Late Glacial vegetation, sedimentation and ice recession chronology in the surroundings of Lake Prossa, central Estonia

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Abstract. Pollen records from Lake Prossa, located in the Saadjärv Drumlin Field, indicate rather homogeneous pollen spectra in the pre-Allerød period and a thick sediment sequence suggesting high input of mineral matter and erosion. This period is characterized by pioneer vegetation with dwarf-shrubs. At the beginning of the Allerød, *Salix*, *Artemisia* and redeposited temperate and thermophilous taxa prevailed in pollen spectra, referring to shrub tundra conditions, followed later by *Betula* and *Pinus*(?) arrival. Silt with organic debris deposited. Vegetational set-back and tundra plant species with scattered birches and silty deposits containing abundantly *Drepanocladus* fragments characterize the Younger Dryas stadial. The sedimentation rate decreased markedly and was followed by a hiatus at the beginning of the Holocene. The AMS ^{14}C dates, and microfossil and sedimentological data show that the ice front receded and stratified sediments started to deposit about 14 200–14 300 cal yr BP, permitting specification of poorly constrained ice recession chronology in central Estonia.

Key words: AMS ^{14}C dates, microfossils, grain size, loss on ignition, ice recession, central Estonia.

INTRODUCTION

During the last decade several publications have been devoted to the Late Glacial chronostratigraphy of the Baltic regions as the AMS ^{14}C method opened up possibilities for dating macrofossils accumulated in these sediments (Stančikaite et al. 2002, 2004, 2008; Saarse et al. 2009; Amon et al. 2010; Amon & Saarse 2010). In previous Late Glacial stratigraphic studies of Estonia chronostratigraphy was mostly based on palynological records (Pirrus 1969, 1971; Pirrus & Rõuk 1979; Pirrus & Raukas 1996) and correlation with the Fennoscandian chronostratigraphical chart (Mangerud et al. 1974). Due to scarcity of terrestrial plant macrofossils preserved in Late Glacial sediments, especially in varved clays, AMS ^{14}C data are still scanty, which prevents working out more precise Late Glacial time control and ice recession chronology in Estonia. Recently Late Glacial chronostratigraphy was established for the Haljala (Saarse et al. 2009), Udriku (Amon & Saarse 2010) and Nakri (Amon et al. accepted) sequences. As Late Glacial deposits are widespread in the inter-drumlin hollows of the Saadjärv Drumlin Field (Pirrus & Rõuk 1979), but deglaciation timing is poorly constrained due to the absence of radiocarbon dates, Lake Prossa, where the thickness of Late Glacial deposits varies between 2 and 3 m (Saarse & Kärson 1982), was selected for future study.

The main objective of the current study was to obtain new chronological, lithological and palynological data in order to adjust the ice recession chronology in the drumlinized landscape of central Estonia. Up to now only two radiocarbon dates were available from the Late Glacial strata of the region (Sohar & Meidla 2009; K. Kihno unpublished data).

STUDY AREA

Lake Prossa (58°38′57″N, 26°34′40″E) in the northwestern part of the Saadjärv Drumlin Field is a medium-size (24.2 ha in area) mesotrophic lake lying 61 m a.s.l. (Fig. 1A, B). The drumlin field, located between the Otepää and Pandivere ice-marginal zones (Kalm 2006), is the largest in Estonia, measuring ca 55 km from north to south, with the width up to 27 km and area totalling 1200 km^2 (Rõuk 1987). This huge relief form is composed of 60–70 m thick Quaternary deposits, underlain by Lower Silurian limestones and dolostones in the northern part and by Devonian sandstones in the southern part (Kajak 1965). The formation of inter-drumlin depressions with 11 lakes is closely connected with the development

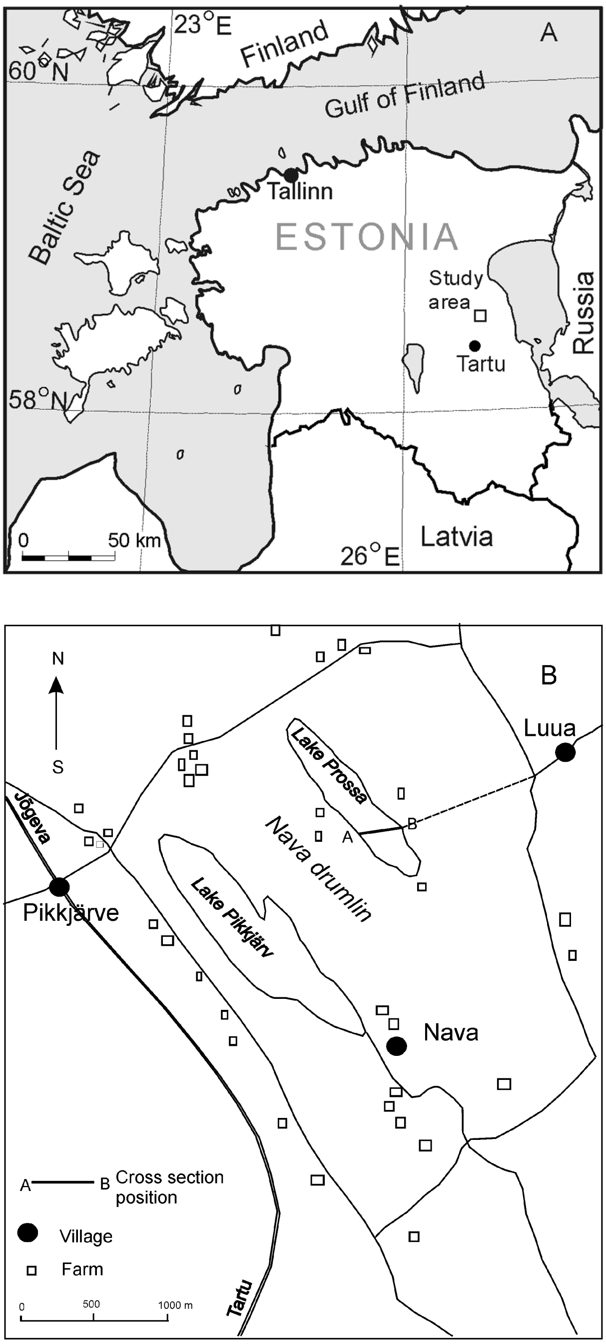

Fig. 1. **A**, location of the study area. **B**, cross section (A–B) position in Lake Prossa.

