New insights on the Yoldia Sea low stand in the Blekinge archipelago, southern Baltic Sea

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Abstract: One sediment core from the Järnavik bay in Blekinge archipelago has been investigated for its content of pollen and diatoms and its chemical properties. Two levels were also dated by radiocarbon. Based on the results the sediment sequence analysed has been divided into three environmental units largely corresponding to the lithology of the sequence. A lowermost unit consisting of weakly varved and homogeneous clay was deposited during the end of the brackish phase of the Yoldia Sea at a moderate water depth. On top of this unit a gyttja-clay unit was deposited. The onset of the deposition of this unit has been dated to c. 11 100 cal. yrs. BP. An increasing organic production and increased terrestrial influence is recorded in the chemical data and a very shallow water depth is indicated in the pollen and diatom flora. These results point to conditions in a bay probably isolated from the Yoldia Sea. A local tentative shore displacement curve have been constructed and it is proposed that this unit represents the low stand at c. –18 m during the Yoldia Sea stage in this part of the Baltic Sea basin. The uppermost unit consists of homogeneous clay with a low content of organic carbon. An increasing water depth is indicated by the composition of both pollen and diatoms. The diatom flora also displays an increase in freshwater species. This environmental change was probably the result of a transgression in the beginning of the Ancylus Lake stage.

Keywords: Baltic Sea, Blekinge archipelago, pollen, diatoms, submarine pine stumps, Yoldia Sea, Yoldia regression, Ancylus Lake, Ancylus transgression, local Blekinge shore displacement curve.

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Introduction

The Yoldia Sea stage of the Baltic Sea was named after the arctic bivalve Yoldia arctica (nowadays Portlandia arctica) and is traditionally defined as starting when the Baltic Ice Lake was drained and lowered 25 m down to the level of the North Atlantic (Munthe 1910). This drainage event has been dated to 11 560±10 cal. yrs. BP in the Swedish clay-varve chronology (Andrén et al. 2002) and Saarnisto & Saarinen (2001) concluded that it more or less coincided with the ice margins retreat from the Salpausselkä II end moraines. They dated this to 11 590±100 cal. yrs. BP by varve chronological and palaeomagnetic methods. Similar ages for the drainage of the Baltic Ice Lake have also been presented by Brunnberg (1995) and Strömberg (1994) based on clay-varve chronological investigations from the Södertörn and Västergötland areas respectively. There are also several investigations indicating radiocarbon ages between 10 300 and 10 000 years BP corresponding approximately to 12 200 and 11 200 cal. yrs. BP (e.g. Svensson 1989; Bodén et al. 1997). As the drainage occurred during the so-called 10 000-year radiocarbon plateau these datings are uncertain but they seem to indicate similar age as achieved by other methods. It is thus reasonable to believe that the final drainage of the Baltic Ice Lake, and hence the onset of the Yoldia Sea stage, took place between 11 600 and 11 550 cal. yrs. BP.

The following c. 250 years was characterised by freshwater conditions in the Baltic Sea basin probably best explained by two facts. Firstly, due to the Preboreal warming, huge amounts of melt water was produced by the ice sheet, and secondly, the narrowness of the straits north of Mt. Billingen that the outflowing melt water had to pass (Strömberg 1992) probably hindered the marine water to enter the Baltic Sea basin.

Brackish water conditions started at c. 11 300 cal. yrs. BP in the western part of the central Baltic Sea where brackish water ostracodes and foraminifera are recorded (Wastegård et al. 1995). Björck et al. (2001) report a similar age for the first marine ingression from Västergötland and Närke area in southern Sweden recorded as findings of fossil ostracodes and foraminifera together with shells of Portlandia arctica in smpmict varved glacial clay of Yoldia Sea age. Some 100 years later brackish-
marine conditions are indicated by the fossil benthic calcareous fauna found in varved glacial clay sequences in the area east of the Närke straits where these conditions seem to have prevailed for 110 to 190 years (Schoning 2001). In the Stockholm area several findings of *Portlandia arctica* are reported from varved glacial clay (De Geer 1913, 1940; Brunnberg & Possnert 1992). Brunnberg (1995) dated the onset of brackish-marine conditions in this area to c. 11 200 cal. yrs. BP based on a distinct change in colour in the clay sequences. He also estimated the brackish marine influence to have lasted for a minimum of 250 years. This estimate was based on the fact that Strömberg (1989) reports symmict varved glacial clay in the vicinity of Uppsala dated to c. 10 950 cal. yr BP, i.e. 250 years after the brackish ingression in the Stockholm area.

