

# Palynomorphs from the *Cyrtograptus centrifugus* graptolite zone (Early Wenlock, Silurian), Bornholm

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Palynomorph assemblages recovered from the *Cyrtograptus centrifugus* graptolite zone on Bornholm contain moderately diverse acritarchs and prasinophycean algae, and minor chitinozoans and miospores. The generally poor preservation is due mainly to a high thermal alteration of the sediments. The identified Early Wenlock (Sheinwoodian) palynomorph assemblages are closely related to those described from contemporaneous deposits elsewhere in northwest Europe and U.S.S.R., and they are characterized by common representatives of the genera *Leiosphaeridia*, *Diexallophasis*, *Oppilatala*, *Saliopidium* and *Michystridium*. The palynomorph assemblages herein described are similar to the marine floras from the open marine deep water deposits of the Wenlock carbonate shelf of the Welsh Borderland and Midlands of England as described by Dorning and Bell (1987) (the *Saliopidium granuliferum* Assemblage). The presence of *Domasia elongata* and *Domasia trispinosa*, together with *?Deunffia* sp. confirm that the Early Wenlock deposits on Bornholm are coeval with the *Deunffia* - *Domasia* facies proper as defined by Cramer (1970, 1971, 1971a).

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## Introduction

The Silurian strata on Bornholm crop out in faulted terrain and are only exposed along the Løså and Øleå rivulets in the southern part of the island (Figure 1).

The oldest Silurian succession comprises a 135 m thick unit of transgressive dark-grey mudstone of Llandovery age, which has come to be called the "Rastrites"-shale. These beds are conformably overlain by 25 m- thick unit of dark grey mudstone of earliest Wenlock age, i.e. the "*Cyrtograptus*-shale". The late Wenlock strata, which represents the youngest Silurian deposits on Bornholm, was probably deposited in a deeper basin than the Llandovery sediments (Gravesen and Bjerreskov, 1984).

A review of the Paleozoic strata on Bornholm has been published by Poulsen (1966), and the stratigraphy of the Llandovery Series at Øleå has been reviewed by Bjerreskov (1971). Bjerreskov (1975) gave a complete review of the Silurian, including information from the Bavnegård well. In this important contribution Bjerreskov described the graptolite faunas from both the Llandovery and Wenlock Series and further presented

a detailed biostratigraphic zonation. The present study was initiated to investigate the palynological potential of these well-dated Silurian deposits.

## Palynomorph assemblages and thermal alteration

A total of twenty-nine samples from both Llandovery and Wenlock deposits were prepared and examined for organic-walled microfossils. Unfortunately, the sediments have been subjected to significant degrees of thermal alterations, and most samples yielded only poorly preserved specimens. The acritarchs are generally greyish and black (grading to dark brown) in colour, and frequently crushed and corroded. According to the Thermal Alteration Index of Staplin (1969, 1977), these sediments have been heated to above 150°C, as the estimated TAI values fall between  $\pm 3.7$  and  $\pm 4.0$ . Data from studies of the Cambrian Alum Shale on Bornholm indicate a thermal maturation corresponding to vitrinite reflectance values around 2% Ro (Buchardt & Nielsen, 1985), and a corresponding conclusion

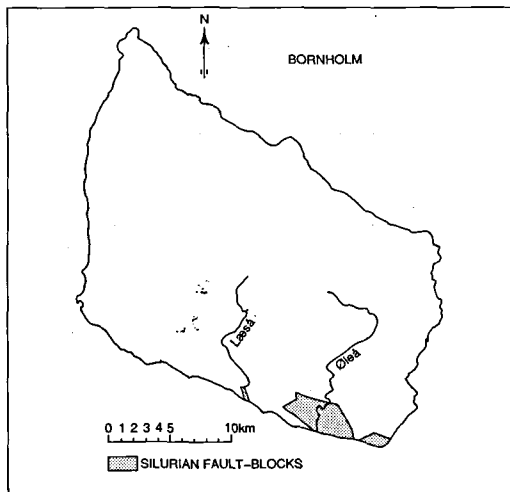


Fig. 1. Sketch-map showing the location of the rivulets Læså and Øleå on Bornholm and the position of the Silurian fault blocks. (From Bjerreskov 1975).

can be reached from the conodont color alteration index of approximately 5. Although, extensive magmatic activity is known to have taken place during the Carboniferous and Permian periods in Scania north of Bornholm (Klingspor 1976) and in the Oslo Region (Larsen et al. 1981), Buchardt and Nielsen (1985) argued that the high thermal alteration of the Lower Paleozoic succession is due to geothermal impact from deep burial rather than from magmatic heating. They further suggested that the major burial event leading to the thermal diagenesis of the Lower Paleozoic rocks on Bornholm is related to the later phases of the Caledonian orogeny.

