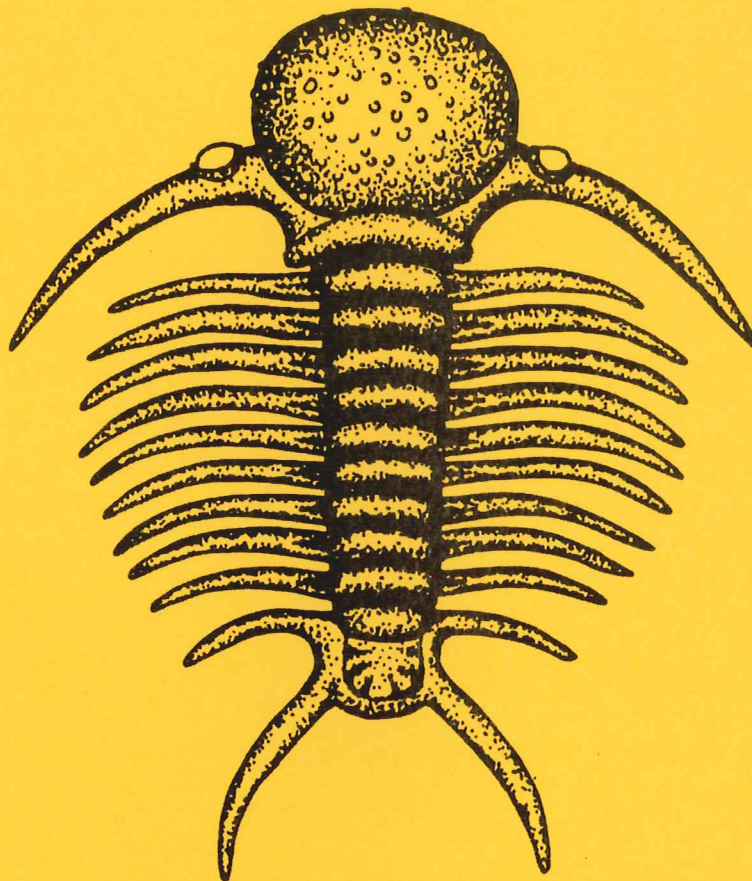


# EXAMENSARBETE I GEOLOGI VID LUNDS UNIVERSITET

Berggrundsgeologi

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2003 -02- 18



Late Triassic and Early Jurassic palynology of the Höganäs  
Basin and the Ängelholm Trough, NW Scania, Sweden

Linda M Larsson

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Lunds univ. Geobiblioteket



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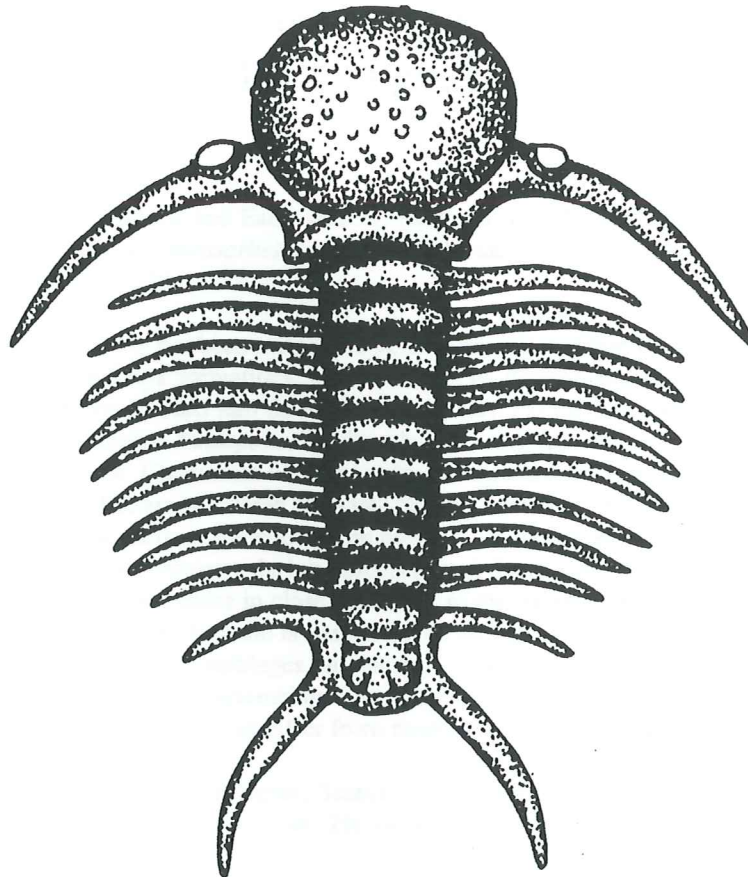
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# Late Triassic and Early Jurassic palynology of the Höganäs Basin and the Ängelholm Trough, NW Scania, Sweden

LINDA M. LARSSON

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**Abstract:** A palynological study has been conducted on Late Triassic and Early Jurassic outcrop- and borehole sections of the Höganäs and Rya formations, NW Scania. The diverse and generally well preserved palynomorph assemblages can be divided into three miospore zones: (1) the latest Rhaetian-?Hettangian Transitional interval; (2) the Hettangian *Pinuspollenites-Trachysporites* Zone; and (3) the Sinemurian *Cerebropollenites macroverrucosus* Zone. Uppermost Rhaetian palynomorph assemblages have previously been considered to be absent in Scania, but are recovered from two borehole sections. All assemblages represent on-shore floras affected by occasional marine influences. The presence of well-preserved palynomorphs in nearly all assemblages indicate minimal transport during dispersal and deposition. The relatively high spore/pollen ratios suggest that deposition took place in close proximity to the parent flora. A transition in the flora at the boundary between the Triassic and Jurassic is demonstrated by the high abundance of fern spores and bryophytes in the uppermost Rhaetian assemblages, in contrast to the more frequently occurring conifer pollen in the Hettangian and Sinemurian. The assemblages are similar in composition to others deposited in paralic environments in Denmark and Scania, but differ from more distally settled ones in the Danish Basin.

**Keywords:** Palynology, Rhaetian, Hettangian, Scania, Transitional interval, *Pinuspollenites-Trachysporites* Zone, *Cerebropollenites macroverrucosus* Zone, Helsingborg Member, Döshult Member, Scania.

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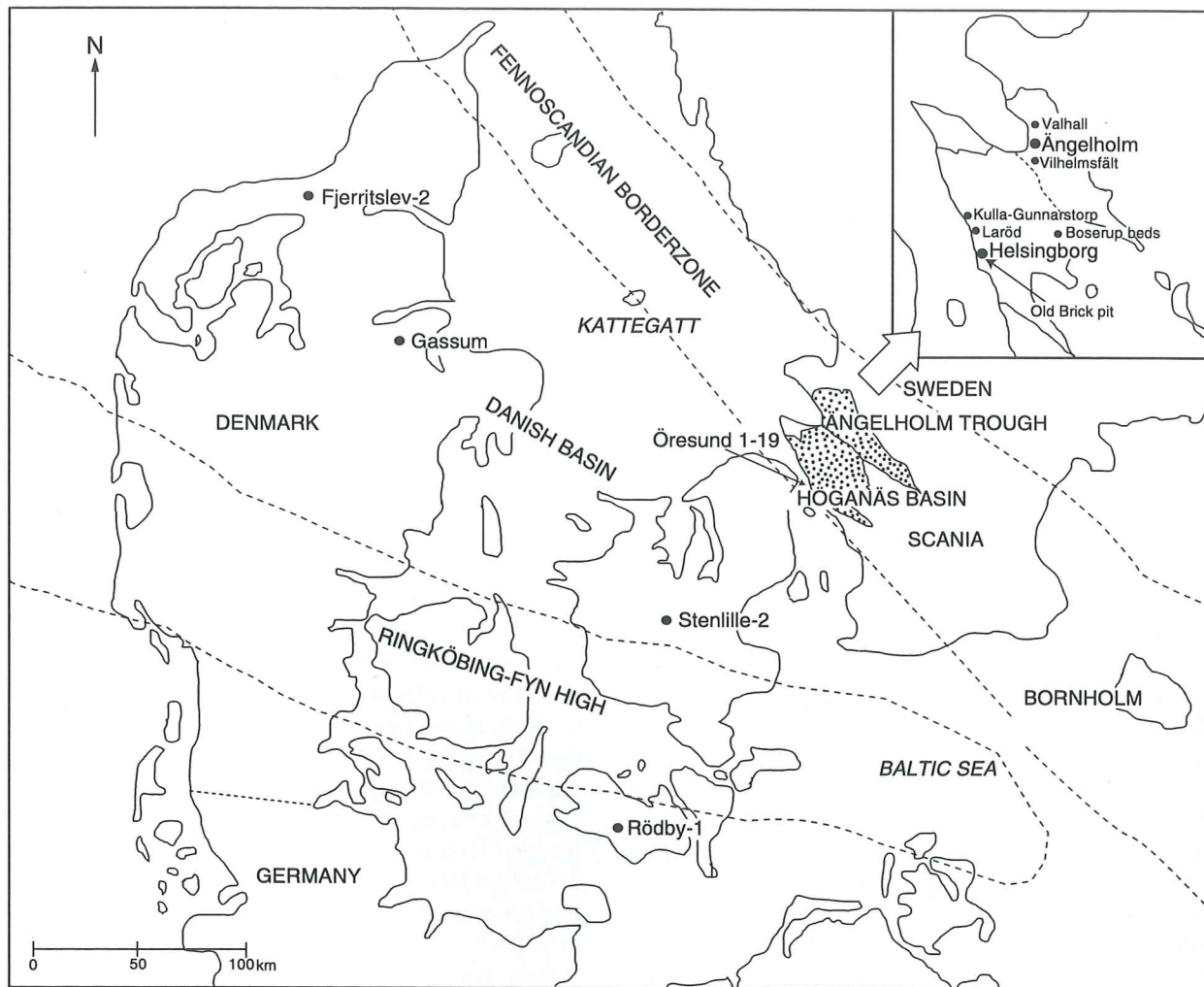


Fig. 1. Map of northwestern Scania and the surrounding areas showing the localities, and the main Jurassic structural elements referred to in the text (after Lund 1977; Koppelhus 1991; and Koppelhus & Nielsen 1994).

The term "palynology" is derived from the Greek word *palunein*, which means "to sprinkle or to dust", and from the Latin word *pollen*, which means "fine flour" (Jansonius & McGregor 1996a). It was constructed in need for a term that was more encompassing than the word "pollen analysis", which refers mainly to work conducted on the Quaternary System (Jansonius & McGregor 1996a). At first, it was used only for the study of spores and pollen, which are the reproductive elements of plants, but since then the study of palynology has broadened. Today, any microscopic specimen resistant to HCl, HF, H<sub>2</sub>NO<sub>3</sub>, NHOH<sub>3</sub>, and similar chemicals can be referred to as a "palynomorph" (Jansonius & McGregor 1996a).

The present study deals mainly with pollen and spores. These land plant derived palynomorphs are usually produced in great numbers and are spread over wide distances by wind and water. The majority of the dispersed spores and pollen will settle on terrestrial ground, or on the floors of lakes, rivers and oceans. Palynomorphs are not only of great stratigraphical importance, but they also provide information about ecological habitats and climates of the past (Batten 1996). Important tools for this purpose are also microalgae, which are often restricted to either marine or freshwater environments. In addition,

dinoflagellate-cysts have proven to be of great stratigraphical importance (Brasier 1980). Samples that contain both terrestrial and marine palynomorphs make it possible to correlate contemporaneous terrestrial and marine strata. Palynological assemblages also give clues regarding the proximity of the source vegetation, and the sedimentary environment. Thus, combined with sedimentology, palynomorphs provide excellent information of ancient paleoenvironments.

The main aim of this study is to palynologically investigate and date a number of localities of presumed Late Triassic to Early Jurassic age in NW Scania. The results are correlated with previous palynological investigations in the area, and the depositional environments interpreted.

## Geological setting

Late Triassic and Early Jurassic strata in Scania (Fig. 1) are well documented (e.g. Troedsson 1951; Sivhed 1984; Pieńkowski 1991; and Ahlberg 1994a, 1994b). Despite this, it is still difficult to distinguish these strata from one another only on lithological grounds. This, together with the absence of biostratigraphical data explains the



System	Stage	Scania <sup>1</sup>		Danish Basin <sup>2</sup>	Bornholm <sup>2</sup>	Miospore zonation
Jurassic	Sinemurian	Rya Fm	Döshult Mb	Fjerritslev Fm	Galgelökke Mb	<i>Cerebropollenites macroverrucosus</i> Zone
	Hettangian	Höganäs Fm	Helsingborg Mb		Rönne Fm	Sose Bugt Mb
Triassic	Rhaetian			Gassum Fm	Munk-erup Mb	
			Bjuv Mb			
		Vallåkra Mb				<i>Rhaetipollis-Limbosporites</i> Zone

Fig. 2. Late Triassic to Early Jurassic lithostratigraphy of Scania ('Lund 1977; Guy-Ohlson 1981), the Danish Basin and Bornholm (Batten et al. 1994; and Koppelhus & Nielsen 1994), and the current miospore zonations applicable to the sedimentary succession in these areas.

traditional lumping of these sediments (Sivhed 1980) (Fig. 2).

During the latest Triassic and Early Jurassic, Scania was situated around 40° N (Fig. 3) and subjected to a humid climate (Sivhed 1980; Ahlberg 1994a, 1994b). The deposition occurred on the border to the Danish Basin (Fig. 1). Today, the sediments are preserved in two minor basins or troughs, the Höganäs Basin and the Ängelholm Trough. Both are associated with the Tornquist Zone, a northwest-southeast oriented horst and graben system, which separates the Fennoscandian Shield from the Danish Basin (Ahlberg 1994a) (Fig. 1). During the Late Triassic (Rhaetian) and Early Jurassic Scania was affected by an extensive transgression, which caused backstepping depositional environments and the Rhaetian alluvial environment was replaced by the Hettangian and Sinemurian marginal-marine- to shallow marine environments (Pieńkowski 1991) (Fig. 3).

The latest Triassic (Rhaetian) and Early Jurassic (Hettangian and Sinemurian) strata in NW Scania are headed under the Höganäs and Rya formations (Fig. 2), which correspond to more distally settled, marine sediments in the Danish Basin (Ahlberg 1994a). The 250 m thick Höganäs Fm, which embraces the Triassic-Jurassic boundary, is built up by three members, the Vallåkra, Bjuv and Helsingborg members, and comprises mainly alluvial and deltaic sediments (Ahlberg 1994a).

The oldest unit, the Vallåkra Member (Fig. 2), comprises a 30 metres thick sequence of mudstone with interbedded lenses of sandstone (Sivhed 1984). The slightly younger Bjuv Member (Fig. 2) consists mainly of floodplain deposits such as paleosols, coals and crevasse splays (Ahlberg 1994a). Two conspicuous coal seams mark the base and the top of the Bjuv Member, the lower B-seam and the upper A-seam, where the latter coincides with the Triassic-Jurassic boundary (Sivhed 1984; Ahlberg 1994a). Both members were deposited on floodplains, which were exposed to occasional marine incursions (Nilsson 1946; Ahlberg 1994a; and Lindström 2002).

The extended transgression between the Triassic and Jurassic systems caused a transition in the depositional environment (Nielsen et al. 1989). As a result the young-

est unit of the Höganäs Fm, the deltaic and tidally affected Hettangian Helsingborg Member, (Fig. 2) comprises mainly mature arenites, heterolites, mudstone and thin coal seams (Ahlberg 1994a). The sands were possibly deposited as delta distributary channels on a delta plain, while the more muddy sediments were deposited in interdistributary bays and lagoons. Similar to the Vallåkra and Bjuv members, the deposition occurred in a freshwater-dominated environment with repeatedly occurring marine incursions.

