P-04-110

Forsmark site investigation

Microfossil analyses of till and sediment samples from Forsmark, northern Uppland

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May 2004

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ISSN 1651-4416
SKB P-04-110

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Keywords: Pollen analysis, Diatoms, Palynomorph, Till, Glacial sediment,
AP PF 400-03-98, Field note no Forsmark 338.

Abstract

Samples of a dark clayey till collected in different excavations, silt in bedrock fractures and silt in the till covering these fractures were analysed on their content of microfossils (pollen and diatoms). No diatoms were identified, but nine samples contained pollen. The pollen spectra show a rather uniform composition dominated by pollen of trees. This indicates an original deposition of the reworked pollen flora during an interglacial most probably the Eemian, ca 120,000 years ago. A high frequency of Palaeozoic palynomorphs reflects erosion and incorporation of material from the Bothnian Sea where Palaeozoic bedrock is present.

Sammanfattning

Prover av en mörk, lerig morän, ofta kallad ”Den gamle blå”, silt funnen i berggrunds-sprickor och siltiga sediment inbakad i moränen ovanpå sprickorna har analyserats med avseende på innehåll av pollen och diatoméer. Nio prover innehöll pollen för en kvantitativ analys, däremot noterades inga diatoméer. Pollenspektra uppvisar en interglacial signatur med höga halter trädpollen där vissa värmekrävande arter ingår. Den ursprungliga avsättningen av den omlagrade pollenfloran kan troligen ha ägt rum under Eem-interglacialen, för cirka 120 000 år sedan. Proverna uppvisar sinsemellan en rätt stor likhet. Den stora andelen pre-kvartära palynomorfer, det vill säga mikrofossil med organiska cellväggar, härrör med största sannolikhet från den paleozoiska berggrunden i Bottenhavet.

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1 Introduction

This document presents the results of microfossil analyses carried out according to activity plan AP PF 400-03-98. The location of analyzed samples are shown in Figure 1-1. The activity comprises preparation and analysis of microfossils (pollen and diatoms) in till and sediment samples from excavations and a coring in the Forsmark area. The samples were collected during activities within the mapping of unconsolidated Quaternary deposits, AP PF 400-02-12 and at a special study of sediment filled bedrock fractures at drill site 5, AP PF 400-03-96 (both internal SKB controlling documents). Controlling documents for the activity and the data references are listed in Table 1-1 and Table 1-2.

