

ACRITARCHS AND CONODONTS FROM THE CAMBRO - ORDOVICIAN FURUHÄLL (KÖPINGSKLINT) SECTION (ÖLAND, SWEDEN)***

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Key - words: Acritarchs, Conodonts, Biostratigraphy, Taxonomy, Cambrian, Lower Ordovician, Öland, Sweden.

Abstract. Cambrian to Lower Ordovician acritarchs and Lower Ordovician conodont species have been recorded from the Furuhall Section at Köpingsklint on Öland, Sweden.

The acritarchs are represented by three different microfloras. The first is found at the base of the section investigated and is characterized by the association of *Cristallinium cambriense* with *Eliasium llaniscum*, *Retisphaeridium dichamerum* and *R. bowellii*. This microflora has been recorded in strata previously referred to the *Paradoxides paradoxissimus* trilobite Superzone.

The second microflora includes *Timofeevia lancarae*, *T. pentagonalis* and *T. phosphoritica* and it has been found in layers dated to the Upper Cambrian *Agnostus pisiformis* trilobite Zone.

The third microflora comprises of several species among which *Aremoricanium ? grootaertii*, *Athabascaella playfordii*, *Dasydiacrodium tremadocum*, *Stelliferidium furcatum* which are indicative of a Tremadocian age. This association includes taxa which usually occur in different bioprovinces, thus it allows transprovincial correlations. This microflora has been recorded in Lower Ordovician (Tremadocian) strata of the *Dictyonema flabelliforme* s.l. - *Clonograptus heres* graptolite Zones.

The new species *Adara denticulata* (Middle Cambrian) and *Cristallinium aciculatum* (Upper Cambrian) are described.

The conodont species are referable to Tremadocian *Paltodus deltifer* Zone and *Paroistodus proteus*, *Prioniodus elegans* and *Oepikodus evae* conodont Zones of the Arenigian. The fauna is typical Baltic, but includes elements of *Tropodus comptus* and *Tropodus sweeti* which otherwise are known from the midcontinent conodont faunal province.

The composition of the multielement species *Baltoniodus ? deltatus*, *B. crassulus*, *Oistodus* aff. *O. lanceolatus*, *Paltodus deltifer*, *P. peracutus* and *P. subaequalis* is revised.

The sequence of Furuhall is characterized by several hiatus, some of which can be related to eustatic sea level lows. The most extensive hiatus is from the Upper Cambrian *Leptoblastus* trilobite Zone into the early Tremadocian *Dictyonema flabelliforme* s.l. Zone. Barren interzones have been recorded at the base and at the top of Hunnebergian Substage. The lower barren interzone corresponds to the Tremadocian - Arenigian stage boundary or the *Paltodus deltifer* - *Paroistodus proteus* zonal boundary. The upper barren interzone coincides with *Paroistodus proteus* and *Prioniodus elegans* zonal boundary.

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*** This is a joint paper and the order of the authorship is alphabetical. The taxonomy for acritarchs has been worked out by M. Tongiorgi and the conodonts by G. Bagnoli and S. Stouge.

Riassunto. Acritarchi del Cambriano e dell'Ordoviciano inferiore e Conodonti dell'Ordoviciano inferiore sono stati ritrovati nella sezione di Furuhöll, a K pingsklint ( land, Svezia).

Gli Acritarchi sono rappresentati da tre diverse microflora. La prima   caratterizzata dalla associazione di *Cristallinium cambriense* con *Eliasium llanicum*, *Retisphaeridium dichamerum* e *R. howellii* e proviene da un livello che   stato da precedenti autori riferito al Cambriano medio (Superzona a Trilobiti *Paradoxides paradoxissimus*).

La seconda comprende *Timofeevia lancarae*, *T. pentagonalis* e *T. phosphoritica*. Questa microflora   stata raccolta in un livello che era gi  stato datato al Cambriano superiore (Zona a Trilobiti *Aagnostus pisiformis*).

La microflora pi  recente comprende *Aremoricanium ? grootaertii*, *Athabascaella playfordii*, *Dasydiacrodium tremadocum*, *Stelliferidium furcatum* ed altre specie del Tremadociano. Questa microflora ha carattere composito, comprendendo taxa tipici di diverse bioprovince: essa assume quindi importanza per le correlazioni transprovinciali.   stata trovata in livelli datati in precedenza all'intervallo compreso tra la Zona a Graptoliti a *Dictyonema flabelliforme* s.l. e la Zona a *Clonograptus heres* (Tremadociano).

Vengono descritte due specie nuove: *Adara denticulata* e *Cristallinium aciculatum*.

Le specie di Conodonti sono riferibili alle Zone a *Paltodus deltifer* e a *Paroistodus proteus* del Tremadociano ed alle Zone a *Prioniodus elegans* e a *Oepikodus evae* dell'Arenigiano. La fauna   tipicamente baltica ma include elementi di *Tropodus comptus* e di *Tropodus sweeti*, che erano in precedenza conosciuti nella provincia faunistica a Conodonti del "midcontinent" nordamericano.

Viene fatta una revisione della composizione degli apparati di *Baltoniodus ? deltatus*, *B. crassulus*, *Oistodus* aff. *O. lanceolatus*, *Paltodus deltifer*, *P. peracutus* e *P. subaequalis*.

L'intera sequenza studiata   caratterizzata da numerosi hiatus, alcuni dei quali sono correlati a regressioni eustatiche. Il pi  importante hiatus si estende dalla Zona a Trilobiti a *Leptoblastus* (Cambriano superiore) alla Zona a Graptoliti a *Dictyonema flabelliforme* s. l. (Tremadociano inferiore). Interzone sterili sono state segnalate alla base ed al tetto del sottopiano "Hunnebergiano": quella inferiore corrisponde al limite Tremadociano - Arenigiano (o al limite tra le Zone a Conodonti *Paltodus deltifer* - *Paroistodus proteus*); quella superiore coincide con il limite zonale *Paroistodus proteus* - *Prioniodus elegans*.

Introduction.

 land is located in the Baltic Sea east of Sweden. It is a flat rocky area with abundant exposures which are world renowned for their excellent fossils. The acritarchs and conodonts described herein were collected in 1984 by the authors at Furu ll (K pingsklint) between Borgholm and K pingsvik (Fig. 1). Further studies on the Cambro - Ordovician stratigraphy of  land, based on both acritarchs and conodonts, are in progress by the authors of this paper.

Conodonts from the sequence at K pingsklint were described by van Wamel (1974). The Lower Ordovician stratigraphy and lithology was recently revised by van Wamel (1974) and his terminology is followed in this paper (Fig. 2). Van Wamel introduced four new formations which in ascending order are: Djupvik Formation, K pingsklint Formation, Bruddesta Formation and Horns Udde Formation.

The Djupvik Formation was named by van Wamel (1974) for a sequence consisting of heterogeneous lithologies characterized by a high content of terrigenous clastic and carbonaceous material. The high content of pyrite and glauconite is also typical for this formation in the northern part of  land. The Djupvik Formation overlies the Middle Cambrian "Tessini sandstone" and ranges in age from Middle Cambrian to Lower Ordovician. The Djupvik Formation is exposed only along the western shore of  land.

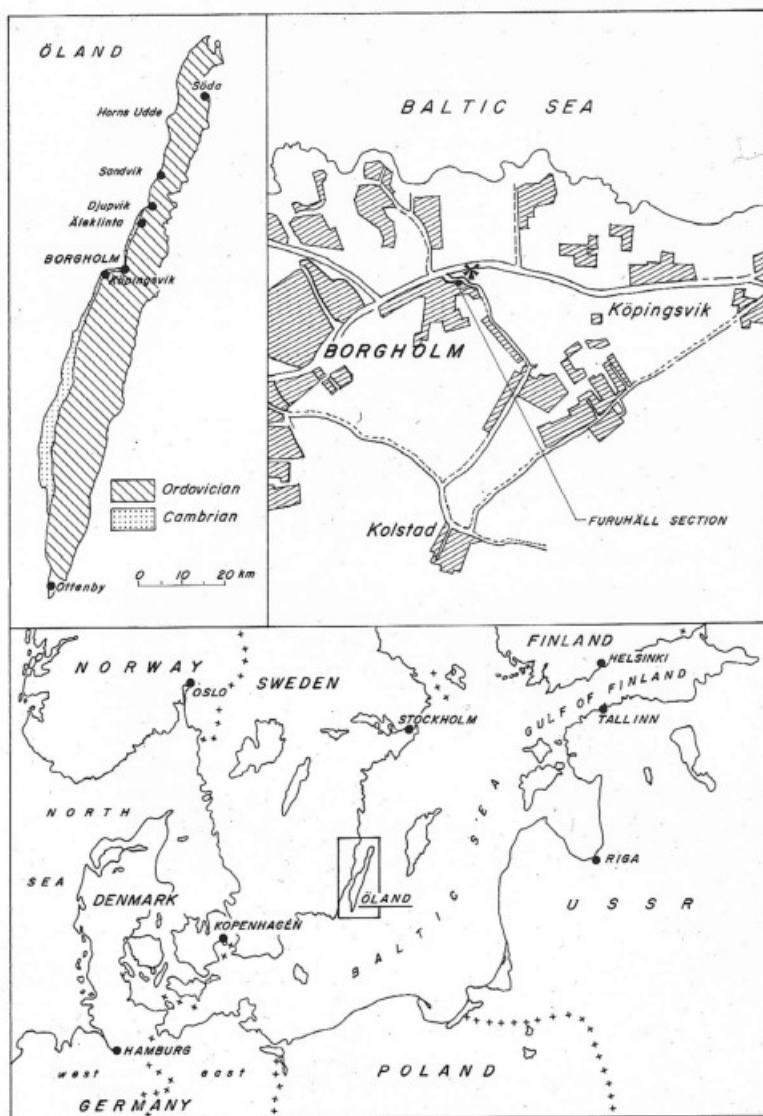


Fig. 1 - Location of the Furuhäll section (Öland, Sweden).

The Djupvik Formation replaces the older terms: "Paradoxides shale" (*pro parte*), "Exporrecta conglomerate", "Olenid shale", "Obolus conglomerate", "Dictyonema shale", and "Ceratomyge shale" of Westergård (1922, 1947). Van Wamel (1974) recorded a thickness of maximal 2.4 m in the northern region of the island, but equivalent strata become thicker towards the South.

The fossil record in the type area includes trilobites, graptolites, and brachiopods. The fossils from the lower part of the Djupvik Formation in the type area (Holm, 1882;

Moberg & Segerberg, 1906; Westergård, 1922, 1947; van Wamel, 1974) suggest a Middle-Upper Cambrian age whereas the upper part includes faunas of Tremadocian age. But its lower limit is ambiguously defined: this question will be later discussed.

At Köpingsklint, the base of the Djupvik Formation overlies the Middle Cambrian "Tessini sandstone" (Westergård, 1922; van Wamel, 1974). The middle part contains *Dictyonema* species whereas the top includes *Clonograptus heres* and shelly fauna elements which are referable to the "Shumardia Zone" (Moberg & Segerberg, 1906; Tjernvik, 1956). The formation varies greatly in the lateral development of beds suggesting several gaps or hiatus within this unit.

The Köpingsklint Formation (van Wamel, 1974) overlies the Djupvik Formation and includes mainly glauconitic fossiliferous mudstones (*sensu* Dunham, 1962), glauconite sands and recrystallized sparry limestones. The latter form characteristic horizons within the formation. The Köpingsklint Formation includes "Ceratomyge limestones" and the lower "Planilimbata limestone". Biostratigraphically the formation contains *Apatokephalus serratus*, *Megistaspis (E.) armata* to *M. (V.) planilimbata* trilobite Zones of the Hunnebergian Substage (Latorpian Stage) (Tjernvik, 1956; Tjernvik & Johansson, 1980). The formation straddles the Tremadocian/Arenigian Series boundary (Tjernvik & Johansson, 1980).

The Köpingsklint Formation underlies the Bruddesta Formation. The Bruddesta Formation (van Wamel, 1974) is a relatively uniform unit throughout its distribution on Öland. It includes fossiliferous mudstones and wackestones, and interbedded marls with several discontinuity surfaces. Pyrite is common locally as minor nodules, and glauconite is less frequent. The unit is highly fossiliferous and nautiloids are common together with trilobites, echinoderms, and brachiopods.

The Bruddesta Formation comprises the upper "Planilimbata limestone" and the lower part of "Limbata limestone". Within the unit a characteristic hardground or "Blommiga Bladet" (the Flowery Sheet) is a local key horizon in the northern part of Öland. The Bruddesta Formation includes the *Megalaspides (M.) dalecarlicus* and *Megistaspis (V.) estonica* trilobite Zones of the Billingenian Substage (Latorpian Stage / Arenigian) in the lower half, whereas the upper part comprises *Megistaspis (M.) lata* trilobite Zone of the Lanna-Volkhovian Stage (Tjernvik, 1956; Tjernvik & Johansson, 1980).

Location and stratigraphy.

One section covering the top of the "Tessini sandstone" and the Djupvik, Köpingsklint and lowermost part of the Bruddesta Formations was investigated at Köpingsklint (Fig. 1, 2). This raised seacliff located near the locality of Köpingsvik, between Borgholm and Köping, is the type area for the Köpingsklint Formation (van Wamel, 1974).

The actual site of the section is to the South of the main road and about 1,300 m South-west of the main cliff exposures of Köpingsklint, or just beneath the property of Furuhäll campsite. The section has already been described by Regnéll (1942, pp. 172-

173). This section does not diverge from the type section depicted by van Wamel (1974) and the lithological units introduced by van Wamel are easily identified.

The investigated section comprises from the bottom to the top:

"Tessini sandstone"

- light green sandstone and shale layers (a few cm).

Djupvik Formation

- gray to light green grainstones and mudstones with calcite prisms and light green shales, irregularly cut by a discontinuous conglomerate with calcite prisms (total thickness about 0.24 m);
- brown to gray grainstone with calcite prisms (0.15 m), followed by a discontinuous shaly layer, and by a brownish, bituminous, calcareous sandstone (0.23 m). This latter level is rich in baryte crystals;
- calcareous shale with small trilobites and brachiopods (0.04 m);
- glauconitic sandstone (0.05 m);
- dark green glauconitic, laminated sandstones interbedded with thin shaly laminae with small brachiopods (0.81 m). Graded bedding occurs;
- repeated, small sequences comprised of dark green glauconitic, laminated sandstone grading into silty shale or calcareous shale (0.60 m) and of coarser glauconitic, laminated sandstone grading into silty sandstone (0.26 m). Brachiopods are present on the surface of fine-grained layers.

Köpingsklint Formation

- glauconitic sand with calcareous nodules (0.07 m);
- green violet glauconitic mudstone with brachiopods (0.29 m);
- glauconitic sand with calcite arranged in rosette-like structures (0.15 m);
- green violet glauconitic mudstone with *Archaeorthis christianae* (0.14 m);
- green glauconitic sandstone with calcareous nodules (0.25 m);
- green violet glauconitic wackestone (0.15 m).

Bruddesta Formation

- red wackestone, locally glauconitic with several discontinuity surfaces (0.40 m).

All samples, from 699 to 708, have been investigated both for acritarchs and conodonts. In the lower and middle part of the section, corresponding to the Djupvik Formation, three samples (699, 698 and 701) yielded rich acritarch associations, whereas conodonts were recorded from the Köpingsklint and Bruddesta Formations. The presence of acritarchs allows refined biostratigraphic correlation for the interval where conodonts are missing.

Sample 699 has been collected near the base of the section, in a light gray, calcareous bed, just above the light green sandstones and shales which may be undoubtedly referred to the Middle Cambrian "Tessini sandstone". The interval where sample 699 has been collected corresponds to the lowermost member ($D_{\bar{a}} - d_1$) of the van Wamel's Djupvik Formation (van Wamel, 1974, pp. 8-11, fig. 3 and 4). But, for both lithological and paleontological reasons, we agree with most of previous authors (e.g. Holm, 1882; Munthe & Hedström, 1904; Westergård, 1922, 1947) and we consider this interval as the top of the Middle Cambrian "Tessini sandstone" (Fig. 2).

The section described here lies within private property and hence it is not accessible without permission from the owner.

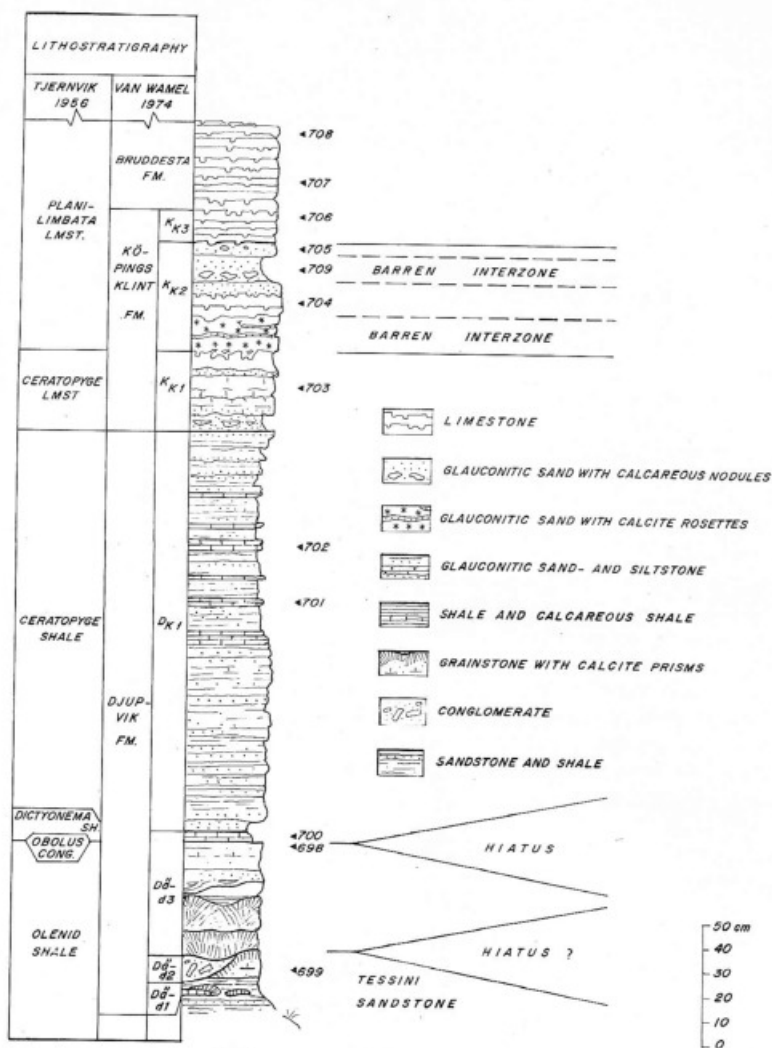


Fig. 2 - The Furuhäll section: lithostratigraphy.

The acritarch microflora

Materials and method; repository.

One hundred grams of each sample (sample 699 excepted: only 70 grams of rock were available) were processed using a standard palynological method. After treatment with HCl and HF and removal of the dissolved compounds, the residue was transferred in absolute ethyl alcohol and sieved through two sieves having a mesh size of 50 μm and 10 μm respectively. The fine fraction passing through the 10 μm sieve was discarded.

Neither oxidation or alkaline treatments were used. After concentration using zinc bromide solution, the residue $> 10 \mu\text{m}$ $< 50 \mu\text{m}$ and the residue $> 50 \mu\text{m}$ were mounted separately. The microfossils have not been coloured. All the illustrated specimens (including SEM preparations) are permanently mounted in polyester resin. The palynological slides were deposited in the collections of Swedish Museum of Natural History (Department of Palaeobotany). Preparations from different samples are given separate numbers, while preparations from the same sample are numbered consecutive following a dash (e.g. S10501-1, S10501-2 are two slides from the same sample S10501).

Acritarch microfloras have been found in samples 699, 698, 701 and 702 from the Djupvik Formation (Fig. 2). Samples 700 and 703 to 709 are barren; no chitinozoans were found in any of the samples. A list of the identified species is reported in Tab. 1.

SPECIES	SAMPLES	699	698	701	702
<i>Acanthodiacrodiium formosum</i> Górká				C	
<i>Acanthodiacrodiium ubui</i> Martin				RR	
<i>Acanthodiacrodiium</i> sp.				RR	
<i>Adara denticulata</i> Tonglorgi sp.nov.	R				
<i>Arenoricanium?</i> <i>grootaertii</i> Martin				C	RR
<i>Athabascaella playfordii</i> Martin				R	RR
<i>Baltisphaeridium</i> cf. <i>B. microspinosum</i> (Eisenack)				RR	
<i>Cristallinium aciculatum</i> Tonglorgi sp.nov.			RR		
<i>Cristallinium cambriense</i> (Slaviková)	C				
<i>Cymatogalea cuvillieri</i> (Deunff)				RR	
<i>Dasydiacrodium tremadocum</i> (Górká)				CC	RR
<i>Dasydiacrodium tunidum</i> (Deunff)				C	
<i>Eliasum</i> cf. <i>E. llaniscum</i> Fombella	R				
<i>Leiofusa</i> cf. <i>L. simplex</i> (Combar)				R	
<i>Leiofusa</i> sp.				RR	
<i>Micrhystridium</i> spp.	R				
<i>Multiplicisphaeridium martae</i> Cramer & Diez	C				
<i>Multiplicisphaeridium</i> sp.A				RR	
<i>Multiplicisphaeridium</i> sp.B				R	
<i>Retisphaeridium dichamerum</i> Staplin, Jansonius & Pocock	RR				
<i>Retisphaeridium howellii</i> Martin	R				
<i>Stelliferidium cortinulum</i> (Deunff)				RR	
<i>Stelliferidium furcatum</i> (Deunff)				CC	RR
<i>Stelliferidium glabrum</i> (Martin)				C	
<i>Stelliferidium simplex</i> (Deunff)				R	?
<i>Stelliferidium stelligerum</i> (Górká)				RR	
<i>Timofeovia lancaerae</i> (Cramer & Diez)		RR			
<i>Timofeovia pentagonalis</i> (Vanguetstaine)		RR			
<i>Timofeovia phosphoritica</i> Vanguetstaine		CC			
<i>Acritarch</i> Gen. et sp. indet.				RR	

Table 1 - List and abundance of the acritarch taxa (RR = very rare; R = rare; C = common; CC = very common; ? = questionably present).