At the beginning of the Sinemurian the sea transgressed even more and the near-shore environments became stepwise succeeded by shallow, tidally affected- and finally fully marine environments (Sivhed 1984; Pieńkowski 1991; and Erlström et al. 1999). The Sinemurian strata in Scania are included in the Rya Formation (Fig. 2) in which the Döshult, Pankarp, Katslösa and Rydebäck members are incorporated (Sivhed 1984).

The only member of the Rya Fm relevant to this study is the Döshult Member (Fig. 2), assigned to the lowermost part of the Sinemurian (Sivhed 1984). It comprises cross-bedded sand- and siltstones in its lower parts, while the upper part consists mainly of claystones interlayered with thin sandstone- and limestone horizons (Sivhed 1984).

## Palynological zonation & previous palynological studies

Early Jurassic palynomorph assemblages of NW Europe vary from taxonomically restricted to extremely diverse depending on geographical location, but often contain a limited number of taxa of biostratigraphical value (Batten & Koppelhus 1996). However, some palynomorphs with long stratigraphical ranges show interesting quantitative variations over time. These variations are the effect of several elements, including depositional environment, sedimentology and vegetation. Combined with the appearances and disappearances of certain key taxa, these quantitative variations may be of help when dating and correlating strata derived from areas with similar depositional environments.



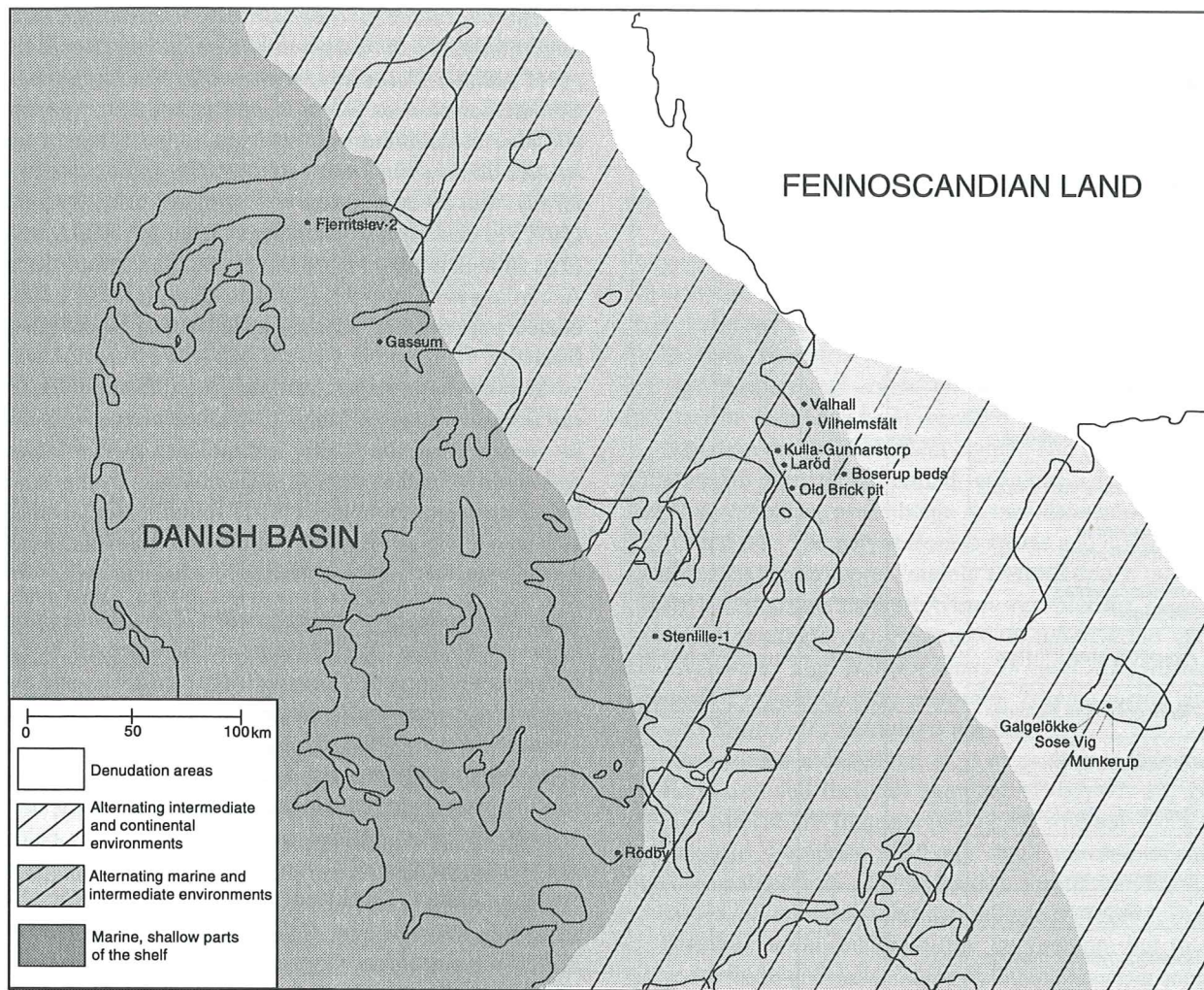


Fig. 3. Paleogeographical map of Scania and the surrounding areas during the Hettangian/Sinemurian (after Grigelis and Norling 1999), and the locations referred to herein.

Extensive studies regarding the microflora have been carried out by several authors (e.g. Lund 1977; Guy-Ohlsson 1981; Dybkjaer 1988, 1991; and Koppelhus & Batten 1996). Lund (1977) established a palynostratigraphical zonation for the Rhaetian to Sinemurian strata in Scandinavia and NW Germany (Fig. 2). The established zones were mainly used to correlate the non-marine deposits of Rödbý, Scania, Poland and Eastern Germany with the increased marine sediments in NW Germany (Fig. 1). Some of the zones have later been modified by, among others, Dybkjaer (1988, 1991), Koppelhus (1991) and Koppelhus & Nielsen (1994).

The zones are defined by their palynomorph content and the presence, or absence, of certain key taxa (Fig. 4). The zones relevant to this study (Fig. 2) are the ones of the Middle to latest Rhaetian, Hettangian and Sinemurian, and these are described below.

**The *Rhaetipollis-Limbosporites* Zone**, Middle Rhaetian (Lund 1977) (Fig. 2). This zone is defined by the presence of *Rhaetipollis germanicus* and *Limbosporites lundbladii*. Other common taxa are *Riccisporites tuberculatus*, *Cingulizonates rhaeticus* and thick-walled *Araucariacites*. Important are also the presence of *Corollina zwolinskai* Lund 1977, *Ovalipollis ovalis*, *Pinuspollenites*

*minus* and *Apiculatisporis parvispinosus* Leschik 1955. For a more comprehensive description, see Lund (1977). Six samples from Bjuv, Lunnom and "Vallåkra norra Skifferbråt", all originating from the Vallåkra and Bjuv Members (Fig. 2), were investigated palynologically by Lund (1977). They were all referred to the *Rhaetipollis-Limbosporites* Miospore Zone, indicating a Middle Rhaetian age (Lund 1977). Based on this palynological evidence Lund (1977) stated that Upper Rhaetian strata are absent in Scania.

**The *Riccisporites-Polydiisporites* Zone**, Late Rhaetian (Lund 1977) (Fig. 2). *Polydiisporites polymicroforatus* or *Semiretisporis gothae* alone or together, are common within this zone, often in association with a variety of trilete spores. *Riccisporites* is also common but less frequent than in the underlying zone, and more common than in the succeeding Hettangian *Pinuspollenites-Trachysporites* Zone.

**The *Corollina-Riccisporites* Zone**, Late Rhaetian (Dybkjaer 1991) (Fig. 2). This zone is characterised by a high abundance of *Corollina torosus* in association with frequent *Riccisporites tuberculatus*. The base is not defined, but the top of the zone is immediately below an abrupt rise in the frequency of *Pinuspollenites minus* and or-



STRATIGRAPHICALLY IMPORTANT SPORE/POLLEN TAXA	UPPER TRIASSIC		LOWER JURASSIC			
	RHAETIAN		HETTAN- GIAN	SINEMU- RIAN		PILIENS- BACHIAN
	L	U		L	U	
<i>Rhaetipollis germanicus</i>			..			
<i>Ovalipollis ovalis</i>			.....			
<i>Limbosporites lundbladii</i>						
<i>Semiretisporis gothae</i>						
<i>Triancoraesporites ancorae</i>						
<i>Riccisporites tuberculatus</i>			■			
<i>Zebbrasporites interscriptus</i>			.....	?		
<i>Polydiisporites polymicroforatus</i>			.....	..		
<i>Kraeuselisporites reissingeri</i>			■			→
<i>Pinuspollenites minimus</i>			■			→
<i>Perinopollenites elatoides</i>				■		→
<i>Retitriletes semimuris</i>						→
<i>Retitriletes clavatoides</i>						→
<i>Cerebropollenites macroverrucosus</i>						→
Dinocysts						
<i>Rhaetogonyaulax rhaetica</i>						
<i>Dapcodinium priscum</i>						

Fig. 4. Ranges of stratigraphically important spore and pollen species and dinocysts referred to in the text (after Dybkjaer 1991; and Batten & Koppelhus 1996).

namented trilete spores. Other dominating taxa are usually known to be more frequent in Early Jurassic strata, such as *Deltoidospora toralis*, *Stereisporites steroides*, *Intrapunctisporis toralis*, *Monosulcites punctatus*, *Pinuspollenites minimus*, *Perinopollenites elatoides*, *Marattisporites scabratus* and *Aratrisporites minimus*. According to Dybkjaer (1991), this zone retains both Rhaetian and Hettangian components. It was established in order to complement the *Riccisporites-Polydiisporites* Zone of Lund (1977). Although they are regarded as representing almost the same stratigraphical interval, the index taxa defining the *Riccisporites-Polydiisporites* Zone occur only sporadically in the samples from the marine Fjertritslev Formation (Fig. 1) in the Danish Basin (Dybkjaer 1991).

**The "Topmost Upper Rhaetian"** -local, informal zone, latest Rhaetian-basal Hettangian, Lund (1977). In this zone *Riccisporites tuberculatus* is more abundant than *Pinuspollenites minimus*. Many typical Rhaetian taxa are

present, but rare, e.g. *Lycopodiacidites rhaeticus*, *Densosporites fissus*, *Limbosporites lundbladii* and *Semiretisporis gothae*. *Deltoidospora toralis*, *Trachysporites*, *Conbaculatisporites*, *Baculatisporites* and *Aratrisporites minimus* are common constituents. Also frequent are *Araucariacites australis* and *Quadraeculina anellaeformis*. This informal zone was primarily used by Lund (1977) to encompass assemblages from the Rödby core (Fig. 2) with a mixed Rhaetian-Hettangian composition. According to Lund (1977) the miospore flora has a Rhaetian aspect qualitatively, but a Hettangian aspect quantitatively.

Similar assemblages were recovered from the Bose-rup Beds in Scania by Lund (1977), but were assumed to be younger than the Rödby assemblages as *P. minimus* was more abundant than *R. tuberculatus*. In the Stenlille-2 drillcore, Dybkjaer (1991) found a similar interval, which she assigned to the basal Hettangian, based on the relatively rare occurrence of Rhaetian taxa.

**The *Pinuspollenites-Trachysporites* Zone**, Hettangian, Lund (1977) (Fig. 2). This zone is characterised by the common presence of *Pinuspollenites minimus* and the absence of *Cerebropollenites macroverrucosus*. According to Dybkjaer (1991), the base of this zone is immediately below a distinct rise in *Pinuspollenites minimus* together with an increase in the ornamented trilete spores. The top has been defined as being immediately below the first appearance of *Cerebropollenites macroverrucosus*. According to Dybkjaer (1988, 1991), this interval is generally dominated by *Deltoidospora toralis*, *Perinopollenites elatoides*, *Corollina torosus* and *Marattisporites scabratus*. Other frequently occurring taxa include *Calamospora tener*, *Monosulcites punctatus*, *Punctatisporites globosus*, *Aratrisporites minimus*, *Intrapunctisporis toralis*, *Alisporites robustus* and *Chasmatosporites* spp.

*Conbaculatisporites mesozoicus*, *Trachysporites fuscus* and *Uvaesporites argenteaformis* dominate the group of ornamented trilete spores. *Kraeuselisporites reissingeri* is relatively common. Taxa that are most common in Rhaetian deposits, such as *Densosporites fissus*, *Zebbrasporites interscriptus*, *Riccisporites tuberculatus* and *Limbosporites lundbladii* may be present. In general, spores dominate the assemblages, whereas bisaccate and non-saccate pollen are less frequent (Dybkjaer 1988). Aquatic palynomorphs are mainly represented by acritarchs. The dinocyst *Dapcodinium priscum* is sporadically abundant, while *Tasmanites* and *Botryococcus* are less common (Koppelhus & Batten 1996).

Based on the palynological content in three samples from Päljsjö, Elinebergbrottet and Höör Lund (1977) assigned the Helsingborg Mb to the Hettangian *Pinuspollenites-Trachysporites* Zone.

**The *Cerebropollenites macroverrucosus* Zone**, Sinemurian, Dybkjaer (1991) (Fig. 2). The base of this zone is defined by the first appearance of *Cerebropollenites macroverrucosus*, while the top is immediately below a distinct rise in *Spheripollenites* and the first appearance of *Leptolepidites*. The index taxon *C. macroverrucosus* only



occurs sporadically throughout the zone. Both Lund (1977) and Dybkjaer (1988) stated that almost the same taxa dominate in this zone as in the underlying *Pinuspollenites-Trachysporites* Zone. *Pinuspollenites minimus* is as common as in the underlying zone (Lund 1977), while there is a general decrease in the abundance of *Deltoidospora toralis* at the beginning of the zone (Dybkjaer 1988). The genera *Alisporites* and *Retitriletes* are generally more abundant than in the preceding zone (e.g. Lund 1977; Dybkjaer 1988; Koppelhus 1991).

Lund (1977) conducted a study on samples from Gan-tofta where it was stated that the Döshult Mb belonged to an un-named zone, later referred to as the *Cerebro-pollenites macroverrucosus* Zone by Dybkjaer (1991).

## Material and methods

The samples investigated herein were collected from outcrop sections at Helsingborg Old Brick pit, Kulla-Gunnarstorp, Laröd, and from the drill-cores of Vilhelmsfält and Valhall (Fig. 1). Thirtyeight samples were prepared using standard palynological preparation techniques (e.g. Vidal 1988; Jansonius & McGregor 1996b). Two slides from each sample were thoroughly examined under a Nikon light microscope. Specimens were identified primarily by using the works of Lund (1977), Dybkjaer (1988, 1991) and Koppelhus (1991). In order to assess the quantitative composition of the assemblages approximately 350 specimens were counted from the majority of the samples. A few samples contained sparse palynomorphs, in which case as many specimens as possible were counted. Range charts are constructed for all sections (Table 1A and 1B) and the records are compared in Fig. 5. The exact intervals of the samples, as well as the lithology and quantitative composition of the palynoflora, can be seen in Figs. 6, 7, 8, 9, 10, 11, 12.

## Results

The studied samples generally contain well to excellently preserved and diverse palynomorph assemblages. 107 different taxa have been identified and these are presented in alphabetical order under their probable plant affinities in Table 2. The majority of the identified taxa are spores and pollen grains. Six taxa are freshwater algae and seven taxa are considered as marine. Four taxa are regarded as reworked, based on their dark colour and poor preservation.

