18. POLLEN

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INTRODUCTION

Pollen analysis was used to envisage the vegetational changes which occurred in the archipelago in the vicinity of the sites under study. As reference for the marine sequences at Solberga and Moltemyr, two localities with limnic sediments on the adjoining land areas were investigated, *i.e.* Vägen and Rörmyr (Fig. 4:4, Chapter 4). In the case of the sediments in the Brastad core, only preliminary pollen analyses were made.

Pollen-analytical investigations have been used to reconstruct the vegetational changes, which took place in the late Pleistocene and early Holocene in south-western Sweden (Fries 1951, Berglund 1976, 1979, Digerfeldt 1979, Hilldén 1979). Fries made an extensive pollen-analytical study of about 20 localities in Bohuslän on the west coast of Sweden (Fries 1951). His material included both marine and limnic sediments. Two of the sites, Moltemyr and Rörmyr, were reviewed in connection with the boundary project.

In Sweden pollen analysis of marine sediments has rarely been performed with a view to deduction of the late Pleistocene and early Holocene vegetational history. Nevertheless the pollen flora in marine sediments has been shown to reflect the main features of the vegetational history of their continental (inland) source (e.g. Stanley 1969, Florer 1973, Heusser 1978, Balsam and Heusser 1976). The interpretation from marine, minerogenic sediments may be affected by limiting factors such as low pollen frequencies, corrosion and irregular transportation of pollen causing over-representation of some species. The presence of reworked pollen and spores, of pre-Quaternary and older Quaternary age, may indicate the origin and source areas of sediments. Increasing frequency of secondary pollen also marks increased erosion due to base-level lowering during periods of continental glaciation (Stanley 1966).

According to Fries 1951 and Berglund 1979, Fig. 6, the vegetational sequences in south-western Sweden during the late Pleistocene and early Holocene were as follows:

Preboreal (PB),	transition from tundra to open woodland with shrubs and, later, closed woodland dominated by birch
	a, *Betula – Empetrum* b, *Betula – Juniperus* c, *Betula – Pinus*
Younger Dryas (DR 3),	shrub and herb tundra *Juniperus – Artemisia* – Gramineae – Cyperaceae
Alleröd (AL),	woodland – open woodland – heaths *Betula – (Pinus) – Empetrum* – Gramineae – *Artemisia*
Older Dryas (DR 2),	shrub tundra – open tundra *Juniperus* – Gramineae – Cyperaceae
Bölling (BÖ),	open woodland – *Betula* woods *Artemisia* – Gramineae – Cyperaceae
Oldest Dryas (DR 1),	open tundra with shrubs and herbs *Artemisia* – Cyperaceae – *Dryas*

TECHNIQUES, ANALYSIS AND DIAGRAM CONSTRUCTION

All samples were first treated by standard methods, hydrofluoric acid and acetolysis (Faegri and Iversen 1975). The pollen concentrations at Solberga and Moltemyr were low, and at Brastad extremely low. A sedimentation-separation method was therefore used (Påsse 1976) for the samples from Solberga, Moltemyr and Brastad. The pollen frequencies in the samples processed then increased noticeably.

Solberga and Moltemyr presented an abundance of both reworked pre-Quaternary pollen and spores and redeposited Quaternary pollen of interstadial and/or interglacial origin. About 500 pollen grains of terrestrial plants, excluding reworked pollen, were counted in each sample.

The diagrams were constructed in accordance with Berglund (1976). Rebedded pollen and spores are represented in three different curves:

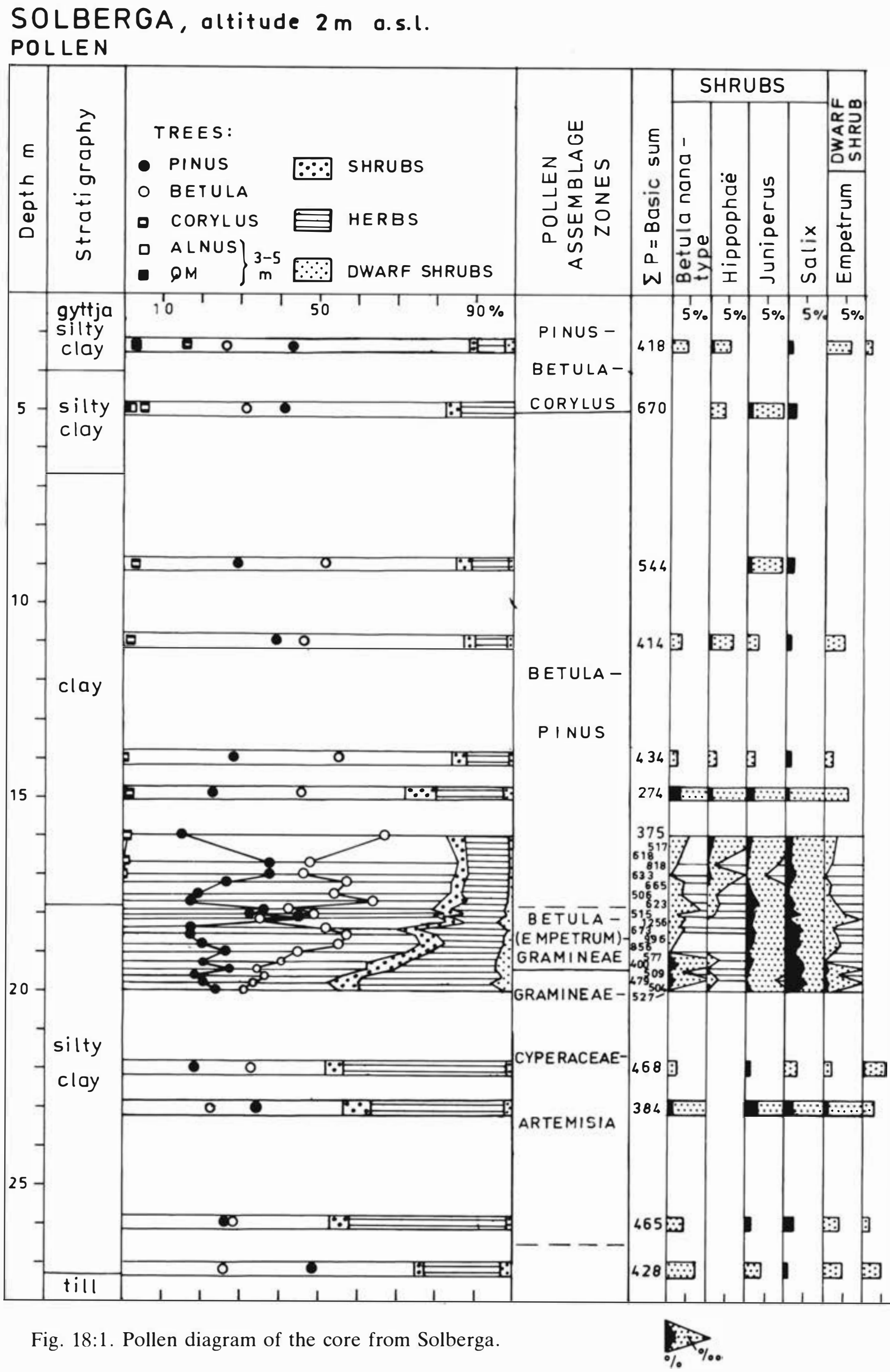
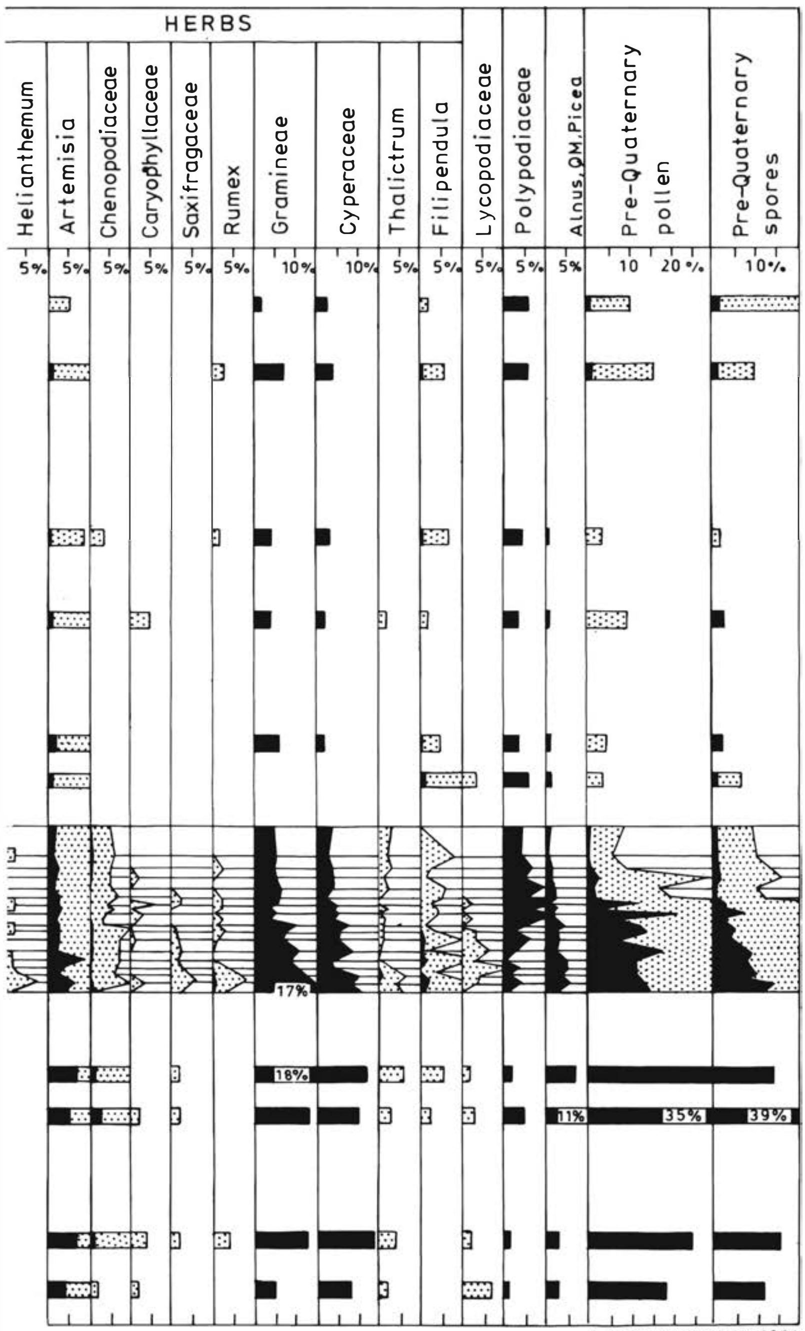


Fig. 18:1. Pollen diagram of the core from Solberga.


HERBS
Helianthemum
Artemisia
Chenopodiaceae
Caryophyllaceae
Saxifragaceae
Rumex
Gramineae
Cyperaceae
Thalictrum
Filipendula
Lycopodiaceae
Polypodiaceae
Alnus, QM, Picea
Pre-Quaternary pollen
Pre-Quaternary spores
5%
10%
10
20 %
17%
18%
11%
35%
39%
A.-M. ROBERTSSON 1981

(1) Quaternary tree pollen including *Alnus,* QM and *Picea,* (2) pre-Quaternary pollen and (3) pre-Quaternary spores. The pollen diagrams were divided into pollen assemblage zones, PAZ. The boundary between the chronozones Younger Dryas (DR 3) and Preboreal (PB) was defined by radiocarbon datings of sediments from Vägen and Rörmyr. The sediments in the cores from Vägen and Rörmyr were classified according to the system, used at the Geological Survey (SGU 1978).

DIAGRAM DESCRIPTION

Solberga, 2 m above sea level

Stratigraphy: see Chapters 6 and 7.

Gramineae – Cyperaceae – *Artemisia* PAZ (26.5–19.5 m)
Pollen spectra characterized by high frequencies of herbs (about 30 %) such as *Artemisia,* Gramineae and Cyperaceae (Fig. 18:1). Pollen of shrubs and dwarf shrubs occur with 4–6 %. There are high values for reworked pre-Quaternary and Quaternary pollen. The pre-Quaternary pollen types include Jurassic, Cretaceous, and Tertiary assemblages with e.g. *Classopollis, Tricolporopollenites, Caytonipollenites, Carya, Platycarya,* and *Sciadopitys* (Fig. 18:2). Palaeozoic palynomorphs were also observed. The rebedded interglacial pollen flora is represented by tree pollen of *Picea, Alnus,* QM, and *Corylus.* But some of the herb pollen and spores may also derive from early Quaternary deposits. Triporate pollen of a Coryloid–Betuloid type (Fig. 18:2), which may be of pre-Quaternary of Quaternary origin, occurs in this zone with 5–6 %. Unidentifiable, corroded, crumpled pollen grains constitute 5–10 %.

