Aalenian to Cenomanian terrestrial palynofloras of SW Scania, Sweden

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I describe dispersed miospore assemblages recovered from 35 drill-core samples from Höllviken 2, Norrevång 1, and Svedala 1 wells, all in SW Scania, Sweden. Over eighty taxa of pollen and spores, ranging from the Aalenian to the Cenomanian were identified. Four pollen/spore zones have been defined on the basis of key taxa and on the variation in the frequency of miospore groups. The palynofacies analysis indicates that a continental depositional environment prevailed during the Aalenian in Scania. A stratigraphic hiatus existed from the Aalenian then on until the Valanginian, when the depositional environment subsequently became marine. The marine conditions continued until the Cenomanian. A gradual increase in marine palynomorphs is found in the Cenomanian succession, indicating a transgression. On the basis of the palynoflora it is suggested that the vegetation consisted of cycads, conifers, pteridophytes and a very limited number of angiosperms.

Key words: Palynology, paleovegetation, paleoclimate, Cretaceous, sealevel-changes, Scania, Sweden.

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Introduction

This paper deals with the palynofloras recorded from Aalenian, and Valanginian to Cenomanian sediments of SW Scania, southern Sweden. The pollen and spores are listed and a pollen/spore zonation, based on the taxa identified, is presented. In addition, paleoclimatological and paleoenvironmental interpretations are presented based on the composition of the miospore assemblages.

Two wells were initially selected for this study, i.e. Höllviken 2 and Svedala 1 in which most of the Cretaceous succession is present. They are situated within two different tectonic settings, Höllviken 2 in the Höllviken Graben and Svedala 1, on the Skurup Platform (Fig. 1). Subsequently a succession in the Norrevång 1 well, located on the

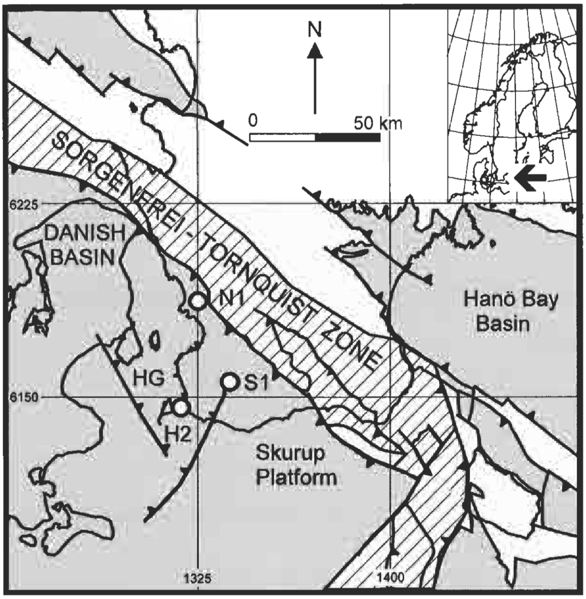

Fig. 1. Geological map of Scania, showing locations of the wells; Höllviken 2 (H2), Svedala 1 (S1) and Norrevång 1 (N1). Grey areas represent present extent of Cretaceous strata, hatched area denotes the Tornquist–Sorgenfrei Zone. HG, Höllviken Graben.

Barsebäck Platform (Fig. 1) was studied in order to investigate the palynoflora of a more northern well, and to compare it with the palynofloras of Höllviken 2 and Svedala 1.

The slides, SEM stubs, and the macerated residues of the samples are deposited in the Department of Geology, Division of Historical Geology and Paleontology, Lund University, Sweden, and labelled as LO number + t.

Previous work on the palynology of Scania

Palynological investigations of the Cretaceous of Scania have been carried out by Ross (1949) who studied the Late Cretaceous palynoflora at Åsen, in the Kristianstad area. Skarby (1964, 1968, 1978, and 1986) continued this work describing the palynofloras from the same area in several publications. Carbonised flowers with pollen grains in situ have been described from the Åsen locality (Friis & Skarby 1981, 1982; Skarby & Nilsson 1982; Friis 1983; Friis *et al.* 1986) and the megaspores from the same locality were described by Koppelhus & Batten (1989).

Early Cretaceous (Berriasian to Hauterivian) palynological assemblages from Kullemölla, SE Scania have been described by Guy-Ohlson (1978), who made a further biostratigraphic study (1984) based on miospores of samples from Sixtorp Bore 1, NE Scania, in the Kristianstad Basin. Erlström *et al.* (1991) presented results of a palynological study on the Upper Jurassic–Lower Cretaceous of Eriksdal, Scania. Westin (1992) carried out an investigation of Albian to Santonian dinoflagellate cysts from the Höllviken 1. Guy-Ohlson & Malmquist (1985) studied the miospores of the Oppegård boring of Scania from the middle Jurassic.

Middle Jurassic palynology of Europe is treated in Lund & Pedersen (1985), Koppelhus (1991), Batten & Koppelhus (1996), and Dybkjaer (1991).

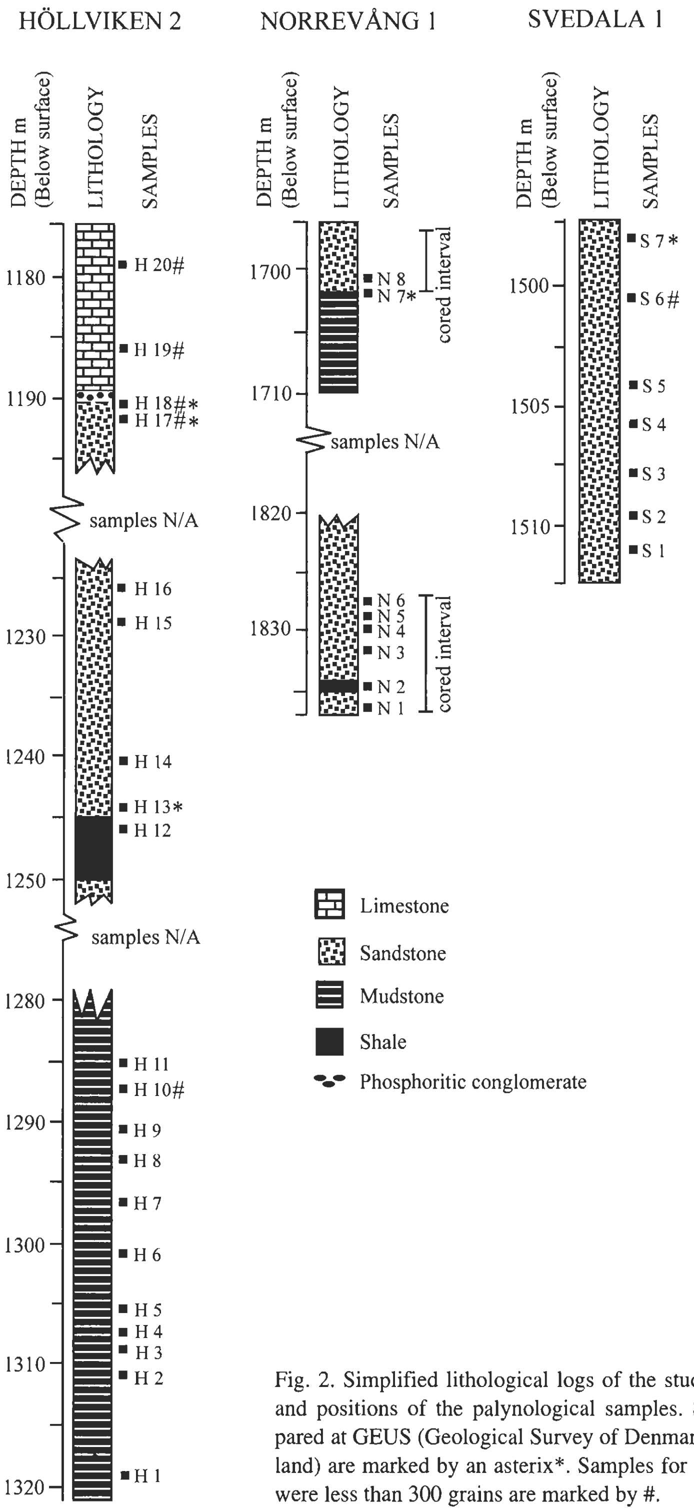

Fig. 2. Simplified lithological logs of the studied intervals and positions of the palynological samples. Samples prepared at GEUS (Geological Survey of Denmark and Greenland) are marked by an asterix*. Samples for which counts were less than 300 grains are marked by #.

Description of the wells

For the present study, drillcore material from three wells, Höllviken 2, Norrevång 1 and Svedala 1, located in SW Scania was sampled (Fig. 2). The wells are situated within the Tornquist Zone. A detailed description on the development of this fault system is presented in Erlström *et al.* (1997).

Höllviken 2. — Höllviken 2, situated in the Höllviken Graben, is the most extensively cored well in SW Scania. Brotzen (1945, 1950) described the lithology of the core. The samples used for this study are from the 1319–1179 m (Fig. 3). The basal part of the succession consists of mudstones with shaly intercalations (1319–1246 m), overlain by green-grey glauconitic sandstone between 1246 and 1190 m: beneath the greensand an organic-rich shale is found. The core is incomplete and sampling is subsequently irregular because the greensand is poorly consolidated. At the top of the greensand, a 20–30 cm thick hardground-phosphoritic bed is present, and is overlain by a limestone succession. For lithological description see Brotzen (1945, 1950) and Norling (1981).

Svedala 1. — Svedala 1 was drilled by the Geological Survey of Sweden (SGU) during 1948 and 1950 on the western margin of the Skurup Platform (Fig. 1). Middle Rhaetian strata is overlain by poorly consolidated glauconitic sandstones. The samples investigated comprise the 1510.9–1498.25 m interval (Figs. 2, 4, no core material remains from the 1498–1490 m interval). A thin phosphoritic conglomerate represents the transition to the Upper Cretaceous carbonates. Above this follows a thick sequence of dense, white limestones with thin conglomerate beds in the lowermost 5 m (Fig. 4).

Norrevång 1. — Norrevång 1 was drilled in 1971 by Oljeprospektering AB in the northern part of the Barsebäck Platform (Fig. 1) and penetrated a Mesozoic sequence down to 2088 m. The sequence rests on a Precambrian gneiss. About 1800 m of it comprises Cretaceous strata. The available biostratigraphic information is poor, but preliminary studies carried out during the drilling indicated, on the basis of foraminifera and dinoflagellate cysts from core material between 1700–1697 m and 1836–1828 m, that the former interval is of Turonian–Coniacian age and the latter of Aptian age. Between 1702 and 1697 m the core comprises a fine-grained calcareous sandstone with shaly intercalations; the 1836–1828 m interval is mainly a glauconitic sandstone with a polymict conglomerate at 1828.66 m and a black, dense shale at 1834.58 m. The latter has yielded ammonites and bivalves, which have not yet been identified. Trace fossils are abundant at several levels. The samples investigated herein are from 1836–1828 m and 1702–1700 m (Figs. 2, 5).