of the glacial relief under an East-Baltic Weichselian ice stream (Rattas & Piotrowski 2003). Most of the depressions probably resulted from increased glacial erosion and formed at the same time with the drumlins, as they are also elongated in the direction of ice movement. A proglacial lake emerged in front of the retreating ice margin and inundated the area (Kajak 1965; Hang et al. 2003; Rosentau et al. 2007). Due to ice recession and opening up of new outflow channels, the water level in the proglacial lake lowered and inter-drumlin basins became isolated. Troughs, scarps and stone fields at different levels indicate water level fluctuations (Saarse & Kärson 1982; Rõuk 1987; Rosentau et al. 2007). Inter-drumlin lake basins are filled with glacial, glacio-lacustrine and lacustrine sediments (Pirrus et al. 1987).

Lake Prossa is surrounded by arable landscape with big drumlins of NW–SE orientation. Almost the entire elevated area has been turned into fields and cultivated meadows. The lake is shallow, with peaty shores covered by a floating mat. Only one place near the eastern shore is sandy, otherwise the bottom is covered by gyttja. Basin morphology resembles that of the reversed drumlin. Cross sections along the Prossa basin show rather even bottom topography (Saarse 1994; Fig. 2). The lake is fed by several ditches; the outflow is via a brook to Lake Raigastvere. In this macrophytic lake 22 plant species have been recorded (Mäemets 1968), among which *Typha angustifolia*, *Phragmites communis*, *Equisetum limosum*, *Schoenoplectus lacustris* and *Carex* are prevailing in the littoral zone. Along with floating-leaf taxa, *Potamogeton natans* and *Nuphar luteum* and aquatics *Charophyta*, *Potamogeton lucens*, *P. perfoliatus* and *P. praelongus* are most common.

MATERIAL AND METHODS

In the winter of 2009, 11 overlapping 100 cm long cores (S-2009) were recovered by a Russian peat sampler from the western part of the ice-covered lake. The cores were taken from the littoral zone where deposits contained more organic debris. Earlier studies have shown that sediments from the deeper part contained few terrestrial macros. The cores were described in the field, photographed, sealed in plastic and transported to the laboratory. Pollen analyses were carried out from the core K-1991 located close to the master core (S-2009) and from the lower portion of the core K-2001 in the central part of the lake, close to borehole 3 on the cross section (Figs 1B, 2). The master core (S-2009) was subject to all analyses, except pollen. As Late Glacial clayey deposits are poor in macroremains, material from parallel cores, visually correlated with the master core, was used for the AMS ^{14}C datings. The organic-rich dark brown silt layer at core depth of 531–533 cm, beige sand stripe at 648 cm and homogeneous clayey silt layer at 708–700 cm facilitated correlation of different cores.

Continuous 1 cm thick samples were used for loss-on-ignition (LOI) analyses to estimate the content of organic and mineral matter and carbonate compounds. Organic matter (OM) was measured at 525 °C and

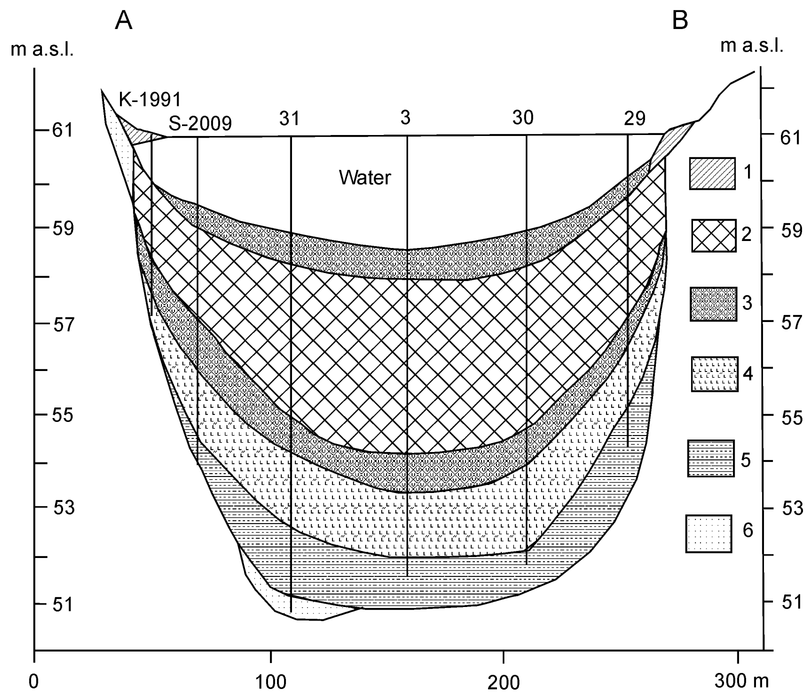

Fig. 2. Stratigraphy of Lake Prossa. For location of the cross section see Fig. 1B. 1, fen peat; 2, gyttja; 3, calcareous gyttja; 4, silt, in the upper part with plant remains; 5, laminated silt and varved clay; 6, sand.

expressed as percentages of dry matter. The percentage of carbonate ($CaCO_3$) was calculated after combusting the LOI residue for 2 h at 900 °C. The amount of the residue containing clastic material and biogenic silica was described as mineral matter and calculated against the sum of organic and carbonate compounds. The grain size distribution for 21 samples was analysed, using the *Partica* laser analyser LA-950V2.

