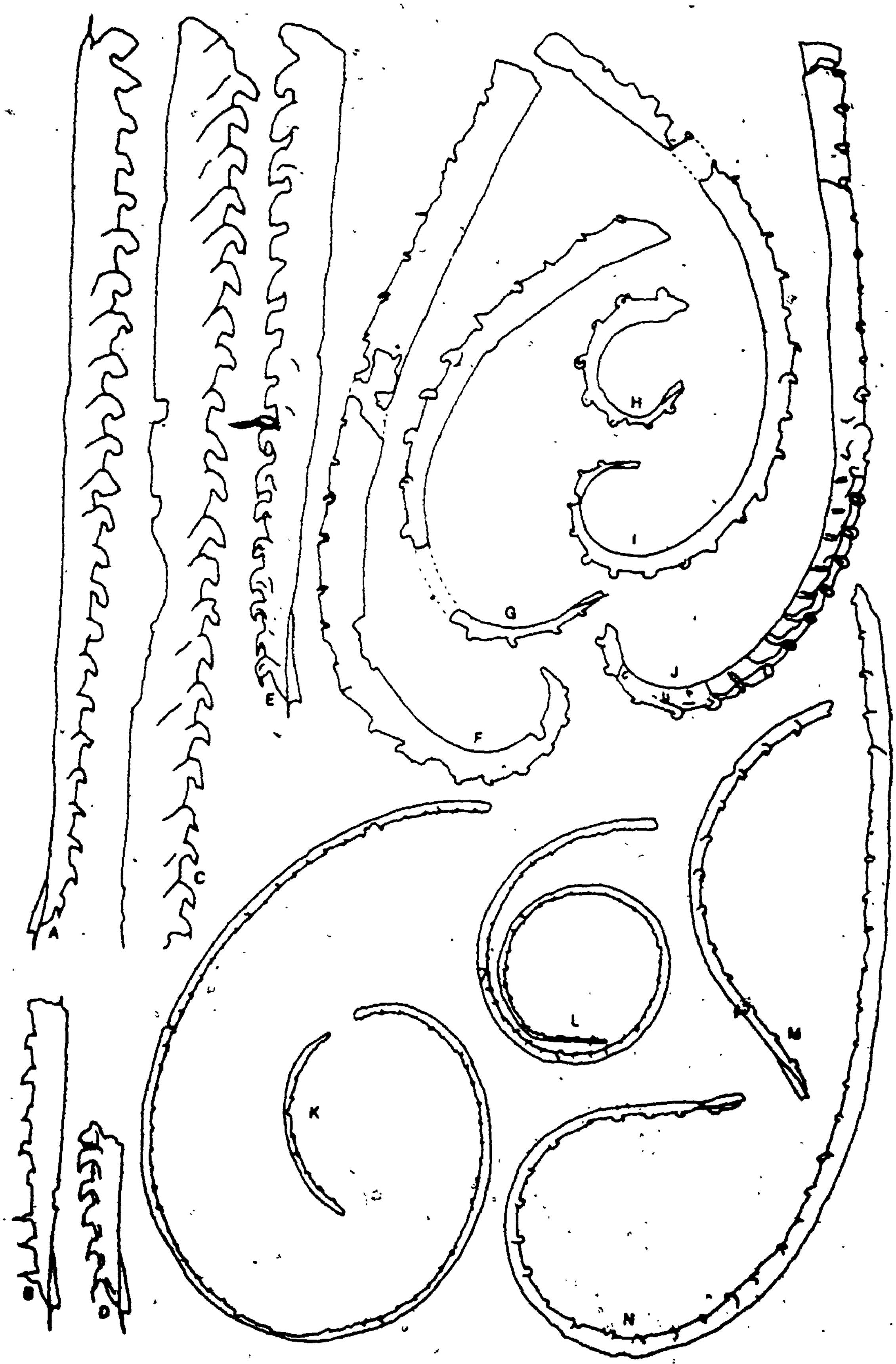
All figures x7.5 unless otherwise stated.

A-D. *Monograptus rickardsi minor* Hutt: A) SC:360; B) TC:26.5; C) TC:27.5; D) TC:27.0.

E. *Monograptus* ex gr. *rickardsi* Hutt: HR:179.5.

F-J. *Monograptus sidjachenkoi* (Obut and Sobolevskaya): F) HR:128.0; G) SC:170: H) HR:128.0; I) HR:131.0; J) TC:15.5.

K-N. *Monograptus speciosus* Tullberg: K) & L) TC:52.5, x3.5; M) & N) TC:52.5.



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is slight proximally, increasing to about 1/3 distally. Sicula 1.2 to 1.45mm long reaching to just below th2 aperture.

Remarks. The present specimens match exactly with the type material and that of Lenz (1982a) except that the thecal spacing is somewhat higher proximally (this may be due, in part to differences in the way this parameter is measured). The spinose but otherwise priodon-like proximal thecae are distinctive for this species and the distal thecae have a relatively smaller hook involving a smaller proportion of the thecal length than seen in other species of the priodon group.

A single specimen from HR:179.5 (text-figure 22E) is identical to M. rickardsi minor except that it has a somewhat longer sicula (1.6mm) and is wider at the first theca (0.9mm) and in these respects seems to be intermediate between the latter and the type subspecies. This specimen is assigned to M. ex gr. rickardsi.

Monograptus sidjachenkoi (Obut and Sobolevskaya, 1965)

Text-figure 42F-J.

1965 Permerograptus sidiachenkoi Obut and Sobolevskaya (sic), p. 61, pl. 9, figs. 2-4.

1967 Pernerograptus sidjachenkoi Obut and Sobolevskaya; Obut and Sobolevskaya, pp. 111-112, pl. 15, figs. 2-7.

1975 Pernerograptus sidjachenkoi Obut and Sobolevskaya; Obut and Sobolevskaya, pp. 162-163, pl. 9, fig. 6.

1977 Paramonoclimacis minor Wang and Ma, p. 361, pl. 111, figs. 6,7.

1977 Paramonoclimacis similis (Geh); Wang and Ma, p. 361, pl. 111, fig. 5.

1977 Paramonoclimacis typicalis Wang and Ma, p. 362, pl. 111, figs. 2-3; text-fig. 47.

1978 Strebtograptus similis (Geh); Ni, p. 409, pl. 3, fig. 16.

1978 Paramonoclimacis shuangheensis Ye, pp. 478-479, pl. 178, fig. 10.

1982a Monograptus sidjachenkoi (Obut and Sobolevskaya); Lenz, pp. 109-110, figs. 8N,P,R; 27B,E,F.

1985 Monograptus aff. M. sidjachenkoi (Obut and Sobolevskaya); Norford (in Norford and Orchard), p. 9, pl. 4, fig. 8.

Material. Numerous compressed and partially compressed specimens, well to rather poorly preserved.

Occurrence. Upper convolutus Zone. Snowblind Creek at 170m, Twilight Creek at 15.0 and 15.5 to 16.0m and Huff Ridge at 126.0, 128.0 and 131.0m

Description. Rhabdosome moderately to tightly coiled proximally to almost straight distally curving through as little as 180° to almost 360°. Widens from 0.3 to 0.45 at th1 to a maximum of 0.8 to 1.1mm. Thecae spaced at 5.5 to 7 in the first 5mm and 10 to 13 in 10mm distally. Proximal thecae have lobate apertures, lobes occupying 1/4 to 1/3 of the stipe width. Apertural lobes recede immediately distally of the more tightly coiled proximal region; distal thecae bear short hoods. Ventral thecal walls are parallel to stipe axis. Sicula only poorly preserved in most specimens but is 0.6 to 0.75mm in length.

Remarks. This species shows a rather wide range of intraspecific variation in its width (proximal and distal), thecal spacing and degree or rhabdosomal curvature. Although Wang and Ma (1977) distinguished at least three taxa in this group, the range of variation shown by Lenz (1982a), Carter (in press) and the present collections suggests that they do, indeed, all represent a single species. The present specimens are somewhat narrower overall than those reported by Lenz (1982a) but match very well with those of Carter (in press). The specimens assigned to M. aff. M. sidjachenkoi by Norford (in Norford and Orchard, 1985) differ from typical specimens only in that the proximal curvature is lower (about 180°). The present ~~collections~~ collections and those of Carter show, however, that this is within the range of variation of this species.

Monograptus speciosus Tullberg, 1883

Text-figure 42K-N.

1883 Monograptus speciosus Tullberg, p. 21, pl. 2, figs. 16-19.

1975 Monograptus speciosus Tullberg; Bjerreskov, p. 76, pl. 12A; text-fig. 22A.

1982a Monograptus speciosus Tullberg; Lenz, pp. 110-111, figs. 9K; 30A,C,F.

Material. Hundreds of very well to poorly preserved, compressed specimens.

Occurrence. Sakmaricus Zone. Snowblind Creek at 522.5, 524.0, 528.0, 534.2, 534.7, 536.5, 537.5 and A16.0m, Cape Phillips at 127.0, 128.0, 129.0, 130.0 and 158.5m, Rookery Creek at 162.0m, Twilight Creek at 49.0, 49.5, 52.0, 52.5, 54.5, 55.5, 59.0 and 61.5m, Middle Island at 59.0 and 64.0m, Cape Becher at 10.0 and 17.0m, Trold Fiord at 119.0, 123.0, 123.5, 125.0, 133.0 and 140.5m and Irene Bay at 68-72m.

Description. Rhabdosome straight over the first four thecae, moderately to strongly ventrally curved mesially, becoming weakly so to straight distally. Complete specimens up to 76mm long and coil through 200 to as much as 520^{o}. Widens slowly from 0.35mm at th1 to 0.7 to 1.0mm distally. Thecae spaced at 6 to 6.5 in the first 5mm, 10 to 11 in 10mm distally. Prothecae elongate and parallel, metathecae form short, open hooks occupying 1/4 to 1/3 the stipe width. Sicula 0.95 to 1.1mm long, extending slightly beyond the aperture of th1.

Remarks. Well preserved, complete rhabdosomes with the proximal end intact show that the proximal end is much like that of M. exiguus with a short sicula extending beyond the tip of th1, and a straight initial portion followed by the mesial region of maximum curvature. In addition, the thecae, which from short, open hooks, also appear to be broadly similar to those of M. exiguus except that they show much greater overlap.

The present specimens show a much higher degree of rhabdosomal curvature than found previously (although see Lenz, fig. 30A) but this is attributed to their completeness. Tullberg (1883, pl. 2, fig. 16) illustrates a fragmentary specimen which shows a comparable degree of mesial curvature. In all other ways, the present specimens appear to resemble the type specimens.

The specimens of Bjerreskov (1975) reach a slightly greater maximum width and show bipolar growth, attributed by her to regeneration.

<u>Monograptus spiralis spiralis</u> (Geinitz, 1842)

Text-figure 43A-D,H.

1842 <u>Graptolithus spiralis</u> Geinitz, p. 700, pl. 10, figs. 26,27.

1965 <u>Oktavites spiralis</u> (Geinitz); Obut and Sobolevskaya, pp. 82-83, pl. 14, figs. 5-8; pl. 15, figs. 1-10.

1966 <u>Oktavites spiralis</u> (Geinitz); Obut and Sobolevskaya, pp. 41-42, pl. 7, fig. 8; pl. 8, fig, 31.

1967 <u>Oktavites spiralis</u> (Geinitz); Obut and Sobolevskaya, pp. 118-119, pl. 16, figs. 6-8.

1971 <u>Monograptus</u> (<u>Spirogr.</u>) <u>spiralis spiralis</u> (Geinitz); Schauer, pp. 76-77, pl. 32, figs. 1-5; pl. 33, figs. 1,2.

1973 <u>Oktavites spiralis spiralis</u> (Geinitz); Golikov, pp. 39-41, pl. 8, figs. 1-6.

1975 <u>Monograptus spiralis spiralis</u> (Geinitz); Berry and Murphy, pp. 59-60, pl. 5, figs. 1,2.

1975 <u>Monograptus spiralis spiralis</u> (Geinitz); Bjerreskov, p. 72, pl. 11C; text-fig. 20F.

1975 <u>Monograptus spiralis spiralis</u> (Geinitz); ~~Hutt, pp.~~ 106-107, text-fig. 21, fig. 3.

1975 <u>Oktavites spiralis</u> (Geinitz); Obut and Sobolevskaya, p. 175, pl. 34, figs. 7,8; pl. 35, figs. 1,2.

1976 <u>Oktavites spiralis spiralis</u> (Geinitz); Sennikov, pp. 196-199, pl. 13, figs. 8,9.

1977 <u>Oktavites spiralis</u> (Geinitz); Obut and Sennikov, pp.

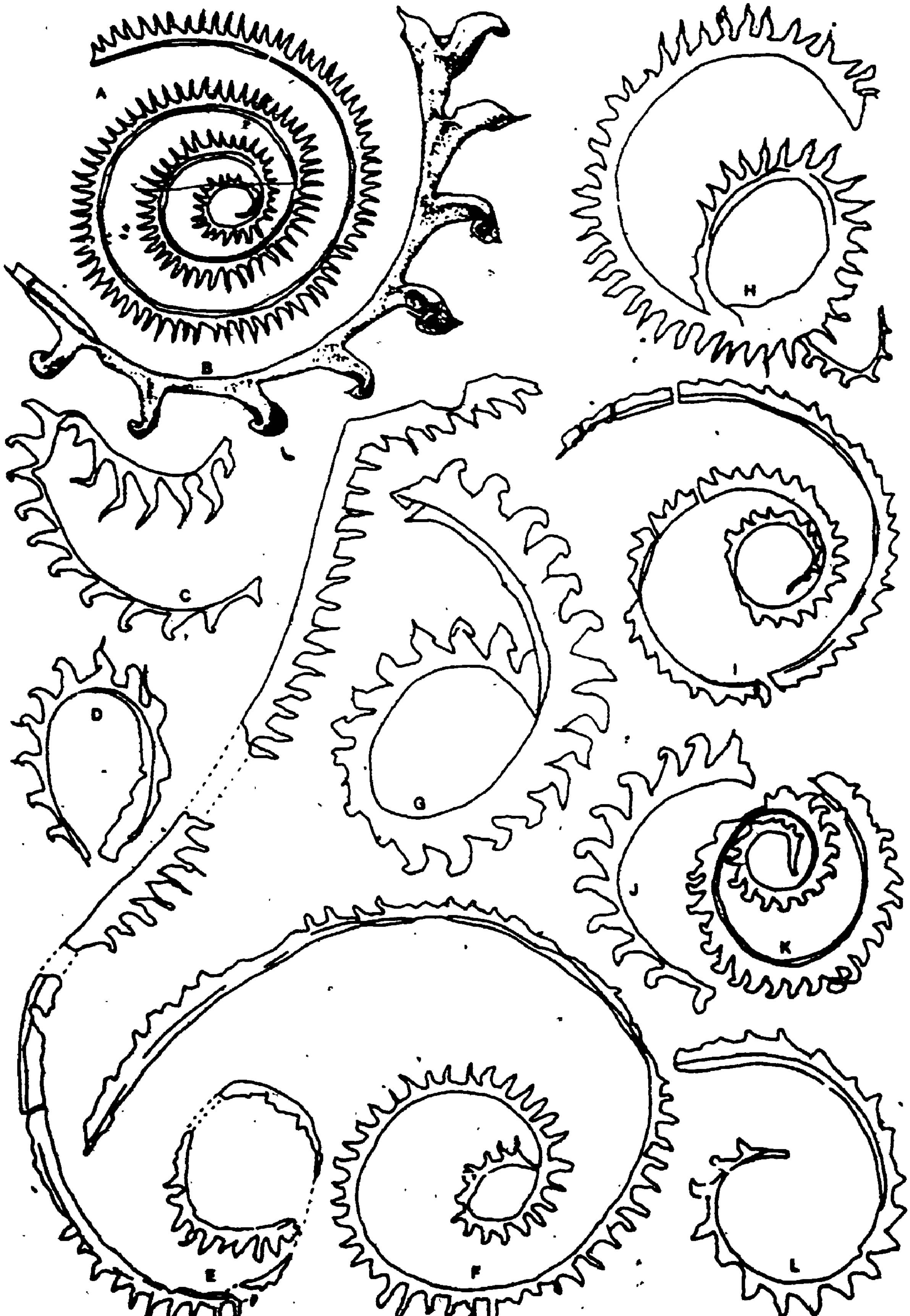
Text-figure 43

All figures x7.5 unless otherwise stated.

A-D,H. *Monograptus spiralis spiralis* (Geinitz): A) TC:49.5, x2; B) TF:123.5, x15; C) TC:52.5; D) TC:31.5, H) TF:123.5, x3.7.

E,F. *Monograptus spiralis excentricus* Bjerreskov: E) TC:42.5, x3.7; F) TC:42.0, x3.7.

G,I-L. *Monograptus spiralis contortus* Perner: G) HR:156.5; I) TF:71.0, 3.7; J) SC:210; K) HR:160.0, x3.7; L) TC:21.5.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124-126, pl. 2, fig. 9; pl. 3, figs 1-4.

1978 _Oktavites spiralis_ (Geinitz); Wang, p. 313, pl. 3, figs. 1,2.

1979 _Oktavites spiralis_ (Geinitz), Paškevičius, pp. 178-180, pl. 14, figs. 8 9; pl. 15, figs. 1,2; pl. 30, figs. 1-4.

1981 _Monograptus spiralis spiralis_ (Geinitz); Bjerreskov, pp. 47-48, pl. 6, fig. 4.

1982a _Monograptus spiralis_ (Geinitz); Lenz, pp. 111-112, figs. 9P; 32A-C,F.

Material. Hundreds of very well to poorly preserved, compressed and partial relief specimens.

Occurrence. _Turriculatus-crispus_ to lower _sakmaricus_ zones. Snowblind Creek at 375.0, 393.0, 396.0, 457.0, 460.0, 492.0, 522.5, 524.0, 526.0, 527.5, 528.0, 530.0, 534.2, 534.7, A2.0, A16.0 and A24.0m, Cape Phillips at 19.5, 55.0, 58.5, 81.0, 86.0, 127.0, 128.0, 129.0, 130.0 and 137.0m, Rookery Creek at 134.5, 139.5 and 162.0m, Twilight Creek at 25.5, 27.0, 28.5, 29.5, 30.5, 31.0, 31.5, 32.5, 34.0, 40.5, 43.5, 45.0, 46.0, 49.0, 49.5, 51.0, 52.5 and 54.5m, Middle Island at 59.0m, Trold Fiord at 96.0, 105.0, 114.0, 119.0, 123.0, 123.5, 125.0 and 133.0m, Huff Ridge at 254.0, 271.0, 272.0 and 274-280m and Irene Bay at 65.5, 68-72 and 69.0m.

Description. Rhabdosome subconcentrically coiled in a plane or low cone through up to at least 5 volutions. Proximal end somewhat more irregularly coiled. Widens from 0.5 to 0.65mm at th1 to a maximum of 2.2 to 3.3mm excluding apertural spine which may be up to 0.7mm long. Thecae spaced at 6 to 7 in the first 5mm, 9 to 10.5 in 10mm distally. Proximal thecae somewhat rastritid in appearance with slender prothecae and slightly triangular, hooked metathecae with a pair of small apertural spines. Distally, thecae become more triangular with shorter, more broad, triangular prothecae although overlap remains very slight. Examination of low relief specimens as well as uncompressed specimens from concretions shows that distally, thecae become increasingly asymmetrical as the aperture undergoes strong dextral torsion resulting in the unique, pointed thecal profile. One of the apertural spines points outward while the other is commonly hidden on compression. The sicula is 1.15 to 1.35mm long usually extending just beyond the aperture of th1.

Remarks. This well known and widespread species is one of the most common in the Llandovery of the Cape Phillips Formation. Work on the uncompressed specimens of this species referred to by Thorsteinsson (1958) and Lenz (1982a) is in progress and shows that the thecal morphology is unique, with strong metathecal asymmetry distally, although the proximal thecae appear to be much as they were illustrated by Sudbury (1958) and Rickards *et al.* (1977) (text-figure 43B). This may support retention of the genus *Oktavites* Levina (for which *M. spiralis* is the type species) although based on thecal rather than rhabdosomal morphology. The relationship of this species to others showing apertural torsion (e.g. *M. proteus*, *M. dextrorsus*) would need to be more clearly defined.

Monograptus spiralis contortus Perner, 1897

Text-figure 43G,I-L.

1897 *Monograptus planus* var. *contortus* Perner, p. 26, pl. 12, fig. 24.

1912 pars? *Monograptus spiralis* (Geinitz); Elles and Wood, pp. 475-476, pl. 48, figs. 7a,c (non 7b,d); text-fig. 331a (non 331b,c).

1944 *Spirograptus spiralis contortus* (Perner); Pribyl pp. 9-10, pl. 2, figs. 1-5; pl. 11, fig. 4.

1971 *Monograptus* (*Spirogr.*) *spiralis contortus* Perner; Schauer, p. 77, pl. 232, fig. 6; pl. 33, figs. 3,4.

1975 *Monograptus spiralis* aff. *contortus* Perner; Hutt, p. 107, text-fig. 25, figs. 1,4,6.

1978 *Oktavites spiralis contortus* (Perner); Wang, p. 313, pl. 4, fig. 1.

1982a *Monograptus spiralis* cf. *contortus* Perner; Lenz, pp. 112-115.

1984a *Oktavites spiralis contortus* (Perner); Chen, p. 69, pl.

14, figs. 6-9,11.

Material. Over a hundred very well to poorly preserved, compressed specimens.

Occurrence. Minor Zone. Snowblind Creek at 210m, Twilight Creek at 20.5, 21.5, 22.5 and 23.5m, Trold Fiord at 71.0m and Huff Ridge at 150.0, 156.5 and 160.0m.

Description. Spiral rhabdosome completes up to 2 1/2 whorls and may be at least 20mm in diameter although is commonly less than 15mm across. Thecae apparently oriented outward obliquely to the spiral plane although it may have spiralled in a low cone. Widens from about 0.5mm at th1 to a distal maximum of 1.5 to 1.9m. Thecae spaced 6 to 7.5 in 5mm proximally, 10 to 12 in 10mm distally. Proximal three to five thecae somewhat axially elongate, becoming broader, triangulate with retroverted apertures distally. A few specimens show traces of slender apertural spines. Sicula seen in a single specimen is 1.15mm long reaching to base of th2 metatheca.

Remarks. The present large populations of this species show the wide variation in range of width as well as form of the proximal end. Although the proximal end is only seen uncommonly in these collections, some specimens show the straight to slightly ventrally curved portion seen in the type specimen, while others appear to only show a weak dorsal curvature. Likewise the number of elongate thecae and their degree of elongation is somewhat variable. This variability can be attributed at least in part to variable modes of compression. The proximal end seems not to have been in the same plane of spiral as the subsequent whorl and therefore may undergo varying degrees of torsion on compression. Similar variability is seen in the proximal end of M. turriculatus whose proximal end clearly points away from the rest of the rhabdosome and is often distorted on compression.

As a result of the recognition of this wide variability, a number of previously reported occurrences only tentatively assigned to this subspecies can now be more confidently placed in this taxon (see synonymy).

This form differs from the type subspecies in having a lesser distal width, relatively broader distal thecae with less pronounced spines (usually not visible), closer thecal spacing and the slender, often differentially curved proximal end.

Monograptus spiralis excentricus Bjerreskov, 1975

Text-figure 43E,F.

1975 Monograptus spiralis excentricus Bjerreskov, p. 73, fig. 20G,H.

Material. Numerous well to poorly preserved, mesial to distal specimens.

Occurrence. Upper *griestoniensis* and lower *sakmaricus* zones. Cape Phillips at 85.0m, Twilight Creek at 42.0, 42.5, 43.5, 46.0 and 49.0m and Irene Bay at 67.0m.

Description. Rhabdosome forms open, eccentric coil up to 2 volutions, often undergoing torsion distally and showing variable ventral to dorsal curvature. Width is up to 2.0mm distally plus spines up to 0.4mm and thecae are spaced at 9 in 10mm, somewhat closer mesially. Thecae triangulate, hooked and strongly pointed, like those of *M. spiralis spiralis*. No proximal ends have been found in these collections.

Remarks. The present specimens match in all respects with the type material of Bjerreskov (1975). This subspecies differs from typical *M. spiralis* in the more eccentric, irregular spiral and the consistently lesser distal width. Otherwise the thecae of the two forms are very similar.

Monograptus sudburiae Hutt, 1974

Text-figure 44Q-S.

1958 *Monograptus revolutus* C, Sudbury, p. 536, fig. 26c.

1974a _Monograptus sudburiae_ Hutt, p. 198, text-fig. 1d.

1975 _Monograptus sudburiae_ Hutt; Hutt, pp. 107-108, pl. 14, fig. 8; pl. 16, fig. 5; text-fig. 23, figs. 7,8; text-fig. 27.

1975 _Monograptus sudburiae_ Hutt; Bjerreskov, pp. 52-53, pl. 8A.

Material. Five moderately to very well preserved, compressed specimens and a few more poorly preserved fragments.

Occurrence. _Orbitus_ Subzone. Trold Fiord at 63.0m.

Description. Rhabdosome at least 40mm long, moderately dorsally curved mesially, weakly so to straight proximally and distally. Widens from 0.3mm at the proximal end to a maximum of 0.8 to 0.9mm. Proximal thecae are spaced at about 3.5 in 5mm and are very elongate and hooked with little or no overlap. Distal thecae spaced at 9.5 to 11 in 10mm and are inclined at about 15^{o}, overlap about 1/3 their length, are weakly geniculate and have introverted apertures possibly with a small hood or lateral flanges. Change from elongate hooked to introverted thecae takes place in the region of maximum curvature over the space of about four thecae. Width also increases rapidly in this region. Sicula is not preserved.

Remarks. The present specimens match very well with those previously reported. The widths of the present specimens are slightly greater than those found by previous authors but this is the result of the fact that this material is compressed while that of Hutt (1974, 1975) and Bjerreskov (1975) is in low relief.

This species is distinguished from the *Monograptus austerus* group and *Monograptus* aff. *M. cygneus* by the introverted distal thecae and the rapid thecal widening in the mesial region. *Pribylograptus argutus* appears to have similar distal thecae but lacks the hooked proximal thecae.

Monograptus ex gr. *triangulatus* (Harkness, 1851)

Text-figure 44A-C.

Material. Eight compressed, poorly preserved specimens.

Occurrence. *Orbitus* Subzone and lower *convolutus* Zone. Trold Fiord at 62.5m and Huff Ridge at 121.0 and 124.5m.

Description. Rhabdosomes all very fragmentary and incomplete with moderate dorsal curvature. Width varies from 0.5mm to a maximum of 1.8mm. Thecae spaced at 21 to 16 in 10mm proximally to 10 to 12 in 10mm distally. Proximal thecae rastritiform, distally becoming triangulate, slender and with hooked aperture. Sicula is 0.65mm long.

Text-figure 44

All specimens x7.5 unless otherwise stated.

A-C. Monograptus ex gr. triangulatus (Harkness): A) HR:124.5; B) & C) TF:62.5.

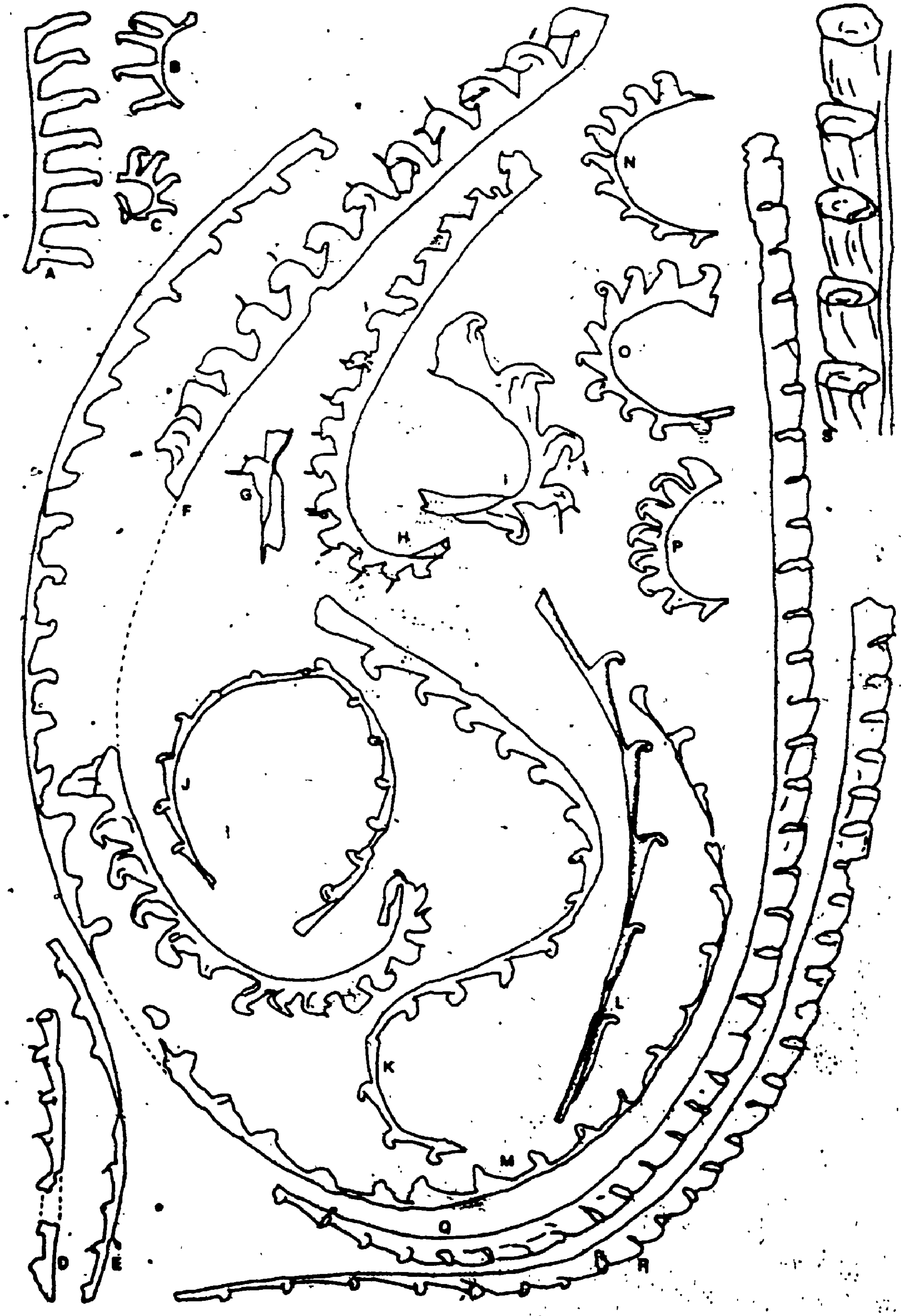
D,E. Monograptus cf. M. yichangensis Ni, both specimens from HR:15.5-16.0.

F-I. Monograptus n. sp. A: F) TF:63.0; G) CM:5-7, x15; H) CM:5-7; I) TF:63.0, x15.

J-M. Monograptus sp. (aff. M. tullbergi Bouček): J) TC:26.5; K) TC:32.5; L) uncompressed proximal end specimen, TC:29.5; M) TC:30.5.

N-P. Monograptus n. sp. D: N) TC:23.5; O) HR:160.0; P) TC:21.5.

Q-S. Monograptus sudburiae Hutt, all specimens from TF:63.0; S) x15.



Remarks. The presence of rastritiform proximal thecae and triangulate distal thecae with the characteristic rhabdosomal shape places these specimens within the *M. triangulatus* group. The poor state of preservation, however, prevents more accurate identification. The very high proximal thecal spacing is somewhat anomalous for species of this group.

Monograptus sp. (aff. *M. tullbergi* Bouček, 1931?)

Text-figure 44J-M.

Material. Several moderately to poorly preserved, compressed specimens.

Occurrence. *Crispus* to middle *griestoniensis* zones. Snowblind Creek at 396.0m, Twilight Creek at 27.0, 29.5?, 30.5 and 32.5m, Trold Fiord at 96.0 and 105.0m and Irene Bay at 65.5m.

Description. Rhabdosome up to at least 30mm long, weakly to moderately dorsally or ventrally curved, usually undergoing torsion mesially, occasionally twice. Widens gradually from a minimum of 0.45mm to 0.7 to 0.9mm distally. Thecae spaced at 7.5 to 9 in 10mm and are axially elongate, especially proximally where slender prothecae terminate in small, tight apertural hooks. Distally prothecae widen somewhat and show inclined ventral walls and metathecal hooks occupy about 1/2 the width. A few specimens show that metathecae may undergo some torsion. Apertures point more-or-less proximally to proximodorsally. No proximal ends are preserved but a few specimens show bipolar growth, apparently resulting from regeneration.

Remarks. The present specimens are mostly fragmentary and rather poorly preserved but show a somewhat unique combination of rhabdosomal and thecal features. The previously reported specimens which they seem to most closely resemble are those of *Monograptus tullbergi*? reported by Bjerreskov (1975). They show a similar thecal form, width and thecal spacing (possibly including the thecal torsion) but the rhabdosome is much more loosely and irregularly curved.

Monograptus crispus shows some similarities in the rhabdosomal form but its thecae are more strongly lobate, it widens more rapidly in the mesial region and is usually more strongly curved. Distal fragments may be confused for poorly preserved specimens of *M.* "*nodifer*" which has a somewhat similar thecal profile and width but the latter has more strongly lobate thecae and is ventrally curved throughout.

Monograptus turriculatus turriculatus (Barrande, 1850)

Text-figure 45B,F,G.

1850 Graptolithus turriculatus Barrande, pp. 56-57, pl. 4, figs. 7-11.

1912 Monograptus turriculatus (Barrande); Elles and Wood, pp. 438-439, pl. 44, fig. 4a-e.

1965 Spirograptus turriculatus (Barrande): Obut and Sobolevskaya, pp. 80-81, pl. 14, figs. 2,3.

1967 Spirograptus turriculatus (Barrande); Obut and Sobolevskaya, pp. 115-116, pl. 16, fig. 4.

1970 Monograptus turriculatus (Barrande); Rickards, p. 77.

1971 Monograptus (Spirogr.) turriculatus turriculatus (Barrande); Schauer, p. 74, pl. 30, figs. 1-5; pl. 31, figs. 11-13; pl. 45, figs. 1-3.

1974 Monograptus turriculatus (Barrande); Sherwin, pp. 172-173, p. 12, fig. 6.

1975 Monograptus turriculatus (Barrande); Bjerreskov, pp. 70-71, pl. 10H.

1975 Monograptus turriculatus (Barrande); Hutt, pp. 111-112, text-fig. 22, figs. 9,10.

1975 Spirograptus turriculatus (Barrande); Obut and Sobolevskaya, p. 174, pl. 34, figs. 4,5.

1976 Spirograptus turriculatus (Barrande); Sennikov, pp. 192-194, pl. 13, figs. 2-4.

1978 Spirograptus turriculatus (Barrande); Wang, p. 311, pl. 3, fig. 9.

Text-figure 45

All figures x7.5 unless otherwise stated.

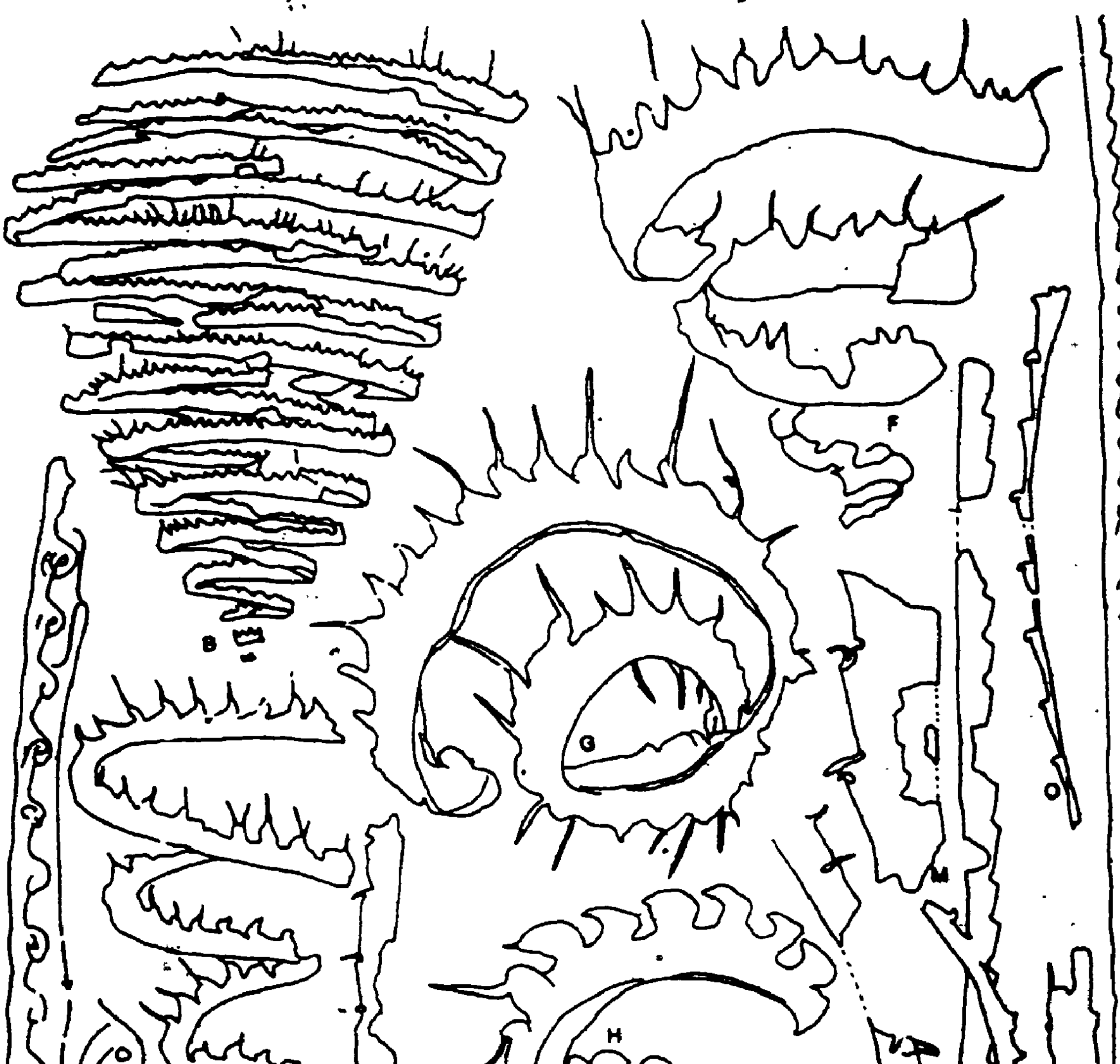
A. *Monograptus* n. sp. C, A2 is an enlargement of the two distal thecae, x15, TC:15.0.

B,F,G. *Monograptus turriculatus turriculatus* (Barrande): B) TC:26.0, x2; F) & G) TF:79.0.

C-E,G. *Monograptus turriculatus minor* Bouček: C) HR:175.0; D) HR:156.5; E) & H) HR:156.5, x15.

I,J,M-Q. *Monograptus* n. sp B: I) & P) CM:5-7; J), N) & O) CM:2-5; M) CM:2-5, x15; Q) SC:140, x3.7.

K,L. *Monograptus* n. sp. B?, both specimens from CM:5-7; K) x 15.


B
F
G
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A1
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L
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Q

1978 Spirograptus turriculatus (Barrande); Ye, p. 481, pl. 179, fig. 11.

1979 Spirograptus turriculatus (Barrande); Paškevičius, pp. 175-176, pl. 14, fig. 5; pl. 29, figs. 16-18.

1982a Monograptus turriculatus (Barrande); Lenz, pp. 118-121, figs. 9N; 32D,E,G; 33A-C.

1984a Spirograptus turriculatus (Barrande); Chen, pp. 70-71, pl. 15, figs. 9,10; pl. 16, figs. 1,2.

1986 Monograptus turriculatus (Barrande); Melchin and Lenz, pp. 579-581, fig. 1a-i.

Material. Numerous well to poorly preserved compressed specimens.

Occurrence. Turriculatus to crispus zones. Twilight Creek at 24.5, 26.0 and 26.5m, Middle Island at 35.0m, Trold Fiord at 74.0 and 79.0m and Huff Ridge at 193.0m.

Remarks. The details of the thecal form and proximal end of this species have been elucidated by Melchin and Lenz (1986) from study of uncompressed specimens from the Cape Phillips Formation. It is worth adding that the largest specimens found in the compressed material complete at least 12 volutions and have a distal stipe width of up to 2.7mm and thecae spaced at 12.5 to 14.5 in 10mm distally. The longest apertural spines found here are 2.6mm long and no unequivocal examples of distally bifurcating spines have been found as reported by Hutt (1975).

It also noteworthy that M. *turriculatus minor* is recognizable as a separate subspecies in the Cape Phillips collections (see description below). The latter form not only reaches a smaller maximum size and width but is also narrower and has more closely spaced thecae at any given point along the rhabdosome (except the proximal end which is similar to the type subspecies). For example, at the level of about the fifth whorl, M. *turriculatus turriculatus* has a width of about 1.5 to 1.8mm and a thecal spacing of about 14 to 15 in 10mm while M. *turriculatus minor* reaches a maximum width of only 0.8 to 0.9mm and a thecal spacing of 18 to 20 in 10mm by the fifth whorl. This distinction is not considered enough to merit recognition of separate species but rather they are considered to be temporal subspecies.

Study of the thecae in uncompressed form has revealed that except for a slight apertural asymmetry, the thecae do not differ significantly from those of other *Monograptus* s.s. species and recognition of a separate genus for these forms is not considered justified.

Monograptus turriculatus minor Bouček, 1932

Text-figure 45C-E,H.

1932 *Monograptus turriculatus* mut. *minor* Bouček, pl. 153, text-fig. 1c,d.

1965 *Spirograptus minor* (Bouček); Obut and Sobolevskaya, pp.

79-80, pl. 14, fig. 1.

1967 Spirograptus minor (Bouček); Obut and Sobolevskaya, pp. 116-117, pl. 16, fig. 5.

1971 Monograptus turriculatus minor Bouček; Schauer, pp. 74-75, pl. 30, figs. 7,8; pl. 31, figs. 7-9.

1975 Spirograptus minor (Bouček); Obut and Sobolevskaya, p. 174, pl. 34, fig. 6.

1976 Spirograptus minor (Bouček); Sennikov, pp. 194-196, pl. 13, figs. 5-7.

1978 Spirograptus minor (Bouček); Wang, pp. 311-312, pl. 1, fig. 7.

1978 Spirograptus minor (Bouček); Ye, p. 481, pl. 179, fig. 10.

1979 Spirograptus minor (Bouček); Paškevičius, pp. 177-178, p. 14, figs. 6,7; pl. 29, fig. 19.

1984a Spirograptus minor (Bouček); Chen, p. 71, pl. 16, figs. 5,8,13.

Material. Over one hundred very well to poorly preserved, compressed specimens.

Occurrence. Minor and turriculatus zones. Twilight Creek at 21.5, 22.5, 23.5 and 24.5m, Trold Fiord at 71.0m, Huff Ridge at 156.5, 158.0, 160.0, 169.0, 171.5, 175.0, 177.5 and 178.5m and Irene Bay at 65m (loose).

Description. Rhabdosome forms tight conical spiral, completing up to 6 whorls. Stipe widens from 0.45 to 0.6mm at th1 to a maximum of 0.8 to 1.1mm. Thecae spaced at 10 to 11.5 in 5mm proximally, 17.5 to 20 in 10mm distally and are hooked with retroverted apertures which bear one or a pair of lateral apertural spines up to at least 0.5mm long. Sicula 0.9 to 1.1mm long and reaches to near the apex of th1.

Remarks. The close similarity between this subspecies and *M. turriculatus turriculatus* in compressed form suggests that the thecal structure is also similar. As noted above, this form is considered a temporal subspecies of *M. turriculatus* distinguished by its consistently smaller size, narrower width and closer thecal spacing throughout its length.

The smaller specimens of *M. turriculatus* illustrated by Elles and Wood (1912, pl. 44, figs. 4c,d) have been considered by many previous workers (see synonymy above) to be specimens of *M. turriculatus minor*. However, those illustrations seem to show that even by the early whorls, the width and thecal spacings had reached values greater than those typical of *M. turriculatus minor* and so they appear to be simply small specimens of *M. turriculatus turriculatus*. This is in accord with the contention of Hutt (1975) and others that *M. turriculatus minor* is not recognizable as a distinct subspecies in Britain.

Monograptus cf. M. yichangensis Ni, 1978

Text-figure 44D,E.

Material. Two rather poorly preserved, compressed specimens.

Occurrence. Upper convolutus Zone. Twilight Creek at 15.5-16.0m

Description. Rhabdosomes fragmentary, up to 9mm long, with weak ventral curvature. Thecae from 0.4 to 0.65mm wide spaced at 9.5 to 10 in 10mm. Thecae axially elongate with slightly inclined, straight ventral walls and a low, hooded metatheca. Aperture appears to face proximally. Hood apparently laterally expanded with a pair of short spines. No proximal ends are preserved.

Remarks. The thecal shape and rhabdosomal form of the present specimens appears to be identical to that of Monograptus yichangensis Ni (1978), although it is not clear if the latter bears apertural spines. The Canadian specimens are slightly wider distally and have a slightly closer thecal spacing so a positive assignment cannot be made on this rather poorly preserved material. Most other slender, hooked monograptids with ventral curvature have a much more strongly hooked to lobate metatheca (e.g. Monograptus exiguus (Nicholson)) and most lack apertural spines.

Monograptus n. sp. A

Text-figure 44F-I.

Material. Numerous compressed specimens, very well to poorly preserved.

Occurrence. *Curtus* and upper *convolutus* zones. Cape Manning at 0-5m, Trold Fiord at 63.0m, Huff Ridge at 126.0 and 128.0m and possibly Twilight Creek at 15.5 to 16.0m.

Description. Rhabdosome moderately dorsally curved proximally, weakly so distally. Widens gradually from 0.4 to 0.7mm at th1 to a maximum of 1.0 to 1.3mm. Thecae spaced at 5.5 to 7 in the first 5mm and 8 to 10 in 10mm distally. Thecae triangular and hooked with retroverted apertures. Proximal thecae are slightly more elongate than distal ones. Aperture is expanded laterally into a pair of spines up to at least 0.4mm long. Thecal overlap is very slight, interthecal septa appear to be absent. Sicula 0.9 to 1.15mm long, reaching to about the base of th2. Theca 1 originates at about 0.3mm above the base of the sicula. Virgella is about 0.2mm long..

Remarks. This new species is very similar to *Monograptus millepeda* (M'Coy) except that it bears a pair of lateral apertural spines on each theca. Otherwise the thecal shape, spacing and dimensions are very similar. Ni (1978) reported a similar, spinose species, Oktavites spinatus which has lower, more elongate thecae and a more gently curved proximal end.

Monograptus n. sp. B

Text-figure 45I,J,K?,L?,M-Q.

Material. Hundreds of well to poorly preserved, compressed specimens, all fragmentary.

Occurrence. Curtus and convolutus zones. Snowblind Creek at 140 and 170m, Cape Manning at 0-7m, Truro Island at 49.0m, Trold Fiord at 61.0 and 62.5m and Huff Ridge at 117.0, 118.5, 121.0, 124.0, 124.5 and 126.0m.

Description. Rhabdosome up to at least 95mm long, weakly to moderately dorsally curved mesially, weakly so proximally, becoming straight distally. Widens very slowly from 0.2 to 0.3mm proximally to 0.8 to 1.1mm in the mesial region (excluding hoods) to a distal maximum of 1.0 to 1.4mm. Proximal 8 to 15 thecae are slender, axially elongate, with small apertural hooks. In the mesial region, prothecae broaden, with inclined ventral walls (at 10 to 25°) and hook gradually retreats into a pronounced hood, formed by the dorsal wall, which is usually 0.3 to 0.5mm long (although it may protrude as much as 0.7mm). Three small fragments probably assignable to this species from Cape Manning show that the hood may actually be an open loop. Further distally, as the degree of curvature decreases, the hood retreats and is only represented by small hooks which appear to originate from the lateral margins of the apertures. In the straight distal portions, this, too, disappears and the thecae form simple, slightly geniculate tubes, inclined at about 15°, with everted apertures and about 1/3 overlap. Sicula is 0.8 to 1.1mm long and extends about 2/3 along the length of th1.

Remarks. In the absence of complete specimens the complete range of thecal variation along the length of this species can only be recognized within a sizable population containing several long fragments which show at least part of the mesial portion and either the proximal or distal ends. The proximal and early mesial portions of this species bear a strong resemblance to Monograptus revolutus Kurck but that species has introverted and/or hooded distal thecae (Hutt, 1974a; Bjerreskov, 1975). The specimens assigned to Pernerograptus revolutus by Chen and Lin (1978) and Chen (1984a) appear to have nearly pristiograptid distal thecae with simple apertures and those specimens may be conspecific with the present material.

