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The sedimentary sequence from the Lake Ķūži outcrop, central Latvia: implications for late glacial stratigraphy

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Abstract. Sediment samples from an outcrop in the near-shore area of Lake Ķūži (Vidzeme Heights, Central Latvia) were investigated using palaeobotanical (pollen and macrofossil analysis) and lithological (grain-size analysis) methods and accelerator mass spectrometry ^{14}C dating. A dark, organic-rich sediment layer was found below 1.7 m of sandy layers approximately 30 cm above the present lake level. Radiocarbon dating of a wood sample from the lowermost layer (11 050 ± 60 ^{14}C BP, 13 107–12 721 cal BP) shows that the layer is of late glacial age. The composition of the pollen spectra is characterized by *Betula nana*, Cyperaceae pollen and spores of *Equisetum*, confirming that the lowermost sediments were formed during the late glacial. Fossils of obligate aquatic organisms in the upper layer, which include oospores of Characeae and seeds of *Potamogeton*, indicate an open water environment. Pollen of *Myriophyllum* and *Potamogeton* and non-pollen palynomorphs, such as algal *Botryococcus* and *Pediastrum* cf. *boryanum*, confirm this conclusion. The pollen assemblage from the greyish loam layer following this lacustrine phase shows a pattern characteristic of the Younger Dryas vegetation before the start of the real expansion of birch forests at the beginning of the Holocene.

Key words: late glacial, palynostratigraphy, plant macrofossils, Vidzeme Heights, Latvia.

INTRODUCTION

The abrupt climate changes that occurred after the Late Weichselian deglaciation have recently gained much scientific interest (Birks & Wright 2000; Wohlfarth et al. 2002; Lowe et al. 2008; Heikkilä et al. 2009). The restudy of previously investigated sites like Bølling Sø (Sarmaja-Korjonen et al. 2006) is just one example. The characteristics and chronology of late glacial environmental changes in the context of the North Atlantic climatic events of the Last Termination were lately studied in Lithuania (Stančikaite et al. 2008, 2009). Attempts to improve the Estonian late glacial chronology and vegetational and environmental history were made by multiproxy studies from Lake Nakri, South Estonia (Veski et al. 2008; Amon et al. 2009), Solova basin (Amon et al. 2010) and at Palaeolake Kahala (Saarse et al. 2009).

The increasing number of the accelerator mass spectrometry (AMS) ^{14}C dates will bring some corrections to the stratigraphical chart of the late glacial in the nearest future. Interpretation of these AMS ^{14}C dates is not always simple because of high risk of contamination (Saarse et al. 2009). If we include also the difficulties that can occur in dating, the series are different not only between the AMS and decay-counting, but also between AMS ^{14}C dates on different plant macrofossils from the same stratigraphic horizon (Turney et al. 2000), and the picture will be even more complex. Therefore it is important to publish all the palynological and macrofossil data and studied sections that include AMS ^{14}C dates.

According to Raukas (2003), the beginning of the late glacial interval in Estonia is placed at the time the deposits of the Raunis Interstadial started to accumulate in Central Latvia (dated by different laboratories as 13 390 ± 500 (Mo-196), 13 250 ± 160 (TA-177) conventional (uncalibrated) ^{14}C ages). As many dates have been obtained from submorainic and intermorainic sequences by the conventional radiocarbon method (Kalm 2006) and the hard-water effect can influence the reliability of the results, new dating possibilities should be used (Raukas 2003; Kalm 2006; Rinterknecht et al. 2006) to shed light on the biostratigraphy and chronology of the late glacial.

The results from the newly investigated late glacial site, Lake Nakri, in southern Estonia (Fig. 1A) (Amon et al. 2009) showed that the area around the lake was deglaciated just before 14 000 cal BP. A single *Pinus* stomata dated to 13 300 cal BP is an evidence that pine grew there already at that time. A short cooling was detected from a drop in the accumulation rates of birch

