TAXONOMY AND BIOSTRATIGRAPHY OF MIDDLE ORDOVICIAN (LLANVIRN) GRAPTOLITES FROM THE TABLE COVE AND BLACK COVE FORMATIONS,

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TAXONOMY AND BIOSTRATIGRAPHY OF MIDDLE ORDOVICIAN (LLANVIRN) GRAPTOLITES FROM THE TABLE COVE AND BLACK COVE FORMATIONS, WESTERN NEWFOUNDLAND

By

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A thesis submitted to the School of Graduate
Studies in fulfilment of the requirements
for the degree of Masters in Science

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Memorial University of Newfoundland
January 1997

St. John's
Newfoundland

0-612-23178-X

Abstract

This thesis provides the first full taxonomic treatment of graptolites from the Middle Ordovician (Llanvirn) Table Head and Goose Tickle groups of western Newfoundland. These rocks represent the upper portion of an autochthonous sedimentary and volcanic sequence that was deposited in a shallow water, near-shore environment during the rifting and passive drifting of the continental margin. Seventeen taxa from these strata are discussed in detail, based almost exclusively on flattened material, including *Glossograptus* sp. nov. Specimen preservation is best in the Port au Port region, quality decreasing to the east and the north.

There is good correlation between graptolite assemblages at the various exposures of the Table Cove and Black Cove formations, but there appears to be insufficient vertical change through the sequences to permit faunal subdivision of this interval (equivalent to the Australian Darriwilian 3).

The graptolite assemblages found in these rocks suggest a low latitude, warm water setting (Pacific Province) at the time of formation. However, the increased number of pandemic species compared to neighbouring Early Ordovician (Arenig) sequences in western Newfoundland suggests that provincialism was becoming less pronounced at this time.

Acknowledgements

Thanks to the following for help over the course of this degree. First and foremost, to Dr. S.H. Williams, for providing supervision through the course of the production of this thesis. To Dr. J. Maletz, for providing unpublished information and material to this thesis. To Dr. A. Aksu, Dr. R. Hiscott and Dr. E. Burden, for their knowledge and assistance over the past two years. To Dr. Mike Melchin, for help with the 'cleared' photos. And to Dr. Rine Zandee, for technical help at the VERY end.

Financially, thanks go to the NSERC operating grant of Dr. S.H. Williams, to the Atlantic Accord Career Development Scholarship Committee, and to the School of Graduate Studies at Memorial University.

Personal thanks go out to all of my family, especially my mother and father for being pretty good friends and for being there whenever I needed them. Also a special thank-you to Ron and Sue for their extra help at the end, when the thumb screws were really on.

And, finally, special thanks to the friends who provided the help and support that kept me going through it all. To Dave R. and Heather D., Ken C. and Mary S., Shawn F., Keith C., Sean T., Cindy S., and last but not least, Kristina C.

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CHAPTER I

INTRODUCTION

I.1: Summary of Previous Research

Reports of graptolites from middle Llanvirn deposits in western Newfoundland date back to the 1930's, when Schuchert and Dunbar (1934, p. 67), in a discussion of the stratigraphy of western Newfoundland, presented a brief listing of the graptolitic fauna found in the 'black slaty graptolitiferous shale' of the 'Table Head series' at Port au Port. Ruedemann (1947, pp. 58-60) provided another brief list of graptolites found from western Newfoundland, including beds from 'Port au Port'. Whittington and Kindle (1963) gave further non-descriptive lists of the graptolites found by them at the "Black Cove" of Port au Port.

Morris and Kay (1966) published a list and accompanying figures of graptolites collected and identified from the Black Cove Formation and possibly the Table Cove Formation (James *et al*, 1988) from the Port au Port Peninsula. More recently, Finney and Skevington (1979) provided another graptolite summary from the Table Cove Formation at the West Bay Centre Quarry. Like most of those listed above, neither report provided descriptions of the graptolites discussed.

Two of the more recent publications dealing with the graptolitic fauna of western Newfoundland have included limited systematic descriptions; they have, however, dealt only with one or two elements of the fauna and not the assemblage as a whole. Whittington and Rickards (1969) provided detailed descriptions of *Glossograptus holmi* and *Cardiograptus crawfordi* based on isolated material collected from "limestone boulders, of upper middle Table Head age". These boulders were contained within conglomerates of the Daniel's Harbour Member of the Goose Tickle Group at Daniel's Harbour (not the Cow Head Group as stated by them) and probably originated from the Table Cove Formation (James *et al*, 1988). Finney and Chen (1984) gave a systematic description of the new genus *Bergstroemograptus*, based on non-isolated material collected from the shales of the Table Cove Formation, West Bay Centre Quarry.

Currently, work is been carried out by Dr. C.E. Mitchell and Dr. J. Maletz dealing with the global correlation of the Llanvirn Series, which includes limited study of some of the taxa from western Newfoundland (e.g., Mitchell and Maletz, 1994; Maletz and Mitchell, 1995).

The present study attempts to rectify the deficiencies revealed by the previous 'piecemeal' approach, through detailed collection and thorough systematic treatment of all taxa present in this interval, both on the Port au Port Peninsula and the Northern Peninsula.

I.2: Geological Setting of Western Newfoundland

Newfoundland is composed of a series of land masses derived from continental margins and islands of the Iapetus Ocean. These are, from east to west, the Avalon Zone, the Gander Zone, the Dunnage Zone (including the Exploits Subzone and Notre Dame Subzone) and the Humber Zone (Williams *et al.*, 1987, Williams *et al.*, 1996) (Fig. 1, inset). The exposures of these zones in Newfoundland provide one of the best cross-section through the Appalachian Orogen in the world (Quinn, in press). The Humber Zone includes all of the west coast of Newfoundland, including the Great Northern Peninsula (Fig. 1).

Much of the Cambro-Ordovician sequence of the Humber Zone, including the Goose Tickle and Table Head sequences, is interpreted by Williams and Stevens (1974) as having been formed along an Early Palaeozoic continental margin. It can be divided into several discrete geological packages, each with its own conditions of formation and tectonic history (James *et al.*, 1988). At the base are found late Precambrian granitic gneisses and minor anorthosites, which make up the core of the Great Northern Peninsula. These are unconformably overlain by an autochthonous sedimentary and volcanic sequence, representing late Precambrian to Middle Ordovician deposition. Most of this ~1-2 km thick sequence represents deposition on a shallow-water, near-shore shelf during the rifting and passive drifting of the continental margin. The Table Head and Goose Tickle groups represent the top of this autochthonous deposition sequence.

The Humber Arm and Hare Bay Allochthons, including the Cow Head Group (see James and Stevens, 1986; Williams and Stevens, 1988) structurally overlie these autochthonous sequences. They represent sedimentary rocks from the continental slope, the deep-water equivalent of the shallow water autochthonous sequence discussed above. These deep-water sedimentary rocks thrust above the autochthonous sequences during the Middle Ordovician Taconic orogeny.

Both the Humber Arm and Hare Bay strata are overlain unconformably by parauthochthonous sediments of Middle-Upper Ordovician and Upper Silurian age, namely the Long Point Group and the Clam Bank Formation, and the Carboniferous Anguille, Codroy and Barachois groups.

The rocks of the Humber Zone represent the development of a passive continental margin and its subsequent destruction during the Taconic, Acadian and Alleghian orogenies (James *et al.*, 1988; Stenzel *et al.*, 1990; Stenzel (Ph.D thesis, 1991); Williams, 1995)).

I.3: Geology of the Table Head and Goose Tickle Groups

Middle Ordovician deposits are represented in western Newfoundland by the Table Head Group and the overlying Goose Tickle Group (Fig. 2). The base of the Table Head Group is represented by the Table Point Formation, which is overlain by the Table Cove Formation. The Goose Tickle Group has the Black Cove Formation as its basal unit, succeeded by the

American Tickle or Mainland formations. The locally developed Cape Cormorant Formation is a partial lateral equivalent of the Table Cove, Black Cove and American Tickle formations.

I.3.1: Table Head Group

I.3.1.A: Table Point Formation

The Table Point Formation forms the base of the Table Head Group. It is made up of a series of massive thick-bedded grey limestones which exhibit a pseudoconglomeratic to stylo-nodular fabric and show extensive bioturbation (Klappa *et. al*, 1980; Stenzel *et. al*, 1990). The formation is dominated by limestones with minor dolostones and was mostly deposited in shallow, subtidal environs (Stenzel *et. al*, 1990).

The Table Point Formation is interpreted as having been deposited in a shallow water environment, after the uplift, fragmentation and erosion of the platform. The unit's general regularity indicates a regionally uniform environment, but variations in bed thickness indicate that the types and amounts of sediments fed to the region at the time were variable. The presence of synsedimentary slumping and sliding indicates episodic seismicity in the region during deposition (Stenzel *et. al*, 1990; Stenzel, Ph.D. thesis, 1991).

Thickness of this unit varies from 60 to 250 m, the

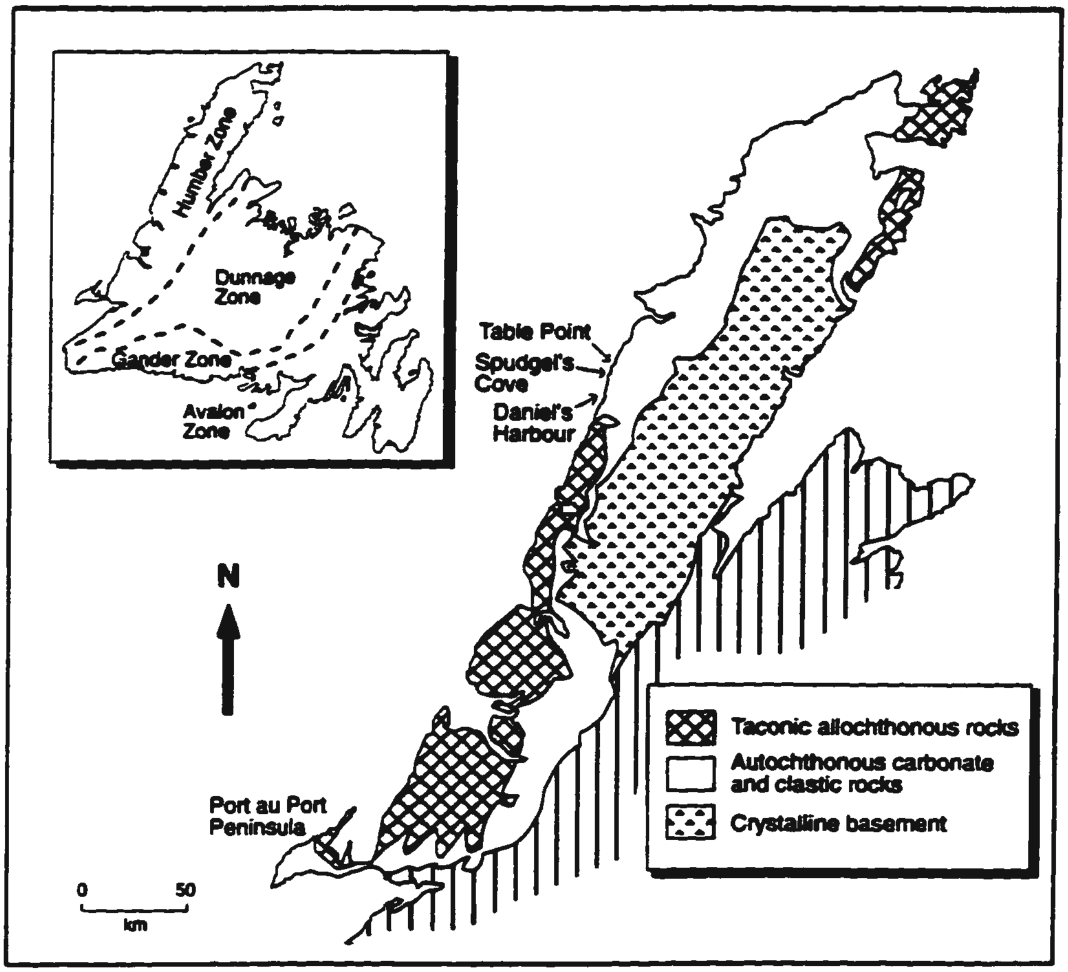

Figure 1: Simplified geological map of western Newfoundland with major tectonostratigraphic divisions (after Stenzel et al., 1990, fig. 1).

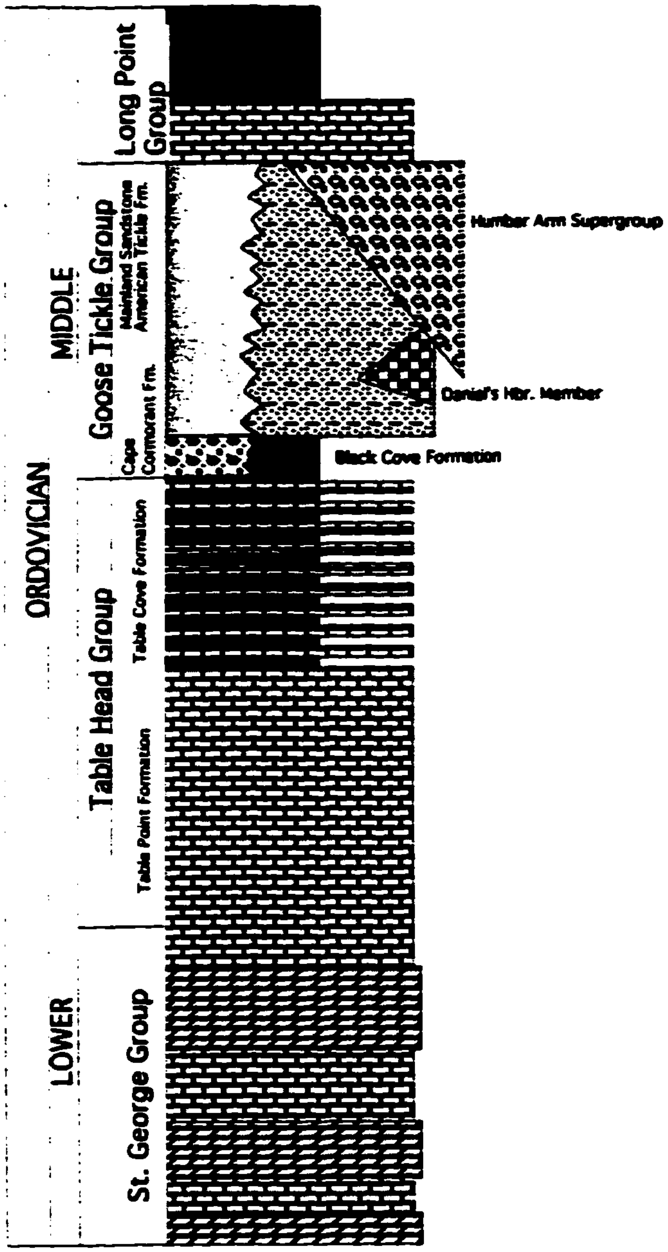

Figure 2: Lithological log of Lower to Upper Ordovician rocks in western Newfoundland (from Stenzel et al., 1990).

thickest being present at the type locality of Table Head (Klappa *et. al*, 1980; Stenzel *et. al*, 1990; Stenzel, Ph.D. thesis, 1991). Overlying the Table Point Formation are the Cape Cormorant, Table Cove and Black Cove formations, which appear to be at least partly coeval.

I.3.1.B: Table Cove Formation

The lower part of the Table Cove Formation, referred to as the "burrowed limestone and parted limestone facies" (Stenzel, Ph.D. thesis, 1991), is composed of thin-bedded, bioturbated packstone and wackestone with only thin shale beds present. The two facies are distinguished in that the parted limestone facies possesses more continuous but less fossiliferous limestone beds and thicker argillaceous partings. Also, the parted limestone facies possesses a distinctive trace fossil assemblage. Syn-sedimentary deformation is common through the Table Cove Formation, with low-angle truncation surfaces, slump folding, imbricately stacked beds and/or "quasi"-conglomeratic fabrics (Stenzel, Ph.D. thesis, 1991).

The upper part of the Table Cove Formation is composed of thinly interbedded calcareous black shales and grey limestones with breccia lenses, giving a ribbon limestone facies. Bioturbation is uncommon or absent in the limestone beds of this facies, and the shale beds are thicker here than in the remainder of the formation. The Table Cove Formation is interpreted as having been deposited on a low-angle carbonate slope with increasing water depth. The lower (burrowed and heavily fossiliferous) beds were deposited *in situ* on the upper slope, whereas the upper beds (ribbon limestones) show platform-derived carbonate muds and grains re-deposited in deeper waters as a result of turbidity and density currents. Graptolites are found in the upper Table Cove Formation beds.

The Table Cove Formation ranges in thickness over 9-126 m, the thickest exposure being at the Bellburns - Spudgel's Cove section (Klappa *et. al*, 1980; Stenzel *et. al*, 1990; Stenzel, Ph.D. thesis, 1991).

I.3.2: Goose Tickle Group

I.3.2.A: Black Cove Formation

The Black Cove Formation was removed from the Table Head Group and assigned to the base of the Goose Tickle Group by Stenzel et al (1990) and Quinn (in press). It is composed of laminated black, non-calcareous shales with minor green silt laminae. The green silty shales become more common towards the top of the sequence; the boundary between the Black Cove Formation and the overlying American Tickle Formation is taken at the gradational point where the green siltstone laminae make up more than 30% of the shale.

The Black Cove Formation is interpreted as having been deposited in a deep water, anoxic basin, with slow continuous deposition of clays from the quiet water column overlying the ocean floor. Green silty shales were deposited by turbidity currents, which carried and deposited coarse-grain sediments from more shoreward regions of the basin.

The Black Cove Formation ranges in thickness from 1.5-22 m, with its maximum depth of 22 m seen at the reference section for the formation (located at Spudgel's Cove) (Stenzel *et. al*, 1990; Stenzel, Ph.D. thesis, 1991).

I.3.2.B: Cape Cormorant Formation

The Cape Cormorant Formation is composed of interbedded slightly calcareous to non-calcareous thin shales, calcarenite and carbonate-lithoclast breccia-conglomerates. Small (< 30 cm) beds of packstone and wackestone are also present in the lower 30 m of the sequence (Stenzel *et al.*, 1990). The conglomerates are polymictic, poorly sorted and clast supported. They are made up of mostly limestone and dolostone fragments, apparently derived from the carbonates making up the underlying Middle Cambrian to Middle Ordovician platform. The lithoclast calcarenites, made up from the same material as the conglomerates, are normally graded and show Bouma sequences. Both the conglomerates and calcarenites become thinner and finer grained towards the top of the sequence (Klappa *et. al*, 1980; Stenzel *et. al*, 1990; Stenzel, Ph.D. thesis, 1991).

The Cape Cormorant Formation is interpreted as having been deposited in a deep-water environment which experienced gradual deposition of fine-grained clays but received frequent turbidity and debris flows. With the exception of the large-scale conglomerates and calcarenites, however, this sequence is lithologically very similar to the nearby Black Cove, Table Cove and American Tickle formations. It is thus considered a lateral facies equivalent to these units, either completely or in part.

The Cape Cormorant Formation is 200 m thick at its type section of Caribou Brook and the adjacent Mainland Beach. (Klappa *et. al*, 1980; Stenzel *et. al.*, 1990).

I.3.2.C: American Tickle Formation

Overlying the Black Cove or Cape Cormorant formations are the Mainland Sandstone and equivalent American Tickle formations. The two units are differentiated primarily on grain size, the American Tickle Formation being the fine grain, darker equivalent. The American Tickle Formation contains several tongues of conglomerate, assigned by Stenzel *et. al.* (1990) and Quinn (1992) to the Daniel's Harbour Member. This unit is composed of at least three massive, as well as several minor, limestone conglomerates and calcarenites, which are interbedded with the fine-grained siliciclastic lithologies of the American Tickle Formation. The conglomerates making up this unit possess limestones reworked from several earlier units, in particular the Table Point and Table Cove formations.

The conglomerates and calcarenites of the Daniel's Harbour Member differ from those of the Cape Cormorant Formation in that they possess no interbedded shales, the conglomerates are very thick and massive, and they are composed almost exclusively of grey-brown limestone clasts. The calcarenites are different in that they are made up of a mixture of carbonate lithoclast and siliciclastic grains, including metamorphic, igneous and sedimentary lithic clasts (Stenzel, PhD thesis, 1991).

The Daniel's Harbour Member is interpreted as being deposited by debris flows and turbidity currents into a deep-water siliciclastic basin. The clasts making up these flows were derived from local uplifts which exposed material from Middle Ordovician platforms and slope carbonates (Table Point and Table Cove formations, respectively).

The Daniel's Harbour Member is at least 28 m thick at the type locality of Daniel's Harbour (Stenzel *et. al*, 1990; Quinn, Ph.D. thesis, 1992).

I.4: Collection Localities

All map numbers and grid references are from Stenzel, PhD thesis (1991).

I.4.1: West Bay Centre Quarry

The West Bay Centre Quarry (Fig. 3; map # NTS 12B/10, grid reference UD 583837) contains exposures representing the

Table Cove, Black Cove and American Tickle formations. It is located immediately off the main highway, approximately 1 km to the west of Piccadilly Provincial Park. The main body of the quarry is an exposure, in total over 16 m thick, of the Table Cove Formation, with three vertical faces at the far end and an isolated outcrop at the quarry entrance. This quarry is made up mostly of calcareous grey shales and limestone beds, sometimes nodular.

At the top of this quarry, a short track leads approximately 50 m to the right to an exposure of the Black Cove Formation. At this locality, the non-calcareous black shales of the Black Cove Formation are visible as low-lying exposures and as a vertical exposure at the far end of the clearing. Immediately overlying this vertical sequence is an exposure of the American Tickle Formation, represented mainly by dark-green, fine-grained sandstone. One thin limestone conglomerate, representing a minor development of the Daniel's Harbour Member, is present.

I.4.2: Piccadilly Beach

The Table Cove Formation (map # NTS 12B/10, grid reference UD 583837) crops out at the Piccadilly Beach exposure some 200 m to the north of West Bay Centre Quarry, at the outflow of a small river (Fig. 3), again immediately off the highway. Approximately 4 m of the Table Cove Formation are visible here, probably representing the upper interval of the Table Cove Formation seen at West Bay Centre Quarry. It is made up of interbedded calcareous grey shales and sometimes nodular limestones. The sequence is truncated by structurally overlying deformed sediments of the Humber Arm Allochthon.

1.4.3: Black Cove Oil Tanks

The Black Cove Formation and basal American Tickle Formation are exposed at the Black Cove Oil Tanks (now dismantled; Fig. 3; map # NTS 12B/10, grid reference 745816). This locality is situated on the mainland of Newfoundland, just before the Port au Port Peninsula, approximately 4 km north along Highway 462 to Point au Mal and Fox River. It is easily seen from Highway 462, as it is some distance below and is overlooked by the highway.

This sequence of non-calcareous black shales is difficult to map, due to much of the exposure having been cleared away and much of the remaining sequence being covered with scree.

It appears to be the uppermost portion of the Black Cove Formation, however, based on the presence of overlying sandstone beds near the entrance.

I.4.4: Mainland Beach

The Cape Cormorant and Mainland Sandstone formations are well exposed at Mainland Beach (Fig. 3; map # NTS 12B/11, grid reference 377797) and particularly at Caribou Brook, which is approximately 1 km south of the community of Mainland and is close to the western tip of the Port au Port Peninsula. Here the bedding is almost vertical, permitting access to almost 200 m of the Cape Cormorant Formation. It is made up of thin to thick bedded conglomerates interbedded with green shales and calcarenites, as well as packstones and wackestones basally. It is overlain by the sandstone beds of the Mainland Sandstone Formation. (Since the work for this thesis has been completed, a new highway development has exposed a similar sequence of the Cape Cormorant Formation, approximately 1 km to the northeast)

I.4.5: Daniel's Harbour

The type locality of the Daniel's Harbour Member of the American Tickle Formation is at Daniel's Harbour (Fig. 4; map # NTS 12I/4, grid reference 577653). It is located alongside the harbour at the town of Daniel's Harbour, approximately 15 km south of Table Point on Highway 430. Two thick beds of massive, limestone-lithoclast conglomerate make up this exposure, totalling over 50 m in thickness. Large clasts of material from the Table Cove and Table Point formations, up to 20 m long by 10 m wide, are found in this unit, in addition to many smaller clasts.

I.4.6: Spudgel's Cove

Spudgel's Cove (Fig. 4; map # NTS 12I/6 and 12I/5, grid reference VF 600706) is located along the coast of western Newfoundland, approximately 6 km past Daniel's Harbour and 1km to the north of the abandoned zinc mine turnoff, on the west side of Highway 430. Once on the beach, the outcrop can be found by progressing approximately 2 km northwards along the beach road, which then ends in a small clearing. Here the Table Cove and Black Cove formations crop out. The Table Cove Formation has been discussed by Stenzel *et al.* (1990) and Quinn (PhD thesis, 1992); it is only accessible at unusually low tides. It was not, therefore, collected for this thesis. The Black Cove Formation comprises a flat, wave cut platform, approximately 15 m by 20 m, with a bedding dip approximately 30°. It is exposed for short periods during low tides, and is overlain by several sandstone beds, each less than 1 m thick. The sequence has been assigned to the Black Cove Formation, but this placement is here considered questionable. Shales from this locality are less friable than those from other Black Cove Formation localities (e.g., Black Cove Oil Tanks). Also, there appears to be more pyritized, non-compressed graptolite specimens from the Spudgel's Cove exposure than at other Black Cove Formation exposures, suggesting earlier pyritization of this material. Another important factor is that Louise Quinn (pers. comm. to S.H. Williams) has detected a sandstone in the middle of the Spudgel's Cove exposure which has not been recorded in other

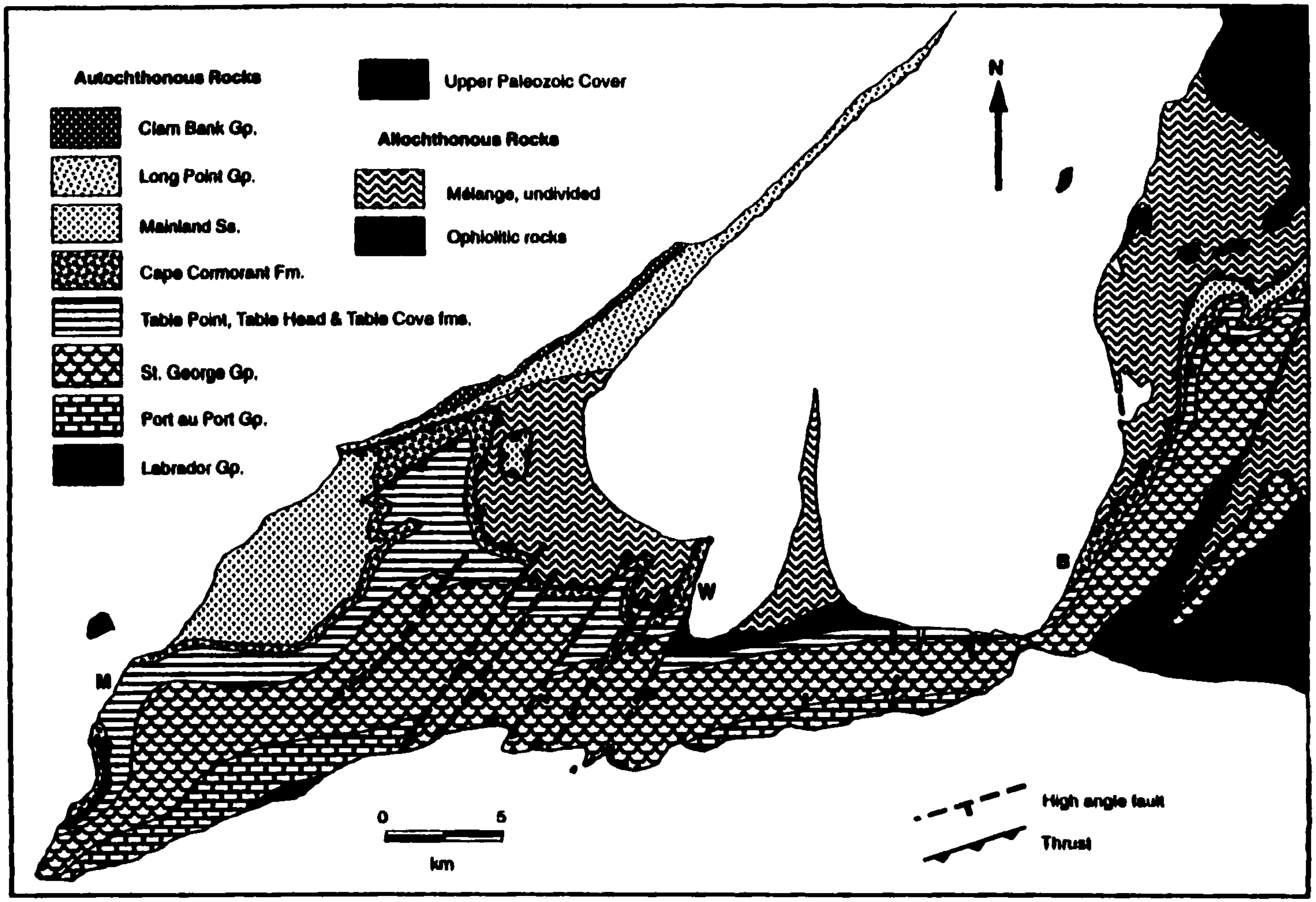

Figure 3: Locality map showing positions of the Black Cove Oil Tanks (B), Mainland Beach (M), West Bay Centre Quarry and Piccadilly Beach (W) and regional geology of the Port au Port Peninsula, western Newfoundland (see Chapter 1.4 for map numbers and grid references giving exact location co-ordinates)

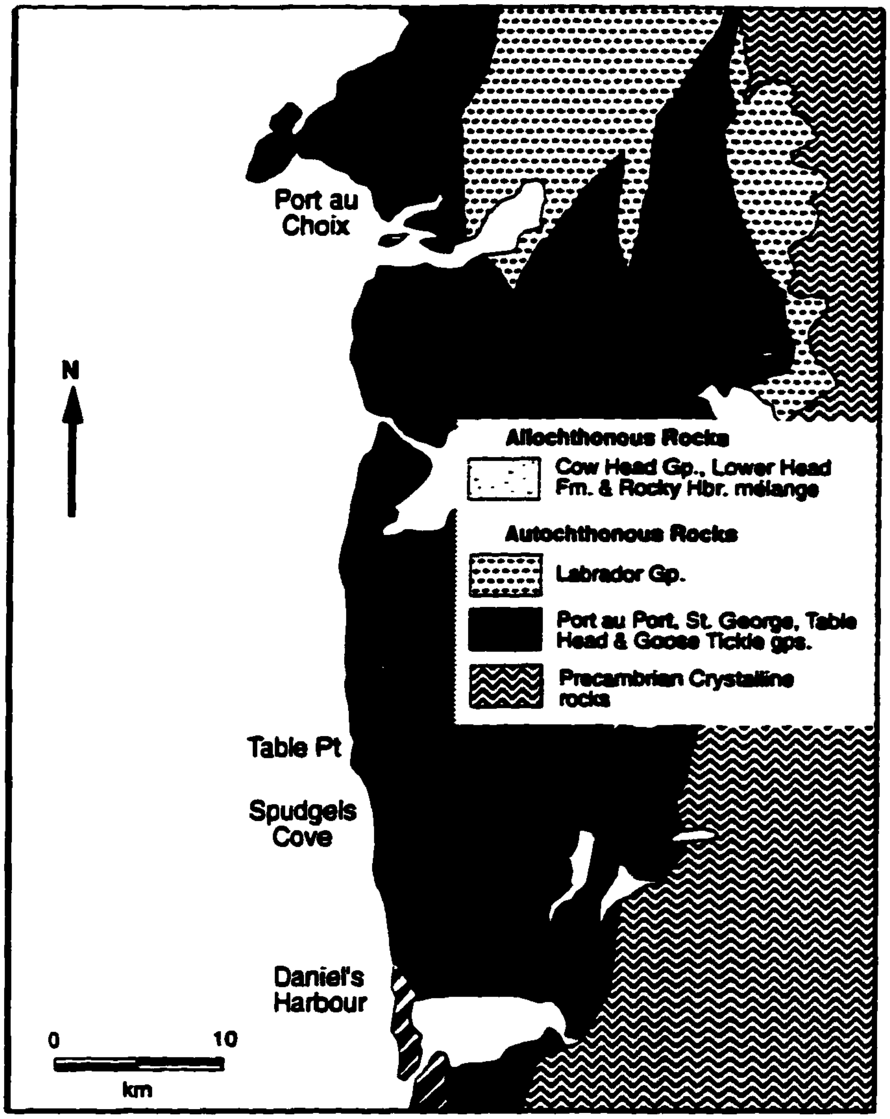

Figure 4: Locality map showing positions of Daniel's Harbour, Port au Choix, Spudgel's Cove and Table Point and regional geology of a portion of the Great Northern Peninsula, western Newfoundland (see Chapter 1.4 for map numbers and grid references giving exact location co-ordinates)

Black Cove Formation exposures. The graptolite fauna also suggests differences between the Spudgel's Cove exposure and the typical Black Cove Formation. The diplograptid fauna from Spudgel's Cove includes some smaller forms, with simpler rhabdosomal features, than other Black Cove Formation exposures, as well as some large specimens of *Hustedograptus*? which are rare or absent from other Black Cove exposures.

All of these suggest that the exposure at Spudgel's Cove may not actually represent the Black Cove Formation. There are two possible explanations for this. First, the Spudgel's Cove exposure may represent a deposit much older in age than the Black Cove Formation, as suggested by the primitive graptolite fauna found there. However, its close proximity to Table Point makes this possibility unlikely.

Secondly, this exposure may actually represent a development of black shales within a higher part of the American Tickle Formation rather than the Black Cove Formation itself. If such is the case, the contact established by Stenzel *et al.* (1990) between the Table Cove and Black Cove formations at this locality probably represents either a disconformity or a fault. The problem may well be compounded due to the difficulty in examining this contact, which is only exposed at a few times through the year during neap tides (Quinn, pers. comm. to S. H. Williams).

I.4.7: Table Point

The Table Point, Table Cove, Black Cove and American Tickle formations are all present at the Table Point Provincial Reserve, located approximately 2 km north of Bellburns on Highway 430 (Fig. 4; map # NTS 12I/5 and 12I/6, grid reference VF 616787/VF 620766). The Table Point Formation here is made up of thick-bedded, conglomeratic limestones. These are overlain by the interbedded limestones and black shales of the Table Cove Formation. Basally they are thin and uncommon, but higher in the sequence these shales become more common and thicker. This is overlain by the Black Cove Formation, which is highly fractured and poorly exposed in this locality due to faulting. The upper Table Cove and Black Cove formations are difficult to collect here, as they are part of a wave-cut platform. Thus, they can be collected from only during low tide. The American Tickle Formation is exposed at the southern end of the section.

CHAPTER II

STUDY METHODS

II.1: Collection Techniques

All specimens discussed in this thesis were collected by the author, unless otherwise indicated.

At the Table Cove Formation exposure at West Bay Centre Quarry, samples approximately 10 cm thick were removed from the quarry wall at regular intervals of approximately 1.0 m and examined by using a hand lens. Any slabs containing well preserved graptolites or graptolitic fragments were transported to the lab. 4-6 sample bags (~35 cm X ~15 cm) were collected from each interval.

Most of the material taken from the Black Cove Formation at West Bay Centre Quarry was collected by digging approximately 10 cm below the ground level, approximately 5 m past the clearing entrance, in order to avoid heavily weathered material. 8 sample bags of material were collected. Three sample bags were also collected from a small vertical exposure at the back of this locality. This exposure is directly opposite to the clearing entrance and ~3 m to the left of the end of the overlying American Tickle Formation exposure. The shale from this locality proved extremely friable, and many potentially good specimens were lost during collection and transport to the lab.

Ten bags of material from the Black Cove Formation exposure at the Black Cove Oil Tanks were collected from a variety of irregular, stratigraphic levels: systematic samples were, however, impossible to collect due to poor exposure.

Specimens from the Black Cove Formation at Spudgel's Cove were collected from the intertidal platform (during periods of low tide). The low angle of the bedding planes at this exposure meant that a sampling interval of >2 m was necessary, to give a true sampling interval of approximately 0.2 m.

Material from the Cape Cormorant Formation exposure at the southern end of Mainland Beach up to Caribou Brook was collected at widely-spaced intervals, in order to permit collection of representative material from approximately the top (20 m - 2 bags), middle (145 m - 3 bags) and bottom (195 m - 1 bag) of the formation.

The Table Point Formation at Table Point was collected systematically (2-3 bags per site) but at irregular intervals, as not all of the shales examined were graptolitic. This site was also collected during low tide, due to its position on an intertidal platform. The Black Cove Formation was not collected here, due to the very poor, tectonically fractured nature of the shales at this exposure.

II.2: Acid Extraction

Uncompressed material was extracted from nodular limestones collected from the Daniel's Harbour Member conglomerates at Daniel's Harbour. This extraction was done by breaking the nodules into fragments of approximately 5 cm^3 and soaking them in 10% acetic acid. Specimens which floated off were gently removed from the acid, washed with water, and stored in 96% ethanol. Extracted specimens which sank were seived from the remaining matrix, washed, and added to 96% ethanol. Specimens used for SEM examination were mounted on aluminum stubs using two-way adhesive tape and gold coated.

Flattened material was extracted from shales from the Black Cove Oil Tanks by soaking overnight in 50% hydroflouric acid. Isolated specimens were removed by seiving and washing with water, and were stored in 96% ethanol. They were later bleached using Schultz solution and mounted between glass slides using standard palynological procedures.

II.3: Graptolite Illustration Techniques

All collected material was examined using a binocular microscope with an attached *camera lucida* and multiple external light sources. This *camera lucida* was employed to prepare drawings of all specimens collected for this study. Drawings were prepared using magnifications of x 8.6, 17 and 26, depending on the actual size of the specimen being observed.

For the purposes of comparison of diplograptid specimens, drawings were photocopied and standardized to magnifications of 10 x. These were then copied onto acetate sheets, which allowed for direct observation and comparison of multiple specimens simultaneously.

Photographs were also taken of representative material for illustrative purposes. Specimens were immersed in 96% ethanol. An external light source was used, at a sufficient distance to prevent glare on the surface of the alcohol. These photographs were taken using a Wild Photomakroskop M400 with attached 35 mm h/m back camera and T-Max 100 film. Prints were subsequently produced at standard magnification.

Scanning electron microscope (SEM) photos were made using a Hitachi SEM. These specimens were mounted and gold coated using standard SEM techniques. The stereopair in Plate 7. Fig. 2 was made using a 7° offset between the two photos.

The 'clear' graptolite photos (Plate 7, fig. 3; Plate 8) were taken by Dr. Henry Williams with the assistance of Dr. Mike Melchin using a standard petrological microscope with infrared TV/video hook-up. Specimens were put into a 'laser liquid' with a high refractive index (similar to the refractive index of the graptolites), providing maximum infra-red (IR) transmission through the graptolites. An infra-red sensitive videocamera was used to capture these transmitted graptolite images, which were then printed with a 'thermal printer'. This method allows for observation of fine detail not usually visible in most larger specimens, such as growth rings (Plate 7, Fig. 3). This method may allow for detailed graptolite developmental studies in the future, as it becomes more refined.

II.4: Graptolite Reflectance Studies In Western Newfoundland

It was originally planned to investigate variation in thermal maturity of the Middle Ordovician of the Port au Port and Northern Peninsula and the effects of thermal maturity on graptolitic preservation using the technique of graptolite reflectance (eg, Goodarzi *et al.*, 1988; Wang *et al.*, 1993). Hydrocarbon-related maturity studies have, however, proceeded at a rapid pace over the past few years (Fowler *et al.*, 1995; Stockmal *et al.*, 1995; Williams *et al.*, 1996), making additional study unnecessary.

CHAPTER III

Graptolite Biostratigraphy

Species ranges for all localities (Fig. 6) were determined in the laboratory after microscopic examination of graptolites collected in the field.

Several days (or, in some cases, weeks) were spent collecting at each locality, with several hours spent at each level. Due to this intensive sampling, it is hoped that the fossil ranges presented in this thesis are representative of the actual species ranges and are not artifacts of incomplete sampling.

The Table Cove Formation at West Bay Centre Quarry was systematically collected in its entirity, as was the Black Cove Formation exposure at Spudgel's Cove. The Cape Cormorant Formation at Mainland Beach was collected from certain beds only to determine the faunal elements present rather than their precise ranges, as were the remaining sections discussed in this thesis.

III.1: Table Cove Formation

At the West Bay Centre Quarry (Fig. 5), over 16 m of the Table Cove Formation is continuously exposed. The lowest visible portion of this exposure is used as the base of this section. *Janograptus terranovensis* (Fig. 11 A-E) occurs rarely in the lowest shales, and extends half way through the sequence. Other species found in the lower portion of the section extend further upwards through the sequence. *Acrograptus* cf. *A. affinis* (Fig. 16) and *Pseudotrigonograptus ensiformis* (Fig. 11 F-J) are also relatively uncommon and extend to 15.0 m above the base of the section. Both *Bergstroemograptus crawfordi* (Fig. 28) and *Archiclimacograptus* sp. A (Figs. 17-20) are common, *Archiclimacograptus* sp. A being the dominant faunal element here, with both occurring throughout the sequence. *Glossograptus* sp. nov. (Fig. 26) also occurs throughout the sequence; it is uncommon below 10.0 m but increases in frequency above this level. Other species which first appear within the basal 5 m of the unit are *Isograptus forcipiformis* (Fig. 13), found commonly through to the top of the sequence, *Paraglossograptus proteus* (Fig. 27), present only occasionally up to 13.7 m, and *Glossograptus holmi* (Fig. 25), which occurs commonly and extends to 15.0 m at this unit. *Cryptograptus schaeferi (Fig. 24)* first appears at 6.0 m and then occurs commonly and continuously to the top of the sequence. ? *Xiphograptus* sp. (Fig. 10 I) is located only at 8.0 m, whereas *Etagraptus harti* (Fig. 14) is found from immediately below the 10 m point through to approximately 15 m in the section, and is a minor component of the assemblage. *Nicholsonograptus fasiculatus* (Fig. 15) has been recorded from the West Bay Centre Quarry by Maletz (pers. comm.), but the location in the section is not known.

The Table Cove Formation was also collected at Table

Point (Fig. 7), but due to the relative rarity of graptolites and clear evidence for syn- and post-sedimentary deformation this region, collecting was not done on a bed-by-bed basis. The graptolites found at this locality include *I. forcipiformis* (Fig. 13), *C. schaeferi* (Fig. 24), *N. fasciculatus* (Fig. 15), *G. holmi* (Fig. 25) and *Archiclimacograptus* sp. A. (Figs. 17-20) *G. holmi* is much more common here than at the West Bay Centre Quarry.

III.2: Black Cove Formation

Due to the poor exposure and deformation of most of the Black Cove Formation exposures, only the section at Spudgel's Cove was collected systematically (Fig. 8). At the base of this exposure, defined as the lowest shales not covered by beach rocks, are found occasional specimens of *A.* cf. *A. affinis* (Fig. 16) and *Pseudophyllograptus* ? cf. *P. angustifolius* (Fig. 12). Neither of these extends beyond the base of the section. Other species found near the base but extending further through the section include the common *G. holmi* (Fig. 25), *Pterograptus* sp. A (Fig. 10 A-H) and *C. schaeferi* (Fig. 24), each of which extend to 1.5 m. *Archiclimacograptus* sp. A (Figs. 17-20) is very common and extends from the base to 2.5 m, whereas the less common *Hustedograptus* sp. A (Figs. 22-23) is found from the base to 4 m. *Pseudoclimacograptus* (*Archiclimacograptus*) *oliveri* (Fig. 21) ranges from 1.25 - 2.5 m, whereas *P. ensiformis*

(Fig. 11 F-J) is restricted to the 2.5 m level. Both of these are uncommon. Species that occur at the other Black Cove Formation exposures include *I. forcipiformis* (Fig. 13), *P. proteus* (Fig. 27), *P. cf. P. angustifolius* (Fig. 12) and *A.* cf. *A. affinis* (Fig. 16). *N. fasiculatus* (Fig. 15) is found only occasionally, whereas *C. schaeferi* (Fig. 24), *G. holmi* (Fig. 25) and *Archiclimacograptus* sp. A. (Figs. 17-20) are common.

III.3: Cape Cormorant Formation

The Cape Cormorant Formation was collected only to determine the faunal elements present, and thus was not collected stratigraphically beyond collecting from the 'top', 'middle' and 'bottom' of the sequence (see Stenzel, PhD thesis 1991, p. 40 for stratigraphic sections of this interval). The graptolite fauna found here includes *A. cf. A. affinis* (Fig. 16) and *G. holmi* (Fig. 25) in the 'lower' portions, *P. angustifolius* in the 'middle' of the section, *Pterograptus elegans* (Fig. 9) from both the 'middle' and the 'top' (190 m) of the sequence, and *Archiclimacograptus* sp. A (Figs. 17-20) through the entire sequence.

