Proc. Estonian Acad. Sci. Geol., 1998, **47**, 1, 20–30

EARLY HOLOCENE VEGETATION HISTORY AND SHORELINE DISPLACEMENT OF THE BALTIC SEA AT THE MUSTJÄRVE BOG, NORTHWEST ESTONIA

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Received 19 September 1997

Abstract. Two new pollen diagrams from the isolation sediments of the Mustjärve Bog support the pre-Ancylus lowstand of the Baltic Sea, when high isostatic uplift resulted in the emergence and isolation of the Mustjärve basin 9600 ^{14}C BP. Black, highly humic organic material accumulated in relatively dry conditions. The high share of *Pinus* pollen in the Pre-Boreal sediments, earlier correlated with the Boreal, appears to be of local origin as indicated by pine stomata. The shoreline of the Yoldia Sea retreated to 28 m a.s.l. or lower. The Ancylus transgression reached 32–33 m a.s.l. 9100 ^{14}C BP at Mustjärve.

Key words: vegetation history, shoreline displacement, Early Holocene, buried organic matter, the Baltic Sea.

INTRODUCTION

The surroundings of the Mustjärve Bog have been of interest for Quaternary scientists since the last century when Schmidt (1869) described freshwater molluscs and buried organic material at Piirsalu. Kessel (Kessel, 1966; Kessel & Raukas, 1967) has studied several sites with organic layers covered by Ancylus coastal deposits in the area. Recently Ploom et al. (1996) reported of a new site of buried organic material at Põlluotsa some 10 km north of Mustjärve. Also, some of the isolation basins since 10 200 BP have been studied (Poska, 1994). Compared to the rest of Northwest Estonia, the area is important due to relatively undulating glacial and bedrock topography, offering isolation basins and ancient shorelines. The major topographic features are the Palivere end-moraine which marks the standstill of the last ice-sheet around 12 000 years ago, radial eskers north of Ellamaa, and bedrock (limestone) elevations at Piirsalu and Turvaste.

Lake Mustjärv (also Turvaste Mustjärv) and the surrounding Mustjärve Bog lie at the border of the Lääne and Harju Counties in Northwest Estonia (59º04´30´´ N, 24º06´00´´ E), in a depression between an esker ridge of the Palivere ice-marginal zone in the east and coastal formations of Ancylus time in the west (Fig. 1). The bog is 2 km in diameter and the thickness of organic deposits in the central part reaches 7.5 m. The coastal formations west of the bog are covered with dunes (up to 45 m a.s.l.). In the western part of the bog, between the lake and the dunes, below peat and lake sediments lies a 10 cm thick layer of highly humic black organic matter resembling soil or decomposed woody fen peat (Fig. 2). This suggests the pre-Ancylus lowstand of the Baltic Sea, when due to great isostatic uplift the depression of Mustjärve emerged and woody fen peat accumulated in relatively dry conditions at the bottom of the basin. During the transgression of the Ancylus Lake, Mustjärve depression was flooded as indicated by a thin sand layer on top of the mentioned peat.

