NEW RESULTS OF STUDIES ON THE FOSSILS IN THE LOWER CAMBRIAN SEDIMENT DEPOSIT OF THE SÖDERFJÄRDEN BASIN

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Fossils *Mickwitzia monilifera* and olenellid trilobite fragments are found in the greenish grey shale in the lower sediment formation of Söderfjärden at a depth of 237.8 and 278.05 m. Microfossils (acritarchs) *Archaeodiscina umbonulata, Baltisphaeridium cerinium, Granomarginata squamacea, Lophosphaeridium tentativum, Tasmanites bobrowskii, T. piritaensis* were also observed in the lower part of the Söderfjärden sedimentary formation. In this lower intersection the microfossil genera resemble those in the upper sediment formation. Only one new species, *Dictyotidium bottnicum*, is described in the lower portion of the formation.

The occurrence of the fossils and microfossils in the Söderfjärden sediment formation suggest Lower Cambrian sedimentation.
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Introduction

The subject of the description of the sediment deposit of Söderfjärden (Lauren et al. 1978) were the fossils and microfossils found at a depth of 73.6 to 139.55 m in hole No. 3 drilled by Paraisten Kalkki Oy. On the basis of its fossils this portion was interpreted as Lower Cambrian. The most important guide fossils and microfossils on which the dating was based were *Volborthella tenuis* and *Tasmanites*. Since seismic sounding suggested that the sedimentary deposit might be markedly thicker than the portion intersected by the drill hole, the fossils and dates of the underlying deposit have still to be established.

Drilling started again in 1979 under the supervision of Jyrki Lehtovaara. The whole sedimentary sequence close to drill hole No. 3 was intersected at a depth of 74.35 to 318.08. Three sites showing fossil imprints or shell fragments were revealed.

Fossils

The drill core showed the imprint of a worm at a depth of 178 m. At 237.8 m a few shell fragments of *Mickwitzia (monilifera Lns)* and at 278.05 two fragments, probably of trilobite, were observed. Both fossils, the brachiopoda *Mickwitzia* and the trilobite, have an important bearing on the dating and


A
2mm


B
1mm


C
2mm


D
5mm

will be discussed in detail in the present context.

Mickwitzia monilifera Linnarsson has a characteristic surface structure that had allowed Wiman (1903) to identify the species in the fragmentary occurrences collected by G. von Schmalenséer in the Åland islands. The structure typical of *Mickwitzia monilifera* was a fairly dense nodular ruling. The surface of the fragments is occasionally folded perpendicular to the nodular ruling (Wiman op.cit.). The dense nodular ruling shows up clearly in the Söderfjärden occurrence (Fig. 1). Moreover the surface of the fragment exhibits undulatory folding, which is, however, oriented diagonally to the nodular ruling. The sedimentary rock of the occurrence is a greenish grey shale.

Mickwitzia fossils or *Mickwitzia* sandstones are encountered in many places in the Baltic area. They have been reported by Wiman (op.cit.) on the basis of boulders from the following sites in Åland: South Lumparn; Slemmern, east of Marianhamn; Ytternäset, in Marianhamn; and Granboda, in Lemland. In Sweden they have been found in the Närke area (Westergård 1940), Kinnekulla (Holm 1901, Högbom and Ahlström 1924), Biludden (Wiman 1903), and in the drilling at File Haidar in Gotland below the *Mobergella* and *Volborthella* occurrences (5 m) close to the upper portion of the Lower Cambrian deposit (Thorslund and Westergård 1938, Martinsson 1974). In Östergotland *Mickwitzia monilifera* has been identified in local erratics but not in situ (Martinsson op.cit.). In Dalsland it has been reported from a clastic dyke west of Lake Väner (Gavelin 1909). The most important site of comparison for the Söderfjärden *Mickwitzia* occurrence may be Finngrundet, where *Mickwitzia* was encountered in a drill core from Lower Cambrian bed. *Volborthella* also occurs in Finngrundet, at a depth of 82.22 m (Thorslund & Axberg 1979). A similar sequence, *Volborthella* at 119 m and *Mickwitzia* at 237.8 m, has been noted at Söderfjärden.