In order to construct the time-scale, seven Accelerator Mass Spectrometry (AMS) ^{14}C dates obtained from the Poznan radiocarbon laboratory and one AMS date from the Trondheim laboratory were calibrated at the one-sigma confidence level, using the IntCal04 calibration curve (Reimer et al. 2004) and Calib Rev 5.0.1 program (Stuiver et al. 2005). Calibrated ages before present (cal yr BP) were applied in the present study.

Pollen analysis was carried out with intervals of samples being routinely 5–10 cm. Altogether 32 samples were analysed and 56 pollen and spore taxa identified. Pollen preparation followed a standard approach (Berglund & Ralska-Jasiewiczowa 1986), with the additional use of heavy liquid treatment (CdJ_2 and KJ solution with the gravity of 2.2 g/cm^3) for samples with a high mineral matter content. A magnification of ×400 and phase contrast at ×1000 for critical determinations were used. Pollen diagrams were plotted with the TILIA and TGView programs (Grimm 2003, 2007). The basis for the percentage calculations was the sum of terrestrial pollen. The percentages of the other identified microfossils were calculated from the basic pollen sum. Redeposited pollen and pre-Quaternary morphs were also identified and displayed in the pollen diagram.

RESULTS

Sediment lithostratigraphy

In the master core (S-2009) basal sandy silt (till) is overlain by reddish-brown varved clay (core depth 745–708 cm) in which 29 annual varves were identified (Fig. 3, Table 1). Varved clay is covered by a beige 8 cm thick massive clayey silt bed at 708–700 cm. It is followed by beige-brown laminated clayey silt at 700–670 cm where 36 couplets were encountered. However, it is not clear whether they are real annual varves or not. Upwards lamination is badly visible, but six sandy layers are easily distinguishable between 670 and 650 cm. Silt includes irregular black stripes, which are obviously pyritized. Beige sandy silt at 650–628 cm ends with one such dark stripe. Silt with plant remains between 628 and 589 cm is characterized by alternation of dark and light bands, but is generally grey in colour. These sediments are overlain by greenish-grey clayey silt at 589–550 cm rich in plant remains, mostly *Drepanocladus*.

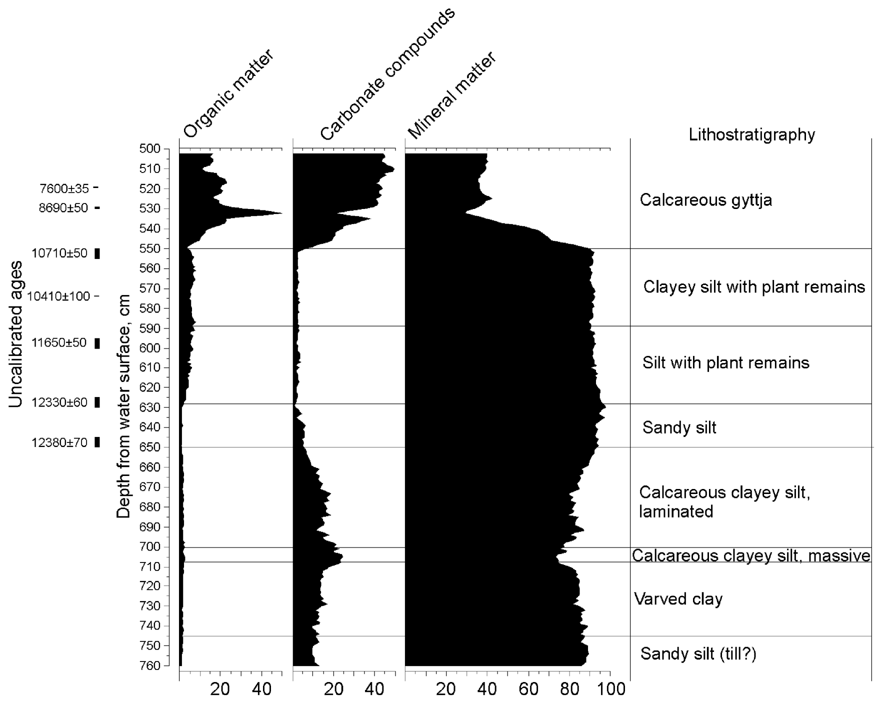

Fig. 3. Distribution of organic matter, carbonates and mineral matter in the Prossa sediment core S-2009 with indication of AMS ^{14}C dates.

Table 1. Lithology of the master core from Lake Prossa (S-2009)

Depth below water surface, cm	Sediment description
500–550	Calcareous gyttja with abundant mollusc shells, olive-brown
550–589	Clayey silt with plant detritus, greenish-grey
589–628	Silt with plant detritus, grey
628–650	Sandy silt, beige
650–700	Laminated clayey silt, beige-brown
700–708	Massive clayey silt, beige
708–745	Varved clay with thick annual laminae, reddish-brown; 29 annual varves
745–760	Calcareous sandy silt, reddish-brown (till?)

The boundary between the Late Glacial and Holocene sediments at 550 cm is sharp due to a hiatus caused by water level lowering. The total thickness of gyttja in the coring site S-2009 was 3.9 m. The basal olive-brown calcareous gyttja layer at 550–500 cm contained abundantly subfossil mollusc shells (Table 1).