After this first ingression of saline water brackish surface water conditions seem to establish in the entire Yoldia Sea basin. Brackish surface water conditions is indicated in the recorded diatom flora found in sediment sequences of Yoldia Sea age from

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**Fig. 1.** Location of the sampling site Järnavik PC0024. The locations of sites discussed in the text are indicated. 1-2 – Järnavik; 3 – Kalvöviken; 4 – Sörevik; 5-7 – Långören; 8-9 – Lövdalen; 10-12 – Haväng.
e.g. the Landsort Deep (Lepland et al. 1999), the Bornholm basin (Andrén et al. 2000b), the Gdansk Bay and offshore the Lithuania coast (Kabaliene 1995), the Gulf of Finland (Heinsalu 2001) and from the eastern Gotland basin (Andrén et al. 2000a). It is thus an ample amount of evidence from the fossil diatom flora in favour of slightly brackish water conditions in the entire Yoldia Sea basin during this time. The only exception was possibly in the vicinity of the retreating ice margin where the freshwater influence was very strong.

The end of the brackish phase is dated to c. 11 000 cal. yrs. BP in the area east of Närke (Schoning 2001), to 11 060 cal. yrs. BP in the eastern Gotland basin (Andrén et al. 2002) and to c. 10 950 cal. yrs. BP in the vicinity of Uppsala (Strömberg 1989). The duration of the brackish phase of the Yoldia Sea stage cannot have been more than maximum c. 350 years based on the dates presented above.

The dates presented above that derive from measurements of varved glacial clays correlated to the Swedish clay varve chronology, the Swedish Time Scale, are corrected for the “missing” c. 760 years as proposed by Andrén et al. (2002).

The remaining part of the Yoldia Sea stage is characterised by freshwater conditions recorded in several sites around the Yoldia Sea basin e.g. the Landsort Deep (Lepland et al. 1999), the Bornholm Basin and the eastern Gotland Basin (Andrén et al. 2000a, 2000b) and the Gulf of Finland (Heinsalu 2001). The Yoldia Sea stage per definition ended when the onset of the Ancylus Lake transgression was recorded in the southern Baltic Sea basin. This occurred c. 10 700 cal. yr BP (Björck 1995) and thus was the ending freshwater phase c. 250 years long.

In this paper we present the results from lithological, chemical, biostratigraphical investigations of an offshore sediment core from a submarine basin in the archipelago of Blekinge, southern Baltic Sea. The core was dated by radiocarbon dating (AMS). The aim of our study is to identify the sea-level regression minimum during the Yoldia Sea stage, i.e. level, chronology and correlation with Yoldia Sea stage as described above.

Material and methods

Coring

The sampling site is situated in a depression of the Järnavik bay, which during a time of low Baltic Sea level might have been an isolated lake. The core analysed, PC0024, was sampled at a water depth of 16 m with a piston corer, diameter 50 mm, from the vessel R/V Skagerak in August 2000. The sampling site was selected after acoustic profiling in order to find the best location and the GPS positioning system (WGS84) was used. The position of the sampling site is N56°10.166'; E015°03.867' and the total recovery was 4.22 m (Fig. 1). Onboard the ship the sediment core was cut into 1.25 m sections for transportation and these were later sliced open in the laboratory. All levels mentioned refer to depth below sediment surface.