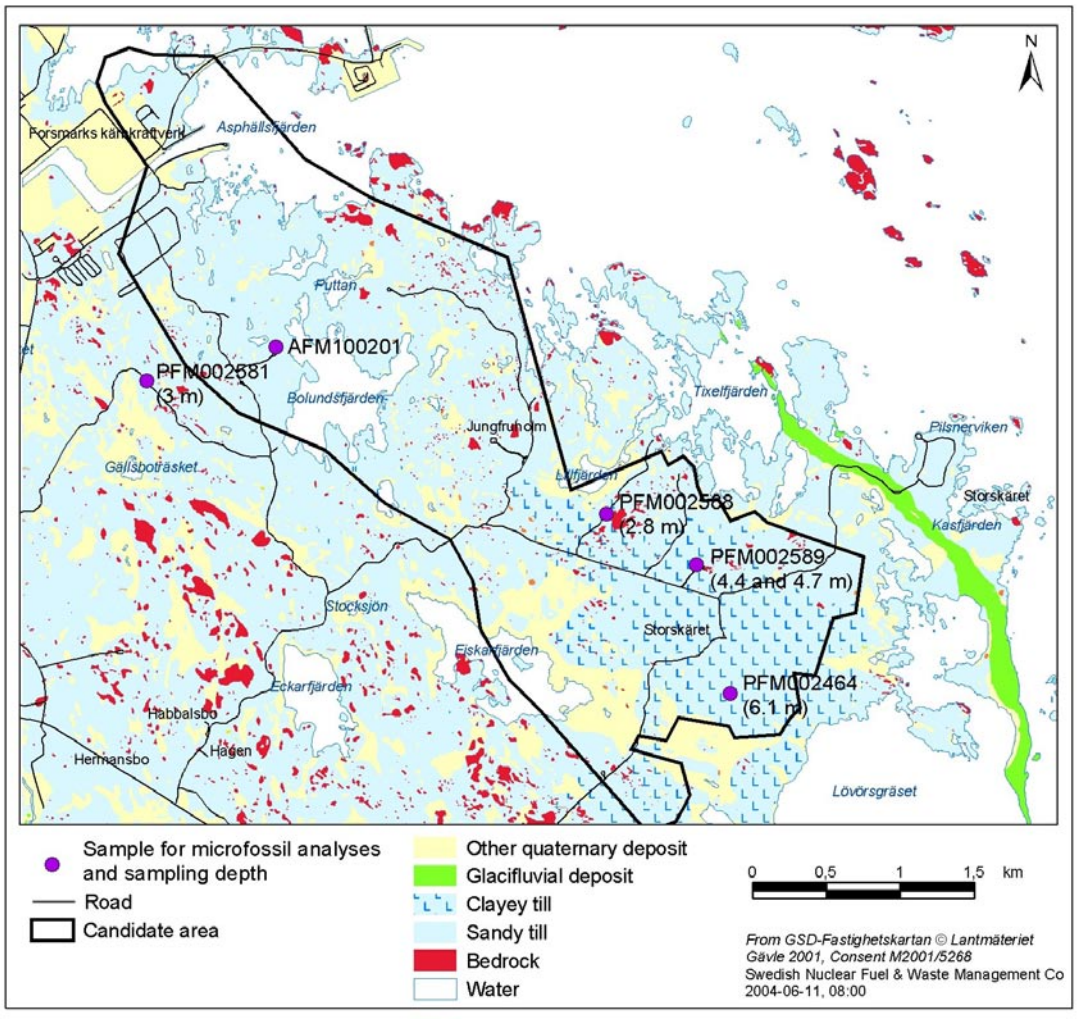

Figure 1-1. *Map showing the location of the analysed samples. The values within brackets are sampling depths.*

Table 1-1. Controlling documents for the performance of the activity.

Activity plan	Number	Version
Mini AP *Analyser av pollen och diatoméer i kvartära avlagringar*	AP PF 400-03-98	1.0

Table 1-2. Data references.

Subactivity	Database	Identity number
Results of microfossil analysis	SICADA field archive	Field note no Forsmark 338
Protocoll from microfossil analysis	SICADA archive	Field note no Forsmark 338

2 Objective and scope

The purpose of this activity is to test if microfossil analyses of till and sediment can contribute at the interpretation of Quaternary deposits and stratigraphy, and be used for relative dating of a dark clayey till and silty sediments found in the general Quaternary stratigraphy and in bedrock fractures.

Pollen and spores found in till beds have been eroded from organic deposits and incorporated by the inland ice. The pollen flora in these deposits originally reflects the composition of the vegetation in the area during the part of the ice free periods that preceded the stadial phases. Under favourable conditions the rebedded pollen flora will show a typical interglacial (temperate) or interstadial (cool) "signature" and can hopefully be used as a guidance when interpreting and dating minerogenic deposits e.g. different till beds and fine-grained non-organic sediments.

In Sweden this method to use rebedded microfossils as stratigraphical markers have been used in the Alnarp valley in Skåne /Miller, 1977/, and in northern Sweden /Lagerbäck and Robertsson, 1988; Eklund et al, 1991; Lundqvist and Miller, 1992/. In south central Sweden reworked sediments interpreted as Eemian interglacial have been studied /Miller and Persson, 1973; Robertsson and García Ambrosiani, 1992; Robertsson et al in MS/. For an overview of the late Quaternary history of Sweden see e.g. /Lundqvist, 1992/.

Joint fillings of glacial sediments were found during the excavation of a basin for cooling water at the construction of the nuclear power plant at Forsmark some 30 years ago. These sediments were investigated for their content of pollen by the author /Stephansson and Ericsson, 1975/. Similar features with sediment in bedrock joints were exposed at Drill site 5 in autumn 2003 and samples were collected for analyses and comparison of pollen flora.

3 Equipment

3.1 Fieldwork/sampling

The samples were all obtained within other activities, i.e. the mapping of Quaternary deposits /Sundh et al, 2004; Hedenström et al, 2004/ and investigations of sediment filled bedrock fractures /Lokrantz and Albrecht in progress/.

The samples were collected at machine cut trenches (Figure 3-1), at excavations at Drill site 5 (Figure 3-2) and at auger drilling on Storskäret (Figure 3-3).