In Estonia *Mickwitzia monilifera* is associated with *Schmidtiellus mickwitzi* trilobite and *Volborthella tenuis* cephalopod in the Lükati formation (Mens and Pirrus 1977). According to Öpik (1956), the occurrence of *Mickwitzia* is confined to the Lükati formation and the upper portion of the Lontova formation. In southern Lithuania, *Mickwitzia* cf. *monilifera* has been encountered in some cores drilled into the Pirita formations, i.e. in rocks of the final stage of the Lower Cambrian (Korkutis, Lapinskas, Lashkov 1972).

The trilobite fragments found at Söderfjärden in the greenish grey shale at a depth of 278.05 m (Fig. 2 and 3) probably correspond to the olenellid trilobite, i.e. the oldest types in the Baltic area. Fig. 2 bears a marked resemblance to the *Olenellus* sp. fragment, Schalenskulptur von gewöhnlichem Aussehen, reported by Wiman (1903, Pl. 1, Fig. 6). The material described by Wiman derives mainly from the Gävle Bay, although he also has an observation on *Olenellus* sp. from Rosenberg in Åland (Wiman op.cit.). This may, however, be another genus resembling *Olenellus*. The surface structure of the *Olenellus? curvicornis* described by Poulsen (1932) from the Lower Cambrian formation in Ella Island, Greenland, is similar to that encountered in the Söderfjärden occurrence.

The trilobite *Schmidtiellus mickwitzi* (Moberg 1892) and the brachiopod *Mickwitzia monilifera* occur in Västergötland, Närke and Estonia in conglomerates that formed during the Lower Cambrian transgression (Martinsson 1974). In the Mjøsa area, *Schmidtiellus* cf. *mickwitzi* is encountered in the Brenn-

Fig. 1. *Mickwitzia monilifera*, shell fragments from a depth of 237.8 m in shale. Photo Kalevi Hokkanen (A–C) and Erkki Halme (D).

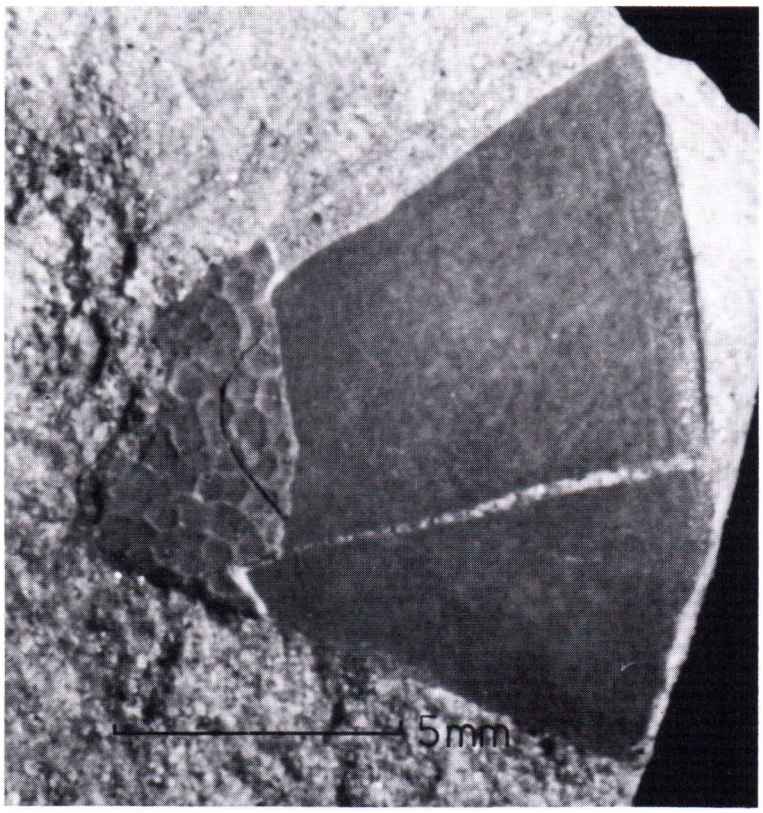


Fig. 2. Fragmentary cephalon of olenellid trilobite from a depth of 278.05 m in shale. A lateral border furrow visible at the right-hand margin. Photo K. Hokkanen.