Chemical analyses

For the chemical analyses the core was sub-sampled every 10 cm (0–300 cm) and every 20 cm (300–420 cm). The total organic carbon (TOC) content together with the stable isotope △13C were analysed by the use of a Finnigan MAT Delta Plus mass spectrometer.

Radiocarbon dating

Two levels, 215–217 cm (Ua-19207) and 265–267 cm (Ua-19208) have been dated by radiocarbon and these levels were selected based on the lithology and the content of organic carbon. Due to the fact that no terrestrial macrofossils were found at the selected levels bulk sediment samples were submitted for dating at the The Sweden Laboratory, Uppsala University. The radiocarbon ages have been calibrated to calendar years using the atmospheric data from Reimer et al. (2004) and the calibration program OxCal v3.10 (Bronk Ramsey 2005). The sediment samples have been regarded as composed of mainly limnic material and therefore no correction for marine reservoir age has been made.

Diatoms

A small amount of sediment was prepared and enriched for diatoms according to Battarbee (1996). Mounting media used for microscope slides was Naphrax™ and diatom enumeration was carried out using a light microscope with differential interference contrast and a magnification of ×1000. Between 432 and 658 diatom valves were counted at each level including Fragilaria spp. sensu Hustedt. The genus Fragilaria has been subdivided into several different genera (Williams & Round 1987). In this paper some taxa has been clumped together as Fragilaria elliptica ag-

Table 1. Sediment description for the core PC0024.

<table>
<thead>
<tr>
<th>Depth below sediment surface (cm)</th>
<th>Lithology units</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>0–51.5</td>
<td>Gyttja, dark greenish brown, possible small shell fragments at 31.5 cm, plant remnants at 49–51 cm.</td>
<td></td>
</tr>
<tr>
<td>51.5–53</td>
<td>Sandy silt, medium greenish grey, upwards coarsening. Upper boundary sharp (erosive) and inclined c. 10°.</td>
<td></td>
</tr>
<tr>
<td>53–59</td>
<td>Gyttja-clay, medium to light greenish grey. Lower c. 2 cm almost laminated up core successively increasing minerogenic content. Upper boundary gradual.</td>
<td></td>
</tr>
<tr>
<td>59–74.5</td>
<td>Clay-gyttja, medium brown. Light grey silt bands (c. 2 mm) at 58.5 and 70 cm. Macro plant remnants at 57.5 cm. Small plant remnants in the whole unit. Piece of wood at 72.5–73 cm. Dark bands at 74.5 cm. Upper boundary relatively sharp.</td>
<td></td>
</tr>
<tr>
<td>74.5–149</td>
<td>Gyttja-clay, light greenish grey. From 97 cm and down core frequent very thin dark bands, some diffuse. Upper boundary gradual.</td>
<td></td>
</tr>
<tr>
<td>195–204</td>
<td>Clay, light brownish grey. The unit gradual more greyish up core. Upper boundary gradual.</td>
<td></td>
</tr>
<tr>
<td>204–259.5</td>
<td>Clay-gyttja, medium brownish. Distinct bands of clay at 240.5–242 and 246–246.5. Below the lower clay band significantly darker brown. Upper boundary diffuse but clearly visible and inclined c. 15°.</td>
<td></td>
</tr>
<tr>
<td>259.5–267.5</td>
<td>Clay, light brownish grey. Frequent darker (brown) bands almost varves. Upper boundary relatively sharp.</td>
<td></td>
</tr>
<tr>
<td>267.5–313</td>
<td>Clay, light brownish grey. Upper boundary gradual.</td>
<td></td>
</tr>
<tr>
<td>313–422</td>
<td>Clay, light reddish brown. Weak varves (c. 2 mm) visible from c. 313 and down core. Sulphide bands and dots occur in the whole unit. Visible varve thickness in the lowermost part of the unit c. 20 mm. Upper boundary gradual.</td>
<td></td>
</tr>
</tbody>
</table>
The core content of organic carbon (TOC) and $\delta^{13}$C.