LOI results

The content of OM in the lowermost clayey sediments (core depth 760–630 cm) was less than 2%, but carbonate content fluctuated around 10–15% and reached 24% between 708 and 700 cm in massive clayey silt (Fig. 3). Organic matter content increased from 2% to 4% between 630 and 620 cm and stabilized around 5–6% between 620 and 550 cm, together with a decrease in carbonate compounds to 1–3%. Gyttja was rather calcareous from a core depth of 550 cm upwards, with carbonate fraction reaching 40–45% and organic matter 15–20%. One OM-rich interlayer was detected at 532–531 cm (Fig. 3).

Grain-size composition

Five different units were distinguished on the basis of grain-size composition (Fig. 4). The basal unit (Pr-1, 760–745 cm) is sandy silt (till), which differs from the overlying sediments in high sand fraction (34%) and low clay fraction (8%) contents. Unit Pr-2 (745–650 cm) is laminated clayey silt with domination of silt fraction (54–73%). Clay fraction reached its highest (35%) at a core depth of 730 cm. Sand fraction fluctuated between 4% and 18%, being lowest between 700 and 690 cm. Sandy silt (unit Pr-3, 650–628 cm) includes 2–4% clay and up to 24% sand fraction. The next silt unit (Pr-4, 628–589 cm) differs from the other beds in a high content of silt fraction amounting to 83–88%. The content of sand is 7–9% and that of clay fraction 3–8%. In the topmost unit analysed, Pr-5 (589–550 cm), sand fraction decreased to 1–3% and clay fraction content increased to 19%. Silt fraction overwhelmingly dominated in the studied portion of sediments, fluctuating between 70% and 88%.

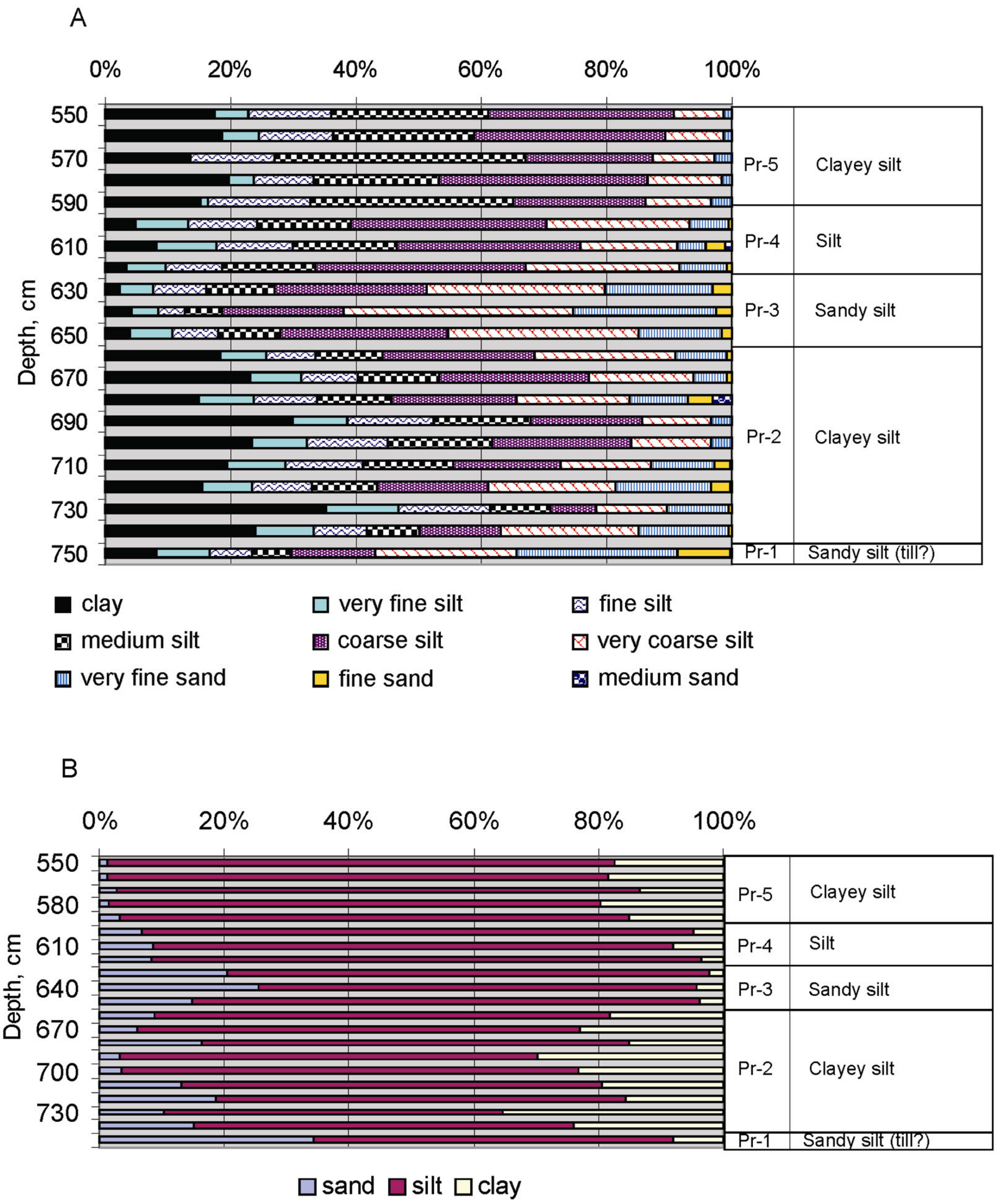

Fig. 4. A, grain-size composition of Lake Prossa Late Glacial sediments. **B**, summary grain-size from the master core S-2009.