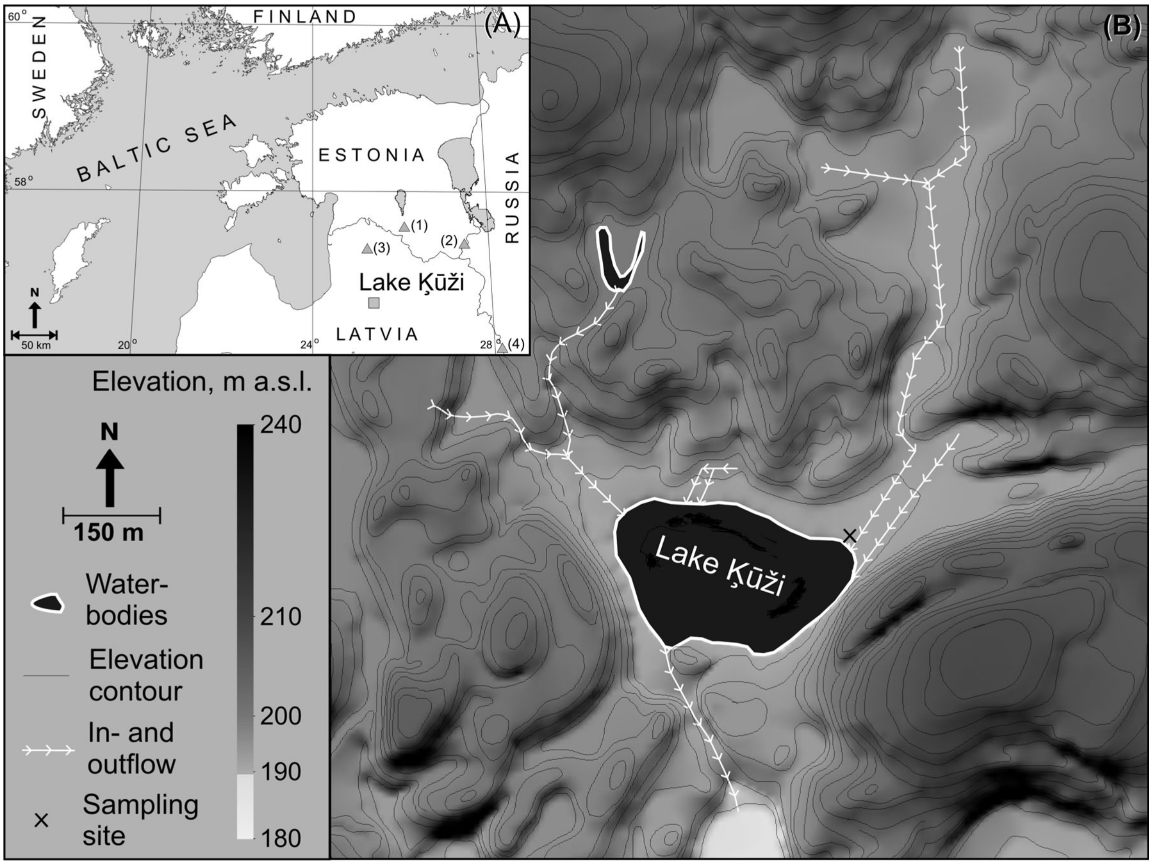

Fig. 1. (A) Location of L. Ķūži and recently studied late glacial sites at Nakri (1) (Amon et al. 2009), Solova (2) (Amon et al. 2010), Burtnieks (3) (Ozola et al. 2010) and Kurjanovas (4) (Heikkilä et al. 2009). (B) Topography of the L. Ķūži surroundings and sampling site.

and pine pollen, centred to 13 100 cal BP. During the Younger Dryas, 12 850 cal BP, the vegetation was dominated by herbs and dwarf shrubs. Gyttja sedimentation started gradually around 11 650 cal BP (Amon et al. 2009). These new data demonstrate that many rapid environmental fluctuations occurred during a few hundred years.

Further investigations are needed to expand the present knowledge of the late glacial environmental history in different parts of the Baltic region. Information on late glacial deposits in Latvia is even more problematic than in Estonia, as there are no well dated sequences and descriptions of the vegetation development of this period. The correlation and biostratigraphy of the late glacial are based on multiple sites where only part of the characteristic layers are represented (Stelle 1968; Danilans 1973). The latest pollen and macrofossil data from the northeastern area of ancient Lake Burtnieks (Fig. 1A) indicate a vegetation development since the Younger Dryas (Ozola et al. 2010) but this is not supported by radiocarbon dates. Although a satisfactory age–depth model was developed with the help of known ages of biostratigraphic boundaries for Lake Kurjanovas (Fig. 1A), also there several problems with AMS radiocarbon dates of macrofossils occurred (Heikkilä et al. 2009).

During the multiproxy studies focusing on the establishment of the development of environmental conditions of the Vidzeme Heights during the Holocene (Kangur et al. 2009) we detected an outcrop near L. Ķūži. This paper reports some initial findings from a pilot and a subsequent study aimed at elucidating the sedimentary history and age of the deposits exposed in the L. Ķūži outcrop and preliminary examination of the palaeoenvironmental information documented at that site. The information obtained is relevant for explaining the rapidity of the response of the regional vegetation and lakes to the warming at the Pleistocene–Holocene transition.