The graptolite biostratigraphy discussed here shows that although we do see the occurrence and disappearance of several species through the intervals studied here, there is as yet no clear means by which to divide these sequences into specific biostratigraphic zones as proposed by others (ie.,

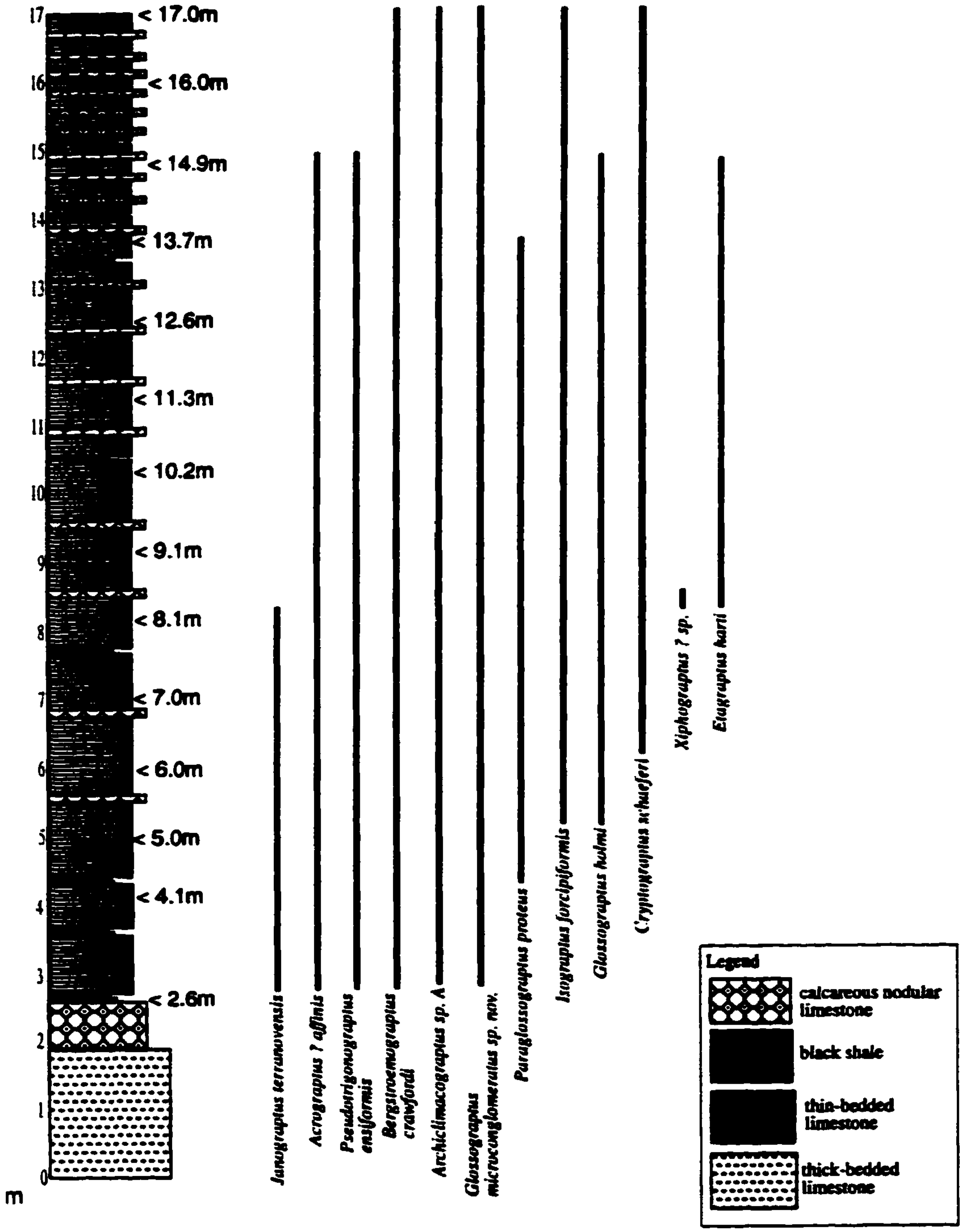

Figure 5: Lithologic log of the Table Cove Formation at West Bay Centre Quarry, Port au Port Peninsula, with sample intervals and graptolite ranges plotted in order of appearance ('<' represents sample intervals)

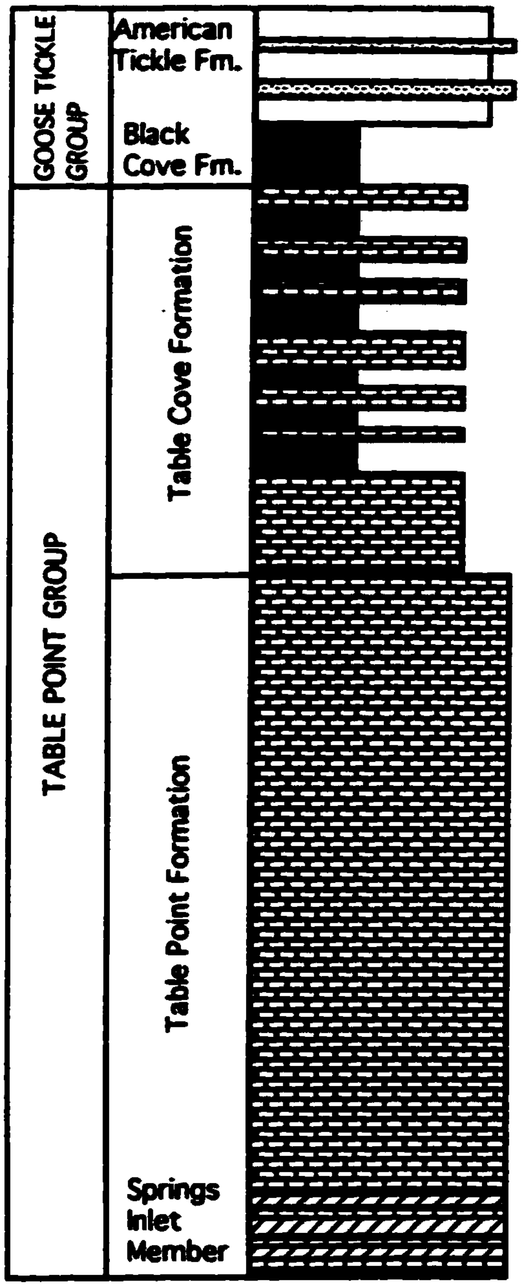

Figure 6: Schematic log of the Table Cove Formation at Table Point, Great Northern Peninsula, western Newfoundland (modified from Stenzel et al., 1990).

Maltez and Mitchell 1995). However, this is partly due to the inability to properly identify certain species (ie., *Archiclimacograptus* sp. A) which may prove valuable to such a study. It is also partly due to the relative rarity of some of the species upon which any proposed biostratigraphic break-down of this region may depend (ie. *Nicholsonograptus fasiculatus*). Perhaps the only way to solve this problem is to continue collecting from these localities, until the true biostratigraphy of all the species present can determined.

111.4: Potential Biases

Morris and Kay (1966), in their examination of the Ordovician graptolite fauna of western Newfoundland, examined a total of 1282 specimens comprising 18 species. Of these, the 9 least common species made up less than 2.5% of the total fauna. Thus, it is clear that certain taxa are rare in this region. When a similar breakdown is carried out for the material used in this thesis, it is found that of the 20 species present, the 9 least common species make up 4.3% of the total. However, this is based only on the specimens drawn, not on the total specimens collected. In the case of rare specimens (i.e., 5 specimens of *Janograptus terranovensis*, 9 specimens of *Etagrapts harti*), all were drawn. However, only exceptional specimens were drawn in the case of more common forms (i.e., 366 secimens of *Archiclimacograptus* sp A. and 256 specimens of *Crytpograptus*

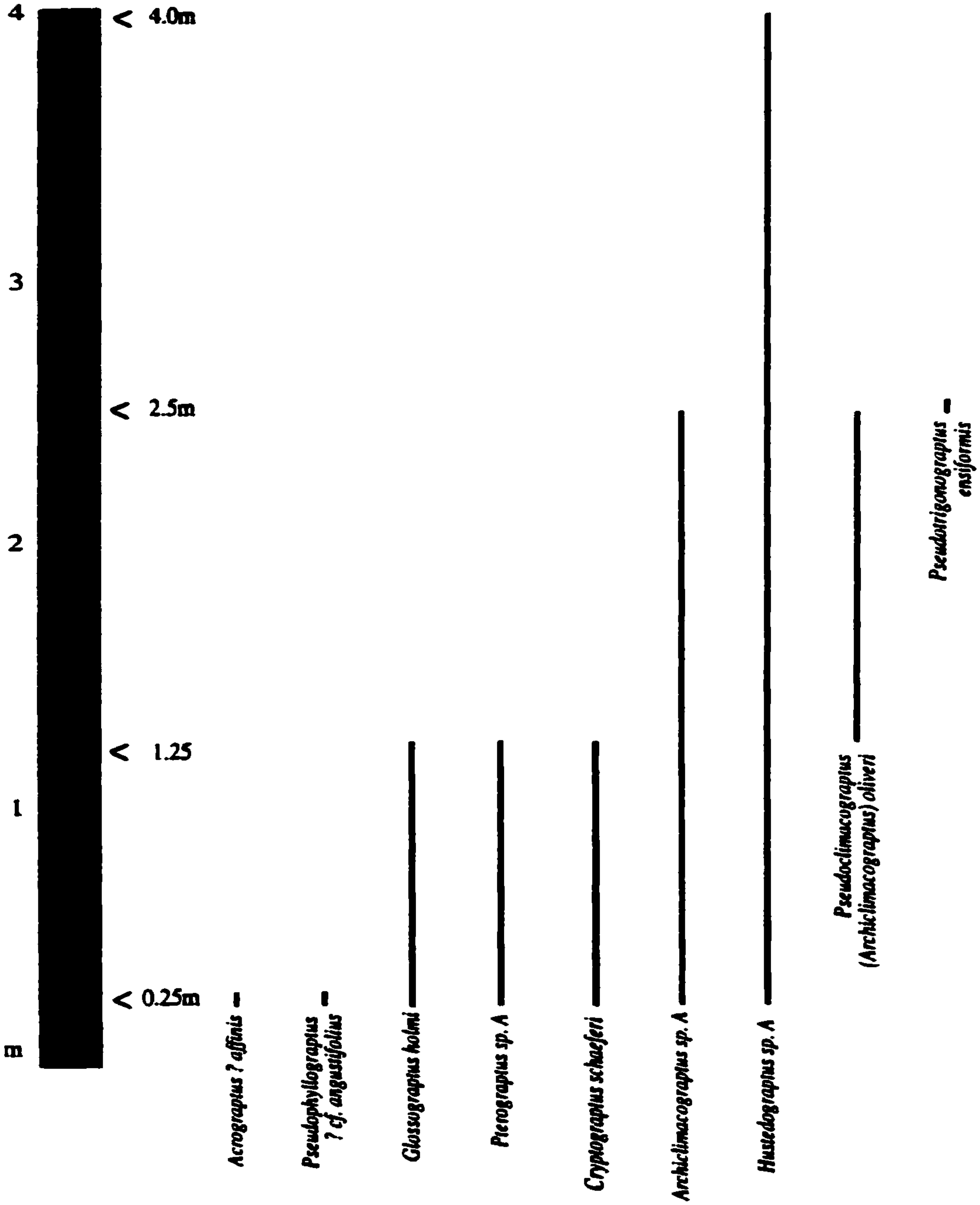

Figure 7: Range chart of graptolites in the Black Cove Formation, Spudgel's Cove, Great Northern Peninsula, western Newfoundland ('<' represents sampling intervals)

schaeferi were drawn, out of over 1000 specimens of each). Thus, the totals given here are certainly biased towards the less common forms, suggesting that their frequency is even less that that suggested here.

Morris and Kay (1966) credit biases in the collection being due to the tendency to keep all specimens of rare forms but not in the case of common forms. As well, they state that chance and collection techniques, as well as other factors, will have some outcome on the total sample collected. Each of these factors are, unfortuntely, possible influences on the material used in this thesis. It is hoped, however, that these influences are minor, and that the biostratigraphic ranges provided here are accurate.

111.5: Graptolite Zonation

Middle Ordovician rocks occur in many parts of the world, and several correlation charts have been published (e.g., Cooper & Fortey, 1982). Cooper & Lindholm (1990), however, provided what is perhaps the most detailed summary of the early Middle Ordovician graptolite sequences seen world-wide, with a precise correlation chart. It is of importance to note that while the early Ordovician of Newfoundland is discussed in the report by Cooper & Lindholm (1990), the early Middle Ordovician (Llanvirn) from western Newfoundland is not included. This reflects the lack of knowledge of the Newfoundland Llanvirn exposures at the time, and demonstrates the importance of the work done in this thesis in terms of the correlation of Newfoundland strata with the rest of the world.

The graptolitic zonation of several other Ordovician strata in Newfouldland has been studied previously, such as the Early Ordovician (Arenig) at Cow Head (Williams and Stevens, 1988) and the Middle Ordovician (late Llandeilo - early Caradoc) in Lawrence Harbour. In terms of Llanvirn strata in western Newfoundland, Williams, Boyce & James (1987) have suggested that the Table Point Formation at Table Point was deposited after the Arenig, based on the presence of "indeterminate diplograptids" (p. 467). They also note that the Table Point Formation compares well with the Australasian graptolite sequence (Vandenberg, 1981; in Williams *et al.*, 1987), suggesting it is probably of Darriwilian 2 or 3 (Llanvirn) age. This agrees with the findings of Finney and Skevington (1979), who suggested that the Port au Port graptolite fauna corresponded to the Australian *Diplograptus decoratus* zone (Darriwilian 3). This would also make the early middle Llanvirn strata of western Newfoundland equivalent to the middle of the *Paraglossograptus tentaculatus* zone of Texas (Berry, 1960).

Maletz and Servais (1993) give descriptions of several early Llanvirn graptolites from the Herscheider Schichten (Rheinisches Schiefergebirge, Germany). Among the fauna they describe from this region is the highly distinctive

Nicholsonograptus fasiculatus, unidentified specimens from the *Archiclimacograptus* (?) *decoratus*, *Pseudoclimacograptus* spp., and specimens identified as *Janograptus* sp. cf. *J. petulis*. They suggest this fauna is similar to faunas from the *D. artus* (formerly *D. bifidus*) Zone of Scandinavia and the *D. murchisoni* zone of Oslo, Norway. This fauna also appears to be similar to that in this thesis, suggesting an early Llanvirn age for the material described here.

Morris and Kay (1966), upon examination of the graptolitic fauna of Black Cove Formation (and probably the Table Cove Formation) (Williams *et al*., 1987), suggested that there appeared to be no biostratigraphically diagnostic faunal changes through these strata. More recently, however, Maletz and Mitchell (1994) have examined the graptolitic faunas of late Lower to Middle Ordovician graptolites, especially diplograptids, from eastern North America (includng Lévis and Les Méchins, Québec, Table Point, Newfoundland, Texas and New York). Based on these studies, they have proposed a graptolite zonation scheme including five faunal zones corresponding to the standard Australian stages (Da 1 to Gi 1).

It is beyond the scope of this thesis to discuss the possible zonation of the regions in Quebec, New York and Texas discussed by Maletz and Mitchell. However, their discussion of Newfoundland strata is important to this thesis. Maletz & Mitchell (1995) and Mitchell & Maletz

(1994) have suggested that the Table Head Group of western Newfoundland be divided into two biozones, the *Nicholsonograptus fasiculatus* and *Pterograptus elegans* zones, based on the first appearance of these two species. This contradicts other works, which suggest that the Cape Cormorant Formation is actually a lateral equivalent facies of the Table Cove, Black Cove and American Tickle Formations (Williams, Boyce and James, 1987; Stenzel, PhD thesis, 1991).

During the present study, *N. fasiculatus* has been identified from the Black Cove Formation and from the Table Cove Formation at Table Point. *P. elegans* has been observed only from the Cape Cormorant Formation, but specimens collected by Dr. R.K. Stevens appear to have originated from the Table Cove Formation at the West Bay Centre Quarry (although this is not absolutely certain). Cooper and Lindholm (1990) show, in their worlwide correlation chart of Ordovician graptolite sequences, the presence of these two species in similarly-aged strata throughout the world (Australasia, China, Sweden, Norway north-west Canada, the UK). Thus, these species certainly have the potential of being important zonation species for this interval of the early Middle Ordovician, if distinct ranges can be demonstrated. The stratigraphic occurrence of these two species as discussed in this thesis is not, however, sufficient evidence to either fully support or refute their proposed biozonation scheme.

CHAPTER IV

COMPARISONS OF THE MIDDLE ORDOVICIAN GRAPTOLITE ASSEMBLAGE FROM WESTERN NEWFOUNDLAND WITH OTHERS IN THE WORLD

IV.1: Latitudinal and Depth Association (Faunal Provinces)

Graptolite distribution was controlled by several environmental factors, such as latitude, water depth and water temperature (Cooper *et al.*, 1991). This has enabled two graptolite faunal provinces to have been established, the Atlantic and Pacific Provinces (Skevington, 1974). The Atlantic Province includes taxa which inhabited a cold water, high latitude environment, whereas Pacific Province graptolites existed in low latitude, warm water settings. These faunal differences and correlation between provinces have been studied by several authors since their recognition (eg., Cooper & Lindholm, 1990; Cooper *et al.*, 1991). Certain faunal elements appear to be restricted to a single province; for example, *Phyllograptus typus*, *Didymograptus* (*Expansograptus*) *latus*, *Pseudotrigonograptus ensiformis* and *Didymograptus* (*Didymograptellus*) *bifidus* are characteristic of the Pacific Province, whereas *Didymograptus* (*Corymbograptus*) *deflexus* and the *Didymograptus artus* group characterize the Atlantic faunal assemblage (Cooper & Lindholm, 1990). The majo~~o~~rity of graptolites, however, were not subject to some latitudinal restrictions and had a pandemic distribution. Diplograptids, *Tetragraptus (T.) serra*, *Pterograptus elegans* and *Nicholsonograptus* are examples of such taxa (Cooper *et al.*, 1991).

Once the endemic taxa have been recognized they may thus be used to determine the paleoenvironments in which these graptolite existed. For example, the graptolitic assemblages found in most of northwest Europe suggests a high latitude setting, whereas Pacific Province graptolites, indicative of low latitude, warmer waters, are found in Australasia and North America (Cooper *et al.*, 1991 Williams *et al.*, 1996).

Western Newfoundland would, therefore, be expected to possess Pacific Province graptolites. This is indeed true for the Arenig Cow Head Group as discussed by Williams and Stevens (1988). However, most references to the Llanvirn graptolite fauna of Newfoundland (eg., Finney and Skevington, 1979; Maletz and Mitchell, 1995) state that the fauna of Newfoundland represents a mixed Atlantic-Pacific Province. It is the opinion of this author that the presence of Pacific faunal elements from the early Middle Ordovician (Llanvirn) in western Newfoundland (eg., *Paraglossograptus* and *P. ensiformis*) and the absence of diagnostic Atlantic Province faunas (e.g., *D. artus* group graptolites) indicates an unambiguous Pacific Province graptolite fauna for this region. The relatively large number of pandemic species present in the Llanvirn (eg., *P. elegans*, *Phyllograptus*, *Xiphograptus*) makes this distinction less pronounced than in the Early Ordovician (Arenig), and suggests that endemism was decreasing into the Middle Ordovician.

IV.2: Australasia

An entire Early and early Middle Ordovician sequence, interpreted as having been deposited in a deep-water, turbidite-dominated setting, is present in Victoria and New Zealand (Cas and Vandenberg, 1988; Cooper, 1989). These two regions are treated as equivalent successions due to the similarity of the graptolitic faunas (Cooper, 1979), which have been well documented (e.g., Cas & Vandenberg, 1988).

The early Middle Ordovician of Australasia is included within the Darriwilian stage. Da 2 and Da 3 contain graptolite faunas similar to that of the Table Cove and Black Cove formations of western Newfoundland. Many of the faunal elements which occur in the Australasian Da2 and Da3 intervals are also found in Newfoundland; some are clearly Pacific Province forms, including *Bergstroemograptus crawfordi*, *Isograptus forcipiformis*, and *Pseudotrigonograptus ensiformis*, while pandemic species such as *Pterograptus elegans*, *Diplograptus decoratus* and possibly "*Climacograptus*" *riddelensis* also occur. The strong similarity of the Australasian and Newfoundland faunas suggests that these two regions are time equivalents that were deposited under similar environmental and latitudinal conditions.

IV.3: Texas, U.S.A.

The Marathon region of Texas has been described by Berry (1960). It is a limestone-shale-chert succession, with the early Middle Ordovician represented by Berry's (1960) *Paraglossograptus* Zone. This zone includes *Glossograptus acanthus*, *Cryptograptus schaeferi*, *P. ensiformis* and *B. crawfordi*, suggesting a Pacific Province assemblage.

IV.4: Northwest Canada

The graptolite fauna of northwest Canada is very similar to that of Australasia (e.g., Lenz and Jackson, 1986). This region, from the Northwest Territories and British Columbia, represents a basin and slope facies of shales, cherts, limestones and debris flows (Cooper & Lindholm, 1990).

The early Middle Ordovician is represented here by the *P. tentaculatus* and *D. decoratus* zones. Among the faunal elements in common between this region and the sequences of western Newfoundland are *C. schaeferi* and *Nicholsonograptus fasiculatus*, and possible "*D.*" *decoratus* and "*C.*" *riddelensis*. Other problematic species are also found in this sequence, such as *Glossograptus acanthus*, which may possibly represent misidentified specimens of *G. holmi*.

IV.5: Kazakhstan

This region and its fauna has been described by Tzaj

(1974). There are several gaps in the sequence, suggesting possible problems with detailed stratigraphy. More important, however, is the possibility of wrongly deduced biostratigraphic ages; such problems are suggested by the identification of "*I. forcipiformis*" from *I. c.* "*gibberulus*"/*D.* (*E.*) *hirundo* Zone (Castlemanian or Yapeenian), late Arenig, whereas this species is elsewhere restricted to Darriwilian (middle Llanvirn) strata. Other species, such as *P. ensiformis* and the problematic *G. acanthus* (as discussed above), appear to indicate a Pacific Province fauna.

IV.6: Yangtze Province, China

The Yangtze Province is interpreted as having been deposited on a shallow warm shelf-platform environment, thus it would not be expected to possess a fauna similar to that of the deep-water Ordovician facies of western Newfoundland. None of the major forms from the Newfoundland sequence is found in the time-equivalent sections from Yangtze, although *P. ensiformis* is found in underlying beds of the "*G.*" *sinodentatus* Zone (late Yapeenian) (Mu *et al*, 1979, in Cooper and Lindholm, 1990).

IV.7: Zhuijiang Province, China

The Zhuijiang Province is interpreted as a deep-water, basinal facies from a mixed faunal province of mid-latitudinal setting. Species such as *N. fasiculatus* and *P. elegans* are found in beds 20-23 (Da 3/4), whereas "*C. tricornis*", (misidentified specimens of *C. schaeferi*) occurs slightly earlier (beds 18, Da 2) (Xiao, Xue & Huang, 1975, in Cooper and Lindholm, 1990).

IV.8: Southwest Sweden (Scania, Västergötland)

The sections from the early Middle Ordovician of Sweden are characterized by interbedded limestone-shale units deposited in a mid-latitude platform setting (Jaanusson, 1982). A few faunal similarities exist between this unit and the equivalent sections in western Newfoundland (eg, *P. elegans*: Kundan/Aserian; Da1/3), but in general, this sequence shows less in common with the western Newfoundland than the other areas discussed here (Hadding, 1913, Ekstrom, 1937, Nilson, 1977, 1983, unpublished data; in Cooper and Lindholm, 1990).

IV.9: Southern Norway (Oslo region)

This sequence is broadly similar to those of southwest Sweden, both in terms of lithology and graptolite fauna. It also is made up of limestone/shale beds, and possesses a graptolitic fauna with only a few elements in common with western Newfoundland, such as *P. elegans* (present in the *D. (D.) murchisoni* Zone (Da3)) (Berry, 1964; Bulman, 1954, in Cooper and Lindholm, 1990).

IV.10: Wales/Shropshire

The units comprising these sequences are represented by discontinuous exposures of a complex basin environment formed in a mid to high-latitude Atlantic Province setting, making detailed stratigraphic correlation of the region with western Newfoundland difficult. A complete stratigraphic framework shows, however, that beds equivalent in age to those studied here possess several elements in common with the Newfoundland material. Slightly earlier units (Fennian 6/7, *D.(D.) artus* Zone); Dal/2) contain *G. acanthus* and *C. schaeferi*, whereas the *D. (D.) murchisoni* Zone include the pandemic species *D.* ? *decoratus* and "*C.*" *riddelensis* (Buckley, 1987, 1988, Fortey and Owens, 1987, in Cooper and Lindholm, 1990).

IV.11: Lake District, Great Britain

The Skiddaw Slates of the Lake District are interpreted as a sequence of off-shelf, basinal turbidite sandstones and shale deposits formed in a mid to high-latitude, Atlantic Province setting. The presence of *C. schaeferi* and the highly characteristic *N. fasiculatus* and *P. elegans* in the *D. (D.) murchisoni* Zone suggests correlation of this zone with the strata studied from western Newfoundland in this thesis. Slightly older beds, from the *D. (D.) artus* Zone, include specimens of *P. ensiformis* and *Glossograptus* sp. (Jackson, 1962, 1978, 1979, in Cooper and Lindholm, 1990).

IV.12: Bohemia

Graptolites from the Middle Ordovician of Bohemia occur in shale associated with fine-grain tuffs and coarse-grained volcaniclastics. Units equivalent to Da3 (*Corymbograptus reflexus* and *Didymograptus pseudogeminus* zones) include no faunal elements in common with western Newfoundland, although the problematic *C. tricornis* is found there. No exposures of the Yapeenian or Darriwilian 1 appear to be present in this region (Boucek, 1973, Kraft, 1975, in Cooper and Lindholm, 1990).

CHAPTER V

SYSTEMATICS

V.1: Morphological terms

No new morphological terms are introduced in this thesis. All of the terms used here are defined and discussed by Bulman (1970), Williams & Stevens (1988) and Palmer & Rickards (1991).

V.2: Collection Abbreviations

Collections referred to in this thesis are abbreviated as: BU, Geology Department, Birmingham University; GSC, Geological Survey of Canada, Ottawa; GSV, Geological Survey of Victoria, Melbourne; NMV, Mational Museum of Victoria, Melbourne; NYSM, New York State Museum, Albany; Q, British Museum (Natural History), London. Figured specimens collected during the present study are here assigned temporary catalogue numbers. These will subsequently be transferred to the collections of the Geologic Survey of Canada in Ottawa.

V.3: Locality Abbreviations

Collection localities throughout this thesis are referred to by abbreviations. These are:

BCOT, Black Cove Oil Tanks:

- BCOT-M: Black Cove Oil Tanks - Mound to immediate left of entrance;
- BCOT-OSS: Black Cove Oil Tanks - Overlying Sandstones;
- BCOT-G: Black Cove Oil Tanks - Ground level;
- BCOT-GS: Black Cove Oil Tanks - Ground level scree;
- BCOT-T7: Black Cove Oil Tanks - Type section, 7.0 m;
- BCOT-T9: Black Cove Oil Tanks - Type section, 9.0 m;
- BCOT-2mUES: Black Cove Oil Tanks - 2.0 m Under entryway sandstones;
- BCOT-1mAGE: Black Cove Oil Tanks - 1.0 m above ground level, far end of clearing.

CC-20, Cape Cormorant Formation:

- CC-20: Cape Cormorant Formation - 20 m;
- CC-145: Cape Cormorant Formation - 145 m;
- CC-195: Cape Cormorant Formation - 195 m.

DH, Daniel's Harbour.

PB, Piccadilly Beach:

- PB2.9: Piccadilly Beach, 2.9 m.

SC, Spudgel's Cove:

- SC-0.5: Spudgel's Cove - 0.25 m;
- SC-2.5: Spudgel's Cove - 1.25 m;

SC-5.0: Spudgel's Cove - 2.5 m;
SC-8.0: Spudgel's Cove - 4.0 m.

TP, Table Point:

TP Loc 1: Table Point, Locality 1 (30 m);
TP Loc 2: Table Point, Locality 2 (27.5 m);
TP Loc 3: Table Point, Locality 3 (26.5 m);
TP Loc 4: Table Point, Locality 4 (27.0 m);
TP Loc 5: Table Point, Locality 5 (21.5 m);
TP Loc 6: Table Point, Locality 6 (21.5 m, 40 m south of Locality 5);
TP Loc 7: Table Point, Locality 7 (21.5 m, 5 m south of Locality 6).

WBCQ, West Bay Centre Quarry:

WBCQ-BC: West Bay Centre Quarry, Black Cove Formation;
WBCQ-BC-GE: West Bay Centre Quarry - Black Cove Formation - ground level at far end of clearing;
WBCQ-BC-G: West Bay Centre Quarry - Black Cove Formation - ground level at clearing entrance;
WBCQ-BC-0.5mAGE: West Bay Centre Quarry - Black Cove Formation - 0.5 m above ground level, far end of clearing.

The West Bay Centre Quarry was sampled at the following intervals (measured upwards from the visible base of the unit): 2.6 m, 4.1 m, 5.0 m, 6.0 m, 7.0 m, 8.1 m, 9.1 m, 10.2 m, 11.3 m, 12.6 m, 13.7 m, 14.9 m, 16.0 m, 17.0 m.

V.4: Systematics

Order Graptoloidea

Family Dichograptidae Lapworth, 1873

Genus Pterograptus Holm, 1881

Type species: *Pterograptus elegans* Holm, 1881, p. 71.

Pterograptus elegans (Holm 1881)

Pl. 1, figs. 1, 2; text fig. 8 A-H

1881 *Pterograptus elegans*; Holm, p. 71.
1911 *Pterograptus elegans* Holm; Hadding. pl. 7, fig. 1-5.
1987 *Pterograptus elegans* Holm; Ni, pp. 45-46, pl. 1, figs. 1-4, text-figs. 11A-C.
1990 *Pterograptus elegans* Holm; Ge, Zheng & Li, pp. 61-62, pl. 4, figs, 2a, b.
1995 *Pterograptus elegans* Holm; Maletz, p. 2 - 4, fig. 2.

Type Material:

Type specimens for *Pterograptus elegans*, originally described from material collected from the $4a_2$ beds of Oslo, Norway by Holm (1881), have not yet been designated.

Material:

At least 13 specimens, collected from the Cape Cormorant Formation south of Mainland. Several large specimens, collected by R.K. Stevens, are apparently from unknown localities at the West Bay Centre Quarry. Most large specimens are fragmentary, some with proximal detail preserved but most with large portions of stipes missing, incomplete or tangled. Small specimens are mostly complete.

Description:

Two stipes emerge from the sicula, diverging from one another by an angle of 90° - 120°. These stipes are slightly curved, angling outwards at the proximal end but curving back inwards towards each other distally. This gives the rhabdosomes of *P. elegans* a generally ovoid, "droopy" appearance (Fig. 9 G, H). The maximum observed stipe length is in excess of 28 cm.

The sicula is relatively large, ranging in length from 1.2 - 1.6 mm and width from 0.25 - 0.5 mm. It appears to be widest at the aperture, although some specimens show a slight reduction in sicular width at the apertural edge. This is attributed to the presence of a very short rutellum, which appears to be slightly drawn inwards towards the sicularaperture (Fig. 9 D). A short nema is visible in some specimens.

Secondary stipes are cladial in origin. They emerge from the inner margins of the primary stipes and alternate between the two primary stipes. These secondary stipes are curved inwards slightly, giving them the same general appearance as the primary stipes (Fig. 9 A). The first secondary stipe emerges from the aperture of the first theca of stipe one. The second secondary stipe emerges from the aperture of the second theca on the second primary stipe. Few specimens show details of the origin of secondary stipes beyond the first and second. Those which do show that these secondary stipes emerge at every second theca (Fig. 9 B). There appears to be no difference in dimensions between the primary and the secondary stipes.

Thecae occur along the inner margins of both primary and secondary stipes, with no thecae along the outer stipe margins. Thecae are straight simple tubes, occasionally showing very slight inward curvature in the distal regions of the rhabdosome (Fig. 9 G). Proximally, thecae occur at a frequency of 9.6 - 11 in 10 mm (4.8 - 5.5 in 5 mm) (2TRD (th2-4) = 1.8-1.9). Distally, this thecal density is increased to 11.0 - 12.4 thecae in 10 mm (5.5 - 6.2 in 5 mm) (2TRD (th 10-12) = 1.8-2.0). This decrease in distal thecal density is due to an increase in thecal overlap distally on the rhabdosome. Proximally, there is little thecal overlap; distally, however, thecal overlap is as high as 50% (Fig. 9 A, G, H). Thus, if overlap is included, distal thecae are much longer (1.6 - 2.0 mm) than proximal thecae (0.8 - 1.3 mm).

In addition, proximal thecae are only slightly inclined: these show inclination angles of 15° - 25°. Distal thecae, on the other hand, show higher angles on inclination: 22° - 30°. As a result of this change in thecal angle (as well as the increase in thecal length distally along the rhabdosome), stipe width is greater distally on the rhabdosome (Fig. 9 A). Stipe width proximally is 0.4 - 0.5 mm, whereas the distal portions of the rhabdosome show stipe widths of 0.7 - 1.1 mm.

Remarks:

The origin of secondary stipes in an alternating manner between the two primary stipes is a characteristic feature of *Pterograptus elegans* (Berry, 1964). Although *P. elegans* would thus appear to be an easy species to identify, such is not always the case. Berry's (1964) specimens of *P. elegans* are more similar in overall morphology to the material described in this thesis as *Pterograptus* sp. A than to previous descriptions of *P. elegans* (e.g., Hadding, 1911). One difficulty is in the manner in which the secondary stipes emerge from the primary stipes. In *P. elegans*, the secondary stipes emerge in alternating fashion from the ventral margins of the two primary stipes, but the direction of these secondary stipes is difficult to ascertain or generalize in many specimens. This difficulty is derived in part from the fact that complete specimens are rare. Stipes appear to have broken from rhabdosomes of *P. elegans* quite easily, indicating these rhabdosomes may have been delicate in life. If such is the case, the apparent direction of secondary

Figure 8: *Pterograptus elegans* Holm, 1881, A-F x5. A: CC145 16D/E. B: CC145 16B. C: CC145 16F. D: CC145 16A. E: CC145 16C. F: CC145 4. G-H x2.5. G: CC190 7. H: CC190 6.

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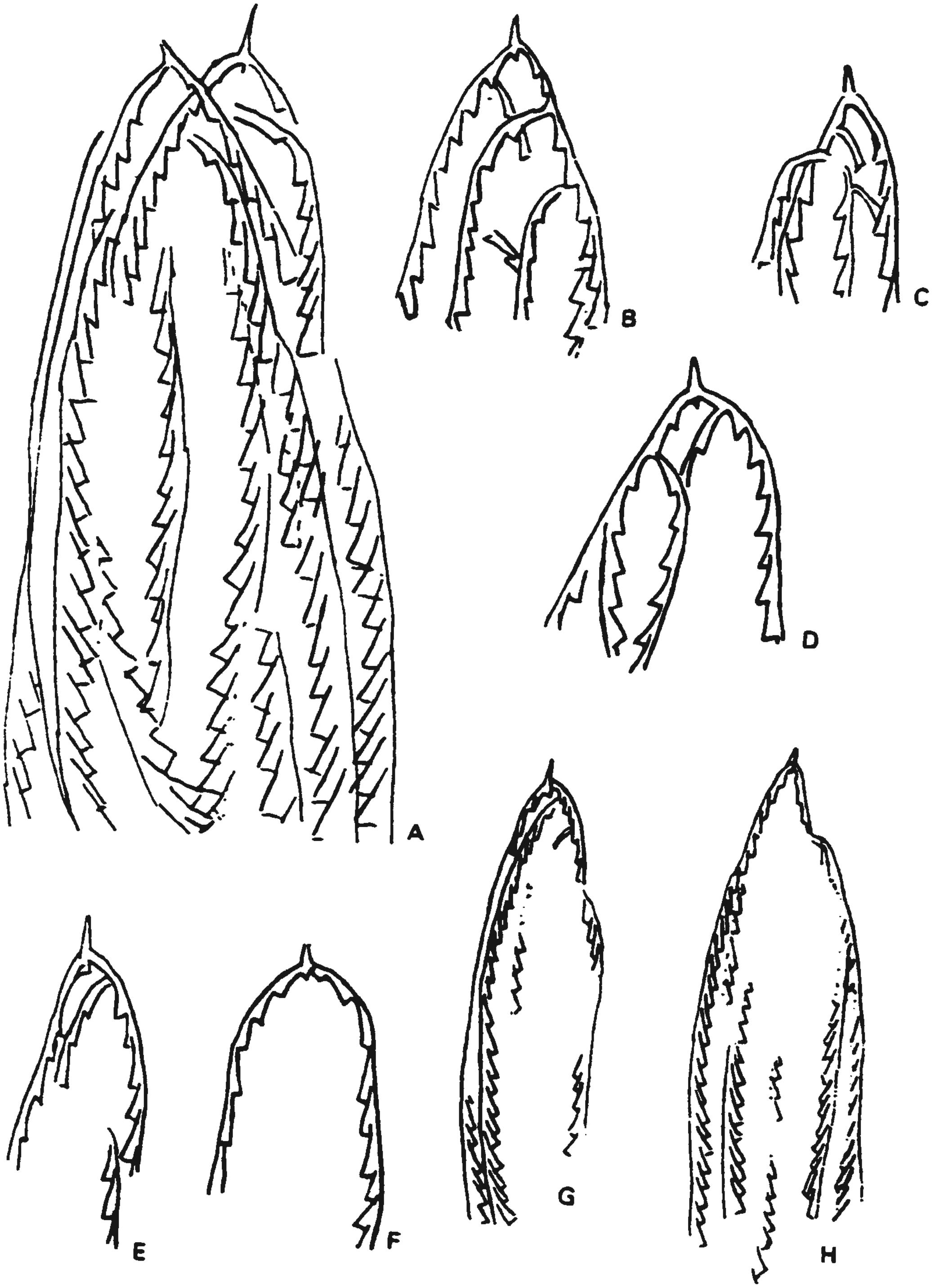


stipes may not be a valid criterion in identifying species of *Pterograptus*, as the direction of these stipes would have depended more on rhabdosome alignment during deposition than on rhabdosome structure during life.

Stipe breakage may also lead to confusion; in cases where such damage is irregular, as seems to be the case in *Pterograptus indistinctus* (Monsen, 1937), determination of the actual species is difficult, whereas in those where the damage appears to have some underlying regularity (e.g., all of the secondary stipes pointing outwards from the rhabdosome are missing), it may lead to the erroneous erection of new taxa.

Some *Pterograptus* species are, however, clearly distinct from *P. elegans*. One example is *Pseudobryograptus parallelus* (Mu, 1957). Initially, this pendant rhabdosome appears very similar to *P. elegans*, with two primary stipes emerging from the sicula at an angle of greater than 90° and secondary stipes emerging quickly from the inner margins of the primary stipes. However, despite these initial similarities, their remaining development is radically different. In *Pseudobryograptus parallelus*, these secondary stipes give rise to a pair of tertiary stipes, which often produce additional cladia, resulting in the development of 5 - 8 stipes per rhabdosome. Specimens of *P. elegans*, on the other hand, possess only primary and secondary stipes.

During the present study, specimens of *P. elegans* were found only in rocks from the Cape Cormorant Formation, although other authors (Maletz, submitted; Stevens, pers. com.) have found specimens of *Pterograptus* (not identified to species) from the West Bay Centre Quarry. It is of interest that the specimens of *P. elegans* found during this study were often closely associated with each other, sometimes intertwined, with several specimens often located on a single slab of shale. In such cases, no other species of graptolite are found on these rocks. This may suggest that *P. elegans* existed in a very specific habitat, in an environment which may have generally excluded the presence of other graptolites.

Pterograptus sp. A

Pl. 1, figs. 3-5; text fig. 9 A-H

cf.1964	*Pterograptus elegans* Holm; Berry, pp. 82 - 85, pl. 1, figs. 1, 3.
cf.1970	*Pterograptus elegans* Holm; Bulman, p. 112, text fig. 77, 7a.

Material:

Ten specimens collected from the Black Cove Formation exposure at Spudgel's Cove. All specimens appear to be incomplete to varying degrees.

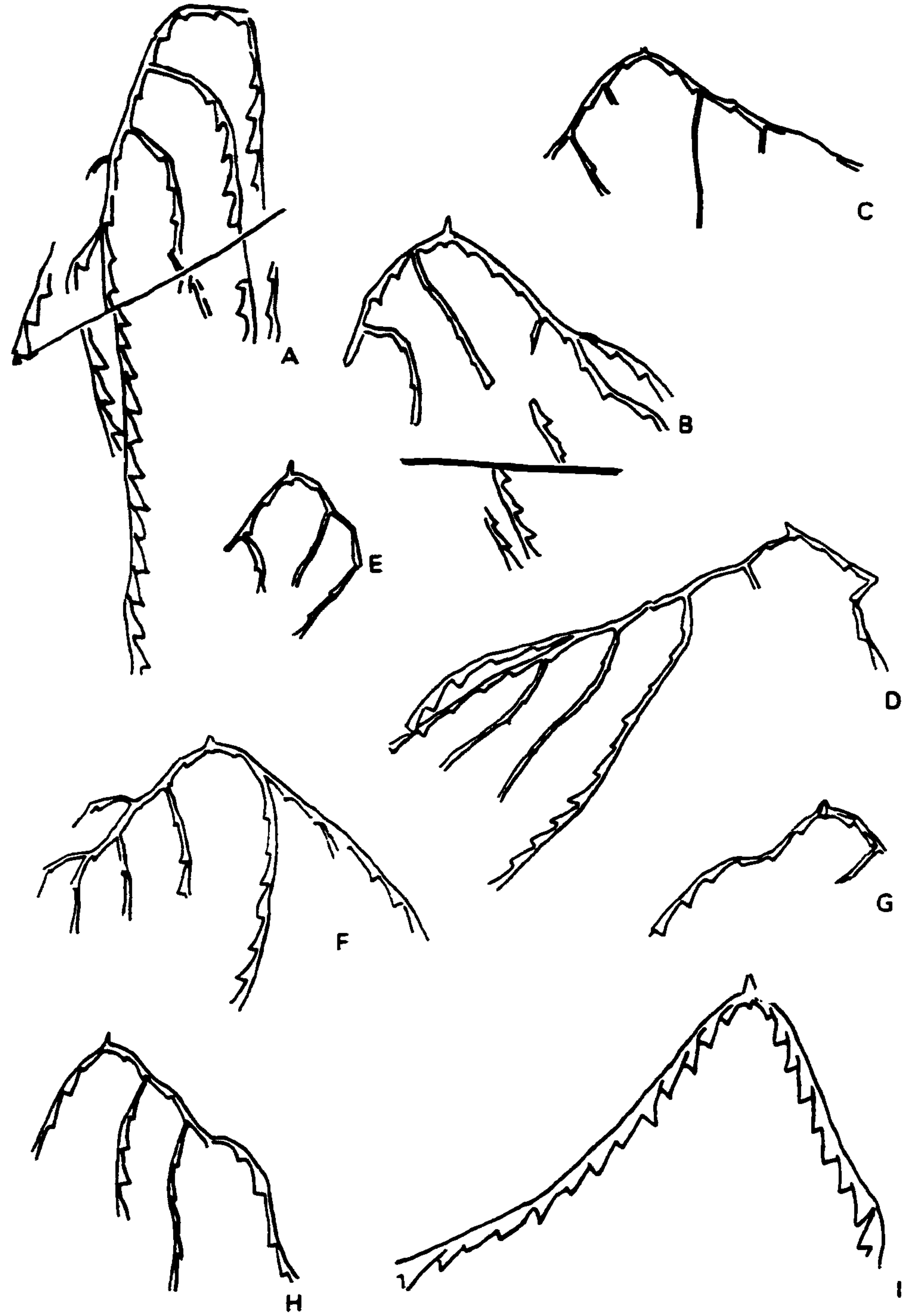
Description:

Two stipes emerge from the sicula, offset from each other by 130° - 140°. These primary stipes are irregular in their appearance: they are straight in some specimens, but show irregular curvature in others. In most cases, however, these primary stipes continue in approximately the same direction, resulting in the rhabdosome being very open (Fig. 9 B, F). Secondary stipes are present, along both the inner and outer margins of the primary stipes, and appear to be cladial in origin, although no thecal apertures are actually visiblealong the outer margins of the primary stipes. These secondary stipes appear to be consistent in their frequency: the first secondary stipes occur at the second theca on each of the two primary stipes. In most specimens, new secondary stipes occur at every second theca along the length of the primary stipes. These stipes are pointed inwards on the rhabdosome, along the ventral side of the primary stipe (Fig. 9 A, C). However, in some specimens, there is evidence of secondary stipes occurring at each theca. In these cases, these secondary stipes alternate between extending towards the ventral margin of the rhabdosome and pointing outwards from the dorsal margins of the primary stipes, dorsal to the rhabdosome (Fig. 9 D, F). The primary stipes are relatively straight, resulting in rhabdosomes being fairly broad, not as "droopy" as in specimens of *P. elegans*. Most secondary stipes do, as with *P. elegans*, "hang" below the ventral margins of the primary stipes. Although incomplete, specimens have been seen with widths in excess of 1.4 mm.

The sicula is distinctive, being very short (0.5 - 0.9 mm) and relatively wide (0.15 - 0.25 mm) for its length. Due to this, these siculae are 'short and stubby' in their appearance. Maximum width is achieved at or near the aperture. In most of the specimens with intact siculae, there appears to be a short rutellum present (Fig. 9 B, D, E).

Thecae occurring along the ventral margins of the primary stipes are straight, simple tubes, gradually widening towards the aperture. Thecal density along the proximal portion of the rhabdosome is 10.0 - 11.6 thecae in 10 mm (5.0 - 5.8 in 5 mm), but decreases distally to 9.4 - 10.2 thecae in 10 mm (4.7 - 5.2 in 5 mm). This decrease in thecal density distally is due to an increase in thecal length, from 0.55 - 0.85 mm (measured from aperture to aperture) proximally to 0.9 - 1.0 mm distally. There is also an increase in the angle of the thecae to the dorsal margins of the stipes distally on the rhabdosome. Proximally, the thecal angle is 10° - 18°, but this value increases to 21° - 24° for distal thecae. The combination of an increase in thecal length and thecal angle of inclination results in an increase in stipe width (measured at the thecal apertures) along the distal portions of the rhabdosome. Proximal stipe width is 0.2 - 0.3 mm, but increases to 0.45 - 0.5 mm distally. Thecae on cladial branches are similar in

Figure 9: *Pterograptus* sp. A., x5. A: SC0.5 1. B: SC0.5 1b. C: SC0.5 22. D: SC0.5 21. E: SC2.5 47. F: SC2.5 30. G: SC2.5 22. H: SC2.5 30 (2). ? **Xiphograptus sp.**, x5. I: WBCQ8.1 7.


A
B
C
D
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appearance to primary stipe thecae.

Remarks:

The irregular nature of the rhabdosomes in material here assigned to *Pterograptus* sp. A makes assignment to a single, previously defined species difficult. Due to this irregularity, it is impossible to determine the true nature of the rhabdosome of this species. However, as given in the above description, certain generalities may be drawn about these specimens. It has an overall appearance similar to other species of *Pterograptus*. However, its irregular nature and alternating stipe development (dichotomous branching) are characters which also occur in other genera, such as the earlier occurring *Sigmagraptus* (Early Ordovician (Arenig)) (Williams & Stevens, 1988). It appears to be closely related to the *Trochograptus* type of branching discussed by Spjeldnaes (1986), in which secondary stipes alternate along opposite sides of a primary stipe. (A good example of this may be seen in *Pleurograptus linearis linearis* (Carruthers), as figured in Williams (1982)). However, no new stipes are seen to emerge from the secondary stipes of *P. elegans*, unlike those seen in Spjeldnaes' *Trochograptus* branching (but see below).

It is of some interest that Berry's (1964) description of *Pterograptus elegans* is based on material which quite strongly resembles the material here referred to as

Pterograptus sp. A. For example, the siculae of Berry's specimens are 0.7 mm long, well within the range of those described here (0.5 - 0.9 mm). Also, the overall rhabdosome shape for Berry's material (open rhabdosome, narrow stipes, stipes arranged irregularly) is more similar to the irregular material described here than for *P. elegans*, as described in this thesis or by other authors (Hadding, 1911). However, it is also true that there appears to be considerable variation in the material identified by different authors as *P. elegans*. For example, some of Hadding's (1911) material seems to possess tertiary branches extending from the secondaries (which may actually represent misinterpreted clusters of colonies, as shown in this thesis). It is worth noting that the range of variation seen for this species may indicate that the material previously assigned to *P. elegans* may in fact consist of more than one species, such as that described here as *Pterograptus* sp. A. Alternatively, it may indicate that the group known as *P. elegans* is able to adopt a wide variety of rhabdosomal arrangements to suit particular environmental conditions, or was genetically less stable than the majority of other graptolites, and thus took on a greater variety of rhabdosome forms.

