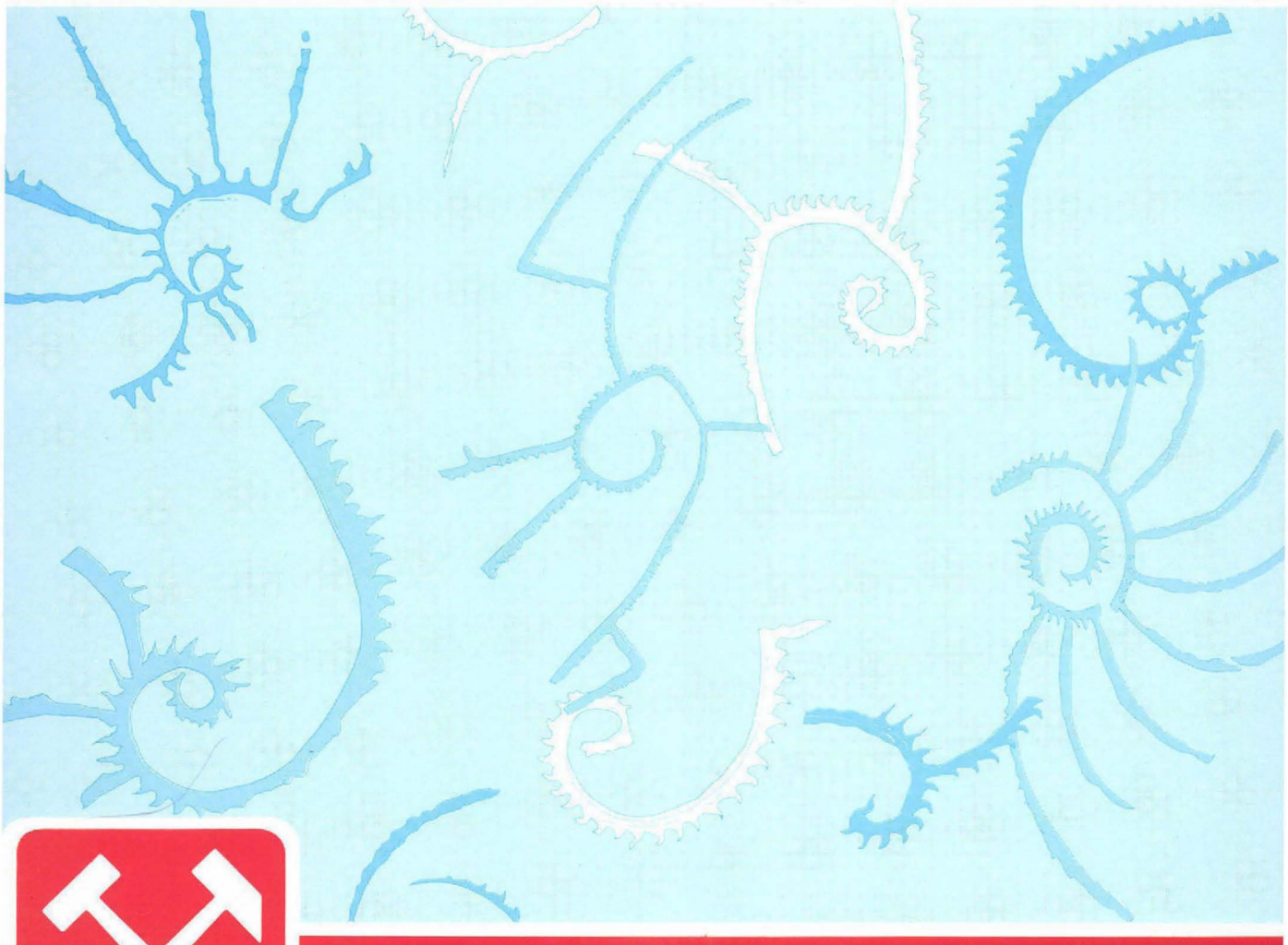
Upper Llandovery and Wenlock *Cyrtograptus* from the Silurian Peary Land Group, North Greenland

Merete Bjerreskov



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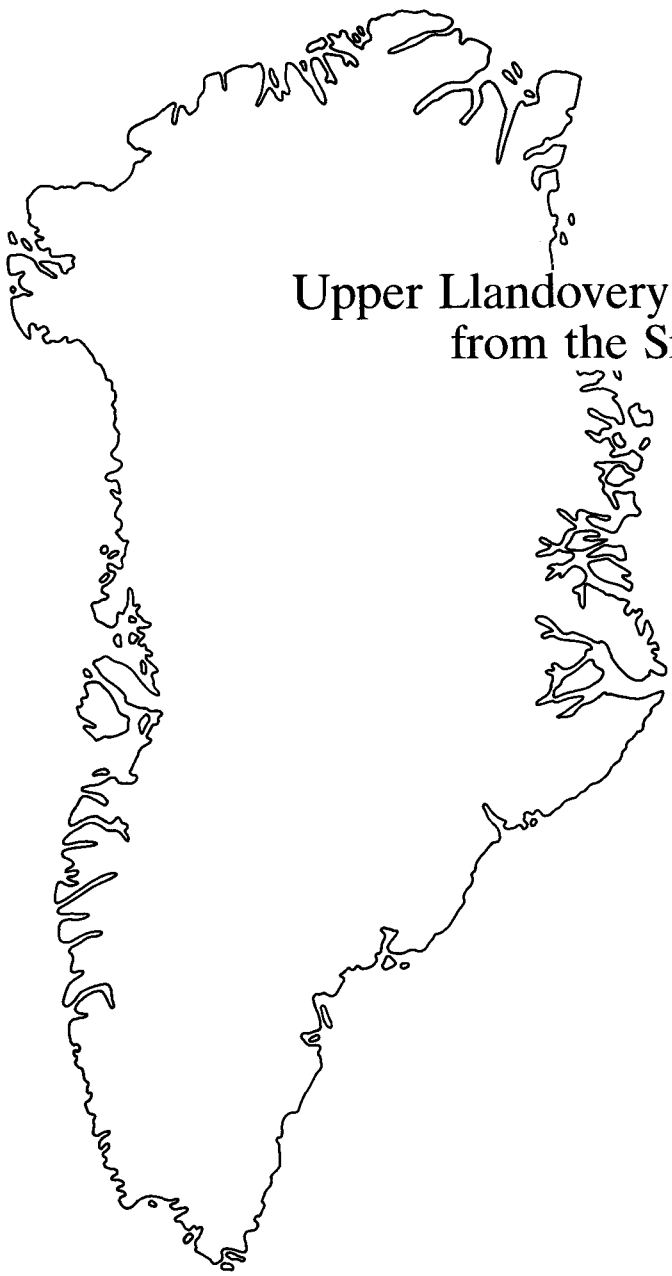

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Recent collections of graptolites from the Silurian Peary Land Group in North Greenland have yielded several samples of *Cyrtograptus*. From this material 16 species and subspecies are described, and one new species, *Cyrtograptus multibrachiatus*, is erected. The described material represents a time span from the uppermost Llandovery to the uppermost Wenlock. The similarities between the graptolite faunas from North Greenland and those described from the Northern Canadian Cordillera, and especially from the eastern part of the Franklinian Basin in Arctic Canada, allow a good correlation with the established graptolite zones in these areas. The following graptolite biozonal levels are represented in North Greenland: the latest Llandovery *C. sakmaricus* Zone, the early Wenlock *C. centrifugus* – *C. insectus* Zone, possibly the *C. murchisoni* Zone, the *M. instrenuus* – *C. kolobus* Zone, the *C. perneri* – *M. opimus* Zone and the *C. lundgreni* – *M. testis* Zone.

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Grønlands Geologiske Undersøgelse
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Geological Survey of Greenland

The Geological Survey of Greenland (GGU) is a research institute affiliated to the Mineral Resources Administration for Greenland (MRA) within the Danish Ministry of Energy. As with all other activities involving the non-living resources in Greenland, GGU's investigations are carried out within the framework of the policies decided jointly by the Greenland Home Rule Authority and the Danish State.

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Contents

Dansk sammendrag

Nye samlinger af graptolitter fra den silure Peary Land Gruppe i Nordgrønland indeholder adskillige eksemplarer af *Cyrtograptus*. Seksten arter og underarter er beskrevet, og der er oprettet en ny art: *Cyrtograptus multibrachiatus*. Det nordgrønlandske materiale har stor lighed med graptolitfaunaer fra de nordlige canadiske Cordillerer og fra den østlige del af det Franklin-iske Bassin i arktisk Canada. Ved korrelation er følgende graptolitzoner fundet repræsenteret i Nordgrønland: *C. sakmaricus* Zonen (seneste Llandovery), og fra tidlig til sen Wenlock: *C. centrifugus* – *C. insectus* Zonen, muligvis *C. murchisoni* Zonen, *M. instrenuus* – *C. kolobus* Zonen, *C. perneri* – *M. opimus* Zonen og *C. lundgreni* – *M. testis* Zonen.

Imaqarnersiuineq

Avannaarsuani ujaqqani ataatsimut Peary Land Gruppe-mik taaguuteqartuni, ukiut 439–409 milliunit matumatu siornatigut pinngorsimasuni, graptolittini ataatsimoortuni immikkoortut *Cyrtograptus*-imik taaguutilinnik arlalinnik ilaqarput. Assigiinngitsut arfersanillit allaaserineqarput, immikkoortorlu nutaaq taaguuserneqarsimavoq, *Cyrtograptus multibrachiatus*. Avannaarsuani graptolittit Canadap avannaani qaqqarsuani Cordillerinik taagutilinni Canadallu Issittortaani Frankliniske Bassin-imi graptolittinut assingusorujussuupput. Avannaarsuani graptolitteqarfiit makua nalunaarsorneqarsimapput. *C. sakmaricus* Zonen, *C. centrifugus* – *C. insectus* Zonen, qularnanngitsumillu *C. murchisoni* Zonen, *M. instrenuus* – *C. kolobus* Zonen, *C. perneri* – *M. opimus* Zonen aamma *C. lundgreni* – *M. testis* Zonen.

Introduction

During the last 15 years numerous graptolites have been collected from the upper Llandovery and Wenlock of North Greenland in connection with a major geological mapping project organised by the Geological Survey of Greenland (Grønlands Geologiske Undersøgelse, GGU). The considerable graptolite material includes many specimens of *Cyrtograptus*. Previous systematic descriptions of Silurian graptolites from North Greenland are few and only a very limited number of specimens of *Cyrtograptus* have been described. The earliest reports of Silurian graptolites are expedition records by Etheridge (1878) and Koch (1920), followed by the lists of middle Llandovery faunas from Washington Land by Poulsen (1934). Norford (1967, 1972) summarised the graptolites recorded during a cooperative venture between the Geological Survey of Canada and GGU in Ellesmere Island and western North Greenland, and a few cyrtograptids from these faunas were described by Jackson & Etherington (1969). Wenlock graptolites from Kronprins Christian Land were mentioned by Lane (1972) and graptolites of Pridoli age from Hall Land were reported by Berry *et al.* (1974).

Llandovery and Wenlock graptolite faunas collected during GGU expeditions to North Greenland were reported in Dawes (1976), Hurst & Peel (1979), Lane & Thomas (1979), Lane & Peel (1980), Hurst (1980), Surlyk *et al.* (1980), Hurst & Surlyk (1982), Dawes & Peel (1984) Higgins & Sober (1985), Larsen & Escher (1985), Escher & Larsen (1986), Bjerreskov (1986, 1989, 1990), Larsen & Escher (1987), Surlyk & Ineson (1987), and Larsen & Escher (1991).

The faunal lists in the above mentioned papers were all based on the provisional investigations by the present author. Systematic descriptions have been made of the Silurian graptolite faunas from Washington Land (Bjerreskov, 1981) including a very few cyrtograptids. The present paper deals with the description of the total material of late Llandovery and Wenlock *Cyrtograptus* recorded in the collections made by J. M. Hurst, F. Surlyk, P.-H. Larsen, J. C. Escher, F. G. Christensen and J. S. Peel. In addition the graptolite faunas listed in Norford (1972) and subsequently donated to GGU have been revised.

Lithostratigraphy and basin development

The Lower Palaeozoic Franklinian Basin extended from Alaska through the Canadian Arctic Islands and into North Greenland. A deep-water trough within this basin was situated along the northern coast of Greenland and was fringed to the south by a shallow shelf dominated by carbonate sediments.

The Silurian deep-water clastic rocks of the Franklinian Basin in North Greenland are included in the Peary Land Group (Fig. 1) which outcrops for 800 km from Washington Land in the west to Kronprins Christian Land in the east. It was erected by Hurst (1980) and described in detail by Hurst & Surlyk (1982). The informal units employed by Dawes & Peel (1984) and Larsen & Escher (1985) lead to a redefinition in Larsen & Escher (1987). The lithostratigraphic subdivisions of the Peary Land Group in the latter paper are these followed here (Fig. 2; see also Higgins *et al.*, 1991).

The Peary Land Group was initiated at the Ordovician–Silurian transition by the onset of the deposition of westward transported turbidites in the deep-water trough of the Franklinian Basin succession in North Greenland. The turbidites may have derived from the rising Caledonides to the east (Surlyk & Hurst, 1983 and Higgins *et al.* 1991) or from Siberia (McKerrow *et al.*, 1991). In the late Llandovery the trough expanded and about 30 000 km^2 of carbonate shelf foundered and was inundated. The extensive submergence resulted in the deposition of uniform sequences of hemipelagic mudstones and siltstone turbidites covering the shelf carbonates (Fig. 2). These are referred to the Thors Fjord Member of the Wulff Land Formation in central North Greenland and the eastern part of western North Greenland, the Profilfjeldet Member of the Lauge Koch Land Formation in the east, restricted to Kron-