All the specimens are transparent, yellow in colour and their preservation is good, even though some specimens of sample 699 and 701 and most of specimens of sample 702 are deformed by pyritisation or show holes left by the pyrite crystals which were removed during the sample preparation.

The residues of samples 698 and 701 contain a large amount of brownish sapropelic debris and are characterized by numerous fossil specimens but low diversity of species. This is true, in particular, for the sample 698 where a single species (*Timofeevia phosphoritica* Vanguetaine 1978) represents more than 95% of the observed specimens. Sample 699 contains a very small amount of organic matter: the acritarchs are estimated as being no more than 3-4 per gram of rock and the assemblage is largely dominated by two species (*Cristallinium cambriense* (Slavíková) Vanguetaine 1978 and *Multiplicisphaeridium martae* Cramer & Diez 1972). On the contrary, sample 702 is very rich in organic matter, but the acritarch content is very low and the preservation poor.

Evaluation of the acritarch assemblages.

Sample 699 is characterized by the association of *Cristallinium cambriense* (Slavíková) Vanguetaine 1978 and *Eliasum* cf. *E. llaniscum* Fombella 1977 with *Retisphaeridium dichamerum* Staplin, Jansonius & Pocock 1965, *R. howellii* Martin 1983 and *Adara denticulata* Tongiorgi n. sp.

Cristallinium cambriense is known from the Middle Cambrian trilobite *P. paradoxissimus* Superzone (i.e. from the basis of the *Ptychagnostus gibbus* Zone, after Downie, 1984; from the *Paradoxides hicksi* Zone at Random Island, Newfoundland, after Martin in Martin & Dean, 1981, and Martin, 1984). Vanguetaine & Van Looy (1983) suggest a possible older age (within the *P. oelandicus* trilobite Superzone) for the appearance of this species. Older datations (Jankauskas, 1976; Volkova et al., 1979) have later been modified (Jankauskas, 1980). The upper limit of the vertical range of *C. cambriense* reaches the Tremadocian.

Eliasum llaniscum appears in the late Lower Cambrian but it disappears before the base of the Upper Cambrian (at the top of the *P. forchammeri* trilobite Superzone - *Lejopyge laevigata* Zone, according to Downie, 1984; within the latter Zone, according to Vanguetaine & Van Looy, 1983; a little earlier, i.e. near the top of the *P. paradoxissimus* trilobite Superzone, at Random Island, Newfoundland, according to Martin in Martin & Dean, 1981 and Martin, 1984). A later disappearance of *E. llaniscum* is proposed by Fombella (1978, 1979 and 1982) but it is not confirmed by macrofossils and is questionable (see Vanguetaine & Van Looy, 1983).

The presence of *Retisphaeridium dichamerum* and *R. howellii* does not contrast with the indication provided by the above mentioned species, both being typically early Middle Cambrian widespread taxa. More precisely, in the macrofossil-bearing sequences of eastern Newfoundland (Martin & Dean, 1983, 1984) *R. dichamerum* appears in the Lower Cambrian (*Catadoxides* Zone) and becomes abundant in Martin's Microflora A0-1 (probably *Paradoxides bennettii* Zone); however, in the British Isles its latest occurrence

seems to be Upper Cambrian, within the *Parabolina spinulosa* trilobite Zone, according to Downie (1984). *R. howellii* has a similar stratigraphic range in Eastern Newfoundland: it appears in the latest Lower Cambrian and it is rare until Martin's Microflora A0 (*Paradoxides hicksii* Zone). However, we have poor information on the worldwide diffusion of *R. howellii* because it has been frequently confused with *R. dichamerum*.

Finally, we may consider sample 699 as surely belonging to Middle Cambrian: the maximum, possible stratigraphic interval we could assign this sample is comprised between the upper part of the *P. oelandicus* trilobite Superzone and the top of the *L. laevigata* Zone. The occurrence of an *Adara* species (*Adara denticulata* Tongiorgi n. sp.) is consistent with this age. In fact, only two species of this genus have been previously described and both belong to Middle Cambrian: *A. matutina* Fombella 1977 has been recorded from the Middle Cambrian of Spain (Oville Formation); *A. alea* Martin 1981 is known from the Manuels River Formation in Eastern Newfoundland, and has a narrow vertical range which coincides with the Martin's Microflora A1. The lower limit of the Microflora A1 is located within the *Paradoxides hicksii* Zone, while its upper limit lies between the *P. hicksii* and the *P. davidis* Zone.

Sample 698 is characterized by the association of *Timofeevia* Vanguetaine 1978 and *Cristallinium* Vanguetaine 1978.

Timofeevia is represented by *T. lancarae* (Cramer & Diez) Vanguetaine 1978, *T. phosphoritica* Vanguetaine 1978 and *T. pentagonalis* (Vanguetaine) Vanguetaine 1978 indicating a Middle to Upper Cambrian age. The occurrence of *T. pentagonalis* and *T. lancarae* suggests an interval between uppermost Middle Cambrian (*Leiopyge laevigata* trilobite Zone) or lowermost Upper Cambrian (basis of the *Agnostus pisiformis* trilobite Zone) and the middle part of the Upper Cambrian i.e. the *Parabolina spinulosa* trilobite Zone (see the acritarch zonations published by Martin, 1982; Vanguetaine & Van Looy, 1983; Downie, 1984).

The lack of *Eliasium* species and the presence of a probable *Stelliferidium* species (Pl. 28, fig. 8) could be indicative of the Upper Cambrian part of the given interval. The presence of a *Cristallinium* species (*Cristallinium aciculatum* Tongiorgi n.sp.) similar to the intermediate forms between *C. cambriense* and *C. randomense* Martin 1981 is consistent with this age: Welsch (1986, p. 76) describes transitional forms between these species from the lower part of the K4 Member of the Kistedal Formation (Finnmark, Northern Norway), i.e. from an interval approximately located between the *Agnostus pisiformis* and the *Olenus* trilobite Zone (Welsch, 1986, fig. 8).

The acritarch association of sample 701 indicates a Tremadocian age. The most significant species are *Dasydiacrodium tremadocum* (Górka) Tongiorgi comb. nov., *Aremoricanium* ? *grootaertii* Martin 1984, *Athabascaella playfordii* Martin 1984, *Acanthodiacrodium formosum* Górka 1967, *Stelliferidium furcatum* (Deunff) Deunff, Górka & Rauscher 1974 emend. Deunff, Górka & Rauscher 1974. *A. grootaertii* and *A. playfordii* have been previously found in Middle and Upper Tremadocian; *D. tremadocum* and *A. formo-*

sum only in Upper Tremadocian.

The association of sample 701 is interesting because forms such as *Acanthodiacrodium formosum* or *Dasydiacrodium tremadocum*, which are already known from the Baltic-Russian Platform (located at middle to low latitude during the Lower Ordovician), occur together with forms such as *Cymatiogalea cuvillieri* (Deunff) Deunff 1964, *Stelliferidium glabrum* (Martin) Tongiorgi comb. nov., emend. and *S. furcatum*, typical of the perigondwanian, high latitude, cold seas. An expansion of the distribution area of planktic organisms both oceanward and shoreward and the possibility of "inter-provincial" mixed associations during transgressive, deglaciation phases is to be expected (see Erdtmann, 1986). Thus, the mixed association of sample 701 is consistent with a probable Middle-Upper Tremadocian age, which corresponds to a time span characterized by a warming trend.

Two characteristic species (*A. ? grootaertii* and *A. playfordii*) also clearly demonstrate relations with the northern border of the Sino-Korean Platform and with the southern Canadian Rockies portion of the North American Platform and can provide a further link for intercontinental correlations (see the paleogeographic reconstructions proposed by previous authors, e.g. Erdtmann, 1982, 1986).

Sample 702 contains taxa recorded also in the sample 701 (*Athabascaella playfordii*, *Dasydiacrodium tremadocum* etc.) and it likewise belongs to the same stratigraphic interval.

Evaluation of the conodont fauna

Van Wamel (1974) introduced a detailed zonal system for the northern Öland region. Some of these zones probably overlap or represent local faunal successions within a single zone. The faunal successions can be related to migrations of faunas as a response to eustatic changes. A list of the conodont species is reported in Tab. 2.

Sample 703, from the lower part of the Köpingsklint Formation, with *Paltodus deltifer* (Lindström), *Paroistodus numarcuatus* (Lindström), and *Drepanodus arcuatus* Pander, indicates the *Drepanodus arcuatus* Zone of van Wamel (1974). This zone is contained within the larger Upper Tremadocian *Paltodus deltifer* Zone of Lindström (1971).

Samples 704 and 705 were collected from the middle upper part of Köpingsklint Formation.

Sample 704 contains *Baltoniodus ? deltatus* (Lindström), *Paroistodus proteus* (Lindström), *Paltodus subaequalis* Pander which indicate the *Prioniodus deltatus* and the *Drepanoistodus inconstans* Assemblage Zones of van Wamel (1974) and the *Paroistodus proteus* Zone of Lindström (1971). It is worthwhile noting that *Oelandodus elongatus* (Lindström) and *Oelandodus ? costatus* van Wamel are already present. Few specimens of *Tropodus comptus* (Branson & Mehl) and *Tropodus sweeti* (Serpagli), typical of midcontinent faunas D and E (Ethington & Clark, 1971), have also been recorded.

SPECIES	SAMPLES					
	703	704	705	706	707	708
<i>Paltodus peracutus</i> (Lindström)	203					
<i>Paltodus deltifer</i> (Lindström)	40	10				
<i>Diaphanodus latus</i> (van Wamel)	4	5				
" <i>Oneotodus</i> " <i>variabilis</i> Lindström	25	4				
<i>Paroistodus numarcuatus</i> (Lindström)	236	12				
Platform elements (A and B)	2	3				
<i>Drepanodus arcuatus</i> Pander	94	118	57	41	29	2
<i>Scolopodus</i> ? <i>peselephantis</i> Lindström	23	18	41	3	4	5
<i>Drepanoistodus</i> cf. <i>D. forceps</i> (Lindström)		132				
<i>Paracordylodus gracilis</i> Lindström		4				
" <i>Paltodus</i> "? <i>sweeti</i> Serpagli		1				
<i>Oelandodus</i> ? <i>costatus</i> van Wamel		32	10			
<i>Baltoniodus</i> ? <i>deltatus</i> (Lindström)		213	76			
<i>Paltodus subaequalis</i> Pander		113				
<i>Paroistodus proteus</i> (Lindström)		239	25			
<i>Tropodus comptus</i> (Brennon & Mehl)		15		2		
Gen. et sp. indet.		6		1		
<i>Oelandodus elongatus</i> (Lindström)		20			10	
<i>Periodon</i> spp.		4		17	5	11
<i>Scandodus furnishi</i> Lindström		27				2
<i>Prioniodus elegans</i> Pander			2	6	3	
<i>Scolopodus rex</i> Lindström			3	2	7	
<i>Paroistodus parallelus</i> (Pander)			13	59	42	15
<i>Drepanoistodus forceps</i> (Lindström)			26	93	102	170
<i>Cornuodus longibasis</i> (Lindström)			1	4	9	1
<i>Protopanderodus rectus</i> (Lindström)				13	7	19
<i>Cepikodus evae</i> (Lindström)				18	68	10
<i>Stolodus stola</i> (Lindström)				49	33	12
" <i>Acodus</i> " <i>gladius</i> Lindström					1	
? <i>Scalpellodus</i> sp.					3	
<i>Oistodus</i> aff. <i>O. lanceolatus</i> Pander					5	46
<i>Protopanderodus</i> cf. <i>P. gradatus</i> Serpagli					6	2
<i>Baltoniodus crassulus</i> (Lindström)						65

Table 2 - List and abundance of the conodont taxa.

In this sample some reworked conodonts are present and they are covered by a red colour. The reworked specimens are *Cordylodus* spp., and two elements of *Drepanoistodus deltifer pristinus* (Viira) sensu Szaniawski, 1980.

In sample 705 there is the first appearance of *Paroistodus parallelus* (Pander), *Cornuodus longibasis* (Lindström), *Scolopodus rex* Lindström, and *Drepanoistodus forceps* (Lindström). A few badly preserved specimens of *Prioniodus elegans* Pander are also present. This sample is also characterized by many reworked specimens known from older strata (*Cordylodus angulatus*, *Drepanoistodus* cf. *D. forceps*, *Paltodus peracutus*, *Paltodus subaequalis*, and *Paroistodus numarcuatus*). Some long ranging species occur both as reworked and not reworked (*Scolopodus*? *peselephantis*, *Drepanodus arcuatus*). This assemblage suggests

correlation with *Prioniodus elegans* Zone, which is usually missing in Balto-Scandic region (Lindström, 1971; van Wamel, 1974).

Samples 706, 707, and 708 with *Oepikodus evae* (Lindström), *Drepanoistodus forceps* (Lindström) and *Stolodus stola* (Lindström) correlate with the *Oepikodus evae* Zone of Lindström (1971). *Prioniodus elegans* is still present in samples 706 and 707. *Oistodus* aff. *O. lanceolatus* Pander appears in sample 707 and *Baltoniodus crassulus* (Lindström) in sample 708.

Sample 706, from the upper part of the Kjöplingsklint Formation, can be correlated with the *Protopanderodus rectus* / *Oepikodus evae* Assemblage Zone of van Wamel (1974), sample 707 with the *Oistodus lanceolatus* Assemblage Zone, and sample 708 with the *Prioniodus crassulus* Assemblage Zone of the same author.

Correlation with trilobite zones

According to the stratigraphical investigations of previous authors (such Holm, 1882; Munthe & Hedström, 1904; Westergård, 1922, 1947) the interval where the acritarch bearing sample 699 was collected belongs to the "Tessini sandstone" and thus, should be referred to the Middle Cambrian *Paradoxides paradoxissimus* trilobite Superzone (Fig. 3). The *P. forchammeri* Superzone is apparently missing owing to the presence of a hiatus at the top of the "Tessini sandstone".

From the sea-cliff South-west of Djupvik (12-17 km North of the Furuhäll section) and between Borgholm and Köping Westergård (1922) listed trilobites from the D_ä-d₂ and D_ä-d₃ Members of van Wamel's Djupvik Formation indicating the presence of the Upper Cambrian *Agnostus pisiformis* trilobite Zone within the interval with sample 698. Toward the South, this stratigraphical sequence becomes more complete. South of Borgholm trilobites have been recorded indicating the presence of the Upper Cambrian *Agnostus pisiformis*, *Olenus* and perhaps *Parabolina spinulosa* trilobite Zones (Tullberg, 1882; Westergård, 1922). Farther away, on Southern Öland, Westergård (1947) also recognized other trilobite Zones until the base of the *Acerocare* trilobite Zone (*Parabolina heres* Subzone). Finally, we assume that sample 698 has been collected within an interval probably corresponding to the Upper Cambrian *Agnostus pisiformis* trilobite Zone and, in any case, no more recent than the *Parabolina spinulosa* trilobite Zone.

The acritarch bearing samples 701 and 702 were collected from the Tremadocian *Shumardia* Zone of Moberg & Segerberg (1906); in terms of graptolites, this corresponds with *Clonograptus heres* Zone. *Apatokephalus serratus* Zone with *Euloma ornatum* follows. It covers sample 703 of this study and corresponds with *Paltodus deltifer* conodont Zone of Lindström (1971).

Precise correlation with trilobite zones for the succeeding samples is less obvious in this section. Tjernvik (1956) only did a reconnaissance investigation at Kjöplingsklint but indicated that *Megistaspis (Ekeraspis) armata*, *Megistaspis (Varvaspis) planilimbata*, *Megalaspides (Megalaspides) dalearlicus* and *M. (Varvaspis) estonica* Zones occurred.

SAMPLES	BIOSTRATIGRAPHY - SWEDEN				BALTO SCAND. STAG. SUBS.	INTERN. SYSTEM. SUBSYS. SERIES				
	CONODONT ZONES		TRILOBITE ZONES	GRAPTOLITE ZON./SUBZON.						
	1	2	3	4						
708		PRIONIODUS CRASSULUS	MEGALASPIS (MEGALASPIS) DALECARLICUS	PHYLLOGRAPTUS DENSUS	BILLINGSMAN	ARENIGIAN				
707	DEFIKODUS EVAE	DISTODUS LANCEOLATUS	"TRANSITION BEDS" MEGISTASPIS (VARVASPIS) cf. ESTONICA	DIDYMOGRAPTUS BALTICUS			LATORPIAN	ARENIGIAN		
706		PROTOPANDERODUS RECTUS — DEFIKODUS EVAE								
705	PRIONIODUS ELEGANS	PRIONIODUS ELEGANS — OELANDICUS ELONGATUS	MEGISTASPIS (VARVASPIS) PLANILIMBATA	TETRAGRAPTUS PHYLLOGRAPTOIDES	MUNNEBERGIAN	LOWER ORDOVICIAN				
709		DREPAÑOISTODUS INCONSTANS — PRIONIODUS DELTATUS								
704	PAROISTODUS PROTEUS	?	MEGISTASPIS (EKERASPIS) ARMATA	EARLIEST DICHOGRAPTUS FAUNA						
703		DREPAÑOISTODUS ARCUATUS	APATOKEPHALUS SERRATUS	?						
702		DREPAÑOISTODUS NUMARCUATUS	SHUMARDIA	CLONOGRAPTUS HERES	TRENAODOCIAN	UPPER CAMBRIAN				
701	PALTODUS DELTIFER	PAROISTODUS AMOENUS								
		DREPAÑOISTODUS ACUMINATUS								
700		CORDYLODUS ROTUNDATUS		FLABELLIFORME DICTYONEMA	D. FL. ANGLICUM ANISOGRAPTUS					
		?			D. FL. NORVEGICUM B. KJERULFI					
	CORDYLODUS ANGULATUS				C. TENELLUS A. MUNNEBERG.					
		CORDYLODUS ANGULATUS — CORDYLODUS PRION			D. FL. AB. FLABELLIFORME					
				D. FL. AB. SOCIALE						
				D. FL. DESMOGRAPTOIDES						
			ACEROCARE							
			PELTURA							
			LEPTOPLASTUS							
			PARABOLINA SPINULOSA							
			OLENUS							
698		TRILOBITE SUPERZONES	AGNOSTUS PISIFORMIS							
		PARADOXIDES FORCHAMMERI								
		PARADOXIDES PARADOXISSIMUS								
699		PARADOXIDES OELANDICUS								

 HIATUS

 BARREN INTERZONE

Fig. 3 - The Furuhall section: biostratigraphical correlations. References: 1) Lindström, 1971; 2) van Wamel, 1974; 3) Holm, 1882; Munthe & Hedström, 1904; Westergård, 1922, 1947; 4) Moberg & Segerberg, 1906; Tjernvik & Johansson, 1980.

The presence of *M. armata* Zone, however, is uncertain and apparently is located above sample 703 and below sample 704. *M. planilimbata* Zone covers sample 704, but the index species was marked at the bed where sample 705 has been collected. As noted above, sample 705 correlates with *Prioniodus elegans* conodont Zone. Samples 706 and

707 are taken from an interval where Tjernvik (1956) did not indicate occurrence of trilobites. Regnéll (1942), however, noted that the trilobite fauna from this interval was transitional in aspect. Samples 706 and 707 initiate the lower *Oepikodus evae* Zone of Lindström (1971).

M. dalecarlicus has been positively recorded from a horizon (Tjernvik, 1956) that corresponds with sample 708. This same level coincides closely with the level where *Baltoniodus crassulus* becomes common in lower *Oepikodus evae* Zone of Lindström (1971). *M. estonica* trilobite Zone is located above the topmost bed exposed at the Furu-häll Section.

Löfgren (1985) recorded conodonts from Finngrundet drillcore, North of Öland, where Tjernvik & Johansson (1980) established the trilobite zonation. At Finngrundet *M. armata* Zone is characterized by a conodont assemblage comprising the species *Paltodus deltifer* and *Paroistodus proteus*. This species association occurs below the entrance of *Paltodus subaequalis* and *Baltoniodus ? deltatus* and has not been recorded by us or by van Wamel (1974) from Köpingsklint. Probably it corresponds with the barren strata at the base of K_{k2} Member in the Furu-häll Section.

The *M. planilimbata* Zone in Finngrundet is characterized by a conodont association identical to that recorded from sample 704 and correlation is obvious. This means that the extent of *M. armata* Zone in the section at Köpingsklint as indicated by Tjernvik (1956) and followed by van Wamel (1974) cannot be confirmed.

Megistaspis planilimbata Zone also comprises sample 705. As a result, *Prioniodus elegans* conodont Zone initiates within the *M. planilimbata* trilobite Zone. In Finngrundet, however, Löfgren (1985) did not positively recognize *P. elegans* Zone above *P. proteus* Zone and probably it is missing there. Similar to the Furu-häll Section, the trilobite fauna is a transitional one between the top of *Megistaspis planilimbata* Zone and *M. dalecarlicus* Zone. Tjernvik & Johansson (1980) labelled the interval "Transition beds" and it is characterized by *Megistaspis* (*V.*) aff. *estonica*. As *Oepikodus evae* appears within the "Transition Beds" at Finngrundet (Löfgren, 1985) it is likely that samples 706 and probably 707 correspond with *M. aff. estonica* "Zone". In this way, *M. aff. estonica* "Zone" largely cover K_{k3} Member of the Köpingsklint Formation.

The conodont fauna from sample 708 is identical with that of *M. dalecarlicus* in Finngrundet (Löfgren, 1985), except that Löfgren did not record or commented upon the appearance of *Baltoniodus crassulus*.

The correlation between trilobite zones and conodont zones is shown in Fig. 3 where also correlation with the Scandinavian graptolite zones (Moberg & Segerberg, 1906; Tjernvik & Johansson, 1980; Bergström, 1986) is indicated.

