Early Holocene water level changes as recorded on the island of Senoren, eastern Blekinge, southeastern Sweden

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Content

Preface

Popular scientific summary .................................................. 1
Summary ................................................................. 2
1. Introduction ............................................................ 3
2. Earlier investigations of Holocene Baltic water level changes in Eastern Blekinge .................................................. 6
3. General geology of the investigated area .................................. 10
4. Methods .................................................................. 11
4.1 Levelling .............................................................. 11
4.2 Mapping of Quaternary deposits ....................................... 11
4.3 Core collection ....................................................... 11
4.4 Subsampling of cores ................................................ 11
4.5 Magnetic analyses .................................................... 11
4.5.1 Subsampling for magnetic analyses .......................... 12
4.5.2 Specific susceptibility ............................................. 12
4.5.3 Saturation Isothermal Remanent Magnetization (SIRM) . 12
4.5.4 SIRM/χ ratio ....................................................... 13
4.5.5 S-ratio ............................................................ 13
4.6 Coarse organic and minerogenic content analyses ............... 13
5. Stratigraphic description and correlation of cores ............... 14
6. Sediment analyses ...................................................... 24
6.1 Magnetic analyses .................................................. 24
6.2 Organic and minerogenic content analyses ........................ 25
6.3 Radiocarbon analyses ................................................ 27
7. Discussion and conclusions ............................................. 28
8. Future research .......................................................... 30
9. References ............................................................... 31
Preface

I had a number of aims when carrying out this study. Some of the aims were the following: to write an M.Sc. examination paper, to learn and understand how to use magnetic parameters, to correlate sediments in different cores and hence determine a stratigraphy of an area, to learn how to use geological equipments such as peat samplers and modern technologies like computers etc.

In this view, I wish to thank my supervisors docent Per Sandgren and professor Björn Berglund for their unconditional assistance which made it possible for me to realize my goals.

I also wish to thank all those who assisted me in one way or another either in the field, laboratories or libraries, I like to express my appreciation for their efforts.

My thanks also goes to the E.F.S. church in Lund and the Swedish Institute for offering me scholarships which made my work possible.

Boniface M. Gichina
Popular scientific summary

This paper presents a study carried out in the fall of 1994 on Senoren, an island of the Karlskrona archipelago. Considering the aim of the study which was to record Early Holocene water level changes in the Baltic Sea, two bays, Sörevik and Norrevik on this island were chosen because they lie in the province of Blekinge in southeastern Sweden. The coastline of Blekinge is characterized by the fairly unique geological feature of being more or less parallel to the land uplift isobases (Berglund & Björck in press). This makes the area very suitable for shoreline studies, because large areas have experienced approximately the same amount of uplift since the last deglaciation, dated to approximately 12,600 ¹⁴C years BP (Björck & Møller 1987). The area has experienced a number of transgressions and regressions ever since. The present Baltic Sea has changed from the Baltic Ice Lake (12,600-10,200 BP) through the Yoldia Sea (10,200-9500 BP), the Ancylus Lake (9500-8000 BP) and finally the Littorina Sea (8000-5000 BP) (e.g. Eronen 1988, Björck in press). Water level and other environmental changes throughout these geological episodes can be recorded by analyzing sea and lake sediments in this area.

In this study the sediments were cored with a Russian peat sampler in along a 550 m longitudinal section trending between Sörevik and Norrevik and along a 130 m transverse section at Sörevik. Geological mapping was done in the field to include non-organic deposits like till, sandy till and boulder rich till.

The oldest organic sediments collected in this study is a black drift peat which was dated to 9300±160 ¹⁴C years BP. This drift peat represents the Yoldia Sea to the Ancylus Lake interphase. The clay gyttja and coarse detritus gyttja which follows respectively were deposited during the Ancylus transgression and the regression there after. Opening of the ocean connection took place about 8000 BP and caused the Littorina transgression during which time fine detritus gyttja and clayey gyttja were deposited. The younger strata namely sand and reed peat were deposited after the cease of Littorina transgression.

The results from magnetic, organic content and minerogenic content analysis have been used for the correlation of the cores, determination of the stratigraphy, and recording of water level changes in the area.
Summary

This is an investigation of Early Holocene water level changes based on the sediments in two bays, Sörevik and Norrevik on Senoren, an island in the Karlskrona archipelago in eastern Blekinge southeastern Sweden. This area has experienced a number of transgressions and regressions since the last deglaciation at approximately 12,600 BP. The history of the Baltic is characterized by many dramatic water level changes, although most of them took place in Late Weichselian and Early Holocene times. Only relatively small and gradual changes have taken place during the last 9000 or 8000 years BP.

Land uplift and shore line regression along different parts of the Baltic coast line were very rapid immediately after the last deglaciation. These large crustal deformations resulted in the closing and opening of the various connections or discharge channels from the Baltic to the ocean. These events, in turn, were the reason for the drastic changes in the physical, chemical and biological environments of the Baltic during Late Weichselian and Early Holocene times and thus gave rise to the well known phases of development: Baltic Ice Lake (12,600-10,200 BP), Yoldia Sea (10,200-9500 BP), Ancylus Lake (9500-8000 BP) and Littorina Sea (8000-5000 BP). The vigorous isostatic rebound slowed down relatively rapidly between 8500 and 8000 BP. These phases have been followed by relatively small and gradual land uplift down to present (Eronen 1988, Björck in press).