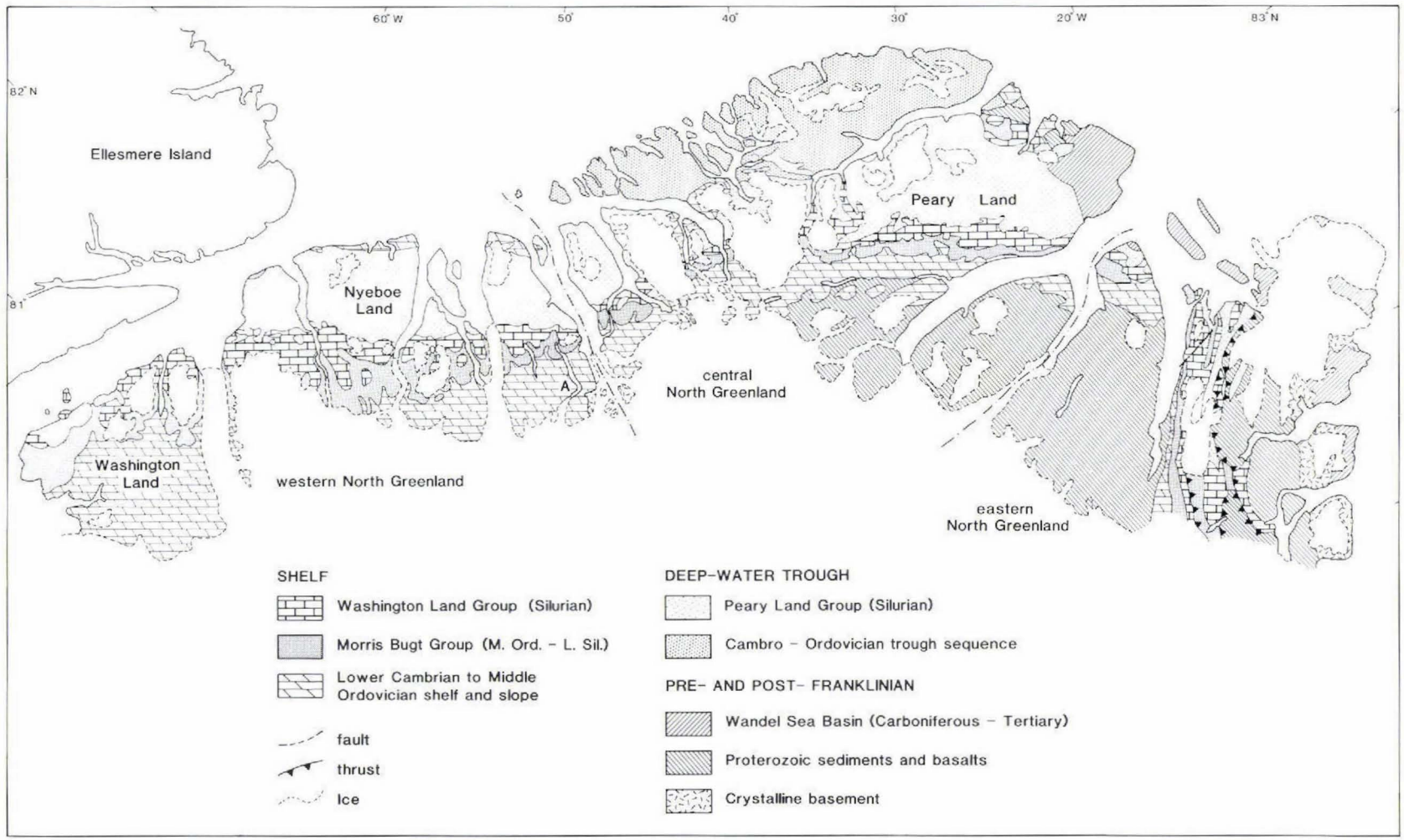


Fig. 1. Simplified geological map of Franklinian Basin sediments in North Greenland. (From Armstrong, 1990; adapted from Smith *et al.*, 1989).

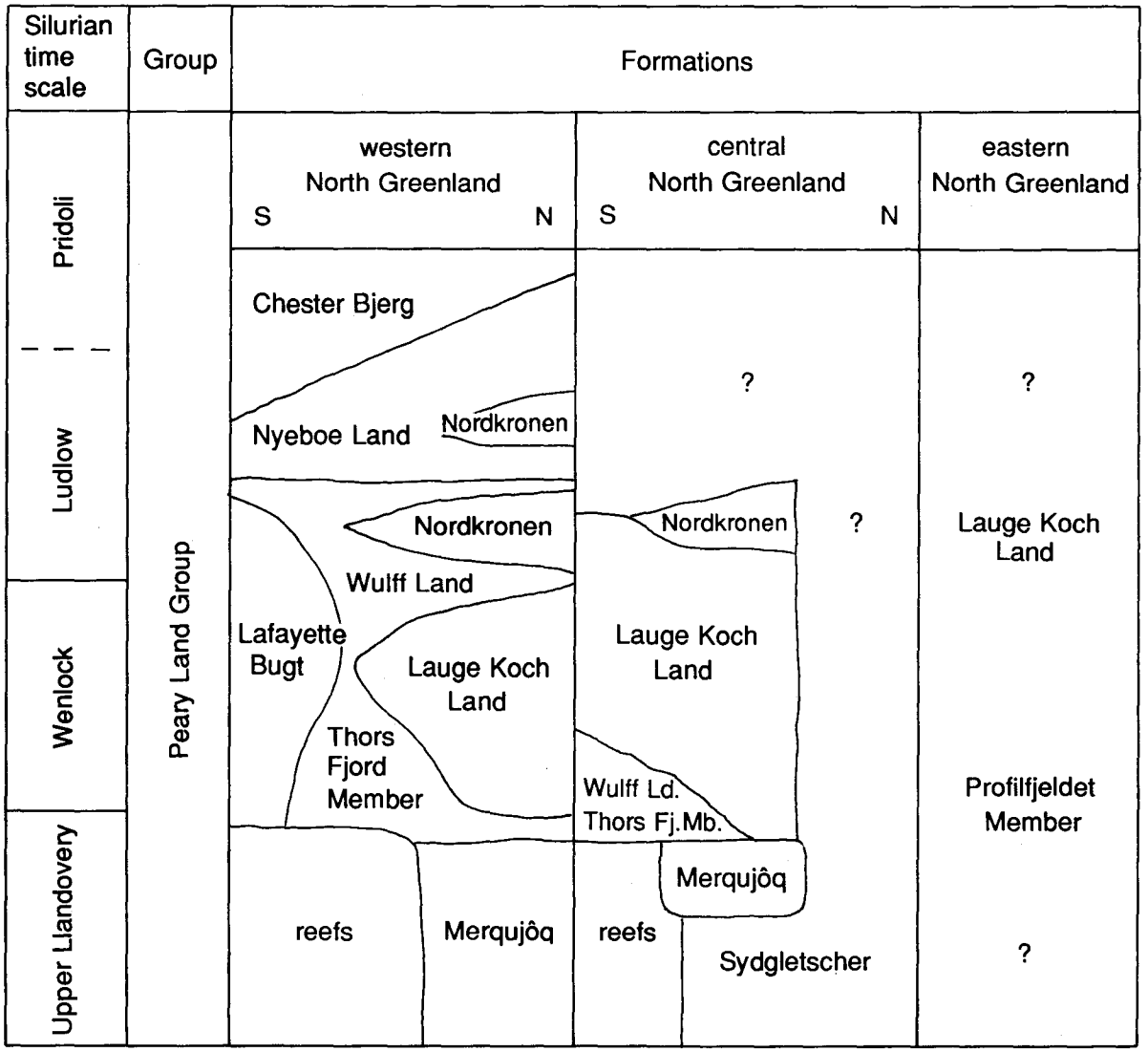


Fig. 2. Lithostratigraphic scheme of the Peary Land Group, North Greenland. Compiled from Larsen & Escher (1987) and Higgins *et al.* (1991).

prins Christian Land and Valdemar Glückstadt Land, and the Lafayette Bugt Formation in the west. From this time onward a wide turbidite basin existed throughout the Wenlock (Hurst & Surlyk, 1982; Higgins *et al.*, 1991).

Following the late Llandovery – early Wenlock phase of trough expansion and submarine fan starvation, the turbidites rebuilt an extensive westwards prograding fan system represented by deposits of the Lauge Koch Land Formation. In the western part the Lafayette Bugt Formation draped the carbonates during the Wenlock, and in Hall Land and Nyeboe Land the formation interfingers with the black mudstones and black-grey siltstones of the Wulff Land Formation. In the Ludlow the deposition of the Nyeboe Land and Chester Bjerg Formations terminated the infilling of the Franklinian Basin which was closed by diastrophism in the Devonian – Early Carboniferous (Higgins *et al.*, 1991).

Biostratigraphy

Rich graptolite faunas have been recorded from the Upper Llandovery, whereas graptolites from the Wenlock are sparsely represented. The main part of the graptolite material has been collected from measured profiles, but there has been no continuous sampling (Fig. 3). Consequently it is impossible to indicate vertical ranges and faunal developments, and no full biozonal and zonal boundaries can be defined. The graptolites from each sample have been listed and the assemblages correlated with established graptolite zones from well defined sections in other areas.

The starved basin deposits of the Thors Fjord Member, Profilfjeldet Member and the Lafayette Bugt Formation are generally rich in graptolites and diverse late Llandovery faunas are recorded. A fair number of cyrtograptids are known from these deposits, demonstrating the presence of the established biozones in the Llandovery – Wenlock transition which are generally based on *Cyrtograptus* index species. However, the few records of cyrtograptids in the turbidites of the prograding fan system in the Wenlock indicate that *Cyrtograptus* was apparently rare in these successions. The ecological and taphonomic aspects of the lack of Wenlock *Cyrtograptus* in the North Greenland turbidites have already been discussed by Bjerreskov (1986).

The state of preservation of the graptolites is generally rather poor, most specimens being preserved with flattened, more or less indistinct carbonised skeletons. Only a few specimens occur with low relief; several have undergone dorsal/ventral embedding and show torsion of the stipes, making it impossible to observe any morphological detail. The state of preservation generally does not allow any observation of the detailed thecal morphology in flattened rhabdosomes.

The graptolite zonation in the latest Llandovery and the main part of the Wenlock is mainly based on species of *Cyrtograptus* in addition to *Monograptus*, *Monoclimacis*, *Pristiograptus* and *Retiolites* which are of minor importance. The genus *Cyrtograptus* generally includes cosmopolitan species but occasionally the species distribution appears to be regional. In this respect the graptolite faunas of North Greenland are closely related to

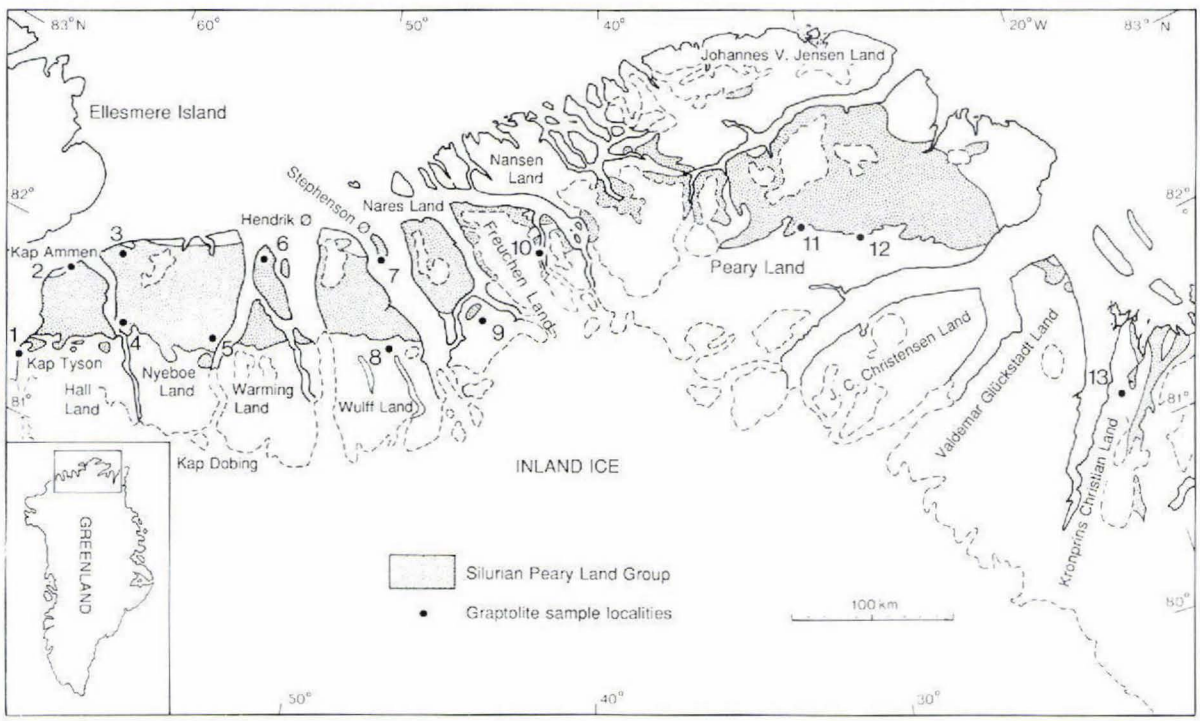


Fig. 3. Localities of the Peary Land Group in North Greenland where *Cyrtograptus* is recorded. 1: GGU 211749, GGU 211752, GGU 211753, GGU 211754, GGU 211761. 2: GGU 319231. 3: GGU 230210. 4: GGU 316302. 5: GGU 324126, GGU 324190. 6: GGU 315516. 7: GGU 319168. 8: GGU 254813. 9: GGU 319104, GGU 319107, GGU 324112, GGU 324412, GGU 324420, GGU 324432. 10: GGU 311247. 11: GGU 184059. 12: GGU 198123, GGU 198128, GGU 198133. 13: GGU 225756.

	British Isles Rickards (1976) Teller (1969)	Canadian Arctic Melchin (1988) Lenz & Melchin (1990, 1991)	North Greenland Bjerreskov (1986) this paper	Canadian Cordillera Lenz (1980, 1982)	China Mu *et al.* (1986)
Wenlock	*ludensis*	*ludensis*	*lundgreni – testis*	*sherrardae*	*lundgreni*
	nassa				
	lundgreni	*lundgreni – testis*		*testis – lundgreni*	
	ellesae	*perneri – opimus*	*perneri – opimus*	*"firmus – nahanniensis* beds"	*ramosus*
	linnarssoni – flexilis				*flexilis*
	rigidus	*instrenuus – kolobus*	*instrenuus – kolobus*	*rigidus*	*rigidus*
	riccartonensis			cf. *perneri*	*riccartonensis*
	murchisoni	*centrifugus – insectus*	? *murchisoni*	*centrifugus*	*murchisoni*
	centrifugus insectus		*centrifugus*		*centrifugus/ insectus*
Late Llandovery	*crenulata*	*sakmaricus*	*sakmaricus spiralis*	*sakmaricus – laqueus*	*grandis spiralis*
	griestoniensis	*griestoniensis*	*griestoniensis*	*spiralis*	*griestoniensis*
	crispus	*crispus*	? *crispus*		*crispus*
	turriculatus	*turriculatus*	*turriculatus*	*turriculatus*	*turriculatus* *sinicus*
	maximus	*minor*			*maximus*
					minor

Fig. 4. Comparison and correlation of Late Llandovery and Wenlock graptolite zonal schemes.

those from the Northern Canadian Cordillera and the Canadian Arctic Islands, the latter situated within the western parts of the Franklinian Basin. Recent papers by Lenz (1978, 1980, 1982, 1988), Melchin (1987, 1988) and Lenz & Melchin (1990, 1991) all deal with Llandovery and Wenlock graptolite faunas from these regions and the biostratigraphic schemes presented in these papers, based on collections from continuous sections, constitute the framework into which the North Greenland graptolite faunas have been incorporated (Bjerreskov, 1986, 1989 and this paper; Fig. 4) The stratigraphic scheme presented in Lenz & Melchin (1990, 1991), which demonstrates a subdivision of the sequences in Arctic Canada into fewer biostratigraphic units than normally applied to the Wenlock sequences, appears to be also useful in North Greenland. The scheme includes about half the number of zones usually recorded in the Wenlock and was explained by Lenz & Melchin (1990) as being caused by the occurrence of new or only tentatively identifiable species which do not allow correlation with European species. The same species reported from Canada are observed in the present material and, as the present cyrtograptid faunas are sparse and from scattered exposures, the Canadian scheme appears to be the most appropriate for this study.