**Lithology**

The core was lithologically described immediately after opening and the lithology is presented in Table 1 and illustrated in Fig. 2. In this paper we focus on the lower part of the core, i.e. below 150 cm as this part of the sediment sequence is relevant for the present investigation.

Varved glacial clay is found in the lowermost part of the core between 313 and 422 cm. The varves, however, becomes increasingly diffuse in the upper part of the unit and gradually converts into a homogeneous clay. Between 259.5 and 267.5 cm a sequence with abundant dark brown bands occurs. A medium brown clay-gyttja is recorded between 204 and 259.5 cm, which gradually changes into homogeneous light brown clay, gradually becoming more greyish up core.

**Pollen**

Preparation for pollen analysis has followed standard technique (Berglund & Ralska-Jasiewiczowa 1986). A percentage diagram for the sediment sequence 150–295 cm is presented in Fig. 4 and includes 24 analysed levels. Local pollen assemblage zones are based on cluster analysis (CONISS, Grimm 1987), including regional as well as local pollen deposition. Three pollen assemblage zones (LPAZ 1–3) have been defined. As a complement to pollen and spore percentages concentration values have been calculated by adding exotic *Lycopodium* spores. The concentration diagram is used for the discussion but excluded in this paper.

**Results**

**Lithology**

The sediment sequence 180 to 380 cm was covered by diatom analyses at every 40 (two lowermost samples) to 10 cm interval, and altogether 14 samples were analysed. A diatom diagram with taxa more than 2% at any level was constructed (Fig. 3). A cluster analysis performed using the software Tilia (CONISS, Grimm 1987) divided the diagram into three diatom assemblage zones (LDAZ 1–3), which fits with a visual inspection of the diatom stratigraphy.

Table 2. Radiocarbon dates of submarine limnic-terrestrial material discussed in this paper. Numbers refer to site map, Fig 1B.

<table>
<thead>
<tr>
<th>Site, depth (m)</th>
<th>Lab. No</th>
<th>Material</th>
<th>$^{14}$C age yr BP</th>
<th>Cal. age BP (mid-intercept)</th>
<th>Cal. age BP (1 $\sigma$ interval)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Järnavik, -18</td>
<td>Ua-19207</td>
<td>Clay gyttja</td>
<td>9830±110</td>
<td>11 255</td>
<td>11 410–11 100</td>
</tr>
<tr>
<td>Järnavik, -18</td>
<td>Ua-19208</td>
<td>Clay gyttja</td>
<td>9765±110</td>
<td>11 095</td>
<td>11 320–10 870</td>
</tr>
<tr>
<td>Kalvöviken, -4.5</td>
<td>LuA-5070</td>
<td>Betula fruits</td>
<td>9650±100</td>
<td>10 995</td>
<td>11 200–10 790</td>
</tr>
<tr>
<td>Sörevik, -4</td>
<td>LuA-4474</td>
<td><em>Pinus</em> needles</td>
<td>9330±140</td>
<td>10 500</td>
<td>10 710–10 290</td>
</tr>
<tr>
<td>Långören, -3</td>
<td>St-806</td>
<td><em>Pinus</em> stumps</td>
<td>9300±130</td>
<td>10 475</td>
<td>10 660–10 290</td>
</tr>
<tr>
<td>Långören, -3</td>
<td>Lu-2485</td>
<td><em>Pinus</em> stumps</td>
<td>9380±90</td>
<td>10 590</td>
<td>10 740–10 440</td>
</tr>
<tr>
<td>Långören, -3</td>
<td>Lu-3807</td>
<td><em>Pinus</em> stumps</td>
<td>9400±110</td>
<td>10 605</td>
<td>10 790–10 420</td>
</tr>
<tr>
<td>Lövden, -14</td>
<td>Lu-2342</td>
<td><em>Pinus</em> stumps</td>
<td>9590±90</td>
<td>10 940</td>
<td>11 100–10 780</td>
</tr>
<tr>
<td>Lövden, -13</td>
<td>Lu-2341</td>
<td><em>Pinus</em> stumps</td>
<td>9450±90</td>
<td>10 815</td>
<td>11 070–10 560</td>
</tr>
<tr>
<td>Haväng, -15</td>
<td>Lu-3053</td>
<td>Carr peat</td>
<td>9400±90</td>
<td>10 810</td>
<td>11 070–10 550</td>
</tr>
<tr>
<td>Haväng, -15</td>
<td>Lu-3054</td>
<td>Gyttja</td>
<td>9580±90</td>
<td>10 930</td>
<td>11 100–10 760</td>
</tr>
<tr>
<td>Haväng, -15</td>
<td>Lu-3055</td>
<td>Peat</td>
<td>9490±90</td>
<td>10 830</td>
<td>11 070–10 590</td>
</tr>
</tbody>
</table>