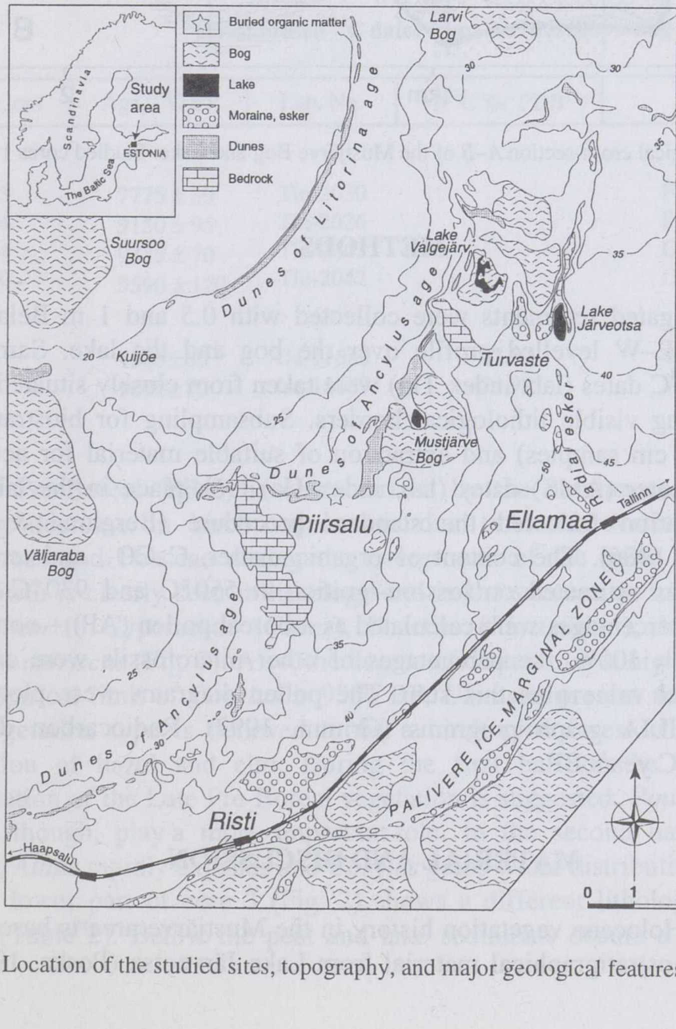

Fig. 1. Location of the studied sites, topography, and major geological features of the area.

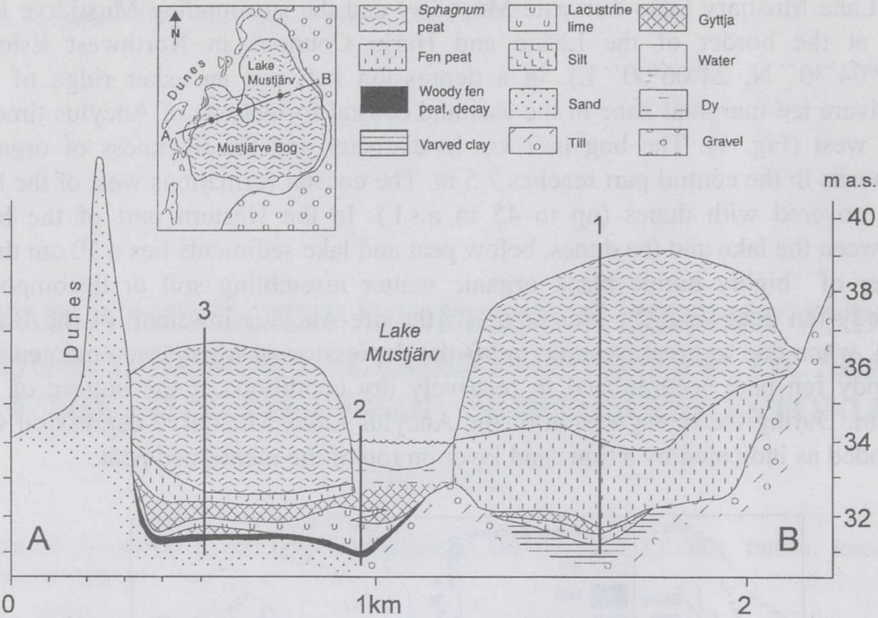

Fig. 2. Geological cross-section *A–B* of the Mustjärve Bog and Lake. Studied cores 1 and 3.

METHODS

The investigated sediments were collected with 0.5 and 1 m Belarus peat corers on an E–W levelled profile over the bog and the lake. Samples for conventional ^{14}C dates (lab. index Tln) were taken from closely situated parallel cores, following visible lithological borders. Subsampling for biostratigraphic studies (0.5–1 cm samples) and extraction of suitable material for accelerator mass spectrometer (AMS) dates (lab. index Ua) took place in the laboratory. Pollen preparation followed the standard procedure (Berglund & Ralska-Jasiewiczowa, 1986). The content of organic matter, $CaCO_3$, and terrigenous compounds was estimated on loss-on-ignition at 550 °C and 930 °C for four hours. Pollen percentages were calculated as arboreal pollen (AP) + nonarboreal pollen (NAP) = 100%, the percentages of other microfossils were calculated from the actual value plus this sum. The pollen diagrams were plotted with TILIA and TILIA graph programs (Grimm, 1992). Radiocarbon dates are uncalibrated ^{14}C years BP.

MATERIAL AND DISCUSSION

The Early Holocene vegetation history in the Mustjärve area is based on the bio- and chronostratigraphical material from Lake Järveotsa (Poska, 1994) and on the more central core 1 of the Mustjärve Bog (Fig. 2). The chronostratigraphy is based on four conventional dates (Table 1) from core 1. Two AMS dates from core 3 are correct, but rather considered not to represent the stratigraphical levels they are taken from due to misfortunate sampling. According to the biostratigraphical material from Lake Järveotsa (Poska, 1994), the Early Pre-Boreal vegetation (PB-1) consisted of a *Betula–Pinus* dominated open heath-forest with a variety of light-demanding shrubs such as *Betula nana*, *Juniperus*, and *Hippophaë* as well as herbs in the under-layer. Similarly to Lake Järveotsa, the Early Pre-Boreal vegetation at Mustjärve (Fig. 3) was an open *Betula–Pinus–Juniperus–Hippophaë* community with up to 50% of NAP, mostly Cyperaceae. Light-demanding herbs, such as *Artemisia*, Chenopodiaceae, *Polygonum aviculare*-type, *Saxifraga oppositifolia*, and Ericaceae, occur widely. One of the reasons for this is the closeness of the northeastern shore of the ancient basin.