Material and methods

A total of 35 samples were studied palynologically (Fig. 2). Between 50 and 200 grams of each sample were processed by the author according to methods described by Vidal (1988). Bleaching the samples with HNO_3 was avoided for those samples that were

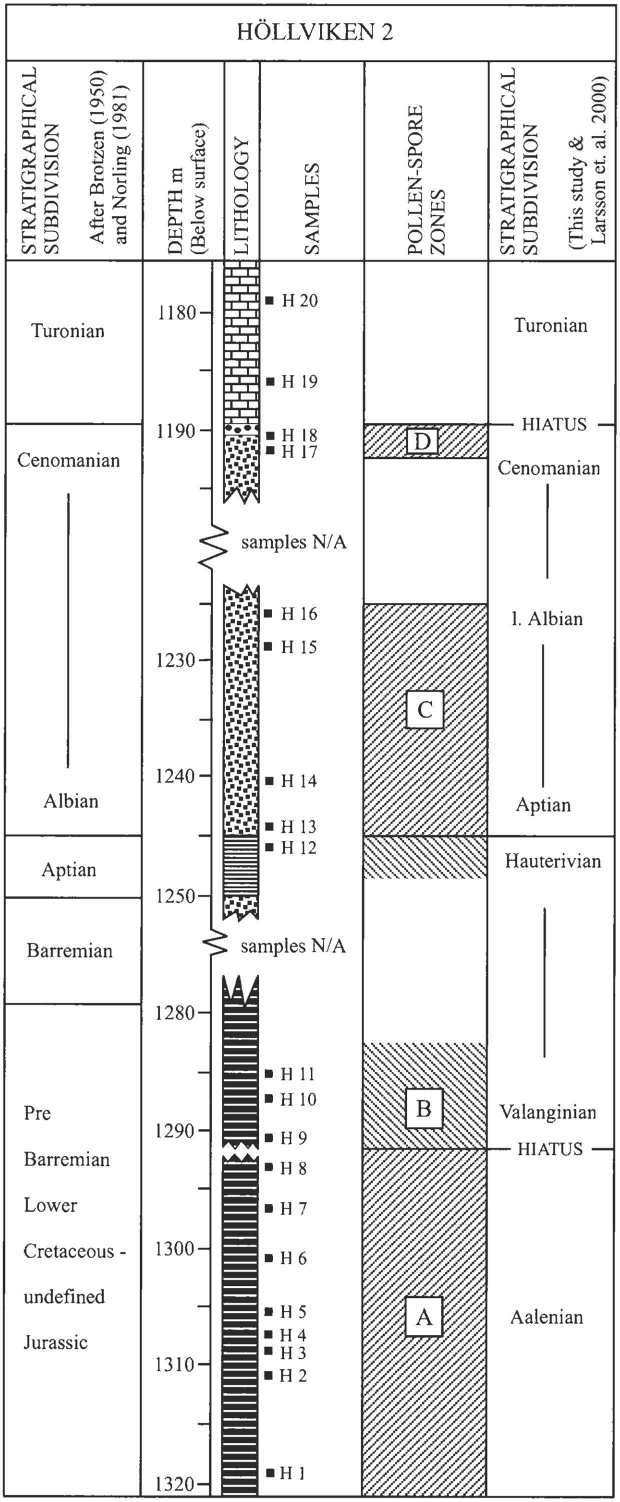

Fig. 3. Pollen/spore zonation of Höllviken 2 borehole, correlated to chronostratigraphy (Aalenian–Turonian).

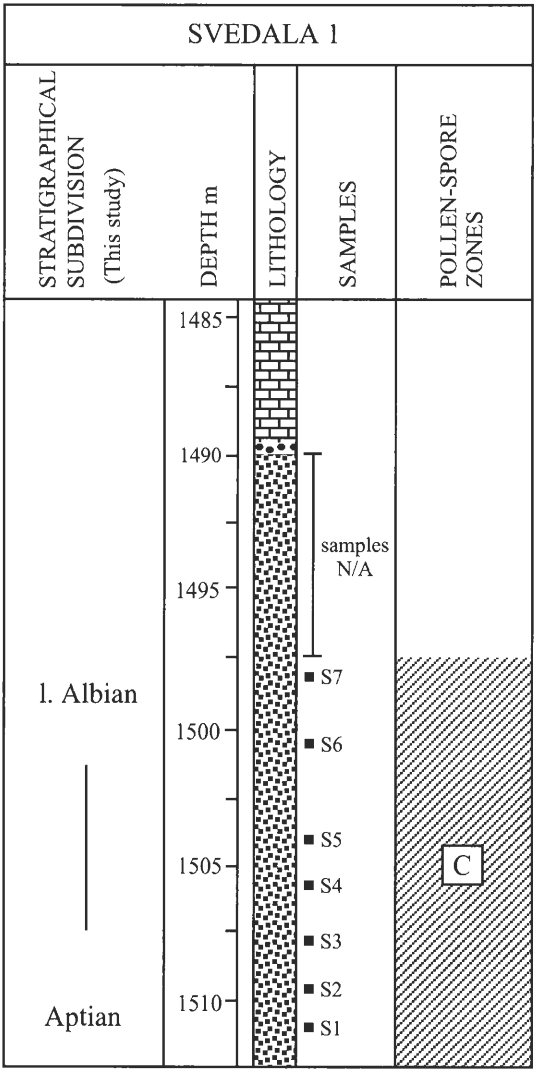

Fig. 4. Pollen/spore zonation of Svedala 1 borehole, correlated to chronostratigraphy (Aptian–early Albian).

later used for palynofacies analyses. A subset of the samples were also processed at the Geological Survey of Denmark and Greenland (GEUS) according to the method described by Poulsen *et al.* (1990; marked by an asterisk* in Fig. 2). Duplicate analyses, where the same sample was prepared according to the two different methods, showed that the results were comparable.

The residue was mounted on slides in epoxy-glue. From each sample 300 whole specimens were counted, with the exception of some samples where the material was too poor (indicated in Fig. 2 by #). The slides were further examined to check for the presence of rare taxa. The palynomorphs were examined using both transmitted light and scanning electron microscopy. The specimens examined by scanning electron microscopy were chosen randomly by leaving 1–3 drops of residue to dry on a glass lamina, which was later attached to the stub and coated with gold.

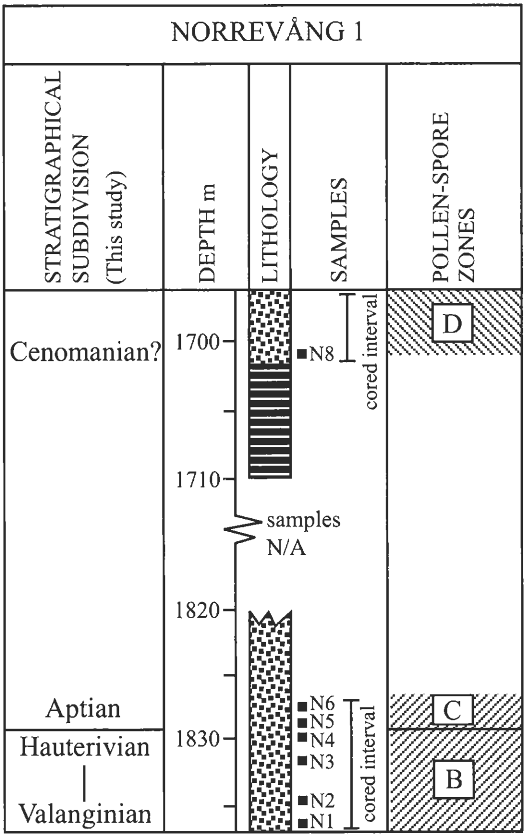

Fig. 5. Pollen/spore zonation of Norrevång 1 borehole, correlated to chronostratigraphy (Valanginian– Turonian).

Palynostratigraphy

As described by Couper (1958) and Pocock (1962), there are two ways of using palynology for dating successions. One is to use key taxa with a limited stratigraphical range (appearance and disappearance of species) and the other is to compare frequency fluctuations of significant groups of miospores in whole assemblages. A combination of both methods has been used herein.

The botanical classification of miospores is based on the following publications dealing with affinities of Mesozoic pollen grains and spores: Couper (1958), Pocock (1962), Burger (1966), Kemp (1970), Traverse (1988), Balme (1995), and Batten & Dutta (1997) who give a detailed description of several gymnosperm pollen grains and discuss their affinities.

The occurrence of selected miospore species is presented in Fig. 6 and the abundance of selected miospore groups in Fig. 7. A full list of species observed is presented in the Appendix.

Based on pollen and spores, four zones, A–D, have been identified. In Höllviken 2 all of the zones are present A–D (Fig. 3); in Svedala 1, Zone C has been recognised (Fig. 4); and in Norrevång 1 Zone B,C and presumably Zone D are present (Fig. 5).