Hiatus and barren intervals in the Furu-häll Section and their significance

The Furu-häll Section at Köpingsklint is condensed indeed. The approximately 3.6 m of strata comprise Middle and Upper Cambrian into Lower Ordovician and span

three important boundaries. Each of them is marked either by faunal hiatus or barren interval which relates with eustatic lows.

1 Cambro-Ordovician hiatuses.

At the Cambro-Ordovician transition an extensive hiatus is known to cover the Upper Cambrian *Leptoaplastus*, *Peltura* and *Acerocare* trilobite Zones and several subzones of *Dictyonema flabelliforme* graptolite Zone in the Lower Ordovician (Westergård, 1947). *Dictyonema flabelliforme norvegicum* is the first graptolite subspecies recorded at Furuhäll and it appears above the *Obolus* conglomerate (Tjernvik, 1956).

This extensive hiatus was formed during at least two eustatic lows. One is at the *Acerocare* Zone of the top of Cambrian and another at *Clonograptus tenellus* Zone in the Lower Tremadocian (Erdtmann, 1986). The very different age suggested by the acritarch assemblages found in D_{ä-d3} Member (sample 698: earlier Upper Cambrian) and D_{k1} Member (sample 701: Upper Tremadocian) of the Djupvik Formation is consistent with the existence of this hiatus.

2 Tremadocian-Hunnebergian Barren Interzone.

The *Megistaspis armata* Zone initiates the Hunnebergian Substage of the Latorpian Stage in the Balto-Scandic region (Tjernvik, 1956). The zone has not been recognized at Furuhäll where a barren interval is noted. This Barren Interzone is marked by the recrystallized calcite rosettes at the base of K_{k2} Member of the Köpingsklint Formation.

The Barren Interzone is a response to a worldwide eustatic low that straddles the Tremadocian-Arenigian Series boundary (based on the first appearance of *Tetragraptus approximatus*) (Tjernvik & Johansson, 1980; Erdtmann, 1986).

3 Hunnebergian-Billingenian Barren Interzone.

The base of Billingenian Substage was first placed at *M. dalecarlicus* Zone, but later Tjernvik & Johansson (1980) included the "Transition Beds" with *M. aff. estonica* in Billingenian. The same authors stressed that *M. planilimbata* was restricted to Hunnebergian Substage. Lindström (1971) found that base of Billingenian coincided with the appearance of *Prioniodus elegans* which however usually is missing in the Balto-Scandic platform sequence.

As described earlier *Prioniodus elegans* Zone is recognized within the range of *M. planilimbata* in the Furuhäll Section where it is very thin indeed (only sample 705 can be referred to this zone). It has been recorded just above the barren, regressive, conglomeratic and glauconitic sand (sample 709) and within the glauconitic and conglomeratic wackestone bed at the very top of K_{k2} Member.

From the above and based on the data from Furuhäll Section *P. elegans* appears

first within the very top of Hunnebergian Substage and ranges into Billingenian Substage. There it occurs together with *Oepikodus evae* in the "Transition Beds". Elsewhere and outside the Balto-Scandic region the two taxa are commonly recorded together.

Whether the "regressive" *P. elegans* marks the top of Hunnebergian Substage or not or the very base of Billingenian Substage (Lindström, 1971) is still in question. The "transgressive" *Oepikodus evae* appears to be a better choice as a marker for basal Billingenian. Not only based on faunal evidence but also in a "practical sense", i.e. for international correlation.

Here the original definition of Hunnebergian Substage (i.e. that *M. planilimbata* is restricted to Hunnebergian Substage) is followed and consequently *P. elegans* Zone is included in that substage. In this way the common occurrence of *P. elegans* and *O. evae* defines the base of Billingenian in the Furuåll Section.

Systematic paleontology

Acritarchs (M. Tongiorgi)

List of acritarch taxa.

The identified acritarch taxa will be described in alphabetical order. They are listed in Table 1 in the same order and their stratigraphic occurrence and abundance in the studied section are indicated. The frequency of the identified taxa in each sample will be indicated using the following convention: very rare (RR) = 1-10 identified specimens; rare (R) = 11-20 identified specimens; common (C) = 21-100 specimens; very common (CC) = more than 100 specimens.

Four taxa (*Baltisphaeridium* cf. *B. microspinosum* (Eisenack) Downie 1959, *Stelliferidium cortinulum* (Deunff) Deunff, Górká & Rauscher 1974 emend. Deunff, Górká & Rauscher 1974, *Stelliferidium stelligerum* (Górká) Deunff, Górká & Rauscher 1974 and Acritarch gen. et sp. nov. indet.) are illustrated but not described here. The *Michhystridium* species of sample 699 are neither described nor illustrated. A single specimen of a possible *Stelliferidium* was observed in a SEM preparation from sample 698. Because of the uncertain identification, this specimen is illustrated (Pl. 28, fig. 8) but neither described nor included in the list of taxa.

Systematic description.

Genus *Acanthodiacrodiium* Timofeev 1958 emend. Deflandre & Deflandre-Rigaud 1962

Type species: *Acanthodiacrodiium dentiferum* Timofeev 1958 (fixed by monotypy).

Remarks. Three genera are here in question: *Acanthodiacrodiium* Timofeev 1958, *Priscotheca* Deunff 1961 and *Actinotodissus* Loeblich & Tappan 1978.

The whole taxonomy of the diacrodians is confused owing to the great number of invalidly published or badly described genera. The review of Deflandre & Deflandre-Rigaud (1962) cannot be considered exhaustive because in some cases the nomenclatural rules are not taken sufficiently into account and the genus *Priscotheca* Deunff 1961 is criticized but neither validated nor rejected. Loeblich & Tappan (1978) add further confusion to this intricate question because in their review the problems of priority are not satisfactorily examined and the new genus *Actinotodissus* Loeblich & Tappan 1978 is arbitrarily introduced in consequence of a merely informal, restrictive emendation of the genus *Acanthodiacrodiium* Timofeev 1958; furthermore, the genus *Priscotheca* Deunff 1961 is still conserved without discussion or comparison with the other conserved genera.

The type species (*A. dentiferum* Timofeev 1958) of the genus *Acanthodiacrodiium* Timofeev 1958 (p. 831) is fixed by monotypy (ICBN art. 7.15 and 7.16) but it is based on largely incomplete (half specimen) holotype. Nevertheless, the photograph of the holotype (pl. 3, fig. 2) is accompanied by a drawing (pl. 1, fig. 2) showing a reconstruction of the whole specimen. Thus, the species may be considered validly published under the ICBN art. 38 (Illustration or figure showing the distinctive morphological features).

The taxonomic significance of *Acanthodiacrodiium* is not quite clear. As observed by Loeblich & Tappan (1978, p. 1238), the type species of *Acanthodiacrodiium* is very similar to the type species of *Lophodiacrodiium* Timofeev 1958 and the possibility to prove them to be cogenetic cannot be excluded. But the holotype of *Acanthodiacrodiium* is not available and a revision based on material from the type locality will probably come up against insurmountable difficulties (Burmann, 1969, p. 298; Loeblich & Tappan, 1978, p. 1237). Nevertheless, the Timofeev's idea of *Acanthodiacrodiium* clearly stands out from the comparison of the numerous *Acanthodiacrodiium* species described by this latter author (see e.g. Timofeev, 1959). All the described species are homopolar. In accordance with the letter of the original diagnosis (Timofeev, 1958, p. 831), most of Timofeev's *Acanthodiacrodiium* species bear (short) spines at the opposite poles (e.g. *A. partiale* Timofeev 1959, p. 78, pl. 6, fig. 46); but some species are characterized by longer (possibly hollow), conical processes (e.g. *A. petrovi* Timofeev 1959, p. 77, pl. 6, fig. 43). The type species of *Acanthodiacrodiium* has not been appropriately chosen because it is not fully representative of the genus, but it cannot be changed under the rules. The emendation of Deflandre & Deflandre-Rigaud (1962, p. 194) represents up to now the better attempt to arrange this intricate question, taking into account the Timofeev's aim as it results from the whole list of the Timofeev's *Acanthodiacrodiium* species. Thus, and for want of a better, definitive solution (i.e. the revision of the Timofeev's collection), the emendation of the genus *Acanthodiacrodiium* proposed by Deflandre & Deflandre-Rigaud is accepted herein.

The second genus in question is *Priscotheca* Deunff 1961. The original diagnosis and discussion (Deunff, 1961, pp. 42-43) are ambiguous: a confusion has been surely ma-

de between the diagnostic characters of the genus and the ones of the type species (*Priscotheca raia* Deunff 1961). Furthermore, the process number at the opposite poles is not specified, even if Deunff recorded altogether 7-15 processes and consequently a different process number at the opposite poles should be admitted in some cases. The minimum process length provided by Deunff (7 μm) compared with the maximum vesicle length (160 μm) may legitimate the use of the term "spines" to indicate these conical processes. If this opinion is accepted, *Priscotheca* Deunff 1961 should be considered a partial junior synonym of *Acanthodiacrodiium* Timofeev 1958 because of the (partial) coincidence of definitions (see e.g. the homopolar *P. complanata* Deunff 1961, p. 43, pl. 3, fig. 7, transferred into the genus *Acanthodiacrodiium* Timofeev by Martin, 1977, p. 19) and to be rejected under the ICBN art. 11.2.

The third genus to be discussed is *Actinotodissus* Loeblich & Tappan 1978. According to these latter authors, *Actinotodissus* should differ from *Acanthodiacrodiium* Timofeev in having long, hollow processes instead of the short, solid processes which Loeblich & Tappan (1978, pp. 1236-1238) suppose to be characteristic of the genus *Acanthodiacrodiium*. But neither the original Timofeev's diagnosis of *Acanthodiacrodiium* (1958, p. 831) nor the emended diagnosis proposed by Deflandre & Deflandre-Rigaud (1962, p. 194) specify whether the processes of *Acanthodiacrodiium* are hollow or not and Loeblich & Tappan do not formally propose a new restricted definition of the genus *Acanthodiacrodiium*. Furthermore, neither the diagnosis nor the description of *Actinotodissus* provided by Loeblich & Tappan specifies the relative length of the processes.

Thus, *Actinotodissus* Loeblich & Tappan 1978 should be considered at least a partial junior taxonomic synonym of *Acanthodiacrodiium* Timofeev 1958 or of *Acanthodiacrodiium* Timofeev, emend. Deflandre & Deflandre-Rigaud 1962 (if this latter emendation is accepted) and should be rejected under the priority rules (ICBN art. 11.2).

In the paper of Loeblich & Tappan, the confusion is considerably increased by the use of the genus *Priscotheca* Deunff 1961 without any discussion or comparison with *Acanthodiacrodiium* or with *Actinotodissus*. This is really astonishing because the letter of the diagnosis of *Actinotodissus* Loeblich & Tappan 1978 largely corresponds to the definition of *Priscotheca* Deunff 1961:

	<i>Priscotheca</i>	<i>Actinotodissus</i>
vesicle shape:	in the form of an elongated small cushion	from elongate-subovate to nearly equal in length and breadth, commonly polygonal in outline
processes	arise from each extremity of this "pseudo-ootheca"	similar processes present on opposite poles
process shape	elongated, hollow	simple, conical, hollow

Finally, it is proposed here to reject both the genus *Priscotheca* Deunff 1961 and *Actinotodissus* Loeblich & Tappan 1978 against the previous validly published genus *Acanthodiacrodiium* Timofeev 1958 emend. Deflandre & Deflandre-Rigaud 1962.

As regards the question of the internal structure of the processes, most of species described here have spine-like processes which appear to be solid in the distal part, while the slightly expanded bases are excavated and freely communicating with the vesicle cavity. Thus, the thin, distal terminations of these spine-like processes are considered here to have a virtual internal cavity.

Acanthodiacrodium formosum Górká 1967

Pl. 30, fig. 1-9

1967 *Acanthodiacrodium formosum* Górká, pp. 5-6, pl. 2, fig. 8, 9.

1969 *Acanthodiacrodium formosum* - Górká, pp. 70-71, pl. 17, fig. 7, 8; pl. 18, fig. 7; text-fig. 31.

Description. Elliptical to subrectangular vesicle with more or less rounded poles, ornamented with spines or horns. Equatorial zone quite narrow, reaching $1/3 - 1/4$ of the whole vesicle length. Processes homomorphic, conical, in form of spines or horns (usually 24 on each cap), with slightly expanded bases and acuminate, often wavy, terminations. Bifidous processes rarely occur. Basal part of the processes hollow and freely communicating with the vesicle cavity, distal part apparently solid.

Vesicle wall rather thick and very finely granulated. Processes gently ornamented by small spines.

Excystment structure in the form of a longitudinal split confined to the equatorial zone.

Dimensions (33 specimens): Vesicle length 38.4-55.5 μm (average 48.6); vesicle width 29.3-42.7 μm (average 36.8); equatorial zone 12.2%-30.6% (average 19%) of the vesicle length; process length 4.2-16.5 μm (average 10.4).

Remarks. The Öland specimens conform to the original diagnosis but are larger than the specimens depicted by Górká (1967, 1969), which are presumably contracted due to the state of preservation. The sharp median constriction shown in some figures by Górká (1969, pl. 18, fig. 7) is presumably due to the fact that the polar caps are folded one on the top of the other. In most of specimens from Öland, the polar caps are only slightly more expanded than the equatorial zone.

Under the optical microscope the surface of the Öland specimens has a smooth appearance and the processes show a fine ornamentation which covers at least their distal part. SEM observation reveals that the vesicle is ornamented with very small grana and the processes are covered by microspines (Pl. 30, fig. 3, 7, 8).

In optical view, the distal part of the processes appears to be solid, but it is difficult to decide whether they are really solid or only appear to be so owing to the extreme thinness of the process termination. Taking into account that in the larger processes the internal cavity extends a little beyond the base through the process stem, it is assumed here that also the thin, distal part of the processes may have an, at least virtual, internal cavity.

Distribution. Upper Tremadocian: Poland (Górka, 1967, 1969); Great Britain, Shropshire (Rasul & Downie, 1974); USSR, Moskovian Sineclyse (Aristova, 1980).

Occurrence and abundance. Sample 701, common.

***Acanthodiacrodium ubui* Martin 1978**

Pl. 30, fig. 11

- 1969 *Acanthodiacrodium ubui* Martin, pp. 127-128, pl. 1, fig. 51; text-fig. 81.
 1970 *Acanthodiacrodium ubui* - Lister (1970b), pl. 5, fig. 1-11; text-fig. 1 a-h, 2 a,b, 3 a-f.
 1971 *Acanthodiacrodium ubui* - Rauscher, p. 293, pl. 1, fig. 20.
 1977 *Acanthodiacrodium ubui* - Martin, p. 22, pl. 2, fig. 6, 10, 21; pl. 3, fig. 2, 3, 9.
 1979 *Acanthodiacrodium invictum* Rasul, pp. 65-66, pl. 2, fig. 6.
 1981 *Acanthodiacrodium ubui* - Martin in Martin & Dean, pp. 13-14, pl. 4, fig. 2,4.
 1986 *Acanthodiacrodium ubui* - Welsch, pp. 70-71, pl. 9, fig. 5-7.

Dimensions (1 specimen): Vesicle length 55 μm , width 40 μm ; process length 5-10 μm ; process number 26 at each pole (estimated only at one pole).

Remarks. The single specimen observed under the SEM corresponds exactly to the description provided by Martin (1981) for *Acanthodiacrodium ubui* although its dimensions are slightly larger. The processes are covered by strong hairs or spines; the equatorial zone is ornamented with fine, longitudinal wrinkles.

According to Martin (personal communication), the processes of *A. ubui* are hollow and freely communicating with the vesicle internal cavity.

Distribution. Uppermost Upper Cambrian to Tremadocian: Eastern Newfoundland, Random Island (Martin in Martin & Dean, 1981). Lower Tremadocian: Belgium, Massif du Brabant (Martin, 1969, 1977; Vanguetaine, 1978b); Northern Norway, Finnmark (Welsch, 1986). Lower to Middle Tremadocian: Great Britain, Shropshire (Rasul & Downie, 1974; Rasul, 1979). Tremadocian: France, Montagne Noire (Rauscher, 1971; Martin, 1973); Great Britain, Shropshire (Lister, 1970b). Tremadocian (cf. *ubui*): France, Montagne Noire (Rauscher, 1974); France, Massif de Mouthoumet (Baudelot & Bessière, 1975, 1977); Algeria, Petite Kabylie (Baudelot, Bouillin & Coiffait, 1981); NE Spain, Celtiberia (Wolf, 1980). Middle to Upper Tremadocian (cf. *ubui*): France, Monts de La-caune (Fournier-Vinas & Donnot, 1977). Uppermost Tremadocian (cf. *ubui*): Great Britain, Isle of Man. Tremadocian to ?Lower Arenigian: British Isles (Downie, 1984). Devonian (reworked): Great Britain, Oxfordshire (Richardson & Rasul, 1978).

Occurrence and abundance. Sample 701, very rare.

pole ornamented with less than 20, short, conical processes in the form of spines with less expanded bases. Process distal part granulated. Vesicle wall very thin, ornamented with scattered grana.

Dimensions (2 specimens): Vesicle length 30.6-34.8 mm; vesicle width 29.4-31.2 mm; equatorial zone 4.2-6 mm; process length 3-9 mm.

Remarks. The processes seem to be hollow at least in their basal part, resembling the ones of *A. formosum* Górka 1967. But this form differs from *A. formosum* in having a thinner vesicle wall, shorter, subsquare shape and less numerous processes, which are proportionally shorter and with narrower bases.

It looks similar in shape to *Diormatosphaera ignorata* Deunff 1961 (Tremadocian beds of the Algerian Sahara) but this latter species has smaller dimensions (Deunff, 1961, p. 44). *D. ignorata* was later transferred into the genus *Acanthodiacrodium* by Martin (1969, p. 122). According to Martin, *A. ignoratum* (Deunff) Martin 1969 (from the Ordovician of Belgium) is characterized by the presence of longitudinal ribs, while the specimens described here have a smooth equatorial zone.

Occurrence and abundance. Sample 701, very rare.

Genus *Adara* Fombella 1977 emend. Martin 1981

Type species: *Adara matutina* Fombella 1977 (by original designation).

***Adara denticulata* Tongiorgi sp. nov.**

Pl. 25, fig. 1-5; Pl. 26, fig. 6, 7

Derivatio nominis. Denticulatus, Lat. = denticulated.

Type locality. Köpingsklint (Furuhäll section), Öland (Sweden).

Type stratum. Top of the "Tessini sandstone" (= base of the Djupvik Formation of van Wamel, 1974), Middle Cambrian, sample 699.

Holotype. Slide Öland 699/1; England Finder graticule coordinate X51/3. Pl. 25, fig. 1.

Repository of the holotype. S10501-1.

Diagnosis. Vesicle spherical, bearing about twenty to forty broad and short, stumpy, more or less conical to tongue-shaped and flattened processes. Processes randomly distributed, hollow and largely open into the internal vesicle cavity. Distal process ends rounded to truncated and roughly tongue-shaped. Vesicle wall very thin, transparent, smooth to irregularly costate. Process bases ornamented by a net of irregular and variably developed, radiating ridges which rise up to the process tips. Process tips echinate to finely denticulate. A membrane is stretched between some adjacent processes. Excystment not observed.

Description. (Based on 28 specimens). The holotype bears about 30-40 processes

(about 12 processes crossing the outline). They are quite variable in shape and length and no clear separation exists between the process bases and the vesicle wall. Furthermore, most of processes are not clearly separated one from the other but are linked by a membrane to form elongated, irregular crests.

The other observed specimens show a high variability in the shape and number of the processes. In fact, the processes vary in number from twenty up to about forty; they may be almost conical or distally more or less enlarged and flattened to tongue shaped. The process shape varies also in the same specimen. But the conical appearance of some processes is probably accentuated by wrinkling. Also the membranes between adjacent processes are very variably developed; in few specimens most of processes are not linked one to another.

Dimensions. Holotype: central body size 28.1x25 μm ; process length about 4 μm . Variation range (6 specimens): Vesicle diameter about 20 to 30 μm ; processes approximately 4-6 μm long and about 4-7 μm wide (at their base).

Remarks. The very thin vesicle is quite transparent in optical view and its features are mostly difficult to distinguish under the optical microscope. Nevertheless, the best preserved specimen in optical view has been chosen as the holotype and no isotypes have been designated, because the delicate features of the specimens we have observed under the SEM are not any more recognizable after permanent mounting on optical microscope slides.

Adara alea Martin 1981 (Eastern Newfoundland, Random Island, Middle Cambrian) has more numerous (40-60 rather than 20-40) and smaller processes. Further, the processes of *A. alea* have a more evident conical shape, are less ornamented and the radiating striae do not rise up to their tips. *Adara matutina* Fombella 1977 (Spain, Provincia de León, Middle Cambrian) has very little processes and no wall and process ornamentation.

Occurrence and abundance. Sample 699, rare.

Genus *Aremoricanium* Deunff, 1955

Type species: *Aremoricanium rigaudae* Deunff 1955 (by original designation).

Remarks. The morphology of *Aremoricanium* Deunff 1955 (1955b) is problematic. Divergent opinions still persist about the presence of one or two distinct layers forming the membrane of the central body. Martin (1984, p. 444) discussed this problem and proposed that the presence of an internal layer may also depend on the state of maturation of the microorganism, in addition to the state of preservation.

***Aremoricanium* ? *grootaertii* Martin 1984**

Pl. 31, fig. 1-8; Pl. 32, fig. 1-5

- 1982 *Acritarch* gen. et sp. nov. A Martin in Dean & Martin, p. 138, pl. 1, fig. 13.
 1984 *Aremoricanium* ? *grootaertii* Martin, pp. 442-444, pl. 58.1, fig. 1-9; pl. 58.2, fig. 1-4.

Dimensions (45 specimens): Diameter of the central body 49-65.4 μm (average 56.4); length of the tubular extension 11.4-21.6 μm (average 16.5); breadth of the tubular extension 16.8-28 μm (average 21.5); length of trunk of processes 7.8-16 μm (average 11.3); length of process/vesicle diameter ratio 12.84%- 27.12% (average 20.1%).