Table 1

Uncalibrated ^{14}C dates from the Mustjärve Bog

Depth, cm	Age, ^{14}C BP	Lab. No.	δ^{13}C ‰ PDB	Material
Core 1				
563–573	7775 ± 80	Tln-2030		Fen peat, bulk
714–724	9150 ± 95	Tln-2026		Fen peat, bulk
724–734	9315 ± 70	Tln-2043		Gyttja, insoluble
740–750	9590 ± 120	Tln-2042		Gyttja, insoluble
Core 3				
499	7885±60	Ua-11688	–27.57	Wood, insoluble
508	9080±70	Ua-11689	–29.98	Wood, insoluble

Late Pre-Boreal (PB-2) is characterized by the dominance of *Betula* (the seeming decrease in birch values are due to local overrepresentation of Cyperaceae and Poaceae during the overgrowth of the basin 9200 BP). The overgrowth is clearly seen in lithology and in the succession from aquatics and *Pediastrum* to Cyperaceae (*Carex*), Poaceae (*Phragmites*), *Menyanthes*, and *Cladium mariscus* (Fig. 3). Also, the degree of destruction is high in the fen peat. The empirical limit of *Corylus* is 9300 BP, *Ulmus* is present somewhat earlier. The vegetation type is believed to be a birch–pine forest with the growing proportion of hazel and elm. During the first half of the Boreal (BO-1), continuation of the Late Pre-Boreal vegetation is suggested, *Pinus*, *Corylus*, and *Ulmus*, though, play a more important role. In the second half of the Boreal (BO-2), *Alnus* rapidly expands and *Corylus* gains wider distribution.

The lower part of core 3 (Fig. 2) shows a different lithology from that of core 1 (Table 2). Below the peat and lake sediments occurs a layer of highly humic black organic matter resembling decay, soil, or decomposed woody fen peat (Fig. 2). The organic content in the layer is up to 80%. In the investigated section the peat is overlain by a thin layer of sand, sandy gyttja, and lake lime. The biostratigraphical material clearly shows that the sand below the black organic matter contains redeposited pollen grains of, e.g., *Alnus, Quercus, Fraxinus,* and *Corylus* from the surrounding glacial sediments (Fig. 4). The pollen composition of the peat itself is highly dominated by *Pinus* pollen. The AP/NAP ratio in favour of the first shows closed growing conditions, moreover, numerous finds of *Pinus* stomata (ventilating organs in needles) indicate that pine trees were growing in the immediate vicinity of the sampling point. Unlike pollen, needles do not travel over great distances by wind but rather drop nearby the tree.

Table 2

Lithology of the lower parts of cores 1 and 3 from the Mustjärve Bog

(for core 3 see also Fig. 5)

Core 1		Core 3	
Depth, cm	Sediment description	Depth, cm	Sediment description
600–724	Unconsolidated woody–*Carex–Phragmites* fen peat	471–475	Beige lake lime
		475–481	White lake lime with subfossil mollusc shells
		481–492	Grey sandy lake lime with subfossil mollusc shells
724–750	Gyttja with coarse plant remains	492–495	Light brown sandy calcareous gyttja
750–758	Silt with plant remains	495–502	Brown sandy gyttja with subfossil mollusc shells
758–763	Silty sand	502–505	Sand with organic debris and mollusc detritus
763–777	Clayey silt	505–512	Black compressed organic matter (fen peat or decay) with pieces of wood
777–790+	Varved clay	512–520+	Grey sand with organic and mollusc debris

The destruction degree of pollen in the peat is high and neither algae nor pollen from aquatic plants is registered, which suggests a relatively dry environment. The vegetation type is thought to be a *Pinus* forest with ferns, *Polypodium vulgare*, *Selaginella*, and *Lycopodium complanatum* in the underlayer. All these pteridophytes prefer somewhat damp sandy minerogenic soil and pine forest.