Betula – (Empetrum) – Gramineae PAZ (19.5–17.9 m)
Rising values for *Betula.* Decreasing frequencies for reworked pollen and spores. Pollen of shrubs and dwarf shrubs occur with slightly higher values than in the preceding zone.

Betula – Pinus PAZ (17.9–6.0 m)
Tree pollen represented by *Betula* and *Pinus* increases. *Corylus* occurs with 1–3 %. Herb pollen decreases to frequencies around 10 %. There is also a marked decline in reworked pre-Quaternary pollen and spores.

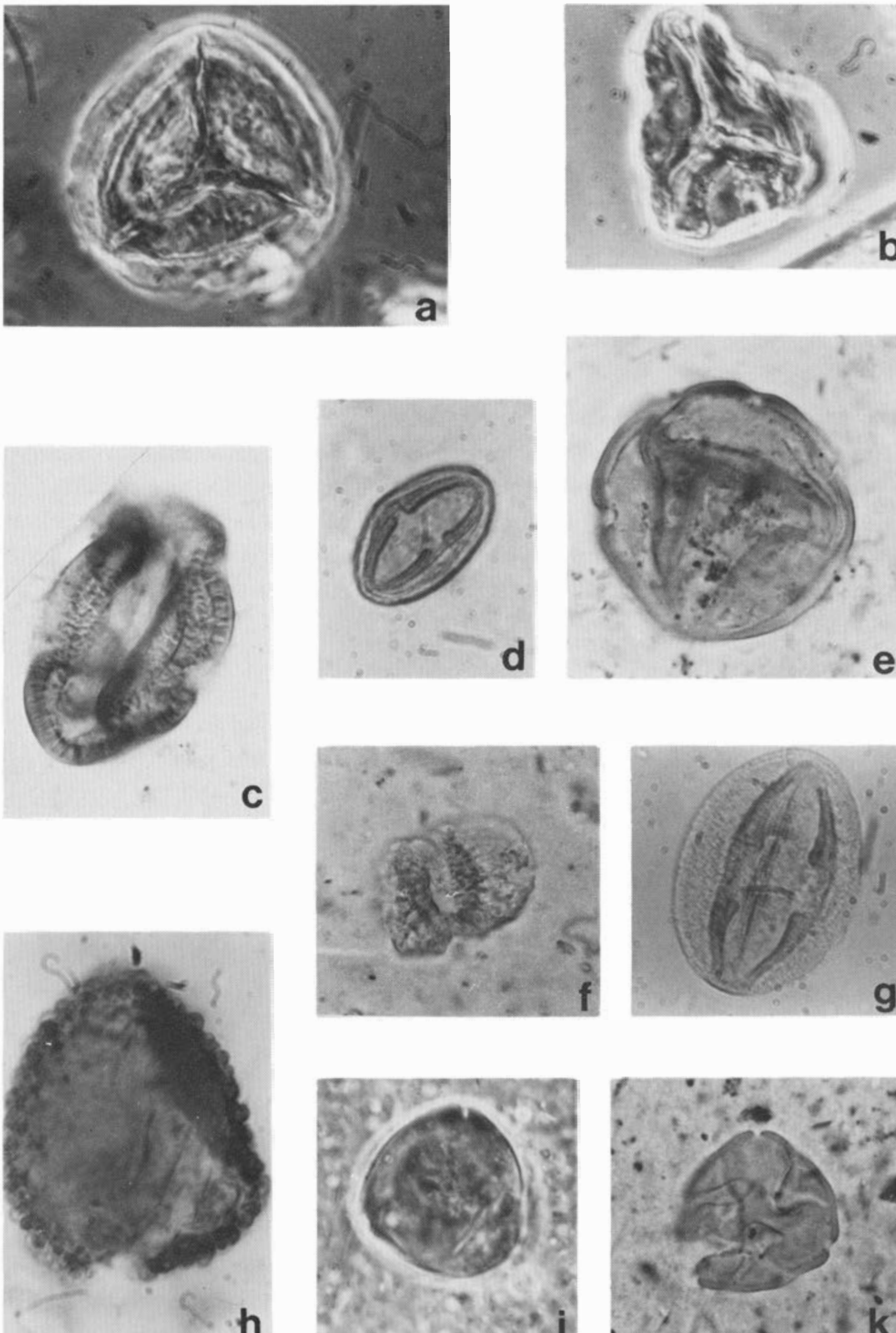


Fig. 18:2. Reworked pre-Quaternary pollen and spores from Solberga and Moltemyr. (a–b) Trilete spores, (c) *Classopollis,* (d) *Tricolporopollenites,* (e) *Carya,* (f) *Cyatonipollenites (Vitreisporites),* (g) *Tricolporopollenites* (cf. *Rhus*), (h) *Sciadopitys,* (i) triporate pollen of Betuloid-Coryloid type, (k) *Platycarya.* Magnification 1000x.

Pinus – Betula – Corylus PAZ (6.0–3.0 m)
This zone is characterized by tree pollen of *Pinus* and *Betula*. Increasing percentage of *Corylus*.

The zone boundary at 19.5 m, indicated by a decrease in herb pollen together with increasing frequencies of *Betula,* is presumed to correspond to the Pleistocene/Holocene boundary. The rise of the *Corylus* curve at about 5 m reflects the immigration of hazel during the early Boreal.

Vägen, 112 m above sea level

The site chosen as a terrestrial reference for Solberga is Vägen, situated about 12 km east of Solberga in the Svartedalen area. On the Geological Map sheet Göteborg NO (Fredén 1979) the Vägen site is to be found 7.5 km WSW of St. Peder's Church on the Göta River. The core was taken in an overgrown creek of Lake Stora Äggdalssjön, situated just above the local highest shoreline. The stratigraphy (Fig. 18:3) is

0–215 cm	fen peat
215–235 cm	*Carex* peat
235–260 cm	*Carex-Sphagnum* peat
260–272.5 cm	*Equisetum* peat
272.5–288 cm	gyttja
288–296 cm	clay gyttja
296–370 cm	gyttja clay
370–568 cm	clay

Diatom analysis confirms that the sediments were deposited in fresh water (see Chapter 16).