The only identifiable assemblages we recovered in our material were found in samples from the deposits representing the *Cyrograptus centrifugus* graptolite zone. These were collected from an exposure near the outlet of Øleå, about 200 m north of Slusegård (Figure 2). A total of 23 acritarchs species, 4 species of prasinophycean algae, 2 chitinozoan species and 2 taxa of miospores/sporelike microfossils were identified (see species list below):

#### Acritarchs:

*Ammonidium* cf. *A. ludlovensis* (Lister) Dorning 1981.

- Ammonidium microcladum* (Downie) Lister 1970.  
 ?*Deunffia* sp.  
*Diexallophasis denticulata* (Stockmans et Wil-lière) Loeblich 1970.  
*Diexallophasis* cf. *sanpetrensis* (Cramer) Dorning 1981.  
*Diexallophasis simplex* Wicander et Wood 1981.  
*Domasia elongata* Downie 1960.  
*Domasia trispinosa* Downie 1960.  
*Eupoikilofusa* sp. I  
*Leiofusa tumida* Downie 1959.  
*Lophosphaeridium papillatum* (Staplin) Downie 1963.  
*Micrhystridium stellatum* group Deflandre 1945.  
*Micrhystridium uncinatum* (Downie) Martin 1965.  
*Multiplicisphaeridium arbusculum* Dorning 1981.  
*Multiplicisphaeridium cladum* Downie 1963.  
*Oppilatala ramusculosa* (Deflandre) Dorning 1981.  
*Rhacobrachion mala* (Cramer) Dorning 1981.  
*Salopidium granuliferum* (Downie) Dorning 1981.  
*Schismatosphaeridium* sp.  
*Tunisphaeridium tentaculiferum* (Martin) Cramer 1970.  
*Veryhachium trispinosum* group (Eisenack) Deunff ex Downie 1959.  
*Visbysphaera dilatispinosa* (Downie) Lister 1970.

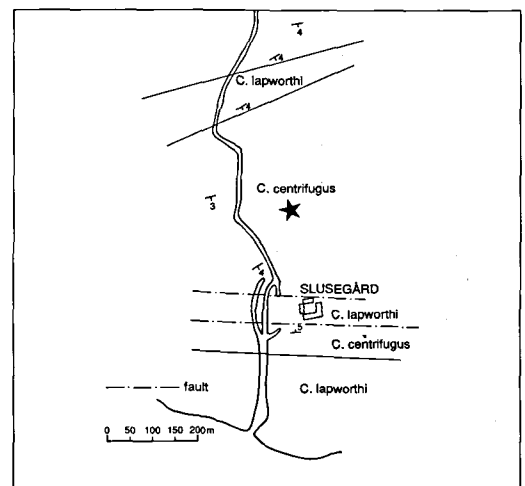


Fig. 2. Map of the outcropping Silurian strata at the rivulet Øleå near the farm Slusegård (After Bjerreskov 1975). The location of the present studied samples is marked by\*.

Fig. 3. Comparisons of the palynomorph assemblages found in the earliest Wenlock on Bornholm and assemblages reported from contemporaneous deposits on Gotland and Ringerike and in England, Belgium, U.S.S.R. and Austria. Data from: 1) Cramer et al. 1979, Gray et al. 1974, Laufeld 1974; 2) Smelror 1987, 1987a, unpubl.; 3) Dorning 1981, 1981a, 1981b, 1982, 1983; Dorning & Bell 1987, Downie 1959, 1963, 1984; Hill 1974; Mabillard & Aldridge 1985; Barron 1989; 4) Martin 1968, 1974; Verniers 1981; 5) Sheshegova 1975; Kirjanov 1978; 6) Priewalder 1987.