saeter limestone above the Precambrian (Skjeseth 1963, Martinsson op.cit.). In the Mjøsa area, however, the olenellid trilobite *Callavia* sp. occurs together with *Volborthella tenuis* in the Bråstad shale, which is younger than the Brennsaeter limestone. With its stripes (Fig. 3), the fossil fragment from Söderfjärden resembles the surface structure of the rear of the head of the trilobite *Strenuaeva* sp. (Ahlberg 1979) and also the structures of the pleural areas of some other trilobites (cf. Dean and Martin 1978, p. 33).

Since fossils are sometimes associated with phosphorite nodules, attention was focused on the sedimentary rock of Söderfjärden at a depth of 314.55 m, where there is a layer of a conglomeratic sandstone, less than 10 cm thick, with phosphorite nodules (Figs 4 and 5). The layer is very similar to that described by Thorslund and Axberg (1979) from the Lower Cambrian Västra Banken formation at a depth of 133.26 to 133.35 m. At Söderfjärden the conglomeratic sandstone contains small amounts of glauconite as well. A larger individual phosphorite nodule was detected in the Söderfjärden formation above the olenellid trilobite at a depth of 277 m. These phosphorites are free from fossils. Lehtovaara had earlier found what may be the remnant of a fossil in a phosphorite-bearing polymictic conglomerate in the upper part of the Söderfjärden sedimentary formation (Laurén et al. 1978, p. 25).

Microfossils (acritarchs)

The main objects of our attention are the microfossils in the lower sediment formation of Söderfjärden at a depth of 140.0 to 317.75 m.

Fig. 3. A shell fragment of trilobite from a depth of 278.05 m. Probably a remnant of the same individual as that shown in Fig. 2.

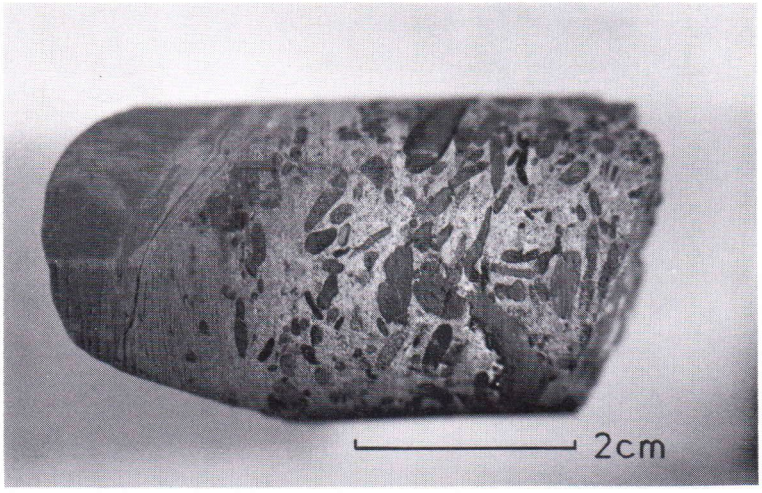


Fig. 4. Conglomeratic sandstone from a depth of 314.55 m.

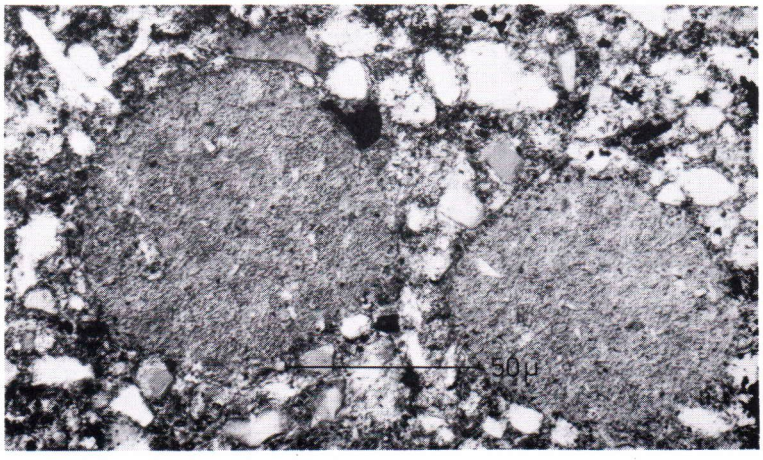


Fig. 5. A detail of conglomeratic sandstone. Small rounded phosphorite nodules in thin section.