Genus Xiphograptus Cooper and Fortey, 1982
Type species: Didymograptus formosus Bulman, 1936, pp. 24-26, pl. 1, figs. 5-7; text-fig. 6.

? *Xiphograptus* sp.
Pl. 4, fig. 4; text fig. 9 I

Material:

Two specimens, both from the 8.1 m interval (Table Cove Formation) at West Bay Centre Quarry.

Description:

Two stipes emerge from the sicula, forming an angle of 130°. One of the stipes is broken from the rhabdosome in the second specimen, but the damaged stipe remains close to what would most likely have been its natural position on the rhabdosome. Due to this damage, the stipe angle cannot be ascertained. The stipes are slightly deflexed, the proximal regions curving downwards from the sicula whereas the distal portion of the stipes turn back up. Stipe width appears to be relatively constant along the length of the rhabdosome, with only a slight increase distally: these stipe widths are 0.5 -0.7 mm proximally, increasing to 0.8 - 0.9 mm distally (Fig. 9 I).

The sicular length is approximately 1.0 mm, with a short nema (0.2 mm) extending from the prosicula. The maximum width of the sicula, near the aperture, is 0.3 mm. A short rutellum is visible, extending approximately 0.1 mm from the sicular aperture. No virgella was observed.

Proximal thecae are slightly introverted, but the majority of thecae are straight, simple tubes. Both types widen towards the thecal aperture. Distal thecae sometimes show a slight curvature towards the apertural end, which is probably due to compression and/or alteration of the specimens during preservation and not to actual curvature of the thecae in life. Thecal overlap is up to one third total thecal length. Thecal angle with respect to the dorsal stipe margin appears to be consistent along the length of the stipes, measuring 25° - 30°.

Thecal length appears to increase distally along the stipes. Proximal thecae measure 1.4 mm long, whereas distal thecae are 1.7 mm in length (actual thecal length, not aperture-aperture distance). Associated with this change, there appears to be a small decrease in thecal density along the distal portions of the rhabdosome. Proximal thecal density is 9.0 - 10.6 in 10 mm (4.5 - 5.3 in 5 mm) (2TRD th2-4 = 1.8 mm), whereas thecal density distally is slightly lower, 9.0 - 9.2 in 10 mm (4.5 - 4.6 in 5 mm (2TRD th 10-12 = 2.0 mm)).

Remarks:

The presence of a virgella is the main defining characteristic of members of the genus *Xiphograptus* (Cooper & Fortey, 1982). Thus, the assignment of this species to the genus *Xiphograptus* is tentative, as a virgella was not seen on the specimens observed here. The material is included in this genus due to its other similarities with members of the genus, in particular *Xiphograptus declinatus* (Williams & Stevens (1988). This species is very similar to ? *Xiphograptus* sp. in terms of their deflexed stipes, the presence of a short nema, the sicular shape and dimensions, thecal shape, and overall rhabdosome appearance.

It is important to note that most of the specimens of *X. declinatus* recorded by Williams and Stevens (1988) lacked a visible virgella. This may be due to breakage of the virgella during deposition or preservation, or to the accidental removal of the virgella (by its sticking to the counterpart surface) during splitting of shales. The lack of a virgella on these specimens may also be due to the development of th1 adjacent to or over the position of the virgella, as seen in specimens of *X. formosus* as described by Bulman (1936; in Williams & Stevens, 1988). Only examination of further specimens will reveal the true lack or presence of a virgella in the material from the Port au Port Peninsula; this would, in turn, indicate whether the current tentative placement of this material into the genus *Xiphograptus* is correct and may permit assignment to an existing or new species.

Genus Janograptus Tullberg, 1880

Type species: Janograptus laxatus Tullberg, 1880, pp. 313-

315, pl. 11.

Janograptus terranovensis (Erdtmann, 1971)

Pl. 2, figs. 1-4; text fig. 10 A-E

1971 *Janograptus terranovensis* n. sp.; Erdtmann, pp. 260-262, pl, 23, figs. 4-7.
1971 *Janograptus terranovensis* (Erdtmann); Erdtmann, p. 1515.

Type Material:

The holotype, GSC 29304, was collected from the "Goose Tickle Group" (GSC locality 83364), GSC locality 83364, at Hare Bay.

Material:

Five specimens, fully flattened, collected from Table Cove Formation in the lower half (2.6 to 8.1 m) of the West Bay Centre Quarry.

Description:

The rhabdosome possesses a pair of horizontally aligned, narrow, elongate stipes and appears to lack a sicula. These stipes exhibit a slightly convex curvature along the thecal margin of the rhabdosome, giving the rhabdosome an overall slightly reclined form. The longest stipe observed measures 35 mm in length and appears to be broken off at its distal end.

The width of the rhabdosome at the narrowest point where the two 'proximal' thecae meet (called the 'axil' by Erdtmann (1971)) is 0.20 - 0.35 mm, with stipe width increasing to widths of 0.45 - 0.65 mm at th^1. Stipe width increases slightly distally, with widths of 0.5 - 0.7 mm at th^5 and widths of 0.6 - 0.7 mm at th^{10}.

Thecae are simple, cylindrical tubes which gradually widen towards the aperture, with ventral margins inclined at 15° - 25° to the dorsal stipe margin. Thecal apertures are usually straight and normal to the dorsal stipe margin.

Thecal densities are relatively consistent through the proximal portions of the rhabdosomes observed here, but show a decrease distally. Density is high proximally, with 7.4 - 8.6 in the first 10 mm (3.7 - 4.3 in 5 mm) of the rhabdosome (2TRD for th^{2-4} = 2.4; 2TRD for th^{8-10} = 2.5 - 2.6). It decreases slightly distally, however, to 7.6 - 8.2 in 10 mm (3.8 - 4.2 in 5 mm) distally (2TRD for th^{20-22} = 2.8). Thecal overlap seems to be approximately one third (Fig. 10 C), but this is difficult to determine as the overlap is not visible in all specimens (nor all thecae).

One specimen of *J. terranovensis* possesses what appears to be a short proximal process emerging from the dorsal margin of the 'axil' (Fig. 10 B). This process measures 0.4 mm in length and is 0.15 mm wide, and maintains a regular width until its end where it comes to an abrupt point. This process projects from the rhabdosome at an angle of 35°. The small size of the process indicates that it was likely not a

Figure 10: *Janograptus terranovensis* Erdtmann, 1971. A: WBCQ5.0 11, x2.5. B: WBCQ5.0 3R, x5. C: WBCQ8.1 1, x2.5. D: WBCQ2.6 6b, x5. E: WBCQ4.1 24, x5. *Pseudotrigonograptus ensiformis* J. Hall, 1865, x5. F: WBCQ6.0 15. G: WBCQ2.6 6R. H: WBCQ14.9 17. I: WBCQ14.9 15. J: SC0.5 14.

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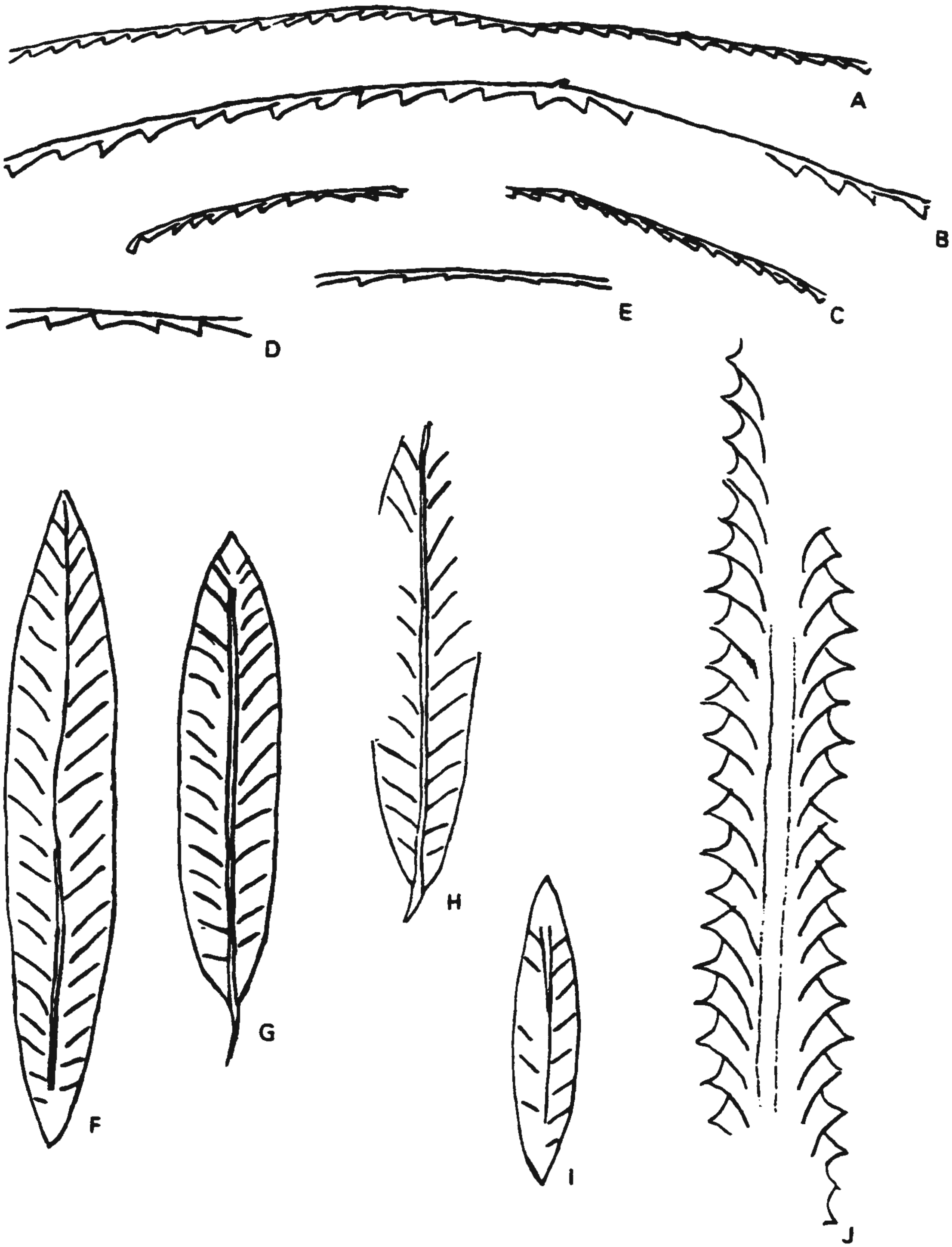


sicula (at least, not a complete sicula - see below), as the thecae found on the rhabdosome are considerably larger.

Remarks:

Other taxa similar in general form to *J. terranovensis* also possess unusual proximal structures, such as *Didymograptus (Expansograptus) abditus* or *Didymograptus (Expansograptus) distinctus* (see Harris & Thomas, 1935; Williams and Stevens, 1988)). In these specimens, however, the proximal process clearly represents the point of a short sicula, as opposed to the irregular structure observed in the specimen of *J. terranovensis* described here (Fig. 10 B).

One question which arises with regards to specimens of *J. terranovensis* is in respect to the original development of the rhabdosome. Some previous authors failed to address the problem when discussing species of *Janograptus* (e.g., Ekstrom, 1937; Berry, 1964). Others have suggested that rhabdosomes of *Janograptus* are in fact regenerated stipes of damaged specimens of dichograptid forms, in particular specimens of *Didymograptus* (e.g., Skevington, 1965; Williams & Stevens, 1988), although there is yet no proof to support this idea.

Another idea regarding the development of species of *Janograptus* is that these forms developed from a sicula in a similar fashion to other graptolites, but that the early proximal development has not yet been discerned (Erdtmann, 1971). Erdtmann draws these conclusions based on the fact that *Janograptus* has a very narrow time range, within the early Middle Ordovician, whereas dichograptid species in general have a much longer stratigraphic range. If specimens of *Janograptus* are, in fact, regenerated fragments of dichograptid stipes, specimens of *Janograptus* (or *Janograptus*-like species) would be expected throughout the entire stratigraphic range of the Dichograptidae.

Erdtmann (1971) further argues that the lack of a noticeable sicula may be due to the resorption of the sicula during astogeny, as seen in multiramous species of the dichograptids. Thus, examples where some sort of proximal process is evident may actually reflect specimens where resorption of the sicula is incomplete.

As more knowledge of this group is gathered, its stratigraphic range, however, seems to be expanding. Erdtmann (1971) states that specimens of *Janograptus* exist from only the early Middle Ordovician. Recent work by Ni (1991) supports this, by reporting occurrences of *Janograptus conspicuous* from the early Middle Ordovician in northwestern Jiangxi, China. Other work, however, in China by Xu *et al.* (1987) has resulted in the description of two more species of *Janograptus*. These are *Janograptus succinctus*, from the late Middle/early Upper Ordovician (*N. gracilis* zone) and *Janograptus reperticius* from the Upper Ordovician (*D. clingani* zone). Legg (1976) supports the notions of

Erdtmann, but stresses that "the taxonomic standing of *Janograptus* is in doubt".

One other point of interest is the report of *J. laxatus* (Tullberg) by Hadding (1913), in which a roughly oval-shaped structure is visible along the dorsal margin of the axle. This structure may be the remains of a degenerative sicula; its location on the rhabdosome, in the same position as the unusual structure here interpreted as a possible sicula, may have some importance.

Erdtmann (1971) provided biometric data for other species of *Janograptus* as a comparison with *J. terranovensis*. Among those listed, each possesses at least one morphological characteristic which sets it aside from *J. terranovensis* (and those described here). For example, *J. laxatus* (Tullberg) possesses a thecal width of 1.0 mm at th^1 and a maximum width of 1.5 mm, whereas the specimens of *J. terranovensis* described in this thesis possess widths of 0.45 - 0.65 mm at th^1 and maximum width of 0.7 mm. In contrast, specimens of *J. macilentus* (Berry) possess a width of 0.35 mm at th^1 and maximum width of 1.2 mm. A range of differences is also visible in other species of *Janograptus*, such as *J. peuviensis* (Lemon & Cranswick), *J. dawanensis* (Lee), *J. gracilis* (Ekström) and *J. petilius* (Berry).

More recently described species of *Janograptus* also possess differences from the material described here. Xu *et al.* (1987) describe two new species, *Janograptus reperticius* and *Janograptus succinctus*, neither of which possesses evidence of a sicula. *Janograptus reperticius* has a stipe width of 2.5 mm proximally, gradually increasing to 3.0 mm distally. This is much higher than widths seen in the specimens of *J. terranovensis* described here, which show widths of 0.45 - 0.65 mm at th^1 and 0.5 - 0.7 mm distally on the stipe. Other characters, such as thecal density, are similar between the two species, but the difference in stipe widths is more than enough to distinguish between these two species.

Janograptus succinctus is much more similar overall to *J. terranovensis*. *J. succinctus* shows a regular stipe width of 0.8 mm, slightly greater than that seen in *J. terranovensis*. The thecal density of 5 in 5 mm in *J. succinctus* is slightly higher than the 3.7 - 4.3 in 5 mm seen in *J. terranovensis*. Other characters, such as thecal angle of inclination and thecal dimensions, are similar between the two species.

Genus Pseudophyllograptus Cooper and Fortey, 1982

Type Species: Phyllograptus angustifolius J. Hall, 1858, p. 172.

Pseudophyllograptus cf. *P. angustifolius* (Hall 1858)

Pl. 3, figs. 1-3; text fig. 11 A-I

cf. 1858 *Phyllograptus angustifolius* J. Hall; p. 172.
cf. 1982 *Pseudophyllograptus angustifolius angustifolius* J

Hall; Cooper & Fortey, pp. 242-244; Fig. 48e, f.

(see Cooper & Fortey (1982) for more complete list of references)

Type Material:

GSC 939b, figured originally by Hall (1858: Pl. 16, fig. 21) and also by Cooper & Fortey (1982: p. 242, Fig. 48f) was designated lectotype by Cooper & Fortey (1982: p. 243). Collected from the Hudson River Group, New York.

Material:

Eleven specimens in total, from the Black Cove Formation at Black Cove Oil Tanks and Spudgel's Cove and Cape Cormorant Formation south of Mainland. All specimens are preserved as flattened carbonaceous films.

Description:

Rhabdosome size is highly variable, with specimens ranging in length from 10 - ~22 mm. Width is also highly variable, with a range of 3.7 - 5.9 mm seen in width maxima. Rhabdosome shape is relatively consistent between specimens, despite noticeable variations in specimen size. Rhabdosomes are ovoid and elongate, with some, generally the larger specimens, being roughly parallel-sided for most of their lengths (Fig. 11 A, C). Others, usually the smaller specimens, possess a more fusiform shape (Fig. 11 E, H).

Distally the rhabdosomes gradually narrow and are very gently rounded, resulting in a 'blunt' end. The proximal portion ofthe rhabdosome also appears to possess this gradual narrowing and rounding, but, as noted above, details of the proximal end itself are absent in most specimens (Fig, 11 E). Maximum rhabdosome width occurs at approximately the middle of the rhabdosome, especially in fusiform shaped specimens. The longer specimens generally have the greatest maximum width.

Details of proximal structure are few. In most specimens, the proximal portion of the rhabdosome has not been preserved. One specimen (Fig. 11 F) possesses an elongate, thin proximal process which could possibly represent a virgella, but the proximal region around this process is incomplete. It is, therefore, difficult to determine the true nature of this structure. A second specimen (Fig. 11 B) exhibits what appears to be a pair of short symmetrical proximal spines, pointing directly downward from the proximal end of the rhabdosome. Again, however, it is difficult to ascertain the true nature or authenticity of this proximal detail, due to the limited amount of material observed here. It is possible that these structures represent apertural processes.

Thecae are moderately curved throughout most of the rhabdosome, initially pointing upwards but curving outwards towards the lateral margins of the rhabdosome. Proximal thecae are nearly straight (in younger specimens) (Fig. 11 F) or only slightly curved (in more mature specimens) (Fig. 11 A), and point slightly downwards. Thecal direction changes rapidly, usually within 3 - 4 thecae of the rhabdosome's proximal end, where thecae curve towards or slightly above the horizontal. This change in thecal direction is maintained along the length of the rhabdosome, so that the most distal thecae are pointing upwards (Fig. 11 C). The distal thecae within the growing tip are not fully developed. As a result, they exhibit less curvature than those making up the main part of the rhabdosome. All thecae possess deeply recessed apertures, giving the rhabdosome margins a highly denticulate appearance.

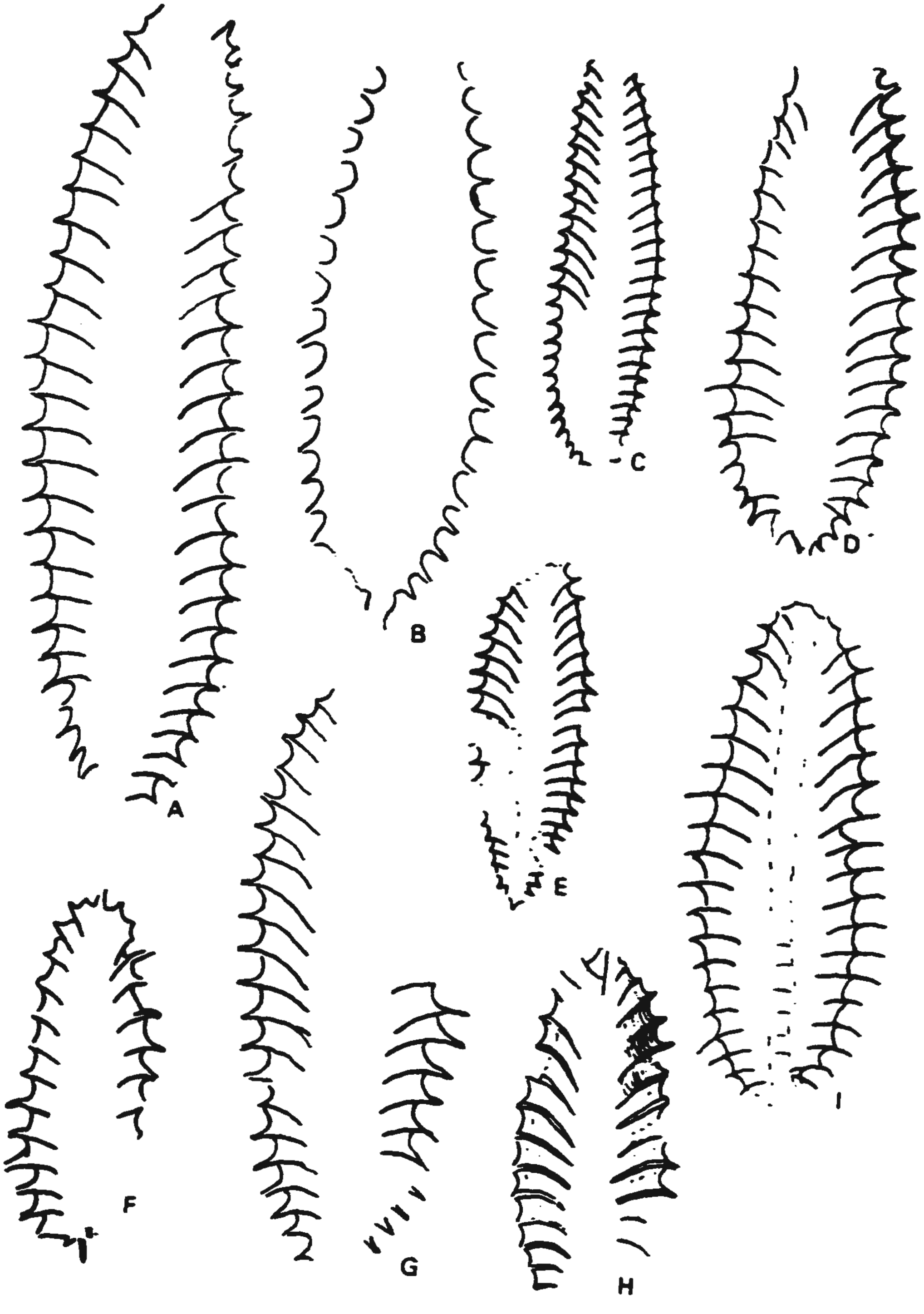
Thecal density is high proximally, with 12.0 - 15.0 thecae present in 10 mm (6.0 - 7.5 in 5 mm) (2TRD th2-4 = 1.0 - 1.4). As thecae get larger distally, this thecal density decreases, such that thecal number is reduced to 10.4 - 12.8 in 10 mm (5.2 - 6.4 in 5 mm) along the wider portions of the rhabdosome (2TRD th 10-12 = 1.5 - 2.1).

Remarks:

Details of internal aspects of the rhabdosome are an important criterion for the identification of species of *Pseudophyllograptus*

and its differentiation from the superficially similar *Phyllograptus* (Cooper & Fortey, 1982). Therefore, non-

Figure 11: *Pseudophyllograptus* cf. *P. angustifolius* Hall, 1858. A: CC145 3, x5. B: CC145 5, x5. C: CC145 4, x5. D: CC145 7, x5. E: BCOT-M 115, x2.5. F: BCOT-OSS 8, x5. G: BCOT-M 43, x5. H: BCOT-G 15, x5. I: SC0.5 8, x5.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compressed material or material showing partial relief is important in studies of this genus. Unfortunately, no such specimens were found during the present study. The material does, however, appear to match closely with that described by Cooper & Fortey (1982) in their reassignment of *Pseudophyllograptus* and its type species *P. angustifolius*. Cooper & Fortey's (1982) material is similar to that described here, for example, in the number of mature thecae in 10 mm (10.4 - 12.8 here; 8.5 - 12 for Cooper & Fortey) and maximum width/length relationships (5 - 6 mm maximum width = 13 - 21 mm length in this report; 5 - 6 mm maximum width = 15 - 24 mm length for Cooper & Fortey).

These similarities could, however, be potentially misleading, as neither the material described by Cooper & Fortey (1982) nor that in this thesis possess details of internal or proximal rhabdosomal characteristics. Therefore, the taxonomic assignment employed here, based on surface characters, is to a genus whose initial description is also based on compressed surface features. This assignment reflects a major problem with the taxon *P. angustifolius* as it currently stands. Due to its being based on material with no proximal or internal detail, it takes the unfortunate risk of becoming something of a 'waste-basket' for imperfect or difficult to identify phyllograptid material. Only description of more complete material, with intact proximal structures and/or internal detail, will allow a more precise description of this genus and species, which is necessary to make this a more viable and useful taxon.

The material identified here as *P.* cf. *P. angustifolius* is readily identified from species of *Phyllograptus*, which, according to Cooper & Fortey (1982), is characterized by a different internal structure and presence of a virgella. *Phyllograptus typus* (J Hall), for example, is easily identified by the much more rounded appearance of the rhabdosome, its longer thecae, higher thecal densities and long, commonly thickened virgella (Hall, 1858; Williams & Stevens, 1988). *P. ilicifolius* (J. Hall) and *P. anna* are both somewhat similar to *P. typus*, in terms of possessing a virgella.

Genus Pseudotrigonograptus Mu and Lee, 1958

Type species: Retiolites ensiformis (subsequently designated Rickards 1973) J. Hall, 1865, pp. 114-115, pl. 14, figs. 1-5.

Pseudotrigonograptus ensiformis (J. Hall 1865)

Pl. 2, figs. 4-6; text fig. 10 F-J

1858 *Graptolithus ensiformis*; J. Hall, p. 167.
1865 *Retiolites ensiformis* (Hall); J. Hall, pp. 114-115, pl. 14, figs. 1-5.
1875 *Trigonograptus ensiformis* (Hall); Hopkinson & Lapworth, pp. 659-660, pl. 34, figs. 8a-c.
1875 *Trigonograptus truncatus* (Lapworth); Hopkinson & Lapworth, p. 660, pl. 34, figs. 9a-d.
1890 *Trigonograptus ensiformis* (Hall); Nicholson, p.340, figs. 1-2.
1898 *Trigonograptus ensiformis* (Hall); Elles, pp. 523 -524, fig. 34.
1904 *Trigonograptus ensiformis* (Hall); Ruedemann, pp.

727-729, pl. 17, figs. 1-9.

1908 *Trigonograptus ensiformis* (Hall); Elles & Wood, pp. 302-303, pl. 35, figs. 1a-c, figs. 202a-c.

1934 *Trigonograptus ensiformis* (Hall); Hsü, pp. 53-54, pl. 4 figs. 1a-i.

1947 *Trigonograptus ensiformis* (Hall); Ruedemann, pp. 447-448, pl. 76, figs. 49-57.

1947 *Trigonograptus ensiformis* var *obtusus*, Ruedemann; p. 448, pl. 76, fig. 58.

1958 *Trigonograptus ensiformis* (Hall); Mu & Lee, pp. 395 -396, 415-416, pl. 2, figs 1-10.

1958 *Trigonograptus ensiformis* var. *minor*, Mu & Lee; pp. 396, 416, text-figs. 3a-c.

1958 *Trigonograptus angustus* (Hall); Mu & Lee, pp. 396 -397, 416, pl. 2, figs. 11, 12, text-figs. 4a-d.

1958 *Trigonograptus uniformis* Mu & Lee; pp. 398, 417-\ 418, pl. 2, figs. 13, 14.

1958 *Pseudotrigonograptus magnus* Mu & Lee; pp. 398, 417-418, pl. 2, figs. 13, 14.

1960 *Trigonograptus ensiformis* (Hall); Berry, p. 94; Pl. 12, fig. 10, pl. 13, figs. 6, 7.

1970 *Tristichograptus ensiformis* (Hall); Jackson & Bulman, p. 108.

1971 *Tristichograptus ensiformis* (Hall); Fortey, pp. 188-198, pls. 26-29, text-figs. 1-6.

1973 *Pseudotrigonograptus ensiformis* (Hall), Rickards, pp. 599-602, figs. 1-3.

1974 *Trigonograptus angustus*, Tzaj; p. 66, pl. 6, figs. 6-8, fig. 11.

1974 *Trigonograptus ensiformis* (Hall); Tzaj, pp. 46-47, pl. 1, figs. 7, 8.

1976 *Pseudotrigonograptus ensiformis* (Hall); Tzaj, pp. 226-227, pl. 1, figs. 9, 10.

1976 *Pseudotrigonograptus ensiformis minor*, Tzaj; p. 227, pl. 1, fig. 8.

1979 *Tristichograptus ensiformis* (Hall); Cooper, p. 91, pls. 19e, g, fig. 83a.

1979 *Pseudotrigonograptus* sp. cf. *P. uniformis* (Mu & Lee); Cooper, pp. 91-92, pls. 17a, 17k, 19h, figs. 83b, c.

1979 Graptoloid gen. 1, spp. 1-3, Cooper, pp. 92-94, pls. 19a-d, f, 1, figs. 84a-e.

1979 *Pseudotrigonograptus ensiformis* (Hall); Mu, Ge, Chen, Ni & Lin, p. 128, pl. 46, fig. 21.

1981 *Pseudotrigonograptus ensiformis* (Hall); Tzaj, p. 181, pl. 46, figs. 10, 11.

1982 *Pseudotrigonograptus ensiformis* (Hall); Cooper & Fortey, pp. 248-249, figs. 53a-d.

1982 *Pseudotrigonograptus minor*, Cooper & Fortey; p. 250, pl. 5, fig. 13, fig. 53e.

1984 *Tristichograptus ensiformis* (Hall); Obut &

Sennikov, pp. 81-82, pl. 13, figs. 3-6.

1988 *Pseudotrigonograptus ensiformis* (Hall); Williams & Stevens, fig. 4C.

1988 *Pseudotrigonograptus ensiformis* (Hall); Williams & Stevens, pp. 61-63, pl. 17, fig. 12, pl. 18, figs. 1-7, pl. 23, figs. 10-13, text-figs. 52A-M, 53; 54.

1990 *Pseudotrigonograptus ensiformis* (Hall); Ge, Zheng & Li, p. 111, pl. 35, figs. 2, 17.

1994 *Pseudotrigonograptus ensiformis* (Hall); Li, pp. 63 -64, pl. 1, figs. H-J, pl. 2, figs. A, B.

Type Material:

GSC 949g, a specimen originally figured by J. Hall (1865: Pl. 14, fig. 4), from Lévis, Quebec, was designated lectotype by Rickards (1973: p. 598).

Material:

Eleven specimens in total, all fully flattened and many poorly preserved. From the Table Cove Formation, West Bay Centre Quarry, with one very poor specimen from the Black Cove Formation, Black Cove Oil Tanks.

Description:

The rhabdosome is fusiform, with lengths reaching 18 mm and width maxima of 3.0 mm (4.2 mm in one unusual specimen, described below). At both proximal and distal ends the rhabdosome gradually tapers and ends in a narrow point. The proximal end possesses, in two of the specimens examined here, a short, slightly curved proximal process (Fig. 10 G, H). This process, 1.5 mm in length, may be a rutellum. It is larger, however, than the 0.5 mm length reported by Williams and Stevens (1988) for their specimens of *P. ensiformis*. No other proximal details are visible in the material discussed here. The outer margin of the rhabdosome is smooth in most specimens, which indicates, as suggested by "previous authors" (Williams & Stevens, 1988), that these specimens have been split along a median septum and thus do not show full thecal outlines. One specimen (Fig. 10 J; Pl. 2-7) does show full thecal outlines, suggesting the preservation of a complete unsplit rhabdosome. The large width of this unfortunately incomplete specimen (4.2 mm) suggests that the maximum size for this species is greater than that suggested by the the other complete but smaller specimens described here.

Only two of the four thecal series possessed by this specis are visible in the material described here, one along each lateral margin of the rhabdosome. Thecae are straight or slightly curved. The earliest thecae emerge from the rhabdosome at approximately 60° - 70° from the longitudinal axis of the rhabdosome. Thecal angle shows a gradual decrease with progression distally along the length of the rhabdosome, such that the most distal thecae are at 30° - 40° to the longitudinal midline of the rhabdosome.

The thecae in each series appear to be slightly offset from each other, with the thecae of one series being slightly higher than the corresponding thecae of the second series

(Fig. 10 F, H). This indicates that the thecae in each series originated at different times, with thecae from one series developing before and slightly below the corresponding thecae of the next series. Thecal density ranges from 11.8 - 13.0 in 10 mm (5.9 - 6.5 in 5 mm) proximally (2TRD th2-4 = 1.6) to 10.0 - 10.6 in 10 mm (5.0 - 5.3 in 5 mm) distally (2TRD th 10-12 = 1.8 - 2.0). All specimens are preserved as very thin, poorly preserved films, suggesting that specimens were poorly sclerotized.

Remarks:

In the absence of non-compressed material, it is difficult to discuss the nature of the stipes making up the rhabdosome of *P. ensiformis*. There are different opinions as to the uncompressed shape of this species (or related species/genera). For example, Cooper & Fortey (1982) discuss specimens of *P. ensiformis* as having a quadriserial rhabdosome, with the four stipes positioned such that they are arranged in diagonal pairs around a central longitudinal axis. In the same paper, they discuss the triserial nature of *Pseudotrigonograptus minor*. This species, which they state is the same as that previously described by Fortey (1971) as *Tristichograptus ensiformis*, is made up of three stipes, with each set against the other two around a central longitudinal axis. This species, when flattened, possesses very similar dimensions to the material described in this thesis, even though it possesses only three stipes. It is also smaller than other related forms, such as *P. ensiformis* as described by Cooper & Fortey (1982) in the same paper.

More recently, Williams and Stevens (1988) discussed the generally accepted combination of both triserial and quadriserial forms into one taxonomic unit, known as *Pseudotrigonograptus ensiformis*. This is based on the idea that the smaller forms may represent a single population of smaller individuals with greater flexibility than the larger forms and, therefore, would be more susceptible to the effects of compression. Changes in outline would result, as a function of preservation related to astogenetic change. This is based on the assumption that thecal development is continuous through the life of the rhabdosome.

It is also a possibility that an overall timewise transition from three-stiped to four-stiped forms occurred. Fortey's (1971) three-stiped material is slightly older in age (Early Ordovician) than the four-stiped specimens of *P. ensiformis* described by Rickards (1973) from the early Llanvirn. Since each of these forms may produce similarly-sized fossils if fully flattened, it is possible that there may have been an overall shift in form from three- to four-stiped forms during this time interval (Williams & Stevens, 1988).

During preservation, three- or four-stiped forms of *Pseutotrigonograptus* produce similarly-shaped outlines if split along the median septum (Williams & Stevens, 1988). Thus, since non-flattened specimens were not found in the material examined for this thesis (ie., all available specimens were fully flattened), it is impossible to determine if the material examined here was originally three- or four-stiped. Also, the low number of specimens of *P. ensiformis*, and the flattened nature of these specimens, make it difficult to draw any new conclusions about this species. The rhabdosomal dimensions and features visible in the few measurable flattened specimens, however, agree well with previous descriptions of this species, making this a relatively certain identification (e.g., Mu & Lee, 1958; Cooper & Fortey, 1982). Unfortunately, without the presence of material preserved in relief or isolated uncompressed material, it is difficult to compare this species to related forms with any great deal of certainty. Comparisons can be made strictly on the basis of flattened material, but these must be used with caution due to the great deal of similarity seen between different forms if flattened, as discussed above.

Family Isograptidae Harris, 1933

Genus Isograptus Moberg 1892

Type species: Didymograptus gibberulus Nicholson, 1875 (*pars*), p. 271, pl. 7, fig.3.

Isograptus forcipiformis (Ruedemann, 1904)

Pl. 3, figs. 4-6; text figs. 12 A-I

1904 *Didymograptus forcipiformis* sp. nov.; Ruedemann, p. 699-700, pl. 15, figs. 10-13, text fig. 91.
cf.1960 *Isograptus forcipiformis* var *latus* (Ruedemann); Berry, p. 67, pl. 12, fig. 1.
1963 *Isograptus forcipiformis* (Ruedemann); Ross & Berry, pp. 94-95.
1971 *Isograptus forcipiformis* (Ruedemann); Cooper, p. 906, text figs. 3a-e.
cf.1986 *Isograptus forcipiformis* (Ruedemann); Lenz & Jackson, p. 32, fig. 8T.
cf.1989 *Isograptus* cf. *I. forcipiformis* (Ruedemann); Carter, p. A12-13, figs. 7Q, R.

Type Material:

N.Y.S.M. 5881 and 5884 are syntypes (Cooper, 1971), figured by Ruedemann (1904, pl. 15, figs. 10-11). From Ash hill quarry, Mt. Moreno, Columbia co. N.Y.

Material:

Over 200 specimens from the Table Cove Formation at West Bay Centre Quarry, Port aux Port Peninsula. Most specimens were collected from above the 8 m level in the exposure. Preservation varies from good to poor, with some specimens showing weak sclerotization.

A number of specimens have also been found at the Piccadilly Beach exposure, below the West Bay Centre Quarry, which appears to be equivalent to the top portion of the West Bay Centre Quarry. Other material has been collected from the overlying Black Cove Formation at the Black Cove Oil Tanks. One specimen was also found in the Table Cove Formation at Table Point.

Description:

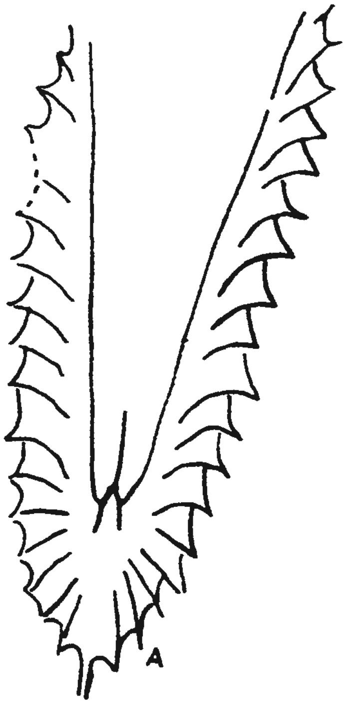
The rhabdosome has a tight V-shape with straight stipes, sub-parallel in most specimens. Stipe length reaches a maximum of 28 mm. Proximal stipe width is 1.0-2.2 mm, whereas maximum width is 1.0-2.4 mm. These wide variations in stipe width can be accounted for by the fact that proximal thecal development continues as rhabdosome size increases. Stipe width is greatest proximally, with gradual tapering of stipe width distally. Stipe width reduction occurs rapidly at the growing tip at the distal end, usually over the last 3-4 thecae. One specimen (not figured), from the Table Cove Formation, had a well developed growing tip at the distal stipe end, 1.3 mm in length.

The sicula is 2.8-4.3 mm long, averaging 3.5 mm. The rutellum (not preserved in all specimens) ranges from 0.4 mm to 1.4 mm in length, with an average length of 0.7 mm. The first theca possesses an apertural process the same size of and immediately adjacent to the rutellum and forms a symmetrical pair with the sicula (Fig. 12 C). These two processes combine to form an apparent single proximal 'spine' in s[ecimens where they immediately adjacent to each other (Fig. 12 A, E). If slightly separate, they are usually joined by a membrane and may be secondarily thickened (Fig. 12 B). In mature specimens, sicular details are obscured by cortical thickening of the dorsal stipe margins, which produces a membrane that links the dorsal margins, often reaching as high as the apex of the sicula (Fig. 12 B, D). The nema (if intact) is narrow and long, extending at least as far as th12. Four to six pairs of pendant thecae are present, with five pairs being most common. The first two to three thecal pairs are straight. Later thecae possess concave curvature throughout their length, particularly apparent in their most distal portions. Initial inclination with the dorsal stipe margin is 25-60°, decreasing to 8-25°. All thecae possess pronounced apertural processes and semicircular apertures. Thecae number 8-14 in 10 mm proximally, reducing to 8-11 in 10 mm distally. The high variation in proximal thecal number may again be due to the continual development of proximal thecae with rhabdosome development mentioned previously. 2TRD studies show a distance range of 1.3 - 2.3 mm between th 5 and th 7, with a distance range of 1.5 - 2.5 mm between th 10 and th 12. Thecal spacing is, therefore, greater in the distal portion of the rhabdosome.

Remarks:

Specimens referred to by Cooper (1971, 1973, 1979) as *I.* cf *I. forcipiformis* were later described as a distinct species, *I. subtilis* by Williams & Stevens (1988). Cooper's

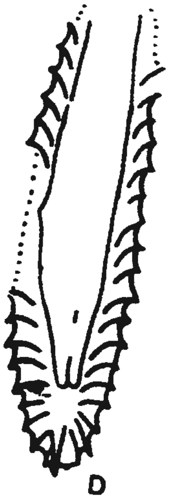
Figure 12: *Isograptus forcipiformis* Ruedemann, 1904. A: WBCQ6.0 11b, x5. B: WBCQ17.0 24, x5. C: BCOT-G 5, x5. D: WBCQ13.7 8, x2.5. E: WBCQ14.9 3, x2.5. F: WBCQ14.9 55, x2.5. G: WBCQ12.6 1Rb, x2.5. H: WBCQ17.0 33, x2.5. I: WBCQ17.0 6, x2.5.



A

B

C



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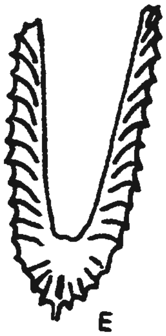

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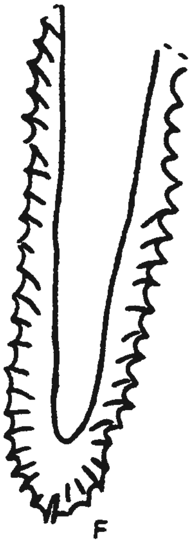
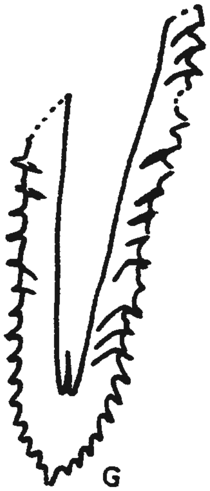


F



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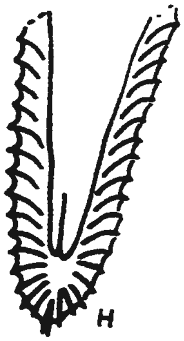
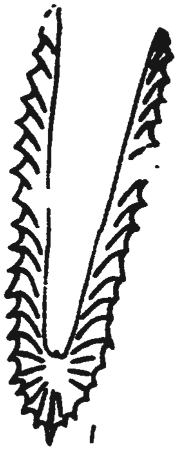


H



I

specimens are much smaller than specimens of *I. forcipiformis*, with sicular lengths of 3 mm and proximal stipe width of 1.3-1.4 mm. Furthermore, these specimens were collected from earlier stratigraphic intervals (*I. v. maximus* zone, late Arenig), whereas *I. forcipiformis* is characteristic of the middle Llanvirn (Darriwilian 1-3) (Cas & Vandenberg, 1988).

Carter (1989) also described specimens of *I.* cf *I. forcipiformis*, collected from the Metaline Limestone and Ledbetter Slate of Washington State, (*P. tentaculatus* zone, middle Llanvirn equivalent). Two specimens are figured, one juvenile and one poorly preserved mature rhabdosome. The mature specimen is lacking much proximal detail, but stipe and overall rhabdosome characteristics appear to match well with the above described *I. forcipiformis*. The juvenile figured, while possibly larger than expected, also matches well with the presently discussed material. Carter's specimens, while not definitely *I. forcipiformis*, may belong to this species.

Other *Isograptus* groups pose potential identification problems as a result of their similarity to *I. forcipiformis*, in particular the *I. victoriae* and *I. caduceus* groups. In general, *I. victoriae* species (*I. victoriae lunatus, I. v. victoriae, I. v. maximodivergens, I. v. maximus, I. v. divergens*) possess a more open V-shape, with a greater degree of stipe divergence than in most specimens of *I.*

forcipiformis (Cooper, 1973; Williams & Stevens, 1988). Many *I. victoriae* species also possess convex-curved stipes, resulting in their distal ends curving back towards one another. In addition, *I. victoriae* specimens have distinctly different proximal development with regards to the sicula/th1 connection. Sicular and th1 development is not symmetrical, resulting in good distinction between the two, especially as th1 usually diverges from the sicula towards the thecal aperture. Another important distinguishing feature is that the proximal region in *I. victoriae* species is generally not as 'robust' as in the case of *I. forcipiformis*. This results in an apparently smaller proximal region with respect to the rest of the rhabdosome in *I. victoriae* specimens. This is partly reflected in the fact that sicular length is most often longer in *I. forcipiformis* than in *I. victoriae*.

Specimens of *I. caduceus* (*I. caduceus imitatus, I. c. australis*) are often more difficult to distinguish from *I. forcipiformis* than specimens of *I. victoriae*, due to more overall similarities between the *I. caduceus* group and *I. forcipiformis*. There are still features which will allow distinction between the two, however. Stipes are most often straight but diverge at higher angles than do stipes of *I. forcipiformis*. Proximal development closely resembles that of *I. forcipiformis*, in that the proximal region is 'deeper' than in *I. victoriae*. However, there is still notably more separation between the sicula and th1 in *I. caduceus* than in

I. forcipiformis, allowing for distinction between the two groups. Also, sicular length in *I. caduceus*, although longer than in *I. victoriae*, is still shorter than in *I. forcipiformis*.

Problematic specimens do, of course, occur. Lenz & Jackson (1986) identified a specimen as *I. forcipiformis* which had measurements which fit well into the ranges given for this species in this paper. However, the proximal development shows none of the characteristic symmetry between the sicula and $th1^1$; in fact, there is a distinct difference between the two in shape and position. Thus, this specimen possesses some characters which suggest its affinity as *I. forcipiformis*, whereas others point towards a species such as *I. caduceus* as its true identity.

Isograptus forcipiformis has been identified as late as the Darriwilian 3 in Australia, making it one of the latest *Isograptus* taxa (Thomas, 1960). A few other members of this genus, however, appear to extend as high as Darriwilian 4 in Australia, including *I. caduceus tenuis* and *I. c. spinifer*. Each of these generic identifications is questionable, however, due to poor preservation of the material (Cooper, 1973). Unidentified *Isograptus* (possibly *I. forcipiformis* or *I. victoriae divergens*) have also been described from the Darriwilian (Da2, possibly Da3) of New South Wales (Jenkins, 1982).

Hughes *et al.* (1982) refer to specimens of *Isograptus* sp. from near the base of the Castell Limestone Formation, Abereiddi, South-West Wales. Thus, *Isograptus* appears to possibly extend beyond the Llanvirn to the Llandeilo. However, as no further identification or description accompanies this *Isograptus* occurrence, it must be considered a tentative identification at best.

Family Sinograptidae Mu, 1957

Genus Etagraptus Reudemann, 1904

Type species: Tetragraptus (Etagraptus) lentus Reudemann, 1904, p. 666, pl. 9, figs. 7-10.