Remarks. For the generic assignment of this species, Martin (1984) is followed. These specimens show the features described by Martin (1984) in having a globular vesicle bearing a prominent, distally open, tubular extension and very numerous flexible, mostly cylindrical, processes. The distal termination of the processes extends into thin straps which are linked to those of neighbouring processes.

SEM observation reveals that two or more adjacent processes may join together a few μm above their bases, to form a larger, usually bundle-shaped trunk which distally splits again into thin anastomosed straps.

In optical view the fine ornamentation of the vesicle wall is seldom detectable: only a few specimens show a kind of granulation or some little spines similar to those described by Martin. Under the SEM the vesicle wall appears to be nearly smooth to scabrate and, more rarely, also ornamented with little grana in the form of scattered, stumpy denticles.

Regarding the wall structure, SEM observation of variously damaged specimens reveals that the vesicle consists of two distinct layers (Pl. 32, fig. 4). Both the "polar" tube and the processes are formed by the external layer only (Pl. 32, fig. 1, 2). This observation provides an explanation for the different appearance, under the optical microscope, of the central body and the "polar" tube: the latter is always more transparent than the vesicle (Pl. 31, fig. 2; Pl. 32, fig. 3).

The population of *A. ? grootaertii* from Öland differs from that described by Martin (1984) in having larger average dimensions, even though the lower part of the size range of the Öland specimens falls within the variation range provided by Martin. This difference may depend on the state of preservation, the specimens from Öland being better preserved than those of Wilcox Pass.

Distribution. *Aremoricanium* ? *grootaertii* was described at Wilcox Pass (Alberta, Canada) in the middle member of the Survey Peak Formation, letter zones D to E (Upper Tremadoc) of the North American trilobite-based succession (Martin in Dean & Martin, 1982; Martin, 1984). Recently, Martin recorded (oral communication to the Dayangcha Intern. Confer. on Cambrian/Ordovician Boundary - Hunjiang, Jilin, China, July 24-30 1986) the occurrence of good preserved specimens of *A. ? grootaertii* in the Middle Tremadocian at Muxiantougou (Dayangcha area, Jilin Province, China) below *Psigraptus* horizon and at Erdaopuzi (the same area) in *Psigraptus* horizon.

Occurrence and abundance. Sample 701, common; sample 702, very rare.

Genus *Athabascaella* Martin 1984

Type species: *Athabascaella playfordii* Martin 1984 (by original designation).

***Athabascaella playfordii* Martin 1984**

Pl. 33, fig. 1-4

1984 *Athabascaella playfordii* Martin, p. 444, pl. 58.3: 1-9.

Dimensions (17 specimens): Vesicle diameter 46.4-76.0 μm (average 65.7); length of process trunk 8.7-13.9 μm (average 11.4), breadth of their bases 1.0-2.2 μm (average 1.5).

Remarks. The features of these specimens correspond to Martin's (1984) original description of *Athabascaella playfordii*. The Öland population of *A. playfordii*, however, differs from the one described by Martin (1984) in having larger average dimensions, even though the lower part of the size range of our specimens falls within the variation range provided by Martin. The size difference may depend on the better state of preservation of the Öland specimens.

Furthermore, the variation range of the process number is slightly wider (between about 80 up to about 120) than in the specimens described by Martin. Also the dimensions of the processes are a little more variable.

Distribution. *Athabascaella playfordii* has been described together with *Aremoricanium* ? *grootaertii* at Wilcox Pass (Alberta, Canada) in the middle member of the Survey Peak Formation, letter zones D to E (Upper Tremadocian) of the North American trilobite-based succession (Martin, 1984).

According to Martin (oral communication to the Dayangcha Intern. Confer. on Cambrian/Ordovician Boundary - Hunjiang, Jilin, China, July 24-30 1986), *Athabascaella playfordii* also occurs (in association with *Aremoricanium* ? *grootaertii*) in the Middle Tremadocian at Muxiantougou (Dayangcha area, Jilin Province, China) below *Psigraptus* horizon and at Erdaopuzi (the same area) in *Psigraptus* horizon.

Type locality. Köpingsklint (Furuhäll section), Öland (Sweden).

Type stratum. Djupvik Formation, Upper Cambrian, sample 698.

Holotype. Slide Öland 698/5; England Finder graticule coordinates S36/2-S37/1. Pl. 28, fig. 4.

Isotypes. 1) Slide Öland 698/SEM1; England Finder graticule coordinates H34/1-3. Pl. 28, fig. 3. 2) Slide Öland 698/SEM3; England Finder coordinates R41/4. Pl. 28, fig. 5.

Repository. Holotype, S10502-5; Isotypes, S10502-24 and S10502-26.

Diagnosis. Globular vesicle, divided into very numerous (40- 50), polygonal, mostly pentagonal and hexagonal, concave fields by thick crests perpendicular to the vesicle surface. Distal margin of the crests ornamented with close spaced, small, simple spines. Spine tips acuminate to blunt or slightly inflated. Fields faintly granulated. Excystment observed in form of a rupture of the vesicle along the sides of some polygonal fields.

Dimensions. Holotype: Vesicle diameter 36.6 μm ; field width about 6-7 μm . Variation range (5 specimens): Vesicle diameter 33-37 μm ; field width 3-7 μm ; crest ornaments 1-2.5 μm .

Remarks. *C. aciculatum* sp. nov. has a high number of polygonal fields: under the SEM 20-30 fields are observable on the visible side of the specimens and therefore it is reasonable to assume that at least 40-50 fields are present on the whole vesicle. On the contrary, *C. cambriense* (Slavíková) Vanguetaine 1978 is usually characterized by no more than 20 fields (see Slavíková, 1968, p. 201 - Middle Cambrian, Bohemia; Gardiner & Vanguetaine, 1971, p. 195 - ?Lower Cambrian to Middle Cambrian, Ireland; Welsch, 1986, p. 76 - Middle Cambrian, Northern Norway). Only Cramer & Diez de Cramer (1972, p. 44 - Middle to Upper Cambrian-?Tremadocian, Spain) describe specimens (under the name of *Cymatiosphaera ovillensis* Cramer & Diez) with "five or six (rarely) to more than twenty fields".

Furthermore, the crest ornamentation of *C. aciculatum* consists of closely spaced spines, whereas the crests of *C. cambriense* are ornamented by irregularly spaced granules and denticles. The strongly ornamented *C. cambriense* described by Vanguetaine (1978a, p. 271, pl. 3, fig. 16 - "Revinien" Rn2a = Middle Cambrian?, borehole Grand-Halleux, Belgium), Martin (in Martin & Dean, 1984, p. 433, pl. 57.1, fig. 1-7, 9, 13 - Middle Cambrian, Eastern Newfoundland) and Welsch (1986, p. 75, pl. 3, fig. 14 - Middle Cambrian, Northern Norway) also differs from *C. aciculatum* in having more spaced and mostly stumpy ornaments.

Regarding the crest ornamentation (but not the field number), *C. aciculatum* may be compared with the transitional forms between *C. cambriense* and *C. randomense* described by Welsch (1986, p. 76) from the K4 Member of the Kistedal Formation at Finnmark, Northern Norway (Upper Cambrian, approximately between the *Agnostus pisiiformis* and the *Olenus* trilobite Zone).

C. aciculatum differs from *C. randomense* Martin 1981 (Martin in Martin & Dean, 1981, p. 18; Eastern Newfoundland, Random Island, Upper Cambrian, *Peltura* trilobite Zone) in having more numerous polygonal fields and smaller spinose ornamentation.

Occurrence and abundance. Sample 698, very rare.

Cristallinium cambriense (Slavíková) Vanguetaine 1978

Pl. 25, fig. 6-9; Pl. 28, fig. 1, 2

- 1968 *Dictyotidium cambriense* Slavíková, p. 201, pl. 2, fig. 1, 3.
 1971 *Dictyotidium cambriense* - Gardiner & Vanguetaine, p. 195, pl. 2, fig. 4, 5.
 1972 *Cymatiosphaera ovillensis* Cramer & Diez, p. 44, pl. 2, fig. 4, 7, 10.
 1973 *Dictyotidium cambriense* - Martin, p. 42, pl. 2, fig. 13; pl. 6, fig. 4.
 1976 *Staplinia cambriense* - Vavrdová pl. 1, fig. 1, 3, 5, 8.
 1976 *Cymatiosphaera ovillense* - Vavrdová, pl. 4, fig. 8.
 1976 *Cymatiosphaera favosa* Jankauskas, p. 190, pl. 25, fig. 7, fig. 15 (erroneously indicated in the text as fig. 13).
 1976 *Cymatiosphaera lazdynica* Jankauskas, p. 190, pl. 25, fig. 4, 5, 8, 10.
 1976 *Cymatiosphaera cristata* Jankauskas, p. 191, pl. 25, fig. 18, 21 (erroneously indicated in the text as fig. 17, 20).
 1976 *Cymatiosphaera nerisica* Jankauskas, pp. 191-192, pl. 25, fig. 11, 19 (erroneously indicated in the text as fig. 14, 18, 21).
 1977 *Dictyotidium cambriense* - Martin, pl. 4, fig. 12; text-fig. 13.
 1978 *Cymatiosphaera ovillensis* - Fombella, pl. 1, fig. 20.
 1978 *Cristallinium cambriense* - Vanguetaine (1978a), p. 271, pl. 2, fig. 16, 17; pl. 3, fig. 16, 26.
 1978 *Dictyotidium ? cambriense* - Martin in Dean & Martin, p. 284, pl. 3, fig. 11.
 1979 *Cristallinium ovillense* - Fombella, pl. 3, fig. 43; pl. 4, fig. 63, 65, 69.
 1979 *Cymatiosphaera cristata* - Volkova, Kirjanov, Piskun, Paskevichiene & Jankauskas, p. 31, pl. 14, fig. 8, 9.
 1979 *Cymatiosphaera favosa* - Volkova, Kirjanov, Piskun, Paskevichiene & Jankauskas, pp. 31-32, pl. 14, fig. 6, 7.
 1979 *Cymatiosphaera nerisica* - Volkova, Kirjanov, Piskun, Paskevichiene & Jankauskas, p. 32, pl. 14, fig. 4, 5.
 1980 *Cymatiosphaera ovillensis* - Jankauskas, fig. 11, 12.
 1981 *Cristallinium cambriense* - Martin in Martin & Dean, p. 17, pl. 3, fig. 4, 5, 9, 11; pl. 5, fig. 3, 5, 8, 11.
 1981 *Cristallinium cambriense* - Erkmen & Bozdogan, p. 54, pl. 2, fig. 2, 3.
 1982 *Cristallinium cambriense* - Cocchio, pl. 1, fig. 17.
 1982 *Cristallinium ovillense* - Fombella Blanco, p. 19, pl. 2, fig. 22.
 1983 *Cristallinium cambriense* - Vanguetaine & Van Looy, pl. 1, fig. 7, 8.
 1984 *Cristallinium cambriense* - Martin in Martin & Dean, p. 433, pl. 57.1, fig. 1-7, 9, 13.
 1984 *Cristallinium cambriense* - Volkova & Golub, pl. 2, fig. 3.
 1985 *Cristallinium cambriense* - Pittau, p. 180, pl. 4, fig. 12; pl. 7, fig. 3.
 1986 *Cristallinium cambriense* - Yin Lei-ming, pp. 338-339, pl. 94, fig. 8; pl. 96, fig. 6-8.
 1986 *Dictyotidium cambriense* - Yin Lei-ming, pp. 343-344, pl. 89, fig. 1-3.
 1986 *Cristallinium cambriense* - Welsch, pp. 75-76, pl. 3, fig. 7-14.

Dimensions (9 specimens): Vesicle diameter 37.8-47.6 μm .

Remarks. Misprints in the text and in the explanation of plate 25 of Jankauskas (1976) were corrected by Jankauskas herself in a letter sent to F. Martin in January 1978 (see Martin, in Martin & Dean, 1981, p. 17).

The rims of the crests delimiting the polygonal areas are always ornamented by grana and denticles which are clearly detectable under the optical microscope. These ornaments are irregularly spaced and largely variable in size and shape on the same specimen. Normally, the vesicle wall is very finely granulated but specimens with weakly

shagrinated vesicle wall are also present. The field number is between 10 and 20.

C. cambriense (Slavíková) Vanguestaine 1978 differs from *C. aciculatum* Tongiorgi sp. nov. in having a lower number of fields and a smaller and more irregular ornamentation of the crest rims.

Distribution. ?Lower Cambrian to Middle Cambrian: Ireland (Gardiner & Vanguestaine, 1971; Smith, 1981). Middle Cambrian: USSR, Prebaltic Region and Eastern European Platform (Jankauskas, 1976; Volkova et al., 1979; datation to the Lower Cambrian later modified by Jankauskas, 1980); Bohemia (Slavíková, 1968; Vavrdová, 1976); South-eastern Turkey (Erkmen & Bozdogan, 1981); Morocco, High Atlas Mountains (Vanguestaine & Van Looy, 1983). Middle Cambrian to early Upper Cambrian: Northern Norway, Finnmark (Welsch, 1986). Uppermost Middle Cambrian and early Upper Cambrian: British Isles (Downie, 1984). Middle to Upper Cambrian: Belgium, Massif de Stavelot, Massif de Rocroi, Massif de Givonne, borehole of Grand Halleux (Vanguestaine, 1978a; Vanguestaine & Van Looy, 1983); USSR, North-West of the Eastern European Platform (Jankauskas, 1980). Upper Cambrian: France, Ardennes (Meillez & Vanguestaine, 1983); USSR, Ladoga Series (Volkova & Golub, 1984). Middle to Upper Cambrian (?Tremadocian): Spain, Provincia de León (Cramer & Diez de Cramer, 1972; Fombella, 1978, 1979; Fombella Blanco, 1982). Middle Cambrian to Tremadocian: Eastern Newfoundland, Random Island (Martin in Martin & Dean, 1981; Martin in Martin & Dean, 1984). Upper Cambrian to ?Lowermost Tremadocian: China, Jilin Province, Dayangcha (Yin Lei-ming, 1986). Uppermost Cambrian - Lowermost Tremadocian: SW Sardinia (Pittau, 1985). Lower Tremadocian: Belgium, Massif de Brabant (Martin, 1977). Middle to Upper Tremadocian: Algeria (Jardiné, Combaz, Magloire, Peniguel & Vachey, 1974). Tremadocian: France, Montagne Noire (Martin, 1973); Eastern Newfoundland, Bell Island (Martin in Dean & Martin, 1978); Algeria, Petite Kabylie (Baudelot, Bouillin & Coiffait, 1981); France, Massif du Mouthoumet (Cocchio, 1982).

Occurrence and abundance. Sample 699, common.

Genus *Cymatiogalea* Deunff 1961 emend. Deunff, Górka & Rauscher 1974

Type species: *Cymatiogalea margaritata* Deunff 1961 (by original designation).

Cymatiogalea cuvillieri (Deunff) Deunff 1964

Pl. 33, fig. 6

- 1961 *Priscogalea cuvillieri* Deunff, p. 41, pl. 1, fig. 2.
 1964 *Cymatiogalea cuvillieri* - Deunff, p. 124, pl. 1, fig. 2, 3.
 1970 *Cymatiogalea cuvillieri* - Martin, Michot & Vanguestaine, p. 346, pl. 1, fig. 1.
 1973 *Priscogalea cuvillieri* - Martin, pp. 17-18, pl. 3, fig. 11, 15; pl. 4, fig. 3, 4, 11, 17, 19; pl. 5, fig. 23, 28; pl. 9, fig. 6; text-fig. 6, 7.
 1973 *Priscogalea cuvillieri fucata* Martin, pp. 19-20, pl. 1, fig. 7; pl. 3, fig. 2, 3, 7; pl. 4, fig. 1, 18; pl. 5, fig.

1-3, 16, 29; pl. 9, fig. 3-5; text-fig. 9-12.

- 1974 *Cymatiogalea cuvillieri* - Deunff, Górká & Rauscher, p. 11, pl. 6, fig. 6-8.
 1974 *Cymatiogalea cuvillieri* - Rasul, pp. 53-54, pl. 5, fig. 1, 2; (*non* pl. 7, fig. 2).
 1974 *Cymatiogalea cuvillieri* - Rauscher, p. 66, pl. 1, fig. 27.
 1977 *Cymatiogalea cuvillieri* - Baudelot & Bessiére, pl. 41, fig. 19.
 1977 *Priscogalea cuvillieri fucata* - Martin, pl. 1, fig. 7.
 1977 *Priscogalea cuvillieri* - Martin, pl. 4, fig. 1.
 1982 *Cymatiogalea cuvillieri* - Cocchio, pl. 2, fig. 2.
 1982 *Cymatiogalea cuvillieri* - Bultynck & Martin, pl. 2, fig. 10.
 1985 *Cymatiogalea cuvillieri* - Albani, Di Milia, Minzoni & Tongiorgi, pl. 2, fig. 8, 9.

Dimensions (1 specimen): Vesicle width 37.8 μm ; vesicle height 34.8 μm ; polar opening 22.8 μm ; polygonal areas width 11.2-22.2 μm ; process length 1.5-2.5 μm .

Remarks. This specimen conforms to the descriptions of *C. cuvillieri* provided by earlier authors. Eleven polygonal areas have been recognized. The dimensions are within the range reported by Martin (1973, pp. 17-20).

According to Rasul (1974, p. 54), *C. columellifera* (Deunff) Deunff, Górká & Rauscher 1974 (Argiles d'El Gassi, Sahara, Tremadocian) is a synonym of *C. cuvillieri*. Nevertheless, *C. columellifera* is not included here within the synonyma of *C. cuvillieri* because with only one specimen it is impossible to discuss this suggestion.

Distribution. Latest Cambrian or Early Tremadocian: SW Sardinia (Pittau, 1985). Lower Tremadocian: Algerian Sahara (Jardiné, Combaz, Magloire, Peniguel & Vachey, 1974); Belgium, Massif du Brabant (Martin, 1977); Argentina, Salta Province (Martin in Dean & Martin, 1982; Bultynck & Martin, 1982), Central Sardinia (Albani, Di Milia, Minzoni & Tongiorgi, 1985). Tremadocian: Algerian Sahara (Deunff, 1961, 1964; Combaz, 1967; Deunff, Górká & Rauscher, 1974); France, Montagne Noire (Martin, 1973; Rauscher, 1974); Great Britain, Shropshire (Rasul & Downie, 1974); NW Libya (Deunff & Massa, 1975); France, Massif de Mouthoumet (Baudelot & Bessiére, 1977; Cocchio, 1982); Spain, Celtiberia (Wolf, 1980); Algeria, Petite Kabylie (Baudelot, Bouillin & Coiffait, 1981); Great Britain, Western Lake District (Molyneux & Rushton, 1985). Tremadocian and Lower Arenigian: British Isles (Downie, 1984). Uppermost Tremadocian (?) to Late Arenigian: Great Britain, Isle of Man (Molyneux, 1979). Lower Llanvirnian: Great Britain, Northern Lake District (Downie & Soper, 1972: uncertain systematic attribution). Caradocian (reworked): Belgium, Sambre-Meuse (Martin, Michot, Vanguetaine, 1970); Bohemia (Vavrdová, 1982a).

Occurrence and abundance. Sample 701, very rare.

Genus *Dasydiacrodium* Timofeev ex Deflandre & Deflandre-Rigaud 1962 emend.
 Deflandre & Deflandre-Rigaud 1962

Type species: *Dasydiacrodium eichwaldi* Timofeev 1959 (designated by Deflandre & Deflandre-Rigaud 1962).

Dasydiacrodium tremadocum (Górka) Tongiorgi comb. nov. emend.

Pl. 34, fig. 1-9; Pl. 35, fig. 1-5, 9

- 1967 *Acanthodiacrodium tremadocum* Górka, p. 5, pl. 2, fig. 4.
 1967 *Dasydiacrodium longicornutum* Górka, p. 6, pl. 2, fig. 5.
 1969 *Priscotheca raia* - Górka (*non* Deunff), p. 66, pl. 17, fig. 9; pl. 18, fig. 2; text-fig. 27a.
 1969 *Priscotheca prismatica* - Górka (*non* Deunff), p. 67, pl. 17, fig. 11; pl. 18, fig. 6; text-fig. 27b.
 1969 *Acanthodiacrodium tremadocum* - Górka, pp. 69-70, pl. 18, fig. 3; text-fig. 30.
 1969 *Dasydiacrodium longicornutum* - Górka, pp. 73-74, pl. 17, fig. 10; pl. 18, fig. 1; text-fig. 33.

Emended. diagnosis (based on more than 500 specimens). Vesicle with elliptical or subelliptical, sometimes subrectangular outline, with more or less inflated to straight or, more rarely, slightly inflected sides. Processes 6-12 on the whole, mostly dissimilar in number on the opposite pole, variable in size and shape also on the same specimen but always conical, hollow and freely communicating with the vesicle cavity. Distal end of the processes mostly acuminate but also blunt or clavate, rarely ribbon-like to filiform. Bifidous processes rarely present. Process bases narrow to very expanded. Process-vesicle contact subangular to concave.

Vesicle wall mostly moderately thick, smooth or, more commonly, very finely granulated. Processes mostly granulated at least on the distal part.

Excystment observed in form of a longitudinal split.

Description. This species shows an extremely high variability in the vesicle outline and in the shape, length, distal termination, number and ornamentation of the processes. The general outline of the vesicle varies from elliptical, with almost straight to convex sides, to subrectangular, with slightly inflected to straight sides. The polar caps are usually more or less rounded.

The conical processes, numbering of 6-12 altogether, are most commonly 3 at one pole and 4 at the other one or 4 and 5 respectively (very rarely, the opposite polar caps bear the same process number). They vary in length and shape at the same pole: their length ranges between 30 and 40 μm and only rarely exceeds 60 μm . The base of the processes can be narrow (with a process-vesicle contact subangular) to very expanded, with a concave process-vesicle contact. Above their base the processes get rapidly narrower. The distal termination of the processes is another very variable feature, often in the same specimen: it can be acuminate, blunt, or clavate, but (rarely) also ribbon-like to filiform. In a few specimens a bifidous process has been observed.