GEOLOGICAL SETTING

The Vidzeme Heights are located distally from the ice-marginal formations of the Luga (North Lithuanian) stage. The most impressive formations of this ice advance occur as a wide belt of heights formed about 13 500 ^{14}C BP (Raukas 2009). Cosmogenic ^{10}Be ages of boulders from the Burtnieks Drumlin Field indicate also that the area was deglaciated by 13 500 cal BP at the latest (Rinterknecht et al. 2006). The topography of the Vidzeme Heights is varied and complex, with the dominance of subglacial landforms. The elevations of the area range from 180 to 240 m. Small depressions between hillocks were formed after the withdrawal of glaciers from marginal landforms. The outcrop near the Raunis River containing the best dated and studied late glacial deposits (Stelle 1968; Danilans 1973) lies 35 km to the north of L. Ķūži.

Lake Ķūži is located in the western part of the Vidzeme Heights in the Piebalga hilly area (57°2′N and 25°20′E; absolute height 191.5 m a.s.l.) (Fig. 1B). It was selected as a reference lake for comprehensive multiple core studies of lake-level changes in the Holocene. The lake is today 6.3 ha in area (maximum length 380 m, width 210 m and depth up to 8 m) with a limited flow-through. The size of the lake's catchment area is 1.2 km^2 and it is covered with forests to the east and west. Meadows and agricultural land are situated to the north and south of the lake.

The NW part of the lake is bordered by an up to 100 m wide peaty area (Fig. 1B). The thickness of fen peat and lacustrine sediments in this area reaches 6.30 m. The results of pollen, macrofossil and ^{14}C AMS studies indicate that fen peat accumulated at the beginning of the Early Holocene (dated at ca 11 200 cal BP) (Kangur et al. 2009). The organic-rich gyttja in the core from the deepest central part of the lake was dated to ca 11 300 cal BP (Puusepp & Kangur 2010). These dates indicate that the formation of the lake sediments started at the very beginning of the Holocene.

METHODS

Sediment samples were taken from the cleaned wall of the outcrop in May 2008 on the northern shore of L. Ķūži (Fig. 1B). The outcrop was described and photographed in the field (Fig. 2), and samples from visually well distinguished layers were wrapped in plastic. The sampling for different analyses was done in the laboratory prior to analysis. At first macrofossils from the layers with different composition were picked out for AMS ^{14}C dating performed in the Poznan Radiocarbon Dating Laboratory, Poland.

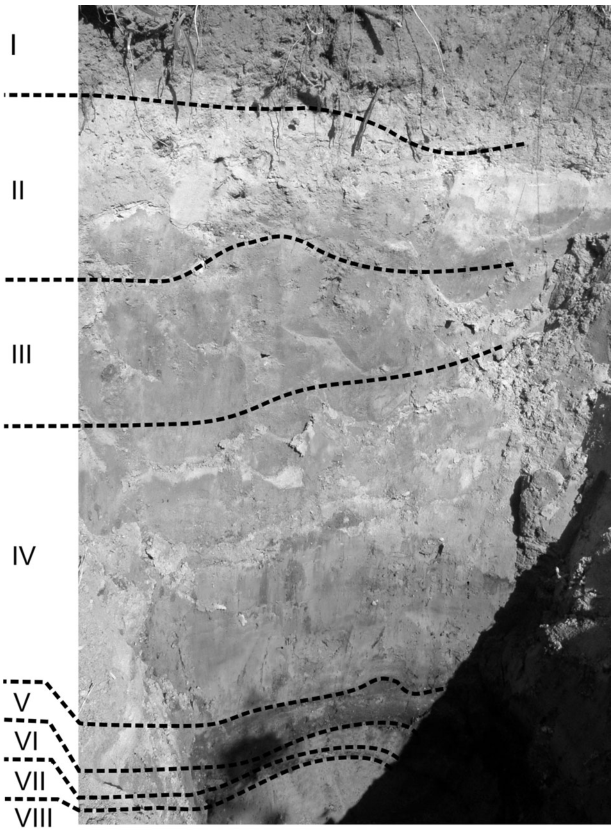

Fig. 2. Lithological units of the studied outcrop of L. Ķūži photographed in the field.

For macrofossil analyses 100 cm^3 samples were dispersed in water and washed gently through a 250 µm mesh sieve. Residues were dispersed in water and examined on a white plate under a stereomicroscope. All seeds, fruits and other identifiable remains were identified with the aid of reference collections and descriptive manuals (Beijerinck 1947; Katz et al. 1977; Birks 1980, 2001; Schweingruber 1990; Grosse-Brauckmann & Streitz 1992; Cappers et al. 2006) and the results were expressed as the number of macrofossils per 100 cm^3.