Etagraptus harti (T.S. Hall, 1914)

Pl. 4, figs. 1-3; text fig. 13 A-I

1914 *Tetragraptus harti* T.S. Hall, pp. 113-114, text figs. 5, 6.
1935 *Tetragraptus harti* T.S. Hall; Benson & Keeble, p. 276, pl. 33, figs. 2, 3, 10.
1937 *Tetragraptus* cf. *harti* T.S. Hall; Monsen, p. 164, pl. 4, figs. 12, 19.
1938 *Tetragraptus harti* T.S. Hall; Harris & Thomas, p. 74, pl. 2 figs. 14a, b, pl. 4, fig. 13.
1956 *Tetragraptus (Eotetragraptus) harti* T.S. Hall; Boucek, p. 94, pl. 5, figs. 3, 4, text-figs. 8g-k.
1964 *Tetragraptus harti* T.S. Hall; Ge, pp. 373-374, 393, pl. 1, fig. 14, text-fig. 2.
1973 *Eotetragraptus harti* T.S. Hall; Boucek, pp. 26-27, pl. 1, figs. 2, 3 text-figs. 5a-d.
1976 *Tetragraptus (Eotetragraptus) harti* T.S. Hall; Tzaj, p. 53, pl. 4, figs. 4, 5.
1979 *Tetragraptus harti* T.S. Hall; Cooper, p. 65, pl. 7, fig. f, fig. 33.
1982 *Etagraptus harti* T.S. Hall; Cooper & Fortey, pp. 268-269, fig. 64.
1984 *Eotetragraptus harti* T.S. Hall; Obut & Sennikov, \ pp. 70-71, pl. 10, figs. 6, 7.
1986 *Tetragraptus harti* T.S. Hall; Lenz & Jackson, p. 31, fig. 6F.

1988 *Etagraptus harti* T.S. Hall; Williams & Stevens, p.84, text-figs. 78A-I.
1990 *Tetragraptus harti* T.S. Hall; Ge, Zheng & Li, p. 59, pl. 35, fig. 11.

Type Material:

The holotype is GSV 9750, figured by T.S. Hall (1914, text-fig. 5), from the latest Bendigonian, Bendigo, Victoria, Australia.

Material:

Nine specimens collected from the Table Cove Formation at West Bay Centre Quarry, Port aux Port Peninsula. All were collected between 8.1 m and 14.9 m at the exposure with the possible exception of one specimen, which was collected from the scree at the 9.1 m interval.

Description:

The rhabdosome has two short, primary, horizontal stipes which together make up a structure referred to as the 'funicle'. In the specimens examined here, this funicle measures 1.9 - 3.9 mm in length and 0.2 - 0.5 mm in width. No complete siculae have been observed on any of these specimens. This is probably due to the fact that in *E. harti* the sicula points upwards from the rhabdosome. Thus, when the rhabdosome fell onto the sediment after the colony died and sank, the funicle was preserved perpendicular to the remainder of the specimen. It was then obscured by the funicle as the specimen flattened during fossilization. One specimen, however, possesses what may be an incomplete sicula (Fig. 13 A). This indeterminate structure appears to be the base of sicula. It is 0.4 mm wide at its base and 0.25 mm at its end, which is 0.3 mm from its apparent base on the funicle.

From each of the distal ends of the funicle develop two secondary stipes, resulting in a total of four secondary stipes. These stipes measure 0.3 - 0.4 mm in width at the base (where they emerge from the funicle, not at the aperture of th^1). This measurement is taken at the base of the secondary stipes instead of at th^1 due to the irregular nature of the location of thecae in this sample of specimens. Distally, these secondary stipes reach maximum widths of 1.2 mm and a maximum observed length of 25.5 mm. Thecal detail varies greatly between different specimens. Some species possess elongate narrow stipes which show no thecal detail (Fig. 13 F). This is doubtless due to oblique preservation, causing thecal detail to be obscured by the dorsal wall of the stipe. Other specimens possess fairly obvious thecal detail (Fig. 13 D, G, H); in these, a thecal density of 9.0 - 9.8 in 10 mm is seen (4.5 - 4.9 in 5 mm) (2TRD (th2-4) = 2.0-2.3). These thecae are inclined from the stipes by 10° - 20°. One specimen shows very clear thecal detail along the majority of one of the stipes, but no such thecal detail is visible within the first 6 mm of the 22 mm long stipe (Fig. 13 D). The thecae on this specimen are inclined by as much as 30° from the stipe.

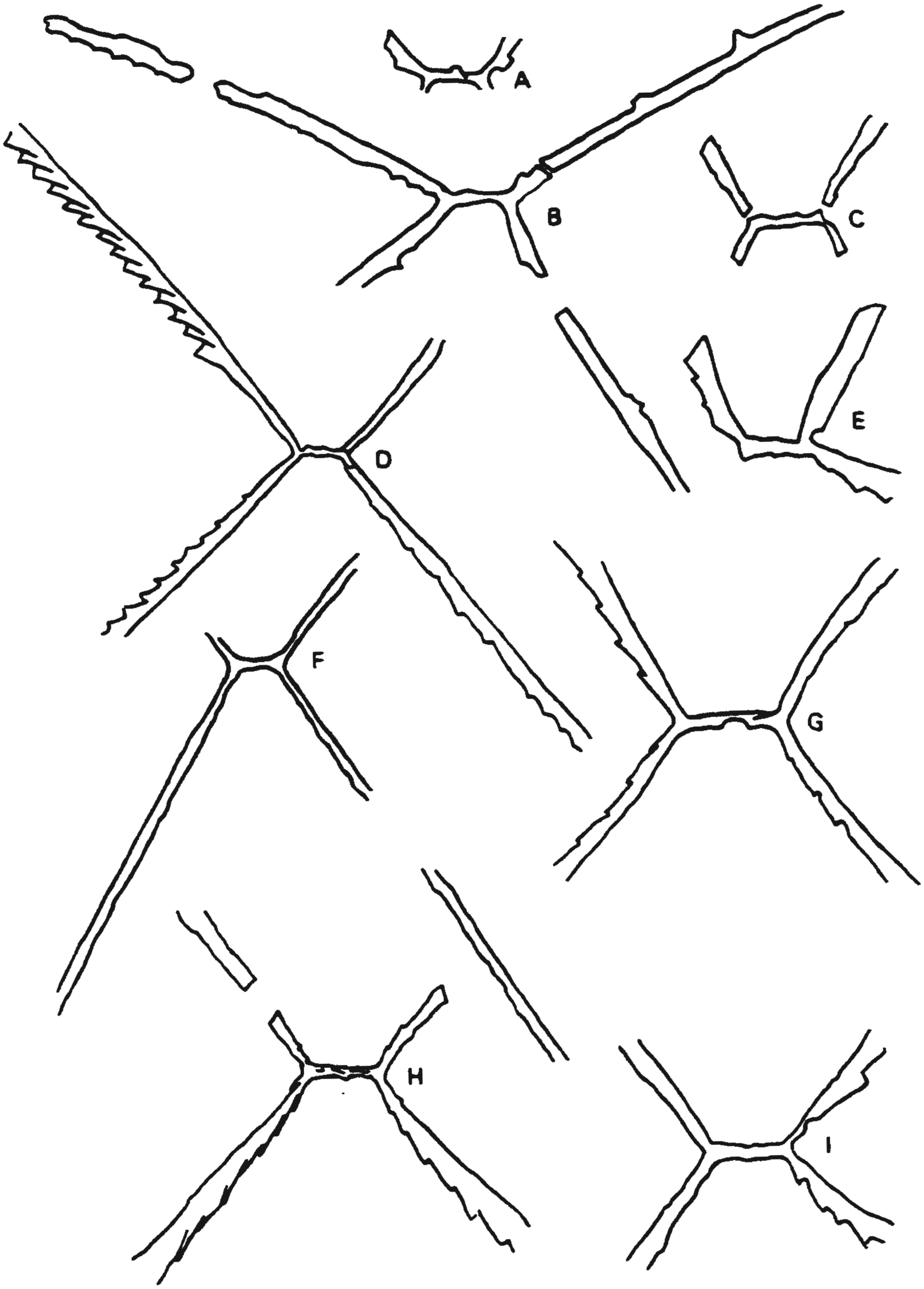
All specimens are preserved as heavy, black carbon films which can easily be picked from the shale surface. This indicates the rhabdosomes were most likely heavily sclerotized in life.

Remarks:

Williams and Stevens (1988) described several specimens of *Etagraptus harti* from the early Ordovician (Arenig) of Cow Head, western Newfoundland. Their rationale for including this material in the genus *Etagraptus* instead of *Tetragraptus*, as had been done previously, was that these specimens possessed low thecal angles, widely spaced thecae, wide, narrow funicles and slender stipes. These characters give these specimens an appearance more sigmagraptine than dichograptine, so they, like Cooper and Fortey (1982), classified this material as *Etagraptus*. The overall similarity of the material described here to the sigmagraptine material of Williams and Stevens (1988) and Cooper and Fortey (1982) has lead the author to classify this material as belonging to the genus *Etagraptus*.

Two of the specimens described within this sample are somewhat problematic. As in the case of Williams & Stevens'

Figure 13: *Etagraptus harti* T.S. Hall, 1914. A: WBCQ9.1 16 (2), x5. B: WBCQ14.9 22, x2.5. C: WBCQ9.1 10, x5. D: WBCQ10.2 17, x2.5. E: WBCQ9.1 16, x5. F: WBCQ9.1 21A, X2.5. G:WBCQ8.1 2, x5. H: WBCQ9.1 25, x5. I: WBCQ10.2 24, x5.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(1988) material from the Early Ordovician from Cow Head, western Newfoundland, some specimens are slightly larger in overall dimensions than the others in this sample. Thus, it is possible that these specimens actually belong to a larger but similar species of *Tetragraptus*, such as *Tetragraptus quadribrachiatus* (J. Hall, 1958; Williams & Stevens, 1988). There is, unfortunately, little thecal detail visible on the first of the two specimens in question (WBCQ14.9-22) (Fig. 13 B), which prevents using thecal densities as a criterion in determining the identity of this specimen. The size of this specimen is not a great deal larger than the others in the sample: its funicle width and length are 0.5 mm and 3.9 mm respectively, whereas the ranges of the remainder of the sample are, again respectively, 0.2 - 0.4 mm and 1.9 - 2.8 mm. There is not enough contradictory information on which to warrant the placement of this specimen into another species. Thus, despite its differences, it is included, although somewhat tentatively, with the other specimens described here as *E. harti*.

The second problematic specimen is WBCQ10.2-17 (Fig. 13 D. The width of the stipes of this specimen reaches a visible maximum of 1.2 mm, higher than that of the rest of the specimens described here. It has thecae which are more highly inclined than those of the other specimens in this sample, reaching up to 30° as compared to the range of 10° - 20° seen in the remainder of the material. The overall rhabdosome size of this specimen, however, is not as large as would be expected for a specimen of *T. quadribrachiatus*, nor are the differences visible in this specimen (in comparison to the other specimens) great enough to warrant placement into another species. So this specimen is, although tentatively, included here as a specimen of *E. harti*.

Genus Nicholsonograptus Boucek and Pribyl, 1951

Type species: Didymograptus fasiculatus Nicholson, 1869, p. 241, Pl. XI, figs. 21, 22.

Nicholsonograptus fasiculatus (Nicholson, 1869)
Pl. 4, figs. 5-6; text fig. 14 A-G

1869	*Didymograptus fasiculatus* n. sp.; Nicholson, p. 241, Pl. XI, figs. 21, 22.
1870	*Didymograptus fasiculatus* (Nicholson); Nicholson, p. 344, text-fig. 5.
1898	*Didymograptus fasiculatus* (Nicholson); Elles, p. 507, text-fig. 24.
1901-08	*Didymograptus fasiculatus* (Nicholson); Elles & Wood, p. 50, Pl. II, figs. 8a-c, text-fig. 32.
1934	*Didymograptus fasiculatus* (Nicholson) var. *praelongus* n. var.; Hsü, p. 40; Pl. II, figs. 11a-e, Pl. III, figs. 1a- c, text-fig. 7.
1937	*Azygograptus falciformis* n. sp., Ekström; p. 32, Pl. VI, figs. 12-16, text-figs. 5, 6.
1951	*Azygograptus falciformis* (Ekström); Hede, p. 48.
1953	*Nicholsonograptus fasiculatus* (Nicholson); Boucek & Pribyl, p. 14.
1956	*Azygograptus fasiculatus* (Nicholson); Lemon & Cranswick, p. 16, text-figs. 3b-d.
1963	*Nicholsonograptus fasiculatus* (Nicholson); Mu, p. 363.
1964	*Azygograptus* sp. sp. indet.; Berry, p. 111, Pl. p, figs. 4,5.
1966	*Nicholsonograptus fasiculatus* (Nicholson); Skevington, pp. 487-497, text-figs. 1-8.
1970	*Nicholsonograptus fasiculatus* (Nicholson); Skevington, pp. 436-437, text-figs. 14a-c.
1976	*Nicholsonograptus fasiculatus* (Nicholson); Legg, p.

31, Pl. 9, figs. 47-49.
1986 *Nicholsonograptus fasiculatus* (Nicholson); Lenz &
1990 *Nicholsonograptus fasiculatus* (Nicholson); Cooper & Lindholm, pp. 508, 518, text-fig. 8.
1992 *Nicholsonograptus fasiculatus* (Nicholson); Vandenberg & Cooper, pp. 62, 76.
1991 *Nicholsonograptus fasiculatus* (Nicholson); Ni, pp. 59-60, text fig. 16A, C,; Pl. 9, figs. 4, 7, 8, Pl. 10, fig. 8.

Type Material:

Strachan (1971) states that Nicholson's specimens, from the Ellergill Beds , Eller Gill, near Milburn, Westmorland, have not been positively identified.

Material:

Rare but well preserved specimens, some showing partial relief, collected from Black Cove Formation at the Black Cove Oil Tanks and above West Bay Centre Quarry. The Table Cove Formation at Table Head also contains rare specimens but these are poorly preserved, being fully flattened and showing little thecal detail. Juvenile and fully flattened incomplete specimens have been isolated from shales at West Bay Centre Quarry and Mainland Beach by Dr. Jorg Maletz.

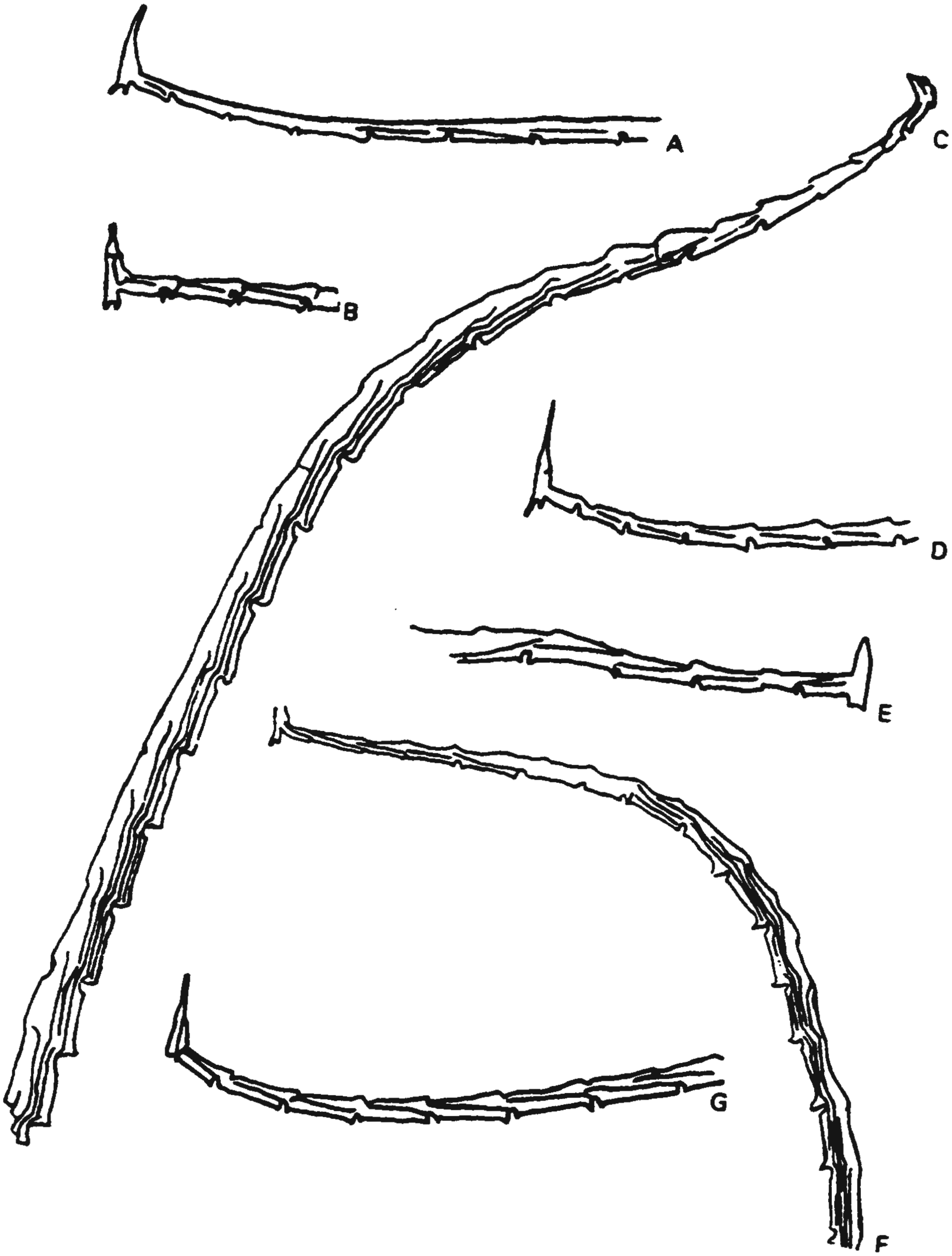
Description:

The rhabdosome of *Nicholsonograptus fasiculatus* is composed of a single stipe originating from the sicula. The stipe is initially approximately horizontal (Fig. 14 B), but may be slightly reclined or declined (Fig. 14 A, F). As stipe length increases, it curves such that the dorsal stipe wall is concave. As stipe length increases this curvature is reversed, resulting in a convex surface along the dorsal margin of the stipe (Fig. 14 C). Thus, larger stipes have an overall distinctive recurved shape. The longest specimen observed was 35.5 mm (an incomplete specimen with an incomplete distal end).

Sicula length ranges from 0.8 to 1.1 mm, with an average of 0.95 mm. Some specimens possess an elongate nema protruding from the prosicula (Fig. 14 D), extending as far as 0.8 mm. A pair of apertural denticles occur on opposite sides of the sicular aperture (Fig. 14 A, B, D). These are present in some specimens but are absent from others, which further serves to increase the variation in sicular length. These denticles appear to develop at different rates. That on the side opposite to the attachment of the stipe (antirutellar, as defined by Williams and Stevens, 1988) appears to develop before that on the same side as the stipe (rutellar). Thus, in juvenile and young specimens, these denticles are very different lengths (Fig. 14 D), whereas they are most often closer or equal inlength in more mature rhabdosomes (Fig. 14 B).

Maximum sicular width ranges from 0.13-0.15 mm. The

Figure 14: *Nicholsonograptus fasiculatus* Nicholson, 1868, x10. A: WBCQBC-5mAGE 2. B: BCOT-G 39. C: BCOT-G 6. D: WBCQBC-GE 3. E: BCOT-M 11. F: BCOT-T7 2. G: BCOT-G 38.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sicula is, for the greatest part of its length, parallel sided, although this is often difficult to see in specimens preserved in shale. It does, however, show up very clearly in isolated material. There is a rapid taper at the proximal end of the sicula immediately prior to the nema. There is also some variation in sicular width around the aperture, most likely due to distortion of the apertural denticles during preservation.

One stipe develops from the sicula. Th1 appears to be prosicular in origin, as suggested by Skevington (1966), running initially downwards parallel to and in contact with the sicula. This continues until immediately before the sicular aperture, where the first theca bends almost 90° away from the sicula (Fig. 14 B).

Stipe width at the aperture of th1 is 0.2-0.25 mm. There is a gradual increase in stipe width distally: at th5 stipe width is 0.25-0.41 mm, whereas at th10 stipe width is 0.5-0.55 mm. Maximum stipe width observed was 0.7 mm. This increase in stipe width is due to increased overlap of thecae, not to increase in thecal width which remains relatively constant along the length of the rhabdosome (1.0 mm proximally, 1.5 mm distally). There is little thecal overlap proximally, but as thecal length increases distally, there is a corresponding increase in thecal overlap. Maximum thecal length proximally (at th1) is 0.6 mm, at th5 is 2.4 mm and at th10 is 4.1 mm. Due to this increase in thecal length, distal thecal overlap may include as many as 3 other thecae. In contrast, there is less than 0.5 thecal overlap in proximalthecae. Thecae number 4.2-5.8 in 5 mm proximally (2TRD (th1-th3) = 1.15-2.2) but number 3.3-4.0 in 5 mm distally (2TRD (th6-th8) = 1.9-2.9).

Thecal development is highly characteristic in *N. fasiculatus*. Each theca is initially slightly curved, resulting in the development of a prothecal fold at the proximal end of each theca (Fig. 14 D). This node is less evident distally, although the initially curved thecal growth pattern is still visible in distal thecae.

There is considerable variation in the thecal apertures in the specimens of *N. fasiculatus* examined in this study. Some specimens possess distinct geniculae, with concave infragenicular walls and straight or slightly curved supregenicular walls angled almost perpendicular to the axis of the thecae (Fig. 14 B). These are the most common apertural forms seen in this material. Other specimens possess much simpler thecal apertures, with only slight geniculae visible, slightly concave infragenicular walls and convex supragenicular walls (Fig. 14 E). These simpler apertural forms may be due to preservation as internal moulds. Such specimens would show little if any apertural detail. Other possible sources of the loss of sicular detail are flattening or oblique preservation of specimens of *N. fasiculatus*. Either of these could result in the loss of apertural detail, due to the alteration of or partial covering of the thecal apertures. Some apertures also possess distinct lappets along the distal margin of the apertures, in some cases raised almost to the degree of the genicula (Fig. 14 G).

Discussion:

The taxonomic position of *Nicholsonograptus fasiculatus* and its relationship to other similar, possibly related forms (in particular, *Holmograptus lentus*) was discussed in detail by Skevington (1966). In this paper he recognized the possibility that *N. fasiculatus* is an intraspecific variant of the two-stiped *H. lentus*, but discussed the importance of maintaining the two as separate genera based on the presence of only one stipe in *N. fasiculatus*. More importantly, however, is the lack of dichotomous thecae in its proximal development. Thus, *N. fasiculatus* is maintained as a separate genera from *H. lentus*, which possess an early dichotomous theca resulting in the development of a second stipe.

An important factor in this discussion is that *H. lentus* and *N. fasiculatus* commonly occur in sequences together but do not overlap over their entire ranges. In Sweden and China, for example, *H. lentus* commonly occurs throughout the entire *artus* (*'bifidus'*) Zone, whereas *N. fasiculatus* occurs only in the upper portion of this sequence (Ekström, 1937; Hsü, 1934; Hede, 1951, in Skevington, 1966). Elsewhere, the stratigraphic range of these two species is known less precisely.

Similarities in morphology and range between these two species possibly reflects their possibly close biological relationship. However, it is important for them to retained as separate genera as each is an important stratigraphic tool. Combining the two genera would reduce their usefulness in this capacity (Skevington, 1966). Unfortunately, North American occurrences of *N. fasiculatus* or *H. lentus* cannot be easily treated in a similar fashion, as only one previous record for each species exists. Lenz & Jackson (1986) reported *N. fasiculatus* from the Canadian Cordillera (from southeastern British Columbia to northern Yukon), whereas Finney & Skevington (1979) reported occurrences of *H. lentus* from the West Bay Centre Quarry of the Port-au-Port Peninsula, western Newfoundland (which, in light of the work done for this thesis, may represent a mis-identification of *N. fasiculatus*). Despite the low number of reports of *N. fasiculatus* from North America, the dimensions of *N. fasiculatus* recorded in this thesis are in close agreement with other descriptions of the species. The occurrences of *N. fasiculatus* in North America appear to be stratigraphically equivalent to those in other parts of the world, being found in the lower Middle Ordovician. Thus, *N. fasiculatus* has potential as a stratigraphic tool for the critical correlation and subdivision for this part of the

Ordovician system. In fact, some authors (e.g., Li, 1983; Ni, 1991; Maletz and Mitchell, 1995), based on work in China and Newfoundland, have suggested using *N. fasiculatus* as a distinct zone, equivalent to the upper part of the *bifidus* Zone of Great Britain.

Genus Acrograptus Tzaj, 1969

Type species: Didymograpsus affinis Nicholson, 1869, p. 240, pl. 11, fig. 20.

Acrograptus cf. *A. affinis* (Nicholson, 1869)

Pl. 5, figs. 1-2; text figs. 15 A-R

cf.1869 *Didymograpsus affinis*, n. sp; Nicholson, pp. 240 -241, Pl. XI, fig. 20.

Type Material:

Strachan (1971) selected BMQ 3108 as neotype, referred to by Elles & Wood (1901-18, Pl. II, fig. 1b). Nicholson's material was, at the time, unknown. Collected from Skiddaw Slates, Outerside.

Material:

Approximately 50 specimens, all fully compressed and most fragmentary. Most are from the Table Cove Formation at West Bay Centre Quarry, with occasional specimens collected from an equivalent interval at Piccadilly Beach. A few specimens were collected from Black Cove exposures at the Black Cove Oil Tanks and Spudgel's Cove, and from the Cape Cormorant Formation exposure at Mainland Beach. Most specimens are small with incomplete stipes, often of unequal length due to breakage. This material is preserved in most cases as light beige films, indicating that the periderm was most likely thin in the living graptolites.

Description:

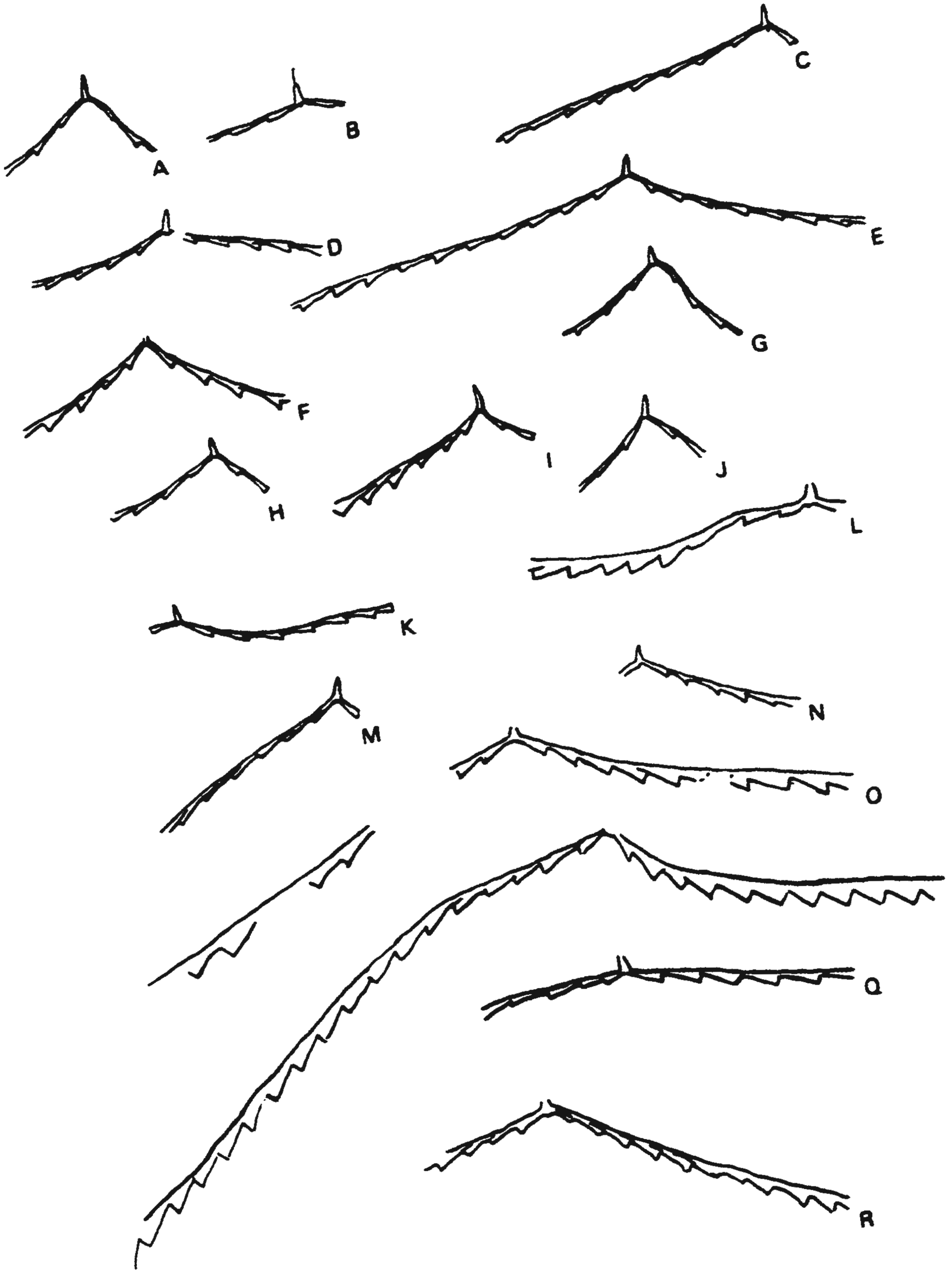
The sicula is short, ranging in length from 0.6 to 1.0 mm but most commonly measuring 0.7 - 0.9 mm. It is widest at the aperture, usually from 0.18 to 0.22 mm wide. It gradually narrows towards the prosicular end, with a rapid decrease in width to a narrow point immediately before the nema. The sicula possesses a short rutellum visible in several specimens (Fig. 15 B, C), reaching a maximum length of approximately 0.15 mm. No details of the origin of $th1^1$ or $th1^2$ are visible, due to both the complete flattening and the very thin preservation of the specimens examined.

One stipe diverges from each of the two lateral margins of the sicula. The anti-rutellar stipe diverges from a point immediately adjacent to the sicular aperture, giving the appearance that the sicular aperture is continuous with the thecal (ventral) margin of the stipe. The second stipe diverges from the rutellar side of the sicula. This second stipe is an equal distance from the prosicula as is the first stipe Thus, this stipe does not obscure the rutellum, which often extends a short distance beyond the thecal margin of the anti-rutellar stipe. In some specimens, however, the stipe on the rutellar margin diverges from a position on the sicula slightly closer to the prosicula than does the anti-rutellar stipe. This uneven stipe positioning gives the proximal end of the rhabdosome an asymmetric appearance in these specimens (Fig. 15 G, R). It is impossible to determine whether there is a true asymmetry in the position of the stipes on the sicula: this asymmetry is clearly evident in some examples but is apparently absent in other similarly preserved specimens. The longest observed stipe is 17.0 mm, and is apparently broken at its most distal end (Fig. 15 P). The angle of the two stipes is inconsistent between specimens. In some cases the two stipes are at almost 180° to each other (Fig. 15 M), but in other specimens there is as little as 100° between the two stipes (Fig. 15 Q).

In most cases, however,the two stipes possess an angle of approximately 130° between them. There is an almost continuous range of divergence values for different specimens in this sample, making it difficult to divide the material on the basis of stipe divergence angle (cf. Cooper & Fortey, 1982).

Stipes of *Acrograptus affinis* are most often relatively

Figure 15: *Acrograptus cf. A. affinis* Nicholson, 1869, x5. A: WBCQ4.1 10. B: WBCQ4.1 34. C: WBCQ4.1 1. D: WBCQ4.1 2. E: WBCQ5.0 4. F: WBCQ5.0 3. G: WBCQ10.2 13. H: WBCQ7.0 10. I: WBCQ7.0 2. J: WBCQ12.6 21. K: WBCQ10.2 22. L: WBCQBC-GE 8. M: BCOT-OSS 9. N: BCOT-M 70. O: WBCQBC-GE 3. P: CC20 6. Q: CC20 6 (2). R: SC0.5 1.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straight, although stipes which gradually curve upwards slightly along the dorsal stipe margin (i.e., gently reflexed) are not uncommon. Stipe width is low, with a gradual but slight increase distally. Proximal stipe width at th^2 ranges from 0.18 - 0.36 mm, but is most often 0.2 to 0.3 mm. Stipe width at th^6 is slightly larger, ranging over 0.26 - 0.52 mm but most often between 0.3 and 0.5 mm. A stipe width range of 0.33-0.6 mm has been measured at th^{10}, but the low number of specimens of this length (5) make it unlikely that these measurements are representative of the species.

Thecae are simple, straight tubes, gradually widening into a simple aperture. Several specimens, however, show thecae with downward curving ventral margins (Fig. 15 F, I). This is an apparent effect of compression on the straight thecae shown in the majority of the specimens in this sample, and is one reason for the variation seen in thecal widths in the material described here. Thecal density is 9.6 to 12.0 thecae in 10 mm proximally (4.8 to 6.0 in 5 mm). Thecal density appears to be fairly consistent along the length of the stipe, with a 2TRD of 1.6 - 2.1 between th^2 and th^4 and a 2TRD of 1.4 - 2.1 between th^8 and th^{10}.

Remarks:

Much of the variation seen in this sample is undoubtedly due to preservational artifacts. Compression has apparently caused a widening of thecal apertures, evident in many specimens. Also, the angle of the rhabdosome to the bedding planes may obscure part of the thecal apertures. These effects combine to lead, at least in part, to the great variation in the stipe widths observed during the present study.

Another source of the variation between specimens of *A. affinis* is the differing maturity of the specimens. If it is assumed that thecal development continues throughout the life of the colony, the thecae would be relatively short in juvenile rhabdosomes but longer in fully mature specimens. This would result in an apparent 'thickening' of the stipes during astogeny, due to the increase in thecal length and the accompanying increase in apertural width. Furthermore, as the thecae grow, they advance along the ventral margin of the following theca. Thus, the thecal apertures are successively positioned over thicker regions of the subsequent theca. A third possible factor contributing to continued increase in stipe width is that as the stipes increased is size, deposition of cortical material along the dorsal margin of the stipes may have continued.

The angle of stipe divergence is commonly employed as a factor to distinguish between species of *Acrograptus*. As mentioned above, there is a wide range of stipe divergence angles seen in the material described here, from 180° to 100°. In his redescription of *Acrograptus gracilis*, Törnquist

(1890) stated that one of the main defining characteristics of this species was the horizontal nature of the first two thecae and two stipes. During the present study it became evident, however, that variation in stipe divergence angle was large and continuous. There is no clear distinction between groups of specimens possessing very low and very high stipe divergence angles. Thus, even though the original description of *A. affinis* by Nicholson (1869) suggests that stipe divergence angle is restricted to 90° to 150°, all of the material described here, including that with angles of up to 180°, is considered to be the same species. This is due not only to the range of stipe divergence angles but also to the similarity of other characteristics, such as stipe width and thecal spacing, which are almost identical to previous descriptions of the species (e.g., Cooper & Fortey, 1982).

An important and related factor in the differentiation of *Acrograptus* species is the nature of the original rhabdosome. If Cooper and Fortey (1982) are correct, the rhabdosomes of this genus may have been flexible, meaning that the stipes would not have been rigidly held in any one orientation. Thus, the angle of divergence seen between the stipes of these specimens would be dependent on the depositional and preservational environment and angle of rhabdosomes to bedding during preservation, rather than on the original form of the rhabdosome.

Unfortunately, there appears to be no significant correlation between the different morphological aspects of the material in question here and the possible reasons for variation suggested above. For example, there is no correlation between thecal length and stipe width in this material, as would perhaps be expected. One possibility is that the material described here may in fact belong to more than one species. However, due to the lack of correlation between morphological characters, there appears to be no way in which to divide these specimens into separate groups. Another possibility (the most likely of the two, in this author's opinion) is the previously-discussed problem of deformation of the material during preservation. This deformation would serve to mask, or at least obscure, any significant differences that would have originally existed. A third possibility is that some of the morphological characteristics discussed here may be invalid for this species and are making the researcher look for morphological trends where none, in fact, exist.

An examination of other species of *Acrograptus* demonstrates the difficulty in assigning the material here to one species with any certainty. Boucek (1973) provided new or revised descriptions for several species of *Acrograptus*, including *A. crassus*, *A. strangulatus*, *A. lipoldi* and *A. nicholsoni*. Based on the material discussed by Boucek, it is evident that there is, in general, great overall similarity between the different species of *Acrograptus*. For example, *A. crassus* and *A. strangulatus* are very similar in their overall appearance (e.g. stipe divergence angles of 160° - 170°, similarly shaped and sized sicula) but are distinguishable by the slightly smaller overall size, narrower thecae and greater thecal overlap of *A. strangulatus*. Both of these species possess slight undulations along the dorsal stipe margins, however, so they are distinguishable from the material of *A. affinis* described in this thesis. Other species of *Acrograptus*, such as *A. lipoldi*, are similar to the material here tentatively identified as *A.* cf. *A. affinis*. *Acrograptus lipoldi* possesses many characteristics almost identical to *A.* cf. *A. affinis*, such as angle of stipe divergence (130° - 140° for *A. lipoldi*, approximately 130° for *A. affinis*), stipe width (0.3 mm proximally for *A. lipoldi*, 0.2 - 0.3 mm for *A. affinis*) and number of thecae in 10 mm 9 (7 - 10 for *A. lipoldi*, 9.6 - 12 for *A. affinis*). Other characteristics, however, are different between these two species. For example, distal stipe width for *A. lipoldi* may be as high as 1.5 mm, but reaches a maximum of only 0.6 mm in *A. affinis*, which allows for identification of specimens between these different species.

Other species of *Acrograptus* are also similar. *Acrograptus* (*Didymograptus*) *nicholsoni* (Lapworth, 1875), *A.* (*Didymograptus*) *primigenius* (Bulman, 1950), *A.* (*D.*) *tenuiramis* (Obut & Sobolevskya, 1962), *A.* (*D.*) *linealis* (Hsü,

1959) and *A.* (*D.*) *demissus* (Törnquist, 1901) all possess several characteristics which overlap with the material described here as *A.* cf. *A. affinis* and have rhabdosomes which share the same general appearance as specimens of *A.* cf. *A. affinis*.

It is, therefore, evident that specific identification of *Acrograptus* material may be problematic. This is in part due to the high similarity of original morphological characters seen between different species, but also to the fact that many of the features of these specimens are highly susceptible to deformation effects during preservation. The large number of species of *Acrograptus* with similar appearances leads the author to believe that taxonomic over-splitting of the genus may have occurred previously this group (e.g. thirty-three taxa are listed by Tzaj (1974)).

In light of these problems, the material described from western Newfoundland is tentatively identified as *A.* cf. *A. affinis*, as this is the species which it seems to match best.

Family Diplograptidae Lapworth, 1873

Archiclimacograptus sp. A

Pls. 6-8, Pl. 9, fig. 1; text figs. 16-19

Material:

Several hundred flattened specimens collected from the Table Cove Formation at West Bay Centre Quarry, Piccadilly Beach and Table Point, from the Black Cove Formation at West Bay Centre Quarry, Spudgel's Cove and the Black Cove Oil Tanks, and from the Cape Cormorant Formation south of Mainland. A small amount of non-flattened material was collected from the Daniel's Harbour Member at Daniel's Harbour.

Description:

Rhabdosome dimensions of *Archiclimacograptus* sp. A are highly variable, including width, length, and thecal densities and style. This suggests that there is probably more than on species actually present in this group. The use of camera lucida overlays in comparing all specimens, however, indicates that there is an almost constant gradation of all characters. Also, several characters are common in different rhabdosome forms. These overlapping characters are insufficient to divide this sample into specific species groups.

This overlap of characters is most likely due to the natureof the material described in this thesis, it being fully flattened and thus deformed. This has lead to the exaggeration and/or reduction of rhabdosomal characteristics which may have been useful in distinguishing if different species are present in this sample.

Figure 16: *Archiclimacograptus* sp. A, x5. A: WBCQ16.0 32. B: WBCQ17.0 50b. C: WBCQ12.6 4. D: WBCQ13.7 31. E: WBCQ16.0 33. F: WBCQ14.9 8R. G: WBCQ16.0 33. H: WBCQ13.7 28R. I: WBCQ12.6 45. J: WBCQ10.2 31. K: WBCQ6.0 51. L: WBCQ12.6 10. M: WBCQ11.3 2. N: WBCQ11.3 13. O: WBCQ12.6 17. P: WBCQ8.1 7. Q: WBCQ13.7 6.

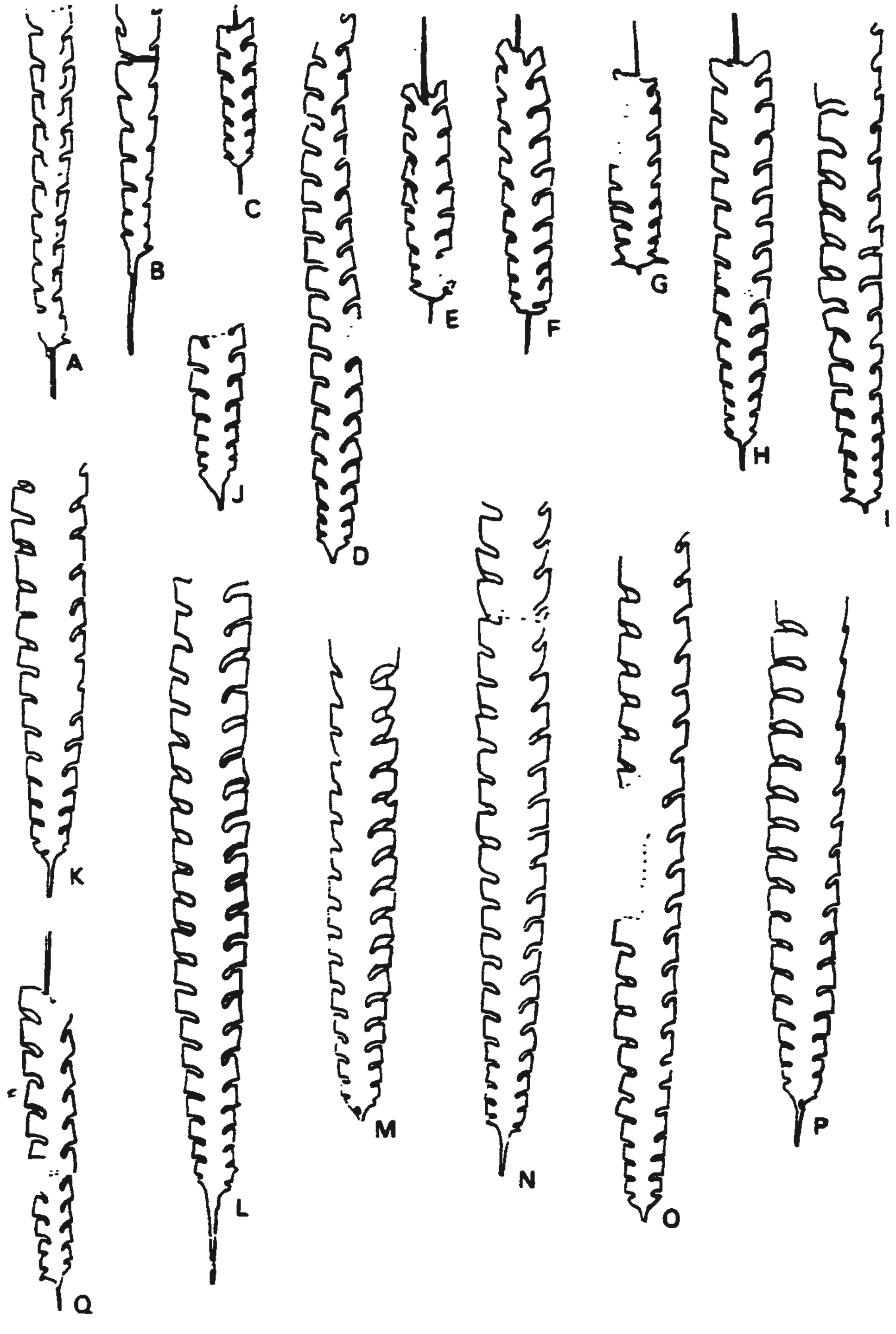
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Figure 17: *Archiclimacograptus* sp. A, x10. A: BCOT-G 25. B: BCOT-G 30. C: BCOT-M 55. D: BCOT-GS 6. E: BCOT-G 3. F: BCOT-T7 11. G: BCOT-G 15R. H: BCOT-G 9. I: BCOT-T7 10.

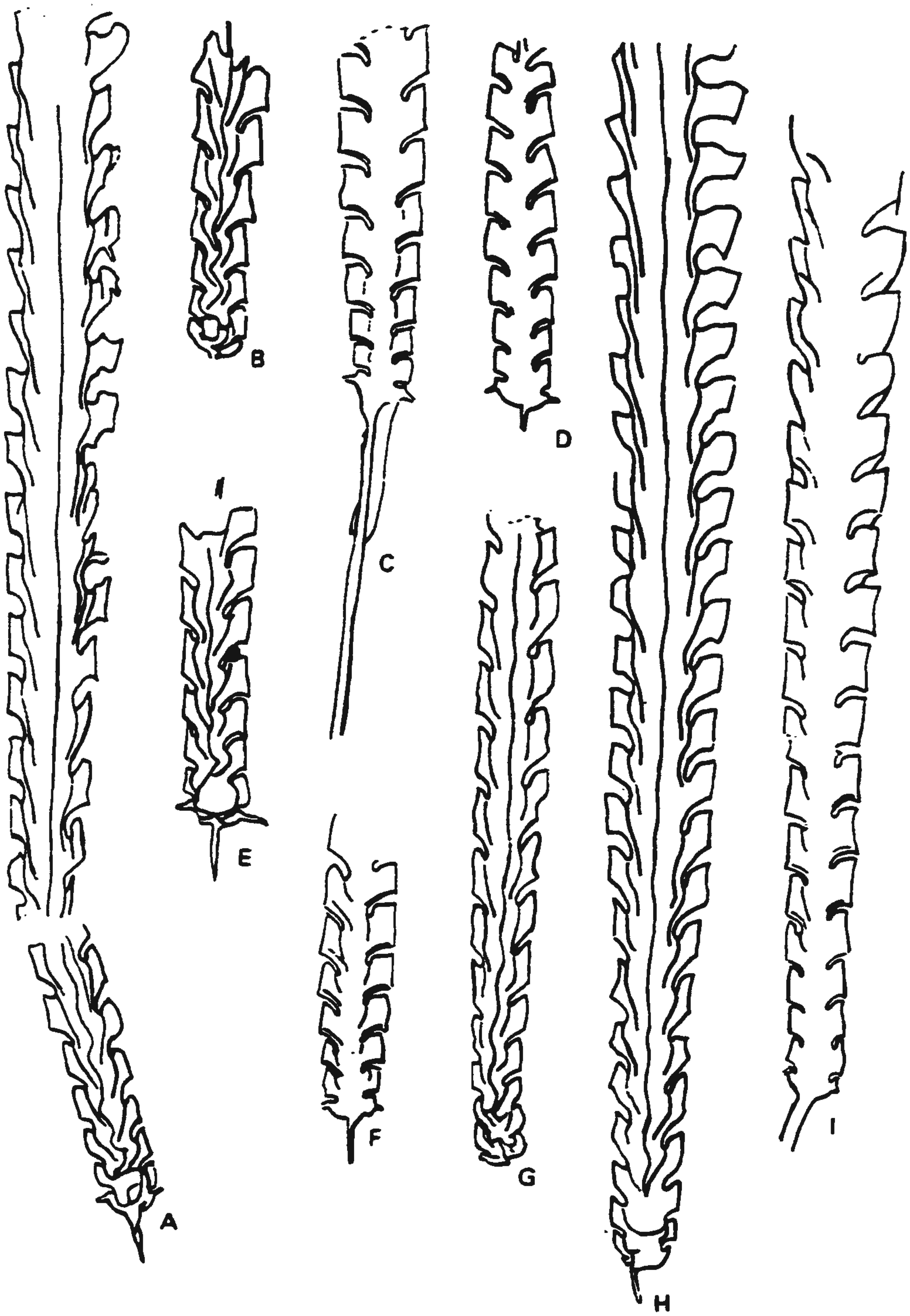
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Figure 18: *Archiclimacograptus* sp. A, x10. A: WBCQ10.2 2R. B: WBCQ8.1 18R. C: WBCQ17.0 42. D: WBCQ17.0 1-2. E: WBCQ13.7 2. F: TP5 15. G: WBCQBC-G 75. H: WBCQBC-GE 5. I: WBCQ17.0 1-5. J: WBCQ17.0 16. K: WBCQ17.0 46. L: TP2 1.

