

# Palynology of the Lower Jurassic Rønne Formation on Bornholm, eastern Denmark

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Outcrop material from the Lower Jurassic Rønne Formation on the Danish island of Bornholm, in the Baltic Sea, has been investigated palynologically. The 34 samples examined came from sections through the Munkerup, Sose Bugt and Galgeløkke Members, which amount to about 210 m in stratigraphic thickness in the type area.

The aim of this study was to reevaluate the established stratigraphy defined by Gry (1969) and Gravesen et al. (1982) and characterize the three members by means of palynomorphs. 108 taxa have been recorded of which 67 are spores, 39 are pollen grains and 7 aquatic palynomorphs. Most of these are of little biostratigraphic value but the associations and relative abundances of a small number of selected species can be used to differentiate between the members, and correlations with other sequences elsewhere in Denmark, as well as in southern Sweden (Scania), Germany and Poland are possible. The assemblages from the Munkerup and lower part of the Sose Bugt Members are referred to Lund's (1977) *Pinuspollenites - Trachysporites* Zone and considered to be of Hettangian age. The upper part of the Sose Bugt and the Galgeløkke Members both correlate with Lund's (1977) unnamed zone with *Cerebropollenites macro-verrucosus*, now called the *Cerebropollenites macroverrucosus* Zone (Dybkjær, in press) for which a Sine-murian age has previously been suggested. The Galgeløkke assemblages are more taxonomically impoverished and poorly preserved than those from the Sose Bugt Member, and there is no palynological evidence to indicate whether they are any younger. They could represent sediments that were deposited at the same time in different environments. The palynological data on all three members of the Rønne Formation support previous environmental interpretations, indicating lacustrine to delta plain conditions of deposition.

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## Introduction

The Rønne Formation was referred to the "Lower Coalbearing Series" by Gry (1969). It was formally established as a formation by Gravesen et al. (1982) who subdivided it into the Munkerup, Sose Bugt and Galgeløkke Members (fig. 1). The sediments of which these are composed were deposited under deltaic conditions. They are exposed on the southwestern coast of Bornholm on the Rønne-Hasle and Arnager-Sose Blocks (fig. 2). Between 150 and 210 m of the Galgeløkke Member and approximately 240 m of the Sose Bugt Member are present on the Rønne-Hasle Block (fig. 2); it is not known whether the Munkerup Member is present there. On the Arnager-Sose Block the Sose Bugt and Munkerup Members are present, but their total thickness is somewhat less, being around 60 m (Gravesen et al. 1982).

All of the samples from the Munkerup and

Sose Bugt Members have come from the Arnager-Sose Block whereas those from the Galgeløkke Member are from the Rønne-Hasle Block. It is not known what underlies the Rønne Formation on the Rønne-Hasle Block, but on the Arnager-Sose Block it rests upon the Kågerød Formation (Risebæk Member), dated on the basis of a sparse ostracod fauna as late Ladinian-Carnian (Christensen, 1972). It is overlain by the Hasle Formation, the transition being marked by a

CHRONOSTRATIGRAPHY		BORNHOLM		SCANIA	DANISH SUBBASIN
System	Stage				
LOWER JURASSIC	Pliensbachian	L	HASLE FM	RYA FM	FJERRITSLÆV FM
	Sinemurian	L	Galgeløkke Mbr		
		L	Sose Bugt Mbr		
	Hettangian	L	Munkerup Mbr		
UPPER TRIAS	Rhaetian			HÖGANÄS FM (part)	GASSUM FM (part)

Fig. 1. Chrono- and lithostratigraphy of the Mesozoic succession on Bornholm, in Scania and in the Danish Subbasin; compiled from Gravesen et al. (1982), Sivhed (1984) and Michelsen (1989).

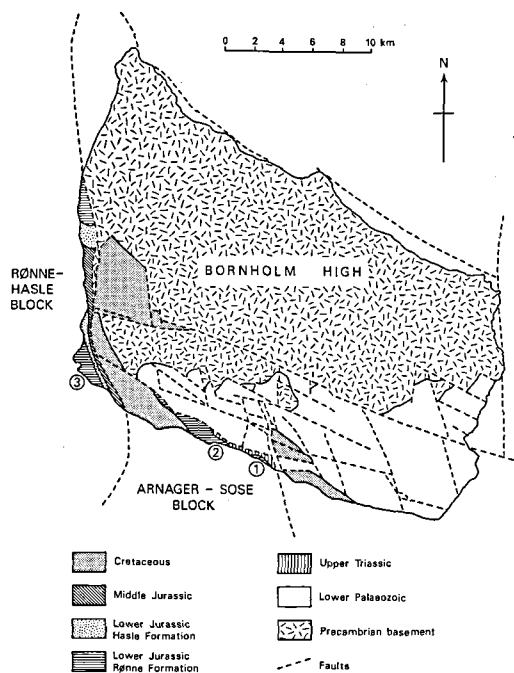


Fig. 2. Geological map of Bornholm with the sampling localities indicated; after Gravesen et al. (1982). 1: Munkerup Member, 2: Sose Bugt Member, 3: Galgeløkke Member.

change from unconsolidated interbedded sand and clay to a limonitic brown to grey sandstone of early Pliensbachian age (Gravesen et al. 1982; Surlyk & Noe Nygaard 1986).

The Rønne Formation has previously been dated as Early Jurassic. The oldest part, namely the Munkerup Member, contains a *Thaumatopteris* flora of "Liassic" (Hettangian) age (Harris, 1937). It was referred to the Lower Lias by Gry (1969) on basis of the abundant occurrence of *Nathorstisporites hopliticus* Jung, 1958 together with other megaspores such as *Verrutrites franconicus* Jung, 1960, *Horstisporites areolatus* (Harris, 1935) Potonié, 1956 and *Horstisporites harrisii* (Murray, 1939) Potonié, 1956.

The Sose Bugt Member was also referred to the Lias (Lias alpha: Hettangian to earliest Sinemurian) by Gry (1969) because of the presence of the megaspore species *Verrutrites franconicus*, *Trileites turbanaeformis* (Harris, 1961) Marcinkiewicz, 1971, *Horstisporites areolatus* and *Horstisporites harrisii* in samples taken from this part of the succession.

Except for an occurrence of the bivalve *Cardinia follini* Lundgren (now *Eomiodon menkei* (Huckriede 1967)) at Galgeløkke, and of plant

fossils referable to *Dictyophyllum* at Ormebæk, the Galgeløkke Member has been regarded as essentially unfossiliferous (Grönwall & Milthers, 1916; Gravesen et al., 1982). Neither these named fossils nor the occurrence of rare agglutinating foraminifers (Sellwood, 1972) and locally abundant trace fossils (Rolle, 1978) are of much biostratigraphic value. Its age has, therefore, previously been suggested solely on the basis of its stratigraphic position between the Sose Bugt Member and the Hasle Formation (Gry, 1969).

## Material and methods

Seven samples were taken from an exposure of the Munkerup Member on the south coast of Bornholm close to Stangegård (fig. 2). The dominant lithology at this locality is grey to black clay with subordinate thin bands of red, brown and white clay and sandstone (Gravesen et al. 1982). Eighteen horizons were sampled from the type locality of the Sose Bugt Member on the south coast between Sose Odde and Lilleå (fig. 2; for details see fig. 6 in Gravesen et al. 1982); their lithologies vary from generally poorly consolidated sand to equally soft silt and mud. Nine samples were taken from exposures of the Galgeløkke Member along the southwestern coast close to the town of Rønne. The lithologies of these are mostly dominated by heterolithic sand, wavy and flaser-laminated sand and clay.

All 34 samples were processed for their palynological content using the standard techniques developed at the Geological Survey of Denmark (Poulsen et al. 1990). Several slides of each preparation were examined by transmitted light microscopy. These have now been deposited in the collections of the Department of Stratigraphy at the Geological Survey of Denmark (DGU).

For each sample 200 specimens were counted from one or two slides, after which only those species not previously encountered were registered; these are indicated as "very rare" on the abundance range-charts (figs 3 and 4). The preservation of the palynomorphs from all three members is generally very good. Their colour is light yellow, except for those reworked from the Carboniferous which are dark brown (for discussion and illustrations of the reworked palynomorphs, see Nielsen & Koppelhus, 1991).

## Systematic palynology

## Palynomorph taxa

For convenience of reference the taxa recorded from the three members (see figs 3 and 4) are listed under three subheadings: miospores, phytoplankton and reworked palynomorphs. All are accompanied by author attributions and dates. In addition, figure references are given alongside all of the forms illustrated in this paper. These are arranged on figures 7–12 approximately according to morphological type. In common with the other palynomorphs, the miospores are, however, listed in alphabetical order and not according to Potonié's (1956 and later papers) classification because this serves no useful purpose here. Those taxa preceded by an asterisk are discussed in the following section.