Betula – Pinus – Empetrum PAZ (360–320 cm)
In this zone the tree pollen consists of *Betula* and *Pinus* (Fig. 18:3). Pollen of *Betula nana* is frequent together with *Salix* and *Juniperus*. *Empetrum* is represented with values over 5 %. There are also high frequencies of Cyperaceae, Gramineae and *Rumex*. *Pediastrum* occurs with over 40 % in two samples. Pollen of Limnophyta occurs. This zone represents the Alleröd interstadial, during which the vegetation comprised *Betula* woods, *Empetrum* heath and open ground with Gramineae.

Artemisia – Gramineae – Cyperaceae PAZ (320–295 cm)
There is a marked increase in *Salix, Artemisia* and Gramineae. Chenopodiaceae, *Thalictrum, Dryas,* and *Rumex* were recorded among the herb pollen. Spores of Lycopodiaceae are more frequent than in the zone below. The pollen flora reflects a change in the vegetation to more open communities with *Salix* shrubs. *Artemisia* and grass dominated among the herbs.

This pollen assemblage zone corresponds to the Younger Dryas stadial.

Betula – *Empetrum* PAZ (295–287 cm)
Pronounced increase of *Betula* pollen from about 20 to 50 %. *Empetrum* pollen reaches its highest values of 9 %. There is a distinct decline in pollen of *Artemisia,* Cyperaceae, *Rumex,* and *Thalictrum.* This pollen assemblage zone represents a transition from tundra to *Empetrum* heath, shrub vegetation and *Betula* stands. Moist meadows with *Filipendula* and Gramineae also occurred.

Betula – *Juniperus* PAZ (287–275 cm)
This zone is characterized by a very marked increase of *Juniperus* pollen. *Empetrum* occurs with about 4 %. Aquatic plants are present in Lake Stora Äggdalssjön where the gyttja was deposited. They are represented in the pollen flora by maxima for *Myriophyllum alterniflorum, Potamogeton* and *Nymphaea.*

Betula – *Pinus* PAZ (275–260 cm)
Pollen of *Betula* increases and reaches frequencies over 50 %. There is a decrease in pollen of *Juniperus* and *Betula nana. Hippophaë* occurs, which indicates that the shore is fairly near the sedimentation area.

The *Betula* – *Juniperus* and *Betula* – *Pinus* pollen assemblage zones represent the gradual change of vegetation from open heath with shrubs and stands of *Betula* to more dense birch forest. At Vägen, the Pleistocene/Holocene boundary can be placed at 295 cm. The clay gyttja above the boundary (293–289 cm) is radiocarbon dated (see Chapter 19).

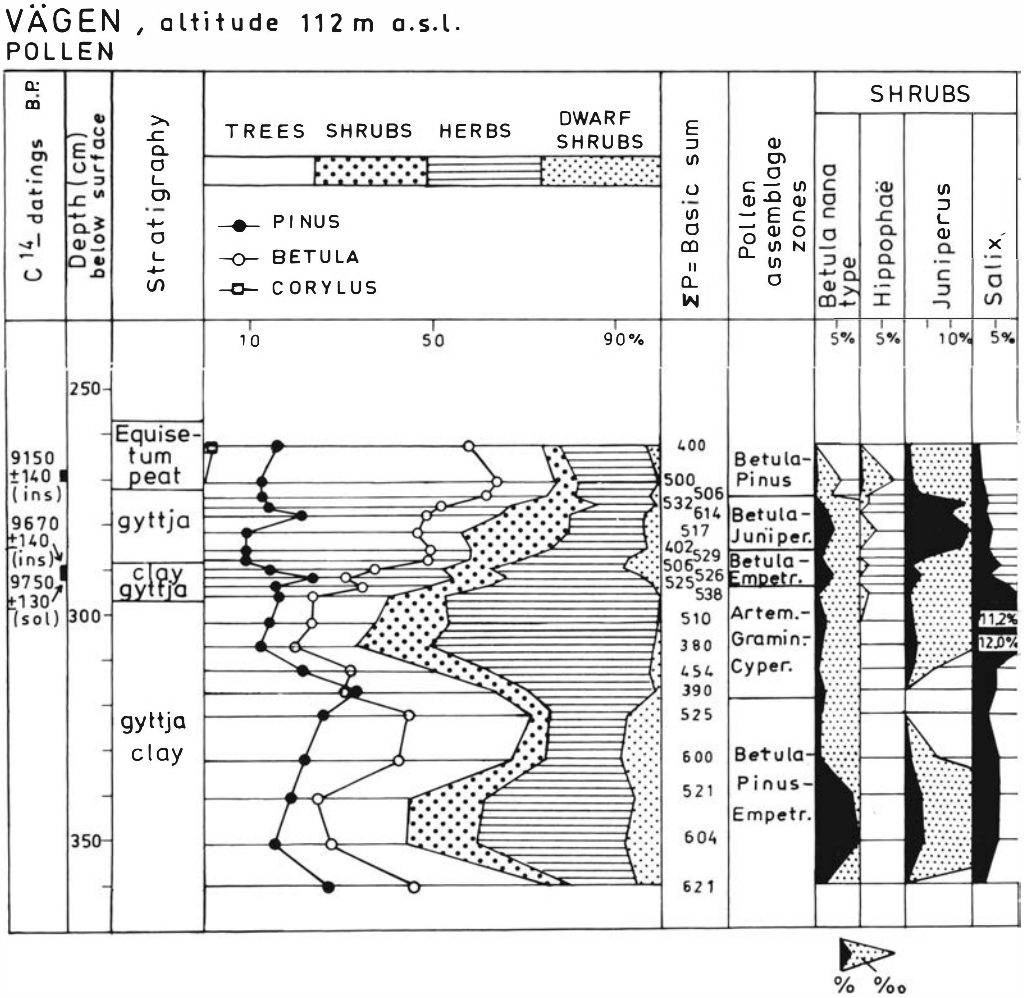
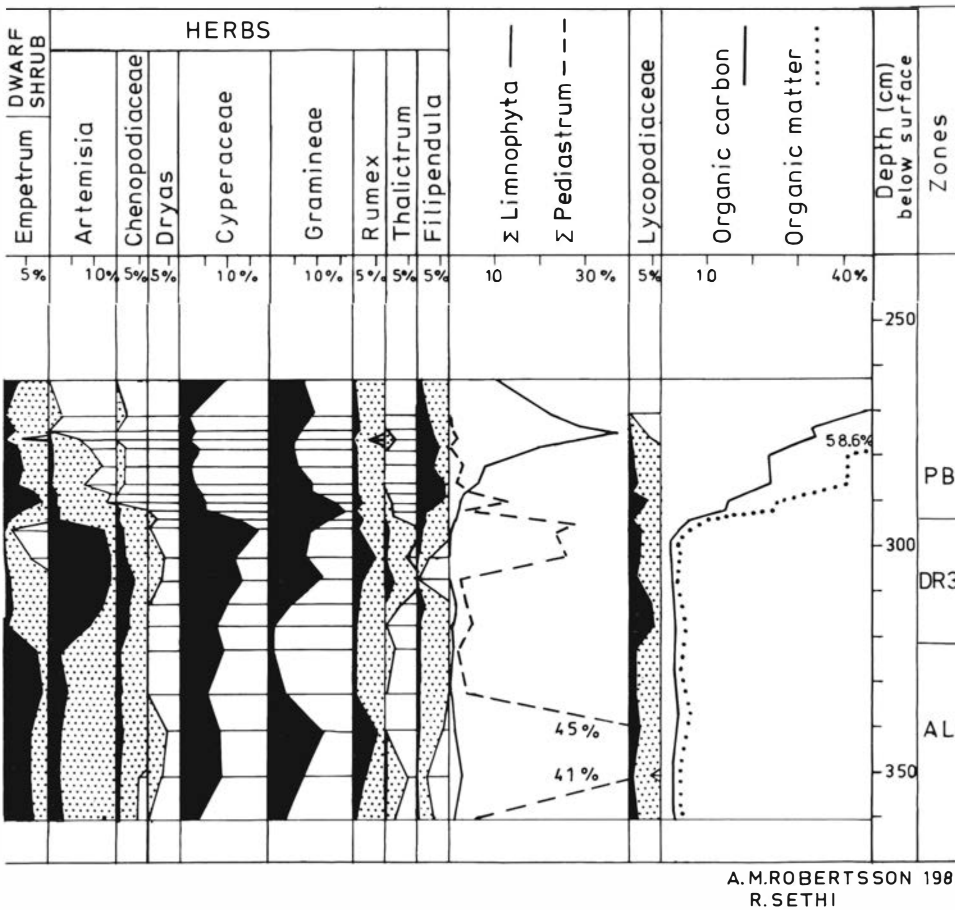