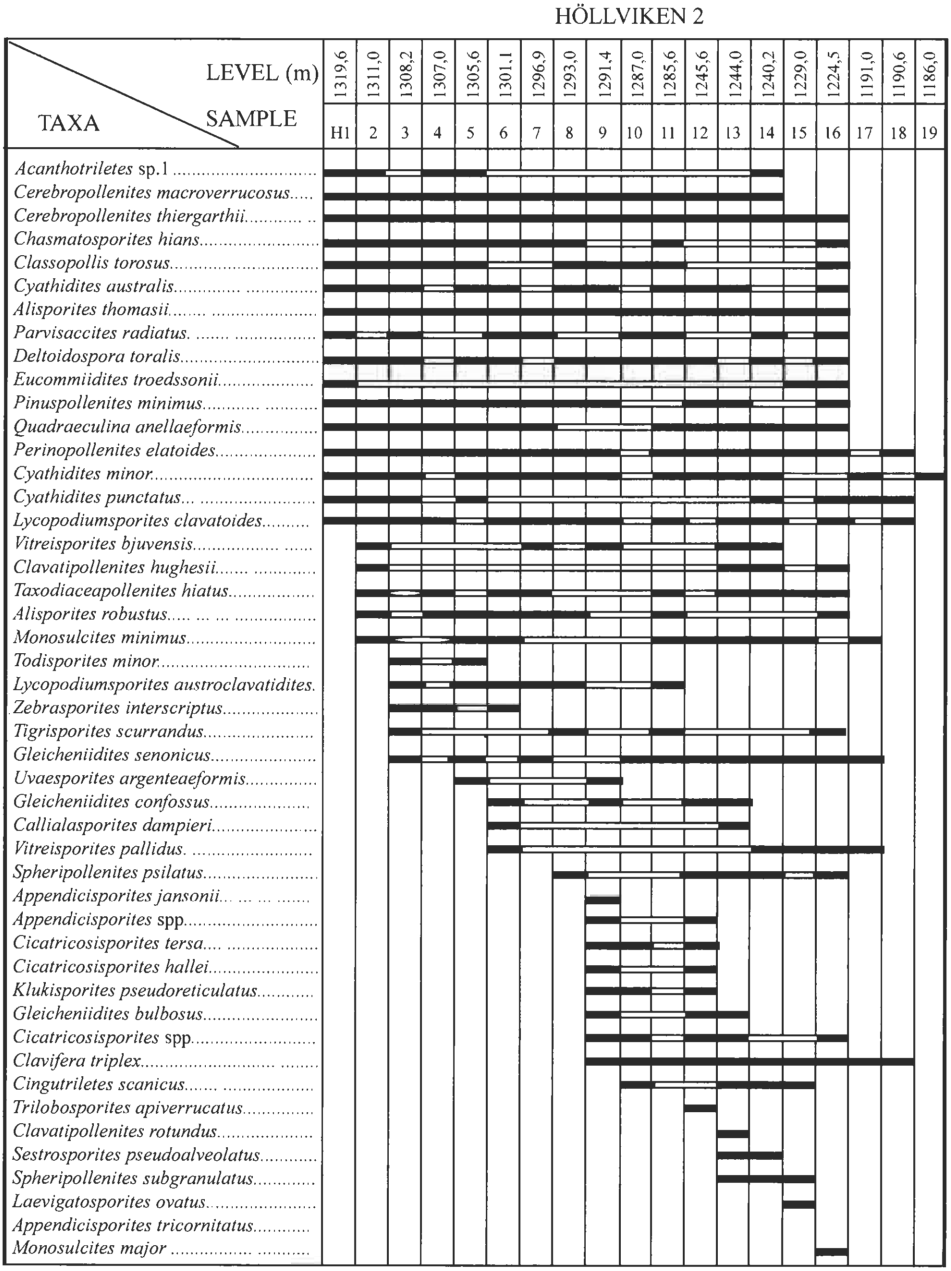

Fig. 6. Occurrence of characteristic spore pollen species in the Cretaceous sequences of Höllviken 2, Svedala 1, and Norrevång 1 wells.

Zone A

Höllviken 2, 1319–1291.4 m, samples H1–H8 (Fig. 3).

This zone is defined on the presence of *Zebrasporites interscriptus* (Thiergart) Klaus, *Cerebropollenites macroverrucosus* (Thiergart) Schulz, *C. thiergartii* Schulz, *Classopollis torosus* Pflug,

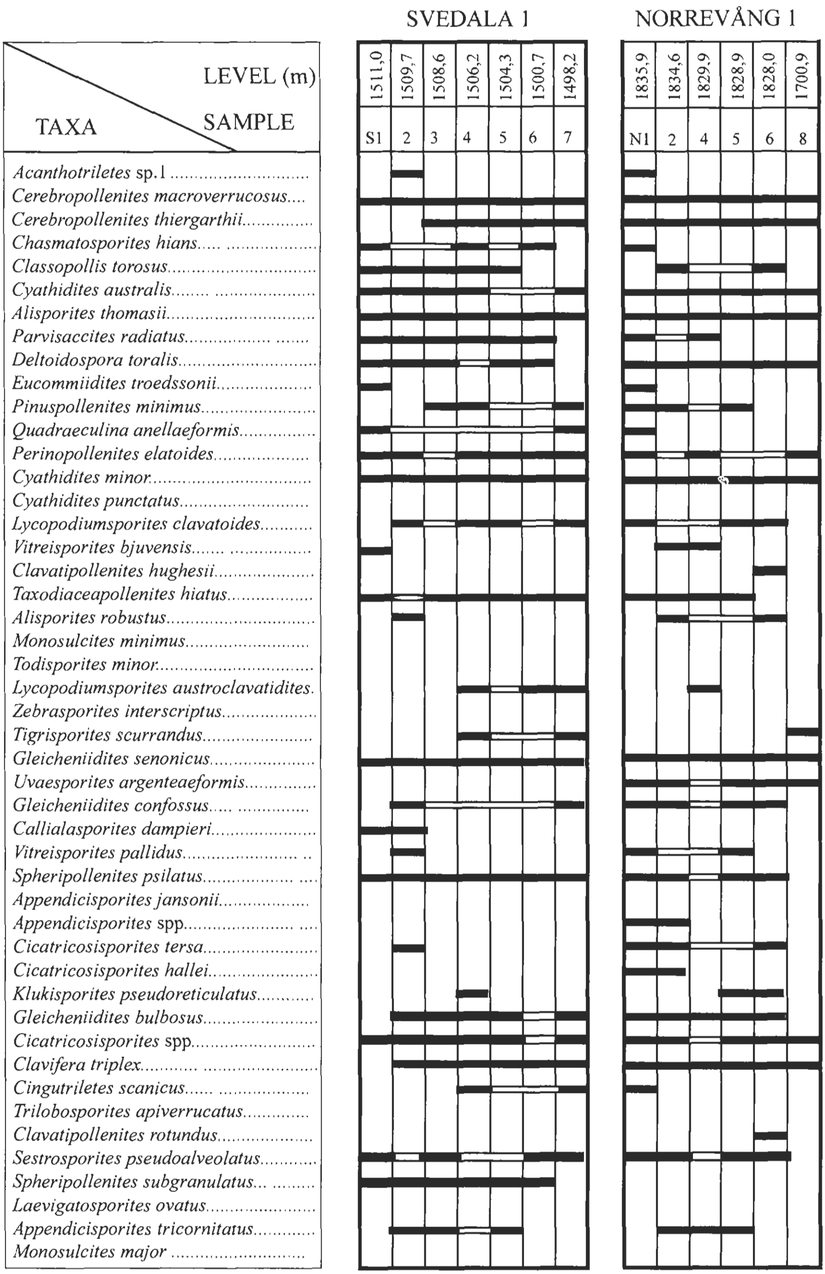

Fig. 6. Continued.

Deltoidospora australis Couper, *D. minor* Couper, *D. toralis* (Leschik) Lund and *Perinopollenites elatoides* Couper which is also the dominant species, making up 26% (mean value for the eight samples of the zone) of the palynoflora (Figs. 6, 7). The relative frequencies of the miospore species are used to compare the assemblages with other assemblages described from the same basin. The species belonging to the genus *Cerebropollenites* constitute 8% of the palynoflora and *Classopollis* spp. 5%. The smooth-walled *Deltoidospora* spp. form 20% of the miospore assemblage.

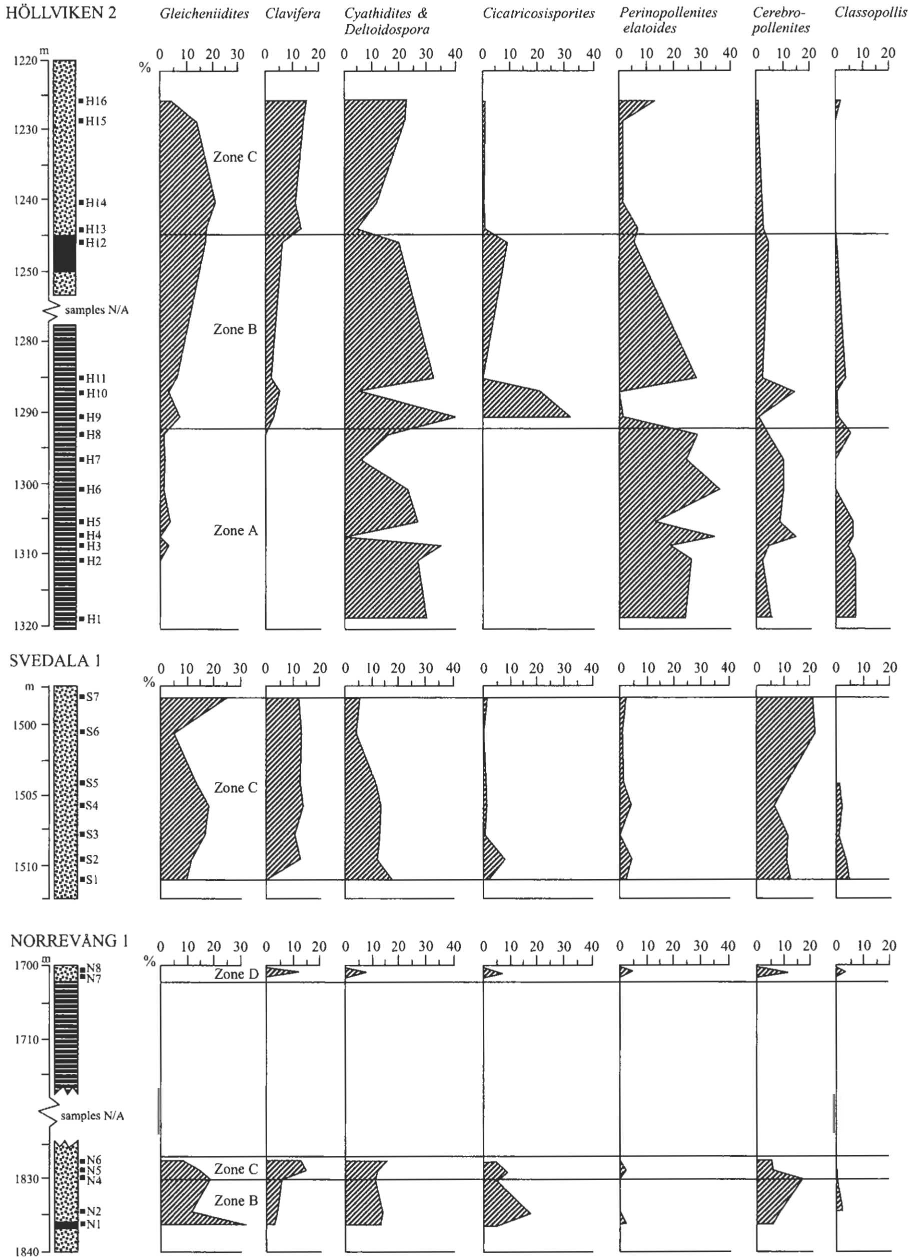

Fig. 7. Pollen diagram, showing frequency of major miospore groups.

Among the bisaccate pollen grains the dominating genera are *Alisporites* and *Pinuspollenites*. Miospores present at low frequencies are *Spheripollenites psilatus* Couper, which first appears at 1293 m and *Monosulcites minimus* Cookson at 1311 m (Fig. 6). Three specimens of *Clavatipollenites* sp. were recovered at 1311 m.