This species also closely resembles members of the Monograptus austerus group (see Hutt, 1974a) but none of these forms show the development of pronounced hoods, loops or lateral hooked lappets on the mesial thecae and the distal thecae tend to show greater overlap and are not geniculate. However, the overall similarities suggest that this new species is a close relative of M. austerus.

Monograptus falcata (Chen and Lin) has a similar proximal end and weak hoods on the mesial thecae but the ventral walls of the mesial prothecae and the distal thecae are more nearly parallel to the rhabdosomal axis and the distal thecae show a distinctly monoclimacid appearance. In addition, the thecal change in the mesial region takes place much more quickly.

Distal fragments bear a strong resemblance to those of Pristiograptus nudus although they tend to be slightly narrower.

Monograptus n. sp. C

Text-figure 45A.

Material. Two well preserved specimens in low relief and several moderately to poorly preserved, compressed specimens.

Occurrence. Upper convolutus Zone. Twilight Creek at 15.0m.

Description. Rhabdosome up to at least 30mm long with a slight ventral curvature. Widens from a minimum of 0.5mm to a maximum of 0.8mm. Thecae spaced at 9.5 to 8.5 in 10mm and are lobate in profile with dorsally facing apertures and rather long, triangular prothecae. Metathecae occupy a greater proportion of the width distally, up to 1/2. No clear proximal ends have been found.

Remarks. The thecae of the present specimens bear a very strong resemblance to the proximal and mesial thecae of Monograptus lobiferus (M'Coy) (e.g. Hutt, 1975, text-fig. 24, fig. 4). Despite the presence of distal fragments up to 30mm long, however, the characteristic, "tall" distal thecae are not found in this species. The thecae of M. lobiferus harpago Törnquist are also wider and do not appear to be as strongly hooked.

Monograptus exiguus (Nicholson) and M. pseudobecki Bouček and Přibyl are both similar to this species but differ in that the ventral prothecal walls are parallel rather than inclined. In addition, M. exiguus in more strongly curved and has more closely spaced thecae while M. pseudobecki has a narrower proximal end, no sign of which is seen in this collection.

Monograptus n. sp. D

Text-figure 44N-P.

1982a ? Monograptus cf. millepeda (M'Coy); Lenz, fig. 25G.

Material. Six moderately to very well preserved, compressed specimens.

Occurrence. Minor Zone. Twilight Creek at 21.5, 22.5 and 23.5m and Huff Ridge at 160.0m.

Description. Rhabdosome up to 7mm long with moderate to strong dorsal curvature. Widens from 0.45 to 0.5mm at th1 to a maximum of 0.9 to 1.15mm. Thecae spaced at 6 in 5mm at the extreme proximal end but this increases to 7 to 9.5 in 5mm distally. Proximal thecae somewhat elongate-triangular with hooked apertures. Distal thecae strongly triangulate, almost isolate, with strongly hooked apertures. Metathecae occupy 3/4 to 4/5 the total width and are near perpendicular to rhabdosomal axis. Sicula 1.0mm long and reaches to apex of th1.

Remarks. This new species is strongly reminiscent of the earlier occurring Monograptus millepeda but it differs in that the metathecae are more nearly parallel sided and occupy a greater proportion of the total width and the proximal thecae are more elongate, more similar to those of M. communis. The distal thecae, in fact, bear some resemblance to those of M. pectinatus but have more strongly hooked apertures. This from differs from all of the above species in the very close distal thecal spacing and, as far as presently known, the small rhabdosomal size (although this may be an artifact of preservation).

Monograptus cf. *millepeda* illustrated by Lenz (1982a), from the *turriculatus* Zone, resembles the present specimens in all respects except that the distal thecal spacing is only about 6 in 5mm, lower than in any found here. For this reason, the two are only tentatively considered synonymous.

Genus *Rastrites* Barrande, 1850

Type species. *Rastrites peregrinus* Barrande, 1850.

Rastrites approximatus approximatus Perner, 1897

Text-figure 46A-C.

1897 *Rastrites peregrinus* v. *approximatus* Perner, p. 15, pl. 13, figs. 36-40, ?42, ?43.

1941 *Rastrites approximatus approximatus* Perner; Přibyl, pp. 7-8, pl. 1, figs. 6,7; pl. 2, figs 9,10.

1967 *Rastrites approximatus approximatus* (Perner); Obut and Sobolevskaya, pp. 130-131, p. 19, figs. 1,2.

1967 *Rastrites approximatus approximatus* Perner; Schauer, p. 177,

1978 *Rastrites approximatus* Perner; Chen and Lin, p. 68, pl. 18, figs, 1-3.

1982a *Rastrites approximatus* Perner; Lenz, pp. 122-123, figs. 10C,I,J; 34A,B,D,F,G.

Text-figure 46

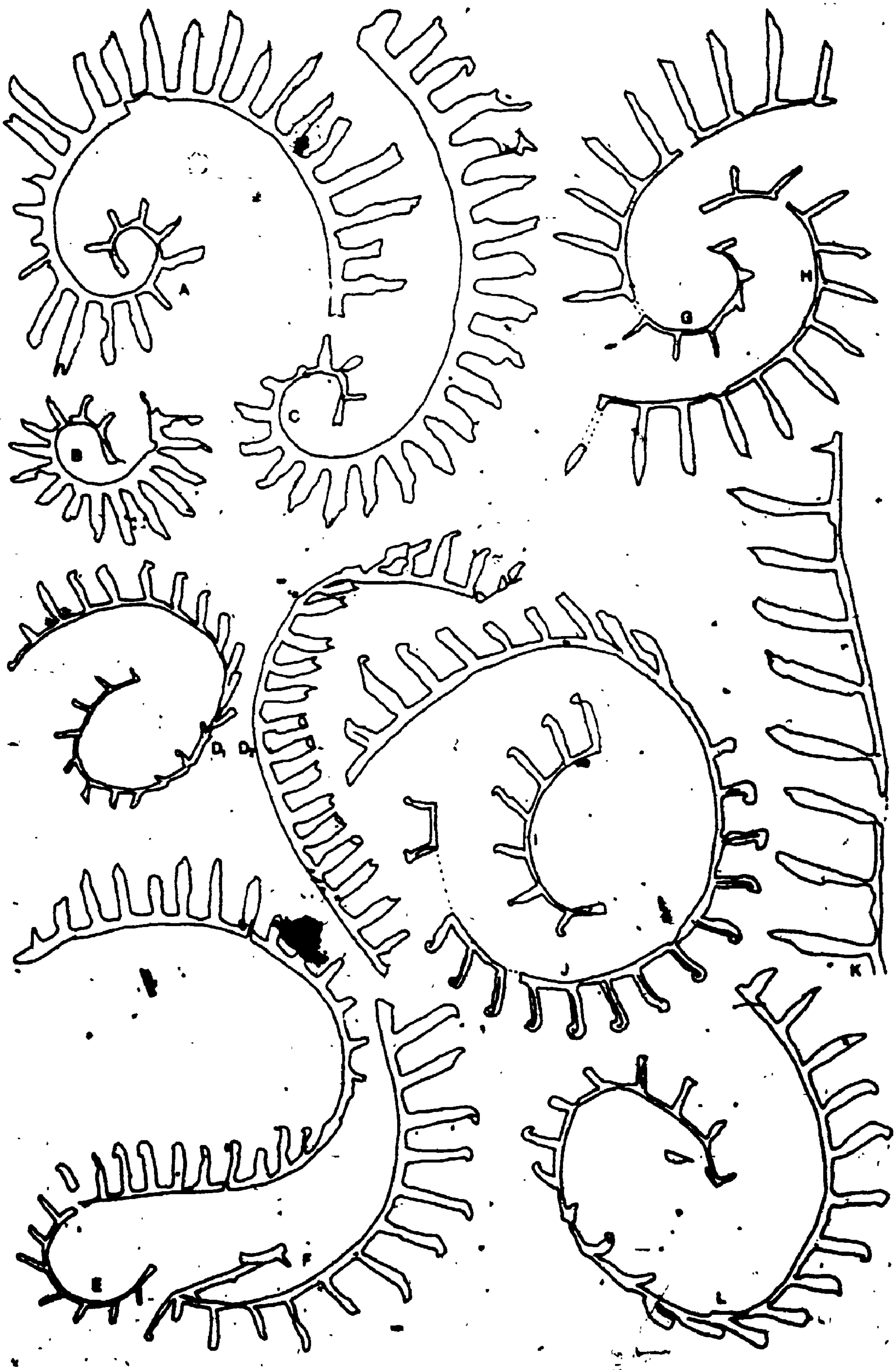
All figures x7.5 unless otherwise stated.

A-C. Rastrites approximatus approximatus Perner: A) TF:61.0; B) & C) CM:2-5.

D-F. Rastrites n. sp.: D) proximal and distal portions, probably of same specimen, TF:62.5; E) & F) TF:63.0.

G,H,K. Rastrites longispinus n. subsp., all specimens from TF:62.5.

I,J,L. Rastrites orbitus Churkin and Carter: I) & J) TF:63.0; L) TF:62.5.


A
B
C
D_1 D_2
E
F
G
H
J
K
L

Material. About 15 moderately well preserved, compressed specimens and numerous more poorly preserved specimens.

Occurrence. Pectinatus Subzone. Trold Fiord at 61.0 and 62.5m and Cape Manning at 2 to 5mm.

Description. Rhabdosome up to at least 20mm long, tightly dorsally curved proximally, more weakly so distally, completing up to at least one and one half volutions. Widens from 0.5 to 0.8mm at th1 to a maximum of 2.0 to 2.5mm. Thecae spaced at 7.5 to 10 in 5mm at the extreme proximal end to 11 to 16 in 10mm distally. Thecae are oriented perpendicular to the stipe axis, proximally they are fairly slender but distally they become rather stout, generally 0.35 to 0.5mm wide, and pointed at their apertures. Sicula 0.6 to 0.8mm long, reaching to or just below the tip of th1.

Remarks. The present specimens match very well with those of Lenz (1982a) and differ from those of Pribyl (1941b) only in that the thecae are broader, 0.35 to 0.5mm rather than 0.3mm. Lenz pointed out that most of his material occurred in stratigraphically older beds than in Europe and the same can be said of the Arctic specimens. It is possible that the Canadian populations represent an older subspecies with broader thecae.

This species differs from Monograptus triangulatus

triangulatus (Harkness) in that the thecae are more closely spaced and appear to be parallel sided rather than triangular. These two forms are, however, very similar.

Rastrites longispinus n. subsp.

Text-figure 46G,H,K.

Material. About ten moderately well preserved, compressed specimens and several more poorly preserved fragments.

Occurrence. Pectinatus Subzone. Cape Manning at 0 to 2m and Trold Fiord at 62.5m.

Description. Rhabdosome up to at least 17mm long (incomplete) with moderate dorsal curvature proximally, becoming straight distally. Widens from about 0.7mm at th1 to 2.2 to 2.8mm distally. Thecae spaced at 11 to 14 in 10mm proximally to 7 to 11 in 10mm distally and are slender with evidence of fine apertural spines. Proximal thecae are perpendicular to the stipe axis, distally they are somewhat inclined. Proximal details cannot be discerned.

Remarks. Although the present specimens are mostly fragmentary, the distinctive features of this species can be seen. The only ways in which this new subspecies differ from the type is that its maximum width is lower and the distal thecal spacing is, at least in some specimens, higher.

Rastrites orbitus Churkin and Carter, 1970.

Text-figure 46I,J,L.

1970 *Rastrites orbitus* Churkin and Carter, p. 45, pl. 4, figs. 18,19; text-fig. 19A,B.

1978 *Rastrites leiboensis* Ye, pp. 484-485, pl. 181, figs. 6,7.

1982a *Rastrites orbitus* Churkin and Carter; Lenz. pp. 130-132, figs. 11C,D,?E;37E,F,?C.

Material. About fifteen moderately well preserved, rhabdosomes and numerous more poorly preserved fragments.

Occurrence. *Orbitus* subzone and lower *convolutus* Zone. Snowblind Creek at 140m, Cape Manning at 2 to 5m, Trold Fiord at 62.5 and 63.0m and Huff Ridge at 121.0, 122.0, 124.0 and 124.5m.

Description. Rhabdosome up to at least 28mm long, with moderate dorsal curvature throughout forming a nearly circular shape. Most complete specimen undergoes one and one half volutions. Rhabdosome may spiral in a low cone as suggested by the irregular compression of the proximal portions of some specimens and the mesial thecae of others.

widens from 0.6 to 0.7mm at the proximal end to a maximum of 1.2 to 1.8mm. Thecae spaced at 5 to 6.5 in 10mm proximally decreasing to 7.5 to 11 in 10mm distally. Thecae are fairly slender with a distinct apertural hook and are somewhat inclined toward the distal end. Sicula indistinct but appears to be 0.7mm long.

Remarks. The more or less circular rhabdosome and the relatively short, slender, hooked thecae are the distinctive features of this species. A high degree of variability of both thecal spacing and maximum width has also been reported by both Churkin and Carter (1970) and Lenz (1982a). The somewhat irregular compression patterns of the thecae was also illustrated by the type material (Churkin and Carter, 1970, pl. 4, fig. 19) where the thecae are not all flattened radially and by a specimen labelled R. cf. orbitus (Lenz, 1982a, figs. 11E, 37C) which shows apparent sigmoidal curvature. The latter specimen is most likely an irregularly compressed specimen of R. orbitus.

Norford (in Norford and Orchard, 1985) reported specimens which he referred to Monograptus triangulatus var. cf. M? triangulatus? orbitus since the distal thecae on his specimens are triangular and judged, from the illustrations of Churkin and Carter, that those may be as well. None of the thecae on the present specimens or those of Lenz bear triangular thecae and none of the type specimens clearly show triangular thecae either. The specimens of Norford do, however, bear a close resemblance to specimens assigned here to Monograptus decipiens decipiens Trnquist which has 6 to 9 proximal, rastritiform thecae and gradually widening, triangulate thecae distally, as well as similar dimensions to Norford's specimens.

Rastrites n. sp.

Text-figure 46D-F.

Material. Five moderately well preserved, compressed specimens and several more poorly preserved fragments.

Occurrence. Orbitus Subzone. Cape Manning at 2 to 5m and Trold Fiord at 62.5 and 63.0m.

Description. Rhabdosome up to 33mm long, moderately dorsally curved proximally with variable dorsal to ventral curvature distally. Holotype "S"-shaped but this may be an artifact of compression of a conical spiral rhabdosome. Widens from 0.6mm at th1 to a maximum of 2.1 to 2.3mm. Thecae spaced at 10 to 11.5 in 10mm proximally and mesially and 9 to 10 in 10mm distally. Proximal and mesial thecae fairly slender with a distinctly hooked aperture. Distal thecae somewhat more robust, generally 0.5mm wide. Apertures appear to face proximally with the dorsal wall forming a slight hood. This appears on most specimens as the thecae coming to a point. Sicula 0.7mm long reaching to the base of the first metatheca.

Remarks. The proximal thecae of this new species resemble those Rastrites orbitus Churkin and Carter but the rhabdosome widens more quickly to a greater maximum width and the distal thecae are not hooked.

Rastrites phleoides Törnquist can have a similar rhabdosomal form and dimensions but its distal thecae bear a distinct pair of apertural spines and the proximal and mesial thecae are longer, more slender and more closely spaced (Hutt, 1975).

The distal thecae of R. rastrum (Richter) appear to be very similar but are commonly more closely spaced, and the rhabdosomal form appears to be simpler.

Genus Cyrtograptus Carruthers, 1867

Type species. Cyrtograptus murchisoni Carruthers, 1867.

Remarks. A high degree of morphologic variability is now known to exist among latest Llandovery (and lowest Wenlock) Cyrtograptus species and much of that variability is seen among the Canadian Arctic collections. This variability, however, is manifest largely in the rhabdosomal form - degree and rate of coiling, distal torsion, cladial number and spacing and overall size and width. Thecal form, however, on close examination seems to be very consistent

7

1.0 4.5 2.8 2.5
3.2 2.2
3.6
4.0 2.0
1.1
1.8
1.25 1.4 1.6

within the genus, showing only minor variations in prothecal/metathecal proportions, degree of metathecal hooking and possibly asymmetry as well as width and spacing. The thecal differences between Cyrtograptus species seems to be much less than between other Late Llandovery "spirograptids" (e.g. M. spiralis, M. proteus, M. turriculatus, etc.) many of which show much more complex and apparently highly specialized thecal forms. Uncompressed specimens of M. spiralis recovered from Cape Phillips concretions show that the distal thecae show a very high degree of metathecal torsion and asymmetry with an elongate outer apertural margin which gives the elongate, pointed thecal form on compression. None of the known Cyrtograptus species, known from well preserved compressed specimens as well as some uncompressed fragments, shows nearly this degree of thecal specialization and casts into doubt the possibility that M. spiralis might be an ancestor to some Cyrtograptus species as previously suggested (cf. Rickards et al., 1977) despite rhabdosomal similarities. In fact, the high degree of thecal uniformity within this early group indicates that they may all be derived from a single Monograptus species or species group. The various lineages within the genus outlined by Rickards et al. (1977) and Liu (1985) may, then, have arisen within this group by making minor changes in coiling rate, timing of cladial generation and thecal size and proportions.

Cyrtograptus cf. *C. lapworthi lapworthi* Tullberg, 1883

Text-figure 47A-D.

Material. About fifteen well to poorly preserved, compressed specimens.

Occurrence. *Sakmaticus* Zone. Snowblind Creek at 528.0m, Cape Becher at 2.0 and 27.0m and Trold Fiord at 119.0, 123.0 and 133.0m.

Description. Rhabdosome up to about 25mm long, moderately to tightly coiled, often sharply bent proximally. Weakly curved distally. A single cladium present, apparently about 15 to 20 thecae from the proximal end although no complete proximal specimens with cladia are preserved. Rhabdosome undergoes torsion beyond the cladium so that distal thecae are on the lateral to ventral side. Widens quickly from 0.6 to 0.85mm at th1 to a maximum of 1.2 to 1.5mm; thecae are spaced at 5.5 to 6.5 in 5mm proximally and 9.5 in 10mm distally. Thecae like those of *C. lapworthi lapworthi* and *C. lapworthi* n. subsp. (described below). Sicula is 1.3 to 1.5mm long reaching to below the tip of th2.

Remarks. The present specimens match with *C. lapworthi lapworthi* in all respects except that the proximal end seems to be more strongly curved and is often sharply bent at

Text-figure 47

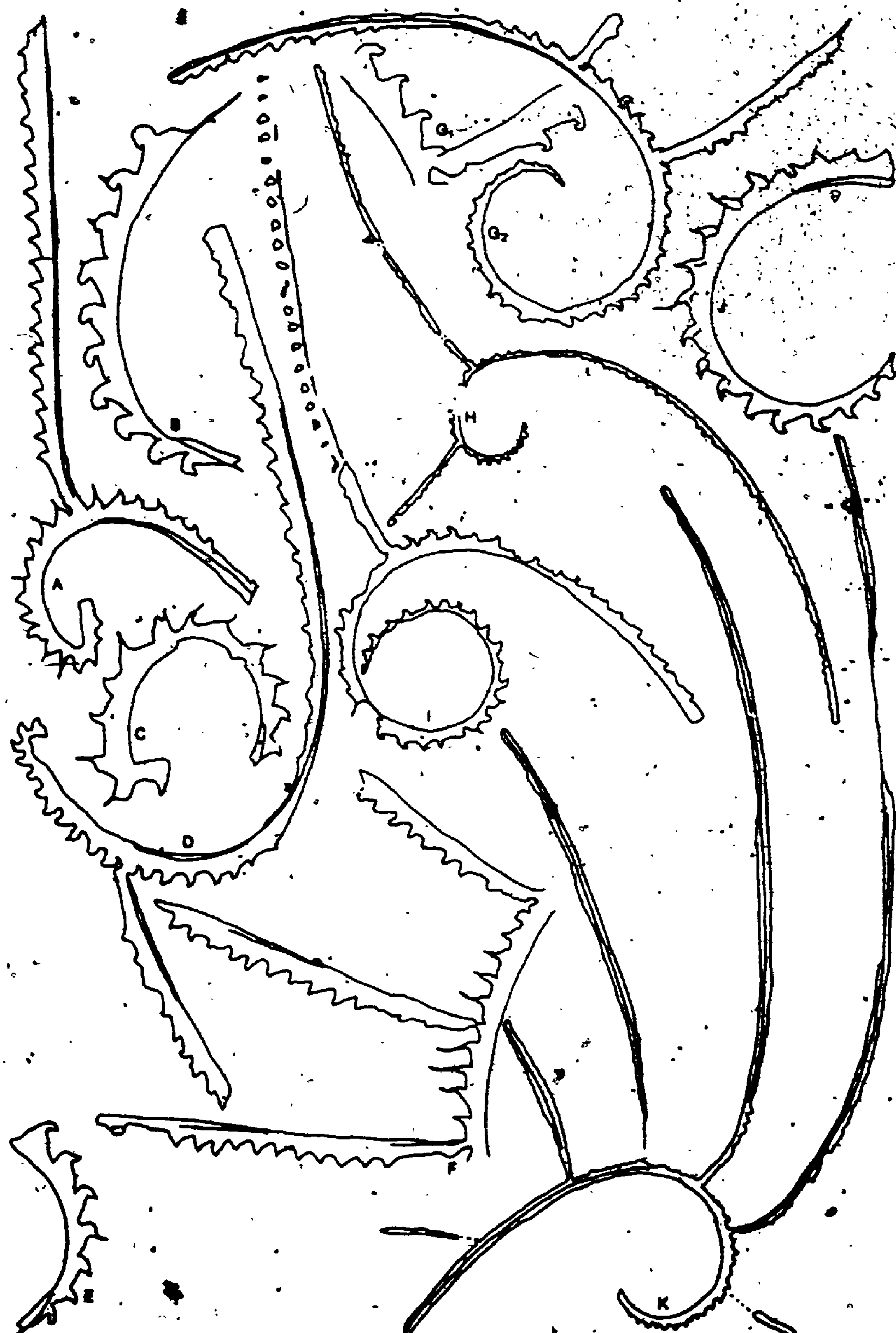
All figures x7.5 unless otherwise stated.

A-D. *Cyrtograptus* cf. *C. lapworthi lapworthi* Tullberg: A) TF:119.0, x3.7; B) TF:133.0; C) & D) SC:528.0m, D x3.7.

E. *Cyrtograptus polyrameus* Fu and Song?, TC:54.5.

F,K. *Cyrtograptus polyrameus* Fu and Song: F) TC:54.5; K) SC:525.0.

G-J. *Cyrtograptus lapworthi* n. subsp.:G) G2, enlargement of thecae and cladium; G1 x3.7; H) TC:55.5, x2; I) CP:151.0, x3.7; J) TC:52.5.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B
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G1
G2
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K

about th5 to 10. This is obviously a preservational feature but may be indicative of some conical spiralling at the proximal end, perhaps more than is typical of *C. l. lapworthi*. More complete specimens preserving both the proximal end and the cladium would be necessary to determine if this is simply a preservational variation or if it represents a unique taxon.

These specimens differ from those of *Cyrtograptus lapworthi* n. subsp. in that the proximal end is shorter, and less attenuated, being wider at the early thecae. The new subspecies of *C. lapworthi* also does not show the sharp bend in the early coiling seen in these specimens.

Cyrtograptus lapworthi n. subsp.

Text-figure 47G-J.

1975 *Cyrtograptus* aff. *C. lapworthi* Tullberg; Berry and Murphy, pp. 85-86, pl. 10, fig. 1; text-fig. 22c.

1978 *Cyrtograptus* aff. *lapworthi* Tullberg; Lenz, p. 629, pl. 1, fig. 2; pl. 2, figs. 3,5,6; text-fig. 2, fig. 7.

Material. Numerous well to poorly preserved compressed specimens.

Occurrence. *Sakmaricus* Zone. Snowblind Creek at A2.0 and A16.0m, Cape Phillips at 127.0, 137.0, 151.0, 158.0 and 159.5m, Twilight Creek at 51.0, 52.0, 52.5, 55.5, 57.0, 59.0, 60.0 and 61.5m, Middle Island at 52.0 and 64.0m, Cape Becher at 5.0 and 17.0m, Trold Fiord at 140.5, 143.0 and 146.0m, Irene Bay at 68-72 and 69.0m, possibly Huff Ridge at 271.0m.

Description.— Rhabdosome up to about 65mm long, coiled through one rather tight volution proximally, becoming loosely curved distally. One or two cladia present, the first arising between the fifteenth and thirtieth theca, the second six to eight thecae later. Proximal end widens gradually from 0.45 to 0.6mm to a maximum of 1.0 to 1.4mm. Thecae spaced at 5 to 6.5 in 5mm proximally, 8.5 to 10 in 10mm distally and have low, triangular prothecae and moderately (proximally) to weakly (distally) hooked metathecae with proximally facing apertures. Sicula is 1.2 to 1.25mm long and reaches to just before the aperture of th2.

Remarks. As noted by Lenz (1978), this subspecies differs from C. lapworthi lapworthi Tullberg primarily in that the proximal end is longer, more tapered and more strongly coiled. The presence of an abundance of fairly complete and well preserved material shows that these forms do, indeed constitute a unique form of this common Llandovery species. The specimens of Berry and Murphy (1975) differ only in that they have a slightly wider proximal thecal spacing.

In the passage from Llandovery to lowest Wenlock beds the distinction of this subspecies from incomplete specimens of Cyrtograptus cf. insectus, which has more distally arising cladia as well as secondary cladia, can be difficult when the latter features are not preserved. Complete description of the rather large collections of Wenlock cyrtograptids collected as part of this study will reveal further distinctions between these species and may show them to be very closely related.

Cyrtograptus polyrameus Fu and Song, 1985

Text-figure 47E?,F,K.

1985 Cyrtograptus polyrameus Fu and Song (in Fu), p. 326, pl. 2, fig. 2.

Material. Four compressed, moderately well preserved rhabdosomes and two, possible proximal specimens.

Occurrence. Sakmaricus Zone. Snowblind Creek at 525.0m, Twilight Creek at 54.5m and Cape Becher at 20.5m.

Description. Rhabdosome loosely coiled through about 180o proximally, becoming weakly dorsally curved distally. Cladia, which originate about halfway through proximal coil (possibly between 15th and 20th theca) are somewhat irregularly spaced, generally at about 4 to 7 thecae mesially, up to 11 or 12 thecae distally. Distal stipe width is 1.4 to 1.6mm and thecae spaced at 9.5 to 10 in 10mm. Thecae have a relatively broad, triangular protheca and short metathecal hook with proximally facing apertures and short apertural spines. Possible proximal specimens (text-fig. 47E) are moderately dorsally curved, have closely spaced thecae (7 to 8 in 5mm) similar in form to the more distal ones, and a 1.1mm sicula which extends to just below the base of th3.

Remarks. Although the present specimens are somewhat wider than those reported by Fu and Song (in Fu, 1985) they are otherwise very similar, with a loosely coiled proximal end similar to that of C. lapworthi but more numerous, irregularly spaced cladia. Cyrtograptus sakmaricus and C. solaris have more tightly coiled proximal ends with more volutions before the first cladium.

Cyrtograptus sakmaricus Koren', 1968

Text-figure 48A-E.

1968 Cyrtograptus sakmaricus Koren', pp. 102-103, text-fig. 2.

1969 Cyrtograptus canadensis Jackson and Etherington, pp. 1115-1118, pl. 129, figs. 1-3; text-fig. 1a-d.

1969 Cyrtograptus shishkaticus Golikov, pp. 506-508, pl. 9, fig. 1.

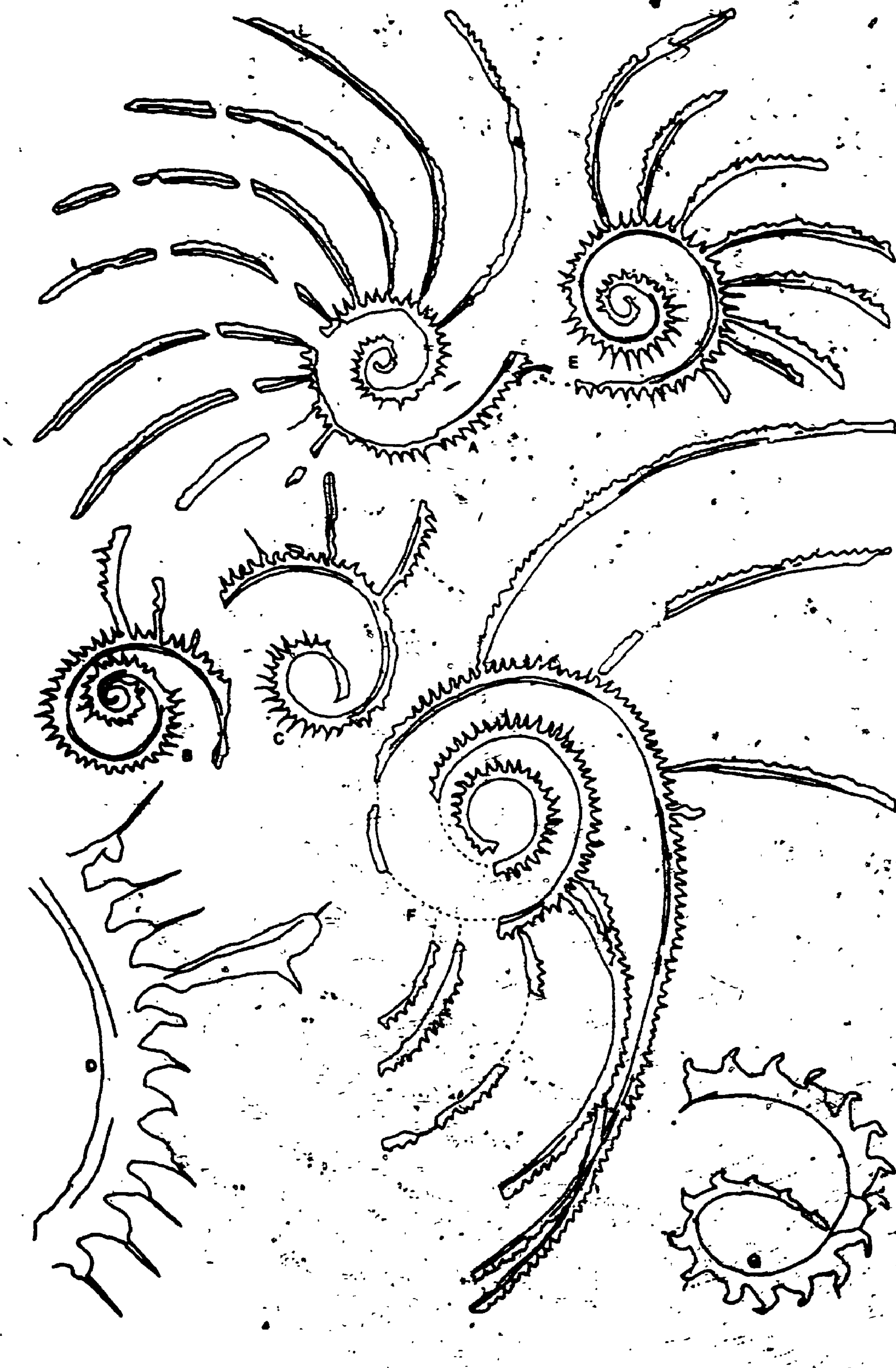
Text-figure 48

All figures x7.5 unless otherwise stated.

A-E. Cyrtograptus sakmaricus Koren': A) TC:55.5, x2; B), C) and E) TF:140.5, x3.7; D) TF:135.0.

F. Cyrtograptus solaris n. subsp., TC:45.0, x2.

G. Cyrtograptus solaris n. subsp.?, TC:45.0.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1969 *Cyrtograptus coronoformis* Golikov, pp. 508-509, pl. 9, fig. 2.

?1974 *Cyrtograptus obusicus* Golikov, pp. 97-98, pl. 6, fig.

1975 *Cyrtograptus* cf. *C. sakmaricus* Koren'; Berry and Murphy, pp. 90-91, pl. 12, figs. 1,2; pl. 13, fig. 2.

1978 *Cyrtograptus sakmaricus* Koren'; Lenz, p. 633, pl. 2, fig. 4.

1981 *Cyrtograptus sakmaricus* Koren'; Hub and Fu, pl. 1, figs. 1,4.

1985 *Cyrtograptus sakmaricus* Koren'; Fu, p. 323, pl. 1, figs. 1,3; text-fig. 1a-c.

Material. Numerous very well to poorly preserved compressed and low relief specimens.

Occurrence. *Sakmaricus* Zone. Snowblind Creek at 536.5 and 537.5m, Cape Phillips at 128.0, 146.0, 151.0, 152.5, 153.0, 156.0, 157.0 and 158.5m, Rookery Creek at 162.0m, Twilight Creek at 48.0, 54.5, 55.5, 57.0, 59.0 and 60.0m, Middle Island at 63.0 and 64.0m, Cape Becher at 1.0, 2.0, 5.0, 7.0, 10.0, 12.0, 14.0, 17.0, 20.0, 27.0 and 30.0m, Trold fiord at 130.0, 135.0, 140.5 and 143.0m, Huff Ridge at 274-280m and Irene Bay at 68-72m.

Description. Rhabdosome variable in size but may be rather large. Coils through 1 1/2 to 2 1/2 volutions before production of first cladium and up to another full volution beyond that point as rate of curvature decreases. Thecae commonly on convex side of stipes but torsion may occur on long distal fragments or cladia. Number of cladia depends on maturity of rhabdosome but may be up to at least 20 on large specimens. Cladia commonly spaced every three thecae, but are occasionally spaced at four or, rarely, two or five thecae. Stipe widens from about 0.5mm at th1 to a distal width of 1.6 to 2.2mm excluding apertural spines which may be up to 1.0mm long. Thecae spaced at 6 to 8 in 5mm proximally, 9 to 11 in 10mm distally and are triangular, somewhat elongate proximally, and have simple apertural hooks with proximally facing apertures. They overlap about 1/3 their length and apertural hooks occupy about 1/2 to 2/3 the total width.

Remarks. Based on the present, large collections of this species it is clear that it shows a wide range of morphologic variation, not only in size and number of cladia, but also in rate of proximal coiling, cladial spacing, and, to a lesser extent, width and thecal spacing. Lenz (1978) demonstrated the synonymy of this species with *C. canadensis* and suggested that some of the species and subspecies of Golikov (1969, 1974) may also be synonymous with *C. sakmaricus*. *Cyrtograptus shishkaticus* Golikov (1969) was distinguished from *C. sakmaricus* primarily on the basis of the distal cladial spacing which varied found to be every fourth theca in some instances instead of every third thecae over the whole rhabdosome. The present collections, however, also show specimens with distal cladia spaced at four thecae, within otherwise normal C. sakmaricus populations, so this is considered to be within the range of variation of this species. Cyrtograptus coronoformis Golikov (1969) was found to have a shorter rhabdosome with longer cladia and a slightly greater width and closer thecal spacing. The relative lengths of the main stipe and cladia are mainly a function of preservation and maturity of the rhabdosome while the minor variations in width and thecal spacing can be considered to be within the range of variation for this species (although Golikov reports a maximum width of 2.6mm for this species, it is not stated whether this includes the apertural spines which often merge imperceptibly into the tip of the theca). Cyrtograptus obusicus Golikov (1974) also shows a width of 2.6mm and slightly closer thecal spacing as well as some minor variations in rhabdosomal and thecal form. The latter may be the result of preservation, but further study of the material would be necessary for more complete comparison. Cyrtograptus sakmaricus asiaticus Golikov (1974) and C. productus Golikov (1974) are both reported to have a substantially greater maximum width (up to 3.6 to 3.7mm) but otherwise seem to be similar and may, indeed represent a separate form of this species.

Cyrtograptus solaris n. subsp.

Text-figure 48F,G?.

1978 Cyrtograptus solaris n. subsp? Lenz, pp. 633-634, pl. 5, fig. 9; text-fig. 2, fig. 1..

Material. Three moderately well preserved, compressed rhabdosomes and one possible, compressed proximal specimen.

Occurrence. Lower sakmaricus Zone: Snowblind Creek at A5.0m and Twilight Creek at 45.0m.

Description. Rhabdosome rather large and tightly coiled through more than three full volutions before production of the first cladium and another full volution thereafter. Cladia spaced irregularly at 2 to 11 thecae and are weakly dorsally curved. Stipe widens gradually from 0.3mm at th1 to a distal maximum of 2.2mm and thecae spaced at 6 in 5mm proximally and 10 in 10mm distally. Thecae triangulate, slightly elongate at the extreme proximal end (if the proximal specimen does, indeed belong to this species) and moderately hooked. Distally metathecae occupy about 2/3 the total width and apertures face proximally although may be somewhat laterally asymmetrical. Thecal overlap is slight proximally, about 1/3 distally. Thecal apertures bear spines up to at least 1.0mm long.

Remarks. The present specimens differ from those of Lenz (1978) only in that the spacing of the cladia is more irregular. The Canadian Arctic specimens differ from _C. solaris solaris_ primarily in that they complete 2 1/2 to almost 3 1/2 full volutions before production of the first cladium and the thecae are somewhat more widely spaced. Otherwise, the thecal and rhabdosomal form of the two subspecies are very similar.

This form differs from _Cyrtograptus sakmaricus_ in that the cladia are more widely and irregularly spaced and the distal metathecae are somewhat taller and more slender - closer in appearance to those of _M. spiralis spiralis_.

This is the only _Cyrtograptus_ species encountered in which the distal thecae bear a resemblance to those of _M. spiralis_ although the degree of metathecal isolation and apertural torsion does not appear to be as great on _C. solaris_ n. subsp. as on _M. spiralis_. The proximal thecae found here questionably referred to this species (text-fig. 48G), however, bear no resemblance to those of _M. spiralis_ with a broader prothecae and short, proximally facing apertural hooks. This contrasts sharply with the isolate, almost rastritid, strongly hooked proximal thecae of _M. spiralis spiralis_. In fact, these proximal thecae more closely resemble the thecae of the other Llandovery _Cyrtograptus_ species (e.g. _C. lapworthi_ ssp.) or other "spirograptids" with more axially elongate proximal thecae such as _M. tullbergi_ ssp.

Cyrtograptus n. sp.

Text-figure 49A-D,F.

?1981 Cyrtograptus n. sp. Bjerreskov, pp. 52-53, pl. 6, fig. 5.

Material. Ten well preserved and several more poorly preserved, compressed specimens.

Occurrence. Lower sakmaricus Zone. Snowblind Creek at A24.0m, Rookery Creek at 149.0m and Twilight Creek at 49.0m.

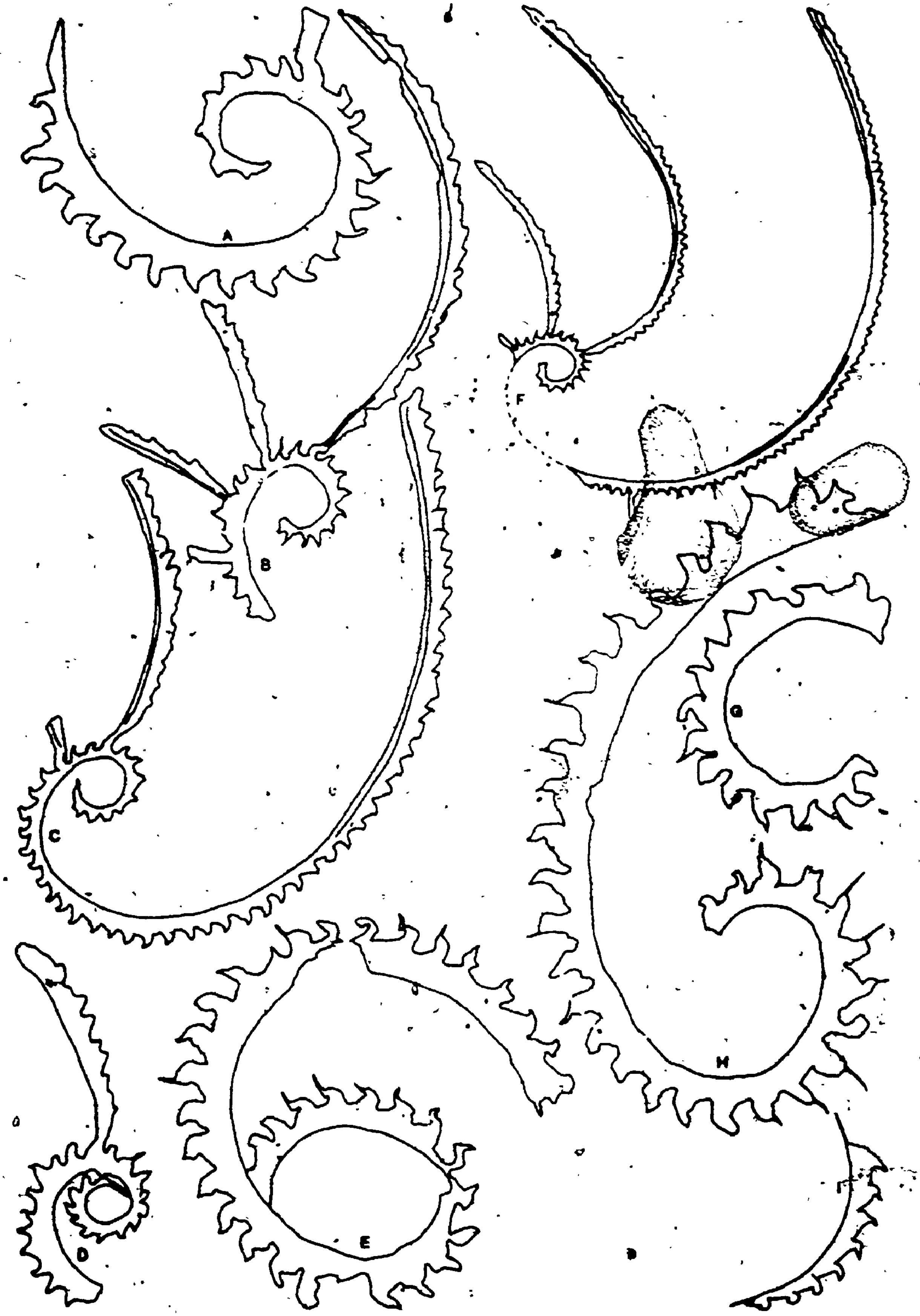
Description. Rhabdosome up to 45mm long, very tightly coiled through 180 to 270° proximally, gradually becoming more weakly curved distally. First cladium originates apparently between th15 and 20 and second and third are spaced at three to four thecae. Distally, the cladia are more widely spaced, up to seven thecae apart. Cladia may number as many as seven but most specimens have much fewer. Rhabdosome widens from 0.4 to 0.5mm proximally to 1.4 to 1.6mm distally and thecae are spaced at 7 to 8 in 5mm proximally, 11 to 12 in 10mm distally. Prothecae are broad and triangular with about 1/3 overlap and metathecae form hooks with proximally facing apertures and have short apertural spines. No well preserved proximal ends have been observed.

Text-figure 49.

All figures x7.5 unless otherwise stated.

A-D,F. Cyrtograptus n. sp., all specimens from TC:49.0 except d), from RC:149.0; B), C) and D) x3.7; F) x2.

E,G-I. Cyrtograptus? sp.: E) CP:100.0; G) TC:42.0; H) TC:45.0; I) TC:49.0.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Remarks. The tightly coiled proximal end with closely spaced proximal cladia, together with the very closely spaced thecae distinguishes this species from all others. *Cyrtograptus* n. sp. described by Bjerreskov (1981) is very similar to these specimens in the rhabdosomal form and thecal width and spacing but the first cladium originates somewhat later (at th27 - although note that none of the present specimens show a complete proximal end). The Greenland specimen shows only one clear cladium although a second, incipient one may be present three thecae after the first (preservation makes it unclear if this second cladium is indeed present - Bjerreskov, pers. comm., 1987). Until more of the Greenland *Cyrtograptus* n. sp. are available, the two are tentatively placed in synonymy.

Cyrtograptus? sp.

Text-figure 29E,G-I

Material. About ten moderately well preserved and several more poorly preserved, incomplete compressed specimens.

Occurrence. Upper *griestoniensis* and lower *sakmaricus* Zone. Cape Phillips at 100.0 and 129.0m and Twilight Creek at 42.0, 42.5, 43.5, 45.5 and 50.0m.

Description. Rhabdosomes incomplete, dorsally coiled through less than 1 to about 1 1/2 volutions, the first generally being about 5mm across. Thecae 0.9 to 1.4mm wide spaced at 5.5 to 7 in 5mm. Prothecae fairly broad, triangular and metathecae have a moderate hook with proximally facing apertures and short apertural spines. Thecae overlap about 1/3 and metathecae occupy 1/3 to 1/2 the total width. No proximal ends are preserved.

Remarks. These specimens strongly resemble the proximal to mesial parts of several Cyrtograptus species and may, in fact belong to more than one species. They occur in samples in which there are no more complete cyrtograptids and many of the specimens occur stratigraphically below the first recognizable Cyrtograptus species in the respective sections. Some of these specimens may belong to a species of Monograptus (although they do not match exactly with any known species) and if this is the case, then this species could be a possible Cyrtograptus ancestor. The thecae bear some resemblance to those of Monograptus cervus Manck with the relatively broad, overlapping prothecae and the apparently simple metathecal hooks although the rhabdosomal form is quite different. The rhabdosomal form is similar to that of Monograptus grobsdorfiensis Hemmann (Přibyl, 1944) but the thecae of the latter are more widely spaced and the prothecae somewhat more elongate. Monograptus grobsdorfiensis does not appear to bear apertural spines.

Genus *Barrandeograptus* Bouček, 1933

Type species. *Cyrtograptus pulchellus* Tullberg, 1883.

Barrandeograptus sp. aff. *B. pulchellus* (Tullberg, 1883)

Text-figure 50M-O.

Material. About ten well to poorly preserved, compressed specimens and one well preserved, uncompressed, pyritized specimen. All are distal fragments.

Occurrence. Middle *griestoniensis* to lower *sakmaricus* Zone. Snowblind Creek at 457.0m, Cape Phillips at 85.0m, Rookery Creek at 149.0 and 162.0m and Twilight Creek at 29.5m.

Description. Rhabdosome up to at least 85mm long, straight of variably weakly curved. One specimen shows two widely spaced, thecal cladia. Width up to 2.0mm, thecae spaced at 7.5 to 9 in. 10mm. Thecae consist of isolate, slightly tapering tubes with apparently simple, strongly everted apertures. Ventral walls inclined at 30 to 35° and may be slightly concave. Metathecae occupy 1/2 to 2/3 the total width.

Remarks. The present specimens resemble *Barrandeograptus pulchellus* in the presence of thecal cladia

Text-figure 50.

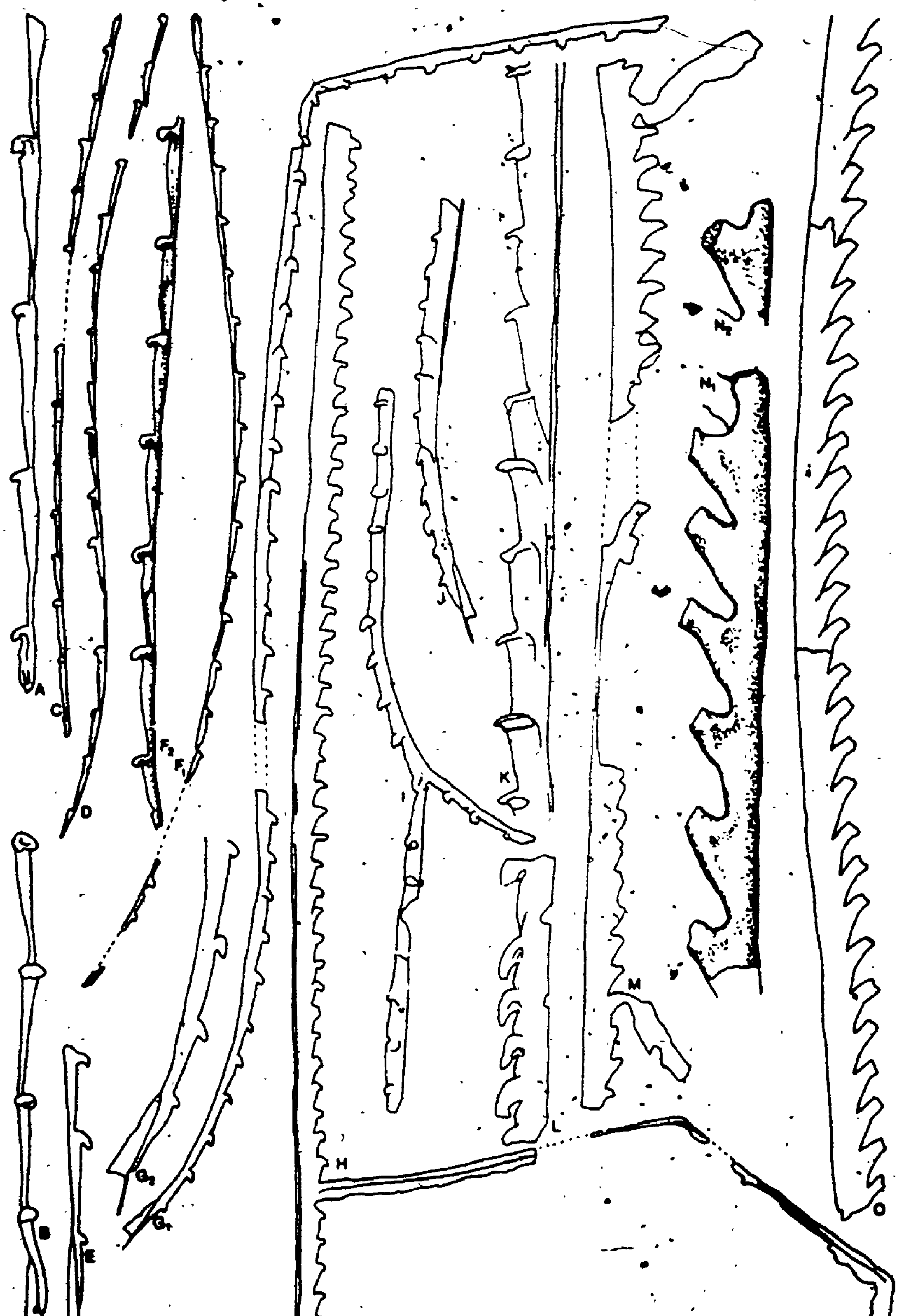
All specimens x7.5 unless otherwise stated.