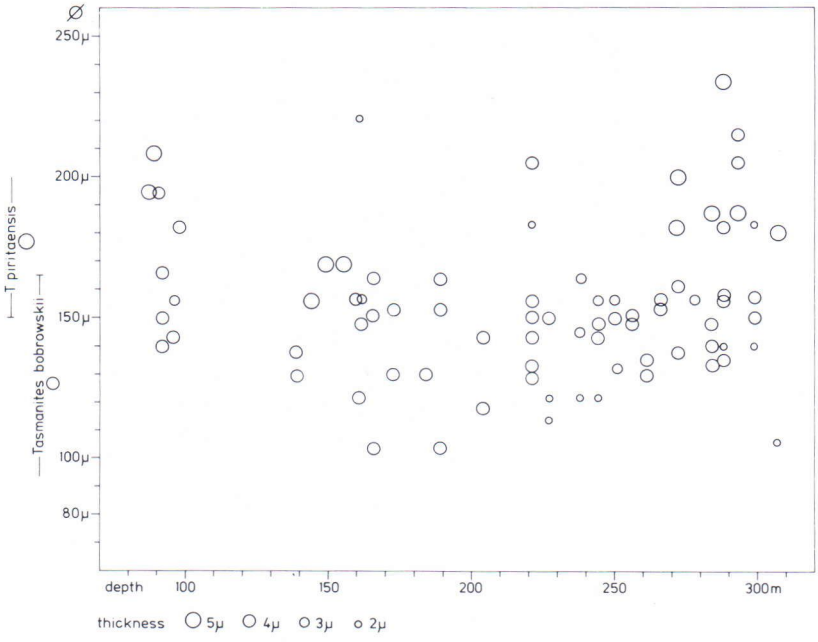


Fig. 6. Diameter and thickness of the shell of the *Tasmanites* from the Söderfjärden sediment formation.

New microfossil analyses were performed on 35 sites at an average interval of 5 m. In this lower intersection the microfossil genera resemble those in the upper sediment formation. The number of genera in the lower formation is, however, smaller than in the upper formation. Thus, the *Cymatiosphaera* genus, whose proportion is almost 40 % at a depth of 129 m, is practically lacking from the sedimentary formation at a depth of 140.0 to 317.75 m.

The genus *Granomarginata* is very rare in the lower portion. Tasmanites *bobrowskii* (Wazynska 1967) and *piritaensis* (Posti et Jankauskas, 1976) are very common at depths of 89.2 and 92.3 m (about 36 %). Deeper down their proportion is low. Nevertheless, species *T. bobrowskii* in particular occurs at a depth of 139.5 to 261.1 m almost uninterruptedly, whereas the *piritaensis* type with a thicker shell is lacking from the greatest part of the deposit: it has been recorded at depths of 150, 272.2 and 307.05 m. Fig. 6 shows the most important parameters of the *Tasmanites* in the Söderfjärden sedimentary formation, i.e. the diameter and the thickness of the shell in graphic presentation. The third important quantity, the spacing between the pores, is 3 to 5 µ for the majority of the species. As shown by the figure, most of the occurrences of *Tasmanites bobrowskii* fall within the size range of 90 to 160 µ (the upper limit 130 µ, which I reported previously, should read 160 µ, Tynni 1978).

Table 1 lists the acritarch genera in the middle and lower portions of the Söderfjärden sediment formation and whose existence has been confirmed by checking. The fairly large *Dictyotidium* species is the most important new species found in the lower portion of the formation.