Figure 3-1. *Sampling of the dark clayey till at PFM002589. Stratigraphical investigations was performed at the site by /Sundh et al, 2004/.*

Figure 3-2. *Sediment in bedrock fractures, as well as the till, was sampled by /Lokrantz and Albrecht/ in progress.*

Figure 3-3. *Clayey till retrieved by auger drilling at the installation of groundwater monitoring wells /Johansson, 2003/. The till stratigraphy was investigated by /Hedenström et al, 2004/.*

4 Execution

4.1 General

Shortly, the microfossil analysis comprises the following sub-activities:

1. Samples are collected in the field.
2. Microfossils are extracted and slides are prepared in the laboratory.
3. The slides are analysed under a microscope at 400X or 1000X magnification and the microfossils are identified according to standard reference literature and counted.
4. The results are summarised and presented as absolute counts in a species list and presented in diagrams as percentage values of identified pollen (or diatoms).

4.2 Preparations and analysis

The samples (3–5 g) were prepared for pollen analysis according to a sedimentation – separation method described by /Påsse, 1976/. This method is used for samples with a low organic content. Preparation for diatom analyses (5–10 g) followed a standard method /Battarbee, 1986/.

The slides for diatom analyses were scanned, but no diatom frustules were noted in either of the samples prepared.

Pollen were found in low frequencies, therefore 2–3 slides had to be analysed in order to reach a sum of at least 100 pollen grains. Some pollen grains were corroded and/or crumpled, which means that the group Varia (unidentified) constitutes 3–10% of all palynomorphs (microfossils with organic walls = pollen, spores, acritarchs) noted. Altogether nine samples contained enough pollen for quantitative analyses to be carried out (Table 4-1).

4.3 Execution of field work

The location of the studied sites is shown in Figure 1-1. The analysed samples (Table 4-1) were cut out of the walls in three open excavations /Sundh et al, 2004/ (PFM002588, PFM002589 and PFM002581) or collected from bedrock fractures at two different sites (AFM100201) /Lokrantz and Albrecht in progress/. At PFM002464 coring was made with an auger drill with a borehole diameter of 100 mm by the company Sweco VBB Viak /Hedenström et al, 2004/.

Table 4-1. The samples collected for analyses of microfossils. Four of the samples contained too few pollen grains for analysis.

Site ID	Sample no	Material	Depth (m)	Analysis	Collected by*
PFM002588	Forsmark 1	Till, clayey, silty	2.8	X	AH, AMR
PFM002589	Forsmark 2	Till, clayey, silty	4.4	X	AH, AMR
PFM002589	Forsmark 3	Till, silty	4.7	X	AH, AMR
PFM002581	Forsmark 4	Till, clayey, silty	3.0	X	AH, AMR
PFM002581		Till, clayey, silty	3.5	⊗	AH, AMR
AFM100201	Forsmark 5	Silt in bedrock fracture (1)		X	JA, HL
AFM100201	Forsmark 5	Silt in bedrock fractures (2)		⊗	JA, HL
AFM100201	Forsmark 6a	Silt in till (1)		X	RL
AFM100201	Forsmark 6b	Silt in till (2)		X	RL
AFM100201	Forsmark 6c	Silt in till (3)		X	RL
PFM002464		Till, clayey	2.0–2.5	⊗	AH
PFM002464	Forsmark 7	Till, silty, grey	6.1–6.4	X	AH
PFM002464		Till, silty, brown	7.7–7.8	⊗	AH

* AH = Anna Hedenström, AMR = Ann-Marie Robertsson, JA = Joachim Albrecht, HL = Hanna Lokrantz, RL = Robert Lagerbäck.

⊗ = Too few microfossils were found for quantitative analysis.

4.4 Nonconformities

The work was performed without any nonconformity according to the Activity plan AP PF 400-03-98.

5 Results

No diatom frustules were identified at a scanning of the slides. The diatoms have probably been dissolved and/or totally broken, and has not been preserved in the reworked fine-grained fraction of the till and sediments.

The results of the pollen analyses are presented as separate pollen spectra for each sample (Figure 5-1, Figure 5-2 and Figure 5-3). In Figure 5-1 the total number of identified pollen of trees (AP = arboreal pollen), shrubs and herbs (NAP = non arboreal pollen) constitutes the basic sum, in Figure 5-2 the number of tree pollen is used as the basic sum, and in Figure 5-3 the total number of palynomorphs is used as the basic sum for calculation.

Four of the samples showed to contained very few pollen after a survey of the slides, and were thus not analysed further.