A-F. _Diversograptus capillaris_ (Carruthers): A) & B) TF:63.0, x15; C) HR:122.0; D) TC:26.5; E) TC:29.5, x15; F) F2 counterpart of F1, x15, TC:29.5.

G-K. _Diversograptus ramosus_ Manck: G) G2 enlargement of proximal end, x15, TC:52.5; H) TF:136.0, x3.7; I) TC:49.0; J) TF:130.0; K) TC:52.5m, x15.

L. _Diversograptus_? cf. _D_? _runcinatus_ (Lapworth), TC:22.5.

M-O. _Barrandeograptus_ sp. aff. _B_. _pulchellus_ (Tullberg): M) RC:149.0; N) N1 and N2, portions of long, single specimen, TC:29.6, x15; O) CP:85.0.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and the unique, inclined, isolate thecal tubes. They differ, however, in that they reach a greater maximum width and that the apertures are strongly everted and appear to be simple. Those of B. pulchellus are perpendicular to slightly introverted and appear to bear lateral lappets.

In the absence of more complete material, especially proximal ends, a more positive identification is unwarranted.

Flattened distal fragments may show the appearance of thecal overlap and the nature of the aperture may be obscured. In these cases, specimens of this species may be very difficult to separate from distal fragments of other cyrtograptids which are commonly obliquely compressed and do not show the full apertural hook.

Genus Diversograptus Manck, 1923

Type species. Diversograptus ramosus Manck, 1923.

Diversograptus capillaris (Carruthers, 1867)

Text-figure 50A-F.

1867 Rastrites capillaris Carruthers, p. 368, pl. 2, fig. 10.

1913 ? Monograptus gemmatus (Barrande); Elles and Wood, pp. 436-437, pl. 34, fig. 5a-d,?e; text-fig. 300a-c.

1953 Diversograptus capillaris pergracilis (Bouček); Bouček and Přibyl, pp. 16-17, pl. 1, fig. 4; text-fig. 2, figs. 1-6.

1968 Diversograptus capillaris (Carruthers); Obut and Sobolevskaya, pp. 116-118, pl. 35, figs. 4-10.

1969 Diversograptus? capillaris (Carruthers); Strachan, pp. 198-200, fig. 6a,b.

1971 Diversograptus capillaris (Carruthers); Schauer, p. 82, pl. 38, figs. 3,4.

1976 Diversograptus (Paradiversograptus) capillaris (Carruthers); Sennikov, pp. 226-228, pl. 17, figs. 4-6.

?1978 Monograptus gemmatus (Barrande); Chen and Lin, p. 63, pl. 13, figs. 9-12; pl. 14, figs. 1,2.

1978 Monograptus capillaris (Carruthers); Ye, p. 479, pl. 179, fig. 3.

1980 Diversograptus (Paradiversograptus) capillaris (Carruthers); Obut and Sennikov, pp. 46-48, pl. 5, fig. 18.

?1983 Monograptus gemmatus (Barrande); Huang and Lu, pp. 157-158, pl. 10, fig. 15.

Material. Numerous very well to poorly preserved compressed and low relief, pyritized specimens.

Occurrence. Orbitus Subzone, minor, turriculatus and lower griestoniensis zones. Snowblind Creek at 140, 170m and 375.0m, Cape Phillips at 26.5, 30.0, 34.0 and 81.0m, Twilight Creek at 15.0, 27.0, 29.5, 30.5, 31.0, 32.5 and ?46.0m, Trold Fiord at 62.5, 63.0 and 105.0m and Huff Ridge at 122.0, 194.0 and 210m.

Description. Rhabdosome up to at least 30mm long, straight or slightly dorsally or ventrally curved. Widens very gradually from a minimum of 0.15 to 0.2 to a maximum of 0.25 to 0.4mm. Thecae spaced at 5.5 to 8 in 10mm and are very slender, axially elongate and the protheca widens slightly to a small apertural hook apparently involving only overgrowth of the dorsal thecal wall. Low relief specimens show ventral wall of protheca to be slightly convex, with a slight bulge about midway along its length. Sicula 0.8mm to 1.1 long and extends to between the midpoint of th1 and its aperture. No sicular or thecal cladia are observed.

Remarks. This species is characterized by its long, very slender thecae with weak apertural hooks and wide but variable thecal spacing. While the continental European and Russian populations of this species tend to show sicular cladia, these are not observed (or only rarely) in the Canadian, British and Chinese collections. This may be due, however, to preservational factors as the other thecal and rhabdosomal similarities are seen in all populations throughout the wide geographic and temporal range of this species.

The present specimens seem to fall into two temporal groups, those from the Middle Llandovery (mostly convolutus Zone) which tend to show a wider thecal spacing and shorter sicula and those from the Upper Llandovery (mostly griestoniensis Zone) which show the somewhat closer thecal spacing and longer sicula. The latter forms appear to be identical to Diversograptus pergracilis Bouček which has a similar, Upper Llandovery age. Since the thecae of the two forms are indistinguishable, the widths are the same and the thecal spacing ranges overlap, the two are considered to be conspecific.

Diversograptus ramosus Manck. is distinguished by its consistently greater width, especially evident in the prothecae.

Diversograptus ramosus Manck, 1923

Text-figure 50G-K.

1923 Diversograptus ramosus Manck, pp. 283-285, figs. 1.3-1.8.

1965 Diversograptus ramosus Manck; Obut and Sobolevskaya, pp. 94-95, pl. 18, figs. 2-4.

1971 Diversograptus ramosus Manck; Schauer, p. 82, pl. 37, fig. 4; pl. 38, fig. 1.

1973 Diversograptus ramosus Manck; Rickards, pp. 184-186, text-figs. 15-17.

1978 Diversograptus sichuanensis Ge; Ye, p. 486, pl. 182, fig. 7.

Material. Numerous moderately well to poorly preserved, compressed and partial relief specimens.

Occurrence. Crispus and middle griestoniensis to upper sakmaricus zones. Cape Phillips at 55.0, 93.5 and 156.0m, Rookery Creek at 162.0m, Twilight Creek at 30.5, 31.5, 32.5, 46.0, 49.0, 49.5, 50.0, 52.5 and 55.5m, Trold Fiord at 119.0, 123.5, 130.0, 136.0 and 143.0m and Irene Bay at 65.5m.

Description. Rhabdosome straight of variably flexed, up to at least 120mm long. Widens slowly from 0.25 to 0.35mm at th1 to a maximum of 0.6 to 0.9mm. Thecae spaced at 8 to 12 in 10mm and have axially elongate prothecae, with parallel ventral walls proximally becoming slightly inclined distally. Metatheca forms a short, open hook, apparently involving only the dorsal wall, with proximally facing apertures. Sicula 1.0 to 1.35mm long extending to or just beyond the aperture of th1. No bipolar specimens have been observed in the present collections but several show thecal cladia. The cladial thecae do not appear to differ from those of the main stipe.

Remarks. Although no specimens showing sicular cladia have yet been found in the Cape Phillips material the presence of thecal cladia combined with the typical thecal and rhabdosomal form indicate that these specimens are, indeed, Diversograptus. Rickards (1973) has illustrated the wide range of variation present in dimensions and thecal spacing for this species and much of variation is manifest in the present collections.

Diversograptus? cf. D? runcinatus (Lapworth, 1876)

Text-figure 50L.

Material. Two rather poorly preserved, compressed fragments.

Occurrence. Minor Zone. Twilight Creek at 22.5m and Huff Ridge at 160.0m.

Description. Short distal fragments are straight and 1.2 to 1.3mm wide. Thecae spaced at 9 to 9.5 in 10mm and are strongly hooked with parallel prothecae and proximally facing apertures.

Remarks. The thecae, despite their poor preservation, show the distinctive "drooping" appearance of the hooked metathecae and the proximally facing apertures. In addition, the width and thecal spacing are in keeping with previous reports of this species. The absence of more well preserved, particularly proximal material, however, prevents more positive identification.

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PLATE 1.

Figures 1-6, _Hedrograptus_ _medius_ _brevicaudatus_ (Churkin and Carter, 1970): 1) compressed specimen, CM:2-5m, x15; 2) CM:2-5m, x15; 3) same as figure 4, broken end of virgula, CM:0-2m, x500; 4) x15; 5) same as figure 2, distal end view showing fringes of complete median septum, x25; 6) CM:0-2m, x50.

Figures 7-9, _Hedrograptus_ cf. _H._ _simplex_ (Rickards, 1970): 7) stereopair, RC:80-105m, x25; 8) same as figure 9, distal end view showing complete median septum and base of interthecal septum, RC:80-105m, x75; 9) x25.

Figures 10-12, _Hedrograptus_ _nikolayevi_ (Obut, 1965): 10) proximal fragment with aberrent, bulbous outgrowth of $th2^1$, CM:0-2m, x25; 11) same as figure 12, distal end view showing fringes of complete median septum, CM:0-2, x50; 11) x25.

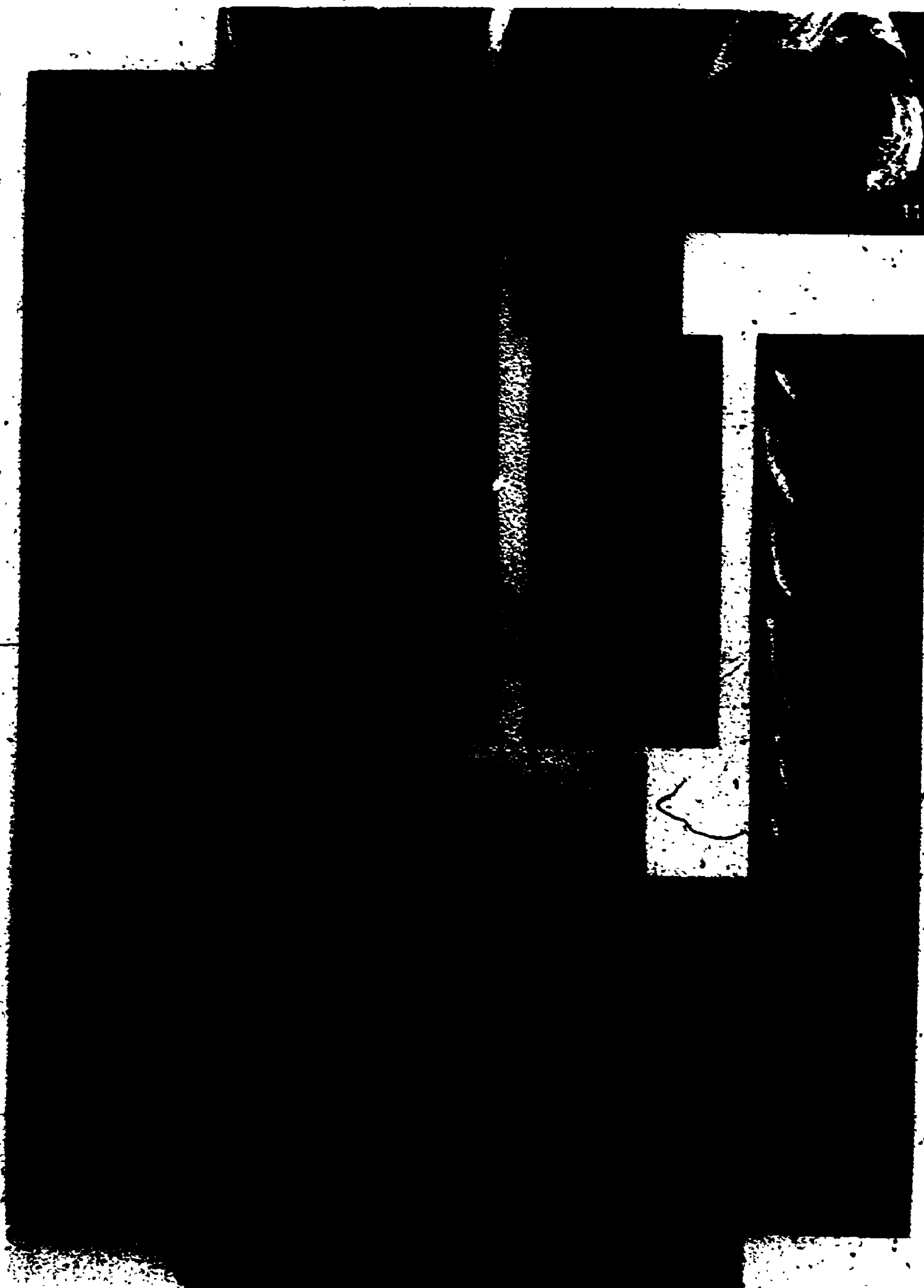

PLATE 2

Figures 1-16, Hedrograptus nikolayevi (Obut, 1965), all specimens from CM:0-2m, except where noted: 1) sicula and early growth of metatheca 1^1, x50; 2) sicula and growth of metatheca 1^1 to point of differentiation protheca 1^2, x50; 3) sicula and metatheca 1^1 with early growth of protheca 1^2, note complete dorsal wall of metatheca 1^1 against reverse side of sicula and fusellar unconformity at base of th1^2, x50; 4) formation of metatheca 1^2 and early differentiation of protheca 2^1 near base of protheca 1^2, x50; 5) completion of metathecae 1^2 and growth of protheca 2^1, x50; 6) same as figure 1, enlargement of metatheca 1^1 early growth showing fusellae, note that terminal fusellum is incomplete, x150; 7) same as figure 2, oblique distal view showing continuity of fusellae across th1^1 and earliest growth of th1^2, formation of fusellar unconformity at point of differentiation of protheca 1^2 and formation of interthecal septum, x100; 8) same as figure 4, oblique distal view showing continuity of fusellae across protheca 1^2 and early growth of protheca 2^1 and formation of interthecal septum, x75; 9) x25; 10) same as figure 12, distal end view showing partial median septum, x75; 11) same as figures 10 and 12, distal end of virgula, x1500; 12) x25; 13) apertural half of sicula with descending portion of $th1^1$, note sinuous downward path and presence of two foramina, one opening downward for metatheca 1^1, the other opening across the reverse side of the sicula for prothecae 1^2, note also the list (list A) separating the foramina, x100; 14) early growth stage with completed $th1^1$ and $th1^2$ and growing $th2^1$, x50; 15) same as figure 16, distal end view shwong origin of partial median septum, RC:80-105m, x100; 16) obverse view showing enclosure of sicula at aperture of $th1^1$, x50.

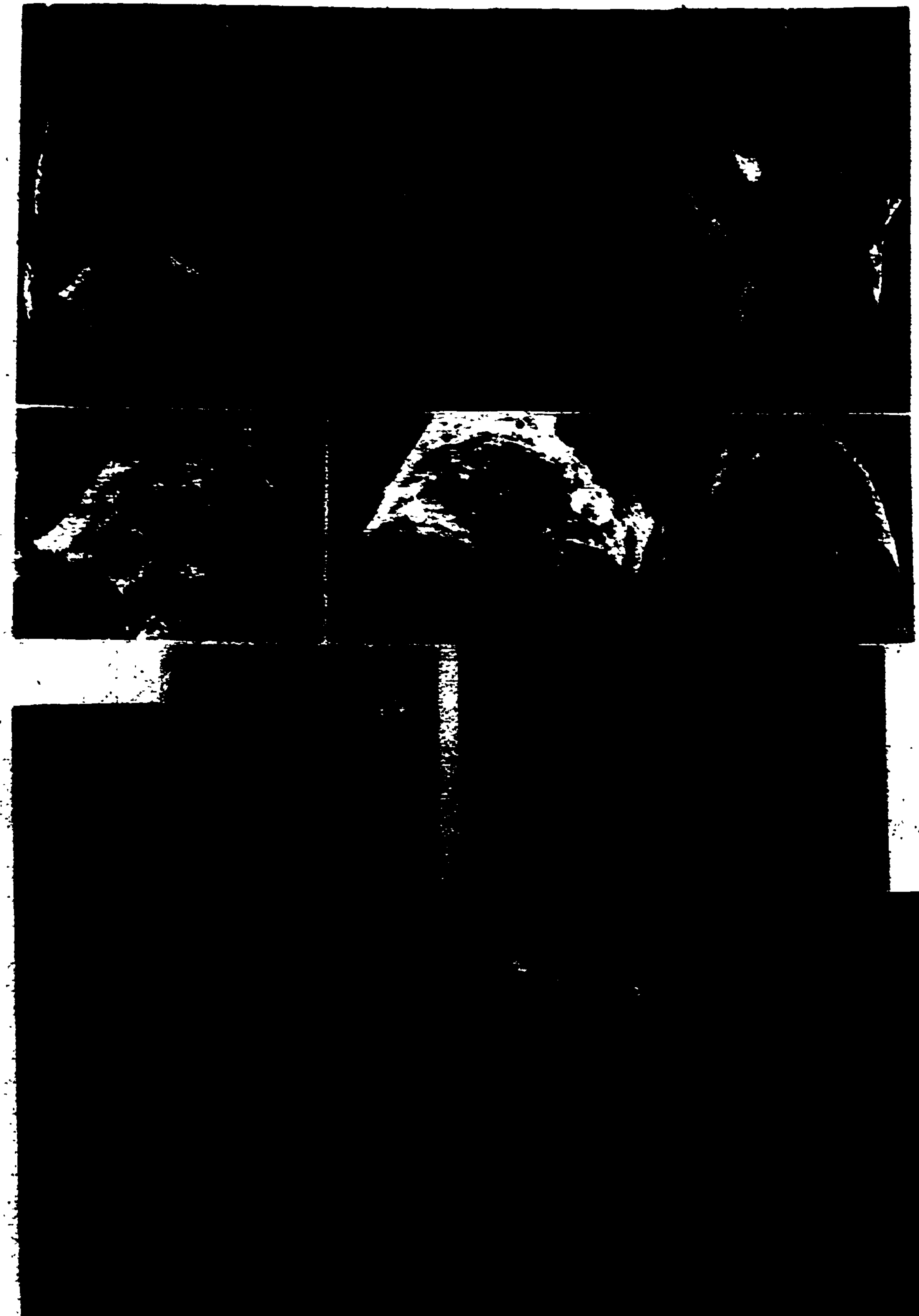

PLATE 3

Figure 1, Hedrograptus nikolayevi (Obut, 1965), malformed immature rhabdosome with aberrent, outwardly-directed th12 and ovate cavity, RC:55.0m,x25.

Figures 2-6, Hedrograptus n. sp. B: 2) same as figure 3, distal end view showing partial median septum at sixth thecal pair, CM:2-5m, x25; 3) note abnormally long th3^1 which has partially overgrown th4^1, x25; 4) same as figure 5, oblique distal view of broken region near distal end showing fring·s of complete median septum by tenth thecal pair, x15; 6) note protuberance on obverse wall beside th4^1, SC:140m, x15.

Figures 7-11, Pseudoglyptograptus n. sp.: 7) same as figure 11, proximal end view showing damaged and overgrown portion, CM:5-7m, x50; 8) same as figure 9, oblique proximal view showing abnormal extra proximal spine beside virgella, CM:5-7, x50; 8) x25; 10) same as figre 11, oblique proximal view showing partially constricted sicular aperture at base of virgella (clogged with debris) and overgrown th1^1 aperture, x30; 11) complete specimen with damaged, overgrown proximal end, x15.

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PLATE 4

Figures 1-15, *Pseudoglyptograptus* n. sp., note the increasing degree of external thecal curvature and apertural lip development with increasing rhabdosomal maturity, figures 11 and 13 being the most mature specimens - note also the more nearly climacograptid appearance of the more distal thecae: 1) CM:5-7m, x15; 2) early growth stage showing partial growth of metatheca 1^2 and protheca 2^1, note early differentiation of th2^1 and curving and interfingering fusellae where it meets th1^2, RC:55.0m, x50; 3) same as figure 2, oblique proximal view showing fusellar unconformity where th1^2 differentiates, bulge marks position of list B which is not connected with the dorsal wall of th1^1 which originates slightly to its right, x100; 4) broken proximal end specimen showing part of sicula and descending portion of th1^1 with two foramina separated by list A - broken list B can be seen emerging from reverse side of sicula, CM:5-7m, x100; 5) immature rhabdosome displaying nearly climacograptid thecae with only very weak apertural lip development, CM:5-7m, x25; 6) immature rhabdosome, flattended distally, SC:140m, x15; 7) same as figures 5 and 8, distal end of virgula showing concentric layering, x1500; 8) same as figure 5, distal end view showing complete median septum by th2^2, x50; 9)

SC:140m, x15; 10) same as figure 9, side view of proximal end showing thecal apertures with strong apertural lips, x25; 11) SC:140m, x15; 12) SC:2-5m, x15; 13) SC:140m, x15; 14) same as figure 12, proximal end view, broken opening to left of sicular aperture reveals list A at terminal end of descending protheca 11, x100; 15) CM:5-7m, 15x.

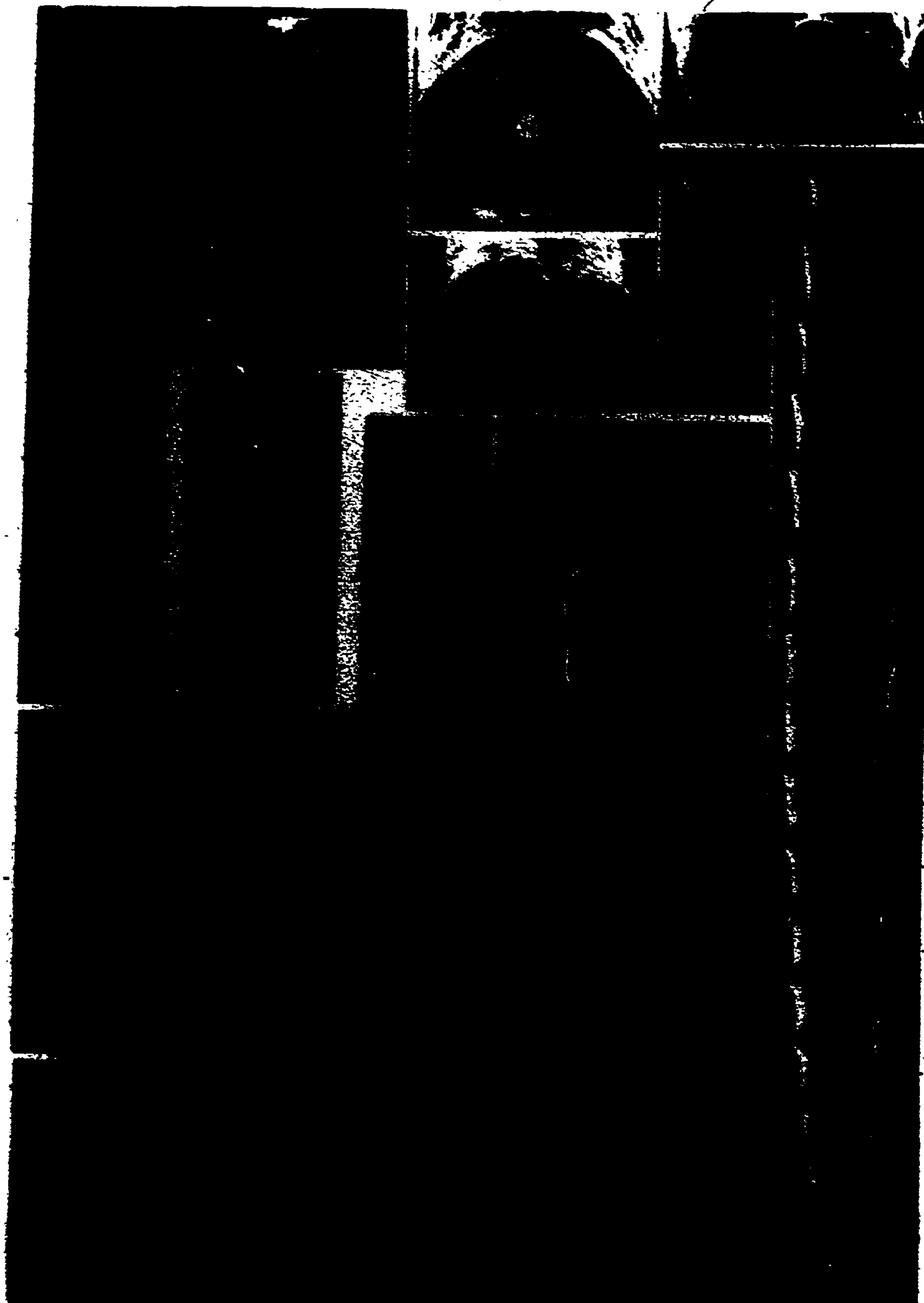

PLATE 5

Figures 1-13, *Metaclimacograptus orientalis* (Obut and Sobolevskaya, 1966), all specimens from CM:0-2m: 1) stereopair, note undulose median septum, x25; 2) stereopair, note incipient growth of th3^1 - ventral wall proceeds slightly ahead of lateral walls, x50; 3) abnormal specimen in which series 1 thecae have terminated after th2^1, x25; 4) broken early growth stage - note that fusellae of th1^2 differentiate very early, and that the line of unconformity runs almost straight down from list B (see figure 6), x50; 5) steropair, same as figure 7, distal end view showing ealy growth of th2^2 and origin of interthecal septum near apex of sicula, x75; 6) same as figure 4, oblique distal view showing position of list B and small ventral wall of th1^1, x100; 7) immature rhabdosome, x50; 8) sicula and early growth of first thecal pair, x50; 9) immature specimen showing early growth of th2^1, x 50; 10) x25; 11) same as figure 2, distal end view, x75; 12) distal view of broken proximal specimen showing insertion of median septum (bottom centre), broken list B (upper centre) and faint silhouette of list A (in side outer wall, upper left), x125; 13) same as figure 8, oblique proximal view showing fusellae of th1^1 and incipient th1^2 - some corticle bandacing is visible on th1^1, x100.

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PLATE 6

Figures 1-6, Metaclimacograptus undulatus (Kurck, 1882), all specimens from SC:140m; 1) stereopair, note angular median septum and somewhat more pronounced hoods on proximal thecae than distally, x25; 2) note less pronounced hood development than on more mature specimen in figure 1, x25; 3) stereopair, immature rhabdosome, note origin of median septum, x50; 4) same as figure 1, oblique side view of $th2^1$ showing thecal apertures, x50; 5) note early growth of $th3^2$ with ventral wall proceeding ahead of lateral walls (see also figure 6), x25; 6) immature rhabdosome, x50.

Figures 7-8, Metaclimacograptus cf. M. undulatus (Kurck, 1882): 7) stereopair, note apertural lips, CM:0-2m x 25; 8) same as figure 7, corticle bandaging on thecal wall, x500.

Figures 9-14, Clinoclimacograptus sculptus (Chen and Lin, 1978), all specimens from CM:5-7m: 9) stereopair, x25; 10) x25; 11) same as figure 14, oblique distal view of proximal end showing list B (right centre) and list A (left centre) separating $th1^1$ and $th1^2$ foramina, x100; 12) same as figure 13, distal view of proximal end, x100; 13) broken proximal end specimen - note origin and sinuosity of median septum, x25; 14) x 25.

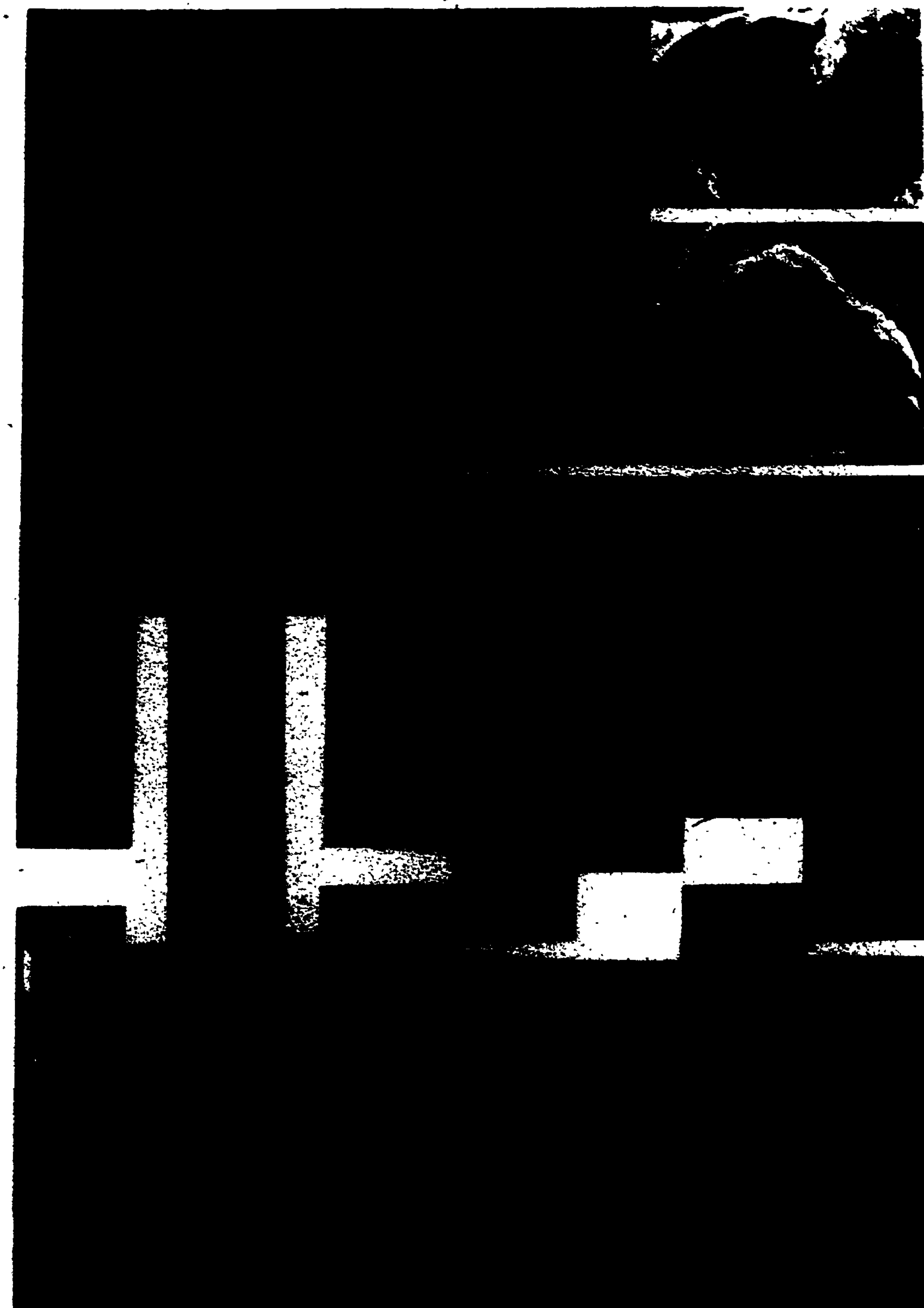

PLATE 7

Figures 1-12, Lithuanograptus minimus Paskevicius, 1976, all specimens from RC:55.0m: 1) stereopair, note the ventral wall of th3[2] which forms an umbrella-hood over th2[2] aperture well in advance of the lateral thecal walls, x50; 2) stereopair, immature specimen showing early growth of second thecal pair, x50; 3) same as figure 11, distal view inside th1[1] showing descending protheca and list A separating th1[1] and th1[2] foramina, x150; 4) same as figure 10, oblique distal view showing base of interthecal septum, list B (centre) and silhouette of list A (right), x150; 5) stereopair, x25; 6) same as figures 7 and 8, distal end of virgula, x1000; 7) same as figure 8, distal end view, note median septum and growth of distal thecal - lateral wall overgrows curved ventral wall as it advances, x 75; 8) x25; 9) same as figure 1, oblique side view showing thecal apertures, x50; 10) broken early growth stage, x50; 11) sicula and early growth of th1[1], x50; 12) same as figure 8, aperture of th5[1], note the unconformable overgrowth of the lateral walls over the hood, x150.

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PLATE 8

Figures 1-14; "*Diplograptus*" *tcherskyi tcherskyi* Obut and Sobolevskaya, 1967, all specimens from CM:0-2m unless otherwise noted: 1) sicula with descending protheca 1^1 and incipient metatheca 1^1, x50; 2) sicula and $th1^1$ to point of differentiation of $th1^2$, x50; 3) early growth stage showing growth of $th1^2$ and late differentiation of $th2^1$, x50; 4) immature specimen showing growth of $th2^1$, x50; 5) x50; 6) same as figure 1, oblique distal view of proximal end showing path sinuous of descending protheca and list A separating $th1^1$ and $th1^2$ foramina, x100; 7) same as figure 2, distal view showing list B and silhouette of list A, x100; 8) proximal end of early growth specimen showing fusellae of $th1^1$, unconformity and closely packed fusellae of base of protheca 1^2 and formation of list B, CM:5-7m, x150; 9) same as figures 10 and 13, distal end of virgula with partial median septum, x500; 10) x25; 11) same as figure 4, oblique distal view of proximal end showing descending protheca with list A and $th1^1$ and $th1^2$ foramina, x150; 12) same as figure 5, distal end view showing origin of partial median septum, x75; 13) same as figure 10, distal end view showing partial median septum at fourth thecal pair, x50; 14) broken proximal end of immature specimen showing list B and base of $th1^1$ dorsal wall directly above it CM:2-5m, x100.

PLATE 9

Figures 1-8, "*Diplograptus*" *tcherskyi tcherskyi* Obut and Sobolevskaya, 1967: 1) mature rhabdosome, this specimen appears transitional between this subspecies and "*D.*" *tcherskyi* n. subsp. but more closely resembles the former, CM:2-5m, x15; 2) mature specimen with aberrent ridge on $th1^1$, CM:2-5m, x15; 3) same as figure, enlargement of proximal end showing ridge on $th1^1$, x50; 4) same as figure 5, distal end view showing fringes of complete median septum formed by fifth thecal pair, CM:0-2m, x40; 5) specimen with aberrent mesial spine on th12, x25; 6) same as figure 5, enlargement of mesial spine on $th1^2$, x 100; 7) same as figure 8, oblique side view of median septum and virgula at distal end of specimen, CM:5-7m, x100; 8) distal fragment with long free virgula, x15.


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PLATE 10

Figures 1-3, "Diplograptus" tcherskyi n. subsp., both specimens from CM:2-5m: 1) same as figure 2, distal end view showing fringes of median septum, x25; 2) mature rhabdosome, x15; 3) immature rhabdosome, partially compressed, x25.

Figures 4-10, "Glyptograptus" sinuatus sinuatus (Nicholson, 1869), all specimens from RC:55.0m: 4) x25; 5) same as figure 6, distal end view showing partial median septum at fourth thecal pair, x50; 6) immature rhabdosome, x25; 7) same as figure 9, faint bandaging on thecal surface, x300; 8) same as figure 9, distal end on showing fringes of complete median septum, x25; 9) mature rhabdosome, note incipient lateral hoods on apertures of first thecal pair, x15; 10) same as figure 4, distal end view showing formation of complete median septum (fringes only), lower wall is reverse side where complete septum begins at sixth thecal pair, x50.

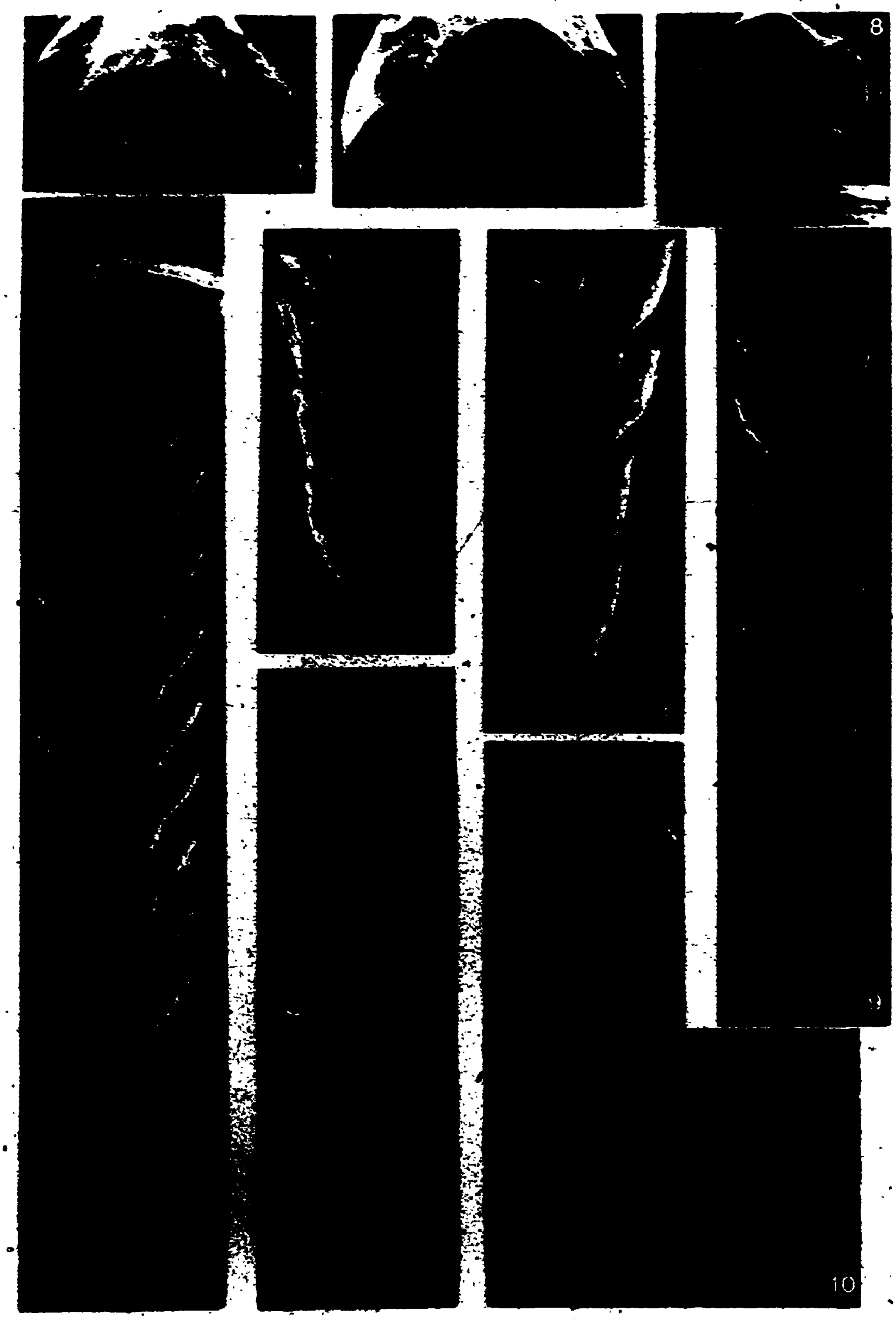
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PLATE 11

Figures 1-13, "*Glyptograptus*" *sinuatus sinuatus* (Nicholson, 1896), all specimens from RC:55.0m unless otherwise noted: 1) sicula and early growth of $th1^1$, x50; 2) sicula and th11 to point of differentiation of $th1^2$, x50; 3) growth of metetheca 1^1 and protheca 1^2, x50; 4) early growth stage with first thecal pair, mote late differentiation of $th2^1$. x50; 5) same as figure 1, distal view showing sinuous path of descending protheca and list A separating $th1^1$ and $th1^2$ foramina, x150; 6) same as figure 4, oblique distal view showing fusellar unconformity and compressed fusellae at point of differentiation of $th1^2$, x150; 7) mature rhabdosome, CM:2-5m, x15; 8) same as figure 2, distal view showing list B and silhouette of list A, x150; 9) same as figure 3, distal view showing list B and lack of dorsal wall on $th1^1$ (formed later at its distal end), x100; 10) immature rhabdosome showing late differentiation and growth of $th2^1$, x50; 11) same as figure 12 and 13, distal end of virgula, x2000; 12) same as figure 13, distal end view showing formation of partial median septum below apex of sicula, x100; 13) immature rhabdosome showing growth of second thecal pair, x50.

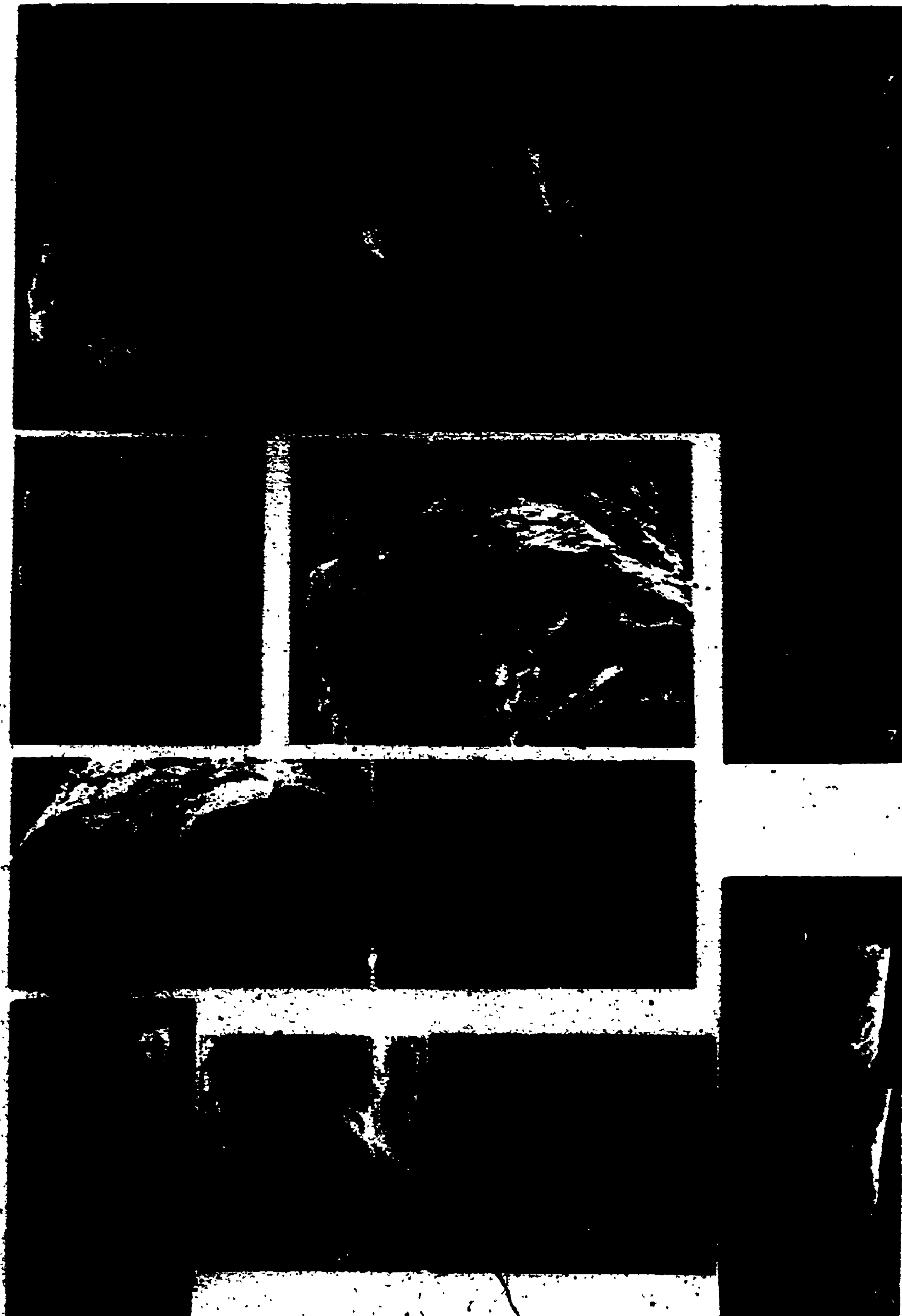

PLATE 12

Figures 1-4,7, "*Glyptograptus*" *sinuatus sinuatus* (Nicholson, 1869), all specimens from RC:55.0m: 1) proximal end of mature rhabdosome showing incipient lateral hood on proximal thecae, x50; 2) gerontic? specimen showing aberrent lateral hoods on proximal thecae, x25; 3) same as figure 4, oblique side view showing hood growth over proximal thecae, x50; 4) gerontic? specimen showing hood growth over proximal thecae, x25; 7) oblique side view showing hoods grown over proximal thecae, x50.

Figures 5,6,8-10, N. gen. A?, n. sp., both specimens from CM:5-7m: 5) same as figure 9, oblique distal view inside proximal end showing descending protheca and list A separating $th1^1$ and $th1^2$ foramina, x150; 6) same as figure 9, oblique side view of broken mesial region showing virgula and partial median septum, x50; 8) oblique proximal view of proximal end showing list B and very short, distally occurring doral wall of $th1^1$, x100; 9) x25; 10) more mature but distally broken specimen, x25.

PLATE 13

Figures 1-5,7,8, Petalograptus ankyratus (Mu, et al., 1974), all specimens from CM:5-7m: 1) note early growth of distal thecae x25; 2) stereopair, sicula and early growth of th1[1], x35; 3) same as figures 1 and 5, distal end of virgula, x1000; 4) immature rhabdosome, x25; 5) oblique distal view, virgula and partial median septum, x200; 7) same as figure 2, proximal view of centre of ancora showing outward-facing "seams", x300; 8) same as figure 2, distal view of descending protheca and single terminal foramen, x200.

Figure 6, Petalograptus cf. P. fortuitus (Obut and Sobolevskaya, 1968), broken, compressed proximal end specimen, CM:0-2m, x25.

PLATE 14

Figures 1-9, *Petalograptus insectiformis* (Nicholson, 1869), all specimens from CM:2-5m: 1) immature specimen showing growth of first thecal pair, x50; 2) same as figure 1, distal view showing short dorsal wall of $th1^1$, x75; 3) central region of loose ancora, x500; 4) stereopair, immature rhabdosome, x50; 5) stereopair, sicula with ancora and early growth of $th1^1$, x50; 6) distal fragment, x25; 7) same as figure 6, proximal view showing orientation of apertural spines and wide axial canal, x25; 8) same as figure 5, distal view of descending protheca and single terminal foramen, x200; 9) immature rhabdosome, x50.

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1.0 2.8 2.5
3.2 2.2
3.6
4.0 2.0
1.1
1.8
1.25 1.4 1.6


8

PLATE 15

Figures 1-5,7, *Petalograptus intermedius* (Boucek and Pribyl, 1941)?, all specimens from RC:55.0m: 1) sicula with descending portion of protheca 1[1], x50; 2) immature rhabdosome showing growth of first thecal pair, x50; 3) same as figure 5, oblique side view showing apparently aborted th1[2], x50; 4) immature rhabdosome, x25; 5) immature specimen with apparently aborted th1[2], x25; 7) same as figure 2, distal view showing formation of dorsal wall of th1[1], x100,

Figures 6, 8-10, *Petalograptus* cf. *P. tenuis* (Barrande, 1850): 6) early growth stage, CM:5-7m, x 25; 8) same as figure 9, distal end view showing virgula attached to obverse wall by very narrow partial median septum, CM:5-7m, x50; 9) immature rhabdosome, x25; 10) early growth stage showing fusellae and early growth of first three thecae, Marshall Peninsula, loose, x50.