Dictyotidium bottnicum n. sp. (Figs. 7 A–G, 8 G)

A spherical or oval vesicle, 70 to 112 µ in diameter. The surface structure consists of slightly elevated polygonal ridges. The polygons vary in shape from trigonal to polygonal. They also vary in size. The pattern may be absent from the central parts in some individuals. They are sepia in colour, the smaller

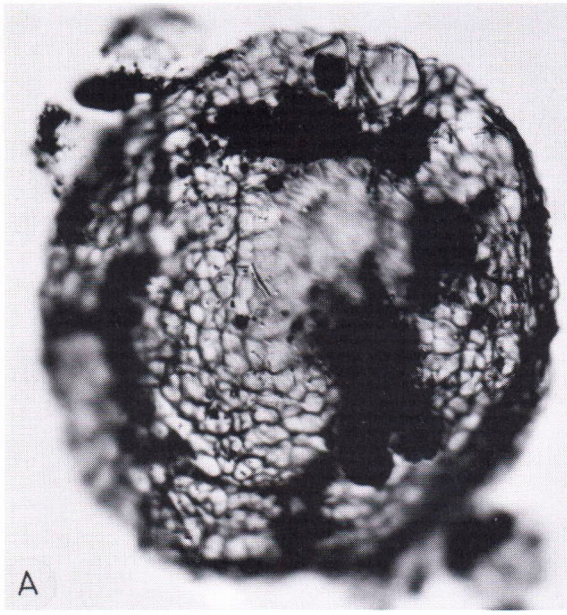
Table 1. Acritarch occurrences in the middle and lower parts of the Söderfjärden sediment formation.

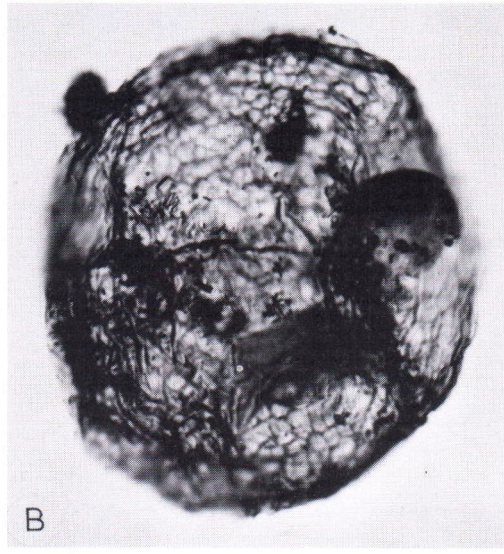
quality of acritarchs: weak – satisfactory o good oo	*depth:*	threads	T. sp.	T. variabilis/Trachysphaeridium sp.	T. tenellus	T. piritaensis	Tasmanites bobrowskii	Micrhystridium sp.	L. sp.	Lophosphaeridium tentativum	Leiosphaeridia sp.	Leiomarginata simplex	G. sp.	Granomarginata squamacea	Dictyotidium bottnicum	Cymatiosphaera sp.	B. sp.	Baltisphaeridium cerinium	A. sp.	Archaeodiscina umbonulata
o	139.5			x			x				X	x				x	x			x
–	144.5			x							x									
o	149.9	x		x		x	x		x		X									x
o	155.4	x		x		x			x	x	X									x
oo	160.6			x	x		x		x		X	x	x							
o	166.0			x			x	x	x		X									x
–	168.2																			
oo	173.6	x		x			x				X						x	x		x
–	178.0																			
o	184.1			x			x		x	x	X						x			
o	189.6			x			x				X									
–	195.3																			
o	199.4								x		X						x			x
o	204.35	x		x			x		x		X						x			x
–	210.2								x		x						x			
–	216.0			x			x		x		X									
oo	221.6			x			x		x	x	X			x						x
–	226.9						x				x									
–	232.0																			
o	234.0			x		x	x			x	x	x	x	x				x		
oo	237.8						x				X	x					x			
o	244.6			x			x		x		X						x			
o	250.2						x		x		X	x								
–	255.6						X				x									
oo	261.1			x			x		x	x	X		x		x		x	x	x	
–	266.4			x			x				X									
o	272.3					x	x		x		X	x				x	x			
o	278.0						x		x		X	x								x
–	284.1					x	x				x									
–	287.8		x				x													
o	293.3		x			x	x		x		X									
oo	299.05						x		x		X				x			x		
o	307.05	x				x					x									
o	312.4								x		X									
–	317.75																			