## Miospores:

*Acanthotriletes varius* Nilsson, 1958  
*Alisporites grandis* (Cookson) Dettmann, 1963  
*A. microsaccus* (Couper) Pocock, 1962  
*A. radialis* (Leschik) Lund, 1977  
*A. robustus* Nilsson, 1958  
*A. thomasi* (Couper) Nilsson, 1958  
*Anapiculatisporites spiniger* (Leschik) Reinhardt, 1961  
*Annulispora folliculosa* (Rogalska) de Jersey, 1959: fig. 9e  
*A. sp. cf. A. folliculosa*  
*Apiculatisporis parvispinosus* (Leschik) Schulz, 1962  
*A. ovalis* (Nilsson) Norris, 1965  
*Aratrisporites minimus* Schulz, 1967: fig. 10c  
*A. parvispinosus* Leschik, 1955: fig. 10d  
*Araucariacites australis* Cookson, 1947  
*Baculatisporites comaumensis* (Cookson) Potonié, 1956  
*B. wellmanii* (Couper) Krutzsch, 1959  
*Calamospora tener* (Leschik) Mädlar, 1964a: fig. 7b  
*Camarozonosporites golzowensis* Schulz, 1967: 9i  
*Cerebropollenites macroverrucosus* (Thiergart) Schulz, 1967: fig. 11b  
*C. thiergartii* Schulz, 1967: fig. 11a  
*Chasmatosporites apertus* Nilsson, 1958: fig. 11e  
*C. elegans* Nilsson, 1958

*C. hians* Nilsson, 1958: fig. 11d  
*C. major* Nilsson, 1958  
*C. minor* Nilsson, 1958  
*C. spp.*  
*Chomotriletes spp.*  
*Cibotiumspora juriensis* (Balme) Filatoff, 1975  
 \* *Cingutriletes infrapunctus* (Schulz) comb. nov.: fig. 9j  
*Clavatipollenites hughesii* Couper, 1958 sensu Schulz 1967: fig. 11g  
*Conbaculatisporites mesozoicus* Klaus, 1960  
*C. spinosus* (Mädlar) Lund, 1977  
*Corollina torosus* (Reissinger) Cornet & Traverse, 1975: fig. 11f  
*C. spp.*  
*Deltoidospora minor* (Couper) Pocock, 1970  
*D. toralis* (Leschik) Lund, 1977: fig. 7a  
*D. spp.*  
*Densoisporites velatus* Weyland & Krieger, 1953  
 \* *Dicyclosporites bicollateralis* (Rogalska) comb. nov.: figs 7g, j  
 \* *D. pseudoverrucatus* (Schulz) comb. nov.: figs 7h, i  
 \* *D. radiatus* (Schulz) Jansonius & Hills 1990: fig. 7e, f  
 \* *Disticyclosporites trizonatus* (Schulz) Jansonius & Hills 1990: fig. 7k  
*Eucommiidites major* Schulz, 1967  
*E. troedssonii* Erdtman, 1948  
*Iraqispora labrata* Singh, 1964: fig. 8e  
 \* *Kraeuselisporites reissingeri* (Harris) Morbey, 1975: fig. 9d  
*Laevigatosporites dubius* Nilsson, 1958: fig. 9l  
*L. mesozoicus* Schulz, 1967  
*Lycopodiacidites infragranulatus* Mädlar, 1964b  
*L. rugulatus* (Couper) Schulz, 1967  
*Marattisporites scabratus* Couper, 1958: fig. 9k  
 \* "Monosaccates": cf. *Paleopicea glaesaria* Bolkhovitina, 1956: fig. 10a  
*Monosulcites punctatus* Orłowska-Zwolinska, 1966  
*Ovalipollis ovalis* Krutzsch, 1955: fig. 10b  
 \* *Peltandripites sp. cf. P. tener* Norris, 1969: fig. 11h  
*Perinopollenites elatoides* Couper, 1958: fig. 10f  
*Pinuspollenites minimus* (Couper) Kemp, 1970: fig. 10g  
*P. pinoides* (Nilsson) Lund, 1977  
*Podocarpidites spp.*

# RØNNE FORMATION

RANGE CHART OF GRAPHIC ABUNDANCES BY LOWEST APPEARANCE

Key to Symbols

- ◻ = Very Rare ( 0- 2 Counts)
- ▤ = Rare ( 3- 5 Counts)
- ▥ = Few ( 6- 15 Counts)
- ▧ = Common ( 16- 25 Counts)
- ▨ = Abundant ( 26- 200 Counts)
- ? = Questionably Present
- ◻ = Not Present

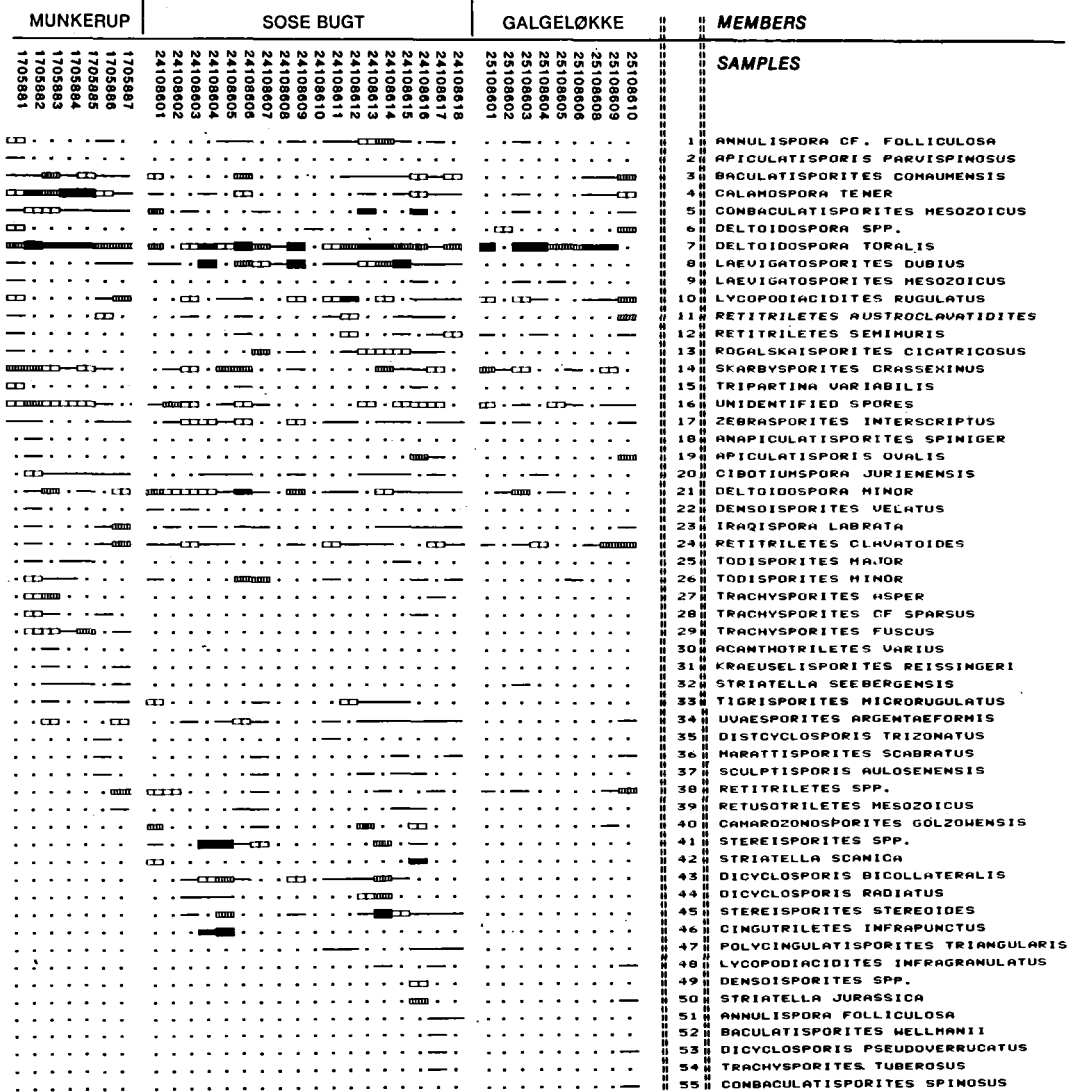


Fig. 3a. For caption see fig. 3b.