	1 Gotland Sweden	2 Ringerike Norway	3 Div. Loc. England	4 Div. Loc. Belgium	5 Div. Loc. U.S.S.R.	6 Karnische alpen Austria
Ammonidium microcladum	x	x	x		x	x
Diexallophasis denticulata	x	x	x	x	x	x
Diexallophasis simplex	x	x	x	x	x	x
Deunffia spp.	x		x	x	x	x
Domasia elongata	x	x	x	x	x	
Domasia trispinosa	x	x	x	x	x	x
Leiofusa tumida	x	x	x	x	x	x
Lophosphaeridium papillatum		x	x	x	x	x
Michhystridium stellatum	x		x	x		x
Michhystridium uncinatum			x	x		
Multiplicisphaeridium arbusculum	x		x	x		
Multiplicisphaeridium cladum			x			?
Oppilatata ramusculosa	x	x	x	x	x	x
Rhacobranthion mala			x	x		
Salopidium granuliferum		x	x	x	x	x
Tunisphaeridium tentaculiferum	x	x	x	x	x	x
Veryhachium trispinosum	x	x	x	x	x	x
Visbysphaera dilatispinosa	x	x	x	x	x	
Visbysphaera oligofurcata	x	x	x	x	x	?
Cymatiosphaera octoplana	x	x	x	x	x	
Leiosphaeridia granulata		x	x	x		
Leiosphaeridia laevigata		x	x	x	x	
Leiosphaeridia wenlockia		x	x	x	x	
Ancyrochitina ancyrea	x	x	x	x		
Ancyrochitina primitiva	x	x	x	x		
Ambitiosporites spp.	x	x	x			
Nodospora/Tetrahedraletes spp.	x	x	x			
No. of taxa in common:	19	21	27	22	17	12(?14)

*Visbysphaera oligofurcata* (Eisenack) Lister 1970.

### Prasinophycean algae:

*Cymatiosphaera octoplana* Downie 1959.

*Leiosphaeridia granulata* Eisenack 1938.

*Leiosphaeridia laevigata* Stockmans & Willière 1963.

*Leiosphaeridia wenlockia* Downie 1959.

### Chitinozoans:

*Ancyrochitina ancyrea* Eisenack 1955.

*Ancyrochitina primitiva* Eisenack 1964.

### Miospores/spore-like microfossils:

*Tetrahedraletes medinensis* Strother & Traverse 1979.

*Nodospora* sp.

With few exceptions, the recovered species occur in low numbers or are present only in one or a few samples. The most common species are: *Oppilatata ramusculosa*, *Salopidium granuliferum* and representatives of the genera *Diexallophasis*, *Michhystridium* and *Leiosphaeridia*.

Although abundant in two samples from the middle of the *C. centrifugus* Zone, *Eupoikiofusa* sp. I was not observed in the samples from the lowermost and uppermost metres of the *C. centrifugus* Zone. Chitinozoans, i.e. *Ancyrochitina ancyrea* and *A. primitiva* were only found in the upper part of the *C. centrifugus* Zone, while the

EPOCH	AGE		GRAPTOLITE ZONES	ACRITARCH ZONES	MIOSPORE ZONES
Wenlock	Homerian	Gleedon	Monograptus ludensis	Eisenackidium wenlockensis	"E."cf. protophanus – cf. s. verrucatus ?
			Gothograptus nassa	Cymatiosphaera pavimenta	
		Whitwell	Cyrtograptus lundgreni		
	Sheinwoodian	Cyrtograptus ellesae			
		Cyrtograptus linnarsoni			
		Cyrtograptus rigidus			
		Monograptus riccartonensis	Deunffia brevispinosa		
		Cyrtograptus munchisoni	Deunffia brevispinosa		
			Cyrtograptus centrifugus		
Llandovery (pars.)	Telychian	Monoclimacis crenulata	Deunffia monospinosa	?	
		Monoclimacis griestoniensis			
		Monograptus crispus		A. avitus – A. dilutus (pars.)	

Fig. 4. Correlation of the acritarchs zones defined in the Llandovery (pars.) and Wenlock Epoch in Shropshire (Dorning & Bell, 1987), the miospore zonation of the old Red Sandstone continent (Richardson & McGregor, 1986) and the standard graptolite zonation.

miospore *Ambitosporites* sp. and the spore-like palynomorph *Tetraedraletes medinensis* were restricted to the lowermost sample within the zone.