### Vilhelmsfält

#### Locality description

This core was drilled in 1917 by the Höganäs-Billesholm Company under the scientific control by Prof. K. A. Grönwall and subsidised by the Swedish Government (Guy 1971). The drill site is situated about five kilometres south of the city of Ängelholm in the Ängelholm Trough (Fig. 1). According to previous studies by e.g. Norling (1972) and Guy-Ohlson (1981), the core penetrates Rhaetian, Lower Jurassic and Middle Jurassic strata. The present study is based on samples from the low-

ermost part of the drill core between 407.5 m and 387.2 (Fig. 7). This interval comprises clay, silt- and sandstones (both heterolithic and homogenous), that are interlayered by coal seams (Fig. 7). Based on the lithology, Guy (1971) considered the lowermost parts of the core to be Rhaetian in age, but no previous palynological study has been carried out on the specific interval.

#### Palynology

All samples, except the four lowermost ones, contain very well preserved palynomorphs and moderate amounts of plant debris. Terrestrial palynomorphs, mainly fern spores and gymnospermous pollen grains dominate, and only five marine taxa have been recorded.

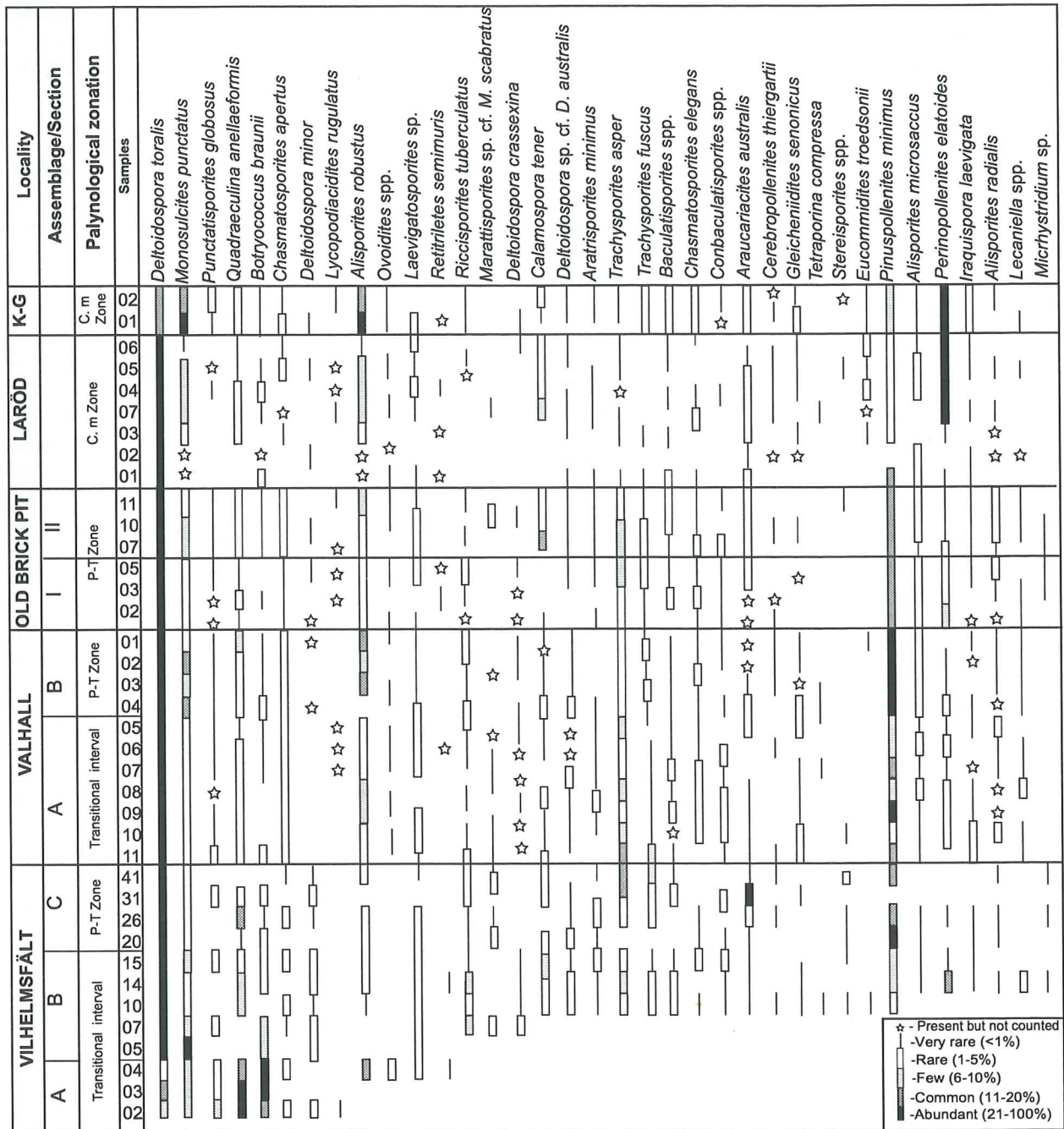
Based on the palynological content and diversity the Vilhelmsfält interval is divided into three assemblages. The first and oldest, assemblage A, includes samples VF-02, 03 and 04. The palynoflora is sparse and dominated by trilete laevigate spores, mainly *Deltoidospora toralis* (Table 1). Also abundant are *Alisporites robustus*, *Quadraeculina anellaeformis*, *Riccisporites tuberculatus* and the freshwater alga *Botryococcus braunii*. *Alisporites thomasi*, *Perinopollenites elatoides*, *Trachysporites asper* and *Retitriletes semimuris* are rare.

The younger assemblage, B, is more diverse than the previous one and includes samples VF-05, 07, 10, 14 and 15. Spores are frequent (60-72%), whereas saccate pollen grains, comprise relatively small amounts of the recorded palynoflora. *Deltoidospora toralis* and *Pinuspollenites minimus* dominate assemblage B (Table 1; Fig. 6). *Quadraeculina anellaeformis* is common, but to a lesser degree than in assemblage A. Other important components of assemblage B are *Monosulcites punctatus*, *Alisporites robustus*, *Chasmatosporites* spp., *Pinuspollenites* (5-9 %; Fig. 6), *Polonisaccus ferrugineus*, *Riccisporites tuberculatus* and *Polydiisporites polymicroforatus*. *Perinopollenites elatoides* is rare in all samples, except in VF-10 where it peaks, constituting almost eighteen percent of the palynoflora. Trilete ornamented spores are frequent, not only *Baculatisporites* spp. and *Conbaculatisporites* spp., but also *Trachysporites* spp. (8%; Fig. 6). *Zebrasporites interscriptus* occurs sporadically. Putative bryophyte spores, such as *Stereisporites* spp. and *Sculptisporis aulosenensis* are present in all samples. *Botryococcus braunii* and one recorded specimen of *Ovoidites* represent the freshwater algae. One single specimen of the marine dinoflagellate cyst *Dapcodinium priscum* is recorded in the uppermost sample of this assemblage together with "Rotundus granulatus" of Koppelhus & Nielsen (1994), and the marine green alga *Tasmanites*.

The third and youngest assemblage, C, is highly diverse. It includes samples VF-20, 26, 31 and 41. Here, saccate pollen grains are more frequent than in the previous assemblages (Table 1). Laevigate trilete spores constitute thirty to fifty-five percent, which is less than in the previous assemblages, whereas trilete ornamented spores comprise between six and twenty-five percent. The base of assemblage C is defined by an abrupt rise in *Pinuspollenites* (27 %; Fig. 6) and is followed by a marked



Table 1 A. Composite range chart from Vilhelmsfält, Valhall, Old Brick pit, Laröd and Kulla-Gunnarstorp, showing the distribution of pollen and spores, and the palynological zonation. (P-T Zone=*Pinuspollenites-Trachysporites* Zone, C. m Zone=*Cerebropollenites macroverrucosus* Zone)



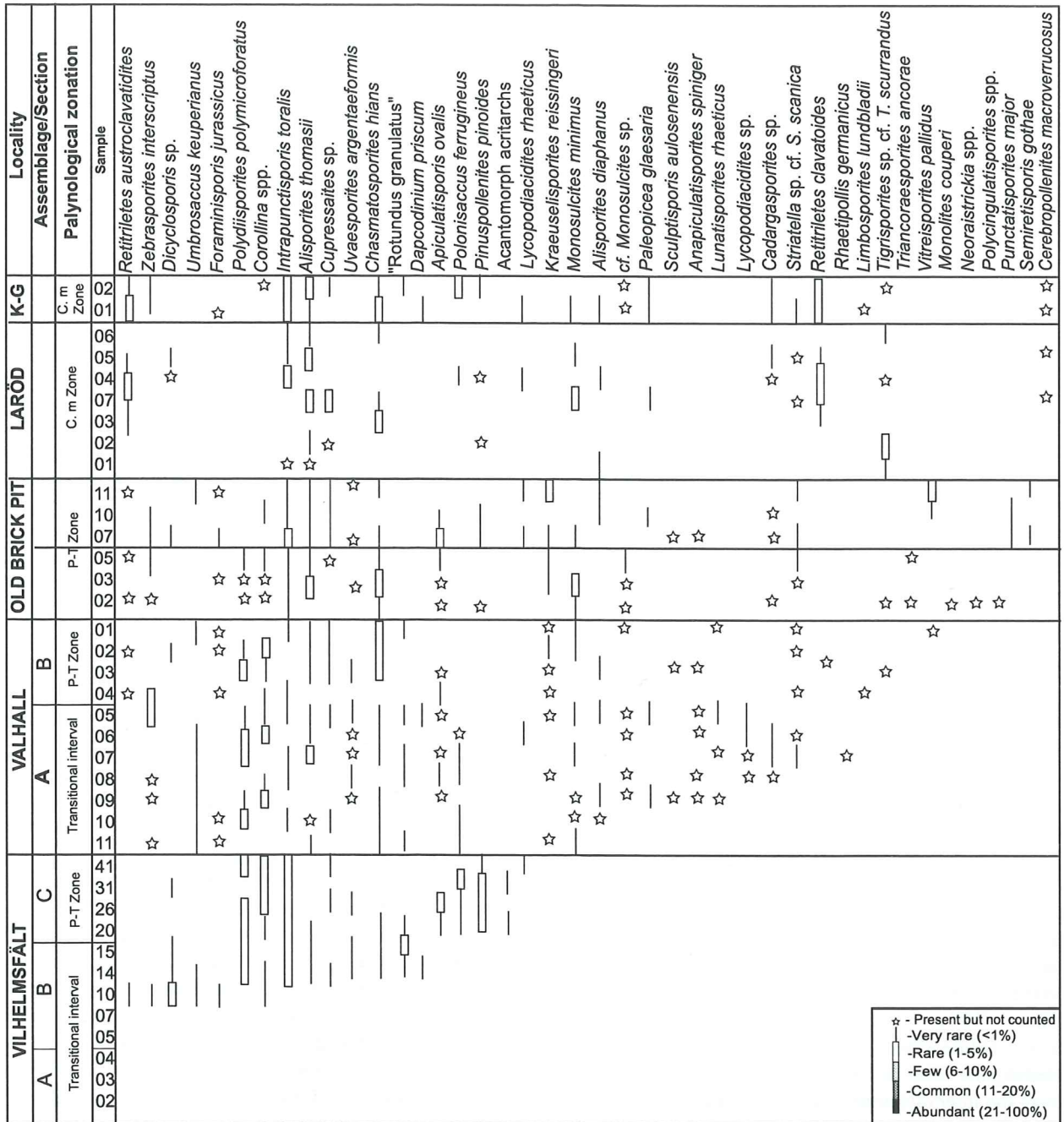
increase in *Trachysporites* in the following sample (13,5 % in sample 26; Fig. 6), and these taxa dominate the samples together with *Deltoidospora toralis*. *Quadraculina anellaeformis* and *Araucariacites australis* are very frequent in the first sample (VF-20). The relative abundance of the latter taxon peaks in sample VF-31, comprising forty percent of the palynoflora. In contrast to assemblage B, *Riccisporites tuberculatus*, *C. tener*, *Conbaculatisporites*, *Laevigatosporites*, *Chasmatosporites* and *Perinopollenites elatoides* are rare, whereas *Corollina torosus* and *Polonisaccus ferrugineus* are fairly common. *Marattisporites* sp. cf. *M. scabratus* is common in all samples. The freshwater alga *Botryococcus* is

even less frequent than in assemblages A and B, while marine palynomorphs, such as "Rotundus granulatus", *Cymatiosphaera* sp. and acanthomorph acritarchs are clearly more frequent in this assemblage.

#### Suggested age

Assemblages A and B are considered to be of approximately the same age. Their difference in diversity is probably a result of the different degree of preservation. The mixed characters of these two assemblages indicate that they are most certainly younger than the upper Rhaetian *Riccisporites-Polydiisporites* Zone, but older than the Hettangian *Pinuspollenites-Trachysporites* Zone. Assign-

Table 1 B. Composite range chart from Vilhelmsfält, Valhall, Old Brick pit, Laröd and Kulla-Gunnarstorp, showing the distribution of pollen and spores, and the palynological zonation. (P-T Zone=*Pinuspollenites-Trachysporites* Zone, C. m Zone=*Cerebropollenites macroverrucosus* Zone)



ment to the late Rhaetian *Riccisporites-Polydiisporites* Zone (Lund 1977) or to the equivalent *Corollina-Riccisporites* Zone (Dybckjaer 1991) is excluded since both *Polydiisporites polymicroforatus* and *Corollina torosus* are virtually absent. Neither can assemblages A or B be referred to the *Pinuspollenites-Trachysporites* Zone. *Pinuspollenites minimus* and *Trachysporites* have not been registered in assemblage A. The base of assemblage B is marked by an increase in both *P. minimus* and trilete ornamented spores, but *Riccisporites tuberculatus* is also relatively frequent, thus indicating an age older than the Hettangian. The more distinct rise of *Pinuspollenites* and *Trachysporites*, which occurs at the top of the assem-

blage B, is instead regarded to mark the lower boundary of the *Pinuspollenites-Trachysporites* Zone.

Assemblages A and B can be correlated with Lund's (1977) informal "Topmost Upper Rhaetic" zone of Rödby (Fig. 1) and to a similar assemblage recorded by Dybckjaer (1991) from the Stenlille-2 borehole. Dybckjaer (1991) also recorded higher amounts of *Pinuspollenites* than *Riccisporites*. The presence of a single specimen of *Dapcodinium priscum* is not sufficient evidence to indicate a Hettangian age for assemblage B.

Assemblage C is correlated with the *Pinuspollenites-Trachysporites* Zone based on a distinct increase of *P. minimus* and ornamented trilete spores near the base of



System	Stage	Scania		Vilhelmsfält	Valhall	Old Brick pit 1 2	Laröd	Kulla-Gunnarstorp	Miospore zonation
Jurassic	Sinemurian	Rya Fm	Döshult Mb				?	?	Cerebropollenites macroverrucosus Zone
	Hettangian	Höganäs Fm	Helsingborg Mb	?	?	?	?	?	Pinuspollenites-Trachysporites Zone
Triassic	Rhaetian		Bjuv Mb	?	?	?	?		Transitional interval Ficcisporites-Polydiisporites or Corollina-Ficcisporites Zone
			Vallåkra Mb						Rhaetipollis-Limbosporites Zone

Fig. 5. Suggested stratigraphical position of the Scanian localities investigated herein, and the applied palynozonation.

the assemblage. An early Hettangian age is also indicated by the relatively common occurrence of *Polydiisporites polymicroforatus*, which is usually more frequent in the early Hettangian than later (Lund 1977). However, the presence of *Retitriletes clavatooides*, recorded outside counting in VF-03, indicates an age close to the middle parts of the Hettangian (Table 1b, Fig 5).