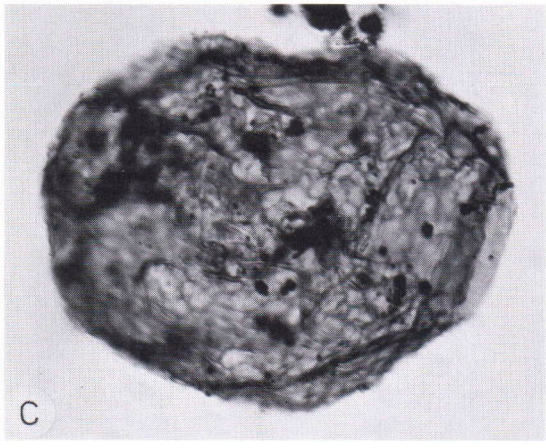
x = present, X = dominant

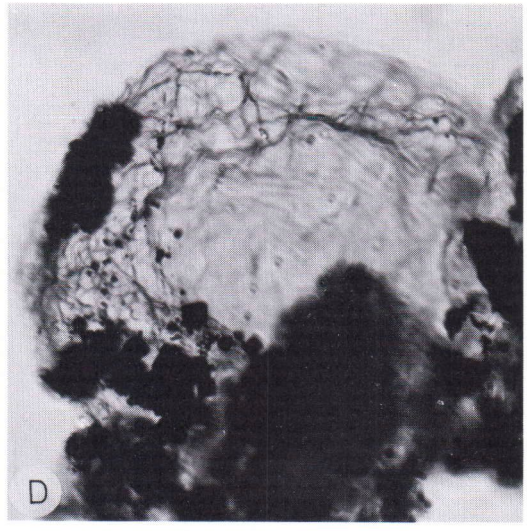
individuals being darker than the larger ones. The large individuals are occasionally raptured.

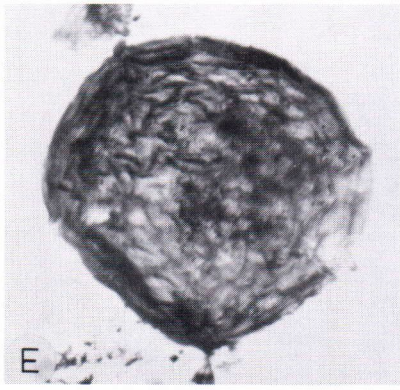
D. bottnicum has been encountered in about ten occurrences at depths of 261.1 and 299.05 m.


A


B
50µ


C


D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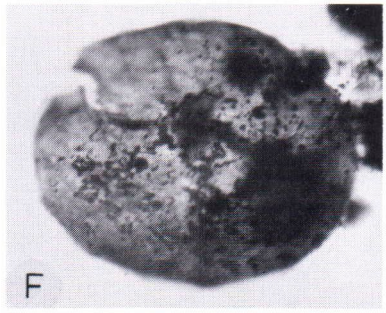
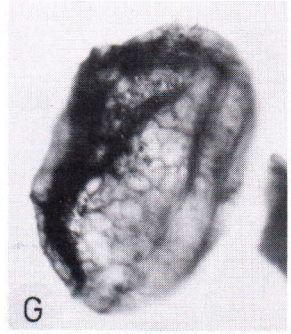