In general the number of tree pollen constitutes ca 90% (84–95%) and dominates all spectra (Forsmark 1-7, Figure 5-1). There is a great similarity in the composition of the tree pollen spectra (Figure 5-2) between the sediment sample from the bedrock filling (Forsmark 5) and the silt lenses from the covering till (Forsmark 6a, 6b and 6c). *Betula*, *Alnus* and *Corylus* are most frequent together constituting over 80% of the tree pollen. *Picea*, *QM* and *Carpinus* were noted with 1–5% each. This composition points to an originally interglacial pollen flora, in contrast to an interstadial signature with higher frequencies of shrubs and herbs. However, the composition of the vegetation during early Weichselian interstadials (Brörup, Odderade) in southern and central Sweden is so far very poorly known. In Denmark and northern Germany the forests included birch and pine mixed with some alder, spruce and larch during these interstadials /Behre, 1989/. The same forest composition may have been present in southern Norway, Sweden and Finland, but at the investigated sites the chronos-tratigraphy and the correlation of the supposed interstadial pollen floras is still uncertain /cf compilation by Donner, 1995/.

In reworked pollen spectra from earlier analysed till samples from central and northern Sweden a supposed interstadial composition includes mainly *Betula* among tree pollen together with only single pollen grains of *Pinus* and other trees /Robertsson et al in MS/. Pollen of shrubs and herbs are frequent including e.g. *Betula nana*-type, Poaceae, Cyperaceae and *Artemisia*.