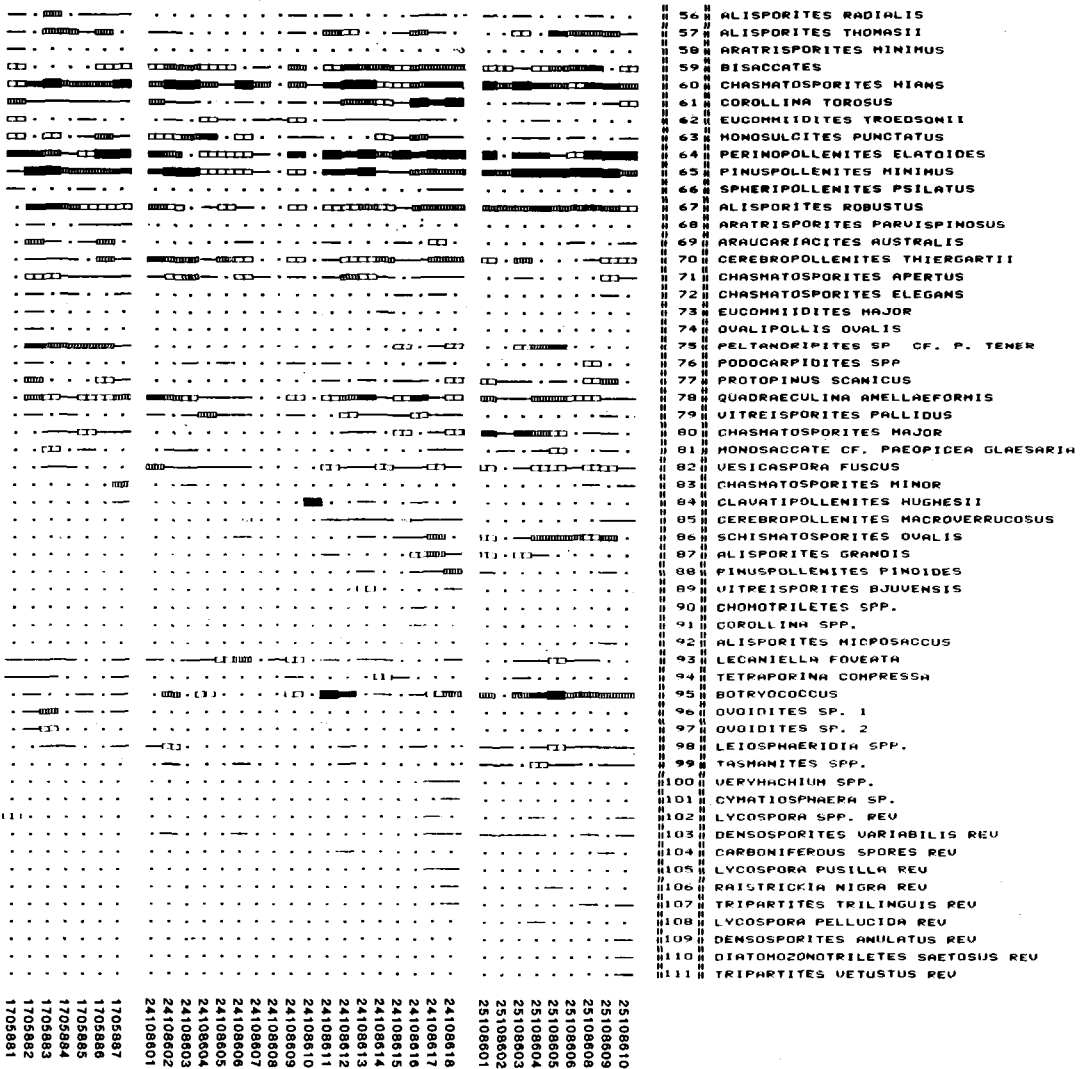


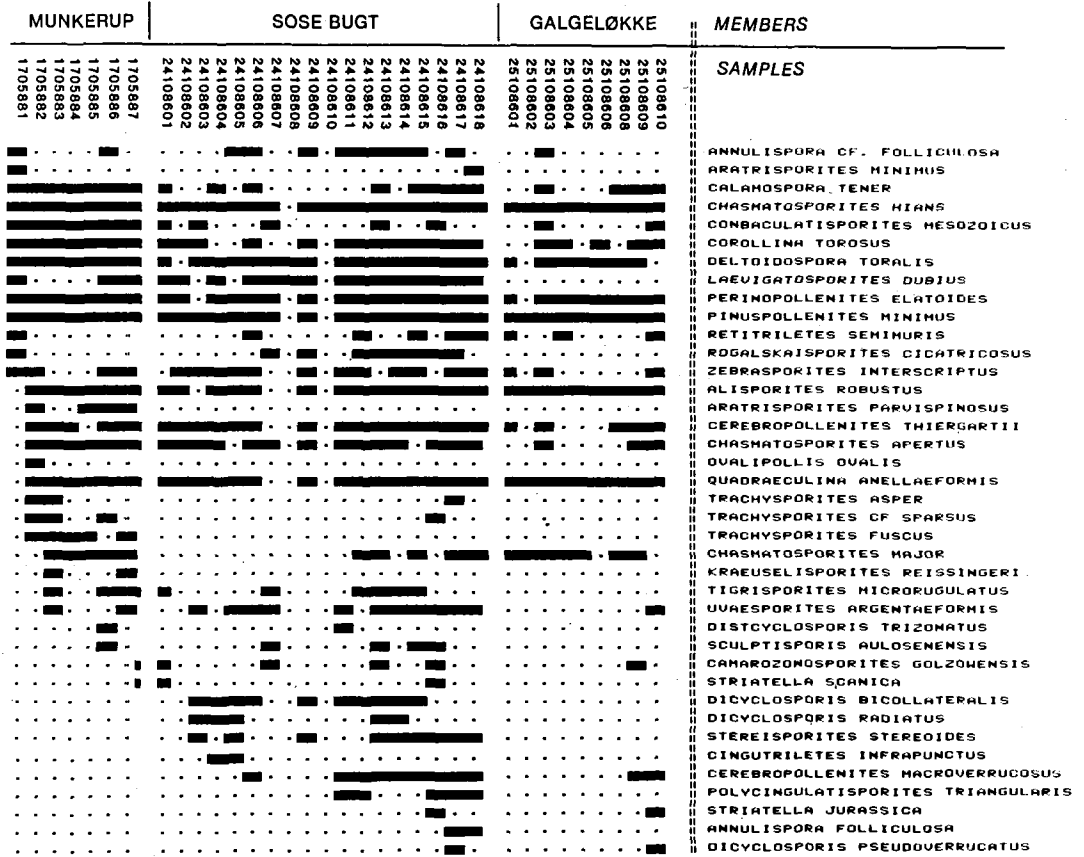
Fig. 3b. Composite range chart of all the species recorded. Although the members are plotted as if in stratigraphic order following Gravesen et al. (1982), it is accepted that the sequences may be, at least partly, diachronous. This applies particularly to the upper part of the Sose Bugt and Galgeløkke Members; hence the spaces between the data-sets. The "unidentified spores" category (16) was used mainly for forms which are too poorly preserved to be identified with confidence, but it also includes a few rare morphotypes (single specimens) that are not closely comparable to any known, previously published taxa. Rev. = reworked spores.

*Polycingulatisporites triangularis* (Bolkhovitina) Playford & Dettmann, 1965: figs 9g, h  
*Protopinus scanicus* Nilsson, 1958  
*Quadraeculina anellaiformis* Malyavkina, 1949: fig. 10e  
*Retitriletes austroclavatioides* (Cookson) Döring, Krutzsch, Mai & Schulz, 1963  
*R. clavatooides* (Couper) Döring, Krutzsch, Mai & Schulz, 1963: fig. 8i  
*R. semimuris* (Danzé-Corsin & Laveine) McKellar, 1974: figs 8j, k

*R. spp.*  
*Retusotriletes mesozoicus* Klaus, 1960  
*Rogalskiasporites cicatricosus* (Rogalska) Danzé-Corsin & Laveine, 1963: fig. 7d  
*Schismatosporites ovalis* Nilsson, 1958  
*\*Sculptisporis aulosenensis* (Schulz) comb. nov.: fig. 7c  
*Skarbysporites crassexinus* (Nilsson) Lund & Ecke, 1988  
*Spheripollenites psilatus* Couper, 1958  
*Stereisporites spp.*

## RØNNE FORMATION

RANGE CHART OF PRESENCE/ABSENCE BY LOWEST APPEARANCE



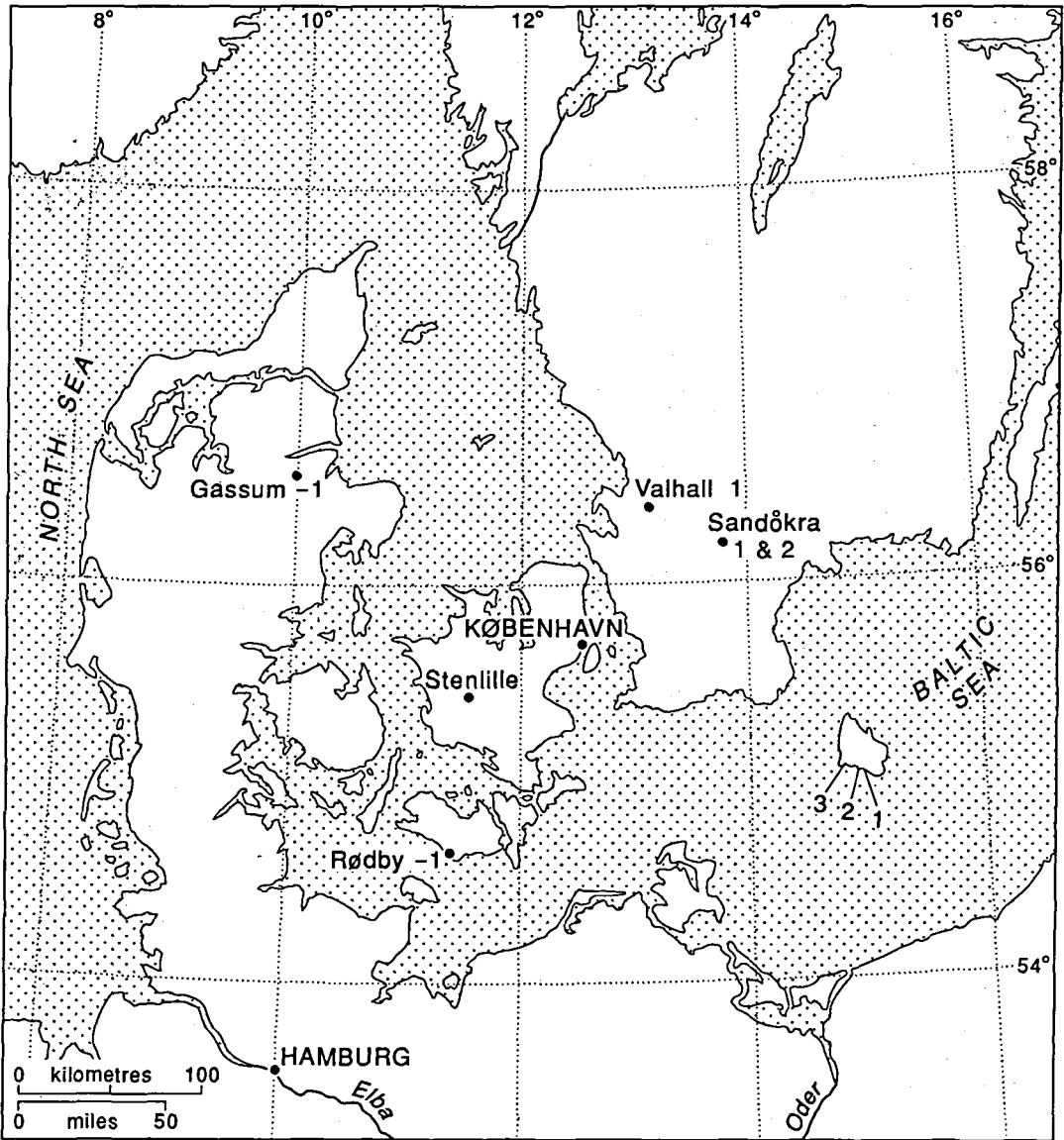


Fig. 5. Map of Denmark and surrounding areas showing the location of the boreholes referred to in the text.