Gleicheniidites senonicus Ross is only present in small quantities, less than 1%, and no other species of this genus is represented. The assemblage is completely devoid of marine palynomorphs.

Age assessment. — Middle Jurassic, tentatively Aalenian.

Comparisons. — The abundant occurrence of *Perinopollenites elatoides* Couper together with the presence of *Classopollis* and *Spheripollenites* makes the assemblage comparable to the assemblage of the *Perinopollenites elatoides* Zone (Dybkjaer 1991) of Toarcian–Aalenian age. Dybkjaer referred only to a distinct increase in abundance of *P. elatoides* and a concurrent decrease in *C. torosa* and *S. psilatus* as marking the base of her *P. elatoides* Zone. According to Batten & Koppelhus (1996), the Toarcian stage of NW Europe was marine, but a facies change is seen in late Aalenian, which was dominated by shallow marine and non-marine deposition. According to Batten & Koppelhus (1996), the Aalenian–Bathonian assemblages are characterised by a high number of *Perinopollenites elatoides*. The younger assemblage of Oppegård Bore 1 (Toarcian–Aalenian age), described by Guy-Ohlson & Malmquist (1985) is very similar to Assemblage A of this study with respect to the composition of the palynoflora.

Zone B

Höllviken 2, 1291.4–1245.6 m, samples H9–H12 (Fig. 3).
Norrevång 1, 1835.9–1829.9 m, samples N1–N4 (Fig. 5).

The zone is defined on the first appearance of the typical Early Cretaceous genera *Appendicisporites* and *Cicatricosisporites* (Fig. 6), which are abundant (maximum of 18% in Höllviken 2), and which together with *Deltoidospora,* characterise Zone B (Fig. 7). Other first appearances within the zone are *Clavifera triplex* (Bolchovitina) Bolchovitina *Appendicisporites jansonii* Pocock, *Cicatricosisporites hallei* Delcourt & Sprumont, *Cicatricosisporites tersa* (Kara-Mursa) Pocock, *Gleicheniidites bulbosus* Kemp, and *Klukisporites pseudoreticulatus* Couper (Fig. 6).

A marked decrease in the abundance, compared to Zone A of *Cerebropollenites* (now 3%) and *Classopollis* (1.5%) in Höllviken 2 is noted (Fig. 7). At the base of the zone (1291.4 m), the first marine palynomorphs appear, still only composing 1–2% of the total organic content but clearly indicating marine influence. The dinoflagellate *Odontochitina operculata* (O. Wetzel) Deflandre and Cookson, is found; its known range is early Barremian to late Maastrichtian (Costa & Davey 1992).

According to Herngreen *et al.* (1996), Early Cretaceous floras are characterised by an increase of the spore genera *Appendicisporites* and *Cicatricosisporites, Appendicisporites jansonii* has previously been encountered in sediments of early Cretaceous age (Pocock 1962). *Clavifera triplex* appears at the Berriasian/Valanginian boundary (Herngreen *et al.* 1996). According to Dörhöfer (1979), the presence of *Appendicisporites crimensis* (Kara-Mursa) Pocock, *Appendicisporites jansonii*, *Cicatricosisporites hallei*, and *Clavifera triplex* excludes an age older than Berriasian.

Age assessment. — Valanginian to Hauterivian (Figs. 3, 5).

Comparisons. — By comparison with the work of Guy-Ohlson (1982) it is shown that assemblage B of this study has much in common with the assemblages from Kullemölla of Berriasian to Hauterivian age (641.00–623.09 m). A similar assemblage was described from the Valanginian-Hauterivian strata from the west Netherlands basins (Van Amerom *et al.* 1976). Assemblage B of this study is also comparable with that of Zone C (Valanginian-Hauterivian) described by Andersen (1988) from the Danish Subbasin, and with that of Zone III of Mamczar (1986) from the Polish lowlands. Both are characterised by the presence of, for example, *Appendicisporites tricornitatus* and *Clavifera triplex.*

Zone C

Höllviken 2, 1245.6–1224.5 m, samples H13–H16 (Fig. 3).
Svedala 1, 1510.95–1498.25 m, samples S1–S7 (Fig. 4).
Norrevång 1, 1828.9–1828 m, samples N5, N6 (Fig. 5).

The zone is defined by the appearance of the typical Aptian–Albian species such as *Reticulisporites vermiformis* Kemp, ranging from Aptian–Albian (Guy-Ohlson 1984), *Monosulcites major* Kemp, ranging from early Aptian to early late Albian (Kemp 1970). *Alisporites elongatus* Kemp, *Clavatipollenites rotundus* Kemp, *Laevigatosporites ovatus* Wilson & Webster, ranging from early late

Aptian to Albian. Characteristic for the assemblage is also an increase in abundance of the spores *Clavifera triplex* and *Gleicheniidites*. There is an abrupt decrease in frequency of the striatrilete spores (*Cicatricosisporites* spp.) of which only a few specimens are present.

Age assessment. — Aptian–early Albian.

Comparisons. — The assemblage is comparable to that described by Kemp (1970) from Aptian–Albian strata of southern England, and to that in Couper (1958), who described the Lower Greensand (Aptian). Taxa in common in the Lower Greensand of England are *Appendicisporites tricornitatus* Weiland & Krieger, *Cicatricosisporites braevilaesuratus* Couper, *Clavatipollenites hughesii* Couper, *Concavisporites punctatus* Couper, *Gleicheniidites senonicus*, *Parvisaccites radiatus* Couper, *Sestrosporites pseudoalveolatus*, *Spheripollenites psilatus*, and *Spheripollenites scabratus* Couper. All of these taxa are represented in Zone C.

Zone D

Höllviken 2, 1191–1190 m, samples H17, H18 (Fig. 3).
Norrevång 1, 1700.9 m, samples N7, N8 (Fig. 5).

This zone reflects considerable marine influence and is very poor in identifiable miospores, so the age assessment is mainly based on foraminifera (Larsson *et al.* 2000). Identifiable miospores are long rangeing taxa such as *Clavifera triplex*, *Deltoidospora australis*, *D. minor*, *Gleicheniidites senonicus* but also *Rugubivesiculites reductus* Pierce is present. The pollen grains of the genus *Rugubivesiculites*, which in high percentages are indicative of a Cenomanian age, are encountered at 1190 m, in Höllviken 2. All of the other palynomorphs consist of corroded specimens of bisaccate pollen grains and psilatrilete spores.

Samples N7 and N8 at Norrevång 1, from 1700.9 m, are tentatively included in pollen Zone D. The marine influence is strong and the assemblage is of the same palynofacies, with many dinoflagellate cysts and amorphous organic matter (AOM).

Age assessment. — Cenomanian.

The samples H19 and H20 are of Turonian age, and the stratigraphy is entirely based on foraminifera.

Paleovegetation and paleoclimate

The relative frequencies of the miospore taxa have been used as a suggestion for the reconstruction of the vegetation. Though many problems are involved in attributing dispersed pollen grains and spores to the parent plant, counts of the frequencies of miospores in large groups such as pteridophytes, gymnosperms and angiosperms may give a picture of the paleovegetation (Fig. 8).

In a study of Jurassic miospores (Hubbard & Boulter 1997) the attribution of pollen groupings to paleoclimatic conditions was a matter of interpretation and closely comparable patterns could be seen in the cyst and pollen diagrams in Riding & Hubbard (1999). They also made paleoclimatological correlations between marine and terrestrial depositional environments and between the northern and southern hemispheres and the results indicated that the patterns reflect global temperature regimes which can be comparable with present day climates.

But caution has to be taken as the climate of the Mesozoic was much more equable than that of the Quaternary or today and there were for example no polar ice caps (Hallam 1985). For that reason humidity levels were playing a very important role in the distribution of fossil groups. (Parrish *et al.* 1982; Parrish 1993).

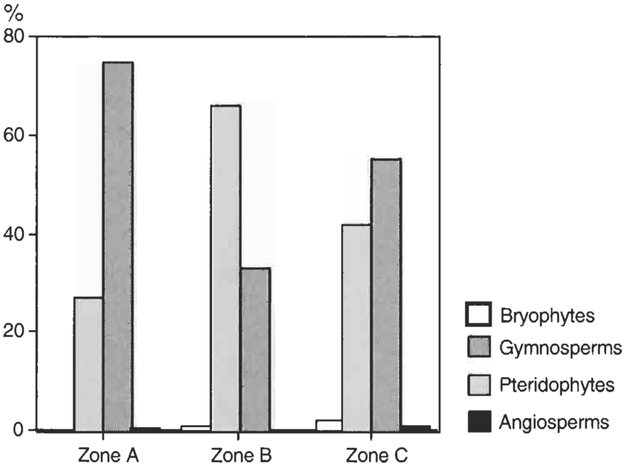

Fig. 8. Relative frequencies of different miospores grouped according to their probable affinities in Zones A, B, and C.

Zone A

Aalenian, samples H1, H8 (Fig. 3).

Evidence based on the palynofloral composition indicates that gymnosperms constituted the dominant terrestrial vegetation in SW Scania of assemblage A (Fig. 8). Gymnosperm pollen grains comprise 72% of the total palynoflora mainly represented by conifers, as for example *Perinopollenites elatoides* and the pollen grain *Cerebropollenites*, which according to Batten & Dutta (1997) is related to an extinct group resembling the extant *Tsuga.* The pollen grains of the arborescent conifers of the family Cheirolepidiaceae (*Classopollis*) are relatively numerous. Pteridosperms, here represented by *Vitreisporites*, do not attain 1%. Pteridophytes compose 27% of the miospore assemblage, represented by *Deltoidospora* species. The family Gleicheniaceae is poorly represented.

Van Amerom *et al.* (1976) stated that both *Classopollis* and *Perinopollenites* was produced by coastal plants. The miospore assemblage suggests that the sediments were deposited in a continental coastal area, under warm, dry climatic conditions. These results are in agreement with Vakhrameev (1991), who states that there were two types of vegetation assemblages in the Euro-Sinian region during the Early and Middle Jurassic. The first one, dominated by ferns and horsetails, characteristic of a moist climate- a typical environment for intra-mountain lowlands. The second type of vegetation occurred under conditions of a drier micro-climate on the near-shore mountain slopes and the vegetation was dominated by Cheirolepidiaceae and Araucariaceae and a low percentage of ferns, just as in this study.

Zone B

Valanginian-Hauterivian, samples H9–H12; N1–N4 (Figs. 3, 5).

This zone is characterised by a high amount of pteridophytes (66% of the palynoflora) and the ferns are not only more abundant but also show a higher degree of diversity than in Zone A. The ferns are still dominated by spores of the genus *Deltoidospora*, but spores belonging to the family Gleicheniaceae increase in both frequency and diversity. The family Schizaeaceae is represented by the spore genera *Appendicisporites* and *Cicatricosisporites.* The gymnosperms comprise 33% of the palynoflora, but a decrease in the *Classopollis* content is seen. Bryophyte spores make up 1%.