Cyrtograptus sakmaricus Zone

This zone is defined in accordance with Lenz (1988) as the zone in which the cyrtograptids first appear, and in which *Cyrtograptus lapworthi* Tullberg, 1883 and *Cyrtograptus sakmaricus* Koren', 1968 are common. The two species, as well as *Cyrtograptus polyrameus* Fu, 1985, *Cyrtograptus multibrachiatus* n. sp. and *Cyrtograptus lapworthi* n. ssp. Melchin, 1987, occur together with faunas of the *M. spiralis* Zone, and the assemblages are regarded as representing the latest Llandovery, as in northern Canada. The associated non-cyrtograptid fauna includes *Monograptus spiralis* (Barrande, 1850), *Monograptus speciosus* Tullberg, 1883, and *Monoclimacis linnarssoni* Tullberg, 1883.

The *sakmaricus* Zone is regarded as being of latest Llandovery Age as discussed by Melchin (1988). The index species, together with *C. polyrameus* and *Cyrtograptus laqueus* Jackson & Etherington, 1969, have a wide occurrence and are reported from North America (Berry & Murphy, 1975), China (Fu & Song, 1986) and the Urals and Siberia (Koren', 1968; Golikov, 1969, 1974). The zone can be correlated with the European *lapworthi* Zone (Wærn, 1960; Teller, 1969; Bjerreskov, 1975). In all of the European papers there are no reports of multibranched forms such as *C. polyrameus* and *C. sakmaricus*. The uppermost Llandovery strata comprising the *M. crenulata* Zone in Britain lack cyrtograptids according to the literature, but recently a few finds have been made (Rickards *et al.*, 1990). The recognition of the large multibranched cyrtograptids in North Greenland emphasises the establishment of a distinct late Llandovery faunal province (Melchin, 1988) in North America, including North Greenland, Siberia, Kazakhstan and China, with faunas being different from the European cyrtograptid faunas (see later).

Cyrtograptus centrifugus Zone

The *C. centrifugus* Zone is reported for the first time from North Greenland; revision of the fauna listed in Norford (1972) has revealed that one sample (GSC 73946 renumbered as GGU 211753) includes a large number of specimens of *Cyrtograptus centrifugus* Bouček, 1931 in various astogenetic stages. *C. centrifugus* is the index species of the earliest Wenlock together with *Cyrtograptus insectus* Bouček, 1931 (Teller, 1969; Bjerreskov, 1975; Rickards, 1976; Lenz & Melchin, 1990, 1991). The latter paper demonstrated the haphazard stratigraphic relationship of the two species. *C. insectus* has not been observed with certainty in North Greenland as only distal fragments, probably referable to this species, are recorded. *C. centrifugus* is associated with the long ranging *Monograptus priodon* Bronn, 1835 and a slender form of *Monoclimacis vomerina* Nicholson, 1872.

?*Cyrtograptus murchisoni* Zone

The *C. murchisoni* Zone was defined by the presence of the index species (Bouček, 1933; 1960), and has been recognised in Poland, Czechoslovakia, Germany and Sweden, but not in North America and China. The only specimen recorded from North Greenland (GGU sample 324190) occurs without any stratigraphically useful associated graptolites and, with the limited material available, the presence of this zone is inconclusive. The *C. murchisoni* Zone has not been reported from North Canada.

Monograptus instrenuus – Cyrtograptus kolobus Zone

GGU sample 184059 includes *Cyrtograptus kolobus* Lenz & Melchin (1991) (described as *Cyrtograptus* sp. aff. *C. rigidus* (Lenz & Melchin, 1990)) associated with *Monograptus instrenuus* Lenz & Melchin, 1991 (described as *Monograptus* sp. aff. *M. riccartonensis* (Lenz & Melchin, 1990)), *Monograptus* aff. *M. deflexus* Bouček, 1931, *Monograptus* aff. *M. flexilis* sensu Lenz & Melchin (1990, 1991). This assemblage may correspond to those of the *C. kolobus – M. instrenuus* Zone in the Canadian Arctic (Lenz & Melchin, 1990, 1991) who reported the same species hitherto not found outside the Franklinian Basin. *Monograptus riccartonensis* Lapworth, 1876 was observed in Washington Land (Bjerreskov, 1981). However, the present material does not allow recognition of separate *M. riccartonensis* and *C. rigidus* Zones as recorded by Bouček (1933), Teller (1969) and Rickards (1976). *M. instrenuus* appears to be very common, being present in the greater part of the samples which lithologically are supposed to be of Wenlock age.

Cyrtograptus perneri – Monograptus opimus Zone

The zone was erected by Lenz & Melchin (1990) and includes, besides the index-species, *Cyrtograptus multiramis* Törnquist, 1910 which was reported to be abundant especially in the upper part. Furthermore, *Cyrtograptus pseudomancki* Lenz & Melchin, 1991 is present. The zone was correlated with the combined *M. flexilis – C. ellesi* Zone of Teller (1969) and Rickards (1976). Two samples from locality 9 (Fig. 3) might indicate this zone in North Greenland. The lower sample (GGU 319104) includes *C. pseudomancki* together with

Monograptus cf. *M. irfonensis* Elles, 1900. The latter species, however, might also indicate the *C. lundgreni* Zone. The upper sample (GGU 319107) includes *C. multiramis* associated with the long ranging species *M. instrenuus* and *Pristiograptus pseudodubius* Bouček, 1932. As both *C. multiramis* and *C. pseudomancki* were reported from the *C. perneri – M. opimus* Zone from Arctic Canada by Lenz & Melchin (1990, 1991), the presence of the two cyrtograptid species in North Greenland most likely indicates the same stratigraphical level.

Cyrtograptus lundgreni – Monograptus testis Zone

Monograptus testis (Barrande, 1850) is present in sample GGU 324134 and probably in samples GGU 230226 which accordingly are referred to the *C. lundgreni – M. testis* Zone. Furthermore, *Monograptus flemingi* (Salter, 1882), *M. instrenuus*, *Monoclimacis* sp. and *Monograptus* sp. have been recorded from this level. No cyrtograptids have been identified with certainty to indicate this level.

The zone is the most widespread Wenlock graptolite zone in the Canadian Cordillera or Arctic Islands (Lenz, 1978). However, evidence for the presence of this zonal level in North Greenland is sparse. Many samples include only forms of the *M. priodon/flemingi* type, being common in the *C. lundgreni* Zone and some may represent this level, as cyrtograptids generally are rare in the turbidites (Bjerreskov, 1986).

Biogeography

At the beginning of the Silurian, following the late Ordovician glaciation, melting of the Ordovician ice caps triggered eustatic sea-level rises. Subsequent re-establishment led to a graptolite fauna with a widely found basal Silurian *P. acuminatus* Zone. In the Silurian the differences between various graptolite successions are at the species and subspecies levels and, like the late Ordovician (Skevington, 1976) Silurian provincialism is not easily recognised. From the Ludlow (Late Silurian) to the Pragian (Devonian), graptolites appear to have had only a tropical occurrence (e.g. Koren', 1979).

Llandovery and Wenlock graptolite provincialism has been reported in a few cases. Within the tropical Silurian Pacific region, e.g. as figured by Berry & Wilde (1990), approximately corresponding to the Pacific province of the early Ordovician graptolite faunas (e.g. Skevington, 1976), Llandovery provincialism was recognised by Melchin (1988) in his analysis of the Arctic Canadian graptolites. He found that the *C. sakmaricus* Zone fauna, especially the cyrtograptids of the *C. sakmaricus – C. polyrameus* groups, and diverse retiolitids from North America together with those from Middle Asia and Siberia and to a lesser extent China, appear to define a faunal province. North Greenland constituted a part of this region and here the common occurrence of the large multibranched cyrtograptids in the upper Llandovery sequences clearly accentuates the presence of a Pacific fauna province. However, retiolitids, though very common in other places in the late Llandovery, are extremely rare in North Greenland. This may be explained by the predominant deposition of starved basin muds on the slopes and of basinal turbidites which accompanied the collapse of the shelf margin and following basin expansion. The large multibranched cyrtograptids are usually common in the deeper water slope deposits and are seldom present in more shallow water sequences. Here retiolitids have their highest occurrence, according to the depth zonation of Berry & Boucot (1972), and are therefore rare in the North Greenland upper Llandovery deposits.

The *C. sakmaricus* Zone *Cyrtograptus* assemblage in the Pacific region is clearly different from the late Llandovery faunas of northern and eastern Europe, with the corresponding *M. crenulata/C. lapworthi* Zones. The region was named the Rheic subprovince by Rickards *et al.* (1990). The extension was defined to be around the northern edge of the Rheic Ocean and within the Törnquist Sea, over the Baltic, Scandinavia, Bohemia, Romania and Poland. However, in spite of the different cyrtograptid species within the two areas, the monograptid faunas have many species in common, for example the rather frequent *M. speciosus*, slender forms of the *M. vomerina* group, *M. praecedens*, *M. parapriodon* (Bjerreskov, 1975; Melchin, 1987).

From the beginning of the Wenlock the large cyrtograptids of the *C. centrifugus*, *C. insectus* and *C. murchisoni* forms appear to be cosmopolitan. It is notable that from the *M. riccartonensis* Zone (= the early part of the *M. instrenuus – C. kolobus* Zone) and to the end of the Wenlock there are a number of endemic species from the North Canadian Cordillera and Arctic Canada (Lenz & Melchin, 1990, 1991) and from North Greenland, having morphologies only slightly different from those of well-known similar species in the Rheic

subprovince, *sensu* by Rickards *et al.* (1990). The North Greenland species comprise the cyrtograptids *C. kolobus* and *C. pseudomancki* and the monograptids *M.* aff. *flexilis sensu* Lenz & Melchin (1989), and *M. instrenuus*, a slender long-ranging *M. priodon* form. Unfortunately, information on Wenlock graptolites from Siberia, the Urals and Middle Asia is sparse (Koren', 1973) and Chinese Wenlock graptolites have not yet been described in detail (Wang, 1978; Ni, 1982; Ge & Li, 1984; Huo & Shu, 1986). Consequently, it cannot be determined if an isolated, specific water mass with a slightly separate graptolite fauna was confined only to the Franklinian Basin, or the fauna constituted part of a larger Pacific faunal region as described by Rickards *et al.* (1990) as being a subprovince with an offshore fauna.

A separate Wenlock Mediterranean province, with location around North Africa, Portugal, South France and Spain, and characterised by occurrence of a cold water fauna with giant graptolites, has been described by several authors (Waterlot, 1952, Romariz, 1962; Berry & Wilde, 1990 and Rickards *et al.*, 1990). However, the presence of a Mediterranean province or subprovince was rejected by Jaeger (1976) who argued that the tectonic deformation of the giant forms is obvious, and he registered no differences between the North European and South European forms.

Consequently separation of Wenlock graptolite faunas into different provinces or subprovinces remains an open question. Detailed descriptions of the Wenlock graptolites from more localities together with analyses of their occurrences in different sedimentary facies and water depths are needed before the relations between the different faunas can be described, as done for the Ordovician graptolite assemblages with regard to ecostratigraphy (Erdtmann, 1976) and latitudinal and depth zonation by Cooper *et al.* (1991).

Systematic descriptions

Graptolite classification is currently under revision and the taxonomic position of the cyrtograptids was recently briefly discussed by Cooper & Fortey (1985) and Mitchell (1987). The division by Bulman (1970) into Monograptidae and Cyrtograptidae subfamilies is not phyletically meaningful, as noted by Rickards *et al.* (1977) and in the latter paper the cladia development has been described as the only structure valid for a phylogenetic classification. A polyphyletic origin with at least four and possibly more basic stocks of cyrtograptids was proposed by Rickards *et al.* (1977), comprising *spiralis – sakmaricus*, *planus – lapworthi*, *?tullbergi – lapworthi*, and *rigidus* – ? relationships. By investigating isolated specimens of *M. spiralis* and *Cyrtograptus*, Lenz & Melchin (1989) recognised increasing asymmetry and elaboration of thecal apertures throughout the rhabdosome of *M. spiralis*. The opposite tendency is present in *C. sakmaricus* which develops from elaborate to asymmetric proximal parts towards more simple distal thecae, suggesting that the two species could not have any ancestral relationship and giving support to the supposed polyphyletic origin of *Cyrtograptus*.

For classification of both monograptids and cyrtograptids investigation of specimens preserved in relief is required to show the detailed thecal morphology and changes during astogeny. According to the study of Lenz & Melchin (1989), some form-groups may show criteria valid for classification of cyrtograptids. *C. laqueus*, which has a long proximal end with elongated thecae, was suggested to have been derived from *Monograptus delicatulus* Elles & Wood, 1913. Lenz & Melchin (1989) proposed that *Monograptus turriculatus* Barrande, 1850 was related to *C. sakmaricus* by the strongly curved asymmetrical proximal end. *C. lapworthi* and *C. polyrameus* might be related to each other. Deng (1990) suggested that the two species were conspecific as there appears to be a continuous transition between them, with a delayed origin of the mother theca to the first cladium in the latter species. However, no details of the thecal structures are known. *Monograptus planus* Barrande, 1850 appears to have asymmetrical thecae (personal communication, David K. Loydell, 1990) and the phylogenetic relationship between this species and *C. lapworthi* awaits detailed analysis of the thecae in *C. lapworthi*. The relationship between *C. rigidus* and *C. kolobus* must remain questionable until more material is available.

New species and subspecies of *Cyrtograptus* have recently been described, e.g. *C. polyrameus*, *Cyrtograptus preclarus* Lenz, 1988, *Cyrtograptus hexaformis* Fu & Song, 1986, *Cyrtograptus robustus* Fu & Song, 1986 and *Cyrtograptus turbinus* Fu & Song, 1986, in which the descriptions have been based on specimens in which the proximal ends with sicula are incompletely preserved, and in which the morphological differences are related to more or less enrolled or eccentrically enrolled proxi-

mal ends. This feature, however, can often be regarded as a preservational phenomenon.

Revision of the classification of *Cyrtograptus* species is required, but as long as the classification of the subfamily Monograptinae remains unsolved, and the basic criteria for classifying the family have not been agreed, the cyrtograptids must await revision. Consequently, currently defined species and subspecies are retained in the present paper, but with additional remarks to description of species in need of redefinition. Many species are ill defined; especially *Cyrtograptus murchisoni bohemicus* Bouček, 1931, *C. centrifugus*, *Cyrtograptus murchisoni murchisoni* Carruthers, 1867 (Strachan, 1969) are in need of redefinition, together with the highly variable *C. lapworthi* and *C. polyrameus*. Also the rather undefined group of forms having secondary cladia, including *C. insectus*, *Cyrtograptus tullbergi* Bouček, 1933 and *Cyrtograptus malgusaricus* Golikov, 1974, which all appear to be closely related, need revision.

All figured specimens are deposited in the Geological Museum, Copenhagen; other GGU specimens are retained by the Geological Survey of Greenland.

Family Diplograptidae Lapworth, 1873, emend.
Subfamily Monograptinae Lapworth, 1873

Genus *Cyrtograptus* Carruthers, 1867

Type species. *Cyrtograptus murchisoni* Carruthers, p. 540, fig. 1; from Wenlock Shales, Wales.

Diagnosis. See Bulman, (1970, V135).