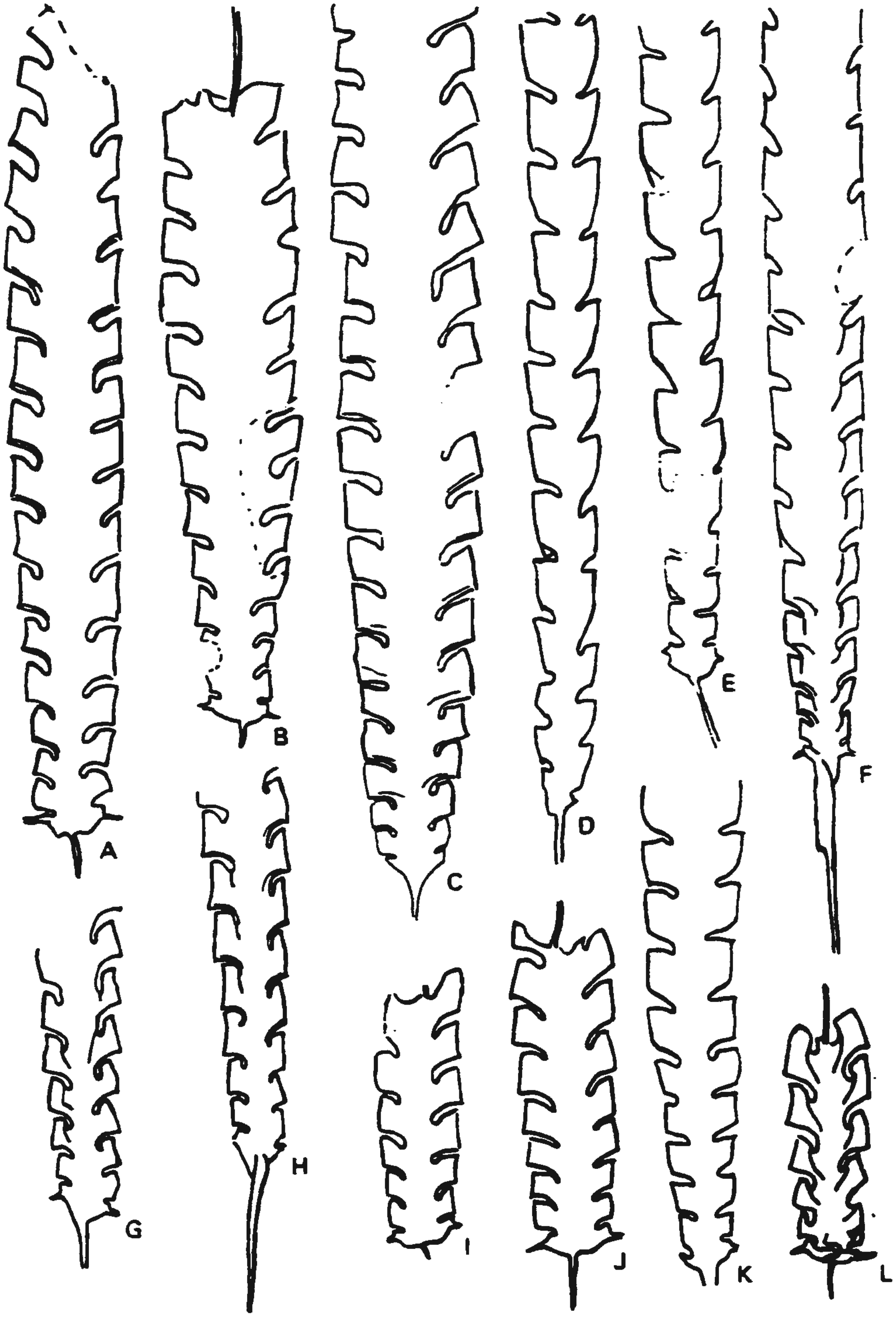
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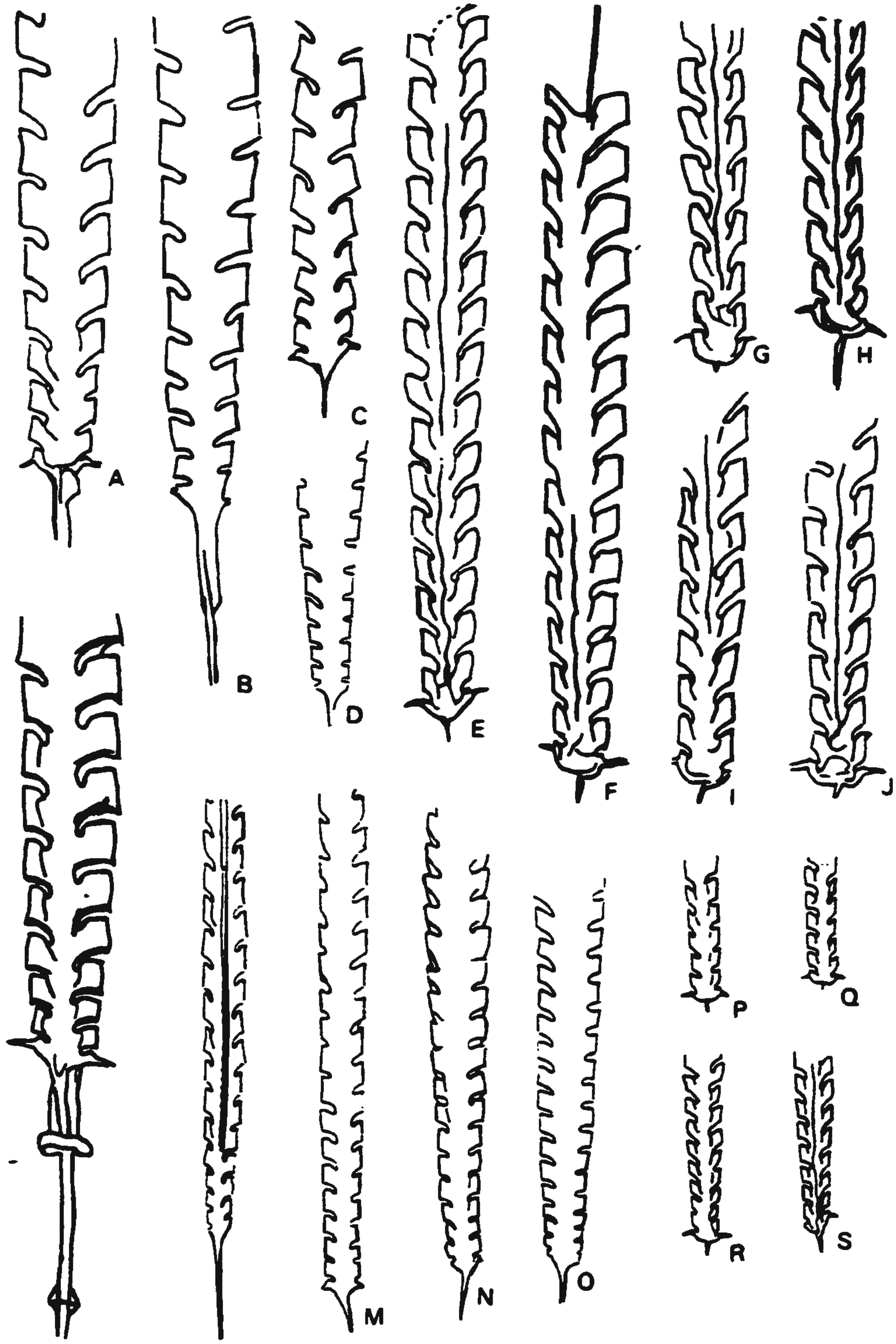
Figure 19: *Archiclimacograptus* sp. A. A: TP7 64, x10. B: TP5 25, x10. C: CC20 2, x10. D: CC145 10, x5. E: SC0.5 25, x10. F: SC2.5 11, x10. G: SC0.5 32, x10. H: SC0.5 16, x10. I: SC0.5 28, x10. J: SC0.5 25, x10. K: BCOT-M 10, x10. L: CC145 5, x5. M: CC190 5, x5. N: CC145 1, x5. O: CC190 4, x5. P: SC0.5 11, x5. Q: SC0.5 33, x5. R: SC0.5 3, x5. S: SC2.5 3, x5.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Most large specimens are incomplete, with the largest seen complete specimen measuring 8.5 cm in length. Most specimens are much smaller than this, however, rarely exceeding 1.0 cm in length.

Width is also highly variable between different specimens. Proximal width, measured at the base of the aperture of th1, ranges from 0.5 - 1.0 mm, whereas width at th5 is 0.75 - 1.6 mm. Maximum observed width reached 2.8 mm, with most specimens having a maximum width of under 2.0 mm.

Thecal densities are also highly variable within this sample. Thecae in 5 mm proximally number 5.5. - 9.0 (2TRD (th2-4) = 0.85 - 1.6), whereas thecae density distally is 4.5 - 7.0 in 5 mm (2TRD (th10-12) = 1.1 - 2.1). These wide ranges strongly suggest that *Archiclimacograptus* sp. A is actually a polyspecific assemblage. However, there is no apparent relationship between thecal density and any other rhabdosomal characters which would allow the separation of this sample into different species groups.

Most specimens possess a virgella, which is seen to measure up to 7.3 mm in length (Fig. 18 H). Most, however, do not exceed 2.0 mm. There are also spines associated with $th1^1$ and $th1^2$ in many specimens (Fig. 17 D). These rarely exceed 0.3 mm in length. Nearly all specimens possess slightly asymmetrical proximal ends, with $th1^1$ being at a slightly lower level on the rhabdosome than $th1^2$. Some specimens possess what appears to be a membraneous attachment between th1^2 and the virgella (Fig. 16 J; Plate 7, Fig. 2; Plate 8, Fig. 1), which could represent a 'hood' for the sicular aperture. Other specimens possess a distinct parasicula, up to 3.5 mm long (Fig. 19 B). A small number of heart-shaped structures have also been found. Some are attached, via the nema, to specimens of *Acrograptus* sp. A, but most are preserved as solitary fragments. The structures show a maximum width of 3.8-4.7 mm and a maximum length of 3.0-4.6 mm. They occur as little as 0.2 mm from the distal end of the rhabdosome, whereas unattached specimens are attached to nemal fragments greater than 4.6 mm in length. It is impossible to determine the true uncompressed shape of these structures, and there is no detail visible other than overall shape.

Some very general trends can be drawn regarding overall rhabdosome shape, insufficient for species designation but of use in describing this sample more precisely. These trends result in there being three main rhabdosomal morphologies in this material. It must be noted, however, that these are VERY general trends - several intermediates exist between each of these simplified groupings, thus making these divisions useful only for the sake of simplifying the description of this material. The first of these, morphotype A, possesses a relatively narrow rhabdosome (< 1.0 mm) and is parallel sided or widens slightly distally (< 1.5 mm in most, up to 2.0 mm in occasional large specimens). Thecae are straight or slightly sigmoidal in shape, with distinct geniculae and short, straight inverted apertures, sometimes possessing small lappets. Thecal length varies, constant in some specimens but increasing distally in most. Thecal density ranges from ~7 in 5 mm proximally (2TRD (th2-4) ~1.0) to ~5 in 5 mm distally (2TRD (th10-12) ~2.0). Thecal supragenicular walls are straight or curved slightly inwards at their distal ends. A median septum is visible in many of these specimens, ranging from nearly straight to zig-zagging with each thecal pair (Fig. 19 F).

The second rhabdosome form, morphotype B, is larger than morphotype A. These specimens have proximal ends reaching almost 1.5 mm in width. Rhabdosome width increases distally in these specimens, often exceeding 2.0 mm. Some narrow slightly towards the distal end, giving them a slightly fusiform shape. Most however, have a near-parallel sided appearance. Thecae are straight and simple, with inverted, straight apertures. Some specimens show slightly curved apertures, but no true lappets are seen. Supragenicular walls are straight and vertical, but are sometimes turned slightly inwards at their distal ends. Thecal densities are ~7.5 in 5 mm proximally (2TRD (th2-4) ~1.1) and ~6.0 in 5 mm distally (2TRD (th10-12) ~1.6) (Fig. 18 C).

Morphotype C is something of an intermediate between types A and B, including characters from both and incorporating other characters. These forms are relatively narrow proximally, <1.0 mm in width. They become wider distally, however, at a relatively regular rate. At th5, these specimens reach ~1.5 mm in width, and they reach a maximum width distally of >2.0 mm. Thecae are straight or slightly curved, and are often pointed slightly inwards. Thecal density is approximately 7.5 in 5 mm proximally (2TRD (th2-4) = 1.1) and approximately 6 in 5 mm distally (2TRD (th10-12) = 1.7). Thecal apertures are highly inverted, with well developed lappets. Many specimens of morphotype C possess the above-mentioned sicular 'hood' between the virgella and th1^2 (Fig. 18 H).

Remarks:

Much confusion currently exists with regards to diplograptid graptolite taxonomy, partially due to the overall similarity of many forms but also partly due to different approaches to diplograptid classification by different authors. This problem will hopefully soon be solved, due to the work of Mitchell (eg., 1987), who is currently revising the overall taxonomy of the diplograptids. This work will be based partially on diplograptid material collected from the same field sites used for this thesis.

As a result of this confusion, coupled with the difficulty of interpreting preservation, it is impossible to assign this material, or the components of it, to specific species. However, comparisons can be drawn between existing taxa and portions of this fauna. For example, J. Maletz (pers. comm.) has suggested the presence of four diplograptid species in the material discussed here. These are *Archiclimacograptus modicellus*, *A. riddelensis*, *A. decoratus* and *A. angulatus*. There appears to be good reason for the assignment of this material to these taxa, as they generally fit, relatively well, the broad morphotypes discussed here. Specimens of morphotype A, the narrow, sub-parallel to slightly widening specimens, could fit into either *A. modicellus*, *A. angulatus* or *A. riddelensis*. Several specimens of morphotype B could belong to *A. decoratus*. Some specimens of morphotype C could belong to either *A. angulatus* or *A. decoratus*. However, the problem is that each of these taxa, as they currently stand, is defined by specific morphological parameters, often overlapping between each other, which are not met by the sample of diplograptids discussed here. As mentioned previously, there are several general morphological groupings distinguishable in the material discussed here, but there are also many specimens which fit into a 'grey zone' of intermediate characters between these groupings. Therefore, it is impossible to assign these specimens to taxa which do not suitable account for the range of variation shown by this material. It is hoped by the author that the end results of the revision by Mitchell will result in a classification scheme for the diplograptids which avoids much of the overlap and personal interpretation which is so common in previous descriptions of diplograptid species.

It must also be remembered, however, that much of the confusion as to the identity of these diplograptids is a result of preservation and distortion of these specimens. It is not intended here to blame the difficulties in assigning this material to established taxa on the previous literature alone, as the diplograptid material itself is a great source of confusion as well.

Of interest is the presence of heart-shaped structures in this material, identical to those reported for *A. decoratus*. These structures indicate that specimens of *A. decoratus* are present in this sample. This seems likely, as many specimens fit well the descriptions of this species given by previous authors (e.g., Harris and Thomas, 1935; Cooper, 1979). There are, however, few such devices found in this material. Based on previous accounts of the high frequency with which this species has been reported from this material (e.g., Maletz and Mitchell, 1995), such structures would be expected to be relatively common at these localities. This is not the case in the present material: few of these heart-shaped structures are seen. This may be a preservational aspect of this structure, suggesting that it may not have preserved readily. It may also suggest, however, that there are few specimens of *A. decoratus* in the samples described here.

These heart-shaped structures may have served as flotation structures, allowing specimens to remain at a certain position or depth in the water column. They may also have been used in maintaining rhabdosome orientation.

A small number of diplograptid specimens have also been collected by S.H. Williams from the middle Table Point Formation at Point Riche (Williams *et al.*, 1987) and at Table Point. Although poorly preserved, these specimens appear to be the same as larger specimens of *Archiclimacograptus* sp. A. This suggests either deposition during the formation of the Table Point Formation was very rapid, with members of this 'species' surviving into the deposition of the later formations, or that this 'species' is a long lived one.

Subgenus Pseudoclimacograptus (Archiclimacograptus) Mitchell 1987

Type species: Pseudoclimacograptus angulatus sebyensis Jaanusson, 1960, pp. 330-331, pl. 4, figs. 5-9; text-fig. 7D.

Pseudoclimacograptus (*Archiclimacograptus*) *oliveri* (Boucek, 1973)

Pl. 5, figs. 3-4; text fig. 20 A-S

1953	*Climacograptus scharenbergi* Lapworth; Bulman, pp. 510-511, pl. 1, figs. 1-7, text-fig. 1.
1973	*Pseudoclimacograptus* (*Pseudoclimacograptus*) *oliveri* sp. n; Boucek, p. 121.
1987	*Pseudoclimacograptus* (*Archiclimacograptus*) *oliveri* Boucek; Mitchell, p. 177.

Type Material:

The holotype was designated by Boucek (1973) as specimen no. 2539, from Holm's Rigshospitalet and Sofianberg/Dalehaugen, Oslo, 4aa collection, as figured by Bulman (1953: Pl. 1 fig. 3; text-fig. 1A.).

Material:

Twenty-five specimens, mostly from the Black Cove Formation at the Black Cove Oil Tanks. Others from the Table Cove and Black Cove formations at West Bay Centre Quarry, Table Cove Formation at Table Point and Black Cove Formation at Spudgel's Cove. Most are preserved as heavily carbonized films which often peel away as complete or fragmented specimens from the shale matrix.

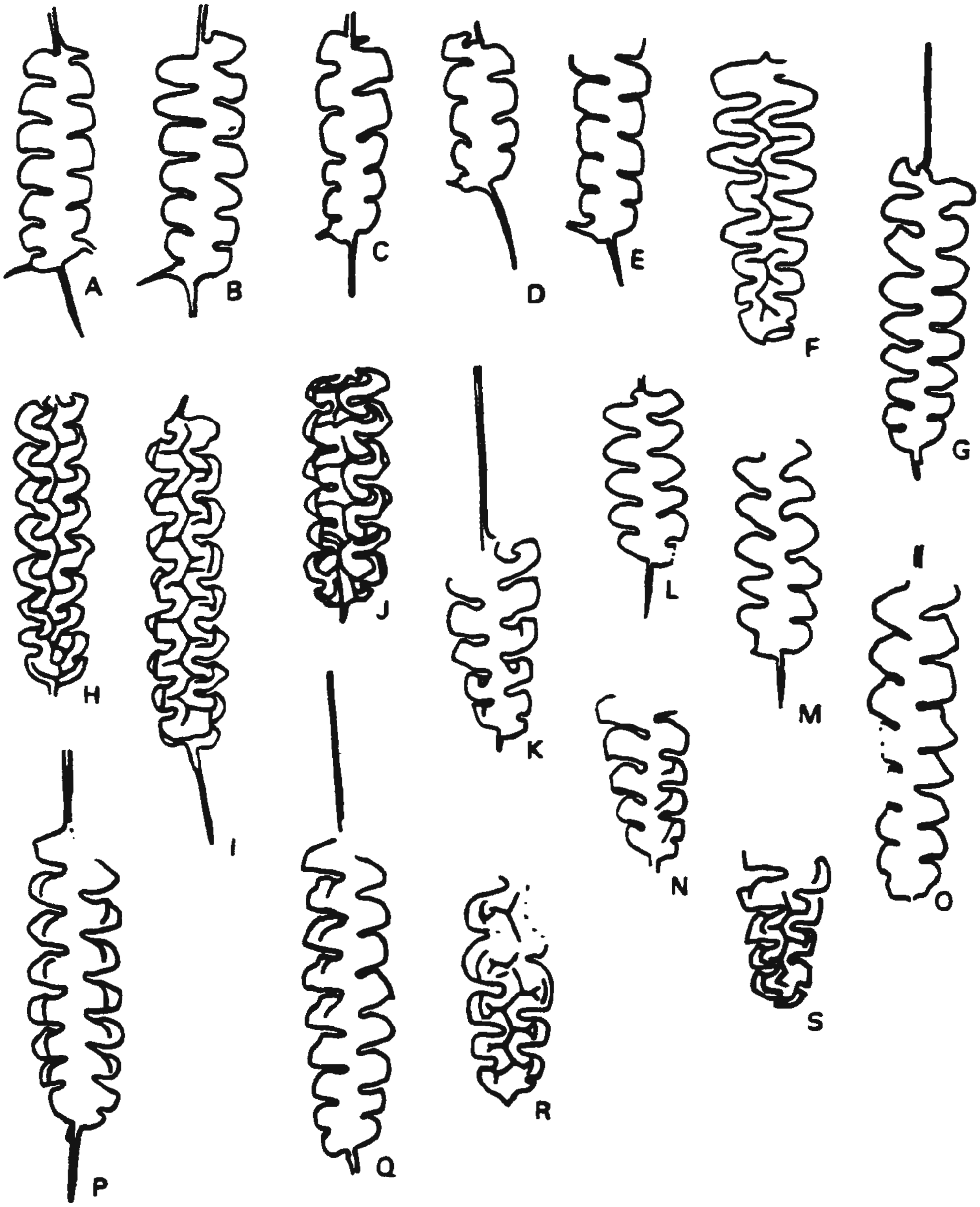
Description:

Rhabdosomes reach a maximum length of 4.1 mm. Proximally (between $th1^1$ and $th1^2$), width ranges from 0.65 to 0.85 mm, with nearly all specimens showing values of 0.7 - 0.8 mm. Width increases distally to 0.9 - 1.35 mm, most being between 1.0 and 1.25 mm. All specimens display a virgellar spine (or evidence of a broken spine) which reaches a maximum of 1.35 mm in length. Five specimens possess additional proximal spines; one of these (Fig. 20 A) has two spines, originating immediately below the apertures of both $th1^1$ and $th1^2$. They are 0.4 mm and 0.2 mm in length, respectively, the shorter one being apparently broken. In each of the other four specimens there is one thecal spine, originating from $th1^1$ and with lengths of 0.3 to 0.5 mm. Each of these proximal thecal spines projects from the thecal margin 70° - 120° from the longitudinal axis of the rhabdosome.

Thecae are pseudoclimacograptid in style with markedly curved, strongly geniculate lateral walls and sigmoidal form. Apertural excavations are deep and short, with little space between apertures and the adjacent geniculae. Due to the short length of specimens, thecal densities in 3 mm were measured: these show thecal counts of 5.5 - 7, suggesting high thecal densities of approximately 18 - 23 in 10 mm (2TRD th2-4 = 0.85 - 1.2, most between 0.9 - 1.0). 2TRD values for the distance between th1 and th3 showed a range of 0.8 - 1.0 mm, with most specimens being between 0.85 - 0.9 mm.

Specimens of *Pseudoclimacograptus* (*Archiclimacograptus*) *oliveri* possess a characteristic 'zig-zag'-shaped median septum, which begins at the level of the aperture of $th1^2$ and continues along the length of the rhabdosome to its distal end (Fig. 20 R). The angles of the median septum occur at approximately the middle of each theca. Interthecal septa extend from the outer margin of the these angles towards the thecal lateral margin. They extend approximately half the distance from the median septum to the lateral margin of the rhabdosome. These median septum extensions occur at the base

Figure 20: *Pseudoclimacograptus* (*Archiclimacograptus*) *oliveri* Boucek, 1973, x10. A: WBCQ12.6 23. B: WBCQ12.6 12. C: WBCQ14.9 21. D: WBCQ17.0 31. E: WBCQ17.0 43bR. F: WBCWBC-G 81. G: BCOT-G 34. H: BCOT-G 36. I: BCOT-G 4. J: BCOT-G 11. K: BCOT-GS 6. L: BCOT-M 33. M: BCOT-M 34. N: BCOT-T7 9. O: BCOT-M 111. P: bcot-M 40. Q: BCOT-M 69. R: SC5.0 18. S: SC2.5 7.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of new thecae. The sigmoidally curved thecae turn back upwards at the point of these lateral extensions of the medial septum, resulting in thecal apertures facing the distal end of the rhabdosome.

Several specimens possess an elongate narrow nema, which extends as far as 2.3 mm from the distal end of the rhabdosome (Fig. 20 P).

Remarks:

The specimens of *P. (A.) oliveri* described here are of some significance, in particular those specimens possessing thecal spines on $th1^1$ or $th1^2$. No previous description of this species has indicated the presence of such spines. To ensure the identification of this material, a comparison of Bulman's (1953) figures with the Newfoundland material has been carried out. This comparison shows that the characters here match almost perfectly with those of Bulman, although he described only four specimens, an insufficient sample size for a critical evaluation. An additional problem is that Bulman's figures of the proximal regions of these specimens only reach to th3, so the only 2TRD values available for comparison are those for th1-th3. Bulman's material suggests values of 0.8 -0.9 mm, whereas that described here show a range of 0.8 - 1.0 mm. Comparisons of proximal width also show nearly identical results, Bulman's material measuring 0.7 - 0.82 mm at th1 (the Newfoundland material measures 0.65

- 0.85 mm).

One difference, however, is the maximum widths given. Bulman (1953) showed only three distal fragments: one showed a maximum width of 1.05 mm, whereas the other two each possessed a width maximum of 1.65 mm. The smaller of the three specimens thus shows a maximum width similar to the material described here (1.0 - 1.25 mm), but the other two specimens are considerably larger. There is unfortunately no indication of what portion of the rhabdosome Bulman's distal fragments are from and it is therefore possible that they are from specimens longer than those described here. Since the material in this thesis showed a regular and continuous increase in width distally, it is likely that longer rhabdosomes than those described in the present study would be wider in their distal regions. Maximum width cannot, therefore, be used for critical comparison of the two sample sets.

P. (*A.*) *oliveri* is relatively easy to distinguish from other forms within both this and other similar subgenera. *P.* (*Pseudoclimacograptus*), with its Pattern D astogeny, possess a much narrower and more rounded proximal end than *P.* (*Archiclimacograptus*) (which has a Pattern C astogentic development), due in part to their different patterns of astogeny and the different location of dicalycal thecae on the rhabdosome, as discussed by Mitchell (1987).

Other members of the subgenus recognized by Mitchell

(1987) include (*Archiclimacograptus*) *angulatus sebyensis* (Jaanusson, 1960), which possesses many similar characteristics to *P.* (*A.*) *oliveri*, such as proximal rhabdosomal width, the presence of spines on th1^1 and th1^2, and the presence of a 'zig-zag' median septum. However, this species possesses thecae with less rounded lateral margins than specimens of *P.* (*A.*) *oliveri* and its thecal apertures are more introverted and possess pronounced lists.

Pseudoclimacograptus (*A.*) *luperus* (Jaanusson, 1960) has many characters in common with *P.* (*A.*) *oliveri*, such as thecal shape, thecal excavation type and the presence of a zig-zag medial septum. *Pseudoclimacograptus* (*A.*) *luperus*, however, possess longer thecae than *P.* (*A.*) *oliveri*, resulting in a lower thecal densities of 4.5 thecae in 3 mm proximally (cf. 5.5 - 7 thecae in 3 mm for *P.* (*A.*) *oliveri*). The shape of th1^1 also different in *P.* (*A.*) *luperus*. The base of th1^1 originates close to the sicula but is pointed proximally, such that most of the theca is free from contact with the remainder of the rhabdosome. The free part of this theca is highly curved, such that the aperture points towards the distal end of the rhabdosome. This species is easily recognized from *P.* (*A.*) *oliveri*.

Pseudoclimacograptus (*A.*) *angulatus angulatus* (Bulman, 1953) differs from *P.* (*A.*) *oliveri* in having a low thecal density (11-12 in 10 mm), highly inclined apertural excavations, introverted apertures and only slightly curved thecal ventral margins.

Family Orthograptidae Mitchell 1987

Genus Hustedograptus Mitchell 1987

Type species: Diplograptus uplandicus Wiman, 1895

Hustedograptus sp. A

Pl. 9, figs. 2-5; text figs. 21-22

cf.1960 *Glyptograptus* cf. *teretiusculus* Hisinger; Jaanusson, pp. 322-324, pl. 3, figs. 6-8; text-fig. 6B.

Material:

Nineteen specimens from throughout the black shales of the Spudgel's Cove exposure of the Black Cove Formation. Several are completely flattened, but some are pyritized and are preserved in relief.

Description:

Most specimens lack a complete distal end so maximum length is impossible to determine. Incomplete specimens have been seen in excess of 2.0 cm.

The rhabdosome possesses a highly non-symmetrical proximal end, apparently with Pattern A primordial astogeny (Mitchell, 1987), and th1^2 appearing at a higher position on the rhabdosome than th1^1. Most specimens possess a narrow virgella, showing a maximum length of 2.5 mm. Single spines, often robust, emerge from immediately below the aperture of both th1^1 and th1^2, with a maximum length of 0.5 mm. Some specimens possess a parasicula with a maximum length of 0.5 mm (Fig. 2F). There is also evidence of a prosicular hood (Fig. 21 F) on a few specimens. Proximal width ranges from 0.5 mm to 1.0 mm, with most being between 0.7 - 0.9 mm. Width at th5 also varies widely, with a range of 0.85 - 1.3 mm. The increase in width distally is gradual but continuous along the length of the rhabdosome in most specimens.

There is much variation in thecal detail and outline. Thecae often lack geniculae, but the thecal margin between the apertural excavation and the thecal free ventral margin is curved slightly outwards in several specimens. Thecae are generally straight, whereas some specimens possess sigmoidally curved thecae (Fig. 21 I). Apertural excavation style is variable, some being deep and wide whereas others are shallow and narrow. Thecal apertures range in style from straight to concavely curved, most often inverted but sometimes horizontal. Thecal density proximally is 5.0 - 8.3 in 5 mm (2TRD (th2-4) = 1.0 - 2.0), whereas distal thecal density in 5 mm is 4.5 - 6.8 (2TRD (th10-12) = 1.35 - 1.9).

Several specimens possess a well developed median septum, usually not appearing until th2. This septum is straight or gently undulating along the length of the rhabdosome (Fig. 21 A, I).

Figure 21: *Hustedograptus* sp. A. A: SC5.0 21, x10. B: SC5.0 11, x10. C: SC5.0 9, x10. D: SC5.0 22, x10. E: SC5.0 17, x10. F: SC5.0 10, x10. G: SC5.0 6, x5. H: SC2.5 6, x10. I: SC5.0 5, x10.

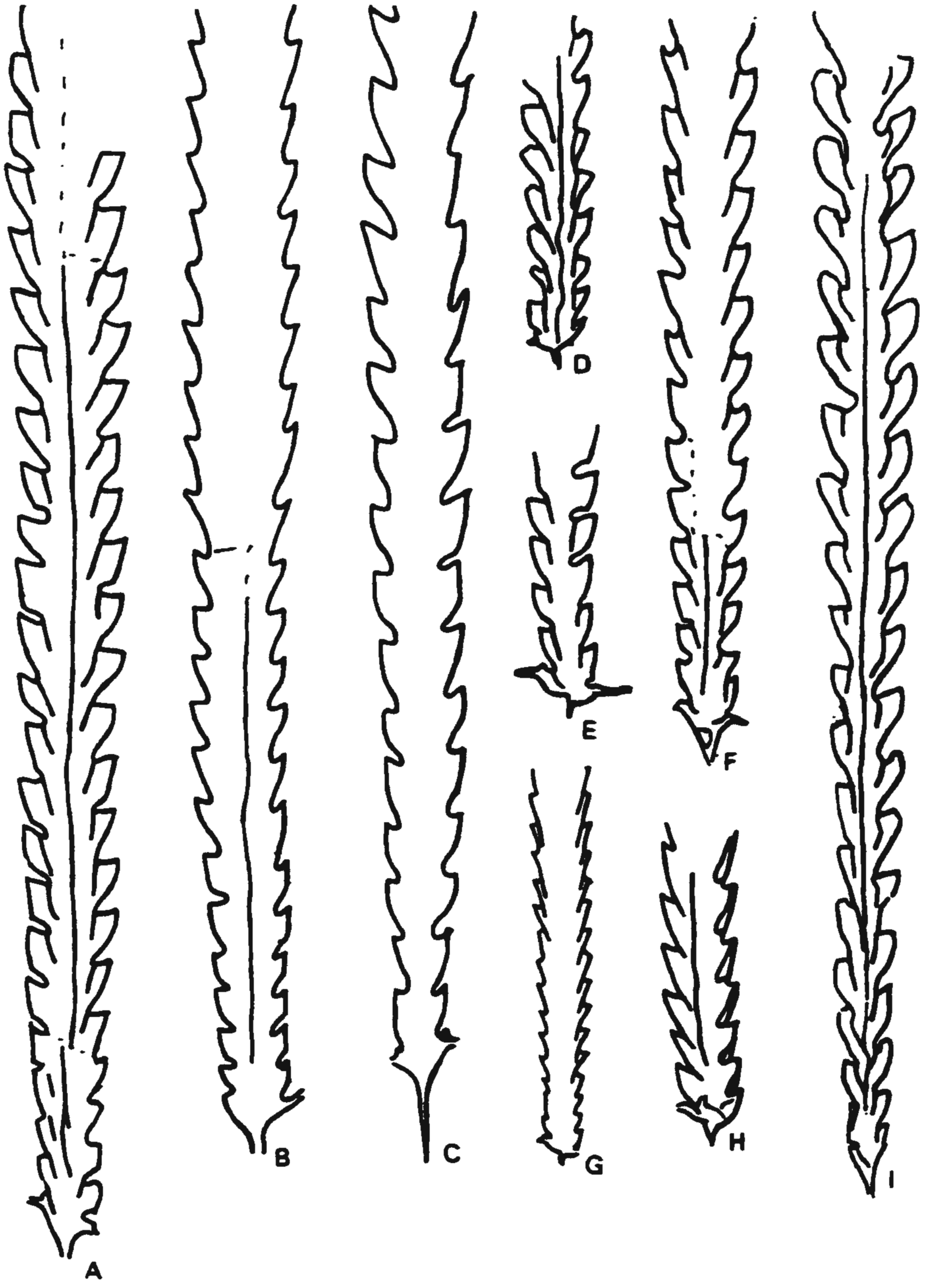
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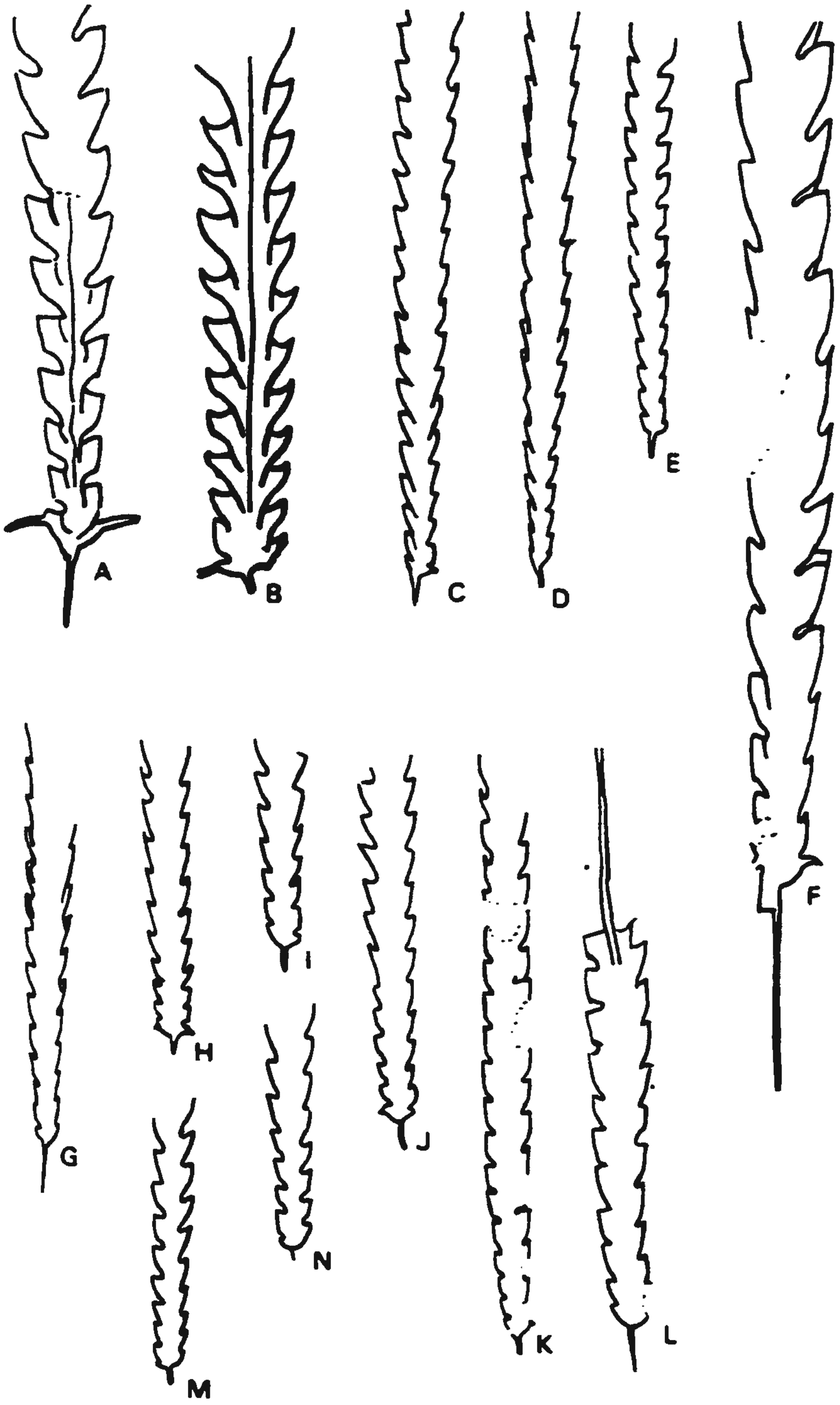
Figure 22: *Hustedograptus* sp. A. A: SC2.5 27, x10. B: SC2.5 7 (2), x10. C: SC8.0 5, x5. D: SC8.0 6, x5. E: SC8.0 7, x5. F: WBCQ12.6 25, x10. G: SC8.0 9, x5. H: SC0.5 12, x5. I: SC0.5 21, x5. J: SC0.5 11 (2), x5. K: WBCQ12.6 9, x5. L: WBCQ4.1 7, x5. M: SC0.5 11, x5. N: SC0.5 17, x5.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Remarks:

There is wide variation in characters within the group referred here to as *Hustedograptus* sp. A. This is most likely due to the possibility that, as with the 'species' *Archiclimacograptus* sp. A described in this thesis, this 'species' may actually contain members of more than one species. However, the low numbers of specimens available, the highly varied preservation and the uncertainty which currently exists with respect to diplograptid taxonomy make the classification of this material a task beyond the scope of this thesis.

Of note is the fact that three specimens from the Table Cove Formation of West Bay Centre Quarry (Fig. 22 F, K, L) also share the same general characteristics as *Hustedograptus* sp. A (eg, glyptograptid thecae, rhabdosome/thecal dimensions), with measurements which most often fall into the ranges seen for the material from Spudgel's Cove. They may not, however, represent members of the same 'species' seen at Spudgel's Cove. Only three specimens have been found from the West Bay Centre Quarry, and nineteen from Spudgel's Cove. The low sample numbers from West Bay Centre Quarry make it impossible to make any definite conclusions about the possible relationship between these two sets of specimens.

Family Cryptograptidae Hadding, 1915

Genus Cryptograptus Lapworth 1880

Type species: Diplograpsus tricornis Carruthers, 1858, p. 468, fig. 2.

Cryptograptus schaeferi Lapworth, 1880

Pl. 5, figs. 5-7; text fig. 23 A-M

1880	*Cryptograptus tricornis* (Carruthers) var. *schaeferi* var. nov.; Lapworth, pl. 5, figs. 28a, b.
1901-08	*Cryptograptus tricornis* var. *schaeferi* (Lapworth); Elles and Wood, p. 299, pl. 32, figs. 13a-c; text-figs. 201a,b.
1931	*Cryptograptus tricornis* var. *schaeferi* (Lapworth); Bulman, pl. 6, figs. 1-5; pl. 7, figs. 3, text-figs. 31a-c.
1933	*Cryptograptus schaeferi* (Lapworth) var. *latus* var. nov.; Bulman, p. 352, pl. 33, figs. 8a-c.
1937	*Cryptograptus tricornis* (Carruthers); Ekström, p. 39, pl. 9, figs. 1-5.
1937	*Cryptograptus tricornis* (Carruthers) var *longispinus* var. nov.; Ekström, p. 40, pl. 8, fig. 13
1937	*Cryptograptus lanceolatus* (Hadding); Ekström, p. 40, pl. 8, figs. 11, 12.
1960	*Cryptograptus schaeferi* (Lapworth); Berry, pp. 69-70, Pl. 12, figs. 7, 8.
1963	*Cryptograptus schaeferi* (Lapworth); Ross & Berry, pp. 96-97, Pl. 5, figs. 28,29.
1964	*Cryptograptus tricornis* (Carruthers); Berry, p. 117, pl. 9, figs. 1, 2a.
1964	*Cryptograptus tricornis* var. *schaeferi* (Lapworth); Berry, p. 117, pl. 11, figs. 7, 8.
1970	*Cryptograptus tricornis schaeferi* (Lapworth); Skevington, p. 418, figs. 6a-h, 7a-d.
1979	*Cryptograptus schaeferi* (Lapworth); Cooper, pls. 15d, jB; fig. 63.
1985	*Cryptograptus schaeferi* (Lapworth); Lenz & Chen, pl.3, fig. 2.
1986	*Cryptograptus schaeferi* (Lapworth); Strachan, p. 25, pl. 3, fig. 6, text-fig. 21.
1986	*Cryptograptus schaeferi* (Lapworth); Lenz & Jackson, p. 33, fig. 8P.
?1987	*Cryptograptus schaeferi* (Lapworth); Xu, Huang, Xiao & Xia, p. 103, Pl. 13, fig, 13.
1989	*Cryptograptus schaeferi* (Lapworth); Bjerreskov, fig. 6a.
1990	*Cryptograptus schaeferi* (Lapworth); Ge, Zheng & Li, p. 107, Pl. 39, figs. 5, 9, 11-13.
1995	*Cryptograptus schaeferi* (Lapworth); Williams, pp.

33-34.

Type Material:

The holotype is BU 1323, as figured by Elles & Wood (1901-1918), Pl. XXXII, fig. 15a. From Skiddaw Slates, Outerside, Keswick.

Material:

The majority of specimens were collected from the Table Cove Formation at West Bay Centre Quarry. Specimens were found in beds above the 6.0 m level of the exposure. Preservation is relatively consistent, with nearly all specimens being preserved in lateral view. Sclerotization is thin in all specimens, and many are incomplete.

Cryptograptus schaeferi was also collected from Piccadilly Beach, equivalent to the upper part of the Table Cove Formation at West Bay Centre Quarry. The Black Cove Formation at West Bay Centre Quarry, the Black Cove Oil Tanks and Spudgel's Cove have also yielded specimens of *C. schaeferi*, as has the Table Cove Formation at Table Point.

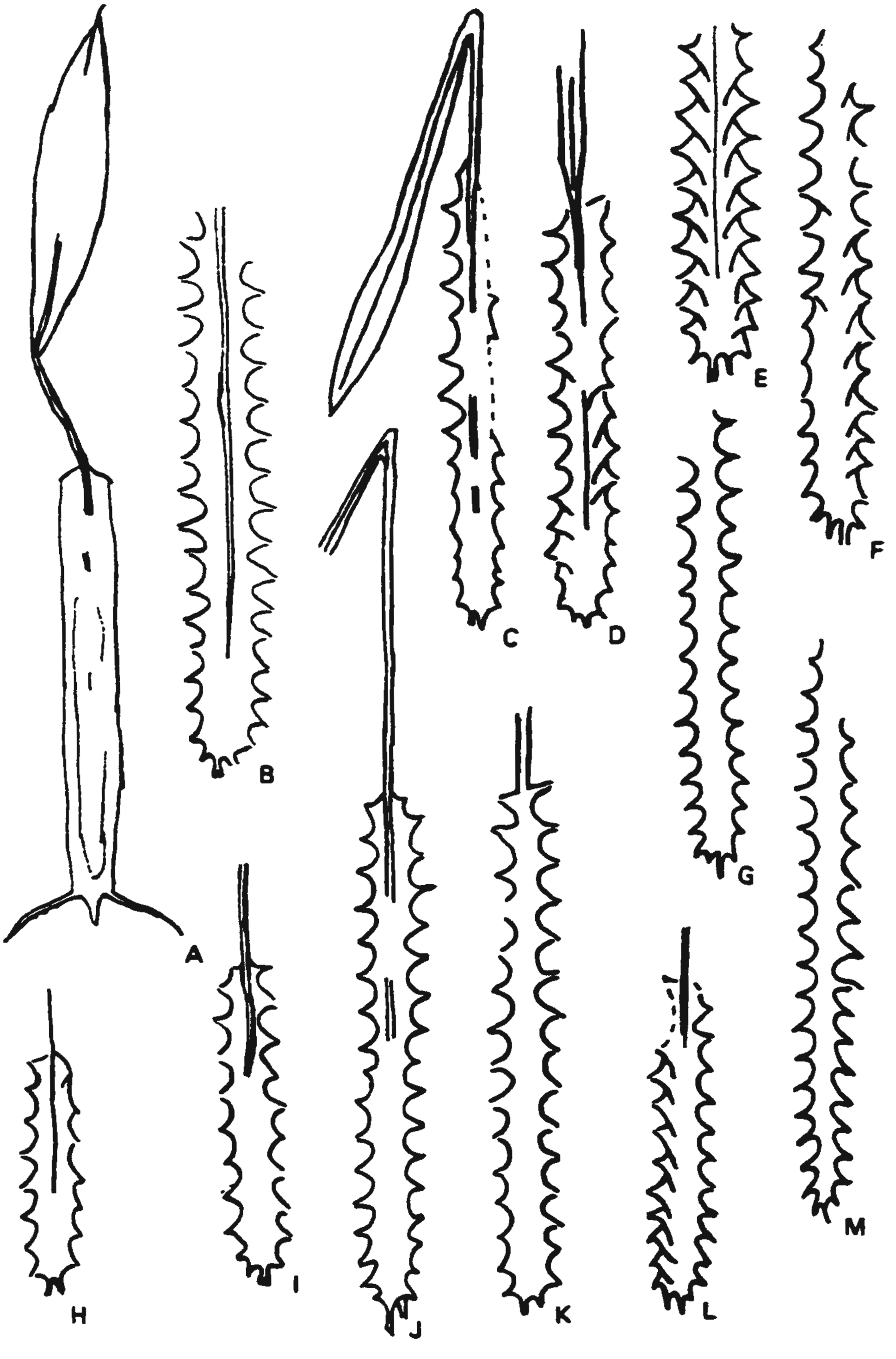
Description:

The rhabdosome is elongate, narrow and subfusiform to almost parallel-sided. Most specimens are preserved as thin films, suggesting a thin periderm in the original rhabdosome. Complete rhabdosome length ranges from 5.7 mm - 15.6 mm, with an average of 9.9 mm; many long but incomplete specimens are, however, also present in the examined material. Proximal width (at th2) averages 1.5 mm with a range of 1.15 - 2.1 mm, most specimens measuring 1.3 - 1.7 mm. The maximum width most commonly occurs midway along the rhabdosome, usually at th 7 -10, and ranges from 1.2 - 2.4 mm, with an average of 1.8 mm. Most are between 1.6 - 2.1 mm.