Fig. 18:3. Pollen diagram of the core from Vägen.



DWARF SHRUB
HERBS
Empetrum
Artemisia
Chenopodiaceae
Dryas
Cyperaceae
Gramineae
Rumex
Thalictrum
Filipendula
Σ Limnophyta
Σ Pediastrum
Lycopodiaceae
Organic carbon
Organic matter
Depth (cm) below surface
Zones
5%
10%
5%
5%
10%
10%
5%
5%
5%
10
30%
5%
10
40%
58.6%
45%
41%
250
300
350
PB
DR3
AL
A.M.ROBERTSSON 1981
R.SETHI

Moltemyr, 55 m above sea level

Stratigraphy: See Chapters 6 and 7.

Betula – (Pinus) – Artemisia – Gramineae PAZ (620–470 cm)
High frequency of herb pollen, 30–40 %, mainly *Artemisia,* Gramineae and Cyperaceae. *Thalictrum,* Chenopodiaceae, *Helianthemum,* and Saxifragaceae too are represented with continuous curves. Pollen of shrubs occurs with frequencies over 10 %, represented by *Betula nana, Salix* and *Juniperus.* Redeposited pollen, pre-Quaternary and Quaternary are each represented with about 10 % (Fig. 18:4). Judging by the composition of the pollen flora, this zone may indicate sedimentation during a stadial (the Younger Dryas?).

Betula – Juniperus – Empetrum PAZ (470–400 cm)
Betula increases to values approaching 50 %. Shrub pollen from *Betula nana, Salix, Juniperus,* and *Hippophaë* are present. Pollen of *Empetrum* occurs with values exceeding 2 %. The lower boundary of this zone constitutes the transition from open *Artemisia* communities to a vegetation with more shrubs and *Betula* stands.

Betula – Hippophaë – Empetrum PAZ (400–320 cm)
Betula shows fairly constant values (around 50 %). Other tree pollen present are *Pinus* and *Populus. Empetrum* has a small maximum in this zone, as has *Hippophaë,* which indicates that the sedimentation area was not far from the shore.

Betula – Juniperus – Salix PAZ (320–290 cm)
Pollen of *Empetrum* decreases. *Juniperus* and *Salix* show slightly higher frequencies than in the preceding zone.

Betula – Hippophaë – Salix PAZ (290–215 cm)
There is an increase of *Betula nana* and *Hippophaë* pollen. *Salix* still appears with 3–5 %. *Corylus* is present with about 2 %. Among the herbal pollen Chenopodiaceae and *Filipendula* show slightly higher values than in the preceding zone. The upper boundary of this zone is marked by an increase in pollen of *Corylus,* which exceeds 10 % at the 210 cm level. The sediments between 222.5 and 202.5 cm are radiocarbon dated (see Chapter 19).

In the Moltemyr core the most marked change in the composition of the pollen flora occurs above 470 cm, with the increase of *Betula* and decrease of herb pollen. This transition may correspond to the Pleistocene/Holocene boundary.

Rörmyr, 115 m above sea level

The limnic locality chosen as reference to Moltemyr is situated in the Skottfjället area 4 km to the north. Rörmyr was investigated by Fries (Fries 1951, pp. 78–80).

The stratigraphy (Fig. 18:5) at the sampling point (Bp 1) about 40 m north-west of Lake Svartevatten is

500–555 cm	fen peat
555–600 cm	*Sphagnum* peat
600–625 cm	*Phragmites* peat
625–650 cm	coarse detritus gyttja
650–680 cm	fine detritus gyttja
680–690 cm	clay gyttja
690–695 cm	gyttja clay
695–720 cm	clay

Later, material was sampled for radiocarbon dating and supplementary diatom analysis. The stratigraphy at this boring point (Bp 2) is

550–565 cm	fen peat
565–630 cm	*Sphagnum* peat
630–670 cm	*Phragmites* peat
670–727.5 cm	coarse detritus gyttja
727.5–740 cm	fine detritus gyttja
740–750 cm	clay gyttja
750–762.5 cm	gyttja clay
762.5–	clay

According to diatom analysis, the sedimentary basin was isolated from the sea during the Younger Dryas. The isolation is indicated at 750 cm in Bp 2 (see Chapter 16).