For pollen analysis 3 cm^3 block samples were treated with KI + CdI_2 heavy liquid (Bates et al. 1978) to separate minerogenic material. The organic fraction was then treated by standard acetolysis according to Moore et al. (1991). In general, at least 500 arboreal pollen (AP) grains were determined in each sample under the microscope but part of the samples yielded only 200 grains. The percentage pollen diagram is based on the total pollen sum. The diagram was made using the TILIA program (Grimm 1990). Pollen and spore nomenclature follows Moore et al. (1991) and that for *Alnaster*, Kupriyanova & Aleshina (1972). Besides the pollen grains, also some non-pollen palynomorphs were counted from the same slides and identified on the basis of descriptions and illustrations in van Geel (2001). The sequences were split into zones by the similarity of the consecutive pollen spectra and using the cluster analyses CONISS provided by the TILIA program (Grimm 1990).

For grain-size analysis samples were measured with a Fritsch Laser Particle Sizer 'Analysette 22' (measuring range 0.3–300 μm). Before measuring, the samples were pre-treated. Concentrated H_2O_2 (30%) (Lu & An 1997; Allen & Thornley 2004; Mikutta et al. 2005) was used for removing organic matter. Carbonates were removed with 10% HCl (Carver 1971; Murray 2002; Schumacher 2002). To avoid flocculation of grains before analysing with the laser particle sizer, 1% of solution sodium hexametaphosphate $(NaPO_3)_6$ was used (Murray 2002; Andreola et al. 2004; Vaasma 2008). Chemical reactions were carried out in a standard 1 L beaker and on a heating plate (Konert & Vandenberghe 1997; Vaasma 2008).

RESULTS

The investigated sediments of the outcrop were divided into eight lithological units described in Table 1. On the basis of the lithological description it was concluded that the uppermost layers (units I–III) were washed out and so we concentrated our investigations only on units IV–VIII. The results of the AMS ^{14}C dating of the two lowermost samples from layers VII and VIII are presented in Table 2. They show good chronological correspondence.

The results of pollen and macrofossil analysis of 11 samples from five layers (IV–VIII) are presented in Fig. 3. They demonstrate no big differences in the pollen composition: domination of AP (mainly *Pinus* and *Betula*) and the presence of *Picea* pollen were recorded in almost all samples. The pollen composition of layers IV and V–VIII differs because layer IV has a higher proportion of non-arboreal pollen (NAP, more than 40%) than the lower layers. On the basis of the species composition we can separate four local pollen assemblage zones (PAZ). Variation in the grain-size composition is not very great, but some differences occur between zones. Silt is dominating in all samples (63–84%), while clay (8–19%) and sand (0–27%) are found in lesser amounts. The sediment is not very well sorted, but the middle parts of the studied layers show better sorting than the upper and lower parts (Fig. 4).

A high proportion of *Pinus* pollen (up to 75%) characterizes zone Kz1, which includes the two lowermost samples from layers VII and VIII. Also pollen of *Picea* is present, together with a few pollen grains of *Betula*. *Betula nana* makes up 8% and *Alnaster* 2% in layer VIII. A single *Tilia* pollen grain, probably redeposited, was found in layer VII. The NAP values are less than 20% and the main pollen types are Cyperaceae, Artemisia, Poaceae and Chenopodiaceae. Spores of *Equisetum* dominate among the Pteridophytes. About one third of the pollen grains in these two samples are corroded and the concentration of grains is also low. From macrofossils only a few *Carex* seeds are found in layers VII and VIII. The grain-size composition of layers VII and VIII is very different: VIII is coarse-

Table 1. Lithological units of the outcrop near L. Ķūži

Unit No.	Depth below surface, cm	Description
I	0–35	Brown deluvium loam
II	36–45	Yellowish sand with fine gravel and rust-coloured ferruginous lenses
III	46–85	Brown loamy sand with alternating layers of clay
IV	86–120	Greyish loam with thin disturbed layers of clay, silt and sand
V	121–129	Dark loam with organic detritus and twig remains
VI	130–133	Greyish sandy loam with organic detritus
VII	134–135	Black organic detritus with wood and plant remains
VIII	135–...	Grey well-sorted medium sand with some plant remains

Table 2. Sample depth, type of material selected for dating, AMS ^{14}C measurements and resulting calibrated ages (probability 95.4%) according to IntCal09 (Reimer et al. 2009) in OxCal v4.1.3 (Bronk Ramsey 2009)

Sample ID	Depth, cm	Dated material	AMS ^{14}C yr BP	Calibrated age, yr BP	Mid intercept cal BP
Poz-26774	130–132	Wood	10 840 ± 60	12 890–12 595	12 742
Poz-26775	133–134	Wood	11 050 ± 60	13 107–12 721	12 900