Sources: site 1–2, 6–7 this paper; site 3–4 Berglund et al. (2005); site 5 Berglund (1964); site 8–9 Hansen (1987), Björck & Dennergård (1988); site 10–12 Gaillard & Lemdahl (1994).
Organic carbon

The organic carbon content is low (Fig. 2), less than 1%, in the clay sequence between 270 and 422 cm. Increasing values are recorded in the light brownish grey clay and two maximum values of c. 5% are recorded in the clay-gyttja unit at 210 and 250 cm. Between these maximum values low values of c. 2% are recorded from 230 to 240 cm. From the maximum value at 210 cm the organic carbon content decreases to a stable value around 1% between 150 and 190 cm.

Stable isotope δ¹³C

Low values of –25‰ to –24‰ are recorded in the clay unit between 270 and 422 cm apart from an outlier of –15‰ at 400 cm (Fig. 2), which most probably is erroneous. From 270 cm the values decrease to a minimum of –32‰ at 250 cm from which level the values show an increasing trend to values of c. –24‰ at 150 cm.

Radiocarbon dates

The two samples dated, Ua-19208 and Ua-19207, were dated to 9765±110 and 9830±110 ¹⁴C years BP respectively. This gives the following calibrated ages: (Ua-19208) 11 320–10 870 and (Ua-19207) 11 410–11 100 cal. yrs. BP. These two dates together with other radiocarbon dates discussed in the text are given in Table 2 and presented as probability plots in Fig. 5.

Results and interpretation of the diatom analyses

Based on the result of the diatom analyses the diagram is divided into the following diatom assemblage zones (Fig. 3).

LDAZ 1 (380–280 cm). – This zone consists of the lowermost metre analysed and is the most brackish water influenced zone.

The brackish water taxa reach between 3.5 to 8.7% and consists in addition to Opephora mutabilis visible in the diagram also elements of Martyana schulzii and M. atomus, Fallacia tenera, Tryblionella levidensis and Epithemia adnata. The most common species, reaching 36% in the lowermost level is the fresh-water planktonic Aulacoseira islandica typical for large lakes i.e. freshwater Yoldia Sea and Ancylus Lake. Diatom composition suggests slightly brackish water environment and a fairly deep basin visible in the lowermost part of the zone as nearly 40% planktonic taxa and only 14% Fragilaria spp. aggregate. The decrease of planktonic diatoms towards the upper part of the zone probably implies a reduced water depth. The sediments of this DAZ were most probably deposited during the brackish phase of the Yoldia Sea stage.

LDAZ 2 (280–205 cm). – This zone consists nearly exclusively of Fragilaria spp. aggregate reaching between 77 and 97% and the amount of benthic taxa reaches 90 to 100%. It is obvious that the water level decreased to a minimum level. Many of the dominating Fragilaria taxa (Pseudostaurosira brevistriata, Fragilaria elliptica aggregate, Staurosirella pinnata, Staurosira construens var. venter), which attain maximum percentages in this zone, are classified as brackish-freshwater taxa. The main cause for the massive increase of Fragilaria spp. aggregate in this zone is the very shallow water, but there is also a slight decrease in salinity and most of the brackish water taxa disappear except for Navicula laterostrata. The interpretation of the diatoms suggests that the water was very shallow.