Chronostratigraphy

Altogether eight AMS ^{14}C dates are available from Late Glacial deposits of Lake Prossa: seven from the master core S-2009 and one from the core K-1991. In the age–depth model (Fig. 5) AMS dates from the master core were considered. The basal reddish-brown till and varved clay (core depth 760–708 cm) did not contain terrestrial macrofossils and therefore AMS dates are absent, but annual varves were rather clear, forming 29 couplets, in the central part of the lake obviously more. Thirty-six couplets were distinguished in the stratified calcareous clayey silt between 700 and 670 cm, however, varve counting in these rhythmites was aggravated. *Dryas octopetala* leaves and *Carex* seeds were indentified between 650 and 645 cm. An AMS date from *Dryas* leaves showed an age of 12 380 ± 70 (14 160–14 580 cal yr BP), which is the oldest date for the whole Prossa sequence (Table 2). According to AMS radiocarbon dates, sandy silt (corresponds to the isolation event) between 650 and 625 cm deposited during 50 years (Table 2). Silt enriched with plant detritus between 625 and 575 cm was formed between 14 200 and 12 300 cal yr BP (Fig. 3). The boundary between the Late Glacial and Holocene sediments at 550 cm is sharp as it includes a hiatus confirmed by the pollen record. Such a hiatus is characteristic of the littoral zone and indicates water level lowering. The AMS date (9620 ± 65 cal yr BP) from the organic-rich bed close to the calcareous gyttja lower limit corresponds to the Boreal chronozone and macroremains at 520 cm showed an age of 8400 cal yr BP (Table 2). One date (10 710 ± 50) appeared to be too old and was rejected from the age–depth model and the date 11 810 ± 115 (13 500–13 790 cal yr BP) from the core K-1991 was considered when interpreting the results of pollen analyses (Fig. 6).

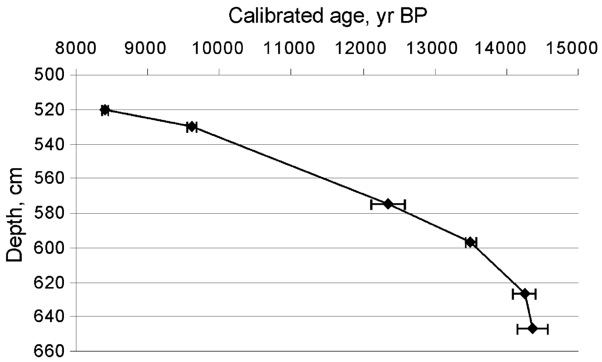

Fig. 5. Age–depth model of Lake Prossa sediment.

Biostratigraphy

Pollen stratigraphy of the Saadjärv Drumlin Field lakes is well studied and available in several publications (Pirrus 1969, 1971, 1983; Pirrus & Rõuk 1979). For this reason the main characteristics of the local pollen assemblage zones are summarized in Table 3 and shown in Fig. 6. The zonal names such as Older Dryas, Allerød and Younger Dryas refer to chronozones as defined by Mangerud et al. (1974).

Table 2. AMS radiocarbon dates from the Lake Prossa master core (S-2009)

Depth below water surface, cm	AMS date	Lab. No.	Calibrated age with indication of the mean value	Dated material
520	7 600 ± 50	Poz-38460	8 365 – 8 430 8 400 ± 35	*Dryas* leaves
529–530	8 690 ± 50	Poz-35525	9 555 – 9 685 9 620 ± 65	Coarse detritus gyttja
550–555	10 710 ± 50	Poz-35466	12 735 – 12 825 12 780 ± 45	Macros, unidentified
575	10 410 ± 100	Poz-38459	12 105 – 12 580 12 345 ± 240	*Dryas* leaves
595–600	11 650 ± 50	Poz-35467	13 420 – 13 575 13 500 ± 80	Macros, unidentified
625–630	12 330 ± 60	Poz-35468	14 090 – 14 405 14 245 ± 155	Macros, unidentified
645–650	12 380 ± 70	Poz-36169	14 165 – 14 580 14 370 ± 205	*Dryas* leaves