SINEMURIAN	Late	GALGELØKKE MBR.
	Early	
HETTANGIAN	Late	SOSE BUGT MBR.
	Early	

Fig. 6. Correlation of the three members of the Rønne Formation with standard Lower Jurassic stages, based on palynological data.

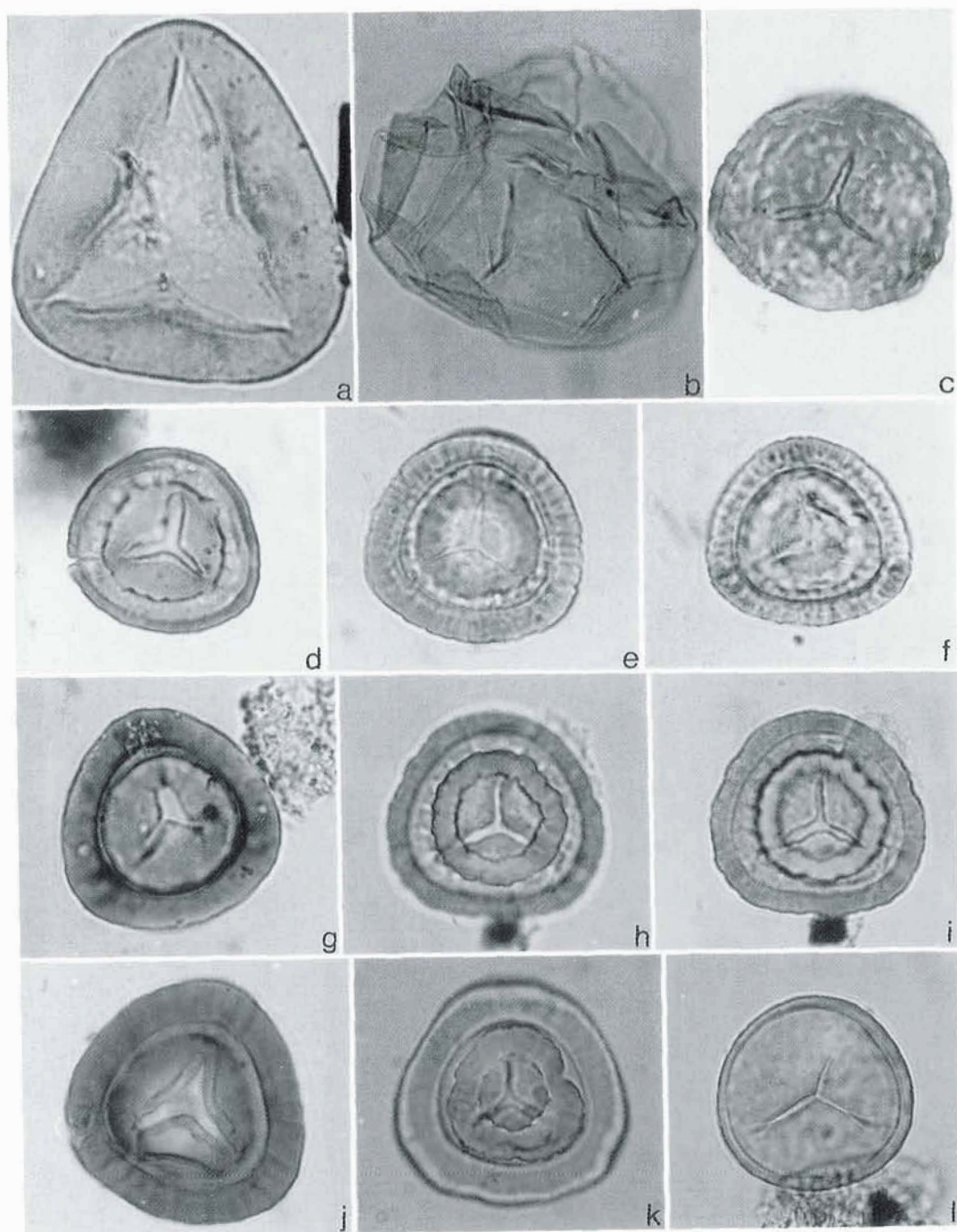


Fig. 7. a; *Deltoidospora toralis* (Leschik) Lund. Sose Bugt Mbr. (sample 241086-9-1). DGU Cat. No. 1991-EBK-1. b; *Calamospora tener* (Leschik) Mädlér. Munkerup Mbr. (170588-5-3). DGU 1991-EBK-2. c; *Sculptisporis aulosenensis* (Schulz) comb. nov., Sose Bugt Mbr. (241086-13-1). DGU 1991-EBK-3. d; *Rogalskaisporites cicatricosus* (Rogalska) Danzè-Corsin & Laveine. Sose Bugt Mbr. (241086-13-1). DGU 1991-EBK-4. e & f; *Dicyclosporites radiatus* (Schulz) Jansonius & Hills. Sose Bugt Mbr. (241086-9-2). DGU 1991-EBK-5. h & i; *Dicyclosporites pseudoverrucatus* (Schulz) comb. nov. Galgeløkke Mbr. (241086-10-3). DGU 1991-EBK-6. g & j; *Dicyclosporites bicollateralis* (Rogalska) comb. nov. Sose Bugt Mbr. (241086-11-2). DGU 1991-EBK-7. k; *Disticyclosporites trizonatus* (Schulz) comb. nov. Sose Bugt Mbr. (241086-11-1). DGU 1991-EBK-8. l; *Stereisporites stereoides* (Potonié & Venitz) Pflug. Sose Bugt Mbr. (241086-9-2). DGU 1991-EBK-9.

Comments relevant to figures 7 to 12.

All magnifications are approximately  $\times 1000$ . Sample and slide numbers and DGU catalogue numbers are indicated for each of the illustrated specimens.