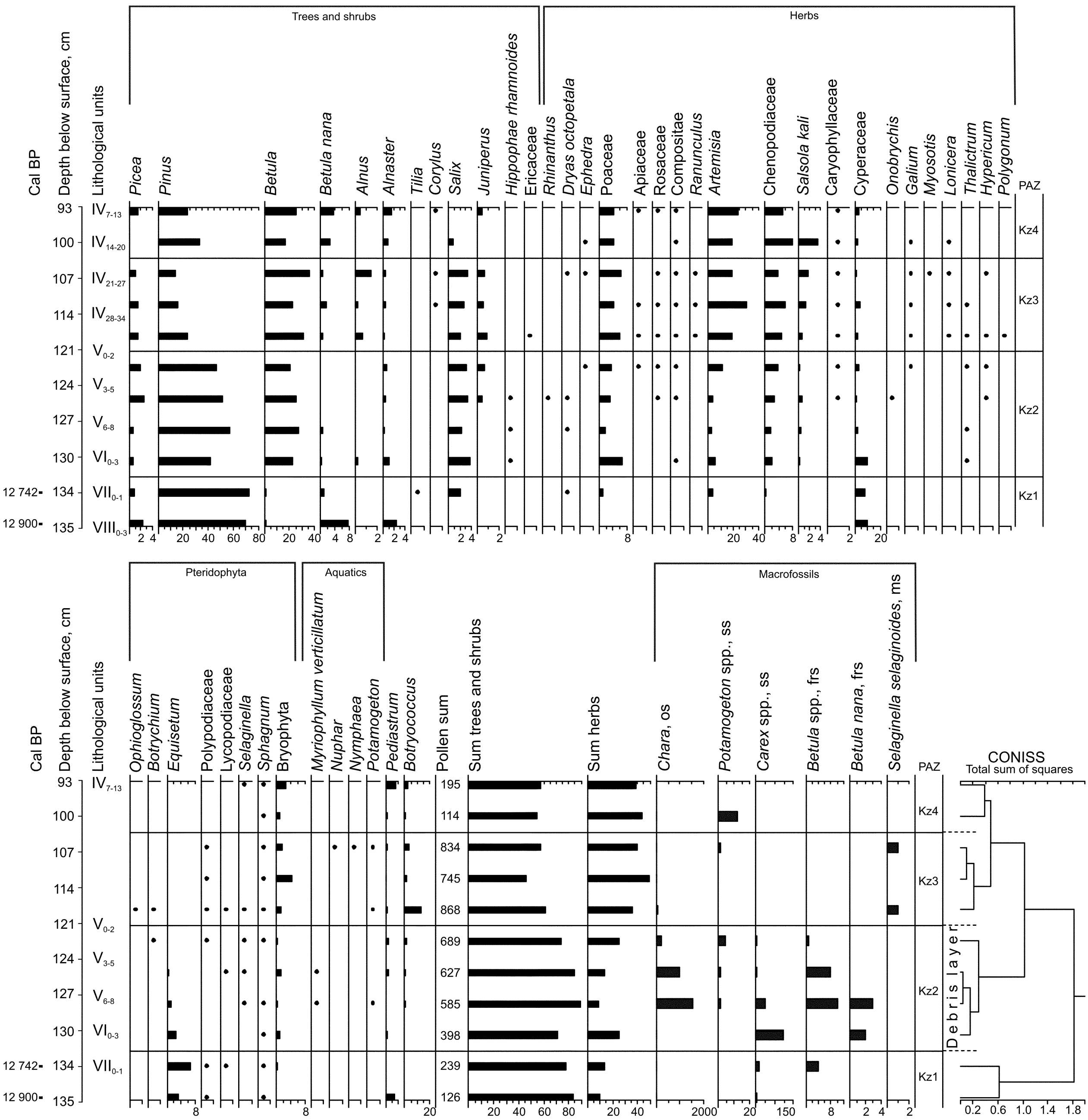

Fig. 3. Percentage pollen diagram and number of macrofossils in 100 cm^3 of sediments of the Ķūži outcrop. Abbreviations: frs, fruits; ss, seeds; os, oospores; ms, megaspores. The depth scale is nonlinear.

grained (mean diameter 50 µm) and poorly sorted, but VII is rather fine-grained (mean diameter 8 µm) with fine and very fine silt fractions dominating.