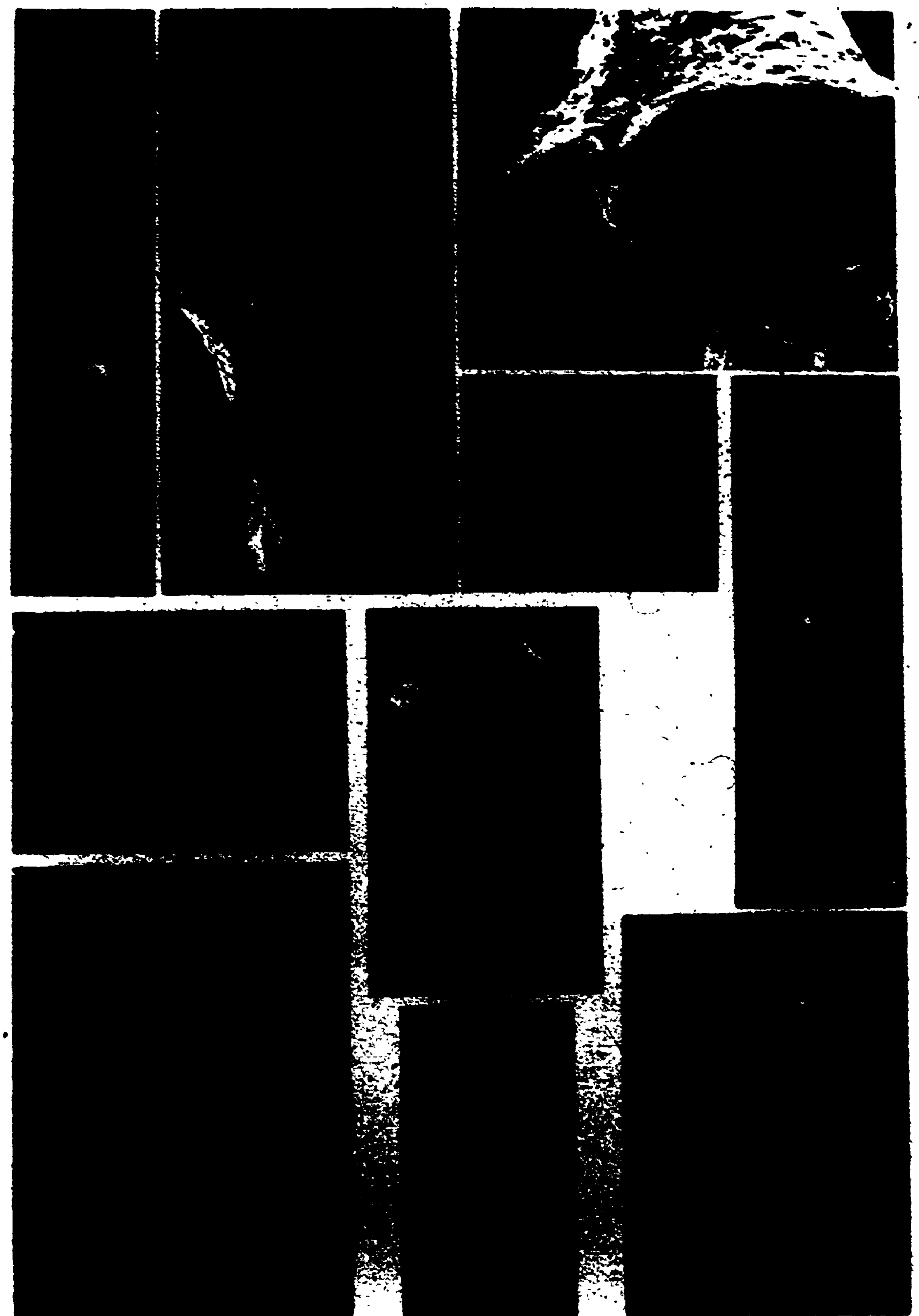

PLATE 16

Figures 1-5, _Petalograptus_ n. sp. A, all specimens from SC:320m: 1) same as figure 3, stereopair, distal end view, x25; 2) same as figure 4, stereopair, distal end view showing sicula and interthecal septa, x50; 3) mature rhabdosome, x25; 4) immature rhabdosome, x50; 5) immature rhabdosome, x50.

Figures 6-9, _Petalograptus_ n. sp. C: 6) same as figure 8, distal end view, CM:2-5m, x75; 7) same as figure 9, distal end view, note interthecal septa and fringe of partial median septum on obverse (lower) wall, CM:5-7, x75; 8) x25; 9) x25.


6

PLATE 17

Figures 1-13, Glyptograptus elegans n. subsp., all specimens from Marshall Peninsula (loose) except where noted; 1) distal fragment, SC:260m, x25; 2) same as figure 5, oblique distal view showing fusellae of proximal thecae, x75; 3) broken proximal end of mature rhabdosome, SC:260m, x25; 4) same as figures 4 and 13, broken end of virgula attached to base of interthecal septum, x500; 5) immature specimen, x 50; 6) sicula and early growth of $th1^1$, x50; 7) same as figure 8, side view of distal end showing fusellae, x100; 8) immature rhabdosome, x50; 9) immature rhabdosome obverse view showing enclosure of sicula, x50; 10) x25; 11) same as figure 8, distal end view showing interthecal septum and tip of virgula, x100; 12) early growth stage specimen showing aperture of sicula and descending portion of protheca 1^1, note single foramen, x150; 130 same as figures 3 and 4, distal end view, x100.

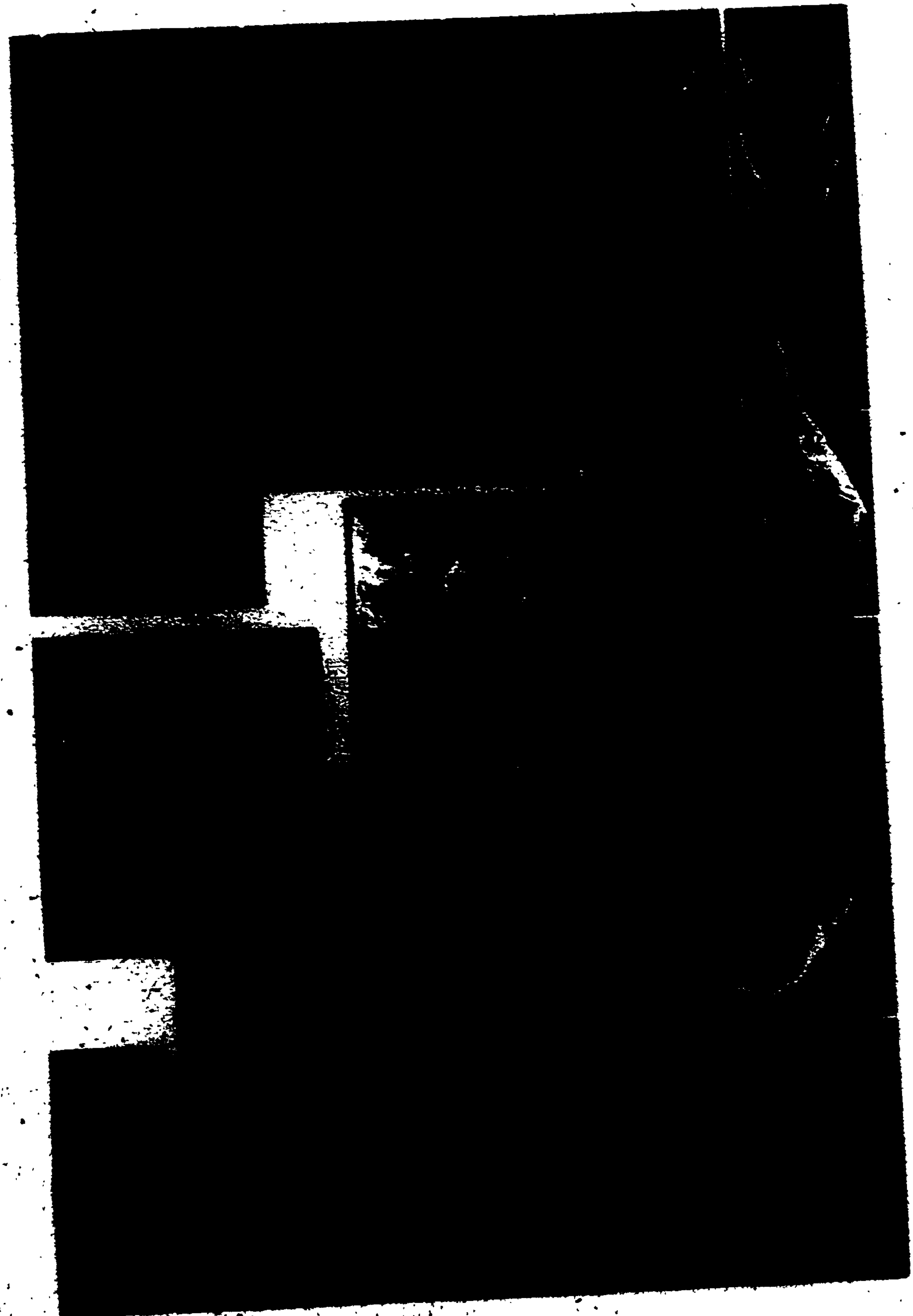

PLATE 18

Figure 1, Glyptograptus elegans n. subsp.?, CM-2-5m, x25.

Figures 2-15, Glyptograptus sp aff. G. fastigans Haberfelner, 1931, all specimens from Marshall Peninsula (loose): 2) broken immature rhabdosome, x50; 3) same as figures 4 and 6, distal end of virgula, x4000; 4) immature specimen in obverse view showing enclosure of sicula, x50; 5) distal fragment, x25; 6) same as figure 4, distal end view, x100; 7) immature rhabdosome, x50; 8) same as figure 2, distal view of proximal end, note short decsending protheca 1^1 and lack of list A (single terminal foramen), x250; 9) same as figure 13, distal end view, note free, central virgula, x100; 10) same as figdre 11, distal end view, x100; 11) immature specimen with aborted or malformed $th1^1$, x50; 12) distal fragment, x25, 13) immature specimen, x50; 14) same as figure 15, distal vieew showing origin of $th1^1$ dorsal wall (interthecal septum), x100; 15) proximal half of early growth stage showing fusellar differentiation of protheca 1^1 and metatheca 1^1, x100.

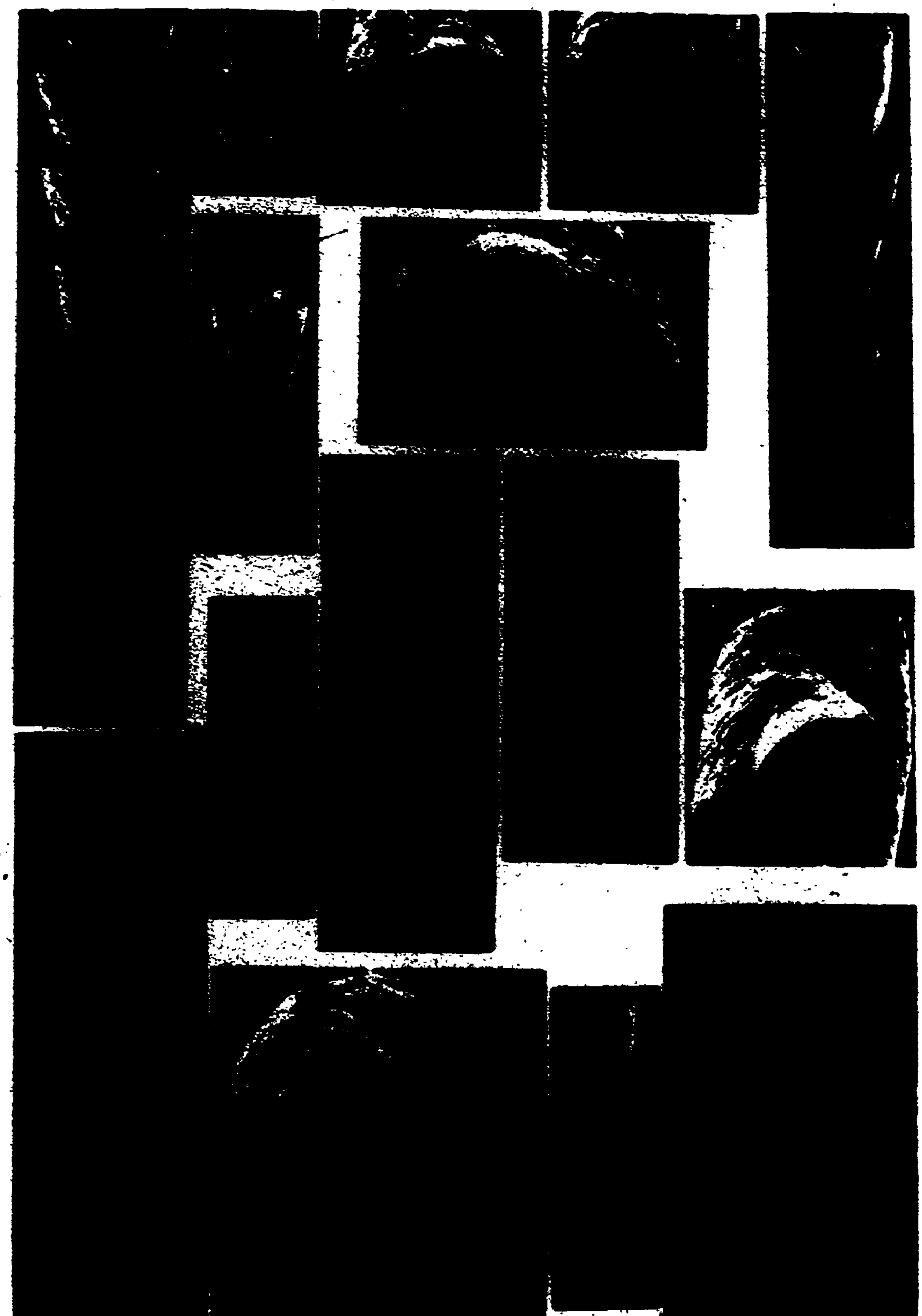

PLATE 19

Figures 1-12, *Glyptograptus tamariscus tamariscus* (Nicholson, 1868): 1) CM:2-5m, x25; 2) distal fragment with long virgula, CM:5-7m, x25; 3) mature rhabdosome with proximal end broken open, CM:2-5m, x25; 4) same as figure 3, aperture of sicula and short decending protheca 1^1 with single terminal foramen, x200; 5) same as figures 3 and 4, proximal end view showing aperture of sicula, th1^1 foramen and base of th1^1 dorsal wall adjacent to sicula (upper centre), x100; 6) same as figure 2, distal end of virgula, x1000; 7) same as figure 8, distal end view showing intethecal septum and laterally embedded virgula, CM:5-7m, x100; 8) immature rhabdosome, x50; 9) same as figure 2, distal end view showing laterally embedded virgula - note strong distal curvature of fusellae of obverse wall where they meet the virgula, x75; 10) CM:2-5m, x25; 11) partially compressed specimen, obverse view showing complete exposure of sicula to th1^2 aperture, CM:2-5m, x25; 12) same as figure 8, oblique distal view showing fusellae of proximal thecae, x100.

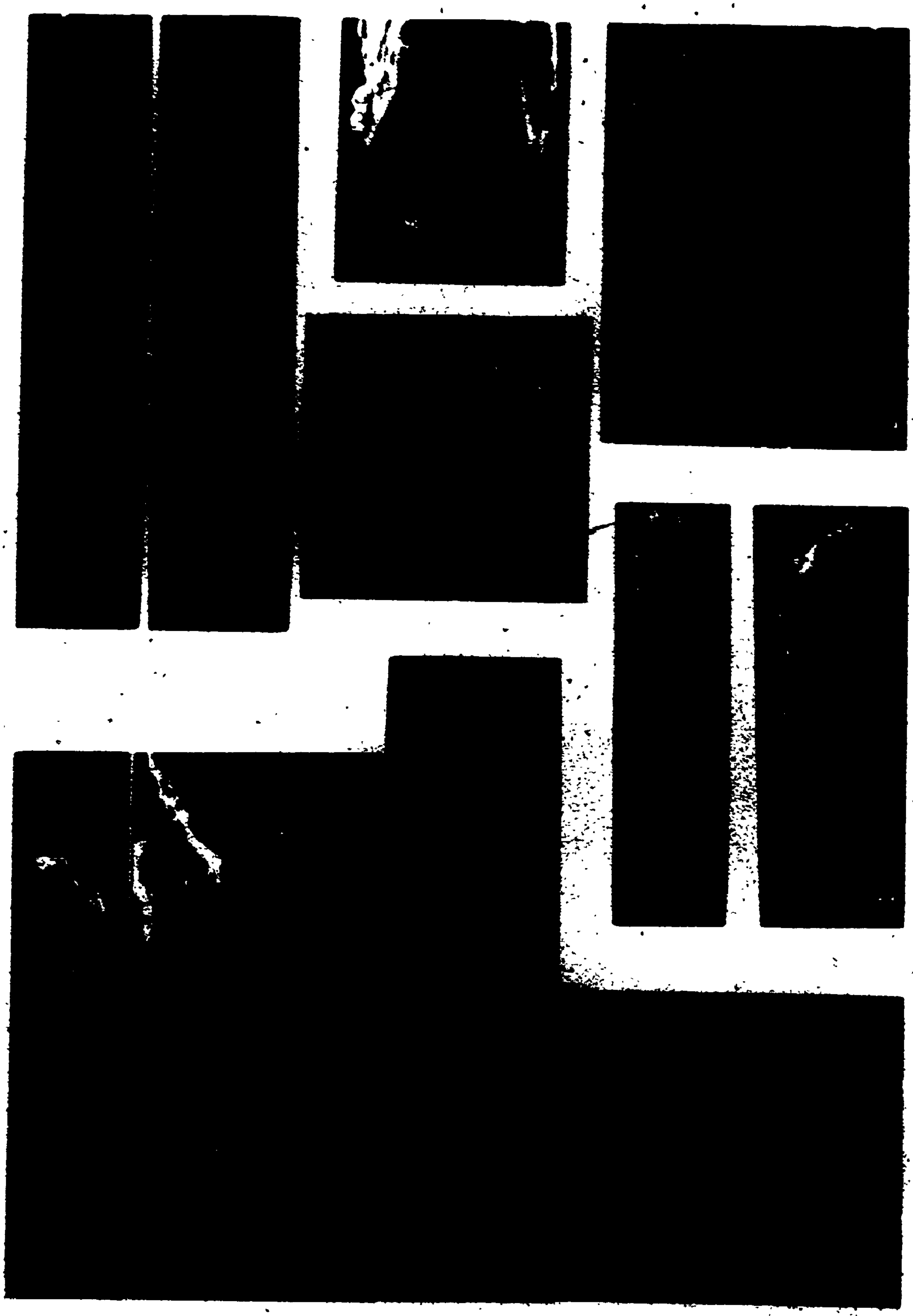

PLATE 20

Figures 1-7, Glyptograptus tamariscus acutus Packham, 1962, all specimens from RC:55.0m except where noted: 1) obverse view, note complete exposure of sicula and curvature of fusellae on obverse wall at virgula, x50; 2) immature specimen with broken sicular aperture, note distal fusellae, RC:88-105m, x50; 3) immature rhabdosome, x50; 4) same as figure 3, oblique distal view showing fusellae of proximal thecae, x100; 5) distal fragment, x25; 6) same as figure 5, distal end of virgula, x1000; 7) distal fragment, x25.

Figures 8-11, Comograptus comatus Obut and Sobolevskaya, 1968, all figures are single specimen from CM:0-2m: 8) proximal end view showing spinose sicula rim and downward-pointing virgula, x50; 9) stereopair, proximal end fragment of apparently mature specimen, x40; 10) distal end of virgula, note concentric layers, x1000; 11) distal end view, note lack of evidence of complete or partial median septum, x50.

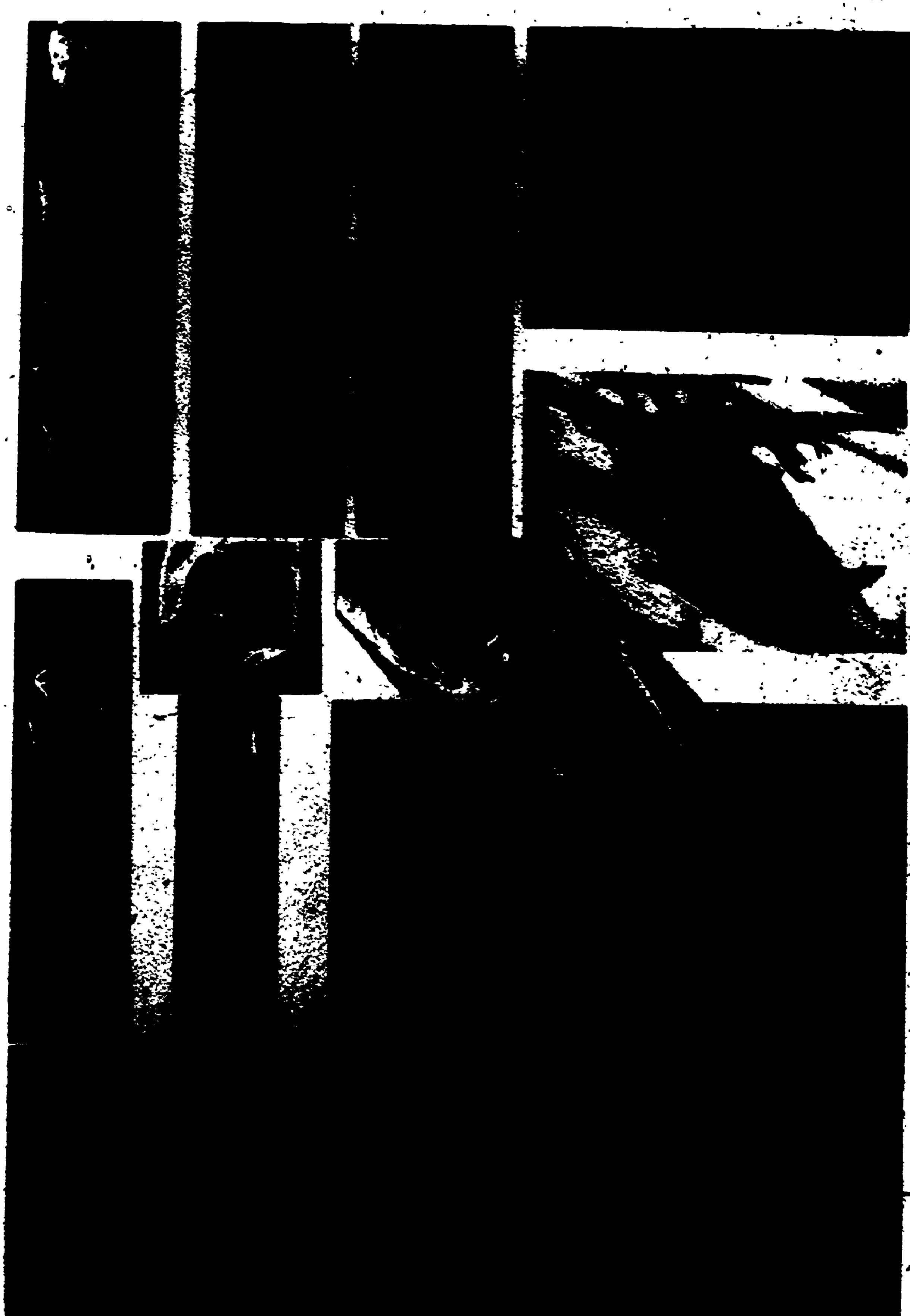

PLATE 21

Figures 1-11, *Comograptus gorbiachinensis* Obut and Sennikov, 1980, all specimens from CM:0-2m: 1) sicula and early growth of th1^1, note short descending protheca 1^1 and that spines on either side of virgella are not yet formed, x50; 2) sicula and th1^1 to point of differentiation of th1^2, x50; 3) same as figure 2, proximal end view showing three sicular aperture spines and virgella, x100; 4) same as figure 6, distal end view showing virgella apparently attached to base of interthecal septum, x75; 5) stereopair, mature rhabdosome, x25; 6) immature specimen showing growth of secong thecal pair, x25; 7) x25; 8) same as figure 2, distal view showing formation of first interthecal septum, x100; 9) same as figure 6, distal view of broken proximal end showing descending protheca and single terminal foramen, x100; 10) distal view of early growth stage specimen showing descnding protheca 1^1 with single foramen, early growth of metatheca 1^1 and sicular aperture with virgella, "antivirgellar" spine and flange of incipient aperutral spine beside virgella, x150; 11) immature rhabdosome showing differentiation of th2 , x50.

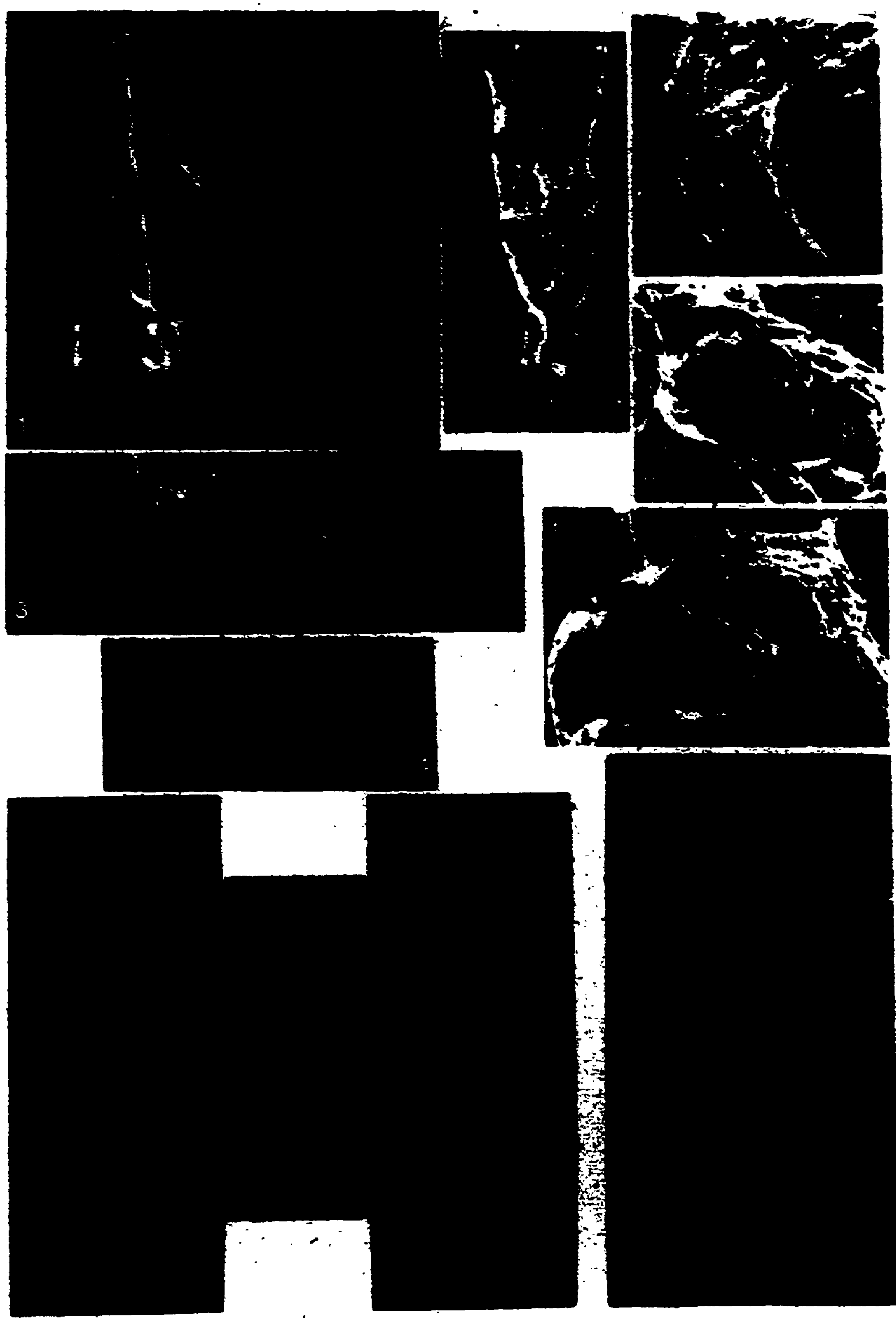
3

PLATE 22

Figures 1-6,8, *Agetograptus hubeiensis* (Ni, 1978), all specimens from RC:80-105m except where noted: 1) proximal fragment of mature, partly compressed rhabdosome with unusual spine development on base of virgella (see figure 5), CM:0-2m, x25; 2) early growth stage with damaged sicula, x50; 3) distal fragment, x25; 4) stereopair, obverse view of immature rhabdosome, x25; 5) same as figure 1, spines grown on base of virgella, x100; 6) same as figure 2, distal view of early thecae showing first interthecal septum, x75; 8) stereopair, x50.

Figures 7, 9-13, *Agetograptus spiniferus* Obut and Sobolevskaya, 1968: 7) same as figure 9, side view showing reduced and aborted first two thecae of second series, CM:0-2m, x50; 9) stereopair, aberrent specimen with reduced and aborted first two thecae of second series, x25; 10) partly compressed specimen, SC:140m, x15; 11) CM:2-5m, x25; 12) same as figure 11, bandaging on thecal surface, x250; 13) obverse view showing enclosure of sicula, CM:2-5m, x25.

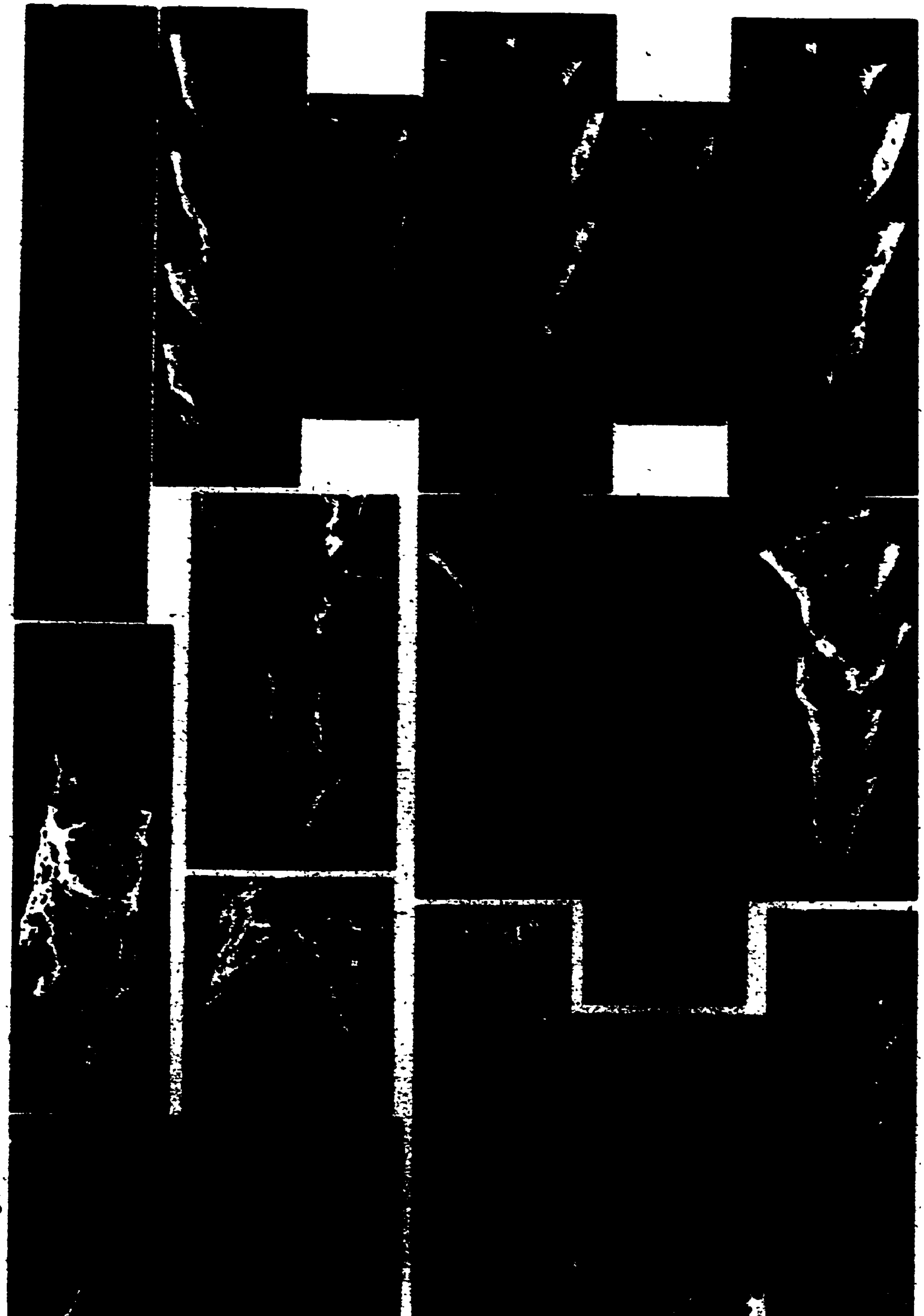

PLATE 23

Figures 1-8, *Agetograptus spiniferus* Obut and Sobolevskaya, 1968: 1) stereopair, distal fragment showing internal arrangement of interthecal septa, SC:140m, x15; 2) immature rhabdosome, CM:5-7m, x 50; 3) stereopair, CM:2-5m, x15; 4) specimen compressed in subscalariform view, SC:140m, x15; 5) same as figure 2, distal view inside proximal end showing very short descending protheca 1 with single terminal foramen, x150; 6) early growth stage, CM:5-7m, x50; 7) partly compressed specimen, SC:140m, x25; 8) same as figure 6, oblique distal view showing fusellar paterns of early thecae.

[redacted]

PLATE 24

Figures 1-9, "*Orthograptus*" *bellulus* (Tornquist, 1890), all specimens from CM:2-5m, except where noted: 1) stereopair, note decreasing degree of spine development distally, x25; 2) stereopair, obverse view, note rapid enclosure of sicula, CM:5-7m, x25; 3) proximal fragment of mature rhabdosome, note very long virgella and very short sicula (see figure 4), x25; same as figure 3, sicula, x75; 5) same as figures 6 and 7, proximal view inside broken proximal end, x100; 6) same as figure 7, view inside broken proximal end showing very short descending protheca 1^1 with single terminal foramen, x200; 7) side view showing thecal aperture, x50; 8) same as figure 2, distal end view showing interthecal septa and free, central virgula, x50; 9) same as figures 8 and 2, distal end of virgula, x1500.

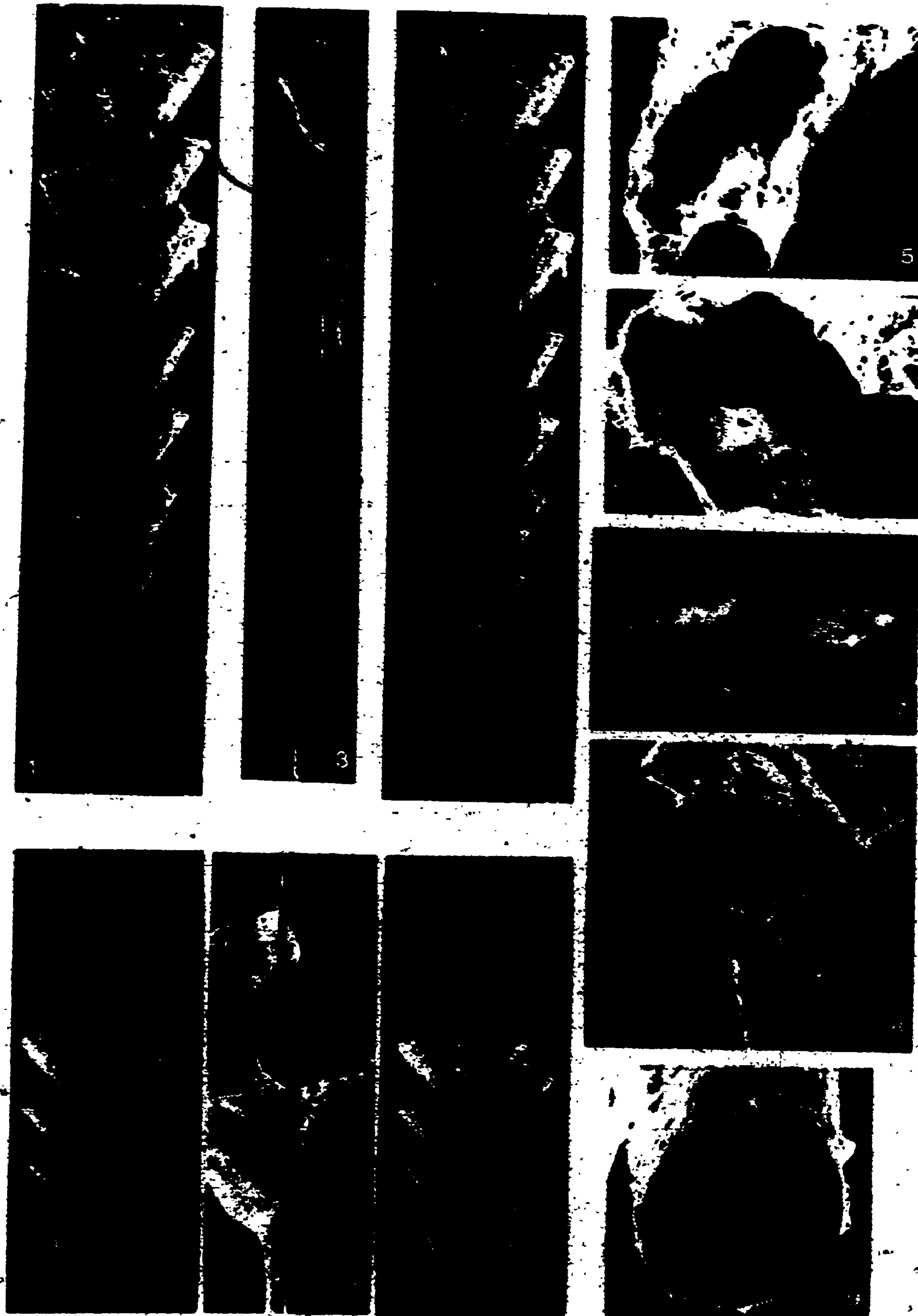
1
3
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PLATE 25

Figures 1-5, "Orthograptus" bellulus (Tornquist, 1890), all specimens from CM:5-7m: 1) stereopair, immature rahbdosome, note fusellae of early thecae and bandaging on thecal surfaces, x50; 2) same as figure 1, distal end view, x75; 3) stereopair, x25; 4) immature rahbdosome showing fusellae of early thecae, x50; 5) same as figure 4, distal end view, x75.

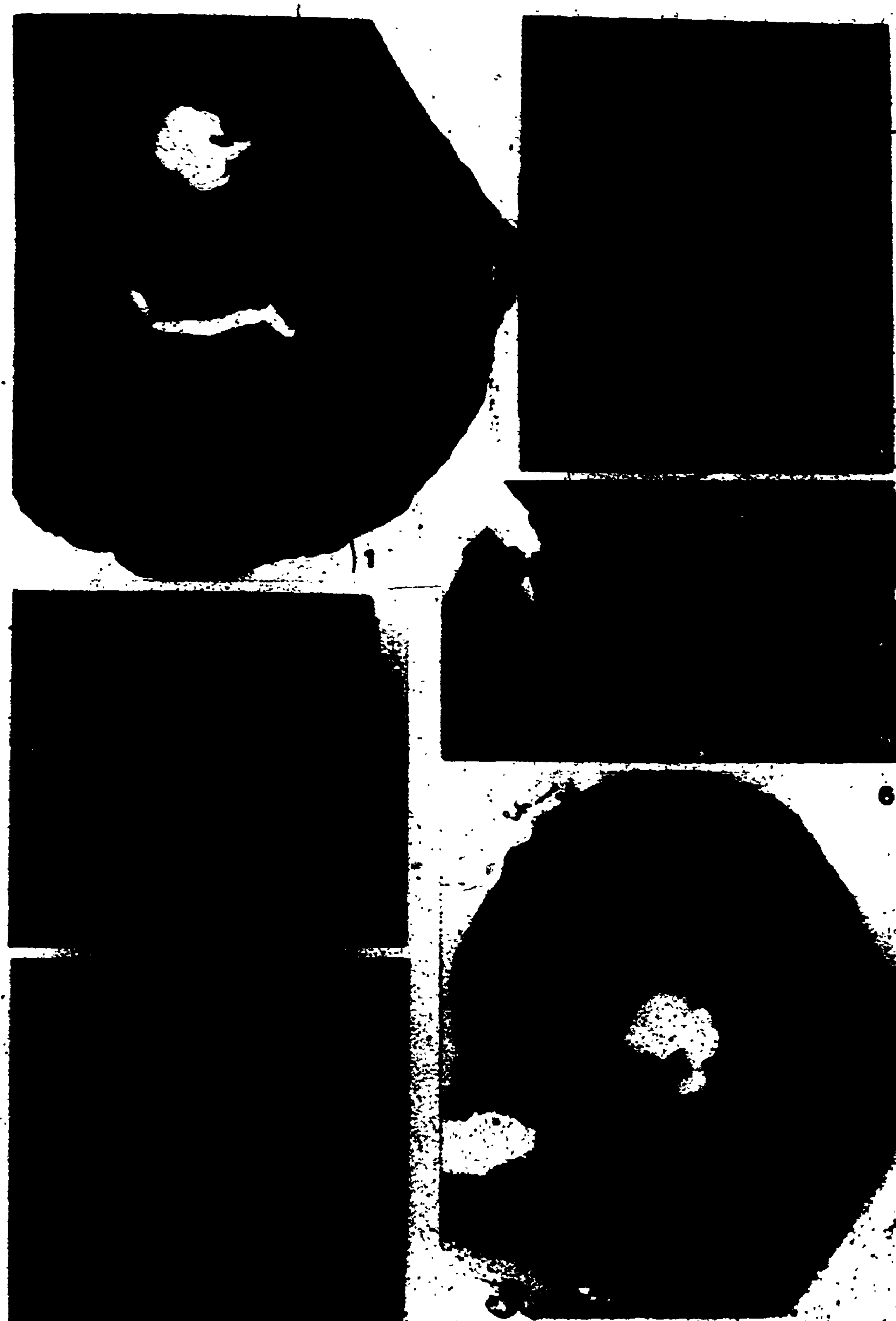
Figures 6-9, "Glyptograptus" kayi n. subsp., all specimens from CM:5-7m: 6) broken proximal end of immature specimen, note very short sicula, x75; 7) obverse view showing rapid enclosure of sicula, x25; 8) mature rhabdosome with broken virgella, x15; 9) very mature rhabdosome, note eversion of apertures of first thecal pair, x15.

PLATE 26

Figures 1-12, "Glyptograptus" kayi n. subsp., all specimens from CM:5-7 except where noted: 1) same as figure 5, stereopair, distal end view showing virgella attached to base of interthecal septum, x25; 2) same as figure 5, base of virgella showing bandaging extending from th11 onto virgella, x300; 3) same as figure 5, tip of virgella, x1000; 4) same as figure 5, th5^2 showing bandaging pattern, x150; 5) x15; 6) x15; 7) "gerontic" specimen, note strong eversion of aperures of first thecal pair and extension of cortcal tissue onto base of virgella, CM:2-5m, x15; 8) immature rhabdosome with proximal end broken open, x25; 9) same as figure 6, distal end of virgula, x1500; 10) same as figure 8, broken proximal end showing very short descending protheca 1^1 and base of th1^1 dorsal wall attached to sicula, x75; 11) same as figure 8, distal view inside broken proximal end faintly showing descending protheca 1^1 with single terminal foramen, x1000; 12) same as figure 7, obliquely broken end of virgella showing concentric layering, x350.

PLATE 27

Figures 1-6, transmission electron micrographs, "Glyptograptus" kayi n. subsp., all specimens from CM:5-7m: 1) transverse section through long virgella near distal end, x3690; 2) same as figure 1, enlargement of corticle layers near outer margin, x12,628; 3) same as figures 1 and 2, enlargment of single corticle layer, x37,515; 4) transverse section, core of virgella near its base, note inner layer of fusellar tissue surrounded by corticle tissue, x18,942; 5) same as figure 6, core region of virgula showing inner fusellar layer surrounded by corticle layers, x18,942; 6) transverse section through virgula at point of attachment to interthecal septum, x3690.


1
6

Appendix A

Graptolite species distribution charts for each of the sampled sections.

Appendix A1 - Snowblind Creek graptolite distribution.

1. "DIPLOGRAPTUS" TCHERSKYI N. SUBSP
2. "GLYPTOGRAPTUS" KAYI N. SUBSP
3. "ORTHOGRAPTUS" BELLULUS
4. AGETOGRAPTUS SPINIFERUS
5. ATAVOGRAPTUS PRAESTRACHANI
6. DIVERSOGRAPTUS CAPILLARIS
7. GLYPTOGRAPTUS TAMARISCUS ACUTUS
8. GLYPTOGRAPTUS TAMARISCUS TAMARISCUS
9. NEOROGRAPTUS N. SP. B
10. METACLIMACOGRAPTUS UNDULATUS
11. MONOGRAPTUS CF. M. CLINGANI
12. MONOGRAPTUS COMMUNIS COMMUNIS
13. MONOGRAPTUS DECIPIENS DECIPIENS
14. MONOGRAPTUS ELONGATUS
15. MONOGRAPTUS FALCATA
16. MONOGRAPTUS MILLEPEDA CURTUS
17. MONOGRAPTUS N. SP. B
18. PETALOGRAPTUS INSECTIFORMIS
19. PRISTIOGRAPTUS CF. P. CONCINNUS
20. PRISTIOGRAPTUS CF. P. PARVUS
21. PSEUDOGLYPTOGRAPTUS N. SP
22. RASTRITES ORBITUS
23. NEOROGRAPTUS SCALARIS FERGANENSIS
24. MONOCLIMACIS? N. SP.
25. MONOGRAPTUS COMMUNIS OBTUSUS
26. MONOGRAPTUS CONVOLUTUS
27. MONOGRAPTUS SIDJACHENKOI
28. PETALOGRAPTUS ANKYRATUS
29. PETALOGRAPTUS INTERMEDIUS
30. PETALOGRAPTUS PALMEUS N. SUBSP
31. MONOGRAPTUS MALLI
32. MONOGRAPTUS PSEUDORUNCINATUS
33. MONOGRAPTUS SPIRALIS CONTORTUS

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33
SC:538.5	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
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SC:534.2	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
SC:530.0	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
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SC:396.0	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
SC:394.0	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
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SC:393-396	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
SC:390.0	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
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SC:210	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	X	X	X
SC:170	X	.	.	.	X	X	.	X	.	X	.	.	X	.	X	.	X	.	.	.	X	.	X	X	X	X	X	X	X	X	.	.	.
SC:140	X	X	X	X	X	X	X	X	X	X	X	X	X	?	X	X	X	X	X	X	X	X	.	.	.	.	.	.	.	.	.	.	.