## Valhall

### Locality description

The Valhall site is situated in the Ängelholm Trough (Fig. 1), approximately five kilometres north of the city of Ängelholm. The drill core was recovered in 1977 by the Geological Survey of Sweden (SGU) and it is the northernmost occurrence of the Höganäs Formation. It penetrates both Rhaetian and Lower Jurassic strata down to a depth of approximately 170 metres. The sedimentary sequence is similar to those from the Höganäs basin, consisting mainly of heterolites, fine-grained sandstones, mudstones and coal beds. Also frequent are fossil rootlets and paleosols, indicating alluvial environments. The Valhall core was investigated palynologically by Guy-Ohlson (1981) who dated the section between 170-160 m as Middle Rhaetian and the succeeding interval as Hettangian. The samples examined herein were derived from the interval between 167.0 m-153.7 m (Fig. 8) and are not equivalent to the samples studied by Guy-Ohlson (1981).

### Palynology

The present palynological investigation yielded eighty-eight different taxa. All samples, except the two lowermost ones (V-10 and V-11), are well preserved and contain large amounts of wood. Several sporomorph tetrads, and excellently preserved tracheids are present in each of the samples V-01, 03, 04, 05, 06, 07, 08 and 09.

All samples are dominated by terrestrial palynomorphs (Fig. 8), mostly fern spores and gymnospermous pollen grains. Only a few marine taxa have been recorded, mainly tasmanitids and "Rotundus granulatus" of Koppelhus & Nielsen (1994). One questionable specimen of the dinoflagellate *Dapcodinium priscum* is re-

corded in sample V-05. Freshwater algae, especially *Ovoidites* spp., *Lecaniella* spp. and *Botryococcus braunii*, are relatively common in the lowermost samples. The Valhall interval can be divided into two assemblages, A and B.

The lowermost assemblage, A (V-11, 10, 09, 08, 07, 06, 05), is dominated by *Deltoidospora toralis* which constitutes nearly fifty percent of the palynoflora. Sample V-11 differs from the others in its low content of *Pinuspollenites minimus* (2%), which is otherwise rather frequent (5-21%; Fig. 6) in the remaining samples. *Quadraculina anellaeformis* and *Aratrisporites minimus* are abundant. Trilete ornamented spores are frequent, especially *Trachysporites asper* and *Conbaculatisporites mesozoicus*. Putative bryophyte spores, such as *Riccisporites tuberculatus* and *Foraminisporis jurassicus* are present. Typical Rhaetian species, such as *Lunatisporites rhaeticus*, *Lycopodiacidites rhaeticus*, *Rhaetipollis germanicus* and *Kraeuselisporites reissingeri*, are recorded, but mainly outside counting. Freshwater algae are common, especially *Lecaniella* and *Ovoidites*.

The base of assemblage B is defined by the abrupt increase of *Pinuspollenites minimus* (Fig. 6) and other bisaccate pollen grains. An increase in *Chasmatosporites* and *Monosulcites* is also recorded. All samples contain *Alisporites* spp. and *Deltoidospora toralis*, sometimes in relatively high quantities. Only a few, poorly preserved Rhaetian taxa have been recorded.

### Suggested age

Based on the mixed character of assemblage A, which includes both Rhaetian and Early Jurassic palynomorphs, it can be referred to the "Topmost Upper Rhaetic" by Lund (1977). Other indications of an age older than Hettangian are the presence of *Rhaetipollis germanicus* and the frequently occurring *Aratrisporites minimus*, which are both considered rare in Early Jurassic deposits (Guy-Ohlson 1981; Batten et al. 1994). In addition, the quantitative differences in *P. minimus* between assemblage A and B, together with the presence of "Rhaetian" taxa in assemblage A, indicate an age not referable to the Hettangian *Pinuspollenites-Trachysporites* Zone

Table 2. The recorded taxa from the sections of Vilhelmsfält, Valhall, Old Brick pit, Laröd and Kulla-Gunnarstorp, placed under their probable plant affinities (mainly after Balme 1995). Taxa illustrated herein are followed by figure references.

## Pollen

### Coniferopsida

- Lunatisporites rhaeticus* Schultz 1967  
*Ovalipollis ovalis* Krutsch 1955  
*Paleopicea glaesaria* Bolkhovtina 1956  
*Pinuspollenites minimus* (Couper) Kemp 1970 (Fig. 15 K)  
*P. pinoides* (Nilsson) Lund 1977  
*Polonisaccus ferrugineus* (Pautsch) Mädlar 1964  
*Quadraeculina anellaeformis* Maljavkina 1949 (Fig. 15 J)  
*Rhaetipollis germanicus* Schultz 1967  
*Umbrosaccus keuperianus* Mädlar 1964

### Coniferopsida?

- Spheripollenites psilatus* Couper 1958

### Araucariaceae

- Araucariacites australis* Cookson 1947 (Fig. 15 L)

### Araucariaceae?

- Cupressaites* sp.

### Taxodiaceae

- Cerebropollenites macroverrucosus* (Thiergart) Schultz 1967 (Fig. 16 B, C, G)

- C. thiergartii* Schultz 1967 (Fig. 16 A)

- Perinopollenites elatoides* Couper 1958 (Fig. 16 D, E)

### Cheirolepidaceae

- Corollina* spp.

- Corollina torosus* Cornet & Traverse 1975 (Fig. 16 F)

### Cycadopsida

#### Cycadales

- Chasmatosporites apertus* (Rogalska) (Fig. 14 L)  
 Nilsson 1958

- C. elegans* Nilsson 1958 (Fig. 15 A)

- C. hians* Nilsson 1958 (Fig. 15 B)

- Eucommidites granulatus* Schultz 1967

- E. troedsonii* Erdtman 1948

### Bennettitales

- Cycadopites nitidus* (Balme 1957) Pocock 1970

- Monosulcites. minimus* Cookson 1947

- M. punctatus* Orłowska-Zwolinska 1966 (Fig. 15 D) cf. *Monosulcites* sp.

### Ginkgopsida

- Alisporites diaphanus* (Pautsch) Lund 1977

- A. microsaccus* (Couper) Pocock 1962

- A. radialis* (Leschik) Lund 1977 (Fig. 15 I)

- A. robustus* Nilsson 1958 (Fig. 15 H)

- A. thomasii* (Couper) Nilsson 1958

### Caytoniales

- Vitreisporites pallidus* (Reissinger) Nilsson 1958

## Spores

### Bryophyta

- Dicyclosporites* spp. (Fig. 15 G)

- Foraminisporites jurassicus* Schultz 1967 (Fig. 15 E)

- Polycingulatisporites* sp.

- cf. *Polycingulatisporites* sp.

- Riccisporites tuberculatus* Lundblad 1954 (Fig. 15 F)

- Sculptisporites aulosenensis* (Schultz) Koppelhus 1991

- Stereisporites* spp.

- Stereisporites stereoides* (Potonié & Vénitz) Pflug 1953

### Equisetopsida

#### Equisetales

- Calamospora* spp.

- Calamospora tener* Leschik emend. Mädlar 1964

### Filicopsida

- Apiculatisporites ovalis* (Nilsson) Norris 1965

- Baculatisporites. comaumensis* (Cookson) Potonié 1956 (Fig. 13 A)

- B. oppressus* (Leschik) Lund 1977

- B. wellmani* (Couper) Krutsch 1959

- Baculatisporites* sp.

- Cadargasporites* sp. (Fig. 14 D)

- Conbaculatisporites mesozoicus* Klaus 1960 (Fig. 13 J)

- C. spinosus* (Mädlar) Lund 1977

- Conbaculatisporites* sp.

- Contignisporites problematicus* (Couper) Döring 1965

- Intrapunctisporites toralis* (Leschik) Lund 1977 (Fig. 13 B)

- Iraquispora laevigata* (Mädlar) Lund 1977 (Fig. 13 E)

- Laevigatosporites dubius* Nilsson 1958

- L. mesozoicus* Schultz 1967 (Fig. 13 L)

- Laevigatosporites* sp.

- Lycopodiacidites rhaeticus* Schultz 1967

- L. rugulatus* (Couper) (Fig. 14 C)

- Lycopodiacidites* sp.

- Monolites couperi* (Couper) Tralau 1968

- Neoraistrickia* spp.

- Striatella* sp. cf. *S. scanica* (Nilsson) Filatoff & Price 1988

- (Fig. 13 H)

- Trachysporites asper* Nilsson 1958 (Fig. 13 C)

- T. fuscus* Nilsson 1958 (Fig. 13 D)

- Tigrisporites* sp. cf. *T. scurrandus* Norris 1967

- Zbrasporites interscriptus* (Thiergart) Klaus 1960

- (Fig. 13 F)

### Davalliaceae

- Triancoraesporites ancorae* (Reinhardt) Schultz 1967

### Dicksoniaceae

- Deltoidospora* sp. cf. *D. australis* (Couper) Pocock 1970

- D. minor* (Couper) Pocock 1970

### Gleicheniaceae

- Gleicheniidites* sp. cf. *G. senonicus* (Couper) Pocock 1970

- (Fig. 13 I)

### Marattiales

- Marattisporites* sp. cf. *M. scabratus* Couper 1958 (Fig. 13 C)

- Punctatisporites globosus* (Leschik) Lund 1977

- P. major* (Couper) Kedves & Simoncsics 1964

### Matoniaceae

- Deltoidospora crassexina* (Nilsson) Lund 1977

- D. toralis* (Leschik) Lund 1977 (Fig. 13 A)

### Schizaceae

- Ischyosporites* sp.

### Lycopsida

- Anapiculatisporites spiniger* (Leschik) Reinhardt 1968

- A. sp. cf. A. telephorus* (Pautsch)

- Jansonius 1967 (Fig. 14 B)

- Anapiculatisporites* sp. (Leschik) Reinhardt 1968

- Limbosporites lundbladii* Nilsson 1958 (Fig. 14 K)

- Retitriteles austroclavatidites* (Cookson) Potonié 1956

- (Fig. 14 H)

- R. semimuris* Danzé-Corsin & Laveine 1963

- (Fig. 13 G)

- R. clavatooides* (Couper) emend. Tralau 1968

- (Fig. 14 J)

- Semiretisporis gothae* Reinhardt 1962

### Pleuromeiaceae

- Aratrisporites minimus* Schultz 1967

### Selaginellales

- Uvaeisporites argenteaformis* (Bolchovitina) Schultz 1967

- (Fig. 14 G)

### Reworked palynomorphs

- Crassispora* spp.

- Densosporites fissus* (Reinhardt) Schultz 1967

- Densosporites* spp.

- Platyptera* sp. cf. *P. trilingua* (Horst) Schultz 1967

### palynomorphs indet.:

- Gen. et spec. indet. 1

- Gen. et spec. indet. 2

### Freshwater palynomorphs

- Botryococcus braunii* Kützing 1849

- Lecaniella korsoddensis* Batten, Koppelhus & Nielsen 1994

- Lecaniella* sp. (Fig. 16 H)

- Ovoidites* sp. 1 (Fig. 16 I)

- Ovoidites* sp. 2

- Tetraporina compressa* Kondratév 1963

### Marine palynomorphs

- Acanthomorph acritarchs*

- Cymatiosphaera* sp. (Fig. 16 J)

- Dapcodinium priscum* Evitt 1961

- Michystridium* sp. (Fig. 16 L)

- Peltandripites* sp.

- "Rotundus granulatus" of Koppelhus & Nielsen (1994)

- Tasmanites* sp. (Fig. 16 K)







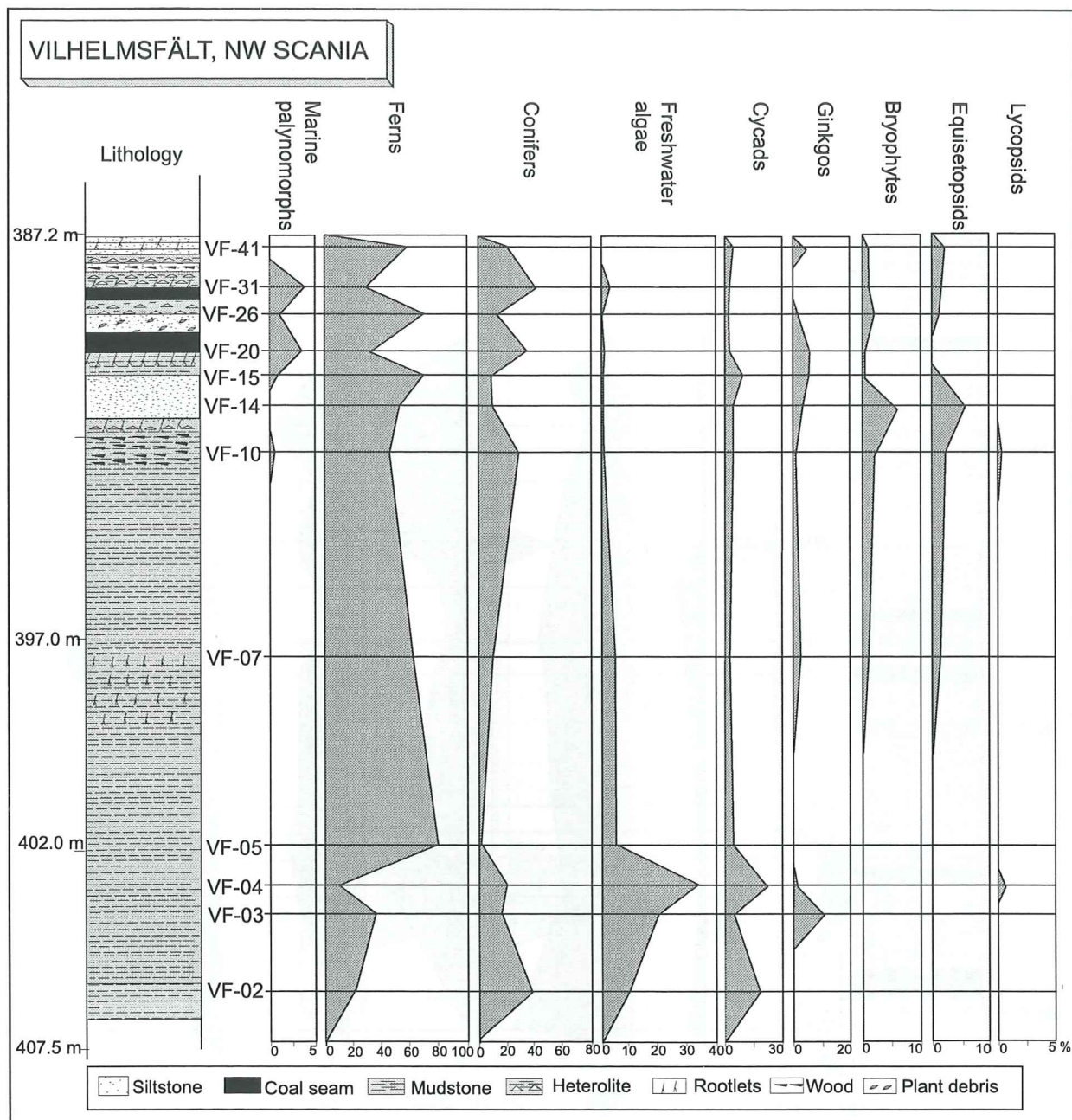


Fig. 7. Lithology and taxonomic composition of the Vilhelmsfält drillcore-section. Note that percentage-scales may differ between the taxonomic affinities. The lithology is after Guy (1971).

freshwater palynomorphs. Spores and gymnospermous pollen grains dominate all samples, whereas marine palynomorphs only comprise one percent or less of the recorded assemblages (Fig. 10).

The most abundant palynomorph in the section II-assemblage is the fern spore *Deltoidospora toralis*, which constitutes at least forty percent in all three samples. Also frequent are *Pinuspollenites minimus* (11-16 %; Fig. 6), *Alisporites robustus*, *Monosulcites minimus*, *Chasmatosporites* spp., *Quadraeculina anellaeformis* and *Araucariacites australis*. Ornamented trilete spores comprise a fair part of the assemblage by the frequent occurrence of *Trachysporites* (3-6 %; Fig. 6), *Apiculatisporis ovalis*, *Baculatisporites* spp. and *Conbaculatisporites* spp. Present, sometimes in large quantities, are monolet fern spores such as *Laevigatosporites* spp. and *Marattisporites*

sp. cf. *M. scabratus*. *Kraeuselisporites reissingeri* is also present. *Ovalipollis ovalis* and *Semiretisporis gothae* are rare, with only one single poorly preserved specimen recorded for each of these taxa. *Botryococcus braunii*, *Lecaniella* spp. and *Ovoidites* spp. represent the freshwater algae. Marine indicators are few and occasional, consisting of tasmanitids, *Peltandripites* spp. and one single specimen of *Cymatiosphaera*.