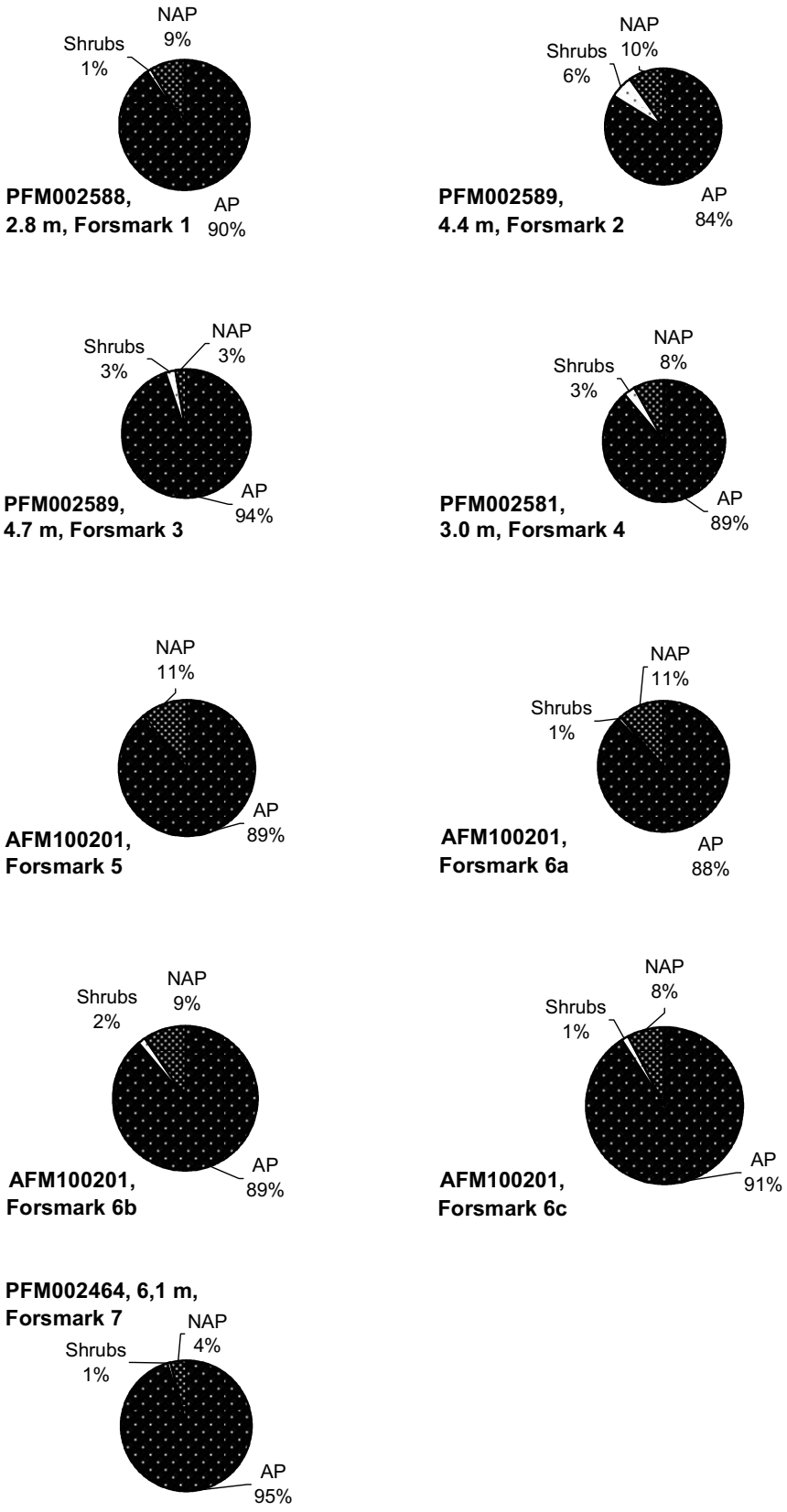

Figure 5-1. *Total pollen spectra (trees, shrubs, herbs) in the analysed samples of till, filling in bedrock fractures and silt in the covering till.*