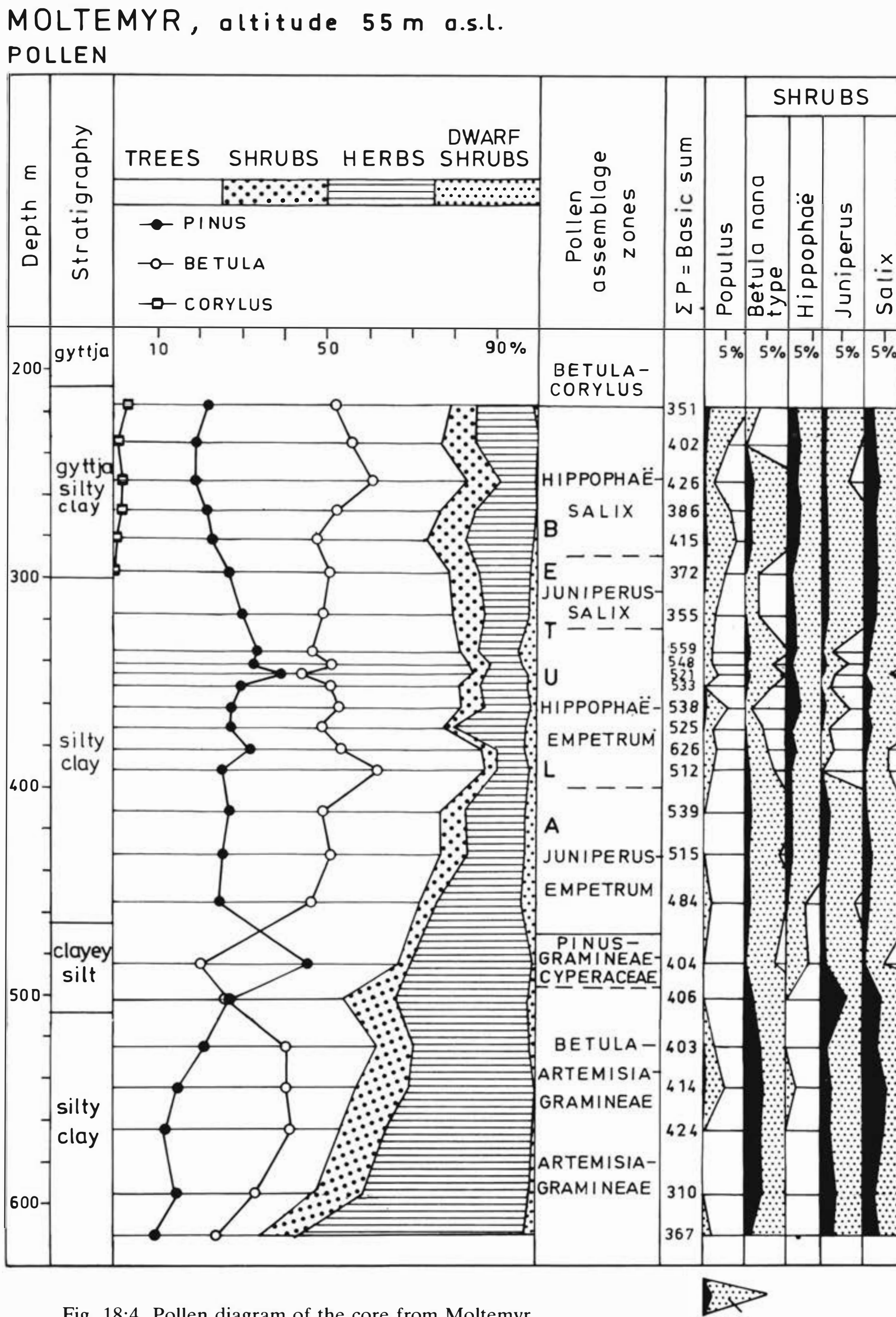
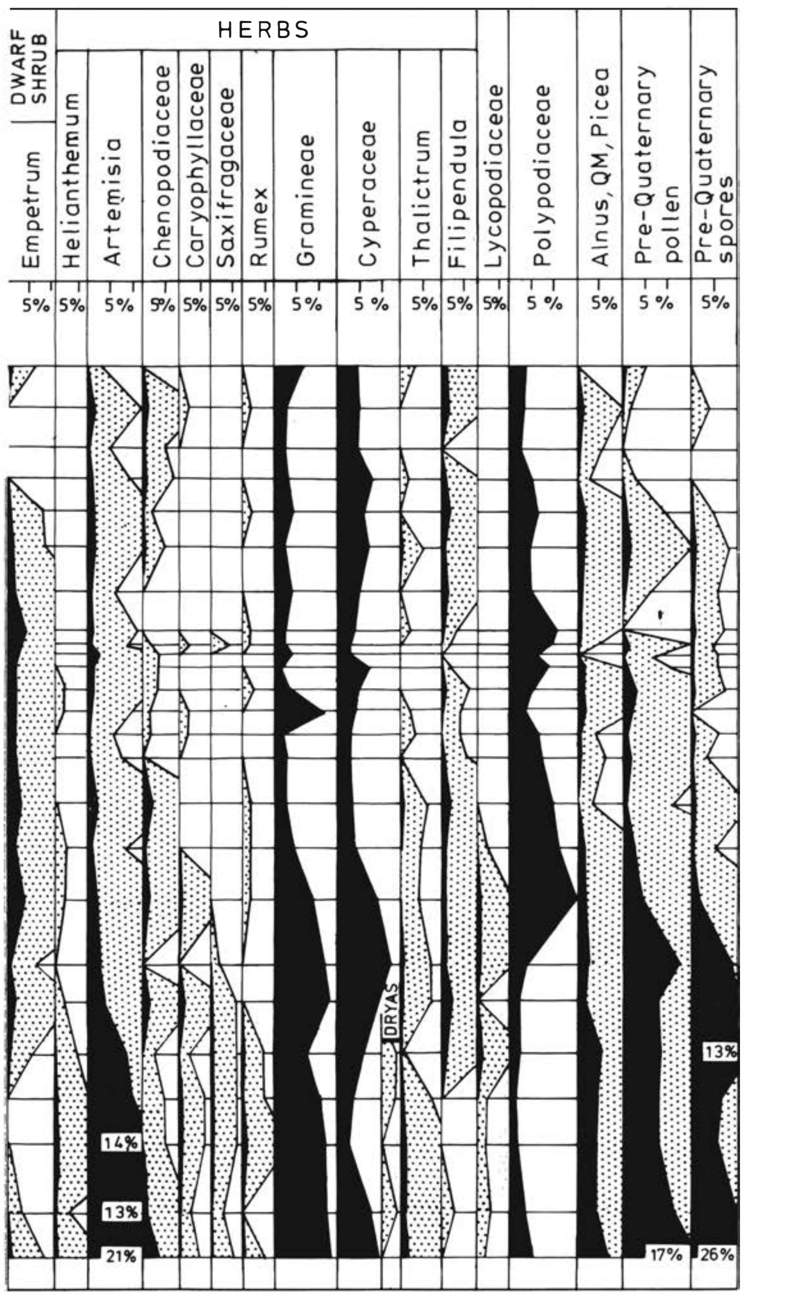