Cyrtograptus centrifugus Bouček, 1931
Fig. 8F-J

1931	*Cyrtograptus centrifugus* n. sp.; Bouček, p. 13, fig. 14a-d.
1933	*Cyrtograptus centrifugus*, Bouček; Bouček, pp. 27–28, fig. 3a-d, pl. 3, figs 1–4.
1940	*Cyrtograptus Murchisoni* Carruthers; Laursen, pl. 4, fig. 1.
1945	*Cyrtograptus centrifugus* Bouček; Waterlot, p. 93, fig. 465.
1968	*Cyrtograptus (Cyrtograptus) centrifugus* Bouček; Schauer, pp. 36–37, pl. 1, fig. 3, pl. 3, figs 3–4.
1975	*Cyrtograptus centrifugus* Bouček; Bjerreskov, p. 86, fig. 25.
1978	*Cyrtograptus centrifugus* Bouček; Lenz, p. 627, pl. 1, fig. 1.
?1985	*Cyrtograptus centrifugus* Bouček; Fu, p. 323, fig. 1, 2a-c, pl. 1, fig. 2.
?1986	*Cyrtograptus centrifugus*; Deng, fig. 2,5.
?1986	*Cyrtograptus centrifugus* Bouček; Fu & Song, p. 142, pl. 23, fig. 2.
1990	*Cyrtograptus centrifugus* Bouček; Lenz & Melchin, fig. 3H.
1991	*Cyrtograptus centrifugus* Bouček; Lenz & Melchin, p. 231, fig. 18F, G, K, L.

Material. More than 60 specimens from GGU 211753, B. S. Norford collection, Lafayette Bugt Formation, Kap Tyson, east outcrops, Hall Land. All preserved flattened.

Description. In well preserved specimens the proximal portion of the main stipe forms up to two volutions but the extreme proximal end with sicula is generally not preserved; only one specimen has 2 complete volutions. The two inner coils have diameters of 4–5 mm and 1 cm. The distal part of the stipe is weakly to moderately curved. There are up to 3 cladia of the first order. Cladium 1 originates around thn + 27–32, there are about 5–7(8) thecae between cladium 1 and cladium 2 and about 12 thecae between cladium 2 and cladium 3. The cladia are generally straight to weakly curved, but can be semicircular. The width of the rhabdosome is about 1 mm at the most proximal theca, increasing to about 1.8 mm at the origin of the first cladium; maximum width is about 2 mm. All measurements are exclusive thecal spines. In the cladia the width decreases to about 1.5 mm, but the cladia are twisted so that exact measurements cannot be made.

The proximal end with sicula has apparently undergone torsion, and neither the sicula nor the initial thecae have been observed. The thecae are triangular and hooked, but so badly preserved that the detailed apertural structures and overlap cannot be distinguished. The retroverted hook occupies up to nearly half of the width of the rhabdosome. In well preserved specimens 0.5 mm long apertural spines are visible. The thecae number 3 per 2.5 mm within the first volution, 5.5 per 5 mm proximally to the origin of the first cladium; distally the number is 5 per 5 mm.

Remarks. *C. centrifugus* is distinguished from other cyrtograptids by the presence of only cladia of the first order, together with the two proximal volutions. The present material is very similar to that earlier described by Bouček (1933), Schauer (1968), Bjerreskov (1975) and Lenz (1978). *C. centrifugus* is difficult to distinguish from *C. murchisoni bohemicus* when the proximal end is missing, as the cladia are situated at approximately equal distances in the two species. *C. centrifugus* may be identical to *Cyrtograptus murchisoni crassiusculus* Tullberg, 1883 and both species are in need of a redefinition (Strachan, 1969; Bjerreskov, 1975).

C. centrifugus has been found in only one sample in North Greenland; it is generally regarded as indicating the base of the Wenlock (Bouček, 1960; Lenz, 1978 and Lenz & Melchin, 1990, 1991).

Associated species. *C. centrifugus* is associated with *M. priodon* and a slender form of *M. vomerina*.

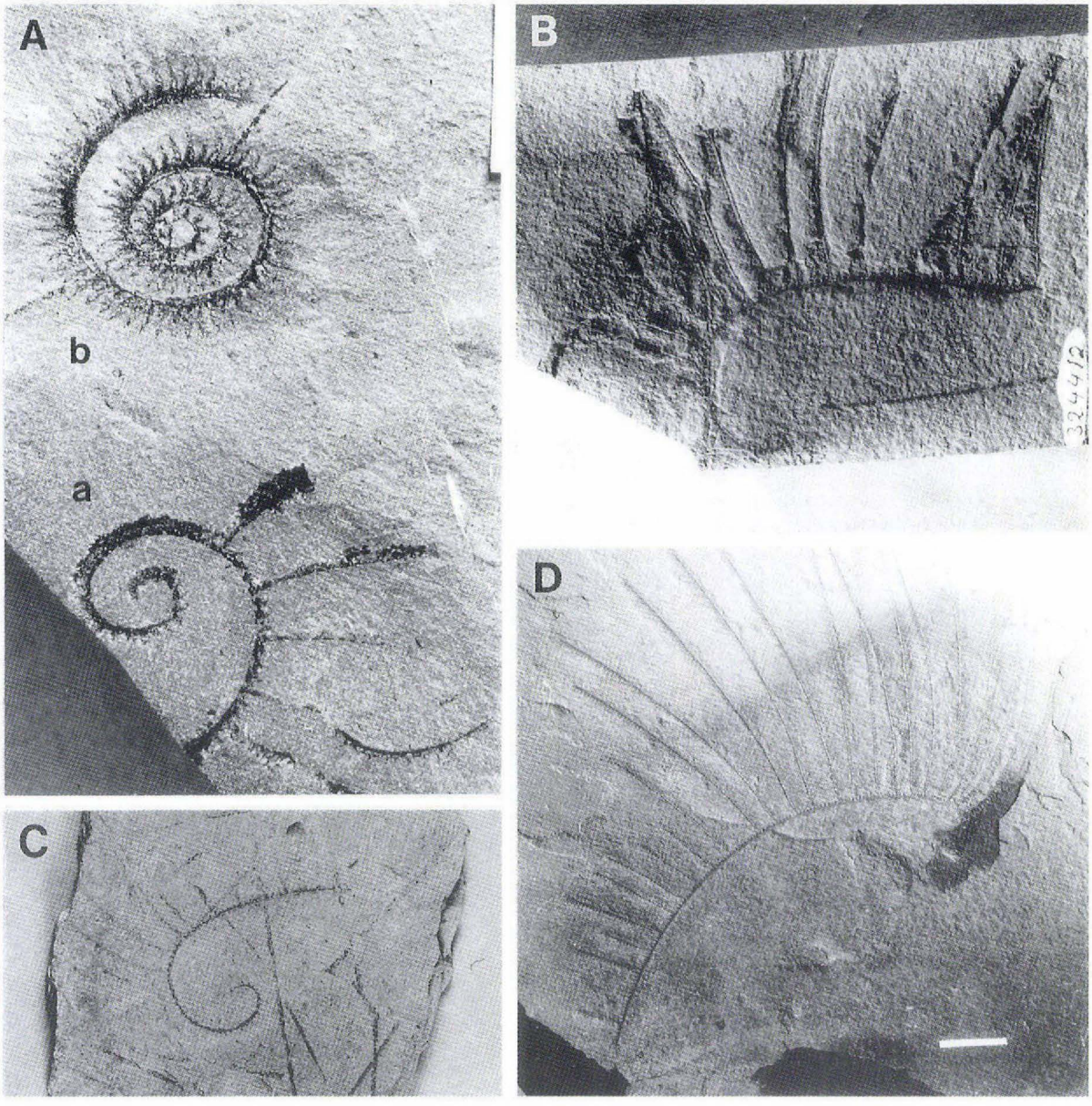


Fig. 5. *Cyrtograptus polyrameus* Fu & Song. A, MGUH 20774 from GGU 319112, Nares Land (a), associated with *Monograptus spiralis spiralis* (Barrande) MGUH 20775 (b), × 2.1. B, MGUH 20776 from GGU 324412, Nares Land. × 0.8. C, MGUH 20777 from GGU 324432, Nares Land. × 0.8. D, MGUH 20778 from GGU 324126, Nyeboe Land, × 0.5.

Cyrtograptus sp. cf. *C. insectus* Boucêk, 1931

Fig. 9F, G

Material. Several fragments, presumably distal parts, on one slab, GGU 311247, Thors Fjord Member, Wulff Land Formation, Freuchen Land.

Description. All the specimens are fragmentary, flattened and nearly all are preserved with the dorsal or ventral side upwards. The cladia of at least two orders originate at distances of 2–4 cm from each other. Only in one distal fragment are some indistinct thecae visible (Fig. 9G). The fragment is 1.8 mm wide, with straight thecal tubes and a tendency to ventral curvature in the apertural regions. The thecae are about 2 mm long, with an inclination at about 30–45° to the main axis, and number 10–11 per 10 cm.

Remarks. The specimens are most likely referred to *C. insectus* but may also be related to *C. tullbergi* or *C. malgusaricus* on account of the great distances between the cladia, as indicated by Bouček (1933). However, there might also be some possibility that the specimens could be referred to *C. murchisoni murchisoni*, being distal fragments of large rhabdosomes with longer distances between the cladia than usually described.

Associated species. *C. lapworthi*? is the only associated species in this sample.

Cyrtograptus kolobus Lenz & Melchin, 1991

Fig. 9E

?1977 *Cyrtograptus rigidus rigidus* Tullberg; Carter & Churkin, pp. 31–32, pl. 5, fig. 5; pl. 6, fig. 4; pl. 7, fig. 6.

1991 *Cyrtograptus kolobus* n. sp.; Lenz & Melchin, p. 233, fig. 11A-C.

Material. One flattened specimen, GGU 184059, from the top of the Thors Fjord Member, Ugledal, Børglum Elv, Peary Land.

Description. The specimen has a 1 cm long main stipe, abruptly curved in the proximal part and nearly straight distally, and only one 0.75 cm long slightly curved cladium. The initial proximal end appears to be characteristically sharply bent, and the sicula and the most proximal thecae cannot be observed with certainty. The cladium originates from the eighth visible theca and the main stipe is twisted at the level of th12. The cladium forms an angle of about 160° to the main stipe. In the cladium there are only 6 thecae preserved. The width of the rhabdosome is 1 mm at the first thecae, and it increases to 1.4 mm at th8 which is the maximum width measured.

The thecae are triangular, with a common canal occupying about half of the width of the rhabdosome, and with slightly hooked retroverted parts. Thecal apertural spines of about 0.8 mm in length are observed, but the detailed apertural morphology is obscure. The thecae number 6 per 5 mm proximally and also 6 per 5 mm in the cladia.

Remarks. The present specimen is very similar to *Cyrtograptus rigidus* Tullberg, 1883. The proximal part has a blunt appearance similar to that of *C. kolobus*, and the specimen from North Greenland appears to be identical to the specimens figured in Lenz (1978) and Lenz & Melchin (1990) as *Cyrtograptus* sp. aff. *C. rigidus*, and described as *C. kolobus* by Lenz & Melchin (1991).

However, the blunt appearance of the precladial part, without any sicula of normal shape, is most likely a consequence of a primary helical shape which has been broken or twisted during the embedding, as described and illustrated for *C. rigidus rigidus* from Idaho by Carler & Churkin (1977). From investigations of European specimens of *C. rigidus*, comprising type material from Scania, the author's new collections from Bornholm, Denmark, and Sardinian samples kindly placed at the author's disposal by Hermann Jaeger, Berlin, it appears that the precladial portions are often broken, but never show blunt appearances caused by twisting of the stipe or spiral shapes. Additional material of *C. kolobus* may demonstrate that *C. kolobus* is a form of *C. rigidus* with helically shaped proximal end as may appear from Carter & Churkin (1977).

C. kolobus was reported by Lenz & Melchin (1991) to be indicative of the *M. instrenuus* – *C. kolobus* Zone in the Cape Phillips Formation being, however, an uncommon species from this level.

Associated species. The present specimen is associated with *Monograptus* aff. *M. flexilis* sensu Lenz & Melchin, 1990, 1991), *Monograptus* aff. *M. deflexus* and *M. instrenuus*, indicating a stratigraphic level corresponding to the *C. kolobus* – *M. instrenuus* Zone of Lenz & Melchin (1990, 1991).

Cyrtograptus lapworthi Tullberg, 1883?

Fig. 7E, F

Material. One cladia-bearing fragment, possibly tectonically compressed, GGU 225756, Profilfjeldet Member, Lauge Koch Land Formation, Kronprins Christian Land. One cladia-bearing fragment, preserved flattened from GGU 230210. Section 21, (Hurst & Surlyk, 1982), Lauge Koch Land Formation, Nyeboe Land.

Description. The two cladia-bearing specimens have about 2 cm long moderately curved main stipes. Specimen GGU 225756 (Fig. 7E) has an indistinct sicula which is about 1.5 mm long. The main stipe is 0.9 mm wide at th1 and 1 mm wide at the origin of the cladium which occurs 12 thecae distal to sicula. GGU 230210 has a 15 mm long main stipe which is 1–1.2 mm wide. Five thecae distal to the cladium the main stipe is twisted. In both specimens the thecae are triangular, hooked with retroverted apertural parts; no spines have been observed. The number of thecae is 7 per 5 mm in the specimen fig. 7E and 4 per 5 mm in specimen fig. 7F.

Remarks. The slender semi-circular rhabdosome with only one cladium and a short procladial portion allows only a tentative comparison with *C. lapworthi* as no

complete rhabdosomes have been preserved. The differences in the number of thecae per 10 mm in the two specimens may be caused by tectonic deformation.

Associated species. GGU 230210: *Retiolites geinitzianus s.l.* (Barrande, 1850), *Pristiograptus* sp., and *C. sakmaricus*. GGU 225756: *Monoclimacis* sp., *M. priodon* and *C. polyrameus*, both samples indicating a *C. sakmaricus* Zone level.

Cyrtograptus lapworthi n. ssp. Melchin, 1987

Fig. 7A-D

1975 *Cyrtograptus* aff. *C. lapworthi* Tullberg; Berry & Murphy, pp. 85–86, pl. 10, fig. 1, text-fig. 22c.
1978 *Cyrtograptus* aff. *lapworthi* Tullberg; Lenz, p. 629, pl. 1, fig. 2; pl. 2, figs 3, 5, 6; text-fig. 2, fig. 7.
1987 *Cyrtograptus lapworthi* n. ssp,; Melchin, pp. 562–564, text-fig. 47G-J.

Material. One specimen from GGU 254813, Wulff Land, and several specimens, fragments with or without cladia, from GGU 324420, Thors Fjord Member, Nares Land. All specimens are preserved flattened.

Description. The main stipe, up to 5 cm long, is coiled into two volutions in the largest specimen (Fig. 7A) and at least one volution in the specimen illustrated in Fig. 7D. The two large specimens lack the proximal end with sicula and the only cladium originates from respectively thn + 25 and thn + 34. The width of the most proximal end is 0.75 mm in the specimen Fig. 7B, gently increasing to 0.9–1.1 mm at the origin of the cladium. The proximal thecae are subtriangular, with slender prolonged prothecae, and the metathecal parts are hooked, the apertures most likely facing ventrally. However, the state of preservation does not reveal any further details of the thecal structures. The thecal spacing is 5 per 5 mm proximally and 4.5 per 5 mm distally.