LDAZ 3 (205–180 cm). – The uppermost zone is characterised by a sharp increase in freshwater, planktonic taxa especially Aulacoseira islandica reaching between 57 to 36%, but also Aulacoseira subarctica, A. ambigua and Stephanodiscus spp. All these species are common in large lakes and especially in as-
semblages found in the Ancylus Lake. *Fragilaria* spp. aggregate decrease simultaneously. This zone shows an increasing water depth and is interpreted to reflect the onset of the Ancylus Lake transgression.

Results and interpretation of pollen analyses
The pollen diagram (Fig. 4) is divided into the following pollen assemblage zones (Fig. 4).

**LP AZ 1 (295–273 cm).** – This zone is dominated by *Betula* and *Pinus* together with *Salix* and *Juniperus*. Cyperaceae and Poaceae are also frequent. Wetland taxa are missing. The upper boundary is characterized by decreasing *Pinus*, *Salix* and *Juniperus* while Poaceae is distinctly increasing. This pollen flora indicates deposition in a large basin where the shore was distant. Correlation with adjacent regional pollen diagrams like Smygen (Fig. 1, Yu et al. 2005) indicates similarities with the upper part of Smygen LPAZ-1a dated to 11 400–11 250 cal. yrs. BP.

**LP AZ 2 (273–190 cm).** – This zone is characterized by increasing *Pinus* and decreasing *Betula* values, high values of Poaceae (possibly *Phragmites communis*) together with frequent occurrences of aquatics, particularly *Nymphaea*, and wetland herbs like *Spartagnum* (possibly this pollen type represents *Typha angustifolia*) and *Thalictrum*, ferns (Polypodiaceae) and *Equisetum*. Distinct decreasing *Betula* and expanding *Pinus* characterize the upper boundary. Poaceae is decreasing as well as aquatics and wetland taxa.

This pollen flora indicates deposition in a smaller basin, possibly an isolated lake, with rich telmatophytic (reeds) shore vegetation quite close to the coring point. The composition of the pollen flora is similar to the lower part of LPAZ 1b of the Smygen basin (Yu et al. 2005), dated to 11 250–11 100 cal. yrs. BP. The lithology of that pollen zone indicates a distinct drop of the Baltic Sea water level, an isolation of a basin with a sill at –1 m.

**LP AZ 3 (190–150 cm).** – This zone is characterized by a monotonous pollen flora with very high *Pinus* values, low *Betula*, Poaceae and wetland plant values. This pollen flora indicates an environment characteristic for a larger basin where the shore is distant from the sampling place.

Discussion

**Palaeoecological history**

The palaeoecological history at the sampling site Järnavik PC0024 is generally well reflected in the analysed parameters and can be divided into three environmental units more or less following the lithology of the core (Table 1, Fig. 2), i.e. unit 1 corresponding to sediment unit 1 and 2, unit 2 to sediment unit 3 and unit 3 to sediment unit 4 and 5.

1. The lowermost part of the core, below 259.5 cm, consisting of weakly varved and homogeneous clay was deposited in a reasonably deep slightly brackish water environment. This is recorded in the diatom flora (LDAZ 1, 380–280 cm) as 40% brackish and freshwater taxa together with planktonic freshwater taxa. A decreasing water depth is indicated upwards in this unit by the increase in benthic diatom species constituting a maximum of 80% in the uppermost part of the unit. This type of environment is also supported by the pollen spectrum in LPAZ 1 (295–273 cm) that indicates deposition in a large basin at some distance to shore. The organic carbon content is low (less than 1%) and the δ¹³C values are stable at c. –25‰ in the unit. All these evidence together with the radiocarbon age of 11 095 cal. yrs. BP (mid-intercept) at 260–261 cm indicates that this unit was deposited during the brackish phase of the Yoldia Sea stage most probably during the end of the phase.