Thecae are straight or rarely slightly concave (Fig. 23 E), with everted apertures. The apertural structure commonly gives an appearance of broad-based spines to the lateral margin of the rhabdosome in specimens preserved in lateral view. This effect may be enhanced or reduced by the direction and/or degree of compression (Skevington, 1970) or by variable orientation of rhabdosomes during preservation (Williams, in press). Proximal thecal number is 11.5 - 15.5 in 10 mm, averaging 13.2, with most between 12.5 - 14.5 in 10 mm (2TRD (th 2-4) = 1.2-1.7). One specimen (Fig. 23 M) possessed an unusually high thecal count of 8.5 thecae in 5 mm (17 in 10 mm) proximally; this is most likely due to preservational deformation. Thecal density reduces distally to 8.5 - 14.0 in 10 mm, with most between 10 - 12 in 10 mm (2TRD (th 10-12) = 1.5-2.15). Two medial proximal spines are visible in lateral view, usually less than 0.5 mm and never exceeding 1 mm.

Few specimens are preserved in scalariform view; those present show three proximal spines, one median and two

Figure 23: *Cryptograptus schaeferi* Lapworth, 1880, x5. A: WBCQ6.0 5b. B: WBCQ10.2 2. C: WBCQ12.6 4. D: WBCQ 17.0 16. E: WBCQ17.0 25. F: PB2.9 33. G: SC2.5 31. H: WBCQ2.6 6R. I: WBCQ7.0 4-2. J: WBCQ16.0 1. K: WBCQ13.7 18. L: SC2.5 16. M: SC0.5 4.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lateral. The midspine, an elongated rutellum, is short and broad-based, 0.5 - 0.6 mm wide at the base and 0.6 - 0.7 mm in length. Only one specimen (Fig. 23 A) shows what appears to be a completely preserved pair of proximal lateral spines; these are 1.0 and 1.2 mm in length. Other specimens possess shorter, apparently incomplete, proximal lateral spines of 0.5 - 0.6 mm. Occasional rhabdosomes preserved in lateral view show portions of these proximal lateral spines, due to oblique preservation of the proximal end of the rhabdosome (Fig. 23 E, J). None of the laterally-oriented specimens observed in this study appeared to possess complete proximal spines, instead showing short, presumably incomplete, spines.

Several *C. schaeferi* specimens possess narrow, elongate nemal vanes with gently tapering distal and proximal ends (Fig. 23 A, C, D, J). These range in length from 5.0 - 13.6 mm, with a width range of 0.6 - 2.0 mm; they are preserved as thin films, suggesting originally thin sclerotization. The vanes appear as bi-lobed structures through which runs a thickened central band, approximately the same width as the regular nema. The distance of the vane from the rhabdosome varies greatly, from 0.2 mm to 8.4 mm. In specimens with no vane (presumably broken off from the rhabdosome), the nema projects from the distal end of the rhabdosome by over 11 mm. The nema is seen to extend through the rhabdosome in some specimens (Fig. 23 B), again indicative of thin rhabdosomal periderm.

Remarks:

Differentiation of different *Cryptograptus* taxa has long been a source of debate and disagreement. Several *Cryptograptus* species share many similar characteristics, and thus have been commonly confused in the literature. In particular, *C. tricornis* (Carruthers) and *C. schaeferi* (Lapworth) have commonly been the source of much contention.

Skevington (1970) provided a revised description of *C. schaeferi*, in which he stated the important defining characteristics of *C. schaeferi* (with respect to *C. tricornis*) were the presence of longer apertural processes, greater rhabdosome width and higher thecal density. Williams (in press), however, upon examination of the type series of *C. schaeferi*, came to the conclusion that the only true differences between *C. schaeferi* and *C. tricornis* are in the sicular form and the differences in rhabdosome orientation. *Cryptograptus tricornis* is most often preserved in scalariform view, with proximal spines visible but little or no detail of thecae. *Cryptograptus schaeferi* is most often preserved in lateral view, with thecal shape and frequency easily seen but with detail of the large proximal spines rarely evident in scalariform view specimens. In the material discussed here, only 3 of approximately 200 specimens are preserved in scalariform view, thus supporting the identification of this species as *C. schaeferi* as suggested by Williams.

However, not all of Williams' (in press) revisions for *C. schaeferi* agree with the material described here. Skevington originally claimed that *C. schaeferi* possessed a higher thecal count than did *C. tricornis*, namely 13-15 (from Skevington, 1970) and 10-12 (from Williams, in press) in 10 mm, respectively. The material described here matches more closely with the descriptions of *C. schaeferi* by Skevington (1970), possessing the high thecal counts of 11.5 - 15.5 (most between 12.5 - 14.5) in 10 mm proximally.

Another observation of note, based on the material described here, relates to rhabdosome width. Proximal width (at th2) ranges from 1.15 - 2.1 mm, with most falling between 1.5 - 1.7 mm. Maximum width falls into the range of 1.2 - 2.4 mm, with most between 1.6 - 2. mm. These are greater than the ranges given by either Skevington (1970) for *C. schaeferi* (1.2 - 2.2 mm, most within 1.4 - .6 mm) or by Williams (in press) (1.4 - 1.7) for *C. tricornis*. Williams states that these are sufficiently close to the values given by Strachan (1969) for *C. tricornis* ("maximum width 1.8, but typically narrower") that they cannot be used as a distinguishing character between the two groups. Thus, the large values seen in the material described here seems to be in contradiction with most other material, indicating a possible difference in the regional population compared to other *C. schaeferi* assemblages. However, as mentioned previously, these differences may also be accounted for by preservational biases in the local material, due to the ease with which *Cryptograptus* material may be altered during taphonomic processes.

There is a great deal of similarity between several of the different species of *Cryptograptus*, resulting in difficulties in correct identification. One example of this is *Cryptograptus inutilus* (Hall), which possesses many characters almost identical to *C. schaeferi*. For example, both of these species possess 10 thecae in 10 mm proximally, both achieve a maximum width of 2.5 mm, and both are subfusiform in shape. Thus, identification of material fitting somewhere between these two species may easily be confused. There are, however, differences between these two species which may allow for reliable distinction of well preserved material. The main difference is in thecal detail; in *C. schaeferi*, thecae are straight or only slightly curved whereas the thecae of *C. inutilus* appear to be invariably, gently curved. Probably the most noticeable difference, however, is in the style of thecal aperture and, as a result, the appearance of the lateral margins of the rhabdosome. In *C. schaeferi* the thecal apertures are curved, resulting in a series of broad-based apertural processes along the lateral margins of the rhabdosome with concave proximal and distal margins. In *C. inutilus* the thecal apertures extend at right angles from the axis of the rhabdosome, resulting in a series of lateral processes with concave proximal margins but with straight or only slightly curved distal margins (Hall, 1865; Ruedemann, 1904).

Cryptograptus antennarius (Hall) is another species which possesses many similarities to *C. schaeferi*. Thecal number (9 - 11 in 10 mm) and overall rhabdosome shape, including the presence of one central and two lateral spines in scalariform view, are very similar between these two species. However, *C. antennarius* possesses a maximum width of 3.5 mm, making it much larger than *C. schaeferi*. In addition, the lateral spines preserved in scalariform view reach 5 mm in length, much larger than those seen in specimens of *C. schaeferi* (which show a maximum length of 1.2 mm). At other times, however, specimens of *C.* (cf.) *C. antennarius* may be more difficult to distinguish from *C. schaeferi*. Williams and Stevens (1988) describe specimens of *C. antennarius* with scalariform widths of 2 mm and lateral spines reaching 3 mm in length. This makes these specimens smaller than Hall's type specimens, and more difficult to distinguish from *C. schaeferi*. The nearly straight thecae of *C. antennarius*, however, enable the distinction between these two species. It is of note, however, that the material described by Williams and Stevens (1988) is much smaller that the type specimens of Hall, indicating that they are probably younger specimens. This could account for the smaller size of the specimens of Williams and Stevens.

Family Glossograptidae Lapworth, 1873

Genus Glossograptus Emmons, 1855

Type species: Glossograptus ciliatus Emmons, 1855, subsequently designated Lapworth, 1873.

Glossograptus holmi (Bulman, 1931)
Pl. 9, figs. 6-9; text fig. 24 A-M

1931 *Glossograptus holmi* n. sp.; Bulman, p. 69-74; Pls. 8,9, text-figs. 32-36.
1963 *Glossograptus* cf. *holmi* Bulman; Whittington & Kindle, p. 754.
1969 *Glossograptus holmi* Bulman; Whittington & Rickards, pp. 800-817, Pls. 101-102, text-figs. 1-5, 11e.
1971 *Glossograptus holmi* Bulman; Erdtmann, pp. 1514, 1523.
1979 *Glossograptus holmi* Bulman; Finney & Skevington, p. 1900.
1986 *Glossograptus holmi* Bulman; Strachan, p. 24.
1994 *Glossograptus holmi* Bulman; Ni & Cooper, p. 162, 164.

Type Material:

Specimen 345 is given as holotype, as noted by Bulman (1931). Collected from Korpa, Bolivia, and kept in the Naturhistoriska Riksmuseum, Stockholm.

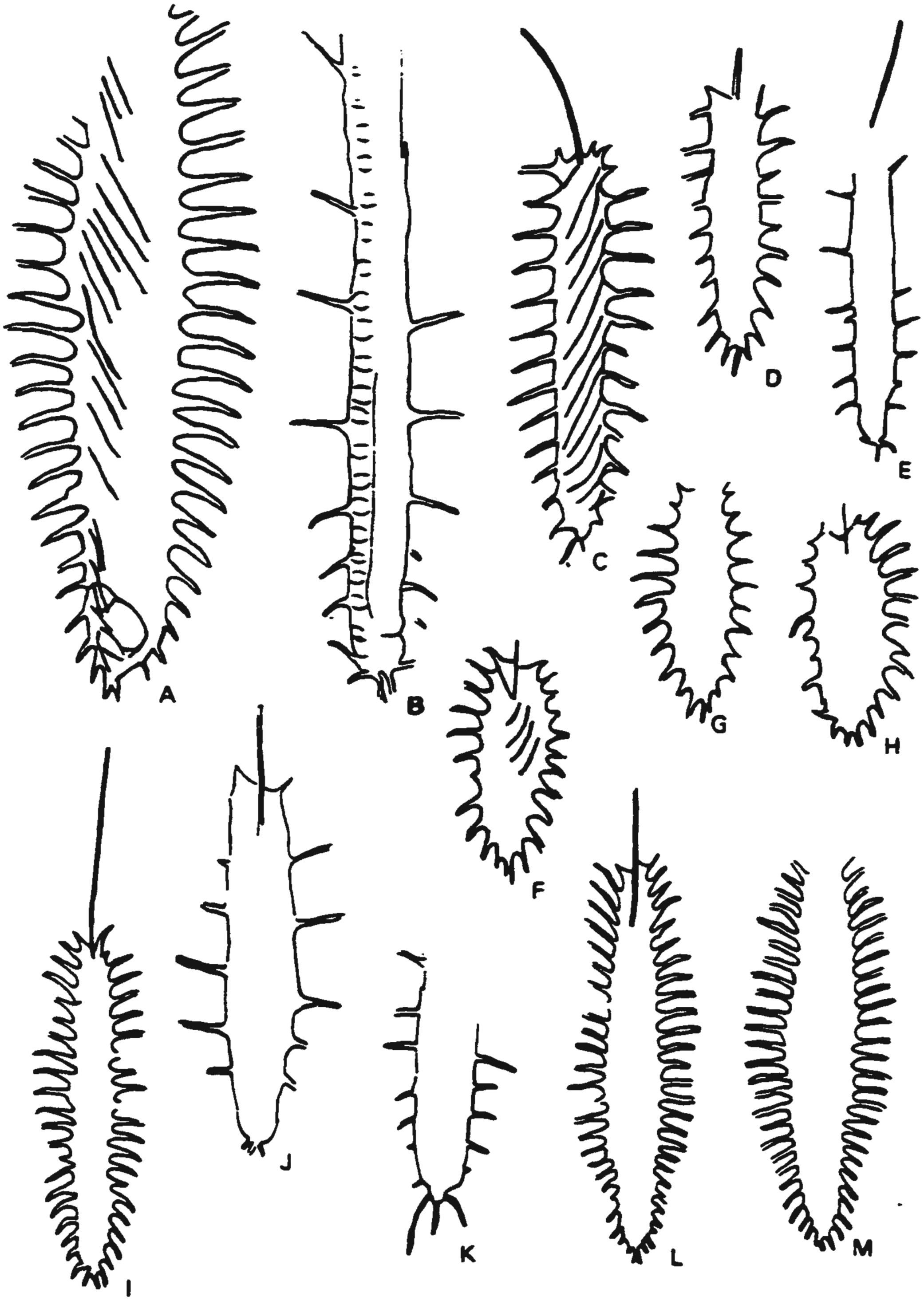
Material:

Over 100 specimens collected, most flattened and many incomplete, from the Black Cove Formation at Black Cove oil tanks, above West Bay Centre Quarry, and at Spudgel's Cove, and from the Table Cove Formation at West Bay Centre Quarry and Table Point. Occasional specimens from most localities display slight relief, whereas material from the upper intervals of the Black Cove oil tanks section show good relief. Material from West Bay Centre Quarry (both Black Cove and Table Cove formations) and Black Cove oil tanks is carbonized with little deformation. Material from Spudgel's Cove and Table Point has, however, been heated and is thus highly reflective. Most specimens are preserved in biprofile view, but scalariform preservation is also common.

Description:

Specimens are mostly preserved in one of two orientations; in biprofile view one of the two thecal series and thecal spines is visible (Fig. 24 A), whereas in scalariform view the rhabdosome is side-on, with associated lateral spines but with thecal detail rarely visible (Fig. 24 J). The overall shape of *G. holmi* in biform view is elongate with regularly spaced straight or slightly downward-curved thecal spines. These reach a maximum length of 3 mm, usually along the middle of the rhabdosome. Several of these biprofile specimens appear to be almost parallel-sided except for distinct narrowing at the proximal end (Fig. 24 C). Most, however, show a distinctly wider region in the centre of the rhabdosome with gradual narrowing at both the proximal and distal ends (i.e., a fusiform shape) (Fig. 24 M). Scalariform view shows specimens as elongate and nearly parallel-sided with rapid proximal narrowing, with larger and

Figure 24: *Glossograptus homli* Bulman, 1931. A: BCOT-M 89, x5. B: SC0.5 20, x5. C: SC0.5 48, x2.5. D: SC0.5 1, x5. E: SC0.5 19, x2.5. F: SC2.5 12, x5. G: SC2.5 17, x5. H: SC2.5 18, x5. I: BCOT-2mUES 10b, x2.5. J: TP7 34, x2.5. K: TP7 19r (3), x2.5. L: TP7 19R, x2.5. M: TP7 19R (2), x2.5.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less common lateral spines along the sides of the rhabdosome (Fig. 24 K). These spines are most often straight, reachinga maximum of 4.5 mm.

Some specimens, in particular those preserved in biprofile view, show a roughly circular bulge in the proximal region of the rhabdosome (Fig. 24 A). It occurs over approximately the first 2-4 thecae and often obscures proximal detail in that region. This bulge is particularly noticeable in specimens preserved in relief. This bulge, according to Whittington & Rickards (1969), is due to development of a series of thecae on both sides of the sicula.

Other proximal details are difficult to ascertain, due to both the complexity of the proximal structures and the compression of the proximal region. There is much variation, however, in overall proximal appearance, which is most likely due to preservational aspects such as the position of specimens (i.e., biprofile, scalariform or oblique) after deposition.

Mature rhabdosomes of *G. holmi* most commonly measure 15 -25 mm; smaller, immature examples are also present in most samples. The maximum width (excluding lateral spines) is usually found at the middle of the rhabdosome, ranging from 2.0 - 4.2 mm, with most specimens between 2.5 - 3.5 mm wide.

Thecal densities are higher at the proximal end of the rhabdosome. Thecae number 6 - 9 in 5 mm proximally, with most specimens possessing 7 - 8 in 5 mm (2TRD [th2-th4] = 1.1-1.7). The thecal density reduces distally, with only 5.0 - 7.0 thecae in 5 mm in the distal portion of the rhabdosome. Most specimens possess between 5.5 - 6.5 thecae in 5 mm distally (2TRD [th10-th12] = 1.1-1.8; 2TRD [th20-th22] = 1.2-2.1). At the distal end of the rhabdosome, thecal density again increases, due to the presence of immature thecae closely associated with each other. This is evident usually in the 3-4 most distal thecae (i.e, the growing tip of the rhabdosome).

Lateral spines also appear to be more common in the proximal region of the rhabdosome (Fig. 24 B). Unfortunately, it is not possible to directly relate these proximal spines to proximal thecal number as thecal detail is not visible in the specimens showing these lateral spines.

Other proximal spines are visible on some specimens of *G. holmi*. Those preserved in biform view often show a pair of short (<1 mm) spines located at the centre of the proximal end of the rhabdosome (Fig. 25 J, L). In many cases these spines appear to project from a short proximal 'process', presumably the sicular/th1 aperture. Thus, these spines are most likely a rutellum extending from the sicula and a parallel-developed th^1 spine. Unfortunately, these spines cannot be identified with any certainty due to the flattened nature of most specimens, which obscures a great deal of proximal detail.

Specimens preserved in lateral view sometimes show proximal spines of different orientation. These spines, often close to 2 mm in length, are irregularly numbered and aligned. In some specimens two proximal spines occur, which project from the proximal end and immediately turn distally, in a fashion similar to that of the lacinia of an archiretiolitid or *Paraglossograptus.* However, none of these spines are seen to come into contact with other parts along the rhabdosome or with other spines at any point along their length. Less common but still present are more irregular spines. Some project from the proximal end of the rhabdosome at the same region as the other proximal spines discussed above, projecting vertically downwards (Fig. 24 K). Others project perpendicular from the sides of the rhabdosome (Fig. 24 E). Some rhabdosomes also possess numerous proximal spines projecting in several directions. Such specimens, however, are uncommon and do not seem to be a major part of the population.

Remarks:

Previous descriptions of *Glossograptus holmi* (Bulman, 1931; Whittington & Rickards, 1969) discussed the frequency of lateral and thecal spines with respect to thecal density. In these reports, lateral spines were reported to occur in association with each of first 2-4 proximal thecae and with every second theca along the remainder of the rhabdosome. In addition, thecal spines were reported to occur with each theca. Neither of these views is, however, fully supported by the material described here. Thecal spines occur in this material at a rate of one spine per theca, in agreement with the previous descriptions. The same is not true for the lateral spines; these seem to be more common proximally in material preserved in scalariform orientation, but do not appear to be associated with individual theca. In fact, one specimen showing lateral spines and some detail of thecal apertures shows what appears to be the first three proximal lateral spines associated with every second theca (Fig. 24 B). Distal lateral spines appear to be more in agreement with previous observations, with these lateral spines apparently occurring at frequencies of 3-5 thecae. Direct observation does not agree with the lateral spine distribution given in previous descriptions of *G. holmi*. As mentioned previously, most specimens possess 7-8 thecae in 5 mm proximally. Thus, if the material discussed here agrees with that of Bulman (1931) and Whittington & Rickards (1969), there should be one lateral spine with each of the first 2 to 4 thecae, and one associated with every fourth theca afterwards. Also, over the course of 7 - 8 proximal thecae, there should be 4 - 6 lateral spines present (in 5 mm). If the specimens preserved in scalariform view are examined, it can be seen that the actual number of lateral spines in 5 mm range from 1.7 to 4.1. Thus, it appears that there are fewer lateral spines present than would be expected. It is here concluded that this feature is related to preservation of the proximal spines. As mentioned previously, these spines can be quite long, up to 4.5 mm; it seems possible that they would be more likely to be damaged and thus not preserved, and many specimens exhibit incomplete sets of proximal spines. In addition, damage may have occurred during collection of the material, with some spines possibly left behind on the counterparts of the slabs containing these fossils. If the spines were hollow, as suggested by Whittington and Rickards (1969), they would have been even more likely to break during deposition and/or burial.

Specimens preserved in biprofile view often bear a remarkable similarity to *Glossograptus acanthus* (Elles & Wood 1901-18), (e.g., Harris & Thomas (1935), Cooper (1979)), as discussed by Bulman (1931). These specimens of *G. acanthus* possess the same fusiform shape, with similar rhabdosome size and thecal counts to many of the specimens of *G. holmi* described here. The main distinguishing feature separating *G. acanthus* from *G. holmi* is that *G. acanthus* has not been recorded in scalariform view, and no trace of lateral spines have been found in association with this species (Harris & Thomas, 1935; Cooper, 1979). This raises the question of whether material described as *G. holmi* may actually belong to *G. acanthus*.

It must be remembered, however, that the ranges of both size and shape for *G. holmi* are quite wide. This broad range in size and shape could result in an overlap in range of the same features with the closely related *G. acanthus*, resulting in confusion between the two species. In such a case, only the presence of scalariform specimens would allow the identification of the material in question as *G. holmi*, which otherwise might be identified as *G. acanthus*.

Another problem relating to the specimens of *G. holmi* described here is with regards to the material collected from the Black Cove Formation at Spudgel's Cove. The glossograptids from that site, numbering only 5, includes specimens which are smaller than those collected in the other regions discussed here. Whereas rhabdosome length reached a maximum of 25 mm in specimens from other localities, those collected from Spudgel's Cove reached a maximum of 10.5 mm. Similarly, glossograptid maximum width is less at Spudgel's Cove than at other localities: 1.8 mm is the maximum seen at Spudgel's Cove, whereas material from the other sites show a maximum width of 3.5 mm. Thecal densities are also slightly higher in the Spudgel's Cove glossograptid material. The question arises as to whether or not these glossograptids are the same as the specimens of *G. holmi* seen at the other localities. The small size of these specimens may suggest that only immature specimens have been examined from this locality. It may also suggest the presence of a different, smaller species of *Glossograptus* preserved at this locality.

However, although these specimens appear to be generally smaller than the other examples of *G. holmi* discussed, their overall rhabdosome characteristics are closer to *G. holmi* than to any other glossograptid species yet described. Only with the collection and description of additional specimens from Spudgel's Cove would it be possible to determine whether this sample of glossograptids is conspecific with *G. holmi*, or if it is sufficiently different to warrant classification as a different taxon. These differences may lead support to the conclusion that the Black Cove Formation at Spudgel's Cove is actually a different age than the other localities reported to be from the Black Cove Formation.

Glossograptus microconlgomeratus (sp. nov.)
Pl. 10, figs. 104; text fig. 25 A-Q

?1986 *Glossograptus* cf. *hystrix* (Ruedemann), Lenz & Jackson; p. 33; fig. 10B.

Type Specimen: The holotype is WBCQ10.2-2 (Fig. 25 C). From the Table Cove Formation, West Bay Centre Quarry.

Derivation of Name:

From *mikro* (Greek), meaning small or little and *conglomeratus* (Latin), meaning crowd or concentrated. In reference to the small size of the rhabdosome in comparison to other glossograptid species and to the closely associated spines, in particular the proximal spines of several specimens.

Diagnosis:

Small, slender, biserial rhabdosome of uniform width. Periderm poorly sclerotized. Almost all specimens preserved in scalariform view, showing two rows of elongate, narrow lateral spines, pointed downward proximally but horizontal for most of the length of the rhabdosome. Spines are dense, occurring at a rate of approximately 5 in 2 mm. Maximum spine length observed is 1.7 mm.

Material:

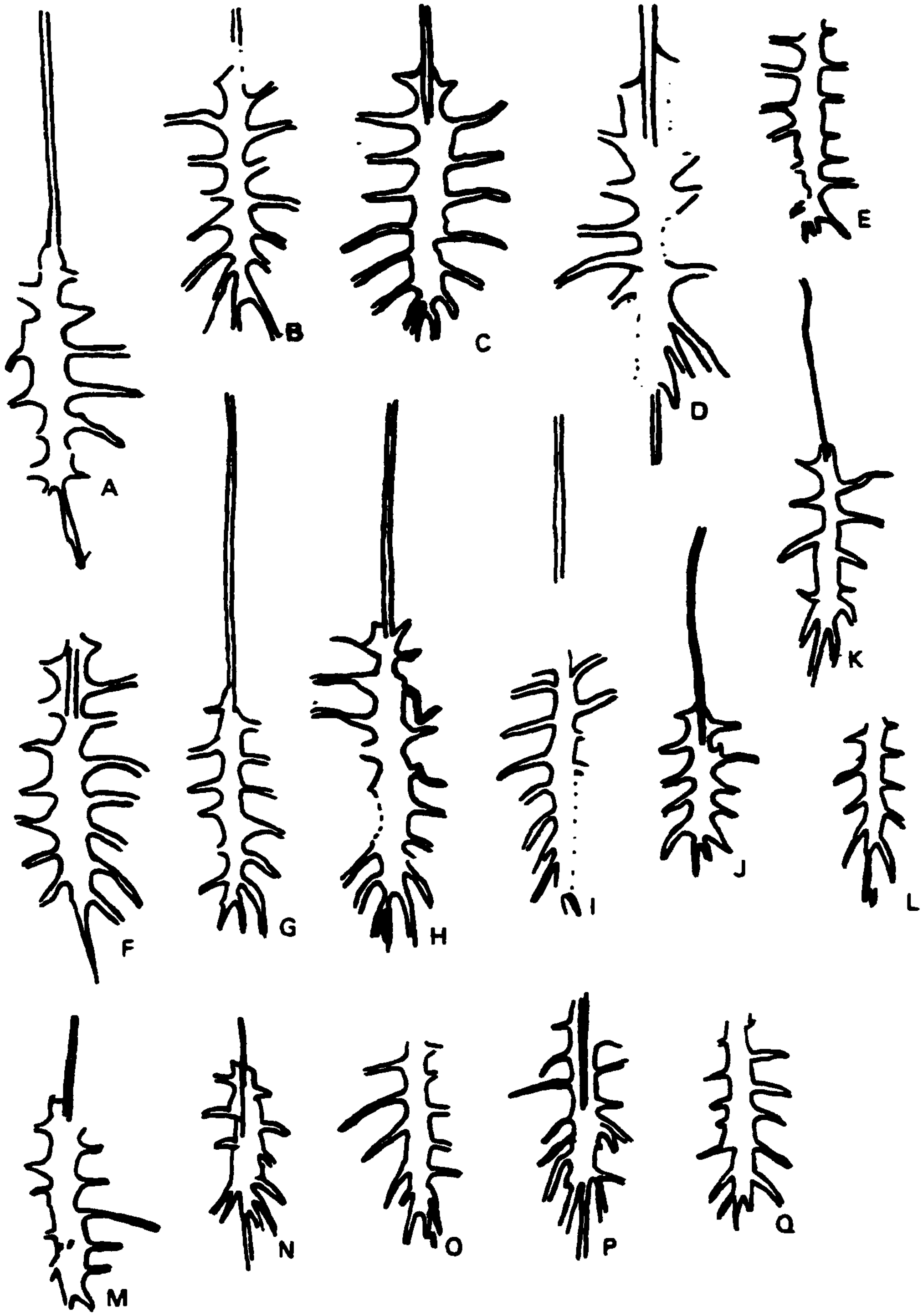
60 fully flattened specimens collected from the Table Cove Formation at the West Bay Centre Quarry and from equivalent levels at the Piccadilly Beach exposure.

Description:

All the specimens are preserved in scalariform view, and thecal detail is not visible. Thus, little information can be determined with respect to thecal detail or frequency. Neither is there any visible evidence of sicular detail.

There are, in well preserved specimens, two proximal spines which seem to be attached to the rhabdosome at its most proximal point (Fig. 25 C, H). This unique arrangement sometimes gives them the appearance of being attached to the

Figure 25: *Glossograptus microconglomeratus* sp. nov., x10. A: WBCQ9.1 35R. B: WBCQ9.1 10. C: WBCQ10.2 2. D: WBCQ10.2 21. E: WBCQ13.7 4. F: WBCQ14.9 23. G: WBCQ14.9 45b. H: WBCQ16.0-2. I: WBCQ17.0-72A. J: PB2.9 21b. L: PB2.9 36. M: PB2.9 83. N: PB2.9 67. O: PB2.9 46. P: PB2.9 84Rb. Q: PB2.9 36.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rhabdosome via a short proximal process, possibly a split rutellum. The spines point almost straight downwards, as do the next set of spines (usually approximately 0.2 to 0.3 mm distally along the rhabdosome). In most specimens the next one or two sets of spines also are angled proximally, but to a lesser degree than the earlier spines. Along the majority of the remainder of the rhabdosome, however, the spines project almost horizontally.

The rhabdosome itself is small, the largest complete specimen seen measuring 5.0 mm in length. Width is uniform, the maximum observed being 0.6 mm. Most specimens are, however, much smaller, with the average lengths of approximately 3 mm and average width of 0.4 mm. All specimens are very thinly preserved as light beige films on the shale surface, indicating a very thin periderm with little secondary cortical material.

The lateral margins of the rhabdosome are roughly parallel, with narrow, elongate spines projecting out at fairly regular intervals of approximately 0.4 mm. These spines are most often straight, but are occasionally "droopy" either proximally or distally on the rhabdosome with no apparent regularity (Fig. 25 F, I). They reach an observed maximum length of 1.7 mm, whereas width rarely exceeds 0.1 mm. These spines are often darker than the periderm of the rhabdosome, indicating that the spines of *G. microconglomeratus* may have been composed of thicker material, and thus been more rigid, than the walls of the rhabdosome itself.

In a few specimens, there is evidence for a different form of spine. These are broad-based and taper gradually to a point, giving them an almost triangular appearance (Fig. 25 A, F). These spines are shorter than the scalariform spines, less than 1 mm in length. At points where these spines are visible, the thickness of the rhabdosome appears to be slightly higher than in areas where they are not visible. Due to these differences in spine shape and size and the characteristics of the rhabdosome where these spines are visible, these spines are interpreted as possibly being apertural spines. Other species of *Glossograptus* (e.g., *Glossograptus holmi*) possess such broad-based spines, which are interpreted as extensions of the thecal apertures or, more commonly, as thecal spines. This interpretation is followed here. No true thecal detail, however, is visible in association with these spines.

Some specimens show local dense accumulations of spines areas, particularly in the proximal region of the rhabdosome (Fig. 25 N, A). These are interpreted as thecal spines (or fragments of the same) visible in addition to the usual scalariform spines. Such specimens are almost impossible to describe precisely, due to the irregular nature of spine orientation and frequency in these specimens. Some of the complexity of the proximal spines which can occur in glossograptids is suggested by Finney (1978, Fig. 3f), in which four proximal 'spines' can be seen in a sicula-th^1 juvenile specimen of *Glossograptus ciliatus*. This complexity if further enhanced if one considers the phylogenetic classification scheme presented by Fortey and Cooper (1986), in which the Superfamily Glossograptacea is not considered to belong to the suborder Virgellina. Thus, among the proximal spines of the glossograptids there is no virgella, meaning that the complex array of spines found of specimens of *G. microconglomeratus* become even more difficult to interpret.

Many specimens of *G. microconglomeratus* possess an elongate nema, in some specimens extending as far as 7 mm from the distal end of the rhabdosome.

Remarks:

Glossograptus microconglomeratus sp. nov. is a fairly typical glossograptid in its highly spinose appearance. It is atypical, however, in its very small size, which is apparently unique for this genus. For example, *G. holmi* is seen to exceed lengths of 25 mm (this thesis), whereas *G. microconglomeratus* sp. nov. has not been observed greater than 5 mm in length.

Glossograptus microconglomeratus sp. nov. is also unusual in its spine length relative to rhabdosome size. Long spines are common in other species of *Glossograptus*, but such species usually have larger rhabdosomes. For example, *Glossograptus acanthus* possesses spine commonly reaching lengths of approximately 4 mm on specimens in which the rhabdosome measures 4 mm in breadth (Elles & Wood, 1901-1918). In *G. microconglomeratus* sp. nov., however, the relative spine-to-rhabdosome size is much higher: specimens less than 0.5 mm in width often possess spines greater than 1 mm in length. This reduction in rhabdosome size is almost reminiscent of the rhabdosome reduction seen in the Silurian retiolitids, in which rhabdosome sclerotization was greatly reduced.

Lenz & Jackson (1986) identified a specimen as "*Glossograptus* cf. *hystrix*" from the Llanvirn in the Canadian Cordilleran. It measures 7.6 mm long and has a maximum width of 0.8 mm, with spines measuring up to 1.6 mm in length and spine spacing similar to that of *G. microconglomeratus* sp. nov.. This specimen also possesses what appears to be different types of spines, some narrow and elongate with others slightly shorter and broad-based. This specimen, although slightly larger than the material described here, is in closer agreement with the description of *G. microconglomeratus* presented here than with *Glossograptus hystrix* as described by Ruedemann (1904). Although it is larger in size and is incomplete, the overall appearance is very similar to that of *G. microconglomeratus*. It is, therefore, listed here, tentatively, as a possible specimen of *G. microconglomeratus* sp. nov..

Genus Paraglossograptus Mu, 1959

Type species: Graptolithus tentaculatus J. Hall, 1858, pp. 167-168.

Paraglossograptus proteus (Harris & Thomas, 1935)

Pl. 10, figs. 5-8; text fig. 26 A-E

1935	*Lasiograptus (Hallograptus) proteus* sp. nov., Harris & Thomas; p. 305, Fig. 1, 12a-b, Fig. 2, 30-33.
1935	*Lasiograptus proteus* Harris & Thomas; Harris, p. 332.
1960	*Lasiograptus (H.) proteus* Harris & Thomas; Thomas, pp. 31, 87, pl. 6, fig. 87.
1962	*L. (Hallograptus) proteus* Harris & Thomas; Mu, Lee, Geh & Yin, p. 97.
cf.1966	*Paraglossograptus etheridgei* Harris; Morris & Kay, Text-fig. 4I.
1969	*Paraglossograptus* ? sp.; Whittington & Rickards, pp. 809-812, Text-figs. 6b, 7, 8, 11f.
1972	*Paraglossograptus proteus* Harris & Thomas; Rickards, pp. 108-111, text-fig. 2c-d.

Type Material:

Geological Survey of Victoria, Australia, no. 37432; figured by Harris & Thomas, 1935, fig. 2, no. 30.

Material:

Seven specimens, one from the Black Cove Formation exposure at the Black Cove Oil Tanks and the remaining six from the Table Cove Formation at West Bay Centre Quarry.

Description:

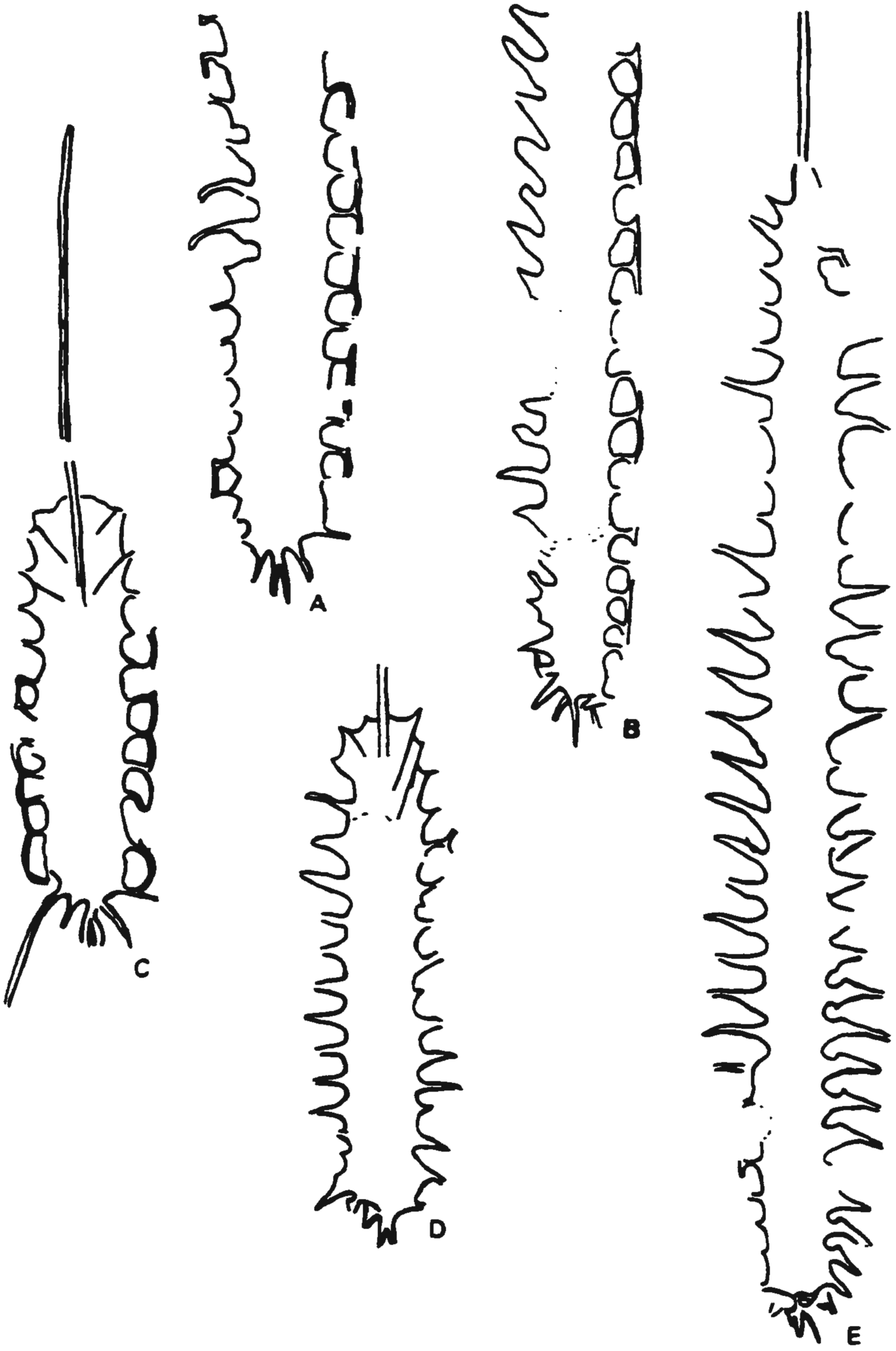
The specimens of *P. proteus* examined in this study are all completely flattened, and are preserved as thick but delicate black films which fracture or peel easily from the shale surface. They reach a maximum observed length of 29.0 mm, whereas the smallest complete specimen measured 10.2 mm. All specimens are relatively narrow, with a maximum width range of 1.6 - 2.2 mm (excluding spines). Width is very consistent along the length of the rhabdosome after a rapidly widening, almost rounded, proximal end. An elongate, narrow nema is present on several of the specimens examined here, the longest measuring 9.3 mm in length beyond the distal end of the rhabdosome.

Thecae are spaced 11 - 14 in 10 mm proximally (5.5 - 7.0 in 5 mm; 2TRD th$^{2-4}$ = 1.3 - 2.0) but are more widely spaced distally on the rhabdosome, numbering 10 - 11 in 10 mm (5.0 -5.5 in 5 mm; 2TRD th$^{10-12}$ = 1.8 - 2.0; 2TRD th$^{18-20}$ = 2.1) No thecal detail is visible on the material described here.

The lateral margins of the rhabdosome are characterized by a well developed lacinia (Fig. 26 C). The lacinia appears to envelop the rhabdosome on the margins perpendicular to the thecal apertures.

In addition to the lacinia, *P. proteus* possesses 'apertural ventral processes' (Rickards, 1972) which are actually extended thecal apertures (Fig. 26 E). Proximally on the rhabdosome, these processes point down and out. Further along on the rhabdosome, they point in a direction

Figure 26: ***Paraglossograptus proteus*** Harris and Thomas, 1935, x5. A: WBCQ11.2 3. B: WBCQ12.6 5. C: WBCQ4.1 11. D: WBCQ13.7 40R. E: WBCQ13.7 38.


A
B
C
D
E

perpendicular to the rhabdosome as a whole. The more distal thecal processes point distally, away from the far end of the rhabdosome. The longest process seen in this material extends 2.0 mm from the inner apertural margin.

There are several additional spines or processes associated with the proximal end of the specimens of *P. proteus* described here (Fig. 26 A, C). Although difficult to interpret in some specimens, there appears to be 2-3 distinct pairs of elongate spines associated with the proximal end. The central pair occurs at the centre of the proximal end of the rhabdosome, and appears to be joined at its base. There were, most likely spines which originally pointed perpendicular to the main plane of the rhabdosome; in association with the first thecal pair. Thus, when the colonies died and were deposited on their widest surfaces, these spines would have pointed into and out from the sediment. As these specimens were flattened, the spines took on the appearance of sharing a common basal point of attachment to the rhabdosome. The second (and, sometimes, third) pairs of proximal spines/processes are also directed towards the proximal end of the rhabdosome, although at a higher angle to the line of the rhabdosome than the first pair of proximal spines. Distal to this point the spines are perpendicular to or point slightly towards the distal end of the rhabdosome, as discussed above. The longest such proximal spine seen in this material measured 3.4 mm in length.

Remarks:

Rickards (1972) provided an overview of the species of *Paraglossograptus*. He grouped many Chinese species, such as *P. typicalis* and *P. latus*, into the single species *Paraglossograptus tentaculatus*. Aside from *P. proteus*, the genus *Paraglossograptus*, therefore, contains the species *P. tentaculatus* (Hall) and *P. tricornis* (Mu, Geh & Yin). Both of these species can be easily distinguished from specimens of *P. proteus*. Specimens of *P. tentaculatus* possess a distinctly wider region at the centre than either the proximal or distal ends of the rhabdosome, approximately 7 mm from the proximal end and giving the rhabdosome a maximum width of 4 mm. Thus, it is much wider than *P. proteus*. *Paraglossograptus tentaculatus* also commonly displays lacinial spines which extend beyond the outer margin of the lacinia. In *P. proteus*, no spines project beyond the outer margin of the lacinia. *Paraglossograptus tricornis* has similar dimensions to *P. proteus*, but possesses a spinose lacinia similar to that of *P. tentaculatus*.

Genus Bergstroemograptus Finney and Chen, 1984
Type species: Cardiograptus crawfordi Harris, 1926, p. 57, Pl. 1, figs. 5-7.

Bergstroemograptus crawfordi (Harris, 1926)

Pl. 11, figs. 1-3; text fig. 27 A-S

1926 *Cardiograptus crawfordi* Harris, p. 57, Pl. 1, figs. 5-7.
1935 *Cardiograptus crawfordi* (Harris); Harris & Thomas, p. 306, Fig. 2, No. 26.
1960 *Cardiograptus crawfordi* (Harris); Berry, p. 65, Pl. 11, fig. 12.
1963 *Cardiograptus crawfordi* (Harris); Ross & Berry, p. 90, Pl. 5, fig. 9.
1966 *Cardiograptus* sp. cf. *C. crawfordi* (Harris); Morris & Kay, Text-fig 4A.
1966 *Skiagraptus* sp.; Morris & Kay, Text-fig. 4b.
1969 *Skiagraptus* sp.; Whittington & Rickards, pp. 812 816, text-figs. 9, 10.
1984 *Cardiograptus crawfordi* (Harris); Carter & Tailleur, p. 47, fig. 5E.
1984 *Bergstroemograptus* n. gen. *crawfordi* (Harris); Finney & Chen, pp. 1194 - 1199, figs. 1-2, 3C-D.
1986 *Cardiograptus crawfordi* (Harris); Lenz & Jackson, p. 33, fig. 8G.
1988 *Cardiograptus crawfordi* (Harris); Cas & Vandenberg, p. 74; text-fig. 3,5h.
1990 *Bergstroemograptus crawfordi* (Harris); Ge, Zheng & Li, p. 109; Pl. 35, figs. 5, 6, 9.
1992 *Bergstroemograptus crawfordi* (Harris); Vandenberg & Cooper, pp. 62, 76; fig. 7H.
1990 *Bergstroemograptus* sp. indet; Cooper & Lindholm, p. 518.