### Regional comparisons and paleoecological aspects

A comparison of the palynomorph assemblages found in the earliest Wenlock on Bornholm and assemblages reported from contemporaneous deposits on Gotland (Sweden), Ringerike (Norway), England, Belgium, U.S.S.R. and Austria is presented in Figure 3. All acritarchs and prasinophycean algae species (excluding those left under open nomenclature) found on Bornholm have been described from Britain. A somewhat lower number of the palynomorph taxa from Bornholm are also reported from Gotland and the Oslo Region, while only 12 (– 14) species are common to both Bornholm and the Karnisch Alps (Austria). This latter disparity may be a result of the more comprehensive data available on Silurian palynomorphs from Britain as compared to Austria.

However, provincialism of early-middle Silurian acritarchs has been well documented by Cramer (1970, 1971, 1971a), Cramer and Diez de Cramer (1972) and Cramer and Diez (1974). These authors recognized distinctive acritarchs facies, with boundaries parallel to the Silurian paleolatitudes. The regions listed in Figure 3 fall within the *Deunffia*-facies, which can be identified by the presence of common *Deunffia*. The

*Deunffia*-facies generally includes a few "baltisphaerids" of the *Hoegkintia digitata* – *H. corallina* group as well as moderately common *Domasia* spp. (Cramer 1970). The Early Wenlock acritarch assemblages described from Gotland yielded among others *Deunffia furcata*, *D. ramusculosa*, *D. monospinosa*, *Domasia rochesterensis*, *D. amphora*, *D. elongata* and *D. trispinosa* (Cramer et al., 1979), and the poor recovery of *Deunffia* and *Domasia* in the contemporaneous Bornholm samples can probably be explained by the poor preservation of the assemblages. The representatives of both *Deunffia* and *Domasia* are small and delicate forms and are likely to have a poorer preservation potential than most larger and more thickwalled species.

The biostratigraphic distribution of acritarch in the British Silurian has been outlined in several papers, the most important ones concerning the Early Wenlock being those of Dorning (1981), Downie (1984), Mabillard and Aldridge (1985) and Dorning and Bell (1987). The acritarch zones defined within the Wenlock Series in Shropshire (England) by Dorning and Bell (1987) are shown in Figure 4. The zones were not directly coeval with the standard graptolite zones, but the oldest Wenlock acritarch zones were defined from the Builderas Formation, which is known to span the *C. centrifugus*, *C. munchisoni* and the lowermost *M. riccartonensis* graptolite Zones (Bassett et al., 1975). The *Deunffia brevispinosa* Zone and the *Deunffia brevifurcata* Zone of Dorning and Bell (1987) are equivalent to the acritarch zones 5 and 5a of Hill (1974), respectively. According to