The oldest organic sediments collected in Sörevik was a black drift peat which was dated 9300±160 14C years BP. This drift peat represents the Yoldia Sea to the Ancylus Lake interphase. This drift gyttja is overlaid by clay gyttja which was deposited during the Ancylus transgression. The Ancylus Lake had no connection to the ocean and therefore it was a fresh water lake dammed above the sea level (Björck in press). This transgression came to an end when the rising water level reached the crest of the Darss Sill in the southwestern part of the Baltic. According to Kolp (1986) the water masses broke through this ridge and rapidly eroded a channel resulting in a 20 m drop of water level. This took place about 9000 BP and the Ancylus Lake was non-dammed until 8000 BP according to Björck (in press). The coarse detritus gyttja above the clay gyttja in Sörevik was deposited during this low water level stage, which probably lasted until the beginning of the Littorina transgression. The coarse detritus gyttja was dated to about 8200-8500 14C years BP.

Fine detritus gyttja was deposited above the coarse detritus gyttja during the Littorina transgression caused by the opening of the ocean connection. The transgression brought in salt water from the ocean according to earlier diatom studies (Berglund 1964) and brackish water plant (i.e. Zostera marina) identified in this study.

Probably several minor transgressions are recorded in the marine sediments of Sörevik (Berglund 1964), but these have not been possible to trace in detail in this study.

The stratigraphy at Norrevik is in agreement with that of Sörevik.

The methods applied in this study involve sediment description, analysis of organic content, coarse organic and minerogenic content and mineral magnetic analysis.
1. Introduction

The province of Blekinge in southeastern Sweden has demonstrated to be a fairly unique laboratory to document Late Weichselian and Holocene Baltic water level changes by studying sea and lake sediments. The area has experienced a number of transgressions and regressions as well as changes in water salinity after the last deglaciation of the outer archipelago, dated to approximately 12,600 BP (Björck & Möller 1987). The Late Glacial Baltic Ice Lake stage was followed by the Yoldia Sea, the Ancylus Lake, the Littorina Sea and finally the present Baltic Sea.

In this study the sediment in two bays, Sörevik and Norrevik on the island of Senoren have been investigated (Fig. 1). The aim of the study was to analyse, describe and document Early Holocene water level changes. The results have been compared with earlier investigations and finally compiled in this paper.

The study was carried out by the author in the fall of 1994 at Lund University under the supervision of docent Per Sandgren and professor Björn Berglund.

The sediments were cored in a 550 m longitudinal section between Sörevik

Fig. 1a. Map of the investigation area on the island of Senoren in the Karlskrona archipelago.
and Norrevik and in a 130 m transverse section at Sörevik (Fig 2).

A total of 11 boring points were cored of which 4 were analysed in the laboratories at the Geological institute at Lund University with respect to magnetic parameters, i.e. magnetic susceptibility and SIRM (saturation isothermal remanent magnetization), loss on ignition and coarse organic and minerogenic matter. The main core (Bp2) was subsampled at three different levels for 14C dating.

Coring, levelling and geological mapping were done in the field between 14th September and 8th October 1994.

Correlation of the cores have been done by use of SIRM/\(\chi\), S-ratios and organic content values. The chronology is based on the 14C dates mainly from bulk sediment dates and stratigraphic correlation with earlier studies in the same area (Berglund 1964).

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Fig. 1b. Map of the Karlskrona archipelago with the lowest shoreline (−20 m) during the Yoldia time.
Fig. 2. A map showing the plan of the bore points
2. Earlier investigations of Holocene Baltic water level changes in eastern Blekinge.

As mentioned above the province of Blekinge is suitable for shore-line displacement studies because large areas have experienced approximately the same amount of uplift since the last deglaciation about 12,600 $^{14}$C years BP (Björck & Moller 1987). Due to this fact the area have been subjected to a number of shore-line displacement studies.

The earliest stratigraphy description was done by Hamberg (1860) at Ronneby Helso brun which was quoted by Södervall (1879). However none of them wrote something about the genesis of the stratlas.

De Geer (1882 a) records a well studied stratigraphy from Ronneby Brunns which was published by Henchen (1880). He explained that "the

Fig. 3. Map showing the four stages of the history of the Baltic sea (from Eronen 1988).
bad gyttja" is a black water gyttja which contains shells of *Cardium*, *Tellia* and *Mytilus*. The black water stratas overlies telmatic sediment layers and hence de Geer (1882 b) concluded that it must have been caused by sinking of the land.

Holst (1899) investigated Ancyclus and Littorina layers using among other things macro- and microfossil content in sediments from a number of places along the coast of Blekinge, e.g. Ronneby, Åryd and Karlshamn. According to him, the highest Ancyclus Sea level was at least 8 m above the present Baltic Sea level. He also concluded that the Littorina Sea had its highest level a little bit higher than the Ancyclus Sea. He stated that the Littorina transgression could have been complex as demonstrated by a peat layer found integrated with Littorina gyttja at Stilleryd in Karlshamn.

Blomberg (1900) documented a number of transgressional stratigrophies from Blekinge, but he seems to quote more of Holst’s (1899) work.

The low lying areas in the Listerland peninsula in western Blekinge were transgressed by the Littorina Sea according to Holst (1909), Kjellmark (1919) and Sundelin (1924). However, these authors found it difficult to document the Ancyclus transgression with certainty.

Sandegren (1938) constructed a shore-line displacement curve for Siretorp in western Blekinge based on pollen analysis and diatom studies from peat and gyttja in the vicinity of Siretorp. His shore displacement curve agrees to a great extent to the one constructed later by Berglund (1964), but differs slightly in dates which could be due to errors in dating techniques.