The increase of the pteridophytes indicates a more humid climate in comparison with mid- Jurassic times. The decrease of the *Classopollis* pollen also indicates a more moist and cooler climate. Investigations from Russia shows that a gradual decline in temperature throughout the Early Cretaceous from the Berriasian to the Barremian is seen as coinciding with a decline in the percentage of *Classopollis* pollen grains (Yasamanow & Petrosyants 1983).

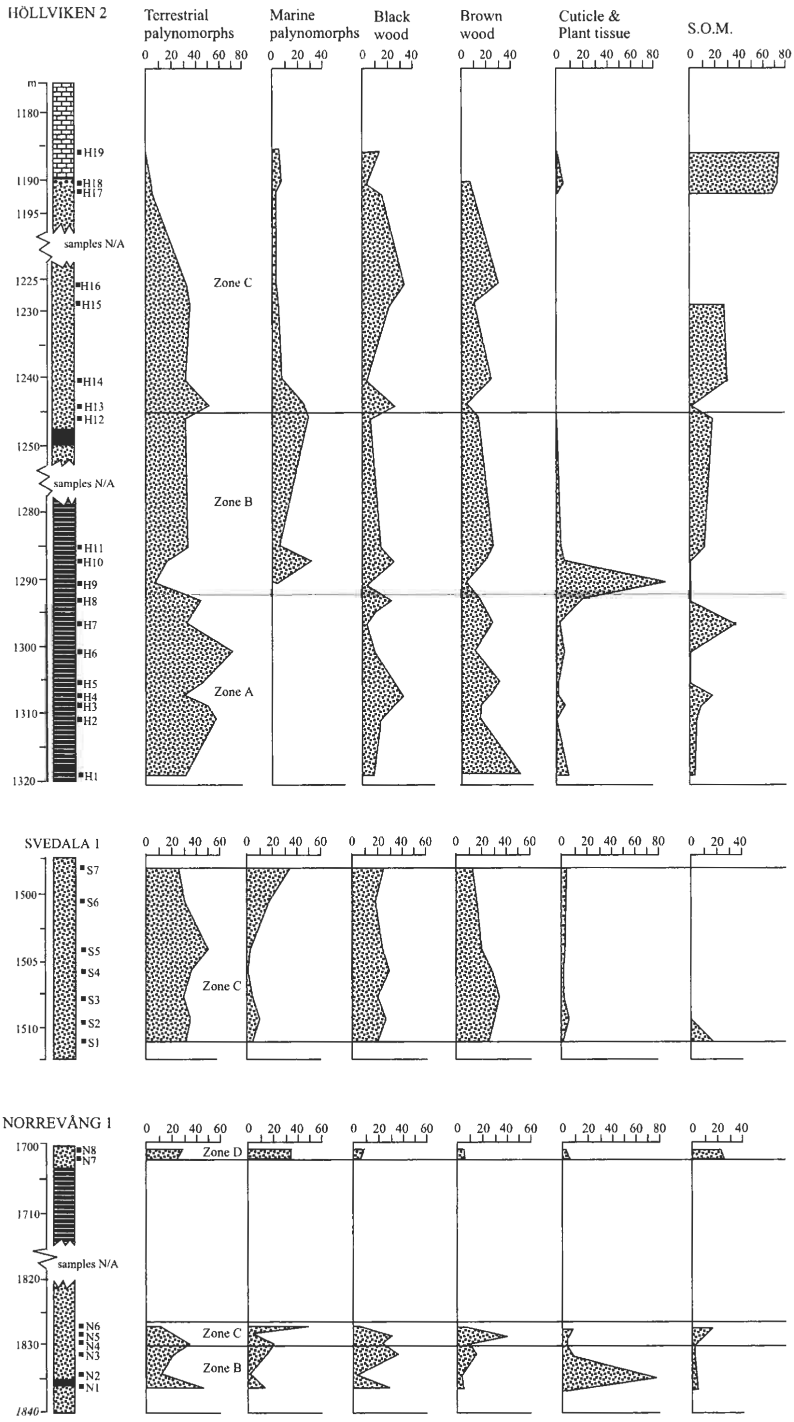

Fig. 9. Palynofacies results from Höllviken 2, Svedala 1 and Norrevång 1 wells.

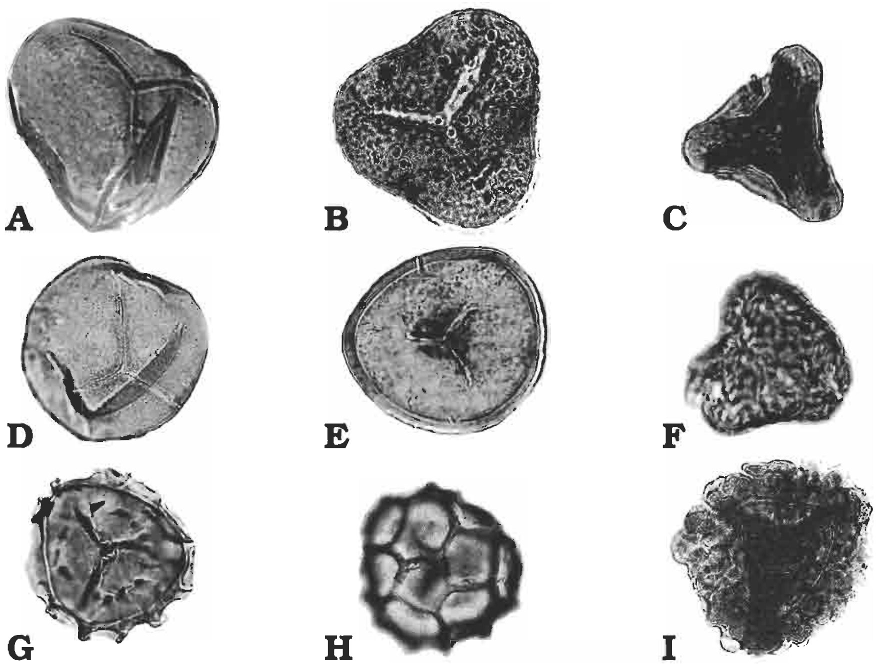

Fig. 10. **A**. *Deltoidospora australis* Couper; H13-1, EFR-Z33, LO 7968t. **B**. *Deltoidospora punctatus* (Delcourt & Sprumont); H9-1, EFR-P36, LO 7970t. **C**. *Deltoidospora juncta* (Kara-Mursa); H16-1, EFR-Z29, LO 7619t. **D**.*Todisporites minor* Couper; H2-1, EFR-H31/1, LO 7973t. **E**. *Stereisporites antiquasporites* (Wilson & Webster); X1200; H13-1, EFR-Z20/2, LO 7974t. **F**. *Reticulisporites vermiformis* Kemp; N1-3, EFR-U43/4, LO 7983t. **G**, **H**. *Lycopodiumsporites clavatoides* (Couper). **G**. Proximal side, H16-1, EFR-Y41, LO 7982t. **H**. Distal side. **I**. *Uvaesporites argenteaeformis* (Bolchovitina); N5-3, EFR-P36, LO 7978t. All × 500.

Zone C

Aptian–early Albian samples, H13–H18; S1–S7, N5–6 (Figs. 3, 4, 5).

Again the gymnosperms are the dominating group (55%), mainly conifers, represented by laevigate spherical pollen grains (*Spheripollenites)* and bisaccate pollen grains. Cycads (*monosulcites*) make up a smaller part of the gymnosperms. Monocolpate grains, e.g. *Monosulcites minimus* with possible cycad or/and ginkgo affinities occur, sparsely in nearly all samples. The pteridophytes constitute 42% of the palynoflora. Notable is the considerable increase of spores belonging to the family Gleicheniaceae. Striatrilete spores (*Cicatricosisporites* spp.) are only represented by a few specimens, suggesting a very limited representation of this family. Bryophytes make up 2% and angiosperm pollen grains 1% of the total palynoflora.

The dominance of ferns and gymnosperm pollen grains suggest a cooler and moist climate. There is a good agreement that both air and seawater temperatures decreased during this period (Vakhrameev 1991). According to Vakhrameev (1991), the 'late Albian is marked by a temperature decrease and increased humidity'.

Palynofacies and sea-level changes

In order to obtain more information on the depositional environment, a palynofacies analysis was attempted; 300 particles of organic matter were counted from each sam-

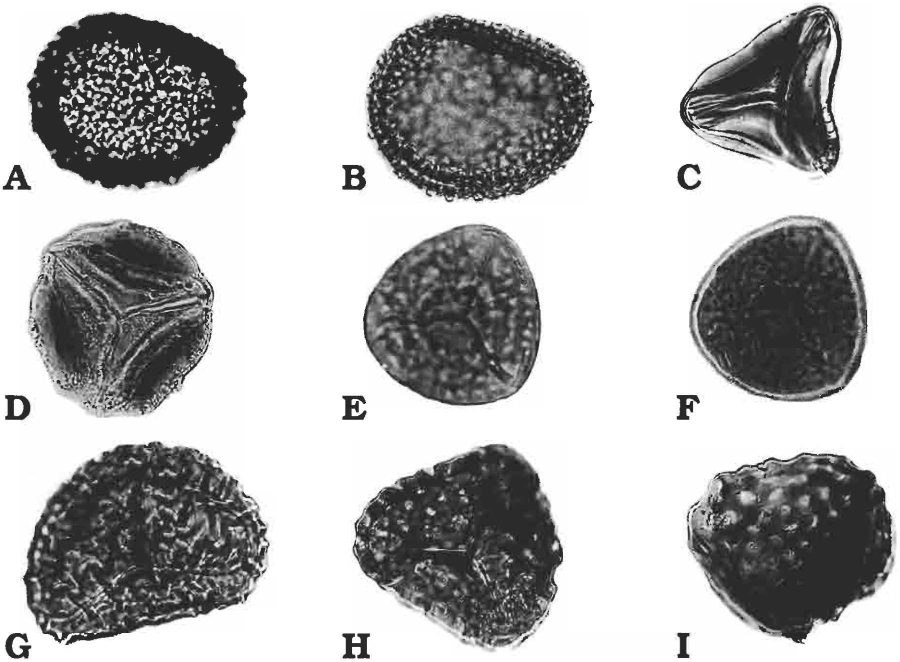

Fig. 11. **A**, **B**. *Baculatisporites comaumensis* (Cookson). **A**. High focus; H13-1, EFR-X22, LO7975t. **B**. Low focus. **C**. *Gleicheniidites senonicus*; H13-1, EFR-G27/3, LO 7999t. **D**. *Gleicheniidites bulbosus*; N1-2, EFR-P41/2, LO 8002t. **E**, **F**. *Staplinisporites caminus* (Balme). **E**. High focus; H9-1, EFR-C36/3, LO 7984t. **F**. Low focus. **G**. *Lycopodiacidites rugulatus* (Couper); H16-3, EFR-E33, LO 7985t. **H**. *Klukisporites pseudoreticulatus* Couper; proximal side; H8-1, EFR-K37, LO 7986t. **I**. *Klukisporites pseudoreticulatus*; N5-3, EFR-S33/1, 7987t. All × 500.

ple and classified in the following groups: terrestrial palynomorphs, aquatic palynomorphs, wood, cuticle and plant tissue and AOM. The results are shown in Fig. 9. Photographs of selected pollen and spores are presented in Figs. 10–15.