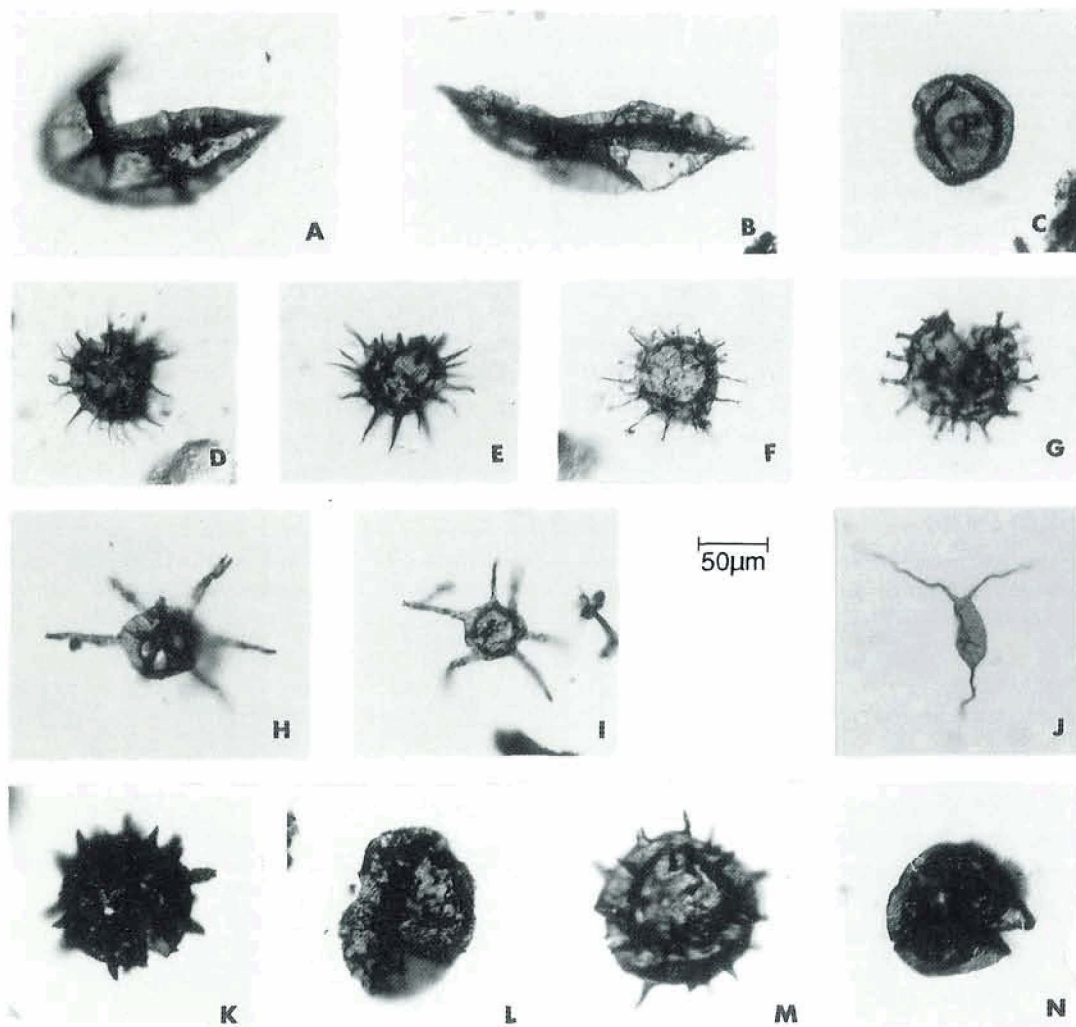


Fig. 5. Palynomorphs from the *Cyrtograptus centrifugus* graptolite zone on Bornholm.

- |  |   |
|--|---|
| A) <i>Eupoikilofusa</i> sp. I. Sample 9C, ref. P38/0.  | H) <i>Diexallophasis denticulata</i> (Stockmans & Williére) Loeblich 1970. Sample 2D, ref. S42/4. |
| B) <i>Eupoikilofusa</i> sp. I. Sample 9Ci, ref. N21/0.                                       | I) <i>Diexallophasis denticulata</i> (Stockmans & Williére) Loeblich 1970. Sample 7B, ref. O32/0. |
| C) <i>Lophosphaeridium papillatum</i> (Staplin) Downie 1963. Sample 2D, ref. S42/0.          | J) <i>Domasia elongata</i> Downie 1960. Sample 2B, ref. P42/3.                                    |
| D) <i>Micrhystridium stellatum</i> group Deflandre 1945. Sample 6C, ref. M42/2.              | K) <i>Rhacobranhion mala</i> (Cramer) Dorning 1981. Sample 6A, ref. J39/0.                        |
| E) <i>Micrhystridium stellatum</i> group Deflandre 1945. Sample 6B, ref. R40/0.              | L) <i>Leiosphaeridia</i> sp. Sample 9B, ref. P51/0.   |
| F) <i>Ammonidium microcladum</i> (Downie) Lister 1970. Sample 9C, ref. N39/0.                | M) <i>Salopidium granuliferum</i> (Downie) Dorning 1981. Sample 9A, ref. G33/2.                   |
| G) <i>Ammonidium</i> cf. <i>A. ludlovensis</i> (Lister) Dorning 1981. Sample 6C, ref. N39/0. | N) <i>Tetrahedraletes medinensis</i> Strother & Traverse 1979. Sample 2B, ref. L44/2.             |

Dorning and Bell (1987), the base of the *Deunffia brevispinosa* zone is synchronous with the Llandovery/Wenlock boundary. Mabillard and Aldridge (1985), however, found that the key species, *Deunffia brevispinosa*, *D. ramusculosa* and

*Domasia amphora* first appear in the uppermost Llandovery in the Wenlock Edge area (i.e. the type Wenlock area). The boundary of the overlying *Deunffia brevifurcata* Zone of Dorning and Hill (1987) is recognized by the earliest appear-

ance of *Deunffia brevifurcata*. As shown by Hill (1974), Dorning (1981), Mabillard and Aldridge (1985), and Dorning and Bell (1987), representatives of the genus *Deunffia* are sensitive biostratigraphic index taxa within the uppermost Llandovery and Early Wenlock in Britain. Because of the poorly preserved assemblages from Bornholm, it was not possible to test the stratigraphic utility of *Deunffia* in the Danish Silurian succession.