The processes are usually rather firm, even if they are hollow and freely communicating with the vesicle interior. Some specimens are characterized by veryhachioid processes with a wavy, ribbon-like to filiform distal termination.

The processes are commonly granulated, at least on the distal part. Specimens with smooth processes are also present. Under the SEM the process granulation appears to be formed by minute denticles, whose size usually increases towards the process tip.

The vesicle wall is mostly moderately thick and usually smooth under optical mi-

croscope. SEM observation often reveals a very fine ornamentation of the vesicle wall: very small grana and, rarely, minute denticles.

Finally, three extreme forms are distinguishable within this population: the first (and more common) has an elliptical or subelliptical vesicle with rounded poles bearing few, relatively short, firm and acuminate processes with narrow bases; the second is characterized by less rounded poles, bearing numerous, often curved or wavy processes; the third typically shows a subrectangular vesicle with a slightly inflected sides ornamented by long, veryhachoid processes often characterized by anomalous, bulbous, ribbon-like or filiform terminations (exceptionally, a very large, distal, club-shaped inflation has been observed). The latter form usually shows thinner vesicle wall. Between these extremes all the intermediate forms have been observed.

In several specimens the excystment in form of a longitudinal split is present.

Dimensions (95 specimens): Vesicle length 48.8-86.6 μm (average 69); vesicle width 31.7-59.2 μm (average 48.5); vesicle length/vesicle width ratio 1-1.8 (average 1.4), exceptionally (2 specimens) 2.1 and 2.3; process length 7.2-61 μm (average 33.3, modal classes between 28 and 40), exceptionally (4 specimens) more than 65 μm up to 71.4 μm ; longest process 30.2%-87.9% (average 58.3%) of the vesicle length, exceptionally (3 specimens) 94.3%, 110.2%, 126%.

Remarks. Some specimens from the Upper Tremadocian of Poland have been identified by Górká (1967, 1969) as *Priscotheca raia* Deunff, 1961, *Priscotheca prismatica* Deunff 1961, *Acanthodiacrodium tremadocum* Górká 1967 and *Dasydiacrodium longicornutum* Górká 1967. All these forms should be assigned to the genus *Dasydiacrodium* Timofeev, because the specimens illustrated show a different process number on the opposite poles.

The assignment of the first group of Górká's specimens to *Priscotheca raia* Deunff 1961 (from the Algerian Tremadocian) is questionable because *P. raia* is an apparently similar, but larger, three to four times longer, form (Deunff, 1961, p. 43, pl. 3, fig. 2). Likewise, the assignment of other Polish specimens to *P. prismatica* Deunff 1961 (Tremadocian of Algeria) is questionable because the size of the Deunff's species is considerably larger, the processes rather longer and the vesicle less inflated (Deunff, 1961, pl. 3, fig. 5). Furthermore, according to the diagnosis (Deunff, 1961, p. 43), *P. prismatica* appears to have 4 processes on each pole and thus should be included in the genus *Acanthodiacrodium* Timofeev 1958, whereas the Górká's form surely is an heteropolar diacrodian.

Within the Öland material, the most common form resembles *A. tremadocum* Górká 1967 in having an inflated outline, with rounded polar caps and acuminate processes with relatively narrow bases. But other specimens are similar to *Dasydiacrodium longicornutum* Górká 1967 or to *P. raia* Deunff *sensu* Górká (1969) or even to *P. prismatica* Deunff *sensu* Górká (1969). Thus, it is not possible to differentiate between them at the specific level.

Like the Öland material, the forms from Poland are very similar to each other, particularly *P. raia* Deunff *sensu* Górká, *A. tremadocum* Górká and *D. longicornutum* Górká, but also *P. prismatica* Deunff *sensu* Górká (see Górká, 1969, p. 66). Apparently,

they display the variability range of a single species, like the highly variable dasydiacrodians from Öland, described here. For the forms from Poland, the specific name of *tremadocum* (Górka, 1967, p. 5) must be retained due to priority. In contrast with the opinion of Górka (1967, 1969), *Priscotheca* cf. *raia* Deunff (1961, pl. 3, fig. 1) is not included within the synonymy of *Dasydiacrodium tremadocum* (Górka) comb. nov. emend. because it is much larger than the species designated by Górka.

Our specimens differ from the Polish material only in having larger dimensions and processes on the average longer, if compared with the vesicle length. But their general features closely correspond to the ones of *D. tremadocum* s.l.

P. raia Deunff 1961 is much larger than the specimens of Öland; furthermore, no information is available about the process number on the opposite poles. If *P. raia* may be assigned to the genus *Dasydiacrodium*, the whole group *P. raia* - *P. cf. raia* and perhaps also *P. cf. prismatica* (pl. 3, fig. 3) of Deunff (1961) may represent a very similar (even if different), larger, north-African species with a variation range comparable to the one of the Baltic *D. tremadocum*.

Distribution. Upper Tremadocian: Poland (Górka, 1967, 1969).

Occurrence and abundance. Sample 701, very common; sample 702, very rare.

***Dasydiacrodium tumidum* (Deunff) Tongiorgi comb. nov.**

Pl. 33, fig. 7-9; Pl. 35, fig. 6, 7

- 1961 *Priscotheca tumida* Deunff, p. 43, pl. 3, fig. 6.
 non 1966 *Priscotheca tumida* - Downie & Ford, pp. 311, 313, pl. 17, fig. 12.
 1967 *Priscotheca tumida* - Combaz, p. 16, pl. 3, fig. 65.

Description. Elliptical, inflated vesicle bearing at the poles few (mostly 5 on the whole), short, conical processes which are hollow and freely communicate with the vesicle cavity. Process number mostly different at the opposite poles. Process tips pointed to slightly rounded, process bases rather narrow with a straight process-vesicle contact. Process and vesicle wall thin, more or less granulated. Excystment observed in the form of a longitudinal split.

Dimensions (17 specimens): Vesicle length 56.7-79.3 μm , width 39.7-54.9 μm ; process length 3.1-17.1 μm (average 8.8).

Remarks. The process number is usually 2 at one pole and 3 at the other, but specimens with 1-2, 2-2, 3-4 and exceptionally even a 2-6 arrangement have been observed. Even when the process number is the same at the opposite poles, their size differs. The processes vary in size and shape even on the same specimen, from short, conical spines to larger and stronger, horn-like processes; slender processes sometimes occur.

In optical view the vesicle wall seems to be usually smooth, but the SEM reveals a

fine ornamentation in the form of close-spaced button like grana. A similar ornamentation, but coarser, also covers the processes.

The process number, which usually differs at the opposite poles, justifies the unambiguous attribution of these specimens to the genus *Dasydiacrodium* Timofeev 1958 emend. Deflandre & Deflandre-Rigaud 1962.

The general shape of the described specimens closely recalls the specimens from the Tremadocian of Northern Africa depicted by Deunff (1961, pl. 3, fig. 6) and by Combaz (1967, pl. 3, fig. 65) under the name of *Priscotheca tumida* Deunff 1961. However, the original diagnosis provided by Deunff (1961, p. 43) does not specify the process number at each pole and the illustration of the holotype is ambiguous. But the specimen depicted by Combaz (from the same area and stratigraphic level as the holotype) seems to be an heteropolar diacrodian. Thus, *Priscotheca tumida* Deunff 1961 is tentatively transferred here to the genus *Dasydiacrodium*. If this interpretation of Deunff's species is correct, also the attribution of the Öland heteropolar specimens to Deunff's species is justified by the close similarity in shape and size.

Distribution. Tremadocian: Algerian Sahara (Deunff, 1961; Combaz, 1967); Great Britain (Rasul & Downie, 1974). Lower Tremadocian to Llanvirnian: Algerian Sahara (Jardiné, Combaz, Magloire, Peniguel & Vachey, 1974).

Occurrence and abundance. Sample 701, common.

Genus *Eliasum* Fombella 1977

Type species: *Eliasum llaniscum* Fombella 1977 (by original designation).

***Eliasum* cf. *E. llaniscum* Fombella 1977**

Pl. 26, fig. 1-5; Pl. 27, fig. 1-5

Dimensions (8 specimens): Vesicle length 61-87.8 μm , width 23.2-32.9 μm .

Remarks. All specimens are apparently smooth under the optical microscope and under the SEM, at low magnification. But, with higher magnification (about 10.000 a faint, hardly detectable ornamentation of the vesicle wall and of the crest rims become recognizable on most specimens. Only a few specimens are completely smooth. The ornamented individuals have a very finely scabrato - irregularly microcorrugated vesicle wall; toward the crest rims the ornamentation size increases and the rims become rugulate to microgranulated. In most of the specimens the crest rims are thickened by these ornaments, forming a slightly inflated, string-like border. In some cases, this narrow, thickened border may be recognized also under the optical microscope.

Eliasum llaniscum Fombella 1977 (p. 118, pl. 1, fig. 6; text-fig. 1:1) from the Spanish Middle Cambrian is a smooth form. But, thin, slightly thickened crest rims seem to

be present in some illustrated specimens of *E. llaniscum*: see e.g. Fombella (1979, pl. 1, fig. 4: Middle Cambrian of Spain) or Erkmén & Bozdoğan (1981, pl 2, fig. 16: South-eastern Turkey, Middle Cambrian).

An ornamented form of *Eliasum* (*Eliasum* cf. *E. llaniscum* from Finnmark, Northern, Middle Cambrian) was recorded by Welsch (1986, p. 66, pl. 2, fig. 9, 10), who describes a very fine microgranulation of the vesicle wall. But Welsch did not notice any ornamentation on the crests. The specimens from Öland differ from the ones described by Welsch by the lack of grana on the vesicle wall and by their gently ornamented crest rims.

According to the original diagnosis and illustrations, *E. asturicum* Fombella 1977 (Spain, Province de Léon, Middle Cambrian) differs from the specimens described herein in having always a stronger, denticulate ornamentation of the crest rims. This ornamentation forms a large band, much wider than the narrow, string like crest border of some specimens from Öland.

Owing to the presence of intermediate passages, both the smooth and the finely ornamented specimens from Öland are considered here to be conspecific and to be compared with *E. llaniscum* Fombella 1977. The faint ornamentation of the crest rims of most specimens probably represents the distinctive characteristic of a particular Baltic population of *E. llaniscum*. Because this form is represented by a small number of individuals (less than 20), which does not allow more detailed analysis, an open nomenclature is preferred herein.

Eliasum llaniscum Fombella 1977 is typically Middle Cambrian in age. In fact, it was recorded only in latest Lower Cambrian to Middle Cambrian (British Isles: Downie, 1984) and in Middle Cambrian (Spain, Province de Léon: Cramer & Diez de Cramer, 1972; Fombella, 1977, 1978, 1979; Fombella Blanco, 1982; Bohemia: Vavrdová, 1976; Eastern Newfoundland, Random Island: Martin in Martin & Dean, 1981, 1983, 1984; SE Turkey: Erkmén & Bozdoğan, 1981; SE Ireland: Smith, 1981; Morocco, High Atlas Mountains: Vanguetaine & Van Looy, 1983).

Occurrence and abundance. Sample 699, rare.

Genus *Leiofusa* Eisenack 1938 emend. Cramer 1971

Type species: *Leiofusa fusiformis* (Eisenack) Eisenack 1938 (by original designation).

Lelofusa* cf. *L. simplex (Combaz) Eisenack, Cramer & Diez 1976

Pl. 31, fig. 9

Dimensions (4 specimens): Vesicle length 442-560 μm ; vesicle width 42-56.4 μm .

Remarks. These specimens are similar to *L. simplex* (Combaz) Eisenack, Cramer & Diez 1976 from the Lower Tremadocian of Algeria (Combaz, 1967, p. 17, pl. 4, fig.

94) in having a fusiform shape with no constriction at the process bases; but they are remarkably larger than the specimens depicted by Combaz (120 x 12 μm) and by Rauscher (1974, p. 77, pl. 3, fig. 4 - Arenigian of France, Montagne Noire: 140-150 x 20 μm). It is possible that *L. simplex* has a very wide size range, like other *Leiofusa* species (e.g. *L. estrecha* Cramer 1964 - from the Lower Gedinnian of Spain - whose length varies from 120 up to 400 μm). But, *L. simplex* is a rare species, always represented by a little number of specimens which provide scanty information on its variability range. Thus, an open nomenclature is preferred herein.

Occurrence and abundance. Sample 701, rare.

Leiofusa sp.

Pl. 37, fig. 9

Description. The single specimen has a fusiform central body, merging into a hollow, flexible conical process at each pole. A slight constriction is present between the vesicle and the processes. Vesicle and processes wall thin and smooth.

Dimensions: Vesicle length about 56.4 μm ; vesicle width 24 μm ; process length 24 μm ; bases of processes 5.4 μm wide.

Remarks. *Leiofusa fusiformis* (Eisenack) Eisenack 1938 (probably Ordovician, Baltic Region) differs from the specimen described here in having longer and more slender processes.

Occurrence and abundance. Sample 701, very rare.

Genus *Multiplicisphaeridium* Staplin 1961 emend. Lister 1970

Type species: *Multiplicisphaeridium ramispinosum* Staplin 1961 (by original designation).

Multiplicisphaeridium martae Cramer & Diez 1972

Pl. 27, fig. 6, 7

- 1972 *Multiplicisphaeridium martae* Cramer & Diez de Cramer, pp. 42-43, pl. 1, fig. 5, 9; pl. 2, fig. 3; text-fig. 2.
- non 1977 *Multiplicisphaeridium* ? *martae* - Martin, p. 7, pl. 1, fig. 14, 19, 23.
- 1978 *Multiplicisphaeridium martae* - Fombella, pl. 1, fig. 10, 11; pl. 3, fig. 14, 15.
- 1979 *Multiplicisphaeridium martae* - Fombella, pl. 1, fig. 10; pl. 2, fig. 32, 35; pl. 3, fig. 41, 52, 55; pl. 5, fig. 74, 77, 78.
- 1981 *Multiplicisphaeridium martae* - Erkmen & Bozdogan, pp. 53-54, pl. 1, fig. 5.
- 1983 *Multiplicisphaeridium martae* - Vanguestaine & Van Looy, pl. 2, fig. 7.
- 1986 *Multiplicisphaeridium martae* - Welsch, pp. 62-63, pl. 2, fig. 11-15.

Dimensions (11 specimens): Vesicle diameter 17.5-21.5 μm ; process length 5-11 μm ; number of visible

processes (on one side of the vesicle) 26-45, mostly less than 30.

Remarks. According to Welsch (1986, pp. 62-63), the process number varies through the stratigraphic sequence: at Finnmark (Northern Norway) *M. martae* shows 20-40 processes in the lowest levels of the *Paradoxides paradoxissimus* Zone, while it bears 40-80 processes in the higher levels. The specimens from Öland have a number of processes similar to those of the oldest specimens from Finnmark.

Under the SEM a few specimens appear to be weakly ornamented with scattered grana.

Distribution. Middle Cambrian: SE Ireland (Smith, 1981); SE Turkey (Erkmen & Bozdogan, 1981); Morocco, High Atlas Mountains (Vanguetaine & Van Looy, 1983); Northern Norway, Finnmark (Welsch, 1986). Upper Middle Cambrian: Spain, Province de Léon (Cramer & Diez de Cramer, 1972). Middle Cambrian to ?Tremadocian (Tremadocian age questionable: see Vanguetaine & Van Looy, 1983): Spain, Cordillera Cantabrica (Fombella 1978, 1979; Fombella Blanco, 1982).

Occurrence and abundance. Sample 699, common.

Multiplicisphaeridium sp. A

Pl. 36, fig. 2, 3

Description. Subspherical, slightly polyhedral central body, ornamented with 40-50 widely conical, hollow processes, freely communicating with the vesicle cavity. Process tips mostly bifurcated into short, pointed pinnae, frequently bearing shorter, acuminate pinnulae. A few processes simple. Vesicle and process wall unilayered, thin and smooth.

Dimensions (2 specimens): Vesicle diameter 20-21 μm ; process length 5-6 μm ; process bases about 2 μm wide.

Remarks. *Multiplicisphaeridium* sp. A differs from *Multiplicisphaeridium* sp. B in having smaller dimensions and relatively larger, widely conical processes which are furcated up to the second order. Furthermore, the processes of *Multiplicisphaeridium* sp. A are fewer: no more than about 20 crossing the outline, instead of 30-45 as in *Multiplicisphaeridium* sp. B.

Occurrence and abundance. Sample 701, very rare.

Multiplicisphaeridium sp. B

Pl. 36, fig. 1

Description. Spherical central body, ornamented with numerous (at least 30-45

crossing the outline) short, conical, hollow processes, freely communicating with the vesicle cavity. Process tips sometimes simple but more commonly bifurcated into very short, spine-like pinnae. Vesicle and process wall unilayered, thin and smooth.

A split of some specimens may be interpreted as an excystment structure in form of a cryptosuture.

Dimensions (7 specimens): Vesicle diameter 26.6 to 31.7 μm (30 on the average); process length 2.6-6.1 μm (4.7 on the average).

Remarks. The species described here differs from *Multiplicisphaeridium* sp. A in having larger dimensions, more numerous, smaller and shorter processes, especially if compared with the vesicle diameter. Furthermore, the processes of *Multiplicisphaeridium* sp. A are more widely conical.

The specimens referred to *Multiplicisphaeridium* sp. B are similar in shape to *Multiplicisphaeridium*? *canadense* Staplin, Jansonius & Pocock 1965 (pp. 182-183, pl. 18, fig. 7-10; text-fig. 9 - probable Upper Cambrian, Alberta, Canada), from which they differ by their larger dimensions; furthermore, *M. canadense* shows processes which are sometimes polyfurcated into lobate pinnulae, which have not been observed here.

M. alloiteaui (Deunff) Eisenack, Cramer & Diez 1973 (Deunff, 1955a, p. 148, pl. 4, fig. 3 - Middle Devonian, Ontario, Canada) has less numerous, shorter and broader processes. Both *M. rigidum ludlovensis* (Lister) Eisenack, Cramer & Diez 1973 (Lister, 1970a, p. 50, pl. 1, fig. 6, 12-14 - Ludlowian, Ludlow, England) and *M. saharicum* Lister 1970 (1970a, p. 94, pl. 12, fig. 2-4 - Ludlowian, Shropshire, England) have a lower process number.

Occurrence and abundance. Sample 701, rare.

Genus *Retisphaeridium* Staplin, Jansonius & Pocock 1965

Type species: *Retisphaeridium dichamerum* Staplin, Jansonius & Pocock 1965 (by original designation).

***Retisphaeridium dichamerum* Staplin, Jansonius & Pocock 1965**

Pl. 25, fig. 10; Pl. 27, fig. 8

- 1965 *Retisphaeridium dichamerum* Staplin, Jansonius & Pocock, p. 187, pl. 19, fig. 1-7.
 non 1978 *Retisphaeridium dichamerum* - Fombella, pl. 1, fig. 15.
 1979 *Retisphaeridium dichamerum* - Fombella, pl. 1, fig. 11?; pl. 4, fig. 57, (non fig. 58, 59?, 62).
 1982 *Retisphaeridium dichamerum* - Downie, p. 279, pl. 11, fig. o-p.
 ?1983 *Retisphaeridium dichamerum* - Vanguetaine & Van Looy (*partim*), pl. 2, fig. 8 (only).
 1983 *Retisphaeridium dichamerum* - Martin in Martin & Dean, p. 361, pl. 43.2, fig. 4, 9, 13, 14, 20.
 1984 *Retisphaeridium dichamerum* - Martin in Martin & Dean, pl. 57.1, fig. 11, 12, 15.
 non 1985 *Retisphaeridium dichamerum* - Pittau, p. 194, pl. 7, fig. 5.

Dimensions (3 specimens): Vesicle diameter about 30 to more than 40 μm .

Remarks. For the interpretation of this taxon, Martin (in Martin & Dean, 1983, p. 361) is followed herein.

Distribution. Lower Cambrian: Great Britain, Scotland and Wales (Downie, 1982); Norway, Mjosen area (Downie, 1982); Western Canada, Rocky Mountains of Banff National Park, Alberta (Downie, 1982); Ireland, Bray Series (Downie, 1982). Late Lower Cambrian and early Middle Cambrian: Eastern Newfoundland, Manuels River (Martin in Martin & Dean, 1983). Early Middle Cambrian: Western Canada, Southern Alberta (Staplin, Jansonius & Pocock, 1965). Lower Middle Cambrian: ?Morocco, High Atlas Mountains (Vanguetaine & Van Looy, 1983); Eastern Newfoundland, Random Island (Martin in Martin & Dean, 1984). Lower Cambrian to middle Upper Cambrian: British Isles (Downie, 1984). ? Early Middle Cambrian to Upper Cambrian-?Tremadocian (age of the specimens referable to *R. dichamerum* not specified; in any case Tremadocian age questionable: see Vanguetaine & Van Looy, 1983): Spain, Cordillera Cantabrica (Fombella, 1978, 1979).

Occurrence and abundance. Sample 699, very rare.

Retisphaeridium howellii Martin 1983

Pl. 27, fig. 9

- 1968 *Retisphaeridium* n. sp. Slavíková, pl. 2, fig. 8.
 1978 *Retisphaeridium dichamerum* - Fombella, pl. 1, fig. 15.
 1979 *Retisphaeridium dichamerum* - Fombella (*partim*), pl. 4, fig. 62 (only).
 ?1983 *Retisphaeridium dichamerum* - Vanguetaine & Van Looy (*partim*), pl. 2, fig. 9 (only).
 1983 *Retisphaeridium howellii* Martin in Martin & Dean, p. 361, pl. 43.2, fig. 2, 3, 5, 6, 11, 12, 16, 18, 19.
 1984 *Retisphaeridium howellii* - Martin in Martin & Dean, pl. 57.1, fig. 14, 16.

Dimensions (2 specimens): Vesicle diameter about 45 µm.

Remarks. Because of their thin membrane, the specimens of this taxon are commonly deformed by folding and pyritisation or partly broken.