Similar organic layers at an altitude of 32 m a.s.l. below transgressive Ancylus sediments at Piirsalu, 1.5 km SW of the Mustjärve Bog (Kessel, 1966), and at 28.8 m a.s.l. in the depression of Lake Valgejärv, 2.5 km NE of the Mustjärve Bog (Kessel & Raukas, 1967), have been analysed biostratigraphically (Fig. 6), but not dated. Of these, Piirsalu-3 and especially Piirsalu-1 with 80% of pine and a high amount of ferns resemble the material from

Fig. 3. Pollen diagram from the Mustjärve Bog, core 1.

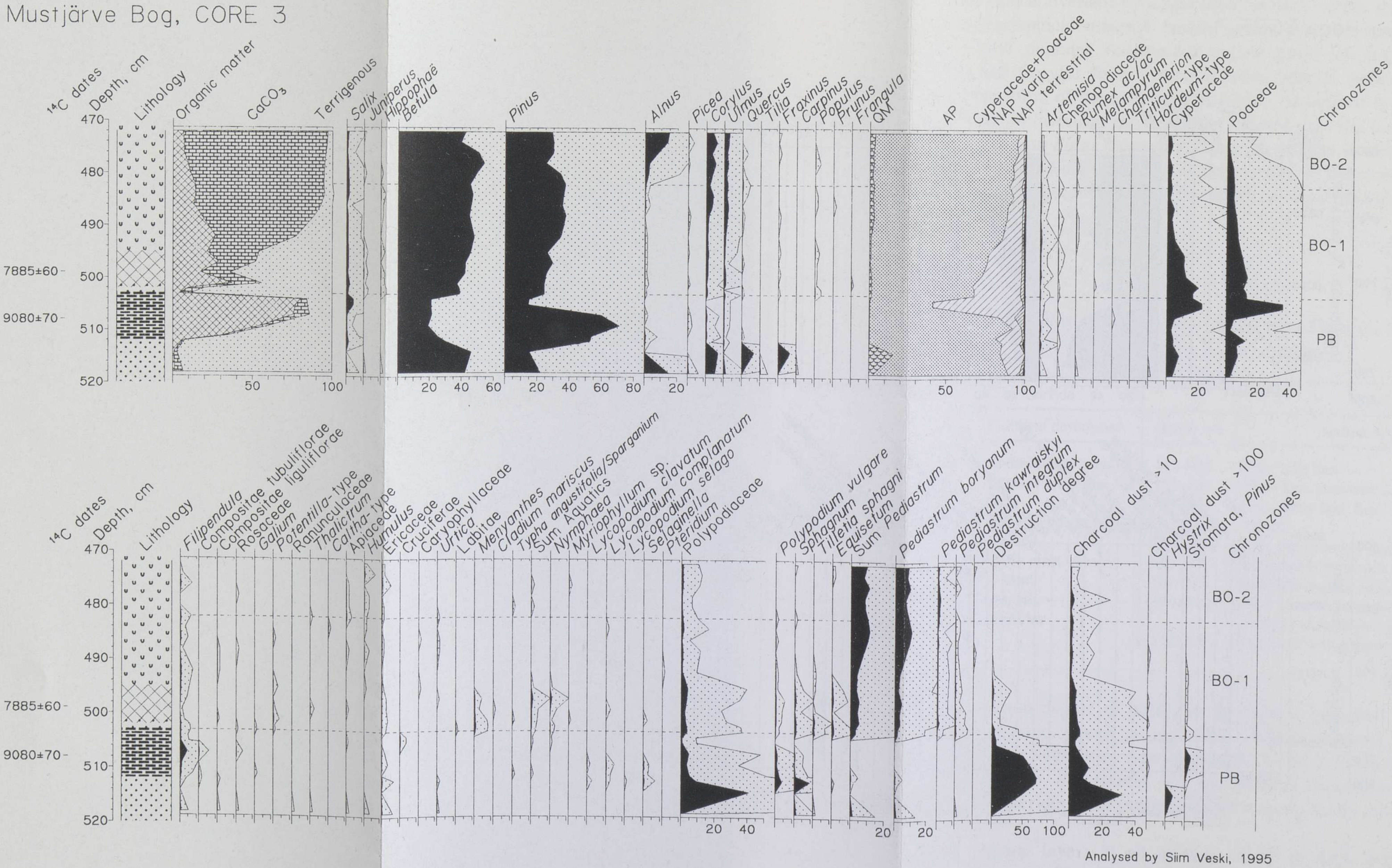

Fig. 4. Pollen diagram from the Mustjärve Bog, core 3. For lithology refer to Fig. 3.