A zonation of Silurian and Devonian spores of the Old Red Sandstone continent and adjacent regions has recently been published by Richardson and McGregor (1986). The presence of *Ambitosporites* sp. and *Tetrahedraletes medinensis* in the *C. centrifugus* Zone on Bornholm give no precise age indications. A general comparison with the zonation scheme of Richardson and McGregor (1986) show that the Early Wenlock deposits are correlative with the *chulusnanus* spore zone, which spans the latest Llandovery and Early Wenlock Epoch. The comparable Sheinwoodian spore assemblages recorded from the Steinsfjorden Formation on Ringerike in the Oslo Graben (Smelror 1987a), can also be related to this spore zone.

The potential use of Silurian palynomorphs in environmental interpretations have been advocated in the recent years by Al-ameri (1983), Dorning (1981b) and Dorning and Bell (1987). The assemblages recorded from the earliest Wenlock on Bornholm appear to be related to the *Salopidium granuliferum* Assemblage of Dorning and Bell (1987). According to these authors, the *Salopidium granuliferum* Assemblage is characterized by moderate species diversities, with 25–35 distinctive forms. Common acritarchs include *Leiosphaeridia*, *Micrhystridium*, *Veryhachium*, *Diexallophasis*, besides *Salopidium granuliferum*. *Eupoikilofusa*, *Multiplicisphaeridium*, *Oppilatala*, *Visbysphaera*, *Leiofusa*, *Helosphaeridium*, *Cymatiosphaera*, *Eisenackidium*, and *Pterospermella* are normally present, while chitinozoans and scolecondts are normally present in small numbers.

The common presence of *Diexallophasis*, *Micrhystridium*, *Leiosphaeridia* and *Salopidium granuliferum* is also a feature of the *Cyrtograptus centrifugus* Zone assemblages from Bornholm. Chitinozoans are rare in the Bornholm samples, and they are also rare in the *Salopidium granuliferum*

Assemblage of Dorning and Bell. In the Welsh Borderlands and Midlands of England, the *Salopidium granuliferum* Assemblage occurs in bedded argillaceous limestones and calcareous mudstones of the Basement Beds of the Much Wenlock Limestone and the top of the Coalbrookdale Formation. Dorning and Bell (1987) suggested that these assemblages were distributed in deeper open marine shelf environments.

As previously noted, research on the potential use of marine palynomorphs as indicators of Paleozoic depositional environments is still at a preliminary stage. In fact, very little information has become available during the thirty years since Staplin (1961) presented his pioneering paper on "reef-controlled distribution of Devonian microplankton in Alberta". However, the similarity between the deep water open marine *Salopidium granuliferum* Assemblage from the Wenlock carbonate shelf in eastern Britain and the assemblages recorded from the *Cyrtograptus centrifugus* zone on Bornholm is noteworthy.

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## Dansk sammendrag

Palynomorf-floraer med en moderat diversitet af acritarker og prasinohyt alger og med relativt få chitinozoer og miosporer er påvist i skiferprøver fra *Cyrtograptus centrifugus* graptolit zonen ved Æleå på Bornholm. På grund af høj termisk påvirkning er palynomorferne gennemgående dårligt bevaret. De beskrevne palynomorf-floraer er sammenlignbare med tidlig Wenlock (Sheinwoodian) marine mikrofloraer beskrevet fra andre lokaliteter i Nordvesteuropa og Sovjet, og kendnetegnes ved slægterne *Leiosphaeridia*, *Diexallophasis*, *Oppilatala*, *Salopidium* og *Micrhystridium*. Palynomorf-floraerne påvist i de tidligste Wenlock aflejringer på Bornholm er sammenlignelige med floraer beskrevet af Dorning og Bell (1987) fra åbne marine dybvands aflejringer på "Wenlock Karbonat-soklen" i Welsh Borderland og Midlands i England (dvs. *Salopidium granuliferum* floraen). Tilstedeværelsen af *Domasia elongata* og *Domasia trispinosa*, sammen med ?*Deunffia* sp. bekræfter at de tidlige Wenlock aflejringer på Bornholm hører til *Deunffia-Domansia* biofacies som defineret af Cramer (1970, 1971, 1971a).

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