Fig. 18:4. Pollen diagram of the core from Moltemyr.


DWARF SHRUB
HERBS
Empetrum
Helianthemum
Artemisia
Chenopodiaceae
Caryophyllaceae
Saxifragaceae
Rumex
Gramineae
Cyperaceae
Thalictrum
Filipendula
Lycopodiaceae
Polypodiaceae
Alnus, QM, Picea
Pre-Quaternary pollen
Pre-Quaternary spores
5%
DRYAS
14%
13%
21%
17%
13%
26%
A.-M.ROBERTSSON 1981

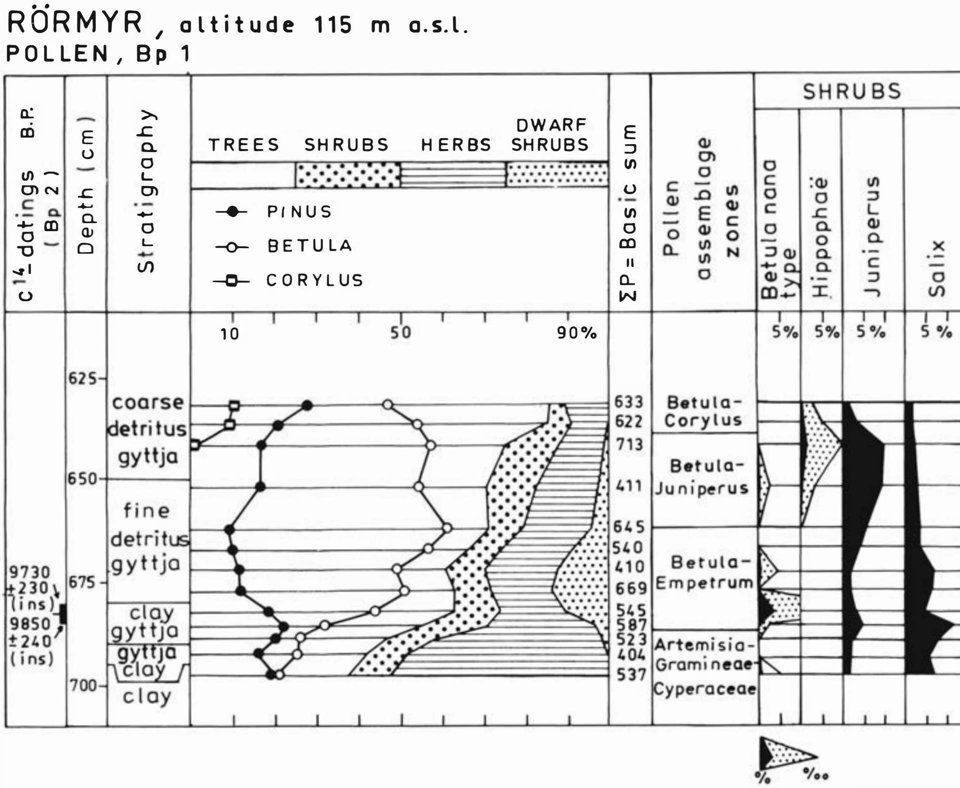
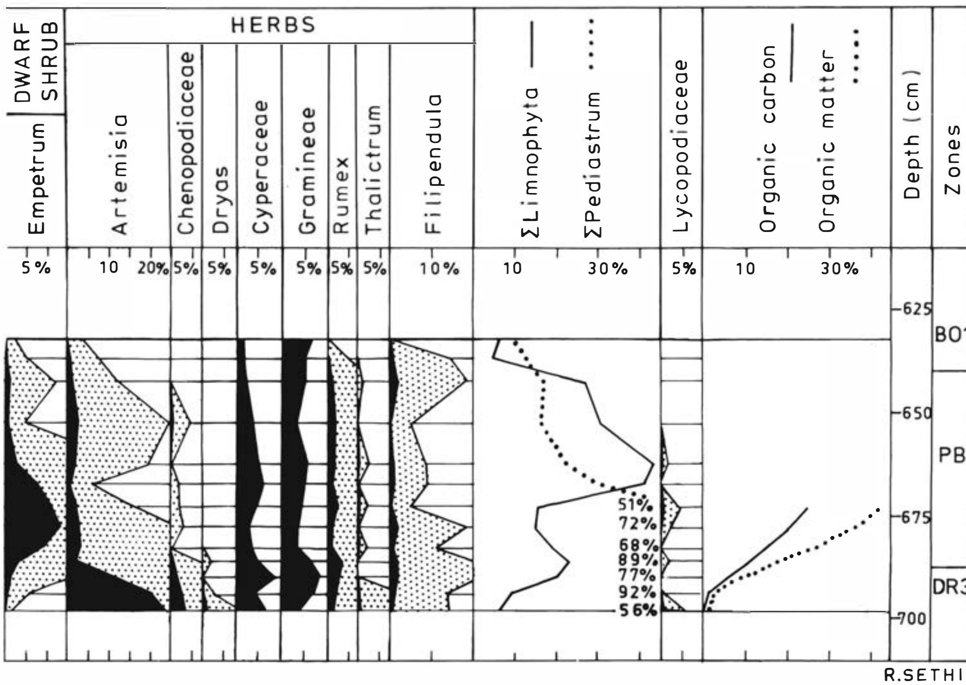


Fig. 18:5. Pollen diagram of the core from Rörmyr, Bp 1. The ^{14}C-datings are made on material from Bp 2.