Mustjärve core 3. So does the 10 cm of buried organic material at Põlluotsa, 10 km north of Mustjärve at 31.0 m a.s.l., the lower part of which is dated to 9350±70 BP (Tln-2023; Ploom et al., 1996).

The age of the peat at Mustjärve remains under discussion although the timescale of core 3 is supported by two AMS dates (Table 1). As mentioned above, the dates, especially 7885±60, Ua-11688, are considered not to represent the stratigraphic levels they are taken from. Both datings were carried out on unidentified pieces of wood, which in the worst case could be roots penetrating the peat. As the black humic layer, from which the wood sample Ua-11689 (9080±70 BP) was taken, formed in dry conditions and is thus made up of totally decomposed material, the surviving piece of wood may represent the period of time when the rising water level of the Ancylus Lake reached the threshold of the Mustjärve basin and improved the preservation conditions (see the curve of destruction degree, Fig. 4). Indirectly the date 9080±70 BP could point to the time of the transgression maximum of the Ancylus Lake in the area.

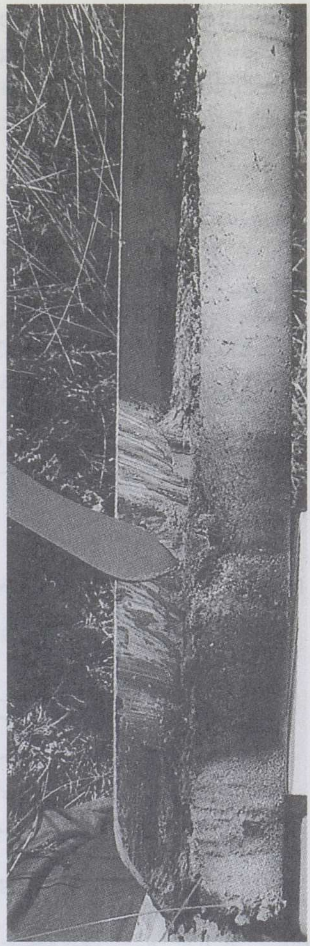

Fig. 5. Isolation sediments of the Mustjärve Bog, core 3. The black highly humic organic matter (woody fen peat or decay) lies on sand. The peat is overlain by 3 cm of sand (pointed with a knife tip), 7 cm of sandy gyttja and lake lime. The extent of the whole core section is 50 cm. (Photo by Siim Veski, 1994.)

The threshold altitude of the Mustjärve depression of 32.0–33.0 m a.s.l. marks the highest level of the transgression shown by the limited amount of sand overlying the peat. Probably only occasionally high stormwater flooded the Mustjärve basin, depositing sand on top of the peat. The efforts to discover large-lake freshwater diatoms in the sand ended in vain as the sediments were barren of any diatoms or they had dissolved (A. Heinsalu, pers. comm.). Nevertheless, diatoms typical of the Ancylus stage, such as *Aulacoseira islandica*, indicating Ancylus inundation, have been recorded elsewhere from similar thin sand and silt layers overlying Pre-Boreal peat (Heinsalu & Veski, 1996). The sandy gyttja in core 3 represents the sediment of a shallow coastal lake with wet surroundings, as indicated by a reed-belt (the curve of Poaceae), *Menyanthes*, and *Equisetum*. The forest composition with *Betula* and *Pinus* dominating is typical of the Pre-Boreal–Boreal transition. The date 7885±60 BP is obviously too young, most probably due to misfortunate sampling of a tree root penetrating from above (from the time when woody–*Carex–Phragmites* fen peat started to accumulate at the sampling point; Fig. 2). The conclusion is based on the rational limit of *Alnus* which is roughly dated to 8500 BP in core 1 and West Estonia in general.