Sample	34 PETALOGRAPTUS PALMEUS PALMEUS	35 GLYPTOGRAPTUS ELEGANS N. SUBSP	36 GLYPTOGRAPTUS SP AFF G. FASTIGANS	37 PETALOGRAPTUS CF P. TENUIS	38 MONOGRAPTUS TURRICULATUS TURRICULATUS	39 PETALOGRAPTUS N. SP H	40 MONOGRAPTUS DEXTROTORSUS N SUBSP	41 MONOGRAPTUS PRIODON	42 RETIOLITES GEINITZIANUS ANGUSTIDENS	43 MONOGRAPTUS DISCUS	44 MONOGRAPTUS EXIGUUS EXIGUUS B	45 MONOGRAPTUS EXIGUUS N SUBSP	46 MONOGRAPTUS KOVALEVSKYI	47 MONOGRAPTUS RICKARDSI MINOR	48 MONOCLIMACIS VOMERINUS VOMERINUS	49 MONOGRAPTUS GRIESTONIENSIS GRIESTONIENSIS	50 MONOGRAPTUS SPIRALIS SPIRALIS	51 MONOCLIMACIS VOMERINUS CF. GEINITZI	52 MONOGRAPTUS 'NODIFER'	53 STOMATOGRAPTUS GRANDIS GIRVANENSIS	54 STOMATOGRAPTUS GRANDIS GRANDIS	55 RETIOLITES GEINITZIANUS GEINITZIANUS	56 BARRANDEOGRAPTUS SP. AFF. B PULCHELLUS	57 MONOGRAPTUS CF M. PARADOXUS HEMMANNI	58 PRISTIOGRAPTUS NUDUS	59 RETIOLITES GEINITZIANUS DENSERETICULATUS	60 MONOGRAPTUS MARRI	61 STOMATOGRAPTUS GRANDIS IMPERFECTUS	62 STOMATOGRAPTUS N SP	63 MONOCLIMACIS LINNARSSONI	64 MONOGRAPTUS SPECIOSUS	65 CYRTOGRAPTUS POLYRAMEUS	66 CYRTOGRAPTUS LAPWORTHI N. SUBSP
SC:538.5	.	.	.	.	.	.	.	X	.	.	.	.	.	.	X	.	.	.	.	.	.	.	.	.	X	X	.	.	.	.	.	.	.
SC:537.5	.	.	.	.	.	.	.	.	.	.	.	.	.	.	X	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
SC:536.5	.	.	.	.	.	.	.	X	.	.	.	.	.	.	X	.	.	.	.	.	.	.	.	X	.	X	.	.	.	.	X	.	.
SC:534.7	.	.	.	.	.	.	.	.	.	.	.	.	.	.	X	.	X	.	.	.	.	.	.	.	.	.	.	.	.	.	X	.	.
SC:534.2	.	.	.	.	.	.	.	.	.	.	.	.	.	.	X	.	X	.	.	.	.	.	.	.	.	.	.	.	.	.	X	.	.
SC:530.0	.	.	.	.	.	.	.	X	.	.	.	.	.	.	X	.	X	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
SC:528.0	.	.	.	.	.	.	.	X	.	.	.	.	.	.	X	X	X	.	.	.	.	.	.	.	X	X	.	.	.	.	X	.	X
SC:527.5	.	.	.	.	.	.	.	.	.	.	.	.	.	.	X	X	X	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
SC:526.0	.	.	.	.	.	.	.	X	.	.	.	.	.	.	X	.	X	.	.	.	.	.	.	.	.	X	.	.	.	.	.	.	.
SC:525.0	.	.	.	.	.	.	.	X	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	X	.	.	.	.	.	X	.
SC:524.5	.	.	.	.	.	.	.	.	.	.	.	.	.	.	X	.	.	.	.	.	.	.	.	.	.	X	.	.	.	.	.	.	.
SC:524.0	.	.	.	.	.	.	.	.	.	.	.	.	.	.	X	X	X	.	.	.	.	.	.	.	.	.	.	.	.	.	X	.	.
SC:522.5	.	.	.	.	.	.	.	X	.	.	.	.	.	.	.	.	X	.	.	.	.	.	.	.	.	.	.	.	.	X	X	.	.
SC:492.0	.	.	.	.	.	.	.	X	.	.	.	.	.	.	X	.	X	X	.	.	.	.	.	.	.	X	X	X	X	.	.	.	.
SC:491.5	.	.	.	.	.	.	.	X	.	.	.	.	.	.	X	X	.	X	.	.	.	.	.	.	.	.	X	.	.	.	.	.	.
SC:491.0	.	.	.	.	.	.	.	X	.	.	.	.	.	.	X	X	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
SC:460.0	.	.	.	.	.	.	.	X	.	.	.	.	.	.	X	X	X	X	.	.	.	.	.	.	X	X	.	.	.	.	.	.	.
SC:457.0	.	.	.	.	.	.	.	X	.	.	.	.	.	.	X	X	X	.	.	.	.	.	X	X	X	X	.	.	.	.	.	.	.
SC:445.0	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	X	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
SC:437.0	.	.	.	.	.	.	.	X	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
SC:396.0	.	.	.	.	.	.	.	X	X	.	.	.	.	.	X	X	X	X	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
SC:394.0	.	.	.	.	.	.	.	.	X	.	.	.	.	.	X	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
SC:393.0	.	.	.	.	.	.	.	X	.	.	.	.	.	.	X	.	X	X	.	.	.	X	.	.	.	.	.	.	.	.	.	.	.
SC:393-396	.	.	.	.	.	.	.	X	.	.	.	.	.	.	.	.	X	X	X	X	X	.	.	.	.	.	.	.	.	.	.	.	.
SC:390.0	.	.	.	.	.	.	.	X	.	.	.	.	.	.	.	.	.	X	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
SC:375.0	.	.	.	.	.	.	.	.	.	.	.	.	X	.	X	X	X	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
SC:360	.	.	.	.	.	.	.	X	X	X	X	X	X	X	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
SC:350	.	.	.	.	.	.	X	X	X	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
SC:320	.	.	.	.	X	X	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
SC:260	.	X	X	X	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
SC:210	X	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
SC:170	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
SC:140	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.

	67 MONOGRAPTUS PARAPRIODON	68 PSEUDOPLEGMATOGRAPTUS GIGANTEUS	69 PSEUDOPLEGMATOGRAPTUS CF. P. LONGISPINUS	70 CYRTOGRAPTUS SAKMARICUS	71 MONOGRAPTUS GRIESTONIENSIS MINUTA	72 MONOGRAPTUS MINIMUS	
SC:538.5	.	.	.	.	.	.	SC:538.5
SC:537.5	.	.	.	X	.	X	SC:537.5
SC:536.5	.	.	.	X	X	X	SC:536.5
SC:534.7	.	.	X	.	.	.	SC:534.7
SC:534.2	.	.	.	.	.	.	SC:534.2
SC:530.0	.	.	.	.	.	.	SC:530.0
SC:528.0	X	X	.	.	.	.	SC:528.0
SC:527.5	.	.	.	.	.	.	SC:527.5
SC:526.0	.	.	.	.	.	.	SC:526.0
SC:525.0	.	.	.	.	.	.	SC:525.0
SC:524.5	.	.	.	.	.	.	SC:524.5
SC:524.0	.	.	.	.	.	.	SC:524.0
SC:522.5	.	.	.	.	.	.	SC:522.5
SC:492.0	.	.	.	.	.	.	SC:492.0
SC:491.5	.	.	.	.	.	.	SC:491.5
SC:491.0	.	.	.	.	.	.	SC:491.0
SC:460.0	.	.	.	.	.	.	SC:460.0
SC:457.0	.	.	.	.	.	.	SC:457.0
SC:445.0	.	.	.	.	.	.	SC:445.0
SC:437.0	.	.	.	.	.	.	SC:437.0
SC:396.0	.	.	.	.	.	.	SC:396.0
SC:394.0	.	.	.	.	.	.	SC:394.0
SC:393.0	.	.	.	.	.	.	SC:393.0
SC:393-396	.	.	.	.	.	.	SC:393-396
SC:390.0	.	.	.	.	.	.	SC:390.0
SC:375.0	.	.	.	.	.	.	SC:375.0
SC:360	.	.	.	.	.	.	SC:360
SC:350	.	.	.	.	.	.	SC:350
SC:320	.	.	.	.	.	.	SC:320
SC:260	.	.	.	.	.	.	SC:260
SC:210	.	.	.	.	.	.	SC:210
SC:170	.	.	.	.	.	.	SC:170
SC:140	.	.	.	.	.	.	SC:140

0?6

Appendix A2 - Snowblind Creek A graptolite distribution

	1 MONOCLIMACIS VOMERINUS VOMERINUS	2 MONOGRAPTUS MARRI	3 MONOGRAPTUS PRIODON	4 CYRTOGRAPTUS LAPWORTHI N. SUBSP.	5 MONOCLIMACIS LINNARSSONI	6 MONOCLIMACIS VOMERINUS CF. GEINITZI	7 MONOGRAPTUS GRIESTONIENSIS MINUTA	8 MONOGRAPTUS SPIRALIS SPIRALIS	9 RETIOLITES GEINITZIANUS DENSERETICULATUS	10 STOMATOGRAPTUS N. SP.	11 CYRTOGRAPTUS SOLARIS N. SUBSP.	12 MONOGRAPTUS SPECIOSUS	13 STOMATOGRAPTUS GRANDIS IMPERFECTUS	14 CYRTOGRAPTUS N. SP.	
A24.0	X	.	.	.	.	.	.	X	.	.	.	.	.	X	A24.0
A16.0	.	.	X	X	.	X	.	X	X	.	.	X	X	.	A16.0
A05.0	X	.	.	.	.	.	.	.	.	.	X	.	.	.	A05.0
A02.0	X	X	X	X	X	X	X	X	X	X	.	.	.	.	A02.0
A00.0	X	X	X	.	.	.	.	.	.	.	.	.	.	.	A00.0

Appendix A3 - Cape Manning graptolite distribution.

CM:5-7	CM:2-5	CM:0-2		
x	x	•	1	"DIPLOGRAPTUS" TCHERSKYI N. SUBSP.
x	x	x	2	"DIPLOGRAPTUS" TCHERSKYI TCHERSKYI
x	x	x	3	"GLYPTOGRAPTUS" KAYI N. SUBSP.
x	x	•	4	"ORTHOGRAPTUS" BELLULUS
x	x	x	5	AGETOGRAPTUS SPINIFERUS
x	•	•	6	ATAVOGRAPTUS PRAESTRACHANI
x	x	•	7	CLINOCLIMACOGRAPTUS SCULPTUS
x	x	x	8	COMOGRAPTUS GORBIACHINENSIS
x	x	•	9	GLYPTOGRAPTUS TAMARISCUS TAMARISCUS
x	•	•	10	MONOGRAPTUS COMMUNIS COMMUNIS
x	•	•	11	MONOGRAPTUS COMMUNIS OBTUSUS
x	•	•	12	MONOGRAPTUS CONVOLUTUS
x	•	•	13	MONOGRAPTUS FALCATA
x	x	x	14	MONOGRAPTUS N. SP. B
x	x	•	15	N. GEN. A? N. SP.
x	•	•	16	PETALOGRAPTUS ANKYRATUS
x	x	•	17	PETALOGRAPTUS N. SP. C
x	•	•	18	PRISTIOGRAPTUS NUDUS
x	•	•	19	PRISTIOGRAPTUS REGULARIS REGULARIS
x	x	•	20	PSEUDOGLYPTOGRAPTUS N. SP.
•	x	•	21	"GLYPTOGRAPTUS" SINUATUS SINUATUS
•	x	•	22	CORONOGRAPTUS GREGARIUS CF. MINUSCULUS
•	x	•	23	CORONOGRAPTUS GREGARIUS GREGARIUS
•	x	•	24	GLYPTOGRAPTUS ELEGANS N. SUBSP.
•	x	x	25	HEDROGRAPTUS MEDIUS BREVICAUDATUS
•	x	•	26	HEDROGRAPTUS N. SP. B
•	x	x	27	LAGAROGRAPTUS INEXPEDITUS
•	x	x	28	LITHUANOGRAPTUS MINIMUS
•	x	x	29	METACLIMACOGRAPTUS ORIENTALIS
•	x	•	30	MONOCLIMACIS CF. M. CRENULARIS
•	x	•	31	MONOGRAPTUS CF. M. ARCIFORMIS
•	x	•	32	MONOGRAPTUS DECIPIENS DECIPIENS
•	x	•	33	MONOGRAPTUS ELONGATUS

CM:5-7	CM:2-5	CM:0-2		
•	×	•	34	MONOGRAPTUS MILLEPEDA CURTUS
•	×	×	35	MONOGRAPTUS N. SP. A
•	×	×	36	MONOGRAPTUS PECTINATUS PECTINATUS
•	×	×	37	PETALOGRAPTUS CF. P. FORTUITUS
•	×	•	38	PETALOGRAPTUS CYPEROIDES
•	×	•	39	PETALOGRAPTUS INSECTIFORMIS
•	×	•	40	PETALOGRAPTUS INTERMEDIUS
•	[illegible]	•	41	PRIBYLOGRAPTUS ARGUTUS ARGUTUS
•	×	×	42	PRISTIOGRAPTUS CF. P. PARVUS
•	×	•	43	PSEUDORETIOLITES CF. P. DECURTATUS
•	×	•	44	RASTRITES APPROXIMATUS APPROXIMATUS
•	×	•	45	RASTRITES N. SP.
•	×	•	46	RASTRITES ORBITUS
•	•	×	47	AGETOGRAPTUS HUBEIENSIS
•	•	×	48	COMOGRAPTUS COMATUS
•	•	×	49	HEDROGRAPTUS ELONGATUS
•	•	×	50	HEDROGRAPTUS NIKOLAYEVI
•	•	×	51	RASTRITES LONGISPINUS N. SUBSP.

CM:0-2
CM:2-5
CM:5-7

Appendix A4 - Cape Phillips graptilite distribution.

	1 MONOCLIMACIS VOMERINUS CF. GEINITZI	2 MONOCLIMACIS VOMERINUS VOMERINUS	3 MONOGRAPTUS RICKARDSI MINOR	4 MONOGRAPTUS SPIRALIS SPIRALIS	5 PARAPLECTOGRAPTUS CF. P. INTERMEDIUS	6 DIVERSOGRAPTUS CAPILLARIS	7 MONOGRAPTUS PRIODON	8 STOMATOGRAPTUS GRANDIS IMPERFECTUS	9 STOMATOGRAPTUS N. SP.	10 MONOGRAPTUS GRIESTONIENSIS GRIESTONIENSIS	11 PRISTIOGRAPTUS NUDUS	12 DIVERSOGRAPTUS RAMOSUS	13 RETIOLITES GEINITZIANUS DENSERETICULATUS	14 MONOCLIMACIS VOMERINUS N. SUBSP. BJERRESKOV	15 BARRANDEOGRAPTUS SP. AFF. B. PULCHELLUS	16 MONOGRAPTUS MARRI	17 MONOGRAPTUS SPIRALIS EXCENTRIBUS	18 CYRTOGRAPTUS? SP.	19 STOMATOGRAPTUS GRANDIS ASIATICUS	20 CYRTOGRAPTUS LAPWORTHI N. SUBSP.	21 MONOGRAPTUS MINIMUS	22 MONOGRAPTUS PARAPRIODON	23 MONOGRAPTUS SPECIOSUS	24 CYRTOGRAPTUS SAKMARICUS	25 MONOGRAPTUS CF. M. PARADOXUS HEMMANNI	26 STOMATOGRAPTUS GRANDIS GRANDIS	27 MONOCLIMACIS LINNARSSONI	28 MONOCLIMACIS N. SP. B	29 MONOGRAPTUS "NOBIFER"	30 MONOGRAPTUS GRIESTONIENSIS MINUTA
CP:160.0	.	.	.	.	X	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	X
CP:159.5	.	.	.	.	X	.	X	.	.	.	.	.	.	.	.	.	.	.	.	X	.	.	.	.	.	.	.	.	.	X
CP:158.5	.	.	.	.	.	.	X	.	.	.	.	.	.	.	.	.	.	.	.	.	X	.	X	X	.	.	.	.	X	.
CP:158.0	.	X	.	.	.	.	.	.	.	.	X	.	.	.	.	.	.	.	.	X	.	.	.	.	.	.	.	.	.	.
CP:157.0	X	.	.	.	.	.	X	.	.	.	.	.	X	.	.	.	.	.	.	.	X	.	.	X	.	.	.	.	.	.
CP:156.0	.	.	.	.	.	.	X	.	.	.	X	X	X	.	.	.	.	.	.	.	X	.	.	X	.	.	X	X	.	.
CP:153.0	.	.	.	.	.	.	.	.	.	.	X	.	.	.	.	.	.	.	.	.	X	X	.	X	.	.	.	.	.	.
CP:152.5	.	X	.	.	.	.	X	.	.	X	X	.	X	.	.	.	.	.	.	.	X	X	.	X	.	X	.	.	.	.
CP:151.0	.	.	.	.	.	.	.	.	.	.	X	.	X	.	.	.	.	.	.	X	.	.	.	X	.	.	.	.	.	.
CP:148.0	.	X	.	.	.	.	X	X	.	.	.	.	X	.	.	.	.	.	.	.	.	X	.	.	.	.	.	.	.	.
CP:147.0	.	X	.	.	.	.	X	.	.	.	.	.	.	.	.	.	.	.	.	.	X	.	.	.	.	.	.	.	.	.
CP:146.0	.	X	.	.	.	.	.	.	.	X	.	.	X	.	.	.	.	.	.	.	X	.	.	X	.	.	.	.	.	.
CP:140.0	.	X	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
CP:137.0	.	.	.	X	.	.	X	.	.	X	.	.	.	.	.	.	.	.	.	X	.	X	.	.	.	.	.	.	.	.
CP:130.0	.	.	.	X	.	.	.	.	.	X	.	.	.	.	.	.	.	.	.	.	.	.	X	.	.	.	.	.	.	.
CP:129.0	.	X	.	X	.	.	X	.	.	X	.	.	.	.	.	.	.	X	.	.	.	X	X	.	.	.	.	.	.	.
CP:128.0	.	X	.	X	.	.	X	X	.	X	.	.	X	.	.	.	.	.	.	.	.	X	X	X	X	.	.	.	.	.
CP:127.0	.	X	.	X	.	.	.	.	.	.	.	.	X	.	.	.	.	.	.	X	X	X	X	.	.	.	.	.	.	.
CP:120.0	.	X	.	.	.	.	.	.	.	.	.	.	X	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
CP:110.0	.	X	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	X	.	.	.	.	.	.	.	.	.	.	.
CP:100.0	.	X	.	.	.	.	X	.	.	.	.	.	.	.	.	.	.	X	.	.	.	.	.	.	.	.	.	.	.	.
CP:093.0	X	.	.	.	.	.	.	X	.	.	.	X	.	.	.	X	.	.	.	.	.	.	.	.	.	.	.	.	.	.
CP:086.0	.	.	.	X	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
CP:085.0	.	.	.	.	.	.	X	X	.	X	.	.	.	.	X	X	X	.	.	.	.	.	.	.	.	.	.	.	.	.
CP:081.0	.	.	.	X	.	X	X	.	.	.	.	.	.	X	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
CP:063.0	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
CP:058.5	.	.	.	X	.	.	X	.	.	.	.	.	X	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
CP:055	.	.	.	X	.	.	.	.	.	.	.	X	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
CP:034.0	X	X	.	.	.	X	X	.	X	X	X	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
CP:030.0	.	X	.	.	.	X	X	X	X	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
CP:026.5	X	.	.	.	.	X	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
CP:019.5	X	X	X	X	X	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
CP:000.0	X	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.

Appendix A5 - Rookery Creek graptolite distribution.

No.	Species	RC:055	RC:080-105 L	RC:134.5	RC:137.0	RC:139.5	RC:140.5	RC:144.0	RC:149.0	RC:156.5	RC:162.0
1	"GLYPTOGRAPTUS" SINUATUS SINUATUS	X	.	.	.	.	.	.	.	.	.
2	GLYPTOGRAPTUS ELEGANS N. SUBSP.	X	.	.	.	.	.	.	.	.	.
3	GLYPTOGRAPTUS TAMARISCUS ACUTUS	X	X	.	.	.	.	.	.	.	.
4	HEDROGRAPTUS NIKOLAYEVI	X	X	.	.	.	.	.	.	.	.
5	LITHUANOGRAPTUS MINIMUS	X	X	.	.	.	.	.	.	.	.
6	PETALOGRAPTUS INTERMEDIUS	J	.	.	.	.	.	.	.	.	.
7	PSEUDOGLYPTOGRAPTUS N. SP.	X	.	.	.	.	.	.	.	.	.
8	AGETOGRAPTUS HUBEIENSIS	.	X	.	.	.	.	.	.	.	.
9	HEDROGRAPTUS CF. H. SIMPLEX	.	X	.	.	.	.	.	.	.	.
10	MONOGRAPTUS GRIESTONIENSIS GRIESTONIENSIS	.	.	J	.	.	.	X	.	.	X
11	MONOGRAPTUS PRIODON	.	.	X	.	.	.	X	X	.	.
12	MONOGRAPTUS SPIRALIS SPIRALIS	.	.	X	.	X	.	.	.	.	X
13	MONOCLIMACIS VOMERINUS VOMERINUS	.	.	.	X	X	.	X	X	X	X
14	PRISTIOGRAPTUS NUDUS	.	.	.	.	X	.	.	.	.	X
15	RETIOLITES GEINITZIANUS DENSERETICULATUS	.	.	.	.	.	X	.	.	X	.
16	MONOGRAPTUS "NODIFER"	.	.	.	.	.	.	X	.	.	.
17	BARRANDEOGRAPTUS SP. AFF. B. PULCHELLUS	.	.	.	.	.	.	.	X	.	X
18	CYRTOGRAPTUS N. SP.	.	.	.	.	.	.	.	X	.	.
19	STOMATOGRAPTUS GRANDIS ASIATICUS	.	.	.	.	.	.	.	X	.	.
20	CYRTOGRAPTUS SAKMARICUS	.	.	.	.	.	.	.	.	.	X
21	DIVERSOGRAPTUS RAMOSUS	.	.	.	.	.	.	.	.	.	X
22	MONOGRAPTUS SPECIOSUS	.	.	.	.	.	.	.	.	.	X

Appendix A6 - Truro Island graptolite distribution.

TI:37.0	TI:38.5	TI:47.0-48.0	TI:49.0	TI:51.0	No.	Species
X	.	.	.	.	1	"DIPLOGRAPTUS" CF. "D". ANGUSTIDENS
X	.	.	.	.	2	HEDROGRAPTUS ANGUSTUS
X	.	.	.	.	3	HEDROGRAPTUS N. SP. A
X	.	.	.	.	4	PARACLIMACOGRAPTUS INNOTATUS OBESUS
.	X	.	.	.	5	GLYPTOGRAPTUS? AFF. G? NANUS
.	X	.	.	.	6	HEDROGRAPTUS MINUTUS
.	X	.	.	.	7	PARAKIDOGRAPTUS ACUMINATUS
.	.	X	X	.	8	GLYPTOGRAPTUS INCERTUS
.	.	X	.	.	9	HEDROGRAPTUS JANISCHEWSKYI
.	.	X	.	.	10	MONOCLIMACIS CF. M. CRENULARIS
.	.	X	.	.	11	MONOGRAPTUS CF. M. ARCIFORMIS
.	.	.	X	.	12	METACLIMACOGRAPTUS HUGHESI
.	.	.	X	.	13	MONOGRAPTUS N. SP. B
.	.	.	X	.	14	PRISTIOGRAPTUS CF. P. PARVUS
.	.	.	.	X	15	GLYPTOGRAPTUS SP. AFF. G. FASTIGANS
.	.	.	.	X	16	MONOGRAPTUS HALLI
.	.	.	.	X	17	PRISTIOGRAPTUS NUDUS

TI:51.0
TI:49.0
TI:47.0-48.0
TI:38.5
TI:37.0

Appendix A7 - Twilight Creek graptolite distribution.

	1 ATAVOGRAPTUS ATAVUS	2 ATAVOGRAPTUS PRAESTRACHANI	3 CORONOGRAPTUS CYPHUS CYPHUS	4 CORONOGRAPTUS GREGARIUS CF. MINUSCULUS	5 DIMORPHOGRAPTUS MINUTUS	6 NEDROGRAPTUS ELONGATUS	7 NEDROGRAPTUS MAGNUS	8 NEDROGRAPTUS N. SP. C	9 NEDROGRAPTUS NIKOLAYEVI	10 "DIPLOGRAPTUS" TCHERSKYI N. SUBSP.	11 "GLYPTOGRAPTUS" KAYI N. SUBSP.	12 DIVERSOGRAPTUS CAPILLARIS	13 NEDROGRAPTUS? CF. N? TANGSHANENSIS	14 METACLIMACOGRAPTUS UNDULATUS	15 MONOCLIMACIS CF. M. CRENULARIS	16 MONOGRAPTUS COMMUNIS OBTUSUS	17 MONOGRAPTUS CONVOLUTUS	18 MONOGRAPTUS FALCATA	19 MONOGRAPTUS N. SP. C	20 MONOGRAPTUS SIDJACHENKOI	21 PETALOGRAPTUS ANKYRATUS	22 PETALOGRAPTUS INTERMEDIUS	23 PETALOGRAPTUS PALMEUS CLAVATUS	24 PETALOGRAPTUS PALMEUS N. SUBSP.	25 PRIBYLOGRAPTUS ARGUTUS ARGUTUS	26 PRISTIOGRAPTUS CF. P. ARTUS	27 PRISTIOGRAPTUS JACULUM N. SUBSP.	28 PRISTIOGRAPTUS NUDUS	29 PRISTIOGRAPTUS REGULARIS REGULARIS	30 PSEUDOGLYPTOGRAPTUS N. SP.	31 GLYPTOGRAPTUS TAMARISCUS TAMARISCUS	32 MONOGRAPTUS CF. M. VICHANGENSIS	33 MONOGRAPTUS DECIPIENS DECIPIENS
TC:61.5	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	X	.	.	.	.	.
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TC:15.0	.	.	.	.	.	.	.	.	.	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	.	.	.
TC:13.5	X	X	X	X	X	X	X	X	X	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.

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	34 MONOGRAPTUS LOBIFERUS LOBIFERUS	35 MONOGRAPTUS N. SP. A	36 PETALOGRAPTUS OVATUS WUXIENSIS	37 MONOGRAPTUS DECIPIENS N. SUBSP.	38 MONOGRAPTUS DEXTROTORSUS N. SUBSP.	39 MONOGRAPTUS HALLI	40 MONOGRAPTUS PSEUDOBECKI	41 MONOGRAPTUS SPIRALIS CONTORTUS	42 GLYPTOGRAPTUS ELEGANS N. SUBSP.	43 MONOGRAPTUS EXIGUUS EXIGUUS B	44 MONOGRAPTUS EXIGUUS PRIMULUS	45 MONOGRAPTUS N. SP. D	46 MONOGRAPTUS PSEUDORUNCINATUS	47 MONOGRAPTUS SP. AFF. M. NODIFER	48 MONOGRAPTUS TURRICULATUS MINOR	49 PETALOGRAPTUS PALMEUS PALMEUS	50 DIVERSOGRAPTUS CF. D? RUNCINATUS	51 MONOGRAPTUS DECIPIENS VALENS	52 PETALOGRAPTUS TENUIS	53 PSEUDORETIOLITES CF. P. DECURTATUS	54 GLYPTOGRAPTUS SP. AFF. G. FASTIGANS	55 MONOGRAPTUS EXIGUUS EXIGUUS A	56 MONOGRAPTUS EXIGUUS N. SUBSP.	57 MONOGRAPTUS KOVALEVSKYI	58 MONOGRAPTUS MARRI	59 MONOGRAPTUS PLANUS	60 PETALOGRAPTUS CF. P. ALTISSIMUS	61 PETALOGRAPTUS CF. P. KURCKI	62 PETALOGRAPTUS N. SP. A	63 MONOGRAPTUS TURRICULATUS TURRICULATUS	64 MONOCLIMACIS N. SP. A	65 MONOGRAPTUS SPIRALIS SPIRALIS	66 STOMATOGRAPTUS GRANDIS GIRVANENSIS
TC:61.5	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
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TC:28.5	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	X	X	.
TC:27.5	.	.	.	.	X	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	X	.	X
TC:27.0	.	.	.	.	X	.	.	.	.	X	.	.	.	.	.	.	.	.	.	.	.	.	.	X	.	.	.	.	.	.	X	X	.
TC:26.5	.	.	.	.	X	.	.	.	.	X	.	.	.	.	.	.	.	.	.	.	.	.	.	X	.	.	.	.	.	X	.	.	.
TC:26.0	.	.	.	.	X	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	X	.	X	.	.	.	X	X	.	.
TC:25.5	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	X	.	.	.	.	.	X	X	X
TC:24.5	.	.	.	.	X	.	.	.	.	.	.	.	.	.	X	.	.	.	.	.	.	.	.	.	.	.	.	.	.	X	.	.	.
TC:23.5	.	.	.	X	X	X	X	X	X	.	.	X	X	X	X	X	.	X	X	X	X	X	X	X	X	X	X	X	X	.	.	.	.
TC:22.5	.	.	.	X	.	X	X	X	X	.	X	X	.	.	X	.	X	X	X	X	.	.	.	.	.	.	.	.	.	.	.	.	.
TC:21.5	.	.	.	X	.	X	X	X	X	?	X	X	X	X	X	X	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
TC:20.5	.	.	X	X	X	X	X	X	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
TC:15.5-16.0	X	X	X	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
TC:15.0	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
TC:13.5	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.

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	67 MONOGRAPTUS CRISPUS	68 MONOGRAPTUS DISCUS	69 MONOGRAPTUS FLAGELLARIS	70 MONOGRAPTUS PRIODON	71 MONOGRAPTUS PROTEUS	72 MONOGRAPTUS RICKARDSI MINOR	73 PSEUDOPLEGMATOGRAPTUS OBESUS OBESUS	74 RETIOLITES GEINITZIANUS ANGUSTIDENS	75 MONOGRAPTUS "NODIFER"	76 MONOGRAPTUS GRIESTONIENSIS GRIESTONIENSIS	77 MONOGRAPTUS SP. AFF. M. TULLBERGI?	78 RETIOLITES GEINITZIANUS DENSERETICULATUS	79 MONOGRAPTUS CF. M. AVAGUSENSIS	80 STOMATOGRAPTUS N. SP.	81 BARRANDEOGRAPTUS SP. AFF. B. PULCHELLUS	82 MONOCLIMACIS VOMERINUS VOMERINUS	83 RETIOLITES GEINITZIANUS GEINITZIANUS	84 DIVERSOGRAPTUS RAMOSUS	85 MONOCLIMACIS VOMERINUS CF. GEINITZI	86 MONOGRAPTUS PARAPRIODON	87 MONOGRAPTUS GRIESTONIENSIS MINUTA	88 STOMATOGRAPTUS GRANDIS GRANDIS	89 PRISTIOGRAPTUS? SP.	90 PRISTIOGRAPTUS INITIALIS	91 CYRTOGRAPTUS? SP.	92 MONOGRAPTUS SPIRALIS EXCENTRICUS	93 STOMATOGRAPTUS GRANDIS IMPERFECTUS	94 CYRTOGRAPTUS SOLARIS N. SUBSP.	95 MONOGRAPTUS CF. M. PARADOXUS HEMMANNI	96 CYRTOGRAPTUS SAKMARICUS	97 CYRTOGRAPTUS N. SP.	98 MONOCLIMACIS LINNARSSONI	99 MONOGRAPTUS SPECIOSUS
TC:61.5	.	.	.	X	.	.	.	.	?	.	.	X	.	X	.	X	.	.	.	X	X	.	.	.	.	.	.	.	.	.	.	X	X
TC:60.0	.	.	.	X	.	.	.	.	.	.	.	X	.	X	.	.	.	.	.	X	.	.	.	.	.	.	.	.	.	X	.	.	.
TC:59.0	.	.	.	X	.	.	.	.	.	.	.	X	.	X	.	X	.	.	.	X	X	.	.	.	.	.	.	.	.	X	.	.	X
TC:57.0	.	.	.	X	.	.	.	.	.	.	.	X	.	X	.	X	.	.	.	X	.	.	.	.	.	.	.	.	X	X	.	.	.
TC:55.5	.	.	.	X	.	.	.	.	.	.	.	X	.	.	.	.	.	X	.	.	.	.	.	.	.	.	.	.	.	X	.	.	X
TC:54.5	.	.	.	X	.	.	.	.	.	.	.	X	?	.	.	X	.	.	.	.	X	.	.	.	.	.	.	.	X	X	.	.	X
TC:52.5	.	.	.	X	.	.	.	.	.	.	.	X	.	.	.	.	X	X	X	.	X	.	.	.	.	.	.	.	.	.	.	.	X
TC:52.0	.	.	.	X	.	.	.	.	.	.	.	.	.	.	.	X	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	X
TC:51.0	.	.	.	X	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	X	.
TC:50.0	.	.	.	X	.	.	.	.	.	.	.	X	.	.	.	.	.	X	X	.	.	.	.	.	X	.	.	.	.	.	.	.	.
TC:49.5	.	.	.	X	.	.	.	.	.	.	.	X	.	.	.	X	.	X	.	.	.	.	.	.	.	.	.	.	X	.	.	X	X
TC:49.0	.	.	.	X	.	.	.	.	.	.	.	X	.	X	.	X	.	X	X	X	.	.	.	.	.	X	.	.	X	.	X	X	X
TC:48.0	.	.	.	.	.	.	.	.	.	.	.	X	.	.	.	X	.	.	.	.	.	.	.	.	.	.	.	.	.	X	.	.	.
TC:47.5	.	.	.	X	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
TC:47.0	.	.	.	X	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
TC:46.0	.	.	.	X	.	.	.	.	.	.	.	.	.	X	.	X	.	X	X	.	X	.	.	.	.	X	.	.	X	.	.	.	.
TC:45.5	.	.	.	X	.	.	.	.	X	.	.	.	.	.	.	X	.	.	.	X	.	.	.	.	X	.	.	.	.	.	.	.	.
TC:45.0	.	.	.	X	.	.	.	.	.	.	.	.	.	.	.	X	X	.	X	.	.	.	.	.	.	.	.	X	.	.	.	.	.
TC:43.5	.	.	.	X	.	.	.	.	X	.	.	.	.	.	.	X	.	.	X	.	.	.	.	.	X	X	.	.	.	.	.	.	.
TC:42.5	.	.	.	X	.	.	.	.	.	.	.	X	.	.	.	X	.	.	.	.	.	.	.	X	X	X	.	.	.	.	.	.	.
TC:42.0	.	.	.	X	.	.	.	.	X	X	.	X	.	.	.	X	X	.	.	.	.	.	.	X	X	X	X	.	.	.	.	.	.
TC:40.5	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	X	.	.	.	.	.	.	.	X	.	.	.	.	.	.	.	.	.
TC:35.5	.	.	.	X	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	X	.	.	.	.	.	.	.	.	.	.	.	.	.
TC:34.0	.	.	.	X	.	.	.	.	.	X	.	.	.	.	.	X	.	.	.	.	.	.	X	.	.	.	.	.	.	.	.	.	.
TC:32.5	.	.	.	.	.	.	.	.	.	X	X	.	.	.	.	X	.	X	X	.	.	.	.	.	.	.	.	.	.	.	.	.	.
TC:31.5	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	X	.	X	.	.	X	X	.	.	.	.	.	.	.	.	.	.	.
TC:31.0	.	.	.	X	.	.	.	.	.	X	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
TC:30.5	.	.	.	X	.	.	.	.	.	.	X	.	.	.	.	X	.	X	X	X	.	.	.	.	.	.	.	.	.	.	.	.	.
TC:29.5	.	.	.	X	.	.	.	.	X	X	?	X	.	X	X	X	X	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
TC:28.5	.	.	.	X	.	.	.	.	X	X	.	.	.	X	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
TC:27.5	.	X	X	X	X	X	.	.	.	X	.	X	X	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
TC:27.0	.	.	X	X	.	X	.	.	X	X	X	X	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
TC:26.5	X	X	.	X	X	X	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
TC:26.0	X	X	X	X	X	X	X	X	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
TC:25.5	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
TC:24.5	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
TC:23.5	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
TC:22.5	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
TC:21.5	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
TC:20.5	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
TC:18.5-16.0	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
TC:15.0	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
TC:13.5	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.

	100 CYRTOGRAPTUS LAPWORTHI N. SUBSP.	101 PARAPLECTOGRAPTUS CF. P. INTERMEDIUS	102 CYRTOGRAPTUS POLYRAKEUS	103 MONOGRAPTUS MINIMUS	104 MONOCLIMACIS N. SP. B	
TC:61.5	X	.	.	X	X	TC:61.5
TC:60.0	X	.	.	X	.	TC:60.0
TC:59.0	X	.	.	X	.	TC:59.0
TC:57.0	X	.	.	.	.	TC:57.0
TC:55.5	X	.	.	.	.	TC:55.5
TC:54.5	.	.	X	.	.	TC:54.5
TC:52.5	X	X	.	.	.	TC:52.5
TC:52.0	X	.	.	.	.	TC:52.0
TC:51.0	X	.	.	.	.	TC:51.0
TC:50.0	.	.	.	.	.	TC:50.0
TC:49.5	.	.	.	.	.	TC:49.5
TC:49.0	.	.	.	.	.	TC:49.0
TC:48.0	.	.	.	.	.	TC:48.0
TC:47.5	.	.	.	.	.	TC:47.5
TC:47.0	.	.	.	.	.	TC:47.0
TC:46.0	.	.	.	.	.	TC:46.0
TC:45.5	.	.	.	.	.	TC:45.5
TC:45.0	.	.	.	.	.	TC:45.0
TC:43.5	.	.	.	.	.	TC:43.5
TC:42.5	.	.	.	.	.	TC:42.5
TC:42.0	.	.	.	.	.	TC:42.0
TC:40.5	.	.	.	.	.	TC:40.5
TC:35.5	.	.	.	.	.	TC:35.5
TC:34.0	.	.	.	.	.	TC:34.0
TC:32.5	.	.	.	.	.	TC:32.5
TC:31.5	.	.	.	.	.	TC:31.5
TC:31.0	.	.	.	.	.	TC:31.0
TC:30.5	.	.	.	.	.	TC:30.5
TC:29.5	.	.	.	.	.	TC:29.5
TC:28.5	.	.	.	.	.	TC:28.5
TC:27.5	.	.	.	.	.	TC:27.5
TC:27.0	.	.	.	.	.	TC:27.0
TC:26.5	.	.	.	.	.	TC:26.5
TC:26.0	.	.	.	.	.	TC:26.0
TC:25.5	.	.	.	.	.	TC:25.5
TC:24.5	.	.	.	.	.	TC:24.5
TC:23.5	.	.	.	.	.	TC:23.5
TC:22.5	.	.	.	.	.	TC:22.5
TC:21.5	.	.	.	.	.	TC:21.5
TC:20.5	.	.	.	.	.	TC:20.5
TC:15.5-16.0	.	.	.	.	.	TC:15.5-16.0
TC:15.0	.	.	.	.	.	TC:15.0
TC:13.5	.	.	.	.	.	TC:13.5

Appendix A8 - Middle Island graptolite distribution.

	1 MONOGRAPTUS HALLI	2 MONOGRAPTUS EXIGUUS N. SUBSP.	3 MONOGRAPTUS HARRI	4 MONOGRAPTUS PRIODON	5 MONOGRAPTUS TURRICULATUS TURRICULATUS	6 MONOCLIMACIS VOMERINUS CF. GEINITZI	7 CYRTOGRAPTUS LAPWORTHI N. SUBSP.	8 MONOCLIMACIS VOMERINUS VOMERINUS	9 RETIOLITES GEINITZIANUS DENSERETICULATUS	10 STOMATOGRAPTUS GRANDIS IMPERFECTUS	11 MONOGRAPTUS SPECIOSUS	12 MONOGRAPTUS SPIRALIS SPIRALIS	13 PRISTIOGRAPTUS NUDUS	[illegible] CYRTOGRAPTUS SAKMARICUS	[illegible] MONOGRAPTUS GRIESTONIENSIS MINUTA	16 MONOGRAPTUS MINIMUS	17 MONOGRAPTUS PARAPRIODON	18 STOMATOGRAPTUS GRANDIS GRANDIS	19 MONOCLIMACIS LINNARSSONI	
MI:67.0	.	.	.	X	.	.	.	X	.	.	.	.	.	.	.	.	X	.	.	MI:67.0
MI:66.0	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	X	.	X	MI:66.0
MI:64.0	.	.	.	X	.	.	X	X	X	.	X	.	X	X	X	X	X	X	.	MI:64.0
MI:63.0	.	.	.	X	.	.	.	X	X	.	.	.	X	X	X	X	.	.	.	MI:63.0
MI:59.0	.	.	.	X	.	.	.	X	.	.	X	X	X	.	.	.	.	.	.	MI:59.0
MI:52.0	.	.	X	.	.	.	X	X	X	X	.	.	.	.	.	.	.	.	.	MI:52.0
MI:39.0	.	.	.	X	.	X	.	.	.	.	.	.	.	.	.	.	.	.	.	MI:39.0
MI:35.0	.	X	?	?	X	.	.	.	.	.	.	.	.	.	.	.	.	.	.	MI:35.0
MI:18.0	?	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	MI:18.0

Appendix A9 - Cape Becher graptolite distribution.

	CYRTOGRAPTUS SAKMARICUS	CYRTOGRAPTUS CF. C. LAPWORTHI LAPWORTHI	MONOCLIMACIS LINNARSSONI	MONOGRAPTUS PRIODON	RETIOLITES GEINITZIANUS DENSERETICULATUS	CYRTOGRAPTUS LAPWORTHI N. SUBSP.	MONOCLIMACIS VOMERINUS VOMERINUS	MONOGRAPTUS MINIMUS	STOMATOGRAPTUS GRANDIS IMPERFECTUS	STOMATOGRAPTUS N. SP.	MONOGRAPTUS PARAPRIODON	MONOGRAPTUS SPECIOSUS	MONOGRAPTUS KOVALEVSKYI	CYRTOGRAPTUS POLYRAMEUS	MONOCLIMACIS N. SP. B	
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	
CB:32.0	.	.	.	.	X	.	X	.	.	.	.	.	.	.	X	CB:32.0
CB:30.0	X	.	.	.	.	.	X	.	X	.	.	.	X	.	.	CB:30.0
CB:29.0	.	.	.	X	.	.	.	X	.	.	.	.	.	.	.	CB:29.0
CB:27.0	X	X	.	X	.	.	X	.	.	.	X	.	X	.	.	CB:27.0
CB:26.0	.	.	.	.	X	.	.	.	.	.	.	.	.	.	.	CB:26.0
CB:22.0	.	.	.	.	X	.	.	X	X	.	.	.	.	.	.	CB:22.0
CB:20.5	.	.	X	.	.	.	.	X	.	.	.	.	.	X	.	CB:20.5
CB:20.0	X	.	X	X	X	.	X	X	X	.	.	.	X	.	.	CB:20.0
CB:17.0	X	.	.	.	.	X	.	.	.	X	.	X	.	.	.	CB:17.0
CB:14.0	X	.	.	.	.	.	.	.	.	X	X	.	.	.	.	CB:14.0
CB:12.0	X	.	.	.	.	.	X	X	.	X	X	.	.	.	.	CB:12.0
CB:10.0	X	.	.	.	X	.	X	X	.	.	.	X	.	.	.	CB:10.0
CB:07.0	X	.	.	X	X	.	X	X	X	X	X	.	.	.	.	CB:07.0
CB:06.0	.	.	.	.	.	.	X	.	X	X	.	.	.	.	.	CB:06.0
CB:05.0	X	.	.	.	X	X	X	X	.	.	.	.	.	.	.	CB:05.0
CB:02.0	X	X	?	X	X	.	.	.	.	.	.	.	.	.	.	CB:02.0
CB:01.0	X	.	.	.	.	.	.	.	.	.	.	.	.	.	.	CB:01.0

Appendix A10 - Trold Fiord graptolite distribution.

	1 GLYPTOGRAPTUS LACINIOSUS	2 HEDROGRAPTUS MAGNUS *	3 PETALOGRAPTUS? N. SP. *	4 ATAVOGRAPTUS ATAVUS	5 GLYPTOGRAPTUS TENUIS	6 HEDROGRAPTUS MODESTUS MODESTUS	7 DIMORPHOGRAPTUS ERECTUS	8 GLYPTOGRAPTUS TAMARISCUS CF. VARIANS	9 HEDROGRAPTUS CF. H. LANPHEREI	10 HEDROGRAPTUS NORMALIS	11 PARACLIMACOGRAPTUS JINYANGENSIS	12 ATAVOGRAPTUS PRAESTRACHANI	13 DIMORPHOGRAPTUS MINUTUS	14 HEDROGRAPTUS NIKOLAYEVI	15 HEDROGRAPTUS RECTANGULARIS	16 LAGAROGRAPTUS ACINACES	17 METACLIMACOGRAPTUS HUGHESI	18 PRIBYLOGRAPTUS ARGUTUS ARGUTUS	19 PRIBYLOGRAPTUS INCOMMODUS	20 PRISTIOGRAPTUS FRAGILIS PRISTINUS	21 AGETOGRAPTUS CF. A. SICHUANENSIS	22 CLINOCLIMACOGRAPTUS SCULPTUS	23 CORONOGRAPTUS GREGARIUS CF. MINUSCULUS	24 PETALOGRAPTUS (PHYSOPHORA) ALASKENSIS	25 "DIPLOGRAPTUS" TCHERSKYI TCHERSKYI	26 COMOGRAPTUS? CF. C? TABUKENSIS	27 CORONOGRAPTUS CYPHUS CYPHUS	28 CORONOGRAPTUS GREGARIUS GREGARIUS	29 CORONOGRAPTUS HIPPOSIDEROS	30 HEDROGRAPTUS JANISCHEWSKYI	31 HEDROGRAPTUS MEDIUS BREVICAUDATUS	32 LAGAROGRAPTUS INEXPEDITUS	33 MONOGRAPTUS AUSTERUS VULGARIS
TF:145.0	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
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TF:061.0	.	.	.	.	.	.	.	X	.	.	.	.	.	.	X	.	X	.	.	.	.	.	.	.	?	.	.	X	.	X	X	X	X
TF:060.0	X	.	.	.	.	.	.	X	.	.	.	.	.	X	X	.	X	.	.	.	X	.	.	.	X	X	X	X	X	X	X	X	?
TF:056.5	X	X	.	X	.	.	.	X	.	.	.	X	X	.	X	.	X	.	X	X	X	X	X	X	.	.	.	.	.	.	.	.	.
TF:054.0	.	.	.	X	.	.	.	.	.	.	.	X	X	X	X	X	X	?	X	X	.	.	.	.	.	.	.	.	.	.	.	.	.
TF:052.0	.	.	.	.	.	X	X	X	X	X	X	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
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	34 MONOGRAPTUS CF. M. ARCIFORMIS	35 PETALOGRAPTUS CF. P. MUTABILIS	36 PRIBYLOGRAPTUS ANGUSTUS	37 PRISTIOGRAPTUS CF. P. CONCINNUS	38 AGETOGRAPTUS SECUNDUS	39 HEDROGRAPTUS SCALARIS FERGANENSIS	40 METACLIMACOGRAPTUS UNDULATUS	41 MONOGRAPTUS DECIPIENS DECIPIENS	42 MONOGRAPTUS INVOLUTUS	43 MONOGRAPTUS N. SP. B	44 MONOGRAPTUS PECTINATUS PECTINATUS	45 PETALOGRAPTUS CF. P. FORTUITUS	46 PETALOGRAPTUS INSECTIFORMIS	47 PETALOGRAPTUS INTERMEDIUS	48 PRISTIOGRAPTUS CF. P. PARVUS	49 PRISTIOGRAPTUS FRAGILIS FRAGILIS	50 RASTRITES APPROXIMATUS APPROXIMATUS	51 AGETOGRAPTUS HUBEIENSIS	52 AGETOGRAPTUS PRIMUS	53 CORONOGRAPTUS CF. C. CIRRUS	54 DIVERSOGRAPTUS CAPILLARIS	55 GLYPTOGRAPTUS ENODIS ENODIS	56 GLYPTOGRAPTUS TAMARISCUS TAMARISCUS	57 MONOCLIMACIS? N. SP.	58 MONOGRAPTUS CF. M. CLINGANI	59 MONOGRAPTUS COMMUNIS COMMUNIS	60 MONOGRAPTUS ELONGATUS	61 MONOGRAPTUS EX GR. TRIANGULATUS	62 MONOGRAPTUS MILLEPEDA CURTUS	63 PSEUDORETIOLITES CF. P. DECURTATUS	64 RASTRITES LONGISPINUS N. SUBSP.	65 RASTRITES N. SP.	66 RASTRITES ORBITUS
TF:145.0	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
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TF:061.0	X	.	.	.	X	?	X	?	X	X	X	X	X	X	X	X	X	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
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67 NEOROGRAPTUS CF. N. ELONGATUS
68 NEOROGRAPTUS SP.
69 METACLIMACOGRAPTUS ORIENTALIS
70 MONOGRAPTUS CALMISTRATUS
71 MONOGRAPTUS CAPIS
72 MONOGRAPTUS N. SP. A
73 MONOGRAPTUS SUDBURIAE
74 GLYPTOGRAPTUS ELEGANS N. SUBSP.
75 GLYPTOGRAPTUS SP. AFF. G. FASTIGANS
76 MONOGRAPTUS CF. LOBIFERUS HARPAGO
77 MONOGRAPTUS DECIPIENS VALENS
78 MONOGRAPTUS EXIGUUS N. SUBSP.
79 MONOGRAPTUS EXIGUUS PRIMULUS
80 MONOGRAPTUS HALLI
81 MONOGRAPTUS PLANUS
82 MONOGRAPTUS PSEUDORUNCINATUS
83 MONOGRAPTUS SPIRALIS CONTORTUS
84 MONOGRAPTUS TURRICULATUS MINOR
85 PETALOGRAPTUS OVATUS WUXIENSIS
86 PETALOGRAPTUS PALMEUS CLAVATUS
87 PETALOGRAPTUS PALMEUS PALMEUS
88 PRISTIOGRAPTUS CF. P. VARIABILIS
89 PRISTIOGRAPTUS NUDUS
90 MONOGRAPTUS EXIGUUS EXIGUUS A
91 MONOGRAPTUS MARRI
92 MONOGRAPTUS TURRICULATUS TURRICULATUS
93 MONOGRAPTUS DEXTROTORSUS N. SUBSP.
94 MONOGRAPTUS DISCUS
95 MONOGRAPTUS FLAGELLARIS
96 MONOGRAPTUS PRIODON
97 MONOGRAPTUS PROTEUS
98 MONOGRAPTUS PSEUDOBECKI
99 STOMATOGRAPTUS N. SP.