In the sediments of Zone A (Aalenian age), 42% of the total organic matter consists of miospores, the rest being mainly composed of wood remains (44%) and AOM (9%). Cuticle and plant tissues are present in low frequencies. This palynoflora is well preserved and is dominated by gymnosperm pollen grains. These results agree with the current opinion that during the Middle Jurassic, a mostly marginal marine to non-marine depositional environment prevailed in Europe (Batten & Koppelhus 1996).

A large stratigraphic gap encompasses the late Jurassic to Berriasian. There are difficulties defining the Jurassic–Cretaceous boundary in Northern Europe because in several areas, no significant lithological change is noted and the beds show a scarcity of stratigraphically important fossils (Norling 1981). In addition, the fact that the marine faunas of the latest Jurassic–earliest Cretaceous showed a distinct provincialism makes the correlation of the boundary within Europe very difficult (Batten 1996). It is suggested that, in Scania, the Jurassic–Cretaceous boundary is within the Vitabäck Clays (Norling *et al.* 1993) although further surveys are necessary in order to verify this.

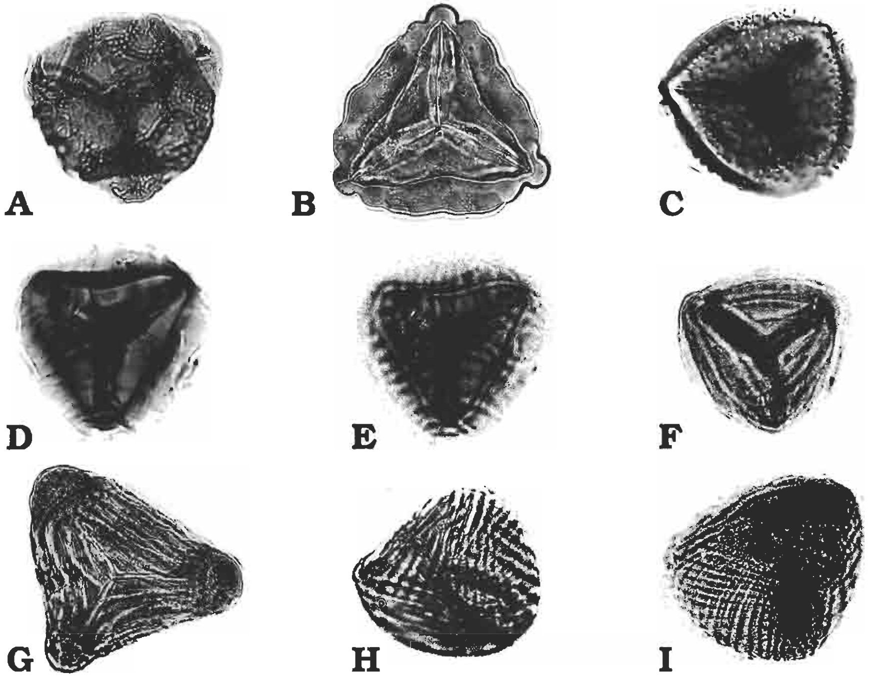

Fig. 12. **A**. *Gleicheniidites apilobatus* Brenner; H9-1, EFR-C42/1, LO 8003t. **B**. *Clavifera triplex* Bolchovitina; H16-1, EFR-M16, LO 8004t. **C**. *Sestrosporites pseudoalveolatus* (Couper); H13-1, EFR-R 25/4, LO 8005t. **D**, **E**. *Zebrasporites interscriptus* (Thiergart). **D**. High focus; H9-1, EFR-P36/2, LO 8008t. **E**. Low focus. **F**. *Appendicisporites* cf. *A. crimensis* (Bolchovitina); H9-1, EFR-M42/2, LO 7993t. **G**. *Appendicisporites jansonii* Pocock; H9-1, EFR-C31/4, LO 7989t. **H**. *Cicatricosisporites tersa* (Kara-Mursa); H9-1, EFR-H40/2, LO 7996t. **I** *Cicatricosisporites hallei* Delcourt & Sprumont; H9-1, EFR-P43, LO 7997t. All × 500.

The facies of Late Jurassic are mainly marine (Batten & Koppelhus 1996) but at the very end of the Late Jurassic, deltaic conditions prevailed in SW Scania (Norling *et al.* 1993), which continued into the Early Cretaceous.

In Zone B, the results from the palynofacies analysis shows that at the base of Zone B (Valanginian), only 1% of the organic matter consists of marine palynomorphs (Höllviken 2).

At 1287 m, Höllviken 2, there is an increase in the frequency of marine palynomorphs to 30%, the frequency of wood remains is high and the particles are angular, perhaps indicating an input of terrestrial debris from a nearby source. During Valanginian times, the first indication of marine influence on the depositional environment is noted, pointing to a marginal marine depositional environment which subsequently became more marine.

Towards the end of the Early Cretaceous, marine influence increased, resulting in the deposition of dark shales and glauconitic sandstone (greensand). The deposition of glauconitic sandstone continued into the Cenomanian (Larsson *et al.* 2000). At the base of Zone C, (Aptian) the fairly high frequency of the marine palynomorphs persists (30%) but the organic matter is still dominated by pollen and spores. A decrease in marine palynomorphs is noted upwards in the zone while the frequency of terrestrial

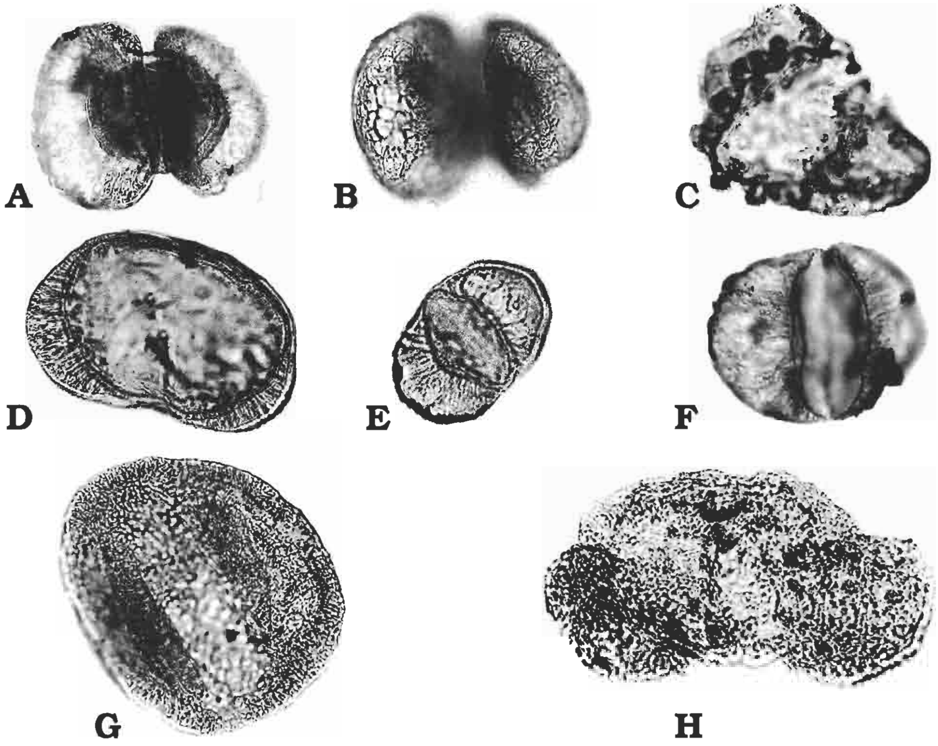

Fig. 13. **A**, **B.** *Podocarpidites dettmanii Kemp.* **A**. Low focus; H13-1, EFR-F40/3, LO 8021t. **B**. High focus. **C**. *Rugubivesiculites reductus* Pierce; H17-1, EFR-P22/4, LO 8023t. **D**. *Parvisaccites radiatus* Couper; S6-1, EFR-P36/2, LO 8017t. **E**. *Vitreisporites pallidus* (Reissinger); S6-1, EFR-K27/1, LO 8016t. **F**. *Vitreisporites* cf.*V. bjuvensis* Nilsson; S1-1, EFR-S33, LO 8019t. **G**. *Quadraeculina anellaeformis* Malyavkina; H16-1, EFR-W34/4, LO 8014t. **H**. *Pinuspollenites minimus* (Couper); H16-3, EFR-O37, LO 8020t. All × 500.

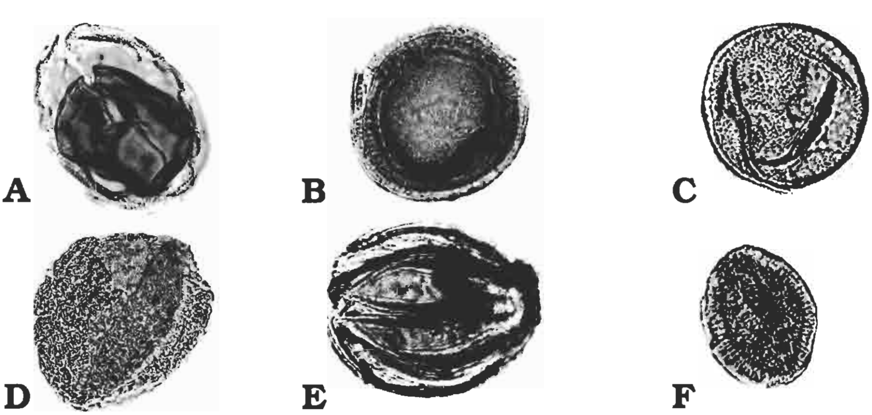

Fig. 14. **A**. *Perinopollenites elatoides*; H13-1, EFR-P29/3, LO 8035t. **B**. *Classopollis* sp; H8, EFR-P44, LO 8040t. **C**. *Spheripollenites subgranulatus* Couper; H13-1, EFR-G17, LO 8028t. **D**. *Cerebropollenites thiergartii* Schulz; S7-1, EFR-K43/3, LO 8029t. **E**. *Eucommiidites troedssonii Erdtmann*; H16-1, EFR-N40, LO 8030t. **F**. *Clavatipollenites hughesii*; H16-1, EFR-M33/1, LO 8032t. All × 500.