F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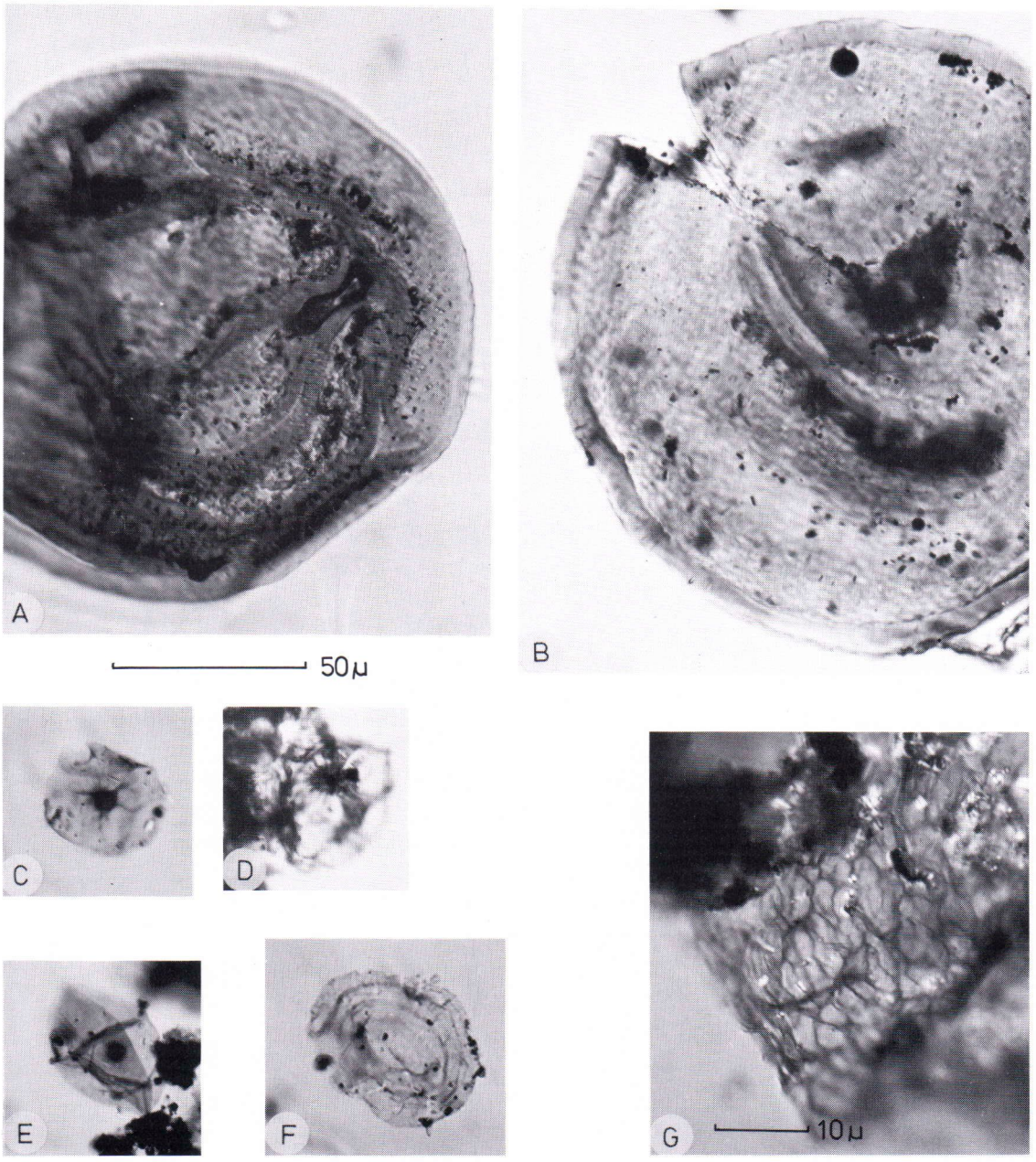

Fig. 8. A. *Tasmanites bobrowskii*, B. *T. piritaensis*, C, D. *Archaeodiscina umbonulata*, E. *A. sp.*, F. acritarch type at a depth of 299.05 m., G. detail of *Dictyotidium bottnicum*.

Fig. 7. *Dictyotidium bottnicum* n. sp.

H o l o t y p e: Fig. 7A, Geological Survey of Finland slide No. 315, Söderfjärden drilling, depth 299.05 m, Lower Cambrian formation.

R e m a r k s: *Dictyotidium* genus of the acritarchs was described by Eisenack in 1955 from the Silurian deposits in the Baltic area. The *Stictosphaeridium brayense* described from the Irish Cambrian (Gardiner & Vanguestaine 1971) corresponds to the type characterised by a similar polygonal surface pattern. It is, however, smaller and has a larger mesh than the species at Söderfjärden. Vidal (1981) has founded the species *Dictyotidium birvetense* Paškev. from Hardgeberg (Holmia A) and the Gislöv formation in Sweden. In the area of the East European Platform the species has been found in the Lontova formation (Volkova et al. 1979, Korkutis 1981). Another Lower Cambrian *Dictyotidium* species, *priscum* Kir. et Vol., has also been encountered in the East European Platform (Volkova et al. 1979) and in Denmark in the Holmia A deposit of Grønne Skifre (Vidal 1981).