	67	68	69	70	71	72	73	74	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91	92	93	94	95	96	97	98	99
TF:145.0	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	X	.	.	.
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TF:074.0	.	.	.	.	.	.	.	X	.	.	X	X	.	X	X	X	.	.	.	.	X	X	X	X	X	X	.	.	.	.	.	.	.
TF:071.0	.	.	.	.	.	.	.	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	.	.	.	.	.	.	.	.	.	.
TF:063.0	X	X	X	X	X	X	X	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
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	100 MONOGRAPTUS GRIESTONIENSIS GRIESTONIENSIS	101 MONOGRAPTUS SP. AFF. M. TULLBERGI'	102 MONOGRAPTUS SPIRALIS SPIRALIS	103 MONOCLIMACIS VOMERINUS VOMERINUS	104 MONOGRAPTUS PARAPRIODON	105 RETIOLITES GEINITZIANUS DENSERETICULATUS	106 CYRTOGRAPTUS CF. C. LAPWORTHI LAPWORTHI	107 DIVERSOGRAPTUS RAMOSUS	108 MONOCLIMACIS VOMERINUS CF. GEINITZI	109 MONOGRAPTUS GRIESTONIENSIS MINUTA	110 MONOGRAPTUS SPECIOSUS	111 MONOGRAPTUS CF. PARADOXUS HEMMANNI	112 CYRTOGRAPTUS SAKMARICUS	113 CYRTOGRAPTUS LAPWORTHI N. SUBSP.	114 MONOGRAPTUS MINIMUS	115 MONOCLIMACIS LINNARSSONI	
TF:145.0	.	.	.	.	.	.	.	.	.	.	.	.	.	.	X	X	TF:145.0
TF:143.0	.	.	.	X	X	X	.	X	.	.	.	.	X	X	X	X	TF:143.0
TF:140.5	.	.	.	X	X	X	.	.	X	.	X	.	X	X	X	.	TF:140.5
TF:136.0	X	.	.	X	.	X	.	X	.	.	.	.	.	.	.	.	TF:136.0
TF:135.0	.	.	.	.	.	X	.	.	X	.	.	.	X	.	.	.	TF:135.0
TF:133.0	X	.	X	X	X	.	X	.	.	X	X	.	.	.	.	.	TF:133.0
TF:130.0	.	.	.	.	.	.	.	X	.	.	.	.	X	.	.	.	TF:130.0
TF:125.0	X	.	X	X	.	.	.	.	.	.	X	X	.	.	.	.	TF:125.0
TF:123.5	X	.	X	X	X	.	.	X	.	.	X	.	.	.	.	.	TF:123.5
TF:123.0	X	.	X	.	X	.	X	.	X	.	X	.	.	.	.	.	TF:123.0
TF:119.0	.	.	.	.	.	.	X	X	X	X	X	.	.	.	.	.	TF:119.0
TF:114.0	.	.	X	.	.	.	.	.	.	.	.	.	.	.	.	.	TF:114.0
TF:105.0	.	X	X	X	X	X	.	.	.	.	.	.	.	.	.	.	TF:105.0
TF:096.0-	X	X	X	.	.	.	.	.	.	.	.	.	.	.	.	.	TF:096.0-
TF:079.0	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	TF:079.0
TF:074.0	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	TF:074.0
TF:071.0	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	TF:071.0
TF:063.0	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	TF:063.0
TF:062.5	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	TF:062.5
TF:061.0	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	TF:061.0
TF:060.0	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	TF:060.0
TF:056.5	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	TF:056.5
TF:054.0	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	TF:054.0
TF:052.0	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	TF:052.0
TF:049.0	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	TF:049.0
TF:047.0	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	TF:047.0

Appendix A11 - Huff Ridge graptolite distribution.

	1 NEDROGRAPTUS CF. N. LANPHEREI	2 PARACLIMACOGRAPTUS JINYANGENSIS	3 NEDROGRAPTUS NORMALIS	4 NEDROGRAPTUS JANISCHEWSKYI	5 NEDROGRAPTUS RECTANGULARIS	6 METACLIMACOGRAPTUS ORIENTALIS	7 ATAVOGRAPTUS PRAESTRACHANI	8 ATAVOGRAPTUS ATAVUS	9 DIMORPHOGRAPTUS ERECTUS	10 GLYPTOGRAPTUS LACINIOSUS	11 NEDROGRAPTUS MAGNUS	12 NEDROGRAPTUS SCALARIS FERGANENSIS	13 LAGAROGRAPTUS ACINACES	14 METACLIMACOGRAPTUS HUGHESI	15 AGETOGRAPTUS HUBEIENSIS	16 NEDROGRAPTUS NIKOLAYEVI	17 CORONOGRAPTUS CYPHUS CYPHUS	18 CORONOGRAPTUS GREGARIUS GREGARIUS	19 GLYPTOGRAPTUS TAMARISCUS CF. VARIANS	20 NEDROGRAPTUS CF. N. MINUTUS	21 NEDROGRAPTUS MEDIUS BREVICAUDATUS	22 MONOGRAPTUS CF. M. ARCIFORMIS	23 PRIBYLOGRAPTUS INCOMMODUS	24 CLINOCLIMACOGRAPTUS SCULPTUS	25 DIMORPHOGRAPTUS MINUTUS	26 PARACLIMACOGRAPTUS INNOTATUS INNOTATUS	27 PARACLIMACOGRAPTUS INNOTATUS OBESUS	28 PSEUDOGLYPTOGRAPTUS CF. P. VAS	29 "DIPLOGRAPTUS" TCHERSKYI TCHERSKYI	30 CORONOGRAPTUS GREGARIUS CF. MINUSCULUS	31 LAGAROGRAPTUS? N. SP.	32 METACLIMACOGRAPTUS UNDULATUS	33 PETALOGRAPTUS PHYSOPHORA ALASKENSIS
HR:274-280	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
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HR:113.5	.	.	.	X	.	.	.	?	.	X	X	X	.	.	.	.	.	.	.	.	.	.	.	.	X	X	.	.	X	X	.	.	X
HR:112.5	.	.	.	.	X	.	X	.	.	.	.	.	.	.	.	.	X	.	.	.	.	.	.	X	X	X	.	.	.	.	X	X	X
HR:112-112.5	.	.	.	.	X	.	X	.	.	.	.	X	.	.	.	.	X	.	.	.	.	.	.	.	.	X	.	.	X	X	X	.	.
HR:111-112	.	.	X	X	X	.	X	.	.	.	.	X	.	X	.	X	.	.	.	.	.	.	X	X	X	X	X	X	.	.	.	.	.
HR:110.5	.	.	X	X	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	X	.	.	.	.	.	.	.	.	.	.	.	.
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	34 CORONOGRAPTUS CF. C. CIRRUS	35 MONOGRAPTUS AUSTERUS VULGARIS	36 AGETOGRAPTUS? SP.	37 GLYPTOGRAPTUS INCERTUS	38 LAGAROGRAPTUS INEXPEDITUS	39 MONOGRAPTUS N. SP. B	40 PRISTIOGRAPTUS CF. P. PARVUS	41 RHAPHIDOGRAPTUS? CF. R. TOERNQUISTI	42 COMOGRAPTUS COMATUS	43 CORONOGRAPTUS GREGARIUS ARCUATUS	44 GLYPTOGRAPTUS ENODIS ENODIS	45 GLYPTOGRAPTUS TAMARISCUS TAMARISCUS	46 MONOCLIMACIS? N. SP.	47 MONOGRAPTUS MILLEPEDA CURTUS	48 MONOGRAPTUS PECTINATUS PECTINATUS	49 PETALOGRAPTUS CF. P. FORTUITUS	50 PETALOGRAPTUS INTERMEDIUS	51 HEDROGRAPTUS? CF. H? TANGSHANENSIS	52 MONOGRAPTUS EX GR. TRIANGULATUS	53 MONOGRAPTUS LOBIFERUS LOBIFERUS	54 RASTRITES ORBITUS	55 DIVERSOGRAPTUS CAPILLARIS	56 MONOGRAPTUS INVOLUTUS	57 MONOGRAPTUS COMMUNIS COMMUNIS	58 MONOGRAPTUS CONVOLUTUS	59 MONOGRAPTUS FALCATA	60 PETALOGRAPTUS ANKYRATUS	61 "DIPLOGRAPTUS" TCHERSKYI N. SUBSP.	62 MONOGRAPTUS N. SP. A	63 MONOGRAPTUS SIDJACHENKOI	64 PETALOGRAPTUS FOLIUM	65 PETALOGRAPTUS INSECTIFORMIS	66 CEPHALOGRAPTUS TUBULARIFORMIS
HR:274-280	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
HR:272.0	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
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HR:128.0	.	.	.	.	.	.	.	.	.	.	.	X	.	.	.	.	.	.	.	X	.	.	.	.	X	X	.	.	X	X	.	.	X
HR:126.0	.	.	.	.	.	X	.	.	.	.	.	.	.	.	.	.	.	X	.	.	.	.	.	X	X	X	X	X	X	X	X	X	.
HR:124.5	.	.	.	.	.	X	.	.	.	.	.	.	.	.	.	.	.	.	X	.	X	.	.	.	X	X	.	X	.	.	.	.	.
HR:124.0	.	.	.	.	.	X	.	.	.	.	.	X	.	?	.	.	.	X	.	.	X	.	.	X	X	X	X	.	.	.	.	.	.
HR:122.0	.	.	.	.	.	.	.	.	.	.	.	.	X	X	.	.	.	.	.	.	X	X	X	.	.	.	.	.	.	.	.	.	.
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HR:118.5	.	.	.	.	X	X	.	.	X	X	X	X	X	X	X	X	X	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
HR:117.0	.	.	.	X	X	X	X	X	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
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	67 MONOGRAPTUS CF. M. CLINGANI	68 MONOGRAPTUS COMMUNIS OBTUSUS	69 MONOGRAPTUS DECIPIENS DECIPIENS	70 PSEUDOGLYPTOGRAPTUS N. SP.	71 PRISTIOGRAPTUS REGULARIS REGULARIS	72 PETALOGRAPTUS PALMEUS CLAVATUS	73 PETALOGRAPTUS PALMEUS N. SUBSP	74 PRISTIOGRAPTUS CF. P. ARTUS	75 PRISTIOGRAPTUS JACULUM N SUBSP	76 MONOGRAPTUS CF. M. DECIPIENS	77 MONOGRAPTUS EXIGUUS PRIMULUS	78 MONOGRAPTUS HALLI	79 MONOGRAPTUS SPIRALIS CONTORTUS	80 HEDROGRAPTUS SP. AFF. H. JANISCHEWSKYI	81 MONOGRAPTUS DECIPIENS N SUBSP	82 MONOGRAPTUS EXIGUUS N SUBSP.	83 MONOGRAPTUS TURRICULATUS MINOR	84 PETALOGRAPTUS CF P. KURCKI	85 PETALOGRAPTUS PALMEUS PALMEUS	86 PETALOGRAPTUS TENUIS	87 PSEUDORETIOLITES OR P. DECURTATUS	88 PRISTIOGRAPTUS NUDUS	89 DIVERSOGRAPTUS CF. D. RUNCINATUS	90 MONOGRAPTUS N. SP. D	91 MONOGRAPTUS PSEUDORUNCINATUS	92 PETALOGRAPTUS OVATUS MUXIENSIS	93 MONOGRAPTUS DEXTROTORSUS N SUBSP	94 MONOGRAPTUS DECIPIENS VALIENS	95 MONOGRAPTUS KOVALEVSKYI	96 MONOGRAPTUS PSEUDOBECKI	97 MONOGRAPTUS SP. AFF M. MODIFER	98 MONOGRAPTUS PLANUS	99 MONOGRAPTUS EXIGUUS EXIGUUS
HR: 274-280	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
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HR: 171.5	.	.	.	.	X	.	.	.	.	.	.	.	.	.	.	X	X	.	X	.	.	X	.	.	.	.	.	X	X	X	X	.	.
HR: 169.0	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	X	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
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HR: 160.0	.	.	.	.	.	.	.	.	.	.	X	.	X	.	X	.	X	.	.	.	.	X	X	X	X	X	.	.	.	.	.	.	.
HR: 158.0	.	.	.	.	X	.	.	.	.	.	.	X	.	.	X	.	X	.	.	.	.	X	.	.	.	.	.	.	.	.	.	.	.
HR: 154.5	.	.	.	.	X	.	.	.	.	.	X	X	X	X	X	X	X	X	X	X	X	.	.	.	.	.	.	.	.	.	.	.	.
HR: 150.0	.	.	.	.	.	.	.	.	.	X	X	X	X	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
HR: 133.5	.	X	X	.	X	X	X	X	X	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
HR: 131.0	X	.	X	X	X	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
HR: 128.0	X	X	X	X	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
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	100 MONOGRAPTUS PROTEUS	101 MONOGRAPTUS MARRI	102 MONOGRAPTUS EX GR. RICKARDSI	103 MONOGRAPTUS CRISPUS	104 MONOGRAPTUS TURRICULATUS TURRICULATUS	105 MONOGRAPTUS DISCUS	106 MONOGRAPTUS FLAGELLARIS	107 PSEUDOPLEGMATOGRAPTUS OBESUS OBESUS	108 STOMATOGRAPTUS N. SP.	109 MONOCLIMACIS N. SP. A.	110 MONOGRAPTUS CF. M. AVAGUSENSIS	111 MONOGRAPTUS PRIDDON	112 STOMATOGRAPTUS GRANDIS GIRVANENSIS	113 MONOGRAPTUS GRIESTONIENSIS GRIESTONIENSIS	114 RETIOLITES GEINITZIANUS GEINITZIANUS	115 RETIOLITES GEINITZIANUS DENSERETICULATUS	116 MONOGRAPTUS SPIRALIS SPIRALIS	117 CYRTOGRAPTUS LAPWORTHI N. SUBSP.	118 CYRTOGRAPTUS SAKMARICUS	119 MONOCLIMACIS LINNARSSONI	120 MONOCLIMACIS VOMERINUS VOMERINUS	
HR:274-280	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	X	X	.	X	X	X	HR:274-280
HR:272.0	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	X	.	.	.	.	HR:272.0
HR:271.0	.	.	.	.	.	.	.	.	.	.	.	X	.	.	.	.	X	X	.	.	.	HR:271.0
HR:254.0	.	.	.	.	.	.	.	.	X	.	.	.	.	.	.	.	X	.	.	.	.	HR:254.0
HR:210.0	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	HR:210.0
HR:206.5	.	.	.	.	.	.	.	.	.	X	.	.	X	.	.	.	.	.	.	.	.	HR:206.5
HR:204.0	.	.	.	.	.	X	X	.	.	X	.	.	.	X	.	X	.	.	.	.	.	HR:204.0
HR:203.5	.	.	.	.	.	.	X	.	.	X	.	.	.	X	.	.	.	.	.	.	.	HR:203.5
HR:203.0	X	X	.	.	.	.	X	.	.	X	.	X	.	X	X	.	.	.	.	.	.	HR:203.0
HR:197.0	.	.	.	.	.	X	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	HR:197.0
HR:195.5	.	X	.	.	.	X	X	.	.	X	X	X	X	.	.	.	.	.	.	.	.	HR:195.5
HR:195.0	.	.	.	.	.	X	X	X	X	.	.	.	.	.	.	.	.	.	.	.	.	HR:195.0
HR:194.0	.	X	.	.	.	X	X	.	.	.	.	.	.	.	.	.	.	.	.	.	.	HR:194.0
HR:193.0	.	.	.	X	X	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	HR:193.0
HR:179.5	.	.	X	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	HR:179.5
HR:178.5	.	X	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	HR:178.5
HR:177.5	.	X	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	HR:177.5
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HR:175.0	X	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	HR:175.0
HR:173.0	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	HR:173.0
HR:171.5	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	HR:171.5
HR:169.0	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	HR:169.0
HR:167.0	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	HR:167.0
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HR:156.5	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	HR:156.5
HR:150.0	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	HR:150.0
HR:133.5	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	HR:133.5
HR:131.0	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	HR:131.0
HR:128.0	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	HR:128.0
HR:126.0	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	HR:126.0
HR:124.5	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	HR:124.5
HR:124.0	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	HR:124.0
HR:122.0	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	HR:122.0
HR:121.0	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	HR:121.0
HR:118.5	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	HR:118.5
HR:117.0	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	HR:117.0
HR:114.5	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	HR:114.5
HR:113.5	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	HR:113.5
HR:112.5	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	HR:112.5
HR:112-112.5	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	HR:112-112.5
HR:111-112	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	HR:111-112
HR:110.5	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	HR:110.5
HR:110.0	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	HR:110.0
HR:109.0	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	HR:109.0
HR:107.0	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	HR:107.0
HR:106.0	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	HR:106.0
HR:104.0	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	HR:104.0
HR:103.0	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	HR:103.0
HR:102.0	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	HR:102.0
HR:100.5	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	HR:100.5
HR:099.0	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	HR:099.0

Appendix A12 - Irene Bay graptolite distribution.

IB:65 LOOSE A	IB:65 LOOSE B	IB:65.5	IB:67.0	IB:68-72L	IB:69.0		
X	.	.	.	.	.	1	MONOCLIMACIS SP. INDET.
X	.	.	.	.	.	2	MONOGRAPTUS HALLI
X	.	.	.	.	.	3	MONOGRAPTUS TURRICULATUS MINOR
X	.	.	.	.	.	4	PETALOGRAPTUS SP. INDET.
.	X	.	.	.	.	5	MONOCLIMACIS LINNARSSONI
.	X	X	.	X	.	6	MONOGRAPTUS SPIRALIS SPIRALIS
.	X	.	X	X	X	7	RETIOLITES GEINITZIANUS DENSERETICULATUS
.	.	X	.	.	.	8	DIVERSOGRAPTUS RAMOSUS
.	.	X	.	.	.	9	MONOGRAPTUS CRISPUS
.	.	X	.	.	.	10	MONOGRAPTUS HARRI
.	.	X	X	X	X	11	MONOGRAPTUS PRIODON
.	.	X	.	.	.	12	MONOGRAPTUS SP. AFF. M. TULLBERGI?
.	.	X	X	.	X	13	PARAPLECTOGRAPTUS CF. P. INTERMEDIUS
.	.	X	.	.	.	14	PRISTIOGRAPTUS NUDUS
.	.	.	X	.	X	15	MONOCLIMACIS VOMERINUS CF. GEINITZI
.	.	.	X	X	X	16	MONOCLIMACIS VOMERINUS VOMERINUS
.	.	.	X	.	.	17	MONOGRAPTUS SPIRALIS EXCENTRICUS
.	.	.	X	.	.	18	STOMATOGRAPTUS GRANDIS IMPERFECTUS
.	.	.	.	X	X	19	CYRTOGRAPTUS LAPWORTHI N. SUBSP.
.	.	.	.	X	.	20	CYRTOGRAPTUS SAKMARICUS
.	.	.	.	X	.	21	MONOGRAPTUS GRIESTONIENSIS GRIESTONIENSIS
.	.	.	.	X	.	22	MONOGRAPTUS SPECIOSUS
.	.	.	.	X	.	23	PSEUDOPLEGMATOGRAPTUS GIGANTEUS
.	.	.	.	.	X	24	MONOGRAPTUS GRIESTONIENSIS MINUTA

IB:65 LOOSE A
IB:65 LOOSE B
IB:65.5
IB:67.0
IB:68-72L
IB:69.0

710 -

Appendix B

Upper Ordovician graptolites from the Cape Phillips Formation, Canadian Arctic Islands

MICHAEL J. MELCHIN

Melchin, M. J., Upper Ordovician graptolites from the Cape Phillips Formation Canadian Arctic Islands. *Bull. geol. Soc. Denmark*, vol. 35 pp. xx–xx.

Ashgill age graptolites have been collected from seven sections of the Cape Phillips Formation across most of its outcrop belt. The earliest graptolite zone recognisable is that of *Orthograptus fastigatus*. It is correlated with the *Dicellograptus ornatus* Zone of the northern Canadian Cordillera and the *Dicellograptus complexus* Subzone of the *Dicellograptus anceps* Zone of Great Britain although no dicellograptids have been found at any of the present sections. The overlying zone is that of *Paraorthograptus pacificus*, an easily recognisable zone around much of the world.

Graptolites of the *Climacograptus extraordinarius* and *Glyptograptus persculptus* zones appear to be entirely absent from this formation. This is attributed to the Late Ordovician glaciation which has induced regression and submarine erosion in many areas worldwide.

The earliest recognisable Silurian zone varies from section to section due to buried or barren intervals and/or hiatuses of varying length. The *Parakidograptus acuminatus* Zone has been recognised at only one section. At the others, the *Atavograptus atavus*, the *Lagarograptus acinaces*, *Coronograptus gregarius*, the *Monograptus convolutus* or the *Monograptus spiralis* Zone (s.l.) are the earliest recognisable Silurian faunas.

Relatively low faunal diversities in the Ashgill and lowest Llandovery portion of the section and the total lack of dicellograptids are interpreted to be due to relatively shallow water, outer shelf or carbonate ramp depositional environment.

M. J. Melchin, Department of Geology, The University of Western Ontario, London, Ontario, Canada N6A 5B7, August 20, 1986.

Introduction

The Cape Phillips Formation occurs in the Queen Elizabeth Island group of the Canadian Arctic Archipelago. The formation was originally defined and described by Thorsteinsson (1958) on Cornwallis Island and has since been mapped from central Melville Island in the west to central Ellesmere Island in the northeast (figure 1). The Cape Phillips ranges in age from late Ordovician to Early Devonian across much of its outcrop area, although in some parts of the Bathurst Island Group (Kerr 1974, Mayr 1980), and Ellesmere Island (Kerr 1976; Trettin 1979) its age range is more restricted.

Probable Ordovician and Silurian graptolites were first reported from Ellesmere Island by Troelsen (1950) from what he called the Thorup Fjord Limestone, now considered the lower portion of the Cape Phillips Formation (Tozer, 1963). Thorsteinsson and Fortier (1954) first reported the well preserved graptolite faunas of Late Ordovician and Silurian age on Cornwallis and Little Cornwallis islands and these faunas were listed in some detail by Thorsteinsson (1958). In the latter report twenty-two zones were recognised from Late Ordovician to Late Silurian in age. Two of these zones were considered Late Ordovician and were named for *Orthograptus* n.sp. A and *Climacograptus latus* Elles and Wood. They were tentatively correlated with *complanatus* and *anceps* zones of Great Britain respectively. In association with these, a diverse cephalopod fauna has been reported (Sweet and Miller 1957) as well as the trilobite *Pseudogygites latimarginatus* which has been subsequently redescribed by Ludvigsen (1979) as *P. arcticus*. *Orthograptus* n.sp. C and *Climacograptus supernus* Elles and Wood (= *C. longispinus supernus*) were also found in association with *C. latus*.

While the presence of *C. latus* and *C. l. supernus* provided a reliable correlation with the *anceps* Zone, the zone of *O.* n.sp. A could not be accurately dated except as Late Ordovician based on the cephalopod and trilobite faunas.

Aspects of these Ordovician faunas have since

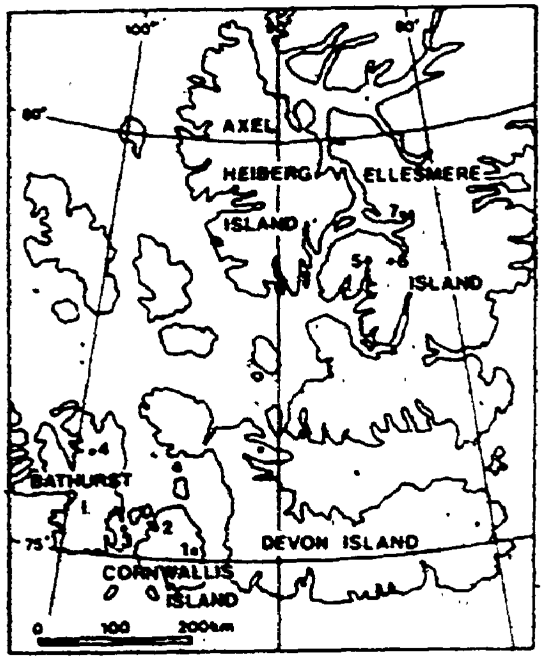

Fig. 1. Map of the east-central portion of the Canadian Arctic Islands showing Ordovician graptolite localities. 1. Snowblind Creek, 75°11'N, 93°47'W. 2. Rookery Creek, 75°22'N, 95°46'W. 3. Truro Island, 75°18'N, 98°08'W. 4. Twilight Creek, 76°10'N, 99°10'W. 5. Trold Fiord, 78°36'N, 84°37'W. 6. Huff Ridge, 78°34'N, 83°32'W. 7. Irene Bay, 79°04'N, 82°15'W.

been found in the Bathurst Island Group (Thorsteinsson and Glenister 1963; Kerr 1974) and on Ellesmere Island (Tozer 1963; Kerr 1976). In addition, Riva (in Ludvigsen 1979) found a species of *Glyptograptus* with a long virgella and basal spines (possibly *Orthograptus thorsteinssoni* n.sp. of this report) and another species of *Glyptograptus* or "*Pseudoclimacograptus*" which he considered to be postpygmaeus Zone.

The earliest Silurian graptolite zone reported by Thorsteinsson (1958) was that of *Monograptus cyphus* Lapworth.

While several other papers have involved description or reports of Cape Phillips graptolites (i.e. Thorsteinsson 1955; Lenz 1974a, b, 1978; Jackson et al. 1978), none has been devoted to the description of Ordovician or earliest Silurian faunas. Chen and Lenz (1984) listed some of the Ordovician graptolites collected as part of the present study.

During the summers of 1983 and 1984, Ashgill graptolites were collected from sections across much of the outcrop belt (figure 1). Section 1 at Snowblind Creek occurs on the line of the Cape Phillips-Allen Bay facies change (Thorsteinsson 1958) and the Ordovician and lowest Silurian parts of the section are largely dolomites. One sample near the base, however, has yeilded two specimens of *O. fastigatus* Davies. At section 2, Rookery Creek, the Ordovician and lowest Silurian parts of the section are mostly covered, but *O. fastigatus* and *O. thorsteinssoni* were collected near the base of the formation. At both of these sections the earliest recognisable Silurian graptolite faunas are of approximately *convolutus* Zone age. The stratigraphy and graptolite faunas of the remaining five sections are illustrated in figure 2.

Identifications of the post-*atavus* Zone graptolites and zonal designations are tentative.

Stratigraphy

The Cape Phillips Formation is divided into three members, A, B and C. Member A, which ranges in age from Ashgill to Middle Llandovery, varies in thickness from 50 to about 156 m. It consists of interbedded carbonates, argillaceous carbonates and shales. The carbonates, for the most part, consist of thinly laminated, argillaceous limestones or weakly bioturbated limestones. At the base of the formation is a persistently developed, medium to thickly bedded carbonate unit 10 to 15 m thick. This unit may be partially or completely dolomitized but where original structures are preserved, a bioturbated lime wackestone is the lithology.

Toward the top of this member the occurrence of bioturbated limestones decreases and laminated limestones and shales dominate with some chert present. The laminated limestones commonly show very fine continuous or discontinuous lenticular bedding, while others show plane laminar layering.

While most workers generally refer to the Cape Phillips as representing "slope" or "basinal" facies, the evidence indicates that, in the Ordovician part of the section, water depths were probably those of deep shelf rather than basinal. Ludvigsen (1979) has examined Pseudogygites-bearing dark limestone/shale sequences in eastern and arctic Canada including the lowest Cape Phillips. He suggested that the transition from light-coloured, bioturbated limestones to dark,

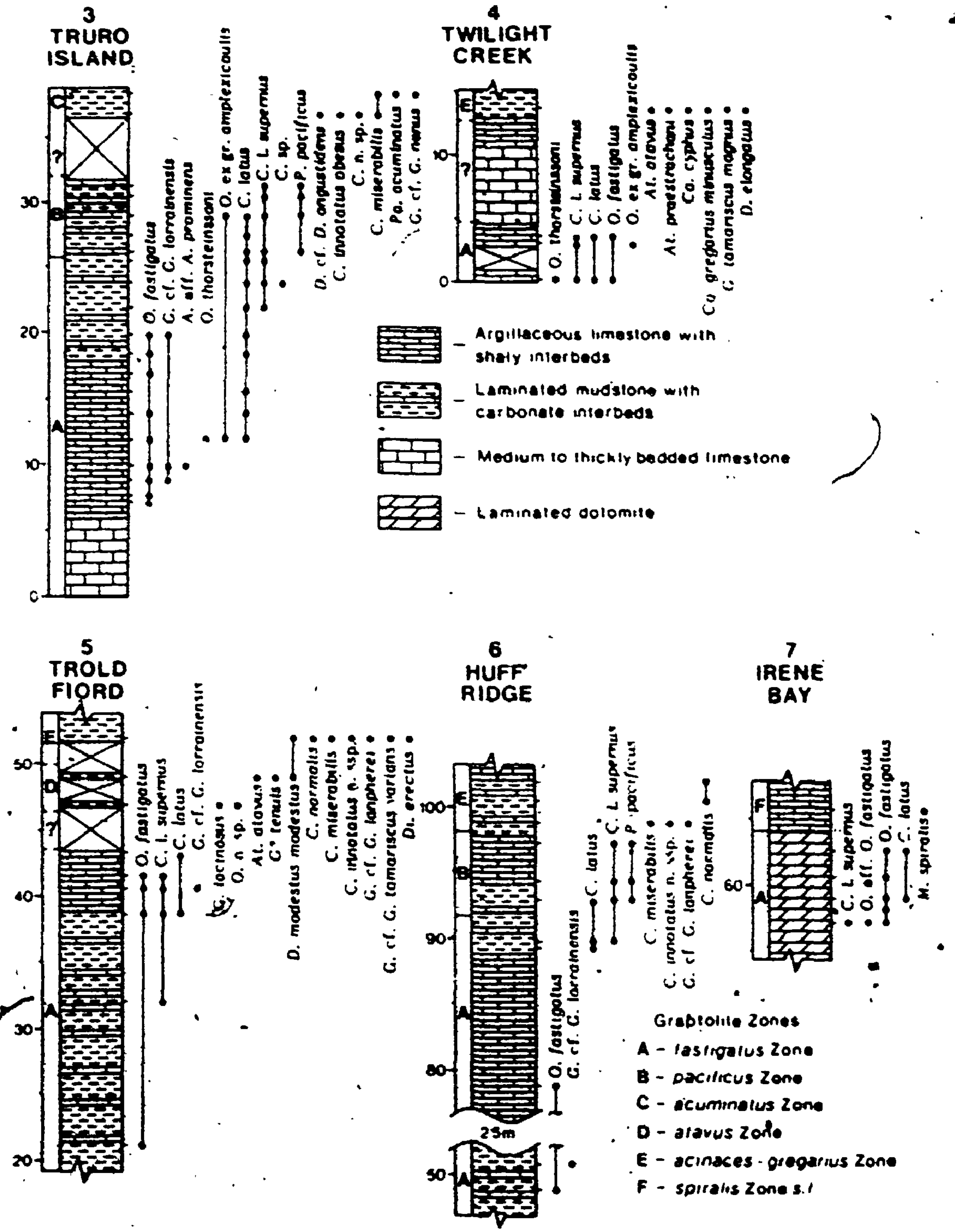

Fig. 2. Lithology and distribution of graptolite faunas of main sampled sections. Measurements are in metres above base. For description of sections 1 and 2, see text

argillaceous, laminated limestones and shales was due not necessarily to increasing water depths but to the establishment of a permanent thermocline over the shelf areas. This has resulted in a drastic reduction of the benthic faunas and preservation of abundant graptolites and other organic material.

Further evidence of relatively shallow depositional depths can be seen in the very gradual nature of the lateral facies change seen during this interval. The Allen Bay Formation is the shallow water carbonate facies equivalent of the lower part of the Cape Phillips. During the Ordovician, patch reefs have been recorded in the Allen Bay but are separated from the Cape Phillips beds by a lateral transition of shallow to deeper shelf carbonates (Mayr 1974; Mirza 1976, Sodero and Hobson 1979). The lack of development of gravity flows (except, possibly, very fine-grained turbidites) or any other evidence of increased slope or shelf break suggests deposition of the lowest Cape Phillips on the deeper portion of a shelf or carbonate ramp (Read 1982) rather than a deep basin. Increased shelf-to-basin relief appears to have begun to develop from Middle Llandovery time onward (Melchin and Lenz 1984).

Graptolite Biostratigraphy

The lowest graptolite-bearing beds at all of the sampled sections have yielded *Orthograptus fastigatus*, often in great abundance. It commonly occurs in conjunction with *Pseudogygites arcticus* and nautiloid cephalopods. *Orthograptus fastigatus* is probably synonymous with *O.* n sp. A of Thorsteinsson (1958) based on its abundance and co-occurrence with this distinctive "Arctic Ordovician fauna".

Orthograptus fastigatus is found to be restricted to the *complexus* Subzone of the *anceps* Zone in Great Britain (Williams 1982). The lower end of its age range in the present sections has not been dated accurately by any independent means but the upper end of its range is consistently below the first occurrence of *P. pacificus* so it is concluded that this interval, here termed the *fastigatus* Zone, is correlative with the *complexus* Subzone. It may also be equivalent to the *ornatus* Zone of the Northern Canadian Cordillera (Lenz and McCracken 1982).

While Thorsteinsson did not report any other graptolite taxa co-occurring with *O. fastigatus*, several other species have been found with it at most of the present sections. *Glyptograptus* cf *G. lorrainensis* (Ruedemann) and *Amplexograptus* aff *A. prominens* Barrass although uncommon here, are the only taxa from this unit closely resembling the faunas of the platform areas of central and eastern Canada (Riva 1969; Jackson 1973) and suggest a possible correlation with the inuiti Zone of that region (Bergstrom and Mitchell 1986). *Orthograptus thorsteinssoni* and *Climacograptus* sp. are also restricted to the *fastigatus* Zone and are relatively uncommon.

Climacograptus latus and *C. longispinus supernus*, although found by Thorsteinsson (1958) to overlie samples yielding *O. fastigatus*, co-occur with the latter at most of the section sampled. Their ranges extend beyond the *fastigatus* Zone, however, to the highest Ordovician beds found, the *pacificus* Zone.

Paraorthograptus pacificus (Ruedemann), a distinctive index fossil in the upper Ashgill of many parts of the world, has been found at two of the sampled sections (sections 3 and 6) together with *C. latus*, and *C. l. supernus*. At sections 2 and 5 this interval is covered while at sections 1 and 4 it is represented by unfossiliferous strata. The *pacificus* Zone appears to be entirely absent at section 7.

Orthograptus ex. gr. *amplexicaulis* occurs rarely in the *fastigatus* and *pacificus* zones.

As in the Northern Cordillera (Lenz and McCracken 1982) evidence of the *extraordinarius* Zone is entirely lacking, as is any evidence of the *persculptus* Zone.

The Ordovician-Silurian Boundary

The actual Ordovician-Silurian boundary beds are only exposed at three of the sampled sections, sections 4, 6 and 7 (figure 2).

At section 3, a 5.0 m buried interval is followed by two exposed beds which have yielded a fauna assignable to the *acuminatus* Zone, including *Parakidograptus acuminatus* (Nicholson) itself.

The boundary interval at section 4 is occupied by 10.0 m of strata, mostly bioturbated limestones with a sparse, poorly preserved shelly fauna, apparently lacking in graptolites. The oldest identifiable Silurian graptolites can be assigned to an undivided *acinaces-gregarius* Zone, correlative, at least in part, with these zones in the Northern Cordillera (Lenz 1982) and the *cyphus* Zone of Alaska (Churkin and Carter 1970).

At section 5, two beds crop out in an otherwise 9.0 m coverede interval. The age of the lower bed can only be considered Lower Llandovery based on the occurrence of *Glyptograptus lacinosus* Churkin and Carter. The overlying bed can be assigned to the *atavus* Zone based on the co-occurrence of *Atavograptus atavus* (Jones) and *Glyptograptus? tenuis* (Rickards). Above the covered interval a more diverse fauna can be found. The co-occurrence of *Dimorphograptus erectus* Elles and Wood, *Glyptograptus* ex gr. *tamariscus* (Nicholson) and *Glyptograptus* cf. G. *lanpheri* Churkin and Carter identify this sample as representing the *acinaces-gregarius* Zone. The occurrence of both *Lagarograptus acinaces* (Törnquist) and *Coronograptus gregarius gregarius* (Lapworth), among other taxa, in immediately overlying samples substantiates this.

At section 6, *G.* cf. *G. lanpheri*, *Climacograptus innotatus* n. ssp. and *C. miserabilis* Elles and Wood occur in a sample only 1.5 m above *pacificus* Zone samples. While these taxa, by themselves, could not allow accurate age assignment, the only other sample in which they co-occur is from the *acinaces-gregarius* Zone at section 5.

At section 7, *fastigatus* Zone samples are separated from beds yielding *Monograptus spiralis* (Geinitz) and other Upper Llandovery taxa by 3.0 m of unfossiliferous dolomites.

Discussion of Faunas

One of the noteworthy features of the Cape Phillips Ordovician graptolite fauna is its overall relatively low diversity and a total lack of observed dicellograptids. Jackson (1973) also noted the lack of dicellograptids in the Late Ordovician cratonic deposits of Canada pointing out that *Dicellograptus* appears to be restricted to the continental margin fold belts. Indeed, the deeper basinal sediments of northwestern Melville Island (Robson 1985) have yielded *Dicellograptus* in association with *G. latus* (Tozer and Thorsteinsson 1964; Lenz pers. comm. 1985).

The present diplograptid fauna is therefore considered to be a moderate to deep shelf fauna in which *Dicellograptus* is excluded by virtue of its apparent deep water or truly pelagic habitat. Erdtmann (1976, table 10) also compared the known latest Ordovician graptolite assemblages of Anticosti Island (shallow shelf) and of Scotland and Texas (pelagic). The Cape Phillips fauna appears to contain elements of both the shallow shelf fauna and the pelagic fauna and probably fits into the deep shelf, carbonate-shale belt of Erdtmann's scheme.

It is also noteworthy that diversity has generally increased from the base of the formation upward through the Ordovician, a trend coinciding with a general subsidence of the shelf during the Ashgill.

This subsidence appears to have been interrupted by a regression, probably associated with the latest Ordovician glaciation (Lenz 1976, Lenz and McCracken 1982). The effects of this regression are manifest as missing strata at some sections (due to erosion and/or nondeposition) and deposition of a massive carbonate unit at section 4 (possibly some missing strata as well).

Early Llandovery faunas also show low diversities and rather sporadic occurrence, possibly owing to deposition in relatively shallow, restricted conditions. It is not until the latest Early and Middle Llandovery that a more widespread, diverse graptolite fauna becomes established across the Cape Phillips belt (Melchin and Lenz 1984).

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Systematic Paleontology

All figured specimens are housed at the Geological Survey of Canada.

Order GRAPTOLOIDEA Lapworth, 1857
Family DIPLOGRAPTIDAE Lapworth, 1873
Genus *Amplexograptus* Elles and Wood, 1907

Amplexograptus aff. *A. pumunchis* Barrass, 1954
Plate 1, figures 1,2

Material. Numerous compressed specimens on a single bedding plane, all incomplete and most poorly preserved

Occurrence. *fastigatus* Zone, Truro Island at 10 0 m

Description. Longest rhabdosome (incomplete) is 13 mm. Widens from 0 8 to 0 9 mm at $th1^1$ to 1 1 to 1.2 mm at $th5^1$ reaching a maximum of 1 3 to 1.8 mm (average 1 5 mm). Thecae number 14 to 16 in 10 mm throughout and are climacograptid in shape. Geniculum is extended into a flange or hood, supragenicular walls are straight and vertical. Thecal excavations occupy 1/4 of total width proximally, 1/5 distally. Apertural margins show lappets on distal fragments. Sicula 1.5 mm long bearing a virgella 0 3 mm long but no apertural spines. Mesial spines are likewise lacking on the first thecal pair

Remarks. The apparent absence of proximal spines distinguishes this form from other contemporaneous species of *Amplexograptus*. However, since very few proximal ends are found in the present collection, and most of these are rather poorly preserved, the lack of proximal spines may be an artifact of preservation. *Amplexograptus* aff. *A. prominens* of Jackson (1973) is otherwise very similar (the overall narrower measurements found there were made on uncompressed specimens) and the two may be conspecific. Compressed specimens of *A. prominens* and *A. elongatus* (Barrass 1954) are wider than the present specimens and *A. inuiti* (Cox 1933) bears both sicular spines and a mesial spine on $theca1^1$

Genus *Climacograptus* Hall, 1865

Climacograptus lanus Elles and Wood, 1906

Plate 1, figures 3–8

1906 *Climacograptus lanus* Elles and Wood, p. 204–205, pl. 27, figs. 3a-h, text-figs. 135a-d

1982 *Climacograptus lanus* Elles and Wood, Williams, p. 39–40, pl. 3, figs. 12–18 (see for further synonomy)

1982 *Climacograptus lanus* Elles and Wood, Lenz and McCracken, fig. 3p,q

Material. Hundreds of compressed and partially compressed specimens in various states of preservation from very good to poor

Occurrence. *fastigatus* and *pacificus* zones, Truro Island at 12 0 to 29.0 m, Twilight Creek at base to 3 5 m, Troid Fiord at 38 5 to 43 0 m, Huff Ridge at 89 5 to 93 0 m and Irene Bay at 59 0 to 62 5 m

Description. Largest rhabdosom (complete) up to 30 mm. Widens gradually from 0 8 to 1 0 mm at $th1^1$ to 1 2 to 1 3 mm at $th5^1$ to a maximum of 1 7 to 2 4 mm (average 2.0 mm) reached by about the fifteenth thecal pair. Thecae number 7 in the first 5 mm and 11 to 12 in 10 mm distally. Thecae have straight supragenicular walls which commonly appear slightly inclined in compressed specimens due to differential widening. Apertural excavations occupy about 1/4 of the rhabdosome width proximally and 1/5 to 1/6 distally. Proximal end bears a virgella and mesial spines on the first thecal pair which are each 0.5 to 0 7 mm long. Sicula is 1 8 mm long.

Remarks. This species is readily distinguishable from any other contemporary taxa. *Climacograptus longispinus supernus* is much narrower overall, especially in the proximal region. Although *Orthograptus fastigatus* has a similar rhabdosomal form, the thecal details distinguish them except in the most poorly preserved material where confusion may occur

The present specimens are, on average, slightly narrower than the British material described by Williams (1982) and Elles and Wood (1906) and the distal thecal spacing is slightly wider. However, the proximal end development and overall rhabdosomal and thecal form which characterize this species are well illustrated by this material

Climacograptus longispinus supernus Elles and Wood, 1906

Plate 1, figures 9–13

1906 *Climacograptus supernus* Elles and Wood, p. 196–197, pl. 26, figs. 11a-d, text-fig. 127a-d

1982 *Climacograptus longispinus supernus* Elles and Wood, Williams, p. 38–39, pl. 3, figs. 3–11, text-fig. 8a-o (see for further synonomy)

1982 *Climacograptus supernus* Elles and Wood, Lenz and McCracken, fig. 3k, l

1983 *Climacograptus longispinus supernus* Elles and Wood, Koren' and Sobolevskaya, p. 126–128, pl. XXXV, figs. 1–11, p. XXXVI figs. 1–5, text-figs. 44, 45

1983 *Climacograptus longispinus supernus* Elles and Wood, Wang et al. pl. 3, figs. 12, 13

1984 *Climacograptus supernus* Elles and Wood, Mu and Lin, p. 57, pl. 4, figs. 4–6

Material. Numerous compressed specimens, very well to poorly preserved

Occurrence. *fastigatus* and *pacificus* zones, Truro Island at 22 0 to 31 5 m, Twilight Creek at base to 3 5 m. Troid Fiord at 32 0 to 41 5 m, Huff Ridge at 90 0 to 97 5 m and Irene Bay at 57 0

Description. Longest rhabdosome up to 18 mm long (complete) excluding spines. Widens gradually from 0 5 to 0 6 mm at $th1^1$ to 0 6 to 0 8 mm at $th5^1$ to a maximum of 1 0 to 1 5 mm by the fifteenth thecal pair; width is thereafter maintained. Thecae number 6 to 7 in the first 5 mm, 11 to 13 in 10 mm distally. Thecae show a sharp geniculum and straight supragenicular walls, parallel to the rhabdosome length. Thecal excavations occupy ~~about 1/3 to 1/4~~ total width. Proximal end bears a virgella up to 0 6 mm long and laterally projecting mesial spines on the first

Plate 1

All figures ×5 unless otherwise indicated.

Fig. 1–2. *Amplexograptus* aff. *A. prominens* Barrass (1) Truro Island - 10.0 m, GSC78380 (2) Truro Island - 10 0 m, GSC78381

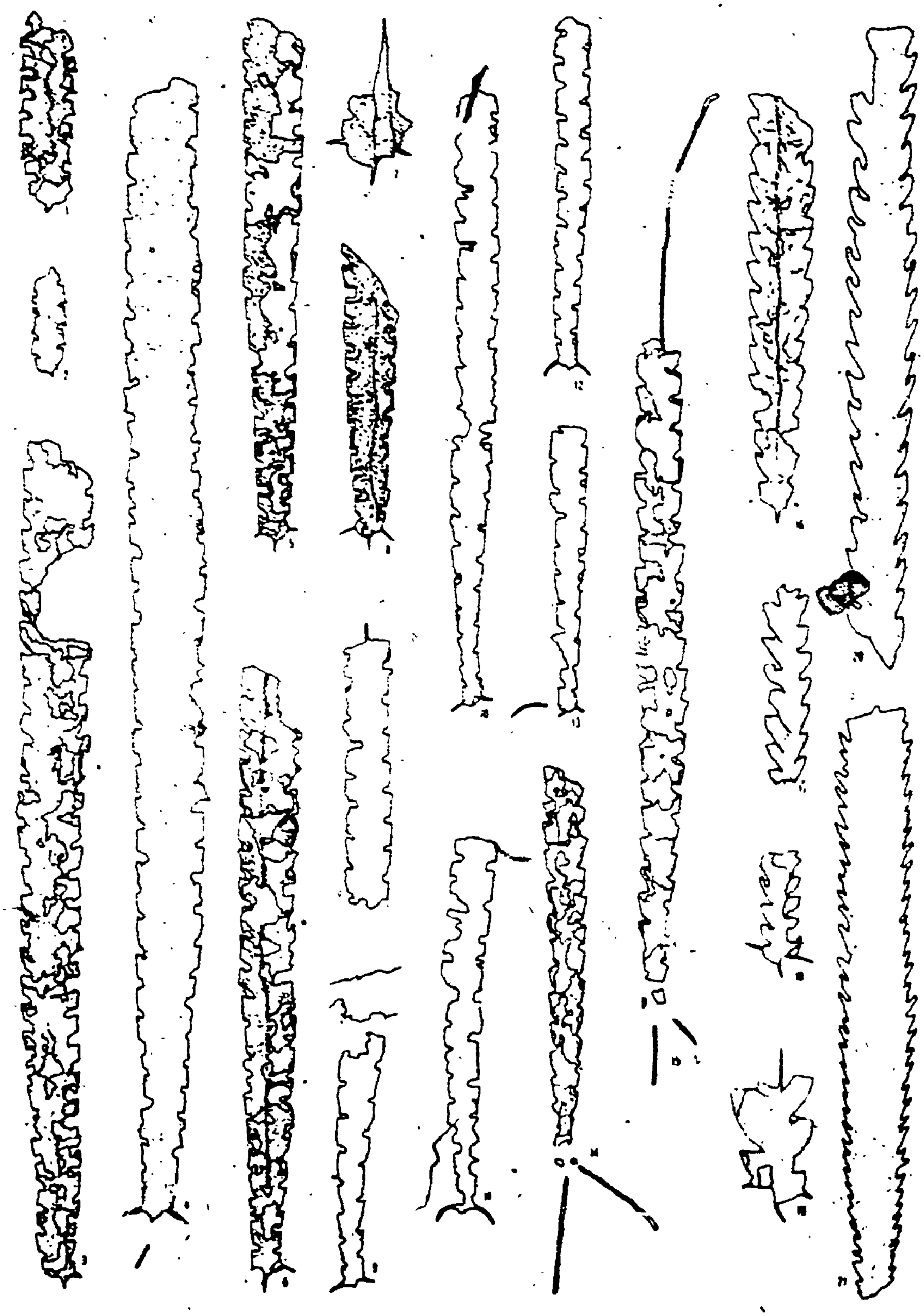
Fig. 3–8. *Climacograptus lanus* Elles and Wood (3) Truro Island - 15 5 m, GSC 78382 (4) Irene Bay - 62 5 m, GSC78383 (5) Truro Island - 14.0 m, GSC78384 (6) Truro Island - 14.0 m, GSC78385 (7) Irene Bay - 62 5 m, GSC78386, ×10 (8) Truro Island - 14 0 m GSC78387.