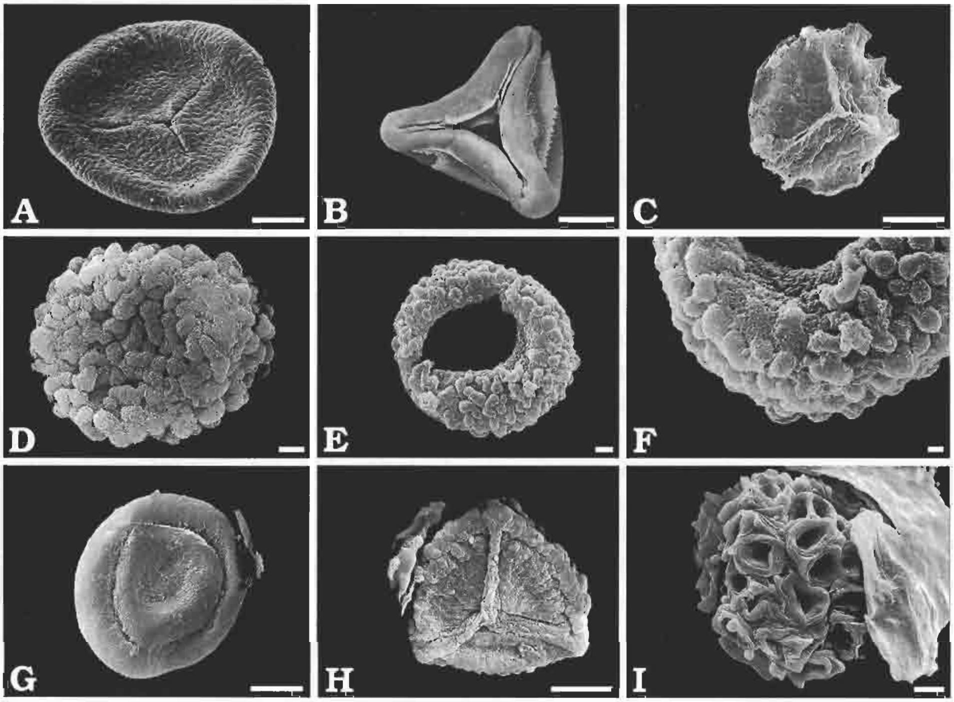

Fig. 15. **A**. *Sestrosporites pseudoalveolatus* (Couper). Proximal side; N1-1, LO 8046t. **B**. *Deltoidospora toralis* (Leschik), proximal side; N1-1, LO 8054t. **C**. *Lycopodiumsporites clavatoides* (Couper), proximal side; H15-1; LO 8055t. **D**. *Cerebropollenites macroverrucosus* (Thiergart), distal side; H15-1, LO 8064t. **E**, **F**. *Cerebropollenites macroverrucosus*. **E**. Proximal side; H15-1, LO 8065t. **F**. Close up. **G**. *Classopollis* sp., distal side, showing the cryptopore and the subequatorial circumpolar canal; H5-3, LO 8063t. **H**. *Uvaesporites argenteaeformis* (Bolchovitina); N5-3, LO 8066t. **I**. *Botryococcus braunii* Kützing; H16-2, LO 8069t. SEM micrographs of spores and aquatic palynomorphs. Scal bars are 10 μm exept **F** which is 1 μm.

palynomorphs is maintained (c. 40% of the organic component). Wood remains however, increase. A shallow marine depositional environment presumably prevailed.

Finally in Zone D (Cenomanian), the organic matter is quantitatively dominated by AOM and miospores are poorly preserved. An inner-shelf environment is suggested.

Conclusions

- The mid Jurassic, tentatively Aalenian–Cretaceous palynofloras from SW Scania are well preserved and comprise over 80 miospore taxa.
- On the basis of the palynofloral content four zones have been defined. The following age assessments are proposed, for borehole sections examined, from the basal beds upwards:
  - Zone A, Aalenian; samples H1–H8 (1319.6–1291.4 m). A stratigraphical gap encompasses the Late Jurassic to Berriasian.

- Zone B, Valanginian-Hauterivian; samples H9–H12 (1291.4–1245.6 m); N1–N4 (1835.9–1829.9 m).
- Zone C, Aptian–early Albian; samples H13–H16 (1245.6–1224.5 m); S1–S7 (1510.95–1498.25 m): N5, N6 (1828.9–1828.0 m).
- Zone D, Cenomanian; samples H17, H18 (1191.0–1190.0 m); N8 (1700.6 m)
- Samples H19, H20, Turonian 1190.0–1179 m (based on foraminifera).

A continental depositional environment prevailed during the Aalenian (Zone A). This is inferred from the composition of the palynoflora and the absence of marine palynomorphs. Conifers initially dominated the vegetation with pteridophytes forming a minor element, and a warm dry climate is proposed during the period of deposition. During the Valanginian, marine conditions prevailed in the area. A marginal marine depositional environment is suggested for the basal sediments of Zone B. The vegetation was dominated by ferns, probably as a result of a more humid climate. During the Aptian to early Albian, gymnosperms, of which the conifers were the main group, dominated over the pteridophytes. The depositional environment was shallow marine with fluctuations in sea level recorded by variations in the frequency of marine palynomorphs. The gradual increase in marine palynomorphs upward in the sequences is probably indicative of a gradual increase in distance from land.

Acknowledgements

I express my appreciation to Dr. Ian Raine and Dr. Karen Dybkjaer for revision and important suggestions concerning the manuscript. I would like to thank Professor Kent Larsson and Nikolaos Solakius for contributing invaluable data and for sharing their knowledge in Cretaceous palaeontology. I would also like to thank the referees, Dr. Richard Lupia and Dr. Johanna H.A van Konijnenburg-van Cittert for comments and suggestions which helped to improve this paper. Ms. Sharon Mc Glinn is acknowledged for the linguistic revision. The financial support of The Royal Swedish Academy of Sciences enabled this study to be accomplished.

References

Andersen, E. 1988. *Nedre Kridt Mikrofloraen i Fredrikshavn nr. 1 Boringen.* MSc. thesis (unpublished), Geologisk Institut Aarhus University, Denmark.

Balme, B. 1995. Fossil in situ spores and pollen grains: An annotated catalogue. — *Review of Palaeobotany and Palynology* **87**, 81–323.

Batten, D.J. 1996. Upper Jurassic and Cretaceous miospores. *In*: J. Jansonius & D.C. McGregor (eds.), Palynology: Principles and Applications. — *American Association of Stratigraphic Palynologists Foundation* **2**, 807–830.

Batten, D.J. & Koppelhus, E. 1996. Biostratigraphic significance of uppermost Triassic and Jurassic miospores in Northwest Europe; *In*: J. Jansonius & D.C. Mc. Gregor (eds.), Palynology: Principles and Applications. — *American Association of Stratigraphic Palynologists Foundation* **2**, 795–806.

Batten, D.J. & Dutta R.J. 1997. Ultrastructure of exine of gymnospermous pollen grains from Jurassic and basal Cretaceous deposits in Northwest Europe and implications for botanical relationships. — *Review of Palaeobotany and Palynology* **99**, 25–54.

Brotzen, F. 1945. De geologiska resultaten från borrningarna vid Höllviken. Del 1: Kritan. — *Sveriges Geologiska Undersökning C* **465**, 1–64.

Brotzen, F. 1950. De geologiska resultaten från borrningarna vid Höllviken. Del. II: Undre kritan och trias. — *Sveriges Geologiska Undersökning C* **505**, 1–48.

Burger, D. 1966. Palynology of uppermost Jurassic and Lower Cretaceous strata in the Eastern Netherlands. — *Leidse Geologische Mededlingen* **33**, 63–69.

Costa, L.I. & Davey, R.J. 1992. Dinoflagellate cysts of the Cretaceous System. *In*: A.J. Powell (ed.), *A Stratigraphic Index of Dinoflagellate Cyst*, 99–153. British Micropaleontological Society, Chapman & Hall, London.

Couper, R.A. 1958. British Mesozoic microspores and pollen grains. — *Palaeontographica Abt. B* **103**, 75–179.

Dybkjaer, K. 1991. Palynological zonation and palynofacies investigation of the Fjerritslev Formation (Lower Jurassic–basal Middle Jurassic) in the Danish Subbasin. — *Danmarks Geologiske Undersogelse A* **30**, 1–150.

Dörhöfer, G. 1979. Distribution and stratigraphic utility of Oxfordian to Valanginian miospores in Europe and North America. — *American Association of Stratigraphic Palynologists Contribution Series* **5B**, 101–132.

Erlström, M. Guy-Ohlson, D., & Sivhed, U. 1991. Upper Jurassic–Lower Cretaceous petrography and stratigraphy at Eriksdal, Scania, Southern Sweden. — *Sveriges Geologiska Undersökning C* **78**, 1–59.

Erlström, M., Thomas, S.A., Deeks, N., & Sivhed, U. 1997. Structure and tectonic evolution of the Tornquist Zone and adjacent sedimentary basins in Scania and the southern Baltic Sea area. — *Tectonophysics* **271**, 191–215.

Friis, E.M. 1983. Upper Cretaceous (Senonian) floral structures of Juglandalean affinity containing Normapolles pollen. — *Review of Palaeobotany and Palynology* **39**, 161–188.

Friis, E.M. & Skarby, A. 1981. Structurally preserved angiosperm flowers from the Upper Cretaceous of Southern Sweden. — *Nature* **291**, 485–486.

Friis, E.M. & Skarby, A. 1982. *Scandianthus* gen. nov., angiosperm flowers of saxifragalean affinity from the Upper Cretaceous of southern Sweden. — *Annals of Botany* **50**, 569–583.

Friis, E.M., Crane, P.R., & Pedersen, K.R. 1986. Floral evidence for Cretaceous chloranthoid angiosperms. — *Nature* **320**, 163–164.

Guy-Ohlson, D. 1978. Jurassic biostratigraphy of three borings in NW Scania (A brief palynological report). — *Sveriges Geologiska Undersökning* **11**, 1–41.

Guy-Ohlson, D. 1982. Biostratigraphy of the Lower Jurassic–Cretaceous unconformity at Kullemölla southern Sweden. — *Sveriges Geologiska Undersökning* **52**, 1–45.

Guy-Ohlson, D. 1984. Albian biostratigraphy of the Sixtorp Bore No. 1, north-east Scania, Sweden. — *Geologiska Föreningens i Stockholm Förhandlingar* **106**,193–205.

Guy-Ohlson, D. & Malmquist, E. 1985. Lower Jurassic biostratigraphy of the Oppegård Bore No 1, NW Scania, Sweden. — *Sveriges Geologiska Undersökning* **40**, 1–27.