2. A clay-gyttja is recorded between 259.5 cm and 204 cm and is interpreted as representing a short time interval with shallow water depth when the site was isolated from the Baltic Sea for the following reasons.

of 2 to 5% is recorded and these values coincide with minimum values of −28 to −32‰ in the δ¹³C record. This indicates an increased productivity and a more terrestrial origin of the organic material deposited. This interpretation is further strengthened by the pollen data in LPAZ 2 (273–190 cm) where aquatic species such as Nymphaea and Nuphar together with wetland herbs like Sparganium and Thalictrum indicate an environment with shallow water depth and shores in close vicinity of the coring site. The diatom zone LDAZ 2 (280–205 cm) records change to a flora totally dominated by benthic taxa indicating a decrease of the water depth. There is also a decrease in the occurrence of brackish water species probably reflecting lower salinity conditions. Traditionally the genus Fragilaria sensu Hustedt has been treated as one group of opportunistic diatoms tolerant to changes in the environment (Denys 1990). They have been useful indicators of changes in salinity and water depth in connection to isolations of basins following the isostatic rebound of the crust after the last Scandinavian deglaciation (Stabell 1985). Fragilaria spp. including the revised genera dominates the shallow and small almost lake-like embayments along Gulf of Finland with a mean salinity of 4.8‰ (Weckström & Juggins 2004). Staurosirella pinnata has a salinity optimum of 0.66 g L⁻¹ in the Limfjord area (Ryves et al. 2004). In a recent study from the Gulf of Finland it is concluded that their wide ecological tolerance make them poor as indicator species, but they seem to respond to increased turbidity (Weckström 2006). All these different datasets point to the conclusion that mass occurrence of Fragilaria indicate a highly dynamic environment. In the present study there is a mass occurrence of Fragilaria spp. aggregate that totally dominate LDAZ 2. This is interpreted as a response to a change in the environment, in this case a lowering of water depth, but from the diatom data it can only be speculated if the basin was totally isolated or still partly connected to the Baltic basin.

The upper part of the unit, 205–206 cm, is dated to 11 255 cal. yrs. BP (mid-intercept) an age somewhat older than the lower part of the unit. A probable explanation are that the environmental conditions resulting in the deposition of the clay-gyttja unit only prevailed for a short period of time making exact dating difficult. This is also supported by the low pollen concentration values. Furthermore, if the interpretation of a closed bay with the shores very close to the sampling site is correct, it is reasonable to assume that the amount of reworked old carbon from the shores incorporated in the sediment increases up core. The onset of a transgression recorded at c. 205 cm will accelerate the effect of reworked older sediments from the shores. Andrén et al. (2000a, 2000b) suggested a correction for this effect of −400 years for sediments from the open Baltic Sea basin but the effect of reworked old carbon are probably even greater in sediments deposited close to the shore.

A reasonable interpretation of sediments in unit 2 is that it was deposited during a short time period when the site was isolated or had a very limited water exchange with the Yoldia Sea. The age of the lower part of the unit, c. 11 100 cal. yrs. BP indicates that it was isolated in the end of the brackish phase of the Yoldia Sea stage. If the transgression recorded at c. 205 cm is the Ancylus Lake transgression, as suggested below, the unit represents c. 400 years and was deposited during the ending freshwater phase of the Yoldia Sea stage. This gives an annual sedimentation rate of c. 1.4 mm/year, a figure that seems reasonable in an environmental setting like this. 3. The uppermost part of the analysed sediment sequence between 204 cm and 150 cm consists of homogeneous grey clay, which records an organic carbon content of c. 1% and δ¹³C values of c. –27‰ indicating less productivity and less terrestrial influence. From the diatom flora, LDAZ 3, 205–180 cm, a sharp increase in the freshwater, planktonic taxa can be interpreted as deeper water which indicates a transgression at the sampling site. Also the pollen spectra (LPAZ 3, 190–150 cm) points to environmental conditions with an increased water depth and a greater distance to the surrounding shores reflected as high Pinus values, low Betula, Poaceae and wetland plant values. These data also point to the onset of a transgression and it are reasonable to assume that the onset of the Ancylus Lake transgression is recorded at c. 205 cm. The onset of the Ancylus Lake transgression is dated to c. 10 700 cal. yrs. BP (Björck 1995) but our date of the transgression is older for reasons stated above. The sediment accumulation rate in the early Ancylus Lake probably also decreased significantly as the water depth at the sampling site increased and the sediment deposited to greater extent constitutes of reworked minerogenic material as reflected in the low organic carbon content. 3