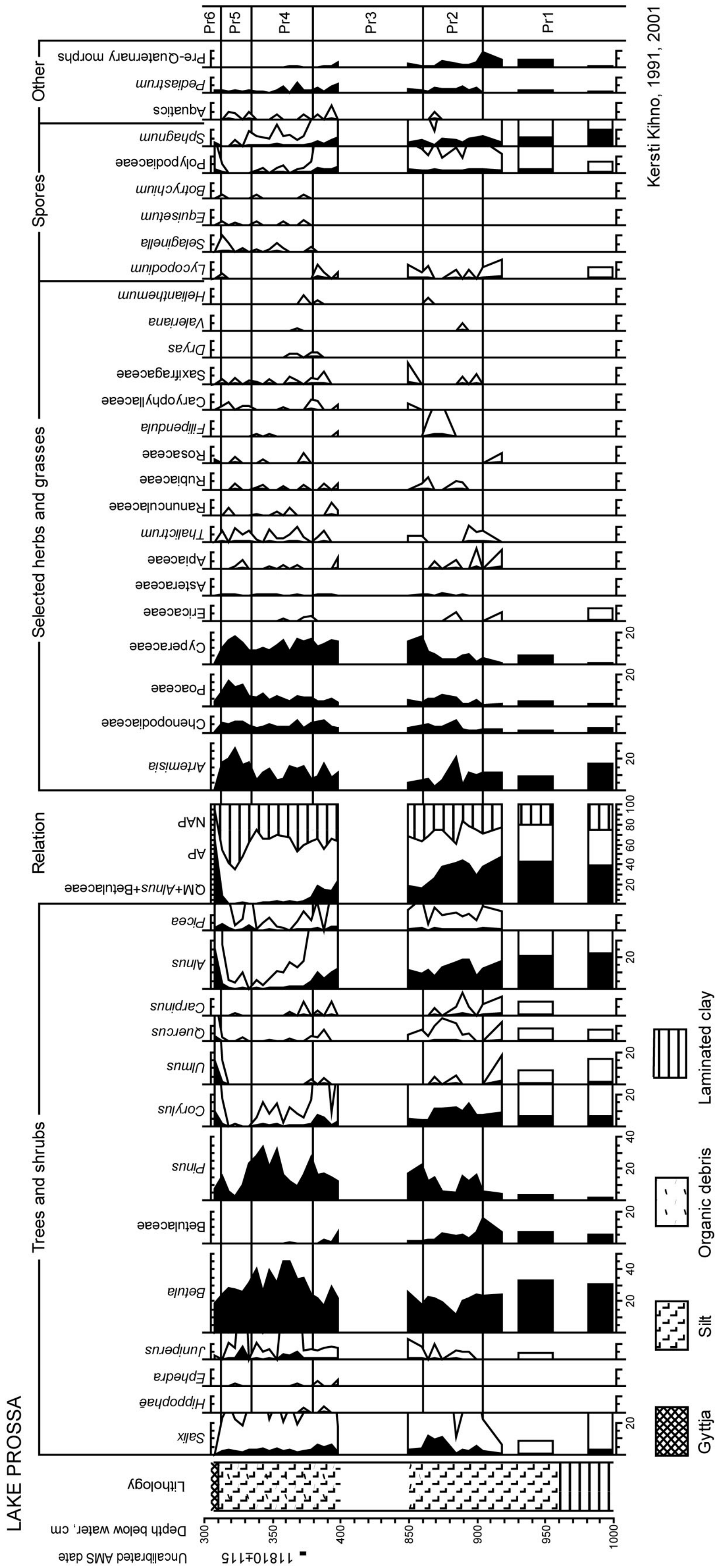

Fig. 6. Pollen diagram from the Prossa sediment cores K-1991 (385–310 cm) and K-2001 (1000–850 cm). Analyses by K. Kihno.

Table 3. Short description of pollen records from the Lake Prossa cores K-2001 (860–1000 cm) and K-1991 (310–385 cm), with indication differentiated local pollen assemblage zones (LPAZ)

Depth below water surface, cm; LPAZ	Short description of pollen spectra
900–1000; Pr-1	High share of *Betula*; *Pinus* and *Salix* increasing upwards. Significant proportion of redeposited *Alnus*, *Corylus* and QM taxa. Among NAP *Artemisia* is dominating
860–900; Pr-2	Sharp decrease in *Betula* and *Pinus* in the middle of the LPAZ coincides with the *Artemisia* peak, maximum of *Salix*, slight increase in Chenopodiaceae and Poaceae
375/860; Pr-3	Rise of *Betula*, *Pinus* and Cyperaceae, decrease in *Salix* and redeposited pollen
335–375; Pr-4	*Betula* and *Pinus* dominating, but curves are fluctuating. Decrease in *Salix*. *Alnus* and QM taxa are very low. In the upper part *Hippophaë*, *Dryas* and *Helianthemum* pollen disappeared
312–335; Pr-5	Rich in NAP assemblage. Increasing levels of *Artemisia*, Poaceae and Cyperaceae. Reduction of total AP, especially *Pinus*. *Salix* is stable, *Juniperus* has a small peak
310–312; Pr-6	Long-lasting hiatus between Late Glacial and Holocene deposits

DISCUSSION

Vegetation development

The most complete Late Glacial pollen record of the Saadjärv Drumlin Field comes from Palaeolake Visusti, 3.7 km SW from Lake Prossa (Pirrus 1971; Pirrus & Raukas 1996). Silty and laminated clayey deposits (800–640 cm) at the Visusti site contain about 30% herb pollen with *Artemisia* dominating (Pirrus 1971; Fig. 7). Among tree pollen *Betula* and *Pinus* were recorded, with a considerable proportion of redeposited *Alnus*, *Corylus*, *Picea* and broad-leaved taxa. High frequency of tree pollen obviously results from long-distance transport, typical of open landscape. The pollen production of local taxa is very low, among which *Betula nana*, *Salix*, *Selaginella selaginoides*, *Dryas octopetala* and steppe xerophytes *Eurotia ceratoides*, *Ephedra* and halophilous taxa *Kochia prostrata*, *Salsola kali* and *Salicornia herbaceae* have been identified (Pirrus 1971). The last two species grow on the sea coast and their presence has been explained by the formation of slightly salty soils during the primitive soil formation (Pirrus 1983). Such pollen spectra are characteristic of the Older Dryas, the lower part possibly even of the Bølling. In the Allerød chronozone Pirrus (1971) has differentiated and described in detail the *Pinus–Betula* and *Pinus* subzones. The Younger Dryas is characterized as an *Artemisia–Betula nana* zone, with a high frequency of NAP up to 40–60% (Pirrus & Raukas 1996).

Pollen assemblages of the Lake Prossa core are similar to those of Visusti (Figs 6, 7). The sediment between 1000 and 850 cm (Fig. 6, Pr1, Pr2) contained abundantly pollen redeposited from the Eemian strata, first of all *Alnus*, *Corylus*, *Ulmus*, *Quercus* and *Carpinus*, which increased the arboreal pollen (AP) frequency. *Salix* was present throughout the studied sequence. Nonarboreal pollen (NAP) includes *Artemisia*, few Chenopodiaceae and Poaceae. Such pollen spectra are characteristic of the Older Dryas and Early Allerød. The shrub and herb tundra community, first of all periglacial light-demanding bushes of *Betula nana* and *Salix*, dominated on the drumlin surfaces. *Salix polaris*, a pioneering dwarf shrub, is adapted to low summer temperature and carbonaceous raw soils (Sarmaja-Korjonen et al. 2006) and was widespread in the Saadjärv Drumlin Field. Macrofossil analysis supports the open tundra-type vegetation, based on findings of *Dryas* leaves and *Betula nana* seeds near the Older Dryas/Allerød boundary with abundant *Drepanocladus*, an inhabitant of the aquatic environment. The average temperature of July could have been below 11 °C (Virtanen et al. 2004), it means 5–6 °C less than the present temperature.