Hallam, A. 1985. A review of Mesozoic climates. — *Journal of the Geological Society of London* **142**, 433–445.

Herngreen, G.F.W., Kedves, L.V., Rovnina, & Smirnova S.B. 1996. Cretaceous palynofloral provinces: a review. *In*: J. Jansonius & D.C McGregor (eds.), Palynology: Principles and Applications. — *American Association of Stratigraphic Palynologists Foundation* **3**, 1157–1188.

Hubbard, R.N.L.B. & Boulter, M.C. 1997. Mid Mesozoic floras and climates. — *Palaeontology* **26**, 321–387.

Kemp, E.M. 1970. Aptian and Albian miospores from Southern England. — *Palaeontographica Abteilung B* **131**, 73–143.

Koppelhus, E.B. 1991. Palynology of the Lower Jurassic Ronne Formation on Bornholm, eastern Denmark. — *Bulletin of the Geological Society of Denmark* **39**, 91–109.

Koppelhus, E.B. & Batten, D.J. 1989. Late Cretaceous megaspores from southern Sweden: Morphology and paleoenvironmental significance. — *Palynology* **13**, 91–120.

Larsson, K., Solakius, N., & Vajda-Santivanez, V. 2000. Foraminifera and palynomorphs from the Greensand-limestone sequences (Aptian–Coniacian) in southwestern Sweden. — *Neues Jahrbuch für Geologie und Paläontologie* **216**, 277–312.

Mamczar, J. 1986. Palinostratigraphy of the uppermost Jurassic and Lower Cretaceous in the Polish Lowlands. — *Prace Institutu Geologicznego* **116**, 1–53.

Norling, E. 1981. Upper Jurassic and Lower Cretaceous geology of Sweden. — *Geologiska Föreningens i Stockholm Förhandlingar* **103**, 253–269.
Norling, E., Ahlberg, A., Erlström, M., & Sivhed, U. 1993. Guide to the Upper Triassic and Jurassic geology of Sweden. — *Sveriges Geologiska Undersökning* **82**, 1–71.
Parrish, J.T. 1993. Climate of the supercontinent Pangea. — *Journal of Geology* **101**, 215–233.
Parrish, J.T, Ziegler, A.M., & Scotese, C.R. 1982. Rainfall patterns and the distribution of coals and evaporites in the Mesozoic and Cenozoic. — *Palaeogeoraphy, Palaeoclimatology, Palaeoecology* **40**, 67–101.
Pocock, S.A.J. 1962. Microfloral analysis and age determination of strata at the Jurassic–Cretaceous boundary in the western Canada plains. — *Palaeontographica Abt. B* **111**, 1–95.
Poulsen, N.E.. Gudmundsson, L., Hansen, J.M., & Husfeldt, Y. 1990. Palynological preparation techniques, a new maceration tank-method and other modifications. — *Danmarks Geologiske Undersogelse C* **10**, 1–23.
Riding, B. & Hubbard, R.N.L.B. 1999. Jurassic (Toarcian to Kimmeridgian) dinoflagellate cysts and paleoclimates. — *Palynology* **23**, 15–30.
Ross, N.E. 1949. Investigations of the Senonian of the Kristianstad District, S. Sweden I. On a Cretaceous pollen and spore bearing clay deposit of Scania. —*Bulletin of the Geological Institution of the University of Uppsala* **34**, 25–43.
Skarby, A. 1964. Revision of *Gleicheniidites senonicus* Ross. — *Stockholm Contributions in Geology* **11**, 59–77.
Skarby, A. 1968. *Extratriporopollenites* (Pflug) emend. from the Upper Cretaceous of Scania, Sweden. — *Stockholm Contributions in Geology* **16,** 1–60.
Skarby, A. 1978. Optical properties of fossil *Schizaea* spores from the Upper Cretaceous of Scania. — *Grana* **17**, 111–123.
Skarby, A. 1986. Normapolles anthers from the Upper Cretaceous of Southern Sweden. — *Review of Palaeobotany and Palynology* **46**, 235–256.
Skarby, A. & Nilsson, L. 1982. Krittidsblommor från Skåne — 78 miljoner år gamla. *Fauna och Flora* **77**, 281–290.
Traverse, A. 1988. *Paleopalynology*. 600 pp. Unwin Hyman (ed.), Boston.
Vakhrameev, V.A. 1991. *Jurassic and Cretaceous Floras and Climates of the Earth.* 318 pp. Cambridge University Press, Cambridge.
Van Amerom, H.W.J., Herngreen, G.F.W., & Romein, B.J. 1976. Palaeobotanical and palynological investigation with notes on the microfauna of some core samples from the Lower Cretaceous in the West Netherlands Basin. — *Mededelingen Rijks Geologische Dienst* **27**, 41–79.
Vidal, G. 1988. A palynological preparation method. — *Palynology* **12**, 215–220.
Westin, H. 1992. *Cretaceous dinoflagellate cyst stratigraphy of the Höllviken1 well, Scania, Southern Sweden.* 175 pp. Doctoral Dissertation 1992. Department of Geology, University of Stockholm.
Yasamanow, N.A. & Petrosyants, M.A. 1983. Climatic conditions of early Cretaceous in Crimean–Caucasian region. Sovetskaya Geologiya **4**, 8–85.

Appendix

The list of miospore species recognised in this study.

Appendicisporites jansonii Pocock
Appendicisporites tricornitatus Weiland & Greifeld
Appendicisporites cf. *A. crimensis* (Kara-Mursa) Pocock
Appendicisporites spp.
Baculatisporites comaumensis (Cookson) Potonié
Calamospora mesozoica Couper
Ceratosporites cf. *C. parvus* Brenner
Cicatricosisporites brevilaesuratus (Couper) Kemp
Cicatricosisporites hallei Delcourt & Sprumont
Cicatricosisporites proxiradiatus Kemp

Cicatricosisporites tersa (Kara-Mursa) Pocock
Cicatricosisporites spp.
Cingutriletes spp.
Clavifera triplex (Bolchovitina) Bolchovitina
Concavissimisporites minimus Herngreen
Contignisporites cf. *C. glebulentus* Dettmann
Deltoidospora australis Couper
Deltoidospora minor Couper
Deltoidospora punctatus (Delcourt & Sprumont) Delcourt, Dettmann & Hughes
Deltoidospora toralis (Leschik) Lund
Deltoidospora juncta (Kara-Mursa) Singh
Densoisporites velatus Weyland & Krieger
Foveosporites subtriangularis (Balme) Kemp
Gleicheniidites apilobatus Brenner
Gleicheniidites confossus Hedlund
Gleicheniidites bulbosus Kemp
Gleicheniidites senonicus Ross
Klukisporites pseudoreticulatus Couper
Laevigatosporites ovatus Wilson & Webster
Lycopodiacidites rugulatus (Couper) Schulz
Lycopodiumsporites austroclavatidites (Cookson) Potonié
Lycopodiumsporites clavatoides Couper
Lycopodiumsporites glebulentus Kemp
Microreticulatisporis crassiexinous Brenner
Microfoveolatosporis sp. 1
Pilosisporites trichopapillosus (Thiergart) Delcourt & Sprumont
Reticulisporites vermiformis Kemp
Sestrosporites pseudoalveolatus (Couper) Dettmann
Staplinisporites caminus (Balme) Pocock
Stereisporites antiquasporis (Wilson & Webster) Dettmann
Stereisporites stereoides (Potonié & Vernitz) Thomson & Pflug
Tigrisporites scurrandus Norris
Todisporites major Couper
Todisporites minor Couper
Trilobosporites apiverrucatus Couper
Tripartina variabilis Maljavkina
Uvaesporites argenteaeformis (Bolchovitina) Schulz
Zebrasporites interscriptus (Thiergart) Klaus

Gymnosperm pollen
Araucariacites australis Cookson
Callialasporites dampieri (Balme) Dev
Callialasporites trilobatus (Balme) Dev
Cerebropollenites macroverrucosus (Thiergart) Schulz
Cerebropollenites thiergartii Schulz
Chasmatosporites apertus Nilsson
Chasmatosporites hians Nilsson
Classopollis torosus (Reissinger) Couper
Classopollis spp.
Eucommiidites stuartii Kemp
Eucommiidites troedssonii Erdtmann
Exesipollenites tumulus Balme
Monosulcites major Kemp
Monosulcites minimus Cookson

Monosulcites subgranulosus Couper
Perinopollenites elatoides Couper
Spheripollenites psilatus Couper
Spheripollenites scabratus Couper
Spheripollenites subgranulatus Couper
Taxodiaceapollenites hiatus (Potonié) Kremp

Gymnosperm pollen (bisaccates)
Alisporites elongatus Kemp
Alisporites grandis (Cookson) Dettmann
Alisporites microsaccus (Couper) Pocock
Alisporites robustus Nilsson
Alisporites thomasii (Couper) Nilsson
Alisporites spp.
Cedripites cretaceus Pocock
Parvisaccites radiatus Couper
Pinuspollenites minimus (Couper) Kemp
Pinuspollenites spp.
Pityosporites sp.
Podocarpidites dettmannii Kemp
Podocarpidites spp.
Quadraeculina anellaeformis Malyavkina
Rugubivesiculites reductus Pierce
Rugubivesiculites rugosus Pierce
Vitreisporites pallidus (Reissinger) Nilsson
Vitreisporites cf. *V. bjuvensis* Nilsson

Angiosperm pollen
Clavatipollenites hughesii Couper
Clavatipollenites rotundus Kemp

Aquatic palynomorph
Botryococcus braunii Kützing
Odontochitina operculata Wetzel
Apteodinium sp.

Lądowe, aaleńsko-cenomańskie palinoflory południowo-zachodniej Skanii (Szwecja)

VIVI VAJDA

Streszczenie

W pracy opisano rozproszone zespoły miospor pochodzące z 35 próbek rdzeni wiertniczych z otworów Höllviken 2, Norrevång 1 i Svedala 1, położonych w południowo-zachodniej Skanii, w Szwecji. Oznaczono ponad osiemdziesiąt taksonów pyłku i zarodników, wieku od aalenu po cenoman. Wyznaczono cztery poziomy pyłkowo-zarodnikowe na podstawie taksonów przewodnich i zmian częstości występowania poszczególnych grup miospor. Analiza palinofacjalna wskazuje, że w aalenie przeważało w Skanii kontynentalne środowisko sedymentacyjne. Luka stratygraficzna trwała od aalenu do walanżynu, kiedy to zapanował morski reżim sedymentacyjny, trwający aż do cenomanu. Stopniowy wzrost udziału form morskich w sukcesji cenomańskiej wskazuje na transgresję. Zbadana palinoflora wskazuje na to, że w kredzie przeważały na badanym obszarze sagowce, szpilkowe, paprotniki i nieliczne okrytozalążkowe.