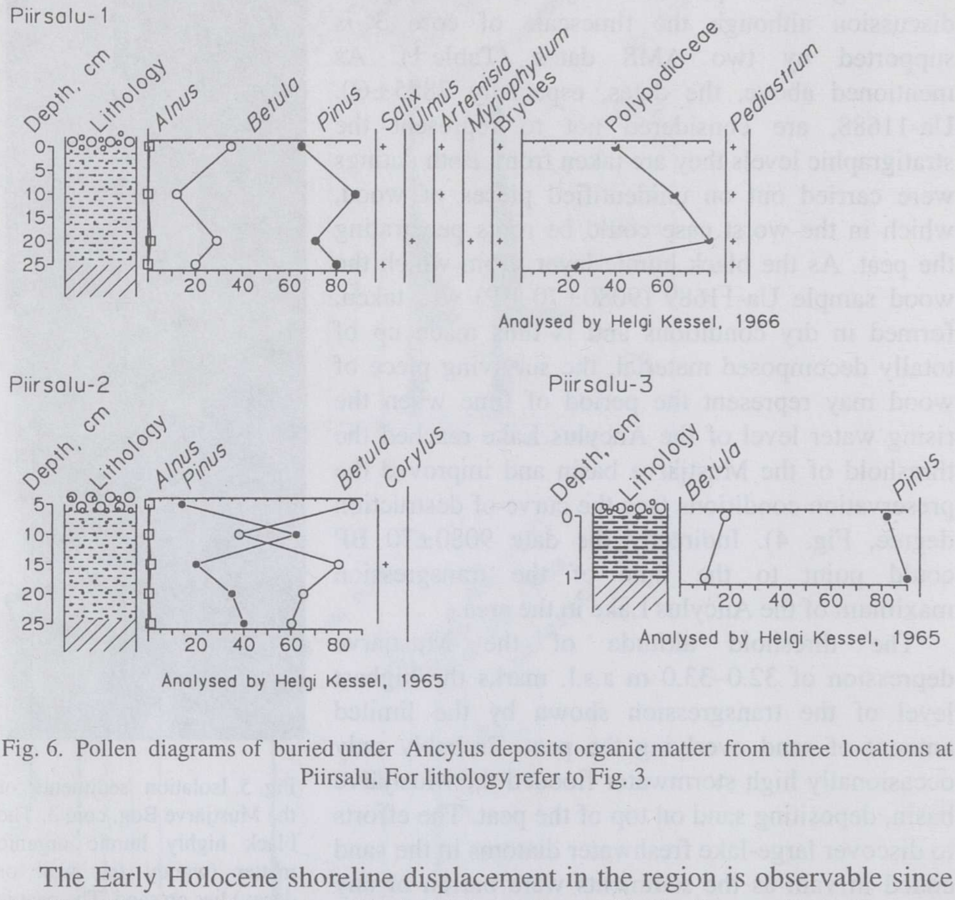

Fig. 6. Pollen diagrams of buried under Ancylus deposits organic matter from three locations at Piirsalu. For lithology refer to Fig. 3.

The Early Holocene shoreline displacement in the region is observable since 10 200 BP, when the basin with the highest threshold (41.5 m a.s.l.) in the area, Lake Järveotsa, isolated during the final drainage of the Baltic Ice Lake (Poska, 1994) (Fig. 7*a*). The depression of the Mustjärve Bog was part of an open bay of the Yoldia Sea, where the basal silty sediments recorded in core 3 deposited on top of the varved clays of the Baltic Ice Lake. The Yoldia Sea had a connection/equilibrium with the ocean and its seemingly regressive shoreline was generated by the fast isostatic uplift of West Estonia. An underwater bar probably started to form between the Piirsalu bedrock island and Turvaste bedrock peninsula, shaping the initial threshold of the Mustjärve basin. Judged by the altitude of the lowest buried organic matter at Valgejärve (Kessel & Raukas, 1967), the shoreline of the Yoldia Sea must have retreated to *c*. 28 m a.s.l. or even