In zone Kz2 (four samples from layers VI and V) *Betula* increases (up to 25%) but still *Pinus* is dominating (50–60%). *Picea* values are 1–3% with a slight trend to increase in the uppermost samples of layer V. There are few *Betula nana* and *Alnaster*-type pollen grains. *Salix* has stable values around 4% and *Juniperus* pollen was present in the uppermost two samples of the zone. The presence of *Hippophae rhamnoides* pollen is characteristic only of this PAZ. The NAP values are around 20% and the diversity of different herbal species is rather high. The dominants among the NAP are Chenopodiaceae, Poaceae and *Artemisia*. Sporadically appeared *Dryas octopetala*, *Ephedra*, Caryophyllaceae, *Onobrychis*,

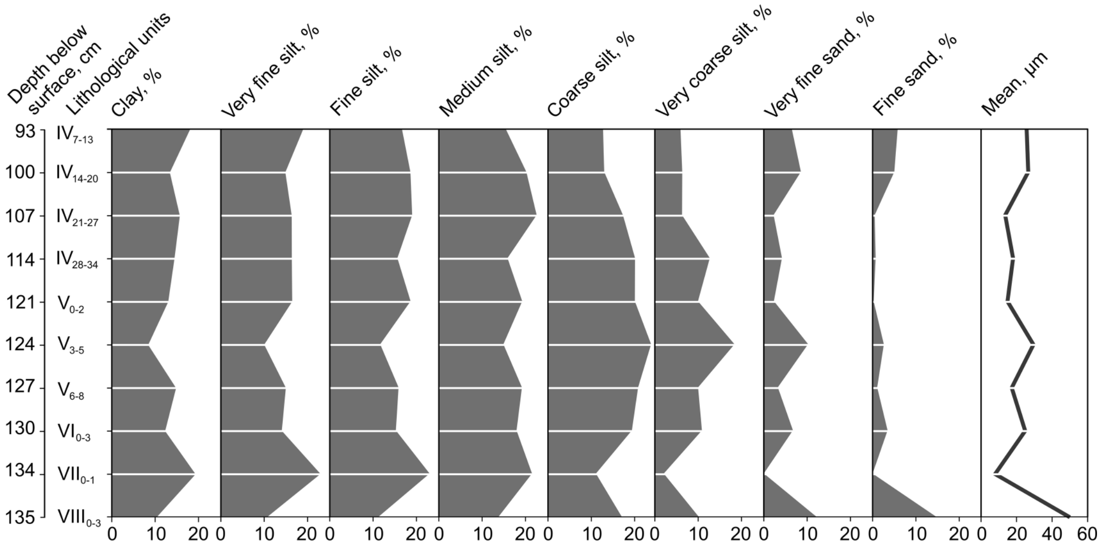

Fig. 4. Grain-size distribution of the studied outcrop. The depth scale is nonlinear.

Thalictrum, Rosaceae and Compositae. From Pteridophyta spores of *Selaginella* are typical of this zone. Single spores of *Botrychium*, Polypodiaceae and *Lycopodium* are also present. Aquatics are represented by *Myriophyllum*, *Potamogeton* and remains of the algae *Pediastrum* and *Botryococcus*. The sample from layer VI is characterized by a high number of *Carex* seeds (over 140) and few seeds of *Betula nana.* In samples from layers V *Chara* oospores are present in high numbers (over 1500 in sample $V_{6–8}$). From aquatics also *Potamogeton* seeds are present. The grain-size distribution is variable in this zone, but characteristic features are the appearance of sand fractions (up to 13%) and domination of the coarse silt fraction (over 20% in all samples).

There is a sharp decrease in *Pinus* at the beginning of zone Kz3 and a corresponding increase in *Betula* and NAP. *Picea* has stable values of about 2% and some pollen grains of *Alnus* and *Corylus* appear in this zone. *Betula nana* and *Alnaster* are present in low values. *Salix* and *Juniperus* proportions are around 2–3%. The increase in NAP is due to the increase in *Artemisia*, Poaceae and Chenopodiaceae. From Chenopodiaceae *Salsola kali* pollen grains are present in all samples. Among other herbs pollen of Apiaceae, Rosaceae, Compositae, *Ranunculus*, *Galium*, *Hypericum* and *Polygonum* occur. The number of different pollen types in this zone is high. Bryophyte spores are dominating among Pteridophytes. From aquatics *Nuphar*, *Nymphaea* and *Potamogeton* are represented with single grains. Remains of *Botryococcus* algae show the highest values. According to macrofossil data, the number of *Chara* oospores and *Potamogeton* seeds decreased significantly in comparison with the previous zone. Only single *Selaginella* spores were also found. At the beginning of zone Kz3 coarse silt is still dominating (20%) but thereafter medium silt is increasing. The percentage of silt decreases, those of clay and sand increase, and the sediment is getting less sorted.