Berglund (1964, 1971) has investigated and documented water level changes in Blekinge. Berglund (1964) constructed a shore-line displacement curve for eastern Blekinge after the last deglaciation based on pollen analysis and diatom studies of Baltic Sea sediments from different places in Blekinge (Fig 5). He concluded that the Yoldia Sea level was below the present sea level from which the Ancyclus transgression began around 9700-9500 ^14C years BP. It reached its maximum level just before 9000 BP which was 6 m in Blekinge above the present sea level (compare with Holst).

Berglund (1964) suggested that a regression took place after the Ancyclus transgression which again brought the Sea below the present sea level. Salt water from the other seas of the world started coming in just before the beginning of the Littorina Sea. The Littorina transgressions took place between 8600 and 7300 BP which brought the Sea level to 5-7 m above
the present sea level.

According to Berglund (1964, 1971), the Littorina transgression was complex being composed of six phases (see Figs. 6 and 7) of which the fourth reached the highest level in eastern Blekinge. This have been followed by a more or less continuous regression down to the present sea level.

Liljegren (1970, 1982) generally agrees with the model put forward by Berglund but his ¹⁴C datings differs slightly from Berglunds datings. He also interpreted his dates in a slightly different way.

Berglund and Björck (1994) have summarized the shore-line displacement development in eastern Blekinge from the Baltic Ice Lake through the Yoldia Sea and the Ancylus Lake to the Littorina Sea as shown in Fig. 7. Their model is the latest available.

The area have been subjected to several studies in the last 30 years concerning the Late Weichselian (Berglund 1966; Björck 1979, 1981) and Holocene shore-line displacement (Berglund 1964, 1971; Mikaelsson 1978; Liljegren 1970, 1982; Björck & Möller 1987). However, there are still more questions to be answered and investigations continues.

Fig. 5. A curve of the shore line displacement in eastern Blekinge according to Berglund (1964). Six transgressional phases were identified of which the fourth reached the highest level at about +8 m.
Fig. 6. A curve of shore-line displacement in eastern Blekinge recently published by Berglund and Björck (in press)
3. General geology of the investigated area.

Senoren is a large island in the archipelago of Karlskrona. Other large islands in the vicinity are Hasslö, Aspö, Tjurkö and Sturkö.

The coast area of the mainland is built of Archaean rocks, in the west metamorphic gneiss, namely the Blekinge coastal gneiss, and in the east the so called Tving granite. The rocks have been strongly deformed, probably in Jotnian time (Kornfält & Bergström 1991). The bedrock in Senoren is mainly composed of Blekinge coastal gneiss which is about 1700 million years old.

The islands in the archipelago are rather flat and only limited areas reach 25-30 m above sea level. The hills are rocky and the valleys are covered with sandy tills or organic deposits (peat or gyttja).

The valley joining the two bays, Sörevik and Norrevik which is about 550 m long have its highest point at about +2.8 m. My study dealt mainly with Quaternary deposits in this valley with two main stratigraphic units: organic deposits (peat and gyttja) at the bays, and sandy till in the middle of the valley. The nearby hills are composed of boulder rich till and sandy till (see Fig 7).

Fig. 7. Map of Quaternary deposits for the area between Norrevik and Sörevik.

4.1 Levelling

The first thing done in the field was marking of bore points. These markings were used for levelling of the bore points. Levelling was done on 29th September 1994.

4.2 Mapping of Quaternary deposits

Mapping of the Quaternary deposits was done in the field. Only deposits thicker than 50 cm were recorded on the map. The following deposits were found: organic deposits (peat and gyttja), sand, boulder rich till, sandy till, sand and bedrock.

4.3 Core collection

Sediment cores were collected during field work between September 14th and October 12th 1994. Coring was done by use of a Russian peat samplers operated with steel rods. The cores were "D"-shaped with a length of 100 cm and a diameter of 5 and 7 cm. The fresh wet sediments were preliminary described in the field and then carefully wrapped with plastic and preserved in 1 m long "C"-shaped plastic tubes. They were finally transported to Lund and stored in a cold room awaiting further analysis.

4.4 Subsampling of cores.

The cores were subsampled for magnetic analysis, coarse organic and minerogenic content analysis, loss on ignition analysis and ¹⁴C dating (see scheme in Fig. 8).

4.5 Magnetic analysis

Some of the factors that influence magnetic parameters in a sample are:

![Diagram of sampling procedure](Fig. 8. A scheme of the sampling procedure.)
1. Concentration of ferri/ferro magnetic iron oxides (e.g. magnetite and haematite) and in few cases iron sulphides.
2. The relative abundance of different ferri/ferro magnetic phases (i.e. magnetite and haematite).
3. The grain size of ferri/ferro magnetic crystals.
4. The relative occurrence of paramagnetic minerals e.g. biotite, and of diamagnetic minerals e.g. quartz and even water (Thompson & Oldfield 1986).

Magnetic parameters can also be affected by temperature but all the magnetic analysis in this study have been carried out at room temperature.

A consideration of processes like weathering and dissolution should be done during the interpretation of magnetic measurements.

4.5.1. Subsampling for magnetic analysis.

The subsamples for magnetic analysis were taken with small plastic cubes with a volume of 6.9 cm³. The cubes were inserted next to each other in the cores from top to bottom. Each cube have a length of 2.0 cm. These cubes were numbered before being removed for magnetic analysis.

4.5.2. Specific susceptibility (χ)

Susceptibility is a measure of the ease with which a material can be magnetized. It depends on the concentration of magnetic minerals like magnetite (Fe₃O₄) and haematite (Fe₂O₃). Susceptibility expresses the ratio between the induced magnetization in a sample and the inducing magnetizing field. It is defined graphically on the Hysteresis loop as the initial gradient of the line expressing magnetization versus field strength (Fig. 9). Susceptibility is affected by the occurrence of para- and diamagnetic minerals but is relatively independent of grain size (Thompson & Oldfield 1986).