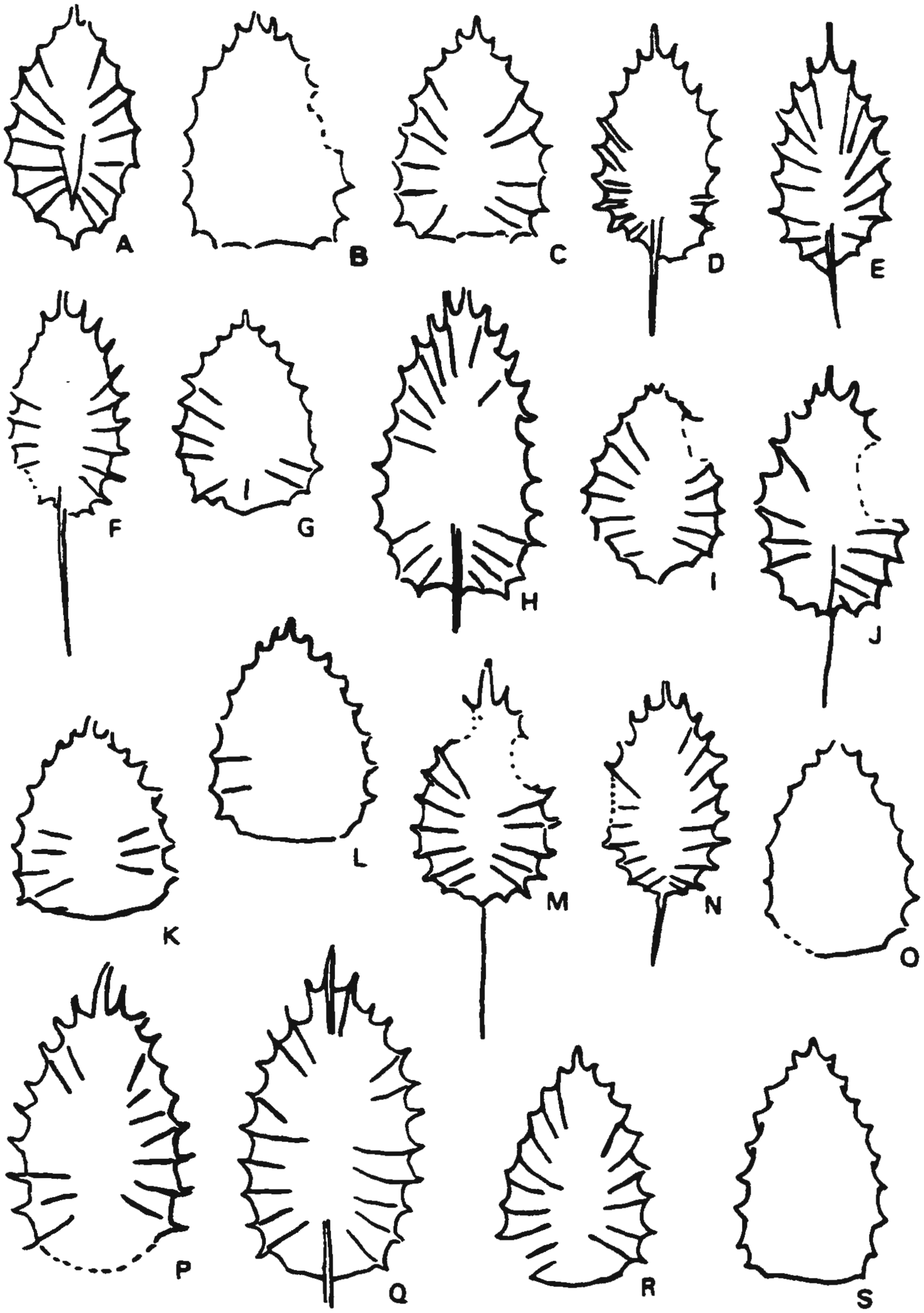
Type Material:

The lectotype was designated as NMV P13357 (figured by Harris 1926, Pl. 1, fig. 5) by Finney & Chen (1984, p. 1196, fig. 3b). Collected from Bendigo East, Victoria.

Materials:

Over 100 specimens from the Table Cove Formation at West Bay Centre Quarry. Specimens were also found from equivalent levels in the Piccadilly Beach exposure. Preservation ranges

Figure 27: *Bergstroemograptus crawfordi* Finney and Chen, 1984, x5. A: WBCQ8.1 18. B: WBCQ10.2 23. C: WBCQ10.2 19. D: WBCQ10.2 25. E: WBCQ10.2 3. F: WBCQ10.2 29b. G: WBCQ13.7 1. H: WBCQ14.9 6. I: WBCQ14.9 12. J: WBCQ14.9 47. K: WBCQ14.9 34. L: WBCQ14.9 10. M: WBCQ16.0 18. N: WBCQ16.0 14. O: WBCQ16.0 7. P: WBCQ16.0 32. Q: WBCQ16.0 10. R: WBCQ17.0 32. S: WBCQ17.0 3.


A
B
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S

from good to poor, with all specimens flattened. Most specimens are preserved as thin films, with occasional specimens showing traces of original periderm which can be 'flaked' off the shale surface.

Description:

The rhabdosome is ovoid, almost 'heart-shaped', with pointed proximal and blunt distal ends. Length ranges from 3.6 to 8.0 mm (mean = 5.6), with most mature spcimens above 5 mm in length. Maximum width is 2.3 - 4.4 mm with an average of 3.7, with most specimens at or above 3.5 mm in width. Mature specimens possess 9 - 11 pairs of thecae. Thecae number 6 - 8 in 5 mm proximally, with most ranging from 6.5 -7.5 (2TRD [proximal] = 1.1-1.45, average = 1.27).

Extending from the sicula at the point of contact with th^1 is an apertural process, possibly a rutellum (referred to as a virgella by Whittington & Rickards. 1969) (Fig. 27 Q). This process has not been seen to extend more than 1 mm beyond the sicular aperture.

The sicula and th 1^1 are directed downwards, with an increase in thecal angle distally. Rhabdosome width increases with thecal inclination, maximum rhabdosome width being reached where thecae become horizontal in orientation, usually at theca 6 or 7. Thecae distal to this point are only gently inclined to the dorsal margin.

Proximal thecae are straight or curve slightly inward, whereas distal thecae are usually straight. Mature thecae possess dorsal apertural processes whereas the thecal ventral margin is curved outwards slightly, both of which give the apertures a highly concave appearance. These concave apertures give the lateral margins of the rhabdosome an overall denticulate appearance.

In some specimens an elongate, narrow nema is present which sometimes projects beyond the distal end of the rhabdosome (Fig. 27 H, Q). The nema sometimes projects distally up to 3.3 mm beyond the last thecae.

Remarks:

Finney & Chen (1984) examined material from the middle of the Table Head Formation from 'a quarry' on the Port-au-Port Peninsula, presumably the West Bay Centre Quarry. An observation made by them on this material was the presence of proximal monopleural development rapidly shifting to dipleural development. This dipleural development is visible in the form of a ridge to the immediate left of the midline of the rhabdosome, indicating some overlap between the two thecal series. This ridge is visible due to the slight amount of relief visible in their material.

Based on this partly monopleural arrangement (as well as other factors, including proximal end development and overall rhabdosome shape and size), they reassigned *Cardiograptus crawfordi* to the type species of a new genus, *Bergstroemograptus*. It was not placed with other partly monopleural genera (i.e., *Apoglossograptus* or *Kalpinograptus*) due to its different proximal development.

The monopleural/dipleural arrangement is not visible in the material described here, due to an absence of visible relief. The specimens described here are fully flattened, with only a few rhabdosomes showing a little thecal and/or apertural detail in slight relief. Thus, the material described here does not clearly show the mid-rhabdosome ridge described by Finney and Chen (1984) due to flattening of the material, as discussed by Whittington and Rickards (1969). However, many of the specimens described here do possess a darker band of material along the middle of the rhabdosome, indicating a possible median thickening of the periderm (Fig. 27 A, Pl. 9-1). This thickening is present adjacent to the proximal end of the rhabdosome and extending to between half way and two thirds of the way along the rhabdosome distally; it agrees with the locations for the mid-rhabdosome ridge given by Finney and Chen (1984), as shown in Fig, 2, and indicates that this mono/dipleural arrangement is probably present .

The overall appearance of the material described here is almost identical to the type material figured by Harris (1926) and that figured by Finney and Chen (1984). Some differences do, however, exist; maximum width for the material described by Finney & Chen (1984) is 4-7 mm, whereas that described here shows maximum widths of 2.3-4.4 mm. Differences, although small, are also seen in maximum length if the material of Finney & Chen (1984) is compared to that described here; their specimens reached a maximum length of 9 mm whereas those discussed here show a maximum length of 8 mm. These differences are most likely not due to sampling error, as over 100 specimens of *B. crawfordi* were examined for this description. The consistency in maximum size (between 5 and 6 mm in length) and the number of thecal pairs (10 to 11 thecal pairs) in 'mature' specimens of *B. crawfordi* indicates that there was a maximum size to the growth of this species. If this were not the case, the large sample size used in this thesis would most likely have shown larger specimens.

Miscellaneous Graptoloids and Enigmatic Specimens

Didymograptus ? sp. A

Text fig. 28 B

Material:

One specimen collected from the 13.7 m level of Table Cove exposure at West Bay Centre Quarry.

Description:

One of the two stipes is broken away from the

Figure 28: Miscellaneous graptoloids. A: Sigmagraptid ? sp. A., CC190 7, x5. B: *Didymograptus* ? sp. A., WBCQ13.7 46, x2.5 C: Diplograptid ? sp. A synrhabdosome, WBCQ, x1.

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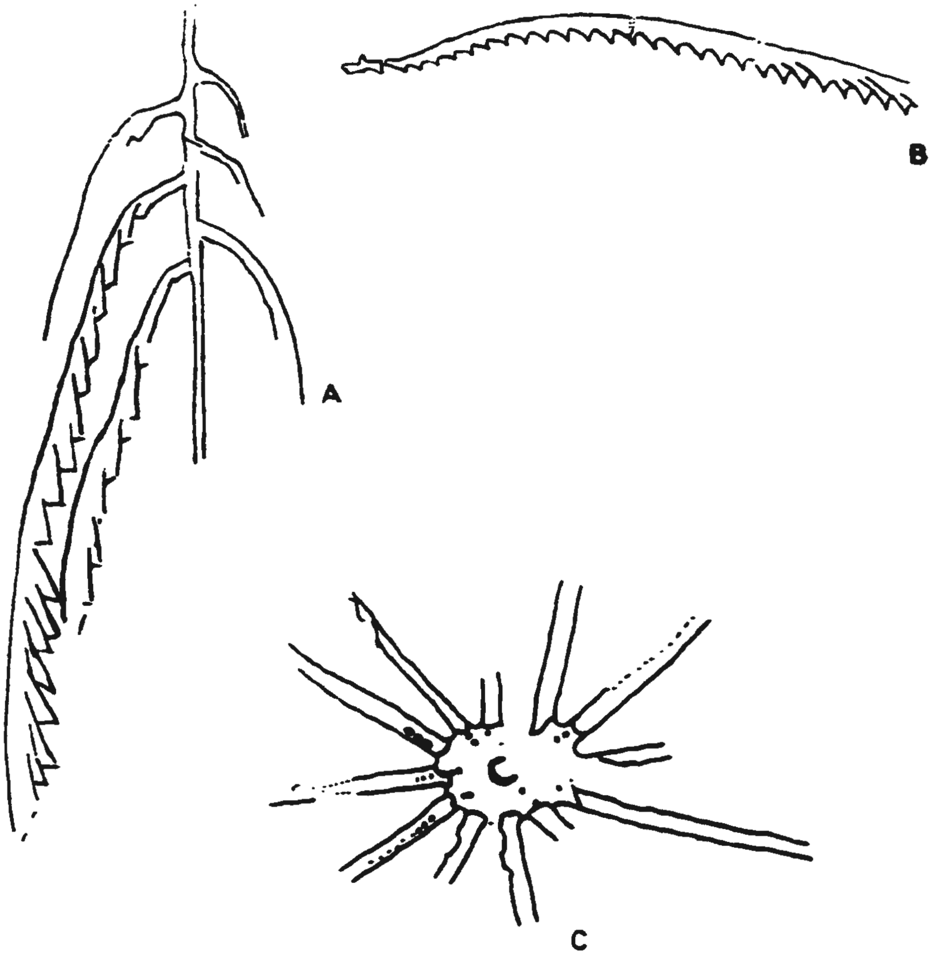

rhabdosome. The one intact is elongate, extending for more than 30 mm from the sicula. The stipe is reflexed in shape, with the dorsal stipe margin changing from concave proximally to convex distally. Proximal stipe width is low, 0.8 mm at th1. Stipe width increases distally: at th10, the width has increased to 1.6 mm, whereas at th20 the width is 2.0 mm.

The sicula is 1.0 mm in length, possessing a 0.1 mm rutellum. Maximum observed width of the sicula is 0.5 mm. The sides of the sicula are straight, forming a regular triangle. The sicular aperture is not discernable in this specimen.

Thecae are slightly concavely curved, more visibly so in proximal thecae. Apertures are simple and straight or slightly curved. Thecal spacing decreases from 5 in 5 mm proximally (2TRD (th2-4) = 1.9 mm) to 3.9 in 5 mm distally (2TRD (th20-22) = 1.5).

Remarks:

Whereas rhabdosome outline is very clear in the one specimen of *Didymograptus* ? sp. A seen in this study, there is little proximal detail visible. As proximal detail is one of the key factors in the identification of species of *Didymograptus* (Cooper & Fortey, 1982; Williams & Stevens, 1988), species identification of this specimen is impossible. Also, the identification of a taxon to the level of species based on one specimen only would be somewhat questionable under any circumstances. However, the lack of a virgella onthis specimes suggests at least a tentative generic assignment of *Didymograptus* and not *Xiphograptus*, which is similar to *Didymograptus* but possesses a virgella (Cooper & Fortey, 1982).

Sigmagraptid ? sp. A

Text fig. 28 A

Material:

One specimen collected from the Cape Cormorant Formation, 190 m, at Mainland Beach.

Description:

This incomplete specimen possesses what appears to be a central primary stipe with secondary stipes emerging from alternating sides. The central stipe is straight and is 0.2 -0.3 mm in width. No sicula is visible.

Three secondary stipes emerge in alternating fashion from either side of the central primary stipe, each curving downwards until they become almost parallel to the primary stipe. Those on the right are short (2.0 - 5.0 mm) and possess no thecal detail, and appear to be broken off distally. The first secondary stipe on the left is also short (6.5 mm) and possesses no thecal detail. The final two stipes are longer and possess thecae on the ventral margin of the stipe, which do not appear until over 1.0 mm along the stipe. The first of these secondary stipes with thecae is 16.5 mm long, with a proximal width of 0.3 mm increasing to 1.1 mm distally. The second is 9.0 mm long, with width increasing from 0.3 mm proximally to 0.7 mm distally. Thecal spacing is difficult to determine for either of these stipes due to the irregular thecal nature, probably due to deformation of the specimen.

The distance between secondary stipes increases distally. The first two secondary stipes are 1.6 mm apart, whereas the final two stipes are 2.0 mm apart.

Remarks:

Little can be said with respect to this solitary specimen, due mostly to its incomplete nature. Its overall rhabdosome style is similar to that seen in other species of sigmagraptine graptolites (eg., Hadding, 1911). However, without further evidence of rhabdosome structure, such as proximal development (or even sicular positioning), it is impossible to determine which stipes (ie., primary, secondary, etc.) may be present in this specimen, let alone the specific identity of this specimen.

Diplograptid ? sp. A Synrhabdosome

Pl. 11, fig. 4; text fig. 28 C

A single specimen found at the top of the Table Cove Formation at the West Bay Centre Quarry. It consists of a central ring, approximately 14 mm across, mostly flaked away but visible as an impression. Central in this ring is an empty disc-shaped region, approximately 3 mm across. Twelve 'diplograptid rhabdosomes' radiate outwards from this ring at regular intervals of approximately 2 mm. These diplograptids are incomplete, with no proximal or distal ends visible. Although no connections between "stipes" and the central ring are intact, the impression of a membrane-like surface is visible between most adjacent diplograptids, suggesting that these were actually joined as a single unit and do not represet a fortuitous arrangement of solitary diplograptids.

Evidence of thecal apertures are visible along the centres of the diplograptid fragments, but are located on the centre of the fragments. In some places where the fragments have broken away, circular impressions of less than 1 mm in diameter, presumably representing thecal apertures, are visible in the underlying sediment matrix. These are also visible in the region occupied by the connecting membrane, suggesting that the distal ends of the diplograptids extended close to the central ring.

Remarks:

This specimen is of possible significance as it presents what may be the best yet evidence for synrhabdosome associations in graptolites. Such associations have been suggested previously (eg., Bulman, 1972). However, specimens used to support these hypothesized synrhabdosomes have been poorly preserved or showed specimens arranged in circular associations with no true evidence of attachment between rhabdosomes visible. As the specimen presented here is incomplete, it is not identifiable beyond "Diplograptid" status. However, it presents important proof of some kind of physical relationship between different rhabdosomes of at least one species of graptolite, suggesting that synrhabdosomes did exist and were real associations between graptolitic colonies.

Enigmatic Specimen #1

Pl. 12, figs. 1-3

A single unusual specimen has been collected from the basal exposure of the Black Cove Formation above the West Bay Centre Quarry. It is a circular specimen consisting of a 'ring' with radial 'arms' projecting outwards. The central ring is approximately 1.0 cm across, with sides approximately 2 - 3 mm wide. Centrally is an empty disc-shaped region, almost 5 mm across, with a regular margin along the interior of the ring (Pl. 10-1, 2).

A total of eleven arms radiate out from the ring, spaced at 1 - 2 mm intervals. These are straight, pointing straight out from the ring. Arm width ranges from 1 - 2 mm along their length, with the longest of these measuring nearly 2 cm in length. One arm has a segment of arm projecting out from beneath it, which may represent a split in the arm or another arm projecting from beneath the first (Pl. 10-3). The surface of this specimen is rough, possibly granular, with some suggestion of plant-like linear striations along the longitudinal axis of the 'arms' and along the centre ring (Pl. 10-3).

Remarks:

This specimen, although probably not a graptolite, is included here for its unusual appearance and mysterious identity. Several contacts with other paleontologists have not provided any possible identification for this specimen, to any taxonomic level.

The striations visible in this specimen are suggestive of plant material, but this specimen is probably too old to actually represent such a highly organized plant structure (E. Burden, pers. com.). Due to these unusual surface characters and the apparent lack of structures representing thecae or thecal apertures, it is unlikely that this specimen is a member of any known graptolite taxon.

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PLATE 1

Fig. 1. *Pterograptus elegans* Holm, 1881, x15. CC145 16D, E.

Fig. 2. *Pterograptus elegans* Holm, 1881, x12. CC145 16A, F.

Fig. 3. *Pterograptus* sp. A, x15. SC2.5 30 (2).

Fig. 4. *Pterograptus* sp. A, x30. SC2.5 47.

Fig. 5. *Pterograptus* sp. A, x18. SC0.5 1b.

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PLATE 2

Fig. 1 *Janograptus terranovensis* Erdtmann, 1971, x9. WBCQ5.0 11.

Fig. 2 *Janograptus terranovensis* Erdtmann, 1971, x30. WBCQ5.0 11.

Fig. 3 *Janograptus terranovensis* Erdtmann, 1971, x9. WBCQ5.0 32.

Fig. 4 *Janograptus terranovensis* Erdtmann, 1971, x30. WBCQ5.0 32.

Fig. 5 *Pseudotrigonograptus ensiformis* J. Hall, 1865, x15. WBCQ6.0 15.

Fig. 6 *Pseudotrigonograptus ensiformis* J. Hall, 1865, x15. WBCQ12.6 6R.

Fig. 7 *Pseudotrigonograptus ensiformis* J. Hall, 1865, x12. SC5.0 14.

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PLATE 3

Fig. 1 *Pseudophyllograptus* cf. *P. angustifolius* Hall, 1858, x15. CC145 3.

Fig. 2 *Pseudophyllograptus* cf. *P. angustifolius* Hall, 1858, x24. BCOT-G 15.

Fig. 3 *Pseudophyllograptus* cf. *P. angustifolius* Hall, 1858, x12. CC145 4.

Fig. 4. *Isograptus forcipiformis* Ruedemann, 1904, x18. WBCQ17.0 6.

Fig. 5 *Isograptus forcipiformis* Ruedemann, 1904, x18. WBCQ 6.0-11b.

Fig. 6 *Isograptus forcipiformis* Ruedemann, 1904, x12. WBCQ 12.6 3-1Rb.


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PLATE 4

Fig. 1. *Etagraptus harti* Ruedemann, 1904, x9. WBCQ10.2 17.

Fig. 2. *Etagraptus harti* Ruedemann, 1904, x30. WBCQ4.2 26 (2).

Fig. 3 *Etagraptus harti* Ruedemann, 1904, x15. WBCQ9.1 25.

Fig. 4 ? Xiphograptus sp., x15. WBCQ8.1 7.

Fig. 5 *Nicholsonograptus fasiculatus* Nicholson, 1869, x48. WBCQBC-0.5mAGE.

Fig. 6. *Nicholsonograptus fasiculatus* Nicholson, 1869, x48. BCOT-G 39.

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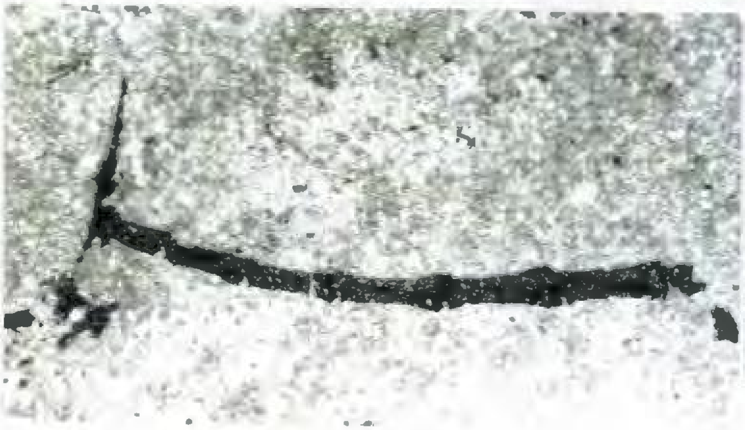

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PLATE 5

Fig. 1. *Acrograptus* cf. *A. affinis* Nicholson, 1869, x12. CC20 6, 6 (2).

Fig. 2. *Acrograptus* cf. *A. affinis* Nicholson, 1869, x15. WBCQ5.0 4.

Fig. 3. *Pseudoclimacograptus* (*Archiclimacograptus*) *oliveri* Boucek, 1973, x30. BCOT-G 4.

Fig. 4. *Pseudoclimacograptus* (*Archiclimacograptus*) *oliveri* Boucek, 1973, x30. WBCQ12.6 23.

Fig. 5. *Cryptograptus schaeferi* Lapworth, 1880, x12. WBCQ6.0 5b.

Fig. 6. *Cryptograptus schaeferi* Lapworth, 1880, x30. WBCQ17.0 25.

Fig. 7. *Cryptograptus schaeferi* Lapworth, 1880, x24. SC0.5 4.

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PLATE 6

Fig. 1. *Archiclimacograptus* sp. A, x15. WBCQ12.6 10.

Fig. 2. *Archiclimacograptus* sp. A, x15. WBCQ13.7 31.

Fig. 3. *Archiclimacograptus* sp. A, x24. WBCQ17.0 46.

Fig. 4. *Archiclimacograptus* sp. A, x24. WBCQ16.0 33R.

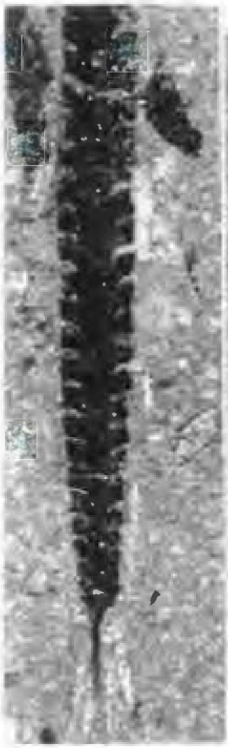
Fig. 5. *Archiclimacograptus* sp. A, x30. BCOT-G 30.

Fig. 6. *Archiclimacograptus* sp. A, x24. BCOT-M 10.

Fig. 7. *Archiclimacograptus* sp. A, x48. BCOT-M 10.

Fig. 8. *Archiclimacograptus* sp. A, x18. BCOT-G 9.

Fig. 9. *Archiclimacograptus* sp. A, x24. SC0.5 25.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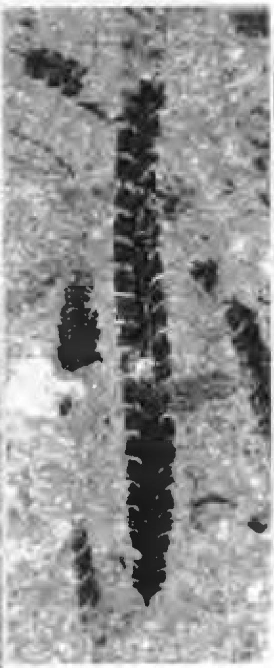
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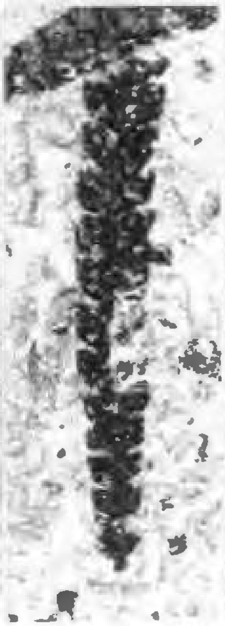
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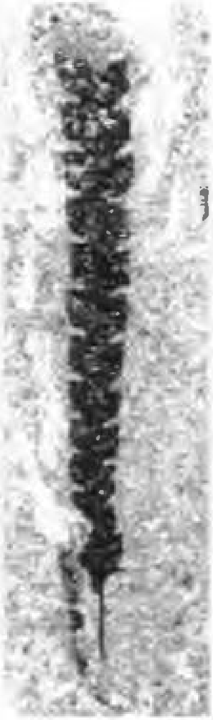
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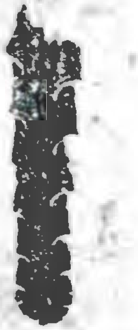
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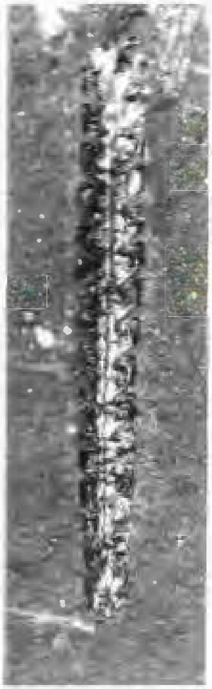
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PLATE 7

Fig. 1. *Archiclimacograptus* sp. A, x35. WBCQ12.6 3D-1.

Fig. 2. *Archiclimacograptus* sp. A, x22, stereopair. DH 3D-1, 2.

Fig. 3. *Archiclimacograptus* sp. A, x58, stereopair. DH 3D-3, 4.

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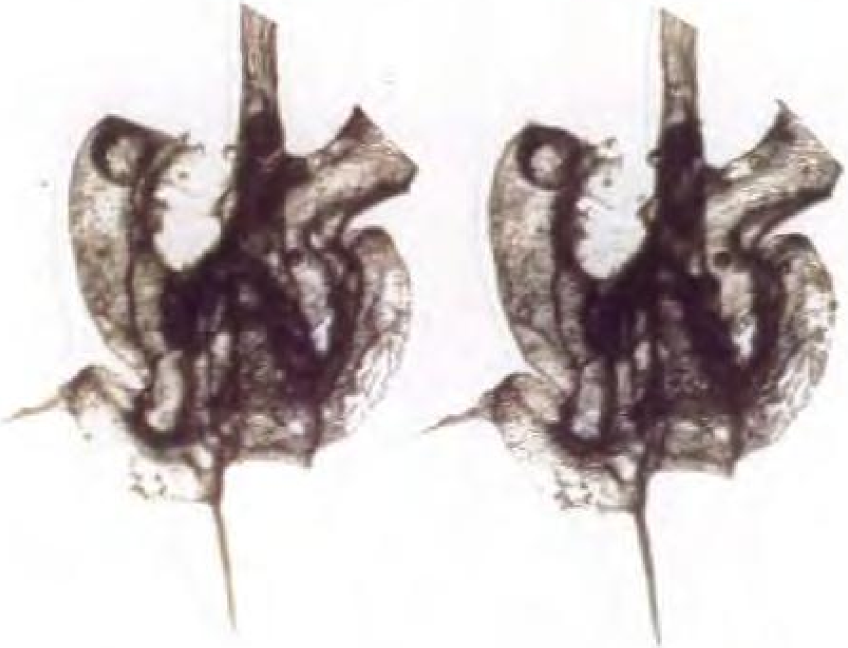

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PLATE 8

Fig. 1. *Archiclimacograptus* sp. A, x58. DH 3D-5.

Fig. 2. *Archiclimacograptus* sp. A, x58. DH 3D-6.

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PLATE 9

Fig. 1. *Archiclimacograptus* sp. A, x24. SC2.5 11.

Fig. 2. *Hustedograptus* sp. A, x18. WBCQ12.6 25.

Fig. 3. *Hustedograptus* sp. A, x30. SC2.5 27.

Fig. 4. *Hustedograptus* sp. A, x30. SC2.5 7 (2).

Fig. 5. *Hustedograptus* sp. A, x24. SC5.0 10.

Fig. 6. *Glossograptus holmi* Bulman, 1931, x15. SC0.5 20.

Fig. 7. *Glossograptus holmi* Bulman, 1931, x24. SC0.5 48.

Fig. 8. *Glossograptus holmi* Bulman, 1931, x12. TP7 19R.

Fig. 9. *Glossograptus holmi* Bulman, 1931, x12. TP7 19R (2).


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PLATE 10

Fig. 1. *Glossograptus* sp. nov., x48. WBCQ10.2 2.

Fig. 2. *Glossograptus* sp. nov., x30. WBCQ14.9 45b.

Fig. 3. *Glossograptus* sp. nov., x30. WBCQ9.1 10.

Fig. 4. *Glossograptus* sp. nov., x30. PB2.9 21b.

Fig. 5. *Paraglossograptus proteus* Harris and Thomas, 1935, x30. WBCQ12.6 5.

Fig. 6. *Paraglossograptus proteus* Harris and Thomas, 1935, x9. WBCQ13.7 38.

Fig. 7. *Paraglossograptus proteus* Harris and Thomas, 1935, x24. WBCQ13.7 38.

Fig. 8. *Paraglossograptus proteus* Harris and Thomas, 1935, x18. WBCQ11.2 3.


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PLATE 11

Fig. 1. *Bergstroemograptus crawfordi* Finney and Chen, 1984, x30. WBCQ10.2 25.

Fig. 2. *Bergstroemograptus crawfordi* Finney and Chen, 1984, x30. WBCQ16.0 4-10.

Fig. 3. *Bergstroemograptus crawfordi* Finney and Chen, 1984, x30. WBCQ17.0 34-3.

Fig. 4. Central detail of "Diplograptid" ? sp. A synrhabdosome, x12.

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PLATE 12

Fig. 1. Enigmatic specimen #1, x4.5.

Fig. 2. Detail of central ring of enigmatic specimen #1, x8.

Fig. 3. Detail of central ring and arm of enigmatic specimen #1, x10.

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Appendix: Numerical morphological data

The following pages contain tabulated data and measurements made on the material discussed in the thesis. Some of the names may seem confusing (and are certainly repetitious at times), but they reflect the character name 'simplifications' used during the different stages of data collection over the course of this project. The abbreviations used (not previously mentioned) are:

pendant th: number of pendant thecae;
2TRD(X-Y): 2TRD between thecae X and Y;
2TRD(X): 2TRD between thecae X and X + 2;
ang1stipediv: angle between primary and first secondary stipe;
apersplen: length of spertural spine;
axilwid: maximum width of axil;
dens in X: density of thecae in X mm;
distdens: density of thecae in distal 5 mm;
distwidth: distal width of rhabdosome;
funicleen: length of funicle;
funiclewid: maximum width of funicle;
last mature: number of last mature theca on rhabdosome;
leftsplen/leftsp/leftspine: length of th1;
max spine le/spinelenmax: maximum spine length;
maxwidth/stipewidmax: maximum width of rhabdosome;
maxthoverlap: maximum thecal overlap;

midspine/virg len/virg: length of virgell;

min spine le: minimum spine length;

pos'n2stipe: position of second stipe;

pq: West Bay Centre Quarry;

pqbc: Black Cove Formation overlying West Bay Centre Quarry;

proxwidth/stipewidprox/sw(prox)/width prox: proximal width of rhabdosome;

proxdens/th angle pro: density of thecae in proximal 5 mm;

rhablen/len: length of total rhabdosome;

rightsplen/rightsp/rightspine: length of th2 spine;

sichood: length of rutellum;

sic len/sicular length: sicular length;

sic width m/sic width max: maximum sicular width;

spinesinX: number of spines in X mm;

spinestot: total number of spines on rhabdosome;

stipe angle: angle between stipes;

stipe len/maxlen: stipe length;

stipe wid(X)/sw(X)/widthX: stipe width at theca #X;

stipewiddist: stipe width at distal end of rhabdosome;

sw max/width max: maximum stipe width;

th(X)len/th(X)length: length of theca #X;

thangledist/th angle dis: distal thecal angle;

thangleprox/th angle prox: proximal theca angle;

thlendist: length of distal theca;

thlenprox: length of proximal theca;

th(X)width/th(X)wid: width of theca #X;

th dens dis: distal thecal density in 5 mm;

th density pro: thecal density in 5 mm proximally;

th in X prox/prox th in X/: thecae in proximal X mm;

th in X dist/dist th in X/th# in 5 dis: thecae in distal X mm;

th pairs: number of pairs of thecae;

vanedist: distance of vane from distal end of rhabdosome;

vanelen: length of vane;

vanewid: maximum width of vane;

wbc: West Bay Centre Quarry

Isograptus forcipiformis

specimens	sicular length	rutellum	# pendent ths	stipe length	last mature th	sw (prox)	sw 10	sw 15	sw max	th angle prox	th angle distal	th density 5	th density dist	2td5-7	2td10-12
PQ6.0-11B	4.1	0.8	6	17.5	14	2.2	2	1.6	2	45	20	4.2	4.2	2	2.1
PQ10.2-23	3.6		5	13.6	13	1.5	1.4		1.6	45	22	6.3	5.1	1.8	1.9
PQ10.2-2			5	19	16	1.9	1.9	1.8	2	42	18	5	4.5	1.9	2.5
PQ10.2-16	4		5	7.7	9	1.6	0.9		1.5	30	25	5.7		2	
PQ10.2-28			6	28	27	2.2	2.1	2.2	2.3	55	15	4.8	4.6	2	2
PQ11.2-13	3	0.8	5	8.8	9	1.5	1		1.5		10	6.6		1.7	
PQ12.6-14			6	19	19	1.7	1.6	1.4	1.7	60	10	5	4.7	1.8	2.1
PQ12.6-31	3.4	0.5	4	17.5	17	1.9	1.9	1.8	2.1	45	25	5	4.5	2	2.1
PQ12.6-16	4.3		5			1.8	1.9	1.6	1.9	50	15	4.7	4.5	1.7	2.2
PQ13.7-6	4.3		5	22	20	1.7	1.7	1.4	1.8	45	20	5	4.3	2.2	2.3
PQ14.9-3	3.2	0.6	5	14.9	14	1.8	1.7	1.4	1.8	60	22	5.6	4.9	1.7	1.9
PQ14.9-55			5	24	20	2.1	2	1.8	2.2	60	25	5	4.3	2	2.2
PQ16.0-5			5			1.9	1.8	1.8	2.1	45	15	5.2	4.5	1.8	2.3
PQ16.0-13	3.7		4	7.5	8	1.8	0.8		1.3	35	15			1.8	
PQ17.0-6	3.6	0.8	5	20	17	1.9	1.7	1.6	1.9	30	18	4.9	4.3	2	2.3
PQ17.0-24	3.1	0.6	5	13.3	11	1.6	1.4	0.7	1.8	40	15	5.2		2.1	2.2
PQ17.0-33	3.4	0.8	5			1.7	1.8	1.6	1.9	45	13	5.5	5.3	1.9	2
PQ17.0-24B	3.6		6	18		2	2	2.1	2.1			5	4.5	2.1	2.4
PQ17.0-24(93)	3.8		6	20	15	2	2	1.6	2		10	5	4.5	2	2
PQ17.0-10			5	14.8	13	1.8	1.7	1.2	1.7	35	10	5.5	5	2	2
PQ17.0-38			5			2	2		2.1	45	10	5	4.5	2	2
PQ17.0-43			5	15	15	1.7	1.7	1.4	1.7	30	8	5.5	4.7	1.6	2
PQ10.2-4	2.9	0.6	5	8.7	9	1.5	1		1.5			5.9		1.5	
PQ10.2-42			5			1.6	1.5		1.6			5.7		1.8	1.8
PQ16.0-27	4.1		5			1.7	1.5		1.7	45		5		2	
PQ6.0-28	4.3	1.4	5	6.6	6	1.2			1.2					1.6	
PQ8.1-16	4		5			1.6	1.4	1.6	1.8			5.3	4.7	2	2
PQ10.2-29B	3.5		6	12.9	13	1.7	1.6	0.9	1.8	30	15	5.6	5.2	2.1	2
PQ11.3-4			4			1.6	1.5		1.8	40	16	6.2		1.6	1.8
PQ11.3-9	4		4			1.7	1.8		1.8	30		4.8		1.8	2.8
PQ10.2-19	3.2		4	6	6	1.5			1.5			5		1.4	
PQ10.2-20RB	3.45	0.85	5			1.1			1.1					1.6	
PQ10.2-19(2)	3.9	0.8	5			1.4			1.4	30				1.7	
PQ11.2-38	4	0.8	5			1.8	2.1	2.2	2.3			5.3	4.8	1.7	1.9
PQ11.2-32	3.7	0.5	5	27	22	1.7	1.6	2	2			4.9	4	1.9	2.1
PQ11.2-34	3.35	0.75	5			1.7	1.8		1.7	40	20	5		2	
PQ12.6-11B			5			1.9	2	1.5	2.1	45	10	4.8		1.8	2.1
PQ12.6-24	3.5	0.8	5	8.1	8	1.3	0.8		1.3	30		5.2		1.7	
PQ14.9-2	3.3		5	17.4	13	1.9	1.7	1.6	1.9	50	15	5.3	5.3	1.8	2.1
PQ14.9-6B	3	0.6	4	9.8	9	1.5	1.1		1.5	35	12	5		1.9	
PQ14.9-2(93)			5	10.6	10	1.5	1.3		1.6	38	10	5.5		1.7	2.7
PQ17.0-6(93)	3.5	0.8	4	6.8	7	1	0.6		1					1.9	
PQ17.0-40	3.8		4			1.6	1.3		1.6	25				2	
PQ17.0-1	3.4		4		7	1.3	0.6		35		6		1.7		
PQ12.6-31(93)			6			1.4	1.1		1.4	25		5.2		1.8	2.1
PQ6.0-6	3.4		6	7.6	7	1.4	0.6		1.4			5.3		1.9	
PQ8.1-5	3.4		5			1.4	1.2		1.4	25	10	6		1.6	1.7
PQ11.2-28	4.2	0.7				1.8	2		2.2			5.3	4.6	2	2
PQ11.2-13	3.2	0.9	5	25.5	22	2	1.8	1.9	2			5	4.7	1.8	2
PQ12.6-1RB	4.3	0.7				2.2	2.1	2	2.3	35	10	5	4.6	1.8	2.3
PQ14.9-1	3.2	0.8	5	10.5	12	1.6	1.4		1.6			5.5		1.8	1.9
PQ12.6-17b			5			1.7	2	1.7	2.1	35	15	5.7	4.3	1.6	2.1
PQ12.6-25B			4.3				2.2	2.3	2.4			5.2	4.8	1.8	2.2
PQ16.0-1	3.4			18.7	16	1.6	1.7	1.5	1.7			5	4.5	2.1	2.2
PQ16.0-4	3.2		4	7.2	9	1	0.8		1	33	10			1.6	
BCOT-GLS(94)-9	2.8	0.4	4	5.3	7	1.2	0.8		1.2					1.5	
BCOT-GLS(94)-5	2.8	0.6	4	8.9	9	1.3	1.1		1.3	35	20	6.5		1.5	1.6
PB2.9-68	3	0.7	5			1.7	1.6		1.7	35	18	5.5	5.2	1.9	2.1
PB2.9-47	3		5	9.4	9	1.4	0.6		1.4	27	10	7		1.8	1.8
PB2.9-53			4	8.5	8	1.3	1.1		1.3	27	12	6.2		1.6	1.6
PB2.9-24			4			1			1	25				1.3	
PB2.9-86			5	5.4	6	1.1			1.1	28				1.5	
PB2.9-54	3.2		4	5.8	6	1			1					1.5	
PB2.9-25	3.4	0.7	4			1.2			1.2	27				1.7	
TPLS-10				10	11	1.5	1.5		1.5			7		1.3	1.6

Etagraptus harti

specimen	funiclelen	funiclewid	stipewidprox	stipewidmax	stipeangle	stipelen	thin5
pqscree	2.8	0.4	0.4	0.6	69	25.5	
pq14.9-22	3.9	0.5	0.7	1	74	21	
pq8.1-2	3.4	0.4	0.4	0.7	64	6	4.5
pq9.1-25	2.5	0.3	0.3	1	77	8.5	
pq9.1-10	2.4	0.3	0.3	0.5	65	3	
pq9.1-16	2.2	0.5	0.3	0.9		4.5	
pq9.1-16(2)1.9.2.3							
pq10.2-17	2.8	0.4	0.35	1.2	77	22	
pq10.1-24	2.7	0.4	0.4	0.9	68	4	

Nicholsonograptus fasiculatus

specimen	sicula length	sicula width	stipe width (th	stipe width (th	stipe width (th	th# in 5 mm (j	th# in 5 (dist)	th1 length	th5 length	th10 length	2TRD (1-3)	2TRD (6-8)	stipe length
pqbc-glle - 3	1.8	0.2	0.25	0.35		5		0.45	2		1.8		5.7
bcot-gl - 40			0.25	0.41		4.7	3.3	0.6	2.4		2.2	2.9	15.4
bcot-gl - 38	1.3	0.15	0.25	0.41		5		0.63	2		1.67	2.25	9.6
bcot-gl - 39	1.2	0.19	0.26					0.63			1.63		3.2
bcot-gl - 6			0.25	0.4	0.55	5.8	4	0.45	2	4.1	1.65	1.9	35.5
bcot-gl - 34	1.3	0.19											1
wbc 4/91 - 11·	1.1	0.14	0.2					0.46					
wbc 4/91 - 116		0.14	0.23					0.45			1.15		
wbc 4/91 - 11	1.63	0.14	0.22					0.33					
wbc 4/91 - 109		0.14	0.2					0.39			1.15		
wbc 4/91 - 10	0.8	0.13	0.4					0.38					
nml-42-08 A	1.4	0.15	0.23					0.49					
m1-1/91 - 08/	1.2	0.14	0.24					0.48		1.38			
tp loc 6 - 55			0.3	0.4	0.5	5.6	3.9	0.5	1.1	1.2	1.7	2.5	30
pcbc 0.5m - 7	1.4	0.16	0.22	0.25		5.2		0.6	1.1		1.4	2.5	8
bcot-llom - 11	0.75	0.15	0.2	0.28		4.2		0.43	1		1.73		6.5
tp 6.0 - 44													17.9
tp loc 5 - 28													20
tp loc 6 - 42													27.7

Acrograptus affinis

specimen	sic len	sic width max	th in 5	th in 10	2TRD (2-4)	2TRD (8-10)	stipe len	stipe wid (2)	stipe wid (6)	sw (10)	nema
pq2.6-9	0.8	0.18									
pq2.6-10	0.7	0.22									
pq2.6-6	0.8	0.2									
pq2.6-1	1	0.26						0.3			
pq4.1-1	0.9	0.2	4.4		2.3		9.1	0.25	0.33		
pq4.1-2	0.8	0.2	4.8		2			0.25			
pq4.1-10	0.8	0.2						0.28			
pq5.0-3		0.2	4.7		2.3			0.35			
pq5.0-4	0.7	0.2	4.9		2.1	2.2	12.6	0.26	0.32	0.33	
pq5.0-31(1)	0.7	0.2						0.28			0.2
pq5.0-31(2)	0.7	0.2									0.9
pq10.2-22	0.65	0.18	4.8		2		6.4	0.22	0.28		
pqbc-glle-8		0.24	6		1.6	1.9	7.5	0.3	0.5	0.5	
pqbc-glle-8(2)		0.26	5.5		1.9	2.1	9	0.36	0.52	0.6	
bcot-ltom-70	0.7	0.26	6		1.9			0.3	0.3		
bcot-ossne-9	0.8	0.2	5		2		7	0.22	0.3		
cc-cb~20m-6		0.24	5.5		1.6	2.1	17	0.36	0.4	0.46	
cc-cb~20m-6(2)		0.3	4.9		2.1			0.3	0.3		
pq4.1-34	0.7	0.22						0.18			0.5
pq4.1-16	0.7	0.2									0.4
pq5.0-26	0.95	0.2						0.22			
pq7.0-2	0.9	0.18	5.6		2			0.32	0.46		
pq7.0-10	0.6	0.18			1.8			0.22			
pq10.2-13	0.6	0.2						0.24			
pq12.6-10	0.75	0.2						0.3			
pq12.6-21	0.7	0.2						0.2			
pq12.6-21(2)	0.65	0.22									0.5
pq12.6-16	0.7	0.18									1.2
pq14.9-15bR	0.85	0.18									
bcot-gl-23	0.8	0.3			1.9			0.3			
pq6.0-16	0.75	0.22									0.6
pq6.0-10	0.75	0.16									
pb2.9-32		0.2						0.18			
pq2.6-2		0.16	6.2		1.5	1.4	7.8	0.2	0.26	0.35	
pq2.6-1	0.95	0.28									
pq2.6-1(2)	1	0.28						0.3			
sc0.5-1		0.32	4.9		2			0.35	0.38		

