R-02-47

Holocene sediment accumulation in the Äspö area

A study of a sediment core

Jan Risberg, Stockholm University

December 2002

Svensk Kärnbränslehantering AB
Swedish Nuclear Fuel
and Waste Management Co
Box 5864
SE-102 40 Stockholm Sweden
Tel 08-459 84 00
+46 8 459 84 00
Fax 08-661 57 19
+46 8 661 57 19

ISSN 1402-3091
SKB Rapport R-02-47

Holocene sediment accumulation in the Äspö area

A study of a sediment core

Jan Risberg, Stockholm University

December 2002

Keywords: siliceous microfossils, diatoms, mineral magnetic parameters, clay mineralogy, Yoldia Sea, Äspö, Simpevarp, biosphere, deposits

Abstract

A sediment core was collected in 1993 in the archipelago above the tunnel between the Äspö Island and Simpevarp nuclear power plant. The sediment sequence consists of four types of accumulations: brownish clay, bluish clay, sand mixed with gravel and gyttja. The sequence was studied according to its content of siliceous microfossils (mainly diatoms), mineral magnetic characteristics, clay mineralogy and it was dated by the AMS technique on bulk sediment samples.

According to the diatom content, both types of clay were probably deposited during the brackish water Yoldia Sea stage. The clay is relatively uniform, except an abrupt increase in the mineral magnetic parameters HIRM and S-ratio at around 810 cm depth, which probably is the result from a change in the material source. The clay mineralogy, with enhanced chlorite values, indicates a relatively uniform material. A major change occurs at the transition from the bluish to brownish clay, where all magnetic concentrations drop dramatically as the result from a major shift in material source and/or sedimentation environment.

The thin layer of sand and gravel is indicative of a major hiatus in the stratigraphy. Mineral magnetic concentrations increase slightly as the result from mixing with single domain ground surface generated particles. Based on a Yoldia Sea age for the underlying clay and deposition in the Litorina Sea c 3000 cal years BP for the superimposed gyttja, it is suggested that the length of the hiatus is about 7000 years.

It is not until the studied site became protected enough by rising land areas, that organic rich gyttja started to accumulate. It is likely that this scenario was established when sea level was situated at around 10 m above present day. Since then it seems, as determined from the mineral magnetic graphs, that the sedimentary conditions have been relatively uniform. More pronounced fluctuations in mineral magnetic concentrations (especially ARM/SIRM ratios) in the upper c 2 m of the core indicate that particles generated from the surrounding islands increase in importance. Also the sequence analysed for diatoms support this interpretation. The minor changes observed in the diatom flora is likely the result from a decrease in salinity as the sampling site is transferred to a more sheltered position by the rising land.

Sammanfattning

En sedimentkärna togs 1993 i skärgården ovanför tunneln mellan Äspö och Simpevarp kärnkraftsverk. Nerifrån och upp består sedimentsekvensen av fyra huvuddelar: brunaktig lera, blåaktig lera, sand blandat med grus och gyttja samt gyttja. Sekvensen analyserades med avseende på kiselmikrofossil (huvudsakligen diatoméer), mineralmagnetiska egenskaper (magnetisk susceptibilitet, ARM, SIRM och S-kvot), lermineralogi (XRD) och daterades med AMS teknik.

Sammansättningen av diatoméer indikerar att båda typerna av lera sedimenterade under Yoldiahavets brackvattenstadium. De båda lertyperna är relativt enhetliga, förutom en abrupt ökning i HIRM och i S-kvoten vid cirka 810 cm djup. Detta är förmodligen orsakat av en förändring i materialtillförsel. Analysen med XRD, med förhöjda koncentrationer av klorit, indikerar också den ett relativt enhetligt material. Vid övergången mellan den brunaktiga och blåaktiga leran sjunker alla magnetiska koncentrationer, förmodligen som ett resultat av en markant förändring i materialkälla och/eller sedimentationsmiljö.

Det tunna lagret med sand och grus indikerar en substansiell lagerlucka i lagerföljden. Koncentrationerna av magnetiska partiklar ökar som ett resultat av en inblandning av mycket finkorniga partiklar från intilliggande markytor. Det antas att inget material sedimenterade på provtagningsplatsen under cirka 7 000 år. Detta baseras på att de underliggande lagren ackumulerades i Yoldiahavet och att de överliggande lagren ackumulerades för cirka 3 000 år sedan.

Organogena sediment började avsättas först när provtagningsplatsen har blivit tillräckligt skyddad av omkringliggande öar. Detta påbörjades förmodligen när strandlinjen var cirka 10 m över nuvarande nivå. Efter denna tid, baserat på de mineralmagnetiska parametrarna, har sedimentationsförhållandena varit likartade. Tillförseln av minerogena markpartiklar har ökat under tiden för ackumulation av de översta cirka 2 m av lagerföljden. Detta ses som fluktuerande ARM/SIRM kvoter. Även diatoméanalysen stöder denna tolkning. De små variationerna i artsammansättning är förmodligen resultatet av en minskning i saliniteten på grund av den regressiva strandförskjutningen.

Contents

1 Introduction

This investigation is part of a major study along the east coast of Sweden conducted by the Swedish Nuclear Fuel and Management Co (SKB). The aim of these investigations is to assess sediment accumulation patterns and sediment types in coastal areas subject to forces generating a regressive shore displacement pattern /cf Brydsten, 1999; Lindborg and Kautsky, 2000; Morén and Påsse, 2001; Jerling et al, 2001; Bergström, 2001; Påsse, 2001/. In the safety analysis of deep repository of nuclear waste, knowledge about these parameters is essential in order to estimate the pathways and sinks for radio-nuclides in non-consolidated near-surface deposits.

This paper is based on an unpublished report compiled in 1996 by the author. The work was part of a study of sediments accumulated in the Äspö area, south-eastern Sweden (Figures 1-1 and 1-2), conducted by the Studsvik Eco and Safety AB. Analysed cores were subject to studies of pH, organic carbon and the distribution of various elements /Landström et al, 1994/. In order to describe the environmental changes occurring throughout sedimentation of the material constituting the core SAS 48, the composition

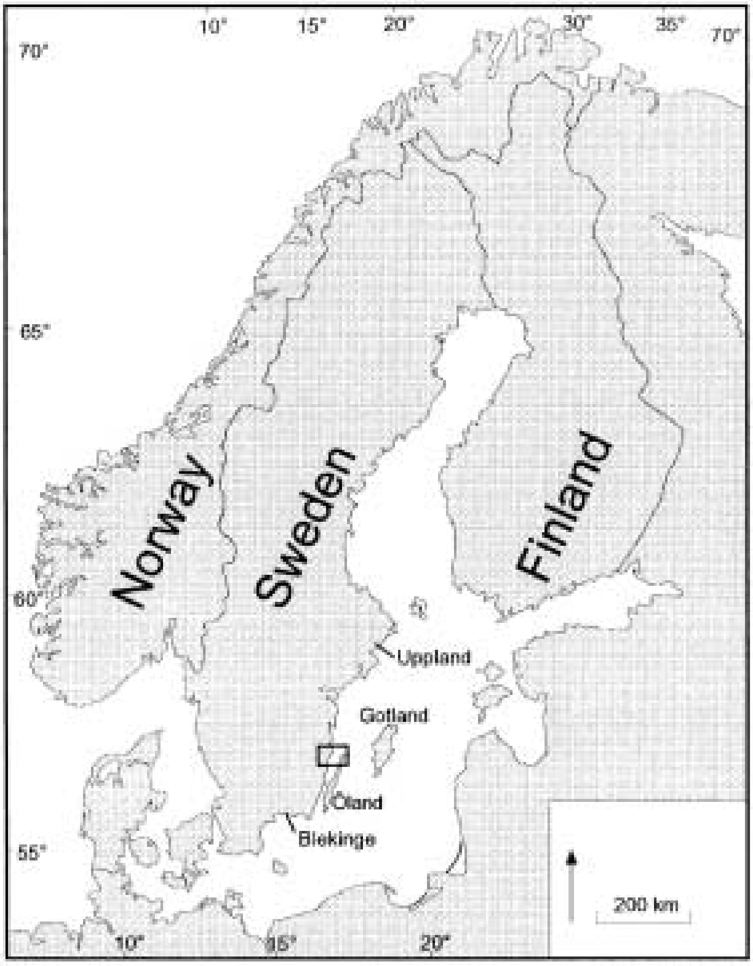


Figure 1-1. *The investigated core was collected in the archipelago of Småland, close to the Swedish mainland in the south-western part of the Baltic Sea (marked by a rectangle).*

of siliceous microfossils and the distribution of mineral magnetic properties were investigated. An attempt was made to separate brownish and bluish clay by applying XRD analyses of the clay mineralogy. Age information was achieved from three AMS radiocarbon dates of bulk sediment.

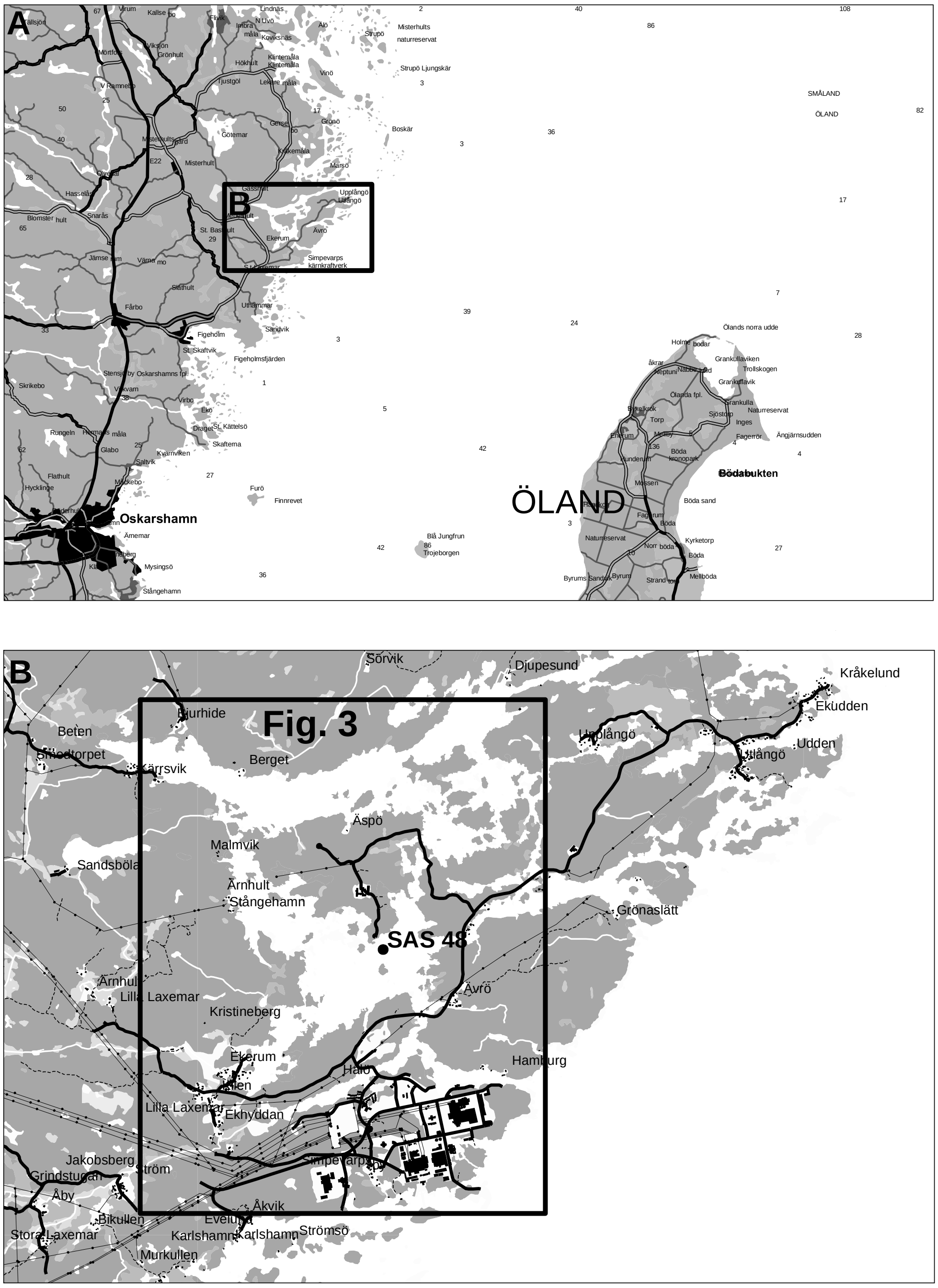


Figure 1-2. A. The coastal area north of Simpevarp nuclear power station where the core was collected. B. The position of SAS 48 in Borholmsfjärden. Water exchange is limited to two narrow straits to the east and the north-east.