In this study susceptibility was measured on a Geofyzica Brno "Kappa" bridge KLY-2

4.5.3. Saturation Isothermal Remanent Magnetization (SIRM).

SIRM is the maximum remanent magnetism a sample can achieve through magnetization in a strong magnetic field. SIRM depends on type of magnetic minerals, concentration and grain size but is independent of para- and diamagnetic materials (Thompson & Oldfield 1986). In this study each sample was subjected to a 1.0 Tesla magnetic field produced by a Redcliffe pulse magnetic charger. This field is assumed to be enough for saturating the samples. The induced remanent magnetization was then measured in a Molspin fluxgate spinner magnetometer. The values got were then divided by the dry weight of every sample to determine specific SIRM.
4.5.4. SIRM/χ ratio.

The ratio of saturation isothermal remanent magnetization to specific susceptibility (SIRM/χ) is used as a rough estimate of magnetic grain sizes. The magnitude of SIRM and χ gives a rough idea of the concentration (Thompson & Oldfield, 1986) of magnetic minerals.

4.5.5 Anhysteric Remanent Magnetization (ARM).

When a sample is subjected to a decreasing alternating field (normally 100-0 mT) in the presence of a weak direct steady field (normally 0.05 mT or 0.1 mT) the sample acquires an anhysteric remanent magnetization. This parameter is particularly sensitive to fine magnetic grain size (Thompson & Oldfield, 1986).

In this study the anhysteric remanent magnetization were grown in a bias field of 0.1 mT and the remanences measured with a Molspin Minispin spinner magnetometer.

4.5.6. S-Ratio.

The S-ratio is the ratio of a moderate (-100 mT) back field isothermal remanence magnetization (IRM_{back}) to the saturation isothermal magnetization remanence (IRM_{sat}/SIRM). This ratio is used for recognising samples with unusual haematite to magnetite ratios. The basic idea behind the S-ratio is that in practice the magnetization of most ferrimagnets will have saturated in fields below 100 mT and that the major differences in high field remanence (i.e. IRM_{back}/SIRM) will be due to the imperfect antiferromagnets such as haematite and goethite (Thompson & Oldfield, 1986). The back field magnetization is done after measurements of SIRM.

4.6 Coarse organic and minerogenic content analysis.

The four cores analysed were first subsampled for magnetic analysis then subdivided at an interval of 5 cm starting from the top. This subdivision gave subsamples of approximately 85 cm³. Each of these subsamples was washed through a 0.5 mm sieve and the remains dried at 105°C for 24 hours to determine the dry weight. The dry samples were then heated in a free oxygen access oven to 550°C for 2 hours. The subsamples were cooled down in an dessicator before weighing in each of the steps. The loss on ignition i.e. difference between dry weight (weight at 105°C) and the remaining weight (weight at 550°C) for each respective subsample is the weight of the organic content in the sample with a diameter large than 0.5 mm i.e. the macro remains according to Digerfeldt (1986). The remains after ignition are the minerogenic component greater than 0.5 mm. Likewise, the difference in weight for a given sample at 550°C and 925°C is equivalent to carbonates content greater than 0.5 mm (Troedsson 1973).
5. Stratigraphic description and correlation of cores

The stratigraphy of the cores was described preliminary in the field and more carefully in the laboratory.

The oldest sediments collected in this study is sand which is present in all the cores but at different depths. This is overlain by a thin layer of blackish drift peat which was dated to 9300±160 14C years BP. This peat represents the Yoldia Sea to the Ancylus Lake interphase. Above this peat there is a layer of clay gyttja with relatively low percentage of plant macro-remains and present in all the bore points.

The clay gyttja is overlaid by layers of gyttja clay and calcareous clay gyttja respectively in Bp 1, Bp2 and Bp17 in Sörevik but not in the other bore points. These sediments were deposited during a transgression in deep water. Above these lies coarse detritus gyttja with frequent plant macro-remains especially water mosses and seeds of Potamogeton. It is present in all the bore points and represents a regression stage. Both the upper and lower boundary is transitional.

Fine detritus gyttja which follows is present in all the bore points but within it lies a thin layer of drift peat which is present in BpN2 and Bp12 in Norrevik and only in Bp 2, Bp3, Bp4 and Bp17 in Sörevik. This thin layer of drift peat seem to be only present at the middle of the valley. This whole strata of fine detritus gyttja has rather frequent plant macro remains of Zostera marina. (Zostera marina is a 0.5-1 m long marine flowering plant. It grows on loose sediments in salt or brackish water like in the Baltic Sea). The fine detritus gyttja is overlaid by clayey gyttja which is present in all the bore points apart from Bp1, probably removed by erosion. There is probably a hiatus between this strata of clayey gyttja and a thin layer of sand that lies above it. This layer of sand is present in all the bore points with the exception of Bp1 probably removed by erosion also. The youngest strata is a layer of high humified Phragmites peat with plant roots, stems and in some cases mixed with clayey

Fig. 10. A transect from Norrevik to Sörevik with coring points and main stratigraphic units.
**Fig. 11. Stratigraphy of BP2.**
gyttja.
Sandy till and till lies on the surface in the valley not covered by organic sediments (Ca. 275 m.) between Sörevik and Norrevik.
The organic deposits have been divided into six main units in this study:

G - Greenish brown or light grey Phragmites peat with plant roots and stems.