Distribution. Late Lower Cambrian and early Middle Cambrian: Eastern Newfoundland, Manuels River (Martin in Martin & Dean, 1983). Lower Middle Cambrian: ?Morocco, High Atlas Mountains (Vanguetaine & Van Looy, 1983); Eastern Newfoundland, Random Island (Martin in Martin & Dean, 1984). Middle Cambrian: Bohemia, Brdy Mountains (Slavíková, 1968, under the name of *Retisphaeridium* n. sp.). ?Early Middle Cambrian to Upper Cambrian-?Tremadocian (age of the specimens referable to *R. howellii* not specified; in any case Tremadocian age questionable: see Vanguetaine & Van Looy, 1983): Spain, Cordillera Cantabrica (Fombella, 1978, 1979).

Occurrence and abundance. Sample 699, rare.

Genus *Stelliferidium* Deunff, Górká & Rauscher 1974

Type species: *Stelliferidium striatulum* (Vavrdová) Deunff, Górká & Rauscher 1974 (by original designation).

Stelliferidium furcatum (Deunff) Deunff, Górká & Rauscher 1974 emend. Deunff,
Górká & Rauscher 1974

Pl. 36, fig. 5-10; Pl. 37, fig. 1-4

- 1961 *Priscogalea furcata* Deunff, p. 41, pl. 1, fig. 11.
1964 *Baltisphaeridium furcatum* - Deunff, p. 121, pl. 1, fig. 4.
1974 *Stelliferidium furcatum* emend. - Deunff, Górká & Rauscher, p. 14, pl. 7, fig. 14.

Description. Vesicle spherical (if unexcysted) to hemispherical (if excysted), ornamented with numerous (more than 80 visible on polar view), relatively short processes. Processes hollow but not in communication with the vesicle cavity, sometimes simple but more commonly bifurcated into short pinnae which may sometimes bear shorter pinnulae of the first and second order. The processes vary slightly in shape and size on a single specimen.

A star-shaped system of very delicate, faint striae radiates from the base of each process; otherwise, the vesicle wall is smooth and rather thin.

Margin of the polar opening and operculum ornate.

Dimensions (41 specimens). Unexcysted specimens: vesicle diameter 23.2-39.6 μm (average 35.4); internal diameter of the polar opening 11-23.2 μm (average 17.1).

Excysted specimens: vesicle width 34.2-48.8 μm (average 39.9); vesicle height 23.2-33.6 μm (average 28.5); polar opening 25.6-36.6 μm (average 31.1); free operculum 18.3-24.1 μm (average 21.1).

Processes: 2.4-8.5 μm (average 5.1).

Remarks. In the unexcysted specimens (e.g. Pl. 36, fig. 8) the margin of the polar opening rises a little, together with the external margin of the operculum, to form a kind of prominent ring. This structure disappears in the fully excysted specimens, which do not show any distinct collar (e.g. Pl. 36, fig. 7; Pl. 37, fig. 1, 4). Also the diameter of the vesicle and that of the polar opening vary in consequence of the excystment. In fact, the excystment seems to produce a kind of slackening of the whole vesicle. A similar phenomenon has been observed by Rasul in *Cymatiogalea*. But, Rasul (1974, p. 42) suggests that "this may be due to lateral compression resulting in stretching out of the margin of the opening in hemispherical view". The presence, in excysted specimens, of opercula fallen down into the vesicle cavity seems to demonstrate that at least a partial stretching out of the opening occurs during the excystment.

The original description of *S. furcatum* provided by Deunff (1961, p. 41, from the Saharian Tremadocian) is inadequate and apparently based on a single, fully excysted specimen, i.e. the holotype. Thus, the size of this specimen (40 μm) may be compared with the vesicle width of the fully excysted specimens from Öland (average 39.9), but no information is available about the variability of the species. The width of the polar opening

ning (28 μm) provided by Deunff (1961, p. 41; 1964, p. 121) and by Deunff, Górká & Rauscher (1974, p. 14) falls within the variation range measured on fully excysted specimens from Öland (25.6-36.6).

Deunff presented two different evaluations of the process length of *S. furcatum* i.e. 7 μm (1961) and 7-10 μm (1964). A further evaluation (4 μm) was given by Deunff, Górká & Rauscher (1974). The variation range of the processes of the Öland specimens is comparable with the whole range provided by both Deunff (1961, 1964) and Deunff, Górká & Rauscher (1974), but not identical, because shorter processes (2.4 μm) may occasionally occur in the Öland material. Otherwise, the shape of the processes of the specimens described herein seems to be very similar to the shape of the processes depicted by Deunff, Górká & Rauscher (1974, pl. 7, fig. 14).

This latter character and the comparable dimensions justify a definite identification of the material from Öland with *S. furcatum*, although doubts may persist due to the incomplete original description.

S. fimbrium (Rasul) Rasul 1979 (Rasul, 1974, p. 47, pl. 3, fig. 1, 2 - Tremadocian, Shropshire, England) differs from the Öland *S. furcatum* in having thicker and longer processes, distally divided into delicate filamentous threads and in having a granulate vesicle wall.

Distribution. Tremadocian: Sahara (Deunff, 1961, 1964; Deunff, Górká & Rauscher, 1974).

Occurrence and abundance. Sample 701, very common; sample 702, very rare.

***Stelliferidium glabrum* (Martin) Tongiorgi comb. nov., emend.**

Pl. 36, fig. 4; Pl. 37, fig. 5, 6

1973 *Priscogalea* ? *glabra* Martin, p. 22, pl. 4, fig. 8; pl. 5, fig. 17; text-fig. 13.

1985 *Stelliferidium pseudoornatum* Pittau, p. 195, pl. 8, fig. 11, 12; text-fig. 24.

Emended diagnosis. Vesicle spherical or, after excystment, hemispherical with a large polar opening. Processes usually lacking or substituted by simple swellings of the vesicle wall or by low ornaments. Vesicle wall thick, mostly smooth to gently shagrinated. Operculum circular to slightly polygonal. Margin of the operculum constituted by a narrow, thin membrane.

Description. This form is characterized by large size, thick vesicle wall, and by the absence of true processes. The processes are usually lacking or are substituted by low swellings of the vesicle wall; but in some cases they may be represented by a variable number of grana in form of small cones or, more rarely, by larger ornaments as cones, truncated cones, tubercles or verrucae, which vary in shape also on a single specimen. Exceptionally, the cones or the verrucae may distally bear a short spine. The major pro-

cesses, if present, seem to be hollow. If the processes are present, a more or less developed, star-shaped system of very faint striae radiates from their bases.

Sometimes, the unexcysted specimens show a thickened ring around the polar opening, formed by the jointing of the thin peripheral membrane of the operculum together with the margin of the vesicle opening. The slackening of the vesicle in consequence of the excystment (see remarks in *S. furcatum*) produces the disappearance of that structure and an enlargement of the vesicle diameter. For the same reason, the free opercula are usually fully extended and their size is larger than the diameter of the *in situ* measured opercula.

Dimensions (19 specimens): maximal (excysted) vesicle width 32.8-47.6 μm (average 32.79); vesicle height 23.2-35.4 μm (average 26.8); polar opening 25.6-38.8 μm (average 32.79); operculum 14.1-21 μm (average 17.94); max. process length a little more than 1 μm ; max. number of the visible processes (on one side) about 30; distance between processes 4.3-5.5 μm .

Remarks. The Tremadocian *Priscogalea* ? *glabra* Martin 1973 (Montagne Noire, France) has a large polar opening, but no processes or polygonal areas. From Tremadocian beds of Sardinia, Pittau recently (1985) described a new species (*Stelliferidium pseudoornatum*), characterized by processes consisting of small cones. Pittau suggested that *S. pseudoornatum* could be a junior synonym of *Priscogalea* ? *glabra* Martin 1973 "but in the description given by Martin no mention has been made of the presence of conical processes" (Pittau, 1985, p. 196). In the Öland Sample 701 both forms are present and are connected by all the intermediate passages. That supports the suggestion of Pittau and thus the two species are considered herein to be part of one and the same species.

From the populations described by Martin and by Pittau, the Öland specimens differ in having larger average dimensions. But, as observed in other species from Öland, the size difference may be a question of states of preservation.

Stelliferidium modestum (Górka) Deunff, Górka & Rauscher 1974, from the Tremadocian of Poland (Górka, 1967, 1969; Deunff, Górka & Rauscher, 1974), is a similar but different species. It differs from *S. glabrum* in having always more closely spaced and larger tubercles, which represent appreciable processes.

Distribution. Lower Tremadocian: Spain, Celtiberia (Wolf, 1980). Tremadocian: France, Montagne Noire (Martin, 1973); SW Sardinia (Pittau, 1985).

Occurrence and abundance. Sample 701, common.

Stelliferidium simplex (Deunff) Deunff, Górka & Rauscher 1974 emend. Deunff,
Górka & Rauscher 1974

Pl. 37, fig. 7

1961 *Priscogalea simplex* Deunff, p. 41, pl. 1, fig. 9.

1964 *Baltisphaeridium simplex* - Deunff, p. 121, pl. 1, fig. 14, 15.

- 1964 *Baltisphaeridium (Archaeletes) spectatissimus* - (non Naumova) Deunff, pl. 1, fig. 12.
 1967 *Priscogalea simplex* - Vanguetaine, p. 590, pl. 2, fig. 20, 22, 23 (non 21).
 1973 *Priscogalea simplex* - Martin, p. 25, pl. 3, fig. 10.
 1974 *Stelliferidium simplex* emend. - Deunff, Górka & Rauscher, p. 15, pl. 5, fig. 5, 6; pl. 6, fig. 3, 17.
 1974 *Priscogalea simplex* emend. - Rasul, p. 47, pl. 3, fig. 3-6.
 1977 *Stelliferidium simplex* - Baudelot & Bessière, p. 41, fig. 20.
 1985 *Stelliferidium simplex* - Pittau, p. 196, pl. 4, fig. 13; pl. 7, fig. 19; pl. 8, fig. 4, 5; text-fig. 24a.

Description. These specimens possess 50-70 visible processes (estimated total about 70-90 processes) which are relatively short and simple and may occasionally develop very small bifurcate, distal terminations. The length of the processes varies on a single specimen. The vesicle wall is always thick and the star-shaped striae well developed.

Dimensions (13 specimens): Vesicle width 31.1-42.7 μm (average 37.1); vesicle height 20.1-31.1 μm (average 26.29); polar opening 25.6-34.2 μm (average 28.87); operculum 13.4- 20.7 μm (average 17.38); process length 2.7-6 μm (average 3.87).

Remarks. Both the emendation proposed by Deunff, Górka & Rauscher for this taxon (1974, p. 15: especially regarding the presence of star-shaped striae at the base of the processes) and the additional morphographic informations provided by Rasul (1974, pp. 47-48: size range, process variability etc.) are accepted herein.

As stated by Rasul (1974, p. 48), *Stelliferidium simplex* is a species with a wide range of variability. The specimens from Öland are contained within the variation range suggested by Rasul.

Distribution. Uppermost Cambrian or Lower Tremadocian: Belgium, Massif de Stavelot (Vanguetaine, 1967, 1974). Lower Tremadocian: Great Britain, Shineton Shales (Rasul, 1974, 1979; Downie, 1984). Tremadocian: Sahara (Deunff, 1961, 1964); France, Montagne Noire (Martin, 1973); France, Massif de Mouthoumet (Baudelot & Bessière, 1977; Cocchio, 1982); Spain, Eastern Sierra Morena (Wolf, 1980). Tremadocian to ?Lower Arenigian: Sardinia (Pittau, 1985). Tremadocian to Arenigian: Sardinia (Naud & Pittau, 1985). Undefined Lower Ordovician: France, Massif de Mouthoumet (Cocchio, 1982).

Occurrence and abundance. Sample 701, rare; sample 702, questionably present.

Genus *Timofeevia* Vanguetaine 1978

Type species: *Timofeevia lancarae* (Cramer & Diez) Vanguetaine 1978 (by original designation).

Timofeevia lancarae (Cramer & Diez) Vanguetaine 1978

Pl. 28, fig. 7,9; Pl. 29, fig. 1

- 1972 *Multiplicisphaeridium lancarae* Cramer & Diez de Cramer, p. 42, pl. 1, fig. 1-4, 6, 8; text-fig. 1.
 1976 *Multiplicisphaeridium lancarae* - Vavrdová, p. 57, fig. 3.

- 1976 *Baltisphaeridium vilnense* Jankauskas, pp. 188-189, pl. 25, fig. 1-3, 6.
 1978 *Multiplicisphaeridium lancarae* - Fombella, pl. 2, fig. 6, 7.
 1978 *Timofeevia lancarae* - Vanguetaine (1978a), p. 272.
 1979 *Timofeevia lancarae* - Fombella, pl. 5, fig. 70, 71, 73, 76.
 1980 *Multiplicisphaeridium lancarae* - Jankauskas, fig. 1-3, 6.
 1980 *Multiplicisphaeridium lancarae* - Volkova, pl. 1, fig. 1.
 1981 *Timofeevia lancarae* - Erkmen & Bozdogan, p. 55, pl. 1, fig. 20, 21.
 1981 *Timofeevia lancarae* - Martin in Martin & Dean, pp. 20-21, pl. 2, fig. 1-3, 8, 9, 11, 12, 19, 20; pl. 6, fig. 1, 3, 5, 7, 8.
 ?1981 *Timofeevia* aff. *T. lancarae* - Martin in Martin & Dean, pl. 6, fig. 2.
 1983 *Timofeevia lancarae* - Volkova, pl. 1, fig. 12.
 1985 *Timofeevia lancarae* - Albani, Di Milia, Minzoni & Tongiorgi, pl. 1, fig. 12.
 1986 *Timofeevia lancarae* - Welsch, pp. 84-85, pl. 3, fig. 18-20.

Description. Globular vesicle, more or less clearly subdivided in polygonal fields by low ridges or folds connecting the process bases. Processes about 30 in number or less, cylindrical or slightly tapering, hollow and freely communicating with the vesicle cavity. Process tips dichotomously furcated up to the fourth order. Rarely, the last order ramifications are in form of thin filaments linking adjacent processes. Process bases slightly widened with a rather abrupt contact with the vesicle wall. Trunk of processes covered by faint close-spaced ribs which radiate out from the process bases and cover the entire vesicle wall with a more or less evident thin rugulated ornamentation.

Vesicle wall thin. Excystment observed in form of a split along the edges of the polygonal fields.

Dimensions (9 specimens): Vesicle diameter 34.2-45.8 μm (41.29 on average); trunk of processes 11.0-21.4 μm , 16.68 on average (27.3%-49.2% of the vesicle diameter; 40.6% on average); bases of process trunk 2.4-3.7 μm width (2.95 on average); pinnae length about 3-5 μm .

Remarks. *T. lancarae* (Cramer & Diez) Vanguetaine 1978 is a variable species: various populations show particular characteristics and a wide variability has been described within each population (see i.g. Cramer & Diez de Cramer, 1972, text-fig. 1 - upper Middle Cambrian, Spain). The Öland specimens are similar to those from Finnmark, Northern Norway (Welsch, 1986, pp. 84-85, pl. 3, fig. 18-20 - Middle to Upper Cambrian, *Paradoxides forchammeri* to *Agnostus pisiformis* trilobite Zone) in having a small number of processes. The fine ornamentation, radiating out from the process bases, is similar to that described by Martin (in Martin & Dean, 1981, pp. 20-21) from Newfoundland (Middle to Upper Cambrian). Some of the Öland specimens are similar to the Newfoundland material due to the presence of filaments linking adjacent processes. But the spiny process ornamentation described by Martin is lacking on the Öland material.

Considering the variability of the species, it is tentatively proposed here that *Timofeevia* aff. *T. lancarae* Martin 1981 (in Martin & Dean, pl. 6, fig. 2 - Newfoundland, Upper Cambrian, *Agnostus pisiformis* trilobite Zone) is synonym of *T. lancarae* (Cramer & Diez) Vanguetaine 1978, the former being an extreme member with well developed radiating striae, very similar to some Öland specimens.

Distribution. Middle Cambrian: Spain (Cramer & Diez, 1972; Fombella, 1978, 1979); Bohemia (Vavrdová, 1976, 1982b); Eastern European Platform (Jankauskas, 1976: datation to the Lower Cambrian later revised by Jankauskas, 1980); Eastern Newfoundland, Random Island (Martin in Martin & Dean, 1981); SE Turkey (Erkmen & Bozdogan, 1981); Morocco (Vanguetaine & Van Looy, 1983); Great Britain (Downie, 1984); Northern Norway, Finnmark (Welsch, 1984, 1986). Upper Cambrian: Eastern Newfoundland, Random Island (Martin in Martin & Dean, 1981); NW of Eastern European Platform (Volkova, 1980, 1983); Northern Norway, Finnmark (Welsch, 1986). Upper Cambrian - Tremadocian?: Spain (Fombella, 1978, 1979).

Occurrence and abundance. Sample 698, very rare.

Timofeevia pentagonalis (Vanguetaine) Vanguetaine 1978

Pl. 29, fig. 2, 3

- | | |
|------|--|
| 1968 | Cf. <i>Cymatigalea</i> sp. 1 Vanguetaine, p. 364, pl. 1, fig. 6, 7. |
| 1974 | <i>Polyedryxium</i> ? <i>pentagonale</i> Vanguetaine, pp. 75-76, pl. 2, fig. 1. |
| 1978 | <i>Timofeevia pentagonalis</i> - Vanguetaine (1978a), pp. 273-274, pl. 3, fig. 17-21, 23-25. |
| 1981 | <i>Timofeevia pentagonalis</i> - Martin in Martin & Dean, p. 21, pl. 5, fig. 7, 9. |
| 1986 | <i>Timofeevia pentagonalis</i> - Welsch, pp. 86-87, pl. 4, fig. 7, 8. |

Description. These specimens closely correspond to Vanguetaine's original description in having a very simple geometric frame with a small number of polygonal fields (mostly 7) and in having short processes both at the corner and along the edges of the fields.

Dimensions (4 specimens): Vesicle diameter 19.5-23.2 μm ; process length 1.2-9.8 μm .

Remarks. The *Timofeevia pentagonalis* specimens from Öland bear processes having less complex distal divisions than the ones described by Martin (in Martin & Dean, 1981, p. 21 - uppermost Middle Cambrian). The Öland specimens are close to a specimen depicted by Welsch (1986, pl. 4, fig. 8 - Upper Cambrian, *Agnostus pisiformis* trilobite Zone). Under the SEM, the vesicle wall appears to be gently scabrate.

Distribution. Middle Cambrian: France, Montagne Noire (Fournier-Vinas, 1978). Uppermost Middle Cambrian: Belgium, Massif de Stavelot (Vanguetaine, 1968, 1974, 1978a); France, Ardenne (Meillez & Vanguetaine, 1983); Eastern Newfoundland, Random Island (Martin in Martin & Dean, 1981). Uppermost Middle Cambrian to lowermost Upper Cambrian: Eastern Sardinia (Naud & Pittau, 1985). Lowermost Upper Cambrian: Northern Norway, Finnmark (Welsch, 1986). Upper Cambrian: Belgium, Massif de Stavelot (Vanguetaine, 1974, 1978a); Algeria, Grande Kabylie (Baudelot & Gery, 1979); Eastern Newfoundland, Random Island (Martin in Martin & Dean, 1981).

Occurrence and abundance. Sample 698, very rare.

Timofeevia phosphoritica Vanguetaine 1978

Pl. 29, fig. 4-9

- 1968 *Archaeohystrichosphaeridium lanischewsky* - (non Timofeev) Vanguetaine, p. 365, pl. 1, fig. 10-12, (nomen nudum).
- 1978 *Timofeevia phosphoritica* Vanguetaine (1978a), pp. 272-274, pl. 3, fig. 1-8, 10-12; text-fig. 11.
- 1978 *Timofeevia phosphoritica sensu lato* - Vanguetaine (1978a), pl. 3, fig. 9, 13-15.
- 1981 *Timofeevia phosphoritica* - Martin in Martin & Dean, pp. 21-22, pl. 2, fig. 7, 15; pl. 4, fig. 1; pl. 5, fig. 2, 10.
- 1981 *Timofeevia phosphoritica* - Erkmen & Bozdogan, p. 55, pl. 1, fig. 1-3, 6.
- 1983 *Timofeevia phosphoritica* - Volkova, pl. 1, fig. 6, 10.
- 1985 *Timofeevia phosphoritica* - Pittau, p. 198, pl. 4, fig. 17.
- 1985 *Timofeevia phosphoritica* - Albani, Di Milia, Minzoni & Tongiorgi, pl. 1, fig. 13-15.
- 1986 *Timofeevia phosphoritica* - Welsch, p. 87, pl. 4, fig. 1-6.

Dimensions (50 specimens): Vesicle diameter 21.4-29.9 μm (average 24.7); trunk of processes 3.1-9.8 μm (average 7.2); pinnae length 1.6-3.7 μm .

Remarks. The general features of these specimens undoubtedly correspond to the characteristics of this well known, very elegant species first described by Vanguetaine (1978). But the geometrical arrangement of the polygonal fields seems to be more regular than it appears from the previous literature. If the specimens are transparent, it is very difficult to distinguish under the optical microscope field superimposed one upon another; thus, one may get the impression of a great number of polygonal fields of various shapes and sizes. But SEM investigations reveal only a definite, small number of basic field patterns, sometimes complicated by individual minor irregularities.

The Öland *T. phosphoritica* population is characterized by an hexagonal symmetry. The observed basic pattern of the present specimens comprises at each pole an hexagonal, "polar" field, surrounded by six, "subpolar", pentagonal facets. The two opposite "subpolar" rings composed of pentagonal fields may be separated by an additional, "equatorial" ring made by six hexagonal facets, or may be directly superimposed. The first arrangement (with an "equatorial" ring) implies the presence of 20 polygonal fields; the other one corresponds to a 14 fields pattern.

Since the processes of *T. phosphoritica* are almost exclusively located at the field corners, the pattern model can be tested using a simple mathematic relation (Euler's relation) which connects corner, edge and facet numbers both in regular and irregular solid figures:

$$\text{number of corners} = (\text{number of edges} + 2) - \text{number of facets}$$

Thus, a 14 fields pattern corresponds to 24 main processes; a 20 fields pattern to 36 main processes. In the present population, the observed and the calculated process numbers are in adequate accordance, considering that an additional process may be present occasionally in the middle of the edges.