Archiclimacograptus sp A

specimen	length	widrprox	width5	width10	widmax	thin5prox	thin5dist	2TRD 2-4	2TRD 10-12	leftap	rightap	virg	nema	parasicula
pq8.1-16R	9.5	0.9	1.6	2	2.1	7.9		1.1	1.7	0.2	0.2	0.4	1.6	
pq8.1-17		0.6	1.4	1.7	2.05	7.6	5.6	1	1.6	0.1	0.1	1.1		
pq8.0-19			1.4			7.1	5.5	1.15	1.9			0.4		
pq8.1-20		0.8	1.4	2	2.3	7.3	5.1	1.2	1.95	0.1		1.2		
pq8.1-20		0.9	1.4	1.7	1.7	7	5	1.2	1.8	0.2		0.4		
pq9.1-38R		0.95	1.4		1.5	7		1.2		0.3	0.3	0.5		
pq9.1-38R(2)	10.7	0.85				7	5.5	1.2	1.65	0.3	0.3	0.6		
pq10.2-1		1	1.35	1.7	1.9	6.8	5.5	1.3	1.6	0.2	0.1	0.5		
pq10.2-38		0.9	1.4		1.6	7.3		1.15		0.2		0.5		
pq10.2-1b		1	1.35		1.6	7		1.3		0.3	0.2	0.5		
pq10.2-2R		0.9	1.4	1.7	1.75	7.4	6.9	1.1	1.6	0.3	0.3	0.6		
pq10.2-2R(2)		0.8	1.2		1.35	7.2		1.2		0.3	0.3	0.4		
pq10.2-3bR		0.8	1.4		1.55	8		1.1		0.2	0.1	0.3		
pq10.2-32b		0.9						1.1		0.1	0.2	0.4		
pq10.2-32b(2)		0.9	1.4					1		0.3	0.2	0.5		
pq10.2-6		0.8	1.2	1.3		8.1		1.1		0.1	0.3	0.5		
pq10.2-17	3.5	0.9	1.1					1.15		0.2	0.2	0.6		
pq10.2-5R	2.4	0.9						1.05		0.1	0.1	0.3		
pq11.3-13		0.85	1.6	2.1	2.2	7.2	5.1	1.2	1.7			1.2		
pq11.3-2		0.8	1.4	1.95	2	7	5.9	1.3	1.6			0.3		
pq11.3-8		0.8	1.45		1.75	7.1		1.1		0.2	0.1	0.6		
pq11.2-16R		0.8	1.1		1.2			1.05		0.2		0.3		
pq11.2-41	6.3	0.75	1.3	1.45		7.2		1.25	1.6		0.1	0.6		
pq11.2-41(2)		0.75	1.2		1.5	6.9		1.2				1.7		
pq12.6-45b	5.6	0.8	1.3		1.4	7.4		1.15		0.2	0.2	0.2		
pq12.6-1	6.4	0.95	1.5		1.7	7.6		1.05		0.4	0.4	0.8		
pq12.6-3R		0.8	1.15			7.7		1.1		0.1	0.3	0.4		
pq14.9-6R	7.9	0.9	1.3	1.4	1.5	7		1.3	1.6			1.1		
pq14.9-2		0.8	1.3		1.55	6.6		1.3				0.3		
pq16.0-32	6.3	0.9	1.5		1.5	7.6		1.1		0.1	0.2	0.7		
pq16.0-33	5.7	0.9	1.3			8.3		1.1		0.3	0.4	0.3		
pq16.0-37		0.8	1.25		1.4	7		1.2		0.2	0.2	0.5		
pq16.0-13		0.85	1.45	1.75	1.85	7		1.3	1.85	0.2	0.3	0.3		
pq16.0-41	6	0.85	1.3		1.45	6				0.2	0.2	0.6	1.5	
pq17.0-30		0.8	1.35		1.45	7.1		1.3		0.3	0.3	0.5		
pq17.0-4		0.95	1.45	1.75	1.75	7.4		1.15	1.6	0.2	0.2	0.5		
pq17.0-27b		0.9	1.25		1.35			1.2		0.3	0.3	0.2		
pq17.0-22	4.6	0.8	1.2		1.4			1.1			0.1	0.6	2.5	
pq17.0-16	6.1	0.95	1.4		1.55	8		1.05		0.3	0.2	0.8	1.1	
pq17.0-12		0.8	1.4	1.55	1.55	7.7		1.05			0.2	0.5		
pq17.0-1-b	4.2	0.85	1.2					1.2		0.1	0.1	0.3	0.2	
pq17.0-23		0.9	1.4	1.8	2.25	7.9	5.7	1.2	1.7	0.2	0.3	0.6		
pq17.0-50	10	0.9	1.3	1.7	1.75	8	5.8	1.1	1.7	0.3	0.1	0.3	0.9	
pq17.0-25		0.7	1.35					1.05		0.2	0.3	0.3		
pq17.0-51		0.9	1.3					1.1		0.2	0.4	0.5		
pq17.0-35		0.95	1.45	1.7	1.85	7.4	5.9	1.1	1.75			1		
pq17.0-33R			1.4	1.7	1.75	7.2	6.2	1.1	1.65	0.3				
pq17.0-33		0.85	1.4			7.2		1.1	1.7	0.2	0.2	0.6		
pqbo-gl-6	10.3	0.8	1.1	1.85	2	8.3	4.6	1.4	1.9		0.1	1.4	2.3	
pqbo-gl-57		0.95	1.35	1.7	2.2	7.9	5.9	1.05	1.7			0.3		
pqbo-gl-43		0.95	1.35	1.7	2.4	7.3	5.8	1.1	1.55			1		
pb2.9-37	3.1	0.95	1.15					1			0.2	0.4	1.6	
pq2.6-6R		0.7	1.2		1.6	7		1.2		0.1	0.1	0.7		
pq7.0-6		1	1.2	1.7	1.7	7		1.2				2		
pq7.0-4	8.5	0.8	1.1	1.7	1.7	7.4		1.1	1.6	0.1		0.8	1.6	
pq8.1-10		0.9	1.6		1.6	6.6		1.3				1.6		
pq10.2-16R		0.9	1.35		1.6	7		1.2		0.2		0.6		
pq10.2-27R		0.8	1.5	1.6	1.6	7.7		1		0.1	0.1	0.5		
pq10.2-31		0.9	1.6		1.65			1.1				0.4		1
pq10.2-11R		0.8	1.1	1.5	2.1	7	5	1	1.6			4.6		
pq10.2-24		0.9			1.2			1				0.9		
pq11.2-7		0.85	1.15		1.3	7.3		1		0.1	0.2	0.9		
pq12.6-46		0.9	1.5		1.5	7		1.2						1.5
pq12.6-45b		0.8	1.4		1.6	7		1.2						
pq12.6-10		1	1.5	2.1	2.2	7.4	5.5	1	1.5			2.1		
pq12.6-51		0.9	1.5	2	2.2	7.5	5.5	1	1.75			1		
pq12.6-17		0.85	1.5	1.6	2.1	7.1	5	1.1	1.65			0.3		
pq12.6-45		0.9	1.4	1.8	2	7.9	5.3	1.1	1.7	0.3			0.3	0.4
pq13.7-13R		0.8	1.35	1.6	1.6	7		1.35				0.2		

pq13 7-12		0.85	1.35		1.5	6.5		1.3			0.1	0.1		
pq13.7-6	6.5	0.75	1.3	1.5	1.5	7		1.3	1.7	0.2		0.6		
pq13 7-27		0.8	1.2		1.3	7.4		1.1		0.1	0.2	0.2		0.3
pq13.7-10	6.5	0.8	1.1	1.1	1.2	7.1		1.25	1.7	0.2		0.9	1.2	
pq13.7-31		0.6	1.3	1.5	1.5	7.6	6	1.1	1.65					0.3
pq13.7-29		0.8	1.2	1.4	1.4	7.4		1.1	1.65		0.2	0.2		0.3
pq13.7-12		0.8	1.2		1.4	7.2		1.2		0.2	0.2	1		
pq13.7-36		0.7	1.3	1.65	1	6	6	1	1.7					0.4
pq14.9-14		0.7	1.3	1.65	1.7	6	6.1	1	1.7	0.1	0.1	1.1		0.2
pq14.9-26		0.8	1.45	1.65	1.65	7		1.2	1.7			0.4		
pq14.9-39		0.8	1.2	1.5	1.5	7.1		1.05	1.8					0.6
pq14.9-39(2)		0.85	1.2		1.35			1.1			0.2	0.5		
pq14.9-2		0.9	1.4	1.8	2	7.3		1.1	1.9			0.4		
pq14.9-1		0.8		1.7	1.75	7		1.2	1.8		0.1	0.3		
pq18.0-14		0.8	1.3		1.35			1		0.2	0.1	0.7		
pq18.0-24		0.9	1.3	1.5	1.5	8		1.05	1.7	0.1	0.1	0.4		
pq18.0-20		1	1.5		1.6	7		1.2				0.4		
pq17.0-7		0.9	1.45	1.65	1.9	7.1	6.3	1.15	1.9			1		
pq17.0-26		0.8	1.3		1.4			1.2				0.5		
pq17.0-44	12.5	0.8	1.25	1.7	1.65	7.1	6	1.1	1.8			0.8	2	
pq17.0-42		0.85	1.5	2	2.2	7.3	6	1.2	1.65			0.5		
pq17.0-42R		0.8	1.2		1.6	7		1.3				1.1		0.3
pq17.0-4		0.8	1.2		1.6	7.4		1.3	1.8			0.4		
pq17 0-4R		0.6	1.1		1.4	7.3		1.2				0.4		
pq17.0-1	7.3	0.8	1.2	1.5	1.5	7.4		1.2	1.7	0.1		1.2		
pb2.9-1R	10.2	0.85	1.25	1.5	1.5	7.5	5	1.08	2		0.1	0.7	1.2	
pqbo-glle-1		0.8	1.1		1.4	7.2		1.1				1		
pqbo-glle-5		0.7	1		1.4	7.5		1.15			0.1	2.4		
pqbo-glle-1(2)		0.8	1.1		1.35	7.5		1.15		0.1	0.1	0.8		
pqbo-0.5magllo-10		0.8	1			8		1.1		0.1	0.1	1.5		
pqbo-gl-51		0.7	1.4	1.7	1	7.6		1.2	1.8			0.7		
pqbo-gl-40		0.85	1.1	1.35	1.35	7.7		1.1	1.6			0.8		
pqbo-gl-45R		0.8	1.15			7.8		1.1			0.1	0.8		
pqbo-gl-45R(2)		0.8	1		1.1			1.1				1.4		
pqbo-gl-43		0.8	1.05	1.35	1.45	8		1	1.85	0.1	0.2	0.8		
pqbo-gl-55		0.9	1.2	1.5	1.7	6.8		1.4	1.75			0.8		
pqbo-gl-60		0.8	1.1		1.45			1.2		0.2	0.2	0.8		
pq10.2-29		0.8	1.1	1.25	1.25	7		1.1				1		0.3
pq10.2-29		0.8	1.1	1.25	1.25	7		1.1				1		
pq12.9-50R		0.85	1.15					1.2		0.45	0.15	0.85		
pq13.7-25		0.8	1.2		1.3			1.25			0.1	0.45		
*pq18.0-33R			0.85	1.15	1.35	6.7	5.5	1.3	1.8		0.2	1.5		0.3
*pq17.0-1-2		0.8	0.9	0.85	1.15	5.5	4.5	1.5	2.1			0.7		
pq17.0-2		0.9	1.3	1.3	1.35	7		1.3	1.8	0.3	0.2	0.5		
*pq17.0-46		0.65	1.05	1.5	1.5	7.3		1.15	1.8	0.1	0.1			
*pq13.7-2		0.7	0.8	1.1	1.2	6.6	5	1.25	2	0.1	0.1	1.1		
*pq17.0-50b		0.65	0.85	1.3		6.3		1.45		0.1	0.1	2.9		0.6
pq17.0-4	4.3	0.75	1		1.1			1.1		0.1	0.1	0.8	0.7	
pqbo-41		0.8	1.3	1.5	1.5	7.2		1.15	1.8			0.9		
pqbo-51		0.8	1.05			7.5		1.1		0.2	0.2	0.9		
pqbc-52		0.65	1.25	1.4	1.6	7.1	6.1	1.1	1.8	0.3	0.2	1.2		
pqbo-67	3.8	0.85	1.15					1.35		0.3	0.2	0.8	2.6	
pqbo-67(2)		0.75	1					1.1		0.1	0.3	0.35		
pqbo-46	4.3	0.75	1					1.1		0.1	0.1	0.5	1	
pqbc-47		0.75	1		1.25	7.8		1.05				0.4		
pqbo-54		0.75	0.95		1.1	7.3		1.2		0.1	0.3	0.4		
pqbo-40		0.75	0.95					1		0.2	0.2	0.4		
pb2.9-60		0.85	1.4	1.65	2	6.9	5	1.25	2			0.5		
*bcot-glle-2		0.7	0.95			6.3		1.3		0.1	0.1	1.1		
bcot-llom-55		0.8	1.15		1.4	7.5		1.1		0.2	0.2	5		
bcot-llom-60		0.75	1	1.4	1.5	6.6	5.2	1.2	1.8		0.1	0.2		
bcot-llom-17		0.85	1.15	1.2		7.3		1.15		0.1	0.1	0.3		
bcot-llom-31		0.8	0.85	1.3		7		1.25				1.4		
*bcot-llom-9	6.1	0.7	1.05		1.15	7.1		1.2				1.4	1.4	
?bcot-llom-10		0.85	1.3	1.5		7.8		1.05		0.4	0.3	4		1.3
bcot-llom-9		0.75	1.1		1.25	7		1.3			0.1	1.1		0.6
bcot-te,7m-10		0.75	0.8	1.25	1.65	7	5	1.2	1.8	0.1	0.1	0.8		0.8
bcot-te,7m-13		0.8		2	2.6	7.9	5.9	1.2	1.6			1.9		0.8
bcot-te,7m-11		0.7	1.15					1.1		0.1	0.2	0.7		
bcot-gl-25		0.7	1	1.3	1.8	7	5.4	1.05	1.9	0.2	0.2	0.7		
bcot-gl-9		0.8	1.15	1.6	2.1	6.9	5.5	1.3	1.55			0.5		

bcol-gl-11-2		0.7	0.85			7.5		1.2		0.2	0.1	0.3		
bcol-gl-5		0.7	0.75		1	8		1.1		0.1	0.1	0.4		
bcol-gl-3	4.8	0.8	1		1.15			1.15		0.2	0.4	0.8	0.8	
bcol-gl-1		0.65	0.85			7.2		1.15		0.3	0.3			
bcol-gl-28	8.9	0.75	1	1.45	1.6	7.7		1.1	1.7			1.7	2.4	0.7
bcol-gl-33		0.7	0.85	1.2	1.9	6.7	5.4	1.3	1.85			1		
bcol-gl-30	4.9	0.8	0.95		1.1			1.3				0.1	0.5	
bcol-gl-6R		0.85	1.05	1.55	1.95	6.7	5.2	1.25	1.8			1		
bcol-gl-15R		0.7	0.95	1.05	1.15	7.1	5.3	1	1.9					
bcol-gl-15R(2)		0.7	0.85	1.3		6.9		1.3		0.1	0.1	0.6		
bcol-gl-21		0.8	0.9					1		0.2	0.2	0.7		
bcol-gle-1		0.9	1.45	1.85	2	8	5.8	1.05	1.7		0.1	2.4		0.6
bcol-gle-4		0.7	1.05		1.4	6.5		1.4		0.1	0.1	0.7		0.3
bcol-gle-6	5.6	0.75	1.05			7.8		1.1		0.2	0.2	0.35	0.3	
bcol-asane-13		0.9	1.2	1.5	1.85	7	5.4	1.15	1.9			0.8		
bcol-asane-18			0.9			6.8	5	1.15	2			0.5		
ac0.5-5	6.9	0.85	0.85	1		9		0.95		0.3	0.3	0.2	1.1	
ac0.5-3		0.85	0.85	1.25		8.7		0.95		0.3	0.3	0.4		
ac0.5-11		0.8	1.2	1.45	1.5	7.2		1.2	1.65	0.2		0.6		
ac0.5-13		0.8	0.8	1		8.9		0.95		0.2	0.1	0.4		
ac0.5-6		0.8	0.8					1.05		0.3	0.1	0.7		
ac0.5-1		0.7	0.85		1.1	7.2		1.2				0.3		
ac0.5-32		0.7	0.8					1.4		0.3	0.2	0.1		
ac0.5-28		0.7	0.95		1	7.2		1.25		0.1	0.1	0.3		
ac0.5-13		0.7	0.85		0.9	7.7		1.2		0.3	0.3	0.5		
ac0.5-24		0.7	0.8	1.05		8		1.1	1.75	0.1	0.3	0.2		
ac0.5-30		0.8	0.85		1.15	7.8		1.2		0.2	0.3	0.2		
ac0.5-25		0.8	1	1.2	1.2	7.6	7	1.3	1.4	0.3	0.3	0.4		
ac0.5-1b		0.8	0.9			8		1.25		0.3	0.3	0.8		
ac0.5-11		0.85	0.9					1.25		0.3	0.3	0.4		
ac0.5-33		0.8	0.9					1.15		0.3	0.3	0.2		
ac2.5-2b		0.75	0.9	1.1		8.9		1	1.25		0.35	0.2		
ac2.5-11	10.3	0.75	1	1.2	1.3	7.4	6.2	1.2	1.6	0.2	0.4	0.4	1.6	
ac2.5-3		0.75	1		1.1	7.5		1.2			0.2	0.6		
ac2.5-7		0.75	0.9					1		0.2		0.3		
?ac2.5-7(2)		0.8	1.15	1.25		8.1		1	1.5	0.3		0.2		
cc-cb-20m-0														
cc-cb-20m-1		0.8	1.1			7.7		1.1				1.1		
cc-cb-20m-2		0.7	0.95			8.9		1.2		0.1	0.1	0.4		
cc-180m-5		0.75	0.95			8.1		1		0.2	0.3	0.8		
cc-180m-4		0.9	1.05	1.25	1.5	7.1	5	1.25	1.8	0.2	0.2	1.1		
cc-180m-3		0.95	1.4	1.7	2.1	8.9	8.3	0.85	1.45			1		
cc-180m-2		0.9	0.95		1.2	7.1		1.1		0.2	0.1	1.1		
cc-180m-1		0.8	1.05	1.3		7.1		1.15		0.1	0.1	1.7		
cc-145-1		0.95	1.3	1.8	2.2	7.5	5.7	1.1	1.7		0.1	0.3		
cc-145-10		0.85	1.2		1.5	7.2		1.1				0.6		
cc-145-6		0.85	1.35	2		7.1		1.35	1.75			0.6		
tploc2-1		0.7	1	1.2	1.3	7.1	5.1	1.2	1.9			7.3		
tploc2-18	3.8	0.8	1.3					1.15		0.2	0.3	0.55	0.8	
tploc2-15		0.75	1.25		1.7	7.1		1.15	2.05			0.3		
tploc3-5		0.85	1.1			7.3		1				0.2		
tploc3-5(2)		0.75	1.25	1.5	1.7	7.1	5.1	1.2	1.8		0.1	2		
tploc4-5		0.65	1	1.25		6.7		1.3				2		
tploc4-8		0.8	1.15	1.4	1.8	7.3	5.2	1.2	1.75			2.2		
tploc5-15		0.7	1.2		1.5	7		1.25		0.4	0.1	1		
tploc5-18R		0.7	1.15	1.45	1.5	7.5	5.6	1.05	1.7	0.2	0.2	2	1.1	
tploc5-25		0.95	1.25	1.5	1.8	6.9	5.2	1.3	1.8			4		1.5
tploc5-26R		0.7	1.2	1.5		7.2		1.15	1.7	0.1	0.1	2.6		1
tploc5-28		0.75	1.25			7.1		1.4				1.2		1
tploc6-4		0.8	1.1		1.25			1.2			0.1	1.4		
tploc6-45		0.8	1.25					1.3				1		
tploc7-58		0.7	1.15			7		1.1				8.6		3.4
tploc7-60		0.75	1.2			7.1		1.1		0.2	0.3	0.6		
tploc7-3		0.7	1.2		1.5	6.8		1.05		0.1		4.1		0.9
tploc7-64		0.8	1.2	1.5		7.1		1.2			0.2	1		
pq2.6-6R		0.7	1.2		1.6	7		1.2		0.1	0.1	0.7		
pq7.0-9		1	1.2	1.7	1.7	7		1.2				2		
pq7.0-4	8.5	0.8	1.1	1.7	1.7	7.4		1.1	1.6	0.1		0.6	1.8	
pq9.1-10		0.9	1.5		1.8	6.9		1.3				1.6		1
pq10.2-18R		0.9	1.35		1.8	7		1.2		0.2		0.6		
pq10.2-27R		0.8	1.5	1.6	1.8	7.7		1		0.1	0.1	0.5		

pq10.2-31		0.9	1.6		1.65			1.1				0.4		
pq10.2-11R		0.8	1.1	1.6	2.1	7	5	1	1.6			4.8		1.5
pq10.2-24		0.9			1.2			1				0.9		
pq11.2-7		0.85	1.15		1.3	7.3		1		0.1	0.2	0.9		
pq12.6-48		0.9	1.5		1.5	7		1.2						
pq12.6-45b		0.8	1.4		1.6	7		1.2						
pq12.6-10		1	1.5	2.1	2.2	7.4	5.5	1	1.5			2.1		0.4
pq12.6-51		0.9	1.6	2	2.2	7.6	5.5	1	1.75			1		
pq12.6-17		0.85	1.5	1.8	2.1	7.1	5	1.1	1.65			0.3		
pq12.6-45		0.9	1.4	1.8	2	7.9	5.3	1.1	1.7	0.3			0.3	
pq13.7-13R		0.8	1.35	1.6	1.6	7		1.35				0.2		0.3
pq13.7-12		0.85	1.35		1.6	6.5		1.3			0.1	0.1		
pq13.7-6	8.5	0.75	1.3	1.5	1.6	7		1.3	1.7	0.2		0.6		0.3
pq13.7-27		0.8	1.2		1.3	7.4		1.1		0.1	0.2	0.2		0.3
pq13.7-10	8.8	0.8	1.1	1.1	1.2	7.1		1.25	1.7	0.2		0.9	1.2	
pq13.7-31		0.8	1.3	1.5	1.5	7.8	6	1.1	1.65					0.4
pq13.7-20		0.9	1.2	1.4	1.4	7.4		1.1	1.65		0.2	0.2		0.2
pq13.7-12		0.8	1.2		1.4	7.2		1.2		0.2	0.2	1		
pq13.7-38		0.7	1.3	1.65	1	8	6	1	1.7					0.6
pq14.9-14		0.7	1.3	1.65	1.7	8	6.1	1	1.7	0.1	0.1	1.1		
pq14.9-28		0.8	1.45	1.65	1.65	7		1.2	1.7			0.4		
pq14.9-38		0.8	1.2	1.5	1.5	7.1		1.05	1.8					
pq14.9-38(2)		0.85	1.2		1.35			1.1			0.2	0.5		
pq14.9-2		0.9	1.4	1.8	2	7.3		1.1	1.9			0.4		
pq14.9-1		0.8		1.7	1.75	7		1.2	1.8		0.1	0.3		
pq16.0-14		0.8	1.3		1.35			1		0.2	0.1	0.7		
pq16.0-24		0.9	1.3	1.5	1.5	8		1.05	1.7	0.1	0.1	0.4		
pq16.0-20		1	1.5		1.8	7		1.2				0.4		
pq17.0-7		0.9	1.45	1.65	1.9	7.1	5.3	1.15	1.9			1		
pq17.0-28		0.9	1.3		1.4			1.2				0.5		0.3
pq17.0-44	12.5	0.9	1.25	1.7	1.85	7.1	6	1.1	1.8			0.8	2	
pq17.0-42		0.85	1.5	2	2.2	7.3	6	1.2	1.65			0.5		
pq17.0-42R		0.8	1.2		1.6	7		1.3				1.1		
pq17.0-4		0.8	1.2		1.6	7.4		1.3	1.8			0.4		
pq17.0-4R		0.8	1.1		1.4	7.3		1.2				0.4		
pq17.0-1	7.3	0.8	1.2	1.5	1.5	7.4		1.2	1.7	0.1		1.2		
pb2.9-1R	10.2	0.85	1.25	1.5	1.5	7.5	5	1.05	2		0.1	0.7	1.2	
pqbo-glle-1		0.8	1.1		1.4	7.2		1.1				1		
pqbo-glle-5		0.7	1		1.4	7.5		1.15			0.1	2.4		
pqbo-glle-1(2)		0.8	1.1		1.35	7.5		1.15		0.1	0.1	0.6		
pqbo-0.5maglle-10		0.8	1			8		1.1		0.1	0.1	1.5		
pqbo-gl-51		0.7	1.4	1.7	1	7.8		1.2	1.8			0.7		
pqbo-gl-49		0.85	1.1	1.35	1.35	7.7		1.1	1.8			0.9		
pqbo-gl-45R		0.8	1.15			7.8		1.1			0.1	0.9		
pqbo-gl-45R(2)		0.8	1		1.1			1.1				1.4		
pqbo-gl-43		0.8	1.05	1.35	1.45	8		1	1.85	0.1	0.2	0.8		0.3
pqbo-gl-55		0.9	1.2	1.5	1.7	6.8		1.4	1.75			0.9		
pqbo-gl-50		0.8	1.1		1.45			1.2		0.2	0.2	0.8		
pqbo-gl-61		0.75	1.1	1.6	2	6.9	5	1.3	1.85	0.1	0.1	0.4		
pqbo-gl-75		0.8	1		1.2	8		1.1		0.1	0.2	0.7		
pqbo-gl-71		0.8	1.15		1.4			1.05		0.2		1.1		
pqbo-gl-46		0.8	1		1	7.5		1.15		0.1	0.1	0.3		

Archiclimacograptus oliveri

Specimen	width-prox	width-max	virg-len	left-sp-len	right-sp-len	2TRD 2-4	2TRD 1-3	length	nema
pq17.0-43bR	0.7	1	0.65	0.3		1	0.9		
pq12.6-12	0.7	1.15	0.4	0.5		1	0.9	3.5	0.5
pq12.6-23	0.75	1.1	1	0.4	0.2	1	0.85	3	0.6
pq8.1-15	0.65	0.9	0.95			1	1	2	0.4
sc5.0-23		1.35				0.9	0.8		
sc5.0-18	0.7	1.2				1.2	0.9		
sc2.5-7	0.7	1.2				0.95	0.85		
bcot-ltom-33	0.8	1.1	0.7			0.85	0.9	2.45	0.2
bcot-ltom-34		1.1	0.7			1.1	0.85		
bcot-gl-11	0.8	1.2	0.2			0.9	0.9		
bcot-gl-4	0.75	1.1	1.35			0.95	0.9	4.6	0.3
bcot-gl-34	0.75	1.05	0.7			0.9	0.85	2.5	1.1
bcot-gl-34	0.75	1.3	0.4			0.9	0.8	4.1	1.7
bcot-gl-36	0.85	1.15	0.15			0.9	0.8	4	
bcot-t37m-9	0.7	1.25	0.2			0.9	0.8		
bcot-ltom-111	0.75	1.25				1.05	0.9	4.3	0.5
bcot-gls-6	0.7	1.25	0.2			1	0.85	2.8	2.4
bcot-ltom-40	0.75	1.3	1			95	0.9	4.1	1.1
bcot-ltom-69	0.8	1.2	0.3			1	0.9	4.3	2.3
pq-bc-81	0.7	1.35				0.85	0.8	3.9	0.1
tp-loc5-18	0.75	1.1	0.25			1.05	0.9		
tp-loc7-30	0.85	1.25	0.4			1	1	3.5	0.5
bcot-gl-13	0.75	1	0.3			1	0.9		
pq17.0-31	0.7	0.95	1.2	0.2		1.05	1	2.2	0.3
pq14.9-21	0.7	1.05	0.75	0.2		1.1	0.85	2.9	0.3

Cryptograptus schaeferi

specimen	rhablen	widthth2	widthmax	proxdens	distdens	2trd(5)	2trd(10)	midspine	leftspine	rightspine	vanelen	vanewidth	vanedist	vigula
PQ17.0-22	7	1.4	1.5	6.2		1.5								6.9
PQ16.0-1	13.6	1.5	2	6.7	5.6	1.4	1.6						8.3	
PQ16.0-10	6.1	2	2	6.7		1.4								
PQ17.0-42Rb	14.6	1.5	1.9	6.6	5	1.35	1.7							10.5
PQ8.1-6	10.5	1.5	1.7	6.5	5.5	1.7	1.75							4.2
PQ8 1-8	8.6	1.3	2.1	6.3				0.6	0.6	0.7				
PQ8.1-1					5.5	1.4					13.6	2	1	
PQ14.9-3	12.4	1.7	2.1	7	6	1.35	1.7							7.3
PQ14.9-16	10.6	1.4	1.75	6.8	5.3	1.25	1.6						0.2	
PQ14.9-11	8.6	1.6	1.7	6.3		1.5								4.6
PQ9 1-23	8.9	1.2	1.8	7										
PQ12.6-4	11.6	1.3		6.7	5.5	1.2	1.9				9.6	1	3	
PQ16.0-2	7.3	1.3	1.5	6.5		1.45								
PQ8.0-5b	11.5		1.4					0.7	1.2	1	8.9	1.6	3	
PQ8.0-2	13.2		2.1	6.8	5.7	1.6	1.75							
PQ8 0-1	8.9	1.4	2	7.1		1.4	1.65							5.2
PQ7.0-4	10.6	1.6	2.1	6.5	5.7	1.4	1.9							11.4
PQ7.0-4-2	9.1	1.6	1.7	6.3		1.5								7.7
PQ12.6-12	13.3		1.2								5.9	0.9	6.6	
PQ8.1-17	16.1		1.8	5.9	4.2	1.5	2							
PQ8.1-11	8.5	1.75	1.75	6.3		1.4	1.8							
PQ8.1-16	7.9	1.5	1.8	6.5		1.45								
PQ8.1-34	6.5	1.6	1.7	6.7		1.4	1.6						3.4	
PQ8.1-35	8.6	1.6	1.7	6.8		1.4	1.6							
PQ8.1-36	8.4	1.65	1.6	6.5		1.35								5.8
PQ8.1-37	11.2	1.6	1.6	6	5.2	1.55	1.9							
PQ12.6-46R	15.6	2.1	2.2	6.1	5	1.65	1.95							6
PQ12.6-46b	14.1		2	6.1	5.5	1.55	1.9							
PQ13.7-16	13.3	1.5	1.6	6.2	5.2	1.55	1.9							
PQ13.7-22	13.3	1.3	1.7	5.8	5.1	1.6	2.15							
PQ14.9-35	7	1.55	1.6	6.7		1.4								
PQ8.0-11		1.65	2	6.4	5.5	1.7	1.85							
PQ12.6-29		1.5		6.6	5.2	1.5	2							
PQ11.2-27	7.7	1.7	1.85	6.7		1.6								
PQ11.2-28			2	6	5	1.6	2							
PQ11.2-24		2	2.25	6.5		1.5	1.65							
PQ10.2-2		1.9	2.4	6.6	5.5	1.35	1.6							
PQ17.0-25		1.9	2.2	6.5		1.4	1.7							
PQ11 2-2	11.3		2	6	4.9	1.5	1.9							6
PQ11.2-19		1.5	2.05	6.3		1.3								
PQ8.1-4		1.5	1.8	6	5	1.45	2							
PQ10.2-40	7.5		2.1	6.8		1.4					8	1.25	4.1	4.1
PQ12.6-1Rb		2	2.3	6.4	4.8	1.6	2							
PQ16.0-23		1.7	1.85	6.7	6	1.3	1.55							
PQ17.0-14					5.6						5	0.6	8.4	
PQ17.0-3			1.6	6.3	5.2	1.4	1.85							
PQ17.0-12		1.15	1.6	6.2	5.4	1.45	1.75							
pQ17.0-42Rb(2)		2.1	2.3	6.9		1.2	1.6							
PQ8.0-11(2)	13		1.1						0.5	0.5				8.8
PB2.9-82b	6.1	1.3	1.6	6.1		1.45								4.3
PB2.9-84	5.7	1.3	1.4	6.2		1.5								
PB2.9-4	6.7	1.8	2.2	6.8		1.4								
PB2.9-83	7.2	1.7	2	6.6		1.3								
PB2 9-85	9.6	1.6	1.6	6.6		1.5								
PQBC0 5-11	10.7	1.5		6.7	5.7	1.45	1.6							
BCOT-LTOM-1	8.6			6.6		1.2	1.65							
BCOT-GL-27	9.4	1.35	1.75	7.1	6	1.3	1.6							3.9
BCOT-GL-28	9.9	1.5	1.8	7.3	7	1.3	1.65							
BCOT-SSNE-10	13.6	1.6	1.8	6.5	5.3	1.55	1.9							
BC-53		1.6	2.4	7.2	6.2	1.4	1.7							
SC2.5-31		1.25	1.55	6.9	5.7	1.3	1.75							
SC2.5-16	8.4	1.5	1.7	7.6		1.2	1.5							
SC2.5-11	7.4	1.35	1.6	7.3		1.3								
SC0.5--30	10.2	1.2	1.6	7.7	6.5	1.2	1.5							6.2
SC0 5-30(2)	6.3	1.2	1.65	7.4		1.4								
SC0.5-4		1.15	1.7	7	6	1.3	1.7							
TP7-7	11.2	1.5	1.7	7	6	1.55	1.85						3	
TP4-2		1.65	2.3	7.3		1.4	1.5							

Glossograptus holmi

Specimen	length	prox width	dist width	max width	prox th in 5	dist th in 5	min spine len	max spine len	nema	2TRD (2-4)	2TRD (10-12)	2TRD 20-22)
tploc2-14	19.3	1.3	1.4	2	8	6.5	0.6	2.5	0.5	1.5	1.8	1.3
tploc4-1	17.5	1.1	1.1	2.5	7.2	6.5	0.6	2	2	1.4	1.5	
tploc5-14		1.2		3.3	7	6	0.6	2.1		1.2	1.1	1 2
tploc5-28	19.6	1	1.5	3.3	7.5	5.5	0.7	1.8		1.6	1.4	1 6
tp6.0-47	25.1	1.2	2.1	4.2	7	5.8	0.5	2.3		1.4	1.6	2.1
tp6.0-47-2		1		2.9	7		0.4	1.3	1.7	1.5	1.6	
tploc7-1	16.4	0.9	1.9	2.9	6.5	5.8	0.8	2.3		1.6	1.8	
tploc7-6	18.2	0.8	2.5	3.5	7.8	6.5	0.6	2.7		1.5	1.4	1.6
tploc7-18	16.9	0.6	1.7	3.5	7.8	6.5	0.7	2.3		1.6	1 6	1.6
tploc7-19	20.3	1.1	2	3.8	7.5	6	0.8	2.2		1.4	1.4	1.7
tploc7-19R	20.7	0.9	1.2	3.1	7.1	6	0.6	2.3		1.6	1.6	1 6
tploc7-47b	18	1.2	3.4	3.8	7.6	5.9	0.6	1.5	2	1.3	1.6	1.7
tploc5-16	19.4	0.5	1.2	3	6.6	5.5	0.7	2.5	1	1.7	1.7	
tploc6-33		0.8		3.1	7		0.8	1.8		1.6	1.4	
tploc2-4		0.5		3.1	7.8	5.5	0.7	2.1		1.1	1.7	1.7
tploc5-18	16	1		3	7.5	8	0.5	2		1.3	1.5	1.6
tploc5-29	16.7	0.5	1.6	2.6	7	5.2	0.5	1.7	2	1.5	1 6	
tploc5-26	20	0.7	1.1	3.3	7	6	0.5	1.9		1.6	1.5	1.8
tploc5-27	19.9		1.1	3	6.9	5.5	0.6	1.3		1.4	1.7	1.5
tploc5-24	22.6	0.5	1.7	3.7	7	6	0.4	2.7		1.5	1.5	1.6
tploc5-19		0.6		2.6	7.1	5.8	0.7	1.6		1.4	1.6	1.6
tploc7-51	20.6	0.8	1.9	3.3	7.5	6.1	0.6	2.4	6.2	1.5	1.4	1.7
tploc7-56		0.4		3.3	7.1	6	0.6	2.1		1.4.	1.8	
tploc7-62		0.7		2.8	7.7	6.5	0.6	1.7		1.4	1.8	
tploc7-49	17.8	0.8	1.8	3.2	7	6	0.8	2.1	2.5	1.4	1.6	1.6
tploc7-38	17.8	0.5	1.8	2.9	7.1	5.7	0.6	1.6	1.4	1.4	1.7	
tploc7-28	20.6	0.5	1.7	3.5	7.7	5.7	0.5	2.6	1.2	1.2	1.6	1.6
tploc5-12		0.5		2.6	7.2	8	0.5	1.9		1.6	1.2	1.6
tploc5-13	18.3	0.6	1.4	2.9	6.9	5.9	0.4	2		1.4	1.5	1.6
tploc7-24		0.5		3	6		0.7	2.1		1.4	1.4	
tploc7-35	18.1		1.6	3.6	7.5	6.1	0.5	2.3		1.2	1.5	1.6
pq14.9-16	18.1	0.7	1.2	2.1	7.6	5.7	0.7	2.3		1.4	1.6	1.7
pq5.0-12		0.4		2.8	7		0.5	1.8		1.3	1.6	
pq11.2-2	14.7	0.7	1.1	2.4	7.5	6.6	0.8	1.9		1.2	1.6	
pqbc-60	20	1.6		3.7	7.1	5.5	0.6	2.2		1.5	1.6	1.6
pqbc-63	20.6	0.6	1.8	3.4	7	5.5	0.6	1.7		1.5	1.5	2
pqbc-70		0.8		4.1	7.5	6	0.5	2 9		1 3	1.4	1.7
pqbc-69		0.8		3	6.8	6.3	0.8	1.6		1.6	1.4	
pqbc-55		1		2.8	7	5.8	0.5	2.5		1.6	1.4	
pb'bcs'-5		0.8		2.8	7.9	5.4	0.8	2.4		1 2	1.8	1.9
sc2.5-18	6	0.3	1.2	1.8	9.1		0.4	1.1	0.8	0.9	1	
sc2.5-17	4	0.4	1.1	1.8	8.5		0.5	1.1		1.2		
sc2.5-12	6.2	0.4	1	1.7	9.2		0.5	0.9	0.5	1.2		
sc0.5-1	7.5	0.5	1.2	1.3	7.8		0.7	0.9	1.3	1.4		
sc0.5-46	10.3	0.9	0.8	1.2	7		0.4	1.2	3.7	1.4	1.4	
bcot-llom-79		0.8			8	6.8	0.4	2.1		1.2	1.4	1.6
bcot-llom-89	18.9	1		3	7.5	6	0.5	2		1.3	1.5	1.6
bcot-1magl,le	12.5	0.9	2.1		7.1	6.5	0.6	1.8		1.4	1.4	
bcot-2msane-	18.5	0.7	1.3	2.2	6.5	5.5	0.8	2.2	17.7	1.6	1.5	1.6
cc-cb20m-4	15.6	0.7	1.4	3.3	9	6.8	0.5	2.4	3	1 1	1.2	1.4

Glossograptus sp. nov.

specimen	length	maxwidth	spinesin2	spinestot	2trd(2-4)	spinelenmax	nema
pq10.2-2	3.7	0.5	4.5	7	1	1	0.8
pq14.9-45b	3.2	0.35	4.8	6	1.1	1	4.4
pq16.0-2	4	0.4	5.1	9	0.9	0.9	3.3
pb2.9-21b	2.1	0.3	5.1	5	0.8	0.8	2.6
pq9.1-35R	3.6	0.5	4	6	1.1	1.1	3.5
pq10.2-23b	4.2	0.6	4	8	1.1	1.7	2.2
pq13.7-4		0.4	5.2	7	0.9	0.6	
pq14.9-23	4	0.5	4	7	1	1	
pq9.1-10	3.5	0.3	3.9	7	0.9	1	0.9
pb2.9-86	2.8	0.35				0.8	2.5
pb2.9-83	3.1	0.4	4.7	6	1	1.2	1.3
pb2.9-36							5.6
pq9.1-35							7
pq10.2-21	5						

Paraglossograptus proteus

specimen	len	widthprox	widthmax	thin5prox	thin5dist	apersplen	nema	2trd(2-4)	2trd(10-12)	2trd(18-20)
pq4.1-11	10.2	2	2.1	5.5	5.5	3.4	9.3	2	2	
pq11.2-3		1.8	2.2	6.7	5	2		1.4	2	
pq12.6-5		1.3	1.7	7	5	1.2		1.3	1.8	2.1
pq13.7-40R	12.5	1.4	1.6	6.3	5.5	1.4	1.5	1.7	2	
pq13.7-38	29	1.5	1.7	6.5	5	1.7	3.8	1.3	1.8	2.1
bcot-gl-16	9.8	1.9		6.7		1	1.2	1.6		
pq5.0-7										

Bergestroemograptus crawfordi

specimen	length	width (max)	th pairs	dens in 5	2trd	nema
pq2.6-1	5.2	3.8	9	7.5	1.2	
pq8.118	5.6	4.3	10	7	1.3	0.3
pq9.1-18	6.2	3.9	11	7	1.35	0.5
pq10.2-29b	6.2	3.4	11	7.7	1.4	4
pq10.2-25	6.4	3.6	11	6.5	1.3	2.1
pq10.2-23	3.9		7		1.2	
pq10.2-19	5.4	3.7	10	8	1.2	
pq10.2-18	5.6	3.9	10	8.3	1.2	
pq10.2-3	6	3.9	9	7.5	1.45	1.3
pq10.2-23	5.6	4.2	10	7.5	1.35	
pq10.2-14	4.9	3.3	10	7.8	1.2	
pq11.3-1	5.3	4.3	11	8	1.25	
pq11.3-11	4.4	2.3	8		1.4	
pq12.6-52	4.8	3.6	9	8	1.2	
pq12.6-24bR	5.7	4	11	8	1.2	
pq12.6-9	5	3.7	9	8		
pq12.6-1Rb	5	3.5	10	8	1.3	
pq13.7-24R	3.7	2.7	7			
pq13.7-27	3.6	2.8	6		1.2	
pq13.7-13R	5.5	3.6	10	6.7	1.3	
pq13.7-11	5.4	3.7	9	7	1.3	0.4
pq13.7-13b	5.4	4.3	10	6.8	1.2	
pq13.7-6	5.2	3.8	10	7.2	1.1	
pq13.7-1	5.6	4	10	7.5	1.2	
pq14.9-5	5.4	3.8	10	7.1	1.3	
pq14.9-6	7.4	4.1	13	6.5	1.4	0.9
pq14.9-47	6	3.7				
pq14.9-34	4.9	3.9	9	7.9	1.1	
pq14.9-32	4.9	3.5	10	7.5	1.15	
pq14.9-39	6	3.6	10	7	1.3	0.9
pq14.9-12	4.8	3.4	10	8.1	1.1	
pq14.9-10	5.3	4	9	7	1.25	
PQ16.0-35b	5.6		11	7.5	1.2	
pq16.0-32	7.4	4.4	11	6.3	1.4	
pq16.0-14	5.9		11	6	1.35	2
pq16.0-10	8	4.4	12	6.5	1.3	0.6
pq16.0-7	5.2	3.6	9	6.5	1.3	
pq16.0-18	5.9	3.6	11	7		3.3
pq16.0-21	5.2	3.5	9	7.2	1.3	
pq17.0-6	5.3	3.8	9	8		
pq17.0-9	6	3.6	11	7.2	1.3	
pq17.0-32	5.8	3.8	10	6.8	1.3	
pq17.0-3	5.9	3.6	9	6.8	1.25	
pq6.0-23	5.3	3.4	9	7.1	1.25	0.5
pq8.1-5R	5.9		10	6.8	1.1	
pq8.1-9	6.2		10	6.5	1.35	
pq12.6-34R	5.9	4	10	6.7	1.25	
pq17.0-17	5.7	4.2	11	6.8	1.25	
pb2.9-10	6.1	3.6	9	6.5	1.4	
pb2.9-56	6.2	3.7	10	6.8	1.2	
pb2.9-53	5.8		9	6.5	1.4	
pb2.9-45	5.8	3.9	10	6.7	1.3	
pb2.9-74	5.8		10	6.7	1.3	
pb2.9-72	6.1	3.6	10	6.6	1.3	
pb2.9-90	4.9	3.1	8	7.5	1.25	0.7
pb2.9-20	5.8	3.7	10	6.8	1.35	
pb2.9-1	5	2.6	9	7.5	1.2	

Pterograptus elegans

specimen	siclen	sicwidmax	thlenprox(w/o	thlenprox(w/o	thlendist(w/o-	thlendist(w/ov	thangleprox	thangledist	maxthoverlap	thin5prox	thin5dist	ang1stipedive	pos'n2stipe	stipewidprox	stipewiddist
cc-190-7	1.6	0.5	0.5	0.8	0.9	1.7	18	30	0.5	5.2	5.9	100		0.5	1
cc-190-6	1.3	0.35	0.7	1.2	0.6	1.7	20	30	0.5	5.1	5.8	90		0.5	0.9
cc-145-16A	1.3	0.3	0.9				22		0.33	5.5		120		0.5	
cc-145-16b	1.2	0.25	1				24		0.5	5.3		95		0.4	
cc-145-16c	1.5	0.35	0.9				26			5.1		90		0.45	
cc-145-16d			0.9	1.3	0.8	1.5	15	29	0.5	4.8	6	95		0.4	1.1
cc-145-16e	1.6	0.3	1	1.3	1	2	15	30	0.5	5.1	5.5	120		0.4	1.1
cc-145-4	0.9	0.25	0.8				18		0.5	4.9		122		0.4	
cc-190-8					0.8	1.6	15	22	0.5	5	6.2			0.4	0.7

Pterograptus sp. A

specimen	siclen	sicwidmax	thlenprox(w/o	thlendist(w/o-	thangleprox	thangledist	maxthoverlap	thin5prox	thin5dist	ang1stipedive	pos'n2stipe	stipewidprox	stipewiddist
sc2.5-30	0.5	0.25	0.55	1	11	23		5.2		138		0.3	
sc2.5-47	0.7	0.15	0.7		10			5.2		128		0.2	
sc0.5-21	0.55	0.2	0.7	0.9	15	21		5.4	4.7	125		0.25	0.45
sc0.5-1b	0.9	0.2	0.85		18			5.5		128		0.3	
sc2.5-30	0.6	0.2	0.7		12			5.8		132		0.25	
sc2.5-22	0.6	0.2	0.7		15			6.1		130		0.25	
sc0.5-22			0.7		18			5		140		0.25	
sc0.5-20			0.6	0.9		24			5.2				0.6

Janograptus terranovenis

specimen	axilwid	th1wid	th10wid	th1len	th5len	2trd(2-4)	2trd(8-10)	thin5prox	thin5dist	stipelen
pq2.6-6b	0.25	0.45			1.15					
pq5.0-3R	0.35	0.45	0.5	0.65	1.3	1.2	1.2	2.4	2.6	4.3
pq5.0-11	0.25	0.55	0.6	0.6	1.2	1.3	1.2	2.4	2.5	4.1
pq8.1-1	0.2	0.65	0.7	0.5	1.3	1	1.3	2.5	2.6	3.7

Pseudophyllograptus angustifolius

specimen	maxwidth	thin5prox	thin5dist	maxlen	2trd(2-4)	2trd(10-12)
bcot-ltom-115	5.5	7.5	5.2	17.5	1.2	1.7
bcot-gl-15	4.9		6			
cc~145-4	5.8	7	6	21	1.4	1.7
cc~145-5	5	6.5	5.5	16	1.2	2.1
cc~145-3	5.8	7	5.8	21	1.2	1.7
sc-0.5-8	5.1	7.8	6.3	13	1	1.5
bcot-ltom-43	5.9	7	6.4	15	1.2	1.6
bcot-ossne-8	4.5	6		10	1.3	
bcot-gis-2	3.7	6.6			1.2	

Pseudotrigonograptus ensif siformis

specimen	proxwid(2)	maxwidth	length	thin5prox	thin5dist	2trd(2-4)	2trd(10-12)	virgella
pq2.6-6R	2	2.6	12.8	6.5		1.6		1.5
pq6.0-15	1.6	3	17.7	6	5.3	1.6	1.8	
pq10.2-40	1.4	1.9		6.3		1.6		
pq14.9-15	1.5	1.8	8.3	6		1.6		
sc5.0-14		4.2			5		2	
pq14.9-17	1.5	3	13	5.9	5.1	1.6	2	1