#### Suggested age

The two investigated sections in the Old Brick Pit and their palynomorph assemblages are very similar in their compositions. The relatively high abundance of trilete ornamented spores together with a dominance of *Pinuspollenites minimus* enables the two sections to be assigned to the Hettangian *Pinuspollenites-Trachysporites* Zone



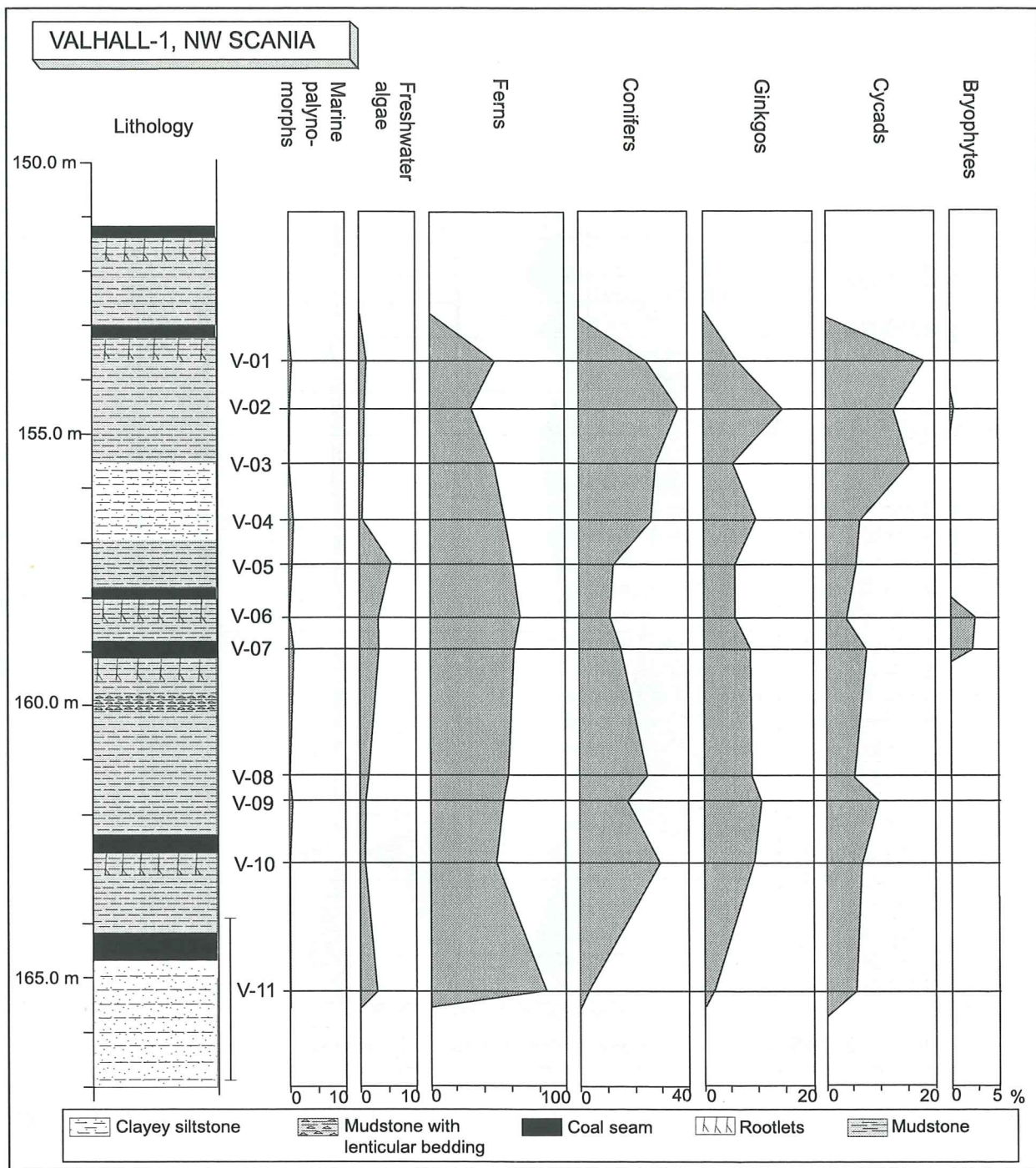


Fig. 8. Lithology and taxonomic composition of the Valhall drillcore-section. Note that percentage-scales may differ between the taxonomic affinities. The lithology is after Guy-Ohlson (1981) and Ahlberg (1994a).

(Lund 1977). A few palynomorphs usually known to be more frequent in older assemblages, e.g. *Foraminisporis jurassicus*, *Riccisporites tuberculatus*, *Kraeuselisporites reissingeri*, *Zebrasporites interscriptus*, *Lycopodiacidites rhaeticus* and *Triancoraesporites ancorae*, probably indicate an early Hettangian age.

### Laröd

#### Locality description

The village Laröd is situated along the coast approximately 5 km north of the city of Helsingborg (Fig. 1). During the spring of the year 2000, a seven metres high section became temporarily available during the construc-

tion of new houses in the area. The section displays cyclothems with three events of shallowing and emergence (Fig. 11). The section begins with a rather mature paleosol, penetrated by numerous rootlets. On top of this follows the first event of shallowing and emergence represented by a layer of coal. The coal is overlain by a mudstone with lenticular bedding, which in turn is succeeded by a sandstone with flaser bedding, bioturbated by rootlets. As a result of the second shallowing up event, the sandstone is overlain by a second layer of coal. Above this follows a coaly clay that gradually turns in to a pure mudstone. This is followed by a sandstone, with very shallow cut and fill troughs, which is probably biotur-

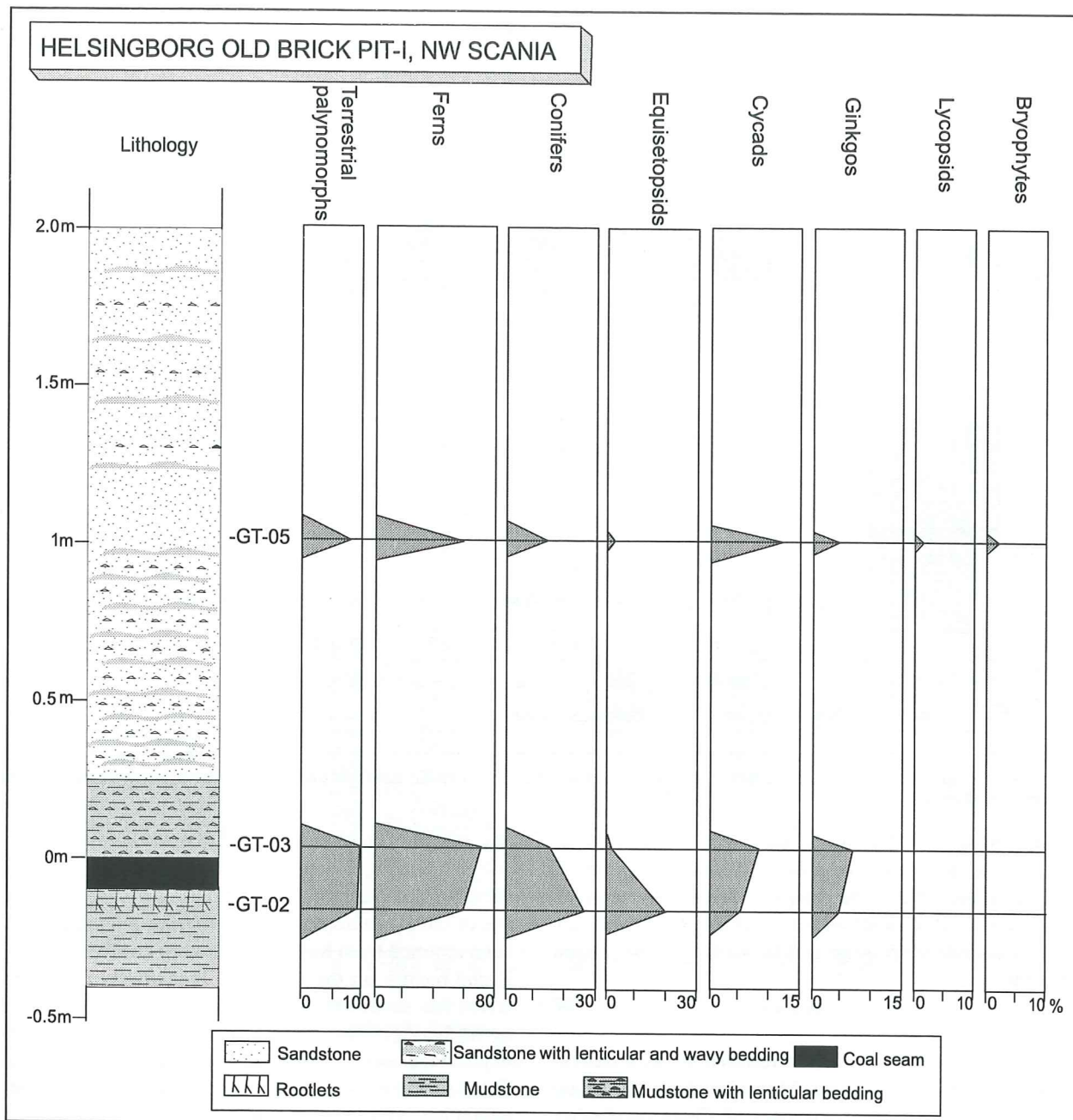


Fig. 9. Lithology and taxonomic composition of section II at the Old Brick pit locality. Note that percentage-scales may differ between the taxonomic affinities.

bated by the *Diplocraterion* Ichnofacies. Representing the third visible shallowing up and emergence sequence of this locality is yet another layer of coal, also marking the top of the section.

According to Ahlberg (pers. communication, 2002), the depositional environment was most probably a very shallow interdistributary bay. No previous palynological investigation has been carried out on this section.

#### Palynology

All but the uppermost sample (L-06) contain moderately preserved palynomorphs (Fig. 11), but only small amounts of palynodebris. Seventyone taxa were found, including twentyfour pollen-, thirtynine spore-, five freshwater- and three marine taxa. Fern spores dominated all the samples.

The Laröd assemblage is characterised by a few, very influential taxa, the most abundant being the laevigate fern spore *Deltoidospora toralis*. This particular species constitutes nearly one-hundred percent of the counted palynomorphs in the two lowermost samples. The remaining samples (L-03, -07, -04, -05 and -06) obtain approximately equal amounts of *Perinopollenites elatoides* and *Deltoidospora toralis*. Relatively common in those samples are also *Alisporites robustus*, *Quadraeculina anellaeformis*, *Araucariacites australis*, *Monosulcites punctatus*, *Chasmatosporites*, *Calamospora tener* and *Pinuspollenites minimus*. Frequently occurring are also *Retitriletes clavatoides*, *R. austroclavatidites* and *Laevigatosporites*. In sample L-07 and L-05 a few specimens of *Cerebropollenites macroverrucosus* were recorded, together with the presence of *Retitriletes semimuris*.



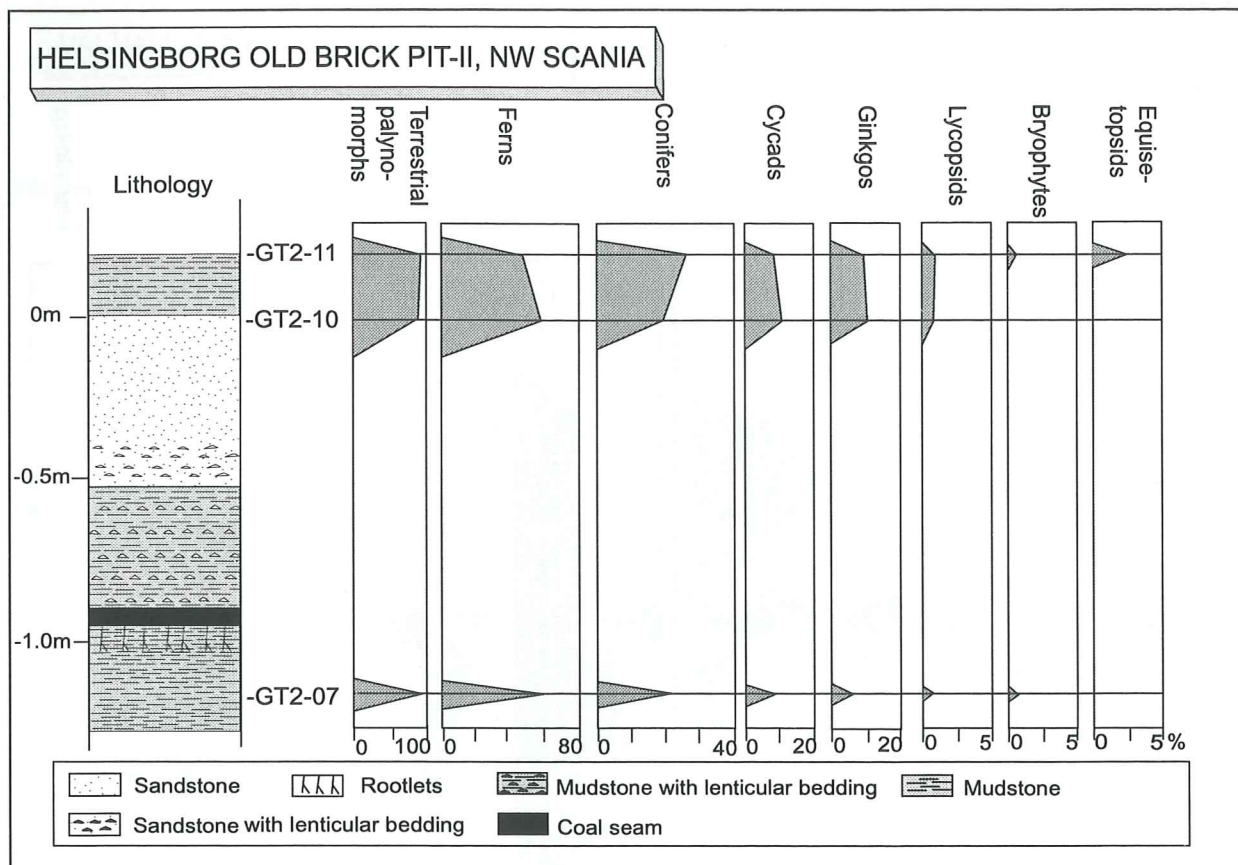


Fig. 10. Lithology and taxonomic composition of section 22 at the Old Brick pit locality. Note that percentage-scales may differ between the taxonomic affinities.

The most common freshwater alga is *Botryococcus braunii*, but *Lecaniella korsoddensis*, *Ovoidites* sp.1, *Ovoidites* sp. 2 and *Tetraporina compressa* were also recorded. Marine indicators, such as the acritarch *Micrhystridium*, the algae *Peltandripites* sp. and *Tasmanites* sp. are present but rare.