2 Site description and field work

2.1 Site description

The Äspö island is located in the archipelago of eastern Småland, c 23 km northeast of Oskarshamn and 32 km south of Västervik. The island and Simpevarp nuclear power plant is located some 20 km west of the boundary between crystalline and sedimentary bedrock in the southern part of the Baltic Sea (cf compilation in /Svensson, 1989/, Figure 4, p 4). The bedrock in the surrounding area is made up from granite, granodiorite, quartz monzonite and quartz monzodiorite, with minor occurrences of greenstones and metavolcanites /Svedmark, 1904; Kornfält and Wikman, 1990/. The Äspö island is made up from younger red granite and quartz syenite, commonly felsic /Lundegårdh et al, 1985/. Exposed bedrock dominates and the sparse Quaternary deposits around Borholmsfjärden consist of wave washed till, similar to the area south of Oskarshamn /cf Rudmark, 2000/.

The sampling site is situated south of the island Äspö in Borholmsfjärden, which is a bay in the southern Baltic Sea (Figure 1-2). The connection to the open Baltic is today restricted to two narrow straits, one to the east and one to the north-east, causing a limited exchange of water between the Baltic and the bay (Figure 1-2B). The topography on the mainland and the surrounding islands rarely reach above 10 m above sea level. The palaeogeographical conditions when sea level was 5 and 10 m above present sea level are shown in Figure 2-1.

Eastern Småland of today belongs to the boreo-nemoral biotic zone and is characterized by a dominance of *Picea* and *Pinus* /Berglund and Digerfeldt, 1996/.

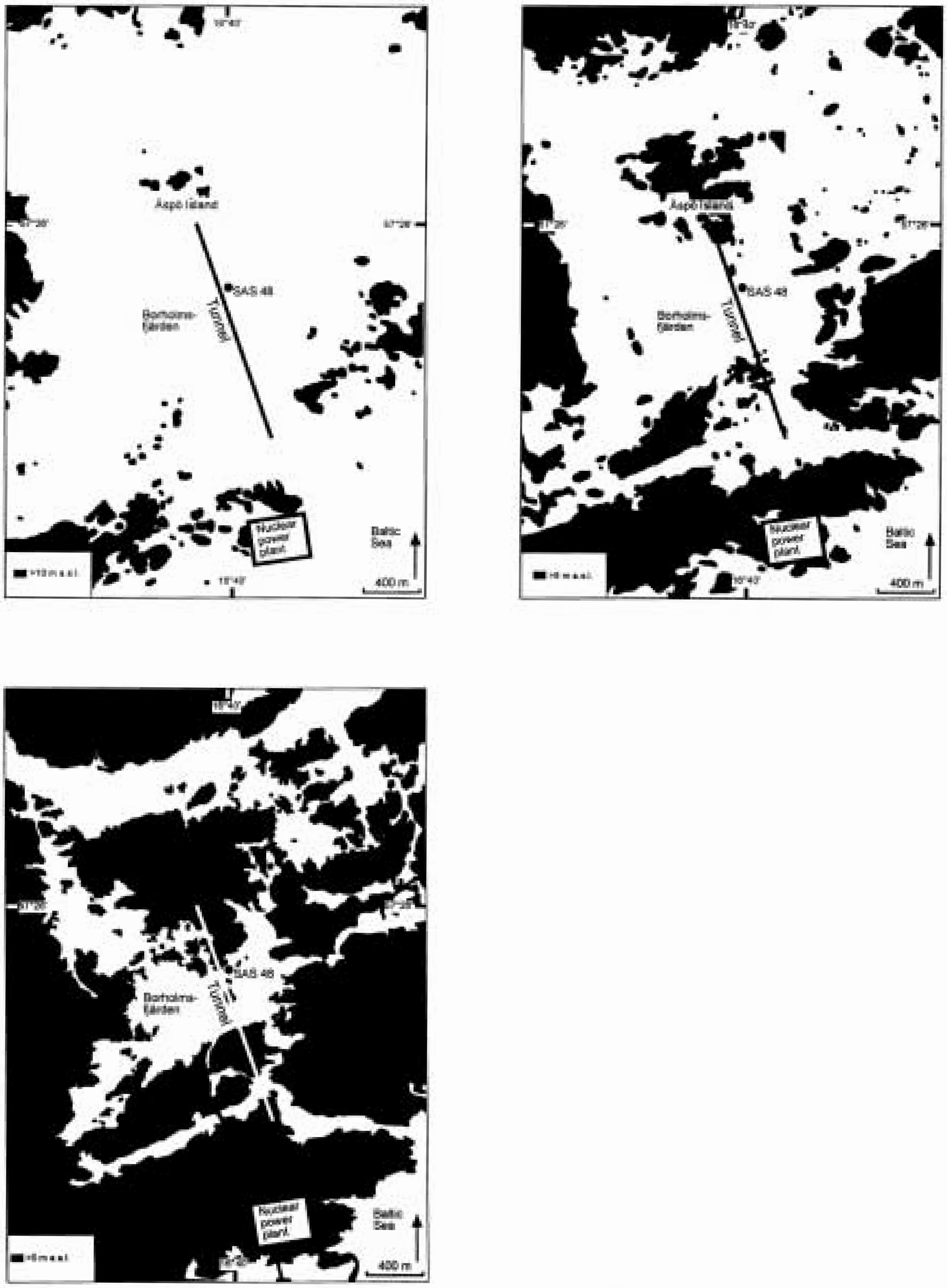


Figure 2-1. *Palaeogeographical map indicating the land-sea configuration when the shoreline was situated at +10 m (upper left) and +5 m (upper right) above the present day situation. Lower left shows the present day situation. The position of the tunnel is marked.*

2.2 Holocene history

The deglaciation southwest of Oskarshamn took place 12,395 varve years before present or 12,250 ^{14}C years BP (c 14,100 cal BP) leaving the northwards expanding Baltic Ice Lake to cover the area /Kristiansson 1986; Björck et al, 1987/. The highest coastline in the investigated area can today be found around 95–100 m above the present day sea level /Svedmark, 1904; Agrell, 1976; Svensson, 1989/. Caused by the drainage of the Baltic Ice Lake and the mainly regressive shore displacement, the 20 m above sea level contour line was first reached prior to the Ancylus transgression c 9500 ^{14}C years BP (c 10,700 cal BP), and secondly after the transgression c 9000 ^{14}C years BP (c 10,200 cal BP, /Svensson, 1989/, Figure 117, p 151). The amplitude of the Ancylus transgression in the Äspö area was c 10 m. When the Ancylus Lake level reached the 15 m contour line, only small islands had emerged above the water surface. It is not until the transition to the Litorina Sea that larger land areas start to appear around Borholmsfjärden.

Recent studies by /Berglund et al, 2001/ and /Yu et al, 2001/ on the coast of Blekinge indicate that the early Litorina Sea (the Mastogloia Sea or the Initial Litorina Sea) was initiated as early as 8900 ^{14}C years BP (10,000 cal years BP). Further north, in southern Uppland, the oldest traces of the Litorina Sea is dated to 8150 ^{14}C years BP (9100 cal years BP) by /Hedenström, 2001/. It can be assumed that the maximum Litorina transgression c 6000 ^{14}C years BP (c 6850 cal BP) reached only 10–12 m above sea level in the Äspö area. Further south, investigations in Blekinge determined the Litorina Limit (LL) at 7–8 m above sea level /Berglund, 1971/. To the east, LL is determined at 13–14 m above sea level in southern Gotland /Munthe, 1910/, 13–15 m above sea level in central Öland /Lundqvist, 1928; Agrell, 1979/ and at 9 m above sea level in southern Öland /Thulin, 1987/. In northeastern Småland, c 60 km north of Äspö, the Litorina Limit is determined to 30–32 m above present sea level /Robertsson, 1997/. The present day uplift in the area is c 1 mm/year /Ekman, 1996/.

2.3 Field work and lithology

The sediment core was sampled in Borholmsfjärden close to the tunnel that has been constructed from the mainland north of Simpevarp nuclear power plant through Hålö to Äspö (Figures 1-2 and 2-1). Several cores had earlier been collected from Borholmsfjärden in order to study the variation in red-ox potential, element distribution etc /Landström et al, 1994/. The sediment core studied was sampled during summer 1993 from a raft using a Russian peat corer with an internal diameter of 4.5 cm and 1 m length /Jowsey, 1966/. The lithology of the sediments varies from minerogenic material in the bottom to organic-rich sediment at the top (Table 2-1). The sampled sequence was resting on a minerogenic layer not possible to penetrate with the sampling equipment used. This layer was in the field interpreted to consist of till, deposited during the Late Weichselian glaciation.

Table 2-1. Lithology of the analysed sediment core SAS 48.

Depth below sea level (cm)	Lithology
000–340	Water
340–706	Gyttja
706–712	Sand and gravel
712–760	Clay, bluish
760–860	Clay, brownish

3 Methods

3.1 Mineral magnetic parameters

The sampled core was divided into 260 segments, each representing 2 cm, and analysed for magnetic susceptibility, ARM (Anhysteretic Remanent Magnetization), SIRM (Saturation Isothermal Remanent Magnetization) and S-ratio. These parameters are largely related to variations in concentrations, mineralogy and grain sizes of the iron oxide minerals in the sediment /Thompson and Oldfield, 1986; Higgitt et al, 1991/. The magnetic susceptibility was measured at Lund University using an air-coiled susceptibility bridge (Kappabridge). Pulse magnetic chargers were used to artificially magnetise the samples. Magnetic saturation was achieved by placing each sample in a high magnetic field of 1 Tesla (T) produced by a Redcliff pulse magnetic charger. The induced artificial remanence was measured on a Molspin spinner magnetometer. After the saturation procedure all samples were placed in a weak negative field of 0.1 T ($IRM_{-0.1T}$) using a Molspin pulse magnetic charger and the remanence was measured on the spinner magnetometer. The S-ratio is calculated as $IRM_{-0.1T}/SIRM$. ARM is a measure of very fine grained magnetic particles which could originate from the upper part of the soil profile /Mullins, 1977/. ARM was induced on an AC demagnetiser with a peak alternating field of 100 mT and a steady field of 0.1 mT. The remanence was measured on the spinner magnetometer. After completion of the magnetic analyses the samples were dried in room temperature to allow calculation of mass specific concentration parameters.

3.2 Siliceous microfossils

Twenty samples, collected between 770 and 480 cm below sea level, were analysed for their content of siliceous microfossils. The preparation technique mainly follows /Battarbee, 1986/. 10% HCl was added to dissolve carbonates and organic matter oxidised with 30% H_2O_2. Clay particles were removed by repeated decanting in 2 hrs intervals in 100 ml beakers. The residue was mounted in Naphrax and studied under an Olympus microscope with X1000 magnification using immersion oil. Pennate diatoms were counted as half if one pole was found. Centric diatoms were countet as half if more than half a frustule, but less than a complete one, was found. Literature used as an aid to identification and ecology of the diatoms were /Cleve-Euler, 1951–1955; Miller, 1964; Mölder and Tynni, 1967–1975; Tynni, 1975–1980; Stabell, 1981; Krammer and Lange-Bertalot, 1986, 1988, 1991a, b; Miller and Risberg, 1990; Risberg, 1991; Snoeijs et al, 1993–1998/. The diatoms are grouped according to their salinity preferences and living conditions: "Ancylus Lake" taxa, marine-brackish planktonic taxa, marine-brackish tychoplanktonic taxa, marine-brackish periphytic taxa, halophilous taxa, indifferent taxa (slighty brackish to freshwater), freshwater taxa and unknown ecology. The diagrams were constructed using Tilia versions 2.0 b.4 and Tilia graph, version 2.0 b.5 /Grimm, 1992/. The zonation was established by cluster analysis /Grimm, 1987/.

Because of taxonomic difficulties, chrysophyte stomatocysts were not identified to species level /cf Duff et al, 1995; Brown et al, 1996/. In general, these algae have their highest diversity in freshwater, but they also occur in brackish water /Westman and Sohlenius, 1996/. In fact, up to 50% of the siliceous microfossils were chrysophyte stomatocysts in a short sediment core collected in the Baltic Sea between the mainland and Gotland /Risberg, 1990/.