Remarks. As noted by Lenz (1978) and Melchin (1987) *C. lapworthi* n. ssp. from Arctic Canada, which is similar to the specimens from North Greenland, differs from *C. lapworthi lapworthi* primarily in that the proximal end is longer, more tapering and more strongly coiled. The largest specimen in the present material is even more strongly coiled than described for *C. lapworthi* n. ssp. from Arctic Canada. *C. lapworthi*, described by Schauer (1968), may include both *C. lapworthi lapworthi* and the new subspecies; the most enrolled forms were found in the uppermost layers of the *S. grandis/M. probosciformis* Zone and have a 450° proximal coiling. *C. lapworthi* n. ssp. is more slender and has a lower number of cladia than *C. murchisoni bohemicus* Bouček.

C. lapworthi n. ssp. appears to be a valid subspecies, but the present lack of well preserved specimens with proximal ends prevents formal erection of a new subspecies.

Associated species. GGU 254813: *R. geinitzianus* sl., *M.* ex. gr. *M. griestoniensis* and *Monoclimacis* sp. GGU 324420: *Retiolites* aff. *R. densereticulatus* Bouček, 1931, *Stomatograptus grandis* (Suess, 1851), *M. vomerina vomerina*, *M. linnarssoni*?, *M. priodon*, *M. spiralis*, *Monograptus exiguus s.l.* (Nicholson, 1868), *M. parapriodon*, *Monograptus* cf. *M. kovalevski* Obut & Sobolevskaya, 1966.

Cyrtograptus multibrachiatus n. sp.

Fig. 6A-C; Fig. 7G, H, J

?1980 *Cyrtograptus centrifugus* Bouček, 1931; Lenz, pp. 1082, 1084, pl. 2A.
?1981 *Cyrtograptus* n. sp. Bjerreskov, pp. 52–53, pl. 6, fig. 5.
?1987 *Cyrtograptus* n. sp. Bjerreskov; Melchin, pp. 573, 576, text-fig. 49A-D, F.

Material. About 25 specimens from GGU 198123, GGU 198128, and GGU 198133, Lauge Koch Land Formation, central Peary Land. Nearly all specimens are badly preserved, generally flattened; a few have a very low relief.

Holotype. MGUH 20779, from GGU 198123, Lauge Koch Land Formation, central Peary Land.

Derivation of name. multibrachiatus = with many arms.

Diagnosis. Rhabdosome with tightly curved circular proximal end, strongly curved main stipe with numerous closely set cladia curved to become parallel with the main stipe, and up to 2 mm wide rhabdosome with triangular spinose thecae.

Description. The proximal end of the main stipe is tightly coiled into one volution with a diameter of 2–3 mm, and distally the main stipe is moderately to slightly curved. The number of cladia are highly variable, some specimens have only one cladium, and the largest specimen (Fig. 6C) has a 15 cm long coiled main stipe with at least 19 cladia, of first order only, distally curved to be parallel with the main stipe. The most proximal 10 cladia have their origin every two to three thecae, and cladia 11 to 19 every eight thecae. The proximal end cannot be observed as it is surrounded by a carbon film,

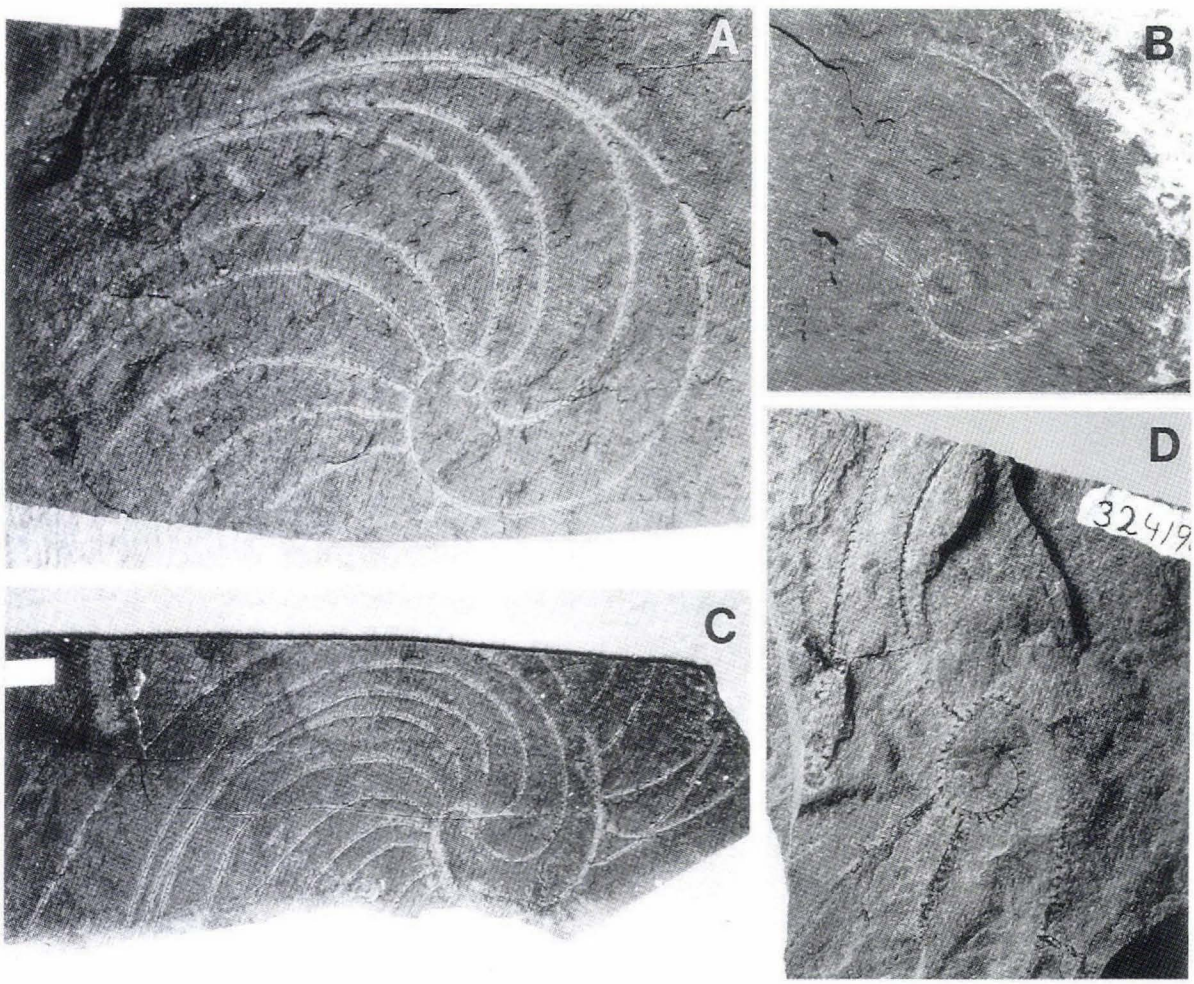


Fig. 6. A-C, *Cyrtograptus multibrachiatus* n. sp. A, holotype, MGUH 20779 from GGU 198123, central Peary Land, × 1. B, MGUH 20780 from GGU 198123, central Peary Land, × 1.5. C, MGUH 20781 from GGU 324412. D, *Cyrtograptus murchisoni murchisoni* Carruthers, MGUH 20782 from GGU 324190, Nyeboe Land, × 1.2.

covering all thecae, apparently a gerontic phenomenon in this large specimen. Cladium 1 originates about 360° from sicula and must have attained a length of more than 25 cm.

The proximal thecae are triangular with hooked apertural parts. Distally, the prothecal parts become wider and the prothecal ventral parts are less inclined to the axis of the main stipe, but the thecae are still triangular with distinct hooks. The thecal overlap is not clearly seen. The exact structure of the apertural parts cannot be observed, but well preserved specimens appear to have right lateral torsion of the thecal apertural parts. Apertural spines are clearly observed in well preserved specimens, and they can attain a length of about 1 mm.

The sicula is 1 mm long and its apex reaches to the base of th1. The rhabdosome is 0.7 mm wide at th1, 0.75 mm at th2, 0.8 mm at th3, 1 mm at th5, 1.5 mm at th10, from th15–30 the width is 1.7–2.0 mm, excluding apertural spines. The cladia have undergone torsion and the width cannot be measured. In the proximal coil the thecae number 3 per 2.5 mm and 5 per 5 mm distal to cladium 1. In the distal end of the main stipe the number is 9–10 per 10 mm.

Remarks. *C. multibrachiatus* is clearly distinguished from other cyrtograptids by the circularly coiled proximal end, with cladium 1 originating almost constantly 360° from the sicula, and the large number of closely set curved cladia. *C. multibrachiatus* is most similar to *C. preclarus* but the former can be separated by the higher number of thecae in the proximal coil, wider rhabdosome and higher number of cladia.

C. multibrachiatus resembles *Cyrtograptus* n. sp. (Bjerreskov, 1981 and Melchin, 1987, 1988) which can be separated by the more open coiled proximal end, closer set thecae and a maximum width of 1.6 mm. However, *Cyrtograptus* n. sp. appears to be so closely related to *C. multibrachiatus* that it might be regarded as a subspecies.

C. multibrachiatus shows some similarity to *C. sakmaricus* due to its closely spaced curved cladia, but the former has a much shorter and more tightly curved precladial part of the main stipe. *C. centrifugus* figured by Lenz (1980) is most likely referable to *C. multibrachiatus* on account of the tight volution of the proximal part and the very closely spaced cladia, of which cladium 1 originates at 360° from the sicula. In *C. centrifugus* there are at least 1½ volutions proximal to the origin of the first cladium and the cladia are usually more widely spaced.

C. multibrachiatus is very similar to the other cladia-rich species from the *C. sakmaricus* Zone, such as *C. sakmaricus*, *C. polyrameus*, and *Cyrtograptus* n. sp. in Melchin (1987) which are characteristic in the Canadian – Middle Asia – China regions. Investigations of better preserved material are needed before it can be concluded, whether the multi-cladia bearing *Cyrtograptus* species with more or less enrolled proximal ends are related to each other phylogenetically.

In the mature specimens (Figs. 6A, C) the carbon film surrounding the proximal part, enveloping the whole inner coil in the largest specimen (Fig. 6C) and only the initial thecae in the less mature specimen in Fig. 6A, is evidently equivalent to the membrane in *Cyrtograptus* described by Lenz (1974) from the uppermost Llandovery beds in Arctic Canada. The structure was interpreted as formed at a late astogenetic stage of development and the occurrence of the present carbon films in the mature rhabdosomes supports Lenz's conclusion.

Associated species. The three samples include: *R. geinitzianus* sl., *M. vomerina*, slender form, *M. vomerina*, *M. priodon*, *M.* cf. *M. parapriodon*, *Monograptus praecedens* Bouček, 1931, *M. spiralis*, *Monograptus* cf. *M. tullbergi* Bouček, 1931, *Monograptus* sp. and *Streptograptus* sp. The present associated assemblage suggests a *C. sakmaricus* Zone level for *C. multibrachiatus* but unfortunately the exact position cannot be given.

Cyrtograptus multiramis Törnquist, 1910

Fig. 10B, D-F

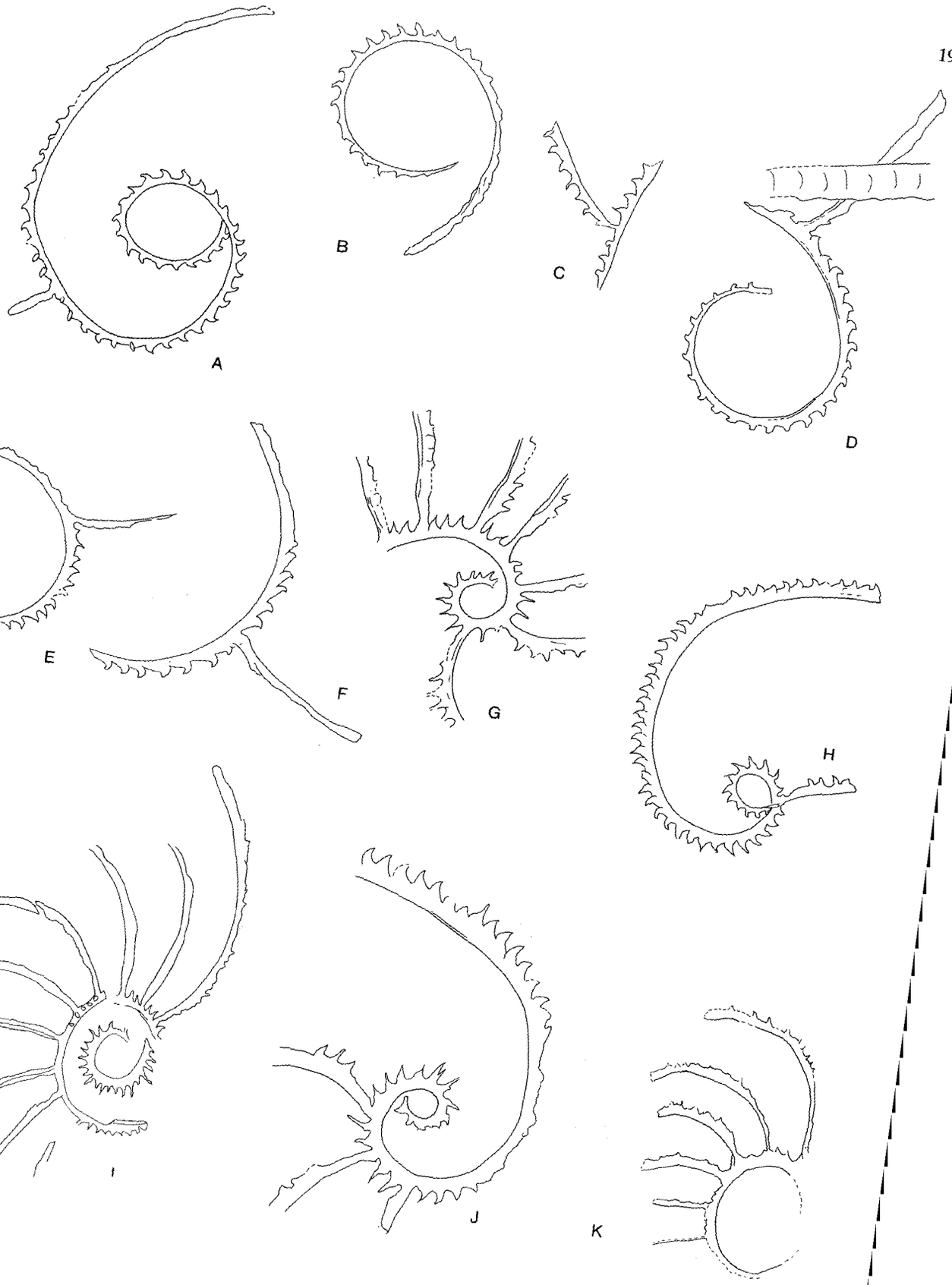
1910 *Cyrtograptus multiramis* n. sp; Törnquist, pp. 1562–1564, pl. 62, figs 5, 6.
1924 *Cyrtograptus multiramis* Törnquist; Hundt, p. 76, pl. 2, fig. 31.
?1924 *Cyrtograptus ruthenicus* Eisel; Hundt, p. 76, pl. 9, fig. 5; pl. 10, fig. 3.
1933 *Cyrtograptus multiramis*, Törnquist; Bouček, pp. 56–57, not figured.
1945 *Cyrtograptus multiramis* Törnquist; Waterlot, p. 93, fig. 472.
1952 *Cyrtograptus multiramis* Törnquist; Münch, p. 139, pl. 53, fig. 2.
1952 *Cyrtograptus* (*Cyrtograptus*) *multiramis multiramis* Törnquist, 1910; Bouček & Přibyl, pp. 4–7, pl. 1, fig. 1; pl. 4, fig. 8; text-fig. 1a-b.
1990 *Cyrtograptus multiramis* Törnquist; Lenz & Melchin, fig. 4H-J.
1991 *Cyrtograptus multiramis* Törnquist; Lenz & Melchin, p. 234, fig. 13A-C, fig. 20A, B, E, H, I.