Artemisia – Gramineae – Cyperaceae PAZ (700–687.5 cm)
High frequencies of herbs and *Salix* indicate open tundra vegetation (Fig. 18:5). Apart from very high values for *Artemisia* (about 20 %), pollen of *Dryas* and *Thalictrum* were observed. There is a low content of organic matter in the sediment. This pollen assemblage zone represents the Younger Dryas.

Betula – Empetrum PAZ (687.5–660 cm)
Pollen of *Empetrum* increases markedly together with *Betula. Artemisia,* Gramineae and Cyperaceae decrease. The organic content of the sediment rises from 12 to 43 %. There is an increase in the frequency of aquatic plants (Limnophyta). The pollen assemblage zone reflects the transition from tundra to a vegetation dominated by *Empetrum* heaths.



Betula – Juniperus PAZ (660–640 cm)
Within this zone there is a marked decrease of *Empetrum* and rising frequencies of *Juniperus* and *Hippophaë*. The vegetation dominated by heath is replaced by shrubs of *Juniperus*. The presence of *Hippophaë* indicates areas of open vegetation and proximity to the shore.

Betula – Corylus PAZ (640 cm–)
The immigration of *Corylus* is registered at 640 cm. Pollen of shrubs and herbs decreases. The vegetation consisting of shrubs and to some extent open *Betula* forest is succeeded by dense woodland.

The Pleistocene/Holocene boundary is placed at 687.5 cm, at the distinct rise of *Empetrum* and *Betula* pollen, together with the marked decrease in *Artemisia*.

Brastad, 40–45 m above sea level

Stratigraphy: see Chapters 6 and 7.

Seven samples from between 2 and 3 m were analysed after treatment with hydrofluoric acid and acetolysis. The pollen frequencies were extremely low in five of the samples (about 10 pollen grains/slide). After preparation by the sedimentation-separation method (Påsse 1976), the analysis were repeated. The pollen content was still very low in samples from above 2.31 m. At 2.31–2.35 m and 2.50–2.55 m, herb pollen (Gramineae, Cyperaceae and *Artemisia*) constitutes about 30 % of the total pollen flora. Pre-Quaternary pollen and spores were frequent, each group represented by 10 % at both levels. The composition of the pollen flora below 2.31 m indicates that the clayey silt is of Younger Dryas age or older.

SUMMARY

A correlation was established between the limnic localities Vägen and Rörmyr and the marine sequences of Solberga and Moltemyr (Fig. 18)6). The Pleistocene/Holocene boundary has been defined by pollen analysis of the limnic sediments from Vägen and Rörmyr. Vegetational changes on nearby terrestrial areas caused by climatic improvement are reflected by distinct changes in the composition of the pollen flora in the sediments. There was a gradual transition from open herb communities to heath and shrub vegetation together with sparse birch wood. During the Preboreal denser woodland dominated by birch replaced the open vegetation.

Evaluation of pollen assemblages in marine sequences is more complicated. The pollen flora may be affected by redeposition of older pollen, corrosion and irregular transportation of pollen grains, and over-representation of some species.

However, in the Solberga core there is a marked change in the composition of the pollen flora around 19.5 m, which is presumed to correspond to the Pleistocene/Holocene boundary.

At Moltemyr the transition from a more or less treeless vegetation of herbs and shrubs to a landscape with *Betula* woods seems to occur about 4.7 m.

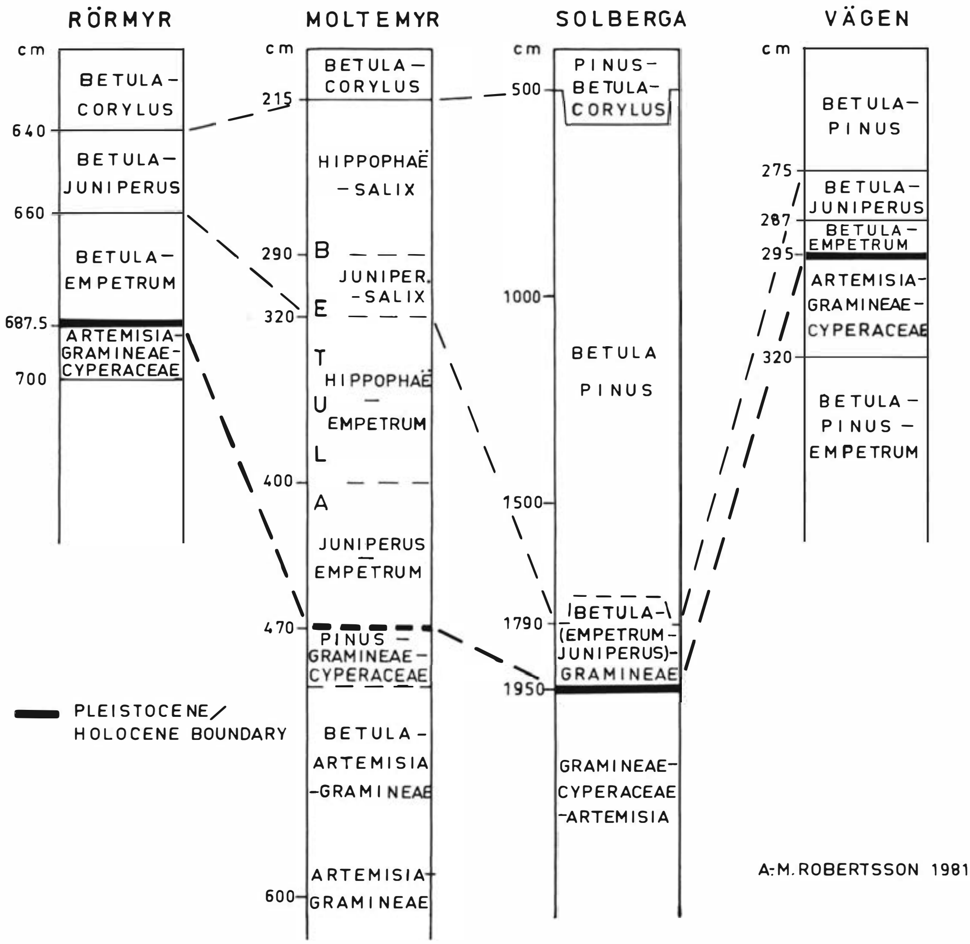


Fig. 18:6. Correlation of the pollen assemblage zones of Rörmyr, Moltemyr, Solberga, and Vägen.

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