3.3 Clay mineralogy

Four intervals, 840–820 cm, 800–780 cm, 750–730 cm and 730–710 cm depth, were analysed regarding the clay mineralogy. The two lower samples represent the brownish clay, while the two upper samples represent the bluish clay. The clay mineralogy was determined using X-ray diffraction (XRD), /cf Brindley and Brown, 1980; Vortisch, 1982/. The samples were dispersed in 0.05 M $Na_4P_2O_7$ x 10 H_2O and then suspended in a 1000 ml beaker with a diameter of 62 mm. After 8 hrs of settling the uppermost 300 ml of the suspension was retrieved using a pipette /cf Olsson S, 1991/. Preparation of the samples were made according to Table 3-1. Identifications of the various clay minerals have been carried out according to /Brindley and Brown, 1980/.

Table 3-1. Preparations of clay for XRD analyses.

Preparations	Effects
1. Air dried suspension on slide:	No effect on intensity peaks
2. Ethylene glycol saturation:	Expands smectites and some vermiculites to 17 Å
3. Magnesium saturation:	Intensifies (collects) refractions near 14 Å
4. Glycerol saturation:	Expands only smectites to 17 Å
5. Potassium saturation:	Collapse smectites and vermiculites to 12 Å and 10 Å, respectively
6. Heat treatment:	Destroys kaolonite and collapses smectites and vermiculites to10 Å
7. Acid treatment:	Breaks down most chlorides and biotites

3.4 Radiocarbon dating

Three bulk sediment samples were dated using the AMS technique at the Ångström Laboratory, Uppsala University /Possnert, 1990/. Each sample correspond to 1 cm of sediment thickness. The samples were treated with 1% HCl in order to remove carbonates. The dated fraction was soluble in 1% NaOH (SOL). The non-calibrated ages are based on the half-life $T_{½}$= 5568 ± 30 years.

4 Results and interpretation

The results from the analysis are compiled in Figure 4-1. The variations in mineral magnetic characteristics were used as a base for four zones. The shorter interval analysed according to the content of siliceous microfossils were divided into five zones.

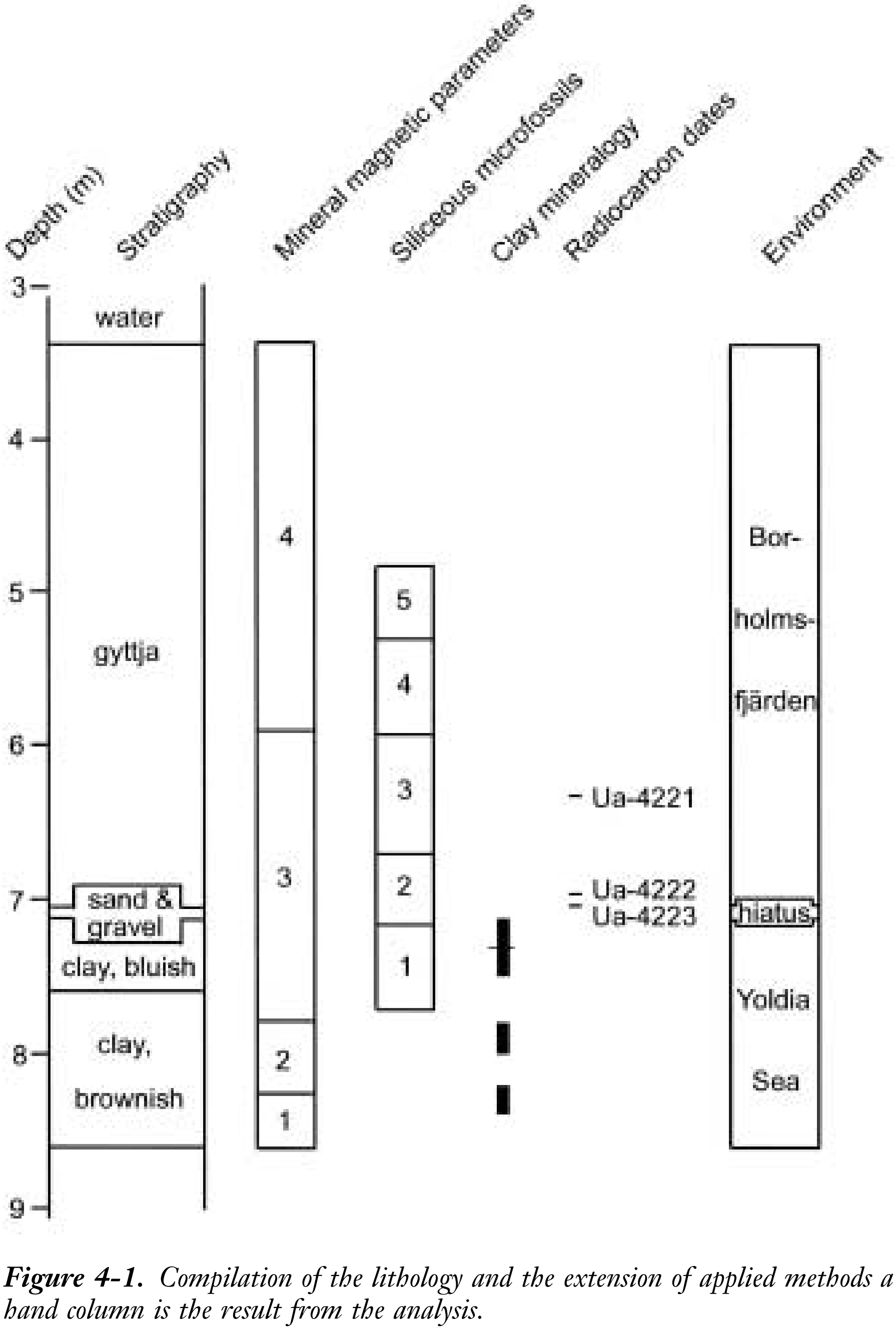


Figure 4-1. Compilation of the lithology and the extension of applied methods and zones. The right hand column is the result from the analysis.

4.1 Chronology

The three dated levels yielded similar ages in the time interval 3400–3600 ^{14}C years BP (Table 4-1). This is probably the result from sedimentation in a high energy environment causing substantial reworking. Because of the regressive shore displacement, and thus a gradually more sheltered position for the sampling site, it is likely that the importance of reworking should have decreased towards the present. Another probable reason for the similarities in age could be extensive bioturbation. Incorporation of carbonates is considered a less probable explanation /cf Olsson I U, 1991/.

/Hedenström and Possnert, 2001/ have shown that bulk dates of sediment accumulated in a near-shore environment during the Litorina Sea stage of the Baltic could be up to 1000 years older as compared with dates of terrestrial macrofossils. In this work, the authors estimate that the yielded ages are c 800 years too old as a result from the combined effect of mixing with older carbon and sedimentation in a brackish water environment. Accordingly, the ages were corrected prior to the calibration procedure which followed /Stuiver et al, 1998/.

Table 4-1. Three bulk sediment dates from the core SAS 48 in the Borholmfjärden bay of the Baltic Sea

Depth (cm)	Laboratory number	δ^{13}C (‰)	^{14}C age (uncorr. years BP)	Calibrated age (^{14}C years BP)
631	Ua-4221	–20.71	3415 ± 80	2750
697	Ua-4222	–21.26	3520 ± 80	2850
707	Ua-4223	–21.07	3415 ± 85	2750

4.2 Mineral magnetic parameters

The results from the mineral magnetic analyses indicate that mineralogy is more or less similar throughout the analysed section (Figure 4-2). This is shown by the S-ratio, which varies slightly around –0.5 in the main part of the sequence (zone 2–4). The exception is in zone 1, the lower part of the brownish clay layer, where the S-ratio varies around –0.7. These low values indicate that the proportion of ferrimagnetic minerals are more important in this zone, possibly reflecting a different source area. In zone 2, constituting the upper part of the brownish clay, the S-ratio increases, while magnetic susceptibility (χ), ARM and SIRM show decreasing concentrations. This is probably the result from a decrease in grain size distribution. χ, ARM and SIRM show uniform and low concentrations in zones 3 and 4. Also the ARM/SIRM ratio displays relatively stable values around 0.1. The somewhat enhanced concentration of χ in the lower part of zone 3 is explained by a higher minerogenic component compared to the gyttja sediment. All concentration parameters increase in the sand and gravel layer. In zone 4, the fluctuating ARM/SIRM graph indicates a higher input of minerogenic matter. This is interpreted as the result of an input of clastic particles from the nearby growing islands.

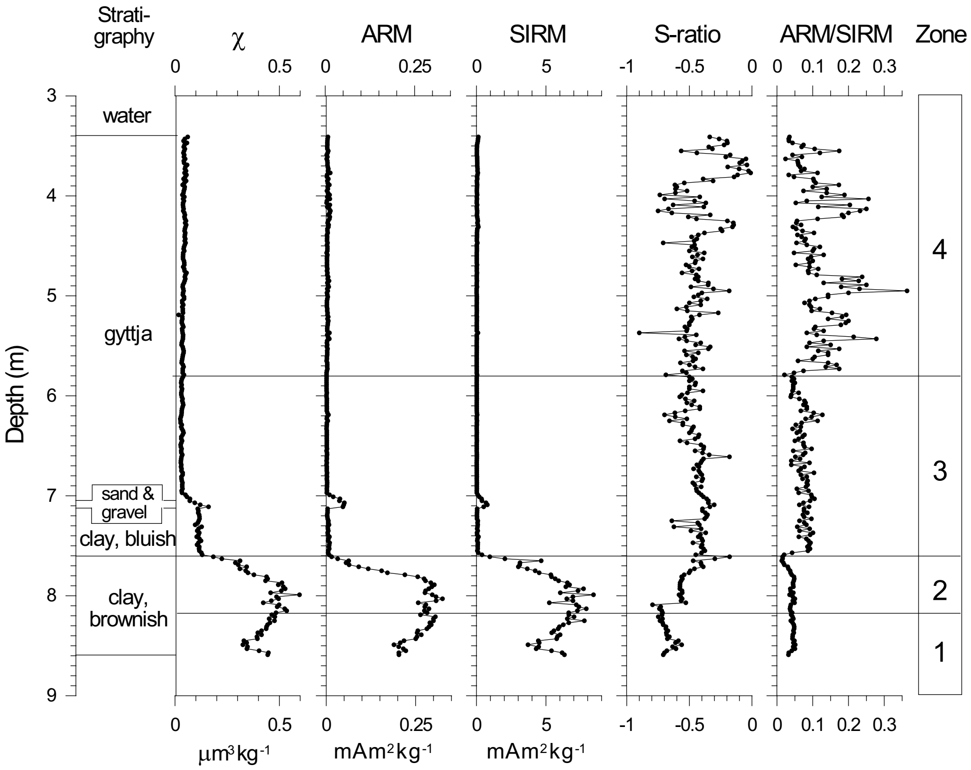


***Figure 4-2.** Mineral magnetic characteristics of the sediment core SAS 48. The zones are based on variations in concentrations and ratios.*

4.3 Siliceous microfossils

Among siliceous microfossils, diatoms are by far the most common group (Figure 4-3). Chrysophyte stomatocysts fluctuate around 5%, while only scattered observations of ebridians (*Ebria tripartita*) were made.