The second half of the Allerød brought about climate amelioration and growth of species richness (Fig. 6, Pr4), indicating ongoing colonization by vegetation. The proportion of AP increased, whereas records of redeposited *Alnus* and QM taxa strongly declined. *Betula* and *Pinus* pollen reached a maximum, accompanied by the disappearance of some taxa, such as *Hippophaë*, *Ulmus*, *Helianthemum* and *Dryas*. The *Pinus* stomata find around 13 300 cal yr BP at Nakri marks *Pinus* arrival in South Estonia (Amon et al. accepted). The temperature of July could have been 12–13 °C, considering the threshold temperature requirement for the flowering of *Pinus* and *Betula* (Kuoppamaa et al. 2009).

Younger Dryas climate deterioration caused the flourishing of cold-tolerant herbs and shrubs (Fig. 6, Pr5). Once again *Cyperaceae*, Chenopodiaceae, *Artemisia* and

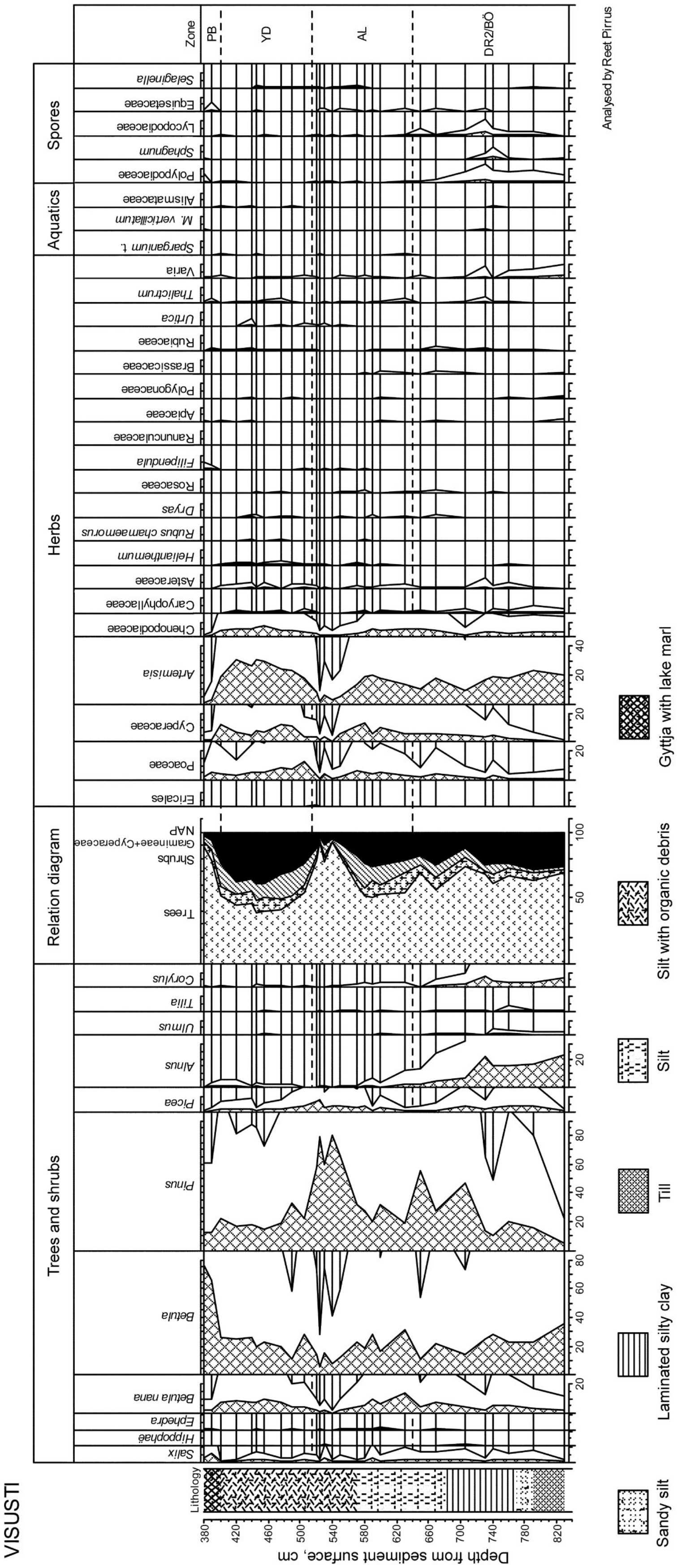

Fig. 7. Simplified pollen diagram from Palaeolake Visusti. Analyses by R. Pirrus. *M.*, *Myriophyllum*.

Poaceae prevailed among herbs, forming up to 60%, and *Juniperus* reached its maxima. *Betula* pollen frequency surpassed that of *Pinus*, which allows us to suggest that single *Betula* stands could have survived the Younger Dryas on the drumlins, but pine has been present with sparse trees, if ever. The absence of tree macroremains at the Nakri site refers to treeless vegetation (Amon et al. accepted). The arrival of *Picea* could be suggested on the basis of pollen percentages (in Visusti up to 9% at the end of the Allerød), but macroremains confirming spruce occurrence in southern and central Estonia have not been found so far. At the same time, *Betula*, *Pinus* and *Picea* macroremain finds in south-eastern Latvia prove the presence of tree population throughout the Younger Dryas (Heikkilä et al. 2009). Obviously the climate conditions were too harsh for temperate trees as mean annual temperature could have been about 9–10 °C below the present-day mean (Arppe & Karhu 2010). The temperature of the warmest month was possibly 10 °C in southern Estonia (Renssen & Isarin 2001) and 8–10 °C in North Estonia, considering the temperature requirement that allows *Potamogeton filiformis* to generate (Isarin & Bohncke 1999; Amon & Saarse 2010). Cold climate and rather open landscape during the Younger Dryas favoured the occurrence of woolly mammoth in Estonia (Ukkonen et al. 2011). Its remains have been found in Puurmanni, ca 17 km SW from Prossa and dated to 11 700–12 100 cal yr BP (Lõugas et al. 2002).