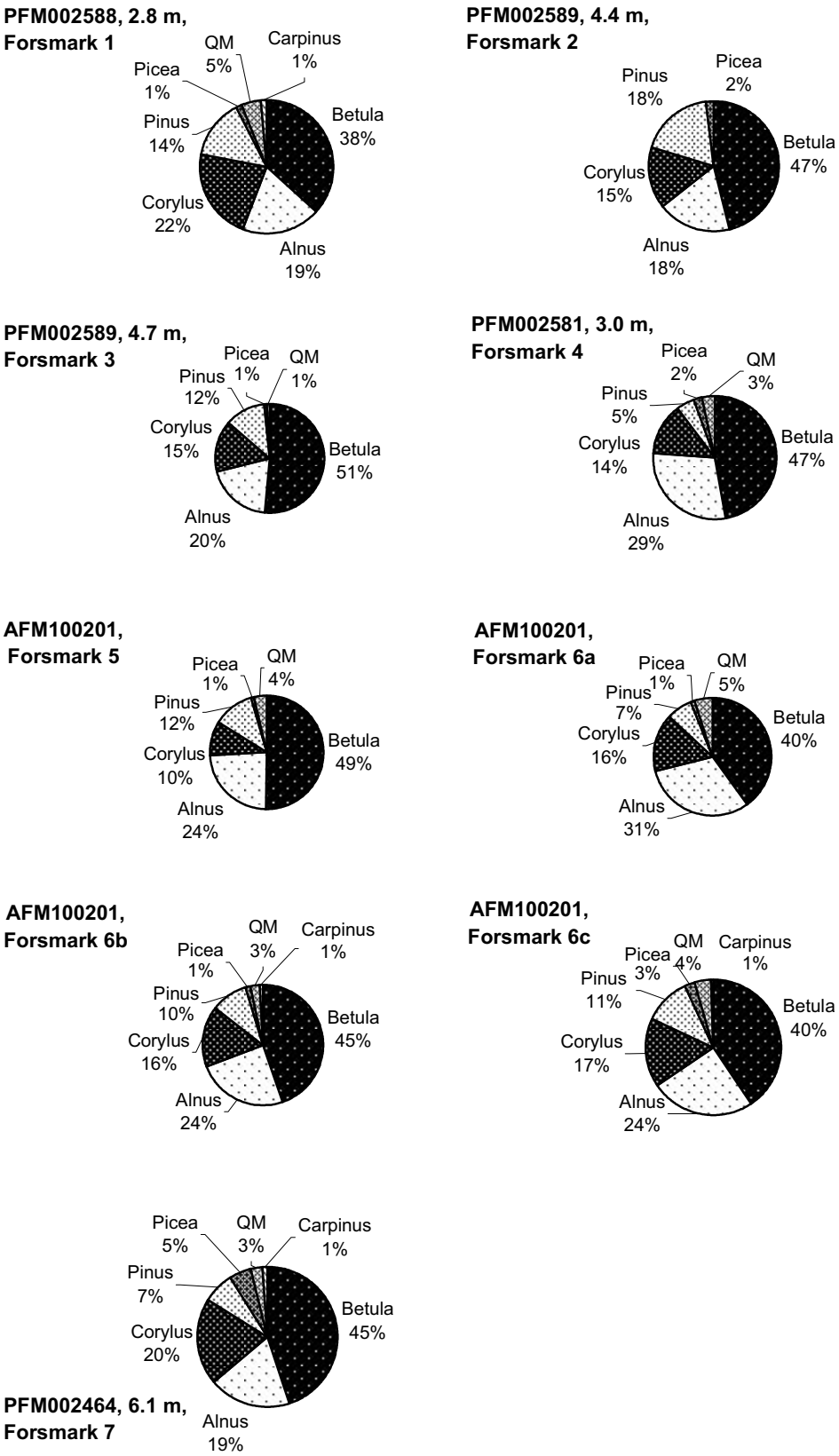

Figure 5-2. *Composition of the tree pollen spectra (sum trees = 100%).*

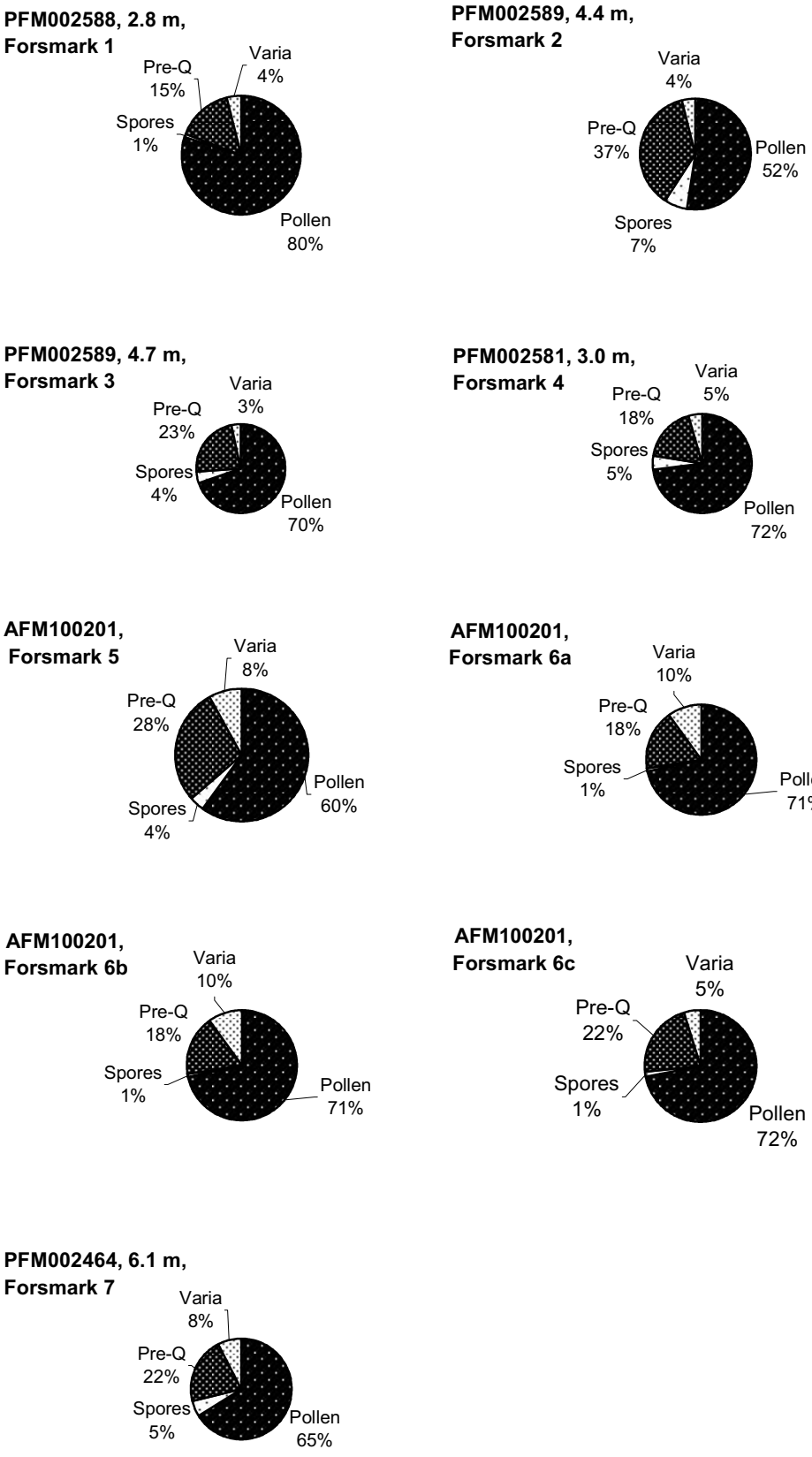

Figure 5-3. *Total palynomorph composition including Varia (= corroded unidentified pollen).*