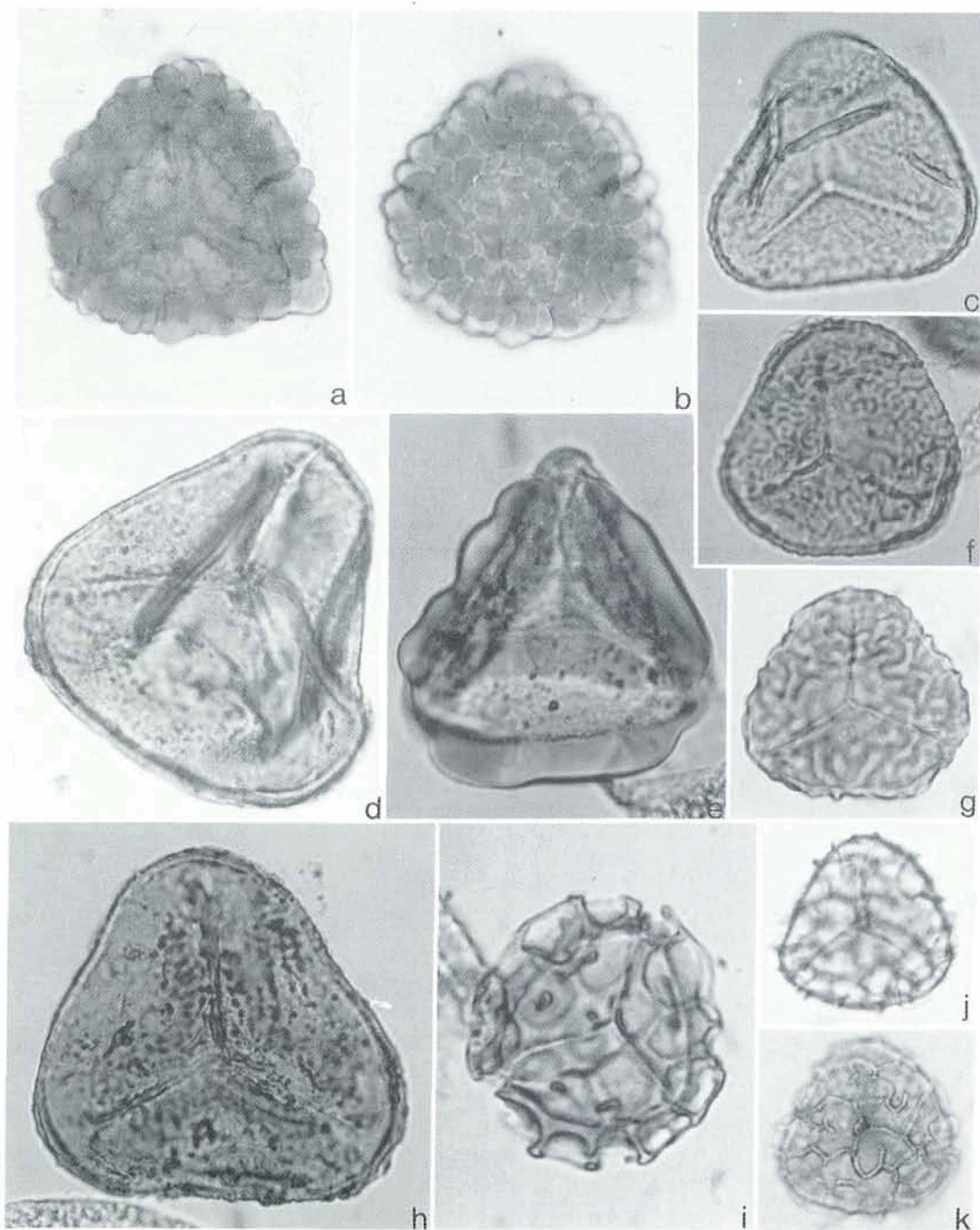


Fig. 8. a & b; *Uvaesporites argenteaeformis* (Bolkhovitina) Schulz. Sose Bugt Mbr. (241086-11-1). DGU 1991-EBK-10. c; *Trachysporites asper* Nilsson. Sose Bugt Mbr. (241086-18-1). DGU 1991-EBK-11. d; *Trachysporites fuscus* Nilsson. Munkerup Mbr. (170588-5-3). DGU 1991-EBK-12. e; *Iraqispora labrata* Singh. Munkerup Mbr. (180588-2-3). DGU 1991-EBK-13. f & g; *Tigrisporites micro-rugulatus* Schulz. Munkerup Mbr. (180588-1-3). DGU 1991-EBK-14. h; *Trachysporites* sp. cf. *T. sparsus* (Bharadwaj & Singh) Lund. Munkerup Mbr. (170588-2-3). DGU 1991-EBK-15. i; *Retiriletes clavatooides* (Couper) Döring, Krutzsch, Mai & Schulz. Sose Bugt Mbr. (241086-9-1). DGU 1991-EBK-16. j & k; *Retiriletes semimuris* (Danzé-Corsin & Laveine) McKellar. Sose Bugt Mbr. (241086-11-2). DGU 1991-EBK-17.

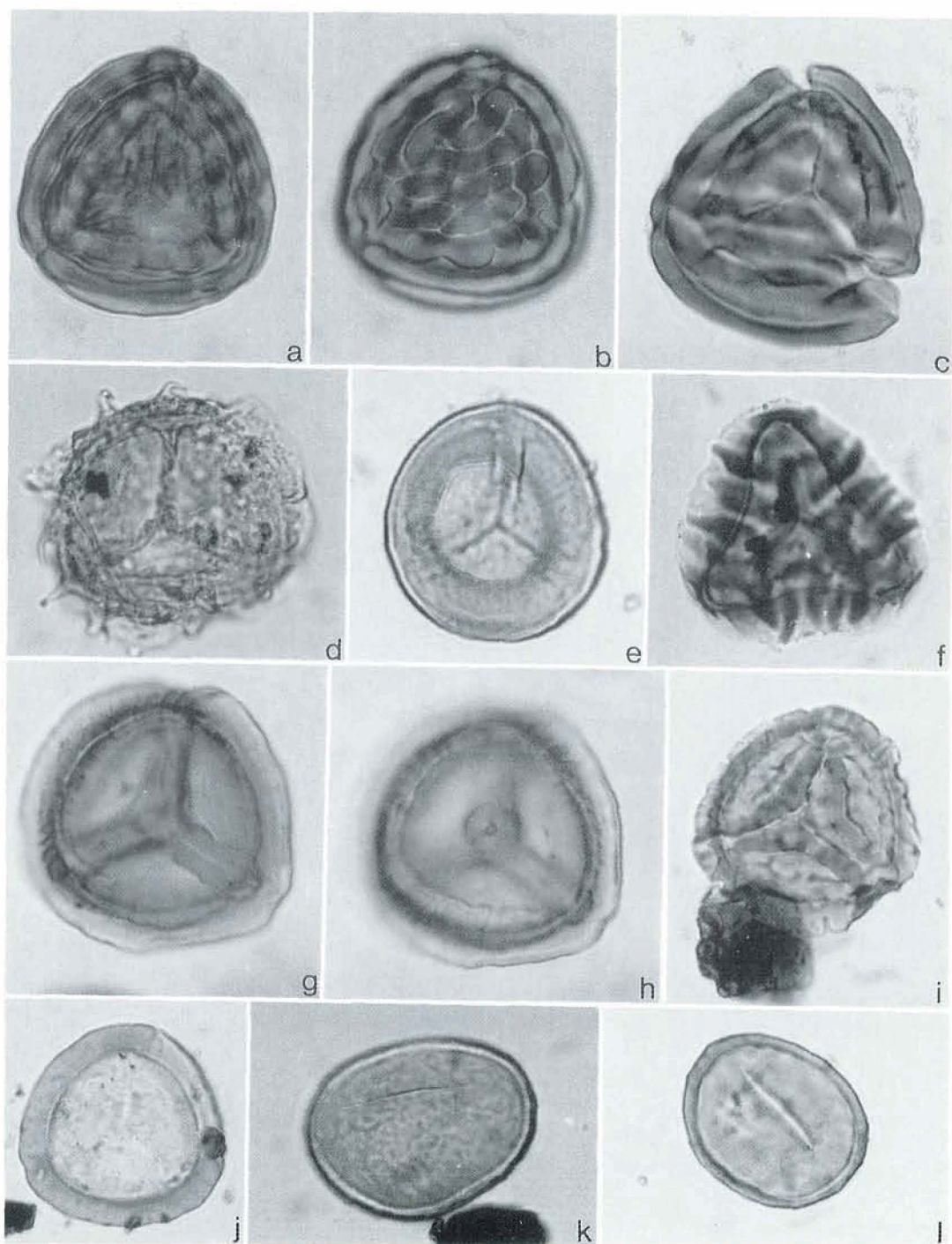


Fig. 9. a & b; *Striatella scanica* (Nilsson) Filatoff & Price. Sose Bugt Mbr. (241086-16-1). DGU 1991-EBK-18. c; *Striatella seebergensis* Mädlér. Sose Bugt Mbr. (241086-12-2). DGU 1991-EBK-19. d; *Kraeuselisporites reissingeri* (Harris) Morbey. Munkerup Mbr. (180588-2-3). DGU 1991-EBK-20. e; *Annulispora folliculosa* (Rogalska) De Jersey. Sose Bugt Mbr. (241086-9-2). DGU 1991-EBK-21. f; *Zebrasporites interscriptus* (Thiergart) Klaus. Sose Bugt Mbr. (241086-11-2). DGU 1991-EBK-22. g & h; *Polycingulatisporites triangularis* (Bolshovitina) Playford & Dettmann. Sose Bugt Mbr. (241086-16-1). DGU 1991-EBK-23. i; *Camazonosporites golzowensis* Schulz. Sose Bugt Mbr. (241086-13-1). DGU 1991-EBK-24. j; *Cinguliriletes infrapunctus* (Schulz) comb. nov. Sose Bugt Mbr. (241086-5-1). DGU 1991-EBK-25. k; *Marattisporites scabratus* Couper. Sose Bugt Mbr. (241086-9-1). DGU 1991-EBK-26. l; *Laevigatosporites dubius* Nilsson. Sose Bugt Mbr. (241086-13-1). DGU 1991-EBK-27.