#### Suggested age

The Laröd assemblage can be referred to the *Cerebropollenites macroverrucosus* Miospore Zone (Dybkjaer 1991) based on the co-occurrence of *Cerebropollenites macroverrucosus* and *Retitriletes semimuris*, where the latter excludes an age younger than Sinemurian. Other indicators are the frequently occurring taxa *Retitriletes clavatooides*, *R. austroclavatooides*, which are known to be more common in Sinemurian deposits (e.g. Lund 1977; Dybkjaer 1988, 1991) (Fig. 4). The ornamented trilete spores *Baculatisporites* spp., *Conbaculatisporites* spp., *Trachysporites*, and the conifer pollen *Pinuspollenites minimus*, which are all frequent in Hettangian deposits (Lund 1977; Guy-Ohlson 1981; Dybkjaer 1988, 1991; Koppelhus 1991; and Koppelhus & Batten 1996) are rare in Laröd (Appendix 1, Fig. 6).

#### Kulla-Gunnarstorp

##### Locality description

The coastal cliff section at Kulla-Gunnarstorp is exposed approximately 10 km north of the city of Helsingborg (Fig. 1). The section, which dips to the south, stretches 150 metres horizontally and the height varies between

two and four metres. Heterolithic mud- and sandstones with lenticular-, flaser- and wavy bedding dominate the entire section (Fig. 12). A rich fauna of marine trace fossils of the *Skolithos* and *Diplocraterion* Ichnofacies has been reported from Kulla-Gunnarstorp (Ahlberg 1994a). Based mainly on the lithology, Pieńkowski (1991) referred this section to the lowermost Sinemurian, whereas Ahlberg (1994a) referred it to the Hettangian. The depositional environment has been interpreted as a tidal flat (Ahlberg 1994a). No previous palynological investigation has been conducted at this locality.

##### Palynology

The two samples collected from this section both yielded excellently preserved palynomorphs and small amounts of palynodebris. Sixtyfive palynomorph taxa were found; twentyfive pollen species, thirty-five spore species, three freshwater algae and a few marine dinoflagellate cysts. Both samples are dominated by pollen of gymnospermous origin, constituting more than seventy percent of the palynoflora (Fig. 12). *Perinopollenites elatoides* is most abundant in the Kulla-Gunnarstorp assemblage, comprising almost one third of the palynoflora. *Alisporites robustus* and *Deltoidospora toralis* are also very frequent. *Quadraeculina anellaeformis*, *Araucariacites australis*, *Chasmatosporites* spp., *Monosulcites punctatus* and *Alisporites thomasii* are common, along with *Retitriletes clavatooides*, *R. austroclavatooides* and *R. semimuris*. Also present, but less frequent, are the trilete ornamented fern spores *Baculatisporites* spp. and *Trachy-*

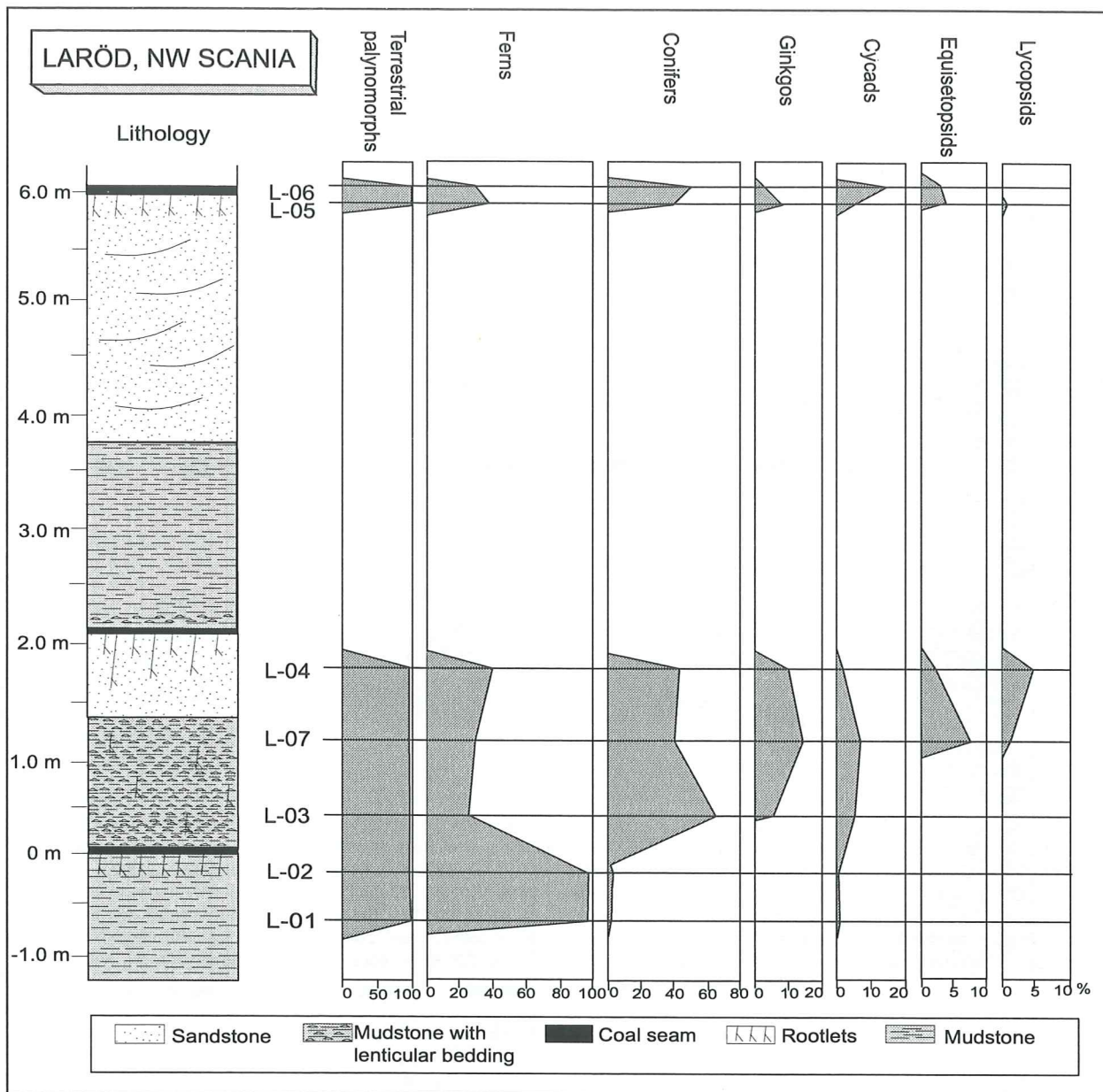


Fig. 11. Lithology and taxonomic composition of the Laröd outcrop section. Note that percentage-scales may differ between the taxonomic affinities.

*sporites* spp. and a few specimens of the important key taxon *Cerebropollenites macroverrucosus*. *Pinuspollenites* occurs, but only in small amounts (4-6%; Fig. 6). Only two typical Rhaetian taxa were recorded, one questionable specimen of *Lycopodiacidites rhaeticus* and one poorly preserved *Limbosporites lundbladii*.

A few specimens of the freshwater algae *Botryococcus braunii*, *Lecaniella* sp. and *Ovoidites* sp. are present in the samples. Marine palynomorphs, such as *Dapcodinium priscum*, "Rotundus granulatus" of Koppelhus & Nielsen (1994) and the green alga *Tasmanites* are present, but rare.

#### Suggested age

Based on the co-occurrence of *Cerebropollenites macroverrucosus* and *Retitriletes semimuris*, the Kulla-Gunnarstorp assemblage is referred to the Sinemurian *Cerebropollenites macroverrucosus* Zone (Dybkjaer 1991).

This is also indicated by the fairly high frequencies of *Retitriletes clavatooides* and *R. austroclavatooides*. The rare occurrence of trilete ornamented spores of the genera *Baculatisporites*, *Trachysporites* and *Conbaculatisporites* and the infrequent occurrence of *P. minimus* also imply an age younger than the Hettangian (Lund 1977; Guy-Ohlson 1981; Dybkjaer 1988, 1991; Koppelhus 1991; and Koppelhus & Batten 1996) (Appendix 1, Fig. 6). The presence of *Dapcodinium priscum* indicates an early Sinemurian age, since this particular species is only known to range into the lower parts of the Sinemurian (Koppelhus & Batten 1996).

#### Discussion and correlation

When comparing palynomorph assemblages it is important to consider the different sedimentological conditions in the area at the time of deposition.



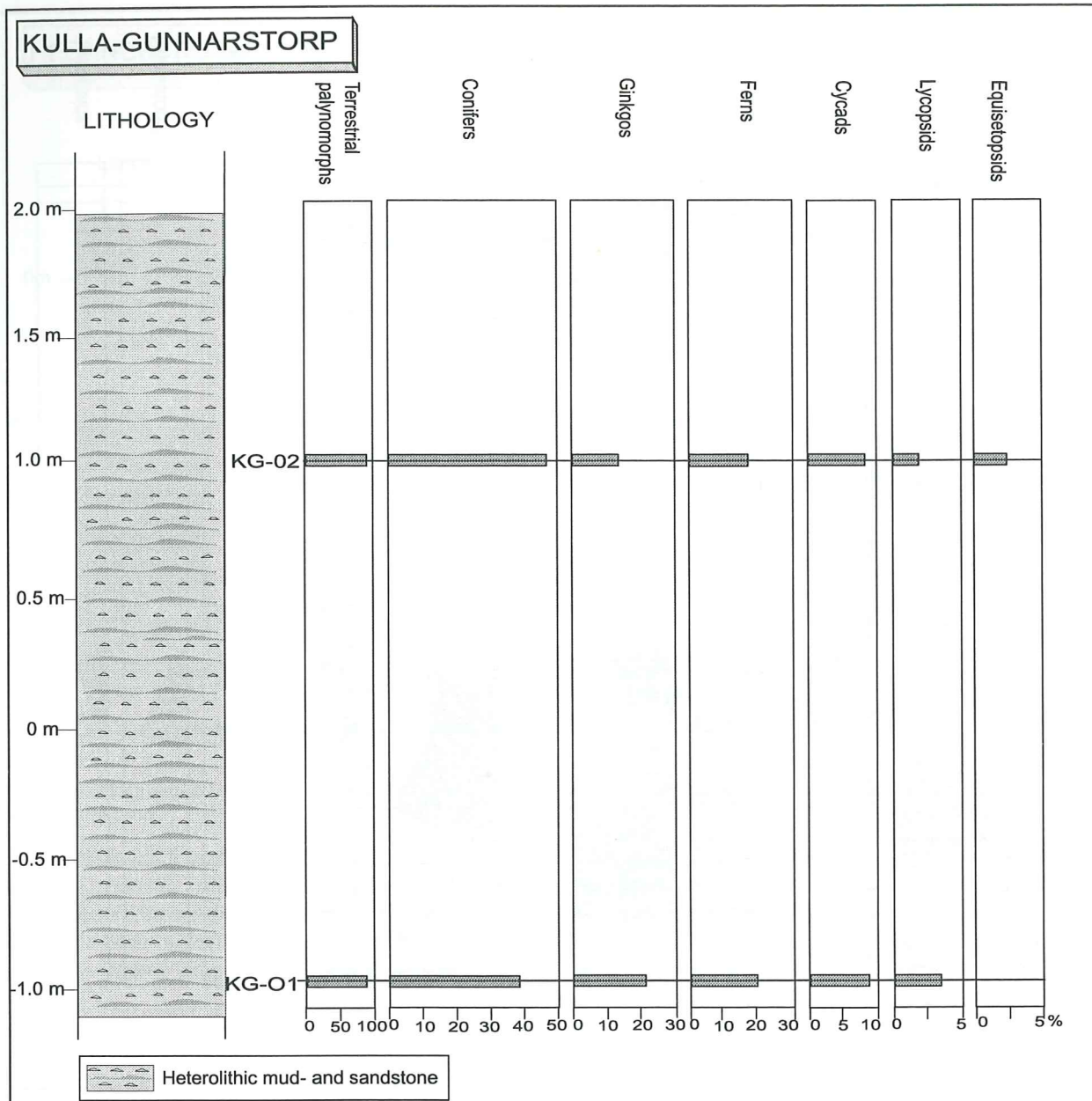


Fig. 12. Lithology and taxonomic composition of the Kulla-Gunnarstorp outcrop section. Note that percentage-scales may differ between the taxonomic affinities.

Areas adjacent to the source vegetation are more probable to reflect transitions and changes in the flora. As a result, the palynoflora will be more representative and not so affected by those forces that sort out certain palynomorphs, e.g. some palynomorphs are more affected by transportation or not able to travel far distances due to their morphology. The ratio between saccate pollen and spores is considered to reflect the distance between the depositional environment and the source vegetation (e.g. Lund 1977; Dybkjaer 1991). Beds deposited under limnic or near shore marine conditions more commonly yield trilete spores and other miospores without gasfilled cavities. As this group comprises heavy and water-transported palynomorphs their abundance is highly related to the closeness of rivers and shorelines. Easily transported types, such as the saccate pollen, are instead more likely to dominate offshore deposits (Lund 1977), as confirmed

by Lund & Pedersen (1985), who recorded the highest abundances of dinocysts along with the highest values of saccate pollen.

#### The Rhaetian-?Hettangian Transitional interval

Vilhelmsfält: Assemblage A and B (V-02, 03, 04, 05, 07, 10, 14, 15), Valhall: Assemblage A (V-11, 10, 09, 08, 07, 06, 05)

This interval corresponds to Lund's (1977) informal *Topmost Upper Rhaetian* zone and Dybkjaer's (1991, p. 47) unnamed interval. As the "*Topmost Upper Rhaetian*" probably does not only represent the Rhaetian (or Hettangian) interval, but instead represents the transition between Triassic and Jurassic floras, a more convenient name would be the "Transitional interval" (Fig. 5), which is used in the discussion below.