All samples from Forsmark contain approximately 20–25% pre-Quaternary palynomorphs (Figure 5-3 and Figure 5-4), which have been identified as Palaeozoic acritarchs, e.g. *Baltispheridium* spp and *Veryhachium* spp /cf Tschudy and Scott, 1969, Figures 10-6 and 10-9/. The presence of these pre-Quaternary microfossils indicates that material has been eroded and transported from the Bothnian Sea, where Palaeozoic bedrock is present /Norling, 1994/. The same kind of pre-Quaternary palynomorphs have earlier been identified at Skulla north of Uppsala, where a reworked clay was found embedded in till. According to the pollen and diatom flora this clay is supposed to be of Eemian age /Robertsson, 2000/.

Two pollen analyses were earlier carried out of silty sediments collected in bedrock joints at Forsmark and for comparison also the overlying till was sampled and analysed for its content of pollen /Stephansson and Ericsson, 1975/. The till sample was rare in pollen (basic sum 76), tree pollen constitutes 92% and herbs 8%. The dominance of tree pollen and that *Betula* is most frequent is in accordance with the spectra in the present investigation. Other similarities are the low frequencies of *Picea* and *QM*. The spectra from Drill site 5 (Figure 5-2) show higher percentages of *Alnus* and *Corylus*, which is in accordance with the content of the earlier analysed sediment samples /Stephansson and Ericsson, 1975 Table 1/. It must be pointed out that pre-Quaternary palynomorphs were not included in the calculations in the earlier study.