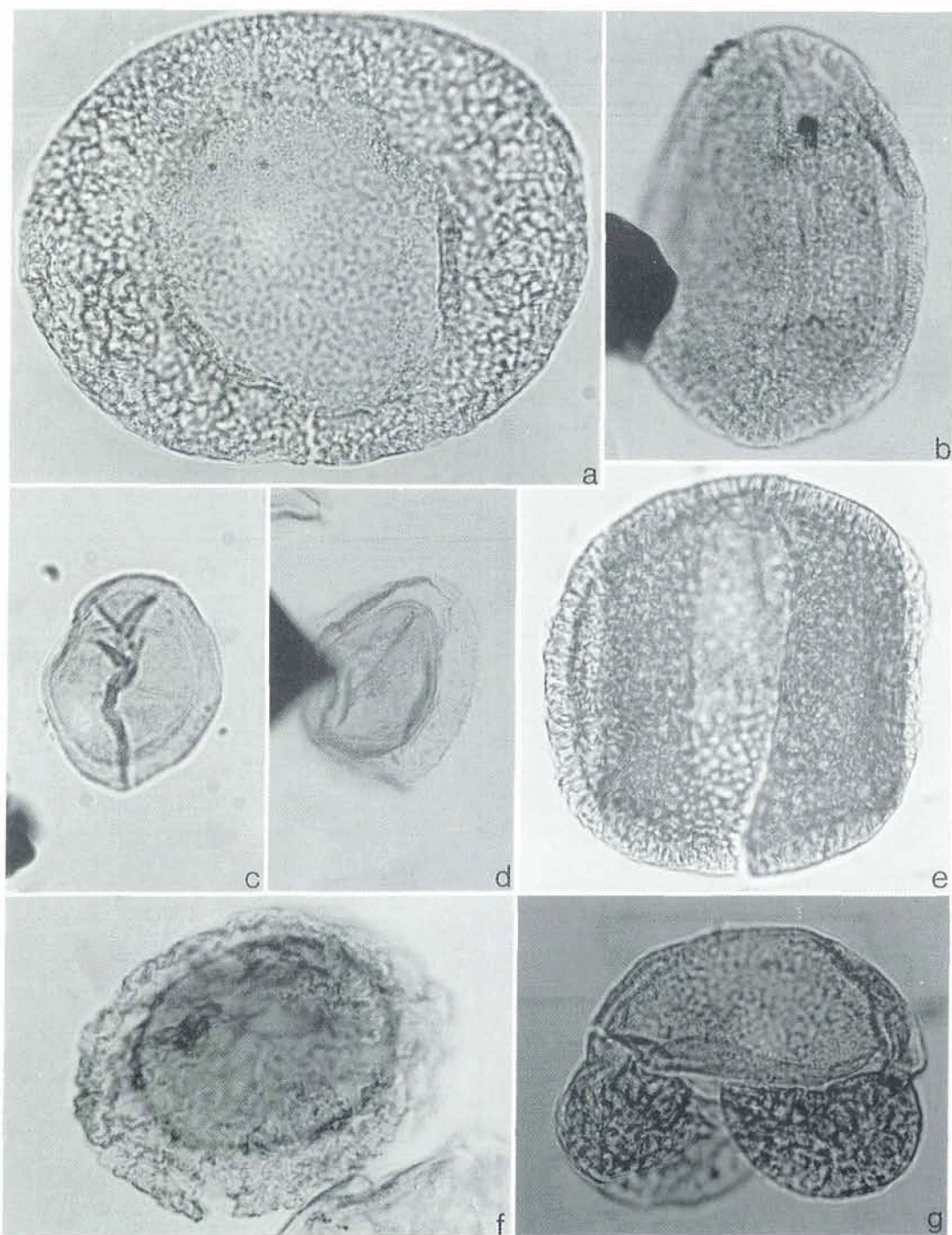


Fig. 10. a: Monosaccate, cf. *Paleopicea glaesaria* Bolkhovitina. Munkerup Mbr. (170588-2-3). DGU 1991-EBK-28. b: *Ovalipollis ovalis* Krutzsch. Sose Bugt Mbr. (241086-17-1). DGU 1991-EBK-29. c: *Aratrisporites minimus* Schulz. Sose Bugt Mbr. (241086-18-1). DGU 1991-EBK-30. d: *Aratrisporites parvispinosus* Leschik. Munkerup Mbr. (180588-2-3). DGU 1991-EBK-31. e: *Quadraeculina anellaeformis* Malyavkina. Munkerup Mbr. (170588-2-3). DGU 1991-EBK-32. f: *Perinopollenites elatoides* Couper. Sose Bugt Mbr. (241086-9-2). DGU 1991-EBK-33. g: *Pinuspollenites minimus* (Couper) Kemp. Munkerup Mbr. (170588-2-3). DGU 1991-EBK-34.

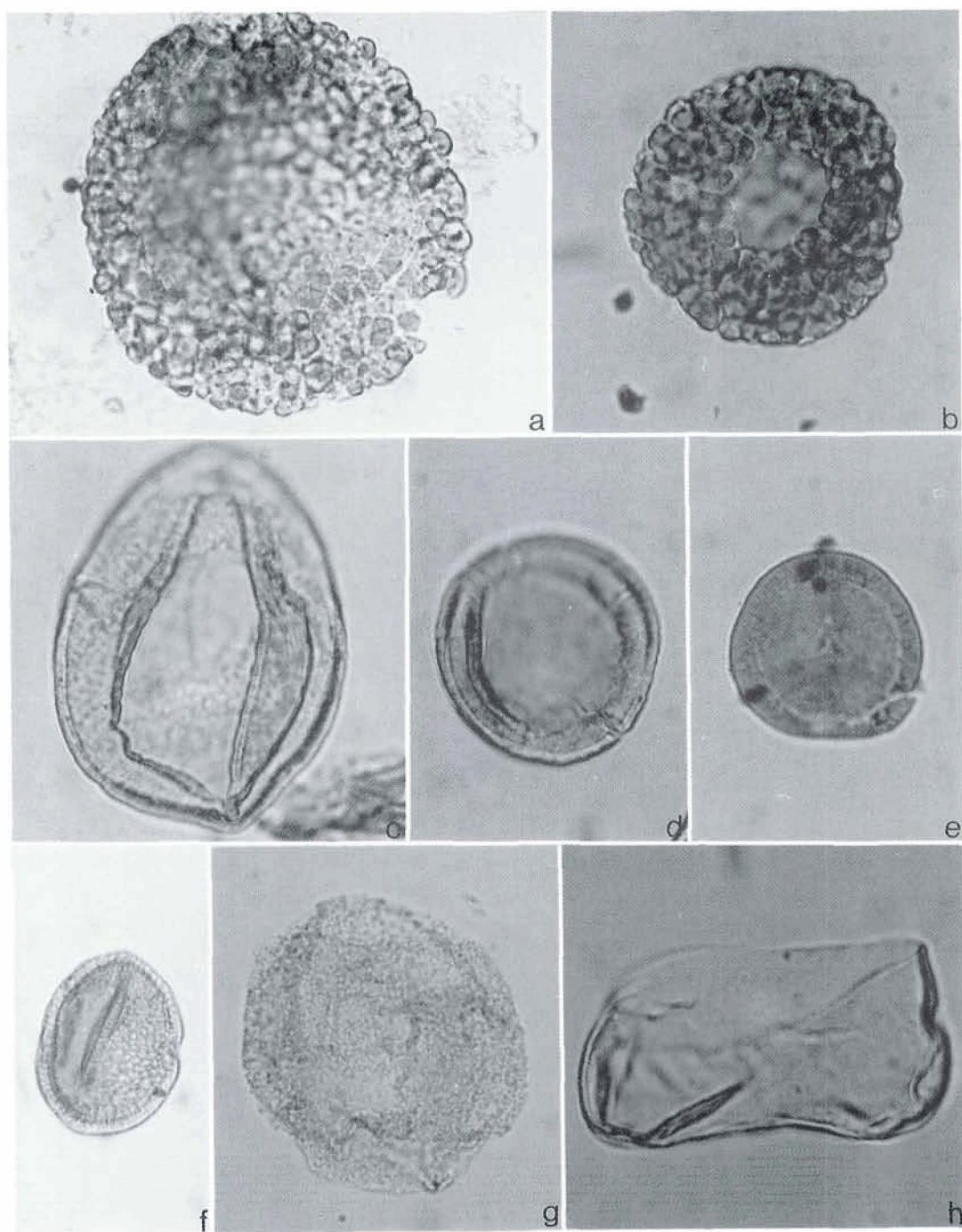


Fig. 11. a; *Cerebropollenites thiergartii* Schulz. Sose Bugt Mbr. (241086-9-2). DGU 1991-EBK-35. b; *Cerebropollenites macroverrucosus* (Thiergart) Schulz. Sose Bugt Mbr. (241086-11-1). DGU 1991-EBK-36. c; *Chasmatosporites hians* Nilsson. Munkerup Mbr. (170588-2-3). DGU 1991-EBK-37. d; *Chasmatosporites apertus* Nilsson. Munkerup Mbr. (170588-2-3). DGU 1991-EBK-38. e; *Corollina torosus* (Reissinger) Cornet & Traverse. Sose Bugt Mbr. (241086-16-1). DGU 1991-EBK-39. f; *Clavatipollenites hughesii* Couper. Sose Bugt Mbr. (241086-13-1). DGU 1991-EBK-40. g; *Peltandripites* sp. cf. *P. tener* Norris. Munkerup Mbr. (170588-2-3). DGU 1991-EBK-41. h; *Tetraporina compressa* Kondrat'ev. Munkerup Mbr. (180588-2-3). DGU 1991-EBK-42.

## Reworked palynomorphs:

- Densosporites anulatus* (Loose) Smith & Butterworth, 1967  
*D. variabilis* (Waltz 1938) Potonié & Kremp, 1956  
*Diatomozonotriletes saetosus* (Hacquebard & Barss) Hughes & Playford, 1961  
*Lycospora pellucida* (Wicher) Schopf, Wilson & Bentall, 1944  
*L. pusilla* (Ibrahim) Schopf, Wilson & Bentall, 1944  
*L. spp.*  
*Raistrickia nigra* Love, 1959  
*Tripartites trilinguis* (Horst) Smith & Butterworth, 1967  
*T. vetustus* Schemel, 1950

## Discussion of selected taxa

Use of the following species requires some comment regarding taxonomy and/or nomenclature.

*Cingutriletes infrapunctus* (Schulz) comb. nov.: fig. 9j

Basionym: *Stereisporites (Cingutriletes) infrapunctus* Schulz 1970, p. 688, pl. 131, fig. 1.

The genus *Cingutriletes* Pierce 1961 was relegated by Schulz (1970) to a subgenus of *Stereisporites*. Morbey (1975) appears to have followed Potonié (1970) in disagreeing with such a subdivision of the genus because he illustrated (pl. 9, fig. 4) a specimen which he recorded as *Cingutriletes infrapunctus* (Schulz) Morbey 1975. This combination was not discussed but it has since been used by several authors. It is, however, invalid according to the International Code of Botanical Nomenclature (ICBN) because Morbey neither indicated, nor provided any information about a basionym. The transfer is, therefore, validated here.

*Dicyclosporites bicollateralis* (Rogalska) comb. nov.: figs 7g, j

1956 *Sporites bicollateralis* Rogalska, p. 84, pl. 29, figs 4–6

1966. *Stereisporites (Dicyclosporites) bicollateralis* (Rogalska) Schulz, p. 79, pl. 3, figs 14, 15.

Jansonius & Hills (1990, card 4642) followed Potonié (1970) and accepted the elevation of the subgenus *Dicyclosporites* Schulz to generic rank.

As a result it is necessary to make this new combination. This also applies to *D. pseudoverrucatus*, as follows:

*Dicyclosporites pseudoverrucatus* (Schulz) comb. nov.: figs 7h, i

1970 *Stereisporites (Dicyclosporites) pseudoverrucatus* Schulz, p. 693, pl. 133, figs 12–16.

*Dicyclosporites radiatus* (Schulz) Jansonius & Hills 1990: figs 7e, f

As indicated above, Jansonius and Hills (1990, card 4642) followed Potonié (1970) and accepted the elevation of the subgenus *Dicyclosporites* to generic rank.

*Disticyclosporites trizonatus* (Schulz) Jansonius & Hills 1990: fig. 7k

Jansonius & Hills (1990) again followed Potonié (1970) and accepted the elevation of the subgenus *Disticyclosporites* to generic rank. This emendation is followed here. Their misspelling of the specific epithet (as *trigonatus*) is regarded as an orthographic error.