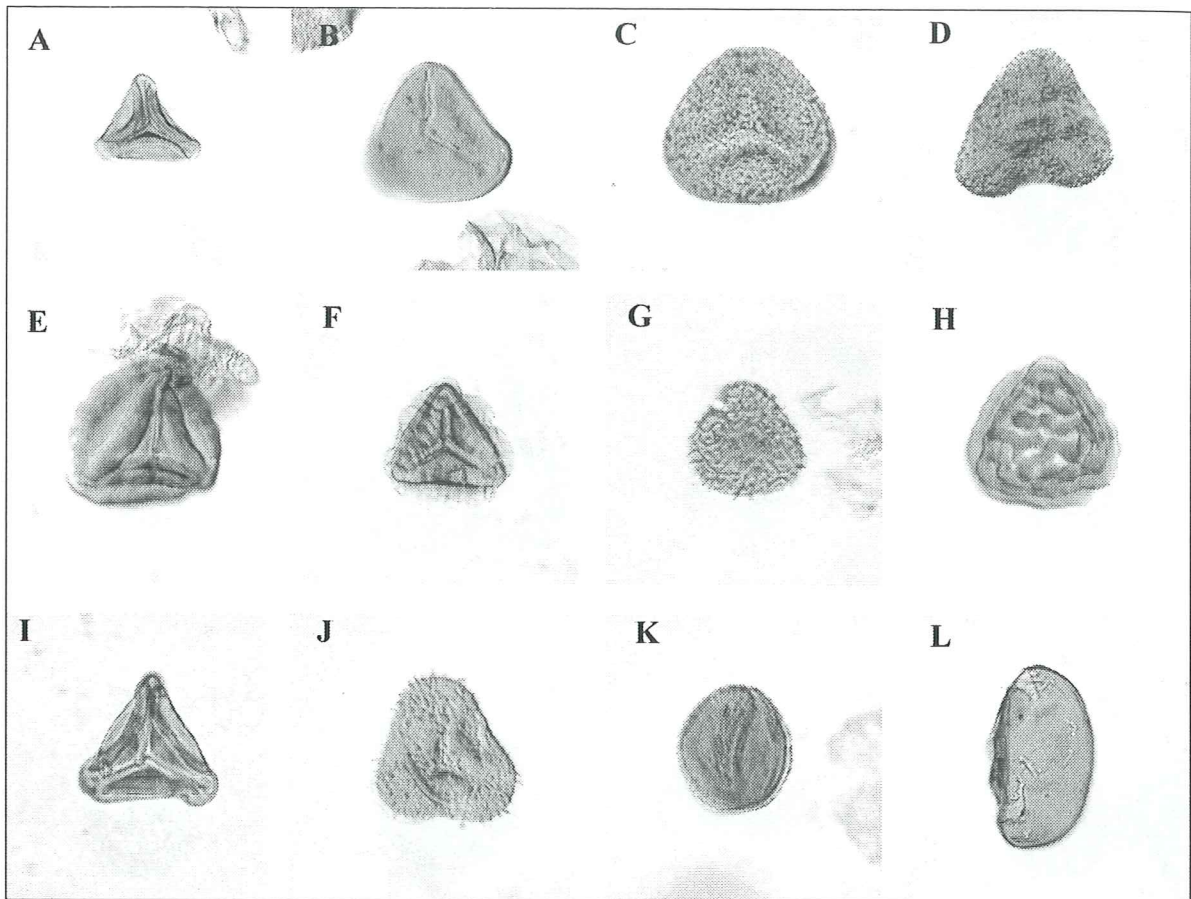


Fig. 13. Photomicrographs of selected taxa (photographed at a magnification of x500), each specimen identified by sample-, slidenummer and England finder coordinates. A; *Deltoidospora toralis* (Leschik) Lund 1977. L-02. J25/3. B; *Intrapunctisporis toralis*. (Leschik) Lund 1977. Laröd-05. K/37. C; *Trachysporites asper* Nilsson 1958. GÅT-I-02. H27/2. D; *Trachysporites fuscus* Nilsson 1958. GÅT-I-02. J40/4. E; *Iraquispora laevigata* (Mädler) Lund 1977. KG-02. Q32/4. F; *Zebbrasporites interscriptus* (Thiergart) Klaus 1960. KG-02. F37/1. G; *Retitriletes semimuris* Danzé-Corsin & Laveine 1963. KG-02. S33/3. H; *Striatella* sp. cf. *S. scanica* (Nilsson) Filatoff & Price 1988. GÅT-II-07. P30/4. I; *Gleicheniidites* sp. cf. *G. senonicus* (Couper) Pocock 1970. KG-02. F36/3. J; *Conbaculatisporites mesozoicus* Klaus 1960. GÅT-II-07. R30. K; *Marattisporites scabratus* Couper 1958. KG-02. S30/4. L; *Laevigatosporites mesozoicus* Schultze 1967. GÅT-II-10. F31/3.

The oldest assemblages in Vilhelmsfält and Valhall differ from the already established upper Rhaetian miospore zones (the *Riccisporites-Polydiisporites* and *Corollina-Riccisporites* zones), but also differ from the Hettangian *Pinuspollenites-Trachysporites* Zone. None of the assemblages possess distinct Rhaetian or Hettangian characters and are comparable to Lund's (1977) "Topmost Upper Rhaetic"-samples. The only notable difference between Lund's samples and the present ones is the relation of *Pinuspollenites minimus* and *Riccisporites tuberculatus*. Lund's Rödbý assemblage has a higher abundance of *R. tuberculatus* (Lund 1977), whereas in the present assemblages *P. minimus* is more abundant (Fig. 6). Similar assemblages, in which *P. minimus* exceeds *R. tuberculatus* have also been recorded from the Boserup Beds in Scania (Lund 1977), and the Stenlille-2 drill-core (Dybckjaer 1991). Lund (1977) referred the Boserup Beds to the basal parts of the Helsingborg Member (i.e. Höganäs Fm), but was unsure whether to refer it to the *Pinuspollenites-Trachysporites* Zone or to the "Topmost Upper Rhaetic". Dybckjaer (1991) referred the Stenlille-2 samples to the basal Hettangian due to the lack of Rhaetian taxa, and chose not to assign the interval to any defined or informal zone. In addition, the dinoflag-

ellate cyst *Dapcodinium priscum* occurs frequently, whereas *Rhaetogonyaulax rhaetica* Sarjeant 1963, which is restricted to Rhaetian strata, is absent (Dybckjaer 1991; Koppelhus & Batten 1996).

To refer a microflora to a certain age based on the quantitative relation between *P. minimus* and *Riccisporites* seems dubious since the amounts of these two taxa are probably, at least partly, facies controlled (Dybckjaer 1991; Batten et al. 1996). The bisaccate *Pinuspollenites* is designed to be dispersed by wind whereas the rather large *Riccisporites* is better transported by water (Batten et al. 1994). *Riccisporites tuberculatus* is a large, robust palynomorph, which is easily recognised, even as fragments (Batten et al. 1994). Thus, it is not surprising that larger amounts of *Riccisporites* occur in coarser sediments, which are very often fluviially deposited.

However, in the present study a number of additional characteristics are provided that enables distinction between assemblages typical of the Hettangian *Pinuspollenites-Trachysporites* Zone and those of the "Transitional interval" in NW Scania. (1) In the "Transitional interval" *Pinuspollenites minimus* is less frequent than, or equally frequent as *Riccisporites tuberculatus*, whereas the assemblages of the *Pinuspollenites-Trachysporites*



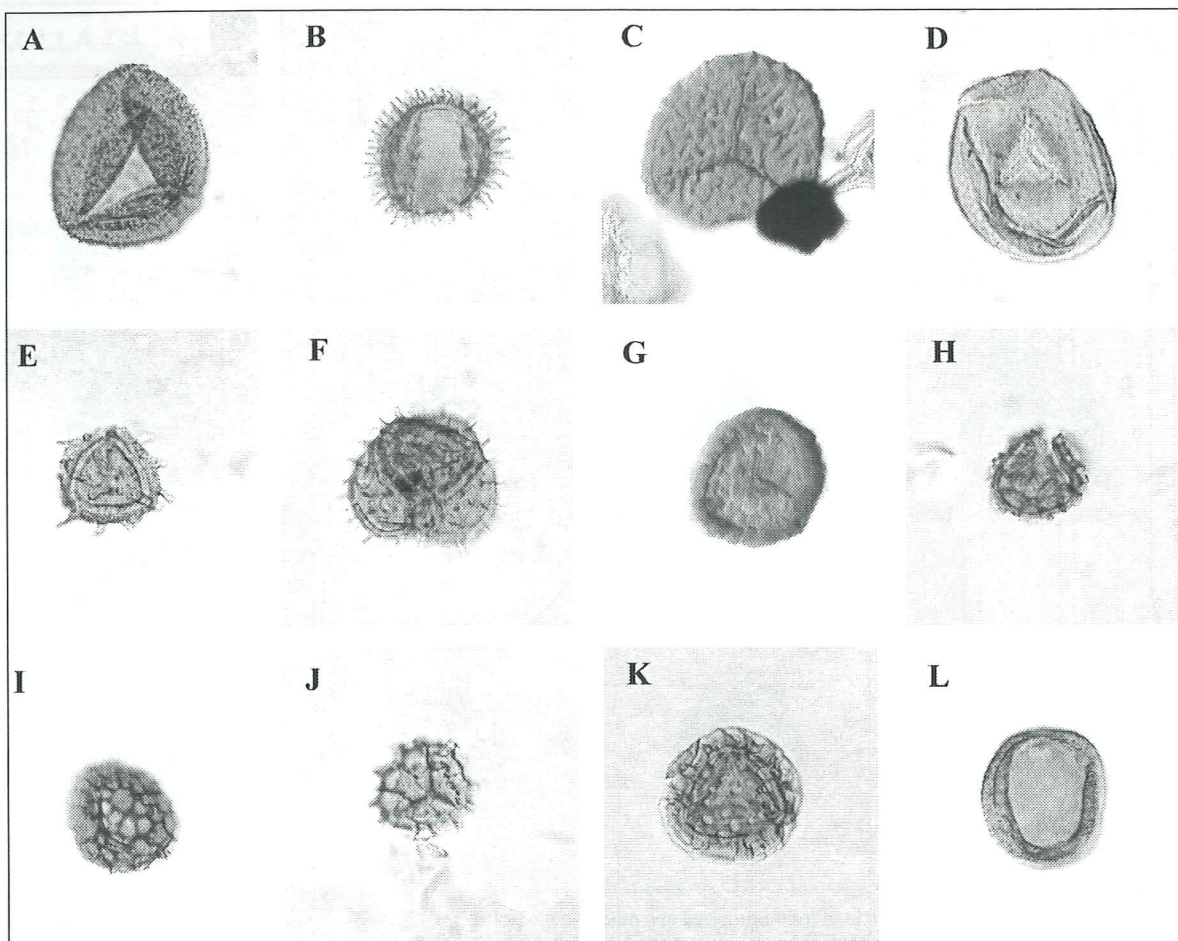


Fig. 14. Photomicrographs of selected taxa (photographed at a magnification of x500), each specimen identified by sample-, slidenummer and England finder coordinates. A; *Baculatisporites comaumensis* (Cookson) Potonié 1956. KG-01. N29/2. B; *Anapiculatisporis* sp. cf. *B. telephorus* (Pautsch) Jansonius 1967. KG-02. Q37. C; *Lycopodiumsporites rugulatus* (Couper) Schultz 1967. Laröd-05. R39/4. D; *Cadargasporites* sp. Laröd-05. O35/3. E; *Kraeuselisporites reissingeri* (Harris) Morbey 1975. V-07. H33/1. F; *Kraeuselisporites reissingeri*-tetrad V-07. R35/2. G; *Uvasporites argenteaformis* (Bolchovitina) Schultz 1967. GÅT-I-02. S29/4. H; *Retitriletes austroclavatidites* (Cookson) Potonié 1975. V-05. U38/3. I; *Retitriletes* sp. L-02. S29/2. J; *Retitriletes clavatooides* (Couper) emend. Tralau 1968. L-05. U33/3 K; *Limbosporites lundbladii* Nilsson 1958. GÅT-I-03. T37/4. L; *Chasmatosporites apertus* (Rogalska) Nilsson 1958. GÅT-II-07. N28/3.

Zone always contain a much higher abundance of *P. minimus* than *R. tuberculatus* (Fig. 6). (2) There appear to be other quantitative differences between the two zones, e.g. the genera *Chasmatosporites*, *Laevigatosporites* and *Riccisporites* seem to decline immediately below the base of the *Pinuspollenites-Trachysporites* Zone, whereas *Trachysporites fuscus* and *Araucariacites australis* increase. (3) The saccate pollen grains increase distinctly at the base of the *Pinuspollenites-Trachysporites* Zone, either indicating a more distal depositional environment or an increase of plants adapted to a more well-drained environment.

Vilhelmsfält A & B, Valhall A, Rödbys, Stenlille-2, Boserup Beds all comply with these characteristics, despite the variations in the ratio between *Pinuspollenites* and *Riccisporites*. It is therefore suggested that they all belong to the same palynostratigraphical interval, i.e. the "Transitional interval".

Lund (1977), who based his study on pollen and spores only, stated that the Upper Rhaetian was not present in the Scanian sections he examined. Lindström (2002), however, recorded the co-occurrence of the two dinoflag-

ellate-cysts *Rhaetogonyaulax rhaetica* Sarjeant 1963 and *Dapcodinium priscum* in the uppermost part of the Lunnon section. This, together with the presence of a typical Rhaetian flora, indicates that Upper Rhaetian strata are present in Scania (Lindström 2002). According to Lindström (personal communication, 2003) the co-occurrence of *Rhaetogonyaulax rhaetica* Sarjeant 1963 and *Dapcodinium priscum* is also recorded in N. Vallåkra, NW Scania.

The "Transitional interval" in the investigated sections is, at the moment, assigned to the topmost Upper Rhaetian based on the mixed Rhaetian and Hettangian characters of the palynoflora. The base of this interval is still undefined but the top is immediately below the abrupt rise in *Pinuspollenites* and *Trachysporites*. However, it is difficult to assign this interval to any specific age due to the lack of other biostratigraphical data. The very few specimens of *Dapcodinium priscum* only suggest an age younger than the Middle Rhaetian but older than Sinemurian. In addition, the absence of *R. rhaetica* may very well infer a Hettangian age, but this is impossible to say due to the very rare occurrence of marine taxa.



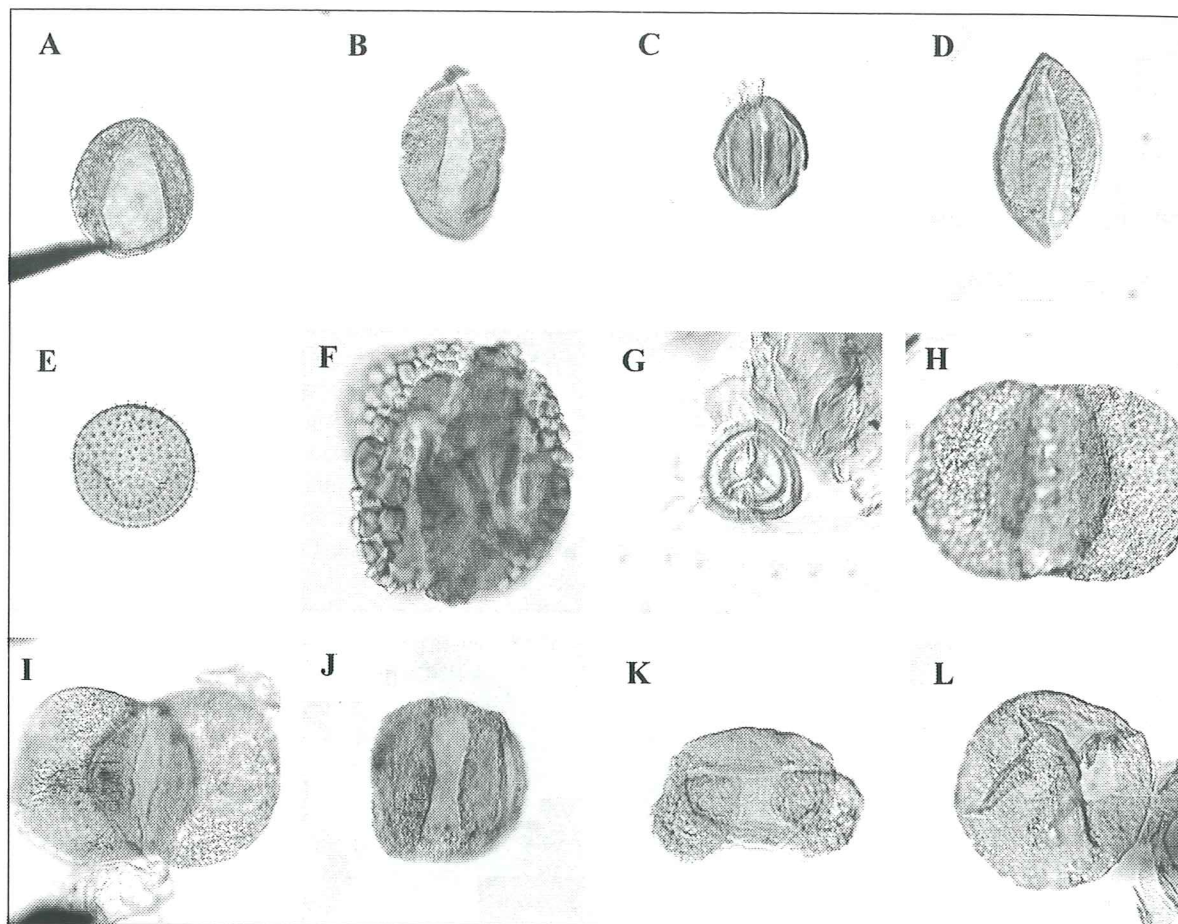


Fig. 15. Photomicrographs of selected taxa (photographed at a magnification of x500), each specimen identified by sample-, slidenumber and England finder coordinates. A; *Chasmatosporites elegans* Nilsson 1958. V-03. J24/2. B; *Chasmatosporites hians* Nilsson 1958. KG-02. X38/3. C; *Eucommidites troedsonii* Erdtman 1948. L-07. K29/3. D; *Monosulcites punctatus* Orłowska-Zwolinska 1966. L-05. T23/3. E; *Foraminisporis jurassicus* Schultz 1967. V-05. F31. F; *Riccisporites tuberculatus* Lundblad 1954. V-05. Q36. G; *Dicyclosporites* sp. Potonié 1970. VF-10. P28. H; *Alisporites robustus* Nilsson 1958. KG-01. O26/4. I; *Alisporites radialis* (Leschik) Lund 1977. GÅT-II-11. L42/3. J; *Quadraeculina anellaeformis* Maljavkina 1949. L-07. O35/3. K; *Pinuspollenites minimus* (Couper) Kemp 1970. V-07. E38/1. L; *Araucariacites australis* Cookson 1947. KG-02. O24/3.