F - Brown or light green clayey gyttja. Plant macro remains are frequent together with plant roots. A thin layer of sand above the clayey gyttja is also included in this unit.

E - Grey to brown fine detritus gyttja with plant macro remains (i.e. leaves of Zostera marina), water mosses and plant seeds. A thin layer of drift peat lies within this strata in some bore points.

D - Dark brown or grey coarse detritus gyttja with plenty of plant macro remains, some wood pieces and seeds of Potamogeton.

C - Grey clay gyttja and gyttja clay. This unit has three subunits:
  Cc - calcareous clay gyttja,
  Cb - gyttja clay and
  Ca - clay gyttja.

B - Blackish drift peat with wood pieces.

A - Brown sand.

This stratigraphy agrees quite well with the earlier studies at Sörevik by Berglund (1964).

Bp 1
This bore point is situated at the outer margin of the bay within Phragmites reed. The ground is at the present sea level (see the figures in this paper)

0 - 32 cm.
Greenish brown high humified Phragmites peat. Phragmites roots and stems are frequent. The water content is high in the upper part. This peat is mixed with some clay gyttja in the lower part (20 - 32 cm)

32 - 116 cm.
Grey green clayey fine detritus gyttja. Zostera marina leaves are frequent. The upper boundary is very sharp and it probably indicates a hiatus caused by erosion.

116 - 202 cm.
Light grey green to yellow brown clayey fine detritus gyttja. Zostera marina leaves are more frequent than above.

202 - 220 cm.
Light brown to green fine detritus gyttja. Fewer plant remains than above. The upper boundary is gradual.

220 - 238 cm.
Light green grey clayey fine detritus gyttja. There are no visible plant macro remains. The upper boundary is gradual.

238 - 260 cm.
Grey brown fine detritus gyttja. A transition layer from above to below.

260 - 302 cm.
Dark brown coarse detritus gyttja. Plant macro remains and wood pieces are frequent. Seeds of Potamogeton and other water plants are frequent. A charcoal piece was found at 270 cm.

304 - 308 cm.
Light yellow to greenish grey calcareous clay gyttja with some shells mollusc.

308 - 340 cm.
Light brown to grey gyttja clay. Slightly banded by occurrence of water mosses. The upper boundary is rather gradual.

40 - 403 cm.
Grey gyttja clay. The upper and lower boundaries are transitional.

403 - 415 cm.
Black drift gyttja with sand and wood pieces.

Bp2, main core

0 - 11 cm.
Dark brown high humified Phragmites peat with plenty of fine roots.

11 - 12 cm.
Brown sand.

12 - 36 cm.
Brown clayey gyttja. Plant roots are rather frequent.

36 - 190 cm.
Dark green to greyish green clayey fine detritus gyttja. Plant macro remains are frequent. Both boundaries are transitional.

190 - 215 cm.
Dark brown green clayey fine detritus gyttja. There is a 0.5 cm layer of drift peat with pieces of wood and charcoal at 196 cm.

215 - 306 cm.
Dark brown to dark green coarse detritus gyttja. Seeds of *Potamogeton* and other water plants are frequent. Plant macro remains are also frequent.

306 - 322 cm.
Dark grey calcareous clay gyttja. Few shell fragments are visible.

322 - 349 cm.
Grey brown gyttja clay. The layer is roughly laminated by water mosses.

349 - 392 cm.
Grey clay gyttja. Water mosses are less frequent than above.

392 - 398 cm.
Black drift peat with wood pieces and plant macro remains.

398 - 401 cm.
Brown sand with no visible plant macro remains.

**Bp 3**

0 - 41 cm.
A greyish mixture of *Phragmites* peat and clayey gyttja. Plant roots and macro remains are frequent. Lower boundary is rather gradual.

41 - 75 cm.
Grey to greenish clayey gyttja. Few plant macro remains are visible.

75 - 145 cm.
Grey green clayey fine detritus gyttja. Slightly laminated. Plant macro remains are rather frequent mainly *Zostera marina*. The upper boundary is gradual.

145 - 151 cm. - Dark brown drift gyttja with wood pieces and sand.

151 - 175 cm.
Greenish clayey fine detritus gyttja with few plant macro remains. Upper boundary rather sharp.

175 - 194 cm.
Greenish brown coarse detritus gyttja. Seeds of *Potamogeton* and other micro remains are frequent. Both boundaries are rather gradual.

194 - 284 cm.
Dark brown coarse detritus gyttja with frequent wood pieces and plant macro remains.

284 - 300 cm.
Light brown to grey clay gyttja with a few plant macro remains.

NB The core stopped in sand.

**Bp 4**

0 - 5 cm.
Dark brown high humified *Phragmites* peat with plenty of fine roots.

5 - 10 cm.
Clayey gyttja

10 - 14 cm.
Brown sand.

14 - 73 cm.
Greyish brown clayey gyttja with a few plant macro remains.

73 - 104 cm.
Grey green clayey fine detritus gyttja. Slightly laminated. Plant macro remains are rather frequent mainly *Zostera marina*. The upper boundary is gradual.

104 - 110 cm.
Dark brown drift gyttja with wood pieces and sand.

110 - 148 cm.
Greenish clayey fine detritus gyttja with few plant macro remains. Upper boundary rather sharp.

148 - 165 cm.
Green brown coarse detritus gyttja. Seeds of *Potamogeton* and other micro remains are frequent. Both boundaries are rather gradual.

165 - 199 cm.
Dark brown coarse detritus gyttja with frequent wood pieces and plant macro remains. There was a large piece of wood at 180 cm.