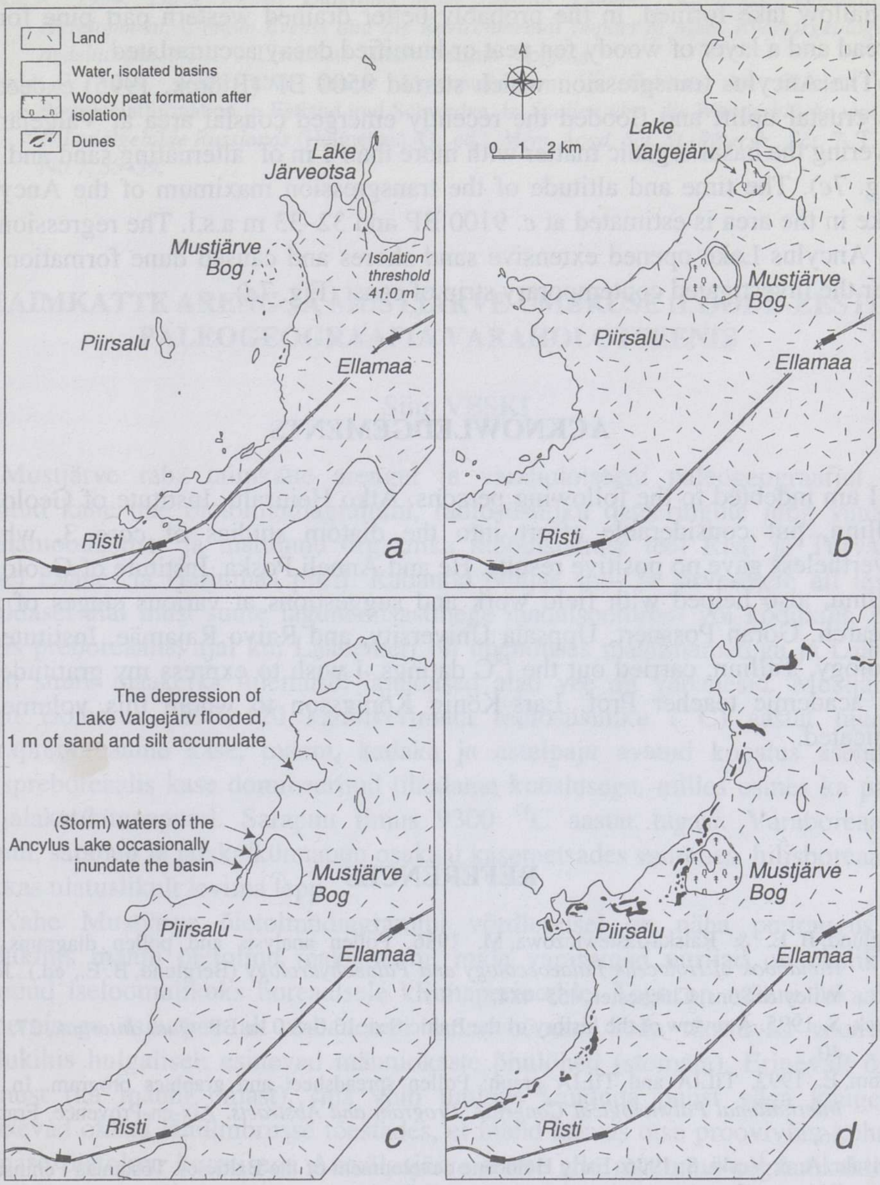

Fig. 7. Palaeogeography of the Mustjärve area. (*a*) The shoreline 10 000 BP at 41 m a.s.l., after the isolation of Lake Järveotsa. (*b*) The shoreline 9500 BP at 28 m a.s.l., or less. (*c*) The transgressive shoreline 9200–9100 BP at 32–33 m a.s.l. The maximal Ancylus shoreline in the area. (*d*) The regressive Ancylus shoreline 9000 BP at 30 m a.s.l. The retreating shoreline generates dune formation all over the contemporary coast.

lower (Fig. 7*b*). The Mustjärve Bog isolated at 9590±120 BP, in its eastern part a shallow lake formed, in the probably better drained western part pine forest spread and a layer of woody fen peat or humified decay accumulated.

The Ancylus transgression which started 9500 BP (Björck, 1995) exceeded the crustal uplift and flooded the recently emerged coastal area at Valgejärve, covering the basal organic matter with more than 1 m of alternating sand and silt (Fig. 7*c*). The time and altitude of the transgression maximum of the Ancylus Lake in the area is estimated at *c*. 9100 BP and 32–33 m a.s.l. The regression of the Ancylus Lake opened extensive sand shores and caused dune formation all over the investigated contemporary strip of coast (Fig. 7*d*).

ACKNOWLEDGEMENTS

I am indebted to the following persons. Atko Heinsalu, Institute of Geology, Tallinn, put considerable effort into the diatom studies of core 3, which nevertheless gave no positive results. He and Anneli Poska, Institute of Geology, Tallinn, also helped with field work and suggestions at various stages of the research. Göran Possnert, Uppsala University, and Raivo Rajamäe, Institute of Geology, Tallinn, carried out the ^{14}C datings. I wish to express my gratitude to my academic teacher Prof. Lars-König Königsson to whom this volume is dedicated.

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TAIMKATTE ARENG JA MUSTJÄRVE ÜMBRUSE (LOODE-EESTI) PALEOGEOGRAAFIA VARAHOLOTSEENIS

Siim VESKI

Mustjärve raba taimkatte arengut ja varaholotseeni paleogeograafiat on uuritud kahe uue õietolmudiagrammi, radiosüsiniku dateeringute ning vanade rannamoodustiste ja mattunud orgaanika mõõdistamise teel Risti ja Turvaste vahel Lääne- ja Harjumaa piiril. Rabanõo põhjas soo- ja järvesetete all levib laialdasel alal must suure lagunemisastmega madalsooturba- või kõdukiht, mis settis preboreaalis, ajal kui Läänemeri oli ühenduses maailmamerega ja Lääne-Eesti suure maakerke tulemusel laialdased alad vee alt vabanesid. Mustjärve nõgu isoleerus 9590±120 kalibreerimata radiosüsiniku (^{14}C) aastat tagasi. Varapreboreaalne kase, männi, kadaka ja astelpaju avatud kooslus asendus hilispreboreaalis kase domineeritud tihedama kooslusega, milles esines ka paju ja jalakat/künnapuud. Sarapuu ilmus 9300 ^{14}C aastat tagasi. Varaboreaalis männi, sarapuu ja jalaka/künnapuu osakaal kasemetsades suurenes, hilisboreaalis hakkas ulatuslikult levima lepp.