The Yoldia Sea low stand level

Based on the water depth at the sampling site and the stratigraphic position of the clay-gyttja unit it is possible to calculate the lowest level of the Yoldia Sea in this area. The present water depth at the sampling site is 16 m and the clay-gyttja unit is recorded between 205 and 267.5 cm below the sediment surface of the core, indicating that the depth of the unit is c. −18 m. This
The environmental history of the site Järnavik PC0024 outlined above correlates well with the general history of the Yoldia Sea stage recorded in other parts of the Baltic Sea basin.

From the Bornholm basin Andrén et al. (2000a) reports a c. 70 cm long sediment sequence representing the end of the brackish phase of the Yoldia Sea stage. This is recorded in diatom flora, the C/S and C/N ratios and is dated to c. 11 100 cal. yrs. BP. The age, however, is derived from extrapolation of the time-depth plot as the organic carbon content was too low for radiocarbon dating.

Ages of the end of the brackish phase of the Yoldia Sea of c. 11 000 cal. yrs. BP have been reported from the Närke area (Robertsson 1995; Schoning 2001), the Uppsala area (Strömberg 1989) and the eastern Gotland basin (Andrén et al. 2002). The similarity of the ages from different areas makes it fair to assume that our site was isolated during the end of the brackish phase of the Yoldia Sea stage as indicated by the age of c. 11 100 cal. yrs. BP for the isolation.

In the eastern part of the Baltic basin, the Pärnu area in southwestern Estonia, peat layers deposited during the Yoldia Sea regression are reported by Veski et al. (2005). This regression minimum took place just prior to the Ancylus Lake transgression and is dated to c. 10 800 cal. yrs. BP. In northern Estonia the amplitude of the regression has been estimated to c. 25 m during the Yoldia Sea stage (Heinsalu 2001) but the isostatic history of this area complicates an exact estimate. Data from the Gotland area points towards an amplitude of the Yoldia Sea regression of c. 17 m (Svensson 1989, 1991) making our estimate of the amplitude of c. 13 m (possibly even 17 m) in the zero-isobase area in Blekinge archipelago fairly likely.

Conclusions

- The gyttja-clay unit in the core Järnavik PC0024 was deposited in a shallow water basin probably isolated or with a very limited water exchange with the Yoldia Sea. This is recorded in the pollen and diatom spectra as well as in the chemical parameters. The onset of the deposition started c. 11 100 cal. yrs. BP and is correlated with the Yoldia Sea regression minimum.
- The stratigraphic position of the unit together with the water depth at the sampling site make it possible to fix the Yoldia Sea regression minimum at c. –18 m in this part of the Blekinge archipelago.
- The sampling site was transgressed during the Ancylus Lake transgression 10 700 cal. yrs. BP. This event is well reflected in both the diatom and the pollen spectra. The unit thus represents sediment deposited during c. 400 years during the end of the brackish phase and the ending freshwater phase of the Yoldia Sea stage.
• The regression minimum confirmed by the submarine Järnävik bay is correlated with submarine pine stumps and peat layers along the Hanö Bay coast. These deposits are found to be slightly younger, i.e. 11 100 to 10 500 cal. yrs. BP, which means that they originate from the time of the Ancylus Lake transgression.

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