199 - 202 cm.
A thin layer of black grey sand with a thickness of 0.3 cm.

202 - 233 cm.
Dark brown to grey gyttja clay with a few plant macro remains.

233 - 243 cm.
Dark grey gyttja clay. It is a transition to above.

243 - 258 cm.
Dark brownish grey clay gyttja with water mosses.

NB. The core stopped at 258 cm., probably in sand.

**Bp E4**

0 - 8 cm.
Dark brown high humified *Phragmites* peat with plenty of fine roots.
8 - 29 cm.
Clayey gyttja
29 - 31 cm.
Brown sand.
31 - 72 cm.
Grey brown clayey gyttja with a few plant macro remains.
72 - 133 cm.
Grey green clayey fine detritus gyttja. Slightly laminated. Plant macro remains are rather frequent. Mainly *Zostera marina*. The upper boundary is gradual.
133 - 183 cm.
Green brown coarse detritus gyttja. Seeds of *Potamogeton* and other micro remains are frequent. Both boundaries are rather gradual.
183 - 196 cm.
Dark grey clay gyttja with wood pieces.
196 - 218 cm.
Grey gyttja clay with wood pieces and plant macro remains.
218 - 226 cm.
Dark grey clay gyttja with a transitional boundary to the layer above and a sharp boundary to the one below.
226 - 227 cm.
Drift peat. Dipping towards south.
227 - 230 cm.
Brown sand.

**Bp 19.**
0 - 8 cm.
Dark brown high humified *Phragmites* peat with plenty of fine roots.
8 - 32 cm.
Brown clayey gyttja. Plant roots are rather frequent.
32 - 98 cm.
Grey green clayey fine detritus gyttja. Slightly laminated. Plant macro remains are rather frequent. Mainly *Zostera marina*. The upper boundary is gradual.
98 - 154 cm.
Green brown coarse detritus gyttja. Seeds of *Potamogeton* and other micro remains are frequent. Both boundaries are rather gradual.
154 - 220 cm.
Dark grey clay gyttja with a transitional boundary to the layer above and a sharp boundary to the one below.
20 - 222 cm.
Black drift peat.
222 - 225 cm.
Brown sand.

0 - 13 cm.
Dark brown high humified *Phragmites* peat with plenty of fine roots.
13 - 30 cm.
Brown clayey gyttja. Plant roots are rather frequent.
30 - 162 cm.
Grey green to brown fine detritus gyttja. Slightly laminated. Plant macro remains are rather frequent. Mainly *Zostera marina*. The upper boundary is gradual.
162 - 248 cm.
Greenish brown coarse detritus gyttja. Seeds of *Potamogeton* and other micro remains are frequent. Both boundaries are rather gradual.
248 - 260 cm.
Brownish clayey gyttja.
260 - 327 cm.
Dark grey clay gyttja with water mosses and a transitional boundary to the layer above and a sharp boundary to the one below.
327 - 330 cm.
Black drift peat mixed with sand.
330 - 335 cm.
Brown silty sand.

**Bp 17.**
0 - 19 cm.
Dark brown high humified *Phragmites* peat with plenty of fine roots.
19 - 25 cm.
Brown gyttja sand.
25 - 137 cm.
Grey brown clayey fine gyttja with a few plant macro remains.
137 - 139 cm.
Dark brown drift gyttja.
139 - 180 cm.
Grey green clayey fine detritus gyttja. Slightly laminated. Plant macro remains are rather frequent. Mainly *Zostera marina*. The upper boundary is gradual.
180 - 226 cm.
Green brown coarse detritus gyttja. Seeds of *potamogeton* and other micro remains are frequent. Wood pieces are also frequent. Both boundaries are rather gradual.
226 - 287 cm.
Dark grey clay gyttja with wood pieces.
287 - 349 cm.
Light green gyttja clay with wood pieces and plant macro remains.
349 - 352 cm.
Sandy drift peat with wood pieces.

**Bp 18**
Black drift peat with wood pieces and plant macro remains.
328 - 335 cm.
Brownish to grey sand.

**Bp 15.**

0 - 9 cm.
Dark brown high humified *Phragmites* peat with plenty of fine roots.
9 - 20 cm.
Light grey to brown clayey gyttja with plant roots and few plant macro remains.
20 - 21 cm.
Sandy drift peat.
NB The core most probably stopped in sand.

**Bp N2**

0 - 47 cm.
Yellow brown high humified *Phragmites* peat with plenty of fine roots.
47 - 52 cm.
Brown clayey gyttja. Plant roots are rather frequent.
52 - 54 cm.
Gyttja sand.
54 - 160 cm.
Dark green to greyish green clayey fine detritus gyttja. Plant macro remains are frequent. Both boundaries are transitional.
160 - 218 cm.
Dark brown green clayey fine detritus gyttja. There is a 2 cm layer of drift gyttja with pieces of wood.
218 - 251 cm.
Dark brown to dark green coarse detritus gyttja. Seeds of *Potamogeton* and other water plants are frequent. Plant macro remains are also frequent.
251 - 323 cm.
Brownish to grey clay gyttja with varying amount of wood pieces and water mosses
323 - 328 cm.