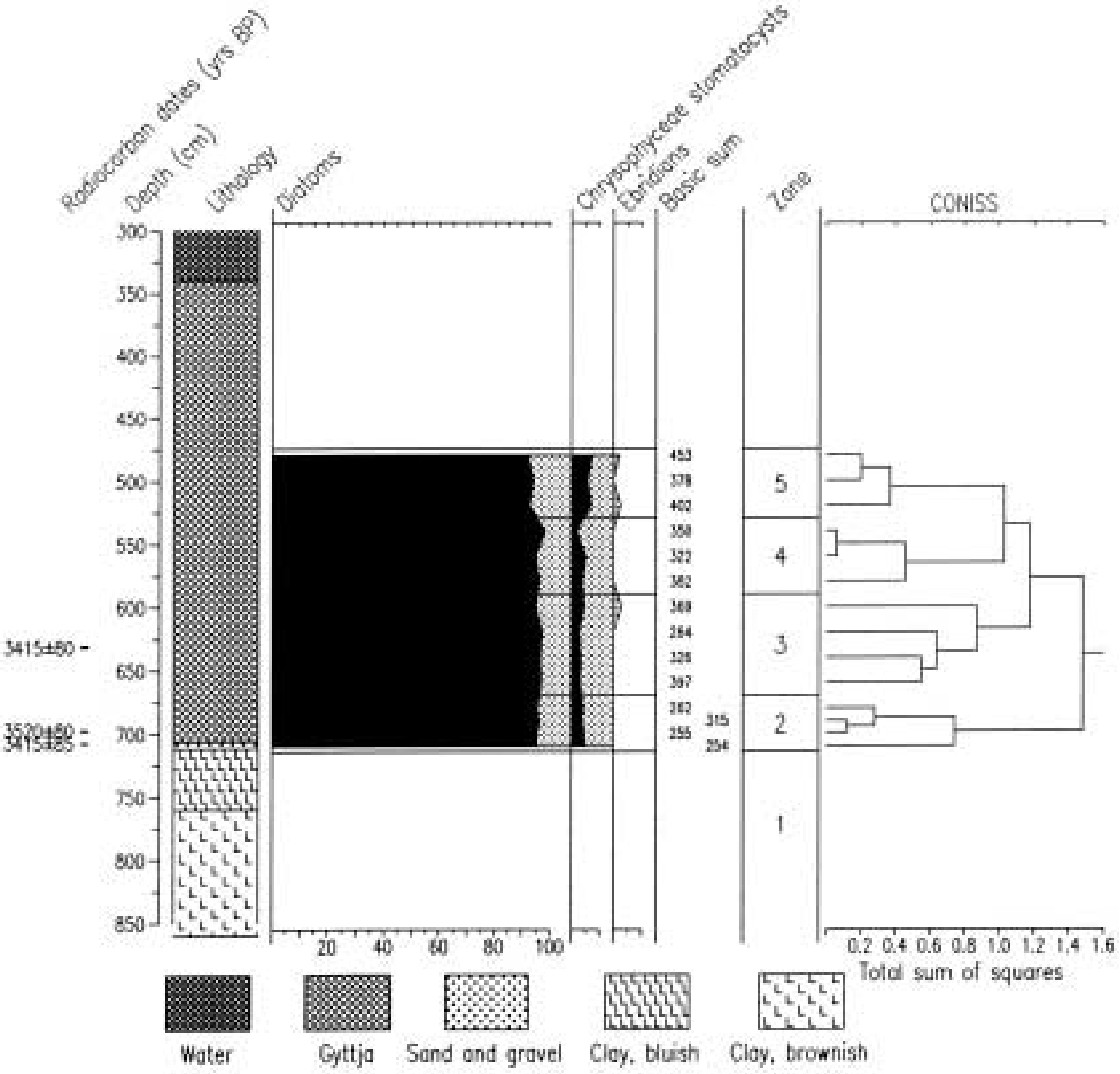


Figure 4-3. *Relative percentages of siliceous microfossils between 710 and 480 cm below water level, in the sediment core SAS 48. The zonation is based on coniss.*

The number of diatom taxa is low. Most common are the marine-brackish epiphytic taxon *Cocconeis scutellum* (15–35%) and the indifferent taxon *Epithemia turgida* (c 20%; Figure 4-4, Table 4-2). Other relatively common taxa are the marine-brackish tychoplanktonic taxon *Hyalodiscus scoticus* (15–25%), together with the periphytic taxa *Fragilaria fasciculata* (c 5%) and *Grammatophora marina* (c 5%). *Rhoicosphenia curvata* dominate with c 5% among halophilous taxa. Marine-brackish tychoplanktonic taxa are, besides *Hyalodiscus scoticus*, relatively sparse in the sequence. Finds of vegetative cells from true planktonic taxa are exotic in the sequence. Occasionally, frustules from *Actinocyclus ehrenbergii* v *crassa*, *Coscinodiscus asteromphalus*, *Cyclotella caspia*, *Thalassiosira decipiens* and *Th hyperborea* v *lacunosa* were noted. The studied sequence has been divided into five zones (1–5) based on the cluster analysis. These are described below from bottom upwards:

Zone 1, between 770 and 715 cm depth, is characterised by scattered occurrences of diatom frustules. Noted taxa were *Cocconeis scutellum* + v *stauroneiformis*, *Hyalodiscus scoticus* and *Navicula rhyncocephala* (Table 4-3, Figure 4-3). In addition, fragments of *Synedra tabulata*, *S crystallina*, *Rhabdonema* sp, *Pinnularia* spp and *Epithemia turgida* were observed. This diatom composition points to a deposition in slightly brackish water. The low frequency and the clayey sediment indicate sedimentation during the Yoldia Sea stage of the Baltic.

Zone 2, between 715 and 670 cm depth, contains abundant diatoms and is dominated by *Hyalodiscus scoticus* with minor occurrences of *Rhabdonema* spp, *Fragilaria construens* v *venter* and *F brevistriata*. The diatom composition implies deposition in a relatively sheltered outer archipelago. The salinity is probably the highest in the sequence as indicated by the high abundance of *Hyalodiscus scoticus*. The minerogenic layer between 712 and 706 cm depth indicate, together with the coarse grain size distribution, a substantial hiatus. The sediment above the minerogenic layer was deposited during the Litorina Sea stage of the Baltic. This interpretation is supported also by the AMS dates, yielding c 3500 ^{14}C years BP (c 2800 cal BP).

Zone 3, between 670 and 590 cm depth, displays decreasing values for *Hyalodiscus scoticus* while *Navicula ammophila* has a peak. The latter is a typical epiphytic taxon living in bays of the Baltic Sea /Tynni, 1975/. In the upper part of the zone, *Chaetoceros* spp resting spores show their highest occurrence throughout the zone, possibly a result from an increase in nutrients /cf Westman and Hedenström, 2002/.
It is likely that the salinity continue to decrease.

In zone 4, 590–530 cm depth, *Melosira jürgensii* reaches c 8% and *Opephora schulzii* c 1%. Also *Melosira moniliformis* shows somewhat higher relative abundance. Both *Melosira* taxa are stated as epilithic by /Balashova and Leskinen, 1993; Snoeijs, 1993/. The relative increase of these taxa from the lower part of zone 4 upwards is probably the result from a gradual growing of the nearby islands allowing the boulder-rich shoreline to become closer to the sampling site.

The uppermost zone 5, 530–475 cm depth, is characterised by an increase in indifferent taxa, e.g. *Fragilaria contruens* v *venter* (c 1%) and *Fragilaria pinnata* (c 1%) and the fresh-water genera *Pinnularia* (c 1%). Because of the growing islands, which prevent saline water to enter the bay, the decrease in salinity continues. *Ebria tripartita* was found, although in very low numbers, in this zone. This planktonic heterotrophic organism is common in estuaries in the Baltic Sea, especially between 2000 and 1500 ^{14}C years BP /Westman, 2000/. It is likely that the archipelago at the time of deposition of sediment representing zone 5 was a suitable environment for *E tripartita*. The decrease in salinity is also shown by the slight increase in chrysophyte stomatocysts, reaching c 10%.

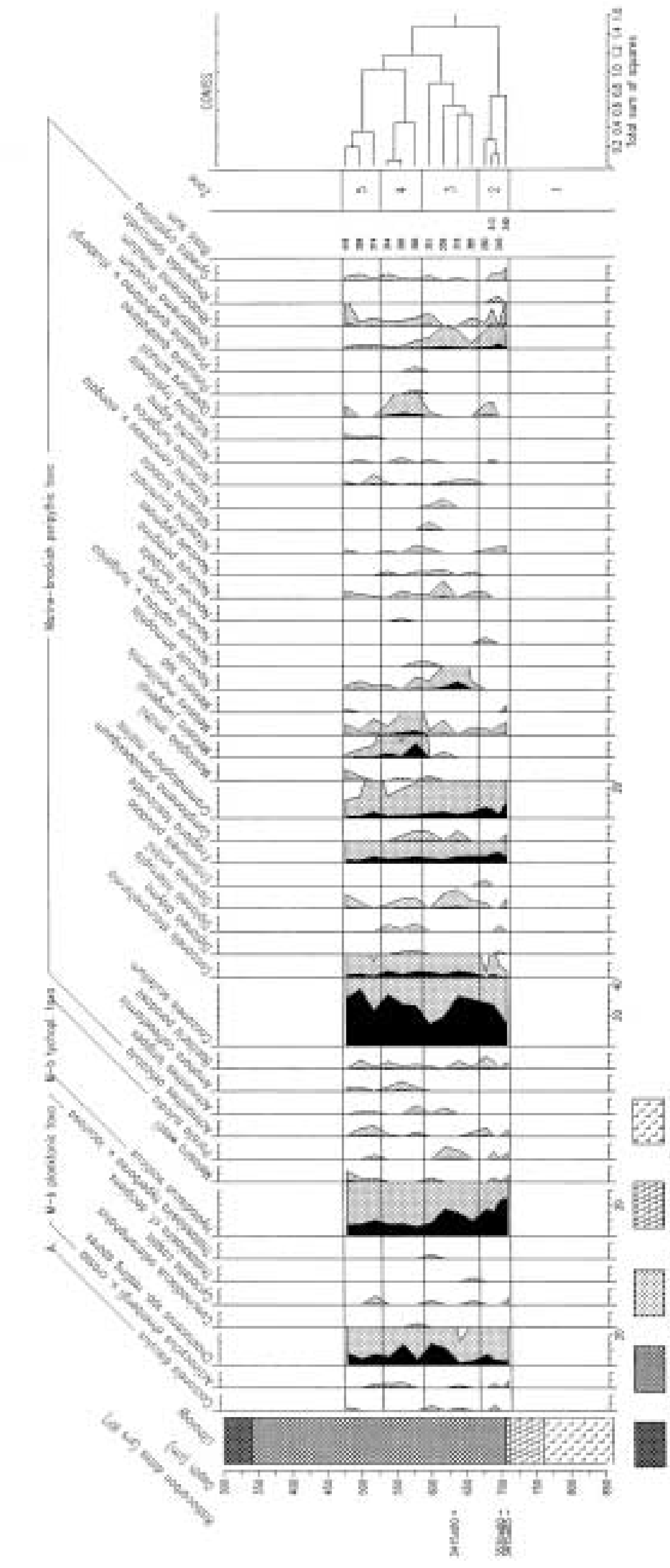


__Figure 4-4.__ Relative percentages of diatom taxa and genera in the sediment core SAS 48. The diatoms are grouped according to their salinity preferences and living conditions. The right hand part of the diagram show the sums of the different groups.

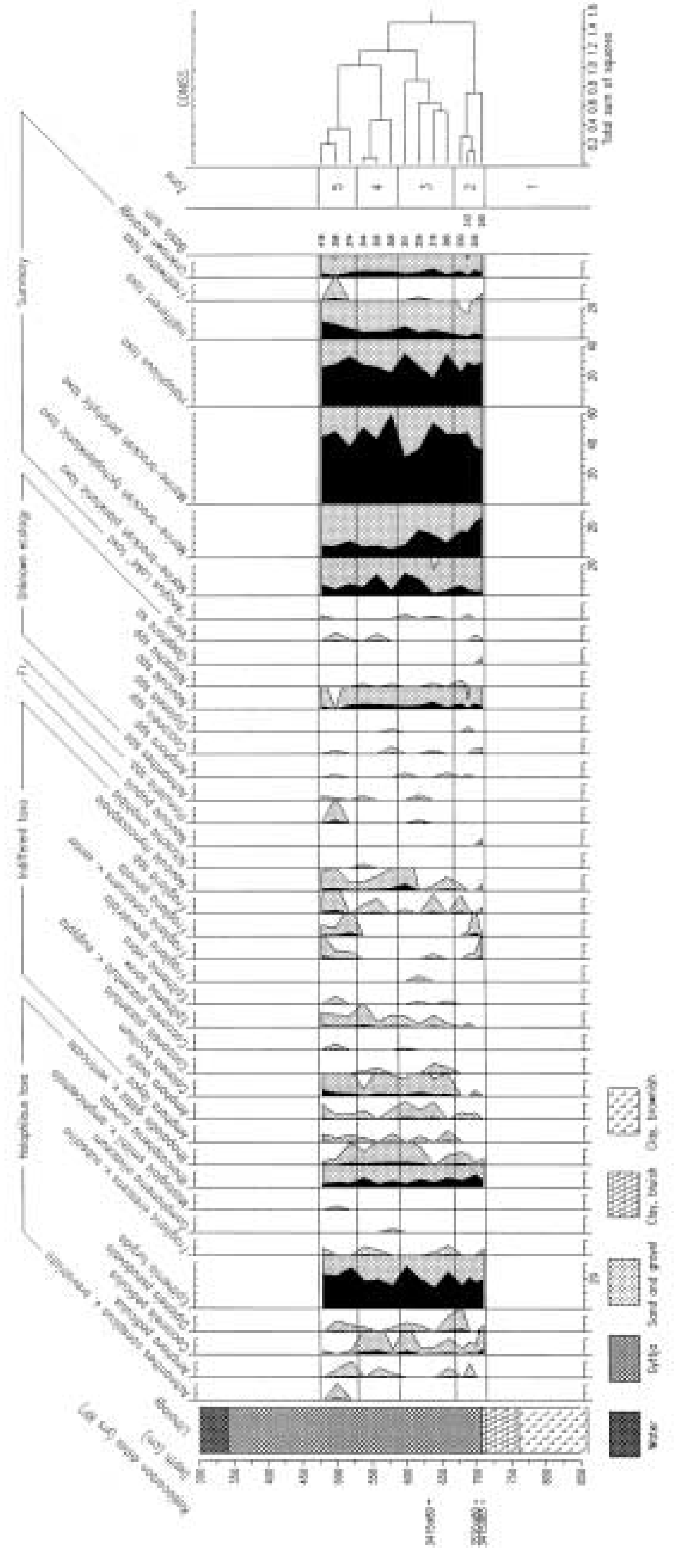


Figure 4-4 (cont). *Relative percentages of diatom taxa and genera in the sediment core SAS 48. The diatoms are grouped according to their salinity preferences and living conditions. The right hand part of the diagram show the sums of the different groups.*

Table 4-2. List of diatoms identified between 710 and 480 cm depth in SAS 48. Between one and four traverses were analysed.