Material. Three rather incomplete specimens and several proximal and distal fragments most likely referable to this species. All specimens are flattened. GGU 319107, Lauge Koch Land Formation, Nares Land.

Description. The most complete specimen (Fig. 10E) has a 2.5 cm long main stipe, coiled into one and a half volutions. The proximal end is very slightly dorsally bent and after 7 mm it turns into a circular to ovate coil with a diameter of 5 mm. The extreme proximal end with sicula is not preserved. Distally to the coil the main stipe becomes slightly dorsally curved at the level of the origin of the first cladium. There are three moderately curved cladia, about 1 cm in length, which arise from thn + 11 and every 3–4 thecae. The main stipe is slender, proximally with 0.3 mm wide metathecal parts, increasing to 1 mm at the level of cladium 1. Torsion of the main stipe prevents measurement of the distal maximum width.

The proximal five thecae are elongated with slender prothecae and with metathecal regions having small retroverted apertural parts, probably with spines. Distally the thecae become triangular with prothecal and metathecal parts of about equal heights. The thecal number is 5–4.5 per 5 mm in the proximal end.

Fig. 7. A-D. *Cyrtograptus lapworthi* n. ssp. Melchin. A-C from GGU 324420, Nares Land, × 3. A, MGUH 20783. B, MGUH 20784. C, MGUH 20785, D, MGUH 20786 from GGU 254813, Wulff Land. E, F, *Cyrtograptus lapworthi* Tullberg. E, MGUH 20787 from GGU 225756, Kronprins Christian Land, × 3. F, MGUH 20788 from GGU 230210, Nyeboe Land, × 3. G, H, J, *Cyrtograptus multibrachiatus* n. sp., GGU 198123, central Peary Land. G, MGUH 20779 (holotype, also Fig. 5A), × 2.2. H, MGUH 20780 (same specimen as in Fig. 5B), × 2.2. J, MGUH 20789, × 3. I, *Cyrtograptus sakmaricus* Koren', MGUH 20790 from GGU 319231, Hall Land, × 1.5. K, *Cyrtograptus sakmaricus*?, MGUH 20791 from GGU 230210, Nyeboe Land. × 3.


A
B
C
D
E
F
G
H
I
J
K

In the cladia the thecae transform into a tube-like morphology with small beak-like apertural parts. However, the state of preservation does not allow any observations of overlap and apertural details. The cladia are 1–1.25 mm wide.

One badly preserved specimen (Fig. 10B) has a tightly coiled proximal part of the main stipe (3 mm in diameter) and four curved cladia with a length of up to 2.5 cm. There might be about 4 thecae between the origin of the two most proximal cladia, the other distances cannot be measured. The specimen is probably referable to this species and might represent a more tightly coiled form.

Remarks. The present specimens are poorly preserved, but the characteristic shape of the rhabdosome and the position of the cladia allow reference of the specimen to *C. multiramis*.

Recent descriptions of *C. multiramis* are rare. However, Lenz & Melchin (1990, 1991) reported the species from the Cape Phillips, Arctic Canada, where it occurs in the uppermost *C. perneri – M. opimus* Zone, with the highest abundance in the upper part of the zone, and in the *C. lundgreni – M. testis* Zone.

Associated species. The present specimens are associated with *Monograptus instrenuus* Lenz & Melchin, 1991 and *Pristiograptus* aff. *P. pseudodubius* Bouček, 1932. Both species are long ranging from middle to late Wenlock.

Cyrtograptus murchisoni murchisoni Carruthers, 1867

Fig. 6D, 9D

	1867	*Cyrtograptus Murchisoni* Carruthers; Carruthers, p. 541, fig. 1.
	1883	*Cyrtograptus Murchisoni* Carruthers; Tullberg, p. 35 (pars), pl. 4, figs 10, 11 (not fig. 9).
	1914	*Cyrtograptus murchisoni* Carruthers; Elles & Wood, pp. 505–507, pl. 51, fig. 3a-c, text-figs 351a-c, 352a-b.
	1933	*Cyrtograptus murchisoni* Carruthers; Bouček, pp. 30–32, pl. 2, figs 1–3, text-fig. 5e, f.
non	1940	*Cyrtograptus murchisoni* Carruthers; Laursen, p. 29, text-fig. 25, pl. 4, fig. 1.
	1945	*Cyrtograptus Murchisoni* Carruthers; Waterlot, p. 93, fig. 461.
	1968	*Cyrtograptus* (*Cyrtograptus*) *murchisoni murchisoni* (Carruthers 1867); Schauer, pp. 37–38, pl. 1, fig. 4; pl. 5, fig. 3.
	1985	*Cyrtograptus murchisoni* Carruthers; Fu, p. 325, fig. 3.
	1986	*Cyrtograptus murchisoni* Carruthers; Fu & Song, p. 143, fig. 3.

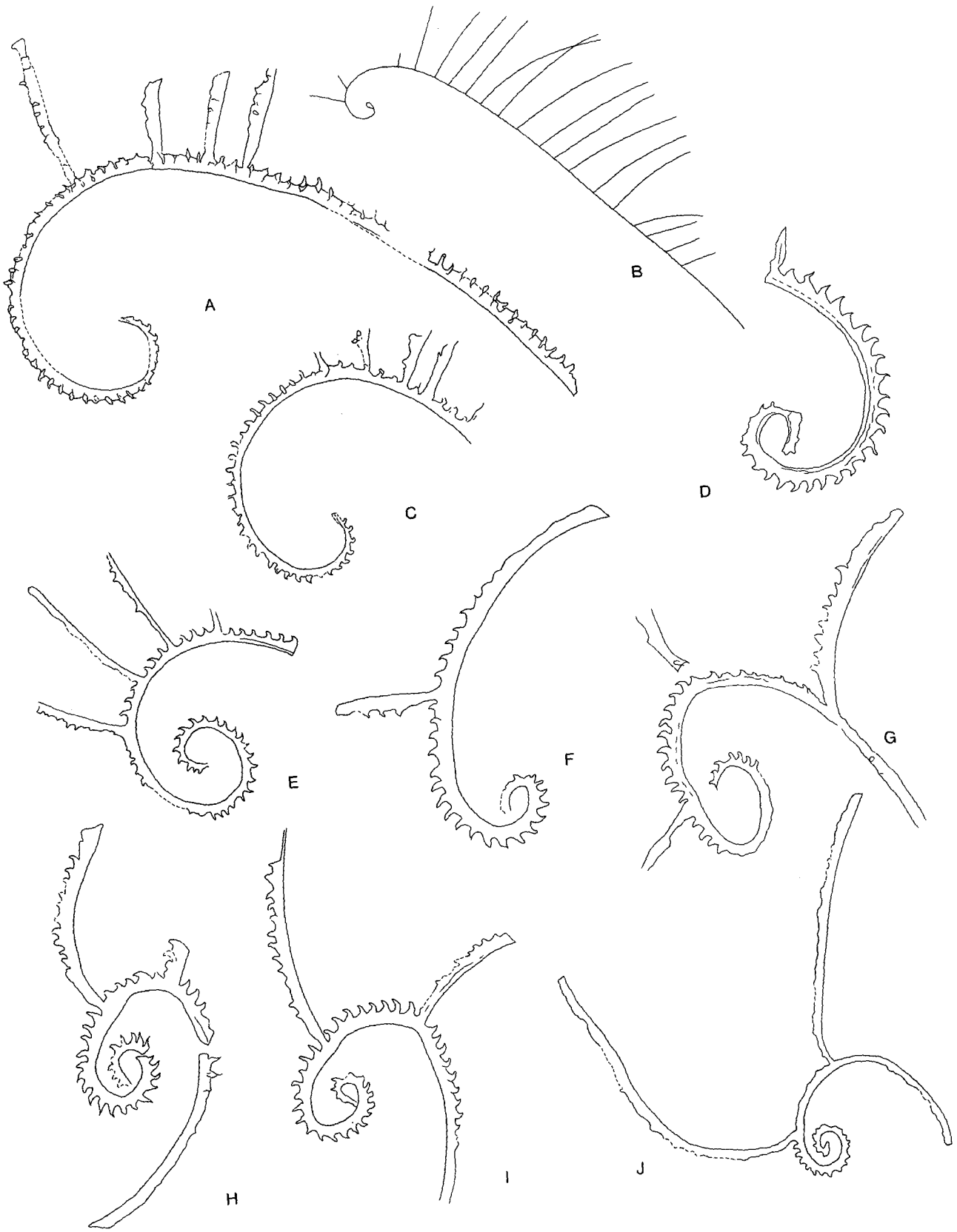
Material. One specimen, GGU 324190, from scree, within the Lafayette Bugt Formation, Nyeboe Land. The specimen is preserved as a weathered relief cast, dorso-ventrally embedded. One specimen probably referable to this species, GGU 319168, 5–10 m above the base of the Thors Fjord Member, Wulff Land Formation, Stephenson Ø. The specimen is badly preserved, and embedded dorso-ventrally.

Description. The main stipe is nearly circularly coiled in the proximal end and moderately curved distally. The proximal end with sicula has not been observed. The main stipe is about 5 cm long and the longest cladium is more than 3 cm long. Cladium 1 originates at th12 + n; 3 thecae separate cladium 1 from cladium 2. Cladium 3 originates 6 thecae distal to cladium 2, and cladium 4 occurs 12 thecae distal to cladium 3; cladium 5 about 23 thecae distal to cladium 4. Cladia of second order originate at th11 in cladium 2, and at th8 in cladium 3. The width of the main stipe is 1.2 mm between cladium 2 and 3, and the maximum width of the cladia is 1.5 mm. The distal width cannot be measured due to the torsion of the rhabdosome.

Remarks: The specimen from GGU 324190 is very similar to Carruthers' material of *C. murchisoni murchisoni*, redescribed by Strachan (1969). However, the preservation state of the present specimens prevents comparison of the rhabdosomal widths and observation of the enrolled *centrifugus*-like proximal end as described for *C. murchisoni murchisoni* by Strachan (1969). The distances between the cladia in the present specimens are rather similar to those noted by Bouček (1933, table p. 31). However, Strachan (1969) questioned the reference of the specimens figured by Bouček (1933, pl. 2, figs. 1–3) to *C. murchisoni murchisoni*, as the proximal ends are less coiled than in the type specimen of Carruthers (Strachan, 1969).

C. murchisoni murchisoni can be confused with *C. insectus*, both species have cladia of second order. Distances between the cladia in the present specimens are too short compared to those of *C. insectus* of Bouček (1933, table p. 38).

Fig. 8. A-E. *Cyrtograptus polyrameus* Fu & Song. A, MGUH 20792 from GGU 324412, Nares Land, × 2.2. B, MGUH 13691a from GGU 211761, Nyeboe Land, × 0.35 (drawing from Jackson & Etherington, 1969). C, MGUH 20793 from GGU 324432, Nares Land, × 2.2. D, MGUH 13691b, proximal end, counterpart of Fig. 8B, × 3. E, MGUH 20774 (same specimen as in Fig. 5A), × 2.2. F-J, *Cyrtograptus centrifugus* Bouček from GGU 211753, Hall Land. F, MGUH 20793, × 3. G, MGUH 20794, × 2.2. H, MGUH 20795, × 2.2. I, MGUH 20796, × 2.2. J, MGUH 20797, × 1.5.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The specimen figured as *C. insectus* by Melchin & Lenz (1990, fig. 7b) has similar distances between the first cladia to those of *C. murchisoni murchisoni*; the proximal end is curved in such a manner that it terminates near cladium 2, which is not like the shape of *C. insectus* of Bouček (1933, text-fig. 7a). The feature suggests that there are no sharp limits between the two species as the distance between the cladia is highly variable; the two species are in need of redefinition.

Associated species: The associated fauna in GGU 324190 represents an interval of 15 m in the section and comprises *R. geinitzianus*, *Monoclimacis vomerina* and *M. priodon*, wide and slender forms; in GGU 319168 only *M. priodon*.

Cyrtograptus murchisoni bohemicus Bouček, 1931?

Fig. 9A-C

Material. Four specimens, GGU 316302, Wulff Land Formation, Nyeboe Land, all preserved flattened, no complete specimens have been observed.

Description. In one proximal fragment (Fig. 9B) without cladia and sicula the proximal end of the main stipe is coiled into one volution. The largest specimen has a 30 mm long stipe which is gently curved, and cladium 1 is more than 20 cm long. In the two most well preserved specimens (Figs 9A, C) the first cladium originates at thn + 12–15, the second cladium 7–9 thecae distal to cladium 1, and cladium 3 at 9–12 thecae distal to cladium 2. The proximal width of the main stipe is 0.75 mm, width at the origin of cladium 1 is 1.5 mm, and the maximum width is about 1.65 mm between cladium 1 and 2, excluding indistinct thecal spines. The maximum width of the cladia is also 1.65 mm.

The thecae are so badly preserved that their exact structure cannot be observed. They are triangular, hooked with slender prothecal parts in the proximal end and get wider towards the distal end of the rhabdosome. Their apertural parts are retroverted, some are apparently prolonged into a short spine. Distally in the rhabdosome the thecae become straight tubes which overlap half of their length and are retroverted only in the extreme apertural parts.

Remarks. The present specimens appear to be very similar to *C. murchisoni bohemicus* described by Bouček (1933) and Schauer (1968) with regard to the dimensions of the rhabdosome and the distances between the point of origin of the cladia. However, the lack of proximal ends precludes a safe reference to the subspecies. On average the cladia in the present material are 1–2 thecae more widely spaced than those in the earlier described specimens (Bouček, 1933). *C. murchisoni bohemicus* (Fu, 1985, text-fig. 4; 1986, text-fig. 19) appears to have a longer distance between cladium 1 and cladium 2 than usually observed in this form.

The majority of the specimens of *C. murchisoni bohemicus* figured by Bouček (1933) have open proximal coils with the sicula placed at the level of cladium 2. However, the specimen figured by Bouček (1933) on pl. 1, fig. 2 (lower left corner) shows a proximal end which in an enrolled position stage would be similar to this of *C. centrifugus*. Consequently a revision of the two species is needed.