*Krauselisporites reissingeri*: fig. 9d

According to Morbey (1975) the genus *Heliosporites* Schulz 1962 is, in exine structure and nature of ornamentation, identical with *Krauselisporites* Leschik 1955 emend. Jansonius 1962. The latter is, therefore, used for the species found in the Rønne material.

“Monosaccates”: cf. *Paleopicea glaesaria*: fig. 10a

This form is rare in the Munkerup Member but very characteristic, the sacchi merging with each other equatorially to give the impression of a monosaccate pollen. *Paleopicea glaesaria* Bolkhovitina, 1956, which was originally described from the Lower Jurassic of the Yakutsk region, is very similar in size and form to the species found here. Closely comparable specimens have also been recorded as Monosaccate indet. by Dybkjær (1988, pl. 6, fig. 7), from the Lower Jurassic Fjerritslev Formation in the Gassum no. 1 well in the Danish subbasin (fig. 5).

*Ovoidites* sp. 1: fig. 12a

The specimens recorded under this heading are smaller (length 60–70 µm, width 30 µm) than the

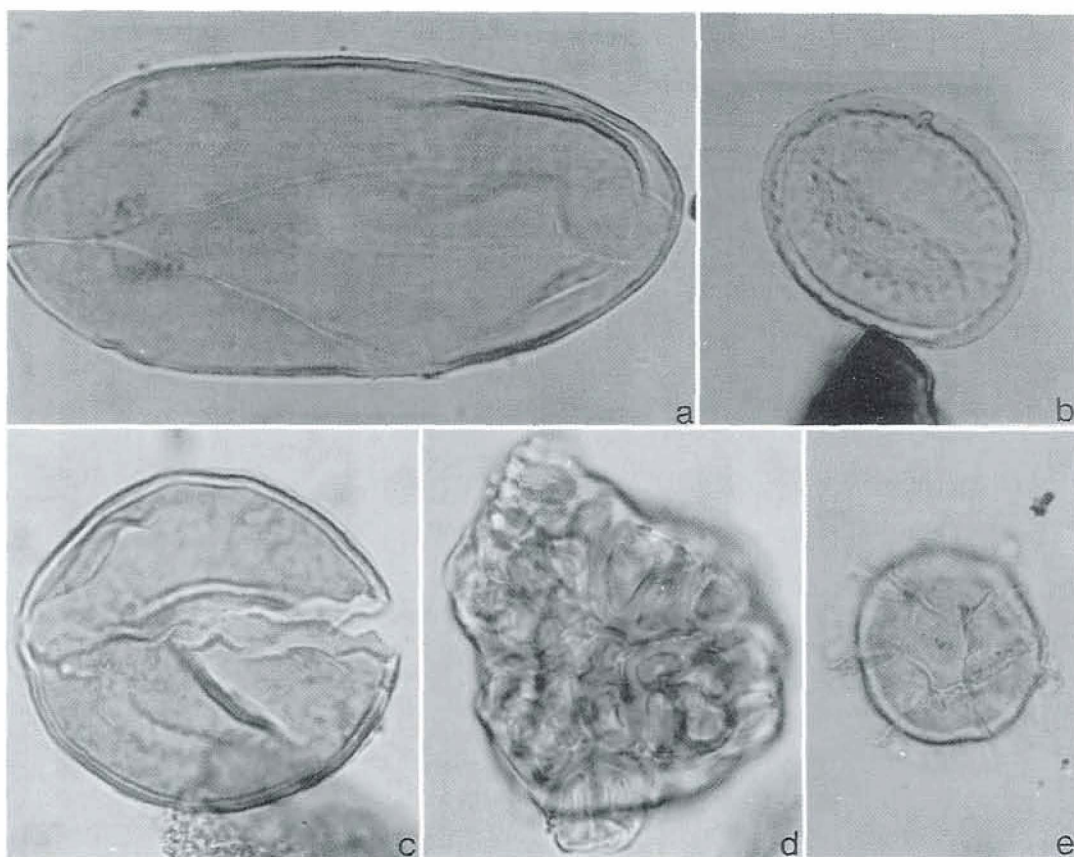


Fig. 12. a; *Ovoidites* sp. 1. Munkerup Mbr. (170588-2-3). DGU 1991-EBK-43. b; *Lecaniella foveata* Singh. Munkerup Mbr. (170588-5-3). DGU 1991-EBK-44. c; *Ovoidites* sp. 2. Munkerup Mbr. (170588-2-3). DGU 1991-EBK-45. d; *Botryococcus* sp. Sose Bugt Mbr. (241086-11-1). DGU 1991-EBK-46. e; *Cymatosphaera* sp. Sose Bugt Mbr. (241086-18-1). DGU 1991-EBK-47.

type species, *O. ligneolus* Potonié ex Krutzsch 1959, which is 130–135  $\mu\text{m}$  in length. They are elliptical, laevigate, and have a thin wall (1.5  $\mu\text{m}$ ) which commonly divides into two equal halves along the long axis, although remaining attached at one point.

*Ovoidites* sp. 2: fig. 12c

This morphotype of the genus *Ovoidites* is circular, laevigate, has a wall that is 2.5  $\mu\text{m}$  thick, and is often partly split into two halves. It is nearly identical to *Schizophacus spriggi* (Cookson & Dettmann) Pierce 1976.

*Peltandripites* sp. cf. *P. tener* Norris 1969: fig. 11g

This form is very common in the samples from the Munkerup and Sose Bugt Members. In the original diagnosis of the species (Norris, 1969) the surface is described as being covered with short, closely spaced, irregularly distributed

spines. The specimens encountered in this study appear instead, however, to be sculptured with closely spaced granules.

*Quadraeculina anellaeformis*: fig. 10e

The specimens of *Quadraeculina* recorded from the Rønne Formation show a rather large variation in size, ranging from 35 to 75  $\mu\text{m}$  in length and 30 to 62.5  $\mu\text{m}$  in width (55 specimens measured). Despite this they are all considered to fall within the circumscription of the species *Q. anellaeformis*.

*Sculptisporis aulosenensis* (Schulz) comb. nov.: fig. 7c

1966 *Stereisporites* (*Sculptisporis*) *aulosenensis* Schulz, p. 77, pl. 3, figs 4–6

1967 *Camarozonosporites* (*Camarozonosporites*) *aulosenensis* Schulz, p. 573, pl. 7, figs 12–14

In common with their approach to *Dicyclosporites*

and *Distyclosporites*, Jansonius & Hills (1990, card 4761) accepted the elevation of the subgenus *Sculptisporites* to generic rank previously made by Potonié (1970); hence this new combination here.

*Striatella jurassica*, *S. scanica*: figs 9 a, b, and *S. seebergensis*: fig. 9 c

The diagnoses of these three species were emended by Filatoff & Price (1988). Although there are intermediate specimens which can be very difficult to determine, there is no doubt that all three species are present in the Rønne material.

*Tetraporina compressa* Kondrat'ev, 1963: fig. 11 h  
The specimens recovered appear to be identical with one figured in Lund (1977, pl. 12, fig. 5), but not with his other specimen (pl. 10, fig. 7), which has four pores. Both were named *Schizocystia* cf. *rara*, but reference to *Tetraporina compressa*, which was described two years before *S. rara*, is preferred here. The Rønne specimens are also very similar to the Type A zygospores (*Mougeotia* cf. *punctata*) described by Van Geel (1976) from Quaternary deposits in the Netherlands. Extant *Mougeotia* occurs widely in fresh and brackish water.

*Tigrisporites microrugulatus*: figs 8 f, g

This species has been used for a wide variety of morphotypes in the Rønne Formation, some of which are almost identical to the specimens described by Schulz (1967). Others that are not so closely comparable are, however, currently included in it, pending the outcome of further taxonomic analysis.

## Palynostratigraphy

### Munkerup Member

The seven samples from the Munkerup Member contain an assemblage of about 73 species of palynomorphs (see composite range chart, figs 3 a & b and 4). A number of these are long ranging spore and pollen species such as *Deltoidospora toralis*, *Cerebropollenites thiergartii*, *Pinuspollenites minimus*, and *Perinopollenites elatoides*.

Species with shorter ranges such as *Kraeuselisporites reissingeri*, *Tigrisporites microrugulatus*, *Trachysporites fuscus*, *T. asper*, *T. sparsus*, *Zebbrasporites interscriptus*, *Aratrisporites minimus*, *A. parvispinosus* and *Ovalipollis ovalis* Krutzsch, 1955 have been found but are rare. All are typical of Rhaetian deposits, but they are also known to occur sporadically in Hettangian rocks (Lund, 1977; Dybkjær, 1988), and other taxa diagnostic of a Rhaetian age, such as *Rhaetipollis germanicus* Schulz, 1967 emend. Schuurman, 1977, *Triancoraesporites ancorae* Schulz, 1967, *Limbosporites lundbladii* Nilsson, 1958, and *Riccisporites tuberculatus* Lundblad, 1954 are absent. There are 6 species in the Munkerup assemblages which are common (more than 16–25 specimens in a count of 200); these are *Chasmatosporites hians*, *Perinopollenites elatoides*, *Pinuspollenites minimus*, *Deltoidospora toralis*, *Calamospora tener* and *Alisporites robustus*, the first four of which are also known to dominate equivalent assemblages of similar age from the Fjerritslev Formation in Rødby no. 1 borehole (Lund, 1977) and Stenlille no. 2 borehole (Dybkjær, in press; fig. 5 herein). The assemblages from the Fjerritslev Formation in Stenlille no. 2 are also dominated by *Calamospora tener*.