**Bp 14**

0 - 32 cm.
Yellow brown high humified *Phragmites* peat with plenty of fine roots.
32 - 37 cm.
Brown clayey gyttja. Plant roots are rather frequent.
37 - 40 cm.
Gyttja sand.
40 - 104 cm.
Dark green to greyish green clayey fine detritus gyttja. Plant macro remains are frequent. Both boundaries are transitional.
104-116 cm.
Drift peat with plenty of wood pieces.
116 - 140 cm.
Dark brown green clayey fine detritus gyttja.
140 - 204 cm.
Dark brown to dark green coarse detritus gyttja. Seeds of *Potamogeton* and other water plants are frequent. Plant macro remains are also frequent.
NB A large piece of wood was found at 180 cm.
204 - 240 cm.
Brownish to grey clay gyttja with varying amount of wood pieces and water mosses
240 - 242 cm.
Black drift peat with wood pieces and plant macro remains.
242 - 243 cm.
Brownish to grey sand.

**BP 13**

0 - 24 cm.
Yellow brown high humified *Phragmites* peat with plenty of fine roots.
24 - 44 cm.
Brown clayey gyttja. Plant roots are rather frequent.
44 - 52 cm.
Gyttja sand.
52 - 114 cm.
Dark green to greyish green clayey fine detritus gyttja. Plant macro remains are frequent. Both boundaries are transitional.
114 -125 cm.
Drift peat with plenty of wood pieces.
125 - 141 cm.
Dark brown to dark green coarse detritus gyttja. Seeds of *Potamogeton* and other water
plants are frequent. Plant macro remains are also frequent.
141 - 240 cm.
Brownish to grey clay gytija with varying amount of plant macro remains like water mosses.

141 - 147 cm.
Black drift peat with wood pieces and plant macro remains.
147 - 149 cm.
Brownish to grey sand.

Fig. 12. A longitudinal section of Sörevik (from Berglund 1964).
Fig. 13 a. Longitudinal section from Sörevik (based on this study).
Fig. 13 b. Transverse section from Sörevik (based on this study).
Fig. 13 c. Longitudinal section from Norrevik (based on this study).
6. Sediment analysis

6.1 Magnetic analysis

The mineral magnetic results of core BP2 is shown in Fig. 14. The SIRM/χ, S-ratio and specific susceptibility (χ) curves are generally very similar for the four cores. The S-ratio is rather uniform and lower (-0.9 to -0.6) for the fine detritus gytta but more inconsistent for the other units. It is a bit higher (-0.8 to -0.4) for the coarse detritus gytta.

The χ is uniform (< 0.2 μm³kg⁻¹) within fine detritus gytta and the upper part of coarse detritus gytta. The more clayey units have more inconsistent and higher specific susceptibility (c) (0.1 to 0.4 μm³kg⁻¹).

The SIRM/χ curves of the four cores indicates an increase of the magnetic grain sizes as the distance from the present sea shore at Sørevik increases (i.e. the magnetic grain sizes in Bp1<Bp2<Bp3<Bp4 ).

An S-ratio below -0.8 indicates the possibility of magnetic parameters being dominated by the presence of magnetite. Likewise an S-ratio above -0.8 indicates a presence of antiferromagnetic minerals, the so called hard magnetic minerals, mostly haematite and/or goethite.

The S-ratio curve for the four cores indicate a possible decrease in concentration of magnetite and an increase of haematite and/or goethite with the distance from the present sea shore at Sørevik (i.e. the concentration of magnetite in Bp1>Bp2>Bp3>Bp4 ). In particular, there is a high concentration of magnetite in the coarse detritus gytta in Bp1 as implied by the χ and the corresponding S-ratios. The SIRM/χ indicates the presence of larger magnetic mineral grains within the coarse detritus gytta and finer grains within fine detritus gytta. The clay gytta, gytta clay and calcareous clay gytta have magnetic minerals with grain sizes that lies between those of fine detritus gytta and coarse detritus gytta. The concentration of magnetic minerals is highest in the coarse detritus gytta, followed by the calcareous clay gytta, gytta clay and clay gytta and lowest in fine detritus gytta as implied by the χ.

![Fig. 14. Result of magnetic analyses](image-url)
6.2 Organic and minerogenic content analysis

The results of loss on ignition, coarse organic and minerogenic content analysis for the four cores analysed are shown in Figs. 15 and 16.

Loss on ignition for Bp2 indicates that the organic content is 10% - 40% in the *Phragmites* peat, calcareous clay gyttja, gyttja clay, clay gyttja and drift peat, 20% - 30% in the fine detritus gyttja and 40% - 90% in the coarse detritus gyttja. The abnormal high peaks in the curves are caused by the presence of wood pieces in the corresponding samples.

The content of both coarse organic and minerogenic matter is higher in both the fine detritus gyttja (lower part of unit E) and the coarse detritus gyttja than in the other units. It is difficult to make definite conclusions on the basis of the results obtained in these analysis until the plant remains have been identified to plant species with definite ecological demands. However, the results shows that there is a lower percentage of organic content in those units which have been deposited in deep water i.e. fine detritus gyttja, calcareous clay gyttja, clay gyttja and gyttja clay. These units also contain relatively lower percentage of coarse organic and minerogenic matter. These units were deposited during transgressional episodes while the coarse detritus gyttja and drift peat were deposited during regresional episodes or during low water level stages.

![Diagram](image)

*Fig. 15. A curve of loss on ignition from profile BP2.*
Fig. 16. Coarse organic and minerogenic matter.
6.3 \(^{14}\)C analysis

The results of \(^{14}\)C datings of the three subsamples taken from the main core (Bp2) are as follows:
(a) 8180±150 \(^{14}\)C years BP for Sörevik 1, sample No. Lu-3818 (215-218 cm). These were wood pieces at the boundary between coarse detritus gyttja (D) and fine detritus gyttja (E).
(b) 8390±190 \(^{14}\)C years BP for Sörevik 2, sample No. Lu 3819 (246-250 cm). These were wood pieces within coarse detritus gyttja (D).
(c) 9300±160 \(^{14}\)C years BP for Sörevik 3, samples No. Lu-3820 (394-398 cm). This was one piece of wood within drift peat (B).