Depth (cm):	**710**	**700**	**690**	**680**	**660**	**640**	**620**	**600**	**580**	**560**	**540**	**520**	**500**	**480**
DIATOMS:														
“Ancylus Lake” taxa														
Cocconeis disculus (Schumann) Cleve	–	–	1	–	–	0.5	–	1	–	–	–	–	–	1
Sum:	**0**	**0**	**1**	**0**	**0**	**0.5**	**0**	**1**	**0**	**0**	**0**	**0**	**0**	**1**
Brackish-marine planktonic taxa														
Actinocyclus ehrenbergii v *crassa* (W Smith) Hustedt	1	–	1	–	–	0.5	–	–	–	1	1	1	–	–
Coscinodiscus asteromphalus Ehrenberg	–	–	–	–	–	–	–	–	1	–	–	–	–	–
Cyclotella caspia Grunow	1	–	–	–	1	–	–	1	–	–	–	2	–	–
Sum:	**2**	**0**	**1**	**0**	**1**	**0.5**	**0**	**1**	**1**	**1**	**1**	**3**	**0**	**0**
Brackish planktonic coastal taxa														
Chaetoceros spp resting spores	6	8	11	18	11	5	29	50	13	43	19	27	15	32
Melosira moniliformis (Müller) Agardh	2	1.5	1	1	2	–	2.5	1	10.5	4.5	2	4	1	3
M westii fo *parma* Smith	1	–	1	–	–	–	–	1	–	–	–	1	1	3
Melosira spp Agardh	1	–	–	–	–	–	–	–	–	–	–	–	–	1
Paralia sulcata (Ehrenberg) Cleve	1	–	1.5	–	–	2	2	–	–	–	–	1	–	–
Thalassiosira cf decipiens (Grunow) Joergensen	–	–	–	–	1	–	–	–	–	–	–	–	–	–
Th hyperborea v *lacunosa* (Grunow) Hasle	–	–	–	–	–	–	–	1	–	–	–	–	–	–
Sum:	**11**	**9.5**	**14.5**	**19**	**14**	**7**	**33.5**	**53**	**23.5**	**47.5**	**21**	**33**	**17**	**39**
Brackish marine periphytic taxa														
Amphora coffeaeformis Agardh	–	–	–	–	–	–	–	–	1	2	1	–	1	1
Achnanthes delicatula (Kützing) Grunow	1	–	–	1.5	1	–	–	–	1	–	0.5	2.5	2	–
A longipes Agardh	–	–	–	–	–	–	1	–	2	–	–	0.5	0.5	–
Bacillaria paradoxa Gmelin	1	–	1.5	2	0.5	1.5	–	0.5	1	0.5	1.5	0.5	2	–
Cocconeis scutellum Ehrenberg	34	53	85	71	119	104	50	50	97.5	84	117	86	133	131
C stauroneiformis W Smith	1	2	6.5	1	12	13.5	5.5	13	14.5	6.5	15.5	4	8.5	7.5
Diploneis didyma (Ehrenberg) Cleve	–	0.5	–	–	–	–	–	–	1	0.5	–	–	–	–
D interrupta (Kützing) Cleve	1	–	–	–	–	–	–	–	2	0.5	1.5	–	–	–
D smithii (Brébisson) Cleve	1.5	–	–	1	2	4	2.5	–	2.5	2	1	–	1.5	4
Entomoneis paludosa (W Smith) Reimer	–	–	–	1	–	–	–	–	–	–	–	–	–	–
Fragilaria fasciculata (Agardh) Lange-Bertalot	10	17.5	20	12	18.5	14	7	11.5	16.5	9.5	10	17.5	6.5	9
Gomphonema pseudoexiguum Simonsen	1	–	–	–	–	2	–	2	2.5	1	–	–	–	–
Grammatophora marina (Lyngbye) Kützing	25	7	18	17.5	14.5	8.5	10.5	13	8.5	6	6	16	5	5
Hyalodiscus scoticus (Kützing) Grunow	60	57	50	44	37	46.5	44.5	29	21.5	23.5	25	39	26	30
Mastogloia smithii Thwaithes	–	–	–	–	–	–	–	1	–	0.5	–	–	1	3
Melosira juergensii Agardh	–	–	–	–	–	–	1	–	36	3	10	3	2	1
Navivula ammophila Grunow	–	–	–	–	2	16	4	2	3	–	1	1	2	1
N capitata v *hungarica* (Grunow) Ross	–	–	–	–	–	–	–	1	1	–	–	–	–	–
N crucigera (W Smith) Cleve	–	–	0.5	1	–	–	–	–	–	–	–	–	–	–
N forcipata Greville	–	–	–	–	–	–	–	–	–	0.5	–	–	–	–
N peregrina (Ehrenberg) Kützing	–	–	–	1	1.5	–	3	1	1	1.5	–	0.5	1	2
N pygmaea Kützing	–	–	–	–	1	–	1	1	1	–	1	–	–	–
Nitzschia acuminata (W Smith) Grunow	1	1	1	0.5	–	–	–	1	2	–	0.5	–	–	1
N bilobata Grunow	–	–	–	–	–	–	–	2	–	–	–	–	–	–
N hungarica Grunow	–	–	–	–	1.5	1	0.5	–	0.5	–	0.5	2.5	–	1
N compressa v *elongata* (Grunow) Lange-Bertalot	–	–	–	–	–	–	1.5	0.5	–	–	–	–	–	–
N sigma (Kützing) W Smith	–	–	0.5	–	–	–	–	0.5	–	1	–	–	0.5	–
N tryblionella Hantzsch	–	–	–	–	–	–	–	–	–	–	–	1	0.5	1.5
Opephora schulzii (Brockman) Simonsen	–	–	3	2	–	–	–	1	7	7	3	–	–	3
Pinnularia quadratarea (A S) Cleve	–	–	–	–	–	–	–	–	1	–	–	–	–	–
P quadratarea v *stuxbergii* Cleve	–	–	–	–	–	–	–	–	1	–	–	–	–	1
Rhabdonema arcuatum (Agardh) Kützing	1.5	8.5	5	3	1.5	4	4	2.5	2	0.5	0.5	1	1	0.5
Rh minutum Kützing	4.5	–	3.5	0.5	2	–	–	3	2	1	1	2	1	8
Rhopalodia operculata (Agardh) Håkansson	–	1	1	–	–	–	–	–	–	–	–	–	–	–
Synedra crystallina (Agardh) Kützing	2	1	1.5	–	–	0.5	–	1	0.5	0.5	1.5	0.5	1.5	1
Sum:	**145**	**149**	**197**	**159**	**214**	**215**	**136**	**137**	**230**	**152**	**197**	**178**	**197**	**212**

Table 4-2 (cont). List of diatoms identified between 710 and 480 cm depth in SAS 48. Between one and four traverses were analysed.

Depth (cm): **DIATOMS:**	**710**	**700**	**690**	**680**	**660**	**640**	**620**	**600**	**580**	**560**	**540**	**520**	**500**	**480**
Halophilous taxa														
Achnanthes conspicua v *brevistriata* Hustedt	–	–	–	–	–	–	–	–	–	–	–	–	4	–
Amphora pediculus Kützing	–	–	3	–	2.5	–	–	–	1	2	–	4	2	–
Cocconeis pediculus Ehrenberg	8.5	1.5	2.5	1	4	1.5	1	7.5	1	7	6	1	–	1
Diplones pseudoovalis Hustedt	1	–	–	4	4	–	1	2	1	–	1	1.5	2.5	–
Fragilaria virescens v *subsalina* Grunow	1	–	–	–	2.5	0.5	–	–	–	1	2	–	–	2
Gomphonema olivaceum (Lyngbye) Kützing	–	–	–	–	–	–	–	–	1	–	–	–	–	–
Mastogloia smithii v *amphicephala* Grunow	–	–	–	–	–	–	–	–	–	–	–	–	1	–
Rhoicosphenia curvata (Kützing) Grunow	11	21.5	20	11.5	24	11	13	9	15.5	6.5	21	10.5	12	11
Rhopalodia gibba v *ventricosa* (Kützing) Grunow	1	0.5	2	2	2.5	–	3	6.5	6.5	5	3	5.5	1.5	1
Sum:	22.5	23.5	27.5	18.5	39.5	13	18	25	26	21.5	33	22.5	23	15
Indifferent taxa (slightly brackish to freshwater)														
Amphora ovalis Kützing	–	–	–	–	3	–	1	–	2	–	1	1.5	1	2
Amphora libyca (Ehrenberg) Cleve	–	1	1	1	–	3.5	1.5	4	2.5	–	2	1	1	4
Caloneis bacillum (Grunow) Mereschkowsky	–	1	–	–	6	3.5	6	4	5	6	1.5	7	8	17
Cocconeis placentula Ehrenberg	–	–	–	–	1.5	2	–	–	–	1	0.5	–	–	–
C placentula v *euglypta* (Ehrenberg) Cleve	–	–	–	–	–	–	–	0.5	–	–	–	–	1.5	–
Epithemia sorex Kützing	–	–	1	–	1	2.5	0.5	2.5	3	1	5.5	3	3	4
E turgida (Ehrenberg) Kützing	47	43	53.5	38.5	94	45	50	98	56.5	59	62	101	77	93
E zebra (Ehrenberg) Kützing	–	–	–	–	1	–	0.5	–	–	–	–	–	2	–
Fragilaria brevistriata Grunow	–	–	–	–	–	–	1	–	–	–	–	–	–	–
F construens v *venter* (Ehrenberg) Grunow	4	1	1	–	–	1	–	–	–	–	–	2	2	7
F pinnata Ehrenberg	–	5	1	–	–	–	–	–	–	–	–	8	2	3
Fragilaria spp Lyngbye	1	–	1	3	–	4	–	1	–	3	2	–	8	9
Navicula rhyncocephala Kützing	1	–	–	1	3.5	1	–	15.5	5.5	3	2	2	5.5	5.5
Nitzschia amphibia Grunow	–	–	–	–	–	–	–	–	–	–	1	–	–	–
Sum:	**53**	**51**	**58.5**	**43.5**	**110**	**62.5**	**60.5**	**126**	**74.5**	**73**	**78.5**	**126**	**111**	**141**
Freshwater taxa														
Navicula pupula Kützing	1	–	–	–	–	–	–	–	–	–	–	–	–	–
Pinnularia spp Ehrenberg	–	–	–	–	–	–	0.5	–	–	–	–	–	6	–
Sum:	**1**	**0**	**0**	**0**	**0**	**0**	**0.5**	**0**	**0**	**0**	**0**	**0**	**6**	**0**
Unknown ecology														
Achnanthes spp Bory	–	–	–	–	–	–	1	–	–	–	1	–	0.5	1
Amphora spp Ehrenberg	–	–	0.5	–	1	–	–	1	–	–	–	–	0.5	–
Cocconeis spp Ehrenberg	1	1	–	–	–	1	–	–	2	–	–	–	1	–
Diploneis spp Ehrenberg	–	–	1	–	–	–	–	–	0.5	–	–	–	–	–
Navicula spp Bory	5	9.5	2	9.5	5.5	15.5	7	8	10.5	10.5	13	11.5	–	10
Nitzschia spp Hassall	–	–	–	1	–	0.5	–	–	0.5	–	0.5	–	–	–
Opephora sp Petit	1	–	–	–	–	–	–	–	–	–	–	–	–	–
Varia	0.5	1	–	–	–	–	–	–	–	1.5	–	0.5	2	–
Sum:	**7.5**	**11.5**	**3.5**	**10.5**	**6.5**	**17**	**8**	**9**	**13.5**	**12**	**14.5**	**12**	**4**	**11**
CHRYSOPHYTE STOMATOCYSTS:	12	11	12	11	12	11	7	17	14	16	6	28	22	34
EBRIDIANS (*Ebria tripartita* (Schumann) (Lemmermann)**):**	–	–	–	–	–	–	–	1	–	–	–	1	–	1
Numbers of traverses analysed:	1	1	2	2	2	2	1	2	2	2	3	4	4	2