Fig. 9–13. *Climacograptus longispinus supernus* Elles and Wood. (9) Irene Bay - 57.0 m, GSC78388 (10) Irene Bay - 57 0 m, GSC78389. (11) Truro Island - 30 5 m, GSC78390. (12) Truro Island - 30.5 m, GSC78391 (13) Irene Bay - 57 0 m, GSC78392

Fig. 14–15. *Climacograptus* sp. (14) Truro Island - 24.0 m, GSC78393. (15) Truro Island - 24 0 m, GSC78394

Fig. 16–20. *Glyptograptus* cf. *G. lorraineus* (Ruedemann) (16) Troid Fiord - 40.5 m, GSC78395 (17) Truro Island - 10 0 m, GSC78396. (18) Truro Island - 10 0 m, GSC78397 (19) Truro Island - 10.0 m, GSC78398, ×10 (20) Truro Island - 10 0 m, GSC78399

Fig. 21 *Orthograptus* aff. *O. fastigatus* Davies. Irene Bay – 57 0 m, GSC78400, ×2.5.



thecal pair up to a least 1.3 mm. Membranes on proximal spines have not been observed in these specimens, nor have details of the sicula.

Remarks. Williams (1982) and Riva (1974) point out that the membrane on the proximal spines is only present on mature rhabdosomes. While many of the present specimens appear to be otherwise fully developed, it is possible that membrane development was somehow prevented, possibly owing to less favourable environmental conditions. Otherwise, the Cape Phillips material fits well within the previously reported range of variation for this distinctive taxon.

Climacograptus sp.
Plate 1, figures 14, 15

Material. Fourteen compressed specimens, moderately to poorly preserved.

Occurrence. *fastigatus* Zone transition, Truro Island at 24.0 m.

Description. Rhabdosome up to 20 mm long (complete) excluding virgella and virgula. Widens from 0.6 mm at th1[1] to 0.9 to 1.0 mm at th5[1] to a maximum of 1.0 to 1.3 mm. Thecae number 10 to 12 in 10 mm throughout the length. Thecae show pronounced geniculum and supragenicular wall is generally inclined, but this may be due to differential spread of the apertures on compression. Thecal excavations semicircular and occupy 1/3 to 1/4 total width. Proximal end bears a virgella up to at least 4.0 mm long as well as (apparently) single mesial spines on the first thecal pair up to 3.0 mm long (the poor state of preservation of proximal portions prevents a more complete or accurate description). In addition, a free virgula extending up to 8.5 mm beyond the distal thecae is commonly present.

Remarks. The very slender rhabdosome combined with the relatively long basal spines and virgella distinguishes this taxon from most other known species of *Climacograptus*. *Climacograptus hastatus* Hall has a similar proximal ornamentation but is substantially wider. *Climacograptus longispinus supernus* is similar but lacks the long, prominent virgella and virgula and does not usually show the inclined supragenicular walls on compression. *Climacograptus infidus spectabilis* Koren' and Sobolevskaya is very similar but apparently lacks the inclined supragenicular walls and the long virgula. Poor preservation of the present specimens, however, prevents positive identification.

Genus *Glyptograptus* Lapworth, 1873
Glyptograptus cf. *G. lorrainensis* (Ruedemann, 1925)
Plate 1, figures 16-20

Material. Numerous compressed specimens, moderately to poorly preserved.

Occurrence. *fastigatus* Zone, Truro Island to 9.0, 10.0 and 20.0 m, and Trold Fiord at 40.5 m.

Description. The longest rhabdosome is 19 mm (incomplete). Widens from 0.75 to 0.9 mm at th1[1] to 1.1 to 1.2 mm at th5[1] to a maximum of 1.5 to 1.8 mm although a few specimens up to 2.0 mm have been found. Thecae number 7 to 7.5 in the first 5 mm and 12 to 13 in 10 mm distally. Thecae show a pronounced glyptograptid profile and th1[1] carries a mesial spine. Lappets are evident on apertural margins, especially on distal thecae. Sicula is 1.5 mm long with a 0.3 mm virgella and paired apertural spines.

Remarks. This form is probably conspecific with *glyptograptus* cf. *G. lorrainensis* as described by Jackson (1973). The only difference is that the present specimens show a greater maximum width, but this is attributed to the greater length of the present specimens. None of the specimens described by Jackson was greater than 4 mm long. *Glyptograptus lorrainensis* is slightly narrower overall and apparently lacks apertural lappets (Walters 1977). *Glyptograptus hudsoni* Jackson, 1971 is wider, particularly at the proximal end, and lacks apertural lappets.

Genus *Orthograptus* Lapworth, 1873
Orthograptus ex gr. *amplexicaulis* (Hall, 1847)
Plate 2, figures 11, 13, 14

Material. Twenty compressed specimens, moderately to poorly preserved.

Occurrence. *fastigatus* and *pacificus* zones. Truro Island at 12.0 and 29.0 m and Twilight Creek at 3.0 m.

Description. Longest rhabdosome is 37 mm (incomplete). Widens very gradually from 1.2 mm at th1[1] to a maximum of 3.0 to 3.5 mm which is thereafter maintained.

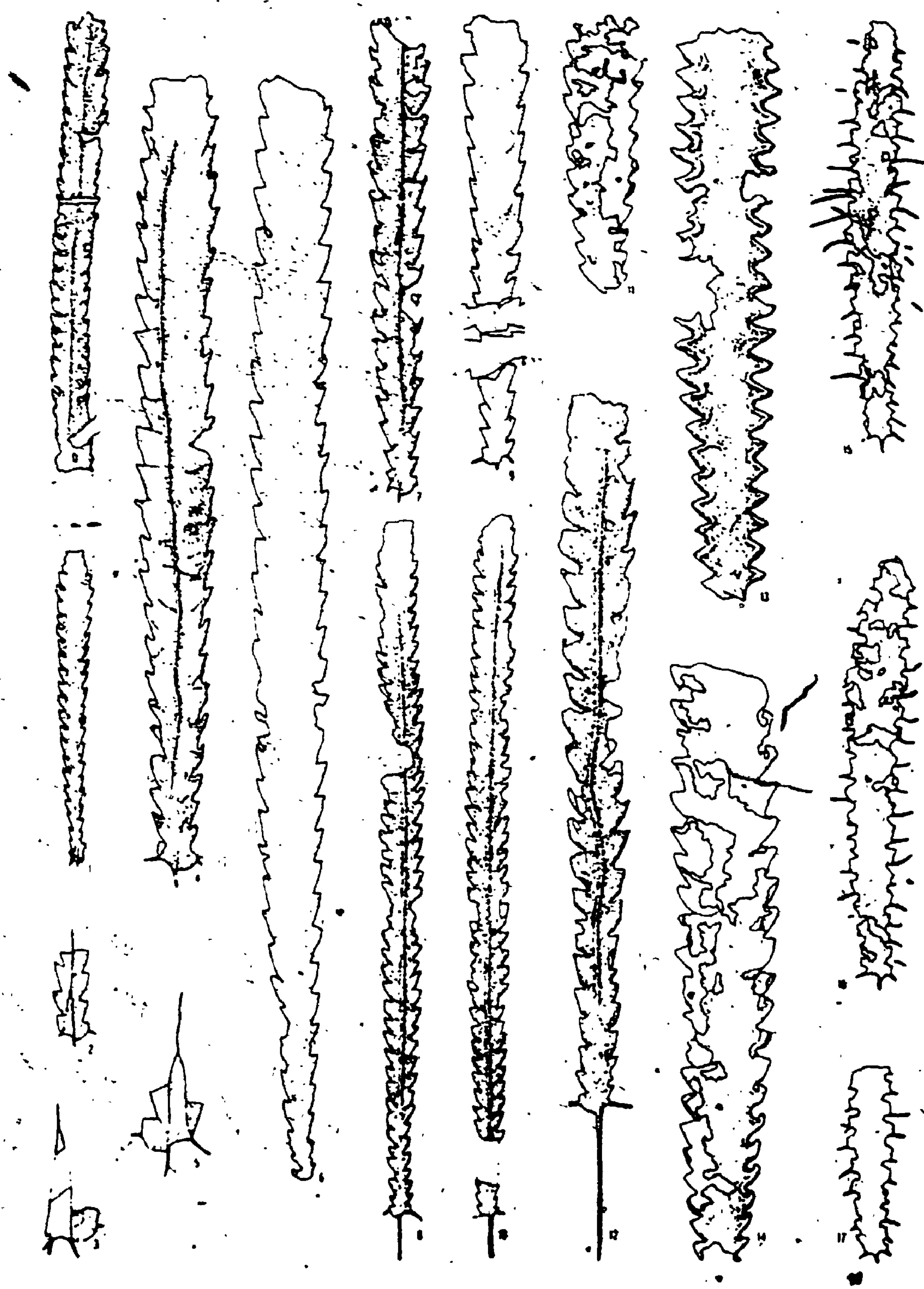
Thecae number 7 in the first 5 mm and 10 to 12 in 10 mm distally. Thecal walls straight to slightly sigmoidal, inclined at 40 to 60° to rhabdosomic axis, with everted apertures.

Remarks. Williams (1982) points out that much needed revision on the *O. amplexicaulis* group is under way. Until such time as this work is published, more specific assignment of this rather poorly preserved material is considered unjustified. Comparison can be made with *O. abbreviatus* (Elles and Wood 1907) which is narrower than the present specimens and also gets narrower distally once its maximum width is achieved. This is not observed in the Cape Phillips material.

Orthograptus fastigatus Davies, 1929
Plate 2, figures 1-7, 9

1929 *Orthograptus fastigatus* Davies, p. 4, text-figs. 3-5
1970 *Diplograptus fastigatus* (Davies), Toghill, p. 21, pl. 14, figs. 1-9
1982 *Orthograptus fastigatus* Davies, Williams, pp. 40-41, pl. 4, figs. 1-6
1984 *Orthograptus fastigatus* Davies, Mu and Lin, p. 60, pl. 5, figs. 11, 12

Plate 2.
All figures ×5 unless otherwise indicated. Fig. 1-7, 9. *Orthograptus fastigatus* Davies. (1) Truro Island - 7.2 m, GSC78401, ×2.5. (2) Irene Bay - 58.0 m, GSC78402. (3) Truro Island - 7.2 m, GSC78403, ×10. (4) Truro Island - 14.0 m, GSC78404. (5) Irene Bay - 58.0 m, GSC78405, ×10. (6) Irene Bay - 58.0 m, GSC78406. (7) Truro Island - 7.2 m, GSC78407. (9) Irene Bay - 58.0 m, GSC78408.
Fig. 8, 10, 12. *Orthograptus thorsteinssoni* n. sp. (8) Holotype, Truro Island - 12.0 m, GSC78409, ×2.5. (10) Paratype, Truro Island - 12.0 m, GSC78410, ×2.5. (12) Paratype, Truro Island - 12.0 m, GSC78411.
Fig. 11, 13, 14. *Orthograptus* ex gr. *amplexicaulis* (Hall). (11) Truro Island - 12.0 m, GSC78412. (13) Truro Island - 29.0 m, GSC78413. (14) Truro Island - 12.0 m, GSC78414.
Fig. 15-17. *Paraorthograptus pacificus* (Ruedeman). (15) Truro Island - 30.5 m, GSC78415. (16) Truro Island - 30.5 m, GSC78416. (17) Huff Ridge - 93.0 m, GSC78417.



Material. Hundreds of compressed specimens, very well to poorly preserved.

Occurrence. *fastigatus* Zone, Snowblind Creek at 25.0 m, Rookery Creek at 4.5 m, Truro Island at 8.0 to 20.0, Twilight Creek at base to 3.5 m, Troid Fiord at 20.0 to 41.5 m, Huff Ridge at 48.0 to 78.5 m and Irene Bay at 57.0 to 62.5 m.

Description. Longest rhabdosome is 53 mm (complete). Widens very gradually from 0.7 to 1.1 mm (average 0.9 mm) at th1[1] to .9 to 1.7 mm (average 1.2 mm) at th5[1] to a maximum of 1.8 to 3.2 mm (average 2.3 mm) which is reached between the fifteenth and twentyfifth thecal pair. Thecae number 6 to 8 in the first 5 mm and 10 to 14 in 10 mm distally. Thecae are straight to slightly sigmoidally curved, especially in the proximal region. Thecal apertures introverted and straight. Sicula 1.4 to 1.6 mm long and bears a virgella and a pair of apertural spines up to 1.3 mm long (generally less than 0.5 mm). Theca 1[1] bears a mesial spine of similar length.

Remarks. The present material shows a wider range of morphologic variation than the British material, particularly in the maximum width. In addition, the thecal spacing is, on average, slightly wider, although there is considerable overlap with the British specimens. Davies (1929) and Williams (1982) reported the presence of mesial spines on both of the first thecae. The presence of many well preserved proximal ends in the present collections, however, shows that theca 1[2] lacks a mesial spine, but the sicula bears a pair of apertural spines although only one is visible in the vast majority of specimens. This may also be the case for the British material.

The very gradual tapering of the proximal end together with the orthograptid thecae with introverted apertures distinguishes this taxon from all others except for *O. thorsteinssoni* which has much longer, more prominent basal spines.

Orthograptus aff. *O. fastigatus* Davies, 1929
Plate 1, figure 21

Material. One compressed specimen well preserved but lacking proximal end.

Occurrence. *fastigatus* Zone, Irene Bay at 57.0 m.

Description. Rhabdosome 37 mm long (incomplete). Widens from 2.2 mm at the first preserved thecal pair (near proximal end) to a maximum of 4.2 mm at the twentieth preserved thecal pair which is thereafter maintained. Thecae number 10 in 10 mm, are orthograptid in profile and are inclined at a relatively low angle to the rhabdosome. Thecal apertures are straight and introverted. Proximal portions are not preserved.

Remarks. This taxon closely resembles *O. fastigatus* except for its greater width. It also resembles wider members of the *O. calcaratus* group although the proximal end appears to taper more gently. It most closely resembles *O. maximus*, which was originally (and probably correctly) considered a variety of *O. fastigatus*. The present specimens are slightly wider with a slightly closer thecal spacing. In the absence of preserved proximal parts, however, it is not possible to make a positive identification.

Orthograptus thorsteinssoni n. sp.
Plate 2, figures 8, 10, 12.

Material. About twenty compressed specimens, very well to poorly preserved. Holotype is GSC78409.

Occurrence. *fastigatus* Zone, Rookery Creek at 4.5 m, Truro Island at 12.0 m (type locality) and Twilight Creek at base.

Diagnosis. Large rhabdosome widening gradually from 0.9 to 1.1 mm at th1[1] to a maximum of 2.3 to 2.8 mm at the twentieth thecal pair. Thecal spacing is 9.5 to 10.5 in 10 mm. Proximal end bears a long virgella up to at least 5.0 mm as well as a pair of proximal spines up to 2.0 mm long.

Description. Longest rhabdosome is 46 mm (complete) excluding virgella. Widens very gradually from 0.9 to 1.1 mm at th1[1] to 1.3 to 1.5 at th5[1] to a maximum of 2.3 to 2.8 mm (average 2.5 mm) attained near the twentieth thecal pair. Thecae number 6 in the first 5 mm and 9.5 to 10.5 in 10 mm distally. Thecae are straight to slightly sigmoidally curved, especially in proximal region, with 1/3 overlap. Thecal apertures are introverted. Sicula is not visible but shows a strongly notched aperture with a very conspicuous virgella up to at least 5.0 mm long. In addition, a pair of proximal spines are present up to 2.0 mm in length.

Remarks. This new species most closely resembles *Orthograptus fastigatus* but differs from it in the very long, prominent virgella and proximal spines. The very gently tapering proximal end distinguishes it from other members of the *O. calcaratus* group of which it is probably a late member. Although many of the thecae appear to be glyptograptid, especially in the proximal region, the best preserved material shows that the thecae are indeed orthograptid in nature.

The spine arising from th1[1] is clearly a mesial spine but is not clear form the present material if the opposite spine arises from th1[2] or the sicular aperture. The possibility exists that it is one of a pair of sicular apertural spines as in *O. fastigatus*.

Genus *Paraorthograptus* Mu et al., 1974
Paraorthograptus pacificus (Ruedemann, 1947)
Plate 2, figures 15–17

- 1947 *Climacograptus innotatus* var. *pacificus* Ruedemann, p. 429, pl. 73, fig. 29
- 1982 *Paraorthograptus pacificus* (Ruedemann), Williams, p. 42, text-fig. 10d-i (see for further synonomy)
- 1982 *Pacificograptus pacificus* (Ruedemann), Lenz and McCracken, fig. 3g, o
- 1983 *Paraorthograptus pacificus pacificus* (Ruedemann), Koren' and Sobolevskaya, p. 154–156, pl. XLV, figs 3–5, pl. XLVI, figs 1–3, text-figs 59, 60a
- 1983 *Paraorthograptus pacificus kimi* (Koren'), Koren' and Sobolevskaya, p. 156–157, pl. XLVI, figs 4–7, pl. XLVII, figs 1–3
- 1983 *Paraorthograptus minor* Wang (in Wang, et al.), p. 142–143, pl. 6, figs 1, 6
- ?1983 *Paraglyptograptus fenxiangensis* Wang (in Wang, et al.), p. 143, pl. 6, fig. 8
- 1984 *Paraorthograptus typicus* Mu, Mu and Lin, p. 61–62, pl. 6, figs 3–5
- ?1984 *Paraorthograptus uniformis* Mu and Li, Mu and Lin, p. 62, pl. 4, fig. 7, pl. 6, figs 7, 8

Material. About twenty specimens, well to poorly preserved.

Occurrence. *pacificus* Zone, Truro Island at 26.2 to 31.5 m and Huff Ridge at 93.0 to 97.5 m.

Description. Longest rhabdosome is 15 mm long. Widens from 0.7 to 1.0 mm (average 0.8 mm) at th[1] to 1.0 to 1.5 mm (average 1.2 mm) at th5[1] to a maximum of 1.3 to 1.9 mm (average 1.7 to 1.8 mm) achieved by the tenth to fifteenth thecal pair. Thecae number 8 in the first 5 mm and 14 in 10 mm distally. Sharp geniculum on all thecae bears paired spines up to 0.6 mm long on proximal thecae and up to 1.0 mm distally.

Supragenicular wall short, straight and slightly inclined. Apertures gently everted, excavations shallow, occupying 1/5 to

1/6 total width. Sicula obscured, bears virgella up to 0.6 mm long.

Remarks. While several different species of *Paraorthograptus* have been identified from various parts of the world, Williams (1982) suggests that the criteria on which they have been separated does not merit the distinction of separate taxa. He recommends that they should be considered synonymous until an integrated study has been carried out on this genus. That suggestion has been followed here. Of the previously described taxa, the present material closely matches *P. typicus* and *P. pacificus kuni* in the observed dimensions. *Paraorthograptus minor* appears to represent juvenile forms of this species and most of the Huff Ridge specimens are equally small.

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Appendix C

NOTE

Uncompressed specimens of *Monograptus turriculatus* (Barrande, 1850) from Cornwallis Island, Arctic Canada

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Isolated specimens of *Monograptus turriculatus* (Barrande, 1850) have been recovered from calcite concretions of the *turriculatus* Zone (late Llandovery) from the Cape Phillips Formation, Canadian Arctic Islands. The sicula shows ventral as well as dextral lateral curvature, and the thecae show a pronounced lateral asymmetry. This asymmetry is manifest as a tear-shaped aperture, a long, laterally directed spine on the outer apertural margin, and a shorter, ventrally directed spine on the inner apertural margin. The latter spine is totally absent on the proximal thecae.

Monograptus sedgwickii (Portlock, 1853) is suggested as a possible ancestor to *M. turriculatus*.

Des spécimens isolés de *Monograptus turriculatus* (Barrande, 1850) ont été récupérés à partir de concrétions de calcite de la zone à *turriculatus* (Llandovery supérieur) de la formation de Cape Phillips, dans les îles de l'Arctique du Canada. La courbure latérale de la sicule est tout aussi bien ventrale que dextre, et les thèques exhibent une asymétrie latérale très prononcée. Cette asymétrie se reconnaît facilement par une ouverture en forme de larme, la présence d'une épine allongée latéralement sur l'ouverture marginale externe et une épine plus courte de direction ventrale sur l'ouverture marginale interne. Cette dernière épine est totalement absente dans les thèques proximales.

Il est proposé que *Monograptus sedgwickii* (Portlock, 1853) soit possiblement l'ancêtre de *M. turriculatus*.

[Traduit par la revue]

Can. J. Earth Sci. 23, 579–582 (1986)

Introduction

The material for the present study has been extracted from calcite concretions within the Cape Phillips Formation, from Snowblind Creek on Cornwallis Island, Northwest Territories (Canada), latitude 75°11'N, longitude 93°47'W. The presence of abundant concretions bearing exquisitely preserved graptolites in the Cape Phillips Formation has been known for some time (Thorsteinsson 1958), and several papers have been published describing some aspects of these faunas (i.e., Thorsteinsson 1955; Lenz 1974*a*,*b*). The present study is part of a larger effort to systematically describe both the compressed and (aspects of) the uncompressed graptolite faunas of the Cape Phillips.

Monograptus turriculatus (Barrande, 1850) is a very common and widespread species of the late Llandovery, but its thecal characteristics and its relationship to other monograptids have, until now, been poorly understood.

The present specimens were found to be associated with a diverse monograptid fauna and were isolated from the calcite concretions with dilute HCl. They were mounted to scanning electron microscopy (SEM) stubs using gum tragacanth and were studied on a Hitachi HHS-2R at 20 kV. Stereopairs were achieved by tilting the specimen stage 8° (Fig. 1*b*), 6° (Fig. 1*a*), or 4° (Fig. 1 *d* and *g*), depending on the magnification and depth of field of the specimen.

Systematic paleontology

ORDER Graptoloidea Lapworth, 1875
SUBORDER Monograptina Lapworth, 1880
FAMILY Monograptidae Lapworth, 1873
GENUS MONOGRAPTUS Geinitz, 1852 emended

Monograptus turriculatus (Barrande, 1850)
(Fig. 1*a*–*i*)

Selected synonymy

Graptolithus turriculatus Barrande, 1850, pp. 56–57, Pl. 4, figs. 7–11.

Monograptus turriculatus (Barrande) Elles and Wood, 1913, pp. 438–439, Pl. 44, figs. 4*a*–*e*, Fig. 301*a*–*c*.

Monograptus turriculatus mut. *minor* Bouček, 1932, p. 155, Fig. 1*c*–*d*.

Spirograptus turriculatus (Barrande) Přibyl, 1944, pp. 27–28, Pl. 10, figs. 1 and 2.

Spirograptus turriculatus minor (Bouček) Přibyl, 1944, p. 29, Fig. 3, figs. 1 and 2.

Monograptus (*Spirogr.*) *turriculatus turriculatus* (Barrande) Schauer, 1971, p. 74, Pl. 30, figs. 1–5, Pl. 31, figs 11–13, Pl. 45, figs. 1–3.

Monograptus turriculatus minor (Bouček) Schauer, 1971, pp. 74–75, Pl. 30, figs. 7 and 8, Pl. 31, figs. 7–9.

Monograptus turriculatus (Barrande) Sherwin, 1974, pp. 172–173, Pl. 12, fig. 6.

Monograptus turriculatus (Barrande) Bjerreskov, 1975, pp. 70–71, Pl. 10, fig. H.

Monograptus turriculatus (Barrande) Hutt, 1975, pp. 111–112, Fig. 22, figs. 9 and 10.

Monograptus turriculatus (Barrande) Lenz, 1982, pp. 118–121, Figs. 9*N*, 32 *D*, *E*, and *G*, 33*A*–*C*.

Occurrence

Snowblind Creek, Cornwallis Island, Northwest Territories, approximately 320 m above base of Cape Phillips Formation, *turriculatus* Zone.

Material

Numerous uncompressed fragments, including three proximal fragments, isolated from calcite concretions.

Description

Sicula 0.9–1.0 mm long (excluding virgella) and 0.2 mm

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wide at aperture. Of this, prosicula occupies 0.25 mm and metasicula 0.75 mm. Virgella up to 0.35 mm, and apertural margin slightly notched with a slight hood developed on ventral side of aperture. Sicula arcs through about 45° of dorsal curvature as well as undergoing a slight dextral torsion near apex. Apex reaches to top of theca 2.

Dorsoventral width of rhabdosome is 0.5 mm at theca 1 and 0.7 mm at theca 5. Maximum width measured in uncompressed fragments (excluding spines) is 1.3 mm, although compressed distal fragments found elsewhere in the Cape Phillips Formation reach as much as 3.0 mm (see also Lenz 1982). Common canal occupies about one-half of total width. Common canal appears to be relatively wider in compressed distal specimens, but this may be an artifact of flattening.

Protheca 1 originates 0.1 – 0.2 mm above aperture of sicula. Free ventral wall of proximal prothecae inclined at about 15° to dorsal margin. Distally this angle increases to as much as 40°. Thecal overlap slight with no interthecal septa. Metathecae form open hooks. Apertures are strongly retroverted proximally and more weakly retroverted distally. Dorsal wall extended as a small, asymmetrical hood over thecal aperture, resulting in aperture being wider on inner side of spiral than on outer side. The result is an aperture with a tear-shaped cross section. Outer apertural margin flaring, extended into curved lateral spine 0.3 mm long on theca 1, up to 1.4 mm on distal thecae. Inner apertural margin unornamented on proximal thecae but bearing a shorter (up to 0.6 mm), ventrally directed spine on distal thecae. Fragmented nature of present material prevents determination of level at which inner apertural spine begins.

Proximal thecae spaced at about 0.5 mm (10 in 5 mm) and distal thecae at about 0.75 mm (6.5 in 5 mm). Thecal axes oriented parallel to the sides of the "cone" formed by the coiling rhabdosome (Fig. 1e) (see also Bulman 1970, Fig. 99, fig. 1e) rather than outward as in most spiralling species. Rhabdosome undergoes dorsal curvature in the proximal region, with dextral lateral curvature beginning between theca 2 and theca 3 (near sicular apex), completing 180° by theca 6, and extending throughout the rhabdosome in progressively widening coils.

Nema consists of a ridge, triangular in cross section (Fig. 1i), extending along dorsal margin of rhabdosome, apparently lacking an axial canal.

Surface shows what appears to be cortical bandaging, with bandage widths of about 6 μm on the sicula and about 8 μm on a distal fragment.

Discussion

Although the rhabdosomal form and generally hooked and spinose nature of the thecae have long been recognised, thecal details have been obscured by a lack of uncompressed specimens. The present material clearly illustrates the asymmetrical nature of the thecal apertures (Fig. 1c and f). It is important to note that the asymmetry is apparently not the result of thecal torsion as in *Monograptus proteus* (Barrande, 1850) (Hutt *et al.* 1970) but only of differential development of the apertural margin. This asymmetry has been masked in compressed specimens by the fact that on compression both spines tend to point ventrally. No evidence of bifurcating spines as reported by Hutt (1975) was found in the present material, but this may be due to the lack of more distal material.

As far as presently known, this is the only taxon in which the sicula undergoes lateral as well as dorsal curvature (Fig. 1b). In addition, this is the first report of the presence of a virgella, although Schauer (1971, Pl. 3, figs. 11 – 13) and Lenz (1982, Fig. 9H) illustrated what appear to be virgellae. Thecal spacing in the proximal region is denser than any previously reported, possibly the result of distortion of the proximal region of compressed specimens. Differences can also result from different techniques of measuring thecal spacing. The distal thecal spacing fits well within the previously reported ranges.

Elles and Wood (1913) pointed out the general similarity of the thecae of *M. turriculatus* to those of *M. sedgwickii* (Portlock, 1843), and this is borne out by the present study. Aside from the lateral asymmetry and the closer thecal spacing, the thecae bear a striking resemblance to those of *M. sedgwickii* (see, for example, Rickards *et al.* 1977, Fig. 22) and to those of *M. halli* (Barrande, 1850) as illustrated by Hutt *et al.* (1970, Pl. 2, figs. 23, 25), considered by the latter authors to be an evolutionary descendant of *M. sedgwickii*. In addition, it is easier to envisage this rhabdosomal form evolving from a straight species (with some proximal dorsal curvature) such as *M. sedgwickii* than from a species dorsally curved throughout. It is therefore suggested that *M. turriculatus* may have evolved from *M. sedgwickii*, the transformation involving lateral rhabdosomal coiling and the development of apertural asymmetry to somehow accentuate the advantages of, or at least accommodate, this type of coiling. This is consistent with the known ranges of these two taxa. *M. sedgwickii* extends from the upper *convolutus* Zone to the lower *maximus* Zone, and *M. turriculatus* extends from the base of the *maximus* Zone through the *turriculatus* Zone and into the *crispus* Zone (Rickards 1976).

Cortical bandaging is visible on a few specimens (Fig. 1h), and bandage widths (6 – 8 μm) appear to be somewhat narrower than any reported by Crowther (1981).

Finally, despite examination of the ends of all broken fragments at high magnification (up to 5000×), an axial canal was not observed in the nema of any of the specimens (Fig. 1i). The significance of this is not known, but it is difficult to imagine the nema housing soft tissue, except possibly at its growing end.

Acknowledgments

Field assistance by D. G. Perry is gratefully acknowledged. Financial support for this project is through the Natural Sciences and Engineering Research Council of Canada (operating grant to A. C. L.), the Polar Continental Shelf Project, and the Northern Research Group of the University of Western Ontario.

FIG. 1. *Monograptus turriculatus* (Barrande). Scanning electron micrographs. (a), (b), (d), and (e) are stereopairs. (a – c) Broken specimen showing sicula and first six thecae. (a) ×20 (note that the protuberance on the dorsal wall of theca 2 is a piece of foreign matter rather than a spine); (c) lateral view of sicula and first two thecae, ×40; (e) apertural view of thecae 5 and 6, ×80. GSC 78418. (b) Lateral view of complete immature specimen showing dorsal and dextral torsion of sicula, ×40. GSC 78419. (d, h) Distal fragment. (d) Oblique view of complete specimen, ×20; (h) obliquely overlapping sets of cortical bandages on dorsal wall of first preserved theca, ×2000. GSC 78420. (f, i) Distal fragment. (f) Apertural view of distal theca and apertural spines, ×40; (i) broken end of nema (broadly triangular area showing faint concentric laminae), ×500. GSC 78421. (e) Oblique view of distal fragment showing one complete whorl, ×20. GSC 78422.

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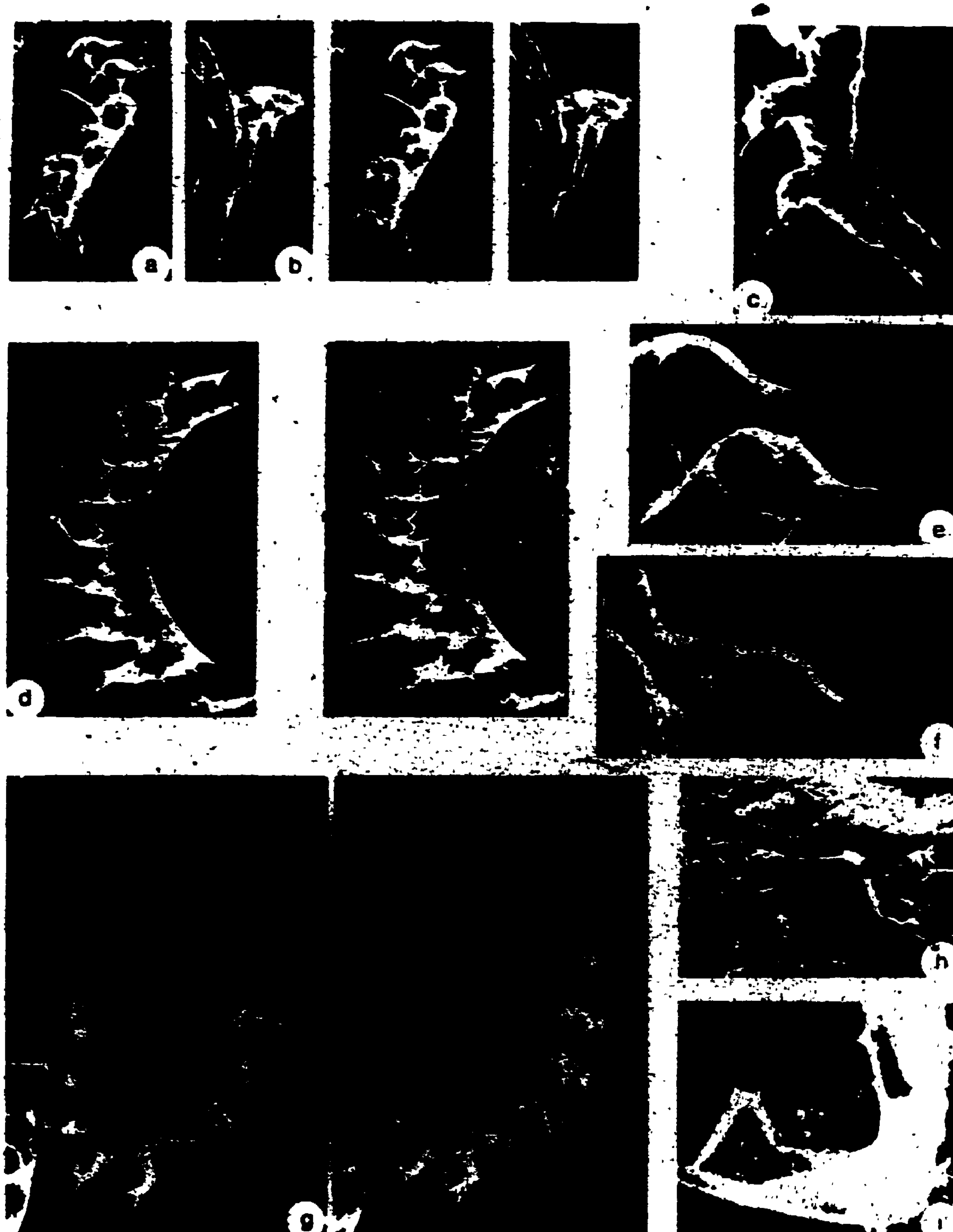

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Appendix D

Silurian retiolitids from the Cape Phillips Formation, Arctic Islands, Canada

A. C. LENZ AND M. J. MELCHIN

Lenz, A. C. & Melchin, M. J. Silurian retiolitids from the Cape Phillips Formation, Arctic Islands, Canada. *Bulletin of the Geological Society of Denmark*, vol. 35, pp. xx-xx, Copenhagen, tryksedato

Isolated retiolitids recovered from limestone concretions in the Cape Phillips Formation include *Pseudoplegmatograptus obesus obesus*, *Pseudoretiolites* cf. *decurtatus*, *Retiolites geinitzianus densireticulatus*, *Stomatograptus grandis grandis*, *S. grandis imperfectus*, *S.* sp., *Paraplectograptus eiseli*, *P. praemacilentus*, *P.* sp. A, *Plectograptus (Sokolovograptus) textor*, *Gothograptus eisenacki* and *Holoretiolites simplex*.

Plectograptus? textor is assigned to *Plectograptus (Sokolovograptus)*, the definition of *Paraplectograptus* is expanded to include morphs with a weak reticulum, and we show that reticular development and density is highly variable within these genera.

Retiolites may occasionally retain a partially to well developed prosicula, *Stomatograptus* and *Pseudoplegmatograptus* have a consistently well developed prosicula, and *Pseudoretiolites* possesses a well developed prosicula and, rarely, a metasicula. A sicula has not been seen in either *Plectograptus (Sokolovograptus)* or *Paraplectograptus*.

Surface sculpture is consistent within the subfamilies Retiolitinae and Plectograptinae, and serves to distinguish them.

Age ranges of taxa recovered in this study are as follows: *Pseudoretiolites*: *triangulatus/magnus* to *turriculatus* zones, *Pseudoplegmatograptus turriculatus* Zone, *Stomatograptus* spp.: *spiralis* to *testis* zones, *Retiolites densireticulatus*: *spiralis* to *testis* zones; *Plectograptus (Sokolovograptus) textor*: *turriculatus* to *nassa* zones, *Paraplectograptus* spp.: *turriculatus* to *nassa* zones; *Gothograptus eisenacki*: *nassa* Zone, *Holoretiolites*: *nilssoni* Zone.

A. C. Lenz & M. J. Melchin, Department of Geology, University of Western Ontario, London, Canada N6A 5B7. August 29th, 1986

Introduction

Retiolitids are, by virtue of their beautifully symmetrical and delicate meshwork structure, inherently fascinating organisms. However, because of these same features, as well as the small size of some, the structures, growth and development of these taxa are inadequately known.

The recovery of free, uncompressed specimens of retiolitids from limestone concretions in the Cape Phillips Formation of the Canadian Arctic Islands presented a unique opportunity. The specimens of most taxa are abundant, preservation is exquisite, and growth stages of most are present. Moreover, graptolite-bearing concretions occur in shales in more or less continuously exposed sequences ranging in age from mid Llandovery to early Ludlow.

In spite of the fact that Silurian retiolitids have long been known and illustrated, the numbers of isolated specimens are, with the exception of such classic studies as Tullberg (1883), Holm (1890), Wiman (1896), and especially Eisenack (1931, 1935, 1951, 1966), relatively few. The present study, in addition to recovering a number poorly known taxa, fills in some of the stratigraphic gaps left in earlier studies.

Material

The graptolite-bearing facies of the central and northern Artic Islands have been named the Cape Phillips Formation by Thorsteinsson (1958). Graptolites are generally abundant both in compressed form in the shales, and uncompressed form in the enclosed limestone concretions (Thorsteinsson, 1958, Thorsteinsson and Kerr, 1968; Lenz, 1978). The Cape Phillips ranges in age from Late Ordovician (Ashgill) to Early Devonian, but graptolite-bearing nodules are most common in Llandovery to lower Ludlow strata.

Uncompressed graptolites, including the retiolitids of this study, were recovered from eight areas (fig. 1). The material studied was collected

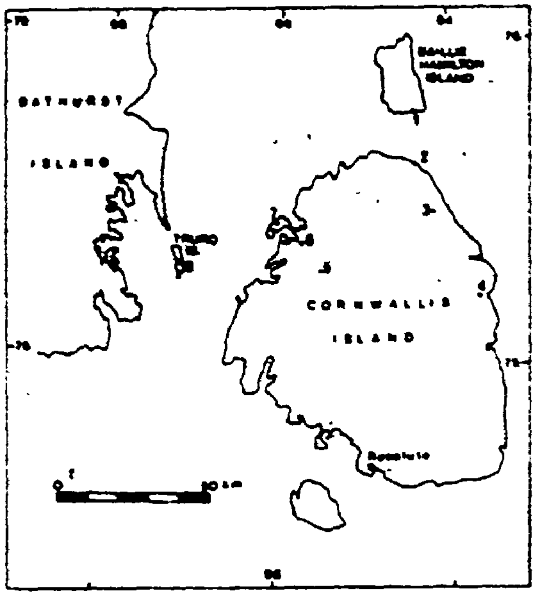

Fig 1 Index map showing sample localities. Localities are as follows: ~~1 southern~~ Baillie Hamilton Island (75°45'N, 94°22'W); 2 Cape Phillips (the type section) (75°37'N, 94°22'W), 3 southwest of Cape Manning (75°27'N, 94°18'W), 4 Laura Lakes area (75°11'N, 93°19'W), 5 Abbott River (75°14'N, 95°36'W), 6. Rookery Creek (75°22'N, 95°42'W). 7 Marshall Peninsula (75°26'N, 96°05'W), 8 Truro Island (75°17'N, 97°08'W)

from strata of the mid Llandovery *triangulatus* or *magnus* zones to the latest Wenlock *lundgreni/testis* Zone or the apparently slightly younger *nassa* Zone. Only rare specimens of *Holoretiolites* were recovered from lower Ludlow strata. Age determinations of the retiolitids were by means of the associated monograptid faunas.

Systematic Paleontology

In this section, we focus discussion on the overall morphologic characteristics of the genera, and species are only briefly discussed. Furthermore, very little discussion is devoted to periderm fine structure since that aspect has already been admirably covered in the works of Andres (1977), Crowther and Rickards (1977), Bates and Kirk (1978) and Crowther (1981)

Family RETIOLITIDAE Lapworth 1873

Subfamily RETIOLITINAE Lapworth 1873, emended herein

Well developed reticula supported on a distinct clathria, sicula unsclerotized or partially sclerotized (prosicula and, rarely, metasicula), ancora stage stage well developed Clathrial 'seams' face in, reticular 'seams' face out, surface fine structure of longitudinal striations composed of peridermal fibrils

Remarks
The surface sculpture is consistent in all members in each of the two subfamilies. The variable occurrence of a prosicula and, rarely, metasicula cannot be used as a diagnostic criterion of the subfamily (cf Bulman, 1970, p 108)
Genus PSEUDOPLEGMATOGRAPTUS Přibyl 1948

Diagnosis
Prosicula well developed Virgella distally forming 4-pronged ancora which develops into basket-shaped corona formed of 2-3 crude rows of cells Lateral bar from near apex of sicula splits into 2 parietal lists to form theca 1[1] Virgula moves quickly to ventral side of rhabdosome, alternately giving off short branches to 'left' and 'right' Branch divides into short ventral and long dorsal, branch to form aboral list, these in turn divide and project laterally to form parietal lists Zig-zag line on dorsal side alternately joins 'left' and 'right' thecal lists Thecae orthograptid in profile, bases marked by a single median thread joining centre of thecal lip and aboral list of previous theca. Thecal spines developed near margin of thecal lips, projecting proximally and laterally (pl. 1, fig. 1) Lacinia not seen Reticulum of very irregular meshwork, meshes vary considerably in size and shape Large irregular openings (stomata) present along medial line Rhabdosome ovate in cross-section Fine structure of lists comprises longitudinal striations only

Remarks
Characteristics of the genus are the irregularly-sized and shaped meshes of the reticula and the paired, proximo-laterally directed thecal spines (see for example Törnquist (1890), Elles and Wood (1908), Bouček and Münch (1944), Münch (1952), Schauer (1971), Hutt (1974), Lenz (1978) The genus is well known but the complex nature of the clathrium and reticulum has not been previously understood. This study, however, has shown that the clathrium, while more complex than that of for example *Retiolites*, is in most ways remarkably similar The presence of stomata is previously unreported in the genus The stomata are irregular in outline, show no indication of thick-

Plate 1
Fig 1 *Pseudoplegmatograptus obesus obesus* Lapworth. Stereopair Field number LL 1, ×10 GSC 78423
Figs. 2, 8. *Pseudoretiolites* cf. *decurtatus* Bouček & Münch. Proximal end and sicula Field number MRC 02, ×50 GSC 78424
Fig. 3 *Pseudoretiolites* cf. *decurtatus*; metasicula. Field number LL 1, ×210 GSC 78425
Fig 4. *Pseudoretiolites* cf. *decurtatus*, Field number ML 64 upper, ×13. GSC 78426
Fig. 5. *Pseudoretiolites* cf. *decurtatus* Stereopair of proximal end. Field number ML 64 upper, ×32 GSC 78427
Fig. 6. *Pseudoretiolites* cf. *decurtatus*. Stereopair of distal end of laterally flattened specimen Field number MRC 02, ×10 GSC 78428
Fig 7 *Pseudoretiolites* cf *decurtatus*. Prosicula Field number ML 64 upper, ×150 GSC 78429
Fig 9 *Plectograptus* (*Sokolovograptus*) *textor* Bouček & Münch Field number CP 390–400, ×18. GSC 78430

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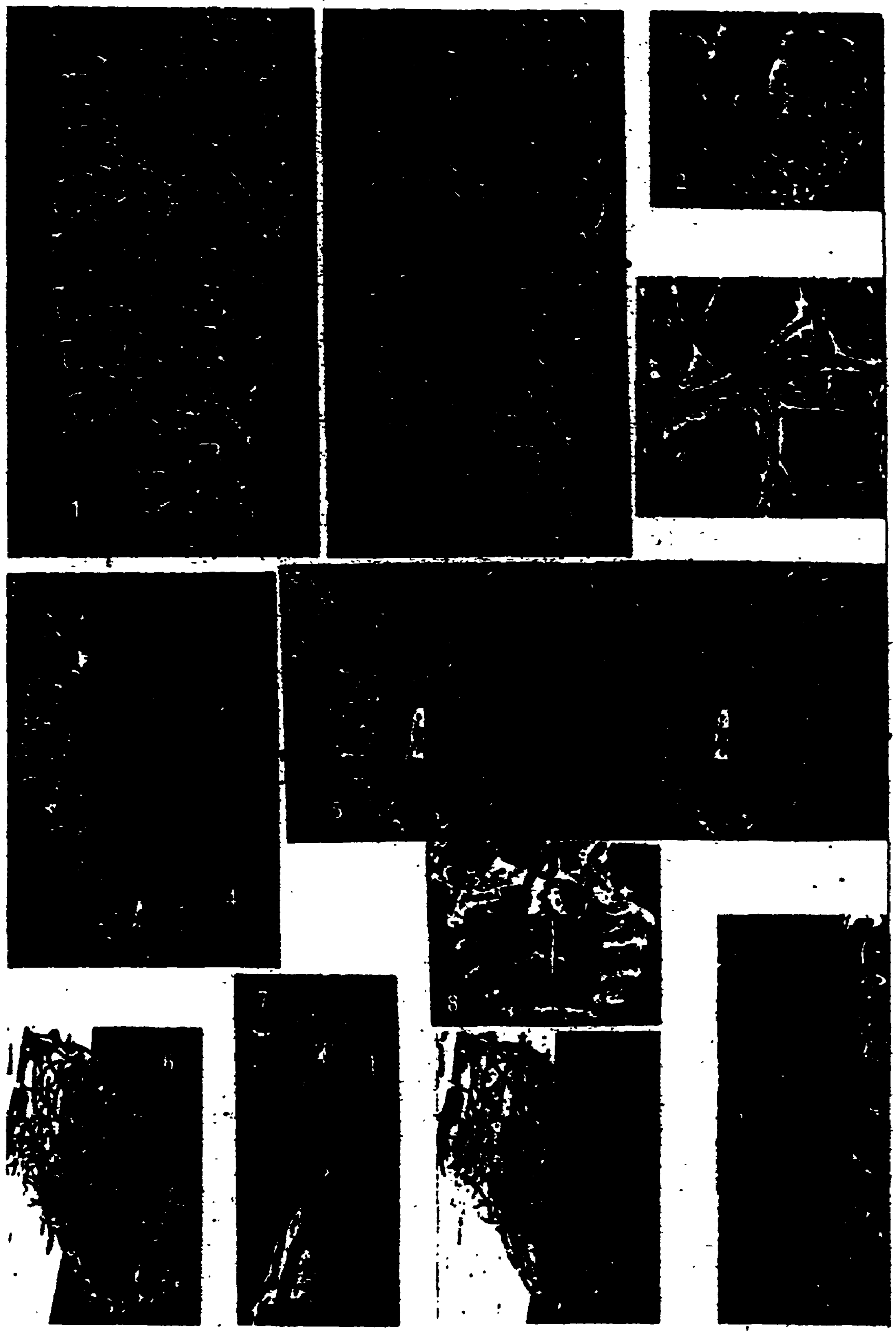


ened rims and, like those of *Stomatograptus*, are elevated above the area of the surrounding reticula.

The lack of any evidence of a lacinia requires comment. By analogy with the sclerotized ventral walls of the thecae of *Stomatograptus*, the lacinia must have been very delicate. Furthermore, most compressed specimens are without lacinia. In fact some illustrations such as those of Figs. 223a,b,c of Elles and Wood (1908) and especially Text-fig. 12 of Hutt (1974) can, by comparison with the uncompressed material of this study, clearly be seen to be laterally flattened and distorted elements of the thecal lips and spines.

All specimens except one, recovered in this study are assignable to *P. obesus obesus* Lapworth. Parameters are as follows: maximum width of somewhat flattened fragments: 4.5 mm; thecae about 13 in 10 mm; mesh of reticula difficult to measure, 3–5 in 2 mm, spines at least 1.2 mm long. The one exception is presumably assignable to *P. longispinus* Bouček and Münch because of its overall finer mesh (about 6 in 2 mm), 1–2 rows of finer ovate meshes along the lateral margins of the thecae, and spines at least 2.5 mm long.

Occurrence and Age

Found only at Laura Lakes area in the Late Llandovery *turriculatus* Zone.