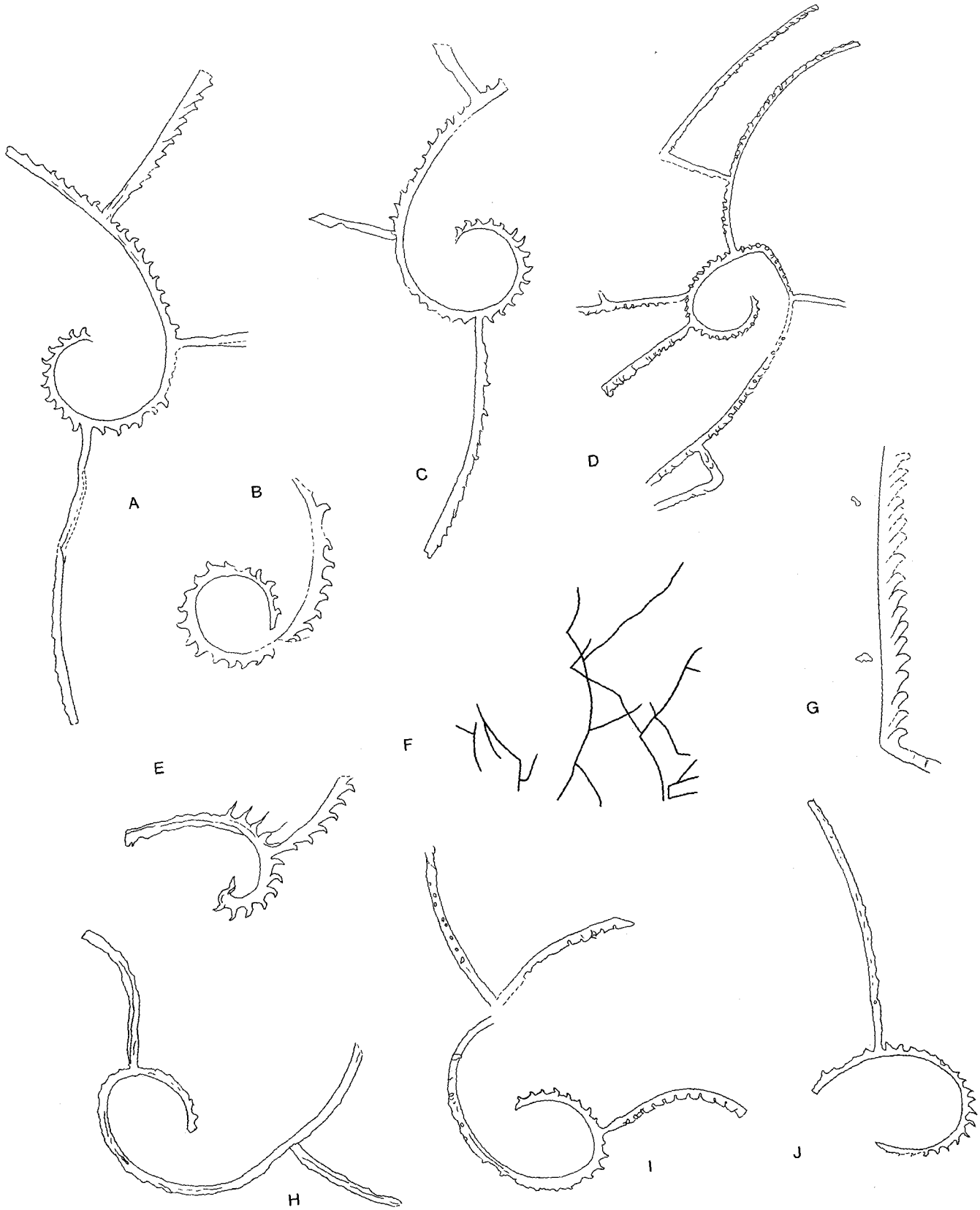
Associated species. C. murchisoni bohemicus? is associated with *R. geinitzianus s.l.*, *M. priodon*, and *Monograptus* sp. aff. *M. minimus* Bouček & Přibyl, 1951. *C. murchisoni bohemicus* is reported from the uppermost part of the *C. centrifugus* Zone and from the *C. murchisoni* Zone by Bouček (1933) and from the *C. murchisoni* Zone by Schauer (1968).

Cyrtograptus polyrameus Fu & Song, 1983

Fig. 5A-D; Fig. 8A-E

1969	*Cyrtograptus* aff. *C. canadensis*; Jackson & Etherington, p. 1119, fig. 3.
1983	*Cyrtograptus polyrameus* Fu et Song; Fu, pl. 2, fig. 16.
1985	*Cyrtograptus polyrameus* Fu et Song sp. nov; Fu, p. 326, pl. 2. fig. 2.
?1986	*Cyrtograptus shishkaticus*; Deng, fig. 2, 7.
?1986	*Cyrtograptus* sp.; Deng, fig. 1, 13–14, fig. 2, 8–9.
1986	*Cyrtograptus polyrameus* Fu et Song; Fu & Song, p. 139, pl. 19, figs 1–5; pl. 20, figs 1–3; pl. 22, ?fig. 4, fig. 5.
1987	*Cyrtograptus polyrameus* Fu and Song, 1985; Melchin, pp. 564–565, text. figs. 47?E, F, K.
1988	*Cyrtograptus polyrameus* Fu and Song; Melchin, fig. 14F.
1988	*Cyrtograptus* aff. *sakmaricus* Koren'; Lenz, pp. 1969–1970, pl. 3G.

Fig. 9. A-C. *Cyrtograptus murchisoni bohemicus* Bouček? from GGU 316302, Nyeboe Land. A, MGUH 20798, × 2.2. B, MGUH 20799, × 2.2. C, MGUH 20800, × 3. D, *Cyrtograptus murchisoni murchisoni* Carruthers, MGUH 20782 (same specimen as in Fig. 6D), × 1.5. E, *Cyrtograptus kolobus*, MGUH 20801 from GGU 184059, Peary Land, × 3. F, G, *Cyrtograptus* sp. cf. *C. insectus* Bouček, from GGU 311247, Freuchen Land. F, MGUH 20802, × 0.5. G, Detail of distal fragment on the same slab as Fig. 9F. MGUH 20803, × 3. H, I, *Cyrtograptus tullbergi* Bouček? from GGU 211754, Hall Land. H, MGUH 20804, × 2.2. I, MGUH 20805. × 2.2. J, *Cyrtograptus* sp. 1, MGUH 20806 from GGU 211761, Hall Land, × 2.2.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Material. One large specimen, most likely referable to this species (Jackson & Etherington, 1969, Fig. 3), GGU 211761, B. S. Norford collection, Kap Schuchert, Lafayette Bugt Formation, Washington Land. One large specimen, without proximal end, GGU 324126, Thors Fjord Member, Wulff Land Formation, Nyeboe Land. Two large specimens and one proximal specimen, GGU 324412, 13 m above base of the Thors Fjord Member, Wulff Land Formation, Nares Land. One large specimen, GGU 324432, Thors Fjord Member (boring), Wulff Land Formation, Nares Land. One specimen, GGU 319112, 5 m above base of Thors Fjord Member, Wulff Land Formation, Nares Land. All 6 specimens appear flattened, but a few thecae show low relief, especially those of the specimen in GGU 211761.

Description. The rhabdosome can attain a large size, one specimen (Fig. 5D) has a 17 cm long main stipe and 23 cladia, of first order only. Cladium 1 attains a length of at least 11 cm. The proximal end is curved into an open fish-hook like form. The mesial part of the main stipe becomes gently curved and the distal end is nearly straight. However, the curvature of the main stipe varies from specimen to specimen between moderately curved to nearly straight. The cladia originate at great distances from the proximal end, at thecal levels of about n + 37–44.

An indistinct sicula has been observed in one specimen (Fig. 8C), 1 mm long and with the apex reaching to the base of th2. Here the cladium originates at th33. Proximally the distances between the cladia are generally three thecae, increasing to four thecae mesially in the main stipe, and distally to five thecae. In the specimen (Fig. 8C) with the indistinct sicula the cladia are more closely set, with 1, 2 or 3 thecae between their points of origin. The cladia in the proximal part of the main stipe are slightly curved, the distal cladia are nearly straight.

The width of the main stipe increases from 0.6 mm at th1, to 0.8 mm at th5 and 1.0 mm at th10. Distal to that the main stipe undergoes torsion and measurements cannot be given exactly. In the specimen Fig. 5B the width is about 1.6 mm at the origin of the first cladium. In GGU 324126 the width of the twisted cladia is about 1.6–1.8 mm. The distal width of the main stipe is 2 mm in the largest specimen, measured without thecal spines (Fig. 5D).

The thecae are subtriangular and hooked, in the proximal part of the rhabdosome with slender prothecal parts, distally becoming wider and with increasing overlap. The interthecal septa cannot be seen in detail. The thecal apertural parts are indistinct, but in well preserved specimens up to 1 mm long apertural spines are observed. Proximal to the origin of cladium 1 the thecae number 6 per 5 mm; distally in the main stipe the number is 4.5 per 5 mm.

Remarks. The North Greenland material is referred to *C. polyrameus* on account of the open coiling in the proximal end which changes to almost straight in the distal part of the main stipe, and by the large number of closely set, very slightly curved cladia. The present specimens are similar to those described by Fu (1985), Fu & Song (1986) and Melchin (1987), but attain a greater length and a larger width than earlier reported. However, Fu Lipu (personal communication, 1990) has informed me that the width of the Chinese specimens can be up to 1.5 mm, which is similar to that of the main number of the North Greenland specimens.

Cyrtograptus aff. *C. canadensis* Jackson & Etherington, 1969 (fig. 8B, D), which is one of the largest specimens observed, can most likely be included into *C. polyrameus*. It is only distinguished from the other specimens by the much more closely coiled proximal end. This feature, however, might be preservational, as during embedding and later compaction the more slender proximal end bent in such a way that the coil looks more tight than the original form. The extreme proximal part is concealed below the main stipe, in another bedding plane.

Until more information is available on the variation and preservation of this species, the North Greenland specimens are included into a complex of *C. polyrameus*. *C. robustus* is comparable to the largest specimens in the present collection; the two species appears to have a close relationship and might be regraded as two distinct subspecies. The closer set cladia in GGU 324432 suggests that there is some variation within the species complex which awaits more material for systematic treatment.

C. polyrameus is clearly distinguished from *C. sakmaricus*, by the much less coiled proximal end and nearly straight distal main stipe in the former species. It has a similar shape of the rhabdosome as *Cyrtograptus ramosus* Bouček, which however has more slender thecae and completely straight cladia.

Deng (1990) proposed that *C. lapworthi* and *C. polyrameus* are conspecific, based on the similarity of curvation of the proximal part. However, *C. polyrameus* has a delayed origin of cladium 1, compared to the typical material of Tullberg, but the variability is very large and further analyses are needed for decision of any conspecificity.

Associated species. GGU 211761: *R. geinitzianus s.l.*, *Pristiograptus* sp., *M. vomerina*, *M.* cf. *M. linnarssoni*,

M. praecedens?, *M. priodon*. GGU 324126: *S. grandis* and *M. spiralis*. GGU 324412: *Retiolites geinitzianus angustidens* Elles & Wood, 1908, *Plegmatograptus* sp., *M. vomerina*, *M. linnarssoni*?, *M. priodon*, *M. speciosus* and *M. spiralis*. GGU 319112: *M. priodon* and *M. spiralis*. In all the samples the associated fauna indicates the latest Llandovery, corresponding to the *C. sakmaricus* Zone.

Cyrtograptus pseudomancki Lenz & Melchin 1991

Fig. 10A

?1924 *Cyrtograptus ruthenicus* Eisel; Hundt, p. 76, pl. 10, fig. 1–2.
?1924 *Cyrtograptus ruthenicus* var. *polypus* Eisel; Hundt, p. 76, pl. 9, fig. 4.
?1975 *Cyrtograptus* sp. aff. *C. mancki*; Berry & Murphy, p. 93, pl. 8, fig. 7.
1978 *Cyrtograptus mancki* Boučck; Lenz, 631–632, pl. 4, figs 2, 3, ?5.
1990 *Cyrtograptus* n.sp. cf. *C. mancki* Boučck; Lenz & Melchin, fig. 4L.
1991 *Cyrtograptus pseudomancki* n.sp.; Lenz & Melchin, p. 235, fig. 19D, G, H.

Material. One badly preserved specimen in low relief. GGU 319104, Lauge Koch Land Formation, Nares Land.

Description. The main stipe is coiled in at least a 540° volution. The inner coil is circular with a diameter of about 1.6–1.8 mm and the outer coil is about 6 mm in diameter. The proximal end with sicula cannot be observed. The first cladium appears to originate nearly 360° from the proximal end, at the level of thn + 7. There are 9 cladia present, of first order only. The three proximal cladia arise at every theca, and the subsequent cladia every second theca. The cladia are straight or slightly curved. During embedding, the cladia have been twisted at their point of origin, and the thecal apertures face either proximally, distally or laterally. The cladia reach a length of about 1 cm.

The thecae appear to have a triangular morphology throughout the rhabdosome, but with increasing heights of the metathecal portions. The prothecal parts are slender and the metathecal parts are situated perpendicular to the main axis, with retroverted slightly hooked apertural regions. Apertural spines are present, with lengths up to 0.5 mm, but the preservation state does not allow any further observation on the detailed apertural structures. The width of the rhabdosome at the most complete proximal theca is 0.75 mm, increasing to 1.25 mm at the level of thn + 10. The thecae in the cladia reach a maximum width of 1.5 mm, but are all badly preserved. The large width might be due to torsion of the spined thecal apertures.

The thecae number 3 per 2.5 mm within the first volution, mesial in the main stipe the number is 5 per 5 mm, and distally the number is 4.5–5 per 5 mm.

Remarks. The present specimen is referred to *C. pseudomancki* by the morphology of the rhabdosome and the thecae. However, there are minor differences between the North Greenland specimen and those reported from Arctic Canada. The latter have a more open proximal coil, slightly more slender rhabdosomes, about 1 mm wide in maximum width (Lenz & Melchin, 1991), and apparently less pronounced triangular thecae in the cladia. However, minor variations in curvature of the main stipe and cladia, as well as in stipe width and thecal overlap, may be due to differences in preservation, caused by the way in which the rhabdosomes were embedded. Small variations in the cladial spacing are also common in many cyrtograptid species.

By the thecal morphology the present specimen is very similar to *Cyrtograptus* sp. (aff. *C. mancki* Boučck) Berry & Murphy, 1975 which has triangular thecae in the main stipe and on the first cladium. The present specimen is distinguished from *Cyrtograptus mancki* Boučck, 1931 by the thecal morphology. In *C. mancki* the thecae are triangular and hooked in the proximal part of the main stipe, but in the distal part and in the cladia the thecae were described as becoming straight tubes with simple apertures (Boučck, 1933). However, as the apparent variations in the thecal morphology can depend on the embedding of the rhabdosome *C. mancki*, and the possibly very similar *C. ruthenicus* and *C. ruthenicus polypus*, are in need of reinvestigation for decision of conspecificity.