Table 1. Result of radiocarbon analyses.

<table>
<thead>
<tr>
<th>Lab. no.</th>
<th>Sample no.</th>
<th>Depth, cm</th>
<th>Unit</th>
<th>Material</th>
<th>(^{14})C years BP.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lu-3818</td>
<td>Sörevik 1</td>
<td>215-218</td>
<td>D/E</td>
<td>Wood fragments</td>
<td>8180±150</td>
</tr>
<tr>
<td>Lu-3819</td>
<td>Sörevik 2</td>
<td>215-218</td>
<td>D</td>
<td>Wood fragments</td>
<td>8390±190</td>
</tr>
<tr>
<td>Lu-3820</td>
<td>Sörevik 3</td>
<td>394-398</td>
<td>B</td>
<td>Wood fragments</td>
<td>9300±160</td>
</tr>
</tbody>
</table>
7. Discussion and conclusions

The drift peat that was dated to 9300±160 \(^{14}C\) years BP in this study was deposited during the transgression at the transition between Yoldia Sea and Ancylus Lake. This was at the beginning of the Early Boreal pollen zone (Berglund 1964). Corresponding drift peat was dated earlier to 8945±140 BP (Berglund 1964). Pine stumps which were transgressed during the same event have been found at Tångören, south of Senoren, at about 3 m water depth and dated to 9300±130 BP (Berglund 1964) and 9380±90 BP (Berglund, B. Berglund, P & Blivik 1986). The Yoldia Sea level was below the present sea level from which the Ancylus transgression began (Berglund 1964). The lowest shore level during the yoldia regression was possibly about -20 m below the present sea level (Berglund, B. Berglund, P & Blivik 1986). This means that Senoren and the other large islands were joined with the mainland.

The clay gyttja, gyttja clay and calcareous clay gyttja were deposited during the Ancylus transgression that followed the Yoldia regression. The above stratigraphic units were deposited in fresh water according to diatom studies by Berglund(1964). The Ancylus Lake was a fresh water lake dammed above the sea level (Björck in press). According to Holst (1899), the highest Ancylus Lake level was at least 8 m above the present sea level while Berglund (1964) suggested that the Ancylus transgression reached its maximum level about 6 m just before 9000 BP. At this time there was an open sound between Senoren and its peninsula NE of Sörevik. Abrasion of exposed shores at 5-6 m above present sea level explains the high minerogenic content of the clay gyttja and gyttja clay. The coarse detritus gyttja dated to about 8500-8200 \(^{14}C\) years BP in this study was deposited during the Ancylus regression. The fact that there is no drift peat and no indication of a hiatus above the coarse detritus gyttja implies that the lowest water level reached during the Ancylus regression was about 1 m below the present sea level.

The Ancylus regression was followed by a transgression starting at about 8500 BP during which time the fine detritus gyttja and the clayey gyttja were deposited. This was the complex Littorina transgression (Berglund 1964). This transgression brought the water level above the highest Ancylus Lake water level. This is supported by the results of the magnetic analysis and coarse organic and minerogenic analysis that indicates that there are finer sediments in the fine detritus gyttja deposited during the Littorina transgression in comparison with the calcareous clay gyttja, gyttja clay and clay gyttja deposited during the Ancylus transgression. Berglund (1964) suggested that the water level was brought to 5-7 m above the present sea level. The Littorina transgression brought in salt water from the ocean according to earlier diatom studies (Berglund 1964) and the presence of blackish water plant (i.e Zostera marina). This study proves that the Littorina transgression was complex as indicated by the presence of drift peat within the lower part of the fine detritus gyttja. The fine detritus gyttja layer can be subdivided in two subunits, the lower one with high coarse matter content and an upper one with low coarse matter content (in the main core Bp2 the boundary is at about 130 cm level). This change is caused by increased water depth possibly occurring at the beginning of the main Littorina
transgression in Blekinge dated to about 7000 BP (Berglund 1964, 1971, Liljegren 1982). Berglund (1964) suggested that the Littorina transgression is composed of six phases (see Fig. 5 & Fig. 6).

The Littorina transgression was followed by a regression that probably eroded some of the sediments deposited during the Littorina transgression as implied by a hiatus above the clayey gyttja represented by sand. Later on shore vegetation colonized this sand and the Phragmites peat was formed.

A preliminary shore displacement curve has been compiled on the basis of the earlier study by Berglund (1964) and the present study. The level of the Baltic Sea at Sörevik is plotted against stratigraphic units and time (Fig. 17).

Fig. 17. A preliminary shore displacement curve for the Baltic Sea at Sörevik based on the investigations carried out in this study.
8. Future research

It is important to get more exact dates of the events that have taken place in the Baltic Sea area in Late Weichselian and Holocene times.

It is also important to improve the correlations of those events along the whole vicinity of the Baltic Sea coast line. Researchers should intensively use the new improved dating techniques – AMS dating which will reduce dating errors caused by old carbonate, reservoirs effects, etc.

Palaeoecological analyses may also be extended to include a wider variety of methods like diatoms, ostracod, and mollusc analysis.

The new magnetic analysis techniques could be used more intensively in calibrations of fossil assemblages in order to obtain record of both short- and long term environmental changes in the Baltic Sea for constructing changes in the temperature, salinity, hydrography etc. The available shore-line displacement curves should be improved to give more details.

The available palaeogeographical maps of the Blekinge area should also be improved by incorporating the most recent findings.
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