In less regular specimens a few fields may be missing (e.g. a ring of only five pentagonal "subpolar" facets may be present): in this case, the lack of a field is compensated by greater dimensions of other fields and by the presence of little four-sided facets that complete the spatial field arrangement. But in any case, in spite of possible irregularities, the observed specimens still keep, on the whole, the above described hexagonal symmetry.

Under the SEM the vesicle wall is smooth to irregularly rugulate; an extremely fine ornamentation made up of small, scattered grana sometimes appears. Irregular small folds radiate out from some process bases.

Distribution. Middle Cambrian: Belgium, Massif de Stavelot (Vanguetaine, 1968, 1978a); Eastern Newfoundland, Random Island (Martin in Martin & Dean, 1981); SE Turkey (Erkmen & Bozdogan, 1981); NW of Eastern European Platform (Volkova, 1983); Northern Norway, Eastern Finnmark (Welsch, 1984, 1986). Upper Cambrian: Belgium, Massif de Stavelot (Vanguetaine, 1978a); Algeria, Grande Kabilye (Baudelot & Gery, 1979); Great Britain, Isle of Man (Molyneux, 1979); Eastern Newfoundland, Random Island (Martin in Martin & Dean, 1981); Great Britain (Downie, 1984); Northern Norway, Eastern Finnmark (Welsch, 1984, 1986); Central Sardinia (Albani, Di Milia, Minzoni & Tongiorgi, 1985). Undefined Upper Cambrian to Lower Tremadocian: SW Sardinia (Pittau, 1985). Tremadocian (reworked): Great Britain, Shropshire (Rasul & Downie, 1974; probably reworked, according to Downie, 1984); Isle of Man (Molyneux, 1979; reworked, according to Molyneux, 1982); Lake District (Molyneux & Rushton, 1985; possibly reworked: see Molyneux, 1982). Caradocian (reworked): Great Britain, Shropshire (Turner, 1982).

Occurrence and abundance. Sample 698, very common.

Conodonts (G. Bagnoli & S. Stouge)

Many species recorded here are considered satisfactory described and are not discussed further in this section. The recorded species are listed in Tab. 2.

For *Paracordylodus gracilis* Lindström and *Oepikodus evae* (Lindström) we follow the interpretation of van Wamel (1974), for *Scandodus furnishi* Lindström, *Paroistodus numarcuatus* (Lindström), *Paroistodus parallelus* (Pander), *Paroistodus proteus* (Lindström) and *Scolopodus rex* Lindström we follow Lindström (1971).

Generic designation in quotation marks is used to identify multielement associations whose generic assignment is still uncertain.

The illustrated specimens are housed in the Mineralogic Museum Collections of Copenhagen, under numbers MGUH 18159 to MGUH 18224.

Type species: *Prioniodus navis* Lindström, 1955.

Baltoniodus crassulus (Lindström, 1955)

Pl. 38, fig. 1-7

- 1955 *Oepikodus crassulus* Lindström, pp. 570-571, pl. 5, fig. 36, ?37.
 1955 *Gothodus costulatus* Lindström, p. 569 (*partim*), pl. 5, fig. 25 (only).
 ?1955 *Prioniodus acodiformis* Lindström, p. 591m, pl. 5, fig. 42.
 1955 *Oistodus linguatus* Lindström, pp. 577-578 (*partim*), pl. 3, fig. 39, 40 (only).
 1971 *Gothodus costulatus* - Lindström, pp. 54-55 (*partim*), pl. 1, fig. 4,5 (only).
 1974 *Prioniodus crassulus* - van Wamel, pp. 83-85, pl. 6, fig. 7-14.
 1977 *Acodus deltatus deltatus* - Lindström, pp. 7-8 (*partim*), *Acodus* - pl. 2, fig. 8, 9 (only).

Material. 13 Pa elements, 10 Pb elements, 5 Sa elements, 7 Sb elements, 5 Sc elements, 14 Sd elements, 11 M elements.

Repository. MGUH 18159-18165.

Discussion. The elements were recognized by van Wamel (1974) and his reconstruction of the apparatus is confirmed by this material. Seven types of elements forming a complete apparatus typical of *Baltoniodus* i.e. Pa, Pb, Sa, Sb, Sc, Sd, and M are present.

Similar to *Baltoniodus ? deltatus* (Lindström) the Pa element has a strong curved anterior edge (cf. van Wamel, 1974, pl. 6, fig. 8), whereas at the Pb element the edge is more straight. Although broken *Prioniodus acodiformis* Lindström, 1955 may be the Pb element of this species.

Gothodus costulatus Lindström, 1955 (*partim*) is the Sb element. The Sc element was described as the prioniodinaform element by van Wamel (1974). *Oepikodus crassulus* Lindström, 1955 is the Sd element.

Oistodus linguatus Lindström, 1955 (*partim*) is the M element, whereas the holotype for *Oistodus linguatus* Lindström, 1955 could be part of *Baltoniodus ? deltatus*.

The oistodiform elements of *Acodus deltatus deltatus* Lindström, *sensu* Lindström, 1977 are here considered the M elements of *Baltoniodus crassulus* (see also description of the M elements of *Baltoniodus ? deltatus* (Lindström) (in this paper).

Gothodus costulatus Lindström *sensu* Lindström, 1971 is a mixture between an early representative of *Baltoniodus triangularis* (Lindström) and *Baltoniodus crassulus* and only the S and M elements belong to the latter species.

Occurrence. Sample 708.

Baltoniodus ? deltatus (Lindström, 1955)

Pl. 38, fig. 8-14

- 1955 *Acodus deltatus* Lindström, p. 544, pl. 3, fig. 30 (= Pa element).
 1955 *Acodus deltatus altior* Lindström, p. 544, pl. 3, fig. 27-29 (= Sb element).

- 1955 *Distacodus rhombicus* Lindström, p. 556, pl. 3, fig. 35, 36 (= Sd element).
 1955 *Drepanodus latus* Lindström, p. 564, pl. 3, fig. 22, 23 (= Sc element).
 ?1955 *Oistodus linguatus* Lindström, pp. 577-578 (*partim*), pl. 3, fig. 41 (only).
 ?1973 *Acodus deltatus deltatus* - McTavish, pp. 39-40 (*partim*), pl. 1, fig. 2, 3, 8 (only).
 1974 *Prioniodus deltatus* - van Wamel, pp. 85-87 (*partim*), pl. 8, fig. 1, 2, 4, 6, 9 (only).
 1977 *Acodus deltatus deltatus* - Lindström, pp. 7-8 (*partim*), *Acodus* - pl. 2, fig. 10-13 (only).
 non 1981 *Acodus deltatus* - Ethington & Clark pp. 18-19, pl. 1, fig. 1-6; text-fig. 4.
 1985 *Acodus deltatus deltatus* - Löfgren, p. 124, text-fig. 4 Z, AA, AB.

Material. 61 Pa elements, 49 Pb elements, 36 Sb elements, 25 Sc elements, 60 Sd elements and 58 M elements.

Repository. MGUH 18166-18172.

Remarks on the generic assignment. This species is tentatively assigned to the multielement genus *Baltoniodus* Lindström because the apparatus consists of Pa, Pb, M, Sb, Sc, and Sd elements, but a Sa element is not present. Van Wamel (1974) in his reconstruction however included a Sa element in the apparatus, but his reconstruction comprises more than one taxon, and his Sa element is different in morphology from the other S elements of this species. It is worth to note that neither Lindström (1977) nor Löfgren (1985) illustrated or described a Sa element for this species.

The generic assignment is queried because all elements are adenticulate and because the phylogenetical relationships are not clear yet.

Description. Two kinds of P elements can be distinguished. In the Pa element (= *Acodus deltatus* Lindström, 1955) the anterior edge is curved, while in the Pb element it is almost straight.

The M element is the oistodiform depicted by van Wamel (1974) and possibly also the holotype of *Oistodus linguatus* Lindström, 1955 belongs to here. But the other specimens of *Oistodus linguatus* depicted by Lindström, 1955 are allocated to *Baltoniodus crasulus* (Lindström) in this paper. The cusp of the M element is slightly bent sideways, with an inner median carina in most specimens. The cusp is prominent, blade-like, erect to reclined and almost straight. The anterior edge of the unit is slightly curved at the junction between cusp and base. The base is more extended posteriorly than anteriorly and has a prominent inner flare. The upper margin of the base is convex close to the cusp and straight in the distal part. The aboral margin is sinuous.

Remarks. *Acodus deltatus sensu* Ethington & Clark, 1981 is probably a species of *Diaphorodus* Kennedy, 1980.

The denticulated elements depicted by van Wamel (1974) for this species have not been recorded here and probably they belong to another taxon.

Occurrence. Samples 704 and 705.

Genus *Drepanoistodus* Lindström, 1971

Type species: *Oistodus forceps* Lindström, 1955.

Drepanoistodus cf. *D. forceps* (Lindström, 1955)

Pl. 39, fig. 1-3

1985 *Drepanoistodus forceps* - Löfgren, text - fig. 4: AC - AE

Material. 47 oistodiform elements, 71 drepanodiform elements, and 14 erectiform elements.

Repository. MGUH 18177-18179.

Remarks. The oistodiforms differ from *Oistodus forceps* Lindström (1955, pp. 574-576, pl. 4, fig. 9-13, text-fig. 3M) by lacking the inner flare on the base and by having the antero-basal corner less extended and pointed. The other elements can not be distinguished from *Drepanoistodus forceps*. Our material probably represents an early form of *Drepanoistodus forceps*; in fact *Drepanoistodus forceps* appears in stratigraphically higher samples.

Also the oistodiform depicted by Löfgren (1985) differs from *Oistodus forceps* Lindström 1955 similarly to our specimen.

Occurrence. Sample 704.

Genus *Oelandodus* van Wamel, 1974

Type species: *Oistodus elongatus* Lindström, 1955.

Oelandodus* ? *costatus van Wamel, 1974

Pl. 39, fig. 9, 10, 12

?1955 *Oistodus* n. sp. Lindström, p. 581, pl. 3, fig. 26.

1974 *Oelandodus costatus* van Wamel, pp. 72-74, pl. 7, fig. 5-7.

1982 *Oelandodus* cf. *O. costatus* Repetski, p. 29, pl. 10, fig. 8, 10, 12; text-fig. 5 Q-S.

Material. 23 elongatiform elements, 11 triangulariform elements, and 8 oistodiform elements.

Repository. MGUH 18186-18188.

Remarks. The elongatiform (P), triangulariform (S) and oistodiform (M) elements of van Wamel (1974) are present. In addition robust types quite similar to the elongatiform, but with a shorter and more straight anterior extension are present.

The triangulariforms are variable and a few specimens with four costae could belong to this apparatus, and they look similar to *Oistodus* n. sp. Lindström, 1955.

At present the generic assignment is tentative because the elements share characte-

istics of *Protoprioniodus* McTavish, 1973 i.e. having a thickened edge (cf. Ethington & Clark, 1981). Nevertheless, the elements are more robust than those included in *Oelandodus elongatus* (Lindström, 1955) and as noted by Ethington & Clark (1981) may belong to another genus.

Occurrence. Samples 704 and 705.

Genus *Oistodus* Pander, 1856

Type species: *Oistodus lanceolatus* Pander, 1856.

Remarks. *Oistodus* Pander includes hyaline P, M and a series of S elements. The S elements display a symmetry transition series of acostate and costate asymmetrical to symmetrical elements. Additional costae may be present on P and S elements.

Oistodus aff. *O. lanceolatus* Pander, 1856

Pl. 40, fig. 1-4

- 1955 *Oistodus lanceolatus* - Lindström, p. 577, pl. 3, fig. 58-60.
 1955 *Oistodus triangularis* Lindström, p. 581, pl. 4, fig. 14-18.
 1955 *Oistodus delta* Lindström, p. 573, pl. 3, fig. 3-9.
 1971 *Oistodus lanceolatus* - Lindström, p. 38.
 1974 *Oistodus lanceolatus* - van Wamel, p. 75, pl. 1, fig. 15-17.
 1978 *Oistodus lanceolatus* - Fähræus & Nowlan, p. 467, pl. 2, fig. 15, 16.
 1978 *Oistodus lanceolatus* - Löfgren, pp. 63-64, pl. 1, fig. 26-28.

Material. 15 P elements, 11 M elements, 9 Sb elements, 16 Sc elements.

Repository. MGUH 18194-18197.

Description. The P element has a straight, slightly reclined cusp, a short anteriorly extended base and a nearly straight aboral outline of the base. The cusp is laterally compressed with a median well developed inner carina. The upper margin of the base is strongly keeled. The base slightly flares at about midlength where the median inner carina reaches the aboral margin.

P elements have not been recognized or illustrated before from Scandinavia.

The Sb elements are asymmetrical with a lateral outer costa and correspond with *Oistodus triangularis* Lindström, 1955.

Sc element is similar to the Sb element but lacks the prominent lateral costa.

M elements are moderately recurved with a gently convex upper margin of the base. The aboral outline is sinuous to almost straight. The unit is keeled on the cusp and the oral margin, but is otherwise unornamented.

Remarks. The M element of *Oistodus* aff. *O. lanceolatus* Pander differs from *Oistodus lanceolatus* Pander, 1856 (p. 27, pl. 2, fig. 17-19) mainly by the degree of curvature.

The specimens illustrated by Pander are strongly recurved in contrast with our specimens. Also *Oistodus lanceolatus* Pander, *sensu* Lindström, 1955, van Wamel, 1974, Fa-hræus & Nowlan, 1978 and Löfgren, 1978 differs from *Oistodus lanceolatus* Pander, 1856 in their lack of strongly recurved M elements, similarly to our material and therefore have been included here in synonymy with *Oistodus* aff. *O. lanceolatus*.

Van Wamel (1974) noted that some elements of this species consisted of white matter. In our material, several specimens do have a superficial white appearance, but, when moistened, they are translucent with white matter confined to the growth axis only.

Occurrence. Samples 707 and 708.

Genus *Oneotodus* Lindström, 1955

Type species: *Distacodus* ? *simplex* Furnish, 1938.

"*Oneotodus*" *variabilis* Lindström, 1955

Pl. 40, fig. 5, 6

- 1955 *Oneotodus variabilis* Lindström, p. 582, pl. 2, fig. 14-18, 47; pl. 5, fig. 4, 5; text-fig. 6.
 1974 *Drepanoistodus acuminatus* - van Wamel, pp. 62-63 (*partim*), pl. 2, fig. 4-6 (only).

Material. 29 specimens.

Repository. MGUH 18198-18199.

Remarks. According to van Wamel (1974) the apparatus of *Drepanoistodus acuminatus* comprises acodiform, scandodiform and drepanodiform elements (= *Oneotodus variabilis* Lindström), oistodiform elements (= *Oistodus acuminatus* Pander) and sub-erectiform elements (= *Distacodus peracutus* Lindström). Based on the material at hand the apparatus of this species forms a symmetry transition series only (= acodiform, scandodiform and drepanodiform elements of van Wamel, 1974). Oistodiform elements like those depicted by van Wamel (1974) have not been recorded here, whereas *Distacodus peracutus* is considered in this paper the erectiform element of *Paltodus peracutus* (Lindström).

Occurrence. Samples 703 and 704.

Genus *Paltodus* Pander, 1856

Type species: *Paltodus subaequalis* Pander, 1856.

Remarks. Based on our material, the apparatus of *Paltodus* Pander consists of oistodiform, drepanodiform, acodiform and erectiform elements. In this way the apparatus style becomes similar to the apparatus of *Drepanoistodus* Lindström, 1971, but, accor-

ding to Lindström (1977) *Drepanoistodus* and *Paltodus*, aside from morphological differences, evolved differently.

Oistodiforms and drepanodiforms outnumber acodiforms and erectiforms.

Paltodus deltifer (Lindström, 1955)

Pl. 40, fig. 7-12

- 1955 *Oistodus inaequalis* - Lindström, pp. 576-577 (*partim*), pl. 3, fig. 52, 55, 56 (only).
 1955 *Drepanodus deltifer* Lindström, p. 562, pl. 2, fig. 42, 43.
 1971 *Paltodus deltifer* - Lindström, p. 44, text-fig. 7, 8.
 1974 *Drepanoistodus inaequalis* - van Wamel, pp. 65-66 (*partim*), pl. 2, fig. 9, 10 (only).
 1977 *Paltodus deltifer* - Lindström, pp. 421-423 (*partim*), *Paltodus* - pl. 1, fig. 2, 3, 4 (only).
 1985 *Paltodus deltifer* - Löfgren, text-fig. 4, O, P, ?Q.

Material. 8 oistodiform elements, 40 drepanodiform elements, and 2 erectiform elements.

Repository. MGUH 18200-18205.

Remarks. The oistodiform element is characterized by a base extended as far anteriorly as posteriorly, by a deep basal cavity and by the lack of a prominent inner carina (cf. Lindström, 1977).

The drepanodiforms have a high triangular base, deeply excavated by the basal cavity. Some drepanodiforms have the anterior edge flexed on the inner side giving a narrow furrow close to the anterior edge. Costae on drepanodiforms have not been noticed in this material (cf. Lindström, 1977).

The acodiform elements are similar to the drepanodiforms but they have a low outer carina on the base. *Acodus tetrahedron* Lindström, 1955 is not the acodiform element of *Paltodus deltifer*, as suggested by Lindström, 1977. *Acodus tetrahedron* has a blade-like cusp and then does not fit with the slender and rounded cusp of the drepanodiform elements of this species. *Acodus tetrahedron* is instead considered in this paper the acodiform element of *Paltodus peracutus* (Lindström).

The rare erectiform elements share features with *Paltodus peracutus* (Lindström) and with *Paltodus subaequalis* Pander. It has a low keel on the anterior part of the base like in *Paltodus peracutus*, but the aboral edge is convex downwards and sinuous like in *Paltodus subaequalis*.

Occurrence. Samples 703 and 704.

Paltodus peracutus (Lindström, 1955)

Pl. 41, fig. 1-7

- 1955 *Distacodus peracutus* Lindström, pp. 555-556, pl. 3, fig. 1, 2, (*non* text-fig. 5d = *Paltodus subaequalis* Pander).
 1955 *Acodus tetrahedron* Lindström, p. 546, pl. 4, fig. 1, 2.
 1974 *Drepanoistodus acuminatus* - van Wamel, pp. 62-63 (*partim*), pl. 2, fig. 3 (only).
 1974 *Drepanoistodus inaequalis* - van Wamel, pp. 65-66 (*partim*), pl. 2, fig. 7 (only).

1977 *Paltodus deltifer* - Lindström, pp. 421-423 (*partim*), *Paltodus* - pl. 1, fig. 1 (only).

Material. 69 oistodiform elements, 125 drepanodiform elements, and 9 erectiform elements.

Repository. MGUH 18211-18217.

Description. The oistodiform and drepanodiform elements of this species show a wide array of variability. All elements have a blade-like cusp and relatively deep basal cavity. In the oistodiforms the cusp varies from suberect to reclined and can be laterally deflected. A low inner median carina is present on the cusp which is keeled. The base is more extended posteriorly than anteriorly and has a keeled oral edge. The aboral margin is almost straight in lateral view. The basal cavity is deep with a tip reaching the cusp and medially located.

The drepanodiforms vary from subsymmetrical to laterally twisted to asymmetrical. The basal cavity excavates the whole base. The symmetrical drepanodiforms can not easily be distinguished from the Sc elements of *Baltoniodus ? deltatus* (Lindström).

The acodiform element conforms with *Acodus tetrahedron* Lindström, 1955.

Distacodus peracutus Lindström, 1955 is the erectiform element of *Paltodus peracutus*.

Generally the elements are small and fragile.

Remarks. The oistodiform element of *Paltodus deltifer* (Lindström) has a similar basal cavity but in lateral view the base is triangular being extended anteriorly and posteriorly. In *Paltodus peracutus* instead the base of the oistodiform is more extended posteriorly than anteriorly.

Occurrence. Sample 703.

Paltodus subaequalis Pander, 1856

Pl. 40, fig. 13-17

- 1856 *Paltodus subaequalis* Pander, p. 24, pl. 1, fig. 24; text-fig. 4a.
 1856 *Paltodus rotundatus* Pander, p. 25, pl. 1, fig. 33, 34; text-fig. 4c.
 1856 *Paltodus bicostatus* Pander, p. 25, pl. 1, fig. 21; text-fig. 4d.
 1856 *Paltodus truncatus* Pander, p. 25, pl. 1, fig. 18-20; text-fig. 4e.
 1955 *Paltodus inconstans* Lindström, p. 583, pl. 4, fig. 3-8.
 1955 *Oistodus inaequalis* - Lindström, p. 576 (*partim*), pl. 3, fig. 53, 54, 57 (only).
 1955 *Distacodus peracutus* Lindström, pp. 555-556 (*partim*), text-fig. 5d (only).
 1971 *Paltodus inconstans* - Lindström, p. 45, text-fig. 8.
 1974 *Drepanoistodus inconstans* - van Wamel, p. 67 (*partim*), pl. 3, fig. 11-15.
 1977 *Paltodus subaequalis* - Lindström, pp. 427-428, *Paltodus* - pl. 1, fig. 7-9.
 1985 *Paltodus subaequalis* - Löfgren, text-fig. 4: V-Y.

Material. 57 oistodiform elements, 47 drepanodiform elements, 3 acodiform elements, and 6 erectiform elements.

Repository. MGUH 18206-18210.

Remarks. The reconstruction of the apparatus for this species by van Wamel (1974) is confirmed by the material at hand. The erectiform (cf. synonymy in van Wamel (1974) under *Drepanoistodus inconstans*) is identical with the specimen of *Distacodus peracutus* figured by Lindström (1955) in text-fig. 5d, which is quite different from the Lindström's holotype of *Distacodus peracutus* (1955, pl. 3, fig. 1, 2). Lindström (1977) in the Remarks of *Paltodus subaequalis* argued that "van Wamel's reconstruction is open to doubt i.a. because the holotype of *Distacodus peracutus* comes from Tremadocian beds, whereas *P. inconstans/subaequalis* has been found in Arenigian." Nevertheless, the specimen included in synonymy by van Wamel and by us comes from Arenigian beds and not from Tremadocian as the holotype of *Distacodus peracutus*. Elements like the holotype of *Distacodus peracutus* are here considered the erectiforms of the Tremadocian species *Paltodus peracutus* Lindström.