Kahe Mustjärve õietolmudiagrammi võrdlemisel on näha puuraugus 3 kõdukihis männi õietolmu maksimumi, mida varasemad uurijad on ekslikult pidanud iseloomulikuks boreaalsele kliimaperioodile. Tegu on männi lokaalse esinemisega äsja vee alt vabanenud rannavööndis. Seda tõestavad veenvalt kõdukihis hulgaliselt esinevad männiokaste õhulõhed (stomata). Erinevalt õietolmust (ka männi omast), mis võib tuulega kanduda puust väga kaugele, varisevad okkad lähiümbrusse tõestades, et mänd kasvas otse proovivõtu kohas. Sarnase õietolmu koostisega Antsülusjärve setete alla mattunud orgaanikakihte on H. Kessel leidnud 32 m ü.m.p. Piirsalust ja 28,8 m ü.m.p. Valgejärve rabast. Õhuke kiht liiva kõdukihi peal Mustjärve raba puuraugus 3 on kantud sinna Antsülusjärve transgressiooni maksimumi ajal 9100 ^{14}C aastat tagasi, kui suurjärve veetase ümbruskonnas tõusis 32–33 m ü.m.p.

On vaadeldud varaholotseense rannajoone muutumist uuritaval alal. Antsülusjärve transgressiooni lõpus boreaalis avas regresseeruv rannajoon laiad liivaplaažid. See viis rannavallide luidestumisele.

СМЕНА РАСТИТЕЛЬНОСТИ И ПАЛЕОГЕОГРАФИЯ В ОКРЕСТНОСТЯХ ОЗЕРА МУСТЪЯРВ В РАННЕМ ГОЛОЦЕНЕ, СЕВЕРО-ЗАПАДНАЯ ЭСТОНИЯ

Сийм ВЕСКИ

На основе двух новых палинологических диаграмм, радиоуглеродных датировок, данных нивелирования древнебереговых образований и анализа погребальной органики изучены развитие растительности и ранне-голоценовая палеогеография в окрестностях оз. Мустъярв, расположенного на границе Ляэнеского и Харьюского уездов. На дне котлована озера под озерно-болотными отложениями залегает слой хорошо разложившегося погребенного торфа, который образовался в пребореале, когда Балтийское море соединилось с океаном, а обширные пространства Западной Эстонии освободились от воды вследствие неотектонического поднятия земной коры. Согласно ^{14}C данным, оз. Мустъярв изолировалось 9590 ± 120 лет т. н. (без калибровки).

В раннем пребореале на рассматриваемой территории доминировала березово-сосново-можжевельниковая ассоциация с облепихой, которую в позднем пребореале сменили более густые березовые леса с примесью ивы и вяза. Лещина появилась 9300 лет т. н. В раннем бореале доля участия сосны, лещины и вяза увеличилась. В позднем бореале, 8500 лет т. н., широко распространилась ольха. На спорово-пыльцевой диаграмме слоя погребенного торфа (скв. 3) четко вырисовывается максимум сосны, которую ранее исследователи ошибочно принимали за признак бореала, хотя этот слой, по новым данным, сформировался в пребореале. Этот вывод убедительно доказывает обилие в слое сосновых иголочек с устьицами (stomata), залегающих in situ. В отличие от пыльцы, которую ветер мог разносить на большие расстояния, хвоя опадала точно в том месте, где росло дерево. Схожий палинологический состав имеет и погребенный под анциловыми отложениями слой органики в оз. Пийрсалу на абсолютной отметке 32 м и слой в болоте Валгеярв на отметке 28,8 м. Тонкий слой песка, залегающий на торфе в болоте Мустъярв (скв. 3), сформировался 9100 лет т. н., во время трансгрессии Анцилового озера. Тогда уровень озера располагался на отметке 32–33 м.

В статье подробно описаны ход изменения уровня воды и характер древнебереговых отложений до времен регрессии Анцилового озера.