A hiatus between the Late Glacial and Holocene sediments has been registered at several sites of the Saadjärv Drumlin Field (Saarse 1994). The gap in sedimentation in our main core (S-2009) lasted at least for 200 years, but considerably longer, up to the Subboreal, in the K-1991 core.

Depositional conditions in Lake Prossa

A proglacial lake which inundated the southern part of the Peipsi basin, Saadjärv Drumlin Field and the Võrtsjärv basin was formed in front of the retreating ice margin (Raukas & Rähni 1968; Raukas et al. 1971; Rosentau et al. 2007). During deposition of varved clay and laminated silt, the ice margin was close to Lake Prossa, which ensured rich sediment supply and formation of thick annual varves. Such conditions lasted for a rather short time, as can be concluded from the number of varves counted in the neighbouring Lake Pikkjärv (63) (Rosentau et al. 2007) and in the Lake Prossa littoral zone (29). Due to ice margin withdrawal and water level lowering, varved clay formation was replaced by the laminated silt deposition. During this sediment cycle Lake Prossa was still flooded and influenced by the ice sheet through proglacial streams which carried carbonate-rich material into the basin (Fig. 3). The AMS ^{14}C dates confirm that sediments corresponding to the proglacial environment deposited before 14 200 cal yr BP (Table 2). Due to ice retreat and opening up of new outflow channels, water level lowered to the threshold elevation (61 m a.s.l.) and Lake Prossa isolated. The water level lowering was accompanied by increased erosion and formation of more sandy deposits (core depth 650–630 cm, Figs 3, 4). The isolation contact at 630–628 cm is marked by a decreased carbonate content, increased OM and sand fraction, disappearance of laminated structure and change of colour from beige to grey. X-ray diffractograms show clear difference between varved clays and silts (L. Saarse unpublished data). Hydromicas formed 65–75% of varved clays, but decreased to 14–32% in silts, which definitely refers to a change in sedimentation conditions.

After isolation of Lake Prossa at the beginning of the Allerød, silt with plant remains deposited (Fig. 3). The supply of carbonate-rich inflow was interrupted and the sedimentation rate slowed down. In the studied core the sediments between 650 and 550 cm were formed during ca 2300 years, in contrast to stratified sediments between 745 and 650 cm which obviously accumulated during 100–200 years. The sedimentation rate was especially tardy during the Younger Dryas, when an only 20–30 cm thick bed was formed (Fig. 6). Increased frequency of *Sphagnum*, *Equisetum* and *Selaginella selaginoides* in pollen composition refers to paludification and water level lowering from the Allerød onwards.

Age of the ice-marginal zones

The Saadjärv Drumlin Field lies between the Otepää and Pandivere ice-marginal zones (Kalm 2006) where two deglaciation stades, Piirissaar–Selguse–Laeva and Siimusti–Kaiu, have been proposed (Raukas et al. 1971) and tentatively dated to 13 800–14 000 and 13 600–13 800 cal yr BP (Rosentau et al. 2007). Lately the age of the Pandivere ice-marginal zone has been revised on the basis of the AMS ^{14}C dates from the Haljala (Saarse et al. 2009) and Udriku sites (Amon & Saarse 2010). As the obtained age of 13 800 cal yr BP is ca 500 years older than suggested earlier, the age of the above-mentioned stades is also older, verified by AMS dates from Prossa. *Dryas octopetala* leaves from sandy silt at a core depth of 650–645 cm and macro-remains at a depth of 630–625 cm, respectively, showed the ages of 14 370 ± 205 and 14 245 ± 155 cal yr BP (Table 2). It means that by 14 200–14 300 cal yr BP the ice margin should have retreated north of Lake Prossa and the Piirissaar–Selguse–Laeva line.

CONCLUSIONS

Pollen, plant macrofossils, AMS ^{14}C dates and lithological parameters indicate considerable changes in the sedimentation environment during the Late Glacial period. Ice retreat north of Lake Prossa and the formation of a proglacial lake facilitated rather quick deposition of varved clays and laminated silt within 100–200 years, most probably at the end of the Bølling(?) and during the Older Dryas. This period is characterized by pioneer vegetation with dwarf-shrubs. Allerød and Younger Dryas minerogenic sediments have been deposited in an isolated lake and their LOI and grain-size composition are rather homogeneous, but pollen assemblages differ largely, first of all the AP to NAP ratio and frequency of redeposited pollen. Two AMS dates suggest that sedimentation in Lake Prossa started no later than 14 200–14 300 cal yr BP, affirming that its surroundings were free of ice. These dates roughly define the age of the Piirissaar–Selguse–Laeva stade as well.

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Taimestik, sedimentatsioon ja jää taandumise kronoloogia Hilis-Glatsiaalis Prossa järve ümbruses Kesk-Eestis

Kersti Kihno, Leili Saarse ja Leeli Amon

On analüüsitud taimestiku arengut, setete kuhjumist ja jää taandumist Prossa järvest kogutud hilisglatsiaalse materjali põhjal. AMS-dateeringud näitavad, et jää hakkas siit taanduma juba 14 200–14 300 aastat tagasi, mis on ligikaudu 300 aastat varem, kui seni oletati.