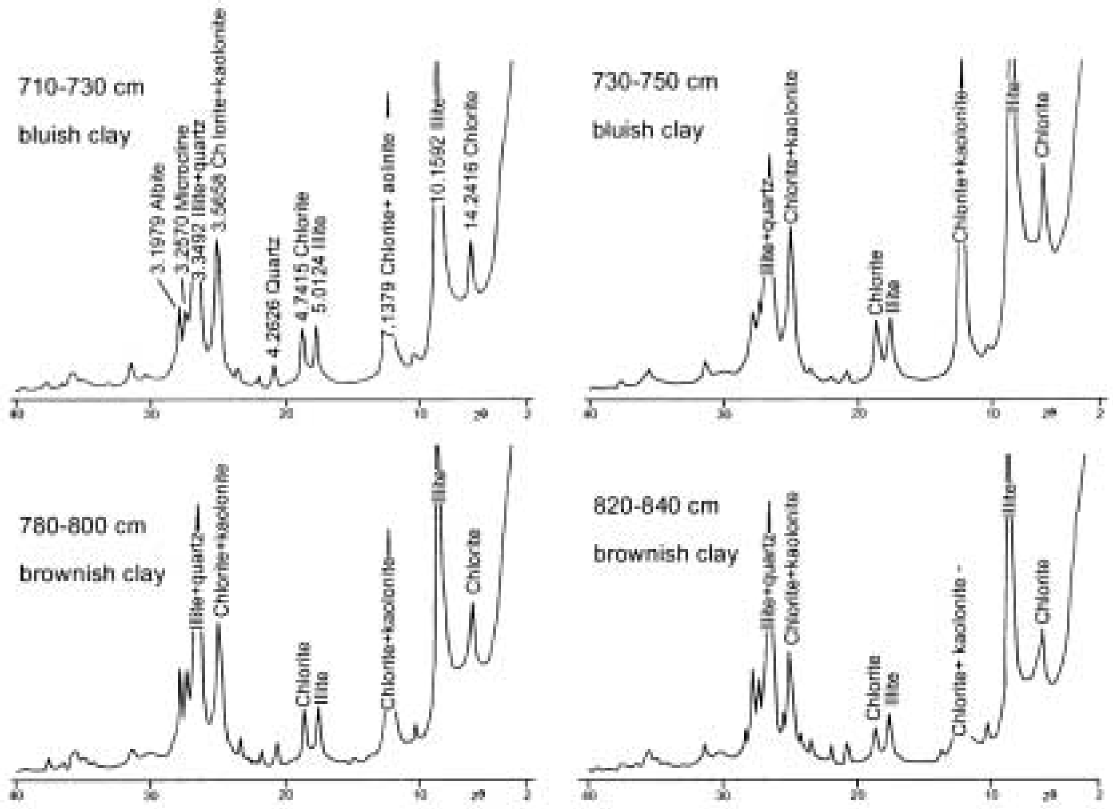
Table 4-3. List of diatoms identified from SAS 48 between 770 and 720 cm depth. Five traverses per slide were analysed for each level. "f" indicates fragments.

Diatom genera/taxa	770 cm	760 cm	750 cm	740 cm	730 cm	720 cm
Cocconeis scutellum Ehrenberg	0.5	–	–	–	–	0.5
C stauroneiformis W Smith	1	–	–	–	–	–
Epithemia turgida (Ehrenberg) Kützing	–	f	–	–	f	f
Fragilaria fasciculata (Agardh) Lange-Bertalot	f	f	f	–	f	f
Hyalodiscus scoticus (Kützing) Grunow	–	1	–	0.5	–	–
Navicula rhyncocephala Kützing	–	–	1	–	–	–
Pinnularia spp Ehrenberg	–	f	f	–	–	–
Rhabdonema sp Kützing	–	f	f	–	–	–
Synedra crystallina (Agardh) Kützing	–	f	–	–	–	–
Chrysophyte stomatocysts	–	–	1	–	1	–

4.4 Clay mineralogy

All four samples analysed are dominated by three clay minerals: illite, kaolonite and chlorite (Figure 4-5). There is no clear evidence of the presence of vermiculite and smectite in the samples. Non-clay minerals, such as feldspar and quartz, were identified in all samples. In general, it is concluded that the clay mineralogy of the four samples are similar. This is expected since the sediment has been deposited during a relatively short time span and in a similar environment. The high concentrations of illite suggest that the sediment has been accumulated in brackish to marine water /cf Kalm and Lutt, 1999/.

Preparation technique 1



Preparation technique 2

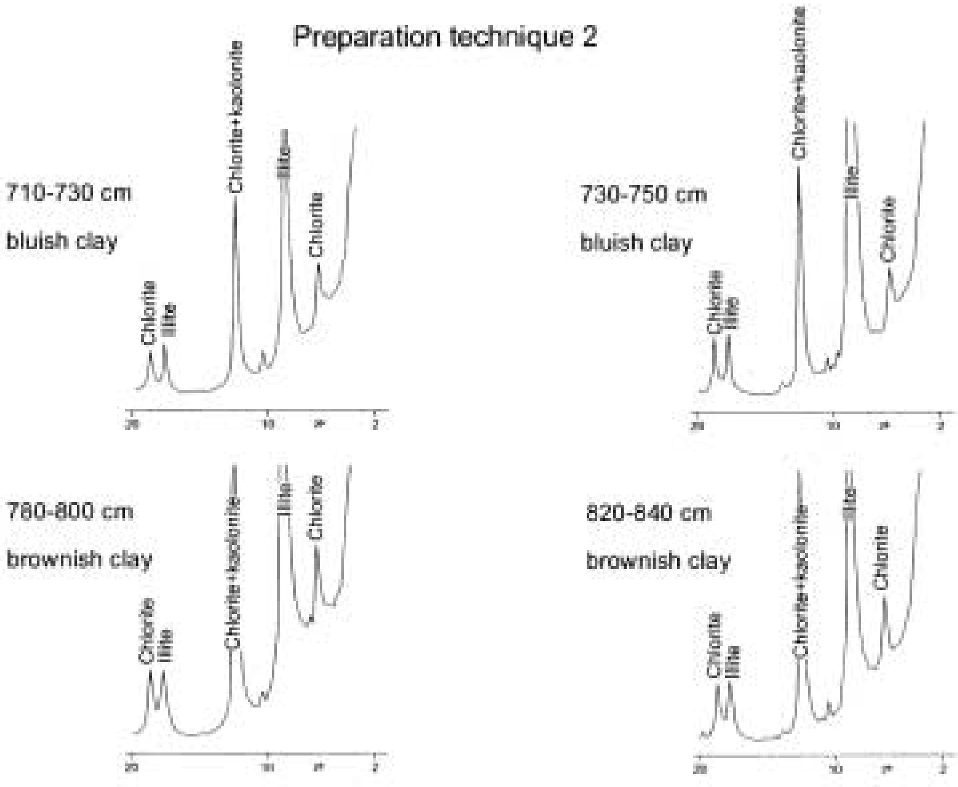


Figure 4-5. *Results from the XRD analyses of clay minerals in the two lower clay units. Preparation techniques are described in Table 3-1.*

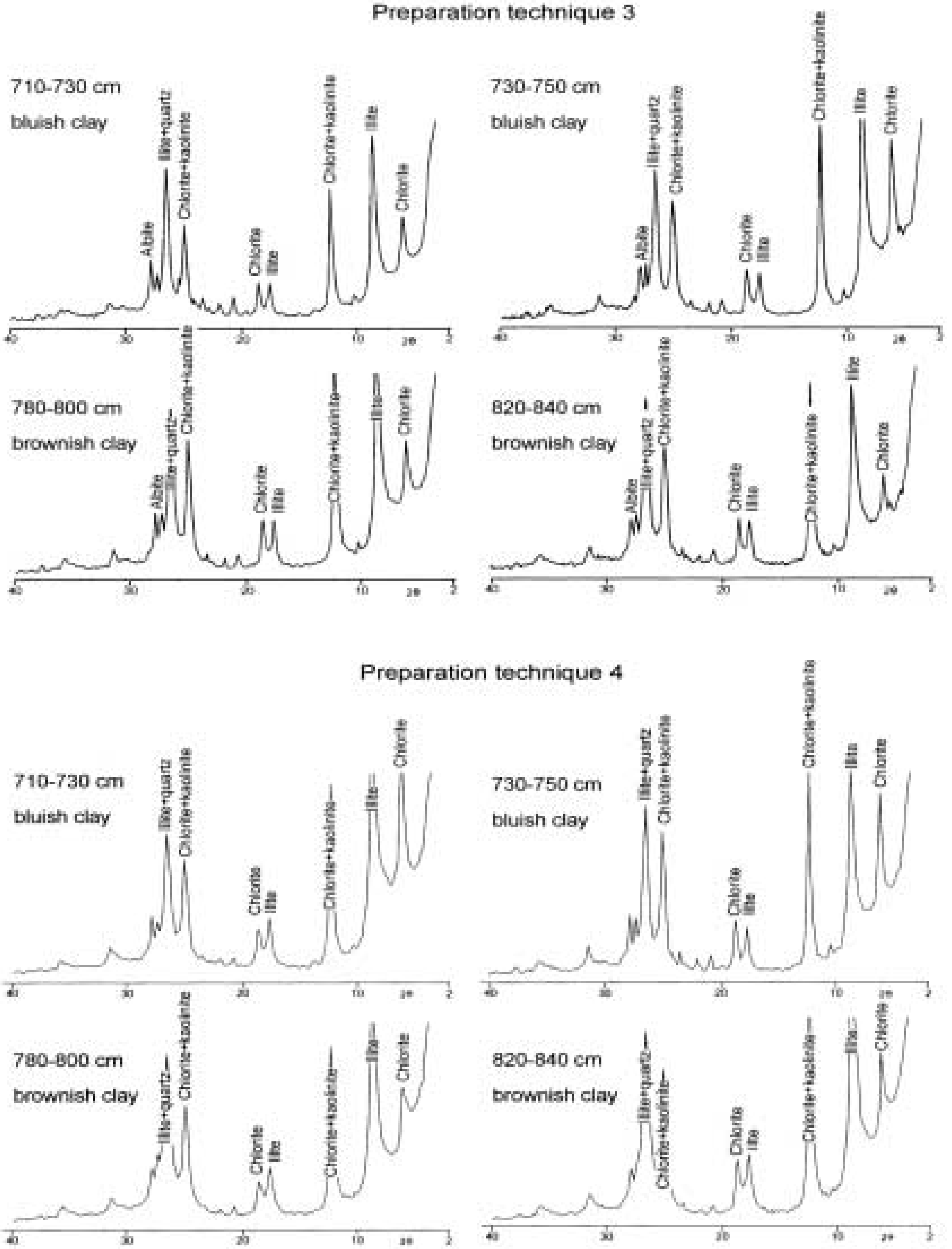
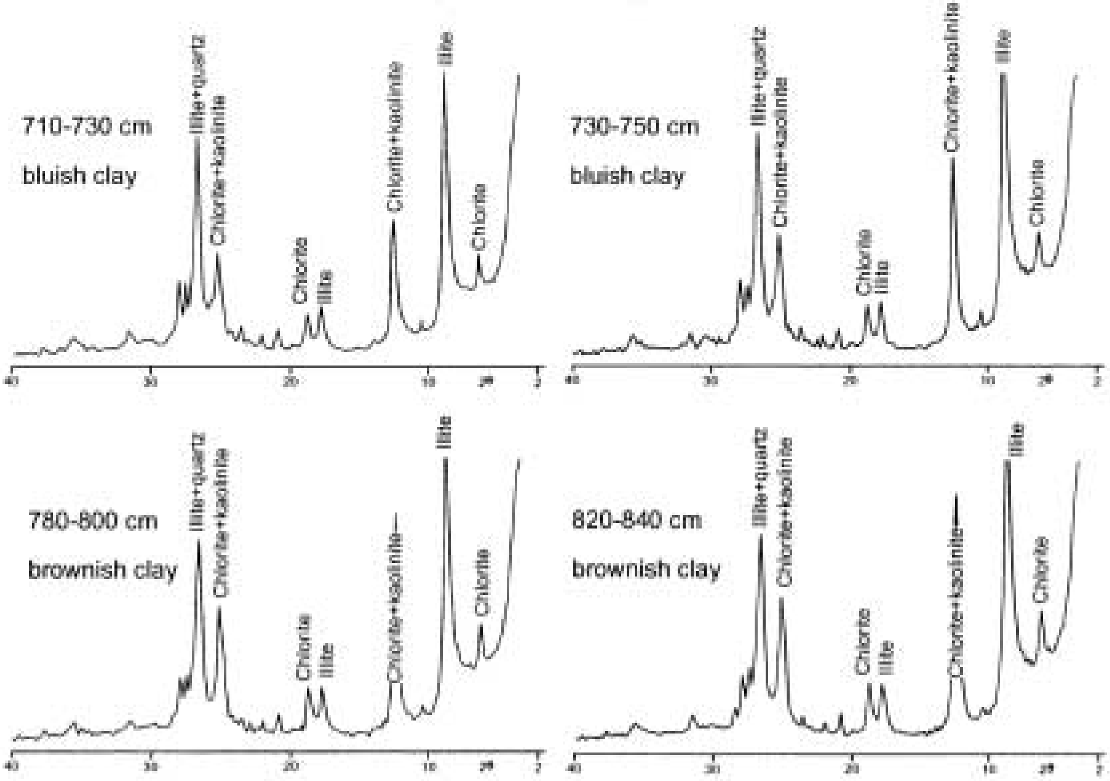
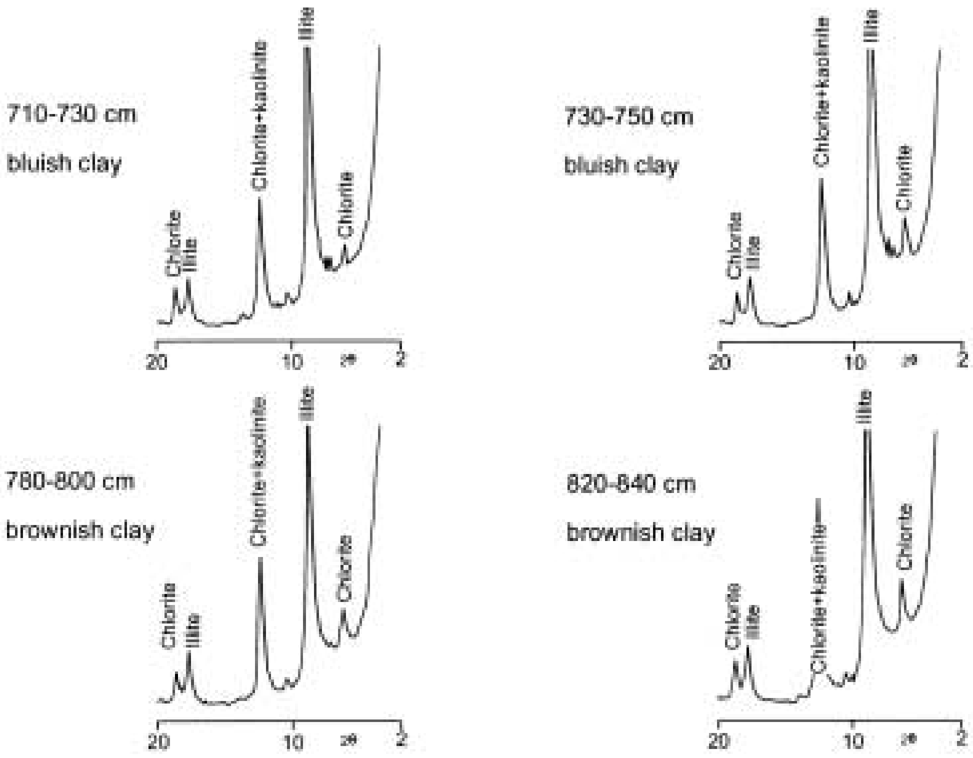