The assemblages found in the Munkerup Member are considered to be referable to Lund's (1977) *Pinuspollenites-Trachysporites* Zone which indicates a Hettangian age. This zone was established on the basis of a palynological study of the Rhaetic and lower Liassic sequence penetrated by the Rødby no. 1 well. It is known from the Fjerritslev Formation in the Gassum no. 1 well (Dybkjær, 1988) and in the Helsingborg Member of the Höganäs Formation in the Valhall no. 1 well in southern Scania (Guy-Ohlson, 1981, fig. 7). In Stenlille no. 2 well the same assemblage is present but was referred to a *Pinuspollenites-Deltoidospora* Zone by Dybkjær (in press), because Lund's (1977) name seemed inappropriate in view of the fact that the assemblages she encountered contain very few *Trachysporites* species.

### Sose Bugt Member

The eighteen samples from the Sose Bugt Member contain 97 species of palynomorphs (figs 3 a, b and 4). The long ranging spores and pollen recorded from the Munkerup Member also occur

in this member. Among the new species appearing for the first time are a complex of small round to triangular sphagnalean spores belonging mostly to the genera *Stereisporites*, *Annulispora*, *Sculptisporis*, *Dicyclosporites*, *Disticyclosporites*, *Rogalskaiisporites*, *Cingutritetes*, and *Polycingulatisporites*. *Camarozonosporites golzowensis* also occurs sporadically. *Striatella scanica* is common in two samples, one in the lower part of the member and one in the upper part; in the latter it occurs together with *Striatella jurassica*. The spore *Laevigatosporites dubius* is very common throughout the member. In the upper part (from samples 24108606 to 24108618; fig. 4) *Cerebropollenites macroverrucosus* and *Retitritetes semimuris* appear sporadically. *Clavatipollenites hughesii* is abundant in sample 24108610 in association with only three other palynomorph species.

The assemblages recovered from the Sose Bugt Member can be divided into two groups, those from the lower part again being referable to Lund's (1977) *Pinuspollenites-Trachysporites* Zone, indicating a Hettangian age. Those from the upper part correlate with Dybkjær's (in press) *Cerebropollenites macroverrucosus* Zone, the age of which is suggested to be Sinemurian on the basis of the presence of *Cerebropollenites macroverrucosus*.

According to Schulz (1970) there is an acme of sphagnalean spores in the lower to upper Sinemurian which he considered might be useful in distinguishing the Sinemurian stage from the Pliensbachian. Coupled with the appearance of *Cerebropollenites macroverrucosus* this acme might also be used to differentiate between the Sinemurian and the Hettangian, but it is still not possible to distinguish the lower from the upper Sinemurian. Abundances of *Clavatipollenites hughesii* are unusual in the Hettangian and Sinemurian but, although perhaps having (unknown) palaeoecological implications, the occurrence of numerous specimens in one of the samples noted above is not regarded as stratigraphically significant because the species is known to be sporadically common elsewhere. Lund (1977) has recorded a few (0,3%) in Rødby no. 1 borehole and Dybkjær (in press) also encountered some in the Fjerritslev no. 2 and Frederikshavn no. 2 boreholes in the Danish subbasin. Guy-Ohlson (1981) recorded numerous *C. hughesii* from the upper Rhaetian in Valhall no. 1 in the southern part of

Sweden. The species is also known from the lower Lias of East Germany (Schulz, 1967).

#### Galgeløkke Member

The nine samples from the Galgeløkke Member yielded 67 species of palynomorphs, 33 spore types of which 5 are reworked Carboniferous forms, 29 pollen and 5 aquatic palynomorphs. Many of the trilete spores recorded from Munke-rup and Sose Bugt Members were not encountered in this unit, and no new taxa were noted apart from Carboniferous spores (Nielsen & Koppelhus, 1991) which seem to be more common in this member than in the other two. Trilete, laevigate spores generally dominate the assemblages. There are fewer pollen grains than in the other members, but species such as *Alisporites thomasii*, *A. robustus*, *Chasmatosporites hians*, *Perinopollenites elatoides*, and *Pinuspollenites minimus* are abundant. Furthermore, *Botryococcus* seems to be consistently present throughout the sequence.

Overall, however, the assemblages encountered in the Galgeløkke Member are similar to those in the upper part of the Sose Bugt Member and all appear to correlate with the *Cerebropollenites macroverrucosus* Zone (Dybkjær, in press). They could have been deposited at the same time but in different environments. This suggestion might be supported by the fact that to date the Galgeløkke Member is known to be present only on the Rønne-Hasle Block and not on the Arnager-Sose Block.

#### Palaeoenvironment

As indicated in the discussion of the palynostratigraphy, there are a number of miospores which are not only long-ranging but also common to abundant in most of the assemblages examined. These are mainly of gymnospermous origin and include species of *Alisporites*, *Cerebropollenites*, *Chasmatosporites*, *Corollina*, *Perinopollenites* and *Pinuspollenites*, but smooth-walled trilete spores referable to *Deltoidospora* are also common, and other trilete forms such as *Baculatisporites comaumensis* and *Lycopodiacidites rugulatus* are sporadically numerous. This association is typical of assemblages encountered in Lower Ju-



rassic rocks elsewhere in north-west Europe (e.g. Ainsworth et al., 1989) and suggests that much of the vegetation of this region was dominated by gymnosperms. The generally good state of preservation implies a mainly local source.

Superimposed on this are, however, some indications of a change in the vegetation which may also have climatic implications (cf. Batten & Lister, 1988). The most significant of these is suggested by the influx of *Stereisporites* in the Sose Bugt Member which, in addition to being of stratigraphic value, also reflects an increase in the importance of plants referable (on present evidence) to the Sphagnales. This in turn coincides with sedimentological evidence of a change from lacustrine conditions (Munkerup Member) to a delta plain environment dominated by fluvial deposition. A relative increase in the number of presumed freshwater algae supports this interpretation. Similar changes have been recorded in the non-marine Early Cretaceous, Wealden succession of south-east England (Batten, 1982; Batten & Lister, 1988).

The reduced diversity of the assemblages recovered from the Galgeløkke Member by comparison with those recorded from the underlying members, and the reversion to domination by trilete, laevigate spores and gymnosperm pollen is not easy to explain. It may reflect a combination of factors including increased distance from source vegetation, which would have meant a longer period of transport of the palynomorphs prior to deposition, and a change to a transgressive sedimentary regime. Again there is a basis for comparison with Wealden data. Batten (1975) found that the assemblages typical of the more transgressive phases of deposition of the Hastings Beds were mainly dominated by gymnosperm pollen and small, unornamented trilete spores, and that during regressions the diversity of the pteridophyte spore assemblages increased markedly. Such comparisons, although lending support to the general suggestions made here, are not meant to imply, however, that the palaeoecology and depositional environments of the Lower Jurassic of Bornholm and the Wealden Cretaceous were necessarily closely comparable.

## Conclusions

It has been possible to distinguish between the three members of the Rønne Formation on the basis of relative abundances of some of the palynomorphs and to a lesser extent on changes in composition, especially of several species of the genus *Stereisporites* in the Sose Bugt Member. The fact that many forms cease to occur in the Galgeløkke Member is probably connected with a change in environment. From a palynological viewpoint it is not possible to conclude that the sediments from the Galgeløkke Member are younger than those from the upper part of the Sose Bugt Member; they could be at least partly synchronous (fig. 6).

The palynomorph assemblages recovered from the Rønne Formation correlate well with those of other Lower Jurassic deposits in Denmark (Rødby no. 1; Lund 1977; Gassum no. 1, Dybkjær, 1988) southern Sweden (Valhall no. 1; Guy Ohlson, 1981), the Netherlands (e.g. Hengreen, 1974), Great Britain (e.g. Orbell, 1973), Germany (Eitzendorf no. 8; Lund 1977; also Schulz, 1967, 1970; Achilles, 1981), and Poland (e.g. Marcinkiewicz, 1971).

The depositional environment of the earliest Jurassic on Bornholm (Munkerup Member) has been interpreted as lacustrine followed by a prograding, fluviially dominated delta plain (Sose Bugt and Galgeløkke Members; Gravesen et al. 1982; L. H. Nielsen, pers. comm. 1989). The palynological data on the three members in the Rønne Formation support this interpretation. The assemblages are dominated by spores and pollen grains; only a few brackish-water indicators have been recovered. The good preservation of the palynomorphs suggests that they were deposited in a low energy environment only a short distance from, or adjacent to the source vegetation.

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## Dansk sammendrag

En palynologisk analyse af aflejringerne fra nedre jura på Bornholm har resulteret i en rig polynomorf flora af hettangien og sinemurien alder. Ialt 34 prøver fra typelokaliteterne for Munkerup, Sose Bugt og Galgeløkke Member er blevet undersøgt. Formålet med arbejdet har været at reevaluere den etablerede stratigrafi defineret af Gry (1969) og Graversen et al. (1982) af karakterisere de tre Member ved hjælp af palynomorfer. 108 taxa er blevet registreret hvoraf 67 er sporer, 19 pollen og 7 akvatiske palynomorfer. Mange af disse er stratigrafisk vigtige arter, men sammensætningen af den relative hyppighed af et lille antal udvalgte arter kan bruges til at skelne mellem de tre Member. Palynomorf floraen fra Munkerup Member og nedre del af Sose Bugt Member er henført til Lunds (1977) *Pinuspollenites-Trachysporites* Zonen, øvre del af Sose Bugt Member og Galgeløkke Member er korreleret til *Cerebropollenites macroverrucosus* Zonen, Dybkjær (in press). De palynologiske data fra alle tre Member af Rønne Formationen støtter de tidligere aflejningsmodeller, som indikerer lakustrine og flodslette aflejningsmiljøer.

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