#### Pinuspollenites-Trachysporites Miospore Zone Vilhelmsfält (VF-20, 26, 31, 41), Valhall (V-04, 03, 02, 01), Old Brick pit I (GÅT-02, 03, 05), Old Brick pit II (GÅT-07, 10, 11)

The younger assemblages recovered from the uppermost parts of the two drillcores from Valhall and Vilhelmsfält, and the assemblages from the two sections of the Old Brick pit can all be assigned to the Hettangian *Pinuspollenites-Trachysporites* Miospore Zone. The results from previous investigations conducted by Lund (1977), Guy-Ohlson (1981), Dybkjaer (1988, 1991) and Koppelhus (1996) are almost identical to the present ones. All characters indicative of the Hettangian assemblage are present, both considering key taxa and quantitative aspects. The only difference is the abundance of *Corollina torosus*, which is sparse in the present assemblages compared to samples derived from the Gassum and Fjerritslev formations in the central parts of the Danish Basin (Fig. 1). Similar to the "Transitional interval"-samples, the *Pinuspollenites-Trachysporites* assemblages have more in common with those from Rödbby (Lund 1977), Stenlille-2 (Dybkjaer 1991) and Bornholm (Koppelhus 1991) than with the ones from the Fjerritslev (Dybkjaer 1991) and

Gassum formations (Dybkjaer 1988). This can probably be explained, as mentioned before, by the similar sedimentary environments present in those areas at the time of deposition (Fig. 3).

#### The *Cerebropollenites macroverrucosus* Miospore Zone

Kulla-Gunnarstorp (KG-01, 02), Laröd (L-01, 02, 03, 07, 04, 05, 06)

The outcrops at Kulla-Gunnarstorp and Laröd can both be referred to the *Cerebropollenites macroverrucosus* Zone based on the co-occurrence of *Cerebropollenites macroverrucosus* and *Retitriteles semimuris*. *C. macroverrucosus* is, in accordance with previous investigations by Lund (1977), Dybkjaer (1988, 1991) and Koppelhus (1991), very infrequent and only found outside counting.

On Bornholm (Koppelhus 1991), in Öresund and NW Scania (Koppelhus & Batten 1996) the most abundant palynomorphs in the *Cerebropollenites macroverrucosus* Zone are *Perinopollenites elatoides*, *Pinuspollenites minimus* and a variety of other bisaccates (including *Alisporites* spp.). This is all reflected at Kulla-Gunnarstorp.



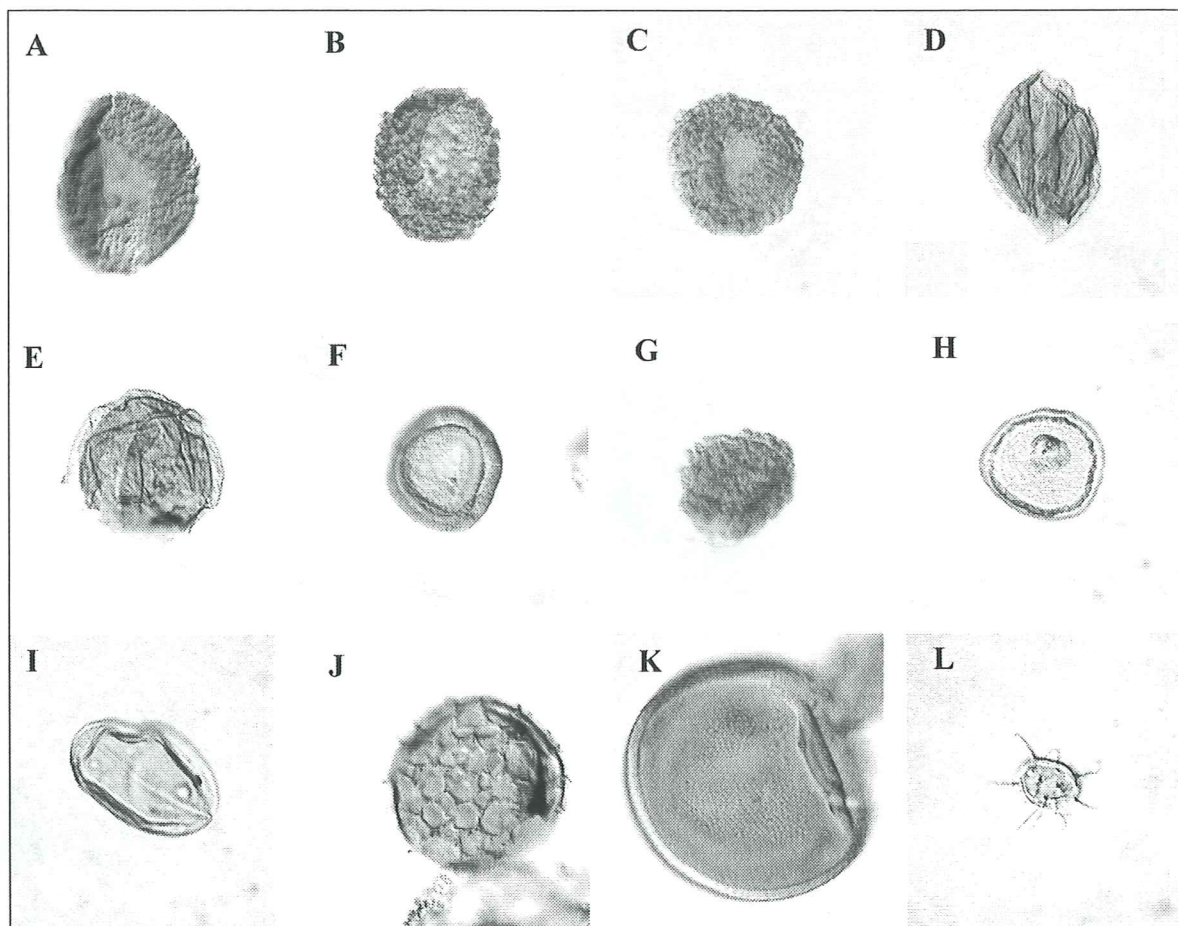


Fig. 16. Photomicrographs of selected taxa (photographed at a magnification of x500), each specimen identified by sample-, slidenummer and England finder coordinates. A; *Cerebropollenites thiergartii* Schultz 1967. GÄT-I-03. P32. B; *Cerebropollenites macroverrucosus* (Thiergart) Schultz 1967. KG-02. M32/2. C; *Cerebropollenites macroverrucosus* (Thiergart) Schultz 1967. KG-01. N29/3. D; *Perinopollenites elatoides* Couper 1958. KG-02. D35/3. E; *Perinopollenites elatoides* Couper 1958. KG-01. T31/1. F; *Corollina torosus* Cornet & Traverse 1975. L-05. P29/2. G; cf. *Cerebropollenites macroverrucosus* (Thiergart) Schultz 1967. L-05. S35/1. H; *Lecaniella* sp. Cookson & Eisenack 1962. V-06. E31/3. I; *Ovoidites* sp. 1 Potonié 1951. V-07. N29/1. J; *Cymatiosphaera* sp. GÄT-II-11. J27/3. K; *Tasmanites* sp. KG-01. L41. L; *Michrystidium* sp. L-05. K32.

Laröd is instead comparable to an Early Sinemurian assemblage from the Örby-drillcore, south of Helsingborg, where several similarities concerning content and quantity can be encountered (Erlström et al. 1999).

Generally, the same taxa that characterise the Hettangian assemblages occur in the Sinemurian, but in different amounts. *Pinuspollenites minimus* is still common but to a lesser degree (4-6 %; Fig. 6), which is opposite to *Alisporites* that increases in numbers (15-24 %). *Deltoidospora* is still frequent but not as dominant as in the Hettangian sections. Typical Rhaetian components, such as *Riccisporites tuberculatus*, are still recorded sporadically, but mainly outside counting (Appendix 1, Fig. 6). Trilete ornamented spores, especially those, which are common in the Hettangian, decrease in number, such as *Trachysporites* (2-6 %), *Conbaculatisporites* and *Baculatisporites*, while there is an increase of the genus *Retitriletes* (Appendix 1, Fig. 6).

There is a difference in diversity and preservation between Laröd and Kulla-Gunnarstorp, perhaps reflecting differences in their depositional environment. Both Pieńkowski (1991) and Ahlberg (1994a) have interpreted the outcrop at Kulla-Gunnarstorp as a tidal flat due to the presence of a marine ichnofauna. However, in this

study only a sparse marine microflora was recorded, perhaps a consequence of deposition in proximity to a freshwater source, e.g. a river outlet. Nevertheless, a distally settled depositional environment is justified by the high abundance of easily transported bisaccate pollen grains (Lund 1977; Dybkjaer 1991).

The assemblage recorded at Laröd is believed to represent an interdistributary bay (Ahlberg, personal communication, 2002). The common occurrence of freshwater algae, together with occasional marine acritarchs, also indicate a freshwater-supported nearshore environment. Both sections retain some Hettangian features, e.g. a relatively high frequency of ornamented spores, and are therefore most probably referable to the lowermost parts of the Sinemurian Döshult Member. Since the Hettangian influence is more evident in Laröd it is considered to be slightly older than the Kulla-Gunnarstorp palynoflora. The presence of Rhaetian forms, such as *Lycopodioidites rhaeticus*, *Ovalipollis ovalis* and *Limboisporites lundbladii* is puzzling. The fact that these species have not been recorded as high as the Sinemurian before (Fig. 4), suggests reworking of Rhaetian sediments during the time of deposition.



## Paleoenvironment

The high abundance of freshwater algae combined with the very rare occurrence of dinocysts, acritarchs and tasmanitids imply that the deposition took place in a predominantly freshwater environment with only occasional marine influences. All samples contain well-preserved palynomorphs, indicating minimal transport during dispersal, and that the source plants grew in close proximity to the site of deposition. As all "Transitional interval" assemblages recorded herein were deposited in on-shore or near-shore environments (Fig. 3), proximate to the source vegetation, they were more affected by the transition from the Rhaetian to the Early Jurassic flora.

A major change in facies occurred at the beginning of the Hettangian. The depositional environment changed from fine-grained floodplain and swamp deposits in the Rhaetian to more distally settled deltaic environments in the Hettangian (Ahlberg 1994a). In this study this is mirrored by an increasing abundance of saccate pollen grains. Despite the relative increase in saccate pollen grains and conifers, fern spores continued to be prominent in the Hettangian assemblages. Equisetopsids, and especially cycads, are other important components of the Hettangian flora (Figs. 7, 8, 9 and 10). Despite increased distance from the source vegetation, all Hettangian assemblages are well preserved and dominated by palynomorphs derived from land plants. The high amounts of coniferous pollen also suggest that the environment was better drained, since conifers are more adapted to such conditions. In accordance with previous interpretations by both Pieńkowski (1991) and Ahlberg (1994a), the present study shows that freshwater deposition, with minor marine influences prevailed in NW Scania during the Hettangian.

The palynofloristic composition of the Sinemurian Laröd outcrop indicates that the deposition took place in a freshwater environment with occasional marine influences, close to the Hettangian-Sinemurian boundary. The stepwise transgression at the beginning of the Sinemurian, which started off with tidal deposits (Pieńkowski 1991; Erlström et al. 1999), is partly mirrored in the Kulla-Gunnarstorp assemblage, comprising high amounts of saccate pollen. However, this alone is not evidence enough for a marine environment. Since only a few marine taxa were recorded it may be assumed that the deposition still occurred at the coastal margin and was highly influenced by the backland flora and freshwater sources. Despite somewhat different depositional environments at Kulla-Gunnarstorp and Laröd it can be stated that equisetopsids, ginkgos and lycopsids were important accessories to the fern- and conifer- dominated vegetation in the Sinemurian (Figs. 11 and 12). Fern spikes occur in L-01 and L-02 where fern spores comprise 97-98% (Fig. 11). This may be the result of newly exposed surfaces in a dynamic, damp depositional environment where ferns were the first colonisers (personal communication; V. Vajda, Lund 2003).

The accumulations of peat and autochthonous coal seams, as well as the formation of kaolinite due to chem-

ical weathering (Ahlberg 1994b), indicate that humid climatic conditions prevailed during the Rhaetian and Sinemurian. In addition, it is possible that the significant rarity of *Corollina torosus*, which is considered by some authors (e.g. Higgs & Beese 1986) to be more prominent in arid-to semi-arid environments, indicate a humid climate. However, this does not explain the high frequencies of *Corollina*, recorded by Dybkjaer (1988, 1991), in the marine Gassum and Fjerritslev formations. Hubbard & Boulter (2000) imply that a series of rapid climatic fluctuations occurred at the Rhaetian-Hettangian boundary, and that a cold event at the beginning of the Jurassic period decreased the humidity. A decrease in humidity could possibly explain the increase in conifer pollen, at the cost of fern spores, at the boundary between the uppermost Rhaetian and Hettangian.

The presence of the reworked Carboniferous taxa *Densosporites*, *Platyptera* and *Crassispora* is interesting since Carboniferous strata are absent in Sweden. However, reworked spores of this age suggest that the Carboniferous continental deposition included southern Sweden (Guy-Ohlson et al. 1987).

## Conclusions

This palynological investigation, conducted on the lowermost intervals of the Vilhelmsfält and Valhall drill-cores, and on outcrop-sections at the Old Brick pit, Laröd and Kulla-Gunnarstorp have revealed the presence of well-preserved microfloras corresponding to the uppermost Rhaetian-Sinemurian interval. All sections can be differentiated biostratigraphically based on their palynological content; the absence and presence of certain key taxa, as well as their quantitative differences. Three assemblage zones are distinguished, namely: (1) An older assemblage zone referable to the "Transitional interval" assigned to the uppermost Rhaetian-Hettangian, which includes the assemblages A and B from Vilhelmsfält, and A in Valhall. (2) The already established Hettangian *Pinuspollenites-Trachysporites* Zone to which the assemblages C from Vilhelmsfält, B from Valhall, and those from the Old Brick pit are assigned. (3) The Sinemurian *Cerebropollenites macroverrucosus* Zone, which includes the assemblages from Laröd and Kulla-Gunnarstorp. All localities correlate well with previous palynological investigations in northwestern Europe (e.g. Lund 1977; Guy-Ohlson 1981; Dybkjaer 1988, 1991; and Koppellhus & Batten 1996), and all localities yielded on-shore floras that were occasionally affected by marine influences. This corresponds well to previous paleoenvironmental interpretations in the area, except in the case of Kulla-Gunnarstorp. This locality has previously been considered marine due the sedimentology and trace-fossils, which are frequently recorded. In the present palynological investigation very few marine indications were recorded implying a more proximal depositional site than previously suggested (e.g. Pieńkowski 1991; Ahlberg 1994a). The quantitative palynological data suggests that ferns, together with conifers, dominated the vegetation over the entire time interval. Bryophytes are more fre-



quent in the older assemblages whereas equisetopsids increase at the beginning of the Hettangian. Lycopsids are present at all sections, but most prominent in those of Sinemurian age.

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