Figure 4-5 (cont). *Results from the XRD analyses of clay minerals in the two lower clay units. Preparation techniques are described in Table 3-1.*



Preparation technique 5



Preparation technique 6

Figure 4-5 (cont). *Results from the XRD analyses of clay minerals in the two lower clay units. Preparation techniques are described in Table 3-1.*

Preparation technique 7

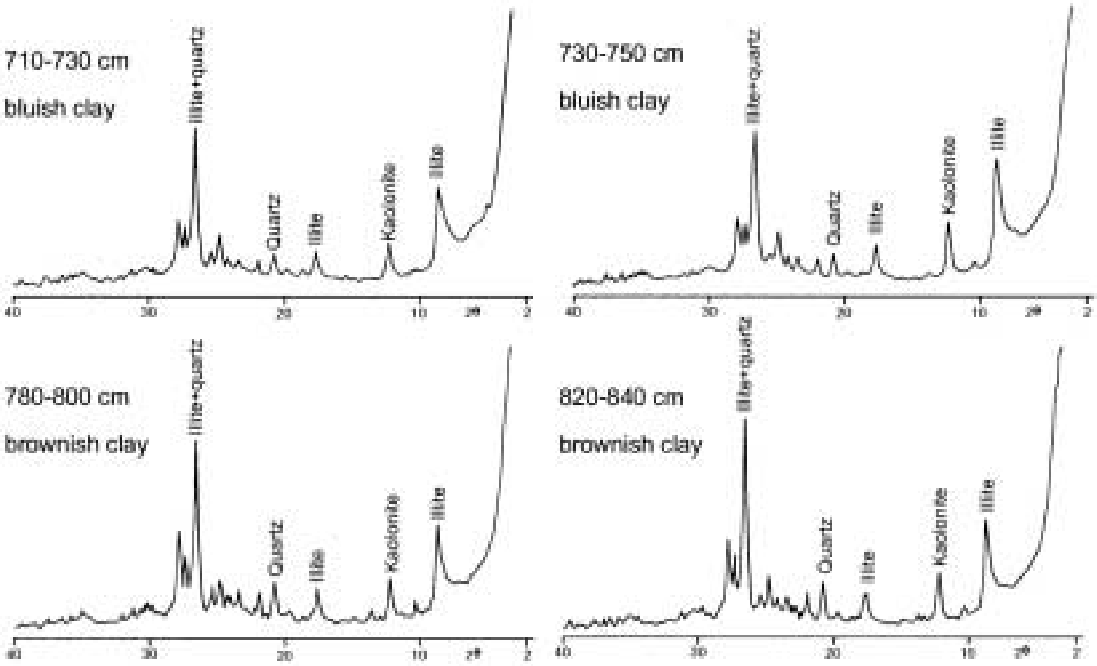


Figure 4-5 (cont). *Results from the XRD analyses of clay minerals in the two lower clay units. Preparation techniques are described in Table 3-1.*

5 Discussion and conclusions

The lowermost brownish clay could, according to its lithological composition and colour, have been deposited during the Baltic Ice Lake stage /cf Brunnberg, 1995/. Furthermore, the superimposed bluish clay is normally the result from sedimentation during the Ancylus Lake stage of the Baltic /cf Paabo, 1985/. The composition of the diatom flora, however, indicates deposition in brackish-marine water both for the bluish and the brownish clay (Table 4-2) either during the brackish water Yoldia Sea stage or during the initial stage of the Litorina Sea *sensu stricto*. The lowermost brownish clay is relatively uniform, except the abrupt increase in HIRM and S-ratio at around 810 cm depth, which probably is the result from a change in the material source. A major change occurs at the transition from brownish to bluish clay. All magnetic concentrations drop dramatically, probably as the result from a major shift in material source and/or sedimentation environment. A similar accumulation environment is also indicated by the clay mineralogy which indicates a relatively uniform material for both types of clay /cf Brunnberg, 1995/. The colour distinction is probably the result from different states of oxidation of iron. The most probable scenario is that sediment constituting both the brownish and bluish clay was accumulated during the brackish water phase of the Yoldia Sea /cf Svensson, 1989/.

The thin layer of sand and gravel is indicative of a major hiatus in the stratigraphy. Mineral magnetic concentrations, especially ARM, increase slightly as the result from mixing with single domain ground surface generated particles /cf Mullins, 1977/. Based on a Yoldia Sea age for the underlying clay and deposition in the Litorina Sea c 3000 cal years BP for the superimposed gyttja, it is believed that the length of the hiatus can represent as much as 7000 years.

It is not until the sampled site became protected enough by rising land areas, that organic rich gyttja could accumulate. It is likely that this scenario was established when sea level was situated at around 10 m above present day (cf Figure 2-1). Since then it seems, as interpreted from the mineral magnetic graphs (Figure 4-2), that the sedimentary conditions have been more or less stable. Also the sequence analysed for diatoms support this interpretation. The minor changes observed is likely the result from a decrease in salinity as the sampling site is transferred to a more sheltered position by the isostatic uplift. The slight variations in salinity that have been observed could also be the result from changes in the inflow of marine water via Öresund and/or the Belt straits /cf Westman and Sohlenius, 1999/. Resting spores from *Chaetoceros* spp dominate among marine-brackish planktonic taxa, however, no vegetative cells were observed. The variations in relative occurrences could be caused by an increase in nutrient availability, and not sea level changes, as the sampling site is transferred to a topographically more closed position. Peaks of *Chaetoceros* spp resting spores prior to the isolation of basins from the Litorina Sea have by /Westman and Hedenström, 2002/ been interpreted as an eutrophication and not an increase in sea level. Also in an off-shore environment, eutrophication has been applied to explain increased occurrences /Risberg, 1990/; cf discussion in /Andrén et al, 1999/. The more varied ARM/SIRM ratios in magnetic zone 4 show the more proximal position, in relation to land areas, of the sampling site. It is concluded that:

- The lowermost clay was accumulated in the brackish Yoldia Sea.
- The mineralogy of the brownish and bluish clay is similar being dominated by illite, kaolonite and chlorite.
- The thin layer of sand and gravel represent a c 7000 year long hiatus.
- Marine-brackish periphytic diatom taxa dominates within the gyttja sequence.
- Variations in the marine-brackish planktonic taxa (resting spores) are dependent on changes in nutrient availability during the regressive shore displacement.
- The ARM/SIRM ratio increase in variability as the nearby land areas grow in size.

6 Acknowledgement

I thank ass. prof. Ann-Marie Robertsson, Department of Physical Geography and Quaternary Geology, Stockholm University (SU), for critically reading the manuscript. Ass prof Eve Arnold, Department of Geology and Geochemistry, SU, commented on the interpretation of the XRD analysis of the clay mineralogy. Dr Gustav Sohlenius, Swedish University of Agricultural Sciences, Uppsala, made the mineral magnetic measurements and prof Per Sandgren, Department of Quaternary Geology, Lund University, constructed the diagram. Torsten Håkansson, SU, and Elinor Andrén, Department of Geosciences, Uppsala University, collected the core.

References

Agrell H, 1976. The highest coastline in south-eastern Sweden. Boreas 5, p 143–154.

Agrell H, 1979. The Quaternary history of the Baltic. In V Gudelis and L-K Königsson (eds): The Quaternary history of the Baltic. *Acta Universitatis Upsaliensis. Symposia Universitatis Upsaliensis. Annum Quingentesimum Celebrantis*: 1, p 219–239. Uppsala

Andrén E, Shimmield G, Brand T, 1999. Environmental changes of the last three centuries indicated by siliceous microfossil records from the southwestern Baltic Sea. The Holocene 9, 1, p 25–38.

Balashova N, Leskinen E, 1993. 62. Melosira moniliformis (O F Müller) C A Agardh 1824. In P Snoeijs (ed): Intercalibration and distribution of diatom species in the Baltic Sea. Volume 1, p 76.

Battarbee R W, 1986. Diatom analysis. In B E Berglund (ed): Handbook of Holocene Palaeoecology and Palaeohydrology, p 527–570. John Wiley & Sons. Chichester.

Berglund B E, 1971. Littorina transgressions in Blekinge, south Sweden. A preliminary report. Geologiska Föreningens i Stockholm Förhandlingar 93, p 525–652.

Berglund B E, Digerfeldt G, 1996. Sweden. Introduction. In B E Berglund, H J B Birks, M Ralska-Jasiewiczowa and H E Wright (eds): Palaeoecological events during the last 15 000 years. Regional synthesis of palaeoecological studies of lakes and mires in Europe, p 233–236. John Wiley & Sons Ltd.

Berglund B E, Sandgren P, Yu S, Barnekow L, Hannon G, Jiang H, Skog G, 2001. The Ancylus Lake and the Littorina Sea in Blekinge, south Sweden. In U Brenner (ed): Abstract Volume. Baltic Sea Science Congress 2001. Past, present and future – a joint venture, p 83. Stockholm Marine Research Centre. Stockholm University.