In PAZ Kz4 *Pinus* slightly increases and *Betula* decreases. The NAP values remain stable but the number of different pollen types decreases. Chenopodiaceae and *Salsola kali* have high values. No pollen of aquatics are found, only *Pediastrum* remains are present. Pollen of *Ephedra* and spores of *Selaginella* appear in low values and sporadically. From macrofossils over 10 seeds of *Potamogeton* were found in sample $IV_{7–13}$. The upper part of layer IV is characterized by coarser material (up to 14% sand at the level of $IV_{14–20}$) and clay (28%); sediment is poorly sorted.

DISCUSSION

From pollen and macrofossil analysis it is possible to draw some conclusions about the sediment succession at the Ķūži site. In the lowermost layers VIII and VII the pollen spectrum (Kz1) was dominated by *Pinus* pollen but the number of counted pollen grains was rather low. The long-distance origin of tree pollen seems likely, since pollen grains such as *Pinus* are known to be easily distributed over long distances (Moore et al. 1991). The local vegetation was very scarce, as only Cyperaceae and

Equisetum were growing at that time. *Pinus* pollen quantities up to 80% were characteristic also of the late glacial sediments of Lithuania (Stančikaite et al. 2009). So, the question of whether most of the AP should be regarded a result of long-distance transportation and/or redeposition or whether trees were growing sparsely at the site still remains open. As to the significance of birch pollen, macroscopic remains of *Betula* seeds were found in layer VII. The NAP composition reflects more local vegetation and rather poor plant diversity. The existence of local vegetation was proved by the presence of *Carex* seeds and a large percentage of Cyperaceae pollen. Together with Poaceae and *Equisetum* these finds indicate most probably tundra-like primary wetland vegetation.

Interpretation of the presence of *Picea* at 2% is complicated. Already Thomson (1929) noted that in sites in eastern and southeastern Estonia spruce was found in ‘arktischen Tonen’ up to 10%. Thomson concluded that this spruce phase is connected with the Baltic ice lake period and Salpausselka ice-marginal formations and the central part of the East European Plain was covered with spruce forest at that time and later. During the Boreal spruce disappeared from many sites. Giesecke & Bennett (2004) divided the migration of spruce into Fennoscandia into two phases: (1) rapid spreading in the early Holocene with the low population density giving rise to small outpost populations and (2) spreading as a front in the mid- to late Holocene. They suggested that the 1% limit of *Picea* in total tree pollen sum should be used for the expression of the first local establishment of spruce. This 1% limit can be followed in the late glacial in lakes Juusa (Kangur 2005) and Tuuljärv (Ilves & Mäemets 1987) in southern Estonia. In such values spruce was found also at Alinlampi in northern Karelia (Vasari et al. 2007) during the late glacial, as well as in Dagdas (Galenieks 1936) and near Jelgava (Stelle 1963) in Latvia.

Considering pollen data, macrofossil finds and modern genetic information, the late glacial history of spruce was studied by Latałowa & van der Knaap (2006). They supported the idea that finds of spruce cones in late glacial sediments of central Russia and Belarus show that macrofossils belong to the Siberian species *Picea obovata* (*Picea abies* ssp. *obovata*) growing nowadays in regions with severe climate and permafrost. Unfortunately it was not possible to determine our macrofossil findings to such a taxonomic level. Still, we found a piece of wood from layer VIII that we identified, according to the microscopic wood anatomy (Schweingruber 1990), as *Picea*. The ^{14}C AMS dating of this wood piece showed an age of 12 900 cal BP. This age fits also with the data from L. Kurjanovas (Heikkilä et al. 2009), where local presence of a reproductive *Picea* population during the Younger Dryas stadial 12 900–11 700 cal BP was evidenced by macrofossils. The only trace of conifers so far discovered from Estonian late glacial deposits is a few pine stomata (dated back to ca 13 300 cal BP) from L. Nakri (Amon et al. 2010).

The high number of *Carex* seeds (over 140) in layer VI and Cyperaceae pollen at the beginning of PAZ Kz2 suggest the development of a local wetland succession where also *Betula pubescens*, *Betula nana* and various *Salix* shrubs were growing. *Pinus* and/or *Picea* were also growing because we found wood debris in all samples from layer V, and pollen of both species were also present. Fossils of obligate aquatic organisms, which include oospores of Characeae, and seeds of *Potamogeton*, indicate open water in layer V. Pollen of *Myriophyllum* and *Potamogeton* and non-pollen palynomorphs, such as algal *Botryococcus*, *Pediastrum* cf. *boryanum* in PAZ Kz2, confirm this conclusion. The combination of aquatic macrofossils with a large quantity of wood debris suggests a near-shore sedimentation environment. An analogous composition was found also in surface samples of modern lakes (Koff & Vandel 2008). The same pattern – an increased abundance of Characeae oospores – was observed at the Pleistocene–Holocene boundary at Nakri (Amon et al. 2009) and Solova (Amon et al. 2010). In the grain-size composition coarser fractions are abundant. This seems to indicate an allochthonous character of deposition in the near-shore lake environment. The occurrence of diverse NAP flora with plants of different ecological requirements, such as *Thalictrum*, *Onobrychis* and Caryophyllaceae, suggests pioneer vegetation (Pirrus & Raukas 1996). A characteristic feature of this period is the presence of *Dryas* and *Hippophae* and maximum occurrence of dwarf willows (*Salix herbaceae*, *S. reticulata*). Pollen and macrofossil content shows a vegetational phase with wood species prevailing, where pine was dominant together with birch. This indicates climate warming. The data from Lithuania (Stančikaite et al. 2009) showed similar processes induced by the rising mean temperature and melting of the buried ice, i.e. ‘thermokarst activity’.