Archaeodiscina sp. (Fig. 8 E)

A dark spot on the sphere distinguishes the species from the *Leiospaeridia* genus. The form also resembles the *Archaeodiscina umbonulata* Volk. but the radial ridges around the spot are lacking. The diameter is about 30 μ. Cf. *Nucellosphaeridium* Timofeev 1966. Very rare at a depth of 261.1 m.

A platy and rounded acritarch type with a concentric ridge pattern was detected at a depth of 299.05 m. Only one individual was encountered (Fig. 8 F).

Comparison of the results with some acritarch types reported from the Lower Cambrian deposits in the Baltic and Scandinavia

The biostratigraphic division, which was developed from the results of recent acritarch studies on the Baltic and Scandinavian Lower Cambrian deposits and from fossil comparisons, is applied in the following to date tentatively the Söderfjärden deposit. The stratigraphic distribution of the Lower Cambrian acritarchs in the East European platform and Scandinavia proposed by Vidal (1981a, b) is based on results by Volkova et al. (1979) from the East European Platform and on those applied to Scandinavia from the studies by Vidal. The acritarch table given by Vidal shows that the Lükati formation has the highest number of species in common with the Söderfjärden deposit. The species significant for dating are *Archaeodiscina umbonulata, Baltisphaeridium cerinium* and *Lophosphaeridium tentativum.* The presence of the former in the lower part of the Söderfjärden deposit is indisputable down to a depth of 278.05 m. Besides in the East European Platform, the species has been encountered in the Norretorp sandstone in Skåne, which also contains *Schmidtiellus mickwitzi* (Holmia A), in *Mickwitzia* sandstone in Västergötland (Holmia A-B) and in the *Lingulid* sandstone (Holmia B).

Baltisphaeridium cerinium Volk. has also been encountered at various sites in Scandinavia and more often in the Holmia A than the Holmia B horizon (Vidal 1981 b, op cit.). Like *Tasmanites bobrowskii,* it occurs in *Mickwitzia* sandstone.

Paleontologic dating of the sedimentary rock of Söderfjärden

The fossils and microfossils suggest that the sedimentary formation at Söderfjärden, 243.73 m thick, deposited in the Lower Cambrian during a rather short period. *Volborthella tenuis* at a depth of 119 m, *Mickwitzia monilifera* at 237.8 m and the trilobite of the olenellid group at 278.05 m are known from the Holmia A stages, which correspond to the Lükati formation. Small changes in the

acritarchs of the thick sedimentary deposit corroborate the concept that the sedimentation took place during the Lükati stage alone.

Guide fossils typical of the Lontova stage preceding the Lükati were not found among the microfossils of Söderfjärden. In the Eastern Europe platform the following acritarchs are confined to the Lontova formations: *Ceratophyton vernicosum* Kir. and *Dictyotidium birvetense* Paškev. (Volkova et al. 1979, Vidal 1981). The deposit of Lower Cambrian shale at Finngrundet, which also contains fossils of *Volborthella tenuis* and *Mickwitzia monilifera* (Thorslund and Axberg 1979), bears the closest resemblance to the Söderfjärden deposit. Acritarch studies demonstrate that the majority of the dyke fillings in the sandstones in Åland were formed in the Lower Cambrian, and that at least some of the Lower Cambrian dykes in Åland are contemporaneous with the Söderfjärden shale (Bergman, Tynni and Winterhalter 1982). Common acritarch species include *Archaeodiscina umbonulata*, (Fig. 8 C D) *Baltisphaeridium* type, *Cymatiosphaera solfensis*, *Lophosphaeridium* sp. and *Tasmanites bobrowskii* (Fig. 8 A).

The Lower Cambrian sediments discovered in the Northern Baltic were deposited during the Lower Cambrian transgression, which probably culminated during the Lükati stage. It corresponds to the transgression of *Volborthella tenuis* time (Öpik 1956, Martinsson 1974).

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