Bergström L, 2001. Late Holocene distribution of lake sediment and peat in NE Uppland, Sweden. 50 pp. SKB R-01-12, Svensk Kärnbränslehantering AB

Björck S, Sandgren P, Holmquist B, 1987. A magnetostratigraphic comparison between ^{14}C years and varve years B.P. during the Late Weichselian, indicating significant differences between the time-scales. Journal of Quaternary Science 87, 33–140.

Brindley G W, Brown G (eds), 1980. Crystal structures of clay minerals and their X-ray identification. Mineralogical Society. London. 495 pp.

Brown K M, Zeeb B A, Smol J P, Pienitz R, 1996. Taxonomic and ecological characterization of chrysophyte stomatocysts from northwestern Canada. Canadian Journal of Botany 75, p 842–863.

Brunnberg L, 1995. Clay-varve chronology and deglaciation during the Younger Dryas and Preboreal in the easternmost part of the Middle Swedish Ice Marginal zone. Stockholm University. Department of Quaternary Research. Quaternaria Ser A, No 2. 94 pp.

Brydsten L, 1999. Shore-line displacement in Öregrundsgrepen. 24 pp. SKB TR-99-16, Svensk Kärnbränslehantering AB

Cleve-Euler A, 1951–1955. Die Diatomeen von Schweden und Finnland. Kungliga Svenska Vetenskapsakademiens Handlingar I–V. 4:e Serien 2:1 (1951) 163 pp, 3:3 (1952) 153 pp, 4:1 (1953) 158 pp, 4:5 (1953) 255 pp, 5:4 (1955) 232 pp.

Duff K E, Zeeb B A, Smol J P, 1995. Atlas of Chrysophycean cysts. Developments in Hydrobiology 99. Kluwer Academic Publishers. Dordrecht. 189 pp.

Ekman M, 1996. A consistent map of the postglacial uplift of Fennoscandia. Terra-Nova 8/2, p 158–165.

Grimm E C, 1987. CONISS: a fortran 77 program for stratigraphically constrianed cluster analysis by the method of incremental sum of squares. Computers and Geoscience 13/1, p 13–35.

Grimm E C, 1992. Tilia and Tiliagraph: Pollen spreadsheet and graphic programs. Programs and Abstracts, 8th International Palynological Congress, Aix-en-Provence, September 6–12, 1992, p 56.

Hedenström A, 2001. Early Holocene shore displacement in eastern Svealand, Sweden, based on diatom stratigrpahy, radiocarbon chronology and geochemical parameters. Stockholm University. Department of Physical Geography and Quaternary Geology. Quaternaria A:10. 36 pp.

Hedenström A, Possnert G, 2001. Reservoir ages in Baltic Sea sediment – a case study of an isolation sequence from the Litorina Sea stage. Quaternary Science Reviews 20, p 1779–1785.

Higgitt S R, Oldfield F, Appleby P G, 1991. The record of land use changes and soil erosion in the late Holocene sediments of the Petit Lac d'Annecy, eastern France. The Holocene 1, 1, p 14–28.

Jerling L, Isaeus M, Lanneck J, Lindborg T, Schüldt R, 2001. The terrestrial biosphere in the SFR region. SKB Report T-01-09, Svensk Kärnbränslehantering AB

Jowsey P C, 1966. An improved peat sampler. New Phytologist 65, p 245–248.

Kalm V, Lutt J, 1999. Illite in Baltic Sea sediments off the northwestern coast of Estonia: a record of environmental changes. In Th Andrén (ed): Proceedings of the Conference The Baltic – past, present and future Stockholm on March 14–16th, 1994. Stockholm University. Department of Quaternary Research. Quaternaria Ser A, No 7, p 45–53.

Kornfält K-A, Wikman H, 1990. Map of solid rocks of the Äspö island. Geological Survey of Sweden and SKB Hard Rock laboratory (map sheet).

Krammer K, Lange-Bertalot H, 1986. Bacillariophyceae. 1.Teil: Naviculaceae. In H Ettl, J Gerloff, H Heynig and D Mollenhauer (eds): Süsswasserflora von Mitteleuropa 2/1. Gustav Fischer Verlag. Stuttgart. 876 pp.

Krammer K, Lange-Bertalot H, 1988. Bacillariophyceae. 2.Teil: Bacillariaceae, Epithemiaceae, Surirellaceae. In H Ettl, J Gerloff, H Heynig and D Mollenhauer (eds): Süsswasserflora von Mitteleuropa 2/2. Gustav Fischer Verlag. Stuttgart. 596 pp.

Krammer K, Lange-Bertalot H, 1991a. Bacillariophyceae. 3.Teil: Centrales, Fragilariaceae, Eunotiaceae. In H Ettl, J Gerloff, H Heynig and D Mollenhauer (eds): Süsswasserflora von Mitteleuropa 2/3. Gustav Fischer Verlag. Stuttgart. 576 pp.

Krammer K, Lange-Bertalot H, 1991b. Bacillariophyceae. 4.Teil: Achnanthaceae. Kritische Ergänzungen zu *Navicula* (Lineolate) und *Gomphonema*. In H Ettl, J Gerloff, H Heynig and D Mollenhauer (eds): Süsswasserflora von Mitteleuropa 2/4. Gustav Fischer Verlag. Stuttgart. 437 pp.

Kristiansson J, 1986. The ice recession in the south-eastern part of Sweden. A varve-chronological time scale for the latest part of the Late Weichselian. Stockholm University. Department of Quaternary Research. Report 7. 132 pp.

Landström O, Aggeryd I, Mathiasson L, Sundblad B, 1994. Chemical composition of sediments from the Äspö area and interaction between biosphere and geosphere. SKB, Arbetsrapport 94-13, Svensk Kärnbränslehantering AB

Lindborg T, Kautsky U, 2000. Variabler i olika ekosystem, tänkbara att beskriva vid platsundersökning för ett djupförvar. SKB, R-00-19, Svensk Kärnbränslehantering AB

Lundegårdh P H, Wikström A, Bruun Å, 1985. Beskrivning till provisoriska översiktliga bergrundskartan Oskarshamn. Sveriges Geologiska Undersökning Ba 34. 26 pp.

Lundqvist G, 1928. Studier i Ölands myrmarker. Sveriges Geologiska Undersökning C 353. 183 pp.

Miller U, 1964. Diatom floras in the Quaternary of the Göta River valley. Sveriges Geologiska Undersökning Ca 44. 67 pp.

Miller U, Risberg J, 1990. Environmental changes, mainly eutrophication, as recorded by fossil siliceous micro-algae in two cores from the uppermost sediments of the north-western Baltic. Beiheft zur Nova Hedwigia 100, p 237–253.

Mölder K, Tynni R, 1967–1975. Über Finnlands rezente und subfossile Diatomeen I–VI. Comptes Rendus de la Société de Finlande N:o XXXIX, p 199–217 (1967), Bulletin of the Geological Survey of Finland 40, p 151–170 (1968), Bulletin 41, p 235–251 (1969), Bulletin 42, p 129–144 (1970), Bulletin 43, p 203–220 (1971), Bulletin 44, p 141–149 (1972), Bulletin 45, p 159–179 (1973).

Morén L, Påsse T, 2001. Climate and shoreline in Sweden duringWeichseland the next 150,000 years. 67 pp. SKB TR-01-19, Svensk Kärnbränslehantering AB

Mullins C E, 1977. Magnetic susceptibility of the soil and its significance in soil science – a review. Journal of Soil Science 28, p 223–246.

Munthe H, 1910. Studier öfver Gottlands senkvartära historia. Sveriges Geologiska Undersökning Ca 4. 213 pp.

Olsson I U, 1991. Accuracy and precision in sediment chronology. Hydrobiologia 214, p 25–34.

Olsson S, 1991. Geochemistry, mineralogy and pore-water composition in uplifted, Late Weichselian-Early Holocene clays from southern Sweden. Lund University. Department of Quaternary Geology. LUNDQUA Thesis. Volume 28. 89 pp.

Paabo K, 1985. Diatomological studies of two cores from the western Baltic. In G Ch Borg (ed): Palaeo-ecology reflected in physical and chemical properties of three Baltic cores. Striae 23, p 83–90.

Påsse T, 2001. An empirical model of glacio-isostatic movements and shore-level displacement in Fennoscandia. 59 pp. SKB R-01-41, Svensk Kärnbränslehantering AB

Possnert G, 1990. Radiocarbon dating by the accelerator technique. Norwegian Archaeological Review 23, p 30–37.

Risberg J, 1990. Siliceous microfossil stratigraphy in a superficial sediment core from the north-western part of the Baltic proper. Ambio 3, p 167–172.

Risberg J, 1991. Palaeoenvironment and sea level changes during the early Holocene on the Södertörn peninsula, Södermanland, eastern Sweden. Stockholm University. Department of Quaternary Research. Report 20. 27 pp.

Rudmark L, 2000. Beskrivning till jordartskartan 5G Oskarshamn NO. Sveriges Geologiska Undersökning Ae 94. 64 pp.

Robertsson A-M, 1997. Shore displacement in north-eastern Småland c. 9000–2500 BP. In I Cato and F Klingberg (eds): Proceedings of the Fourth Marine Geological Conference – the Baltic, Uppsala 1995. Sveriges Geologiska Undersökning Ca 86, p 145–152.

Snoeijs P, 1993. 61. Melosira lineata (Dillwyn) C.A. Agardh 1824. In P Snoeijs (ed) 1993: Intercalibration and distribution of diatom species in the Baltic Sea. Volume 1, p 75.

Snoeijs P et al (eds), 1993–1998. Intercalibration and distribution of diatom species in the Baltic Sea. Volumes 1–5. Opulus Press. Uppsala. Vol. 1 (1993): P. Snoeijs (ed.), 129 pp, Vol. 2 (1994): P Snoeijs and S Vilbaste (eds), 125 pp, Vol. 3 (1995): P Snoeijs and M Potapova (eds), 126 pp, Vol 4 (1996): P Snoeijs and J Kasperoviciene (eds), 126 pp, Vol 5 (1998): P Snoeijs and J Balashova (eds), 144 pp.

Stabell B, 1981. The diatom *Fragilaria virescens* var. *subsalina*. In L-K Königsson and K Paabo (eds): Florilegium Florinis Dedicatum. Striae 14, p 126–129.

Stuiver M, Reimer P J, Bard E, Beck J W, Burr G S, Hughen K A, Kromer B, McCormack G, van der Plicht J, Spurk M, 1998. Intcal98 radiocarbon age calibration, 24,000–0 cal BP. Radiocarbon 40 (3), p 1041–1083.

Svedmark E, 1904. Beskrifning till kartbladet Oskarshamn. Sveriges Geologiska Undersökning Ac 5. 85 pp.

Svensson N-O, 1989. Late Weichselian and early Holocene shore displacement in the central Baltic, based on stratigraphical and morphological records from eastern Småland and Gotland, Sweden. Lund University. Department of Quaternary Geology. Thesis 25. 195 pp.

Thompson R, Oldfield F, 1986. Environmental magnetism. Allen & Unwin. London. 227 pp.

Thulin B, 1987. Diatoms and palaeoenvironment at Ottenby, southern Öland, SE Sweden. Striae 28. 61 pp.

Tynni R, 1975–1980. Über Finnlands rezente und subfossile Diatomeen VIII–XI. Geological Survey of Finland Bulletin 274. 55 pp (1975), Bulletin 284. 37 pp (1976), Bulletin 296. 55 pp (1978), Bulletin 312. 93 pp (1980).

Vortisch W, 1982. Clay mineralogical studies of some tills in northern Germany. Geologica et Palaeontologica 15, p 167–192.

Westman P, Sohlenius G, 1996. Chrysophyte cyst and diatom flora of a Litorina Sea sediment sequence from the north-western Baltic proper. In A-M Robertsson, T Hackens, S Hicks, J Risberg and A Åkerlund (eds): Landscapes and Life. PACT 50, p 175–184.

Westman P, Sohlenius G, 1999. Diatom stratigraphy in five offshore sediment cores from the northwestern Baltic proper implying large scale circulation changes during the last 8500 years. Journal of Paleolimnology 22, p 53–69.

Westman P, 2000. The siliceous microalgae *Dictyocha speculum* and *Ebria tripartita* as biomarkers and palaeoecological indicators in Holocene Baltic Sea sediments. GFF 122, p 287–292.

Westman P, Hedenström A, 2002. Environmental changes during isolation processes from the Litorina Sea as reflected by diatoms and geochemical parameters – a case study. The Holocene 12,4, p 497–506.

Yu S, Barnekow L, Berglund B E, Sandgren P, 2001. Littorina transgression(s) of the Baltic Sea in Blekinge, SE Sweden. In U Brenner (ed): Abstract Volume. Baltic Sea Science Congress 2001. Past, present and future – a joint venture. Stockholm Marine Research Centre, Stockholm University, p 326.