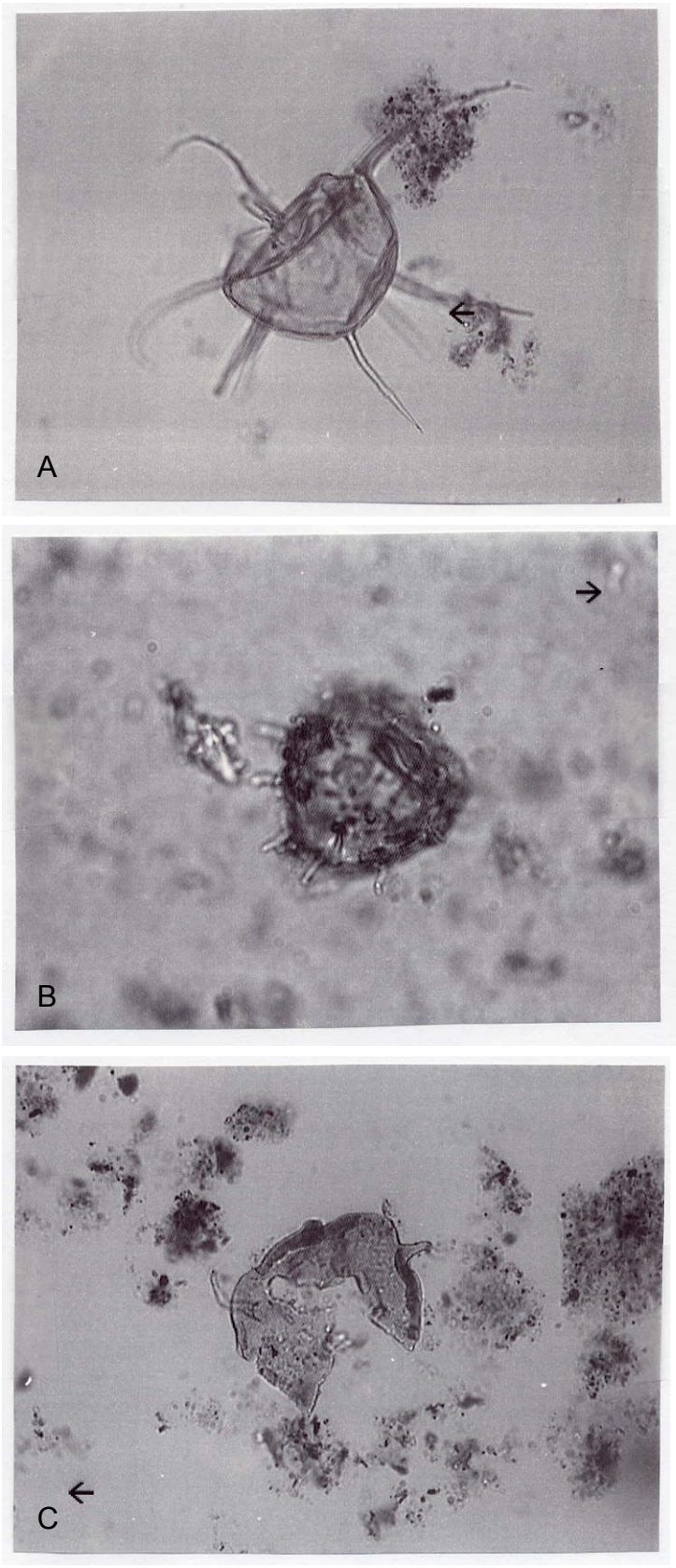

Figure 5-4. *Examples of noted Palaeozoic achritarcs: a, c) sample Forsmark 2 at 4.4 m depth (dark clayey till), magnification 400X; b) sample Forsmark 3 at 4.7 m (silty till), magnification 1000X.*

5.1 Discussion

The questions that are expected to be answered by means of the pollen analytical results are:

1. When was the original pollen flora deposited?
2. When did the accumulation of the dark clayey till and related sediments take place?
3. Can the composition of the pollen flora give any indication of the source material?

1. The composition of the reworked pollen flora in all analysed samples from Forsmark shows an interglacial "signature" with a dominance of tree pollen including *Corylus*, *QM* and *Carpinus*. Those taxa were probably not growing in the area during the early Weichselian Brörup and Odderade interstadials. The most natural explanation is then that the interglacial deposits available for a glacier to erode would have been accumulated during the preceding (Eemian) interglacial. It should be stressed that our present knowledge about the vegetation history in Sweden and the presence of sediments from the Holsteinian interglacial (or still older ones) is so far very fragmentary /cf García Ambrosiani et al, 1998/.

Furthermore it seems reasonable to believe that sediments representing the later part of the interglacial were first reworked. This is in agreement with the find of pollen of *Picea* and *Carpinus*, which both spread during the later part of the Eemian interglacial /Behre, 1989/.

Factors which can influence the composition of the reworked pollen flora, and thus also restrict the possibilities to determine its original age are:

- Different preservation favours robust pollen grains and spores which will be better represented than those with thin walls.
- Spatial variations with varying plants communities and factors influencing the forest composition (soils, local climate).

2. Different alternatives have been presented about the extension of the Weichselian ice sheet during the stadials /e.g. Lundqvist, 1992; Kleman et al, 1997/. /Björnbom, 1979/ studied the dark clayey till at several sites in central and northern Sweden, and concluded that it had been accumulated after an early Weichselian interstadial. Later studies have shown that the till probably was deposited after the early Weichselian Odderade interstadial /Lundqvist and Miller, 1992/. This alternative is supported also by new microfossil analyses of the clayey compact till from sites in the Stockholm area and northwards /Robertsson et al in MS/.
3. The large contribution (approx 20%) of pre-Quaternary palynomorphs in the pollen flora suggests (heavy) erosion and incorporation of fine-grained material from the Bothnian Sea with Paleozoic bedrock.

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Appendix 1

Number of NAP, spores, green algae and pre-Quaternary palynomorphs

	Forsmark 1	Forsmark 2	Forsmark 3	Forsmark 4	Forsmark 5	Forsmark 6a	Forsmark 6b	Forsmark 6c	Forsmark 7
Dwarf shrubs and shrubs									
Ericales		2	1	2			1	1	1
Betula nana-type		2		6	3		1	3	2
Juniperus									1
Salix			1					1	
Herbs									
Artemisia	1	1	4		6	5	5	6	1
Caryophyllaceae			2						
Chenopodiaceae				1				1	
Compositae tubuliflorae	1								
Cyperaceae	3	2			1		4	2	
Filipendula						1			
Poaceae	9		7	5	5		4	7	3
Thalictrum							1		
Aquatic plants									
Typha – Sparganium-type							1		
Spores									
Lycopodiaceae		7	4	1		1			1
Polypodiaceae	2	5	3	5	5				1
Sphagnum		2	1		3				6
Green algae									
Pediastrum					1			3	
Pre-Quat Palynomorphs	31	78	45	24	60	28	32	68	34