Genus PSEUDORETIOLITES Bouček and Münch 1944

Diagnosis

Prosicula characteristically present (pl. 1, fig. 7); metasicula rarely preserved (pl. 1, fig. 3). Corona developed from four-pronged ancora, hemispherical and basket-like, formed of 3–4 rows of gently spiralled list joined to longitudinally arrayed lists (pl. 1, fig. 5). In specimens with metasicula, "struts" anchor sicula to reticula. First theca develops from clathrial list arising from mouth of sicula, second theca formed from clathrial bar emerging near top of sicula, remaining thecae developing in manner similar to that of *Pseudoplegmatograptus*. 'Floor' of theca marked by long median list arising from aboral list of previous theca and connected to lip of theca. Lip of theca formed of fine, laterally elongate meshes, divided medially by a zig-zag list. Thecae distinctly orthograptid in profile, with moderately accentuated lips and curved, anterolaterally directed apertures. Reticulum moderately fine, meshwork polygonal, with meshes of more or less uniform size. Median region of both sides of rhabdosome generally bear large, irregularly shaped, thin-walled stomata, the margins of which stand above the adjacent reticula. Stomata at least twice the size of reticulum mesh-size.

Remarks

Obut and Zaslavskaya (1976) tentatively suggested that *Pseudoretiolites* be assigned to a separate (new) subfamily Pseudoretiolitinae because of the presence of a metasicula. However, in view of the fact that the metasicula is rarely present (at least in our material), and that clathrial development is essentially like that of *Retiolites*, the move seems unnecessary.

The corona with its beautiful symmetry and nearly square meshes, the moderately regular reticular meshwork, the normally poorly-seen clathrium, and the dense mesh network forming the lip of theca, are all distinctive of the genus and are, we feel, sufficient justification for the retention of *Pseudoretiolites* as a separate taxon, unlike Bulman (1970) who placed it in synonymy with *Retiolites*. The basket-like corona is especially diagnostic, and make recognition of the genus easy.

Some studies, based on the study of flattened specimens, note the presence of 'membranes' (eg. Perner (1899), Elles and Wood (1908), Bouček and Münch (1944), Münch (1952), Hutt (1974)). On the other hand, the excellent but flattened material of Chen (1983) gives no indication of 'membranes', while clearly showing the fine meshwork forming the lip of the thecae as is recognized in all our specimens. We have seen no sclerotization or membrane formation and offer no overall explanation, but we do suggest that the flattening of the fine meshwork of the thecae could readily lead to the appearance of a continuous membrane in these areas.

One species, *P.* cf. *decurtatus* Bouček and Münch, has been recovered. It is characterised by a ovate rhabdosome outline, thecae 14–12 in 10 mm, reticular meshwork 6–7 in 2 mm, maximum length of incomplete specimen 8.5 mm, and ovate stomata about 1.2 mm long.

Occurrence and Age

Found at Rookery Creek and southwest of Cape Manning in the *triangulatus/magnus*, *convolutus* and *turriculatus* zones; fairly common.

Genus RETIOLITES Barrande 1850 (not illustrated)

Remarks

Retiolites, particularly of the *geinitzianus* group, is widely known, and its morphology has been understood for nearly 100 years (see for example, Holm (1890), Bulman (especially illustration of 1938, fig. 40c), Bouček and Münch (1944), and particularly the SEM studies of Bates and Kirk (1978) and Crowther (1981)).

Characteristics of the *R. geinitzianus* group include the relatively low, parabola shaped corona made up of relatively few and coarse, polygonal meshes and the accompanying two large pores at the 'top' of the corona, the very robust clathria with strong parietal lists welded to the reticula and clearly marking the position of the thecae, the thecal apertures which distally are more or less parallel to the rhabdosome, and the strong, fine, relatively uniform sized meshwork of the reticula. The development of 'thecal hoods' over the 3–4 proximal thecae is not widely known, although they and the succeeding thecal con-

Plate 2

Fig. 1. *Stomatograptus grandis imperfectus* Bouček. Field number MCP 165, ×8. GSC 78431

Fig. 2. *Stomatograptus grandis grandis* (Suess). Field number MCP 165, ×8. GSC 78432

Figs 3, 12. *Holoretiolites simplex* (Eisenack). Distal and proximal portions. Field number LL 10, ×35. GSC 78433

Fig. 4. *Stomatograptus grandis imperfectus*. Enlargement of theca of fig. 1, showing remnants of thecal "floors". Field number MCP 165, ×50. GSC 78431

Fig. 5. *Gothograptus eisenacki* Obut & Sobolevskaya. Field number LL 7, ×20. GSC 78434

Fig. 6. *Stomatograptus* sp. Field number CP 450–500, ×10. GSC 78435

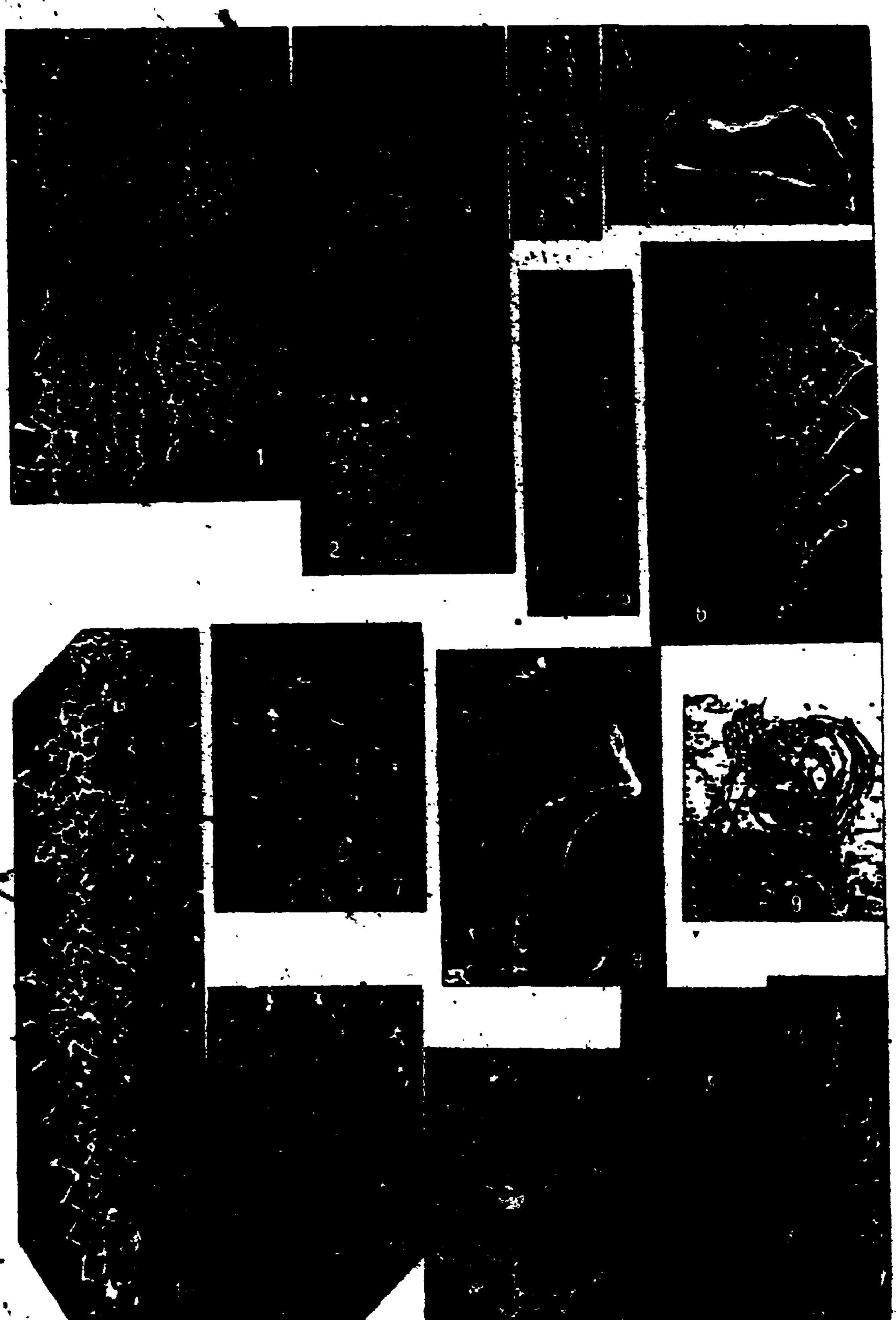
Fig. 7, 8. *Stomatograptus* sp. Immature rhabdosome and enlargement of the prosicula. Field number LL B-81, ×30 & ×225. GSC 78436

Fig. 9. Same as fig. 4; distal end showing virgula, crossection of the thecae and projecting mouth of stomata. Field number CP 450–500, ×18. GSC 78431

Figs. 10, 11. *Stomatograptus* sp. Rhabdosome and lateral view showing thecae. Field number MCP 165, ×10 & ×13. GSC 78437

Fig. 13. *Gothograptus eisenacki* Obut & Sobolevskaya. Field number MRC 05 top, ×30. GSC 78438

Fig. 14. *Gothograptus eisenacki*. Field number MRC 05 top, ×25. GSC 78439



strictions' were illustrated by Crowther (1981). Specimens which otherwise are identical may or may not possess hoods and constrictions, although they are more common in, but not restricted to, stratigraphically lower specimens.

The presence of a prosicula in the geinitzianus group has been documented by Kuhne (1953) and Obut and Zaslavskaya (1976). However, the present study shows that in the great majority of cases, no evidence of the prosicula remains, and that the nature of the prosicula is variable: some siculae are represented by a thickening, some by 2–3 threads, some by only the anterior portion and, most rarely, by a complete prosicula.

One species, *R. geinitzianus densireticulatus* Bouček, is recognized in this study. It is characterized by a maximum uncompressed width of 3.5 mm, 14–11 thecae in 10 mm, thecae about 2 times longer than wide and inclined about 50° to the virgula and, above all, a fine reticulum. The meshes form 4–5 rows per theca and are spaced about 6 per mm. It differs from *R. g. angustidens* in possessing a much finer reticulum.

Occurrence and Age

Occurs commonly in every section, appears in the late Llandovery *spiralis* Zone and extends to the late Wenlock *lundgreni/testis* Zone. It is most abundant in the *spiralis* and *grandis* (= *sakmaricus*) zones.

Genus STOMATOGRAPTUS Tullberg 1883

Remarks

The overall similarity between the morphology of *Retiolites* and *Stomatograptus* has long been recognized, and in fact Bouček and Münch (1944) in their diagnosis of the latter genus simply state (p. 46) "... sonst wie die Untergattung *Retiolites*". The presence of large and distinct median stomata, generally with thickened rims, and of solid thecal walls, was beautifully shown by Holm (1890) and these features are generally considered to be characteristic of *Stomatograptus* (see Bulman, 1970, p. V130).

Stomata of various sizes are present in all Cape Phillips specimens, but it is interesting to note that in one fully developed, large specimen, stomata are irregular and even joined (pl. 2, fig. 1), a feature which surely must have weakened the rhabdosome and throws doubt on Rickards, et al. (1977, p. 31) statement that stomata "... are almost certainly a strengthening feature of the reticula". Furthermore, the walls of the stomata of some specimens are not in the least thickened.

The other diagnostic feature, that of the solid thecal walls, has not been observed in any of the Cape Phillips specimens. However, a close examination of the lists where the 'floor' of the theca would have been clearly shows thin and ragged remnants of the wall (pl. 2, fig. 4). It is probable therefore, that acid treatment destroyed the delicate walls. The supposed pore-bearing *Retiolites* described by Bjerreskov (1975) might then be explainable as a *Stomatograptus* which has had its thecal walls destroyed.

The proximal end of the genus consistently shows the presence of a well developed prosicula, while the corona is crudely rounded, basketshaped and composed of relatively small and regular polygonal meshes.

Several taxa are recognized, or tentatively recognized, in this study; ie, *S. grandis grandis* (Suess) (pl. 2, fig. 2), *S. grandis imperfectus* Bouček and Münch (pl. 2, figs. 2,4,9) and *S.* sp. (pl. 2, figs. 6,8,10). The first named taxon is characterized by having a maximum uncompressed width of 4 mm, thecal spacing of about 6.5 in 5 mm, thecae inclined at 50°–60° to the virgula, subrounded, heavy-rimmed stomata 0.6–0.7 mm in diameter and a dense reticula with uniform, fine mesh sizes. *S. g. imperfectus* is incomplete, but 5 mm wide with thecae numbering 5 in 5 mm distally and inclined about 50°–60° to the virgula, thecal lips are acute and moderately projecting, and the reticular meshwork is coarser than that of *S. grandis grandis*. *S.* sp. possesses a slowly widening rhabdosome, thecae which are distinctly orthograptid in profile, numbering 5–6 in 5 mm, and inclined at 30°–50° to the virgula; the reticular meshwork is moderately fine proximally but becomes increasingly coarse and quadrate distally.

Most juvenile specimens from the highest range of the genus must, of necessity, also be assigned to '*S.* sp.'

Occurrence and Age

Large specimens are common in the *spiralis* and *sakmaricus* zones of most sections, and rarer juveniles occur in the late Wenlock *lundgreni/testis* Zone. *S. grandis grandis* is found only in the *spiralis* Zone.

Subfamily PLECTOGRAPTINAE Bouček and Münch, 1952, emended herein

Clathria well developed, sometimes without reticula, lacinia absent; development with ancora stage, proximal end of rhabdosome usually somewhat inflated (corona), narrowing distally and in some genera terminates in a slender tubular "appendix". Virgula free or incorporated into ventral wall. Surface of lists pustulose on outside surface (pl. 3, fig. 6). Seams of the clathria and reticula generally face in and out, respectively.

Genus PLECTOGRAPTUS Moberg and Törnquist, 1909

Remarks

The genus is typically characterized by a clathria of open, subhexagonal meshes and a free, central virgula. *P. macilentus*, the type species, while not recovered uncompressed, occurs in

Plate 3

Fig. 1. *Gothograptus eisenacki* Obut & Sobolevskaya. Field number MRC 05, ×23. GSC 78440

Fig. 2. *Paraplectograptus praemacilentus* Bouček & Münch. Stereopair of simple rhabdosome. Field number CP 600–625, ×15. GSC 78441

Fig. 3. *Paraplectograptus praemacilentus*. Stereopair. Field number CP 450–500, ×20. GSC 78442

Fig. 4. *Paraplectograptus eiseli* (Manck). Field number RK 20–26C, ×15. GSC 78443

Fig. 5. *Paraplectograptus praemacilentus*. Same as fig. 2, distal end of rhabdosome showing virgula. Field number CP 600–625, ×30. GSC 78441

Fig. 6. *Plectograptus (Sokolovograptus) textor* Bouček & Münch. Field number CP 390–400, ×150. GSC 78444

Fig. 7. *Paraplectograptus* sp. A. Field number CP 450–500, ×20. GSC 78445

Fig. 8. *Gothograptus eisenacki*. Field number MRC 05 top, ×28. GSC 78446

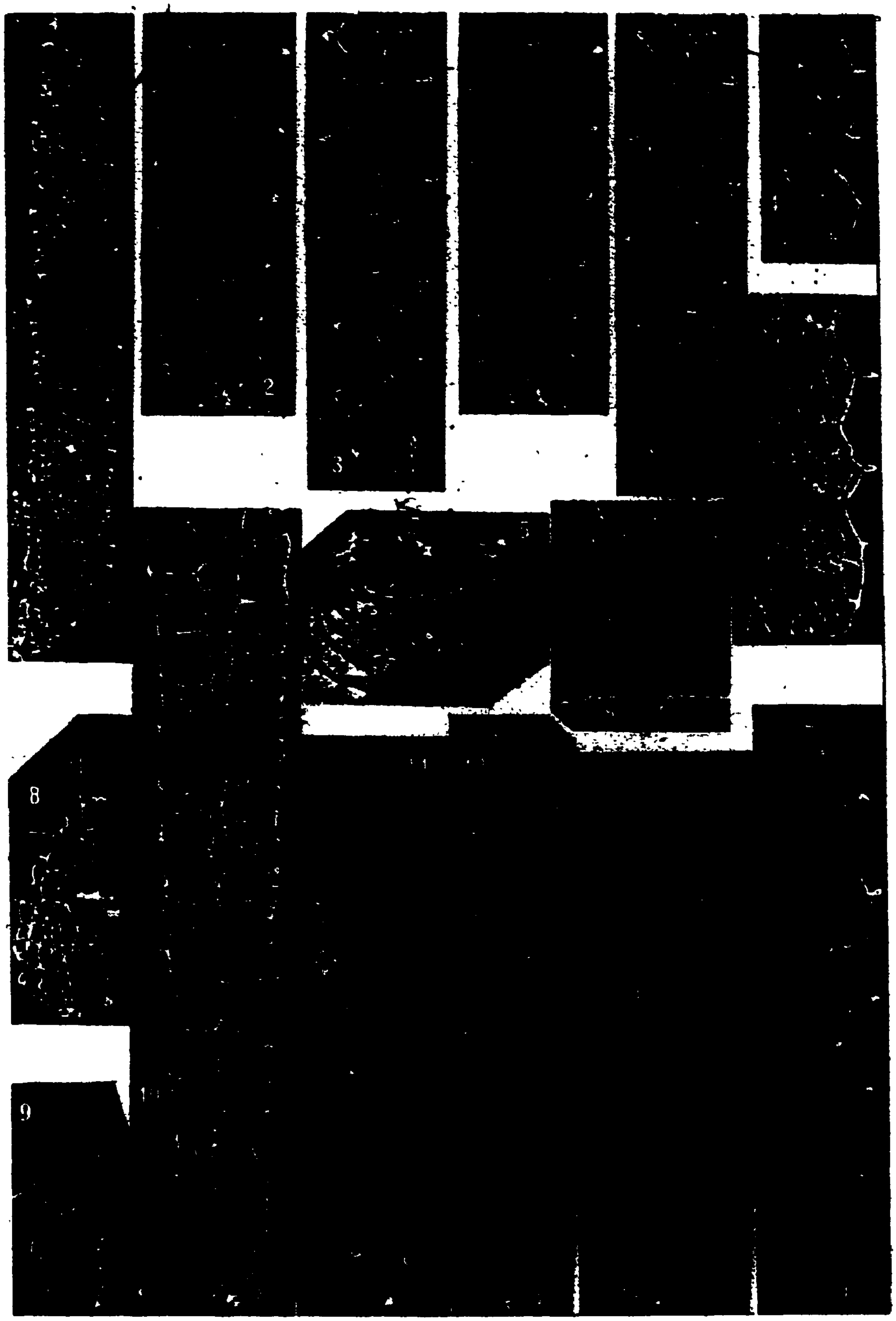
Fig. 9. *Paraplectograptus praemacilentus* (= "*Retiolites tenuis*" Eisenack?). Field number LL 9, ×40. GSC 78447

Fig. 10. *Plectograptus (Sokolovograptus) textor*. Field number CP 390–400, ×15. GSC 78449

Fig. 11. *Paraplectograptus eiseli*? Field number CP 315–325, ×13. GSC 78449

Fig. 12. *Paraplectograptus eiseli*. Stereopair. Field number MCP 152.5, ×20. GSC 78450

Fig. 13. *Plectograptus (Sokolovograptus) textor*. Field number CP 390–400, ×17. GSC 78451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compressed form in Lower Ludlow strata of the Cape Phillips Formation (Jackson, et al., 1978)

Subgenus SOKOLOVOGRAPTUS Obut and Zaslavskaya, 1976 (= Genus *Sokolovograptus* Obut and Sobolevskaya, 1976)
Type species. *Plectograptus? textor* Bouček and Münch, 1952
Species assigned: *Plectograptus? textor* Bouček and Münch, 1952
Sokolovograptus parens Obut and Zaslavskaya, 1976
Plectograptus? boučeki Rickards, 1967

Diagnosis
Virgula free, attached only to ancora, extends only to level of theca 4 or 5. Corona of few lists, weakly rounded, rectangular in cross-section. Clathrium and reticulum complex and disorderly, meshes polygonal to triangular to quadrate, relatively fine proximally, becoming coarser distally. Thecae generally climacograptid proximally (pl. 3, fig. 13), more or less orthograptid distally. Thecae marked by one or two shorter, transverse, curved lists, the outer margins of which are sometimes joined by a vertical list, and by a longer and more projecting lower apertural lip. Rhabdosome rectangular in cross-section, widening abruptly proximally, and then maintaining constant width or widening very gradually. Occasional specimens narrow slightly distally. Seams of lists all face inward making distinction between clathrium and reticulum difficult; in this way it differs from other plectograptids.

Remarks
This subgenus is similar to the type *Plectograptus macilentus* in its possession of a free central virgula and rectangular cross-section; it differs markedly, however, in the possession of a complex and disorderly clathrium/reticulum. Bouček and Münch (1952) tentatively suggested that *P. textor* might be assignable to a new subgenus of *Plectograptus*.

Obut and Zaslavskaya (1976) noted the occurrence of a delicate prosicula in juvenile stages of *S. parens*; we have not recovered any prosicula-bearing specimens of *P.* (*Sokolovograptus*) *textor*.

We recognize one species, *P.* (*Sokolovograptus*) *textor*, from the Cape Phillips. It is characterized by an extremely variable meshwork, a width of 0.7–1.5 mm exclusive of apertural lips and 0.9–2.0 mm inclusive of apertural lips, a thecal spacing of 7–8 in 5 mm, and a length of at least 8 mm. *P.* (*S.*) *textor* differs from the species described as *P.? boučeki* by Rickards (1967), in being narrower, possessing more closely spaced thecae, and apparently possessing a coarser clathrial meshwork and somewhat different thecal apertural lists. It differs from *S. parens* Obut and Zaslavskaya primarily in being much wider, but is otherwise very similar and might possibly be conspecific.

Occurrence and Age
Recovered in almost all sections, sometimes in considerable abundance. It is rare in the *turriculatus* Zone, and common in the *spiralis* to *lundgreni/testis* zones.

Genus PARAPLECTOGRAPTUS Přibyl, 1948
Diagnosis
Ancora four-pronged; corona simple, of few meshes, somewhat rhomboid in profile, and square in cross-section. Rhabdosome walls (clathrium) sharply angular. Virgula central proximally, quickly moving to ventral side and becoming incorporated in, and part of, ventral wall. Horizontal lists arise alternately on left and right sides of virgula and join outer walls. Dorsal wall either of zig-zag pleural lists connected directly to outer walls, or with very short horizontal lists connecting pleural lists to outer walls. Reticulum may or may not be present, lists generally few in number and finer than clathrium, sometimes more common in proximal region and absent in distal portions, and/or may be more common along median line of rhabdosome. Clathrial seams face in, those of the reticulum face out.

Remarks
Paraplectograptus, as visualized in this study, incorporates the type *Paraplectograptus eiseli* (pl. 3, fig. 4) and "*Plectograptus praemacilentus*" of Bouček and Münch (1952) (Pl. 3, figs. 2,5). In its simpler, more orderly morph this genus is superficially similar to *Plectograptus* (s.s.), but differs strikingly in possessing a virgula which is part of the ventral wall. The morphology of *Paraplectograptus* ranges from one with only a clathrium, to one with a moderately complex but delicate reticulum over the clathrium. The clathrial structures of species recognized herein are essentially identical.

Bouček and Münch (1952), in their discussion of *Plectograptus praemacilentus* imply that the virgula of the Czech specimens is, like the typical *Plectograptus*, free throughout its length. However, an examination of their illustrations shows the virgula to be suspiciously straight throughout, an observation suggesting that the virgula in their material is probably attached. This is further suggested by an examination of flattened material from the Arctic identified as the same species by Lenz (1978). These flattened but well preserved specimens are clearly the same species as the uncompressed material studied herein, yet the attachment of the virgula to the ventral wall is recognizable only with difficulty, and then only after comparison with the uncompressed rhabdosomes. We suggest therefore that the virgula of the type *P. macilentus* of Czechoslovakia is attached.

Three species, *P. eiseli*, *P. praemacilentus* and *P.* sp. A are recognized in this study. *P. eiseli* has few reticular lists or none, is about 0.9 mm in width, and a thecal spacing of 6–7 in 5 mm (slightly higher than that stated by Bouček and Münch (1952)). *P. praemacilentus* and *P.* sp. A (pl. 3, fig. 7) are characterized by the possession of a reticula, that of the latter species being finer, denser and more disorderly over the entire surface, and/or more dense in the medial region. In some cases, the meshwork still retains a crude overall zig-zag pattern. The rhabdosomes of both are generally parallel-sided, up to 1.4 mm in width, and thecae number 5–7.5 in 5 mm.

Eisenack (1951) illustrated "*Retiolites tenuis*", a species subsequently described as "*Gothograptus tenuis*" by Obut and Sobolevskaya (1965). By comparison with early growth stages of our material (pl. 3, fig. 3) we feel that Eisenack's species is nothing more than a juvenile stage of *P. praemacilentus*.

Occurrence and Age
Very common in most sections. *P. praemacilentus* ranges in age from the *turriculatus* Zone (rare) to the *nassa* Zone. *P.* sp. A ranges from the *spiralis* Zone to about the *rigidus* Zone (lower Wenlock). Both species are most abundant in upper Llandovery strata. *P. eiseli* is less common and ranges from the *spiralis* Zone to about "mid" Wenlock.

Genus GOTHOGRAPTUS Frech, 1897
Diagnosis (based primarily on *G. eisenacki* Obut and Sobolevskaya, 1965)
Corona rounded, width nearly equal to maximum width of rhabdosome which is attained at the level of the first theca, composed of a few irregular clathrial lists. Coronal meshwork made finer through addition of reticular lists, but maintains two large, adjacent basal-lateral pores. Rhabdosome of most specimens narrow rapidly distally and thecae generally number 3–4 per side. Clathrial pattern complex and irregular; reticulum well developed, relatively fine, list widths becoming coarser with maturity. Thecae long, outer margins undulose (pl. 2, figs. 13,14), overall rather similar in profile to those of *Pseudoglyptograptus*, apertures generally horizontal. Meshwork of tubular appendix finer than that of more proximal regions. Virgula moves to ventral side early in development, but becomes at-

tached to, and incorporated in, ventral wall about two-thirds along length of typical rhabdosome, then joined by alternating left and right bars for remainder of length; extends beyond rhabdosome. Seams of clathrium face in, and those of reticulum face out

Remarks

The species recognized in this study, *G. eisenacki*, characteristically possesses only 3–4 thecae per side, but may range from 2 to 5 or rarely more, typically narrows rapidly distally and, most uniquely, possesses thecae more like those of *Pseudoglyptograptus* than *Climacograptus*. It differs from the type additionally in being consistently smaller, in possessing a relatively coarser reticulum (particularly that of the thecal margins), and in that the virgula is free for a relatively much greater part of its length. No hint of such thecal hoods as illustrated for *G. nassa* by Wiman (1896) is present

Occurrence and Age

Found only at Laura Lakes area and Rookery Creek in the latest Wenlock *nassa* beds

Genus HOLORETIOLITES Eisenack 1951

Remarks

The genus is represented by only two partial specimens, probably assignable to *H. simplex* (Eisenack) (1935) from Lower Ludlow strata. The thecae are climacograptid and appear to number 2 per side, the clathrium is simple and more or less zigzag, and the distal appendix is not developed. The fine structure is pustulose

Occurrence and Age

Found only at Laura Lakes area in Lower Ludlow strata

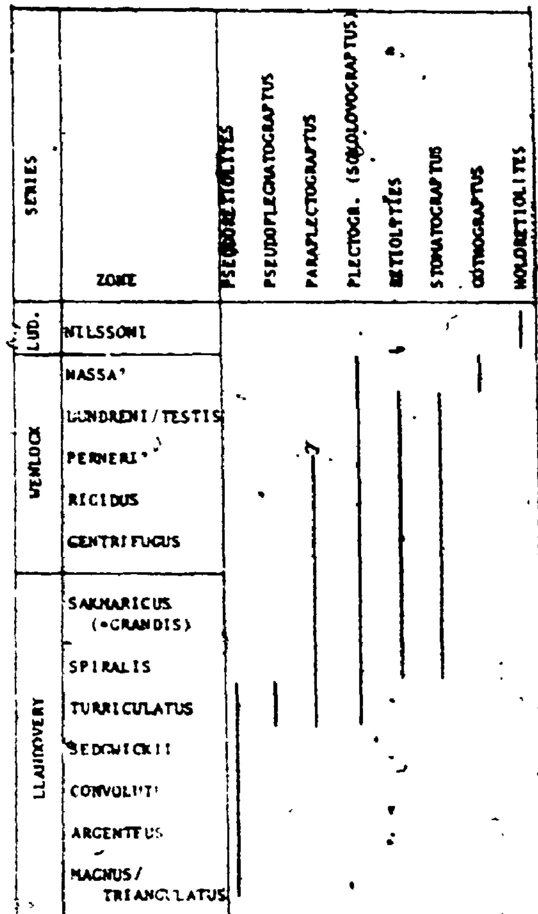

Table 1 Biostratigraphic ranges of Arctic Islands retiolitids. Zonal scheme extracted from Thorsteinsson 1958, Lenz 1978, 1982

Stratigraphic Distribution of Retiolitids

The present study extends or modifies the stratigraphic ranges of the taxa *Retiolites*, *Stomatograptus*, *Paraplectograptus* and *Plectograptus* (*Sokolovograptus*). In most cases, the ranges of the genera are considerably extended beyond that shown in the literature, particularly that of Rickards, et al. (1977)

A composite of the zonal schemes of Thorsteinsson (1958) and Lenz (1978) from the Arctic Islands, and Lenz (1982) from the northern Cordillera, is used as a standard against which to display the stratigraphic ranges of the taxa recognized in this study (Table 1). It must be emphasized that the study is a preliminary one, and that subsequent recovery of additional material and taxonomic revision could alter the ranges somewhat.

In their section on the evolution of the retiolitids, Rickards, et al. (1977) relied heavily on their assessment of the stratigraphic ranges of the taxa. In view of the much extended ranges of most of the genera and species recovered in this study, it is clear that the evolutionary history must be completely reevaluated. Furthermore, much more attention must be directed to the development of the clathrium and reticulum in order to understand the phylogenetic relationships

Acknowledgements. Hermann Jaeger very kindly sent photographs of isolated specimens of *Plectograptus macilentus*, and Peter Crowther offered a number of written comments on retiolitids in general. R. Thorsteinsson directed Melchin to the Cape Manning section, and A. D. McCracken collected some material from Marshall Peninsula and Rookery Creek. Financial support for field and laboratory studies was through a Natural Sciences and Engineering Research Council operating grant to Lenz, transportation costs to the field were supplied to Melchin by the Northern Research Group of the University of Western Ontario, and air support in the field was through the Polar Continental Shelf Project of the Department of Energy, Mines and Resources

Dansk sammendrag

De retiolitide graptolitslægter *Pseudoretiolites, Pseudoplegmatograptus, Paraplectograptus, Plectograptus, Retiolites, Stomatograptus, Gothograptus* og *Holoretiolites* beskrives fra den arktisk Canadiske Cape Phillips Formation. Den biostratigrafiske spændvidde er fra mellem Llandovery (*magnus/triangulatus* zonen) til øvre Ludlow (*nilssoni* zonen).

På basis af overflade ornamentikken bliver Retiolitinae og Plectograptinae emenderede. *Paraplectograptus* emenderes til også at inkludere former med et reticulum.

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APPENDIX E

Author's note: this manuscript is a preliminary draft only - subject to revision.

A NEW RETIOLITID GRAPTOLITE GENUS FROM THE LLANDOVERY OF SWEDEN AND ARCTIC CANADA

by M. J. MELCHIN, D. B. E. BATES, N. H. KIRK and A. C. LENZ

In 1970, Hutt, et al. described and illustrated a single specimen of Retiolites s.l. from the Llandovery of Sweden which superficially bore rather little resemblence to the other Llandovery retiolitids, (e.g. Retiolites, Stomatograptus, Peudoretiolites and Pseudoplegmatograptus) as known at that time, being smaller and much simpler in form. Those authors considered that it bore close affinities with Retiolites, Paraplectograptus and Orthoretiolites. Since that time much more work has been done on uncompressed Llandovery retiolitids (e.g. Bates and Kirk, 1978, 1984; Lenz and Melchin, in press) which has helped to reveal a great deal more about their architecture and interrelationships. In the course of this work several more specimens of forms bearing close affinities with Retiolites s.l. have been found and enough material has now been accumulated to merit description of these forms as a new genus. The fact that it has only been previously reported once from compressed specimens (Sennikov, 1976) is not suprising since its small size and its fine, open meshwork would make it almost totally undetectable in compressed form. If fragments were found they would probably have been considered small fragments of a larger species of Pseudoretiolites or Pseudoplegmatograptus, both known to occur contemporaneous strata.

All of the material used in the present study has been chemically isolated from calcite concretions and studied using stereopair scanning electron micrographs. The Swedish material was aquired from the Osmundsberget locality (turriculatus Zone) described by Thorslund and Jaanusson (1960) and Hutt et al. (1970) while the Canadian Arctic material was collected from a small stream section ?km west of Cape Manning (lat, long) and Snowblind Creek (lat, long) both on Cornwallis Island, N. W. T.

SYSTEMATIC PALAEONTOLOGY

Subfamily Retiolitinae

Tribe Retiolitini

Genus Rotaretiolites n. gen.

Type species. Rotaretiolites exutus n. sp.

Composition of Genus. Rotaretiolites exutus n. sp., R. hystricosus n. sp., R. cancellatus n. sp. and possibly Pseudoplegmatograptus singularis Sennikov.

Diagnosis. Ancora simple, consists of four branches terminating in four connecting loops. One further set of looping lists may emerge from this, forming a simple corona. Sicula unsclerotized, its aperture represented by a circular list attached to the virgella. Clathria very pronounced, consisting of virgula and opposite zig-zag list with parietal lists branching from them. Thecae defined by everted apertural loop, aboral list and a single, curving ventral list arising from about the middle of the aboral list of the previous theca. Weak, open reticulum or apertural and ventral spines may be present.

Description. Rhabdosome relatively small and narrow. Ancora simple consisting of four branches terminating in four loops connecting the branches giving it a four-spoked, wagon wheel appearance when viewed end-on. From the loops, another single set of looping lists may emerge forming a small corona. Sicula unsclerotized, represented only by a thickening or circular list attached to the virgella where its aperture is interpreted to have been. At the probable position of the sicular apex is a bend where the virgella is joined to the virgula and forming a continuous rod. Clathria (thecal framework) consists of the virgula on the obverse side and zig-zag list on the reverse side. Obverse and reverse parietal lists arise as alternating branches from the virgula, and zig-zag lists respectively. Apertural list arises from the parietal lists and consists of a large loop defining an everted aperture. Aboral list arises at the junction of the apertural and parietal lists. Each theca has a single, ventral list extending from the aboral list of the subjacent theca to the centre of the apertural list. A pair of pleural lists may be present joining the successive apertures at their lateral margins. Thecal shape as thus defined is glyptograptid with a high inclination and low overlap. Thecae appear to be very wide in proportion to their length. Zig-zag list arises from a branch of the sicula apertural loop. The ventral list of th11 arises from the ancora and that of th12 is connected to both the ancora and branches from the sicular area. The clathria may be elaborated by an open reticulum arising from the ancora and connected to the apertural and pleural lists. It consists only of diagonally crossing lists. These crossing lists form a layer outside of the clathria. Apertural and ventral lists may bear spines. List surfaces are weakly to strongly striated when viewed at high magnification.

Discussion. This new genus differs from all other members of the Retiolitini in having a reduced, simpler corona, consisting of only a single or double set of loops, an unsclerotized sicula and a reticulum which is reduced or absent. The clathria is similar to that of Retiolites but differs in that the apertural list is the dominant thecal element rather than the parietal lists, and the latter genus lacks ventral lists. Pseudoretiolites has a distinctive, basket-shaped corona with a pair of spiralling lists crossing the main branches and defining several series of subrectangular cells. The ventral lists of the thecae of Pseudoretiolites, while also present, become strongly zig-zag near the aperture with many small branching lists.

The clathria of Rotaretiolites most closely resembles that of Pseudoplegmatograptus (=Sinostomaograptus sensu Bates and Kirk, 1984, 1985). The corona of the latter is slightly more developed but is basically almost identical to that of R. cancellatus n. sp. while the central four branches with terminal, joining loops, are the same. The clathria also has the same pattern except that the apertures are not everted and the rhabdosomal dimensions and proportions are different. The ventral list of Pseudoplegmatograptus is seldom preserved intact in the Canadian arctic material and was not noted in the Swedish specimens illustrated by Bates and Kirk. In addition, like Rotaretiolites hystricosus, Pseudoplegmatograptus is the only other genus of the Retiolitini shown to have apertural spines. It is mainly the unsclerotized sicula, reduced reticulum and smaller rhabdosome which differentiate the two.

Pseudoplegmatograptus singularis is a species described by Sennikov (1976) which appears to have a clathria like that of Rotaretiolites and a much reduced to absent reticulum although it is known only from compressed specimens. A specimen illustrated by Sennikov (pl. 8, fig. 3) preserved in subscalariform view clearly shows the prominent, looping apertural lists with a single ventral list joined to what appears to be the aboral list of the previous theca. Like Rotaretiolites cancellatus, P. singularis has the thecal apertures joined in series, by a pair of lists which resemble pleural lists. Pseudoplegmatograptus singularis also resembles R. cancellatus in its dimensions and thecal spacing although P. singularis differs in lacking the diagonal crossing elements of the reticulum. By virtue of the close similarities, P. singularis is here assigned questionably to Rotaretiolites. The absence of a well preserved ancora in Sennikov's material prevents positive assignment.

Among the Plectograptini, Paraplectograptus is the only genus with which Rotaretiolites could be confused. Both genera share a simple, well defined clathria with opposite virgula and zig-zag lists and a reduced to absent reticulum. The thecae of Paraplectograptus, however, are each defined by a pair of zig-zag pleural lists and lack the single ventral list. The ancora of Rotaretiolites is also more regular with its distinctive "wagon wheel" form. Another important difference between the two is that when a reticulum is present on Paraplectograptus (or any of the Plectograptini) it is incorporated within the walls defined by the virgula and the zig-zag lists (where present). In

Rotaretiolites (and all other Retiolitini) the reticulum forms a separate layer outside of the clathria connected to it at the parietal and/or apertural lists.

The striated surface texture is unique among the Silurian retiolitids, contrasting with the smooth surface of the other Retiolitini (striated only at the level of the cortical fibres) and the pustulose texture of the Plectograptini.

A similar striated surface texture can be seen on some of the Ordovician archiretiolitids and Rotaretiolites shows some similarities to a few of these forms, particularly Orthoretiolites. The archiretiolitids, however, possess a very different proximal development pattern; they are now thought to have been derived from a different group of diplograptids and their similarities are considered to be result of convergence rather that relatedness (Mitchell, 1987).

The reduced reticulum and simpler, smaller rhabdosomal appearance may lead one to speculate that Rotaretiolites is a "missing link" between the structurally complex Retiolitinae and the apparently simpler, generally smaller Plectograptinae. Indeed, the unique, striated surface texture could be regarded as intermediate in nature between the smooth and pustulose in which the pustules are arranged in well defined rows. Lenz and Melchin (in press a) show that the earliest plectograptids do, indeed range as low as turriculatus Zone in the Canadian arctic. However, the differences in skeletal architecture between Rotaretiolites and Paraplectograptus are still large. To derive the latter from the former would require disappearance of the ventral lists and reorientation of the pleural lists seen in R. cancellatus and R? singularis. The rest of the reticulum would also have to be incorporated into the lateral walls defined by the virgula and zig-zag list.

An equally strong case could be made for independent origins of the Plectograptini from one or several of the known sedgwickii to turriculatus Zone diplograptids. Observations on members of the Glyptograptus tamariscus group found uncompressed in arctic Canada have shown that the virgula of some of these forms is embedded in the obverse wall in a manner similar to that of Paraplectograptus and later in Gothograptus, and that the rhabdosomal forms and dimensions are also similar. Likewise, other late glyptograptids such as G. elegans as well as some of the orthograptids and possibly slender petalograptids (such as P. tenuis) possess a free, central virgula similar to that of Plectograptus (Sokolovograptus) and many later plectograptids. However, none of these late glyptograptids and very few of the orthograptids or petalograptids are known to possess an ancora, which is probably a key factor in development of the "retiolitid condition".

Rotaretiolites exutus n. sp.

Plate 1, figures 2,4.

1978 "Retiolites" sp. Bates and Kirk, pl.?

1984 Retiolites sp. Bates and Kirk, text-fig. 4a.

1985 Retiolites sp. Bates and Kirk, fig. 28f.

1986 Retiolites sp. Bates and Kirk, fig. 6B.

Holotype. UCW from the turriculatus Zone, Osmundsberg, Sweden, pl. , fig.

Derivation of name. Named exutus - Latin, meaning bare, stripped.

Material. Three very well preserved, uncompressed specimens; all are complete, relatively immature rhabdosomes.

Occurrence. turriculatus Zone, Osmundsberg, Sweden.

Diagnosis. Small, simple retiolitid with clathria completely unadorned by either reticulum or spines. Thecae defined by a large apertural loop and a curving ventral list extending from the aboral list of the subjacent theca to the centre of the apertural list.

Description. Rhabdosome up to 1.7mm long. Ancora simple, consisting only of four branches with terminal loops and is 0.6mm across. Clathria, as described above for the genus. Reticulum or thecal spines of any kind appear to be enirely lacking. Width across the first thecal pair is 1.1mm, and is 1.4mm across the second thecal pair. Thecae spaced at 15.5 in 10mm. Ventral list of th11 arises directly from the centre of one of the ancora loops and that of th12 from sicula apertural loop and is connected to the ancora by a single list. List surfaces are strongly, longitudinally striated.

Remarks. Comparison of the species of this genus to members of other genera is given in the discussion of the genus. This species differs from other members of *Rotaretiolites* by its total lack of ornamentation or reticulum. It appears to represent the basic skeletal structure upon which other species of *Rotaretiolites* and indeed many other Retiolitinae are built.

Rotaretiolites hystricosus n. sp.

Plate 1, figures 1,3; plate 2 figures 4,5.

1970 *Retiolites* sensu lato sp., Hutt, *et al*., p. 7. pl. 1, figs. 19-20.

Holotype. Cn54919 from nodule 1 *turriculatus* Zone, Osmundsberg, Sweden.

Derivation of Name. Named *hystricosus* - Latin meaning spiny, thorny.

Material. Three very well preserved but broken, uncompressed specimens.

Occurrence. *turriculatus* Zone, Osmundsberg, Sweden and Snowblind Creek, Cornwallis Is. Arctic Canada at approxiomately 350m.

Diagnosis. Small, simple retiolidltid with thecae defined by large, looping apertural lists and a curving ventral list extending from the aboral list of the subjacent theca to the centre of the apertural list. Thecae ornamented by a pair of laterally directed apertural spines and proximoventrally directed mesial spine. Reticulum is absent.

Description. Rhabdosome up to 3.2mm long. Ancora simple, four branches with terminal loops, and clathria as described above for the genus. Reticulum is lacking. Ancora is 0.8mm wide. Width at first thecal pair is 1.1mm and the maximum observed width is 1.4 to 1.7mm. Thecae spaced at 13 to 14 in 10mm. Each theca bears a pair of laterally-directed apertural spines and a proximo-ventrally directed mesial spine. Theca 11 appears to bear three such mesial spines, one of which arises a the junction of the ancora with the mesial list. List surfaces strongly str.ated, the striae being spaced at approximately 2.3 m.

Remarks. This species differs from Rotaretiolites exutus in having prominent apertural and mesial spines on the thecae. The possibility exists that the specimens of R. exutus found here (which have been recovered from the same locality as the Swedish specimen of R. hystricosus) are less mature rhabdosomes R. hystricosus which had not yet developed the spinose ornamentation. However, since thll is the most spinose theca of R. hystricosus and two of the specimens of R. exutus found here show a very well preserved thll with no sign of spines, they are considered to be two separate species.

The specimen found by Hutt et al. (1970) showed the apertural spines to be directed proximolaterally on the reverse side and distolaterally on the obverse side but the two specimens found here show that those spines are simply laterally directed and the orientation of the spines of the Swedish specimen are the result of slight compression. Examination of the illustration of the Swedish specimen and comparison with the Canadian material suggests that the width of 2.0mm estimated by Hutt et al. was somewhat overestimated and that a figure of 1.6 to 1.7mm is more likely.

Rotaretiolites cancellatus n. sp.

Plate 2, figures 1-3.

Holotype. GSC from the convolutus Zone, Cape Manning, Cornwallis Is., Arctic Canada.

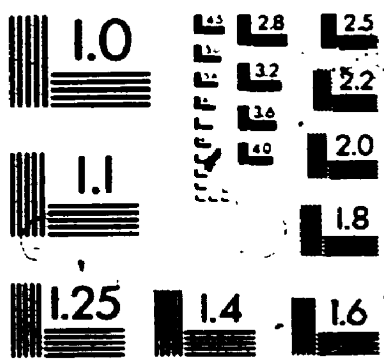
Derivation of Name. Named cancellatus - Latin meaning cross-barred, latticed.

Material. One very well preserved, uncompressed distal fragment and one partially compressed proximal specimen.

Occurrence. convolutus Zone, Cape Manning at 5-7m.

Diagnosis. Simple retiolitid with well-defined, simple clathria and a weak, open reticulum consisting of diagonally crossing lists. Thecae defined by a looping apertural list, a ventral list arising from the aboral list of the subjacent thecae, extending to the centre of the apertural list and a pair of pleural lists.

Description. Rhabdosome at least 4mm long. Ancora consists of four branches with terminal loops and a second set of loops forming a weak corona. Clathria as described for the genus except for the addition of pleural lists running longitudinally, joining the thecal apertures on their lateral margins. An open reticulum, consisting of fine, diagonally crossing lists forms a layer outside of the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obverse and reverse walls, is joined to the clathria at the apertural and pleural lists. The exact patterns of list architecture at the proximal end is not clear due to dorsoventral compression of the proximal specimen found.. However, it appears to be similar to that of other Rotaretiolites species described above with the addition a few extra connection lists and a reticulum arising from the ancora. Maximum width is 1.8mm and the distal thecae are spaced at 12.5 in 10mm. Apertures are slightly everted and overlap is very low. List surfaces are weakly striated.

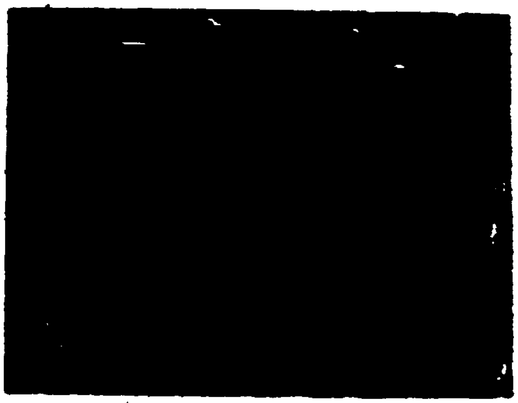
Remarks. This species differs from the other known species of Rotaretiolites in that it possesses a reticulum of diagonally crossing lists. Rotaretiolites exutus and R. hystricosus also lack the pleural lists and the extra row of loops on the ancora. Rotaretiolites? singularis (Sennikov) is very similar to R. cancellatus in both the dimensions and the possession of pleural lists but it lacks the crossing reticulum. The ancora of R? singularis is not known.

The possession of a weak reticulum and a more complex ancora in this species may be a primitive feature considering its earlier stratigraphic occurrence (convolutus Zone rather than turriculatus Zone for the other three species). If this genus evolved from another member of the Retiolitinae such as Pseudoplegmatograptus, which it most closely resembles, then R. cancellatus seems to be an intermediate stage in the progressive loss of reticulum and simplification of the ancora.

Plate 1

Figures 1,3. <u>Rotaretiolities</u> <u>hystricusus</u> n. sp.: 1) stereopair, x50; 3) stereopair, x50.

Figures 2,4. <u>Rotaretiolites</u> <u>exutus</u> n. sp.: 2) stereopair, x55; 4) stereopair, x65.



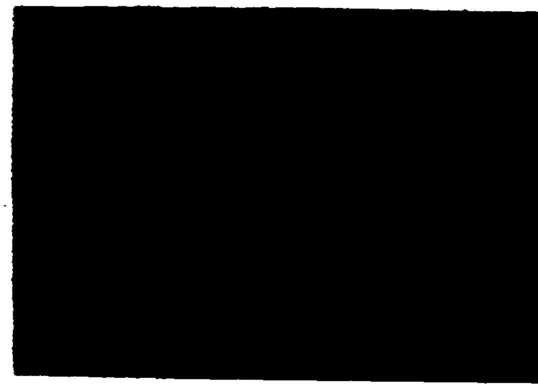


Plate 2

Figures 1-3. Rotaretiolites cancellatus n. sp.: 1) stereopair, x40; 2) stereopair, distorted proxomal end, x50; 3) same as figure 1, list junction showing surface texture, x800.

Figures 4,5. Rotaretiolites hystricosus n. sp.: 4) same as plate 1, figure 1, junc tion of virgula with brnaching list, x1750; 5) same as plate 1, figur 1, list junction showing surface texture, x1500.