In layer IV PAZ (Kz3-4) the proportion of AP (including the shrubs *Betula nana*, *Alnaster*) was lower and NAP increased as compared with the previous layer. *Artemisia* was the most common taxon among NAP (up to 30%). Values of Chenopodiaceae and Poaceae remained at about the previous level. From Chenopodiaceae *Salsola kali* showed an increase. *Dryas* and *Ephedra* were also present. Such a pollen assemblage is characteristic of the Younger Dryas and therefore may have been outwashed, so that younger organic-rich material of layer V was buried under older sediments of layer IV due to slope processes or glacio-karstic slumping. The advance of birch forests at the beginning of the Holocene is clearly seen in the pollen diagram from the mire around 11 200 cal BP (Kangur et al. 2009).

An extremely rapid formation of a new type of vegetation, confirming increasing humidity and rising temperatures, occurred after 11 100 cal BP as a delayed response to the Pleistocene/Holocene warming 11 500 cal BP. A similarly delayed reaction was registered in southeastern Karelia (Wohlfarth et al. 2002). We support the explanation that this phenomenon may have regional reasons, such as extended permafrost or the cold surface water of the Baltic Sea (Wohlfarth et al. 2002). The influence of the different stages of the Baltic Sea on the regional climate could be seen also during the Holocene (Punning et al. 2000, 2002). The increase in temperature and humidity in the Early Holocene most probably caused an intensive melting of the ice in the surroundings of L. Ķūži and a breakthrough of the melting waters. This caused the sedimentation of greyish loam with thin disturbed layers of sand, loamy sand and deluvium loam also above layer IV (Table 1).

CONCLUSIONS

Lithostratigraphy, pollen and macrofossil analyses and AMS ^{14}C dating of a sediment sequence from the Ķūži outcrop provide valuable information about the late glacial vegetation development in central Latvia. Such information has so far been very scarce. Our data showed that an open forest dominated by *Pinus* with the presence of some *Picea* trees was growing in the area about 12 900 cal BP. The water table continued to rise after that time, indicated by the presence of oospores of Characeae and seeds of *Potamogeton* and confirmed also by the presence of pollen of *Myriophyllum* and *Potamogeton* and non-pollen palynomorphs, such as algal *Botryococcus* and *Pediastrum* cf. *boryanum*. Regression of the forest cover and establishment of the pollen assemblage shows a pattern characteristic of the Younger Dryas vegetation before the real advance of birch forests at the beginning of the Holocene at 11 300 cal BP.

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Ķūži järve (Kesk-Lätis) kaldalähedase paljandi setted: lisateave Hilis-Glatsiaali stratigraafiale

Tiiu Koff ja Jaanus Terasmaa

Vidzeme kõrgustikul (Kesk-Lätis) asuva Ķūži järve kompleksuuringutel sattusime paljandile, kus 1,7 m liivakate setete alt, 30 cm tänapäevasest järve veepinnast kõrgemal leidsime orgaanikarikka tumeda settekihi. Läbilõikest võetud proovidest määrasime õietolmu ja makrojäänuste koostise. Alumisest settekihist leitud puutüki (kuusepuit) vanuseks AMS-meetodil määrati (11 050 ± 60 ^{14}C BP) 13 107–12 721 cal BP, mis kinnitas meie oletust antud kihi hilisglatsiaalsest päritolust. Õietolmu koostises domineeris antud kihis männi õietolm, kuid leidus ka kuuse õietolmu ja ka *Betula nana*, Cyperaceae ning *Equisetum*’i oma, mis on samuti iseloomulikud hilisglatsiaalsele taimestikule. Ülemistest kihtidest leitud Characeae oospoorid ja *Potamogeton*’i seemned viitavad veelisele keskkonnale antud settimiskohas. *Myriophyllum*’i, *Potamogeton*’i õietolm ja mõnede vetikate, nagu *Botryococcus*, *Pediastrum* cf. *boryanum*, jäänused kinnitavad seda.