The acodiform elements may be difficult to distinguish from the drepanodiforms due to the presence of costae, but they can be recognized by their triangular cross section of the base.

Occurrence. Sample 704.

Genus *Tropodus* Kennedy, 1980

Type species: *Paltodus comptus* Branson & Mehl, 1933

Remarks. According to Kennedy (1980) the apparatus of *Tropodus* consists of costate and keeled simple cones forming a symmetry transition series. Based on this material and supported by larger collections from the St. George Group, Newfoundland, Canada (Stouge, 1982), P and M elements complete the apparatus.

Hence the original diagnosis of *Tropodus* Kennedy is accordingly emended.

Tropodus comptus (Branson & Mehl, 1933)

Pl. 41, fig. 8-11

- | | |
|------|--|
| 1933 | <i>Paltodus comptus</i> Branson & Mehl, p. 61, pl. 4, fig. 9. |
| 1933 | <i>Scolopodus pseudoquadratus</i> Branson & Mehl, p. 63, pl. 4, fig. 19. |
| 1980 | <i>Tropodus comptus</i> - Kennedy, pp. 65-66, pl. 2, fig. 20-27. |
| 1981 | " <i>Scandodus</i> " sp. 1 s.f. Ethington & Clark, pp. 96-97, pl. 11, fig. 6, 7; text-fig. 22. |
| 1982 | <i>Acodus?</i> sp. cf. <i>A. delicatus</i> - Stouge, p. 33, pl. 4, fig. 1, 2, 5. |

Material. 5 P elements, 2 M elements and 10 S elements.

Repository. MGUH 18218-18221.

Discussion. P element has been described by Ethington & Clark (1981) as "*Scando-*

dus" sp. 1 s.f. and as *Acodus?* sp. cf. *A. delicatus* Branson & Mehl by Stouge (1982, pl. 4, fig. 1, 5).

The M element has been depicted by Stouge (1982, pl. 4, fig. 2).

The S elements have been described by Kennedy 1980 as *Tropodus comptus*.

Occurrence. Samples 704 and 706.

Platform element A

Pl. 41, fig. 14

Material. 1 specimen and 1 fragment.

Repository. MGUH 18224.

Description. The complete specimen is Y shaped and has three processes branching from a main denticle. The processes carry a row of nodes. The unit is completely excavated by the basal cavity. The element is albid.

Remarks. A similar platform-like element was described by Lindström (1955) as *Ambalodus* n. sp. Compared to our specimen, *Ambalodus* n. sp. has a posterior process longer and sinuous. Possibly our element belongs to the same apparatus.

Occurrence. Sample 703.

Platform element B

Pl. 41, fig. 12

1985 *Polonodus?* sp. Löfgren, text-fig. 4: AAC-AAD.

Material. 3 fragments.

Repository. MGUH 18222.

Remarks. Few fragments with a surface ornamentation similar to *Polonodus?* sp. Löfgren have been recorded and may be part of this taxon. Perhaps platform elements A and B are part of the same apparatus.

Occurrence. Sample 704.

Genus et species indet.

Pl. 38, fig. 15-17

Material. 2 P elements and 5 S elements.

Repository. MGUH 18173-18175.

Description. P and S elements have been recorded.

The P element has a laterally compressed cusp which is fairly wide above the base. The relatively small base is expanded on the inner side where two low flares are present. These flares produce a double undulation of the inner basal margin. The outer side is flat.

S elements are asymmetrical and bear variably developed costae. The most asymmetrical elements are strongly twisted. The S elements are close to *Tripodus* Bradshaw, 1969 and probably our specimens belong to this genus.

Occurrence. Samples 704 and 706.

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PLATE 25

- Fig. 1-5 - *Adava denticulata* Tongiorgi sp. nov. Furuhäll, sample 699. 1-4) x 1500; 5) x 4000.
 1) Holotype. S10501-1.
 2) S10501-3.
 3) SEM. S10501-2.
 4) SEM. S10501-4.
 5) Enlargement of processes on right side of fig. 4. SEM.
- Fig. 6-9 - *Cristallinium cambriense* (Slavíková) Vanguetaine 1978. Furuhäll, sample 699. 6, 8, 9) x 1000; 7) x 2000.
 6) S10501-1.
 7) Enlargement of fig. 9 (upper side). SEM.
 8) SEM. S10501-3.
 9) SEM. S10501-3.
- Fig. 10 - *Retisphaeridium dichamerum* Staplin, Jansonius & Pocock 1965. Furuhäll, sample 699. SEM. S10501-4; x 1000.

PLATE 26

- Fig. 1-5 - *Eliasum* cf. *E. llaniscum* Fombella 1977. Furuhäll, sample 699. 1-3, 5) x 1000; 4) x 7500.
- 1) Specimen with weakly microgranulated crest rims. S10501-2.
 - 2) Smooth specimen. SEM. S10501-4.
 - 3) Specimen with thickened crest rims. S10501-1.
 - 4) Particular of a specimen with microgranulated crest rims. SEM. S10501-3.
 - 5) Nearly smooth specimen. S10501-1.
- Fig. 6, 7 - *Adara denticulata* Tongiorgi sp. nov. Furuhäll, sample 699.
- 6) SEM. S10501-3; x 1500.
 - 7) Enlargement of the middle part of fig. 6, showing the membrane stretched between adjacent processes. SEM; x 3000.

PLATE 27

- Fig. 1-5 - *Eliasum* cf. *E. llaniscum* Fombella 1977. Furuhäll, sample 699. 1-4 x 1000; 5) x 3000.
- 1) Smooth specimen. S10501-1.
 - 2) Specimen with smooth crest rims. SEM. S10501-4.
 - 3) Specimen with evident microgranulation of the crest rims. S10501-1.
 - 4) Specimen with thickened crest rims. SEM. S10501-4.
 - 5) Enlargement of lower right side of fig. 4, showing the very finely scabrato - microcorrugated vesicle wall and the thickened, string-like crest border. SEM.
- Fig. 6, 7 - *Multiplicisphaeridium martae* Cramer & Diez 1972. Furuhäll, sample 699; x 1500.
- 6) SEM. S10501-4.
 - 7) SEM. S10501-4.
- Fig. 8 - *Retisphaeridium dichamerum* Staplin, Jansonius & Pocock 1965. Furuhäll, sample 699. SEM. S10501-4; x 1000.
- Fig. 9 - *Retisphaeridium howellii* Martin 1983. Furuhäll, sample 699. SEM. S10501-4; x 1000.

PLATE 28

- Fig. 1, 2 - *Cristallinium cambriense* (Slavíková) Vanguetaine 1978. Furuhäll, sample 699.
- 1) S10501-1; x 1000.
 - 2) Enlargement of a specimen with well developed granulation of the vesicle wall. SEM. S10501-3; x 2000.
- Fig. 3-6 - *Cristallinium aciculatum* Tongiorgi sp. nov. Furuhäll, sample 698. 3-5) x 1000; 6) x 2000.
- 3) Isotype. SEM. S10502-24.
 - 4) Holotype. S10502-5.
 - 5) Isotype. SEM. S10502-26.
 - 6) Enlargement of middle part of fig. 5. SEM.
- Fig. 7-9 - *Timofeevia lancarae* (Cramer & Diez) Vanguetaine 1978. Furuhäll, sample 698. 7) x 1000; 9) x 2000.
- 7) S10502-18.

9) Enlargement of the processes on upper side of fig. 7, showing the faint close-spaced ribs which cover the process trunk.

Fig. 8 - ? *Stelliferidium* sp. Furuhäll, sample 698. SEM. S 10502-26; x 1000

PLATE 29

- Fig. 1 - *Timofeevia lancarae* (Cramer & Diez) Vanguetaine 1978. Furuhäll, sample 698. S10502-14; x 1000.
 Fig. 2, 3 - *Timofeevia pentagonalis* (Vanguetaine) Vanguetaine 1978. Furuhäll, sample 698; x 1000.
 2) SEM. S10502-26.
 3) SEM. S10502-24.
 Fig. 4-9 - *Timofeevia phosphoritica* Vanguetaine 1978. Furuhäll, sample 698. 5-8) x 1000; 4) x 2000; 9) x 3000.
 4) Particular of a specimen with the vesicle wall ornamented by small, scattered grana. SEM. S10502-26.
 5) Specimen with a 20 fields pattern (36 processes); p) polar field. SEM. S10502-24.
 6) Specimen with a 14 fields pattern (24 processes); p) polar field. SEM. S10502-24.
 7) Specimen with still inflated vesicle. S10502-23.
 8) Specimen with collapsed vesicle (deeply concave fields). S10502-2.
 9) Particular of a process. SEM. S10502-27.

PLATE 30

- Fig. 1-9 - *Acanthodiacrodium formosum* Górka 1967. Furuhäll, sample 701. 1, 3-6, 9) x 750; 2, 7, 8) x 3000.
 1) S10503-30.
 2) Particular of the ornamentation of both the processes and the vesicle wall. SEM. S10503-32.
 3) SEM. S10503-32.
 4) S10503-7.
 5) SEM. S10503-32.
 6) S10503-2.
 7) Particular of the ornamented processes. SEM. S10503-46.
 8) Particular of the strong ornamentation of a process. SEM. S10503-33.
 9) SEM. S10503-33.
 Fig. 10 - *Acanthodiacrodium* sp. Furuhäll, sample 701. S10503-4; x 750.
 Fig. 11 - *Acanthodiacrodium ubui* Martin 1978. Furuhäll, sample 701. SEM. S10503-41; x 750.

PLATE 31

- Fig. 1-8 - *Aremoricanium* ? *grootaertii* Martin 1984. Furuhäll, sample 701. 1-6) x 500; 7) x 3000; 8) x 1500.
 1) Lateral view. SEM. S10503-42.
 2) Lateral view: note the transparent polar tube. S10503-21.
 3) Polar view. S10503-3.
 4) Polar view: note the tube near the centre. SEM. S10503-41.
 5) Lateral view. SEM. S10503-35.
 6) Polar view: note the thin anastomosed straps linking the processes. S10503-12.
 7) Note the vesicle wall, ornamented by scattered, stumpy denticles. SEM. S10503-38.
 8) Particular of the anastomosed filaments linking the distal part of the processes. SEM. S10503-41.
 Fig. 9 - *Leiofusa* cf. *L. simplex* (Combaz) Eisenack, Cramer & Diez 1976. Furuhäll, sample 701. S10503-23; x 400.

PLATE 32

- Fig. 1-5 - *Aremoricanium* ? *grootaertii* Martin 1984. Furuhäll, sample 701. 1,3) x 500; 2,4) x 1500; 5) x 2000.
- 1) Lateral view. SEM. S10503-38.
 - 2) Particular of the polar tube of the specimen on fig. 1. Note the unilayered wall of the tube. SEM.
 - 3) Lateral view. Note the transparent tube. S10503-11.
 - 4) Particular of a damaged specimen, with broken polar tube. The internal layer of the vesicle wall is recognizable within the resulting opening. The processes arise from the external layer only. SEM. S10503-46.
 - 5) Particular of the specimen on Pl. 31 fig. 1 (lower side of the specimen on the left here). Filaments linking the processes cover the vesicle with a continuous net. SEM.
- Fig. 6,7 - Acritarch gen. et sp. indet. Furuhäll, sample 701.
- 6) SEM. S10503-38; x 400.
 - 7) Enlargement of the central part of fig. 6 (rotated to the left). SEM; x 1500.

PLATE 33

- Fig. 1-4 - *Athabascaella playfordii* Martin 1984. Furuhäll, sample 701. 1-3) x 500; 4) x 1500.
- 1) SEM. S10503-43.
 - 2) S10503-22.
 - 3) S10503-23.
 - 4) Particular of the processes. SEM. S10503-44.
- Fig. 5 - *Baltisphaeridium* cf. *B. microspinusum* (Eisenack) Downie 1959. Furuhäll, sample 701. SEM. S10503-32; x 750.
- Fig. 6 - *Cymatiogalea cuvillieri* (Deunff) Deunff 1964. Furuhäll, sample 701. S10503-6; x 1000.
- Fig. 7-9 - *Dasydiacrodium tumidum* (Deunff) Tongiorgi comb. nov. Furuhäll, sample 701. 7) x 3000; 8-9) x 400.
- 7) Particular of a specimen showing the button-like ornamentation of both the processes and the vesicle wall. SEM. S10503-45.
 - 8) SEM. S10503-44.
 - 9) SEM. S10503-32.

PLATE 34

- Fig. 1-9 - *Dasydiacrodium tremadocum* (Górka) Tongiorgi comb. nov., emend. Furuhäll, sample 701. Transition from subelliptical to subrectangular forms; x 400.
- 1) S10503-1.
 - 2) S10503-21.
 - 3) S10503-28.
 - 4) S10503-26.
 - 5) S10503-3.
 - 6) S10503-24.
 - 7) S10503-3.
 - 8) S10503-21.
 - 9) S10503-23.

PLATE 35

- Fig. 1-5, 9 - *Dasydiacrodium tremadocum* (Górka) Tongiorgi comb. nov., emend. Furuhäll, sample 701. 1-3, 5) Transition to forms with numerous, long and wavy processes; x 400; 4, 9) x 2000.

- 1) Excysted specimen. S10503-3.
- 2) S10503-23.
- 3) Note the long process with club-shaped termination. S10503-1.
- 4) Particular of the club-shaped termination of a process. SEM. S10503-44.
- 5) SEM. S10503-36.
- 9) Particular of a specimen showing the ornamentation of both the processes and the vesicle wall. SEM. S10503-42.

Fig. 6, 7 - *Dasydiacrodium tumidum* (Deunff) Tongiorgi comb. nov. Furuhäll, sample 701; x 750.

6) S10503-7.

7) S10503-6.

Fig. 8 - *Stelliferidium cortinulum* (Deunff) Deunff, Górká & Rauscher 1974 emend. Deunff, Górká & Rauscher 1974. Furuhäll, sample 701. S10503-2; x 1000.

PLATE 36

Fig. 1 - *Multiplicisphaeridium* sp. B. Furuhäll, sample 701. S10503-2; x 1000.

Fig. 2, 3 - *Multiplicisphaeridium* sp. A. Furuhäll, sample 701; x 1000.

2) SEM. S10503-45.

3) S10503-6.

Fig. 4 - *Stelliferidium glabrum* (Martin) Tongiorgi comb. nov., emend. Furuhäll, sample 701. Unexcysted specimen. S10503-6; x 1000.

Fig. 5-10 - *Stelliferidium furcatum* (Deunff) Deunff, Górká & Rauscher 1974 emend. Deunff, Górká & Rauscher 1974, Furuhäll, sample 701. 5) x 1500; 6-9) x 1000; 10) x 2000.

5) Particular of the processes and of the vesicle wall ornamentation. SEM. S10503-45.

6) SEM. S10503-32.

7) Note the ornamented operculum. SEM. S10503-32.

8) Unexcysted specimen: note the ornamented operculum. SEM. S10503-32.

9) S10503-2.

10) Particular of the processes. SEM. S10503-45.

PLATE 37

Fig. 1-4 - *Stelliferidium furcatum* (Deunff) Deunff, Górká & Rauscher 1974 emend. Deunff, Górká & Rauscher 1974. Furuhäll, sample 701; x 1000.

1) Note the smooth, inner face of the operculum. SEM. S10503-46.

2) SEM. S10503-45.

3) Note the ornamented operculum. S10503-19.

4) SEM. S10503-45.

Fig. 5, 6 - *Stelliferidium glabrum* (Martin) Tongiorgi comb. nov., emend. Excysted specimens. Furuhäll, sample 701; x 1000.

5) SEM. S10503-45.

6) S10503-2.

Fig. 7 - *Stelliferidium simplex* (Deunff) Deunff, Górká & Rauscher 1974 emend. Deunff, Górká & Rauscher 1974. Furuhäll, sample 701. S10503-7; x 1000.

Fig. 8 - *Stelliferidium stelligerum* (Górká) Deunff, Górká & Rauscher 1974. Furuhäll, sample 701. S10503-30; x 1000.

Fig. 9 - *Leiofusa* sp. Furuhäll, sample 701. S10503-2; x 750.

PLATE 38

Fig. 1-7 - *Baltoniodus crassulus* (Lindström). Furuhäll, sample 708.

- 1) Pa element. MGUH 18159; x 60.
- 2) Pb element. MGUH 18160; x 105.
- 3) Sc element. MGUH 18161; x 50.
- 4) Sa element. MGUH 18162; x 60.
- 5) Sd element. MGUH 18163; x 55.
- 6) Sb element. MGUH 18164; x 55.
- 7) M element. MGUH 18165; x 60.

Fig. 8-14 - *Baltoniodus ? deltatus* (Lindström). Furuhäll, sample 704.

- 8) Pa element. MGUH 18166; x 70.
- 9) Pb element. MGUH 18167; x 75.
- 10) Sc element. MGUH 18168; x 90.
- 11) Sb element. MGUH 18169; x 90.
- 12) Sd element. MGUH 18170; x 90.
- 13) M element. MGUH 18171; x 90.
- 14) M element. MGUH 18172; x 90.

Fig. 15-17 - Genus et species indet. Furuhäll, sample 704.

- 15) S element. MGUH 18173; x 55.
- 16) P element. MGUH 18174; x 40.
- 17) S element. MGUH 18175; x 55.

Fig. 18 - *Drepanoistodus deltifer pristinus* (Viira). Furuhäll, sample 704. Reworked specimen. MGUH 18176; x 120.

PLATE 39

Fig. 1-3 - *Drepanoistodus* cf. *D. forceps* (Lindström). Furuhäll, sample 704.

- 1) Erectiform element. MGUH 18177; x 85.
- 2) Drepanodiform element. MGUH 18178; x 65.
- 3) Oistodiform element. MGUH 18179; x 100.

Fig. 4,8,11 - *Oelandodus elongatus* (Lindström). Furuhäll, sample 704.

- 4) Triangulariform element. MGUH 18180; x 70.
- 8) Elongatiform element. MGUH 18181; x 100.
- 11) Oistodiform element. MGUH 18182; x 145.

Fig. 5-7 - *Drepanoistodus forceps* (Lindström). Furuhäll, sample 708.

- 5) Oistodiform element. MGUH 18183; x 55.
- 6) Drepanodiform element. MGUH 18184; x 55.
- 7) Erectiform element. MGUH 18185; x 70.

Fig. 9,10,12 - *Oelandodus ? costatus* van Wamel. Furuhäll, sample 704.

- 9) Oistodiform element. MGUH 18186; x 80.
- 10) Triangulariform element. MGUH 18187; x 80.
- 12) Elongatiform element. MGUH 18188; x 80.

Fig. 13-15 - *Paroistodus numarcuatus* (Lindström). Furuhäll, sample 703.

- 13) Drepanodiform element. MGUH 18189; x 80.
- 14) Drepanodiform element. MGUH 18190; x 50.
- 15) Oistodiform element. MGUH 18191; x 55.

Fig. 16, 17 - *Paroistodus proteus* (Lindström). Furuhäll, sample 704.

- 16) Oistodiform element. MGUH 18192; x 50.
- 17) Drepanodiform element. MGUH 18193; x 50.

Plate 40

Fig. 1-4 - *Oistodus* aff. *O. lanceolatus* Pander. Furuhäll, sample 708.

- 1) M element. MGUH 18194; x 70.
- 2) Sc element. MGUH 18195; x 55.
- 3) P element. MGUH 18196; x 50.
- 4) ?Sb element. MGUH 18197; x 60.

Fig. 5, 6 - "*Oneotodus*" *variabilis* Lindström. Furuhäll.

- 5) Sample 703. MGUH 18198; x 65.
- 6) Sample 704. MGUH 18199; x 70.

Fig. 7-12 - *Paltodus deltifer* (Lindström). Furuhäll, sample 703.

- 7) Oistodiform element. MGUH 18200; x 55.
- 8) Oistodiform element. MGUH 18201; x 75.
- 9) Drepanodiform element. MGUH 18202; x 60.
- 10) Erectiform element. MGUH 18203; x 65.
- 11) Acodiform element. MGUH 18204; x 120.
- 12) Drepanodiform element. MGUH 18205; x 55.

Fig. 13-17 - *Paltodus subaequalis* Pander. Furuhäll, sample 704.

- 13) Acodiform element. MGUH 18206; x 45.
- 14) Erectiform element. MGUH 18207; x 50.
- 15) Oistodiform element. MGUH 18208; x 85.
- 16) Drepanodiform element. MGUH 18209; x 55.
- 17) Drepanodiform element. MGUH 18210; x 40.

Plate 41

Fig. 1-7 - *Paltodus peracutus* (Lindström). Furuhäll, sample 703.

- 1) Oistodiform element. MGUH 18211; x 100.
- 2) Oistodiform element. MGUH 18212; x 100.
- 3) Oistodiform element. MGUH 18213; x 80.
- 4) Drepanodiform element. MGUH 18214; x 80.
- 5) Drepanodiform element. MGUH 18215; x 85.
- 6) Acodiform element. MGUH 18216; x 85.
- 7) Erectiform element. MGUH 18217; x 85.

Fig. 8-11 - *Tropodus comptus* (Branson & Mehl). Furuhäll, sample 704.

- 8) M element. MGUH 18218; x 60.
- 9) Sa element. MGUH 18219; x 90.
- 10) S element. MGUH 18220; x 75.
- 11) P element. MGUH 18221; x 50.

Fig. 12 - Platform element B. Furuhäll, sample 704. MGUH 18222; x 60.

Fig. 13 - Indeterminable specimen. Furuhäll, sample 704. MGUH 18223; x 120.

Fig. 14 - Platform element A. Furuhäll, sample 703. MGUH 18224; x 120.