Associated species. The specimen is associated with *Monoclimacis flumendosae* (Gortani, 1922), *M. flemingi*, *Monograptus* cf. *M. irfonensis* Elles, 1900, *Cyrtograptus*? (proximal end, similar to this of *C. multiramis*). *C. pseudomancki* was reported by Lenz & Melchin (1990, 1991) from the *C. perneri – M. opimus* Zone in Arctic Canada, with an occurrence below or associated with *C. multiramis*. Lenz (1978) reported a specimen possibly referable to this species from the *C. lundgreni* Zone in the Cape Phillips Formation. The similar *Cyrtograptus* sp. aff. *C. mancki* in Berry & Murphy (1975) is associated with *C. radians* and *C. hamatus* within a *C. lundgreni – M. testis* sequence.

The presently associated fauna does not include any precise stratigraphic indicators. *M. irfonensis*, however, has been reported from the *C. lundgreni* Zone, but the present specimens appear to have less developed retro-

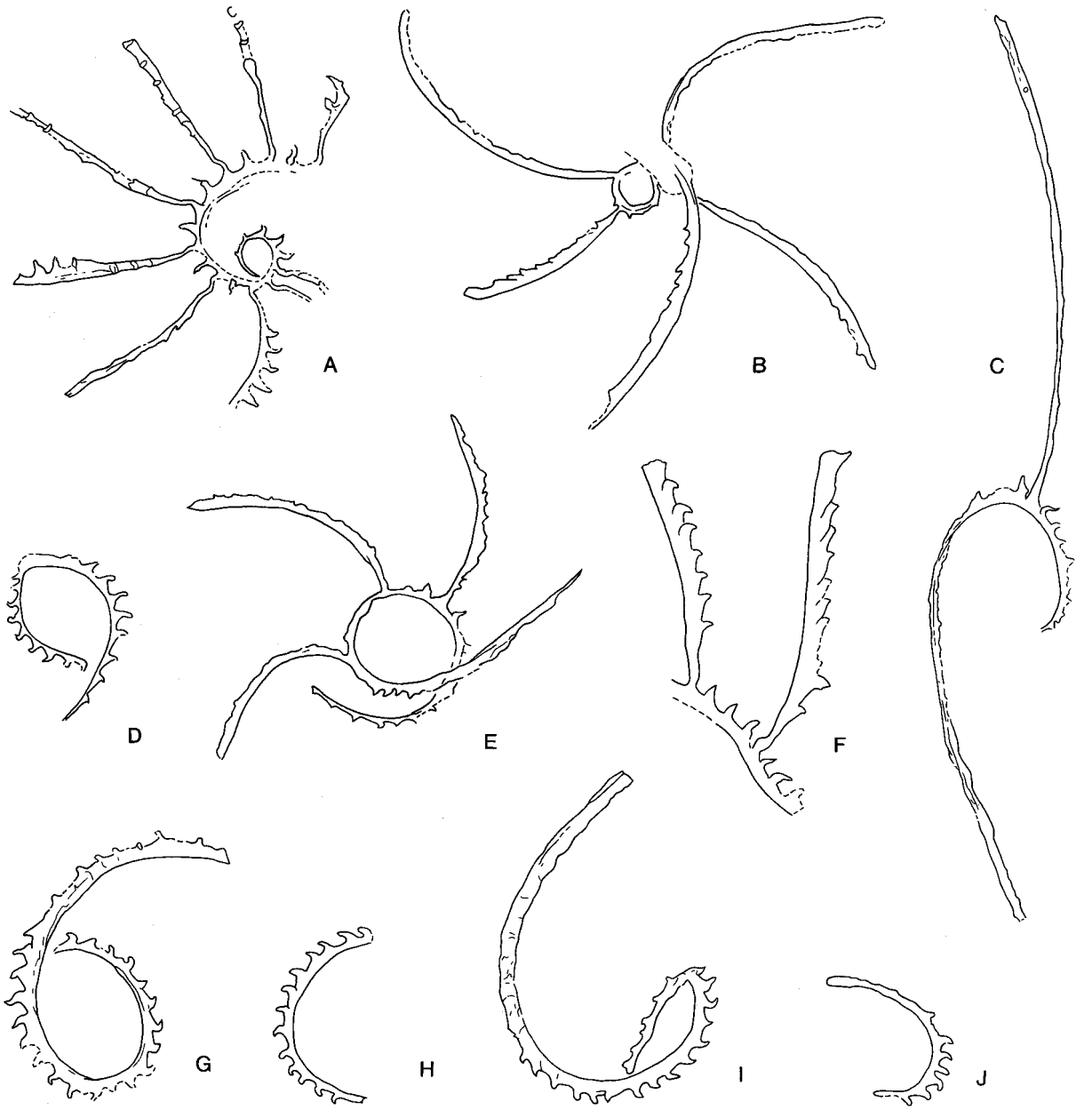

Fig. 10. A, *Cyrtograptus pseudomancki* Lenz & Melchin, 1991, MGUH 20807 from GGU 319104, Nares Land. B, *Cyrtograptus multiramis* Törnquist?, MGUH 20808 from GGU 319107, Nares Land. C, J, *Cyrtograptus* sp. 2 from GGU 315516, Hendrik Ø. C, MGUH 20809. J, MGUH 20810. D-F, *Cyrtograptus multiramis* Törnquist from GGU 319107, Nares Land. D, proximal part, MGUH 20811. E, MGUH 20812. F, distal fragment, MGUH 20813. G-I, *Cyrtograptus*? sp. from GGU 211752, Hall Land. G, MGUH 20814. H, MGUH 20815. I, MGUH 20816. All figures × 3.

verted apertural parts of the thecae, and a precise reference to *M. irfonensis* is uncertain. Consequently, the associated graptolite assemblage might indicate the *C. perneri – M. opimus* as well as the *C. lundgreni – M. testis* Zone.

Cyrtograptus sakmaricus Koren', 1968

Fig. 7I, K

1968 *Cyrtograptus sakmaricus* n. sp.; Koren', p. 102, fig. 2.

1969 *Cyrtograptus canadensis* n. sp.; Jackson & Etherington, p. 1115–1118, pl. 129, figs 1–3, text-fig. 1A-D.
1969 *Cyrtograptus shishkaticus*; Golikov, pp. 506–508, pl. 9, fig. 1.
1969 *Cyrtograptus coroniformis*; Golikov, pp. 508–509, pl. 9, fig. 2.
?1974 *Cyrtograptus sakmaricus asiaticus* Golikov, subsp. nov.; 96–97, pl. 6, fig. 2; pl. 7, figs 1–12.
?1974 *Cyrtograptus obusicus*; Golikov, pp. 97–98, pl. 6, fig. 3.
1975 *Cyrtograptus* cf. *C. sakmaricus* Koren'; Berry & Murphy, pp. 90–91, pl. 12, figs 1, 2; pl. 13, fig. 2.
1978 *Cyrtograptus sakmaricus* Koren'; Lenz, p. 633, pl. 2, fig. 4.
?1979 *Cyrtograptus murchisoni* Carruthers; Deng, pp. 309–310, pl. 1, figs 6–9.
1983 *Cyrtograptus sakmaricus*; Fu, pl. 2, fig. 17.
1985 *Cyrtograptus sakmaricus* Koren'; Fu, p. 323, pl. 1, figs 1, 3, text-fig. 1a-c.
1986 *Cyrtograptus sakmaricus* Koren'; Fu & Song, p. 141, pl. 22, fig. 2; pl. 23, fig. 1; ?pl. 22, fig. 6.
1986 *Cyrtograptus sakmaricus*; Huo *et al.*, fig. 6a.
1987 *Cyrtograptus sakmaricus* Koren'; Melchin, pp. 565, 568–570, text-fig. 48A-E.
1988 *Cyrtograptus sakmaricus* Koren'; Lenz, p. 1969, pl. 3C.
1988 *Cyrtograptus sakmaricus* Koren'; Melchin, fig. 14I.

Material. One rather complete specimen, GGU 319231, from scree, basal Thors Fjord Member, Wulff Land Formation, Kap Ammen, Hall Land. One badly preserved specimen possibly referable to this species. GGU 230210, section 21 (Hurst & Surlyk, 1982), Lauge Koch Land Formation, Nyeboe Land.

Description. The most well-preserved specimen is nearly completely flattened, with two proximal coils, but without the sicula (Fig. 7I). Nine first order cladia are present, the two proximal ones with only two thecae between their points of origin. The stipe width of the inner volution is about 1.8–2.0 mm; the distal width cannot be measured, as the rhabdosome is preserved dorso-ventrally. The thecae are so badly preserved that the apertural modifications described by Lenz & Melchin (1988) cannot be observed. Up to 1 mm long apertural spines are present. Proximally the thecae number 5 per 5 mm, and distally the number is 4.5 per 5 mm.

The incomplete specimen has a circularly coiled fragmentary main stipe with two volutions and 6 curved cladia originating every third thecae, but is too badly preserved for further description.

Remarks. The present specimens are no different from earlier described material. The distal cladia may be spaced every four thecae, as described by Golikov (1969) for *C. shishkaticus*. This species was later included in the *C. sakmaricus* variation by Lenz (1978) and Melchin (1987). The species, index fossil for the latest Llandovery appears to have a wide occurrence in certain regions (see above) but the present sparse material may indicate that *C. sakmaricus* is rare in North Greenland.

Associated species. GGU 319231 is associated with *Pristiograptus*? and *C. lapworthi*; GGU 230210 with *R. geinitzianus s.l.*, *Pristiograptus* sp, and *Cyrtograptus lapworthi*?.

Cyrtograptus tullbergi Bouček, 1933?

Fig. 9H, I

Material. Two badly preserved specimens, GGU 211754, B. S. Norford collection, Lafayette Bugt Formation, Kap Tyson, east outcrops, Hall Land.

Description. The two specimens are only fragments, comprising proximal parts without the sicula and with respectively one or two cladia of first order only. The maximum length of the main stipe is 6 cm. The main stipe is curved into approximately 3/4 of a circle in the proximal end, with diminishing curvature distally. The first cladium originates at 7–8 thecae from the proximal end, and the second cladium 2 cm distally from the first one. The cladia are slightly curved at their point of origin.

The proximal thecae are subtriangular; the ventral walls are slightly inclined. The apertural parts are hooked and the retroverted parts occupy one-third of the width of the rhabdosome which is 0.9–1.0 mm. Both the main stipe and the cladia have undergone torsion so the exact width as well as structural details of the thecae cannot be observed.

Remarks. The two fragments are similar to the specimens described by Lenz (1978) as *Cyrtograptus* cf. *C. insectus*, both with regard to the proportions of the proximal end of the main stipe and the position and curvature of the cladia.

C. tullbergi might be distinguished from *C. insectus* by the less enrolled proximal part which in *C. insectus* forms a nearly complete circle (Bouček, 1933), by the apparent earlier origin of cladium and by the more closely spaced cladia 1 and 2. However, *C. tullbergi* is an ill-defined species; the proximal end with sicula has not been recorded, and is in need of revision, together with the very similar early Wenlock *C. insectus* and *C. malgusaricus*.

Associated species. C. tullbergi? is associated with dendroids, *M. priodon*, *Monograptus* cf. *M. parapriodon*,

Monoclimacis?. The sample was found 3 m above GGU 211753 with *C. centrifugus*, indicating early Wenlock. *C. tullbergi* was reported by Boucek (1933) from an unknown graptolite zone, associated with *M. vomerina*, *Monoclimacis vomerina gracilis* (Elles & Wood, 1910) and *Barrandeograptus pulchellus* (Tullberg, 1883).

Cyrtograptus sp. 1

Fig. 9J

Material. One flattened incomplete specimen, GGU 211761, from the B. S. Norford collection, Lafayette Bugt Formation, Kap Tyson, east outcrops, Hall Land.

Description. Rhabdosome with 2 cm long main stipe curved in a half circle in the procladial portion and apparently becoming more straight distal of the origin of the cladium. The only cladium is very slightly curved, 2 cm long and arises from about thn + 20. The proximal end of the main stipe is missing.

The thecae in the procladial part are indistinct, apparently triangular and number about 5 per 5 mm.

Remarks. The shape of the main stipe and the position of the cladium are similar in *C. laqueus* but the present specimen is far too incomplete for further references.

Associated species. R. geinitzianus s.l., *Pristiograptus* sp., *M. vomerina*, *Monoclimacis* cf. *M. linnarssoni*, *M. praecedens*? and *C. polyrameus.*

Cyrtograptus sp. 2

Fig. 10C, J

Material. Two badly preserved specimens and several fragments, possibly referable to this species. GGU 315516, Thors Fjord Member, Wulff Land Formation, Hendrik Ø.

Description. The 3.5 cm long main stipe lacks the extreme proximal end with sicula. The proximal part is fish-hooked, the retroverted portion is about 1 cm long; distal to that, the main stipe becomes very gently curved. Only one cladium is observed, originating at the point where the proximal part of the main stipe recurves. About this point the main stipe twists to become ventrally curved. The cladium is slightly curved and at least 1.5 cm long.

The precladial part of the main stipe includes a minimum of about 7 thecae which are triangular and hooked. The preservation state does not allow for any observation of thecal overlap. The width of the main stipe is about 1 mm, but the rhabdosome is tectonically compressed.

The other fragment is a part of the proximal end, with 7 triangular thecae preserved, but without any sicula. Distal to the triangular thecae the main stipe is twisted. No cladia have been observed in this specimen.

Remarks. The specimens cannot with certainty be referred to any *Cyrtograptus* species. The proportions of the present fragments are similar to those of *C. lapworthi* as well as to those of *C. laqueus*, but the specimens might also have some relationship to Wenlock cyrtograptids such as *Cyrtograptus rigidus* n. subsp. A, which was described and reconstructed by Thorsteinsson (1955), and members of the *C. perneri* group.

Associated species. The specimens are associated with fragments of badly preserved *Monograptus* sp., with *M. parapriodon / M. instrenuus* type of morphology.

Cyrtograptus? sp.

Fig. 10G-I

Material. Three flattened specimens, GGU 211752, B. S. Norford collection, Lafayette Bugt Formation, Kap Tyson, east outcrops, Hall Land.

Description. The three specimens might just as well be monograptids, as they all lack cladia, but characteristic for all three specimens is the dorsally curved *Cyrtograptus*-like proximal end, which in one specimen forms an approximately circular coil. Further, there is torsion of the stipe immediately distal to the level of the termination of the coil.

One proximal end is observed (Fig. 10H). Here the sicula is about 1 mm long and the apex may reach to the base of th2. The two proximal thecae are slightly elongated; distal to that the thecae become triangular, with retroverted hooks and pointed apertural parts. Thecal overlap cannot be observed. The width of the rhabdosome is 0.75 mm at th1, increasing to a maximum of 1.2 mm. The thecae number about 5.5 per 5 mm in the proximal coil.

Remarks. The shape of the stipes in the present specimens appears to be similar to those of the proximal ends of *C. lapworthi* forms. The specimens might represent a *Cyrtograptus* assemblage in which the majority of colonies do not have any cladia, or in which cladial origin is at a late astogenetic stage. The material could also belong to a *Monograptus* species which was a *Cyrtograptus* ancestor. The sample was found between an

underlying *M. spiralis* Zone assemblage, including *Monograptus proboscifórmis* Bouček, 1931, and an overlying *C. centrifugus* Zone fauna, suggesting a late Llandovery age.

Associated species. The specimens are associated with *M. vomerinus s.l.*, *M. priodon*, both slender and wide forms, *Monograptus* cf. *M. speciosus* and *Monograptus* sp.

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